Climate Impacts on Surface Inflow into Evergreen Lake and Lake Bloomington Watersheds

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Introduction

- During the 20th Century, the global average surface temperature increased by approximately 0.6°C (Hallett 2002)

- With these increased temperatures, the global water cycle has intensified (Huntington 2006)

- On a national scale, temperatures will increase by 2-4 °C (3-12 °F) in the United States by the year 2100 (USEPA 2016)

- Most existing climate impact studies focus on regional scale watersheds, not local (Cousino et al. 2015, Fontaine et al. 2001, Jha et al. 2006, Stone 2001, Vörösmarty et al. 2000)

- Comprehending the effects of climate change on a local watershed scale can serve as the basis for further understanding of the overall global issue

Local Problem – Quantifying and Predicting Surface Water Behavior

- The City of Bloomington pumps water from two surface reservoirs, Evergreen Lake and Lake Bloomington, to serve its municipality and adjacent communities

- Droughts in 1988 and 2005 demonstrated that these surficial reservoirs were vulnerable (WHPA 2010)

- City of Bloomington developed an interim water supply plan in 2010 to address future implications of climate stresses on water supply
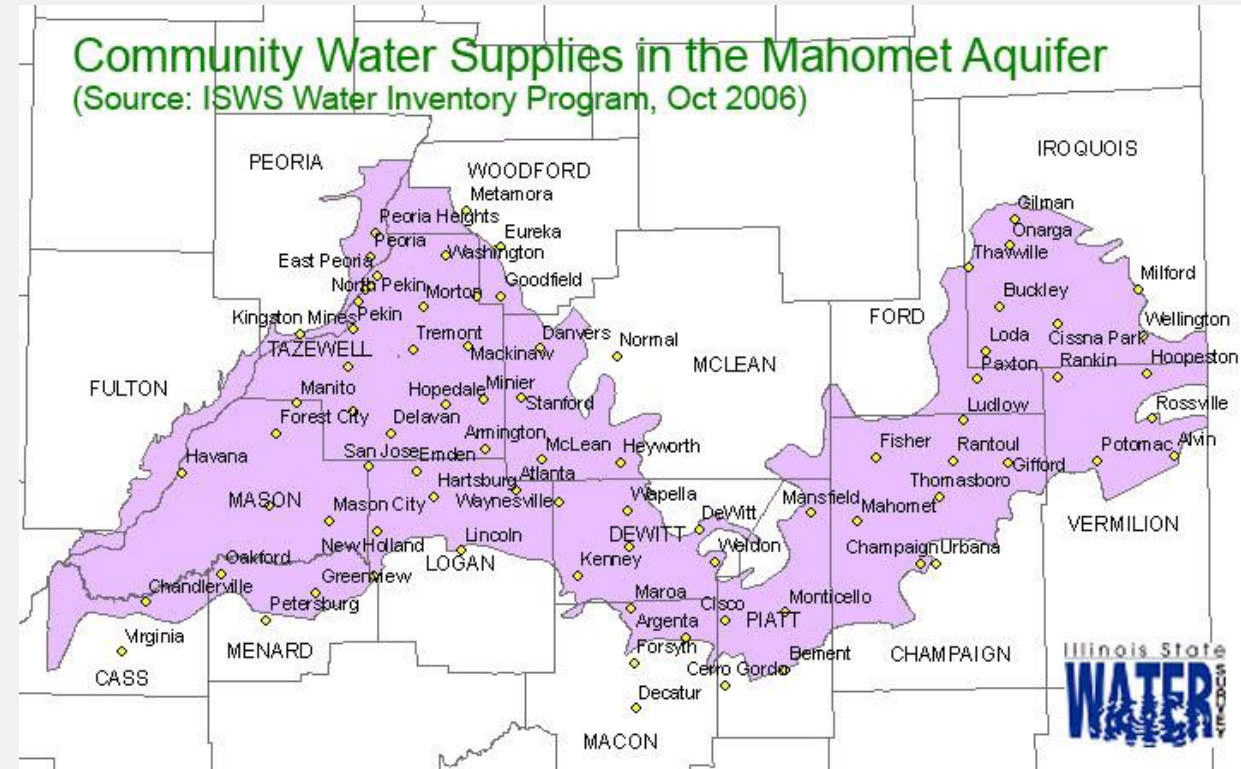
Local Problem – Quantifying and Predicting Surface Water Behavior

- Switch to Mahomet Aquifer is not ideal due to combination with Normal and smaller town consumption

- Land use of the study area is predominantly tile-drained agricultural fields, which promotes deep percolation instead of runoff
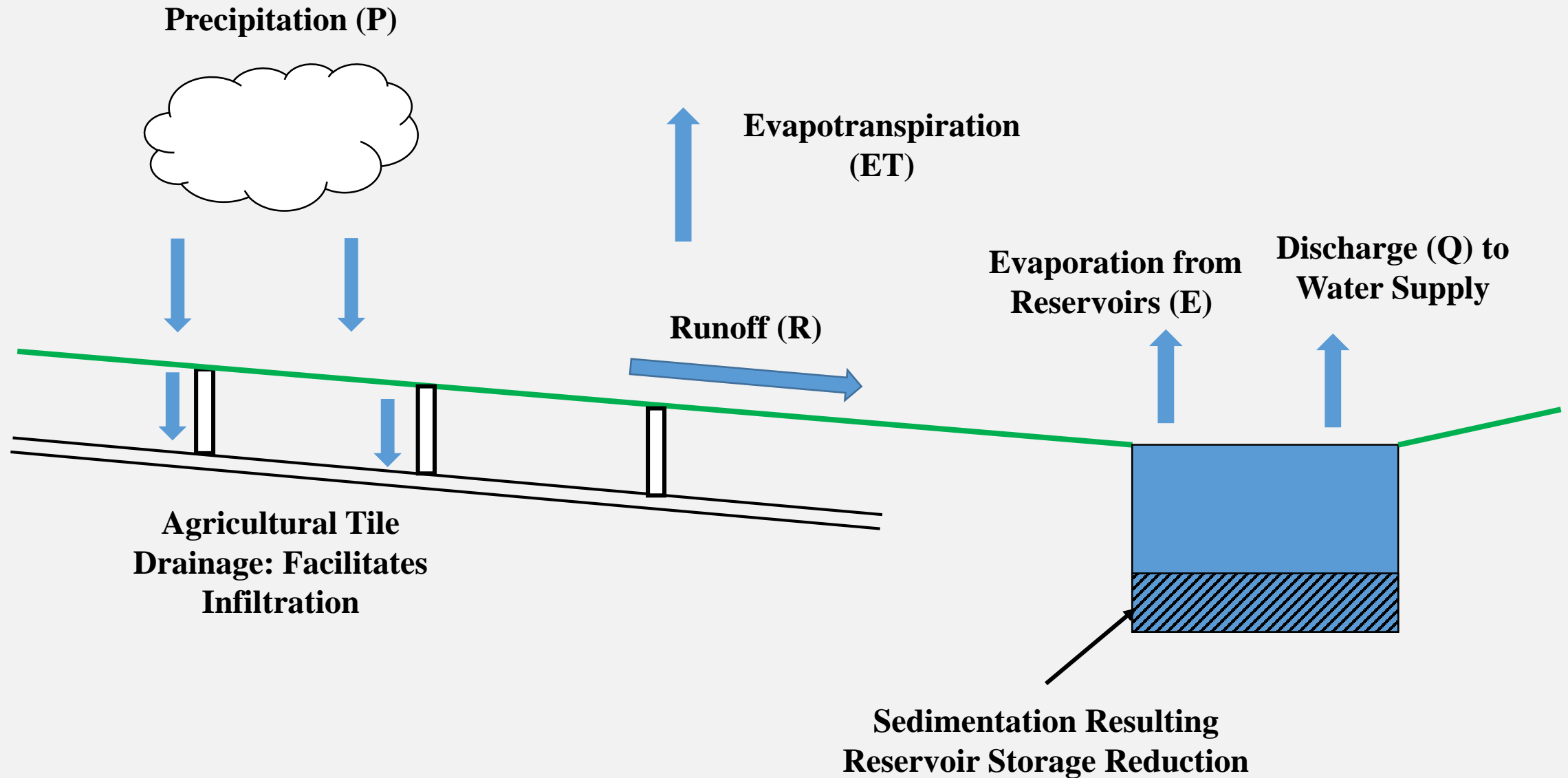

http://www.cityblm.org/Home/ShowImage?id=178&t=636130888246430000

http://www.mahometaquiferconsortium.org/images/CWS_MahometAquifer_ISWS1006.jpg

Local Problem – Quantifying and Predicting Surface Water Behavior

Impacts of Tile Drainage

- Modification of natural drainage

- Facilitates nutrient loading

- Essentially watershed baseflow

Hypothesis

The hypothesis of this study is that the water cycle of small-scale tile-

drained watersheds are highly sensitive to climatic stresses, which will

amplify current trends by the continued warming climate

Objectives

- Characterize hydrology of the watershed

- Evaluate predicted change in precipitation and temperature

- Measure and analyze the potential climate change impact on the water balance components

Study Area

- Wisconsin Episode glacial moraines and till plains (ISGS 2005)

- Topography is mostly flat land used for row crop agriculture

- Mackinaw River flows westward to the Illinois River

- 36-38" annual precipitation

- Average Temperature is 17°C (63°F)

