Supporting information for the article: Regional effects of agricultural conservation practices on nutrient transport in the Upper Mississippi River Basin

Ana María García†, Richard B. Alexander‡, Jeffrey G. Arnold§, Lee Norfleet¦, Michael J. White§, Dale M. Robertson±, Gregory Schwarz‡.*

AUTHOR ADDRESS

† U.S. Geological Survey, 3916 Sunset Ridge Rd., Raleigh, North Carolina 02906, United States

‡ U.S. Geological Survey, 432 National Center, Reston, Virginia 20192, United States

§ U. S. Department of Agriculture, Agricultural Research Service, Grassland Soil and Water Research Laboratory, 808 East Blackland Rd. Temple, Texas 76502, United States

¦ U. S. Department of Agriculture, Natural Resources and Conservation Service, 101 East Blackland Rd. Temple, Texas 76502, United States

± U.S. Geological Survey, 8505 Research Way, Middleton, Wisconsin 53562, United States

Modifications to previously published SPARROW Models Modifications were made to the published Upper Midwest models as developed by Robertson and Saad[1] (table S1, S2, S3) to facilitate the inclusion of conservation effects variables for the Upper Mississippi River Basin. Cropland-related terms were specified separately for the Upper Mississippi River Basin (UMRB), so that the conservation effects could be applied to these region-specific source terms. The nitrogen model was developed with two terms to account for nutrient contamination from cropland agriculture: agricultural fertilizer and cropland area. Robertson and Saad[1] discuss that while fertilizer applications are the primary source of nutrients to the landscape, agricultural activities supply additional nutrient input, not accounted for with this term, including nitrogen fixation by legumes in crop rotations. In order to fully account for all agricultural sources while limiting correlated terms we kept cropland as a surrogate source term for both fertilizer loss and other nutrient input associated with crop agriculture.

The phosphorus model source terms were retained as they were specified in the published Upper Midwest model but a modification was made to the land-to-water delivery set of variables: the previous model was estimated with a tile-drainage variable, a significant negative predictor of lower phosphorus land-to-water delivery in areas with low topographic relief. The STATSGO soil erodibility factor (K-factor) is a coefficient representative of susceptibility to erosion. The phosphorus model was changed to substitute the K-factor for the tile-drainage land-to-water delivery variable. This change provided a direct representation of erosion processes an important feature given that many conservation practices have been developed to support erosion control. With this change, the SPARROW model had an explicit representation of near-stream sediment-bound phosphorus delivery.

Table S. 1. Description of spatial datasets for explanatory variables used in the Upper Midwest SPARROW models[1].

Explanatory variable	*Spatial dataset*	*Model Coefficient Units*
Sources		
Point source	Permitted municipal wastewater discharge in kg	Dimensionless
Urban non point	Extent (km^2) of urban land, 2001 National Land Cover Dataset[3]	$kg/km^2/yr$
Atmospheric deposition	Wet deposition of inorganic nitrogen, in kg	Dimensionless
Fertilizer	Inorganic fertilizer (P or N) applied to cropland in kg[4]	Dimensionless
Cropland	Area (km^2) classified as cropland land in the National Land Cover Dataset[3]	$kg/km^2/yr$.
Manure, confined	Nitrogen or phosphorus in animal waste from confined sources[4].	Dimensionless
Manure, unconfined	Nitrogen or phosphorus in animal waste from unconfined sources[4]	Dimensionless
Forest and wetlands	Extent (km^2) of forest and wetland, 2001 National Land Cover Dataset[3].	$kg/km^2/yr$.
Land to water delivery		
Artificial drainage	Fraction of stream catchment underlain by tile drains.	Dimensionless
Drainage density	Stream drainage density in km/km^2	km^2/km
Temperature	Annual mean air temperature[5]	1/deg. Celsius
Clay content	Clay content, high value reported in STATSGO[6].	Dimensionless
Soil permeability	Logarithm of soil permeability, STATSGO[6]	Dimensionless
K factor	Soil erodibility factor, STATSGO[6]	Dimensionless
Precipitation	Annual mean precipitation[5].	1/mm
In-channel processing		
Loss in small streams	Product of travel time and inverse mean water depth for streams with flow < 1.1 m^3/s	m/day
Loss in medium streams	Product of travel time and inverse mean water depth for streams with flow rate between 1.1 and 2.0 m3/s	m/day
Loss in reservoirs	Inverse of areal hydraulic loading	m/yr.

