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Nutrient and Sediment Transport From a New Vineyard Within Oak Woodland[1]

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Abstract

Water quality was investigated in the vicinity of Cuesta Ridge Vineyard, San Luis Obispo County, where drainages carry water from chaparral, oak woodland, and a new vineyard. Three drainages were instrumented with gauges above and below the vineyard for stage height and turbidity to assess the effectiveness of water quality protection measures at the Cuesta Ridge Vineyard. Water samples were taken during storm events and analyzed for pH, EC, nitrogen, phosphorus, and sediment concentrations. Erratic flow conditions may have made it difficult to identify differences above and below the vineyard. Water quality was good at all sites and data collected serves as baseline information for future study. Landform, geology, soil type, proximity to wetlands, and land use practices in the surrounding areas should be investigated to consider possible relationships with turbidity and nutrient concentrations.

Keywords: Buffers, rainfall, rangelands, turbidity, water quality.

Introduction

California vineyard acreage rapidly expanded during the last 20 years. Some of theses vineyards have been established in existing farm land, while other installations have converted rangelands and oak woodlands. There is minimal information available for land managers to help them use best management practices to protect water quality when these conversions are made (Dahlgren and others 2001). Available data are primarily qualitative. Data collection of runoff and erosion is not a straightforward or easy task; inputs from nearby waterways, variable adjacent land uses, and changes in land-use practices are confounding factors. Hence, qualitative data is abundant, relative to quantitative data.

Hajrasuliha and others (1998) followed the fate of nitrogen isotopes applied in the springtime as ammonium and nitrates to drip-irrigated table grapes in the San Joaquin Valley of California. They concluded that between 20 and 25 percent of the fertilizer was taken up by the vines during the growing season, while the vast majority remained within the rootzone at harvest, with nitrates moving deeper than ammonium. No assessment was made of nutrient movement with winter rainfall.

Bramley and Lanyon (2002) concluded that vineyards in Australia were inherently ‘leaky’ of nutrients below the rootzone, due to the tendency to over-fertilize because nutrients and irrigation are applied uniformly over vineyard blocks

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which themselves tend to be highly non-uniform in their soil conditions and vine growth.

Battany and Grismer (2000) investigated the effects of slope, cover and surface roughness on rainfall runoff and erosion using a rainfall simulator; they observed significant correlations between the slope, cover and surface roughness, and the total infiltration, runoff, sediment discharge, and average sediment concentration.

Slattery (2003), in his survey of Australian vineyard areas, concluded that many key Australian winegrape-growing areas have a moderate to high likelihood of nitrogen and phosphorous nutrient leakage out of the vineyard system, with the severity of leakage depending upon specific management practices in a given vineyard. The author recognized that the information required for determining the extent of nutrient loss was largely unknown, and suggested immediate research efforts to quantify these losses as they relate to best management practices such as cover cropping.

Stimson and O'Conner (2005) overviewed best management practices employed to reduce sediment loss in vineyards. They estimated by modeling with the RUSLE2 equation that management practices such as cover cropping should lead to significant reductions in sediment losses.

Ramos and Martinez-Casasnovas (2006) quantified the loss of nitrogen and phosphorous from a vineyard site in Spain. Even without considering the infrequent extreme runoff-generating rainfall events, the loss of nitrogen and phosphorous due to the smaller intensity runoff events was significant, being responsible for over 60 percent of the annual nutrient losses.

In a watershed-scale experiment that looked at pesticide movement rather than nutrients, Louchart and others (2001) looked at the movement of the pesticides diuron and simazine from vineyards to waterways; they noted fast movement of the compounds through bordering ditches, and concluded that the majority of the compounds likely re-infiltrated the soil through the same ditches.

Methods

We monitored the effects of a new vineyard on three streams. An above- and below-sampling design was used to monitor vineyard runoff. We were not able to obtain samples prior to the vineyard installation. Samples were collected near peak flow conditions during every storm event from 2000 to 2004. StatView SAS Institute Inc. (Version 5) was used for statistical analysis. The vineyard and sampling layout is shown in figure 1. This project was funded by the Regional Water Quality Control Board, Central Coast Vineyard Team, and Robert Mondavi Winery.

