PRELIMINARY INVENTORY OF LAND USE AND MAJOR SOURCES OF NONPOINT SOURCE WATER POLLUTION IN THE LOWER YELLOW RIVER AND PAINT CREEK BASINS

Chippewa County Land Conservation Department
Technical Report #96-2

Prepared as a contributing component of:

. Wi. Lake Planning Grant
#3007-1
WPL-035

. EPA Lakes Diagnostic Study Grant
#CL995799-01-0

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12/19/95

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Table of Contents

List of Tables

List of Figures

I. Introduction

A number of detailed environmental studies are now being conducted in association with efforts to relicense the Lake Wissota hydro electric dam. (FERC project no. 2567). These studies are being administered by the Wisconsin Department of Natural Resources, Bureau of Water Resources, Western District, through EPA Lakes Diagnostic Grant #CL995799-01-0 and Wis. Lakes Planning Grant #3007-1.

The individual studies are being coordinated as a comprehensive Lake Planning Project, to document the biological effects of lake draw-down on Little Lake Wissota and Moon Bay, and to assess water quality impacts from land use in the contributing watersheds.

Individual segments of the Lake Planning Project are being conducted by the Wisconsin Department of Natural Resources (WDNR), University of Wisconsin-Eau Claire, Northern States Power, Winona State University and the Chippewa County Land Conservation Department (LCD).

Major components of the project include:

1. An inventory of land use and non-point source pollution in the Lower Yellow River and Paint Creek watersheds;
2. Water quality monitoring, conducted at 4-6 key sites on Lake Wissota, and on tributary streams in the Lower Yellow River Basin;
3. A revised bathymetric map for the lake;
4. A hydrologic budget for Lake Wissota, Moon Bay and Little Lake Wissota;
5. A water quality model, to estimate a phosphorus budget for Moon Bay and Little Lake Wissota;
6. A survey of benthic invertebrate populations; and
7. An evaluation of fish stranding in draw-down areas.

II. Issue

Lake Wissota is one of the largest and most heavily used recreational resources in western Wisconsin. It is a major impoundment on the Chippewa River and receives inflow from extensive areas of the Chippewa River Basin. Given its physical characteristics, Lake Wissota is moderately eutrophic with a Trophic State Index range of 53-64.

For purposes of water quality management, WDNR has classified Lake Wissota as a Class IB lake, indicating that it is sensitive to increased phosphorous loads and that water quality is now poor to very poor. It is further classified as a high-value resource which should be protected. To date, information has not been adequate to allow the state to rank Lake Wissota for future management based upon its potential for response to non-point source pollution controls (Lower Chippewa River Water Quality Basin Plan, 1995).

Algal blooms now occur regularly during most years, from June until late September. The most frequent of these blooms occur in Moon Bay, and Little Lake Wissota, where the Yellow River and Paint Creek adjoin the larger water body. (Art Bernhardt, pers. comm.)

Information regarding basin pollutant loads is limited to baseline data collected through the National Eutrophication Survey (NES) (Lower Chippewa River Basin Plan, 1989). Results of that survey suggest that unit area phosphorous loads contributed by the Yellow River and Paint Creek Basins are 211% and 159% higher than the load contributed by the Chippewa River (NES, 1974). Ongoing observation following storm events indicate that large volumes of sediment and nutrients are being delivered in runoff to Moon Bay and Little Lake Wissota (Figure 1).

Before informed water quality and lake management decisions can be made, greater information regarding non-point source pollutant loads and potential lake response must be gathered.

Figure 1: Post-Storm Event Sediment Delivery to Moon Bay and Little Lake Wissota

III. Purpose

This component of the Lake Wissota Planning Project has been conducted to document existing land cover in the Lower Yellow River and Paint Creek basins; and to estimate the non-point pollutant load contributed to Moon Bay and Little Lake Wissota. For the purposes of this investigation, major sources of non-point pollutants were assumed to be phosphorus and sediment delivered from upland land use, barnyards and streambank erosion.

Individual inventories of each pollutant source were conducted to estimate the volume and rate of sediment and phosphorous delivered from designated watersheds. Results of this study will be used by other researchers, who will compare estimated pollutant loads to concentrations of suspended solids and dissolved phosphorous as sampled from tributary streams in these same watersheds. If validated, these estimates will be used as inputs to a water quality model and phosphorus budget being developed for Lake Wissota.

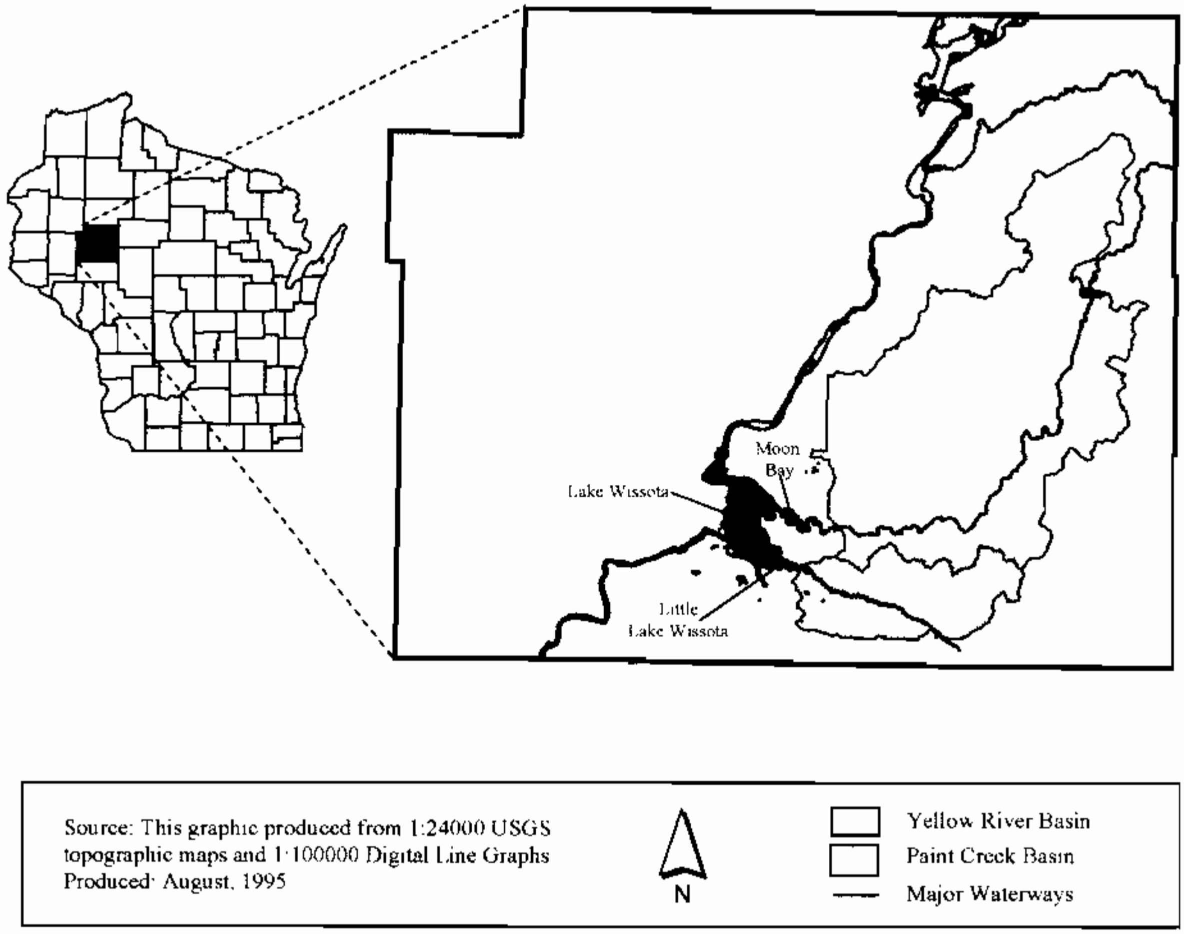
The ultimate purpose of this pollutant inventory and water quality modeling effort is to determine whether best management practices, applied in the watershed area, can effectively reduce non-point source pollution to a level that will improve water quality in Moon Bay and Little Lake Wissota.

IV. Study Area

Lake Wissota is a 2550 ha (6300 acre) impoundment located in west central Wisconsin. It is situated at the confluence of the Chippewa River and Yellow River. Moon Bay and Little Lake Wissota are major bays of Lake Wissota which receive inflow from the Lower Yellow River and Paint Creek Basins. The Lower Yellow River and Paint Creek basins cover an large part of eastern Chippewa County with have a combined drainage area of approximately 53,381 ha (132,000 acres) (Figure 2).

The Lower Yellow River and Paint Creek basins are formed on a gently rolling till plain underlain by cambrian sandstone or pre-cambrian granite or gneiss. Drainage patterns are poorly defined. Many perched and groundwater contact wetlands are found in closed surface depressions and along drainage ways. Soils are generally of the Mangor-Almena-Spencer Association. The location of major watersheds within these basins is provided in Figure 3.
Land is used predominately to support dairy based agriculture (Chippewa County Animal Waste Management Plan, 1986). Forested regions are located mainly in the upper reaches of the Lower Yellow River Basin. Urban land uses are limited to the Village of Boyd, City of Cadott, and urbanizing areas of the Towns of Lafayette and Hallie.

Figure 2: Location of Lower Yellow River and Paint Creek Basins in Chippewa County, Wisconsin



Source: This graphic produced from 1:24000 USGS topographic maps and 1:100000 Digital Line Graphs
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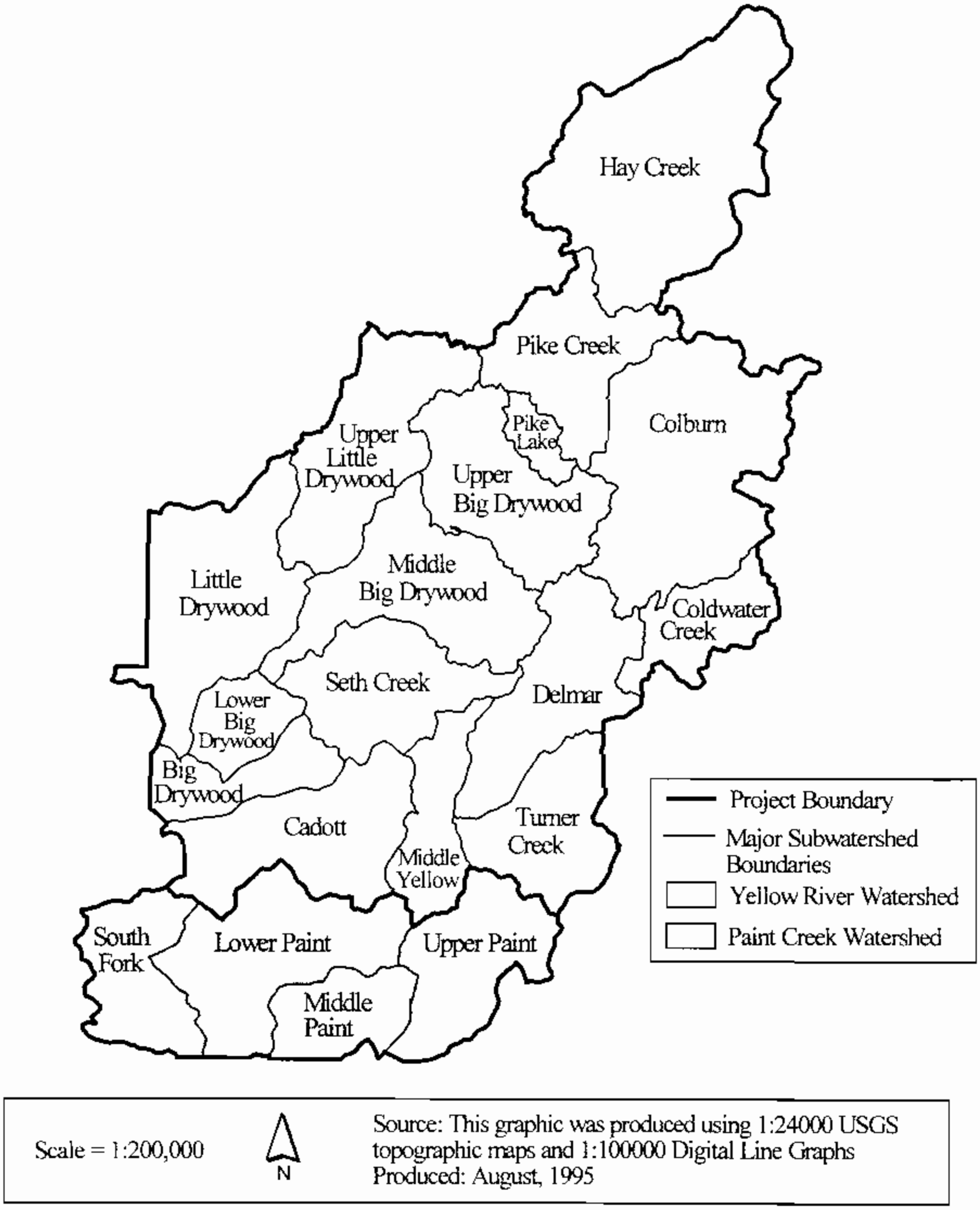
Figure 3: Watersheds of the Lower Yellow River and Paint Creek Basins