The modifications did not impact predictive power or accuracy of the published SPARROW model (table S2 and table S3) and notably, source shares remained stable (table S4). Model predictions associated 70% of total nitrogen loads with agricultural activities in the original Upper Midwest model. Removing the agricultural fertilizer source term kept the agriculture source share at 69% and the nested estimation increased that source share to 72%. In the phosphorus model the coefficient for confined manure increased from 0.086 kg P/kg for the whole Upper Midwest area to 0.12 kg P/kg for the UMRB and 0.04 kg P/kg for the rest of the area. There is evidence that important regional differences are reflected in this change. Confined animal production is greatest in the Upper Mississippi relative to the rest of the study area. Substantial hog production in Iowa alone contrasts sharply with the total number of animal operations in Ohio, Wisconsin and Michigan[2]

Table S.2. Upper Midwest SPARROW nitrogen model[1] and the baseline SPARROW model without conservation used in this study(* indicates $p < 0.01$)[a].

Explanatory variable	Upper Midwest SPARROW Model		SPARROW without conservation variable	
	Coefficient	P	Coefficient	P
Sources				
Point source	0.789	*	0.801	*
Atmospheric deposition	0.513	*	0.545	*
Fertilizer (UM)	0.131	*		
Cropland (UM)	6.260	0.0353	12.100	*
Cropland (UMRB)	--	--	19.300	*
Manure, confined (UM)	0.291	*	0.251	*
Manure, confined (UMRB)	--	--	0.340	*
Land to water delivery				
Artificial drainage	1.130	*	1.250	*
Drainage density	0.134	0.0183	0.107	0.0567
Temperature	-0.0412	0.0357	-0.0328	0.0801
Clay content	0.0139	*	0.0193	*
Precipitation	0.00159	*	0.00178	*
In-channel processing				
Loss in small streams	0.424	*	0.432	*
Loss in medium streams	0.233	0.0158	0.212	0.0203
Loss in reservoirs	6.710	*	5.320	*
MODEL DIAGNOSTICS				
Number of sites	708		708	.
RMSE of log-transformed residuals	0.41		0.40	.
R^2 of nutrient yield	0.85		0.85	.
Eigenvalue spread	142.2		42.64	.

[a]UMRB, Upper Mississippi River Basin; UM, Upper Midwest drainage area exclusive of the Upper Mississippi River

Table S. 3. Upper Midwest phosphorus SPARROW model[1] and the SPARROW model without conservation variable (* indicates $p < 0.01$)[a].

Explanatory variable	*Upper Midwest SPARROW Model*		*SPARROW without conservation variable*	
	Estimate	*P*	*Estimate*	*p*
Point source	1.070	*	0.998	*
Urban non point	52.3	*	63.195	*
Fertilizer (UM)	0.0294	*	0.0187	*
Fertilizer (UMRB)	--	--	0.0126	*
Manure, confined (UM)	0.0856	*	0.0153	0.0524
Manure, confined (UMRB)	--	--	0.0651	*
Manure, unconfined	0.0324	*	0.0617	*
Forest and wetlands	0.00001	*	0.00002	*
Artificial drainage	-1.160	*	--.	--.
Soil permeability	-0.652	*	-0.306	*
K factor	--	--	6.550	*
Loss in small streams	0.198	*	0.149	0.0296
Loss in medium streams	0.298	*	0.254	*
Loss in reservoirs	4.840	*	3.860	*
MODEL DIAGNOSTICS				
Number of sites	810		810	.
RMSE of log-transformed residuals	0.49		0.49	.
R^2 of nutrient yield	0.73		0.73	.
Eigenvalue spread	21.29		40.13	

[a]UMRB, Upper Mississippi River Basin; UM, Upper Midwest drainage area exclusive of the Upper Mississippi River. * indicates $p < 0.01$.

Table S. 4. Share (%) of total nutrient load for the Upper Midwest SPARROW model[1] and the baseline SPARROW model without conservation used in this study.

