Water Pollution Studies
Fox River Valley, Wisconsin

Executive Summary

FOX VALLEY

WATER QUALITY PLANNING AGENCY

EXECUTIVE SUMMARY

WATER POLLUTION STUDIES
FOX RIVER VALLEY, WISCONSIN

A TECHNICAL PROGRESS REPORT
PREPARED BY

FOX VALLEY WATER QUALITY PLANNING AGENCY
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I. BACKGROUND

During the Spring of 1976, the Fox Valley Water Quality Planning Agency (FVWQPA) entered into several contracts with public and private consultants to conduct studies to identify the existing and projected magnitudes of non-point source pollution in the Fox River Valley Watershed. These studies were necessary in order to complete portions of the FVWQPA's Areawide Waste Treatment Management Planning responsibilities pursuant to Section 208, PL 92-500 (Water Pollution Control Act Amendments of 1972).

Working under the guidance and regulations of the U.S. Environmental Protection Agency (U.S. EPA) and the Wisconsin Department of Natural Resources (WDNR), the Agency has attempted to identify the existing non-point source problems in the watershed as well as potential (projected) problems that are a result of man's activities on the land.

The results of, and conclusions reached in, these studies should not be confused with the Non-Point Source Control and Management Plan that the Agency will be preparing. These studies provide a data base from which the FVWQPA will analyze the water quality impacts of non-point source pollution and recommend appropriate control strategies and management options. These studies also provide the Agency with a benchmark to gage the effectiveness of implementation measures. Finally, these studies conclude with recommendations on future study needs.

In addition to the Non-Point Source Study, the Agency sponsored studies of the Trophic Status of the Winnebago Pool and Lower Green Bay and developed a Nutrient Budget for the pool lake system. The determinations of trophic status permitted the Agency to define the existing lake and lower bay conditions and provide a benchmark by which the results of future pollution control efforts can be measured. The nutrient budget effort will serve as a tool for the Agency in its decision-making regarding water quality goals and objectivies for the lake system.

The following is a summary of these Agency studies.

II. NON-POINT SOURCE (NPS) STUDY

INTRODUCTION

The consulting consortium of URS/McMahon has completed the study, Characterization of Non-Point Waste Sources in support of the Areawide Waste Treatment Management Planning Program of the FVWQPA for the Lower Fox River Valley and Winnebago Pool. The effort conducted by the consultant was primarily data gathering and research. The study is a highly technical report consisting of: conclusions drawn from literature reviews, lists of data gathered from field study and calculations of the amounts of several important NPS pollutants moving into the surface waters of the study area. The study does not assess the importance of NPS pollution to actual water quality, nor does it identify needed management practices.

The NPS Study does fairly represent the relative significance of NPS pollution from each land use and to each sub-basin. To get a general appreciation of this you should refer to figures 2 through 5 which portray the percent contributions of NPS categories for the monitored year of the study. Despite the application of some very specialized techniques for data reduction, some of the estimates in this report are rough. But a larger and more expensive study would probably be no more revealing or useful for the initial planning effort.

The task remaining is to apply this information to determine the degree to which NPS pollutants degrade water quality, and how much control of these pollutants would be desirable to improve and maintain water quality. Equally important is the parallel study of existing land management practices, good and bad, that result in the NPS pollution amounts reflected in the study.

Once these decisions are made, management plan development begins. A control strategy for each sub-basin must be developed. Such strategies should take into account the significance of the various sources of pollution, and select the priority pollutants for NPS control. The NPS Study provides the information needed for this effort.

FINDINGS

It would be meaningless to attempt to summarize in a few paragraphs the findings of a study as comprehensive and complex as this. These paragraphs then are meant to assist the reader in locating the detailed information desired.

The Characterization of Non-Point Waste Sources is comprised of six volumes, five separate and complete reports followed by a summary report. This last report, Report № 6, Summary of Non-Point Waste Loads, synopsizes the first five reports and then presents, in two appendices, projections of NPS loads from urban and non-urban watersheds in the study area. Most of the raw concentration and flow data and some details of methodology are referenced in Report № 6 but not formally presented. The reader would have to refer to Reports № 1 through 5 for specific methodology, raw concentration and flow data.

Tables 1 and 2 portray the gross pollutant loadings from the non-urbanized and urbanized watersheds in the study area.

In sum, a number of important conclusions have been made and a great deal of valuable information is presented in the six reports. The non-point source waste load projections are based on monitoring and represent the monitoring year June, 1976 through June, 1977. Since drought conditions prevailed for a portion of that year, the amount of NPS pollution estimated may be low in comparison with that which would have been found in a "wet" or "normal" year. We can therefore expect the significance of rural runoff in general, and agricultural runoff in particular, to increase under more normal climatic conditions. Additional study to demonstrate this quantitatively would be desireable.

The more significant findings from each of the reports are described on the following pages.

Table 1

SUB-WATERSHED ANNUAL POLLUTION YIELD, (non-urbanized)

SUB-WATERSHED	NON-URBANIZED AREA (sq. mi.)	SUS SOLIDS (tons/sq. mi.)	COD (tons/sq. mi.)	TOTAL-P (lbs./sq.mi.)	ORTHO-P (lbs./sq. mi.)
LFR-M1	24.37	0.76	2.16	39.17	32.18
East River	127.31	0.62	1.76	31.86	26.17
LFR-M2	10.85	0.84	2.39	43.34	35.60
Plum Creek	41.13	0.71	2.02	36.69	30.14
Kankapot Creek	19.21	0.78	2.23	40.36	33.15
LFR-M3	16.18	0.80	2.28	41.23	33.87
LFR-M4	3.29	0.98	2.78	50.32	41.33
Neenah Slough	20.22	0.78	2.21	40.10	32.94
LFR-M5	10.46	0.85	2.40	43.54	35.77
Mud Creek	26.32	0.75	2.14	38.80	31.87
LFR-M6	7.30	0.88	2.51	45.55	37.41
Apple Creek	51.47	0.69	1.97	35.68	29.31
Ashwaubenon Creek	31.97	0.73	2.09	37.87	31.10
Dutchman Creek	29.92	0.74	2.11	38.18	31.36
LFR-M7	2.41	1.02	2.89	52.31	42.97
Duck Creek	129.95	0.62	1.75	31.78	26.10
LW-M1	10.75	0.84	2.40	43.39	35.64
LW-M2	18.18	0.79	2.24	40.64	33.38
LW-M3	8.75	0.86	2.46	44.53	36.57
Brothertown Creek	5.40	0.92	2.61	47.30	38.85

Table 1 (con't.)

SUB-WATERSHED ANNUAL POLLUTION YIELD, (non-urbanized)

SUB-WATERSHED	NON-URBANIZED AREA (sq. mi.)	SUS SOLIDS (tons/sq. mi.)	COD (tons/sq. mi.)	TOTAL-P (lbs./sq. mi.)	ORTHO-P (lbs./sq. mi.)
LW-M4	13.97	0.81	2.32	42.00	34.50
LW-M5	12.18	0.83	2.36	42.72	35.09
Taycheedah Creek	19.16	0.78	2.23	40.37	33.16
De Neveu Creek	18.74	0.79	2.23	40.48	33.25
Fond du Lac River	160.35	0.60	1.71	30.95	25.42
LW-M6	12.70	0.82	2.35	42.50	34.91
Van Dyne Creek	19176	0.78	2.22	40.21	33.03
LW-M7	37.41	0.72	2.05	37.13	30.50
LW-M8	12.38	0.83	2.35	42.64	35.02
Campbell Creek	2.03	1.04	2.95	53.45	43.90
Sawyer Creek	12.91	0.82	2.34	42.41	34.84
RL-M1	5.20	0.92	2.62	47.52	39.03
Spring Brook	21.00	0.77	2.20	39.91	32.78
Upper Fox River	7.57	0.88	2.50	45.34	37.24
RL-M2	8.86	0.86	2.45	44.46	36.52
RL-M3	10.38	0.85	2.41	43.59	35.80
Pumpkinseed Creek	14.33	0.81	2.31	41.86	34.39
Alder Creek	14.94	0.81	2.30	41.65	34.21
Wolf River	7.23	0.89	2.52	45.60	37.46
Rat River	77.14	0.66	1.87	33.92	27.86
RL-M4	12.76	0.82	2.34	42.47	34.89
Arrowhead Creek	30.59	0.74	2.10	38.08	31.28
RL-M5	8.44	0.87	2.47	44.73	36.74
Daggets	10.30	0.85	2.41	43.63	35.83
RL-M6	13.35	0.82	2.33	42.24	34.69

Report № 1 TEST WATERSHED MONITORING AND SAMPLING PROGRAM

The significant content of Report № 1 is the estimation of pollutant loading from each sub-watershed in the 208 Study Area. To provide a basis for this estimation, three distinct watershed types were extensively monitored. The three include an agricultural/developed watershed, an agricultural watershed and five small urban sub-basins.

