MODELING THE IMPACT OF TILE DRAINAGE ON STREAMFLOW AND WATER QUALITY IN RED RIVER USING SWAT

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Reality

- Associated with the wet weather pattern in the Red River basin since early 1990's
  - Problem #1: Wet field conditions and salinity concerns for farmers
  - Problem #2: Spring flooding in the Red River basin
    - At Fargo station, 7 out of 15 major floods (>30 ft) occurred after 1993 in more than 100 yrs station history
    - 3 consecutive years of historic crest – 2009 (1^{st}), 2010 (7^{th}), and 2011 (4^{th})
- Subsurface (tile) drainage is being rapidly adopted by farmers in the RRV to solve Problem #1

QUESTIONS:

- Will tile drainage aggravate the spring flood situation in the RRV streams?
- Will tile drainage worsen the water quality in the RRV streams (nitrate and salinity)?

Arguments based on plot or field scale research

- Streamflow
  - Tile drainage increases water yield in general.
  - Tile drainage decreases water yield during spring snow-melting.
    - Creates storages in drained soils before spring-melt.
- Water quality
  - Tile drainage increases loads of nitrate and salinity
  - Tile drainage decreases loads of sediment and phosphorus

Our arguments

- The impact is unclear at the watershed scale.
  - Both the areas and locations of the tiled fields are important
    - Streamflow (ft^3/s) involves both volume and time
    - What's the level of changes in pollutant loads to receiving waters brought by tile drainage?
- Watershed-scale hydrologic modeling may be able to help.

Objective

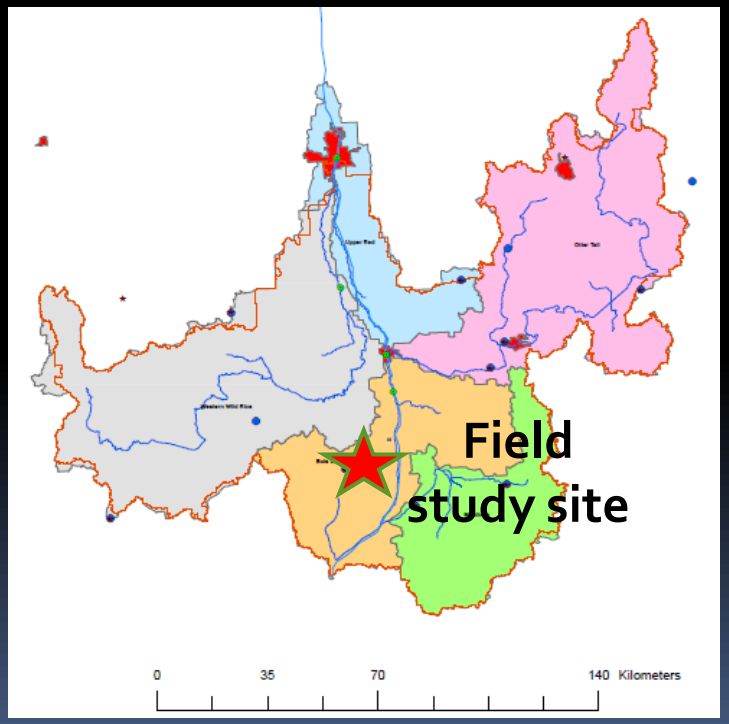
- Apply SWAT (Soil and Water Assessment Tool) to model the impact of tile drainage on streamflow and water quality in the upper Red River basin
  - Impact analysis at the field scale
  - Impact analysis at the watershed scale
    - Estimation of the current and potential tiled areas

Study area and model inputs

- Study area
  - South to Fargo, five 8-digit HUC's, of 6,400 sq miles
  - Land uses: Ag (65%), Pasture (11%), Wetlands (10%), Forest (9%), & Urban (5%)

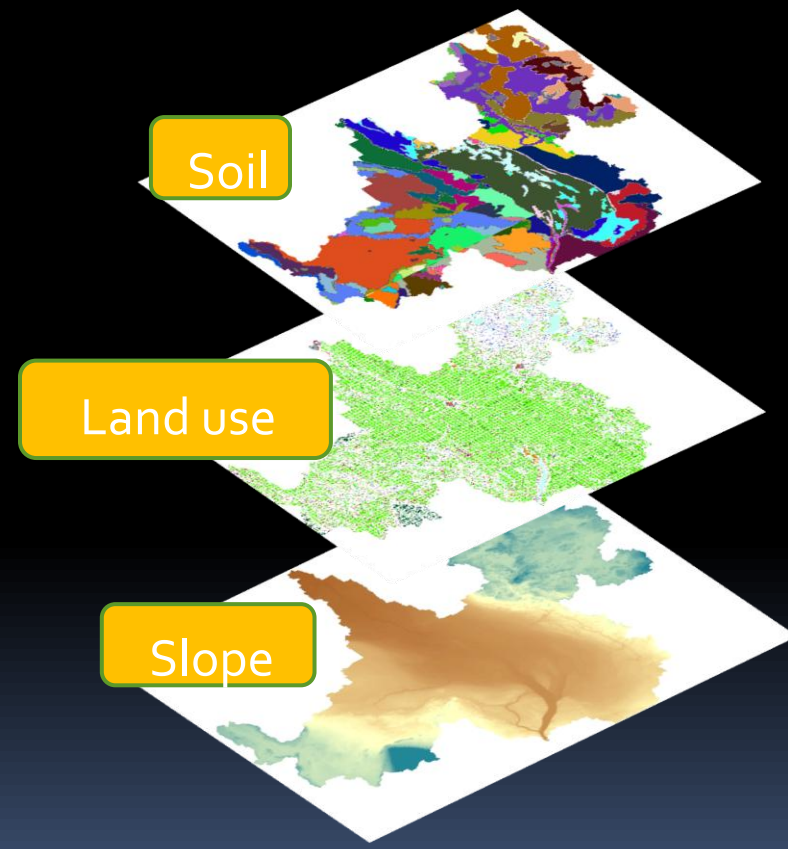
- Model inputs:
  - LiDAR DEM & NHD for watershed delineation
  - NLCD 2001 for landuse
  - STATSGO for soils
  - NOAA precip and temp

Upper Red River of the North (URRNB)



