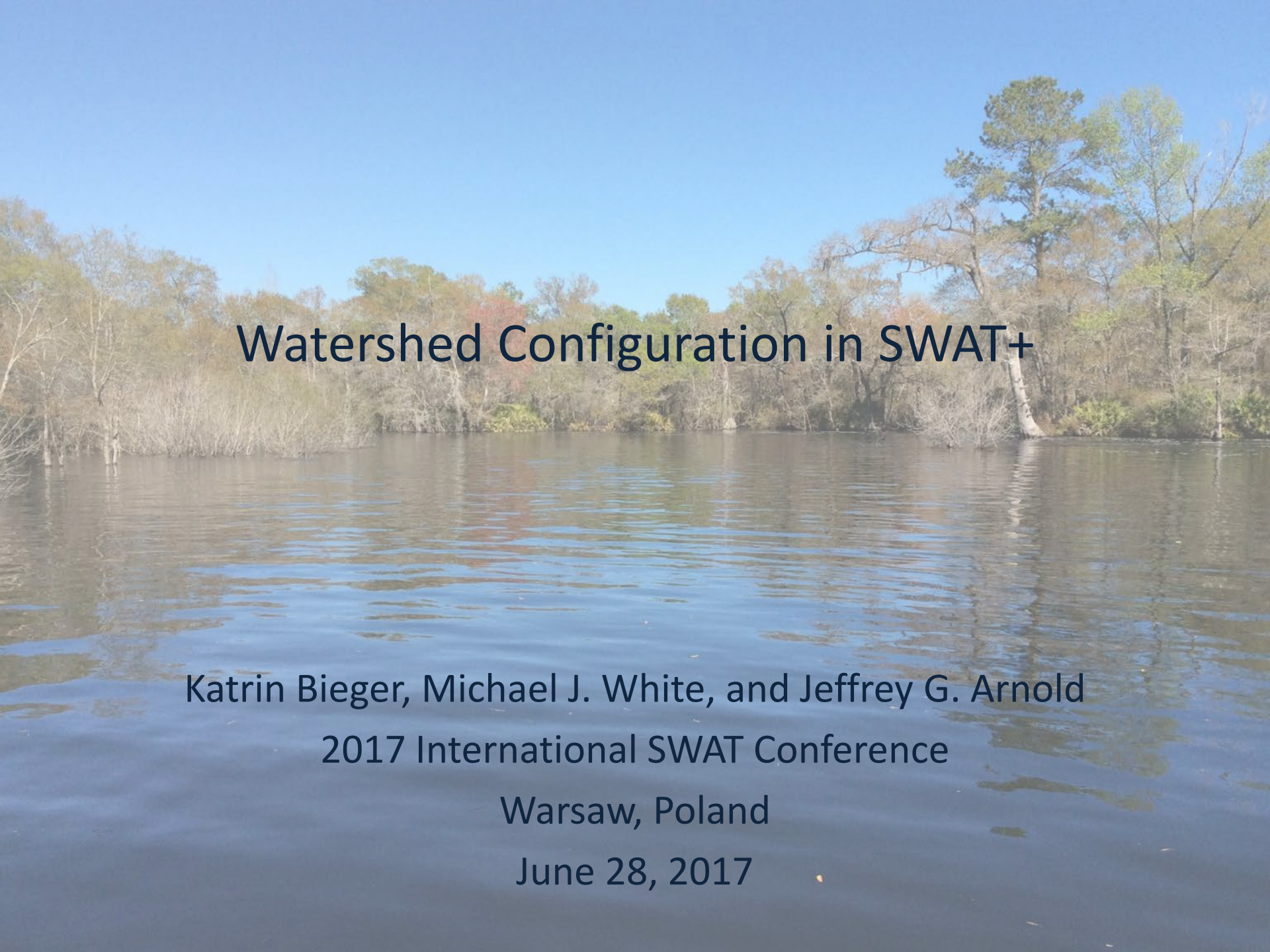


Watershed Configuration in SWAT+

Katrin Bieger, Michael J. White, and Jeffrey G. Arnold

2017 International SWAT Conference

Warsaw, Poland

June 28, 2017

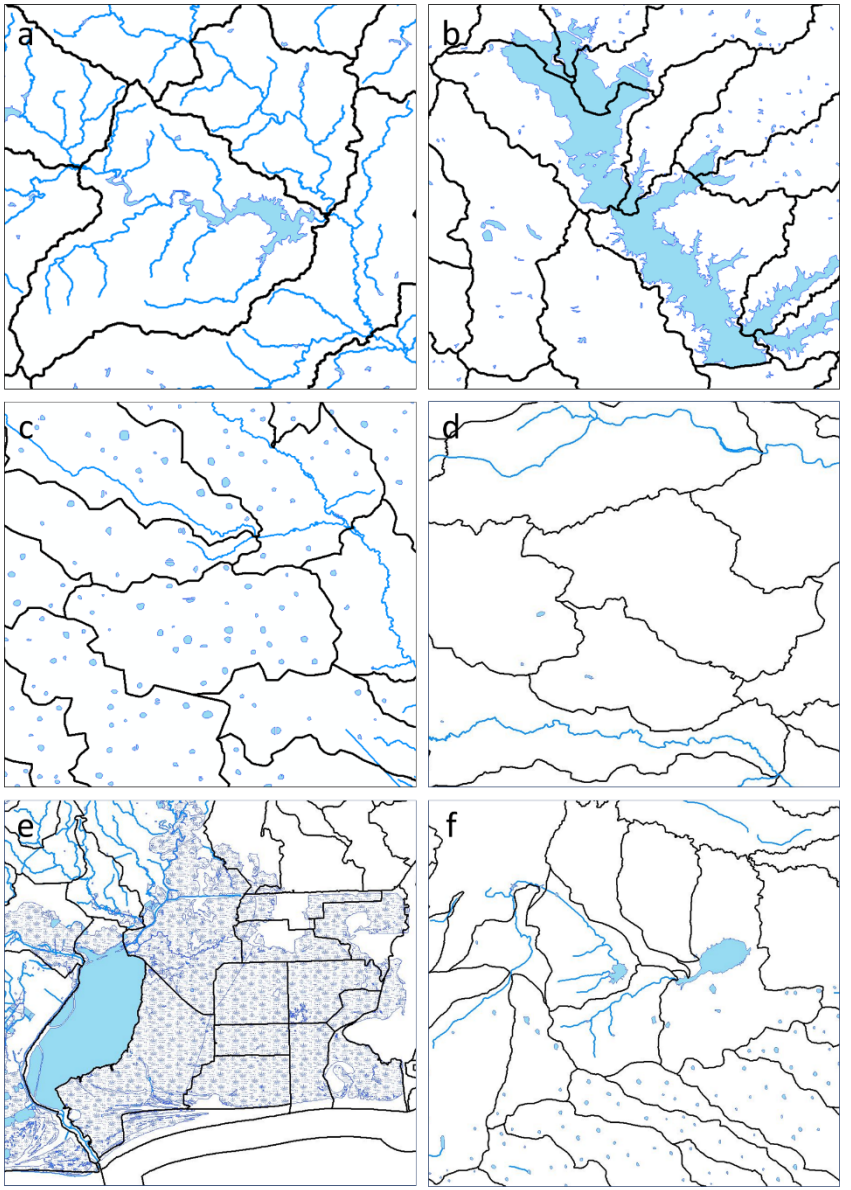
Motivation

"A major challenge of the ongoing evolution of the model will be meeting the desire for additional spatial complexity while maintaining ease of model use."

(Gassman et al. 2007)

Model vs. reality

a. Subbasin with reservoir at outlet
b. Reservoirs spanning multiple subbasins
c. Playa lakes and potholes
d. No water features in subbasin
e. Swamp/marsh covering entire subbasins
f. Unconnected drainage



Watershed configuration

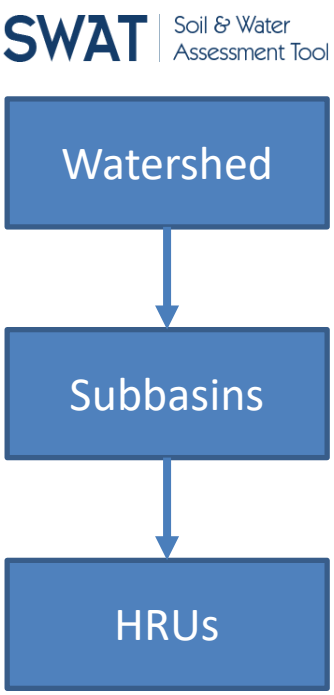
SWAT Soil & Water Assessment Tool

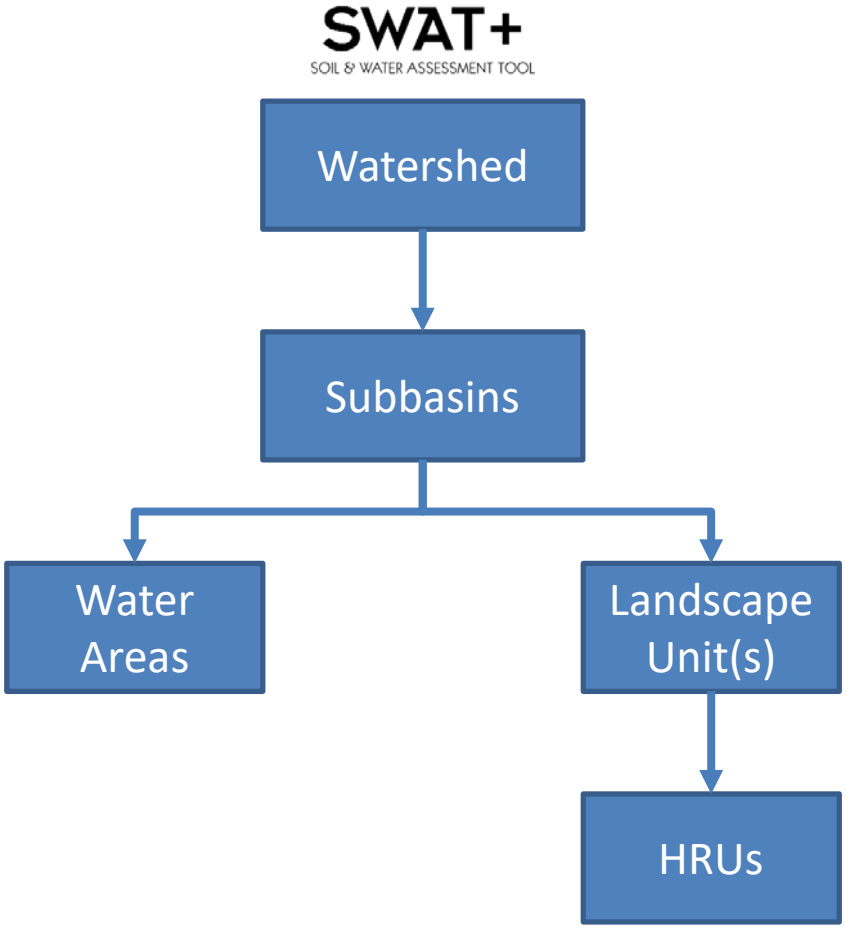
- Subdivision of subbasins into HRUs
- Water areas defined as HRUs

