15 February 2013

Evaluation of Land Use Change Scenarios in the LaSalle Watershed

Technical Memo

Prepared for: Agriculture and Agri-Foods Canada

Submitted by:

Greenland International Consulting Ltd.

Project No. 12-G-2882

Contents

List of Figures

List of Tables

List of Appendices

1. Introduction

Lake Winnipeg is one of the largest freshwater lakes in North America and plays an essential role in the economic and social fabric of the communities that surround it. Due to trends in land use management in recent decades the Lake is experiencing eutrophic conditions that are severely impacting the health of the Lake and impairing beneficial uses that were once derived from the Lake.

Phosphorus is a key determining factor in the eutrophic conditions experienced in the Lake. The excess loading of phosphorus contributes to proliferation of algae which at the end of its life cycle begins a decomposition process that consumes vital dissolved oxygen from the water column in the Lake that can result in the waters becoming un-inhabitable to aquatic life.

Agriculture and Agri-Foods Canada (AAFC) has been assessing a variety of software modeling tools for the purpose of managing watershed processes and in particular nutrient loading in the Lake Winnipeg Basin. This study applied the CANWET 4 model to evaluate phosphorus loading under five (5) land use scenarios to determine if changing the land use profile in the study area could provide benefits in the form of reduced phosphorus loading.

2. Background

2.1 Study Location

The LaSalle River is a tributary of the Lake Winnipeg basin located just west of the City of Winnipeg.

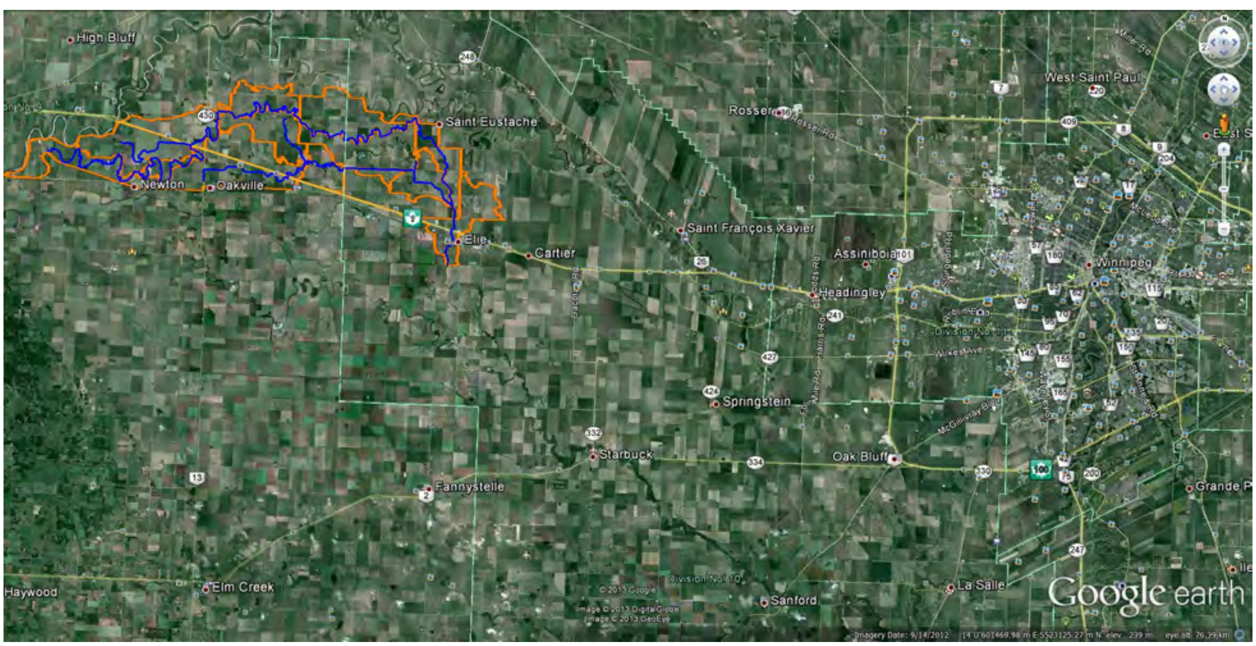


Figure 2-1 Study Area Location West of Winnipeg

2.2 Watershed Characteristics

The watershed encompasses approximately 177 square kilometers and is comprised largely of agriculture including cereals, oil seed, nursery and greenhouses, vegetable row crops, pasture lands and livestock operations. Smaller, fragmented portions of the watershed exhibit natural forest cover, grasslands, and residential development. Soil in the watershed is largely clay. The topography is generally flat with maximum reported stream reach gradient of 0.04%. The 13-catchment watershed delineation and associated stream network was provided by AAFC for the study. The watershed and stream delineation is depicted in **Figure 2-2**.

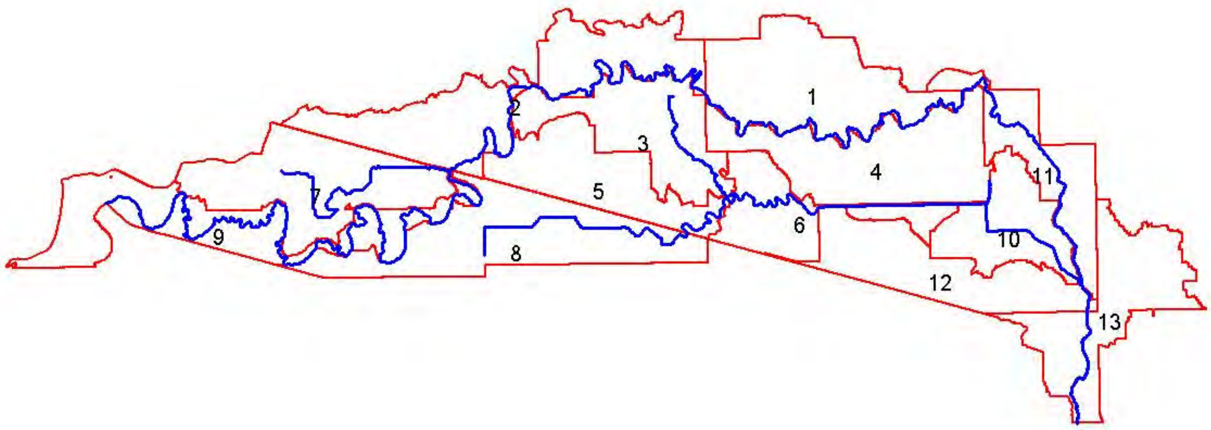


Figure 2-2 LaSalle River Catchment and Stream Delineation

3. Study Method

3.1 Scenarios

Five (5) scenarios were considered in the study in order to assess water quality and nutrient loading under existing conditions and under scenarios of land use change. Scenarios are described below.

Base Scenario: existing conditions land use with cropping practices classified according to potential for nutrient loss as high, moderate or low.

Scenario 2: would see conversion of 45 ha of cropland to wetland

Scenario 3: would see conversion of 2,083 ha of marginal cropland to hay

Scenario 4: would see conversion of 15 ha of marginal cropland to wetland
Scenario 5: represents a hybrid of scenarios 2, 3 and 4 with conversion of cropland and marginal lands to hay and wetland.

3.2 Watershed In-Stream Water Quality Modeling

CANWET™ 4.1 was used to simulate point and non-point source flow and phosphorus loads and to route flow and concentrations through the watercourse network. The simulation can consider sediment, BOD, nitrogen species, total phosphorus, pH and temperature; however in this analysis only phosphorus was specifically accounted for.

The model simulates one-dimensional continuous daily water balance and non-point source loads from a network of catchments in the watershed. It routes catchment and point source flows and loads at a daily time step and computes in-stream concentrations and flows at nodes within the stream network corresponding with catchment outlets.

The simulations included a continuous period from 1993 through 2003. The simulation was driven by interpolated daily weather data derived using ANUSPLINE applied to Environment Canada weather station data by AAFC.

The base model was calibrated with available monitoring data during a previous initiative. These model parameters were applied again in this analysis with some modifications and compared against available monitoring data.

A mix of generic land use classes and new land use classes were implemented in the model to differentiate between the land use sources of loading computed in the simulation. Recommendations are made in **Section 5** on how these land use classes might be better parameterized. **Appendix A** contains screen shots showing examples of catchment parameters used in the model setup.

