Long-Term Water Quality Monitoring Strategy for the Cosumnes River Watershed

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The most important step in formulating a water quality monitoring program is the initial specification of the objectives. The goal of our water quality monitoring in the Cosumnes River watershed was to develop a protocol that addressed both spatial and temporal dynamics. Our four-year water quality investigation can be characterized as a *baseline monitoring* program that was undertaken with the potential for serving as the basis of a *trend monitoring* program. Baseline monitoring is used to characterize existing water quality conditions, and to establish a database for planning or future comparisons. The intent of baseline monitoring is to capture a representation of the temporal variability of a particular water quality parameter. In turn, trend monitoring implies that measurements will be made at regular, well-spaced time intervals in order to determine the long-term trend in a particular water quality parameter. There is no explicit end point at which continued baseline monitoring becomes trend monitoring. Given the focus on utilizing total maximum daily loads (TMDLs) to address non-point source water impairments, it is critical to establish baseline monitoring programs to serve as the basis of evaluating the effectiveness of best-management practices (BMPs) applied to address non-point source pollution. This latter type of monitoring is termed *effectiveness monitoring*. Our monitoring design could also be utilized to determine whether specific water quality criteria are being met, termed *compliance monitoring*. A flow diagram demonstrating the role of various monitoring objectives in shown in Figure 1 (MacDonald et al., 1991). Because the objectives of a monitoring program are constantly evolving, it is prudent to also consider the potential future objectives that might be asked of a water quality monitoring program. A generalized structure for development of a water quality monitoring program is shown in Table 1.

To develop an effective baseline monitoring program in the Cosumnes River watershed, we established a source-search protocol to examine spatial patterns in water quality parameters. This is a commonly used strategy that seeks to determine the source of any potential water quality impairments. This strategy is being employed throughout the USA to identify impaired water bodies for inclusion on the 303d list for TMDL development. In the 1998-99 water year (1 Oct to 30 Sept.), the year prior to the start of CALFED funding, we began a pilot monitoring program collecting data from about 24 sites throughout the Cosumnes watershed on a biweekly basis. We used these initial findings to refine our final site selection for the three water years funded by CALFED (99-00, 00-01, 01-02). This process resulted in the final selection of 28 sampling sites located throughout the approximately 1500 km^2 watershed (Fig. 2). This allowed us to divide the entire Cosumnes River watershed into subwatersheds for the purpose of identifying the contribution of each subwatershed (*i.e.,* cumulative effects) to the overall water quality at its confluence with the Mokelumne River. Grab samples were collected every two weeks from each site, except the high elevation sites that were inaccessible during the winter due to the snowpack. As the watershed is oriented in an east-west direction, we established several north-south transects across the Cosumnes mainstem and its major tributaries (*e.g.,* E6, E16, 49, Wilton Road, Twin Cities Road) to follow the evolution of water quality in its flow from high to low elevation. This approach allowed us to examine the major climate, land use and geologic/soils associations occurring throughout the watershed. A factor that typically drives site selection is the availability of flow data from an established and regularly maintained gauging station. Unfortunately, only one major gauging station monitoring flow exists in the Cosumnes watershed at Michigan Bar (watershed area about 1100 km^2). Another major consideration for selection of sampling sites is long-term accessibility to the site. Thus, all samples were collected from bridges (or right-of-ways) of public roads. For consistency, grab samples were collected from the center of the stream at the 0.6 depth. This sampling designed served as the “basic” monitoring component for water quality study.

