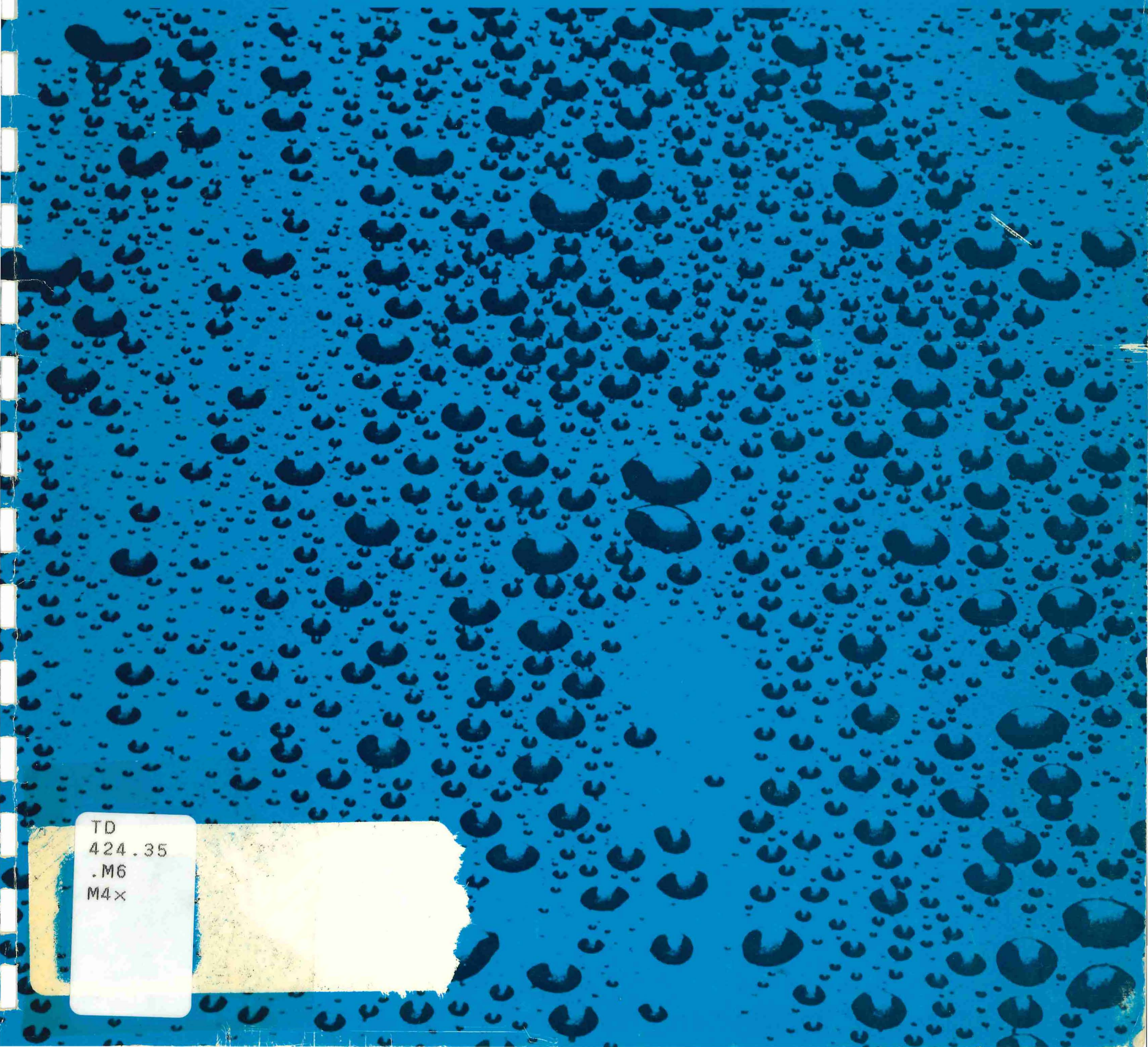
WATER POLLUTION FROM NONPOINT SOURCES

An Assessment and Recommendations

APRIL 1979

Metropolitan Council OF THE TWIN CITIES AREA



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An Assessment and Recommendations

April 1979

Metropolitan Council
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ABOUT THIS REPORT

In 1977, the U.S. Congress reaffirmed the goal of the 1972 amendments to the Federal Water Pollution Control Act. Congress restated that:

> By 1983, the nation's waters should be clean enough for swimming and fishing; and
>
> By 1985, all discharge of pollutants into our waters should be eliminated.

Through Section 208 of the Act (P.L. 92-500), planning agencies throughout the nation have been funded to establish comprehensive water quality management programs for controlling point source pollution, such as municipal and industrial wastewater; and nonpoint source pollution, such as urban stormwater and agricultural runoff.

Under the law, states or local governments and interested citizens are working through a designated planning agency to develop a management plan to meet water quality goals. The Metropolitan Council is the designated 208 planning agency for the Twin Cities Metropolitan Area.

The Council's initial two-year program, which began in November 1976, has been devoted to development of a total point source pollution plan and implementation program, and a partial nonpoint source program designed to assess the nature of the problem. The point source program is scheduled for Council action in March 1979.

This report completes Phase I of the nonpoint source pollution program. The report, including its five major recommendations, was adopted by the Metropolitan Council in June 1978.

The report provides an overview of problems resulting from nine categories of nonpoint source pollution: agricultural runoff, stream channel erosion, urban stormwater runoff, construction erosion, landfill leachates, mining, barge washing, dredging and miscellaneous nonpoint sources.

The report identifies nonpoint sources of pollution that should be addressed in Phase II of the water quality management program. The Council has submitted a request to the U.S. Environmental Protection Agency for full funding of the Phase II nonpoint source program.

If funded, the Phase II nonpoint source program will begin in summer 1979. It will include refinement in data used to assess nonpoint sources, evaluation of management practices, development of a management strategy, evaluation of existing laws and agency responsibilities and implementation of a remedial program.

The Phase I nonpoint sources study relied solely on existing information and techniques about water quality for the numerical values that were used to estimate the magnitude of pollution from nonpoint sources. This was done because funding for the study was inadequate for collection of original water quality data. The studies on urban runoff, landfill leachates, mining, dredging and barge cleaning were done by Metropolitan Council staff. Data used in the studies on agricultural runoff, construction erosion, stream channel erosion and local nonpoint sources were provided under contract by the Association of Metropolitan Soil and Water Conservation Districts, which subcontracted with the U.S. Department of Agriculture Soil Conservation Service (SCS). Analysis of contracted information was performed by Metropolitan Council staff.

The report has four major sections. Section I summarizes the findings, conclusions and recommendations. Section II gives Metropolitan Area background information. Section III details the individual sources of pollution. Section IV compares the water pollution potential of the nine nonpoint source categories of pollutants. Concluding the report are appendices containing background data, detailed methodology used in the studies, selected bibliography, watershed conversions and a glossary of terms.

SECTION I. FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

This study was conducted by the Metropolitan Council in its role as the designated Section 208 water quality management planning agency for the Twin Cities Metropolitan Area. Goal of the nonpoint source pollution program in 1976 and 1977 has been to assess the nature and extent of the problem.

Section I of the report gives the major findings of the study, offers seven conclusions, and makes five recommendations for further action relative to nonpoint source pollution potential in the Metropolitan Area.

FINDINGS

Nine categories of nonpoint source pollution were studied: agricultural runoff, construction erosion, urban stormwater runoff, stream channel erosion, landfill leachates, mining, barge washing, dredging and miscellaneous nonpoint sources. Details of the nine studies are given in Section III of the report. Major findings from these studies follow.

Agricultural Runoff

Sediment and nutrient runoff from agricultural loads are thought to be major pollutors of Metropolitan Area streams and lakes. Agriculture is the largest single land use in the Seven-County Region, using 55 percent of the land. Estimates of soil erosion on agricultural land vary from 0.5 to 16 tons per acre per year, while estimates of sediment production on a watershed basis vary from 0.25 to 5.50 tons per acre per year. Estimates for annual total nitrogen and total phosphorus losses from fields amount to 11 million and 1.8 million pounds respectively, or an average of 8.5 pounds and 1.3 pounds per acre of rural land per year. It is estimated that more than half of the 3,400 feedlots in the Metropolitan Area are potential contributors to water pollution, and that the 220,000 animal units generate 30 million pounds of nitrogen and 10 million pounds of phosphorus annually. No statistics are available on the quantities, rates and manners in which chemical pesticides are used in the Metropolitan Area.

Construction Erosion

Land disturbance from construction has long been recognized as a potential large sediment contributor to the pollution of streams and lakes. During 1976, a typical construction year, approximately 3,000 acres of land were disturbed for construction activity in the Seven-County Area. It is estimated that 140,000 tons of soil on construction sites are eroded annually, with 55,000 tons of this reaching area streams. This large amount of sediment from only 3,000 acres equals an annual figure of 18 tons per acre. The Minnesota Chapter of the Soil Conservation Society of America surveyed 5,375 miles of roadway in the Metropolitan Area and found that 106,000 tons of soil have been lost, averaging 20 tons per mile or 85 tons per erosion site.

Urban Stormwater Runoff

Urban stormwater runoff was found to have contributed significant levels of many pollutants to area streams and lakes, including 172,000 tons of sediment, 42,000 tons of chemical oxygen demand, 1,950 tons of total nitrogen, 220 tons of total phosphorus and 100 tons of lead. Additionally, over 120,000 tons of salt were applied in the urban study area in the winter of 1976 by 35 large municipalities, the seven counties and the two State Department of Transportation Districts. Loading of pollutants seemed to be concentrated in the central cities of Minneapolis and Saint Paul and just northwest and southwest of this area. 1976 loadings from major point source discharges were less than loadings from urban stormwater for total suspended solids, nitrates, lead and zinc for municipal discharges and less for all measured pollutants for industrial discharges.

Stream Channel Erosion

Stream channel erosion was found to be an extremely large sediment contributor, which is potentially difficult to manage. It is estimated that more than 570,000 tons of soil are eroded annually from stream channels in major actively eroding areas occurring over 1.3 million feet of channel. The Minnesota River Valley is the major contributor of sediment with the 150 to 200 feet high bluffs of the valley walls producing an estimated 350,000 tons of soils annually. Additionally, eight other watersheds discharging to the Minnesota River contribute an estimated 120,000 tons of soil from channel erosion. Thus, approximately 85 percent of the annual soil losses noted from stream channel erosion areas is discharged to the Minnesota River. Serious erosion problems appear to be caused by streams with steep gradients trying to reach an equilibrium, as well as stormwater dischargers, cattle or human activities on fragile banks or agricultural and urban use of steep valley walls.

Landfill Leachates

There is a high potential for water pollution from sanitary landfills and closed dumps in the Metropolitan Area. Half of the 14 sanitary landfills evaluated have leachate problems, and landfills with highly penetratable cover materials may begin to have leachate problems in several years. The average annual leachate volume produced in the 14 sanitary landfills is 116 million gallons, which percolate downward and laterally to ground and surface waters. In addition, there are 68 abandoned dump fills in the Metropolitan Area; leachate production was not estimated for these sites.

Mining

More than 600 small-to large-scale mining operations for gravel and aggregates exist in the Seven-County Area. Approximately 116 acres of new land are mined annually, with an average soil loss (based on available figures) of 7,700 tons or 67 tons per acre per year. Approximately 50 percent of these soils move off site. Another 327 tons of sediment is discharged annually from eight mining operations permitted by the Minnesota Pollution Control Agency (MPCA). Minimal water quality degradation is expected from these mining activities because of the small amount of sediment generated.

Barge Washing

It is estimated that in recent years approximately 320 barges have been washed each month of the barging season. Efforts are underway by MPCA to bring all barge washers into compliance with discharge standards. Consolidation of washing into three commercial operations, elimination of all but one discharge, and the MPCA compliance program result in a minimal problem from barge washing.

Dredging

A nine-foot navigation channel is maintained by the U.S. Army Corps of Engineers (COE) on the Mississippi, Minnesota and St. Croix Rivers within the Metropolitan Area. Every year from ten thousand to several hundred thousand cubic yards of sediments are dredged from area streams and deposited on the stream banks temporarily or permanently. Most pollution resulting from this activity is short-term and localized, with no major degradation occurring generally. Under oxidizing conditions, most chemical pollutants settle out of the water column and remain immobile in the bottom sediments. Little toxic material dissolves into the water during dredging and disposal operations. The current efforts of the interagency Great River Environmental Action Team (GREAT) and COE have been effective in defining and alleviating environmental problems associated with dredging.

Miscellaneous Nonpoint Sources

A catalogue of miscellaneous sources of nonpoint pollution recorded approximately 70 specific problem sources, which fall into four categories: 1) sediments from storm sewers, open sand and gravel pits and street sanding; 2) nutrients from septic tank failures or drainage from residential lawns, and sanitary sewer seepage; 3) landfill leachates; and 4) industrial waste spillage or runoff from industrial sites. These pollution problems are not severe and could be taken care of locally or through management programs being developed by the 208/201 water quality projects, or by special state programs.

CONCLUSIONS

The Phase I study of nonpoint sources presents seven major conclusions:

1. Significant loads of pollutants are contributed to the waters of the Region by nonpoint sources.

2. Major water pollution potential exists from five sources---agricultural runoff, construction erosion, urban runoff, stream channel erosion and landfill leachates.

3. Less significant pollution potential exists from mining, barge cleaning, dredging and miscellaneous nonpoint pollution problems.

4. All the study results must be considered tentative, as all analyses were made using existing data.

5. The study provides significant insights on each of the sources of pollution, the geographic location of problems and the general magnitude of the problems.

6. The study has provided the first opportunity to compare generally the pollution loadings from nonpoint sources to that from sanitary and industrial sewage discharges. In many instances nonpoint sources may be worse pollutors.

7. Abatement and management programs for these sources of pollution would require substantially more authoritative information.

RECOMMENDATIONS

The Phase I study concluded that nonpoint sources contribute significantly to Metropolitan Area water pollution. The following recommendations are made:

1. Top priority should be assigned to future management of nonpoint source pollution from: a) urban sources including urban stormwater runoff and construction erosion, b) agricultural runoff, c) landfill leachates, and d) stream channel erosion.

2. Future management efforts on dredging, mining, barge washing and mis-

cellaneous catalogued nonpoint sources should be assigned low priority.

3. Further water pollution abatement programs must consider nonpoint sources of pollution and change to a balanced approach from the historic practice of considering only point sources of pollution if water quality goals are to be reached.

4. Upgrading of municipal treatment plants and industrial dischargers should be viewed in light of potential large capital expenditures for treatment structures versus reduced expenditures for minimum-structural or source control of diffuse sources of pollution.