Mapping tile drained area

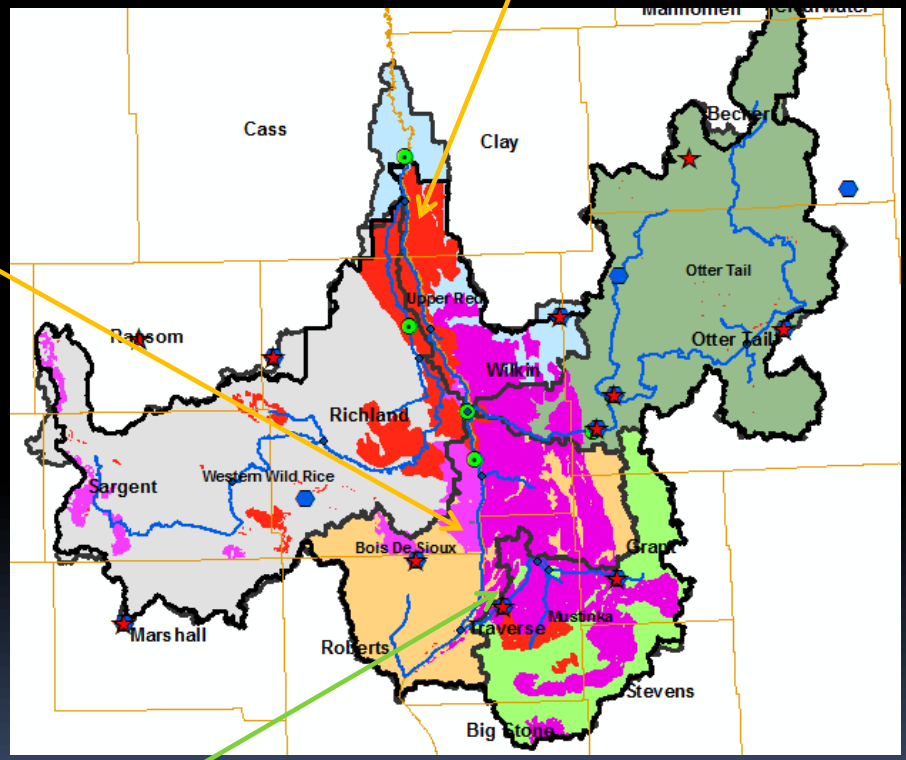
- Locations and areas
  - Existing tiled
  - Potential tiled
- Potential tiled area (PTA) = Crops grown on poorly drained soils (C and D) and on flat land
- Existing tiled area = PTA x percentage of tiled area
- Percentage: ND - Schuh (2008); MN – Sugg (2007)



Estimation of tile drained areas

Existing tiled area (<1%)

Experimental field

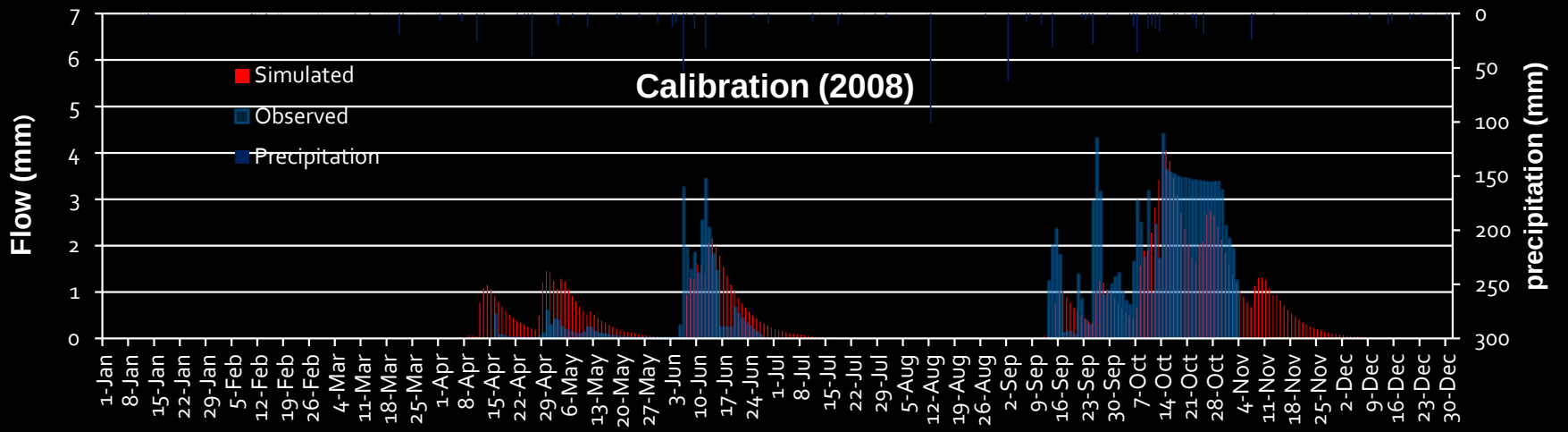


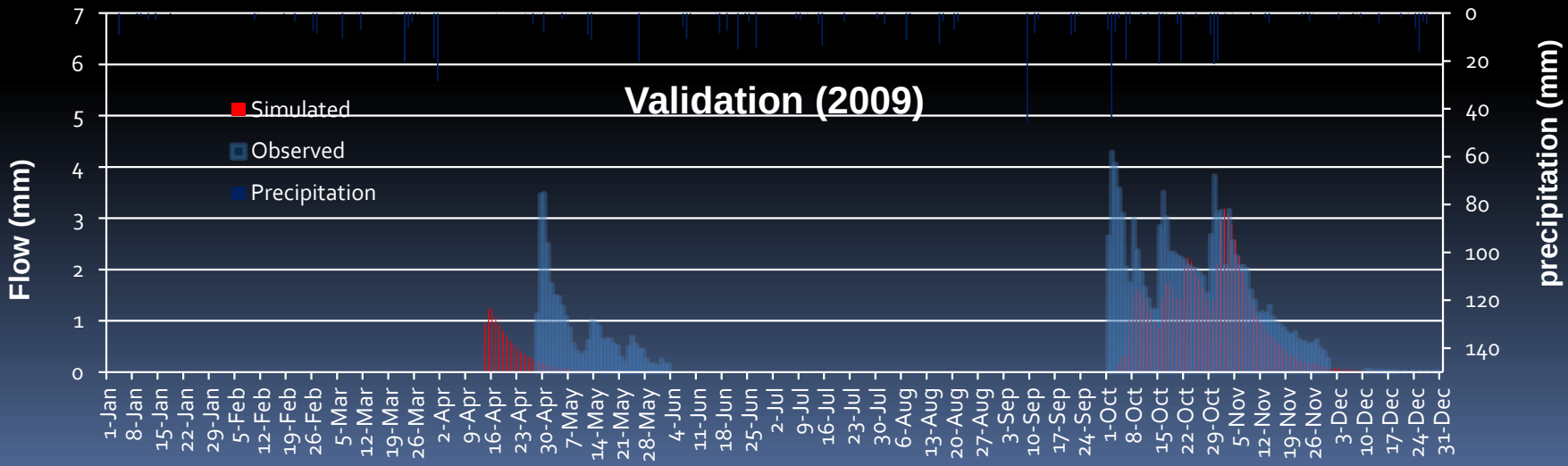
Potential tiled area (17%)

