Uncertainty Analysis in Water Quality Modeling

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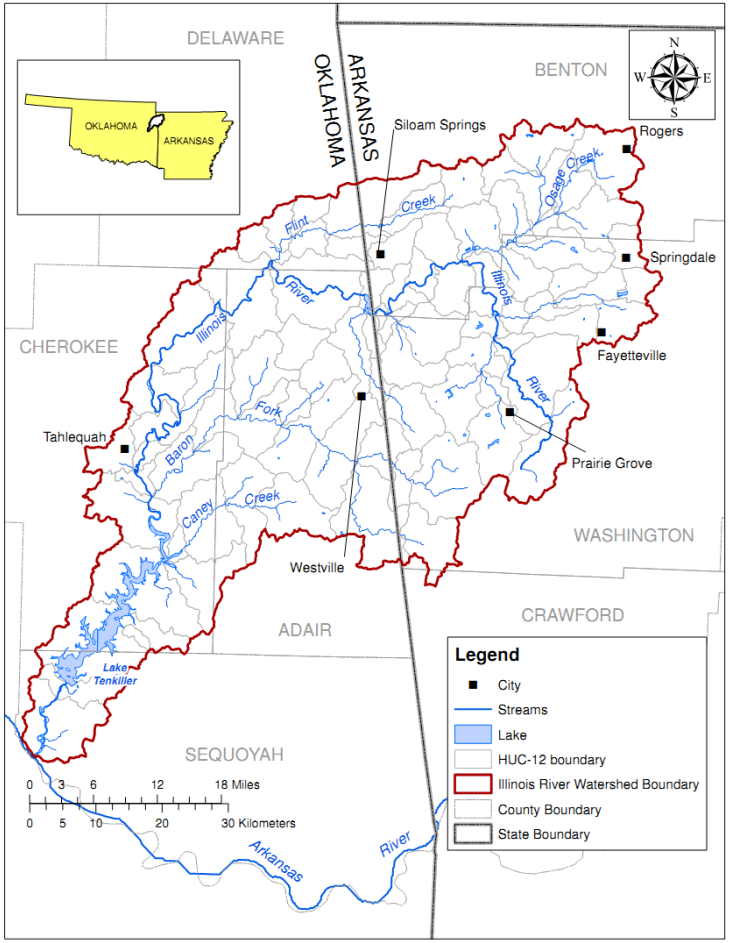
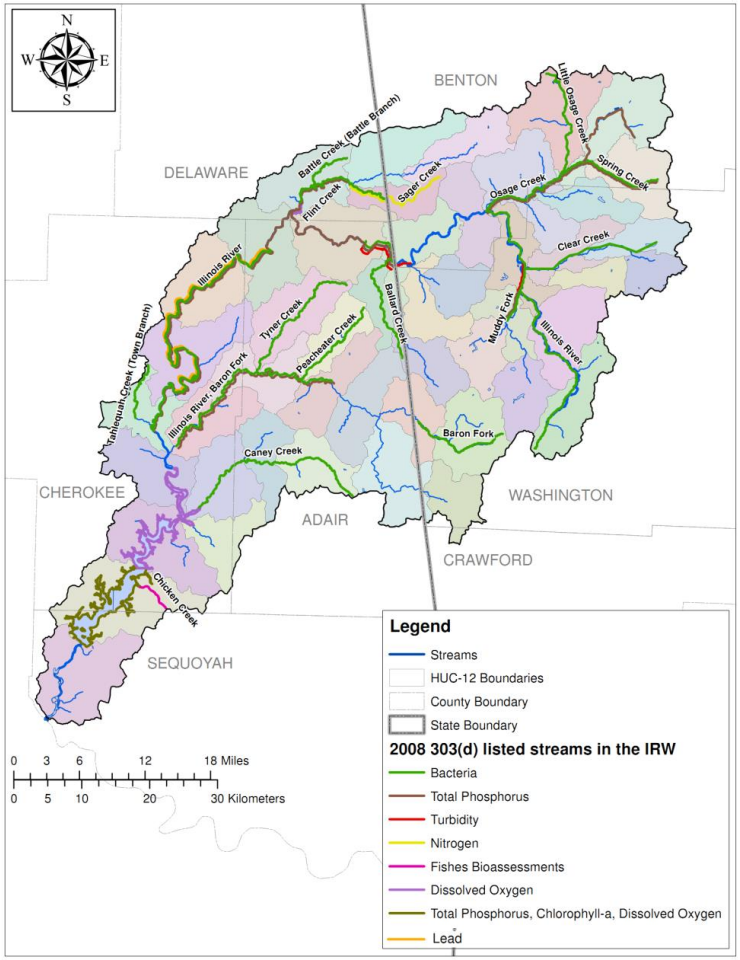
ILLINOIS RIVER WATERSHED



