Rainfall-runoff relationships complementing previous sediment transport studies at the Arroyo de los Piños, Socorro, New Mexico

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Abstract

In semi-arid climates, sediment influx to large rivers, such as the Rio Grande, from small ephemeral streams is challenging to quantify (Bull, 1997). Small ephemeral streams are not studied as often as perennial streams because of their erratic nature and the fact that they are usually located in hard to access, remote deserts where flash floods are common. The Arroyo de los Piños is currently one of very few study sites collecting data on water velocity and discharge, bedload and suspended sediment, as well as other measurements that may be relevant during a flood event. This study site is located close to the confluence of the arroyo and the Rio Grande, yet data on the contributing watershed are lacking. Gaining a clearer picture of stream connectivity and rainfall-runoff relationships in this channel will be useful for quantifying flow generation as well as aquifer recharge and transmission loss through the stream bed. These processes affect flow conditions, and thus sediment transport.

Over the past monsoon season seventeen Hobo U20 pressure transducers were installed in the Arroyo de los Piños watershed (Figure 1). These absolute pressure loggers monitored water level at five-minute intervals. Atmospheric pressure loggers allow compensation of barometric pressure, which can very considerably under different atmospheric conditions. To determine the hydrostatic pressure associated with a change in water stage, we subtract the atmospheric pressure from the total (atmospheric and hydrostatic) pressure monitored by the loggers in the channel. In addition, one recording rain gauge was added to the two existing gauges. For this analysis, we focus on the two rain gauges towards the middle of the watershed (Rain Gauge A and B in Figure 1). The placement of the loggers and rain gauges aim to capture geologic heterogeneities within the watershed. Being able to determine the geology that experiences overland flow during a given event likely has implications for the composition of the sediment transported to the monitoring study site (Stonestrom et al., 2007).

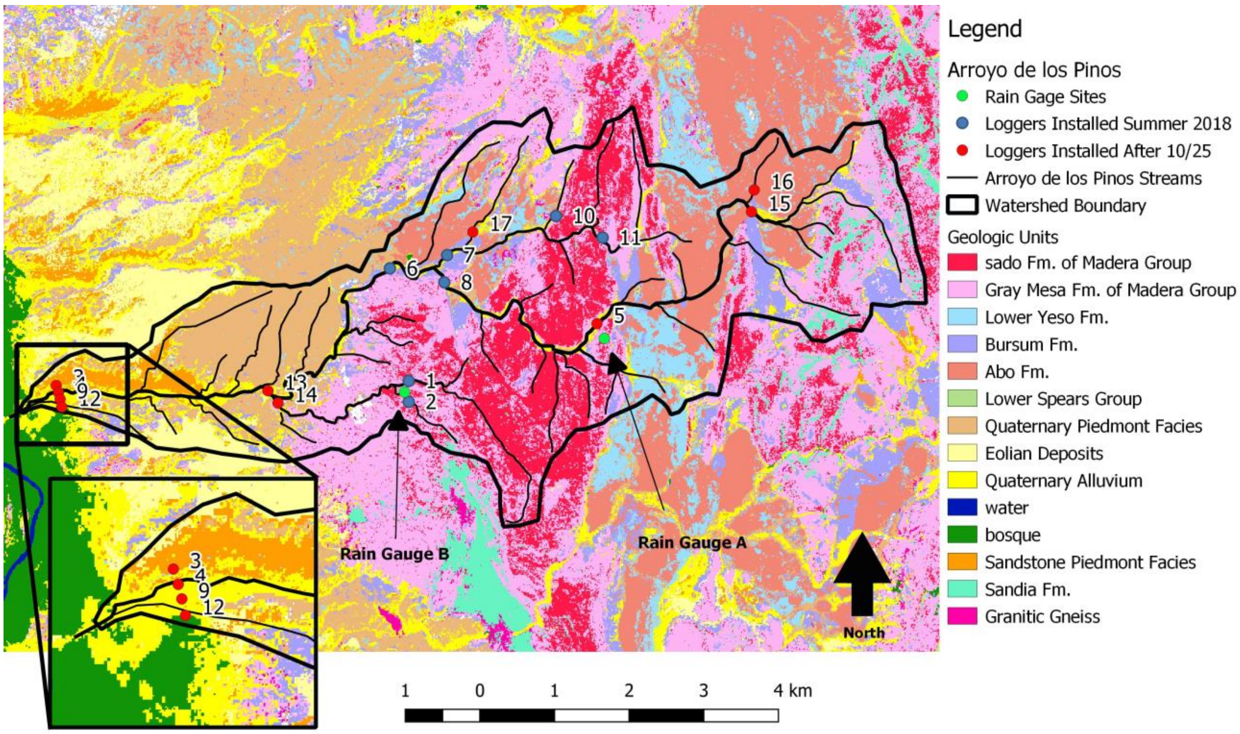

Figure 1: Arroyo de los Piños pressure transducer and rain gauge sites, with inset of closely placed pressure transducers in the lower braided reach. The underlying geologic map is adapted from Cather 2005. Red circles are pressure transducers installed after the two storms looked at in this paper (we do not have flood data at these sites).

