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Parcel-level land use and water quality impacts in the Santa Margarita River Watershed

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Abstract

The Santa Margarita River (SMR) watershed has reaches that are impaired by poor water quality from nonpoint source (NPS) pollutants. We analyzed land use in the SMR using various online databases for four different NPS hotspots in hopes of identifying the sources of NPS pollutants. We utilized ArcGIS to produce maps of the study area and to perform a spatial analysis on the various land uses. We then sampled water for nutrient analysis at six sampling sites chosen based on our land use analysis. We also measured discharge at two locations, and used that data to calculate loading rates. The overall analysis found that high concentrations of total nitrogen and phosphate are attributable to a cluster of nurseries on the east side of the Rainbow Creek watershed. Nutrient loads decrease further downstream of the nurseries, when the land use in the sub-watershed is urban and agricultural, suggesting that other land uses are not contributing significant nutrient loads, and that the riparian corridor may be removing nutrients from the stream.

Keywords: watershed, nutrient load, non-point source pollutant, land use, water quality

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Introduction

With the growth of urbanization, pollution in the Earth's water systems continues to increase. As urbanization expands, land area covered by impervious surfaces increases, runoff increases, and consequently water pollution increases. One type of pollution that is of increasing concern is non-point source (NPS) pollutants. NPS pollutants are attributed to runoff from agriculture, construction, and urban areas (National Research Council, 2000). They are carried over extensive areas and are challenging to identify and manage. It is known that agricultural development releases a large amount of NPS pollutants into water bodies by releasing nitrogen and phosphorus into watersheds (Jain, 2002). In addition, nurseries and greenhouses are also found to be a major source of NPS pollution in Mediterranean climates (Robinson and Melack,2013) (Figure 1). These land uses can attribute more pollution than agricultural and urban land use (Robinson and Melack, 2013). The result of multiple agriculture developments and nurseries near a watershed is a large accumulation of pollutants downstream. The Santa Margarita River watershed is a water body of concern in Southern California because of its regions that are impaired by poor water quality from NPS pollutants.

The San Diego Regional Water Quality Control Board (SDRWQCB) created a Basin Plan for Total Maximum Daily Loads (TMDL) for Rainbow Creek in 2006 (California Regional Water Quality Control Board, 2006). Rainbow creek has repeatedly exceeded the amount of water quality objectives for total nitrogen (1 mg/L) and total phosphorus (0.1 mg/L). In 2000 concentrations were as high as 23 mg/L for total nitrogen (TN), and 1.7 mg/L for total phosphorus (TP). They also found that nutrient concentrations were contributing to more algae growth. They stated that a 74% reduction of total nitrogen and an 85% overall reduction of total phosphorus is required to meet the TMDL standards per year of 1,658 kg/yr TN and 165 kg/yr TP.

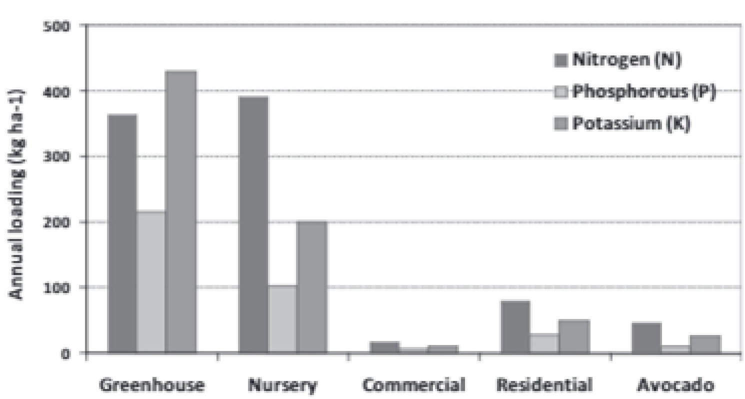


Figure 1. Amount of fertilizer and subsequent nutrients being used across five land use classes. From Robinson and Melack, 2013

Project description: SDRWQCB and SCCWRP have identified water quality hotspots in the Santa Margarita watershed. The sites are located in Rainbow near the San Diego Riverside border. The intention of this project is to provide enough materials to assist enforcement of water quality regulations and exhibit the relationship between land use and water quality. This project provides a detailed analysis of the watersheds that discharge into the hotspots including the watershed boundaries, a summary of land use from the National Land Cover database, and a comprehensive description of land use in parcel boundaries from SANGIS. In addition, water samples from six sites within the watershed were taken, filtered, and analyzed for total nitrogen (TN) and phosphate. Loads were then calculated from discharge data and the analyzed TN and phosphate.

Methods

I. Study Area

The Santa Margarita River watershed is alocation of growing concern of NPS pollutant loading. It is located in Southern California in the lower region of Riverside County and the upper region of San Diego County. It drains a total of 723 mi^2 in northern San Diego and Riverside counties (Sutala et al., 2016) (Figure 2). The Santa Margarita watershed is one of the last undammed rivers in the region and is important for its array of valuable uses associated with water supply, industry, agriculture, and a variety of ecosystems (California Water Board, 2017). Recently, parts of the watershed were identified as regions of increasing concern due to eutrophication and nutrient loading to the total maximum daily load (TMDL). Eutrophication is largely caused by algal biomass (Smith, 2003). Excess amounts of this biomass are often caused by nutrient loading of nitrogen and phosphorus. In Mediterranean vegetation types, these nutrient loads are predominantly generated by orchards, vineyards, greenhouses, and nurseries (Robinson and Melack, 2013). Irrigated agriculture is also a known contributor of total nitrogen (TN) loading. Additionally, roads are a known contributor for total phosphorus (TP) loading (California Water Board, 2017). These nutrient loads are not in compliance with the 303(d) listings and existing TMDL standards because of high amounts of nitrogen and phosphorus found in the water system (WQIP).

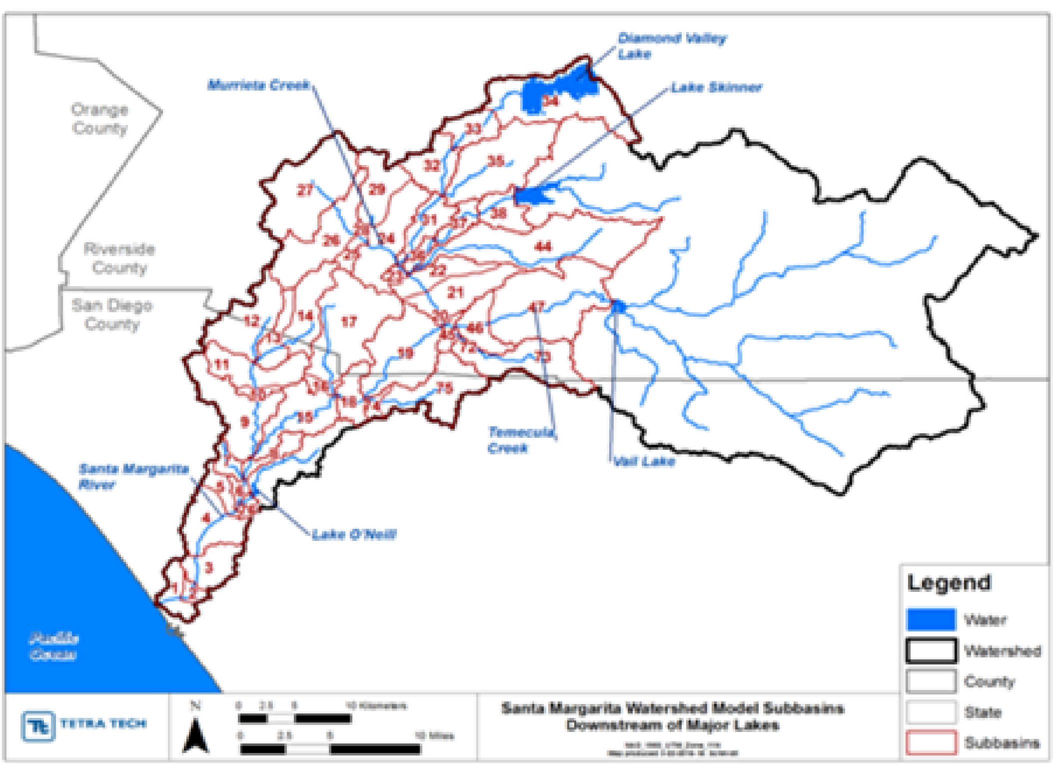


Figure 3.13. Santa Margarita Watershed Model Sub-basins Downstream of Diamond Valley, Skinner, Vail, and Lake O'Neill

Figure 2. Map of the Santa Margarita watershed and its sub-basins from Sutala et al., 2016

Figure 3. Google Earth snapshot of RBC04, RBC02, SMG06, and RVT02, the four locations with the highest TN according to author (year), and the USGS Streamgage on the SMR.

SCCWRP has identified several regions of eutrophication and nutrient loading that are considered high priority water quality conditions (HPWQC) within the watershed. One of the sub-watersheds with HPWQC is the Rainbow Creek region located at the lower half of the watershed at the border between San Diego and Riverside counties. Previous reports (County of Riverside et al., 2016) have determined the location of water quality hotspots in the Santa Margarita watershed, but detailed investigation of the land uses and parcels in the watersheds draining to these hotspots has not been assessed with adequate detail (Table 1). The hotspots that will be studied are RBC04, RBC02, HST02, and RVT02 (Figure 3).

Location	Drainage area (ha)	TN (mg/L)
RBCO2	4270	42.8
RBCO4	4530	33.2
SMGO6	7343	13.9
RVT02	1239	25.8
HST01 (MS4)	99	16.5
HST02 (MS4)	83	26.7

Table 1. The location of hotspots of high TN and TP are identified (the four highest are marked in blue), from County of Riverside et al., 2018

II. Watershed Delineation

In order to identify contributing sources of pollution, we first must establish the boundaries of the watersheds. The method used for this process includes the utilization of ArcMap. First, we obtained the location of four different hotspot locations from the Southern California Coastal Water Research Project Authority (SCCWRP). Then we uploaded the flow lines and the flow accumulation grid from the National Hydrology Dataset (NHD) (USGS, 2013). We then displayed the flow network by symbolizing using the classification design and changed the break value to 100. This break value displays a detailed map of possible flow lines. ESRI's spatial analysis tool, Snap Pour Point, identifies the pour point for each site when given the hotspot location and the flow accumulation grid. With the snap pour point and the flow direction grid, we used the Watershed tool to delineate the watershed at the hotspot. After delineating the boundary, we calculated the area using the cell count in the raster watershed and converted it to hectares.

$$\# \text{ of cells} \times 30m \times 30m / 1 \text{ cell} \times 1 \text{ hectare}/10{,}000m^2 = \_\_ \text{ hectares}$$

II. National Land Cover Database

After delineating the watersheds, we worked with the 2011 National Land Cover database (NLC) to determine the general use of the land. The National Land Cover database provides a description of land cover at a 30m resolution. The NLC raster file overlays the watershed delineations. We use the tool Tabulate Area to obtain a table that sorts the amount of land in each land use category (Table 2).