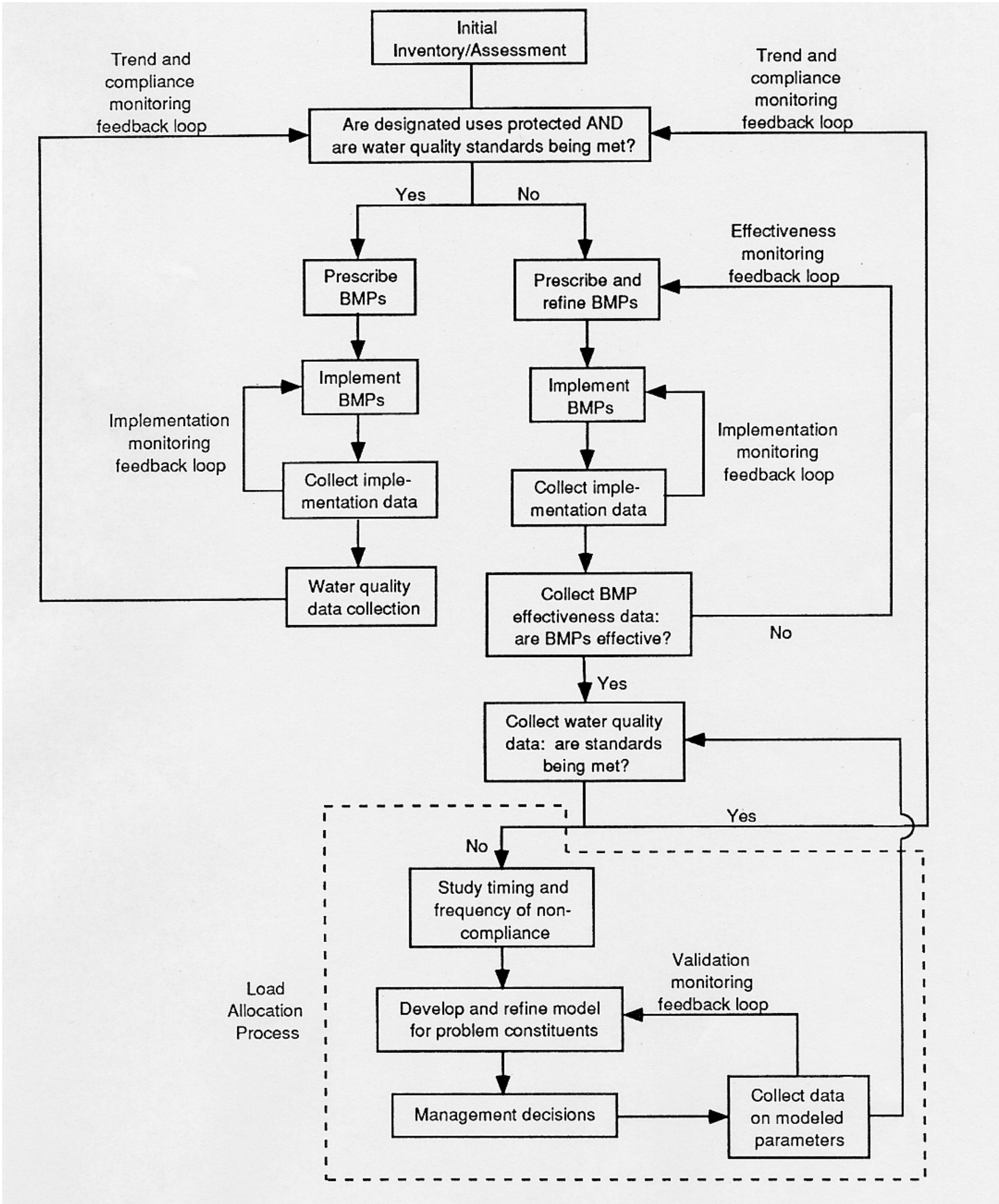

Figure 1. Flow diagram for monitoring and controlling nonpoint sources of pollution (MacDonald et al., 1991).

Table 1. Key steps for development of a water quality monitoring program. Adapted from Monitoring Guidelines to Evaluate Effects of Forestry Activities on Streams in the Pacific Northwest and Alaska (MacDonald et al., 1991).

Key steps in development of water quality monitoring program
Develop propose and general objectives for monitoring
Define approximate budget and personnel constraints
Review existing data
Determine monitoring parameters, sampling locations, sampling procedures, and analytical methods
Evaluate hypothetical or real data
Reassess monitoring objectives and compatibility with existing resources
Initiate monitoring activities on a pilot basis
Analyze and evaluate data
Reassess monitoring objectives and compatibility with existing resources
Modify monitoring project as necessary
Continue monitoring
Prepare regular reports and recommendations

