JP3.12 PRECIPITATION INDUCED ISOTOPIC VARIATIONS IN STREAMFLOW

Madhav V. Machavaram*, Kathy E. Bashford, Mark E. Conrad, Norman L. Miller
E.O. Lawrence Berkeley National Laboratory, Berkeley, California

1. INTRODUCTION

Understanding the pathways through which precipitation reaches streams and the response of streams to the precipitation is an important aspect of hydrogeological studies. These types of studies aid in the formulation of numerical models for the simulation of the catchment response which are critical for assessing potential flood hazards and guiding land-use management. Utilizing variations in the stable isotope compositions of hydrogen and oxygen in precipitation, stream waters and sub-surface waters is an effective way to estimate the response of various hydrologic compartments in a watershed during a precipitation event. As part of the DOE Water Cycle Pilot Study's Intensive Observation Period (IOP), the Rock Creek drainage was chosen to be studied for the stream response to intense short-term precipitation events.

2. STUDYAREA AND SAMPLING

Rock Creek is a small stream approximately 16 km in length that drains into the Whitewater River of the Walnut River Watershed (WRW) in Butler County, Kansas. The drainage basin for Rock Creek is 32 km^2 and is composed of approximately 70% grasslands, 25% cropland and 5% woodlands. The drainage area is subject to local land management practices, which include agriculture and cattle farming. A stock pond of approximately 20000 m^2 is located in the stream channel near the headwater region of the creek. The pond is mainly fed by precipitation and two small streams and drains into the creek when the water level exceeds the height of an outlet pipe.

Samples from Rock Creek were collected prior to and after two short and intense precipitation events on May 24^{th} and 25^{th} of 2002.

**Corresponding author*: Madhav Machavaram, MS 70A-4418, Lawrence Berkeley National Laboratory, Berkeley, CA 94720. E-mail: mvmachavaram@lbl.gov

Prior to the precipitation event, samples were collected from the creek at six locations, from the stock pond and from the two streams draining into the pond. Soil cores were taken from well-drained and moderately drained soils near downstream and in the catchment area of the pond. Precipitation samples were collected from two samplers installed in the headwater region just below the pond and at a downstream sampling location just before the creek flows into the White Water River. Precipitation amounts were measured with two tipping bucket rain gauges located near Rock creek.

The hydrogen and oxygen isotopic compositions of the samples were analyzed at the Center for Isotope Geochemistry of Lawrence Berkeley National Laboratory. The isotopic ratios are reported using the standard per mil notation relative to the international standard V-SMOW.

3. DATA ANALYSIS

During dry weather periods, the headwater region of Rock Creek is characterized by little to no-flow in the stream. The stream channel in this area is generally dry with isolated pockets of water seeping into the channel through shallow subsurface flow. Following precipitation events, streamflow is dominated by outflow of the pond. In the downstream region, the flow appears to mainly consist of surface run-off and seepage from the drainage of saturated soils. Since the isotopic ratios are distinctive of these components, isotopic variations can be effectively used to understand the response of the creek and the hydrology of the drainage basin to a precipitation event.

During summer months, the $\delta^{18}O$ value of precipitation averages about -5‰. The oxygen isotope values of samples collected from the creek at its baseflow condition range from -1.4‰ to -3.6‰ with most values around -2.8‰. This deviation from the rainfall $\delta^{18}O$ value is the result of evaporation. The pond, with its $\delta^{18}O$ value of 0.2‰ represents an extreme degree of evaporation. The variation of $\delta^{18}O$ in the stream could be due to the variation in the canopy cover and the extent of subsurface inflow at a particular location. Soil moisture tends to be evaporated in the upper 30 cm (average δ^{18}O value: -3.5‰). The δ^{18}O values of soil moisture are similar to the values of soil cores obtained elsewhere in the Whitewater watershed.