III. SanGIS

To obtain a better understanding of the land use in the watersheds, we used the San Diego parcel layer from SanGIS. The layer contains parcel polygons and associated information. The field of focus in the information is NUCLEUS_US. The field contains a description of property use with 255 categories. We aggregated the different types in order to make a more comprehensive classification system (Table 3). We then cross checked the land use given in the parcel data with Google Earth Pro to assure the land use was accurate. We altered a few parcel labels to match the land use in Google Earth Pro. Similarly to using the NLC data, we used the Tabulate Area tool in ArcMap to calculate the amount of each land use in the watersheds.

National Land Cover Data Classification	
52	**Shrub/Scrub**
21	**Developed, Open Space**
22	**Developed, Low Intensity**
71	**Grassland/Herbaceous**
23	**Developed, Medium Intensity**
82	**Cultivated Crops**
43	**Mixed Forest**
90	**Woody Wetlands**
42	**Evergreen Forest**
24	**Developed High Intensity**
95	**Emergent Herbaceous Wetlands**
31	**Barren Land (Rock/Sand/Clay)**
11	**Open Water**

Legend Description	
AGGREGATED CATEGORIES	NUCLEUS_US LABELS
VACANT/SLIVERS	VACANT RESIDENTIAL - GENERIC, SLIVER LEFT OVER-PARCEL NON-BUILDABLE, SPECIAL-SLIVER, SMALL PARCEL, VACANT LAND COMMERCIAL
NURSERY	AGRICULTURAL PRESERVE (UNDER COVER), GARDENING/NURSERY, GROWING HOUSES
RESIDENTIAL	SINGLE FAMILY RESIDENCE, SINGLE FAMILY RESIDENCE - GENERIC, MANUFACTURED HOME IN CO-OP PARK, DUPLEX - GENERIC, 2 - 4 UNITS GENERIC, SINGLE FAMILY WITH AG BUILDINGS, SINGLE FAMILY RESIDENCE W/GRANNY FLAT, PARCEL USED FOR ACCESS (DRVWY FOR MULT PRCLS), MH ON PRIVATE PROPERTY - NOT A PARK
COMMERCIAL	CHURCH, SERVICE STATION - GENERIC, GENERIC- RADIO STATION/BANK/MISC, MEETING HALL/GYM, WAREHOUSE-PROCESSING/STORAGE/DISTRIBUTION, GENERIC COMMERCIAL OFFICE/RETAIL 1-3 STORIES
AGRICULTURE	MISC AGRICULTURAL, IRRIGATED FARM VACANT WATER AVAILABLE, AVOCADO, IRRIGATED CROPS OTHER VEG., FLORAL, FEEDING
RURAL/Open Space	1 - 10 ACRES RURAL LAND OTHER, 11 -40 ACRES NON-IRRIGATED, 41 - 160 ACRES NON-IRRIGATED, MISC TREES
POULTRY	POULTRY
UNKNOWN	UNKNOWN

Table 3. Aggregated legend for SanGIS classification system

It is important to note that the parcel data only contains parcels in San Diego. Unfortunately, no data was found for the Riverside portion of the watershed. The only information located was the parcel boundary lines however these did not include an informative land use description. Because of this, we were not able to perform an analysis of the Riverside half of the watershed at the same level of detail, though we concluded that the majority of land is rural. The only non-rural land is the highway, storage lots, four houses, and what appears to be a truck rest stop. There was no significant agricultural land or nursery business. Because these identified land uses do not commonly produce significant adverse amounts of runoff, we consider the Riverside portion of this watershed to be of little importance in the contribution to the hotspots.

IV. Sample Data Collection

To pinpoint the source of nutrient loading, water samples were taken for quality analysis. The proposed sample sites are stationed at points on the flowlines surrounding the majority of nurseries located within all of the watersheds (Fig 4). Two upstream points were chosen to sample the water before they run through the nurseries, and two were chosen downstream within the cluster of nurseries. The last sample site is located further downstream at a greater distance from the cluster of nurseries and greenhouses. These proposed sample sites would help to confirm if the pollutants are runoff from improper agricultural practices, or if further research must be conducted.

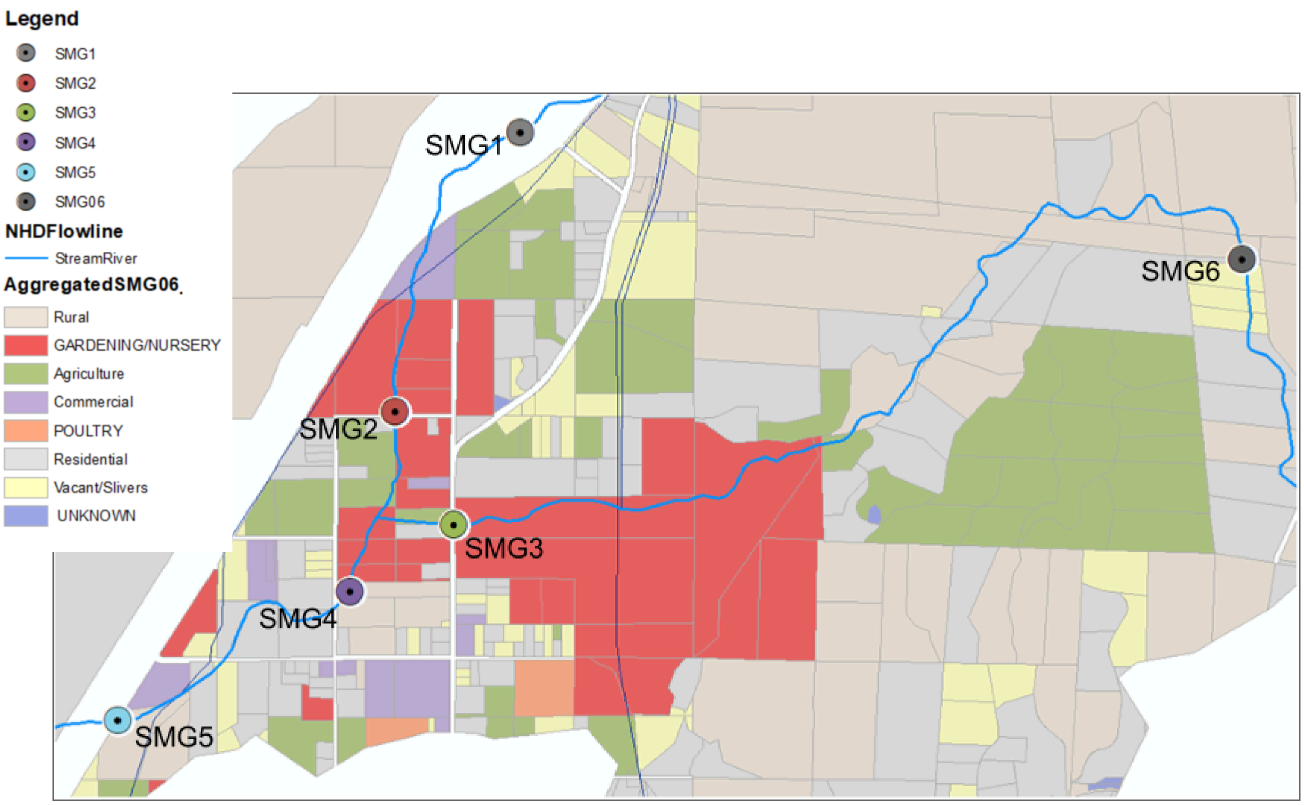


Figure 4. Land use within each sample site watershed

Once the samples were gathered, they each required filtering to remove any organic compounds with the potential for skewing data. In order to properly filter the samples into newer bottles, we utilized sterile filters (0.7 um pore size) and a 150 mL syringe to push the water through a pressure gradient into blank 60mL bottles to create a set of filtered samples.

V. Pressure Transducer & Discharge Measurements

Use of the pressure transducers is designed for the measurement of water level and air pressure on set intervals. This requires installation in pairs as one transducer would be in the stream to gauge water pressure while the other would be located 10-15 feet away in a tree or bush to gauge the pressure of the air. Installation of the water transducers required a cage and mounting apparatus to avoid potential damage or sedimentary buildup which can disrupt the efficiency of the sensors.

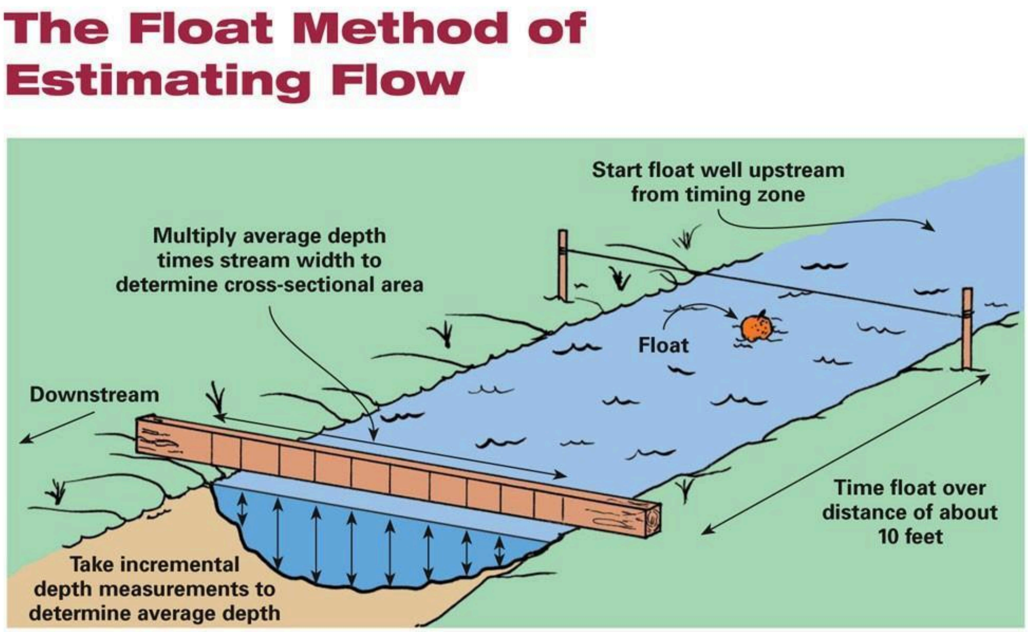


Figure 5. Float method used to measure discharge of the stream (Source: https://polarpedia.eu/en/floating-method/)

Stream flow discharge was measured with the orange peel float method were utilized on sites SMG-01 and SMG-03. Discharge data was collected along ten foot long straights on a cross section of the stream measuring the width and averages of the depths across the stream in the same locations as the pressure transducers for SMG-01 and SMG-03. Fig 5 lays out the methods utilized to gather the discharge data. Assuming the discharge is similar at other downstream sampling sites we calculated the approximate discharges for all sampling sites using the discharge to area ratio from the sampling site of the known discharge.

$$Q(ft^3/sec)/A(km^2)$$

VI. Chemical Analyses

TN Analysis

The chemical analysis for total nitrogen (TN) and total organic carbon (TOC) was performed using a series of varying standards for the chemicals relatively ranging from 0.5 to 5 for TN and 0.5 to 20 for TC. Each of the standards were then placed into separate 20mL vials that were separated by two 20mL vials of Ultra-pure water (UP) for every five vials that contained the standard. Once the standards are set up, a single vial of stock Nitrate (NO3) is diluted to a 20mL stock containing 10ppm NO3 after which the samples are then placed into separate vials starting with the earliest date of sampling using a 3:1 ratio of UP: sample resulting in 15mL of UP and 5mL of sample in each of the vials respectively utilizing the naming convention of SMGxy to signify the batch and sample number within each batch starting from zero. For example, SMG01 is the first sample taken within the first batch while SMG24 would be the fourth sample taken within the third batch. The samples vials are then placed into the cake tray 6 at a time spaced out by the placement of two 20mL UP vials.

