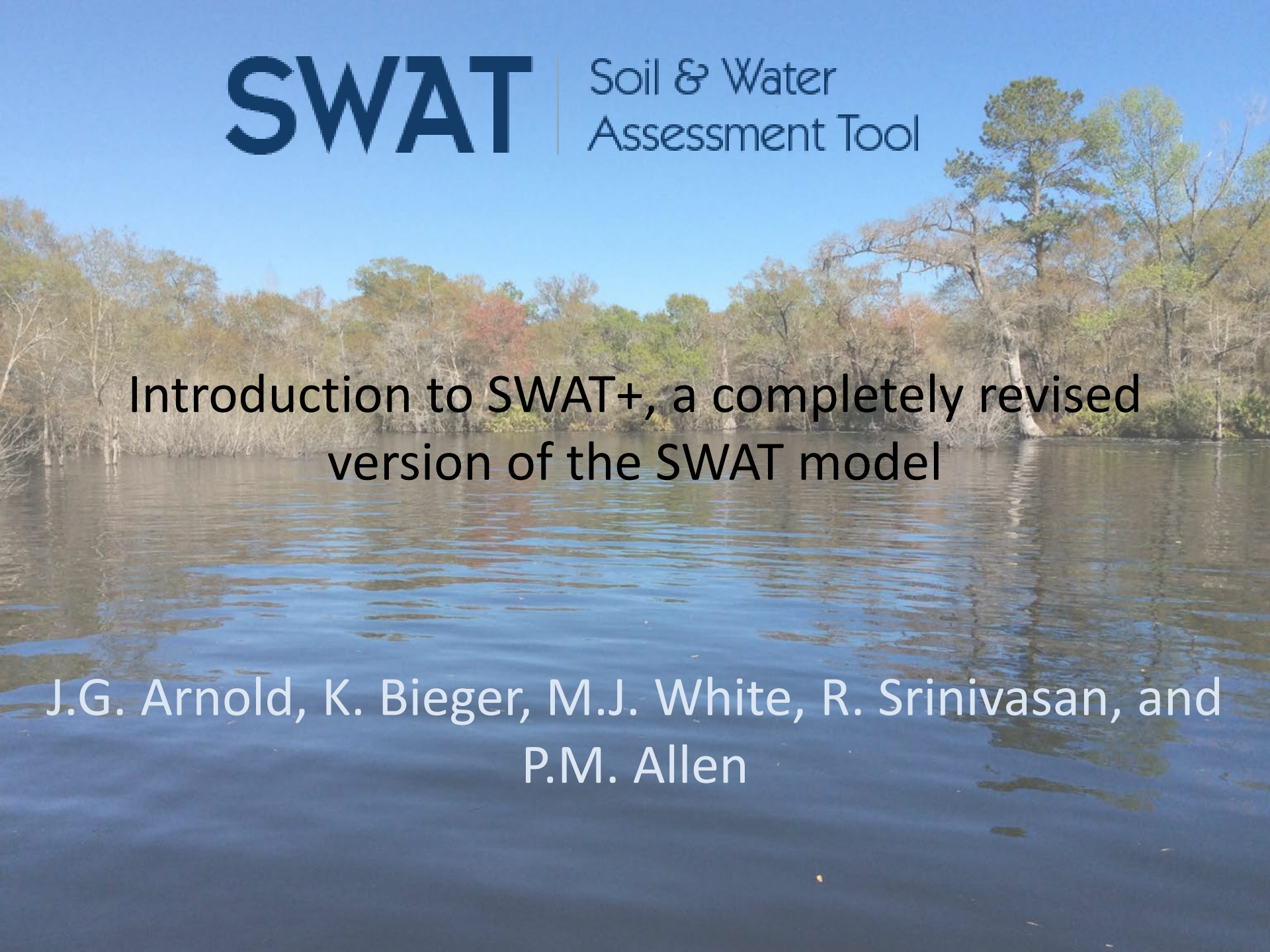


Introduction to SWAT+, a completely revised version of the SWAT model

J.G. Arnold, K. Bieger, M.J. White, R. Srinivasan, and P.M. Allen

SWAT+, a completely restructured version of SWAT

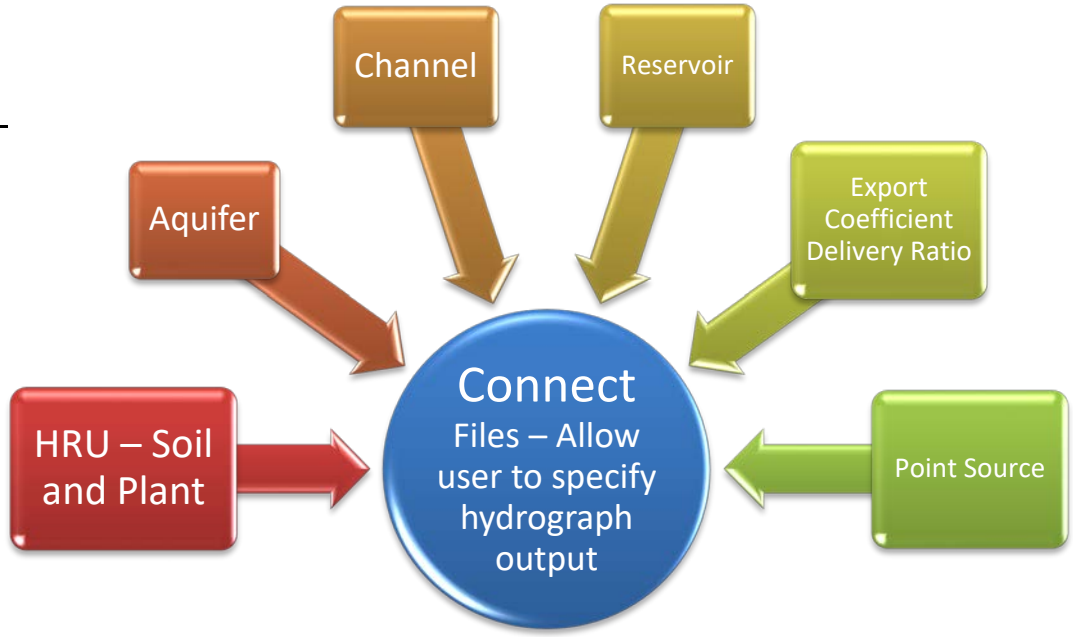
- SWAT+ SOIL & WATER ASSESSMENT TOOL is expected to facilitate
  - maintenance of code and input files
  - linkage of SWAT and other models
  - addition of new process subroutines

- HRUs, aquifers, channels, reservoirs, etc. are separate spatial objects → flexible spatial representation of interactions and processes within a watershed using "connect" files

Code

- FORTRAN - continue as language of choice for scientists/engineers.
- MODULAR – Extensive use of data structures and modules. Easier to maintain, link to other models, and add process subroutines.
- RECODING - Spatial objects with new input/output data structure is complete. Continue recoding process subroutines and modules.

- VERSION CONTROL – Bit Bucket



SWAT+ input files

SWAT Soil & Water Assessment Tool	SWAT+ SOIL & WATER ASSESSMENT TOOL	**Advantages of SWAT+**
• One file for each data type for each object	• One file for each data type with one line for each object	• Reduced number of input files • Decrease in run time • Data files can be maintained as databases

