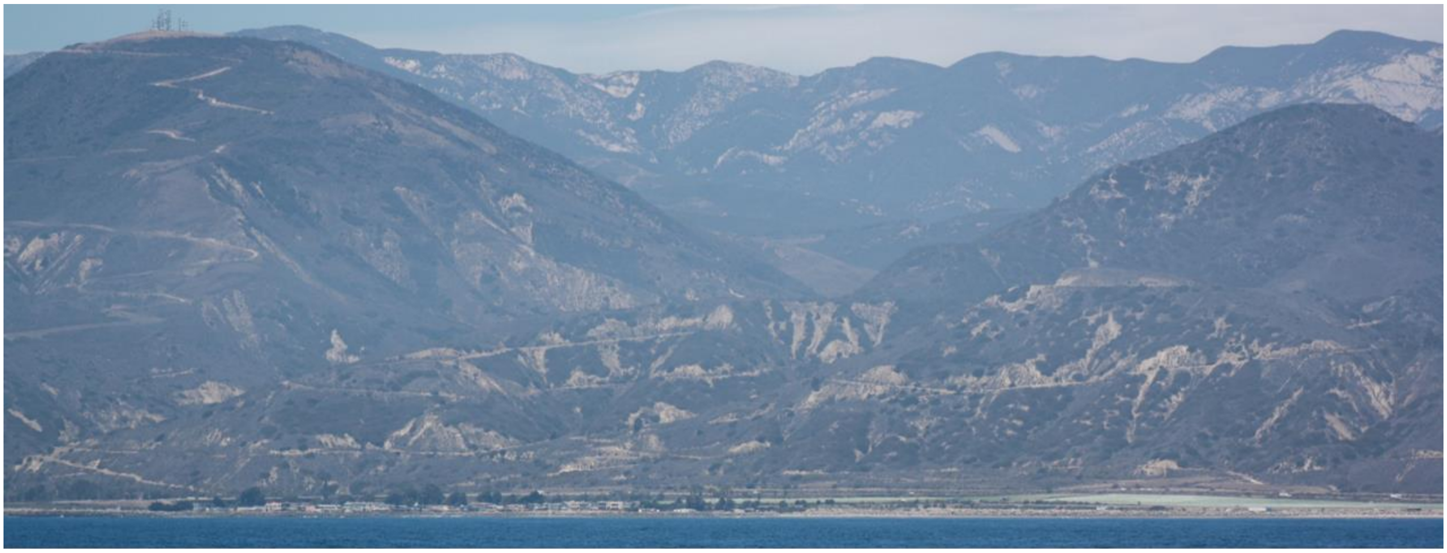
Northern Ventura County Coastal Watershed Project



Prepared by Blue Tomorrow and

Dr. Arturo Keller at the University of California, Santa Barbara

On behalf of the Rose Foundation for Communities and the Environment

ROSE FOUNDATION for COMMUNITIES and the ENVIRONMENT

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Project Elements

The Northern Ventura County Coastal Watershed Project (NVCCWP) is an exploratory study that assessed water quality and identified sources, pathways, receptors, and toxicity of pollutants found in five small coastal watersheds. These watersheds drain the Rincon and San Miguelito oil fields which are located upstream of residential communities, popular beaches, and coastal habitat. Hydraulic fracturing has been documented to have occurred in one canyon, and enhanced oil recovery projects were performed in the oil fields at the time of the study.

The NVCCWP includes several elements which were developed to support the objectives of the study. Though each element can be read as a stand-alone document, data, analyses, and information presented in these elements are used in a holistic approach to assessing the conditions of the study watersheds.

Watershed Assessment

Contains a comprehensive review of existing data in the study watersheds using relevant literature, spatial, and quantitative analyses to inform the Toxicity Analysis, Source Assessment, and Recommendations & Mitigation Strategies.

Environmental Sampling

Presents the methods, observations, and results from sampling and field testing activities conducted in the study watersheds from October 2013 through April 2014. Pollutant loading rates are also included in this element.

Toxicity Analysis

Examines the toxicity of pollutant concentrations found through the Environmental Sampling and compares results with EPA Regional Screening Levels, California Toxics Rule, and California Maximum Contaminant Levels and Public Health Goals.

Source Assessment

Explores potential natural and anthropogenic sources of pollutants found through the Environmental Sampling and relative contributions to detected concentrations.

Recommendations & Mitigation Strategies

Based on data, analyses, and other information included in Watershed Assessment, Environmental Sampling, Toxicity Analysis, and Source Assessment, recommendations and mitigation strategies were developed to address potential impacts to human and environmental health.

Project Authors

Blue Tomorrow, LLC

Blue Tomorrow provided project management, water and soil sampling, field data collection, analyses, and development of the report elements for the NVCCWP.

Based out of Santa Barbara, Blue Tomorrow was founded by Alex Dragos and Eric Hopkins. Blue Tomorrow combines disciplines of hydrology, environmental science, and economics to provide consulting services for the sustainable management of water resources. Working with its network of environmental scientists and professionals, Blue Tomorrow tackles a diversity of environmental problems. Existing research is paired with Blue Tomorrow generated field data (soil and water quality sampling, stream and riparian surveys, and erosion and sediment surveys) to spatially analyze land use impacts and identify sources, pathways, receptors, and toxicity of pollutants. Blue Tomorrow uses this whole basin assessment approach to develop feasible solutions to mitigate impacts from pollutants to people and the environment.

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Dr. Arturo Keller provided review and direction in the development of the NVCCWP.

Dr. Keller is known for his expertise in the fate and transport of pollutants, including nanoparticles, organic liquids (NAPLs), and persistent organic pollutants. Dr. Keller is known for his involvement in the phasing out of the gasoline additive MTBE as part of a UC-wide project; his research found MTBE to seriously affect water resources while providing only modest air quality benefits relative to other alternatives. Dr. Keller was scientific advisor and moderator of the award-winning Santa Clara River Nitrogen TMDL process. Consensus was reached through a combination of science-supported decision-making and a willingness to try out many ideas proposed by the stakeholders. He has also worked with several Regional Water Quality Control Boards on other TMDL processes, including nutrients in the Napa River, PCBs in San Francisco Bay, organophosphate pesticides in the Newport Bay watershed, and an assessment of TMDL priorities in the South Coast area of Santa Barbara County.

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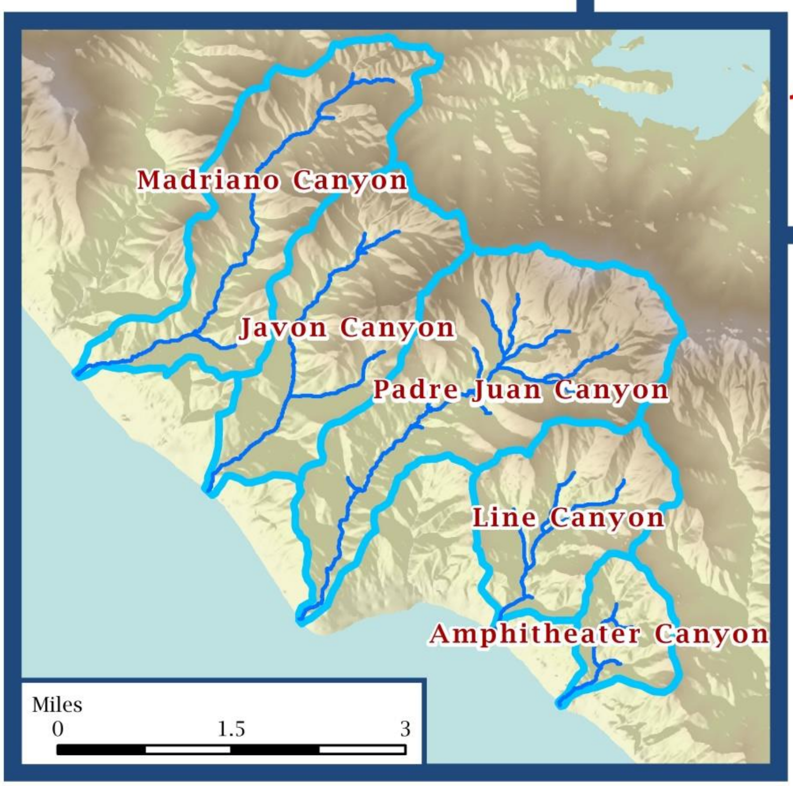
EXECUTIVE SUMMARY

NORTHERN VENTURA COUNTY COASTAL WATERSHED PROJECT

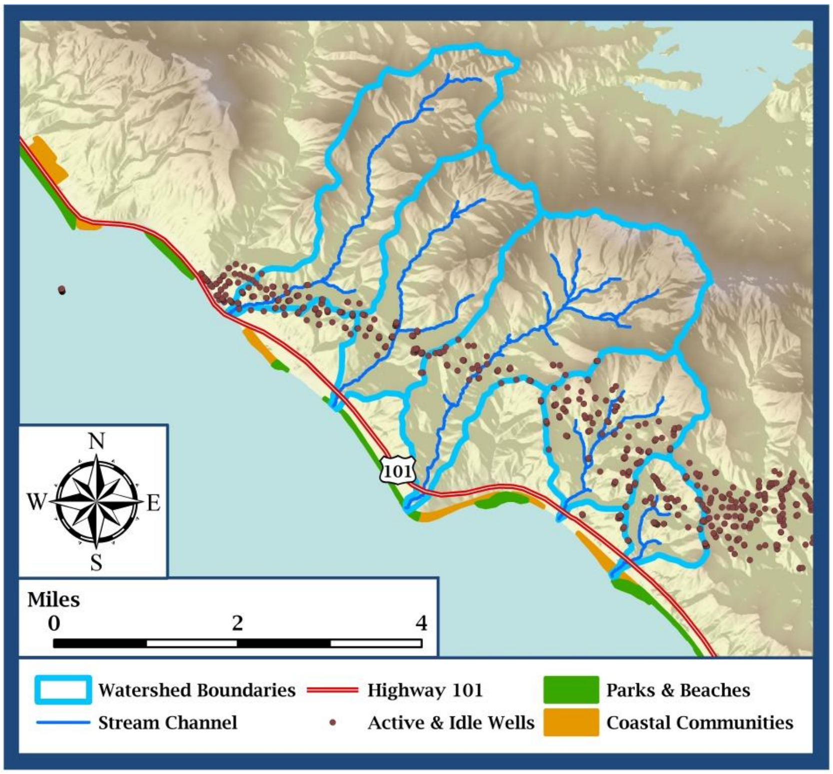
The Northern Ventura County Coastal Watershed Project (NVCCWP) assessed water quality and identified potential sources, pathways, receptors, and toxicity of pollutants detected in samples from Madriano, Javon, Padre Juan, Line, and Amphitheater Canyons. From October 2013 through April 2014, water and sediment samples were collected from each canyon to characterize water quality and inform strategies to mitigate impacts from pollutants being discharged from the watersheds.

NVCCWP Watersheds

Located in northern Ventura County, California, the study watersheds are roughly 17 miles south of the city of Santa Barbara and 7 miles north of the city of Ventura, along Highway 101. Collectively, the watersheds span 9.5 square miles and the threatened California coastal scrub inhabits the majority of the area. These five watersheds drain the Rincon and San Miguelito oil fields, which are upstream of residential communities, popular beaches, and coastal habitat. Oil field infrastructure covers about 5% of the study area, and approximately 275 people live in three residential communities near the creeks. Each year, over 140,000 people visit campgrounds and 570,000 go to beaches downstream or adjacent to the watershed outlets. The watersheds discharge into coastal waters, which are home to kelp forests, marine mammals, fish, and bird species.



The Rincon and San Miguelito oil fields have been in production since the early 20th century, and over 400 wells have been drilled in the watersheds. Oil field productivity has steadily declined since the late 1970's. Currently, over 90% of fluid extracted from the oil fields is produced water, which contains a complex mixture of organic and inorganic constituents with high levels of total dissolved solids (TDS).



As a result of declining productivity, enhanced oil recovery and well stimulation methods are used in the study watersheds. Hydraulic fracturing has been performed on at least 3 wells in Line Canyon, and roughly 9 million barrels (~380 million gallons) of produced water was injected into the oil fields in 2013 as part of water flood enhanced oil recovery projects.

Oil field development has led to large areas cleared for roads and well pads. This infrastructure covers about 11% of Line Canyon and 9% of Amphitheater Canyon. Roads, well pads, staging areas, and other cleared areas influence surface runoff and water quality, as unvegetated and compacted surfaces generate unnatural quantities of surface runoff and are sources of sediment and erosion.

Environmental Sampling

A total of 17 water samples and 10 sediment samples were collected from the study watersheds and tested for up to 68 constituents. Additionally, three samples were collected from the Line Canyon base flow, the only creek that flowed during dry periods. The 2014 water year was one of the driest on record in the study area, and only two rain events generated enough runoff for sampling (November 21, 2013 and February 27-March 1, 2014). Water and sediment samples were analyzed for a wide range of pollutants including metals, diesel and residual range organics (DRO & RRO), polycyclic aromatic hydrocarbons (PAHs), and other organic compounds and hydrocarbons. Pollutants were selected for analysis based on association with oil production operations and pollutants known to occur in hydraulic fracturing fluids, focusing on those that are of concern to public health and the environment.

Stormwater and Sediment Sample Results

Stormwater samples showed high levels of total suspended solids (TSS) and metals, most notably in Line and Amphitheater Canyons. Stormwater in Line and Amphitheater Canyons had the greatest concentration of TSS out of any project samples at 130,000 and 189,000 mg/L, respectively.

Samples of stormwater had high concentrations of total suspended and dissolved solids which were associated with high concentrations of metals. Stormwater in Amphitheater Canyon was found to contain 1790 mg/L of aluminum, 1.14 mg/L of arsenic, 14 mg/L of barium, 1.12 mg/L of lead, and 9.78 mg/L of zinc. The greatest TDS concentration in stormwater was detected in Line Canyon at 5,290 mg/L. The majority of the TDS can be accounted for by chloride, sulfate, sodium, calcium, and magnesium. The highest concentrations of PAHs were found in Line Canyon, which included 1.9 ug/L of naphthalene and several other PAHs, which were detected above reporting limits. DRO and RRO were detected in all canyons at concentrations above 0.5 mg/L, with the highest concentrations found in Madriano Canyon (5.9 mg/L of DRO and 4.1 mg/L of RRO).

Sediment samples collected early in the study showed the highest concentration of oil and grease in Madriano and Line Canyons at 1,740 and 1,610 mg/kg, respectively. DRO was also detected in all of the first sediment samples, with the highest concentration being 200 mg/kg in the Madriano Canyon sample. The first sediment samples detected bis(2-ethylhexyl)phthalate in all creeks, except Madriano Canyon, with the highest concentration found in Line Canyon at 0.17 mg/kg. Several of the metals were detected at relatively high concentrations, indicating how rich the local geology is in these naturally occurring metals.

Line Canyon Base Flow

Streams in the study watersheds have been classified historically as ephemeral or intermittent. However, the Line Canyon base flow exhibited perennial characteristics over the duration of the project, despite extreme drought conditions, and was measured at 0.03 to 0.04 cfs (0.85 to 1.1 L/s). This base flow had concentrations of DRO and RRO up to 2.3 and 1.5 mg/L, respectively.

Conductivity of the base flow was measured in field tests and lab samples, and ranged between 14,000 and 16,000 µS/cm. The high conductivity in the base flow was due to high TDS concentrations, which were measured at between 9,450 and 10,500 mg/L (roughly 1/3 the concentration of seawater). Chloride, sodium, and sulfate constitute the majority of this TDS (approximately 39% Cl^-, 29% Na^+, 21% SO_4^{2-}). The greatest difference between levels of metals in Line Canyon base flow and stormwater runoff was boron, which was detected at a much higher concentration (20.4 mg/L) in the base flow. Although the Line Canyon base flow discharge rate was very small compared to the stormwater discharges, the DRO and RRO can add up to annual loads of 66 and 36 kilograms (assuming constant flow at 0.04 cfs).

Pollutant Loading Rates in Stormwater

The loading rates from Line Canyon on February 27, 2014 at the time of sampling included 390 kg/hr of aluminum, over 0.2 kg/hr of both arsenic and lead, 2 kg/hr of zinc, 0.380 kg/hr of DRO, 0.400 kg/hr of RRO, 0.0023 kg/hr of bis(2-ethylhexyl) phthalate, and many PAHs in the range of 10's of milligrams per hour (mg/hr).

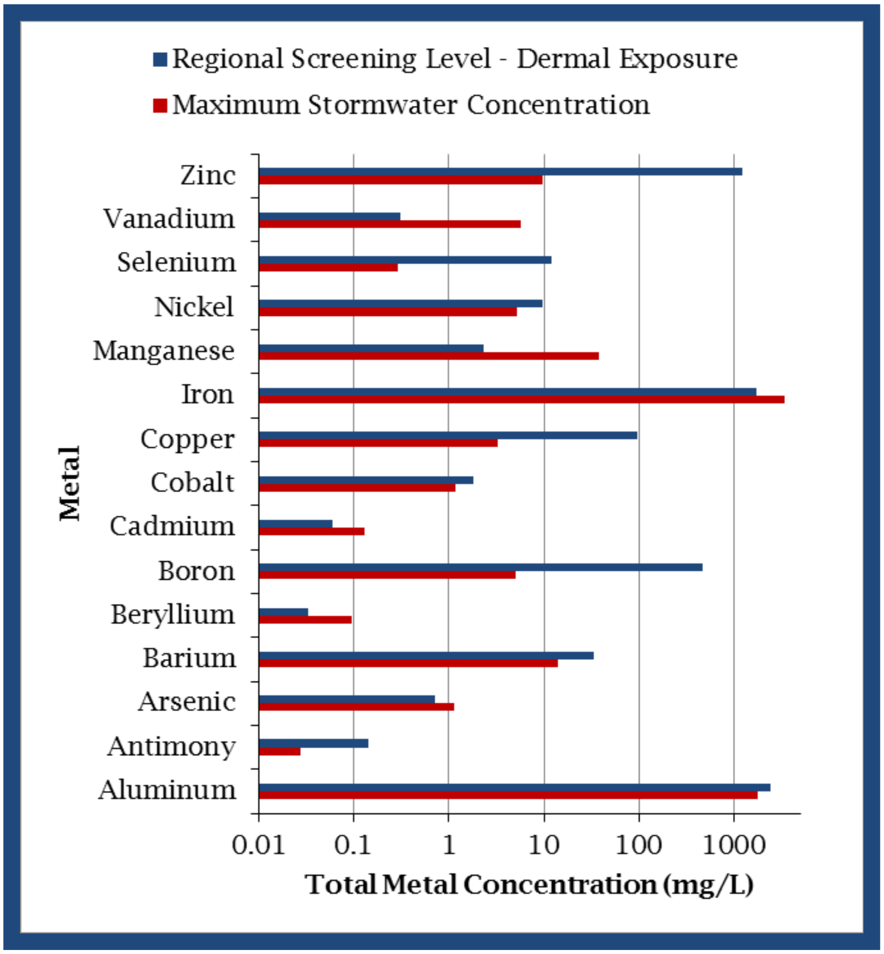
The picture to the left shows the discharge from the Line Canyon outlet during the storm on February 28, 2014.

On March 1, 2014 Line Canyon was sampled while discharging 1,300 L/s (45 cfs). This resulted in a sediment loading rate of 560,000 kg/hr (1.2 million lbs/hr), which (with an assumed sediment density of 2,500 kg/m^3) yields a loading rate of about 220 m^3 of sediment per hour. Amphitheater Canyon had higher TSS concentrations measured in samples and a much higher discharge rate that, at peak flow, was estimated to be discharging over 2,000 m^3/hr.

Toxicity of Pollutants

Various beneficial uses are designated for the watersheds, including the potential to be used for municipal and domestic water supply. Children live adjacent to (and play in) these stream channels, and during the study people were observed swimming in the effluent from the watersheds and walking barefoot up the creeks. Exposure to pollutants through dermal contact, ingestion, or inhalation can increase the likelihood of adverse health effects including cancer. The Line Canyon base flow had the greatest potential human toxicity of all water samples for dissolved metals and salts.

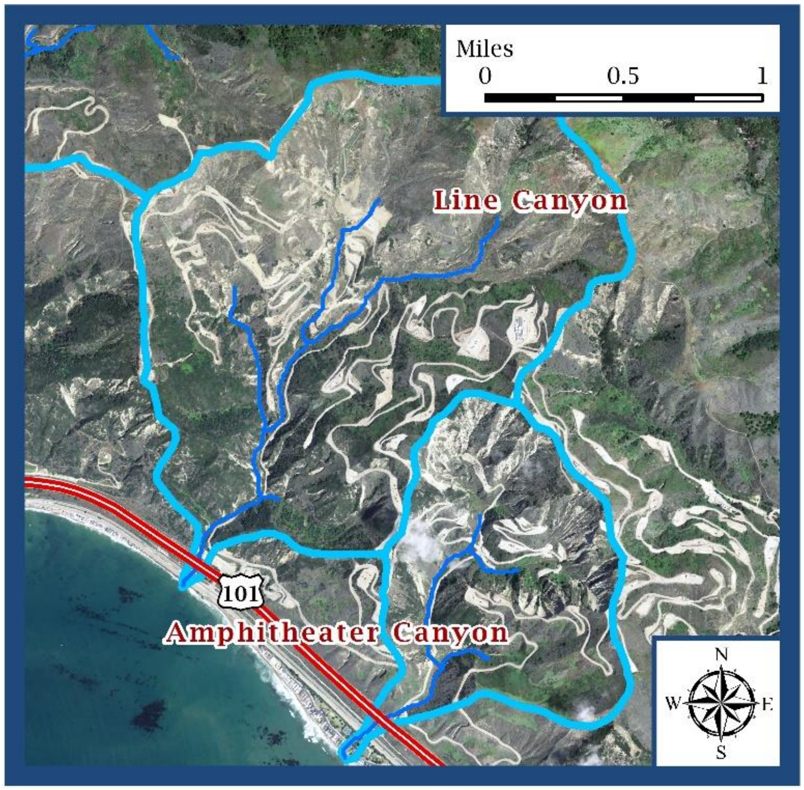
Maximum Stormwater Total Metal Concentrations



Arsenic was detected at relatively high concentrations in sediments and stormwater samples from all five canyons. Arsenic was found to have the maximum increased carcinogenic risk through residential soil exposure pathways of 18 in one million from a sediment sample collected in Javon Canyon, and 25,000 in a million for chronic dermal exposure from a water sample collected in Amphitheater Canyon. Based on EPA Regional Screening Levels (RSLs), these high concentrations of total metals (excluding arsenic) in stormwater samples are 19 and 44 times greater than what would be expected to cause no observable adverse effect from chronic dermal exposure to Line and Amphitheater Canyon stormwater, respectively. These metals are shown in the graph above with the maximum concentration detected in water samples and the RSLs for dermal exposure to tap water.

The organic pollutants detected in sediments and waters were detected at low enough concentrations that they did not have an appreciably high risk with respect to RSLs, except for the propargyl alcohol detected in one water sample from Padre Juan Canyon, which could be harmful when chronic ingestion is considered. 1,2,4- trimethylbenzene and propargyl alcohol were found to be the organics with the highest non-carcinogenic risk. The California Toxics Rule criteria identified several PAHs and bis(2-ethylhexyl)phthalate as potential pollutants of concern, most of them found in Line Canyon.

Sources of Pollutants



The primary sources of sediment, metals, and salts found in stormwater runoff are upstream geology and soils. The watersheds are in one of the most tectonically active areas on earth, and the soils are highly erosive. Oil field roads and clearings exacerbate erosion of sediment that is rich in heavy metals, increasing the transport of these metals along with carcinogenic organic compounds onto the beaches and into coastal waters.

The persistent Line Canyon base flow exhibits characteristics of a deep ground water source, and potentially originates from thousands of feet deep. The base flow may originate from or be mixed with produced water that is being injected into the oil fields as part of the water flooding enhanced oil recovery projects. Fractures and faults in the study watersheds may be providing pathways for deep groundwater or injected water that surfaces as a spring and sustains this base flow.

DRO, RRO, and PAHs were detected in the base flow, and the volume of produced water and the hazardous chemicals that are being injected into deep geologic formations pose a potential risk of deep springs being hydraulically connected to the petroleum source formations and returning these pollutants to the surface.

Project Recommendations

Recommendations have been developed for the study area based on the research and analysis presented in the four project elements: Watershed Assessment, Environmental Sampling, Toxicity Analysis, and Source Assessment.

The primary mitigation strategies focus on controlling erosion in the study watersheds, which has been linked to the mobilization and transport of toxic heavy metals that are naturally occurring in the geology of the area, and the transport of organic compounds and PAHs originating from well pads and oil field operations.

Environmental sampling, and surveys of habitat and species, should be conducted in the oil fields. Continued monitoring in the study watersheds and investigation of the Line Canyon base flow is needed for a more thorough assessment of the risks posed to people and habitats. Designated beneficial uses and environmentally sensitive areas should be reevaluated to protect human uses and receiving ecosystems. The hydraulic fracturing of wells and water flood projects used in the study area should be studied further, considering the local geology, to assess the risk of these fluids reaching the surface.

Recommendations & Mitigation Strategies

- Erosion Control
- Hazard Signage and Education
- Base Flow Investigation & Tracer Test
- Continued Monitoring
- Watershed and Erosion Modelling
- Reevaluating Beneficial Uses and Environmentally Sensitive Areas
- Environmental Sampling within Study Watersheds
- Investigate Potential Hydraulic Fracturing and Water Injection Effects in the Geologic Environment

NVCCWP Summary

The primary objectives of this project were to examine water quality in the study watersheds and test for a wide range of constituents that are known to occur in hydraulic fracturing fluids and other oil field operations. The study was exploratory in nature, and sought to assess the toxicity and identify sources of detected pollutants. The study indicates impacts to water quality from various upstream oil production operations.

Oil field roads and clearings increase the suspended sediment and metal concentrations found in stormwater, which poses a risk to people and other organisms. The Line Canyon base flow may be hydraulically connected to formations which are drilled or injected with produced water. These creeks are pathways for pollutants originating from upstream land uses and mitigation strategies should be implemented to protect human and environmental health along the coast.

WATERSHED ASSESSMENT

NORTHERN VENTURA COUNTY COASTAL WATERSHED PROJECT

The following watershed assessment was completed as part of the Northern Ventura County Coastal Watershed Project (NVCCWP), which includes Environmental Sampling, a Pollutant Source Assessment, Toxicity Analysis, and Recommendations & Mitigation Strategies.

The study area is comprised of five small coastal watersheds covering approximately ten square miles in northwestern Ventura County, California:

- Madriano Canyon
- Javon Canyon
- Padre Juan Canyon
- Line Canyon
- Amphitheater Canyon

This watershed assessment examines the physical characteristics and land uses within a study area that encompasses the five watersheds and an approximate 1 to 2 mile radius from the watershed outlets. The primary objective of this assessment is to present data and analyses to inform management of the region and identify potential concerns.

Land uses in the watersheds can impact ecosystems and recreational and residential uses of the study area. Oil field infrastructure (roads, well pads, and other clearings) is estimated to cover almost 11% of Line Canyon and 9% of Amphitheater Canyon. There are over 420 wells within the watershed boundaries, and the greatest densities of active and idle (unplugged) wells are in Line and Amphitheater Canyon. Directly downstream, the coastal marine environment sustains fisheries and is home to extensive kelp bed ecosystem habitats. This coastline has popular beaches that attract roughly 600,000 visitors per year, and there are three small beach communities near the drainages.

This watershed assessment has been split into ten sections:

1) Geology
2) Soils
3) Hydrology
4) Flora, Fauna & Habitat
5) Residential & Recreational Uses
6) Agriculture
7) Transportation
8) Oil Operations
9) Water Quality
10) Watershed Assessment Summary

Location of Study Watersheds in Southern California
Madriano Canyon
Javon Canyon
Padre Juan Canyon
Line Canyon
101
Amphitheater Canyon
Kern County
Bakersfield
San Luis Obispo County
Santa Barbara County
Santa Barbara
Ventura County
Los Angeles County
San Bernardino County
Oxnard
Los Angeles
Orange County
Irvine
N
W
E
S
BLUE TOMORROW
0
50
100
Miles

Watershed Assessment Table of Contents

How to Use This Report

This report is structured to provide the reader with an understanding of the physical and ecosystem characteristics, residential and recreational land uses, intensive land uses, and water quality in the study watersheds. The first three sections (Geology, Soils, and Hydrology) describe the physical processes and characteristics, and potential natural sources of pollutants. Sections 4.0 and 5.0 (Flora, Fauna & Habitat, and Residential & Recreational Uses) discuss ecosystem characteristics and nonextractive land uses, and potential receptors of pollutants. Section 6.0 provides information on agricultural uses in the area, which are potential receptors and possible sources of pollutants. The transportation routes and pollutants from this land use are presented in section 7.0. Oil production operations represent the most intensive extractive land use in the study area, and are described in section 8.0. Lastly, the water quality of the area is put into context in section 9.0 by examining existing water quality data and the water quality of nearby watersheds.

This report was designed to help the reader navigate and thoroughly understand the main points of the watershed assessment. At the beginning of each section there is an introduction and Section Highlights. The information in the Section Highlights is expanded in further detail in summaries at the end of each section. Data and analyses supporting these elements are given in the body of each section and organized into subsections. Section 10.0 is an overall Watershed Assessment Summary which provides the most important points relevant to the physical and ecosystem characteristics, residential and recreational land uses, intensive land uses, and water quality of the study area.

ACRONYMS

AADT	Annual Average Daily Traffic
ASBS	Area of Special Biological Significance
BMP(s)	Best Management Practice(s)
CWA	Clean Water Act
DOGGR	Department of Oil, Gas, and Geothermal Resources
DOT	Department of Transportation
DRO	Diesel Range Organics
EMC	Event Mean Concentration
EPA	Environmental Protection Agency
ET	Evapotranspiration
GIS	Geographic Information System
HCL	Hydrochloric Acid
HF	Hydrofluoric Acid
HUC	Hydrological Unit Code
MCL	Maximum Contaminant Level
MSDS	Material Safety Datasheet
NAL	Numeric Action Level
NHD	National Hydrography Dataset
NLCD	National Land Cover Dataset
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NRCS	National Resource Conservation Service
PAH(s)	Polycyclic Aromatic Hydrocarbon(s)
PET	Potential Evapotranspiration
PM10	Particulate Matter less than or equal to 10 micrometers
RWQCB	Regional Water Quality Control Board
SSURGO	Soil Survey Geographic database
STEP	Septic Effluent Pump
SWAMP	Stormwater Ambient Monitoring Program
TDS	Total Dissolved Solids
TMDL(s)	Total Maximum Daily Load(s)
TSS	Total Suspended Solids
UPRR	Union Pacific Railroad
USDA	United States Department of Agriculture
USGS	United States Geological Survey
VCWPD	Ventura County Watershed Protection District

1.0 | GEOLOGY

The geology of Ventura County is dominated by the geologic forces and rock units associated with the Transverse Range of Southern California. The geology of the Transverse Range that intersects the study area consists of Pliocene (2.6 to 5.3 million years ago) marine sedimentary rocks, Miocene (5.3 to 23 million years ago) marine sedimentary rocks, and Oligocene (23 to 33.9 million years ago) shallow marine and non-marine sedimentary rocks. These rocks have been faulted and folded by the tectonic forces of the region, which ranks as one of the most active uplifting regions in the world, giving the area a diverse and interesting geologic landscape. Tectonic plate convergence near the study area has been estimated around 23 to 27 mm per year and uplift roughly 10 mm per year [4, 9].

> **Section Highlights**
>
> - Geology in the watersheds is dominated by marine sedimentary rocks that are sources and reservoirs of petroleum
> - The study watersheds are located within one of the most tectonically active uplifting regions on Earth
> - Two active faults run through the watersheds: Javon Canyon Fault (a.k.a. Padre Juan Fault) and Red Mountain Fault
> - Marine sedimentary rock in the region is prone to high rates of erosion, and landslides are abundant throughout the watersheds
> - Many of the oil field roads in the watersheds are susceptible to failure and numerous wells have been severely damaged due to landslide activity

The sedimentary rocks dating to the Oligocene epoch include the shallow marine Vaqueros Formation and the non-marine Sespe Formation, the oldest formation in the area. The marine sedimentary rocks dated to the Miocene epoch include (from oldest to youngest) Rincon Shale, Monterey Formation, and a portion of the Sisquoc Formation. The Pliocene dated rock formations include the Sisquoc Formation and Pico Formation. Finally, the study area contains Pleistocene (2.5 million to 11,700 years ago) and Holocene (11,700 years ago to present) sedimentary deposits that are weakly to strongly cemented. These most recent deposits (from oldest to youngest) consist of the Santa Barbara Claystone, the Punta Gorda Marine Terrace, and alluvial and colluvial deposits.

Oil field operations have concentrated in the region due to the high organic content of the marine sedimentary rocks. In some locations, the Monterey Formation is a significant petroleum source rock and the Pico Formation a significant reservoir[8], but most of the Tertiary (Pliocene, Miocene, and Oligocene) rock formations act as either significant source or reservoir formations, or both. The faulting and folding also concentrate oil production operations by fracturing and increasing the porosity of reservoir formations, forcing hydrocarbons to pool in folds, thus creating larger more accessible reservoirs.

Landslides and other forms of mass wasting can be triggered by earthquakes and prolonged, intense rainfall, both prevalent in Southern California. Extreme rates of uplift and the weak nature of the folded and faulted marine sedimentary rocks make landslides a common occurrence in the study area. Landslides in the region have caused property damage and loss of life, including the destruction of wells and oil field infrastructure[5]. The La Conchita landslides of 1995 and 2005, which occurred just northwest of the study area, are examples of the region's geologic instability[6]. The La Conchita slide was reported to have occurred in the Pico Formation, which is the dominant formation in the study area.

Erosion rates in the area are high due to the uplift rate and weak geology. Measurements of sedimentation rates from nearby mountainous streams in the Transverse Range have been as high as those recorded anywhere on Earth[10]. Observations of nearby mountainous watersheds show that erosion in the region is episodic based on a cycle of colluvial deposit accumulation on hill slopes and in stream channels, which can then be mobilized by intense rain events[10].

1.1 Surficial Extent of Geology

Maps have been created for the study area to show the distribution of geologic map units, landslides, and faults. The geologic maps were created with data derived from USGS Maps published in 2003 and 2004[1,2,3]. The geologic features in these hand drawn maps were digitized and geo-referenced using ArcGIS (Figure 1.1 and 1.2).

ArcGIS was used to calculate the approximate acreage of each geologic unit and the total landslide area within each watershed. The percentage of watershed area covered by landslides and each geologic map unit was also calculated. The percentages indicate the potential influence of landslides and each geologic unit on the watershed in which they are found (Table 1.1 to 1.5).

Figure 1.1 – Distribution of Geologic Map Units within the study watersheds based on USGS maps[1,2,3]. The geologic formations are described in Section 1.3.

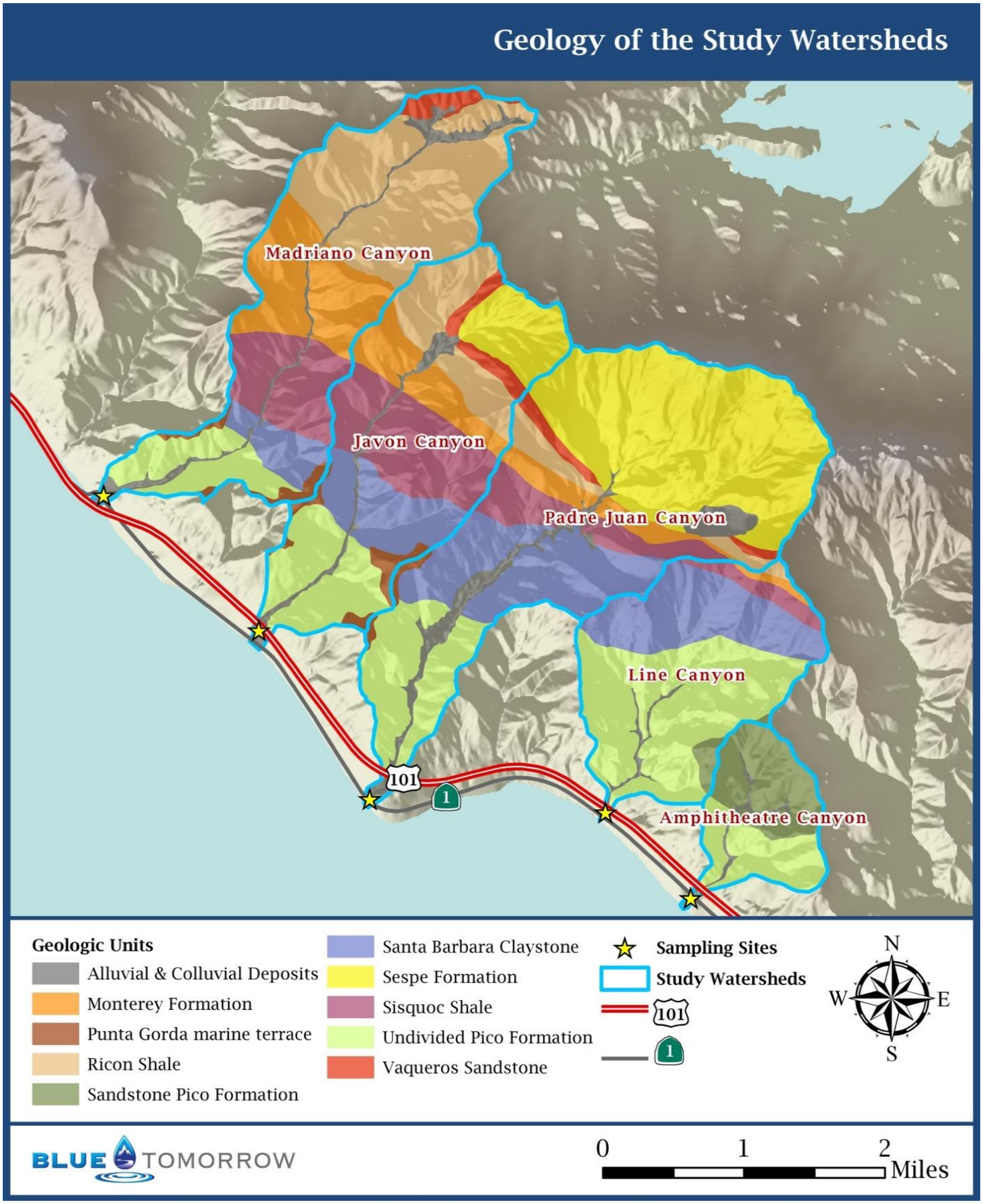
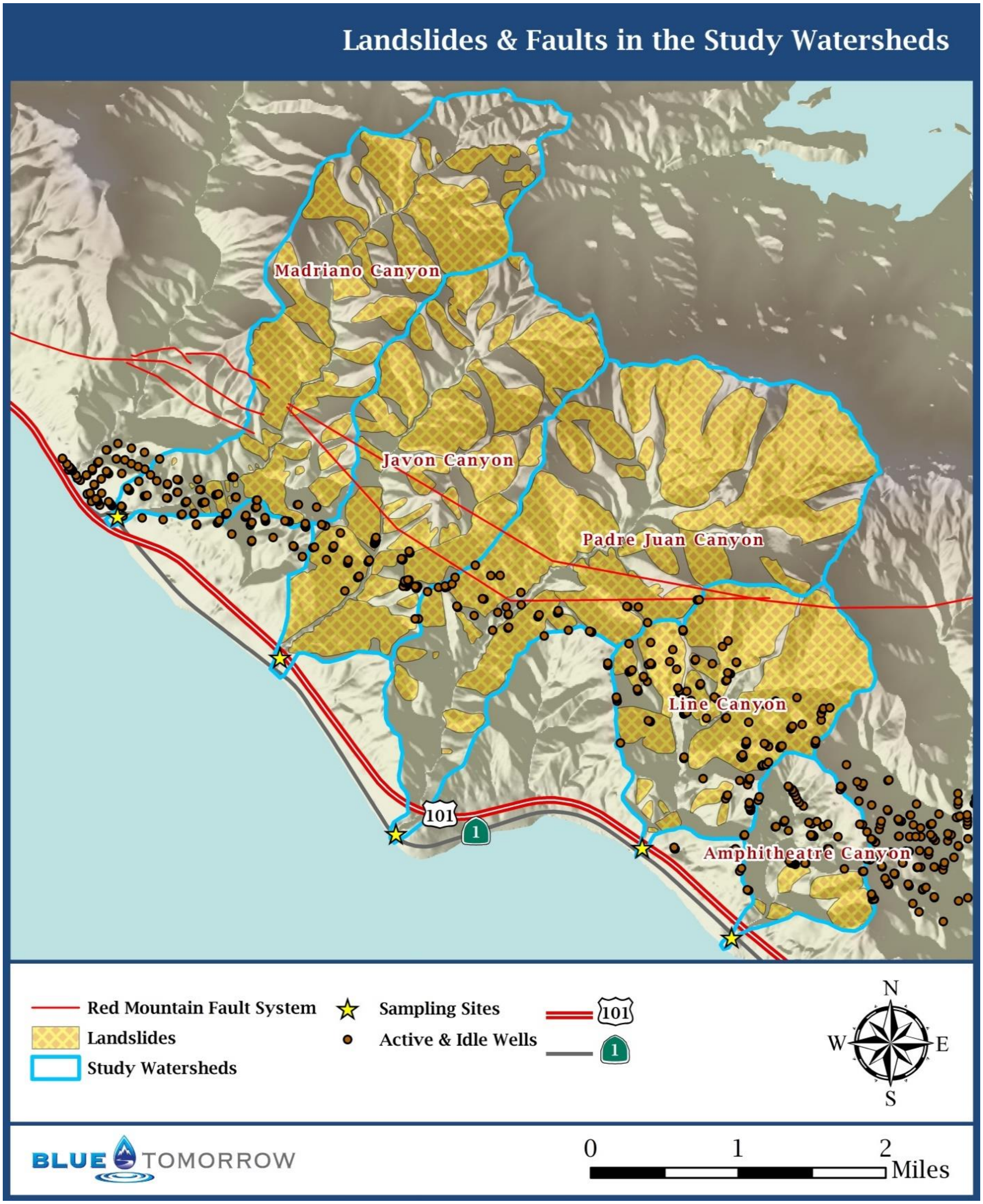


Figure 1.2 – Distribution of landslides and the approximate location of the Red Mountain Fault System based on USGS maps and California fault line data[1,2,3]. There is considerable uncertainty in the exact location of the faults in the map. This map also displays the distribution of wells within each watershed. Landslides and Faults within the study area are described in detail in Sections 1.1 & 1.2.



Madriano Canyon Watershed

The two most abundant surficial geologic units in Madriano Canyon are the Rincon Shale and Monterey Formation at 38% and 20% of the watershed areas, respectively (Figure 1.1; Table 1.1). The Rincon Shale and Monterey Formation are both Miocene marine sedimentary formations, which are primarily shale. Both formations may be significant hydrocarbon source rocks in the region and are known to be susceptible to landslides, though the Monterey Formation is often more susceptible to landslides than the Rincon shale. Landslides are abundant in both these formations and cover 48% of the watershed area (Figure 1.2; Table 1.1).

Table 1.1 – **Madriano Canyon geologic formations and landslides**

MADRIANO CANYON FORMATIONS	PERCENTAGE OF WATERSHED AREA	COVERAGE (ACRES)
Rincon Shale	38%	559
Monterey Formation	20%	294
Sisquoc Shale	14%	201
Undivided Pico Formation	11%	161
Santa Barbara Claystone	6%	84
Alluvial & Colluvial Deposits	6%	82
Vaqueros Sandstone	3%	36
Punta Gorda marine terrace	2%	34
TOTAL	**100%**	**1451**
AREA MAPPED AS LANDSLIDES	**48%**	**699**
The amount of watershed area covered by the different geologic formation and landslides were calculated from USGS maps using ArcGIS[1,2,3].		

Javon Canyon Watershed

The two most abundant surficial geologic units in Javon Canyon are the Sisquoc Shale and Undivided Pico Formation at 22% and 17% of the watershed areas, respectively (Figure 1.1; Table 1.2). The Sisquoc Shale is generally a siltstone and claystone hydrocarbon rich rock, but is known for its conglomerate lower layers, which can contain very large inclusions. The Pico Formation has a range of layers consisting of siltstone and claystone to sandstone and conglomerate. The Sisquoc Shale is generally susceptible to landslides. The Pico Formation is also noted as susceptible to landslides but the sandstone portions are generally thought to be resistant to landslides. Landslides cover 65% of Javon Canyon and are prevalent in the undivided Pico Formation, indicating the Pico formation in this area probably does not contain abundant sandstone layers and most likely consists of finer grained layers (Figure 1.2; Table 1.2).

Table 1.2 – **Javon Canyon geologic formations and landslides**

JAVON CANYON GEOLOGIC FORMATIONS	PERCENTAGE OF WATERSHED AREA	COVERAGE (ACRES)
Sisquoc Shale	22%	286
Undivided Pico Formation	17%	222
Rincon Shale	15%	195
Santa Barbara Claystone	13%	178
Sespe Formation	11%	149
Monterey Formation	11%	140
Alluvial & Colluvial Deposits	4%	52
Vaqueros Sandstone	4%	49
Punta Gorda marine terrace	4%	46
TOTAL	**100%**	**1317**
AREA MAPPED AS LANDSLIDES	**65%**	**851**
The amount of watershed area covered by the different geologic formation and landslides were calculated from USGS maps using ArcGIS[1,2,3].		

Padre Juan Canyon Watershed

The two most abundant surficial geologic units in Padre Juan Canyon are the Sespe Formation and Santa Barbara Claystone at 44% and 18% of the watershed areas, respectively (Figure 1.1; Table 1.3). The Sespe Formation is the oldest formation in the study area and the only formation, besides the very recent alluvial and colluvial deposits, that is not derived from marine sediments. In contrast, the Santa Barbara Claystone is one of the younger marine sedimentary rocks in the study area, which was likely deposited no more than 2 million years ago. The Santa Barbara Claystone is highly susceptible to landslides and erosion, whereas the Sespe Formation is one of the most resistant formations in the study area. Despite the Sespe Formation's resistance to erosion, landslides cover 61% of the watershed area (Figure 1.2; Table 1.3).

Table 1.3 – **Padre Juan Canyon geologic formations and landslides**

PADRE JUAN CANYON GEOLOGIC FORMATIONS	PERCENTAGE OF WATERSHED AREA	COVERAGE (ACRES)
Sespe Formation	44%	856
Santa Barbara Claystone	18%	354
Undivided Pico Formation	13%	256
Sisquoc Shale	7%	140
Alluvial & Colluvial Deposits	7%	130
Monterey Formation	4%	87
Rincon Shale	3%	66
Vaqueros Sandstone	2%	36
Punta Gorda marine terrace	1%	17
TOTAL	**100%**	**1942**
AREA MAPPED AS LANDSLIDES	**61%**	**1194**
The amount of watershed area covered by the different geologic formation and landslides were calculated from USGS maps using ArcGIS[1,2,3].		

Line Canyon Watershed

The two most abundant surficial geologic units in Line Canyon are the Undivided Pico Formation and Santa Barbara Claystone at 56% and 32% of the watershed areas, respectively (Figure 1.1; Table 1.4). These two formations range from claystone to sandstone and are susceptible to landslides, with the Santa Barbara Claystone being noted as highly susceptible. Line Canyon has the greatest abundance of mapped landslides out of the five watersheds in the study area, covering 70% of the watershed area (Figure 1.2; Table 1.4).

Table 1.4 – **Line Canyon geologic formations and landslides**

LINE CANYON GEOLOGIC FORMATIONS	PERCENTAGE OF WATERSHED AREA	COVERAGE (ACRES)
Undivided Pico Formation	56%	518
Santa Barbara Claystone	32%	292
Sisquoc Shale	5%	47
Sandstone Pico Formation	3%	26
Alluvial & Colluvial Deposits	2%	17
Monterey Formation	2%	15
Rincon Shale	1%	7
TOTAL	**100%**	**922**
AREA MAPPED AS LANDSLIDES	**70%**	**648**
The amount of watershed area covered by the different geologic formation and landslides were calculated from USGS maps using ArcGIS[1,2,3].		

Amphitheater Canyon Watershed

The two most abundant surficial geologic units in Amphitheater Canyon are the Sandstone Pico Formation and Undivided Pico Formation at 52% and 42% of the watershed areas, respectively (Figure 1.1; Table 1.5). The Undivided Pico Formation is typically susceptible to landslides, while the Sandstone Pico Formation is known to be resistant. Amphitheater Canyon has the least abundance of mapped landslides relative to watershed area out of the five study watersheds, at about 19%, which could be due to the resistance of the sandstone portion of the Pico Formation (Figure 1.2; Table 1.5).

Table 1.5 – **Amphitheater Canyon geologic formations and landslides**

AMPHITHEATER CANYON GEOLOGIC MAP UNITS	PERCENTAGE OF WATERSHED AREA	COVERAGE (ACRES)
Sandstone Pico Formation	52%	186
Undivided Pico Formation	42%	149
Alluvial & Colluvial Deposits	6%	20
TOTAL	**100%**	**355**
AREA MAPPED AS LANDSLIDES	**19%**	**67**
The amount of watershed area covered by the different geologic formation and landslides were calculated from USGS maps using ArcGIS[1,2,3].		

1.2 Tectonic Faulting & Folding

The study area is transected by two faults, the Javon Canyon Fault (a.k.a. Padre Juan Fault) and Red Mountain Fault. These two faults are separated by the Ventura Avenue Anticline (western portion a.k.a. Rincon Anticline), which concentrates the hydrocarbon reservoir (and resulting oil fields) along its axis. These geologic structures are oriented northwest-southeast and generally perpendicular to the orientation of the watersheds[4] (Figure 1.2). The major faults bisect all the watersheds except Amphitheatre Canyon.

The tectonic activity in the study area is one of the most prominent in the world. Maximum uplift of the Ventura Avenue Anticline has been measured between 10 and 15 mm per year, rivaling any current known uplift rate[9]. The vertical slip displacement of the Javon Canyon fault was determined by Sarna-Wojcicki et al. (1980) by measuring the displacement of the Pleistocene Punta Gorda Marine Terrace. This long-term stress and displacement rate was determined to be about 1.1 mm per year and has been relatively constant over the last 50,000 years. The Javon Canyon Fault, which is clearly exposed in Javon Canyon, is estimated to have ruptured four to five times in the last 3,500 years[9].

The faults intersecting the study area may impact oil field operations by severing or damaging oil well casings, potentially resulting in leaks that may go undetected for a long time. The folding and faulting of the region also increases the likelihood of landslides by creating steep slopes, uplifting and orienting sedimentary beds parallel to slopes, and generating earthquakes that can trigger slides.

1.3 Landslides

Landslides, including debris flow, soil creep, soil slumps and flows, rock fall, or any other mass movement of soil and or rocks, are widespread throughout the study watersheds and surrounding areas. Roughly 58% of the mapped study area shows evidence of landslides, with the greatest occurrence in Line Canyon at about 70% of the watershed (Figure 1.2). The large number of landslides in the study region has been attributed to the fast uplift and significant deformation in the recent geologic past combined with weak sedimentary rocks and steeply entrenched valleys[4]. Most of the landslides in the region are dormant, but many are still active and a wet winter or significant earthquake could trigger dormant slides to move.

The La Conchita landslide, triggered in 1995 and again in 2005, which resulted in loss of life and significant property damage, consisted of Pico and Monterey formation geology, and was in direct contact with the Red Mountain Fault[6]. The Pico Formation is the greatest occurring formation in the surficial geology of the study area and has been recognized as especially prone to landslides, although all the sedimentary rocks have been prone to landslides[4, 5, 6].

Landslides have the potential to directly impact the oil field in the study area, and have in the past. From field observations and aerial photographs, the California Geological Survey has found that most oil field roads in the study area require constant rebuilding and re-grading due to landslide activity, and many roads continue to fail after rehabilitation[4, 5]. In 2002, three wells in the study area were impacted significantly by an active landslide, and were subsequently plugged. In 2004, while conducting environmental inspections, district staff identified several locations within the study area where significant landslide movement was evident. After the inspections, eight wells were plugged and abandoned following department recommendations[12].

In the nearby east Ventura oil field, landslides that occurred between 1920 and 1970 were associated with the destruction of 61 wells, of which only 53 were subsequently repaired[5]. The operators of the east Ventura oil field reported an episode of landslides that occurred in 1926 and destroyed equipment and several wells. After the 1926 event the oil field operator stated "the danger of placing facilities upon such slide areas, and more particularly, the drilling of wells within these areas did not occur to the Company's operating personnel until severe and large earth movements took place[5]." The most notable landslide events in the region occurred in

1920, 1931, 1941, 1958, and 1969, after which geologist and engineers surveyed the slides in the east Ventura oil field and put forth the opinion that the landslides resulted from infiltration of water into the formation[5]. The general recommendation at the time was to dewater the formation and to grade and oil the surface to prevent infiltration of water[5].

1.4 Geologic Formations

A total of 10 geologic units have been mapped within the study area. All the geologic units in the study area are sedimentary rocks of marine origin, with the exception of the Sespe Formation and Alluvial & Colluvial deposits, which are non-marine sedimentary rocks and deposits. The marine sedimentary rocks in the region are significant hydrocarbon sources and reservoirs, hence the oil production activities in the region. Sedimentary rock are typically soft and weak and, therefore, prone to very high rates of erosion. Descriptions of the geologic units are given below in chronological order starting with the youngest unit and ending with the oldest.

Alluvial & Colluvial Deposits
Pleistocene & Holocene (last 2.6 million years) – Covers 5% of entire study area

Alluvium is defined as sedimentary material transported and deposited by water, while colluvium is hill slope derived material transported by gravity without water entrainment. Alluvium tends to be better sorted and organized sediment than colluvium, and is often found in layers of different grain sizes.

Alluvial and colluvial deposits occur in all the study watersheds in the valley bottoms and along stream channels. These surficial deposits have the greatest coverage relative to watershed area in Padre Juan Canyon at about 7% of the watershed area. The geologic formations that intersect these deposits are present underneath but for this analysis these deep deposits are considered surficial geology.

The alluvium and colluvium deposited within the Holocene (the last 11,700 years) are mostly unconsolidated sandy clay with some gravel. These deposits are eroded from the sandstone-rich bedrock formations. The alluvium deposits that date to the Pleistocene epoch (about 2.6 million to 11,700 years ago) are unconsolidated and consolidated silt, sand, clay, and gravel[1, 2, 3]. The Pleistocene alluvium is only found in a single isolated deposit in the upper reaches of Padre Juan Canyon (Figure 1.1).

Punta Gorda marine terrace

Late Pleistocene – Covers 2% of the entire study area

The Punta Gorda marine terrace is an inter-fingering of marine and terrestrial sediments dated 40,000 to 60,000 years old[1, 2, 3]. These marine terrace deposits cap the canyon ridges between Madriano, Javon, and Padre Juan Canyons, and consist of consolidated clayey sand with gravel lenses[1, 2, 3].

The Punta Gorda marine terrace has the greatest coverage relative to watershed area found in Javon Canyon at 4% (Table 1.2).

Santa Barbara Claystone

Pleistocene (2.6 million to 11,700 years ago) – Covers 15% of the entire study area

The Santa Barbara Claystone is a marine sedimentary rock that locally contains Monterey Formation shale fragments and is noted for its highly susceptibility to landsides[1, 2, 3]. This formation contains fine to medium grained sandstone and pebbly sandstone that is weakly to strongly cemented with carbonate[7]. The Santa Barbara Claystone Formation also contains a diversity of marine invertebrate fossils[8].

The Santa Barbara Claystone has the greatest coverage relative to watershed area in Line Canyon at about 32% (Table 1.4).

Undivided Pico Formation

Pliocene (5.3 to 2.6 million years ago) – Covers 22% of the entire study area

The undivided Pico Formation is a marine sedimentary rock consisting of claystone, siltstone, and sandstone, that is locally pebbly and generally susceptible to landslides[1, 2, 3]. The Pico Formation typically can be divided into six members, but the only distinguished member mapped in the study area is the sandstone Pico Formation described below.

The undivided Pico Formation has the greatest occurrence relative to watershed area in Line Canyon at about 56% (Table 1.4). Collectively, the Pico Formation (undivided plus sandstone) is the most prevalent surficial geology in the study area at about 26% of the entire area.

Sandstone Pico Formation

Pliocene (5.3 to 2.6 million years ago) – Covers 4% of the entire study area

The sandstone Pico Formation is the only one out of six members of the Pico Formation that is individually mapped in the study area. The other members may be represented in the undivided Pico Formation map units. The sandstone member of the Pico Formation is well bedded, pebbly sandstone and includes some interbedded claystone[4]. The sandstone Pico Formation is generally resistant to landslides[1, 2, 3].

The sandstone Pico Formation has the greatest occurrence relative to watershed area in Amphitheatre Canyon at about 52% (Table 1.5). Collectively, the Pico Formation (undivided plus sandstone) is the most prevalent surficial geology in the study area at about 26% of the entire area.

Sisquoc Shale
Pliocene-Miocene (around 5.3 million years ago) – Covers 11% of the entire study area

The Sisquoc Shale is a marine sedimentary rock that consists of a silty shale or claystone and is generally susceptible to landslides[1, 2, 3]. The Sisquoc Shale also has higher than average levels of silica and diatom fossils, and may contain layers of sandstone derived from volcanic material in areas[4, 5]. This formation is known for its thick beds of conglomerate that contain large pieces of Monterey Formation, some up to 10 meters across[8].

The Sisquoc Shale has the greatest occurrence relative to watershed area in Javon Canyon at 22% (Table 1.2). The Sisquoc Shale in the study area has enough organic content that it may qualify as a hydrocarbon source rock[7].

Monterey Formation
Miocene (23 to 5.3 million years ago) – Covers 9% of the entire study area

The Monterey Formation is a marine sedimentary rock that consists of hard siliceous shale with some soft clay shale in the lower portions of the unit[4, 5]. This formation, also known as the Modelo Formation, contains some sandstone and limestone rich layers[1, 2, 3, 4]. The Monterey Formation has abundant levels of silica and diatom fossils and is generally susceptible to landslides[1, 2, 3].

The Monterey Formation is known for its high organic content and role as a major hydrocarbon source rock in the region[7]. The maximum thickness of this formation has been estimated around 830 meters, and portions of the formation that are highly fractured act as oil reservoirs[7].

The Monterey Formation has the greatest coverage relative to watershed area in Madriano Canyon at about 20% (Table 1.1).

Rincon Shale

Miocene (23 to 5.3 million years ago) – Covers 14% of the entire study area

The Rincon Shale is a marine sedimentary rock that consists of clay shale and siltstone, and is susceptible to landslides[1, 2, 3, 4, 5]. This rock unit also contains areas of bentonite clay in the upper and lower portions of the formation, and has some siliceous shale, sandstone, and tuff[4, 5]. The Rincon Shale is generally less resistant to erosion than the Monterey Formation[7].

The Rincon Shale has the greatest coverage relative to watershed area in Madriano Canyon at 38% (Table 1.1). The Rincon Shale within the study area has enough organic content to qualify as an important hydrocarbon source rock[7].

Vaqueros Sandstone

Early Miocene (about 23 million years ago) – Covers 2% of the entire study area

The Vaqueros Sandstone is a shallow marine sedimentary rock that consists of weakly to moderately cemented fine-grained sandstone and conglomerate containing calcium carbonate and feldspar[1, 2, 3, 4, 5, 7]. Vaqueros Sandstone is moderately to strongly resistant to erosion and is a prominent cliff forming unit[7].

A proportion of the oil that is produced in the region is derived from Vaqueros Sandstone oil reservoirs. The regional thickness of this formation has been estimated to be about 100 meters[11].

The Vaqueros Sandstone has the greatest coverage relative to watershed area in Javon Canyon at 4% (Table 1.2).

Sespe Formation

Oligocene (23 to 33.9 million years ago) – Covers 17% of the entire study area

The Sespe Formation is the oldest geologic formation in the study area. This formation is characterized as a non-marine fluvial sandstone, mudstone, and conglomerate with some siltstone and claystone[1, 2, 3, 4, 5]. The Sespe Formation is moderately hard and is more resistant to erosion and landslides than the other younger and weaker sedimentary formations in the study area[4, 5]. The Sespe Formation has the greatest coverage relative to watershed area in Padre Juan Canyon at 44% (Table 1.3).

1.5 Geology Summary

The study watersheds are located within one of the most tectonically active uplifting regions on Earth, with estimated uplift rates being as high as 0.4 inch per year. The tectonic activity is highlighted by the two active faults that run through the watersheds: Javon Canyon Fault (a.k.a. Padre Juan Fault) and Red Mountain Fault. Marine sedimentary rocks cover approximately 77% of the study watersheds (excluding the Punta Gorda Marine terrace and areas covered by alluvial and colluvial deposits). These sedimentary rocks act as both sources and reservoirs of petroleum hydrocarbons, where the Ventura Avenue Anticline has attracted oil extraction operations to the region.

Marine sedimentary rock found in the study watersheds is prone to high rates of erosion and landslides due to the weak nature of the rock and fast uplift rates which cause slope instability. Landslides are mapped as about 58% of the study watersheds. Oil field roads in the watersheds need to be frequently rebuilt and re-graded, and many wells have been severely damaged due to landslide activity.

1.6 Geology References

1) Tan, S.S., and Clahan, K.B., 2004, Geologic map of the White Ledge Peak 7.5′ quadrangle, Santa Barbara and Ventura Counties, California—A digital database: California Geological Survey Preliminary Geologic Map, scale 1:24,000. Available at: http://www.conservation.ca.gov/cgs/rghm/rgm/preliminary_geologic_maps.htm.

2) Tan, S.S., Jones, T.A., and Clahan, K.B., 2003a, Geologic map of the Pitas Point 7.5′ quadrangle, Ventura County, California—A digital database: California Geological Survey Preliminary Geologic Map, scale 1:24,000. Available at: http://www.conservation.ca.gov/cgs/rghm/rgm/preliminary_ geologic_maps.htm.

3) Tan, S.S., Jones, T.A., and Clahan, K.B., 2003b, Geologic map of the Ventura 7.5′ quadrangle, Ventura County, California—A digital database: California Geological Survey Preliminary Geologic Map, scale 1:24,000, Available at: http://www.conservation.ca.gov/cgs/rghm/rgm/preliminary_geologic_maps.htm

4) California Geological Survey, 2002. Seismic hazard zone report for the Pitas Point 7.5-minute quadrangle, Ventura County, California. Available at: http://gmw.consrv.ca.gov/shmp/download/evalrpt/pitap_eval.pdf.

5) California Geological Survey, 2003. Seismic hazard zone report for the Ventura 7.5-minute quadrangle, Ventura County, California. Available at: http://gmw.consrv.ca.gov/shmp/download/evalrpt/vent_eval.pdf.

6) Jibson, R.W., 2005. Landslide Hazards at La Conchita, California. US Geological Survey. Open-File Report 2005-1067. Available at: http://pubs.usgs.gov/of/2005/1067/pdf/OF2005-1067.pdf.

7) Minor, S.A., Kellogg, K.S., Stanley, R.G., Gurrola, L.D., Keller, E.A., and Brandt, T.R., 2009, Geologic map of the Santa Barbara coastal plain area, Santa Barbara County, California: U.S. Geological Survey Scientific Investigations Map 3001, scale 1:25,000, 1 sheet, pamphlet 38 p. Available at: http://pubs.usgs.gov/sim/3001/.

8) Johnson, S.Y., Dartnell, P., Cochrane, G.R., Golden, N.E., Phillips, E.L., Ritchie, A.C., Kvitek, R.G., Greene, H.G., Endris, C.A., Seitz, G.G., Sliter, R.W., Erdey, M.D., Wong, F.L., Gutierrez, C.I., Krigsman, L.M., Draut, A.E., and Hart, P.E. (S.Y. Johnson and S.A. Cochran, eds.), 2013, California State Waters Map Series—Offshore of Carpinteria, California: U.S. Geological Survey Scientific Investigations Map 3261, 42 p., 10 sheets. Available at: http://pubs.usgs.gov/sim/3261/.

9) Sarna-Wojcicki, A.M., Lajoie, K.R., Yerkes, R.F., 1980. Recurrent Holocene Displacement on the Javon Canyon Fault – A Comparison of Fault-Movement History with Calculated Average Recurrence Intervals. Recent Reverse Faulting in the Transverse Ranges, California. US Geological Survey Professional Paper 1339.

10) Scott, K.M., Williams, R.P., 1978. Erosion and sediment yields in the Transverse Ranges, Southern California. US Geological Survey Professional Paper 1030.

11) Dibblee, T.W., Jr., 1982, Geology of the Santa Ynez-Topatopa Mountains, Southern California, in Fife, D.L., and Minch, J.A., eds., Geology and mineral wealth of the California Transverse Ranges: Santa Ana, California, South Coast Geological Society Annual Symposium and Guidebook no. 10, p. 41–56.

12) California Department of Conservation. Division of Oil, Gas, and Geothermal Resources (DOGGR). Annual Reports of the State Oil & Gas Supervisor. Available at:http://www.conservation.ca.gov/dog/pubs_stats/annual_reports/Pages/annual_reports.aspx

2.0 | SOILS

Soil characteristics have a direct influence on the runoff patterns and water quality of the study watersheds. The depth, porosity, and hydraulic conductivity of different soils influence the amount of water that is infiltrated and stored as soil moisture, as well as the timing and quantity of runoff.

Several characteristics of soils in the study watersheds can affect water quality and the fate and transport of pollutants. Soils can impact water quality by leaching salts and metals, influencing TDS, conductivity, and the acidity and alkalinity of streams. Organic matter can influence the transport of many pollutants that readily sorb to organic particles. The steep slopes of the study watersheds can also have a considerable effect on the transport of pollutants by increasing the potential for overland flow, and increasing the source of Total Suspended Solids (TSS) and Total Dissolved Solids (TDS) through erosion. Very small silt and clay particles, which are characteristic of the soils found in the study watersheds, easily suspend in water, and can impact the level of TSS in the streams.

Section Highlights

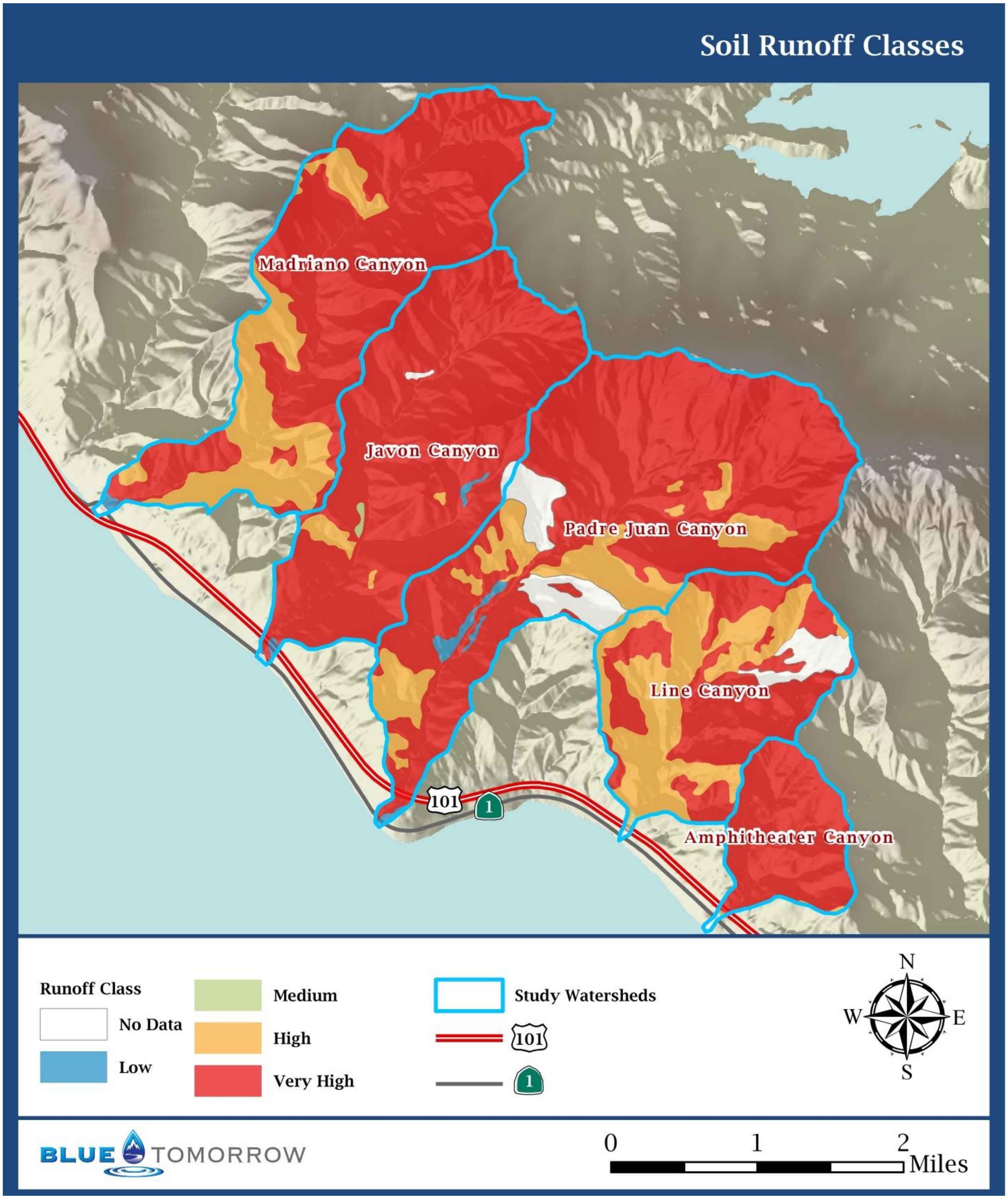
- Soils influence groundwater infiltration, runoff, water quality, erodibility, and fate and transport of pollutants
- Hydraulic conductivity of soils in the watersheds is low, with saturated vertical hydraulic conductivity ranging from 0.26 to 2.6 feet per day
- Javon Canyon has the most erodible soils, while soils in Line Canyon have the lowest tendency to erode (based on soil texture, and not considering slope)
- Alluvial soils (deep soils that are moderately alkaline with low runoff potential) cover roughly 3% of the watersheds
- Hillslope soils (shallow soils that are more acidic and have higher runoff potential than alluvial soils) comprise approximately 81% of soils in the watersheds
- Miscellaneous soils cover 16% of the study watersheds and are areas that may generate significant runoff and sediment transport

Soil descriptions in this section outline the physical characteristics of the soils. All soils data and descriptions are derived from the USDA Soil Survey Geographic database (SSURGO) and Natural Resource Conservation Service (NRCS) Official Soil Descriptions databases and associated soil surveys[2, 3]. The map units are areas delineated by a combination of field surveys and evidence from aerial photographs. The descriptions of the soil map units are assumed to represent the dominant characteristics of the designated areas but may contain other soil types, characteristics, and (or) variations not described. These descriptions use the surface runoff class terminology established by the USDA Soil Survey Manual and the USDA NRCS Field Book for Describing and Sampling Soils[1, 4].

2.1 Surface Runoff Classes

Surface runoff classes are relative, not quantitative, and assume the soil surface is bare and surface ponding is low[1].These relative surface runoff classes are based solely on topographic slope and the saturated hydraulic conductivity of the soil, which is a parameter describing the resistance to saturated groundwater flow caused by the soil (see Section 2.2). The majority of the soil map units within the study watersheds have a high to very high runoff class (Figure 2.1) due to the steep slopes and low hydraulic conductivity of the soils. Quantifying the actual surface runoff for a given soil type or location in the study area requires hydrologic modeling, which is beyond the scope of this project. All soil map unit descriptions in Section 2.5 have the surface runoff class italicized under the soil series or miscellaneous area name.

Figure 2.1 – Soil Runoff Classes of soil types within the study watersheds. Data is from the USDA SSURGO database[3]. Landslide areas do not have data on the runoff class.

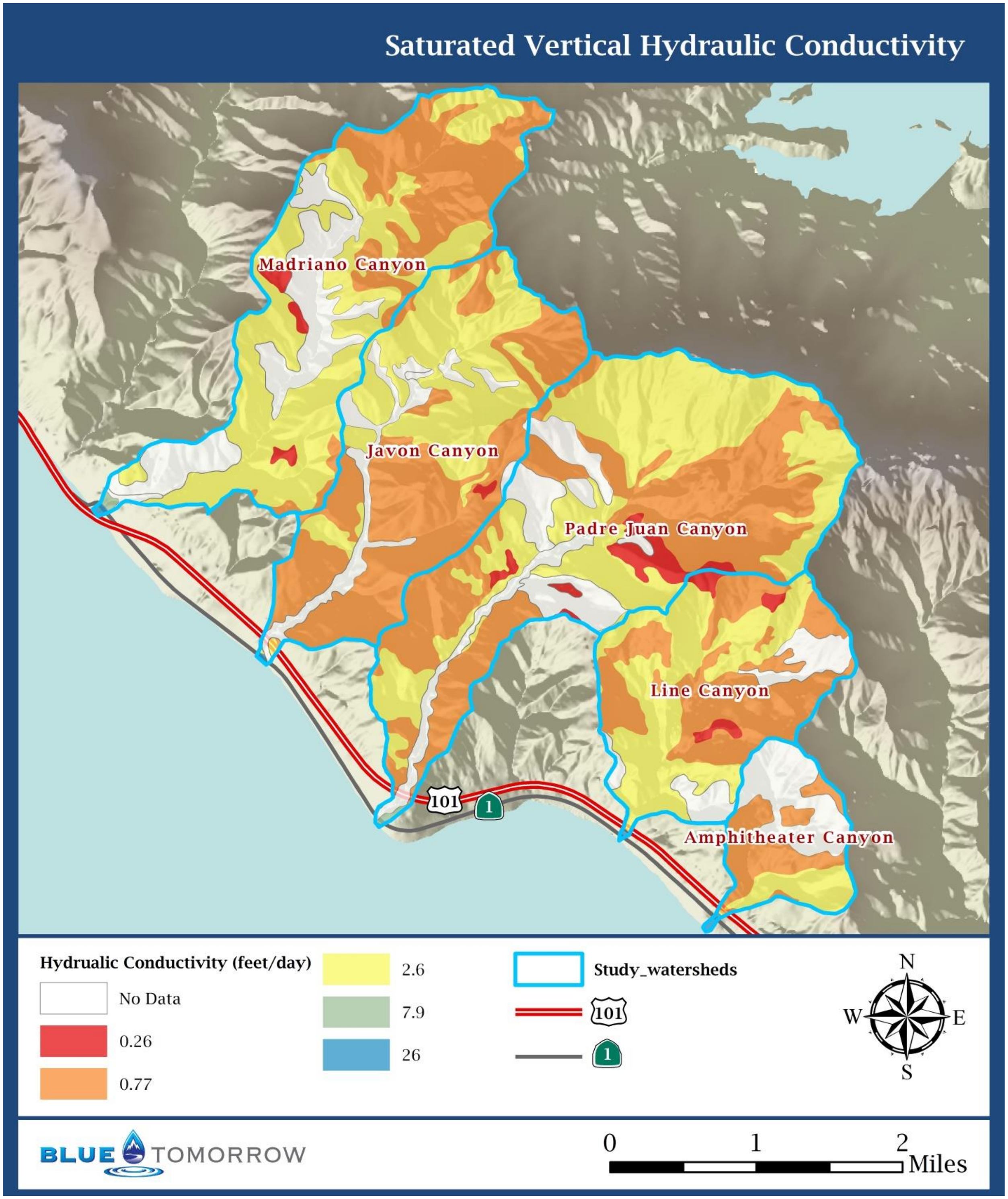


2.2 Vertical Hydraulic Conductivity

Soil hydraulic conductivity is a quantitative measure of a soil's resistance to groundwater flow. Saturated vertical hydraulic conductivity dictates infiltration rates during large storm events and influences surface runoff generation. Hydraulic conductivity can have wide ranges even within the same soil type due to the intrinsic heterogeneous nature of soils; therefore, a representative value was used in this analysis.

The representative values of saturated vertical hydraulic conductivity for the soil types found in the watersheds range from 0.26 to 2.6 feet per day ($9.2x10^{-5}$cm/s to $9.2x10^{-4}$cm/s), with small areas at the outlets of the watersheds having higher representative values (Figure 2.2). Miscellaneous areas do not have hydraulic conductivity data, but badland and gullied land are assumed to have very low hydraulic conductivity values due to the limited or nonexistent soil in these areas.

Figure 2.2 – Saturated vertical hydraulic conductivity of soil types within the study watersheds. Data is from the USDA SSURGO database[3]. Miscellaneous areas do not have data, but badland and gullied land likely have low hydraulic conductivity values.