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V. Methods

A. Methods to Classify Land Cover

A single seven band Landsat Thematic Mapper (TM) satellite image was used to document the type and extent of land cover within the Lower Yellow River and Paint Creek basins. The Landsat image was recorded on June 11, 1992. The original image covered an area of 185km x 170km. This larger scene was clipped to include only the area within Chippewa County. The Chippewa County subset was then used for all further analyses.

Earth Resource Data Analysis Software (ERDAS) software (v.7.5) was used to classify the raw satellite data into land cover classes. From the original satellite data a Normalized Difference Vegetation Index (NDVI) image was calculated to assist in distinguishing row crops. The original data were submitted to Principal Components Analysis (PCA) to help distinguish between heavy urban and light urban land cover. The NDVI and PCA bands were then added to the original seven bands of TM data.

An iterative self-organizing data analysis technique (ISODATA) was used to assign each picture element (pixel) in the image to one of 200 unique spectral clusters based upon similar reflectance patterns in each of the input bands. These spectral clusters were then used as a base for determining land cover within the watersheds.

The 200 spectral clusters were re-classified, using a supervised classification approach, and merged to assign each spectral cluster to one of the following land cover types:

1) water,
2) wetland,
3) coniferous forest,
4) deciduous forest,
5) hay/pasture,
6) row crops,
7) heavy urban, and
8) light urban

Accuracy assessment was performed on the classified image using 180 randomly generated points. The actual land cover for each of these points was determined through GIS analysis of USGS TIGER files, and manual interpretation of aerial photographs taken during June and July of 1992. These reference data points were then compared to the same pixels on the classified land cover map to determine the overall accuracy of the classification.

B. Methods to Estimate Phosphorus Delivery from Upland Land use.

The rate of phosphorus delivered to the stream network from upland land use, was estimated by assigning phosphorus delivery coefficients to the acreage of individual land cover types, as determined through the land cover analysis,

Phosphorus delivery coefficients were selected based upon soil types as reported in EPA manual 440/5-80-011; (6/90). Phosphorus delivery coefficients assigned to land cover types are as follows:

	kg/ha/yr
Row crops	1.25
Grassland/Pasture/Hay	.66
Forest (hardwood and Pine)	.035

The estimated rate of phosphorus delivery was calculated for each land cover type in each watershed using the following equation:

$$\begin{array}{l}\text{Estimated Rate of Phosphorous}\\ \text{Delivery from Upland Landuse}\\ \text{within a watershed (Kg/yr)}\end{array} = \sum_{1}^{X} \left(\begin{array}{l}\text{Area of Each Land}\\ \text{Cover Type}\end{array}\right)_X \left(\begin{array}{l}\text{Phosphorous Delivery}\\ \text{Coeffecient for Each}\\ \text{Land Cover Type (Kg/ha/yr)}\end{array}\right)_X$$

Where X = # of Land Cover Types

The total estimated rate of phosphorus delivery from all land cover types in each basin was then obtained by calculating the sum of the estimated rates of phosphorous delivery from all land cover types within each of the watersheds situated in the basin.

For the purpose of geographic comparison, each watershed was placed in one of three categories, based upon the total volume of upland phosphorus as delivered to the stream network. Categories of pollutant load were assumed as follows:

Low < 1100 kg/yr

Medium 1100 - 1800 kg/yr

High > 1800 kg/yr

C. Methods to Estimate Sediment Delivery from Upland Land use.

The rate of sediment delivered to the stream network from upland land use, was estimated by assigning sediment delivery coefficients to the acreage of individual land cover types, generated through the land cover analysis.

The statistical relationship that exists between soil erosion and sediment delivery was assumed to be similar to that documented in an adjacent watershed with similar physical characteristics. (Duncan Creek Watershed Plan; Upland Soil Erosion and Sediment Inventory, Oct. 1991).

During the inventory phase of the Duncan Creek study, the WIN model (WDNR Bureau of Water Resources) was applied to calculate current rates of soil erosion and associated rates of sediment delivery using a sample of approximately 1300 parcels located in 33 minor subwatersheds. From this data set, sediment delivery coefficients were developed for each of 11 major watersheds using linear regression. Results indicate that soil erosion sediment delivery coefficients in that basin range from 0.14 to 0.29, with mean of 0.17.

As part of the same study, linear regression was applied to the WIN data set, to determine the average rate of soil erosion and associated sediment delivery from specific land cover types. Results suggest that the average rate of sediment delivery for individual land cover types in the Duncan Creek Basin are as follows:

Land Cover Type	kg/ha/yr
Row Crops	1530
Grassland/Pasture/Hay	160
Woodland	90
Residential	630

New sediment delivery coefficients were not developed for the current investigation. Instead, sediment delivery rates for the Lower Yellow River and Paint Creek basins were estimated by multiplying the average sediment delivery rate for each land cover type, as reported above, by the area of each land cover type, as measured in the study area.

The following equation was used:

$$\text{Estimated Rate of Sediment Delivery in a Basin (Kg/yr)} = \sum_{1}^{X} \left(\text{Area of Each Land Cover Type (ha)}\right)_X \left(\text{Sediment Delivery Rate for Each Land Cover Type (Kg/ha/yr)}\right)_X$$

Where X = # of Land Cover Types

D. Methods to Estimate Total Barnyard Phosphorus Delivery.

The rate of phosphorus delivered to the stream network from barnyard runoff was estimated by assigning average discharge rates to documented barnyard locations.

To develop estimates of barnyard phosphorus delivery in the study area, an inventory of barnyard size and location was completed using 7.5 min. topographic maps, and 1993 CFSA section slides. A windshield survey was then conducted to verify operational status and approximate herd size. Results of this inventory showed that the herd size and physical characteristics of barnyard locations in the study area were similar to those as previously documented in an adjacent agricultural basin (Duncan Creek Watershed Plan; Barnyard Inventory, Oct. 1991)

During the inventory phase of Duncan Creek study, the BARNY model (WDNR 1989), was applied to calculate the rate of phosphorus discharge at 355 barnyard sites. As part of that effort a spatial analysis was conducted using pc Arc Info software (V.3.4D+) to calculate the average phosphorus delivery from barnyards located within each of five shoreland buffer zones. Individual buffer zones were selected based upon the distance to stream channels and areas of concentrated flow, as defined on 7.5' USGS topographic quadrangle maps.

The mean phosphorus delivery rate for barnyards located within each buffer zone was then calculated using the following equation:

$$\text{Mean Barnyard Phosphorous Delivery Within a Buffer Zone (Kg/yr)} = \frac{\sum_{1}^{x} \left(\begin{array}{l} \text{Phosphorous Delivery Rate} \\ \text{for Each Barnyard (Kg/yr)} \end{array} \right)_{X}}{X}$$

Where X = # of Barnyards Within a Buffer Zone

Results of that initial buffer analysis are provided in Appendix A-1.

To estimate the rate of barnyard phosphorus delivery in the Lower Yellow River and Paint Creek basins, the location of each barnyard within the study area was plotted on 1:24000 USGS topographic maps and digitized into pc ARC\INFO format. A buffer analysis was then conducted, as previously described, to determine the number of barnyards within each of the defined buffer zones.

Individual barnyards located within each buffer zone were assigned the average barnyard phosphorus delivery rate, as previously calculated for barnyards in the Duncan Creek basin for that particular buffer zone. Average discharge rates were assumed as follows:

Buffer Category	Mean Phosphorous Delivery (kg/yr)
< 100'	14
100-200'	32
200-500'	18
500-1000'	14
>1000'	11

The estimated volume of phosphorus delivered from each buffer zone and watershed was then calculated as the sum of the assigned phosphorus delivery rates using the following equation:

$$\text{Estimated Phosphorous Delivery from each Buffer Zone (Kg/yr)} = \sum_{1}^{X} \left(\begin{array}{c} \text{Phosphorous Delivery Rate} \\ \text{for Each Barnyard (Kg/yr)} \end{array} \right)_X$$

Where X = # of Barnyards Within a Buffer Zone

For purposes of geographic comparison, each major watershed was categorized based upon the total volume of barnyard phosphorus delivered to the stream network. Categories of pollutant load were assumed as follows:

Low < 400 kg/y

Medium 400 - 600 kg/yr

High > 600 kg/yr

E. Methods to Estimate Sediment Delivered from Streambank Erosion Sites.

The rate of sediment delivered to the stream network from streambank erosion sites was estimated by developing a linear equation based upon the physical characteristics of the stream and associated watershed.

Rates of streambank erosion and associated sediment delivery are thought to be related to the physical parameters affecting stream geomorphology. Specifically, the physical parameters assumed to be of greatest significance include; watershed size, cumulative drainage area, main channel length, stream gradient and stream sinuosity.[1]

To assess the nature of this relationship, an investigation was conducted, as part of the Duncan Creek Clean Water Project streambank inventory, to quantify the amount of sediment delivered to a stream from streambank erosion sites. To obtain these values, each perennial stream reach, as delineated on 7.5' USGS topographic maps, was inventoried to document the number and location of erosion sites, as well as the width, height and rate of lateral recession at each site. The volume of sediment delivered from each site was then calculated using the following equation:

$$\text{Sediment Delivered from Streambank Erosion Site} = \text{Site Length} \times \text{Site Height} \times \text{Site Lateral Recession} \times \frac{90}{200}$$

To obtain quantitative measures of the physical parameters thought to affect streambank and sediment delivery, a spatial analysis was performed in pc Arc/Info (v.3.4D+) on the streams of the Duncan Creek Watershed. Each stream segment[2], as delineated on USGS 7.5 minute topographic maps, was digitized as a map layer. Main channel length for each segment was then determined from this layer. The physical parameters of watershed size and cumulative drainage area were obtained by overlaying existing topographic layers over the stream segment layer and digitizing the areal extent of the land area draining to each stream segment.