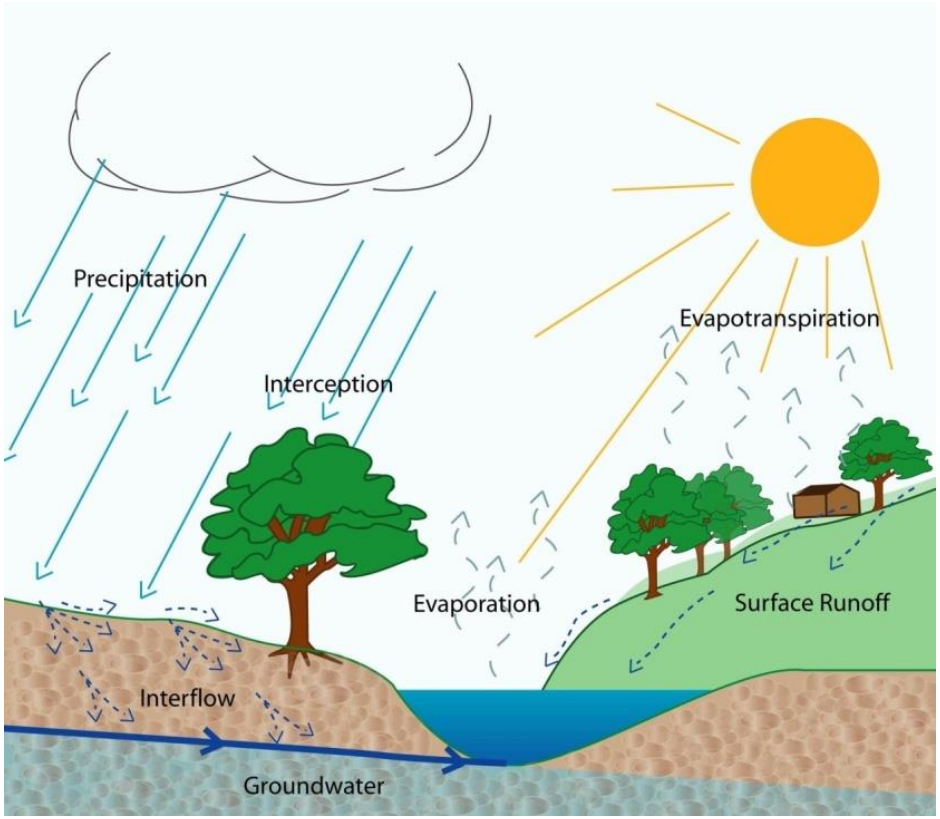
IMPAIRED STREAMS



HSPF: HYDROLOGIC SIMULATION PROGRAM - FORTRAN

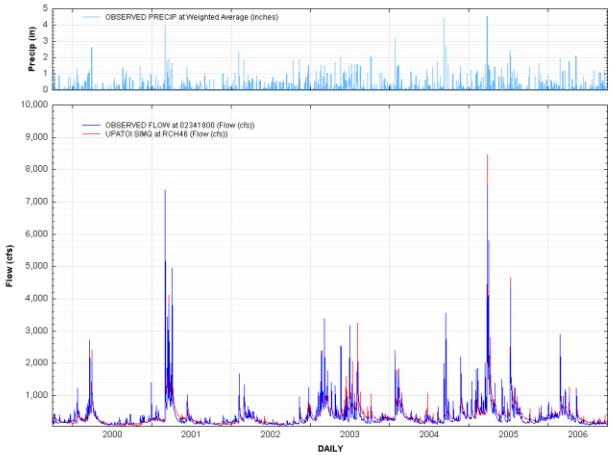
- Continuous simulation model
- Natural and developed watersheds and water systems
- Land surface and subsurface hydrology and quality processes
- Stream/lake hydraulics and water quality processes
- Time series data management and storage
- Time series data statistical analysis and operations
- Core watershed model in EPA BASINS and Army Corps WMS
- Development and maintenance activities sponsored by U.S. EPA and U.S. Geological Survey

CONTINUOUS SIMULATION

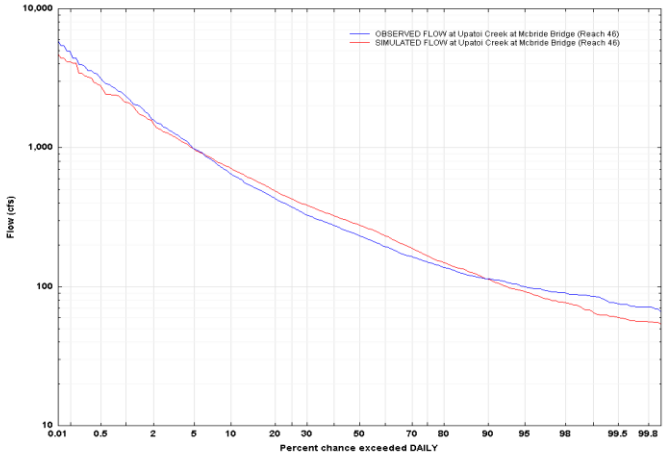


Representing hydrologic processes, storages, and pathways (fluxes) for a watershed, continuously for many days to multiple years, with time steps of one day or less, usually in the range of minutes to hours

