JE Fuller/ Hydrology & Geomorphology, Inc.

September 3, 2008

Michael D. Park
Noah's Ark Group Study (NAGS)
Flood Study Review Chairman
5150 Alamo Mine Trail
Las Cruces, NM 88011

RE: Talavera Floodplain Delineation Study

Dear Mr. Park:

I have reviewed the technical information from the URS floodplain delineation study you provided on behalf of the NAGS and offer the following recommendations and findings summarized in this letter.

Summary & Recommendations

It is our professional opinion that there are ***serious technical flaws*** in the hydrologic modeling, application of the hydrologic modeling to the FLO2D floodplain model, the execution of the FLO2D floodplain delineation modeling, and the generation of the floodplain maps based on the modeling effort. Furthermore, the floodplain delineation did not follow critical FEMA guidelines for floodplain delineation of alluvial fans. Finally, and most importantly, based on our interpretation of the data provided, we do not believe the floodplain delineation accurately depicts the flood hazards in the study area. Areas that should be mapped in the floodplain are not, and many areas that are unlikely to be flooded are mapped in the regulatory floodplain. The URS floodplain delineation should not have been approved and should be revised immediately.

Hydrologic Modeling

- ***Rainfall***. The rainfall values presented in Table 2 of the URS Hydrology Report do not match the values shown in the NOAA website printouts presented in the URS Hydrology Report Appendix. However, since the rainfall values are not a variable used in the regression equation used to estimate the recommended 100-year discharges, this error has little significance for the results of the floodplain delineation.

- ***Regression Equation***. The National Flood Frequency (NFF) regression equation discharge estimates described in the hydrology report and subsequently used in the floodplain delineations differ

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significantly from the discharge values URS estimated using HEC-HMS. No explanation is provided in the Hydrology Report for the differences between the discharge estimates. The study contractors and review agencies decided that the NFF regression equation results provided more realistic values, but no technical justification for this decision was provided in the project documentation. While the use of regression equations is not unusual in some parts of the country, a serious consequence of using the NFF equations rather than the HEC-HMS model is that regression equations only estimate the peak discharge, rather than the entire flood hydrograph. The URS floodplain delineation is based on FLO-2D modeling, a key element of which is routing and accounting for the entire flood hydrograph. Therefore, the regression equation approach does not provide critical information needed for the FLO-2D model, and URS had to make simplifying assumptions to generate a flood hydrograph.

- ***Subbasin Delineation***. The watershed subbasin delineations were generated using automated procedures (software) and digital elevation model (DEM) data. As is often the case when using automated procedures, the subbasin delineations are crude but reasonable where the topography is well defined, but have significant problems in areas of complex topography. The subbasin delineations would have been improved by applying engineering judgment, and by using visual interpretation of the topographic mapping and aerial photography. URS made two key errors. First, flow paths frequently cross the subbasin boundaries. Second, the concentration points are not located at the subbasin outlets. Examples of the first error are shown in Figures 1 and 2, where the aerial photography clearly shows flow paths crossing the delineated boundary between BASIN4 and BASIN5. The same error is depicted in Figure 3, in which the USGS topographic quadrangle mapping clearly depicts a flow path that crosses a subbasin boundary. The correct method of delineating the watershed boundary would be to place a concentration point where flow crosses from one subbasin to another, or to identify a split flow point. The consequence of incorrectly delineating subbasin boundaries is that the basin area is the primary variable used to estimate the 100-year discharge. Therefore, errors in basin area are directly correlated to errors in discharge. If the discharge is incorrect, the floodplain delineation will be incorrect.

- ***Subbasin Size***. The individual subbasins used in the hydrologic modeling are rather large. Because of their large size, they tend to include more than one significant flow path within their boundaries. Typically, subbasins are delineated so that each concentration point represents one significant flow path and/or confluence point. For example, as shown in Figure 4, the BASIN4 subbasin has four significant wash segments, some of which breakout into BASIN5 and BASIN7 at various locations. These flow paths and breakout points are also discernable on the USGS topographic maps and could have been identified without inspection of the aerial photographs. The subbasin delineations should be refined to better represent the flow concentration points and discharge values at the floodplain delineation reaches. The consequence of this error on the floodplain delineation becomes more apparent because of how URS chose to enter the discharge estimates into the delineation model, as discussed below.

