



Assessing Water Quality of the Lower San Dieguito River Watershed Spring 2025

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Introduction:

The Watershed from Crest to Coast

Spanning 55 miles from Julian, California to Del Mar, California, and encompassing approximately 92,000 acres, the San Dieguito River Park helps to conserve San Diego County's most intact watershed, the San Dieguito River Watershed. Intact watersheds maintain uninterrupted hydrological connectivity from the watershed's headwaters to its outlet, supporting ecological connectivity in turn. Intact watersheds have become increasingly rare due to human development such as installation of impermeable surfaces, dams, and other structures that impede water flow (Jumani et al. 2022). Covering 346 square miles in total, the San Dieguito River Watershed supports upwards of 178,000 people and provides essential habitat for threatened and endangered wildlife such as the Belding's Savannah Sparrow (*Passerculus sandwichensis beldingi*), Western Snowy Plover (*Anarhynchus nivosus nivosus*), California Least Tern (*Sternula antillarum browni*), and the Belding's orange-throated whiptail (*Aspidoscelis hyperythra beldingi*) (2010 U.S. Census; Project Clean Water; City of San Diego).

From the crest of the Volcan Mountains to the coast of Del Mar, the water within the San Dieguito River Watershed is an essential resource across four distinct geographic regions of climate variability and wildlife communities: the highlands, the foothills, the valley, and the coast, each categorized by its own distinct microclimate and plant communities, influenced primarily by elevation and proximity to the ocean (The San Dieguito River Park). The San Dieguito River Watershed begins 55 miles inland in the Volcan Mountains. This high-elevation region (approximately 5,000 feet above sea level), known as the highlands, is characterized by cool, temperate winters due to altitude and experiences several inches of snow per year (Western Regional Climate Center). The highlands provide habitat for pine forests, oak groves, and semi-forested areas. Much of the precipitation received by the mountains in the form of rain and snow is stored in underground aquifers and later brought to the surface by the Ironside Spring. Ironside Spring is the surface expression of a montane headwater spring system that contributes to four distinct watersheds, where elevation gradients, slope aspect, and topographic watershed divides control watershed partitioning and downstream flow dominance toward the San Dieguito River Watershed. This means that due to the range's natural topography, a majority of water is fed into the San Dieguito River Watershed compared to the three other watersheds with a source in the Volcan Mountains.

In the western foothills of the Volcan Mountains, the Santa Ysabel Creek carries water during the wet season (December-March) from Volcan Mountain into the San Pasqual Valley. The foothills have a reduced water supply and thus much less forest cover compared to the Volcan Mountains. Sage scrub and chaparral plant communities thrive in the foothills' more arid landscape, with some riparian habitat along the creek. At the westernmost edge of the foothills, the Sutherland Dam creates the Sutherland Reservoir, which is used for water storage and recreation (County of San Diego).

From the foothills, water travels through the San Pasqual Valley where the Santa Ysabel Creek feeds into the main San Dieguito River. The San Dieguito River and other smaller tributaries feed into Lake Hodges, a reservoir created by the Lake Hodges Dam. This reservoir is used primarily for water storage for an emergency supply, but is also used for hydroelectric generation and is open to recreational visitation from February through October and boating a few days each week (City of San Diego). The valley is the most arid portion of the watershed and is home to rolling grasslands that are prone to fires in the dry season and flooding in the wet season.

Downstream of Lake Hodges, the San Dieguito River feeds into the San Dieguito Lagoon located in Del Mar, California. The lagoon is a site of significant environmental restoration and pollution mitigation. One form of pollution mitigation that has been implemented is the construction of four treatment ponds (with Treatment Pond 1 being closest to the roadway and shopping centers and Treatment Pond 4 being closest to the lagoon). In these ponds, plant root systems help filter out pollutants and prevent them from reaching the lagoon. The lagoon contains brackish water, a combination of freshwater from the San Dieguito River and saltwater from the Pacific Ocean brought in by tidal flow. This creates essential estuarine habitat where aquatic species, shorebirds, and terrestrial wildlife alike can find protection. As such, the lagoon serves as a breeding ground for numerous species, such as nesting California Least Terns (*Sternula antillarum browni*) (California Department of Fish and Wildlife). The dominant plant communities at the lagoon are low-growing coastal sage scrub and California coastal salt marsh, with some larger chaparral species present. The lagoon marks the completion of the San Dieguito River Watershed from its origin in the Volcan Mountains to its outlet, the Pacific Ocean.

Although the watershed is considered intact, it is not without impact from human activity. Agricultural and residential lands become increasingly common traveling down the watershed. Development also takes the form of golf courses and highways that surround the area. Highways create barriers to wildlife movement, fragmenting the watershed and causing stress within the ecosystem. Additionally, impervious surfaces created by concrete and cement surrounding the watershed can increase runoff. Coupled with high levels of agricultural and urban activity, pollutants enter the watershed via these pathways which can negatively impact water quality (California Waterboards Surface Water Ambient Monitoring Program).

San Dieguito River Park Focused Planning Area



Figure 1: A map of the San Dieguito River Park focused planning area including the boundaries of the San Dieguito River watershed. Different color blocks represent distinct regions of climate variability and plant communities influenced by elevation and proximity to the Pacific Ocean.

Watershed Health

Maintaining healthy watersheds is crucial for ensuring clean and safe water supplies, supporting biodiversity, preventing flooding, and preserving soil quality. Watersheds are interconnected systems that act as buffers and reduce flood severity by maintaining the steady flow of water through the landscape (EPA). In addition to their role in mitigating flood risk, watersheds contribute to climate regulation by storing carbon, which helps to mitigate global climate change (EPA, USDA). Healthy watersheds are also integral to ecosystem health. By protecting these systems of water availability, diverse plant and animal species that depend on this resource are protected in turn (EPA, USDA).

Healthy watersheds are also vital for supplying freshwater that people rely on for drinking and industry (Sun et al. 2018). Watersheds directly support economic activities such as agriculture, fishing, and tourism (EPA; Jordan & Benson 2015). For example, farms depend on reliable water sources to grow crops or support livestock, while fisheries thrive in clean, well-maintained aquatic ecosystems. Tourism is another economic sector that relies heavily on well-preserved watersheds, particularly in regions where outdoor activities such as hiking, fishing, boating, and wildlife viewing are popular (U.S. Forest Service). Additionally, watersheds can serve as a source of energy for regions. One such example of this in the San Dieguito River Watershed is the Lake Hodges hydroelectric dam, which provides the region with up to 40 megawatts of energy by allowing the water to flow downhill from the Olivenhain Reservoir (San Diego County Water Authority). Watersheds are also deeply tied to cultural and recreational values. Many communities depend on nearby watersheds for outdoor recreation such as hiking, biking, fishing, and birdwatching. These natural spaces help foster a sense of community and connection to the environment, which is why preserving them is important for both ecological health and quality of life (Jordan & Benson 2015).

The San Dieguito River Park serves as an example of a successful watershed preservation effort. Located in Southern California, this park spans more than 55 miles across the San Dieguito River Watershed, acting as a crucial conservation. The park provides a natural habitat for a diverse range of species, including birds, mammals, and aquatic life, and plays a significant role in maintaining the integrity of the watershed's ecosystems. It also offers a variety of recreational opportunities for visitors, featuring scenic trails for hiking, biking, and wildlife observation, all of which help foster a healthy and engaged community.

History of Water Quality Testing in the San Dieguito River Watershed

Previous large-scale water quality testing of the San Dieguito River Watershed was conducted from 1998 to 2005. Researchers with the Surface Water Ambient Monitoring Program (SWAMP), a State of California Water Boards program dedicated to monitoring the quality of surface waters in California, analyzed five sites distributed throughout the watershed. The study focused on toxicants and factors that could affect aquatic life but also addressed potential risks to human health in the San Dieguito hydraulic unit. Water chemistry, water and sediment toxicity, and physical habitat were monitored at each site.

