Flash Floods: Spatial and Temporal Analysis

A Case Study of the March 2008 Flash Floods in Southwestern Missouri

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The Flash Flood Problem

Floods In General:

- Leading cause of weather-related fatalities in the US and second most common worldwide
- In the 1990s alone: 100,000 killed and over 1.4 billion affected globally

Flash Floods:

- Highest mortality when compared to other floods
- Sudden and high intensity events
- Small spatial scale
- Many complex factors contribute:
  - Physical factors:
    - Basin geography
    - Soil characteristics
    - Land use (urban vs. rural)
    - Vegetation cover
  - Socio-economic factors:
    - Population growth and density
    - People's reactions to flash floods

Water rescue in raging water. Source of Photo: http://press.weather.com/content/ss220-erin-midwest_flood-mike_rescue.jpg

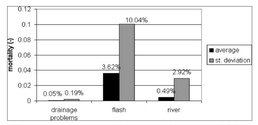


Figure 1. Mortality by flood type (Jonkman 2005)

The Event: March 17th – 19th, 2008 and Its Impacts

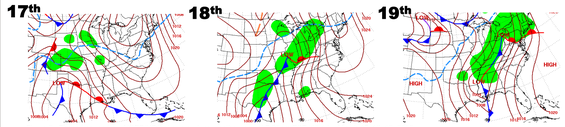


Figure 2: These images from NCEP/HPC shows surface weather map at 7:00am EST (12z) for March 17, 18, 19, 2008.

Source: http://www.hpc.ncep.noaa.gov/dailywxmap/index_20080319.htm

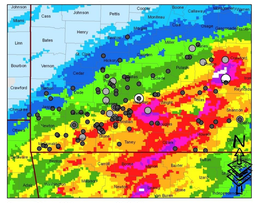
Storm Dynamics:

- Low pressure developed over TX / OK
- Strong southerly flow transported moisture from Gulf of Mexico which collided with stationary frontal boundary
- Convergence produced heavy rain
- Grounds previously saturated
- Previous 60-90 days were in the top 5 wettest periods on record

Storm Impacts:

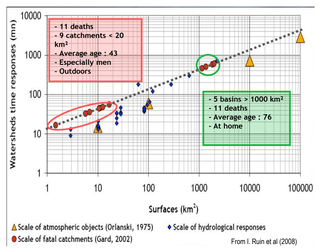
- 2 fatalities (17 nationwide)
- 20 water rescues
- 135 flood reports from various sources
- 6"+ precipitation amounts from Texas to Ohio.
- Some areas of SW Missouri received 10"+ of rainfall

Storm Total Precipitation with Flood Reports



Background Information

Human Exposure Over Time and Space Scales: Insight from a French Case Study:



"A rational subdivision of scale for atmospheric processes" (Orlanski 1975) relates scales in space with the life time of atmospheric phenomena (orange triangles).

- Elementary convective cells (10 – 100 km² / 1 hour duration)
- Mesoscale Convective Systems (1,000 – 10,000 km² / 10 hours – 1 day)
- Extra Tropical Cyclones (100,000 – 1,000,000 km² / 1 week cycle)

Atmospheric phenomena relate strongly to hydrological features. The time needed for a catchment to react from rainfall is of the same order of magnitude as the duration of the meteorological event (gray dashed line). The catchments where fatalities occurred were plotted along this line drawn from historical flood records (blue diamonds).

Two conclusions were :

- Fatalities in small catchments (<20 km²) occurred among middle-aged people traveling (outdoors).
- Fatalities in large catchments (>1000 km²) affected older people in their homes.

Research Questions:

This project was one of the first in the field to integrate social and geo-physical data using Geographic Information Systems (GIS)

1. Can we identify different impacts of a flash flood disaster as indicated by flood reports?
2. What are the social and natural factors that account for spatio-temporal distribution and severity of these impacts.
   - Storm dynamics
   - Catchment size
   - Land use
3. How does this study compare with the results of the Ruin et al. (2008) study?