- ***Discharge Inflow Points***. The inflow values in FLO2D model are based in part on the 100-year discharge values presented in the URS Hydrology Report. However, the 100-year discharge values taken from the Hydrology Report were inexplicably applied at single grid cell locations in the FLO2D model, despite the fact that the floodplain at the inlet point spans many individual grid cells. Also, for some unknown and inexplicable reason, URS applied the discharge values at grid cells located along a single flow path within each subbasin, rather than at the concentration point at the outlet of the subbasin. These inflow locations appear to be chosen arbitrarily, with no explanation provided to justify their selection. For example, in BASIN7, which covers an area of 92 square miles at the downstream end of the watershed, discharge is entered at a grid located on the northeast side of the basin (Figure 5), completing missing several of the key flow paths. Since the FLO2D model has the ability to model rainfall runoff, there was no need to take the unusual approach used by URS. Use of FLO2D's rainfall component would also distribute floodwater to all the washes with significant capacity within the study area, whereas URS's approach lumped flows at single grid locations within the subbasins. The red dots in Figure 5 depict the flow inflow locations used in the URS delineation.

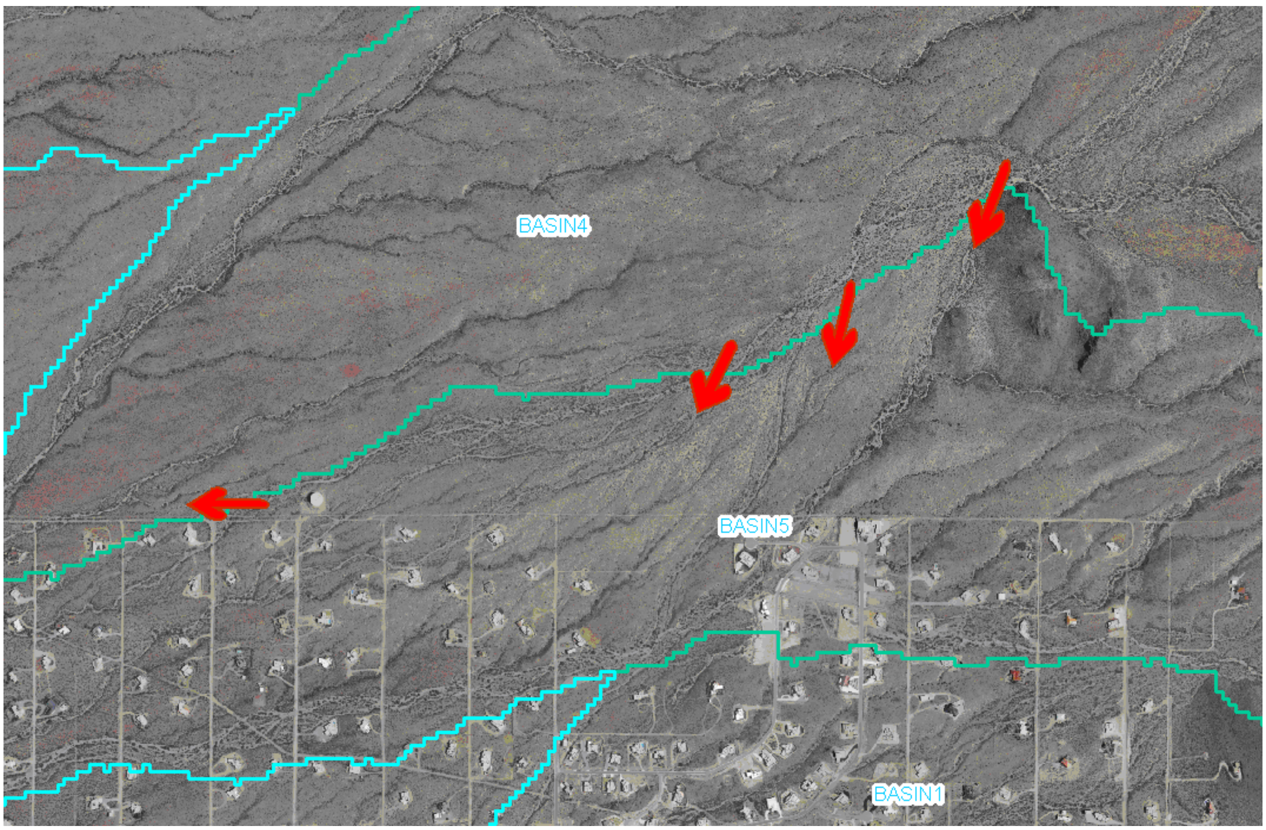

Figure 1. Aerial photograph showing active flow paths crossing a subbasin boundary drawn using automated methods. Note the rectilinear pattern of the subbasin boundary, an artifact of the software used. The red arrows indicate points where flow breakouts over the subbasin boundary, rather than continue towards the subbasin outlet which is located to the left of the photograph area.

