

Table S1. USGS reference sites used to estimate natural background concentrations of nutrients in streams of the conterminous United States [ref. (5)].

Site ID	Site Name	Drainage Area (km <sup>2</sup> )	Runoff (cm yr <sup>-1</sup> )	Nutrient Criteria Region	Yield	
					TN (kg km <sup>-2</sup> yr <sup>-1</sup> )	TP (kg km <sup>-2</sup> yr <sup>-1</sup> )
1054200	Wild River, Maine	180.0	83.5	Nutrient Poor Largely Glaciated Upper Midwest and Northeast	100.5	6.9
1137500	Ammonoosuc R., NH	229.0	61.4	Nutrient Poor Largely Glaciated Upper Midwest and Northeast	61.4	3.1
1170100	Green R., CT	107.0	54.2	Nutrient Poor Largely Glaciated Upper Midwest and Northeast	54.2	8.0
1362200	Esopus Ck., NY	169.0	67.4	Nutrient Poor Largely Glaciated Upper Midwest and Northeast	235.7	25.0
1434025	Biscuit Brook, NY	10.4	83.9	Nutrient Poor Largely Glaciated Upper Midwest and Northeast	384.8	4.2
1466500	MacDonalds Branch, NJ	6.1	21.5	Eastern Coastal Plain	41.5	2.2
1545600	Young Womens Creek, PA	120.0	60.1	Nutrient Poor Largely Glaciated Upper Midwest and Northeast	302.3	5.7
1608000	S. Fork Potomac R., WV	724.0	33.8	Central and Eastern Forested Uplands	375.3	12.6
2038850	Holiday Creek, VA	22.0	37.2	Southeastern Temperate Forested Plains and Hills	77.3	11.6
2084557	Van Swamp, NC	56.0	32.6	Eastern Coastal Plain	838.0	10.5
2135300	Scape Ore Swamp, SC	249.0	43.8	Eastern Coastal Plain	268.5	8.5
2229000	Middle St. Marys R., FL	326.0	26.4	Southern Coastal Plain	276.9	5.8
2327100	Sopchoppy R., FL	265.0	75.4	Southern Coastal Plain	559.1	15.4
2337500	Snake Ck., GA	92.0	46.9	Southeastern Temperate Forested Plains and Hills	199.4	43.6
2369800	Blackwater R., AL	227.0	63.3	Southern Coastal Plain	234.7	8.4
2450250	Sipsey Fork, AL	239.0	63.8	Central and Eastern Forested Uplands	122.4	18.7
2479155	Cypress Ck, MS	136.0	69.6	Southern Coastal Plain	357.8	11.2
3237280	Upper Twin Ck, OH	32.0	34.4	Central and Eastern Forested Uplands	145.0	4.9
3460000	Cataloochee Ck, NC	127.0	90.5	Central and Eastern Forested Uplands	347.0	23.3
3497300	Little R, TN	275.0	103.2	Central and Eastern Forested Uplands	165.4	13.3
4001000	Washington Ck, MI	34.0	35.9	Nutrient Poor Largely Glaciated Upper Midwest and Northeast	209.2	5.9
4062085	Peshekee R., MI	114.0	66.4	Nutrient Poor Largely Glaciated Upper Midwest and Northeast	325.2	8.7
4063700	Popple R., WI	360.0	28.7	Nutrient Poor Largely Glaciated Upper Midwest and Northeast	200.3	7.0
5124480	Kawishiwi R, MN	655.0	22.7	Nutrient Poor Largely Glaciated Upper Midwest and Northeast	137.5	3.5
6169500	Rock Ck, MT	850.0	1.1	South Central Cultivated Great Plains	12.3	2.1
6409000	Castle Cr, SD	205.0	5.6	Western Forested Mountains	14.0	1.9
6623800	Encampment Ck, WY	188.0	46.2	Western Forested Mountains	84.7	8.0
6719505	Clear Ck., CO	1003.0	20.1	Western Forested Mountains	54.2	16.4
6752000	Cache la Poudre R., CO	2664.0	10.6	Western Forested Mountains	29.7	3.0
6753400	Lonetree Ck. At Carr, CO	445.0	0.1	South Central Cultivated Great Plains	0.5	0.1
6775900	Dismal R, NE	2500.0	7.5	Great Plains Grass and Shrublands	54.1	14.9
6879650	Kings Ck, KS	10.6	28.5	Great Plains Grass and Shrublands	50.4	9.2
6925315	Paddy Ck., MO	79.0	31.6	Central and Eastern Forested Uplands	63.1	13.1
7056000	Buffalo R. nr St. Joe, AR	2149.0	55.0	Central and Eastern Forested Uplands	55.0	11.6
7060710	N. Sylamore Ck, AR	150.0	29.8	Central and Eastern Forested Uplands	68.0	7.5
7083000	Halfmoon Ck, CO	61.0	36.4	Western Forested Mountains	85.5	4.9
7340300	Cossatot R, AR	232.0	88.1	Central and Eastern Forested Uplands	93.9	11.6

