STATE OF MICHIGAN
DEPARTMENT OF ENVIRONMENTAL QUALITY
LANSING

JENNIFER M. GRANHOLM
GOVERNOR

STEVEN E. CHESTER
DIRECTOR

October 20, 2009

TO: Mary Fales, Macatawa Area Coordinating Council

FROM: Dave Fongers, Hydrologic Studies Unit, Land and Water Management Division

Dave Fongers

SUBJECT: Macatawa Watershed Loading Analysis, Ottawa and Allegan Counties

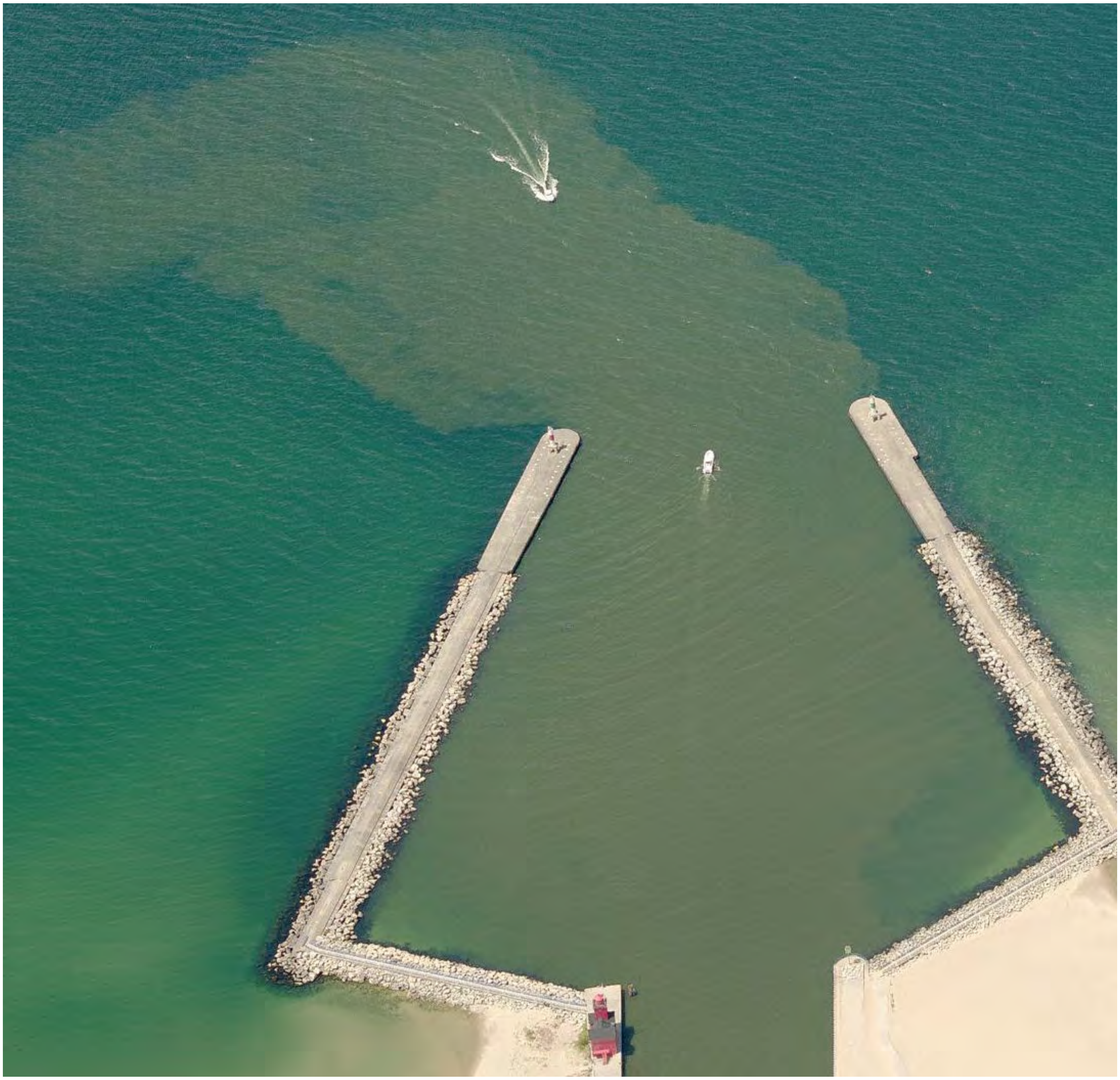
As requested, the Hydrologic Studies Unit of the Land and Water Management Division has completed its loading analysis of the Macatawa watershed. Nothing in the report is an authorization to do any work within the watershed that would require a permit, or guarantees that grant proposals based on this report will be permitted or funded.

If you have any questions or comments regarding this report, please contact me at 517-373-0210.

Attachment

cc: Julia Kirkwood, WB, MDEQ
Michelle Storey, WB, MDEQ
Peter Vincent, WB, MDEQ
Amy Peterson, WB, MDEQ
Ralph Reznick, WB, MDEQ
Marlio Lesmez, LWMD, MDEQ

Macatawa Watershed Modeled Pollutant Loads



Dave Fongers
Hydrologic Studies Unit
Land and Water Management Division
Michigan Department of Environmental Quality
August 31, 2009

DEQ
Michigan's Nonpoint Source Program
www.michigan.gov/deqnps

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This Nonpoint Source (NPS) Pollution Control project has been funded wholly by the United States Environmental Protection Agency (EPA) through a Part 319 grant to the Michigan Department of Environmental Quality. This study is in support of a NPS Macatawa watershed planning grant, 2008-0016. The contents of the document do not necessarily reflect the views and policies of the EPA, nor does the mention of trade names or commercial products constitute endorsement or recommendation for use.

The cover depicts the flow from Lake Macatawa into Lake Michigan. Aerial photography courtesy of www.bing.com/maps/.

For comments or questions relating to this document, contact Dave Fongers at:

MDEQ, LWMD, P.O. Box 30458, Lansing, MI 48909
fongersd@michigan.gov or 517-373-0210

