A study on the near stream flow generation mechanism of a mountainous catchment.

Werellagama, D.R.I.B., Nagoya University, Student Member
Matsubayashi, U., Nagoya University, Member
Takagi, F., Nagoya University, Member

Introduction

This paper presents a brief review of the dynamic nature of the near stream flow mechanism, observed at the Nagoya University experimental catchment in Kanedaira in Gifu prefecture. Kanedaira catchment is a small, forested, mountainous catchment. The basin is consisted of weathered granite, overlain by a thin soil cover of about 1m depth. The basin characteristics and topography are given in Matsubayashi et al.(1990). They have observed the runoff ratios in this catchment to vary between 1.5% to 18.5%. Hydrological data obtained during the summers of 1995 and 1996 also support this observation, showing that the runoff hydrograph can be produced by the rainfall on a narrow contributory area, which is only few meters (<10m per unit length of the channel, for most rain events).

Previous isotopic data (Matsubayashi et al., 1990) have shown that more than 80% of the direct runoff in this catchment occurs as the outflow of stored water. Volumetric behavior observed in this series of experiments indicate almost instantaneous stream response to the rainfall. Therefore the near stream flow generation mechanism should be a one which responds to the rain input very fast but releases stored water. The streamwater specific electric conductivity (SC) showed rising and falling behavior with discharge peak for varying background conditions.

Observations and Discussion

In this paper, the data for a typical rain event (rain Event 8, September 9/10, 1996) are discussed. If the total volume of the runoff hydrograph is generated by the current rainfall only, the rainfall on a narrow strip of 7.5m width along the length of the stream, can generate the hydrograph. But as previous finding shows stored water to be the major contributor, the storage capacity of the stream bank is assessed to verify its ability to store subsequent rain hydrograph volumes. For this rain event, a saturated zone of $3m^2$ per unit length of the stream, can store the volume of the runoff hydrograph, even assuming a low effective porosity of 0.1 for the soil matrix. Therefore it is possible for the near stream flow mechanism to be a one which takes in the rainfall on the stream bank, and pushes out the stored water to the stream.

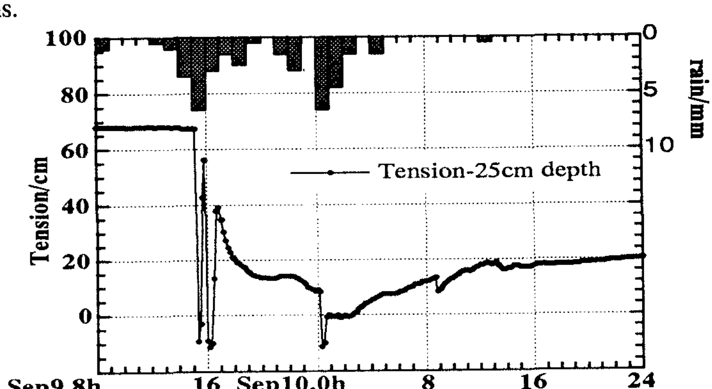

Fig 1: Event 8, Rain and Tension

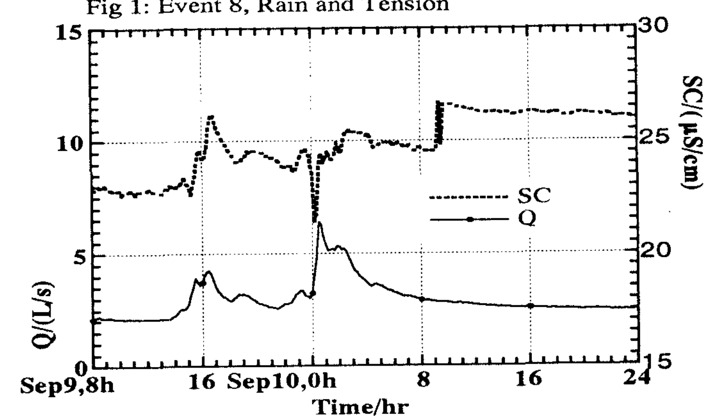

Fig 2: Event8, Streamwater SC and Discharge

Figures 1 and 2 show the rainfall, runoff, streamwater SC and soilwater tension data for rain Event 8. This event delivered 41.5 mm of rain. The antecedent conditions were dry, with antecedent rainfall index for previous 10 days $\sum Pi/i$ (Pi is the rainfall on the i th preceding day), showing a value of only 3.3 mm/day. The flow hydrograph (Q) shows the typical fast response to the rain input. The SC of streamwater rises with the hydrograph peak at the first rain peak, and falls with the second rain peak. The streamwater temperature did not vary significantly during this period.