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Table S1. (continued)

Site ID	Site Name	Drainage Area (km <sup>2</sup> )	Runoff (cm yr <sup>-1</sup> )	Nutrient Criteria Region	Yield	
					TN (kg km <sup>-2</sup> yr <sup>-1</sup> )	TP (kg km <sup>-2</sup> yr <sup>-1</sup> )
7373000	Big Crk, LA	132.0	51.5	Texas-Louisiana Coastal and Miss Aluvial Plain	447.7	27.9
8066295	Menard Ck., TX	299.0	55.1	Texas-Louisiana Coastal and Miss Aluvial Plain	241.1	34.4
8103900	South Fk Rocky Ck, TX	86.0	15.0	Great Plains Grass and Shrublands	107.1	4.7
8227000	Saguache Ck., CO	1327.0	4.3	Western Forested Mountains	18.9	5.1
8313350	Rito de los Frijoles, NM	47.0	3.4	Western Forested Mountains	3.4	1.4
8377900	Rio Mora, NM	138.0	31.0	Western Forested Mountains	51.1	6.2
9352900	Vallecito Ck, CO	187.0	59.5	Western Forested Mountains	128.4	9.8
9430600	Mogollan Ck, NM	179.0	21.8	Western Forested Mountains	34.7	6.1
9508300	Wet Bottom Ck, AZ	94.0	23.6	Western Forested Mountains	57.9	7.1
10172200	Red Butte Ck, UT	18.8	13.5	Xeric West	23.1	11.3
10244950	Steptoe Ck, NV	29.0	9.9	Xeric West	9.9	1.7
10249300	South Twin Creek, NV	52.0	6.0	Xeric West	6.0	0.3
10309010	East Fork Carson R., NV	970.0	41.4	Xeric West	41.4	25.0
10343500	Sagehen Ck, CA	27.0	21.3	Western Forested Mountains	35.4	3.4
10346000	Truckee R. at Farad, CA	2416.0	25.1	Western Forested Mountains	25.1	3.4
11264500	Merced R, CA	469.0	60.9	Western Forested Mountains	124.5	9.0
11475560	Elder Ck, CA	16.8	47.5	Western Forested Mountains	47.9	10.2
12416000	Hayden Ck, ID	57.0	31.2	Western Forested Mountains	62.3	2.8
12447390	Andrews Ck, WA	57.0	39.4	Western Forested Mountains	157.5	8.6
13010065	Snake R. at Flagg Ranch, WY	1324.0	53.8	Western Forested Mountains	126.6	28.0
13018300	Cache Ck, WY	27.0	31.5	Western Forested Mountains	85.4	11.3
13120500	Big Lost R., ID	1144.0	25.2	Western Forested Mountains	25.3	10.7
13169500	Big Jacks Ck, ID	655.0	0.4	Xeric West	2.1	0.5
13331500	Minam R, OR	622.0	54.7	Western Forested Mountains	142.9	14.4
14200400	Little Abiqua Ck., OR	25.0	107.8	Western Forested Mountains	584.0	14.3
14203750	Gales Ck., OR	18.0	163.1	Western Forested Mountains	791.2	81.5

*Regional indicator variables*

Regional indicator variables were developed by first conducting exploratory regressions based on eq 1 with a single "regional" coefficient (i.e.  $b_R = b$ ) representing all nutrient ecoregions. Indicator variables (**R**) were then added to represent combinations of nutrient ecoregions that displayed strongly biased regression errors (negative or positive) in the exploratory regressions. The resulting combinations of nutrient ecoregions were as follows (see Figure 1):

Total Nitrogen Model

Regional Indicator 1: Willamette/Central Valleys, Western Forested Mountains, Great Plains Grass and Shrubland, Glaciated Upper Midwest and N.E., Mostly Glaciated Dairy Region, S.W. Temperate Forested Plains/Hills, Central/E. Forested Uplands

