Land Use and Water Quality at Wildcat Creek, CA

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Abstract Urban creeks and their associated watersheds are the focal point for a variety of different land uses including, urban development, industry, agriculture, livestock grazing, and recreational activities. These land uses can threaten the water quality of urban creeks. Most land-use studies have focused on multiple watersheds over a regional scale. More localized information is needed on single streams to provide important water quality information so they can be better managed. This study looked at the relationship between various land uses and water quality along Wildcat Creek, Berkeley, CA to determine if urban development, recreational activities, and livestock grazing may negatively affect the health of the creek. The study area was divided into seven discrete usage zones based on varying land uses. Water samples were collected three times over a four-month period to look for temporal variation in pH, conductivity, turbidity, and nitrates. Samples were also collected and analyzed for *E-Coli* bacteria once during the study. Regulatory guidelines and/or standards were used to assess the water quality of the creek. pH levels were found to be consistent throughout each usage zone. Conductivity levels increased downstream with the exception of the Lake Anza usage zone (a swimming reservoir), where they dropped sharply, possibly due to a settling effect. Turbidity levels fluctuated between usage zones showing no set pattern. Nitrate loading generally increased downstream throughout the study area. Conductivity levels were significantly correlated over time among the different usage zones, while the other sample parameters did not show significant temporal correlation. Sample results indicate that the creeks water quality is within applicable regulations and guidelines. No significant differences were found in the levels of the measured parameter between adjacent zones, which indicates that no specific land use is affecting the water quality of Wildcat Creek.

Introduction

Urban streams are a common feature in most urban communities in the United States and are a focal point for a variety of human activities. California alone has more than 200,000 miles of rivers and streams (SWRCB 2000), many of which run through urban areas. Urban creeks and their associated watersheds have been subjected to many different land uses including urban development, industry, agriculture, livestock grazing, and recreational activities. These may degrade the water quality of streams (Staubitz et. al. 1997).

Urban development causes an increase in stormwater runoff into creeks due to a reduction of pervious surface area, which can lead to the erosion of channel banks, siltation of creek beds, alteration of stream habitat, and downstream flooding (USEPA 2000). Fertilizer use associated with agriculture and recreation (i.e. golf courses and park lawns) can elevate leaching of nitrates and phosphates into creeks. Excessive levels of these nutrients may accelerate growth of algae and underwater plants that can deplete creeks of dissolved oxygen necessary to maintain populations of fish and desirable plant species (USEPA 2000). Livestock grazing has been shown to degrade water quality in streams and affect stream channel morphology, hydrology, riparian soil zones, in-stream and stream-bank vegetation, and aquatic and riparian wildlife (Belsky et. al. 1999). Finally, recreational activities such as swimming and wading can directly impact streams via direct input of human wastes. Bacteria entering streams associated with these activities, as well as from animal waste or leaky septic systems' are all health hazards to humans commonly found in urban streams (Ebbert et. al. 2000).

Most studies that have found stream degradation occurring by land use have been conducted on a regional scale encompassing several watersheds and associated stream systems. There are few studies that have focused on land use practices on a single stream. A study focusing on multiple land uses occurring on or adjacent to a single stream system will provide more detailed water quality information than larger scale studies. This information will be valuable for local communities who are trying to improve the water quality of their urban creeks.

Wildcat Creek is a semi-urban creek located in Berkeley, CA. During its course, this creek flows through many adjacent land uses. These land uses include upland cattle grazing, a residential area, a nature preserve, a working farm, a swimming reservoir, a botanical garden, a golf course, picnicking and camping areas, and other recreational activities such as bicycling, hiking, and horseback riding on an extensive network of trails. The purpose of this study is to determine if the multiple land use practices in Wildcat Creek and its surrounding watershed are having an affect on the water quality of the creek. Information obtained from this study may help to identify sources of pollution entering the creek, and may aid in future restoration/remediation projects on the creek and others like it.

In two previous studies on Wildcat Creek, Kaufman (1999) found that nitrogen input from Tilden Golf Course was not greatly affecting downstream ecosystems, and Ho (1998) found no correlation between increasing levels of urbanization and water conductivity, turbidity, and pH. This present study is more comprehensive than the Kaufman and Ho studies because it investigates how multiple land uses may be affecting the water quality of Wildcat Creek by increasing the number of sample sites and number of in-water parameters measured.

Water Quality In order to determine the water quality of Wildcat Creek, several in-water parameters were measured including nitrates, *E-Coli*, conductivity, turbidity, pH, temperature, and stream flow. A summary of the in-water parameters that were measured in this study are summarized below:

Nitrates are essential plant nutrients that in excess amounts can accelerate eutrophication, causing excessive algal growth in creeks, which can in turn change the composition of plants and animals. Excessive nitrate levels can be harmful to cold-water fish. (USEPA 1986). Fertilizer use and leaky sewage systems are examples of sources of excess nitrates that can leech into creeks via groundwater.

