Modeling the Impacts of Future Flooding on Arcadia Lake Watershed Infrastructure

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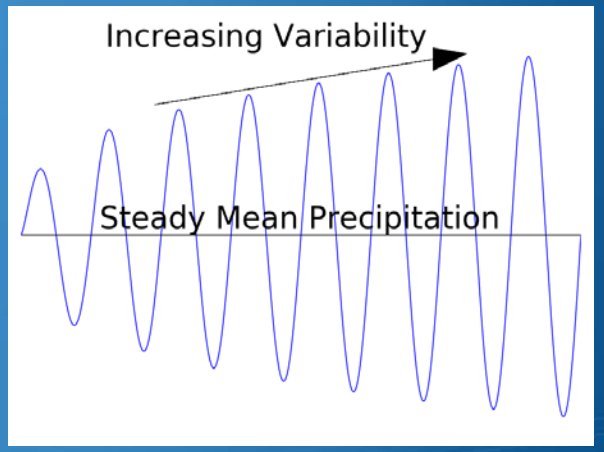
Overview

- Rationale and goals for the study
- Downscaling storm magnitude and frequency
- Stormwater Management Model (SWMM)
- Future Research Plans

Study Rationale

- Climate changes are predicted to increase the magnitude and frequency of storms and flooding
- In addition to destruction of buildings, flood risks pose threats to energy and transportation infrastructure
- May 2015 storms in Southern Plains
  - Roads in OK were submerged in 9” of water
  - Thousands of OG&E customers experienced power outages in Oklahoma City and Del City
  - Flooding on the Wichita River (TX) caused 390 homes to be evacuated and 100,000 to go without power



http://www.nytimes.com/interactive/2016/08/16/us/louisiana-flooding-pictures-maps.html

Significance

- The recent storm events highlighted the vulnerability of OK infrastructure to flood inundation risks
- There is a critical need to analyze future flood risks associated with climate change and adapt accordingly
- Addressing this need will require research expertise in climate science and engineering/hydrologic modeling

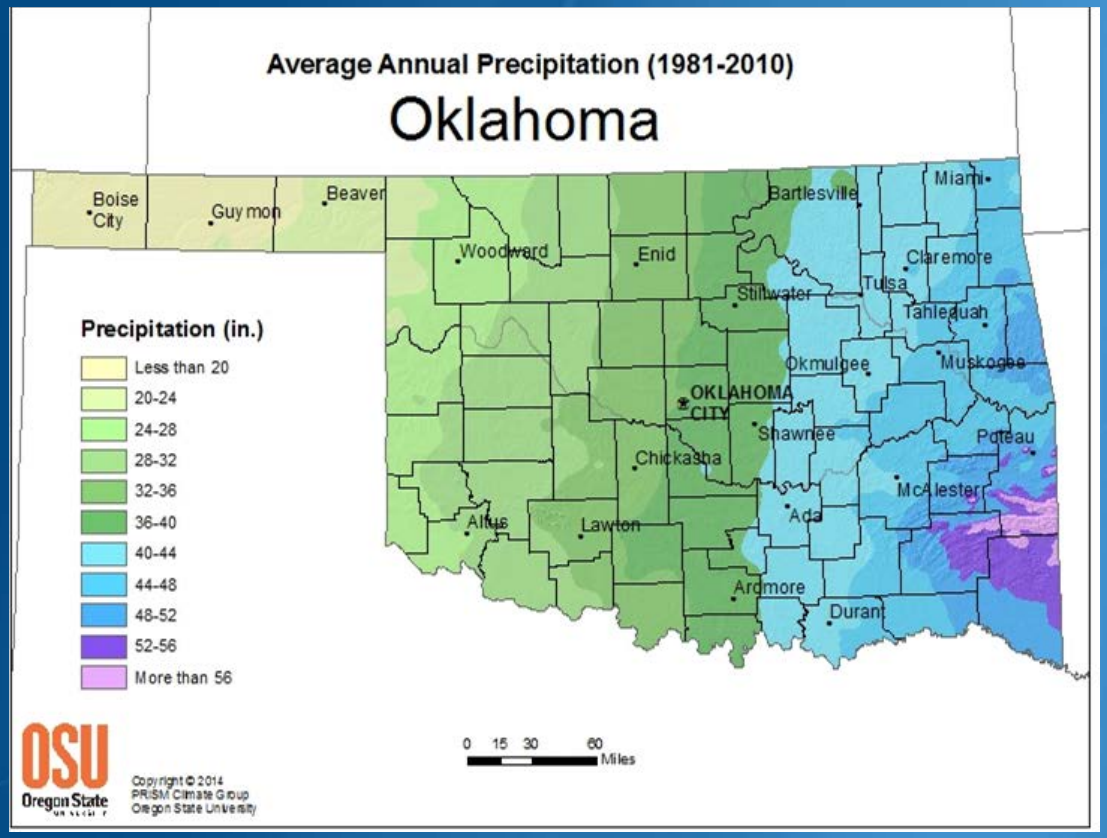
Flood Inundation Vulnerability

- Energy and water facilities withdraw large amounts of water and are often located in flood plains
  - Thermal power plants
  - Petroleum refineries
  - Oil and gas wells
  - Water and wastewater treatment plants
  - Abandoned industrial facilities
- Inundation of these facilities extends threats to locations dependent on these resources
- Inundation presents a threat to water quality

