Climate Change: Impacts on Stormwater

Tuttle Creek Dam, KS, 1993
Kansas Drought, 2012

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Dialog on Sustainability
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Outline for Today’s Talk, Three Parts

1. Background

2. Research
   - Grand challenges, water
   - Precipitation patterns
   - Design storms
   - Flood frequency analysis
   - Antecedent soil moisture

3. Concluding remarks
Global Water Withdrawal and Population

- World population increased 4.4 times
- Water withdrawal increased 7.3 times
Too Much Too Little

Enterprise Bridge, Lake Oroville, California, USA

2011

2015

Kansas drought; August 21, 2012

Kansas flood; May 4, 2015

Flash flooding 2.97” breaks the daily rainfall of 2.91” in 1908

Manhattan, Kansas, USA

Source: USDA Drought Monitor

Intensity:
- D0 Abnormally Dry
- D1 Moderate Drought
- D2 Severe Drought
- D3 Extreme Drought
- D4 Exceptional Drought
Spatiotemporal Precipitation Patterns - Mean values

Total annual precipitation - Spatial

Rahmani et al. 2015
Spatiotemporal Precipitation Patterns - Extreme values

Extreme precipitation magnitude - Spatial

Extreme precipitation frequency – Spatiotemporal

Rahmani et al. 2016
Design Storms

Rahmani et al. 2014

Figure 3 - Rainfall frequency of 24-hour 2-year return period based on Hershfield [1961] Design Storms.
Precipitation shifts- 2-yr return period


_periods_  
<table>
<thead>
<tr>
<th>Increase in area</th>
</tr>
</thead>
</table>
| 2 vs. 1          | 64%  
| 3 vs. 1          | **90%**  
| 3 vs. 2          | 68%  

1: 1920-1949  
2: 1950-1979  
3: 1980-2009

Rahmani et al. 2014
Precipitation shifts-100-yr return period

<table>
<thead>
<tr>
<th>Periods</th>
<th>Increase in area</th>
</tr>
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<tbody>
<tr>
<td>2 vs. 1</td>
<td>69%</td>
</tr>
<tr>
<td>3 vs. 1</td>
<td>66%</td>
</tr>
<tr>
<td>3 vs. 2</td>
<td>42%</td>
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</tbody>
</table>

1: 1920-1949
2: 1950-1979
3: 1980-2009

Design storms- 100-yr return period

- 1920-1949: 28% of the state gained more than 50 mm of rainfall, 53% between 25 and 50 mm, and 19% less than 25 mm.

- The majority of the state was over-predicted by 25–50 mm during the second period (69%) and third period (84%).
2018 Flash flooding 11.2” (284 mm) breaks the daily rainfall of 2.97” in 2015, Manhattan, KS

2018 Flood Processes - Manhattan, KS

Growing season, ET was high.

Successive rainfall provided enough moisture and increased the chance of flooding.

Flooding magnified by connected impervious surfaces in addition to antecedent moisture.

Rainfall:
- 2.6 in (64 mm)
- 11.2 in (279 mm)

Flood frequency analysis

Rahmani and Berton 2018
Shifts in Seasonal Precipitation—From June to May

Rahmani et al. 2016, 2018
Remote Sensing Soil Moisture-Flashflooding

- Using remote sensing soil moisture against in situ soil moisture

- NASA Soil Moisture Active Passive (SMAP) launched in 2015

- Large scale soil moisture information for flood and drought assessment and prediction

- Streamflow prediction

- Regional scale water management

Tavakol et al. 2019
Concluding Remarks

• **Climate change: “Stationarity is Dead!”** *(Milly et al. 2008)*
  - Extreme precipitation: Rethinking of design storms
  - Precipitation distribution: Short-, mid-, and long-term decisions for sustainable water management
  - Trends: Policy makers and water managers
A Long-term Vision for the Future of Water in Kansas

• Governor Support

• Focus: sustainable water supply
  – Surface water and groundwater
  – Reduce vulnerability to extreme events; floods and drought
  – Develop and maintain water infrastructure
  – Sedimentation management
  – Provide reliable, sustainable water supply
Thank you!

Questions?

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References


Other relevant publications on climate and hydrologic extremes

- Berton, R. *, and V. Rahmani (2018), Potential Improvement in Flood Frequency Analysis in Nonstationary Conditions in the Conterminous United States, Water Resources Research, in review
- Bandad, DA*, and V Rahmani (2018), Analysis of PDSI and Vegetation Condition Index (VCI) and their Links to Streamflow, American Society of Agricultural and Biological Engineers (ASABE) Annual International Meeting, Detroit, MI. August 1, 2018, doi: 10.13031/aim.201801344
Ideas for Collaboration?

• Changes in Interconnected Climatic and Hydrologic Extremes

Precipitation changes ; Flooding/Flash Flooding ; Soil moisture ; Streamflow Prediction ; Sedimentation ; Wetlands ; Surface water/groundwater ; Drought ; Heatwaves ; Ecosystem health ; Plant/animal/human health ; Water quality

...?
Climate Change: Global Warming

- Temperature increase of 0.74 °C for 1906 to 2005 (IPCC 2007)
  - Steeper slope for the last 50 years
  - Greater rate of runoff for higher latitudes and wet tropical regions (Karl et al. 2009)

Global Temperature and CO2 Concentration

Global Runoff and Temperature

Climate Central 2017

Karl et al. 2009
Sustainable Water Resources Management in the USA and Kansas

30-yr average: Expected

Extreme conditions
Water Resources Management

- **Access to reliable, sustainable clean water** *(NAE, 2014)*

  - **Extreme events:**
    - Flooding in eastern Kansas and drought in western Kansas

  **Kansas drought; August 21, 2012**

  **Kansas flood; May 4, 2015**

  Flash flooding 2.97” breaks the daily rainfall of 2.91” in 1908

  Manhattan, KS

Source: USDA Drought Monitor
Evaluation of Remote Sensing Soil Moisture

Bias

RMSE

ubRMSE

Apr-15 Sep-15 feb-16 Jul-16 Dec-16 May-17 Oct-17
Correlation between Remote Sensing and In-situ Soil Moisture

Tavakol et al. 2019
Groundwater Use for Agricultural Production - Dry Heatwaves

- High Plains Aquifer, Ogallala
- 85% of diverted water goes to irrigation
AMF and PDS flood quantiles using LP3 and GEV distributions

Figure 1a-h: Performance of LP3 and GEV distributions in estimating flood quantiles with return periods of two to 400 years. The left column of the box belongs to LP3 while the right side represents GEV. The first and second rows describe results for AMF and PDS, respectively. The green circle in the middle of the box indicates a reference site while the red circle belongs to a nonreference site. Blue and gray themes.