aquifer.aqu: Aquifer properties - LREW Sub Water

AQU_NUMB	AQU_NAME	GW_FLO	GW_STORE	GW_HT	GW_NO3N	GW_MINP	GW_PARN	GW_PARP	GW_DELAY	ALPHA_BF	REVAP	RCHG_DP	SP_YLD	HL_NO3N	FLO_MIN	REVAP_MIN
1	aqu1	2500.000	1000.000	1.000	0.000	0.000	0.000	0.000	31.000	0.050	0.020	0.050	0.000	0.000	1000.000	750.000
2	aqu2	2500.000	1000.000	1.000	0.000	0.000	0.000	0.000	31.000	0.050	0.020	0.050	0.000	0.000	1000.000	750.000
3	aqu3	2500.000	1000.000	1.000	0.000	0.000	0.000	0.000	31.000	0.050	0.020	0.050	0.000	0.000	1000.000	750.000
4	aqu4	2500.000	1000.000	1.000	0.000	0.000	0.000	0.000	31.000	0.050	0.020	0.050	0.000	0.000	1000.000	750.000
5	aqu5	2500.000	1000.000	1.000	0.000	0.000	0.000	0.000	31.000	0.050	0.020	0.050	0.000	0.000	1000.000	750.000
6	aqu6	2500.000	1000.000	1.000	0.000	0.000	0.000	0.000	31.000	0.050	0.020	0.050	0.000	0.000	1000.000	750.000
7	aqu7	2500.000	1000.000	1.000								0.050	0.000	0.000	1000.000	750.000
8	aqu8	2500.000	1000.000	1.000								0.050	0.000	0.000	1000.000	750.000
9	aqu9	2500.000	1000.000	1.000								0.050	0.000	0.000	1000.000	750.000
10	aqu10	2500.000	1000.000	1.000								0.050	0.000	0.000	1000.000	750.000
11	aqu11	2500.000	1000.000	1.000								0.050	0.000	0.000	1000.000	750.000
12	aqu12	2500.000	1000.000	1.000								0.050	0.000	0.000	1000.000	750.000
13	aqu13	2500.000	1000.000	1.000								0.050	0.000	0.000	1000.000	750.000
14	aqu14	2500.000	1000.000	1.000								0.050	0.000	0.000	1000.000	750.000
15	aqu15	2500.000	1000.000	1.000								0.050	0.000	0.000	1000.000	750.000
16	aqu16	2500.000	1000.000	1.000								0.050	0.000	0.000	1000.000	750.000
17	aqu17	2500.000	1000.000	1.000								0.050	0.000	0.000	1000.000	750.000
18	aqu18	2500.000	1000.000	1.000								0.050	0.000	0.000	1000.000	750.000
19	aqu19	2500.000	1000.000	1.000								0.050	0.000	0.000	1000.000	750.000
20	aqu20	2500.000	1000.000	1.000	0.000	0.000	0.000	0.000	31.000	0.050	0.020	0.050	0.000	0.000	1000.000	750.000
21	aqu21	2500.000	1000.000	1.000	0.000	0.000	0.000	0.000	31.000	0.050	0.020	0.050	0.000	0.000	1000.000	750.000
22	aqu22	2500.000	1000.000	1.000	0.000	0.000	0.000	0.000	31.000	0.050	0.020	0.050	0.000	0.000	1000.000	750.000
23	aqu23	2500.000	1000.000	1.000	0.000	0.000	0.000	0.000	31.000	0.050	0.020	0.050	0.000	0.000	1000.000	750.000
24	aqu24	2500.000	1000.000	1.000	0.000	0.000	0.000	0.000	31.000	0.050	0.020	0.050	0.000	0.000	1000.000	750.000
25	aqu25	2500.000	1000.000	1.000	0.000	0.000	0.000	0.000	31.000	0.050	0.020	0.050	0.000	0.000	1000.000	750.000
26	aqu26	2500.000	1000.000	1.000	0.000	0.000	0.000	0.000	31.000	0.050	0.020	0.050	0.000	0.000	1000.000	750.000
27	aqu27	2500.000	1000.000	1.000	0.000	0.000	0.000	0.000	31.000	0.050	0.020	0.050	0.000	0.000	1000.000	750.000
28	aqu28	2500.000	1000.000	1.000	0.000	0.000	0.000	0.000	31.000	0.050	0.020	0.050	0.000	0.000	1000.000	750.000
29	aqu29	2500.000	1000.000	1.000	0.000	0.000	0.000	0.000	31.000	0.050	0.020	0.050	0.000	0.000	1000.000	750.000
30	aqu30	2500.000	1000.000	1.000	0.000	0.000	0.000	0.000	31.000	0.050	0.020	0.050	0.000	0.000	1000.000	750.000

