EXECUTIVE SUMMARY--ASSESSING THE RESPONSE OF EMERALD LAKE, AN ALPINE WATERSHED IN SEQUOIA NATIONAL PARK, CALIFORNIA, TO ACIDIFICATION DURING SNOWMELT USING A SIMPLE HYDROCHEMICAL MODEL

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PREFACE

This executive summary contains the findings and additional research needs from a report by the U.S. Geological Survey (USGS), in cooperation with the California Air Resources Board, titled "Assessing the Response of Emerald Lake, an Alpine Watershed in Sequoia National Park, California, to Acidification During Snowmelt Using a Simple Hydrochemical Model," (USGS Water-Resources Investigations Report 90-4000). That report includes a full discussion of the model, its limitations, and its computer code. The data analyzed in that report and this executive summary were collected by various researchers who contributed to the Integrated Watershed Study, an intensive 5-year study of Emerald Lake and its watershed by the California Air Resources Board.

SUMMARY

A simple process-oriented model, called the Alpine Lake Forecaster (ALF), was constructed using data collected from the Integrated Watershed Study of Emerald Lake, Sequoia National Park, California. ALF is able to capture the basic solute patterns during snowmelt in this alpine catchment where ground water is a minor contributor to stream flow. It includes an empirical representation of primary mineral weathering as the only alkalinity-generating mechanism. During a heavy snow year, such as the one used for calibrating the model, the model accurately simulated the surface-water chemical change in response to the initial ionic pulse from the snowpack and to the dilution that occurs at peak snow melt. During a light snow year, there is evidence that cation exchange may be a substantial source of alkalinity during the initial phases of snowmelt. Because the model does not consider cation exchange, it overpredicts the acidification during the initial period of snowmelt, and therefore is a conservative predictor. However, the minimum alkalinity observed in the main inflows to Emerald Lake and in the lake outflow is accurately simulated by the model. The representation of the lake as simply a mixing volume with no additional chemical reactions is supported by the observations.

The model predicts a change of 2 to 5 microequivalents per liter in the minimum alkalinity of the lake outflow during snowmelt if the deposition of both nitrate and sulfate were doubled and a moderate acidic pulse is released from the snowpack. This change would not be sufficient to acidify the lake. Atmospheric deposition would have to increase between two and 18 times the current loadings of both nitrate and sulfate to exhaust the alkalinity of the lake; the precise increase depends on hydrologic conditions and on the pattern of solute release from the snowpack. Although these increases in deposition seem to be large, one should remember that the current loadings to the system are very low. The most likely manner in which acidification of Emerald Lake could occur under conditions ranging from current to double present-day deposition is an acidic rainstorm during the latter part of snowmelt when the alkalinity of the water in the lake is at a minimum owing to dilution from the snowpack. An acidic rainstorm that exhausted the alkalinity of the lake was observed during summer 1984 after the lake had stratified. The infrequency of rainstorms in the Sierra Nevada, however, makes intensive sampling of storms difficult.

ADDITIONAL STUDY NEEDS

Further testing and regionalization of the model. The modest data requirements of the model permit its application to other watersheds that are less intensively studied than Emerald Lake. The model can be calibrated with only water-quality and quantity measurements from the outflow of the watershed. To run the model for any particular year requires an estimate of solute loadings (hydrogen ion, base cation, nitrate, sulfate, chloride and ammonium) in the snowpack. If there are no internal sources of sulfate and chloride in the watershed, these loadings can be estimated from the mass export from the watershed. The applicability of the empirical weathering formulation and the relative importance of primary mineral weathering and cation exchange can be further tested using data from other watersheds. Successful application of ALF to other watersheds in the Sierra Nevada would permit a more regional assessment of the episodic acidification risk.

Further field study of nonreactive solutes. The pattern of solute release from the snowpack is not consistent across the nonreactive solutes. Sulfate, typically the mobile anion in such watersheds, has a nearly constant concentration in the stream. Point measurements and laboratory studies indicate that an acidic pulse should come from the snowpack at the beginning of snowmelt. Additional field observations and experiments need to be conducted to determine why a large increase in sulfate concentration was not observed in the stream.

Input/output budgets also were inconsistent between the study years. In 1986, a year with a large snowpack, sulfate output exceeded sulfate input; in 1987, a year with a small snowpack, the reverse occurred. The large volume of water flowing through the soils in 1986 may have leached more sulfate from them. Alternately, the water may have taken a different flowpath through the watershed owing to the high discharge rates. Whatever the case, available data indicates that the hydrology of the watershed influences the sulfate concentration in the streams and lake. If surface water chemistry at Emerald Lake is to be understood and predicted accurately, soil chemical reactions involving sulfate will need to be identified and quantified.

To identify potential mechanisms that could control the stream-water sulfate concentration, paired mini-catchments having an area of several hundred square meters need to be selected and experiments conducted. These catchments would represent the extremes in soil interactions--that is, one catchment would have only bedrock and the other would be predominantly covered with soil. Meltwater draining the bare rock catchment would not be affected by soil or talus, and thus, the existence or absence of an acidic pulse from the snowpack could be ascertained. In addition to runoff, soil solutions prior to and during the initial phases of melt need to be monitored to determine the effects of the soil on the nonreactive solutes, and on sulfate and chloride. Finally, internal sources of sulfate in the watershed (such as volcanic glass) needs to be quantified.

Relative importance of snowmelt and rainstorms on acidification. The apparent attenuation of the acidic pulse renders this watershed much less sensitive to acidification from an acidic snowpack than if solutes were released with a pronounced acid pulse. Under current depositional loads and even with double the current loads, the watershed is more susceptible to acidification from an acidic rainstorm that falls during the late snowmelt period when the water in the lake is most dilute. Because rain storms are infrequent at Emerald Lake, it is impractical to design a field effort based solely on sampling storms. One field effort that is feasible and that would provide insight on the watershed's response to acidic pulses is an intensive sampling of the inflow streams over the diel melt cycle. Sampling in the early-, mid- and late-snowmelt period would provide information on the chemical changes in response to a more acidic pulse, a clean pulse, and the response after the system has been strongly leached. In addition, if the streams were sampled at points above and below the inflow meadow, the influence of vegetation could be assessed.