Illinois River Basin (IRB) Calibration and Load Reduction Strategies using OK-HAWQS

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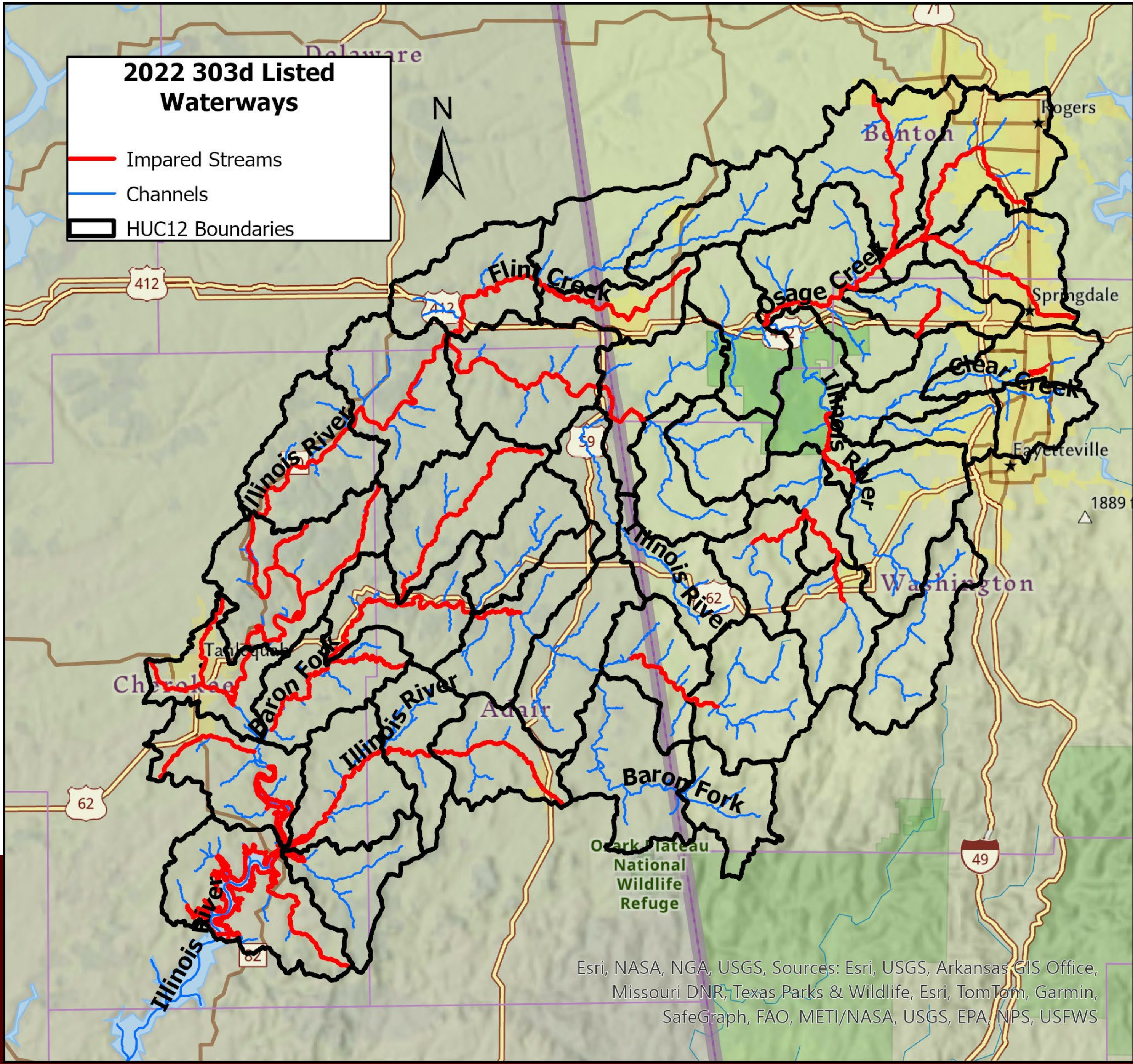
Why the IRB?

- Located along the OK and AR boarder
- Urban areas in the northeast headwaters
- Cattle grazing across both states
- Poultry farms concentrated in AR
- Water quality degradation starting in the 1980’s
- Ongoing litigation for 20+ years between Arkansas and Oklahoma
- In 2022 most rivers and Lake Tenkiller listed as Category 5 impairments on EPA 303d list
- Requires management strategies to reduce N and P loading into the waterways



Why use HAWQS?

- Web-based interactive water quantity and quality modeling systems using **SWAT** as the core modeling engine
- Supplied with **Federally Approved** Input Dataset
- Allows analysis at various watershed scales
- Supports simple and complex economic, policy, and impact analyses on:
  - Flow, Sediments, Nutrients, pathogens

Benefits of HAWQS

- Datasets, tools, and output visualizations are public domain
- Cloud based interface (accessed by phone/ tablet/ laptop/ desktop)
- Complete input datasets compatible across SWAT versions
- Calibrated models
- Model sharing, uploading, and group access to projects
- Output coupled with other models (CE-QUAL-W2, WMOST, AQUATOX, and others)
- **More efficient – reduces SWAT modeling time and effort by 90%**

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OK.HAWQS
Hydrologic and Water Quality System
Oklahoma Watershed and Water Quality Assessment Tool

Inputs (Federally Approved):

- Modeled at the huc12 scale [~100 km^2] for subbasins and streams (**NHDPlus v2**)
- County level soil (**SSURGO**)
- Land Use for crops, fields, and wetlands (**NLCD 2019, NASS-CDL 2017-19, NWI**)
- High resolution Weather Data (**PRISM**)
- 10-meter DEM Elevation (**NED**)
- Current Point Sources (**ICIS-NPDES**)

State Specific Inputs:

- **Local** management for urban areas
- **Local** management for pasture lands for grazing cattle, hog and dairy farms, poultry litter, and fertilizer

Calibration Data:

- USGS Gages for Flow
- USGS, DEQ, and AWRC Gages for Water Quality

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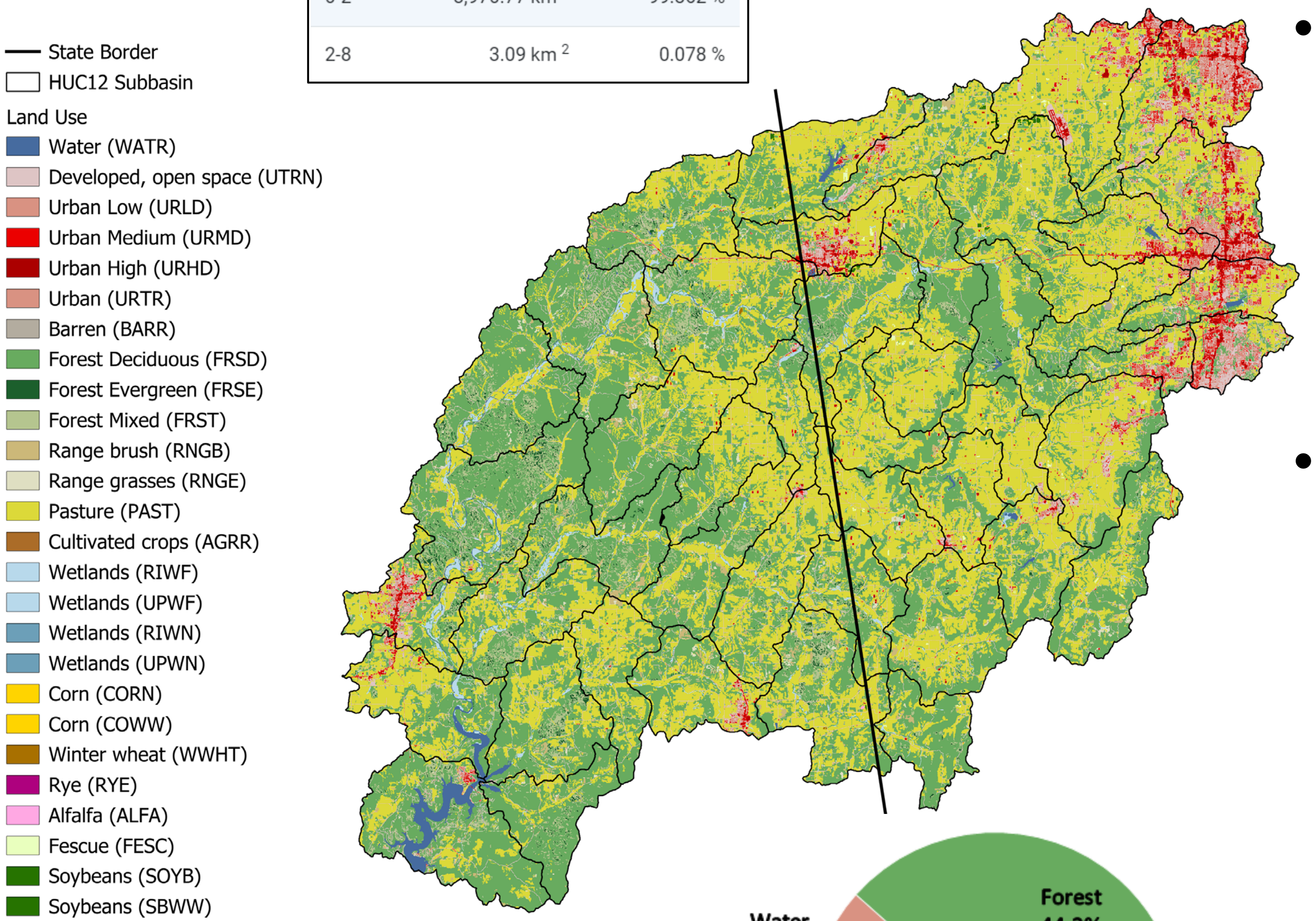
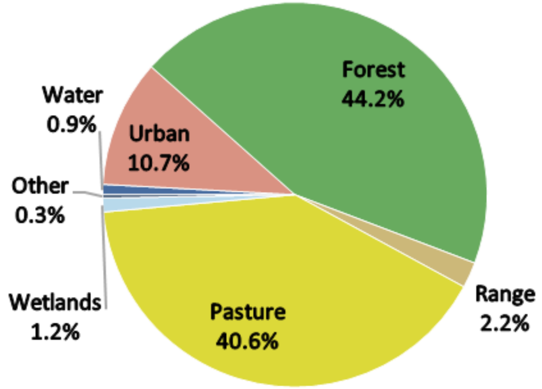
Slope Class	Area	% of Total Area
0-2	3,970.77 km ^{2}	99.862 %
2-8	3.09 km ^{2}	0.078 %