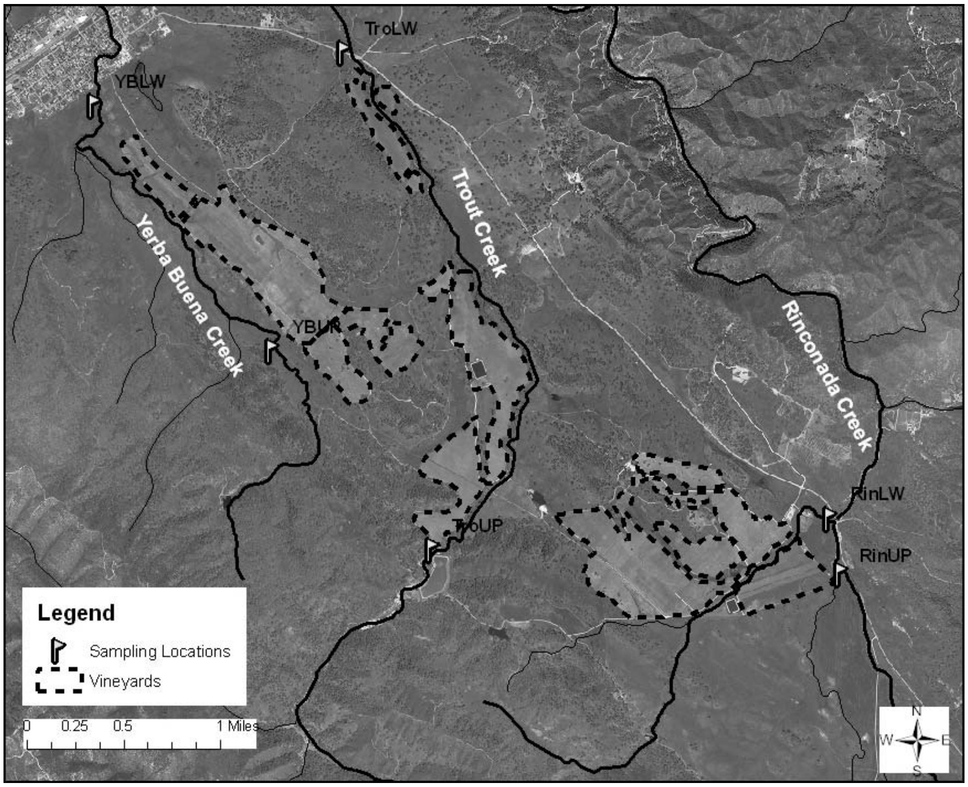


Figure 1—Water quality sampling locations on Yerba Buena, Trout and Rinconada creeks. Sampling sites were upper Yerba Buena (YBUP), lower Yerba Buena (YBLW), upper Trout (TroUP), lower trout (TroLW), upper Rinconada (RinUP) and lower Rinconada (RinLW).

The Cuesta Ridge Vineyard is a 900-acre vineyard, situated within a 14,000-acre ranch. The ranch is situated in a watershed characterized by headwaters with steep slopes and chaparral vegetation draining down through gentler slopes with oak woodland annual grassland vegetation type. It is located within the Paso Robles Hydrologic Area (HA 309.8) in San Luis Obispo County. Three major creeks, Rinconada, Trout and Yerba Buena (*fig. 1*), drain the vineyard to the Salinas River. This hydrologic unit is part of a salmon or steelhead trout Evolutionarily Significant Unit (ESU) (NOAA 2000).

Rinconada Creek runs along the north east side of the vineyard and has an un-named creek, which drains the vineyard. Trout Creek carries water from the chaparral in the Los Padres National Forest and several private summer residences, south of the ranch. All of Yerba Buena Creek upstream from the sample stations is within the ranch, draining the north side of Cuesta Ridge, east of Highway 101, before it flows through the town of Santa Margarita. Grazing is the dominant land use in the watershed.