5. A grant application should be prepared and submitted to the U.S. Environmental Protection Agency (EPA) for a nonpoint source management planning program covering the top priority items identified in recommendation #1. The major subjects to be addressed in a nonpoint program should include:

   a) Verification of information theoretically derived in this Phase I nonpoint source report;

   b) Identification of management practices that are both effective and cost efficient for use in remedial programs;

   c) Evaluation of the need for, and start of a monitoring program;

   d) Evaluation of available simulation techniques for predicting water quality effects of future development;

   e) Identification of costs and methods of financing a management program;

   f) Evaluation of existing laws and agency responsibilities and assessment of added legislation which may be required to designate an implementation agency or group;

   g) Assessment of the impact of a nonpoint management program relative to current Metropolitan Council programs and regional development;

   h) Formulation of a series of alternative management schemes for consideration; and

   i) Dissemination of program findings to local units of government and individuals for their use in management efforts.

SECTION II. METROPOLITAN AREA BACKGROUND

This section provides information about the Metropolitan Council and the Twin Cities Metropolitan Area.

METROPOLITAN COUNCIL AUTHORITY

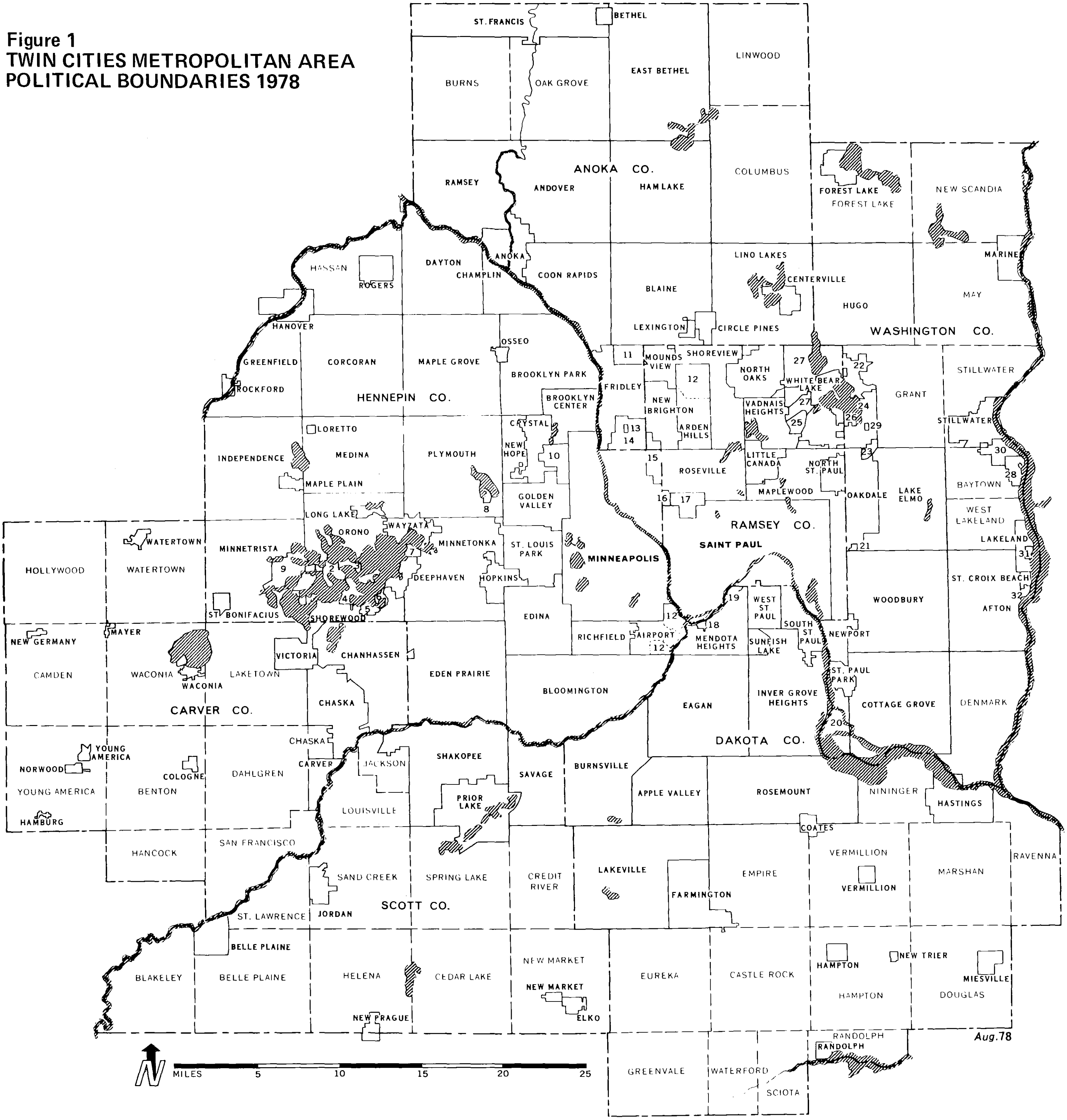
The Metropolitan Council was created in 1967 by the State Legislature to coordinate the planning and development of the Twin Cities Metropolitan Area. The Area (Figure 1) includes seven counties, Anoka, Carver, Dakota, Hennepin, Ramsey, Scott and Washington; 138 municipalities, 50 townships, 7 regional agencies, 49 school districts and 54 special purpose governmental units.

The 1977 population of the Area was about 1,973,470, with projections for growth reaching 2,030,000 by 1980 and 2,260,000 by 1990. The largest concentration of people live in the central cities of Minneapolis and Saint Paul, at a population density of 22,000 people per square mile.

The Metropolitan Area encompasses 3,000 square miles---1,300 square miles in agricultural use, 800 square miles in urban use and 900 square miles in open space or other uses.

To enable the Council to carry out its planning and coordinating responsibilities,

Figure 1
TWIN CITIES METROPOLITAN AREA
POLITICAL BOUNDARIES 1978



1 SPRING PARK	9 MOUND	17 FALCON HEIGHTS	25 GEM LAKE
2 ORONO	10 ROBBINSDALE	18 MENDOTA	26 BIRCHWOOD
3 MINNETONKA BEACH	11 SPRING LAKE PARK	19 LILYDALE	27 WHITE BEAR
4 TONKA BAY	12 U. S. GOVT.	20 GREY CLOUD	28 BAYPORT
5 EXCELSIOR	13 HILLTOP	21 LANDFALL	29 WILLERNIE
6 GREENWOOD	14 COLUMBIA HEIGHTS	22 DELLWOOD	30 OAK PARK HEIGHTS
7 WOODLAND	15 ST. ANTHONY	23 PINE SPRINGS	31 LAKELAND SHORES
8 MEDICINE LAKE	16 LAUDERDALE	24 MAHTOMEDI	32 ST. MARY'S POINT

ANOKA —— County Boundary
ORONO —— Municipal Boundary
CAMDEN – – – Township Boundary

the Legislature has authorized the Council to:

1. Prepare and maintain a Metropolitan Development Guide that serves as a long-range regional development plan upon which to base development decisions.

2. Review applications for federal and state funds to assure consistency with the regional development goals, policies and programs described in the Metropolitan Development Guide.

3. Prepare policy plans that give clear development direction to the regional commissions and agencies that operate public transit, regional parks, airports, housing and water quality management activities.

4. Approve financial proposals, capital programs and detailed plans of regional agencies.

5. Review the long-range plans of local governments and require that local plans be consistent with regional sewer, park, airport and transportation plans of the Council.

6. Conduct urban research in broad-ranging areas and present findings to the Legislature for action.

7. Provide technical assistance to other governmental units.

8. Provide information to the public on matters pertaining to the Region and its development.

9. Enter into various other activities such as park financing, local planning assistance, housing and health care.

The Metropolitan Development Guide Plan, the long-range development plan for the Region, calls for providing facilities and services that meet basic human needs and public expectations in accordance with an orderly economic settlement pattern. The plan provides a 'framework' for physical growth in the Region, within which a comprehensive set of public services will be provided based in part on the Region's fiscal capacity and public values. This plan, called the Development Framework, is designed to help bring about a settlement pattern which will not dramatically differ from today's pattern.

In much of the rest of the Region, productive agricultural use will continue to predominate. Little urban development is predicted in prime farming areas. There will be modest growth, but plans call for the growth to occur primarily in and around small agriculturally-oriented communities. Consistent with a rural-urban distinction, services such as central water, sewer and transit facilities will be conveniently provided to urban dwellers. Rural area residents will have available public services necessary for agricultural activity.

PHYSICAL SETTING

The climatic character of the Twin Cities Metropolitan Area is one of generally mild, humid summers and relatively long, severe winters. Temperature extremes for Saint Paul range from -34°F. in January of 1936 and 1970 to 108°F. in July of 1936. Minnesota experiences predominantly frontal rainstorms during the summer, but convection-type storms do occur during periods of hot weather. Annual precipitation averages approximately 27 inches at the Minneapolis-Saint Paul Airport. February is the lowest month for total precipitation and May or June are the highest months. Annual snowfall averages about 44 inches.

Physiographically, most of the Area is characterized by a young glaciated plain or moraines, lakes and lake plains. The entire area was glaciated. The land surface configuration results from glacial and post-glacial deposition and erosion.

Maximum land surface relief in the Region is about 600 feet, ranging from less than 700 feet above mean sea level along the floodplains of the Minnesota, Mississippi and St. Croix Rivers to more than 1,200 feet atop the moraines hills in the extreme northeastern part (Washington County). Most of the surface is gently undulating upland and lies between 850 and 1,050 feet. The lowest water surface elevation is 675 feet where the Mississippi River flows out of the area to the southeast.

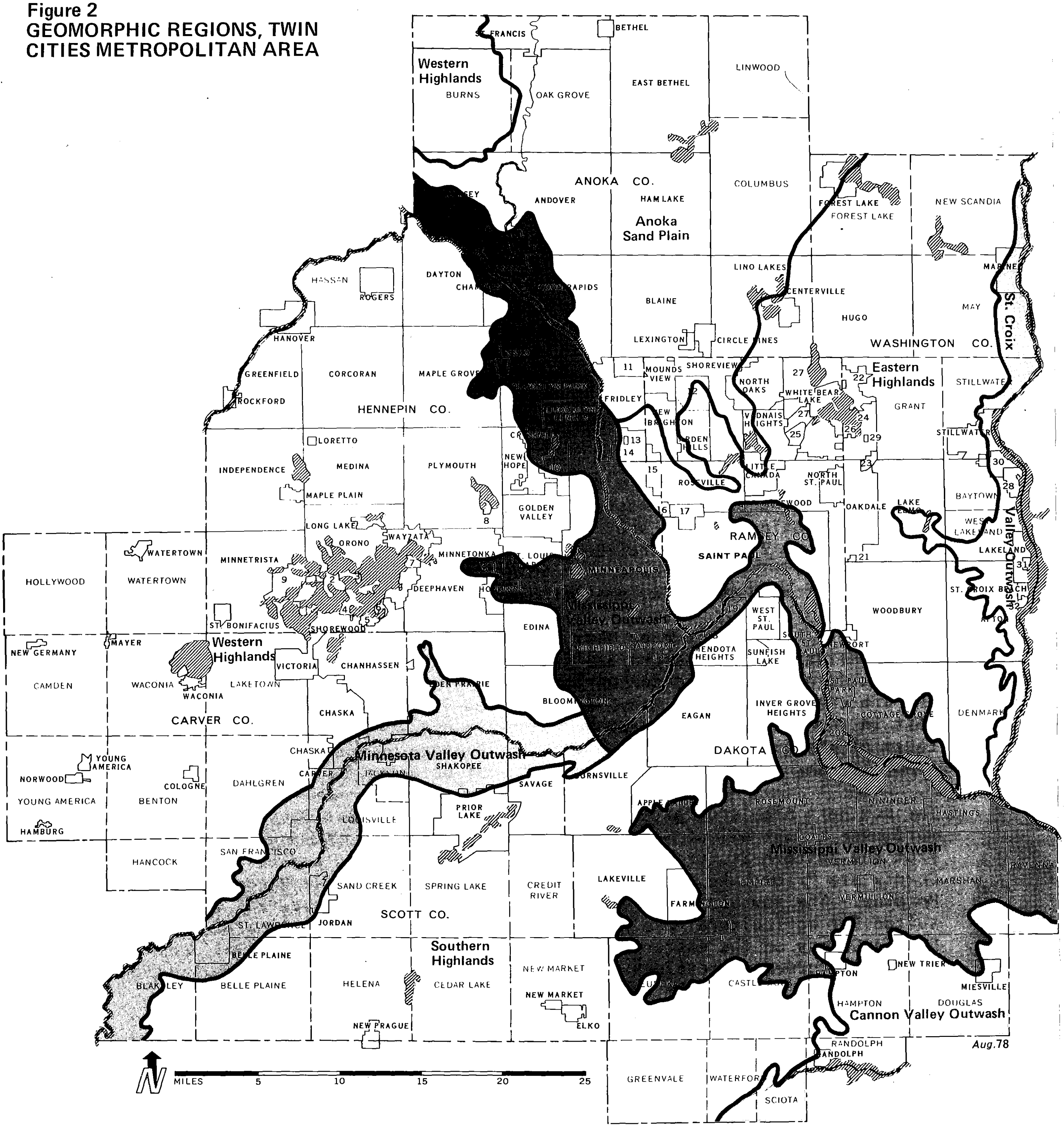
The dominant land features in the Metropolitan Area are the highland moraines occurring in the eastern, western and southern portions of the area. These broad, undulating uplands are composed generally of well-drained, heterogeneous tills. Figure 2 is a generalized map of the geomorphic regions of the Metropolitan Area. The three general highland regions delineated in Figure 2 are comprised of more specific, smaller geomorphic regions.

The eastern highlands occupy most of Washington and Ramsey Counties. The highland consists of the eastern St. Croix moraine in all areas except the southeastern corner, which is Kenyon-Taopi Till Plain. The dominant soils are loamy and are characterized by many lakes located in glacially-formed depressions left in the moraine. Drainage patterns are not well defined in this area because of the flat topography; but the headwaters of Rice Creek and several minor streams draining to the east and west do occur in the highland.

The southern highlands extend from northern and southern Dakota County westward over almost all of Scott County. Northern Dakota County consists of soils from the Eastern St. Croix Moraine; south Dakota County and eastern Scott County are Prior Lake Moraine; and western Scott County is Waconia-Waseca Moraine. The southern highlands are loamy and well-drained, and generally well suited for agricultural use. An area of prime farmland is located in central Dakota County on the eastern St. Croix Moraine. Again, many lakes occur in the glacially-formed depressions. The major streams traversing the southern highlands are Sand Creek, the Credit River and Robert Creek.