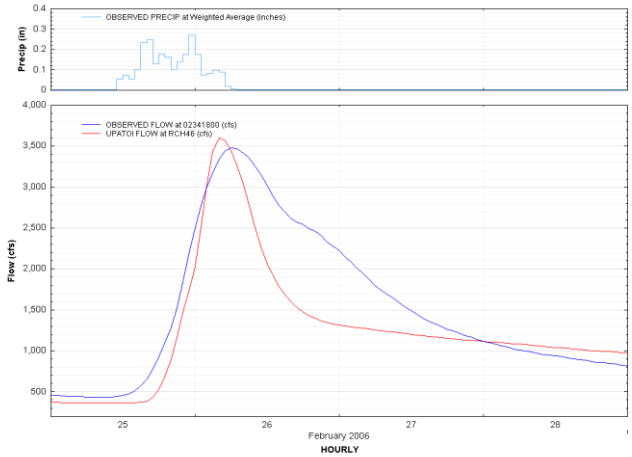
RESULTS FROM A CONTINUOUS SIMULATION



Daily Flow

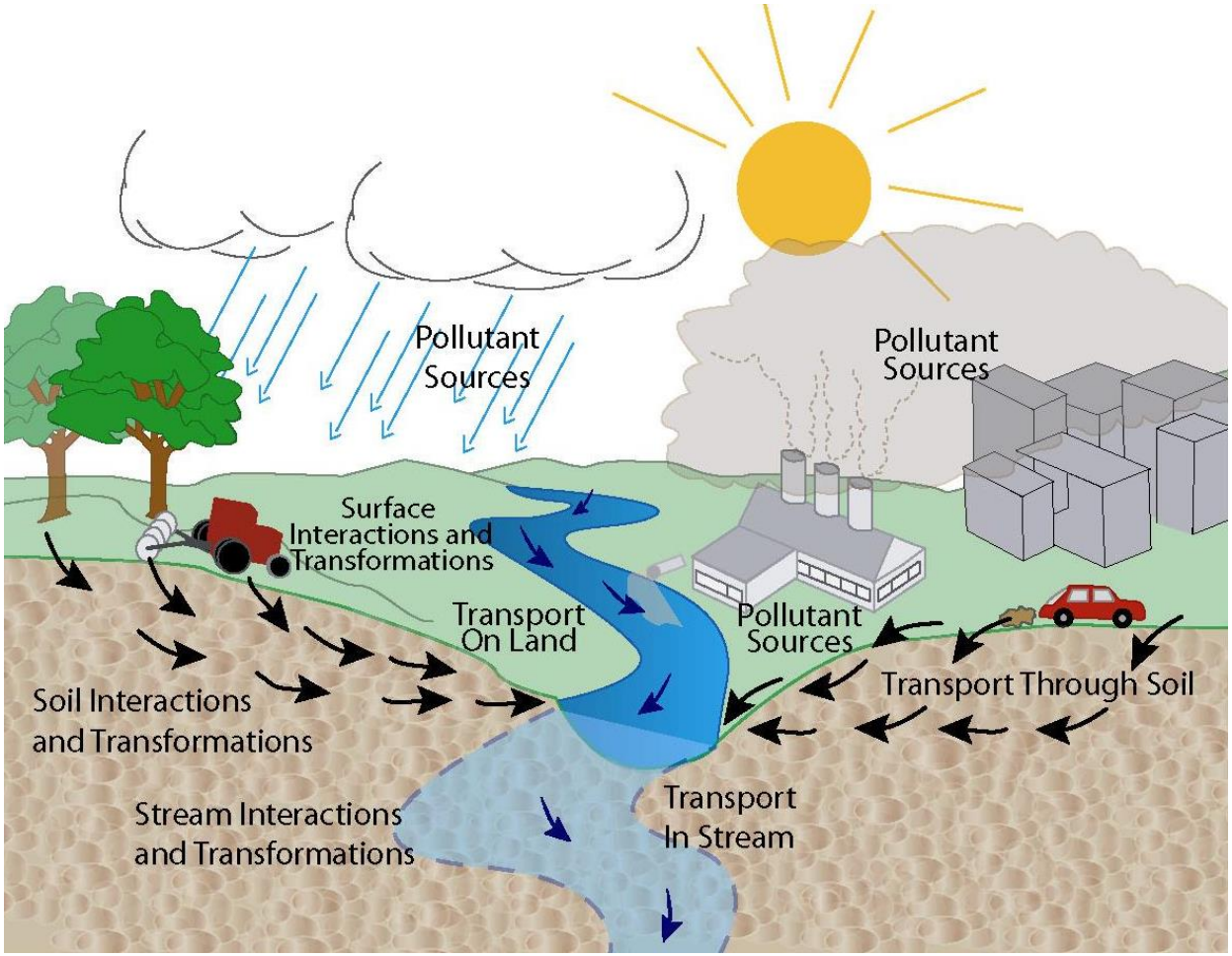


Flow Duration/Frequency



Storm Hydrographs

COMPONENTS OF A WATER QUALITY SIMULATION



COMPONENTS OF WATERSHED WATER QUALITY MODELS

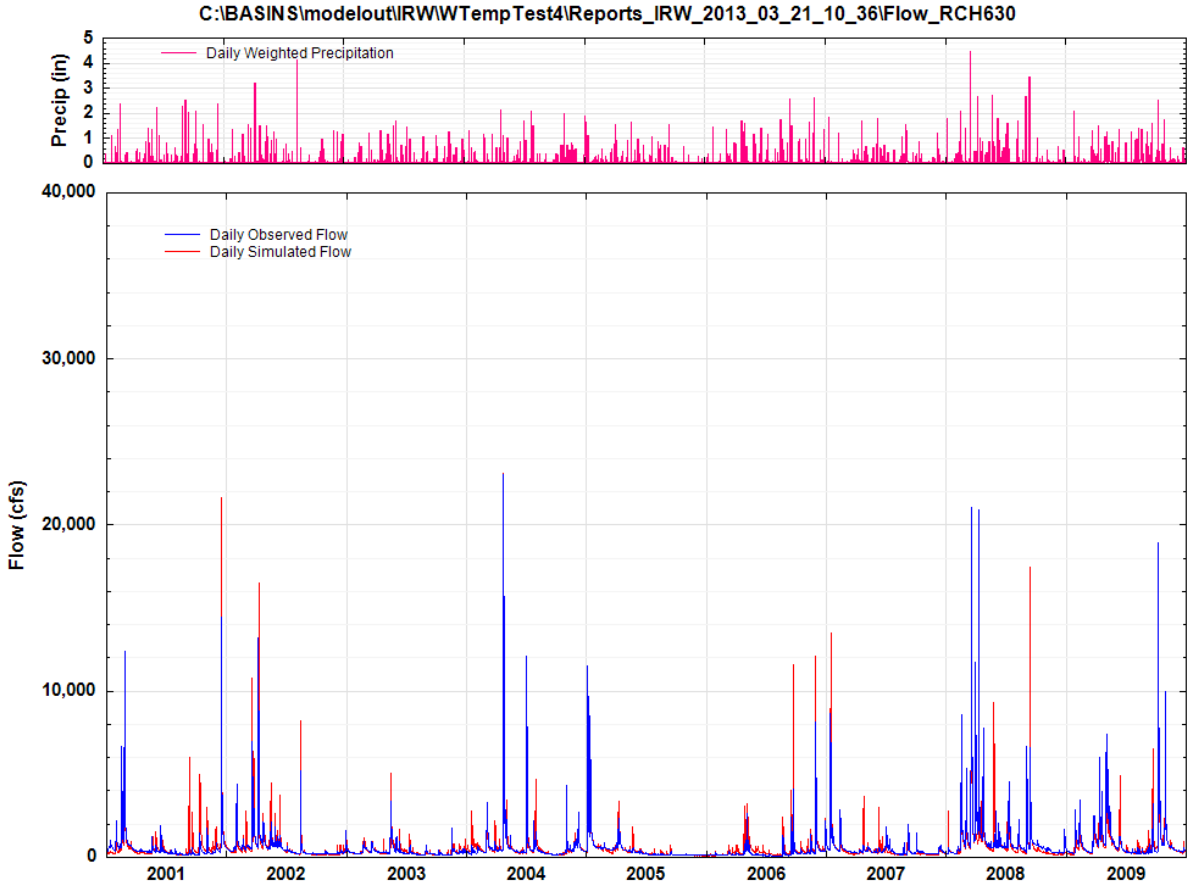
Nonpoint Loading Simulation

- Runoff quantity - surface and subsurface
- Sediment erosion/solids loading
- Runoff quality
- Atmospheric deposition
- Inputs needed by instream simulation

