Hydrologic response to land use changes in Upper East Fork White River

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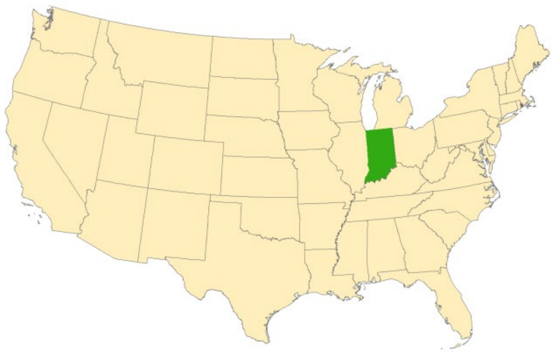
Objectives of this study

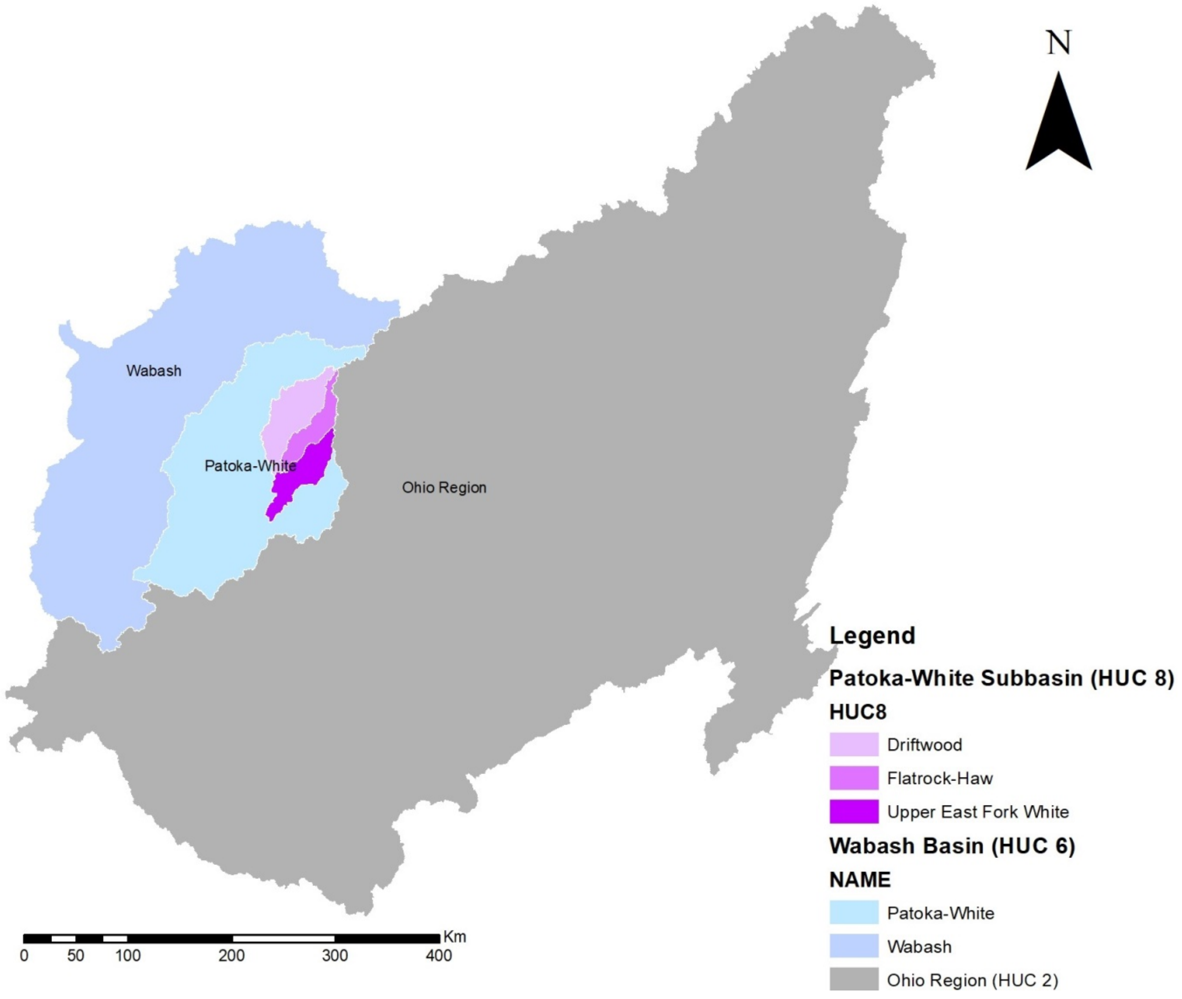
- Set up a monthly hydrological model in highly irrigated basin to explore the impacts of land use change in the hydrological regime
- Integrate water abstraction volumes from surface and groundwater (shallow) resources
- Assess the (potential) change in hydrological regime during a long period of time (1980-2015)

Overview of the area



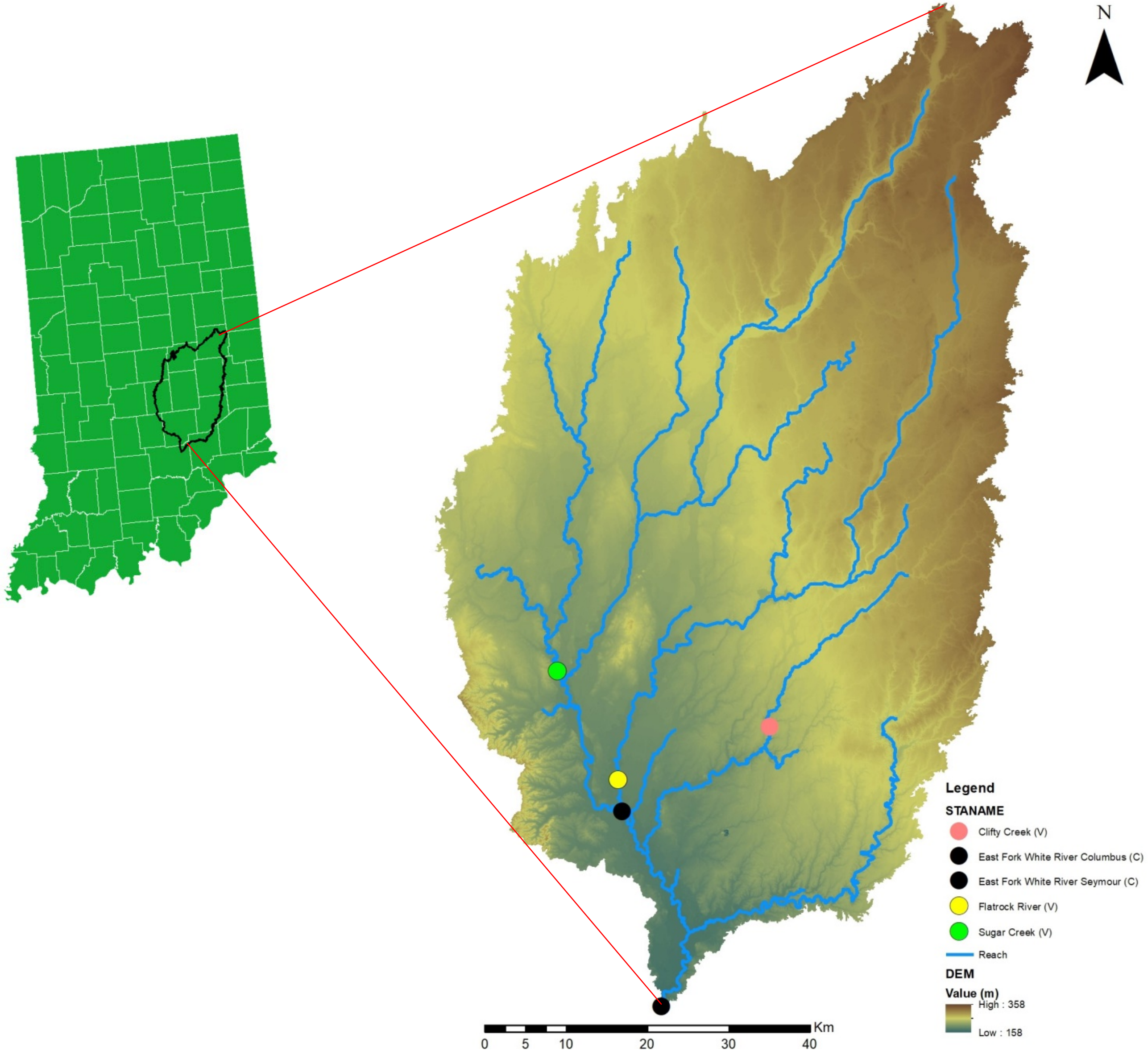
East North Central Region

Indiana State



Summary

- Area = 5,680 km^2
- Cover 3 HUC-8 (catalog units of Patoka White river)
- Humid continental/subtropical climate (cold winter and hot wet summers)
- 440,000 population (+1%/y)
- Agricultural use covers more than 60% of the basin area
- Extensive tile drainage (<2% slope)