The western highlands extend over most of Carver and Hennepin Counties, as well as extreme northwestern Anoka County. The principal morainic unit is the Waconia-Waseca Moraine, which overlaps most of Carver County and extreme western Hennepin County. Central Hennepin County is composed of Emmons-Faribault Moraine, while the highlands in southern Hennepin County and Anoka County consists of Eastern St. Croix Moraine. The western highland soils are loamy and generally well-drained. As with the other highlands, many lakes (including Minnetonka) occur in glacially-formed depressions. Most of the western highlands not occupied by residential uses are well suited for agricultural purposes, with dairy-related production comprising the largest percentage of agricultural

Figure 2
GEOMORPHIC REGIONS, TWIN CITIES METROPOLITAN AREA



Based on Map by the University of Minnesota, Agricultural Experiment Station (1975).

activity. Major streams found in the western highlands are Carver Creek, Riley-Purgatory Creeks, Nine Mile Creek, Minnehaha Creek, Basset Creek, Shingle Creek, Elm Creek and the Crow River.

The Anoka Sand Plain covers almost all of Anoka County and extends into parts of Ramsey and Washington Counties. The material comprising the plain is generally fine sand, with pockets of organic peats located in ice-remnant depressions of the eastern Sand Plain. The sandy soils are generally well-drained, but high groundwater levels in the area have resulted in many marshes, peat bogs and shallow lakes. Major streams flowing through the Sand Plain are the Rum River, Cedar Creek, Coon Creek and lower Rice Creek.

The remainder of the Metropolitan Area is characterized by river eroded valleys and associated flat outwash plains and floodplains. The Mississippi River cuts across the Region from northwest to southeast. The Mississippi outwash plain, approximately 610 square miles in size, covers all of eastern Hennepin County, southern Ramsey County, and essentially all of Dakota County. The soils are generally sandy and well-drained. The soils in Dakota County are well-suited for agricultural use, but may need irrigation to help production. The Vermillion River drains over one-third of Dakota County to the east, where it joins the Mississippi River at Hastings.

The Minnesota River enters the Metropolitan Area from the extreme southwest corner and flows northeastward until it joins the Mississippi just south of Saint Paul. The Minnesota River has a very large floodplain and sizeable outwash plain. The floodplain soils are very poorly drained, but the outwash soils are sandy and well drained. The Minnesota River itself tends to be relatively turbid probably due to inputs of sediments from agricultural erosion over most of its length.

The St. Croix River flows through a narrow valley and forms the extreme eastern boundary of the Metropolitan Area, joining the Mississippi around Hastings. The northern half of the metropolitan reach of the St. Croix is narrow, the river widens south of Stillwater to form Lake St. Croix, as a result of the water-level controls of Lock and Dam No. 3 on the Mississippi River. The St. Croix outwash plain is very narrow because of the physiographic nature of the river. The outwash soils are sandy and well-drained, as with the other major river outwash soils.

The Metropolitan Area has 951 lakes, mostly located in the highland moraines. These lakes can generally be characterized as small and shallow, although some exceptions do exist. Water quality degradation has definitely affected these lakes, with eutrophic conditions now the norm on most of these water bodies.

SECTION III. NONPOINT SOURCES OF POLLUTION

Details of the nine categories of nonpoint source pollution which were studied are given in this section of the report. The five sources determined to have major water pollution potential are discussed first. They are agricultural runoff, construction erosion, urban runoff, stream channel erosion and landfill leachates. Four nonpoint sources determined to have less significant pollution potential are also discussed. They are mining, barge cleaning, dredging and miscellaneous nonpoint sources.

A common methodology has been used to assess the magnitude of each potential source of pollution. This section gives the geographic and geological background for each potential source, describes the pollutants and pollution process, gives information on the scope of regional activities for each source, assesses the pollution potential for each source, and makes conclusions and recommendations for each potential source. The Appendix contains detailed methodology, charts and tables and bibliographic references for each of the nine nonpoint sources.

AGRICULTURAL RUNOFF

Background

Much of the recent literature on water pollution has identified agriculture as a major potential source of water pollution. The agricultural pollutants are generally identified as (1) sediments, a product of land erosion and runoff; (2) nutrients, which are associated with runoff and sediments; and (3) pesticides, also associated with runoff and sediments.

The literature also includes discussions of pollution problems associated with animal feedlots. If improperly managed, feedlot runoff can severely impact both ground and surface water quality.

Several desk studies were undertaken to estimate the magnitude of the potential water pollution problems in the Metropolitan Area attributable to agricultural land use.

Agricultural Pollutants and Pollution Process

Agriculture may pollute water by generating sediments, nutrients and pesticides.

Sediments cause two forms of pollution. First, they fill drainageways, lakes and reservoirs, destroying lake and stream bottom flora and fauna. While suspended in the water they cause water turbidity, which diminishes the amount of light available to aquatic organisms, lowers the aesthetics of the water body, and increases the cost of treating the water for domestic or industrial use. Secondly, sediments are hosts for nutrients or pesticides which are adsorbed by the soil particles; especially the clay, silt and organic components of the sediments.

Nutrients of particular concern are nitrogen and phosphorus in all their forms. These two nutrients, when present in excess in water, will cause abnormal algae growths resulting in a lower dissolved oxygen level, a lower aesthetic or recreational value of surface water, unhealthy water supply and noxious odors. The nutrients may come from various sources. Rainfall may add 7 to 10 pounds of nitrogen per acre per year to the soil.[1] Spreading of chemical fertilizers, manure or organic matter is the primary source of nitrogen and phosphorus. The decomposition of organic matter and the weathering of soil or subsoil will also provide a source of nitrogen and phosphorus.

Pesticides, including herbicides, insecticides and fungicides, are widely used in agriculture to control weeds, insects and plant diseases. The nature and seriousness of their impacts on water and aquatic organisms depend on the type of pesticides used and the timing and manner in which they are used.

Water pollution occurs through the detachment of soil, the transport of soil particles and chemicals, and the dissolving of chemicals by runoff during and after a rainfall. Rainfall droplets and overland flow of water detach soil particles which may be carried to a stream or lake to become sediments. These sediments may have nutrients or pesticides attached to them. In addition, water while running overland may transport organic matter, or dissolve fertilizers, or wash off pesticides which then find their way to a stream or lake and decrease water quality.

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1 Water Research in Action, 1977.

The magnitude of the pollution problems is greatly influenced by agricultural practices, such as soil and water conservation measures, the timing of plowing or application of fertilizers, manure and pesticides, and the rate of application of fertilizers and pesticides. Retaining all agricultural runoff and encouraging infiltration would diminish surface water pollution, but it is impractical.

Land in Agricultural Use

More than 1 million acres, or 55 percent of land in the Metropolitan Region, is in some agricultural use,[2] and well over 220,000 animal units have been estimated to be maintained in feedlots throughout the agricultural areas of the Region.[3] Agriculture is the largest land use of the Region and presents a serious potential for water pollution.

Because of an almost all encompassing definition of "farm," it is difficult to ascertain how much of the land area reported in agricultural use is "hobby farms" or large lots and how much is actually in production.

A 1977 report prepared by the Association of Metropolitan Soil and Water Conservation Districts as part of the Metropolitan Council's 208 water quality management program, indicated that in 1976, approximately 770,000 acres were in cropland and 160,000 acres were in pasture (Table 1).

The percentage of land reported in agricultural use varies with each metropolitan county, from about 3 percent in Ramsey County to more than 70 percent in Carver and Scott Counties. Similarly, individual watersheds vary from completely urbanized to entirely agricultural use. Figure 3 illustrates the present distribution of farmland as a percentage of the total land in each city or township.

Crop and Animal Production and Distribution

The Region's farm products are important to both local and national markets. They range from corn and soybeans, to cattle and poultry, to sod. The region-wide capital investment in farm buildings and property improvements, not including machinery, is more than $500 million.[4]

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2 Minnesota Department of Agriculture and U.S. Department of Agriculture, 1977

3 Feedlots with less than 10 animal units were not included in the survey. An animal unit is defined as a measure used to compare differences in the production of animal wastes. One animal unit equals 1 slaughter steer, or 2.5 swine, or 10 sheep, or 100 chickens for example.

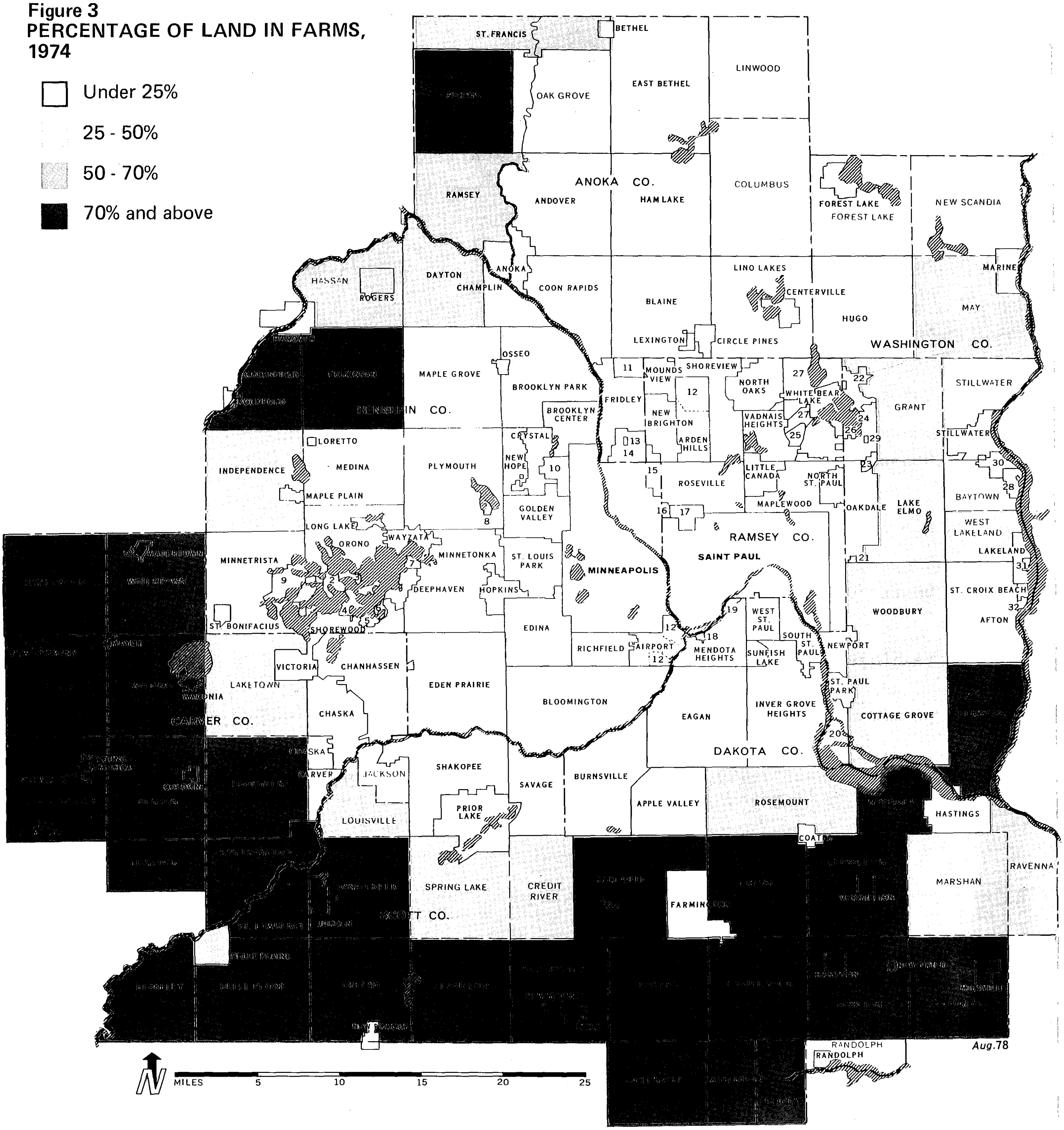
4 Metropolitan Council, 1976

TABLE 1. AGRICULTURAL LAND USE IN THE METROPOLITAN AREA

COUNTY	ACRES IN COUNTY	PERCENTAGE OF COUNTY IN AGRI-CULTURAL USE	ACRES IN CROPS	ACRES IN PASTURE
Anoka	283,520	28	74,847	5,374
Carver	239,360	73	134,832	41,373
Dakota	376,320	62	212,000	21,500
Hennepin	389,760	31	80,451	41,937
Ramsey	109,440	3	2,359	672
Scott	232,960	71	134,539	32,265
Washington	268,160	56	132,360	16,808
TOTAL	1,899,520	48%	769,386	159,929

SOURCE: Association of Metropolitan Soil and Water Conservation Districts for the Metropolitan Council, 1977.

Figure 3
PERCENTAGE OF LAND IN FARMS, 1974



Source: Metropolitan Council, 1975.

Major crops grown in the Metropolitan Area are grains (corn, rye, wheat, barley, oats) beans (soybeans), and forage (hay, alfalfa). The relative proportion of one crop to another varies from year to year, depending on the farmers' perception of and the response to the potential market. Acreage of corn increased from 240,000 in 1967, to 319,000 in 1975, to 330,000 in 1976.[5] The same period saw a five-fold increase in the number of acres of wheat harvested, 8,000 acres in 1967, 39,000 acres in 1975 and 44,000 acres in 1976. However, acreage planted in soybeans decreased from 121,000 acres in 1973, to 93,000 acres in 1975, to 74,000 acres in 1976.

Acreage of land in major crops has increased during the 1967 to 1975 period, from approximately 613,000 acres harvested in 1967 to 686,500 acres harvested in 1975. Conversely, acreage for other agricultural uses (pastures, woodlots, feedlots, minor crops, marshes) decreased from 370,000 acres in 1967 to 150,000 acres in 1974.

While all crops grown in the Metropolitan Area are represented in each of the seven counties there are large inter-county differences in the percentage of the income derived from each type of agricultural products. Appendix Table 1.1 illustrates crop distribution in the Metropolitan Area through agricultural income distribution.

Most farm animals in the Metropolitan Area are dairy cattle, beef cattle, hogs, chickens and turkeys. Some farms also raise sheep, horses or rabbits. A few highly specialized enterprises raise fur animals.

A 1977 survey of feedlots in the Metropolitan Area[6] showed that there were the equivalent of more than 220,000 animal units in the Region. This is equal to 150 animal units per square mile of land in agricultural use in the Twin Cities. Appendix Table 1.5 lists the number of feedlots, number of animals, and animal densities for each watershed studied.

As with crop production, there are great variations in the number of animal units produced within each watershed. The kind of animals kept in a feedlot also varies by watershed from exclusively dairy cattle to exclusively poultry. Figure 4 depicts animal density and fairly accurately represents the parts of the Twin Cities Metropolitan Area where agriculture remains a strong business.

Pollution Potential from Agriculture

The potential for water pollution by sediments from cropland and nutrients from cropland and feedlots was estimated for the 60 watersheds in the Metropolitan Area. In addition, an attempt was made to gather information on the potential for water pollution resulting from agricultural use of pesticides.