E-Coli is a type of bacteria that indicates possible sewage contamination and is commonly found in human and animal feces. The presence of *E-Coli* and can be an indicator of harmful pathogens that can be a health risk to the public. *E-Coli* density is computed in terms of the Most Probable Number (MPN). Levels of *E-Coli* exceeding 235 MPN/100mL are considered hazardous to humans in designated bathing areas (CRWQCB 1995). Leaking sewage systems, swimming activities, and livestock grazing are potential sources of this type of bacteria.

pH indicates the alkalinity or acidity of a substance (i.e. creek water). The pH scale measures the logarithmic concentration of hydrogen and hydroxide ions. pH affects biological and chemical processes in water, and a range of 6.5 to 9.0 appears to provide adequate protection for fish and invertebrate populations (USEPA 1997). The California Regional Water Quality Control Board (CRWQCB) requires that waters in the San Francisco Basin have pH levels ranging from 6.5 to 8.5 (CRWQCB 1995).

Conductivity is a general measure of stream water quality related to the amount of dissolved solids in the water. Geology, agricultural and storm runoff, and leaky sewage systems can affect conductivity. Conductivity levels outside the 150 to 500 microsiemens per centimeter (uS/cm) range can indicate that water is not suitable for certain types of fish and macroinvertebrates (USEPA 1997).

Turbidity is a measure of water clarity related to the amount of suspended material such as silt, algae, and organic material present in water. High turbidity levels can increase stream temperatures, reduce photosynthesis, and the production of dissolved oxygen, which can have adverse affects on aquatic organisms. Erosion from development can increase turbidity levels. Turbidity levels in surface waters above 50 nephelometric turbidity units (NTU) are considered poor (NSW 2000).

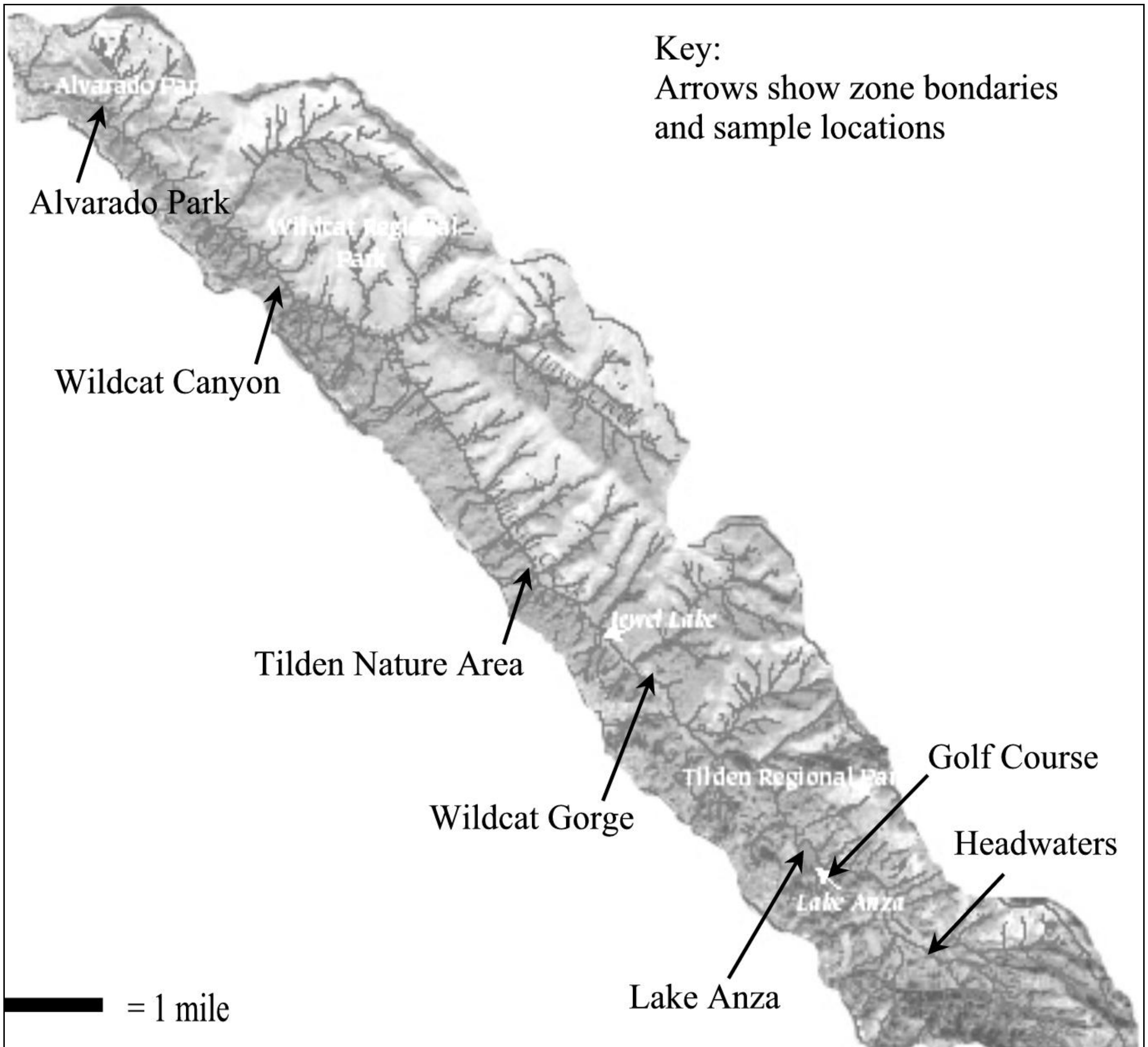
Temperature affects the rates of biological and chemical processes, and aquatic organisms depend on certain temperature ranges for their survival (USEPA 1997).