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[1] Sinuosity is defined as the ratio of watershed length or main channel length to the straight line length from the upper to lower end of the stream.

[2] A stream segment is defined as the portion of a stream lying entirely within a minor subwatershed.

The sinuosity ratio of each stream segment[2] was calculated using the following equations:

$$\text{Straight Line Length} = \sqrt{(\text{x\_end} - \text{x\_begin})^2 + (\text{y\_end} - \text{y\_begin})^2}$$

$$\text{Sinuosity Ratio} = \frac{\text{Stream Segment Length}}{\text{Straight Line Length}}$$

Correlation analysis was used to quantify relationships between streambank erosion and the physical characteristics of the drainage network thought to affect the rate of this erosion. The extent of these correlations are as follows:

Variable	Streambank Erosion Correlation Coefficient
Cumulative Drainage Are	-0.10
Main Channel Length	0.31
Sinuosity Ratio	0.26
Stream Gradient	0.08

1. Approach Used to Calculate Streambank Erosion in the Study Area.

The information obtained from the streambank erosion inventory and analysis in the Duncan Creek watershed was used to estimate the rate of streambank erosion within the study area of the Lower Yellow River and Paint Creek basins. Regression analysis was used to predict the sediment delivery from each stream reach in the Duncan Creek watershed based upon its physical characteristics and those of the associated watershed. The regression analysis of the Duncan Creek data yielded the following predictive equation:

$$\text{Streambank Erosion} = (13.2 \times (\text{main channel length})) + (.11 \times (\text{cumulative area})) + 4.9$$

To input variables for the equation, all perennial stream segments and associated watershed boundaries within the study area were first digitized into pc ARC\INFO format. A spatial analysis was then conducted to calculate watershed area, cumulative drainage area, main channel length, sinuosity ratio, and stream gradient for each stream segment.

The predictive equation was then applied to each watershed, using the variables main channel length and cumulative area, to estimate the rate of sediment delivery from streambank erosion sites, in each watershed, and cumulative totals for each basin.

To validate the model a representative sample composed of nine stream segments was field checked to document the number of erosion sites, and to measure the rate of lateral recession at each site. These rates of streambank erosion were then compared to the predicted rates of sediment delivery for the same stream segment. The accuracy of the estimates was then quantified by comparing the paired sets of observed and predicted data.

VI. Results

A. Results of Land Cover Classification.

Table 1 shows the area and percent of each land cover class as determined for the watersheds of the Lower Yellow River and Paint Creek basins. Figure 4 illustrates the distribution of land cover types within the study area. Figure 5 illustrates the proportion of major land cover types found within each basin.

Results show that the land cover pattern is very similar in both basins. The grassland/pasture/hay land cover type is dominant, comprising approximately 55% of the study area. Deciduous and coniferous forest covers approximately 32% of each basin. It is important to note that row crops comprise approximately 10% of the study area, and tend to be concentrated in specific watersheds, including Turner Creek, Drywood, and South Fork Paint watersheds.

In developing land cover estimates, difficulties were encountered in attempting to separate permanent grassland vegetation (grassland/pasture) from hay managed as part of a multi-year crop rotation. Additional difficulties were encountered in separating the combined grassland/hay/pasture land cover type from sedge meadow wetlands. Total estimates of wetland areas, as reported in Table 1, are low for both basins based on comparison with USDA and WDNR wetland maps.

Areas of urban land use are limited to the village of Boyd, City of Cadott and shoreland areas of the Yellow River and Little Lake Wissota.

Results of the land cover classification evaluation indicate that the land cover map for the project area has an accuracy of 87%. This error in the classification is attributed to similarity in spectral signatures between land cover classes. Major sources of error may result from differences in planting dates between fields, confusion between fallow cropland and grassland, and seasonal differences between the satellite imagery and the aerial photography used in the classification accuracy assessment.

Table 1: Land Cover within the Lower Yellow River and Paint Creek Basins, Reported by Land Cover Type and Watershed

Yellow River	Water		Wetlands		Rowcrops		Deciduous Forest		Coniferous Forest		Grass/Hay/Pasture		Heavy Urban		Light Urban		Total	
Watersheds	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%
Pike Creek	5	0.2	19	0.8	77	3.2	1400	58.2	235	9.8	671	27.9	0	0.0	0	0.0	2407	5.4
Upper Big Drywood	2	0.1	1	0.0	258	9.3	850	30.6	59	2.1	1608	57.9	0	0.0	0	0.0	2778	6.2
Middle Big Drywood	0.2	0.0	2	0.1	543	16.7	504	15.5	49	1.5	2145	66.1	0	0.0	0	0.0	3243	7.2
Seth Creek	0.2	0.0	0	0.0	322	13.5	811	34.1	10	0.4	1234	51.9	0	0.0	0	0.0	2377	5.3
Upper Little Drywood	0.8	0.0	2	0.1	397	13.3	453	15.2	36	1.2	2094	70.2	0	0.0	0	0.0	2983	6.6
Hay Creek	2	0.0	47	0.5	187	1.9	6970	72.0	486	5.0	1984	20.5	0	0.0	0	0.0	9676	21.6
Little Drywood	0.5	0.0	4	0.1	315	7.4	1655	39.0	69	1.6	2196	51.8	0	0.0	0	0.0	4240	9.4
Big Drywood	0	0.0	0	0.0	197	15.8	374	29.9	120	9.6	558	44.7	0	0.0	0	0.0	1249	2.8
Lower Big Drywood	0	0.0	3	0.3	143	14.9	333	34.8	28	2.9	450	47.0	0	0.0	0	0.0	957	2.1
Cadott	2	0.1	8	0.3	305	10.3	714	24.2	87	3.0	1695	57.5	0	0.0	136	4.6	2947	6.6
Middle Yellow	0.5	0.0	3	0.2	69	4.8	443	30.8	31	2.2	891	62.0	0	0.0	0	0.0	1438	3.2
Turner Creek	0	0.0	0.2	0.0	438	20.9	148	7.1	8	0.4	1498	71.4	0	0.0	5	0.2	2097	4.7
Delmar	2	0.1	23	0.8	256	9.4	517	19.1	51	1.9	1861	68.7	0	0.0	0	0.0	2710	6.0
Coldwater Creek	0	0.0	0	0.0	151	20.6	54	7.4	1	0.1	527	71.9	0	0.0	0	0.0	733	1.6
Colburn	5	0.1	28	0.6	220	4.3	1377	27.2	256	5.1	3174	62.7	0	0.0	0	0.0	5060	11.3
Yellow River Basin Totals	20.2	0.04	140.2	0.3	3878	8.6	16603	37.0	1526	3.4	22586	50.3	0	0.0	141	0.3	110,933Ac 44894	100

Paint Creek	Water		Wetlands		Rowcrops		Deciduous Forest		Coniferous Forest		Grass/Hay/Pasture		Heavy Urban		Light Urban		Total	
Watersheds	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%
South Fork	2	0.1	8	0.4	346	19.3	619	34.6	138	7.7	678	37.9	0	0.0	0	0.0	1791	21.1
Lower Paint	4	0.1	8	0.3	289	9.2	1024	32.5	74	2.4	1748	55.5	0	0.0	0	0.0	3147	37.1
Middle Paint	0	0.0	0	0.0	123	9.7	8	0.6	5	0.4	1129	89.2	0	0.0	0	0.0	1265	14.9
Upper Paint	0	0.0	0	0.0	179	7.8	870	38.1	1	0.0	1234	54.0	0	0.0	0	0.0	2284	26.9
Paint Creek Basin Totals	6	0.07	16	0.2	937	11.0	2521	29.7	218	2.6	4789	56.4	0	0.0	0	0.0	20,971Ac 8487	100