The purpose of this study was solely to determine if agriculture in the Metropolitan Area has the potential to pollute ground and surface waters, and if so,

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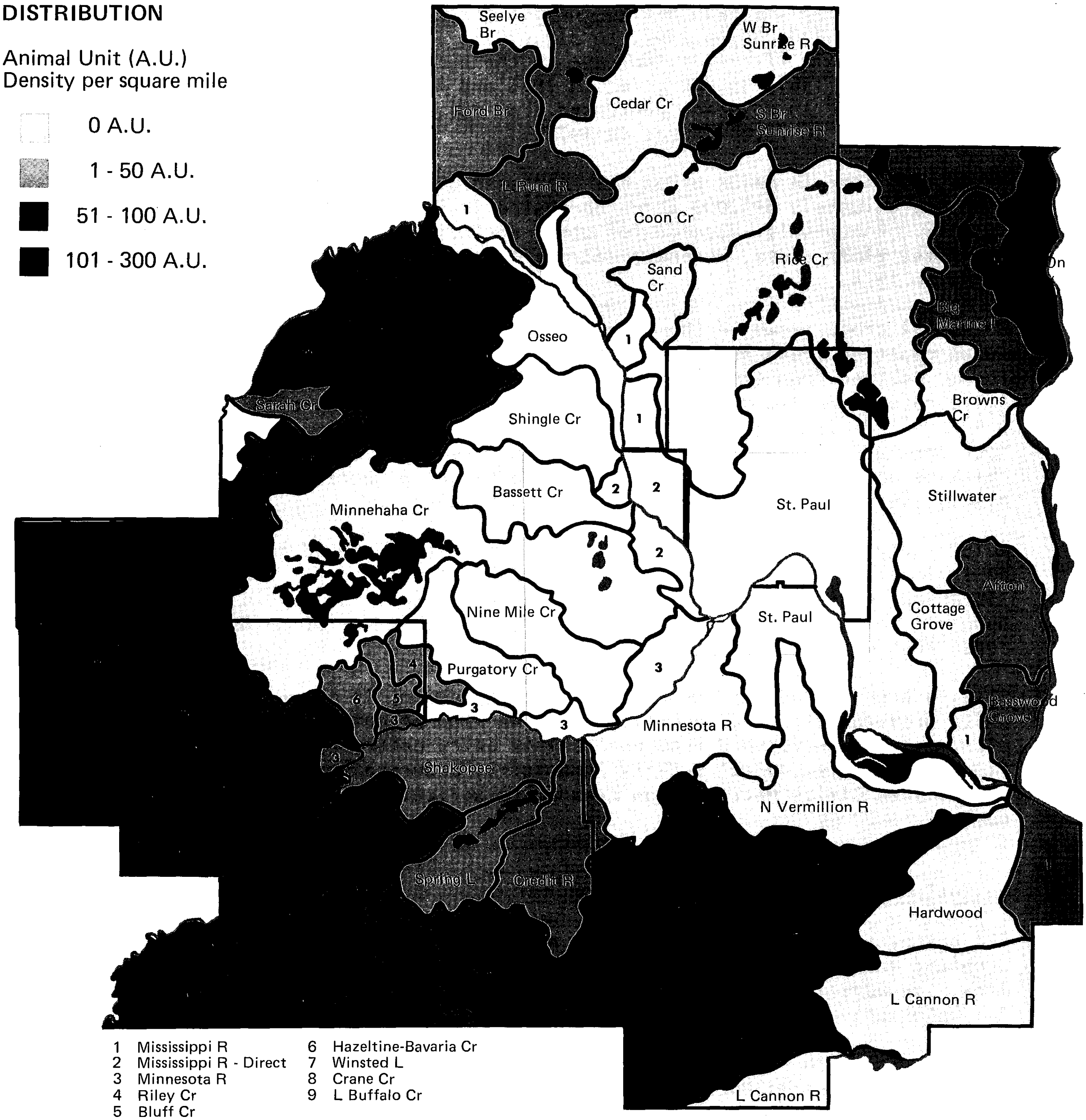
5 Minnesota Department of Agriculture and U.S. Department of Agriculture, 1977

6 Association of Metropolitan Soil and Water Conservation Districts, 1977

Figure 4
FEEDLOT SURVEY – ESTIMATED ANIMAL UNIT DENSITY DISTRIBUTION

Animal Unit (A.U.)
Density per square mile

- 0 A.U.
- 1 - 50 A.U.
- 51 - 100 A.U.
- 101 - 300 A.U.



to determine the relative magnitude of this potential for water pollution. This knowledge would provide the focus of further studies for the management of nonpoint source water pollution. No original data were collected in the field to verify or supplement the sediment or nutrient estimates. Rather, existing data were used or interpreted to fit study needs. The results identified in the tables and on the maps that follow should not be used to point to any specific source of pollution. Details of methodology are included in Appendix A.

Estimates of Sediments

Estimated gross sheet and rill soil erosion from agricultural land, computed with the universal soil loss equation, is approximately 6,200,000 tons per year. Soil loss estimates for more than 40 watersheds or political subdivisions of watersheds exceed the generally accepted soil loss standard for soil conservation of 3-5 tons of soil per acre per year. The ten watersheds with highest per acre annual gross soil erosion are:

Hennepin:	Pioneer Creek,	8.2 tons
	Bassett Creek,	13.5 tons
	Minnesota River,	15.5 tons
	Carver Creek,	15.6 tons
Scott:	Porter Creek,	8.2 tons
	Credit River,	10.4 tons
	Vermillion River,	11.9 tons
	Chub Creek,	12 tons
Washington:	Basswood Grove,	10.1 tons

This study also indicates a very wide range in the percentage of agricultural land subjected to adequate control measures to prevent soil loss or maintain soil losses within limits necessary for continued crop production. On a county basis, percentage of land adequately protected varies from 27 to 86 percent, with the range even greater when the data are compared on a watershed basis. The phrase "adequately treated or protected" applies to land on which soil conservation measures are taken to maintain the productivity of the land. The phrase does not mean that the volume of erosion contributed is not causing water pollution problems. Figure 5 and Appendix Table 1.3 indicate the amount and percentage of agricultural land in each watershed with adequate treatment.

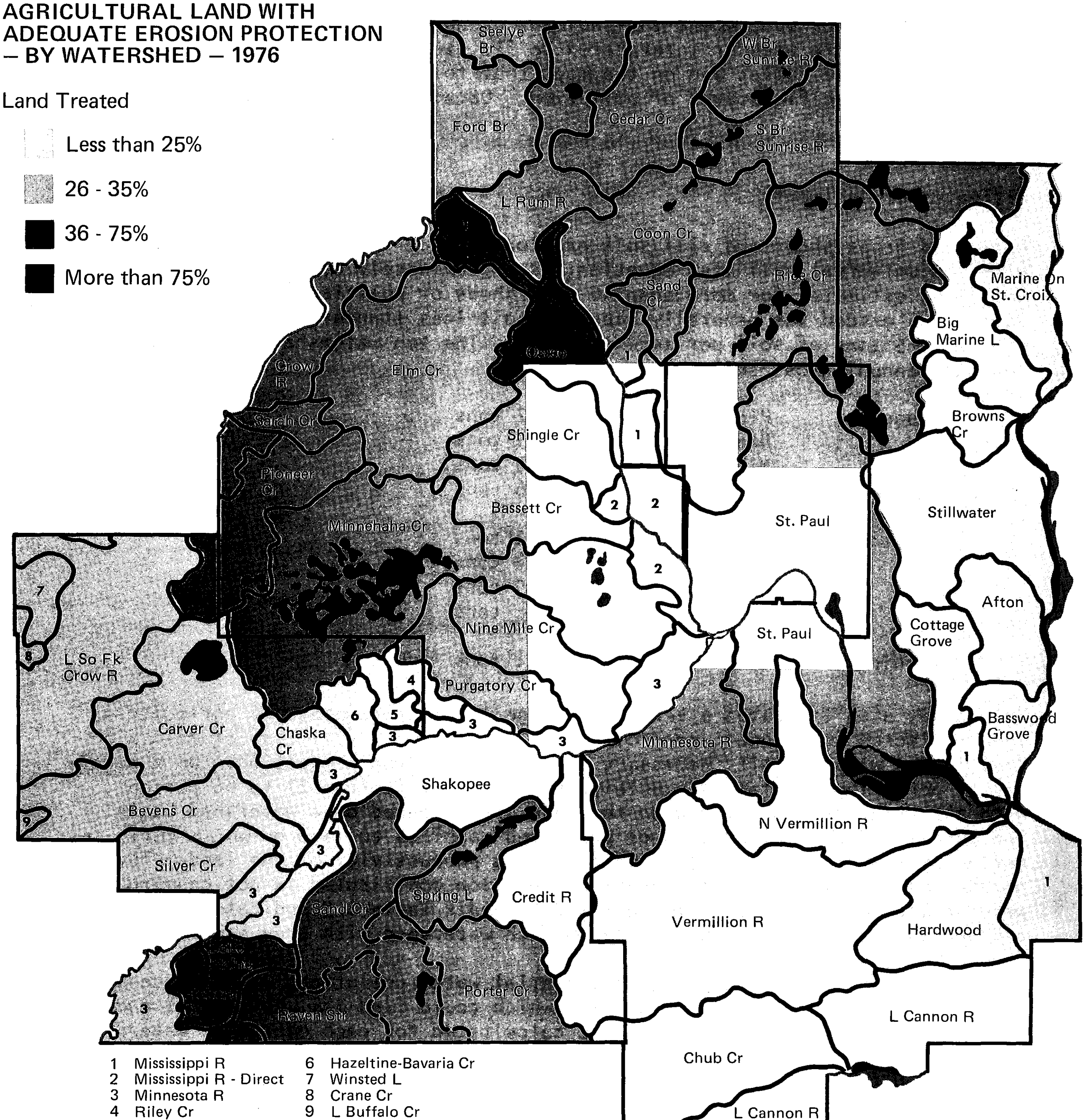
Since the study was concerned with potential water pollution, it was necessary to estimate the amount of eroded soils which could find its way to a stream or a lake. This sediment production was calcultated for each of the 60 watersheds in the Metropolitan Area. The percentage of soil which could reach the water was estimated on the basis of proximity of the source of soil to the water and trapping efficiency of the land. It is estimated that agricultural land use generates 2.3 million tons of sediments annually, at an average rate of 1.8 tons per acre in agricultural use per year.

This estimated average is comparable to the national per acre estimated sediment production for small rural watersheds. In the Metropolitan Area, estimated sediment production varies from 0.2 tons per acre to 5.5 tons per acre per year

Figure 5
ESTIMATED PERCENTAGE OF AGRICULTURAL LAND WITH ADEQUATE EROSION PROTECTION – BY WATERSHED – 1976

Land Treated

- Less than 25%
- 26 - 35%
- 36 - 75%
- More than 75%



1 Mississippi R
2 Mississippi R - Direct
3 Minnesota R
4 Riley Cr
5 Bluff Cr
6 Hazeltine-Bavaria Cr
7 Winsted L
8 Crane Cr
9 L Buffalo Cr

(Figure 6 and Appendix Table 1.2). Estimates of annual average sediment production exceed 3.5 tons per acre per year in 10 watersheds:

Carver:	Bluff Creek,	3.9 tons
Hennepin:	Sarah Creek,	3.6 tons
	Bassett Creek	4.5 tons
	Carver Creek,	5.2 tons
	Minnesota River,	5.2 tons
Scott:	Credit River,	3.6 tons
	Vermillion River,	4.5 tons
	Chub Creek,	4.6 tons
Washington	Basswood Grove,	4.4 tons

"Sediment export" means the amount of sediment transported to another watershed. Export is estimated using a sediment yield curve (Appendix Figure 1.1) that relates the amount of sediment as a percentage of the eroded soil leaving a watershed to the size of the watershed or drainage area. The larger the drainage area, the smaller the percentage of eroded soil leaving the watershed will be. It is estimated that about 1 million tons of soil transported by the smaller creeks and streams of the area go to the Mississippi, the Minnesota and the St. Croix Rivers.

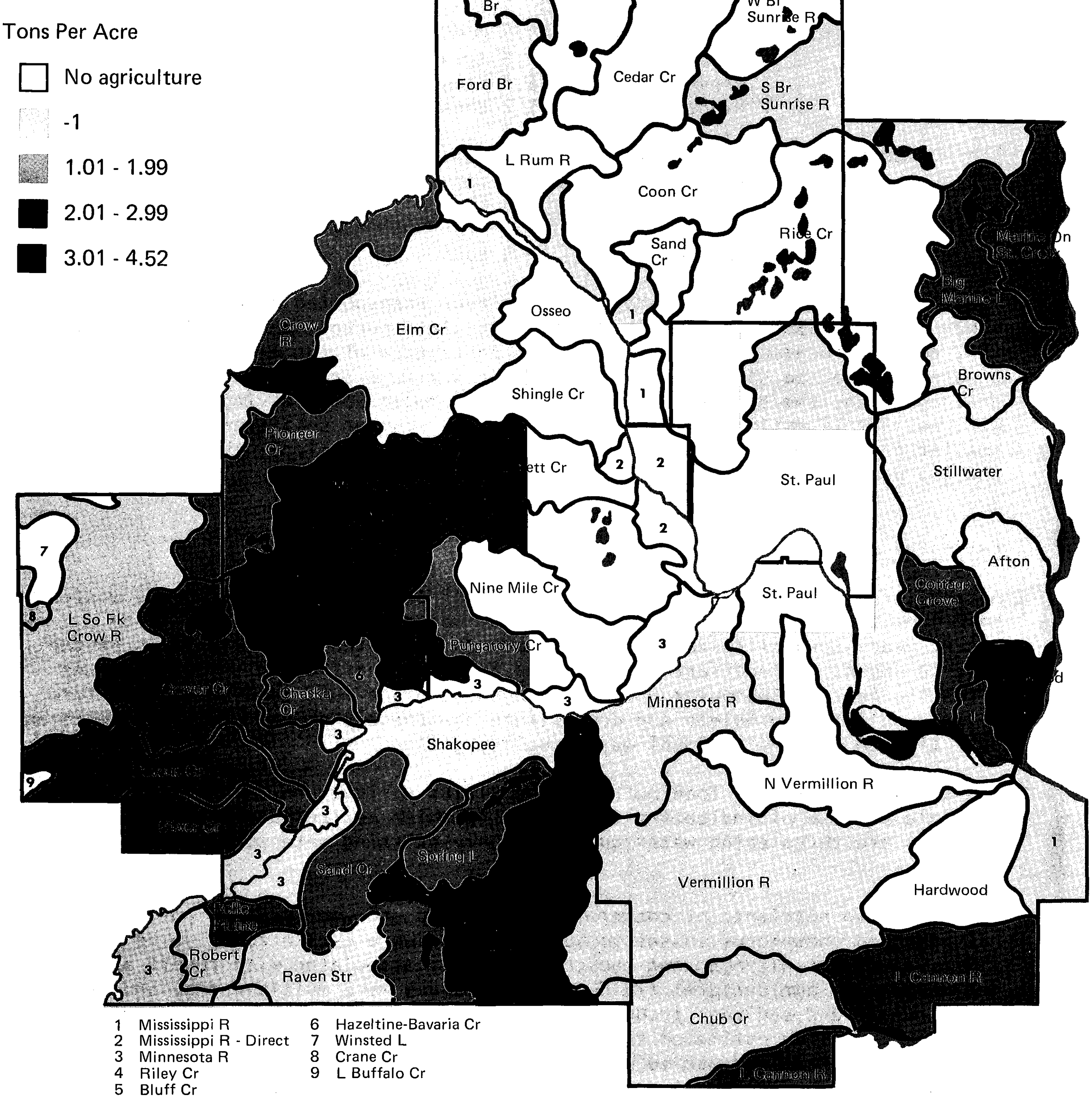
Estimates of Nutrients

Agricultural fertilizers, natural fertility of eroding soils and animal wastes have long been suspected of causing serious water pollution problems. In recent years several research efforts have demonstrated the seriousness of the adverse impact of land fertilization and feedlot runoff on water quality. As a result, Section 208 water quality management plans must identify agriculture-related pollution problems and demonstrate how these problems will be eliminated over time to satisfy national water quality goals.