4. Catchment and In-stream Modeling

4.1 Watershed Model Validation Summary

The scope of the study did not permit a detailed calibration of the model; however, results of a previous preliminary calibration completed in 2011 were applied and verified summarily as shown in Figures 4-1, 4-2 and Table 4-1. Graphically, the simulated flows at a daily time step appear to agree reasonably well, but there is some discrepancy in the timing of peak flows and the magnitude of some of the peaks. There are some smaller peaks in 1997 that appear in the simulated output, but are not evident from the gauge data. This could be due to the localized nature of precipitation events and discrepancies between the magnitude of interpolated precipitation data and the actual precipitation received by the watershed or parts of the watershed. Because some of the low flow conditions are under predicted by the simulation, the overall water balance between the observed and simulated flow is under predicted by approximately 20%. This could be due to an over estimate of ET during the summer months that should be corrected in a future calibration update of the model.

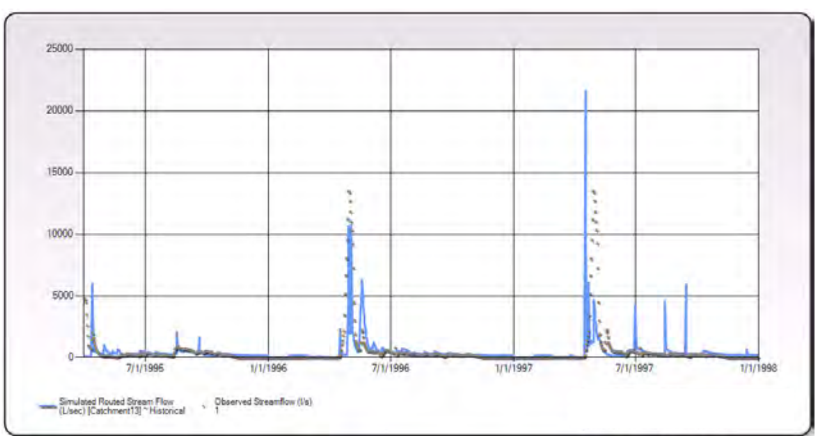


Figure 4-1 Measured and Simulated Stream Flow near Elie (L/sec)

With the exception of two (2) measured phosphorus concentrations in 1996 and 1997, the simulated total phosphorus concentrations generally fall within the range of the observed data from 1995 through 1997. Since the concentration is directly linked to the simulated flows, recommended updates to the flow calibration will impact the phosphorus concentrations as well. In general the average annual simulated phosphorus concentration was found to be somewhat less than the observed average and median concentrations. Comparison of the 2009 – 2012 phosphorus concentration data suggests an upward trend in phosphorus concentration in the LaSalle River at Elie; however this does not necessarily imply that the loading rate follows the same trend.

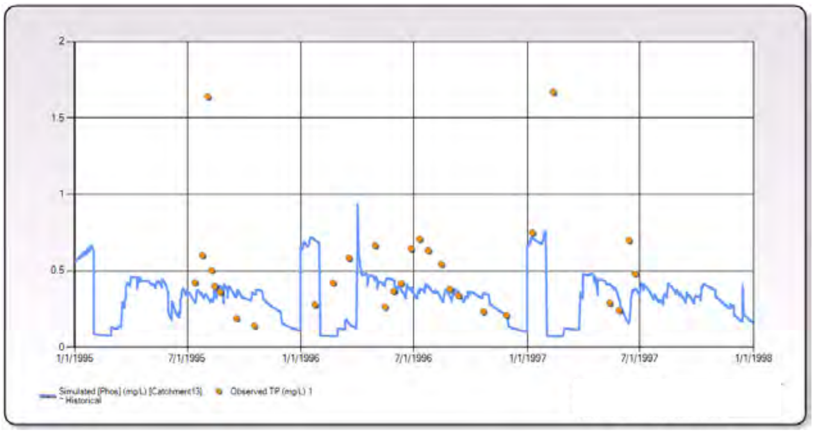


Figure 4-2 Measured and Simulated Total Phosphorus Concentration near Elie (mg/L)

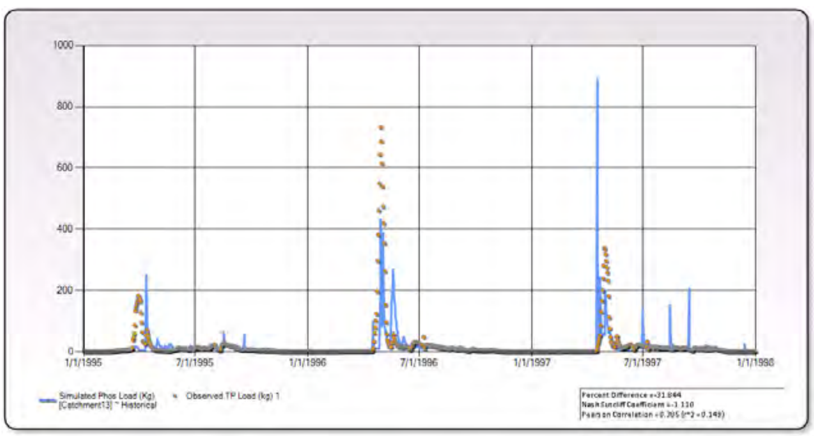


Figure 4-3 Simulated and Interpolated Phosphorus Loading near Elie (kg/day)

Table 4-1 Statistical Comparison - Simulated and Measured Phosphorus

	Measured Dissolved Phosphorus Near Elie 2009 – 2012	*Measured Total Phosphorus Near Elie 2009 – 2012*	*Measured Dissolved Phosphorus Near Elie 1995 – 1997*	*Measured Total Phosphorus Near Elie 1995 – 1997*	*CANWET Simulated Total Phosphorus Catchment 13 1995-1997*
average	0.54	0.59	0.43	0.52	0.33
median	0.47	0.56	0.37	0.42	0.35
90th	0.88	0.92	0.62	0.71	0.46
10th	0.23	0.28	0.15	0.23	0.12

4.2 Results of Scenario Analysis

As shown in **Tables 4-2** through **4-6,** there is a modest reduction in phosphorus loading associated with the land use changes from the alternative land use scenarios. The maximum load reduction of 154 kg/year was found in Scenario 5 which is a hybrid of the alternative land use scenarios. The evaluated load reduction would be greater if the impact to shallow groundwater / interflow could be better established as this component of the simulation was maintained at the calibrated value of 0.5 mg/L for each catchment and for each simulated scenario. In reality this value will be reduced due to proposed land use changes. In CANWET, groundwater phosphorus concentration is a function of groundwater nitrogen concentration which is estimated based on a relationship between land use and hydrologic soil group.

The scenario analysis included conversion to wetlands. The simulations including this change were run to determine the change in load associated with the change in land use, but the simulation did not consider the potential of these additional wetland areas to intercept load carried from upstream drainage areas. Use of grid-based flow direction mapping could be used to determine the drainage area upstream of a proposed wetland reinstatement project. This would result in a greater predicted reduction in loading and improved confidence in the results.

Maps depicting the average annual loading rates in kg/ha/year are provided in **Appendix B**. The maps show a notable difference in the loading rates from the areas proposed for change in land use. As described in more detail in Section 5, there are a number of changes to the simulation approach and additional information that would reduce the uncertainty of the scenario results and very likely increase the amount of load reduction estimated for the proposed land use changes.

Included with this Technical Memo are a series of GIS shape files that show in detail the spatial loading by land use and catchment area.

Table 4-2 Scenario 1 (Base) Simulated Flows and Loads

Average Yearly (1994-2003) ***BASE SCENARIO 1***

Routed Average Annual Flows, Concentrations and Loads

Catchment	Catchment Area (ha)	Catchment Stream Q m3/year	Flow Routing Average Annual m3/year	GWLF TP Load kg/year	Average Annual Routed Load kg/year	Average Annual TP Concentration mg/L
1	1653	810,166	6,764,529	379	2,003	0.296
2	1938	949,473	5,954,363	441	1,624	0.273
3	1230	578,100	578,100	282	282	0.487
4	1633	767,369	767,369	369	369	0.481
5	1122	549,927	1,545,147	260	719	0.465
6	891	418,723	2,541,970	198	1,199	0.472
7	1536	691,200	691,200	351	351	0.507
8	1746	995,220	995,220	459	459	0.461
9	1567	658,098	658,098	318	318	0.483
diversion in 9		3,655,592	4,313,690	515	833	0.193
10	883	441,550	3,750,889	214	1,782	0.475
11	938	459,522	7,224,051	226	2,229	0.308
12	1237	667,818	11,642,758	322	4,333	0.372
13	1318	856,505	12,499,263	378	4,710	0.377