Literature was surveyed and a field inventory made to determine what pollutants should be monitored. A significant portion of Report № 1 consists of appendices listing the results of the monitoring program. These results were applied to other sub-watersheds in the area to calculate a gross loading of pollutants on a sub-watershed basis for the monitoring year.

Since it was not possible to monitor all storm events, the load calculations made from measured concentration and flow values of events in urban test watersheds were extended to represent the unmonitored events in that monitoring year. Urban watersheds had been surveyed to determine the characteristics of the watersheds which impacted the quality of runoff waters. A characterization of land use in all urban areas in the remainder of the study area allowed projection of annual loads per unit of urban area to the unmonitored urban lands. The urban loads from each watershed were then summed to give annual load per metropolitan area. (Table 2).

In the case of rural non-point source loads, only a monitoring year annual estimate is made for each sub-watershed. In the case of urban areas the loads are expressed either as annual for the monitoring year or annual for an average runoff year.

Pollutant loading estimates were not calculated for all pollutants measured in the test watersheds. Projections of pollutant loadings from all study area lands were accomplished for four pollutants; namely, total phosphorus, ortho phosphorus, Chemical Oxygen Demand (C.O.D.) and Total Suspended Solids.

To estimate average annual urban NPS loads from urban lands, a statistical summary of the long-term sequence of storm events was used to characterize the period of study. Since there is some question as to the precision of this latter approach, estimates of monitoring year urban loads are most reliable.

For rural lands, annual pollutant yields were calculated from one year's monitoring on a total of 5 watersheds. This became the verification of pollutant load projections for the study area. Yields of pollutants commonly associated with sediments were correlated to watershed drainage area as in the Water Yield/Sediment Yield method of Report № 2.

In this approach, for example, Brothertown Creek was said to represent several other watersheds of like land use, size and topography. Pollutant yields were plotted versus drainage area of sub-watersheds in the form of a sediment yield equation (model). A separate equation was developed for each group of similar watersheds.

Any technique for estimating pollution loads by non-point sources to some degree limits precision. Therefore, rural NPS estimates should be qualified as appropriate for certain purposes in that they represent reality within a certain margin of error. Some are surprised to hear that some of our NPS estimates may be ± 50% accurate. Bear in mind when hearing such qualifications that we are comparing the relative amounts of several kinds of NPS pollution and each of these estimated numbers is extremely large.

For example, if a NPS load is estimated at 5×10^4 kilograms and you have reason to believe that this estimate could be 50 percent high or low, the lowest estimated load would be 50 percent of the original estimate or 2.5×10^4 kilograms. The difference between these two numbers is 25,000 kilograms.

While it would seem that these are therefore only rough estimates, when considered in relation to the total pollution load to a sub-basin the significance of that source changes only a very small percentage when using the lowest probable value. It is reasonable to judge relative significance of each NPS category within this margin of error.

On the other hand, the actual load estimates represent, at best, the runoff conditions encountered in one monitoring year. Therefore, the projected loads may not be adequate information from which to identify exact levels of needed non-point source control in each sub-watershed. Further study of NPS run-off will be needed to define the needed control levels.

Table 2

PROJECTED URBAN AREA LOADINGS FOR STUDY PERIOD (1976-77)

WATERSHED	AREA (acres)	C.O.D. (lbs.)	SUS. SOLIDS (lbs.)	TOTAL-P (lbs.)	ORTHO-P (lbs.)
Appleton					
HOV to Plum Cr.	12	2,321	5,408	11.26	9.34
HOV to Kankapot Cr.	712	86,089	180,648	384.93	310.19
HOV to LFR-M3	3,533	447,991	935,695	2,090.92	1,692.66
HOV to LFR-M6	4,887	680,717	1,444,651	3,265.18	2,663.79
Total	9,144	1,217,119	2,566,404	5,752.31	4,675.99
Fond du Lac					
LW-M5	56	3,498	4,708	16.90	12.43
Taycheedah	378	89,364	213,446	430.64	360.24
Denaveu Cr.	1,717	207,852	430,489	958.64	771.66
Fond du Lac R.	2,669	455,047	1,013,098	2,209.04	1,825.51
LW-M6	707	81,649	156,540	411.04	333.50
Total	5,527	837,412	1,818,283	4,026.27	3,303.35
Green Bay					
LFR-M1	1,131	197,981	446,908	939.88	780.18
East R.	5,703	664,214	1,277,277	3,055.06	2,453.46
LFR-M2	2,797	304,837	600,393	1,434.61	1,143.99
Ashwaubenon Cr.	1,364	196,086	421,536	928.83	761.20
Dutchman Cr.	1,869	216,156	432,468	1,033.49	828.91
LFR-M7	3,337	366,190	696,491	1,805.19	1,456.91
Duck Cr.	3,562	454,583	957,493	2,090.96	1,694.73
Total	19,763	2,380.050	4,832,569	11,288.06	9,119.40

Table 2 (con't)

PROJECTED URBAN AREA LOADINGS FOR STUDY PERIOD (1976-77)

WATERSHED	AREA (acres)	C.O.D. (lbs.)	SUS. SOLIDS (lbs.)	TOTAL-P (lbs.)	ORTHO-P (lbs.)
Watershed N-M/L.L. BDM					
LFR-M4	2,084	250,561	503,529	1,210.65	978.13
Neenah Slough	3,681	455,144	928,161	2,175.09	1,762.96
LFR-M5	607	76,483	154,720	371.21	303.01
Mud Cr.	2,294	471,699	1,102,224	2,249.93	1,875.99
LW-M1	519	58,802	116,712	282.27	225.55
Total	9,185	1,312,691	2,805,349	6,289.17	5,145.67
Oshkosh					
LW-M7	1,562	192,952	399,384	902.94	728.74
LW-M8	3,608	623,609	1,401,818	2,994.29	2,473.60
Campbell Cr.	1,291	212,609	480,096	990.35	820.21
Sawyer Cr.	883	113,248	243,328	498.85	404.89
RL-M1	350	26,218	40,482	129.92	99.54
RL-M6	258	34,210	74,667	146.94	120.48
Total	7,922	1,202,848	2,639,778	5,663.31	4,647.48
Total Omro Area	457	59,922	124,848	288.65	234.08
Total Winnconne Area	366	47,891	101,743	223.58	181.21

Report № 2 SEDIMENT SOURCE AND DELIVERY RATE STUDY

The original purpose of this study was to estimate sediment source and delivery rates for the 45 sub-watersheds comprising the 208 Study Area. Due to the lack of historical sediment discharge data for streams within the study area, no local sediment or water discharge data was used in the analysis. The consultant investigated several methods for developing these estimates. Four mathematical techniques of predicting sediment delivery were compared to see which would most accurately portray the situation in the study area. The Water Yield/Sediment Yield (WY/SY) method was concluded to be most appropriate for water quality purposes in the FVWQPA study area using discharge data from nearby stations of record.

The 3 tested procedures included the Universal Soil Loss Equation, the United States Geological Survey (USGS) method, and the WY/SY method. Keep in mind the conclusion to use the WY/SY method is because it seems best suited for water quality planning purposes. FVWQPA is principally concerned with the delivery or yield of sediments to a major water course. Thus the Agency most needs to know how much sediment comes out of the mouth of a stream and selection of the appropriate model is heavily biased toward providing that answer.

Table 3 portrays the amounts of sediment per square mile on an annual basis actually flowing out of the mouth of the respective streams. One column lists predictions for a "dry" year, such as the monitored year, the other for a "wet" year. Figure 1 displays the sub-watersheds in the watershed for which the estimates were made.

The WY/SY projection method appears to represent realistic ranges of potential sediment yield. Indeed, the dry year estimates in Table 3 closely resemble the sediment yield actually measured during the monitoring period.