SWAT+ SOIL & WATER ASSESSMENT TOOL

- Separation of water and land areas within subbasins
- Water areas defined as ponds or reservoirs
- Definition of one or more LSUs to aggregate HRUs

Watershed delineation





Landscape units

- Differences in hydrologic properties
- Runoff routing across the landscape

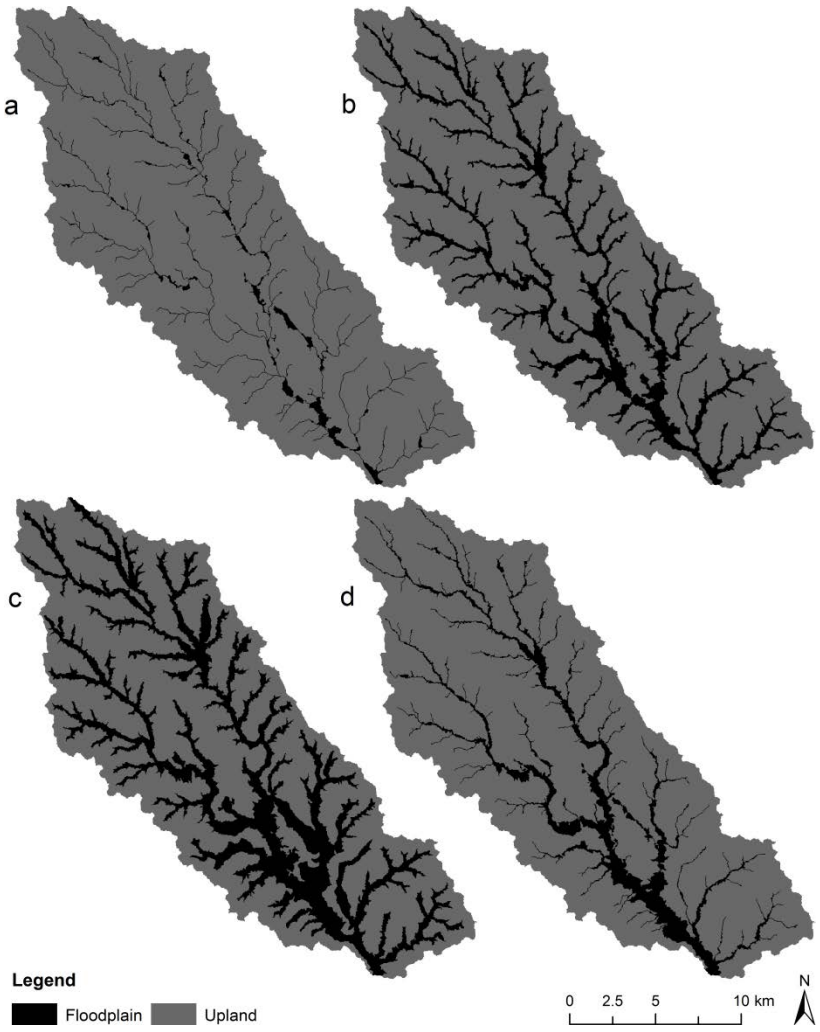
Delineation methods:

a) Topographic Wetness Index (Beven and Kirkby, 1979)

b) Slope Position (USDA Forest Service, 1999)

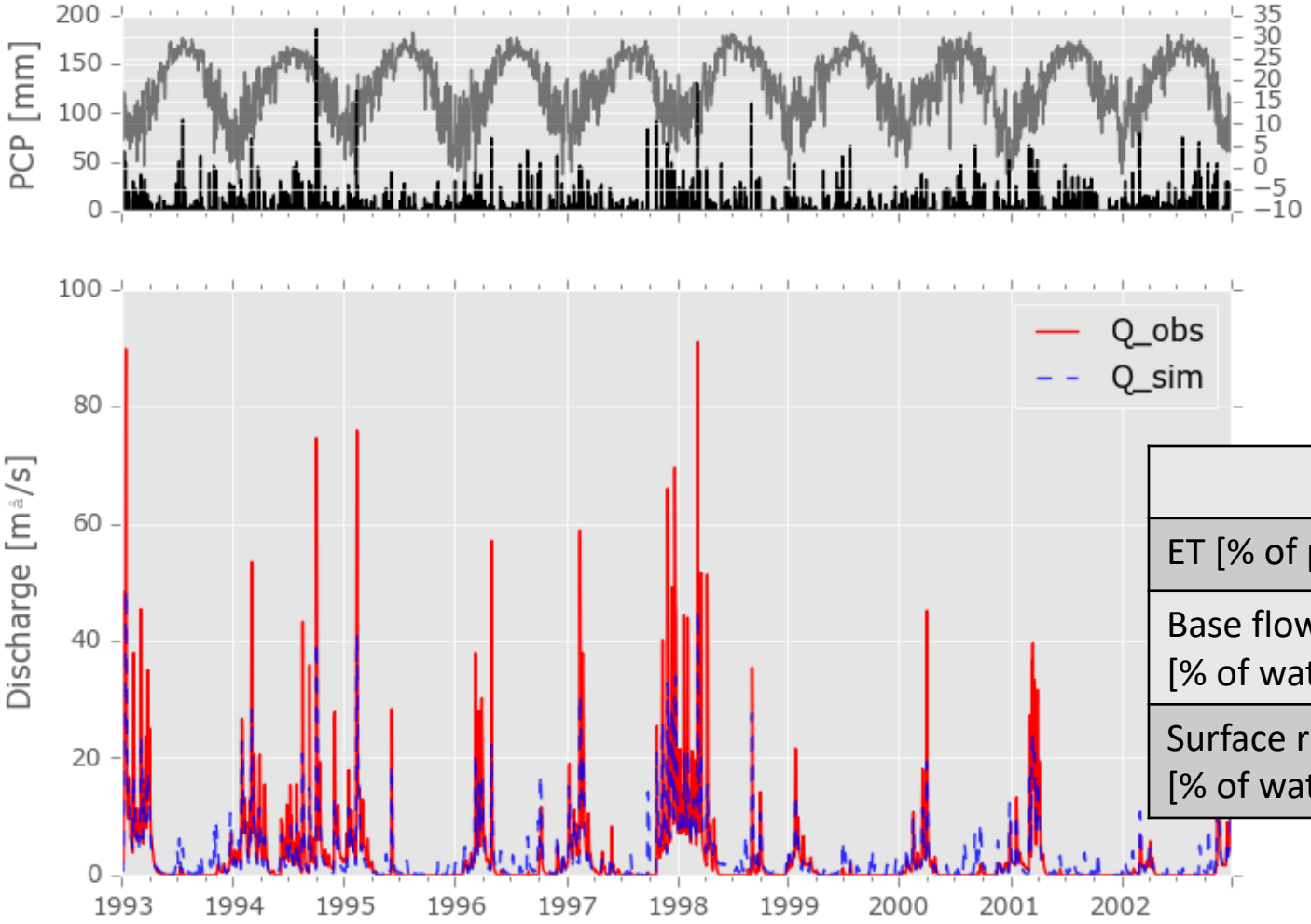
c) Uniform Flood Stage (Williams et al., 2000)

d) Variable Flood Stage (Nardi et al., 2006)



Rathjens et al., 2016. Delineating floodplain and upland areas for hydrologic models - A comparison of methods. Hydrological Processes 30(23):4367-4383.

