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Evidences of Bedrock Groundwater Control of Sediment Cover Moisture and Runoff Generation Processes in a Watershed Underlaid by Fractured Bedrock

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The participation of the bedrock groundwater on hydrological processes, such as storm runoff generation, in mountainous watersheds has been commonly relegated to secondary roles. That role is more diminished when the bedrock is covered with tick soil or any deposit cover. The present study is aimed to show evidences that the bedrock groundwater can influence hydrological processes and it can represent an important factor that determines the characteristics of watersheds discharge as a response of a rainfall events.

The study was carried out in a small watershed (0.02 m^2) in Katsuragawa Study Site, in Hira range, 18km to the north of Kyoto in Shiga prefecture (Figure 1). The geology of the bedrock is fractured sedimentary rock, shale interbedded sandstone and chert. The study site is crossed by the Hanaore fault system, a main strike-slip fault and high-angle sub-faults with evidence of activity during the Quaternary. The bedrock is covered by a talus deposit that increase is depth downslope from few cm in the almost 10 m at the outlet of the watershed. Above that deposit is presented a soil cover with a constant depth of 1.5 m to 2 m.

In the watershed, in addition to the runoff observation, four groundwater observation points were installed. Each point contain up to three boreholes screened at different, observing the groundwater in the deposit talus, upper bedrock and deep bedrock. Additionally, sets of tensiometers were installed on each borehole observation points to measure the soil moisture at different depth of the soil cover (Figure 1). The record periods are the rainfall seasons from 2014 to 2016. From 2015, the electrical conductivity of groundwater (EC) and temperature of groundwater and soil cover were measured.

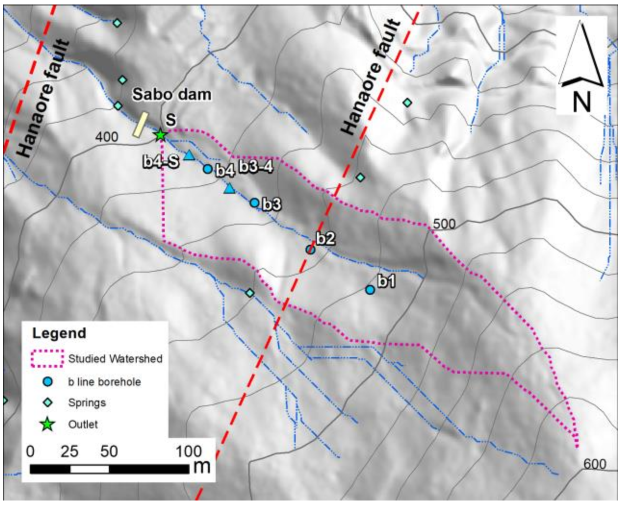

Figure 1. Study site

As a result, during 2014 it was observed the biggest rainfall event in the observation period (Acc. Rainfall 451mm in 2.5 days; Max Intensity. 61mm/h). In general the discharge of the watershed showed to be directly related to rainfall however only for this event a delayed discharge, not associated to any rainfall and detached from the main discharge, was observed (Figure 2). The volume of the discharge represent almost the double generated from the direct rainfall discharge. The delayed discharge showed a significant reduce in the discharge temperature not observed for regular discharges. From groundwater in boreholes we can observe that the delayed discharge has a similar timing with the peak of water level in the most shallow boreholes and b3. The tensiometers in b3 and b4 shows that also the delayed discharge is correlated to an increase in the potential of the deepest tensiometers (140 cm and 200cm deep) representing an upward flow