Study Area - Mackinaw River Watershed

N

0   5   10   20 Kilometers
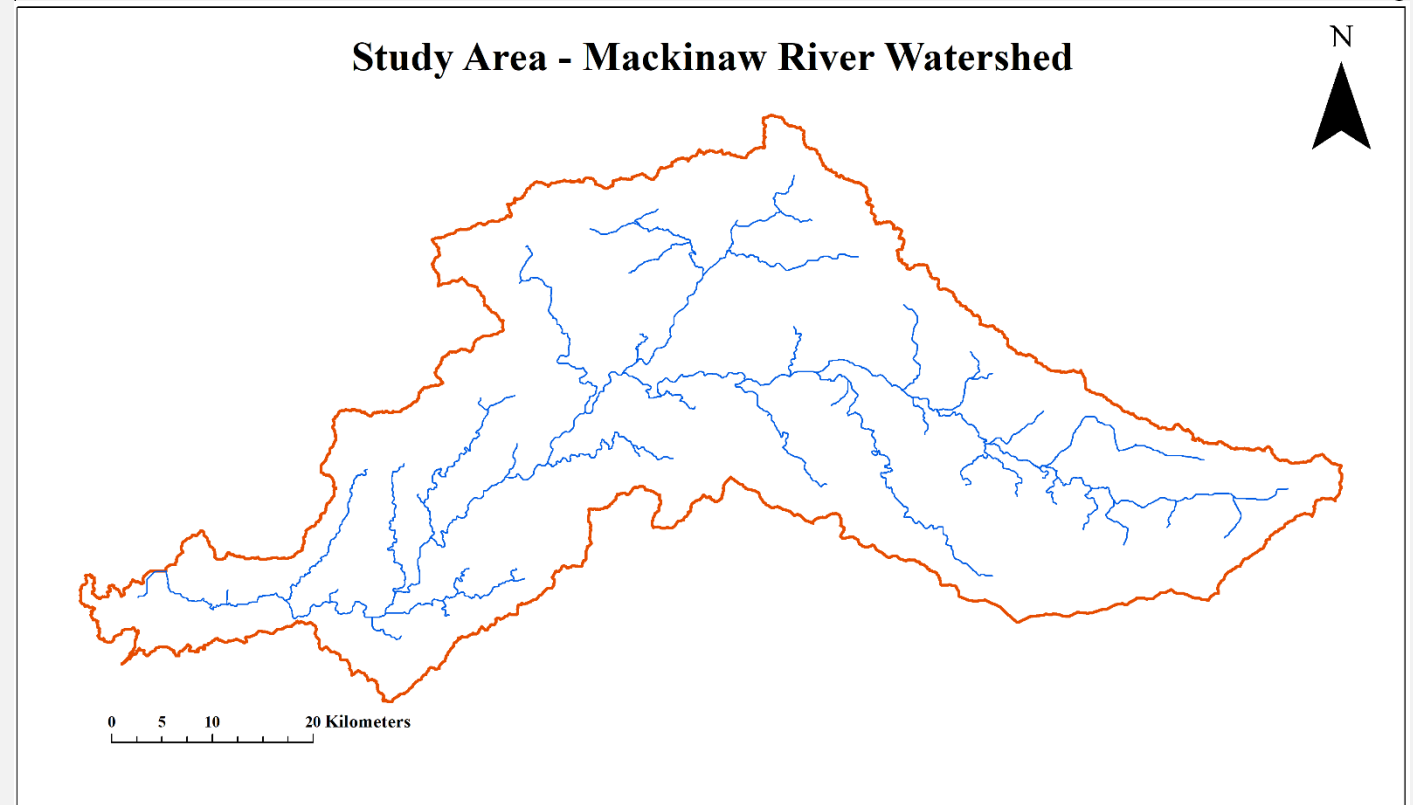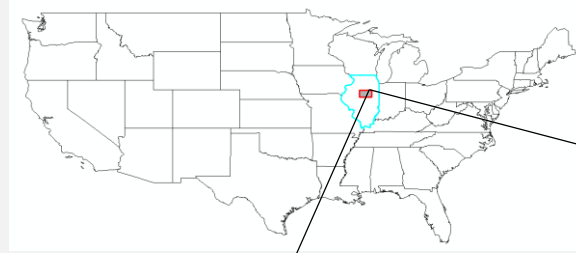
Data Overview

- Climate Data:
  - Precipitation (P)
  - Temperature (T)

  P & T will be calculated as outputs from simulations of general circulation models (GCMs)
  - Humidity, wind speed, solar radiation

- Spatial Data:
  - Digital Elevation Model (DEM) - ASTER
  - Soil Survey – USDA SSURGO V 2.2
  - Land Cover – USDA

- Hydrologic Data:
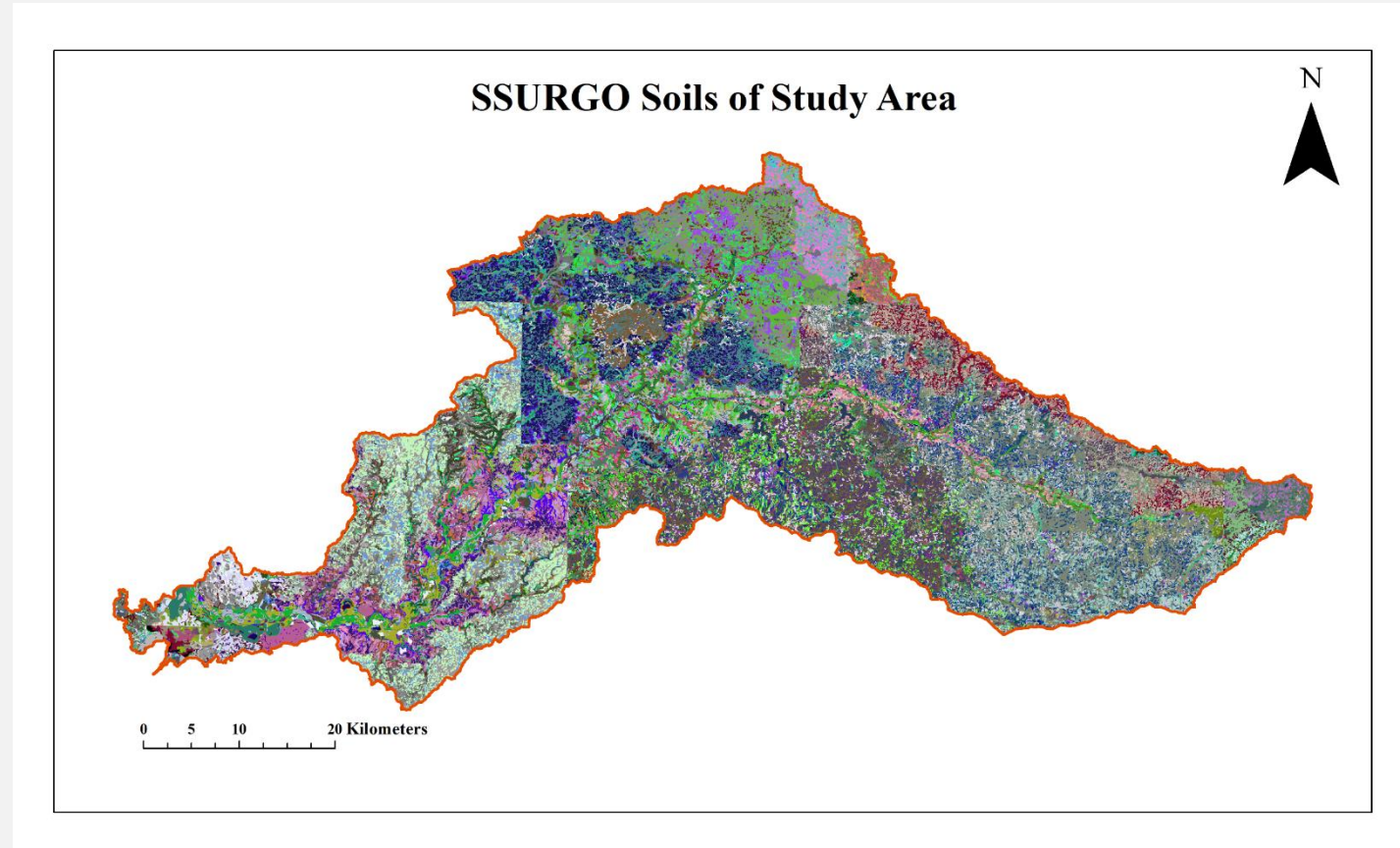 - Streamflow discharge of Mackinaw River and Sugar Creek

Data

Spatial Data:

- Digital Elevation Model (DEM) – ASTER

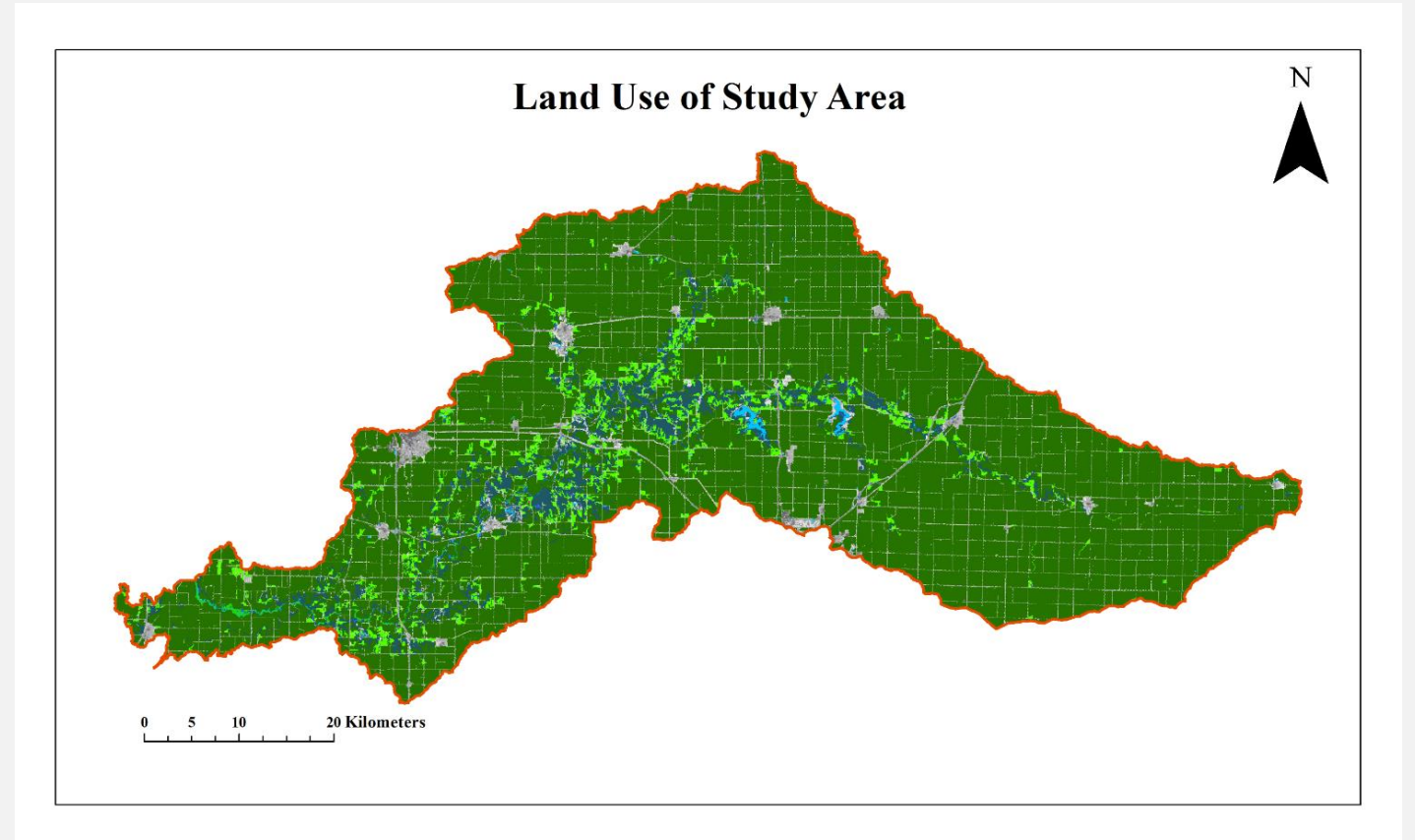- Soil Survey – USDA SSURGO V 2.2

- Land Cover - USDA

DEM of Study Area

Data

Spatial Data:

- Digital Elevation Model (DEM) – ASTER

- Soil Survey – USDA SSURGO V 2.2
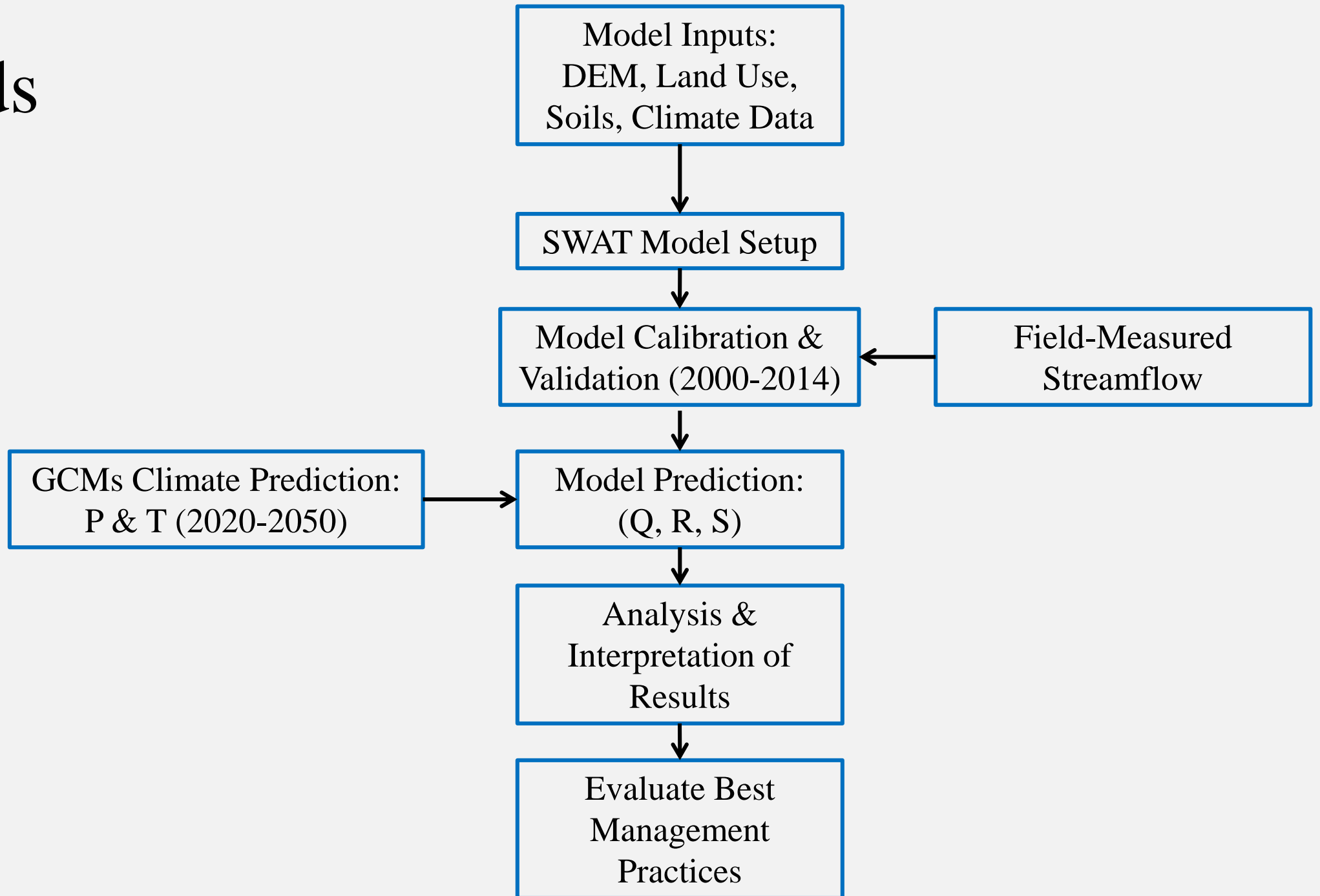
- Land Cover - USDA

SSURGO Soils of Study Area
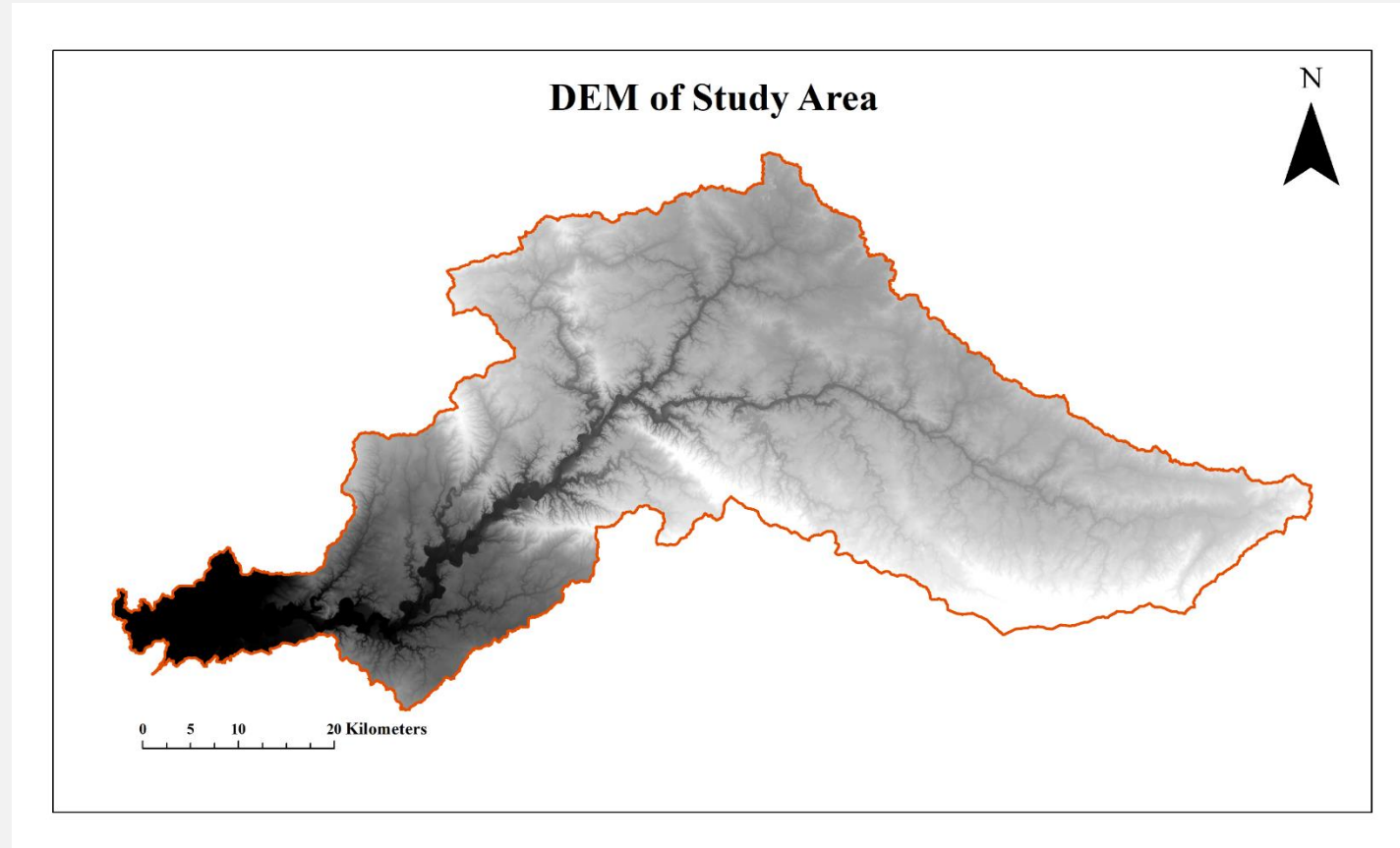
Data

Spatial Data:

- Digital Elevation Model (DEM) – ASTER

- Soil Survey – USDA SSURGO V 2.2

- Land Cover – National Land Cover Map

Land Use of Study Area

N

0   5   10   20 Kilometers

Methods

Representative Concentration Pathways (RCPs)

- The Intergovernmental Panel on Climate Change (IPCC) establishes four (4) Representative Concentration Pathways (RCPs) of greenhouse gas emissions as standards for climate projection studies

- Simulation of the 4 RCPs in general circulation models (GCMs) provides outputs of P & T for the study area

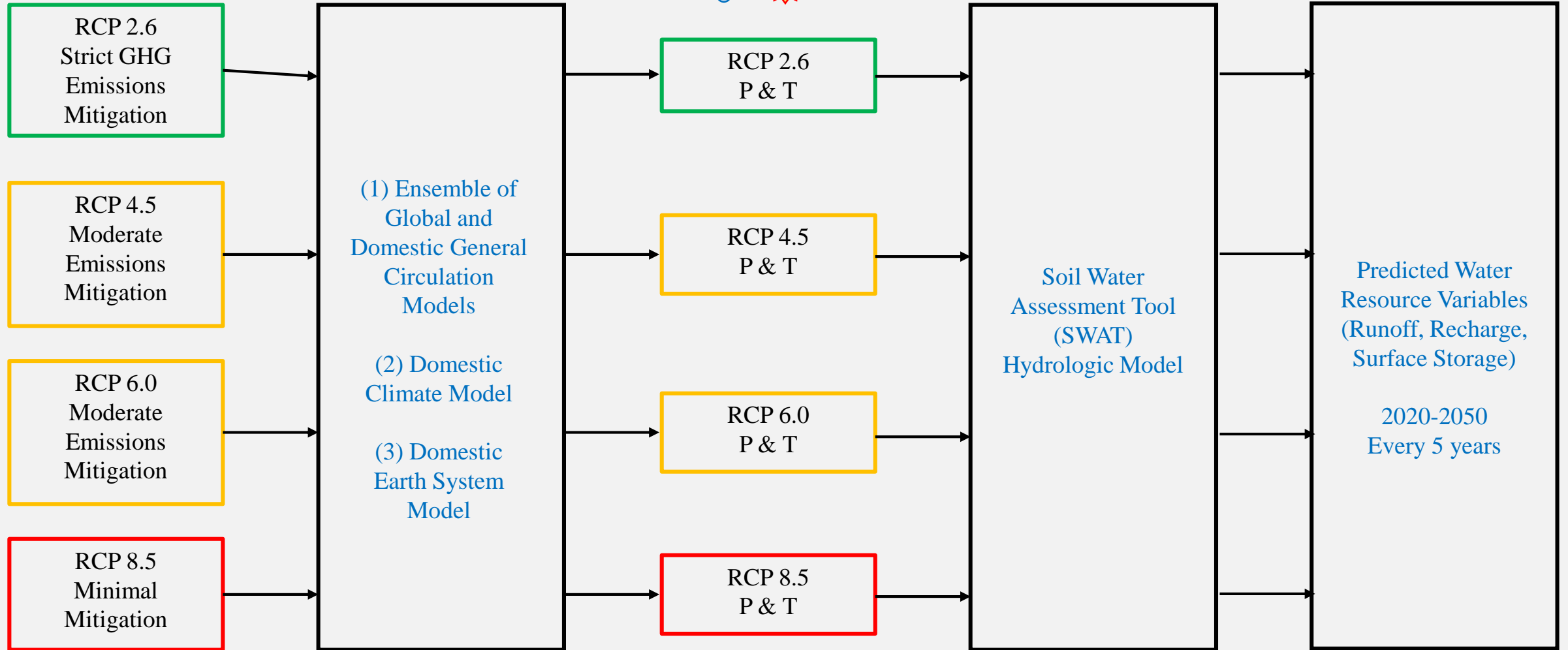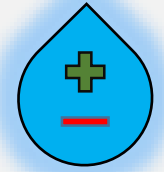| RCP 2.6 Best mitigation of emissions practices	RCP 4.5 Moderate mitigation of emissions practices	RCP 6.0 Moderate mitigation of emissions practices	RCP 8.5 No mitigation of emissions practices

Climate Modeling

RCP 2.6 Strict GHG Emissions Mitigation		**RCP 2.6** P & T	
RCP 4.5 Moderate Emissions Mitigation	(1) Ensemble of Global and Domestic General Circulation Models	**RCP 4.5** P & T	Soil Water Assessment Tool (SWAT) Hydrologic Model
RCP 6.0 Moderate Emissions Mitigation	(2) Domestic Climate Model (3) Domestic Earth System Model	**RCP 6.0** P & T	Predicted Water Resource Variables (Runoff, Recharge, Surface Storage) 2020-2050 Every 5 years
RCP 8.5 Minimal Mitigation		**RCP 8.5** P & T	

Soil-Water Assessment Tool (SWAT)

- Semi-distributed, basin-scale water balance model

- Daily time step

- Based on the following equation from (Arnold 1998):

$$SW_t = SW + \sum_{t=1}^{t} (P_i - Q_i - ET_i - QR_i)$$

- SW = soil water content minus 15-bar water content

- t = time in days; P= precipitation; Q = runoff;
  ET = evapotranspiration; QR = percolation & return flow

SWAT

- Runoff: Watershed divided into subbasins - hydrologic response units (HRUs)
- HRUs share similarities in soil, land use, and slope
- Runoff for daily rainfall is predicted using the USDA Soil Conservation Service (SCS) curve number (CN) equation as follows (USDA-SCS, 1972):

$$Q = \frac{(P - 0.2\ s)^2}{P + 0.8s} \quad P > 0.2s$$

$$Q = 0.0 \quad P \leq 0.2s$$

- Daily surface runoff (Q) determined by daily rainfall (P) and a retention parameter, (s).
- The retention parameter, s, is related to the CN by the SCS equation (USDA-SCS, 1986).