Study Objectives

- The overall goal of the research is to investigate the risks of infrastructure to future climate change and identify approaches to mitigate the impacts of these changes
- The specific objectives of the research are to:
  - Determine probabilities of future extreme storm events
  - Analyze future flood inundation risks to infrastructure in the study area
  - Evaluate approaches for inundation risk mitigation (detention basins, low impact development, etc.)

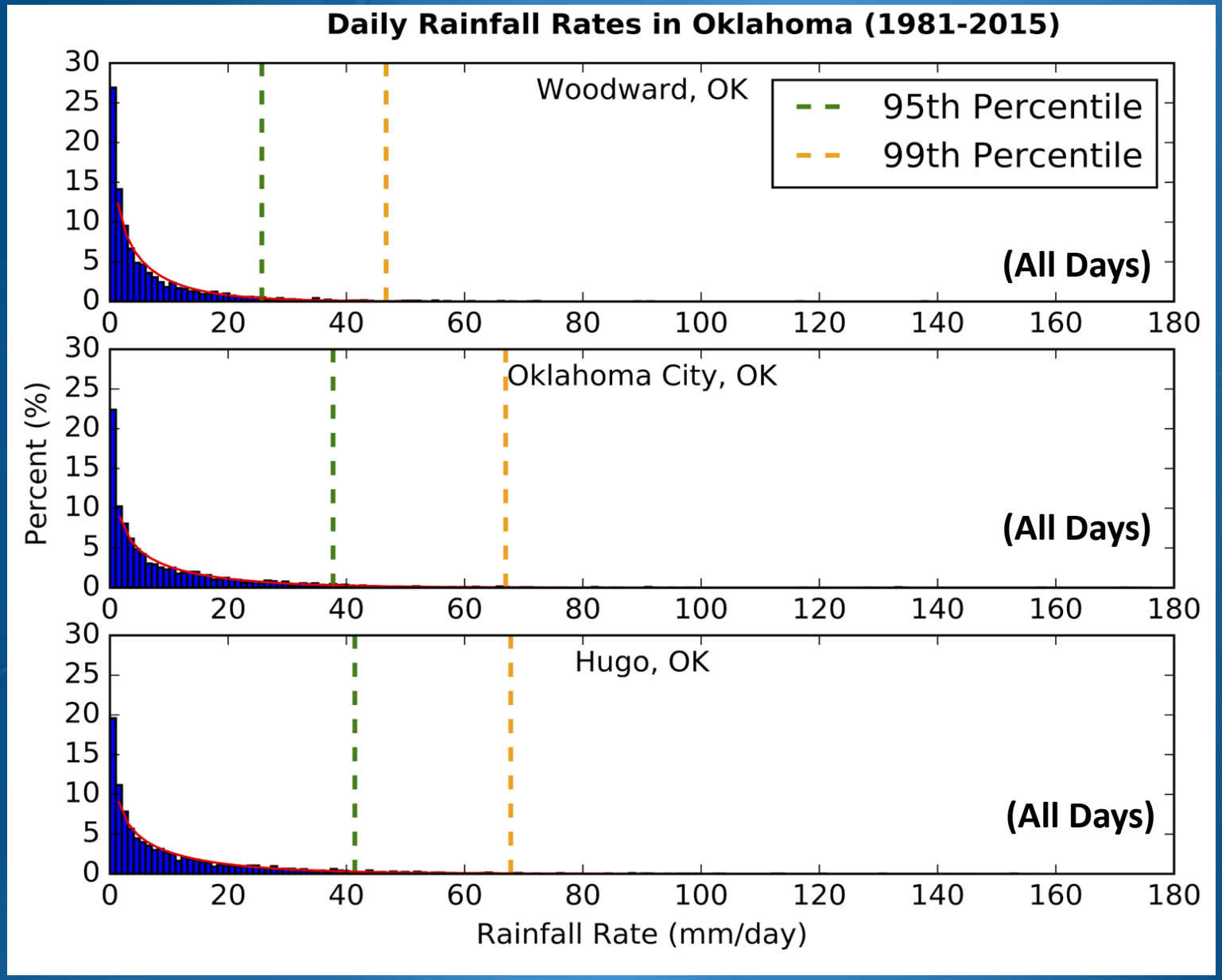
Observed Annual Rainfall Statistics - Oklahoma



http://www.prism.oregonstate.edu/

- PRISM - Hi-res (4 km) temperature & precipitation data [*Daly et al.*, 2002, 2008]
- Official climatological dataset for USDA.
- Will also explore **Oklahoma Mesonet** and Livneh for comparison.
- **Aim:** Use PRISM to calculate climatological precipitation **distributions** (e.g., daily, 30-day) for calculating **observed** thresholds of extremes.