Model Set-up

- IRB model created using subbasin 111101030906 (Lake Tenkiller) as outlet (HUC12 scale)
  - Model had 46 subbasins
  - 6,906 HRUs
  - total land area of 3,976.24 km ^{2} (981,962 acres)
- Scenario was created and run:
  - PRISM Weather Data
  - Simulation from 1/1/1998 to 12/31/2020
  - 2-year warm-up period
  - Daily output print setting
  - SWAT model Rev 688
  - Management updated using literature values and stakeholder input



Urban Management

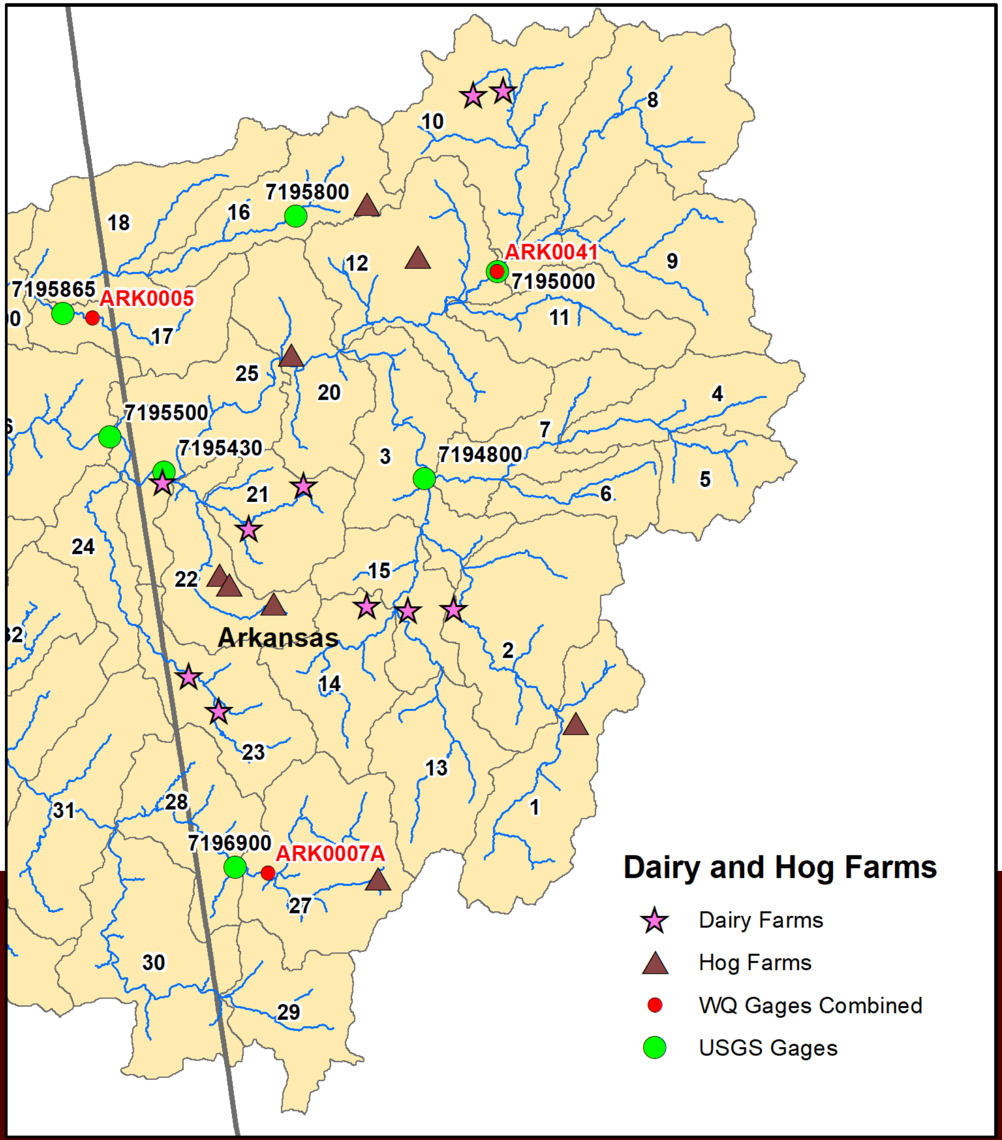
- **Automatic Fertilization**
  N application when stress factor falls below 0.8
  P application when stress factor falls below 0.5

- **Automatic Irrigation**
  25mm water applied when soil moisture falls below 60%

- **Mowing**
  Lawn mowed 6 times per growing cycle

Hog and Dairy Farms

- Hog and Dairy Farm locations and application amount from AR DEQ Permit Data System