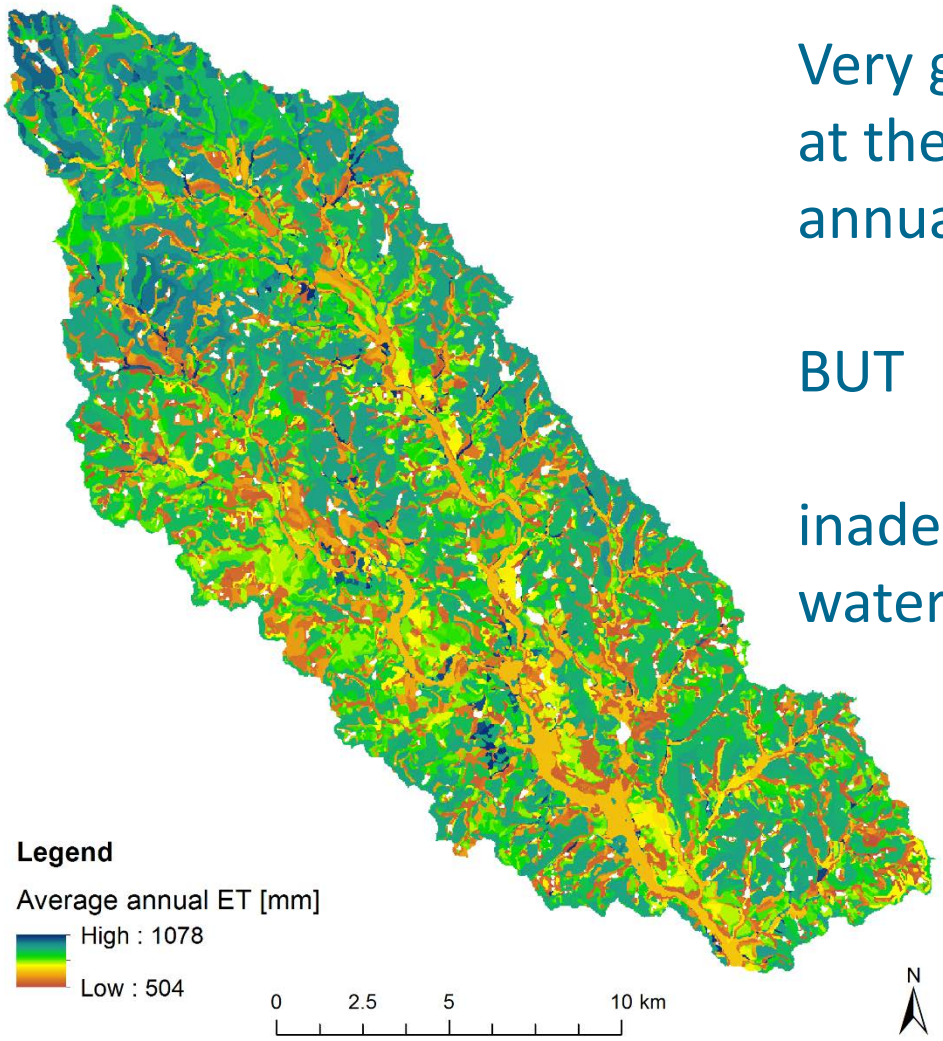
Streamflow and water balance (1 LSU)



NSE (daily)	0.77
NSE (monthly)	0.90
R^2 (daily)	0.82
R^2 (monthly)	0.95
PBIAS	2.62

	Obs	**Sim**
ET [% of precip]	69	66
Base flow [% of water yield]	54	61
Surface runoff [% of water yield]	46	39

Spatial distribution of average annual ET



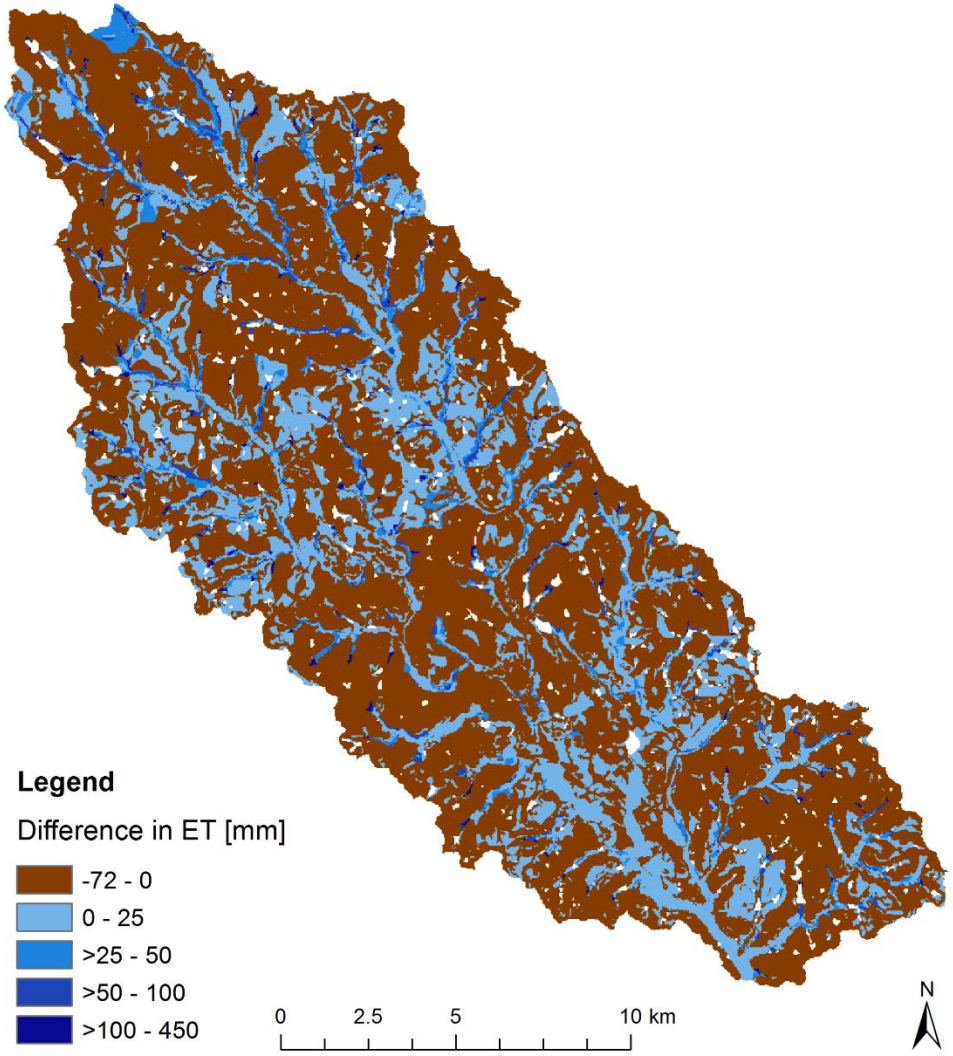
Very good simulation of streamflow at the watershed outlet and average annual water balance

BUT

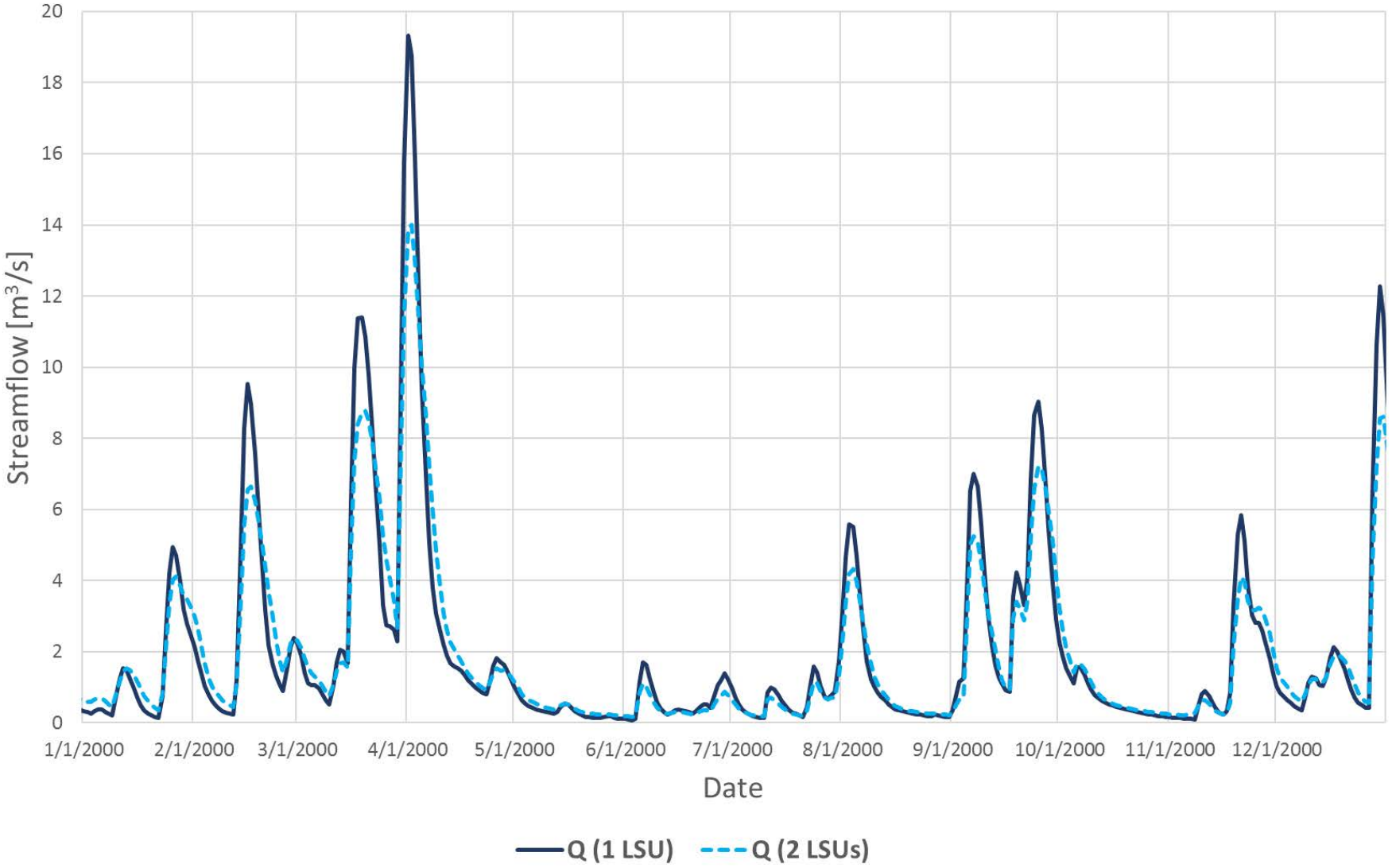
inadequate simulation of internal watershed processes!

