EXECUTIVE SUMMARY--APPLICATION OF A HYDROCHEMICAL MODEL AND A MULTIVARIATE SOIL-SOLUTION MIXING MODEL TO ALPINE WATERSHEDS IN THE SIERRA NEVADA, CALIFORNIA

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INTRODUCTION

This executive summary contains the findings and a list of topics which might warrant additional study from a report prepared by the U.S. Geological Survey (USGS), in cooperation with the California Air Resources Board, titled "Application of a Hydrochemical model and a multivariate soil-solution mixing model to Alpine Watersheds in the Sierra Nevada, California," (USGS Water-Resources Investigations Report 93-4030). That report includes additional information on the hydrochemical model and the mathematics used in the sensitivity analysis and for the multivariatesoil-solution mixing model. The data analyzed in that report were collected by various researchers who contributed to the Integrated Watershed Study, an intensive 5-year study of Emerald Lake and its watershed, and to surveys of other alpine lakes by the California Air Resources Board.

PRINCIPAL FINDINGS OF THE STUDY

The Alpine Lake Forecaster, a computer model that simulates the chemical effects of acidic deposition on streamwater and lakes in alpine catchments, was applied to four alpine catchments in the Sierra Nevada, California that were studied between 1986 and 1988. The geochemical processes contained within the model seem to be applicable to three of the four lakes. At one lake, which turns over infrequently because of its geomorphology, alkalinity seems to be controlled by biological, rather than geocheimcal processes, thereby rendering ALF unsuitable. Even where applicable, however, parameter estimation for ALF requires that calibration data be collected over a large range of discharge. Therefore, it is critical that peak discharge during snowmelt be sampled.

Qualitatively, the smaller the amount of more readily weatherable minerals, such as hornblende, that are in the granitic bedrock, the more sensitive the watershed is to acidic pulses. A sensitivity analysis of ALF has quantified this relation using data for Emerald Lake, another watershed in the Sierra Nevada of California, for which the model was originally developed. The more extensive data set at Emerald Lake was required for this analysis. Changing the stoichiometric coefficient from 1.2 to 1.0 has little effect on the chemistry of the streamwater, but a stoichiometric coefficient of 0.5 or less substantially lowers the alkalinity of the streamwater. This coefficient may be used as an index value to compare other watersheds to Emerald Lake.

Additional insights into the geochemical and hydrologic processes operating in the catchment can be gained by comparing the chemistry of soil-water solutions to the chemistry of streamwater. A multivariate mixing model that relates these solutions was developed using data from Emerald Lake, the only site for which soil solution data were available. This analysis indicates that streamwater may be considered a mixture of soil solutions from the bench meadow and the ridge or inlet meadow site. The similarity between the ridge and inlet meadow soil solutions was unexpected. The higher solute concentrations at the bench site indicate that the residence time of the soil solution may be longer at this site than at the other two sites. This mixing model presents a method for the determination of hydrologic flowpaths that can affect streamwater quality, and may serve as a means of parameterizing compartmentalized hydrochemical models.

TOPICS FOR ADDITIONAL STUDY

Applicability of stoichiometric coefficient as an index. This analysis indicated that the stoichiometric coefficient, that is, the slope of the regression model relating sum of base cation (SBC) concentration to silica concentration, may be a useful indicator of the sensitivity of a watershed to acidification. To test the use of this coefficient, the lake inlets at Emerald Lake and at additional sites could be monitored during snow melt for major ion chemistry. The hypothesis is that the ANC of the inlets with a coefficient value similar to that of Emerald Lake would decrease during snowmelt to the same extent as Emerald Lake and that watersheds with smaller coefficients would experience greater ANC depressions.

Soil process studies. The bench meadow and inlet meadow or ridge sites seem to be important in the control of surface-water chemistry at Emerald Lake. *In situ* acidification studies could help to determine processes that control the response of these soil solutions to changes in atmospheric deposition or to changes in the relative amounts of nitrate and sulfate. Further hydrologic and chemical characterization of these soil environments also may indicate why soil solutions at the inlet and ridge sites seem to have a similar composition.

Source of "missing" calcium. Soil solutions measured to date (1992) do not have a sufficiently high calcium concentration to explain the streamwater chemistry at Emerald Lake. Additional field research is needed to determine if the discrepancy can be explained hydrologically (for example, a deep ground-water source that is rich in calcium) or mineralogically (for example, a small quantity of a readily weatherable mineral, such as calcite).

Distriibuted hydrochemical model development. The multivariate mixing model indicates that the bench meadow and inlet meadow or ridge site soil environments should be included in a distributed model of Emerald Lake. The development of a distributed hydrochemical model would require a representation of the physical and chemical processes linking snowmelt or rainfall inputs with discharge from these soil environments.