Several floods have been recorded in the arroyo tributaries since the loggers have been installed. Here we investigate two flood events (October 2-3 and October 23-25, 2018) to illustrate how flow propagated through the network of tributaries.

Both flood events produced small floods that arrived at the basin outlet to the Rio Grande. The first event took place from the evening of October 2, to the morning of October 3 (Figure 2). Rainfall in this event was most intense in the northern portion of the watershed, and therefore runoff was only registered in tributaries located in this part of the basin.
Water first occurred at sites 10 and 11 (Figure 1, 2), on two small tributaries draining the Madera Group, which is dominated by limestone. Subsequent flow was observed at sites 8, and 7, larger channels farther downstream.

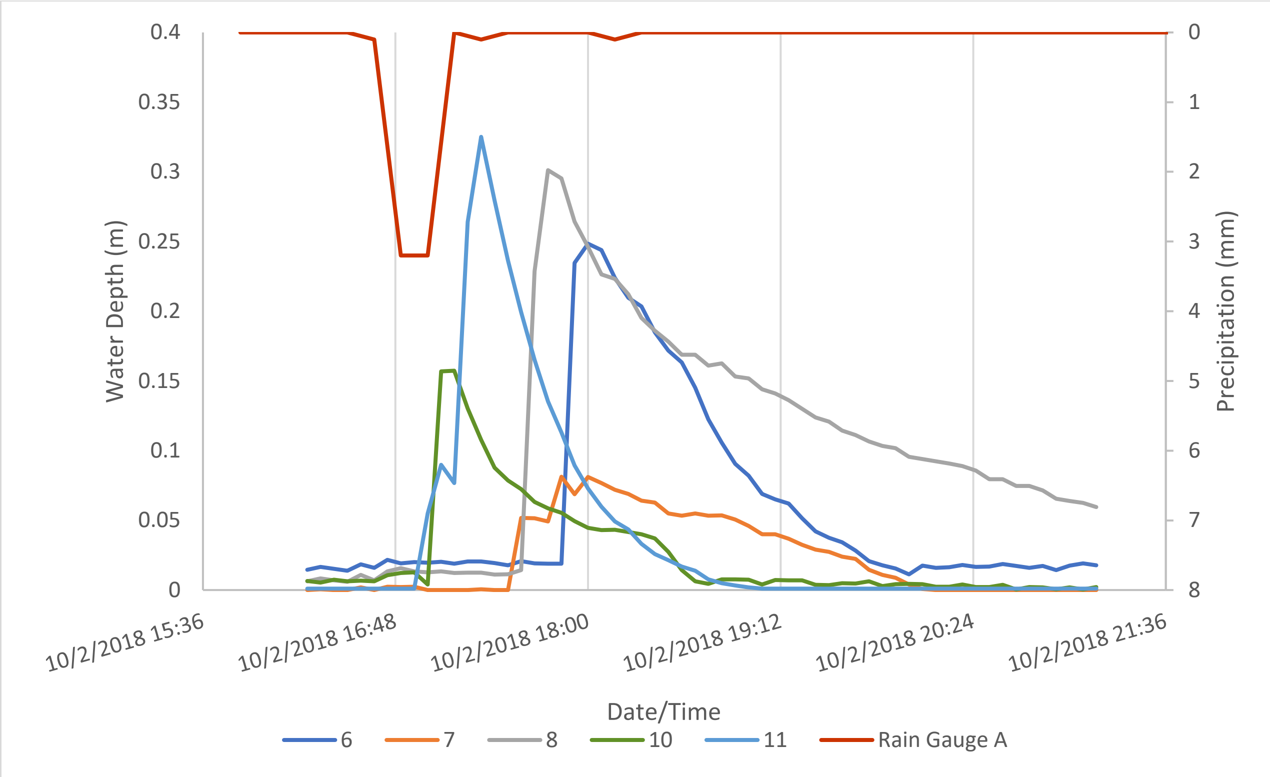

Figure 2: Tributary stage hydrographs as of October 2-3, 2018. Flow was quickly routed downstream from upper tributaries (10 and 11) to the confluence of two main tributaries (7 and 8) and eventually to the basin outlet.