In total, 14 different pesticides and 25 polycyclic aromatic hydrocarbons (PAHs) were detected across all sites. All sites in the San Dieguito hydraulic unit failed to meet certain aquatic life and human health thresholds. Reference

(most upriver) sites had the lowest number of these exceedances, whereas mainstem (most downstream) sites had the higher number of exceedances of aquatic life thresholds, suggesting that water quality deteriorates along a gradient from the headwaters to the mouth of the San Dieguito River. This is not an unexpected result, as toxicants tend to accumulate over time as water flows further away from the source (EPA). Overall, the study found that the ecological health of the watershed was moderately impacted, and the severity of that impact increased along a downstream gradient. The pollution gradient may be exacerbated by increasing agricultural and developed land use towards the lower reaches of the watershed, or the operation of dams and reservoirs where flow is partially interrupted, but is consistent with common trend for water to accumulate pollution the further it flows from its source (California Water Board's Surface Water Ambient Monitoring Program).

Several other studies have been conducted since the long-term SWAMP monitoring study. A 2018 study by UC San Diego master's student Alberto Vasquez sampled primarily for concentrations of the nutrients nitrate and phosphorus while also considering dissolved oxygen, pH, and turbidity (Vasquez 2018). Vasquez found that the San Dieguito River Watershed had one of the highest and therefore healthiest Water Quality Index scores (a standardized measure of water quality) among 8 out of 11 San Diego County watersheds that he sampled (Vasquez 2018).

Since 2015 the county of San Diego has worked in conjunction with the cities of San Diego, Escondido, Poway, and Solana Beach to produce an annual San Dieguito Water Quality Improvement Plan (WQIP) report (Project Clean Water). The most recently available of these reports, from 2023-2024, indicates that while 61% of the watershed remains undeveloped, there is significant concern about urban and agricultural runoff contributing to harmful bacteria, excessive nutrient loading, and aquatic toxicity. A 2021 update to the watershed's WQIP focused on the Lake Hodges Reservoir, which is situated roughly halfway between the headwaters and mouth of the San Dieguito River. Researchers found excess nutrients negatively impacting municipal and domestic water supplies during both dry and wet seasons. To address this and other pollution concerns, several pollution mitigation and prevention methods are employed across the watershed, one of which is the use of treatment ponds. (San Dieguito WQIP Reports 2015-2025)

Additionally, a study of four treatment ponds along the San Dieguito Lagoon conducted by California State University San Marcos and San Diego Coastkeeper indicated a significant reduction in toxicant and sediment pollution when water was filtered through the treatment ponds before flowing into the lagoon (Lawrence and Flanders 2023).

There is a long but inconsistent history of water quality testing in the San Dieguito River Watershed. Overall, studies seem to indicate that despite being amongst the "healthiest" of watersheds in the county, there is still evidence of pollution that may be harmful to aquatic life and human health.

Testing Sites and their Land Use Histories

Our study focused on three geographic areas along the watershed with five unique testing sites: the Kit Carson Creek at Sikes Adobe (33.06554° N, 117.06622° W), the San Dieguito River at San Dieguito River Park's Santa Fe Valley Staging Area (33.04037° N, 117.15762° W), and the San Dieguito Lagoon (32.9729429° N, 117.2510830° W) along with the two lagoon treatment ponds, Treatment Pond 1 (32.97821° N, 117.24777° W) and Treatment Pond 2 (32.97813° N, 117.24812° W).

The easternmost sampling site, located upstream of Lake Hodges, was the Kit Carson Creek at San Dieguito River Park's Sikes Adobe Historic Farmstead (33.06554° N, 117.06622° W). The Sikes Adobe, originally used as a grazing land for the San Diego Mission, was first acquired by Joseph Snook in 1842. The land had originally been a

swamp which accumulated large amounts of decomposed plant matter. Snook and his wife, Maria Antonia, cultivated the land until it became suitable for farming with rich, fertile soil. They grew crops and raised livestock including hundreds of wild cattle, tame cows, horses, mules, oxen, and sheep. Following Snook's death and revitalization of the farm, Zenas Sikes purchased the property in 1869. The land was used for farming by the Sikes family who grew wheat and barley on the property. In 1917, the house along with the buildings in the Bernardo community was bought by Col. Ed Fletcher as a part of the Lake Hodges Dam Project. This land has been plowed and transformed into fields suitable for farming, leading to environmental impacts such as reduced biodiversity and soil erosion. In the 1960s, the Sikes Act was enacted which protected the land, transforming a portion of it back to a riparian habitat. In addition to the preserve, San Dieguito River Park maintains a garden with common agricultural plants that may be non-native to the area as a historical re-enactment of life on Sikes Adobe. Wildlife such as coyotes (*Canis latrans*) and mule deer (*Odocoileus hemionus*) are monitored by the park's trail cameras as they travel through the habitat corridor connecting the coastal and inland areas (The San Dieguito River Park).

Similarly, the San Dieguito River Park's Santa Fe Staging Area (33.04037° N, 117.15762° W), located downstream of Lake Hodges on Del Dios Highway, was historically used for agriculture. It has a long and complicated history of Spanish, Mexican, and United States governance. In 1830, the Act of Secularization led to the rise of the Mexican Republic. Under the rule of the Mexican Republic, Juan María Osuna took possession of the land and transformed it into a ranch (used specifically for cattle grazing and other livestock). In addition to developing the land, he built two adobe houses: Osuna 1 and Osuna 2. After Osuna's death in 1851, his son Leonardo took possession of the land. By 1906, the Santa Fe Railway purchased the Osuna land, and approximately 3.5 million Eucalyptus trees were planted to provide lumber for the railroad construction. Later on, Colonel Ed Fletcher and Santa Fe recognized the land's agricultural potential and revitalized the land, it soon became known as the "Avocado Belt". Later, in 1921, the Santa Fe field was split into land parcels for more agricultural growth. Today, this land is managed by the San Dieguito River Park as restored wildlife habitat. There have also been new housing developments in the area leading to habitat fragmentation and the introduction of invasive plants such as pampas grasses, eucalyptus species, and ice plants due to homeowners cultivating them as ornamental plants. Native plants at this site include California sagebrush (*Artemisia californica*), black sage (*Salvia mellifera*), and California buckwheat (*Eriogonum fasciculatum*) which are common in the coastal sage scrub habitat. Other plants include chamise (*Adenostoma fasciculatum*), mission manzanita (*Xylococcus bicolor*), and California scrub oak (*Quercus berberidifolia*) which are common to the chaparral habitats. To help improve water quality, treatment ponds have been installed to filter water coming down from the rolling hills full of housing settlements into the lower elevation San Dieguito River (San Dieguito River Park).

The San Dieguito Lagoon (32.9729429° N, 117.2510830° W) also has a rich history of agriculture. The land was first inhabited by the Kumeyaay people who practiced seasonal agriculture and controlled land burns. In 1769, Mission San Diego de Alcalá's agricultural operations began on the land. In the 1800s, a car trestle was built for State Route 1 which narrowed the mouth of the river leading to sediment build-up and floods upstream. In 1918, Lake Hodges Dam was built and seasonal scouring was done to remove sediment. Later, in 1936 and 1937, the San Diego Fair and Del Mar Race Track sought permanent locations for their race tracks and golf courses. Additionally, in 1938, the Del Mar Municipal Airport was built which included a 2600 foot runway built on the south side of the river; this required leveling of the shore and wetlands. Following these developments, in 1965, the Interstate 5 was built over the lagoon again forming a large dam. Since all of these projects, there has also been restoration efforts. In 1991, the San Dieguito Lagoon Wetland Restoration Project Phase I sought to restore 150 acres of wetland damaged by the San Onofre Nuclear Generating Station. The lagoon was opened to tidal flux, fish nurseries were built, and habitat was restored. In 2001, San Dieguito River Park was identified as a state wildlife corridor and in 2010, the California Fish and Wildlife Service created the San Dieguito Lagoon State Marine Conservation Area which provided nesting for the native birds. Then, in 2012, the California Coastal Commission ordered Del Mar Fairgrounds to restore a portion of land adjacent to the river mitigating other environmental impacts.