Table 4-3 Scenario 2 (Crop to Wetland) Simulated Flows and Loads

Average Yearly (1994-2003) ***SCENARIO 2***

Routed Average Annual Flows, Concentrations and Loads

Catchment	Catchment Area (ha)	Catchment Stream Q m3/year	Flow Routing Average Annual m3/year	Catchment TP Load kg/year	Average Annual Routed Load kg/year	Average Annual TP Concentration mg/L	Compare Base Load Reduced (kg/year)
1	1653	810,166	6,729,483	378	1,997	0.297	1.10
2	1938	930,096	5,919,317	439	1,619	0.274	1.90
3	1230	578,100	578,100	282	282	0.487	0.00
4	1633	767,369	767,369	368	368	0.480	0.60
5	1122	549,927	1,527,687	258	711	0.465	2.10
6	891	418,723	2,524,510	198	1,190	0.471	0.30
7	1536	691,200	691,200	350	350	0.507	0.30
8	1746	977,760	977,760	453	453	0.463	6.20
9	1567	642,429	642,429	315	315	0.490	2.80
diversion in 9		3,655,592	4,298,021	515	830	0.193	0.00
10	883	441,550	3,733,429	214	1,773	0.475	0.10
11	938	459,522	7,189,005	226	2,223	0.309	0.00
12	1237	667,818	11,590,252	322	4,317	0.372	0.00
13	1318	856,505	12,446,757	378	4,695	0.377	0.00
TOTAL							15.40

Table 4-4 Scenario 3 (Marginal to Hay) Simulated Flows and Loads

Average Yearly (1994-2003) ***SCENARIO 3***

Routed Average Annual Flows, Concentrations and Loads

Catchment	Catchment Area (ha)	Catchment Stream Q m3/year	Flow Routing Average Annual m3/year	Catchment TP Load kg/year	Average Annual Routed Load kg/year	Average Annual TP Concentration mg/L	Compare Base Load Reduced (kg/year)
1	1653	793,632	6,728,618	375	1,992	0.296	4.00
2	1938	930,096	5,934,986	435	1,617	0.272	6.50
3	1230	528,900	528,900	259	259	0.490	22.40
4	1633	751,042	751,042	361	361	0.481	8.00
5	1122	493,812	1,401,732	260	673	0.480	0.00
6	891	374,178	2,304,810	177	1,110	0.482	20.70
7	1536	691,200	691,200	350	350	0.506	0.50
8	1746	907,920	907,920	413	413	0.455	45.60
9	1567	658,098	658,098	318	318	0.482	0.10
diversion in 9		3,655,592	4,313,690	515	833	0.193	0.00
10	883	441,550	3,497,402	214	1,685	0.482	0.00
11	938	450,144	7,178,762	221	2,213	0.308	4.90
12	1237	667,818	11,343,982	321	4,219	0.372	0.90
13	1318	856,505	12,200,487	373	4,592	0.376	4.70
TOTAL							118.30

Table 4-5 Scenario 4 (Marginal to Wetland) Simulated Flows and Loads

Average Yearly (1994-2003) ***SCENARIO 4***

Routed Average Annual Flows, Concentrations and Loads

Catchment	Catchment Area (ha)	Catchment Stream Q m3/year	Flow Routing Average Annual m3/year	Catchment TP Load kg/year	Average Annual Routed Load kg/year	Average Annual TP Concentration mg/L	Compare Base Load Reduced (kg/year)
1	1653	810,166	6,745,152	378	2,001	0.297	0.70
2	1938	930,096	5,934,986	440	1,623	0.273	0.90
3	1230	578,100	578,100	282	282	0.487	0.00
4	1633	767,369	767,369	369	369	0.481	0.20
5	1122	549,927	1,545,147	259	714	0.462	1.30
6	891	418,723	2,541,970	198	1,194	0.470	0.30
7	1536	691,200	691,200	351	351	0.507	0.00
8	1746	995,220	995,220	456	456	0.458	3.30
9	1567	658,098	658,098	317	317	0.482	0.20
diversion in 9		3,655,592	4,313,690	515	832	0.193	0.00
10	883	441,550	3,750,889	214	1,777	0.474	0.00
11	938	459,522	7,204,674	226	2,227	0.309	0.00
12	1237	667,818	11,623,381	322	4,326	0.372	0.00
13	1318	856,505	12,479,886	378	4,703	0.377	0.00
TOTAL							6.90

Table 4-6 Scenario 5 (Hybrid of Scenarios 2, 3 and 4) Simulated Flows and Loads

Average Yearly (1994-2003) ***SCENARIO 5***

Routed Average Annual Flows, Concentrations and Loads

Catchment	Catchment Area (ha)	Catchment Stream Q m3/year	Flow Routing Average Annual m3/year	Catchment TP Load kg/year	Average Annual Routed Load kg/year	Average Annual TP Concentration mg/L	Compare Base Load Reduced (kg/year)
1	1653	793,632	6,712,949	374	1,987	0.296	4.40
2	1938	930,096	5,919,317	433	1,613	0.272	7.90
3	1230	528,900	528,900	259	259	0.490	22.40
4	1633	751,042	751,042	360	360	0.480	8.60
5	1122	493,812	1,384,272	234	643	0.465	26.10
6	891	374,178	2,287,350	177	1,079	0.472	21.10
7	1536	691,200	691,200	350	350	0.506	0.70
8	1746	890,460	890,460	409	409	0.460	49.70
9	1567	642,429	642,429	315	315	0.490	2.80
diversion in 9		3,655,592	4,298,021	515	830	0.193	0.00
10	883	441,550	3,479,942	214	1,654	0.475	0.10
11	938	450,144	7,163,093	221	2,208	0.308	4.90
12	1237	667,818	11,310,853	321	4,183	0.370	0.90
13	1318	856,505	12,167,358	373	4,556	0.374	4.70
TOTAL							154.30

5. Recommendations

Based on the analysis completed under a limited project scope, the following recommendations can be made to reduce uncertainty associated with the simulated results and improve the resolution and usability of the results in future assessments using the CANWET approach.

1. Additional resources are needed to better establish and/or verify appropriate land use parameters used in the modeling including runoff concentrations, soil nutrient concentrations, evapotranspiration coefficients and runoff coefficients. This information might require the development of a specialized monitoring program targeting specific land uses and locations in the watershed. Anecdotally, soil phosphorus values in Pennsylvania with high fertilizer application rates can be in the range of 200 to 2,000 mg/kg suggesting that the values derived for this study in the 1,100 mg/kg range could be on low side, but this is likely a less sensitive parameter since most of the load is dissolved phase.
2. Establish additional upstream monitoring locations for flow and water quality in order that simulated flows and concentrations can be calibrated and verified at multiple locations especially where there are distinct variations in the composition of the catchments.
3. Extend the period of simulation in order to compare results directly against more recent monitoring data.
4. Undertake field study or access existing data sets to estimate groundwater phosphorus and nitrogen concentrations as a function of land use and soil conditions.
5. Calibrate phosphorus loads and concentrations with specific consideration for dissolved and particulate fractions in order to better establish the proportion of the load associated with dissolved runoff, animal manure and shallow groundwater (interflow) and the portion associated with soil loss.
6. Calibrate the sediment loading portion of the model with sediment data at multiple locations. This procedure should also validate the parameter values used in the Revised Universal Soil Loss Equation (RUSLE) for use in Canada and appropriateness for the land use classes considered. The current model does not differentiate C and P values between different agricultural land use classifications. If sediment simulation is accurate, and TP is still too low, this would indicate that the dissolved fraction is more important, and further suggests that organic P from animals or dissolved P in shallow groundwater and runoff (from excessive fertilizer/manure application) is under estimated.
7. Verify livestock and manure management practices in the watershed as these can be significant contributors to loading and an additional source of uncertainty. Change in the distribution of land use between crops and pasture will impact how manure losses are contributed from land use sources. If the majority of manure is spread on crop land and the amount of crop land is reduced, the same amount of manure loss from spreading is allocated to a smaller area of crop land.
8. Apply overlay grid-based analysis in CANWET to further investigate the distribution of loading sources within catchment land uses. This approach would determine a probable spatial distribution of the source loads determined in this analysis according to proximity to water courses and wetness index (potential for saturated conditions).
9. Consideration of management practices in the model was restricted to vegetated buffer strips and it was assumed that the portion of each land use serviced by these features was unchanged between scenarios. Only those vegetative buffer strips identified along major water courses were included in the assessment. The proportion of land use within each catchment that might be serviced by vegetated buffer strips is a rough estimate at best without application of a more robust spatial analysis. Reductions were applied only during growing season periods. Future analysis should consider a more detailed stream network and use of grid-based flow direction mapping in CANWET to better assess the