Difference in water balance and average annual ET

	1 LSU	2 LSUs
ET	755	755
Surface runoff	113	114
Lateral flow	41	41
Percolation	228	263
Groundwater flow	136	???



Comparison of streamflow



Watershed configuration

SWAT Soil & Water Assessment Tool

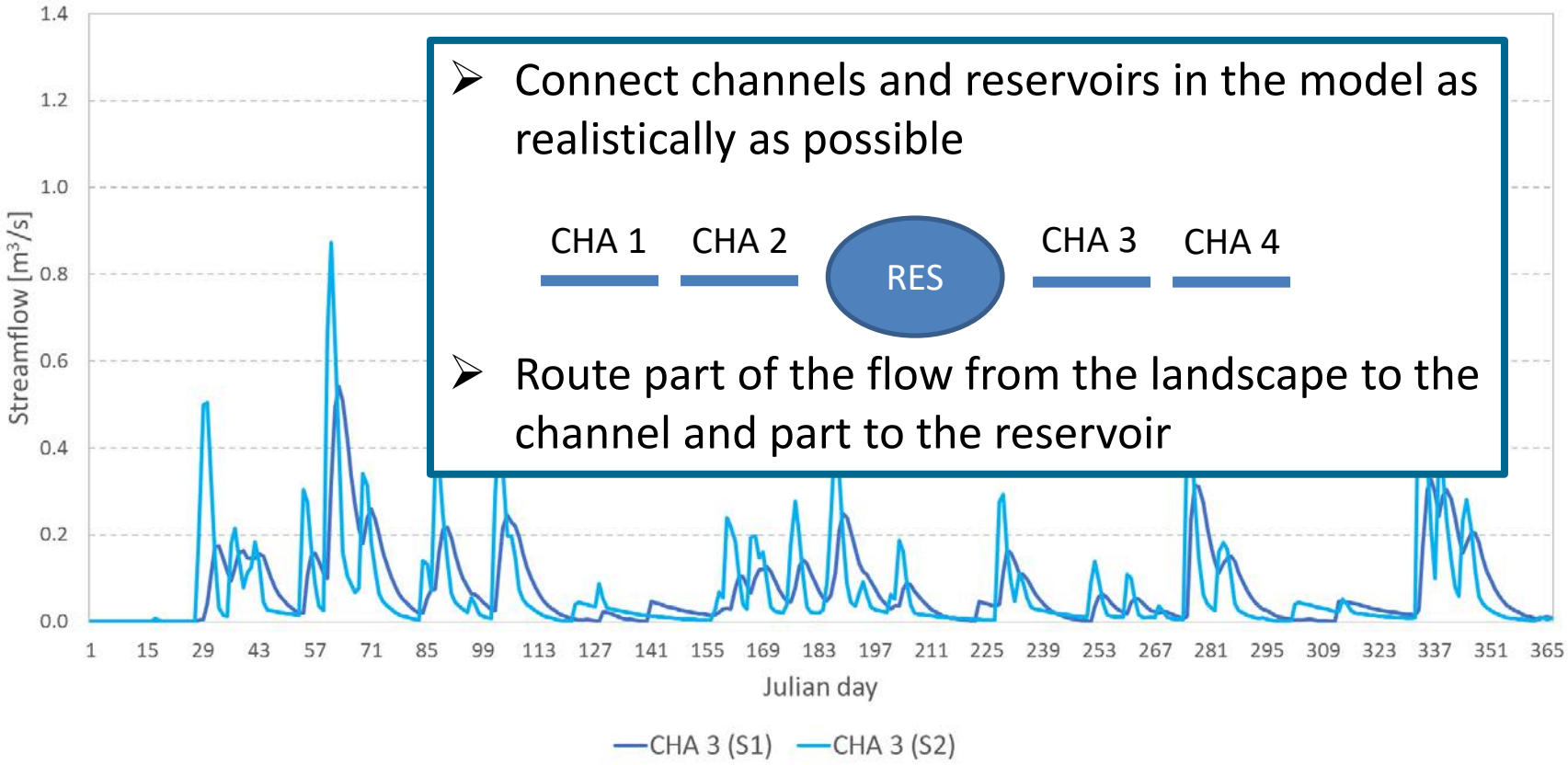
- Subdivision of subbasins into HRUs
- Water areas defined as HRUs
- One channel per subbasin
- Reservoirs at subbasin outlet

SWAT+ SOIL & WATER ASSESSMENT TOOL

- Separation of water and land areas within subbasins
- Water areas defined as ponds or reservoirs
- Definition of one or more LSUs to aggregate HRUs
- As many channels per subbasin as desired
- Reservoirs anywhere along the stream network

Placement of reservoirs

Is placing a reservoir at the HUC12 outlet always appropriate? What if the reservoir is actually located further upstream?



- Connect channels and reservoirs in the model as realistically as possible

CHA 1 — CHA 2 — RES — CHA 3 — CHA 4

- Route part of the flow from the landscape to the channel and part to the reservoir

Watershed configuration

SWAT Soil & Water Assessment Tool

- Subdivision of subbasins into HRUs
- Water areas defined as HRUs
- One channel per subbasin
- Reservoirs at subbasin outlet
- All spatial connections defined in fig.fig file
- One predefined receiving object

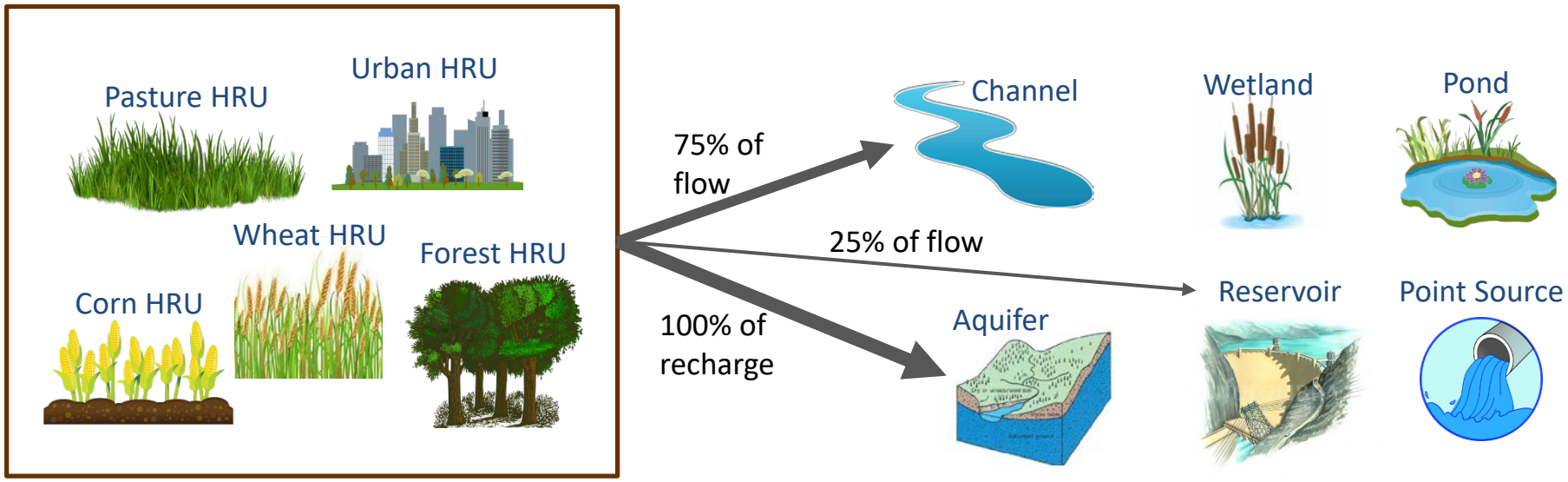
SWAT+ SOIL & WATER ASSESSMENT TOOL

- Separation of water and land areas within subbasins
- Water areas defined as ponds or reservoirs
- Definition of one or more LSUs to aggregate HRUs
- As many channels per subbasin as desired
- Reservoirs anywhere along the stream network
- One *.con file per spatial object to define outflow hydrographs, fractions, and receiving objects

Spatial objects and connections in SWAT+

HRUs, aquifers, channels, reservoirs, etc. are separate spatial objects

- flexible spatial representation of connectivity within a watershed using "connect" files



Spatial connections

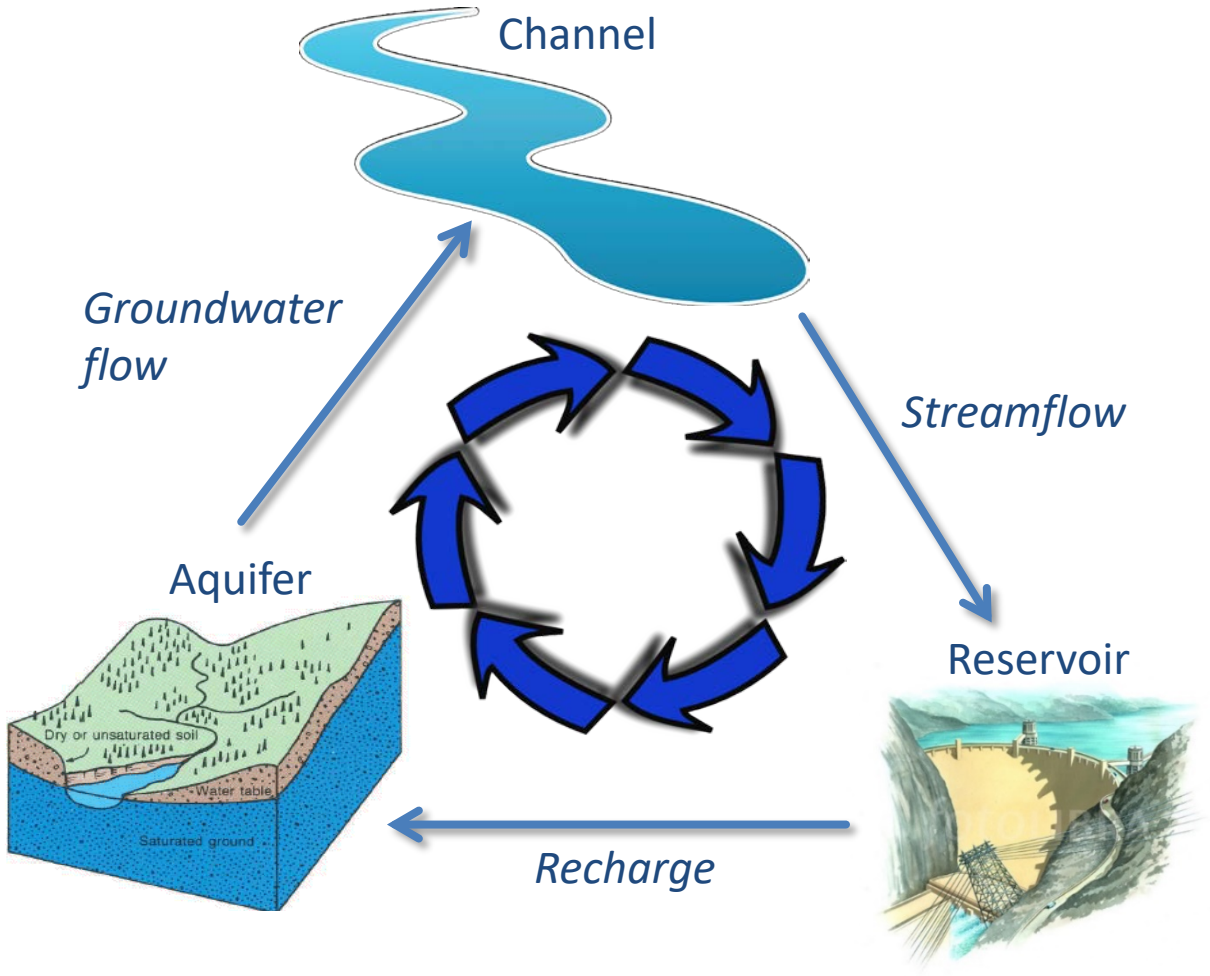
channel.con: Channel spatial connections - LREW Sub Water