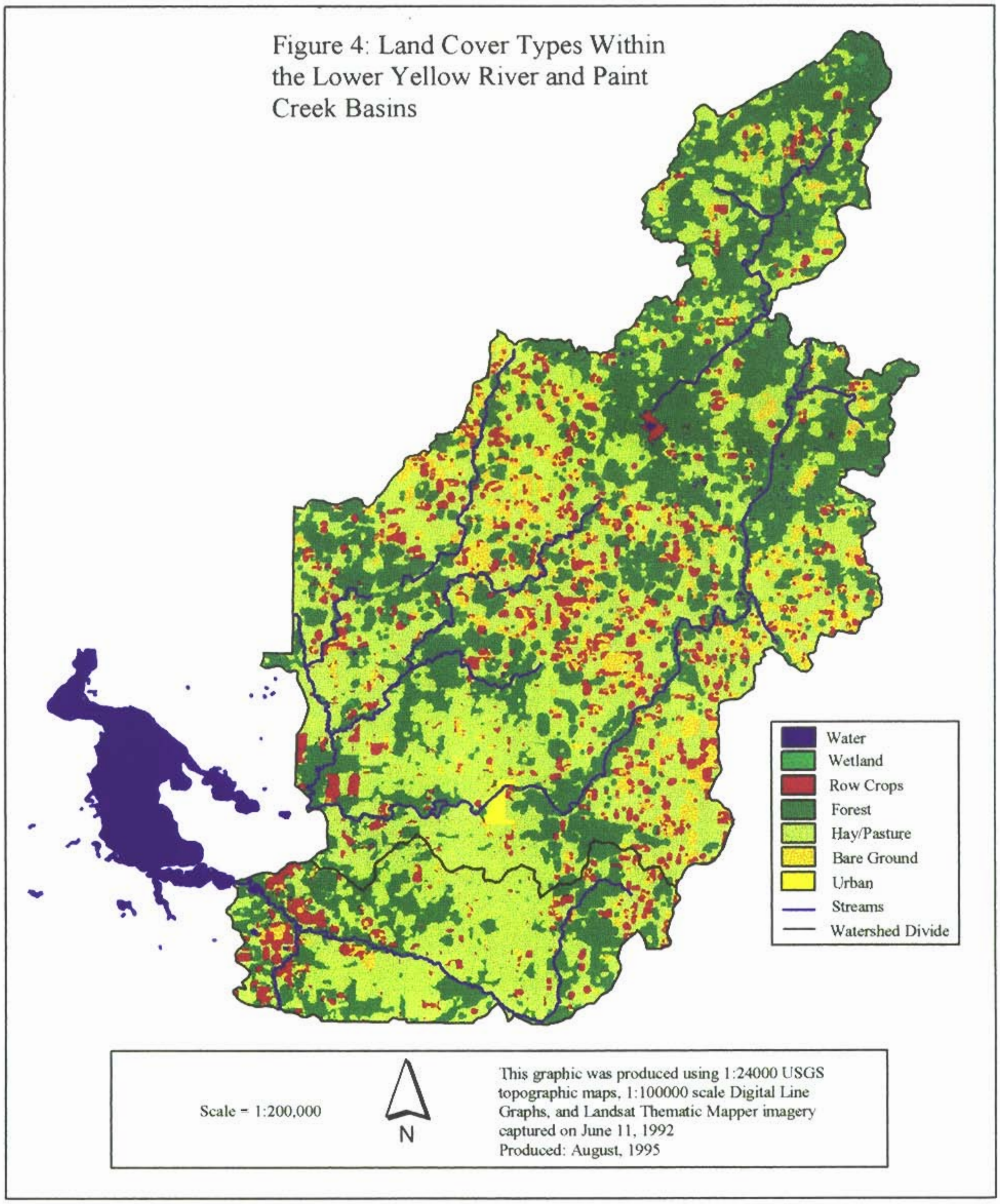

Figure 4: Land Cover Types Within the Lower Yellow River and Paint Creek Basins

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This graphic was produced using 1:24000 USGS topographic maps, 1:100000 scale Digital Line Graphs, and Landsat Thematic Mapper imagery captured on June 11, 1992
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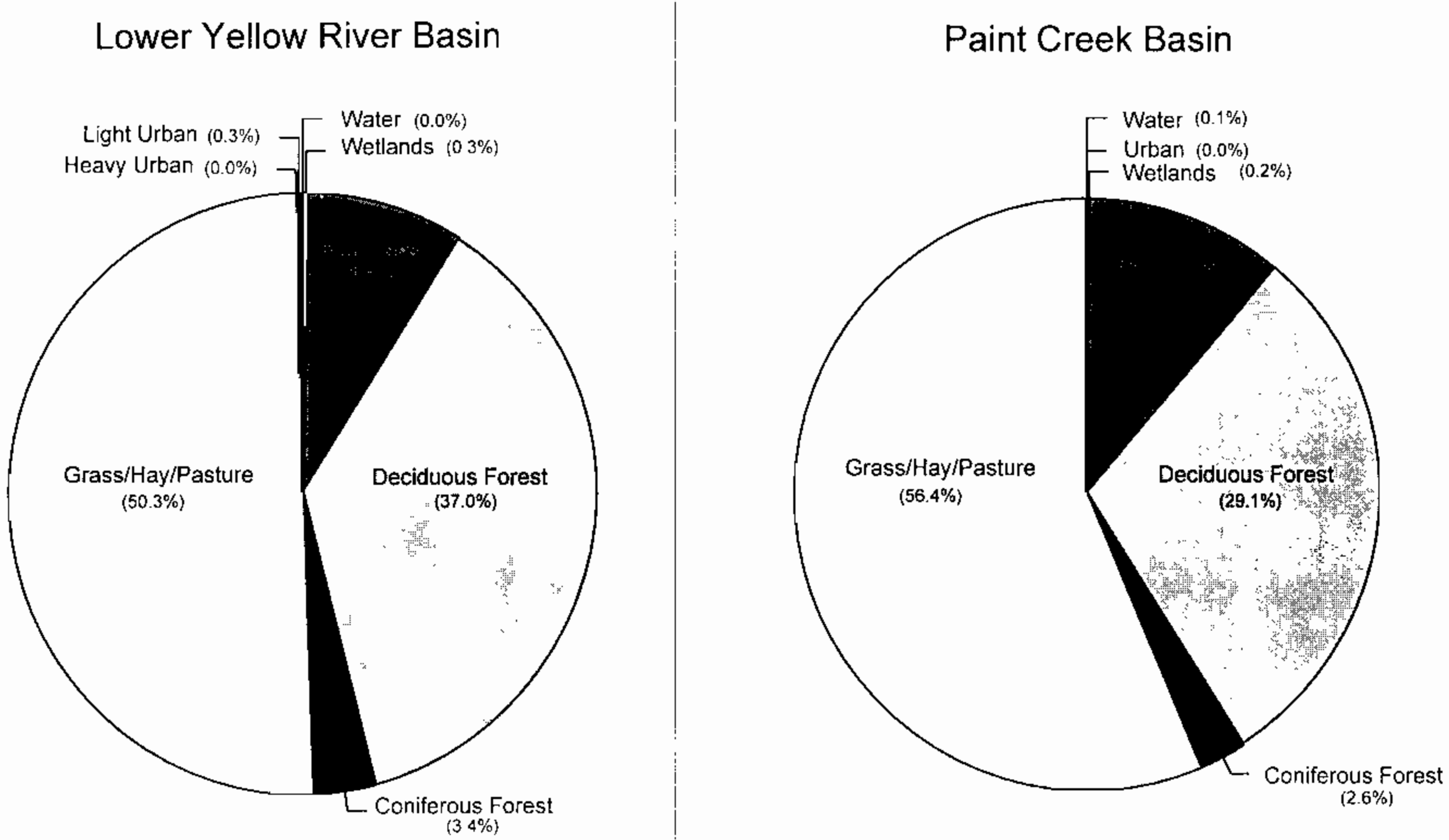
Figure 5: Proportion of Land Cover Types Within the Lower Yellow River and Paint Creek Basins



Lower Yellow River Basin

Paint Creek Basin

B. Results of Upland Phosphorus and Sediment Delivery Analysis.

As may be anticipated, results of the upland phosphorus and sediment analyses are strongly related to results of the land cover classification. Table 2 shows the estimated rate of upland phosphorus and sediment delivered in runoff from the Lower Yellow River and Paint Creek basins.

Results indicate that after accounting for land cover distribution and total area, approximately 2×10^4 kg/yr of phosphorus and 8.7×10^6 kg/yr of sediment are contributed from upland runoff to the stream network of the Lower Yellow River basin. Approximately 4×10^3 kg/yr of phosphorus and $1.9\ 10^6$ kg/yr of sediment are contributed to streams in the Paint Creek basin.

When calculated by unit area, average pollutant loading rates are significantly higher in the Paint Creek basin than in the Lower Yellow River Basin; reflecting more intensive agricultural land use. Average rates of upland phosphorus load in Lower Yellow River basin are approximately 0.45 kg/ha/yr, as compared to 0.53 kg/ha/yr in the Paint Creek basin. Results are similar when comparing average rates of upland sediment load, with approximately 196 kg/ha/yr in the Lower Yellow River basin and 228 kg/ha/yr discharged in the Paint Creek Basin.

Figures 6 and 7 show the location of watersheds in the study area and the approximate upland phosphorus and sediment load attributed to each area. In the Lower Yellow River basin areas of greatest upland pollutant load include the Colburn, Delmar, Turner Creek and Drywood Watersheds; with additional contributions from other surrounding agricultural watersheds. In the Paint Creek basin, the watersheds with relatively high rates of upland phosphorus and sediment delivery include the South Fork and Lower Paint watersheds.

Table 2: Estimated Rates of Phosphorous and Sediment Delivery from Upland Landuse within the Lower Yellow River and Paint Creek Basins

Yellow River Watersheds	Estimated Upland Phosphorous Delivery (kg/yr x 100)	Estimated Upland Sediment Delivery (kg/yr x 100)
Pike Creek	6	3012
Upper Big Drywood	14	5634
Middle Big Drywood	21	9964
Seth Creek	12	6332
Upper Little Drywood	19	7645
Hay Creek	18	10643
Little Drywood	19	7557
Big Drywood	6	3760
Lower Big Drywood	5	2756
Cadott	15	6303
Middle Yellow	7	1963
Turner Creek	15	7651
Delmar	16	5433
Coldwater Creek	5	2644
Colburn	24	6550
Yellow River Basin Totals	202	87,847
Paint Creek Watersheds	Estimated Upland Phosphorous Delivery (kg/yr x 100)	Estimated Upland Sediment Delivery (kg/yr x 100)
South Fork	9	6341
Lower Paint	16	6354
Middle Paint	9	2503
Upper Paint	11	4189
Paint Creek Basin Totals	45	19,387

Figure 6: Rates of Upland Phosphorous Delivery in the Lower Yellow River and Paint Creek Basins; Shown by Watershed