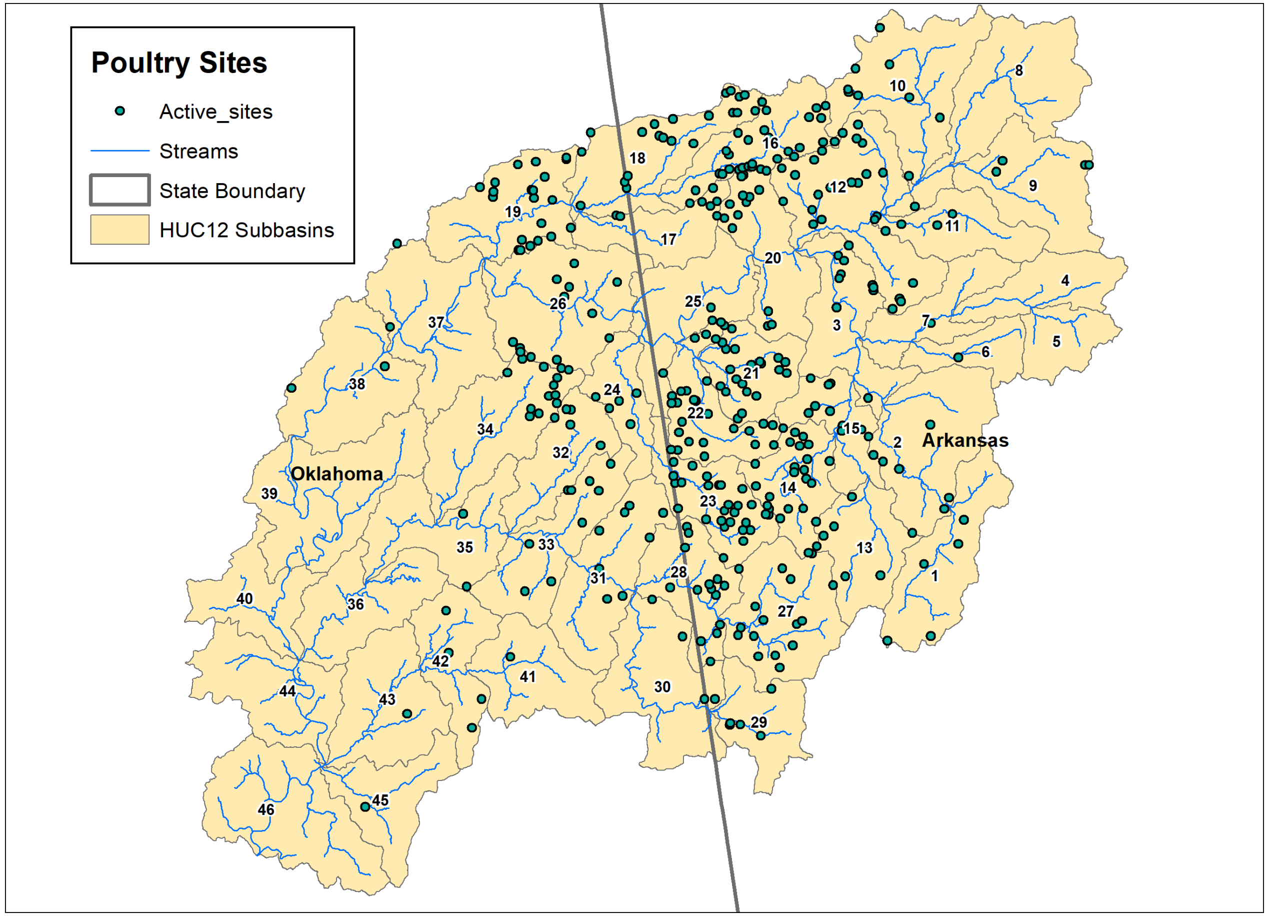


Poultry Litter Application

Active Poultry Houses
- 1811 houses
  - 466 houses (97 farms) in OK
  - 1345 houses (281 farms) in AR

Number of Birds
- Houses >10 = 46,000 birds per house/cycle
- Houses <=10 = 24,000 birds per house/cycle
- 5 cycles of birds for 45 days each
- 234,557,040 in IRB
  - 53,027,040 in OK
  - 181,530,000 in AR

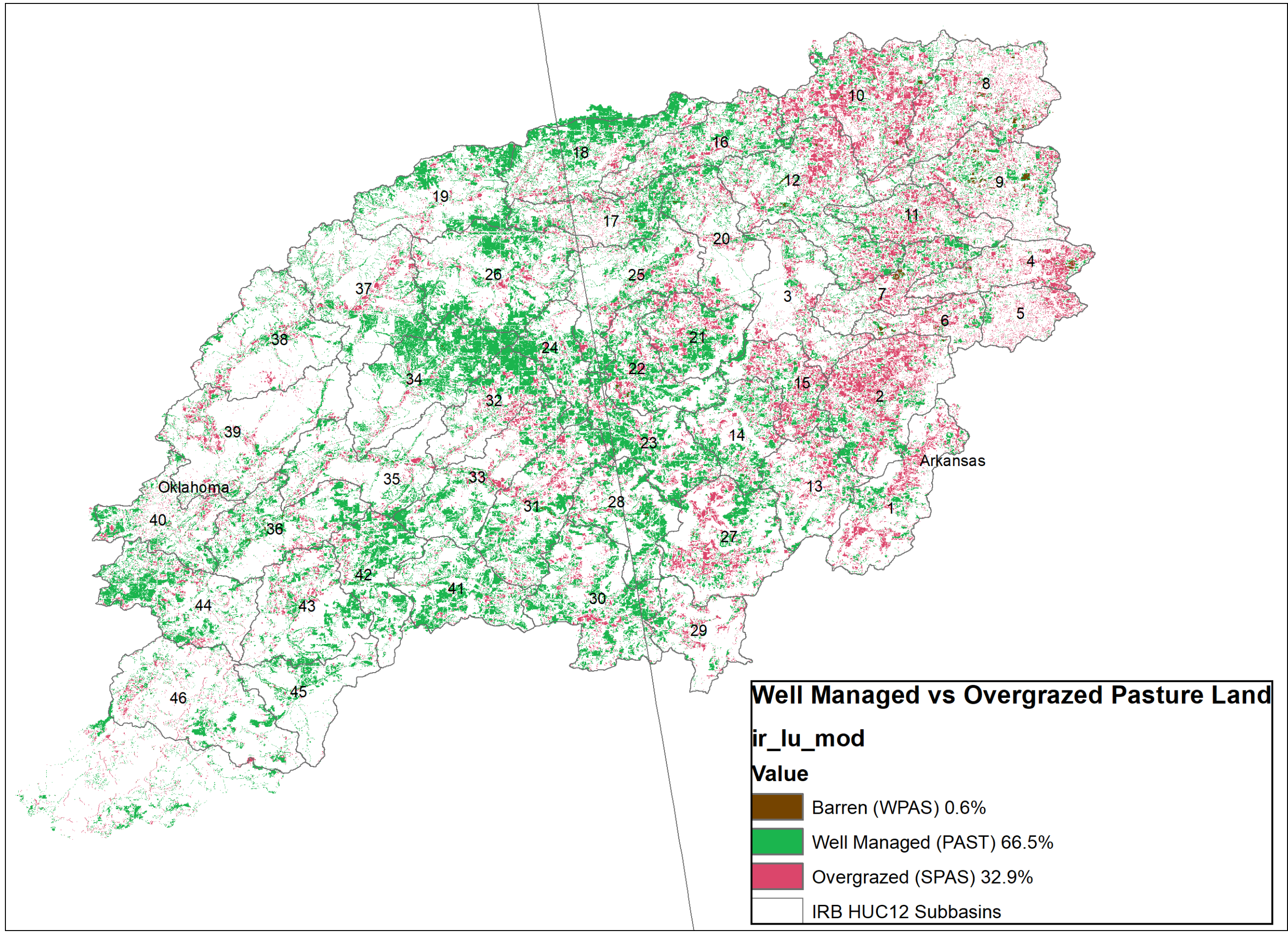
Litter Application
- 50% of litter is exported out of state, 50% applied
- 6.7 tonnes/ha applied once in March
- 224 kg/ha of Nitrogen in May and September
- Total applied 115,720 tonnes/year onto 10.2% in the IRB
  - 5.5% in OK and 13.7% in AR



Grazing using Well Managed and Over Grazed

Cattle in the IRB
- ~168,000
- Stocking rate of 1 cattle/ha

Grazing Management
- Mittelstet et. al. (2016)
- 66.5% Well Managed (220 days)
- 33.5% Over Grazed (270 days)



Distribution of Managed Land

(km²)	IRB Watershed	Arkansas	Oklahoma
Total Pasture Area	1,729.7	1018.9 **(58.9%)**	710.9 **(41.1%)**
Hog Farms	28.7 **(1.7%)**	28.7 **(2.8%)**	0
Dairy Farms	18.6 **(1.1%)**	18.6 **(1.8%)**	0
Grazing Cattle Total	1,682.4 **(97.3%)**	971.5 **(95.4%)**	710.9 **(100%)**
Well Managed with Poultry Litter	101.3 **(6.0%)**	82.2 **(8.5%)**	19.1 **(2.7%)**
Well Managed	999.7 **(59.4%)**	443.0 **(45.6%)**	556.8 **(78.3%)**
Over Grazed with Poultry Litter	70.7 **(4.2%)**	50.8 **(5.2%)**	19.9 **(2.8%)**
Over Grazed	510.6 **(30.4%)**	395.5 **(40.7%)**	115.1 **(16.2%)**
Urban Management	227.9	195.3 **(85.7%)**	32.6 **(14.3%)**