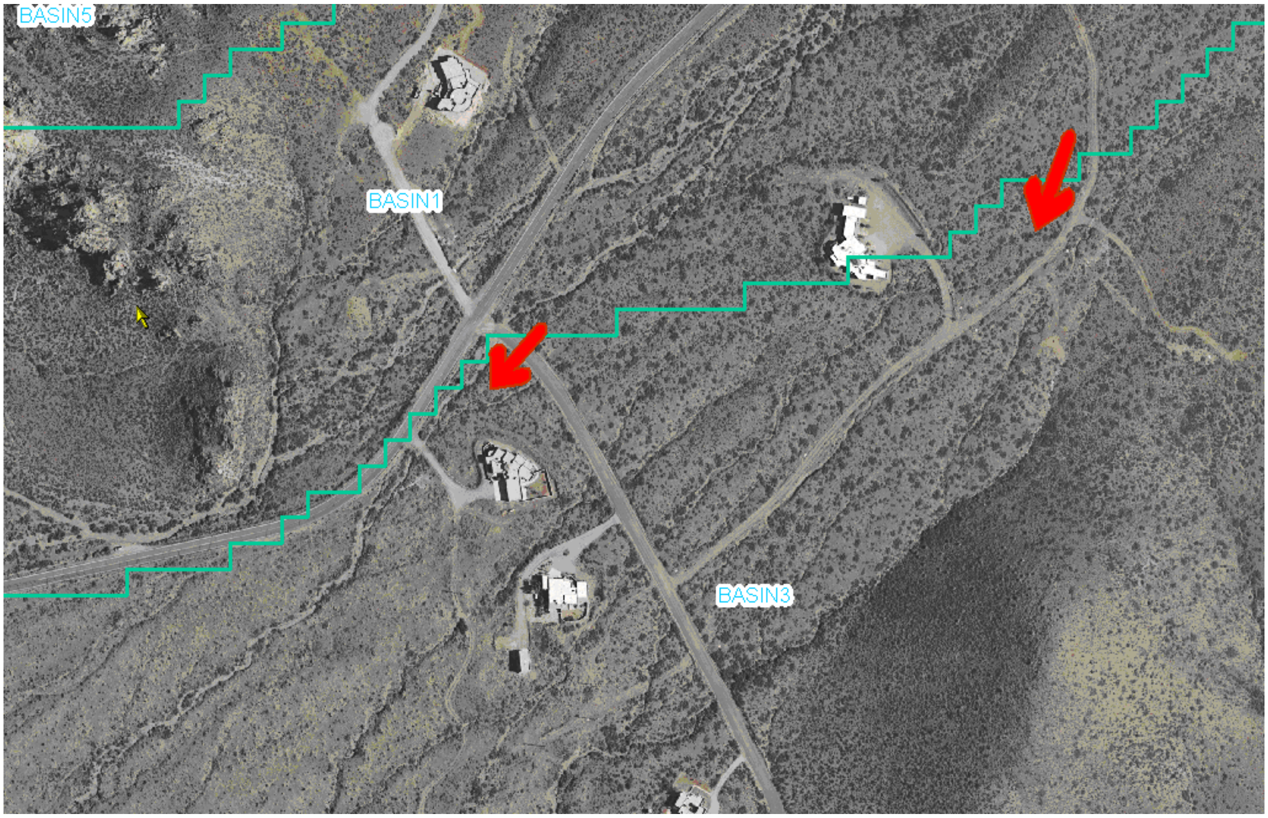

Figure 2. Aerial photograph showing active flow paths crossing a subbasin boundary drawn using automated methods. Note the rectilinear pattern of the subbasin boundary, an artifact of the software used. The red arrows indicate places where flow breaks out of the subbasin.