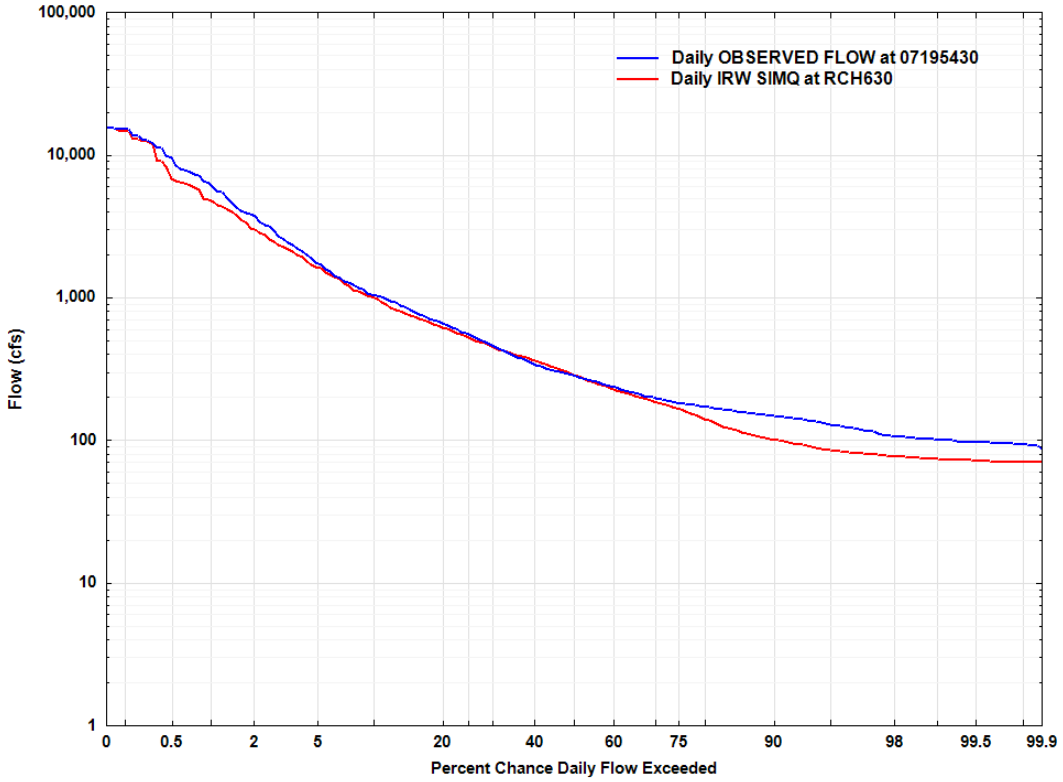
Instream Simulation

- Hydraulics
- Sediment transport
- Sediment-contaminant interactions
- Water quality constituents and processes
- Point source accommodation
- Lake/reservoir simulation
- Benthal processes and impacts