The Cake machine requires 30 minutes to warm up which is then followed by the placement of the cake tray containing the samples into the slot. Once the testing of each vial is completed, the data for TN and TOC are extracted as ASCI text which is then converted into two separate Excel workbooks and used to create a line of best fit (Fig 6).

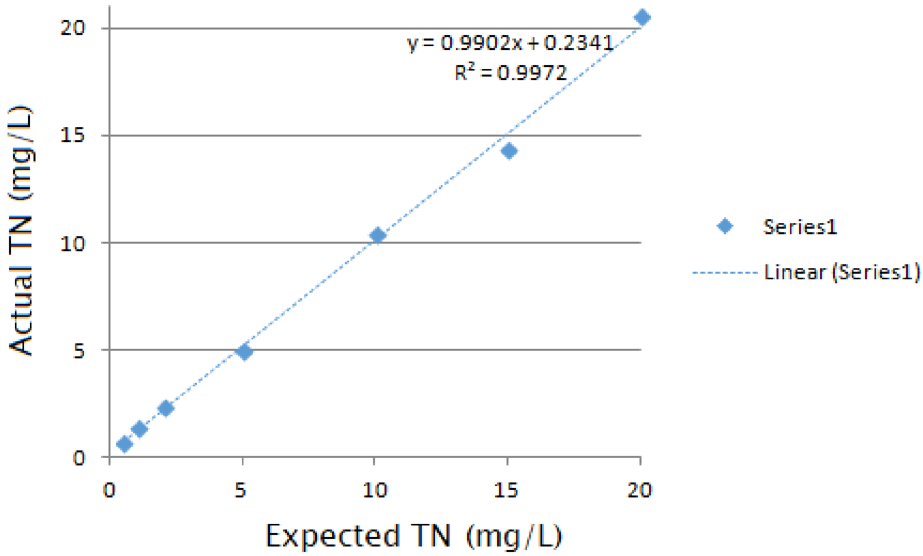


Figure 6. Trendline of standards expected values vs. actual values used to correct TN and TOC results

Phosphorus Analysis:

Phosphate was analyzed using series of varying standards for the chemicals ranging from 0.02ppm to 0.5ppm of phosphate. A 50 ppm stock solution of Monopotassium Phosphate was diluted to a 1ppm solution. Standard curves were then created in 1.5 ml centrifuge tubes using the 1ppm solution and ultra pure water following a standard curve to create concentrations of 0ppm, 0.02ppm, 0.05ppm, 0.10ppm, 0.20ppm, and 0.50ppm as seen in Table 4. 150 microliters of each standard was pipet into wells on the standard plate. Following that, 150 microliters of each sample was pipet into the consecutive wells on the standard plate. An excel spreadsheet was created to keep track of which wells held which standards or samples. 30 microliters of AMP were added to every well, and allowed to sit for 10 minutes. 30 microliters of malachite green was then added to each well, the plate was then placed in a dark drawer and allowed to sit for 30 minutes. The sample plate was then read using a plate reader.

Concentration	µl 1ppm	µl matrix
0 ppm	0	1000
0.02	20	980
0.05	50	950
0.10	100	900
0.20	200	800
0.50	500	500

Table 4. Dilutions used to create the standard curve

VI. Nutrient Loading

To calculate loading we used the calculated discharge for all sampling sites, and the sampling watershed drainage area.

$$\text{Load (kg/day)} = Q\ (ft^3/sec) \times C\ (mg/L) \times sec/day \times L/ft^3 \times kg/1E6\ mg$$

Where 'Q' is discharge, 'C' is nitrogen concentration, 'sec/day' is a unit conversion of 86400, 'L/ft^3' is a unit conversion of 28.32, and 'kg/mg' is also a conversion factor of 1e-6. After calculating load, we divided each sampling sites load by its drainage area.

Figures

Table 5 Drainage area results for four hotspots in the Santa Margarita watershed

Location	Drainage area		
Source:	**2016-2017 Rainbow Creek TMDL Monitoring Results**		**GIS-derived Topographic Watershed Boundaries**
	Acres	Hectares (=0.404686 x acres)	Hectares
RBC02	4270	1728	1796 (3.9%)
RBC04	4530	1833	1858 (1.4%)
SMG06	7343	2972	3005 (1.1%)
RVT02	1239	501	544 (8.6%)

Table 6 Total amount of nurseries and agriculture in each watershed

Nursery/Agricultural Land Use				
Locatio n	Nurseries (ha)	Agriculture (ha)	Nurseries + Agriculture (ha)	% of Wshed Area in Nurseries +Agriculture
RBCO2	128.97	98.51	227.48	20.58%
RBCO4	1154.935	1339.756	2,494.691	10.07%
SMGO6	1352.86	2446.54	3,799.40	15.51%
RVT02	17.30	8.51	25.81	23.31%

Table 7 Land use summary using the National Land Use database

Classification		RBCO4		RBCO2		RVT02		SMG06	
		Hectares	%Land Cover	Hectares	% Land Cover	Hectares	% Land Cover	Hectares	% Land Cover
52	Shrub/Scrub	1250.82	67.33%	1231.38	68.55%	375.75	69.02%	2070.18	68.89%
21	Developed, Open Space	209.16	11.26%	187.56	10.44%	61.83	11.36%	370.98	12.35%
22	Developed, Low Intensity	118.98	6.40%	108.36	6.03%	41.22	7.57%	166.5	5.54%
71	Grassland/ Herbaceous	112.41	6.05%	111.51	6.21%	37.62	6.91%	142.92	4.76%
23	Developed, Medium Intensity	55.71	3.00%	53.01	2.95%	24.03	4.41%	63.99	2.13%
82	Cultivated Crops	54.09	2.91%	48.06	2.68%	0.54	0.10%	111.78	3.72%
43	Mixed Forest	28.26	1.52%	28.26	1.57%	2.16	0.40%	38.79	1.29%
90	Woody Wetlands-	11.16	0.60%	11.16	0.62%			15.93	0.53%
42	Evergreen Forest	5.31	0.29%	5.31	0.3%	0.99	0.18%	11.97	0.40%
24	Developed High Intensity	6.57	0.35%	6.57	0.37%	0.27	0.05%	6.57	0.22%
95	Emergent Herbaceous Wetlands	2.34	0.13%	2.34	0.13%	N/A	N/A	2.34	0.08%
31	Barren Land (Rock/Sand /Clay)	1.8	0.10%	1.8	0.10%	N/A	N/A	1.8	0.06%
11	Open Water	1.08	0.06%	1.08	0.06%	N/A	N/A	1.08	0.04%
Total		1857.7	100%	1796.4	100%	544.4	100%	3005	100%

Results

I. Delineation

RBC02

RBC02 is located near Rainbow, CA. The watershed has old highway 395 running through the west half. The watershed boundary was created in ArcMap (Fig 7). The 2016-2017 Rainbow Creek TMDL Monitoring Results (Table 5) lists the area as 4270 Acres, or 1728 Hectares. The calculated watershed area is 1796 ha. This is a 3.9% difference.

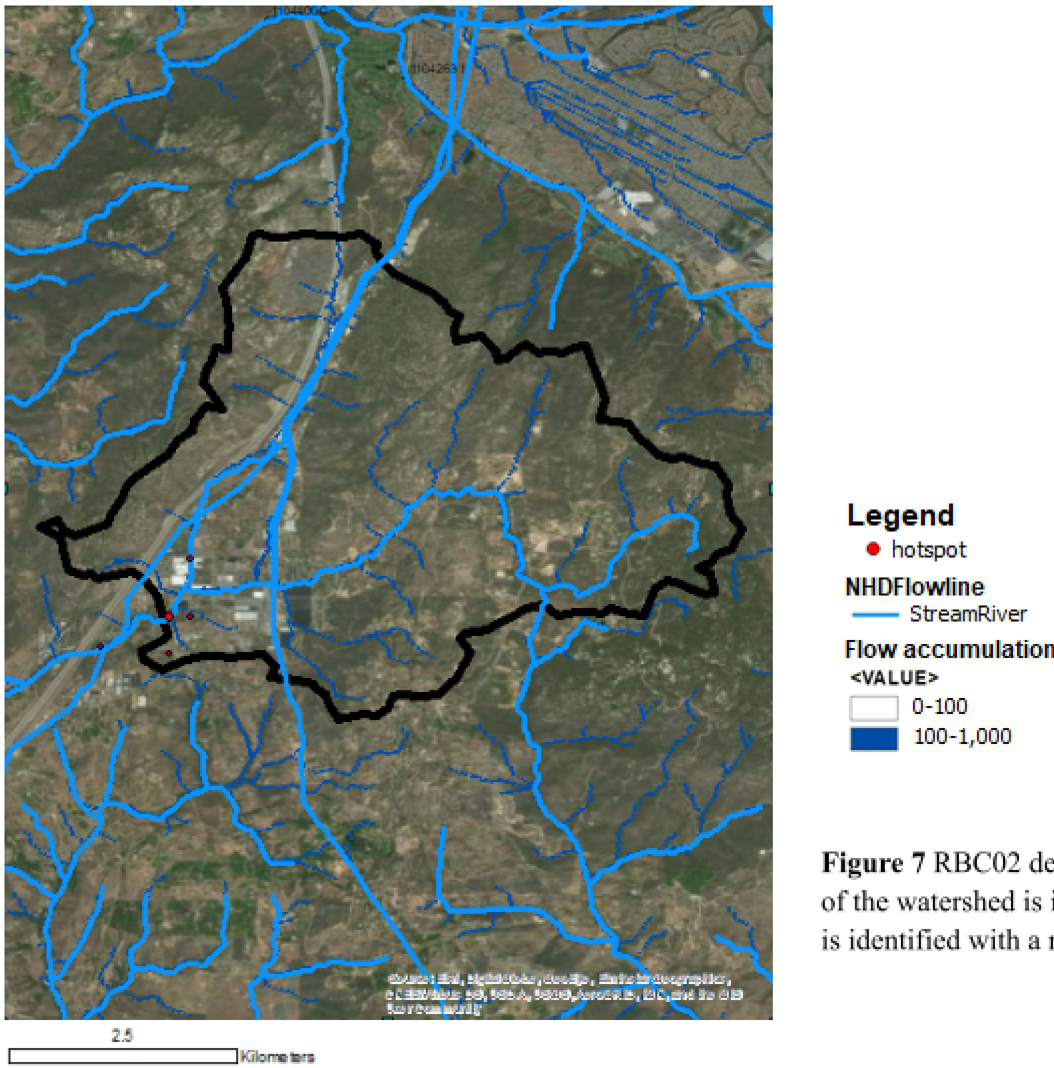
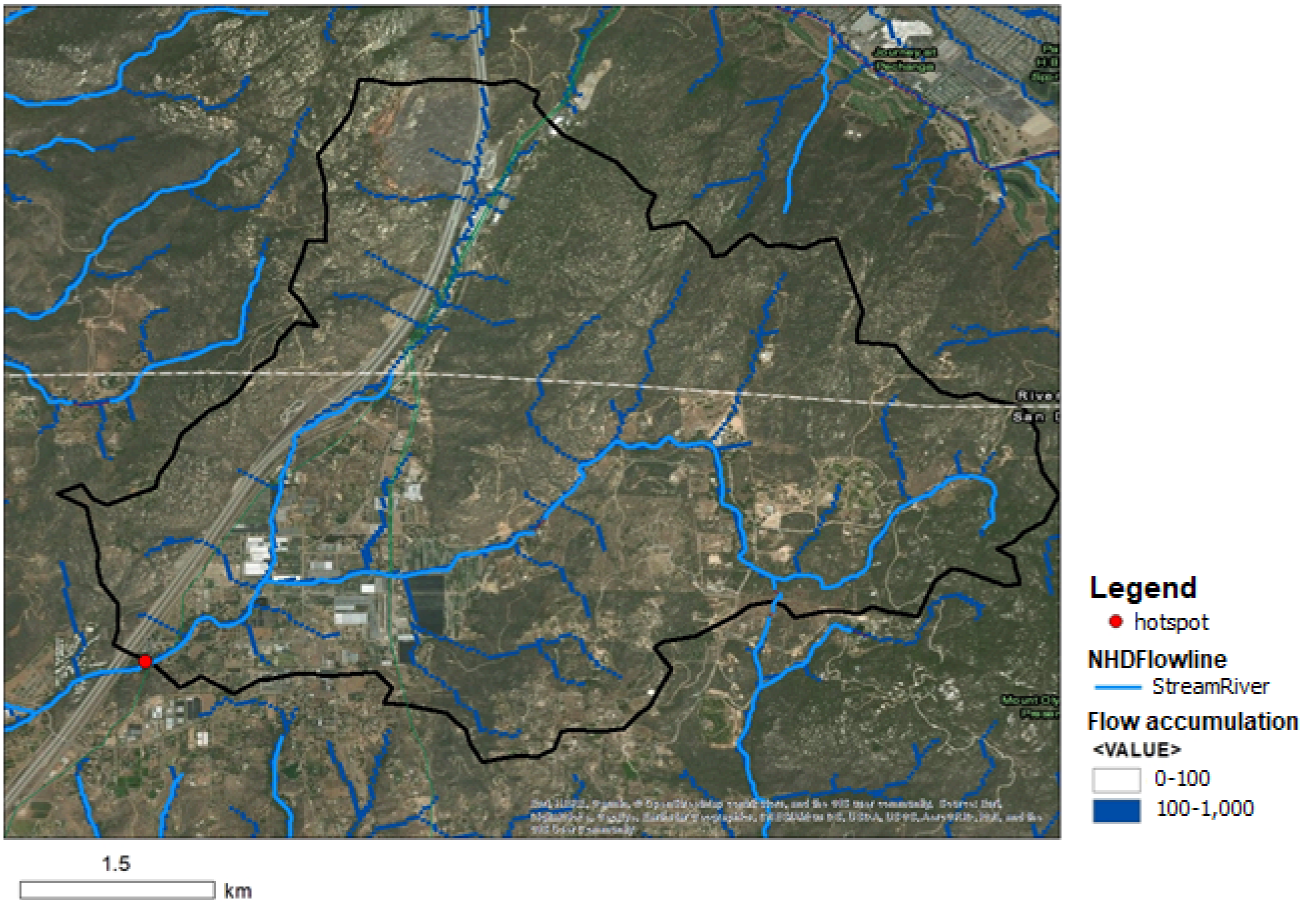