Model calibration

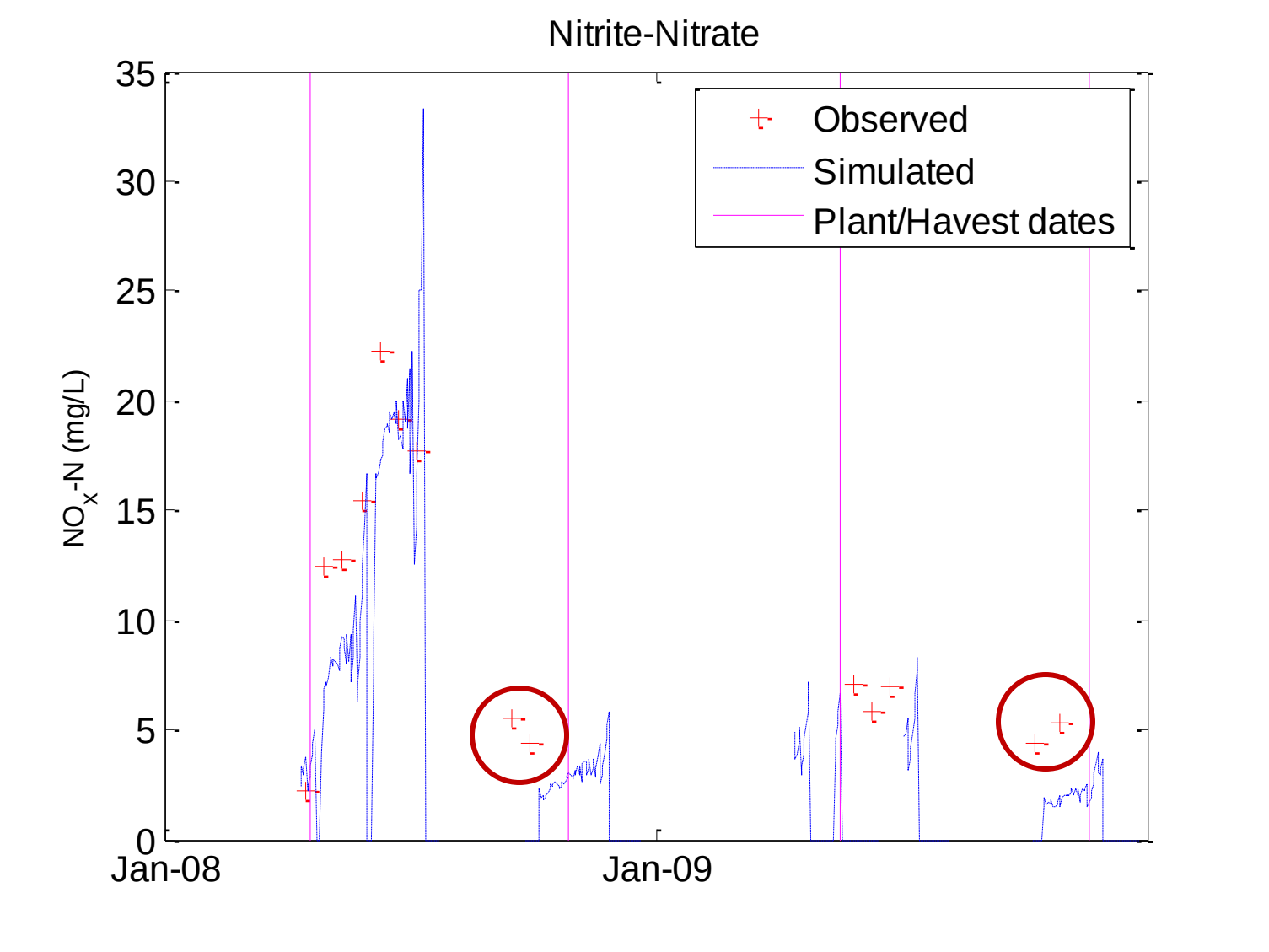
- Tile drainage algorithm calibrated at the Fairmount experimental field (22 ha)
  - 2008 - 2009
- Streamflow calibrated at the 5 USGS stream stations
  - 1990-2000 (calibration) & 2001-2009 (validation)