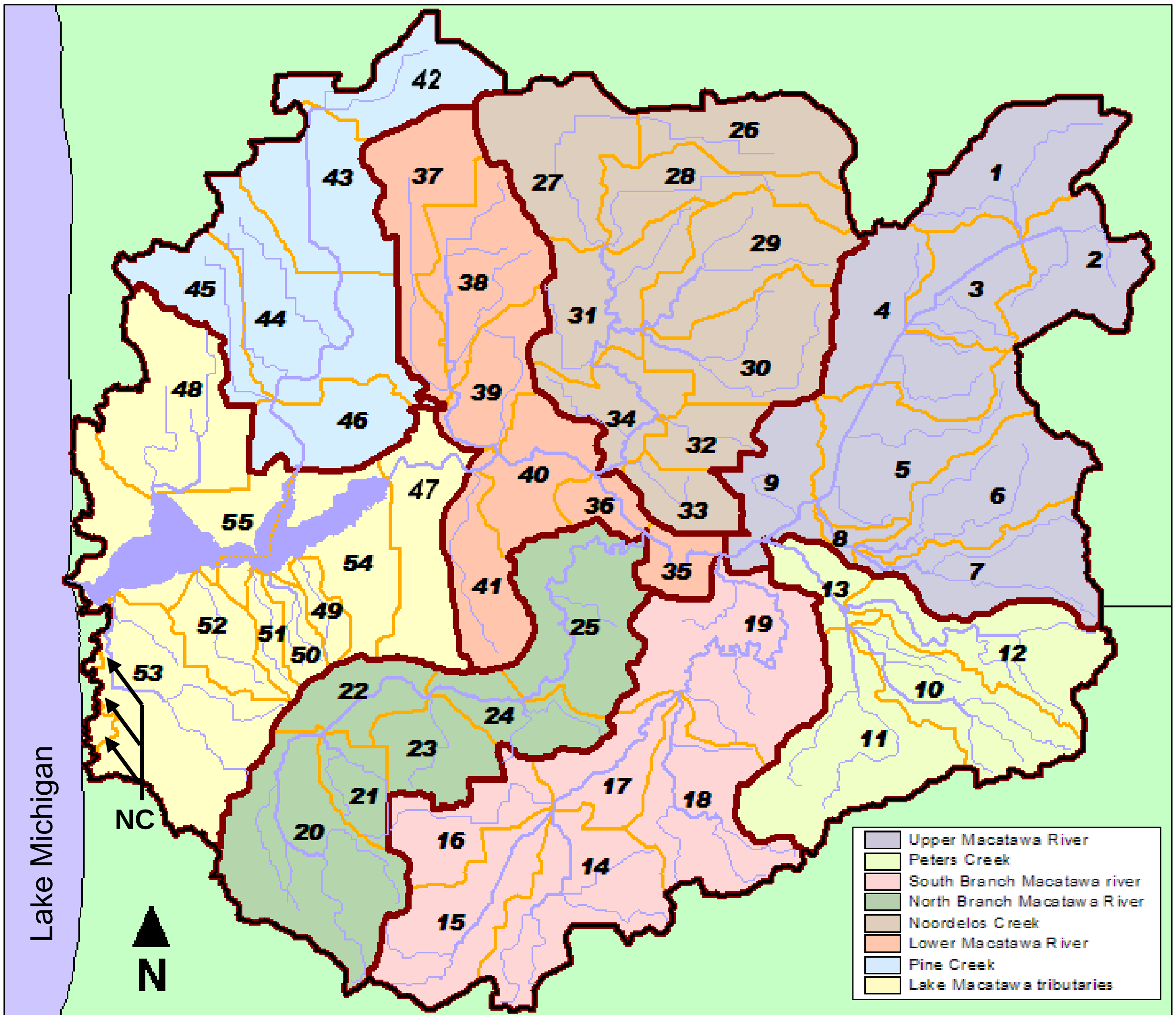
Purpose

The EPA requires watershed management plans funded through Section 319 grants to quantify pollutant loads in order to focus management efforts and implementation practices where they will provide the greatest pollutant load reductions. This study of the Macatawa watershed was conducted by the Hydrologic Studies Unit (HSU) of the Michigan Department of Environmental Quality (MDEQ) to help fulfill those requirements. The modeling estimates annual runoff volumes using precipitation, land use, and soil data. Pollutant loads for each subbasin are then estimated using annual runoff and loadings by land cover as defined in the Water Quality Trading Rules, www.state.mi.us/orr/emi/admincode.asp?AdminCode=Single&Admin_Num=32303001&Dpt=EQ&RngHigh. The modeling does not include local anomalies, such as gully erosion, or in-stream processes, such as channel erosion. The modeled load estimates do not replace in-stream monitoring data.

Watershed Description

The 175-square mile Macatawa watershed includes portions of Ottawa and Allegan Counties. This study divides the watershed into 55 subbasins, Figure 1. Some areas have been identified as non-contributing, meaning that they do not have an apparent overland outlet for surface runoff. We have assumed that these areas, all within the Kelly Lake Drain subbasin and totaling 0.27 square miles, do not contribute surface runoff to Kelly Lake Drain or its tributaries. Runoff may pool within the areas, but that runoff has no natural outlet and therefore must either evaporate or infiltrate. If these areas become developed, artificial drainage may be installed, potentially increasing runoff to Kelly Lake Drain. Runoff from the non-contributing areas has not been included in the model.

For this analysis, Lake Macatawa is considered hydraulically equal to Lake Michigan. Further, we assume Lake Macatawa begins where the flood insurance study begins to show an increase in predicted flood elevations, which is 4,000 feet upstream of Butternut Drive/River Avenue. This is approximately equivalent to Windmill Island.



1	Beaver Dam Drain to Macatawa River	29	Hunters Creek to Brower Drain
2	Macatawa River to Beaver Dam Drain	30	Brower Drain to Hunters Creek
3	Macatawa River at 72nd Avenue	31	Noordeloos Creek to Drain #52
4	Macatawa River at I-196 Overpass	32	Cedar Drain to Noordeloos Creek
5	Macatawa River to Hunderman Creek	33	Drain #4 and 43 to Noordeloos Creek
6	Big Creek to Hunderman Creek	34	Noordeloos Creek to Macatawa River
7	Hunderman Creek to Big Creek	35	Macatawa River to North Branch
8	Hunderman Creek to Macatawa River	36	Macatawa River to Noordeloos Creek
9	Macatawa River to South Branch	37	North Holland Creek to Drain #40
10	Unnamed tributary to Peters Drain	38	Drain #15 and 17 to Drain #40
11	Peters Drain	39	Drain #40 to Macatawa River
12	Unnamed tributary to Peters Creek	40	Macatawa River to Windmill Island
13	Peters Creek to Macatawa River	41	Maplewood Intercounty Drain to Macatawa River
14	Kleinheksel Drain to South Branch	42	Troost and Boven Dam Drains to Pine Creek/Harlem Drain
15	Jaarda Drain to South Branch	43	Pine Creek/Harlem Drain at Quincy St.
16	South Branch Macatawa River to Jaarda Drain	44	Pine Creek/Harlem Drain to Drain #37
17	South Branch Macatawa River to unnamed tributary near 146th	45	Drain #37 to Pine Creek/Harlem Drain
18	East Fillmore Drain (including Eskes Drain)	46	Pine Creek/Harlem Drain to Lake Macatawa
19	South Branch Macatawa River to Macatawa River	47	Macatawa River/Lake Macatawa
20	North Branch Macatawa River to Den Bleyker Drain	48	Winstrom Creek and Drains #20A, 23, 53 to Lake Macatawa
21	Vanderbie Drain and Rotman Drain	49	Old Lela Drain to Lake Macatawa
22	North Branch Macatawa River to Den Bleyker Drain	50	Weller Drain to Lake Macatawa
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25	North Branch Macatawa River to Macatawa River	53	Kelly Lake Drain to Lake Macatawa
26	Bosch and Hulst Drain at 104th Avenue	54	East Lake Macatawa drainage (does not include lake)
27	Bosch and Hulst Drain to Noordeloos Creek	55	West Lake Macatawa drainage (does not include lake)
28	Tributary to Bosch and Hulst Drain to Noordeloos Creek	NC	Non-contributing

Figure 1 – Macatawa Watershed Subbasin Identification

Hydrologic Analysis Parameters

GIS Data

This study uses soil, 1978 land cover, and 2005 land cover GIS data as described in the Macatawa Watershed Hydrologic Study, www.michigan.gov/documents/deq/lwm-nps-macatawa-hydro_289356_7.pdf.

Runoff Curve Numbers

Surface runoff volumes were modeled using the weighted Q runoff curve number technique. The runoff curve number technique, developed by the Natural Resources Conservation Service (NRCS) in 1954, represents the runoff characteristics from the combination of land use and soil data as a runoff curve number. The runoff curve numbers (CN) were calculated for each land cover and soil complex using GIS technology from the land use and soil data. In the weighted Q method, runoff from each land cover and soil complex is calculated and then summed for the area of interest.

Rainfall

The rainfall used in this study is based on 2002 – 2008 data from the Hudsonville weather station in the Michigan Automated Weather Network, Figure 2. The data for the West Olive station is shown as a consistency check. Hudsonville's annual average precipitation for the period is 30.18 inches.

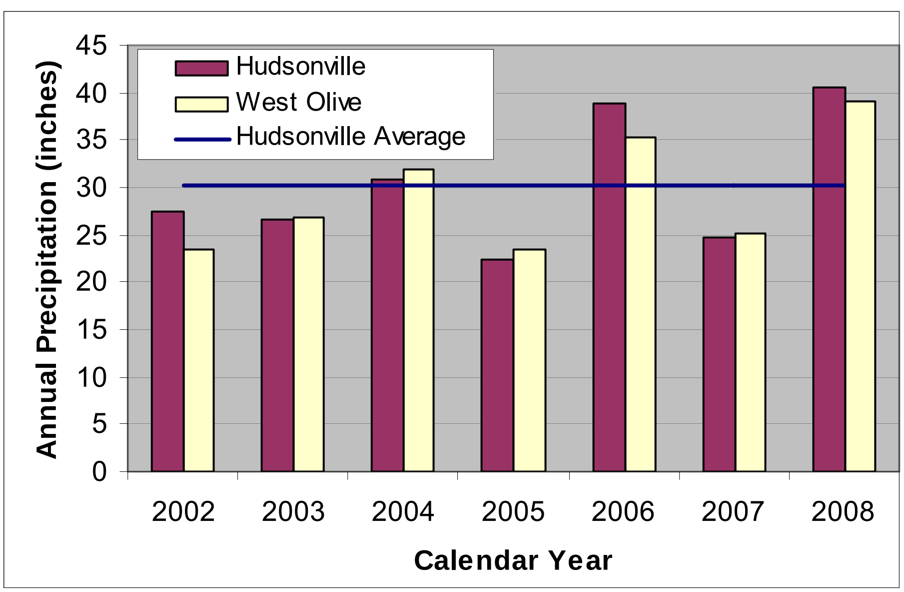

Figure 2 – Annual Precipitation

Annual Runoff Calculations

Runoff by curve number per storm event was calculated for each year. The runoff for each curve number was summed for each of the seven years and then averaged. The results are shown in Table 1.

Table 1

Curve Number	Runoff Volume (inches)	Curve Number	Runoff Volume (inches)	Curve Number	Runoff Volume (inches)
100	30.18	75	2.85	50	0.33
99	25.07	74	2.63	49	0.30
98	21.78	73	2.42	48	0.27
97	19.24	72	2.24	47	0.24
96	17.18	71	2.06	46	0.21
95	15.45	70	1.90	45	0.18
94	13.97	69	1.75	44	0.16
93	12.68	68	1.62	43	0.14
92	11.56	67	1.49	42	0.12
91	10.55	66	1.37	41	0.10
90	9.66	65	1.26	40	0.08
89	8.86	64	1.16	39	0.07
88	8.14	63	1.07	38	0.05
87	7.49	62	0.98	37	0.04
86	6.89	61	0.91	36	0.03
85	6.35	60	0.83	35	0.02
84	5.85	59	0.76	34	0.02
83	5.40	58	0.70	33	0.01
82	4.98	57	0.64	32	0.00
81	4.60	56	0.59	31	0.00
80	4.25	55	0.54	30	0.00
79	3.92	54	0.49		
78	3.62	53	0.45		
77	3.34	52	0.41		
76	3.08	51	0.37		

Event Mean Concentrations

Event Mean Concentrations are as defined in the Water Quality Trading Rules, www.state.mi.us/orr/emi/admincode.asp?AdminCode=Single&Admin_Num=32303001&Dpt=EQ&RngHigh and shown in Table 2. For the Macatawa watershed, Total Suspended Solids (TSS), Total Phosphorous (TP), NO_2 plus NO_3, and Total Kjeldahl Nitrogen (TKN) were calculated for each subbasin. Loads were calculated using the following equation, as described in the trading rules.

$$Load_P = \Sigma\, EMC_L \times R_L \times A_L \times K$$

where:

$Load_P$= total average annual load, expressed in pounds.
EMC_L= event mean concentration of stormwater runoff from a specific land use L (mg/l).
R_L = total average annual storm water runoff from land use L (in/yr).
A_L = area (acres) for land use L.
K = 0.2266, a unit conversion constant, for all parameters.

