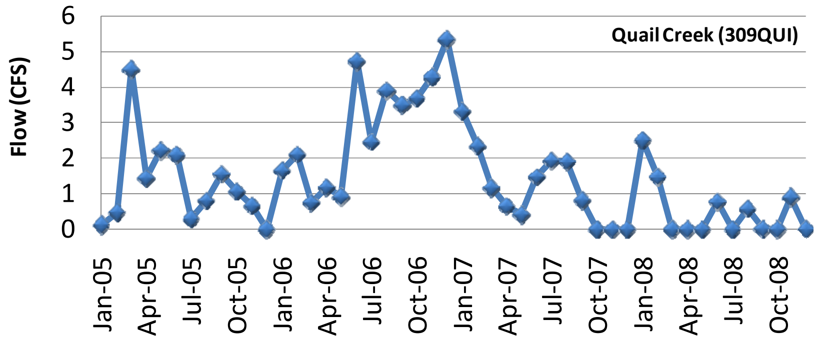
Preliminary Trend Analysis

A major goal of the Cooperative Monitoring Program (CMP) is to show trends in water quality over time, in impaired water bodies in agricultural areas of the Central Coast. The CMP has been monitoring 25 sites monthly since January, 2005 (Phase I) and an additional 25 sites since January, 2006 (Phase II). We now have four full years of data for the Phase I sites. It would be preferable to have data from a longer period of time, but it is important to conduct preliminary trend analyses to evaluate the suitability of the current CMP dataset. The optimal dataset length for trend analysis depends on the variability of the data (the more variability, the longer the dataset needed). In a recent trend analysis of Central Coast data from the CCAMP Coastal Confluence sites (Conley et al. 2008), significant water quality trends were detected in 9% of CCAMP Coastal Confluence sites with 4 to 5 years of monthly data.

Thus far, the CMP has approached trend analysis in 3 ways. These are described below, followed by a discussion of trends identified as "significant" in a statistical analysis.

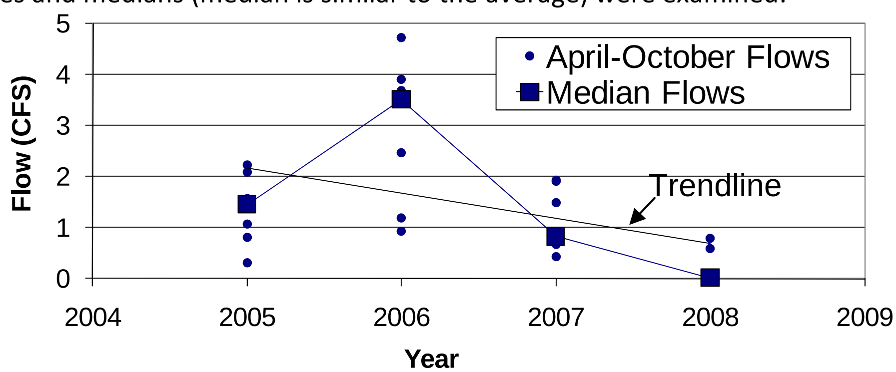
I. Three Approaches to Data Analysis

1) Simple scatterplot analysis: Every result for a certain water quality parameter was graphed, month-by-month, for each CMP site. For example:



The above graph shows Flows (CFS) from January 2005 through December 2008 at Quail Creek (309QUI). There's quite a bit of variability from month to month, so it's hard to say if there are any real trends, especially when you factor in winter rains. But it's a good "first look." Visual inspection suggests that perhaps Flows are going down overall, since there are fewer high values later in the dataset…

2) Annually grouped, growing season analysis: Results from November through March were removed because these have more potential to be impacted by precipitation, and ag inputs may be lower during the winter months. April through October results were grouped by year, and then the year-to-year ranges and medians (median is similar to the average) were examined:



The above graph shows Flow results for Quail Creek in April through October only, in each year from 2005 through 2008. There's quite a range throughout each year, but you can see a net downward trend from 2005 through 2008 (despite an apparent increase in 2006).