Figure 7 RBC02 delineation. The boundary of the watershed is in black and the hotspot is identified with a red circle.

RBC04

RBCO4 has old highway 395 running through it and is located in Rainbow, CA. The watershed boundary (Fig. 8) was created in ArcMap. The 2016-2017 Rainbow Creek TMDL Monitoring Results (Table 5) lists the area as 4530 Acres, or 1833 Hectares. The calculated watershed area is 3005. This is a 1.1% difference.



re 8. RBC04 delineation, the boundary of the watershed is in black and the hotspot is identified with . circle.

SMG06

SMG06 is located west of Rainbow, CA closer to the tail end of rainbow creek in close proximity to The Santa Margarita River. The watershed boundary (Fig. 9) was created in ArcMap. The 2016-2017 Rainbow Creek TMDL Monitoring Results (Table 5) lists the area as 7343 Acres, or 2972 Hectares with a calculated watershed area of 3005 Hectares. This is a 1.1% difference. It is important to note that SMG06 contains the RVT02, RBC04, and RBC02 watersheds within it as well.

ation

RVT02

RVT02 is located near Old Hwy 395 in Rainbow. The majority of the urbanized land is located in the southern half of the watershed on the east side of the highway. The watershed boundary (Fig. 10) was created in ArcMap. The 2016-2017 Rainbow Creek TMDL Monitoring Results has the area as 1239 (Table 5) acres which is 501 hectares. The computed watershed area is 544 hectares with a percent difference between the two of 8.4%.

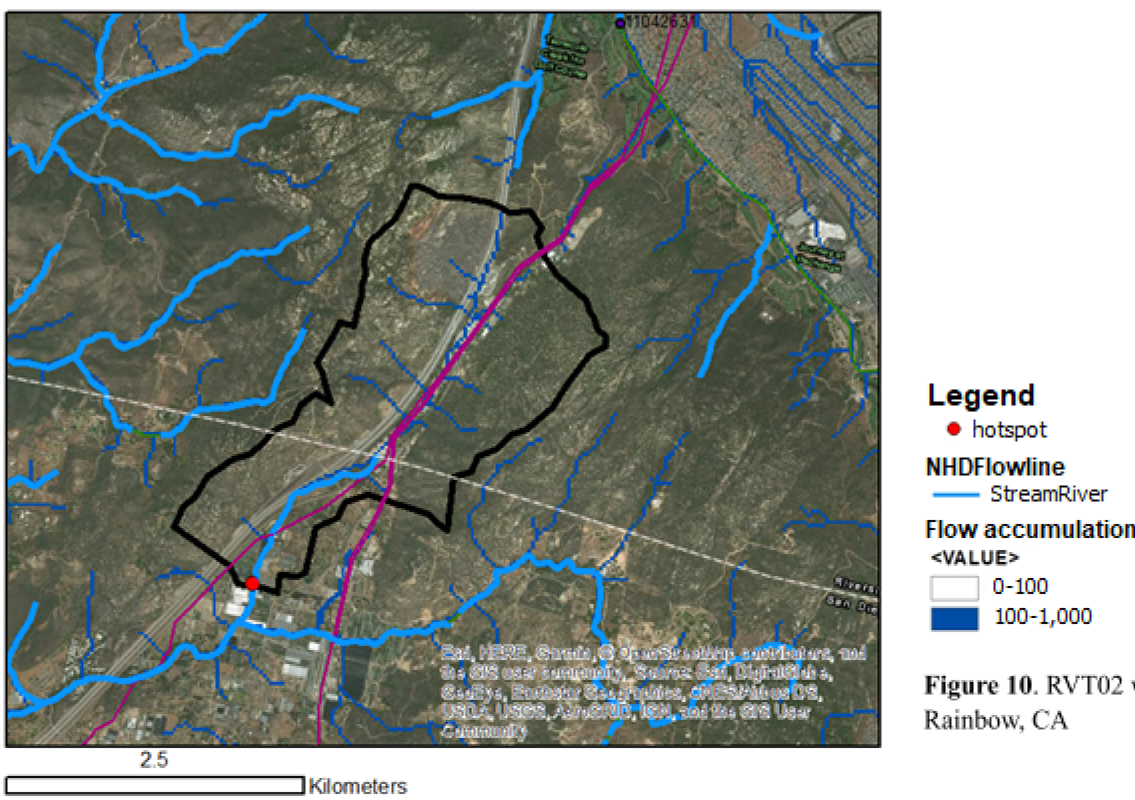


Figure 10. RVT02 watershed boundary in Rainbow, CA

II. National Land Use

RBC02

Scrub/Shrub covered the largest area of land in RBC02 at 68.55% followed by developed open space at 12.35%. Undeveloped land accounts for a little over 75% of the entire watershed. Of the total land use, cultivated crops only accounted for 2.68% which was the 6^{th} largest in land use. In figure 7, it is evident that a majority of the land is its natural state.

RBC04

Scrub/shrub covered the largest amount of land in RBCO4, with 67.33% (Table 7). This was followed by developed open space at 11.26%. Cultivate crops only accounted for 2.91% and was 6th on the line. It can also be seen in figure 8 that most of the land has been kept in its natural state, and developed land has formed around the flow lines.

SMG06

Scrub/Shrub covered the largest area of land in SMG06 at 69.89% followed by developed open space at 12.35% (Table 7). Undeveloped land accounts for a little over 75% of the entire watershed. Of the total land use, cultivated crops only accounted for 3.72% which was the 6^{th} largest in land use. In figure 9, it is evident most of the land has been kept in its natural state with the developing land forming around the flow lines.

RVT02

Scrub /shrub land is the largest amount of land cover in the RVT02 watershed covering 69.02% (Table 7). This is followed by developed open space and developed low intensity. Cultivated crops were 6th^{h} down the line and only occupied 0.1% of the land cover. From this, it is clear that the large amount of land is in its natural state of undeveloped scrubland. Looking at the satellite imagery of the watershed in Figure 10, it is apparent that scrubland makes up the majority. The developed land in the watershed is localized down the center of the watershed. This is because there is a highway that runs through it and the local businesses are aggregated near it. The stream line also runs along the highway through the developed land.

III. SanGIS Land Use

RBC02

In regard to land use types based on SANDAGs parcel data, the most predominant land use in watershed RBC02 is categorized as Rural with land coverage of 395.54 ha (Table 8). This accounts for approximately 35.78% of RBC02 watershed. Followed by residential, unknown, and nurseries as the next dominant land coverage. After careful analysis, majority of unknown parcels were later identified as vacant land use. This suggest that there is approximately 20% of the land cover is vacant, making it the third highest land cover of this watershed delineation (Fig 11).

RBC04

When viewing SANDAG's parcel data RBC04 is predominantly residential, covering 15188.212 hectares, this is 61.314% of the land use in the watershed (Table 9). The second largest land cover is rural, with 23.585%. Agriculture and nursery are 4th and 5th on the list, covering 5.408% and 4.662% respectively. Vacant/slivers, commercial, and poultry follow this (Fig 12).

SMG06

When utilizing SANDAG parcel data, rural land use accounted for the largest percentage at 39.14% followed by residential areas at 27.36% (Table 10). Nurseries account for 5.52% of the total land use however; this must be taken into perspective as there is a larger area of total land in SMG06.The unknown value which accounts for 6.62% are open water reservoirs located on the southern side of the watershed just west of the break (Fig 13)

RVT02

Rural land use was the highest amount of land in the watershed (Table 11). The second most abundant land use was Nurseries. This includes growing houses, undercover agricultural preserves, and gardening/nurseries. The nurseries under this category are located directly above the RVT02 site (Figure 14). There is also a block of agriculture located above the nursery parcels.