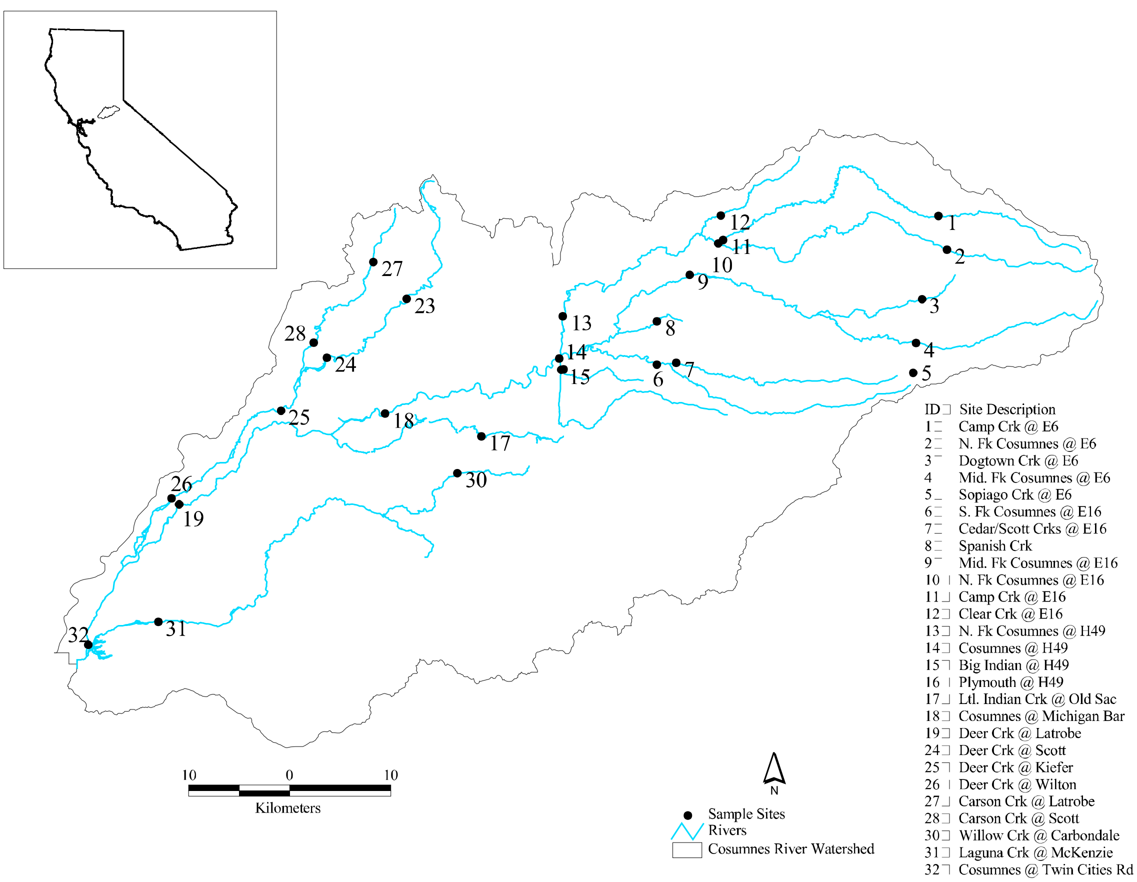

Figure 2. Cosumnes River Watershed with the 28 sampling sites utilized during this study.

We also recognize that tremendous temporal variability in water quality parameters occur at the inter-annual, seasonal and storm-event scales. In total, we collected four years of biweekly samples that allows us to document inter-annual and seasonal variability. It is important however to keep in mind that it typically requires decades of water quality data to statistically address water quality trends associated with basin-wide water quality drivers (*e.g.,* atmospheric deposition, climate change). Thus, the need for long-term water quality records collected and analyzed with consistent analytical methods is critical to address many issues related to current environmental concerns. Our four years of water quality data are sufficient to document seasonal dynamics in water quality constituents. While we understand the basic mechanisms regulating temporal patterns in water quality, we require further data to calibrate and validate basic water quality simulation models. In the final three years of monitoring, we collected several grab samples during the rising and falling limbs of the storm hydrograph to examine storm-event water quality dynamics. This design allowed us to follow the general trends in various water quality parameters, however, it is deficient for developing precise parameter fluxes and determining hysteresis loops associated with the rising and falling limb dynamics. While using automatic- pump samplers to collect several samples along the storm hydrograph is desirable, it was beyond the monitoring budget of the project in terms of sampling equipment and personnel to analyze samples (analytical cost $100 sample). Table 2 shows the water quality parameters examined during the four years of our monitoring program.

Table 2. Selected water quality parameters measured in this study.

Water Quality Parameters		
Temperature*	Calcium	Total N*
pH*	Magnesium	Ammonium*
Electrical conductivity*	Potassium	Nitrate*
Turbidity*	Sodium	Total P*
Transparency*	Chloride	Ortho-phosphate*
Chlorophyll-a*	Sulfate	Dissolved oxygen
Phaeophytin*	Bicarbonate	Fecal coliform
Total suspended solids*	Silicon	Total coliform
Volatile suspended solids*	Dissolved organic carbon*	E. coli

*Parameters proposed for analysis under the basic long-term monitoring program.