The study for nutrient loading from Twin Cities agriculture was undertaken for the sole purpose of indicating the extent to which agricultural fertilizers and feedlots are threatening water quality. Only existing data were used in this study.

There are two nutrients of concern, nitrogen and phosphorus. The potential nitrogen and phosphorus losses to surface water were estimated by using literature values for nitrogen and phosphorus losses associated with runoff and sediments from agricultural fields. These values were multiplied by the estimated runoff and sediment production for each of the watersheds in the Metropolitan Area. The estimated total annual delivery of nitrogen and phosphorus from agricultural land use to water bodies in the Metropolitan Area is 11 million pounds and 1.8 million pounds respectively. As related in the literature, for example Johnson and Straub, 1971, approximately 90 percent of the total annual loading of nitrogen and 75 percent of the total annual loading of phosphorus are delivered to the water bodies with the spring runoff during March, April and May. It is conceivable that land in agricultural use contrib-

Figure 6
DISTRIBUTION OF ESTIMATED SEDIMENT PRODUCTION BY WATERSHED



utes 10 million pounds of nitrogen and 1.4 million pounds of phosphorus over two to three months in the spring. Such sudden loading of streams has serious implications for the development of a nutrient control program. Figures 7 and 8 show estimated nutrient losses on a watershed basis.

In addition, animal wastes from feedlots were estimated. There are more than 3,400 feedlots in the Metropolitan Area with a total of 220,000 animal units. It is estimated that these animals generate annually 30 million pounds of nitrogen and 10 million pounds of phosphorus. Information is lacking to make any reasonable estimate of how much of this nitrogen and phosphorus finds its way to a stream or lake. The survey of feedlots indicated that from 35 to 90 percent of the feedlots on a county basis are presenting a potential for water pollution and are in need of some better management system to prevent water pollution.

Estimates of Pesticides

There are no readily available statistics on the use of pesticides (herbicides, insecticides, fungicides) by farmers in the Metropolitan Area. Some statewide information on pesticide use is reported by the Minnesota Crops and Livestocks Reporting Service. Considering that crops grown in the Metropolitan Area and the farming techniques are no different from those crops and techniques in the remainder of the state, pesticide use in the Region should be causing problems no different from the rest of the state. A review of available water quality data for lakes and streams has provided no reason to believe that pesticide use on agricultural land is causing any serious problems in the Region. However, lack of specific data is a serious hindrance to making a valid determination.

Table 2 shows the percentage of applied pesticides lost in runoff (in dissolved form and adsorbed on sediments) as reported in the literature. The lack of data on the use of pesticides in the Region and on the quantities in streams and lakes warrants a research effort to ascertain the apparent lack of a problem.

Conclusions

1. Agriculture is a very important land use in the Metropolitan Area. The percentage of land in agricultural use varies greatly, from 2.5 percent in Ramsey County to 91 percent in Carver County.

2. Soil conservation programs have received a varying degree of acceptance in the Metropolitan Area. The four metropolitan counties (Carver, Dakota, Scott and Washington) with the strongest farming communities have the greatest need for soil conservation programs. These counties report only 27 to 42 percent of the agricultural land being adequately protected for the purpose of soil conservation.

3. Soil losses on a watershed basis are estimated to range from 0.5 tons to 16 tons per acre per year. Estimated sediment production on a watershed basis varies from 0.25 tons to 5.30 tons per acre per year. Variations are owing to the Region's geomorphology, variations in soil types, crops grown in the area and soil conservation practices.

TABLE 2 -- PERCENTAGES OF APPLIED PESTICIDES LOST IN RUNOFF* IN FIELD EXPERIMENTS

Pesticides	Inches		Percent	Percent of Appln.	
Atrazine	0	Silty clay loam	14	4.8-5.0	Hall (80)
Atrazine	0	Silty clay loam	14	2.6	Hall, Pawlus, and Higgins (81)
Atrazine	0	Silt loam	10-15	2.5-15.9	Ritter et al (134)
Carbaryl	2	Silt loam	10	0.1	Caro, Freeman, and Turner (36)
Carbofuran	3	Silt loam	9	0.9	Caro et al (35)
Carbofuran	2	Silt loam	10	1.9	Caro et al (35)
DDT	0	Loamy sand	2-4	1.0-2.8	Bradley, Sheets, and Jackson (27)
DDT	0	Gravelly loam	8	0.7	Epstein and Grant (63)
Dieldrin	3	Silt loam	14	2.3	Caro et al (34)
Dieldrin	3	Silt loam	10	0.02	Caro et al (34)
Endosulfan	0	Gravelly loam	8	0.25-0.35	Epstein and Grant (63)
Endrin	0	Gravelly loam	8	0.01-1.0	Epstein and Grant (63)
Endrin	0	Silty clay loam	0.2	0.1	Willis and Hamilton (169)
Fluometuron	0	Various	0.1-4	3.0	Wiese (167)
Methyl parathion	0	Loamy sand	4	0.01-0.02	Sheets, Bradley, and Jackson (142)
Methyl parathion	0	Sandy loam	2	0.13-0.25	Sheets, Bradley, and Jackson (142)
Propachlor	0	Silt loam	10-15	3.1	Ritter et al (134)
Toxaphene	0	Loamy sand	2-4	0.4-0.6	Bradley, Sheets, and Jackson (27)
Trifluralin	6	Loamy sand	4	0.3-0.5	Sheets, Bradley, and Jackson (142)
Trifluralin	6	Sandy loam	2	0.5-0.8	Sheets, Bradley, and Jackson (142)

* Both water and sediment.

SOURCE: Control of Water Pollution from Cropland Volume II - An overview

Agriculture Research Service, U.S.D.A., and Office of Research and Development, Environmental Protection Agency, June 1976.

Figure 7
ESTIMATED YEARLY NITROGEN LOSSES FROM AGRICULTURAL LAND

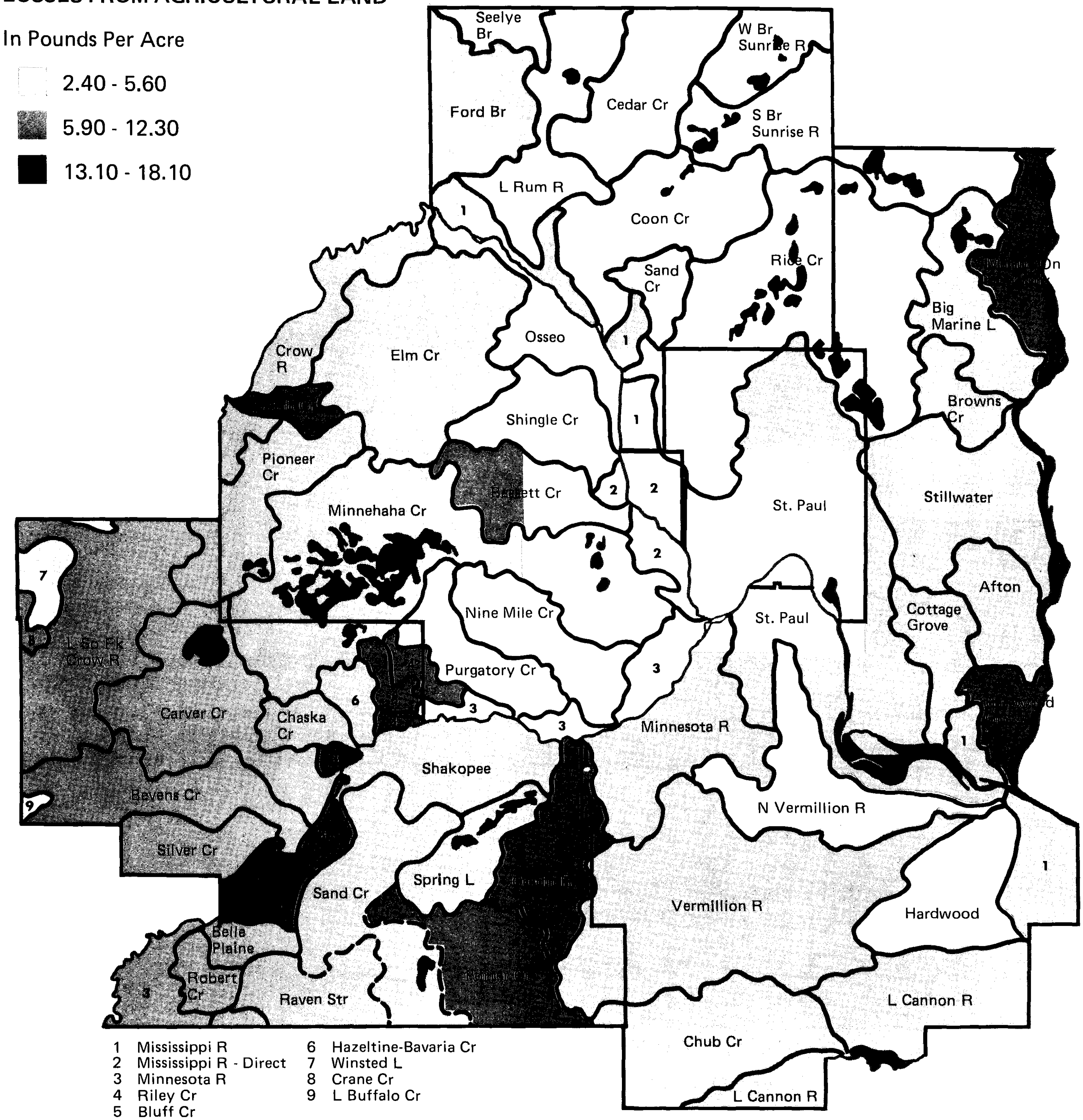
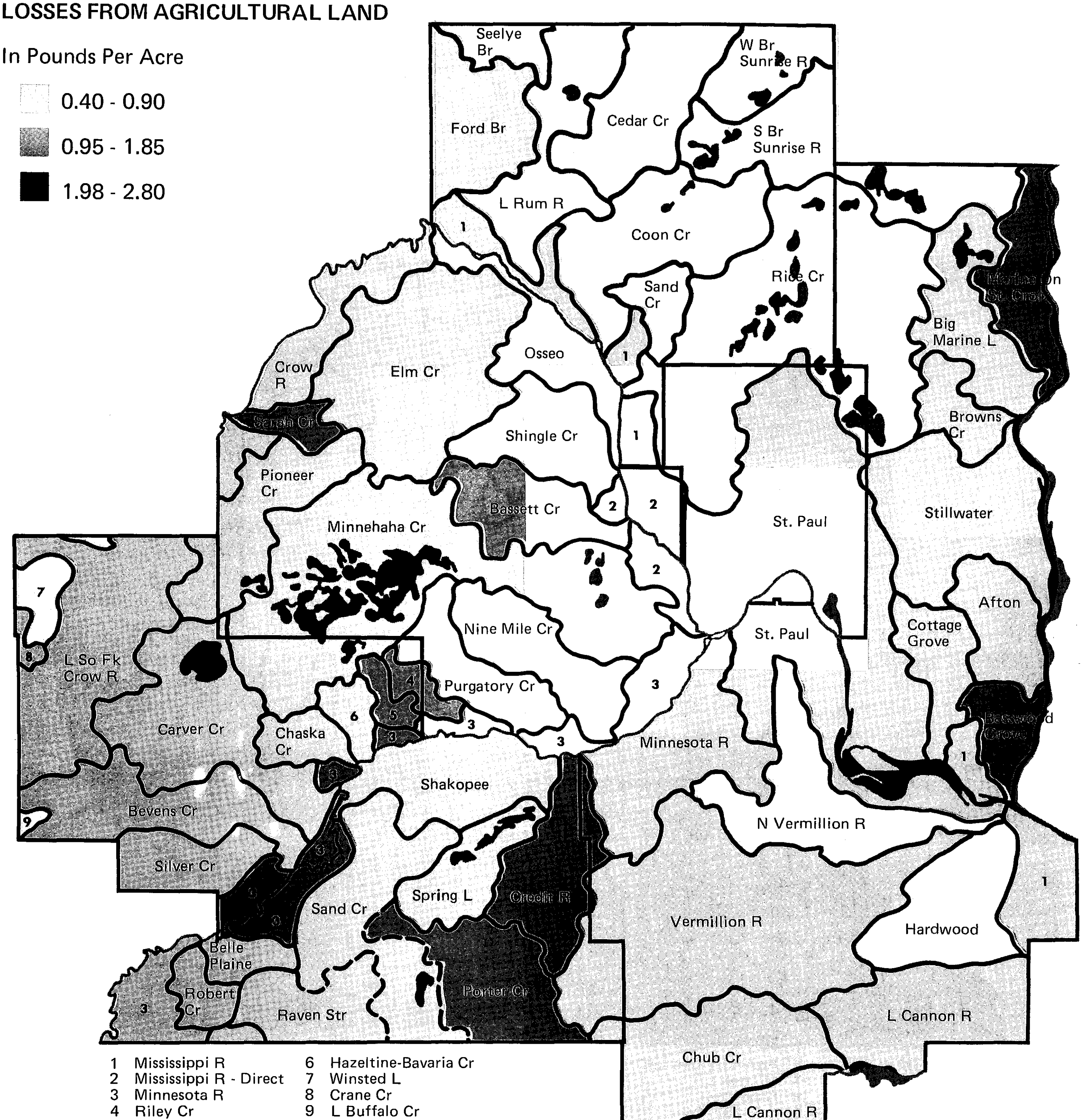


Figure 8
ESTIMATED YEARLY PHOSPHORUS LOSSES FROM AGRICULTURAL LAND

In Pounds Per Acre

0.40 - 0.90
0.95 - 1.85
1.98 - 2.80



4. Estimates for total annual nitrogen and total phosphorus losses amount to 11 million and 1.8 million pounds respectively, or an average of 8.5 pounds of nitrogen and 1.3 pounds of phosphorus per acre of rural land per year.