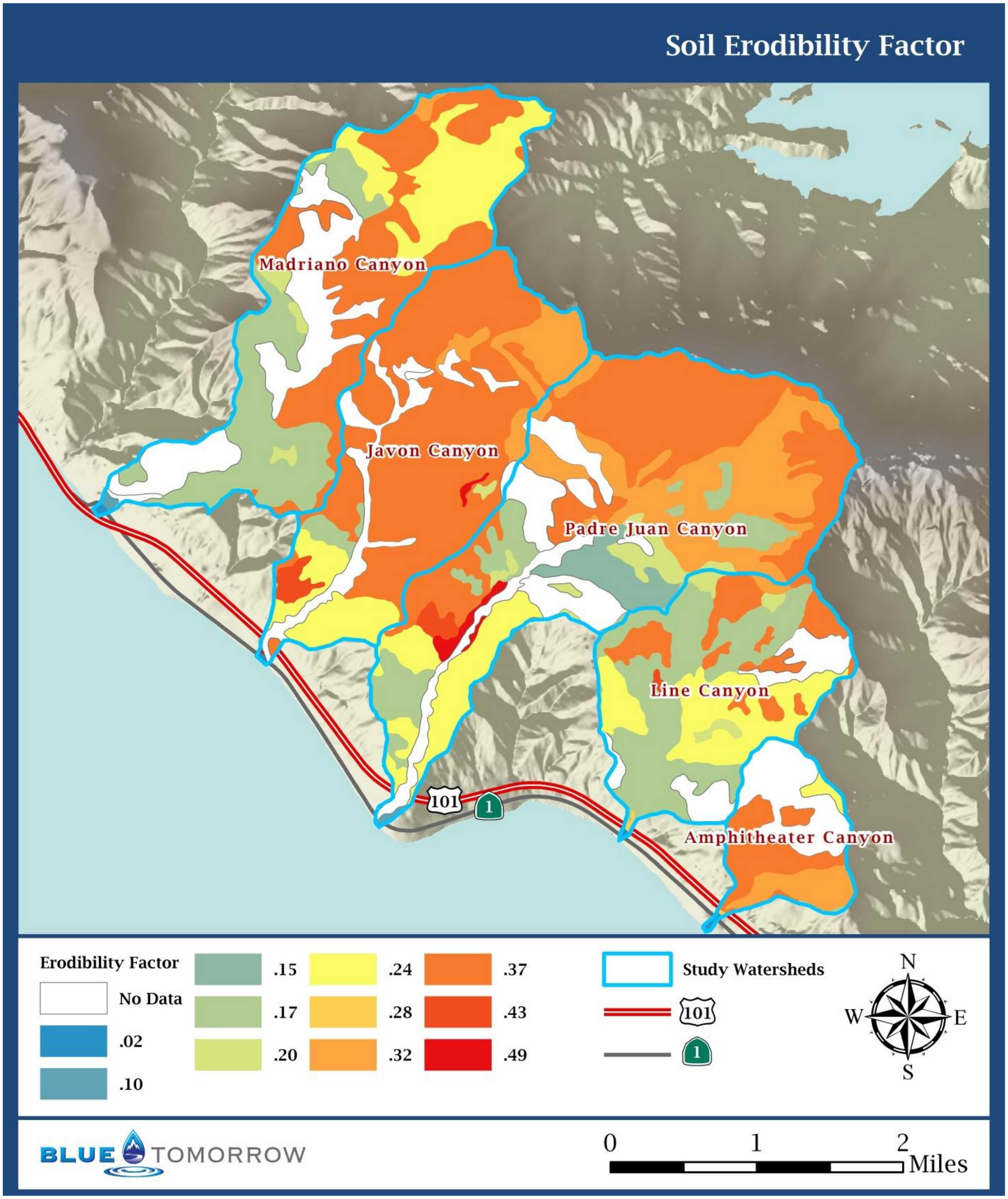


2.3 Erodibility Factor

The erodibility factor is a quantitative measure of the tendency of soil particles to be transported by water. The erodibility factor is a parameter used in the universal soil loss equation to model soil loss, and ranges in value from 0.02 to 0.69. This parameter is mainly influenced by the particle sizes constituting the soil. The most erodible soils with the highest erodibility factors are in the silt range. Undisturbed clay soils have higher cohesion and resist detachment compared to silt, while sandy and rockier soils have greater permeability and larger particle size reducing the likelihood of transport. The soil erodibility factor values shown in Figure 2.3 take into account rock fragments, but do not take into account slope, which is very steep in many parts of the watersheds and has a strong influence on erosion rates.

The soil erodibility of the study watersheds generally ranges from 0.15 to 0.49 with small areas at the outlets having lower erodibility values. The dominant erodibility value is 0.37 and is most widespread in Javon Canyon (Figure 2.1). The least erodible soils are found in Line Canyon.

Figure 2.3 – Soil erodibility factor of soil types within the study watersheds. Data is from the USDA SSURGO database[3]. Miscellaneous areas do not have data, but badland and gullied land are known for their high erosion rates.



2.4 Extent of Soil Types

ArcGIS was used to calculate the approximate acreage and percentage of watershed area covered by each soil map unit within each watershed (Tables 2.1 to 2.5; Figure 2.4). The percentages indicate the potential influence each soil map unit may have in the watershed. For example, Badland, a Miscellaneous Area with high runoff and erosion potential, is found in over 40% of the watershed area in Amphitheater Canyon, and thus is expected that Badland has a large influence on the characteristics and hydrology of Amphitheater Canyon (Table 2.5). All soils data is from the USDA Soil Survey Geographic (SSURGO) Database[3].

Madriano Canyon Watershed

The three most widespread soil types in Madriano Canyon are Calleguas shaly loam, Los Osos clay loam, and Millsholm-Malibu complex at 24.4%, 19.2%, and 16.6% of the watershed areas, respectively. Additionally, badland covers 20.3% of Madriano Canyon (totaling 80.5%; Table 2.1).

The Calleguas and Millsholm soil types are shallow soils with low-medium to high runoff potential and up to 35% shale fragments. The Los Osos and Malibu soil types are moderately deep with high to very high runoff potential and are much more clay rich and less rocky than the Calleguas and Millsholm soil types.

The oil wells, oil field roads, and associated operations in Madriano Canyon are located within the badlands and Calleguas shaly loam map units, near the outlet of the watershed.

Table 2.1 – **Madriano Canyon soil map units**

SOIL MAP UNIT	PERCENTAGE OF WATERSHED AREA	AREA (ACRES)
Calleguas shaly loam	24.4%	355
Badland	20.3%	294
Los Osos clay loam	19.2%	278
Millsholm-Malibu complex	16.6%	241
Millsholm loam	7.5%	109
Nacimiento silty clay loam	4.9%	71
Linne silty clay loam	3.7%	54
Diablo clay	1.7%	25
Sespe clay loam	0.8%	11
Terrace escarpments	0.5%	7
Pico sandy loam	0.3%	4
Coastal beaches	0.2%	3
TOTAL	**100%**	**1452**
Watershed area covered by the different soil map units was calculated from SSURGO data using ArcGIS.		

Javon Canyon Watershed

The three most widespread soil types in Javon Canyon are Millsholm-Malibu complex, Nacimiento silty clay loam, and San Benito clay loam at 32.1%, 28.1%, and 10.2% of the watershed areas. Additionally, Gullied land and Landslides cover 10.8% of Javon Canyon (Totaling 81.2%; Table 2.2).

The Millsholm soil type is a shallow soil with low-medium to high runoff potential and up to 35% shale fragments. The Malibu and Nacimiento soil types are moderately deep. Malibu soils are classified as having high to very high runoff potential, while Nacimiento soils have medium to high runoff potential. The San Benito soil type is a deep soil with medium to very high runoff potential.

The oil wells, oil field roads, and associated operations in Javon Canyon are located within the Nacimiento silty clay loam, Calleguas shaly loam, and San Benito clay loam map units in the lower third of Javon Canyon.

Table 2.2 – **Javon Canyon soil map units**

SOIL MAP UNIT	PERCENTAGE OF WATERSHED AREA	AREA (ACRES)
Millsholm-Malibu complex	32.1%	423
Nacimiento silty clay loam	28.1%	370
San Benito clay loam	10.2%	134
Gullied land	10.1%	133
Sespe clay loam	8.8%	116
Linne silty clay loam	2.9%	39
Castaic-Balcom complex	1.9%	25
Calleguas shaly loam	1.6%	22
Malibu loam	1.3%	17
Lodo rocky loam	0.8%	11
Landslides	0.7%	9
Garretson silt loam	0.4%	5
Diablo clay	0.3%	4
Garretson gravelly loam	0.3%	4
Garretson loam	0.2%	3
Coastal beaches	0.1%	1
Rincon silty clay loam	0.0%	1
TOTAL	**100%**	**1317**
Watershed area covered by the different soil map units was calculated from SSURGO data using ArcGIS.		

Padre Juan Canyon Watershed

Padre Juan Canyon has the greatest diversity of soils among the five watersheds. The three most widespread soil types in Padre Juan Canyon are Lodo rocky loam, Sespe clay loam, and San Benito clay loam at 26.2%, 22.2%, and 9.7% of the watershed areas, respectively. Additionally, Gullied land and Landslides cover 13.6% of the Padre Juan Canyon (Totaling 71.7%; Table 2.3).

The Lodo soil type is a shallow soil with medium to high runoff potential and up to 35% pebble size rock fragments. The Sespe soil type is a moderately deep with high to very high runoff potential, with generally less than 5% rock fragments of gravel size or larger. The San Benito soil type is a deep soil with medium to very high runoff potential.

The oil wells, oil field roads, and associated operations in Padre Juan Canyon are mainly located within the Nacimiento silty clay loam, Linne silty clay loam, and San Benito clay loam map units in the middle reaches of the watershed, with some additional activity in the areas mapped as Landslides and Calleguas shaly loam.

Table 2.3 - **Padre Juan Canyon soil map units**

SOIL MAP UNIT	PERCENTAGE OF WATERSHED AREA	AREA (ACRES)
Lodo rocky loam	26.2%	510
Sespe clay loam	22.2%	431
San Benito clay loam	9.7%	189
Gullied land	7.2%	141
Landslides	6.4%	124
Santa Lucia shaly silty clay loam	5.0%	96
Calleguas-Arnold complex	3.7%	71
Diablo clay	3.6%	69
Calleguas shaly loam	3.2%	63
Sorrento clay loam	3.0%	59
Nacimiento silty clay loam	2.6%	51
Millsholm loam	2.4%	48
Linne silty clay loam	2.2%	43
Garretson silt loam	1.1%	21
Castaic-Balcom complex	1.0%	20
Cortina stony sandy loam	0.2%	4
Malibu loam	0.1%	3
Coastal beaches	0.0%	1
TOTAL	**100%**	**1944**
Watershed area covered by the different soil map units was calculated from SSURGO data using ArcGIS.		

Line Canyon Watershed

The three most widespread soil types in Line Canyon are San Benito clay loam, Calleguas-Arnold complex, and Calleguas shaly loam at 25.4%, 22.5%, and 17.5% of the watershed areas, respectively. Additionally, Landslides and Badland covers 11.9% of the Line Canyon (Totaling 77.3%; Table 2.4).

The San Benito soil type is a deep soil with medium to very high runoff potential. The Calleguas soil type is a very shallow to shallow soil with medium to high runoff potential. The Arnold soil type, found in the Calleguas-Arnold complex, is a deep soil with very low to medium runoff potential.

The oil wells, oil field roads, and associated operations are spread throughout Line Canyon. The majority of the activity appears to be occurring in the San Benito clay loam and Calleguas-Arnold complex, which are also the most common soil map units in Line Canyon.

Table 2.4 - **Line Canyon soil map units**

SOIL MAP UNIT	PERCENTAGE OF WATERSHED AREA	AREA (ACRES)
San Benito clay loam	25.4%	234
Calleguas-Arnold complex	22.5%	208
Calleguas shaly loam	17.5%	162
Nacimiento silty clay loam	13.2%	122
Landslides	6.5%	60
Badland	5.4%	50
Rincon silty clay loam	3.8%	35
Diablo clay	3.2%	30
Sespe clay loam	1.0%	10
Lodo rocky loam	0.5%	5
Castaic-Balcom complex	0.5%	4
Mocho loam	0.3%	3
Coastal beaches	0.2%	1
Santa Lucia shaly silty clay loam	0.1%	1
TOTAL	**100%**	**925**
Watershed area covered by the different soil map units was calculated from SSURGO data using ArcGIS.		

Amphitheater Canyon Watershed

Amphitheater Canyon has the least soil diversity and greatest percentage of badland out of any of the watersheds. The three most widespread soil types in Amphitheater Canyon are Malibu loam, Nacimiento silty clay loam, and Linne silty clay loam at 19.3%, 18.5%, and 9.7% of the watershed areas, respectively. Additionally, Badland covers 41.5% of the Amphitheater Canyon (Totaling 89%; Table 2.5).

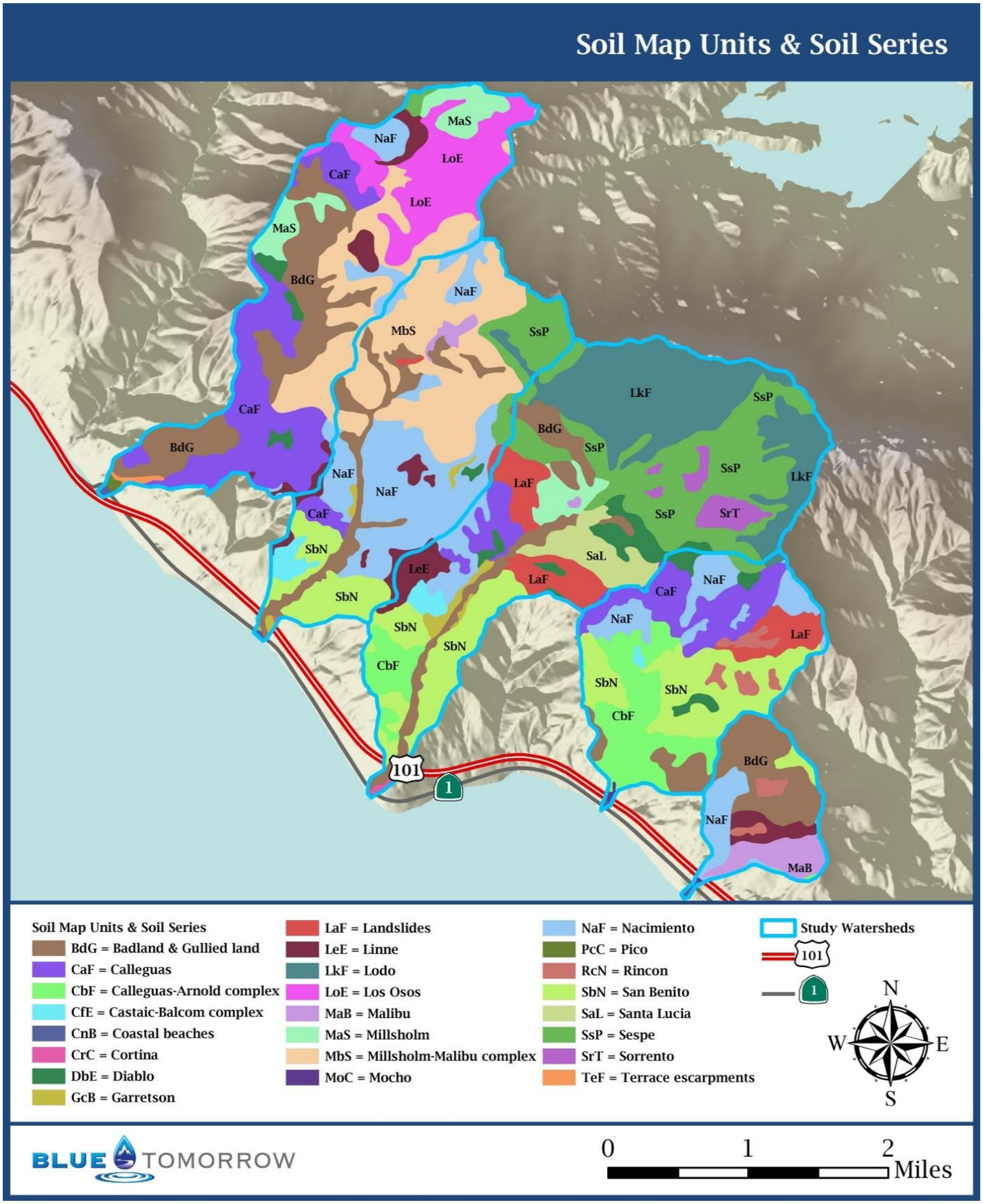
The Malibu, Nacimiento, and Linne soil types are all moderately deep soils, and all fall within the range of medium to very high runoff potential, with Malibu on the high side, Nacimiento on the medium side, and Linne covering the whole range.

The oil wells, oil field roads, and associated operations are spread throughout Amphitheater Canyon. The activity appears to be relatively evenly distributed.

Table 2.5 - **Amphitheater Canyon soil map units**

SOIL MAP UNIT	PERCENTAGE OF WATERSHED AREA	AREA (ACRES)
Badland	41.5%	147
Malibu loam	19.3%	69
Nacimiento silty clay loam	18.5%	66
Linne silty clay loam	9.7%	34
Rincon silty clay loam	4.9%	17
San Benito clay loam	4.3%	15
Calleguas-Arnold complex	0.9%	3
Coastal beaches	0.8%	3
Mocho loam	0.2%	1
TOTAL	**100%**	**355**
Watershed area covered by the different soil map units was calculated from SSURGO data using ArcGIS.		

Figure 2.4 – Soil series and miscellaneous soil map units within the study watersheds. Data is from the USDA SSURGO database[3]. Soil series descriptions are given in Section 2.5 Refer to Figures 1 to 3 for canyon names.



2.5 Soil Series Descriptions

The 25 soil map units in the study area have been split into three groups: Alluvial Soils (6 units), Hill Slope Soils (14 units), and Miscellaneous Areas (5 units). The soils were separated into these groups due to the distinct characteristics and locations these soils have within the study watersheds. Alluvial soils are typically very deep, on low slopes and are least likely to generate or perpetuate surface runoff. The Hill Slope Soils cover the majority of the study area and range from zones with very little soil to areas with deep soils (up to 60 inches). Miscellaneous Areas have essentially no soil but can be significant areas of erosion and runoff generation. Miscellaneous Areas are not soils and do not have Official Soil Series Descriptions.

2.5.1 Alluvial Soils

Alluvial soils are derived from parent material that has been transported and deposited by water. These soils are generally found directly in the path of surface waters and also control the discharge rate of groundwater to the creeks.

The Alluvial soil map units in this study comprise six soil types and collectively cover only about 2.8% of the total study area. Individually, none of the alluvial soil types cover more than 1% of the study area. Alluvial soils have the greatest coverage relative to watershed area in Amphitheater Canyon at 5.1% of the watershed area. Despite their limited coverage within the study area, these soils can have a disproportionate effect on hydrology and influence the fate and transport of pollutants due to their close proximity to stream channels.

The Alluvial soils in the study area are mostly moderately deep to very deep (20 to greater than 80 inches) and found on alluvial fans, floodplains, or other low sloping areas. These soil types are dominated by moderately alkaline conditions (pH 8.0), and have a lower runoff classification (generally low to medium) than the Hill Slope Soils.

The soil descriptions listed below are listed in order of their coverage relative to the entire study area, with the soil type with the greatest coverage described first and the soil with the least coverage described last.

Sorrento clay loam

18% to 35% clay content – negligible to medium runoff

The Sorrento clay loam soil is found only in the far upper reaches of Padre Juan Canyon and covers about 3% of the watershed area (Table 2.3; Figure 2.4). The Sorrento soil series is about 40 to 80 inches deep and is formed from alluvium weathered from sedimentary rocks. The typical pH for this soil type is 8.0 to 8.2, with more alkaline conditions and the presence of lime and carbonates near bedrock. Organic matter content ranges from 2% to 4% in the upper portion of the soil, and rock fragments can comprise as much as 15%.

Rincon silty clay loam

35% to 45% clay content – low to high runoff

The Rincon silty clay loam soil is found in Amphitheater Canyon and Javon Canyon, and has the greatest coverage relative to watershed area in Line Canyon at 3.8% of the watershed area (Table 2.3; Figure 2.4). The Rincon soil series is about 36 to 64 inches deep and is formed from alluvium weathered from sedimentary rocks. The typical pH for this soil type is 6.5 to 8.0, with more alkaline conditions and the presence of lime and carbonates near bedrock. Organic matter content is around 2% in the upper portion of the soil, with virtually no gravel sized rock fragments in the surface layers.

Garretson silt loam

18% to 27% clay content – low to medium runoff

The Garretson silt loam soil is found along portions of the stream channel in Javon and Padre Juan Canyon and covers around 1% of the area in each watershed (Table 2.3; Figure 2.4). The Garretson silt loam map units also include two small map units within Javon watershed of Garretson loam and gravelly loam variants. The Garretson soil series is about 40 to 80 inches deep and is formed from alluvium weathered from sedimentary rocks. The typical pH for this soil type is 6.2 to 6.8, with more neutral conditions near bedrock. Organic matter content ranges from 0.5% to 2% in the upper portion of the soil, and rock fragments range between 2 and 35%.

Pico sandy loam

14% to 18% clay content – low to medium runoff

The Pico sandy loam soil is only found in one small patch at the outlet of Madriano Canyon (Table 2.3; Figure 2.4). The Pico soil series is about 40 to 60 inches deep and is formed from alluvium weathered from sedimentary rocks. The typical pH for this soil type is 8.0, with the presence of lime and carbonates throughout the profile. Organic matter content ranges from 1.5% to 4% in the upper portion of the soil, and rock fragments range between 1% and 20%.

Cortina stony sandy loam

0% to 20% clay content – negligible to low runoff

The Cortina stony sandy loam soil is only found in one small patch at the outlet of Padre Juan Canyon (Table 2.3; Figure 2.4). The Cortina soil series is about 40 to 80 inches deep and is formed from gravely and cobble rich alluvium that may be weathered from a variety of bedrock parent material. The typical pH for this soil type is 6.2 to 7.0, and organic matter content is generally below 1% in this soil type. Rock fragments typically range between 35% and 65%, but can have less than 35% in surface soil layers.

Mocho loam

18% to 35% clay content – low to medium runoff

The Mocho loam is found in two small patches at the outlet of Line and Amphitheater Canyon (Table 2.3; Figure 2.4). The Mocho soil series is about 40 to 80 inches deep and is formed from gravely and cobble rich alluvium weathered mostly from sandstone and shale bedrock parent material. The typical pH for this soil type is 7.9 to 8.4, and organic matter content is generally between 1.5% and 4% in this soil type. Rock fragments typically range between 0.5% and 15% near the surface, but can be as much as 35% at 40 inches deep.

2.5.2 Hill Slope Soils

There are a total of 14 different hill slope soils mapped in the study area. These soils were formed *in situ* or from material that has only been transported a short distance by physical forces other than water. These soil types are generally shallower, are more acidic, and have a greater runoff potential than alluvial soils. For this study, the hill slope soil units were defined as soils present on slopes that range from 9% to 75% grade with the majority between 30% and 50%.

Several hill slope soil types are classified as soil complexes. A complex is a sequence of two different soil types that occurs in a map unit at a scale that is too small to be delineated given the mapping resolution standards[1].Complexes are assumed to have some combination of the characteristics of the two soil series describing the complex.

The soil descriptions listed below are listed in descending order of their coverage relative to the entire study area.

Nacimiento silty clay loam

Covers 11.4% of entire study area – medium to high runoff

The Nacimiento silty clay loam soil is found in all watersheds and is the most common mapped soil type in the study area. This soil has the greatest coverage relative to watershed area in Javon Canyon at 28.1% of the watershed area (Table 2.2; Figure 2.4).

The Nacimiento soil series is about 20 to 40 inches deep, and is formed from sandstone and calcareous shale parent material[2]. The typical pH for this soil type is 8.0, and free lime and carbonates are present in the soil.

Organic matter content ranges from 2% to 5% in the shallow layers and decreases to less than 1% within the first 20 inches depth[2]. Fragments of shale and other rock range from 1% to 35%, with the majority of Nacimiento soil examples less than 20%[2].

Millsholm-Malibu Complex

Covers 11.1% of entire study area – low to very high runoff

The Millsholm-Malibu complex is the second most commonly mapped soil type in the study area, but occurs only in Madriano Canyon and Javon Canyon at 16.6% and 32.1% of the watershed area, respectively (Table 2.1 & 2.2; Figure 2.4).

The Millsholm and Malibu soil series are both formed from shale and sandstone parent material and are slightly acidic (pH 6.1 to 6.5)[2]; however, Millsholm soil series is a shallower and rockier soil that typically has less potential to generate surface runoff, as compared to the Malibu soil series[2].

Calleguas shaly loam

Covers 10%t of entire study area – medium to high runoff

The Calleguas shaly loam soil is found in all watersheds and is the third most common mapped soil type in the study area, covering about 10% of the entire area. This soil has the greatest coverage relative to watershed area in Madriano Canyon at 24.4% of the watershed area (Table 2.1; Figure 2.4). The Calleguas soil type also is found as part of the Calleguas-Arnold complex which covers an additional 22.5% of Line Canyon (Table 2.4; Figure 2.4).

The Calleguas soil series is about 8 to 20 inches deep, and is formed from sedimentary rock parent material[2]. The typical pH for this soil type is 8.0, with the presence of free lime and carbonates in the soil[2].

Rock fragments average 5% to 35% of the soil volume, are angular and subangular pieces of shale 0.6 to 1 centimeters in diameter, and are usually most numerous just above the bedrock contact[2]. Distinct soil layers (horizons) are lacking in the profile of this soil type[2]**.**

San Benito clay loam

Covers 9.6% of entire study area – medium to very high runoff

The San Benito clay loam soil is found in all watersheds except Madriano Canyon and has the greatest coverage relative to watershed area in Line Canyon at 25.4% of the watershed area (Table 2.4; Figure 2.4).

The San Benito soil series is about 40 to 60 inches deep and is formed from soft shale, sandstone or consolidated sediment parent material[2]. The typical pH for this soil type is 6.8 to

8.0, with more alkaline conditions (pH 8.0) and the presence of lime and carbonates near bedrock[2].

Organic matter content is 1.5% to 4% in the upper 20 inches and greater than 1% to a depth of 30 inches[2]. The typical San Benito soil contains 15% fine sand or coarser[2].

Sespe clay loam
Covers 9.5% of entire study area – high to very high runoff

The Sespe clay loam soil is found in all watersheds except Amphitheater Canyon, and has the greatest coverage relative to watershed area in Padre Juan Canyon at 22.2% of the watershed area (Table 2.3; Figure 2.4).

The Sespe soil series is about 24 to 40 inches deep, and is formed from reddish sandstone and shale bedrock parent material[2].The typical pH for this soil type is 6.5 to 6.0, with more acidic conditions at greater depths (pH 6.5)[2].

The Sespe surface soil (A horizon) has 3% to 4% organic matter in the shallow layers and 1% to 2% organic matter in the deeper layers[2]. Rock fragments of cobblestone size are less than 2% and gravel-size fragments are less than 5% throughout the soil profile, except when near the bedrock where rock fragments are more common[2].

Lodo rocky loam
Covers 8.8% of entire study area – medium to high runoff

The Lodo rocky loam soil has the greatest coverage relative to watershed area in Padre Juan Canyon at 26.2% of the watershed area, and covers less than 1% of the Javon Canyon and Line Canyon watershed areas (Table 2.2 – 2.4; Figure 2.4).

The Lodo soil series is about 4 to 20 inches deep and formed from hard shale and fine grained sandstone parent material.[2] This soil is typically slightly acidic (pH 6.1-6.5).[2]

Rock fragments in the pebble size range comprise 5% to 35% of the soil. Organic matter content generally equals 1% to 6% in the surface soil layer (A horizon)[2].Typically there is only one distinct soil layer, but if lower soil layers (B and C horizons) are present they have less than 1% organic matter[2].

Calleguas-Arnold Complex

Covers 4.7% of entire study area – very low to high runoff

The Calleguas-Arnold complex is found in Padre Juan Canyon, Line Canyon, and Amphitheater Canyon, and has the greatest coverage relative to watershed area in Line Canyon at 22.5% (Table 2.3 – 2.5; Figure 2.4).

The Arnold soil series is about 40 to 60 inches deep and is formed from soft sandstone bedrock parent material[2]. The typical pH for this soil type is 6.0 to 5.1, with strong acidic conditions at greater depths (pH 5.1).

Organic matter content averages 0.5% to 1.0% in the upper 10 inches of the soil profile and decreases regularly with increasing depth. The typical Arnold soil is sand or loamy sand throughout the profile with some areas having 1% to 15% gravel. Some cementation due to clay content may be present in the lower soil layers near bedrock (B and C horizons).

The Calleguas portion of the complex is typically much shallower and rockier than the Arnold portion, and is usually alkaline and calcareous. For more information on the Colleagues portion of the complex refer to the characteristics described for the Colleagues soil series under the Colleagues shaly loam description.

Los Osos clay loam

Covers 4.6% of entire study area – very high runoff

The Los Osos clay loam soil is only found in the Madriano Canyon watershed covering about 19.2% of the watershed area (Table 2.1; Figure 2.4).

The Los Osos soil series is about 20 to 40 inches deep and formed from sandstone and shale bedrock parent material[2]. The typical pH for this soil type is 7.0 to 6.0, with more neutral conditions at greater depth (pH 7.0)[2].

The organic matter content of the surface soil layer (A horizon) is 2% to 4%. Clay content increases 6% to 15% from the top to the bottom of the soil profile (top of A horizon to bottom of B horizon), and the soil lacks abrupt layer boundaries[2]. The deeper layers of the soil (B horizon) averages 35% to 50% clay[2].

Linne silty clay loam

Covers 2.8% of entire study area – medium to very high runoff

The Linne silty clay loam soil is found in all watersheds except Line Canyon and has the greatest coverage relative to watershed area in Amphitheater Canyon at 9.7% of the watershed area (Table 2.5; Figure 2.4).

The Linne soil series is about 20 to 40 inches deep and is formed from fairly soft shale and sandstone parent material[2]. The typical pH for this soil type is 8.0, and there is increasing presence of lime and carbonates with increasing depth[2].

Shale or mudstone rock fragments typically make up 0.5% to 5% of the soil volume, but can be as high as 35%[2]. The organic matter content is 2% to 6% in the shallow layers and decreases with depth to around 1% to 2% at 21 to 35 inches[2].

Millsholm loam

Covers 2.6% of entire study area – low to very high runoff

The Millsholm loam soil is found in Madriano Canyon and Padre Juan Canyon at 7.5% and 2.4% of the watershed area, respectively (Table 2.1 & 2.3; Figure 2.4).

The Millsholm soil series is about 10 to 20 inches deep and is formed from sandstone, mudstone and shale[2]. Typically this soil can be slightly acidic (pH 6.1-6.5) near the surface, but is generally neutral[2].

The organic matter content of the surface soil layer (A horizon) is 1% to 3%[2]. The deeper layers of the soil (B horizon) average 18% to 30% clay. Shale rock fragments can range up to 35% throughout the soil profile[2].

Diablo clay

Covers 2.1% of entire study area – low to high runoff

The Diablo clay loam soil is found in all watersheds except Amphitheater Canyon and has the greatest coverage relative to watershed area in Padre Juan Canyon at 3.6% of the watershed area (Table 2.5; Figure 2.4).

The Diablo soil series is about 40 to 80 inches deep and is formed from shale, sandstone, and consolidated sediment parent material[2]. The typical pH for this soil type is 7.4 to 8.4, with more alkaline conditions (pH 8.0) and the presence of lime and carbonates near bedrock.

Clay content in most of the soil profile, especially towards the surface, is 45 to 60%. Shale and other rock fragments can be as much as 30% in soil layers near the bedrock contact.

Santa Lucia shaly silty clay loam

Covers 1.6% of entire study area – very low to high runoff

The Santa Lucia shaly silty clay loam soil is found in Padre Juan Canyon and Line Canyon at 5.0% and 0.1% of the watershed area, respectively (Table 2.3 & 2.4; Figure 2.4).

The Santa Lucia soil series is about 20 to 40 inches deep and is formed from white shale containing some ash and some siliceous and diatomaceous parent material[2]. The typical pH for this soil type is 6.0 to 5.5, with strong acidic conditions at deep depths (pH 5.5).

Organic matter content for this soil type ranges from 2% to 20%. The typical Santa Lucia soil contains an average of 35% to 80% shale fragments and 35% to 50% clay.

Malibu loam
Covers 1.5% of entire study area – high to very high runoff

The Malibu loam soil is found in Javon Canyon, Padre Juan Canyon, and has the highest coverage relative to watershed area in Amphitheater Canyon at 19.3% of the watershed area (Table 2.5; Figure 2.4).

The Malibu soil series is about 20 to 40 inches deep and is formed from inter-bedded shale and sandstone bedrock parent material[2]. The typical pH for this soil type is 6.4[2]. The top soils (A horizon) average 18% to 27% clay and 10% to 15% rock fragments, while deeper soils (B horizon) average 40% to 55% clay and 0% to 10% rock fragments[2].

Castaic-Balcom Complex
Covers 0.8% of entire study area – low to very high runoff

The Castaic-Balcom soil complex is found in Padre Juan Canyon and Line Canyon, and has the highest coverage relative to watershed area in Javon Canyon at 1.9% of the watershed area (Table 2.2; Figure 2.4).

The Castaic and Balcom soil series are both around 20 to 40 inches deep and formed from shale and sandstone parent material, but Castaic soils may include some mudstone parent material[2]. The typical pH for Castaic soils is slightly acidic to slightly alkaline, while the typical Balcom soil is more alkaline. At deep depth both soils may have the presence of free lime and carbonates.

Both soil series have less than 1% organic matter content, between 10% and 35% small shale rock fragments, and 10% to 40% clay content[2].

2.5.3 Miscellaneous Areas

The five Miscellaneous Areas mapped in the study watersheds are described as areas with essentially no soil[1, 4]. These map units occur in all five watersheds and cover 16.3% of the entire study area. The greatest coverage of these map units relative to watershed area occurs in Amphitheater Canyon where badland alone covers about 41.5% of the watershed area (Table 2.5; Figure 2.4). Excluding coastal beaches, all the miscellaneous map units indicate potential areas of high erosion, sediment sources, and areas that may have a very high potential to generate runoff.

The soil descriptions listed below are listed in order of their coverage relative to the entire study area, with the soil type with the greatest coverage described first and the soil with the least coverage described last.

Badland
Covers 8.2% of entire study area – very high runoff

Badlands are found in Madriano, Line, and Amphitheater Canyon. Badlands are moderately steep to very steep barren land with many intermittent drainage channels[1]. Local relief between these channels can range from 10 to 200 meters in height[1]. In the study area, these badlands are most likely areas where these channels have cut into shale or other soft bedrock and will have very few rock fragments. The potential for these areas to create runoff is very high and erosion very active.

Gullied Land
Covers 4.6% of entire study area – very high runoff

Gullied lands are only mapped in Javon and Padre Juan Canyon, but they are mapped extensively along the main channel of these watersheds (Figure 2.4; Table 2.2 & 2.3). Gullied lands are described as networks of V- or U-shaped channels. These areas are shaped by erosion, and are said to resemble miniature badlands[1]. Gullied lands may be created or exacerbated by various land uses and are prevalent in many areas of Ventura County due to the highly erosive soils and soft marine sedimentary geology. These areas could be significant sources of total suspended solids and other sediment pollutants, because of their high potential to create runoff.

Landslides
Covers 3.2% of entire study area – very high runoff

Similar to badland and gullied land, the landslide map units in the study area are characterized as miscellaneous areas with essentially no soil. Landslides are mapped in Javon Canyon, Padre Juan Canyon, and Line Canyon at 0.7%, 6.4%, and 6.5% of the watershed areas, respectively (Table 2.2 – 2.4; Figure 2.4). Areas mapped as landslides will typically be steep unstable slopes with signs of mass soil movement. These map units may indicate large sediment source areas.

Terrace Escarpments

Covers 0.1% of entire study area – very high runoff

The Terrace Escarpments map unit is only found at the outlet of Madriano Canyon and only covers about 0.5% of that watershed. This map unit is assumed to be the steep sides of an alluvial terrace that has been cut by current and past stream channels. These steep alluvial areas may be significant sources of sediment and have characteristics similar to the alluvial soils.

Coastal Beaches

Covers 0.1% of entire study area

The Coastal Beaches map unit is found at the outlet of all the study watersheds. These beach deposits have the greatest coverage within Amphitheater Canyon, due to its small size, and cover about 0.8% of the watershed area. This map unit is made up of beach sand deposits that may be partially covered by water during high tide.

2.6 Soils Summary

Soils influence groundwater infiltration, runoff, water quality, erodibility, and the fate and transport of pollutants. The timing and volume of surface runoff and the degree to which water infiltrates to groundwater are all influenced by hydraulic conductivity, specifically vertical hydraulic conductivity. In the study watersheds, hydraulic conductivity of soils is low, with saturated vertical hydraulic conductivity for the soil types ranging from 0.26 to 2.6 feet per day. Alluvial soils cover roughly 3% of the watersheds, but these soils can have a disproportionately large effect on downstream water quality due to their proximity to streams, thickness (generally greater than 40 inches deep), and tendency to retain groundwater. Hill slope soils comprise approximately 81% of the soils in the watersheds and influence downstream water quality, but due to their shallow depths and steep slopes are unlikely to have significant groundwater retention. Miscellaneous soils, including badlands and gullied land, cover about 16% of the watershed area, have essentially no soil and are designated as highly erosive. All watersheds in the study area have highly erosive soils with high runoff potential.

2.7 Soils References

1) Soil Survey Division Staff. 1993. Soil survey manual. Soil Conservation Service. U.S. Department of Agriculture Handbook 18.
2) Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture. Official Soil Series Descriptions. Available at: http://soils.usda.gov/technical/classification/osd/index.html.
3) Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture. Soil Survey Geographic (SSURGO) Database. Available at: http://www.arcgis.com/apps/OnePane/basicviewer/index.html?appid=a23eb436f6ec4d6982000dbaddea5ea. Accessed November 1, 2013.
4) National Soil Survey Center, Natural Resource Conservation Service, U.S. Department of Agriculture. Field Book for Describing and Sampling Soils. September 2012.

3.0 | HYDROLOGY

The hydrology of the study watersheds is driven by the Southern California Mediterranean climate and the soils, geology, and vegetation of the drainages. Climate and local weather patterns dictate the amount and timing of precipitation. Soils and geology determine the amount of precipitation that infiltrates and is temporarily stored as groundwater or soil moisture, where and when surface runoff occurs, and what types of vegetation communities are present. Lastly, the types and extent of vegetation influence the actual evapotranspiration that occurs.

> **Section Highlights**
>
> - Average annual precipitation in the study area ranges from 15 inches at the bottom of Madriano Canyon to 20 inches at the top of Red Mountain
> - Creeks in the study watersheds are historically intermittent or ephemeral; however, Line Canyon had persistent base flow during the study
> - Roads and other impermeable surfaces can influence runoff timing and modify flow paths
> - Groundwater is very limited in the study watersheds

Land use can influence the hydrology of the study watersheds through vegetation conversion and disturbance and compaction of the soil surface. When vegetation is cleared and roads are built, the hydrology of a watershed is affected by the subsequent decrease in evapotranspiration and increase in the volume of surface runoff. If adequate runoff and erosion control features are not put in place, roads can act as extensions of the channel network by collecting water, which would normally infiltrate into the natural hill slope soils. This modification of the natural drainage can concentrate runoff, increasing the volume and velocity of flow, and routing it along road surfaces to nearby waterways.

The following subsections detail the precipitation, the creek and flow characteristics, the groundwater, and the evapotranspiration within the study watersheds.

3.1 Precipitation

There are two active and two inactive precipitation gauges within close proximity to the study watersheds[1]. The two currently active gauges are Sea Cliff County Fire Station, which has been active since 1982, and the Red Mountain precipitation gauge, which has been active since 2002. The inactive stations are the Sea Cliff CWOD Santa Fe Energy gauge station, which was active from 1976 to 1982, and the Sea Cliff gauge station, which was active from 1966 to 1976. All four gauging stations have records of hourly and daily rainfall totals, except the Sea Cliff gauge, which only collected daily totals.

The Sea Cliff precipitation gauges are located no more than 0.25 mile from each other at the base of Madriano Canyon and are stationed 10 to 50 feet above sea level (Figure 3.1). Due to their juxtaposition, the records from these three precipitation stations were joined to make a 45 year record from 1967 to 2013 for the base of Madriano Canyon (Figure 2; excludes the 1976 and 1982 water years).

The Red Mountain precipitation gauging station is located about 0.25 miles to the east of the top of Padre Juan Canyon at an elevation of 2075 feet (Figure 3.1). Although the Red Mountain station has not been active long, it gives some idea of the orographic effect on precipitation caused by the 2050-foot difference in elevation. The highest elevation within the study watersheds is about 2165 feet at the top of Padre Juan Canyon, and this area most likely receives the greatest average precipitation in the study watersheds.

The precipitation contours shown in Figure 3.1 are the predicted daily totals for the 10-year storm event. Contours were taken from the Ventura County Watershed Protection District 2010 Design Hydrology Manual[2]. These predicted contours indicate that on average the greatest amount of precipitation falls around the ridge top between Padre Juan and Line Canyons.

Figure 3.1 – The location of the precipitation gauges to the study watersheds and predicted daily total precipitation contours created by the Ventura County Watershed Protection District for the 10-year storm event are shown[1,2]. The extent of the stream channel with greater than 0.6 square miles (1 km^2) contributing area (red) and full extent as shown in the National Hydrography Dataset (NHD; green) are mapped[3]. The location of alluvium and colluvium is also mapped due to its potential to store groundwater.

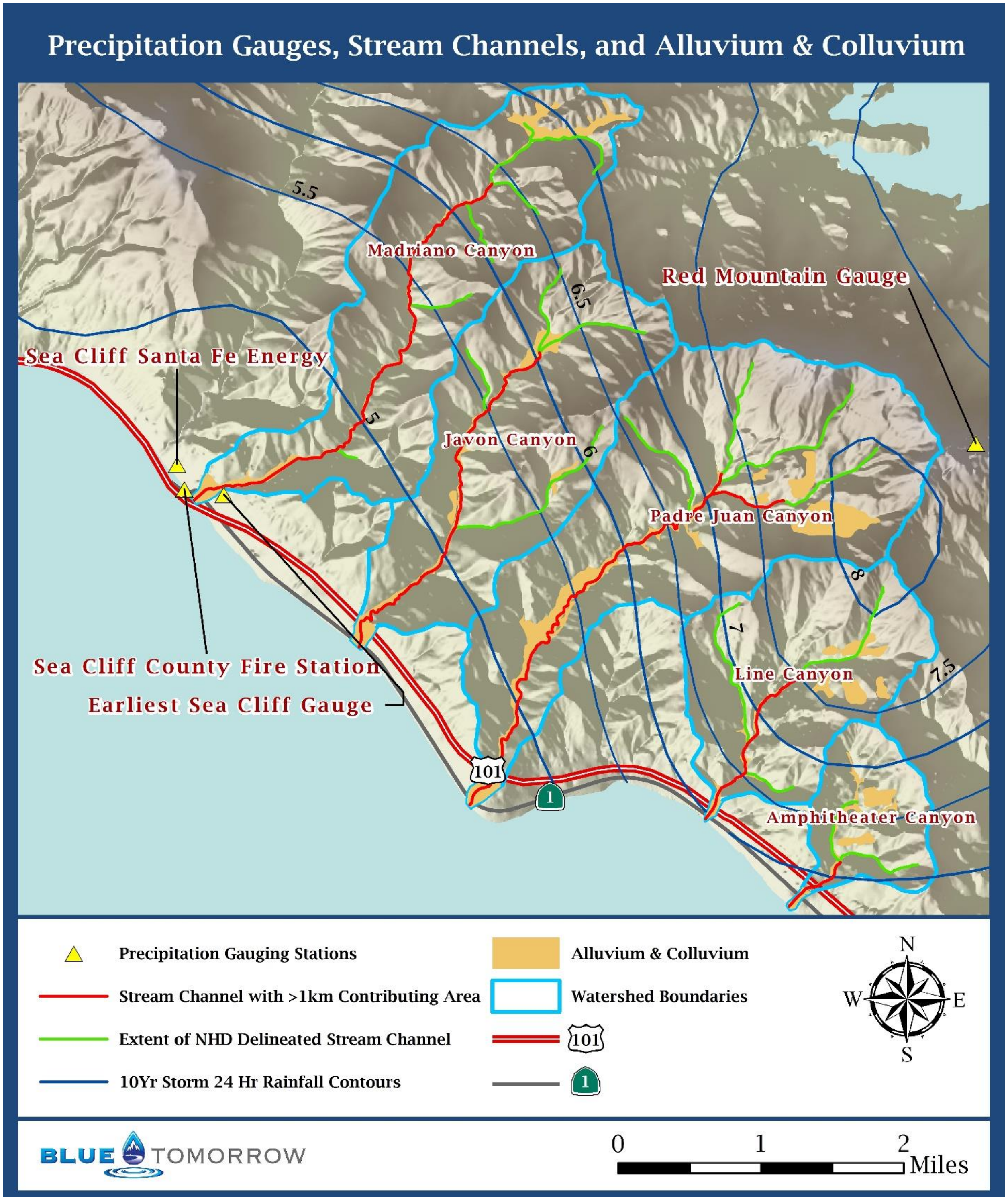
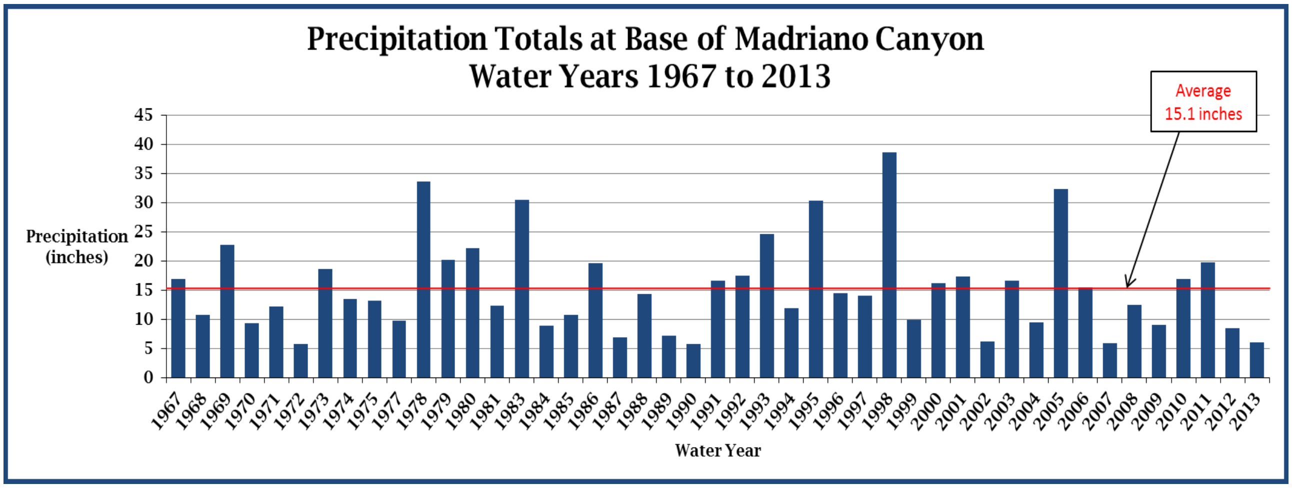


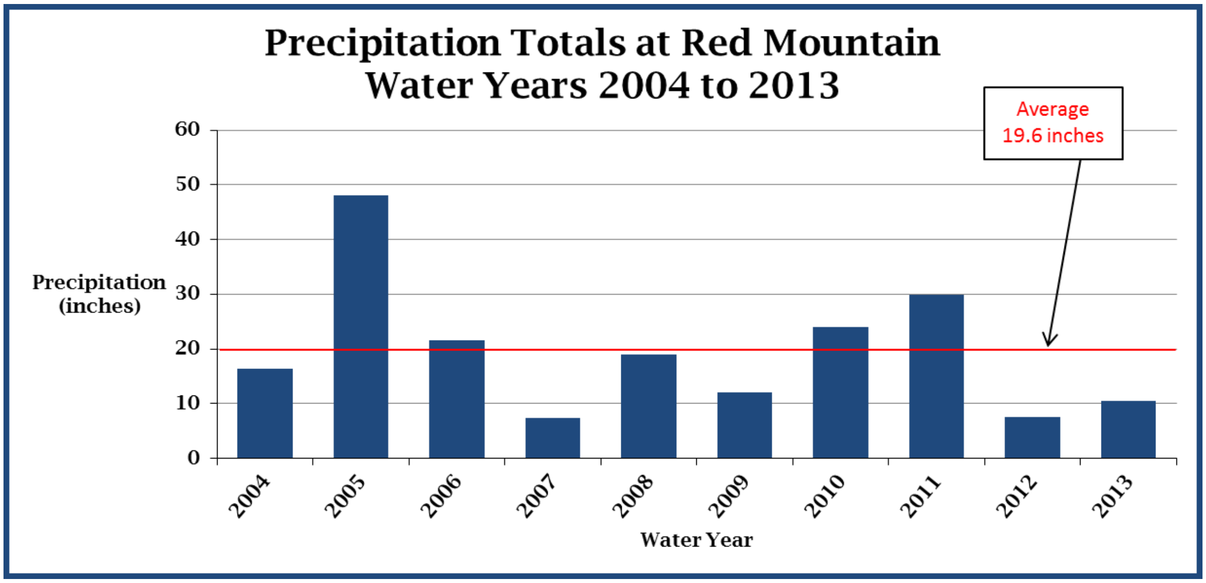
Figure 3.2 *–* Water year precipitation total at the base of Madriano Canyon. This 45 year record is the product of three separate precipitation gauging stations that were active over different time periods[1]. The three stations are no more than 650 meters apart and no more than 50 feet above sea level (Figure 3.1). This is not a continuous record and there is no data for water years 1976 and 1982. The average water year precipitation calculated for the 45 year record is 15.1 inches. A water year extends from October to September. Monthly precipitation averages based on these records are shown in Figure 3.4.



The average precipitation measured at the base of Madriano Canyon over the 45 years of rainfall records is 15.1 inches. The wettest water year on record for the study area was 1998, when a total of 38.52 inches was measured at the Ventura County Fire Station (Figure 3.1). About 44% of the years on record at the base of Madriano Canyon fall below the average of 15.1 inches. The greatest 24-hour rainfall total measured at the base of Madriano Canyon was 4.67 inches on January 10, 2005.

There are only 10 years of rainfall records at the Red Mountain precipitation gauge since 2002 (Figure 3.3). Rainfall at the tops of the study canyons are, on average, greater than precipitation at the base due to the over 2000-foot difference in elevation. Over the 10-year record, annual precipitation at Red Mountain averaged 19.65 inches. Over this same time period, annual precipitation at the Sea Cliff County Fire Station averaged 13.56 inches. The greatest 24-hour rainfall total recorded at the Red Mountain gauge was 6.73 inches on January 10, 2005.

Figure 3.3 – Water year precipitation totals at Red Mountain since the gauge became active in 2003[1]. The average precipitation at this gauge over the 10 year interval was 19.6 inches. The greatest water year total was 48.07 inches during the 2005 water year. A water year extends from October to September.



3.2 Creeks and Watershed Flow Characteristics

The creeks along the northern Ventura County coast are all historically intermittent or ephemeral and are bounded by the perennial Rincon and Ventura rivers. Intermittent streams do not have flow the dry portion of the year when there is not enough rain to sustain elevated groundwater levels that feed the streams. Ephemeral streams flow only as a direct result of storm events and are not fed by groundwater at any time of the year.

During the 2013-2014 winter season (when this study was conducted), all the creeks, except for Line Canyon creek, exhibited ephemeral characteristics by only generating flow during storm events, which quickly ceased following the end of the storm event. Line Canyon has exhibited perennial flow over the study period, which was also the driest year in California on record to date.

The flow characteristics of intermittent and ephemeral streams in Southern California are very "peaky", meaning they are capable of producing flash floods that discharge large volumes of water and sediment over a short interval. In all the study watersheds, there is a total 26.2 miles of stream channel mapped in the National Hydrography Dataset (NHD) and classified as intermittent[2]. The approximate length of stream channel with a contributing area greater than 0.6 square miles (1 km^2) is 12.3 miles. Aerial imagery shows that this dataset does not represent the full drainage network, which includes many unmapped ephemeral tributaries and large gullies.

Table 3.1 – **Estimated length of stream and watershed area**

WATERSHED	ESTIMATED LENGTH OF STREAM WITH GREATER THAN 0.6 mi^2 CATCHMENT (miles)	ESTIMATED LENGTH OF STREAM NHD CHANNEL (miles)	TOTAL WATERSHED AREA (mi^2)
Madriano Canyon	3.6	6.5	2.3
Javon Canyon	2.9	6.2	2.1
Padre Juan Canyon	4.0	8.0	3.0
Line Canyon	1.3	3.9	1.4
Amphitheater Canyon	0.50	1.7	0.56
TOTAL	12.3	26.2	9.3

Stream length was estimated using ArcGIS. All the stream channel data was acquired from the National Hydrography Dataset (NHD)[2]. The upstream extent of the stream channel with greater than 0.6 mi^2 contributing area was determined by delineating a National Elevation Dataset (NED) using HEC-GeoHMS.

3.3 Groundwater

There is very limited groundwater in the study watersheds due to the lack of any large aquifer. The greatest potential for groundwater exists in Padre Juan Canyon, where nearly half of the total alluvium and colluvium is located (about 47%). Based on soil and geology maps, there is a maximum surface area of about one square mile of alluvium and colluvium deposits and soils in the study watersheds. The majority of each watershed is steep uplands that have relatively thin well-drained soils with poor water storage potential. Due to this, groundwater in the watersheds would most likely be found in the canyon bottoms where the thickest alluvium and most gentle slopes are found.

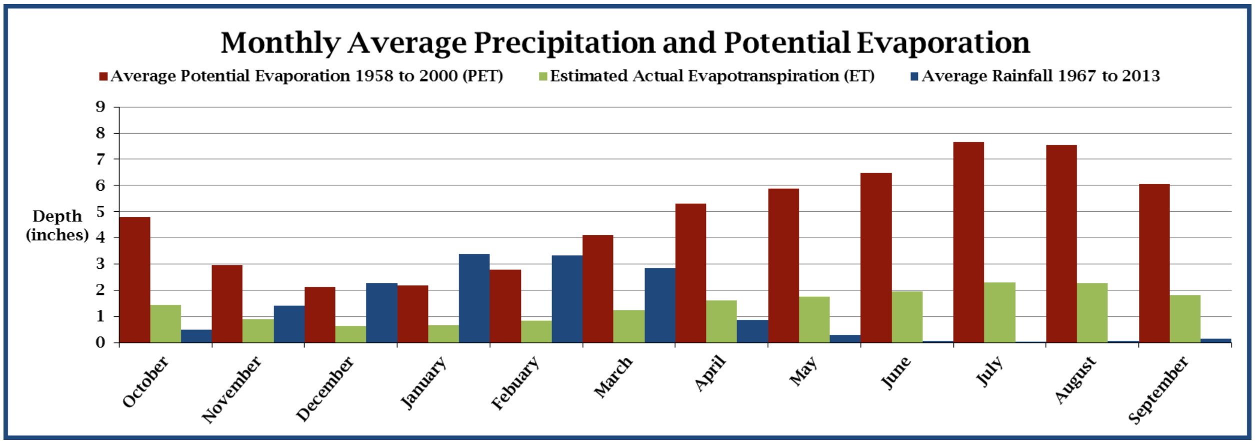
The Water & Environmental Resources Division of the Ventura County Watershed Protection District (VCWPD) has defined the alluvium at the outlets of the watersheds within its defined boundary of the North Coast groundwater basin[1]. The North Coast basin includes a portion of the Rincon Creek alluvium and a thin strip of sediment deposits between the bluffs and the ocean, and is described as an atypical groundwater basin that does not have well-defined boundaries[1]. In their 2012 annual report, the VCWPD reported eight active water supply wells in the North Coast Basin, the majority of which are along Rincon Creek.

3.4 Evapotranspiration

The evaporation pan closest to the study area is located below the Casitas Lake dam, over the coastal ridge[1]. Evaporation measured at this pan is likely higher than the evaporation that occurs in the watersheds due to the coastal influences on temperature, air humidity, and radiation (from fog). The greatest monthly average potential evaporation (PET) at this pan, from 1958 to 2000, was 7.65 inches during July, and the lowest was 2.11 inches during December (Figure 3.4). As is typical in all Mediterranean climates, the maximum potential evaporation occurs during the time of year with the least rainfall and the minimum occurs during the wet season.

Based on a landscape coefficient with average vegetation density and average microclimate coefficients, the actual evapotranspiration from the natural landscape is estimated to not be more than 30%, and in areas less than 10%, of the total potential evaporation measured from a evaporation pan (DWR)[3]. Natural California vegetation in the study area (including coastal sage-scrub, live oak, and manzanita) are adapted to water-limited environments and have lower evapotranspiration rates than could be sustained by other plants adapted to wetter conditions.

Figure 3.4 *–* Monthly average rainfall at the base of Madriano Canyon (blue) from 1967 to 2013 and monthly average potential evaporation (PET) from a class A pan at the base of Casitas Lake (red) from 1958 to 2000[1]. The estimated actual evapotranspiration (ET) is 30% of the average potential evaporation (PET).



3.5 Hydrology Summary

Average annual precipitation in the study areas ranges from about 15 inches at the bottom of Madriano Canyon to 20 inches at the top of Red Mountain. The actual amount of evapotranspiration (ET) is estimated to be no more than 30% (and in some areas less than 10%) of the potential evapotranspiration (PET) that would occur from an open body of water. The creeks in the study watersheds are historically intermittent or ephemeral; however, Line Canyon was observed to have a persistent base flow during the study. Padre Juan Canyon is the largest watershed (3 mi^2) with the greatest stream length and the smallest watershed is Amphitheater Canyon (0.56 mi^2). Land use can modify natural stormwater flow paths by collecting and channeling water on impermeable surfaces. Groundwater is very limited in the study watersheds, and the greatest potential groundwater resources exist in Padre Juan Canyon where the largest amount of alluvium and colluvium is found and deepest sediments likely exist.

3.6 Hydrology References

1) Ventura County Watershed Protection District. Hydrologic Data Server and Board-Accepted 2010 Design Hydrology Manual. Available at: http://portal.countyofventura.org/portal/page/portal/PUBLIC_WORKS/Watershed_Proection_District/About_Us/VCWPD_Divisions/Planning_and_Regulatory/Hydrology. Accessed November 1, 2013.
2) U.S. Geological Survey. National Hydrography Dataset (NHD). Available at: http://nhd.usgs.gov/data.html. November 1, 2013
3) California Department of Water Resources (DWR), University of California Cooperative Extension, 2000. A guide to estimating irrigation water needs of landscape plantings in California. The Landscape Coefficient Method and Water Use Classifications of Landscape Species III. Available at: http://www.water.ca.gov/wateruseefficiency/docs/wucols00.pdf

4.0 | FLORA, FAUNA & HABITAT

All information on the types of plant communities found in the watersheds comes from a 1930's US Forest Service survey[1], aerial photos, knowledge of plant communities dominant in the region, and observations of plant communities near the watershed outlets. While the California coastal sage scrub is classified as a threatened habitat due to urbanization in southern California, limited access to the canyons prevented the generation of survey data of plant and animal communities. Based on the available information, endangered or threaten plant or animal species are not known to live in the study watersheds

Marine and beach habitats are receptors of runoff and sediment from the study watersheds and are emphasized in this section. There is considerable information and publically available reports on the Southern California coastal habitats and species. These data have been compiled by various groups and agencies to support oil and chemical spill response and restoration efforts in the region. The main source of this information is the Environmental Sensitivity Index developed by the NOAA Office of Response and Restoration in collaboration with various government agencies and industry groups[3].

Section Highlights

- Vegetation cover of the study area is approximately 60% California coastal scrub, 15% oak forest and woodland, 13% grassland, 8% hard chaparral, and 4% oil field infrastructure
- Watersheds provide potential habitat for the California red-legged frog, Southwestern pond turtle, Bald Eagle, and Osprey
- Beaches and coastal environments provide habitat for dozens of marine mammal, bird, and fish species, including shorebird and grunion breeding habitat
- Watershed outlets discharge runoff and sediment into coastal marine habitat and kelp forests

The coastal beaches in the area support large numbers of shorebirds. The giant kelp forests, which wash up onto shore when detached from the sea floor, provide food and habitat for macrofauna and foraging habitat for shorebirds. Many marine birds and marine mammal species are present along this section of the coast year-round or during certain months (Tables 4.2 and 4.3).

4.1 Extent & Descriptions of Vegetation Types

Coastal Sage Scrub

The most prevalent vegetation community in the study area is California coastal scrub, which covers an estimated 60% of the study watersheds based on National Land Cover Dataset[2] and estimates from aerial photos. This community is wide-spread throughout the watersheds, mainly in the areas closest to the coast where it is nearly the only plant community. This vegetation type has the greatest coverage in Line and Amphitheater Canyon, where it is estimated to cover between 80% and 90% of the watersheds. The dominant species in the coastal scrub of the study watersheds is purple sage (*Salvia leucophylla*) and California sagebrush (*Artemisia californica*) [1,4].

California coastal scrub is adapted to the Mediterranean coastal environments with well-drained shallow soils, and in areas that receive coastal fog[5,6]. This association is distinguished from chaparral by being more diverse, less woody, shorter in mature height, and having typically smaller, softer deciduous leaves compared to the leathery scrupulous evergreen leaves of chaparral[5,6]. Coastal scrub and chaparral are found adjacent to each other, share some of the same species and associations, and are both adapted to periodic fire disturbance.

The coastal sage scrub association in northern Ventura County is noted as a threatened habitat of conservation importance in Southern California[4]. The greatest threats to coastal sage scrub include fragmentation and development, invasion of non-native species, altered fire regime, and air pollution[4,5].

Oak Forest & Woodland

Coastal and Canyon live oak (*Quercus agrifolia* and *Quercus chrysolepis*) woodland is estimated to be the next most widespread vegetation community at about 15% of the study area. Live oak woodland appears to be most dominant in the upper portions of Padre Juan Canyon, near the avocado and lemon orchards (Figure 4.1). Live oaks also are found along areas of the stream corridors as part of the riparian vegetation, where there is likely more moisture. These trees are very dense in the upper portions of the larger canyons. Coastal live oak may also occur in a stunted shrub form in many areas.

Annual & Perennial Grassland

The grassland in the study area is found almost entirely within the upper portions of Madriano Canyon. This grassland is used for cattle grazing and likely was converted or expanded for use as pasture from other vegetation such as coastal sage scrub or oak woodland.

The grassland in the study area is likely not natural, but converted to grassland from coastal scrub, chaparral and oak woodland to create grazing pasture. It is uncertain exactly when this vegetation conversion first took place, but it is likely still occurring. After controlled burns between 2003 and 2007, the land owner planned to reseed with grass, with the intent of increasing grazing pasture[7].

Hard Chaparral

Hard chaparral vegetation is estimated at around 8% of the study watersheds. The National Land Cover Dataset[1] had chaparral more widespread than 8% but this was adjusted based on aerial photos and a 1930's US Forest Service survey[2], which did not indicate a large presence of hard chaparral species (such as manzanita), only coastal scrub species (which is also known as soft chaparral). The largest stands of chaparral are believed to be on the south-southeast facing slopes at the top of Padre Juan Canyon (Figure 4.1).

Hard chaparral differs from coastal scrub in that it is dominated by woody shrubs such as manzanita species, is taller in height, and is evergreen[6]. Like coastal scrub, hard chaparral is adapted to a regular fire regime that helps regulate the density, diversity, and reproduction of the hard chaparral species.

Oil Field Infrastructure

Oil field roads and developed areas are estimated to cover about 4% of the study watersheds and are present in all watersheds. The greatest density of oil field infrastructure is in Line Canyon where it occupies as much as 11% of the watershed. Padre Juan Canyon has the lowest percent cover of oil field infrastructure.

Riparian Habitat

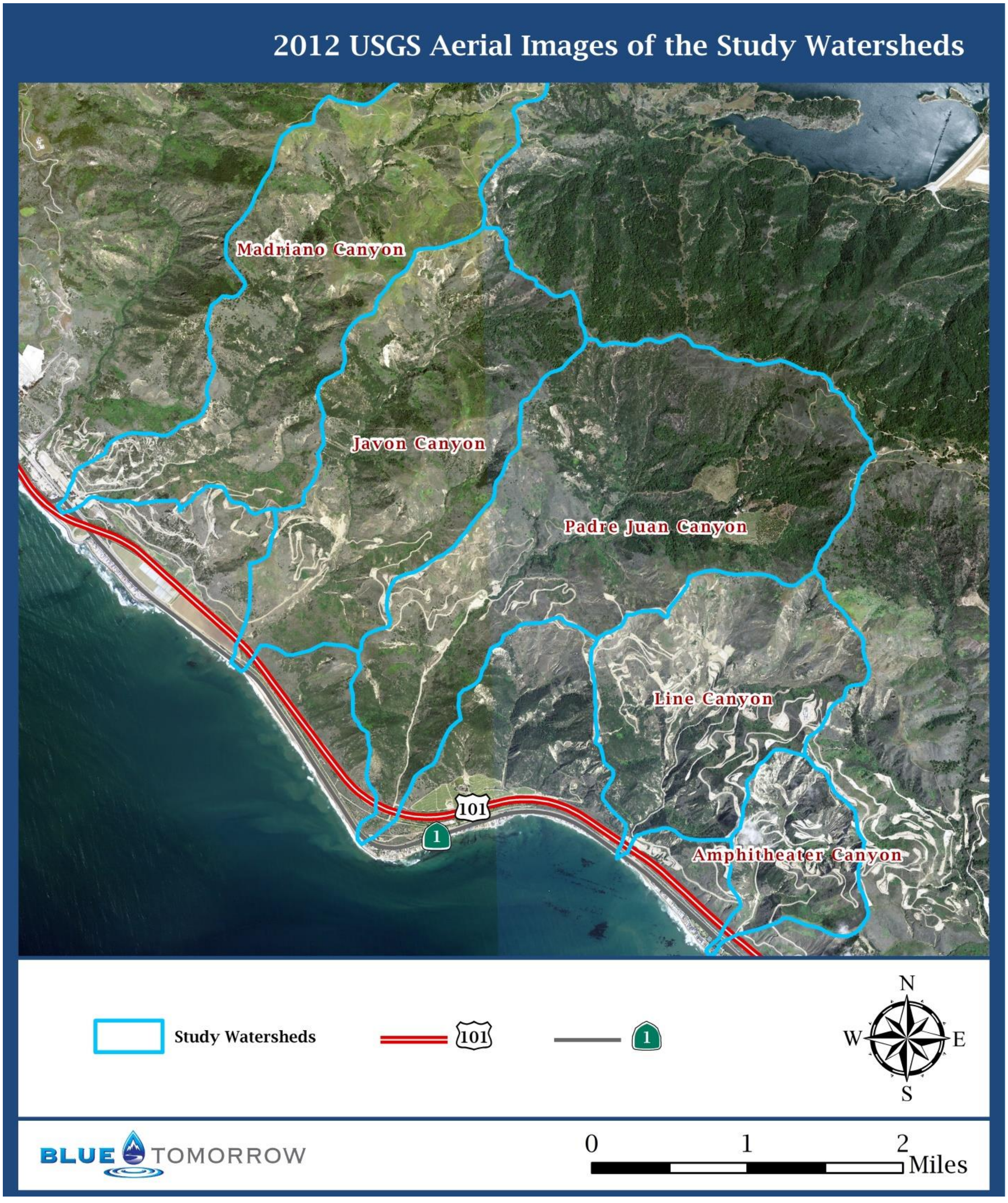
A thin riparian corridor, covering less than 1% of the study area, can be seen along the main stream channels, especially in the upper portions of the larger canyons. This riparian corridor ranges in width from 20 to 200 feet and is most pronounced in the upper reaches of Madriano and Padre Juan Canyons. Aerial imagery shows little to no riparian habitat in Amphitheater Canyon. Although these riparian areas are very small, in arid Mediterranean climate these habitats are ecological hotspots due to the contrast in soil moisture availability between riparian corridors and the adjacent uplands[8]. The riparian areas are most likely live oak and drought-tolerant species with deep roots that tap moisture when the temporary streams are dry. Near the outlets of the watersheds, these riparian areas are observed having dense willow and poison oak that provide habitat for several small bird species.

The National Land Cover Dataset was referenced to estimate vegetation cover, though this remotely sensed data is not suitable at the scale of the study watersheds for accurate mapping or analysis[2]. Aerial imagery, surveys, and observations were used in conjunction with this dataset for analysis.

Table 4.1 – **Estimated percentage of land coverage**

LAND COVER	PERCENTAGE OF STUDY AREA
California Coastal Scrub	60%
Oak Forest & Woodland	15%
Annual & Perennial Grassland	13%
Hard Chaparral	8%
Oil Field Roads & Infrastructure	4%
TOTAL	**100%**
Study watershed vegetation and land cover was estimated using National Land Cover Dataset[2] and aerial imagery.	

Figure 4.1 – 2012 USGS aerial images of the study watersheds show the distribution of different vegetation types. The large extent of oil field development can be seen in Line and Amphitheater Canyon. The darker vegetation in the upper reaches of Padre Juan Canyon is oak woodlands and chaparral on steeper slopes. The largest areas of grassland are the lighter green areas at the top of Madriano Canyon.



4.2 Potentially Sensitive Habitats & Species

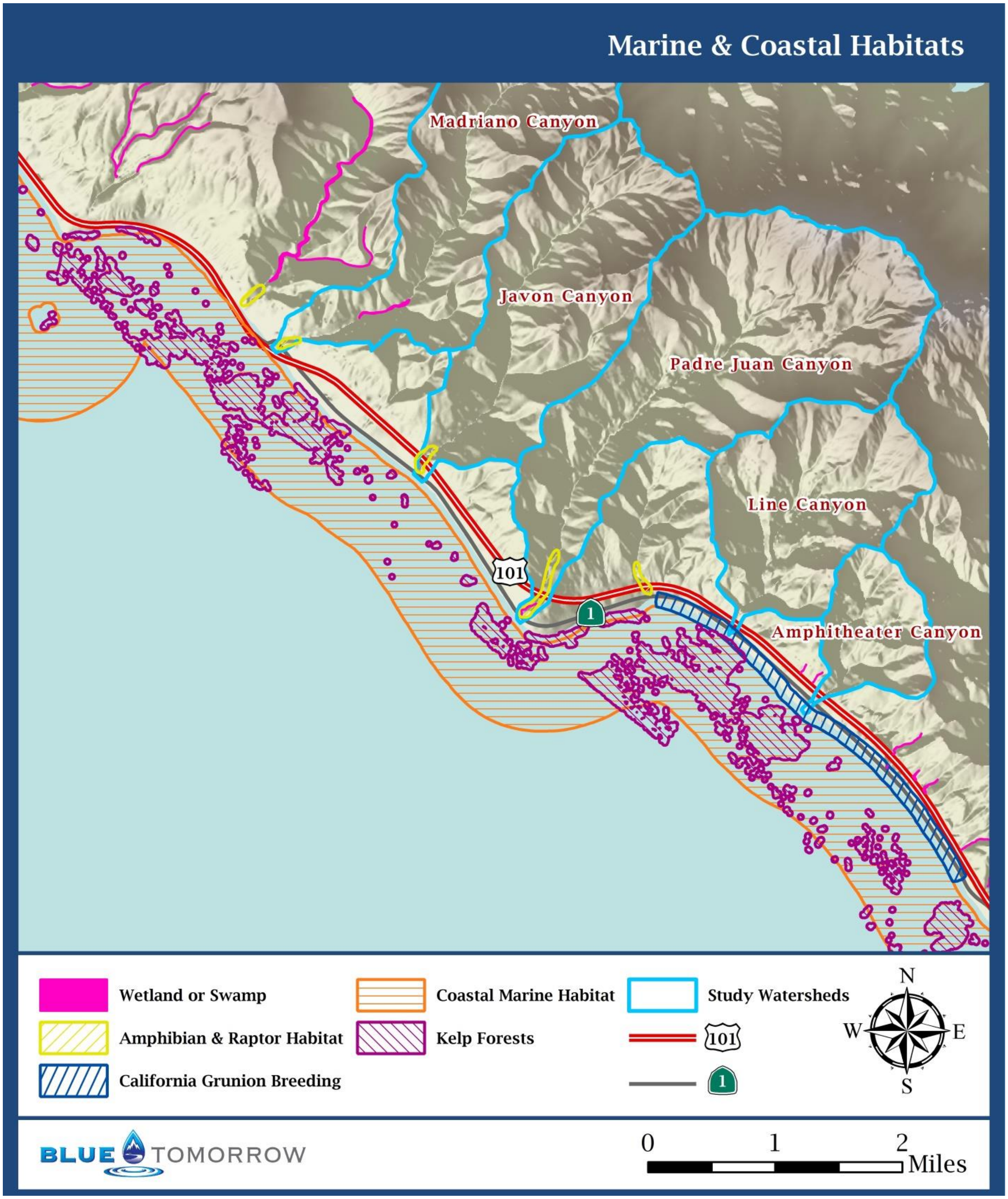
General Study Watershed Species

There are no endangered or sensitive species presently known to inhabit the study watersheds, but the study area is likely habitat for a large number of native mammals including top predators such as coyotes, bobcats, mountain lions, and occasional black bears. Other species that may be present in the area include deer, rabbits, opossum, skunks, raccoons, snakes and lizards[9]. Some of the birds that visit or reside in the area include California and spotted towhees, scrub jays, common yellowthroats, house and canyon wrens, black phoebes, house finches, warblers, raptors, crows, and turkey vultures[9]. There is possible habitat for red-legged frog, but due to the limited amount of seasonal water in the ephemeral streams, aquatic habitat and organisms are limited. During very wet periods the larger canyons may have intermittent flow that may support some aquatic organisms. Additionally, there may be wet groundwater spring-fed areas in the watersheds that support aquatic plants and amphibians, and are hotspots of biodiversity.

Terrestrial Habitats

Only very small terrestrial habitat areas at the outlets of Madriano, Javon, and Padre Juan Canyon were identified for amphibian and raptor habitat (Figure 4.2). These areas are designated as potential year-round habitat for the California red-legged frog and Southwestern pond turtle, and potential year-round habitat for various raptor species including Bald Eagle, and potential Osprey habitat from August to May[3]. Other possible sensitive areas include a length of Madriano creek designated as swamp and a few very small areas designated as potential scrub-shrub wetlands between Line and Amphitheater Canyons and at the outlet of Padre Juan Canyon (Figure 4.2).

Figure 4.2 – Location of marine and coastal habitats. Data are derived from the Environmental Sensitivity Index developed by the NOAA Office of Response and Restoration[3]. The coastal marine habitat is a strip approximately 0.7 miles wide running along the coast that contains habitat and foraging area for the species listed in Tables 4.2 and 4.3. There is a small swamp area in Madriano Canyon and scrub-shrub wetlands found around some of the watershed outlets to the southeast.



Beaches

Beaches in the area provide foraging habitat for many different shorebird species, which may occur in high densities[10]. Southern California beaches are noted for their high species richness, abundance, and biomass of insects and other macrofauna, which has been related to the amount of giant kelp and other macrophyte wrack that is washed up on beaches. A study of Santa Barbara and Ventura County beaches showed shorebirds, which feed on these macrofauna, can be found in densities of 9 to 177 individuals per kilometer (0.62 miles) of beach[10]. The most common shorebirds observed during this study were: sanderlings (*Calidris alba*), willets (*Catoptrophorus semipalmatus*), marbled godwits (*Limosa fedoa*), black-bellied plovers (*Pluvialis squatarola*), whimbrels (*Numenius phaeopus*), and at select beaches western snowy plovers (*Charadrius alexandrinus nivosus*)[10]. The beaches adjacent to the study area are also noted for potential habitat for Peregrine Falcon[3], which likely feed on small- to medium-sized shore birds.

Solimar beach, located along the coast in front of Line and Amphitheater Canyon, is noted for its California grunion breeding[3] (Figure 4.2). The anchovy-sized California grunion breed by beaching themselves in mass on full moon and new moon nights to spawn on the sand. Additional sensitive species in the coastal beach area consist of several invertebrate species including pismo clam, nuttall cockle, pacific littleneck, and other chione clam species[3].

Coastal watersheds in the area deliver sediment and sand to the beaches helping to replenish and sustain them. The watersheds also provide nutrients and food sources to coastal marine habitats.

Kelp Forest and Rocky Bottom Habitat

Giant kelp (*Macrocystis pyrifera*) forests and rocky bottom habitat are found along the coast adjacent to the study watersheds (Figure 4.2). Kelp forests provide excellent habitat for fish and can act as nurseries for juveniles. Kelp forest and coastal hard bottom habitats can be impacted by excess turbidity, changes in land use, nutrient and pollution inputs, and changes in coastal sediment budgets[11].

The greatest coverage of kelp habitat along the coast between the outlets of the study watersheds is in front of Line and Amphitheater canyons[3] (Figure 4.2).

Sensitive Coastal Marine Species

Sensitive coastal marine species were compiled by the NOAA Office of Response and Restoration with input and collaboration from industry and many state and federal agencies[3]. This database is used to help orchestrate oil spill response efforts, providing information on the location, density, and seasonality of species and habitat which would possibly be impacted by an oil spill. Information on the coastal habitats and species likely to be found within 1 mile of the study area coast were extracted from the database and are presented in Figure 4.2 and Tables 4.2 and 4.3.

Table 4.2 - **Bird species that utilize the coastal marine habitat zone**

COMMON NAME	LATIN NAME	MONTHS PRESENT
Bonaparte's gull	*Larus philadelphia*	September to May
Brandt's cormorant	*Phalacrocorax penicillatus*	September to May
Brown pelican	*Pelecanus occidentalis*	April to November
California gull	*Larus californicus*	September to May
Caspian tern	*Hydroprogne caspia*	January to December
Common loon	*Gavia immer*	September to May
Double-crested cormorant	*Phalacrocorax auritus*	January to December
Elegant tern	*Thalasseus elegans*	May to November
Forster's tern	*Sterna forsteri*	January to December
Heermann's gull	*Larus heermanni*	January to December
Least tern	*Sternula antillarum*	February to September
Pacific loon	*Gavia pacifica*	September to June
Red-breasted merganser	*Mergus serrator*	November to April
Red-throated loon	*Gavia stellata*	November to April
Ring-billed gull	*Larus delawarensis*	September to May
Surf scoter	*Melanitta perspicillata*	October to May
Western grebe	*Aechmophorus occidentalis*	October to May
Western gull	*Larus occidentalis*	January to December
The coastal marine habitat zone is shown in Figure 4.2 as an orange strip along the coast. The coastal marine habitat zone is approximately 0.7 miles wide. Habitat and species data were derived from the Environmental Sensitivity Index developed by the NOAA Office of Response and Restoration[3].		

Table 4.3 - **Marine mammals and sea turtles that utilize the near coastal area**

COMMON NAME	LATIN NAME	MONTHS PRESENT
Baird's beaked whale	Berardius bairdii	January to December
Bottlenose dolphin	Tursiops truncatus	January to December
Cuvier's beaked whale	Ziphius cavirostris	January to December
Gray whale	Eschrichtius robustus	January to April
Leatherback sea turtle	Dermochelys coriacea	March to July
Loggerhead sea turtle*	Caretta caretta	January to December
Long-beaked common dolphin	Delphinus capensis	January to December
Mesoplodont beaked whales	Mesoplodon spp.	January to December
Pacific harbor seal	Phoca vitulina richardii	January to December
Sperm whale	Physeter macrocephalus	January to December
Baird's beaked whale	Berardius bairdii	January to December

The near coastal area is defined as the 0.7 mile wide zone along the coast. Gray whales can be found off the coast year-round but are most common during January to April; other months of the year, their presence is considered secondary to rare. Data were derived from the Environmental Sensitivity Index developed by the NOAA Office of Response and Restoration[3].
* Species was noted in database as “rare”.

4.3 Flora, Fauna & Habitat Summary

Vegetation cover of the study area is primarily comprised of California coastal scrub, which covers 60% of the total watershed area, in addition to oak forest and woodland, grassland, and hard chaparral. All of these vegetation types provide habitat to a diversity of species. Of the vegetation communities present in the watersheds, the coastal sage scrub may be the most threatened, with human development replacing most of its historic range in Southern California. Beaches and coastal environments provide habitat for dozens of marine mammal, bird, and fish species, including shorebird and grunion breeding habitat. The study watershed outlets are designated as potential habitat for the California red-legged frog, Southwestern pond turtle, Bald Eagle, and Osprey. Runoff and sediment from roads and oil infrastructure in the watersheds discharges onto beaches and into coastal marine habitats and kelp forests, which can stress or degrade these sensitive environments.