TABLE 3

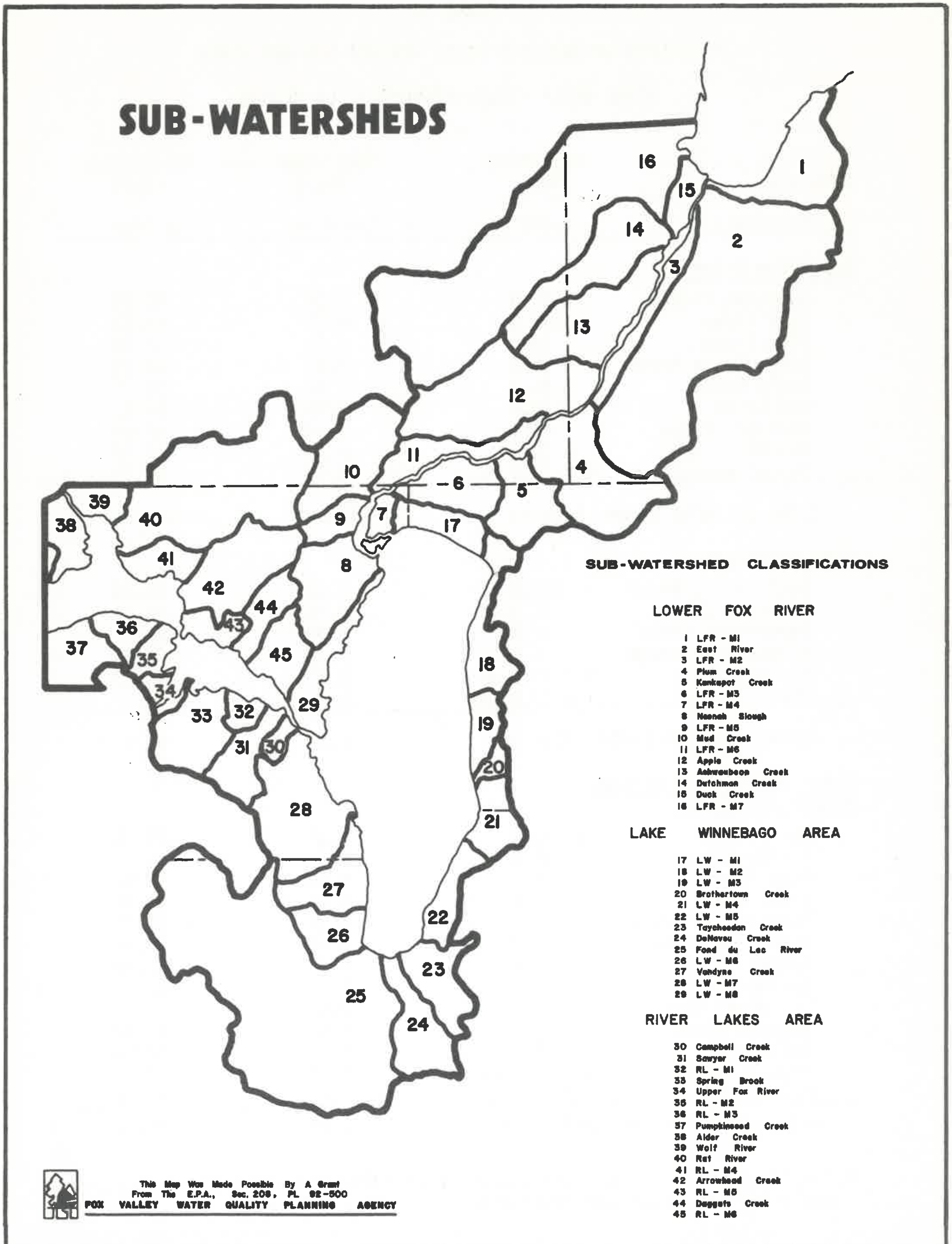
ESTIMATES OF SEDIMENT YIELD FOR WET AND DRY YEARS

USING WATER YIELD/SEDIMENT YIELD METHOD

Watershed Tributary	Tributary Area (mi^2)	"Dry" Year Yield T/mi^2/yr	"Wet" Year Yield T/mi^2/yr
Lower Fox River			
Dutchman Creek	32.0	5.76	53.92
East River	143.0	4.78	44.72
Plum Creek	26.0	5.92	55.34
Ashwaubenon Creek	30.0	5.81	54.36
Apple Creek	51.0	5.44	50.87
Mud Creek	25.0	5.95	55.61
Kankapot Creek	44.1	5.54	51.80
Neenah Slough	21.2	6.07	56.77
Miscellaneous	4 X 13.0 ea.	6.45	60.35
TOTAL SEDIMENT LOAD*	(424.3)	5.50	51.39
Lake Winnebago			
Fond du Lac River	171.0	4.83	46.36
De Neveu Creek	21.3	6.26	60.15
Taycheedah Creek	17.8	6.41	61.51
Brothertown Creek	5.4	7.20	67.35
Miscellaneous	6 X 13.0 ea.	6.45	60.35
Miscellaneous	7 X 13.0 ea.	6.45	60.35
TOTAL SEDIMENT LOAD*	(384.5)	5.73	54.3
Lakes Poygan, Winneconne, Buttes des Mortes			
Wolf River	3,846.0	4.68	20.54
Willow Creek	54.0	5.58	53.55
Pine River	58.0	5.53	53.07
Alder Creek	22.2	6.03	56.44
Pumpkinseed Creek	24.5	5.96	57.75
Upper Fox River	1,600.0	3.65	35.06
Sawyer Creek	15.0	6.34	59.28
Spring Brook	20.1	6.11	57.15
Arrowhead River	29.4	5.83	54.50
Daggets Creek	10.5	6.63	61.98
Rat River	74.0	5.19	48.56
Miscellaneous	3 X 13.0 ea.	6.45	60.35
Miscellaneous	3 X 13.0 ea.	6.45	60.35
TOTAL SEDIMENT LOAD*	(5,831.7)	4.47	26.79

* Total sediment load was calculated by dividing the total of tributary yields by the total watershed area.

Figure 1


SUB-WATERSHEDS
SUB-WATERSHED CLASSIFICATIONS
LOWER FOX RIVER
1 LFR - M1
2 East River
3 LFR - M2
4 Plum Creek
5 Kankapot Creek
6 LFR - M3
7 LFR - M4
8 Neenah Slough
9 LFR - M5
10 Mud Creek
11 LFR - M6
12 Apple Creek
13 Ashwaubenon Creek
14 Dutchman Creek
15 Duck Creek
16 LFR - M7
LAKE WINNEBAGO AREA
17 LW - M1
18 LW - M2
19 LW - M3
20 Brothertown Creek
21 LW - M4
22 LW - M5
23 Taycheedah Creek
24 DeNeveu Creek
25 Fond du Lac River
26 LW - M6
27 Vandyne Creek
28 LW - M7
29 LW - M8
RIVER LAKES AREA
30 Campbell Creek
31 Sawyer Creek
32 RL - M1
33 Spring Brook
34 Upper Fox River
35 RL - M2
36 RL - M3
37 Pumpkinseed Creek
38 Alder Creek
39 Wolf River
40 Rat River
41 RL - M4
42 Arrowhead Creek
43 RL - M5
44 Daggets Creek
45 RL - M6
This Map Was Made Possible By A Grant
From The E.P.A., Sec. 208, PL 92-500
FOX VALLEY WATER QUALITY PLANNING AGENCY

This study further concluded that the spring season is the most significant period of sediment yield to surface waters. The peak three-month period (March through May) may represent from 49% to 78% of the annual sediment yield under both "wet" or "dry" conditions.

Report № 3 SURVEY OF TOXIC CHEMICAL USE AND DISTRIBUTION

This study has attempted to answer only the following question: Of the toxic chemicals widely used in the study area, which may be found in large amounts in non-point source runoff? As a corollary we may ask, are non-point sources of toxics comparable to point sources in terms of the amounts and kinds of substances present?

To answer the central question, the general body of literature pertaining to toxics was reviewed. Additionally, local users of each class of toxic substances were interviewed. Interviewees included farmers, park superintendants, highway department officials and so on. The types and amounts of specific chemicals used were noted. The toxic substances most likely to enter run-off waters were identified. Monitoring was then conducted to test for the presence of those chemicals deemed common and dangerous.

Such a testing procedure is seen as identifying or verifying the potential of a toxicity problem in non-point source runoff. Positive results would point to the need for further study and possible control.

Some discussion of toxicity is perhaps in order. No individual could sense toxic substances dissolved in surface waters. Laboratory studies of toxicity point out possible toxic effects. Such studies usually demonstrate temporary, long-term or cumulative harm from exposure to some concentration of a certain compound. Toxic effects may be brought about by ingestion of polluted water, contaminated fish or (for aquatic life) by direct contact.

The subject of toxics can be highly emotional. It is quite difficult for an individual to understand the real risks, or to know what preventive measures are needed. In an atmosphere of fear and ignorance, with new toxic chemical problems coming to light each year, even professionals may lose sight of what a toxicity threat means to a community.

If protection of both the community and the aquatic environment from potential toxic effects is the motive, then it is logical to study and plan to control the most common and widespread toxic substances first. It is this course the FVWQPA pursued. The reader is cautioned that many other uncommon chemicals probably exist in runoff in this area, but were not tested for at this time. Also, FVWQPA did not have the opportunity to test in more than seven test watersheds. Therefore, some unique sources of toxics could have been missed. Careless spills, poor pesticide application practices or atypical peak runoff events are not considered in this approach. These problems are more properly addressed by the U.S. Environmental Protection Agency, the Wisconsin Department of Natural Resources or the University of Wisconsin-Extension.

In making comparisons between point and non-point sources, actual NPS toxic chemical loads are not calculable but a low concentration in a large NPS runoff volume may be deemed "not a problem" worthy of priority for management planning efforts. The very same chemical may be a problem elsewhere or where we have not detected it due to study design, but this initial determination is enough to set planning priorities in the study area.