One of the most recent restoration projects was Phase II of the San Dieguito Lagoon Wetland Restoration which involved restoring 84 acres of land. These 84 acres included 64 acres of salt marsh, 15 acres of brackish wetlands and 5 acres of coastal sage shrub riparian habitat to help wildlife such as the Ridgway's Rail (*Rallus obsoletus*), the Least Bell's Vireo (*Vireo bellii pusillus*), Coastal California Gnatcatcher (*Poliopitila californica californica*), and Belding's Savannah Sparrow (*Passerculus sandwichensis beldingi*). In 2018, partners like SANDAG (San Diego Association of Governments) and SCE (Southern California Edison) continued to restore wetland habitat by excavating soil to lower tidal levels, planting native species, and establishing irrigation systems to help these new plants survive. They work to restore not only land within the park but also 141 acres of land adjacent to the park to offset impacts of the San Onofre Nuclear Power Plant. Four treatment ponds were established to mitigate the impacts of agricultural runoff and polluted water on the lagoon habitat. These treatment ponds are essential for maintaining the health of the salt marsh ecosystem including saline-adaptive plants like the cordgrass (*Spartina foliosa*) and pickleweed (*Salicornia pacifica*) and riparian plants such as mulefat (*Baccharis salicifolia*). Many native birds, fish, and tidewater invertebrates reside near the waters such as striped mullet (*Mugil cephalus*) and the endangered tidewater goby (*Eucyclogobius newberryi*) (San Dieguito River Park).

Sampling Sites



Figure 2: Map of the San Dieguito River Watershed with sampling locations labeled and pictured.

Seasonality

The transition from winter to spring in San Diego, which occurs from February through March, is characterized by sporadic rainstorms and a temporary increase in rainfall, which can significantly influence water quality across the region. Rainfall can cause runoff of pollution into water sources and lead to nutrient loading, bacterial contamination, or chemical pollution (Delpha et al. 2023).

In recent years, precipitation has fallen below San Diego County's historical average. On average, coastal areas of San Diego County receive just over 10 inches of rainfall annually, while inland mountainous regions receive approximately 33 inches (San Diego County Water Authority). However, recent measurements have shown precipitation levels as low as 84% of the historical average during some water years, reflecting ongoing variability and prolonged drought conditions. The San Diego County Water Authority reports that the region experiences highly variable precipitation patterns and relies heavily on seasonal rainfall to replenish local reservoirs, groundwater basins, and imported water supplies stored throughout the county. Periods of below-average precipitation reduce natural groundwater recharge and reservoir levels, increasing the region's vulnerability to drought and reducing the availability of locally sourced water. Additionally, when rainfall does occur following prolonged dry periods, hardened soils and urban surfaces can increase runoff, transporting accumulated pollutants into rivers, reservoirs, and coastal waters. These fluctuations in precipitation and runoff influence both water availability and water quality, highlighting the importance of precipitation patterns in maintaining the health and stability of San Diego County's watershed systems (San Diego County Water Authority).

During the winter and early spring, cooler temperatures slow plant and algal growth. As temperatures increase and daylight hours lengthen, biological activity also increases. This leads to greater primary production and changes in nutrient cycling, both of which can affect water quality (Paerl & Huisman, 2008). Understanding how seasonal changes in temperature and precipitation influence watershed processes is essential for evaluating the health of local aquatic ecosystems and identifying the impacts of changing climate patterns in Southern California.

Methods:

We assessed the concentrations of nutrients nitrate and phosphate, dissolved oxygen (DO) concentration, pH, and presence or absence of fecal coliform bacteria utilizing the Earth Force Low Cost Water Monitoring Kit by LaMotte. Specific nutrients nitrate and phosphate were chosen because they directly influence biological activity, and elevated concentrations can indicate nutrient pollution and increase the risk of harmful algal blooms (HABs), which lead to oxygen depletion (hypoxia) in a process called eutrophication. Dissolved oxygen was measured as an indicator of the water's ability to support aquatic life, as low oxygen levels can result from excess biological activity or pollution. pH was measured as an indicator of the chemical condition of the water, as deviations from neutral pH can affect organism survival and indicate chemical contamination. The presence or absence of fecal coliform bacteria was assessed as an indicator of fecal contamination from human or animal sources and the potential presence of harmful pathogens. Nitrate concentration results were omitted from this report due to expired test tabs which produced unreliable results. Nitrate sampling will be included in the Fall 2025 report.

Our three selected locations were sampled on weekly rotation from early February 2025 to late March 2025 for a total of 9 sampling events and 3 sampling dates at each location. At each of the three sites, water was collected using a bucket provided by the Earth Force Low Cost Water Monitoring Kit according to the kit's instructed procedure. All tests were conducted in the field at the site of water collection.

Nitrate

Nitrate (NO_3^-) enters aquatic ecosystems primarily through the decomposition of plants and animals, as well as from animal waste. Because nitrogen is vital for aquatic organisms to build essential cellular components, such as proteins, maintaining appropriate nitrogen concentrations is crucial for ecosystem

health. However, when nitrogen concentrations become excessive, they can contribute to eutrophication by encouraging the overgrowth of plants and promoting bacterial decomposition. This can create harmful feedback loops that deplete dissolved oxygen, leading to the suffocation of aquatic life. Potential sources of nitrogen contamination are sewage and fertilizer.

To test for nitrate, one Nitrate Wide Range CTA TesTab (3703A) from the Earth Force Low Cost Water Monitoring Kit was added to a 10 mL vial. The provided vial was filled with the water sample up to the 5 mL mark and the cap secured. Following the test kit procedure, the vial was shaken vigorously until the tablet was fully dissolved and allowed to sit for 5 minutes. This test is photosensitive, so the vial is blocked from UV exposure by placing the TesTube in a black glove and storing it in a dark cooler while the test develops. The tablet has a cadmium reducing agent that reacts with nitrate in the water sample, converting it into nitrite (NO_2^-). The nitrite then reacts with Griess-type reagents contained in the tablet, forming a red azo dye whose intensity is proportional to nitrate concentration. The shade of red can be compared colorimetrically to determine nitrate concentration. After 5 minutes the resulting color was compared to the provided nitrate color chart and the concentration was recorded in parts per million (ppm) (**Figure 3**).



Nitrite then undergoes a diazotization/coupling reaction (Griess reaction) to form a red/pink azo dye

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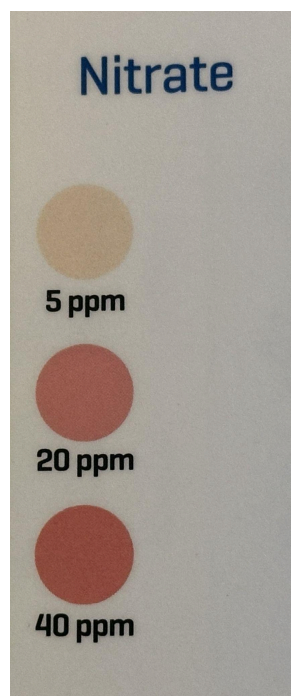


Figure 3 : Nitrate concentration key from the Earth Force Low Cost Water Monitoring Kit.