Table 2 – Water Quality Trading Rule Event Mean Concentrations

Land use category (non-site specific)	TSS (mg/l)	BOD (mg/l)	TP (mg/l)	DP (mg/l)	TKN (mg/l)	NO2+3 (mg/l)	Pb (ug/l)	Cu (ug/l)	Zn (ug/l)	Cd (ug/l)
Forest/rural open	51	3	0.11	0.027	0.94	0.80	0.0	0.0	0.0	0.0
Urban open	51	3	0.11	0.03	0.94	0.80	14.2	0.0	40.2	0.8
Agricultural	145	3	0.37	0.09	1.92	4.06	0.0	0.0	0.0	0.0
Low density residential	70	38	0.52	0.27	3.32	1.83	56.9	26.2	161.1	3.9
Medium density residential	70	38	0.52	0.27	3.32	1.83	56.9	26.2	161.1	3.9
High density residential	97	14	0.24	0.08	1.17	2.12	40.5	33.0	217.9	3.2
Commercial	77	21	0.33	0.17	1.74	1.23	49.3	37.0	156.3	2.7
Industrial	149	24	0.32	0.11	2.08	1.89	72.4	58.0	670.8	4.8
Highways	141	24	0.43	0.22	1.82	0.83	49.3	37.0	156.3	2.7
Water/wetlands	6	4	0.08	0.04	0.79	0.59	11.1	6.5	30.3	0.6

Results

Annual Runoff Volume

Although the calculated annual runoff results are not the primary purpose of this study, the results are detailed separately because they are used to calculate the pollutant loadings and because the trends may be of interest to watershed stakeholders.

Both the 1978 and 2005 use the same rainfalls. Only the land use is varied. The modeled changes are therefore caused by land use changes. Runoff volumes for pervious and impervious surfaces were calculated separately as detailed in the Macatawa Watershed Hydrologic Study, www.michigan.gov/documents/deq/lwm-nps-macatawa-hydro_289356_7.pdf.

Average annual runoff volumes for each subbasin are shown in Table 4. Table 3 details the total volume to key points in the watershed. The model calculated a total of 48,600 acre-feet of runoff from the watershed with the 1978 land use scenario. Using 2005 land use, it calculated 57,800 acre-feet, an increase of 9,200 acre-feet or 19 percent.

Table 3 – Annual Runoff Volume Summary

Description	Scenario	Volume		
		(acre-feet)	(gallons)	Increase
Macatawa River	1978	34,400	11,210,000,000	19%
	2005	40,900	13,330,000,000	
Other Tributaries to Lake Macatawa	1978	7,600	2,460,000,000	31%
	2005	9,900	3,230,000,000	
Direct Drainage to Lake Macatawa	1978	2,100	680,000,000	16%
	2005	2,400	790,000,000	
Total to Lake Macatawa	1978	44,100	14,360,000,000	21%
	2005	53,200	17,340,000,000	
Lake Macatawa	Both	4,500	1,480,000,000	NA
Total including Lake Macatawa	1978	48,600	15,830,000,000	19%
	2005	57,800	18,820,000,000	

Table 4 – Annual Runoff Volume by Subbasin

ID	Subbasin	Volume (acre-inches)		Volume (inches)		
		1978	2005	1978	2005	Change
1	Beaver Dam Drain to Macatawa River	11,100	11,800	4.44	4.73	6%
2	Macatawa River to Beaver Dam Drain	11,000	10,400	5.36	5.08	-5%
3	Macatawa River at 72nd Avenue	7,450	7,390	4.35	4.31	-1%
4	Macatawa River at I-196 Overpass	15,600	17,000	5.39	5.85	9%
5	Macatawa River to Hunderman Creek	14,200	15,100	5.25	5.61	7%
6	Big Creek to Hunderman Creek	13,400	14,100	5.55	5.85	5%
7	Hunderman Creek to Big Creek	11,000	11,200	4.77	4.86	2%
8	Hunderman Creek to Macatawa River	774	1,030	3.03	4.04	33%
9	Macatawa River to South Branch	9,080	10,600	5.29	6.19	17%
10	Unnamed tributary to Peters Drain	11,000	11,100	4.71	4.79	2%
11	Peters Drain	15,300	15,500	4.47	4.52	1%
12	Unnamed tributary to Peters Creek	12,900	13,000	5.17	5.19	0%
13	Peters Creek to Macatawa River	2,020	2,290	2.39	2.71	14%
14	Kleinheksel Drain to South Branch	15,800	16,000	5.52	5.56	1%
15	Jaarda Drain to South Branch	12,200	12,400	5.07	5.14	1%
16	South Branch Macatawa River to Jaarda Drain	7,550	7,830	4.57	4.74	4%
17	South Branch Macatawa River to unnamed tributary near 146th	6,120	6,920	4.25	4.80	13%
18	East Fillmore Drain (including Eskes Drain)	12,400	12,600	4.78	4.85	1%
19	South Branch Macatawa River to Macatawa River	18,900	19,700	4.72	4.90	4%
20	North Branch Macatawa River to Den Bleyker Drain	19,900	21,000	4.88	5.15	6%
21	Vanderbie Drain and Rotman Drain	4,660	5,180	5.49	6.11	11%
22	North Branch Macatawa River to Den Bleyker Drain	8,070	11,600	6.25	8.98	44%
23	Den Bleyker Drain	8,110	12,100	5.73	8.54	49%
24	North Branch Macatawa River at M-40	8,640	12,000	6.57	9.12	39%
25	North Branch Macatawa River to Macatawa River	15,700	20,100	5.15	6.60	28%
26	Bosch and Hulst Drain at 104th Avenue	4,510	5,810	2.28	2.94	29%
27	Bosch and Hulst Drain to Noordeloos Creek	12,800	12,900	4.71	4.71	0%
28	Tributary to Bosch and Hulst Drain to Noordeloos Creek	6,750	7,200	3.85	4.10	7%
29	Hunters Creek to Brower Drain	9,630	11,500	3.90	4.67	20%
30	Brower Drain to Hunters Creek	14,700	24,200	5.89	9.67	64%
31	Noordeloos Creek to Drain #52	9,760	12,000	4.38	5.37	22%
32	Cedar Drain to Noordeloos Creek	5,800	8,130	6.23	8.73	40%
33	Drain #4 and 43 to Noordeloos Creek	5,630	7,560	5.97	8.02	34%
34	Noordeloos Creek to Macatawa River	7,310	10,200	4.95	6.90	40%
35	Macatawa River to North Branch	4,630	5,610	6.32	7.66	21%
36	Macatawa River to Noordeloos Creek	3,170	3,940	4.96	6.16	24%
37	North Holland Creek to Drain #40	9,250	16,200	3.73	6.54	75%
38	Drain #15 and 17 to Drain #40	10,500	16,400	4.54	7.12	57%
39	Drain #40 to Macatawa River	6,380	13,100	4.54	9.35	106%
40	Macatawa River to Windmill Island	14,900	20,200	8.15	11.08	36%
41	Maplewood Intercounty Drain to Macatawa River	14,400	18,000	8.99	11.21	25%
42	Troost and Boven Dam Drains to Pine Creek/Harlem Drain	6,600	7,290	3.52	3.88	10%
43	Pine Creek/Harlem Drain at Quincy St.	4,180	8,620	1.65	3.40	106%
44	Pine Creek/Harlem Drain to Drain #37	11,900	20,100	3.40	5.71	68%
45	Drain #37 to Pine Creek/Harlem Drain	3,200	4,440	2.12	2.94	39%
46	Pine Creek/Harlem Drain to Lake Macatawa	8,420	12,200	4.95	7.20	45%
47	Macatawa River/Lake Macatawa	25,300	27,200	11.08	11.92	8%
48	Winstrom Creek and Drains #20A, 23, 53 to Lake Macatawa	9,070	13,300	2.86	4.20	47%
49	Old Lela Drain to Lake Macatawa	2,770	3,680	6.20	8.25	33%
50	Weller Drain to Lake Macatawa	2,890	3,040	5.47	5.76	5%
51	Arbor Creek to Lake Macatawa	2,190	2,390	4.80	5.22	9%
52	Ottogan Intercounty Drain to Lake Macatawa	3,990	4,400	3.51	3.87	10%
53	Kelly Lake Drain to Lake Macatawa	10,200	12,000	2.59	3.07	18%
54	East Lake Macatawa drainage (does not include lake)	17,100	18,800	8.66	9.57	10%
55	West Lake Macatawa drainage (does not include lake)	7,960	10,300	3.88	4.99	29%
	Average	9,614	11,612	4.93	6.05	24%
	Minimum	774	1,030	1.65	2.71	-5%
	Maximum	25,300	27,200	11.08	11.92	106%

Annual Pollutant Loadings

The calculated Total Suspended Solids (TSS), Total Phosphorous (TP), NO_2 plus NO_3, and Total Kjeldahl Nitrogen (TKN) results for each subbasin are detailed in Table 5. The loadings per acre for each subbasin are shown in Figures 3 through 6.