The level of stream flow has an important impact the water quality of streams. Streams with high flow rates can receive discharges of pollution with little effect while small streams have little capacity to dilute and degrade wastes (USEPA 1997).

Methods

Regulatory guidelines and standards for these parameters were used to assess the water quality of the creek. Comparisons were also made between portions of the creek with differing land uses to look for potential changes in water quality.

Wildcat Creek flows through a narrow southeast-northwest trending canyon between the Berkeley Hills and San Pablo. The creek empties into the San Francisco Bay in Richmond, CA. The study site for this project includes the portions of Wildcat Creek that flow through Tilden and Wildcat Canyon parks (Figure 1). The watershed encompasses over 4,500 acres and consists mainly of clay soils with chaparral and coyote brush dominating the north-facing slopes. Coast live oak and bay laurel are abundant on east-facing slopes, annual grasses tend to dominate the south-facing canyon slopes, and grassland and live oak and bay laurel are plentiful on the west slopes.



Source: San Francisco Estuary Institute

Figure 1. Wildcat Creek Study Site

Experimental Design To determine if there is a relationship between land use and water quality in the Wildcat Creek study site, the study area was partitioned into distinct usage zones based on the dominant land use in each zone. A topographical map was used to determine the zone boundaries, which were designated as the location for water sample collection.

The boundaries were determined by the natural topography of the creek's watershed and accessibility and are presented in Table 1.

Land Usage Zone I.D.	**Land Usage Zone/Boundaries**	**Dominant Land Uses**	**Possible effects on creek**
Headwaters	Above the southern boundary of Tilden golf course	Picnicking, hiking, bicycling, and camping	Minimal. Low impact uses near headwaters
Golf Course	Tilden golf course and botanical garden	Golfing and hiking	High nutrient levels associated with fertilizer use
Lake Anza	Lake Anza	Swimming, picnicking, and hiking	High levels of bacteria from swimming activities
Wildcat Gorge	Lake Anza outlet to Tilden Nature Area	Picnicking, bicycling, hiking, and horseback riding	Minimal. Low impact uses
Tilden Nature Area	Tilden Nature Area to Wildcat Canyon Park southern boundary	Working farm (livestock, chickens, and duck pond), nature preserve, and park headquarters.	High levels of bacteria and nutrients associated with farm, and development
Wildcat Canyon	Wildcat Canyon Park south boundary to boundary where creek leaves park and enters residential area	Upland livestock grazing, hiking, bicycling, horseback riding	High nutrient and bacteria levels associated with grazing activities
Alvarado Park	Residential area to Alvarado Park	Residential area, upland livestock grazing, hiking, bicycling, and horseback riding	High nutrient and bacteria levels associated with grazing activities and development

Table 1. Wildcat Creek Land Use Study Zones

Data Collection Methods outlined in *Wildland Water Quality Sampling and Analysis* (Stednick 1991) and the EPA's *Volunteer Stream Monitoring: A Methods Manual* (USEPA 1997) were followed to collect and analyze the water samples. pH, conductivity, turbidity, flow, and temperature readings were taken directly in the field and water samples were collected for analysis of nitrates by an outside laboratory. Samples were analyzed for *E-Coli* at a U.C.

Berkeley laboratory. In-water parameters were collected and analyzed using methods described below.

Samples were collected for nitrate analysis by dipping a one-liter or 100 mL container below the water level of the creek at each sample location opposite to the direction the creek was flowing. Samples were stored at four degrees Celsius pending analysis (Allen-Diaz et. al. 1998). A mass spectrometer was used to calculate the concentration of nitrates in the water samples and results are reported in milligrams per liter.

Water samples were collected and stored for *E-Coli* analysis using the same procedure as nitrates. The samples were analyzed using the Colilert® method and the multiple-tube fermentation technique (APHA 1992). Results are reported in MPN per 100 milliliters.

pH readings of the creek were collected using a Oakton pH Testr 2 direct reading meter. To obtain a measurement, the tip of the meter was dipped into the water. An electrode produced a current that was transformed into a pH reading.

Conductivity was measured using a similar procedure to the pH meter with a Cole-Parmer TDSTestr 40 meter. Conductivity measurements are reported in microsiemens per centimeter.

A portable HACH 2100P Turbidimeter testing kit was used to measure turbidity. Water was poured into a vial to a pre-measured mark and placed in a designated chamber in the meter. A light source was directed through the sample and the light scattered due to suspended particles in the sample was converted into a turbidity reading (See Stednick 1991 for a more detailed treatment of light scattering). Turbidity measurements are reported in nephelometric turbidity units.

Temperature measurements were collected by dipping a standard thermometer in the creek until reading stabilized at each sample location halfway to the bottom of the creek.