EX: Daily Rainfall Rate Distributions - PRISM

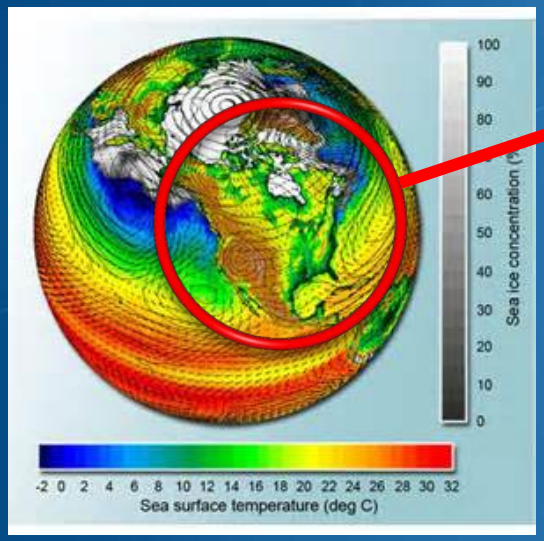


Global and Regional Climate Models

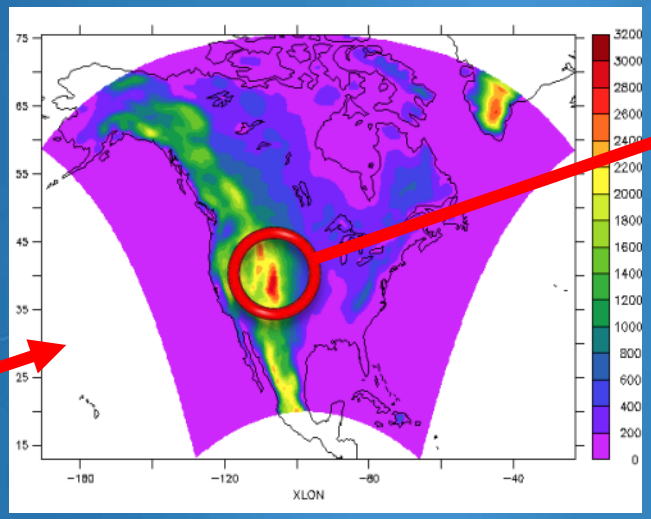
Catchment

Regional

Global



50 km resolution



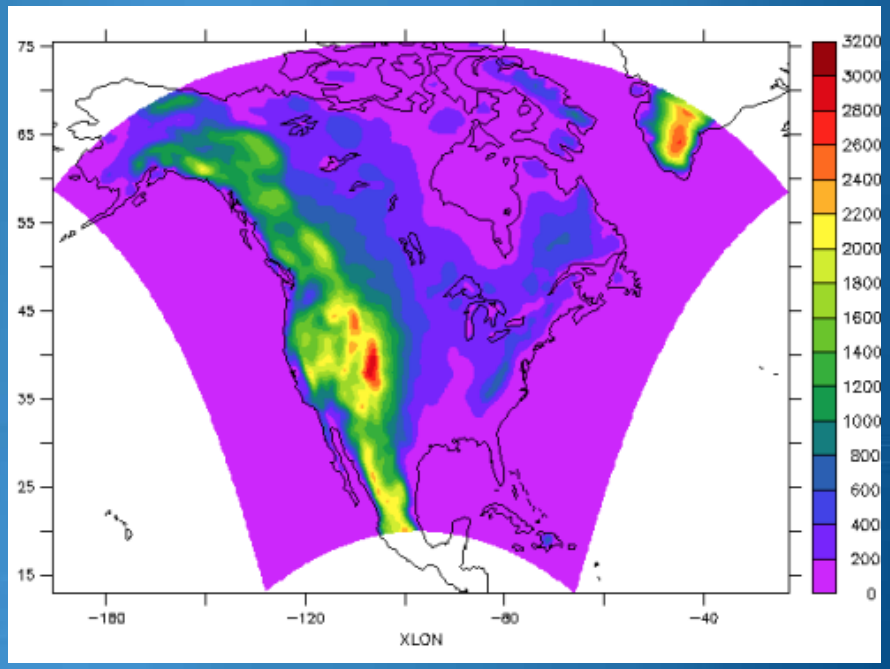
4 km resolution

How To Investigate the Future - NARCCAP

- NARCCAP - **Regional climate models** run over N. America (50 km resolution) *[Mearns et al.*, 2007].