Proposed monitoring strategy for future watershed studies in the Cosumnes watershed

A long-term basic water quality monitoring program is essential to provide background information for all watershed studies in the Cosumnes basin (*e.g.,* water quality modeling, terrestrial-aquatic linkages, aquatic biology, and hyporheic investigations). While each specific study will undoubtedly require additional spatial and temporal intensity of sampling and possibly analysis for a greater number of water quality parameters, we feel the following design will provide a valuable baseline for all studies.

Sampling sites. A minimum of five sites is proposed for intensive water quality monitoring. A sixth possible location is highly desirable if logistical/legal aspects can be negotiated.

1. Cosumnes mainstem at the breach of the upper floodplain at the TNC.
2. Cosumnes mainstem at Michigan Bar
3. North Fork Cosumnes at Sand Ridge Road (near Highway 49)
4. Middle Fork Cosumnes at E16
5. South Fork Cosumnes at E16
6. Optional - Cosumnes mainstem at Highway 99 (highly desirable)

To allow for the calculation of constituent loads, gauging stations should be installed at sites #3, 4 and 5. It will be very difficult to determine a flux for the Cosumnes in the vicinity of Twin Cities Road to the TNC floodplain due to the multiple channels and extensive floodplain flow during storm events. It may be possible to gain some information on flows in the lower Cosumnes from the existing stage measurements acquired at a gauge at Highway 99.

Each of the five intensive sites should be equipped with an automatic pump sampler ($4,500 each) to collect flow-proportional samples during storm events. All samplers should be equipped with water sensors to automatically start the sampling algorithm without human intervention. For a typical 2-3 day storm event, about 15 samples should be collected during the rising limb and about 9 samples during the falling limb of the hydrograph. This intensity of sampling should be adequate to study hysteresis dynamics for the various water quality constituents. The longitudinal sampling coupled with the storm-event multiple samplings should allow the study of the propagation of storm flow and associated water quality from the upland tributaries to the confluence with the Mokelumne. During baseflow conditions, grab samples should be collected from each site biweekly when flows at Michigan Bar are less than 800 cfs and weekly when flows exceed 800 cfs. Coupling of parameter concentrations and stream discharge will allow calculation of constituent fluxes (loads – kg or Mg) with a high degree of confidence and precision.

In addition, all five sites should be equipped with data logged sensors to provide continuous readings of temperature, electrical conductivity and turbidity ($5,000 per site). Continuous measurement of pH, dissolved oxygen, and chlorophyll will not provide sufficient data to warrant the effort and expense in the Cosumnes watershed. Values of pH show little fluctuation, dissolved oxygen is always near saturation and phytoplanktin algae is only a minor contributor relative to periphyton. The grab samples should be analyzed for the parameters asterisked in Table 2. In addition, samples should be analyzed for selected trace elements (*e.g.,* Hg, Cu, Zn, Cd, Pb, As) in both the dissolved and particulate fractions. Selected samples from the lower two mainstem sites should be analyzed for the common suite of pesticides at key times of the year to ascertain whether pesticide concentrations merit further investigation.

The analytical cost for the basic monitoring design of the water quality parameters listed in Table 2 would be about $112,000 (based on 224 samples per site x 5 sites x $100 per sample). In addition, a 50% time field person would be required to collect samples and maintain the automated sensors ($21,000 with benefits) and vehicle rental to collect samples is estimated at about $7,000 per year.

192	storm samples = 8 storm events x 24 samples per storm
20	biweekly baseflow samples (<800 cfs)
12	weekly baseflow samples (>800 cfs)
224	total samples per site

The final step of the monitoring process is to make the data readily available to interested parties. This is best accomplished by developing a web-based system that stores data in a standardized database format (e.g., M.S. Access) that can be accessed through automated queries. Several examples of such web-based data storage-retrieval programs are available (*e.g.,* EPA STORIT, U.S.G.S. Water Quality database).

References

MacDonald, L.H., A.W. Smart and R.C. Wissmar. 1991. Monitoring Guidelines to Evaluate Effects of Forestry Activities on Streams in the Pacific Northwest and Alaska. EPA Publication 910/9-91-001.