DEVELOPMENT OF A HYDROLOGIC MODELING SYSTEM FOR THE DRY VALLEY CATCHMENT, PUTNAM COUNTY, TENNESSEE

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Introduction

In July 2015, the karstic Dry Valley area southeast of Cookeville experienced massive flash flooding due to lack of drainage combined with a greater than 50-year rainfall event. This flood resulted in the severe damage of several properties including a used car dealership. A HEC-HMS model was developed to simulate various flood events.

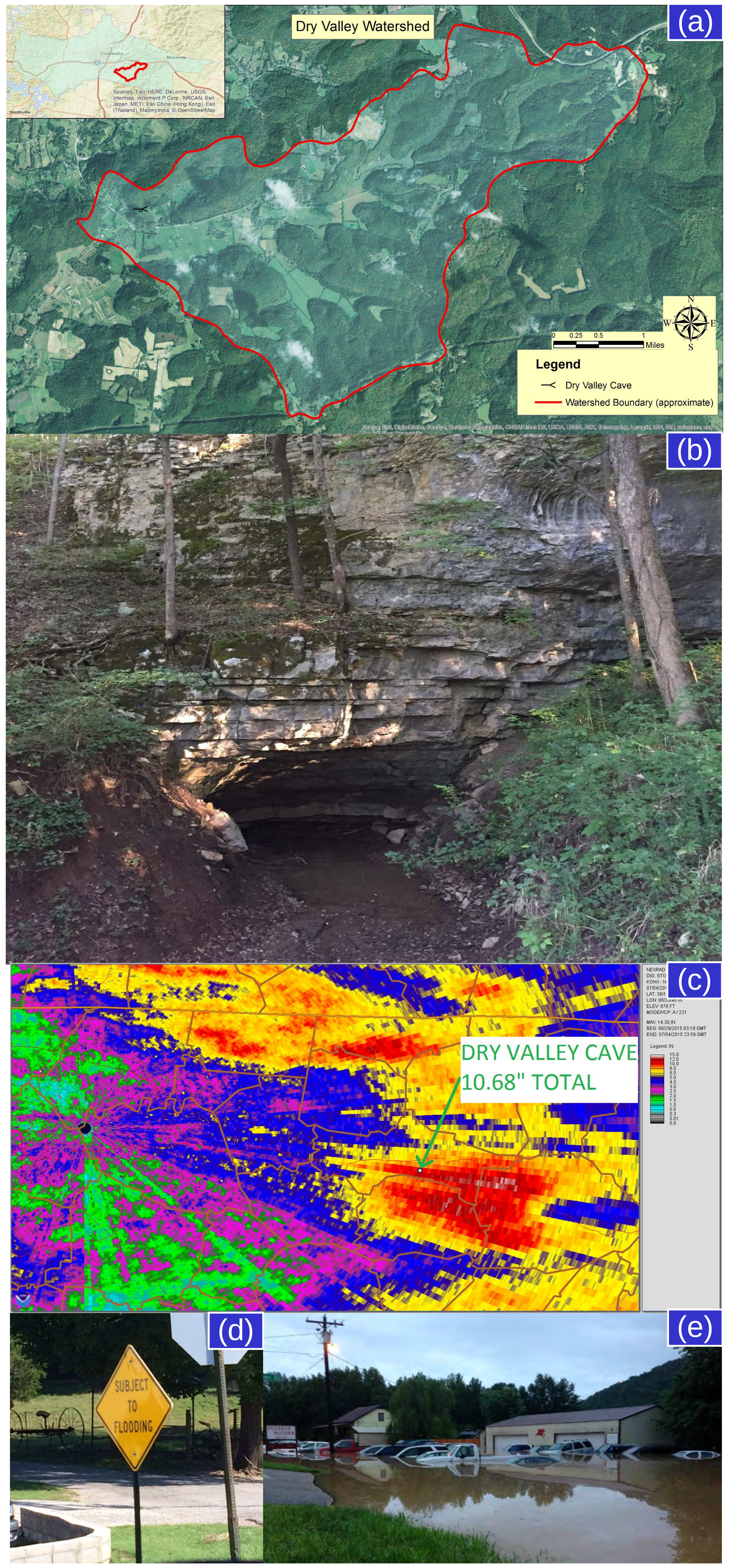
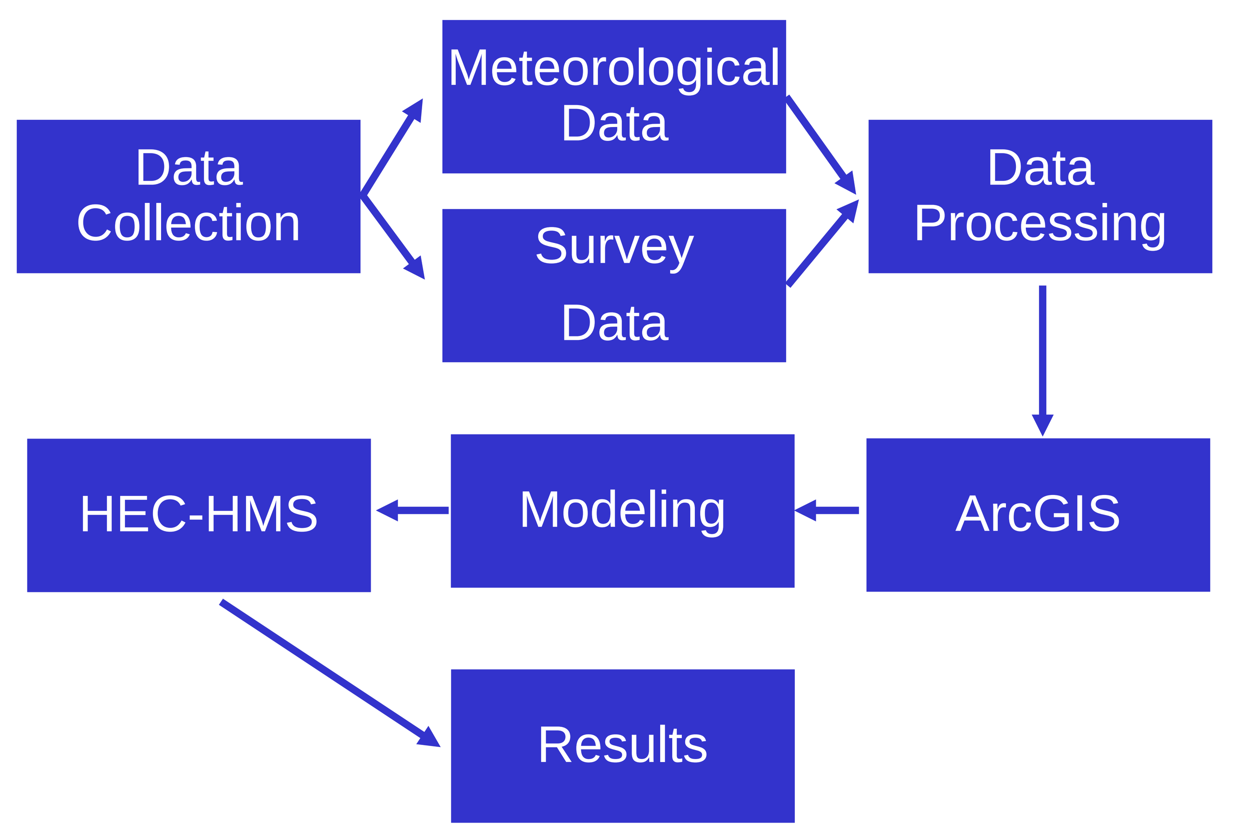