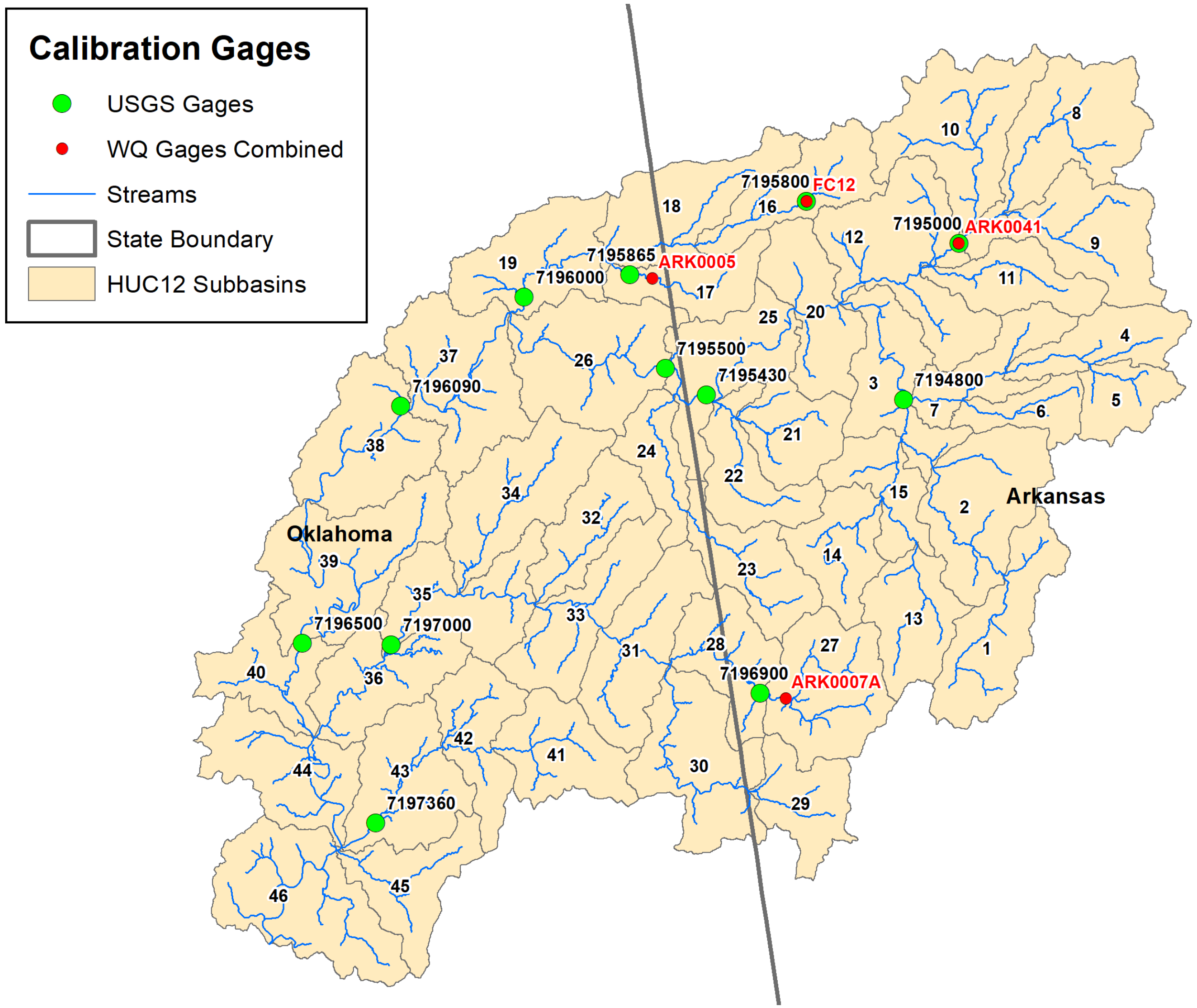
Calibration Parameters use for Flow

Parameter Name	Description	Fitted Value	Minimum Value	Maximum Value
V__EPCO.hru	Plant uptake compensation factor	0.745	0.5	1
R__CN2.mgt	Initial SCS runoff curve number for moisture condition II	0.048	-0.1	0.1
V__ALPHA_BF.gw	Baseflow alpha factor	0.067	0.005	0.1
A__GW_DELAY.gw	Groundwater delay	1.25	-30	90
A__GWQMN.gw	Threshold depth of water in the shallow aquifer required for return flow to occur	937.50	-1000	1000
V__GW_REVAP.gw	Groundwater revap coefficient	0.046	0.02	0.1
A__RCHRG_DP.gw	Deep aquifer percolation fraction	-0.036	-0.05	0.05
A__REVAPMN.gw	Threshold depth of water in the shallow aquifer for revap to occur	-265.63	-750	750
V__ESCO.hru	Soil evaporation compensation factor	0.712	0.6	0.85
R__SOL_AWC(..).sol	Available water capacity of the soil layer	-0.014	-0.05	0.05
V__CANMX.hru	Maximum canopy storage	4.90	0	10
V__SLSOIL.hru	Slope length for lateral subsurface flow	17.19	0	150
V__LAT_TTIME.hru	Lateral flow travel time	0.73	0	14
V__ALPHA_BF_D.gw	Baseflow alfa factor for deep aquifer	1.00	0	1

R = multiplied by (1+fittedvalue), V = replaced, A = added to.

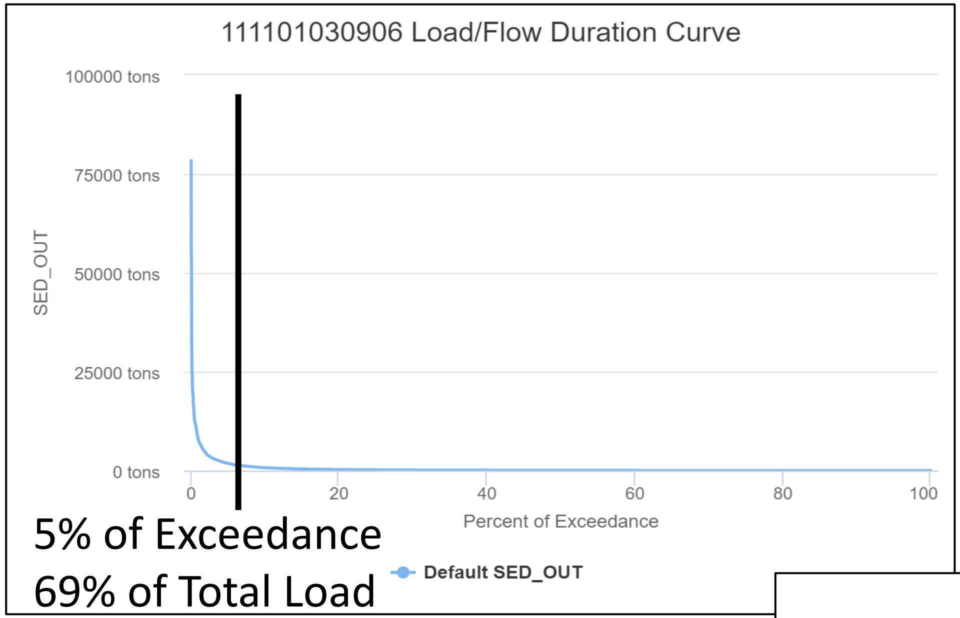
Flow Calibration

HUC12 Subbasin	USGS Gage	NSE	PBIAS	KGE
3	07194800	0.86	-3	0.84
8	07195000	0.86	-1.9	0.92
16	07195800	0.63	3.8	0.8
25	07195430	0.88	6.3	0.92
27	07196900	0.78	-7.6	0.81
17	07195865	0.81	11.7	0.69
19	07196000	0.83	-7.6	0.87
25	07195500	0.89	9.8	0.88
35	07197000	0.86	-8.5	0.85
37	07196090	0.92	-0.4	0.96
39	07196500	0.88	8.5	0.87
43	07197360	0.77	-11.7	0.83