Moderate rainfall over three days (October 22 – 24) caused two distinct flow events on October 22 and on October 24 (Figure 3). Both events were small although recession limbs lasting a few hours are observed. Some water remained in the stilling well after each event and slowly infiltrated into the local aquifer. This is why the graphs of water depth do not return to zero as soon as expected; it is a remnant effect of pooled water. Tributary 6 was first to respond with a small pulse of water, shortly followed in tributaries 2, 8, 11, 10, and 7. From this order and timing it appears that the storm cell was strongest in the center, and weaker towards the eastern and western portions of the watershed.

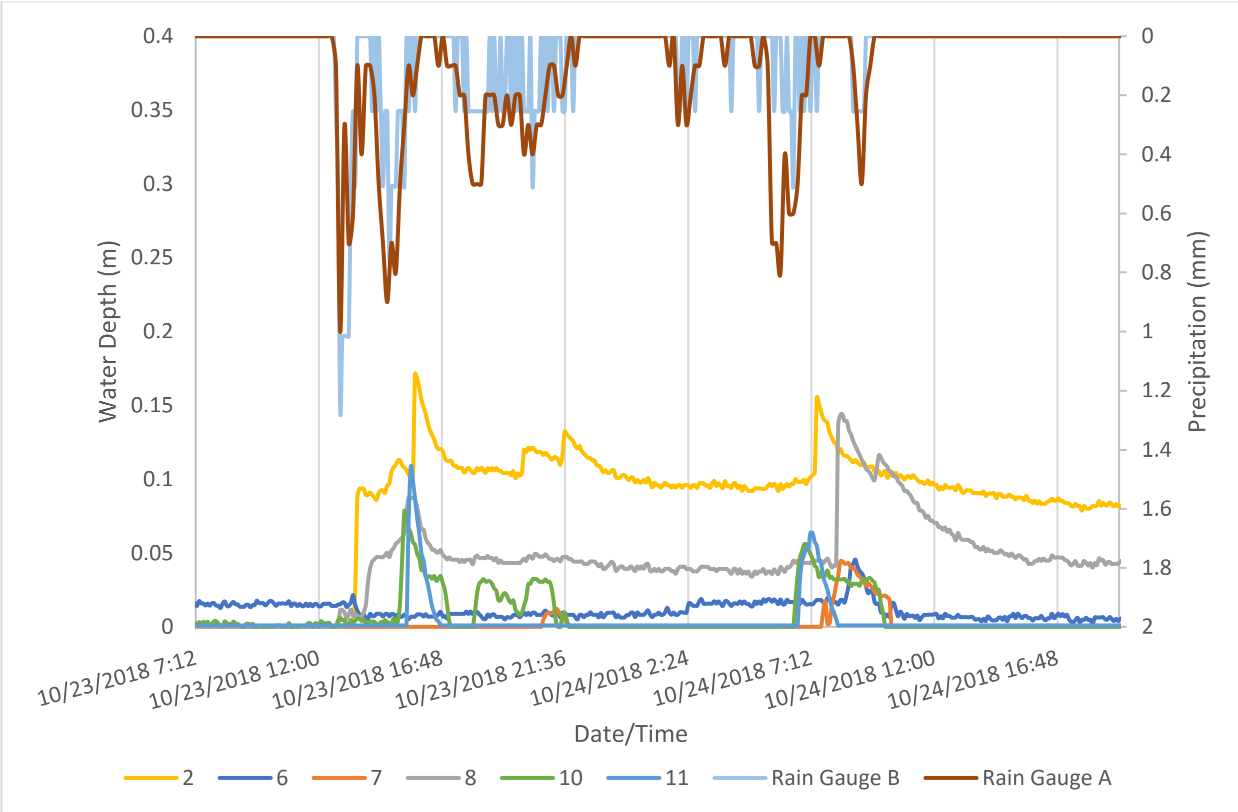

Figure 3: Tributary histograms for October 23. Flow was initiated at pressure transducer 2 in the southern portion of the basin, quickly followed by flow at 8, 10, 11, and 7 in the northern part of the basin.