Field-scale calibration – tile flow



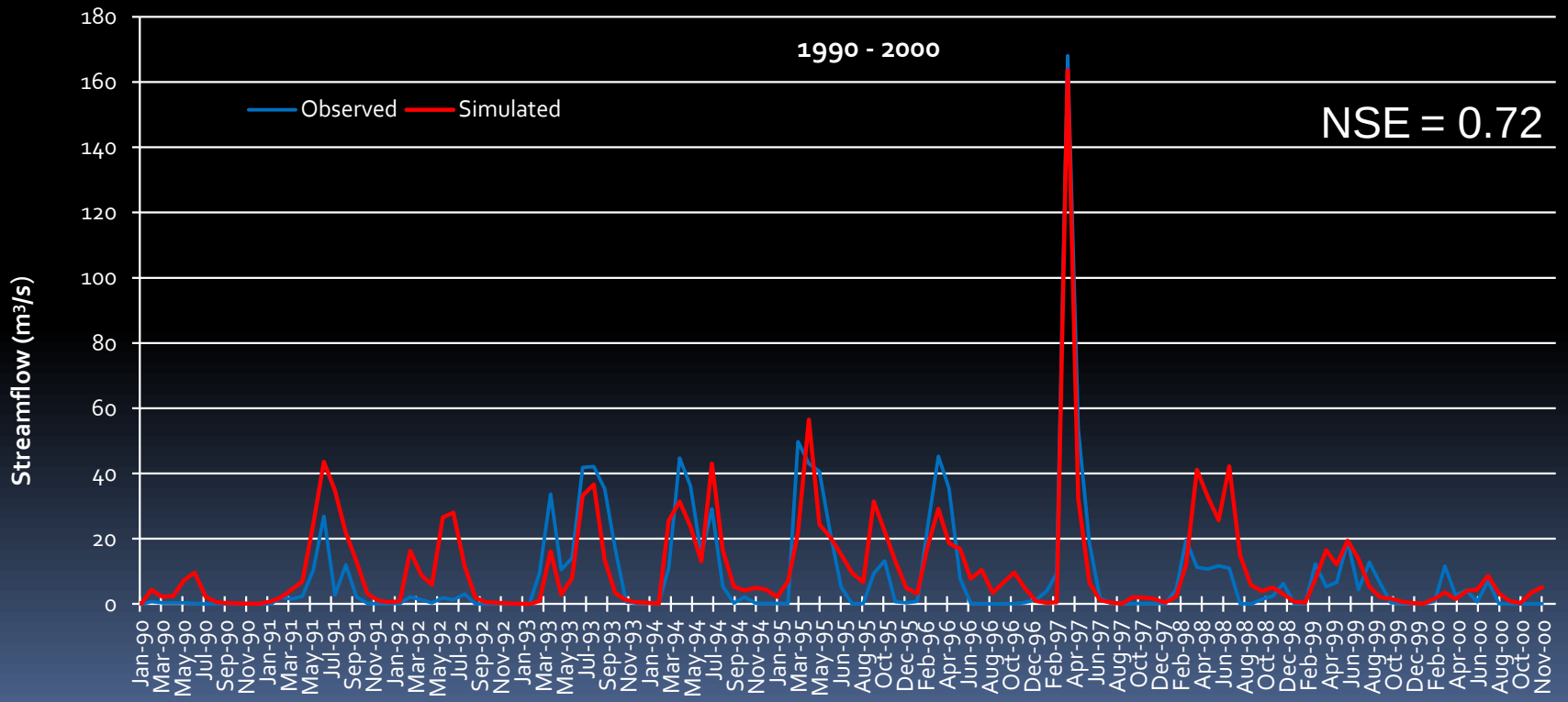


Field-scale calibration - nitrate



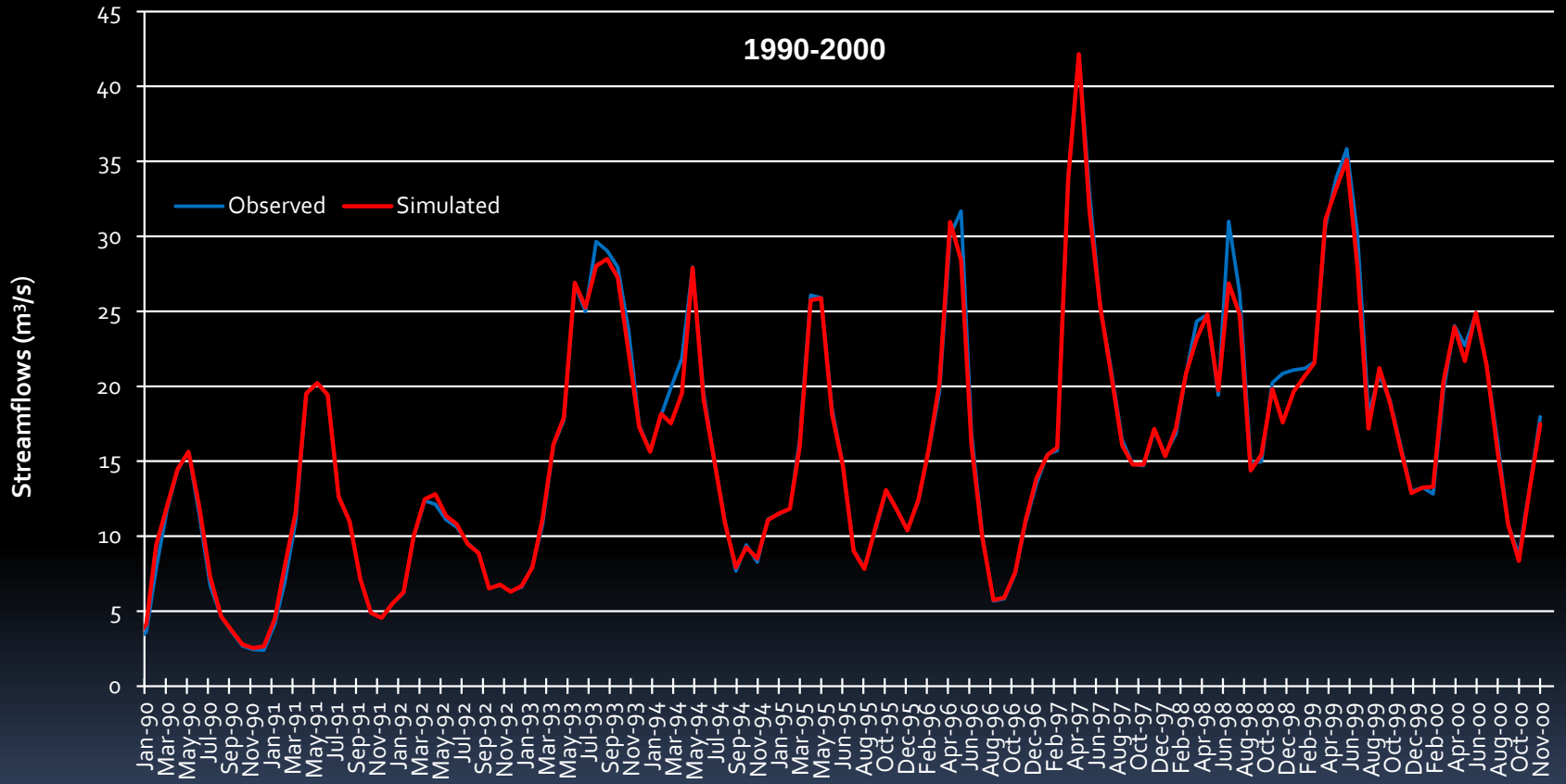
Watershed-scale calibration – streamflow