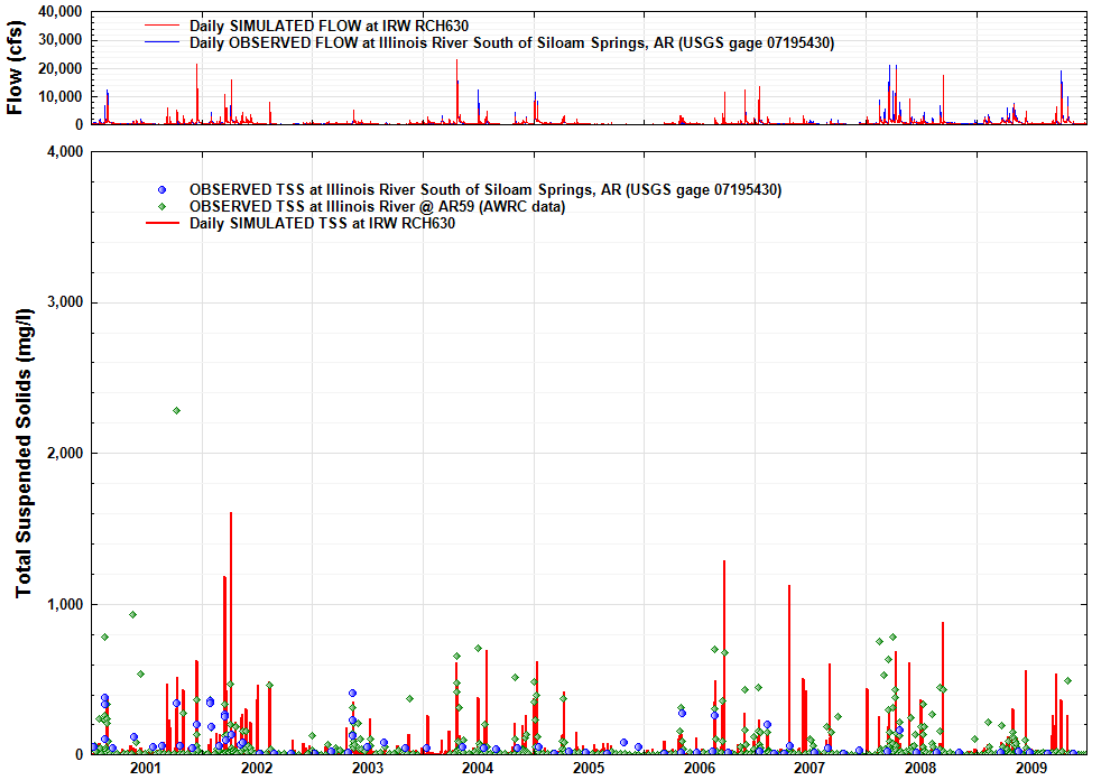
HYDROLOGY CALIBRATION RESULTS



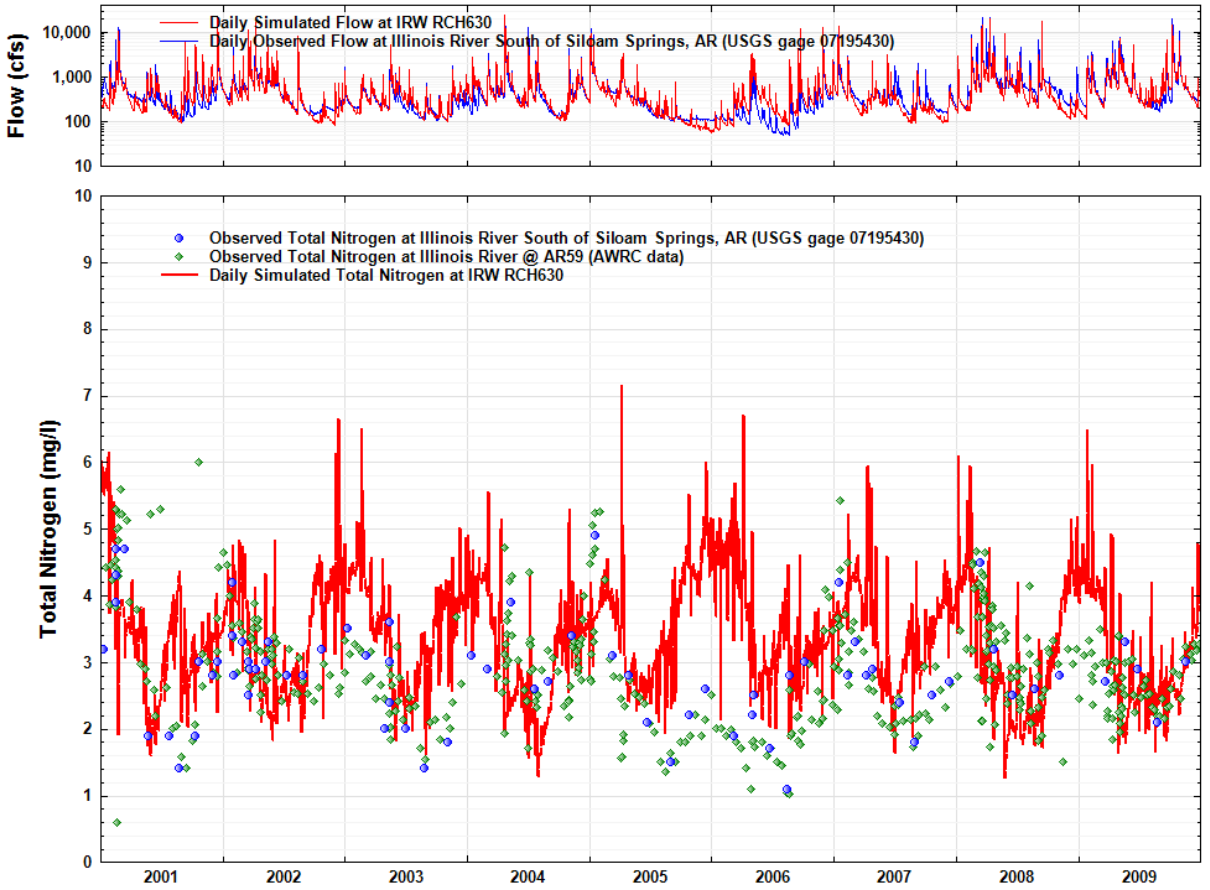
HYDROLOGY CALIBRATION RESULTS



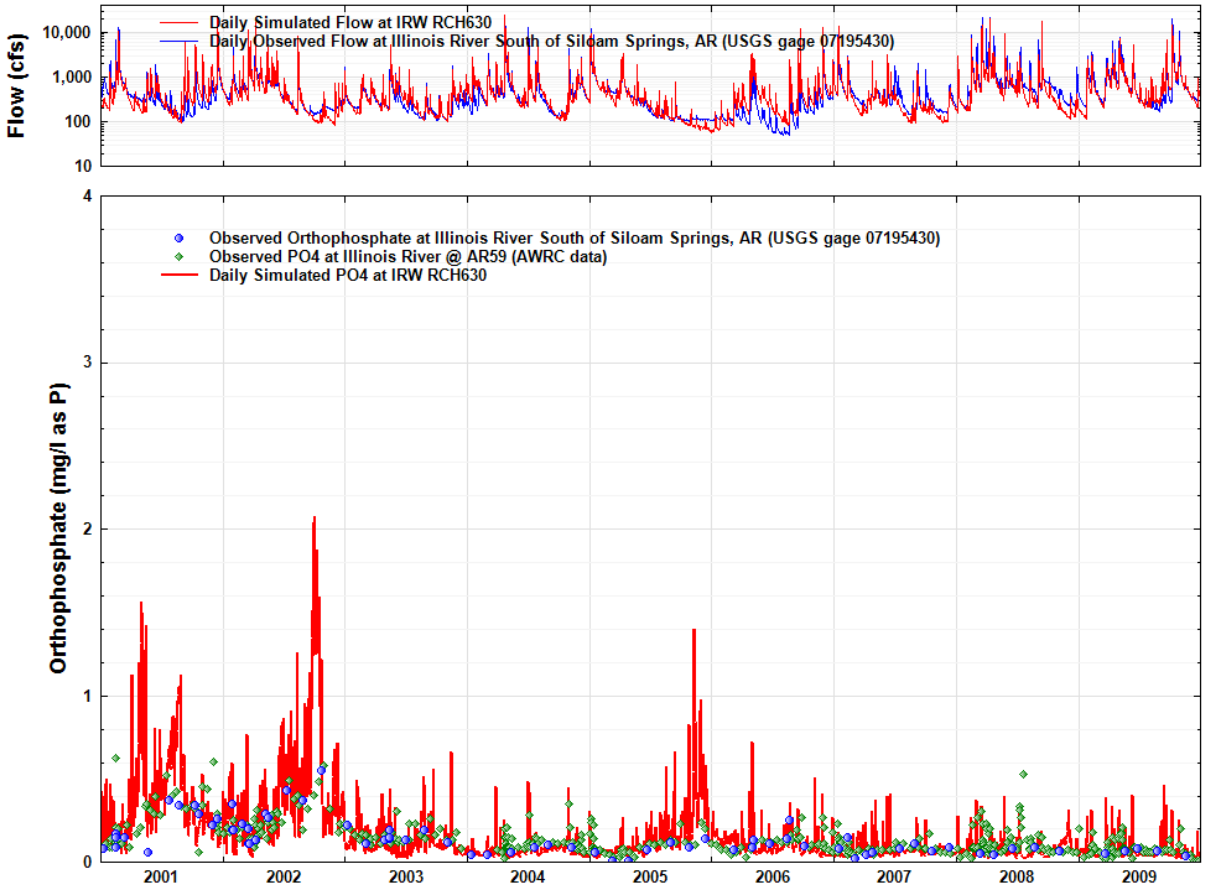
SEDIMENT CALIBRATION RESULTS



TOTAL NITROGEN CALIBRATION RESULTS



TOTAL PHOSPHORUS CALIBRATION RESULTS



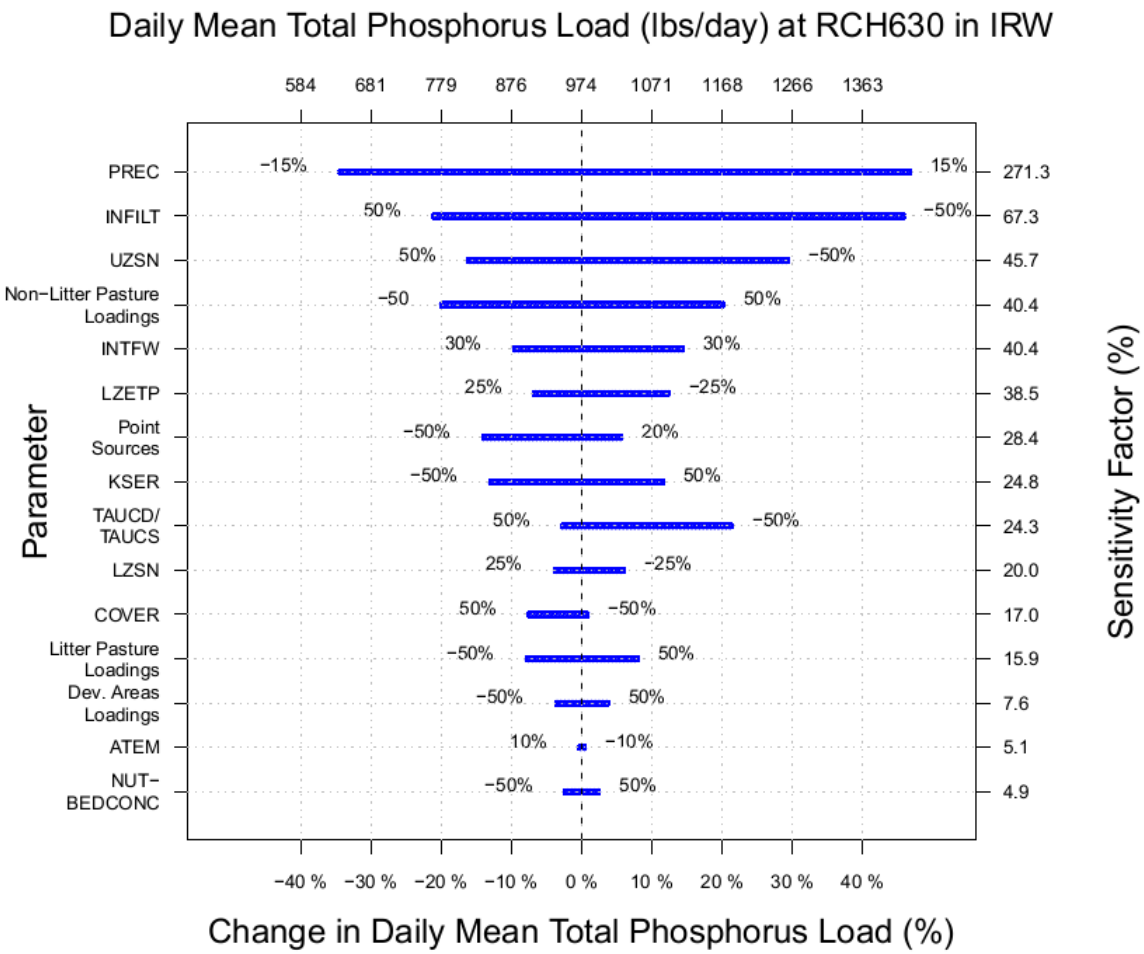
IMPORTANT CALIBRATION PARAMETERS

			Calibration Value			%Change to the Calibrated Value		Parameter Value Range	
Category	**Model Input Parameter**	**Input/Parameter Definition**	**Weighted Mean**	**Min**	**Max**	**Decrease**	**Increase**	**Decrease**	**Increase**
Meteorologic Timeseries	Mean Precipitation, in/yr	Mean Annual Precipitation	43.6	30.25	56.9	85	115	25.71	65.44
	Mean Daily Air Temperature, F	Mean Daily Air Temperature	59.09	9.5	94.8	90	110	8.55	104.28
	Total Daily Solar Radiation, ly/day	Total Daily Solar Radiation	412.59	12.34	754.52	85	115	10.49	867.70
Hydrology	LZSN, in	Lower Zone Nominal Soil Moisture Storage	7	4	8.5	75	125	3.00	10.63
	INFILT, in/hr	Index to Infiltration Capacity of the Soil	0.097	0.035	0.3	50	150	0.02	0.45
	INTFW	Interflow Inflow Parameter	1.93	1	3.5	70	130	0.70	4.55
	LZETP	Lower Zone Evapotranspiration	0.395	0.1	0.75	75	125	0.08	0.94
	DEEPFR	Fraction of Groundwater Inflow to Deep Losses	0.19	0.03	0.35	50	150	0.02	0.53
	UZSN, in	Upper Zone Nominal Soil Moisture Storage	1.055	0.5	2	50	150	0.25	3.00