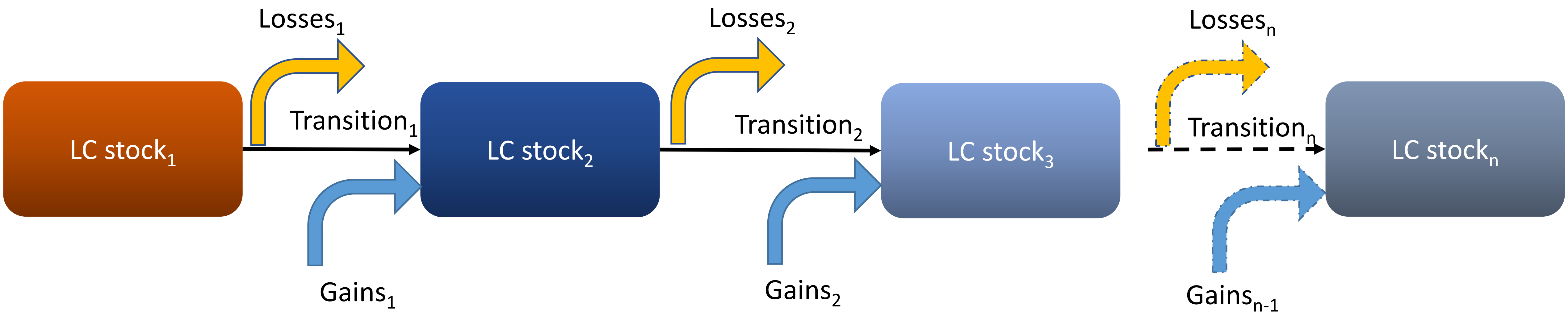


Data sources

- NOAA – Climate data (rainfall , T_{min}, T_{max})
- USGS
  - Water Watch program 5 USGS Streamflow stations (1980-2015)
  - MRLC program land cover 1992
  - Water uses 1980-2015
- USDA – NASS database
  - land use geospatial data 2001*, 2011
- Indiana DNR – Significant Water Withdrawal Facility (SWWF) dataset on water use locations

Land accounting workflow

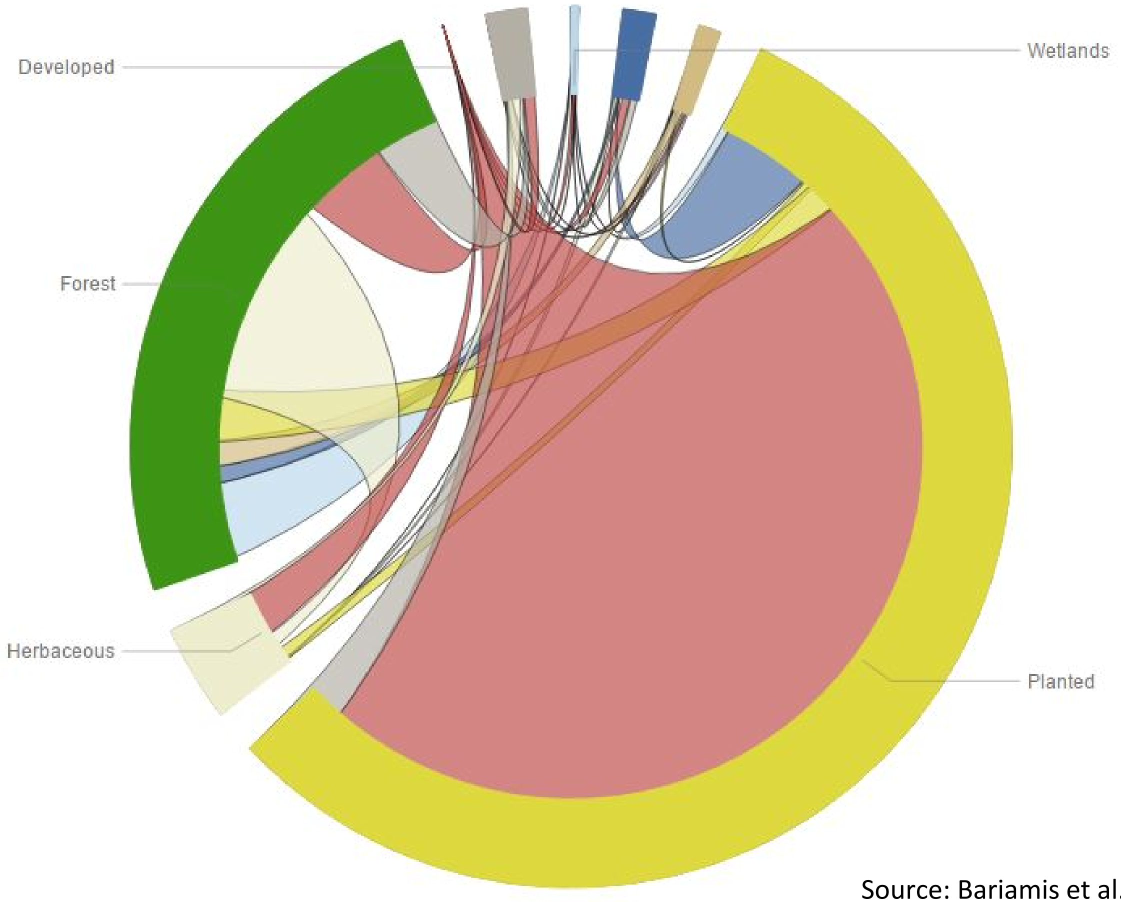
This applies also for Land Cover (LC) and Land Use (LU)