Nitrate concentration results were omitted from our final results as test tabs had expired and the integrity of the results could not be guaranteed.

Phosphate

Phosphate (PO_4^{3-}) is important for the growth of plants and animals as it plays a key role in storing and transferring energy for living organisms. In aquatic ecosystems, phosphate can be found in soil and water, supporting the growth of aquatic plants, which in turn supports fish and other life. Agricultural runoff, animal waste, and industrial waste are common sources of phosphate pollution.

According to the Earth Force Low Cost Water Quality Monitoring Kit instructions, one 10 mL vial was filled with our water sample. One Phosphate TesTab (5422A) was then added to the vial. The tube was shaken and allowed to settle for 5-10 minutes for the tablet to completely dissolve. The tablet uses ascorbic acid as a reducing agent to produce the blue complex. Concentration of phosphate (ppm) is then determined colorimetrically according to the provided chart. (**Figure 4**).

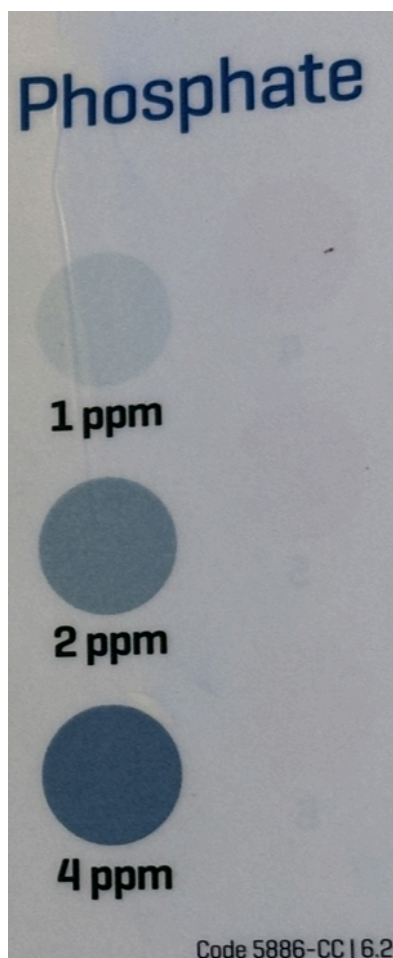
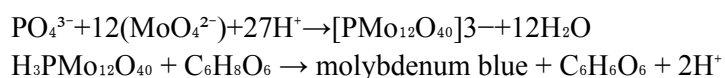


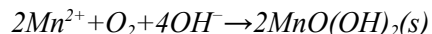
Figure 4: Phosphate concentration key from the Earth Force Low Cost Water Monitoring Kit.

Dissolved Oxygen

As stated in the LaMotte Earth Force Low Cost Monitoring Kit Instruction Manual, dissolved oxygen is an indicator of aquatic ecosystem health. Water bodies with consistently high dissolved oxygen levels are more likely to be healthy and stable as long as percent saturation does not exceed 120%. Dissolved oxygen (DO) levels can be expressed in parts per million (ppm).

Percent saturation is another measurement of dissolved oxygen which accounts for both the concentration of dissolved oxygen (ppm) and the temperature. It is important to take into consideration both of these factors because temperature affects the solubility of oxygen (O₂) in the water. When the temperature increases, the average kinetic energy of the water molecules increases causing greater molecular movement. As a result, there is less space available in the solution to hold oxygen. In essence, warmer water can hold less oxygen than colder waters. Percent saturation measurements compare the amount of O₂ present in the water and the maximum amount of O₂ that can be dissolved in the water (also known as the saturation point). So, two water samples that have the same concentration of O₂ but different temperatures will have different values of percent saturation.

For the DO test, the temperature of the water was first recorded in degrees Celsius by submerging the provided thermometer in the water for 1 minute as instructed by the Earth Force Low Cost Water Monitoring Kit. Next, a 0125 test tube was submerged in the water sample until completely full; this 0125 test tube can hold about 1 dram or 3.697 mL of water. Then, two DO TesTabs (3976A) were mixed in and the cap was secured. These dissolved oxygen TesTabs contain reagents that react indirectly with dissolved oxygen through a modified Winkler reaction. Dissolved oxygen oxidizes manganese compounds, which subsequently generate iodine. The iodine then reacts with an indicator to produce a colored complex, with color intensity proportional to dissolved oxygen concentration. After the tabs fully dissolved, the sample was allowed to sit for 5 more minutes (as per the kit's provided procedure) before the resulting color was compared to the provided DO color key to estimate the concentration of DO in ppm (**Figure 5**). Then, the percent saturation was determined using the key in the kit manual (**Figure 6**).



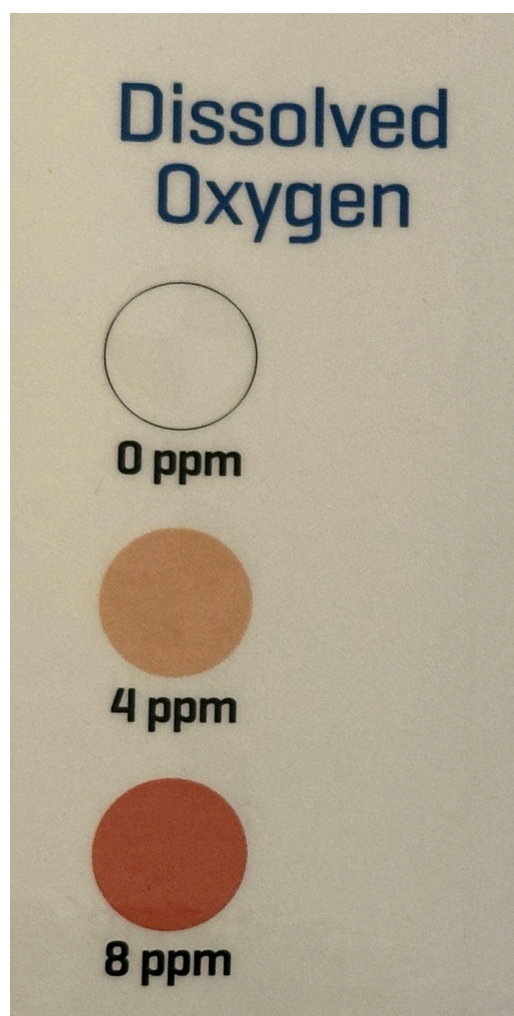


Figure 5: Dissolved oxygen concentration key from the Earth Force Low Cost Water Monitoring Kit.

	Dissolved Oxygen		
	0 ppm	4 ppm	8 ppm
2	0	29	58
4	0	31	61
6	0	32	64
8	0	34	68
10	0	35	71
12	0	37	74
14	0	39	78
16	0	41	81
18	0	42	84
20	0	44	88
22	0	46	92
24	0	48	95
26	0	49	99
28	0	51	102
30	0	53	106

Calculations based on solubility of oxygen in water at sea level, from *Standard Methods for the Examination of Water & Wastewater*, 18th edition.