Rinconada Creek watershed area is approximately 10,000 acres above the lower sampling site. There are approximately 8,000 acres of rangeland, with more than 1,000 acres farmed, above the upper sampling site. Trout Creek is approximately 6,400 acres above the lower sampling site, and 3500 acres above the upper sampling site. Yerba Buena Creek is approximately 2,800 acres above the lower sampling site, with 700 acres above the upper sampling site. Each of these watersheds contain approximately one third of the vineyard.

The operators and managers of the vineyard had a land management plan to protect water quality. The best management practices consisted of leaving adequate cover between vineyard rows and in buffer strips and biofilter areas. Cover crops were planted between rows using a variety of mixes to reduce erosion and compliment vine growth requirements. Cultivation was reduced to minimize the number of tractor passes per season. Roads were managed with soil cement, gravel, waterbars, mulch and the use of cover crops in low-use areas.

Rainfall was measured by two recording rain gages on the Cuesta Ridge Vineyard. Six permanent sampling sites, on three different streams, were established for collecting stream gage data and surface water samples. The sites were above and below the vineyard on Rinconada Creek, Trout Creek, and Yerba Buena Creek. The locations were labeled RinUP (Rinconada Creek above the vineyard), RinLW (Rinconada Creek below the vineyard), TroUP (Trout Creek above the vineyard), TroLW (Trout Creek below the vineyard), YBUP (Yerba Buena Creek above the vineyard) and YBLW (Yerba Buena Creek below the vineyard).

Turbidity: Turbidity was measured using an OBS3 sensor (D&A Instrument Co. 1991; Jordan 1996; Teti 1996). The infrared signal was emitted every 15 minutes. Data were stored on a Hobo datalogger and the voltage converted to NTUs (range set at 0-250 during 2001 to 2002 and 0-725 NTU from fall 2002 to 2004).

Suspended Sediment: One bottle was collected for each location during each sampling session. Suspended sediment samples were taken using a DH48 integrating sediment sampler and submerged in the fastest flow water with the nozzle pointed upstream. The bottle was slowly raised and lowered to collect water from the entire water column, taking care not to disturb bottom sediments. Samples were suction-filtered and dried at 45^{o}C for two days.

Nutrient: Grab samples were collected in opaque plastic bottles. Samples were frozen and shipped FedEx within two weeks after sampling. Nutrients, EC, pH were analyzed at the DANR laboratory at UC Davis.

Stage Height: Stream height was measured with an AG5 Aquatape (Consillium). Data were collected every 15 minutes and stored on a Hobo datalogger. Voltage readings were converted to centimeters. Lower Rinconada was equipped with a 12-foot aquatape. The other sites were initially instrumented with 8-foot tapes. In the fall of 2001, upper Rinconada and lower Trout were equipped with 12-foot aquatapes, due to storm events in February 2001 that swamped the original installations at those two sites. The aquatapes were installed in steel pipes (old oil field pipes) acting as still wells anchored to the bank. Each still well was installed so the aqua tape was below the stream bed surface.

In addition to automated sampling, field measurements were taken each time the site was visited for grab samples. The still wells were outfitted with stream gages measuring in centimeters.

Velocity: Stream velocity was measured with a FP101 hand-held flow meter (Global Water). The units were measured in feet/second. Several measurements were taken at each site, at 1/3 and 2/3 depths, the results were averaged.

Results

Rainfall

Rainfall was highest (24.2 inches) in 2000 to 2001 (01-02), a slightly below average rainfall year (*fig. 2A*). The average recorded rainfall is approximately 30 inches. Stream flow began in January 2001, and the largest storm events were in March of the same year. Rainfall during subsequent years was well below average: 9.8 in 01-02; 18.8 in 02-03; 11.3 inches during 03-04 (Figure 2B-D). Low amounts and timing of rainfall equated to very low stream flow, rarely exceeding baseflow conditions