Source	***Upper Midwest SPARROW***	***SPARROW without conservation variable***

Source	***Upper Midwest SPARROW***		***SPARROW without conservation variable***	
	TN	TP	TN	TP
		% of total load		
Point sources	9.4	21	8.5	20
Atmospheric deposition	20	--	19	--
Urban land	--	5.4	--	6.7
Forest	--	5.1	--	7.5
Total agricultural sources	70	68	72	65
Confined animal operations	*16*	*31*	*17*	*31*
Unconfined animals		*7.3*	*--*	*17*
Agricultural Fertilizer	*34*	*30*	*--*	*17*
Cropland	*20*	*--*	*55*	*--*

Use of mean annual nutrient loads. Regression-model methods (also known as rating-curve methods[7–9]) were used to estimate the long-term mean annual load that serves as the dependent variable in the Upper Midwest SPARROW models. Although recent literature[10,11] has documented cases of bias in estimates of mean annual nutrient loads, regression-models remain accurate and efficient methods for estimating stream loads. Recent research has demonstrated that most of the rating curve models produce nearly unbiased estimates of mean annual load for total nitrogen, whereas larger bias can occur for total phosphorus[11,12].

In published discussions the ratio of observed to predicted loads on sampled days also known as the observed-to-estimated statistic was used to estimate the potential bias and has been shown to be a good indicator of the true bias in cases where the approximate bias measure is large[11]. We conducted a sensitivity evaluation to assess the effects of cases of potentially biased loads on the SPARROW model analyses of conservation effects by removing the sites with large estimated bias as predicted by the computed observed-to-estimated ratio. Sites with over-predictions of more than 40%, the inflection point of 0.6 bias in figure 3 in Hirsch[11] and under-predictions of more than 50% were removed. We found that the results for the SPARROW models with conservation were virtually unchanged coefficients and predictions for total nitrogen and total phosphorus. Application of the potential bias filter to total nitrogen led to the elimination of mean load values for 11 monitoring sites (697 vs. 708) and led to the elimination of values for 65 monitoring sites (745 vs. 810) for total phosphorus. The root mean square error (RMSE) of the models changed by less than 3%, and the conservation intensity coefficient values changed by less than 10 %; the statistical significance of the conservation coefficient for total nitrogen (TN) changed from 0.025 to 0.013; and for total phosphorus (TP) from 0.415 to 0.439. We conclude from these evaluations that the interpretations with the SPARROW model are relatively insensitive to the presence of a relatively small number of load estimates (<10%) with potentially large bias.

Description of CEAP Conservation Effects Datasets

Conservation effects information were obtained from the CEAP cropland agriculture assessment for the Upper Mississippi River Basin[13] (table S6). Farmers were surveyed over 4 years, with surveys in 2003 and 2004 focused on characterizing the most prevalent and well established cropping and conservation systems, while data collection for 2005 and 2006 documented conservation systems that were adopted as a result of the 2002 Farm Bill. The CEAP survey, summarized in the Upper Mississippi River Basin CEAP assessment[13], documented conservation practices that were in place in the early 2000s, including practices that were adopted in prior decades. Most of the conservation practices that have been implemented in the Upper Mississippi Basin are structural management practices that mitigate soil loss. Practices for controlling water erosion were found in 45% of cropland in the Upper Mississippi River

Basin and reduced tillage in 91% of the cropped land. The farmer survey also found evidence of some nitrogen or phosphorus management. Appropriate rates of nitrogen application, defined as rates under 1.4 the amount of nitrogen removed in the crop yield were practiced on 39% of the cropland area, and 53% satisfied similar criteria (1.1 times phosphorus crop uptake) for phosphorus nutrient management. Implementation of complete nutrient application management was limited throughout the basin, with inconsistent use of appropriate fertilizer rates, timing, and methods of application.