Sediment	KSER	Coefficient in Sediment Washoff Equation	0.245	0.04	1	50	150	0.02	1.50
	KRER	Coefficient in Soil Detachment Equation	0.313	0.109	0.452	50	150	0.05	0.68
	COVER*	Fraction of Land Protected From Raindrop Splash	0.826	0.6	0.97	75	125	0.45	1.00
	TAUCD, lb/ft2¥	Critical Bed Shear Stress for Deposition	0.21	0.012	0.65	50	150	0.01	0.98
	TAUCS, lb/ft2¥	Critical Bed Shear Stress for Scour	0.506	0.07	1.261	50	150	0.04	1.89
	M, lb/ft2.d	Bed/Bank Erodibility Factor	0.28	0.001	1	50	150	0.00	1.50
	KSAND	Coefficient in Sandload Equation	0.551	0.09	1.5	50	150	0.05	2.25
Water Temperature	CFSAEX*	Correction Factor for Solar Radiation on Water Surface	0.526	0.25	0.95	70	130	0.18	1.00
	LGTP1, degrees F	Lower Layer/Groundwater Soil Temperature	53.06	39	65	75	125	29.25	81.25
	KATRAD	Longwave Radiation Coefficient	15	15	15	75	125	11.25	18.75
	MUDDEP	Depth of Mud Layer in the Two Interface Model	1	1	1	75	125	0.75	1.25
	KMUD	Heat Conduction Coefficient Between Water and the Mud/Ground	30	30	30	75	125	22.50	37.5
	TGRND	Temperature of ground beneath stream bed	56.16	48	65	75	125	36	81.25
Water Quality Loadings (applies to BOD/Organics, NO3, NH4, PO4)	Loading of pollutants from Urban areas					50	150		
	Loading of pollutants from non-litter pasture land uses					50	150		
	Loading of pollutants from all litter pasture land uses					50	150		
	Loading of pollutants from point sources					50	120		