4.4 Flora, Fauna & Habitat References

1) Critchfield, William B. 1971. Profiles of California vegetation. Berkeley, Calif., Pacific SW. Forest & Range Exp. Sta., 54 p., illus. (USDA Forest Serv. Res. Paper PSW-76)

2) Fry, J., Xian, G., Jin, S., Dewitz, J., Homer, C., Yang, L., Barnes, C., Herold, N., and Wickham, J., 2011. Completion of the 2006 National Land Cover Database for the Conterminous United States, *PE&RS*, Vol. 77(9):858-864.

3) Environmental Sensitivity Index (ESI). National Oceanic and Atmospheric Administration (NOAA). Office of Response and Restoration. Available at http://response.restoration.noaa.gov/maps-and-spatial-data/download-esi-maps-and-gis-data.html. Accessed March 15, 2014.

4) Davis, F.W., Stine, P.A., Stoms, D.M., 1994. Distribution and conservation status of coastal sage scrub in southwestern California. Journal of Vegetation Science. 5: 743-756.

5) Western Riverside County Multiple Species Habitat Conservation Plan (MSHCP), 2002. Volume 2 Section C, Habitat Accounts and Vegetation Associations. Available at: http://www.rctlma.org/mshcp/volume2/SectionC.html#TOC1_6.

6) Santa Barbara City College. Biological Sciences, Introduction to the Chaparral. Soft Chaparral or Coastal Sage Scrub Community. Available at: http://www.biosbcc.net/b100plant/htm/soft.htm.

7) Ventura County Fire Protection District. Fire Management Plan, July 2005. Available at: http://fire.countyofventura.org/LinkClick.aspx?fileticket=hlthDPzu3zc%3D&tabid=56.

8) Levick, L., J. Fonseca, D. Goodrich, M. Hernandez, D. Semmens, J. Stromberg, R. Leidy, M. Scianni, D. P. Guertin, M. Tluczek, and W. Kepner. 2008. The Ecological and Hydrological Significance of Ephemeral and Intermittent Streams in the Arid and Semi-arid American Southwest. U.S. Environmental Protection Agency and USDA/ARS Southwest Watershed Research Center, EPA/600/R-08/134, ARS/233046, 116 pp.

9) California Department of Fish and Wildlife. Ventura County Area Contingency Plan, Section 9813.1 Environmentally Sensitive Sites. Office of Spill Prevention and Response.

10) Dugan, J. Utilization of Sandy Beaches by Shorebirds: Relationships to Population Characteristics of Macrofauna Prey Species and Beach Morphodynamics. MMS OCS Study 99-0069. Coastal Research Center, Marine Science Institute, University of California, Santa Barbara, California. MMS Cooperative Agreement Number 14-35-0001-30758. 41 pages.

11) MBC Applied Environmental Sciences, 2011. Status of the kelp beds 2010, Ventura, Los Angeles, and Orange Counties. Central Region Kelp Survey Consortium Report

5.0 | Residential & Recreational Land Uses

Over the past 250 years, human activity and development of the study watersheds has increased dramatically. Presently, there are three residential communities and a number of beaches that provide recreational uses to tourists and local populations. Information on the higher intensity land uses in the study area is included in the Agriculture (Section 6.0), Transportation (Section 7.0), and Oil Production Operations (Section 8.0) sections.

Section Highlights

- The Chumash people are the earliest known inhabitants of coastal Ventura County
- Spanish colonization established Missions and transportation routes that later influenced modern development in the study area
- Near the watershed outlets, there are three residential communities along the coast: Seacliff, Faria, and Solimar
- Campgrounds in the study area generate over $1.2 million annually for Ventura County
- 570,000 people are estimated to frequent Faria, Hobson, Mondos, and Rincon Parkway, the majority of which are local families
- Beaches in the area are prominent locations where people visit to participate in surfing, swimming, fishing, and other activities

Approximately 250 homes are in the Sea Cliff, Faria, and Solimar Beach communities. From the point at the Mussel Shoals community to the Solimar Beach community, there are roughly 275 residents living on the coast near the watershed outlets. Many of the people that live in the area are children and other sensitive populations[1].

Recreational uses popular in the study area include camping, surfing, fishing, and other beach activities. Recreation provides value to the local population and economy, and Ventura County generates millions of dollars annually from tourism to this area. However, participating in these activities can also expose people to contaminants from the watersheds. Recreational activities are explored to evaluate benefits from recreational uses and identify potential pathways for pollutants.

Figures 5.1 and 5.2 highlight the various parks, public beaches, and residential communities. Active and idle oil wells are also shown for perspective on the proximity of oil operations to other human uses.

Figure 5.1 – Location of parks, public beaches, and residential communities in northwestern portions of the study area. These boundaries were approximated from aerial imagery and do not represent official or jurisdictional boundaries.

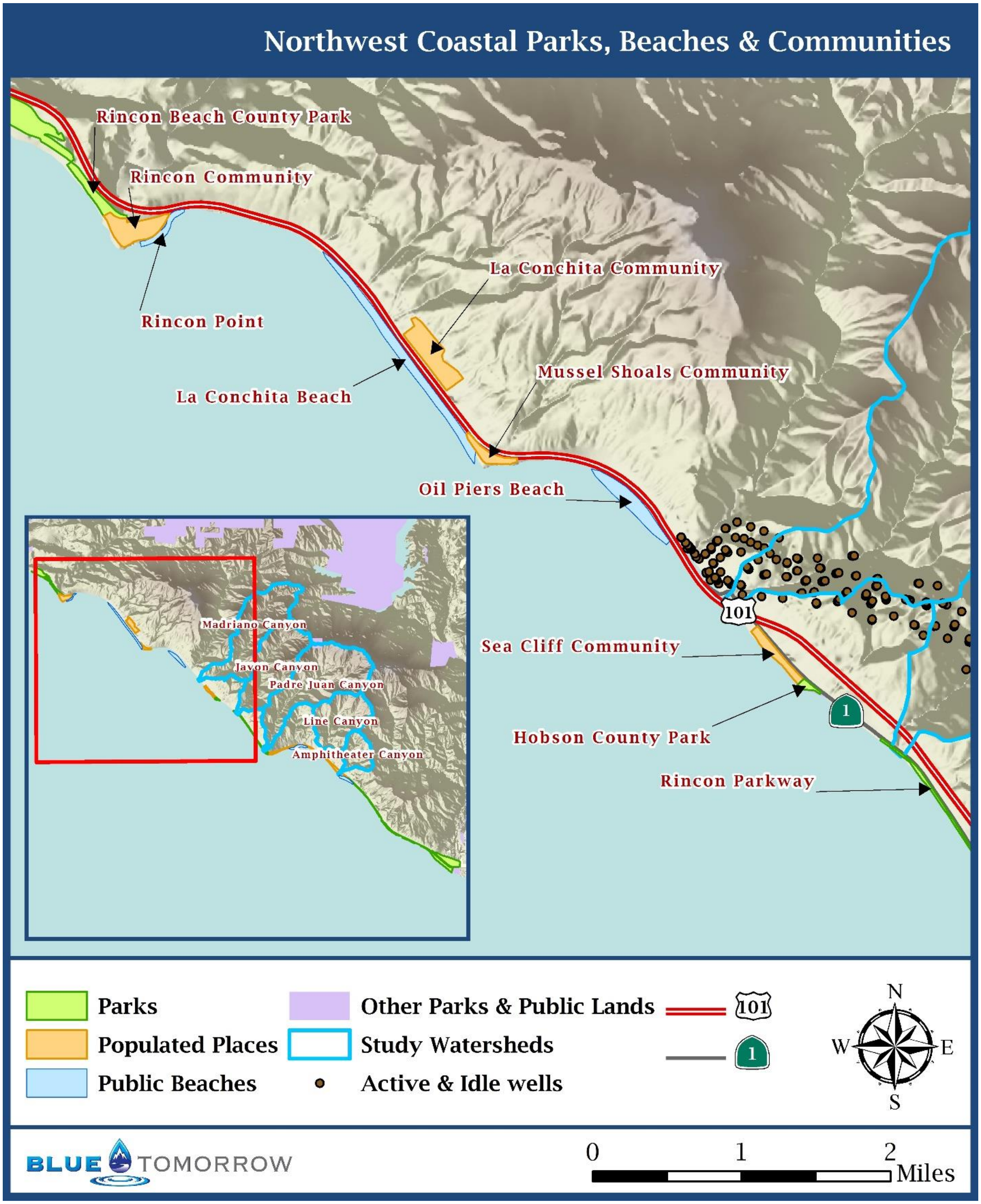
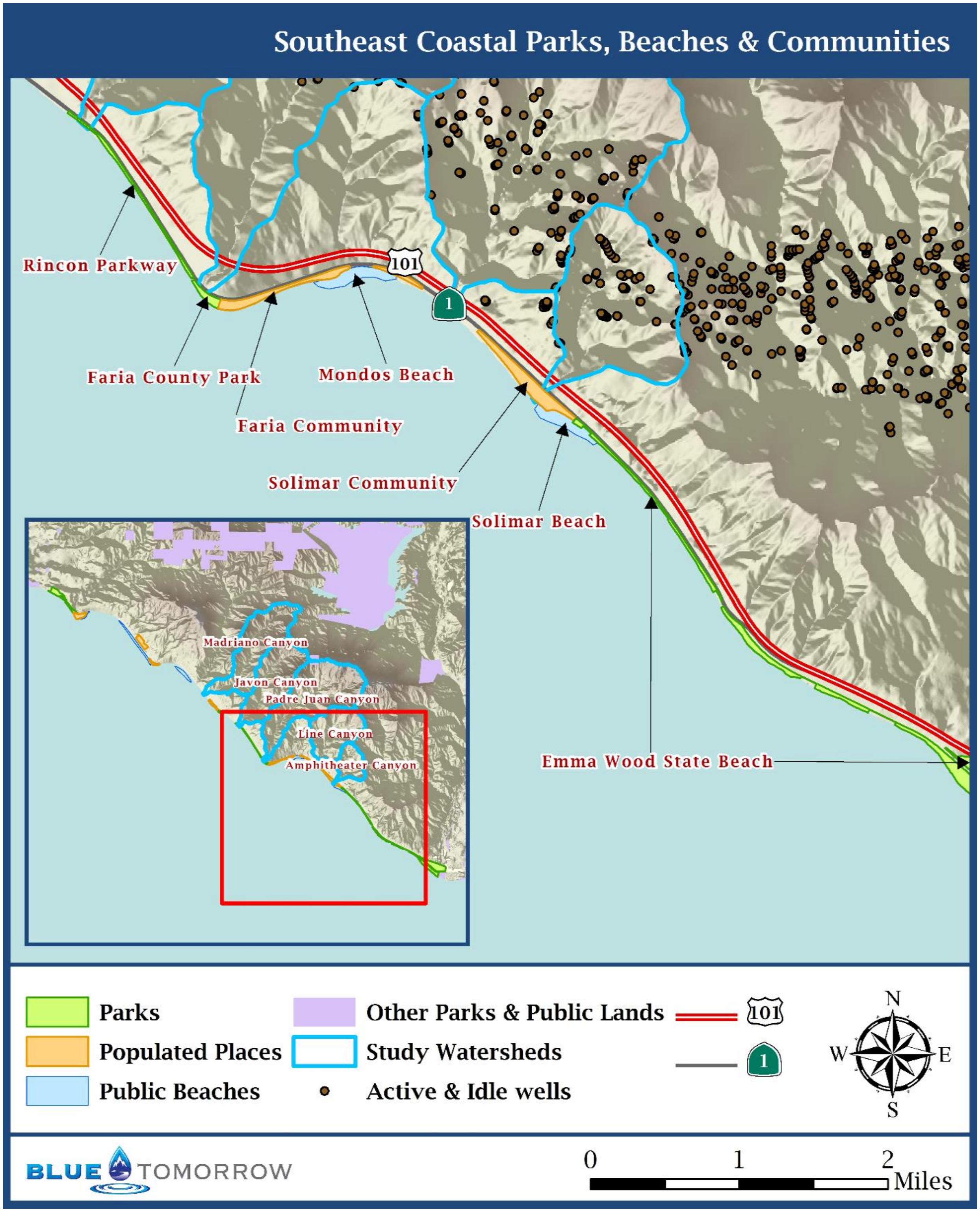


Figure 5.2 – Location of parks, public beaches, and residential communities in southeastern portions of the study area. These boundaries were approximated from aerial imagery and do not represent official or jurisdictional boundaries.



5.1 History of Human Activity in Study Watersheds

To understand how human activity has developed in the area, it is worth noting the major historic events that have influenced the present day. Resources in and around the watersheds have attracted people to the Ventura and Santa Barbara coastline. The earliest known inhabitants, the Chumash, used tar from natural seeps for canoe building and basket weaving[2]. Development has increased since the arrival of the Spanish as people have continued to utilize the area's resources.

Spanish colonization in the 18th century brought about the development of the missions and the El Camino Real road that connected coastal California. Under Mexican rule from 1822 until 1848, 17 rancho land grants allocated private property in what would later become Ventura County, including the 4,460 acre Rancho El Rincon and 8,800 acre Rancho Cañada de San Miguelito that extend into the watershed areas[4]. After the Mexican-American war, the Treaty of Hidalgo transferred control of California to the United States in 1848, which led to further settlement towards the end of the century.

The incorporation of California as the 31st state in 1850 led to the immigration of settlers who began building infrastructure and communities throughout the region. William Dewey (W.D.) Hobson, a prominent businessman, helped establish Ventura as a county in 1873, and was a leader in developing the area. In the early 20th century, Hobson and Faria County parks were donated by the Hobson and Faria families to the County and remain popular destinations for locals and tourists[3].

Highways 1 and 101 were built along the historic route of the El Camino Real in the early 20th century and expanded through 1960[5]. The largest growth in housing construction in Census Tract 12.06, which encompasses the study area (Figure 5.3), occurred in the 1970s and 1980s[1]. Of these homes, 48 were built prior to 1939, and there were no reported new houses constructed after 2009[1]. This development has led to the current non-extractive residential and recreational land uses, which can serve as pathways for exposure of people to pollutants.

5.2 Residential Communities

Three residential beach communities are found between the outlets of the study watersheds (from north to south): Seacliff community, Faria community, and Solimar community, also referred to as the Dulah community (Figure 5.3). Each community is zoned Residential Beach (R-B), which provides for the development and preservation of small-lot, beach-oriented residential communities[6]. The majority of homes in these communities are valued in the millions of dollars, and construction has remained stagnant over the past 5 years[1].

The following section provides population estimates from 2010 census data for census blocks most closely within the study area (Figure 5.3). The most recent and detailed demographic information is available for the surrounding area (Census Tract 12.06; Table 5.3), which also includes a portion of the Ventura River watershed (Figure 5.3). Estimates for the number of housing units were conducted through aerial imagery in the communities and census information.

Figure 5.3 – Boundaries of census units used to analyze residential housing, population, and demographics in and around the study watersheds. Census tract 12.06 contains detailed demographic data (Table 5.1) and encircles the entire study area, while census blocks adjacent to the coast (green) were used to quantify the local population closest to the watersheds.

Residential Development and Population Estimates

The Seacliff community covers 11.34 acres and consists of an estimated 49 single-family homes. This community is located between Madriano and Javon Canyons and is bounded by Highway 101 to the north, Highway 1 to the east, and Hobson County Beach Park to the south (Figure 5.1)[1].

The Faria community is located between Padre Juan and Line Canyons, and divided by Mondos Beach. The entire area is 20.7 acres and includes an estimated 102 homes in the west and 27 in the eastern part of the community, separated by Mondos Beach access (Figure 5.2) [1].

The Solimar Beach community is located southeast of Line Canyon, and divided by the outlet of Amphitheater Canyon watershed. There are an estimated 68 homes, and the community is bounded by Highway 1 and the beach (Figure 5.2)[1].

The total estimated residential housing and population found between Highway 101 and the coast, from Muscle Shoals point to the Solimar community in the southeastern end, is 278 housing units and a population of 274 people. These census blocks include 43% of the houses and 29% of the population included in the larger Census Tract 12.06 (Figure 5.3) [1].

The residential communities of Solimar, Faria, Seacliff and Mussel Shoals are all connected to the North Coast Sewer System, which is operated and maintained by the Ventura Regional Sanitation District. This Septic Tank Effluent Pump (STEP) services approximately 300 connections[7].

Demographics

In 2012, the population of Census Tract 12.06 was estimated as 942 people occupying 398 homes. Potentially sensitive groups represent a large fraction of the total residential population. 153 were children 15 years old and under, including 34 children under 5 years old. Women between 15-50 years old accounted for 20 percent of the population, with seniors 65 and over classifying another 20 percent[1]. A greater proportion of senior citizens live in this area compared to the county as a whole (Table 5.1).

The mean property value of these homes is estimated to be $982,800. Median household income in this tract was estimated to be $98,128 and the per capita income $55,872, well exceeding values for all of Ventura County. Table 5.1 highlights various characteristics of the demographics in Census Tract 12.06 and Ventura County that were updated for 2012[1].

Table 5.1 *–* **Population and housing statistics for Census Tract 12.06 and Ventura County**

	CENSUS TRACT 12.06	VENTURA COUNTY
Population (Number and % of Total Population)		
Total Population	942	836,000
Ages 16 and Over	84%	76%
In Labor Force	54%	52%
65 Years and Over	20%	13%
Women Ages 15-50	20%	24%
Children Under 5 Years	4%	7%
Housing (Number and % of Total Housing Units)		
Total Housing Units	644	282,000
Occupied Housing Units	62%	95%
Owner-Occupied Housing Units	47%	61%
Homes Valued $1,000,000 or Greater	23%	4%
Income (in US Dollars)		
Median Household Income	$98,128	$76,483
Mean Household Income	$131,752	$98,429
Per Capita Income	$55,872	$32,826
Median Value of Housing Unit	$982,800	$465,600

Data from 2008-2012 U.S. Census Bureau American Community Survey that produces population, demographic and housing unit estimates annually[1].

5.3 Recreational Use

Along the coastline of northern Ventura County there are a number of beaches and parks that people regularly visit (Figures 5.1 and 5.2). These popular destinations provide opportunities for camping, surfing, fishing, and other beach uses for both tourists and residents of Ventura and Santa Barbara counties. The Ventura County Coastal Area Plan[6], in accordance with the State Coastal Act, specifies several policies aimed at protecting recreational uses, including:

§ 30213 - Lower cost visitor and recreational facilities; encouragement and provision; overnight room rentals. Lower cost visitor and recreational facilities shall be protected, encouraged, and, where feasible, provided. Developments providing public recreational opportunities are preferred.

§ 30220 - Coastal areas suited for water-oriented recreational activities that cannot readily be provided at inland water areas shall be protected for such uses.

§ 30221 - Oceanfront land suitable for recreational use shall be protected for recreational use and development unless present and foreseeable future demand for public or commercial recreational activities that could be accommodated on the property is already adequately provided for in the area.

§ 30222 - The use of private lands suitable for visitor-serving commercial recreation facilities designed to enhance public opportunities for coastal recreation shall have priority over private residential, general industrial, or general commercial development, but not over agriculture or coastal-dependent industry.

The main recreational uses of the study area, which provide value to people and the local economy, include camping, surfing, and other beach activities. From July 1, 2012 to June 30, 2013, camping at Hobson and Faria County Parks, and along the Rincon Parkway, generated over $1.2 million in revenue for the County. There are numerous surf breaks along the shoreline near the watershed outlets attract surfers from across the world. The beaches on the outer edges of the watersheds are also popular sites for surf fishing and many other recreational uses[7].

Camping

Hobson County Beach Park was one of the first parks to be established in Ventura County when the descendants of W.D. Hobson donated it to the County in 1915[3]. Located between the Madriano and Javon Canyon outlets, the park has 31 sites and allows group camping, tent camping, and Recreational Vehicle (RV) campers (Figure 5.1). The County currently oversees Hobson Park, which is connected to the STEP sewer system that sends waste to Ventura for treatment. In County Fiscal Year 2012-2013, Hobson County Beach Park saw 18,132 visitors and earned $132,993 for Ventura County[7]

The Rincon Parkway is found on the southwestern shoulder of Highway 1 to the south of Hobson County Beach Park and offers day use and 127 spaces for RV camping (Figure 5.1 and 5.2). Both creeks from Javon and Padre Juan Canyons run under the Rincon Parkway and out into the ocean. The State presently implements the Rincon Parkway Plan on behalf of the County. Utilities (water, sewer, electricity) are not available at the Rincon Parkway. In County Fiscal Year 2012-2013, RV camping at Rincon Parkway attracted 94,461 visitors and generated $781,853 from usage fees[7].

The Faria County Beach Park was granted to the County by Manuel del Terra Faria in 1915[3]. The park is located to the southeast of Rincon Parkway, and provides 42 sites for group camping, tent camping, and RV campers (Figure 5.2). The County manages Faria Park which is also connected to the STEP sewer system. In County Fiscal Year 2012-2013, Faria County Beach Park saw 32,718 visitors and earned $332,784 from usage fees[7].

Beaches

The beaches in the study area draw hundreds of thousands of visitors year-round, and provide access for a number of recreational activities. Public beaches near the watershed outlets include Hobson, Rincon Parkway, Faria, Mondos, and Solimar beaches (Figures 5.1 and 5.2). Free parking is available in some areas along Highway 1, allowing for easy public access for visitors making day-trips to the beach (Figures 5.1 and 5.2). While these beaches have limited amenities, they are popular for recreational activities including surfing and fishing. These activities provide public benefit and promote County priorities for the availability and accessibility of the beach and its resources. However, public access to beaches and coastal waters near drainage outlets allows for possible exposure to pollutants from discharges. Pictures 5.1 and 5.2 show people near effluent from Line Canyon while using the beach and waters for recreational purposes.

Picture 5.1 – Coastal Waters off Line Canyon
People in coastal waters near effluent from Line Canyon during storm event on February 28, 2014.

Picture 5.2 – Beach by Line Canyon outlet
Woman and dog walking near Line Canyon base flow on January 25, 2014.

While the number of visitors at the beaches is not regularly tracked, a study which sought to assess the recreational value of beaches in the study area, estimated the number of visitors to Faria, Hobson, Mondos, and Rincon Beach North Parkway beaches (Table 5.2)[12].

Table 5.2 - **2007 Estimates for number of visitors to beaches**[12]

BEACH	ANNUAL ATTENDANCE ESTIMATES
Faria County	250,000
Hobson	20,000
Mondos	200,000
Rincon Parkway North	100,000
Total	**570,000**
Beach attendance was estimated using counts from each site between May 2007 and November 2007, weighting for peak and non peak attendance, and survey data, which was used to calibrate attendance estimates.	

A 2003 survey at Rincon Parkway showed that almost 73% of respondents lived within 20 miles of the beach[8]. The majority of the visitors were families, and almost 70% visited the beach between 6 and 40 days a year. About 41% of the respondents spend 3-5 hours on the beach for a typical day at Rincon Parkway and 22% spend between 5-8 hours per day[8].

The economic value of the beaches to visitors was also estimated through a benefits transfer method, by applying survey data to a rating system for amenities (Weather, Water Quality / Surf, Beach Width and Quality, Overcrowding, Beach Facilities and Services, Availability of Substitutes)[8]. Based on attendance and responses from the beach visitors, this projected to a recreational value of roughly $4.8 million[12].

Surfing

The north coast of Ventura is known for numerous surf breaks, including several found between the outlets of the study watersheds: Stanley's (Hobson Park), Pitas Point (Faria Park), Mondos, and Solimar (Figures 5.1 and 5.2). Stanley's, found off the Seacliff exit, in the northern part of the study area, was named after the diner once located in front of the break that was demolished in 1970 during the construction of Highway 101. Pitas Point is located off the coast of Faria County Beach Park. Mondos is known for its calmer surf, and is a popular break for long boarders. Three different breaks off the coast of the Solimar Beach community are notable locations for surfing: the Solimar Reef, Solimar Point, and Solimar Beachbreak[10].

There are several popular surf breaks to the north and south of the study area. Rincon is located approximately 3.5 miles from the Madriano Canyon outlet, and attracts surfers from across the world (Figure 5.1). It is home to the oldest surfing competition in Santa Barbara County, and people were known to surf at Rincon as early as the 1940's. The break off of Mussel Shoals is another surfing location north of the watershed outlets. Popular surfing locations to the south include the Gold Coast Beachbreaks, Summer Beach, and Emma Wood State Beach (all found along the Emma Wood State Beach; Figure 5.2) [10].

During field tests and monitoring of the watersheds from October 2013 to May 2014, over 200 surfers were observed in the water at one time at the nearby surf breaks when winter swells brought good surf conditions. Many surfers have been seen within 200 feet of discharges from the study watersheds as shown in Picture 5.4.

Picture 5.3 - Mondos Beach
Children and adults at the beach and in coastal waters on Saturday afternoon, January 25, 2014.

Picture 5.4 – Coastal waters off Line Canyon
Surfers in coastal waters near discharge of Line Canyon base flow on January 25, 2014.

Fishing

Surf fishing, or beach fishing, is another popular recreational activity found off the coast of the study area. Surfperch, California Corbina, and Cabezon are some of the types of fishes caught from the beaches near the watershed outlets. These fish are consumed on occasion and may be a potential pathway for public exposure to pollutants that bioaccumulate. Beach fishing is overseen by the California Department of Fish and Wildlife that regulates the types of fish that can be legally caught[11]. Picture 5.5 captures the catch and release of a shark off the coast of Line Canyon.

Picture 5.5 – Fishing near Line Canyon
Fishermen dragging catch through effluent from Line Canyon on February 2, 2014.

5.4 Residential & Recreational Land Uses Summary

There is a long history of human activity in coastal northern Ventura County, beginning with the native Chumash people. Spanish colonization in the 18th century brought about the development the El Camino Real road that connected coastal Missions, and over the last 250 years, development in the study area has increased dramatically. Presently, there are three residential communities (Seacliff, Faria, and Solimar) along the coastline in the study area, which have approximately 250 homes. From the point at Mussel Shoals community to Solimar ((Figures 5.1 & 5.2) there is an estimated population of 274 year-round residents.

The Ventura County Coastal Area Plan and State Coastal Act have several specific policies that strive to protect recreational activities in the area. The campgrounds of Hobson County Beach Park, Rincon Parkway, and Faria County Beach Park along this section of coastline generate over $1.2 million annually for Ventura County. The beaches associated with these parks and along the coastline were estimated to have over 570,000 visitors per year, providing a recreational value of $4.8 million. The majority of these visitors were local families that went to the beaches between 6 and 40 times a year for a minimum of 3 hours.

5.5 Residential & Recreational Land Uses References

1) US Department of Commerce. United States Census Bureau. American Fact Finder. Ventura County, California. Census Tract 12.06. Available at: http://factfinder2.census.gov/faces/nav/jsf/pages/searchresults.xhtml?refresh=t. Accessed December 12, 2013.
2) Santa Ynez Band of Chumash Indians. Chumash History. Available at: http://www.santaynezchumash.org/history.html.
3) County of Ventura. History of the Ventura County Parks Department. Available at: http://portal.countyofventura.org/portal/page/portal/GSA/parks_department_-_Directory/docs/HISTORY_OF_THE_VENTURA_COUNTY.pdf
4) Ventura County. Genealogical Society. Spanish and Mexican Land Grants. Available at: http://www.venturacogensoc.org/cpage.php?pt=38
5) California Department of Transportation. Frequently Asked Questions. Available at: http://www.dot.ca.gov/hq/paffairs/faq/faq62.htm
6) County of Ventura. 2008. Ventura County General Plan. Coastal Area Plan.
7) County of Ventura Parks Department. December 9, 2013. Personal communication.
8) King, Philip, H. July, 2006. Economics of Regional Sediment Management in Ventura and Santa Barbara Counties: A Pilot Study. Interim Report to the Coastal Sediment Management Workgroup. Available at: http://dbw.ca.gov/CSMW/PDF/Economics_of_RSM_0706.pdf.
9) Henemann et al. September 17, 2004. Southern California Beach Valuation Project. Using revealed preference models to estimate the effect of coastal water quality on beach choice in Southern California.
10) Surfline. Ventura. Available at: http://www.surfline.com/travel/index.cfm?id=2952
11) California Department of Fish and Game. Guide to California Beach Fishing. Available at: http://www.dfg.ca.gov/marine/beachfishing.asp
12) California Coastal Sediment Management Workgroup, and U.S. Army Corps of Engineers Los Angeles District. January 2009. Beach Erosion Authority for Clean Oceans and Nourishment. Coastal Regional Sediment Management Plan. Central Coast from Pt. Conception to Pt. Mugu.

6.0 | AGRICULTURE

The California Coastal Act (incorporated into the Ventura County General Plan through the County Coastal Area Plan) requires the maximum achievable preservation of prime agricultural land in the coastal zone. According to US Soil and Conservation Service, there are approximately 1,130 acres of prime soils on the north coast of Ventura County[1]. The Los Angeles Regional Water Quality Control Board Basin Plan designates Madriano, Javon, and Padre Juan Canyons as having intermittent beneficial use of water for agricultural supply. This beneficial use supports the "uses of water for farming, horticulture, or ranching, including, but not limited to, irrigation, stock watering, or support of vegetation for range grazing"[2].

Roughly 172 acres dedicated to the production of avocados, lemons, and strawberries are found in and adjacent to the watersheds[3,4]. Estimates of acreage were determined through personal communication with growers and aerial imagery. Padre Juan Canyon contains 68.5 acres of avocado and lemon orchards, with the remaining agricultural acreage in the study area consisting of orchards and strawberry fields located along the coast. Approximately 800 acres are used for grazing, primarily in Madriano Canyon. The strawberry field (Seacliff field) and lemon and avocado orchards (Faria West field) are located on the coast, but not within the mapped watershed boundaries, and are included in this section due to their proximity to the drainages.

Section Highlights

- Agriculture is a designated beneficial use of water resources in the larger three watersheds
- There are 68.5 acres of avocado and lemon orchards in the watershed boundaries, and 36 acres of lemon trees, 2 acres of avocado trees and 65 acres of strawberry fields adjacent to the watersheds
- Agriculture in these areas generated roughly $5.1 million in 2012, and use about 400 acre-feet of water per year
- The only known groundwater used for agriculture is at Padre Juan Canyon Ranch where it represents 30% of its total water usage
- All other water used for agriculture in the study area is likely purchased from Casitas Municipal Water District
- Pesticides used for avocados and lemons contain petroleum derivatives, such as mineral oil

In the nearby Ventura River watershed, annual estimates of water use for these crops are 2.1 acre-feet per acre of avocados and citrus, and 3.2 acre-feet per acre of strawberry production[5]. Estimated annual pesticide usages in Ventura County include 2.27 lbs of pesticides per acre of avocados, 9.22 lbs of pesticides per acre of lemons, and 3.3 lbs of pesticides per acre of strawberries[6]. Petroleum oil derivatives, including mineral oil, are common pesticides, herbicides, and fungicides used for avocados and lemons in California[7]. The following section discusses the characteristics of agricultural sites found in and bordering the watersheds.

6.1 Padre Juan Canyon Ranch

The Padre Juan Canyon Ranch, located deep in the Padre Juan Canyon watershed, consists of approximately 37.5 acres of avocado orchards and 31 acres of lemons orchards. The ranch uses roughly 120 acre-feet of water per year for the orchards, approximately 30% of which comes from three wells on site. The remaining 70% of the water is purchased from Casitas Municipal Water District. According to the grower, one of the wells exhibits high levels of boron, but water quality is sufficient for agricultural purposes and trees do not appear stressed from poor water or soil quality[3].

In 2013, pesticides were applied 14 times to orchards in Padre Juan Canyon Ranch. These included over 250 gallons of an insecticide that is 98% refined petroleum oil (most likely a mineral oil). This was applied through an on-the-ground application in 30 acres of lemon trees[8]. Table 6.1 shows the application dates, types, amounts, and active ingredients of pesticides in Padre Juan Canyon Ranch[8,9].

Table 6.1 - **2013 Padre Juan Canyon Ranch pesticide use**[8,9]

PRODUCT	DATE OF APPLICATION	AMOUNT	ACTIVE INGREDIENT	PERCENT OF TOTAL INGREDIENTS
Insecticide, Miticide	3-Jul-13	259 gallons	Petroleum Oil, Unclassified	98%
Insecticide, Miticide	3-Jul-13	370 ounces	Abamectin	2%
Insecticide	13-Sep-13	40 pints	Chlorpyrifos	40.20%
Herbicide	30-Sep-13	15 gallons	Glyphosate, Isopropylamine Salt	41%
Herbicide	30-Sep-13	15 gallons	Simazine	41.90%
Vertebrate Control	30-Oct-13	10 pounds	Strychnine	0.50%
Herbicide	31-Oct-13	5 gallons	Glyphosate, Isopropylamine Salt	41%
Insecticide	31-Oct-13	40 pints	Chlorpyrifos	40.20%
Herbicide	31-Oct-13	5 gallons	Simazine	41.90%
Herbicide	31-Dec-13	3 gallons	Glyphosate, Isopropylamine Salt	41%
Herbicide	31-Dec-13	3 gallons	Simazine	41.90%
Vertebrate Control	31-Dec-13	6 pounds	Zinc Phosphide	2%

Specific products and amounts obtained from Ventura County Office of the Agricultural Commissioner Permit Use Reports for Padre Juan Canyon Ranch. Detail on active ingredients obtained from California Department of Pesticide Regulation. Remaining ingredients in pesticides are classified as inert ingredients.

The 2012 Crop Report generated by the Ventura County Agricultural Commissioner estimates the production and market value for crops (per acre) grown countywide. In Ventura County that year, lemons generated over $200 million, the second highest grossing crop in the County. Avocados grown in the County garnered almost $115 million in 2012. Table 6.2 shows the 2012 estimated quantity and revenue from avocados and lemons grown at the Padre Juan Canyon Ranch[10].

Table 6.2 - **2012 Padre Juan Canyon Ranch crop production and revenue estimates**[10]

CROP	ACRES	TONS PER ACRE	TONS PRODUCED	PRICE PER TON	REVENUE
Avocados	37.5	3.4	127.5	$1,731.30	$220,741
Lemons	31	19.41	601.71	$668.10	$402,002
Crop production and revenue estimates were generated by applying Padre Juan Canyon Ranch acreage to 2012 Ventura County averages, stated by the Office of the Agricultural Commissioner the Ventura County Crop & Livestock Report.					

6.2 Faria West

The Faria Family Partnership is a 250 acre agricultural preserve located between Padre Juan and Javon Canyon watersheds[1]. The Faria West site totals 38 acres, of which 36 acres is dedicated to lemon trees and 2 acres for avocado orchards. According to the grower, the site has produced lemons for the last 30 years. These orchards use approximately 76 acre-feet of water per year, 100% of which comes from the Casitas Municipal Water District[4]. A palm nursery of about 18 acres is also located within the preserve, with the remaining acreage comprised of open fields and hilly terrain. Information on production, price, or pesticide application was not available for the nursery.

In 2013, three gallons of an insecticide containing 98% mineral oil and 0.05 gallons of an insecticide with 8% abamectin was applied in the air over 1.5 acres of the site[6]. Table 6.3 shows the active ingredients of the products used and reported to the Ventura County Office of the Agricultural Commissioner in 2013[6,9].

Table 6.3 - **2013 Faria West pesticide use [6,9]**

PRODUCT	DATE OF APPLICATION	AMOUNT	ACTIVE INGREDIENT	PERCENT OF TOTAL INGREDIENTS
Insecticide	21-Jun-13	3 gallons	Mineral oil	98%
Insecticide, Miticide	21-Jun-13	0.05 gallons	Abamectin	8%
Specific products and amounts obtained from Ventura County Agricultural Commissioner Permit Use Reports. Detail on active ingredients obtained from California Department of Pesticide Regulation. Remaining ingredients in pesticides are classified as inert ingredients				

Based on 2012 estimates, crop production from the Faria West site generated nearly $500,000. Table 6.4 shows the 2012 estimates for amounts and revenue for avocados and lemons grown at Faria West[10].

Table 6.4 - **2012 Faria West crop production and revenue estimates[10]**

CROP	ACRES	TONS PER ACRE	TONS PRODUCED	PRICE PER TON	REVENUE
Avocado	2	3.4	6.8	$1,731.30	$11,773
Lemons	36	19.41	698.76	$668.10	$466,842
Crop production and revenue estimates were generated by applying the Faria West acreage to 2012 Ventura County averages (Office of the Agricultural Commissioner the Ventura County Crop & Livestock Report).					

6.3 Seacliff Field

The Seacliff site is 65 acres of strawberry fields found between Madriano and Javon Canyons. Approximately 208 acre-feet of water is used each year for crop production, based on estimates for strawberries grown in the Ventura River watershed[3]. In 2013, 900 gallons of a liquid fumigant was applied to the soil in 40 acres of the strawberry field to control nematodes[6]. Table 6.5 shows the active ingredients the product used in 2013 and reported to the Ventura County Agricultural Commissioner[6,11].

Table 6.5 - **2012 Seacliff pesticide use [6,11]**

PRODUCT	DATE OF APPLICATION	AMOUNT	ACTIVE INGREDIENT	PERCENT OF TOTAL INGREDIENTS
Soil Fungicide & Nematicide	20-Jun-13	900 gallons	1,3-dichloropropene	60.8%
			chloropicrin	33.3%
Specific products and amounts obtained from Ventura County Agricultural Commissioner Permit Use Reports. Detail on active ingredients obtained from manufacturer fact sheet for the product. Remaining ingredients in pesticides are classified as inert ingredients				

In Ventura County, strawberries are the highest grossing crop, generating over $700 million. In 2012, an estimated 2,000 tons of strawberries were harvested at the Seacliff site resulting in nearly $4 million in revenue (Table 6.6)[10].

Table 6.6 - **2012 Seacliff crop production and revenue estimates[10]**

CROP	ACRES	TONS PER ACRE	TONS PRODUCED	PRICE PER TON	REVENUE
Strawberries	65	30.91	2009.15	$1,958.58	$3,935,081
Crop production and revenue estimates were generated by applying Seacliff acreage to 2012 Ventura County averages (Office of the Agricultural Commissioner the Ventura County Crop & Livestock Report).					

6.4 Grazing

There are approximately 800 acres of grazing pasture in the watersheds, the vast majority of which are found in upper Madriano Canyon. This area was estimated from aerial imagery and spatial analysis of the grassland that was likely historically converted from coastal scrub, chaparral, and oak woodland to create grazing pasture, and not likely to be naturally so extensive in the upper portions of Madriano Canyon. It is not known if this grazing pasture is irrigated. For more information on the native vegetation in the watersheds, see Section 4.0 Flora, Fauna & Habitat.

Potential impacts from grazing include nutrient loads from manure and increased erosion from overgrazed pasture. Some Best Management Practices (BMPs) frequently recommended for rangelands include reducing grazing intensity, evenly distributing manure, and keeping cattle out of areas that may be susceptible to erosion.

6.5 Agriculture Summary

Agriculture is a designated intermittent beneficial use of water resources in Madriano, Javon, and Padre Juan Canyons, and there are State and County policies directed at the preservation of agricultural land in the coastal zone. Avocado and lemon orchards and strawberry fields in the study area, generated roughly $5.1 million in 2012, with the greatest revenue generated from the Seacliff strawberry fields. These crops and orchards use about 400 acre-feet of water per year. Padre Juan Canyon Ranch uses groundwater for 30% of its water demand, with the rest purchased from Casitas Municipal Water District (CMWD). The orchards and crops outside the watershed boundaries use only water from CMWD. Pesticides used for avocados and lemons contain petroleum derivatives, such as mineral oil, which may be a source of pollutants. In addition to the orchards and strawberry fields, a large portion of upper Madriano Canyon is cattle grazing pasture (approximately 800 acres).

6.7 Agriculture Section References

1) County of Ventura. 2008. Ventura County General Plan. Coastal Area Plan.
2) LA Regional Water Quality Control Board. Basin Plan. Chapter 2 Beneficial Uses. Available at: http://www.swrcb.ca.gov/losangeles/water_issues/programs/basin_plan/index.shtml
3) Padre Juan Canyon Ranch grower. April 8, 2014. Personal communication.
4) Faria West grower. April 7, 2014. Personal communication.
5) Krist, John. Farm Bureau of Ventura County Farm. Agriculture in Watershed. Available at: ucanr.org/sites/wshedUVR/files/79387.pdf
6) Office of the Agricultural Commissioner. Permit Use Report for Seacliff and Faria West.
7) PAN Pesticides Database. California Database. Pesticide Use in Ventura in 2009, South Coast Region. Available at: http://www.pesticideinfo.org/DS.jsp?sk=1016
8) Office of the Agricultural Commissioner. Permit Use Report for Padre Juan Canyon Ranch.
9) California Department of Pesticide Regulation. California Product/Label Database Queries & Lists. Available at: http://www.cdpr.ca.gov/docs/label/labelque.htm
10) Office of the Agricultural Commissioner. 2012. Ventura County's Crop & Livestock Report.
11) Dow AgroSciences, LLC. August 2, 2012. Inline Soil Fungicide and Nematicide. Fact Sheet.

7.0 | TRANSPORTATION

Each day, thousands of vehicles pass through the study area on Highways 1, 101 and the rail lines owned by Union Pacific Railroad (UPRR). Pollutants from transportation activities (including heavy metals, oil and grease, and other organic compounds) build up during dry periods and mobilize during storm events when they are carried by runoff into drainage networks.

The three major transportation routes intersecting the study area are within close proximity to the sampling sites used for the Environmental Sampling element of this project. These transportation routes span roughly five miles from where they intersect the farthest southeast watershed (Amphitheater) to where they intersect the farthest northwest watershed (Madriano). Along this length there are highway storm drains that discharge directly into the study watersheds.

Additionally, the high traffic concentration along these routes warrants consideration of impacts from atmospheric deposition. As a result of these activities, typical concentration levels of pollutants found along highways and railways were examined to assess the potential contributions to affected water quality in the study watersheds.

Section Highlights

- Over 70,000 vehicles travel each day through the study watersheds on Highways 1, 101, and the railway owned by Union Pacific Railroad
- Transportation activities emit various pollutants, including heavy metals and organic compounds that enter the watersheds
- Contributions of pollutant concentrations in stormwater from transportation activities depend on several conditions, including antecedent dry days, precipitation, and traffic
- Diesel-electric trains, lubricants, and railroad ties are sources of heavy metals and organic compounds, including polycyclic aromatic hydrocarbons
- Pollutant levels from transportation activities are greatest within 100 meters of highways and other major sources

7.1 Traffic in the Study Watersheds

Union Pacific Railroad (UPRR) locomotives haul freight through the area, and UPRR allows Amtrak to use the railroad to carry passengers on the Pacific Surfliner from San Luis Obispo to San Diego. Annual rail traffic through the study area is estimated to range between 4,400 to 5,500 commuter trains and 200 to 420 freight trains[1].

Highway 1 is a scenic coastal route with the majority of traffic resulting from residents of coastal communities and tourists. Beaches and campgrounds in the study area are all accessible from Highway 1, and public parking is available in various locations along the shoulders of the highway. California Department of Transportation (Caltrans) Traffic Data Branch operates an automated traffic counter on Highway 1 near the Seacliff Community. In 2012, an average of 4,900 vehicles passed through this checkpoint each day, projecting to roughly 1.8 million vehicles that travelled this stretch of Highway 1 for that year[2].

Highway 101 has three lanes in both north and south directions through the study area, and is the primary transportation route for cars and trucks traveling along coastal California. Caltrans traffic counter locations for Highway 101 are at two points that border the watersheds (one near Solimar Beach and another by Seacliff). Over 6,000 vehicles are estimated to pass through the watersheds per hour during peak times on Highway 101[2]. According to Caltrans estimates roughly 70,000 vehicles travel through the study watersheds on Highways 1 and 101 each day, projecting to roughly 26 million vehicles per year[2]. Tables 7.1 show the Average Annual Daily Traffic (AADT), for Highways 1 and 101 in 2012.

Table 7.1 - **Average Annual Daily Traffic (AADT) on Highways 1 and 101 in 2012**

HIGHWAY	AADT	ANNUAL TRAFFIC
101	68,000	24,820,000
1	4,300	1,569,500
TOTALS	***72,300***	***26,389,500***

AADT is the total volume for the year divided by 365 days. The AADT back count (of vehicles travelling N-S) was used for both Highway 1 and 101. Traffic counting is generally performed by electronic counting instruments. Caltrans adjusts the resulting counts to estimate the annual average daily traffic by compensating for seasonal influence, weekly variation and other variables, in the event that they are present[2].

No current construction activities or road maintenance is occurring in the study watersheds. The nearest Caltrans construction activity is the structure (seawall) restoration located south of Solimar[18].

7.2 Pollutants from Transportation Activities

Cars and trucks are known to emit a number of contaminants that deposit on solid surfaces or enter the atmosphere as they travel through roads and highways. Worn tires and brake pads, incomplete combustion, weathered paint, and rust are some sources of heavy metals that originate from motor vehicles[3]. Table 7.2 highlights sources of heavy metals typically found in highway stormwater runoff. In addition to the metals listed below, cobalt, mercury, and molybdenum have been found to be pollutants resulting from trains including locomotive wheels, breaks pads, and break blocks[4].

Table 7.2 - **Sources of heavy metals associated with highway stormwater runoff [5]**

METALS	SOURCES
Cadmium	Tire wear, brake pads, combustion of oils
Chromium	Corrosion of welded metal plating, moving engine parts, brake lining wear
Copper	Metal plating, bearing and bushing wear, moving engine parts, brake lining wear
Iron	Auto body rust, steel roadway structures, moving engine parts, corrosion of vehicular bodies
Lead	Leaded gasoline, tire wear
Nickel	Diesel fuel and gasoline, lubricating oil, metal plating, bushing wear, brake lining wear, asphalt paving
Zinc	Tire wear, motor oil, grease

Oils and greases and other organic compounds, including polycyclic aromatic hydrocarbons (PAHs) also result from transportation activities. Engines and rail lubrication systems can be significant sources of oils and greases. Oil leaks, tire wear, and automobile exhaust are sources of carcinogenic PAHs found in highway runoff [3].

UPRR and Amtrak use diesel-electric engines to carry freight and passengers through the study area[10,11]. Diesel exhaust from trains and other heavy-duty engines is composed mainly of carbon-based compounds. SO_2, SO_3, and water vapor are other gases that result from diesel engine combustion. Other particles that are commonly detected in diesel ash include metals cadmium, copper, iron, magnesium, molybdenum, silicon, palladium, rhodium, platinum, and zinc. Diesel exhaust also contains a number of carcinogenic pollutants including arsenic, benzene, bis(2-ethylhexyl)phthalate, dioxins, formaldehyde, inorganic lead, mercury compounds, and polycyclic organic matter (including PAHs)[7].

Railroad ties, treated with creosote to protect against fungi and insects, contain PAHs that can leach into the surrounding environment[8].

7.3 Pollutant Pathways from Transportation Activities

Pollutants from transportation activities can be deposited directly onto near-vehicle surfaces or enter the atmosphere as gases and solid or liquid particles. Pollutants in the atmosphere (gases and particles) are deposited in watersheds through either wet or dry deposition. Wet deposition occurs when raindrops incorporate pollutant particles from the atmosphere and bring them to the ground surface, while dry deposition results from molecular diffusion, impaction, and gravitational settling. In semi-arid regions such as Ventura County, dry deposition is expected to be the predominant process of atmospheric deposition[9,10].

The seasonal first flush and subsequent storm events wash pollutants from roadways and less permeable surfaces into the drainage network. Almost all metals deposited on impervious surfaces in the urban environment are washed off with the succeeding rainfall, while between 20% and 30% of deposited metals are sequestered and infiltrated into natural land surfaces[10].

Longer antecedent dry periods lead to greater concentrations of pollutants in stormwater runoff. Higher rainfall intensities are found to increase the levels of particulate pollutants such as total metals, total suspended solids (TSS), and oil and grease, as they mobilize particulates off highway surfaces. Storms with greater rain intensity also mobilize dissolved parameters such as dissolved metals, and total dissolved solids (TDS), but they also have a diluting effect in highway runoff.

7.4 Highway Runoff Pollutant Concentrations

Between 1997 and 2001, the California Department of Transportation (Caltrans) collected samples from urban and non-urban highways to assess pollution levels generated through motor vehicle transportation (Table 7.3). Urban highways are classified as having an annual average daily traffic (AADT) greater than 30,000 vehicles, and non-urban highways less than 30,000 vehicles. Eight sites were sampled having an AADT between 60,000 and 100,000 (the same range as the study watersheds), including six in southern California. A 2002 study used results from these samples and the event mean concentrations (EMC) to assess the correlation between pollutant levels and AADT. Highways with greater AADT were found to have higher pollutant concentrations in storm runoff. An EMC is the total pollutant mass discharged over the total discharge of the storm event, and does not reflect temporal pollutant variability throughout the duration of the storm. Table 7.3 shows the mean and median EMC values for the constituents tested from Caltrans samples for sites with an AADT between 60,000 and 100,000 [11].

Table 7.3 - **Event mean concentrations (EMC) from Caltrans 1997-2001 study**[11]

CONSTITUENT	MEAN EMC	MEDIAN EMC	UNIT
Chemical Oxygen Demand (COD)	143.4	110	mg/L
Hardness	77.2	55.3	mg/L as CaCO3
pH	7.2	7.2	PH
Temperature	10.6	10.1	^{o}C
Total Dissolved Solids (TDS)	95.3	89	mg/L
Total Suspended Solids (TSS)	149	49	mg/L
Oil and Grease	6.3	4.6	mg/L
Total Metals			
Arsenic (As)	1.3	0.98	µg/L
Cadmium (Cd)	0.79	0.66	µg/L
Chromium (Cr)	6.4	5	µg/L
Copper (Cu)	22.7	16.4	µg/L
Lead (Pb)	21.2	12.3	µg/L
Nickel (Ni)	7.8	6.2	µg/L
Zinc (Zn)	149.2	110	µg/L
Calcium (Ca)	31.5	15.2	mg/L
Magnesium (Mg)	5.3	1.2	mg/L
Sodium (Na)	4800	4300	ug/L
Dissolved Metals			
As	0.61	0.35	µg/L
Cd	0.28	0.19	µg/L
Cr	1.7	1.4	µg/L
Cu	12.2	9.8	µg/L
Pb	1.6	0.7	µg/L
Ni	4.2	2.9	µg/L
Zn	74.5	42.5	µg/L
Nutrients			
Ammonia-N (NH_3)	0.91	0.78	mg/L
Nitrate-N (NO_3)	1.22	0.88	mg/L
Nitrite-N (NO_2)	0.28	0.11	mg/L
Ortho-phosphate (Ortho-P)	0.1	0.08	mg/L
Total Kjeldahl Nitrogen (TKN)	1.8	1.2	mg/L
Total Phosphorus (TP)	0.21	0.16	mg/L

Water quality data obtained between 1997-2001 from eight highways with an average annual daily traffic (AADT) between 60,000 and 100,000: three sites in Los Angeles County, one site in Placer County, two sites in Riverside County, one site in San Bernardino County, and one site in San Joaquin County. On average, up to eight storms were monitored annually at each highway site during the 4-year period.

In 1999, Caltrans initiated a study to characterize highway runoff from first flush events in the Los Angeles area. Over a three-year period, samples were collected from three highways sites with clearly defined runoff areas in Caltrans District 7. AADT at these sites ranged from 260,000 to 388,000. Tables 7.4 and 7.5 show results of conventional pollutants, heavy metals, nutrients, and PAHs from samples collected during this study[12].

Table 7.4 - **Summary statistics from Caltrans 1999 Los Angeles highway runoff study[12]**

CONSTITUENT	EMC MINIMUM	EMC MAXIMUM	EMC MEAN	EMC MEDIAN	EMC STD DEV	GRAB MEAN	GRAB MEDIAN
TSS (mg/L)	8.8	466.4	67.7	57.6	62.9	71.3	45.9
Turbidity (NTU)	10.9	170.5	46.8	33	39.2	52	31.9
Conductivity (uS/cm)	23.4	1991.7	239	135	302.7	315.1	157
COD (mg/L)	19.3	2282.8	252.3	119.8	373	321.3	138.5
Oil & Grease (mg/L)	1.5	80.2	14	9.3	14.6	18.1	10.6
Total Metals (ug/L)							
Cd	0.5	20.2	2.5	1.4	3.9	3	1.1
Cr	2.4	40.1	10.1	8.8	6.3	10.5	8.4
Cu	16.2	920.8	93.1	55.7	125.2	113.9	64.7
Ni	2.3	253.7	20	11.2	33.9	23.3	12.8
Pb	4.6	239.1	33	25	38.1	24.6	19.2
Zn	83.4	8881.3	506.4	267.9	1137	564.9	274
Dissolved Metals (ug/L)							
Cd	0.5	17.8	1.3	0.5	2.7	2.4	0.8
Cr	0.5	19.3	2.8	2	2.8	3.5	2.3
Cu	5.3	735.3	65.9	35.4	103.9	85.5	39.2
Ni	0.5	229.2	15.7	7.9	31.3	18.9	8.7
Pb	0.5	43.5	4.9	3.6	6.5	6	4.1
Zn	42.4	8150	415.4	177.7	1055.7	465.5	184
Nutrients (mg/L)							
TKN	0.8	111.3	9.7	4.1	16.4	11.6	4.7
NH_3	0.1	65	4.6	1.4	9.7	5.5	1.3
NO_2	0	3	0.3	0.2	0.4	0.5	0.2
NO_3	0	34.7	2.7	1.2	5.3	3.2	1.5
TP	0.1	8.2	0.9	0.4	1.6	895.8	437.1
PO4-P	0	2.7	0.3	0.1	0.5	653.2	355
Dissolved P	0.1	7.3	0.7	0.2	1.3	740.1	291
Event Mean Concentrations (EMCs) of pollutants in runoff during storm events were calculated using results from grab samples and flow-weighted composite samples. Samples were collected for 71 events over three years at three highway sites in the Los Angeles area. Site 7-201 was located at the intersection of Highways 101 and 405, and sites 7-202 and 7-203 were located on Highway 405 near Santa Monica Boulevard and the Getty Center.							

Table 7.5 - **EMC ranges of PAHs from Caltrans 1999 Los Angeles highway runoff study**[12]

PAH COMPOUND	MINIMUM (µg/L)	MAXIMUM (µg/L)	SAMPLES (n)
Napthalene	0.002	0.028	6
Phenanthrene	0.014	0.083	8
Anthracene	0.014	0.014	2
Fluoranthene	0.031	0.277	8
Pyrene	0.073	0.532	8
Benz[a]anthracene	0.017	0.102	8
Chrysene	0.051	0.332	8
Benzo[b]fluoranthene	0.022	0.124	8
Benzo[k]fluoranthene	0.009	0.06	8
Benzo[a]pyrene	0.028	0.147	8
Indeno[1,2,3,cd]pyrene	0.007	0.065	7
Benz[g,h,i]perylene	0.041	0.296	8
Total PAHs	0.3	1.882	8
Results show levels of particulate phase PAHs. Dissolved PAH levels were generally at or below detection limits. The monitoring site was 7-201, located near the intersection of the US 101 and the 405 Freeway, on the south side of US 101.			

From 2000 to 2003 Caltrans monitored highway runoff from 34 sites across California (Table 7.6). Up to 635 samples were collected and tested for a broad range of constituents, including total and dissolved metals commonly associated with highway runoff, total petroleum hydrocarbons, oil and grease, TDS, TSS, and conductivity.

Table 7.6 - **Summary statistics from Caltrans 2000-2003 California highways runoff study**[13]

CONSTITUENT	MINIMUM	MAXIMUM	MEAN	MEDIAN	STD DEV	SAMPLES
Conductivity (µS/cm)	5	743	96.1	72.7	73.4	634
pH	4.5	10.1	7.1	7	0.7	633
Temperature (^{o}C)	4.7	25.4	12.5	12	3.4	183
Turbidity (NTU)	44	1400	471	460	299	75
TSS (mg/L)	1	2988	112.7	59.1	188.8	634
Chloride (mg/L)	4.3	9000	1260	620	1830	75
TDS (mg/L)	3.7	1800	87.3	60.3	103.7	635
Dissolved organic carbon (mg/L)	1.2	483	18.7	13.1	26.2	635
Total organic carbon (mg/L)	1.6	530	21.8	15.3	29.2	635
Oil and grease (mg/L)	1	20	6.6	6	4.2	39
Total petroleum hydrocarbons (mg/L)	0.12	13	2.2	1.4	3.4	22

Table 7.6 - continued

CONSTITUENT	MINIMUM	MAXIMUM	MEAN	MEDIAN	STD DEV	SAMPLES
Total Metals (ug/L)						
As	0.5	70	2.7	1.1	7.9	635
Cd	0.2	30	0.7	0.44	1.6	635
Cr	1	94	8.6	5.8	9	635
Cu	1.2	270	33.5	21.2	31.6	635
Iron (Fe)	1400	104,000	18500	12600	18200	75
Ni	1.1	130	11.2	7.7	13.2	635
Pb	1	2600	47.8	12.7	151.3	635
Zn	5.5	1680	187.1	111.2	199.8	635
Dissolved Metals (ug/L)						
As	0.5	20	1	0.7	1.4	635
Cd	0.2	8.4	0.24	0.13	0.5	635
Cr	1	23	3.3	2.2	3.3	635
Cu	1.1	130	14.9	10.2	14.4	635
Fe	32	3310	378	150	543	75
Ni	1.1	40	4.9	3.4	5	635
Pb	1	480	7.6	1.2	34.3	635
Zn	3	1017	68.8	40.4	96.6	635
Nutrients (mg/L)						
NO3-N	0.01	4.8	1.07	0.6	2.4	634
Ortho-P	0.01	2.4	0.11	0.06	0.2	630
Total P	0.03	4.69	0.29	0.18	0.4	631
TKN	0.1	17.7	2.06	1.4	1.9	626
Summary statistics from flow-weighted composite samples (EMCs) AADT ranged from 1,800 to 322,000 vehicles. The land uses of the sites included 15 rural sites, 10 with commercial uses, 6 residential, and 1 mixed use.						

During the 2006-2007 storm season, Caltrans Stormwater Monitoring and Research Program monitored highway runoff from a site in Ventura County on Pacific Coast Highway, between Sycamore Canyon Road and Deer Creek Road, roughly 35 miles from the study watersheds (sampling site 7-304). AADT at site 7-304 was estimated at 9,900 for this study. The study sought to characterize stormwater runoff from the highway that is a tributary to an Area of Special Biological Significance (ASBS), defined in the California Ocean Plan (Ocean Plan) as a marine area that requires "protection of species or biological communities to the extent that alteration of natural water quality is undesirable" [14]. Table 7.7 shows the results from the ASBS study.

Table 7.7 - **Summary statistics from Caltrans 2006-2007 ASBS study**[14]

CONSTITUENT	EMC MINIMUM	EMC MAXIMUM	EMC MEAN	STD DEV	DETECTION
Conductivity (uS/cm)	420	570	463	97	100%
Hardness as CaCO3 (mg/L)	80	100	87	10	100%
pH	7.2	8.6	8.1	0.74	100%
TSS (mg/L)	15	44	28	13	100%
TDS (mg/L)	280	390	315	64	100%
Turbidity (NTU)	40	84	63	20	100%
Oil & Grease* (mg/L)	<4.5	5.2	-	-	25%
Nutrients (mg/L)					
Ammonia	0.15	2.7	0.96	1.5	100%
Nitrate-N	0.58	1	0.84	0.21	100%
TOC	21	34	25	8.3	100%
DOC	21	35	-	-	100%
Total Phosphorus	0.074	0.15	0.12	0.041	100%
Dissolved Ortho-P	<0.02	0.036	-	-	50%
Total Metals (ug/L)					
Antimony (Sb)	0.72	1.3	1	0.26	100%
As	3.3	8.3	6.1	2.5	100%
Be	<0.5	<0.5	-	-	0%
Cd	<0.2	0.3	-	-	50%
Cr	5	8.5	6.5	1.6	100%
Cr (VI)	1.9	2.5	2.3	0.36	100%
Cu	11	24	15	8.3	100%
Mercury (Hg)	<0.0048	<0.2	-	-	0%
Ni	4.7	9.9	6.2	3.3	100%
Pb	1.9	4.2	2.8	1.1	100%
Selenium (Se)	<0.5	1.3	0.7	0.52	75%
Silver (Ag)	<0.5	<0.5	-	-	0%
Thallium (Ti)	<0.5	<0.5	-	-	0%
Zn	34	130	61	62	100%
Dissolved Metals (ug/L)					
Ag	<0.5	<0.5	-	-	0%
As	1.1	2.1	1.8	0.62	100%
Be	<0.5	<0.5	-	-	0%
Cd	<0.2	<0.2	-	-	0%
Cr	2.2	3.1	2.8	0.45	100%
Cu	9.1	20	12	6.5	100%

Table 7.7 - continued

CONSTITUENT	EMC MINIMUM	EMC MAXIMUM	EMC MEAN	STD DEV	DETECTION
Hg	<0.2	<0.2	-	-	0%
Ni	2.4	4.2	3.1	0.94	100%
Pb	<1	<1	-	-	0%
Sb	0.5	0.75	0.66	0.13	100%
Se	0.86	1.2	0.97	0.19	100%
Ti	<0.5	<0.5	-	-	0%
Zn	7	46	20	21	100%
Polycyclic Aromatic Hydrocarbons, PAHs (ug/L)					
Acenaphthylene	<5	<5	-	-	0%
Anthracene	<5	<5	-	-	0%
Benzo(a)Anthracene	<2	<2	-	-	0%
Benzo(a)Pyrene	<2	<2	-	-	0%
Benzo(b)Fluoranthene	<5	<5	-	-	0%
Benzo(g,h,i)Perylene	<10	<10	-	-	0%
Benzo(k)Fluoranthene	<5	<5	-	-	0%
Chrysene	<2	<2	-	-	0%
Dibenzo(a,h)Anthracene	<5	<5	-	-	0%
Fluorene	<5	<5	-	-	0%
Indeno(1,2,3-cd)Pyrene	<10	<10	-	-	0%
Phenanthrene	<5	<5	-	-	0%
Pyrene	<5	<5	-	-	0%

Four samples were collected from Highway 1 in Ventura County for each constituent, with exception of mercury, which was sampled nine times. Of the tested metals, total and dissolved Beryllium, dissolved cadmium, total and dissolved mercury, dissolved lead, total and dissolved silver, and total and dissolved thallium were not detected in any of the samples. None of the tested PAHs were found above detection limits.
*Oil & grease is not a composite flow weighted sample, value is not Event Mean Concentration (EMC).

7.5 Pollutant Contributions from Railroads

Studies of railway pollution focus primarily on emissions found at rail yards, where idling trains, maintenance, and line-switching lead to increased pollutant concentrations. Of the few studies found discussing pollution from passing locomotives, the majority test particulates in ambient air.

In 2006, The U.S. Department of Transportation and Caltrans initiated a study that tested air quality up to 300 feet from the Alameda corridor railroad. Concentrations of particulate matter (PM10), particles with a diameter or 10 microns or less, were measured in a time window of one to three minutes as locomotives arrive and pass through the sampling site. Background concentrations were measured two minutes before trains arrived. The study found that beyond 33 feet from the railway, passing locomotives increased aerosol particulate matter concentration by 12-15% above background levels, up to 300 feet from railroad. During sampling, average increases in PM10 concentrations in air due to passing locomotives ranged from approximately 0.006 mg/m^3 and 0.025 mg/m^3 [(15)].

Wood railroad ties are commonly treated with creosote to protect against fungus and insects. About 80% of creosote is composed of PAHs that can migrate from ties through the track bed gravel (ballast rock) and into the surrounding environment. A study initiated in 1997 sought to assess PAH contamination of the Des Plaines River wetlands in Illinois from new and weathered creosote-treated railroad ties. PAH levels were tested from samples of stormwater and sediment from ballast rock and wetland cores in mesocosms up to 75 cm from treated, untreated and weathered railroad ties. PAHs were only detected from one stormwater sample (of 16 total samples), 18 months after the installation of new railroad ties. These levels are shown below in Table 7.9.

Maximum concentration of total PAHs in the ballast reached roughly 1000 mg/kg of dry sediment within 5 cm of the railroad ties after five months. In the wetland sediment, the highest total PAH concentrations were 3.945 mg/kg found 75 cm from the ballast in the mesocosm of new railroad ties at the 15 month interval. Due to the uniform distribution of PAH concentrations in wetland sediments at all distances, detected PAHs were considered a result of atmospheric deposition, as opposed to creosote-treated railroad ties. The study found that on average, the use of railway ties treated with creosote may increase total PAH levels by 0.3 µg /g (or mg/kg) of dry sediment within half a meter of the outer edge of the ballast[8].

Table 7.9 - **Detected PAH levels from stormwater in mesocosms near railroad ties**[8]

COMPOUND	UNTREATED TIES (mg/L)	NEW TIES (mg/L)	WEATHERED TIES (mg/L)
Benzo(a)anthracene	0.00016	0.00019	ND
Fluoranthene	ND	ND	0.0013
Phenanthrene	ND	0.00066	0.00058
Pyrene	ND	ND	0.00082
From 1997-1998 sixteen stormwater samples were collected in three mesocosms (new creosote-treated railroad ties; weathered creosote-treated railroad ties; untreated railroad ties). Table 7.9 shows the detected dissolved and particulate PAH levels from stormwater in mesocosms at 18 months after installation of new ties. No PAHs were detected in earlier samples taken after 10 days, 2 months, 3 months, 12 months, or 15 months.			

7.6 Pollutants from Dry Deposition

Resuspension of dust is the most significant source of metals in the atmosphere. This results from vehicles driving on roads and wind blowing over other surfaces. Particles between 10 and 100 microns are responsible for the majority of atmospheric deposition of metals. In the Los Angeles region, the main source of lead in the atmosphere is from historic leaded gasoline that was banned in California in 1992. Legacy impacts of leaded gasoline are still observed as the atmospheric levels of lead appear to be a result of the resuspension of dust containing lead from gasoline before 1992[9,10]. In the Los Angeles urban region, the highest concentration of metals from deposition were found within roughly 100 m of large highways[16].

A 2006 study that was initiated by the Southern California Coastal Water Research Project (SCCWRP) tested for chromium, copper, lead, and zinc concentrations from dry atmospheric deposition in coastal California. Samples were collected from eight sites, including in Santa Barbara, Oxnard, and Malibu. Comparisons between the 2006 study were made with findings from 1975 in the same areas. This study evaluated the differences in metal dry deposition and found that over the thirty year period atmospheric lead decreased, while copper and zinc increased. Table 7.10 shows the rates for the dry deposition of metals from 2006 in sites near the study area[16].

Table 7.10 - **Dry deposition of metals in a 48 hour period in Southern California [16]**

METALS (µg/m^2)	SANTA BARBARA	OXNARD	MALIBU
Chromium	0.34	0.23	0.29
Copper	2.0	0.89	1.9
Lead	1.3	0.52	1.0
Zinc	14	4.8	12
Ten 48-hour sampling events were performed for each sampling site in Santa Barbara, Oxnard, and Malibu using deposition plates between June and October, 2006. Sampling sites were located at least 100 m from major transportation routes and 1 km from the coast.			

7.7 Transportation Summary

Three major transportation routes traverse the watersheds adjacent to the coast. Over 70,000 vehicles travel each day through the study watersheds on Highways 1, 101, and the railway owned by Union Pacific Railroad. Transportation activities emit various pollutants, including heavy metals and organic compounds. Diesel-electric trains, lubricants, and railroad ties are sources of pollutants, including polycyclic aromatic hydrocarbons (PAHs) that can find their way into near track soils and waterways. Copper, lead, and zinc are a few of the metals known to be found in highway runoff in concentrations generally ranging from 10 to over 100 micrograms per liter (zinc being the most prevalent). Roadway stormwater runoff also contains PAHs emitted from vehicles. Four of the most dominant PAHs in roadway runoff are Fluoranthene, Pyrene, Chrysene, and Benz[g,h,i]perylene (all measured above 0.2 ug/L in LA highway study, with the greatest being Pyrene at 0.532 ug/L). Contributions of pollutant concentrations in stormwater from transportation activities depend on several conditions, including antecedent dry days, precipitation, and traffic. Pollutant levels from transportation activities are greatest within 100 meters of highways and other transportation routes.

7.8 Transportation Section References

1) Union Pacific Railroad Employee. January 14, 2014. Personal Communication.
2) California Department of Transportation (Caltrans). Traffic and Vehicle Data Systems Unit. Division. Available at: traffic-counts.dot.ca.gov/2012all. Accessed February 3, 2014.
3) Caltrans. August 2003. A Review of the Contaminants and Toxicity Associated with Particles in Stormwater Runoff. CTSW-RT-03-059.73.15.
4) Abbasi, S, et al. 2013. Particle Emissions from Rail Traffic: A Literature Review. Critical Reviews in Environmental Science and Technology Vol. 43, Iss. 23.
5) Nixon, H., Saphores, J.D., 2007. Impacts of motor vehicle operation on water quality in the United States. Transportation Research Part D: Transport and Environment. Volume 12, Issue 8, Pages 564-576.
6) Union Pacific Railroad. Available at: www.up.com/aboutup/special_trains/diesel electric/index.htm.
7) California Environmental Protection Agency. Air Resources Board. The Report on Diesel Exhaust. Available at: http://www.arb.ca.gov/toxics/dieseltac/de-fnds.htm.
8) Brooks, Kenneth M., 2004. Polycyclic aromatic hydrocarbon migration from creosote treated railway ties into ballast and adjacent wetlands. Res. Pap. FPL-RP-617. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory. 53 p.
9) Sabin, L.D., J.H. Lim, M.T. Venezia, A.M. Winer, K.C. Schiff and K.D. Stolzenbach. 2006b. The dry deposition and resuspension of particle-associated trace metals near a freeway in Los Angeles. Atmospheric Environment 40:7528-7538.
10) Stolzenbach, K.D., 2006. Atmospheric Deposition. Southern California Environmental Report Card.
11) Kayhanian, M., Singh, A., Suverkropp, C., Borroum, S. 2002. The Impact of Annual Average Daily Traffic on Highway Runoff Pollutant Concentrations.
12) Kayhanian, M., Stenstrom, M., 2005. Caltrans. First Flush Phenomenon Characterization.
13) Kayhanian, M., Suverkropp, C., Ruby, A., Tsay, K., 2006. Journal of Environmental Management 85 (2007) pages 279-295.
14) Caltrans. February 2008. Stormwater Monitoring and Research Program. Annual Data Summary Report.
15) Rahai, H., 2008. Center for Energy and Environmental Research and Services Department of Mechanical and Aerospace Engineering California State University Long Beach. Development of an Exposure Model for Diesel Locomotive Emissions near the Alameda Corridor.
16) Sabin, L.D., Schiff, K.C., March, 2007. Southern California Coastal Research Project. Metal Dry Deposition Rates along a Coastal Transect in Southern California.

8.0 | OIL PRODUCTION OPERATIONS

Oil production operations have a long history in the study watersheds, with the first exploratory well drilled in 1916 and the first production well drilled in 1927. Development activity peaked in 1948, with 24 new wells drilled within the watersheds (1951 was the peak for the two oil fields as a whole, totaling 33 new wells).

Initially, development was more rapid in Madriano, Javon, and Padre Juan Canyons, in what is primarily the Rincon Oil Field, compared to Line and Amphitheater Canyons, or what is primarily the San Miguelito Field. The slow development in the southeastern watersheds was attributed to their rugged topography and frequent landslides, making access to the canyons difficult.

Section Highlights

- The two oil fields within the study watersheds (the Rincon Field and San Miguelito Field) have been in production since the early 20th century
- From 1916 until 2013, a total of about 430 wells have been drilled within the study watersheds. Since 2007, there have been 20 new wells drilled, the majority in Line Canyon
- Oil field development has led to large areas cleared for roads and well pads: 10.8% of Line Canyon and 8.8% of Amphitheater Canyon have been cleared for oil field infrastructure
- Over the life of the oil fields the composition of production fluid has changed from almost 100% oil in 1927 to over 90% produced water in 2014
- Water flood injection projects are used in the study area (roughly 9 million barrels of produced water was injected into the subsurface in 2013)
- Hydraulic fracturing has been performed on at least three wells in Line Canyon, and acid well treatments are frequently used in the oil fields

Line Canyon has the greatest density of oil field infrastructure including wells, roads, and clearings, and is the only watershed where the use of hydraulic fracturing has been confirmed by the oil field operator. Of the five watersheds, Line Canyon has the most recent activity in terms of new wells drilled and quantity of produced and injected fluid.

Fluids currently being used in the study watersheds for hydraulic fracturing or well treatments, such as acid treatments, can contain a number of potentially hazardous additives in various concentrations. Recent hydraulic fracturing in Line Canyon injected more than 360,000 gallons of fluid to fracture the oil reservoir formation at around 7,200 to 8,000 feet using upwards of 8,000 psi pressure[1]. The acid well treatments recorded in the watersheds use much less fluid (generally 3,000 to 8,000 gallons per treatment) but these well treatment fluids tend to have much higher concentrations of additives than fluids used for hydraulic fracturing[1].

Produced water is brought to the surface with the produced oil as part of the production fluid, and is the largest volume of fluid being transported around the Rincon and San Miguelito Fields. As an oil field matures and the remaining oil in the reservoir becomes harder to extract, produced water becomes a larger portion of the production fluid, often greater than 90%. Produced water originates from the deep rock formations were it has interacted with the rock minerals, organic compounds and hydrocarbons possibly since the formations were deposited 10 to 20 million years ago. This interaction over millennia has resulted in very salty water containing high concentrations of dissolved solids and high concentrations of organic pollutants. Concentrations of Total Dissolved Solids (TDS) in produced water from the Rincon and San Miguelito Fields generally ranges from 27,000 to 36,000 mg/L, the majority of which is sodium chloride (sea water is generally 30,000 to 40,000 mg/L TDS) [15].

The oil field operations and production have changed over the years. In the early years of the two oil fields, produced water was a much smaller fraction of the total production fluid, whereas now produced water is often greater than 90%. Between the 1960s and 1970s, produced water started being injected into water disposal and water flood wells instead of being released to the ocean. Waste management and environmental awareness has improved, but new chemicals and techniques, such as enhanced oil recovery and hydraulic fracturing, have also emerged, and the extent of their impacts is unknown.

The following sections describe the oil production operations within the study watersheds and the general area in detail. These sections describe various oil field operations over time and the spatial extent of these activities. Fluids known to be used in wells within the study watersheds are also characterized. Nearly all the information on the oil fields and wells was gathered from the California Department of Oil, Gas, and Geothermal Resources (DOGGR), and fluid additive ingredients data was taken from relevant Materials Safety Data Sheets.

8.1 Oil Fields

The study watersheds contain two separate oil fields: the Rincon Field and the San Miguelito Field (Figure 8.1). The Rincon Oil Field is the larger of the two fields with the onshore portion totaling roughly 8.2 square miles. The onshore Rincon Field intersects Madriano, Javon, Padre Juan and Line Canyons and currently has about 450 total wells, with about 296 within the boundaries of these four watersheds. The San Miguelito Field is approximately 2.2 square miles and contains about 280 total wells, with approximately 130 wells located within the watershed boundaries of Line and Amphitheater Canyons (Figure 8.1).

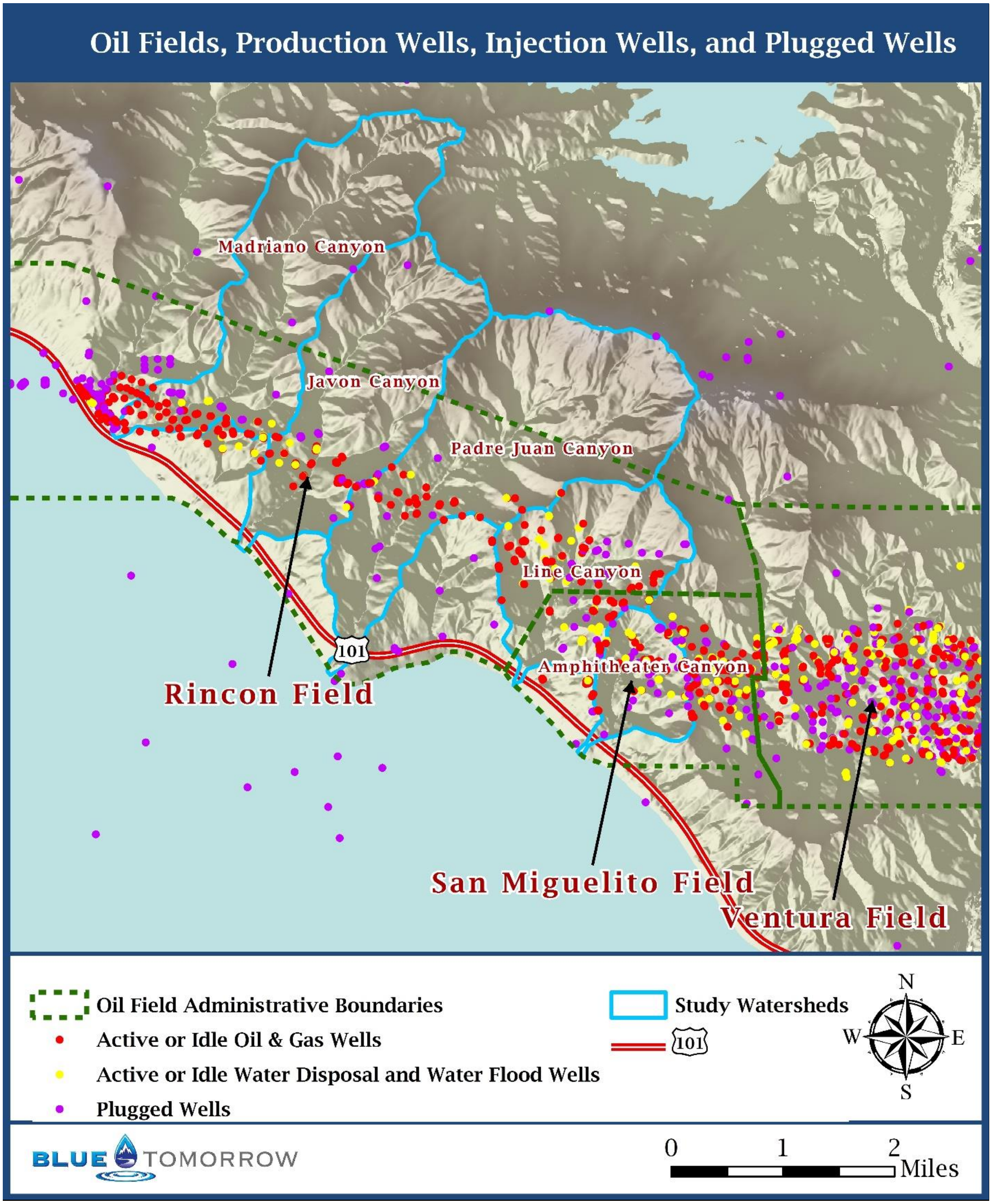
The Rincon Oil Field was the first of the two fields to be drilled with exploratory wells drilled in the area as early as 1916[1]. The Rincon Oil Field discovery well, known as "Hobson-State 1", was completed on November 2, 1927 and initially produced at a rate of 1,500 barrels of oil per day, before dying the following day[2]. The first steady production well in the Rincon Field was completed on December 24, 1927 and was producing 930 barrels of oil per day from a depth of 2,541 to 2,557 feet. Initially this first production well produced 99.5% oil, with produced water making up the remaining 0.5% of the production fluid[2].