$$s = \frac{1000}{CN} - 10$$

- Curve number ranges from 30 to 100; 100 represents highest runoff
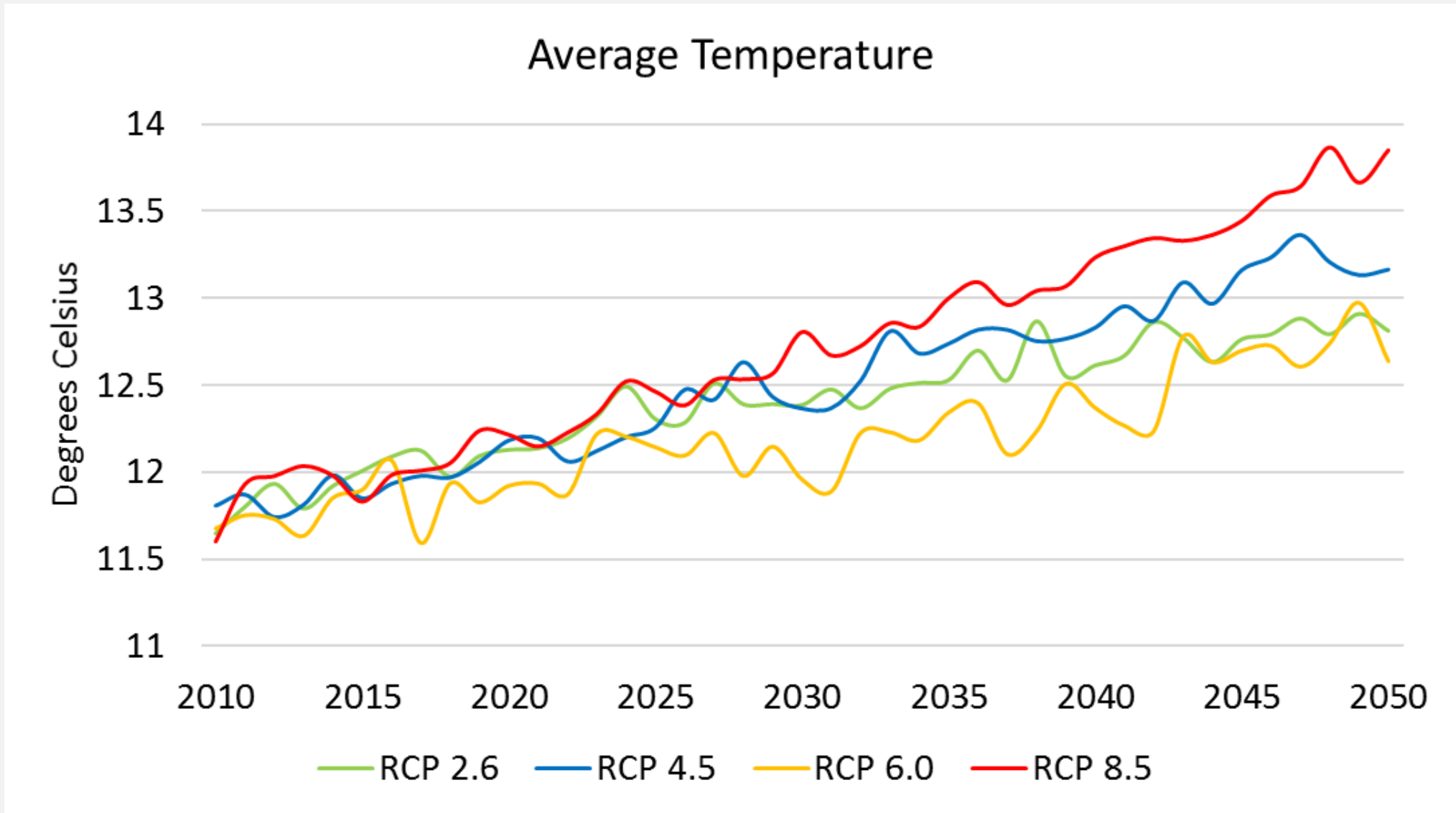
Results – Calibration & Validation
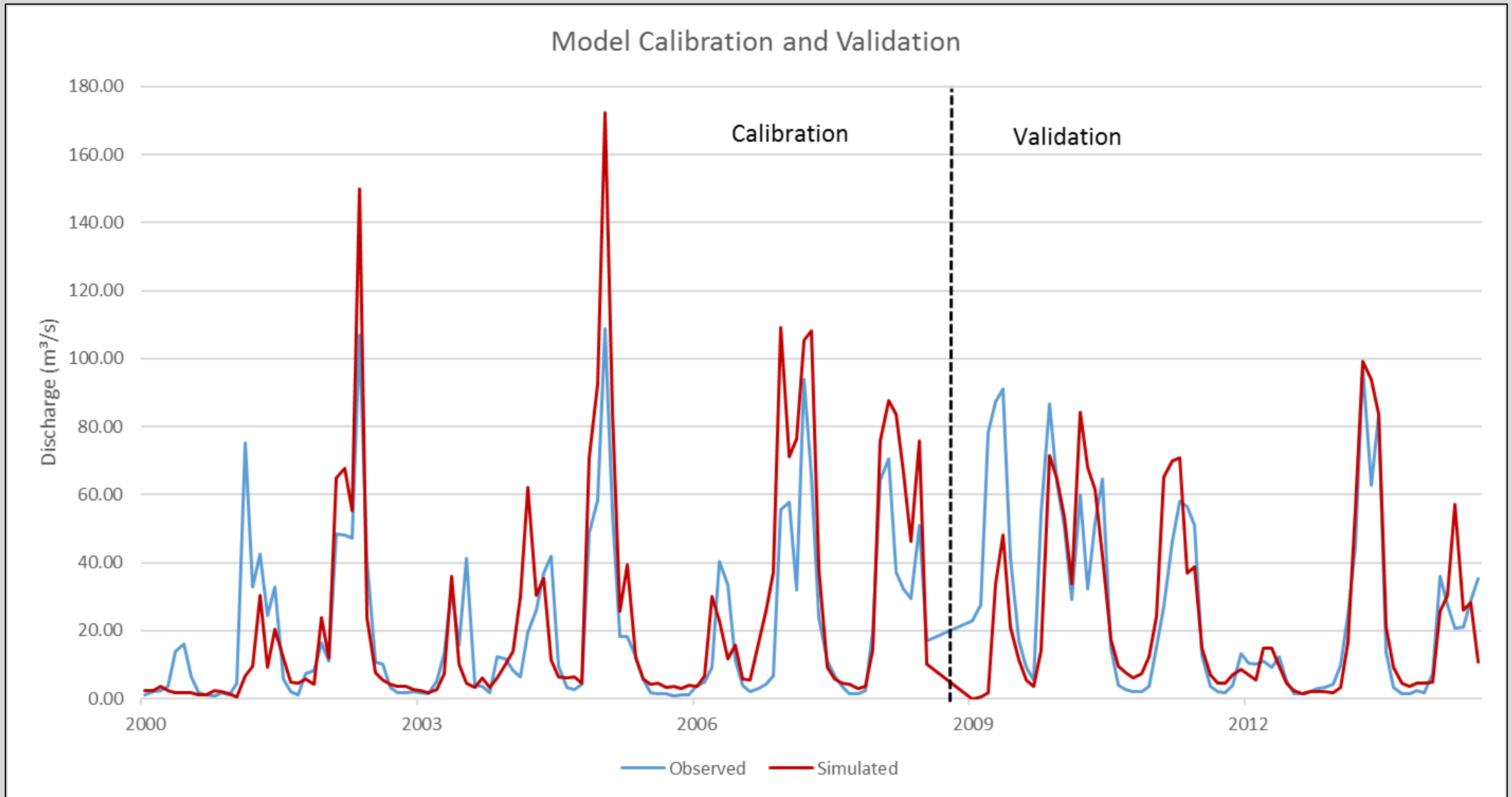
Results – Calibration & Validation
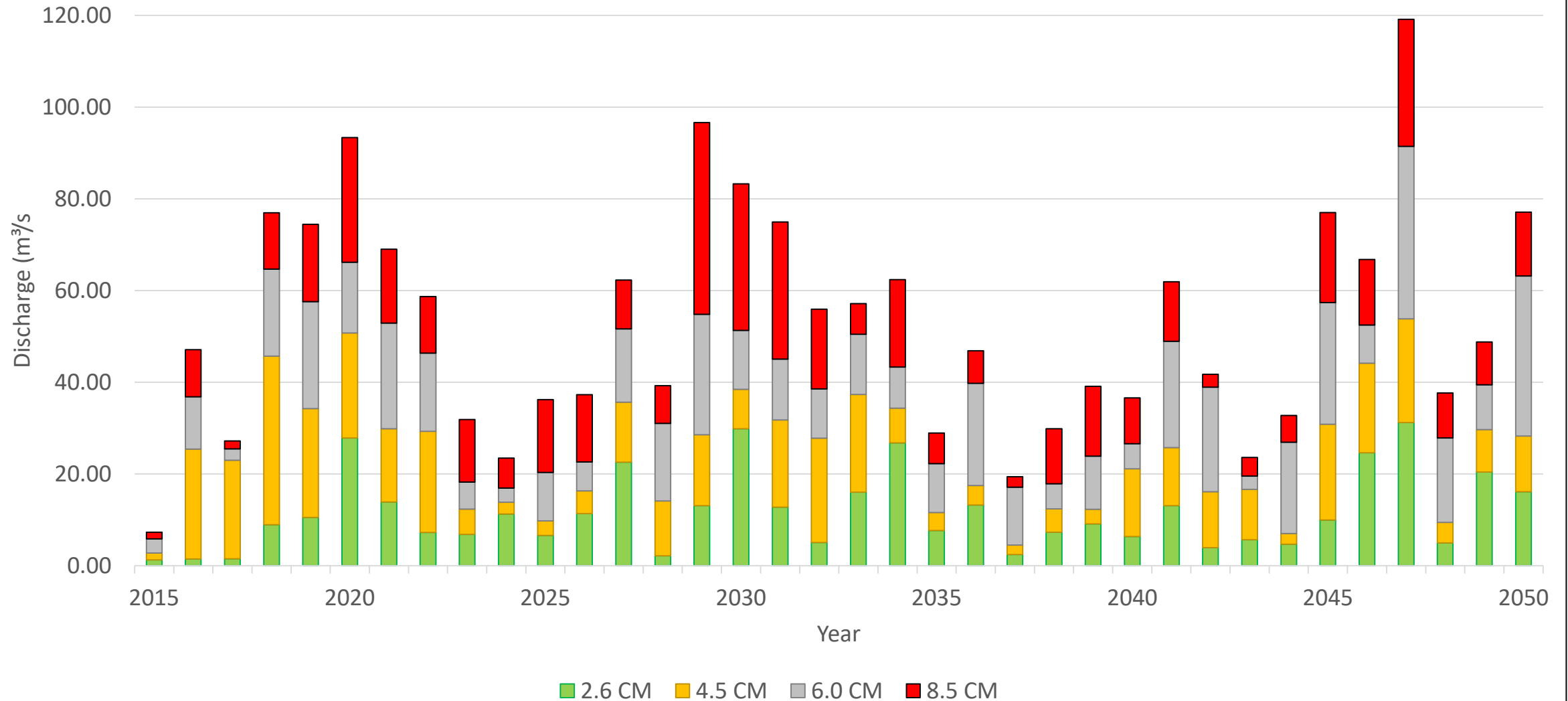
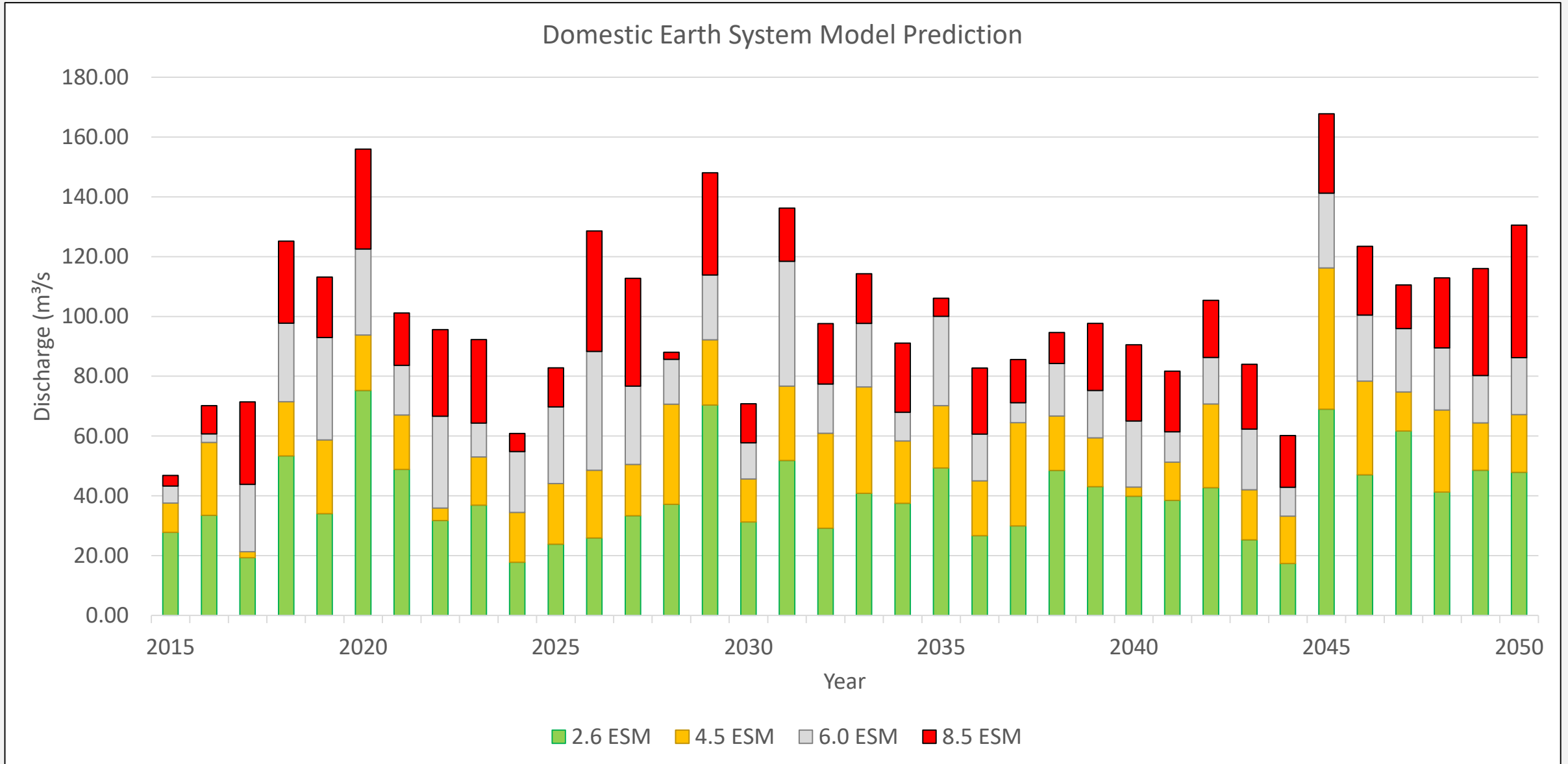# Predicted Precipitation & Temperature
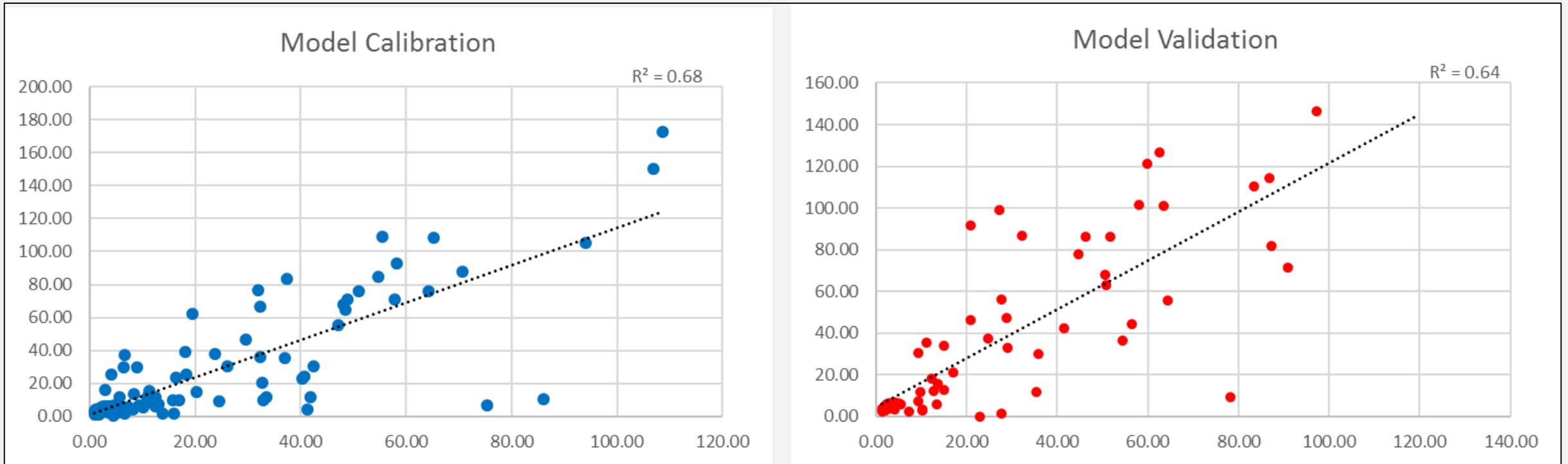
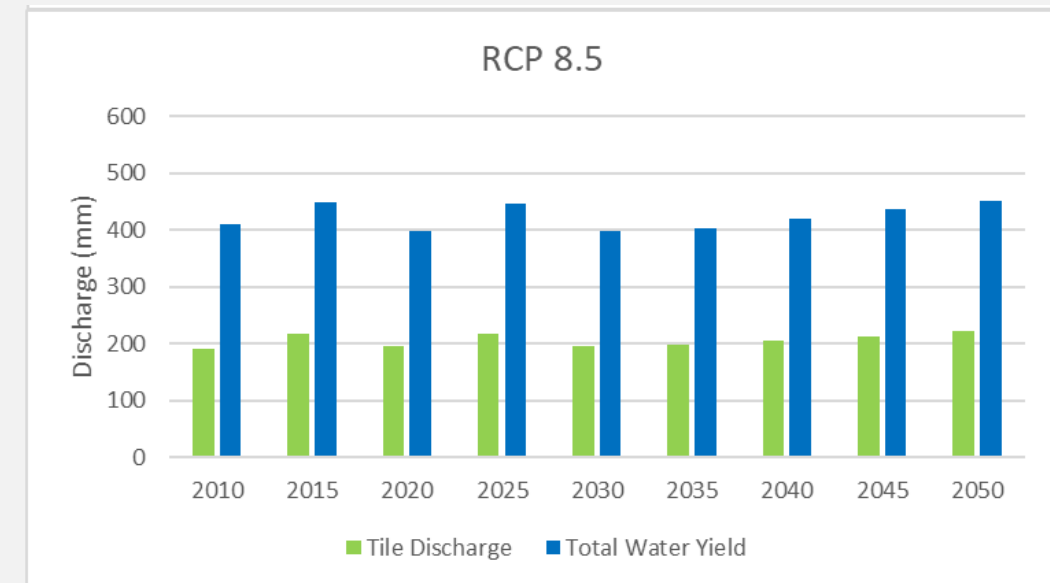Projected Precipitation (mm) of Watershed
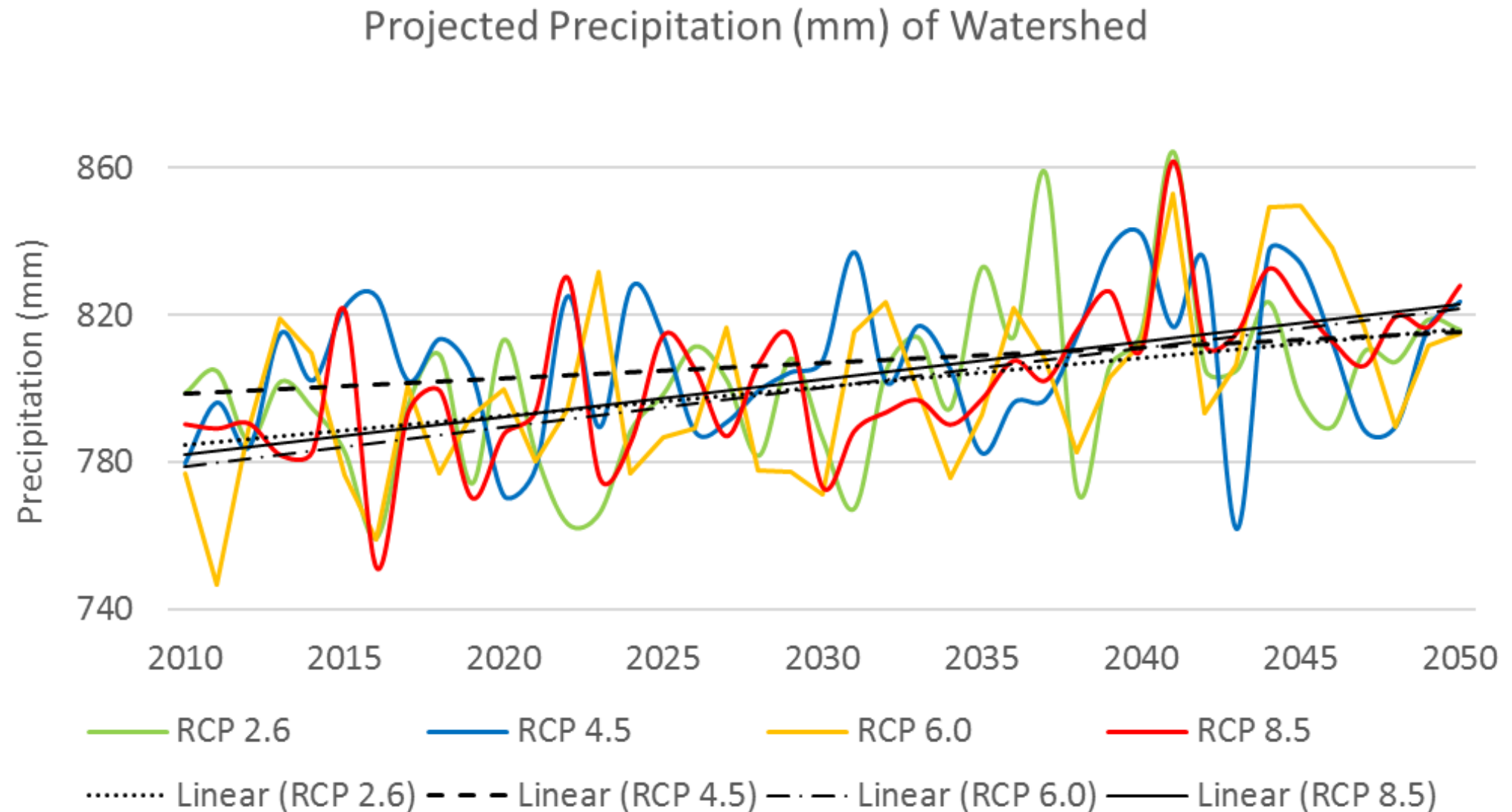
Predicted Precipitation & Temperature
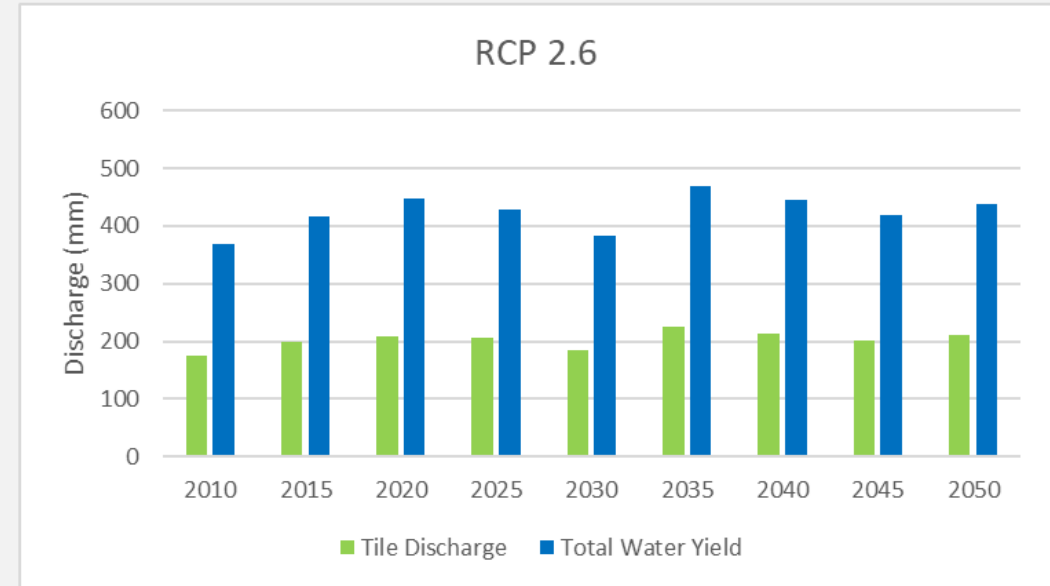
Results – Discharge of Watershed