- Two experiments: **Current** (1968 - 2000) and **Future** (2041 - 2070) for comparison
  - Total of 24 model-submodel combinations, each with 30-year samples for analysis.

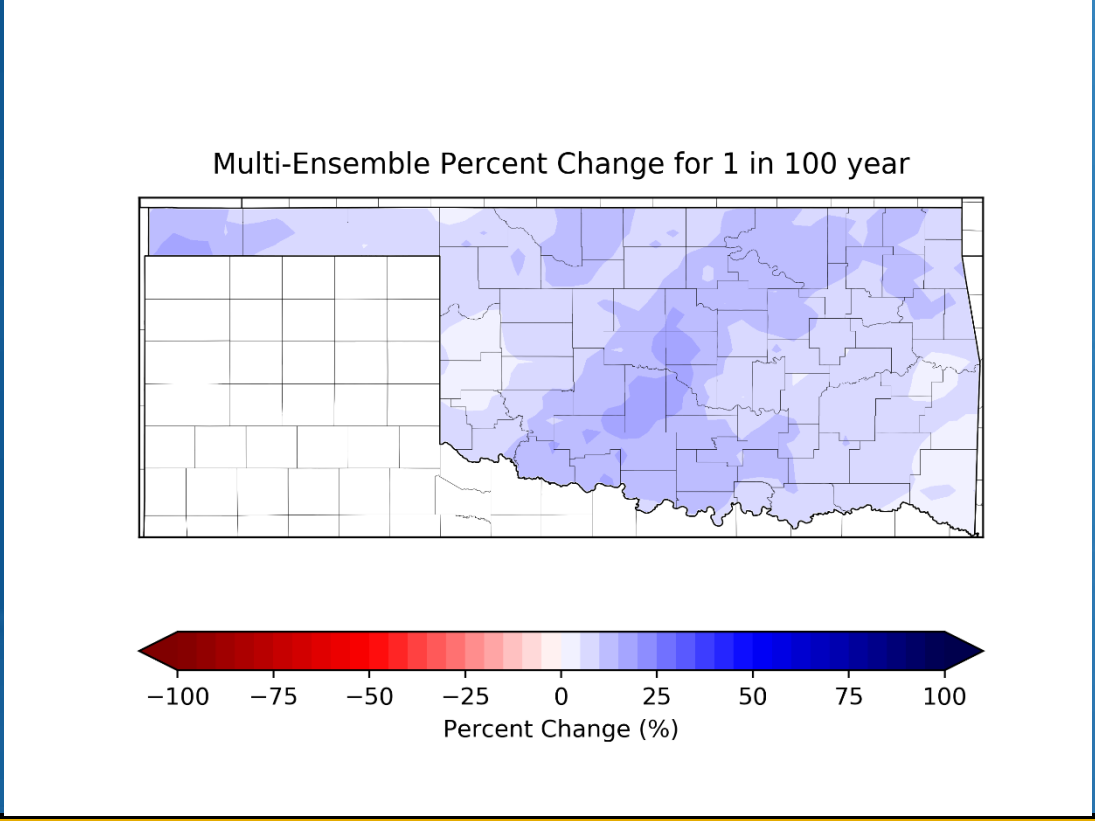
- <u>Many variables available:</u> e.g., Precip, temperature, winds, radiation, runoff



http://www.narccap.ucar.edu/data/data-tables.html

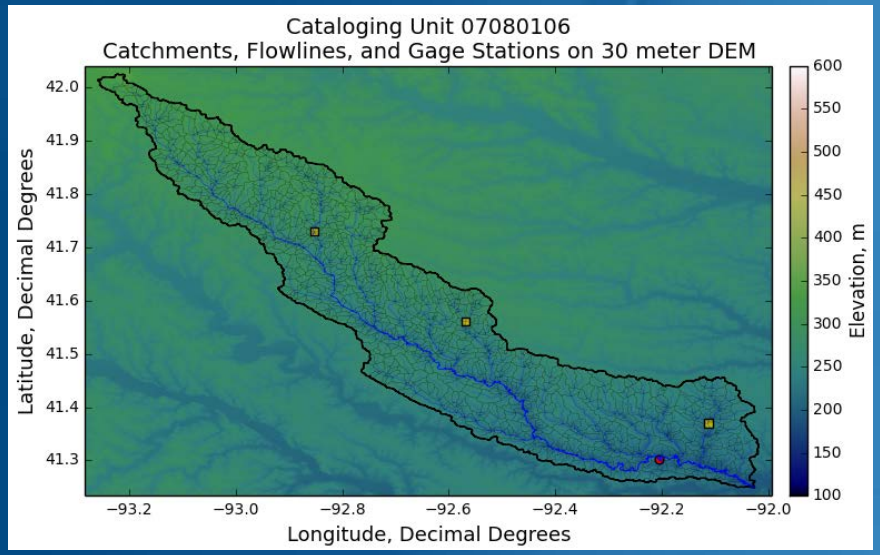
Used in several previous studies for extreme precipitation events [e.g., *Gutowski et al.*, 2010; *Mailhot et al.*, 2012; *Singh et al.*, 2013; *Kawazoe and Gutowski*, 2013].