RBC02 Figures

RBCO2		
Aggregated Categories	Area (ha)	% Land Cover
Rural	395.54	35.78%
Residential	236.25	21.37%
Unknown	145.75	13.18%
Nursery	128.97	11.67%
Agriculture	98.51	8.91%
Vacant/Silvers	89.15	8.06%
Commercial	6.12	0.55%
Poultry	5.18	0.47%
Total	1105.51	100%

Table 8 Land use summary using the SanGIS parcel data for RBC02

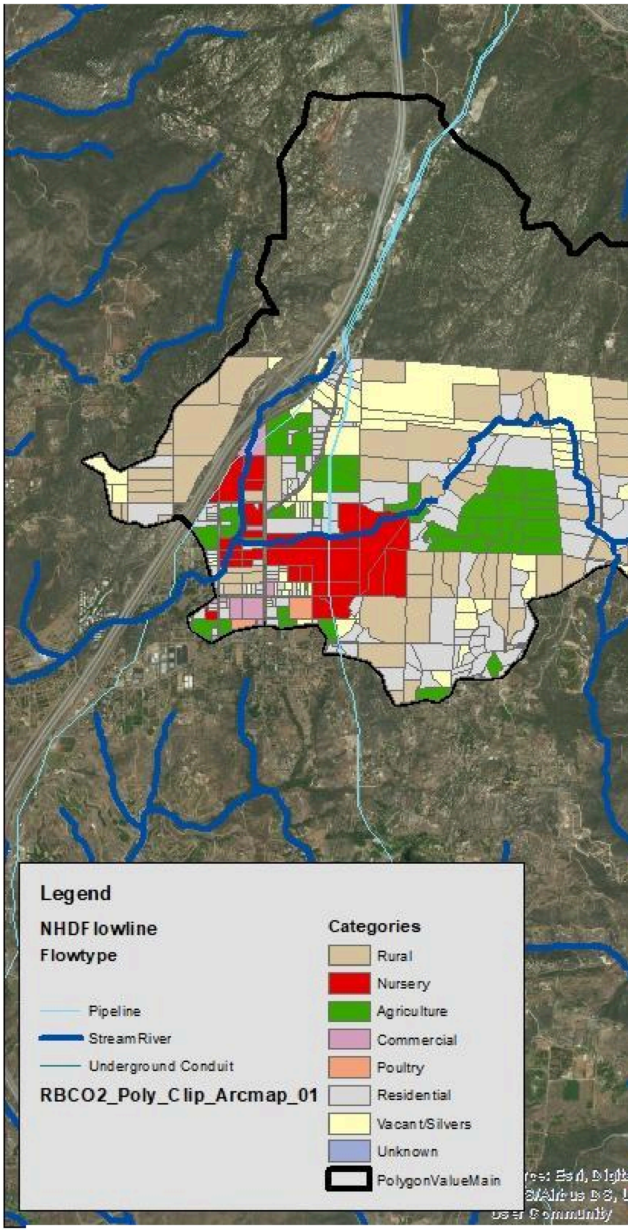


Figure 11 Map of RBC02 watershed with lab
parcel data depicting land use

RBC04 Figures

RBC04		
Aggregated Categories	Area (ha)	% Land Cover
Rural	539.745	46.847%
Residential	264.902	22.991%
Nursery	107.3	9.313%
Agriculture	124.467	10.803%
Vacant/Slivers	94.444	4.103%
Commercial	16.113	1.398%
Poultry	5.187	0.450%
Total	1152.156	100%

Table 9 Land use summary using the SanGIS parcel data for RBC04

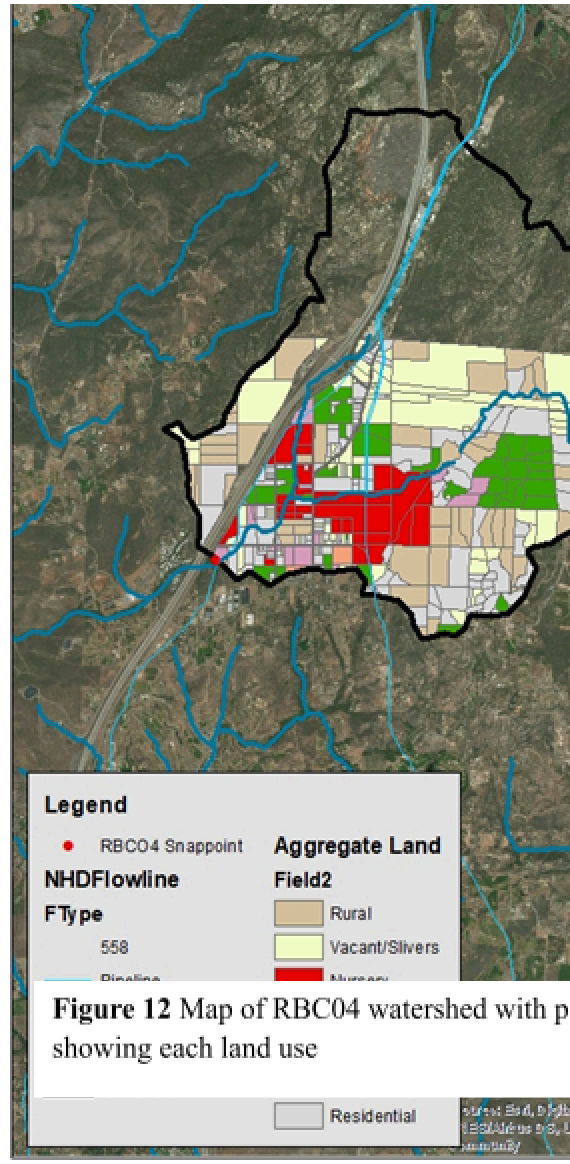
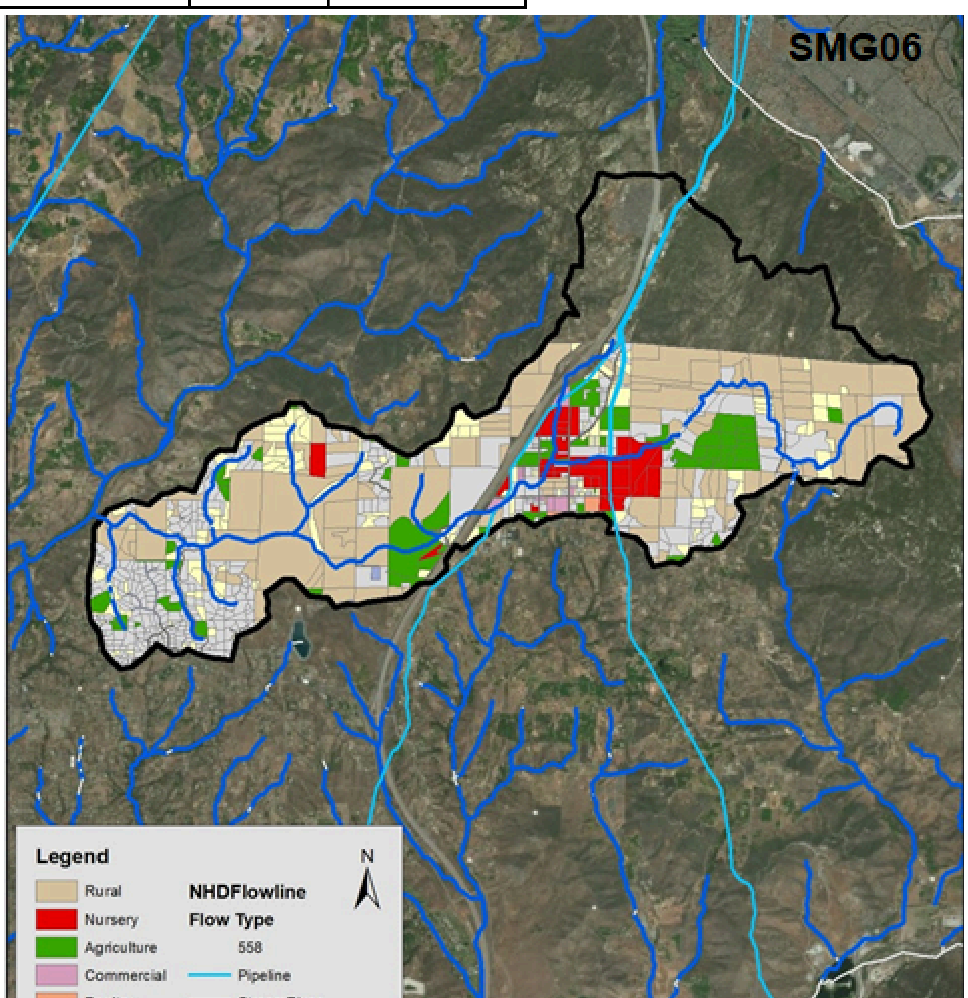


Figure 12 Map of RBC04 watershed with p showing each land use

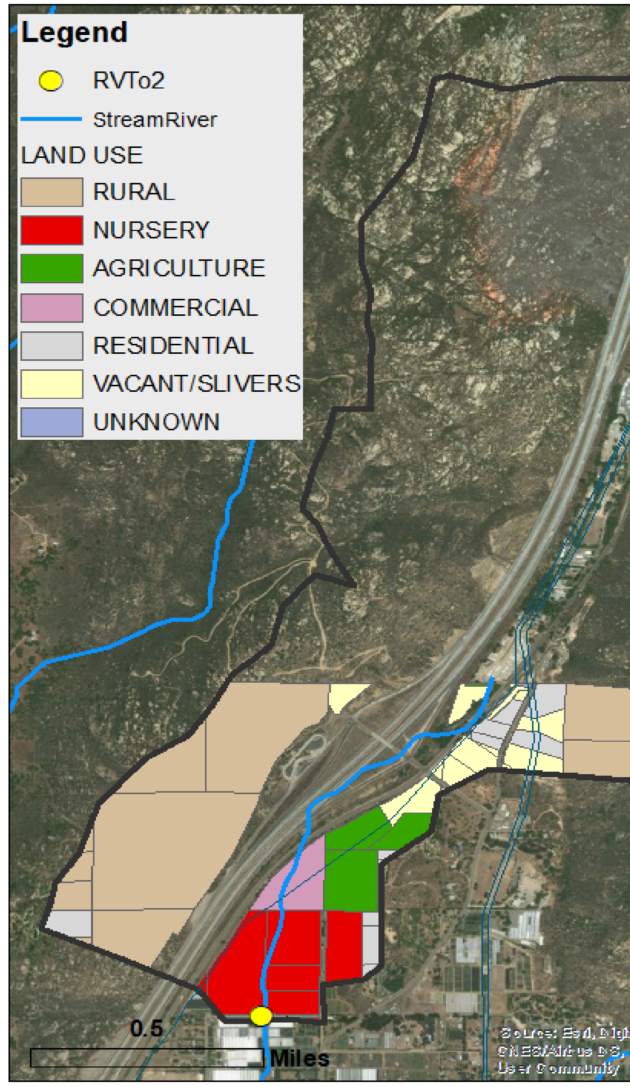
SMG06 Figures

SMG06		
Aggregated Categories	Area (ha)	% Land Cover
Rural	890.63	39.14%
Residential	622.39	27.36%
Unknown	150.44	6.62%
Nursery	125.68	5.52%
Agriculture	227.29	9.99%
Vacant/Slivers	233.603	10.27%
Commercial	19.798	0.87%
Poultry	5.481	0.24%
Total	2275.31	100%



RVT02 Figures

RVT02		
Aggregated Categories	Area (ha)	% Land Cover
Rural	62.54	56.5%
Nursery	17.30	15.62%
Vacant/Slivers	10.06	9.1%
Agriculture	8.51	7.69%
Residential	7.87	7.11%
Commercial	4.36	3.93%
Poultry	0	0%
Unknown	0.06	0.05%
Total	110.70	100%



IV. Sampling

As the hotspot labeled SMG06 is the westernmost point and contains all other watersheds from the delineations, it will be the sole focus of the analysis moving forward. Figure 4 depicts the final sampling locations that were used for gathering water samples. Fig 15 illustrates the land use type in each sample sites watershed. The majority land use is rural for all sites. SMG1 and SMG6 have zero percent nurseries making them ideal controls.