3) Seasonal Mann-Kendall statistical analysis: Results from January 2005 through December 2008 were fed into a statistical software program to test for positive or negative trends, and whether or not these are statistically significant. This test takes into account the fact that seasonal patterns might affect the variability of results, and has been used by researchers on the Central Coast for trend analysis in the past. We tried two different kinds of Mann-Kendall tests:
   a. 12 season test: Each month was designated as its own season, so we were basically comparing January of each year to January of every other year, February of each year to February of every other year, etc.
   b. 2 season test: We lumped November through March together as the "winter" season, and April through October together as "summer". Thus, the "summer" months of each year were compared to the "summer" months of every other year, and "winter" months compared to "winter" months.

Following the example of trend analysis with Flow data from Quail Creek, the downward trend in Flow for April-October was statistically significant ($p < 0.05$), there was a non-significant upward trend in November-March results, and the overall trend in the 12 season test was downward but non-significant (see Tables 1-3 on the following pages).

II. Results of Statistical Analysis with Seasonal Mann-Kendall Test

We used the "SeaKen" macro in MiniTab (statistics software) to test for statistically significant trends, with an alpha of 0.05.

- Trend: A general direction (up or down) in the values of water quality monitoring results over time. If values mostly increase over time, the trend is "positive." If values mostly decrease, the trend is "negative." If values don't change at all, there is no trend (or the trend is "0"). The words "positive" and "negative" refer to *direction of trends*, and should not necessarily be interpreted as "good" and "bad." Statistical analysis must be performed to determine whether or not trends are *significant*.
- Statistically significant: Means that a positive or negative trend is strong enough that we can be very confident it is not due to random, or natural, variability. We decide beforehand how confident we want to be, by choosing an "alpha" value.
- Alpha (α) of 0.05: This is our pre-designated confidence level for significance. Alpha of 0.05 indicates a confidence level of 95%. (With an alpha of 0.05, if we find a significant trend, we can be 95% it's a real trend, and not due to random variability in the data.) The statistical test returns a "*p* value," and the *p* value has to be smaller than our alpha in order for the trend to be considered significant. Trends with *p* values greater than our alpha might also be real, but we can't be sure.
- Insufficient data: The statistics software we used returned the result "insufficient data" if there were not enough data points to run a test. For example, if a site was frequently dry, there may not have been enough nitrate tests conducted to look for trends.

Tables summarizing the results of trend analysis for Flow, Nitrate Concentration, and Turbidity are provided on the following pages. The data is considered preliminary as outside variables have not been considered; for example precipitation during April, May and October of the Summer data set may have influenced flows.

Table 1: Trends in ***Flow*** identified with the seasonal Mann-Kendall test on 2005-2008 CMP results. Trends in flow can be caused by changes in the amount of agricultural or urban runoff, dam release schedules, and/or inter-annual weather patterns, with other possible factors as well. When trends are caused by changes in runoff (discharges), there is an especially strong likelihood of changes in pollutant loads. The 2-season Mann-Kendall test showed significant downward trends in SUMMER (April-October) flows at 18 of 27 CMP sites in the Salinas and Santa Maria areas. Flows at most of these sites are strongly influenced by agricultural discharges, so these trends could indicate that agricultural discharges have been reduced over the past 5 years. There were also significant downward trends at two sites on the mainstem Salinas River which are more likely to be dominated by dam releases. The 2-season Mann-Kendall test showed significant downward trends in WINTER (November-March) flows at 2 CMP sites, and the 12-season Mann-Kendall test showed overall significant downward trends at 5 sites. No significant (and very few non-significant) upward trends in Flow were identified.

Table 2: Trends in ***Nitrate concentration*** identified with the seasonal Mann-Kendall test on 2005-2008 CMP results. Trends in Nitrate concentration can be caused by many factors. It is important to recognize that changes in bottom-of-watershed Nitrate concentrations are not caused exclusively by changes in the Nitrate concentrations of individual inputs. Obviously, if the Nitrate concentration of each individual input increases, an upward trend will occur at the bottom of the watershed. However, changes in the volume (Flow) of individual inputs can change the way that these inputs combine to create the mixed, bottom-of-watershed Nitrate concentration. For example, if inputs with low nitrate concentrations are eliminated, but high-Nitrate inputs remain constant in volume, there will be less dilution of the high-Nitrate inputs, and a resultant increase in concentrations measured at the bottom of the watershed, even though no individual inputs increased in concentration.