Regional Indicator 2: Cultivated Great Plains, Corn Belt and N. Great Plains, TX-LA Coastal/MS Alluvial Plains, Southern Coastal Plain, Southern FL Coastal Plain, Eastern Coastal Plain

Regional Indicator 3: Xeric West

Total Phosphorus model

**Regional Indicator 1:** *Willamette/Central Valleys, Western Forested Mountains, Xeric West, Mostly Glaciated Dairy Region, Central/E. Forested Uplands, Southern Coastal Plain, Southern Florida Coastal Plain*

Regional Indicator 2: Great Plains Grass and Shrublands, Cultivated Great Plains, Corn Belt and Northern Great Plains, SE Temperate Forested Plains/Hills, TX-LA Coastal and MS Alluvial Plains

Regional Indicator 3: Nutrient Poor Largely Glaciated Upper Midwest and Northeast,  
Eastern Coastal Plain

Three nutrient ecoregions do not contain reference sites; in model applications (see below) these were combined with adjacent ecoregions as follows: the Corn Belt and Northern Great Plains was combined with the Cultivated Great Plains; the Mostly Glaciated Dairy Region was combined with the Glaciated Midwest and Northeast; and the Southern Florida Coastal Plain was combined with the Southern Coastal Plain.

*In-stream nutrient loss rates*Table S2. First-order rate coefficients ( $\text{day}^{-1}$ ) used to determine in-stream losses of TN and TP during transport through RF1 streams and rivers.

Contaminant	Channel characteristics	Coefficient Value ( $\text{day}^{-1}$ )	Bootstrap 90% CI ( $\text{day}^{-1}$ )	Reference
<i>Total nitrogen</i>	Streamflow: Q < 28.3 $\text{m}^3/\text{s}$	0.455	0.344-0.579	(S1)
	Streamflow: 28.3 $\text{m}^3/\text{s}$ < Q < 283 $\text{m}^3/\text{s}$	0.118	0.063-0.176	"
	Streamflow: 283 $\text{m}^3/\text{s}$ < Q < 850 $\text{m}^3/\text{s}$	0.051	0.007-0.092	"
	Streamflow: Q > 850 $\text{m}^3/\text{s}$	0.005	0.000-0.019	"
<i>Total phosphorus</i>	Streamflow: Q < 28.3 $\text{m}^3/\text{s}$	0.258	0.189-0.350	(S2)
	Streamflow: 28.3 $\text{m}^3/\text{s}$ < Q < 283 $\text{m}^3/\text{s}$	0.096	0.016-0.183	"
	Streamflow: Q > 283 $\text{m}^3/\text{s}$	0.000 <sup>a</sup>	<sup>a</sup>	"
	Reservoir reach	0.359 <sup>b</sup>	0.226-0.470	"

<sup>a</sup> Estimation resulted in a small, statistically insignificant coefficient value ( $p > 0.5$ ); coefficient assumed = 0.<sup>b</sup> For purposes of predicting background TP yields and concentrations in this study, loss coefficients for stream reaches with present-day reservoirs were replaced with ones based on flow characteristics of the river prior to impoundment.

*Atmospheric deposition of TN*

Data from the National Atmospheric Deposition Program (NADP, 1993) were used to develop a TN deposition surface for the conterminous United States. Approximately weekly measurements of nitrate and ammonium deposition at 188 monitoring stations for the period of record (early 1980s to 1993) were used to determine long-term mean deposition rate for each station. Spatially continuous values of wet TN deposition over the conterminous U. S. were developed through linear interpolation of the set of 188 point estimates. The interpolated deposition surface was used to assign average TN deposition rates to the water-quality reference basins for model calibration and to the RFI reach watersheds for model application. Statistical details of the procedure are given in reference (S3).

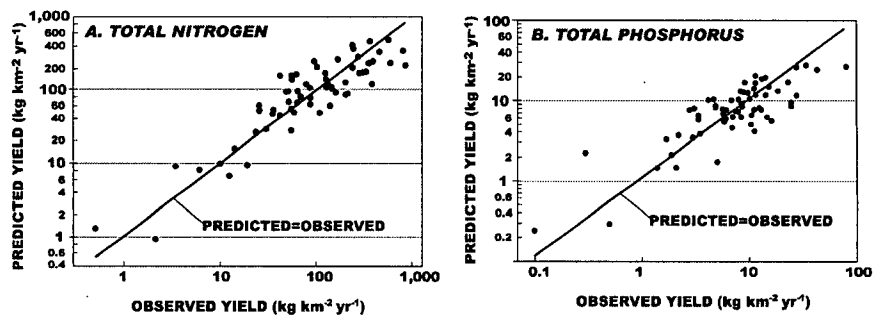


Figure S1. Model-predicted yield vs. observed yields for 63 USGS reference sites: A) total nitrogen; B) total phosphorus.