Locally, any polluted sediments containing large amounts of toxic chemicals are likely to have built them up over a long history of pollution and no amount of management on the land will reverse that. The role of suspended sediments in transporting toxic substances has not been adequately defined in this study and the following conclusions do not reflect adequate assessment of sediment bound pesticides and some other similarly transported toxic chemicals. This is especially important since no appreciable soil loss was found in the dry year of monitoring.

On the basis of literature review:

The presence and concentration of pesticides must be continually evaluated since new compounds are introduced every year. Of the pesticides (includes herbicide, insecticide, etc.) used in the area, insecticides are most significant due to toxicity and widespread use. PCB's (polychlorinated biphenols) are expected to arise principally from point source discharges with the exception of landfill or sludge disposal sites. Pesticides, when found in urban runoff are generally higher in concentration there than in rural runoff.

The frequency and intensity of city and county pest control spraying and any aerial pesticide applications in the study area should be more carefully documented due to the high risk to water quality of any of these practices.

On the basis of the monitoring:

No pesticides or PCB's were found in runoff from urban or agricultural areas during the monitoring of storm events.

On the basis of literature review and monitoring it was found that:

Heavy metals (lead, zinc, etc.) in urban runoff were generally higher in concentration than in rural runoff. Many heavy metals are closely associated with sediment and move by sediment transport.

The monitoring program found heavy metal concentrations occur at significant levels in many urban areas and were highest in an industrial basin. Lowest levels in the urban area were found in the new residential and central business districts. Highest heavy metal concentrations were found in the runoff event which occurred after a long period of little rainfall.

The most common heavy metals found in urban runoff samples were lead and zinc. The highest concentration found was 17.1 mg/l zinc which occurred in the industrial area in October.

Heavy metals were not found to be a significant toxicant in the agricultural test watershed runoff.

Sanitary sludge represents the most concentrated and possibly widespread source of toxicants in the study area. High levels of heavy metals were reported by the Wisconsin Department of Natural Resources in sludges from selected area wastewater treatment plants. These sludges represent a potential source of heavy metals in runoff if applied openly to the land. Approximately half of the metals in raw municipal wastewaters are removed by secondary treatment and are deposited in the sludge. Information on disposal sites in the study area is fragmented and not sufficient to characterize sludge disposal practices and their impact on runoff quality.

Aquatic impacts of storm water discharged toxic substances cannot be understood without examination of the actual discharge points and quantitative analysis of plant and animal tissues from organisms in the receiving water. These analyses were not included as part of the study.

Report Nº 4 SEPTIC TANK STUDY

Septic tanks or any other kind of on-site waste treatment system are a water quality concern from the standpoint of nutrients or disease organisms contributed to surface waters. This study shows shoreline septic systems on the Winnebago Pool are an insignificant source of the nutrient phosphorus under even wet year conditions. A related, but separate, study effort concluded that shoreline septic systems were a significant potential health threat, even under dry year conditions.

Nutrient pollution from septic systems, the contribution of phosphorus and nitrogen compounds, affects the total water resource, degrading the quality everywhere by contributing to the advanced rate of eutrophication. Septic systems have been and may continue to be a source of nutrients contributing to algal bloom conditions.

Eliminating the septic system failures that cause nutrient loading will also prevent disease organism pollution, and vice-versa. Any approach to correcting one of the problems will also correct the other and will simultaneously benefit the general public and the private property owner.

PUBLIC HEALTH

Consider first the concern for public health. With few exceptions, disease organisms do not survive to travel long distances in surface waters and the impacts of a failing system or group of systems is therefore localized. Dilution and the sterilizing effect of sunlight and aerated water are the major factors limiting the extent of disease organism concentration. Hence, lakeshore property owners or the users of a commercial waterfront enterprise experience the waterborn impacts of nearby failing systems. Those impacts become too small to be measureable and are therefore insignificant in open lake, off-shore waters.

Some degree of disease organism presence, (defined as indicator levels, in excess of federal guidlines for public health), in the near-shore water of the Winnebago Pool is attributable to failing septic systems. This was documented for FVWQPA in the study "Public Health Studies on the Winnebago Pool". In that investigation, empirical verification of failure-caused problems was attempted at a variety of in-shore locations around the Winnebago Pool. Problem levels of indicator organisms (fecal coliforms) were detected in near-shore water adjacent to public and private beaches, marinas, launch sites, etc. It was concluded that further on-site evaluation during a more normal wet year is required to determine the extent of the problem and confirm a cause and effect relationship of failure to health risk. By all appearances, septic tanks in the Winnebago Pool Lakes drainage represent a very high failure risk and therefore a public health threat during the swimming season.

NUTRIENT POLLUTION

The significant question this study attempts to answer is a simple one. How great a contribution to lake eutrophication is the overall septic system situation? Further, the study attempts to define critical areas where system failure causes the greatest contribution of nutrient loading.

Nutrient loadings were estimated under several hydrologic conditions. All calculations were based on literature values conditioned by the consultants appraisal of local conditions for hydrogeologic variables, soils and so on. Comparing the significance of pollution from septic systems to other pollution sources is valid using the existing information.

Septic tank pollutant loads were calculated by estimating the number of households within the Winnebago Pool Lakes drainage area served by septic systems, pollution loading generated by this population and the removal efficiencies of various pollutant transport mechanisms during different hydrologic conditions.

Taking into account the variation between year-round and seasonal households, the lake system receives the discharge of approximately 11,800 people within 200 feet of its shoreline and an additional 27,100 people from its direct drainage area.

Table 4 presents the estimated annual net loads of nutrients from septic systems to the Winnebago Pool under a variety of hydrologic conditions.

TABLE 4

ANNUAL SEPTIC TANK CONTRIBUTIONS

	NITROGEN	PHOSPHORUS	BOD
	Shoreline Lots		
Maximum	40,800 kg	12,300 kg	131,900 kg
Moderate	34,500 kg	10,300 kg	66,000 kg
Minimum	27,200 kg	7,200 kg	22,000 kg
	Inland Lots		
Maximum	79,700 kg	6,500 kg	10,100 kg
Moderate	69,600 kg	2,600 kg	5,000 kg
Minimum	56,300 kg	0	0
	Total		
Maximum	120,500 kg	18,800 kg	142,000 kg
Moderate	104,000 kg	12,900 kg	71,000 kg
Minimum	83,500 kg	7,200 kg	22,000 kg

Report No 5 INSTREAM ALTERATION

The Instream Alteration Study provides a preliminary assessment of water quality impacts resulting from dredging activities. Potential impacts include: release of heavy metals, release of nutrients, and increases in turbidity. The study was based upon a review of applicable research literature, no actual monitoring was undertaken.

Instream alteration activities in the FVWQPA Study Area include underwater pipeline construction, marina construction and maintenance, private shoreline development, and U.S. Army Corps of Engineers (U.S.A.E.) dredging to maintain navigation. The total volume of dredged material removed per year in the study area is estimated at 151,800 cubic yards*. About 54,300 cubic yards/yr. are removed in U.S.A.E. navigation maintenance projects, the remainder is private permitted work generally involving small projects of less than 2,000 cubic yards each.

The preliminary conclusion reached in the study is that dredging and disposal of spoils does not create a serious long-term water quality problem in the region. The recognized impacts of U.S.A.E. dredging activities are short-term localized turbidity increases from clam shell dredging. It should be realized that dredging for navigation maintenance involves relatively small yearly amounts in the Winnebago Pool and Lower Fox River, and is an infrequent activity. Smaller shoreland development dredging activities may also have water quality and land use impacts, but they are typically localized. Turbidity levels may be elevated temporarily or wetlands may be damaged or destroyed, but these smaller scale operations are best reviewed on-site through the permitting process utilized by WDNR, U.S. EPA, and the U.S.A.E.

A substantial increase of rural lands soil loss or of stream bank erosion could increase the need for more frequent dredging. This could imply further water quality impacts. In any case, it is non-point source pollution from

* This excludes the proposed Green Bay Harbor Projects which are estimated to remove 115,000 cubic yards per dredging year.

the land that should have control priority since it is often erosion transported sediment that is deposited in navigation channels, streambeds, and small harbors.

An estimate was made of the total pounds of pollutants available from localized spoil disposal operations (see Table 5). Water quality impacts from these loading levels are not likely to be significant. However, in cases where elevated levels of toxic compounds (such as PCB's) are suspected in bottom sediments, special precautions should be taken to ensure that spoils are properly disposed of and contained. This is especially important since the long-term effects of upland disposal of highly polluted spoils are unknown.

