Executive Summary

As part of a CALFED-funded project, historical data analyses, field investigations and a series of numerical hydrologic models of both surface and groundwater have been developed for the Cosumnes River Basin. In the upper basin (above Michigan Bar), an existing USGS Modular Modeling System model has been modified to provide model results at water quality sampling points in the upper basin. In order to be able to quantify how changes in the basin affect the hydrologic response of the watershed, a physically based model of the Upper Cosumnes has been developed and initial test simulations carried out. In order to assess links between river flows and groundwater conditions in the lower Cosumnes basin (below Michigan Bar) a combination of historical data analyses, field investigations, and numerical modeling have been conducted between January 2000 and 2003. The aim of these investigations was to analyze river aquifer interactions along the alluvial reaches of the river between Michigan Bar and the basin outlet and to assess management alternatives for enhancing fall flows to promote Chinook salmon spawning on the Cosumnes. Results from investigations associated with the above cited hydrologic investigations in the Cosumnes Basin are presented here.

The Hydrologic Model of the Upper Cosumnes River Basin (HMCRB) under the USGS Modular Modeling System (MMS) uses a modified Precipitation-Runoff Modeling System (PRMS) to simulate daily stream flows when precipitation and temperature values are given. The MMS-HMCRB is capable of simulating hydrologic state variables which describe the hydrologic conditions of the Cosumnes River basin in time and lumped space, i.e., flood peak discharges, fall low flows, snow accumulation, soil moisture storage, water storage in ground reservoir, etc. The model may be used to study the hydrologic conditions in Cosumnes River basin under different water use scenarios (e.g., with diversions and without diversions). During the course of this project, the existing Watershed Hydrologic Model for the Cosumnes River basin (the modified MMS PRMS) was restructured so that hydrographs can be obtained at points that coincide with the water quality sampling points in the watershed. Re-calibration of model parameters for the reconstructed model has also been carried out. Hydrographs were generated with the modified MMS PRMS model for the upper basin of the Cosumnes River for the period October 1998 through February 2002 for 8 subbasin outlets in the upper watershed. The hydrographs from these 8 subbasin outlets were then provided to the water quality group for their studies

The physically based watershed hydrologic model, WEHY (watershed environmental hydrology) model (Kavvas et al. 2003; Chen et al. 2003), for the upper basin of the Cosumnes River represents a new approach to the modeling of hydrologic processes in order to account for the effect of heterogeneity within natural watersheds. Toward this purpose, the point location-scale conservation equations for various hydrologic processes were upscaled in order to obtain their ensemble averaged forms at the scale of the computational grid areas. Over hillslopes these grid areas correspond to areas along a complete transect of a hillslope. The resulting upscaled conservation equations, although they are fundamentally one-dimensional, have the lateral

source/sink terms that link them dynamically to other hydrologic component processes. In this manner, these upscaled equations possess the dynamic interaction feature of the standard point location-scale two dimensional hydrologic conservation equations. A significant computational economy is achieved by the capability of the upscaled equations to compute hydrologic flows over large transactional grid areas versus the necessity of computing hydrologic flows over small grid areas by point location-scale equations in order to account for the effect of environmental heterogeneity on flows. The emerging parameters in the upscaled hydrologic conservation equations are areal averages and areal variance/covariances of the original point-scale parameters, thereby quantifying the spatial variation of the original point-scale parameters over a computational grid area, and, thus, the effect of land heterogeneity on hydrologic flows. Also, by requiring only areal average and areal variance of parameter values over large grid areas, it is possible to achieve very significant economy in parameter estimation. Using this technology, a physically based model of the upper basin of the Cosumnes River has been developed and initial simulations carried out. Future work including the installation of meteorologic and streamflow observation stations and the subsequent collection of data for model verification is required prior to the use of the physically based numerical model in management scenarios involving the upper basin.

In the lower basin of the Cosumnes River (below Michigan Bar), field data collection, historical data analyses and numerical simulations were used to analyze management alternatives which might enhance fall run Chinook salmon spawning in the basin. A regional groundwater model and a channel routing model with seepage were used in separate numerical simulations to assess different fall flow augmentation alternatives as well as scenarios that increase net recharge. Historical data analyses examined historical trends and conditions in order to determine changes in the lower basin with time as well as to provide a frame of reference for the numerical simulations carried out. Field data were collected to define current conditions and trends. Based on these analyses, general recommendations pertaining to flow augmentation, and increasing net recharge to the regional aquifer system are presented. Suggestions for further monitoring and field work in the lower basin of the Cosumnes River are also included.

Four project deliverables have been identified for the hydrology program of the CALFED Cosumnes River Project #99-N06. They are 1) linked surface water groundwater model for the Cosumnes River; 2) hydrologic analysis of management alternatives for enhancing flows to promote Chinook Salmon spawning in the Cosumnes River; 3) identify links between surface flows and groundwater conditions in the Cosumnes River basin and management recommendations; 4) hydrologic and biologic monitoring strategies using a physically based and spatially distributed model, Cosumnes and Mokelumne River basins. These deliverables have been met during the course of the project and are described in the following report.

Four numerical models have been used or developed which describe the surface and groundwater systems and their interaction in the Cosumnes Basin. The first model, the USGS

MMS model, has been used to assist in the water quality and ecological monitoring and modeling in the upper Cosumnes Basin which addresses deliverables 1 and 4. The USGS model and its use are described in chapter 1 of the report. The second model, a physics based distributed parameter model of the upper Cosumnes is described in Chapter 2. This model satisfies deliverable 1. Future efforts with the physics based model as a means of satisfying deliverable 4 are described in Chapter 4 of the report. Chapter 3 presents two models used to analyze links between surface and groundwater conditions and analyze management alternatives for enhancing flows to promote Chinook salmon spawning in the Cosumnes River. This work directly addresses deliverables 2 and 3 for the hydrology program of the CALFED project. A summary table is shown below.

Report Chapter	**Deliverable Met**
1 – USGS MMS Model Work	1, 4
2 – Physics Based Model of Upper Cosumnes	1
3 – Links Between River Flows and Groundwater Conditions of the Lower Cosumnes	2,3
4 – Future Directions and Recommendations	4