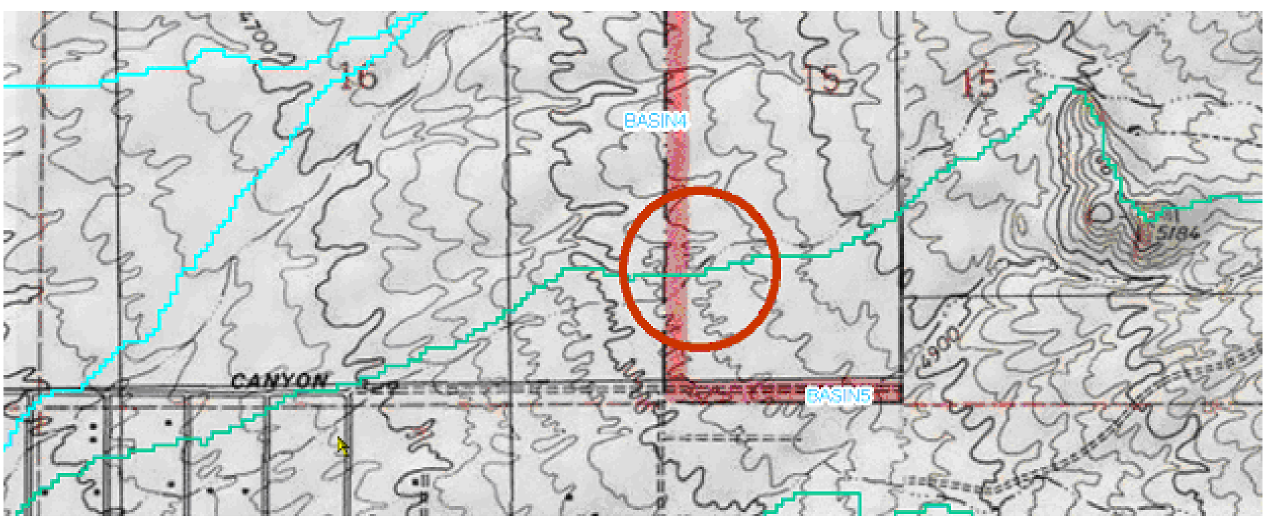

Figure 3. USGS topographic map showing active flow paths crossing subbasin boundaries drawn using automated methods. The red circle indicates one area where the USGS map shows a flow path that crosses the drainage area boundary.

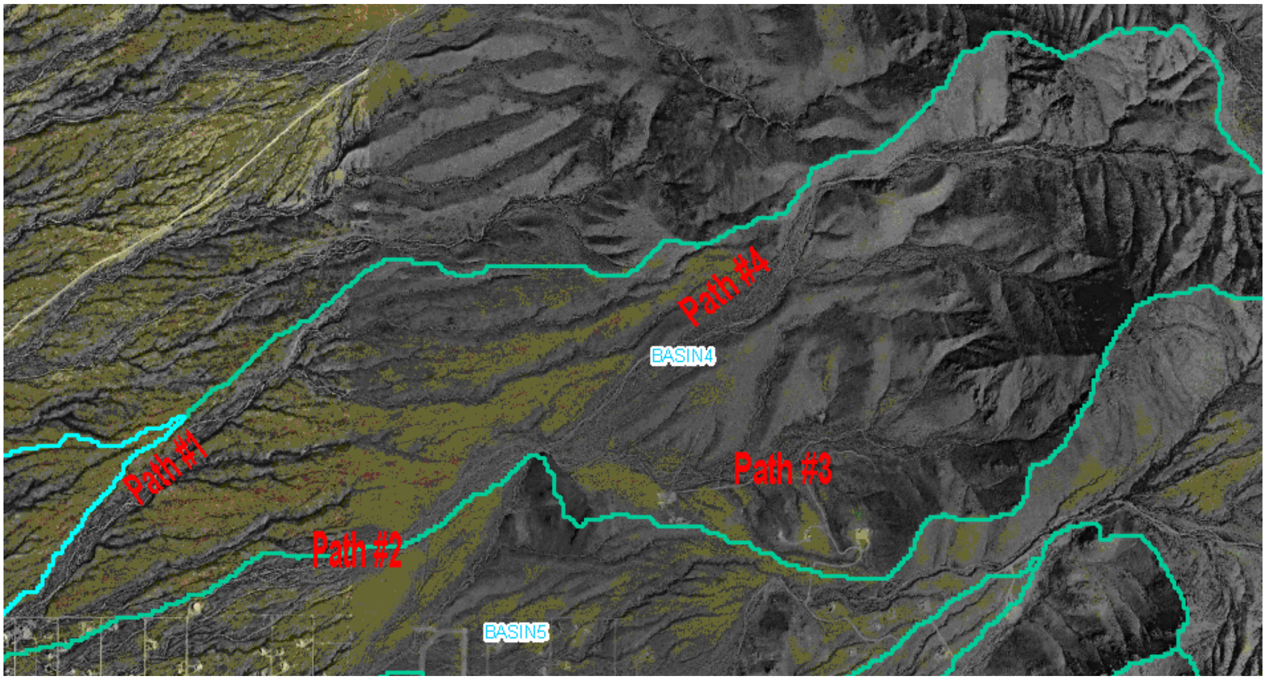

Figure 4. Aerial photograph of the BASIN4 subbasin showing significant flow paths within a single subbasin.