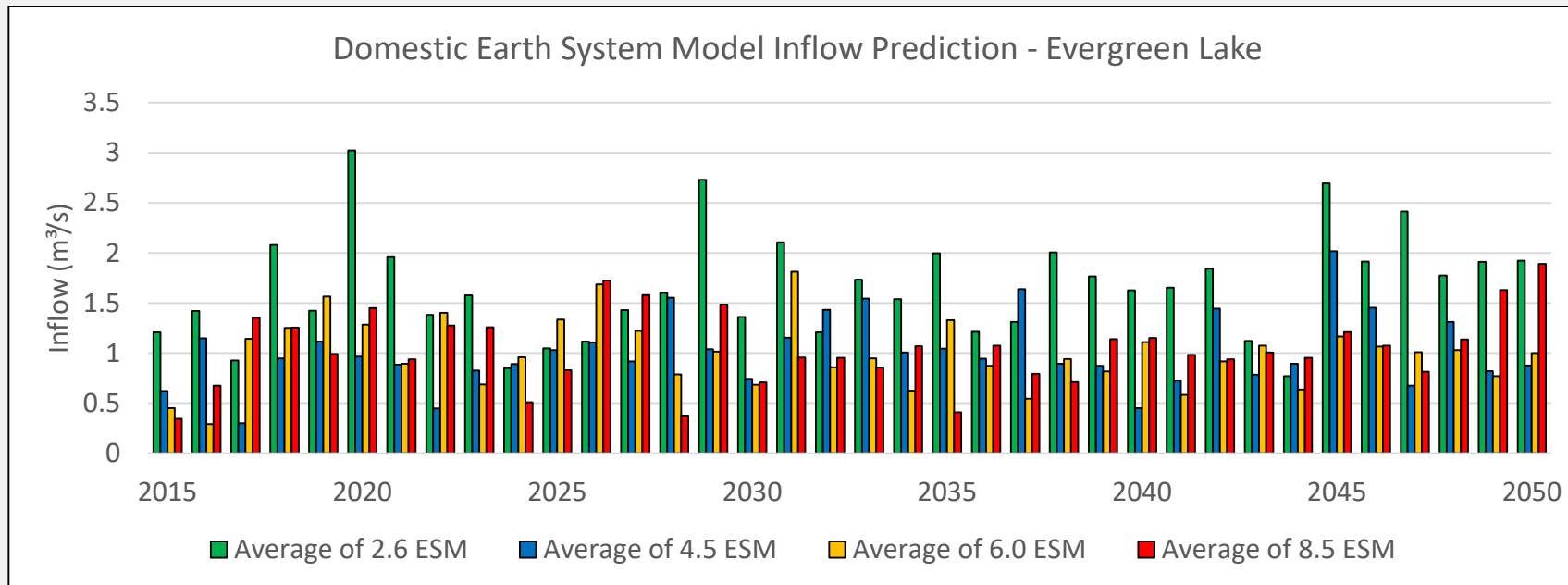# Results – Discharge of Watershed
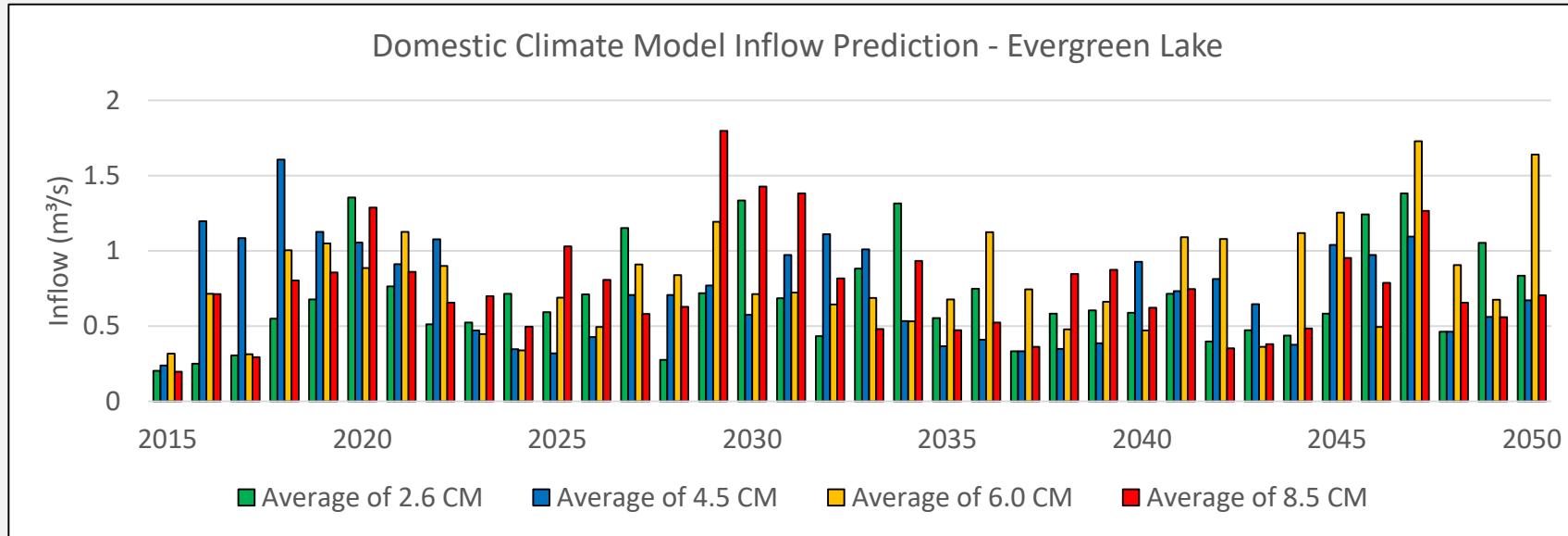