The 2-season Mann-Kendall test showed a significant upward trend in SUMMER (April-October) Nitrate concentrations at 1 of 27 CMP sites in the Salinas and Santa Maria areas (p values for upward trends at 2 other sites were only slightly above the alpha value of 0.05). The 2-season test also showed significant upward trends at 2 sites for the WINTER (November-March) period (p values for upward trends at 3 other sites were only slightly above the alpha value of 0.05). The 12-season test showed overall significant *downward* trends at 2 sites (the p value for an upward trend at 1 other site was only slightly above the alpha value of 0.05). In summary, there are 3 sites with upward trends in "summer" Nitrate concentrations that are likely to be real, and 5 sites with upward trends in "winter" that are likely to be real. On a 12 month basis, there are 2 sites with downward trends in Nitrate concentration that are likely to be real, and 1 site with a probable upward trend. The majority of trends in Nitrate concentration, significant and non-significant, were upward in direction.

Table 3: Trends in ***Turbidity*** identified with the seasonal Mann-Kendall test on 2005-2008 CMP results. Turbidity measures the amount of light scattered by particles suspended in water, and is used as a proxy for concentration-based parameters like "Total Suspended Solids" or "Suspended Sediment Concentration." Trends in Turbidity can be caused by many factors. It is important to recognize that changes in bottom-of-watershed Turbidity levels are not only caused by changes in the Turbidity of individual inputs. A trend in Turbidity at the bottom of the watershed could be caused by increased or decreased Turbidity in individual inputs. Or, for example, it could be caused by a decline (or rise) in low-Turbidity inputs, while higher-Turbidity inputs remain more constant in volume.

The 2-season Mann-Kendall test showed significant upward trends in SUMMER (April-October) Turbidity at 4 of 27 CMP sites examined (all 4 of which are on the mainstem Salinas River), and a significant downward trend at 1 site (the p values for trends at 2 other sites, 1 up and 1 down, were only slightly above the alpha value of 0.05). No significant trends were identified during the WINTER season. On a 12 month basis, there was 1 site with a significant upward trend in Turbidity, and 1 site with a significant downward trend.

Table 1. Trends in Flow identified with the seasonal Mann-Kendall test on 2005-2008 CMP results.

Site	12 season; α=0.05 Trend	12 season; α=0.05 Significant?	2 season; winter; α = 0.05 Trend	2 season; winter; α = 0.05 Significant?	2 season; summer; α=0.05 Trend	2 season; summer; α=0.05 Significant?
306MOR	insufficient data		insufficient data		insufficient data	
309ALG	↓	YES	↓	NO	↓	YES
309ASB	↓	NO	↓	NO	↑	NO
39BLA	↓	NO*	↓	NO	↓	YES
309CRR	insufficient data		↓	NO	↓	NO
309ESP	↓	YES	↓	NO	↓	YES
309GAB	insufficient data		↓	YES	↓	YES
309GRN	insufficient data		↑	NO	↓	YES
309JON	↓	NO*	↓	NO	↓	YES
309MER	↓	NO	↓	NO	↓	NO
309NAD	insufficient data		↓	YES	↓	NO
309OLD	insufficient data		↑	NO	↓	NO
309QUI	↓	NO*	↑	NO	↓	YES
309SAC	insufficient data		↓	NO	↓	YES
309SAG	insufficient data		↓	NO	↓	YES
309SSP	insufficient data		↓	NO	↓	YES
309TEH	↓	YES	↓	NO	↓	YES
312BCC	insufficient data		insufficient data		insufficient data	
312BCJ	↓	NO	↓	NO*	↓	NO
312GVS	↓	YES	↓	NO*	↓	YES
312MSD	insufficient data		↑	NO	↓	YES
312OFC	↓	NO	↓	NO	↓	YES
312OFN	↓	NO	↑	NO	↓	YES
312ORC	↓	YES	↓	NO	↓	YES
312ORI	↓	NO	↓	NO	↓	NO
312SMA	↓	NO*	↑	NO	↓	YES
312SMI	insufficient data		↓	NO	↓	YES

* Trend not significant at alpha = 0.05, but p value very low (less than 0.1)

Sites with:	12 Season Overall	2 Season Winter	2 Season Summer
Signif. ↓ trends:	5	2	18
Signif. ↑ trends:	0	0	0
No signif. trends:	10	23	7
Insufficient data:	12	2	2

Table 2. Trends in Nitrate Concentration identified with the seasonal Mann-Kendall test on 2005-2008 CMP results.