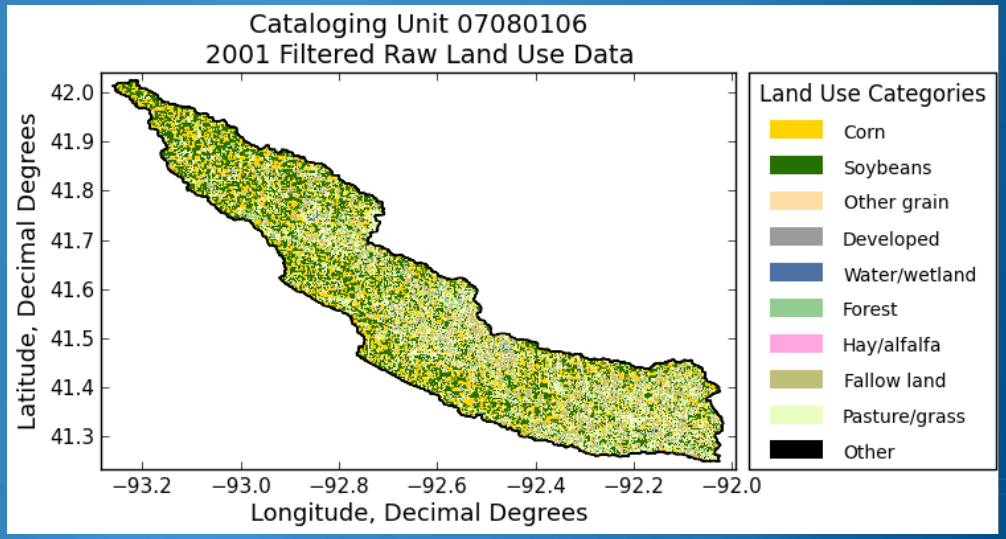
Changes in 1-in-100 Year Rain Event Totals



- **To Do w/ NARCCAP Simulations:**
  - Rainfall distributions from **CURRENT** runs, along w/ extreme thresholds (1-in-50, 1-in-100, 1-in-500)
  - Compare simulations to PRISM. Apply **bias correction –** i.e., mapping simulated PDFs to PRISM PDFs [e.g., *Argueso et al.,* 2012; *Piani et al*., 2013].
  - Bias correct **FUTURE** PDFs with a scale based on the mapping function.
  - Compute **NEW** extreme thresholds from **FUTURE** runs.