Domestic Earth System Model Prediction
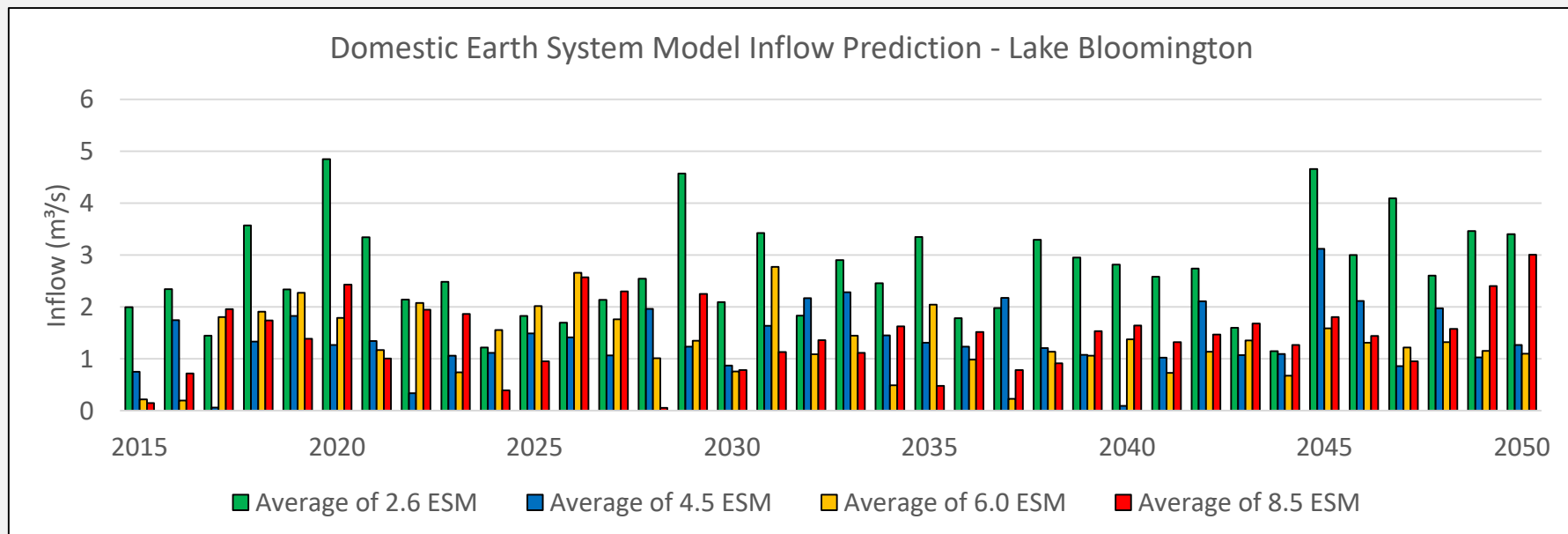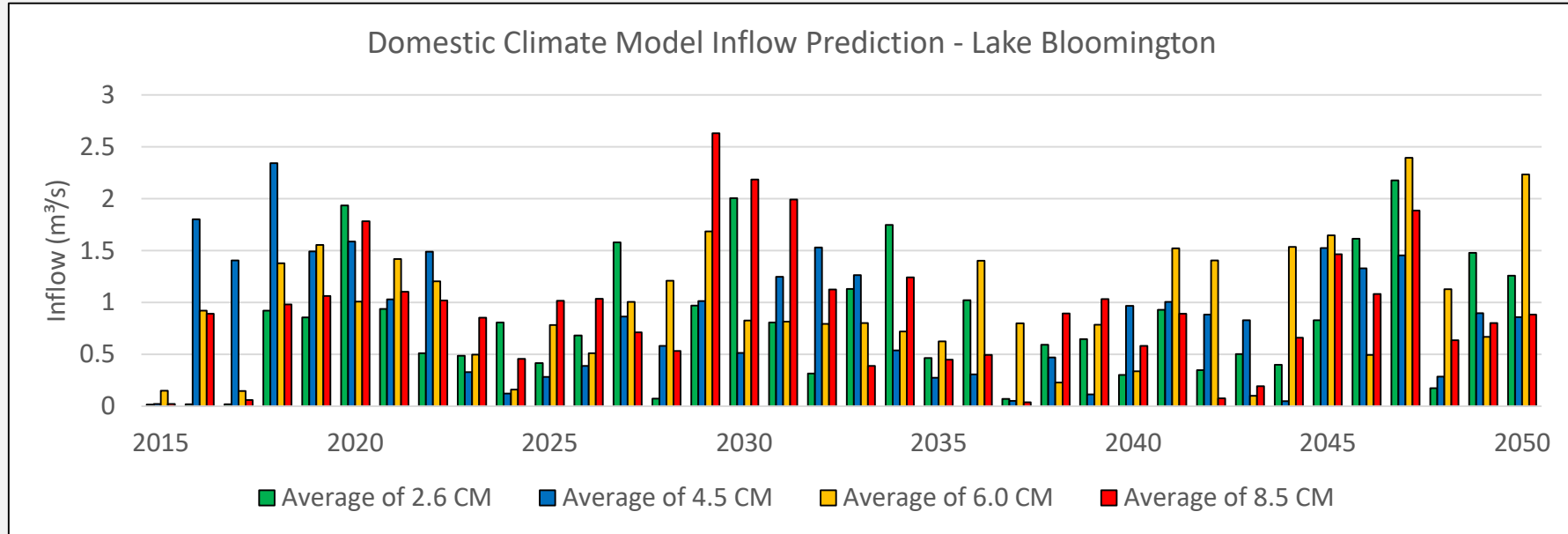
Results – Tile Drainage