Data & Methods:

Data Used: Stage IV Radar-derived rainfall, catchment boundaries, streams & stream gauges, media & NWS flood reports, low water crossings, political boundaries, cities, urban areas, elevation, roads

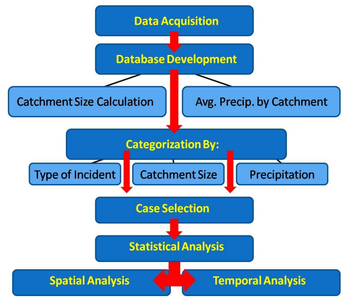
Methods & Analysis Tools:

Spatial & Temporal Analysis:

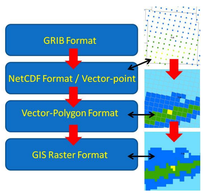
Geographic Information Systems (GIS) → computer-based system for management, mapping, analysis, and visualization of georeferenced data.

Integration of physical and social data from diverse sources.

Qualitative & Statistical Analysis:



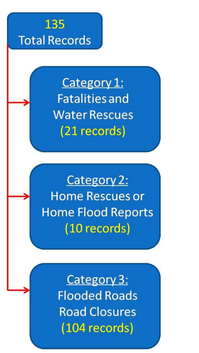
Database Development:



Stage IV Radar:

- mosaic of radar data in the contiguous US
- corrected by comparing rain gauge data
- manually checked for quality.
- GRIB format transformed to raster form to be compatible with GIS
- Raster format provides a continuous grid making analysis easier.

Classification & Incident Selection

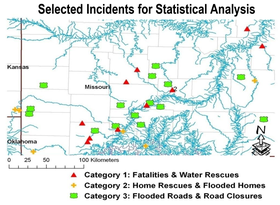


39 Records Selected

Flood Report Data:

- Various sources lead to inconsistent quality:
  - Emergency managers
  - Trained spotters
  - National Weather Service
  - Public
  - Co-op observers
  - Law enforcement
  - Fire department
  - Mesonet
- Missing data in reports deemed "vague"
- Some locations of reports not defined correctly
- Manual correction needed

Selected Incidents for Statistical Analysis

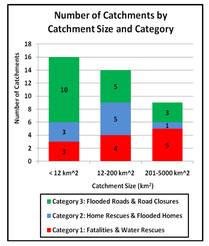


Results: Statistical Analysis

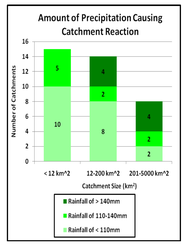
- Determine the natural breaks within the fields of catchment size and precipitation/rainfall amounts
- Analysis performed for each of the 39 selected incidents.

Classification of Catchments:

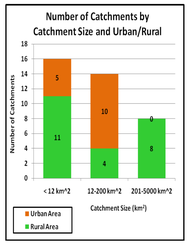
- Small: 0 – 12 km²
- Medium: 12 – 200 km²
- Large: 201 – 5000 km²



- 77 % of incidents occurred outdoor s (category 1 & 3)
- 41% occurred in catchments <12 km² & 77 % occurred in catchments <200 km²
- Category 1: # of incidents increase by size of catchment
- Most Cat 2 incidents in medium sized catchments



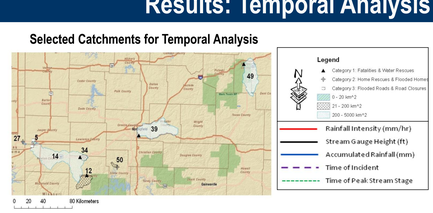
- Most small catchments needed <110 mm to cause reaction
- Most large sized catchments needed rainfall >140 mm to cause reaction
- Category 3: # of incidents decrease by size of catchment



- 39% of incidents were in urban areas. 61% in rural areas
- All incidents happening in urban areas occurred in catchments sized <200 km²
- All incidents occurring in catchments >200 km² were in rural areas

Results: Temporal Analysis

Selected Catchments for Temporal Analysis



- Performed on 8 of the 39 selected catchments
- Determine circumstances surrounding each incident.