The San Miguelito Field had two exploratory wells completed in the area in 1922 and 1924, but neither was found to be productive[2]. The first production well was completed on November 22, 1931 to a depth of 6,750ft and then deepened to 7,197ft on August 11, 1932, producing 600 and then 2,449 barrels per day respectively, with only about 3% water. The San Miguelito Field was initially considered an area of the Rincon Field, until they were separated in 1951. This field has very rugged terrain, which was blamed for the slow development of the field[2].

In the early years of oil production, many of the wells were still flowing and did not require pumping. Additionally, the production fluid had a relatively high oil to water ratio. For the first half of 1942, produced water was less than 18.3% of the production fluid In the Rincon Field, and by the end of 1953, production fluid from wells in the San Miguelito Field was not more than 10% produced water[2]. Presently, produced water is often 90% or more of the total production fluid from wells in the two fields. Now that the oil reservoirs have been "depleted" enhanced oil recovery methods are used in the oil fields.

The depth to underlying oil reservoirs appears to deepen from northwest to southeast, but generally, the majority of oil currently being produced from the two fields is from a depth of 6,000 to 8,000 feet below the surface[1].

Figure 8.1 – The location of oil field administrative boundaries that intersect the study watersheds. Well locations are also shown for active and idle production well, injection wells, and plugged wells (all types). All oil field and well data is from the California Division of Oil, Gas, and Geothermal Resources (DOGGR), downloaded September 2013[3].



8.2 Well Types

There are four main types of wells in the study area: oil and gas production wells, water flood injection wells, water disposal injection wells, and exploratory wells that did not find oil (dry holes).

Oil and Gas Production Wells

The basic oil and gas production well is the most common well type. If the pressure is high enough in the oil reservoir, oil and gas production wells can be as simple as a well head with a valve open to a production line that caries the production fluid to a collection tank for processing (a flowing well). If the pressure in the reservoir is not high enough, which is the case for most wells in the study area, a pump jack may be used to pull the production fluid to the surface. Produced water from these wells is often injected into a water flood injection well as part of an enhanced oil recovery project, or into a water disposal well. The difference between a water disposal well and a water flood well is that disposal wells inject produced water into subsurface areas that are not oil reservoirs, while water flood wells inject produced water back into a reservoir from which oil is being produced.

Water Flood Wells

Enhanced oil recovery projects are used to increase production from a depleted reservoir, and involve methods of gas or fluid injection to increase reservoir pressure and sweep oil to the production wells. In the study area water flood injection wells are commonly used, and are credited for increasing production in the Rincon Field by 50,000 barrels and the San Miguelito Field by 440,000 barrels in 2009[2]. There are a total of 77 active or idle water flood wells located within the study watersheds, and Line Canyon has the greatest number with 33 water flood wells.

The first water flood injection project in the study area started in the San Miguelito Field in 1955 and involved a 9,700 foot pipeline to pump ocean water to the injection well[2]. In the first year, 47,143 barrels or approximately 2 million gallons were injected into this well. The ocean water was treated with a bactericide, a corrosion inhibitor, and sulphur dioxide to reduce pH and remove oxygen. The first water flood project in the Rincon Field was started on December 2, 1961[2].

By the end of 1988, the water flood projects in the Rincon and San Miguelito Fields, along with the Ventura Field, accounted for 93.5% of all the water injected in the DOGGR District 2, which encompasses all of Ventura County and part of northwestern Los Angeles County (which totaled 53 fields in 1988)[2].

Water Disposal Wells

In the early years (pre 1970) of oil exploration, produced waste water from the study watersheds was discharged into the ocean[2]. Since then, many water disposal wells have been drilled in the study watersheds, but wells are often reworked and redrilled many times during their life, being converted to and from oil wells to water flood wells to disposal wells[1]. Water disposal wells inject produced water into formations that do not contain hydrocarbons. Currently there is only one active and one idle water disposal well in the study area, found in Javon and Padre Juan Canyon[1]. These two disposal wells are or were injecting produced water at a depth of about 4,500 to 6,000 feet at pressures ranging from 1400 to 1850 psi[1]. Both of these wells have also suffered from holes or ruptures in the well casing at depths from about 4400 to 3400 feet[1].

Experimental gas injection

In 1940, an experimental gas injection project was started in San Miguelito Field[2]. Natural gas was injected from 1940 until 1949 at a depth around 6,700 to 7,100 feet, but was found to be ineffective at re-pressurizing the reservoir. From 1948 to 1949 over 2.7 million Mcf (1,000 cubic feet) of gas was injected. This experimental injection program was, for the most part, unsuccessful, as injected gas quickly created channels through the sand and migrated to surrounding wells, resulting in high gas to oil ratio wells[2].

8.3 Well Status & Well Densities

There are several well status designations as defined by DOGGR, but only a few are reported to be present in the study area (Table 8.1). Within the boundaries of the study watersheds there are about 100 plugged wells, 110 active wells, 215 idle wells, and only two new wells. The well status applies to all well types[3].

The current well status was spatially analyzed with ArcMap using well data acquired from DOGGR[3]. Well densities for each watershed were then calculated for active wells, idle wells, and plugged and abandoned wells (Table 8.2). The highest density of wells is in Amphitheater and Line Canyons. These two watersheds may experience a greater impact from the oil fields because they have far less buffering and dilution capacity per well compared to the other watersheds.

Table 8.1 - **Explanations of well status designation**

WELL STATUS	EXPLANATION
New	Recently permitted, in the process of being drilled.
Active	Well has been drilled and completed
Plugged and Abandoned	Well gas been plugged and abandoned to Division standards
Idle	Well is idle, not producing
Table copied from DOGGR GIS metadata[3]. The well statuses listed are only those found within the study watersheds.	

Table 8.2 - **Well densities calculated for each of the study watersheds**

WATERSHED	WELL DENSITIES (wells/mi^2)			
	ACTIVE WELLS	IDLE WELLS	PLUGGED & ABONDONED	TOTAL
Madriano Canyon (5.88 Km^2)	2.6	22.2	7.4	32.2
Javon Canyon (5.33 Km^2)	3.8	24.9	7.6	36.3
Padre Juan Canyon (7.86 Km^2)	4.5	10.7	5.0	19.9
Line Canyon (3.73 Km^2)	42.9	40.0	19.2	102
Amphitheater Canyon (1.44 Km^2)	49.9	42.9	44.7	138
There are two "new" wells included with the active wells. Spatial data is from the California Division of Oil, Gas, and Geothermal Resources (DOGGR), downloaded September 2013[3].				

8.4 Drilling Operations over Time

Many of the negative impacts from oil field operations occur when a new well is first drilled, due to the excavation of a well pad, movement of heavy machinery and drilling fluids, and spills and discharges that occur during a new drilling. The year in which drilling first began (spud year) for every well in the study watersheds was compiled from DOGGR records and is displayed in Figure 8.2 and Figure 8.3[1].

Figure 8.2 – All new wells drilled from 1916 to 2013. Current well status is not considered. Data is from the California Division of Oil, Gas, and Geothermal Resources (DOGGR), downloaded September 2013[1,3].

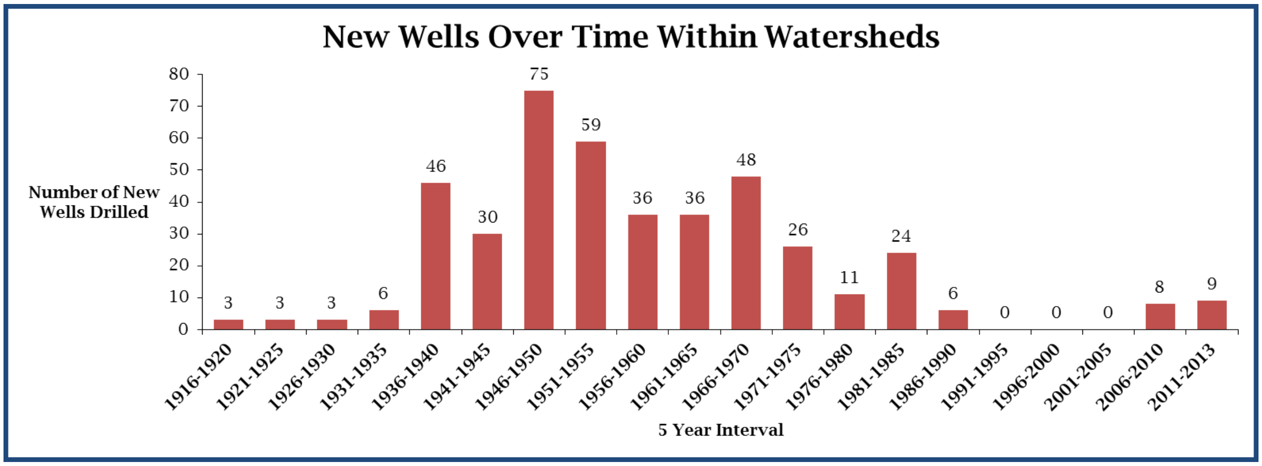
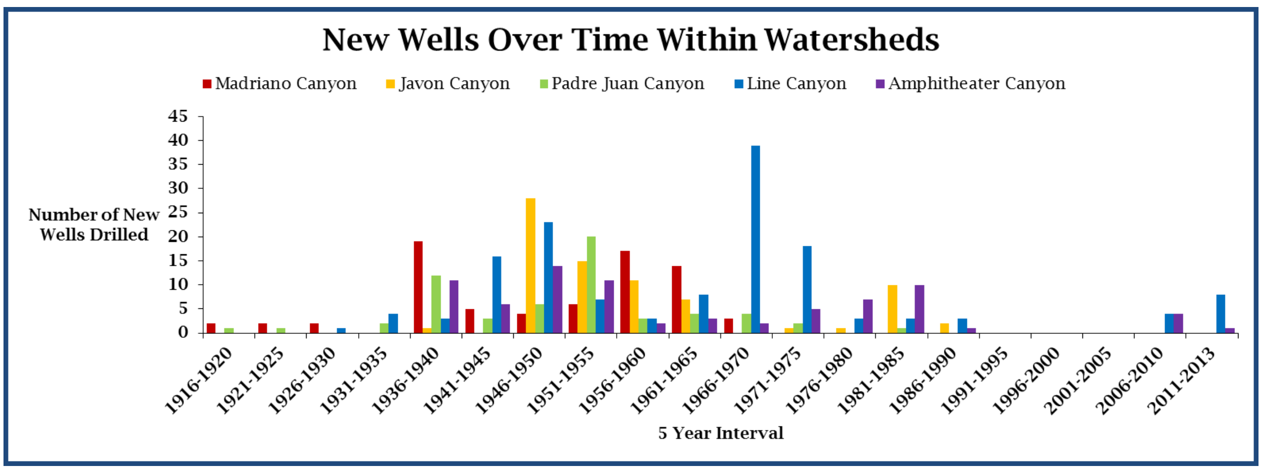


Figure 8.3 – New wells drilled within each watershed from 1916 to 2013. Current well status is not considered. Data is from the California Division of Oil, Gas, and Geothermal Resources (DOGGR), downloaded September 2013[1,3].

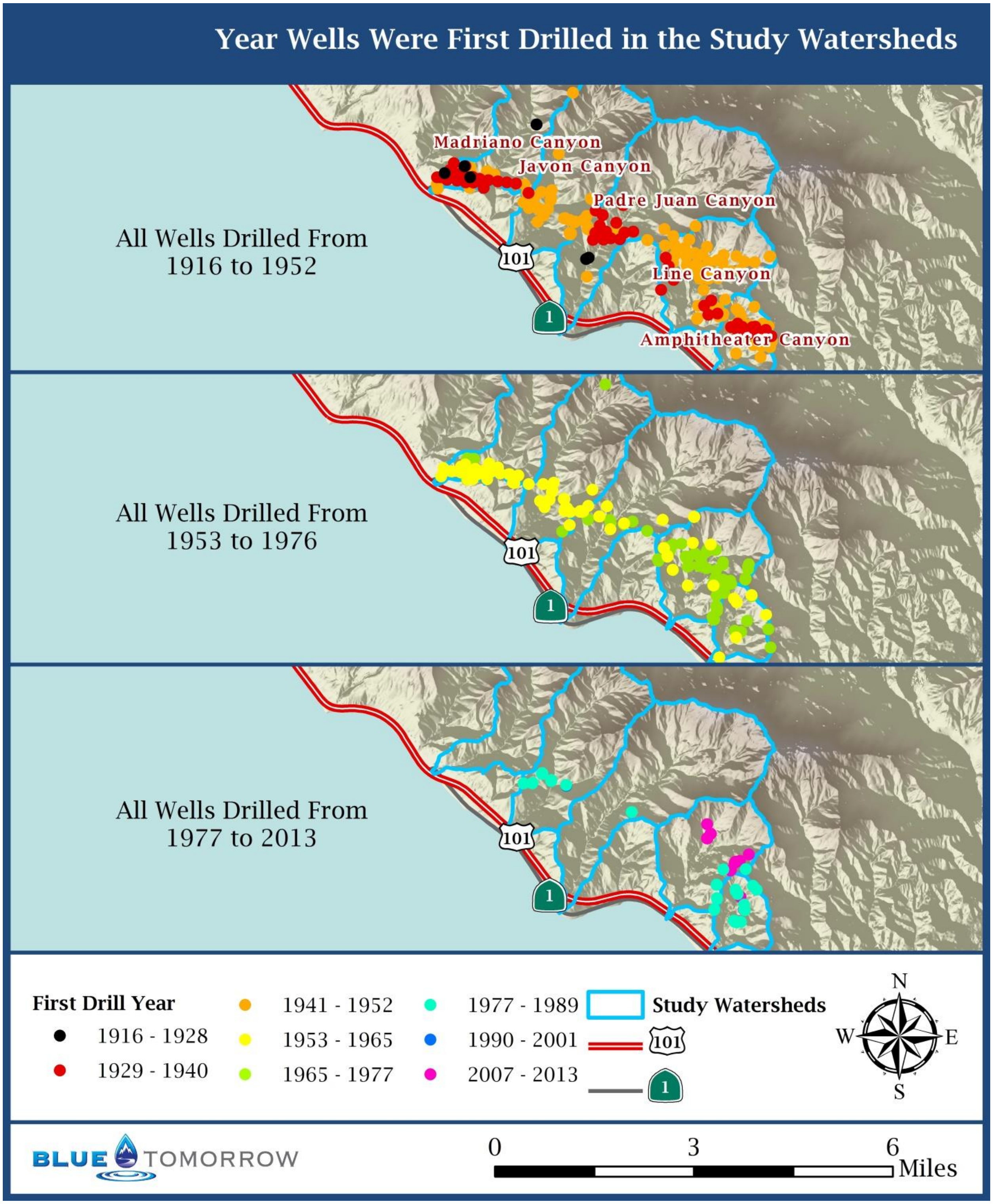


The total number of new wells drilled in the watersheds quickly peaked from the late 1930s to the late 1940s and then slowly declined (Figure 8.2). The resurgence of activity in the late 1960s was due to the development of two new oil zones between 12,000 and 15,000 feet deep beneath Line Canyon in the Rincon and San Miguelito Grubb lease[2] (Figure 8.2 and Figure 8.3).

Since the first exploratory well was drilled in 1916 until 2013, a total of about 430 wells have been drilled within the study watersheds, and 58 have been drilled since 1977 (Figure 8.2). The DOGGR records show no new wells were drilled in the watersheds from 1991 to 2007[1]. Since

2007 there have been 20 new wells drilled, with the majority of them in Line Canyon (Figure 8.3). Figure 8.4 shows the distribution of new wells for eight time classes between 1916 and 2013, and shows the drilling of new wells being more focused in the southeast of the study area in recent years (Line and Amphitheater Canyon).

Figure 8.4 – The year wells were first drilled is mapped for wells within the study watershed boundaries. There were approximately 200 new wells drilled from 1916 to 1952, 174 new wells drilled from 1953 to 1976, and 58 new wells drilled from 1977 to 2013[1]. Data is from the California Division of Oil, Gas, and Geothermal Resources (DOGGR), downloaded September 2013[3].



8.5 Oil Field Production and Injection

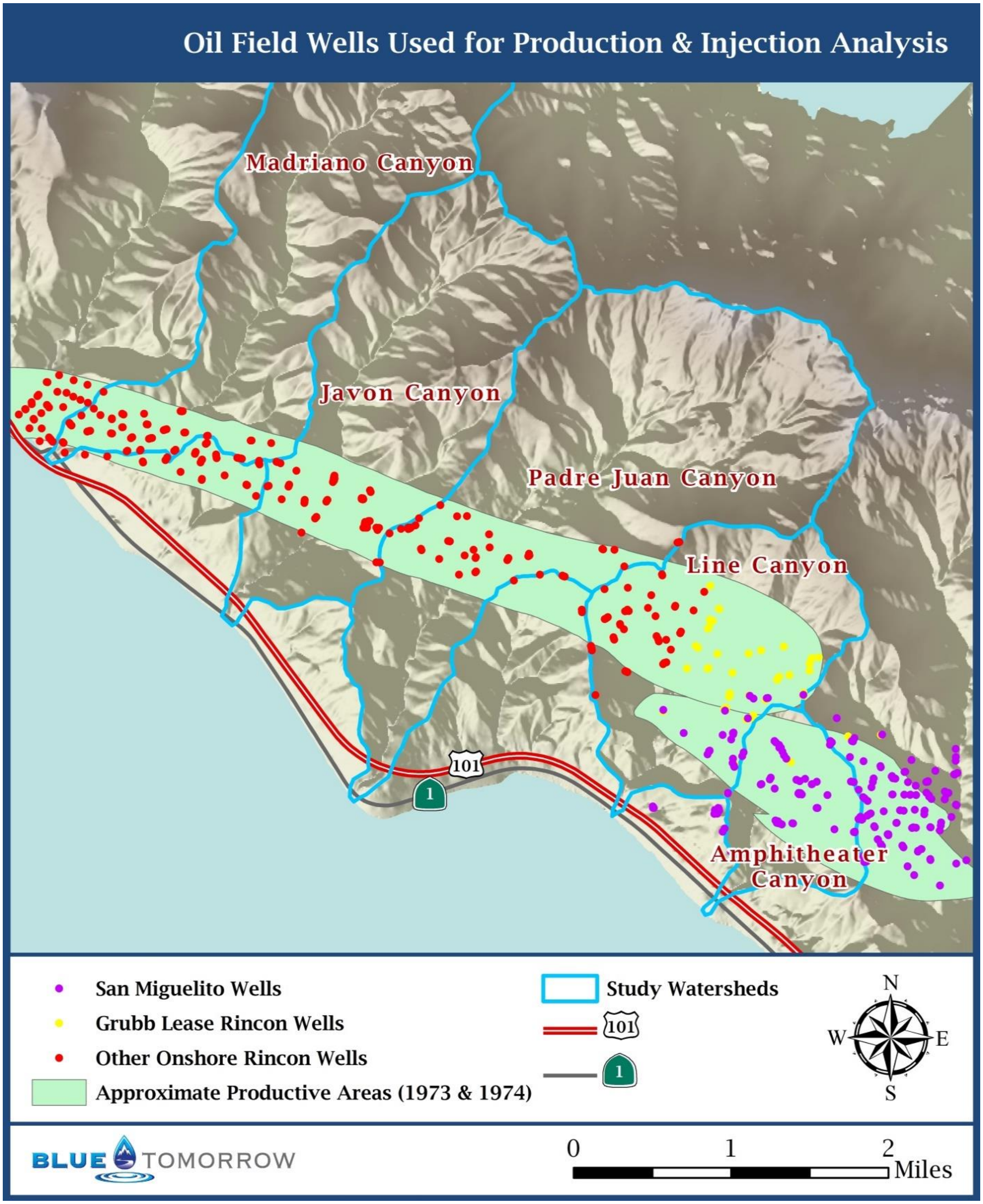
The Rincon Field and San Miguelito Field have ranked around 35th and 45th, respectively, in terms of California's largest oil producing fields for at least the last 10 to 15 years[2]. From 2008 to 2009 the San Miguelito Field was ranked 9th in the state for the oil fields with the most production increase over the previous year[2].

Production and injection data is gathered by DOGGR and used to generate statewide statistics[2]. This data has been compiled from 1978 to 2012. Production and injection statistics were analyzed by oil field and not individual wells, therefore these statistics were not able to be narrowed to only the wells located within watershed boundaries.

Three oil production areas, the San Miguelito Field as a whole, the Rincon Field Grubb lease, and the onshore Rincon Field as a whole (Figure 8.5), that overlap the study watersheds were analyzed to assess the production and injection activity from 1978 to 2012. It is important to note that the Rincon Field Grubb lease wells are included in the onshore Rincon Field as a whole, but were also analyzed separately here due to the recent activity in this portion of the Rincon Field.

Production data include the volume in barrels (42 gallons) of oil extracted and produced water extracted each year, which averages greater than 90% of the total production fluid in the study area. Produced water contains a complex mixture of organic and inorganic constituents with high levels of Total Dissolved Solids (TDS). In the study area, produced water is injected into water flood enhanced recovery wells.

Figure 8.5 – The three areas analyzed for oil production and injection are mapped. The three areas are not entirely confined to the watershed boundaries. Yearly production and injection statistics for the three areas are shown in Figures 6 to 10. The approximate productive areas and well data are from the California Division of Oil, Gas, and Geothermal Resources (DOGGR), downloaded September 2013[3].



Oil production has declined steadily for all portions of the study area (Figure 8.6). Of the three areas analyzed, the San Miguelito Field has been the most productive over the 35 year interval (Figure 8.6). The year and area with the greatest production during this interval was the San Miguelito Field in 1980 with a total of about 2.4 million barrels of oil, or about 62% of the total produced that year between the Rincon onshore and San Miguelito Fields (Figure 8.6). The most recent increase in production occurred from 2007 to 2009 in the San Miguelito Field, an increase of 200,000 barrels, but then decreased again by 2011 (Figure 8.6). By 2012, production in the Grubb lease portion of the Rincon Field had reached about 48% of the entire onshore Rincon Field production (Figure 8.6).

Figure 8.6 – Total annual oil production for the San Miguelito Field as a whole, the Rincon Field Grubb lease, and the onshore Rincon Field as a whole (Figure 8.5). Data is from the California Division of Oil, Gas, and Geothermal Resources (DOGGR), downloaded February 2014[4].

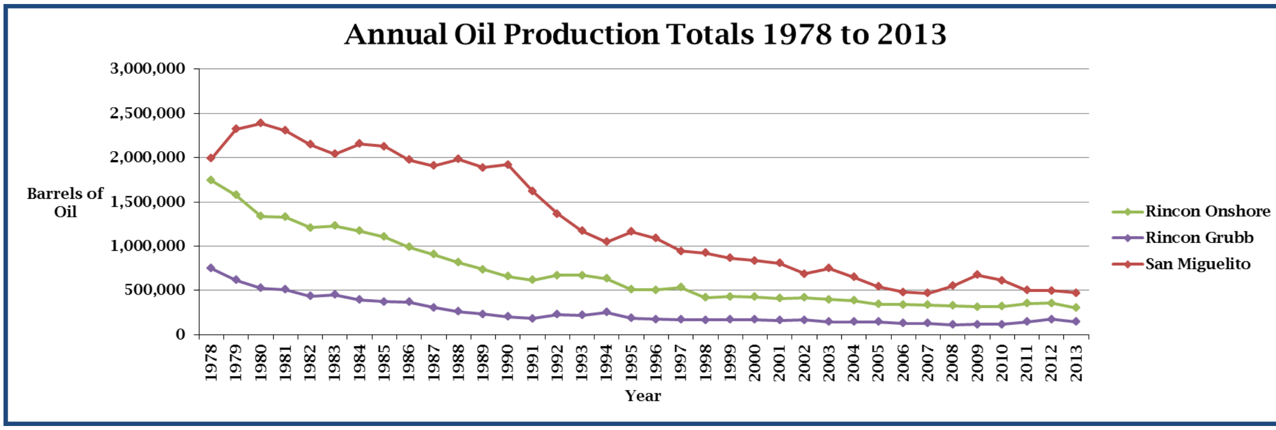
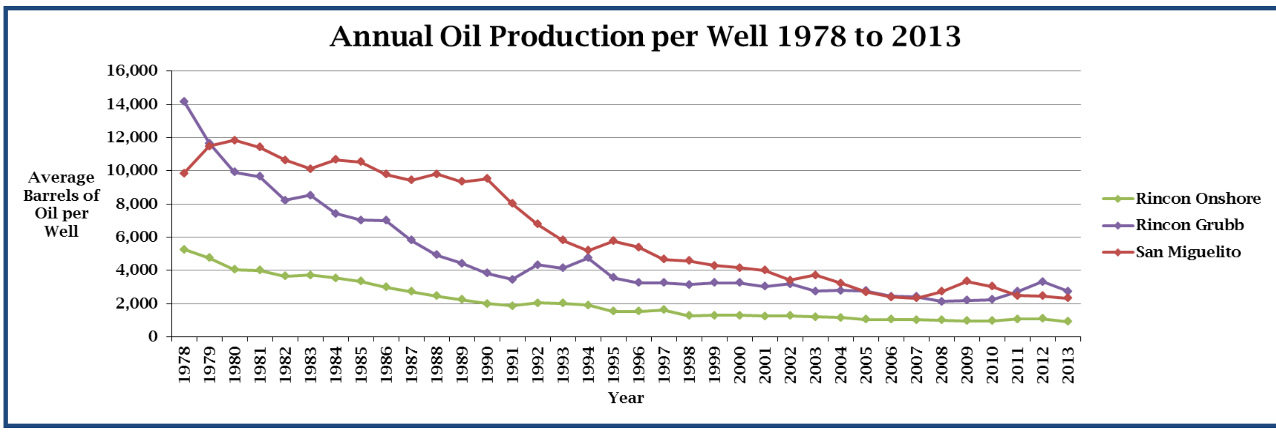
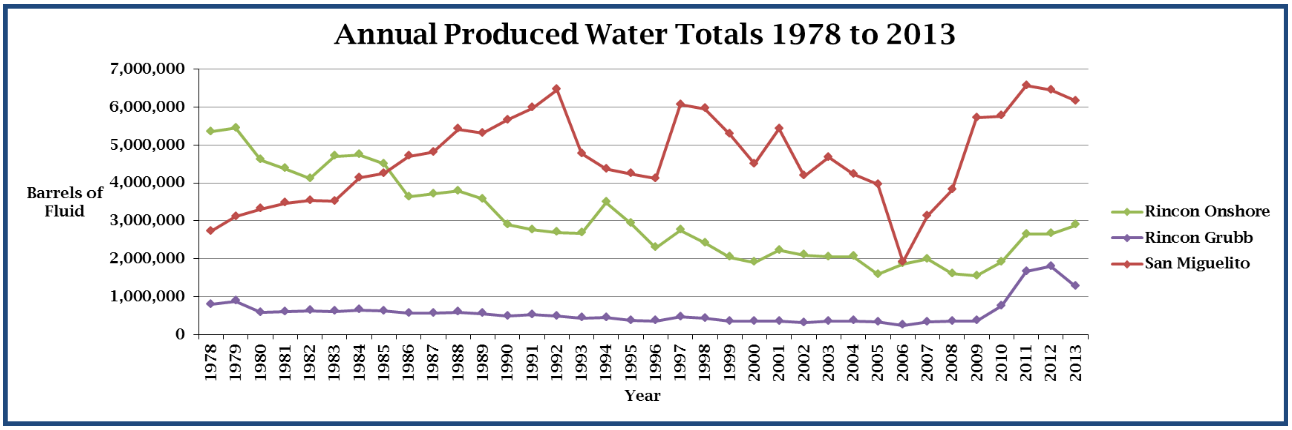


Figure 8.7 – Annual oil production per well for the San Miguelito Field as a whole, the Rincon Field Grubb lease, and the onshore Rincon Field as a whole (Figure 8.5). Data is from the California Division of Oil, Gas, and Geothermal Resources (DOGGR), downloaded February 2014[4].



The volume of produced water has varied considerably in the study area over the 35 year interval from 1978 to 2012. In 1985, the San Miguelito Field surpassed the Rincon Field for total annual produced water (Figure 8.8). The greatest volume of produced water extracted in the study area in a single year between 1978 and 2012 was about 9.2 million barrels in 2011, approximately 71% of this or 6.6 million barrels of the total produced water came from the San Miguelito Field (Figure 8.8 and Figure 8.10). Between 2009 and 2012, the volume of produced water from the Grubb lease portion of the onshore Rincon Field increased by almost a factor of five (4.9 times), and was approximately 67% of the total produced water in the onshore Rincon Field during 2012 (Figure 8.8).

Figure 8.8 – Total annual produced water for the San Miguelito Field as a whole, the Rincon Field Grubb lease, and the onshore Rincon Field as a whole (Figure 8.5). Data is from the California Division of Oil, Gas, and Geothermal Resources (DOGGR), downloaded February 2014[4].



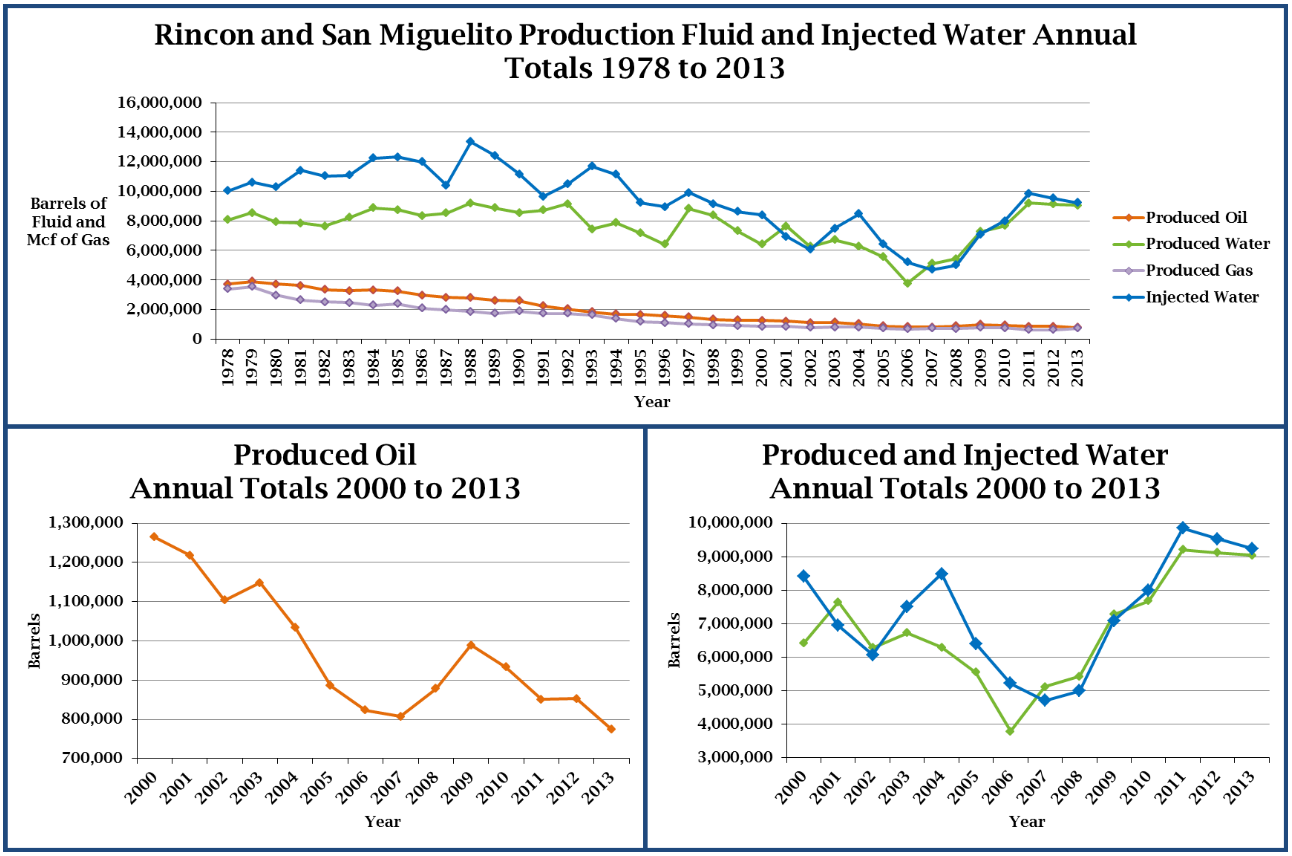
The ratio of water to oil in production fluid, from wells in the study area, has increased from 68% in 1978 to 91% in 2012 (Figure 8.9). For the 35 year interval the San Miguelito Field produced a cumulative total of about 46 million barrels of oil and 170 million barrels of produced water (about 78% of production fluid), and 254 million barrels of water was injected. The onshore Rincon Field produced a total of about 26 million barrels of oil and 110 million barrels of produced water (about 81% of production fluid), and 89 million barrels of water was injected.

Without considering the volume of gas, these production and injection volumes amount to a fluid deficit of about 50 million barrels for the Rincon Field (injected water minus the sum of produced oil and water), and a fluid surplus of about 41 million barrels for the San Miguelito Field.

Based on the average price of oil for each of the 35 years adjusted to December 2013 dollars (US Energy Information Administration) the oil production from 1978 to 2012 for the San

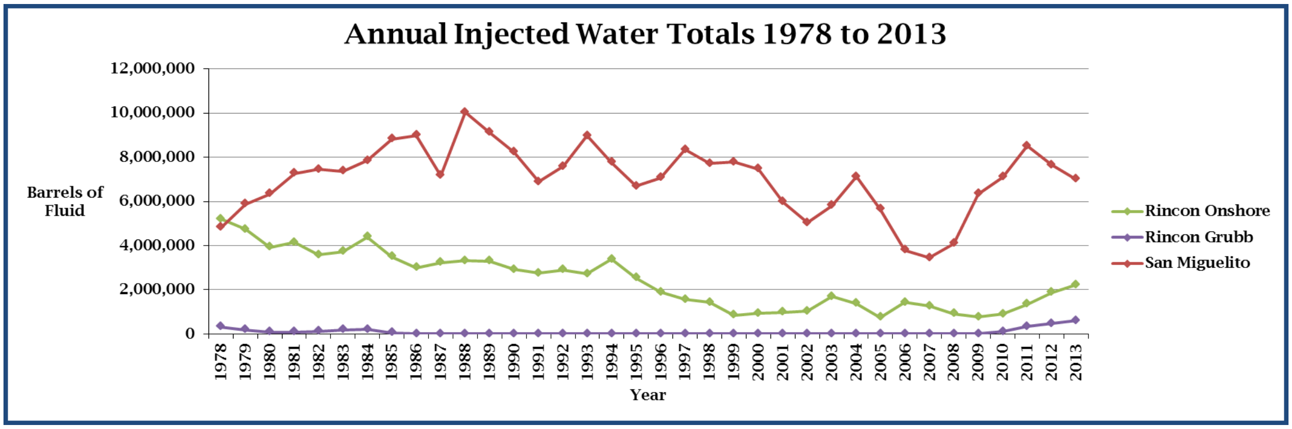
Miguelito Field was worth about $2.4 billion, and the onshore Rincon Field was worth about $1.3 billion.

Figure 8.9 *–* The annual sum of produced oil, produced water, produced gas, and injected water for both the onshore Rincon Field and the San Miguelito is graphed from 1978 to 2012. Data is from the California Division of Oil, Gas, and Geothermal Resources (DOGGR), downloaded February 2014[4].



Produced water is injected into water flood wells to facilitate enhanced oil recovery. The San Miguelito Field has dominated compared to the onshore Rincon Field in terms of injected water each year since 1978. The total annual volume of injected water in the two fields peaked in 1988 at 13.3 million barrels, of which the San Miguelito Field accounts for about 75% or 10 million barrels, injection then slowly declined until 2007 (Figure 8.9 and Figure 8.10). Injection in the study area increased again from 2008 to 2012, with 80% to 90% of that injected water occurring in the San Miguelito Field (Figure 8.10). Injection in the onshore Rincon Field has declined relatively steadily over the 35 year interval. No injection occurred in the Grubb lease portion of the Rincon Field for the 23 year period from the beginning of 1987 to the end of 2009 (Figure 8.10). Since 2009, there has been an increase in injection in the Rincon Field of about 1.1 million barrels.

Figure 8.10 – Total annual injected water for the San Miguelito Field as a whole, the Rincon Field Grubb lease, and the onshore Rincon Field as a whole (Figure 8.5). Data is from the California Division of Oil, Gas, and Geothermal Resources (DOGGR), downloaded February 2014[4].



8.6 Oil Field Roads, Well Pads, & Clearings

To support the oil field operations and maintain access to the wells, extensive road and well pad networks have been developed in the study area. Roads and cleared areas, such as well pads and staging areas, are of particular interest because of their influence on surface runoff and water quality. These un-vegetated and compacted surfaces generate unnatural quantities of surface runoff due to the reduced infiltration capacity compared to natural undisturbed areas. Roads and cleared areas also are major sources of fine sediments, which can increase the sediment yield of a watershed above natural levels. In the well fields, well pads and other cleared areas including roads are assumed to be areas where the majority of spills take place.

To assess the extent of this infrastructure in the watersheds, roads and cleared areas, including well pads, were digitized from 2010 and 2012 aerial imagery (Figure 8.11)[5]. Cleared areas were defined as well pads including one or more active or idle wells, areas containing tanks or pipes, and cleared staging areas. The extent of these cleared areas was drawn to include any un-vegetated tailings that were bulldozed off the cleared area and areas from where the road appears to start widening to the area. Roads and cleared areas were then clipped to the watershed boundaries, and the road length and well pad area within each watershed was estimated. These estimates give a relative measure of the influence road surfaces and well pads have on the hydrology of the five watersheds, but may not give the full picture due to hydrologic connectivity along roads and cleared areas that extend beyond the clipped watershed boundary.

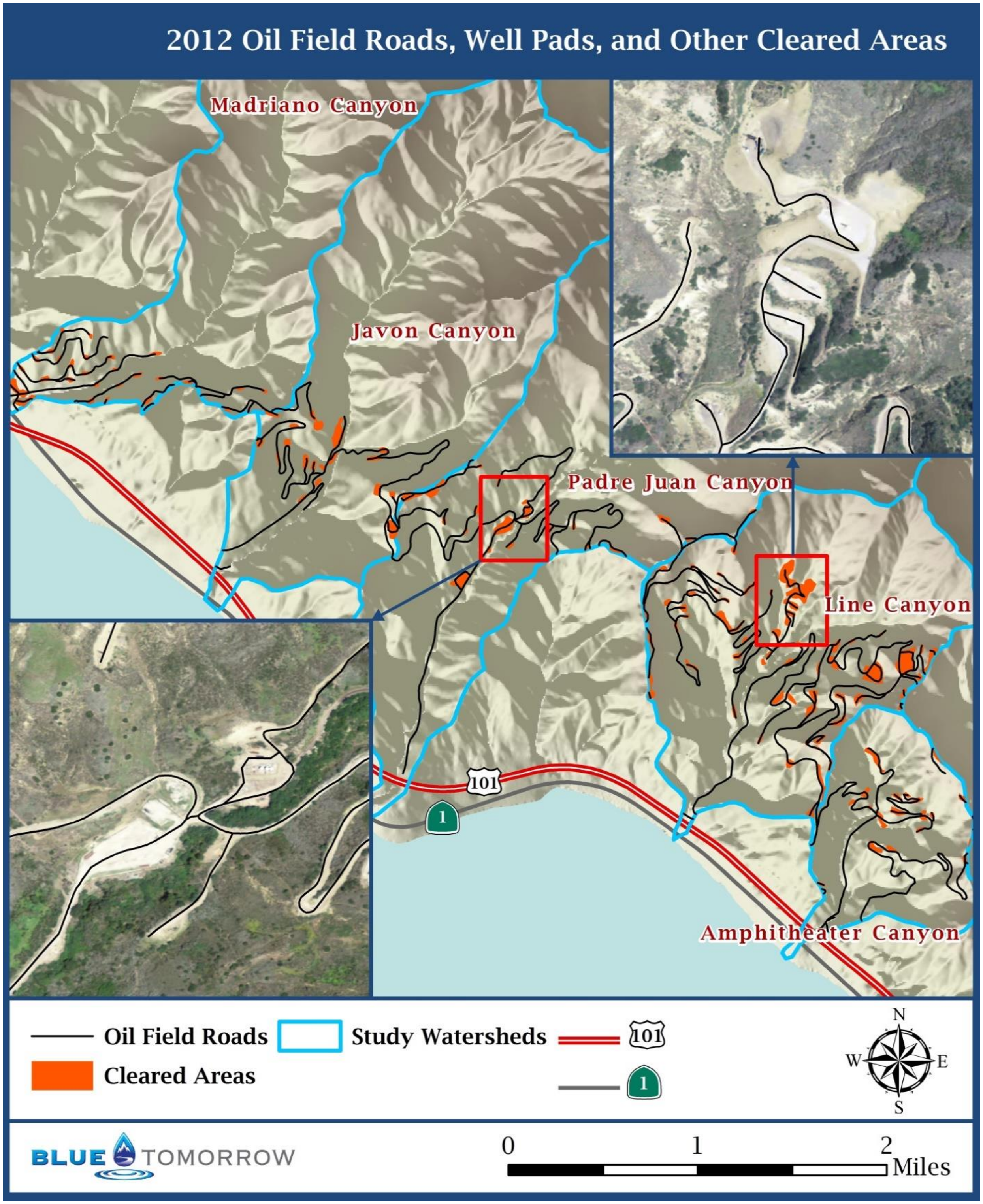
Table 8.3 - **Road length and cleared areas estimated for each of the five watersheds**

WATERSHED (area)	ROAD LENGTH (miles)	ROAD DENSITY (mi/mi^2)	PADS & STAGING AREAS (mi^2)	PERCENT OF WATERSHED AREA CLEARED
Madriano Canyon ($2.3\ mi^2$)	5.0	2.2	0.019	1.9%
Javon Canyon ($2.1\ mi^2$)	5.8	2.8	0.023	2.6%
Padre Juan Canyon ($3.0\ mi^2$)	8.3	2.8	0.022	2.2%
Line Canyon ($1.4\ mi^2$)	16.3	11.6	0.078	10.8%
Amphitheater Canyon ($0.56\ mi^2$)	5.9	10.5	0.017	8.8%
Estimates were performed using aerial imagery from 2010 and 2012[5] and ArcMap. Road density and percent area cleared were then calculated using the watershed area for each watershed. The percent area cleared includes the pads and staging areas plus the road length that does not overlap these areas, and assumes an average road width of 10 meters (33 feet).				

Between the aerial imagery taken in 2010 and 2012, over 50,000 m^2 were cleared within the study watersheds for the construction and renovation of well pads (over a 10% increase in the cleared area). The majority of this new construction took place in Line Canyon (approximately 39,600 m^2 or 7.4 football fields). Line Canyon has both the greatest total length of roads at about 16.3 miles and cleared well pads and staging areas at about 0.078 mi^2.

The possible impact of this oil field infrastructure depends on the Best Management Practices (BMPs) in place to mitigate the sediment and storm runoff within each watershed and the buffering capacity present between roads and cleared areas and the stream channels.

Figure 8.11 – Roads and cleared areas were digitized from 2010 and 2012 orthorectified aerial imagery produced by the National Agriculture Imagery Program[5]. Total oil field road length and cleared area were quantified for each watershed (Table 8.3).



8.7 Hydraulic Fracturing Operations

Hydraulic fracturing is a well stimulation method by which water, sand, and various chemical additives are injected at high pressure into the oil and gas barring formation with the intent to fracture the hydrocarbon containing rock. The hydraulically fractured well stimulations that have occurred in the study area have been recorded to inject from 77,000 to over 300,000 gallons per well at pressures around 6,000 to 8,000 psi[1,6].

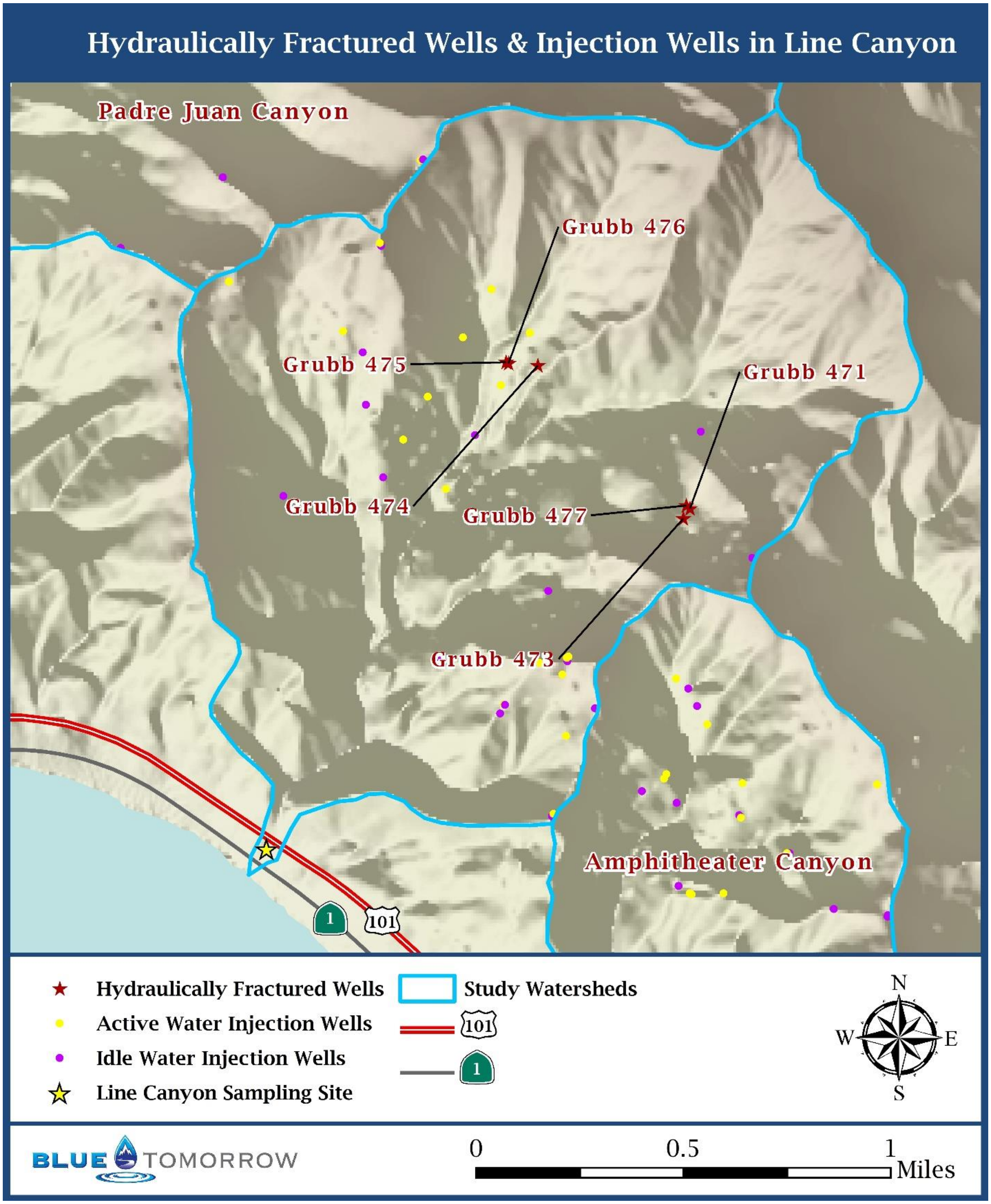
According to well records on file with DOGGR, there have been at least three hydraulically fractured well stimulations since 2010[1,3]. All reported hydraulically fractured well stimulations have taken place in Line Canyon in the Rincon Grubb lease (Figure 8.12). Wells were directionally drilled and are on record as active oil and gas wells, except for Grubb 471, which is in the process of being converted to a water flood injection well[1]. In addition to well stimulation projects highlighted in Table 8.4, there are plans contained in well history logs to conduct fracturing on two wells that were first drilled after 2000; these two wells are also located in Line Canyon: Grubb 482 and Grubb 483. It could not be confirmed whether or not these plans were executed[1].

Table 8.4 - **Records of hydraulically fractured well stimulations [1]**

WELL	TOTAL DEPTH (Ft)	SHALLOWEST PERFORATION (Ft)	DATE WELL WAS FIRST DRILLED	FRACTURE DATE
Grubb 471	8,510	7,710	12/14/2010	2/15/2011
Grubb 473	7,998	6,990	3/2/2011	5/26/2011
Grubb 474	7,597	6,650	1/28/2011	Unknown ~3/2011
Grubb 475	7,677	6,990	2/11/2011	Unknown ~4/2011
Grubb 476	7,985	6,976	1/11/2011	Unknown ~4/2011
Grubb 477	8,090	7,150	3/23/2011	6/15/2011

Depths are measured from the top of the well head and do not represent the true vertical depth from the land surface, which would be different due to directional drilling and topography. There is uncertainty in whether Grubb 474, 475, and 476 had fracture stimulations performed; the DOGGR GIS dataset and plans in the well records indicated they were fractured, but no evidence for whether the wells were fractured or not was found in the well history logs.

Figure 8.12 – Location of 6 hydraulically fractured well stimulations that have taken place in Line Canyon[1,3]. No hydraulically fractured well stimulations were found to have taken place in any other of the four watersheds.



8.8 Oil Field Fluids

Many additives and complex mixtures of fluids are being used and transported in and around the onshore Rincon and San Miguelito Oil Fields. Produced water constitutes the largest volume of fluid being transported around the oil fields and is known for its high concentrations of Total Dissolved Solids (TDS), metals, sulfur compounds, and hydrocarbons.

All the fluids and chemicals being used in the oil fields are not freely disclosed; therefore, information about the fluids and chemicals being used was taken from well records obtained from the California Division of Oil, Gas, and Geothermal Resources (DOGGR). There are many other additives and chemicals being used in the Rincon and San Miguelito Fields. Those listed below do not represent a comprehensive list of all additives and chemicals used in the study watersheds.

Hydraulic Fracturing Fluids

Hydraulic fracturing fluids, or "fracking fluids", are known to contain many different hazardous and nonhazardous additives that are engineered for the geologic setting in which they are used. The additives used in fracking fluid have various intended purposes, including those listed in Table 8.5. The constituent makeup of the 361,620 gallons of fracking fluid used in well "Grub 477" was disclosed to DOGGR and FracFocus and is summarized in Table 8.6[1]. This well is located in Line Canyon and had a hydraulically fractured well stimulation on May 27, 2011, within four months of other fracturing jobs at nearby wells (Figure 8.9; Table 8.4).

***Table 8.5 -* Descriptions of purposes for additives in hydraulic fracturing fluid**

PURPOSE	DESCRIPTION OF PUPOSE
Proppants	Holds fractures in the rock open and increase the permeability and flow of fluid
Clay control	Reduces the swelling of clay in the fractured rock which could close fractures when it swells
Breaker and catalyst	Reduces the fluid viscosity after fracturing to minimize return of proppants and maximize the return of fracturing fluids
Buffer	Controls and maintain pH of the fracturing fluid
Corrosion inhibitor	Limits corrosion of metal equipment and protect the well casing and other metal equipment from the strong acids that are used
Iron control	Controls the iron hydroxide precipitates which form as the acid reacts and is spent and that could reduce fracture permeability
Gellant	Increases the viscosity of the fluid to carry proppants and reduce friction during pumping, creates a viscoelastic fluid
Acidifier	For well bore scale removal, and rock matrix and fracture acidizing to increase production
Surfactant	Lowers the surface tension between oil and water allowing the oil-water production fluid to flow more smoothly through small fractures
Non-emulsifier	Reduces or limits emulsions created by mixing of oil and water which that can block and reduce fracture permeability
Scale inhibitor	Reduces the scale build up that occurs from high levels of total dissolved solids and can reduce fracture permeability
Crosslinker	Increases viscosity and can be adjusted by pH and or temperature
Biocide	Controls bacteria growth that can break down gellants needed to maintain viscosity

The purposes listed are taken from the Hydraulic Fracturing Fluid Product Component Information Discloser for the hydraulically fractured well stimulation on well "Grubb 477" in Line Canyon (Table 6). All the descriptions of purposes are taken from Halliburton product fact sheets[7].

Table 8.6 - **Fluid product component information discloser for the hydraulically fractured well stimulation on well "Grubb 477"**

INGREDIENT	PURPOSE	TRADE NAME OF PRODUCT CONTAINING INGREDIENT	MAXIMUM CONCENTRATION IN FLUID (% BY MASS)	APPROXIMATE MAXIMUM CONCENTRATION IN FLUID (mg/L)
Silicon Dioxide, Crystalline Silica Cristobalite, and Quartz (Sand)	Proppant, Breaker, Scale inhibitor, Biocide	Super LC, High Perm CRB, Scalessorb 3, X-Cide 207	20.8	280,000
Phenol Formaldehyde Resin	Proppant	Super LC	1.07	14,000
Hydrochloric Acid	Acidifier	HCl:HF	0.756	10,000
Petroleum Distillate Blend	Gellant	GW-3LDF	0.357	4,800
Potassium Carbonate	Buffer	BF-7L	0.207	2,800
Guar Gum	Gellant	GW-3LDF	0.204	2,700
Hydrofluoric Acid	Acidifier	HCl:HF	0.176	2,400
Surfactants	Surfactant	Inflo 250W	0.115	1,500
Glyoxal	Crosslinker	XLW-56	0.0656	880
Methanol	Surfactant, Corrosion Inhibitor	Inflo 250W, CI-27	0.0477	640
Oxyakylated Amine Quat	Clay Control	Clay Master-5C	0.0472	640
Calcined Diatomaceous Earth	Scale inhibitor, Biocide	Scalessorb 3, X-Cide 207	0.0422	570
2-Butoxyethanol	Surfactant	Inflo 250W	0.0288	390
D-Glucitol	Crosslinker	XLW-56	0.0219	290
Sodium Tetraborate	Crosslinker	XLW-56	0.0219	290
Citric Acid	Iron Control	Ferrotrol 300L	0.0148	200
Ammonium Chloride	Clay Control	Ammonium Chloride	0.0126	170
Amino Tri (Methylene Phosphonic Acid)	Scale inhibitor	Scalessorb 3	0.0121	160
Sodium Hydroxide	Crosslinker	XLW-56	0.0109	150
Ammonium Persulphate	Breaker	High Perm CRB	0.00705	95
Hemicellulase Enzyme Concentrate	Breaker	Enzyme G-I	0.00419	56
Erthrobic Acid	Iron Control	Ferrotrol 210	0.00302	41

Table 8.6 - continued

INGREDIENT	PURPOSE	TRADE NAME OF PRODUCT CONTAINING INGREDIENT	MAXIMUM CONCENTRATION IN FLUID (% BY MASS)	APPROXIMATE MAXIMUM CONCENTRATION IN FLUID (mg/L)
Ethoxylated Alcohols (C14-15)	Corrosion Inhibitor	CI-27	0.00227	31
Tall Oil Acid	Corrosion Inhibitor	CI-27	0.00227	31
Thiourea Polymer	Corrosion Inhibitor	CI-27	0.00227	31
Hexamethylenetetramine	Proppant	Super LC	0.00214	29
Isopropyl Alcohol	Non-emulsifier	NE-118	0.00129	17
Propargyl Alcohol	Corrosion Inhibitor	CI-27	0.00076	10
Aromatic Hydrocarbon Solvent	Non-emulsifier	NE-118	0.00069	9.3
Phosphonic Acid	Scale inhibitor	Scalessorb 3	0.0004	5.4
Alkenes (C>10)	Corrosion Inhibitor	CI-27	0.00038	5.1
5-Chloro-2-Methyl-4-Isothiazolin-3-One	Biocide	X-Cide 207	0.00032	4.3
Magnesium Nitrate	Biocide	X-Cide 207	0.00032	4.3
2-Methyl-4-Isothiazolin-3-One	Biocide	X-Cide 207	0.00016	2.2
Magnesium Chloride	Biocide	X-Cide 207	0.00016	2.2
Naphthalene	Non-emulsifier	NE-118	0.0001	1.4
Xylene	Non-emulsifier	NE-118	0.0001	1.4
		TOTAL	24	

Data was acquired from FracFocus and DOGGR[1,6]. The well was fractured on May 27, 2011. The approximate maximum concentration in the fluid was calculated assuming a fluid density of 1.3465g/cm^3 (approximated by assuming 79% water and 21% sand), and gives perspective to the ingredient concentrations that would be released in a spill prior to dilution from entering a stream or other water body.

Well treatments and Acid treatments

Additional acid treatments (not only acidification during fracking) are commonly used in the study area to remove scaling and to clean the well perforations[1]. This type of treatment is most often used on injection wells. Fluids used in conjunction with acids during the treatment of a well include lubricants, corrosion inhibitors, and solvents[1]. A few of the additives and acid treatment fluids known to be used in the study watersheds are listed below in Table 8.7. These fluids are injected at pressures up to 2,500psi[1].

Hydrochloric acid (HCL) is the main acid used in acid treatments in the Rincon and San Miguelito Fields[1]. One possible impact from the strong acids used to treat wells is that they dissolve heavy metals, which then can leach or be released into surface waters at higher concentrations than would naturally be present in the environment.

Table 8.7 - **Ingredients in Injection Fluid Additives**

INGREDIENT	PRODUCT CONTAINING INGREDIENT	MAXIMUM INGREDIENT CONCENTRATION IN PRODUCT (% By Mass)	GALLONS OF PRODUCT USED/ TOTAL TREATMENT GALLONS	APPROXIMATE MAXIMUM CONCENTRATION IN TREATMENT FLUID (mg/L)
Solvent Naphtha, Light Aromatic	Aromatic 100 Solvent[8]	100	360/4000	79,000
1,2,4 Trimethylbenzene	Aromatic 100 Solvent[8]	32	360/4000	25,000
Propylbenzene and Isopropylbenzene	Aromatic 100 Solvent[8]	1.1	360/4000	860
Xylenes	Aromatic 100 Solvent[8]	2.2	360/4000	1,700
Methanol	HAI-OS Corrosion Inhibitor[9]	60	32/4000	4,300
Propargyl Alcohol	HAI-OS Corrosion Inhibitor[9]	10	32/4000	710
Hydrochloric Acid (HCL)	FE Acid[10]	30	8000/8000	320,000
HCL	HCL	17	4000/4000	180,000
Hydrofluoric Acid (HF)	HF	1.5	4000/4000	15,000
Aromatic Ketones	A261 Corrosion Inhibitor[11]	100	20/2898	7,000
Aliphatic Alcohol Polyglycol Ether	A261 Corrosion Inhibitor[11]	13	20/2898	920
Methanol	A261 Corrosion Inhibitor[11]	10	20/2898	700
Aliphatic Acid	A261 Corrosion Inhibitor[11]	5	20/2898	350
Prop-2-yn-1-ol	A261 Corrosion Inhibitor[11]	5	20/2898	350
Aromatic Hydrocarbon	A261 Corrosion Inhibitor[11]	5	20/2898	350
Formaldehyde	A261 Corrosion Inhibitor[11]	5	20/2898	350

Table 8.7 - continued

INGREDIENT	PRODUCT CONTAINING INGREDIENT	MAXIMUM INGREDIENT CONCENTRATION IN PRODUCT (% By Mass)	GALLONS OF PRODUCT USED/ TOTAL TREATMENT GALLONS	APPROXIMATE MAXIMUM CONCENTRATION IN TREATMENT FLUID (mg/L)
Propan-2-ol	A261 Corrosion Inhibitor[11]	5	20/2898	350
Ethylene Glycol Monobutyl Ether	Mutual Solvent	100	14/2898	4,300
Evidence that the products listed below are being used in the study area comes from the proposed "well operations procedure" and well history records from wells in the Rincon and San Miguelito Fields[1]. Product ingredients were taken from Material Safety Data Sheet (MSDS) provided by Halliburton, ExxonMobil, and Schlumberger (refer the superscript on the product name for specific MSDS references). The approximate maximum concentration in fluid was calculated using the fluid densities from the product MSDS, and gives perspective to the ingredient concentrations that would be released in a spill prior to dilution from entering a stream or other water body.				

Drilling mud

Drilling mud is used during the drilling or reworking of a well. The 1953 San Miguelito Oil Field biography indicates that by 1953, oil-water emulsion based mud was becoming the dominant mud used in the study area[2]. Oil used for the drilling fluid is typically diesel fuel or a more highly refined petroleum distillate ("mineral oil").

Drilling muds consist of a base fluid and additives such as clay, barite, potassium chloride, calcium chloride, and sodium aluminate. Potassium chloride is commonly used in the study area during most if not all drilling and well maintenance operations at concentrations usually ranging from 3% to 6%, but sometimes as high as 14%. Currently, both water and oil emulsion based muds are used in the Rincon and San Miguelito Fields. Water-based drilling muds are used primarily when drilling above production zones, while oil-based muds are often used when drilling through the oil producing formations.

The oil in the oil-based mud currently used for drilling in the Rincon and San Miguelito fields is a hydrotreated light petroleum distillate named LVT 200[1]. This oil consists of hydrocarbons mainly in the diesel range (DRO) from C10 to C20. LVT 200 is more refined and less harmful to the environment than diesel fuel. This oil is mostly unregulated, except for the Clean Water Act, which considers petroleum hydrocarbons hazardous if spilled into navigable waters with a reportable quantity of a "film or sheen upon or discoloration of any water surface"[12, 13].

When drilling through a tight spot in the formation, or when the drill pipe gets stuck, additional LVT oil and other oils and solvents are often added to reduce friction. Crude oil is also intentionally added to drilling mud in the two fields and incorporated while drilling through oil bearing formations[1].

Table 8.8 - **Ingredient concentrations in oil based drilling mud**

INGREDIENT IN OIL BASED DRILLING MUD	MAXIMUM CONCENTRATION IN DRILLING MUD (% By Weight)	APPROXIMATE MAXIMUM CONCENTRATION IN DRILLING MUD (mg/L)
Hydrotreated light petroleum distillate	95	850,000
Barite (Barium Sulfate)	40	360,000
Calcium Chloride	6	53,000
Naphtha, Tall Oil, Fatty Acids, Amides, and other distillates	4	36,000
Calcium Oxide	0.6	5,300
The approximate maximum concentration in the drilling mud was calculated assuming a fluid density of 0.89 g/cm^3 (based on specific gravity from MSDS). Data were acquired from the PetroDrill MSDS for LVT 200 oil based mud[13].		

Produced water

Produced water represents the greatest volume of fluid being pumped in and out of wells and transferred around the well fields. Produced water is extracted with the oil from a production well as part of the total production fluid. Currently, production fluid in the study area is greater than 90% produced water (water cut)[4]. The chemistry of produced water is characterized by a complex mixture of hydrocarbons, dissolved salts, and minerals incorporated from the formation rocks. Produced water also likely contains chemicals injected into the well field during well treatments. The chemical makeup of produced water extracted from a well is very site-specific, not only varying largely between fields but also between wells within a single field due to differences in geology[14].

Produced water from the Rincon and San Miguelito Fields generally has Total Dissolved Solid (TDS) concentrations in the range of 27,000 to 36,000 mg/L (Table 8.9)[15]. The dominant ions in produced water from the study area are sodium, chloride, and bicarbonate. These three ions account for 90% to 97% of the TDS in the samples of produced water from the two fields.

Table 8.9 - **Maximum and minimum concentrations of select ions and Total Dissolved Solids (TDS) observed in produced water from Rincon and San Miguelito Fields**

MEASUREMENT (all units except pH are in mg/L)	RINCON FIELD MIN-MAX VALUE	SAN MIGUELTIO FIELD MIN-MAX VALUE
pH	7.1 to 8.0	6.79 to 7.9
Bicarbonate	795 to 2,130	73 to 29,00
Calcium	308 to 765	391 to 732
Chloride	15,600 to 18,600	14,500 to 17,600
Magnesium	115 to 355	90 to 1,300
Potassium	No data	47 to 362
Sodium	9,905 to 11,953	8,400 to 10,013
Sulfate	2 to 1,250	8 to 2,800
Total Dissolved Solids (TDS)	28,800 to 33,800	27,800 to 36,200

These ranges give an idea of the inorganic chemistry of produced water in the study area but due to the small dataset (7 Rincon samples, 4 San Miguelito samples) it is likely a more thorough sampling of produced water from the fields would yield concentrations that fall outside of these ranges. These samples were also taken from produced water that originated from different depths (generally, water produced from deeper has higher TDS). Data were acquired from USGS Produced Waters Database[15].

No information was found on the organic chemistry of produced water from the Rincon and San Miguelito Fields, but it can be assumed to be high in organic compounds from interaction with oil in the formation. Produced water may also contain corrosion inhibitors, biocides, and anti-scaling agents that are added before reinjection to help maintain injection efficiency.

A study on produced water discharges from a processing facility in Carpinteria, a few miles northwest of the study area, found over a thousand hydrocarbon substances[16]. The produced water from this facility originates from the offshore oil platforms in the Santa Barbara Channel, and discharges of produced water have ceased since the study was completed. This study also found the dominant elements in the produced water were barium and strontium, at concentrations of 13 mg/L. The produced water from Carpinteria was also noted for high levels of organic and inorganic sulfur compounds, including organic thiocarboxylic acids, thiopyranones, organopolysulfides, and inorganic sulfides, thiosulfates, and polysulfides[16].

8.9 Oil Production Operations Summary

The Rincon Field and San Miguelito Field are the two oil fields that intersect the study area, which have been in production since the early 20th century. A total of about 430 wells were drilled within the study watershed boundaries from 1916 until 2013. Twenty new wells have been drilled since 2007, the majority in Line Canyon. Oil field development has led to large areas cleared for roads and well pads; approximately 10.8% of the land area in Line Canyon and 8.8% in Amphitheater Canyon has been converted from natural vegetation. Oil field roads, well pads, and other cleared areas have compacted soils which reduced permeability and infiltration; this leads to greater surface water accumulation and runoff volume, and flows with greater erosive power compared to those generated off natural landscapes.

Over the life of the oil fields, the composition of production fluid has changed from almost 100% oil in 1927 to over 90% produced water in 2014. Enhanced oil recovery methods and water flood injections have been used in the study watersheds since 1955 in an attempt to boost production from the depleting fields and wells (roughly 9 million barrels of produced water was injected into the subsurface in 2013). The produced water used in these water flood projects represents the greatest volume of fluid being moved around the oil fields.

Well stimulations and well treatments, such as hydraulic fracturing and acid treatments, are also performed in the study watersheds. The fluids used in these operations have many different chemical additives, with the greatest concentrated chemical mixtures being acid treatment fluids. Hydraulic fracturing well stimulations in the area has been recorded to use over 300,000 gallons of fluid per treatment, while acid treatments generally use under 10,000 gallons of fluid per treatment. At least three wells have been hydraulically fractured in Line Canyon, but acid well treatments appear to be much more extensively used, especially on injection wells.

8.10 Oil Production Operations Section References

1) California Department of Conservation. Division of Oil, Gas, and Geothermal Resources (DOGGR). Oil & Gas well records. available at http://owr.conservation.ca.gov/WellSearch/WellSearch.aspx. accessed January 2014.
2) California Department of Conservation. Division of Oil, Gas, and Geothermal Resources (DOGGR). Annual Reports of the State Oil & Gas Supervisor. available at http://www.conservation.ca.gov/dog/pubs_stats/annual_reports/Pages/annual_reports.aspx.
3) California Department of Conservation. Division of Oil, Gas, and Geothermal Resources (DOGGR). GIS mapping data. available at http://www.conservation.ca.gov/dog/maps/Pages/GISMapping2.aspx. accessed January 2014.
4) California Department of Conservation. Division of Oil, Gas, and Geothermal Resources (DOGGR). Production and Injection database. available at http://opi.consrv.ca.gov/opi/opi.dll. accessed February 2014.
5) United States Department of Agriculture. Natural Resources Conservation Service. Geospatial Data Gateway. available at http://datagateway.nrcs.usda.gov/. accessed January 2014.
6) Frac Focus. Chemical Disclosure Registry. available at: http://www.fracfocusdata.org/DisclosureSearch/StandardSearch.aspx. accessed September 2013.
7) Halliburton. Products and Services information. accessed at http://www.halliburton.com/en-US/ps/default.page?node-id=h8cyv98a.
8) ExxonMobil, 2007. Material Safety Data Sheet (MSDS). Aromatic 100 Fluid. available at http://www.alchemchemical.com/product-details/items/116.html. accessed February 15, 2014.
9) Halliburton, 2012. Material Safety Data Sheet (MSDS). HAI-OS Acid Inhibitor. available at http://www.halliburton.com/public/projects/pubsdata/Hydraulic_Fracturing/disclosures/pdfs/Penn_Sys_1_Add_B_HAI-OS.pdf. accessed February 15, 2014.
10) Halliburton, 2011. Material Safety Data Sheet (MSDS). 15% FE Acid. available at http://www.michigan.gov/documents/deq/State_Excelsior_2-25_HD-1_MSDS_60545_405122_7.PDF. accessed February 15, 2014.
11) Schlumberger, 2006. Material Safety Data Sheet (MSDS). Corrosion Inhibitor A261. available at http://newyork.sierraclub.org/fingerlakes/MSDS/Corosion%20Inhibitor%20A261%20MSDS.pdf. accessed February 15, 2014.

12) Conoco, 1993. Material Safety Data Sheet (MSDS). LVT-200 drilling mud oil. available at ftp://ftp.consrv.ca.gov/pub/oil/WellRecord/083/08320181/08320181%20Mud&MSDS_10-9-970001.pdf. accessed February 15, 2014.
13) PetroDrill, 2007. Material Safety Data Sheet (MSDS). LVT 200 Oil Based Mud. available at http://www.geodf.com/store/geodf_products/77_2.pdf. accessed February 15, 2014.
14) Guerra,K., Dahm, K., Dundorf, S., 2011. Oil and gas produced water management and beneficial use in the Western United States. US Department of the Interior. Bureau of Reclamation. Water Treatment Engineering Research Group. available at http://www.usbr.gov/research/AWT/reportpdfs/report157.pdf.
15) US Geological Survey. Produced Waters database. available at http://energy.cr.usgs.gov/prov/prodwat/data.htm. accessed February 15, 2014.
16) Higashi, R.M., Jones, A.D., Fan, T.WM., 1997. Characterization of Organic Constituent Patterns at a Produced Water Discharge Site / Barium Relations to Bioeffects of Produced Water. US Department of Interior. Minerals Management Service. available at http://www.coastalresearchcenter.ucsb.edu/scei/Files/97-0022.pdf.

9.0 | WATER QUALITY

This section discusses existing data obtained in the study watersheds to provide background information on constituent levels previously found in the drainages. Though previous water quality data in the study area is sparse, the information that is available documents high levels of Total Dissolved Solids (TDS), Total Suspended Solids (TSS), and conductivity in each of the study watersheds, and high levels of dissolved sulfate in Madriano, Javon and Padre Juan Canyons and dissolved chloride in Javon and Padre Juan Canyons.

The study watersheds have various beneficial uses, and water quality objectives may differ depending on the constituent and designated use. Madriano, Javon, and Padre Juan Canyons are designated for the potential beneficial use of Municipal and Domestic Supply (MUN) which protects sources of water for community or individual water supply systems, including drinking water supply. These three canyons are also designated as having intermittent beneficial uses of Agriculture (AGR), and Industrial Process Supply (PROC)[1].

Section Highlights

- Numerous designated beneficial uses exist for inland surface water, groundwater, and coastal waters in and around the study watersheds
- The watersheds have various water quality objectives, which have been determined to maintain beneficial uses of water resources
- Previous water quality testing in the watersheds has shown high levels of conductivity, Total Dissolved Solids, Total Suspended Solids, chloride, and sulfate
- Nearby watersheds with similar land uses and physical characteristics have demonstrated high levels of Total Dissolved Solids, sodium, chloride, sulfate, and boron, among other impairments

This section discusses the regulations and water quality objectives for the watersheds and examines the results of previous water quality testing. Water quality data from other watersheds in the region was reviewed to give insight into possible background contaminant levels.

9.1 Regulatory Framework

Water quality in the five study watersheds is regulated by the Clean Water Act (CWA) and the California Porter-Cologne Water Quality Control Act (California Water Code). The five study watersheds are within the jurisdiction of Region 4, the Los Angeles Regional Water Quality Control Board (RWQCB). This regulatory agency monitors and enforces state and federal laws, and the National Pollution Discharge Elimination System (NPDES) and Total Maximum Daily Load (TMDL) programs[2,3,4].

Applicable water quality objectives depend on the designated beneficial uses in the study watersheds and those specified through the NPDES Program. The oil fields in the study watersheds operate under an Industrial General Permit (through NPDES) that was established in 1997. On April 1, 2014 updates to the 1997 permit, which include numeric action levels, were adopted by the State of California, but these regulations do not go into effect until July 1, 2015[5].

Section 303(d) of the CWA requires states to develop lists of impaired waters and determine the TMDL of a pollutant that a water body can receive and still meet water quality objectives[6]. The RWQCB oversees the listing of impaired water bodies within its jurisdiction and the TMDL program.

The study watersheds have not yet been listed in accordance with Section 303(d). In surrounding watersheds, there are a number of Section 303(d) listed waters (and in some cases sources and causes) of impairments are specified. This information allows for comparisons between the study watersheds and those in more thoroughly tested areas.

9.2 Beneficial Uses of Water Resources

The Los Angeles RWQCB's Basin Plan (Basin Plan) incorporates all applicable State and Regional policies and regulations, including the CWA and California Water Code. The Basin Plan designates beneficial uses of water resources and establishes water quality objectives, and includes existing, potential, and intermittent beneficial uses for water resources in the study area[1]. Designations of beneficial uses and water quality objectives contained in this section were obtained from the Basin Plan.

The study watersheds are located within the Pitas Point Hydrologic Unit 401.00. The Basin Plan identifies beneficial uses in this Hydrologic Unit for groundwater, inland surface waters for Madriano, Javon, and Padre Juan Canyon watersheds, and coastal features in the near shore and offshore zones[1].

Existing designated beneficial uses of groundwater in Pitas Point Hydrologic Unit 401.00 include Municipal and Domestic Supply (MUN), Industrial Service Supply (IND), and Agriculture (AGR), and a potential beneficial use of Industrial Process Supply (PROC)[1].

For inland surface waters, Madriano, Javon and Padre Juan Canyon watersheds are designated as Wildlife Habitat (WILD). Water quality objectives under this designation are aimed at protecting waters that support terrestrial ecosystems. In Javon Canyon, there is an existing designated use for Wetland Habitat (WET) that protects uses of water for the preservation or enhancement of wetland habitats, vegetation, or dependent species, and maintains its natural functions that enhance water quality[1].

Madriano, Javon, and Padre Juan Canyon watersheds are classified as having the potential beneficial use of Municipal and Domestic Supply that protects the uses of water for community or individual water supply systems, including drinking water supply[1]. Intermittent beneficial uses are designated for the Madriano, Javon and Padre Juan Canyon watersheds for Agriculture, Industrial Service Supply, Industrial Process Supply, Ground Water Recharge (GWR), Warm Freshwater Habitat (WARM), Cold Freshwater Habitat (COLD), Water Contact Recreation (REC1), Non-contact Water Recreation (REC2), and Spawning, Reproduction, and/or Early Development (SPWN). Though there are different objectives for the various uses, protection of the most sensitive use applies in selecting limits to receiving waters[1].

Near shore and offshore zones have existing designated beneficial uses of water for Navigation, Shellfish Harvesting (SHELL), Commercial Sport Fishing (COMM). Other designations include the protection of water for Marine Habitat (MAR), Rare, Threatened, or Endangered Species (RARE), Migration of Aquatic Organism (MIGR), and SPWN. Tables 9.1 – 9.3 show the beneficial uses of water in Madriano, Javon, and Padre Juan Canyons, the Pitas Point groundwater basin, and the nearshore and offshore waters of the Ventura County coast[1].

9.2.1 Designated Beneficial Use Acronyms

AGR	Agriculture
COLD	Cold Freshwater Habitat
COMM	Commercial Sport Fishing
GWR	Groundwater Recharge
E	Existing Beneficial Use
I	Intermittent Beneficial Use
IND	Industrial service supply
MAR	Marine Habitat

MIGR	Migration of Aquatic Organisms
MUN	Municipal and Domestic Supply
P	Potential Beneficial Use
PROC	Industrial process Supply
RARE	Rare, threatened, or endangered species
REC1	Water Contact Recreation
REC2	non-contact Water Recreation
SHELL	Shellfish Harvesting
SPWN	Spawning, Reproduction, and/or Early Development
WARM	Warm Freshwater Habitat
WET	Wetland Habitat
WILD	Wildlife Habitat

Table 9.1 - **Beneficial Uses of Inland Surface Waters**

BENEFICIAL USE	MADRIANO CANYON	JAVON CANYON	PADRE JUAN CANYON
Municipal & Domestic Supply (MUN)	Potential (P)*	P*	P*
IND	Intermittent (I)	I	I
PROC	I	I	I
AGR	I	I	I
GWR	I	I	I
WARM	I	I	I
COLD	I	I	I
WILD	Existing (E)	E	E
MIGR	I	I	I
SPWN	I	I	I
WET†		E	
REC1	I	I	I
REC2	I	I	I

P* designations for MUN under SB 88-63 and RB 89-03. Some designations may be considered for exemption at a later date.

†Waterbodies designated as WET may have wetlands habitat associated with only a portion of the waterbody. Any regulatory action would require a detailed analysis of the area[1].

Table 9.2 - **Beneficial Uses of Ground Waters**

BENEFICIAL USE	PITAS POINT AREA
MUN	E
IND	E
PROC	P
AGR	E
Ground waters in the Pitas Point area (between the lower Ventura River and Rincon Point) are not considered to comprise a major basin[1].	

Table 9.3 - **Beneficial Uses of Ventura County Coastal Waters**

BENEFICIAL USE	NEARSHORE	OFFSHORE
IND	E	
NAV	E	E
COMM	E	E
MAR	E	E
WILD	E	E
RARE	Ee	Ee
MIGR	Ef	Ef
SPWN	Ef	Ef
SHELL	E	E
Nearshore is defined as the zone bounded by the shoreline or the 30-foot depth contours, whichever is further from the shoreline. Longshore extent is from Rincon Creek to the San Gabriel River Estuary. e: One or more rare species utilizes all ocean, bays, estuaries, and coastal wetlands for foraging and/or nesting. f: Aquatic organisms utilize all bays, estuaries, lagoons, and coastal wetlands, to a certain extent, for spawning and early development. This may include migration into areas which are heavily influenced by freshwater inputs[1].		