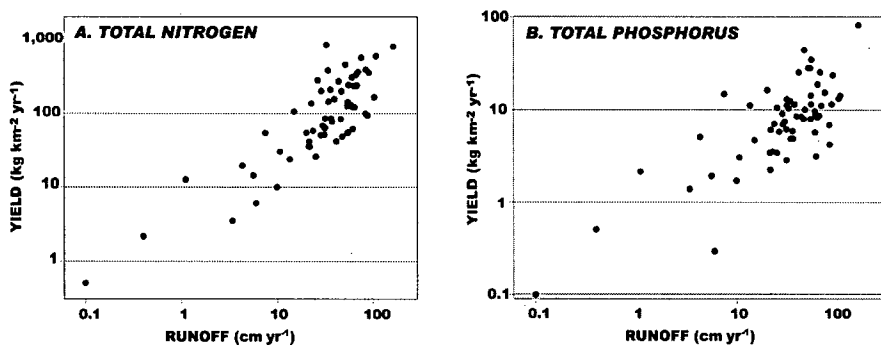


Figure S2. Yield vs. runoff for 63 USGS reference sites: A) total nitrogen; B) total phosphorus.

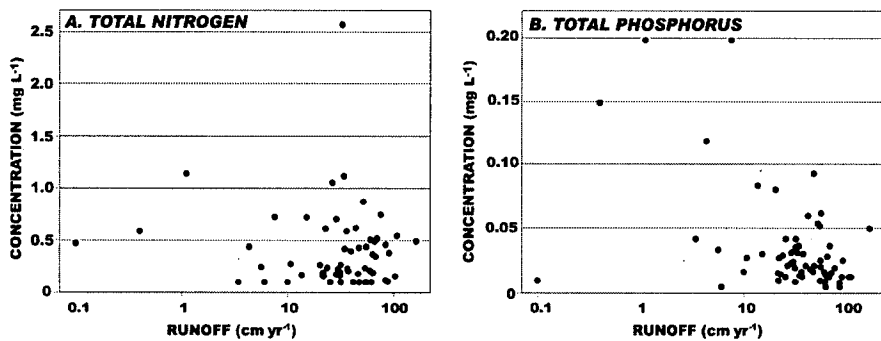


Figure S3. Concentration vs. runoff for 63 USGS reference sites: A) total nitrogen; B) total phosphorus.

Table S3. Upper quartile of predicted background nutrient concentrations compared with EPA-estimated lower quartile of actual concentrations, by nutrient ecoregion. Accuracy (standard deviation) of upper-quartile estimate is shown in parenthesis. Accuracy statistics are based on bootstrap procedures (2) which account for the error associated with the parameters of the background yield models (Table 1, main text), the loss coefficients of the in-stream transport models (Table S1), and the unexplained variance ("model error") of the background yield model regressions.

Region	Total Nitrogen		Total Phosphorus	
	Upper quartile of predicted background concentrations (mg/l)	EPA-estimated lower quartile of actual concentrations (mg/l)	Upper quartile of predicted background concentration (mg/l)	EPA-estimated lower quartile of actual concentrations (mg/l)
	With Deposition	W/o Deposition		
1. Willamette/Central Valleys	0.21 (0.07)	0.18 (0.07)	0.02 (0.005)	0.05
2. Western Forested Mountains	0.21 (0.05)	0.18 (0.07)	0.02 (0.005)	0.01
3. Xeric West	0.11 (0.04)	0.05 (0.07)	0.03 (0.015)	0.02
4. Great Plains Grass/Shrublands	0.21 (0.10)	0.12 (0.08)	0.07 (0.035)	0.02
5. Cultivated Great Plains	0.51 (0.22)	0.37 (0.24)	0.07 (0.035)	0.07
6. Corn Belt and N. Great Plains	0.62 (0.26)	0.44 (0.21)	0.06 (0.020)	0.08
7. Mostly Glaciated Dairy Region	0.33 (0.12)	0.17 (0.06)	0.03 (0.005)	0.03
8. Glaciated Upper Midwest and N.E.	0.28 (0.08)	0.18 (0.07)	0.02 (0.010)	0.01
9. S.E. Temperate Forested Plains/Hills	0.28 (0.08)	0.17 (0.06)	0.05 (0.020)	0.04
10. TX-LA Coastal/MS Alluvial Plains	0.67 (0.24)	0.55 (0.22)	0.06 (0.025)	0.13
11. Central/E. Forested Uplands	0.29 (0.09)	0.17 (0.06)	0.02 (0.005)	0.01
12. Southern Coastal Plain	0.71 (0.29)	0.61 (0.29)	0.03 (0.005)	0.04
13. Southern FL Coastal Plain	0.79 (0.43)	0.65 (0.42)	0.04 (0.015)	NA
14. Eastern Coastal Plain	0.76 (0.30)	0.63 (0.28)	0.02 (0.005)	0.03