Bois De Sioux River near Doran



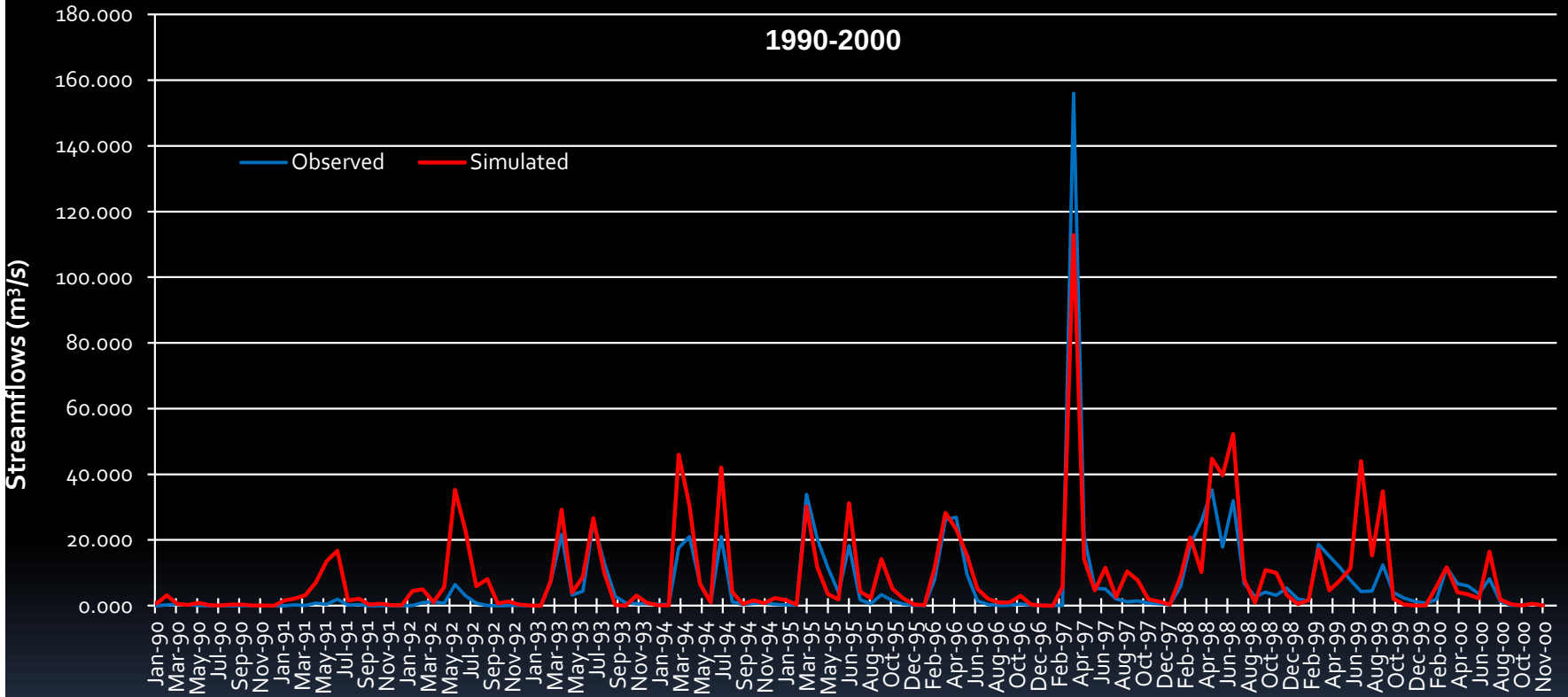
Otter Tail River

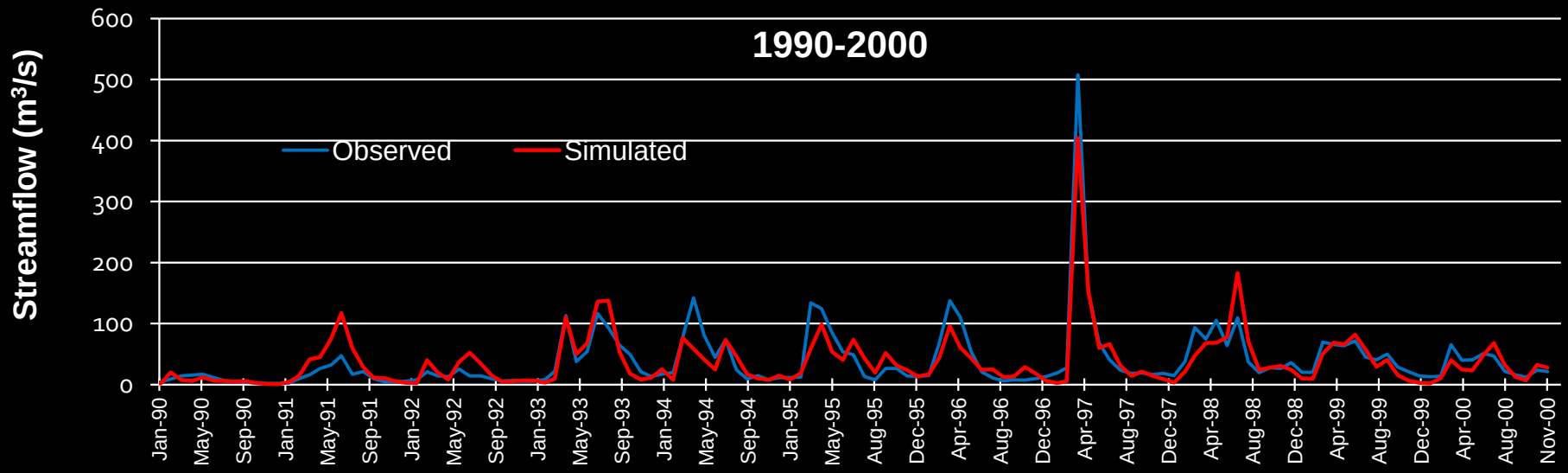
NSE = 0.99



Wild Rice River

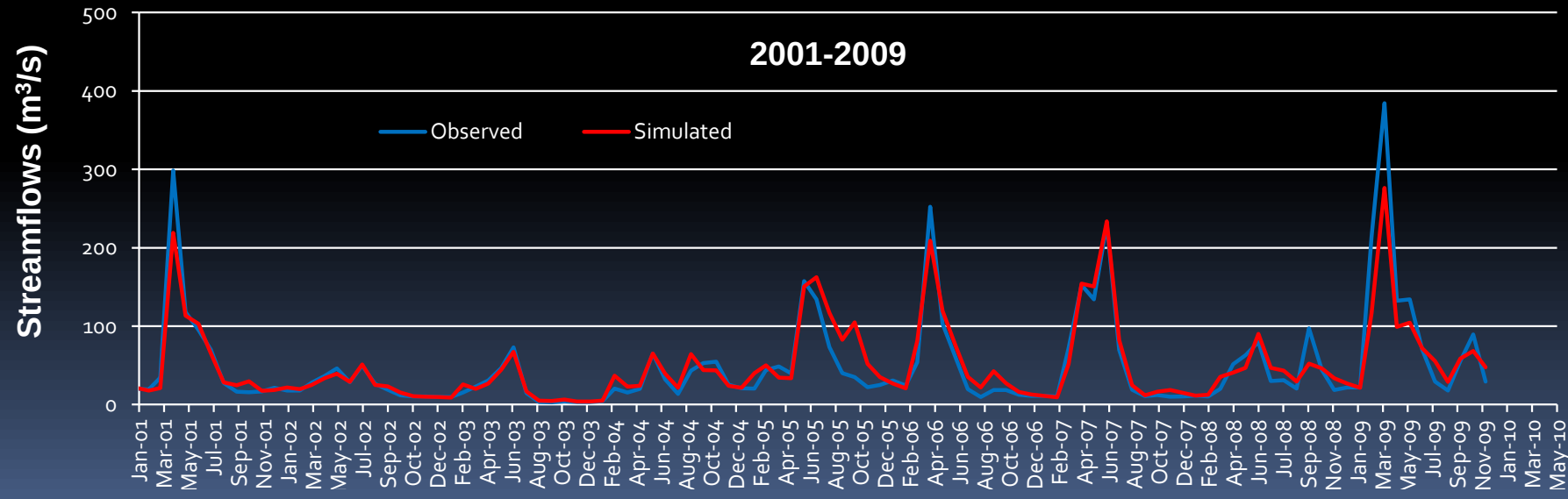
NSE = 0.69





Red River at Fargo

NSE = 0.84



Results of impact analysis