The estimated loadings are based on typical practices for the land covers. It does not include local anomalies, such as gully erosion, or in-stream processes, such as channel erosion. The modeled load estimates do not replace in-stream monitoring data. A full review of the available monitoring data is beyond the scope of this study. However, Figure 7 depicts the loads estimated by this model compared to points that are approximately equivalent that have been measured by MDEQ's Surface Water Assessment Section staff.

Table 5 – Annual Pollutant Loads by Subbasin

Subbasin	Scenario	TSS (pounds)	TP (pounds)	NO_2+NO_3 (pounds)	TKN (pounds)	TSS (pounds per acre)	P (pounds per acre)	NO_2+NO_3 (pounds per acre)	TKN (pounds per acre)
1	1978	343,000	889	9,490	4,690	138	0.357	3.81	1.88
	2005	325,000	991	8,840	5,500	130	0.397	3.55	2.21
2	1978	334,000	926	6,310	4,510	163	0.452	3.08	2.21
	2005	287,000	870	5,380	4,440	140	0.425	2.63	2.17
3	1978	228,000	615	5,290	3,120	133	0.359	3.09	1.82
	2005	201,000	635	4,640	3,440	117	0.371	2.71	2.01
4	1978	483,000	1,340	10,900	6,740	166	0.462	3.76	2.32
	2005	478,000	1,460	10,600	8,040	165	0.505	3.64	2.77
5	1978	450,000	1,190	11,200	6,040	167	0.439	4.17	2.24
	2005	435,000	1,240	10,400	6,630	161	0.461	3.86	2.46
6	1978	429,000	1,120	12,000	5,870	178	0.466	4.97	2.44
	2005	416,000	1,230	11,200	6,750	173	0.511	4.64	2.80
7	1978	347,000	887	9,650	4,650	151	0.386	4.20	2.03
	2005	315,000	828	8,450	4,530	137	0.360	3.68	1.97
8	1978	23,500	64	642	341	92	0.252	2.51	1.33
	2005	25,400	92	607	545	99	0.358	2.38	2.13
9	1978	247,000	757	4,970	4,040	144	0.441	2.90	2.35
	2005	204,000	841	4,090	5,010	118	0.489	2.38	2.92
10	1978	350,000	898	9,750	4,700	151	0.386	4.19	2.02
	2005	351,000	918	9,770	4,840	151	0.395	4.20	2.08
11	1978	478,000	1,250	13,200	6,630	139	0.366	3.86	1.93
	2005	474,000	1,270	13,100	6,780	138	0.370	3.81	1.98
12	1978	412,000	1,060	11,500	5,540	165	0.423	4.59	2.21
	2005	410,000	1,070	11,400	5,640	164	0.428	4.57	2.25
13	1978	49,000	148	1,260	865	58	0.175	1.49	1.02
	2005	45,100	181	1,200	1,110	53	0.214	1.42	1.31
14	1978	512,000	1,310	14,300	6,860	178	0.458	4.98	2.39
	2005	514,000	1,330	14,200	7,010	179	0.465	4.96	2.44
15	1978	392,000	1,020	10,900	5,320	162	0.421	4.52	2.21
	2005	387,000	1,040	10,700	5,530	160	0.432	4.45	2.29

Subbasin	Scenario	TSS (pounds)	TP (pounds)	NO_2+NO_3 (pounds)	TKN (pounds)	TSS (pounds per acre)	P (pounds per acre)	NO_2+NO_3 (pounds per acre)	TKN (pounds per acre)
16	1978	213,000	562	5,950	3,040	129	0.340	3.60	1.84
	2005	206,000	590	5,700	3,290	125	0.357	3.45	1.99
17	1978	164,000	442	4,280	2,490	113	0.307	2.97	1.73
	2005	171,000	509	4,190	2,960	119	0.353	2.91	2.06
18	1978	379,000	998	10,500	5,310	146	0.383	4.03	2.04
	2005	383,000	1,040	10,600	5,560	147	0.398	4.05	2.14
19	1978	549,000	1,470	14,700	7,900	137	0.366	3.67	1.97
	2005	523,000	1,600	13,900	8,920	130	0.398	3.46	2.22
20	1978	583,000	1,590	14,100	8,260	143	0.391	3.46	2.03
	2005	558,000	1,680	13,000	9,090	137	0.413	3.20	2.23
21	1978	137,000	389	3,270	2,060	161	0.459	3.86	2.43
	2005	147,000	433	3,160	2,400	173	0.511	3.73	2.83
22	1978	253,000	702	5,510	3,500	196	0.544	4.27	2.71
	2005	340,000	933	5,280	5,140	263	0.723	4.09	3.98
23	1978	232,000	649	5,150	3,350	164	0.459	3.64	2.37
	2005	330,000	973	4,420	4,950	233	0.688	3.13	3.49
24	1978	237,000	659	5,060	3,450	180	0.502	3.85	2.63
	2005	345,000	885	5,280	5,070	262	0.673	4.02	3.86
25	1978	467,000	1,290	11,800	6,780	153	0.424	3.85	2.23
	2005	517,000	1,630	10,900	9,140	170	0.535	3.57	3.00
26	1978	125,000	320	3,340	1,760	63	0.162	1.69	0.89
	2005	128,000	429	3,410	2,560	65	0.217	1.72	1.29
27	1978	413,000	1,060	11,500	5,530	151	0.388	4.22	2.03
	2005	399,000	1,070	11,100	5,680	146	0.392	4.06	2.08
28	1978	219,000	561	6,130	2,920	125	0.320	3.50	1.67
	2005	216,000	577	6,020	3,080	123	0.329	3.43	1.76
29	1978	305,000	815	8,450	4,320	123	0.330	3.42	1.75
	2005	305,000	1,050	8,150	5,960	123	0.426	3.30	2.41
30	1978	434,000	1,210	9,140	6,860	174	0.483	3.66	2.75
	2005	639,000	1,930	10,400	11,600	256	0.772	4.18	4.65
31	1978	297,000	809	8,200	4,330	133	0.363	3.68	1.94
	2005	264,000	1,010	7,110	5,980	119	0.455	3.19	2.68
32	1978	118,000	522	2,280	3,050	127	0.560	2.44	3.28
	2005	146,000	708	2,780	4,290	157	0.760	2.98	4.60
33	1978	166,000	475	3,630	2,430	176	0.504	3.85	2.58
	2005	165,000	620	2,790	3,710	175	0.658	2.96	3.93
34	1978	159,000	623	3,560	3,780	108	0.422	2.41	2.56
	2005	184,000	848	3,630	5,200	124	0.574	2.46	3.52
35	1978	139,000	380	2,930	1,900	189	0.519	4.00	2.59
	2005	154,000	437	2,610	2,340	210	0.597	3.57	3.19
36	1978	67,500	279	1,760	1,700	106	0.437	2.75	2.65
	2005	62,700	353	1,410	2,250	98	0.552	2.21	3.51
37	1978	260,000	743	6,250	3,990	105	0.300	2.52	1.61
	2005	427,000	1,220	8,190	7,220	172	0.495	3.31	2.92
38	1978	306,000	857	7,580	4,530	133	0.371	3.28	1.96
	2005	433,000	1,270	8,660	7,150	188	0.548	3.75	3.10
39	1978	155,000	522	3,250	2,950	110	0.371	2.31	2.10
	2005	252,000	1,000	4,470	5,580	179	0.713	3.18	3.97