Figure 6: Dissolved oxygen percentage calculator key from Earth Force Low Cost Water Monitoring Kit.

pH

pH is the measurement of hydrogen ion concentration and can indicate the acidity or alkalinity of the water sample. The scale ranges from 0 to 14 with 0 being the most acidic, 14 being the most basic, and 7 being neutral. pH of water can be affected by industrial waste, agricultural runoff, and drainage from mining operations. Water bodies can become more acidic due to acid rain. Power plants, vehicles, and industrial facilities release the pollutants nitrogen oxides (NO_x) and sulfur dioxide (SO₂) which can react with other chemicals in the atmosphere to produce nitric acid (HNO₃) and sulfuric acid (H₂SO₄). Agricultural runoff can also cause chemicals from pesticides or fertilizer to enter water sources, changing pH. Natural water with a pH between 6.5 and 8.2 is typically ideal for aquatic organisms. When the water is more acidic, it increases the solubility of toxic metals and displaced nutrients in the water. If the water is too basic, it can harm aquatic life due to tissue damage and desaturation of cell membranes.

The provided test tube from the Earth Force Low Cost Water Monitoring Kit was filled to the 10 mL line and a Phenol Red TesTabs (Code 1332) was added. The test tube was capped and was inverted several times per the kit's instructions until the tablet dissolved. Lastly, the resulting color was compared to a phenol red color chart to determine the pH value of the sample (**Figure 7**).

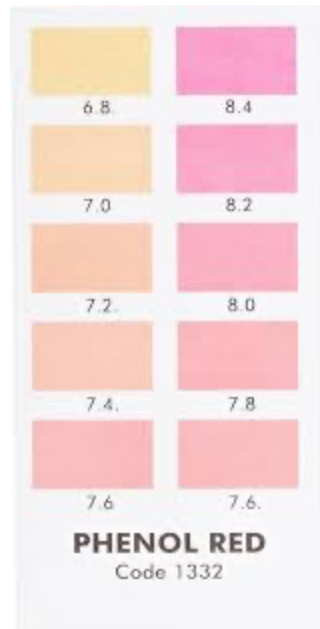


Figure 7: Phenol Red indicator chart from LaMotte used to determine pH of water samples.

Fecal Coliform Bacteria

Fecal coliform bacteria are normally found in a healthy mammalian digestive system, but are not naturally found in aquatic ecosystems in significant concentrations. As such, the presence of fecal coliform bacteria in a water sample is likely due to sewage waste contaminating a water source. The threshold for coliform bacteria permissible in a water source is dependent on its use. Coliform bacteria concentration in well or drinking water is permissible only at 0 bacteria colonies per 100 mL of water. Even at a very low number of colonies, the presence of coliform bacteria in potable water is associated with significant health risks, like gastrointestinal issues, pneumonia, or other respiratory illnesses. For water used in primary contact (i.e. swimming), a range of fewer than 1000 colonies per 100 mL of water is recommended. For secondary contact (i.e. boating and fishing), fewer than 5000 colonies per 100 mL of water is generally considered safe.

The provided Earth Force Low Cost Water Monitoring Kit test tube was filled to the 10 mL line and one Coliform Tablet (4890) was added. The cap was replaced while keeping the tube upright. The tube was incubated, still upright, for 48 hours at a stable room temperature (between 70 and 75 degrees Fahrenheit). The tube was kept out of direct sunlight and left undisturbed during this incubation period. When done incubating, the appearance of the tube was compared to the provided Coliform color chart and the results were recorded as either negative or positive. A positive result is indicated by a yellow color and many gaseous bubbles with gel having risen to the surface (>20 coliform bacteria colonies per 100 mL of water) whereas a negative result is recorded when liquid gel is clear, red, or yellow but with no gaseous bubbles and gel remaining at the bottom of the tube (<20 coliform bacteria colonies per 100 mL of water). A

quantitative analysis cannot be concluded from this test that is designed to indicate presence or absence of fecal coliform bacteria. A positive result is likely indicative of sewage contamination in the water sample.

Results:

Each week, one of the three sampling locations was visited on a rotating schedule, with the exception of postponements due to dangerous weather conditions. Results were recorded in a data table (**Table 1**). N/A was entered for all criteria on March 30, 2025 when no water was available to sample at Coast Treatment Pond 1 and February 9, 2025 when the phosphate test was contaminated. Fecal coliform bacteria presence/absence was not tested in the two treatment ponds due to health risks.

Pearson's correlation coefficient was used to determine if a strong correlation existed between the different factors measured. A "yes" result for a rain event was assigned a value of 1 and a "no" result was assigned a value of zero. When calculating correlation, phosphate concentrations of "4+" were treated as if they were 4 ppm as no results approached the 8 ppm threshold for the next darker color on the key.

Location	Date	Phosphate (ppm)	pH	DO (ppm)	DO %	Temp (C)	Positive Bacteria Test	Rain Event at least 0.5 in Prior <7 days
Del Dios Hwy	2/9/2025	N/A	7.7	8	74	12	Y	Y
Coast Treatment Pond 1	2/16/2025	4+	8.4	4	41	15	N/A	Y
Coast Treatment Pond 2	2/16/2025	4	7.4	4	39	14	N/A	Y
Lagoon	2/16/2025	2	8.4+	8	81	15	N	Y
Sikes Adobe	2/23/2025	3	8.4	8	81	16	Y	N
Del Dios Hwy	3/2/2025	1	7.7	8	81	16	Y	N
Coast Treatment Pond 1	3/9/2025	3	7.6	8	81	16	N/A	Y
Coast Treatment Pond 2	3/9/2025	2	7.1	8	81	16	N/A	Y
Lagoon	3/9/2025	4	7.8	8	81	16	Y	Y
Sikes Adobe	3/16/2025	2	7.6	8	81	16	Y	Y
Del Dios Hwy	3/23/2025	2	7.8	4	41	16	Y	N
Coast Treatment Pond 1	3/30/2025	N/A	N/A	N/A	N/A	N/A	N/A	N
Coast Treatment Pond 2	3/30/2025	2	7.2	8	92	22	n/a	N
Lagoon	3/30/2025	1	8.2	8	92	22	Y	N

Table 1: Results from water quality sampling at each site and location.

The highest concentrations of the nutrient phosphate were recorded in Treatment Ponds 1 and 2 on February 16, 2025 following a 0.60-inch rain event in Del Mar, CA three days earlier on February 13, 2025. The Pearson's correlation coefficient between phosphate concentration and rain events was approximately $r \approx 0.57$, indicating a moderate positive correlation.