Figure 15. Six sampling locations used to gather water for chemical analysis

Land U	% Land Use	km^2	% Land Use	km^2	% Land Use	km^2	% Land Use	km^2	% Land Use	km^2	% Land Use	km^2
Nursery	0	0	2	0.106	8	0.888	6	1.104	6	1.136	0	0
Ag	0.4	0.018	3	0.153	7	0.835	7	1.167	7	1.258	7	0.249
Rural	97	4.267	91	4.986	60	6.835	69	12.132	69	12.829	63	2.216
Residential	1	0.044	1	0.083	18	2.033	13	2.298	12	2.294	20	0.677
Poultry	0	0	0	0	0	0	0	0.024	0.2	0.051	0	0
Commercial	0	0	1	0.044	0	0	0	0.056	0.8	0.168	0	0
Vacant	1.6	0.079	2	0.081	6	0.692	5	0.869	5	0.938	10	0.35
Unknown	0	0	0	0	1	0.008	0	0.008	0	0.009	0	0
Total Area	100	4.407	100	5.453	100	11.291	100	17.657	100	18.682	100	3.493

V. Pressure Transducers

The pressure transducers were located at sample site SMG1 and SMG3 (Fig 16 & 17). One was hung in a tree while the other was in the water. Using these, we calculated the height of the water level. The section that the water level dips drastically is when the transducers were taken out of the field and is therefore negligible. The calculated water level is very similar to the water level found from a gage at sample site SMG5 from One Rain. This shows that there were no localized storm events and thus, the water level gage from One Rain can be used as the water level for all sample sites.

Figure 16. Graph of water level at SMG01 based on corrected data gathered from pressure transducers . The red arrows point to sampling times.

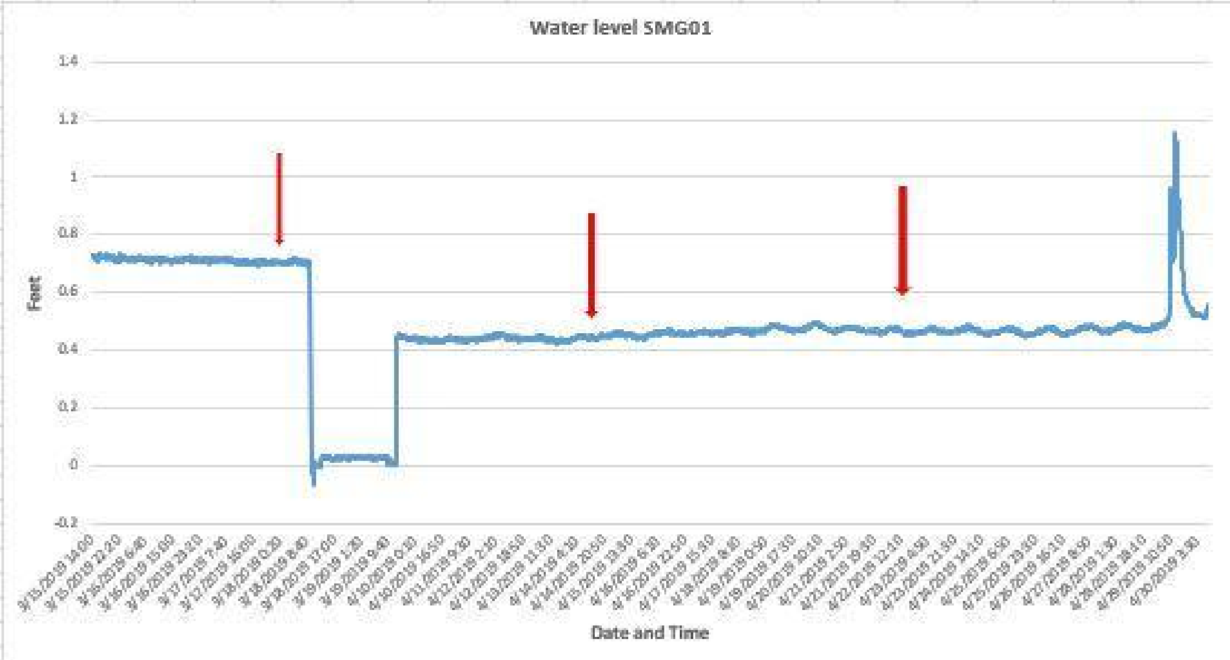
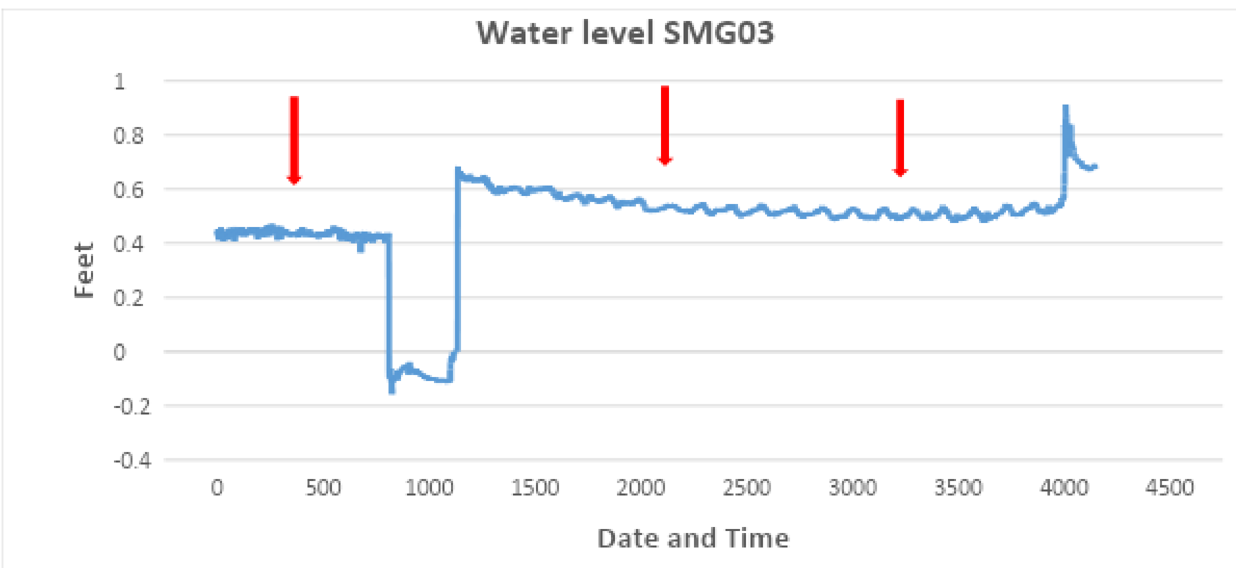


Figure 17. Graph of the water level at SMG02 based on corrected data gathered from pressure transducers with arrows pointing to sampling times.



VI. Discharge

Discharge was measured at sample site SMG1 and SMG3. The total discharge for SMG1, the site furthest upstream, was 1.96 ft/sec. The discharge for SMG3, the site in the middle of the cluster of nurseries was 2.2295 ft/sec (Table 12). The discharge was then calculated for the rest of the sampling sites assuming that their discharge is similar to that of SMG3. This was done by using the discharge over area ratio (Q/A) of SMG3. The area was of the unknown sampling sites was multiplied by the Q/A to find the discharge (Table 13).

Location	Date	Time to move 10ft (s)	Time Avg	Q - Tot Discharge (ft^3/sec)
SMG-01	04/16/19	7.56	9.42	1.96
		10.42		
		10.28		
SMG-03		7.64	8.31	2.23
		9.53		
		7.76		

Table 12: Stream discharge rates at SMG-01 and SMG-03

Site	Q(ft^3/sec)
SMG1	1.96
SMG2	2.24
SMG3	2.23
SMG4	3.49
SMG5	3.69
SMG6	0.69

Table 13 Calculated discharges for all sampling sites on April 16, 2019. Measurements were made for SMG1 and SMG3, and for the other sites were calculated based on the area-normalized discharge at SMG1 and SMG3.

VII. Chemical Analysis

TN Testing

The results for the total nitrogen in the water samples are shown in figure 18. The sites above the nurseries are SMG1 and SMG6 (Figure 4). They have the lowest amount of nitrogen. The value at SMG4, located directly beneath the cluster of nurseries, is consistently higher than at the downstream sampling point SMG5. Sampling points SMG2, SMG3, SMG4, and SMG5 are located near nurseries, and are all higher than the controls, SMG1, and SMG6 (Fig 18).

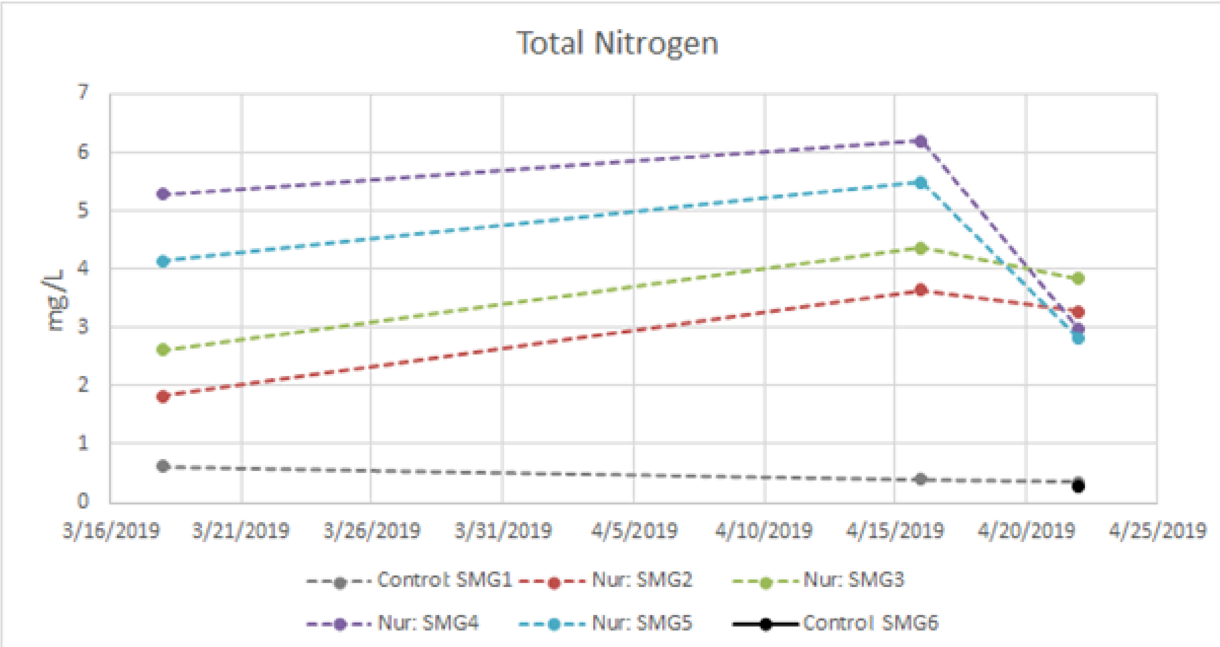


Figure 18. Shows total nitrogen levels from upstream to downstream over the span of around one month.