Figure 1a: Dry Valley Watershed south of I-40 through Cookeville
Figures 1b-1e: Dry Valley flooding propensity (radar image courtesy NOAA, flood image courtesy WSMV)

Research Objective

"To **explore** the karst drainage flooding problem in the Dry Valley area and **develop** a HEC-HMS model to simulate the 10-year, 50-year, 100-year and 500-year floods for this region while also analyzing previous storm events."

Methodology



Data Collection

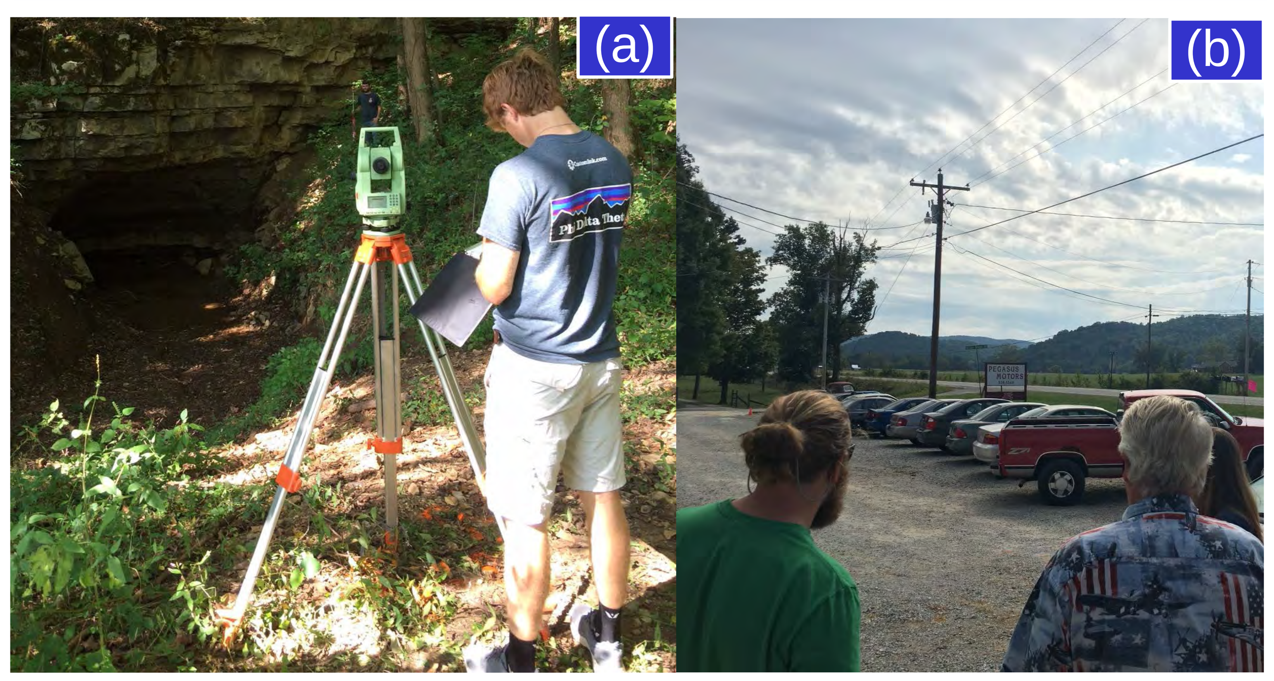


Figure 2a-2b: Collection of survey data and witness testimony

- GPS-RTK and Leica Total Station used to establish control points for future study
- Cross-sectional cave characteristics measured
- High water marks from July 2015 storm event captured
- Terrain rolling to mountainous
- Approximately located portions of the wet-weather conveyance system leading to the cave
- Discussed past flood events with local residents to ascertain patterns in karst-related flooding

Meteorological Data

- SCS Type II 24-hour storm assumed
- CoCoRaHS observation 3.3 miles southwest of Cookeville:
  - 6.74" of rain over 24 hours ending 06:00 on July 3, 2015

Table 1: NOAA Precipitation Frequency Dataset (PFD) Data

Model	Depth (inches)
10-year	5.10
50-year	6.67
100-year	7.38
500-year	9.12
Past Event	6.74