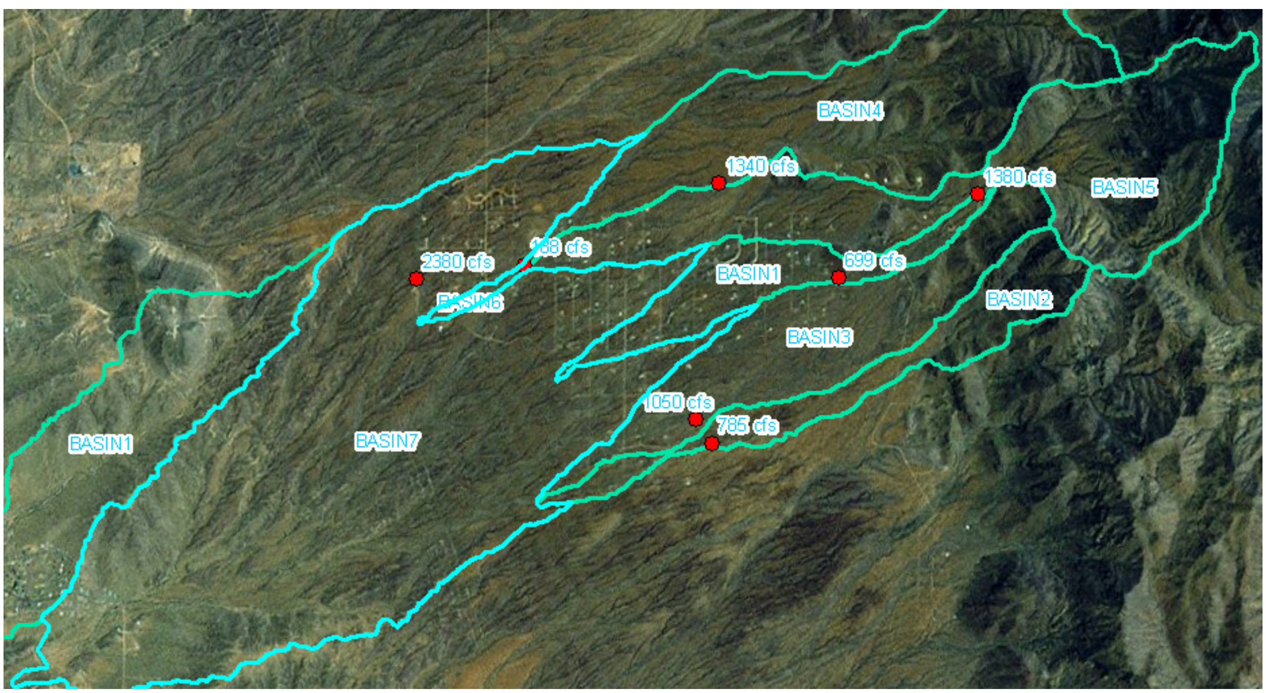

Figure 5. Watershed subbasin map showing flow inflow points used for FLO2D modeling. Note the odd location on the northern area of the watershed chosen for inflow for BASIN7 (2380 cfs).

Summary. While the peak discharge estimates obtained by URS using regression equations are within the range of likely values for the watersheds considered, URS' description and application of the results have serious technical deficiencies. Most importantly, the peak discharges were applied in a manner that overestimates some flood hazards and completely ignores some flood flow paths.

Hydraulic Modeling

- ***Alluvial Fan Methodology***. URS determined that "the majority of the study area is an active alluvial fan.[1]" However, URS did not follow the floodplain mapping procedures established by FEMA in the *Guidelines and Specifications for Flood Hazard Mapping Partners, Appendix G: Alluvial Fans* (2002). The FEMA guidelines outline a three stage approach that must be used to identify the landform (Stage 1), the boundaries of the active and inactive areas on the fan (Stage 2), and the 100-year floodplain (Stage 3). URS provided no documentation of how the required three stage methodology was applied to the study area. On this basis alone, the URS floodplain delineation should not have been approved by FEMA.

- ***FLO2D Model***. The FLO2D model was used to model the alluvial fan floodplains. FEMA Guidelines (Table G-1; Section G.2.3.4) note that traditional hydraulic methods like FLO2D are not appropriate for active alluvial fans unless certain conditions are met. First, the three-stage approach must be applied as noted above. Second, geomorphic mapping of active and inactive surfaces must be completed to identify areas where use of FLO2D would be appropriate and to identify the lateral boundaries of flood hazard areas. Third, model verification and calibration is required.[2] URS' floodplain delineation and technical documentation notebook met none of these conditions. The FLO2D model, if it had been applied correctly, could have been used to appropriately delineate the floodplains in the Fillmore watershed. Unfortunately, there are a number of serious technical flaws in URS' FLO2D model application, as noted in the following comments.

- ***Hydrograph Shape***. 100-year peak discharge values were obtained from the regression equations. Since the regression equation does not provide any information regarding the shape of the flood hydrograph, the hydrograph shape required for the FLO2D model was approximated as an isosceles trapezoid shape that varies from zero cfs (non-flood condition is dry streambeds) and the 100-year peak discharge. The hydrograph duration was "guess-timated" at 3 hours, with a time to peak of one hour, although no technical justification for the flow duration or rise time was provided in the TDN. Inexplicably, a constant peak discharge for a one hour duration was used over the second hour of the hydrograph. The flow hydrograph then decreases linearly to zero cfs over the third hour. There are a number of potential problems with the hydrograph used by URS for the FLO2D floodplain modeling, including the following:

    - Duration. The URS HEC-HMS model computed a flow duration of approximately six hours (blue line on Figure 6), rather than three hour duration used by URS in the FLO2D model.
    - Peak. A discharge at the 100-year peak flow rate sustained for a one-hour period is highly improbable. The HEC-HMS model results (and common sense) suggest a near instantaneous peak duration. The consequence of this error is that the total flow volume is overestimated, flood attenuation is underestimated, and floodplain limits are overestimated.