CHA_NUMB	CHA_NAME	LATITUDE	LONGITUDE	AREA	CHA	WST_NAME	CONST_TYPE	OVERFLOW	RULE	OUT_TOT	OBJ_TYP1	OBJ_ID1	HYDRO_TYP1	FRAC1
1	cha1	31.742	-83.732	175.320	1	1	0	0.000	0	1	cha	49	tot	1.000
2	cha2	31.720	-83.696	102.060	2	1	0	0.000	0	1	cha	146	tot	1.000
3	cha3	31.674	-83.652	371.700	3	1	0	0.000	0	1	res	173	tot	1.000
4	cha4	31.647	-83.682	86.490	4	1	0	0.000	0	1	cha	165	tot	1.000
5	cha5	31.620	-83.736	169.920	5	1	0	0.000	0	1	cha	202	tot	1.000
6	cha6	31.572	-83.572	103.050	6	1	0	0.000	0	1	cha	126	tot	1.000
7	cha7	31.531	-83.549	120.240	7	1	0	0.000	0	1	cha	186	tot	1.000
8	cha8	31.506	-83.620	139.770	8	1	0	0.000	0	1	res	174	tot	1.000
9	cha9	31.738	-83.758	363.780	9	1	0	0.000	0	1	res	175	tot	1.000
10	cha10	31.717	-83.679	83.700	10	1	0	0.000	0	1	res	176	tot	1.000
11	cha11	31.687	-83.755	174.960	11	1	0	0.000	0	1	res	177	tot	1.000
12	cha12	31.652	-83.711	165.960	12	1	0	0.000	0	1	cha	243	tot	1.000
13	cha13	31.608	-83.602	83.790	13	1	0	0.000	0	1	cha	213	tot	1.000
14	cha14	31.568	-83.620	467.640	14	1	0	0.000	0	1	cha	180	tot	1.000
15	cha15	31.543	-83.665	100.440	15	1	0	0.000	0	1	cha	151	tot	1.000
16	cha16	31.495	-83.543	191.250	16	1	0	0.000	0	1	res	178	tot	1.000
17	cha17	31.742	-83.750	91.710	17	1	0	0.000	0	1	res	179	tot	1.000
18	cha18	31.713	-83.659	113.940	18	1	0	0.000	0	1	res	180	tot	1.000
19	cha19	31.682	-83.668	71.550	19	1	0	0.000	0	1	cha	171	tot	1.000
20	cha20	31.646	-83.703	201.240	20	1	0	0.000	0	1	cha	246	tot	1.000

173	sre173	31.674	-83.652	3.060	173	12	0	0.000	0	1	cha	195	tot	1.000
174	sre174	31.506	-83.620	2.880	174	11	0	0.000	0	1	cha	248	tot	1.000
175	sre175	31.738	-83.758	18.810	175	8	0	0.000	0	1	cha	65	tot	1.000
176	sre176	31.717	-83.679	0.720	176	20	0	0.000	0	1	cha	110	tot	1.000
177	sre177	31.687	-83.755	0.540	177	2	0	0.000	0	1	cha	135	tot	1.000
178	sre178	31.495	-83.543	3.600	178	22	0	0.000	0	1	cha	32	tot	1.000
179	sre179	31.742	-83.750	2.430	179	25	0	0.000	0	1	cha	57	tot	1.000
180	sre180	31.713	-83.659	1.350	180	20	0	0.000	0	1	cha	116	tot	1.000

OUT_TOT	OBJ_TYP1	OBJ_ID1	HYDRO_TYP1	FRAC1	OBJ_TYP2	OBJ_ID2	HYDRO_TYP2	FRAC2	OBJ_TYP3	OBJ_ID3	HYDRO_TYP3	FRAC3	OBJ_TYP4	OBJ_ID4	HYDRO_TYP4	FRAC4	OBJ_TYP5	OBJ_ID5	HYDRO_TYP5	FRAC5
4	cha	1	sur	0.70	aqu	1	rhg	1	sub	2	sur	0.30	sub	2	lat	1.00	null	0	null	0.00
2	cha	1	tot	1.00	aqu	2	rhg	1	null	0	null	0.00	null	0	null	0.00	null	0	null	0.00
4	cha	2	sur	0.70	aqu	3	rhg	1	sub	4	sur	0.30	sub	4	lat	1.00	null	0	null	0.00
2	cha	2	tot	1.00	aqu	4	rhg	1	null	0	null	0.00	null	0	null	0.00	null	0	null	0.00
5	cha	3	sur	0.68	aqu	5	rhg	1	sub	6	sur	0.28	sub	6	lat	1.00	res	1	sur	0.04
2	cha	3	tot	1.00	aqu	6	rhg	1	null	0	null	0.00	null	0	null	0.00	null	0	null	0.00
5	cha	4	sur	0.68	aqu	7	rhg	1	sub	8	sur	0.28	sub	8	lat	1.00	res	2	sur	0.04
3	cha	4	tot	0.96	aqu	8	rhg	1	res	3	tot	0.04	null	0	null	0.00	null	0	null	0.00
5	cha	5	sur	0.68	aqu	9	rhg	1	sub	10	sur	0.28	sub	10	lat	1.00	res	4	sur	0.04
2	cha	5	tot	1.00	aqu	10	rhg	1	null	0	null	0.00	null	0	null	0.00	null	0	null	0.00
5	cha	6	sur	0.68	aqu	11	rhg	1	sub	12	sur	0.28	sub	12	lat	1.00	res	5	sur	0.04
3	cha	6	tot	0.96	aqu	12	rhg	1	res	6	tot	0.04	null	0	null	0.00	null	0	null	0.00
5	cha	7	sur	0.68	aqu	13	rhg	1	sub	14	sur	0.28	sub	14	lat	1.00	res	7	sur	0.04
3	cha	7	tot	0.96	aqu	14	rhg	1	res	8	tot	0.04	null	0	null	0.00	null	0	null	0.00
4	cha	8	sur	0.70	aqu	15	rhg	1	sub	16	sur	0.30	sub	16	lat	1.00	null	0	null	0.00

Infinite loop



Conclusions and outlook

Advantages of SWAT+

- More realistic simulation of water areas and stream networks
- Improved simulation of landscape position, overland routing, and floodplain processes
- More flexibility in defining spatial interactions of objects within the watershed

Next steps

- Improve the simulation of runoff generation and routing processes within and across landscape units (when and how do the hillslopes become connected to the stream?)
- Daily update of connect files during simulation?
- Enhance the simulation of interactions between streams/rivers and floodplains

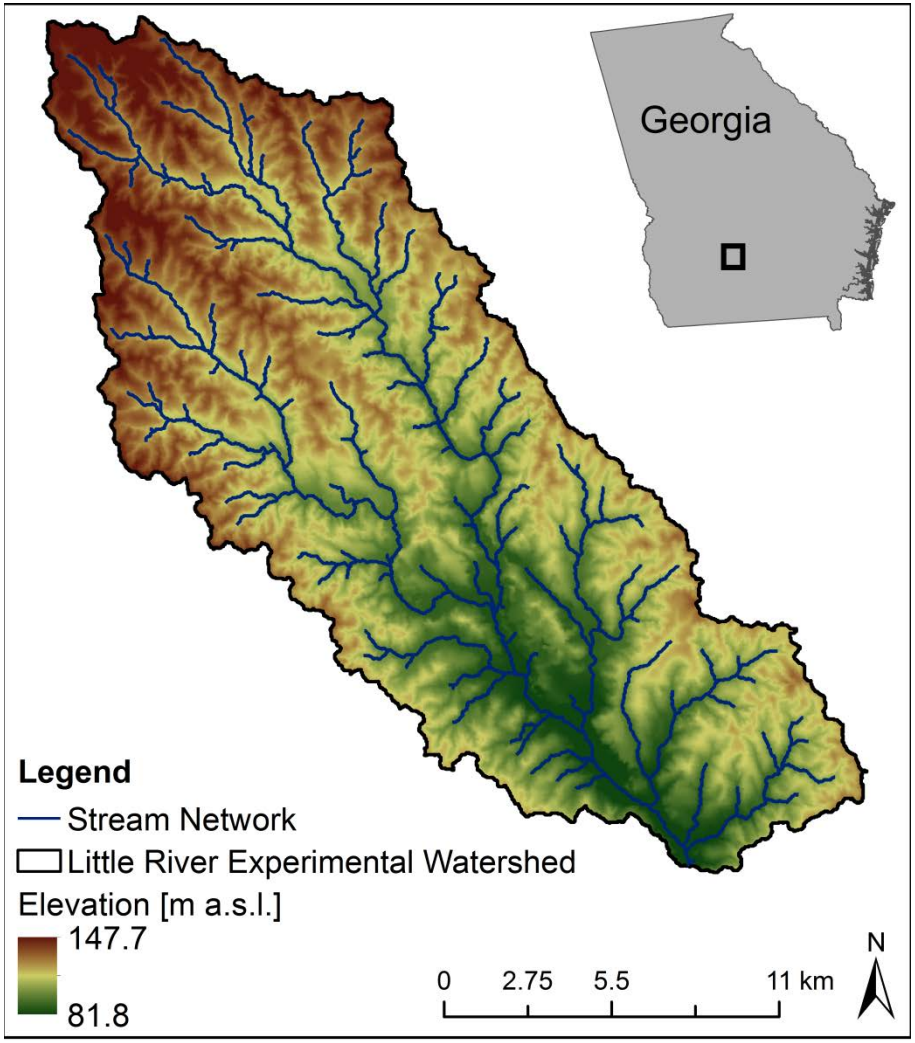
Thank you for your attention!