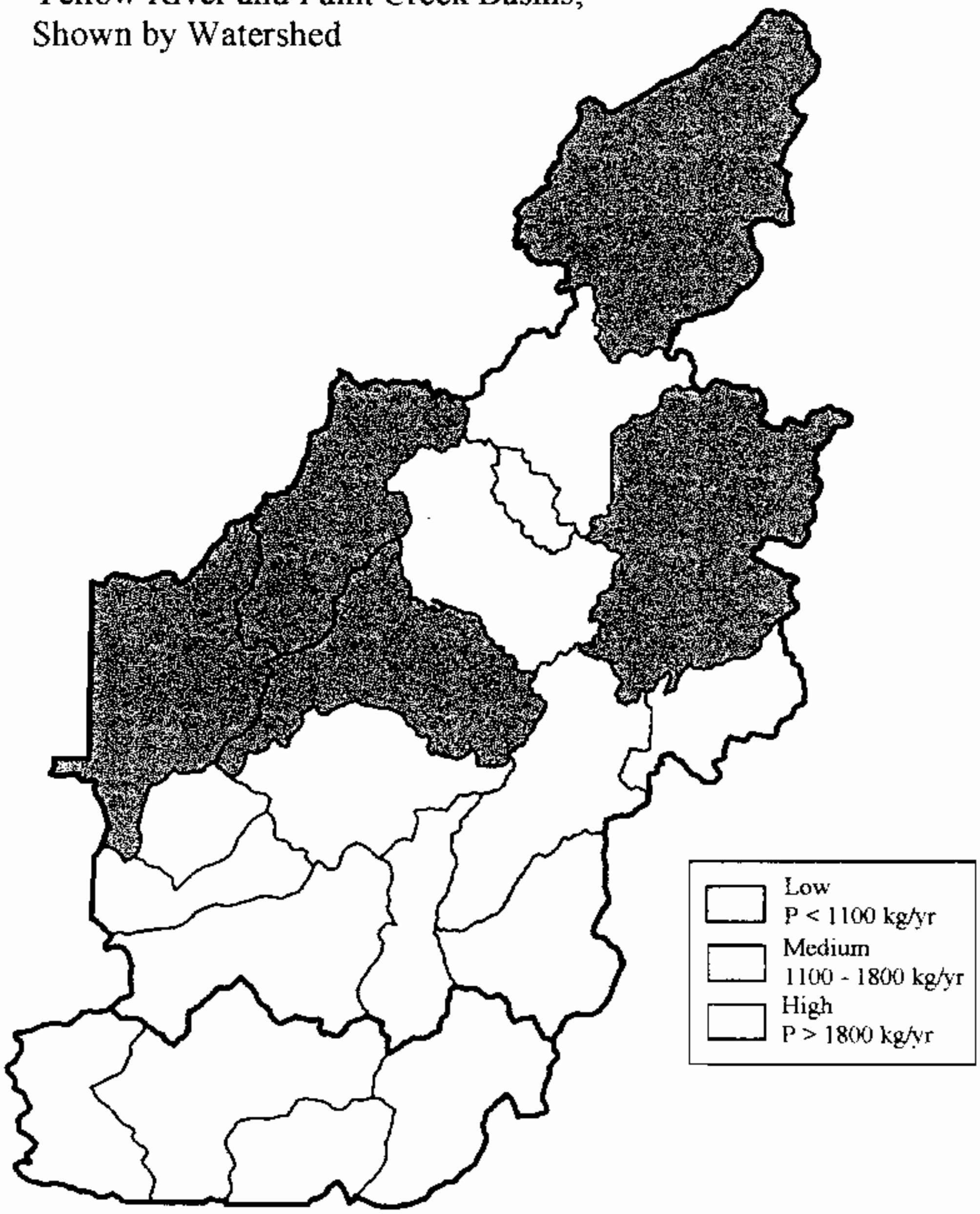


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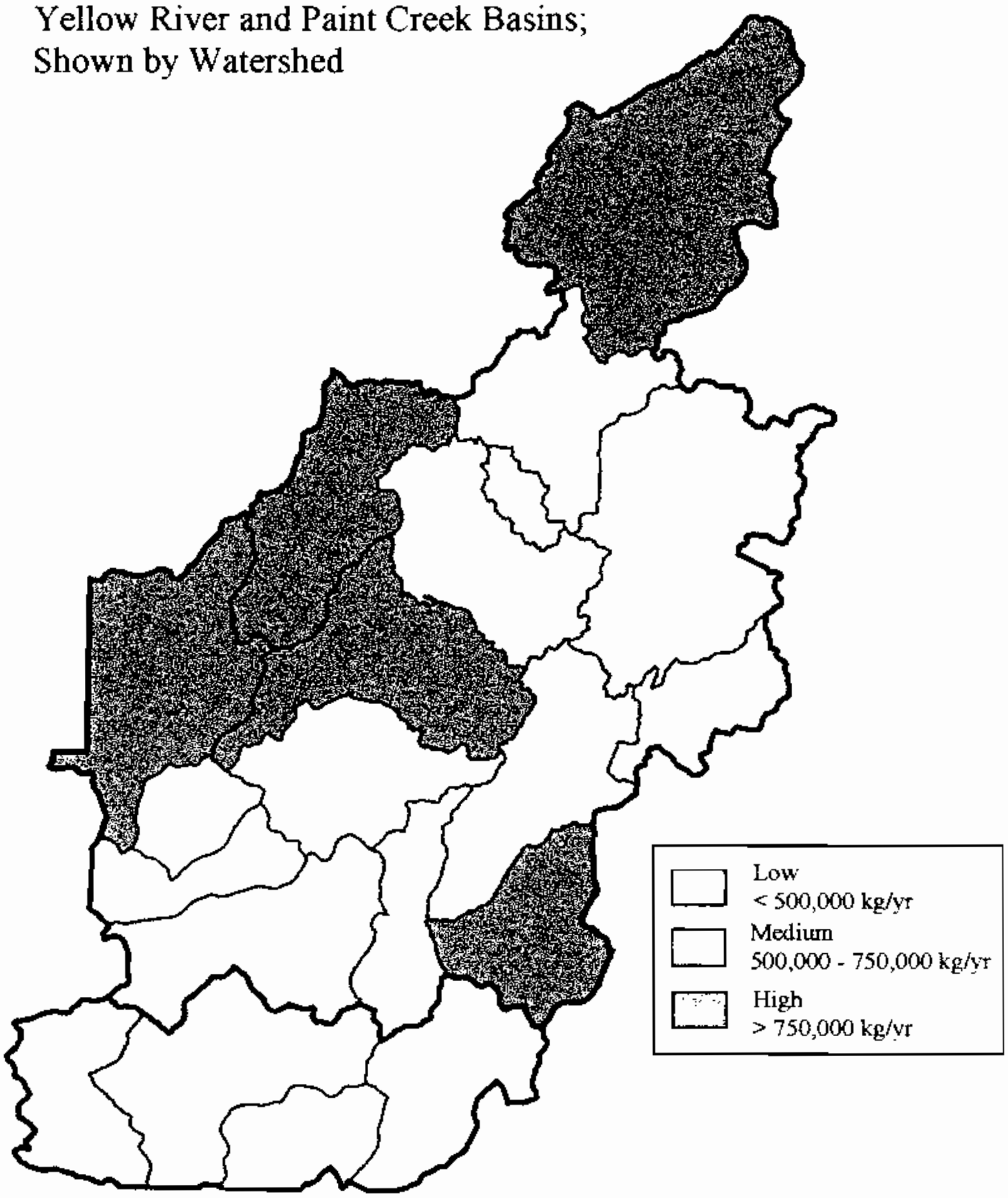
Figure 7: Rates of Upland Sediment Delivery in the Lower Yellow River and Paint Creek Basins; Shown by Watershed



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Source: This graphic was produced using 1:24000 USGS topographic maps and 1:100000 Digital Line Graphs
Produced: August, 1995

C. Results of Barnyard Analysis.

Table 3 provides the results of the barnyard analysis, showing the number of barnyard sites and the estimated rate of barnyard phosphorus delivered from each of four riparian zones. Results are presented by watershed, as well as for the Lower Yellow River and Paint Creek basins.

Results of the barnyard analysis indicate that there are 432 active barnyards in the Lower Yellow River basin with a combined phosphorus delivery rate of approximately 6×10^3 kg/yr. There are 88 sites in the Paint Creek basin with an estimated combined discharge of approximately 1×10^3 kg/yr.

Results of the buffer analysis suggest that less then 5% of all barnyards are located within 200 ft. of an intermittent or perennial stream. These barnyards represent less than 9% of the total barnyard phosphorus load. The largest number of yards, representing the greatest potential phosphorus load, are situated 200 ft - 1000 ft from areas of channelized flow.

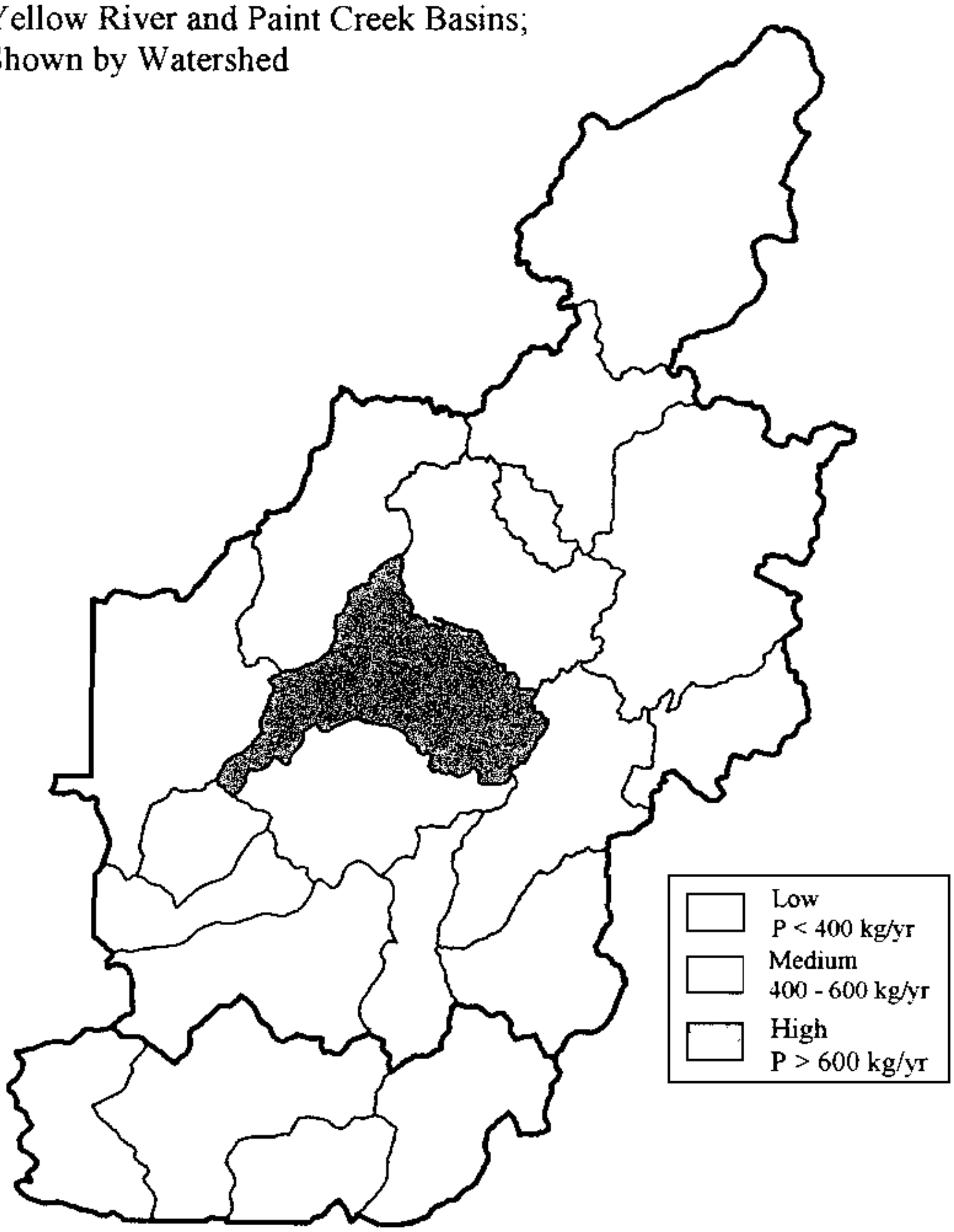
Figure 8 shows the location of watersheds within the study area, and the relative rate of total barnyard phosphorus delivered from each. As anticipated results show that the highest rates of total barnyard phosphorus are found in agricultural watersheds having the greatest area of cropland.

Table 3: Estimated Rate of Barnyard Phosphorous Delivery Within the Lower Yellow River and Paint Creek Basins

	DISTANCE TO STREAM											
	Less than 100 ft		100 - 200 ft		200 - 500 ft		500 - 1000 ft		More than 1000 ft		TOTAL	
Yellow River Watersheds	yards	Estimated Phos (kg/yr)	yards	Estimated Phos (kg/yr)	yards	Estimated Phos (kg/yr)	yards	Estimated Phos (kg/yr)	yards	Estimated Phos (kg/yr)	yards	Estimated Phos (kg/yr)
Pike Creek	0	0	1	32	3	54	2	27	7	76	13	189
Upper Big Drywood	1	13	3	96	5	90	9	122	18	196	37	517
Middle Big Drywood	1	13	2	65	22	396	16	218	11	120	52	812
Seth Creek	0	0	0	0	8	144	7	95	8	87	23	326
Upper Little Drywood	2	26	0	0	5	90	17	231	20	218	44	565
Hay Creek	0	0	0	0	4	72	6	82	28	305	48	459
Little Drywood	0	0	1	32	7	126	8	109	23	251	39	518
Big Drywood	0	0	0	0	2	36	4	54	6	65	12	155
Lower Big Drywood	0	0	0	0	2	36	3	41	6	65	11	142
Cadott	0	0	0	0	7	126	9	122	11	120	27	368
Middle Yellow	0	0	0	0	5	90	9	122	10	109	24	321
Turner Creek	0	0	3	96	8	144	11	150	11	120	33	510
Delmar	0	0	3	96	10	180	13	177	7	76	33	529
Coldwater Creek	1	13	1	32	6	108	8	109	9	98	25	360
Colburn	0	0	2	65	5	90	8	109	7	76	22	340
Yellow River Basin Totals	5	65	16	514	99	1782	130	1768	182	1982		6111

	Less than 100 ft		100 - 200 ft		200 - 500 ft		500 - 1000 ft		More than 1000 ft		TOTAL	
Paint Creek Subwatershed	yards	Estimated Phos (kg/yr)	yards	Estimated Phos (kg/yr)	yards	Estimated Phos (kg/yr)	yards	Estimated Phos (kg/yr)	yards	Estimated Phos (kg/yr)	yards	Estimated Phos (kg/yr)
South Fork	0	0	0	0	1	54	4	54	14	153	19	225
Lower Paint	0	0	1	32	7	204	15	204	8	87	31	449
Middle Paint	0	0	1	32	3	82	6	82	9	98	19	266
Upper Paint	0	0	0	0	4	54	4	54	11	120	19	246
Paint Creek Basin Totals	0	0	2	64	15	270	29	394	42	458	88	1186

Figure 8: Rates of Barnyard Phosphorous Delivery in the Lower Yellow River and Paint Creek Basins; Shown by Watershed



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Source: This graphic was produced using 1:24000 USGS topographic maps and 1:100000 Digital Line Graphs
Produced: August, 1995

D. Results of Streambank Erosion Analysis.

Table 4 provides results of the watershed and stream analysis conducted to document the physical characteristics of watersheds and associated stream networks in the study area. Physical characteristics are presented by watershed and include the following: number of perennial stream segments, average cumulative drainage area, average length of perennial stream segments, sinuosity ratio, and estimated rate of streambank erosion.

Results of the watershed analysis show that the stream drainage network is composed of relatively low gradient meandering streams, characteristic of a glaciated basin formed in upland till.