Field-scale analysis (100% tiled)

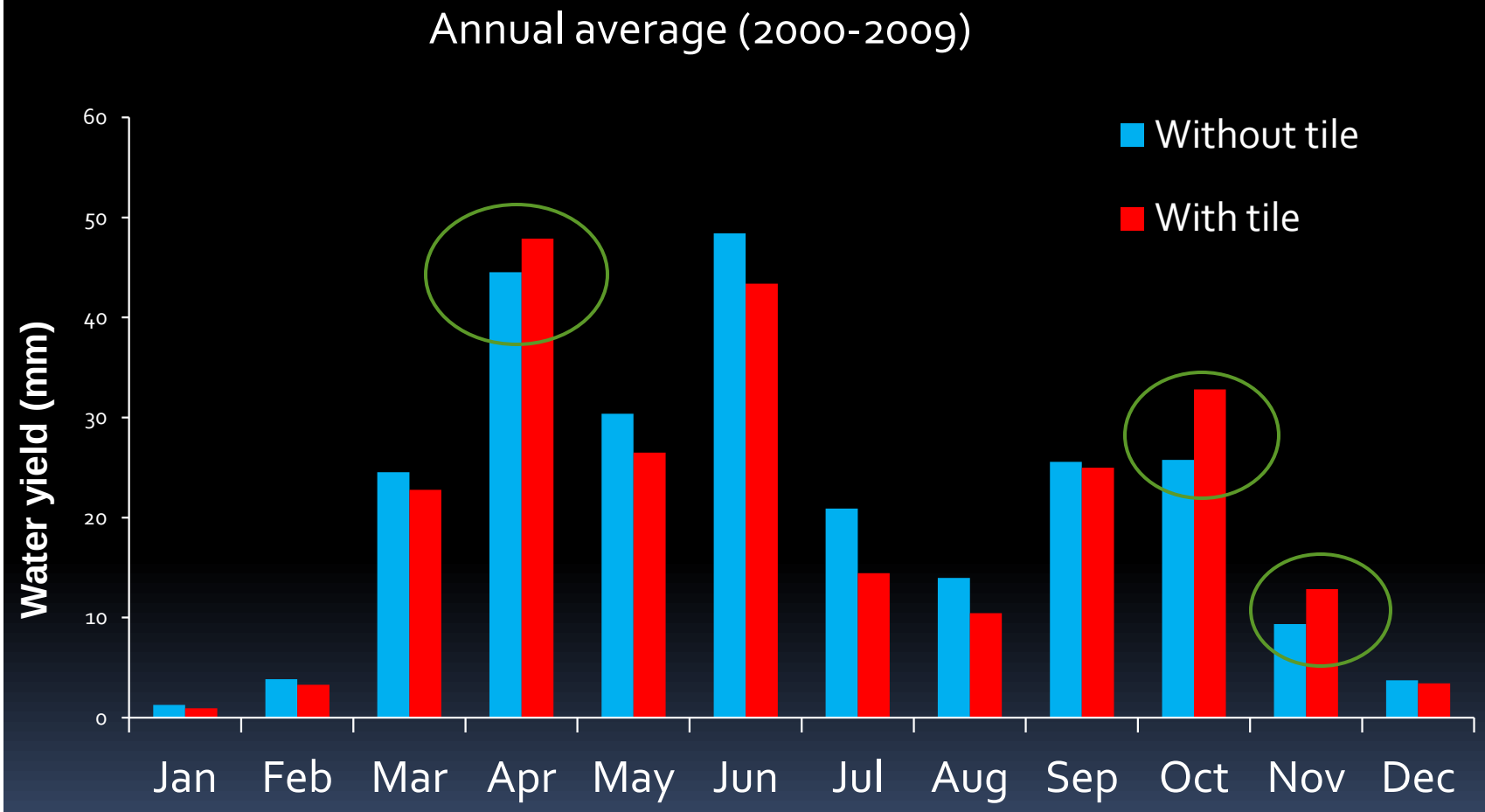
Annual average (2008-2009)

Components (mm)	Without Tile	With Tile	Changes (%)
Annual precipitation	720		
Tile flow	0	120	
Surface runoff	317	205	-35.0
ET	378	386	2.0
Water yield	318	326	2.6