5. The scarcity of data on generation of animal wastes and the fact that each feedlot has to be evaluated relative to its actual contribution of nutrients or pathogens to a stream or lake prevent inclusion of data on water pollution by feedlot runoff. It is estimated that well over half the 3,400 feedlots are potential contributors to water pollution. The 220,000 animal units in the Metropolitan Area generate an estimated 30 million pounds of nitrogen and 10 million pounds of phosphorus on an annual basis.

6. A great variety of chemicals are used to control weeds, insects and fungal and bacterial diseases associated with crop production. However, no statistics are available on the quantities, rates and manners in which these pesticides are used, other than as a total volume of use in the state.

Recommendations

1. Based on these findings, abatement of pollution from agricultural lands should receive high priority in future water pollution programs.

2. A Phase II study proposal should contain an agricultural element which addresses monitoring water quality from agricultural land, the nutrient-sediment-pesticide relationship, management techniques, available modeling options, costs and financing of pollution abatement and institutional responsibilities and arrangements.

CONSTRUCTION EROSION

Background

Land disturbance for construction has long been recognized as a potential large contributor to the pollution of streams and lakes. Improperly managed land development for residential, commercial or industrial use and for new highways can cause acute siltation problems in creeks and lakes, and substantial damage to low lying lands that receive the eroded soils.

Increasing awareness of monetary and environmental costs associated with siltation problems has led many states, such as Maryland and Iowa, to adopt mandatory erosion control programs. However, much more must be done to prevent pollution from construction sites.

In Minnesota, while there are no laws requiring mandatory control of erosion, special districts have been created to implement water resource and soil conservation programs, including prevention of erosion and siltation. These are watershed districts, organized under Minnesota Statutes Chapter 112, and soil and water conservation districts, organized under Minnesota Statutes Chapter

40. Both types of districts are operating in the Metropolitan Area, although organized watershed districts only partially cover the Region.

During 1976, approximately 3,000 acres of land were disturbed for construction activities in the Metropolitan Area.[7] This is far fewer acres than for 1970 through 1972; however, it does show the building industry's recovery from the slump of 1973 through 1975.

By volume, the major pollutant from construction activities is sediment. Several desk studies were undertaken to estimate the magnitude of the water pollution problem attributable to sediment from construction activities in the Metropolitan Area. In addition, results of a statewide survey of roadside erosion problems undertaken for the Soil Conservation Society of America have been included in this report.

Construction Pollutants and Pollution Process

Sediments are by far the most obtrusive pollutant generated by land disturbing construction activities. Sediments pollute surface water in two ways. First, they silt drainageways and lakes and destroy stream and lake bottom fauna. In addition, sediments in suspension in water diminish the amount of light available to aquatic organisms, and lower the aesthetic value of the water.

Secondly, sediments carry chemicals, such as nutrients and pesticides, oil and toxicants, which have become bound to the soil particles. These sediments cause accumulation of the bound chemicals in receiving waters.

Construction activities also are the source of many potential pollutants which can be carried away by runoff. These potential pollutants include pesticides (insecticides, herbicides, rodenticides), petro-chemicals (gasoline, oil, asphalts), solid wastes (metals, rubber, roofing materials), construction chemicals (acids, soil additives, concrete curing compounds), wastewater (pesticide washwater, concrete cooling water, clean-up water from concrete mixers), garbage, cement lime, and fertilizers (relandscaped areas).

Availability of these pollutants and severity of the damage they cause depend upon several factors, including:

1. The nature of the construction activity;
2. The physical characteristics of the site;
3. On-site runoff and erosion control practices used; and
4. Use of "good-housekeeping" practices, including proper disposal of washwater and cleaning oil spills.

This study did not examine generation of pollutants other than sediments. Data for other pollutants are not available and no sampling of runoff was possible given limited funds available for this study.

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7 Association of Metropolitan Soil and Water Conservation Districts

Water pollution from sediment occurs through the detachment and transport of soil particles by rainfall and runoff. Rainfall detaches soil particles and runoff transports them to a stream or lake. In addition, overland runoff itself may detach some soil particles.

As in the case of sediments, the other construction-related pollutants are transported to receiving lakes and streams via runoff. The volume and velocity of the runoff and the distance to a stream or lake are very important determinants in the volume of construction-related pollutants.

Construction Activities in the Twin Cities Metropolitan Area

During 1976, most of the approximately 3,000 acres of land disturbed for construction was for housing. The remainder was consumed by commercial and industrial complexes. There were no major highway or utility lines (sewer and water) under construction. Since the survey of construction activities in the Metropolitan Area considered only projects ten acres or larger in size, local road construction projects of less than half a mile in length were not recorded. The size of construction projects recorded ranged from 40 to 100 acres.

Construction sites seem to occur in a haphazard manner. Since the decision to develop land is reached by any number of "developers" at any one time, it can be expected that land development will continue to appear haphazard, though each part may fit within locally developed plans. Unlike agriculture, which is a permanent land use with a continual potential for pollution of a lake or stream, land development is an activity at one location, with pollution potential limited to duration of the activity; usually one or two construction seasons. Then, new construction causes another pollution problem at another location in the same or another watershed. Thus, predicting the magnitude of the contribution of construction activities to water pollution in a given watershed within a given period of time is highly speculative.

In 1975, the Metropolitan Council adopted a Metropolitan <u>Development Framework</u>, a guide to accommodate the expected regional growth rationally and economically. Up to the mid-1970's, a large proportion of development occurred in the rural areas of the Region. For example, in 1973, more than 30 percent of permits issued for single family homes were for construction outside the sewered areas. The scattering of development outside the limits of established municipalities burdened townships ill-prepared to provide adequate control over land development, especially the potential pollution from sediments.

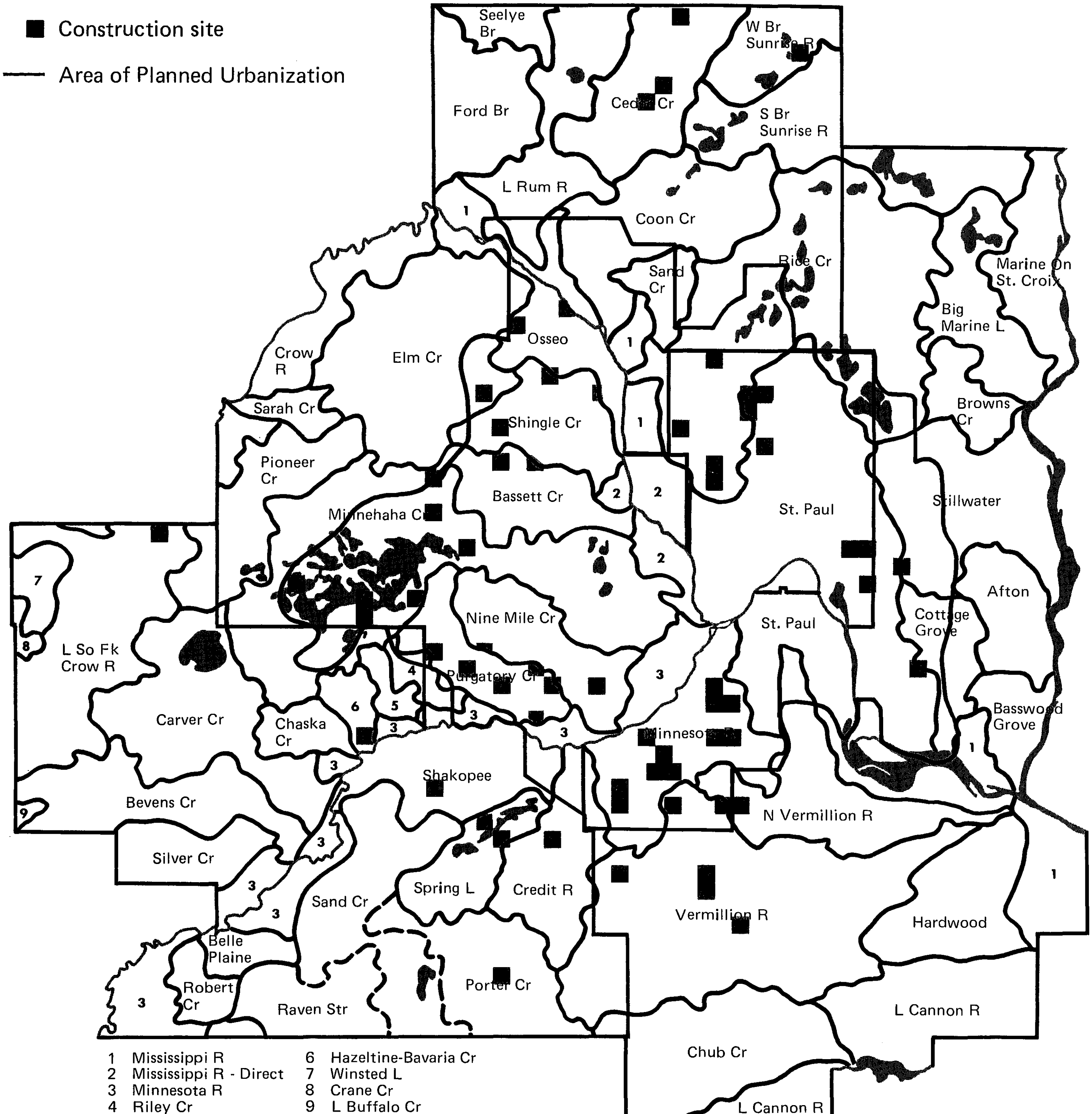
With the adoption and implementation of the <u>Development Framework</u>, it is expected that most land development activities will occur within the limits of cities which have planned for adequate services and have regulatory controls over land development.

A survey of the location of developments greater than ten acres in size for 1976 (Figure 9) indicates that most of the construction sites were within or fairly close to the Metropolitan Urban Service Area as delineated on Figure 10.

Figure 9
1976 CONSTRUCTION SITES IN THE METROPOLITAN AREA

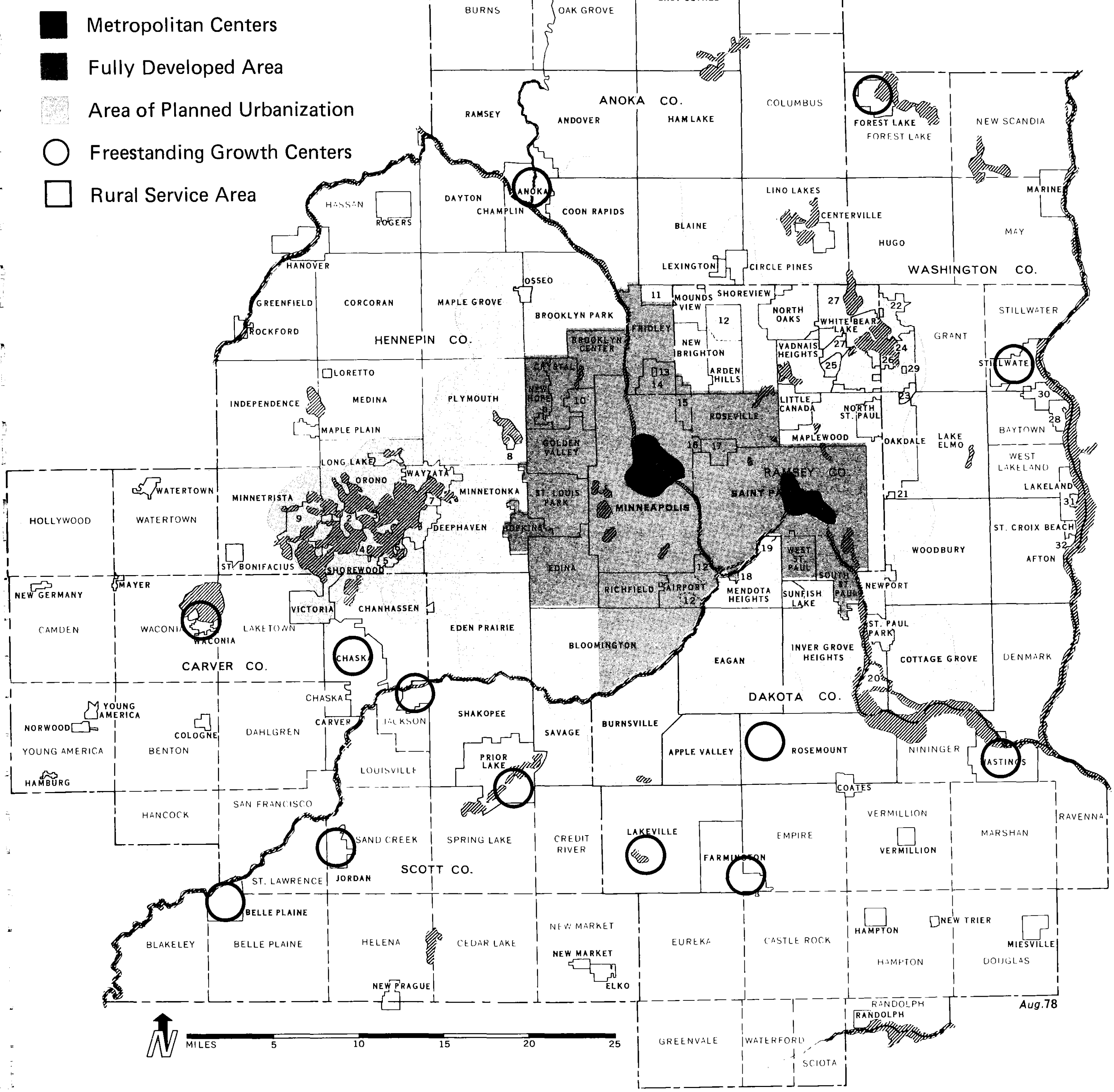
■ Construction site

—— Area of Planned Urbanization



1 Mississippi R
2 Mississippi R - Direct
3 Minnesota R
4 Riley Cr
5 Bluff Cr
6 Hazeltine-Bavaria Cr
7 Winsted L
8 Crane Cr
9 L Buffalo Cr

Figure 10
GENERALIZED POLICY AREAS BASED ON DEVELOPMENT FRAMEWORK



Pollution Potential from Twin Cities Area Construction

Sediment generated from land-disturbing construction activity was estimated to assess the nature and extent of the problem in the urbanizing section of the Seven-County Area. The study was designed to identify areas where construction was occurring and to roughly quantify the amount of sediments associated with the construction.

