4 OUTLOOK AND FUTURE WORK

Restoration of fall flows on the lower Cosumnes River is a complex challenge. Changes that have been imposed on the groundwater system over many decades and that have adversely affected river flows can not easily be reversed in a few months or years. Demands on water are increasing and regional groundwater levels are further declining. Sensible management strategies will have to be developed within that context. Specific strategies may need additional analyses of local conditions and more specific assessment of potential impacts of implemented changes that were beyond the scope of this study. Based on the results of this study, future efforts have been identified which can build upon the work completed here. A general description of these future efforts is provided here. The future work is broken down into three parts: upper basin, lower basin, ties between the upper and lower basins.

Upper Basin

Significant possibilities exist for future modeling efforts in the upper basin. Atmospheric modeling of the Cosumnes River Basin for the reconstruction of historically significant hydrologic events can be accomplished using a regional scale model such as the National Center for Atmospheric Research/ Penn State Model MM5. The research group headed by M. L Kavvas has extensive experience in using the MM5 model for generating spatially distributed data fields to drive physically based watershed models in other basins. Such work coupled with further field monitoring of stream flow, rainfall, snowfall, and other atmospheric variables would provide an opportunity to verify the physically based watershed model of the Upper Cosumnes River developed in this study.

Once the verification process is complete, the physically based watershed model of the Upper Cosumnes can be used to examine a variety of issues. These issues include watershed response changes due to land use/land management changes, watershed response due to climate change and climate variability, and watershed response associated with extreme hydrologic events. One example of such studies would be the investigation of hydrologic system response to releases from Sly Park Reservoir for minimum flows for fish passage. The model could be used to help find an optimal combination of Sly Park reservoir releases and flow augmentation from Folsom South Canal to increase salmon spawning in the Cosumnes Basin.

The model is also capable of being used to assist and interact with field monitoring efforts for sediment and nutrient transport in the basin. The model can identify critical areas for the field monitoring efforts to sample through scenario simulations. The model can also be used to examine potential impacts and benefits of restoration activities in the watershed. Such work can be used to guide restoration activities.
Lower Basin

During the course of the study described in this report, three main areas for future work in the lower basin have been identified: further field monitoring and analysis of the resulting data, construction of a detailed sub-regional groundwater flow model, and investigations into natural recharge from inundated floodplains. Work involved in the three areas is described below.

**Further field monitoring**

During the course of this study monitoring efforts and field investigations were conducted to compliment the numerical analyses. Results from these efforts revealed local information like the seasonal development of perched aquifers above the regional water table, estimates of travel times of river water to the water table through a thick unsaturated zone, significant variations in seepage rates over small scales and evidence for gaining river reaches at the upper and lower ends of the river, which was not completely represented in the coarser regional numerical analyses. This information can be of great importance for the development of specific management strategies especially if easy large scale solutions are not at hand. It is therefore recommended to continue monitoring efforts and to continue investigations of geologic factors affecting the exchange between the river and the aquifer. Monitoring should include monthly or at least seasonal readings of groundwater levels around the river, quasi continuous measurements of groundwater levels and river stage at certain sites and synoptic measurements of river flows at various locations along the river. Geologic factors that need further analyses are hydraulic parameters of varying stream bed materials and the extent and effects of certain low permeability layers that outcrop in the river bed.

**Construction of a detailed sub-regional groundwater flow model**

The regional groundwater flow model used in this study was able provide a general description of groundwater surface water interactions along the lower Cosumnes River under current and scenario conditions. But the regional model has numerical limitations and lacks detail in its description of the local complexities of river aquifer exchange as they were observed in the field. To evaluate specific management scenarios that take these complexities into account a more detailed sub-regional model is needed. The construction of such a model has been initiated. Geological heterogeneity is built into the sub-regional model by means of detailed geostatistical simulations of the alluvial fan hydrofacies. Different realizations of the geostatistical model can be used to quantify effects of geologic heterogeneity on river seepage and to address uncertainty of predictions. Boundary conditions are taken from the coarser regional model. Due to the finer spatial resolution of the model spatial variations in seepage can be better accounted for. Seepage of river water to the water table through partially unsaturated zones along extended reaches of the river is described by a kinematic wave solution to vertical one dimensional unsaturated flow. The
local-scale model is not based on the IGSM code to avoid any errors arising from strong coupling between the river and groundwater. Further work is needed to refine and calibrate this model and to include new data from further field investigations.

**Quantification of natural recharge from inundated floodplains**

Efforts in recent years to restore a natural flood regime on the lower Cosumnes has resulted in extended areas of the floodplain being inundated during the winter season. These areas of the floodplain can provide significant additional sources for groundwater recharge. Further work is needed to quantify local recharge rates on the floodplain and to assess their potential for regional groundwater level recovery. Preliminary simulations with the regional groundwater model, making simplifying assumptions of uniform and steady recharge from floodplains during periods of inundation, indicate that recharge from these areas could raise groundwater levels around the river significantly. Further analyses are needed to verify these preliminary results.

**Upper and Lower Basin Linkages**

Work conducted in this study broke the watershed into two distinct areas: the upper and lower watersheds. Future work should look into the dynamic interactions between the upper and lower basins. Such work would include field monitoring and analysis, and extension of the physically based watershed model to include the entire Cosumnes watershed and subsequent modeling studies. The modeling studies would look to identify and quantify the linkages between the upper and lower basins and examine how changes in one basin affect the hydrologic response of the other.

The Cosumnes River Basin provides a unique opportunity to study the behavior of Sierra Nevada watershed behavior. Investigations into watershed response and interactions between the upper and lower basin would provide valuable information on how watersheds on the west slope of the Sierra Nevada mountains behave in this transition from mountain to valley. For example, the effect of climate change on outflow from the upper basin and, in turn, groundwater conditions in the lower basin is a key issue needing investigation. It is possible that unanticipated benefits of climate change, with respect to groundwater storage, could be realized.