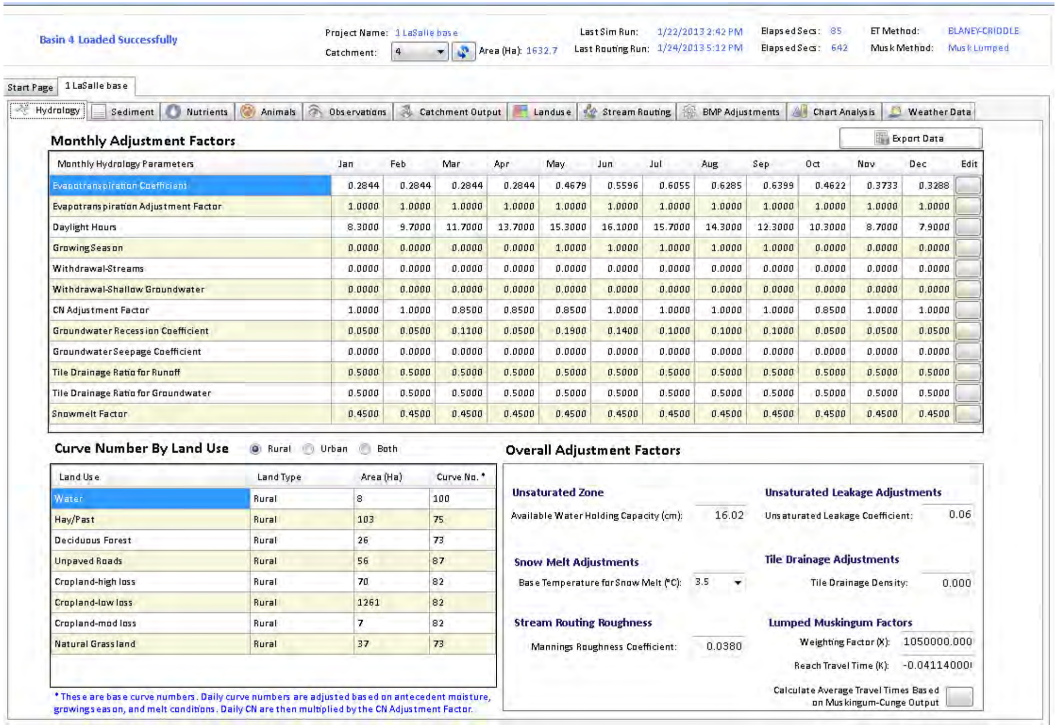
proportion of land serviced by such features. It was not possible to complete this level of analysis under the current scope of work.

10. The approach recommended in #9 using flow direction mapping should be applied to further reduce predicted upstream loads that are intercepted by existing or reintroduced wetlands in all scenarios. This is expected to have important implications for the estimated load reductions.
11. Determine loading reductions that could reasonably be expected from reintroduction of wetlands. These complex systems have been shown to retain nutrients, but in some cases they may also release stored nutrients under certain hydraulic conditions. The model needs input from the user to be able to represent the net efficiency of wetlands in reducing nutrients.
12. In-stream uptake and fall out of phosphorus should be better defined to improve the model response to in-stream assimilative capacity.
13. A livestock operation north of Benard in Catchment 4 at Benard Road and Road 65 N should be classed as a point source with discharge volume and concentrations. Given the apparent algae growth immediately downstream of this facility, it is strongly suggested that the model should be updated to specifically account for such facilities. Better understanding of operational practices are needed to account for such operations in the simulation.

Appendix A

Water Quality Model Input Parameters and Results Summary

Sample CANWET Input Screens for LaSalle River Model



Basin 4 Loaded Successfully

Project Name: 1 LaSalle base
Catchment: 4
Area (Ha): 1632.7
Last Sim Run: 1/22/2013 2:42 PM
Elapsed Secs: 85
ET Method: BLANEY-CRIDDLE
Last Routing Run: 1/24/2013 5:12 PM
Elapsed Secs: 642
Musk Method: Musk Lumped

Start Page | 1 LaSalle base

Hydrology | Sediment | Nutrients | Animals | Observations | Catchment Output | Landuse | Stream Routing | BMP Adjustments | Chart Analysis | Weather Data

Monthly Adjustment Factors

Export Data

Monthly Hydrology Parameters	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Edit
Evapotranspiration Coefficient	0.2844	0.2844	0.2844	0.2844	0.4679	0.5596	0.6055	0.6285	0.6399	0.4622	0.3733	0.3288	
Evapotranspiration Adjustment Factor	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	
Daylight Hours	8.3000	9.7000	11.7000	13.7000	15.3000	16.1000	15.7000	14.3000	12.3000	10.3000	8.7000	7.9000	
Growing Season	0.0000	0.0000	0.0000	0.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.0000	0.0000	0.0000	
Withdrawal-Streams	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	
Withdrawal-Shallow Groundwater	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	
CN Adjustment Factor	1.0000	1.0000	0.8500	0.8500	0.8500	1.0000	1.0000	1.0000	1.0000	0.8500	1.0000	1.0000	
Groundwater Recession Coefficient	0.0500	0.0500	0.1100	0.0500	0.1900	0.1400	0.1000	0.1000	0.1000	0.0500	0.0500	0.0500	
Groundwater Seepage Coefficient	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	
Tile Drainage Ratio for Runoff	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	
Tile Drainage Ratio for Groundwater	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	
Snowmelt Factor	0.4500	0.4500	0.4500	0.4500	0.4500	0.4500	0.4500	0.4500	0.4500	0.4500	0.4500	0.4500	

Curve Number By Land Use (Rural / Urban / Both)

Land Use	Land Type	Area (Ha)	Curve No. *
Water	Rural	8	100
Hay/Past	Rural	103	75
Deciduous Forest	Rural	26	73
Unpaved Roads	Rural	56	87
Cropland-high loss	Rural	70	82
Cropland-low loss	Rural	1261	82
Cropland-mod loss	Rural	7	82
Natural Grassland	Rural	37	73

* These are base curve numbers. Daily curve numbers are adjusted based on antecedent moisture, growing season, and melt conditions. Daily CN are then multiplied by the CN Adjustment Factor.

Overall Adjustment Factors

Unsaturated Zone
Available Water Holding Capacity (cm): 16.02

Unsaturated Leakage Adjustments
Unsaturated Leakage Coefficient: 0.06

Snow Melt Adjustments
Base Temperature for Snow Melt (°C): 3.5

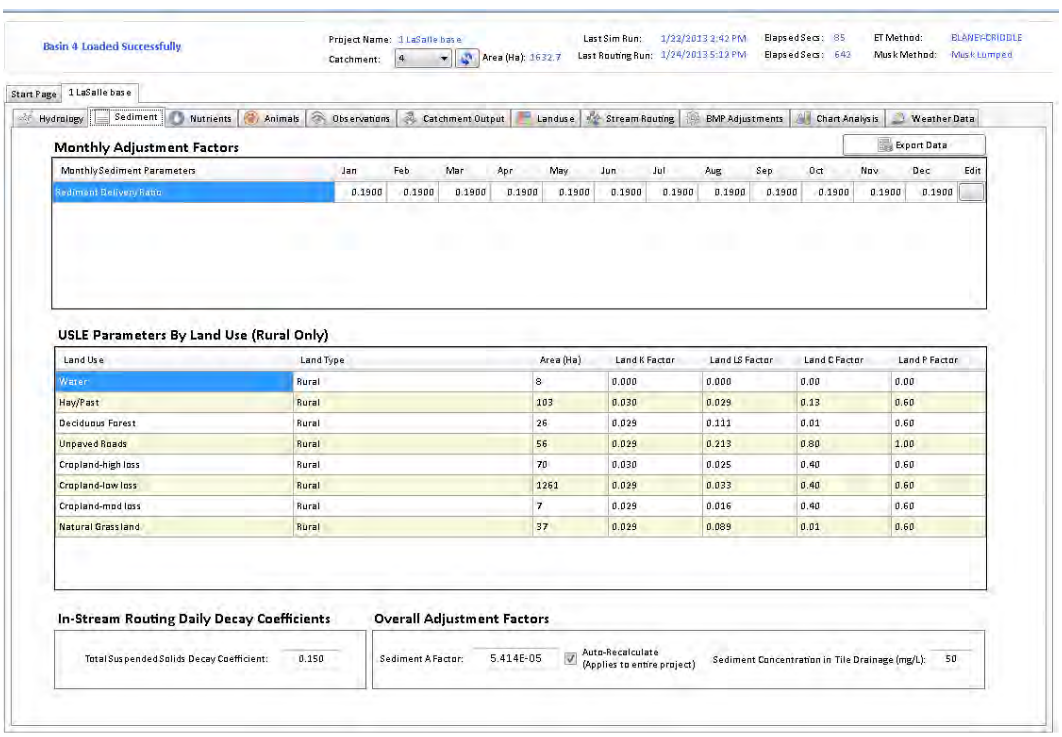
Tile Drainage Adjustments
Tile Drainage Density: 0.000