The regional- and national-scale CEAP assessments applied deterministic models to deduce the benefits of conservation practices by representing conservation practice adoption obtained through a National Resources Inventory (NRI) survey and represented with the field-scale plant growth model APEX[14,15]. The APEX model, a well-established process model, was calibrated and validated using measured data gathered at experimental fields across the country. Using temporally explicit data derived from experimental sites in Tifton, Georgia, APEX models were validated for representing flow processes and pesticide transport under various tillage and crop rotation practice[14]. The baseline scenario UMRB (figures S1a and S1d, table S7, columns 2 and 3) includes simulations of NRI fields represented in the survey and then regionalized to a HUC-8 (Hydrologic Unit Code) scale. The simulation provided long-term nutrient and sediment loads for climatic conditions over a 47-year period (1960-2007) and model parameters calibrated for a period between 1986 and 2006. Regional-scale calibration of the baseline scenario was conducted to establish reasonable measures of accuracy[14]. Using the modeling framework, conservation practices documented in the farmer surveys were removed and a 'no-practice' scenario was developed. Like the baseline scenario, the no-practice scenario was simulated over

47 years to obtain long-term loads of total phosphorus and total nitrogen delivered to the outlet of 131 HUC8 within the UMRB (figures S1b and S1e, table S7, columns 4 and 5).