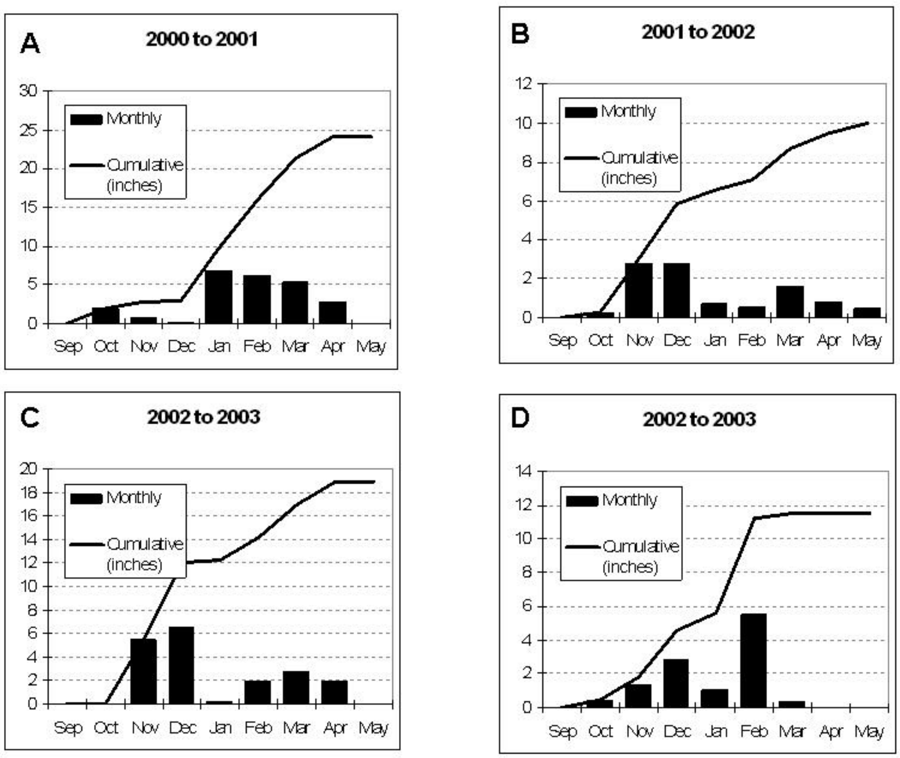


Figure 2—Cumulative (line) and monthly (bar) rainfall is shown for 2002 to 2001 (A), 2001 to 2002 (B), 2002-2003 (C), and 2003 to 2004 (D).

Turbidity and Suspended Sediment

Maximum turbidity was over 700 NTU in Rinconada Creek, above and below the vineyard. Moderate turbidity was over 200 NTU in Trout Creek, above and below the vineyard. Yerba Buena Creek maximum turbidity was never over 100 NTU. Upper Yerba Buena, above the vineyard was twice the value of the Lower Yerba Buena site.

Suspended sediment grab sample values confirm the trend monitored by the automated turbidity sensor. The highest sediment measured was in Rinconada Creek, over 7,000 mg/L. The highest sediment in Trout Creek was between 2,700 and 3,700 mg/L. Yerba Buena high sediment values were between 780 and 1,100 mg/L. See the high, low and average values for each sampling site in table 1. There were no significant differences (p=.21) between sediment concentrations above and below the vineyard, see figure 3. This indicates that the vineyard did not increase sediment loading above that which was already in the streams coming into the vineyard.

Table 1—*Turbidity was measured every 15 minutes at six locations. Suspended sediment grab samples were taken during and after storms. High values are shown in bold*.