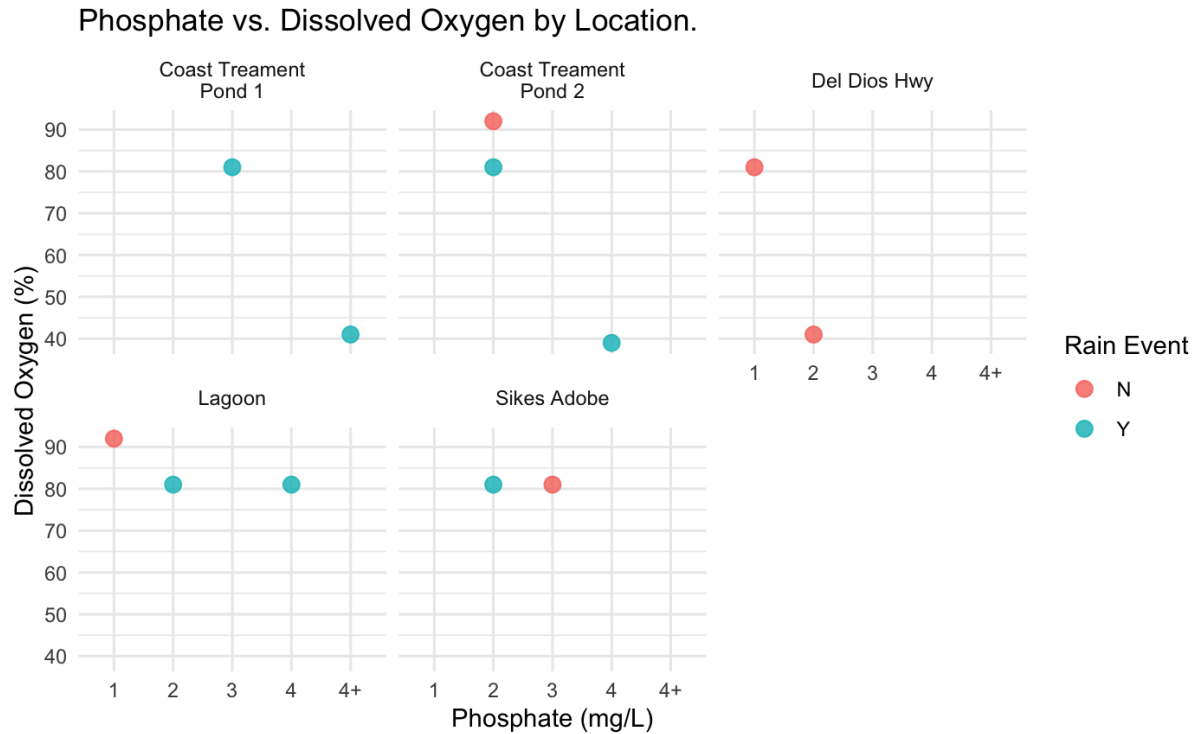


Figure 8: Phosphate (ppm) vs. percentage of dissolved oxygen for each sampling location.

Results also indicated a moderate negative correlation ($r \approx -0.52$) between percentage of dissolved oxygen (DO%) and concentrations of phosphate with lower dissolved oxygen concentrations occurring alongside higher phosphate concentrations. Although rain events were moderately correlated with higher phosphate concentrations, there was not a strong correlation between DO% and rain events ($r \approx -0.20$).

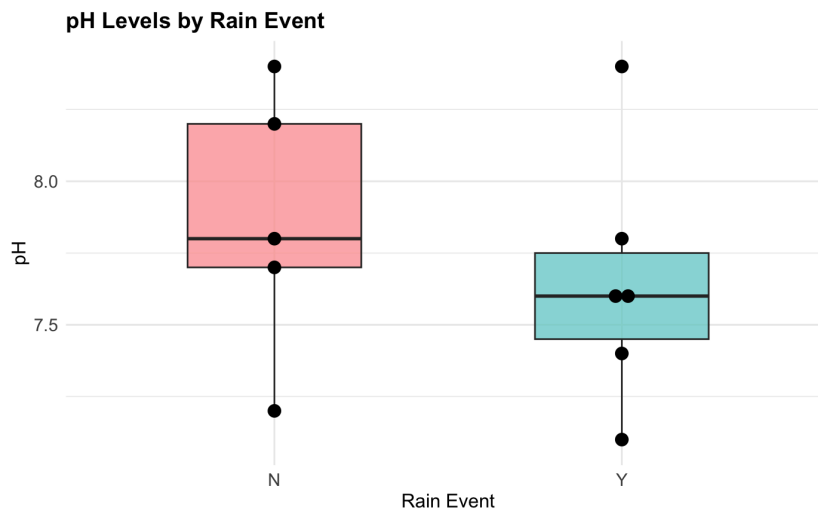


Figure 9: pH of water sample compared to recent rain events.

There was almost no correlation ($r \approx -0.13$) for pH and rain events across the watershed overall, however correlation for pH and rain events was slightly higher at inland locations such as the Santa Fe Staging Area on Del Dios Highway ($r \approx -0.50$) and a near perfect negative correlation between rain events and pH exists for Kit Carson Creek at Sikes Adobe ($r \approx -1.0$).

Discussion:

The percentage of dissolved oxygen (DO%), pH and the presence of >20 coliform bacteria colonies per 100 mL of water can serve as key indicators of watershed health. While elevated concentrations of nutrients such as phosphate and nitrate often signal declining water quality, the most harmful effects typically result from the subsequent reduction in dissolved oxygen caused by nutrient enrichment and algal blooms.

Rain Events and Water Quality

Higher concentrations of phosphate were positively correlated ($r \approx 0.57$) with rain events, which may be evidence that rainfall delivered phosphate into water sources. Although a direct source cannot be identified without isotopic analysis and correlation does not necessarily imply causation, rainfall is known to wash phosphate-containing pollutants into aquatic systems (Masoner et al. 2019; Yang & Toor 2018).

A negative correlation between phosphate concentrations (ppm) and DO% ($r \approx -0.52$) was an expected result, as higher concentrations of nutrients are known to cause oxygen-consuming algal blooms (Li et al. 2022). However, surprisingly rain events did not seem to correlate strongly with dissolved oxygen despite the fact that phosphorus was positively correlated with rain events and moderately negatively correlated with DO%. Some explanations for this result include that phosphorus was not the main driver of low dissolved oxygen, that samples were taken before algal blooms driven by phosphorus runoff had decayed, or that re-aeration occurred with quick-moving streams fed by recent rains.

Although pH and rain events were not correlated overall, this result may be influenced by a well-buffered system at the coastal sampling locations due to the flux of seawater. The inland locations, however, demonstrated a strong negative correlation between pH and rain events. The easternmost sampling location, Kit Carson Creek at Sikes Adobe, showed a strong negative correlation between pH and rain events ($r \approx -1.0$), though this result is based on a limited number of samples and should be interpreted cautiously until additional data is collected. This pattern suggests that rain events may be associated with a rapid decrease in pH. This could be driven by dilution from low-alkalinity precipitation and episodic inputs of acidic runoff and organic acids from surrounding soils. In contrast to more buffered systems, these inland waters appear to have limited capacity to resist short-term pH changes during storm events, resulting in pronounced pH declines following rainfall (DeWit et al. 2001). However, more data is necessary to determine a significant trend.

Potential Sources of Pollution

With the exception of February 16, 2025 at the San Dieguito Lagoon, all testing dates and locations yielded a positive result for the fecal coliform bacteria test (>20 coliform bacteria colonies per 100 mL of water). There are several possible explanations for this including nearby agricultural practices present at all three sampling locations that could contribute to runoff of waste (**Figure 10b,c,d**). Additionally, in March of 2023 there was documented sewage contamination in the watershed when approximately 3,725 gallons of untreated sewage were discharged into Lake Hodges due to a fractured sewage force main, which could explain positive results downstream (California Regional Water Quality Control Board, San Diego Region).

As the San Dieguito River Park limits activities that could cause pollution or disturbances within protected portions of the watershed, pollution likely originates from nearby or, in some cases, historical land use. (Cantoni, Kalantari, & Destouni 2023). Kit Carson Creek at Sikes Adobe, for example, is adjacent to a mall and development with many impermeable surfaces that contribute to runoff, agricultural lands that may contribute excess nutrients from fertilizers and dung that may contribute both nutrients and coliform bacteria colonies, as well as golf courses that may also utilize fertilizers (**Figure 10b**). Similarly, the Santa Fe Staging Area is surrounded by agricultural lands, large housing settlements, and nearby golf courses, all of which could contribute to nutrient loading. The lagoon, while actively being restored and benefiting from the implementation of treatment ponds, is adjacent to areas of high urbanization, a major highway (I-5), and many livestock staging locations which could be contributing pollutants including excess nutrients and fecal coliform bacteria.

Limitations & Future Directions

The small sample size of our study is a limiting factor for determining long-term trends. Future studies should expand on known datasets to see if correlations persist through different seasons or determine if concentrations of pollutants are seasonally affected. Causation cannot be inferred from correlation, which limits the ability to directly infer sources of pollution. Although many adjacent land use activities such as agriculture and urban development are fairly well-documented sources of pollution, determining pollution sources for the San Dieguito River Watershed would require more advanced testing such as isotopic analysis, chemical fingerprinting, microbial source tracking, tracer studies, or modeling.