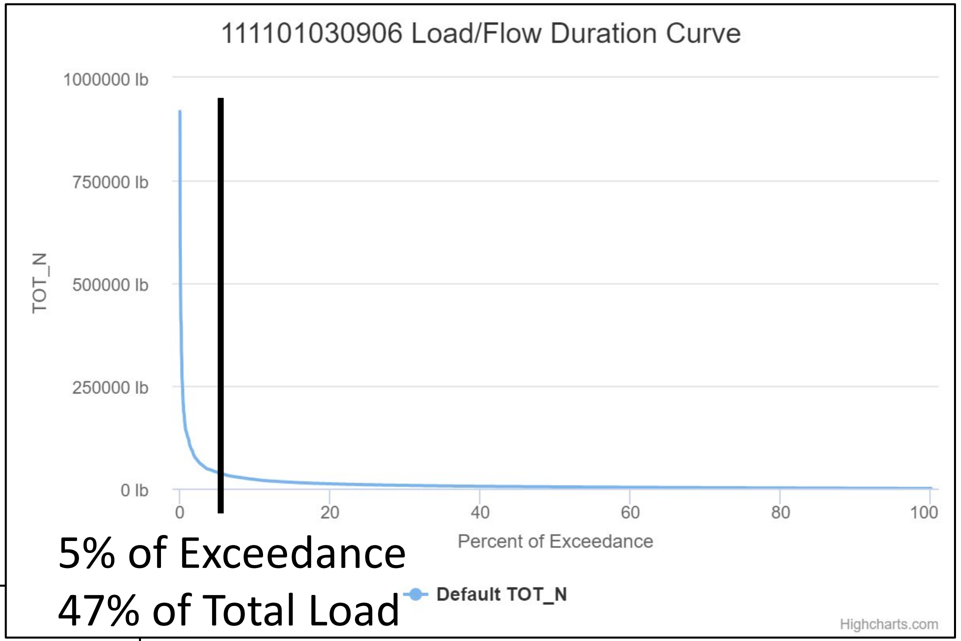
Acceptable Criteria:
NSE >= 0.5; KGE >= 0.5; -25 < PBIAS > 25

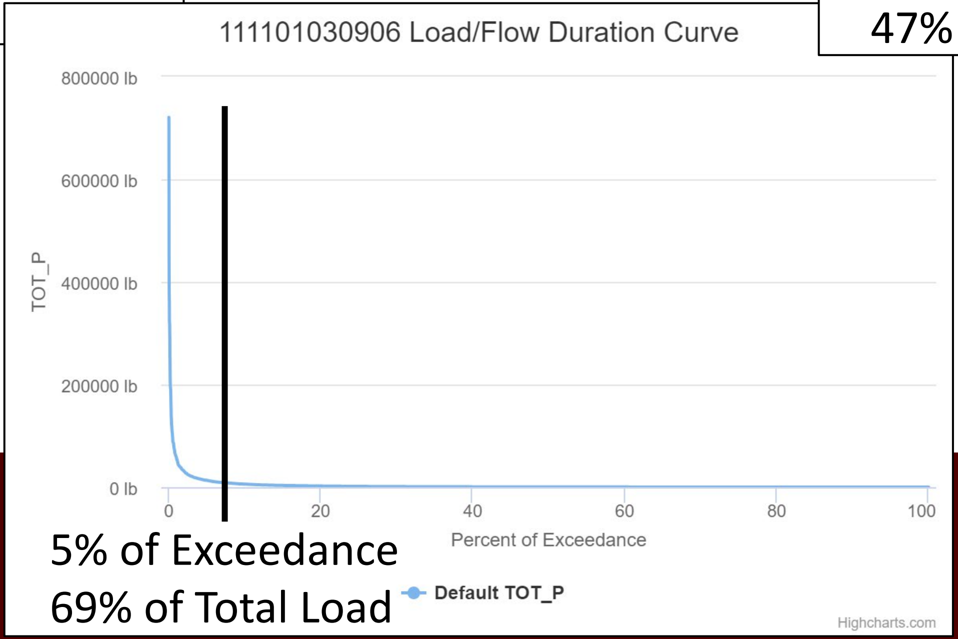
Water Quality Calibration Results - Overview



Example Loading at the outlet of the IRB

Across the watershed most of the sediment and nutrient loading is happening during extreme flow/rainfall events (top 5%)





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Calibration Parameters use for Sediment, Phosphorus, and Nitrogen

Parameter Name	Description	Fitted Value	Minimum Value	Maximum Value
v__CH_COV1.rte	Channel erodibility factor	0.32	0.3	0.7
v__CH_COV2.rte	Channel cover factor	0.015	0.005	0.2
v__SPCON.bsn	Maximum amount of sediment that can be reentrained	0.003	0.0001	0.01
v__SPEXP.bsn	Sediment reentrained in channel sediment routing	1.589	1.0	2.0
v__ADJ_PKR.bsn	Peak rate adjustment factor for sediment routing in the subbasin	0.727	0.5	2.0
v__PRF_BSN.bsn	Peak rate adjustment factor for sediment routing in the main channel	0.635	0	2.0
v__P_UPDIS.bsn	Phosphorus uptake distribution parameter	77.292	20	100
v__PPERCO.bsn	Phosphorus percolation coefficient	13.28	10	17.5
v__PHOSKD.bsn	Phosphorus soil partitioning coefficient	179.69	120	200
v__PSP.bsn	Phosphorus sorption coefficient	0.6	0.01	0.7
v__ERORGP.hru (Pasture)	Organic P enrichment ratio	0.32	0	5
v__CDN.bsn	Denitrification exponential rate coefficient	1.1104	1.0	1.2
V__CMN.bsn	Rate factor for humus mineralization of active organic N	0.0025	0.001	0.003
v__NPERCO.bsn	Nitrogen percolation coefficient	0.9896	0	1.0
V__RSDCO.bsn	Residue decomposition coefficient	0.0748	0.02	0.1
V__SDNCO.bsn	Denitrification threshold water content	0.929	0.6	1.0
V__N_UPDIS.bsn	Nitrogen uptake distribution parameter	94.792	0	100

R = multiplied by (1+fittedvalue), V = replaced, A = added to.

RESEARCH

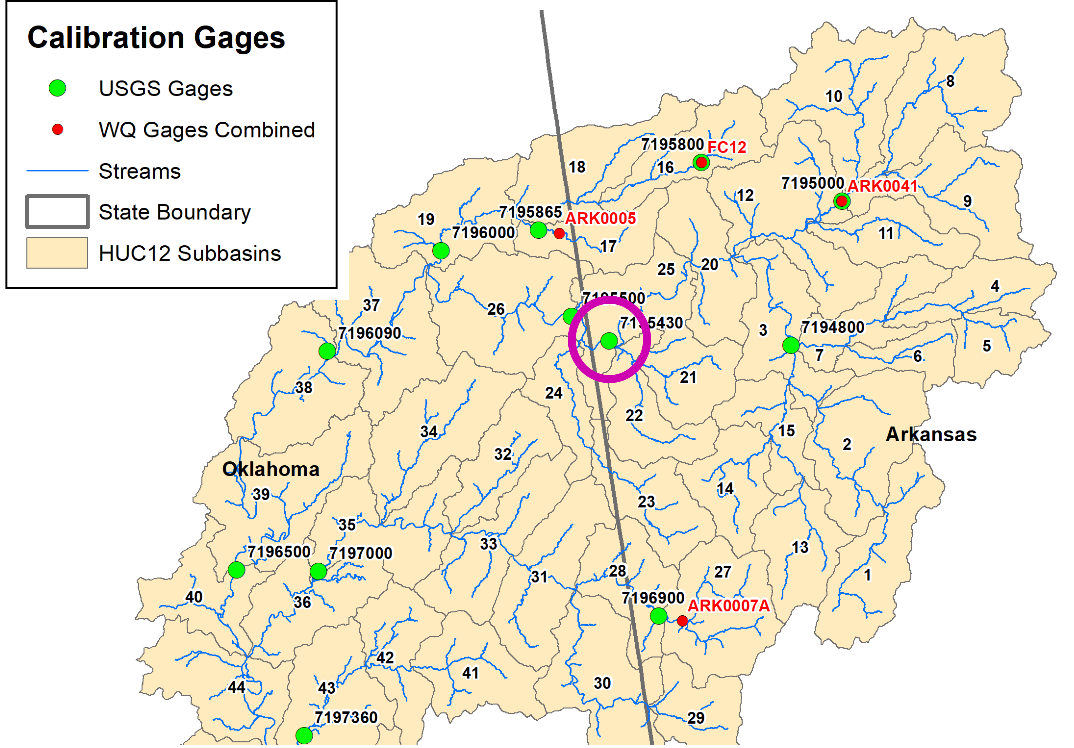
Sediment Calibration

HUC12 Subbasin	USGS Gage/Combined	NSE	PBIAS	KGE
3	07194800	0.32	-149.1	-0.54
8	07195000-ARK0041	0.12	58.6	-0.11
16	07195800 (FC12)	0.16	-13.1	0.06
25	**07195430**	**0.53**	**-50**	**0.35**
27	07196900-ARK0007A	-79.93	-1555.3	-15.93
17	07195865-ARK0005	-0.53	-219	-1.27
19	07196000	0.29	-127.6	-0.33
25	07195500	**0.54**	**-45.4**	0.38
35	07197000	0.37	**-35.1**	0.26
37	07196090	**0.53**	**-8.5**	**0.48**
39	07196500	**0.55**	**4.2**	**0.47**
43	07197360	-0.96	-210.9	-1.2