Data Processing

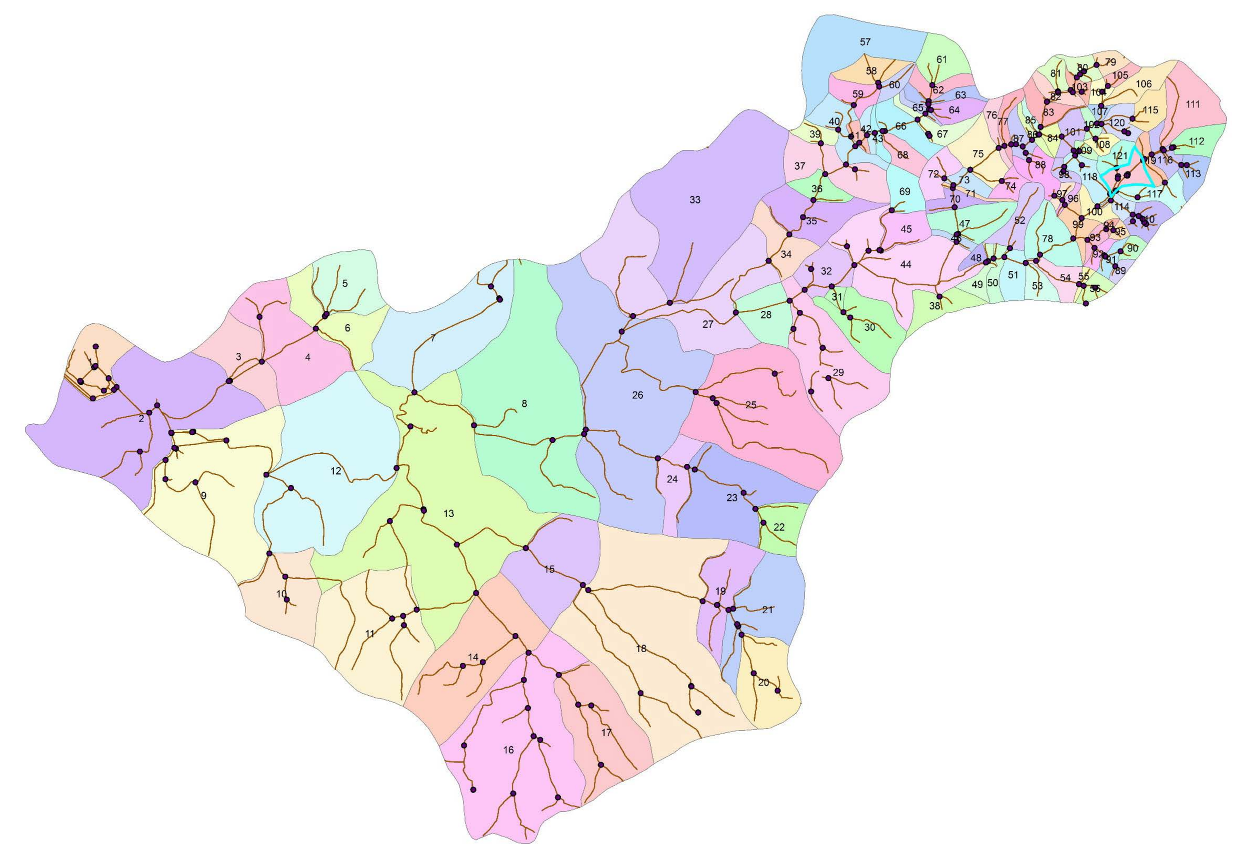


Figure 3: Subbasin delineation

- Watershed divided into 122 subbasins:
  - Ranged in area from 2.6 acres to 500 acres
  - SCS Curve Number assigned based on areal average from NLCD 2011 and SSURGO Hydrologic Soil Group Data
  - Slope calculated from areal average within ArcGIS, 0.5%<s_0<64%
  - Flow lengths calculated within ArcGIS
  - Times of concentration estimated using NRCS TR-55 methods:

$$t_c = \frac{l^{0.8}\left(\frac{1000}{CN}-9\right)^{0.7}}{1140\sqrt{Y}}$$

  - Resulting t_c values between 6 min and 3 h, average of 30 min per subbasin
  - Basin lag times were estimated as 60% of time of concentration, minimum lag time of 3.5 min to ensure model stability

Modeling

- 30 reaches and 44 junctions identified:
  - Muskingum Routing method used to model channel effects
  - Channels modelled as trapezoidal with bottom width 2', side slope 1:1 and normal depth of 1 foot to calculate velocity, V
  - Travel time through reach approximated as:

$$k = \frac{L}{V}$$

  - x was assumed as 0.2 based on other studies
  - SCS Unit Hydrograph method used to transform rainfall hyetographs to runoff hydrographs
- Assumptions:
  - Canopy infiltration not significant– most of study area is open field (**Figure 4**)
  - Surface infiltration not accounted for due to lack of data
  - Highly rural, agricultural area allowed assumption of no significant impervious area
  - Baseflow not significant– few if any relatively permanent streams, system is comprised almost entirely of wet-weather conveyances