To obtain estimations of sediment movement resulting from gross soil losses associated with construction activities, the Area was divided into 60 watersheds as delineated on maps of the Conservation Needs Inventory (CNI) of the U.S. Dept. of Agriculture Soil Conservation Service (USDA-SCS), 1975. Estimates of average annual gross soil loss, annual sediment production, and annual net sediment export were determined using the same methods in the previous section of the report on sediments from agricultural activity. Those methods include application of the Universal Soil Loss Equation (USLE) and a sediment delivery curve based on watershed size. Appendix A.2 contains a complete discussion of methodology. The basic information used in this section was compiled by the Association of Metropolitan Soil and Water Conservation Districts (1977) under contract to the Metropolitan Council.

In addition, a survey of roadside erosion problems conducted by the Minnesota Department of Transportation (Mn/DOT) under contract with the Minnesota Chapter of the Soil Conservation Society of America provided data on sediments generated by highway embankments in disrepair. Neither study provided actual soil loss data collected in the field, although sites were identified in the field, site characteristics were noted, and use of regulatory controls or implementation of erosion control measures were recorded.

Study results indicate that 100 of the 186 local units of government interviewed have no erosion or sedimentation control and are outside of an organized watershed district that would provide some form of control. Of the remaining units of government, 65 rely solely on the watershed district regulations and 21 have adopted their own regulations.

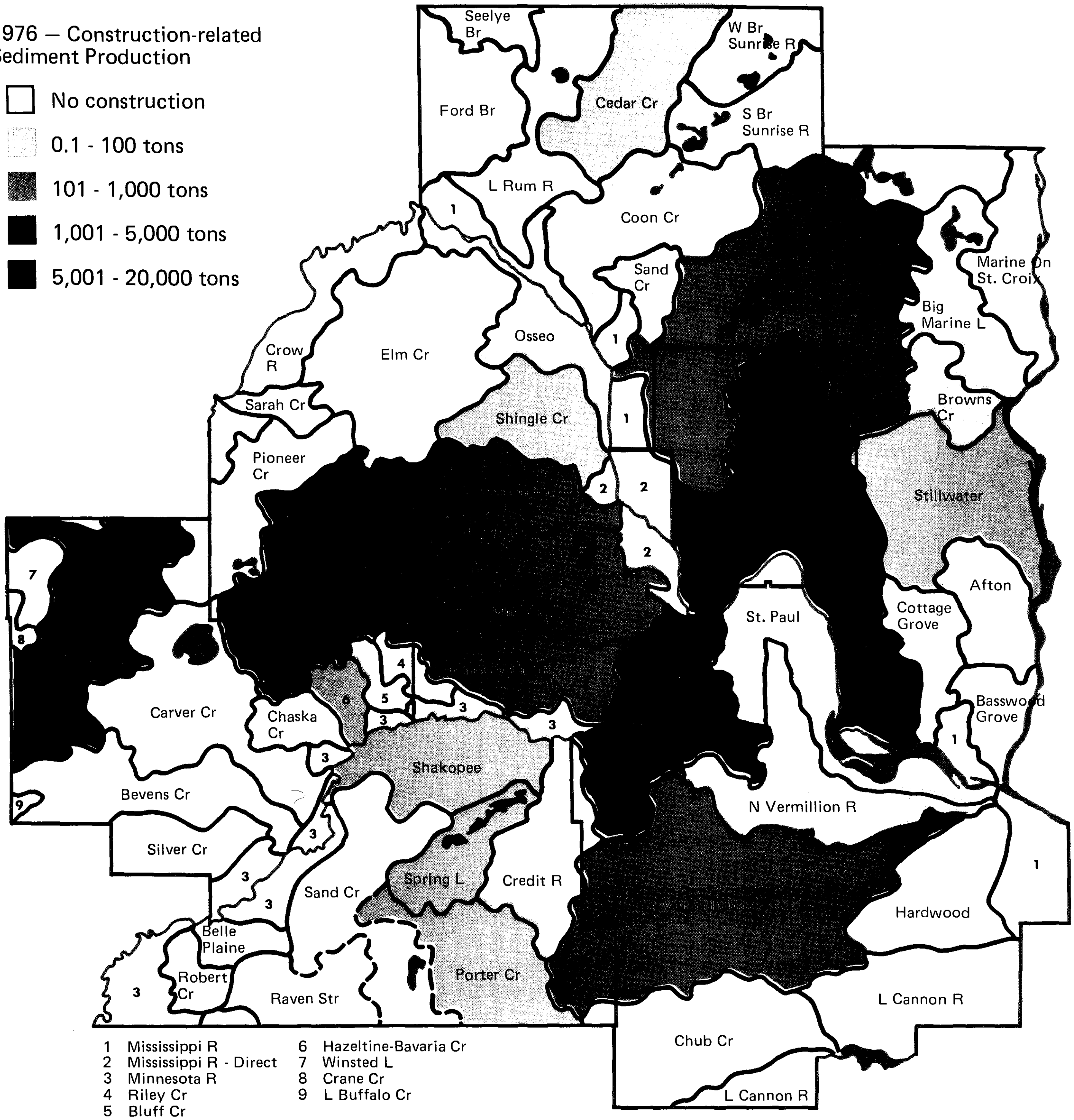
Application of the Universal Soil Loss Equation (USLE) indicated that for a typical construction year such as 1976, 140,000 tons of soil are eroded annually as a direct result of land development in the Region. Appendix Table 2.1 shows the problem areas and the variability in erosion, with values occurring from 0.5 to 203 tons per acre per year. The average erosion figure is 47 tons per acre per year.

A sediment delivery ratio was applied to the erosion data to arrive at a sediment production figure, i.e., that portion of erosion reaching a water body. This analysis showed that approximately 55,000 of the 140,000 tons of sediment eroded annually reached the lakes and streams of the Region. Figure 11 graphically displays the sediment production on a watershed basis. Appendix Table 2.1 lists the sediment production by watershed.

To estimate the amount of sediment that migrated from the watersheds, the sediment yield ratio was applied to the sediment production figures for an entire watershed. Appendix Table 2.1 shows that approximately 11,000 tons of sediment are exported annually from watersheds.

In 1972, the Minnesota Chapter of the Soil Conservation Society of America

Figure 11
1976 – ESTIMATED CONSTRUCTION-RELATED SEDIMENT PRODUCTION



sponsored a comprehensive survey of the amount and location of roadside erosion throughout Minnesota on a countrywide basis. The survey only recorded erosion sites and the volume of soil loss that occurs on existing roadways; it does not provide information on erosion problems that may occur during the construction period. Appendix A.2 details the methodology for this study. Results of this study show that erosion on county roads seems to be slightly more severe than on state roads and township roads. On the average, a site on a county road was losing 93 tons compared with 82 tons on a state road and 67 tons on a township road. Erosion occurs mostly in the road ditch (57 percent of the sites) and on the roadside backslope (40 percent of the sites). The most important cause of roadside erosion problems is inadequate design. This accounts for 50 percent of the sites within the Region. However, for Washington and Carver Counties, where 62 percent of the inadequate design cases in the Region are located, the reports show that design is the cause of erosion problems in 68 and 72 percent of the cases respectively. An additional cause of roadside erosion in the Region, disturbance of the roadside, accounts for 20 percent of all sites.

Conclusions

1. Soil losses from construction sites in the Region were estimated to be 140,000 tons for 1976. This represents an average of 47 tons of soil per acre of land disturbed.

2. Soil loss estimates for construction activity ranged from 2 tons per acre to more than 200 tons per acre.

3. Sediment production for 1976 is estimated to be 55,000 tons or 18 tons per acre of disturbed land.

4. While the total volume of sediments is small, sediment production by construction activities can be characterized as serious because it introduces a high volume of soils per acre of disturbed land.

5. In the Metropolitan Area, 54 percent of local units of government have no regulation to control erosion from construction sites and are outside of a special district that could regulate such problems.

6. Recently published reports of a 1972 roadside erosion survey indicate that more than 100,000 tons of soil were lost from existing roadways.

7. Roadside erosion is most likely to occur on the backslope or in the ditch as a result of inadequate design for these areas.

8. Roadside erosion in the Metropolitan Area is not a serious problem, though some localized erosion occurrences may be acute and contribute significantly to the degradation of surface water.

Recommendations

1. Based on these findings, abatement of pollution from construction activities should receive high priority in future water pollution programs.

2. A Phase II study proposal should contain a construction-oriented element that would address delivery of sediments generated by construction, control options, costs and financing mechanisms, and institutional arrangements that could be effective in controlling construction erosion.

URBAN STORMWATER RUNOFF

Background

The problem of urban stormwater runoff and the variable pollutants it carries has received an increasing amount of national attention in the past five years, largely because the contribution of unrecorded sources to water degradation had previously not been assessed. Literally hundreds of millions of dollars of pollution abatement funds are at stake, requiring careful allocation decisions.

The primary water quality problems occurring as a result of urban runoff are caused by accumulation of pollutants and/or by short, intense 'shock loads' that result in immediate water quality effects. National studies are showing repeatedly that urban nonpoint inputs are a significant part of total water pollution loading. They contribute a load of pollutants equivalent or greater in some parameters than those released annually by municipal and industrial point dischargers.

This study is an initial attempt to estimate urban stormwater runoff pollutant inputs into Metropolitan Area water bodies. The report approximates average yearly urban nonpoint pollution from a defined area (1,350 square miles) of urban and related land use and evaluates the potential effects of this pollution. The goals of the report are to grossly determine which parameters are creating the most serious problems, and where problems are located, and to recommend a study program outline to be followed if additional Phase II funds become available.

Urban Stormwater Pollutants and Pollution Process

The primary pollutants moved by urban stormwater are sediment, oxygen-demanding substances, nutrients, heavy metals, bacteria, chlorides from road salt, oil and grease, pesticides and poisonous compounds called polychlorinated biphenyls (PCB's).

Sediment from urban runoff merits primary attention both as a pollutant itself, and because of the tendency of some metals, nutrients and pesticides to adsorb onto fine soil or organic particles under certain conditions. Urban stormwater quality has sediment concentrations generally far greater than those of raw sewage, with predominant sources of sediment being erosion, atmospheric fallout and vehicular deposition. The detrimental effects of sediment include decreased light penetration, settling on lake or stream bottoms, transport of adhered pollutants, clogging of fish gills and decreased aesthetics. In general, urbanization will increase sediment loads, with areas of rapid development contributing the largest loads, but with fully developed areas also contributing large sediment volumes.

Oxygen-demanding substances introduced by urban runoff threaten receiving water bodies with oxygen depletion resulting from biological and chemical degradation of oxidizable material. Oxygen demand is best represented through chemical oxygen demand (COD), but biochemical oxygen demand (BOD) has historically been used as the most convenient means of reporting demand. BOD and COD concentrations occurring in stormwater runoff are approximately equal to those of secondary treatment effluent. The degree to which oxygen is lost as a result of this demand depends upon the amount of degradeable material in the stormwater, benthic oxygen demands and the physical nature of flow in the receiving water body.

Nutrient (nitrogen and phosphorus) input resulting from urban runoff is critical, since it becomes a contributing factor in eutrophication of downstream inactive waters. Nutrient input levels are generally less than inputs from municipal treatment sources, but nevertheless are significant to the total water quality condition. Phosphorus input to water bodies, particularly lakes, has in most cases been found to be the limiting element in determining algal productivity. Nutrient character in the stormwater runoff is highly dependent upon oxygen conditions, pH and physical conditions such as sediment and organic content in the water.

Toxic heavy metal loading from urban runoff merits attention as a potential non-degradeable aid to stream deterioration. Metals are capable of reaching critical levels in quiet areas where they are able to accumulate in bottom sediments. Loading of heavy metals during a storm contributes a significant portion of the entire load to urban streams. This study derives loading figures for chromium (Cr), copper (Cu), lead (Pb), nickel (Ni) and zinc (Zn). Highest metal loadings come from high traffic and industrialized areas.

Other constituents of urban runoff of concern, but of variable severity, include bacteria, chlorides (Cl) from road salt, oil and grease, pesticides and PCB's. These pollutants can be locally severe depending upon receiving water conditions and proximity to source areas.

The major identified sources of urban stormwater pollution include: vehicular and industrial emissions and leakages, combined sewer overflows, skid control grit and deicing salts, street and construction litter, vegetation and animal droppings, improperly applied pesticides, atmospheric fallout and precipitation and urban erosion. The largest inputs of urban pollutants within a developed area come from industrial land uses, with commercial and high density residential uses following for most pollutants.

Once pollutants are present on the urban surface, how they are moved about, either suspended in the water or in solution, becomes very important for the purpose of controlling them. Characteristically, an urban runoff event consists of the washing-off of accumulated debris from a parking lot, rooftop, street, etc.,rapidly enough to move sand, grit, leaves and the like and dissolve the soluble chemicals. Extreme stress on the assimilative ability of the receiving water body is generally caused by an increase in both pollutant concentration and water runoff volume as the storm begins and overcomes normal watershed depression storage. The phenomenon of highest concentration during an event occurring on the rising limit of a hydrograph (runoff versus time) followed by gradual tapering-off is commonly called 'first flush'.

The spring thaw of snow and ice can have an impact as great or greater than rain. Pollutants trapped by ice and snow are released together with the melt-water to produce a flush effect when temperatures rise enough to melt significant amounts of ice and snow.

Other factors affecting pollutant migration include the storm pattern; physical factors such as soil type, land slope, and type of vegetative ground cover; infiltration into drainage systems; and amount of temporary storage available in the watershed. The worst time for an urban stormwater runoff to occur is during a period of low flow, high temperature and low wind, when design loads for point source inputs have not taken into account nonpoint inputs. These conditions overstress the ability of the stream or lake to assimilate the pollutants.

Pollutants behave in various ways during stormwater runoff events. A typical storm would contribute extremely variable amounts of sediment. The largest amount of sediment per volume of runoff would follow a first flush behavior, that is it would correspond with the greatest flow of water and then diminish. Associated with, and often adhered to this sediment are several harmful pollutants, including metals, nutrients, bacteria, pesticides and PCB's. Pollutants that adsorb to sediment generally tend to adsorb to the fine fraction, thus increasing mobility and management difficulties.

The question of scale between individual runoff parameters becomes important in analyzing the effects of urban runoff. For pollutants such as COD and bacteria, the immediate areas downstream must be considered critical soon after an event. Pollutants such as metals and nutrients, however, migrate far downstream and have long-lasting effects. Figure 12 from EPA depicts time and space scales for stormwater pollutants.