Stream Routing Roughness
Mannings Roughness Coefficient: 0.0380

Lumped Muskingum Factors
Weighting Factor (X): 1050000.000
Reach Travel Time (K): -0.04114000

Calculate Average Travel Times Based on Muskingum-Cunge Output

CANWET hydrology inputs



Basin 4 Loaded Successfully

Project Name: 1 LaSalle base
Catchment: 4
Area (Ha): 1632.7
Last Sim Run: 1/22/2013 2:42 PM
Elapsed Secs: 85
ET Method: BLANEY-CRIDDLE
Last Routing Run: 1/24/2013 5:12 PM
Elapsed Secs: 642
Musk Method: Musk Lumped

Start Page | 1 LaSalle base

Hydrology | Sediment | Nutrients | Animals | Observations | Catchment Output | Landuse | Stream Routing | BMP Adjustments | Chart Analysis | Weather Data

Monthly Adjustment Factors

Export Data

Monthly Sediment Parameters	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Edit
Sediment Delivery Ratio	0.1900	0.1900	0.1900	0.1900	0.1900	0.1900	0.1900	0.1900	0.1900	0.1900	0.1900	0.1900	

USLE Parameters By Land Use (Rural Only)

Land Use	Land Type	Area (Ha)	Land K Factor	Land LS Factor	Land C Factor	Land P Factor
Water	Rural	8	0.000	0.000	0.00	0.00
Hay/Past	Rural	103	0.030	0.029	0.13	0.60
Deciduous Forest	Rural	26	0.029	0.111	0.01	0.60
Unpaved Roads	Rural	56	0.029	0.213	0.80	1.00
Cropland-high loss	Rural	70	0.030	0.025	0.40	0.60
Cropland-low loss	Rural	1261	0.029	0.033	0.40	0.60
Cropland-mod loss	Rural	7	0.029	0.016	0.40	0.60
Natural Grassland	Rural	37	0.029	0.089	0.01	0.60

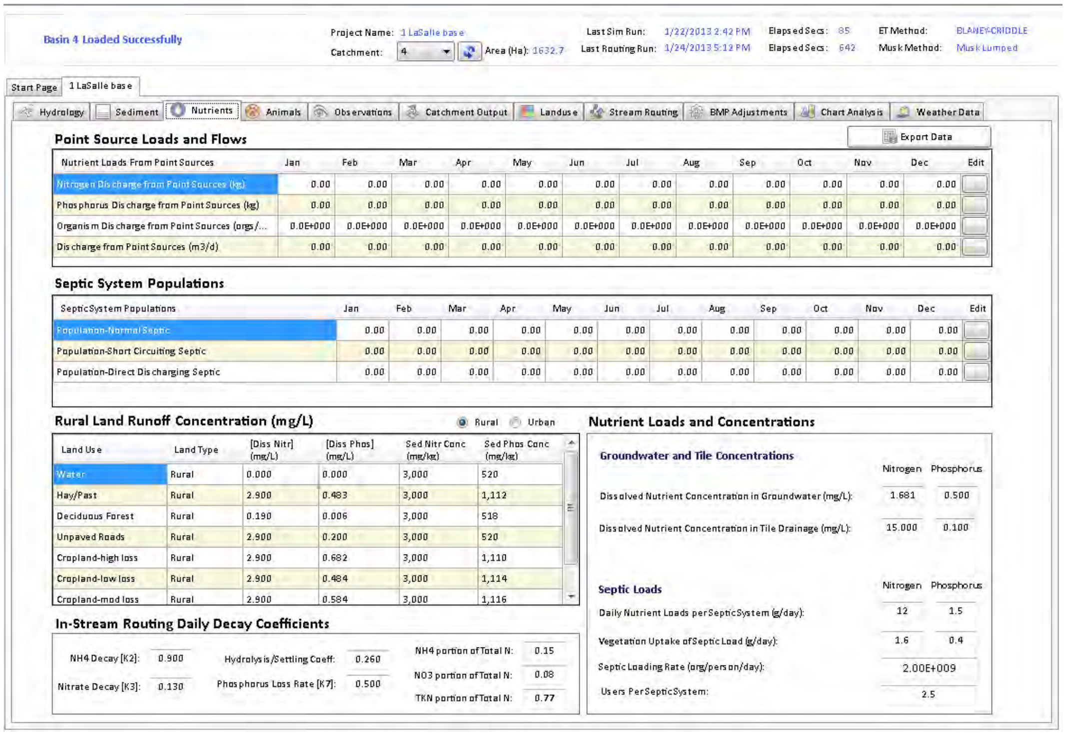
In-Stream Routing Daily Decay Coefficients

Total Suspended Solids Decay Coefficient: 0.150

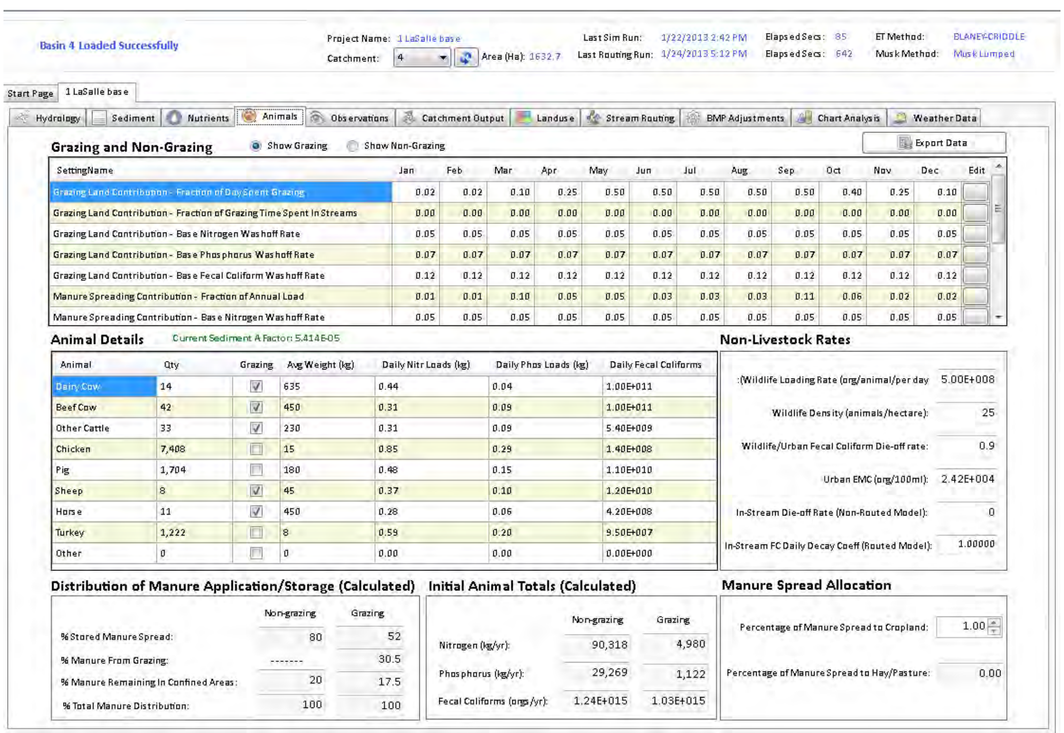
Overall Adjustment Factors

Sediment A Factor: 5.414E-05
Auto-Recalculate (Applies to entire project)
Sediment Concentration in Tile Drainage (mg/L): 50