Stream flow was measured by estimating currant velocity and the cross-sectional area of the stream. To estimate the cross-sectional area, stream width was measured at each sample location in meters. The width was divided into three subsections where depth measurements were taken and averaged (also in meters). The velocity of the creek was estimated by timing (seconds) how long it took for a floatable object (sample cap) to travel a distance of two meters. The velocity and cross-sectional area were combined to report the stream flow in cubic feet per second.

Water samples were collected and direct measurements were taken on November 23, 2001, January 25, 2002, and March 20, 2002. Water samples were collected and analyzed for *E-Coli* only for the March 20, 2002 sample date. Each round of sampling was done at least 72 hours after a large rain event to avoid high variability in levels of stream flow and the other measured parameters. The samples were collected at the zone boundaries as opposed to dispersing them throughout each zone to allow for the maximum runoff from each zone to be represented in the samples. Three water samples were collected systematically, one, two, and three meters upstream from each of the seven zone boundaries to avoid the potential of a localized anomaly skewing the sample results.

Results

pH readings remained constant over the time of the study and among the usage zones. Average readings ranged from 7.7 to 8.2 indicating that the creek was slightly basic (Figure 2).

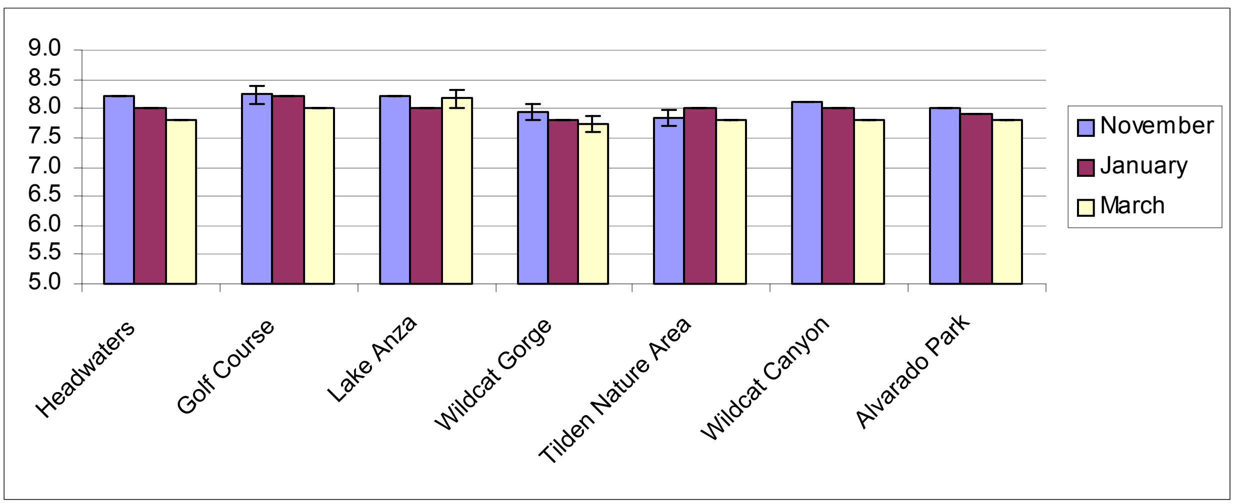


Figure 2. pH Results for Wildcat Creek. Error bars indicate 95% confidence interval. Note: Some intervals may be too small to be seen.

Conductivity levels (Figure 3) ranged from 318 to 739 µS/cm over the study period and consistently increased downstream with the exception of the Lake Anza usage zone where it dropped sharply on each of the sample occasions.