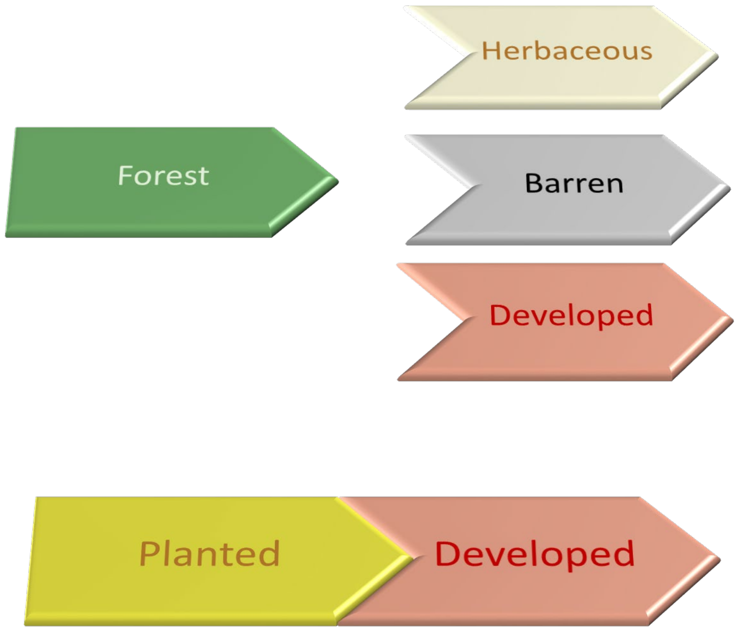


Losses: **Consumption**
Gains: **Formation**
Transition: No change

$$Stock_2 = Stock_1 - Losses_1 + Gains_1$$

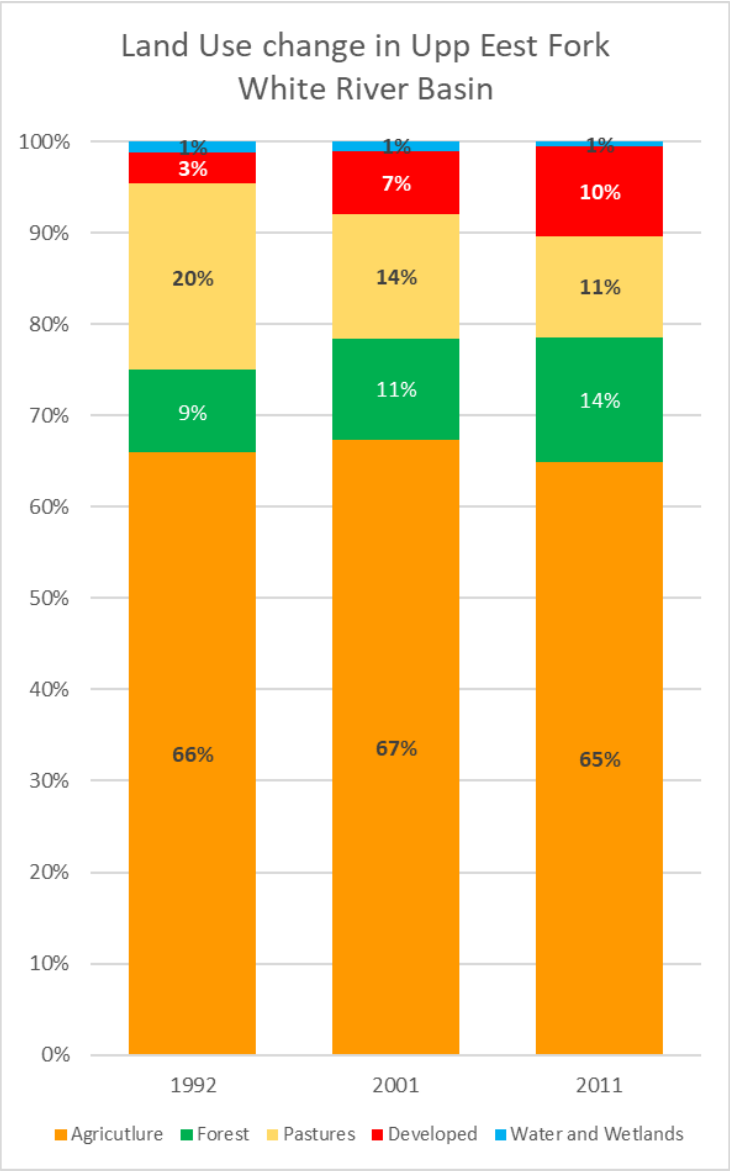
Wabash basin land cover trends

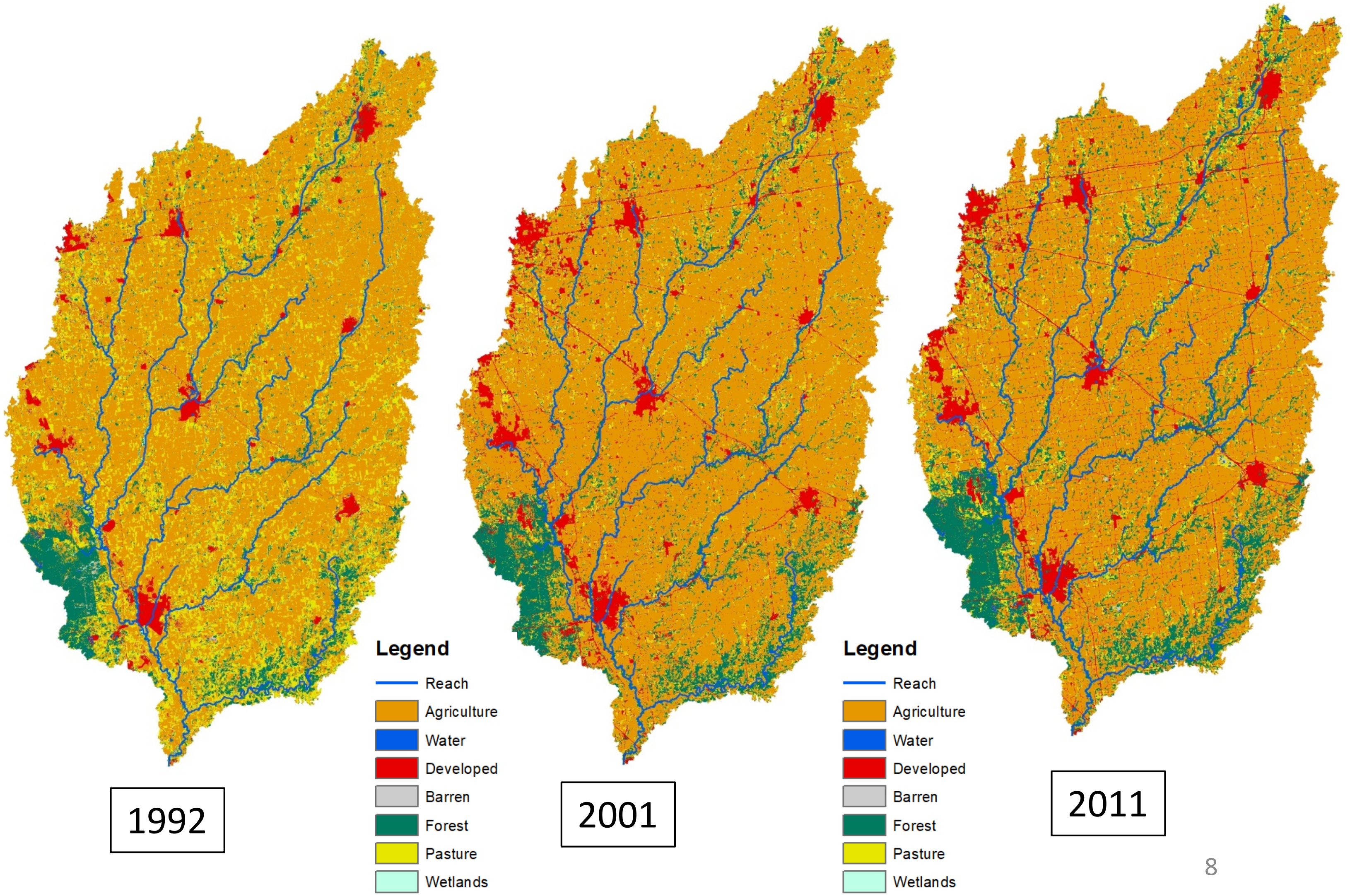




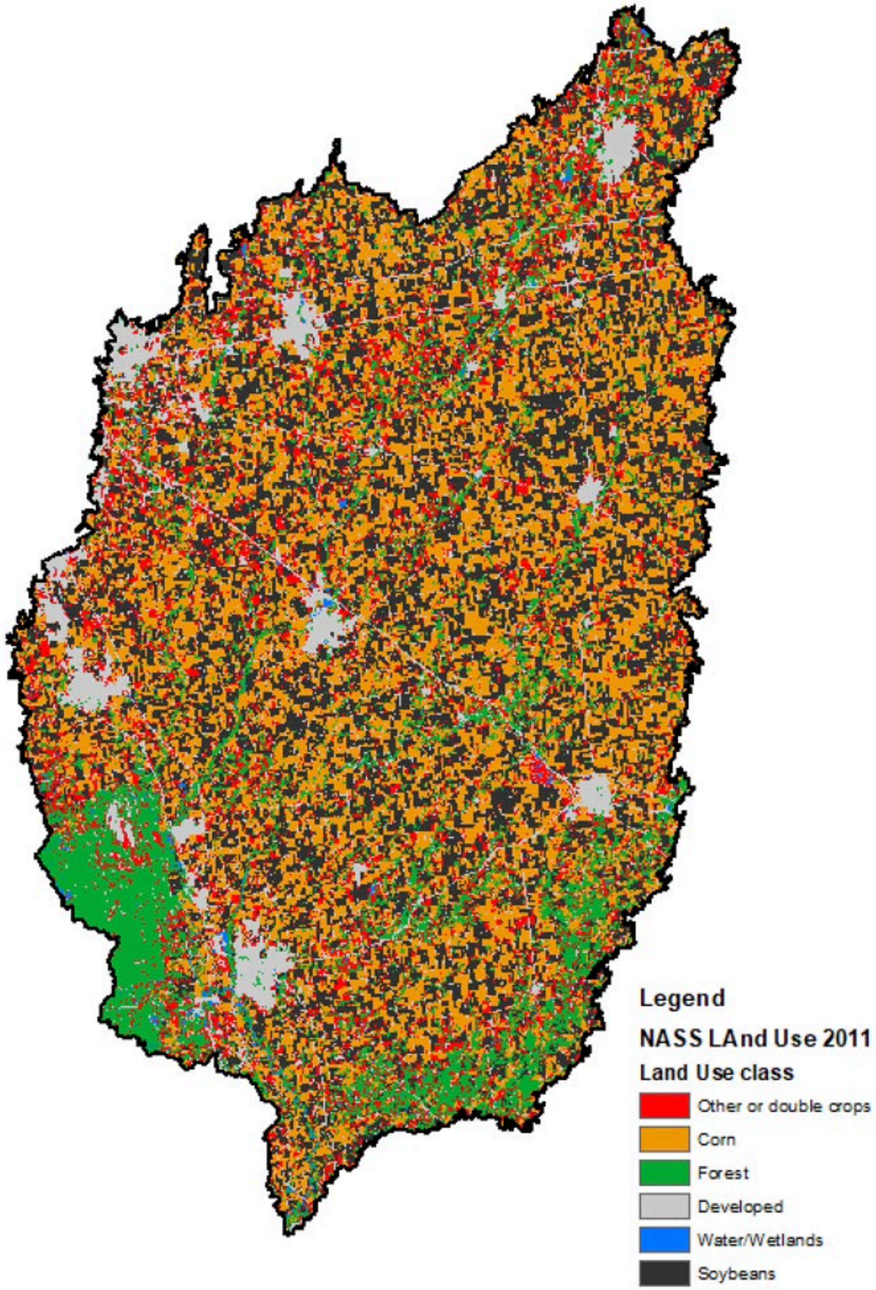