SWAT+
SOIL & WATER ASSESSMENT TOOL

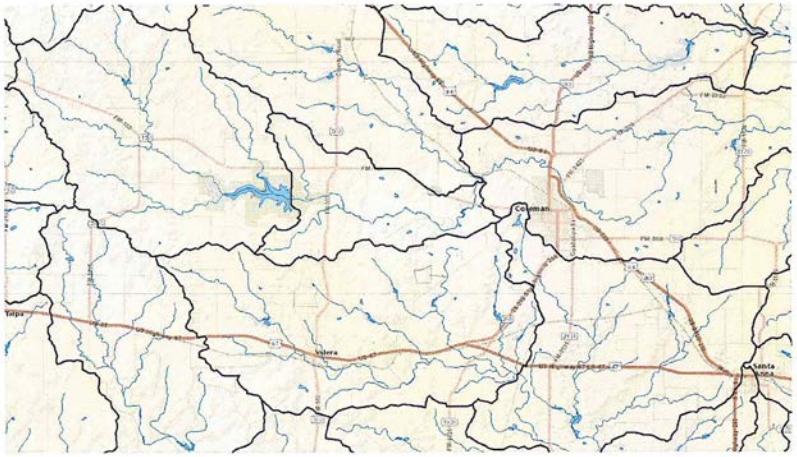
5 HRUs = 1 aquifer.aqu file

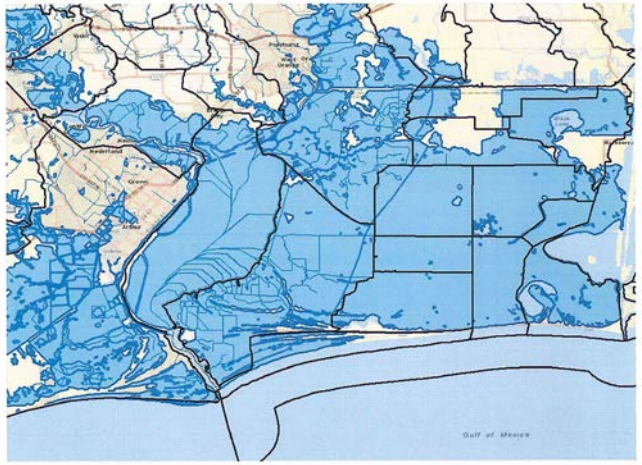
5000 HRUs = 1 aquifer.aqu file

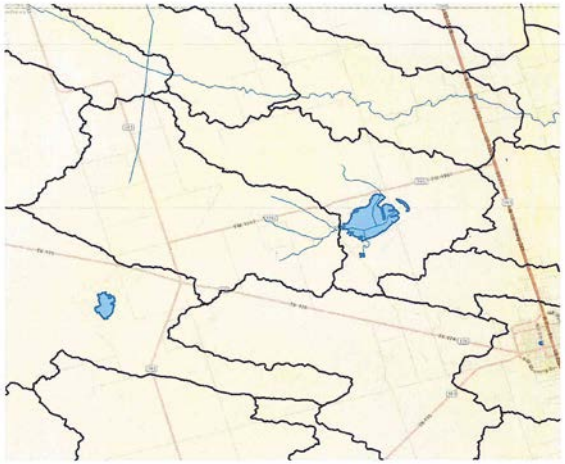
Watershed configuration

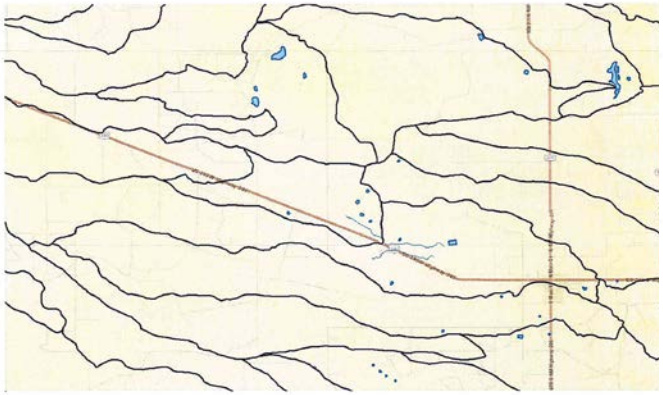
SWAT Soil & Water Assessment Tool	SWAT+ SOIL & WATER ASSESSMENT TOOL	**Advantages of SWAT+**
• Subdivision of subbasins into HRUs • Water areas defined as HRUs	• Separation of water and land areas within subbasins • Water areas defined as ponds/ reservoirs • Definition of LSUs to aggregate HRUs	• More 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

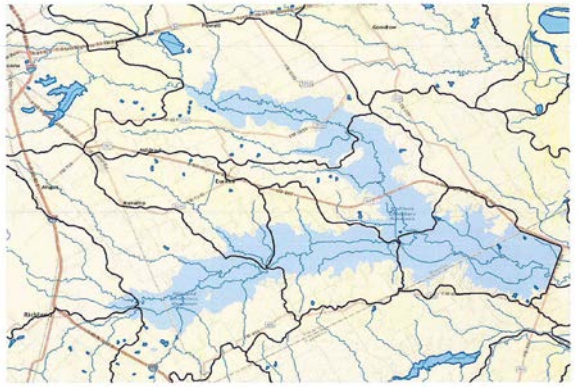
Simulation of “non-classical” hydrography. Playa lakes, non-draining lakes, no hydrography, all wetland, etc