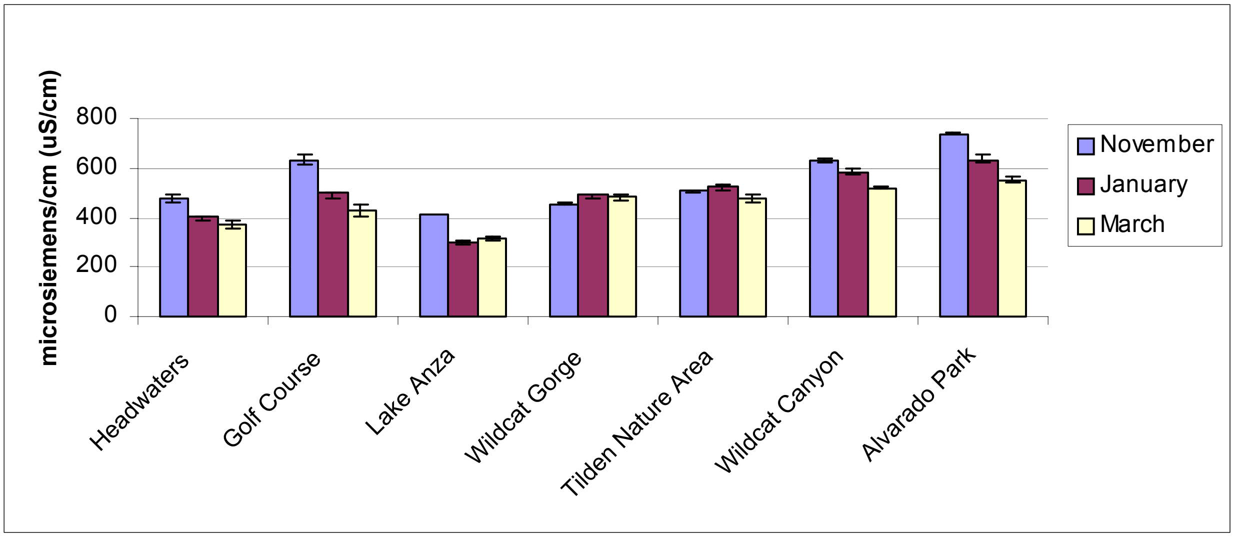


Figure 3. Conductivity Results for Wildcat Creek. Error bars indicate 95% confidence interval. Note: Some intervals may be too small to be seen.

Turbidity levels (Figure 4) fluctuated throughout the study area and over time and ranged from 1.23 to 27.87 NTU over the duration of the study.

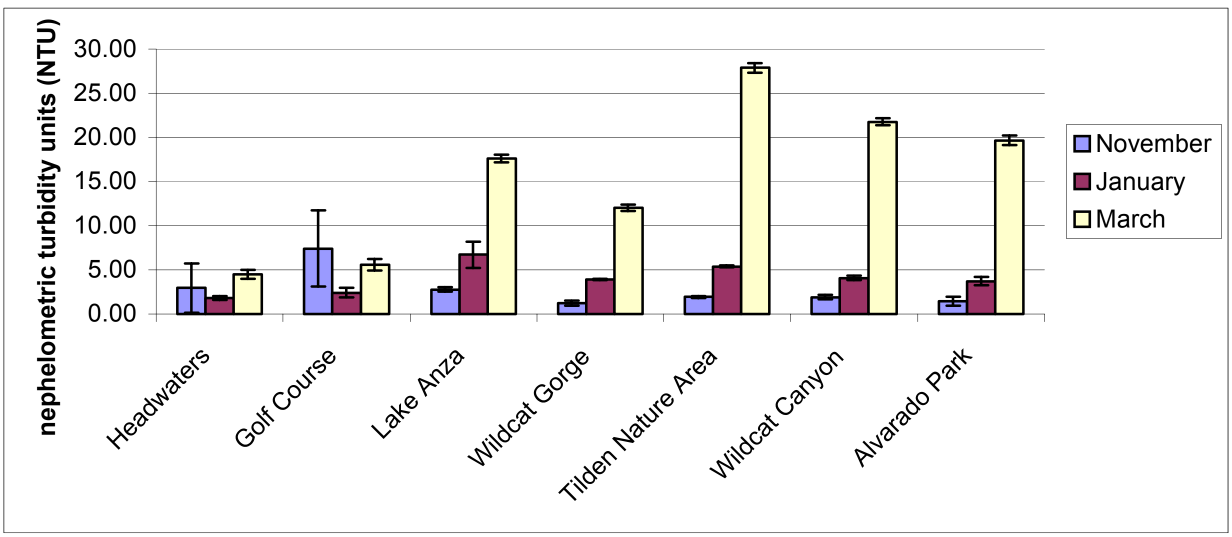


Figure 4. Turbidity Results for Wildcat Creek. Error bars indicate 95% confidence interval. Note: Some intervals may be too small to be seen.

Turbidity levels increased sharply (150 to 500 percent) in all usage zones for the samples collected in March 2002.

Results of Kendall's coefficient of concordance test (Zar 1999) indicated that the conductivity levels in the creek showed consistent patterns ($P<0.025$) among sites through time (Figure 5).

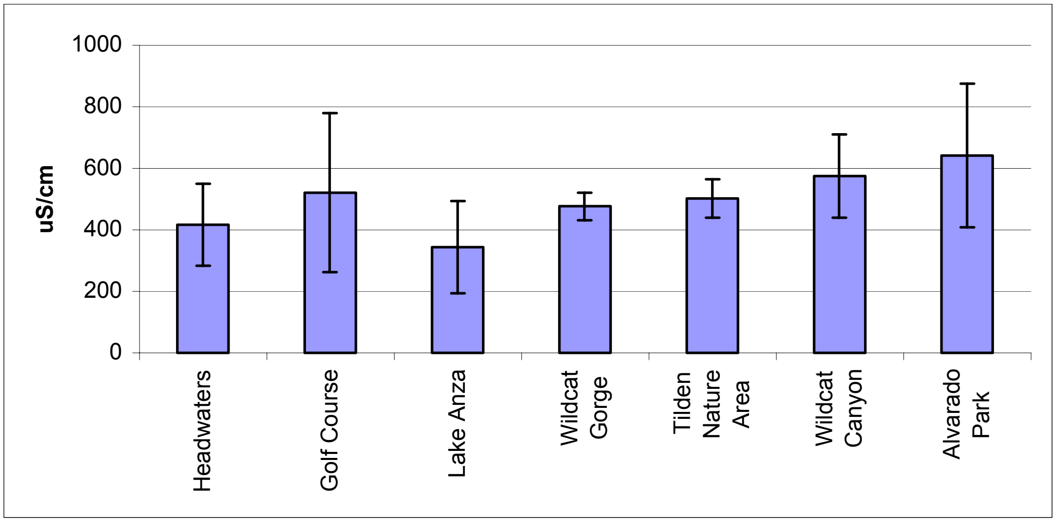


Figure 5. Combined average of conductivity results for November, January, and March sample dates with associated 95% confidence interval.