K. Bieger, J.G. Arnold, H. Rathjens, M.J. White, D.D. Bosch, P.M. Allen, M. Volk, and R. Srinivasan
Introduction to SWAT+, a completely restructured version of the Soil and Water Assessment Tool
Journal of the American Water Resources Association 53(1):115-130

TEXAS A&M AGRILIFE RESEARCH

kbieger@brc.tamus.edu

Little River Experimental Watershed (LREW)



Area: 334 km^2
Average annual precip: 1208 mm
Average temperature: 19.1°C
Average streamflow: 2.95 m^3/s

Gently sloping uplands
Broad, wooded floodplains

Watershed configuration

SWAT Soil & Water Assessment Tool	SWAT+ SOIL & WATER ASSESSMENT TOOL	Advantages of SWAT+
• Subdivision of subbasins into HRUs • Water areas defined as HRUs	• Separation of water and land areas within subbasins • Water areas defined as ponds or reservoirs • Definition of LSUs to aggregate HRUs	• More realistic simulation of water areas • Improved simulation of landscape position, overland routing, and floodplain processes
• HRUs represented by their entire area within a LSU during calculation of land phase processes	• HRUs represented by a contiguous field with user-defined dimensions, actual HRU area used as expansion factor	• Calculation of land phase processes independent of HRU area

Spatial connections

SWAT Soil & Water Assessment Tool	SWAT+ SOIL & WATER ASSESSMENT TOOL	**Advantages of SWAT+**
• All spatial connections defined in fig.fig file • One predefined receiving object	• One *.con file per spatial object to define outflow hydrographs, fractions, and receiving objects	• More flexibility in defining spatial interactions of objects within the watershed

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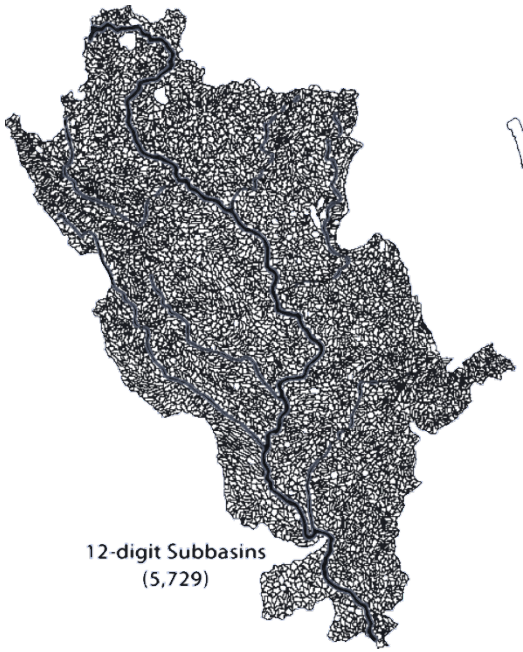
2	cha2	31.720	-83.696	102.060	2	1	0	0.000	0	1	cha	146	tot	1.000
3	cha3	31.674	-83.652	371.700	3	1	0	0.000	0	1	res	173	tot	1.000
4	cha4	31.647	-83.682	86.490	4	1	0	0.000	0	1	cha	165	tot	1.000
5	cha5	31.620	-83.736	169.920	5	1	0	0.000	0	1	cha	202	tot	1.000
6	cha6	31.572	-83.572	103.050	6	1	0	0.000	0	1	cha	126	tot	1.000
7	cha7	31.531	-83.549	120.240	7	1	0	0.000	0	1	cha	186	tot	1.000
8	cha8	31.506	-83.620	139.770	8	1	0	0.000	0	1	res	174	tot	1.000
9	cha9	31.738	-83.758	363.780	9	1	0	0.000	0	1	res	175	tot	1.000
10	cha10	31.717	-83.679	83.700	10	1	0	0.000	0	1	res	176	tot	1.000
11	cha11	31.687	-83.755	174.960	11	1	0	0.000	0	1	res	177	tot	1.000
12	cha12	31.652	-83.711	165.960	12	1	0	0.000	0	1	cha	243	tot	1.000
13	cha13	31.608	-83.602	83.790	13	1	0	0.000	0	1	cha	213	tot	1.000
14	cha14	31.568	-83.620	467.640	14	1	0	0.000	0	1	cha	180	tot	1.000
15	cha15	31.543	-83.665	100.440	15	1	0	0.000	0	1	cha	151	tot	1.000
16	cha16	31.495	-83.543	191.250	16	1	0	0.000	0	1	res	178	tot	1.000
17	cha17	31.742	-83.750	91.710	17	1	0	0.000	0	1	res	179	tot	1.000
18	cha18	31.713	-83.659	113.940	18	1	0	0.000	0	1	res	180	tot	1.000
19	cha19	31.682	-83.668	71.550	19	1	0	0.000	0	1	cha	171	tot	1.000
20	cha20	31.646	-83.703	201.240	20	1	0	0.000	0	1	cha	246	tot	1.000
21	cha21	31.614	-83.724	225.090	21	1	0	0.000	0	1	res	181	tot	1.000
22	cha22	31.563	-83.572	69.120	22	1	0	0.000	0	1	cha	126	tot	1.000
23	cha23	31.537	-83.580	158.850	23	1	0	0.000	0	1	cha	220	tot	1.000
24	cha24	31.482	-83.574	90.180	24	1	0	0.000	0	1	cha	79	tot	1.000
25	cha25	31.738	-83.743	101.790	25	1	0	0.000	0	1	cha	57	tot	1.000

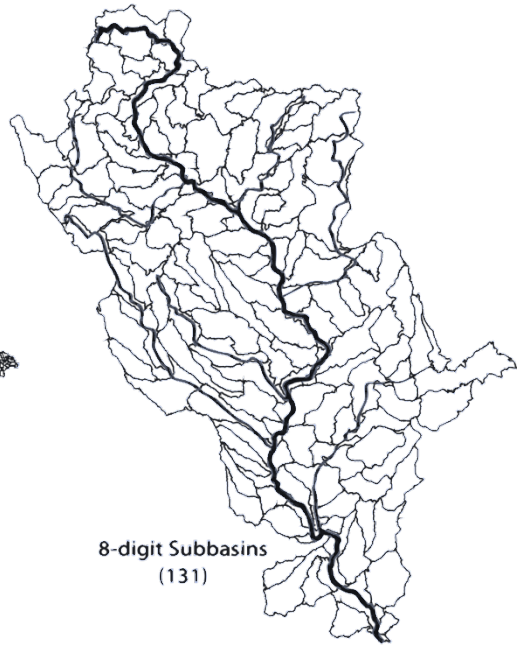
National model assessments

- Conservation Effects Assessment Project: Predict benefit of conservation practices in agriculture
- Real-time and forecast simulations: County-level maps of current and near-future soil moisture, plant growth etc. to inform stakeholders

CEAP II



CEAP I

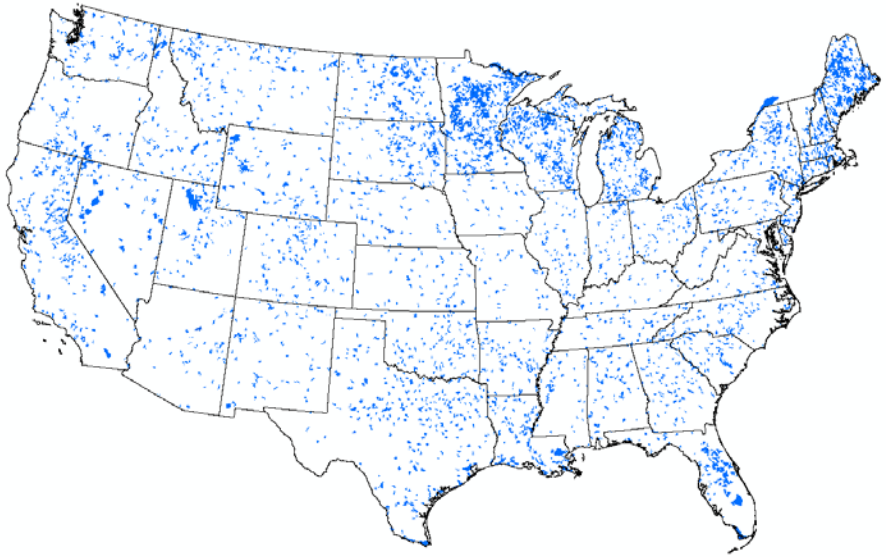


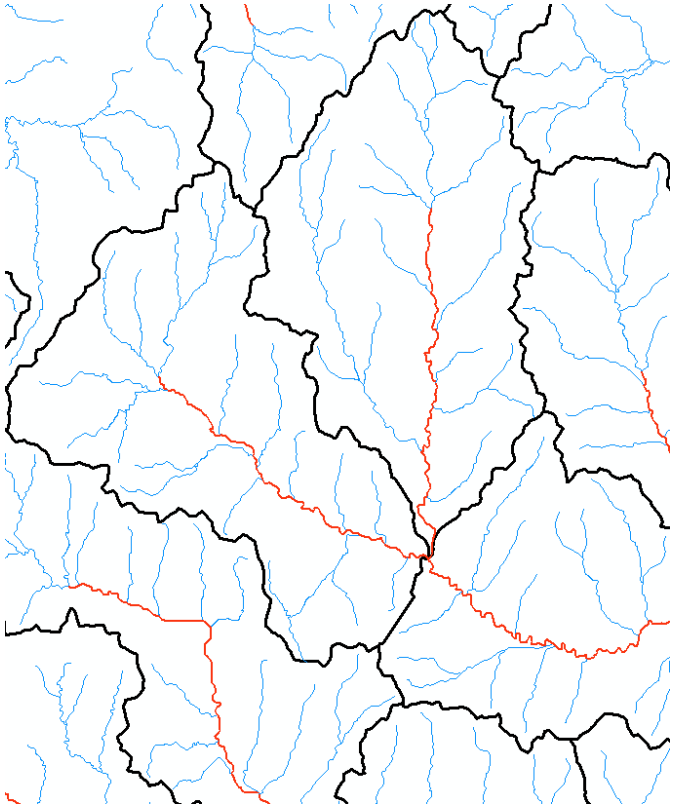
- More localized processes in CEAP II:
  - Low order streams
  - Gullies
  - Riparian floodplains