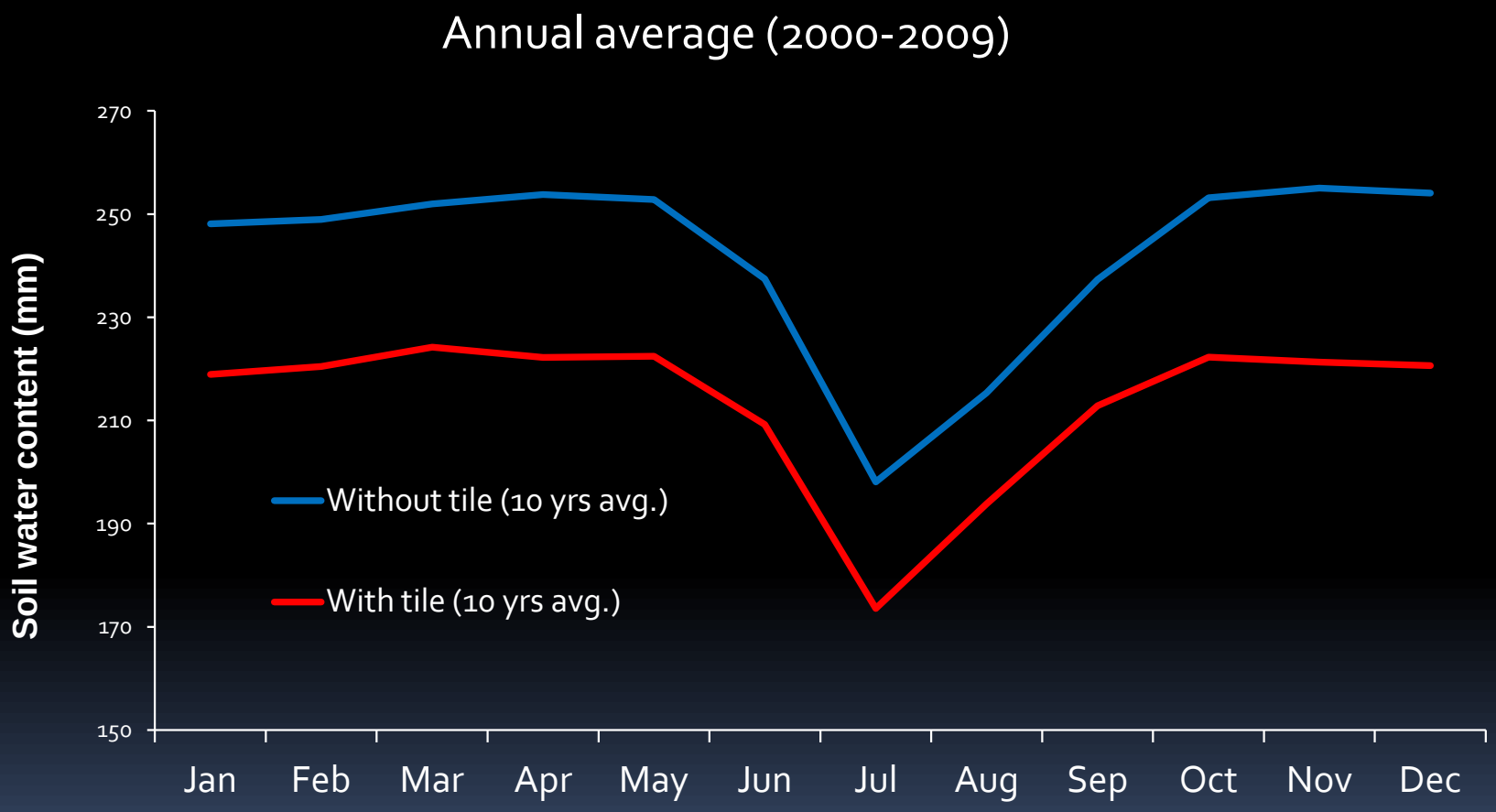
Annual average (2000-2009)

Components (mm)	Without Tile	With Tile	Changes (%)
Annual precipitation	665		
Tile flow	0	81	
Surface runoff	252	163	-35.5
ET	404	416	3.1
Water yield	252	244	-3.4