Constituent	Units	RinLW	RinUP	TroLW	TroUP	YBLW	YBUP
Turbidity High	**NTU**	**718**	**720**	**281**	**255**	**38**	**64**
Turbidity Low	NTU	2	1	1	1	1	1
Turbidity Average	NTU	360	360.5	141	128	19.5	32.5
Sediment High	**mg/L**	**7333**	**6952**	**2736**	**3740**	**782**	**1099**
Sediment Low	mg/L	0	0	0	0	0	0
Sediment Average	mg/L	3667	3476	1368	1870	391	549

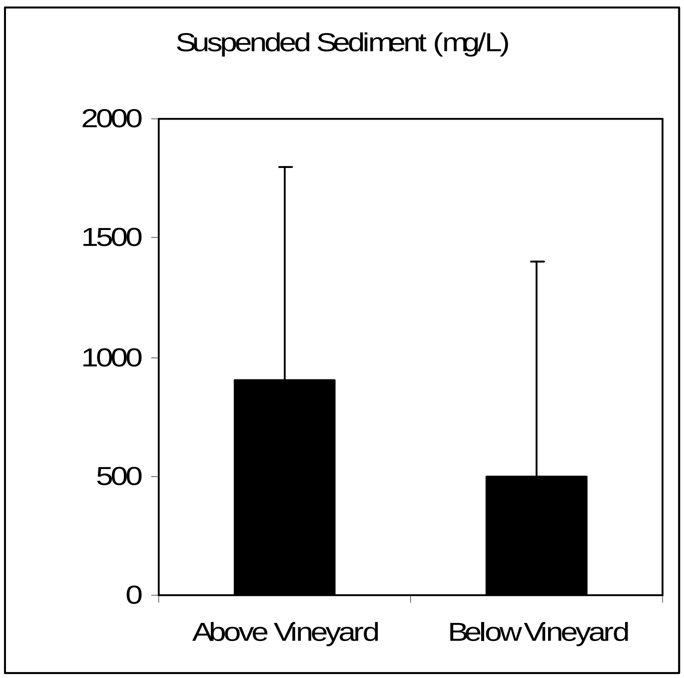


Figure 3—Suspended sediment (mg/L) was sampled above and below vineyards. There was no significant difference between above and below vineyard sediment concentrations. (n=67 above vineyards; n=91 below vineyards).

pH

The pH varied from 6.4 in Lower Yerba Buena Creek to 8.7 in lower Rinconada Creek. See high, low and averages for the pH values in table 2.

Table 2—*pH was measured at the DANR lab prior to nutrient analysis.*

Constituent	Units	RinLW	RinUP	TroLW	TroUP	YBLW	YBUP
High	Units	8.7	8.5	8.7	8.2	8.1	8
Low	Units	6.8	7	6.8	6.8	6.4	6.5
Average	Units	7.8	7.8	7.8	7.5	7.3	7.3

Electrical Conductivity

The highest EC recorded at four sites was 0.7 mmhos/cm, and the low at all sites was 0.1 mmhos/cm. See the high, low and average EC values in table 3.

Table 3——*EC was measured at the DANR lab prior to nutrient analysis.*

Constituent	Units	RinLW	RinUP	TroLW	TroUP	YBLW	YBUP
High	mmhos/cm	0.7	0.7	0.7	0.6	0.7	0.3
Low	mmhos/cm	0.1	0.1	0.1	0.1	0.1	0.1
Average	mmhos/cm	0.4	0.4	0.4	0.4	0.3	0.2

Nutrients

Total Kjeldahl nitrogen was highest in upper Rinconada and Trout Creeks, 27 and 25 ppm, respectively. The highest values at the other sites varied from 11 to 22 ppm. High values at all sites were over 10 ppm. Low values were between 0.1 and 0.3 ppm TKN.

Ammonia concentrations were highest in Rinconada Creek 0.6 ppm and never higher than 0.2 ppm at all other sites. There were periods in which no ammonia was detectable at all sites.

Nitrate concentrations were highest in Lower Yerba Buena 2.1 ppm. High values in Rinconada were 1.5 and 1.3 ppm. Trout Creek and upper Yerba Buena never exceeded 0.6 ppm. A small amount of nitrate 0.1 ppm was always detected in the lower drainages, and there were periods when no nitrate was detectable in the upper drainages.

Total phosphorus was highest in Rinconada Creek, 12.8 ppm in lower Rinconada and 10.4 ppm in upper Rinconada. High concentrations of phosphorus at all other sites were between 1.2 and 5.3 ppm. Low concentrations varied from 0.1 to 0.3 ppm. See high, low and average values for TKN, NH3, NO3, Psol, Ptot in table 4.