TABLE 5

PRELIMINARY ESTIMATES OF
POLLUTANT LOADING DUE TO NAVIGATIONAL
MAINTENANCE DREDGING

Area Within Fox Valley	Assumed Drainage Time (1)	Pollutant Loading Range (lbs/day) (2)			
Lower Fox River	6 months - 1 year	Copper	0.8	-	1.6
		Cadmium	0.006	-	0.01
		Lead	0.03	-	0.07
		Zinc	0.1	-	0.19
		Chromium	0.01	-	0.03
		Mercury	0.006	-	0.01
		Nickel	0.008	-	0.02
		Arsenic	0.003	-	0.006
		TP	0.05	-	0.1
		TKN	6.2	-	12.5
Lakes Region	6 months - 1 year	Copper	2.0	-	4.0
		Cadmium	0.01	-	0.02
		Lead	0.09	-	0.18
		Zinc	0.21	-	0.42
		Chromium	0.36	-	0.72
		Mercury	0.02	-	0.04
		Nickel	0.02	-	0.03
		Arsenic	0.01	-	0.02
		TP	0.25	-	0.49
		TKN	31.1	-	62.3
Wolf River	10 days - 6 months	Copper	0.05	-	1
		Cadmium	0.0002	-	0.003
		Lead	0.002	-	0.03
		Zinc	0.006	-	0.1
		Chromium	0.0006	-	0.01
		Mercury	0.0006	-	0.01
		Nickel	0.002	-	0.03
		Arsenic	0.006	-	0.01
		TP	0.07	-	1.2
		TKN	8.6	-	154.7

(1) Assumed 30 days per month.

(2) Assumes all available pollutants are released, thus not taking into consideration complex chemical interactions, rainfall and erosion control measures - significant figures were purposely ignored.

III. TROPHIC STATUS STUDIES

The Winnebago Pool and Lower Green Bay are nutrient rich bodies of water that support elevated rates of biological activity. In an attempt to quantify the fertility and biological productivity of the water bodies, two trophic status studies were sponsored by FVWQPA. Each study was conducted to explore, and if possible, develop models that would enable the FVWQPA to determine the importance of each pollution source (urban runoff, septic tanks, municipal treatment plants, etc.) to the trophic state of the Winnebago Pool and Lower Green Bay.

Trophic state is broadly defined as the degree of nutrient richness and biological productivity of a body of water. Productivity is usually reflected in the amount of algae and/or aquatic plants present, while nutrient richness is indicated by the amount of phosphorus present. This definition becomes more specific when applied to a particular lake.

Among all the parameters measured in these studies, phosphorus and chlorophyll are the most important in determining trophic state. Where water is not too clouded by non-living matter it is possible to discover a statistically reliable correlation between the amount of phosphorus nutrients present and the amount of algae present (chlorophyll a). The correlation serves as a tool enabling us to view the degree to which nutrient pollution degrades the lake by causing nuisance algae blooms.

Eutrophication is the rate at which nutrient richness and biological productivity increase in a lake over time. It follows that a lake designated as eutrophic at the present time must be compared to its historic trophic state to determine if it can be made better. Making it better means slowing down or reversing eutrophication by controlling nutrient pollution. Where historical data and modern evidence is adequate, the potential to make things better has been assessed.

A considerable amount of information was collected in each of these studies, only the highlights are presented here.

WINNEBAGO POOL

The Winnebago Pool is the largest and one of the most important reservoirs in Wisconsin. Its trophic state has a tremendous influence on the quality of water in both the Lower Fox River and Green Bay. In a comparison of 12 Wisconsin lakes by two different trophic assessment methods, Winnebago was determined to be the most eutrophic. However, in comparison to other shallow lakes elsewhere in the country and around the world, Winnebago does not have excessively high levels of chlorophyll a.

Usually when a lake in temperate latitudes is polluted and nutrient rich, one species of plankton prevails all summer and becomes a nuisance. Blue-green algae grow in tremendous numbers for long periods of time each summer in both the Winnebago Pool and Lower Green Bay. Presently, algal populations during summer months render the water unacceptable for high quality domestic or recreational use. Wind blown algal concentrations exaggerate these problems and make swimming conditions unpleasant at best. Oxygen production and consumption by the large plankton community induces extreme and rapid changes in dissolved oxygen. This is important to fish and bottom dwelling organisms during summer calm periods and under critical winter ice conditions.

In the entire Winnebago Pool, phosphorus nutrients are present in such excessive amounts that a slight reduction in phosphorus pollution would not reduce algae bloom problems at all. However, phosphorus is a critical nutrient that when reduced sufficiently will reverse eutrophication. Nitrogen nutrients are not easily controlled, and their control will not aid in reducing blue-green algae problems.

Based upon summer phosphorus and chlorophyll a concentrations in the Winnebago Pool, a regression equation (a model) was developed to aid in understanding the impact of nutrient amounts on biological productivity among nusiance algae species. If the equation is appropriate a 55 % reduction in summer phosphorus concentration will be required to reduce algal mass to a point where there is good recreational potential, but at which nuisance conditions will occasionally occur. In order to achieve a high recreational potential with no nusiance blooms, a 76% reduction in summer phosphorus concentration would be required.

Phosphorus control at either level of nutrient reduction may be costly and difficult to implement. Three techniques were evaluated as to their applicability to improving water quality by means other than on-land pollution control. These are classed as in-lake management techniques that can be designed to supplement pollution control measures and enhance the rate of water quality improvement. It was suggested that the following techniques may be cost-effective for this purpose and should be investigated:

I. To decrease turbidity, stabilize lake sediments, and remove a portion of the available phosphorus.

   a.) Adjust spring or early summer water levels to generally lower the lake and prevent excessive peak flow levels that destroy or prevent re-establishment of aquatic vegetation.

   b.) Begin artificial propagation of reed canes in the up river lakes of the Pool. This could be accomplished on natural or man-made underwater gravel ridges and would reduce wave energy and sediment resuspension.

   c.) Continue or increase fish management efforts such as rough fish removal. This would improve water clarity by reducing sediment disturbance and the "nutrient pumping" action of carp and sheep head species.

LOWER GREEN BAY

Water quality along the East and Southeast shore of the Lower Green Bay is greatly influenced by the water quality of the Lower Fox River. Improvements of water quality in the upper watershed will have a corollary benefit in the Lower Green Bay.

Summer dissolved oxygen levels in the Inner Bay area have increased substantially since the early 1970's. Even the lowest dissolved oxygen levels found at the mouth of the river would not likely cause extreme stress for fish and aquatic life.

Average water clarity in the Lower Bay has not been shown to have increased substantially in recent years and there is no evidence to suggest that water clarity will improve greatly in the near future.

In spite of apparent decreases in the total phosphorus concentrations in the Lower Bay over recent years, the relative abundance of algae has not been found to have changed measureably. We may presume that phosphorus nutrients are present in luxurious amounts. Present sources of phosphorus to the Bay waters are sufficient to allow continued algal bloom conditions comparable to those presently documented in the report.

Table 6 portrays the relative amount of phosphorus pollution entering the Bay as compared to Inner Bay phosphorus concentration.

An analysis of the critical sources affecting Inner Bay phosphorus levels was made. The objective was to predict certain average Green Bay total phosphorus concentrations given the measurement of incoming phosphorus loads.

It was concluded that loading of phosphorus from the Lower Fox River accounts for approximately half of the variability of average total phosphorus concentration in the Inner Bay area. Wind resuspension of bottom sediments,

Table 6

Phosphorus loadings (Fox River, Green Bay Metropolitan Sewerage District) and mean phosphorus concentrations in the inner bay area for the same dates.

Date	Fox River Load (Kg/day)	GBMSD Load (Kg/day)	Mean Inner Bay Total Phosphorus (mg/l P)
13 July 1970	642	679	.17
20 July 1970	501	690	.16
3 August 1970	1055	707	.22
17 August 1970	714	547	.20
29 Sept. 1970	718	673	.13
20 July 1971	1370	373	.20
17 August 1971	1247	373	.21
5 June 1972	1269	685	.29
21 June 1972	1666	698	.35
26 June 1972	907	606	.26
5 July 1972	885	470	.20
17 July 1973	794	286	.23
23 July 1973	915	89	.20
15 August 1973	1182	411	.17
10 Sept. 1973	1184	239	.22
21 June 1976	543	330	.11
28 June 1976	885	783	.10
6 July 1976	2048	480	.39
20 July 1976	1111	631	.18
2 August 1976	759	365	.28
9 August 1976	651	266	.15
16 August 1976	778	467	.18
24 August 1976	647	498	.21
30 August 1976	799	398	.20
14 June 1977	1408	92	.20
27 June 1977	918	140	.17
13 July 1977	830	105	.20
26 July 1977	1302	152	.24
9 August 1977	861	98	.24
22 August 1977	748	111	.16

short-term fluctuations in river flow rates, and non-point source runoff are some of the factors accounting for the remainder of the variability. It was also concluded that:

1. A high correlation has been found between river load of total phosphorus and average Green Bay concentration of total phosphorus.

2. Total Phosphorus loadings from the Green Bay MSD did not correlate with Inner Bay concentrations nor did they appear significant to the variability in Inner Bay concentrations.

3. Some internal regeneration of ortho-phosphorus from Bay sediments to the Bay waters is apparent in the Inner Bay area. Sediment phosphorus may have an important role in the total phosphorus balance which in turn impacts the trophic condition of Green Bay.