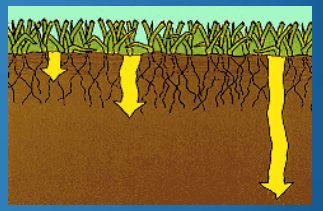
Basic Equation for Hydrologic Modeling





Physical Hydrography +

Land Use +



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Hydrology Parameters

Climate

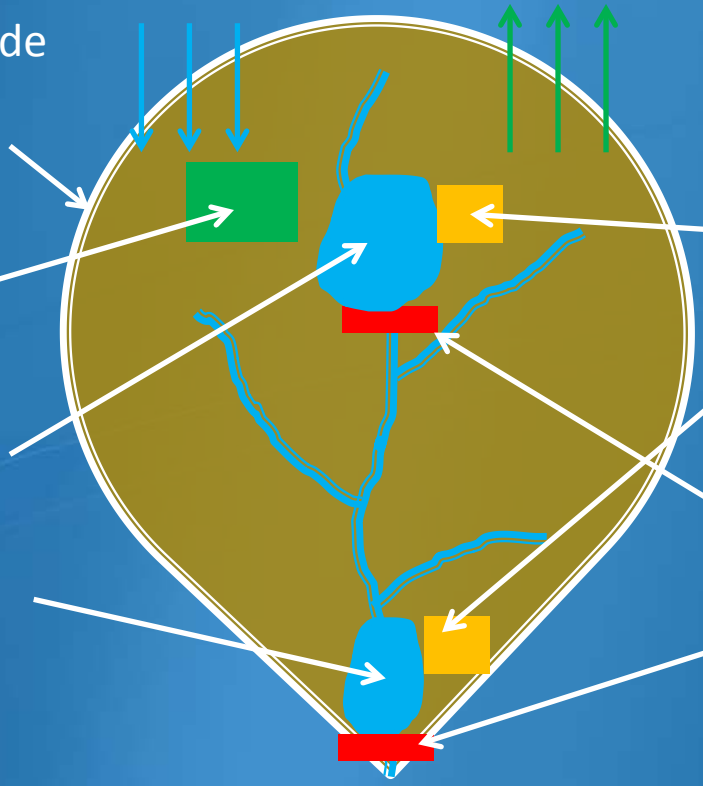
Surface Water flow/quality

Water Movement on Land Surfaces/Watersheds

Precipitation produces water resources

Evapotranspiration consumes water resources

Watershed: all precipitation inside boundary exits at the outlet



Agriculture consumes water

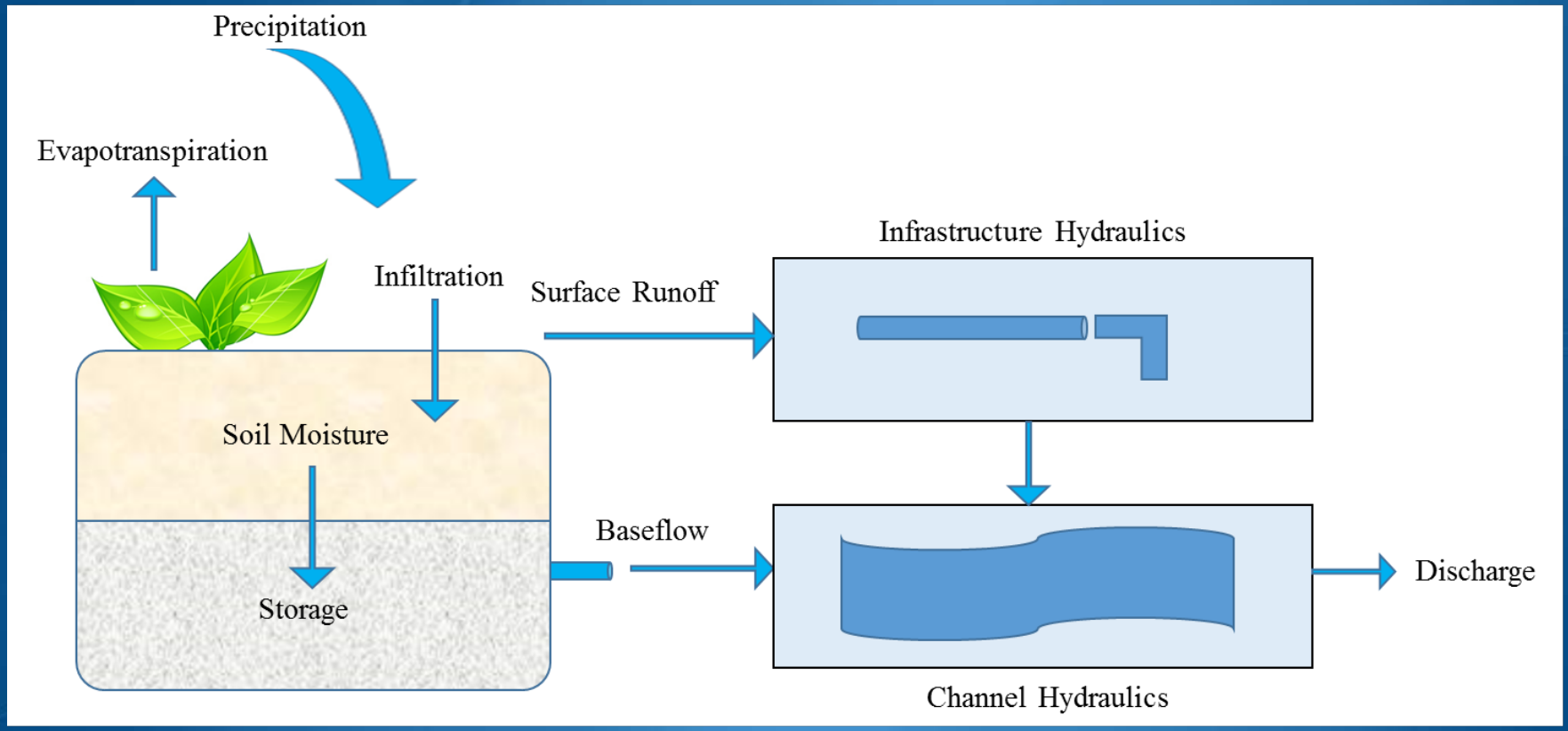
Cities consume water for drinking, electricity, and industry

Reservoirs needed for storage increase evaporation

Dams create storage, flood control, and hydropower

Human activities alter hydrologic cycle and water quality:
Need Data/Models to Predict Downstream Implications

EPA's Stormwater Management Model (SWMM)