There were no statistical differences ($p=0.25$) for TKN above and below the vineyard. This indicates that the vineyard did not increase the TKN loading from other sources already in the streams, figure 4.

Table 4—*Nitrogen (TKN, NH_3, NO_3) and Phosphorus (P_{sol} P_{tot}) were analyzed by DANR lab.*

Constituent (units are ppm)	Units	RinLW	RinUP	TroLW	TroUP	YBLW	YBUP
Nitrogen – Total Kheldahl (TKN)	**High**	**18.1**	**26.8**	**10.8**	**24.8**	**21.3**	**15.8**
	Low	0	0	0	0.1	0.3	0.3
	Average	2.9	2.4	1.3	4.4	4.1	4.3
Ammonia (NH_3) – N	**High**	0.6	0.6	0.2	0.1	0.1	0.1
	Low	0.0	0.0	0.0	0.0	0.0	0.0
	Average	0.6	0.6	0.2	0.1	0.1	0.1
Nitrate (NO_3) – N	**High**	1.5	1.3	0.6	0.5	2.1	0.5
	Low	0.0	0.0	0.0	0.0	0.0	0.0
	Average	0.3	0.2	0.2	0.2	0.5	0.2
Phosphorus, soluble (P_{sol})	**High**	0.3	0.3	0.6	0.5	0.5	0.2
	Low	0	0	0.16	0	0	0
	Average	0.1	0.1	0.3	0.3	0.2	0.1
Phosphorus, total (P_{tot})	**High**	12.8	10.4	2.4	5.3	2.2	1.2
	Low	0.0	0.0	0.0	0.0	0.0	0.0
	Average	0.9	0.6	0.6	1.1	0.7	0.3
n =		38	39	40	18	16	11

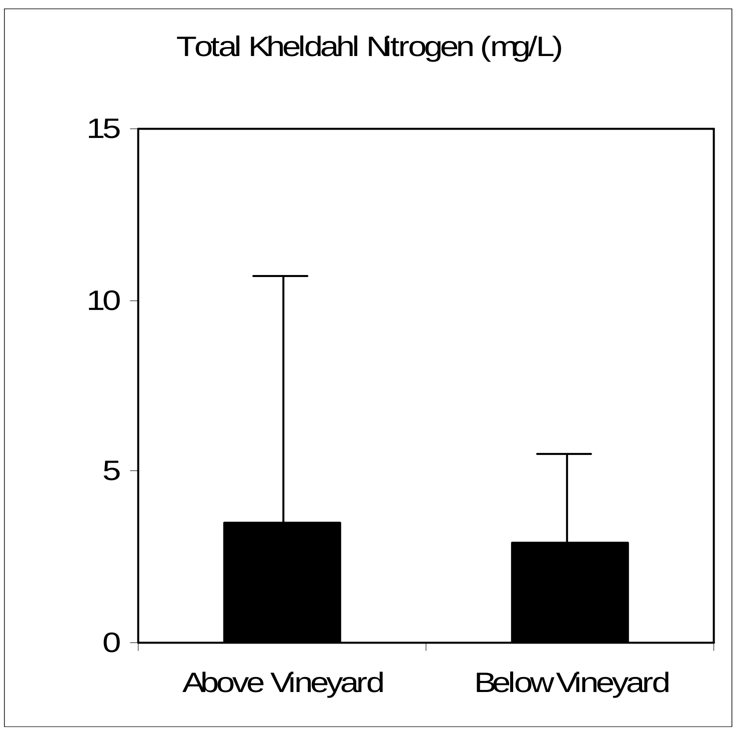


Figure 4—Total Kheldahl nitrogen was measured above and below vineyards. Although highly variable, there was no significant difference between sites.