Source: Bariamis et al., EWRA 2017

Study area – land cover

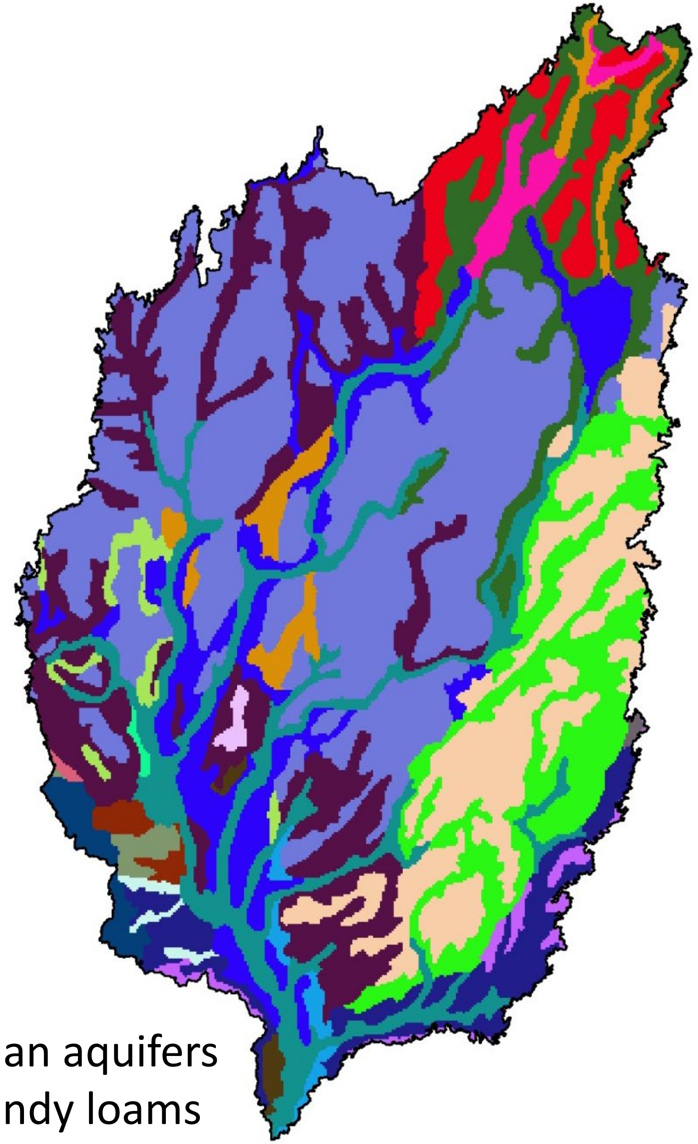




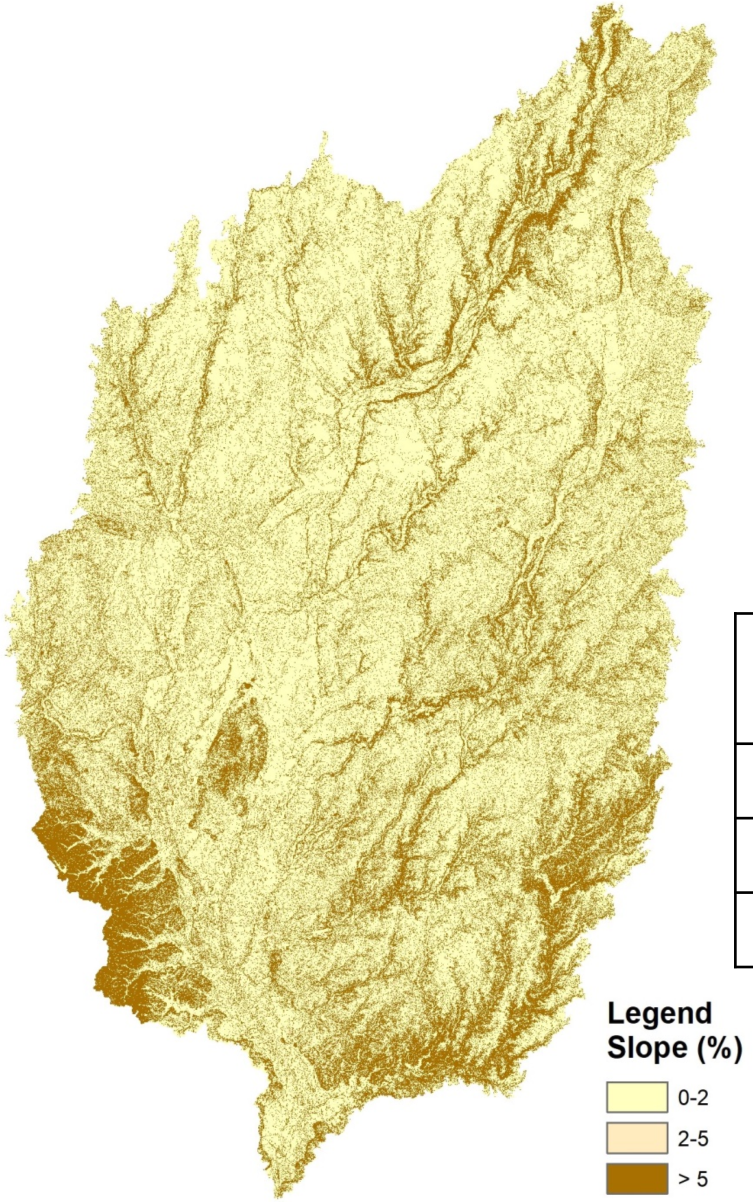
Land use 2011



Soil and slope

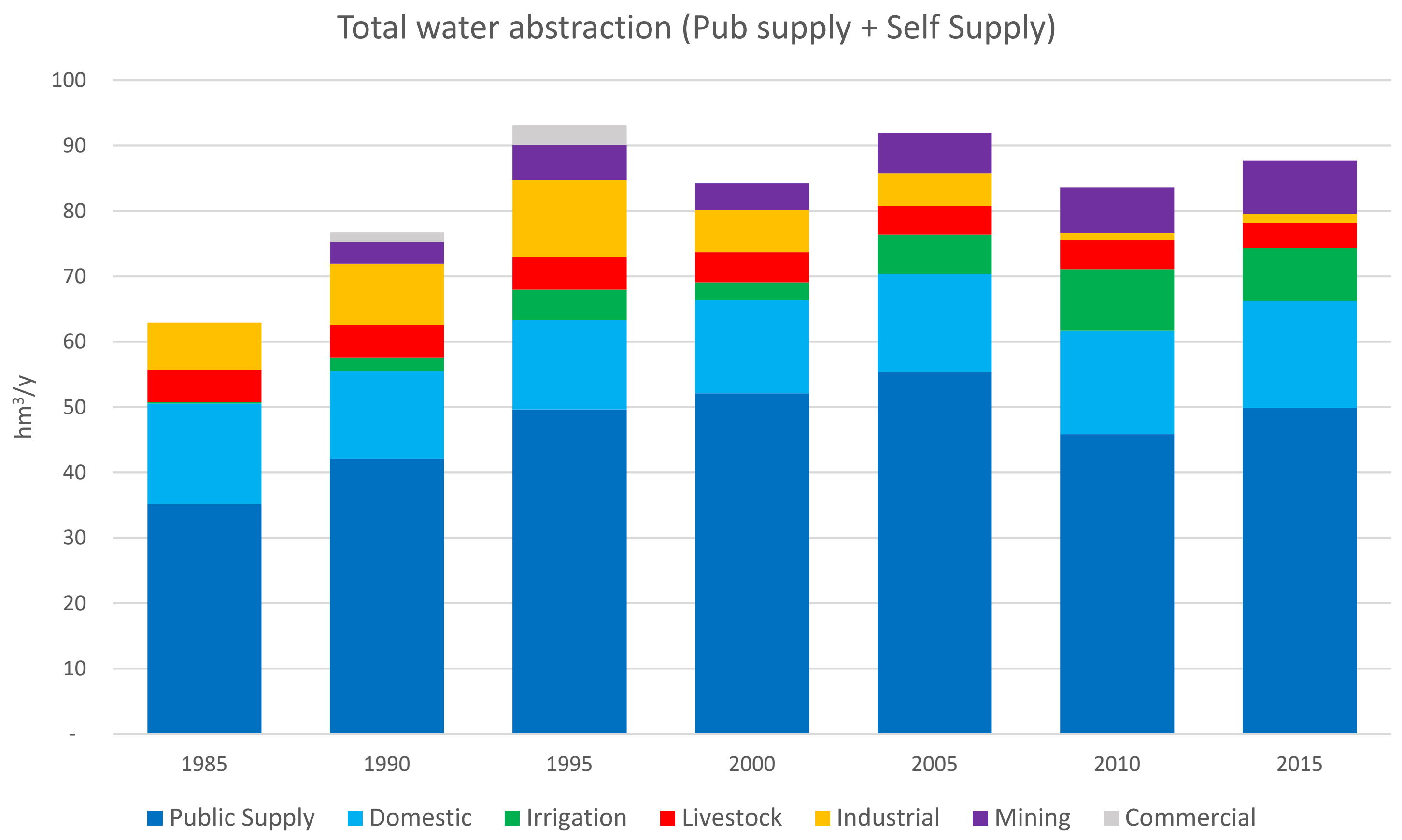


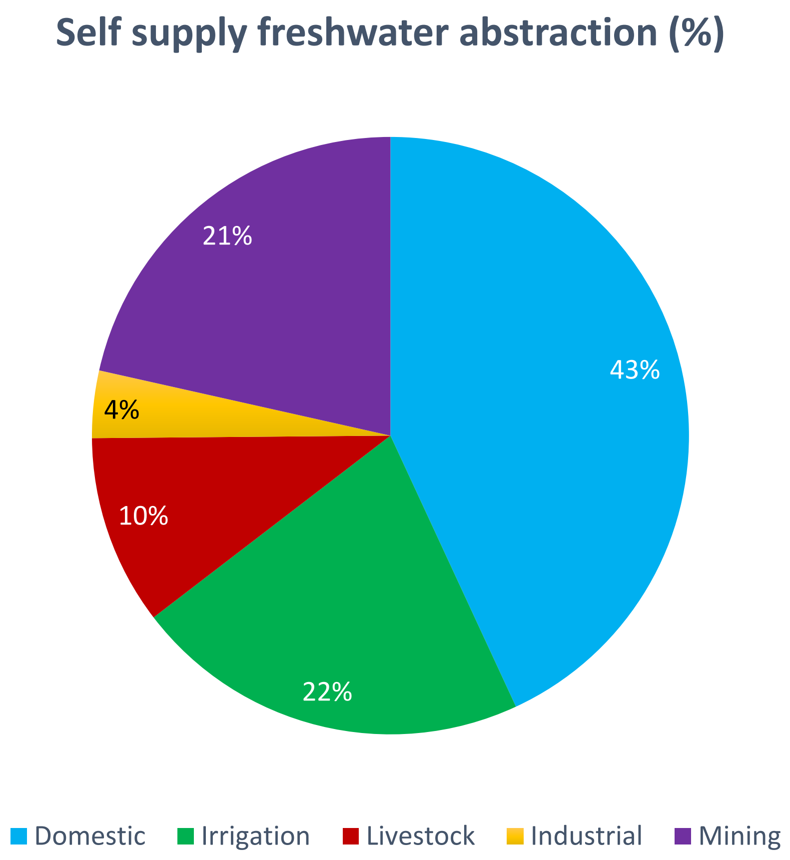
Silurian-Devonian aquifers
Silt, clay and sandy loams