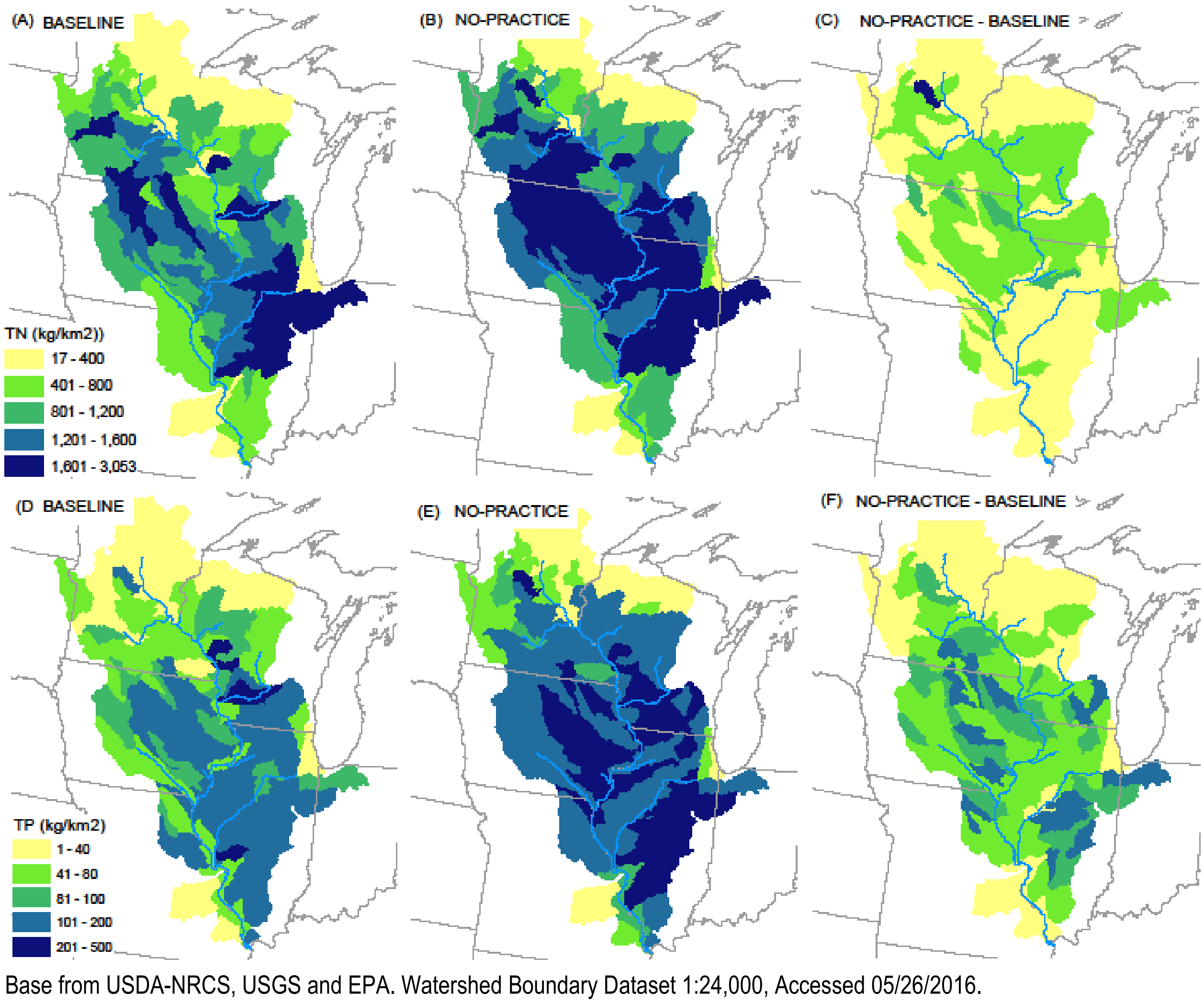

Figure S1. Spatial distribution of nutrient loads as predicted by modeling (APEX) scenarios loads for 8-digit HUCs in the Upper Mississippi River Basin.

Estimation tables for conservation variable independence test

A test was performed to determine the extent of independent information contained in the conservation intensity variable (equation 4). Estimation tables (table S5 and S6) are provided to support the analysis described in the main article.

Table S. 5. Estimation result for independence and model robustness test: total nitrogen SPARROW with conservation variable and regression residuals.

Explanatory variable	SPARROW with conservation variable			SPARROW with residual variable		
	Coefficient	Standard Error	P	Coefficient	Standard Error	P
Source						
Point source	0.799	0.111	*	0.80	0.111	*
Atmospheric	0.552	0.0391	*	0.554	0.0393	*
Cropland (UM)	12.1	1.530	*	12.1	1.538	*
Cropland (UMRB)	20.1	2.784	*	20.3	2.781	*
Manure (UM)	0.251	0.0580	*	0.253	0.0583	*
Manure (UMRB)	0.417	0.119	*	0.381	0.114	*
Land to water delivery						
Conservation variable or residual	-6.4	2.134	0.003	-6.58	2.196	0.003
Artificial drainage	1.22	0.131	*	1.25	0.131	*
Drainage density	0.104	0.0557	0.0632	0.12	0.0559	0.0325
Temperature	-0.0332	0.0186	0.0743	-0.0329	0.0186	0.0768
Clay content	0.02	0.00383	.	0.0196	0.00383	.
Precipitation	0.00173	0.00026	.	0.00173	0.00026	.
In-channel processing						
Small streams	0.445	0.0989	.	0.444	0.0990	.
Medium streams	0.221	0.0915	0.0161	0.216	0.0911	0.0179
Loss in reservoirs	5.52	1.280	.	5.41	1.264	.
Model diagnostics						
No. of sites, UM	708			708		
No. of sites, UMRB	252			252		
RMSE of residuals	0.399			0.399		
R^2 of nutrient yield	0.856			0.856		
Eigenvalue spread	43.66			43.16		

all variables significant at the 1 % significance level; UMRB, Upper Mississippi River Basin; UM, Upper Midwest drainage area exclusive of the Upper Mississippi River

Table S. 6. Estimation result for independence and model robustness test: total phosphorus SPARROW with conservation variable and regression residuals.

	SPARROW with conservation			SPARROW with residual		
Explanatory variable	Coefficient	Standard Error	P	Coefficient	Standard Error	P
Source						
Point source	0.998	0.137	.	0.997	0.137	.
Urban non-point	64.2	14.510	.	63.8	14.500	.
Fertilizer (UM)	0.019	0.00313	.	0.0188	0.00310	.
Fertilizer (UMRB)	0.0133	0.00305	.	0.013	0.00296	.
Manure, confined (UM)	0.0156	0.00795	0.05	0.0154	0.00790	0.0515
Manure, confined (UMRB)	0.0693	0.0114	.	0.0668	0.0109	.
Manure, unconfined	0.0611	0.0107	.	0.0615	0.0107	.
Forest and wetlands	19.8	2.240	.	20	2.248	.
Land to water delivery						
Conservation intensity or residual	-1.49	1.306	0.253	-0.875	1.332	0.512
Soil permeability	-0.323	0.0966	.	-0.313	0.0962	.
K factor	6.26	1.178	.	6.43	1.167	.
In-channel processing						
Loss in small streams	0.147	0.0684	0.0316	0.148	0.0685	0.0312
Loss in medium streams	0.262	0.0967	.	0.258	0.0964	.
Loss in reservoirs	3.89	0.948	.	3.87	0.946	.
Model diagnostics						
Number of sites, UM	810			810		
Number of sites, UMRB	324			324		
RMSE of log-transformed residu	0.489			0.489		
R2 of nutrient yield, UM Model	0.735			0.735		
Eigenvalue spread	43.051			41.81		

all variables significant at the 1% significance level; UMRB, Upper Mississippi River Basin; UM, Upper Midwest drainage area exclusive of the Upper Mississippi River