SWAT+
SOIL & WATER ASSESSMENT TOOL

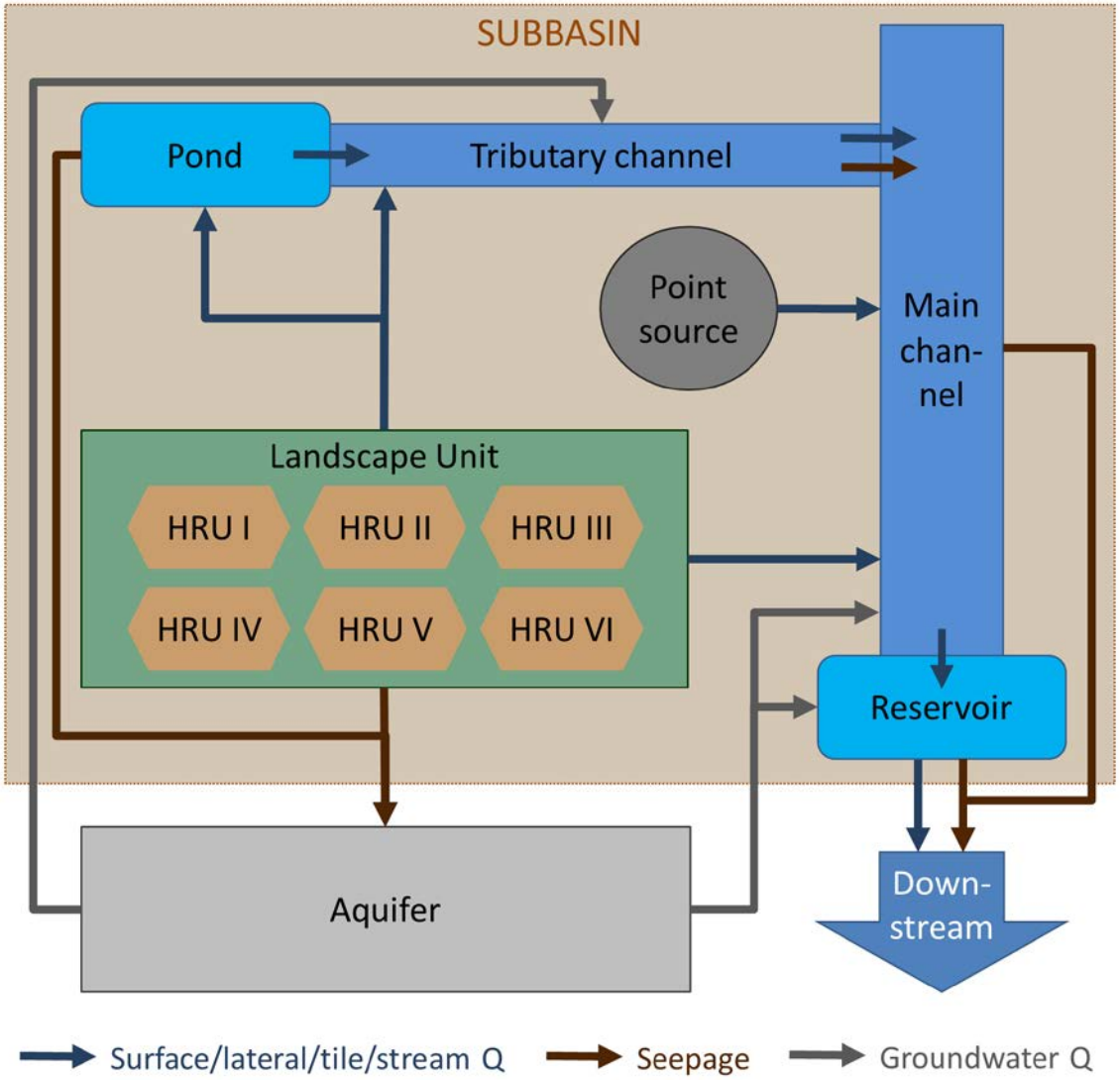
Constructing a national SWAT+ model

- Define connections between HUC12s based on 2015 NRCS HUC12 data
- Identify main and tributary channels based on drainage area, length, and connectivity
- Classify water bodies (reservoirs, ponds, wetlands) based on NHDPlus
- Define internal connections