Subbasin	Scenario	TSS (pounds)	TP (pounds)	NO_2+NO_3 (pounds)	TKN (pounds)	TSS (pounds per acre)	P (pounds per acre)	NO_2+NO_3 (pounds per acre)	TKN (pounds per acre)
40	1978	323,000	1,140	5,820	6,410	177	0.623	3.19	3.51
	2005	409,000	1,530	6,170	8,820	224	0.839	3.38	4.83
41	1978	353,000	1,110	5,720	6,600	220	0.695	3.57	4.12
	2005	457,000	1,380	6,620	8,340	285	0.860	4.13	5.20
42	1978	184,000	497	4,480	2,690	98	0.265	2.39	1.43
	2005	198,000	561	4,670	3,090	106	0.299	2.49	1.64
43	1978	101,000	297	2,460	1,760	40	0.117	0.97	0.69
	2005	183,000	550	3,790	3,470	72	0.217	1.49	1.37
44	1978	216,000	1,030	5,150	6,310	61	0.293	1.46	1.80
	2005	340,000	1,750	7,300	10,600	97	0.498	2.08	3.02
45	1978	63,000	197	1,530	1,220	42	0.130	1.02	0.81
	2005	70,800	284	1,870	1,820	47	0.189	1.24	1.20
46	1978	162,000	702	3,240	4,360	96	0.413	1.90	2.57
	2005	198,000	1,040	4,070	6,410	117	0.611	2.39	3.77
47	1978	442,000	1,790	8,210	11,100	194	0.785	3.60	4.87
	2005	471,000	1,940	8,400	12,000	206	0.850	3.68	5.26
48	1978	163,000	654	2,780	3,930	51	0.206	0.88	1.24
	2005	216,000	1,070	4,200	6,590	68	0.337	1.33	2.08
49	1978	57,000	242	1,340	1,400	128	0.542	3.02	3.14
	2005	63,400	323	1,300	1,900	142	0.724	2.91	4.26
50	1978	73,300	272	1,940	1,590	139	0.516	3.68	3.01
	2005	60,700	299	1,540	1,830	115	0.566	2.92	3.47
51	1978	57,200	191	1,520	1,080	125	0.418	3.31	2.35
	2005	54,200	222	1,390	1,320	119	0.486	3.04	2.87
52	1978	92,600	338	2,430	1,990	82	0.298	2.14	1.75
	2005	77,800	388	1,980	2,430	68	0.342	1.75	2.14
53	1978	200,000	712	5,210	4,360	51	0.181	1.33	1.11
	2005	195,000	927	5,010	5,930	50	0.236	1.28	1.51
54	1978	333,000	1,550	6,540	9,460	169	0.788	3.32	4.81
	2005	363,000	1,710	6,910	10,400	185	0.870	3.51	5.30
55	1978	121,000	787	2,980	5,060	59	0.383	1.45	2.46
	2005	159,000	1,040	3,830	6,580	77	0.505	1.87	3.20