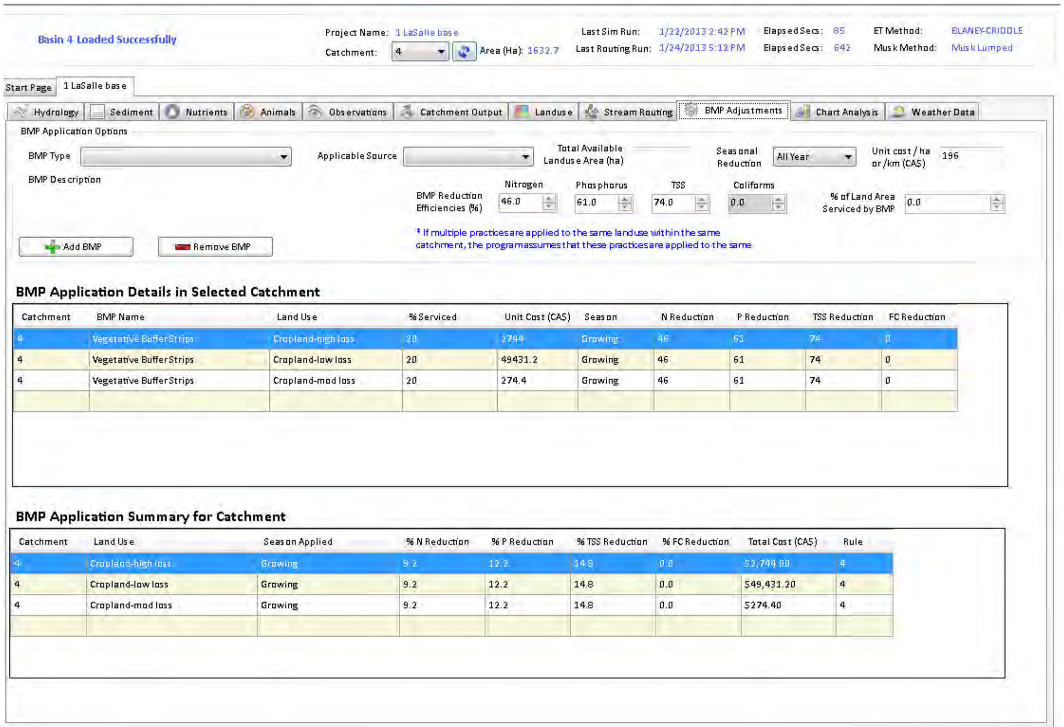
CANWET sediment inputs



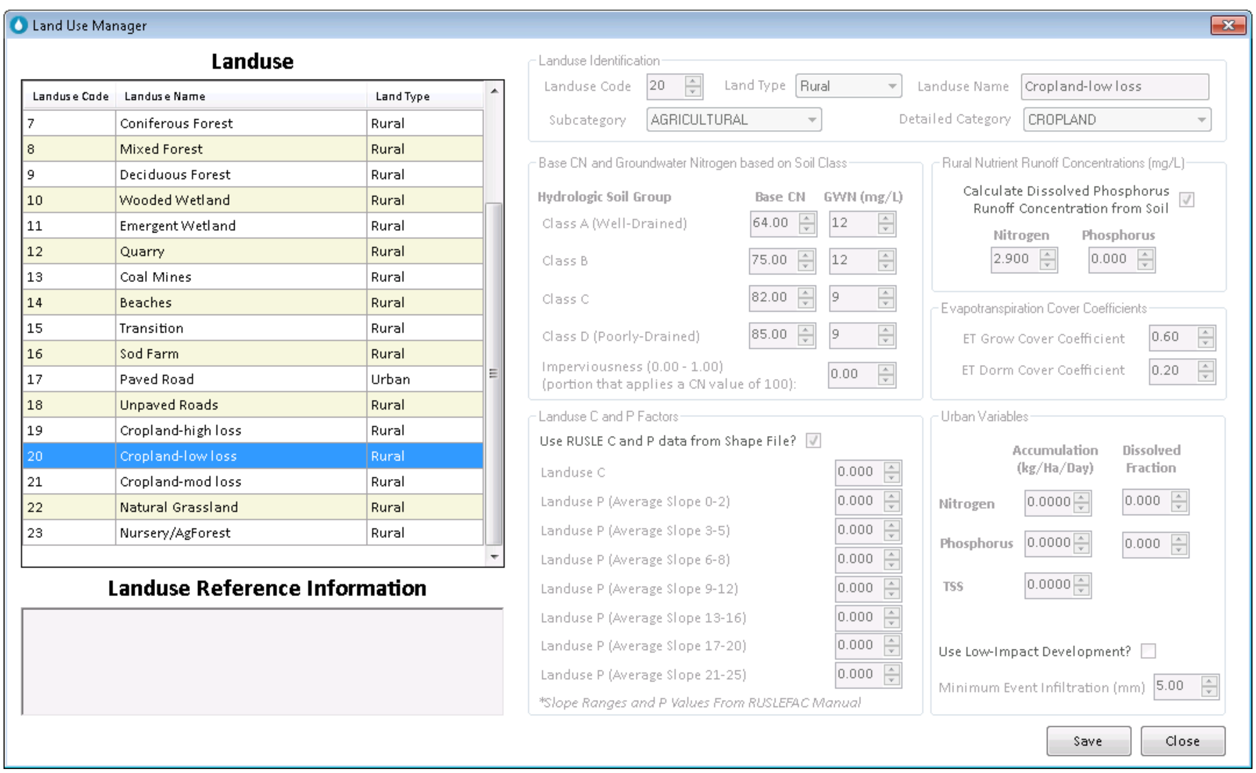
CANWET nutrient inputs



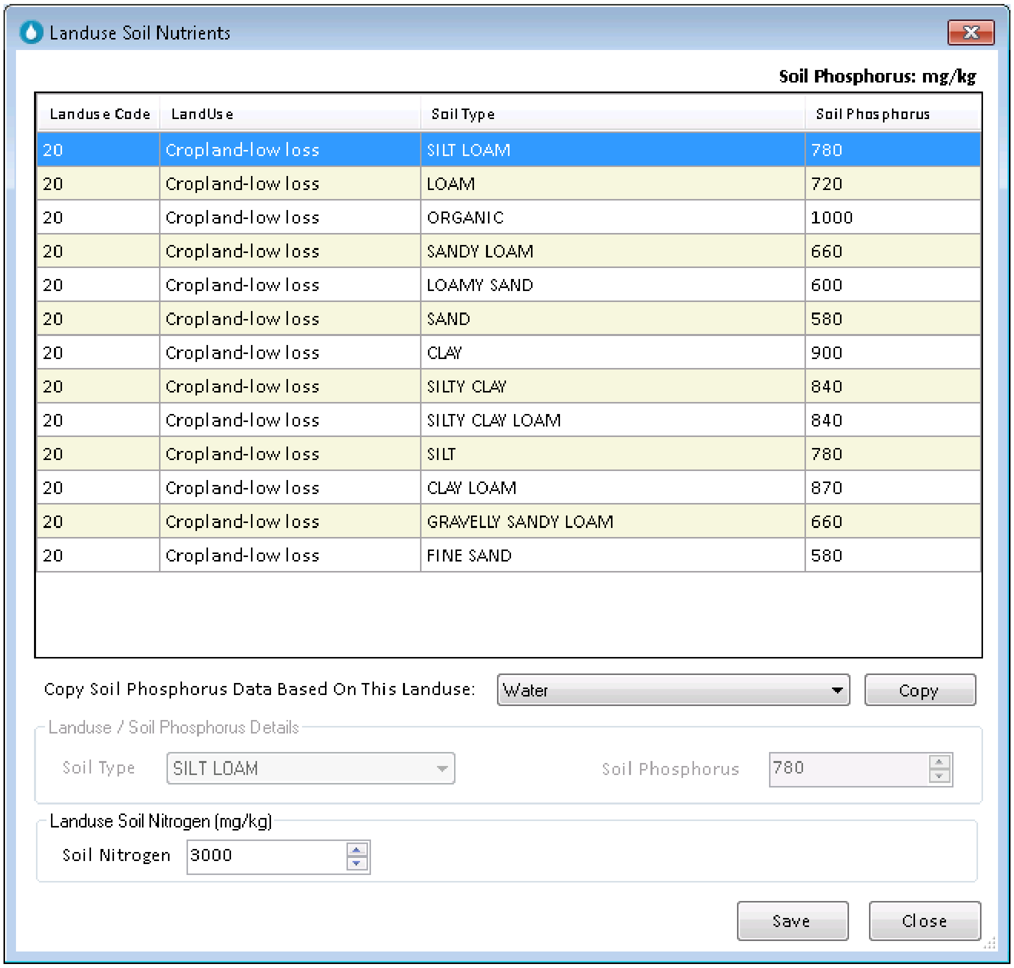
CANWET livestock / animal inputs



CANWET best management practices inputs

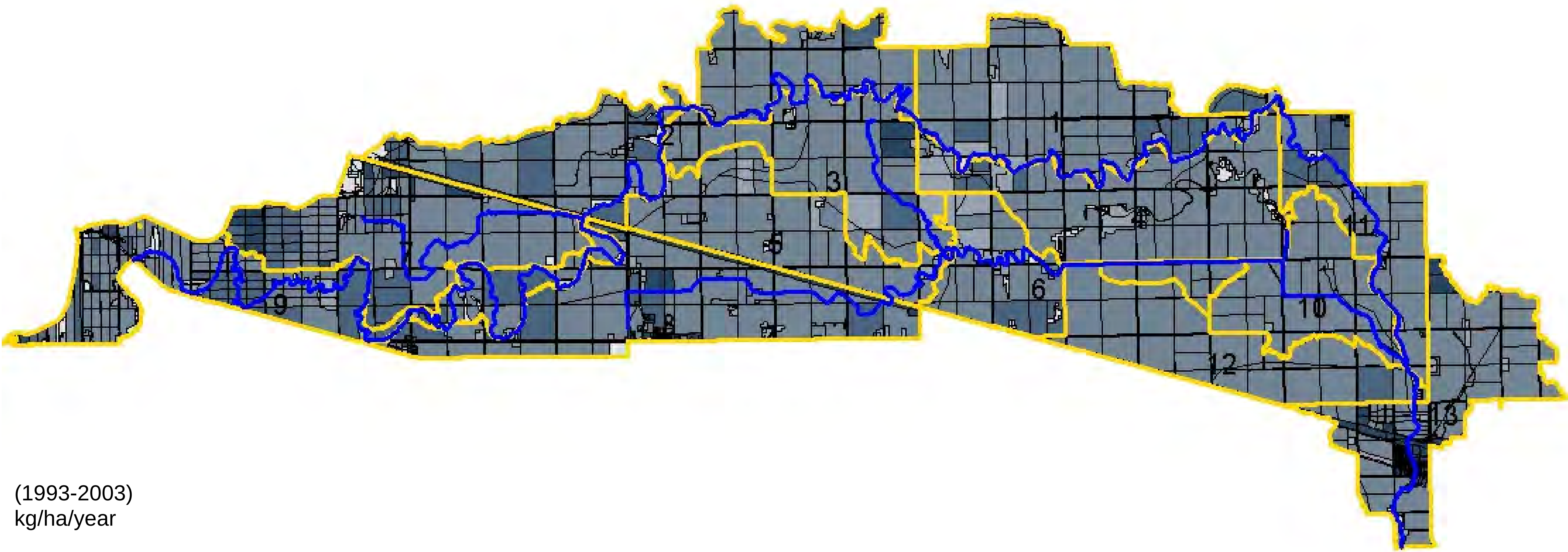


CANWET Land Use Manager – generic setting used for cropland – low loss potential



CANWET Land Use Manager – soil nutrient dialog box

Appendix B
Spatial Output from Simulations



(1993-2003)
kg/ha/year

- 0.000 - 0.001
- 0.001 - 0.025
- 0.025 - 0.050
- 0.050 - 0.075
- 0.075 - 0.100
- 0.100 - 0.500