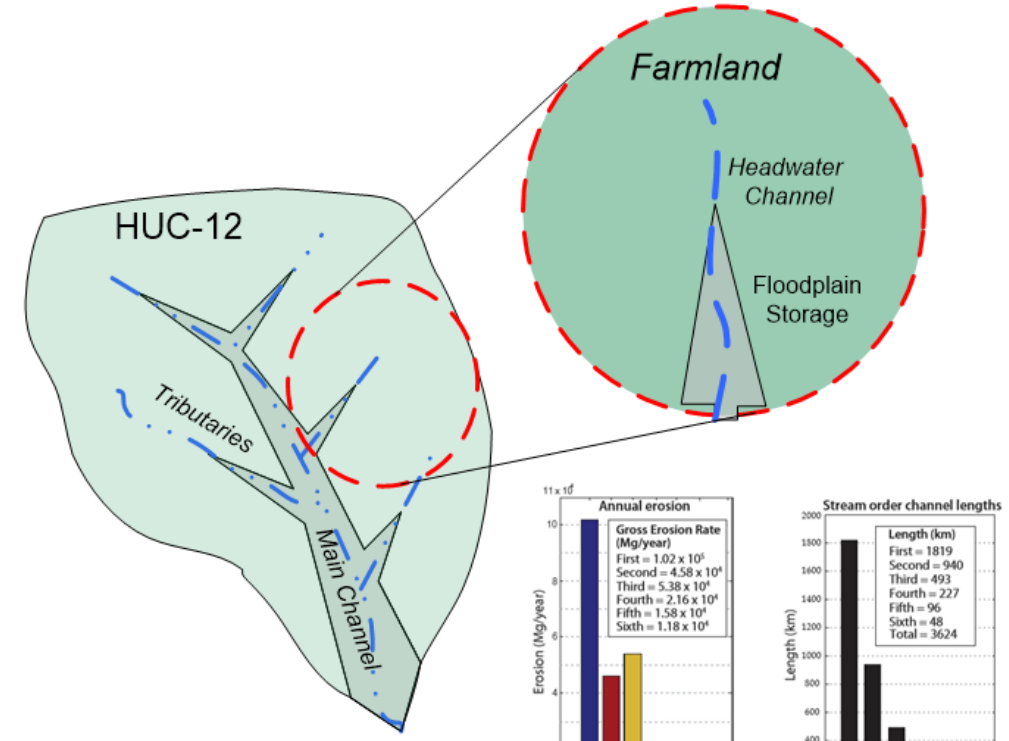
Additions to the model

- New spatial objects: pumps, canals, water rights, animal herds
- 3 Tier approach for:

  Tier 1 – Export coefficients and delivery ratios

  Tier 2 – hru-lte – water balance and plant growth

  Tier 3 – hru – full carbon, nutrient and constituent simulation



Aquifers and reservoirs

SWAT Soil & Water Assessment Tool	SWAT+ SOIL & WATER ASSESSMENT TOOL	**Advantages of SWAT+**
• Aquifers tied to HRUs • Definition of one aquifer per HRU	• Aquifers independent from HRUs	• Any number of aquifers can be defined • Facilitation of SWAT-MODFLOW linkage
• Placement of reservoirs on main channel at subbasin outlet	• Placement of reservoirs anywhere in the watershed	• More realistic representation of reservoir position and interactions with the landscape

Decision tables

Precise, compact way to model complex rule sets and their corresponding actions

CONDITIONS	ALTERNATIVES
ACTIONS	ACTION ENTRIES

Actions

irrigate
release
fertilize
plant
harvest
tillage
fire
grow_init
grow_end
drainage
lu_change
chan_change
(herd)
(water rights)

Alternatives

< > =

Action Entries

yes no

Conditional Variables

soil_water
w_stress
month
jday
hu_plant
hu_base0
year_rot
year_cal
year_seq
prob
land_use
ch_use
n_stress
soil_n
soil_p
n_applied
biomass
cover
lai
vol
flow
lat
long
elev
day_len
plant
plant_type

Decision tables

Precise, compact way to model complex rule sets and their corresponding actions

CONDITIONS	ALTERNATIVES
ACTIONS	ACTION ENTRIES

NAME	CONDS	ALTS	ACTS				
pl_growth_init	2	2	1				
VAR	OBJ	OB_NUM	LIM_VAR	LIM_OP	LIM_CONST	ALT1	ALT2
phu_base0	null	0	null	-	0.15	>	<
phu_base0	null	0	null	-	0.25	<	-
ACT_TYP	NAME	OPTION	CONST	FILE_POINTER		OUTCOME	
grow_init	start_growth	file	0	corn		y	n

Printing output

SWAT Soil & Water Assessment Tool	SWAT+ SOIL & WATER ASSESSMENT TOOL	**Advantages of SWAT+**
All output printed at simulation time step	User-defined time step for printing output for each object	Printing of output according to needs of user
Varying layout of output files	Standardized layout of output files in database format	Easy loading and editing in any text editor, spread-sheet or database program
Specification of additional print commands in fig.fig file	Specification of additional print commands in separate file	Easier printing of user-defined output files