4. It was concluded that, "the unique, estuary-like setting of Green Bay in combination with shallow depths and high flushing rates .... appear to make it unsuitable for the application of conventional models of trophic status." FVWQPA, therefore does not presently have a model of Green Bay adequate for the purpose of determining how the trophic state will be affected by waste management alternatives. Intuitively, we may expect that a growth limiting level of phosphorus could be reached and algal blooms controlled by a defined amount of pollution abatement beyond existing levels. Future investigations of other sources of phosphorus variability will be necessary to create a model to aid decision-making.

IV. NUTRIENT BUDGET

A nutrient budget was developed to provide a means of comparing the relative impact of controlling sources of phosphorus to reduce the water quality problems of the Winnebago Pool area which are caused by nutrient pollution. The budget is the technical link between the Non-Point Source and Trophic Status Studies.

Six sources of nutrient pollution in the area were in the nutrient budget. These included: septic tanks, municipal waste-water treatment plants, urban runoff, rural runoff and pollutant loadings from the Upper Fox and Wolf Rivers. (The pollution impacts of instream alteration activities were analyzed in Report № 5. Since phosphorus loads from that source were deemed insignificant, those loads were not included in any budget calculations.) The budget is keyed to phosphorus due to the role of phosphorus in causing nusiance algae blooms and its potential for control.

The following assumptions were made in developing a nutrient budget for the Winnebago Pool: 1) most of the phosphorus found in lake waters at the start of the summation period is flushed out by the end of the period (1 year); 2) complete mixing of the water column (both horizontal and vertical) is characteristic for most of the year; and 3) blue-green algae concentrate available phosphorus and are skimmed over the Neenah/Menasha dams, thereby removing phosphorus at a greater rate than hydraulic flushing would indicate.

By adding all estimated annual phosphorus pollution loads and subtracting the loss of phosphorus over the dams, the amount of phosphorus remaining in the water column at the end of one year is obtained (P residual). When P residual is divided by the volume of the lake, a predicted phosphorus concentration is derived. If the predicted phosphorus concentration is less than measured phosphorus concentration, the difference is attributed to lake sediments (an unmeasurable phosphorus source).

In order to apply the nutrient budget tool to develop a pollution control strategy, a target in-lake phosphorus concentration was selected. By selecting a phosphorus concentration that would decrease the duration and intensity of nusiance algae blooms, the nutrient budget can evaluate the degree to which phosphorus pollution would have to be reduced from each source to meet a generally high recreational use potential. In this manner, a number of pollution control strategies can be applied to controllable sources of phosphorus to test their effectiveness on improving water quality. A nutrient budget provides a rough estimate of phosphorus concentrations and the amount of pollution reduction from each source needed to meet a desired phosphorus level in the lake.

Figures 2 and 3 compare the significance of phosphorus sources to the Winnebago Pool in the June 1976 through June 1977 monitoring year.

Since a nutrient budget could not be developed for the Lower Green Bay (it is an open-ended system), Figure 5 was developed to represent the controllable sources of phosphorus that enter the Lower Fox-Green Bay system. The budget for the Winnebago Pool is summarized in Tables 7 and 8.

Table 7

ANNUAL

Winnebago Pool Phosphorus Budget

water year 6/22/76 through 6/22/77

estimated loading rates a			*unmeasureable flux b*		*loss through outflow c*	
Known Sources of Loading		kg. total P	Source	kg. total P (net. est. sig.)	Location	kg. total P
Upper Fox R. + Wolf R.	(WC)	$1.57X10^5$	lake sediment (WLS) and other unknowns	$1.72X10^5$	Neenah/Menasha channels (WLA)	$1.73X10^5$
municipal treatment plants	(STPT)	$0.539X10^5$	rainfall**	from literature less then 8% of WLS		
rural runoff in direct drainage	(AR)	$0.152X10^5$	dryfall	?		
septic tanks, least case est.	(ST)	$0.072X10^5$	municipal water supply withdrawal	?		
urban runoff direct drainage	(UR)	$0.048X10^5$	biological export and import	?		
sum a.		$2.381X10^5$	sum b.	$1.72X10^5$	sum c.	$1.73X10^5$
areal loading rate a.		$0.366\ gr/m^2/yr$	areal loading rate b.	$0.264\ gr/m^2/yr$		
volumetric loading rate a.		$0.099\ gr/m^3/yr$	volumetric loading rate b.	$0.072\ gr/m^3/yr$	volumetric loss rate c.	$0.072\ gr/m^3/yr$

total areal. loading rate (a+b) = $0.632\ gr/m^2/yr$

total volumetric loading rate (a+b) = $0.171\ gr/m^3/yr$

assumed residual mass of total P* = (.1mg/1) ($2.37X10^{12}$ liters) = $2.37X10^5$ kg. total P

$$\text{replacement time} = \frac{\text{residual mass in pool}}{\text{nex flux}} = \frac{2.37X10^5\ \text{kg.}}{\text{sum a+ sum b+ sum c}} = \frac{2.37X10^5}{5.831X10^5} = 0.41\ \text{yr}$$

mean hydraulic retention time = .64 year

* based on average concentration, midlake June of 1977

** based on 0.032 gr. $P./m^3$ rainfall and 23.42 in. cumulative precipitation

Table 8

SUMMER

Winnebago Pool Phosphorus Budget

7/4/76 through 9/15/76

estimated loading rates a			*unmeasureable flux b*		*loss through outflow c*	
Known Sources of Loading		kg. total P	Source	kg. total P (net. est. sig.)	Location	kg. total P
Upper Fox R. + Wolf R.	(WC)	$0.272X10^5$	lake sediments (WLS) and other unknowns	$5.053X10^5$	Neenah/Menasha channels (WLA)	$0.412X10^5$
municipal treatment plants	(STPT)	$0.135X10^5$	rainfall**	from literature less than 1 % of WLS		
rural runoff in direct drainage	(AR)	$0.053X10^5$	dryfall	?		
septic tanks, least case est.	(ST)	$0.072X10^5$	municipal water supply withdrawl	?		
urban runoff direct drainage	(UR)	$0.017X10^5$	biological export and import	?		
sum a.		$0.549X10^5$	sum b.	$5.053X10^5$	sum c.	$0.412X10^5$
areal loading rate a.		$0.084\ gr/m^2$/summer	areal loading rate b.	$0.776\ gr/m^2/s.$		
volumetric loading rate a.		$0.023\ gr/m^3$/summer	volumetric loading rate b.	$0.211\ gr/m^3/s.$	volumetric loss rate c.	$0.017\ gr/m^3/s.$

total areal loading rate (a+b) = $0.860\ gr/m^2/s.$

total volumetric loading rate (a+b) = $0.234\ gr/m^3/s.$

assumed residual mass of total P* =(0.319mg/1)($2.37X10^{12}$ liters) = $5.19X10^5$ kg. total P

$$\text{replacement time} = \frac{\text{residual mass in pool}}{\text{net flux}} = \frac{5.19X10^5\ \text{kg.}}{\text{sum a+ sum b+ sum c}} = \frac{5.19X10^5}{6.014X10^5} = .86\ \text{summers}$$

mean hydraulic retention time = .64 year

* based on average concentration, midlake Sept. of 1976

** based on 0.032 gr. P/m^3 rainfall and 7.70 inches cumulative precipitation

(replacement time calculation assumes no flushing of initial residual mass from June 76)

SYNOPSIS

Taken together the Trophic Status Studies offer a view of water quality for most of the surface water in the 208 area. They will serve as benchmark studies to which future progress in pollution control may be compared. It is fortunate that both bodies of water were studied simultaneously and that all information is comparable.

This is the first time a study of this scope has been attempted for the Winnebago Pool, formerly a relatively neglected, unstudied resource from a water quality standpoint.

The water quality problems of the Winnebago Pool are the cause of some of the water quality problems in the Lower Fox River and in Lower Green Bay. As the River and Bay continue to respond to point source pollution control, attention will turn to the many studies still needed in the Upper Fox and Wolf Basins and to the steps in pollution control that remain to be taken in the Winnebago Pool drainage basin.