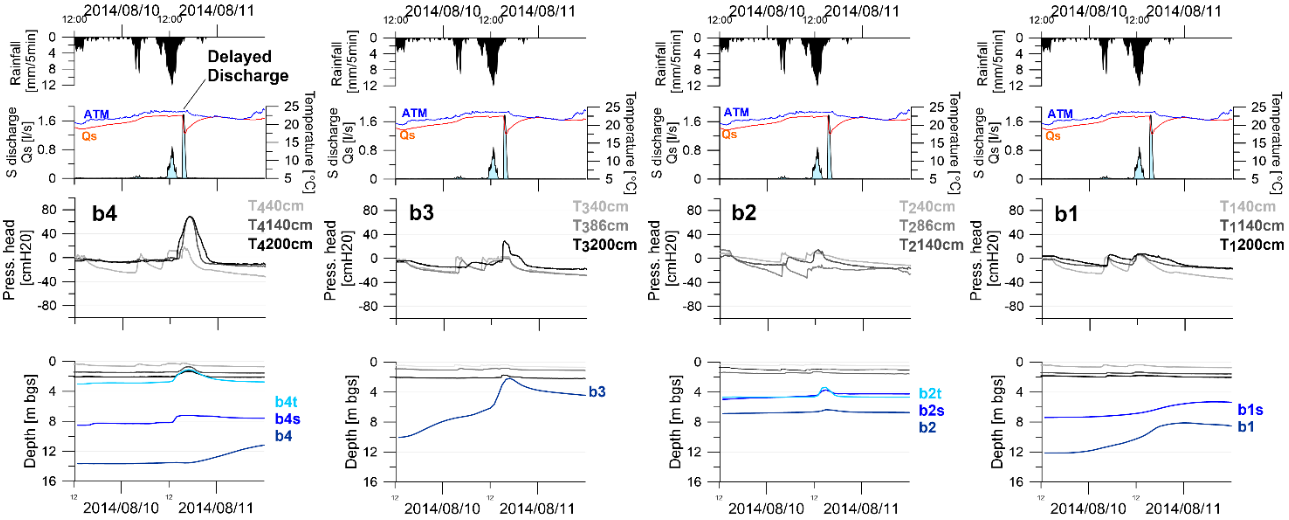

Figure 2. Detailed observation of 2014.

of water. These result suggest that the delayed discharge may be a direct discharge from groundwater apparently coming deeper than the soil cover. However it is not possible to confirm the direct contribution of groundwater from bedrock. During 2015 and 2016 additional observations methods and point where added in order to analyze an eventual generation of a delayed discharge, but the rainfall in the two subsequent years were not big enough to generate it. Although, it was possible to have a complete records of temperature fluctuation in soil and groundwater and EC in groundwater as a response of rainfall events. The observations suggest the generation of an apparent flow of groundwater in the upper bedrock but mainly through the talus deposit that might be responsible of the generation of the delayed discharge observed in 2014. This may validate previous authors that proposed the importance of the soil-bedrock interface in the runoff generation processes (McDonnell, 2013). However, for this case, the groundwater temperature changes in the shallowest boreholes as a response of rainfall events (b4t and b2t in Figure 3) demonstrate different sources of water during rainfalls. Additionally the clear differences in EC values and the deep, middle and shallow bedrock and talus deposit groundwater may also suggest the interaction of the geological features in bedrock in the generation of the talus deposit flow at the interface soil bedrock and its eventual discharge at the outlet of the watershed. The mentioned of the geological features are related to the different fracture levels of bedrock observed in boreholes that can be related to the presence of the sub fault traces of the Hanaore fault system.

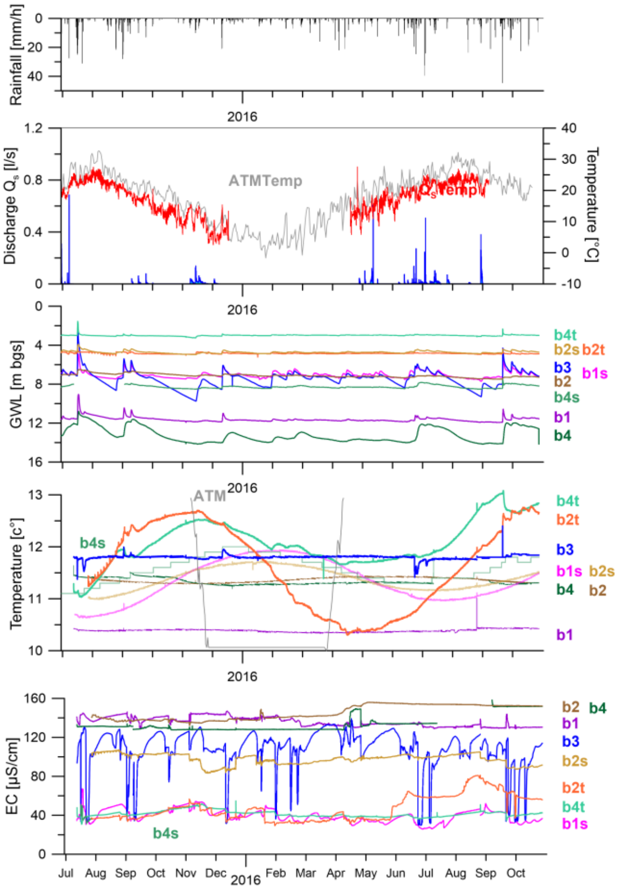

Figure 3. Summary of observation of 2015 and 2016.

References:

McDonnell, JJ. 2013. Are all runoff processes the same? Hydrological Process, 27: 4103-4111.