The other measured parameters did not show temporal correlation. These results show that the levels of the tested parameters remained relatively consistent in the different usage zones relative to each other over the time of the study.

Nitrate concentrations (Figure 6) ranged from none detected (< 0.05) to 0.82 mg/L over the study period and generally decreased downstream.

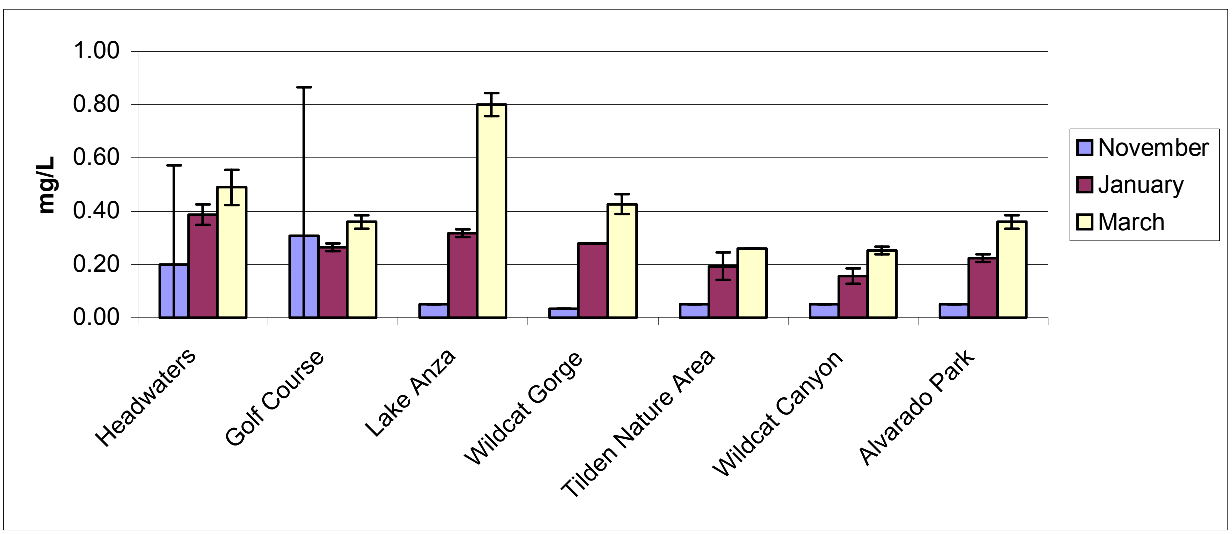


Figure 6. Wildcat Creek nitrate concentrations. Error bars indicate 95% confidence interval. Note: Some intervals may be too small to be seen.

The high variability in the nitrate levels for the headwaters and golf course zones for the November sample data is not consistent with the results for the rest of the study and its cause is undetermined. The nitrate load was also calculated for Wildcat Creek to account for the varying flow rates in the creek. The nitrate load was calculated by multiplying the stream flow (Figure 7) by the nitrate concentrations (Figure 8).