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Table S4. Frequency distribution of the accuracy (standard deviation as a percent of the estimate) of total nitrogen and total phosphorus concentration estimates in individual RF1 stream reaches. Accuracy statistics are based on bootstrap procedures (2) which account for the error associated with the parameters of the background yield models (see Table 1, main text), the loss coefficients of the in-stream transport models (Table S1), and the unexplained variance ("model error") of the background yield model regressions.

Statistic	Total nitrogen, w. deposition (%)	Total nitrogen, w.o. deposition (%)	Total phosphorus (%)
25 <sup>th</sup> percentile	39	58	37
Median	58	61	56
75 <sup>th</sup> percentile	64	70	64
Mean	53	62	51

Table S5. Estimated percent of reaches in nutrient ecoregions with predicted background nutrient concentration greater than the EPA-estimated lower-quartile of actual concentrations. Estimates include the effects of the errors associated with single-reach concentration predictions (Table S4).

Region	Total Nitrogen		Total Phosphorus	
	Percent of reaches above lower quartile	EPA-estimated lower quartile of actual concentrations (mg/l)	Percent of reaches above lower quartile	EPA-estimated lower quartile of actual concentrations (mg/l)
	With Deposition	W/o Deposition		
1. Willamette/Central Valleys	6	3	0.38	0.05
2. Western Forested Mountains	59	48	0.12	0.01
3. Xeric West	1	<1	0.38	0.02
4. Great Plains Grass/Shrublands	13	3	0.29	0.02
5. Cultivated Great Plains	11	6	0.71	0.07
6. Corn Belt and N. Great Plains	<1	<1	2.18	0.08
7. Mostly Glaciated Dairy Region	8	<1	0.54	0.03
8. Glaciated Upper Midwest and N.E.	50	22	0.20	0.01
9. S.E. Temperate Forested Plains/Hills	2	<1	0.69	0.04
10. TX-LA Coastal/MS Alluvial Plains	14	9	0.85	0.13
11. Central/E. Forested Uplands	24	7	0.30	0.01
12. Southern Coastal Plain	16	11	0.90	0.04
13. Southern FL Coastal Plain	NA	NA	NA	NA
14. Eastern Coastal Plain	30	21	0.71	0.03

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Table S6. Effect on predicted total-phosphorus (TP) concentrations of replacing loss coefficients in stream reaches in present-day reservoirs with coefficient values based on flow characteristics of the reach prior to impoundment (see Table S1). The frequency distributions apply only to RFI reaches in large reservoirs (5187 of a total 60,221 reaches). The results indicate that changing coefficient values for purposes of simulating natural channel conditions had little effect on predicted TP concentration for the majority of reservoirs. The exceptions are mostly large reservoirs with long water residence times. TP concentrations in reaches downstream of reservoirs would show progressively smaller effects than those summarized here.

River Size (Q = mean streamflow)	Ratio of concentration w/o reservoir to concentration with reservoir					
	Reservoir Reaches	Minimum	25 <sup>th</sup>	Median	75 <sup>th</sup> Maximum	
Small (Q < 1000 ft <sup>3</sup> s <sup>-1</sup> )	3,818	1.00	1.04	1.09	1.23	4.83
Medium (1000 < Q < 10,000 ft <sup>3</sup> s <sup>-1</sup> )	941	1.00	1.10	1.21	1.39	2.98
Large (Q > 10,000 ft <sup>3</sup> s <sup>-1</sup> )	428	1.00	1.11	1.31	1.60	3.41

## Literature Cited

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- (3) Alexander, R.B.; Smith, R.A.; Schwarz, G.E.; Preston, S.D.; Brakebill, J.W.;  
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