Stage Height

Upper Rinconada Creek was over 8 feet deep and the lower site over 9 feet deep in March 2001. Upper Trout Creek overtopped the banks, greater than 6 feet deep during that large storm. Lower Trout Creek swamped the 8-foot stillwell, and it needed to be moved downstream to a safer location. Upper Yerba Buena Creek overtopped the banks at 3.5 feet, which occurred in March 2001. Lower Yerba Buena Creek exceeded 5.5 feet deep, as it flooded the channel banks during this same storm. This large storm created many problems with the aquatapes and stage height measurements, which required corrections. By fall of 2002, those corrections had been made. Lower trout creek site was moved downstream to a wider part of the channel, and upper Trout Creek station was moved from the north to the south side of the creek because over 4 feet of debris and gravel had accumulated on the north bank. The upper Trout Creek cross-sectional area was reduced by 45 square feet during the March 2001 storm event.

Discussion

Suspended sediment movement is directly related to storm events in these streams. For demonstration stage height and sediment concentrations are shown for a large storm event December 16-22, 2002. Figure 5 graphically illustrates turbidity, stage height, and daily rainfall in Rinconada Creek during this storm.

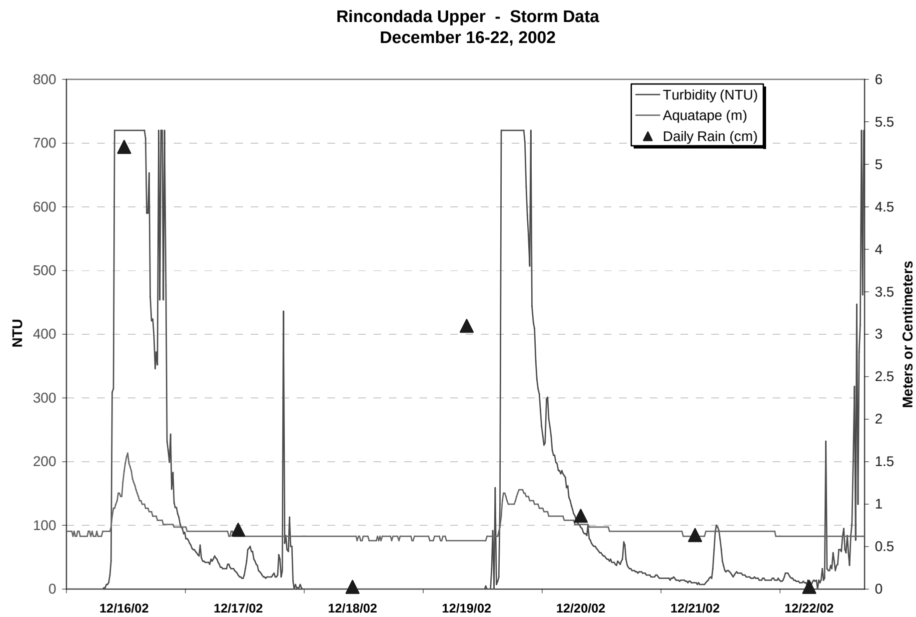
Overall, there were no significant differences in sediment concentrations. The flow conditions may have contributed to this. Rainfall between 2001 and 2004 was below average each year. Our results are limited by infrequent rainfall events sufficient to produce storm flow in the three drainages. From January 2001 to March 2004, there were only seven storms that produced measurable stormflow at all six sites. Rinconada Creek was dry in the summer of 2002 and 2003. Base flow resumed in the fall. Upper Trout Creek only had surface flow after large storm events. Lower Trout Creek had base flow through the entire study period. Trout Creek is aggrading due to post-fire gravel, debris, and sediment transport from the Los Padres National Forest. Upper Yerba Buena Creek flowed during the winters of 2001 and 2002. It only flowed during, and shortly after large storm events, in 2003 and 2004. Lower Trout Creek had base flow through the entire study. Upper and Lower Rinconada Creek began to flow in the fall as temperatures began to drop. Yerba Buena Creek only flowed during and after storm events. The most ephemeral of the sites is Upper Trout Creek, where the bed load is a thick layer of gravel, and water flows under the stream bed for long periods of the year.