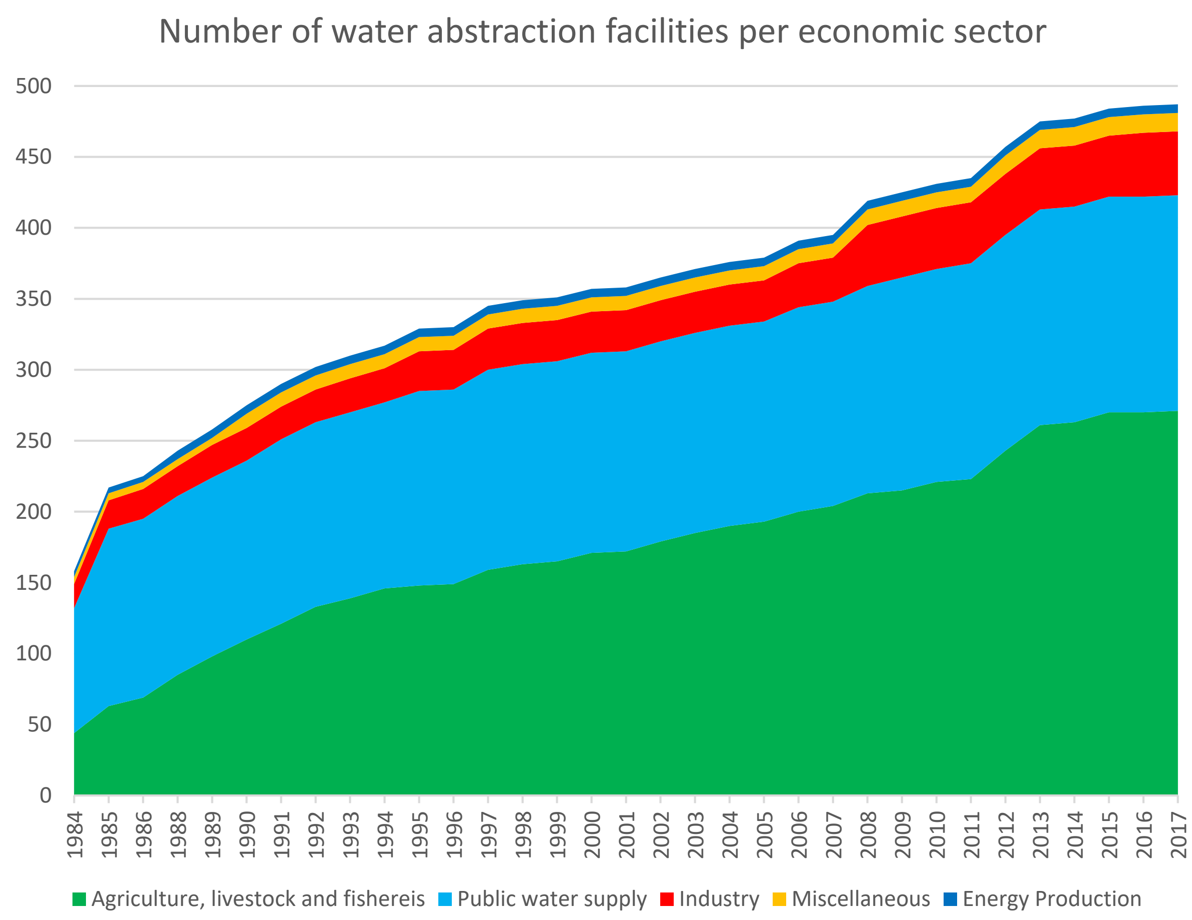
Slope ranges	% of Area
0-2%	62.3%
2-5%	10.8%
>5%	37.7%

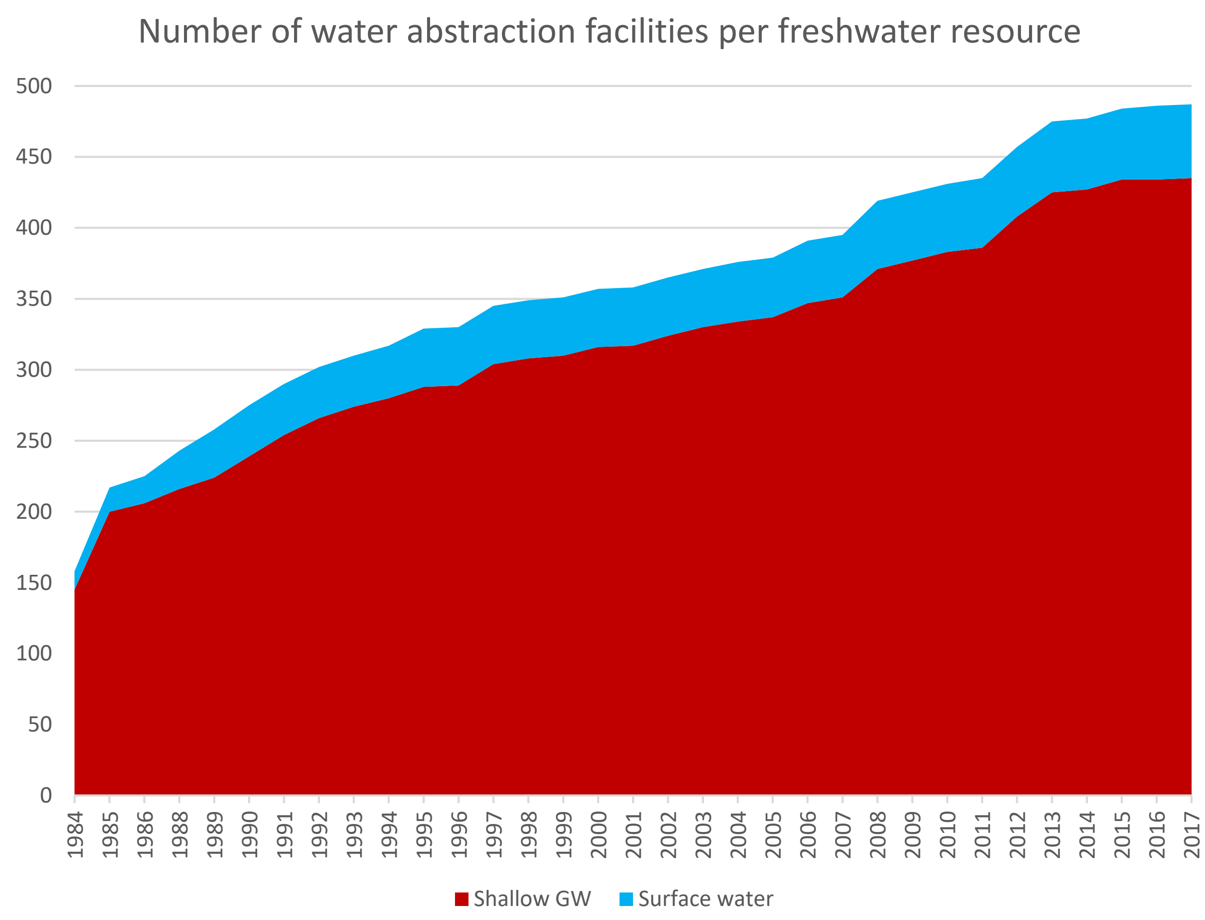
Fresh water abstractions per economic sector





Water abstraction facilities & water bodies

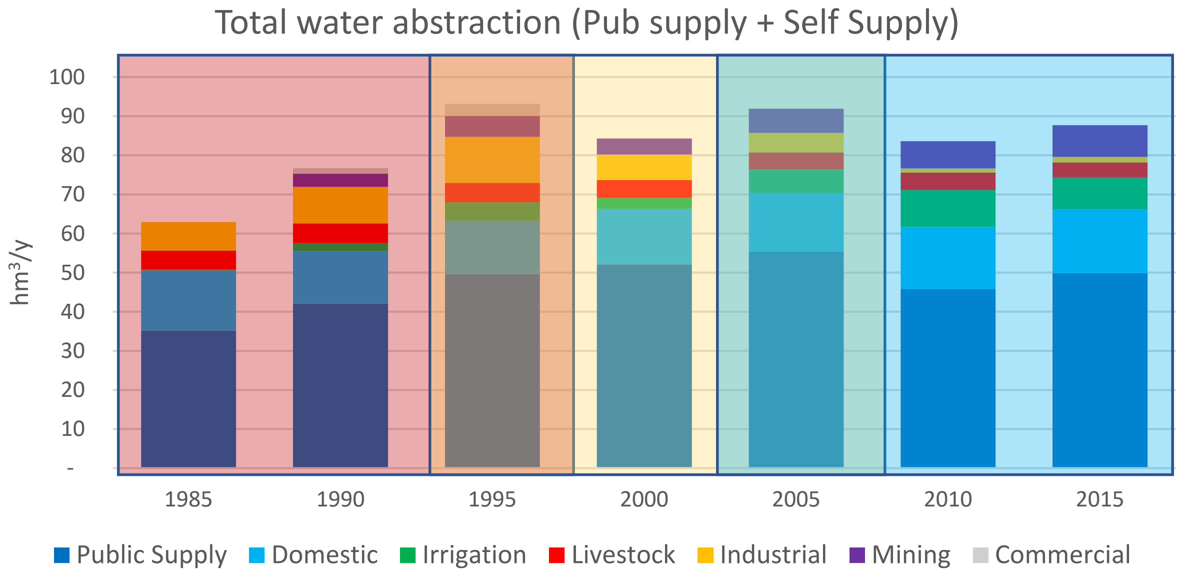




Source: Significant Water Withdrawal Facilities data, DNR IN

Water uses

- Data collected have been grouped in 3 configuration periods
  - Period 1: 1980-92
  - Period 2: 1993-02
  - Period 3: 2003-15