Through pressure transducer data we can infer the pathway the storm took, and to some degree the intensity of the storm. We can also document which lithologic units produced flow most readily. We have limited rainfall and runoff data from 2018, but now that pressure transducers and rain gauges are installed and fully functional, our instrument coverage for the 2019 monsoon season will allow us to more accurately describe rainfall-runoff relationships in the Piños.

It would be very helpful to have discharge hydrographs instead of stage hydrographs. This would allow us to make better comparisons between the flooding at each cross section, since the cross-sectional area of the channel, channel slope, and roughness vary at each pressure transducer site. Discharge is calculated by multiplying the cross-sectional average water velocity by the cross-sectional area to get a volumetric flux of water. However, at the pressure transducer sites it is not feasible to collect velocity measurements for every flood, and so we will use the Manning's equation to circumvent the velocity measurement. For SI units, the Manning's equation is:

$$V = \frac{1}{n}\left(\frac{A}{P}\right)^{2/3} S^{1/2}$$

Where V is velocity, n is the roughness coefficient, A is the cross-sectional area, P is the wetted perimeter, and S is water surface slope. We make the assumption that water surface slope is essentially equal to bed slope. Figure 4 shows the discharge hydrograph that corresponds with pressure transducer 6 and 8 for the flood on October 2nd. In figure 2, cross section 6 and 8 appear to have similar storm hydrographs. In comparison, in figure 4, cross section 6 and 8 show very different trends. This highlights the importance of comparing discharge at each site instead of stage.

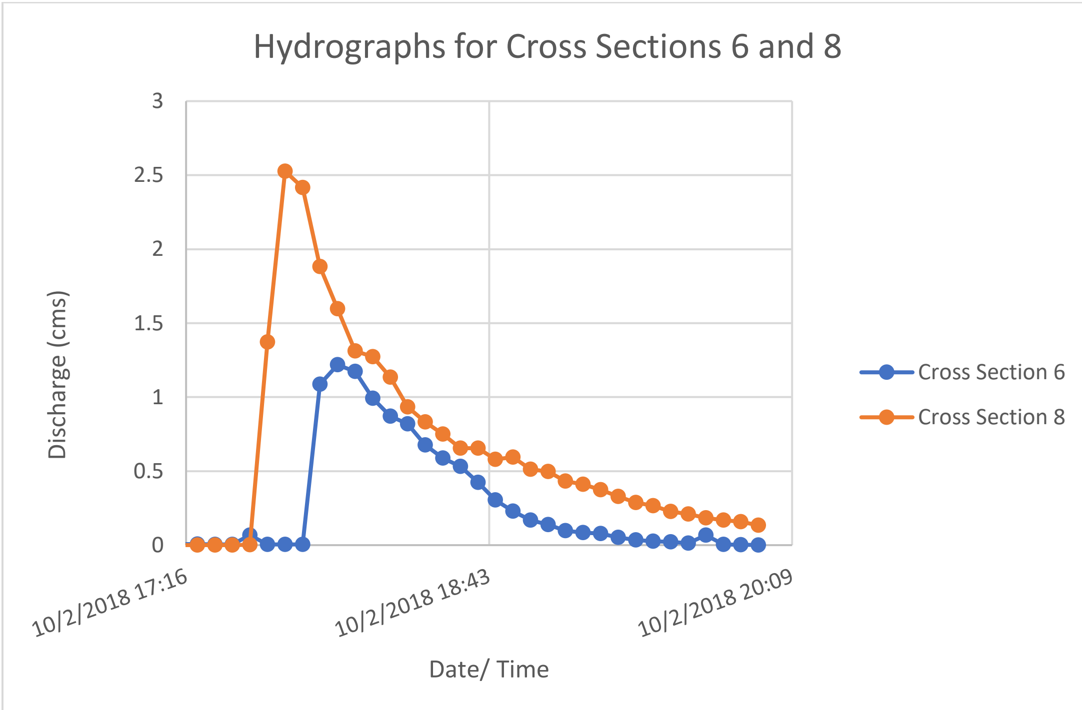

Figure 4: Discharge Hydrograph for cross sections 6 and 8 on October 2.

It is extremely important that we continue to collect more physical precipitation measurements when trying to find a relationship between rainfall and runoff in the Arroyo de los Piños watershed. Radar data available through NEXRAD is not well correated with the precipitation measurements collected using a tipping bucket rain gauge (shown in figure 5). Figure 5 shows precipitation plotted against the NEXRAD reflectivity. Both the reflectivity and rainfall data are taken over 15-minute intervals. The rainfall data is a point source measurement (collected at rain gauge A) while the reflectivity values were averaged over the five raster cells surrounding the rain gauge.