Seasonal impact on water yield



Impact on soil water content



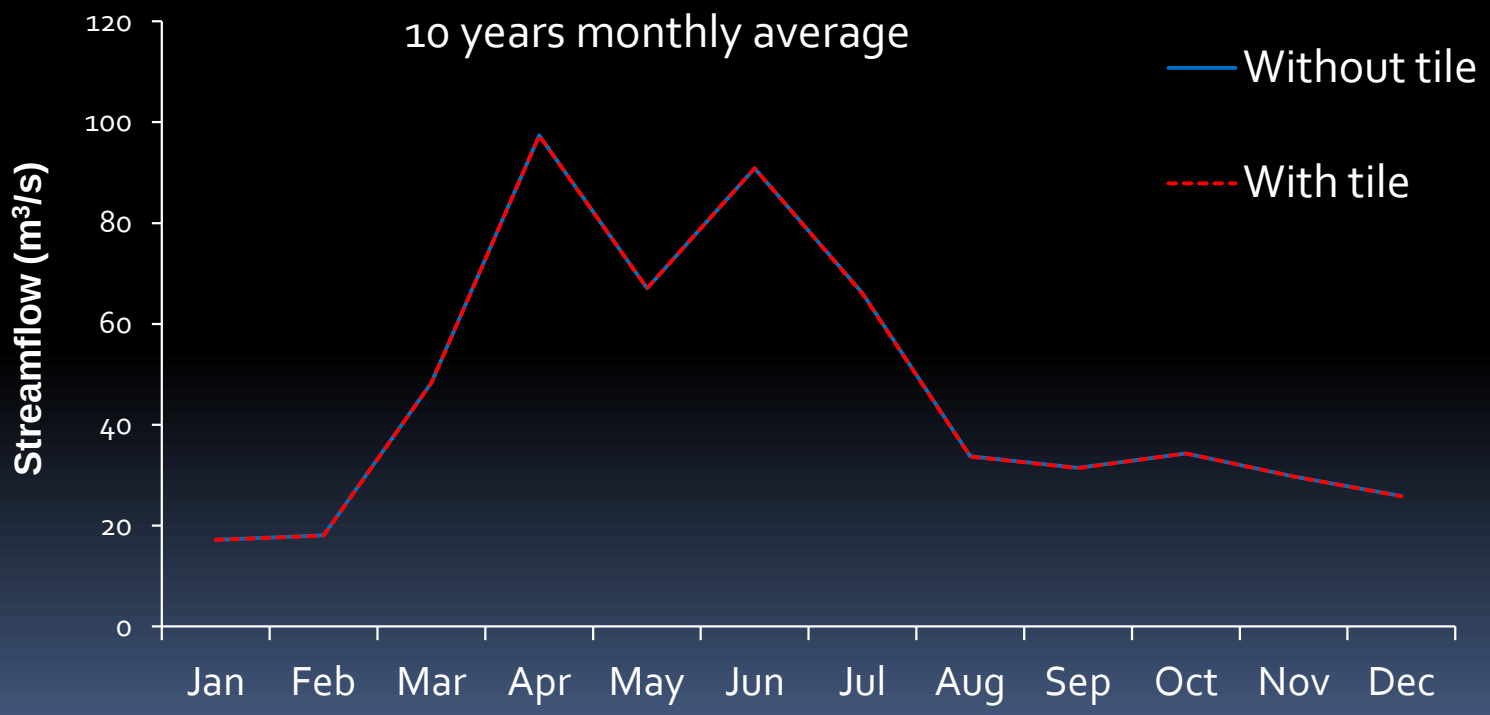
Impact on nitrate loading

Annual average (2008-2009)

Items (kg/ha)	Without tile	With tile	Change (%)
Crop yield (Bu corn/ac)	142.7	155.5	9.0
Surface NO_3	6.73	3.89	-42.2
Tile NO_3	0.0	5.00	
Edge-of-field	6.77	8.91	31.6
Groundwater NO_3	5.32	1.46	
Total NO_3	12.09	10.37	-14.2

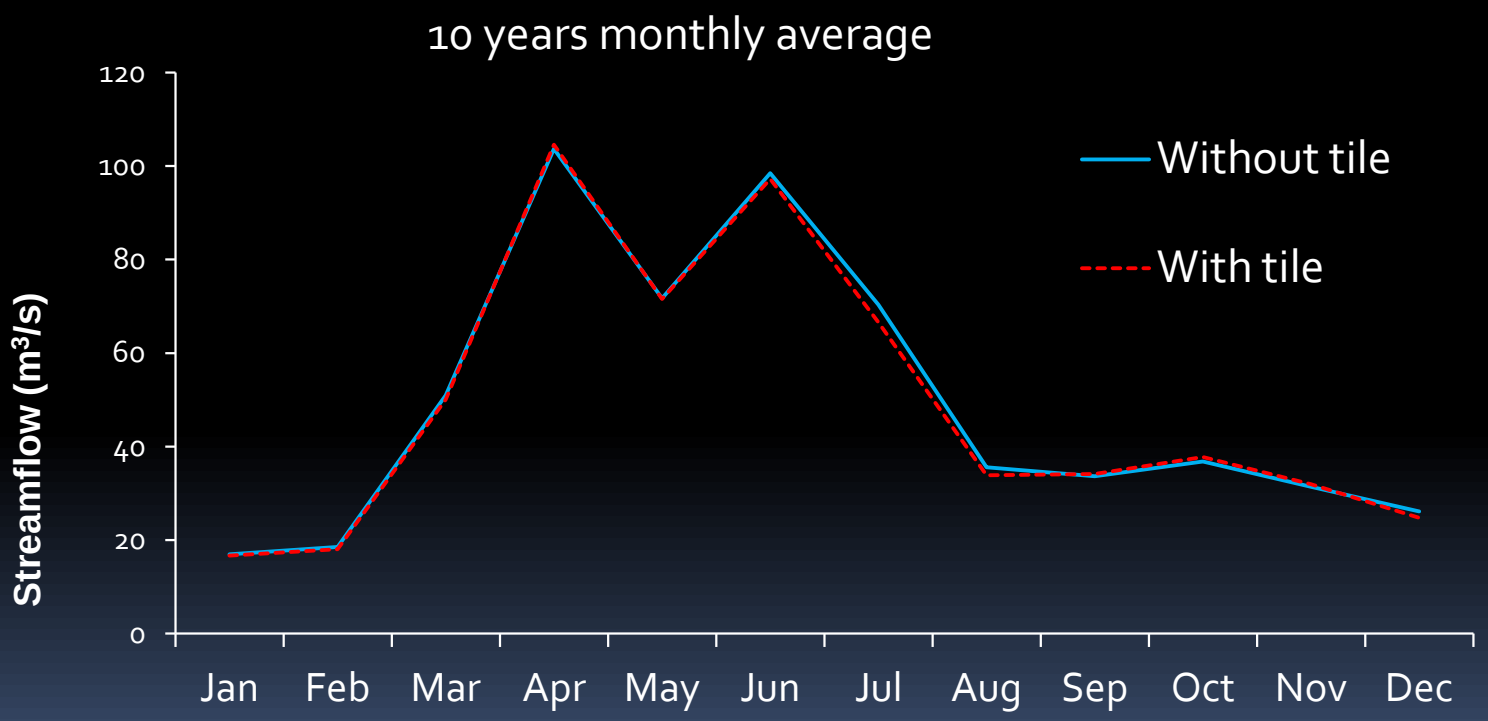
Watershed analysis - Impact on streamflows at Fargo

Existing tiled area: < 1%



Impact on streamflows at Fargo

Potential tiled area: 17 %



Summary of preliminary results

- On water quantity
  - Tile drainage decreases surface runoff by about 35%.
  - Tile drainage decreases monthly average soil water content.
  - Seasonally, tile drainage increases the water yield during the months of Apr, Oct, and Nov, while decreasing the water yield during growing season.
  - The effect of tile drainage (up to 17% of basin area) on streamflow in Red River at Fargo is small.

- On water quality (nitrate)
  - Decrease nitrate load through surface runoff by about 40%.
  - Increase edge of the field nitrate load by about 30%.
  - Decrease total nitrate load by about 15%.

Future research

- Improve mapping the existing and potential tile drained areas
  - Seasonal groundwater depth in SSURGO database
  - LiDAR and remote sensing data
- Improve snow melting algorithm in SWAT
  - Improve soil temperature modeling algorithm in SWAT
- Continue modeling water quality impact

Acknowledgement

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THANK YOU!