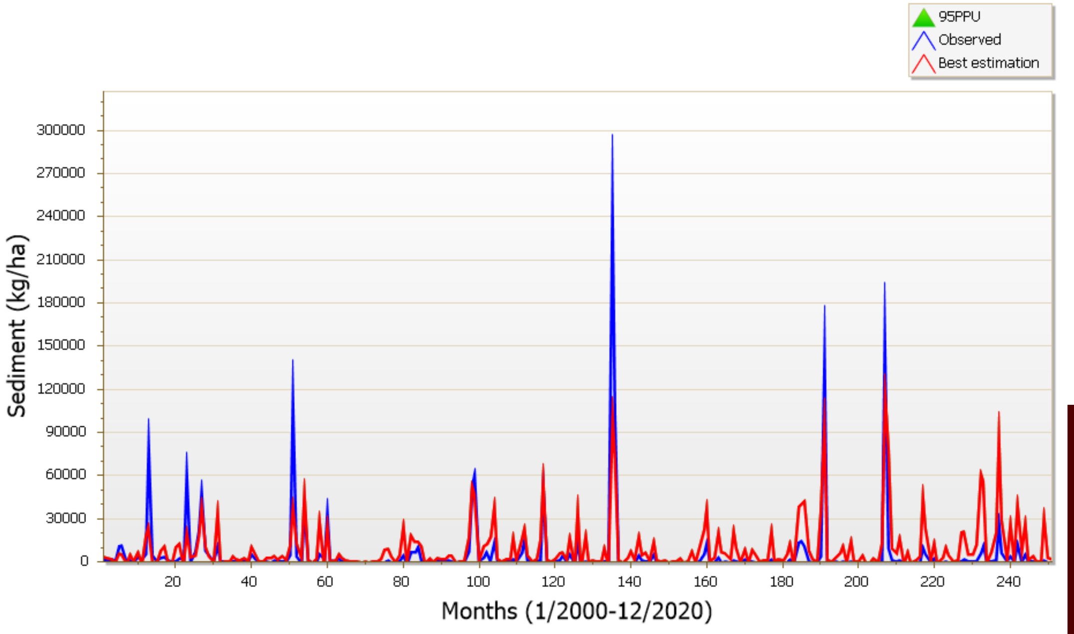
Red subbasin numbers indicate observations from LOADEST might not be acceptable

Acceptable Criteria:

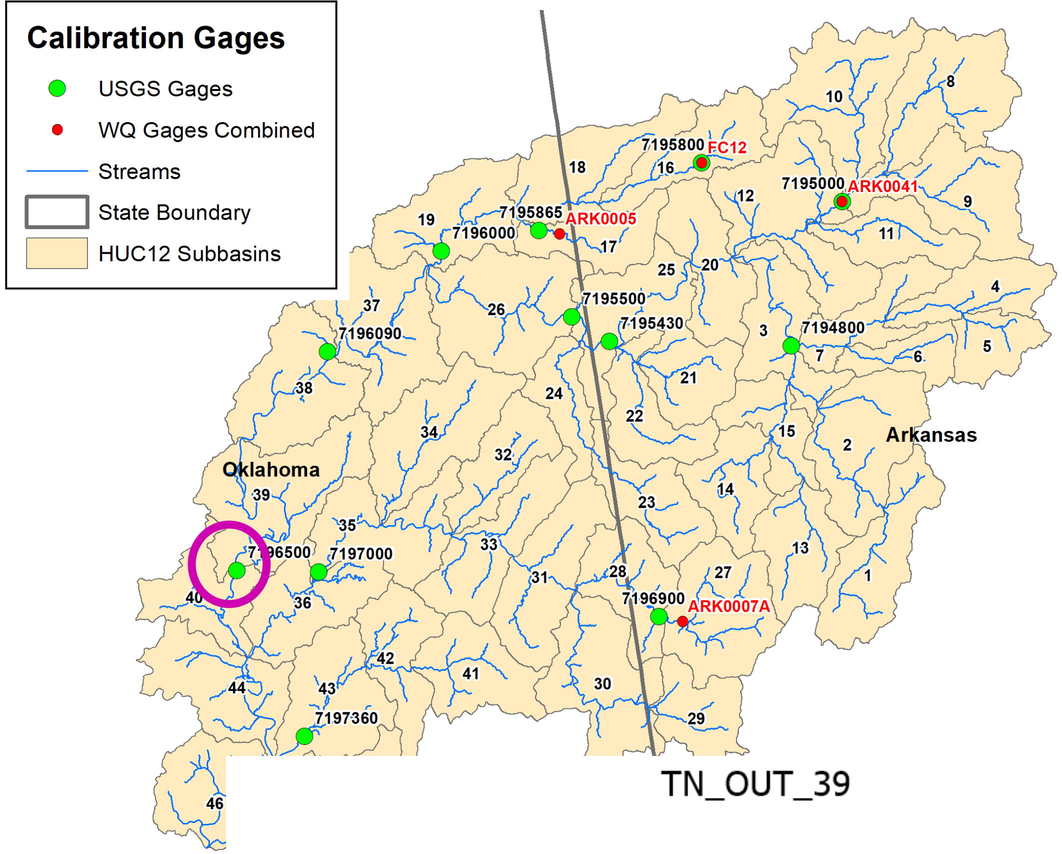
NSE >= 0.5; KGE >= 0.5; -55 < PBIAS > 55



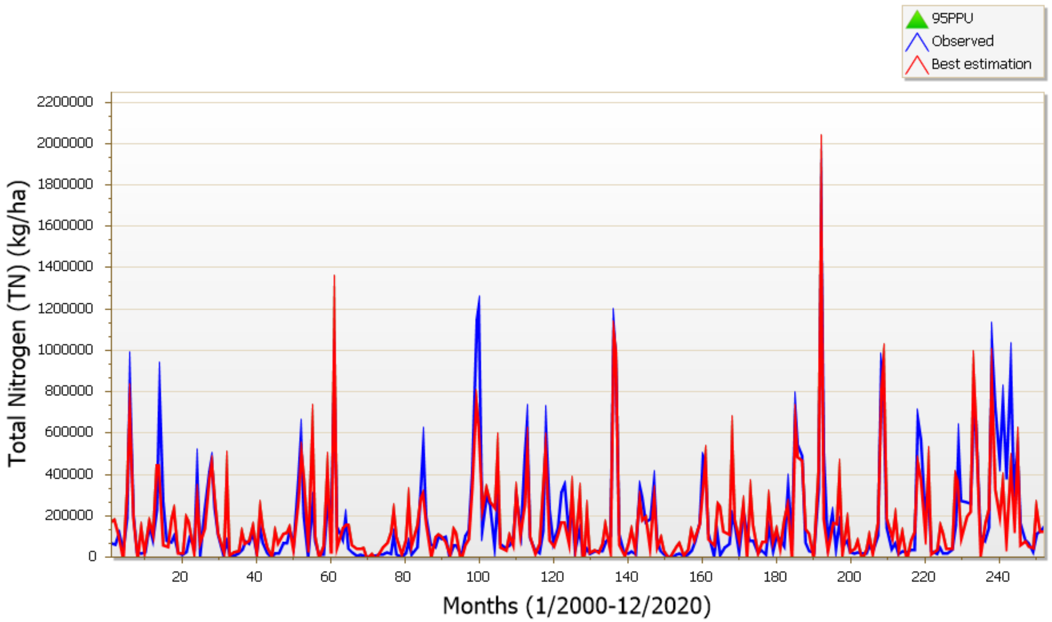
SED_OUT_25_07195430



Nitrogen Calibration



TN_OUT_39



		NOx			TN		
HUC12 Subbasin	USGS Gage/Combined	NSE	PBIAS	KGE	NSE	PBIAS	KGE
3	07194800	0.22	**-11**	**0.59**	-2.39	-122.7	-0.67
8	07195000-ARK0041				**0.52**	**34**	**0.54**
16	07195800 (FC12)				0.34	**-0.1**	**0.68**
25	07195430	0.4	**14.6**	**0.68**	**0.73**	**-3.8**	**0.86**
27	07196900-ARK0007A				**0.61**	**-3.6**	**0.6**
17	07195865-ARK0005				0.38	**34.9**	**0.47**
19	07196000	**0.53**	**21.1**	**0.66**	**0.72**	**-0.7**	**0.81**
25	07195500				**0.75**	**-0.2**	**0.87**
35	07197000	**0.56**	**13.8**	**0.65**	**0.74**	**-5.9**	**0.74**
37	07196090	**0.56**	**0.7**	**0.79**	**0.78**	**-9.8**	**0.85**
39	**07196500**	**0.58**	**5.5**	**0.73**	**0.76**	**-4.7**	**0.83**
43	07197360	0.37	**-3.1**	**0.69**	**0.52**	**-33.7**	**0.6**