9.3 Water Quality Objectives

Water quality objectives for beneficial uses designated in the study area are highlighted below. Maximum contaminant levels found in Title 22 of the California Code of Regulations are included for the designated beneficial use of Municipal and Domestic Supply for inorganic and organic chemicals (Tables 9.4 & 9.5). Additional water quality objectives exist for miscellaneous Ventura County Coastal streams (Table 9.6). Other water quality objectives are also discussed, including benchmark values for receiving waters from activities under the current Industrial General Permit.

Water Quality Objectives for Beneficial Uses

Water quality objectives for the beneficial use of Municipal and Domestic Supply (MUN) are Maximum Contaminant Levels (MCLs) that apply for drinking water.

Table 9.4 - **Water quality objectives for inorganic chemicals for MUN beneficial use[1]**

CONSTITUENT	MAXIMUM CONTAMINANT LEVEL (mg/L)
Aluminum	1
Antimony	0.006
Arsenic	0.01
Asbestos	7 MFL*
Barium	1
Beryllium	0.004
Cadmium	0.005
Chromium	0.05
Cyanide	0.15
Fluoride	2
Mercury	0.002
Nickel	0.1
Nitrate (as NO_3)	10
Nitrate + Nitrite (sum as nitrogen)	1
Perchlorate	0.006
Selenium	0.05
Thallium	0.002
*(MFL = million fibers per liter; MCL for fibers> 10 microns long)	

Table 9.5 - **Water quality objectives for organic chemicals for MUN beneficial use [1]**

CONSTITUENT	MAXIMUM CONTAMINANT LEVEL (mg/L)
Volatile Organic Chemicals	
Benzene	0.001
Carbon Tetrachloride	0.0005
1,2-Dichlorobenzene	0.6
1,4-Dichlorobenzene	0.005
1,1-Dichloroethane	0.005
1,2-Dichloroethane	0.0005
1,1-Dichloroethylene	0.006
cis-1,2-Dichloroethylene	0.006
trans-1,2-Dichloroethylene	0.01
Dichloromethane	0.005
1,2-Dichloropropane	0.005
1,3-Dichloropropene	0.0005
Ethylbenzene	0.3
Methyl-tert-butyl ether	0.013
Monochlorobenzene	0.07
Styrene	0.1
1,1,2,2-Tetrachloroethane	0.001
Tetrachloroethylene	0.005
Toluene	0.15
1,2,4-Trichlorobenzene	0.005

Table 9.5 – continued

CONSTITUENT	MAXIMUM CONTAMINANT LEVEL (mg/L)
1,1,1-Trichloroethane	0.2
1,1,2-Trichloroethane	0.005
Trichloroethylene	0.005
Trichlorofluoromethane	0.15
1,1,2-Trichloro-1,2,2-Trifluoroethane	1.2
Vinyl Chloride	0.0005
Xylenes	1.750*
Non-Volatile Synthetic Organic Chemicals (SOCs)	
Alachlor	0.002
Atrazine	0.001
Bentazon	0.018
Benzo(a)pyrene	0.0002
Carbofuran	0.018
Chlordane	0.0001
2,4-D	0.07
Dalapon	0.2
Dibromochloropropane	0.0002
Di(2-ethylhexyl)adipate	0.4
Di(2-ethylhexyl)phthalate	0.004
Dinoseb	0.007
Diquat	0.02
Endothall	0.1
Endrin	0.002
Ethylene Dibromide	0.00005
Glyphosate	0.7
Heptachlor	0.00001
Heptachlor Epoxide	0.00001
Hexachlorobenzene	0.001
Hexachlorocyclopentadiene	0.05
Lindane	0.0002
Methoxychlor	0.03
Molinate	0.02
Oxamyl	0.05
Pentachlorophenol	0.001
Picloram	0.5
Polychlorinated Biphenyls	0.0005
Simazine	0.004
Thiobencarb	0.07
Toxaphene	0.003
2,3,7,8-TCDD (Dioxin)	$3x10^{-8}$
2,4,5-TP (Silvex)	0.05
*MCL is for either a single isomer or the sum of the isomers	

Table 9.6 - **Water quality objectives for selected constituents in inland surface waters** [1]

CONSTITUENT	OBJECTIVE (mg/L)	BENEFICIAL USE
TDS	500	MUN
	50-1500	PROC
	450-2000	AGR
Chloride	250	MUN
	20-1000	PROC
	100-355	AGR
Sulfate	400-500	MUN
	20-300	PROC
	350-600	AGR
Boron	0.5-4.0	AGR
Nitrate (as N)	10	MUN
Site-specific objectives have not been determined for Miscellaneous Ventura Coastal Streams at this time. According to the Basin Plan, these areas are often impaired (by high levels of minerals) and there is not sufficient historic data to designate objectives based on natural background conditions. The water quality objectives above "illustrates the mineral or nutrient quality necessary to protect different categories of beneficial uses and will be used as a guideline for establishing effluent limits in these cases. Protection of the most sensitive beneficial use(s) would be the determining criteria for the selection of effluent limits."[1]		

Other relevant water quality objectives defined in the Basin Plan include general objectives for bioaccumulation, oil and grease, and numeric objectives for nitrogen and dissolved oxygen.

Bioaccumulation

Toxic pollutants shall not be present at levels that will bioaccumulate in aquatic life to levels which are harmful to aquatic life or human health[1].

Oil and Grease

Waters shall not contain oils, greases, waxes or other materials in concentrations that result in a visible film or coating on the surface of the water or on objects in the water, that cause nuisance, or that otherwise adversely affect beneficial uses[1].

Nitrogen (Nitrate, Nitrite)

The primary drinking water standard for nitrate (as NO3) is 45 mg/L[1].

Waters shall not exceed 10 mg/L nitrogen as nitrate-nitrogen plus nitrite-nitrogen (NO3-N + NO2-N), 45 mg/L as nitrate (NO3), 10 mg/L as nitrate-nitrogen (NO3-N), or 1 mg/L as nitrite-nitrogen (NO2-N)[1]*, or as otherwise designated in Table 9.6.*

Dissolved Oxygen

At a minimum…the mean annual dissolved oxygen concentration of all waters shall be greater than 7 mg/L, and no single determination shall be less than 5.0 mg/L, except when natural conditions cause lesser concentrations[1]*.*

The dissolved oxygen content of all surface waters designated as WARM shall not be depressed below 5 mg/L as a result of waste discharges[1]*.*

The dissolved oxygen content of all surface waters designated as COLD shall not be depressed below 6 mg/L as a result of waste discharges[1]*.*

The dissolved oxygen content of all surface waters designated as both COLD and SPWN shall not be depressed below 7 mg/L as a result of waste discharges[1]*.*

Industrial General Permit Water Quality Benchmarks

Oil operations in the study watersheds are regulated under an Industrial General Permit through NPDES. An updated Industrial General Permit was adopted by the State of California on April 1, 2014, and will come into effect on July 1, 2015[5]. Table 9.7 shows the recently adopted numeric action levels (NAL) for constituents. Unless otherwise noted, these values are for annual NAL, which are compared with the average of results found from sampling over the entire year.

Table 9.7 – **Industrial General Permit Numeric Action Levels**[5]

PARAMETER	NUMERIC ACTION LEVEL (NAL)	UNIT
*** Specific Conductivity	200	uS/cm
* pH	6.0-9.0	N/A
* Total Suspended Solids	100 (annual NAL); 400 (Instantaneous Maximum NAL)	mg/L
* Total Oil & Grease	15 (annual NAL); 25 mg/L (Instantaneous Maximum NAL)	mg/L
Zinc, Total (H)	0.26**	mg/L
Copper, Total (H)	0.0332**	mg/L
Cyanide, Total (H)	0.022	mg/L
Lead Total (H)	0.262**	mg/L
Chemical Oxygen Demand	120	mg/L
Aluminum, Total (pH 6.5-9.0)	0.75	mg/L
Iron, Total	1	mg/L
Nitrate + Nitrite Nitrogen	0.68	mg/L as N
Total Phosphorus	2.0	mg/L as P
Ammonia (as N)	2.14	mg/L
Magnesium, Total	0.064	mg/L
Arsenic, Total (c)	0.15	mg/L
Cadmium, Total (H)	0.0053**	mg/L
Nickel, Total (H)	1.02**	mg/L
Mercury, Total	0.0014	mg/L
Selenium, Total	0.005	mg/L
Silver, Total (H)	0.0183**	mg/L
Biochemical Oxygen Demand	30	mg/L

* Minimum parameters required by this General Permit
** The NAL is the highest value used by U.S. EPA based on their hardness table in the 2008 MSGP
***Specific conductivity required under the previous General Permit and not included in this updated version
(H) Hardness dependent

9.4 Existing Water Quality Data in Study Watersheds

Vintage Petroleum (Vintage/Oxy), a subsidiary of Occidental Petroleum Corporation, is the primary oil field operators in the study watersheds and has tested for several water quality parameters in accordance with its Industrial General Permit.

Vintage/Oxy Water Quality Samples

From January 27, 2007 to May 17, 2011, Vintage/Oxy sampled stormwater runoff up to nine times for TSS, TDS, and conductivity in the Amphitheater, Javon, Line, Madriano, and Padre Juan Canyon watersheds[7]. Many of the results from these samples were found well above water quality objectives for TDS and benchmarks values listed in the Industrial General Permit. Table 9.8 shows the geometric mean values of TDS, TSS, and conductivity from samples taken by Vintage/Oxy from 2007 to 2011, for each of the study watersheds. Median values, confidence bounds, and outliers of these parameters are shown for each watershed in Figures 9.1, 9.2, and 9.3.

Table 9.8 **- Geometric mean values of Vintage/Oxy samples**

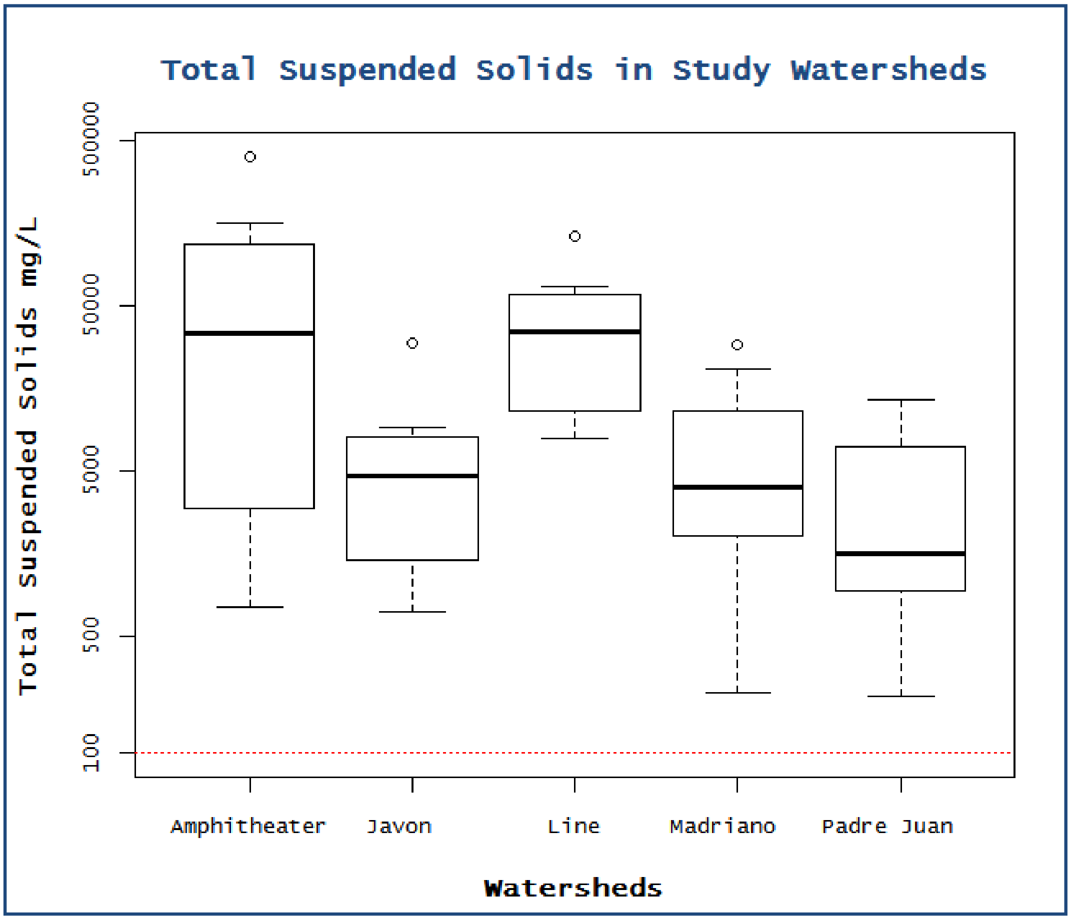
PARAMETER & OBJECTIVES	MADRIANO	JAVON	PADRE JUAN	LINE	AMPHITHEATER
Total Dissolved Solids (mg/L) *Objective: 500 mg/L;* *450 – 2000 mg/L* *Beneficial Use – MUN; AGR*	1,152	3,602	2,875	4,363	3,104
Total Suspended Solids (mg/L) *Benchmark: 100 mg/L* *Industrial General Permit*	4,072	3,888	2,071	28,506	18,309
Conductivity (µS/cm) *Benchmark: 200 µS/cm* *Industrial General Permit*	1,683	8,757	4,443	7,026	3,353
Samples collected by Vintage/Oxy between January 27, 2007 through May 17, 2011[7]. Water quality objectives for designated beneficial uses specified in the Basin Plan. Various beneficial uses may have differing objectives, and the most stringent levels are included above. Water quality benchmarks from Industrial General Permit are also included for the permit levels in place at the time of sampling.					

TSS levels were measured from nine samples taken by Vintage/Oxy from the Amphitheater, Line, Javon, and Madriano Canyons during storm events from January 27, 2007 through May 17, 2011, and seven samples were collected from Padre Juan Canyon within the same timeframe[7].

Geometric mean values of TSS ranged from roughly 2,000 to 4,000 mg/L in Madriano, Javon, and Padre Juan Canyon (Table 9.8). These values exceeded water quality benchmarks and are an order of magnitude less than those found in Amphitheater (roughly 18,000 mg/L) and Line Canyons (approximately 28,000 mg/L).

In the Javon, Madriano and Padre Juan Canyon watersheds, the median values of the TSS samples ranged from roughly 1,600 to 6,000 mg/L, an order of magnitude above the Industrial General Permit benchmark of 100 mg/L for oil and gas activities (Figure 9.1). In the Amphitheater and Line Canyon watersheds, the median values were approximately 34,400 and 35,050 mg/L.

Figure 9.1 – TSS results from Vintage/Oxy samples[7]. Median values are identified by the black horizontal lines inside the boxes. TSS levels are displayed on a logarithmic scale due to the large variation between measurements. The boxes represent the interquartile ranges (IQR). Whiskers indicate 1.5xIQR, and outliers are shown as hollow points. The red dashed line represents the Industrial General Permit benchmark value.

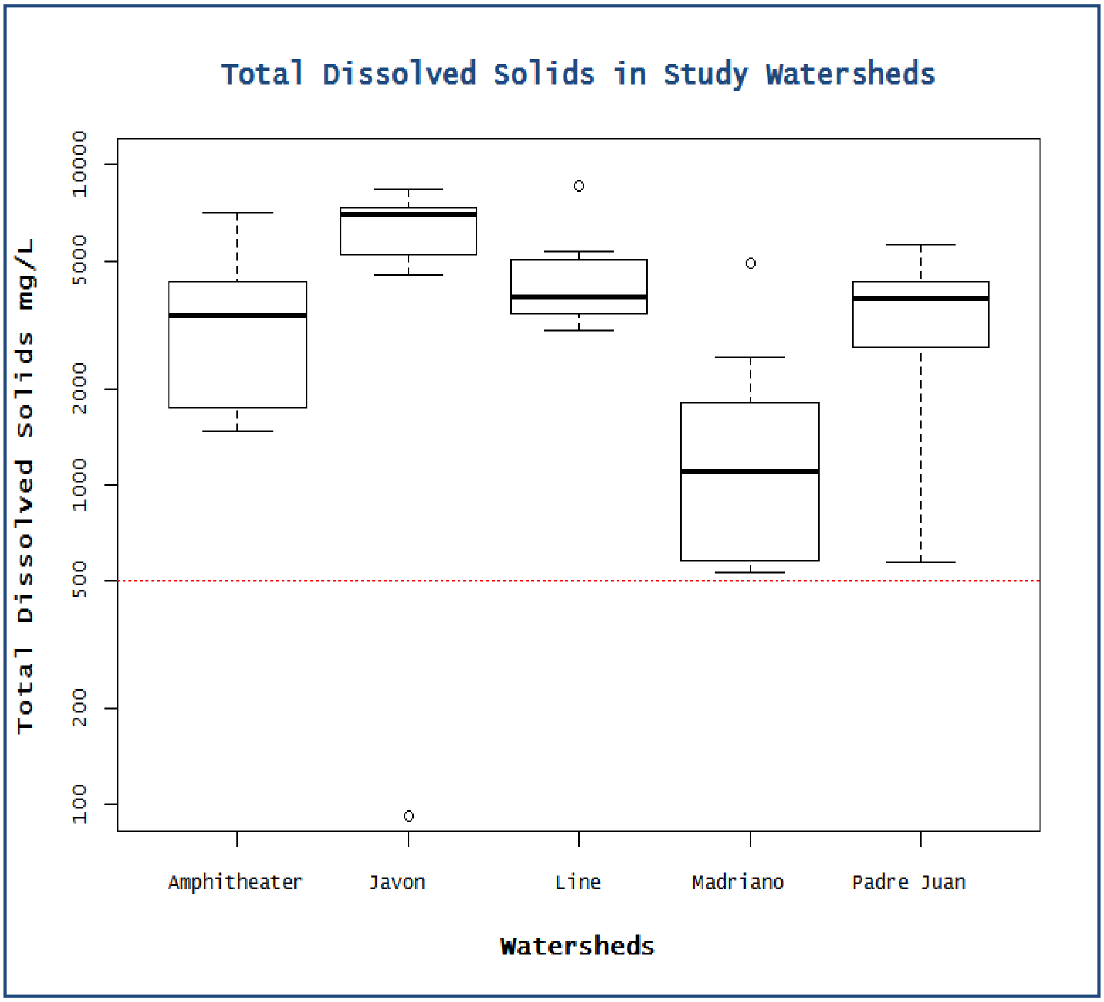


Total Dissolved Solids (TDS) levels were measured from eight samples taken by Vintage/Oxy from the Amphitheater, Line, and Javon Canyons by Vintage/Oxy from January 27, 2007 through May 17, 2011. Seven samples were collected and analyzed from Madriano and Padre Juan Canyons from in the same timeframe[7].

The geometric mean values of TDS were lowest in Madriano Canyon, followed by Padre Juan, Amphitheater, Javon and Line Canyons (Table 9.8). These values ranged from roughly 1,100 to 4,400 mg/L.

TDS levels were also found to be above the MUN water quality objective (500 mg/L) with median values ranging from 970 up to 7,030 mg/L (Figure 9.2). Outliers include the measurements of 8,630 mg/L in Line Canyon and 4,940 in Madriano Canyon, both taken on May 17, 2011. TDS results from Javon Canyon had the largest variability.

Figure 9.2 – TDS results from Vintage/Oxy samples[7]. Median values for Total Dissolved Solids (TDS) are identified by the black horizontal lines inside the boxes. TDS levels (in mg/L) are on a logarithmic scale due to the large variation between measurements. The boxes represent the interquartile ranges (IQR). The whiskers indicate 1.5xIQR, and outliers are shown as hollow points. The red dashed line represents the threshold level for the potential Beneficial Use of Municipal and Domestic Supply established for Madriano, Javon, and Padre Juan Canyon Watersheds.

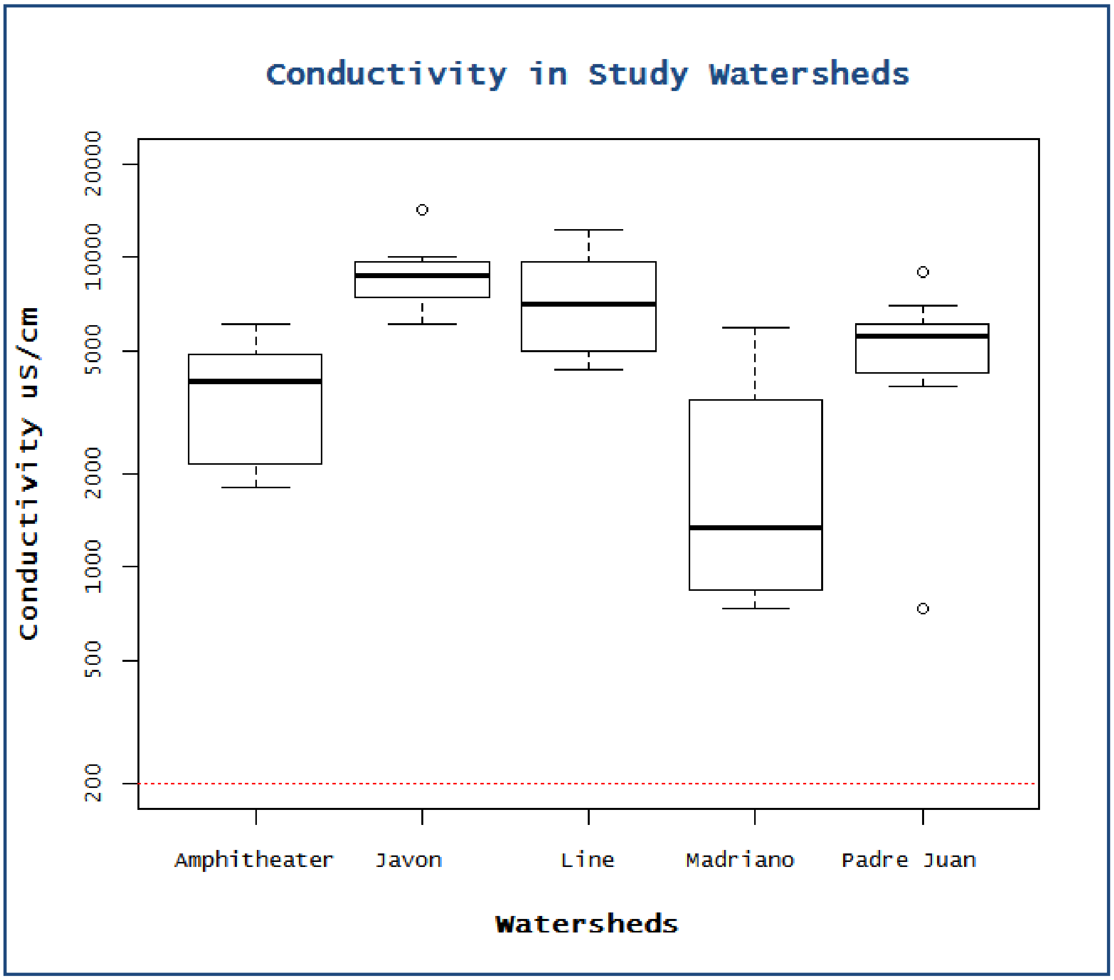


Conductivity levels were measured from nine samples taken by Vintage/Oxy from Madriano and Padre Juan Canyons during storm events from January 27, 2007 through May 17, 2011. Eight samples were taken from Line Canyon, and seven samples taken from Amphitheater and Padre Juan Canyons during this same timeframe[7].

Geometric mean values for measurements of conductivity were lowest in Madriano Canyon, followed by Amphitheater, Padre Juan, Line, and Javon Canyons (Table 9.8). These values ranged from roughly 1,700 uS/cm to almost 9,000 uS/cm. Variation between results were lowest at Madriano Canyon, and greatest at Line Canyon.

Vintage/Oxy's samples showed high conductivity in each of the watersheds. Median values ranged from 1,340 to 8,700 uS/cm and exceed the Industrial General Permit benchmark of 200 uS/cm (Figure 9.3). Several outliers were identified in Javon and Padre Juan Canyons, most notably the measurement of 750 uS/cm in Padre Juan Canyon on November 26, 2008.

Figure 9.3 – Conductivity results from Vintage/Oxy samples[7]. Median values for conductivity (uS/cm) are identified by the black horizontal lines inside the boxes. Conductivity is displayed on a logarithmic scale due to the large variation between measurements. The boxes represent the interquartile ranges (IQR). Whiskers indicate 1.5xIQR, and outliers are shown as hollow points. The red dashed line represents the Industrial General Permit benchmark value of 200 uS/cm.



SWAMP Water Quality Samples

On June 5 and 7, 2006, the RWQCB tested the upper and lower parts of Javon Canyon, Madriano Canyon, and Padre Juan Canyon under the Surface Water Ambient Monitoring Program (SWAMP). Grab samples were taken once at each location, and up to 79 parameters were tested. Tables 9.9 through 9.14 show the detected results from the SWAMP sampling activities. From these samples, only sulfate (highlighted in red) were found to exceed water quality objectives in each of the three watersheds. Conductivity values are also highlighted in red as they were found well above the Industrial General Permit benchmark. In upper Padre Juan Canyon and in Javon Canyon, chloride (highlighted in red) was also found at levels above water quality objectives[8].

Table 9.9 - **SWAMP Results from lower Javon Canyon[8]**

ANALYTE	UNIT	RESULT
Aluminum, Total	ug/L	313
Ammonia as N, Total	mg/L	0.225
Arsenic, Total	ug/L	0.3*
Chloride, Dissolved	***mg/L***	***392***
Chlorophyll a, Particulate	ug/L	4.88
Chromium, Total	ug/L	1
Copper, Total	ug/L	7.7
Hardness as CaCO3, Dissolved	mg/L	3520
Manganese, Total	ug/L	203
Mercury, Total	ng/L	5.81
Nickel, Total	ug/L	59.4
Nitrate as N, Dissolved	mg/L	1.81
Nitrite as N, Dissolved	mg/L	0.219
Nitrogen, Total Kjeldahl, Total	mg/L	3.32
Ortho Phosphate as P, Dissolved	mg/L	0.0146
Oxygen, Dissolved, Total	mg/L	11.3
Oxygen, Saturation, Total	%	127.5
pH	none	8.22
Phosphorus as P, Total	mg/L	0.91
Salinity, Total	ppt	4.28
Selenium, Total	ug/L	28.2
Specific Conductivity, Total	***uS/cm***	***7720***
Sulfate, Dissolved	***mg/L***	***4490***
Suspended Sediment Concentration, Particulate	mg/L	20.9
Temperature	Deg C	20.27
Turbidity, Total	NTU	11.3
Zinc, Total	ug/L	3.4

Detected results from grab samples collected through the SWAMP from lower Javon Canyon on June 5, 2006. Velocity not included in data obtained from California Environmental Data Exchange Network. Water quality parameters found to exceed water quality objectives are highlighted in red.
Comments from sampling activity: “Hwy 1 stopped the reach at 120m; velocity recorded from a single measure; not Area Method; less than 25 results for embeddedness.” Latitude 34.332661, Longitude -119.402321
*Above detection limit, below reporting limit

Table 9.10 - **SWAMP Results from upper Javon Canyon[8]**

ANALYTE	UNIT	RESULT
Aluminum, Total	ug/L	435
Ammonia as N, Total	mg/L	0.104
Chloride, Dissolved	***mg/L***	***386***
Chlorophyll a, Particulate	ug/L	4.09
Chromium, Total	ug/L	1.2
Copper, Total	ug/L	7.6
Hardness as CaCO3, Dissolved	mg/L	3400
Lead, Total	ug/L	0.2*
Manganese, Total	ug/L	195
Mercury, Total	ng/L	4.54
Nickel, Total	ug/L	58.4
Nitrate as N, Dissolved	mg/L	1.97
Nitrite as N, Dissolved	mg/L	0.187
Nitrogen, Total Kjeldahl, Total	mg/L	2.29
Ortho Phosphate as P, Dissolved	mg/L	0.014
Oxygen, Dissolved, Total	mg/L	9.74
Oxygen, Saturation, Total	%	112.1
pH	none	8.78
Phosphorus as P, Total	mg/L	0.0595
Salinity, Total	ppt	4.14
Selenium, Total	ug/L	26.4
Specific Conductivity, Total	***uS/cm***	***7477***
Sulfate, Dissolved	***mg/L***	***4540***
Suspended Sediment Concentration, Particulate	mg/L	26.67
Temperature	Deg C	20.95
Turbidity, Total	NTU	8.55
Zinc, Total	ug/L	3.8

Results from grab samples collected through the SWAMP from upper Javon Canyon on June 5, 2006. Velocity measured at 0.401 ft/s. Water quality parameters found to exceed water quality objectives are highlighted in red.
Comments from sampling activity: "Deep entrenched stream, cemented river rock and hard pan walls. Stream had high sinuosity within transects with a dirt dam mid reach; velocity recorded from a single measure; not Area Method; less than 25 results for embeddedness."
Latitude 34.334579, Longitude -119.401901
*Above detection limit, below reporting limit

Table 9.11 - **SWAMP Results from lower Madriano Canyon**[8]

ANALYTE	UNIT	RESULT
Aluminum, Total	ug/L	322
Ammonia as N, Total	mg/L	0.091*
Arsenic, Total	ug/L	2.29
Cadmium, Total	ug/L	0.43
Chloride, Dissolved	mg/L	207
Chlorophyll a, Particulate	ug/L	15.1
Chromium, Total	ug/L	9.36
Copper, Total	ug/L	35.4
Hardness as CaCO3, Dissolved	mg/L	2780
Lead, Total	ug/L	0.35
Manganese, Total	ug/L	569
Mercury, Total	ng/L	1.81
Nickel, Total	ug/L	70.8
Nitrate as N, Dissolved	mg/L	0.58
Nitrite as N, Dissolved	mg/L	0.182
Nitrogen, Total Kjeldahl, Total	mg/L	1.91
Orthophosphate as P, Dissolved	mg/L	0.0099*
Oxygen, Dissolved, Total	mg/L	9.96
Oxygen, Saturation, Total	%	105.1
pH	none	8.08
Phosphorus as P, Total	mg/L	0.0516
Salinity, Total	ppt	2.54
Selenium, Total	ug/L	11.5
Specific Conductivity, Total	***uS/cm***	***4725***
Sulfate, Dissolved	***mg/L***	***3100***
Temperature	Deg C	17.56
Turbidity, Total	NTU	12.8
Zinc, Total	ug/L	20.9

Detected results from grab samples collected through the SWAMP from lower Madriano Canyon on June 7, 2006. Velocity not included in data obtained from California Environmental Data Exchange Network. Water quality parameters found to exceed water quality objectives are highlighted in red.
Comments from sampling activity: "Dirt Road and Culvert cut Reach length Short; velocity recorded from a single measure; not Area Method; less than 25 results for embeddedness." Latitude 34.344978, Longitude -119.418488
*Above detection limit, below reporting limit

Table 9.12 - **SWAMP Results from upper Madriano Canyon**[8]

ANALYTE	UNIT	RESULT
Aluminum, Total	ug/L	498
Ammonia as N, Total	mg/L	0.138
Arsenic, Total	ug/L	2.97
Cadmium, Total	ug/L	0.43
Chloride, Dissolved	mg/L	199
Chlorophyll a, Particulate	ug/L	48.2
Chromium, Total	ug/L	10.2
Copper, Total	ug/L	34
Hardness as CaCO3, Dissolved	mg/L	2840
Lead, Total	ug/L	0.63
Manganese, Total	ug/L	715
Mercury, Total	ng/L	4.01
Nickel, Total	ug/L	72.1
Nitrate as N, Dissolved	mg/L	0.675
Nitrite as N, Dissolved	mg/L	0.193
Nitrogen, Total Kjeldahl, Total	mg/L	2.31
Ortho Phosphate as P, Dissolved	mg/L	0.0139
Oxygen, Dissolved, Total	mg/L	10.25
Oxygen, Saturation, Total	%	113.9
pH	none	8.25
Phosphorus as P, Total	mg/L	0.203
Salinity, Total	ppt	2.97
Selenium, Total	ug/L	12.8
Specific Conductivity, Total	***uS/cm***	***5480***
Sulfate, Dissolved	***mg/L***	***2920***
Suspended Sediment Concentration, Particulate	mg/L	157.9
Temperature	Deg C	18.28
Turbidity, Total	NTU	30.6
Zinc, Total	ug/L	21.8

Detected results of grab samples collected through the SWAMP from upper Madriano Canyon on June 7, 2006. Velocity not included in data obtained from California Environmental Data Exchange Network. Water quality parameters found to exceed water quality objectives are highlighted in red.
Comments from sampling activity: "entrenched stream, cemented river rock and shale walls with veins of oil; power line down cut length reach short; velocity recorded from a single measure; not Area Method; less than 25 results for embeddedness." Latitude 34.34623, Longitude -119.412132

Table 9.13 - **SWAMP Results from lower Padre Juan Canyon**[8]

ANALYTE	UNIT	RESULT
Aluminum, Total	ug/L	327
Ammonia as N, Total	mg/L	0.064*
Arsenic, Total	ug/L	1.49
Cadmium, Total	ug/L	0.23
Chloride, Dissolved	***mg/L***	***682***
Chlorophyll a, Particulate	ug/L	5.52
Chromium, Total	ug/L	8.41
Copper, Total	ug/L	22.4
Diazinon, Total	ug/L	0.0053*
Hardness as CaCO3, Dissolved	mg/L	1560
Lead, Total	ug/L	0.66
Manganese, Total	ug/L	87
Mercury, Total	ng/L	4.78
Nickel, Total	ug/L	9.13
Nitrate as N, Dissolved	mg/L	1.38
Nitrite as N, Dissolved	mg/L	0.139
Nitrogen, Total Kjeldahl, Total	mg/L	1.31
OrthoPhosphate as P, Dissolved	mg/L	0.016
Oxygen, Dissolved, Total	mg/L	9.13
Oxygen, Saturation, Total	%	103.2
pH	none	8.27
Phosphorus as P, Total	mg/L	0.154
Salinity, Total	ppt	2.95
Selenium, Total	ug/L	42.4
Specific Conductivity, Total	***uS/cm***	***5441***
Sulfate, Dissolved	***mg/L***	***1820***
Suspended Sediment Concentration, Particulate	mg/L	210.1
Temperature	Deg C	20.66
Turbidity, Total	NTU	23.1
Zinc, Total	ug/L	12.7

Detected results of grab samples collected through the SWAMP from lower Padre Juan Canyon on June 7, 2006. Velocity not included in data obtained from California Environmental Data Exchange Network. Water quality parameters found to exceed water quality objectives are highlighted in red.

Comments from sampling activity: "Heavy vegetation, Large and Small boulders on banks and streambed, velocity recorded from a single measure; not Area Method; less than 25 results for embeddedness." Latitude 34.31966, Longitude -119.390869

*Above detection limit, below reporting limit

Table 9.14 - **SWAMP Results from upper Padre Juan Canyon**[8]

ANALYTE	UNIT	RESULT
Aluminum, Total	ug/L	25.3
Ammonia as N, Total	mg/L	0.081*
Arsenic, Total	ug/L	1.12
Cadmium, Total	ug/L	0.18
Chloride, Dissolved	***mg/L***	***696***
Chlorophyll a, Particulate	ug/L	2.89
Chromium, Total	ug/L	7.61
Copper, Total	ug/L	22
Diazinon, Total	ug/L	0.0071*
Hardness as CaCO3, Dissolved	mg/L	1550
Lead, Total	ug/L	0.11
Manganese, Total	ug/L	47.6
Mercury, Total	ng/L	2.45
Nickel, Total	ug/L	7.33
Nitrate as N, Dissolved	mg/L	1.33
Nitrite as N, Dissolved	mg/L	0.176
Nitrogen, Total Kjeldahl, Total	mg/L	1.12
Ortho Phosphate as P, Dissolved	mg/L	0.0164
Oxygen, Dissolved, Total	mg/L	9.46
Oxygen, Saturation, Total	%	111.2
pH	NA	8.3
Phosphorus as P, Total	mg/L	0.0388*
Salinity, Total	ppt	2.93
Selenium, Total	ug/L	42.6
Specific Conductivity, Total	***uS/cm***	***5427***
Sulfate, Dissolved	***mg/L***	***1800***
Suspended Sediment Concentration, Particulate	mg/L	24.06
Temperature	Deg C	22.53
Turbidity, Total	NTU	7.6
Zinc, Total	ug/L	10.9

Detected results of grab samples collected through the SWAMP from upper Padre Juan Canyon on June 7, 2006. Velocity not included in data obtained from California Environmental Data Exchange Network. Water quality parameters found to exceed water quality objectives are highlighted in red.
Comments from sampling activity: "velocity recorded from a single measure; not Area Method; less than 25 results for embeddedness." Latitude 34.3255, Longitude -119.386726
*Above detection limit, below reporting limit

9.5 Water Quality in Nearby Watersheds

The amount of previous water quality data in the area of study is sparse relative to those in nearby watersheds. Areas with greater population and diverse land uses are more likely to contain various pollutants and promote more frequent testing that can lead to identifying water quality impairments. There are a number of watersheds within the Los Angeles RWQCB's jurisdiction that are located nearby, have similar natural composition, or similar land uses to those in this study, and have been subject to frequent and ongoing testing. The following section summarizes the impairments identified in the Ventura River, Malibu Creek, and Rincon Creek watersheds (Relative location shown in Figure 9.4).

The climate in each of these surrounding watersheds closely mimics that found in the study area. These watersheds all exhibit a Mediterranean climate, with cool winters and hot dry summers, and average mean temperatures ranging between 50 and 70 degrees Fahrenheit. Average rainfall in these watersheds is around 20 inches per year, though rainfall fluctuates periodically, depending on climatic conditions (namely La Niña and El Niño), that can influence precipitation [9,10,11].

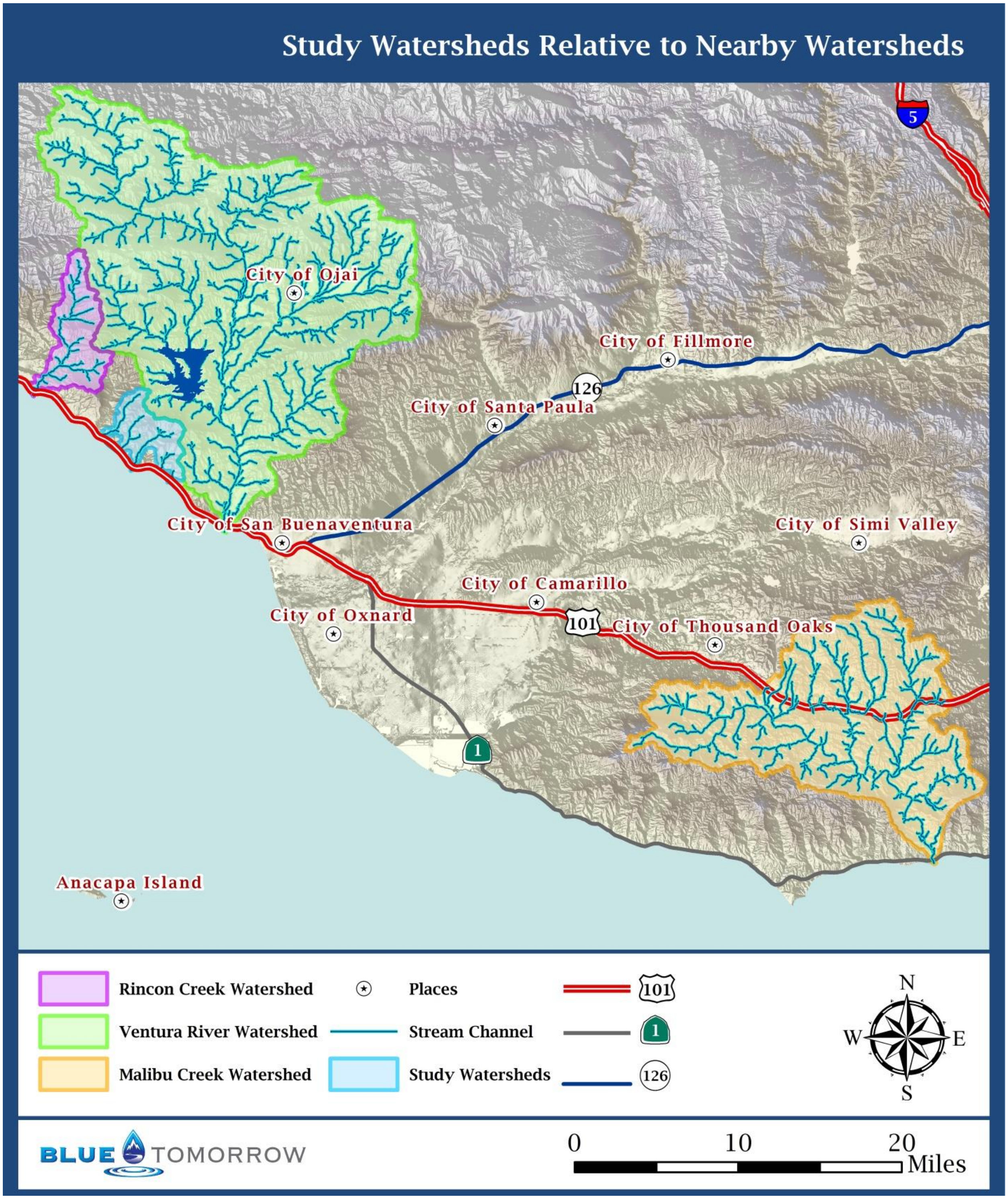
These watersheds have similar geology to the study area, as they also are within the Transverse Range and were formed from layers of marine sediment that were uplifted, folded, and faulted. A number of faults run through Ventura County and each of the surrounding watersheds. Tectonic forces uplift the Transverse and coastal mountains at high rates, which, when coupled with the weak marine sedimentary rocks, produce high erosion rates[12].

Soils in these watersheds are predominantly clay loams, loams, fine sandy loam, and fine sand, that result from the marine sandstone and shale. There are also various amounts of alluvial deposits found in these areas, with the larger watersheds containing considerably more than the study watersheds. Overall, these soils are well drained and range from having slow to rapid permeability. Each of the watersheds has been documented as being prone to landslides and debris flows due to structurally weak marine sediment rocks and extreme rates of uplift [9,10,11,12].

While some areas are more developed than the study watersheds, there are similarities in land uses. Predominantly, the land uses of the surrounding watersheds are open space. Of the three watersheds used for comparison, Ventura River watershed has the greatest oil and gas activity due to the geology of the region. Other similar land uses include rangeland, crop production, and residential development[9].

Many waters in the surrounding watersheds have been listed as impaired under Section 303(d) and undergo routine monitoring. By examining the water quality impairments found in these three watersheds, and factoring natural characteristics and human influences, comparisons can be made to help identify similar impairment sources found in the study watersheds. Figure 9.4 shows the locations of the Rincon Creek, Ventura River, and Malibu Creek watersheds relative to the study watersheds. Tables 9.15 – 9.17 list the water quality impairments in these three watersheds[13].

Figure 9.4 – The location of the Rincon Creek, Ventura River, and Malibu Creek Watersheds relative to the study watersheds. Available water quality data was compiled for these nearby watersheds and compared to available water quality data from the study area.



Ventura River Watershed
Hydrological Unit Code (HUC) 1807010101

The Ventura River watershed is located in northwestern Ventura County (with a small fraction in southeastern Santa Barbara County), and covers an area of roughly 228 square miles (Figure 9.4). The total population of the watershed is estimated to be 44,140, and though the watershed is largely undeveloped, urban areas are found in and around the city of Ojai and the northern tip of the city of Ventura[9]. The Ventura River and its tributaries drain into the Ventura River estuary and then into the Pacific Ocean. The major tributaries of the Ventura River are Matilija Creek, San Antonio Creek, Cañada Larga, and Coyote Creek.

The Ventura River Watershed is located directly south of the study watersheds (Figure 9.4), and shares similar characteristics with the study area, including climate, geology, soils, beneficial uses, and land uses. A number of land uses are found in the Ventura River Watershed, including oil and gas activities, agricultural, commercial, and residential purposes. The majority of the land is undeveloped, with roughly 85% of the watershed area classified as open space. Oil and gas extraction is the largest industrial use, but it represents only about 2% of the watershed and is found in the southern portion of the area. A small fraction of land use is for commercial purposes and primarily located in the city of Ventura. Residential use composes about 4.8% of the watershed area. Agricultural lands account for 4.5% of the watershed area, and consist primarily of citrus and avocado orchards with some cattle grazing and irrigated row crops [9]. These various land uses may be contributing to water quality impairments in the watershed.

Water Quality Impairments

A number of the water bodies in the Ventura River watershed have been classified as impaired under Section 303(d) of the Clean Water Act, requiring that TMDLs be established for impaired waters. Table 9.15 identifies those waters and the impairments [13,14,15].

Table 9.15 - **Ventura River Watershed Section 303(d) Listed Impairments[13]**

WATER BODY	IMPAIRMENT	POTENTIAL SOURCES
Ventura River - Reach 4	Low Dissolved Oxygen	Nutrients – point and nonpoint Sources
	Pumping	Hydromodification
	Water Diversions	Hydromodification
Ventura River - Reach 3	Indicator Bacteria	Unknown source
	Pumping	Hydromodification
	Water Diversions	Hydromodification
Ventura River - Reaches 1& 2	Algae	Nutrients – point and nonpoint Sources
	Low Dissolved Oxygen	Nutrients – point and nonpoint Sources
San Antonio Creek	Indicator Bacteria	Unknown source
	Low Dissolved Oxygen	Unknown source
	Nitrogen	Unknown source
	Total Dissolved Solids	Unknown source
Canada Largo Creek	Fecal Coliform	Unspecified nonpoint source
	Low Dissolved Oxygen	Unspecified nonpoint source
	Total Dissolved Solids	Source unknown
Ventura River Estuary	Algae	Nutrients – point and nonpoint sources
	Eutrophic Conditions	Nutrients – point and nonpoint Sources
	Low Dissolved Oxygen	Nutrients – point and nonpoint Sources
	Total Coliform	Unspecified nonpoint source
	Trash	Urban runoff/storm sewers, recreational and tourism activities, agriculture storm runoff

Of these impairments, only high TDS have been found in the study watersheds, and the pollutant sources of TDS impairments to San Antonio and in Canada Largo Creek are unknown[15]. According to the US EPA Section 303(d) list, several of the impairments listed in the Ventura River Watershed have originated from nonpoint sources. These include nutrients that lead to eutrophication, algae, excess nitrogen, and low dissolved oxygen, pathogens from horses and other wildlife that cause impairments from fecal coliform and total coliform, and hydromodification from water diversions and pumping. Unidentified point sources are also found to contribute to algae, low dissolved oxygen, and eutrophic conditions. Trash found in the waters is attributed to anthropogenic activities and the effects of urban runoff[13].

Rincon Creek Watershed

Hydrological Unit Code (HUC) 1807010102

The Rincon Creek watershed is approximately 9,350 acres and located in northwestern Ventura County and southwestern Santa Barbara County (Figure 9.4). Population in the watershed is roughly 14,200, and is focused near the City of Carpinteria. The area is predominantly open space, with small areas for residential and agricultural uses. The major tributaries of Rincon Creek are Long Canyon Creek and Casitas Creek[10].

The Rincon Creek watershed is located directly north of the study watersheds (Figure 9.4). This watershed shares a number of similar characteristics with the study watersheds, including climate, geology, soils, beneficial uses, and land uses. The geologic formations in Rincon Creek consist of marine sedimentary rocks that have been uplifted, faulted and folded, as seen in the study watersheds. Soils in the Rincon Creek area are mostly loams and sandy loams, whereas in the Casitas Creek subwatershed the soils are primarily shaly loams, loams, and clay loams that are highly erosive. Approximately 91% of Rincon Creek watershed is open space, with 7% of the area used for agriculture and roughly 2% for residential development[10].

Water Quality Impairments

Rincon Creek has been classified as impaired under Section 303(d) of the Clean Water Act, as identified in Table 9.16.

Table 9.16 - **Rincon Creek Section 303(d) Listed Impairments[13]**

IMPAIRMENT	POTENTIAL SOURCES
Boron	Natural Sources, Agriculture, Unknown
Chloride	Unknown
E.coli	Natural Sources, Agriculture, Other Urban Runoff
Fecal Coliform	Natural Sources, Agriculture, Other Urban Runoff
Sodium	Natural Sources, Agriculture, Other Urban Runoff
Turbidity	Construction /Land Development, Natural Sources, Agriculture

High Total Suspended Solids (TSS) were also found within Casitas Creek and various parts of Rincon Creek[10]. Of these impairments high levels of boron, chloride, sodium and turbidity have been found in the study watersheds.

Malibu Creek Watershed

Hydrological Unit Code (HUC) 1807010401

The Malibu Creek watershed is roughly 110 square miles and lies in southeastern Ventura County and the northeastern end of Los Angeles County. More than 75% of the Malibu Creek Watershed is open space, with several small cities and rural residential communities located throughout the area. The watershed has a growing population of over 90,000 people [11].

While the Malibu Creek watershed is the furthest of the three nearby watersheds, it also has similar climate, geology, soils, and beneficial uses. Much research has been done in the Malibu Creek area and many of its waters are listed as impaired under Section 303(d) (Table 9.17)[13].

The Monterey Formation contains large offshore and onshore oil and gas deposits throughout California and is a natural source of many water quality impairments found in Malibu Creek. The Santa Monica Mountains are also part of the Transverse Ranges. Like the study watersheds, soils in the lowland area consist of shales are loamy, silty and clayey, including the Castaic, Nacimiento, and San Benito series [16].

Roughly 80% of the watershed is undeveloped. Residential development is the most prominent human use, mainly in Agoura Hills, Westlake, Malibu and Calabasas. Golf courses occupy over 450 acres, and there is some agriculture in the western end of the watershed [11,16].

Impairments to Malibu Creek and Lagoon, include unnatural rates of riparian habitat erosion and sediment deposition[16]. As with the study watersheds, high levels of specific conductance were found in Malibu Creek, and ranged from 1500 – 4000 umho/cm. A study by the Los Virgenes Water District, which aimed to characterize the source of brackish water in Malibu Creek, attributes these values to the sedimentary rock found in the Monterey Formation. Table 9.17 lists the impairments found in the Malibu Creek watershed and the likely sources of those impairments.

Table 9.17 - **Malibu Creek Section 303(d) Listed Impairments and Sources[13]**

IMPAIRMENT	POTENTIAL SOURCES
Benthic-Macroinvertebrate Bioassessments	Source Unknown
Coliform Bacteria	Point Source; Nonpoint Source
Fish Barriers (Fish Passage)	Dam Construction
Invasive Species	Nonpoint Source
Nutrients (Algae)	Urban Runoff and Storm Sewers; Onsite Wastewater Systems (Septic Tanks); Golf course activities; Groundwater Loadings; Nonpoint Source; Atmospheric Deposition; Major Municipal Point Source-dry and/or wet weather discharge; Irrigated Crop Production; Livestock Agriculture
Unnatural Scum and Foam	Major Municipal Point Source-dry and/or wet weather discharge; Groundwater Loadings; Golf course activities; Onsite Wastewater Systems (Septic Tanks); Urban Runoff and Storm Sewers; Irrigated Crop Production; Livestock Agriculture; Atmospheric Deposition
Sedimentation and Siltation	Source Unknown
Selenium	Source Unknown
Sulfates	Source Unknown
Trash	Nonpoint Source

9.6 Water Quality Summary

There are numerous designated beneficial uses that exist for inland surface water, groundwater, and coastal waters in and around the study watersheds, including municipal and domestic supply, agricultural supply, industrial service and process supply, contact and non-contact water recreation, and various habitat and ecosystem uses. The associated water quality objectives and policies directed at maintaining these beneficial uses are outlined in the Regional Water Quality Control Board's (RWQCB) Basin Plan. In addition, the oil fields operate under an Industrial General Permit through the National Pollution Discharge Elimination System (NPDES).

Previous water quality testing in the watersheds has shown levels of conductivity, Total Dissolved Solids (TDS), Total Suspended Solids (TSS), and sulfate, which exceeded the Industrial General Permit benchmark levels and other relevant water quality objectives. In the study watersheds, TDS was measured 2 to 6 times, TSS 20 to 280 times, conductivity 3 to 40 times, and sulfate up to 10 times above water quality objectives or benchmark levels. Nearby watersheds, with similar land uses and physical characteristics, have also demonstrated high levels of total dissolved solids, sodium, chloride, sulfate, and boron, among other impairments. A study done in the Malibu Creek Watershed attributed high levels of TDS, conductivity, and various metals found in the creek to runoff from the Monterey Formation found in the Malibu watershed.

9.7 Water Quality References

1) Los Angeles Regional Water Quality Control Board. Basin Plan. Available at: http://www.swrcb.ca.gov/losangeles/water_issues/programs/basin_plan/index.shtml
2) U.S. Environmental Protection Agency (EPA). National Pollutant Discharge Elimination System. Available at: cfpub.epa.gov/npdes/
3) EPA. NPDES State Program Status. Available at: cfpub.epa.gov/npdes/statestats.cfm
4) California EPA. National Pollutant Discharge Elimination System. Available at: waterboards.ca.gov/water_issues/programs/npdes/#role
5) State Water Resources Control Board. February 19, 2014. National Pollutant Discharge Elimination System (NPDES). General Permit for Stormwater Discharges Associated with Industrial Activities. Order NPDES No. CAS000001.
6) EPA. Total Maximum Daily Load Program. Available at: http://water.epa.gov/lawsregs/lawsguidance/cwa/tmdl/
7) Environmental Defense Center. Press Release. February 23, 2012. Environmental Defense Center Takes Legal Action to Address Water Pollution from Oil and Gas Field in Coastal Ventura County. Table 2. Discharges of pollutants by Vintage/Oxy at the Rincon Grubb Oil Field. Available at: www.edcnet.org/news/PressReleases/12-02-23.pdf
8) Surface Water Ambient Monitoring Program. SWAMP RWB4 Monitoring. RWB4 Miscellaneous Ventura Coastal 2006 2007. Accessed from the California Environmental Data ExchangeNetwork on November 3, 2013.
9) Gardner et al., 2013. Sustainable Water Use in the Ventura River Watershed.
10) Santa Barbara County Water Agency. Prepared by Tetra Tech, Inc., 2007. Rincon Creek Watershed Assessment.
11) Heal the Bay. Malibu Creek Watershed: An Ecosystem on the Brink. Available at: http://www.healthebay.org/about-bay/current-issues/keeping-ocean-healthy/malibu-creek-watershed
12) Rockwell et al., 1984. Uplift of Transverse Range Sedimentary Marine Layers.
13) EPA, 2010. Final Approved Section 303(d) List.
14) Ventura River Watershed Council, October 2013. Water Quality Impairments. Available at: http://venturawatershed.org/wpcontent/uploads/2013/05/WaterQualityImpairmentsPg_Final.pdf
15) EPA, 2012. Ventura Reaches 3 & 4 Total Maximum Daily Loads for Pumping and Water Diversion Related Water Quality Impairments - Draft. Available at: http://www.epa.gov/region9/water/tmdl/pdf/ventura-river-reaches3-4_tmdl.pdf
16) Los Virgenes Municipal Water District. Orton, R., 2012. Natural Source Assessment. Available at: http://www.lvmwd.com/Home/ShowDocument?id=2273

10.0 | SUMMARY

This watershed assessment covers five coastal watersheds in northern Ventura County: Madriano, Javon, Padre Juan, Line, and Amphitheater Canyon. Information is presented on **physical and ecosystem characteristics, residential and recreational land uses, intensive land uses and water quality** within the five watershed boundaries and the coastal area that receives runoff from the watersheds. The assessment has nine detailed sections: 1) Geology, 2) Soils, 3) Hydrology, 4) Flora, Fauna & Habitat, 5) Residential & Recreational Uses, 6) Agriculture, 7) Transportation, 8) Oil Production Operations, and 9) Water Quality. The data and analyses contained in these sections provides information on potential and likely sources, pathways, and receptors of pollutants, and can be used to help inform management of the area and its resources.

Physical and Ecosystem Characteristics

The marine sedimentary geology that dominants the study area, and the soils derived from this parent material, is naturally rich in metals. The watersheds are within one of the fastest uplifting regions on Earth, with tectonic uplift rates estimated around 10 mm per year. The naturally weak sedimentary geology and soils, along with the steep topography of the watersheds, create conditions that are prone to erosion and landslides. These natural conditions increase downstream sediment yields and concentrations of total suspended solids.

The hydrology of the area dictates the transport of pollutants through the watersheds and into coastal environments. Rainfall in the watersheds typically averages about 15 to 20 inches per year from the coast to the top ridgeline. All of the watersheds are noted as being intermittent, but, with the exception of Line Canyon, exhibited ephemeral stream flow over the 2013-2014 winter season. Over the course of this project, Line Canyon had a persistent base flow with a discharge rate, which was measured between 0.3 to 0.4 cubic feet per second (cfs).

The vegetation in the watersheds is dominated by coastal scrub (covering approximately 60% of study watersheds), a plant community threatened by development in southern California. There are no threatened or endangered species known to live in the study watersheds, but the coastline and coastal marine environment of the study area provides habitat to many sensitive bird, marine mammal, and fish species, including fish caught by local sport and commercial fisherman. The near coastal marine habitat includes giant kelp forests that provide habitat to many fish, enrich the near coastal ecosystem, and are susceptible to sedimentation and impacts from upstream land uses. The coastal environments located near the watershed outlets are receptors of runoff from the watersheds which may contain pollutants of concern.

Residential and Recreational Land Uses

Three residential communities (Sea Cliff, Faria, and Solimar), with an estimated 248 homes, and three County-owned parks (Hobson County Beach Park, Rincon Parkway, and Faria County Beach Park) are also located in the study area between the watershed outlets. Approximately 278 permanent residents live along the coast between the point at Mussel Shoals (1.5 miles up the coast from Madriano Canyon outlet) and the Solimar Beach community (at the outlet of Amphitheater Canyon). The beaches along the coastline adjacent to the watersheds attract over 570,000 visitors per year, and campgrounds associated with the County parks generate over $1.2 million annually. These beaches are popular destinations for people that participate in surfing, swimming, fishing, and other recreational activities.

Intensive Land Uses

The three most intensive land uses in the study area are agriculture, transportation, and oil production operations. Agricultural practices within the watershed boundaries include 68.5 acres of orchards in upper Padre Juan Canyon and approximately 800 acres of cattle grazing pasture in upper Madriano Canyon and a small portion of upper Javon Canyon. Vehicles travelling the three major transportation routes through the watersheds (Highways 101, 1, and the railroad) emit heavy metals and Polycyclic Aromatic Hydrocarbons (PAHs), which are deposited in the watersheds through wet and dry deposition.

The primary land use in the watersheds is oil production operations, which have been occurring in the study area since the 1920s. Line and Amphitheater Canyon have the greatest density of oil field infrastructure, covering approximately 10.8% and 8.8% of the watershed area, respectively. Line and Amphitheater Canyons also have the greatest well densities, with over 80 active and idle oil wells (unplugged wells) per square mile. The oil-to-water ratio in production fluid extracted from active wells has changed over the life of the oil fields from nearly 100% oil in some of the early wells to over 90% water (produced water) in recent decades. This has spurred the use of enhanced oil recovery techniques and, specifically, water flood projects to boost production.

There are many potentially harmful fluids and chemicals associated with the oil field production operations in the watersheds. Water flood injection projects take produced water that is recovered with the oil and inject it into injection wells with the intent of sweeping oil through the reservoir to a production well. The largest volume of fluid being moved around the oil fields is produced water; about 9 million barrels (378 million gallons or about 1,200 acre feet) of produced water were extracted and injected in 2013. Produced water contains a complex mixture of organic and inorganic compounds that are dissolved in the water from millions of years of interaction with the hydrocarbon-rich marine sedimentary rock, from which it was pumped. Hydraulic fracturing, which injects fluid with harmful chemical additives into wells at high pressure, has been used on at least three wells in the study area, all located in Line Canyon. Acid well treatments are much more frequent than hydraulic fracturing and use a much more concentrated mixture of chemical additives, but a smaller volume is used per well and at a much lower pressure.

Water Quality

Three of the study watersheds (Madriano, Javon, and Padre Juan) have many designated beneficial uses of water resources assigned to them that specify water quality objectives. Previous water quality data collected in the watersheds shows high levels of conductivity, total dissolved solids, total suspended solids, chloride, and sulfate above these water quality objectives and the Industrial General Permit (NPDES permit) benchmarks covering the oil field operations. Nearby watersheds have also been found to have high levels of total dissolved solids, chloride, sulfate, and other salts and metals, many of which have been attributed to natural sources.

The information contained in this watershed assessment is used in conjunction with water and sediment sample results that tested for 68 different organic and inorganic constituents. The sample data is organized and analyzed in the Environmental Sampling Report. Results are also analyzed for their toxicity in the Toxicity Analysis, and possible sources of selected pollutants are proposed in the Source Assessment element. This Watershed Assessment document also serves as a resource for local managers and future research of small watersheds in the area.

ENVIRONMENTAL SAMPLING

NORTHERN VENTURA COUNTY COASTAL WATERSHED PROJECT

The following Environmental Sampling was completed as part of the Northern Ventura County Coastal Watershed Project (NVCCWP), which also includes a Watershed Assessment, Pollutant Source Assessment, Toxicity Analysis, and Recommendations & Mitigation Strategies.

The study area includes five coastal watersheds covering approximately ten square miles. These watersheds have varying levels of oilfield development and there are agricultural and recreational uses downstream and on the coast. A sampling plan was implemented to collect water and sediment samples from Madriano, Javon, Padre Juan, Line, and Amphitheater Canyons (the study watersheds).

From October 2013 to the end of April 2014, 17 water samples and 10 sediment samples were collected, and flow measurements and field tests performed on these watershed drainages. Samples were analyzed for a wide range of pollutants including metals, diesel and residual range organics (DRO & RRO), polycyclic aromatic hydrocarbons (PAHs), and other organic compounds and hydrocarbons. Pollutants were selected for analysis (the analytes) based on association with oil production operations and pollutants known to occur in hydraulic fracturing fluids, focusing on those that are of concern to the health of people and the environment.

Only two storms that generated sufficient runoff in the study watersheds occurred over the course of project; the first one began on November 20, 2013 and the second began three months later on February 26, 2014. High levels of total suspended solids (TSS), total dissolved solids (TDS), conductivity, and total and dissolved metals were found in all stormwater samples, and DRO and RRO were detected above reporting limits. Sediment sample results showed detections of oil and grease, DRO, RRO, and many of the PAHs above reporting limits. In sediment samples, metals were found at relatively high levels including aluminum, arsenic, boron, cadmium, lead, and selenium. High TSS concentrations in stormwater samples resulted in large discharge rates of sediment and metals.

This Environmental Sampling Report contains six sections:

1) Sampling Site Locations
2) Analytical Methods & Pollutant Descriptions
3) Sampling Events & Observations
4) Results & Loading Analysis
5) Environmental Sampling Summary
6) Appendix – Detailed Field Notes

Environmental Sampling Table of Contents

ACRONYMS

BTEX	Benzene, Toluene, Ethylbenzene, and Xylene
COC	Chain of Custody
COD	Chemical Oxygen Demand
DEHP	Bis (2-ethylhexyl) Phthalate
DRO	Diesel Range Organics
EC	Electrical Conductivity
EPA	Environmental Protection Agency
HEM	N-Hexane Extractable Material
NPDES	National Pollutant Discharge Elimination System
NVCCWP	Northern Ventura County Coastal Watershed Project
PAHs	Polycyclic Aromatic Hydrocarbons
PVC	Polyvinyl Chloride
RRO	Residual Range Organics
SDWA	Safe Drinking Water Act
TDS	Total Dissolved Solids
TSS	Total Suspended Solids
VOA	Volatile Organics Analysis

UNITS

FAU	Formazin Attenuation Unit
cfs	Cubic Feet per Second
L/s	Liters per second
m	Meters
cm	Centimeters
kg	Kilograms
mg	Milligrams
µg	Micrograms

1.0 | SAMPLING SITE LOCATIONS

Water and sediment samples were collected from five coastal watersheds in northwestern Ventura County: Madriano, Javon, Padre Juan, Line, and Amphitheater Canyons. Sampling sites were determined based on accessibility, and efforts were made to sample upstream of the Union Pacific Railroad and Highways 1 and 101. Samples were collected from the main channel of each watershed. All water samples, sediment samples, and field measurements for a given canyon were taken at the sampling site within approximately 30 m (98 feet) of each other. Access to the study watersheds is limited by private property boundaries; therefore all the sampling sites were located downstream near the outlets of the watersheds. All sampling sites were located within about 200 meters (656 feet) of the coastline (Figure 1.1).

Madriano Canyon

Watershed Area: 5.88 km^2 (2.27 mi^2)

Sampling Site Coordinates: 34° 20’ 43” N, 119° 25’ 14” W

The Madriano sampling site is the northernmost sampling site, and the only one located upstream of both Highways 1 and 101. This sampling site is no more than 15 m (50 feet) upstream of the Union Pacific Railroad.

Javon Canyon

Watershed Area: 5.33 km^2 (2.06 mi^2)

Sampling Site Coordinates: 34° 20’ 55” N, 119° 25’ 35” W

Javon Canyon is the second most northern sampling site. The sampling site is located approximately 100 m (328 feet) upstream of the railroad tracks at the culvert for Highway 101.

Padre Juan Canyon

Watershed Area: 7.86 km^2 (3.04 mi^2)

Sampling Site Coordinates: 34° 18’ 44” N, 119° 21’ 50” W

Padre Juan Canyon is the third most northern sampling site. The sampling site is located approximately 6 m (20 feet) upstream of the Union Pacific Railroad.

Line Canyon

Watershed Area: 3.73 km^2 (1.44 mi^2)

Sampling Site Coordinates: 34° 19’ 7” N, 119° 22’ 0” W

Line Canyon is the second most southern sampling site. The sampling site is located approximately 20 m (66 feet) upstream of the Union Pacific Railroad directly downstream of the Highway 101 culvert.

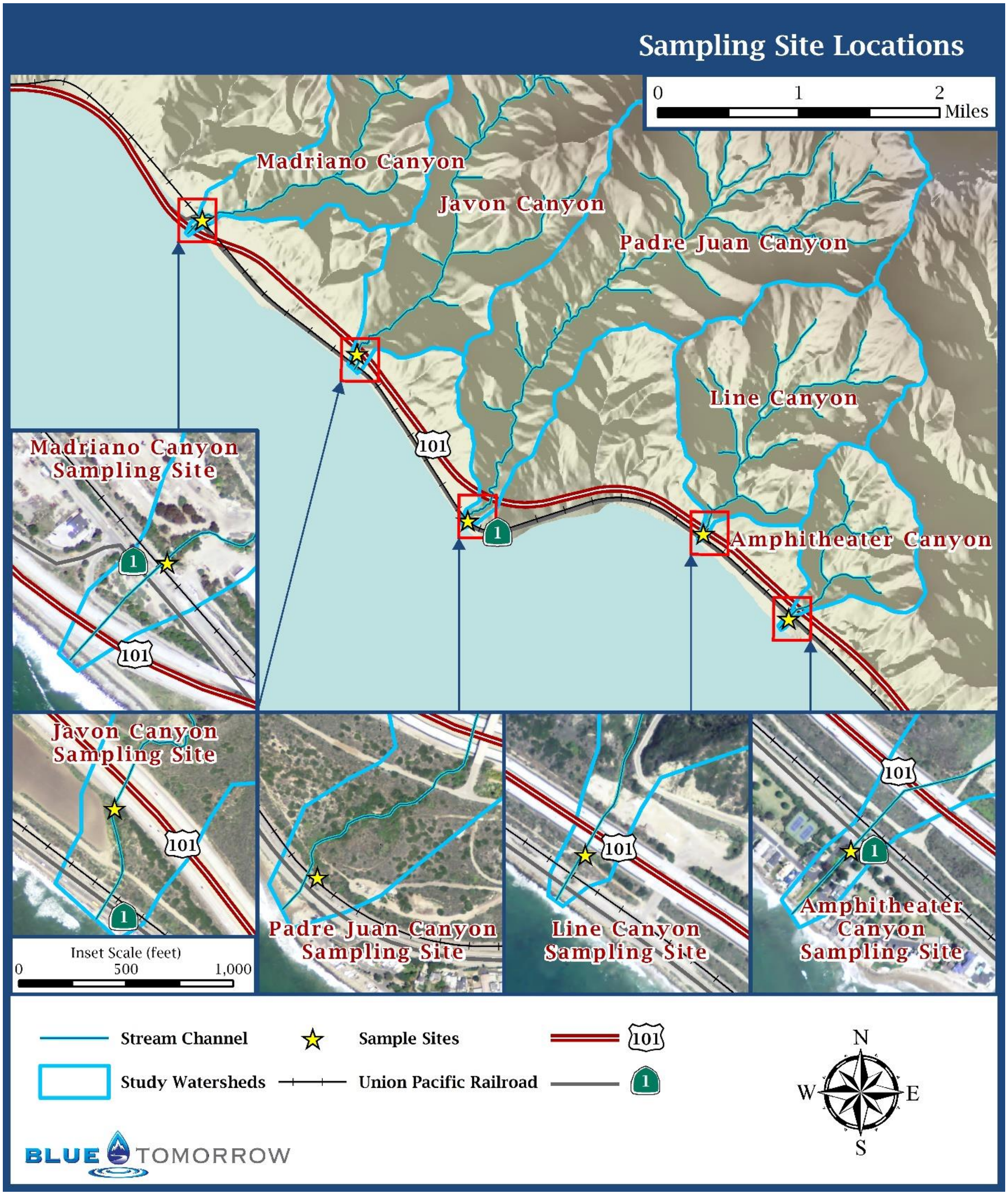
Amphitheater Canyon

Watershed Area: 1.44 km^2 (0.55 mi^2)

Sampling Site Coordinates: 34° 19’ 10” N, 119° 23’ 6” W

Amphitheater Canyon is the southernmost sampling site. The sampling site is located directly on the downstream side of the culvert for Highway 1, approximately 100 m (328 feet) upstream of the coastline.

Figure 1.1 – Locations where water and sediment samples were collected and field measurements were performed. The sites are located in five coastal watersheds in northwestern Ventura County, approximately 4 miles southeast of the Santa Barbara County line and 4 miles northwest of the city of Buenaventura (Ventura). From October 2013 through April 2014, 14 stormwater samples, 3 base flow samples, and 10 sediment samples were collected from these sites.



2.0 | Analyzed Pollutants, Methods & Sampling Strategies

A total of 16 different standardized analytical methods were used to analyze up to 68 constituents in water samples and 53 constituents in sediment samples (Table 2.1 and 2.2). All samples were collected in the field by Blue Tomorrow and sent to ALS Environmental for laboratory analysis following proper handling, holding time, and Chain of Custody (COC) procedures.

Section Highlights

- Up to 68 constituents were tested for in water samples and sediment samples by a certified laboratory using standardized analytical methods
- Analyzed constituents included metals, salts, organic compounds (including 17 PAHs), and conventional water quality parameters
- The constituents were selected based on their association with oil production operations, emphasizing those known to occur in hydraulic fracturing fluids
- Many of the constituents are regulated by the Safe Drinking Water Act and are known carcinogens with varying levels of persistence in the environment
- Stream discharge, TDS, conductivity, pH, and temperature were also measured in the field over the course of the study

The list of pollutants that were tested for in samples (the analyte list) include those regulated by the NPDES industrial stormwater discharge permit program and pollutants known to occur in hydraulic fracturing fluids, focusing on those that are of concern to the health of people and the environment[9,3]. Approximately 100 possible study pollutants were identified from "Hydraulic Fracturing Fluid Product Component Information Disclosure" documents and a list of hydraulic fracturing fluid components summarized by the US House of Representatives Committee on Energy and Commerce[5,3]. The analyte list also considered stormwater pollutants known to be associated with oil production operations[3,9]. The list was then refined based on pollutant chemical properties, fate and transport, toxicity, testing methods and detection limits.

The initial list of 28 pollutants was expanded to the 68 constituents found in Tables 2.1 and 2.2 after the first stormwater sample results were obtained. Section 2.4 describes the reasoning for these additions to the analyte list.

Many of the tested pollutants can affect human and or ecosystem health if discharged to the environment in sufficient quantities, including several toxic metals and many carcinogenic compounds (including PAHs). The pollutants included in the analyte list have varying levels of mobility in the environment, ranging from alcohols that biodegrade rapidly in days to weeks to heavier compounds such as bis(2-ethylhexyl)phthalate which sorbs strongly to sediment and can bioaccumulate and persist in the environment for months. To determine which of these pollutants should be tested in sediments, the solubility, biotic and abiotic degradation rates, and tendency for adsorption to soils and sediments were considered for each pollutant.

2.1 Analyte List and Analytical Methods

The different analytes in water and sediment samples are listed below in Tables 2.1 and 2.2. The tables include the analytical methods used by a certified third party laboratory (ALS Environmental) to determine the concentration of the analytes. Both tables apply to water samples, but only Table 2.2 applies to sediment samples.

Table 2.1 – **Water sample analyte list and analytical methods**

ANALYTE	ANALYTICAL METHOD
pH	9040B
TSS	SM 2540D
TDS	SM 2540C
Chemical Oxygen Demand (COD)	SM 5220C
Electrical Conductance (EC)	120.1
Organic Compounds	
Acrylamide	CAS SOP*
Formaldehyde	8315A
Methanol	8015B
2-Propyn-1-ol (Propargyl Alcohol)	8015B
Ethylene Glycol	8015C
Salts	
Ammonia	SM 4500-NH3 E
Chloride	300.0
Fluoride	300.0
Nitrate	300.0
Sulfate	300.0
*Acrylamide was analyzed for using the Columbia Analytical Services (now ALS Environmental) Standard Operating Procedure (CAS SOP)	

Table 2.2 – **Analyte list and analytical methods used for both water and sediment samples**

ANALYTE	ANALYTICAL METHOD	ANALYTE	ANALYTICAL METHOD
Organic Compounds		**Metals**	
Oil and Grease	1664A	Aluminum	6010C
Diesel Range Organics (DRO)	8015C	Antimony	6010C
Residual Range Organics (RRO)	8015C	Arsenic	6010C
Benzene	8260C	Barium	6010C
Toluene	8260C	Beryllium	6010C
Ethylbenzene	8260C	Boron	6010C
m,p - Xylene	8260C	Cadmium	6010C
o – Xylene	8260C	Calcium	6010C
1,2,4 - Trimethylbenzene	8260C	Chromium	6010C
1,3,5 - Trimethylbenzene	8260C	Cobalt	6010C
Bis (2-ethylhexyl) Phthalate	8270D	Copper	6010C
Polycyclic Aromatic Hydrocarbons (PAHs)		Iron	6010C
Naphthalene	8270D	Lead	6010C
2-Methylnaphthalene	8270D	Magnesium	6010C
Acenaphthylene	8270D	Manganese	6010C
Acenaphthene	8270D	Mercury	7471B
Dibenzofuran	8270D	Nickel	6010C
Fluorene	8270D	Potassium	6010C
Phenanthrene	8270D	Selenium	6010C
Anthracene	8270D	Silver	6010C
Fluoranthene	8270D	Sodium	6010C
Pyrene	8270D	Thallium	6010C
Benz(a)anthracene	8270D	Vanadium	6010C
Chrysene	8270D	Zinc	6010C
Benzo(b)fluoranthene	8270D		
Benzo(k)flouranthene	8270D		
Benzo(a)pyrene	8270D		
Indeno(1,2,3-cd)pyrene	8270D		
Dibenz(a,h)anthracene	8270D		
Benzo(g,h,i)perylene	8270D		

2.2 Field Testing

Water quality tests were performed in the field by Blue Tomorrow using handheld measurement instruments. The physical water quality parameters tested in the field were turbidity, conductivity, pH, TDS, temperature, and dissolved oxygen. Several procedures were used to verify the quality of the data collected including using multiple instruments, performing triplicate tests, and calibrating the instruments using standard solutions (when applicable). In addition, the third party laboratory used standard analytical methods to test for conductivity, pH (although it exceeded holding time), and TDS, and the results were compared to field measurements performed when the sample was collected.

Stream discharge was measured as part of field testing activities and during stormwater sampling using a velocity-area method. During each stream discharge measurement, flow velocity was measured several times using a float. The cross-sectional area of flow was measured during each activity and used to calculate the discharge rate in cubic feet per second (cfs).

The majority of field tests were performed on the Line Canyon base flow and not during stormwater runoff events. Due to the flashy stormwater response of the study watershed and the priority given to collecting stormwater samples it was not feasible to perform field tests on all creeks during all the stormwater sampling activities. Additionally turbidity readings were not attainable during stormwater runoff events due to the high concentrations of suspended sediment, which did not allow light to be transmitted and exceeded the limit of the instrument.

2.3 Description of Individual Pollutants

The following descriptions of analytes in water and sediment samples provide some information on the general mobility of the pollutant in the environment, and other information which was used to select the analytes. Whether an organic compound was included as an analyte in sediment samples depended on if it was likely to be found adsorbed to sediments.

Physical Parameters

The list of physical parameters that were tested include commonly performed stormwater runoff tests: pH, TSS, TDS, and conductivity[7]. The TSS and TDS concentrations may be affected by many oil field operations[9]. High levels of TSS and TDS can impact local aquatic environments, can facilitate the transport of pollutants, and may be indicators of excessive erosion and inadequate stormwater controls. The pH, TDS, and electrical conductance of stormwater runoff may be influenced by acids and salts used in hydraulic fracturing fluids, oil production, and found in produced water[9].

Salts and Metals

Salts and metals may be indicators of inorganic acids and salts used in hydraulic fracturing fluids and other well treatment and stimulation operations. Hydrochloric and hydrofluoric acids are commonly used to treat wells in the project area. Acids and salts tend to dissociate quickly in water and can be detected from their ions, which are often metals. Both acids and salts can affect pH and conductance of stormwater. High levels of specific dissolved metals may be indicators of produced water, while high levels of total metals in stormwater runoff can be linked to levels of TSS and upstream erosion. Sample results for salts and metals are compared to known natural background concentrations in the NVCCWP Source Assessment to assess possible upstream land use impacts.

Formaldehyde

Aqueous formaldehyde adsorbs very little to soils and sediments making it very mobile[1,3,4]. Formaldehyde is not expected to volatilize from water very rapidly[1,4]. Phenol Formaldehyde Resin was the third largest component by mass on the fracking fluid discloser document[4] after water and sand for a well found in the Line Canyon watershed, but this resin decomposes very slowly[2,5]. Phenol Formaldehyde Resin is a polymer resin made using formaldehyde, which may leach from the resin slowly into the environment. Formaldehyde occurs naturally in the environment (produced by various processes) and has a rapid biodegradation rate[1,4]. It is only likely to be found above natural concentrations if it enters stormwater and is sampled within days of being released.