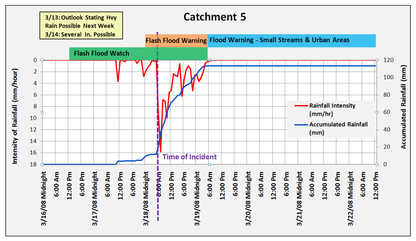
Cat 3: Flooded Bridge

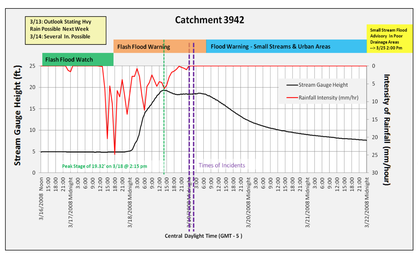
Size: **17.5 km²**

Precip: **1.23 in.**

Urban Area

- Flooded Bridge- water flowing 3 feet over bridge
- Incident occurred during peak rainfall
- Quick reaction of small catchments, urban areas



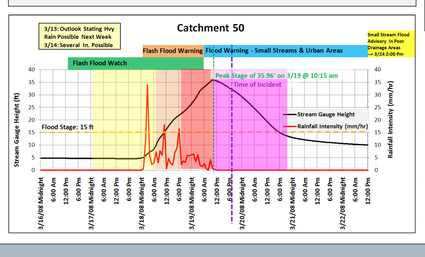


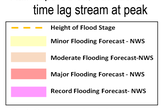
Cat 1: Fatality & Water Rescue

Size: **642 km²**

Precip: **7.20 in.**

- Elderly couple's car submerged in river. Male trapped and died, wife survived
- Rain tapered off, but due to time lag stream at peak





Cat 2: Flooded Homes

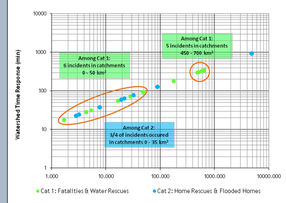
Size: **21.9 km²**

Precip: **8.615 in.**

Urban Area

- 30 homes swept away as James River @ record levels
- Rain tapered off, but danger still imminent
- Small tributaries to James River were backed up.

Comparison to French Study Results



- ¾ of all Category 2 (blue dots- flooded homes or home rescues) incidents occurred in catchments between 0 – 35 km²

Hypothesis from French Study: Is human vulnerability dependant on the size of the catchment?

Comparison of Two Studies:

- In Missouri study there is no relationship between vulnerability and catchment size for all incidents.
- Within category 1 US incidents (green dots- water rescues & fatalities) there are two clusters with a gap in middle-sized catchments. This is similar to the results in the French study.
- No conclusion can be made between indoor vs. outdoor fatalities.

Key Findings:

- Time lag: small catchments reacted much faster than large catchments
- Most cat. 1 and 2 flood reports occurred when the rain intensity was low
- 77% of incidents occurred in catchments <200 km²
- Not as clear of a relationship between human vulnerability and catchment size as seen in the Ruin (French) study
- We can use flood reports to identify different impacts of a flash flood disaster. However, the spatial accuracy and data consistency of the reports can be improved.
- NWS provided timely warnings for the flash floods.

Recommendations for Future Work:

1. By looking at a larger dataset, make a more definitive conclusion on the spatial and temporal relationship of catchments in flash flood events (in progress).
2. Understanding human risk perception and human behavior before, during, and after flash flood events.
3. Determine forms of communication most effective in informing people about the imminent danger of flash floods.
4. Take strides to further integrate the physical and social sciences using GIS.

References:

Jonkman, S. N., 2005: Global Perspectives on Loss of Human Life Caused by Floods. *Natural Hazards*, **34**: 151-175.

Ruin, Isabelle et al., 2008: Human exposure to flash floods – Relation between flood parameters and human vulnerability during a storm of September 2002 in Southern France. *Journal of Hydrology*, **361**, 199-213.

Acknowledgments

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