The monitoring of Rock Creek began at 12noon on 23rd May 2002. Precipitation samples were collected from three rain events during the 24th and 25th of May (Figure 1). The first event was an intense, regional storm that occurred at 6 A.M. on May 24th (hour 18), producing 133 mm of rain with an average δ^{18}O value of -4.4‰. Later that day, in the early afternoon, a local convective storm produced 30 mm of rain with a δ^{18}O value of -3.8‰. The third event was similar in character to the first storm, and resulted in another 123 mm of precipitation with a δ^{18}O value of -5.4‰. Throughout this time period and continuing through hour 100, stream samples were collected from an upstream and a downstream location. The upstream station was located in the headwaters region immediately below the pond. The downstream station was located near the confluence of the Rock reek and the Whitewater River.

The stream level was measured near the downstream station throughout the monitoring period. Based on the change in the stream level measured over time, a hydrograph was constructed. The effect of the successive precipitation events on the stream flow is evident from the hydrograph presented in Figure 1. Efforts are currently underway to quantify the relationship between stream height and flow volume.

The δ^{18}O values of the stream samples collected from the upstream and downstream stations during the monitoring period are plotted on Figure 2. It is clear from the figure that the isotopic compositions of the upstream samples varied differently than the downstream samples. The isotopic variations observed at the upstream station are primarily a function of the isotopic composition of the pond. Outflow from the pond into the creek began immediately following the first precipitation event. The outflow continued through the monitoring period, with highest flow intensity observed following the third precipitation event. Outflow from the pond gradually started to decrease at approximately hour 54.

The δ^{18}O data from the upstream station indicate a gradual replacement of residual pond waters by precipitation during, the monitoring period, with the isotopic signature of the pond gradually shifting towards the isotopic signature of the precipitation.

During the first 44 hrs, the δ^{18}O data from the downstream station indicate that the streamflow at this location is primarily comprised of precipitation. It is believed that the outflow from pond does not significantly contribute to the flow downstream, at least to the rising limb of the flood hydrograph. The drainage area near the downstream station is characterized by a combination of agricultural lands with subsurface tile-flow installations and also clayey soils with low permeability. These two factors seem to facilitate rapid overland and shallow subsurface flow to the creek, effectively reducing the stream response time to an intense precipitation event. Gradually, the isotopic composition of the stream appears to be increasingly influenced by the residual soil moisture, which seeps into the stream as it is replaced by infiltrating precipitation water. The δ^{18}O values of soil moisture after precipitation (-4.4‰) and that of a shallow seepage (-2.6‰) near the downstream station suggest replacement of shallow evaporated soil moisture. It is also possible that the evaporated water from pond may have contributed to the observed isotopic shift, but this is not believed to have been very significant.

4. SUMMARY

As part of the DOE Water Cycle Pilot Study's Intensive Observation Period (IOP), measurements were made at Rock Creek, located in Walnut River Watershed (WRW), Kansas. Stable isotope analyses of various hydrologic components in the study area provided a better understanding of the influence of these components on the overall stream response. The response of the creek to intense precipitation events appears to be governed and altered by land management practices in the drainage area. This information, which otherwise could not be inferred from traditional methods of hydrologic investigations, signifies the importance of stable isotope studies in flood hydrology.