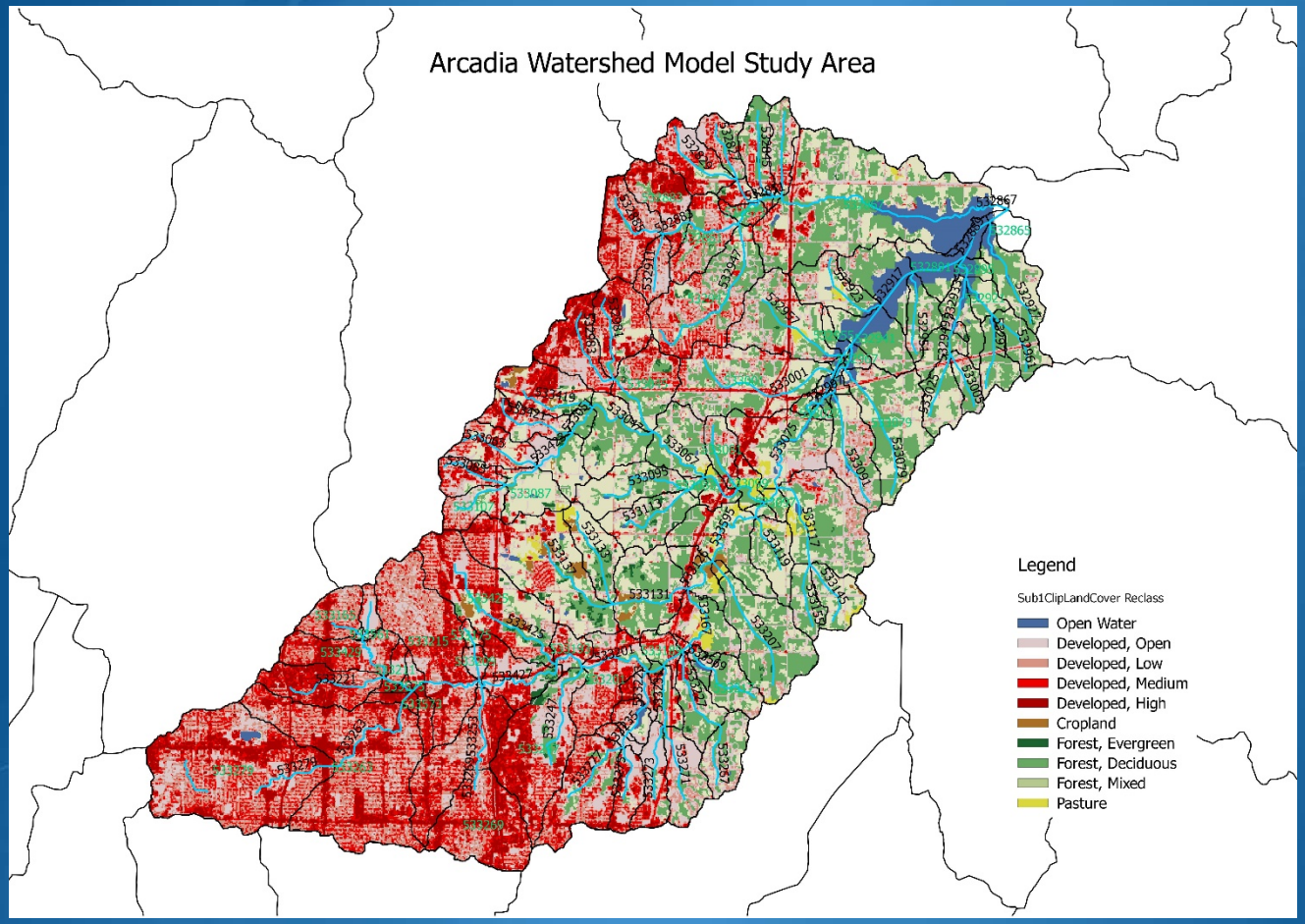


SWMM is a **distributed, dynamic rainfall-runoff** simulation model used for **single event** or long-term (**continuous**) simulation of runoff quantity and quality.

SWMM Features

- Approved for National Flood Insurance Program
- Sophisticated representation of stormwater infrastructure
- Simulation of low impact development
- Small time steps (1 min to 1 day)
- Single event or continuous simulations (essential for consideration of antecedent soil moisture)
- Free and open source (EPA Sponsorship)
- Cons
  - Difficult learning curve
  - Very data intensive (climate data, observed hydrology, land use, catchment areas, infrastructure)