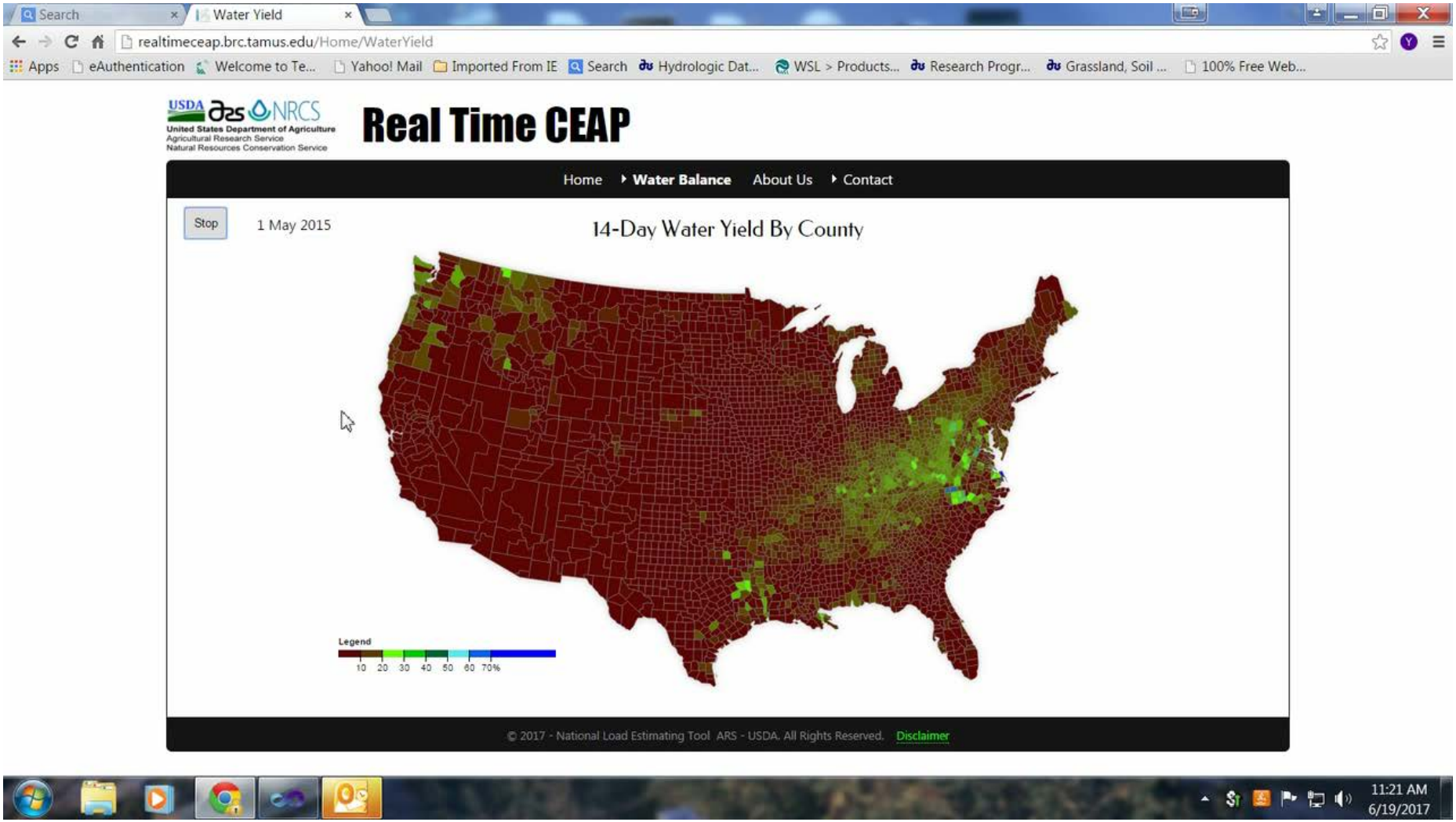
Calibration

SWAT Soil & Water Assessment Tool	SWAT+ SOIL & WATER ASSESSMENT TOOL	**Advantages of SWAT+**
• Changes of parameter values made in the original data file(s)	• Changes of parameter values listed in calibration file that overrides original values	• Rapid model calibration • Better tracking of modified parameters

NAME	CHG_TYPE	VAL	CONDS	LYR1	LYR2	OBJ_TOT		
awc	abschg	-0.358	1	1	3	2	22	-28
texture	=	LS-SL-SCL-SCL						

Next steps

- Interfaces – GIS based, Web based
- Further Recoding – Build soil, plant and water objects from basic organic and mineral objects
- Dynamic Land Use Updates – Using decision tables
- Soft Calibration – Water, Sediment and Nutrient budgets
- Real Time Simulation - 10 km^2 grid of the U.S. using NEXRAD inputs to current day. Projecting future with weather forecasts.