Annual Phosphorus Loading by Land Use

Base Scenario

Legend

- Watercourse
- Catchment Boundaries

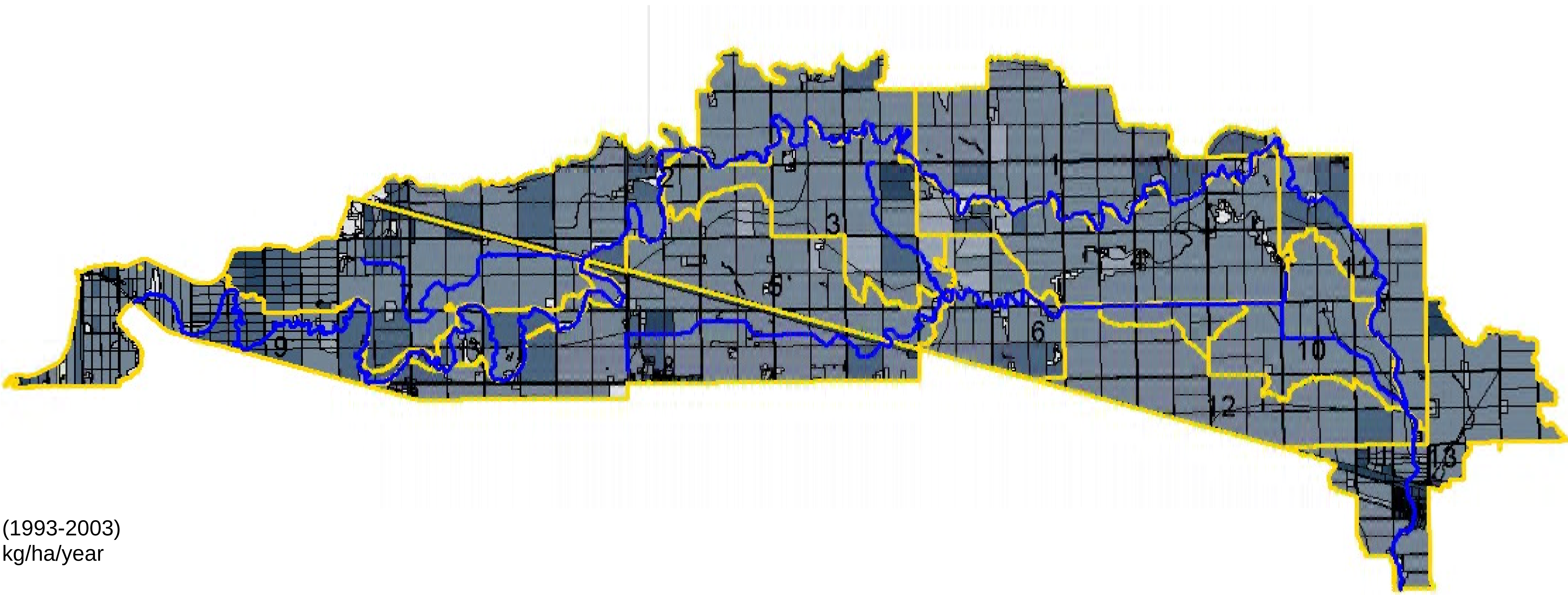
Notes:

Phosphorus load is calculated for each land use by catchment.

N

N.T.S.

GREENLAND® international consulting ltd.



(1993-2003)
kg/ha/year

0.000 - 0.001
0.001 - 0.025
0.025 - 0.050
0.050 - 0.075
0.075 - 0.100
0.100 - 0.500

Annual Phosphorus Loading by Land Use

Scenario #2

Legend

Watercourse

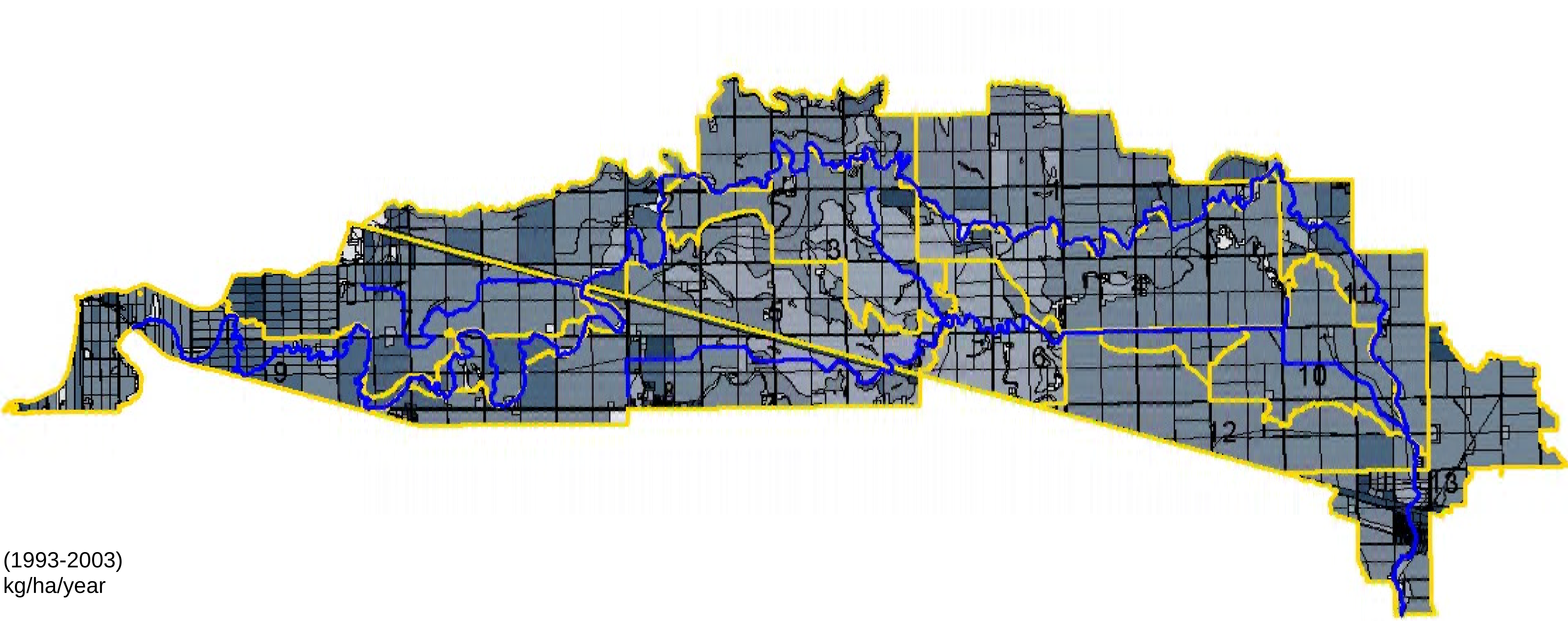
Catchment Boundaries

Notes:

Phosphorus load is calculated for each land use by catchment.