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[1] URS Meeting Minutes for March 3, 2005 – Fillmore Arroyo, Paragraph #1.
[2] See http://www.fema.gov/plan/prevent/fhm/en_hydra.shtm, a list of numerical models meeting the minimum requirement of NFIP. For FLO2D, "calibration to actual flood events [is] required." In practice, calibration is rarely possible due to lack of data. Instead, model verification is typically done using landform interpretation and field data.

For example, the inflow hydrograph at the grid cell in BASIN7 in the FLO2D file INFLOW.DAT is:

H 0.000 0.000
H 1.000 2380.000
H 2.000 2380.000
H 3.000 0.000

By contrast, the three hydrographs described in the Hydrology Report are shown in Figure 6, which was taken from the URS documents. The FLO2D hydrograph was not shown in the URS Hydrology Report and is not shown in Figure 6. The shape of the FLO2D hydrograph can be inferred from the data above.

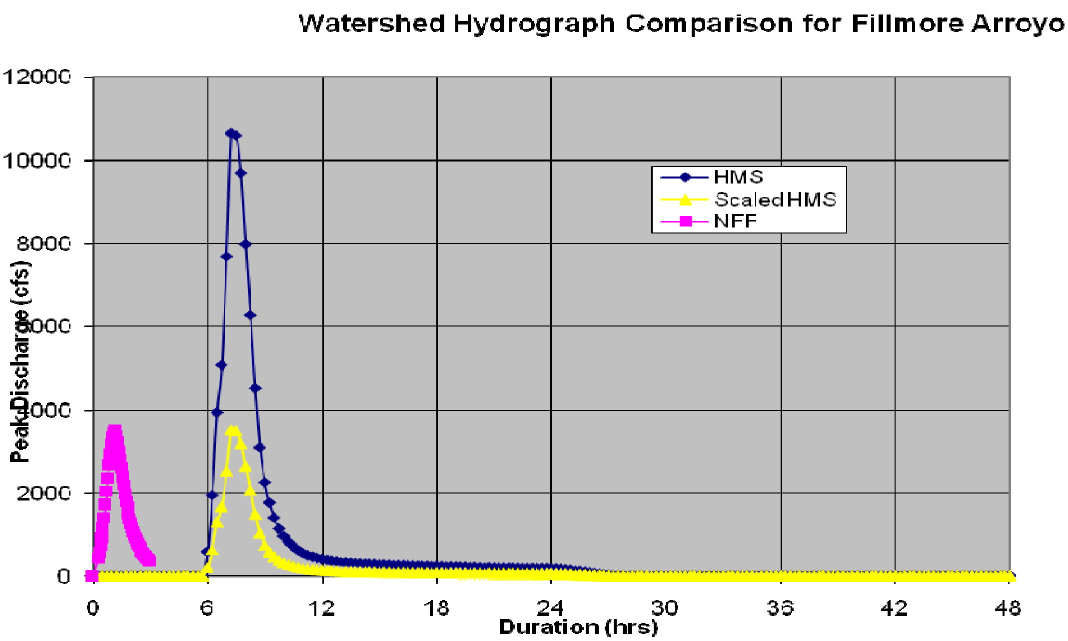

Figure 6. Hydrographs from URS HEC-HMS modeling.
Key to Acronyms: HMS=HEC-HMS Model NFF=National Flood Frequency (Regression Eqn)

- ***Bulking Factor***. The URS Hydraulics Report (p. 6) states that a bulking factor of 12.5% was used to account for sediment discharge in the hydraulic models. However, the flows used in the HEC-RAS and FLO2D models match values presented in the Hydrology Report, which were not bulked. This indicates that the bulking factor has not been applied to the models.

- ***Infiltration***. The FLO2D model includes a file INFIL.DAT that can be used to represent channel infiltration. However, in the CONT.DAT file used for the URS floodplain delineation, the infiltration option is turned off. In dry desert washes and sheetflow floodplains on arid region alluvial fans, infiltration can significantly attenuate flood peaks over long routing distances such as those modeled in the study area. The failure to consider infiltration results in overestimating the extent of the floodplain.

- ***FLO2D Model Grid Size***. The FLO2D model uses a 50 foot grid element, meaning that a single value represents the elevation and hydraulic characteristics of a 50 ft x 50 ft area. Selection of very small grid sizes significantly slows the speed of the computer computations, but increases the resolution of the mapping. Selection of large grid sizes speeds the computations (sometimes by days or weeks), but results in loss of resolution that may be critical if small watercourses are being mapped. For the case of the Fillmore watershed, the 50 foot grid size can be used to accurately model large areas with relatively uniform topography, but the representations of many channel geometries in the study area are grossly inaccurate, resulting in less flow in channels and more flow in the overbanks. Figure 7 shows an example of the affect of the grid cell size with respect to a moderately small channel in the study area. It can be seen in Figure 7 that channels with widths smaller than 50 ft and a single elevation representing the channel and overbank geometry do not accurately depict the actual flood limits.