- Ensemble: 46-49% of total water yield

- Domestic Earth System Model (GFDL ESM2M) : 38%

- Domestic Climate Model (CCSM4.0) : 42-48%

- Nutrient loading will remain consistent as a portion of total water yield
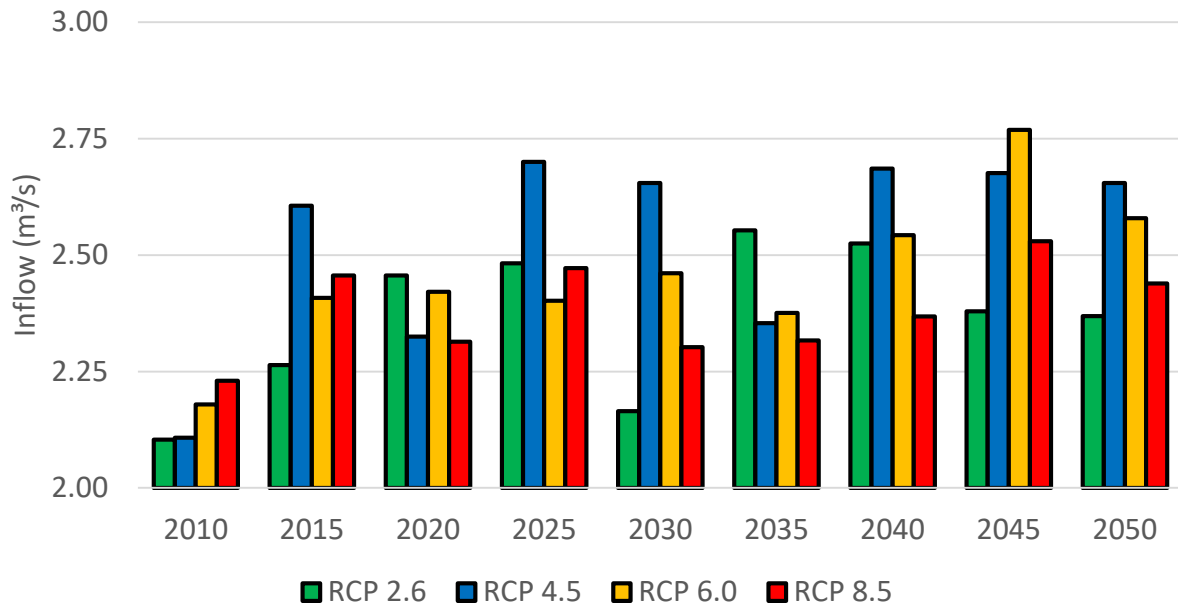
Results – Lake Inflow

Domestic Climate Model Inflow Prediction - Evergreen Lake

■ Average of 2.6 CM ■ Average of 4.5 CM ■ Average of 6.0 CM ■ Average of 8.5 CM

Domestic Earth System Model Inflow Prediction - Evergreen Lake

■ Average of 2.6 ESM ■ Average of 4.5 ESM ■ Average of 6.0 ESM ■ Average of 8.5 ESM

Results – Lake Inflow

Domestic Climate Model Inflow Prediction - Lake Bloomington

Domestic Earth System Model Inflow Prediction - Lake Bloomington

Results – Lake Inflow
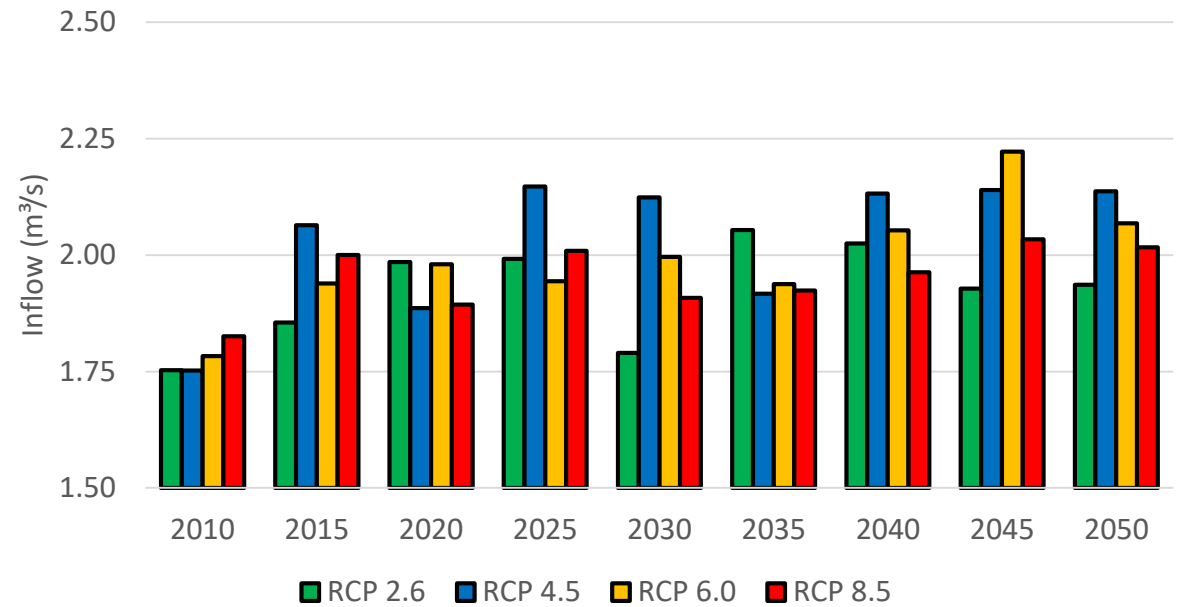
Conclusions

- General trends are toward warmer and wetter

- All models and scenarios predict similar drought timing and length
  - All RCPs and GCMs arrive at similar prediction
  - Water yield
  - Lake inflow

- Tile drains will remain a strong component of flow

- Decision-makers have a sufficient tool to prepare future best management practices of water supply