Table S. 7. Nutrient loads from APEX models for scenarios ([HUC, Hydrologic Unit Code; TN, total nitrogen; TP, total phosphorus). Values have been aggregated in a manner protective of confidentiality agreement as per Title 7, U.S. Code, Public Law 107-347. *Asterix indicates HUC8s that had 10 or fewer NRI survey points or fewer than 250,000 acres of cropland.

8-Digit HUC	Baseline Scenario, in kg		No Practice Scenario, in kg	
	TN	TP	TN	TP
07010101*	150,843	6,442	234,933	15,318
07010102*	64,941	2,773	101,143	6,595
07010103*	99,798	4,262	155,433	10,135
07010104*	897,514	38,329	1,397,852	91,146
07010105*	66,585	2,844	103,704	6,762
07010106*	1,052,621	44,952	1,639,427	106,898
07010107*	1,062,577	45,378	1,654,933	107,910
07010108*	1,430,379	61,085	2,227,774	145,261
07010201*	1,384,562	81,836	2,634,979	167,171
07010202	2,407,756	364,372	6,761,219	575,144
07010203*	785,222	88,807	1,561,648	197,347
07010204	2,567,811	263,380	4,098,956	587,243
07010205	4,165,445	171,757	5,120,995	408,565
07010206*	495,248	25,068	639,342	62,064
07010207*	1,462,003	65,057	2,151,147	102,940
07020001	2,205,768	219,113	4,278,021	247,092
07020002*	1,155,084	87,252	1,969,402	138,649
07020003	2,345,552	130,488	3,121,862	151,664
07020004	13,112,362	170,956	15,577,621	283,801
07020005	4,802,995	170,247	7,022,777	460,607
07020006	1,888,508	52,442	2,083,853	115,801
07020007	3,446,977	98,648	4,941,326	286,903

07020008	3,486,647	270,865	4,486,465	395,869
07020009	6,999,475	249,958	8,931,042	545,758
07020010	2,229,496	163,869	3,617,926	265,749
07020011	4,135,648	136,766	5,730,037	425,576
07020012	6,877,838	235,883	8,583,749	529,062
07030001*	547,220	45,871	792,177	73,607
07030002*	110,140	9,232	159,442	14,815
07030003*	263,741	22,109	381,801	35,476
07030004*	788,044	66,059	1,140,802	106,001
07030005	5,474,842	484,679	7,641,686	739,477
07040001	3,240,519	206,461	4,543,204	371,228
07040002	5,482,035	243,545	7,695,633	585,952
07040003*	1,341,280	161,421	2,846,138	381,056
07040004	4,303,788	226,334	6,820,876	555,179
07040005*	3,450,389	396,074	4,449,097	490,128
07040006*	1,789,943	419,743	2,344,732	454,428
07040007*	5,161,114	499,892	8,473,387	813,003
07040008	2,971,305	144,421	4,862,181	401,573
07050001*	568,255	62,758	884,223	89,841
07050002*	160,412	17,716	249,606	25,361
07050003*	167,129	18,458	260,058	26,423
07050004*	551,677	60,927	858,426	87,220
07050005	3,568,290	429,294	6,178,138	598,063
07050006*	1,766,471	195,089	2,748,682	279,280
07050007	3,931,474	428,961	5,555,481	619,016
07060001*	1,613,332	327,178	3,216,584	547,993
07060002	2,041,750	154,893	3,594,085	342,755
07060003	2,096,497	196,020	3,673,062	436,865
07060004	4,860,081	462,370	8,616,288	968,472