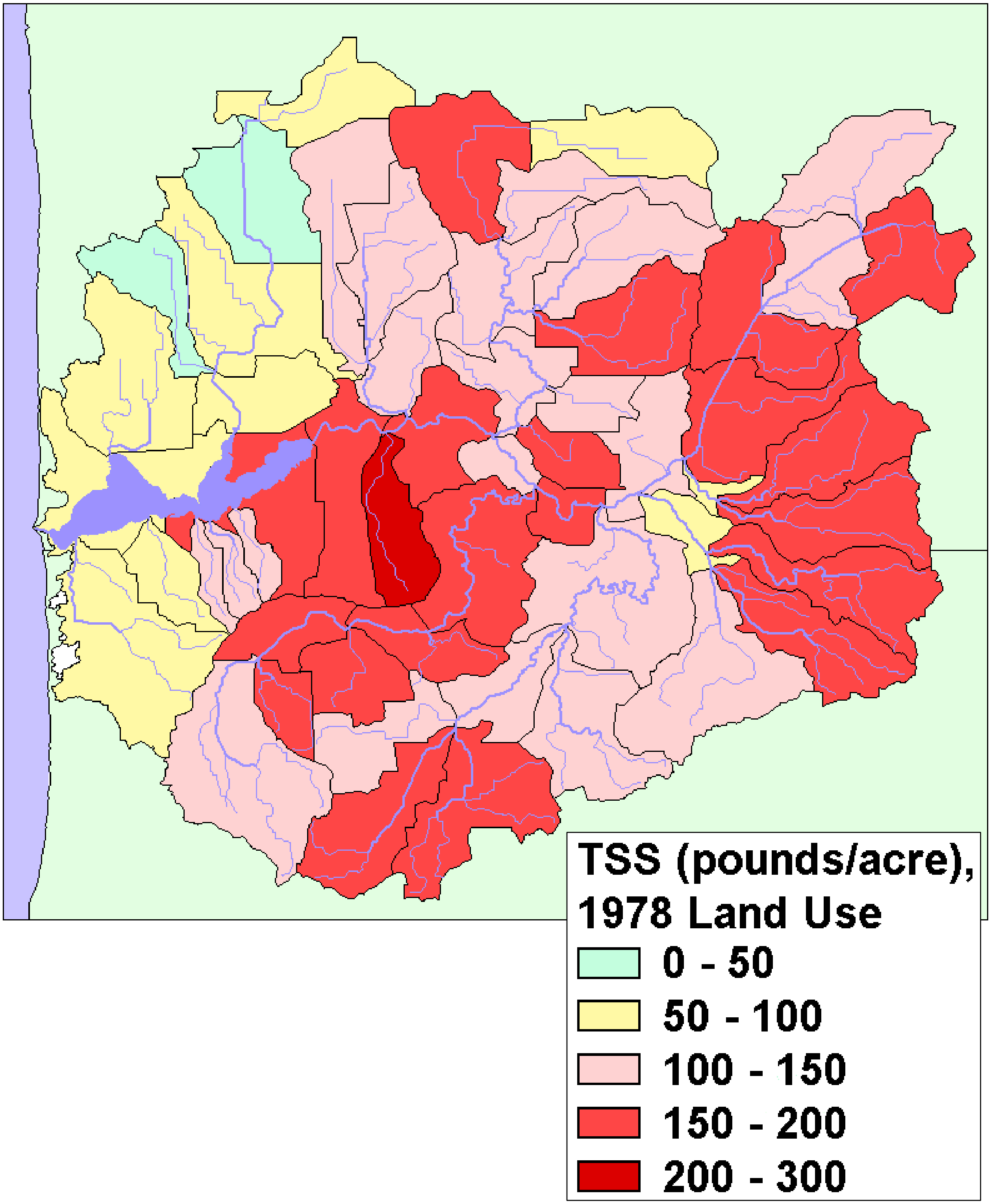

Figure 3 – Total Suspended Solids (TSS) Loading per Acre, 1978

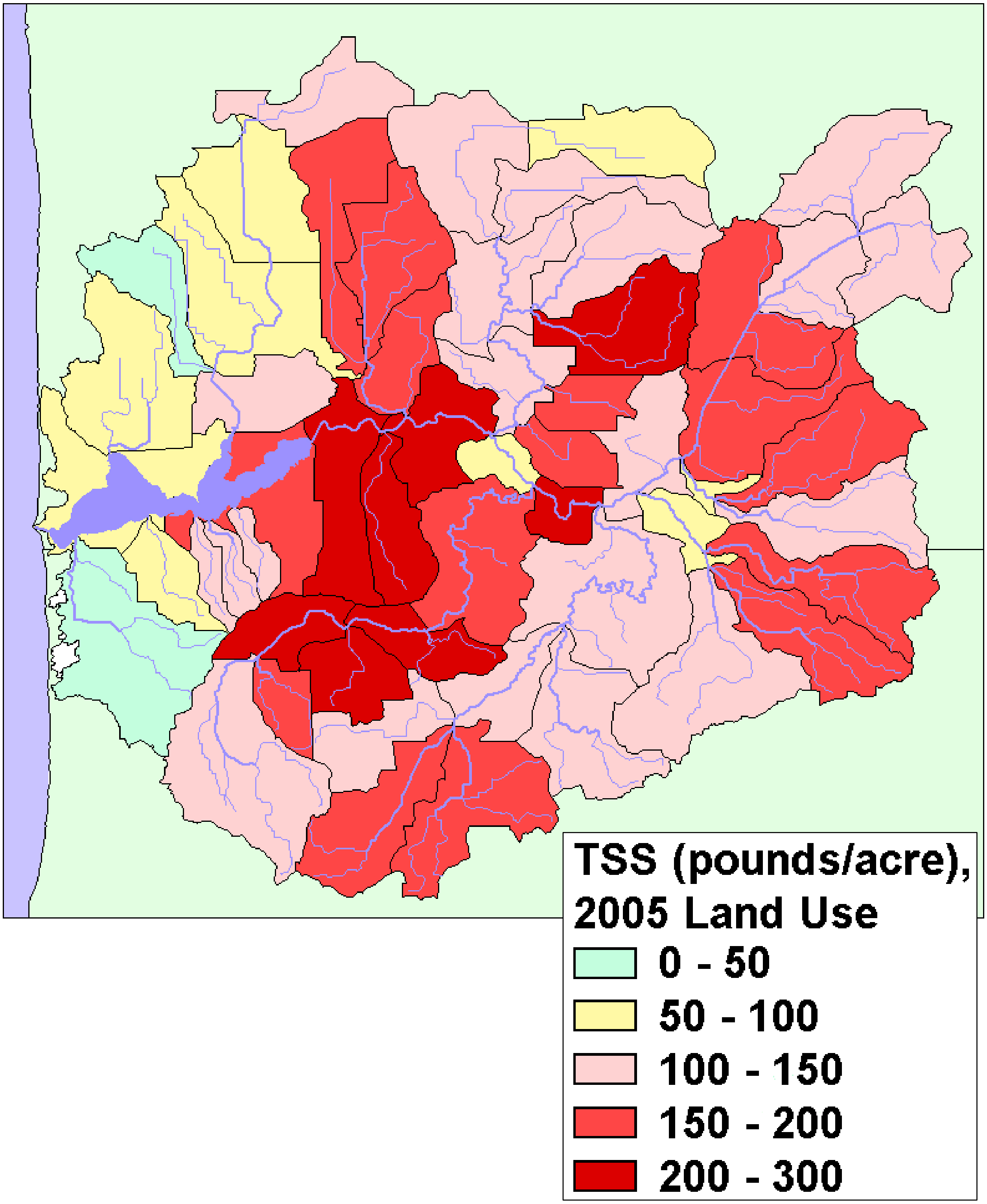

Figure 4 – Total Suspended Solids (TSS) Loading per Acre, 2005

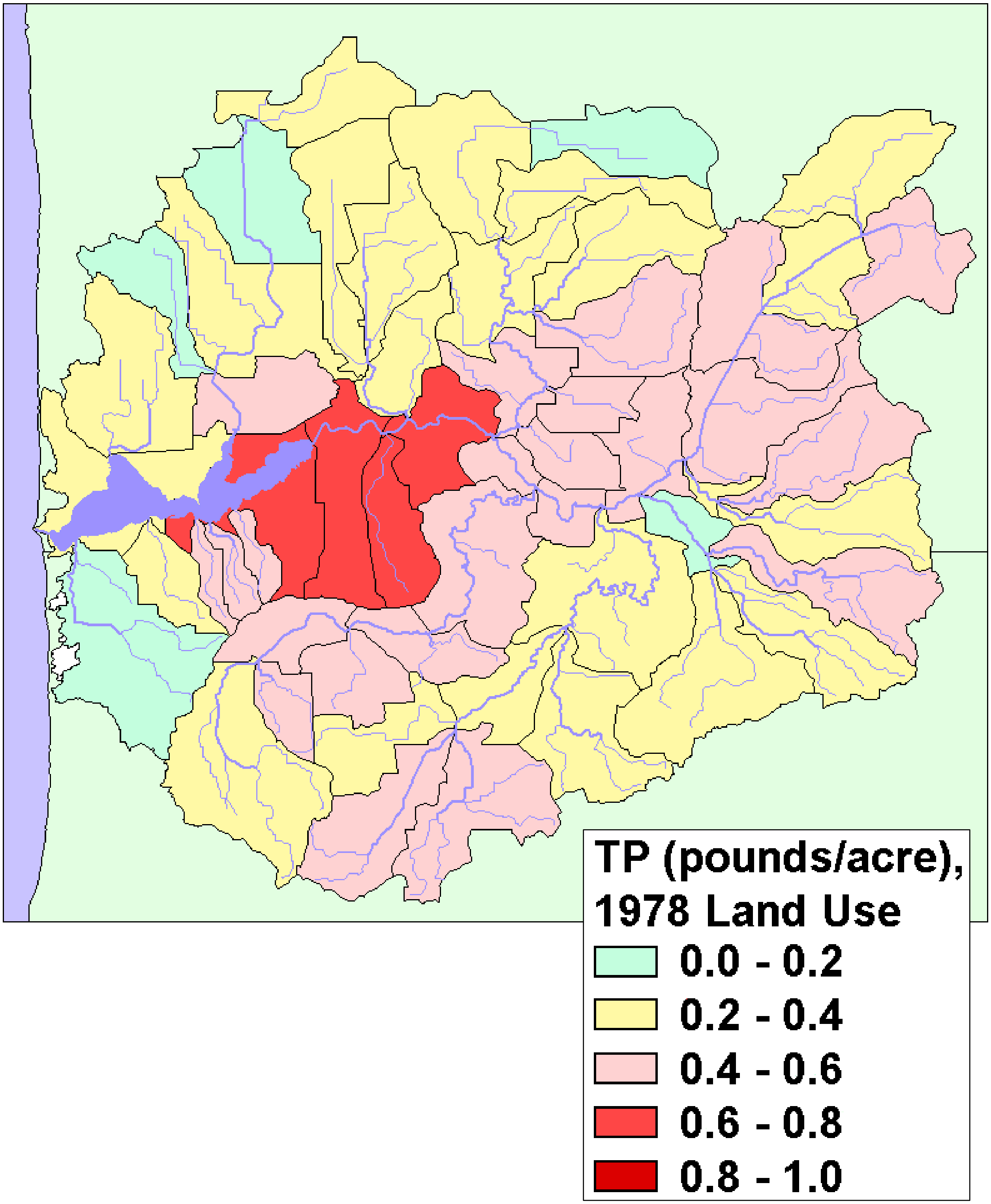

Figure 5 – Total Phosphorous (TP) Loading per Acre, 1978