Search
Water Yield
realtimeceap.brc.tamus.edu/Home/WaterYield
Apps
eAuthentication
Welcome to Te...
Yahoo! Mail
Imported From IE
Search
Hydrologic Dat...
WSL > Products...
Research Progr...
Grassland, Soil ...
100% Free Web...
USDA ARS NRCS
United States Department of Agriculture
Agricultural Research Service
Natural Resources Conservation Service
Real Time CEAP
Home
Water Balance
About Us
Contact
Stop
1 May 2015
14-Day Water Yield By County
Legend
10 20 30 40 50 60 70%
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Disclaimer
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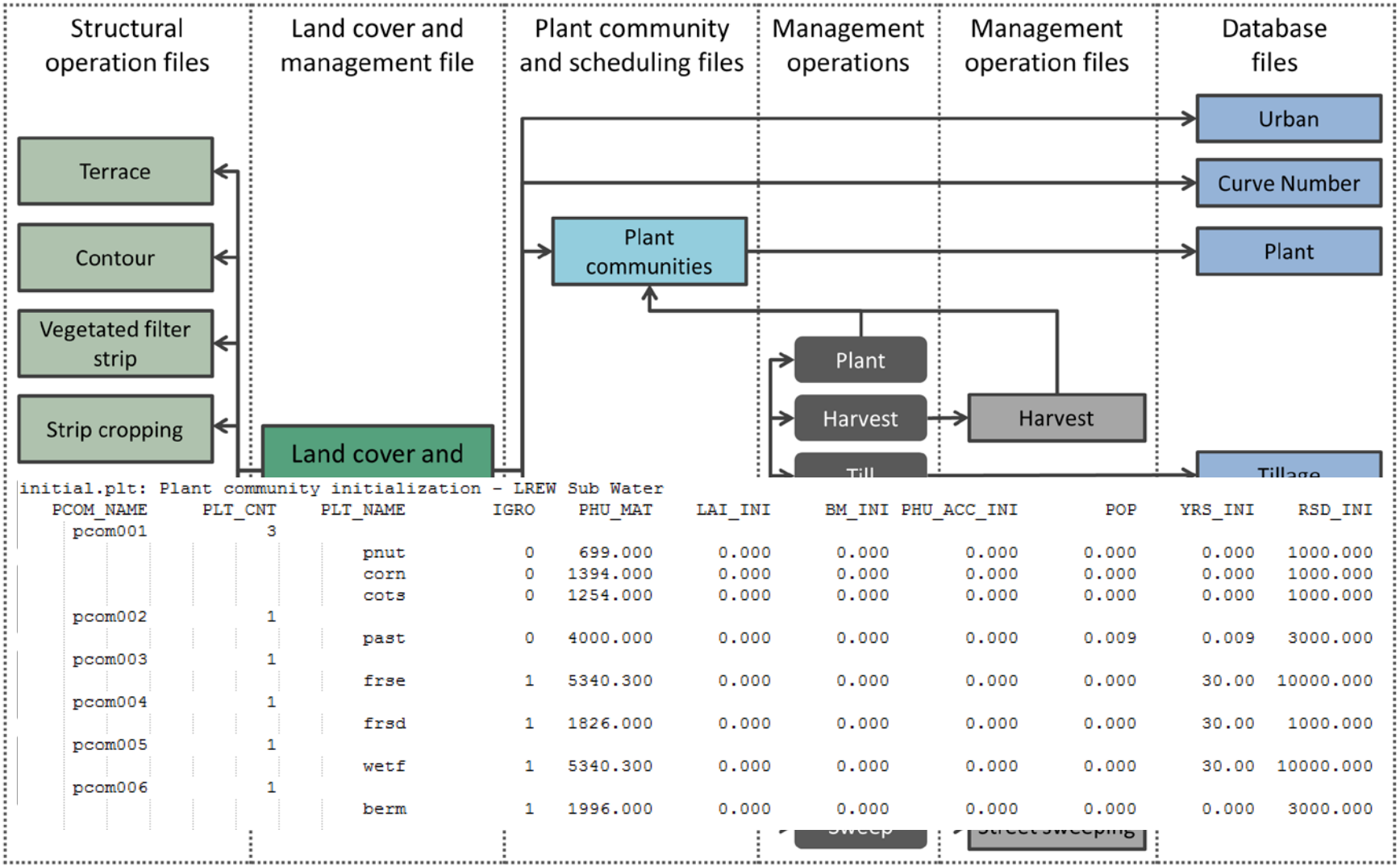
6/19/2017