07060005	4,159,061	534,217	6,661,283	863,988
07060006	7,329,477	471,185	10,367,098	898,400
07070001	296,880	40,498	436,868	57,033
07070002	4,054,585	480,471	7,380,998	779,391
07070003	8,330,663	540,070	12,434,777	880,671
07070004*	2,300,812	313,861	3,385,708	442,006
07070005	9,765,161	1,921,971	11,808,469	2,397,353
07070006*	1,602,684	371,475	3,069,303	534,894
07080101	3,581,484	163,202	4,442,896	298,782
07080102	10,864,553	453,398	13,098,631	783,869
07080103	3,114,964	367,639	4,686,497	567,686
07080104	9,512,019	835,010	10,720,881	1,273,335
07080105	7,415,680	673,149	9,389,661	946,374
07080106	2,132,910	203,129	3,456,830	427,664
07080107	4,072,966	414,456	6,888,469	877,579
07080201	7,500,115	518,802	9,135,727	1,030,120
07080202	3,978,611	236,492	5,424,322	457,324
07080203*	1,396,087	95,585	3,055,947	321,522
07080204	2,969,173	269,654	4,161,165	503,281
07080205	7,824,715	1,117,141	10,244,811	1,412,310
07080206	3,137,256	434,231	4,999,590	610,530
07080207	6,303,994	552,461	9,117,007	886,172
07080208	4,990,842	638,548	7,554,901	1,178,158
07080209	5,436,767	544,183	7,908,774	915,749
07090001	6,983,768	1,017,922	10,766,185	2,062,103
07090002	2,655,490	258,902	3,733,974	400,036
07090003	6,092,362	911,447	9,070,123	1,290,148
07090004	2,654,456	330,811	3,533,901	489,283
07090005	8,240,085	696,083	10,683,919	1,034,882

07090006	6,156,220	493,367	7,265,696	786,399
07090007	8,752,317	433,213	11,102,250	625,643
07100001	3,702,309	138,921	4,290,928	221,514
07100002	3,726,592	156,551	6,090,560	436,812
07100003	5,601,199	272,899	6,759,806	582,035
07100004	6,827,896	411,252	7,676,624	650,554
07100005	4,972,074	233,168	6,176,501	362,456
07100006	7,677,460	559,649	9,487,736	899,455
07100007	2,939,999	228,481	4,230,319	497,838
07100008	5,938,297	497,223	8,059,133	917,525
07100009	3,233,620	397,362	5,132,979	765,752
07110001	2,572,873	561,292	5,246,082	966,010
07110002	1,234,789	132,437	2,067,354	341,597
07110003*	703,567	113,547	1,631,158	322,456
07110004	3,937,711	341,684	5,472,863	677,996
07110005*	1,031,763	189,959	1,935,846	421,991
07110006	1,858,833	435,114	3,559,747	593,859
07110007	1,567,614	245,254	2,132,237	329,917
07110008	1,626,771	348,541	2,783,744	493,422
07110009*	892,495	114,456	1,271,225	159,920
07120001	14,901,452	734,516	20,521,847	1,526,032
07120002	12,235,840	918,602	14,564,422	1,390,135
07120003*	256,159	17,282	330,151	29,703
07120004*	1,485,827	150,176	1,724,742	257,018
07120005	4,697,252	412,003	5,496,780	603,534
07120006	3,628,369	276,406	5,977,136	557,704
07120007	5,164,731	333,067	5,878,242	497,072
07130001	8,630,129	467,680	8,745,161	771,852
07130002	6,383,176	668,778	7,279,756	997,982

07130003	4,965,429	621,939	6,173,056	778,524
07130004	5,319,287	325,038	5,812,593	784,483
07130005	6,968,679	658,900	7,806,673	855,951
07130006	7,396,300	650,506	7,983,010	1,017,226
07130007	6,391,208	463,265	6,433,697	751,564
07130008	3,896,056	375,161	4,456,442	621,297
07130009	7,880,773	925,667	8,828,971	1,448,901
07130010	3,535,048	462,891	4,547,216	619,968
07130011	8,897,113	716,871	9,947,803	1,132,834
07130012	4,003,842	603,017	5,040,095	793,981
07140101	1,386,402	236,239	1,749,014	360,595
07140102	151,753	25,481	208,797	37,372
07140103*	117,225	19,683	161,291	28,868
07140104*	85,499	14,356	117,638	21,056
07140105	1,901,666	199,989	2,661,758	350,718
07140106	3,478,005	829,220	4,959,872	1,137,403
07140107*	539,030	90,508	741,654	132,745
07140108*	655,303	91,830	893,308	122,567
07140201	6,729,713	730,407	7,699,328	1,142,368
07140202	2,884,624	548,406	4,288,849	911,089
07140203	1,941,256	237,185	2,692,371	477,253
07140204	3,020,898	743,088	4,432,876	995,205