Water quality in Yerba Buena Creek was generally better than in Trout Creek and Rinconada Creek. This may be due, in part, to the smaller size of the Yerba Buena watershed relative to the other study sites. Yerba Buena is one third the size of Rinconada and less than half the size of Trout Creek within the study area. Yerba Buena Creek is entirely within the ranch boundaries and the watershed above the vineyard in is good ecological condition with grazing being the only use.

Rinconada Creek had the highest turbidity of the three study drainages. The suspended sediment measured for Rinconada Creek was three times higher than Trout Creek and over 14 times higher than Yerba Buena Creek. High sediment loads measured 7,000 mg/L in Rinconada Creek, which was very similar both above and below the vineyard indicating the vineyard did not contribute to increased sediment loads. The land uses and the number of dirt roads may contribute to the amount of turbidity in Rinconada Creek, although no measure of roadways and farming activities was made during this study. There was 1,400 to 1,900 mg/L in Trout Creek and 400 to 500 mg/L in Yerba Buena Creek. In all cases, the vineyard did not add increased sediment loads. In some cases, the sediment concentrations were lower after the water passed through the vineyard.

Water quality values in Trout Creek was typically in the mid-range between Yerba Buena Creek and Rinconada Creek. Trout Creek had less sediment than Rinconada, and more than Yerba Buena. Trout had total phosphorus and nitrogen between the values of Yerba Buena and Rinconada Creek.

Ammonia, nitrate, and soluble phosphorus concentrations were very low. Variations observed may be influenced by factors that were not measured in this study. Landform, geology, soil type, proximity to wetlands, and land use practices in the surrounding areas should be investigated to consider possible relationships with turbidity and nutrient concentrations. The data serve as baseline information given the unusual flow patterns. Each of the three drainages showed high suspended sediment and low nutrients during major storm events between 2001 and 2004.



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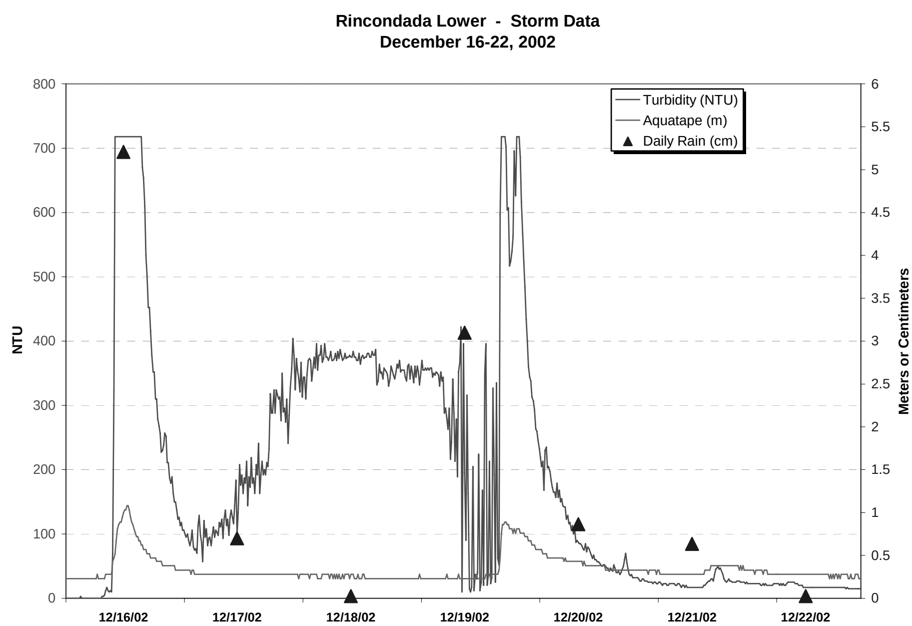

b.

Figure 5—Upper and lower Rinconada Creek (a and b) show similar stream flow characteristics to the other two drainages. Turbidity is generally high after several inches of rainfall. The long period of turbidity indicated December 17 to 19 (arrow) is probably watercress or other vegetation clinging to the turbidity sensor.

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