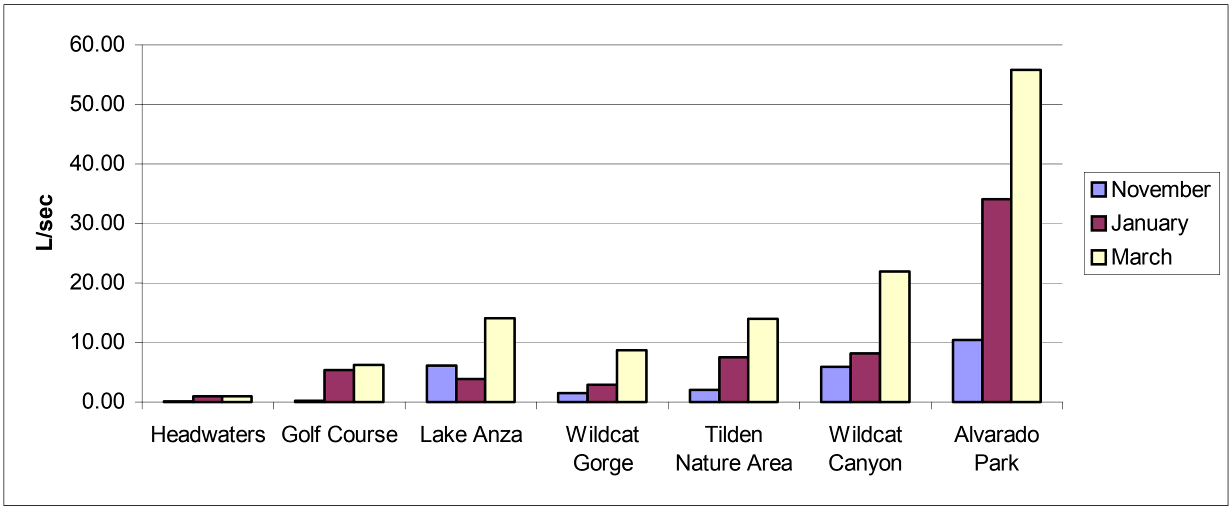


Figure 7. Wildcat Creek stream flow by sample date

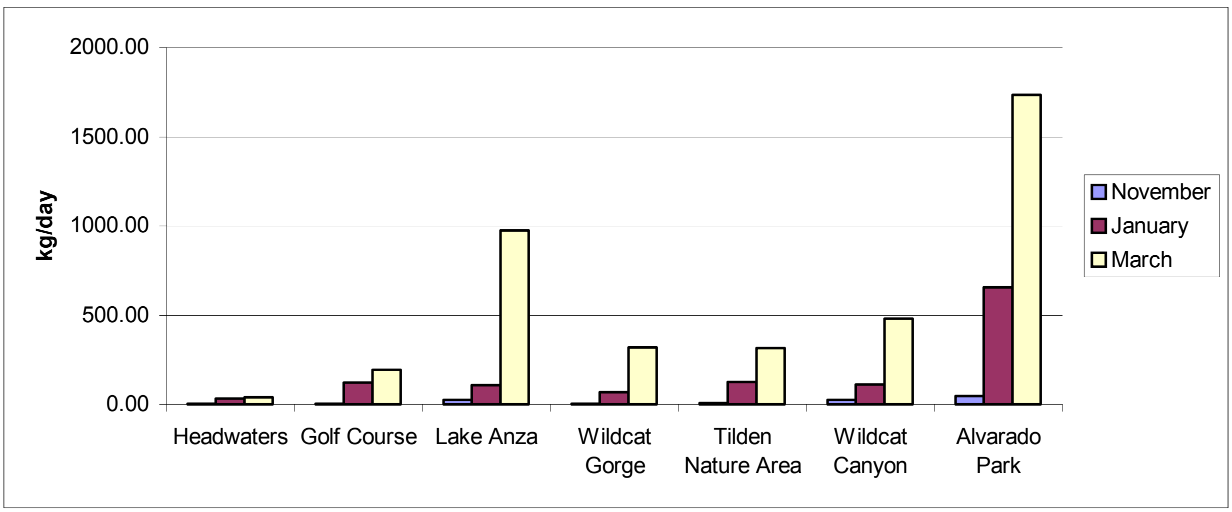


Figure 8. Wildcat Creek nitrate load by sample date

The nitrate load increased consistently downstream with the exception of the Lake Anza zone in March were it rose sharply in comparison to adjacent zones.

Water samples collected in March 2002 indicated the presence of *E-Coli* in the Golf Course, Wildcat Gorge, Wildcat Canyon, and Alvarado Park zones (Figure 9).

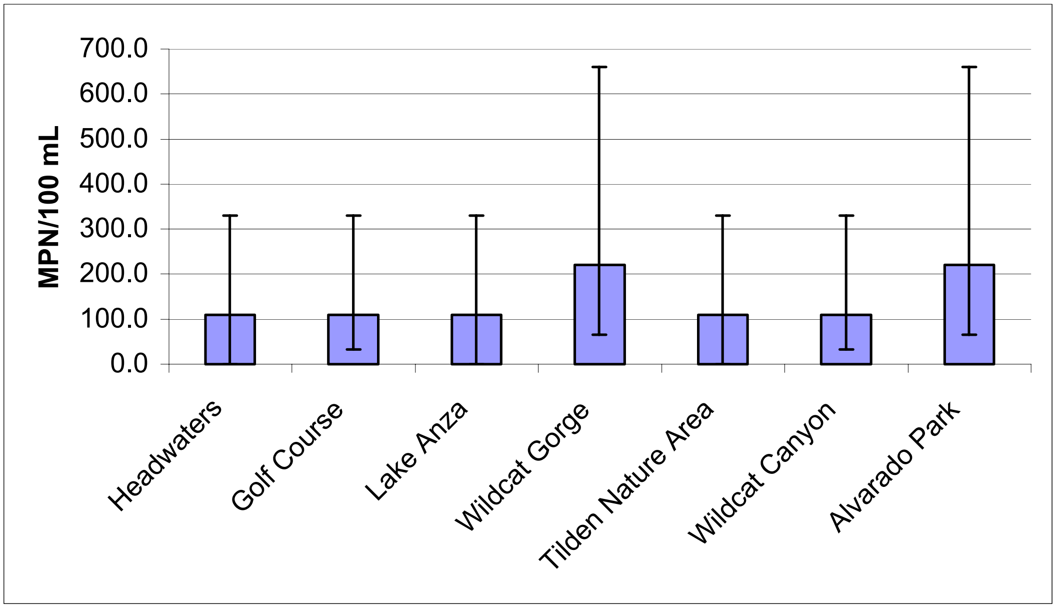


Figure 9. *E-Coli* results for Wildcat Creek. The error bars refer to the estimated 95% confidence interval of the analytical method, and range from 30 to 300 percent of the reported result (APHA 1992).