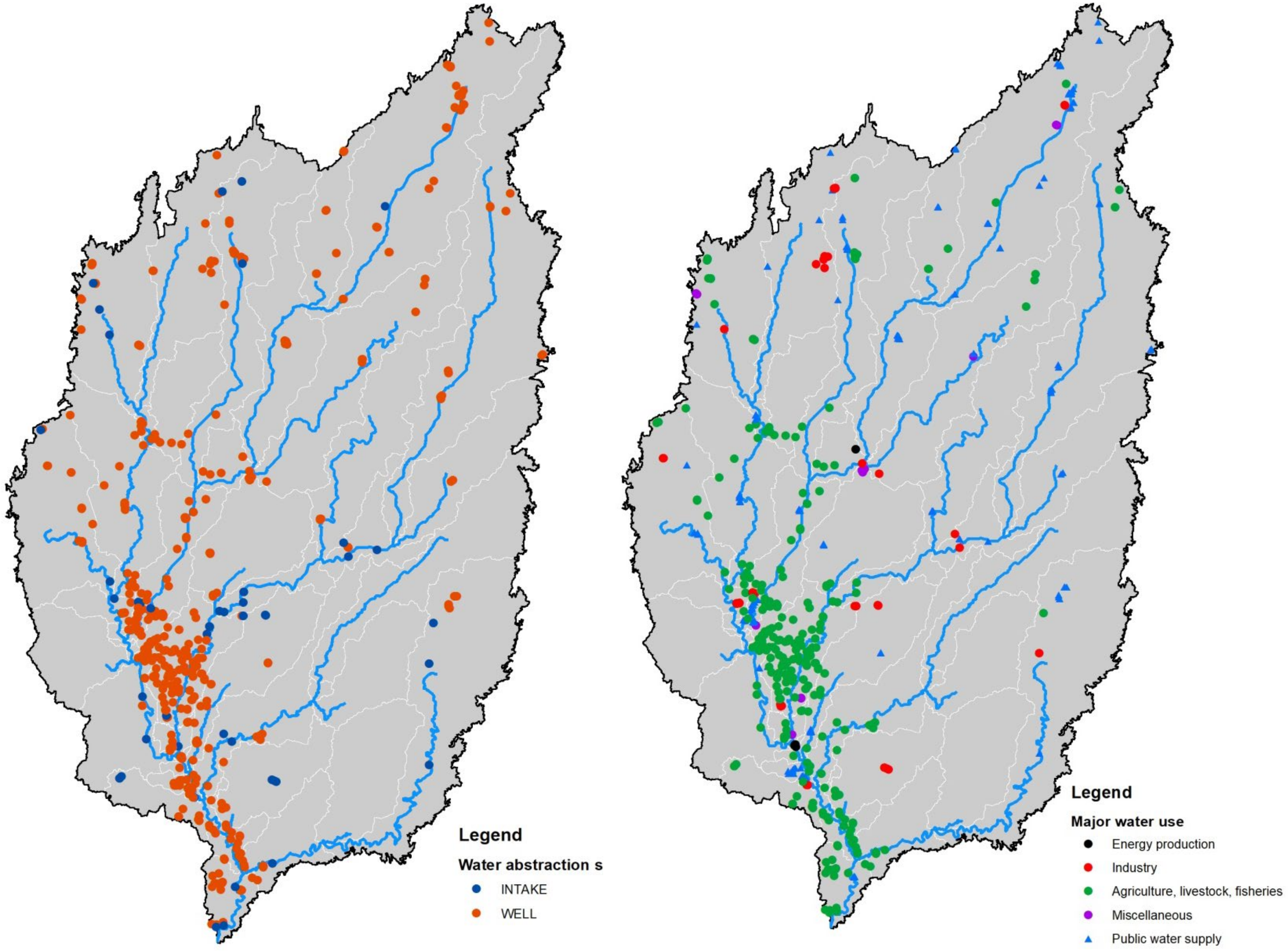
COUNTY	Configuration 1	Configuration 2	Configuration 3
Bartholomew County	1.70	2.20	2.20
Decatur County	0.46	0.50	0.55
Hancock County	0.60	0.65	0.77
Henry County	0.78	1.02	0.77
Johnson County	1.08	1.41	1.62
Rush County	0.44	0.41	0.33
Shelby County	0.78	0.90	1.02
Total (hm^3/month)	**5.84**	**7.09**	**7.26**

Total	Configuration 1	Configuration 2	Configuration 3
hm^3/year	70.08	85.08	87.12

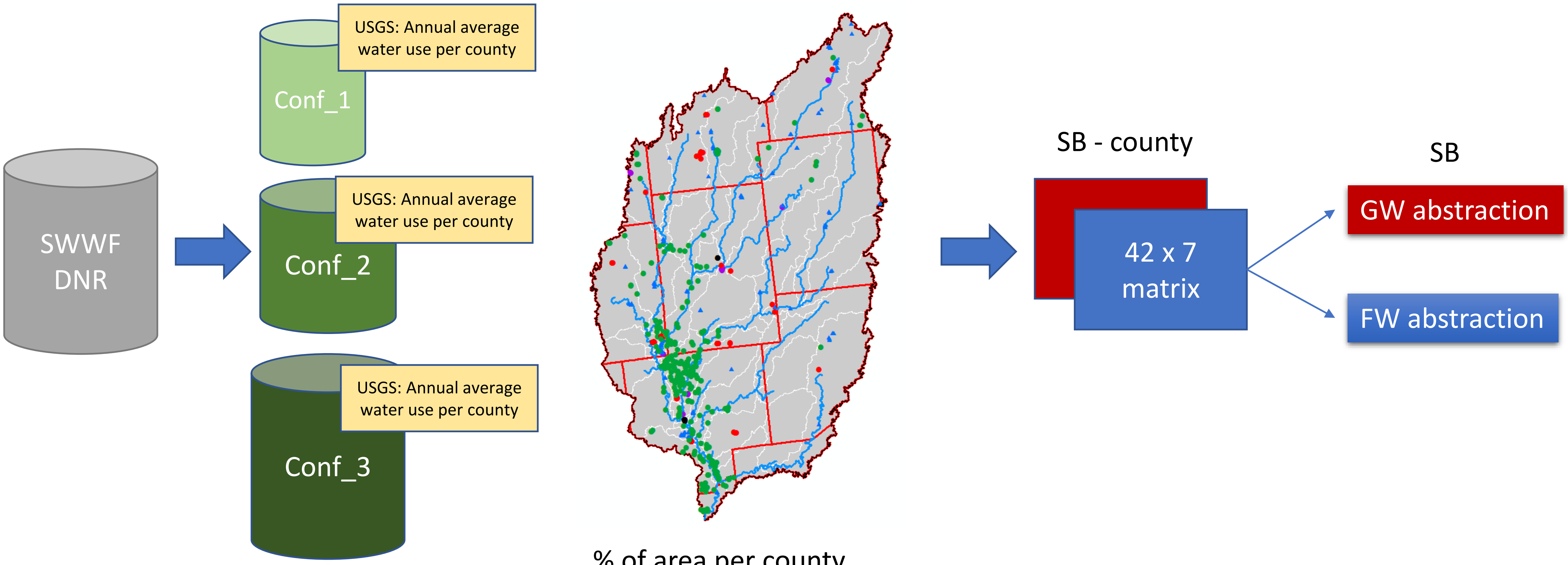
Water abstractions facilities analysis

As of 2015:

- 56% for agriculture and livestock breeding
- 30% for water supply
- 90% from pumping

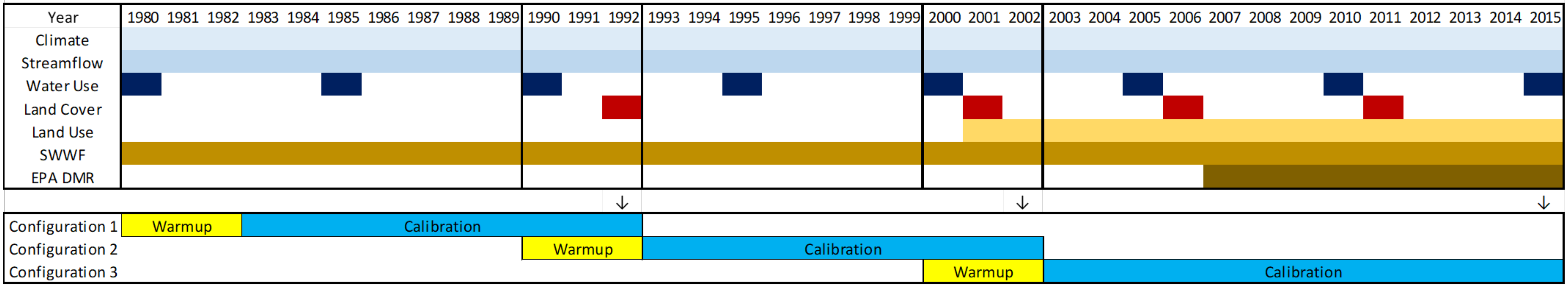


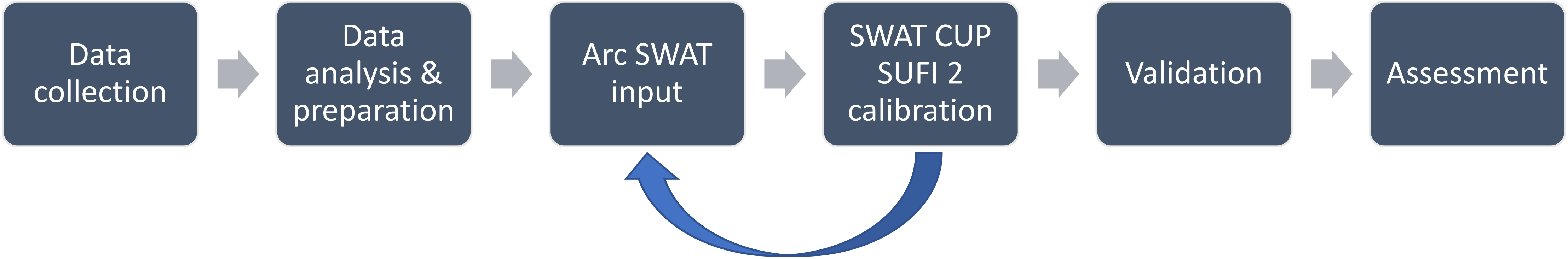
Water uses integration workflow



% of area per county
number of facilities per county

General workflow for SWAT and SWAT-CUP





SWAT input (soft)