Results of the streambank analysis suggest that erosion sites in the Yellow River basin, contribute sediment to the stream network at a rate of approximately 3×10^6 kg/yr. Results for the Paint Creek basin suggest that streambank erosion sites contribute sediment to the stream network at a rate of approximately 5.6×10^5 kg/yr.

Figure 9 shows the location of watersheds in the study area and the estimated rate of streambank erosion delivered to the stream network of each watershed. The greatest rates of streambank erosion are found in the Colburn, Delmar, and Cadott watersheds.

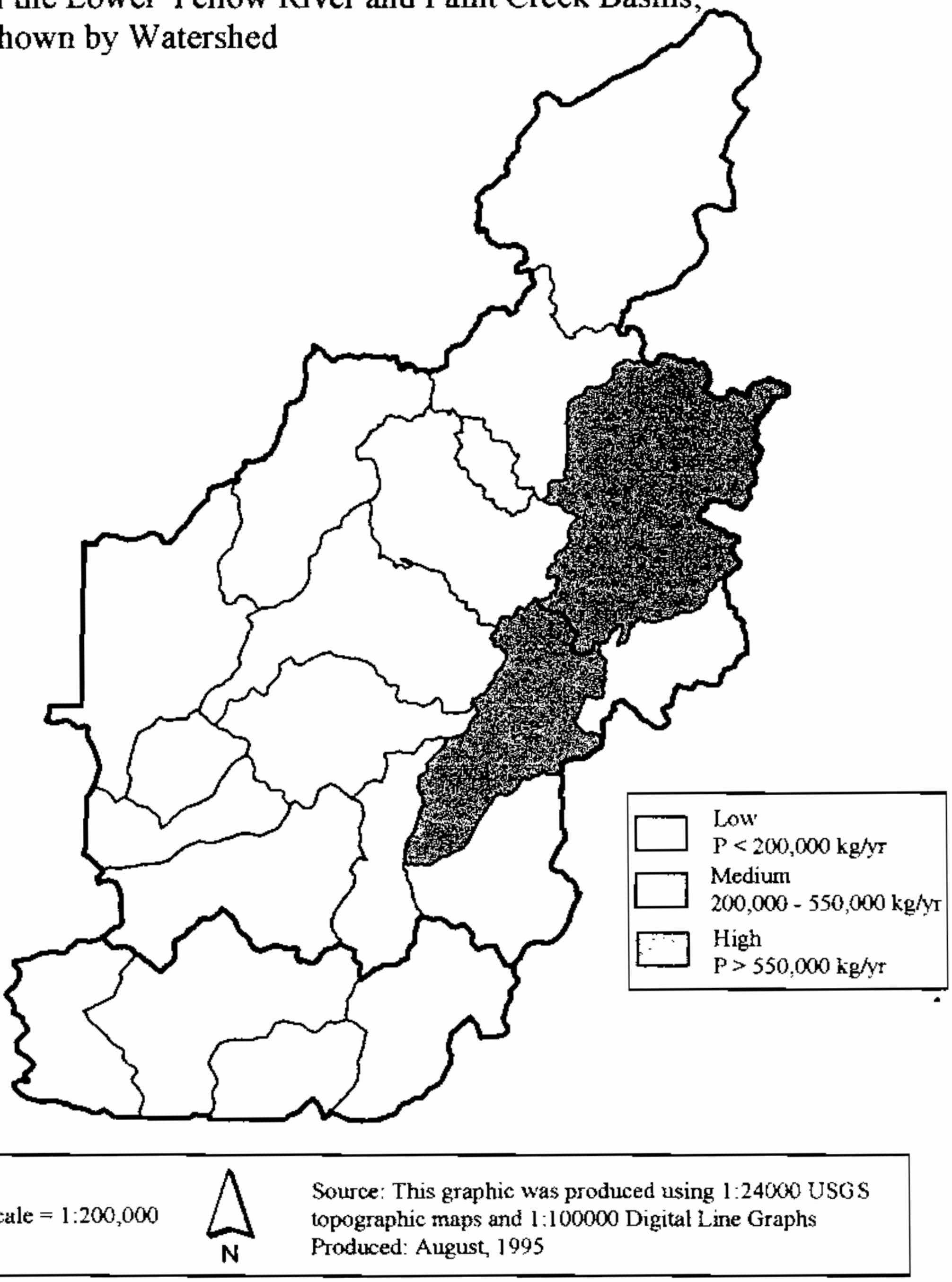
Table 5 contains results of the stream inventory sub-sample comparing sediment delivery, as measured at inventoried sites in the study area, to predicted rates of sediment delivery at the same sites. Results of the statistical analysis indicates that observed rates of sediment delivery ranged from 3.4×10^4 kg/yr below predicted rates to 1.1×10^4 kg/yr above predicted rates, at a 95% confidence interval.

Results of this sub-sample analysis suggest that the regression equation developed to predict sediment delivery from streambank erosion sites provided estimates that are within two orders of magnitude of observed conditions. Error in the predictive equation may be a result of the method used to calculate observed erosion, or the complexity of variables affecting stream geomorphology and streambank erosion.

Table 4: Summary of Physical Characteristics of Perennial Streams and Contributing Watersheds and Estimated Rate of Streambank Erosion in the Lower Yellow River and Paint Creek Basins

		Cumulative Drainage Area		Length of Stream Segment		Sinuosity Ratio		
Yellow River Watersheds	Number of Perennial Stream Segments	Mean (km)	Standard Deviation	Mean (km)	Standard Deviation	Mean (km)	Standard Deviation	Estimated Erosion Rate x 1000 (Kg/yr)
Pike Creek	4	15	8	2	0.5	1.3	0.1	75
Upper Big Drywood	2	15	2	1	0.8	1.1	0.1	21
Middle Big Drywood	10	52	13	2	1.0	1.5	0.3	178
Seth Creek	0	0	0	0	0.0	0.0	0.0	0
Upper Little Drywood	12	25	10	1	0.8	1.2	0.2	150
Hay Creek	8	35	20	2	1.4	1.6	0.3	184
Little Drywood	6	55	11	3	1.1	2.0	1.1	169
Big Drywood	3	165	7	2	0.5	2.2	0.5	71
Lower Big Drywood	3	82	4	2	1.9	1.6	0.4	73
Cadott	11	157	73	1	1.3	1.3	0.2	504
Middle Yellow	3	778	4	1	0.5	1.2	0.2	122
Turner Creek	2	23	20	1	0.3	1.3	0.2	29
Delmar	20	820	8	1	0.6	1.1	0.2	815
Coldwater Creek	3	623	370	1	0.7	1.5	0.3	31
Colburn	19	785	10	1	0.5	1.1	0.2	657
Yellow River Basin Totals	106	231	324	2	0.8	1.4	0.3	3079
Paint Creek Watersheds	Number of Perennial Stream Segments	Mean (km)	Standard Deviation	Mean (km)	Standard Deviation	Mean (km)	Standard Deviation	Estimated Erosion Rate x 1000 (Kg/yr)
South Fork	5	74	6	2	0.5	1.6	0.3	95
Lower Paint	9	47	10	2	1.0	1.7	0.4	166
Middle Paint	6	24	5	1	0.5	1.6	0.3	102
Upper Paint	9	10	4	1	0.8	1.8	1.7	121
Paint Creek Basin Totals	29	28	6	1	0.6	1.7	0.7	484

Figure 9: Rates of Streambank Erosion and Sediment Delivery in the Lower Yellow River and Paint Creek Basins; Shown by Watershed



Source: This graphic was produced using 1:24000 USGS topographic maps and 1:100000 Digital Line Graphs
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Table 5: Comparison of Inventoried and Predicted Rates of Streambank Sediment Delivery Within the Study Area

Yellow River Basin	Stream Segment Code	Length (km)	Cumulative Drainage Area	Inventoried Sediment Delivery (kg/yr)	Predicted Sediment Delivery (kg/yr)
	DL5555	0.9	869	2,300	44,400
	LT33	1.1	57	13,900	14,400
	CA5	2.4	934	113,000	57,800
	HY33332R	0.8	26	0	11,700
	UT333	3.3	24	4,000	29,700
	BD444	1.4	164	6,200	21,000
	CO5555555555	1.3	872	6,300	47,600
	MR444443L3	2.1	32	2,700	21,600
Paint Creek Basin	Stream Segment Code	Length (km)	Cumulative Drainage Area	Inventoried Sediment Delivery (kg/yr)	Predicted Sediment Delivery (kg/yr)
	SF443	0.7	8	6,800	9,900

E. Results of Combined Pollutant Load From Major Non-point Sources

Results from individual pollutant inventories, as previously described, were combined to provide an estimate of total non-point pollutant load from major upland sources. These results provide insight into the approximate pollutant load to Moon Bay and Little Lake Wissota from the Lower Yellow River Basin and Paint Creek Basin, respectively.

Figure 10 and 11 show the geographic distribution of the combined rates of sediment delivery from inventoried sources within the Lower Yellow River and Paint Creek Basins. Results coincide with the findings of the land cover analysis and show the greatest sources of non-point pollution to be contributed from agricultural watersheds.

Figure 12 shows the volume and relative contributions of phosphorus discharged from upland runoff and barnyards in the Lower Yellow River and Paint Creek basins. Results suggest that approximately 80% of total phosphorus delivered in runoff to the stream network is attributed to upland land use. Of this amount approximately 60% is generated from areas used for hay, grass and pasture, with 25% generated from row crops. Urban contributions appear negligible. In both basins, barnyard phosphorus discharge represents approximately 25% of the total phosphorus load.

Figure 13 shows the volume and relative proportion of sediment associated with upland runoff and stream erosion sites in the study area. Results suggest that nearly 50% of the sediment contributed to the stream network is generated from cropland areas, with approximately 20% generated from streambank erosion sites.