Methanol

Methanol is cited as being one of the most common chemical components used in hydraulic fracturing fluids[3] and was reported to be used in the project area[5]. Methanol is used as a corrosion inhibitor during well treatments. It does not adsorb to soils or sediments, making it very mobile, and it rapidly degrades and volatilizes from soil and water[1]. Methanol is only likely to be found if it enters stormwater and is sampled within days to weeks of being spilled.

2-Propyn-1-ol (Propargyl Alcohol)

Propargyl alcohol is cited as a frequent component of hydraulic fracturing fluids[3], and is used as a corrosion inhibitor during well treatments in the project area. Propargyl alcohol does not adsorb to soils or sediments, making it very mobile. This pollutant is volatile but may take several weeks to months to volatize from a water body. Propargyl alcohol will biodegrade within weeks, but abiotic degradation is limited[1]. It is only likely to be found if it enters stormwater and is sampled within weeks of being spilled.

Diesel Range Organics (DRO)

DRO incorporates diesel fuel which is a constituent in some hydraulic fracturing fluids[3] and may be released through many oil production operations. If diesel fuel is used in hydraulic fracturing fluids, an Underground Injections Control permit is required through the Safe Drinking Water Act (SDWA) [6,8]. DRO fuels are mixtures of petrochemicals, often including benzene, toluene, ethylbenzene, xylene, and Polycyclic Aromatic Hydrocarbons (PAHs), and are expected to degrade into many byproducts[8]. DRO includes any hydrocarbons with a carbon chain ranging from 10 to 28 carbons. DRO can also include portions of crude oil, kerosene, heating oils, heavy fuel oils, and lubricating oils.

Residual Range Organics (RRO)

RRO incorporates the heavier portions of crude oil, ranging from hydrocarbons with carbon chains containing from 25 to 36 carbons. RRO includes heavier fuel oils, lubricating oils, waxes, asphalts and pitch. Heavier ranges of organics are generally more persistent and less mobile in the environment. RRO levels would be expected to rise with increased oil production activities and well pad spills.

Oil and Grease

Oil and grease pollution may come from various sources including well heads, oil field equipment, and diluted in hydraulic fracturing fluids[9]. Oil and grease are made up of many chemicals, have many constituents such as benzene, toluene, ethylbenzene, and xylene, and are expected to degrade into many byproducts. The analytical method used to measure oil and grease in this study is total n-Hexane Extractable Material (total HEM). Hydrocarbons and fuels that volatize at low temperatures may not be detected by this test, and some crude oils and heavy fuel oils that contain large proportions of material not soluble in hexane may only be partially quantified.

Benzene, Toluene, Ethylbenzene, and Xylene (BTEX)

BTEX are common aromatic hydrocarbons found in a variety of oil and gas products. These compounds affect the central nervous system and benzene is a carcinogen[1]. All BTEX compounds are regulated under the SDWA[3]. The BTEX compounds have moderate to high mobility in soil and are expected to volatize from soil and water when exposed to air in hours to days[1]. All the compounds biodegrade within weeks in aerobic conditions and undergo less biodegradation in anaerobic conditions[1]. All compounds adsorb to soils and sediments to some degree, but toluene, ethylbenzene, and xylene adsorb more than benzene[1].

Polycyclic Aromatic Hydrocarbons (PAHs)

PAHs are a diverse group of hydrocarbons with multiple aromatic rings and are common byproducts of combustion and pyrolysis processes. Only a few are intentionally produced. PAHs are abundant in crude oil and many petroleum products including fuels, and would be expected to be associated with oil production activities. Heavier PAHs with more than three rings are generally more persistent in the environment having slight to no mobility in soils, low volatility, low biodegradation, and high bioaccumulation potential[1]. Low molecular weight PAHs may volatize at significant rates from wet soils but heavier PAHs will not, and PAH volatilization from dry soils is not expected. PAHs with three rings or less are expected to biodegrade fairly rapidly[1]. Atmospheric deposition of PAHs is common, and vehicle emissions and forest fires are among many known sources of atmospheric PAHs. Detected concentrations need to be compared to known natural background concentrations to assess possible upstream land use impacts.

1,3,5 – Trimethylbenzene, 1,2,4 – Trimethylbenzene

1,3,5 – and 1,2,4 – trimethylbenzene have been used in the fracturing of wells by the oil and gas company operating in the project area[5], and are found in solvent products used in well treatments. These pollutants are expected to bioaccumulate in aquatic organisms[1]. Both these compounds have low mobility in soils, and volatize within hours to days from water and soil surfaces[1]. Both compounds are known to biodegrade quickly in aerobic conditions, but biodegrade minimally in anaerobic or methanogenic conditions[1].

Bis (2-ethylhexyl) Phthalate (DEHP)

DEHP is a major constituent of plastics such as PVC and vinyl chloride resins. DEHP is a probable carcinogen regulated under the SDWA, and is cited as being a component of some hydraulic fracturing fluids[3,11]. This compound has a tendency to bioaccumulate in aquatic organisms[1,11]. DEHP is not volatile and strongly adsorbs to soil and sediments; it is considered to be immobile in some soils[1,11]. DEHP will biodegrade in water in weeks to months[1,11].

Acrylamide

Acrylamide is known to be used in some hydraulic fracturing fluids, and is a neurotoxin and carcinogen regulated by the SWDA[3,12]. Acrylamide does not significantly adsorb to soils and sediments, and is expected to have very high mobility in soils[1,12]. This compound has low volatility and degrades in weeks to months[1,12].

Ethylene Glycol

Ethylene glycol is known to be a common constituent of hydraulic fracturing fluids and solvents used during oil field production activities, and is classified as a probable human carcinogen[1,3]. Ethylene glycol has very high mobility in soils and low volatility. This compound degrades in days to weeks in both aerobic and anaerobic conditions[1,10].

2.4 Adaptive Sampling Strategy

This project adjusted the original analyte list based on the occurrence of rainstorms within the sampling timeline, results from initial samples, and the project budget. This strategy was adopted because of the exploratory nature of the project and the limited sampling budget.

Initial sampling goals for the project were 41 water samples (30 stormwater; 11 base flow) and 10 sediment samples. Due to the lack of qualifying storm events (storms predicted to deliver greater than or equal to 1.27 cm (0.5 inches) of cumulative rainfall to the study watersheds within a 12 hour period) and a persistent California drought, these goals were not feasible within the sampling timeline. When rain did fall and the first stormwater samples were collected, the sample results showed unexpectedly high levels of the initial list of metals and organics (especially in Line Canyon). These factors prompted a reduction of the sampling goals and an expansion of the analyte list as the best strategy to most efficiently use the sampling budget within the sampling timeline. The goal for base flow samples was reduced to 4 because none of the creeks except for Line Canyon had generated base flow (groundwater fed flow) during this dry winter.

After the first stormwater sampling event, subsequent water samples were analyzed for an additional 17 polycyclic aromatic hydrocarbons (PAHs), residual range organics (RRO), sulfate, and 17 more metals. All 24 metals were also analyzed in dissolved form in subsequent stormwater samples. The second sediment sample collected from each of the sampling sites also included the PAHs, RRO, and metals analyses (Table 2.2).

After the first stormwater event only one subsequent qualifying storm event (beginning February 26, 2013) occurred during the sampling timeline. Samples were collected multiple times during the storm due to the intensity and extent of the event, which delivered between 8.9 and 17.8 cm (3.5-7 inches) over three days, and the lack of other qualifying rain events at that point in the sampling timeline. Samples taken during the beginning of the storm were collected from each creek and analyzed for the full analyte list. Samples taken during the latter days were only analyzed for total dissolved solids (TDS), total suspended solids (TSS), conductivity, and salts. This smaller subset of constituents were analyzed instead of the full analyte list because of the assumption that the organics would exhibit a first flush response and have higher concentrations earlier in the storm event. The limited sampling budget also was taken into consideration to account for possible future storm events. The stormwater runoff later in the storm event had a greater discharge rate and it was decided to sample to determine how sediments, dissolved solids, and salts were changing.

2.5 Pollutant Description References

1) United States National Library of Medicine. Toxicology Data Network. Hazardous Substances Data Bank: Comprehensive, peer-reviewed toxicology data for about 5,000 chemicals. Available at: http://toxnet.nlm.nih.gov/cgi-bin/sis/htmlgen?HSDB. Accessed September 25, 2013.

2) Hydraulic Fracturing Fluid Component Information Disclosure. Fracture date, 5/27/2011; Operator, Occidental; Well, Grubb #477; AIP number, 04-111-22084. Available at: http://www.fracfocusdata.org/DisclosureSearch/StandardSearch.aspx.

3) United States House of Representatives. Committee on Energy and Commerce Minority Staff. Chemicals used in hydraulic fracturing. April 2011.

4) U.S. Department of Health and Human Services. National Toxicology Program. Report on Carcinogens, Background Document for Formaldehyde. January 22, 2010.

5) Frac Focus. Chemical Disclosure Registry. Available at: http://www.fracfocusdata.org/DisclosureSearch/StandardSearch.aspx. Search: State, California; County, Ventura; Operator, Occidental Oil and Gas. Accessed September 18, 2013.

6) United States Environmental Protection Agency. Fact Sheet: Underground Injection Control (UIC) permitting guidance for oil and gas hydraulic fracturing actives using diesel fuels. Draft: UIC Program guidance #84. May 2012.

7) Environmental Defense Center. Notice of intent to sue pursuant to the clean water act. Notice of intent to sue sent to Vintage/Oxy. February 23, 2012.

8) United States Environmental Protection Agency. Permitting guidance for oil and gas hydraulic fracturing actives using diesel fuels. Draft: Underground Injection Control program guidance #84. May 2012.

9) U.S. Environmental Protection Agency, Office of Water. Industrial Stormwater, Fact Sheet Series. Sector 1: Oil and Gas Extraction Facilities. December 2006.

10) World Health Organization Geneva, 2000. Concise International Chemical Assessment Document 22. Ethylene glycol: Environmental aspects.

11) United States Environmental Protection Agency. National Primary Drinking Water Regulations. Technical Factsheet on: Di (2-Ethylhexyl) Phthalate (DEHP).

12) United States Environmental Protection Agency. Toxicological Review of Acrylamide. CAS No. 79-06-1. In Support of Summary Information on the Integrated Risk Information System (IRIS). March 2010.

3.0 | Sampling Event Observations

From October 2013 to the end of April 2014, stormwater, base flow, and sediment samples were collected from the sampling sites in Madriano, Javon, Padre Juan, Line, and Amphitheater Canyons. Grab samples were collected to test for a wide range of analytes, and field tests were performed on site when possible. The following narratives describe relevant observations from the sampling events and field tests as they occurred.

3.1 Stormwater Sampling Observations

The 2014 water year was abnormally dry in the study area, as indicated by the rain gauges at Red Mountain (located at the top of Padre Juan Canyon) and Sea Cliff County Fire Station (found at the base of Madriano Canyon). Several storms registered precipitation to the north and south of the watersheds, yet received only trace amounts of precipitation in the watersheds. The geographic position of the study watersheds may have influenced their ability to receive rain, as the watersheds appeared to be in a rain shadow from storms originating from the northwest.

From October 2013 to April 2014, only two storms generated enough runoff to collect stormwater samples. The first storm event of the rainy season occurred in November 2013, and subsequent stormwater samples were collected from the high intensity multi-day storm that began at the end of February 2014 (Table 3.1).

Section Highlights

- 14 stormwater samples, 3 base flow samples, and 10 sediment samples were collected from October 2013 through April 2014
- Only two storm events generated enough stormwater to sample during the sampling timeline, including a storm event that started on November 20, 2013 and delivered 1 to 2.2cm, and a multi-day storm beginning on February 26, 2014 which delivered 8.9 to 17.8 cm of rain to the study watersheds
- The second storm event produced large discharge rates from all the canyons over three days when 11 of the stormwater samples were collected (Amphitheater Canyon had a peak discharge measured at 7,400 L/s)
- 23 field tests were performed over the course of the study, 15 of which were in Line Canyon
- Odors of possible petroleum hydrocarbons were observed in Line Canyon during the two storm events

Table 3.1 – **Stormwater sampling events**

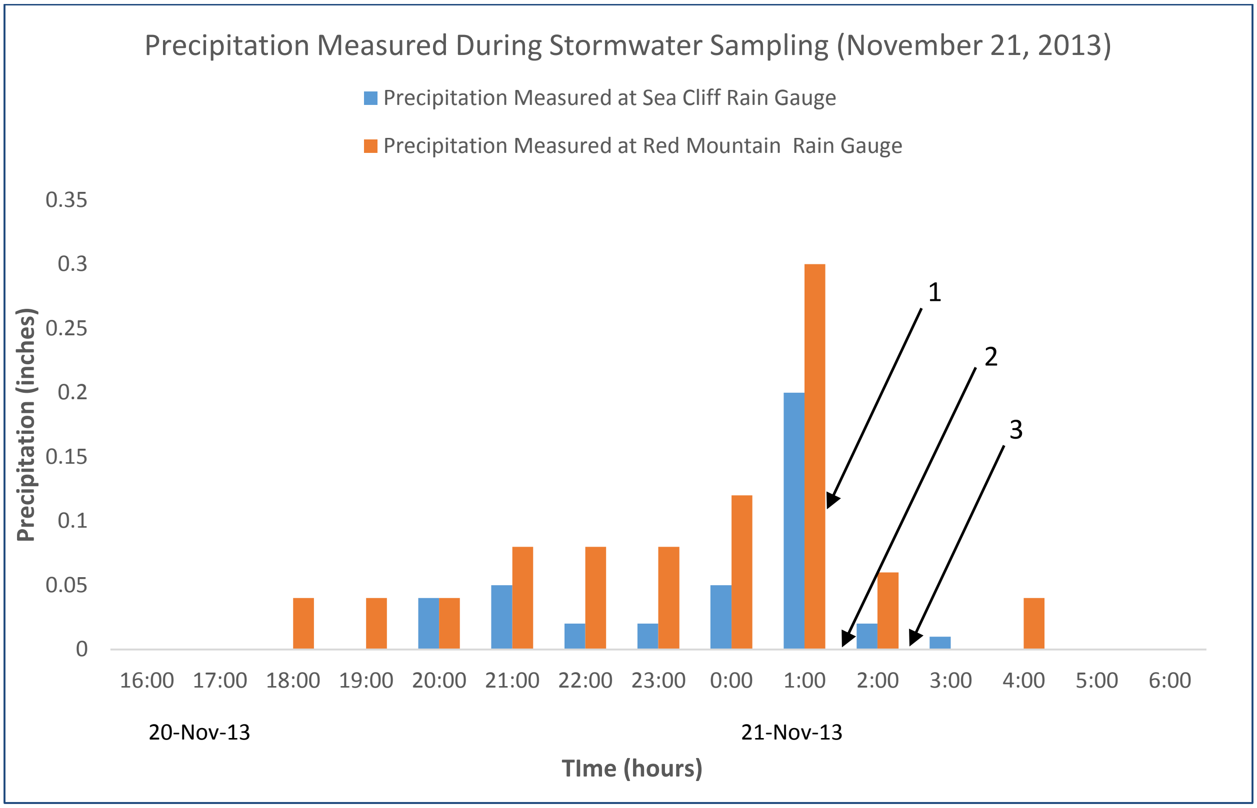
DATE	SAMPLING ACTIVITY
21-Nov-13	Stormwater samples (Madriano, Padre Juan, Line)
27-Feb-14	Stormwater Samples (Madriano, Padre Juan, Line, Amphitheater); Field tests (Line, Amphitheater)
28-Feb-14	Stormwater Samples (Javon all tests; sampled for subset of tests Line, Amphitheater); Field tests all 5 creeks
1-Mar-14	Stormwater Samples (sampled for subset of tests Javon, Padre Juan, Line, Amphitheater); Field tests all 5 creeks

3.1.1 First Stormwater Sampling Events (November 21, 2013)

Stormwater samples were collected from Madriano, Padre Juan, and Line Canyons. A short, low-intensity storm began at 8:00 pm the night before, and around 1:00 am on November 21, 2013, enough stormwater runoff was generated to sample at the three canyons before runoff stopped. By the time the storm ended at 3:00 am, rain gauges at Sea Cliff and Red Mountain registered 1.04 cm (0.41 inches) and 2.2 cm (0.88 inches), respectively. Peak rainfall intensity was between 0.51 and 0.76 cm (0.2 and 0.3 inches) per hour at 1:00 am on November 21. At the time samples were collected, flow was estimated to be between 2.8 and 7.1 liters per second (L/s), equivalent to 0.1 and 0.25 cubic feet per second (cfs), in Madriano and Padre Juan Canyons, and 57 L/s (2 cfs) in Line Canyon. During sampling in Line Canyon, there was a strong odor of possible petroleum hydrocarbons, which was also observed to a lesser degree in Madriano Canyon. Detailed observations of sampling activities are included in the Appendix in Section 6.0.

Figure 3.1 shows precipitation amounts recorded by two rain gauges near the study watersheds, estimated stormwater flow, and sampling times during the first qualifying storm event. Rain gauges were located at Sea Cliff County Fire Station and Red Mountain. Data from these gauges are unverified and generated via telemetry, and were obtained from Ventura County Watershed Protection District.

Figure 3.1 – Stormwater samples were collected from 1) Madriano Canyon at 1:00 am; 2) Padre Juan Canyon at 1:45 am; and 3) Line Canyon at 2:30 am. Precipitation measurements for the first storm event on November 20-21, 2013 are from Sea Cliff and Red Mountain rain gauges.



3.1.2 Stormwater Sampling Events (February 27, 2014 - March 1, 2014)

The largest storm of the 2013-2014 rainy season first hit the study watersheds on February 26, 2014 and delivered between 8.9 to 17.8 cm (3.5 and 7 inches) of rainfall during the multi-day storm event (based on unverified preliminary data from Seacliff County Fire Station and Red Mountain rain gages). This storm consisted of multiple precipitation events over the duration of the storm. A total of 11 stormwater samples were collected on February 27, 28 and March 1.

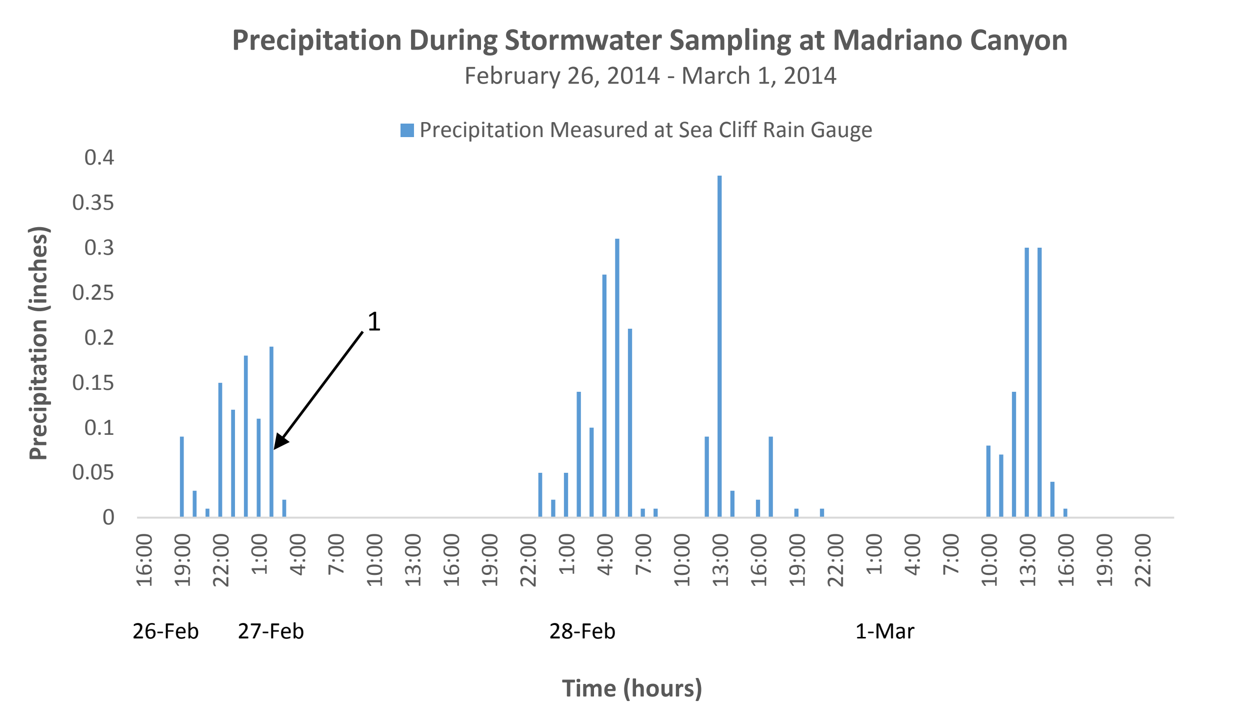
Stormwater samples were collected from all five watersheds during the first 18 hours of the storm, beginning on February 27, 2014. On February 28th, additional stormwater samples were collected from Line and Amphitheater Canyons. The precipitation event that occurred between the hours of 10:00 am and 2:00 pm on March 1st generated the largest stormwater discharge observed from the canyons. At Red Mountain, hourly measurements show rainfall exceeded 3.8 cm (1.5 inches) during this timeframe. Four additional samples were collected during this latter portion of the storm from Javon, Padre Juan, Line, and Amphitheater Canyon. Stormwater runoff from all five creeks discharged into the ocean during this storm event.

All precipitation amounts shown in these figures were obtained from the Ventura County Watershed Protection District and are unverified telemetry data. Rain gauges used to produce hydrographs were selected based on their proximity to the study watershed. Stormwater flow was measured in the field at various times throughout the February-March storm, and is included in Section 4.0. Figures 3.3, 3.4, 3.5, 3.6, and 3.7 shows the precipitation measured from Sea Cliff and Red Mountain rain gauges and stormwater sampling times that occurred during the multi-day storm beginning on February 26, 2014.

Madriano Canyon

Madriano Canyon was monitored throughout the duration of the February-March multiday storm event. In almost every case, stormwater runoff ceased within thirty minutes after rain stopped. Stormwater was collected at the end of the first precipitation event, and rain had stopped prior to sampling from Madriano Canyon on February 27 at 2:45 am. The majority of the runoff appeared to come from above the check dam, with a small amount from the oil field road. Stream flow decreased considerably from what was observed upon arrival, and was measured at 4 L/s (0.14 cfs) after samples were collected. Field tests were performed again on February 28 at 4:45 pm, and on March 1 at 2:55 pm. Figure 3.3 shows the precipitation and time samples were collected at Madriano Canyon over the duration of this storm event.

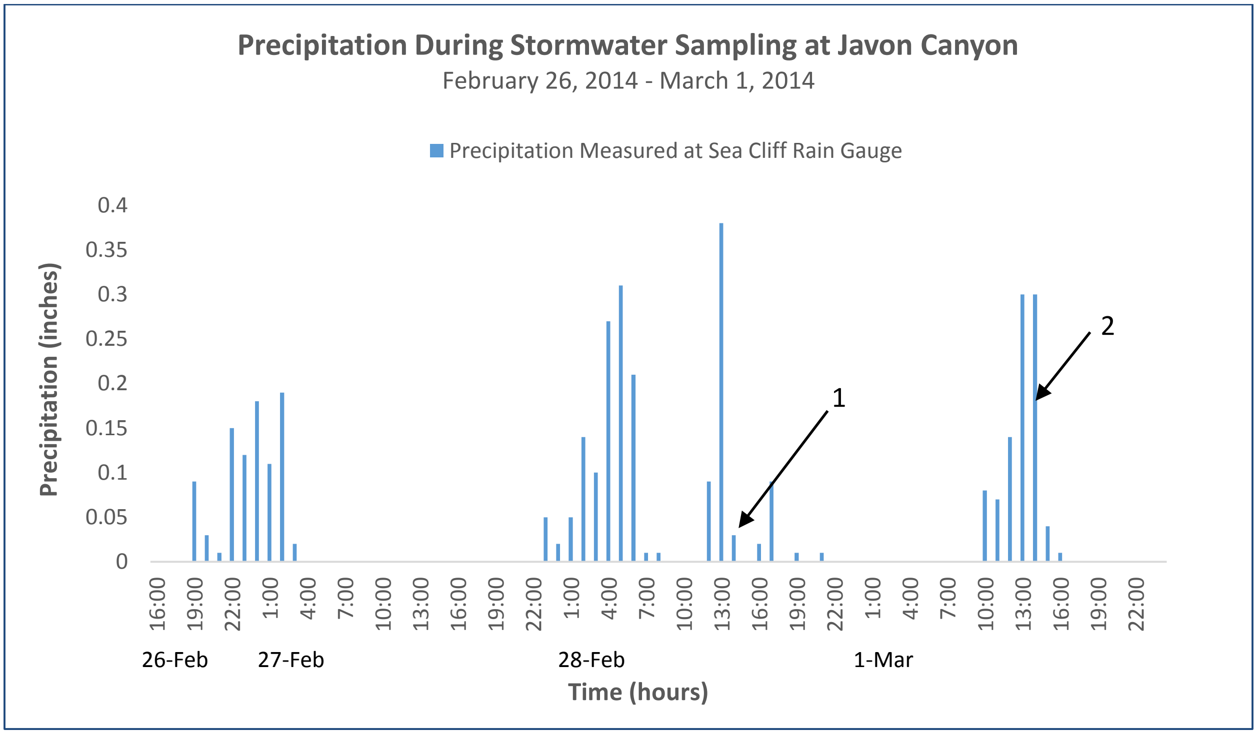
Figure 3.3 – Precipitation measurements shown are from a rain gauge at Sea Cliff County Fire Station (at the base of Madriano Canyon). A stormwater sample was collected on February 27, 2014 from 1) Madriano Canyon at 2:45 am. Stormwater flow was measured at various times throughout the storm event presented in Section 4.0 and in the Appendix.



Javon Canyon

Javon Canyon was monitored throughout the duration of the February-March multiday storm event. The watershed required several hours of precipitation prior to the generation of stormwater runoff, and there was not enough runoff to sample during the first wave of the storm on February 27. Stormwater was sampled on February 28 at 2:05 pm, when flow was measured at 33 L/s (1.2 cfs). By March 1, 2014, the watershed became more responsive to precipitation and stormwater continued several hours after precipitation ended. On March 1 at 2:30 pm flow was measured at 110 L/s (3.9 cfs) when stormwater samples were collected and field tests performed. Figure 3.4 shows the precipitation and times when stormwater samples were collected at Javon Canyon over the duration of this storm event.

Figure 3.4 – Precipitation measurements are from the rain gauge at the Sea Cliff County Fire Station (at the base of Madriano Canyon). Stormwater samples were collected 1) on February 28, 2014 at 2:05 pm; and 2) on March 1, 2014 at 2:30 pm. Stormwater flow was measured at various times throughout the storm event presented in Section 4.0 and in the Appendix.

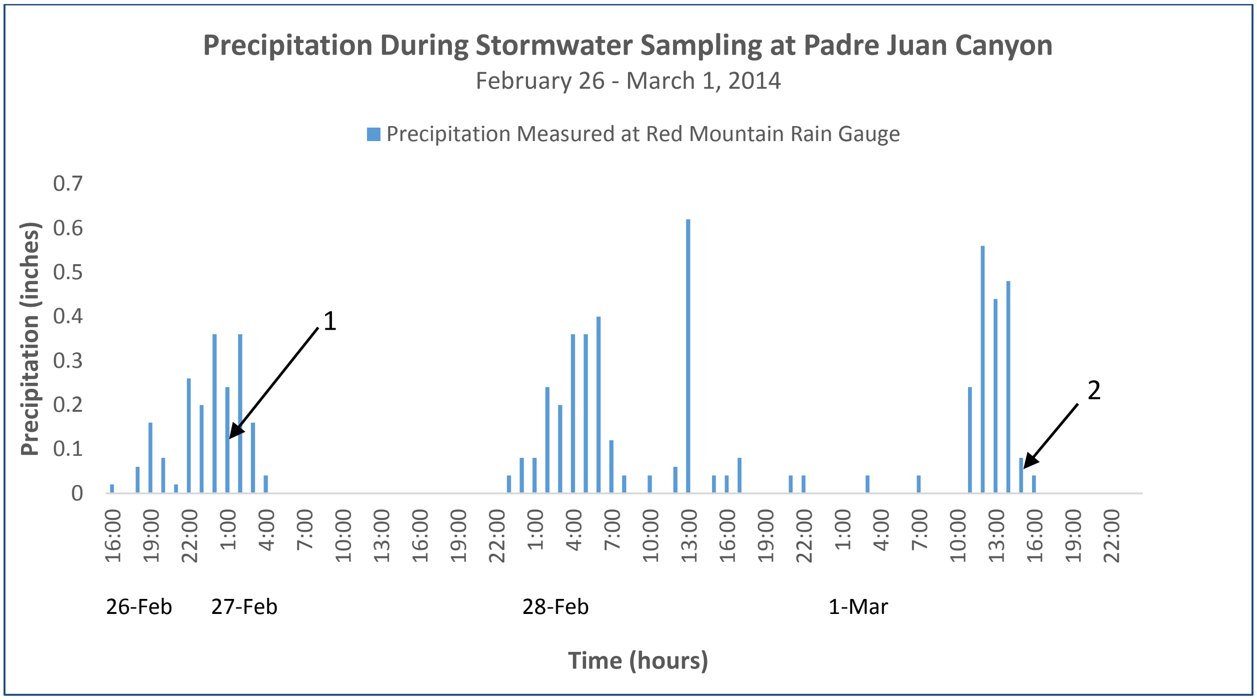


Padre Juan Canyon

Padre Juan Canyon was monitored throughout the duration of the February-March multi-day storm event. A larger lag between precipitation and runoff was observed in this watershed, possibly due to its size relative to other study watersheds. On several occasions, stormwater runoff continued hours after precipitation ceased.

On February 27 at 1:55 am, stormwater samples were collected and flow was measured at approximately 14 L/s (0.49 cfs). Field tests were performed on February 28 at 10:55 am and flow was measured at 11 L/s (0.4 cfs). On March 1 at 3:45 pm, stream flow was the largest that was observed over the course of the project in Padre Juan Canyon at 260 L/s (9.3 cfs). Figure 3.5 shows the precipitation near Padre Juan Canyon for the duration of the February-March storm event and times stormwater samples were collected.

Figure 3.5 – Precipitation measurements are from a rain gauge at Red Mountain (at the top of Padre Juan Canyon). Stormwater samples were collected 1) on February 27, 2014 at 1:55 am; and 2) on March 1, 2014 at 3:45 pm. Stormwater flow was measured at various times throughout the storm event presented in Section 4.0 and in the Appendix.



Line Canyon

Line Canyon was monitored throughout the duration of the February-March multi-day storm event. Stormwater flow in Line Canyon was very responsive to precipitation, and exhibited the second largest flow of all watersheds during the 2013-2014 rainy season. Strong odors of possible petroleum hydrocarbons were observed throughout stormwater sampling and monitoring of Line Canyon.

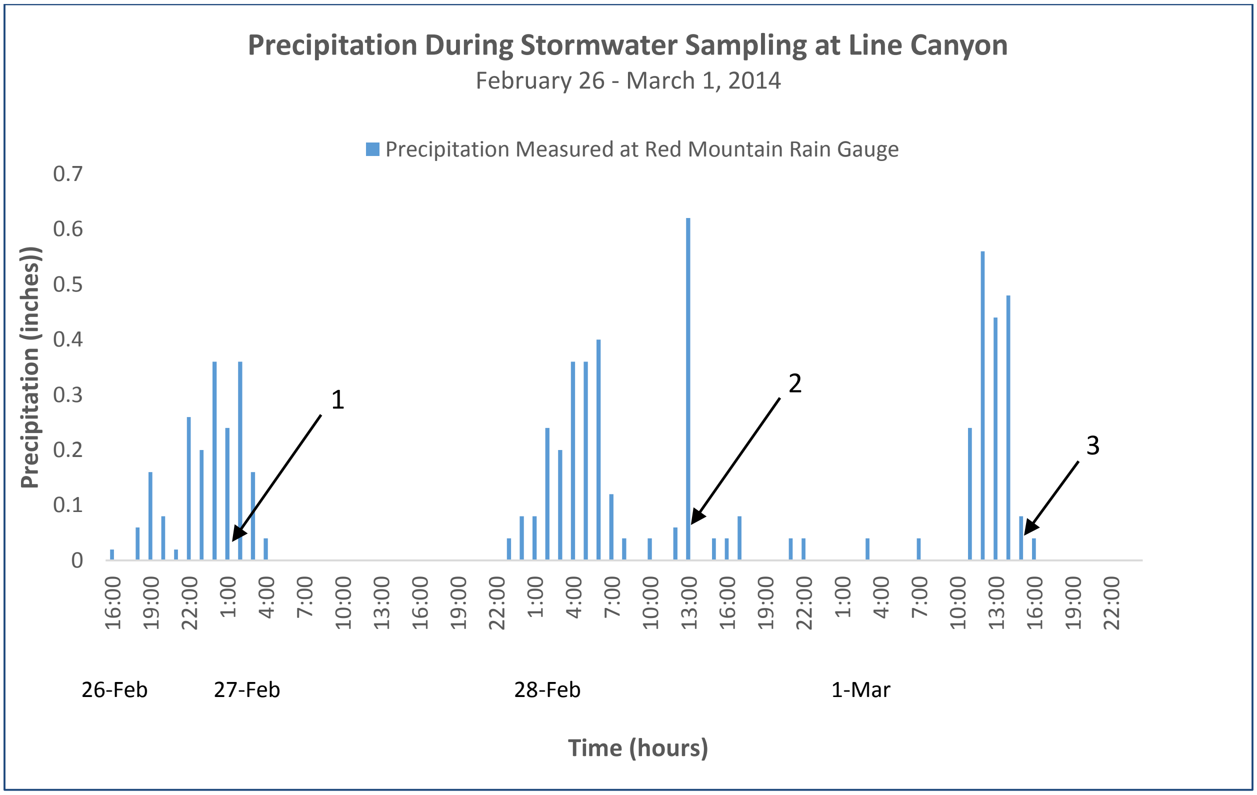
Stormwater sampling commenced at Line Canyon on February 27 at 1:15 am. A strong odor of possible petroleum hydrocarbons was observed during the sampling, and flow was measured at 130 L/s (4.7 cfs). Field tests were performed and a 28 L/s (1 cfs) flow was measured on February 27 at 4:05 am.

A second wave of the storm came through the study area on February 28, and field tests were performed again on runoff in Line Canyon at 10:15 am, and stormwater samples were collected at 1:45 pm. At 10:15 am, with no observable precipitation, stream flow was measured at 37 (1.3) cfs and then 57 L/s (2 cfs) 20 minutes later, possibly due to controls of an upstream check dam. Precipitation reached its peak from 1:00-2:00 pm, and at 1:45 pm, flow was measured at 280 L/s (10 cfs).

On March 1, the strongest wave of rain passed through the study area between 11:00 am and 3:00 pm. At 1:45 pm, a 1300 L/s (45 cfs) flow was measured in Line Canyon. After rain decreased, field tests and stormwater samples were collected at 3:25 pm, and the flow appeared to be darker in color than previously observed.

Figure 3.6 shows the precipitation at Line Canyon over the duration of this storm event, and times stormwater samples were collected

Figure 3.6 – Precipitation measurements are from a rain gauge at Red Mountain (at the top of Padre Juan Canyon). Stormwater samples were collected 1) on February 27, 2014 at 1:15 am; 2) on February 28, 2014 at 1:45 pm; and 3) on March 1, 2014 at 3:25 pm. Stormwater flow was measured at various times throughout the storm event presented in Section 4.0 and in the Appendix.



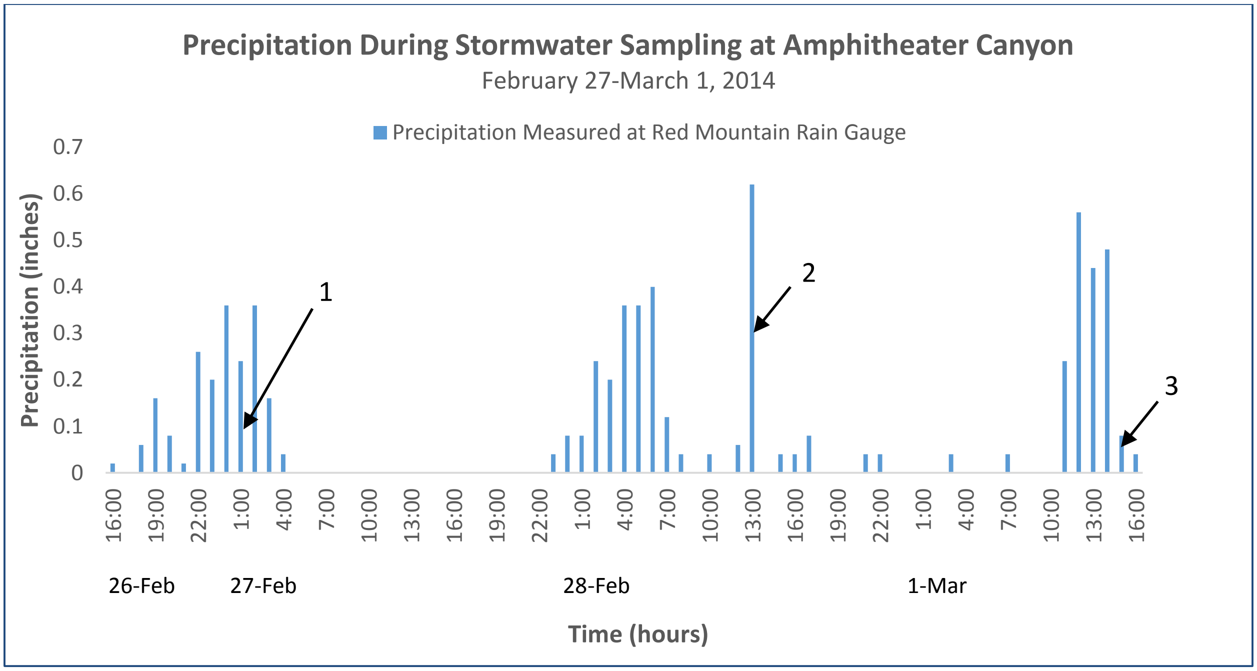
Amphitheater Canyon

Amphitheater Canyon was monitored throughout the duration of the February-March multi-day storm event. Amphitheater Canyon was very responsive to precipitation, likely due to the small watershed with steep slopes and modified hydrology (from tunnels, culverts and concrete channels).

Stormwater was collected on February 27 at 12:45 am, on February 28 at 1:20 pm, and again on March 1 at 3:15 pm. Stream flow varied throughout the storm. On February 27 at 12:45, flow was measured at 37 L/s (1.3 cfs) and then 3.4 L/s (0.12 cfs) at 3:55 am. On February 28 at 1:20 pm, flow was measured at 130 L/s (4.6 cfs), and then quickly doubled, with no increase in rain. On March 1 at 1:30 pm, during the highest intensity of rainfall, a muddy stream flow was measured at 7,400 L/s (260 cfs), with large rocks being discharged in the creek. Field tests were performed on March 1 at 3:15 pm, and flow decreased substantially from the peak discharge recorded at 1:30 pm.

Figures 3.6 shows the precipitation and times stormwater samples were collected at Amphitheater Canyon from February 26-March 1, 2014.

Figure 3.7 – Precipitation measurements are from a rain gauge at Red Mountain (at the top of Padre Juan Canyon). Stormwater samples were collected 1) on February 27, 2014 at 12:45 am; 2) on February 28, 2014 at 1:20 pm; and 3) on March 1, 2014 at 3:15 pm. Stormwater flow was measured at various times throughout the storm event presented in Section 4.0 and in the Appendix.



3.2 Sediment Sampling Observations

Sediment samples were collected from all five creeks on two events over the course of the project (a total of 10 sediment samples). Initial sediment samples were collected prior to the first storm event, in an attempt to capture pollutants that may have persisted since the last storm in May 2013. A second set of sediment samples were collected several days following the February-March storm. These were collected when the sediment was still wet.

3.2.1 Initial Sediment Samples (October 23, 2013)

Prior to the first sampling event the Sea Cliff rain gauge last registered precipitation on October 9, 2013, when it received 0.025 cm (0.01 inches) of rainfall. Before October 9, 2013, the area received 0.025 cm (0.01 inches) of precipitation on July 23, 2013. Between May 7, 2013 and November 20, 2013, the Sea Cliff rain gauge registered 0.025 cm (0.01 inches) of precipitation on 8 different days. May 6, 2013 was the last substantial rain event, registering 1.04 cm (0.41 inches) at the base of Madriano.

Initial sediment samples were collected at all five watersheds. During the duration of the first sediment sampling event, the weather was overcast with a marine layer of fog covering the watersheds. In Madriano, Javon, Padre Juan, and Line Canyons, in-channel sediment was sampled approximately 2-3 cm (0.79 to 1.2 inches) deep. In Amphitheater Canyon, sediment was sampled 3-4 cm (1.2 to 1.6 inches) deep from the creek bed. Line Canyon, sediment appeared recently deposited.

3.2.2 Second Sediment Sampling Event (March 7, 2014)

Sediment samples were collected at all five watersheds four days after the storm (second stormwater sampling event) ended on March 3, 2014. All sediment that was sampled from each creek was still wet from the previous storm. It was sunny and 20° C (68° F) during the collection of sediment on March 7.

Sediment samples of finer deposits were collected from between 1 to 5 cm (0.39 to 2 inches) deep in each watershed. Sampled sediment was primarily clay, and in Amphitheater Canyon sediment appeared to have a gelatinous consistency.

3.3 Base Flow Sampling Observations

Base flow samples were collected from Line Canyon on three occasions: 1) October 23, 2013; 2) January 22, 2014; 3) April 21, 2014. The first base flow samples were obtained the same day as the initial sediment samples. Prior to this sampling activity, Line Canyon had not received a large amount of precipitation since May 6, 2013. Base flow samples were then collected two months after the first storm event. Between the second base flow samples and the first qualifying storm event, the watersheds received between 0.79 to 1.7 cm (0.31 and 0.68 inches) of rain, the bulk of which occurred on December 7 and 8, 2013. Base flow samples were collected a third time on April 21, 2014. This was more than 6 weeks after the largest storm hit the watersheds (between February 26 and March 2, 2014). Prior to the final base flow samples, the last precipitation event in the area was on April 1-2 that registered 0.69 cm (0.27 inches) at the base of Madriano and 0.91 cm (0.36 inches) at the top of Red Mountain. When base flow samples were collected in October, January, and April, stream flow measured 0.85 L/s, 1 L/s, and 0.96 L/s (0.03 cfs, 0.037 cfs, and 0.034 cfs) respectively.

3.4 Field Test Observations

Over the course of the project, a number of field tests were performed on the base flow at Line Canyon. These included testing levels of total suspended solids (TSS), total dissolved solids (TDS), electrical conductivity, pH, turbidity, dissolved oxygen, and temperature, found in the base flow that discharged into the ocean. Table 3.4 shows the dates of these field tests, which were additional to those completed during sampling of stormwater and the Line Canyon base flow. Notable observations that were recorded during the monitoring and testing of the Line Canyon base flow are included in detail in Section 6.4 of the Appendix.

Table 3.4 – **Field tests and observations**

DATE	ACTIVITY	Storm Event
9-Oct-13	Sampling training; Field tests of Line Canyon base flow	No
21-Nov-13	Monitored following afternoon; Field tests of Line Canyon base flow	No
7-Dec-13	Monitored duration of storm	Yes, No Runoff
24-Jan-14	Monitored watersheds; Base flow stopped (see photo 7.3 in Appendix)	No
25-Jan-14	Monitored watersheds ; Base flow returned	No
31-Jan-14	Field tests of Line Canyon base flow	No
2-Feb-14	Monitored duration of storm	Yes, No Runoff
6-Feb -14	Monitored duration of storm; Field tests of Line Canyon base flow	Yes, No Runoff
12-Feb-14	Field tests of Line Canyon base flow	No
25-Feb-14	Field tests of Line Canyon base flow	No
4-Mar-14	Field tests of Line Canyon base flow; After-storm observations	No
1-Apr-14	Field tests of Line Canyon base flow	Yes, No Runoff

4.0 | RESULTS & LOADING ANALYSIS

A total of 17 water samples and 10 sediment samples were collected from October 2013 to the end of April 2014, and sent to a certified laboratory for analysis of up to 68 constituents. A total of 23 field testing activities were performed over this same time frame. Of the five study watershed creeks, the most samples and field tests were performed on Line Canyon Creek. The analyte list differed based on the type of sample, the results from previous samples, and the sampling timeline. Each constituent on the list of analytes was detected at least once in one or more samples, except for benzo(k)fluoranthene, which is a polycyclic aromatic hydrocarbon (PAH).

Notable results from stormwater samples include high levels of total suspended solids (TSS), total dissolved solids (TDS), conductivity, and total and dissolved metals. Diesel range organics (DRO) and residual range organics (RRO) were detected above reporting limits for all stormwater samples.

Sediment sample results show detections of oil and grease, DRO, RRO, and many of the PAHs above reporting limits. Metals found at fairly high levels in sediment samples include arsenic, boron, cadmium, and lead.

Loading analysis of the storm event that occurred from the February-March storm showed the high TSS concentrations in Line and

Section Highlights

- DRO and RRO were detected in all water and sediment samples except for the second sediment sample from Line Canyon, with the highest concentrations detected in Madriano Canyon
- High levels of total metals were detected in all stormwater samples, with the highest concentration of TSS and total metals found in Amphitheater Canyon during the February-March 2014 storm event (TSS was 189,000 mg/L)
- The majority of TDS in water samples can be accounted for by chloride, sulfate, and dissolved metals (over 90% in Amphitheater Canyon and Line Canyons)
- The most detection and highest concentrations of PAHs were found in Line and Amphitheater Canyon stormwater samples
- Line Canyon base flow was consistently measured above 9,000 mg/L TDS and 14,000 uMHOS/cm conductivity over the course of the project
- The greatest loading rate of pollutants was found in Line Canyon due to the high discharge rate at the time of sampling

Amphitheater Canyon stormwater runoff result in very large storm event loads of sediment and metals.

4.1 Stormwater Sample Results

A total of 14 stormwater samples were collected over the duration of the project. Three stormwater samples were collected during the first storm in November from Madriano, Padre Juan, and Amphitheater Canyons. Laboratory results from the Line Canyon sample showed the highest TSS and TDS concentrations to be 5,290 and 59,700 milligrams per liter (mg/L), respectively (Table 4.1-4.2). The November stormwater samples from Madriano and Line Canyons also had notable concentrations of DRO of 5.9 and 5.5 mg/L respectively (Table 4.1-4.2). The sample taken from Line Canyon during this event had a concentration of almost 2 micrograms per liter (µg/L) of naphthalene, which informed the decision to add PAHs in subsequent samples (Table 4.2). The highest concentrations of total metals during this event were found in the sample from Line Canyon.

During the three day February-March storm event there were eleven samples collected; all five creeks were sampled once for the full expanded analyte list, then during the following days of the storm Javon and Padre Juan Canyons were sampled once more, and Line and Amphitheater Canyons twice more. The samples taken during these following days were only analyzed for TDS, TSS, conductivity, and salts. This event produced large stormwater discharge rates in Line and Amphitheater Canyons of approximately 45 and 260 cfs, respectively. The highest concentration of TSS measured during this event was 189,000 mg/L in a sample from Amphitheater Canyon (Table 4.2). Notable results from this event are 4.7 µg/L of bis(2-ethylhexyl)phthalate detected in a sample from Line Canyon (Table 4.2). Generally the most detections and highest concentrations of PAHs were from samples taken in Line and Amphitheater Canyons (Table 4.3).

Many of the total and dissolved metals were found to be at high concentrations (Table 4.4). Across the canyons, concentrations of total metals correlate with TSS concentrations (Table 4.5) and, therefore, are generally highest in Amphitheater Canyon, where the highest concentrations of TSS were found. Javon Canyon had sediment-rich discharge at the time of sampling and was also found to have elevated concentrations of metals.

TDS concentrations differed between watersheds and fluctuated throughout storm event. In Line and Amphitheater Canyons, these concentrations decreased over the three day event, which would be expected as elevated salt and metal concentrations are being flushed out. The total mass of the 24 dissolved metals on the analyte list account for about 25% of the total dissolved solids (Table 4.3). In samples taken from Javon, Line, and Amphitheater Canyon the remaining TDS is mostly chloride and sulfate (Table 4.3). Madriano and Padre Juan Canyons had lower flow rates at the time of sampling, much lower TDS concentrations, and a larger percentage of unknown TDS.

Flow rate would be expected to have a large influence on most pollutant concentrations. Given the small sample size, no clear relationship is seen between flow and analyte concentration, but the highest concentrations of TSS and the pollutants is associated with the greatest discharge rates.

Table 4.1 *–* **Conventional and selected analysis results from stormwater samples: Madriano, Javon, and Padre Juan Canyons**

	MADRIANO CANYON		JAVON CANYON		PADRE JUAN CANYON		
Sample Date	**Nov-21 2013**	**Feb-27 2014**	**Feb-28 2014**	**Mar-1 2014**	**Nov-21 2013**	**Feb-27 2014**	**Mar-1 2014**
Sample Time	**1:00 am**	**2:45 am**	**2:05 pm**	**2:30 pm**	**1:45 am**	**1:55 am**	**3:45 pm**
Stream Flow (cfs)	**0.1 - 0.25**	**0.14**	**1.2**	**3.9**	**0.1 - 0.25**	**0.49**	**9.3**
pH	7.71	-	-	-	7.43	-	-
Conductivity (uMHOS/cm)	287	360	3,480	2,750	726	253	2,560
CONVENTIONAL & SELECTED ANALYTE (mg/L)							
TDS	215	287	2,890	1,980	431	161	1,680
TSS	275	2,160	15,600	12,200	154	303	9,210
COD	135	61.4	55.9	-	78.2	26.2	-
Oil and Grease, Total HEM	ND	1.1*	2.0*	-	ND	ND	-
Diesel Range, DRO, C10-28	5.9	2.2	0.9	-	1.7	0.6	-
Residual Range, RRO, C25-36	-	4.1	2.7	-	-	1.0	-
Benzene	ND	ND	0.00008*	-	ND	ND	-
Toluene	0.0001	0.00011*	0.00016*	-	0.0001	0.00006*	-
Ethylbenzene	ND	ND	0.00006*	-	ND	ND	-
m,p-Xylenes	ND	ND	ND	-	ND	ND	-
o-Xylenes	ND	ND	ND	-	ND	ND	-
1,3,5 - Trimethylbenzene	ND	ND	ND	-	ND	ND	-
1,2,4 - Trimethylbenzene	ND	ND	ND	-	ND	ND	-
Bis(2-ethylhexyl) Phthalate	ND	0.00034*	0.00035*	-	0.00016*	0.0011	-
Acrylamide	0.000042*	ND	0.000031*	-	0.000042*	0.000062	-
Formaldehyde	0.041*	ND	ND	-	0.042*	ND	-
Methanol	0.20*	ND	ND	-	ND	ND	-
2-Propyn-1-ol	ND	ND	ND	-	0.33*	ND	-
Ethylene Glycol	ND	1.3*	ND	-	ND	1.3*	-
Chloride	17.9	12.8	217	143	90.5	19.2	334
Fluoride	0.17*	0.28	0.6*	0.4*	0.78	0.36	0.4*
Nitrate as Nitrogen	0.69	0.42	0.41*	0.27*	0.99	0.5	0.23*
Ammonia as Nitrogen	0.296	0.516	0.918	-	0.217	0.156	-
Sulfate	-	80.6	1660	1290	-	34.5	619

- Analysis or measurement was not performed.

* Data value is considered an estimate; laboratory measurement of the analyte was above the method detection limit but below the method reporting limit.

Table 4.2 – **Conventional and selected analysis results from stormwater samples: Line and Amphitheater Canyons**

	LINE CANYON				AMPHITHEATER CANYON		
Sample Date	**Nov-21 2013**	**Feb-27 2014**	**Feb-28 2014**	**Mar-1 2014**	**Feb-27 2014**	**Feb-28 2014**	**Mar-1 2014**
Sample Time	**2:30 am**	**1:15 am**	**1:45 pm**	**3:25 pm**	**12:45 am**	**1:20 pm**	**3:15 pm**
Stream Flow (cfs)	**2**	**4.7**	**2.1**	**45**	**1.3**	**4.6**	**-**
pH	7.67	-	-	-	-	-	-
Conductivity (uMHOS/cm)	7,990	4,270	3,520	3,540	4,620	3,980	3,020
CONVENTIONAL & SELECTED ANALYTE (mg/L)							
TDS	5,290	3,220	2,720	2,120	3,860	3,300	2,350
TSS	59,700	52,800	130,000	122,000	87,800	189,000	135,000
COD	150	52.4	-	-	64.8	-	-
Oil and Grease, Total HEM	ND	ND	-	-	ND	-	-
DRO (C10-C28)	5.5	0.79	-	-	0.5	-	-
RRO (C25-36)	-	0.84	-	-	0.56	-	-
Benzene	0.00012*	0.00014*	-	-	0.0001*	-	-
Toluene	0.00037*	0.00032*	-	-	0.00023*	-	-
Ethylbenzene	0.00029*	0.00025*	-	-	0.00018*	-	-
m,p-Xylenes	ND	0.00011*	-	-	ND	-	-
o-Xylenes	0.00009*	ND	-	-	ND	-	-
1,3,5 - Trimethylbenzene	0.00018*	ND	-	-	ND	-	-
1,2,4 - Trimethylbenzene	0.0012*	0.00011*	-	-	ND	-	-
Bis(2-ethylhexyl) Phthalate	ND	0.0047	-	-	0.001	-	-
Acrylamide	0.000059*	0.000042*	-	-	0.000074*	-	-
Formaldehyde	0.028*	ND	-	-	ND	-	-
Methanol	ND	ND	-	-	ND	-	-
2-Propyn-1-ol	ND	ND	-	-	ND	-	-
Ethylene Glycol	ND	ND	-	-	ND	-	-
Chloride	1090	430	270	216	220	117	70
Fluoride	0.6	0.4*	0.5*	0.5*	0.4*	0.5*	0.4*
Nitrate as Nitrogen	3.02	1.5	0.74	0.47*	9.7	18.2	8.13
Ammonia as Nitrogen	1.56	0.908	-	-	1.55	-	-
Sulfate	-	1430	1640	1760	2440	2470	1610

- Analysis or measurement was not performed.
* Data value is considered an estimate; laboratory measurement of the analyte was above the method detection limit but below the method reporting limit.

Table 4.3 – **PAH analysis results from stormwater samples**

	MADRIANO CANYON		JAVON CANYON	PADRE JAUN CANYON		LINE CANYON		AMPHITHEATER CANYON
Sample Date	**Nov-21 2013**	**Feb-27 2014**	**Feb-28 2014**	**Nov-21 2013**	**Feb-27 2014**	**Nov-21 2013**	**Feb-27 2014**	**Feb-27 2014**
Sample Time	**1:00 am**	**2:45 am**	**2:05 pm**	**1:45 am**	**1:55 am**	**2:30 am**	**1:15 am**	**12:45 am**
Stream Flow (cfs)	**-**	**4.7**	**1.2**	**-**	**0.49**	**-**	**4.7**	**1.3**
POLYCYCLIC AROMATIC HYDROCARBONS – PAHs (µg/L)								
Naphthalene	0.062*	0.017*	0.016*	0.14*	0.022	1.9	0.097	0.0088*
2-Methylnaphthalene	-	ND	0.0052*	-	0.0050*	-	0.2	0.0087*
Acenaphthylene	-	ND	ND	-	0.014*	-	ND	ND
Acenaphthene	-	ND	0.0052*	-	ND	-	0.05	ND
Dibenzofuran	-	0.033	0.012*	-	0.02	-	0.035	0.011*
Fluorene	-	ND	ND	-	0.011*	-	0.11	0.012*
Phenanthrene	-	0.035	0.029	-	0.02	-	0.22	0.016*
Anthracene	-	ND	0.0085*	-	ND	-	ND	ND
Fluoranthene	-	0.011*	0.017*	-	0.019*	-	0.016*	0.026
Pyrene	-	0.016*	0.022	-	0.015*	-	0.022	0.022
Benz(a)anthracene	-	ND	ND	-	0.0041*	-	0.013*	0.0043*
Chrysene	-	0.029	0.039	-	0.015*	-	0.047	0.015*
Benzo(b)fluoranthene	-	ND	0.01*	-	ND	-	ND	0.0086*
Benzo(k)flouranthene	-	ND	ND	-	ND	-	ND	ND
Benzo(a)pyrene	-	ND	ND	-	ND	-	ND	ND
Indeno(1,2,3-cd)pyrene	-	ND	ND	-	ND	-	ND	ND
Dibenz(a,h)anthracene	-	ND	ND	-	ND	-	ND	ND
Benzo(g,h,i)perylene	-	0.0072*	0.011*	-	0.0076*	-	0.012*	0.0048*

- Analysis or measurement was not performed.
* Data value is considered an estimate; laboratory measurement of the analyte was above the method detection limit but below the method reporting limit.

Table 4.4 – **Metal analysis results from Stormwater Samples**

	MADRIANO CANYON		JAVON CANYON	PADRE JUAN CANYON		LINE CANYON		AMPHITHEATER CANYON
Sample Date	**Nov-21 2013**	**Feb-27 2014**	**Feb-28 2014**	**Nov-21 2013**	**Feb-27 2014**	**Nov-21 2013**	**Feb-27 2014**	**Feb-27 2014**
Sample Time	**1:00 am**	**2:55 am**	**2:05 pm**	**1:45 am**	**1:55 am**	**2:30 am**	**1:15 am**	**12:45 am**
Stream Flow (cfs)	**-**	**4.7**	**1.2**	**-**	**0.49**	**-**	**4.7**	**1.3**
TOTAL METALS (mg/L)								
Aluminum	-	38.3	373	-	4.61	-	816	1790
Antimony	-	ND	0.0275*	-	ND	-	ND	ND
Arsenic	0.0058*	0.0282	0.218	0.0055*	0.0083*	0.863	0.5	1.14
Barium	0.117	0.608	5.65	0.0699	0.079	12.9	7.28	14
Beryllium	-	0.0024	0.0164	-	0.00023*	-	0.0459	0.096
Boron	0.0582	0.118	1.18	0.409	0.114	5	2.3	3.51
Cadmium	-	0.0037	0.0195	-	ND	-	0.0526	0.13
Calcium	-	84.4	607	-	24.9	-	954	1970
Chromium	-	0.0915	1	-	0.0129	-	1.8	4.34
Cobalt	-	0.0324	0.21	-	0.0038*	-	0.501	1.18

Table 4.4 – continued

	MADRIANO CANYON		JAVON CANYON	PADRE JUAN CANYON		LINE CANYON		AMPHITHEATER CANYON
Sample Date	**Nov-21 2013**	**Feb-27 2014**	**Feb-28 2014**	**Nov-21 2013**	**Feb-27 2014**	**Nov-21 2013**	**Feb-27 2014**	**Feb-27 2014**
Sample Time	**1:00 am**	**2:55 am**	**2:05 pm**	**1:45 am**	**1:55 am**	**2:30 am**	**1:15 am**	**12:45 am**
TOTAL METALS (mg/L)								
Copper	0.0253	0.0893	0.634	0.0204	0.0169	2.79	1.53	3.23
Iron	-	79.9	692	-	9.39	-	1400	3340
Lead	0.0068*	0.0141	0.221	0.0126	0.0087*	0.985	0.452	1.12
Magnesium	6.13	39.9	408	13.8	6.79	1520	665	1670
Manganese	-	0.99	7.45	-	0.161	-	16	38.3
Mercury	-	0.00027*	0.00074*	-	0.00002*	-	0.00146	0.00444
Nickel	-	0.174	1.28	-	0.0156	-	2.24	5.11
Potassium	7.05	17.6	120	8.09	4.2	475	287	563
Selenium	-	ND	0.291	-	ND	-	ND	ND
Silver	-	ND	ND	-	ND	-	ND	ND
Sodium	-	18.6	435	-	16.5	-	665	730
Thallium	-	ND	ND	-	ND	-	ND	ND
Vanadium	-	0.112	1.24	-	0.0185	-	2.32	5.6
Zinc	-	0.279	1.93	-	0.076	-	4.14	9.78
DISSOLVED METALS (mg/L)								
Aluminum	-	ND	ND	-	0.0083*	-	ND	ND
Antimony	-	ND	ND	-	ND	-	ND	ND
Arsenic	-	ND	ND	-	ND	-	ND	ND
Barium	-	0.0196	0.0716	-	0.0114	-	0.0393	0.0207
Beryllium	-	ND	ND	-	ND	-	ND	ND
Boron	-	0.0606	0.648	-	0.105	-	1.49	0.416
Cadmium	-	ND	ND	-	ND	-	ND	ND
Calcium	-	34.5	245	-	17.5	-	178	235
Chromium	-	0.0009*	ND	-	0.0012*	-	0.0007*	0.0009*
Cobalt	-	0.0006*	0.0005*	-	ND	-	0.0007*	0.0008*
Copper	-	0.0068	0.0035*	-	0.0037*	-	0.0015*	0.007
Iron	-	0.0294	0.0162*	-	0.0196*	-	0.0153*	0.035
Lead	-	ND	ND	-	ND	-	ND	ND
Magnesium	-	6.31	128	-	3.33	-	121	182
Manganese	-	0.0047	0.0909	-	0.0132	-	0.0205	0.0131
Mercury	-	ND	ND	-	ND	-	ND	ND
Nickel	-	0.0047	0.0099	-	0.001*	-	0.0064	0.0128
Potassium	-	5.41	15.7	-	2.9	-	13.2	14.6
Selenium	-	0.0046*	0.0076*	-	ND	-	0.0141*	0.0153*
Silver	-	ND	ND	-	ND	-	ND	ND
Sodium	-	17.9	394	-	16.6	-	561	557
Thallium	-	ND	ND	-	ND	-	ND	ND
Vanadium	-	0.0014*	0.0009*	-	0.0017*	-	0.0012*	0.001*
Zinc	-	0.0016*	0.0007*	-	0.0029*	-	0.0015*	0.0027*

- Analysis or measurement was not performed.

* Data value is considered an estimate; laboratory measurement of the analyte was above the method detection limit but below the method reporting limit.

Table 4.5 – **Squared Pearson Correlation Coefficients for TSS, TDS, total metals, and total dissolved metals during beginning of February-March storm**

	TSS	TDS	TM	TDM
TSS	1			
TDS	0.732	1		
TM	0.971	0.757	1	
TDM	0.696	0.998	0.716	1

The correlation coefficients measure the linear dependence between the two variables, where 1 is a total positive correlation, 0 is no correlation, and -1 is a total negative correlation. Correlations coefficients are calculated with a limited dataset using only one sample from each canyon (5 sample points total) taken during February 27th and 28th. Only these sample results were used because they are the only stormwater samples that were tested for the full list of 24 metals in both total and dissolved form.
TSS – total suspended solids
TDS – total dissolved solids
TM – total metals
TDM – total dissolved metals

Table 4.6 – **Percentage of TDS accounted for by chloride, sulfate, and total dissolved metals in February-March storm**

	Madriano	Javon	Padre Juan	Line	Amphitheater
Sample Date	**Feb-27 2014**	**Feb-28 2014**	**Feb-27 2014**	**Feb-27 2014**	**Feb-27 2014**
Time	2:55am	2:05pm	1:55am	1:15am	12:45am
Flow (cfs)	0.14	1.2	0.49	4.7	1.3
TDS (mg/L)	287	2890	161	3220	3860
Constituent Ratio (decimal percent)					
TDM	0.22	0.27	0.25	0.27	0.26
chloride	0.04	0.08	0.12	0.13	0.06
sulfate	0.28	0.57	0.21	0.44	0.63
TOTAL	**0.55**	**0.92**	**0.59**	**0.85**	**0.95**

4.2 Line Canyon Base Flow Sample Results

Line Canyon was the only one of the five canyons to sustain base flow during the project sampling timeline, and this base flow was sampled three times. Up to 91 different analyses were performed on these base flow samples by a certified laboratory using the methods listed in Section 2.0. The discharge rate of this base flow was measured at least nine times over the duration of the study and was always measured between 0.85 and 1.1 L/s (0.03 and 0.04 cfs) regardless of the occurrence of storm events. The small 0.25 L/s (0.01 cfs) variation in measurements may be due to measurement error.

Sample results of the base flow showed TDS concentrations up to 10,500 mg/L and electrical conductivity up to 14,700 µS/cm. DROs and several PAHs were found in Line Canyon base flow at detectable concentrations. Three PAHs (benzo(a)pyrene, indeno(1,2,3-cd)pyrene, and dibenzo(a,h)anthracene) were detected in the base flow first sample but in none of the stormwater samples (Table 4.7). Most notable results from the metals analysis are the very high boron, sodium, and chloride, and sulfate concentrations that are an order of magnitude higher in some cases than the stormwater samples (Tables 4.7 and 4.8).

Table 4.7 – **Line Canyon Base Flow Sample Results: conventional tests, selected organics and Polycyclic Aromatic Hydrocarbons (PAHs)**

	SAMPLE RESULTS		
Sample Date	**Oct-23 2013**	**Jan-22 2014**	**Apr-21 2014**
Sample Time	**2:00 pm**	**6:45 am**	**6:40 am**
Stream Flow (cfs)	**0.03**	**0.037**	**0.034**
pH	8.27	-	-
Conductivity (uMHOS/cm)	14,700	14,200	12,900**
CONVENTIONAL & SELECTED ANALYTES (mg/L)			
TDS	9,760	9,450	10,500
TSS	ND	ND	48.5
COD	155	118	-
Oil and Grease, Total HEM	-	ND	1.9*
DRO C10-C28	-	2.3	1.4
RRO C25-36	-	1.5	0.5*
Benzene	-	ND	ND
Toluene	-	ND	0.00011*
Ethylbenzene	-	ND	ND
m,p-Xylenes	-	ND	ND
o-Xylenes	-	ND	ND
1,3,5 – Trimethylbenzene	-	ND	ND
1,2,4 – Trimethylbenzene	-	ND	0.00011*
Bis(2-ethylhexyl) Phthalate	-	ND	ND
Acrylamide	-	0.000027*	0.000044*
Formaldehyde	-	ND	ND
Methanol	-	ND	ND
2-Propyn-1-ol	-	ND	ND
Ethylene Glycol	-	ND	ND
Chloride	4050	3620	4130
Fluoride	0.7 *	0.5*	0.6*
Nitrate as Nitrogen	2.6	2.29	1.57
Ammonia as Nitrogen	0.866	2.11	1.11
Sulfate	-	-	2220
POLYCYCLIC AROMATIC HYDROCARBONS – PAHs (ug/L)			
Naphthalene		0.069	0.016*
2-Methylnaphthalene		0.0061*	ND
Acenaphthylene		ND	0.12*
Acenaphthene		ND	ND
Dibenzofuran		ND	ND
Fluorene		ND	ND
Phenanthrene		ND	ND
Anthracene		ND	ND
Fluoranthene		ND	ND

Table 4.7 – continued

	SAMPLE RESULTS		
Sample Date	**Oct-23 2013**	**Jan-22 2014**	**Apr-21 2014**
POLYCYCLIC AROMATIC HYDROCARBONS – PAHs (ug/L)			
Pyrene		ND	ND
Benz(a)anthracene		ND	ND
Chrysene		ND	ND
Benzo(b)fluoranthene		ND	ND
Benzo(k)fluoranthene		ND	ND
Benzo(a)pyrene		0.0059*	ND
Indeno(1,2,3-cd)pyrene		0.0047*	ND
Dibenz(a,h)anthracene		0.0039*	ND
Benzo(g,h,i)perylene		0.0070*	ND

- Analysis or measurement was not performed.
* Data value is considered an estimate; laboratory measurement of the analyte was above the method detection limit but below the method reporting limit.
**Data was flagged by Blue Tomorrow for inconsistencies with field tests and TDS results. At the time report was submitted, the laboratory could not determine if there were any issues with their quality controls. Sample was reanalyzed after the holding time and was found to be as high as 15,400 uMHOS/cm. Conductivity is not expected to change significantly over time.

Table 4.8 – **Line Canyon Base flow Sample Results: total metals**

	SAMPLE RESULTS			
Sample Date	**Oct-23 2013**	**Jan-22 2014**	**Apr-21 2014**	
Sample Time	**2:00 pm**	**6:45 am**	**6:40 am**	
Stream Flow (cfs)	**0.03**	**0.037**	**0.034**	
METALS (mg/L)	**TOTAL**	**TOTAL**	**TOTAL**	**DISSOLVED**
Aluminum	-	0.0398	0.499	ND
Antimony	-	0.0117*	ND	ND
Arsenic	0.0073*	0.0086*	ND	ND
Barium	0.205	0.207	0.139	0.114
Beryllium	-	ND	ND	ND
Boron	20.4	19.1	19.7	19.1
Cadmium	-	ND	ND	ND
Calcium	-	187	317	290
Chromium	-	ND	0.0028*	0.0011*
Cobalt	-	0.0008*	0.0019*	0.0018*
Copper	0.0043	0.0015*	0.0042*	0.0042
Iron	-	0.38	1.33	0.0193*
Lead	0.006*	ND	ND	ND
Magnesium	240	229	235	222
Manganese	-	0.216	0.243	0.151
Mercury	-	ND	0.00004*	ND
Nickel	-	0.0094	0.0176	0.0149
Potassium	18.1	19.2	25.2	23.8
Selenium	-	ND	ND	ND
Silver	-	ND	ND	ND
Sodium	-	2870	3090	2990
Thallium	-	ND	ND	ND
Vanadium	-	0.0028*	0.0034*	0.0021*

Table 4.8 – continued

Sample Date	Oct-23 2013	Jan-22 2014	Apr-21 2014	
Sample Time	**2:00 pm**	**6:45 am**	**6:40 am**	
Stream Flow (cfs)	**0.03**	**0.037**	**0.034**	
METALS (mg/L)	**TOTAL**	**TOTAL**	**TOTAL**	**DISSOLVED**
Zinc	-	0.001*	0.0039*	0.0004*

- Analysis or measurement was not performed.
* Data value is considered an estimate; laboratory measurement of the analyte was above the method detection limit but below the method reporting limit.
The sample collected on April 21, 2014 is the only base flow sample that tested for total and dissolved metals.

4.3 Sediment Sample Results

There were a total of ten sediment samples collected, two from each of the five creeks. The samples were collected from an approximately 0.19 to 0.37 m^2 (2 to 4 ft^2) area of undisturbed stream deposited sediments. These sediment samples had up to 53 different analyses performed on them by a certified laboratory using the methods listed in Section 2.0.

The first sediment sample was collected on October 23, 2013, before any substantial rainfall had occurred in the 2013-2014 rainy season. The first sediment sample results showed the highest concentration of oil and grease in Madriano and Line Canyons at 1,740 and 1,610 mg/kg, respectively (Table 4.11). DROs were also detected in all of the first sediment samples, with the highest concentration being 200 mg/kg in the Madriano Canyon sample. Another notable detection from the first sediment samples was that of bis(2-ethylhexyl)phthalate, found in all the creek sediments except Madriano Canyon, with the highest concentration found in Line Canyon at 0.17 mg/kg (Table 4.9).

A second sediment sample was collected from each of the five creeks on March 7, 2014, after two significant stormwater runoff events were sampled, and within a week of the larger February-March 2014 storm event. This second sediment sample added 17 PAHs, 17 metals, and Residual Range Organics (RRO) to the analyte list. Several PAHs were detected above reporting limits, especially in Madriano and Padre Juan Canyons (Table 4.9). For all sediment samples, several of the metals detected were relatively high, including aluminum, arsenic, boron, cadmium, lead, and selenium (Table 4.10).

Generally, the concentrations of metals that were analyzed for in the first sediment sample from a given canyon were within a factor of two of the concentration in the second (post-storm) samples (Table 4.11). The largest differences between the first and second sample occurred in Padre Juan Canyon samples.

Table 4.9 – **Selected organics and PAHs in sediment samples**

	MADRIANO CANYON		JAVON CANYON		PADRE JUAN CANYON		LINE CANYON		AMPHITHEATER CANYON	
Sample Date	**Oct-23 2013**	**Mar-7 2014**	**Oct-23 2013**	**Mar-7 2014**	**Oct-23 2013**	**Mar-7 2014**	**Oct-23 2013**	**Mar-7 2014**	**Oct-23 2013**	**Mar-7 2014**
Time	**10:15 am**	**10:00 am**	**11:00 am**	**10:20 am**	**11:15 am**	**10:40 am**	**12:35 am**	**11:00 am**	**12:00 am**	**11:25 am**
SELECTED ORGANICS (mg/kg)										
Oil and Grease, Total HEM	1,740	1,600	200	430	160	960	120	1,610	310	ND
Diesel Range, DRO, C10-28	200	61	50	22	24	25	48	ND	15	10
Residual Range, RRO, C25-36	-	340	-	96	-	170	-	9.3*	-	43
Benzene	ND	0.000092*	ND	ND	ND	ND	ND	ND	ND	ND
Toluene	0.00001*	ND	ND	ND	ND	ND	ND	ND	ND	ND
Ethylbenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
m,p-Xylenes	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
o-Xylenes	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,3,5 – Trimethylbenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,2,4 - Trimethylbenzene	ND	ND	0.0000081*	ND	ND	ND	ND	ND	ND	ND
Bis(2-ethylhexyl) Phthalate	ND	ND	0.04*	ND	0.012*	ND	0.17	ND	0.0091*	ND
POLYCYCLIC AROMATIC HYDROCARBONS – PAHs (µg/kg)										
Naphthalene	ND	0.81*	ND	ND	ND	0.65*	ND	ND	ND	ND
2-Methylnaphthalene	-	0.51*	-	0.78*	-	0.49*	-	ND	-	0.47*
Acenaphthylene	-	ND	-	ND	-	ND	-	ND	-	ND
Acenaphthene	-	ND	-	ND	-	ND	-	ND	-	ND
Dibenzofuran	-	ND	-	ND	-	ND	-	ND	-	ND
Fluorene	-	ND	-	ND	-	ND	-	ND	-	ND
Phenanthrene	-	6.1	-	2.5*	-	4.2	-	ND	-	ND
Anthracene	-	ND	-	ND	-	ND	-	ND	-	ND
Fluoranthene	-	7.9	-	1.7*	-	3.5	-	ND	-	2.7*
Pyrene	-	9.4	-	2.9*	-	5.9	-	ND	-	2.2*
Benz(a)anthracene	-	2.6*	-	ND	-	1.3*	-	ND	-	ND
Chrysene	-	20	-	4.8	-	12	-	0.93*	-	2.8*
Benzo(b)fluoranthene	-	7.7	-	2.2*	-	3.9	-	ND	-	2.6*
Benzo(k)fluoranthene	-	ND	-	ND	-	ND	-	ND	-	ND
Benzo(a)pyrene	-	ND	-	ND	-	ND	-	0.76*	-	ND

Table 4.9– continued

	MADRIANO CANYON		JAVON CANYON		PADRE JUAN CANYON		LINE CANYON		AMPHITHEATER CANYON	
Sample Date	**Oct-23 2013**	**Mar-7 2014**	**Oct-23 2013**	**Mar-7 2014**	**Oct-23 2013**	**Mar-7 2014**	**Oct-23 2013**	**Mar-7 2014**	**Oct-23 2013**	**Mar-7 2014**
Time	**10:15 am**	**10:00 am**	**11:00 am**	**10:20 am**	**11:15 am**	**10:40 am**	**12:35 am**	**11:00 am**	**12:00 am**	**11:25 am**
POLYCYCLIC AROMATIC HYDROCARBONS – PAHs (µg/kg)										
Indeno(1,2,3-cd)pyrene	-	3.7*	-	ND	-	ND	-	ND	-	ND
Dibenz(a,h)anthracene	-	2.5*	-	ND	-	1.1*	-	ND	-	ND
Benzo(g,h,i)perylene	-	12	-	3.0*	-	5.1	-	ND	-	1.5*

- Analysis or measurement was not performed.

* Data value is considered an estimate; laboratory measurement of the analyte was above the method detection limit but below the method reporting limit.

Table 4.10 – **Metals in sediment samples**

	MADRIANO CANYON		JAVON CANYON		PADRE JUAN CANYON		LINE CANYON		AMPHITHEATER CANYON	
Sample Date	**Oct-23 2013**	**Mar-7 2014**	**Oct-23 2013**	**Mar-7 2014**	**Oct-23 2013**	**Mar-7 2014**	**Oct-23 2013**	**Mar-7 2014**	**Oct-23 2013**	**Mar-7 2014**
Time	**10:15 am**	**10:00 am**	**11:00 am**	**10:20 am**	**11:15 am**	**10:40 am**	**12:35 am**	**11:00 am**	**12:00 am**	**11:25 am**
METALS (mg/kg)										
Aluminum	-	9,470	-	6,970	-	10,600	-	3,930	-	6,570
Antimony	-	ND	-	ND	-	ND	-	ND	-	ND
Arsenic	5.6	7.8	10.9	5.6	4.5	5.9	2.9	3	5.5	5
Barium	207	199	147	147	197	130	82.9	69.9	102	115
Beryllium	-	0.47	-	0.34	-	0.52	-	0.17	-	0.32
Boron	12.1	13.5	27.3	12.4	11.3	24.4	19.7	10.6	29.4	10
Cadmium	-	0.71	-	0.53	-	0.42	-	0.23	-	0.41
Calcium	-	13,800	-	13,400	-	14,100	-	7,180	-	10,300
Chromium	-	26.9	-	19	-	25.2	-	9.3	-	16
Cobalt	-	6.55	-	4.59	-	7.1	-	2.76	-	4.68
Copper	14.4	17.4	18.6	13.7	8.5	16.4	4.5	6	10.1	12.1
Iron	-	18,200	-	13,600	-	19,700	-	8,210	-	14,100
Lead	7.9	7.8	28.1	5	3.5	7.2	2.3	2.4	3.7	4.3
Magnesium	6,110	7,310	8,270	6,130	3,710	9,110	2,240	3,220	11,500	6,170
Manganese	-	213	-	176	-	309	-	110	-	178
Mercury	-	0.062	-	0.023	-	0.016	-	0.013	-	0.019
Nickel	-	40.8	-	28.5	-	38.5	-	10.4	-	20.9
Potassium	2,100	2,570	2,190	2,020	1,150	2,530	787	1,220	2,180	2,160
Selenium	-	8.3	-	6.5	-	8.7	-	3.8	-	6.2
Silver	-	ND	-	ND	-	ND	-	ND	-	ND
Sodium	-	305	-	1,230	-	2,180	-	1,930	-	1,370
Thallium	-	ND	-	ND	-	ND	-	ND	-	ND
Vanadium	-	33.1	-	23.3	-	34.9	-	12.7	-	20.6
Zinc	-	56.8	-	41.6	-	52.2	-	22.8	-	37.3
- Analysis or measurement was not performed.										