APPENDIX

Figure 2

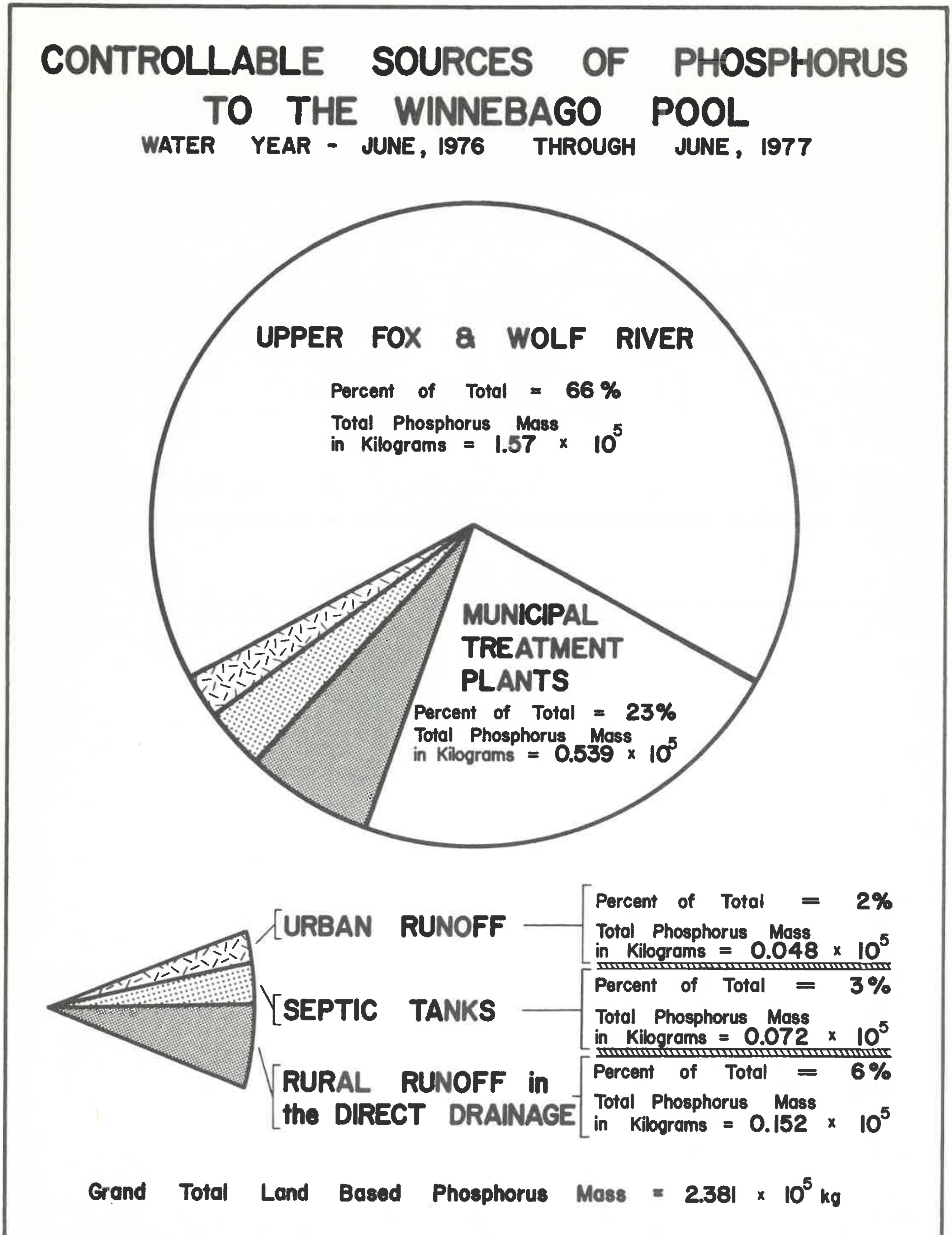
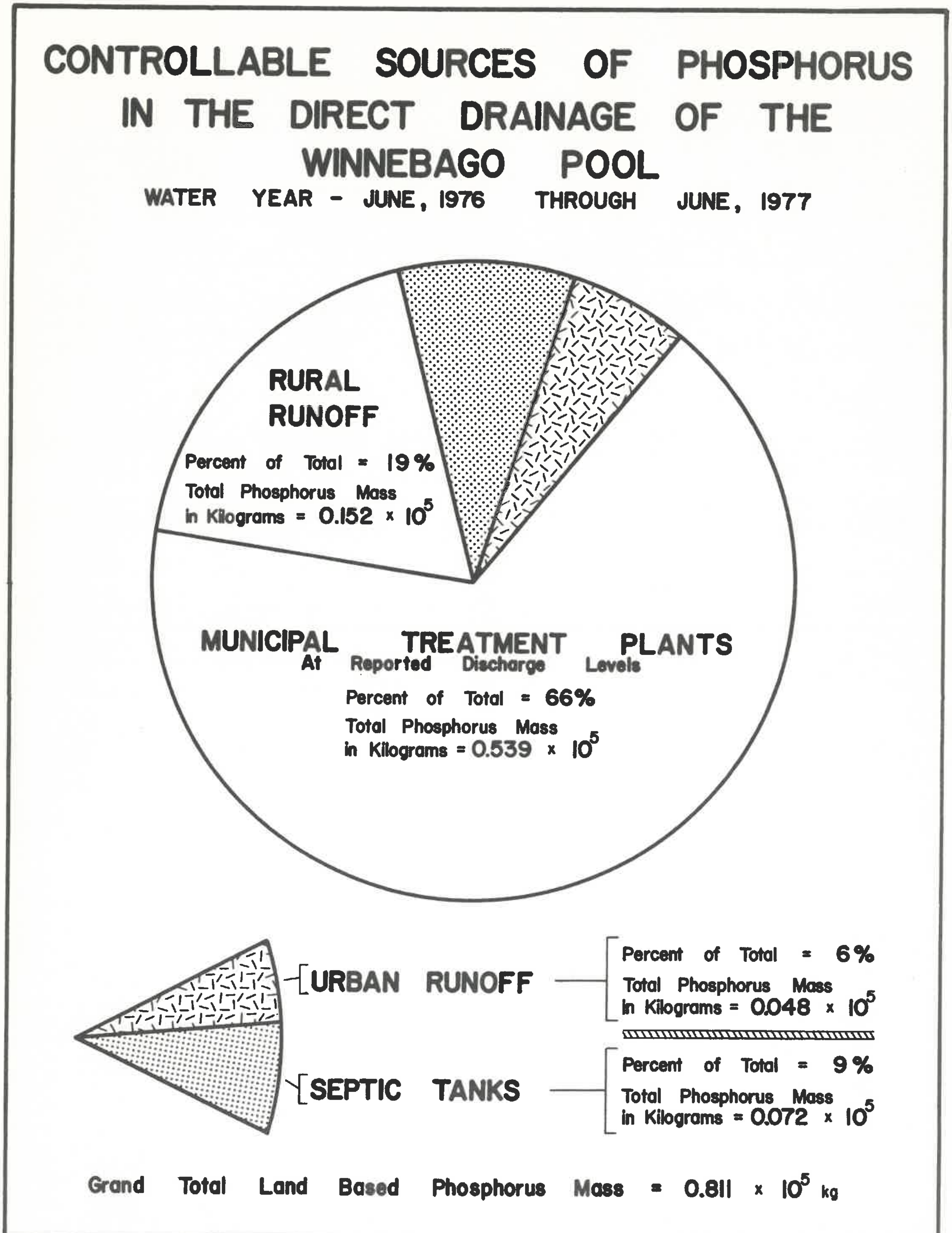

CONTROLLABLE SOURCES OF PHOSPHORUS TO THE WINNEBAGO POOL
WATER YEAR - JUNE, 1976 THROUGH JUNE, 1977
UPPER FOX & WOLF RIVER
Percent of Total = 66 %
Total Phosphorus Mass in Kilograms = 1.57 x 10^5
MUNICIPAL TREATMENT PLANTS
Percent of Total = 23%
Total Phosphorus Mass in Kilograms = 0.539 x 10^5
URBAN RUNOFF
Percent of Total = 2%
Total Phosphorus Mass in Kilograms = 0.048 x 10^5
SEPTIC TANKS
Percent of Total = 3%
Total Phosphorus Mass in Kilograms = 0.072 x 10^5
RURAL RUNOFF in the DIRECT DRAINAGE
Percent of Total = 6%
Total Phosphorus Mass in Kilograms = 0.152 x 10^5
Grand Total Land Based Phosphorus Mass = 2.381 x 10^5 kg

Figure 3



CONTROLLABLE SOURCES OF PHOSPHORUS
IN THE DIRECT DRAINAGE OF THE
WINNEBAGO POOL
WATER YEAR - JUNE, 1976 THROUGH JUNE, 1977
RURAL RUNOFF
Percent of Total = 19%
Total Phosphorus Mass
in Kilograms = 0.152 x 10^5
MUNICIPAL TREATMENT PLANTS
At Reported Discharge Levels
Percent of Total = 66%
Total Phosphorus Mass
in Kilograms = 0.539 x 10^5
URBAN RUNOFF
Percent of Total = 6%
Total Phosphorus Mass
in Kilograms = 0.048 x 10^5
SEPTIC TANKS
Percent of Total = 9%
Total Phosphorus Mass
in Kilograms = 0.072 x 10^5
Grand Total Land Based Phosphorus Mass = 0.811 x 10^5 kg