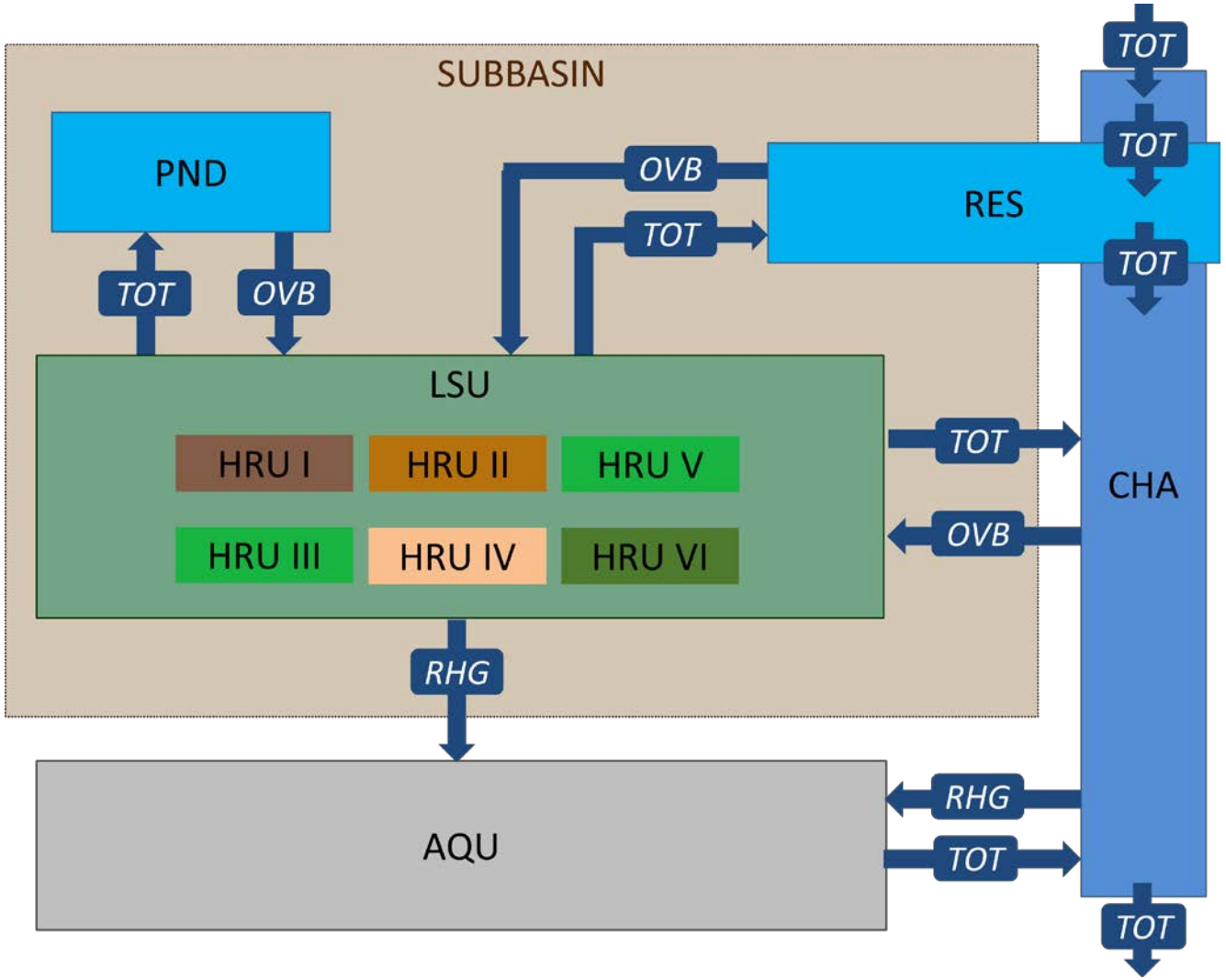




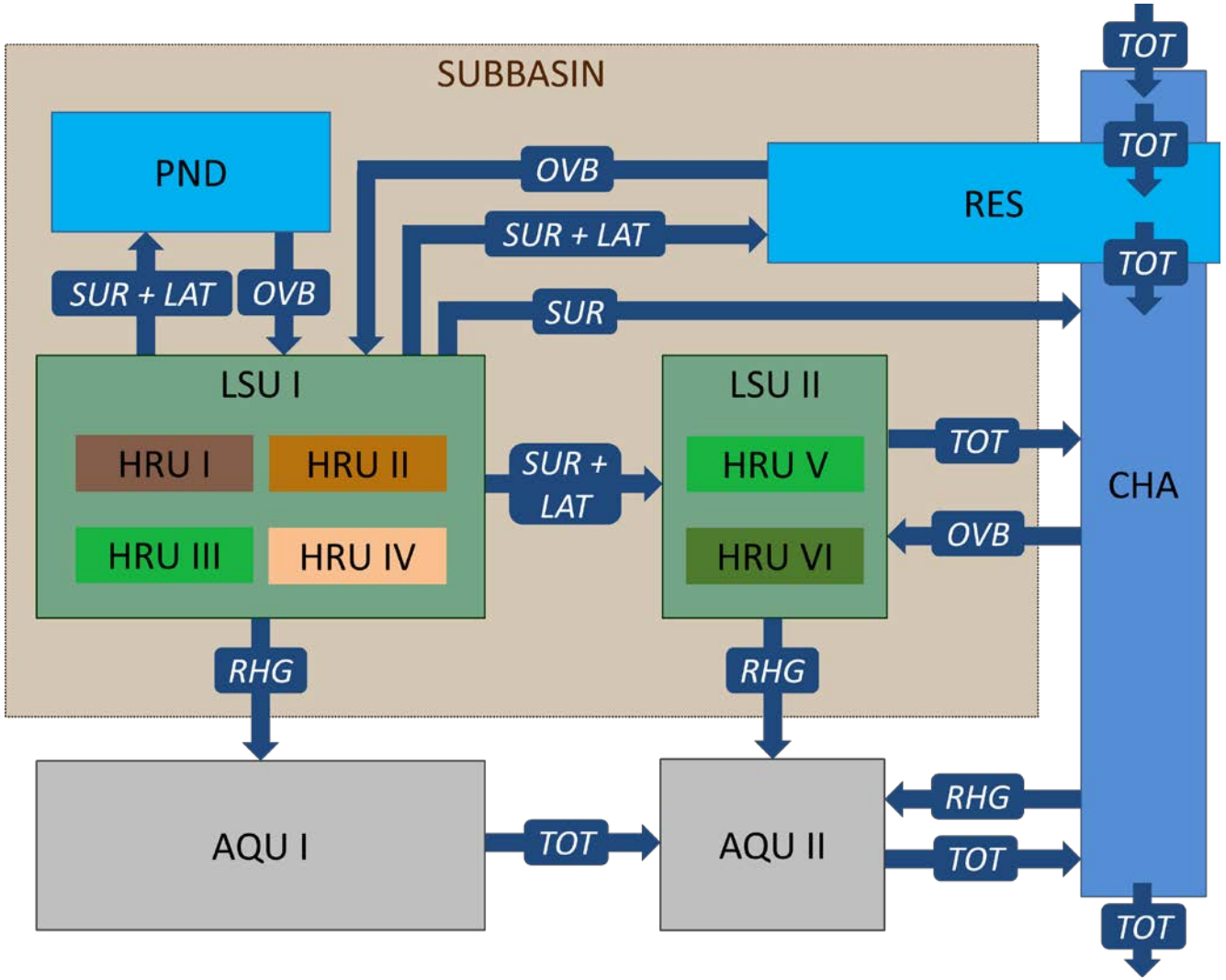
Conceptual model



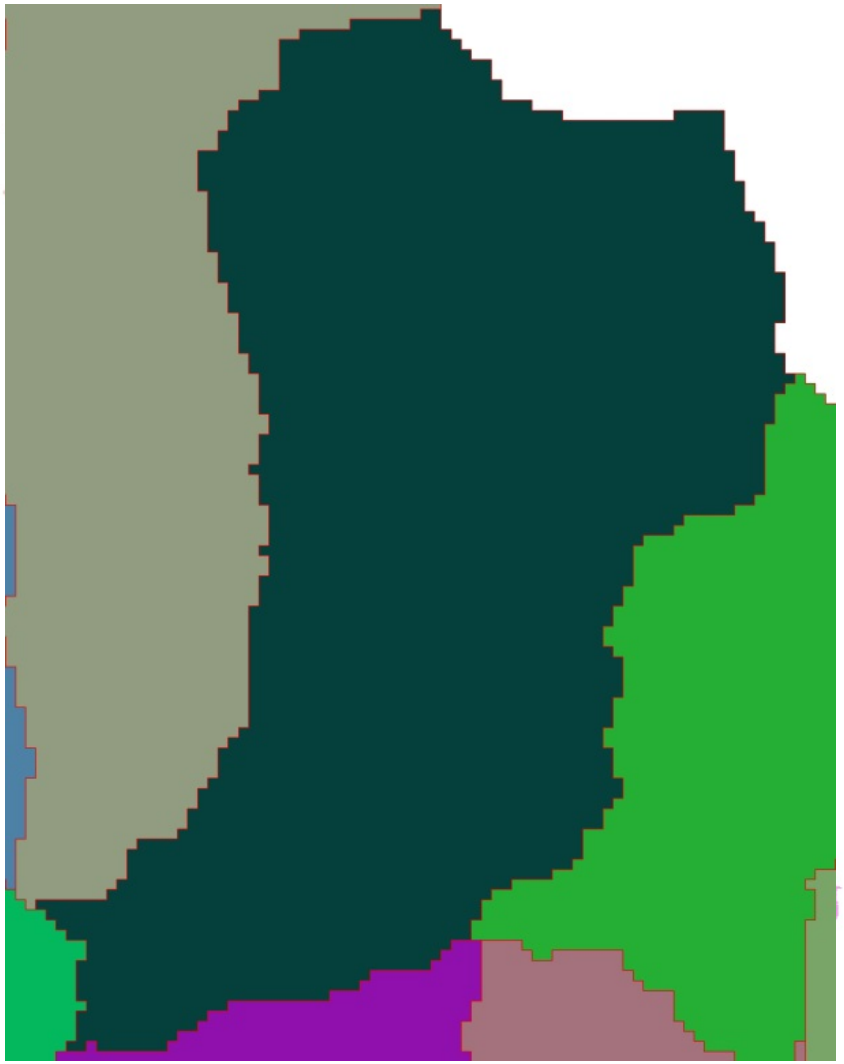
Conceptual flow paths: 1 landscape unit

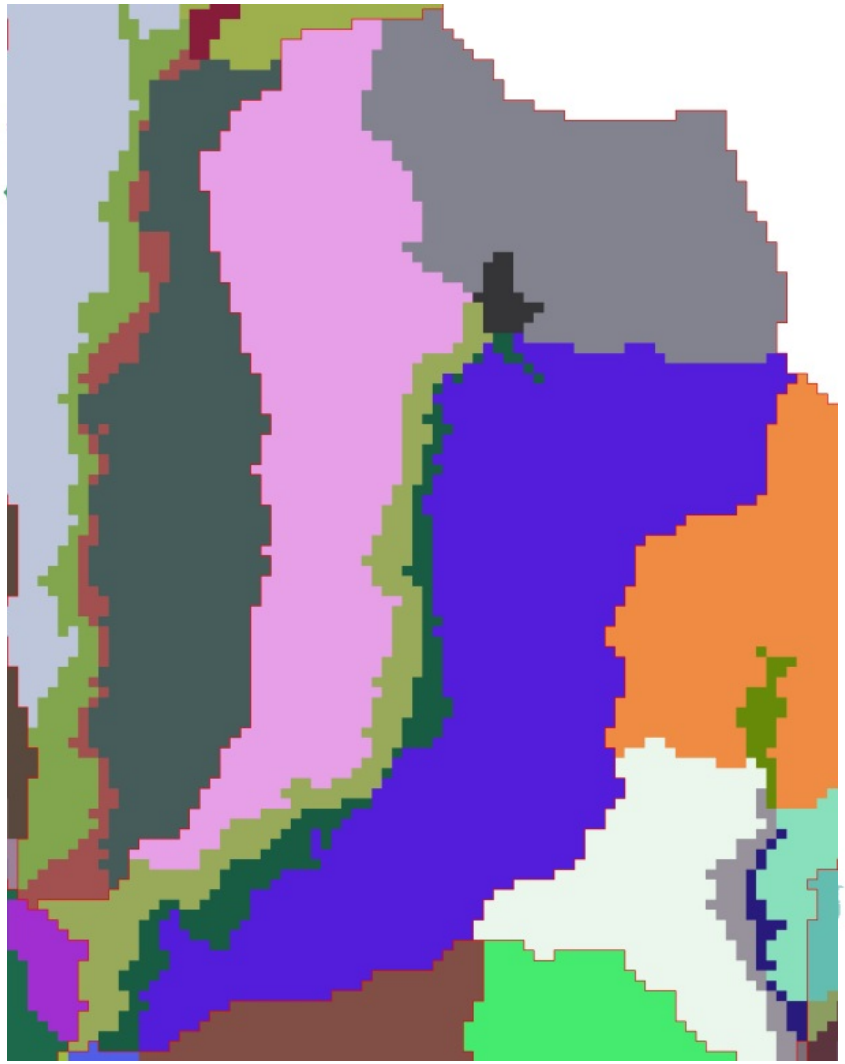


Conceptual flow paths: 2 landscape units



2 SWAT+ setups

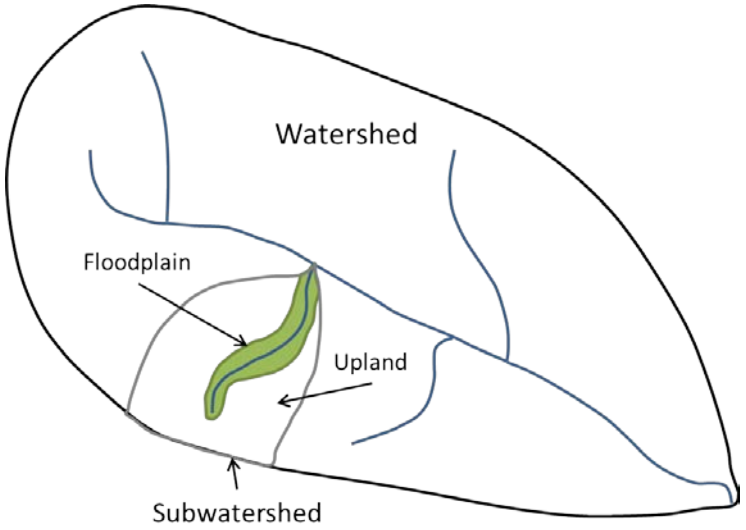




Landscape units

- Hydrologic landscape units are
  - elements of a (sub)watershed
  - defined to account for landscape position and processes

- Two landscape units
  - Upland and floodplain
  - Different hydrologic properties and processes (slope, storage, sediment processes)



ET and surface runoff (1 LSU)