Just like nitrogen concentrations, the level of phosphorus at the upstream value at SMG4, located beneath the cluster of nurseries, is consistently higher than at the downstream sampling point SMG5, except on the last day of sampling, most likely due to stochasticity in hydrologic conditions (Fig 19). The sampling points at SMG2, SMG3, SMG4, and SMG5, all located near nurseries or agricultural land, all have higher concentrations than our controls SMG1, and SMG6, with the exception of SMG3 having a lower amount the first time sampling, most likely due to variations in hydrologic conditions (Fig 4).

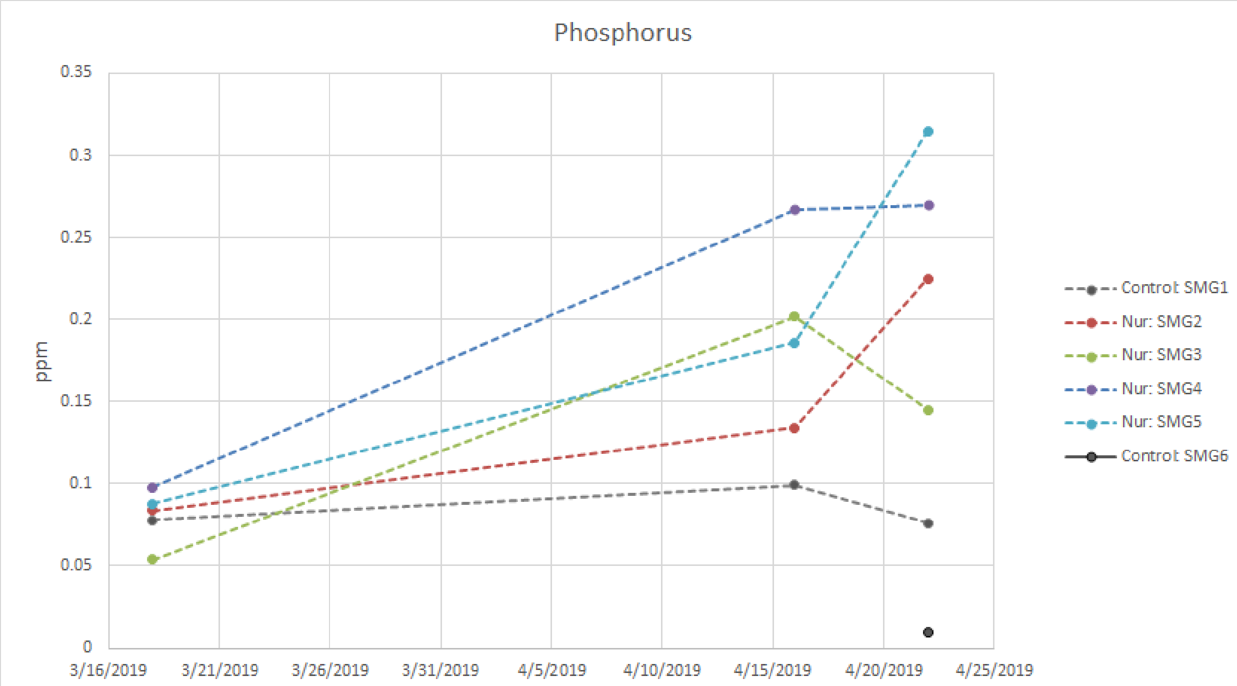


Figure 19. Total inorganic phosphorous at six sampling sites

VIII. Loading

The discharge rates were applied throughout the watershed and are estimated to be representative of the streamflow rates through the survey area. The results were also utilized to derive the load rates (kg/km^2) compared to the percent nurseries as a means to determine TN concentration variability across each sample point using SMG-01 and SMG-06 as the controls.

Site	A(km^2)	Avg TN (mg/L)	Q(ft^3/sec)	Load (kg/day)	kg/km^2per day	% Nursery
SMG1	4.407	0.454	1.962	2.180	0.495	0
SMG2	5.453	2.921	2.24	16.063	2.946	1.944
SMG3	11.291	3.61	2.230	19.715	1.746	7.865
SMG4	17.657	4.821	3.486	41.124	2.329	6.25
SMG5	18.682	4.147	3.689	37.434	2.004	6.08
SMG6	3.493	0.273	0.690	0.460	0.132	0
SMG5-SMG4	1.025	-0.673	+0.202	-3.689	-3.60	0.17

Table 14. Calculated loads for each sample site

Discussion

I.Watershed Analysis
Nurseries and greenhouses are likely the leading cause of NPS pollution in the Rainbow Creek region of the Santa Margarita River watershed (figure 1). The growth of urbanization has attributed to the growth of pollution through an increase in impermeable surfaces and an increase in businesses emitting pollutants. RBC02, RBC04, SMG06, and RVT02 are the four locations in the Rainbow creek area with the highest TN. After detailed land use analysis, all of the watersheds have a consistent theme of high levels of undeveloped land use. Most of the land has been kept in its natural state. In addition to this, the watersheds also exhibit a cluster of nurseries/greenhouses upstream from the hotspot locations. There is a clear spatial clustering of nursery parcels localized on the east side of highway 395. This cluster is within all four watersheds at their points of intersection while the cluster of nurseries is the predominant point of interest for the identified hotspots (Figure 20). As such, the nurseries are likely to be a large contributing factor to the high TN found in each pour point.