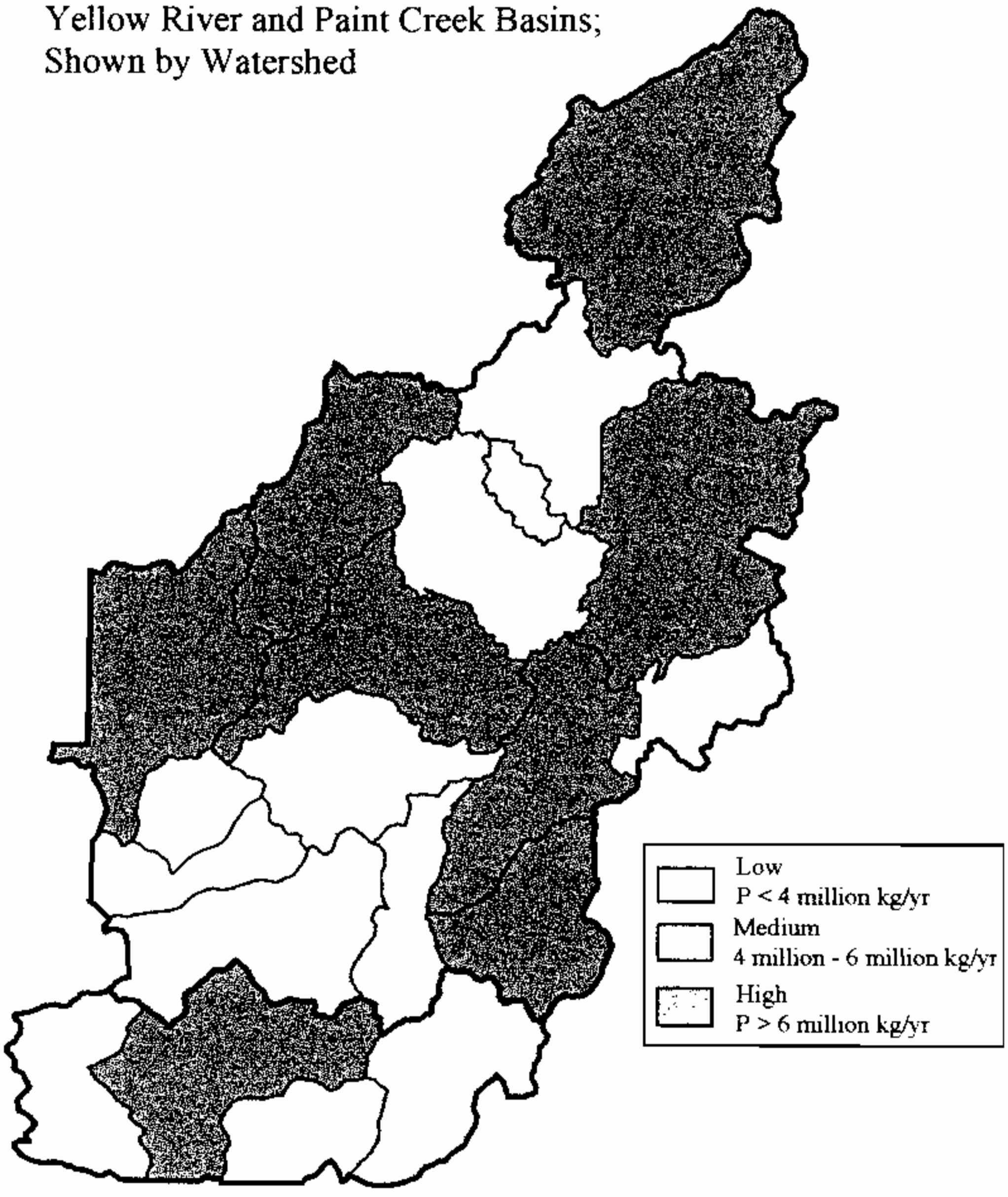
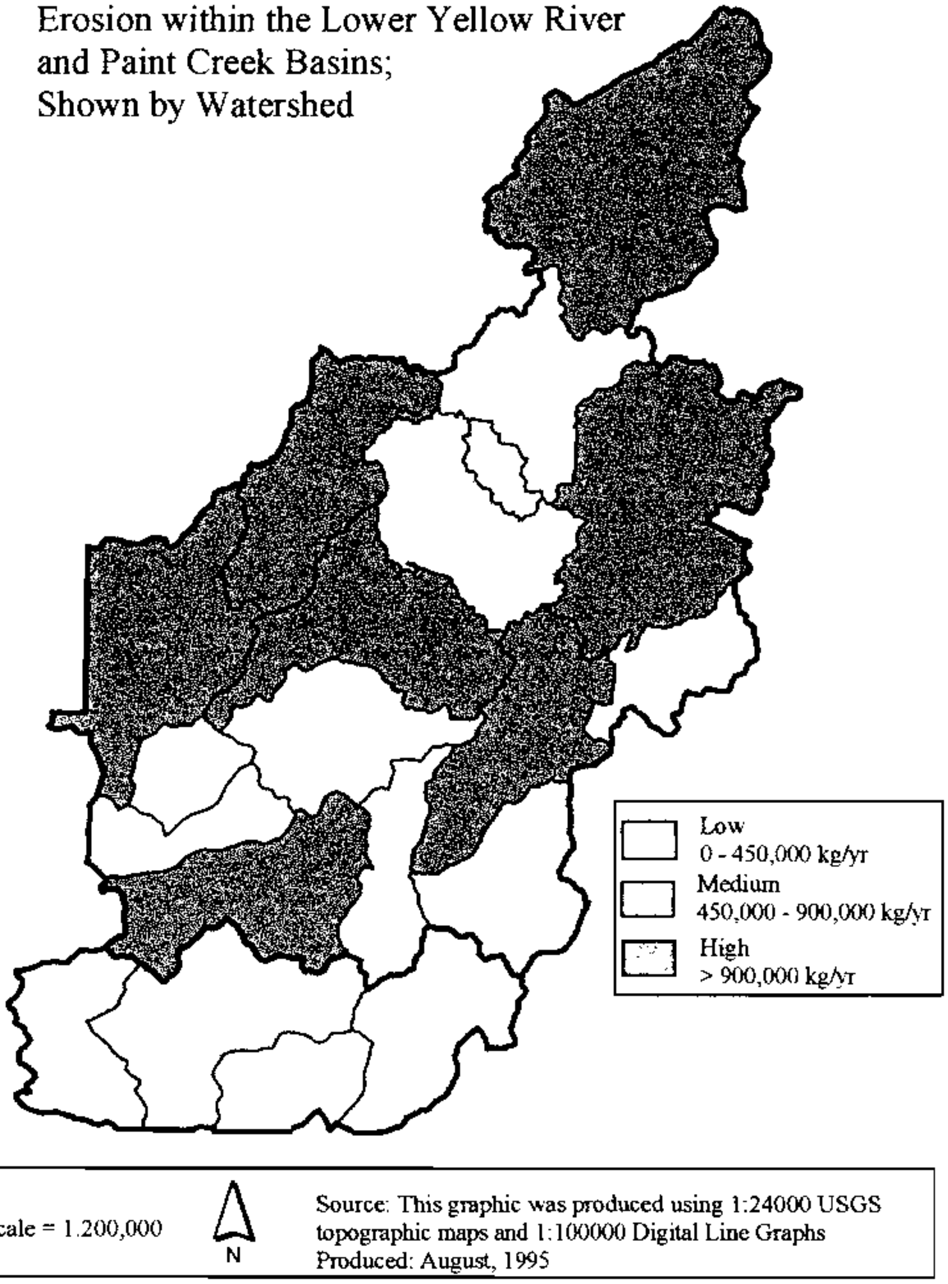


Figure 10: Combined Rates of Phosphorous Delivery from Upland and Barnyard Runoff within the Lower Yellow River and Paint Creek Basins; Shown by Watershed

Scale = 1:200,000

Source: This graphic was produced using 1:24000 USGS topographic maps and 1:100000 Digital Line Graphs
Produced: August, 1995

Figure 11: Combined Rates of Sediment Delivery from Streambank Erosion and Upland Erosion within the Lower Yellow River and Paint Creek Basins; Shown by Watershed



Source: This graphic was produced using 1:24000 USGS topographic maps and 1:100000 Digital Line Graphs
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Figure 12: Total Volume and Relative Proportion of Phosphorous Delivered to Stream Networks from all Inventoried Sources Within the Lower Yellow River and Paint Creek Basins

* Total kg/yr x 1000

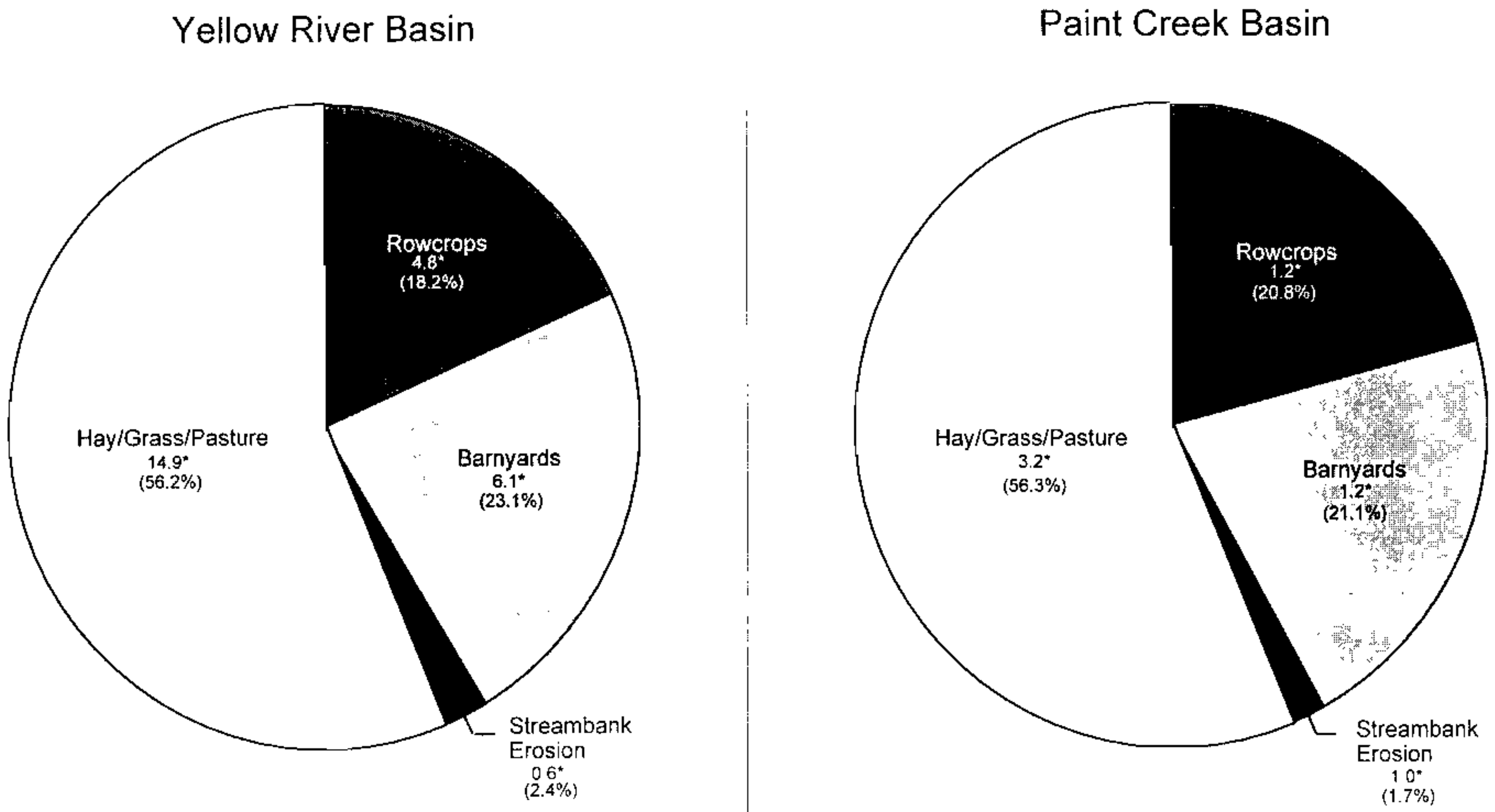
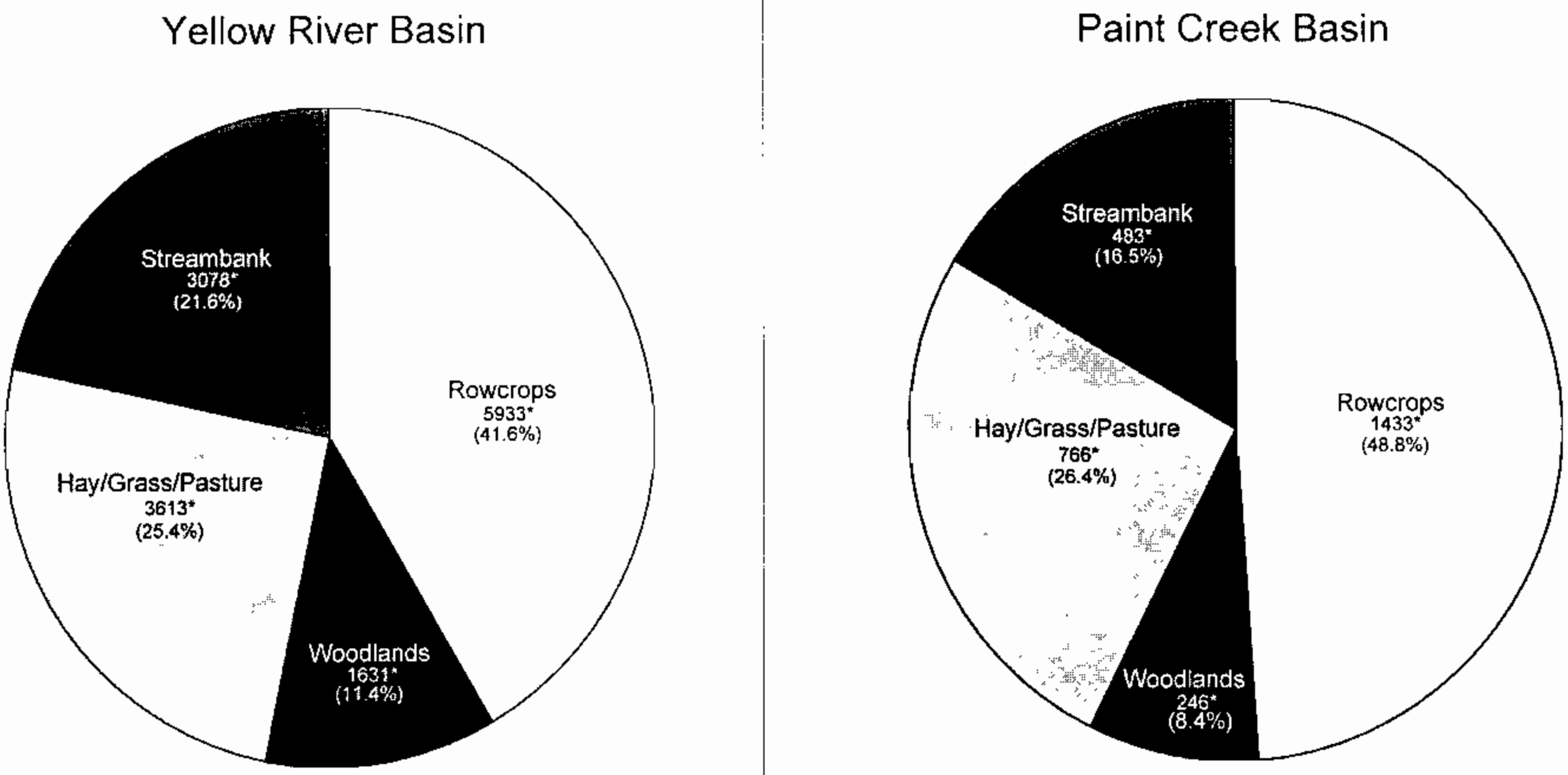