Additionally, future studies could increase the parameters examined including salinity, turbidity, and nitrates. Equipment such as continuous in-field samplers could also increase the parameters tested while mitigating the need to delay testing when unsafe weather conditions do not permit in-field data collection.

This study represents the first monitoring effort by the EcoLogik Institute to collect data on water quality at the San Dieguito River Park. As data is collected across seasons, data should be compared across the dry and wet seasons. With additional data, statistical significance testing could be applied to determine whether observed relationships between water quality parameters are unlikely to be attributable to random variation alone, while recognizing that such tests would not establish causation.

Conclusion

Overall, consistently positive fecal coliform bacteria tests along with large variability in DO% indicate that the San Dieguito River Watershed has room for improvement when it comes to water quality. Water contaminated by sewage can not only lead to eutrophication, but pose serious health risks to humans and wildlife.

The San Dieguito River Park's protected status makes the San Dieguito River Watershed one of the healthiest watersheds in San Diego County, however, even a protected watershed is not immune to pollution. We recommend exercising caution when recreating in or near water sources and to be aware of alerts or closures due to health risks.

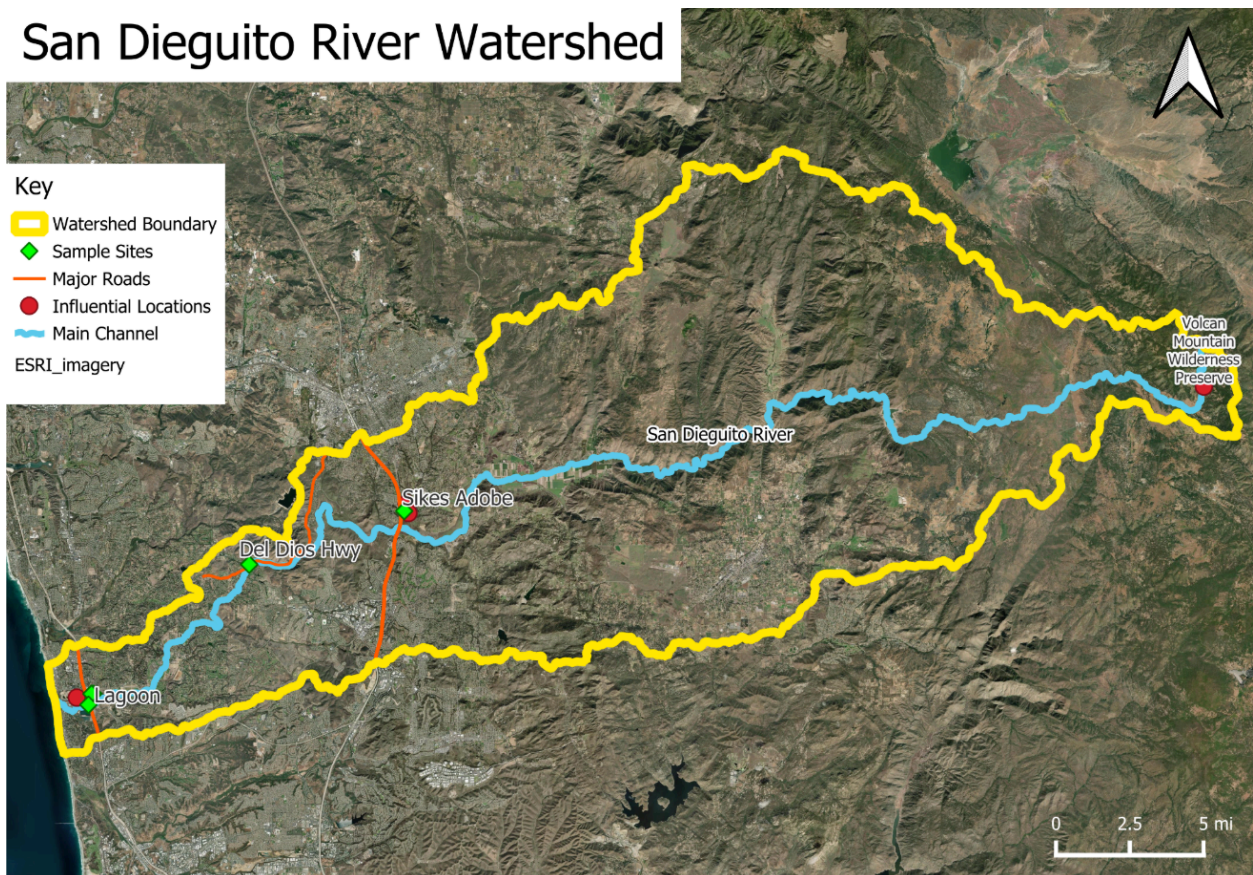


Figure 10a: Sampling sites as they relate to the greater watershed.

Sikes Adobe Sampling Site

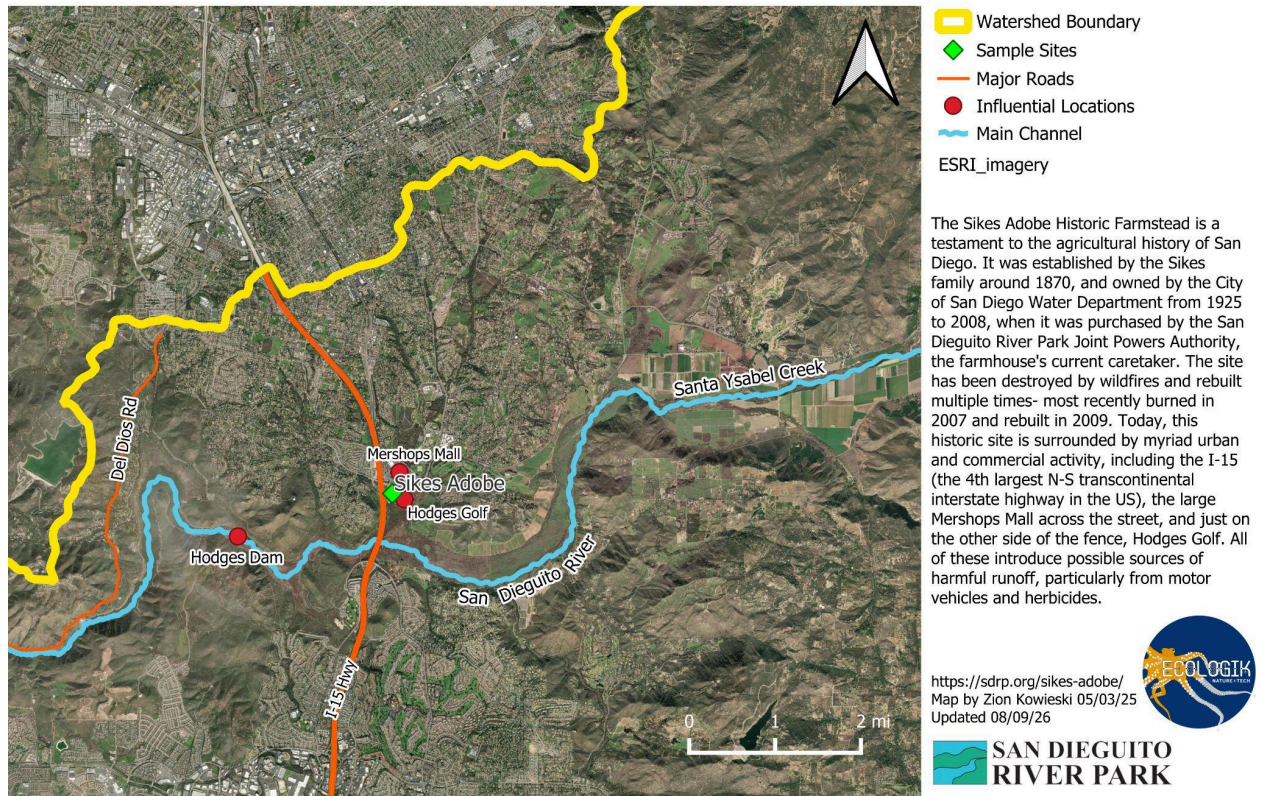


Figure 10b: Sikes Adobe sampling site.