The results for the remaining usage zones were below the detection limit for the analysis. Results ranged from <110 to 220 MPN/100 mL, which is within the CRWQCB maximum limit for bathing (235 MPN/100mL).

Discussion

The results of this study indicate that the water quality in the Wildcat Creek is generally in good condition based on the measured in-water parameters. pH levels in the creek are within CRWQCB limits and EPA guidelines. Conductivity was generally within the range the EPA considers suitable for mixed fisheries and most species of macroinverebrates. Turbidity was variable among the months of the study and ranged from fair to good according guidelines set by the New South Wales Environmental Protection Authority[1]. *E-Coli* levels were below maximum levels that the CRWQCB considers safe for bathing, but due to inherent uncertainties in the analytical method, the upper 95% confidence interval of the analysis exceeded the safe level for all samples. Based on the analytical uncertainties, it is not possible to determine whether the *E-Coli* levels in Wildcat Creek are actually below CRWQCB standards. All nitrate concentrations were well below EPA's standard for drinking water.

[1] I could find no EPA or CRWQCB standard for turbidity in surface waters.

An interesting trend found in this study was that conductivity levels dropped sharply in the Lake Anza from the preceding Golf Course zone on each of the three sample occasions. It appears that Lake Anza acts as a sink for inorganic dissolved solids such as nitrate, calcium, chloride and other cations and anions. SFEI (2001) estimated that the long-term sediment capture rate for Lake Anza is 378 cubic yards per year. This deposition of sediment in Lake Anza may account for the decreased conductivity levels found in the outflow of the lake.

The increasing trend in conductivity as Wildcat Creek flows downstream may be due to the bedrock and soil that underlies the creek. The lower portion of the study area (Tilden Nature Area, Wildcat Canyon, and Alvarado Park usage zones) are made up of clay rich soils of the Orinda Formation while the upper portions (Headwaters, Golf Course, and Lake Anza) have mostly volcanic bedrock of the Moraga and Bald Peak formations (SFEI 2001). Groundwater samples collected from the Orinda and Moraga formations in nearby Strawberry Creek indicated that dissolved solids concentrations were almost twice as high in the Orinda formation than in the Moraga formation (LBNL 1996), which could account for the general increasing trend in conductivity in the downstream portions of Wildcat Creek. No data was available for the Bald Peak formation. Another possible cause of the higher conductivity levels in the lower portion of the study area may be due to livestock grazing in the upland areas of the Wildcat Canyon and Alvarado Park usage zones. A recent subwatershed analysis of tributaries that feed Wildcat Creek found that at least 26% of the incision of these tributaries was caused by grazing practices (SFEI 2001). Sediments from these tributaries eventually migrate to Wildcat Creek.

Turbidity levels fluctuated over the entire study area showing no temporal correlation ($P>0.25$), however, significant temporal correlation ($P=0.02$) did occur downstream of the Lake Anza usage zone. On all three sample occasions, turbidity levels were higher in the Tilden Nature Area zone compared to the zones above and below it. This effect may be caused by Jewel Lake, which is located within the Tilden Nature Area zone. Increased erosion has been associated with Jewel Lake due to incising of the creek channel below the dam. SFEI (2001) calculated that the creek channel below the Jewel lake dam has incised 12 feet since it was constructed in 1922. Additionally, they calculated that bed incision from the effects of the dam occurs at a rate of 233 cubic yards per year. This effect may also be occurring downstream of Lake Anza, but I wouldn't have been able to observe it because I collected samples directly below the spillway. The elevated turbidity levels found during the March 2002 sample date were probably because the creek had not completely flushed out the sediments from the rain event that occurred approximately three days prior to the sampling. Much of the creek appeared visually murky at the time.

The results of the nitrate sampling in Wildcat Creek were surprising. The headwaters zone had either the highest or second highest concentration of nitrates in the study area for all three sample periods. I had expected the headwaters to have the lowest nitrate concentrations due to its close proximity to the creek's source. Upon further analysis it appears that the high nitrate concentrations in the headwaters was related to lower stream flow levels in that portion of the creek. In order to account for the low stream flow, I calculated the nitrate load. The nitrate load calculation showed that the input of nitrates from the headwaters zone is actually is very low and that the load increased downstream with increasing stream flow.

This study attempted to determine if the various land uses along Wildcat Creek were negatively affecting the water quality of the creek. Data from the in-water water quality parameters tested did not show that any single land use was degrading the water quality in Wildcat Creek. Due to time constraints, this study only represented the winter and part of the fall seasons. The potential effects of different land uses, such as swimming and the increased usage of the surrounding parkland by the public that occur in spring and summer were not represented in this study. Further research encompassing these seasons should be conducted to represent the entire spectrum of land uses occurring along Wildcat Creek. Additionally, due to time and resource constraints, only in-water parameters were analyzed in this study. To more fully assess the relationship between water quality and land uses along Wildcat Creek other water quality parameters should be analyzed. These include biological parameters such as species diversity, richness and habitat along the creek. Physical parameters such as sinuosity, grade, bed composition, and bank cover stability should also be assessed. Finally, testing should be conducted for chemical parameters such as pesticide and herbicides.

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