Site	12 season; α=0.05 Trend	12 season; α=0.05 Significant?	2 season; winter; α = 0.05 Trend	2 season; winter; α = 0.05 Significant?	2 season; summer; α=0.05 Trend	2 season; summer; α=0.05 Significant?
306MOR	↑	NO	↑	NO	↑	NO
309ALG	↑	NO	↑	NO*	↑	NO
309ASB	↑	NO	↑	NO	↑	NO
39BLA	↑	NO*	↑	NO*	↑	NO
309CRR	insufficient data		↓	NO	↓	NO
309ESP	↑	NO	↓	NO	↑	NO
309GAB	insufficient data		insufficient data		insufficient data	
309GRN	insufficient data		↑	NO	↓	NO
309JON	↓	NO	↑	NO	↑	NO
309MER	↑	NO	↑	NO	↑	NO
309NAD	insufficient data		↑	YES	↑	YES
309OLD	insufficient data		insufficient data		insufficient data	
309QUI	insufficient data		↓	NO	↑	NO*
309SAC	↓	NO	↑	YES	↑	NO*
309SAG	insufficient data		↓	NO	↓	NO
309SSP	insufficient data		↑	NO*	↓	NO
309TEH	↑	NO	↑	NO	↑	NO
312BCC	insufficient data		insufficient data		insufficient data	
312BCJ	↓	NO	↑	NO	↓	NO
312GVS	↓	YES	↓	NO	↓	NO
312MSD	insufficient data		↑	NO	↑	NO
312OFC	↓	NO	↓	NO	↓	NO
312OFN	↓	YES	↓	NO	↓	NO
312ORC	↑	NO	↑	NO	↓	NO
312ORI	↑	NO	↑	NO	↑	NO
312SMA	↑	NO	↑	NO	↑	NO
312SMI	insufficient data		↑	NO	↓	NO

* Trend not significant at alpha = 0.05, but *p* value very low (less than 0.1)

Sites with:	12 Season Overall	2 Season Winter	2 Season Summer
Signif. ↓ trends:	2	0	0
Signif. ↑ trends:	0	2	1
No signif. trends:	14	23	23
Insufficient data:	11	4	3

Table 3. Trends in Turbidity identified with the seasonal Mann-Kendall test on 2005-2008 CMP results.

	12 season; α=0.05		2 season; winter; α = 0.05		2 season; summer; α=0.05	
Site	**Trend**	**Significant?**	**Trend**	**Significant?**	**Trend**	**Significant?**
306MOR	↓	NO	↓	NO	↑	NO
309ALG	↑	NO	↑	NO	↑	NO
309ASB	↓	NO	↑	NO	↓	NO
39BLA	↑	NO	↑	NO	↑	NO
309CRR	insufficient data		↑	NO	insufficient data	
309ESP	↓	NO	↓	NO	↓	NO
309GAB	insufficient data		↓	NO	↑	NO
309GRN	↑	YES	↑	NO	↑	YES
309JON	↓	NO	insufficient data		insufficient data	
309MER	↑	NO	↑	NO	↓	NO
309NAD	insufficient data		↓	NO	↓	NO
309OLD	insufficient data		↑	NO	↓	NO
309QUI	insufficient data		↑	NO	↑	NO
309SAC	↑	NO	↓	NO	↑	YES
309SAG	insufficient data		↑	NO	↑	YES
309SSP	insufficient data		↑	NO	↑	YES
309TEH	↑	NO	↓	NO	↑	NO*
312BCC	insufficient data		insufficient data		insufficient data	
312BCJ	↓	YES	↓	NO	↓	NO*
312GVS	↓	NO	↓	NO	↓	NO
312MSD	insufficient data		↑	NO	↓	YES
312OFC	↑	NO	↑	NO	↑	NO
312OFN	↓	NO	↑	NO	↓	NO
312ORC	↓	NO	↑	NO	↓	NO
312ORI	↓	NO	↓	NO	↓	NO
312SMA	↑	NO	↑	NO	↑	NO
312SMI	insufficient data		↑	NO	↑	NO

* Trend not significant at alpha = 0.05, but *p* value very low (less than 0.1)

Sites with:	12 Season Overall	2 Season Winter	2 Season Summer
Signif. ↓ trends:	1	0	1
Signif. ↑ trends:	1	0	4
No signif. trends:	15	25	19
Insufficient data:	10	2	3