Acceptable Criteria:

NSE >= 0.5; KGE >= 0.5; -70 < PBIAS > 70

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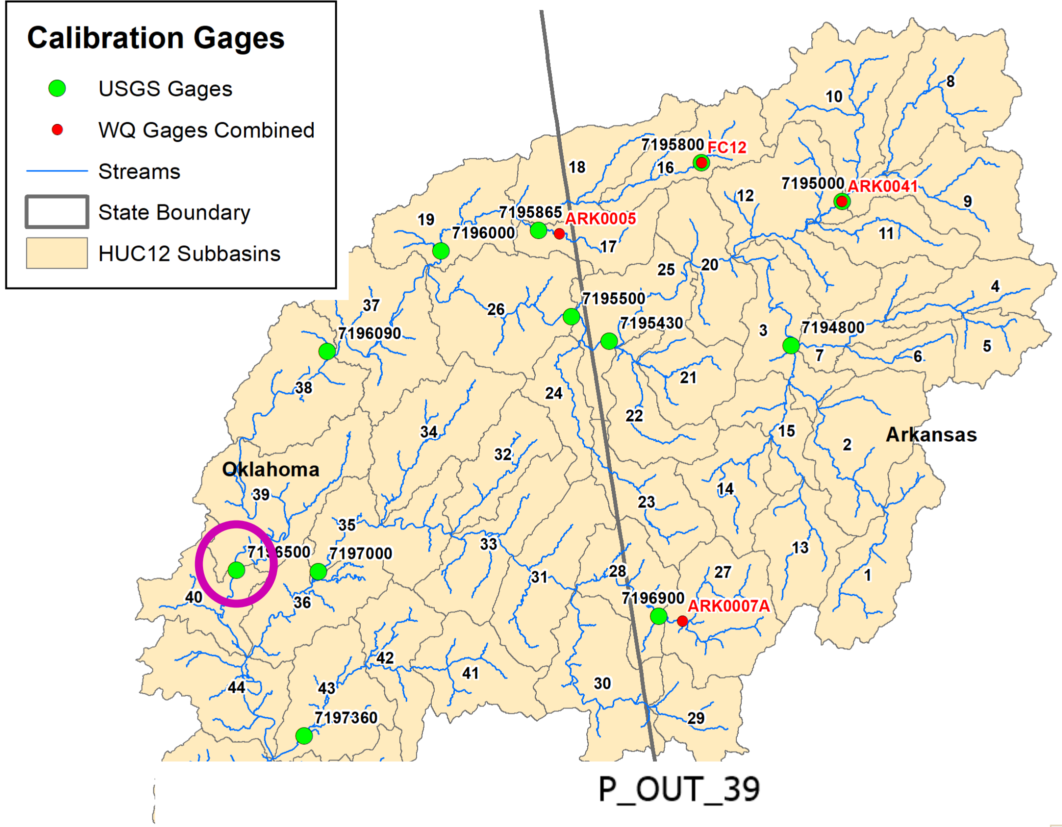
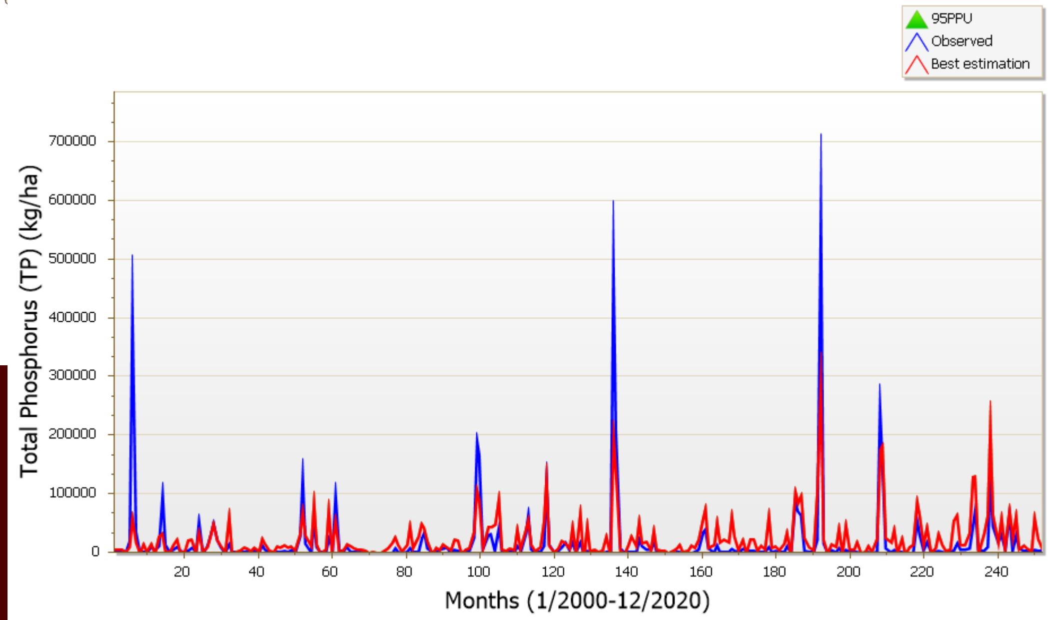


Phosphorus Calibration

HUC12 Subbasin	USGS Gage/Combined	OP NSE	OP PBIAS	OP KGE	TP NSE	TP PBIAS	TP KGE
3	07194800	**0.79**	**-49.5**	0.48	0.4	**-6.9**	0.29
8	07195000-ARK0041				0.35	**6**	0.42
16	07195800 (FC12)				-0.1	-221	-1.23
25	07195430	0.1	**-1.6**	**0.51**	-0.41	-130.9	-0.41
27	07196900-ARK0007A				-1.06	-189.1	-1.03
17	07195865-ARK0005				0.1	**56.7**	-0.06
19	07196000	**0.54**	**40.1**	0.37	0.47	**-48.1**	0.39
25	07195500				-0.25	-118	-0.28
35	07197000	0.66	-73.1	0.25	0.38	**-0.8**	0.29
37	07196090	**0.78**	**23.7**	**0.59**	0.61	**-45.5**	0.38
39	**07196500**	**0.49**	**46**	0.29	**0.55**	**-22.5**	**0.46**
43	07197360	-4.67	-175.9	-1.49	0.41	**-48.4**	0.37



Acceptable Criteria:

NSE >= 0.5; KGE >= 0.5; -70 < PBIAS > 70

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Loading by Land Use from Calibrated Model

	Total N (kg)	Total P (kg)	Sediment (tonnes)
All Land	4,111,108	407,744	484,749
Range Land (2%)	55,085 **(1.3%)**	2,955 **(0.7%)**	4,841 **(1.0%)**
Forest Land (47%)	636,171 **(15.5%)**	25,555 **(6.3%)**	18,517 **(3.8%)**
Pasture Land (43%)	3,219,955 **(78.3%)**	362,169 **(88.8%)**	385,698 **(79.6%)**
Urban Land (6%)	161,349 **(3.9%)**	15,072 **(3.7%)**	31,638 **(6.5%)**
Other Land (2%)	38,548 **(0.9%)**	1,994 **(0.5%)**	44,056 **(9.1%)**