N

N.T.S.



(1993-2003)
kg/ha/year

- 0.000 - 0.001
- 0.001 - 0.025
- 0.025 - 0.050
- 0.050 - 0.075
- 0.075 - 0.100
- 0.100 - 0.500

Annual Phosphorus Loading by Land Use

Scenario #3

Legend

- Watercourse
- Catchment Boundaries

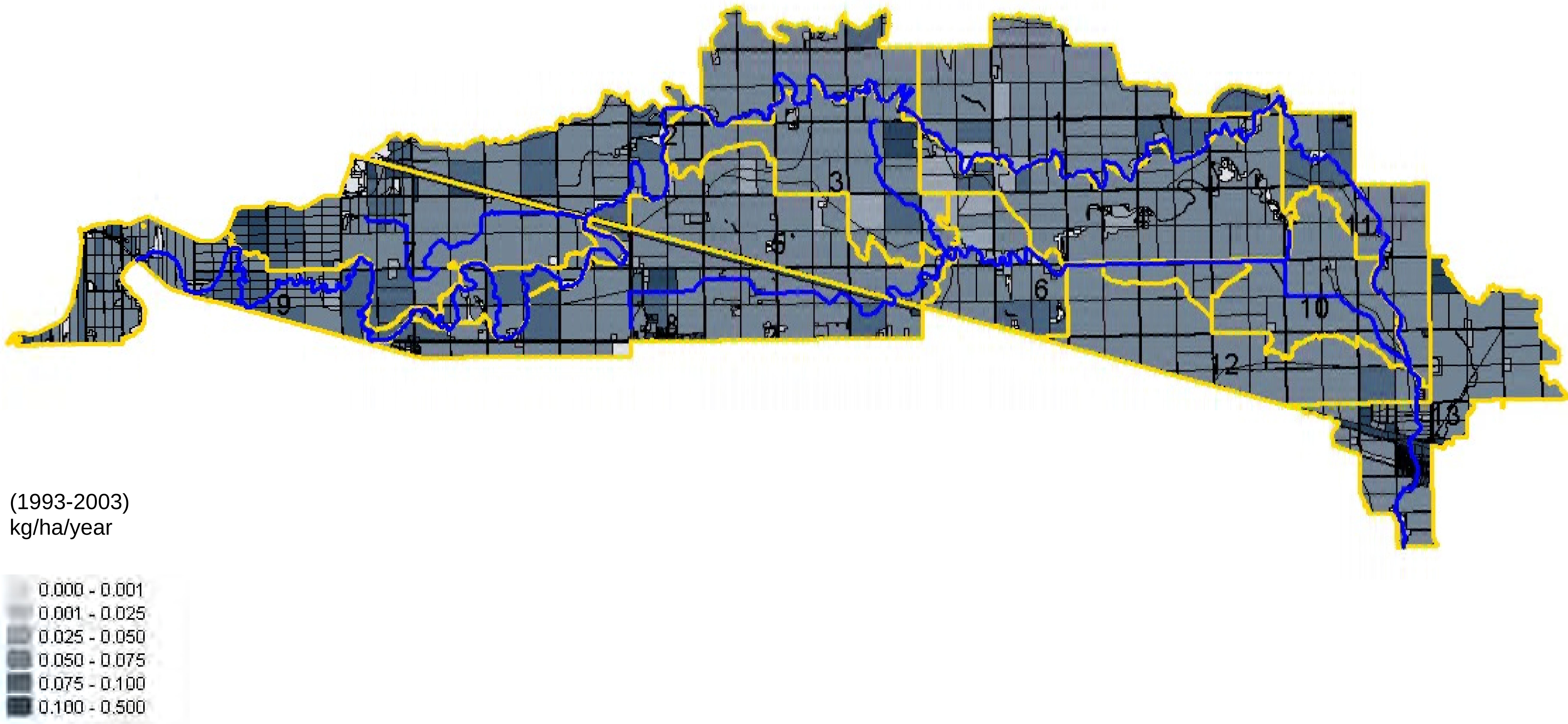
Notes:

Phosphorus load is calculated for each land use by catchment.

N

N.T.S.

GREENLAND® international consulting ltd.



Annual Phosphorus Loading by Land Use

Scenario #4

Legend

Watercourse

Catchment Boundaries

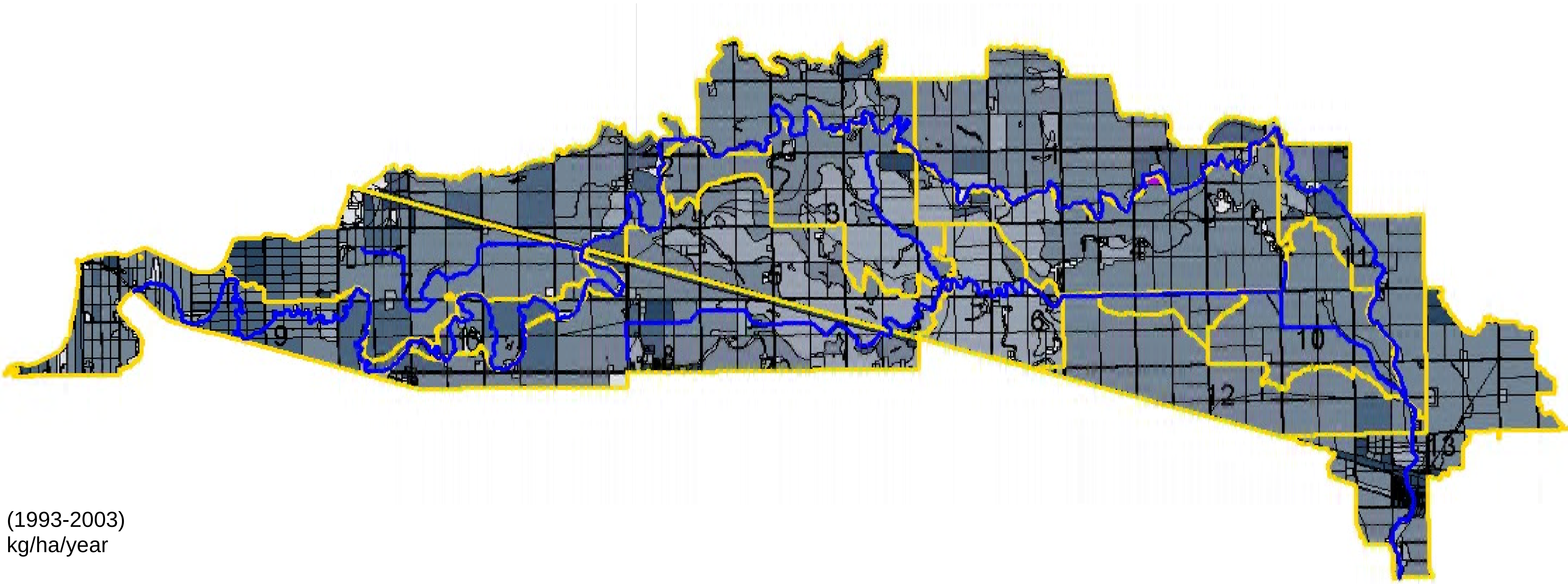
Notes:

Phosphorus load is calculated for each land use by catchment.

N

N.T.S.

GREENLAND® international consulting ltd.



(1993-2003)
kg/ha/year

- 0.000 - 0.001
- 0.001 - 0.025
- 0.025 - 0.050
- 0.050 - 0.075
- 0.075 - 0.100
- 0.100 - 0.500

Annual Phosphorus Loading by Land Use

Scenario #5

Legend

- Watercourse
- Catchment Boundaries

Notes:

Phosphorus load is calculated for each land use by catchment.

N

N.T.S.

GREENLAND®
international consulting ltd.