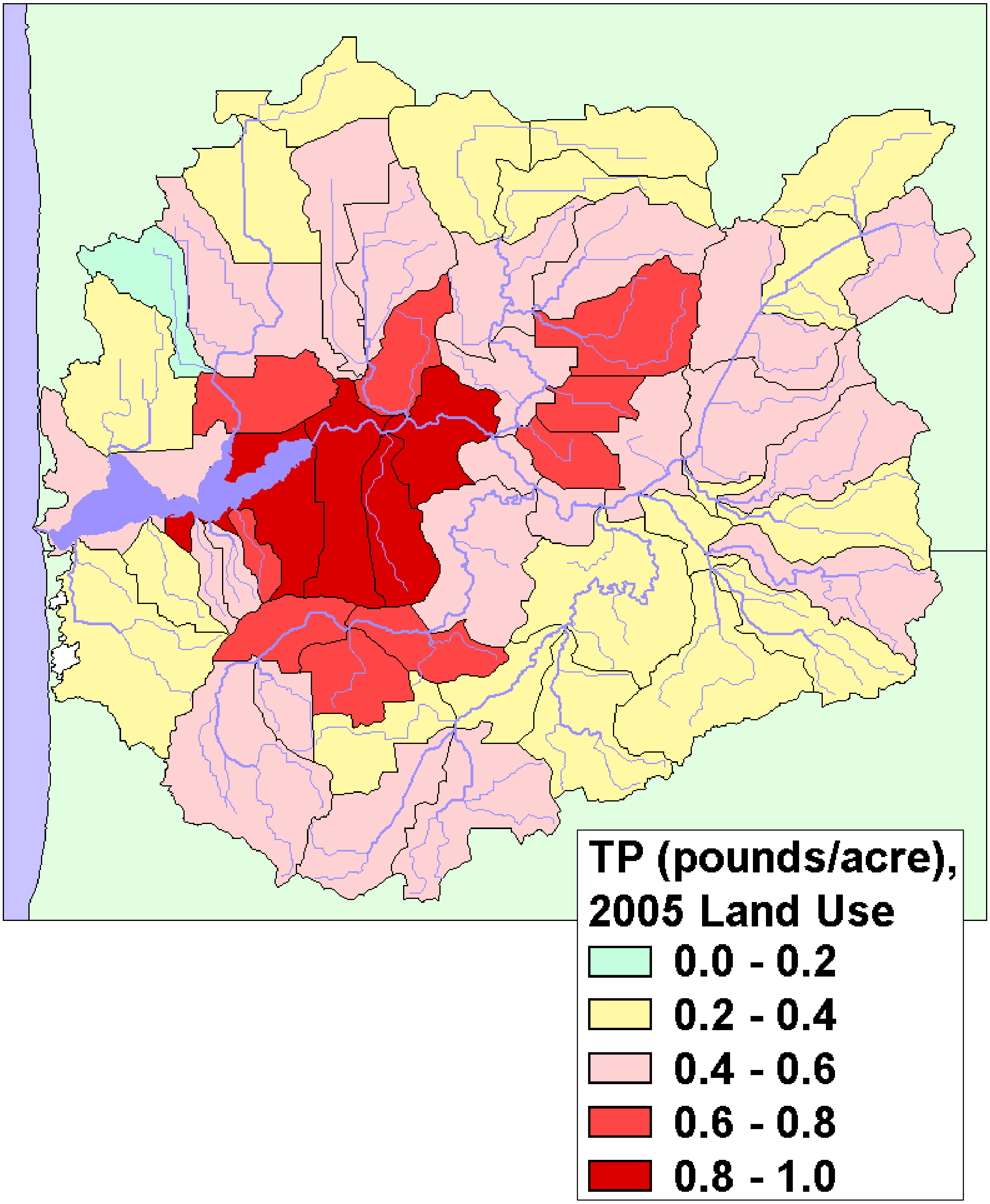

Figure 6 – Total Phosphorous (TP) Loading per Acre, 205

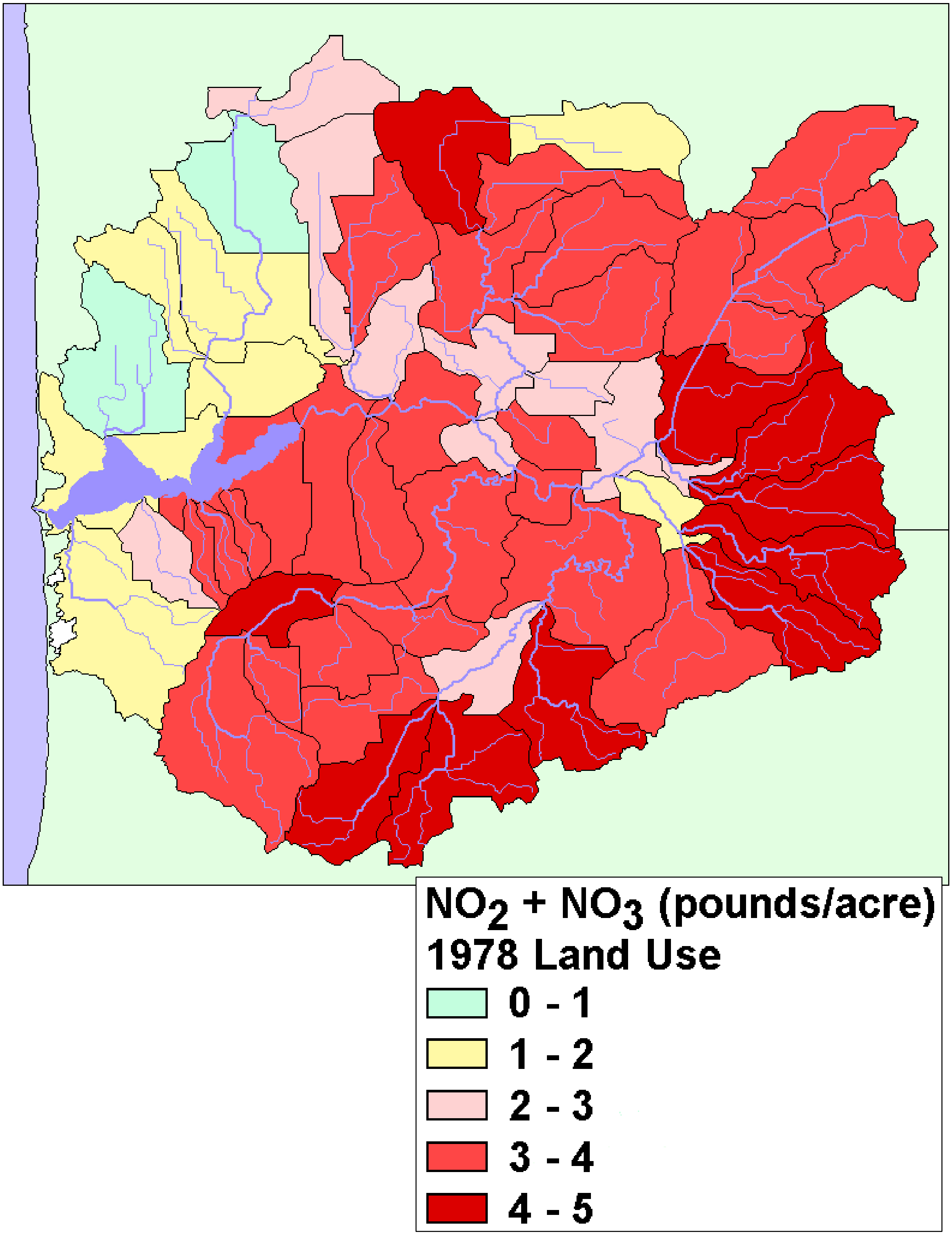

Figure 7 – NO_2 plus NO_3 Loading per Acre, 1978

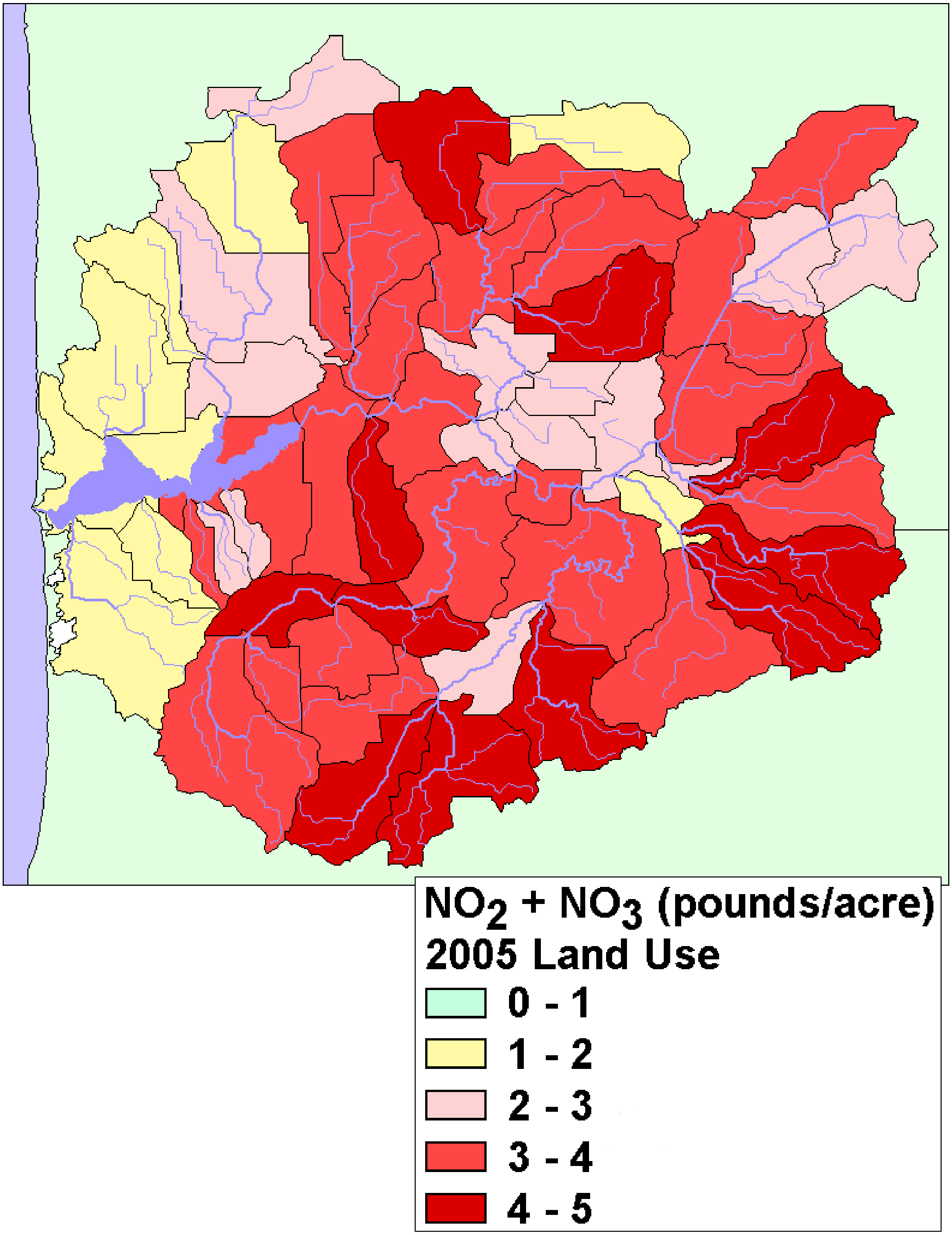

Figure 8 – NO_2 plus NO_3 Loading per Acre, 2005

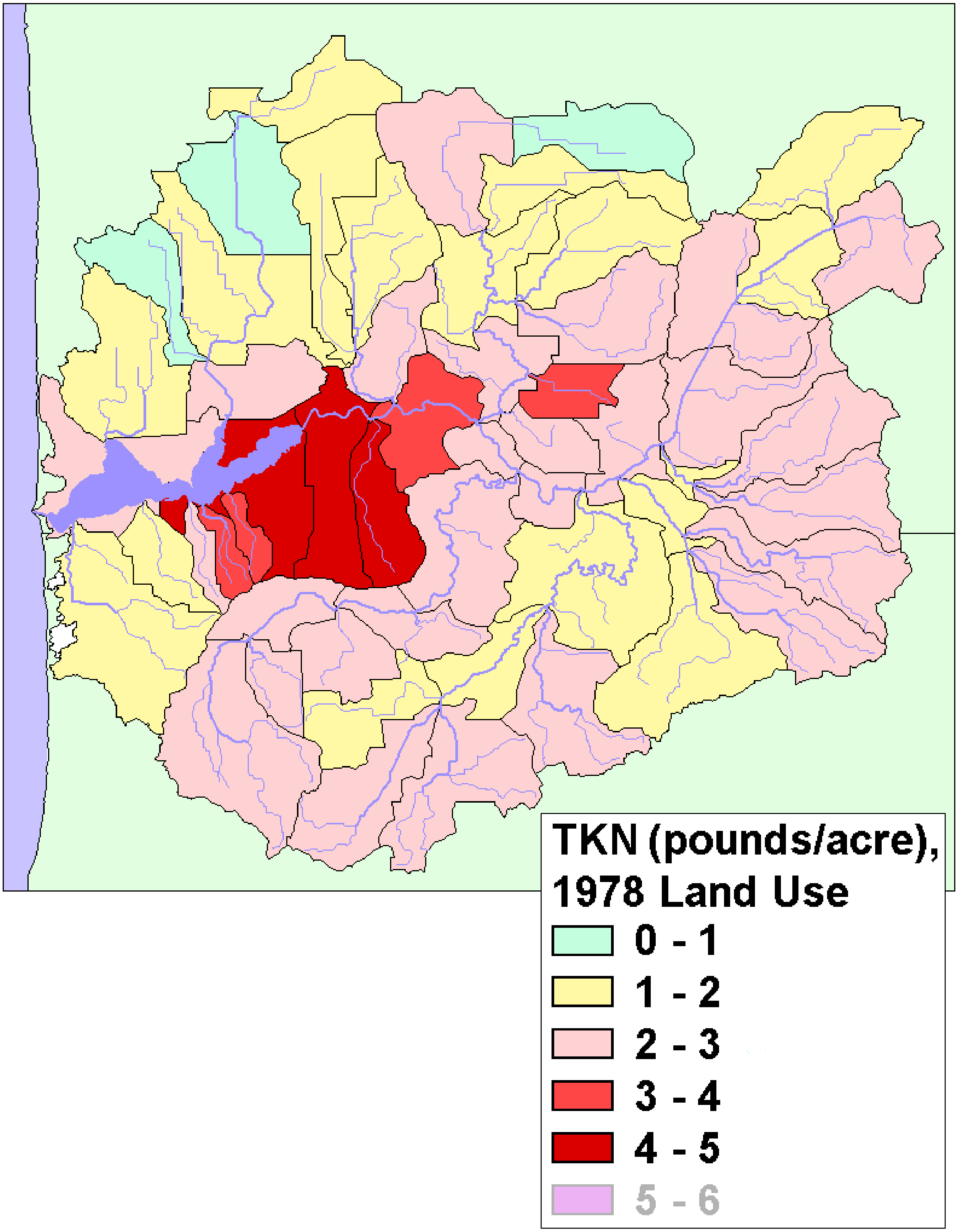