REFERENCES

(1) Robertson, D. M.; Saad, D. A. Nutrient Inputs to the Laurentian Great Lakes by Source and Watershed Estimated Using SPARROW Watershed Models1: Nutrient Inputs to the Laurentian Great Lakes by Source and Watershed Estimated Using SPARROW Watershed Models. *JAWRA J. Am. Water Resour. Assoc.* **2011**, *47* (5), 1011–1033.
(2) USDA-NASS. Census of Agriculture, Web Maps, 2012.

(3) Homer, C.; Huang, C.; Yang, L.; Wylie, B.; Coan, M. Development of a 2001 national land-cover database for the United States. *Photogramm. Eng. Remote Sens.* **2004**, *70* (7), 829–840.
(4) Ruddy, B. C.; Lorenz, D. L.; Mueller, D. K. *County-level estimates of nutrient inputs to the land surface of the conterminous United States, 1982-2001*; US Department of the Interior, US Geological Survey, 2006.
(5) Oregon State University --PRISM Group. 800m Normals (1971 – 2000). 2007.
(6) Soil Survey Staff. *State soil geographic (STATSGO) database data use information: U.S. Department of Agriculture*; Miscellaneous Publication; 1492; U.S. Department of Agriculture, Natural Resources Conservation Service., 1994; p 113.
(7) Crawford, C. G. Estimation of suspended-sediment rating curves and mean suspended-sediment loads. *J. Hydrol.* **1991**, *129* (1–4), 331–348.
(8) Cohn, T. A.; Caulder, D. L.; Gilroy, E. J.; Zynjuk, L. D.; Summers, R. M. The validity of a simple statistical model for estimating fluvial constituent loads: An Empirical study involving nutrient loads entering Chesapeake Bay. *Water Resour. Res.* **1992**, *28* (9), 2353–2363.
(9) Schwarz, G. E.; Hoos, A. B.; Alexander, R. B.; Smith, R. A. *Section 3. The SPARROW Surface Water-Quality Model: Theory, Application and User Documentation*; Techniques and Methods; Report 6-B3; 2006; p 256.
(10) Stenback, G. A.; Crumpton, W. G.; Schilling, K. E.; Helmers, M. J. Rating curve estimation of nutrient loads in Iowa rivers. *J. Hydrol.* **2011**, *396* (1–2), 158–169.
(11) Hirsch, R. M. Large Biases in Regression-Based Constituent Flux Estimates: Causes and Diagnostic Tools. *JAWRA J. Am. Water Resour. Assoc.* **2014**, *50* (6), 1401–1424.
(12) Aulenbach, B. T. Improving regression-model-based streamwater constituent load estimates derived from serially correlated data. *J. Hydrol.* **2013**, *503*, 55–66.
(13) Conservation Effects Assessment Project (CEAP). *Assessment of the Effects of Conservation Practices on Cultivated Cropland in the Upper Mississippi River Basin*; United States Department of Agriculture (USDA), Natural Resources Conservation Service (NRCS), 2012; p 187.
(14) White, M. J.; Santhi, C.; Kannan, N.; Arnold, J. G.; Harmel, D.; Norfleet, L.; Allen, P.; DiLuzio, M.; Wang, X.; Atwood, J.; et al. Nutrient delivery from the Mississippi River to the Gulf of Mexico and effects of cropland conservation. *J. Soil Water Conserv.* **2014**, *69* (1), 26–40.
(15) Wang, X.; Kannan, N.; Santhi, C.; Potter, S. R.; Williams, J. R.; Arnold, J. G. Integrating APEX output for cultivated cropland with SWAT simulation for regional modeling. *Trans ASABE* **2011**, *54* (4), 1281–1298.