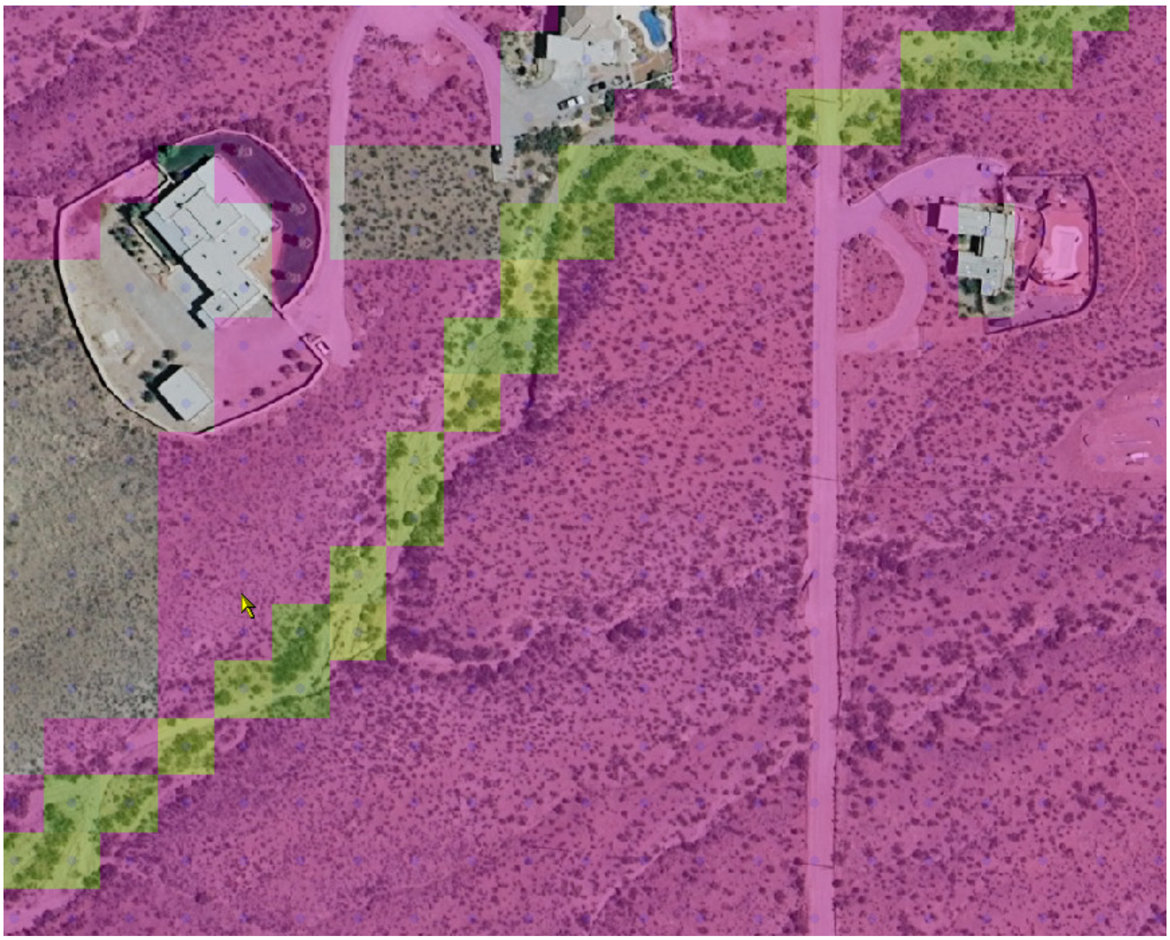

Figure 7. FLO2D flow depths showing grid size affect on floodplain delineation of a small channel. Note the obviously upland areas that are shown as flood prone and channel areas with equal depths to overbank areas.

- ***Flood Zone Delineation***. The Hydraulics Report states that the FLO2D output "…shapefile was then modified to eliminate any cells that had a depth less than 0.5-feet…..The resulting floodplain consists of Zone AO polygons of depths varying from 1-foot to 3-feet." However, the flow depths from the FLO2D model results (Figure 8) show that majority of the inundated areas in the Fillmore watershed are less than one foot deep. These shallow flooding areas (<1 ft flow depth) could be delineated as Zone X, as mandated in the FEMA Guidelines (p. E-3, April 2003), but are mapped as Zone AO1 in the URS floodplain delineation. Most of the Talavera subdivision falls within the less than one foot flow depth category.[3]