Table 4.11 – **Percent difference from first to second sediment sample**

METAL	MADRIANO	JAVON	PADRE JUAN	LINE	AMPHITHEATER
Arsenic	39%	-49%	31%	3%	-9%
Barium	-4%	0%	-34%	-16%	13%
Boron	12%	-55%	116%	-46%	-66%
Copper	21%	-26%	93%	33%	20%
Lead	-1%	-82%	106%	4%	16%
Magnesium	20%	-26%	146%	44%	-46%
Potassium	22%	-8%	120%	55%	-1%

4.4 Field Testing Results

Field test were performed eight times on the Line Canyon base flow and another 15 times total for all creeks during stormwater runoff events (Table 4.12-4.14). Field tests consisted of onsite measurements of turbidity, TDS, pH, electrical conductivity (EC), temperature, and flow at time of measurement.

Line Canyon base flow tests represent the majority of field tests performed during the sampling timeline. The flow rate of the base flow from Line Canyon did not fluctuate from 8.5 L/s to 11.3 L/s (0.03 to 0.04) cfs over the duration of the project, except during storm events. This base flow was found to have TDS concentrations ranging from 9,000 to 9,550 mg/L, and electrical conductivity ranging from 14,400 to over 16,000 (Table 4.12). Stormwater runoff in Line Canyon and the other four canyons saw more diluted but still fairly high levels of these parameters (Table 4.13 and 4.14). The lowest TDS and EC readings were seen in stormwater runoff from Madriano Canyon (Table 4.13). The flow tested in Madriano Canyon during these storm events was generated by impervious roads and other surfaces just upstream of the sampling site.

Turbidity measurements are only reported for Line Canyon base flow because stormwater runoff was very turbid and beyond the 1100 FAU limit of the measurement instrument. Dissolved oxygen was also measured during most tests of Line Canyon base flow and during several of the stormwater tests and always found to be between about 9 and 12 mg/L. This data was not reported below due to concerns about the accuracy of the data and disagreement between testing instruments.

Table 4.12 – **Line Canyon Base Flow Field Test Results**

	FIELD TEST RESULTS							
Date	**Oct-9 2013**	**Oct-23 2013**	**Jan-22 2014**	**Jan-31 2014**	**Feb-12 2014**	**Feb-25 2014**	**Mar-4 2014**	**Apr-21 2014**
Time of Tests	**-**	**12:35 pm**	**7:45 am**	**1:05 pm**	**10:30 am**	**3:00 pm**	**4:00 pm**	**6:40 am**
Stream Flow (cfs)	**-**	**0.03**	**0.037**	**0.04**	**0.032**	**0.035**	**0.032**	**0.034**
FIELD TEST								
Turbidity (FAU)	26	19.7	22.5	24	30.5	17	323	35
TDS (mg/L)	9,200	9,250	9,080	9,057	9,007	9,047	9,457	9,547
pH	8.24**	8.23**	8.32	8.36	8.28	8.2	7.93	8.12
EC (µS/cm)	14,900**	15,000**	14,637	14,710	14,400	14,487	15,513	16,040
Temperature (c°)	-	16.8	8.67	15.7	13.5	16.3	17.1	13

- Analysis or measurement was not performed.
**Data is flagged for poor data quality; instruments were not calibrated to sufficient accuracy; data values reported for pH are flagged but assumed to be reasonably close to the actual value, while the data values reported for EC are estimated from TDS measurements and the relationship established from data generated in this study.

Table 4.13 – **Stormwater Field Test Results: Madriano, Javon, Padre Juan, and Amphitheater**

	MADRIANO CANYON		**JAVON CANYON**		**PADRE JUAN CANYON**		**AMPHITHEATER CANYON**	
Date	**Feb-28 2014**	**Mar-1 2014**	**Feb-28 2014**	**Mar-1 2014**	**Feb-28 2014**	**Mar-1 2014**	**Feb-27 2014**	**Mar-1 2014**
Time of Tests	**4:45 pm**	**2:55 pm**	**11:20 am**	**2:30 pm**	**10:55 am**	**3:45 pm**	**3:45 am**	**3:15 pm**
Stream Flow (cfs)	**0.056**	**-**	**0.12**	**3.9**	**0.4**	**9.3**	**0.12**	**260***
FIELD TEST								
TDS (mg/L)	170	251	4,410	1,860	3,790	2,057	2,840	1,910
pH	8.06	8.19	7.8	8.21	8.44	8.23	8.69	8.44
EC (µS/cm)	246	384	6,963	2,910	6,180	3,367	4,517	2,993
Temperature (c°)	14.1	-	15	13.1	14.8	13.3	14.2	13.6

Any flow in these for creeks was considered stormwater runoff because these watersheds were not observed to have any intermittent or perennial flow over the timeframe of the project. Turbidity is not reported for stormwater runoff because the sediment rich water was well beyond the 1100 FAU limit of the meter and transmitted essentially no light.
- Analysis or measurement was not performed.
* Measurement was not taken during field tests, but during a period of peak discharge that occurred within 1 to 2 hours following test; reported discharge rate may be as much as twice that which was occurring during tests.

Table 4.14 – **Line Canyon Stormwater Field Test Results**

	FIELD TEST RESULTS						
Date	**Nov-21 2013**	**Dec-7 2013**	**Feb-6 2014**	**Feb-27 2014**	**Feb-28 2014**	**Mar-1 2014**	**Apr-1 2014**
Time of Tests	**7:30 pm**	**10:25 am**	**4:25 pm**	**4:07 am**	**10:15 am**	**3:25 pm**	**12:00 pm**
Stream Flow (cfs)	**0.06**	**1.3**	**0†**	**1**	**1.3**	**45 ††**	**0.0777**
FIELD TEST							
TDS (mg/L)	9,990	4,223	-	4,027	4,820	2,173	9,103
pH	8.39**	8.14**	8.7	8.46	8.04	8.04	8.18
EC (µS/cm)	16,200**	6,800**	12,610	6,243	8,390	3,270	14,920
Temperature (c°)	15.3	10.2	12	13.8	15.3	13.7	13.6

Field measurements taken from Line Canyon within 12 hours of storm event were considered stormwater runoff. Turbidity is not reported for stormwater runoff because the sediment rich water was well beyond the 1100 (FAU) limit of the meter and transmitted no light.

† Flow stopped during tests, likely due to the closing of the upstream check dam. Flow was visually estimated to be greater than usual base flow at start of field tests, and flow had resumed typical base flow rate of 0.035 cfs by the next day.

†† Measurement was not taken during field tests, but during a period of peak discharge that occurred within 1 to 2 hours following test; reported discharge rate may be as much as twice that which was occurring during tests.

- Analysis or measurement was not performed.

**Data is flagged for poor data quality; instruments were not calibrated to sufficient accuracy; data values reported for pH are flagged but assumed to be reasonably close to the actual value, while the data values reported for EC are estimated from TDS measurements and the relationship established from data generated in this study.

4.5 Loading Analysis

During and between many of the water sampling activities flow rate was measured. This was used along with sample concentrations to calculate the loading rate (mass per time) of several organics and metals discharged from Line Canyon during the storm event on February 27th 2014 (Table 4.15). Line Canyon was selected for loading analysis of metals and organics because it had the highest concentration of organic pollutants and the greatest discharge at the time of sampling which resulted in the greatest loading rate at the time the sample was collected. Total suspended sediment loading rates were calculated for all canyons that had a discharge and sample taken at the same time during the February-March 2014 storm event (Table 4.16).

The calculated loading rates are highly dependent on flow. Although Amphitheater Canyon had higher concentration of TSS and metals in samples collected on February 27th the loading rate was less than Line Canyon because the discharge rate was over 3 times as much at the time of sampling (Table 4.16).

Total annual loading of diesel range organics (DRO), residual range organics (RRO), and naphthalene was also estimated for the Line Canyon base flow (Table 4.17). High and low annual load estimates were based on flow estimates of 1.1 and 0.85 L/s (0.04 and 0.03 cfs) and the average concentration from the base flow samples collected on January 22, and April 21, 2014. These high and low estimates are plus and minus about 15% of the average.

Loading from February-March 2014 storm

The greatest loading rate of organic and inorganic pollutants, at the time of sample collection, was seen in Line Canyon. On February 27th Line Canyon had an estimated loading rate of 380 and 400 grams per hour for DRO and RRO, respectively. Other organic loading rates worth noting from the Line Canyon flow during this sampling are 2.3 grams per hour of bis (2-ethylhexyl) phthalate, and several PAHs in the range of 10's of milligrams per hour (Table 4.15).

Loading rates of total metals were also calculated for Line Canyon as these were the greatest rates observed at the time of sampling, based on the measured flow and sample concentration. These metal loading rates include 390 kilograms per hour of aluminum, 670 kg/hr of iron, 320 kg/hr magnesium, and 140 kg/hr potassium. Metal loading rates are expected to be much higher from Amphitheater Canyon during its peak discharge. Concentration of metals and TSS was much higher in samples collected from line canyon, but a sample was not able to be collected during the peak discharge of 7400 L/s (260 cfs) on observed on March 1st which would have yielded much higher loading rates than the 130 L/s (4.7 cfs) discharge from Line Canyon during the time of sampling.

The greatest sediment loading rate calculated at the time of sampling was from Line Canyon during a discharge that was measured at 1300 L/s (45 cfs) with a TSS concentration measured at 122,000 mg/L. The loading rate from Line Canyon during this time was estimated at 560 metric tons per hour and 220 cubic meters per hour (Table 4.16). Amphitheater Canyon is assumed to have far exceeded this loading rate during the peak discharge of 7400 L/s (260 cfs), but a sample was not able to be collected during peak discharge. If the concentration of 189,000 mg/L from a previous sample collected from Amphitheater is used this would equate to over 5,000 metric tons per hour and over 2,000 cubic meters per hour (assuming sediment density of 2,500 kg/m^3). This estimate of TSS loading rate from Amphitheater may be conservative, although not verified by samples, because of the larger stream power during this large discharge being able transport more sediment in suspension (=higher TSS concentrations) and observations from the field of vary sediment rich effluent and boulders being moved by this flow.

Annual Loading from Line Canyon Base Flow

Though the base flow in Line Canyon is small (approximately 0.03 to 0.04 cfs), concentrations of DRO and RRO detected can add up to appreciable quantities over a year. DRO and RRO annual loads for Line Canyon may be as much as 66 and 36 kilograms, respectively (Table 4.17).

Table 4.15 – **Loading rates of selected constituents discharged from Line Canyon at 1:15am on February 27, 2014**

METALS	LOADING RATE (kilograms/hour)	ORGANIC POLLUTANTS	LOADING RATE (milligrams/hour)
Aluminum	390	DRO	380,000
Arsenic	0.24	RRO	400,000
Barium	3.5	Benzene	67*
Boron	1.1	Toluene	150*
Cadmium	0.025	Ethylbenzene	120*
Chromium	0.86	m,p-Xylenes	53*
Cobalt	0.24	1,2,4 – Trimethylbenzene	53*
Copper	0.73	Bis(2-ethylhexyl) Phthalate	2,300
Iron	670	Acrylamide	20*
Lead	0.22	Naphthalene	46
Magnesium	320	2-Methylnaphthalene	96
Manganese	7.7	Acenaphthene	24
Mercury	0.0007	Dibenzofuran	17
Nickel	1.1	Fluorene	53
Potassium	140	Phenanthrene	110
Sodium	320	Fluoranthene	7.7*
Vanadium	1.1	Pyrene	11
Zinc	2.0	Benz(a)anthracene	6.2*
		Chrysene	23
		Benzo(g,h,i)perylene	5.7*

The discharge measured at the time of sampling was 4.7 cfs. Together with the high concentration of metals and organics this yielded the greatest loading rate that could be calculated at the time of sampling. All calculations were made and then rounded to two significant figures.
*Estimates were made using constituent concentrations that were above method detection limits but below the method reporting limits.

Table 4.16 – **Sediment loading rates from February-March 2014 storm event**

	MADRIANO	JAVON		PADRE JUAN		LINE			AMPHITHEATER	
Sample Date	Feb-27	Feb-28	Mar-1	Feb-27	Mar-1	Feb-27	Feb-28	Mar-1	Feb-27	Feb-28
Sample Time	2:55am	2:05pm	2:30pm	1:55am	3:45pm	1:15am	1:45pm	3:25pm	12:45am	1:20pm
Discharge rate (cfs)	0.14	1.2	3.9	0.49	9.3	4.7	2.1	45	1.3	4.6
Discharge rate (L/hr)	14,000	120,000	400,000	50,000	950,000	480,000	210,000	4,600,000	130,000	470,000
Concentration in sample (mg/L)	2,160	15,600	12,200	303	9,210	52,800	130,000	122,000	87,800	189,000
TSS Loading Rates										
Pounds per hour	68	4200	11,000	33	19,000	56,000	61,000	1,200,000	26,000	200,000
Metric tons per hour	0.031	1.9	4.9	0.015	8.7	25	28	560	12	89
Cubic meters per hour	0.012	0.76	1.9	0.0061	3.5	10	11	220	4.7	35
Cubic meters of sediment were estimated using an assumed density of 2,500 kg/m^3.										

Table 4.17 – **Loading rates of DRO, RRO, and naphthalene from Line Canyon Base Flow**

POLLUTANT	ESTIMATED LOADING	
LOADING RATE	**HIGH ESTIMATE**	**LOW ESTIMATE**
DRO (milligrams/hour)	7,500	5,700
RRO (milligrams/hour)	4,100	3,100
Naphthalene (milligrams/hour)	0.17	0.13
ANNUAL LOADS	**HIGH ESTIMATE**	**LOW ESTIMATE**
DRO (grams)	66,000	50,000
RRO (grams)	36,000	27,000
Naphthalene (grams)	1.5	1.1
High and low estimates were generated using high and low flow estimates of 0.04 and 0.03 cfs, and average of the pollutant concentrations detected in the base flow samples collected on January 22, and April 21, 2014. Estimates were rounded to two significant figures.		

5.0 | ENVIRONMENTAL SAMPLING SUMMARY

This Environmental Sampling Report describes observations and results from sampling activities in five coastal watersheds in northern Ventura County: Madriano, Javon Padre Juan, Line, and Amphitheater Canyons. Up to 68 different constituents, including several pollutants known to cause cancer, were tested for in water samples and 53 constituents were tested for in sediment samples from October 2013 to the end of April 2014. The initial analyte list of 28 pollutants outlined in the project sampling plan was developed from a list of chemicals known to be found in hydraulic fracturing fluids and known to adversely affect human health, and then was expanded after review of initial samples, lack of qualifying storm events, and based on the project budget. Many of the pollutants that were analyzed for are regulated by the Safe Drinking Water Act.

Sampling Activities and Observations & Discharge Measurements

Sampling activities included a total of 17 water samples, 23 field test activities, and 10 sediment samples. The 17 water samples comprised of three base flow samples from Line Canyon and 14 stormwater samples. Three stormwater samples were taken during a storm that occurred on November 21st 2013, and 11 stormwater samples were taken during a large multi-day storm event that occurred from February 26th to March 2st 2014 (February-March storm event). Field tests were performed on the Line Canyon base flow (the only base flow observed in any of the canyons) over the duration of the sampling timeline, and at least once in each of the canyons during the February-March storm event. Field tests included measurements of stream discharge, conductivity, total dissolved solids (TDS), pH, temperature, and turbidity.

The 2013-2014 winter season was very dry in the study watersheds, while California was experiencing one of its driest years on record. The first storm event of the season that delivered between 0.41 and 0.88 inches of rain generated the greatest discharge from Line Canyon, which was also noted as having effluent that resembled a mud slurry and a strong odor of possible petroleum hydrocarbons. The February-March storm event was much larger and delivered between 3.5 and 7 inches of rain to the study watersheds over the duration of the storm. This storm produced large discharges from all the canyons, with the greatest flows occurring in Line and Amphitheater which were measured at 45 and 260 cfs. During this event all creeks discharged a very sediment rich effluent, though Line and Amphitheater had larger discharge rates and more sediment rich runoff than the other three canyons.

Detected Pollutants and Concentrations

Stormwater samples were collected from Madriano, Padre Juan, and Line Canyons during the first storm event on November 21st, with the greatest flow and generally the highest pollutant concentrations observed in Line Canyon. The stormwater samples collected from Line Canyon were found to contain several organic pollutants including 5.5 mg/L of diesel range organics (DRO) and 1.9 ug/L of naphthalene. Samples from Line Canyon collected during the first storm also contained 5,290 mg/L of total dissolved solids (TDS) and 59,700 mg/L of total suspended solids (TSS), which is associated with high levels of metals. Total metals observed in this sample included 12.9 mg/L of barium, 2.79 mg/L of copper, 0.985 mg/L of lead, and 475 mg/L of potassium. After reviewing these sample results, a greater number of Polycyclic Aromatic Hydrocarbons (PAHs) and metals were tested for in subsequent samples.

The February-March storm had more than one sample collected from each of the five canyons except Madriano (only one collected). Samples collected during this large storm event contained very high concentrations of TSS, most notably in Line and Amphitheater Canyons. A sample collected from Amphitheater Canyon had 189,000 mg/L of TSS which was the highest concentration of TSS found in any of the project water samples. These samples also contained high concentrations of total metals. The sample collected from Amphitheater Canyon was found to contain 1790 mg/L of total aluminum, 1.14 mg/L of total arsenic, 14 mg/L of total barium, 1.12 mg/L of total lead, and 9.78 mg/L of total zinc. The highest concentration of PAHs during this event was found in the sample from Line Canyon, which included several PAHs above reporting limits. During this event, DRO and residual range organics (RRO) were detected in all the canyons at concentrations above 0.5 mg/L, with the highest concentration being RRO at 4.1 mg/L from Madriano Canyon. The majority of TDS can be accounted for by chloride, sulfate, and the dissolved metals.

Pollutant Loading Rates

Metals and organic pollutant loading rates were calculated for Line Canyon because it had the most detections and highest concentration of organics and had the greatest discharge rate at the time of sampling. Amphitheater had higher concentrations of metals in the sample taken on February 27th 2014 but the Line Canyon sample on this day yielded greater loading rates of total metals because it had a much greater discharge rate at the time of sampling. Additionally, Madriano, Javon, and Padre Juan Canyons had higher concentrations of DRO and RRO, but the discharge rate measured in Line Canyon at the time of sampling yielded the greatest loading rates. The loading rates from Line Canyon on February 27th 2014 at the time of sampling included 390 kg/hr of aluminum, over 0.2 kg/hr of both arsenic and lead, 2 kg/hr of zinc, 380 g/hr of DRO, 400 g/hr of RRO, 2.3 g/hr of bis (2-ethylhexyl) phthalate, and many PAHs in the range of 10's of mg/hr.

TSS loading rates were calculated for all samples and creeks that had discharge measured at the time of sampling. Again, the greatest loading rate was observed in Line Canyon due to it having the largest discharge at the time of sampling. On March 1st 2014 Line Canyon was sampled while discharging 1300 L/s (45 cfs) which resulted in a sediment loading rate of 560,000 kg/hr (1.2 million lbs/hr), which (with an assumed sediment density of 2,500 kg/m^3) yields a loading rate of about 220 m^3/hr of sediment. Amphitheater Canyon had higher TSS concentrations measured in samples and a much higher discharge rate that, at peak flow, is estimated to discharge over 2,000 m^3/hr, though this could not be verified as a sample was not collected during peak flow.

Sediment samples

Two sediment samples were collected for each of the canyons, one on October 23rd 2013 at the beginning of the project, and one at the end of the sampling timeline on March 7th 2014. Sediment samples were analyzed by a certified laboratory for metals, and organic compounds that are likely to adsorb to sediment particles. The first sediment sample results showed the highest concentration of oil and grease in Madriano and Line Canyons at 1,740 and 1,610 mg/kg, respectively. The first sediment samples detected bis(2-ethylhexyl)phthalate in all the creeks, except Madriano Canyon, with the highest concentration found in Line Canyon at 0.17 mg/kg.

Line Canyon Base Flow Samples and Field Tests

Line Canyon had a persistent base flow over the duration of the project that was measured frequently at 0.03 to 0.04 cfs (0.85 and 1.1 L/s). This base flow has concentrations of DRO and RRO up to 2.3 and 1.5 mg/L, respectively. In the two base flow samples DRO was found at higher concentrations than RRO, where as in all stormwater samples from the canyons in which both were tested for, RRO was always at a higher concentration than DRO. The concentration of TDS in base flow samples was found to be very high (10,500 mg/L). Chloride and sodium constitute the majority of this TDS at 4,130 and 2,990 mg/L respectively, and dissolved metals constitute most of the remaining dissolved solids. The greatest difference between levels of metals in Line Canyon base flow and stormwater runoff was boron, which was detected at a concentration of 19.1 mg/L in dissolved form. Although the discharge rate from the Line Canyon base flow is very small compared to the stormwater discharges, the DRO and RRO can add up to annual loads of 66 and 36 kilograms.

The Environmental Sampling was designed to test for a wide range of constituents in order to identify possible pollutants of concern from upstream land uses, particularly hydraulic fracturing that has occurred in Line Canyon. Sample results are used in the Toxicity Analysis section to compare with maximum contaminant levels (MCLs) and toxicity screening levels to gauge potential risks to human health and the environment. Potential natural and anthropogenic sources of pollutants are explored and compared with results from sampling activities in the Source Assessment to understand the contributions from various sources to pollutant concentrations found in the Environmental Sampling. These project elements are used to inform the Policy Recommendations and Mitigation Strategies for the study watersheds.

6.0 | ENVIRONMENTAL SAMPLING APPENDIX

6.1 Additional Stormwater Sampling Notes

6.1.1 First Stormwater Sampling Event (November 21, 2013)

The following observations were taken from field notes that were recorded during the first stormwater sampling event.

Madriano Canyon

November 21, 1:00 am – Stormwater samples collected for the first stormwater event at Madriano Canyon. At the beginning of stormwater sampling it appeared that the creek was starting to flow at an estimated rate of 0.1 to 0.25 cubic feet per second (cfs). Depth of the flow was approximately 2 inches at the deepest part of the stream. A large amount of foam was observed in the runoff. Runoff appeared soapy and not overly rich with sediment. When water was collected from the creek, the sampling bottles filled up with foam. A slight odor was observed of possible petroleum hydrocarbons. Rain was steady at about 0.2 inches per hour throughout stormwater sampling at Madriano Canyon.

Padre Juan Canyon

November 21, 1:45 am – Stormwater samples were collected from runoff found in Padre Juan Canyon. At the beginning of the sampling activity there was a light rain, and flow was estimated between 0.1 and 0.25 cubic feet per second. The stream was approximately 1 inch deep and 4 inches wide. At 2:00 am, the rain stopped and the flow decreased. The runoff contained foam, but not as much as was observed in Madriano Canyon.

Line Canyon

November 21, 2:30 am – Stormwater samples collected were collected from Line Canyon, after Javon and Amphitheater Canyons were monitored for flow. Upon arriving at the sampling site, a strong odor was observed of possible petroleum hydrocarbons. Rain had stopped 30 minutes prior to arriving at the Line Canyon sampling site, and there was no rain during the sampling of stormwater from Line Canyon. Depth was approximated up to 6 inches and width between 2 to 3 feet. Flow was estimated at 2 cubic feet per second based on observations the following day. Wetted width was estimated using the high water mark in the creek. A large amount of sediment was observed in the stormwater, and was noted as having the appearance of a mud slurry. A substance presumed to be oil was seen in the eddy areas.

6.1.2 Stormwater Sampling Events (February 27, 2014 - March 1, 2014)

The following observations were taken from field notes that were recorded during the February-March sampling event.

Madriano Canyon

February 27, 2:45 am - There was no rain as sampling commenced at Madriano Canyon. There was a large amount of foam in the stormwater that increased upstream. The flow was measured to be 0.14 cfs. The majority of the flow appeared to come from above the check dam, with a small amount from the oil field road. Stormwater was collected at the end of the first precipitation event. The flow decreased considerably after samples were collected.

February 28, 4:45 pm - Field tests and flow measurements were performed on the stormwater runoff at Madriano Canyon. There was a light drizzle upon arrival to the site. The flow was measured to be 0.056 cfs, and the majority of the water in the creek was observed to originate from a close by oil field road.

March 1, 2:55 pm - Field tests were performed on the stormwater runoff in Madriano Canyon. There was light rain during the field tests. Based on observations, it appeared that all of the water was coming from the oil field road. The wetted bank and channel depth indicated that the flow had decreased from earlier levels.

Javon Canyon

February 27, 2:10 am - Javon Canyon was monitored for stormwater runoff. Precipitation stopped at 2:10 am and sufficient amounts of stormwater from deeper in the canyon were not available to sample. At 2:30 am, there was a very small amount of runoff coming from Highway 101. The creek bed upstream from the culvert appeared dry with no evidence of recent flow.

February 28, 11:20 am - Stream flow was measured at Javon Canyon. There was a small flow that was measured at 0.12 cfs after heavy rain the night before.

February 28, 2:05 pm - Stormwater samples were collected from Javon Canyon. Rain was heavy and increased to its peak between 12:15 to 1:00 pm, following a night of substantial rain. Flow was measured at 1.17 cfs.

March 1, 2:30 pm - Field tests and flow measurements were performed and stormwater samples collected at Javon Canyon. There was a light rain during the field testing and sampling activities. The flow was measured at 3.88 cfs. The flow appeared to have increased. There was some water from Highway 101, but the majority was observed to originate upstream from

Highway 101, deeper in the canyon. Sediment was being discharged with the stream flow, but not as much as other watersheds.

Padre Juan Canyon

February 27, 1:55 am – Stormwater samples were collected and flow measurements completed in Padre Juan Canyon. Rain slowed to a light drizzle at 1:55 am then stopped at 2:10 am. Sampling ended at 2:25 am. Flow decreased during sampling and was measured at approximately 0.49 cfs after all samples were collected. Stormwater was considerably less turbid and had less foam than stormwater sampled in Line and Amphitheater Canyons. High water mark was approximately 6 cm higher and 0.1 m wider than the sampled discharge.

February 28, 10:55 am – The creek at Padre Juan Canyon was monitored and field tests and flow measurements conducted. There was sporadic light rain during the field tests that increased during measurements of stream flow. The discharge was measured at 0.4 cfs.

March 1, 3:45 pm – Field tests and flow measurements were performed and stormwater samples collected from the stream flow in Padre Juan Canyon. Rain had stopped several hours before field tests and stormwater sampling activities were initiated. Stream flow was measured at 9.29 cfs.

Line Canyon

February 27, 1:15 am – When sampling commenced at Line Canyon the rain subsided to a drizzle, and then increased at 1:30 am. When the site was first monitored at 11:15 pm, stream flow was 1/2 to 2/3 less than what was observed during sampling. Discharge during sampling was approximately 4.67 cfs. A strong odor of possible petroleum hydrocarbons (similar to the first stormwater sampling event at Line Canyon) was observed at the sampling location. Branches, sticks and other debris were found in the creek as a result of the discharge and there was not as much foam as what was observed in Amphitheater Canyon. VOA vials were overfilled and preservatives were likely washed out.

February 27, 4:05 am – Field tests were conducted and flow measured from Line Canyon. During the course of measurements, the flow rapidly decreased. At 4:15 am, flow was measured at approximately 1 cfs. At 4:20 am, flow was observed to increase and the odor of suspected petroleum hydrocarbons also increased.

February 28, 10:15 am – Field tests and flow measurements were conducted at Line Canyon. There was no rain throughout the duration of these tests. Flow decreased while performing the first velocity tests, and the discharge was measured to be 1.27 cfs. After completion of the first stream flow measurements, flow increased. At 10:35 am, flow was measured at 2.04 cfs. This increase in flow may be due to the opening and closing of a check dam valve. Large amounts of fine sticky clay sediment was found along the banks, and possibly sand at the bottom of the creek bed.

February 28, 1:45 pm – Stormwater was collected and flow measured for the runoff from Line Canyon. Precipitation increased since field tests were completed in the morning, and additional flow measurements were completed. Stream flow was measured at 9.97 cfs.

March 1, 1:45 pm – Stream flow was measured stormwater runoff found in Line Canyon. Precipitation was intense during the flow measurements, and the flow greater than any other time during monitoring, field tests, or sampling activities at Line Canyon. Odor of possible petroleum hydrocarbons was observed, and the flow was measured at 45.4 cfs.

March 1, 3:25 pm – Stormwater samples were collected and field tests performed at Line Canyon. Oder of possible petroleum hydrocarbons would come and go during sample collection. The flow appeared to have a different color (cappuccino brown) than had previously been observed. Flow was fluctuating (increasing then decreasing) during field tests).

Amphitheater Canyon

February 27, 12:45 am - Collection of stormwater samples from Amphitheater Canyon. Rain had been steady in the area since 5:30 pm. Stream flow was measured at 1.31 cfs during the sampling activity. Flow dropped after arrival to the sampling location. Evidence from recent flow from high water marks showed a decreased in width of 1.3 m and depth of 6 cm. A large amount of foam was observed in the stormwater runoff. At 3:55 am, flow decreased to approximately 0.12 cfs.

February 28, 10:00 am – The creek in Amphitheater Canyon was monitored following a night of heavy rain. There was a light rain prior to arriving at the site, which stopped when monitoring commenced. The wet mark on the inside of the tunnel was approximately 0.3 to 0.35 m high, and the width of the tunnel 1.8 meters wide. A few meters downstream of the tunnel, the wetted width of the creek was roughly 3.45 m. The channel bottom was gravel to course sand, with the majority of the gravel 1.5 to 2 cm in diameter. Some gravel was found to be 4 to 7 cm in diameter. There was a small stream flow in Amphitheater Canyon that was observed during monitoring.

February 28, 1:20 pm – Flow was measured and stormwater was sampled from Amphitheater Canyon. Precipitation increased since monitoring commenced earlier that morning. At 1:25 pm, flow increased to almost double the amount observed upon arrival, with no increase in rain. Flow was measured at 4.63 cfs. After measurements and samples were collected, the flow decreased again by two to threefold at 1:33 pm.

March 1, 1:30 pm – Stream flow was measured at Amphitheater Canyon. Precipitation was intense and flow was increasing during the measurements. Large rocks were being carried and the flow resembled a mud slurry. The flow was measured at 261 cfs, the largest of any discharge (in all five canyons) that was measured during the Environmental Sampling element.

March 1, 3:15 pm – Stormwater samples were collected and field tests performed at Amphitheater Canyon. Flow decreased considerably since stream flow was measured earlier that day at 1:30 pm.

6.2 Additional Sediment Sampling Notes

6.2.1 Initial Sediment Samples (October 23, 2013)

Initial sediment samples were collected at all five watersheds. During the duration of the first sediment sampling event, the weather was overcast with a marine layer of fog covering the watersheds. The following observations were taken from field notes that were recorded during the initial sediment sampling event.

Madriano Canyon

October 23, 10:00 am – The first sediment samples were collected from the creek in Madriano Canyon. The top 2-3 cm layer of in-channel sediment was collected and placed into media.

Javon Canyon

October 23, 11:00 am – Sediment samples were collected from Javon Canyon. The top 2-3 cm layer of sediment found on the south side of the culvert was sampled.

Padre Juan Canyon

October 23, 11:15 am – Sediment samples were collected from Padre Juan Canyon. Samples were of in-channel sediment that was approximately 2-3 cm deep. The sample appeared to be transported and deposited washload.

Line Canyon

October 23, 12:35 pm – Sediment samples were collected from Line Canyon. Sampled sediment appeared to be recently deposited.

Amphitheater Canyon

October 23, 12:00 pm – Sediment samples were collected from Amphitheater Canyon. Sampled sediment was 3-4 cm deep, in the creek channel. The location of the sediment was selected due to deposits of sediment down stream of culvert and concrete channel.

6.2.2 Second Sediment Sampling Event (March 7, 2014)

Sediment samples were collected at all five watersheds four days after the storm (second stormwater sampling event) ended on March 3, 2014. All sediment that was sampled from each creek was still wet from the previous storm. It was sunny and 68° Fahrenheit during the collection of sediment on March 7. The following observations were taken from field notes that were recorded during the second sediment sampling event.

Madriano Canyon

March 7, 10:00 am – Samples were collected from the sediment in the Madriano Canyon creek channel. Finer deposits were taken from the top layer (approximately 1 cm deep) that was about 5 m upstream of the railroad tracks. There was sticky clay and some plants were sprouting along the bank. The top 2-3 cm layer of in-channel sediment was collected and placed into media.

Javon Canyon

March 7, 10:20 am – Sediment samples were collected from roughly 5 ft upstream of the end of the culvert in Javon Canyon. Fine clay with some courser sand was sampled, that had a gelatinous consistency. Small sprouts were found in the area where samples were collected. There appeared to be more gravel deposited and not much fine sediment. Spoon used to scoop sediment was noticed to have been slightly scuffed.

Padre Juan Canyon

March 7, 10:40 am – Sediment samples were collected from Padre Juan Canyon. Fine clay layer was very superficial. There was some coarser material, but mainly clay. The first sample contained more sand. Attempts were made to fill the remaining vials with more clay.

Line Canyon

March 7, 11:00 am – Sediment samples were collected from Line Canyon, approximately 5 m under the end of the culvert, upstream of the railroad tracks. Some courser sediment was included in the initial sample. Along the left side (facing downstream) of the bank, towards the end of the tunnel, there contained more fine sediment. The base flow in Line Canyon appeared to have roughly the same flow rate.

Amphitheater Canyon

March 7, 11:25 am – Sediment samples were collected from Amphitheater Canyon. Sampled sediment was mainly from the top layer, although some was collected by digging over 5 cm deep. Sediment was thick, with a lot of clay and silt, and had a consistency of a tacky gelatinous mud.

6.3 Additional Base Flow Sampling Notes

The following observations were taken from field notes that were recorded during the Line Canyon base flow sampling activities.

October 23, 12:35 pm – Initial base flow samples were collected at Line Canyon after completion of the sediment sampling activity. As noted, the weather was overcast with a marine layer of fog covering the watersheds. Prior to the collection of base flow samples, the last registered amount of rainfall was on October 9, 2013 that registered trace amounts of precipitation. Water samples were collected of base flow in Line Canyon. Field tests and flow measurements were also performed during the sampling activity. Samples were collected by scooping water from the base flow and pouring in sampling media. An oily sheen was visible in the base flow. Stream flow was measured at 0.03 cfs.

January 22, 7:45 am – The weather was sunny and 54° Fahrenheit, with a marine layer of fog covering the watersheds. Prior to the collection of base flow samples, the last registered amount of rainfall was on December 8, 2013 that registered 0.14 inches at the base of Madriano and 0.32 inches at the Red Mountain rain gauge. Water samples were collected, and field tests and flow measurements conducted for the base flow at Line Canyon. Flow was measured at 0.037 cfs.

April 21, 6:40 am – Final base flow samples were collected at Line Canyon early in the morning. The weather was sunny and 54° Fahrenheit. There were some larvae found in the channel sediment of the base flow during sampling. The following observations summarize field notes from sampling activities during the first stormwater sampling event. Water samples were collected, and field tests and flow measurements conducted for the base flow at Line Canyon. Flow was measured at 0.034 cfs.

6.4 Additional Field Test Notes

The study watersheds were monitored numerous times over the course of the project (October 2013 to May 2013). In addition to field tests and stream flow measurements performed during sampling activities, field tests were performed seven times on the Line Canyon base flow. The following observations were taken from field notes that were recorded during these additional field tests.

Line Canyon

December 7, 10:25 am – Field tests were performed and stream flow measured for the Line Canyon base flow. There was a light rain most of the morning, since 4:00 am, that stopped just before field tests began. There was a slight odor of possible petroleum hydrocarbons. Flow was measured at 0.037 cfs. The base flow exceeded the limit on the turbidity meter. Flow was measured at 1.3 cfs. At 11:10 am, the flow decreased to one half the amount observed when field tests began.

Line Canyon

January 31, 1:05 pm – Field tests were performed and stream flow measured for the Line Canyon base flow. The weather was sunny and 66° Fahrenheit. There appeared to be a soapy film in the base flow, and larvae was found in the first conductivity sample. The beach by the drainage outlet appeared to be eroded, and the flow did not flow straight into the ocean (as was usually observed), instead pooling on the beach. There was a strong odor of sewage by the outlet. The base flow was measured at 0.0399 cfs.

Line Canyon

February 6, 4:25 pm – Field tests were performed for the Line Canyon base flow. The weather was cloudy and 54° Fahrenheit, and it had lightly rained for approximately two hours before field tests began. The base flow increased when first arrived at 3:10 pm, and then decreased at 4:10 pm to less than what was usually observed. The majority of the water was coming from two drainage points under Highway 101, with a small trickle coming from the check dam upstream. The dam appeared closed, and the flow completely stopped at 4:55 pm after pH and conductivity were measured.

Line Canyon

February 12, 10:30 am – Field tests were performed and stream flow measured for the Line Canyon base flow. The weather was sunny and 66° Fahrenheit. There was a soapy film in parts of the creek where salt grass was present. A strong odor of sewage was observed by the beach, near the drainage outlet. The base flow was measured at 0.032 cfs.

Line Canyon

February 25, 3:00 pm – Field tests were performed and stream flow measured for the Line Canyon base flow. The weather was partly cloudy and 63° Fahrenheit. There was an increased amount of algae than what was observed on February 12. A soapy film was seen by the rocks in the stream channel. The base flow was measured at 0.035 cfs.

Line Canyon

March 4, 4:00 pm – Field tests were performed and stream flow measured for the Line Canyon base flow. The weather was sunny, and on March 3 the Red Mountain rain gauge measured 0.16 inches and the Seacliff County Fire Station gauge 0.02 inches of precipitation. This followed the largest storm event of the 2014 water year. The base flow was measured at 0.0315 cfs. Measurements were taken of the high water marks and length used to estimate flow during the March 1 precipitation event. Eight surfers were observed 50 to 100 m directly in front of the drainage outlet where the Line Canyon base flow discharged into the coastal waters.

Amphitheater Canyon

March 4, 3:05 pm – Amphitheater Canyon was monitored following the storm event that ended on March 3. Sediment was observed in the channel and on the banks, and there was larger gravel in the channel further downstream. Measurements were taken of the high water marks and length used to estimate flow during the March 1 precipitation event.

Line Canyon

April 1, 12:00 am – Field tests were performed and stream flow measured for the Line Canyon base flow. When field tests began, there was a slight drizzle and rain increased to showers at 12:30. On April 1, the Red Mountain rain gauge measured 0.28 inches and the Seacliff County Fire Station gauge 0.13 inches of precipitation. The base flow was measured at 0.078 cfs.

6.5 Field Photos

Picture 7.1 – Madriano Canyon
First flush event on November 21, 2013 at 1:00 am

Picture 7.2 – Line Canyon
First flush event on November 21, 2013 at 2:45 am

Picture 7.3 – Beach at Line Canyon outlet
Base flow stopped on January 24, 2014 at 1:30 pm

Picture 7.4 – Beach at Line Canyon outlet
Base flow discharge on January 25, 2014 at 4:20 pm

Picture 7.5 – Madriano Canyon
Stormwater flow on February 27, 2014 at 3:25 am

Picture 7.6 – Amphitheater Canyon
Stormwater flow on February 28, 2014 at 1:20 pm

Picture 7.7– Javon Canyon
Stormwater discharge on February 28, 2014 at 2:25 pm

Picture 7.8 – Line Canyon outlet
Stormwater discharging into ocean on February 28, 2014 at 4:20 pm

Picture 7.9 – Amphitheater Canyon
Peak flow (260 cfs) on March 1, 2014 at 1:30 pm

Picture 7.10 – Line Canyon
Peak flow (45 cfs) on March 1, 2014 at 2:20 pm

Picture 7.11 – Padre Juan Canyon
Stormwater flow on March 1, 2014 at 4:00 pm

Picture 7.12 – Pacific Ocean near Line Canyon
Coastal waters by Line Canyon outlet on
March 7, 2014 at 10:45 am

TOXICITY ANALYSIS

NORTHERN VENTURA COUNTY COASTAL WATERSHED PROJECT

The following Toxicity Analysis was completed as part of the Northern Ventura County Coastal Watershed Project (NVCCWP), which also includes a Watershed Assessment, Environmental Sampling, Source Assessment, and Recommendations & Mitigation Strategies.

To assess toxicity, screening levels and water quality criteria were selected to compare to maximum concentrations of pollutants detected in samples from the study watersheds: Madriano, Javon, Padre Juan, Line, and Amphitheater Canyons. The screening levels and water quality criteria were selected based on the potential and current beneficial uses of waters in the study area, which include: municipal and domestic water supply (MUN), agricultural supply (AGR), wildlife habitat (WILD), groundwater recharge (GWR), warm and cold freshwater habitat (WARM and COLD), water contact recreation (REC1), and spawning, reproduction, and early development (SPWN). Based on the limited number of samples that were collected over the sampling timeline, maximum concentrations from samples were considered for a conservative approach. When considering human health effects it is important to use a cautious approach to protect public health. If continuous monitoring was implemented over a longer timeframe, it would be possible to consider a 95 or 99 percentile from the distribution of sample data.

This analysis has identified metals found in the sediments and waters of the study watersheds as potential pollutants of most concern. Arsenic is identified as the most hazardous pollutant of concern that was found in both sediment and water samples from all the study watersheds. There are several organics, including PAHs, which have been identified as approaching concentrations that would be of concern through the ingestion pathway (water and or aquatic organisms). Dissolved metals and salts are more bioavailable than particulate metals and solids making these concentrations of greater concern than total recoverable metal concentrations. The Line Canyon base flow has the greatest potential dissolved metal and salt toxicity with respect to human health. Due to the high levels of total suspended solids (TSS), total recoverable metals concentrations were very high in Line and Amphitheater Canyon stormwater samples, making chronic exposure to these waters a concern.

The following toxicity analysis has been separated into three main sections:

1) EPA Regional Screening Levels (RSLs)
2) California Toxics Rule (CTR)
3) California Maximum Contaminant Levels (MCLs) and Public Health Goals (PHGs)

The section covering EPA Regional Screening Levels is the most comprehensive, and considers four different human exposure pathways. The California Toxics Rule assesses the human risk associated with consumption of water and aquatic organisms, and the toxicity of a few metals to aquatic life. The California MCLs and PHGs are drinking water standards that provide insight into the level of treatment that would be required if these waters were to be used for drinking water supply.

Toxicity Analysis Table of Contents

Data Disclaimer: Blue Tomorrow and its contractors are not liable for any damages that may result from the use of data or analysis contained in this assessment.

ACRONYMS

CTR	California Toxics Rule
CWA	Clean Water Act
DEHP	Bis (2-ethylhexyl) Phthalate
EPA IRIS	Environmental Protection Agency Integrated Risk Information System
EPA RSL	Environmental Protection Agency Regional Screening Level
GWR	Beneficial Use of Groundwater Recharge
HI	Hazard Index
HQ	Hazard Quotient
MCL	Maximum Contaminant Level
MUN	Beneficial Use of Municipal and Domestic Supply
NVCCWP	Northern Ventura County Coastal Watershed Project
PAHs	Polycyclic Aromatic Hydrocarbons
PHG	Public Health Goals
TDS	Total Dissolved Solids
TSS	Total Suspended Solids
WER	Water Effects Ratio

UNITS

kg	Kilograms
mg	Milligrams
L	Liter
µg	Micrograms

1.0 | EPA Regional Screening Levels

Environmental Protection Agency (EPA) Regional Screening Levels (RSLs) were used to assess the human health risk of water and sediments sampled from the five study watersheds. The screening levels used in this analysis are from the EPA's generic tables and were not calculated using site specific information[1]. The RSLs are chemical specific concentrations that take into account assumptions of exposure pathways, exposure time, and the population being exposed[1, 3]. These assumptions represent Reasonable Maximum Exposure for chronic exposures to the individual pollutants. The EPA Integrated Risk Information System (IRIS) definition of chronic exposure is "repeated exposure by the oral, dermal, or inhalation route for more than approximately 10% of the life span in humans." [2]

Section Highlights

- EPA Regional Screening Level (RSL) generic tables were used to determine risk associated with four exposure scenarios: residential soil, protection of groundwater, tap water, and dermal exposure to tap water
- The greatest carcinogenic risk from water and sediment samples for all exposure pathways considered is from arsenic
- The metals found in water and sediments represent the greatest health risk in the study area, and the Line Canyon base flow has the greatest risk in terms of dissolved metals
- The greatest risk from organic pollutants is from propargyl alcohol and 1,2,4-trimethylbenzene through ingestion pathways
- Line and Amphitheater Canyons generally have higher toxicity from waters sampled, but Madriano and Padre Juan Canyons have greater risk in terms of sediments

Four different screening levels were considered in this analysis and presented in the tables below for contaminants detected in water and sediments from the five study watersheds. These four screening levels are the residential soil screening levels, soil screening levels for the protection of groundwater resources, tap water screening levels, and screening levels for dermal exposure (from tap water).These screening levels were selected for comparison due to the coastal area near the watershed outlets being areas with residential communities, areas of high recreational activity, and designation of the potential beneficial use of MUN in the area. During the study timeline recreationalists were observed swimming in the effluent from the watersheds, people were observed walking barefoot up stream channels, and children live adjacent to (and play in) the stream channels.

All the screening levels considered in this section, with the exception of the dermal exposure screening levels, considered potential health risks associated with ingestion, dermal exposure, and inhalation of the pollutant when applicable[3]. The residential and protection of groundwater resources screening levels are soil screening levels and are compared to the concentration of pollutants detected in the sediment samples. The tap water and dermal exposure screening levels are water screening levels and are compared to the concentration of pollutants detected in water samples.

Compounds are separated into carcinogens and non-carcinogens and have different measures of risk. Pollutants that may present a carcinogenic toxicity risk are considered a concern if they exceed a target risk of 1 in a million (10^{-6})[3]. It is generally considered unacceptable if exposure to the pollutant increases the risk of developing cancer above this level. For carcinogenic compounds the cancer risk for the given exposure scenario has been calculated for the maximum concentrations that were detected in study samples. Compounds that may present a non-carcinogenic toxicity risk are considered a concern if they exceed a Hazard Quotient (HQ) equal to 1. HQs that exceed 1 generally indicate an unacceptable level of risk and a level at which the pollutant may cause deleterious effects over a lifetime of exposure (chronic exposure).

Screening levels are compared to the maximum concentrations that were detected in sediment and water samples in sections 1.1 and 1.2. Screening levels were also used to calculate the total cancer risk and Hazard Index ($HI = \Sigma HQ$) for each canyon and the Line Canyon base flow based on different media (soil or water) and exposure pathways (Section 1.3).

1.1 RSLs and Maximum Sediment Concentrations

Maximum concentrations of pollutants detected in study sediment samples were compared to residential soil RSLs and RSLs for the protection of groundwater resources (Table 1.1 and 1.2). These RSLs were selected because of the residential communities and recreational activity at the outlets of the watersheds, and the potential beneficial use of GWR and MUN in the study area.

Arsenic is the most toxic carcinogen detected in sediment samples, and the only one found at a concentration above the 1 in a million target risk for residential soil (over 10 times the screening level). When considering the protection of groundwater resources, benzene and naphthalene are also found above the carcinogenic RSLs for residential soils. Both maximum concentrations of these organics are from Madriano Canyon (Table 1.1).

There are no non-carcinogenic compounds that exceed the residential soil screening levels with an HQ of 1 or greater, although several exceed a HQ of 0.1 including aluminum, cobalt, iron, and manganese. All of the non-carcinogenic organics are at least 1000 times less than these residential soil RSLs. If the protection of groundwater resources is considered several of the metals are found above RSLs, with cobalt, iron, manganese and selenium all exceeding 10 times the RSLs (Table 1.2). The maximum concentrations of these four metals were all detected in Padre Juan Canyon sediment samples.

Table 1.1 – **RSLs and risk of carcinogenic pollutants detected in sediment samples**

CARCINOGENIC COMPOUNDS	RESIDENT SOIL RSL (mg/kg)	PROTECTION OF GROUNDWATER RSL (mg/kg)	MAXIMUM CONCENTRATION FROM SEDIMENT SAMPLES (mg/kg)	CANYON WITH MAXIMUM CONCENTRATION	CANCER RISK FOR RESIDENT SOIL RSL	CANCER RISK FOR PROTECTION OF GROUNDWATER
ORGANIC COMPOUNDS						
Benzene	1.1**	0.0002	0.092*	Madriano	8.4E-08	4.6E-04
Benz[a]anthracene	0.15	0.01	0.0026*	Madriano	1.7E-08	2.6E-07
Benzo[a]pyrene	0.015	0.0035	0.00076*	Line	5.1E-08	2.2E-07
Benzo[b]fluoranthene	0.15	0.035	0.0077	Madriano	5.1E-08	2.2E-07
Chrysene	15	1.1	0.02	Madriano	1.3E-09	1.8E-08
Dibenz[a,h]anthracene	0.015	0.011	0.0025*	Madriano	1.7E-07	2.3E-07
Indeno[1,2,3-cd]pyrene	0.15	0.2	0.0037*	Madriano	2.5E-08	1.9E-08
Bis(2-ethylhexyl)phthalate	35**	1.1	0.17	Line	4.9E-09	1.5E-07
Naphthalene	3.6**	0.00047	0.00081*	Madriano	2.3E-10	1.7E-06
METALS						
Arsenic, Inorganic	0.61**	0.0013	10.9	Javon	1.8E-05	8.4E-03

The maximum concentration of pollutant detected in any of the sediment samples was used. The canyon that the maximum concentration was detected in is named in the far right column. Risk increased by the presence of the pollutant above 1 in a million (1.0E-06) is generally considered unacceptable.
*Measured concentration is above the detection limits for the analytical method that was used but below reporting limits and is considered an estimate.
** Compound has systemic toxicity, and the carcinogenic screening level is less than 100 times more than the non-carcinogenic screening level.

Table 1.2 – **RSLs and hazard of non-carcinogenic pollutants detected in sediment samples**

NON-CARCINOGENIC COMPOUNDS	RESIDENT SOIL RSL (mg/kg)	PROTECTION OF GROUNDWATER RSL (mg/kg)	MAXIMUM CONCENTRATION DETECTED IN SEDIMENTS (mg/kg)	CANYON WITH MAXIMUM CONCENTRATION	HQ FOR RESIDENT RSL	HQ FOR PROTECTION OF GROUNDWATER
ORGANIC COMPOUNDS						
Fluoranthene	2,300	4	0.0079	Madriano	0.0000034	0.00011
2-Methylnaphthalene	230	0.14	0.00078*	Javon	0.0000034	0.0056
Pyrene	1,700	9.5	0.0094*	Madriano	0.0000055	0.00099
1,2,4-Trimethylbenzene	62	0.021	0.0081*	Javon	0.00013	0.39
Toluene	5,000	0.59	0.01*	Madriano	0.000002	0.017
METALS						
Aluminum	77,000	23,000	10,600	Padre Juan	0.14	0.46
Barium	15,000	120	207	Madriano	0.014	1.7
Beryllium and compounds	160	13	0.52	Padre Juan	0.0033	0.04
Boron And Borates Only	16,000	9.9	29.4	Amphitheater	0.0018	3
Cadmium (Diet)	70	NA	0.71	Madriano	0.01	NA
Cadmium (Water)	NA	0.52	0.71	Madriano	NA	1.4
Cobalt	23	0.21	7.1	Padre Juan	0.31	34
Copper	3100	22	18.6	Javon	0.006	0.85
Iron	55,000	270	19,700	Padre Juan	0.36	73
Lead and Compounds	400	NA	28.1	Javon	0.07	NA
Manganese (Non-diet)	1,800	21	309	Padre Juan	0.17	15
Mercury (elemental)	10	0.033	0.062	Madriano	0.0062	1.9
Nickel Soluble Salts	1,500	20	40.8	Madriano	0.027	2.0

Table 1.2 – continued

NON-CARCINOGENIC COMPOUNDS	RESIDENT SOIL RSL (mg/kg)	PROTECTION OF GROUNDWATER RSL (mg/kg)	MAXIMUM CONCENTRATION DETECTED IN SEDIMENTS (mg/kg)	CANYON WITH MAXIMUM CONCENTRATION	HQ FOR RESIDENT RSL	HQ FOR PROTECTION OF GROUNDWATER
Selenium	390	0.4	8.7	Padre Juan	0.022	22
Vanadium and Compounds	390	63	34.9	Padre Juan	0.089	0.55
Zinc and Compounds	23,000	290	56.8	Madriano	0.0025	0.2

The organic compounds may have carcinogenic effects, but the primary risk for the considered exposure pathway is from non-carcinogenic effects. The maximum concentration of pollutant detected in any of the sediment samples was used. A hazard quotient greater than 1 is generally considered unacceptable and a level at which adverse health effects may occur as a result of a lifetime of exposure at that level.
*Measured concentration is above the detection limits for the analytical method that was used but below reporting limits and is considered an estimate.

1.2 RSLs and Maximum Water Concentrations

The maximum concentration of pollutants detected in water samples was compared to RSLs for tap water (Tables 1.3 to 1.6). Dermal exposure to tap water was singled out for comparison to assess the risk of bathing in the effluent from the watersheds because of the frequent recreationalists and surfers that swim in the coastal area near the outlets. On several occasions during site visits and sampling activities people were observed swimming directly in the stormwater runoff from the canyons. Additionally, there is a potential beneficial use of MUN in the Madriano, Javon, and Padre Juan Canyon watersheds. The tap water RSLs includes ingestion of tap water, dermal exposure to tap water, and inhalation of volatile compounds from tap water. Cancer risk and non-carcinogenic HQs were calculated for each of the constituents based on the maximum water sample concentration.

Five of the carcinogenic compounds had maximum concentrations above the tap water RSLs: acrylamide, benzo(a)pyrene, dibenz(a,h)anthracene, naphthalene, and arsenic (Table 1.3). Of these carcinogenic constituents naphthalene and arsenic were found at the most toxic levels. Benzo(a)pyrene and dibenz(a,h)anthracene were only ever detected in Line Canyon base flow. The concentration of total arsenic in Amphitheater Canyon equates to a cancer risk of about 1 in 40 people and 1 in 7300 people for the cumulative tap water risk and dermal exposure to tap water respectively.

Of the non-carcinogenic non-metal pollutants only fluoride, nitrate, and propargyl alcohol were detected above tap water RSLs in water samples, and none were found to exceed the dermal exposure RSLs for tap water (Table 1.4). Of these three propargyl alcohol was found at the most toxic concentration (HQ=11 for tap water).

Both the maximum concentration of total metals and dissolved metals were compared to the cumulative tap water RSLs and dermal exposure RSLs for tap water (Tables 1.5 and 1.6). For most metals the dissolved form is more bioavailable and therefore more toxic, but total recoverable metals also have toxic effects. The stormwater runoff from the study canyon occurs very rapidly and it is likely many of the metals would be found in dissolved form at higher concentrations given more time and a longer flow path.

Most of the maximum total metals concentrations were detected in stormwater samples from Amphitheater Canyon and are associated with the high levels of TSS in stormwater from this canyon. All the total metals concentrations exceed the tap water RSLs, with the most hazardous being aluminum, cobalt, iron, and manganese (HQ>100; Table 1.5). When considering dermal exposure alone, total recoverable concentrations of beryllium, cadmium, iron, manganese, and vanadium are found to be the most hazardous (HQ>1; Table 1.5).

Dissolved metal concentrations indicate a much lower metal toxicity, with only the dissolved boron in the Line Canyon base flow above the tap water RSL (Table 1.6). Of the 16 metals that were detected in dissolved form in water samples, 9 were found at maximum dissolved concentrations in the Line Canyon base flow. Several of the dissolved metals are found with HQs above 0.1 for tap water RSLs (cobalt, manganese, and selenium). None of the dissolved metal concentrations have a high hazard when considering only dermal exposure to tap water.

Table 1.3 – **RSLs and carcinogenic risk of pollutants detected in water samples**

CARCINOGENIC COMPOUNDS	TAP WATER RSL (ug/L)	DERMAL EXPOSURE RSL (ug/L)	MAXIMUM CONCENTRATION DETECTED IN WATER SAMPLES (ug/L)	CANYON WITH MAXIMUM CONCENTRATION	CANCER RISK FOR TAP WATER RSL	CANCER RISK FOR DERMAL EXPOSURE
ORGANIC COMPOUNDS						
Acrylamide	0.043	22	0.074*	Padre Juan, Amphitheater	1.7E-06	3.4E-09
Benz[a]anthracene	0.029	NA	0.013*	Line	4.5E-07	NA
Benzo[a]pyrene	0.0029	NA	0.0059*	Line base	2.0E-06	NA
Benzo[b]fluoranthene	0.029	NA	0.01*	Javon	3.4E-07	NA
Chrysene	2.9	NA	0.047	Line	1.6E-08	NA
Dibenz[a,h]anthracene	0.0029	NA	0.0039*	Line base	1.3E-06	NA
Ethylbenzene	1.3	11	0.29*	Amphitheater	2.2E-07	2.6E-08
Indeno[1,2,3-cd]pyrene	0.029	NA	0.0047*	Line base	1.6E-07	NA
Benzene	0.39**	8.4**	0.14*	Line	3.6E-07	1.7E-08
Bis(2-ethylhexyl)phthalate	4.8**	NA	4.7	Line	9.8E-07	NA
Naphthalene	0.14**	NA	1.9	Line	1.4E-05	NA
METALS						
Arsenic, Inorganic	0.045	8.3	1,140***	Amphitheater	2.5E-02	1.4E-04

The maximum concentration of pollutant detected in any of the water samples was used (stormwater from any canyon or Line Canyon base flow). Risk above 1 in a million (1.0E-06) is generally considered unacceptable.
*Measured concentration is above the detection limits for the analytical method that was used but below reporting limits and is considered an estimate.
**Compound has systemic toxicity, and the carcinogenic screening level is less than 100 times more than the non-carcinogenic screening level.
***Arsenic reported is the total recoverable concentration. Dissolved arsenic was never detected in water samples.

Table 1.4 – **RSLs and non-carcinogenic organic compounds detected in water samples**

NON-CARCINOGENIC COMPOUNDS	TAP WATER RSL (ug/L)	DERMAL EXPOSER RSL (ug/L)	MAXIMUM CONCENTRATION DETECTED IN WATER SAMPLES (ug/L)	CANYON WITH MAXIMUM CONCENTRATION	HQ FOR TAP WATER RSL	HQ FOR DERMAL EXPOSURE
ORGANIC COMPOUNDS						
Acenaphthene	400	680	0.05	Line	0.00013	0.000074
Anthracene	1,300	1,800	0.0085*	Javon	0.0000065	0.0000047
Dibenzofuran	5.8	9.2	0.035	Line	0.006	0.0038
Ethylene Glycol	31,000	37,000,000	1300*	Madriano, Padre Juan	0.042	0.000035
Fluoranthene	630	NA	0.026	Amphitheater	0.000041	NA
Fluorene	220	330	0.11	Line	0.0005	0.00033
Formaldehyde	3,100	200,000	42	Padre Juan	0.014	0.00021
Methanol	31,000	11,000,000	200*	Madriano	0.0065	0.000018
2-Methylnaphthalene	27	46	0.2	Line	0.0074	0.0043
Propargyl Alcohol	31	7,800	330*	Padre Juan	11	0.042
Pyrene	87	110	0.022	Javon, Line, Amphitheater	0.00025	0.0002
Toluene	860	3,700	0.37*	Line	0.00043	0.0001
1,2,4-Trimethylbenzene	15	NA	1.2*	Line	0.08	NA
1,3,5-Trimethylbenzene	87	200	0.18*	Line	0.0021	0.0009
Xylenes	190	NA	0.11*	Line	0.00058	NA
Naphthalene	NA	500	1.9	Line	NA	0.0038

These organic compounds may have carcinogenic effects, but the primary risk for the considered exposure pathway is from non-carcinogenic effects. The maximum concentration of pollutant detected in any of the water samples was used (stormwater from any canyon or Line Canyon base flow). A hazard quotient greater than 1 is generally considered unacceptable and a level at which adverse health effects may occur as a result of a lifetime of exposure at that level.

*Measured concentration is above the detection limits for the analytical method that was used but below reporting limits and is considered an estimate.

Table 1.5 *–* **RSLs and non-carcinogenic total recoverable metals in water samples**

NON-CARCINOGENIC COMPOUNDS	TAP WATER RSL (ug/L)	DERMAL EXPOSER RSL (ug/L)	MAXIMUM TOTAL METALS CONCENTRATION DETECTED (ug/L)	CANYON WITH MAXIMUM CONCENTRATION	HQ FOR TAP WATER RSL	HQ FOR DERMAL EXPOSURE
TOTAL METALS						
Aluminum	16,000	2,400,000	1,790,000	Amphitheater	110	0.75
Antimony (metallic)	6	140	27.5*	Javon	4.6	0.2
Barium	2,900	33,000	14,000	Amphitheater	4.8	0.42
Beryllium and compounds	16	33	96	Amphitheater	6	2.9
Boron And Borates Only	3,100	470,000	20,400	Line base flow	6.6	0.043
Cadmium (Water)	6.9	59	130	Amphitheater	19	2.2
Cobalt	4.7	1,800	1,180	Amphitheater	250	0.66
Copper	620	95,000	3,230	Amphitheater	5.2	0.034
Iron	11,000	1,700,000	3,340,000	Amphitheater	300	2.0
Manganese (Non-diet)	320	2,300	38,300	Amphitheater	120	17
Mercury (elemental)	0.63	NA	4.4	Amphitheater	7.0	NA
Nickel Soluble Salts	300	9,500	5,110	Amphitheater	17	0.54
Selenium	78	12,000	291	Javon	3.7	0.024
Vanadium and Compounds	63	310	5,600	Amphitheater	89	18
Zinc and Compounds	4,700	1,200,000	9,780	Amphitheater	2.1	0.0082

The maximum concentration of pollutant detected in any of the water samples was used (stormwater from any canyon or Line Canyon base flow). A hazard quotient greater than 1 is generally considered unacceptable and a level at which adverse health effects may occur as a result of a lifetime of exposure at that level.
*Measured concentration is above the detection limits for the analytical method that was used but below reporting limits and is considered an estimate.

Table 1.6 – **RSLs and non-carcinogenic dissolved metals and salts in water samples**

NONCARCINOGENIC COMPOUNDS	TAP WATER RSL (ug/L)	DERMAL EXPOSER RSL (ug/L)	MAXIMUM DISSOLVED METALS CONCENTRATION DETECTED (ug/L)	CANYON WITH MAXIMUM CONCENTRATION	HQ FOR TAP WATER RSL	HQ FOR DERMAL EXPOSURE
DISSOLVED METALS						
Aluminum	16,000	2,400,000	8.3*	Padre Juan	0.00052	0.0000035
Barium	2,900	33,000	114	Line base flow	0.039	0.0035
Boron And Borates Only	3,100	470,000	19,100	Line base flow	6.2	0.041
Cobalt	4.7	1,800	1.8*	Line base flow	0.38	0.001
Copper	620	95,000	7	Amphitheater	0.011	0.000074
Iron	11,000	1,700,000	35	Amphitheater	0.0032	0.000021
Manganese (Non-diet)	320	2,300	90.9151	Line base flow	0.47	0.066
Nickel Soluble Salts	300	9,500	14.9**	Line base flow	0.05	0.0016
Selenium	78	12,000	15.3*	Amphitheater	0.2	0.0013
Vanadium and Compounds	63	310	2.1*	Line base flow	0.033	0.0068
Zinc and Compounds	4,700	1,200,000	2.9*	Padre Juan	0.00062	0.0000024
SALTS						
Fluoride	620	95,000	780	Padre Juan	1.3	0.0082
Nitrate	25,000	3,800,000	80,600	Amphitheater	3.2	0.021

The maximum concentration of pollutant detected in any of the water samples was used (stormwater from any canyon or Line Canyon base flow). A hazard quotient greater than 1 is generally considered unacceptable and a level at which adverse health effects may occur as a result of a lifetime of exposure at that level.
*Measured concentration is above the detection limits for the analytical method that was used but below reporting limits and is considered an estimate.
**Nickel RSLs are for soluble salts but maximum concentration used for comparison is total dissolved nickel.

1.3 Comparing Toxicity Levels between Canyons

Total Hazard Index (HI = ΣHQ) and total cancer risk were calculated to compare between canyons and sampled media. The summed risk and hazard, while insightful for screening purposes, may not represent the actual summed risk because 1) the non-carcinogenic effects of carcinogens and the carcinogenic effects of non-carcinogens were not considered (risks were kept separate based on whether they were carcinogenic or non-carcinogenic), 2) there may be other compounds in the runoff that were not tested for and may be hazardous to human health, and 3) to get accurate additive risk the sums would need to be done for constituents that affect the same target organ or organ system. For example if a group of compounds only affect the nervous system, those compounds should be singled out and grouped together under the assumption that they have compounding effects, and not grouped with compounds that primarily affect another organ or organ system.

The additive Hazard Index (HI) and total cancer risk include all of the constituents and screening levels listed in Tables 1.1 through 1.6 and the maximum concentration of those constituents found in sediments and stormwater from each watershed, and samples of the Line Canyon base flow.

Total Cancer Risk

The highest total cancer risk determined for the four RSLs exposure scenarios (tap water, dermal exposure to tap water, residential soil, and protection of groundwater resources from soil contaminants) was found in Line and Amphitheater Canyon for the tap water RSLs (Table 1.7). In Amphitheater Canyon this equates to a risk of 1 in 40 developing cancer over a lifetime of exposure to these concentrations in tap water. This very high risk is almost entirely a result of the high concentrations of total arsenic detected in stormwater runoff and the ingestion exposure pathway. The next highest cancer risk levels are found when considering the protection of groundwater resources from soil contaminants, and are found in Madriano and Javon Canyons; though all canyons for this exposure scenario have a risk of greater than 1 in 1,000 (Table 1.10). The carcinogenic effects of the sediments from the canyons are almost entirely a result of the arsenic levels detected in the sediment samples and the ingestion exposure pathway.

Non-carcinogenic Organics

Non-carcinogenic organics only have a HI approaching or exceeding 1 (i.e. approaching unacceptable risk) when the ingestion pathway is considered in the tap water and protection of groundwater from soils RSLs (Tables 1.7 and 1.10). The highest HI for tap water RSLs is 11 from Padre Juan Canyon and is due to the propargyl alcohol detected at an estimated 330 ug/L in one stormwater sample. The next greatest HI approaching 1 are 0.11 from Line Canyon for the tap water RSLs, and 0.39 from Javon Canyon for the protection of groundwater resources RSLs; both these HI values are primarily due to the 1,2,4-trimethylbenzene that was detected in these samples.

Non-carcinogenic Metals and Salts

The non-carcinogenic total metals have very high HI due to the very high concentration of total metals detected in stormwater samples (Tables 1.7 and 1.8). The greatest HI value for non-carcinogenic total metals and the tap water exposure scenario is 940 and is from samples collected in Amphitheater Canyon (Table 1.7). All of the maximum total recoverable metals concentrations detected in Amphitheater Canyon that have RSLs are found at concentrations that exceed an HQ of 1, but the majority of the 940 HI value for this canyon is due to aluminum, cobalt, iron, and manganese. These four metals constitute the majority of the non-carcinogenic toxicity in terms of total metals for the other canyons as well. For the dermal exposure pathway, the highest HI value was 44 and was also calculated for Amphitheater Canyon stormwater samples (Table 1.8). The dermal exposure pathway in Amphitheater Canyon had a high HI primarily due to manganese and vanadium, beryllium, cadmium, and iron.

Non-carcinogenic metals had the greatest HI values in Madriano and Padre Juan Canyons for the residential soil and protection of groundwater exposure scenarios, but all HI values for all the canyon sediments were relatively high (Tables 1.9 and 1.10). The highest HI values are for the protection of groundwater resources because it includes a greater expected exposure from ingesting drinking water compared to the incidental ingestion expected for residential soils (primarily by children). The top four metals contributing to the toxicity risk associated with the protection of groundwater resources are cobalt, iron, manganese, and selenium. The four major contributing metals to toxicity levels associated with residential soil RSLs are aluminum, cobalt, iron, and manganese.

The non-carcinogenic dissolved metals and salts are of most concern due to the much higher bioavailability of dissolved solids compared to particulate solids. The highest HI values are from the Line Canyon base flow, but Line and Amphitheater Canyon stormwater also have fairly high HI values for the tap water RSLs. The major contributor to non-carcinogenic toxicity from dissolved metals and salts in Line Canyon base flow is primarily due to the high concentration of dissolved boron (HQ=6.2), though fluoride, nitrate, cobalt and manganese also contribute to the HI of 8.7 for the base flow with the tap water RSLs (Table 1.7). The main contributors to the toxicity levels in the Line and Amphitheater stormwater are fluoride and nitrate, though boron, cobalt, and selenium are also large contributors to these toxicity levels.

Table 1.7 – **Tap water RSLs and canyon total cancer risk and HI from water samples**

	MADRIANO	JAVON	PADRE JUAN	LINE	AMPHITHEATER	BASE FLOW LINE
Total Cancer Risk	6.3E-04	4.8E-03	1.9E-04	1.9E-02	2.5E-02	2.0E-04
Non-carcinogenic Organics HI	0.068	0.0027	11	0.11	0.0028	0.0077
Non-carcinogenic Total Metals HI	24	200	3.1	400	940	10
Non-carcinogenic Dissolved Metals and Salts HI	0.85	1.8	1.6	2.4	4.7	8.7
The summed cancer risk and non-carcinogenic Hazard Index (HI) for each canyon use maximum concentrations of pollutants detected in water samples from the given canyon. For dermal exposure naphthalene is placed in the non-carcinogenic organics HI because of the lack of a carcinogenic risk RSL for this exposure pathway. Dermal exposure RSLs are based on the dermal exposure to tap water and the associated chronic exposure from daily bathing and other tap water contact.						

Table 1.8 – **Dermal exposure RSLs and canyon total cancer risk and HI from water samples**

	MADRIANO	JAVON	PADRE JUAN	LINE	AMPHITHEATER	BASE FLOW LINE
Total Cancer Risk	3.4E-06	2.6E-05	1.0E-06	1.0E-04	1.4E-04	1.0E-06
Non-carcinogenic Organics HI	0.0071	0.0017	0.045	0.014	0.007	0.0003
Non-carcinogenic Total Metals HI	1	9.3	0.15	19	44	0.25
Non-carcinogenic Dissolved Metals and Salts HI	0.012	0.055	0.021	0.029	0.04	0.13
The summed cancer risk and non-carcinogenic Hazard Index (HI) for each canyon use maximum concentrations of pollutants detected in water samples from the given canyon. For dermal exposure naphthalene is placed in the non-carcinogenic organics HI because of the lack of a carcinogenic risk RSL for this exposure pathway. Dermal exposure RSLs are based on the dermal exposure to tap water and the associated chronic exposure from daily bathing and other tap water contact.						

Table 1.9 – **Residential soil RSLs and canyon total cancer risk and HI from sediment samples**

	MADRIANO	JAVON	PADRE JUAN	LINE	AMPHITHEATER
Total Cancer Risk	1.3E-05	1.8E-05	9.8E-06	4.8E-06	9.0E-06
Non-carcinogenic Organics HI	0.000013	0.00014	0.0000071	0	0.0000045
Non-carcinogenic Metals HI	1.1	0.83	1.2	0.45	0.76
The summed cancer risk and non-carcinogenic Hazard Index (HI) for each canyon use maximum concentrations of pollutants detected in sediment samples from the given canyon.					

Table 1.10 – **RSLs for protection of groundwater resources and canyon total cancer risk and HI from sediment samples**

	MADRIANO	JAVON	PADRE JUAN	LINE	AMPHITHEATER
Total Cancer Risk	6.0E-03	8.4E-03	4.5E-03	2.2E-03	4.2E-03
Non-carcinogenic Organics HI	0.022	0.39	0.0042	0	0.0036
Non-carcinogenic Metals HI	140	110	150	63	110
The summed cancer risk and non-carcinogenic Hazard Index (HI) for each canyon use maximum concentrations of pollutants detected in sediment samples from the given canyon.					

2.0 | California Toxics Rule

The California Toxics Rule is a list of numeric water quality criterion for Priority Toxic Pollutants promulgated by the US EPA for the protection of public health and aquatic life for waters in the state of California. The CTR criteria were developed to satisfy section 303 (c)(2)(B) of the Clean Water Act (CWA)[4]. There are 19 criteria for the protection of human health from consumption of water and aquatic organisms that apply to pollutants detected in water samples, and only 4 metal criteria that apply to concentrations of dissolved metals detected in water samples for the protection of aquatic life (Tables 2.1 and 2.2). The criterion for the protection of human health is separated into criteria that apply to the consumption of both water and organisms (more stringent) and to the consumption of aquatic organisms only such as fish (less stringent). The criterion for the protection of aquatic life is separated into criterion for exposure concentrations that apply to maximum concentrations and continuous concentrations (4 days). Human health criterion for carcinogens is based on a cancer risk of one in a million (10^{-6}).

Section Highlights

- Several carcinogenic PAHs were identified by the California Toxics Rule (CTR) criteria that could be harmful to human health from consumption of water and aquatic organisms; two of which were only detected in Line Canyon base flow
- The greatest exceedance of CTR organic pollutant criteria was chrysene detected in Line Canyon stormwater at over 10 times the criteria for consumption of water and organisms
- The metal of most concern to human health is mercury that was detected at 4.4 ug/L in a test for total recoverable metals
- The level of dissolved selenium was found at a level that may be harmful to aquatic life in freshwater, and the dissolved nickel and copper found in water samples may be harmful in saltwater

Protection of Human Health

For the maximum concentration of organics that were detected in water samples there are six pollutants that exceeded the criterion for the consumption of water and aquatic organisms, but none exceeded the criterion for the consumption of organisms alone (Table 2.1). The greatest exceedance of these criteria was for chrysene which was detected at over 10 times the criteria in stormwater runoff from Line Canyon. Chrysene is a PAH with carcinogenic effects. Benzo(a)anthracene, benzo(b)flouranthene, and bis(2-ethylhexyl)phthalate were also detected at maximum concentrations more than twice the criterion for the protection of human health from consumption of water and aquatic organisms (Table 2.1). Additionally, two of the six organics with maximum concentrations detected above human health criterion were only detected in the Line Canyon base flow: benzo(a)pyrene and indeno(1,2,3-cd)pyrene (both carcinogenic PAHs).

Of the four metals with CTR human health criterion all have maximum total recoverable metal concentrations that exceed the criteria, but none have dissolved concentrations that exceed the criteria (Table 2.1). Most notable of the metals is the total mercury concentration of 4.4 ug/L, which is over 85 times both of the human health criterion. As indicated by the criteria concentrations, mercury is one of the more toxic metals considered in this analysis.

Protection of Aquatic Life

Four metals were identified for comparison to aquatic toxicity levels. Only dissolved concentrations of metals are analyzed for aquatic toxicity because of the bioavailability of metals in dissolved form. Aquatic toxicity of metals is hardness dependent because of the interaction between metals and dissolved solids at high concentrations which buffers the toxic effects of most metals. The freshwater criterion for copper, nickel, and zinc were calculated using the equations established in the CTR. A maximum hardness concentration of 400 mg/L was used along with a water effects ratio (WER) of 1 to derive these metals criteria. The saltwater criteria were also analyzed for the creeks because the creeks discharge directly into the coastal environment, although mixing in the coastal zone was not analyzed. Additionally, while the creeks are considered for freshwater habitat, the threshold salinity for the saltwater criterion is 10 g/L, which is approximately the concentration of TDS in the Line Canyon base flow. At salinities between 1 g/L and 10 g/L the more stringent of the two criteria (saltwater or freshwater) apply, while below 1 g/L salinity only the freshwater criteria should be applied.

Of the four metals analyzed using the CTR only selenium was found to exceed the freshwater criterion, which was detected at over three times the criterion concentration in Amphitheater Canyon (Table 2.2). The Line Canyon base flow was found to have a sample with a dissolved nickel concentration that exceeds the saltwater criterion (dissolve nickel in Amphitheater Canyon stormwater was also detected above this criteria at 12.8 mg/L). Dissolved copper In Amphitheater Canyon stormwater was detected above both the saltwater maximum instantaneous and continuous criterion (Table 2.2).

Table 2.1 – **California Toxics Rule water quality criterion for protection of human health**

COMPOUND	CRITERION FOR CONSUMPTION OF WATER AND ORGANISMS	CRITERION FOR CONSUMPTION OF ORGANISMS ONLY	MAXIMUM CONCENTRATION DETECTED IN WATER SAMPLES	CANYON WITH MAXIMUM CONCENTRATION
ORGANICS (ug/L)				
Acenaphthene	1,200	2,700	0.05	Line
Anthracene	9,600	110,000	0.0085*	Javon
Benzene	1.2	NA	0.14*	Line
Benzo(a)anthracene	0.0044	0.049	0.013*	Line
Benzo(a)pyrene	0.0044	0.049	0.0059*	Line base
Benzo(b)flouranthene	0.0044	0.049	0.01*	Javon
Bis(2-ethylhexyl)phthalate	1.8	5.9	4.7	Line
Chrysene	0.0044	0.049	0.047	Line
Dibenzo(a,h)anthracene	0.0044	0.049	0.0039*	Line base
Ethylbenzene	3,100	29,000	0.29*	Amphitheater
Flourene	1,300	14,000	0.11	Line
Fluoranthene	300	370	0.026	Amphitheater
Indeno(1,2,3-cd)pyrene	0.0044	0.049	0.0047*	Line base
Pyrene	960	11,000	0.022	Javon, Line, Amphitheater
Toluene	6,800	200,000	0.37*	Line
METALS (ug/L)				
Antimony	14	4,300	27.5*/ND	Javon
Copper	1,300	NA	3,230/7	Amphitheater
Mercury	0.05	0.051	4.4/ND	Amphitheater
Nickel	610	4,600	5,110/14.9	Amphitheater/ Line base flow

Highlighting is yellow if maximum concentration detected in water samples exceeds either criterion. For metals, the first value of maximum concentrations detected in water samples is total recoverable metal concentrations, and the second value is for dissolved concentrations (Total/Dissolved metals).
*Measured concentration is above the detection limits for the analytical method that was used but below the reporting limit and is considered an estimate.

Table 2.2 – **California Toxics Rule water quality criterion for protection of aquatic life**

METAL	FRESHWATER CRITERION FOR MAXIMUM CONCENTRATION	FRESHWATER CRITERION FOR CONTINUOUS CONCENTRATION	SALTWATER CRITERION FOR MAXIMUM CONCENTRATION	SALTWATER CRITERION FOR CONTINUOUS CONCENTRATION	MAXIMUM DISSOLVED CONCENTRATION IN WATER SAMPLES	CANYON WITH MAXIMUM CONCENTRATION
METALS (ug/L)						
Copper	50**	29**	4.8	3.1	7	Amphitheater
Nickel	1500**	170**	74	8.2	14.9	Line base flow
Selenium	NA	5	290	71	15.3*	Amphitheater
Zinc	380**	380**	90	81	2.9*	Padre Juan

*Measured concentration is above the detection limits for the analytical method that was used but below reporting limits and is considered an estimate.
**Metal concentration was converted for very hard water.