OUTPUTS OF INTEREST

Hydrology	**Water Quality**
Mean Annual Flow (cfs)	Mean Daily TSS Load (tons/day)
Annual Peak Daily Flow (cfs)	Mean TSS Conc. (mg/l)
Mean Annual Runoff (in)	Geom. Mean TSS Conc. (mg/l)
10% High Runoff Volume (in)	10% High TSS Conc. (mg/l)
25% High Runoff Volume (in)	50% Low TSS Conc. (mg/l)
50% High Runoff Volume (in)	**Mean Daily TP Load (lbs/day)**
50% Low Runoff Volume (in)	10% High TP Conc. (mg/l)
25% Low Runoff Volume (in)	50% Low TP Conc. (mg/l)
10% Low Runoff Volume (in)	Mean Daily TN Load (lbs/day)
5% Low Runoff Volume (in)	10% High TN Conc. (mg/l)
2% Low Runoff Volume (in)	50% Low TN Conc. (mg/l)
	Geom. Mean TP Conc. (mg/l)
	Mean Ann. TP Load (lbs/yr)
	Geom. Mean TN Conc. (mg/l)
	Mean TN Conc. (mg/l)
	Mean TP Conc. (mg/l)
	Mean Annual TN Load (lbs/yr)
	Mean Water Temp. (F)
	Mean Summer Water Temp. (F)

SENSITIVITY OF TP LOAD TO THE PARAMETERS



UNCERTAINTY ANALYSIS

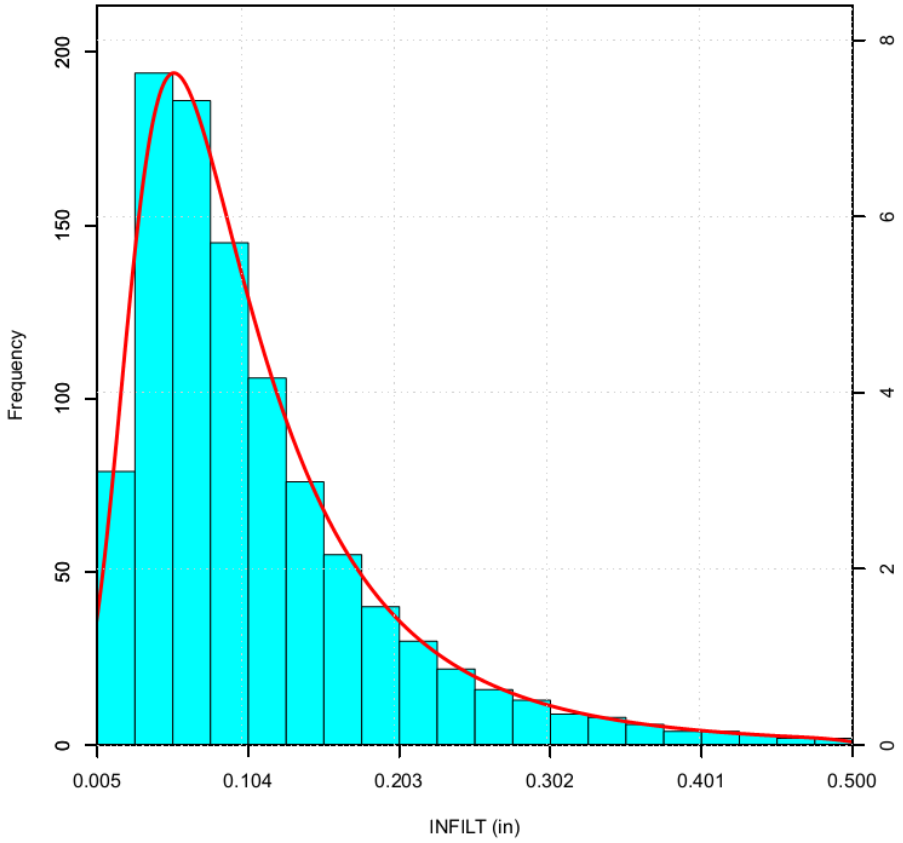
SELECTED PARAMETERS FOR UA

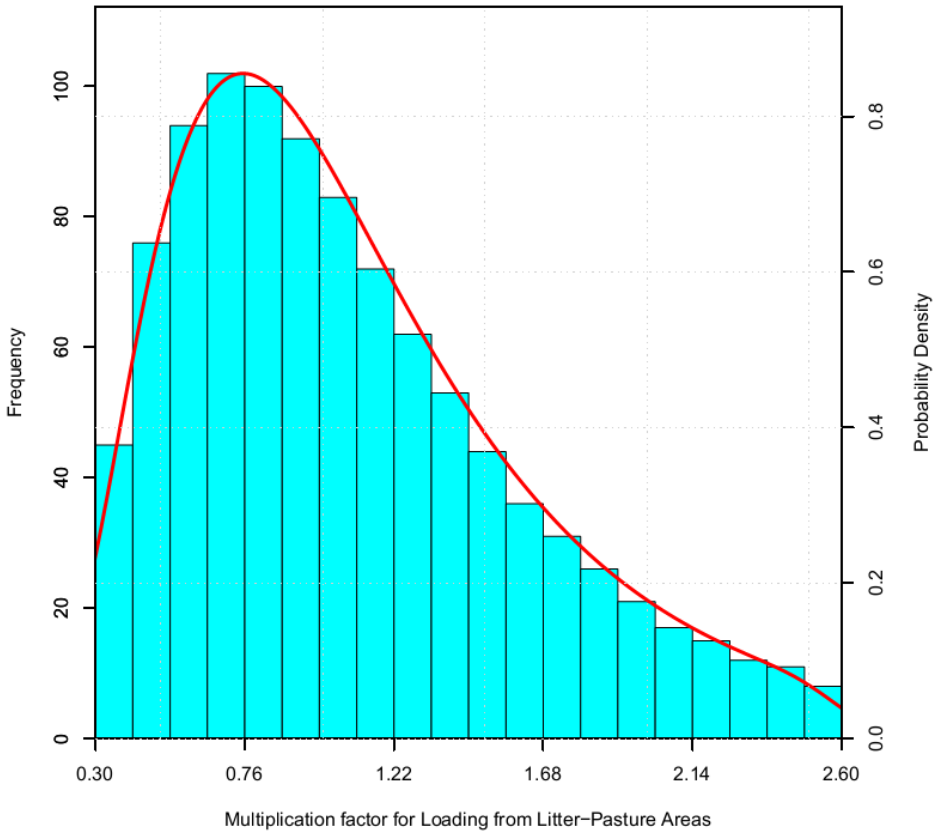
Parameter Details					Calibrated Values					Distribution Parameters		
Category	Name	Definition	Type	Distribution Type	Min	Max	Mean	90% Range	Std. Dev. (90% Range/ 3.3)	Lower and upper limits	Std. Dev. For Underlying Normal Distribution	Mean for Underlying Normal Distribution
Hydrology	INFILT, in/hr	Index to Infiltration Capacity of the Soil	Soil/ Climate	LN	0.035	0.300	0.10	0.03 – 0.30	0.08	0.01 – 0.50	0.75	-2.45
	INTFW	Interflow Inflow Parameter	Soil/ Climate	LN	1.000	3.500	1.93	1.00 – 3.50	0.76	0.50 – 6.00	0.38	0.62
	UZSN, in	Upper Zone Nominal Soil Moisture Storage	Soil	LN	0.500	2.000	0.97	0.50 – 2.00	0.45	0.20 – 3.00	0.42	0.00
	LZSN	Lower Zone Nominal Storage	Soil/ Climate	LN	4.000	8.500	7.00	4.00 – 8.50	1.36	2.50 – 9.00	0.23	1.76
	LZETP	Lower Zone Evapotranspiration	Vegetation	NO	0.100	0.750	0.40	0.10 – 0.80	0.21	0.05 – 0.90		
Soils/ Sediment	KSER	Coefficient in Sediment Washoff Equation	Soil/ Vegetation	LN	0.040	1.000	0.25	0.04 – 2.00	0.59	0.01 -10.00	1.19	-1.27
	COVER	Fraction of Land Protected from Raindrop Splash	Vegetation	NO	0.600	0.970	0.83	0.30 – 0.99	0.21	0.05 – 1.00		
	TAUCD, lb/ft2	Critical Bed Shear Stress for Deposition	Soil/ Sediment	LN	0.012	0.650	0.21	0.05 - 0.50	0.14	0.01 – 1.00	0.70	-1.85
	TAUCS, lb/ft2	Critical Bed Shear Stress for Scour	Soil/ Sediment	LN	0.070	1.261	0.51	0.10 – 1.50	0.42	0.05 – 2.00	0.82	-0.95
	KSAND	Coefficient in Sandload equation	Soil/ Sediment	LN	0.090	1.500	0.55	0.05 – 2.00	0.59	0.01 – 5.00	1.12	-1.16
Nutrient Loadings	Point Sources	Loading from Point Sources to the reach	Nutrient Loading	UN				0.5 – 1.2	0.21	0.50 -1.20		
	Dev. Areas Loading	Loading of N and P from Developed Areas	Nutrient Loading	LN				0.6 – 1.5	0.27	0.50 – 1.60	0.28	-0.05
	Pasture Litter Loading	Loading of N and P from Pasture areas treated with Litter	Nutrient Loading	LN				0.4 – 2.5	0.64	0.30 – 2.60	0.56	0.00
	Non-Litter Pasture Loadings	Loading of N and P from Pasture areas not treated with Litter	Nutrient Loading	LN				0.4 – 2.0	0.48	0.30 – 2.10	0.49	-0.11