Watershed Study Area

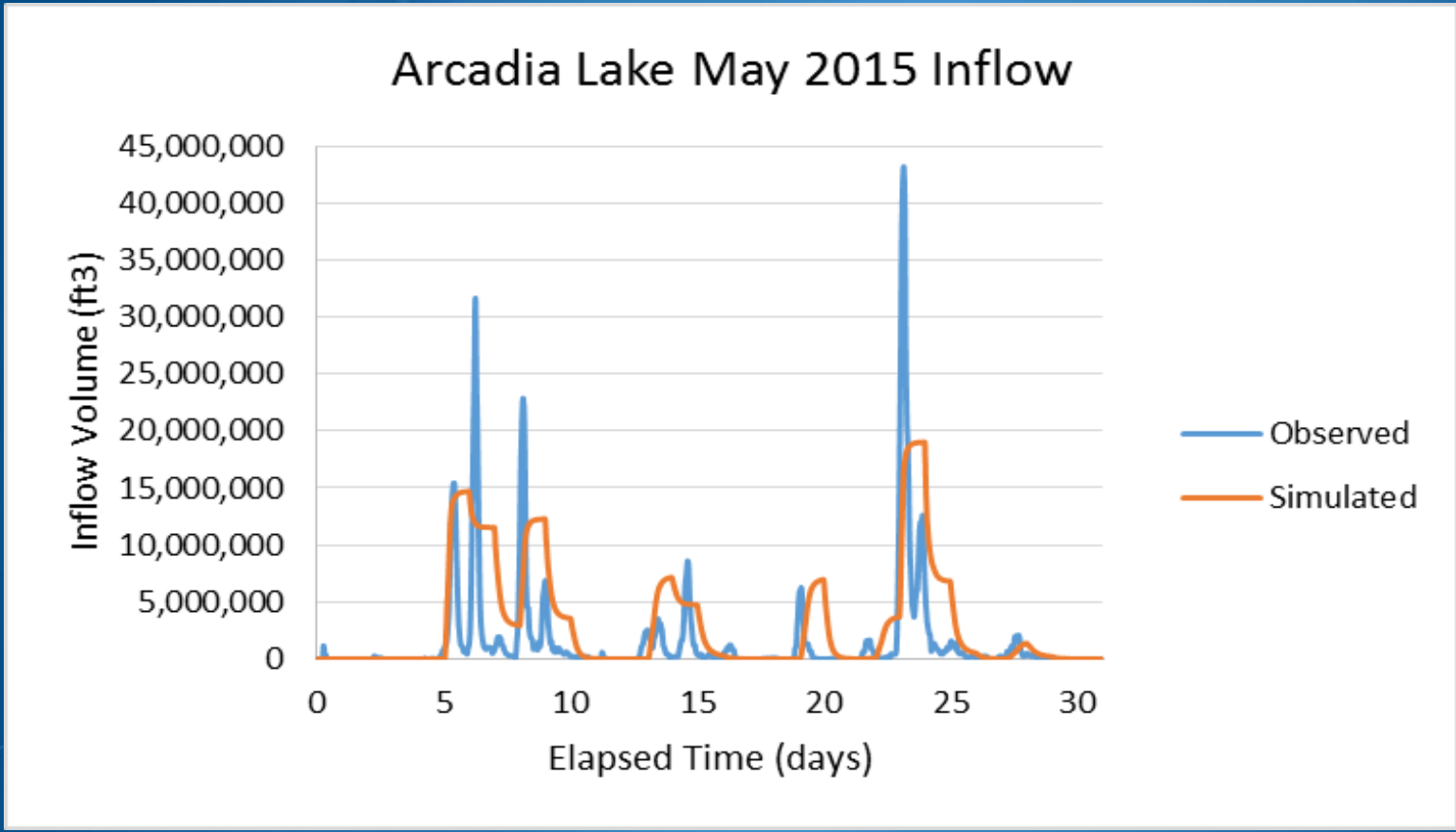


The Lake Arcadia Watershed is highly urbanized, with approximately half forested land and half developed.

Hydrologic Model Calibration

- Observed Data at Arcadia Lake collected from Corps of Engineers (e.g. inflow volume, precip.)
- Catchment Attributes and Flowline Attributes collected from NHDPlus hydrologic dataset
- Model built using collected data and run to create simulated data
- Simulated data compared with Observed data to analyze adjustments needed

Preliminary Calibration Results



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Future Plans

- Calibrate SWMM model to better match observed data
- Changes in magnitude of the rainfall intensity for various return periods (2-year, 5-year, 100-year, etc.)
- Flood inundation threats for the 100-year storm event in the select watershed
- Impacts of potential mitigation alternatives

Potential Extensions of Proposed Research

- Additional watersheds/infrastructure
- Cost analysis/policy
- Low impact development quantification
- Threats to agriculture
- Water quality
  - Implications of inundation of pollutant sources (contaminated areas, etc.)
  - Non-point source pollutant loadings
- Drought risk analysis (with a different model)

Acknowledgements

- Southern Plains Transportation Center
- Army Corps of Engineers, Tulsa District
- Oklahoma Water Resources Board
- Oklahoma Department of Transportation

Questions?