3.0 | California MCLs and PHGs

California's Maximum Contaminant Levels (MCLs) and Public Health Goals (PHGs) are regulatory drinking water criteria established to protect public health from adverse pollutants that may be found in drinking water supplies[5]. These regulatory levels are compared to the concentrations of pollutants detected in water samples as these waters have the potential beneficial use of MUN and may be used to determine the level of treatment that would be needed to achieve this use.

MCLs are established by taking into account the health risk of the pollutant along with economic and technical feasibility of the proposed MCL. The level that MCLs are set at may be higher than PHGs because it may be that 1) it is currently not technically feasible to measure or reduced the concentration below a certain level; or 2) it becomes far too expensive (cost prohibitive) to reduce the constituent to very low levels[5]. The PHGs are set to a level that is solely protective of public health without considering economic and technical feasibility, therefore PHGs are generally set at a lower contaminant concentration than MCLs.

Section Highlights

- Most organics and dissolved metals and salts are below the MCLs and PHGs for constituents tested in water samples
- Nitrate (NO3) concentration detected in Amphitheater Canyon during the second storm of the season was above both the MCL and PHG
- All the metals, when considered in total recoverable concentration, are found above MCL and PHG levels in at least one water sample
- Amphitheater and Line Canyons had the most and greatest concentrations of total metals above the MCLs and PHGs of all the water samples

Maximum concentrations in water samples were compared to California MCLs and PHGs to illustrate the utility of these waters for drinking water supply, which is a designated beneficial use in several of the canyons. A total of 20 of the constituents analyzed for in water samples also have established MCLs and PHGs, including 12 metals (Tables 3.1 and 3.2).

Organics and Dissolved Metals

Of the organic pollutants only bis(2-ethylhexyl)phthalate was found to be above the MCL, at a concentration of 0.0047 mg/L in one sample from Line Canyon. Out of the dissolved metals, only nickel was detected above the 0.012 mg/L MCL in two samples; one was from Amphitheater Canyon stormwater at a concentration of 0.0128 mg/L and the other was from the Line Canyon base flow at a concentration of 0.0149 mg/L. Nitrate (NO3) was detected in Amphitheater Canyon at a concentration of 80.6 mg/L (18.2 mg/L as N) during the second storm of the season, a concentration which is greater than both the MCL and PHG (both criterion are set at 45 mg/L as NO3; Table 3.2).

Total Recoverable Metals

If total recoverable metal concentrations are considered for comparison to MCLs and PHGs there are many samples that had concentrations above these levels (Table 3.3). All of the 12 metals were detected in total concentrations above MCL levels in one or more samples. The metal constituents that were found at the greatest concentration above MCL levels were all from Amphitheater Canyon samples due to the high levels of TSS in samples from this canyon, with the exception of selenium (Table 3.3). The two canyons with the most total metals detected above MCL and PHG levels are Line and Amphitheater. Aluminum, arsenic, lead, and nickel were detected above the MCL, PHG, or both in at least one stormwater sample from each canyon. Samples of the Line Canyon base flow were also found to have a concentration of antimony above the MCL and concentrations of arsenic, lead, and nickel above PHGs.

Tables 3.1 and 3.2 list all of the California MCLs and PHGs for pollutants that were detected in water samples. Table 3.3 shows the maximum concentration of total metals, for the 12 metals with MCLs and PHGs, which were detected in stormwater samples from each of the five study canyons, and the maximum total metal concentration detected in the base flow from Line Canyon. The concentrations in Table 3.3 are highlighted yellow if they are above the MCL and orange if they are only above the PHG.

Table 3.1 – **MCLs and PHGs for organics detected in study samples (mg/L)**

COMPOUND	MCL	PHG	Date of PHG
Benzene	0.001	0.00015	2001
Benzo(a)pyrene	0.0002	0.000007	2010
Di(2-ethylhexyl)phthalate (DEHP)	0.004	0.012	1997
Ethylbenzene	0.3	0.3	1997
Toluene	0.15	0.15	1999
Xylenes	1.75	1.8	1997

Table 3.2 – MCLs and PHGs for metals and salts detected in study samples (mg/L)

METALS & SALTS	MCL	PHG	DATE OF PHG
Aluminum	1	0.6	2001
Antimony	0.006	0.02	1997
Antimony	--	0.0007	2009 draft
Arsenic	0.010	0.000004	2004
Barium	1	2	2003
Beryllium	0.004	0.001	2003
Cadmium	0.005	0.00004	2006
Chromium, Total	0.05	(0.0025) withdrawn Nov. 2001	1999
Copper	1.3	0.3	2008
Lead	0.015	0.0002	2009
Mercury (inorganic)	0.002	0.0012	1999 (rev2005)*
Nickel	0.1	0.012	2001
Selenium	0.05	0.03	2010
Fluoride	2	1	1997
Nitrate (as NO3)	45	45	1997

Table 3.3 – Maximum total metal concentrations from water samples (mg/L)

METALS	MADRIANO	JAVON	PADRE	LINE	AMPHITHEATER	BASE FLOW LINE
Aluminum	38.3	373	4.61	816	1790	0.499
Antimony	ND	0.0275*	ND	ND	ND	0.0117*
Arsenic	0.0282	0.218	0.0083*	0.863	1.14	0.0086*
Barium	0.608	5.65	0.079	12.9	14	0.207
Beryllium	0.0024	0.0164	0.00023*	0.0459	0.096	ND
Cadmium	0.0037	0.0195	ND	0.0526	0.13	ND
Chromium, Total	0.0915	1	0.0129	1.8	4.34	0.0028*
Copper	0.0893	0.634	0.0204	2.79	3.23	0.0043
Lead	0.0141	0.221	0.0126	0.985	1.12	0.006*
Mercury (inorganic)	0.00027*	0.00074*	0.00002*	0.00146	0.00444	0.00004*
Nickel	0.174	1.28	0.0156	2.24	5.11	0.0176
Selenium	ND	0.291	ND	ND	ND	ND

Highlighting is yellow if exceeding MCL and orange if exceeding only the PHG.
*Measured concentration is above the detection limits for the analytical method that was used but below reporting limits and is considered an estimate.

4.0 | Toxicity Analysis Summary

This Toxicity Analysis compares sample results collected during the NVCCWP Environmental Sampling activities to four different toxicity screening criteria: EPA Regional Screening Levels (RSLs), California Toxics Rule (CTR), and California Maximum Contaminant Levels (MCLs) and Public Health Goals (PHGs) for drinking water. Of these the RSLs are the most comprehensive, analyzing four different exposure pathways.

This analysis found arsenic to be the pollutant of most concern. Arsenic was detected at relatively high concentrations in sediments and stormwater samples from all five canyons. Arsenic was found to have a maximum increased carcinogenic risk through the residential soil exposure pathways of 18 in one million from a sediment sample collected in Javon Canyon, and 25,000 in a million for dermal exposure to tap water from a water sample collected in Amphitheater Canyon.

Although dissolved metals are more bioavailable the greatest concern for metals toxicity is from total recoverable metals measured at very high concentrations in stormwater samples. The high concentrations of total suspended solids (TSS) detected in Line and Amphitheater Canyons was associated with these high concentrations of total metals. High total metal concentrations in stormwater samples resulted in hazard quotients (HQ) for Line and Amphitheater Canyons of 19 and 44 for the dermal exposure pathway, and 400 and 940 for the tap water exposure pathways in which the ingestion pathway is considered.

The organic pollutants detected in sediments and waters were found at low enough concentrations that they did not have an applicably high cancer risk. The RSLs identified Propargyl alcohol and 1,2,4- trimethylbenzene as the organics with the highest risk, both non-carcinogenic. Propargyl alcohol was detected in Padre Juan Canyon and had a tap water HQ equal to 11. The CTR criteria identified several PAHs and bis(2-ethylhexyl)phthalate as potential pollutants of concern, most of them from Line Canyon.

Maximum concentrations in water samples were compared to California MCLs and PHGs because water resources in Madriano, Javon, and Padre Juan Canyon have been designated for the potential beneficial use of municipal and domestic water supply. Total recoverable metals exceeded California MCLs and PHGs in water samples from each canyon and were found to be the greatest pollutants of concern if runoff from the canyons is to be used for drinking water.

5.0 | Toxicity Analysis References

1) EPA. Pacific Southwest, Region 9. Regional Screening Level (RSL) Tables. Updated May 2014. Available at: http://www.epa.gov/region9/superfund/prg/

2) EPA. Terminology Services. Integrated Risk Information System (IRIS) glossary. Accessed June 2014. Available at: http://ofmpub.epa.gov/sor_internet/registry/termreg/searchandretrieve/glossariesandkeywordlists/search.do;jsessionid=NG2L1YD1bFQnFWPrgTiHuHm9KrEKRmCOaeJ2rGnKMxOVXXbJqinS!1167716176

3) EPA. Mid-Atlantic Risk Assessment. User's Guide for RSLs. Updated May 2014. Available at: http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/usersguide.htm

4) EPA. Establishment of numeric criteria for Priority Toxic Pollutants for the State of California – Final Rule. 40 CFR Part 131. Federal Register: Vol. 65, No. 97: Thursday, May 18, 2000: Rules and Regulations. Available at: http://www.epa.gov/fedrgstr/EPA-WATER/2000/May/Day-18/w11106.pdf

5) California Department of Public Health (CDPH). MCLs and PHGs for regulated contaminants in drinking water. Available at: http://www.cdph.ca.gov/certlic/drinkingwater/Pages/MCLsandPHGs.aspx

Source Assessment

Northern Ventura County Coastal Watershed Project

The following Source Assessment was completed as part of the Northern Ventura County Coastal Watershed Project (NVCCWP), which also includes a Watershed Assessment, Environmental Sampling, Toxicity Analysis, and Recommendations & Mitigation Strategies.

Pollutants found in the study watersheds have a wide range of sources, both natural and anthropogenic. This element of the NVCCWP discusses potential sources and their contributions to concentrations found in field tests and laboratory analyses from 17 water samples and 10 sediment samples collected in Madriano, Javon, Padre Juan, Line, and Amphitheater Canyons from October 2013 through April 2014. Field tests and laboratory analyses completed through the NVCCWP study found high levels of suspended sediment and dissolved solids in stormwater runoff, along with high concentrations of metals and detections of various organic compounds.

Heavy metals, petroleum hydrocarbons, and other organic compounds have the tendency to sorb to sediment as it mobilizes throughout the watersheds. While much of the high concentrations of suspended sediment and metals can be attributed to the highly erosive soils and geology, land uses (specifically oil field roads and land clearings) exacerbate erosion and sediment transport, and are considered the main anthropogenic drivers of these pollutants in the study watersheds. Metals, suspended and dissolved in stormwater, are transported through the drainage network to highly frequented beaches and into the ocean. The high sediment transport and yield of the study watersheds increases the potential for these pollutants to accumulate in sensitive areas.

This Source Assessment is divided into four sections:

1) Erosion & Sediment Transport
2) Metals & Salts in Stormwater
3) Organic Compounds
4) Line Canyon Base Flow

Within these sections, anthropogenic and natural sources of pollutants found in stormwater, sediment and base flow samples are explored, as is the origin of the Line Canyon base flow which was found to contain high levels of total dissolved solids and metals. Background samples were not collected, and samples were taken only from locations near the watershed outlets. As samples were not collected from areas upstream of oil field operations, pollutants attributed to these land uses could not be verified. This Source Assessment relies on data from the Watershed Assessment and Environmental Sampling elements of the NVCCWP, and other relevant water quality studies to determine potential pollutant sources.

Source Assessment Table of Contents

ACRONYMS

DEHP	Bis (2-ethylhexyl) Phthalate
DRO	Diesel Range Organics
NPDES	National Pollutant Discharge Elimination System
NVCCWP	Northern Ventura County Coastal Watershed Project
PAHs	Polycyclic Aromatic Hydrocarbons
Propargyl Alcohol	2-propyn-1-ol
PVC	Polyvinyl Chloride
RRO	Residual Range Organics
SWAMP	Stormwater Ambient Monitoring Program
TDS	Total Dissolved Solids
TSS	Total Suspended Solids
USGS	U.S. Geological Survey

UNITS

cfs	Cubic Feet per Second
L/s	Liters per second
m	Meters
cm	Centimeters
kg	Kilograms
mg	Milligrams
µg	Micrograms

Data Disclaimer: Blue Tomorrow and its contractors are not liable for any damages that may result from the use of data or analysis contained in this assessment.

1.0 | Erosion & Sediment Transport

Natural sources of sediments found in stormwater runoff include exposed rocks and soils on steep and unstable terrain, characteristic of watersheds in the Transverse Mountain Range. Soils found in the study watersheds consists of very small silt and clay particles, which easily suspend in water, and can impact the level of TSS in streams. Driven by the weak geology and tectonic forces in the area, these watersheds are prone to high rates of erosion. Surface runoff classes of soils in the study watersheds (based on topographic slope and saturated hydraulic conductivity of the soil) show high to very high levels of runoff potential. While erosion is a natural process, other anthropogenic factors can increase sediment discharge into creeks and coastal waters.

Oil field infrastructure is the predominant upstream intensive land use in the watersheds, and is a potential contributing source to high TSS levels. Well pads, roads, and other clearings expose soils and alter watershed hydrology. Many of the roads are sources of finely crushed soil and rock particles, and are avenues for runoff, which create gullies and funnel sediments (from sumps and other deposits) into the creeks. Disturbance and compaction of soils by roads and construction of other cleared areas reduces infiltration capacity which increases surface runoff, the transport of suspended solids, and downstream erosion.

Section Highlights

- Sediment is a pollutant and vehicle for other pollutants of concern
- Natural sources of sediment include the marine sedimentary geology and soils, and tectonic activity contributes to landslides and mass movement of soil and rock
- Oil field roads and other infrastructure are likely anthropogenic sources of sediment loads discharging into coastal waters
- Line Canyon has the least erodible soils of all watersheds with respect to soil texture, yet highest TSS concentrations in stormwater runoff (along with Amphitheater Canyon)

Soils with the highest erodibility factor (based on soil texture) are most widespread in Javon Canyon, while the least erodible soils are found in Line Canyon. However, stormwater samples showed TSS levels in Line and Amphitheater Canyons to be an order of magnitude higher than in Javon Canyon. Line and Amphitheater Canyons have by far the greatest density of oil field infrastructure among the study watersheds. These canyons have cleared areas and road densities that are roughly 4 times greater (per square mile) than Madriano, Javon, and Padre Juan Canyons. Increased traffic, roads on unstable and steep topography, and other land clearings are suspected to influence the high levels of TSS found in Line and Amphitheater Canyons.

1.1 Natural Sources

Landslides and other mass movements of soil and rock are widespread throughout the study watersheds. The large number of landslides in the region has been attributed to the fast uplift and significant deformation in the recent geologic past combined with weak sedimentary rocks and steeply entrenched valleys[1]. The Pico Formation is the most prevalent formation in the surficial geology of the study area and is especially prone to landslides[1, 2, 3]. In Javon Canyon, Padre Juan Canyon, and Line Canyon, landslides are found at 0.7%, 6.4%, and 6.5% of the watershed areas (Tables 2.2-2.4 of the Watershed Assessment).

Badlands, moderately steep to very steep barren land with many intermittent drainage channels, are possible sources for sediment as these areas have a high potential to generate runoff and erode[4]. Badlands are mapped in Madriano, Line, and Amphitheater Canyon and cover 8.2% of the study area. Soils in the watersheds have a high degree of surface runoff and are prone to erosion. The majority of soils in the study watersheds have high to very high runoff potential, and Javon Canyon has the most erodible soils of the watersheds (Figures 2.1 and 2.4 of the Watershed Assessment).

In nearby basins, stormwater samples from undeveloped watersheds showed TSS event mean concentration ranges between 81 and 92 mg/L in Santa Monica Canyon (2001), and 8 and 880 mg/L in open space Arroyo Sequit (2003 to 2005)[5]. Surface water from 22 natural open-space sites, sampled in 2004 and 2006 from twelve watersheds in coastal southern California, showed TSS concentrations in stormwater positively correlated with watersheds with sedimentary rock. Stormwater samples collected from seven creeks in Ventura and Los Angeles County showed ranges of flow-weighted mean concentrations from 107 mg/L in Arroyo Seco to 52,000 mg/L in Sespe Creek[6].

A number of natural characteristics and processes found in the study watersheds contribute to the large amounts of sediment that is discharged from the creeks into coastal waters. Geology, soils, and tectonic activity all make this area susceptible to landslides and erosion. Though natural background levels of TSS in stormwater runoff from the study watersheds were not available, previous studies of undeveloped watersheds with similar physical characteristics in coastal Southern California suggest that natural sources can lead to TSS concentrations ranging in the thousands to tens of thousands of milligrams per liter (mg/L).

1.2 Anthropogenic Sources

Possible anthropogenic sources of sediment in the study watersheds include oil field roads and other areas disturbed by human activity. Extensive road and well pad networks have been developed in the study area to support the oil field operations influencing surface runoff and water quality. Roads and cleared areas are sources of fine sediments, and can create or exacerbate gullied lands by discharging accumulated water into them. Gullied lands are also potential sources of TSS and other sediment pollutants[7,8].

Gullies often originate from unpaved roads, and different road surfaces can generate varying concentrations of TSS, which are transported into waterways[7]. Paved roads have lower TSS concentrations than graveled road surfaces[7]. Unmaintained gravel roads can generate higher concentrations of TSS further downslope, due to the storage and remobilization of road generated sediment[9]. Oil field roads are used frequently by heavy trucks and machinery. In the Pacific Northwest, high traffic on graveled road segments has been shown to increase sediment production by up to 130 times more than road segments with no traffic over the course of a year[10]. A study in northwestern California found that roughly 40% of the total erosion in logging areas was attributable to the road network[11].

Road systems in areas of unstable topography are known to contribute to landslides and extensive gullying that transport sediment into streams[8]. Road cuts and culverts can disrupt natural hydrology by collecting and diverting water along their length and discharging onto unchanneled hillslopes[8]. These diversions often result in further gullying or road failures[7]. The California Geological Survey has found that most oil field roads in the study area require constant rebuilding and re-grading due to landslide activity, and many roads continue to fail after rehabilitation[1,2].

Of all the study watersheds, Line and Amphitheater Canyons have by far the greatest density of oil field roads and other cleared areas. Line Canyon has both the greatest total length of roads at about 16.3 miles and cleared well pads and staging areas at about 0.078 mi^2. Amphitheater Canyon has the second largest road density in the watersheds (10.5 mi/mi^2) and percent of watershed cleared (8.8%). Table 1.1 shows the extent of oil field infrastructure development in the study watersheds.

Table 1.1 - **Road length and cleared areas estimated for each of the five watersheds**

WATERSHED (area)	ROAD LENGTH (miles)	ROAD DENSITY (mi/mi^2)	PADS & STAGING AREAS (mi^2)	PERCENT OF WATERSHED AREA CLEARED
Madriano Canyon ($2.3\ mi^2$)	5.0	2.2	0.019	1.9%
Javon Canyon ($2.1\ mi^2$)	5.8	2.8	0.023	2.6%
Padre Juan Canyon ($3.0\ mi^2$)	8.3	2.8	0.022	2.2%
Line Canyon ($1.4\ mi^2$)	16.3	11.6	0.078	10.8%
Amphitheater Canyon ($0.56\ mi^2$)	5.9	10.5	0.017	8.8%
Estimates were performed using aerial imagery from 2010 and 2012[12] and ArcMap. Road density and percent area cleared were then calculated using the watershed area for each watershed. The percent area cleared includes the pads and staging areas plus the road length that does not overlap these areas, and assumes an average road width of 10 meters (33 feet).				

1.3 Total Suspended Solids in Stormwater

TSS concentrations in stormwater samples were greatest in Line and Amphitheater Canyons, which also experienced the greatest flow rates during the February-March storm. Peak concentrations were an order of magnitude higher in these watersheds than those found in Madriano, Javon, and Padre Juan Canyons (Table 1.2).

Table 1.2 – **TSS concentrations (in mg/L) from stormwater samples 2013-2014**

WATERSHED	Nov-21 2013	Feb-27 2014	Feb-28 2014	Mar-1 2014
Madriano Canyon	275	2,160	-	-
Javon Canyon	-	-	15,600	12,200
Padre Juan Canyon	154	303	-	9,210
Line Canyon	59,700	52,800	130,000	122,000
Amphitheater Canyon	-	87,800	189,000	135,000

Existing water quality data from stormwater samples collected by the oil field operator and the Stormwater Ambient Monitoring Program (SWAMP) from 2006 through 2011 showed similar concentrations to those found in the 2013-14 study samples. Line and Amphitheater Canyons again showed maximum concentrations an order of magnitude higher than in Madriano, Javon, and Padre Juan Canyons (Table 1.3).

Table 1.3 – **Range of TSS concentrations from stormwater samples 2007-2011[13,14]**

PARAMETER	MADRIANO	JAVON	PADRE JUAN	LINE	AMPHITHEATER
TSS (mg/L)	158 to 29,000	21 to 30,200	24 to 13,600	7,900 to 133,000	750 to 396,000
Stormwater samples collected by the oil field operator between January 27, 2007 and May 17, 2011[13], and Stormwater Ambient Monitoring Program (SWAMP) on June 5 and 7, 2006 [14]. TSS levels were measured from nine samples from Madriano, Javon, Line, and Amphitheater Canyons, and seven samples from Padre Juan Canyon by the oil field operator, and once in the upper (above Highway 101) and lower (below Highway 101) parts of Madriano, Javon, and Padre Juan Canyons through SWAMP monitoring.					

1.4 Erosion & Sediment Transport Summary

Sediment is a pollutant and also a vehicle for other pollutants of concern. Sediment in creek beds and on beaches can potentially expose people and coastal ecosystems to harmful pollutants. Changes in coastal sediment budgets and excess turbidity can impact kelp forest ecosystems and coastal hard bottom habitats[15].

Existing water quality data and results from stormwater samples collected from October 2013 through April 2014 show extremely high levels of TSS in Line and Amphitheater Canyons. A substantial portion of these concentrations can be attributed to natural sources, from marine sedimentary rock, highly erodible soils, and tectonic uplift. However, when comparing results between the watersheds, it appears that land uses are elevating sediment discharge.

Of the study watersheds, Line and Amphitheater Canyons have the highest density of roads and greatest percentage of cleared areas. Roads constructed in unstable topography are prone to landslides, gullies, and other failures, all of which are known to occur in the study watersheds. Road networks are likely contributing significant amounts of erosion, modifying hydrology of the watersheds, and increasing suspended sediment found in stormwater runoff.

2.0 | Metals & Salts in Stormwater

Salts and metals found in stormwater samples are a result of watershed soils and geology, which are rich in metals. High concentrations of total metals in stormwater runoff can be linked to levels of TSS and upstream erosion. Salts tend to dissociate quickly in water and can be detected from their ions.

> **Section Highlights**
>
> - Soils and geology are the main sources of metals and salts found in stormwater and sediment samples
> - TSS concentrations strongly correlate with levels of total metals
> - Anthropogenic influences on erosion and sediment discharge likely increase concentrations of metals above natural levels
> - Vehicles from the railroad and Highways 1 and 101 are potential sources of metals, though are not expected to substantially contribute to detected concentrations

Total dissolved solids (TDS) ranged from 161 mg/L in Padre Juan Canyon to 5,290 in Line Canyon in the NVCCWP stormwater samples. Low levels in Padre Juan Canyon are likely indicative of runoff originating from roads, as TSS levels and conductivity were also among the lowest of all sample results. Line Canyon and Amphitheater had the highest levels of TSS, total metals, TDS and conductivity.

Land uses are a contributing source to the high TSS levels found in stormwater samples through increased erosion. Comparing sample results from each watershed, it appears that metal concentrations are largely driven by erosion and correlate strongly with TSS levels. Additional samples collected from soils across California and from Monterey Formation rock in the Malibu Creek Watershed, show possible background levels of metals and salts.

2.1 Natural Sources

Soils and geologic formations are sources of metals found in stormwater samples. During storm events, runoff mobilizes sediment and transports metals (found in sediment) into creeks. Results from the NVCCWP show that Amphitheater and Line Canyons had the highest concentrations of total metals found in stormwater runoff (10,150 mg/L and 4,826 mg/L, respectively), and both canyons also had the highest levels of TSS.

Soils & Geology

Soils and geologic formations are primary sources of metals found in stormwater and sediment samples. Rock erodes and weathers to form soils, which leach salts and metals into water bodies during storm events. Marine sedimentary rocks, such as the Monterey Formation, are known to influence loading of metals in streams, and contain large amounts of aluminum, arsenic, and selenium[16,17].

Data from samples of soils and Monterey Formation rock show that the high concentrations of metals found in the study watersheds are most likely a result of sediment (originating from these sources) which discharges to the creeks and coastal waters. Table 2.1 shows the potential contributions that soils and geology may have on concentrations of metals found in sediments in the study watersheds. Maximum values of metal concentrations found in 50 soils throughout California[18], used to characterize natural background levels, show that soils can be a major source of most all metals. Sampled Monterey Formation rock from the Malibu Creek Watershed indicates that exposure and weathering of marine sedimentary rock is another potential significant source of metals found in stormwater and sediment samples[17].

Table 2.1 –**Comparison of metals concentrations found in study watersheds with natural background levels of California soils and Monterey Formation rock**[17,18]

METALS (mg/Kg)	CALIFORNIA BACKGROUND SOILS MAXIMUM	MONTEREY FORMATION MAXIMUM	NVCCWP SEDIMENT SAMPLES MAXIMUM	NVCCWP SEDIMENT SAMPLES CANYON
Aluminum	10.6	15,800	10,600	Padre Juan
Antimony	1.95	1.2	ND	-
Arsenic	11	3.2	10.9	Javon
Barium	1,400	101	207	Madriano
Beryllium	2.7	0.5	0.52	Padre Juan
Boron	74	12	29.4	Amphitheater
Cadmium	1.7	102	0.71	Madriano
Calcium	45,577	163,000	14,100	Padre Juan
Chromium	1579	58.9	26.9	Madriano
Cobalt	46.9	16	7.1	Padre Juan
Copper	96.4	37.8	18.6	Javon
Iron	87,000	23,100	19,700	Padre Juan
Lead	97.1	3.3	28.1	Javon
Magnesium	32,378	4,410	11,500	Amphitheater
Manganese	1687	219	309	Padre Juan
Mercury	0.9	0.07	0.062	Madriano
Nickel	509	113	40.8	Madriano
Potassium	30,000	3,940	2,570	Madriano
Selenium	0.43	13.4	8.7	Padre Juan
Silver	8.3	-	ND	-
Sodium	73,400	400	2,180	Padre Juan
Thallium	1.1	3.9	ND	-
Vanadium	288	372	34.9	Padre Juan
Zinc	236	108	56.8	Madriano

California background soils show maximum metal concentrations (mg/kg) from samples collected in 50 soil types chosen to characterize natural background concentrations in soils[18]. In Malibu Creek Watershed, four samples freshly-exposed (graded) Monterey Formation rock were tested twice (on 2009 and 2010) and maximum concentrations are shown above[17]. NVCCWP sediment samples were collected in the study waters on October 23, 2013 and March 7, 2014.

Table 2.2 –**Comparison of dissolved metals concentrations in stormwater from study watersheds (NVCCWP) with stormwater runoff from Monterey Formation rock[17]**

	MONTEREY FORMATION STORMWATER SAMPLES		NVCCWP STORMWATER SAMPLES	
CONSTITUENT (mg/L)	FRESH EXPOSURE (MAX)	WEATHERED	MAXIMUM	CANYON
Aluminum	34.5	0.03	0.083*	Padre Juan
Antimony	0.003	-	ND	-
Arsenic	0.013	0.006	ND	Line
Barium	0.378	0.0277	0.0716	Javon
Beryllium	0.0032	-	ND	-
Boron	0.001	-	1.49	Line
Cadmium	0.0215	0.0002	ND	-
Calcium	53	318	245	Javon
Chromium	0.065	-	0.0012*	Padre Juan
Cobalt	0.0319	0.0033	0.0008*	Amphitheater
Copper	0.068	0.004	0.007	Amphitheater
Iron	40.3	0.27	0.035	Amphitheater
Lead	0.0212	0.0004	ND	-
Magnesium	19	191	182	Amphitheater
Manganese	-	-	0.0909	Javon
Nickel	0.111	0.022	0.0128	Amphitheater
Potassium	12	16	14.6	Amphitheater
Selenium	0.004	-	0.0153*	Amphitheater
Silver	0.001	-	ND	-
Sodium	13	392	561	Line
Thallium	0.0017	-	ND	-
Vanadium	0.205	0.007	0.0017*	Padre Juan
Zinc	0.39	0.02	0.0029*	Padre Juan

Dissolved metal concentrations in stormwater found in study watersheds and runoff from exposed and weathered Monterey Formation rock. Stormwater samples from Monterey Formation in Malibu Creek Watershed were collected during the first flush on October 9, 2009[17]. Stormwater samples were collected twice in the study watersheds on November 21, 2013 and February 27 and 28, 2014. Results with asterisk (*) in NVCCWP stormwater samples are for those above detection limits but below reporting limits.

Geologic formations are also major sources of salts that are transported in sediment or as dissolved ions in stormwater runoff in the study watersheds[16]. Stormwater samples collected in Cheeseboro Creek, a tributary to Malibu Creek that drains marine sedimentary rock (Monterey and Calabasas Formations), found comparable levels of TDS to stormwater runoff in the study watersheds, although major ion composition differed (Table 2.3)[19]. Stormwater in the study watersheds had much higher levels of chloride, and lower levels of calcium and magnesium than in Cheeseboro Creek.

Total metals from NVCCWP stormwater samples were extremely high due to the high TSS. Stormwater samples collected from several undeveloped watersheds in southern California highlight how high these metal concentrations are (Table 2.4). Out of these undeveloped watershed Sespe creek had one of the highest measured TSS concentrations, but all the total metal concentrations from these watersheds were still orders of magnitude less than those detected in Line and Amphitheater Canyons.

Table 2.3 – **Major ions found in stormwater from Cheeseboro Creek and the study watersheds (NVCCWP)** [19]

CONSTITUENT	CHEESEBORO MAXIMUM	NVCCWP MAXIMUM	CANYON
Conductivity (uMHOS/cm)	3,590	7,990	Line
TDS (mg/L)	4,048	5,290	Line
MAJOR IONS (mg/L)			
Calcium	1,260	245	Javon
Chloride	288	1,090	Line
Magnesium	1,150	182	Amphitheater
Potassium	23.8	15.7	Javon
Sodium	259	561	Line Canyon
Sulfate	1,940	2,470	Amphitheater

Stormwater data from Cheeseboro Creek, in the Malibu Creek Watershed, were collected by the Los Angeles County Sanitation Districts from 1999 (one sample) and from 2002 – 2009[19]. NVCCWP results show the maximum concentrations of select ions measured in stormwater samples collected on November 21, 2013, and February 27 and 28, 2014.

Table 2.4 – **Comparison of total metal concentrations from undeveloped Southern California watersheds with study watersheds (NVCCWP)**[20]

CONSTITUENT	ARROYO SECO	PIRU CREEK	SANTIAGO CREEK	SESPE CREEK	TENAJA CREEK	NVCCWP MAXIMUM	CANYON
TDS (mg/L)	402	-	335	418	349	5,290	Line
TSS (mg/L)	107	5,455	13.97	51,969	184	189,000	Amphitheater
Total Metals (ug/L)							
Arsenic	0.89	0.47	0.22	0.36	0.73	1,140	Amphitheater
Cadmium	0.37	0.04	0.11	0.20	0.34	130	Amphitheater
Chromium	6.97	8.94	0.25	5.40	2.82	4,340	Amphitheater
Copper	3.63	5.51	0.38	4.83	2.33	3,230	Amphitheater
Iron	2,265	7,962	121	7,253	3,322	3,340,000	Amphitheater
Lead	2.26	1.85	0.11	1.54	1.44	1,120	Amphitheater
Nickel	2.20	5.76	0.27	5.36	1.21	5,110	Amphitheater
Selenium	0.52	0.53	1.04	0.69	0.50	ND	-
Zinc	12.64	16.11	1.46	14.35	12.50	9,780	Amphitheater

Flow weighted mean concentrations from stormwater samples collected between December 2004 and April 2006. Each site was sampled during two to three storms. These sites were selected to capture natural conditions of watersheds in southern California, without influence from anthropogenic land uses[20]. These results are compared to the maximum concentrations found in the NVCCWP stormwater samples.

2.2 Anthropogenic Sources

Although metals are found in soils and geology, which would influence water quality in the absence of human activity, accelerated erosion and sediment discharge caused by roads, construction, and development in the oil fields increases metal concentrations above natural levels. As a result, a significant amount of metals can be attributable to oil field roads and clearings.

Oil field roads and clearings

Maximum values of metal concentrations in sediment samples were found in Madriano, Javon, and Padre Juan Canyons. This is likely a result of differences in geologic formations and sources of sediment found in the study watersheds (Watershed Assessment, Figure 1.1). In contrast, Amphitheater and Line Canyons had the highest and second highest concentrations for 20 of 21 total metals that were above reporting limits in stormwater samples. This is due to the high TSS concentrations in Amphitheater and Line Canyons, which positively correlate with concentrations of total metals (Environmental Sampling Report, Table 4.5). As discussed in Section 1.0, TSS concentrations (and metals as a result) are likely a factor for metal loads from road systems in the oil fields.

Transportation

Other anthropogenic sources of metals include those from vehicles and machinery in the oil fields, and from the railroad, Highways 1 and 101. Atmospheric deposition is another potential source of metal pollutants. Cars and trucks are known to emit a number of contaminants that deposit on solid surfaces or enter the atmosphere. Table 2.5 highlights some of the sources of heavy metals that are found in stormwater runoff from highways.

Table 2.5 – Heavy metals and primary sources associated with highway stormwater runoff[21]

METALS	SOURCES
Cadmium	Tire wear, brake pads, combustion of oils
Chromium	Corrosion of welded metal plating, moving engine parts, brake lining wear
Copper	Metal plating, bearing and bushing wear, moving engine parts, brake lining wear
Iron	Auto body rust, steel roadway structures, moving engine parts, corrosion of vehicular bodies
Lead	Leaded gasoline, tire wear
Nickel	Diesel fuel and gasoline, lubricating oil, metal plating, bushing wear, brake lining wear, asphalt paving
Zinc	Tire wear, motor oil, grease

Though trains and vehicles from the railroad and Highways 1 and 101 are potential sources of heavy metals, they are not suspected to be significant sources of metals found in the stormwater and sediment samples. Samples were collected after several hours of precipitation, after highways drained pollutants built up since previous storms. Most samples were collected when there was no observable flow coming from the highways. Table 2.6 shows the differences in total metal concentrations found in stormwater from the study watersheds and from several studies conducted throughout California. For many metals, concentrations found in the study watersheds greatly exceed maximum levels expected from highway runoff (Table 2.6).

Table 2.6 – **Metal concentration ranges from California highway runoff studies[22,23,24]**

CONSTITUENT	HIGWAY RUNOFF MAXIMUM	NVCCWP STORMWATER MAXIMUM	CANYON
TOTAL METALS (mg/L)			
Antimony	0.0013	0.0275*	Javon
Arsenic	0.07	1.14	Amphitheater
Beryllium	ND	0.096	Amphitheater
Cadmium	0.03	0.13	Amphitheater
Chromium	0.094	4.34	Amphitheater
Cr (VI)	0.0025	-	-
Copper	0.9208	3.23	Amphitheater
Lead	2.6	1.12	Amphitheater
Mercury	0.0002	0.00444	Amphitheater
Nickel	0.2537	5.11	Amphitheater
Selenium	0.0013	ND	-
Silver	ND	ND	-
Thallium	ND	ND	-
Zinc	8.8813	9.78	Amphitheater

Highway runoff maximum presents results from three studies initiated by the California Department of Transportation that sampled stormwater runoff from California highways, including: 1) a three-year study that began in 1999 that sampled runoff from three sites in Los Angeles County; 2) a four-year study that began in 2000 that sampled runoff from 34 sites throughout California; and 3) a 2006 study that sampled runoff from a site in Ventura County. For additional information on these studies, see the Transportation section of the Northern Ventura County Coastal Watershed Assessments. Also presented are results from stormwater samples collected from the study watersheds.
Results with asterisk (*) in NVCCWP stormwater samples are for those above detection limits but below reporting limits.

2.3 Metals & Salts in Stormwater Summary

Line and Amphitheater canyons have the largest percentage of land clearings of the study watersheds (between 3 to 5 times greater). During the February 2014 storm event, stormwater in Line and Amphitheater canyons had much higher concentrations of total metals than those found in Madriano, Javon or Padre Juan canyons.

Comparing results of TSS and metal concentrations in the study watersheds with the amount of oil field road and other clearings, it becomes evident that land uses are influencing water quality. While stormwater showed high amounts of TSS in all watersheds, values from Line and Amphitheater Canyons (which have the greatest density of oil field infrastructure and cleared areas) were an order of magnitude greater than the next highest TSS concentrations found in Javon Canyon stormwater. Heavy metals, petroleum hydrocarbons, and other organic compounds sorb to sediment, and during storm events are transported through the watersheds. As these watersheds drain near highly frequented beaches and into the ocean, this higher sediment transport increases the potential for these pollutants to accumulate in sensitive areas.

3.0 | ORGANIC COMPOUNDS

Over the course of the study, a number of organic compounds were found at relatively low levels in water and sediment samples. The major source of organic compounds detected in stormwater samples is likely from spills around well pads and on oil field roads. The concentration of organics detected in stormwater runoff could be indicative of much larger upstream contamination due to the distance from spill areas (well pads) and the amount of dilution, volatilization, and degradation that is expected for most of the organics that were detected.

> **Section Highlights**
>
> - Organic compounds were detected at various levels in stormwater and sediment samples in the study watersheds
> - More abundant organic compounds detected in stormwater samples likely result from concentrated sources in the oil fields
> - DEHP and propargyl alcohol are not known to have natural sources and are used in hydraulic fracturing fluids
> - Napthalene has various sources (natural and anthropogenic), but detected levels are most likely a result of oil spills around well pads.

A possible source of various organic compounds, including polycyclic aromatic hydrocarbons (PAHs), is incomplete combustion of vehicles and heavy machinery which emit particulates which are likely deposited in the study area. Diesel exhaust contains benzene, bis(2-ethylhexyl)phthalate, and polycyclic organic matter (including PAHs)[26], and oil leaks and tire wear are also sources of PAHs[26]. However, it is not likely that deposition from the highways and railroad are the major source of organics detected in stormwater samples as samples were taken several hours after the flush from highways had occurred, and in many cases after precipitation and runoff from highways had stopped. Instead sediments with organic contaminants sorbed to them are likely from oil field operations further upstream.

Three organic compounds were selected to review possible sources due to their abundance and or toxic effects. These compounds were found at potentially hazardous concentrations in sediments and or stormwater from the canyons. Bis(2-ethylhexyl)phthalate (DEPH) and 2-Propyn-1-ol (propargyl alcohol) are not known to have any natural source, while naphthalene is a component of crude oil. However, according to California Division of Oil, Gas and Geothermal Resources and the U.S. Geological Survey there are no known natural oil or gas seeps in the study watersheds[27]. Likely sources for these constituents are listed below along with detected concentrations.

3.1 Bis(2-ethylhexyl)phthalate (DEHP)

DEHP was detected at the highest concentration in Line Canyon, where it was found at a maximum of 170 ug/kg in sediments and 4.7 ug/L in stormwater. These are fairly low levels as DEHP is found at concentrations from less than 50 ug/kg to 210,000 ug/kg in some river sediments[28]. Urban areas tend to have higher concentrations of DEHP than undeveloped areas, while industrial sites and areas downstream of industrial sites have some of the highest concentrations of DEHP[28].

DEHP is a plasticizer used to soften and add flexibility to plastics. It is most commonly used in polyvinyl chloride (PVC) were it can represent up to 50% of the mass[28], but it has many applications including rubber, and industrial and lubricating oils. Due to its high production volume and widespread use DEHP is considered a ubiquitous contaminant that is frequently found at low concentrations in soil, water, and air. It is considered fairly non-toxic at low concentrations although it is known to have health effects in animal studies including reproductive and development effects, carcinogenic effects and neurological effects, but these effects are considered unlikely and or inconclusive in humans[28].

DEHP is known to be a component of some hydraulic fracturing fluid products, and is part of a "diverting agent" additive[46]. In these additives it represents a maximum of about 5% of the additive by mass[46]. However, DEHP was not disclosed in the hydraulic fracturing fluid disclosure document for the Line Canyon well "Grubb 477" that was fractured in 2011[29]. A study of flow back fluids after hydraulic fracturing, conducted by Gradient for Halliburton Energy Services, Inc., found the maximum concentration in sampled flow back fluids to be 870 ug/L with a median sample concentration of 5 ug/L[50] (maximum NVCCWP stormwater sample concentration was 4.7 ug/L from Line Canyon). DEHP is known to degrade in water in weeks and upstream spills or leaks would be diluted by stormwater runoff, therefore it is more likely that the detected levels are from a concentrated upstream source other than hydraulic fracturing fluid.

Some hydraulic fluids, which are used to drive hydraulic pistons, can contain high concentrations of DEHP[34]. The recent increased drilling activity in Line Canyon would require hydraulic fluid for the drill rigs and machinery used, and a possible source of the DEHP in samples from Line Canyon could be from spilled hydraulic fluid. Other possible sources of DEHP are leachate from plastics and runoff from lubricating oils and worn rubber from roads.

3.2 2-Propyn-1-ol (Propargyl Alcohol)

Propargyl alcohol was detected only once at an estimated concentration of 0.33 mg/L in Padre Juan Canyon. It was selected for researching possible sources because of the relatively high toxicity of this compound. The median lethal concentration (LC50) for freshwater fish for this compound is 1-5 mg/L[30]. Propargyl alcohol will not bioaccumulate, and it is subject to volatilization and rapid biodegradation from soil and water[30].

Propargyl alcohol is not known to have any natural source. It is manufactured by many companies for use as a chemical intermediate, corrosion inhibitor, solvent stabilizer, soil fumigant and polymer modifier[31]. Propargyl alcohol is used as a corrosion inhibitor in hydraulic fracturing fluid and its use was disclosed by the oil field operator as being used in the fracturing of Grubb 477 on May 27, 2011, a well located in Line Canyon[29,46]. But, due to the high biodegradation rate, low concentration in hydraulic fracturing fluid, and that the pollutant was detected in Padre Juan Canyon where no hydraulic fracturing has been reported, the most likely source is a release of more concentrated fluid in which propargyl alcohol is used as a corrosion inhibitor. Corrosion inhibitors are commonly used in wells in the study area during operations such as acid treatments and have been noted in well records to be used several times in wells found in Padre Juan Canyon.

3.3 Naphthalene

Naphthalene was detected in all stormwater samples from all canyons. It is a common PAH that is created from combustion processes. It is used in the production of phthalic anhydride and as insecticides and repellents including those used in mothballs. Naphthalene occurs naturally in crude oil and is found in many petroleum derived products[32].

Naphthalene is a carcinogen present in some hydraulic fracturing fluids[33] and was used in the fracturing of Grubb 477[29]. Naphthalene has moderate to low soil mobility, but can volatize from water and soils in hours to weeks[34,35]. Biodegradation is in the range of days to weeks for water and weeks to months for soil[34].

Naphthalene was detected at the highest concentration of 1.9 ug/L in the stormwater runoff from Line Canyon. Higher levels of naphthalene in study samples were associated with more detections and higher levels of other PAHs. The most likely source of the naphthalene detected in Line Canyon is from oil spills around well pads. During the stormwater sampling from Line Canyon when the maximum concentration of naphthalene was detected, it was noted that precipitation had stopped for at least an hour (eliminating the highway as a potential source), and that there was a strong odor of hydrocarbons.

3.4 Organic Compounds Summary

A number of organic compounds were detected in stormwater and sediment samples over the course of the study. Dilution, degradation and volatilization of the compounds are expected to decrease the levels detected at sampling locations downstream. While many of these compounds may result from various sources, it is likely that those chemicals detected originate from concentrated sources in the oil fields. Sources of DEHP, propargyl alcohol, and naphthalene are explored due to their abundance and or toxic effects.

DEHP is not known to have natural sources, and is used in both hydraulic fracturing fluids for well stimulations and hydraulic fluid for hydraulic piston driven oil field machinery. Hydraulic fracturing fluids are not a likely source for the DEHP due to the limited amount of recent hydraulic fracturing and the low concentration of DEHP in fracking fluids. Propargyl alcohol is also not known to have natural sources, is used as a corrosion inhibitor and solvent stabilizer, and was used in the fracturing of a well in Line Canyon in 2011. A possible source of the propargyl alcohol is corrosion inhibitors that are frequently used in the oil fields. Naphthalene has both natural and anthropogenic sources, and was used in the fracturing fluid of a well "Grubb 477". Naphthalene is naturally found in crude oil, and the most likely source is from oil spills around well pads.

4.0 | LINE CANYON BASE FLOW

Line Canyon sustained base flow throughout the course of the project, though creeks in the study watersheds have been classified historically as intermittent or ephemeral (Watershed Assessment, Section 3.0 Hydrology). Additionally, the past three water years have been exceptionally dry, with the watersheds receiving less than half of average annual rainfall totals. This lack of rain appeared to have no major effect on base flow discharge rates, which was consistent (between 0.03 and 0.04 cubic feet per second) during dry periods, from October 2013 through April 2014.

The flow characteristics of intermittent and ephemeral streams in Southern California are very "peaky", meaning they are capable of producing flash floods that discharge large volumes of water and sediment over short intervals. During storm events, Line Canyon would exhibit large stormwater discharges, and within hours after precipitation ended, would return to its usual base flow rate. There is very limited groundwater in the study watersheds due to the lack of any large aquifer, and the greatest potential for groundwater exists in Padre Juan Canyon, where nearly half of the total alluvium and colluvium is mapped (about 47%).

Section Highlights

- There is very limited groundwater in the study watersheds, and despite one of the driest water years on record, Line Canyon base flow remained relatively constant at 0.03 and 0.04 cfs during dry periods from October 2013 through April 2014.
- Major ion concentrations of the base flow are characteristic of deep formation or produced water, and similar to produced water found in the oil fields
- Potential natural sources of the base flow are connate water that is being forced to the surface by tectonic or geothermal activity
- Possible anthropogenic sources of the base flow include water flood injections, which is concentrated in Line Canyon. In 2012, over 10 million barrels of produced water was injected into the Rincon and San Miguelito oil fields, an area that is transected by two faults

Water quality samples of the Line Canyon base flow show extremely high levels of total dissolved solids (TDS), and cations and anions characteristic of deep formation water. Produced water data from Rincon and San Miguelito oil fields show similar proportions of major ions found in the Line Canyon base flow. Produced water samples were collected from similar depths to where fracking and water injections occur in Line Canyon[36].

The study area is transected by two faults, the Javon Canyon Fault (a.k.a. Padre Juan Fault) and Red Mountain Fault, and has uplift rates that rival anywhere on Earth. The major faults bisect all the watersheds except Amphitheater Canyon (Watershed Assessment, Figure 1.2). The Javon Canyon Fault, which is clearly exposed in Javon Canyon, is estimated to have ruptured four to five times in the last 3,500 years[37].

The base flow is most likely not being generated by a shallow groundwater source, and may be the result of:

1) Geothermal activity or tectonically induced pressure bringing deeper formation water to the surface through faults and fractures; or

2) Land uses (specifically water injected into the oil field and surfacing due to a ruptured casing and or channeling up faults and fractures)

It is also possible that a combination of oil field operations and tectonic activity are sources of the Line Canyon base flow.

4.1 Natural Sources

Based on sample results, geology of the study area, and comparisons with other water quality data, the base flow in Line Canyon most likely originated from a water source that has had millions of years to interact with rock and dissolve high concentrations of solids. Due to the high tectonic activity in the study area, it is possible that the base flow in Line Canyon is natural.

Saline springs are known to exist in areas with high tectonic activity and uplift. Tectonic compression can drive deep formation water to the surface. Typical characteristics of saline springs found in the central Coast Ranges in California include major ion composition dominated by sodium-chloride, boron of up to 331 ppm, and perennial flow[38].

Geothermal activity can also force formation water to the surface. Geothermal springs are found in transverse zones, which have geology consisting of multiple interlacing faults, and greater transfer of heat from the earth's interior. In Ventura County, Sespe Hot Springs is a perennial flow that originates at depths of 3000-4000 meters. Water quality in these springs has been found to contain up to 1200 mg/L of TDS which primarily consists of sodium, chloride, sulfate, and silicic acid[39].

Saline and thermal spring waters have chemical characteristics similar to oil field brines high in sodium and chloride[40]. In the base flow samples, TDS concentrations ranged from 9,000 to 10,500 mg/L, and primarily consisted of chloride (39%), sodium (29%), and sulfate (21%). The ionic composition of TDS concentrations found in the base flow is indicative of connate water that is associated with marine sedimentary formations, which have high concentrations of salts.

4.2 Anthropogenic Sources

Produced water, or oil field brine, is another possible source of the Line Canyon base flow. Produced water is injected into water flood wells to facilitate enhanced oil recovery, and may be channeling up to the surface through faults and fractures in this highly tectonically active region, or from failed well casings. Of the five watersheds, Line Canyon has the most recent activity in terms of new wells drilled and quantity of produced and injected fluid. Water injection in the study area has increased from 2008 to 2012, with 80% to 90% of that injected water occurring in the San Miguelito Field (Watershed Assessment, Figure 8.10). Since 2009, there has been an increase in injection in the Rincon Field of about 1.1 million barrels, and over 9 million barrels of water was injected into the two oil fields in 2013[41] (Watershed Assessment, Figure 8.9).

Line Canyon base flow sample results show a similar composition of major ions to produced water found in the Rincon and San Miguelito oil fields (Tables 4.1 & 4.2). Though TDS concentrations in produced water were three times greater than what was found in base flow samples, the ratios of major ions show similarities (with exception of sulfate, which was found at higher levels in the base flow).

Table 4.1 – **Major ions in Line Canyon base flow and produced water found in Rincon and San Miguelito fields[42]**

CONSTITUENT	LINE CANYON BASE FLOW MIN to MAX (mg/L)	RINCON FIELD MIN to MAX (mg/L)	SAN MIGUELITO MIN to MAX (mg/L)
Bicarbonate (HCO_3^-)	-	795 to 2,130	73 to 29,00
Calcium (Ca^{2+})	187 to 317	308 to 765	391 to 732
Chloride (Cl^-)	3,620 to 4,130	15,600 to 18,600	14,500 to 17,600
Magnesium (Mg^{2+})	222 to 229	115 to 355	90 to 1,300
Potassium (K^+)	19.2 to 23.8	No Data	47 to 362
Sodium (Na^+)	2,870 to 3,090	9,905 to 11,953	8,400 to 10,013
Sulfate (SO_4^{2-})	2,220	0 to 1,250	8 to 2,800
TDS	9,007 to 10,500	28,800 to 33,800	27,800 to 36,200
Data acquired from USGS Produced Waters Database shows the major ion concentrations found in produced water in the Rincon and San Miguelito oil fields. 7 samples from Rincon and 4 from San Miguelito were collected at depths of 2,200 to 13,500 feet). The only date listed for produced water samples collected in the Rincon and San Miguelito fields is from 1958. The composition of produced water within a field or even well may change in time as a result of water flooding.			

Table 4.2 – **Percentages of major ions to TDS in produced water from Rincon and San Miguelito oil fields and the Line Canyon base flow sampled on January 22 and April 21, 2014[42]**

CONSTITUENT	RINCON AVERAGE	SAN MIGUELITO AVERAGE	LINE CANYON BASE FLOW 2	LINE CANYON BASE FLOW 3
Bicarbonate	5.47%	3.99%	-	-
Calcium	1.76%	1.70%	1.98%	2.76%
Chloride	54.66%	51.03%	38.31%	39.33%
Magnesium	0.69%	1.47%	2.42%	2.11%
Potassium	0.00%	0.33%	0.20%	0.23%
Sodium	34.46%	30.71%	30.37%	28.48%
Sulfate	0.60%	2.31%	-	21.14%
Other ions	2.40%	8.45%	0.21%	0.18%

Data acquired from USGS Produced Waters Database shows the major ion concentrations found in produced water in the Rincon and San Miguelito oil fields. 7 samples from Rincon and 4 from San Miguelito were collected at depths of 2,200 to 13,500 feet). The only date listed for produced water samples collected in the Rincon and San Miguelito fields is from 1958. The composition of produced water within a field or even well may change in time as a result of water flooding.

Organic Compounds

Diesel range organics (DROs), residual range organics (RROs), and several PAHs were found in Line Canyon base flow at detectable concentrations. However, the only PAH that was detected above reporting limits was naphthalene. Though naphthalene is a product of incomplete combustion of biomass and petroleum products[43], naphthalene is also found in crude oil which is a likely source of the detected levels in the base flow. Naphthalene is found in diesel fuel at much higher concentrations than diesel particulate matter[44], and naphthalene has been found to occur in groundwater under anaerobic conditions where there is an ongoing source (e.g., petroleum products) in the aquifer[43]. The presence of naphthalene at the concentrations detected in the base flow samples suggest that the source is likely not from atmospheric deposition, but from deeper in the subsurface.

DRO includes any hydrocarbons with a carbon chain ranging from 10 to 28 carbons, and were detected in the base flow on January 22, 2014 at 2.3 mg/L, and again on April 21, 2014 at 1.4 mg/L. DRO incorporates diesel fuel which is a constituent in some hydraulic fracturing fluids[33] and may be released through many oil production operations. RRO incorporates the heavier portions of crude oil, ranging from hydrocarbons with carbon chains containing from 25 to 36 carbons. RRO was detected in the base flow on January 22, 2014 at 1.5 mg/L and on April 21, 2014 at 0.5 mg/L. The diesel and residual ranges tested for did not encompass the entire spectrum of hydrocarbons, and it is likely that additional organic compounds were in the base flow at the time of sampling.

Several PAHs were detected in the base flow and not in stormwater runoff. These PAHs include benzo(a)pyrene, indeno(1,2,3-cd)pyrene, and dibenzo(a,h)anthracene, which are all products of incomplete combustion, and more likely to be found as a result of deposition[45]. The Ventura County Air Pollution control district has classified the Rincon area leases and La Conchita Oil and Gas Plant as air toxic "hot spot" under AB2588[46]. These areas are possible sources of deposition of PAH particulates.

A number of other organic compounds were detected that may be from other sources than deposition. These include acenaphthylene, toluene, and 2-methylnaphthalene and these compounds are found in higher concentrations in diesel fuels than diesel particulate matter[45]. 1,2,4 – trimethylbenzene was detected in the base flow and occurs naturally in petroleum crude oil[51]. 1,2,4 – trimethylbenzene has been used in the fracturing of wells by the oil and gas company operating in the project area[47], and is found in solvent products used in well treatments. Acrylamide was also detected and is known to be used in soil conditioning, oil drilling and some hydraulic fracturing fluids[48]. Polyacrylamide is a polymer used in enhanced oil recovery projects including water flooding[34].

4.3 Line Canyon Base Flow Summary

Throughout the duration of the study, Line Canyon base flow exhibited characteristics of a perennial stream, and stream flow remained between 0.03 and 0.04 cfs during dry periods, despite drought conditions in the watersheds. Sample results showed extremely high levels of TDS, and ratios of major ions that exhibit deep formation water. Produced water data from Rincon and San Miguelito oil fields show similar proportions of major ions found in the Line Canyon base flow. These factors, along with the geology in the watersheds, indicate that the base flow is originating from a deep source that has had millions of years to interact with rocks.

It is possible that tectonic activity in the area is forcing connate water to the surface. Saline springs share similar chemical composition to oil field brines, and are found in areas with extreme uplift (as found in the study area).

It is also possible that oil field water flood injections are the source of the Line Canyon base flow. Over 9 million barrels of water were injected into the two oil fields in 2013, and Line Canyon has the most recent activity in terms of new wells drilled and quantity of produced and injected fluid[6]. It is possible that this injected fluid is channeling up a fault or fracture[49], creating the Line Canyon base flow. The presence of DRO, RRO, and naphthalene indicate that this water may be interacting with hydrocarbons in the subsurface.

5.0 | REFERENCES

1) California Geological Survey, 2002. Seismic hazard zone report for the Pitas Point 7.5-minute quadrangle, Ventura County, California. Available at: http://gmw.consrv.ca.gov/shmp/download/evalrpt/pitap_eval.pdf.

2) California Geological Survey, 2003. Seismic hazard zone report for the Ventura 7.5-minute quadrangle, Ventura County, California. Available at: http://gmw.consrv.ca.gov/shmp/download/evalrpt/vent_eval.pdf.

3) Jibson, R.W., 2005. Landslide Hazards at La Conchita, California. US Geological Survey. Open-File Report 2005-1067. Available at: http://pubs.usgs.gov/of/2005/1067/pdf/OF2005-1067.pdf.

4) Soil Survey Division Staff. 1993. Soil survey manual. Soil Conservation Service. U.S. Department of Agriculture Handbook 18.

5) Stein, E. D.; Tiefenthaler, L. L.; Schiff, K. C. 2007. Sources, Patterns and Mechanisms of Storm Water Pollutant Loading from Watersheds and Land Uses of the Greater Los Angeles Area, California, USA. South. Calif. Coast. Water Res. Proj. Tech. Rep. 510

6) Stein, E. D.; Yoon, V. K. 2007. Assessment of Water Quality Concentrations and Loads from Natural Landscapes. South. Calif. Coast. Water Res. Proj. Costa Mesa, CA.

7) Weaver WE, Hagans DK, Popenoe JH. 1995. Magnitude and causes of gully erosion in the lower Redwood Creek basin, Northwestern California. In Geomorphic Processes and Aquatic Habitat in the Redwood Creek Basin, Northwestern California. Nolan KMC, Kelsey HMC, Marron DCC, (eds). US Geological Survey Professional Paper 1454: Chapter I.

8) Madej, 2001. US Geological Survey Western Ecological Research Center, 1655 Heindon Road, Arcata, CA 95521, USA

9) Clinton, B. D., and J. M. Vose. 2003. Differences in surface water quality draining four road surface types in the southern Appalachians. Southern J. Applied Forestry 27(2): 100-106.

10) Reid, L. M., and T. Dunne. 1984. Sediment production from forest road surfaces. Water Resources Res. 20(11): 1753-1761.

11) McCashion, J. and Rice, R. 1983. Erosion on Logging Roads in Northwestern California: How much is avoidable? Journal of Forestry, Volume 81, Number 1, pp. 23-26(4).

12) United States Department of Agriculture. Natural Resources Conservation Service. Geospatial Data Gateway. available at http://datagateway.nrcs.usda.gov/. accessed January 2014.

13) Environmental Defense Center. Press Release. February 23, 2012. Environmental Defense Center Takes Legal Action to Address Water Pollution from Oil and Gas Field in Coastal Ventura County. Table 2. Discharges of pollutants by Vintage/Oxy at the Rincon Grubb Oil Field. Available at: www.edcnet.org/news/PressReleases/12-02-23.pdf

14) Surface Water Ambient Monitoring Program. SWAMP RWB4 Monitoring. RWB4 Miscellaneous Ventura Coastal 2006 2007. Accessed from the California Environmental Data Exchange Network on November 3, 2013.

15) MBC Applied Environmental Sciences, 2011. Status of the kelp beds 2010, Ventura, Los Angeles, and Orange Counties. Central Region Kelp Survey Consortium Report
16) Keller et al., February, 2014. Natural Sources of Pollutants Expected Loads and Concentrations in Southern California.
17) Los Virgenes Municipal Water District. Orton, R., 2012. Natural Source Assessment. Available at: http://www.lvmwd.com/Home/ShowDocument?id=2273
18) Bradford, G. R. et al., March, 1996. Background Concentrations of Trace and Major Elements in California Soils.
19) Los Angeles County Dept. Public Works. 2009.
20) Stein, E. D.; Yoon, V. K. 2007. Assessment of Water Quality Concentrations and Loads from Natural Landscapes. South. Calif. Coast. Water Res. Proj. Costa Mesa, CA.
21) Nixon, H., Saphores, J.D., 2007. Impacts of motor vehicle operation on water quality in the United States. Transportation Research Part D: Transport and Environment. Volume 12, Issue 8, Pages 564-576.
22) Kayhanian, M., Stenstrom, M., 2005. Caltrans. First Flush Phenomenon Characterization.
23) Kayhanian, M., Suverkropp, C., Ruby, A., Tsay, K., 2006. Journal of Environmental Management 85 (2007) pages 279-295.
24) Caltrans. February 2008. Stormwater Monitoring and Research Program. Annual Data Summary Report.
25) Caltrans. August 2003. A Review of the Contaminants and Toxicity Associated with Particles in Stormwater Runoff. CTSW-RT-03-059.73.15.
26) California Environmental Protection Agency. Air Resources Board. The Report on Diesel Exhaust. Available at: http://www.arb.ca.gov/toxics/dieseltac/de-fnds.htm
27) USGS. Natural oil & gas seeps in California. Available at: http://walrus.wr.usgs.gov/seeps/index.html
28) California Environmental Protection Agency. Integrated Risk Assessment Branch Office of Environmental Health Hazard Assessment. September 2009. Toxicological Profile for Di-(2-Ethylhexyl) Phthalate (DEHP).
29) California Department of Conservation. Division of Oil, Gas, and Geothermal Resources (DOGGR). Oil & Gas well records. available at http://owr.conservation.ca.gov/WellSearch/WellSearch.aspx. accessed January 2014.
30) BPPD Consortium. July, 22, 2009. Robust Summaries and Test Plan for Propargyl Alcohol (CAS No. 107-19-7). High Production Volume Chemical Challenge Program.
31) NCI. Technical Resources International, Inc. August, 1996. Summary of Data for Chemical Selection. Propargyl Alcohol. CAS No. 107-19-7.
32) United States National Library of Medicine. Toxicology Data Network. Hazardous Substances Data Bank: Comprehensive, peer-reviewed toxicology data for about 5,000 chemicals. Available at: http://toxnet.nlm.nih.gov/cgi-bin/sis/htmlgen?HSDB. Accessed June 25, 2014.

33) United States House of Representatives. Committee on Energy and Commerce Minority Staff. Chemicals used in hydraulic fracturing. April 2011.
34) United States National Library of Medicine. Toxicology Data Network. Hazardous Substances Data Bank: Comprehensive, peer-reviewed toxicology data for about 5,000 chemicals. Available at: http://toxnet.nlm.nih.gov/cgi-bin/sis/htmlgen?HSDB. Accessed June 25, 2014.
35) Gervais, J.; Luukinen, B.; Buhl, K.; Stone, D. 2010. Naphthalene Technical Fact Sheet; National Pesticide Information Center, Oregon State University Extension Services. Available at: http://npic.orst.edu/factsheets/naphtech.pdf.
36) US Geological Survey. Produced Waters database. available at http://energy.cr.usgs.gov/prov/prodwat/data.htm. accessed February 15, 2014
37) Sarna-Wojcicki, A.M., Lajoie, K.R., Yerkes, R.F., 1980. Recurrent Holocene Displacement on the Javon Canyon Fault – A Comparison of Fault-Movement History with Calculated Average Recurrence Intervals. Recent Reverse Faulting in the Transverse Ranges, California. US Geological Survey Professional Paper 1339.
38) Criss, Davisson, Melchiorre, 1999. Relationship between seismicity and subsurface fluids, central Coast Ranges, California Journal of Geophysical Research, Vol. 104, No. Bi, Pages 921-939.
39) McCulloh et al., 1981. Precipitation of Laumontite with Quartz, Thenardite, and Gypsum at Sespe Hot Springs, Western Transverse Ranges, California. Clays and Clay Minerals. Vol. 29. No 5. 353-364.
40) USGS, 1963. Data of Geochemistry, Sixth Edition. Chapter F. Chemical Composition of Subsurface waters.
41) California Department of Conservation. Division of Oil, Gas, and Geothermal Resources (DOGGR). Production and Injection database. available at http://opi.consrv.ca.gov/opi/opi.dll. accessed February 2014.
42) US Geological Survey. Produced Waters database. available at http://energy.cr.usgs.gov/prov/prodwat/data.htm. accessed February 15, 2014.
43) Price, P. October, 2006. Available Data on Naphthalene Exposures: Strengths and Limitations. The LifeLine Group, Inc.
44) Liang et al., 2005. The organic composition of diesel particulate matter, diesel fuel, and engine oil of a non-road diesel generator. J. Environ. Monit., 983-988.
45) Ventura County Air Pollution Control District. 2013. Air Toxics “Hot Spots” Information and Assessment Act of 1987. Annual Report. Prepared by: Air Toxics Section Engineering Division.
46) Frac Focus. Chemical Disclosure Registry. Available at: http://www.fracfocusdata.org/DisclosureSearch/StandardSearch.aspx. Search: State, California; County, Ventura; Operator, Occidental Oil and Gas. Accessed September 18, 2013.
47) United States House of Representatives. Committee on Energy and Commerce Minority Staff. Chemicals used in hydraulic fracturing. April 2011.
48) Office of Environmental Health Hazard Assessment. Acrylamide. Frequently Asked Questions. http://www.oehha.org/prop65/acrylamideqa.html

49) Bernard Endres, George V. Chilingarian, T.F. Yen. Journal of Petroleum Science and Engineering, 6 (1991) 95-106.
50) Gradient. 2013. National human health risk evaluation for hydraulic fracturing fluid additives. Prepared for: Halliburton Energy Services, Inc.
51) U.S. EPA. Office of Pollution Prevention and Toxics. December 1994. Chemicals in the environment. 1,2,4 Trimethylbenzene. CAS No. 95-63-6.

RECOMMENDATIONS & MITIGATION STRATEGIES

NORTHERN VENTURA COUNTY COASTAL WATERSHED PROJECT

Recommendations have been developed for the study area of the Northern Ventura County Coastal Watershed Project (NVCCWP) based on the research and analysis presented in the four project elements: Watershed Assessment, Environmental Sampling, Toxicity Analysis, and Source Assessment.

The primary mitigation strategies focus on erosion control in the study watersheds, which has been linked to the mobilization and transport of toxic heavy metals that are naturally occurring in the geology of the area, and the transport of organic compounds and PAHs likely originating from well pads and oil field operations. These include specific Best Management Practices (BMPs) for stream rehabilitations, on-the-ground investigation of road erosion and sediment sources, permitting of large oil field construction activities, and other BMPs that should be incorporated into the Storm Water Pollution Prevention Plan (SWPPP) for the oil fields.

Several of the recommendations are aimed at generating data and information on the study area, and increasing protection of beneficial uses and water quality. It is recommended that monitoring and sampling of the creeks continue, including stormwater and channel sediment sampling. Future monitoring and sampling efforts could be improved by sampling within the oil fields, testing well pad runoff and sediments for the organics, metals and salts that were found to be of concern in this study. Coastal areas and their beneficial uses would benefit from increased protection through designation as an Area of Special Biological Significance (ASBS).

To better assess risk of the potential pollutants of concern identified in the Toxicity Analysis coastal marine waters could be sampled near the watershed outlets during large discharge events. Based on the current study it is believed that educating the public about potential pollution hazards and the placement of hazard warning signs are justified, and continued monitoring will help better evaluate the potential risk to people and species from exposure of pollutants.

Recommendations are organized with supporting evidence and justification, which is derived directly from the four project elements, followed by specific recommendations. Recommendations are numbered for referencing purposes, and not ordered by importance. For additional information, support, or justification for these recommendations refer to the four project elements.

1.0 Erosion Control

Erosion, a natural mechanism accelerated from the presence of oil field infrastructure and activity, is a dominant driver of water quality in the study watersheds. The natural geology and soils are known to be highly erosive and sensitive to disturbance. Oil field roads and clearings, which disturb and compact native soils, and change hydrologic flow paths and response (hydro-modification), can have drastic effects on the erosion rates of the small study watersheds. The greater sensitivity of the study area to erosion (from the naturally sensitive geology and soils) warrants greater erosion mitigation measures compared to less erodible landscapes. These practices are necessary to limit the impact to downstream ecosystems and coastal environments from oil field operations. As noted in the watershed assessment there have been large scale (>50,000 m^2) land clearing and excavation activities in the oil fields in the recent past, which undoubtedly have large sedimentation impacts downstream and in the coastal environment. The following recommendations include strategies to mitigate erosion and sediment transport from oil field roads and clearings. The majority of the BMPs are derived from the USDA National Core BMP Technical Guide and the EPA National Management Measures to Control Nonpoint Source Pollution from Forestry; refer to these documents for details on unpaved-road placement, construction, and maintenance BMPs.

Recommendations

1.1 Specific road and staging area construction BMPs should be integrated into the Storm Water Pollution Prevention Plan (SWPPP) for the oil fields that include specific actions and structures such as those listed below:

- **1.1A** Use water bars, rolling dips, or inlaid open top box culverts to divert water off roads and from road ditches at a minimum of every 300-500 feet for road grades between 2-5 percent and every 300-100 feet for slopes between 6-15 percent
- **1.1B** These diversions should have adequately sized energy dissipation structures and rip rap to prevent hill slope erosion where water leaves the road surface
- **1.1C** Create out-sloped roads and limit the use of inboard ditches that can accumulate water. If inboard ditches must be used, divert water from ditch using the same spacing as above to limit water accumulation and increasing erosive power of flow
- **1.1D** Gravel roads that are not paved. This will maintain infiltration but decrease the availability of fine sediment. Gravel is preferred over paving because impervious pavement creates greater hydro-modification and flow energy that can impact highly erosive soils and slopes
- **1.1E** Minimize driving on unpaved roads during and after rain while roads are still wet

1.1F Decommission and re-vegetate well pads and roads that are no longer in use

1.1G Minimize the grading of well pads and road surfaces, where possible, to the minimum needed for operation

1.1H Re-vegetate exposed and disturbed slopes using native vegetation

1.2 Perform on the ground investigation of oil fields and road network to assess erosion sources, and quantify erosion from road surfaces and well pads, and to assess shortcomings and improvements that could be made to road networks and clearings

1.3 Remove sediment settling ponds and restore stream channel to its natural grade to reestablish aquatic organism passage. Downstream sediment basins are ineffective because they cannot trap silt sized sediment given the flow regimes (Amphitheater Canyon would require a basin in excess of 400 km^2 to trap silt in a 250 cfs flow). Sediment and erosion control should be placed upstream closer to sources and not focused on downstream point source control

1.4 Require permits for dredging and filling through the CWA and permitted by the U.S. Army Corps of Engineers and follow permit guidelines during large construction and development of the oil field

2.0 Hazard Signage and Education

The toxicity analysis indicates potential hazards from bathing and chronic exposure to runoff and sediments from the watersheds. The greatest risk comes from carcinogenic arsenic, which occurs naturally in the geology. Propargyl alcohol, a toxic unnatural organic pollutant which is known to be used as a corrosion inhibitor in the oil fields, was also detected in one sample of runoff from Padre Juan Canyon (which discharges to the coast adjacent to Faria County Park and Rincon Parkway). During sampling activities and site visits performed through this study, several people were observed swimming in the ocean directly in front of the stormwater discharge, children and families from the residential communities were observed playing in and around the Amphitheater Canyon stream channel, and foot prints were observed from people walking barefoot in stream channel sediments. As documented in the Watershed Assessment, the coastal area adjacent to the watershed outlets is home to three residential communities and is a popular tourist and local recreational area. Signage and education measures are recommended to prevent people from exposing themselves to potentially hazardous pollutants.

Recommendations

2.1 Educate local communities of the potential hazard from frequent contact with water and sediments directly discharged from the watersheds, specifically Line and Amphitheater Canyons

2.2 Place hazard warning signs next to stream outlets that have the highest potential risk to people being exposed to carcinogenic compounds and other potentially hazardous pollutants

2.3 If through further monitoring and testing of stormwater runoff, propargyl alcohol continues to be detected, and other organics are detected at or near chronic toxicity levels, signs should include warnings for specific hazardous organics originating from the oil fields

3.0 Base Flow Investigation and Tracer Test

From October 2013 through April 2014 sampling and field tests at the stream in Line Canyon revealed a persistent perennial base flow of 0.85 to 1.1 L/s (0.03 to 0.04 cfs) despite a prolonged drought. None of the other study watersheds exhibited any base flow, intermittently or perennially. The base flow was consistently measured to have between 9,000 and 10,000 mg/L total dissolved solids (TDS) consisting mostly of chloride, sulfate, sodium, magnesium, calcium, potassium, and boron. Due to these factors and the lack of surficial sedimentary deposits sufficient for groundwater storage, it is likely this base flow is originating from either a very deep ground water source (potentially thousands of feet), or from produced water improperly reinjected for disposal or water flooding enhanced oil recovery. The study area contains fractures and faults caused by the tectonic activity in the region, and these faults may be providing pathways for deep springs. Diesel range organics (DRO), residual range organics (RRO) and PAHs were detected in samples of the base flow. The volume of produced water and the hazardous chemicals that are being injected into deep geologic formations and the potential risk of this deep spring to be hydraulically connected to these formations warrant further investigation and monitoring.

Recommendations

3.1 Perform a tracer test analysis on the base flow coming from Line Canyon to determine if there is any connectivity between the base flow and the injection wells in the oil field

3.2 Collect water samples from the spring source where the base flow originates and test for organics and metals

3.3 Sample the base flow spring source for radioactivity (i.e. radon) known to naturally occur in the subsurface and oil reservoirs

4.0 Continued Monitoring

The study area has been found to have complex and potentially hazardous water and sediment quality and attracts visitors that frequently come in contact with these waters and sediments. The small watershed size and high density of oil wells and infrastructure may result in large fluctuations in water quality that would be revealed through a more continuous monitoring program over multiple years. This study tested for many constituents that should continue to be tested for in future samples. Additionally, there may be many other organics present in runoff from the oil fields that were not tested for that, if sampled, could provide a better characterization of downstream risk and impact.

Recommendations

4.1 Continue stormwater monitoring of runoff from the coastal watersheds

4.2 Research and add other potential pollutants of concern that may be originating from oil field operations

4.3 Continue to sample stream sediments, particularly from creeks with a high level of nearby residential and recreational activity

4.4 Sample coastal marine waters directly below stream outlets during large stormwater events to assess arsenic levels and other pollutants in coastal waters during discharge events

4.5 Sample fish tissue from fish caught near the watershed outlets to assess for possible bioaccumulating pollutants originating from the study watersheds

5.0 Watershed and Erosion Modelling

It is clear from the extent of oil field infrastructure found in Line and Amphitheater Canyons (about 11% and 9%) that these operations are having an influence on the hydrology and erosion rates of these watersheds. However, the exact size of the effect is unknown. While there is a difference in the hydrologic response and sediment yield between the five study watersheds, the differences between the driving factors are unknown. Modelling the coastal study watersheds would allow for a better understanding of the hydro-modification caused by land use and help identify the areas with the greatest need for mitigation and erosion control. Spatially modelling erosion from the watersheds would allow for the generation of a sediment budget based on natural characteristics.

Recommendations

5.1 Model hydrology of the coastal watersheds using impervious surfaces and or factors to represent the oil field development, and calibrate using field flow measurements. Then rerun the model without development to assess the size of the effect land use is having

5.2 Spatially model erosion to identify significant natural source areas and compare the expected natural erosion rates to measured rates

6.0 Reevaluating Beneficial Uses and Environmentally Sensitive Areas

The study area has a large amount of coastal habitat and sensitive ecosystems that are important for local fisheries and recreationalists. There are unique terrestrial and marine ecosystems located along the northern Ventura coastline that would greatly benefit from increased protection, such as the California coastal scrub in the watersheds and kelp forests along the coast. The beaches and coastal waters near the outlets of the study watersheds are frequently visited by people participating in a variety of beach and coastal activities including fishing and wildlife viewing. The coastal areas are habitat for numerous marine mammals and fish, and the near coastal zone provides rocky hard-bottom habitat. The section of coastline adjacent to the study area is threatened by pollution from the oil fields, roads and highways, agricultural practices, and leaky sewer systems.

Recommendations

6.1 Consider designating the coastline from the Rincon Creek outlet to the Ventura River outlet an Area of Special Biological Significance (ASBS), to provide additional protection to water quality, coastal ecosystems, and beneficial uses of the coastline

6.2 Reevaluate the beneficial uses designated to the canyons and coastline to develop site specific uses and water quality objectives for the northern Ventura county coastal streams based on background water quality

6.3 Study coastal kelp forests and potential impacts from sedimentation from the watersheds, comparing the extent of kelp forests over time to periods of intense oil field development (such as that mentioned in the watershed assessment between 2010 and 2012 when >50,000 m^2 were cleared)

6.4 Perform vegetation, endangered species, and other biological surveys within the study watersheds. If surveys reveal extensive California coastal scrub habitat and or other endangered habitat and species additional conservation of the inland watershed should be considered.

7.0 Environmental Sampling within the Study Watersheds

Well pads are the most likely source of organic pollutants detected downstream, and due to the large amount of dilution and volatilization that would be expected for most compounds, the detections downstream indicate either wide spread low level contamination or small areas of high level contamination. The greatest impacts to ecosystems are likely occurring upstream of the sampling locations used in this study. Testing of well pad soils and stormwater runoff, as well as the runoff from undisturbed hill slopes above the oil fields, would allow for better assessment of sources of organics and total and dissolved metals.

Recommendations

- **7.1** Sample well pad soils and runoff for pollutants detected downstream
- **7.2** Sample above and below areas that drain oil field infrastructure to better understand impacts from this land use
- **7.3** Consider other pollutants that were not tested for in the NVCCWP that may impact downstream water quality and coastal environments

8.0 Investigate Potential Hydraulic Fracturing and Water Injection Effects in the Geologic Environment

The study area is within one of the most tectonically active regions in the world with active faults traversing the watersheds. Hydraulic fracturing is used to purposefully fracture the bedrock to increase permeability and connectivity for better producing oil wells. But in an already highly fractured environment fractures may have unanticipated effects creating connectivity with faults and waters that discharge to the surface. Such influence on natural seeps and springs from oil wells and production is known to occur and is plausible in such a tectonically active region. Historic gas injection tests in the oil field proved that there was large connectivity and quick depressurizing of the injection zone.

Recommendations

8.1 Detailed geophysical mapping to identify fault planes and fractures capable of allowing migration of hydrocarbons and produced water from oil producing zones to the surface

8.2 Develop Ventura County hydraulic fracturing policies and regulations aimed at preventing adverse effects and near surface contamination in this highly faulted and tectonically active region

8.3 Evaluate potential contamination scenarios based on detailed fault plane mapping. Based on whether there is an appreciable risk, develop containment strategies such as plugging springs and fractures, stopping injection operations, or depressurizing oil reservoirs that may be allowing contaminated fluids to migrate upward towards the surface