PARAMETER VALUE GENERATION

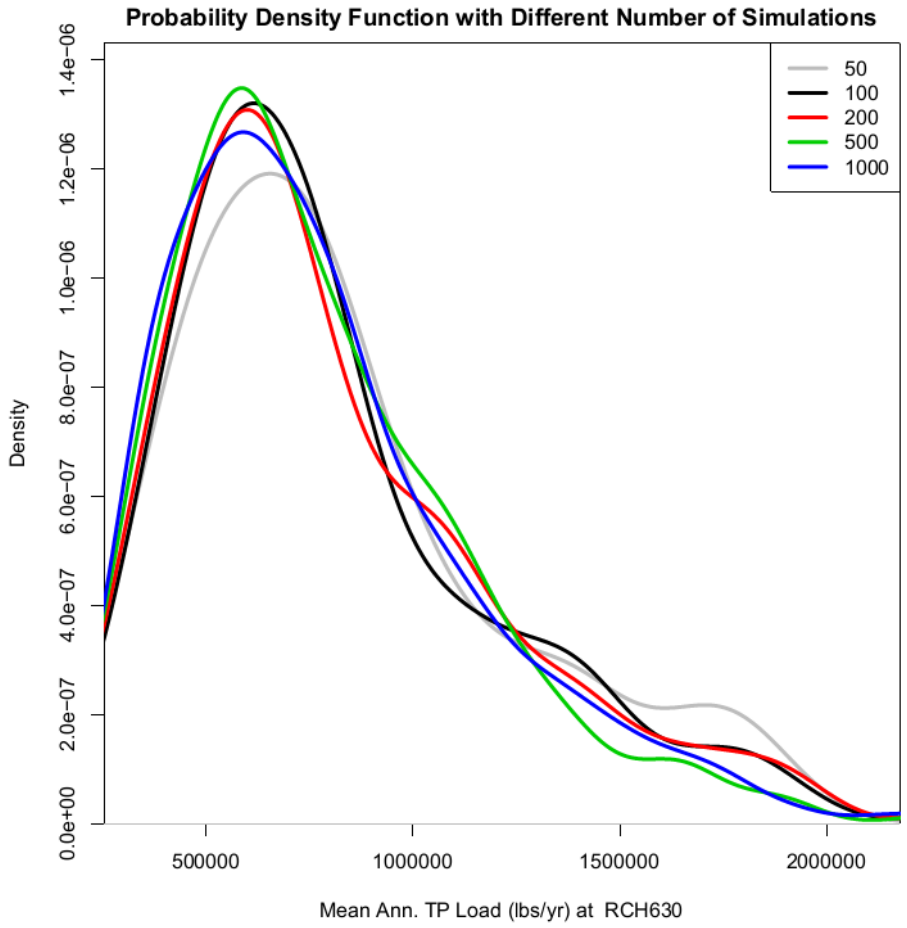
- Package ‘pse’ (Chalom and Prado, 2014)
- Parameter space exploration with Latin Hypercube
- The parameter generation function requires the type of distribution, and its parameters
- Correlation between the variables can be provided

GENERATED PARAMETER SETS





PDF OF OUTPUT



UNCERTAINTY ANALYSIS RESULTS

RCH630	10% High TSS Conc.(mg/l)	Mean TSS Conc.(mg/l)	Mean Daily TSS Load (tons/day)	Mean Daily TN Load (lbs/day)	Mean Daily TP Load (lbs/day)	Mean Summer Water Temp. (F)	Mean Water Temp. (F)
5th Percentile	16.6	8.54	146.94	8414.50	871.70	75.47	61.40
Mean	246.8	94.37	822.10	13935.40	2134.50	76.22	61.79
95th Percentile	779.2	300.59	1894.19	23048.93	4181.14	76.78	62.10
% Uncertainty	154.5	154.70	106.30	52.50	77.50	0.90	0.60

CONCLUSIONS

- In general the uncertainty of water quality parameters is greater than the uncertainty of hydrology parameters.
- Mean daily TP concentration and Mean daily TP load has %uncertainty of 56 and 78, respectively.
- Watershed planners use this information when developing nutrient management plans.