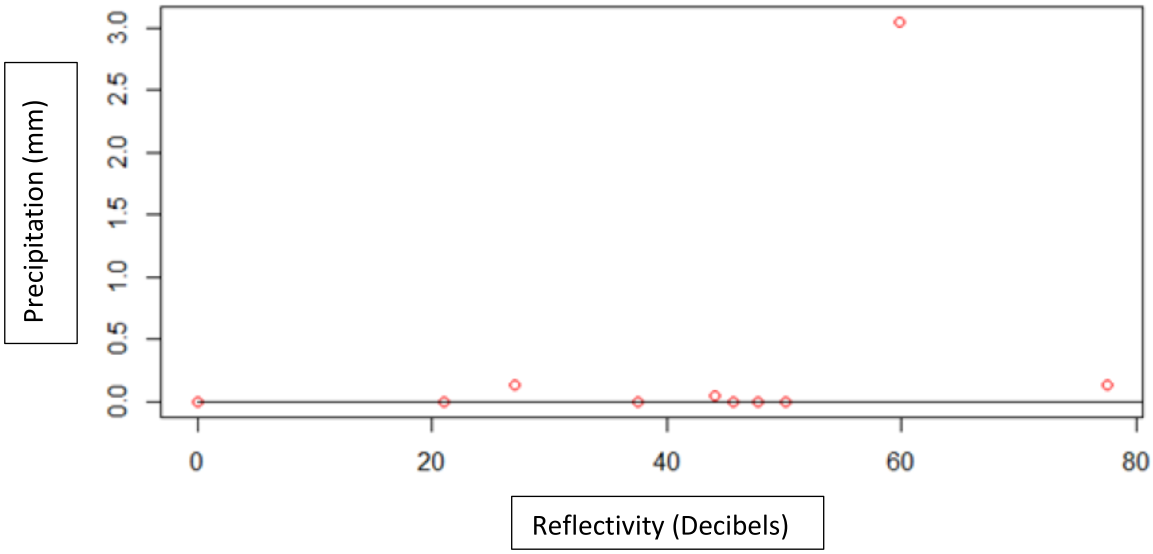

Figure 5: Correlation between NEXRAD reflectivity and tipping bucket precipitation.

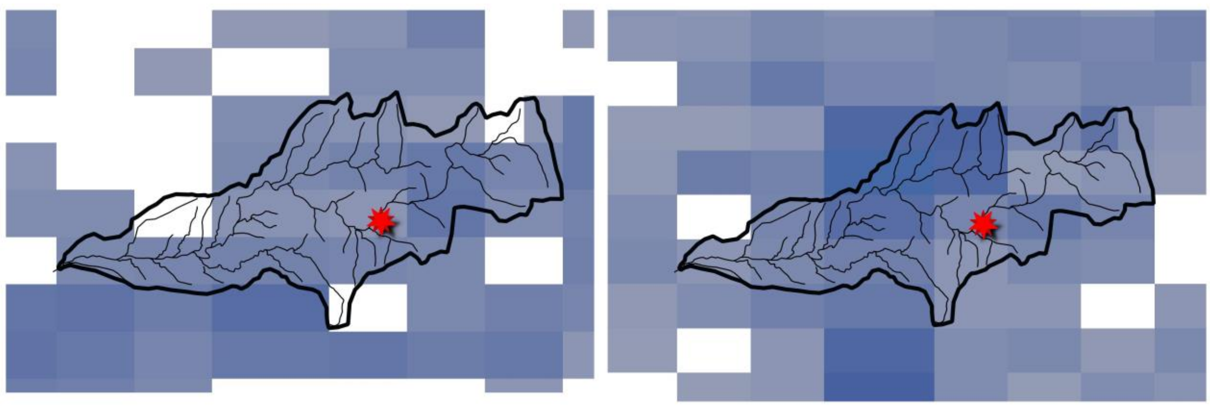

Figure 6: NEXRAD reflectivity raster for October 2nd storm. The left image is from 17:00, and the right is from 18:00. The red star shows the location of the rain gauge used in this analysis.

Figure 6 shows two reflectivity rasters (the left is from 17:00 and the right is from 18:00). Our rain gauge (shown as a red star) measured rain at 17:00, but no rain at 18:00. However, this is the opposite trend shown by the NEXRAD reflectivity raster (figure 6). This highlights the need for a wider array of tipping bucket rain gauges in the watershed to accurately capture the spatial distribution of the storms.

References

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