Figure 9 – Total Kjeldahl Nitrogen (TKN) Loading per Acre, 1978

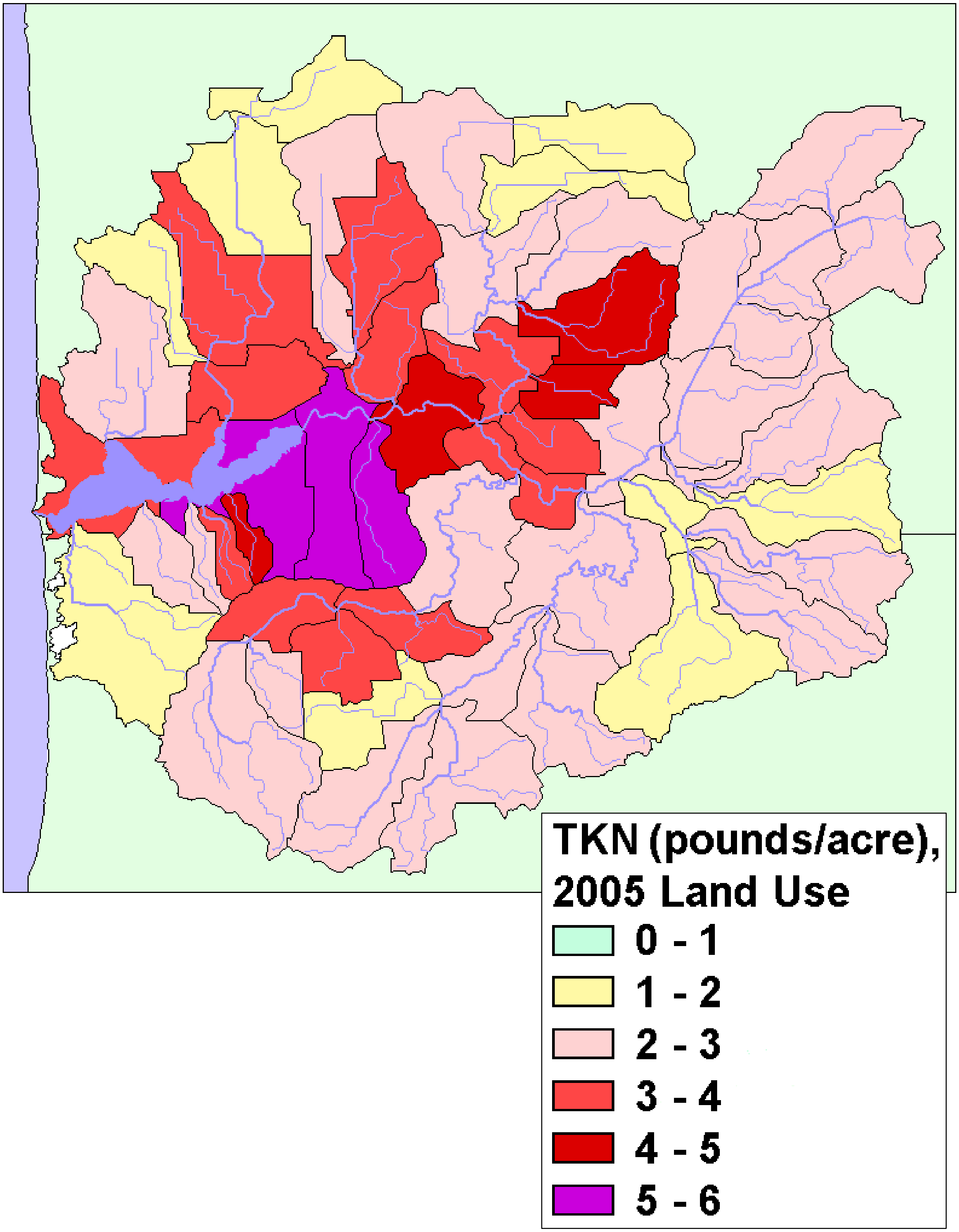

Figure 10 – Total Kjeldahl Nitrogen (TKN) Loading per Acre, 2005

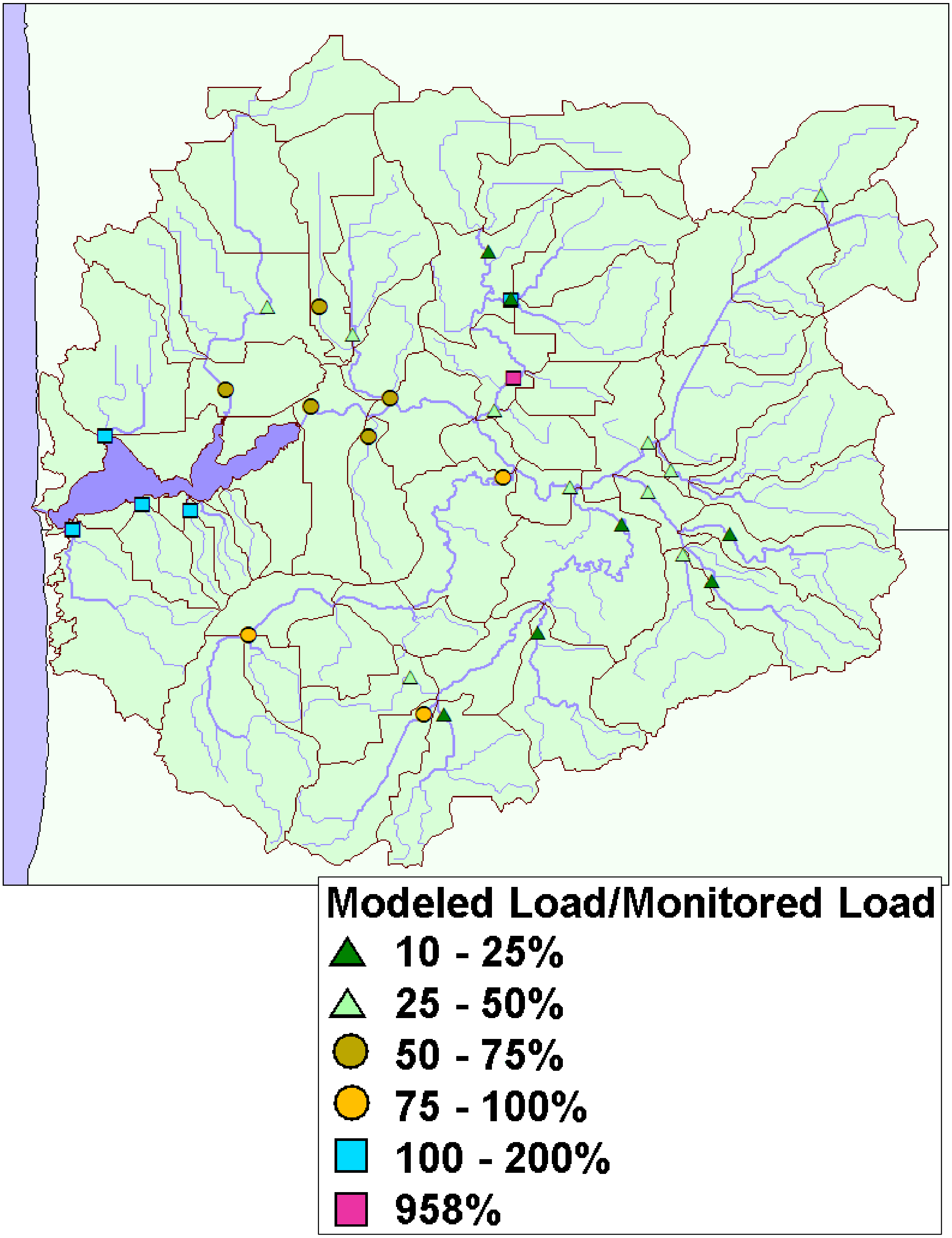

Figure 11 – Modeled Total Phosphorous Estimates Compared to Selected Monitoring Locations