Figure 4: Basin characteristics

Result: Storm Hydrograph

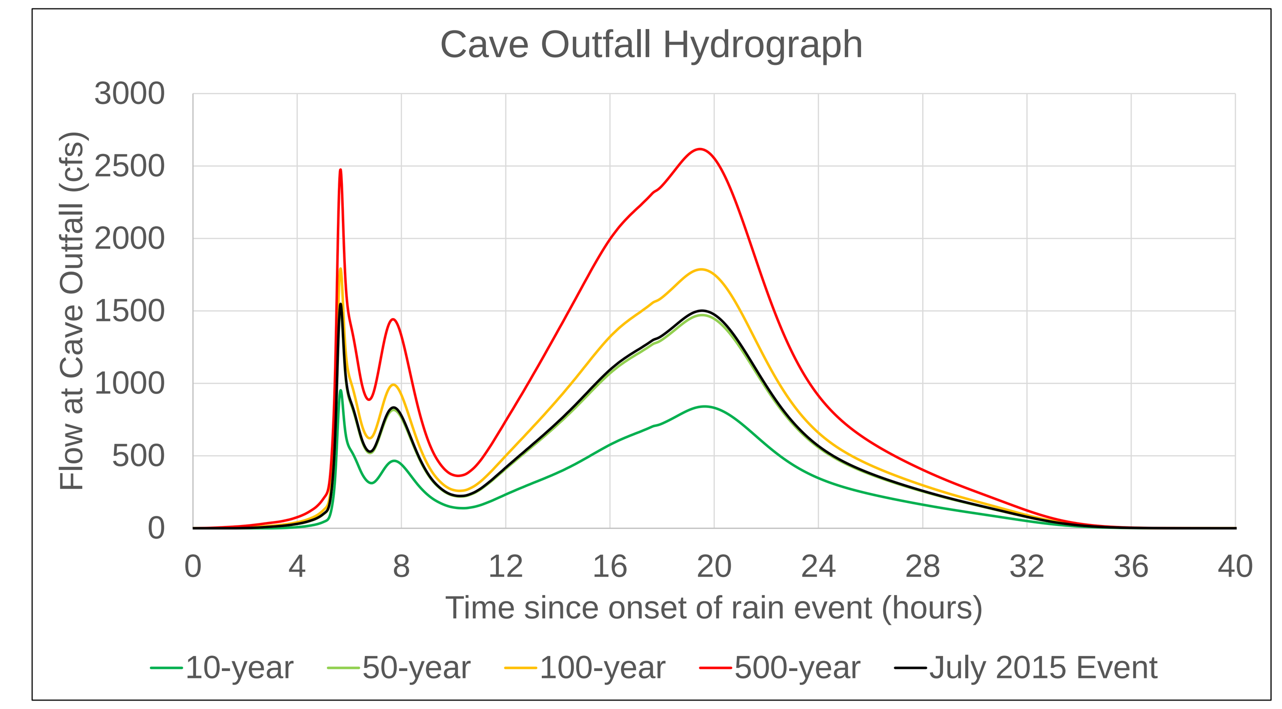


Figure 5: Simulated Hydrograph for Past Event, July 2015

Result: Design Peak Flow Rates

- Hydrographs share same timing but differ in maximum flow

Table 2: NOAA Precipitation Frequency Dataset (PFD) Data

Model	Modelled Flowrate (cfs)	Representative Flow (cfs)
10-year	952	900-1100
50-year	1522	1400-1600
100-year	1792	1700-1900
500-year	2617	2500-2700
Past Event	1549	1400-1600

Conclusions

- Model involves assumptions that must be satisfied for the model to be valid; future work can determine their accuracy or needed changes
- Higher-resolution elevation data needed, particularly around the mouth of the cave.
- Flow taken at the mouth of the cave would be beneficial to help calibrate the model.
- Flood early warning system could be developed from current model to forecast flooding based on anticipated rainfall events

Future Studies

- Locate and account for impervious areas within the basin
- Calculate canopy cover and surface infiltration
- Further map the inner dimensions of the cave to determine controlling sections of flow
- Measure the flow at the entrance of the cave to develop stage-storage-discharge rating curve

References

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