	Percent of Pasture	Total N (kg/ha)	Total P (kg/ha)	Sediment (t/ha)
Average of All Pasture Land		18.6	2.1	2.24
Dairy Farms	1.1%	35.5	11.3	0.22
Hog Farms	1.7%	34.5	14.2	0.90
Well Managed	57.8%	14.0	1.3	1.79
Litter Well Managed	5.8%	38.2	3.8	0.22
Litter Over Grazed	4.1%	57.8	5.4	1.57
Over Grazed	29.5%	16.8	1.7	3.59

Load Reduction Strategies

- **Reduced Litter Application**
  - 2.24 tonnes/ha
  - Same Grazing Management
- **Reduced Litter and Well Managed**
  - 2.24 tonnes/ha
  - All Grazing Well Managed
- **No Litter Applied**
  - No Litter
  - Same Grazing Management
- **No Litter and Well Managed**
  - No Litter
  - All Grazing Well Managed
- **No Litter and No Grazing**
  - No Litter
  - No Grazing
- **15 m Filter Strip on Over Grazed Pasture**
  - Same Grazing Management
  - Apply 15 m Filter Strip on Over Grazed Pasture
- **15 m Filter Strip on all Pasture**
  - Same Grazing Management
  - Apply 15 m Filter Strip on All Pasture

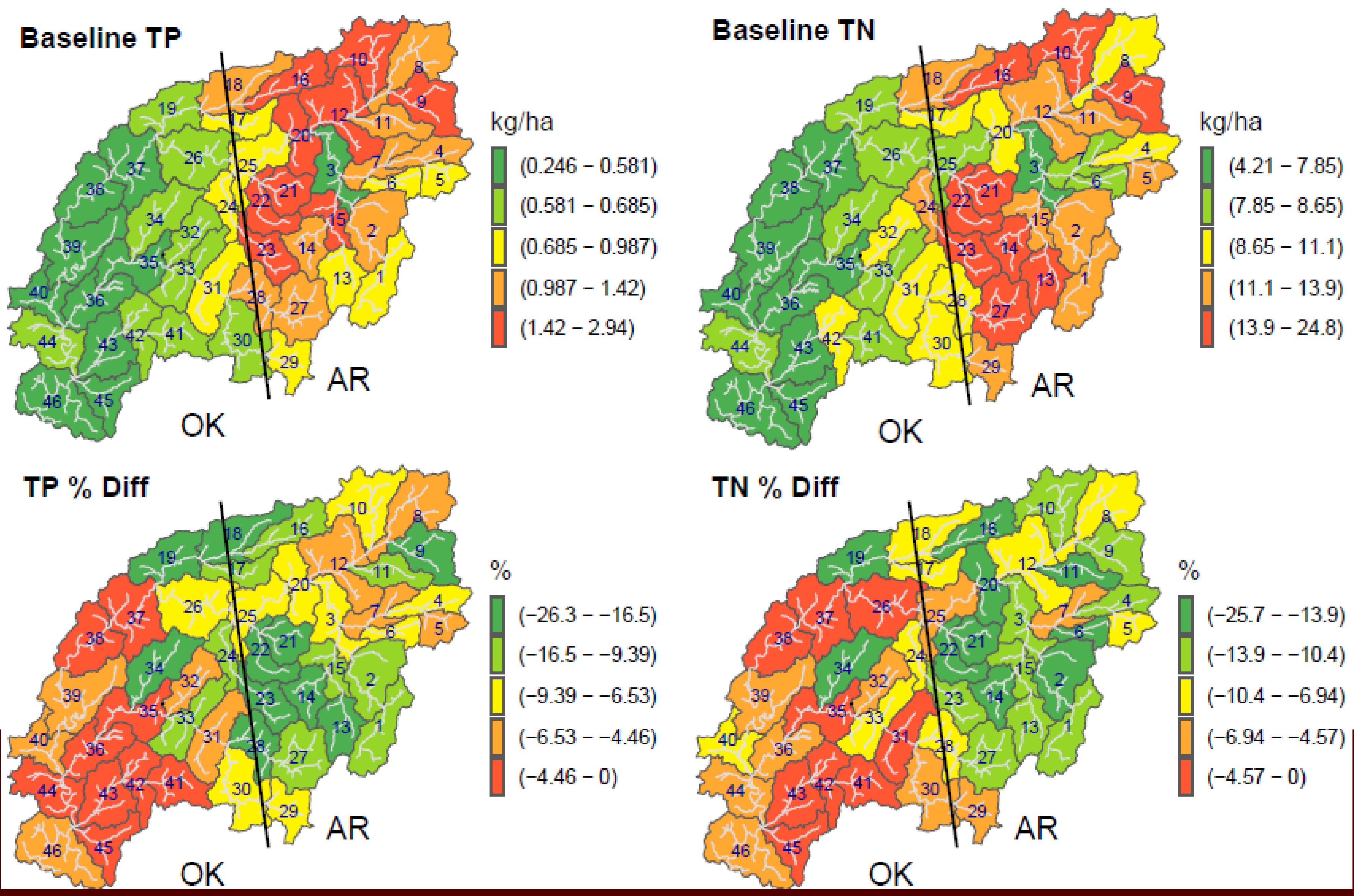
Load Reduction by Strategy

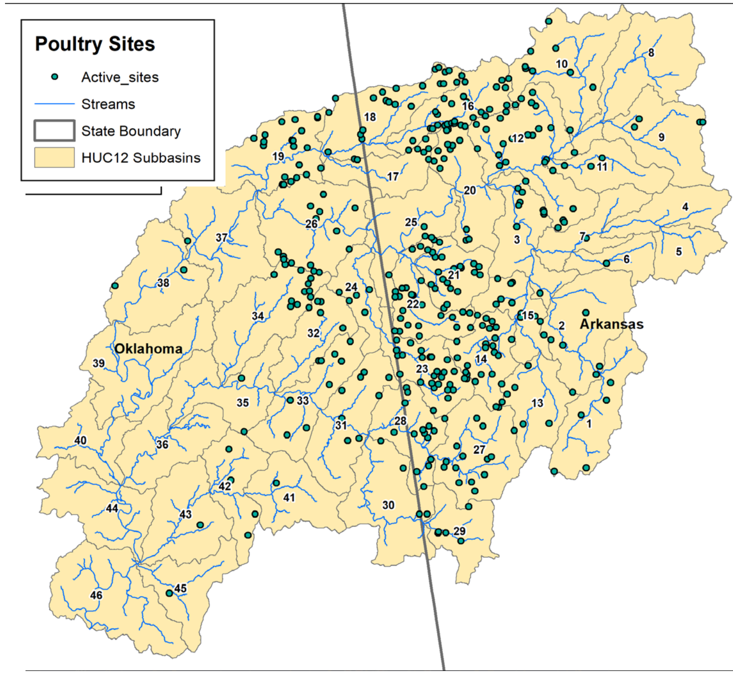
	SYLD (t/ha)	OP (kg/ha)	TP (kg/ha)	NOx (kg/ha)	TN (kg/ha)
Baseline Loading	57.9	41.7	48.7	299.8	491.8
Reduced Litter	2.5%	-10.7%	-9.1%	-3.4%	-1.7%
Reduced Litter Well Managed	-21.9%	-11.3%	-11.8%	-5.8%	-10.5%
No Litter	9.6%	-17.3%	-14.7%	-23.5%	-13.6%
No Litter Well Managed	-13.3%	-19.7%	-18.5%	-24.2%	-19.9%
No Litter No Grazing	-65.8%	-30.3%	-31.5%	-33.8%	-48.0%
15m Filter Strip Over Grazed	-31.5%	-25.6%	-24.9%	-20.5%	-25.0%
15m Filter Strip All Pasture	-63.3%	-64.2%	-60.8%	-51.9%	-58.9%

- **No litter application is an extreme BMP that is not realistic to implement**
- **No grazing is an extreme BMP that is not realistic to implement**

Reduced Litter and Well Managed Grazing

Reduced Litter, all Well Managed IRB Subbasin Output - Percent Change from Baseline (2000-2020)





**Moderate Reduction in loading

**Attainable solution to implement

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Continuation of Work

- More targeted scenario development
- Examine influence of point source contributions
- Evaluate impacts of unpaved roads in loadings
- Downscale models if necessary for target subbasins
- Analysis of filter strips during high flow and base flow
- Incorporate an economic model to valuate strategies

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Questions? Comments?