Figure 13: Total Volume and Relative Proportion of Sediment Delivered to Stream Networks from all Inventoried Sources Within the Lower Yellow River and Paint Creek Basins

* Total kg/yr x 1000



VII. Discussion

Evaluation of Remote Sensing Techniques

The land cover classification proved to be an effective method for distinguishing the following land cover classes; row crops, hay/grass/pasture,woodlands and urban areas at 85% accuracy.

Difficulties were encountered in attempting to separate hay from permanent grassland; oats from all other classes; and delineating wetland boundaries. To alleviate these difficulties, cultivated hay crops were grouped with permanent grassland vegetation. This decision was made based on the assumption that the phosphorus and sediment delivery coefficients are comparable among these land cover types and are not expected to significantly affect pollutant source estimates.

For the purpose of general basin wide inventories, the use of remote sensing technologies, at this level of quantifiable error, should be recognized as being a cost effective means of obtaining general land cover and associated land use information. To improve the utility of satellite imagery, it is recommended that two distinct images be used in future analyses. This will record land cover at different times during the growing season, adding a multi-temporal property to the classification.

Limitations of pollutant load estimates

The major focus of this study was to document existing land cover and to estimate rates of pollutant load from major non-point sources. These pollutants and sources included phosphorous and sediment from upland erosion, phosphorous from barnyards runoff, and sediment delivered from streambank erosion.

The accuracy of sediment and phosphorous delivery estimates are largely dependant upon the accuracy of the sediment and phosphorous coefficients applied in the analysis. This accuracy assumes the coefficients used are valid and can be applied to the physical conditions of the study area. This investigation recognizes that these coefficients have not been validated for this study area.

It should be noted that the sediment delivery estimates reflect the estimated rate of sediment delivery to the stream network and do not estimate the volume of sediment which is transported through the system or deposited to surface water impoundments.

Phosphorous and Sediment

Estimates of phosphorous delivery, developed through the land cover analysis and barnyard inventory, offer an indication of relative pollutant contributions from each of these sources. Phosphorus delivery estimates associated with upland runoff suggest that row crops in the basin account for approximately 20% of the total phosphorous load. Notably, the greatest proportion of the total phosphorous load is generated from extensive areas of hay, grassland, and pasture. Cumulatively, the hay,grass,pasture areas cover a much larger area(≈53%) than any other land cover type. When comparing phosphorous delivery on a kg/ha/yr basis, however, row crops deliver nearly 20 times as much phosphorous as does hay/gras.pasture land cover.

Results of this study suggest that while barnyards are a significant and visible source of phosphorus load to the stream network; the greatest potential barnyard phosphorous load is from sites which are widely dispersed throughout the basin and not generally located on streams.

Estimates of sediment delivery, as developed through the upland watershed analysis and streambank inventory, provide insight regarding the relative pollutant contribution of each of these sources.

Estimates of sediment delivery from upland land use indicate approximately 80-85% of the sediment delivered to the stream network may be attributed to upland erosion. The volume of sediment delivered from streambank erosion is relatively minor.
The rate of streambank erosion appears to be consistent throughout the basins with the exception of the Delmar and Colburn watersheds which each contribute approximately three times as much sediment from streambank erosion as each of the other watersheds (Figure 9). Both these watersheds have a large drainage area, coupled with a low sinuosity ratio. These factors indicate stream networks in these watersheds have a higher flow velocity with fewer meanders, resulting in increased erosive capacity.

Control of Non-Point Source Pollutants

Based upon the land cover analysis, runoff from upland land use in the Lower Yellow River and Paint Creek basins is the most significant source of both phosphorous and sediment delivered to Little Lake Wissota and Moon Bay.

Phosphorous in runoff occurs as particulate phosphorous and dissolved phosphorous. Particulate phosphorous is the major portion of P transported in runoff from cultivated land, accounting for approximately 75% - 90% of total phosphorous (Schuman *et al.*, 1973). Of this particulate phosphorous, approximately 10% - 90% may ultimately become available for algal uptake. When considering possible impacts on eutrophication, the combination of dissolved phosphorous and bioavailable particulate phosphorous should be recognized (Sharpley, *et al.*, 1993).

Research conducted in agricultural watersheds suggests that concentrations of soil phosphorous are affected by crop rotations, P fertilizer application rate, tillage, subsoil P, and crop removal of P (Pierzynsky and Logan, 1993). Other research indicates that phosphorous movement in a watershed can be controlled by agricultural management practices which affect transport (runoff and erosion potential); and those that affect the concentration of soil phosphorous in the surface horizon (Sharpley *et al.*, 1993).

The effectiveness of installing best management practices, and the amount of pollutant reduction that can be achieved in a watershed through their use, is the subject of ongoing research. It is important to note that the current investigation did not document the extent of agricultural best management practices now used in the study area. Consequently, it is difficult to accurately determine, from study results, the potential for reducing non-point source pollutant loads.

Certain assumptions regarding anticipated pollutant load reductions can be drawn from the results of earlier priority watershed projects administered through the Wisconsin Non-Point Source Pollution Abatement Program. In selected agricultural basins with similar physical characteristics and land uses, it has been possible to readily achieve up to 50% of the stated pollutant reduction goals for control of barnyard phosphorous and streambank sediment erosion. Using these same watershed projects, it has not been possible to adequately measure or document the amount of phophorous or sediment reduction resulting from widespread installation of upland best management practices (D. Simonson, pers. comm.)

Given these experiences, and lack of information regarding soil phosphorous levels and agricultural management practices in the Lower Yellow River and Paint Creek basins; it is not possible to accurately estimate the amount of phosphorous and sediment reduction which could be readily achieved in the study area. It is likely, however, that widespread adoption of best management practices within the study area would significantly reduce the rate of phosphorous and sediment delivery to Moon Bay and Little Lake Wissota.

Recognizing limited resources, strategies to control non-point source pollutants must be targeted to areas of greatest need. Although representing the largest source of total phosphorus and sediment, it may not be feasible to further reduce the concentrations of sediment and phosphorus delivered in runoff from permanent, hay, grass and pasture land use. Similarly, it is questionable whether it is cost effective to control the limited volume of sediment contributed from streambank erosion. As such it is very likely that strategies to control non-point source pollution will focus on upland phosphorous discharged from row crops and barnyard phosphorous discharged from feedlot sites.

VIII. Conclusions

This study was initiated to document the major land cover types in the Lower Yellow River and Paint Creek Basins and to estimate major non-point source pollution loads within these basins.

The ultimate purpose of this investigation was to assess whether non-point source pollutant loads can be reduced to levels which would affect water chemistry and associated trophic status of Moon Bay and Little Lake Wissota.

This study suggests the following conclusions:

1) The classification of Landsat satellite imagery provides a viable means of determining land cover types for river basin based analysis.

2) Major sources of non-point source pollutants in the Lower Yellow River and Paint Creek Basins are phosphorous and sediment delivered in upland runoff and phosphorous delivered in barnyard runoff.

3) Sediment and phosphorous movement in the basin can be limited by upland management practices which affect soil fertility, soil erosion, storm runoff, and sediment delivery.

4) Large reductions of upland sediment and phosphorous could be obtained through use of the following best management practices including: manure and nutrient management; crop residue management; contour plowing and strip cropping; field and streambank buffers; and animal waste management systems; and construction site erosion control.

5) Management practices which limit the rate and volume of phosphorous and sediment delivered to the stream network will likely impact concentrations of suspended sediments and bioavailable phosphorous, delivered to Moon Bay and Little Lake Wissota.

6) The extent of this impact on the water chemistry trophic status of Moon Bay and Little Lake Wissota should be evaluated through use of specific hydrologic and limnologic models to document response to potential phosphorous reductions associated with upland best management practices.

APPENDIX A-1.

Results of Spatial Barnyard Phosphorus Delivery Analysis Within the Duncan Creek Watershed.

The average phosphorus delivery from barnyards within the Duncan Creek basin is estimated at 39 lbs/yr. This value is consistent with other priority watershed projects.

Results of the spatial analysis within the Duncan Creek basin, compiled by buffer category, are shown below.

Subbasin	Sed. Del. Coefficient
Beaver Creek	.29
Bloomer	.16
Como Creek	.17
Glen Loch	.20
Hallie	.10
Hay Creek	.15
Lower Duncan	.15
Middle Duncan	.17
Tilden Creek	.14
Trout Creek	.16
Upper Duncan	.18

Buffer	Number of Barnyards	Mean Phos. Delivery	Standard Deviation	Minimum	Maximum
< 100'	9	14	22	0.0	75
100-200'	15	32	27	0.3	83
200-500'	80	18	31	0.0	171
500-1000'	83	14	27	0.0	181
> 1000'	150	11	21	0.0	134

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