Figure 4

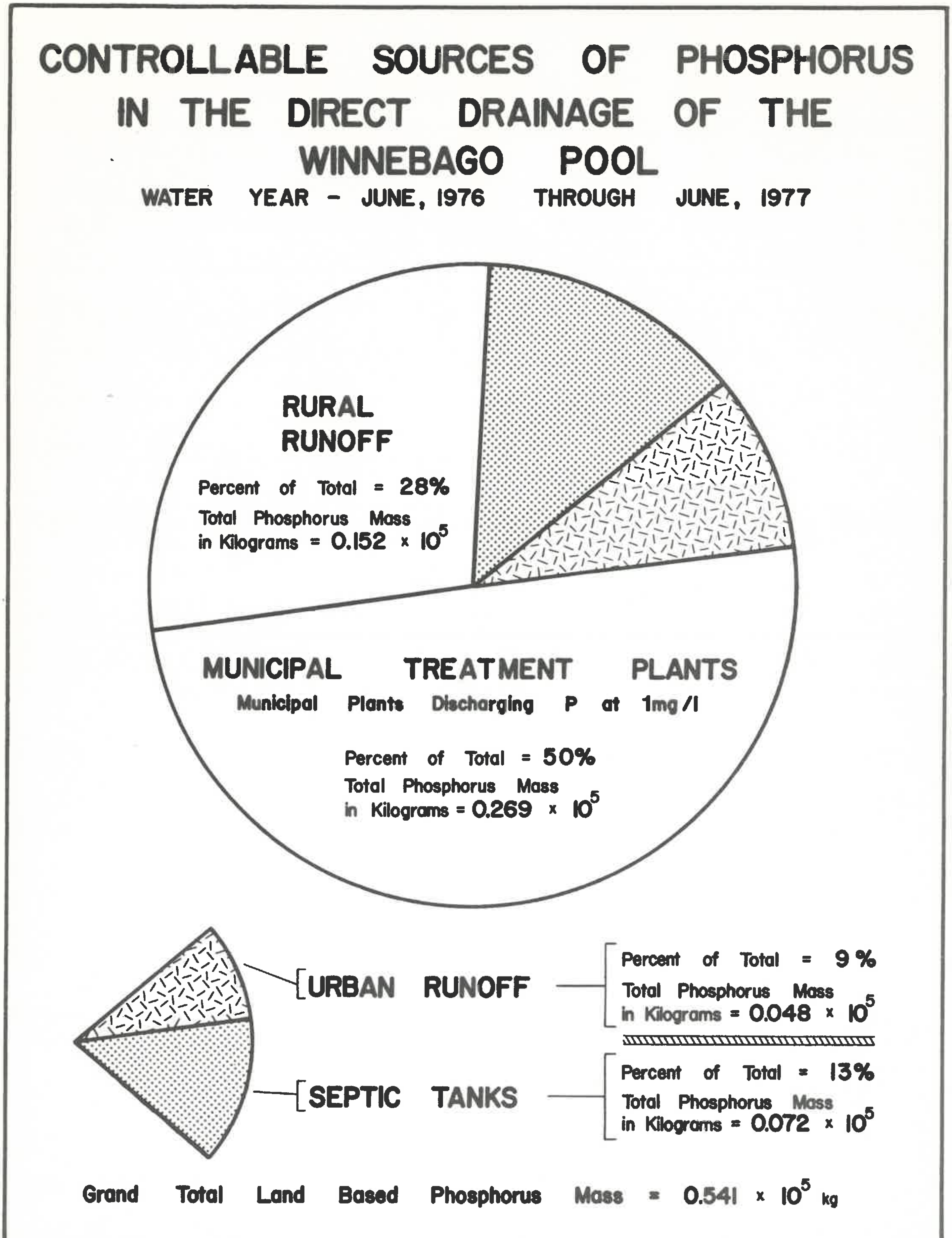
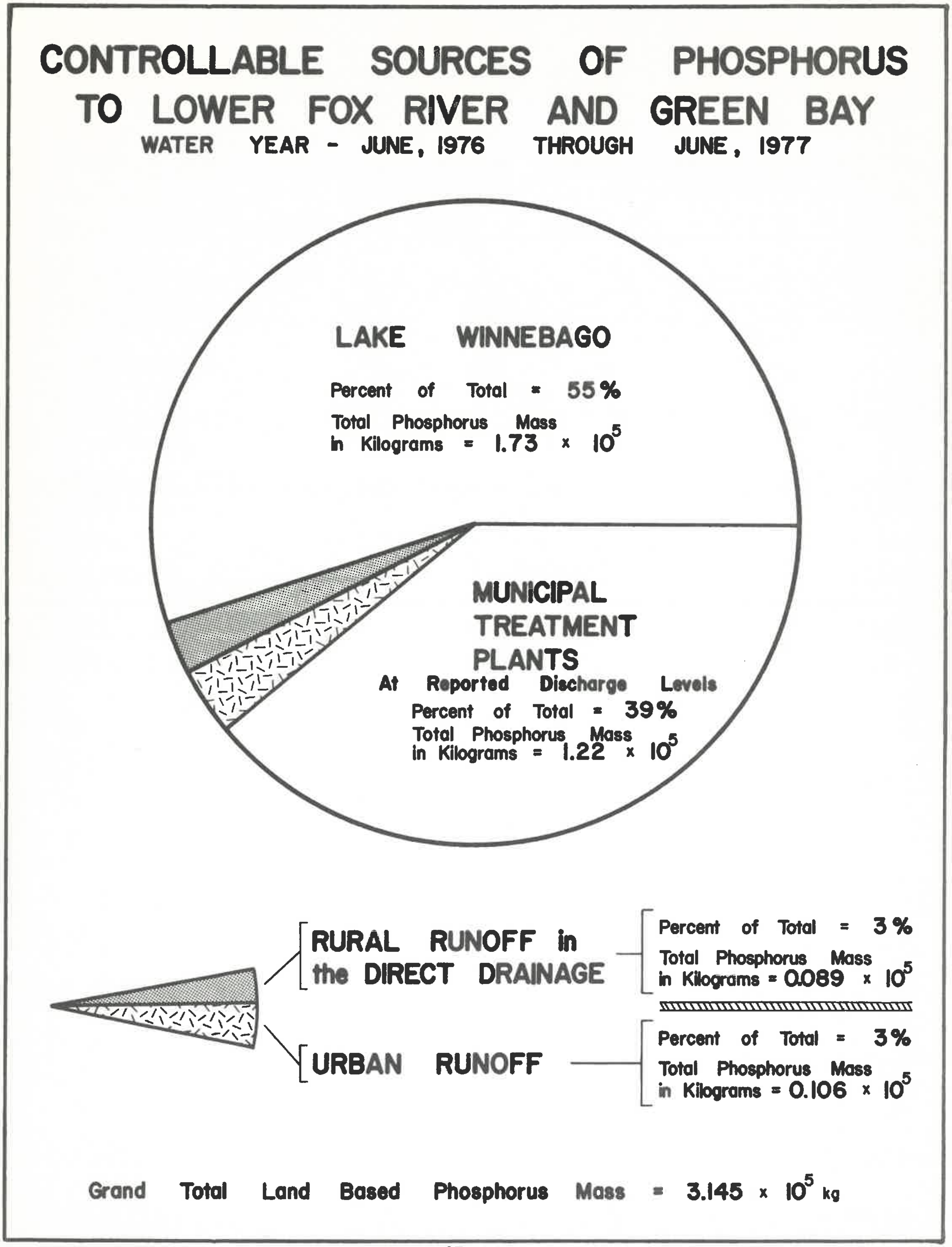

CONTROLLABLE SOURCES OF PHOSPHORUS
IN THE DIRECT DRAINAGE OF THE
WINNEBAGO POOL
WATER YEAR - JUNE, 1976 THROUGH JUNE, 1977
RURAL RUNOFF
Percent of Total = 28%
Total Phosphorus Mass in Kilograms = 0.152 x 10^5
MUNICIPAL TREATMENT PLANTS
Municipal Plants Discharging P at 1mg/l
Percent of Total = 50%
Total Phosphorus Mass in Kilograms = 0.269 x 10^5
URBAN RUNOFF
Percent of Total = 9%
Total Phosphorus Mass in Kilograms = 0.048 x 10^5
SEPTIC TANKS
Percent of Total = 13%
Total Phosphorus Mass in Kilograms = 0.072 x 10^5
Grand Total Land Based Phosphorus Mass = 0.541 x 10^5 kg

Figure 5


CONTROLLABLE SOURCES OF PHOSPHORUS
TO LOWER FOX RIVER AND GREEN BAY
WATER YEAR - JUNE, 1976 THROUGH JUNE, 1977
LAKE WINNEBAGO
Percent of Total = 55%
Total Phosphorus Mass in Kilograms = 1.73 x 10^5
MUNICIPAL TREATMENT PLANTS
At Reported Discharge Levels
Percent of Total = 39%
Total Phosphorus Mass in Kilograms = 1.22 x 10^5
RURAL RUNOFF in the DIRECT DRAINAGE
Percent of Total = 3%
Total Phosphorus Mass in Kilograms = 0.089 x 10^5
URBAN RUNOFF
Percent of Total = 3%
Total Phosphorus Mass in Kilograms = 0.106 x 10^5
Grand Total Land Based Phosphorus Mass = 3.145 x 10^5 kg