Thank you for your attention!
jeff.arnold@ars.usda.gov
kbieger@brc.tamus.edu

Land cover and management



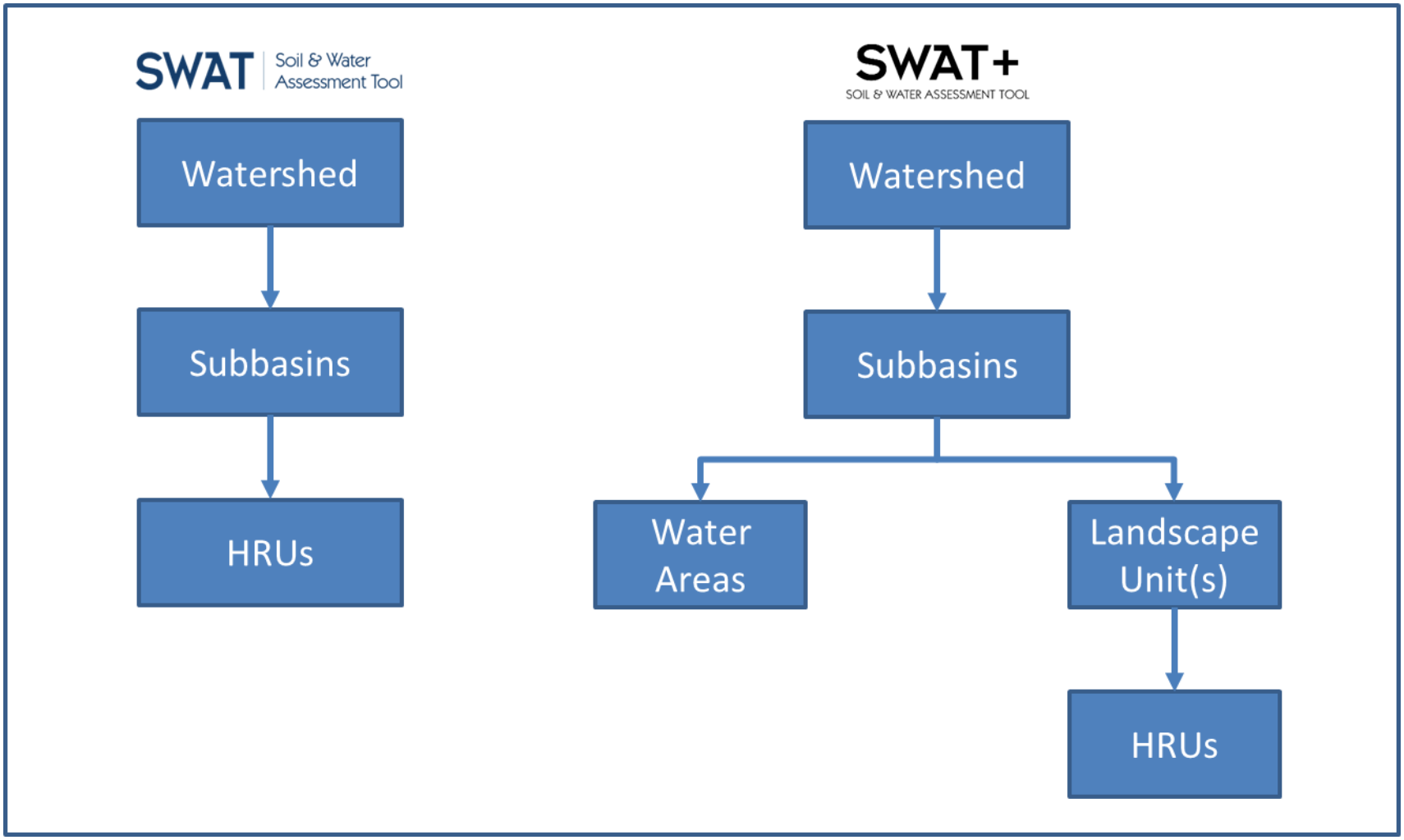
initial.plt: Plant community initialization - LREW Sub Water

PCOM_NAME	PLT_CNT	PLT_NAME	IGRO	PHU_MAT	LAI_INI	BM_INI	PHU_ACC_INI	POP	YRS_INI	RSD_INI
pcom001	3									
		pnut	0	699.000	0.000	0.000	0.000	0.000	0.000	1000.000
		corn	0	1394.000	0.000	0.000	0.000	0.000	0.000	1000.000
		cots	0	1254.000	0.000	0.000	0.000	0.000	0.000	1000.000
pcom002	1									
		past	0	4000.000	0.000	0.000	0.000	0.009	0.009	3000.000
pcom003	1									
		frse	1	5340.300	0.000	0.000	0.000	0.000	30.00	10000.000
pcom004	1									
		frsd	1	1826.000	0.000	0.000	0.000	0.000	30.00	1000.000
pcom005	1									
		wetf	1	5340.300	0.000	0.000	0.000	0.000	30.00	10000.000
pcom006	1									
		berm	1	1996.000	0.000	0.000	0.000	0.000	0.000	3000.000

Simulating Constituents
Pesticides, Pathogens, Metals and Salts

SWAT Soil & Water Assessment Tool	SWAT+ SOIL & WATER ASSESSMENT TOOL	**Advantages of SWAT+**
• Limited number of constituents that can be simulated and routed at the same time • No simulation of salt	• Definition of suites of constituents that will be simulated for each object • Simulation of salt as a constituent	• More comprehensive simulation of constituents • Routing of more than one pesticide at the same time

Watershed configuration



Spatial connections

SWAT Soil & Water Assessment Tool	SWAT+ SOIL & WATER ASSESSMENT TOOL	**Advantages of SWAT+**
• All spatial connections defined in one file (fig.fig)	• One connect file per spatial object to define outflow hydrographs, fractions, and receiving objects	• More flexibility in defining spatial interactions of objects within the watershed • Easier to set up grid-based models

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
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