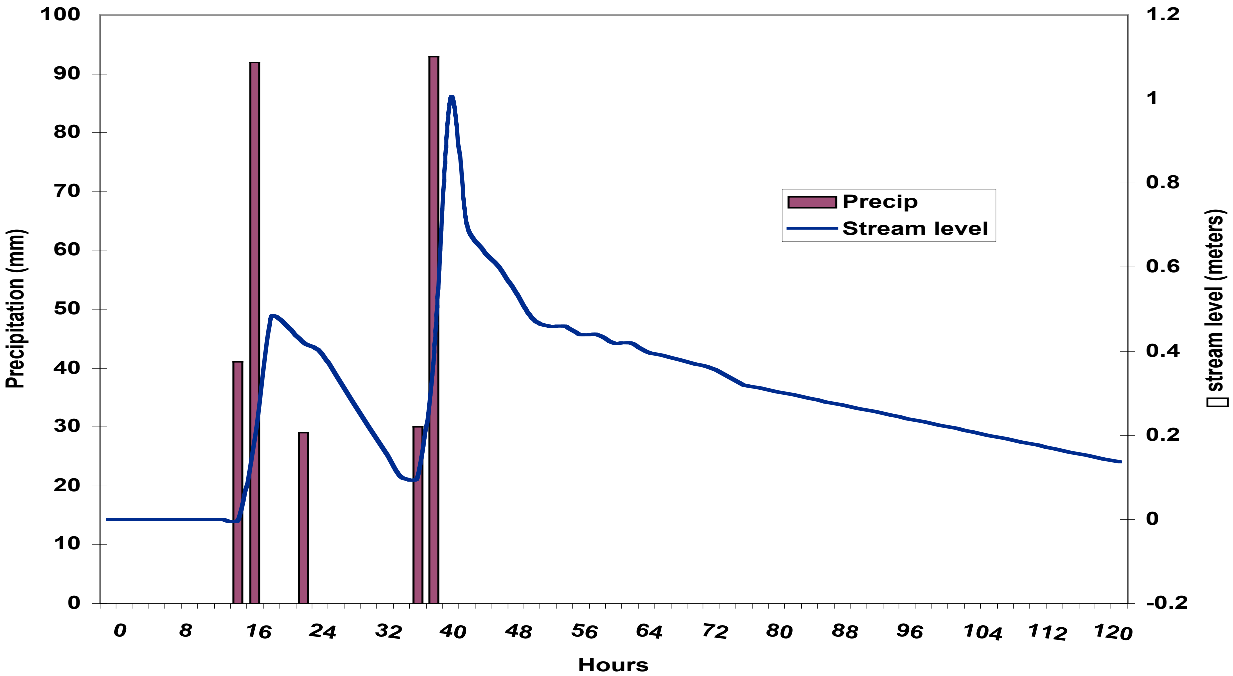

Figure 1. Plot showing the response of Rock Creek to the precipitation events. The stream level is plotted as the change from a reference datum. The 0 hr in the graph corresponds to 12 noon on 23rd May 2002.

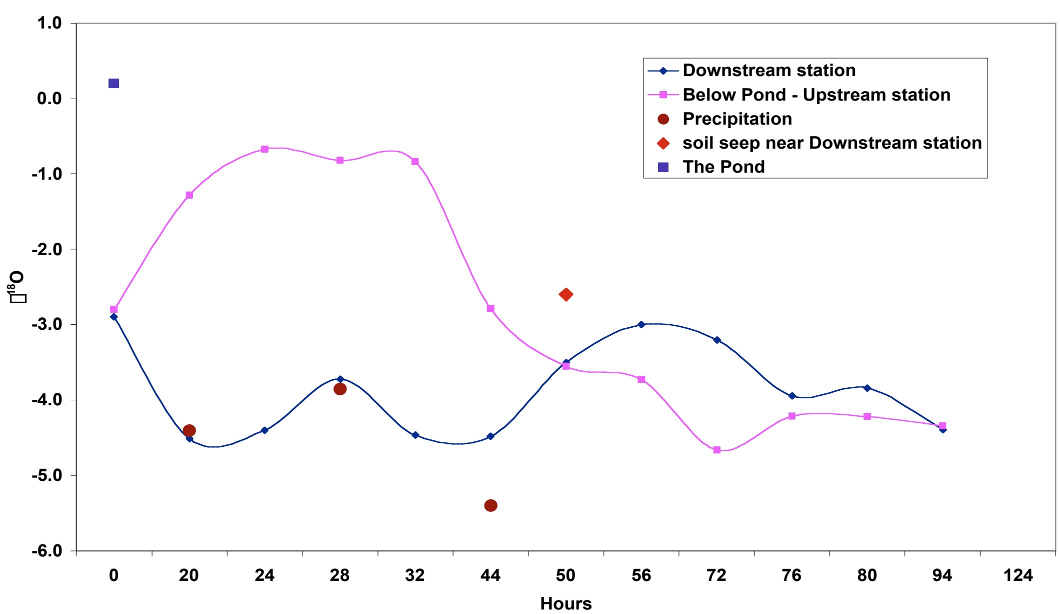

Figure 2. Variation of □^{18}O in the stream at an upstream and a downstream location, plotted as a function of time. Precipitation samples were plotted at the time precipitation event ended. The 0 hr in the graph corresponds to 12 noon on 23rd May 2002.