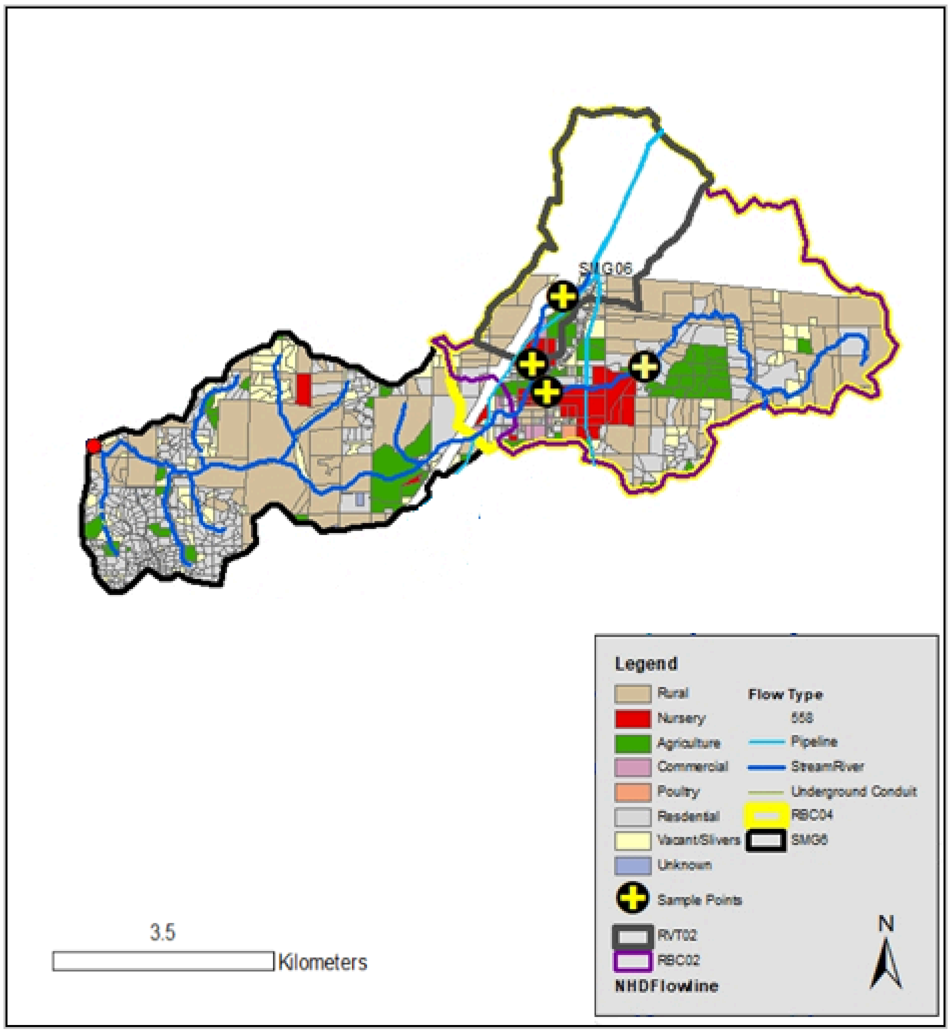


Figure 20 Map of all four watersheds overlaid on SanGIS parcel data

II. Temporal/Hydrological Analysis

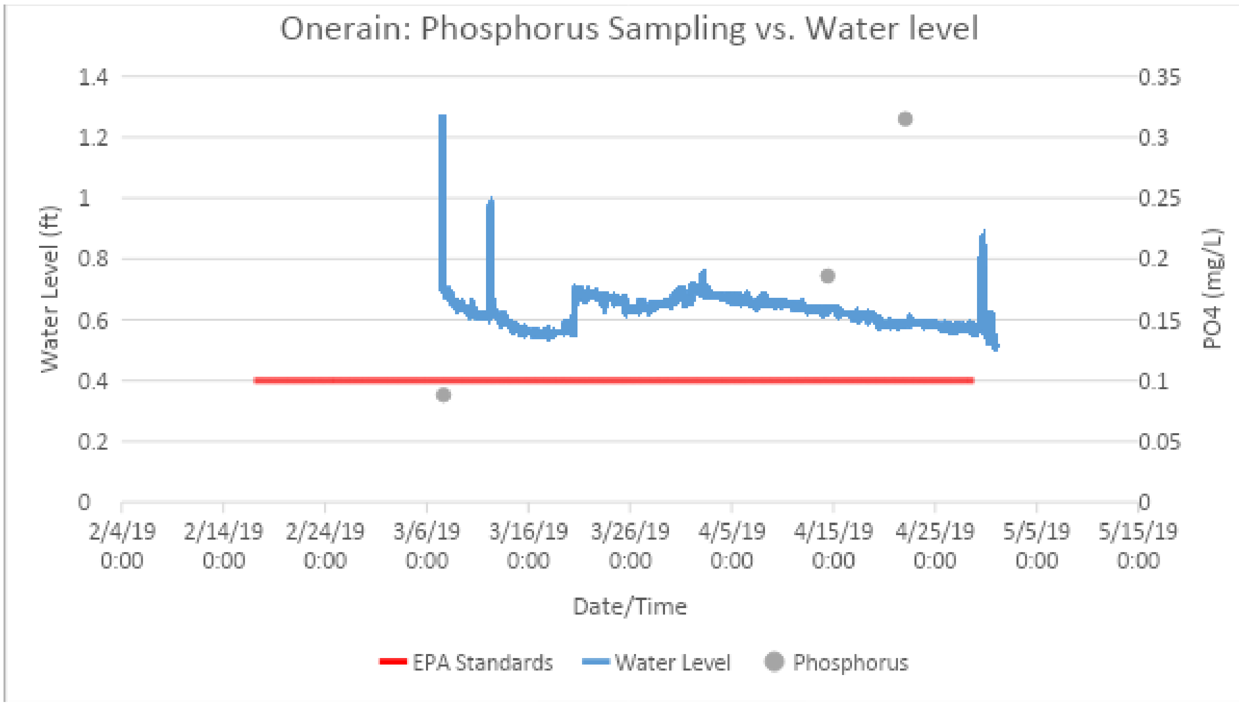


Figure 21 Concentrations of phosphorus displayed over hydrograph at site SMG05

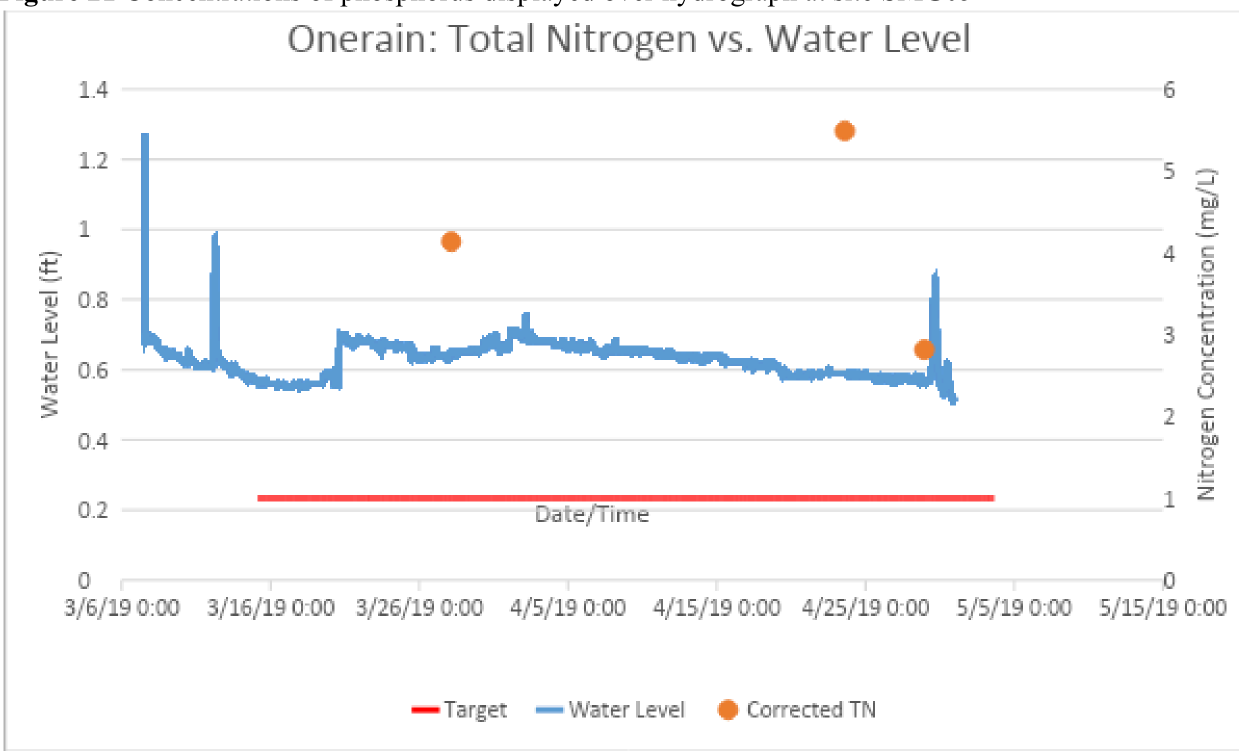


Figure 22 Concentrations of total dissolved nitrogen displayed over hydrograph at site SMG05

The figures above utilize data gathered from the One Rain San Diego website which is then combined with the EPA standard and the respective phosphorus or nitrogen levels for the sampling dates at SMG5 (Fig 21 &22). The hydrographs created show a solid line at the EPA target standard for nitrogen (1mg/L) and phosphorus (0.1mg/L). The plotted points of nitrogen levels on the hydrograph for SMG5 show that total nitrogen content is well above the target goal (Fig 22). The plotted points of phosphorus have one point within the target goal and the other two above it (Fig 21). The phosphorus point that is within the EPA target of 0.1 mg/L could be attributed to dilution from the winter storm event that occurred before sampling. All samples increased in phosphorus content from the first sampling date (3/18/19) after the storm to the second sampling date (4/16/19).

By observing the changes in nutrient load over the time series, it becomes apparent that SMG1 and SMG6 both contain very little changes to their nutrient loads (Fig 18 &19). Although the EPA standard for Total Nitrogen is at 1mg/L and Total Phosphorus is at 0.1 ppm, all downstream sites, SMG2 to SMG5, consistently exceed the values for nitrogen while the phosphorus levels are nearing the EPA limit during the first batch of sampling (Fig 19). The values only increase during the second round of sampling leading to a spike in concentrations that are significantly higher than the EPA standard.

The increase and sudden drop in total nitrogen at SMG5 (Fig 22) towards the end of the sampling periods could best be attributed to the recession limb hydrologically seen as a slight dip around April 15th to the 20th from a hydrological perspective. However, the data does not appear to be consistent when observing the nitrogen levels across all six sites as the control sites remain at a consistent level that all display an increase in concentration followed by a relatively steep drop a week later (Fig 18). One potential factor for the concentration inconsistency is that the nurseries in the area were outputting a higher volume of total nitrogen positively skewing the data.

The loads calculated in Table 14 include the sub-watershed between SMG5 and SMG04. This watershed is the difference between the drainage areas of sample site 5 and sample site 4. Sample site 4 is located directly downstream of the cluster of nurseries (Fig 4). Sample site 5 is located downstream of the nurseries but is separated from the nurseries by a greater distance. The TP and NP concentrations at the site directly beneath the nurseries (SMG4) are consistently higher than that of the site further downstream of them (SMG5). Table 14 illustrates that the nutrient loading and percent nursery decrease from SMG4 to SMG5. The concentrations decrease when there are no additional nurseries in the watershed. This shows that nurseries are directly correlated to the amount of Nitrogen and Phosphorous in the water. The exact reason for the decrease, rather than maintaining the same amount, is not known for certain. We speculate that it could be from dilution do to other tributaries contributing less polluted water or from retention.

III. Spatial Analysis

Rainbow creek is a small tributary to the Santa Margarita River located in Northern San Diego County. After conducting a spatial analysis of this watershed, using geographical information systems, we were able to tabulate the percent land-uses. Based on our findings (Table 7), the watershed is primarily rural with greater than 60%, while the remaining land-uses consist of commercial nurseries, agricultural field uses, and rural residential. The dominating land-uses in this region is the commercial nurseries and agricultural fields. It is believed that these particular land-uses are the reason for the nutrient loading we are seeing in these waters. The percent of the watershed in nurseries correlates with area-normalized nutrient loads (Figure 23).

After extensive sampling and data collection there is significant evidence that suggest that the land-use in this region has an impact on the nutrient loads. Based on the nutrient data for total nitrogen and phosphorus, the graph strongly suggest that nutrient loads get significantly higher when going downstream through the nurseries and greenhouses. It is also notable that nutrient levels appear to decrease after passing through the cluster of nurseries/greenhouses. This decrease in nutrient levels can be caused by many biological factors such as the natural processes of the nitrogen cycle or via dilution. Results suggest that there is potentially excessive agricultural runoff coming from these parcels of nurseries. We believe that majority of the nutrient loading is coming from these particular land-uses because of their use of fertilizers and commercial irrigation systems, potentially causing surface-runoff into Rainbow Creek. After observing the land-use parcel data in ArcMap, it is evident that majority of the stream runs through nursery properties.

According to a report done by The Regional Water Quality Control Board, majority of the nursery properties are owned and operated by Hines Nurseries. Hines Nurseries has channelized the creek and is currently using the creek as a part of an irrigation water recovery system. This system works by collecting runoff water which is stored in the creek and in an adjacent storage pond. Within this system is an earthen dam located in the creek near the point discharge from the site. This dam helps prevent water from leaving the boundaries of the property. However, there are potential problems with this recovery system that may influence the nutrient loading in the creek. For example, over exceeding the system capacity may result in unintended discharge of irrigation waters downstream of the nursery. This can be caused by excessive storm water runoff or by over-abundance of water from the irrigation systems.

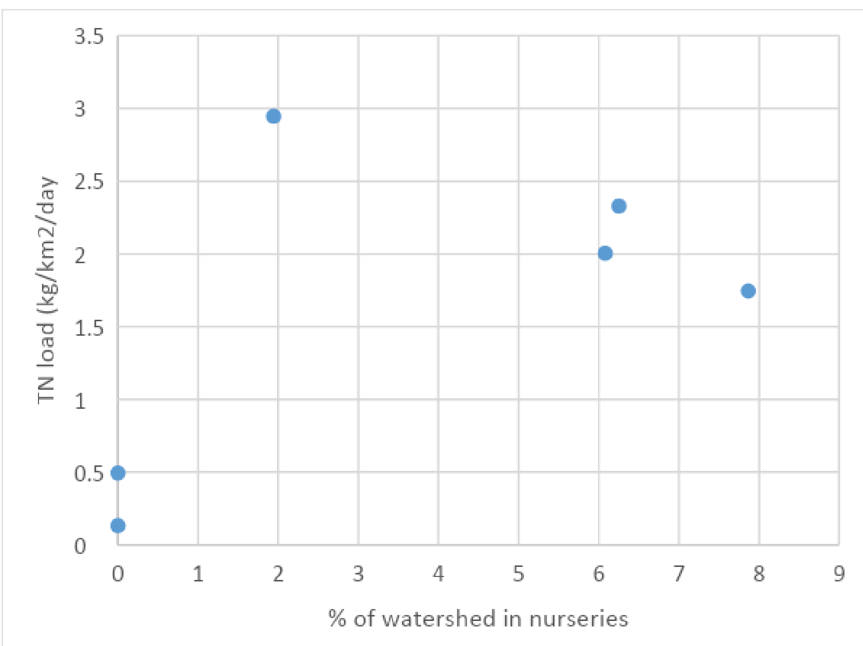


Figure 23. TN load (kg/km2/day) versus the percent of the watershed area cover by nurseries and greenhouses.

Conclusion

Land-use, particularly nurseries and greenhouses, are contributing nutrients to the watershed. Our data shows TN and TP to be higher than the water quality objectives from 2006 for total nitrogen (1.0mg/L) and phosphorus (0.1mg/L). TN concentrations downstream of the nurseries/greenhouses were 10 times the concentrations upstream (Table14). We were unable to accurately assess which parcels were not registered as a part of the program and suggest the tracking and monitoring of these nurseries for excessive nutrients in their runoff, in addition to continued monitoring of registered nurseries. Random testing of registered nurseries might be beneficial to corroborate expected values TN and TP. Continued field analysis of sampling sites is strongly recommended.

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