Santa Fe Staging Area Sampling Site

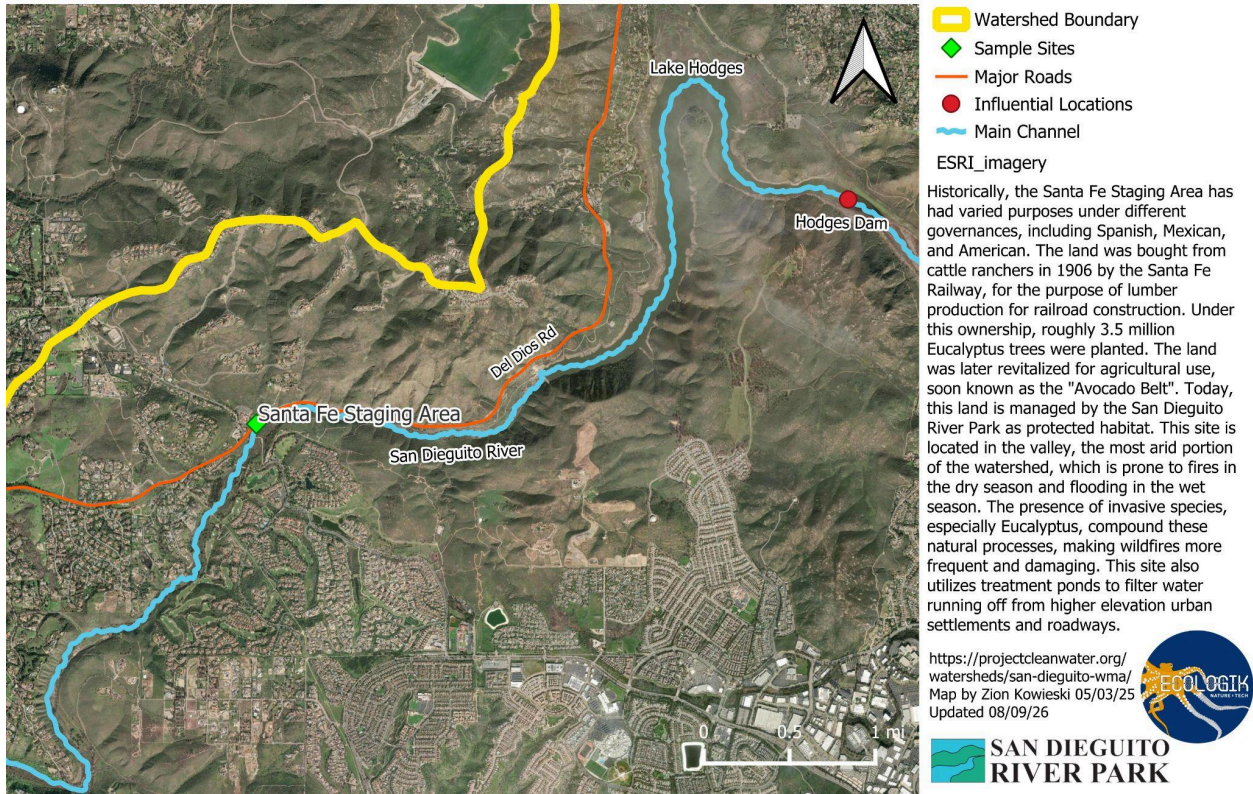


Figure 10c: Santa Fe Staging Area sampling site.

Lagoon & Treatment Pond Sampling Sites

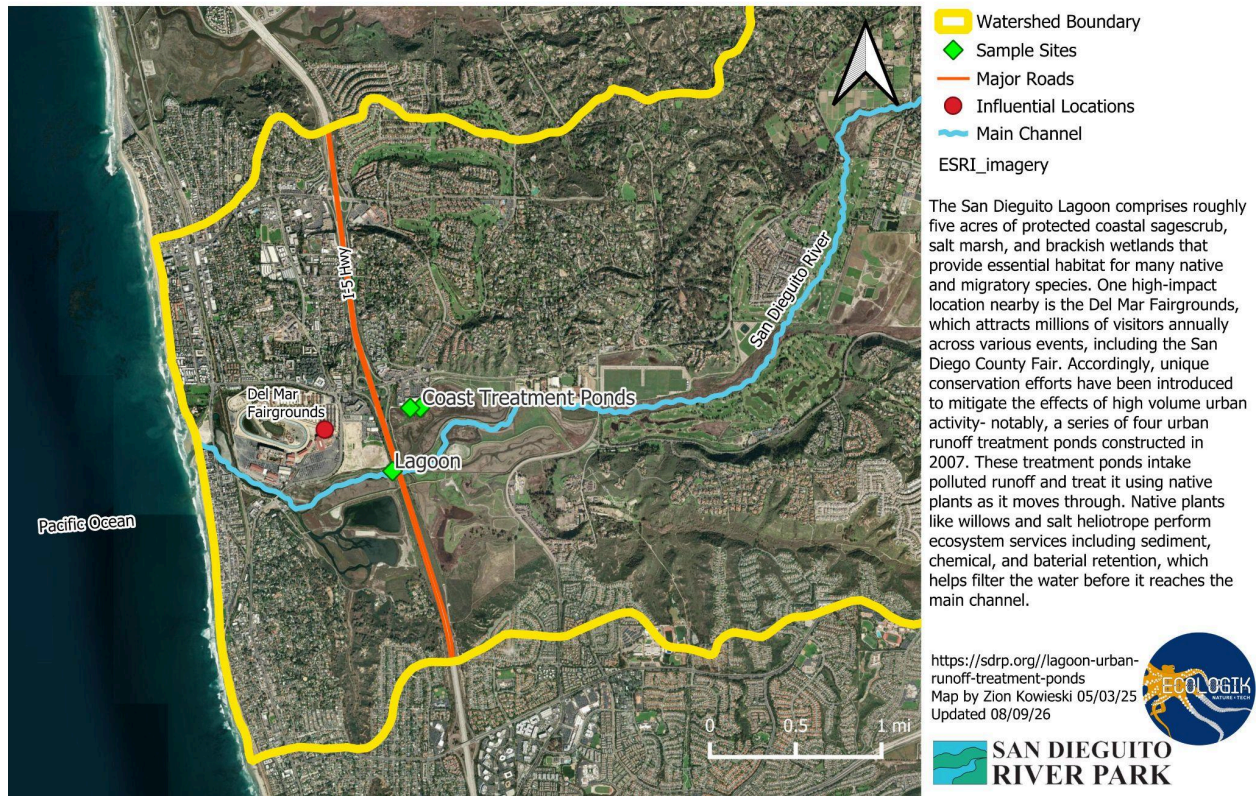


Figure 10d: Lagoon and treatment ponds sampling sites.

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Appendix

The EcoLogik Institute is a 501(c)(3) non-profit dedicated to building the next generation of environmental stewards.

The Conservation Leadership Academy (CLA) allows middle and high school girls and gender-expansive youth the opportunity to participate in hands-on science and science communication projects at their local public lands under the guidance and mentorship of EcoLogik's staff of practicing women in STEM.