Tensiometer data (Figure 1) were for a tensiometer located 1.4 m from the stream bank as shown in Fig 3. The data recording frequency was once in 10 minutes. The tension data show the soil at the 25 cm depth getting quickly saturated with the rain input and then tension increasing fast, before the next burst of rain again saturates that layer. A similar but less pronounced effect is seen for the second rain peak. The soil tension behavior shows the induction of high hydraulic gradients in response to the rain input, and fast drainage of water from that layer when the rain input stops.

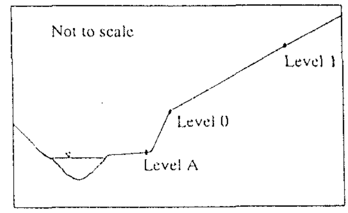

Fig3: Schematic diagram of tensiometer / sampler locations

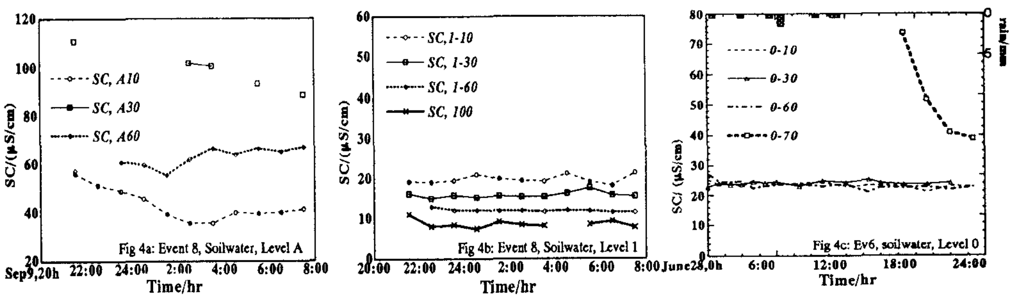

Figure 4: Soilwater SC behavior for Rain Events 6 and 8

SC values in the soil layers at level A (1.4 m from the stream) showed the highest SC in the 30 cm depth as shown in Figure 4a. These values are higher than the stream SC for the whole duration of the Event 8. On the other hand, the SC values in the hillslope soil (at Level 1, 7m from the stream bank, Fig 4b), show SC values lower than that of streamwater, throughout the rain event. Fig 4c shows the soilwater behavior at station 0, for rain event 6 of June 28, 1996. For this small rain, the soilwater showed typical low SC values. The granite layer did not yield a sample during rain, but when the water reached the granite layer after a lag period, it gave a very high SC value which decreased sharply in the following samples.

The Specific Electric Conductivity (SC) response of the streamwater for rain event 8 was shown in the Figure 2. While the SC peaks are almost in phase with the rising limb of the hydrograph peaks, one hydrograph peak has accompanying rising SC and the other shows a falling SC. This chemical behavior can be explained by a conceptual model where the high hydraulic gradients induced in the surface layers due to rain input, push out stored water in the discharge position. The first rain peak shown in Fig 1, after dry antecedent conditions, pushed out old water with higher SC, replacing it with new water. The water pushed out in the second rain peak was this stored (relatively new) water, resulting in the observed SC trough. The values finally stabilized during the long recession period, showing the possible effect of blending of upslope water with near stream water during the recession period.

The observed flow behavior is compared with the concept of the groundwater ridging (Ragan ,1968). A ridge in groundwater table forms in the near stream area with a high groundwater table, when a small quantity of rainwater infiltrates the soil and converts the tension saturated capillary fringe into a pressure saturated zone. This very rapid, but localized, response in the groundwater table causes immediate gravity drainage of groundwater into the stream. As the rainfall decreased this ridge drained and produced a more typical groundwater profile. The groundwater table away from the stream did not respond as rapidly because of the larger depth of overlying soil. While the rapid saturation and drainage of the surface soil layers and the chemical behavior of the stream and soil water show circumstantial evidence to the existence of a groundwater ridging type flow phenomena, further instrumentation is needed to prove that the near stream flow mechanism at Kanedaira catchment is of groundwater ridge type.

Conclusion

Rapid saturation of the tension saturated layer with rain water input and its drainage was demonstrated. Due to the transient nature of the phenomena, the necessity of more intensive, high frequency data gathering is emphasized. The stream SC behavior is explained by the mobilization of vadose zone water due to rainwater input and possible later effect of blending of upslope water with near stream water during the recession.

References

Matsubayashi, U. et al., (1990), Separation of runoff.., J. Hydroscience & Hydraulic Engg, 7(2), 51-59.
Ragan, R.M., (1968), An experimental.., Intl. Assocs.. Sci. Hydrology, Publication 76, 241-249.