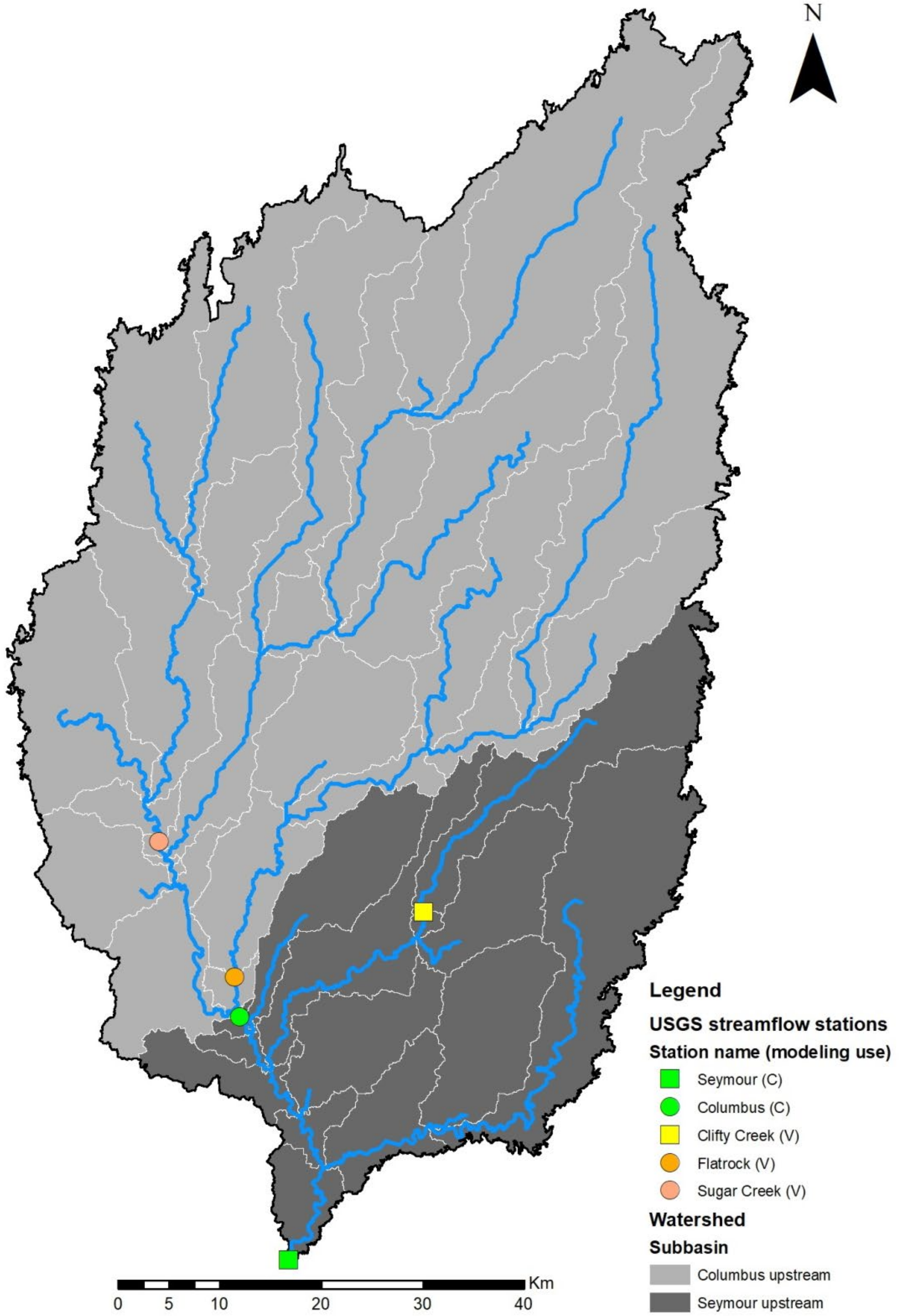
Parameter	Physical explanation	Value
DDRAIN	Depth to subsurface drain	1200 mm
TDRAIN	Time to drain soil to field capacity	24 hr.
GDRAIN	Drain tile lag time	72 hr.
SMFMX	Maximum melt rate for snow during year	1 mm/C-day
SMFMN	Minimum melt rate for snow during year	1mm/C-day
TIMP	Snow pack temperature lag factor	0.4

Y. Panagopoulos et al. / Journal of Hydrology 524 (2015)

Results

- Calibration has been conducted in 2 streamflow stations' locations: Columbus and Seymour (outlet)
- Validation implemented in 3 different locations as first run results were initially satisfactory (NS > 75%)

Station Name	Purpose	USGS STATID	Upstream Area
Columbus	**Calibration**	**03364000**	**72**%
Flatrock	Validation	03363900	23%
Sugar Creek	Validation	03362500	18%
Seymour	**Calibration**	**03365500**	100%
Clifty Creek	Validation	03364500	4%



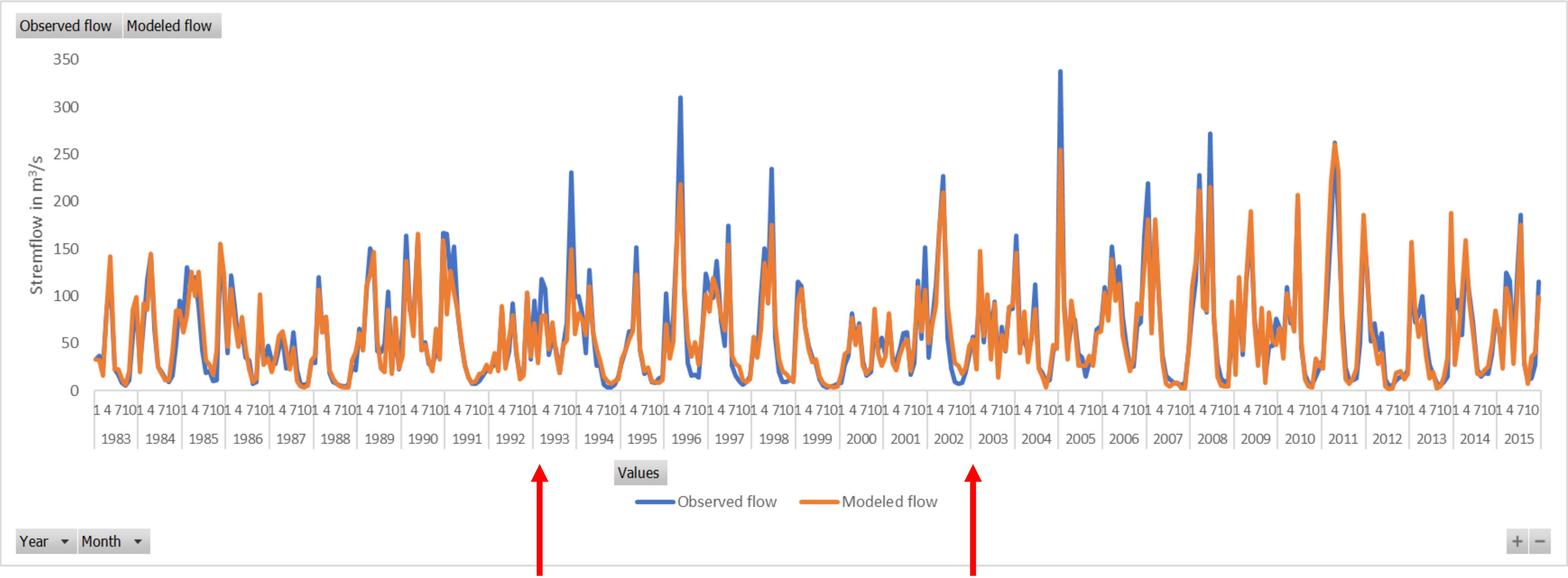
SWAT-CUP calibration input

SWAT Parameter	Physical explanation
CN2 (.mgt)	Initial SCS runoff curve number for moisture condition II
SOL_AWC(1) (.sol)	Available water capacity of first soil layer (mm/mm)
ALPHA_BF (.gw)	Baseflow alpha factor (days)
GW_DELAY (.gw)	Groundwater delay (days)
GWQMN (.gw)	Threshold depth of water in the shallow aquifer for return flow to occur (mm H2O)
GW_REVAP (.gw)	Groundwater "revap" coefficient
RCHRG_DP (.gw)	Deep aquifer percolation fraction
ESCO (.hru)	Soil evaporation compensation factor

Calibration results - Columbus

Columbus	PBIAS	NS	R2	Qm	Qo
1983-1992	5%	87%	0.87	53	52.97
1993-2002	5%	93%	0.93	54.94	58.04
2003-2015	3%	90%	0.9	65.85	67.72

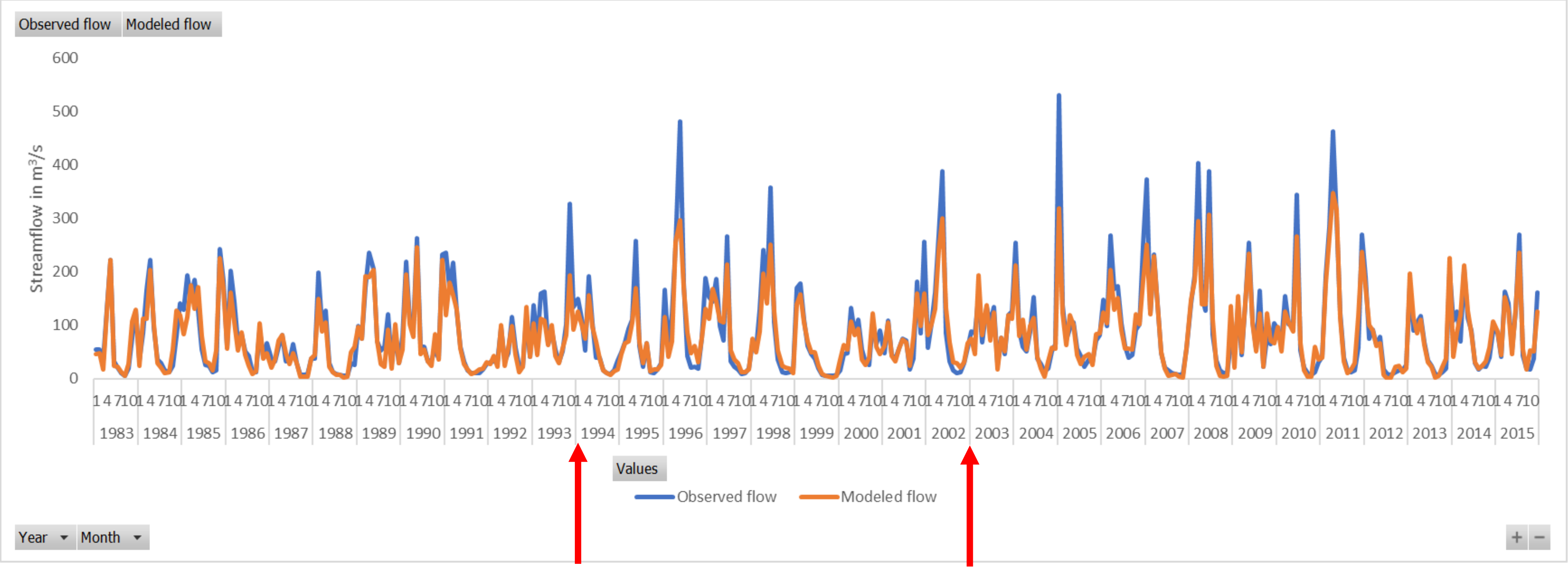
Q_m = Modeled streamflow
Q_o = Observed streamflow