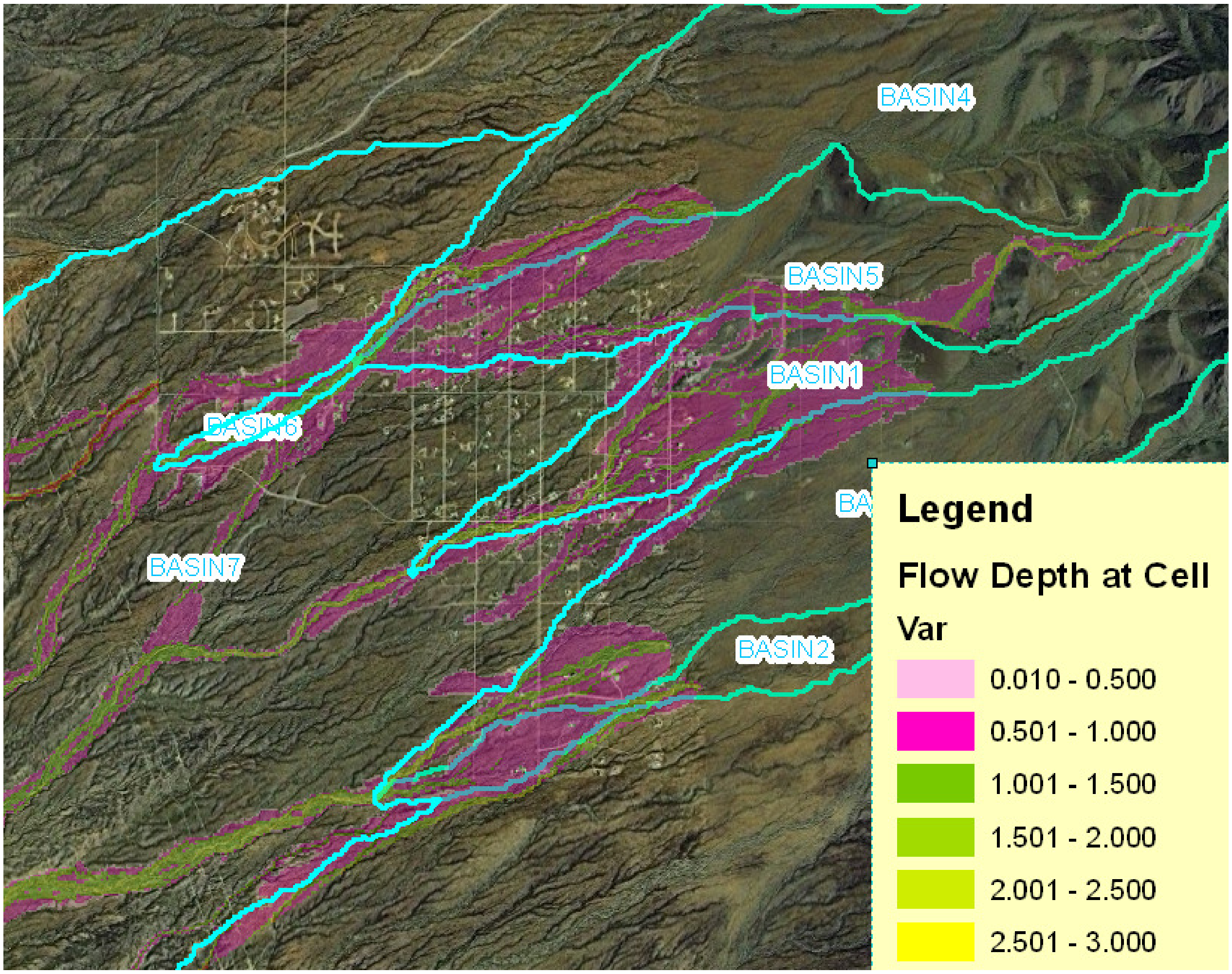

Figure 8. FLO2D results showing areas of inundation of less than one foot (magnenta).

Summary. While many elements of the basic methodology used by URS are acceptable, the implementation of that methodology in the Talavera study area has serious technical flaws that compromise the floodplain delineation. Some areas that should be mapped as within the floodplain are shown as outside the floodplain limits. Some areas that are mapped as within the floodplain are clearly outside the regulatory floodplain.

Limitations & Assumptions

1. Our review focused on the portion of the study area nearest the Talavera subdivision. We did not evaluate the URS floodplain delineation downstream of Talavera. As such, there may be additional significant technical deficiencies not described in this letter in the areas outside our area of focus.

[3] Note that other errors in hydrology, grid size, hydrograph, etc. may significantly change flow depths (increase or decrease) if the area had been correctly modeled.

2. Our review is based on the documentation provided. It is possible that additional documentation may exist, although it is unlikely that such documentation would affect our conclusion that the URS study has serious technical deficiencies.

Thank you for the opportunity to assist you with this evaluation. Please do not hesitate to contact me if you have any further questions regarding this matter.

Sincerely,

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Principal

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