Calibration results - Seymour

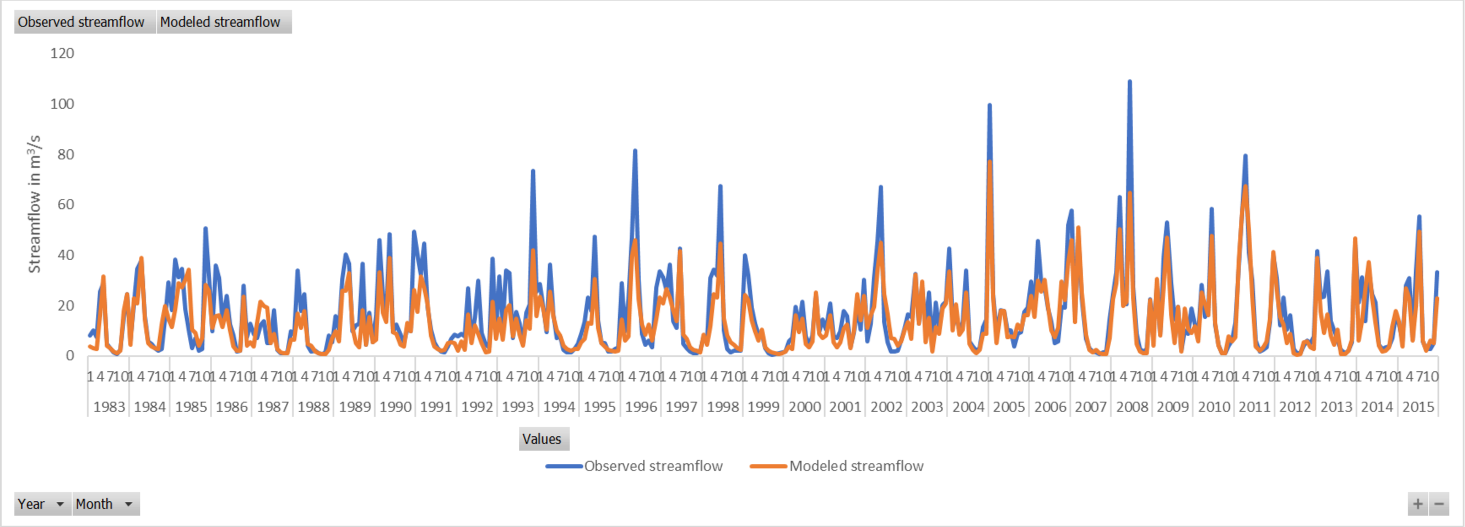
Seymour	PBIAS	NS	R2	Qm	Qo
1983-1992	6%	89%	0.89	70.26	75.68
1993-2002	7%	89%	0.92	78.85	87.86
2003-2015	6%	89%	0.9	92.10	97.4

Q_m = Modeled streamflow
Q_o = Observed streamflow

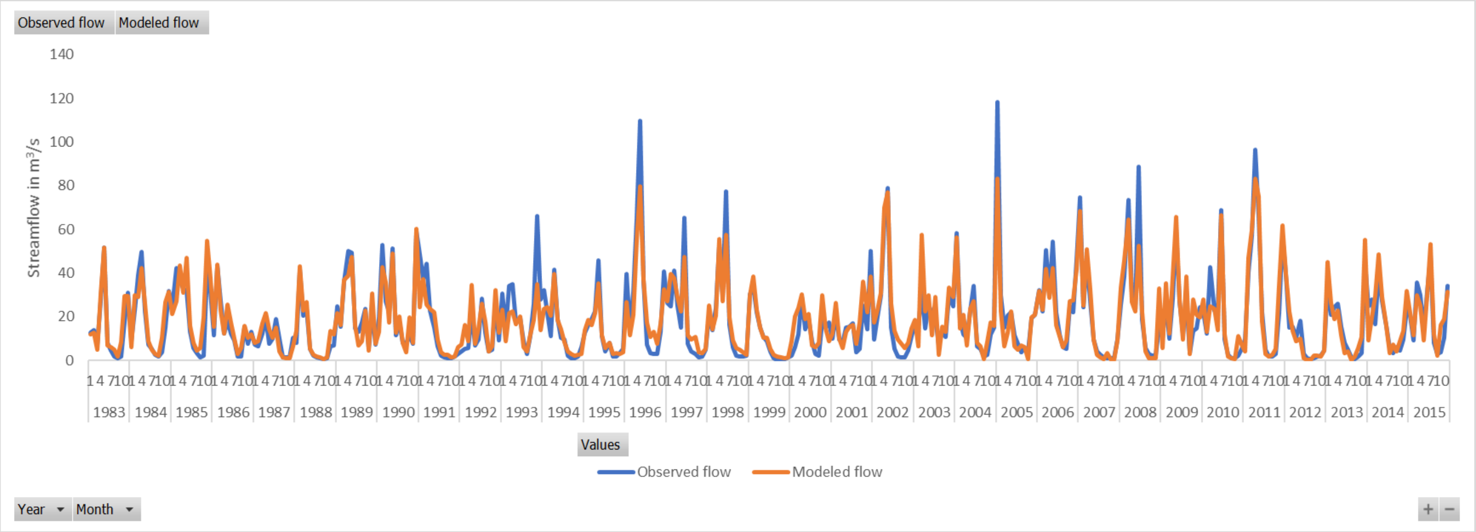


Validation results – Sugar Ck & Flatrock

Sugar creek	PBIAS	NS	R2	Qm	Qo
1983-1992	22%	62%	0.69	11.5	14.76
1993-2002	21%	74%	0.86	12.3	15.65
2003-2015	15%	85%	0.89	15.89	18.61

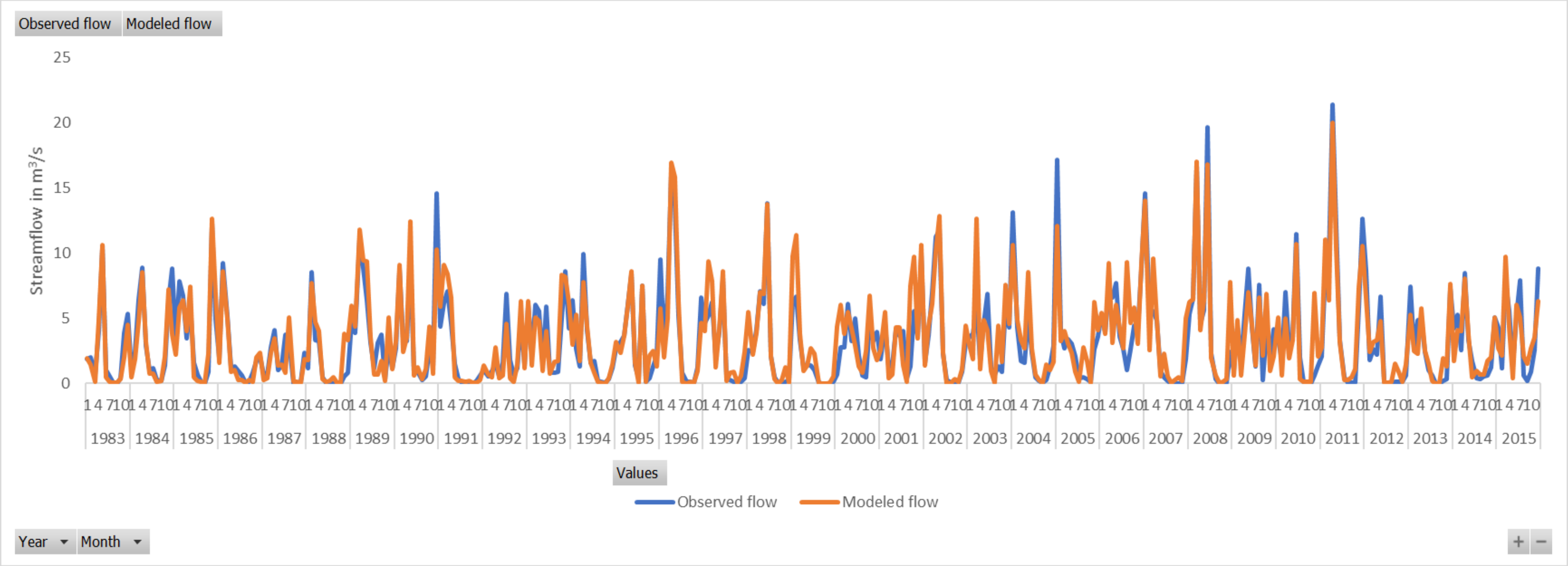


Flatrock	PBIAS	NS	R2	Qm	Qo
1983-1992	-6%	84%	0.85	17.37	16.35
1993-2002	-2%	85%	0.87	18.35	18
2003-2015	-1%	86%	0.86	20.6	20.3



Validation results – Clifty Ck

Clifty creek	PBIAS	NS	R2	Avg Qm	Avg Qo
1983-1992	0.1%	84%	0.86	2.75	2.75
1993-2002	-9.4%	79%	0.83	3.55	3.24
2003-2015	-4.8%	79%	0.80	3.76	3.59



Hydrological summaries after calibration

Hydrological ratio	1983-1992	1993-2002	2003-2015
Streamflow / Precipitation	0.31	0.31	0.41
Baseflow / Total Flow	0.57	0.37	0.45
Surface Runoff / Total Flow	0.43	0.63	0.55
Percolation/ Precipitation	0.24	0.20	0.21
Deep recharge / Precipitation	0.07	0.09	0.03
ET / Precipitation	0.62	0.60	0.56

Future work

- Apply monthly variability in water uses and integrate water return flows
- Assess seasonal variability of sediment loads
- Estimate energy consumption for water pumping based on SWWF database
- Explore future scenarios to support sustainable use of freshwater resources and environmental protection

Thank you for your attention!

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