Urban Runoff Study Area

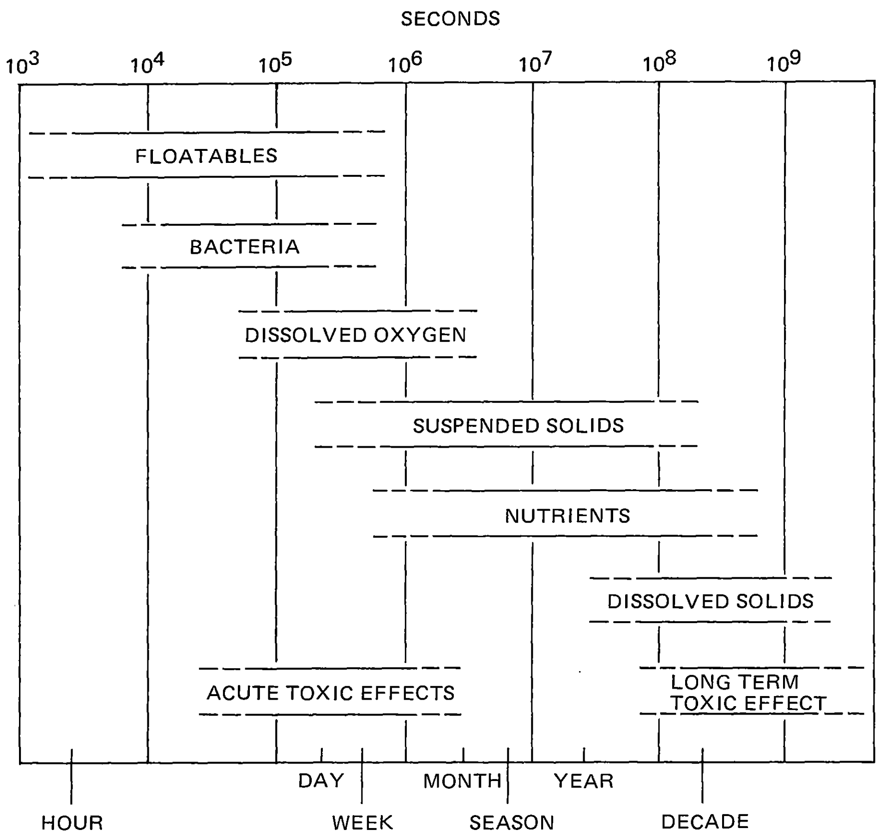
The urban study area was delineated based on Metropolitan Council development information and current land use data. The intent was to choose a study area that represented the total area that would contribute to urban stormwater runoff.

Sixty-one subwatersheds and three smaller cities designated as Freestanding Growth Centers (Jordan, Belle Plaine and Waconia) outside of the urban study area were chosen for evaluation of urban stormwater runoff. Figure 13 delineates the subwatersheds and the urban study area. Hickok and Associates (1972) arrived at these watersheds by selecting areas draining to a lake with a surface area of more than 200 acres, junctions of significant streams, major changes in land characteristics, and areas with no surface outlet under normal conditions. See Appendix C for a comparison between watershed numbers as used by Hickok and the Soil Conservation Service Conservation Needs Inventory (CNI) watersheds used in several other studies.

Land use was assumed determining runoff quality, influencing such critical factors as population density, traffic patterns, drainage patterns, industrial and commercial activity and amount of impervious watershed cover.

Land use categories used in this study were:

a) High density residential (HDR), five or more units per acre;



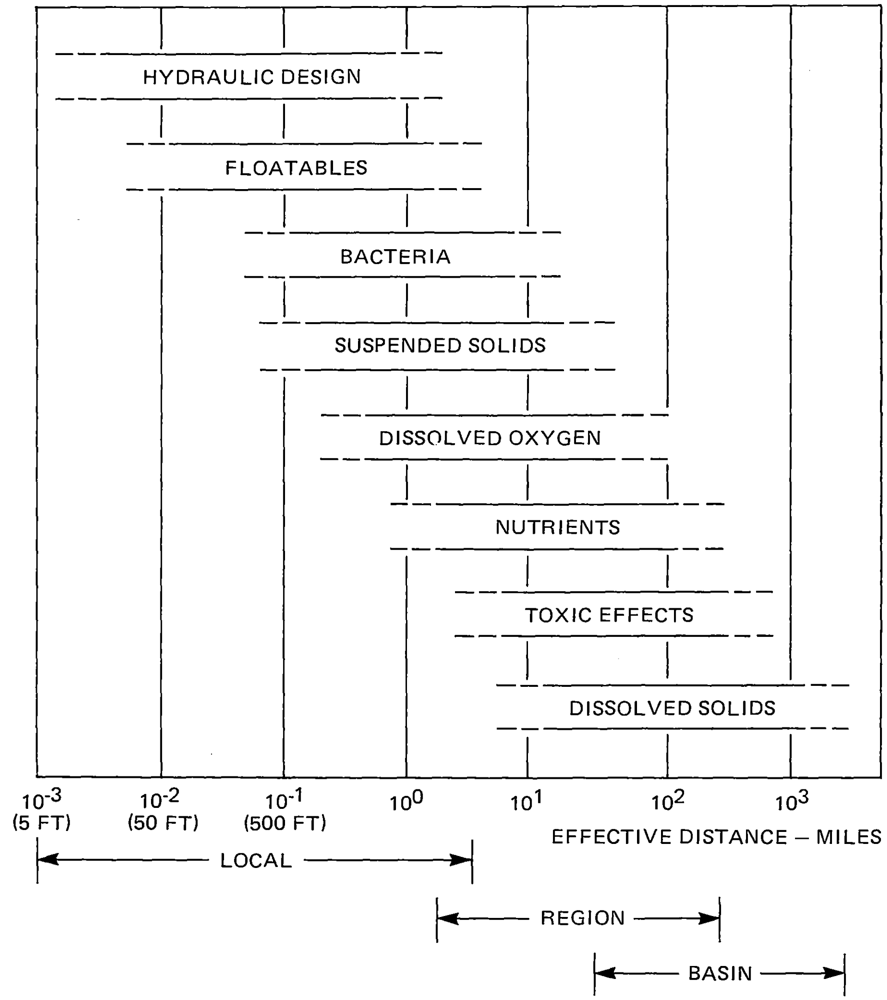


Figure 12
TIME AND SPACE SCALES FOR STORMWATER RUNOFF POLLUTANTS, FROM U.S. EPA (1976), VOLUME I, CH. 3

Figure 13
URBAN STUDY AREA SUBWATERSHEDS

Watersheds

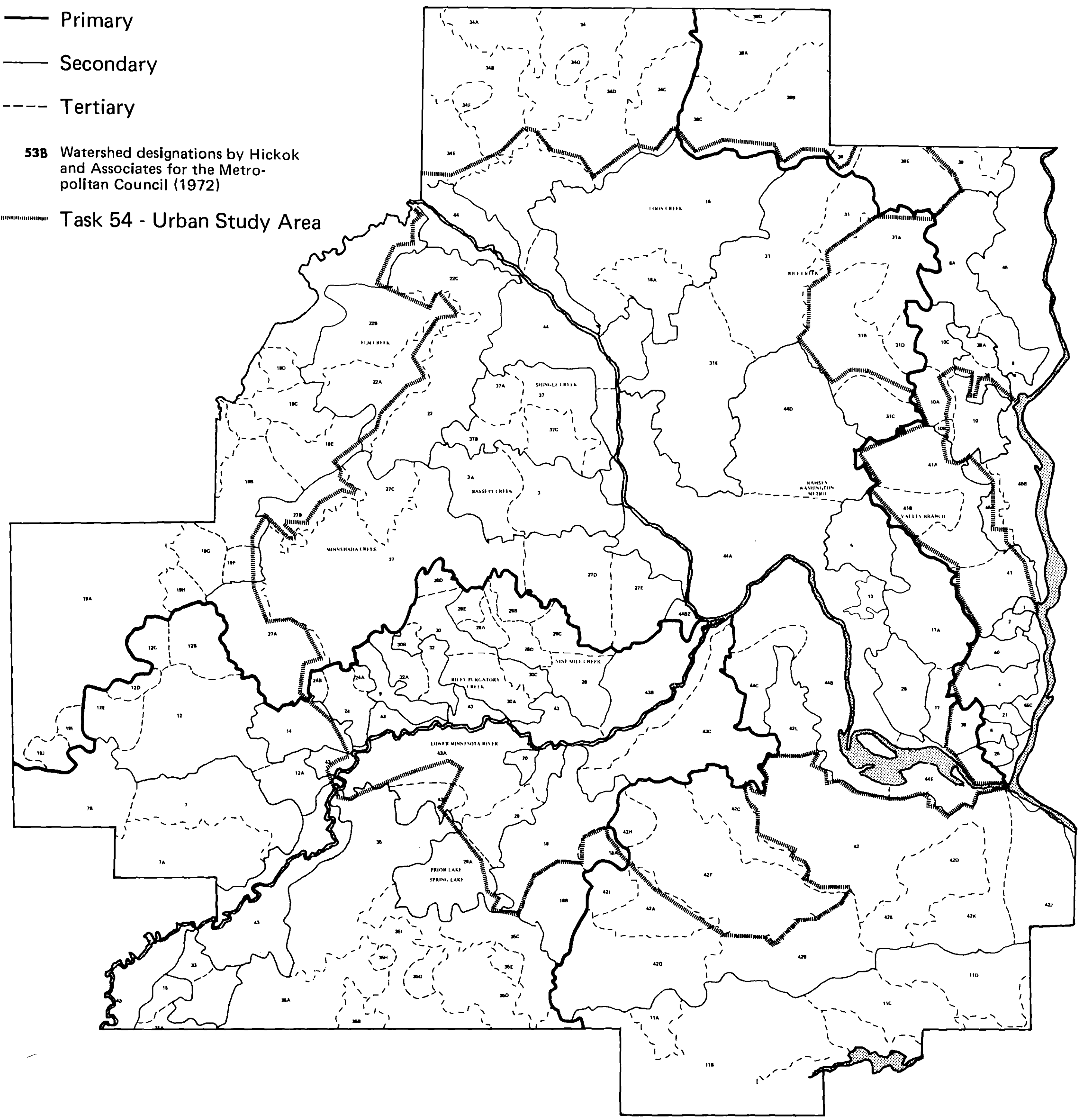
—— Primary

—— Secondary

---- Tertiary

53B Watershed designations by Hickok and Associates for the Metropolitan Council (1972)

Task 54 - Urban Study Area



b) Medium density residential (MDR), 2-5 units per acre;

c) Low density residential (LDR), less than two units per acre;

d) Commercial-industrial (C-I), including apartment complexes and large institutions;

e) Open space (OS); and

f) Lakes and open waters.

Land use acreage was updated from 1970 to 1975 in each of the study subwatersheds and Freestanding Growth Centers (as defined in the Metropolitan Development Framework), using aerial overlays for areas outside the central cities. The totals for the defined urban study area are:

HDR	-	44,509 acres
MDR	-	60,123 acres
LDR	-	24,032 acres
C-I	-	64,473 acres
OS	-	603,026 acres
Lake	-	64,945 acres
TOTAL	-	861,188 acres

Information on precipitation volumes and patterns was obtained from the Kuehnast et al. (1975) report on the precipitation patterns of the Metropolitan Area. Average annual precipitation from 1959-1975 is used in study calculations.

The majority of pollution will be moved in storms that result in greater than 0.10 inches of precipitation. Daily weather records from the U.S. Department of Commerce, National Oceanic and Atmospheric Administration (NOAA), Local Climatological Data program were checked for the ten years 1967-1976. Appendix Table 3.1 shows that approximately 92 percent of the total precipitation in the Twin Cities during these ten years fell during events over 0.10 inches. An average of 57 storms per year occurred.

Once the precipitation has fallen, a certain percentage of the moisture will run off. This runoff amount depends on how hard the surface is, subwatershed depression storage, degree of evaporation and infiltration capacities of exposed soils. Hickok and Associates (1972) determined the percentage of actual annual runoff per subwatershed and reported this figure as 'runoff coefficient' (c), not to be confused with the C factor used to determine peak flow volume in the rational method of flow analysis. The runoff coefficients were updated to take into account land use changes since 1970. Once determined, the C factor could be multiplied by annual precipitation to arrive at a figure for the annual volume of runoff to be expected for each subwatershed of the study area. The C factors, precipitation (P), and total annual runoff (Q) are included in Appendix Table 3.3.

Pollution Potential from Urban Surfaces

The potential for water pollution from nonpoint sources in the urban and urbanizing areas of the Region was estimated in this study. The pollutants studied are sediment, oxygen-demanding substances, nutrients, fecal coliform, chlorides and several heavy metals.

The purpose of the urban stormwater runoff study was to identify the extent to which urban runoff may be a cause of pollution of lakes and streams in the Metropolitan Area. The study identifies problem watersheds so that future focus may be placed on them.

No new data were collected to arrive at the conclusions presented. Instead, existing literature values for pollutant concentrations expected from various urban surfaces were combined with known rainfall and runoff figures to arrive at estimated pollutant washoff loads. Full details of the methodology are presented in Appendix A.3. Caution should be used in interpreting the results, and the tables and maps that follow should not be used to identify specific sources of pollution nor to design abatement programs.

Estimates of Pollutants

All of the pollutants inventoried were roughly quantified using literature values from reliable studies. Appendix Table 3.2 lists the data used for input to the loading equations presented in Appendix A.3. The results of applying these literature concentration figures to loading equations are presented in Appendix Table 3.3 by subwatershed. The following list summarizes the totals of each pollutant in tons per year:

BOD (biochemical oxygen demand)	-	6,869	tons per year
COD (chemical oxygen demand)	-	42,046	" " "
TSS (total suspended solids)	-	172,559	" " "
VSS (volatile suspended solids)	-	85,893	" " "
TS (total solids)	-	351,765	" " "
TP (total phosphorus)	-	221	" " "
DP (dissolved phosphorus)	-	107	" " "
NO_3-N (nitrate-nitrogen)	-	239	" " "
NH_3-N (ammonia-nitrogen)	-	354	" " "
KN (Kjeldahl nitrogen)	-	863	" " "
ON (organic nitrogen)	-	1,003	" " "
TN (total nitrogen)	-	1,951	" " "
Cl (chlorides)	-	28,796	" " "
Average fecal coliform	-	variable by watershed	
Cr (chromium)	-	23.1	
Cu (copper)	-	21.2	
Ni (nickel)	-	17.8	
Pb (lead)	-	101	
Zn (zinc)	-	58.5	

The subwatersheds that consistently ranked high in urban nonpoint loading are identified in Figure 14. It is apparent in viewing this figure that the central cities and surrounding higher density urbanized areas potentially contribute the largest pollutant loads. Appendix Table 3.4 lists the loading

Figure 14
SUBWATERSHEDS CONSISTENTLY HIGH IN URBAN NONPOINT LOADING

Watersheds

- Primary
- Secondary
- Tertiary

53B Watershed designations by Hickok and Associates for the Metropolitan Council (1972)

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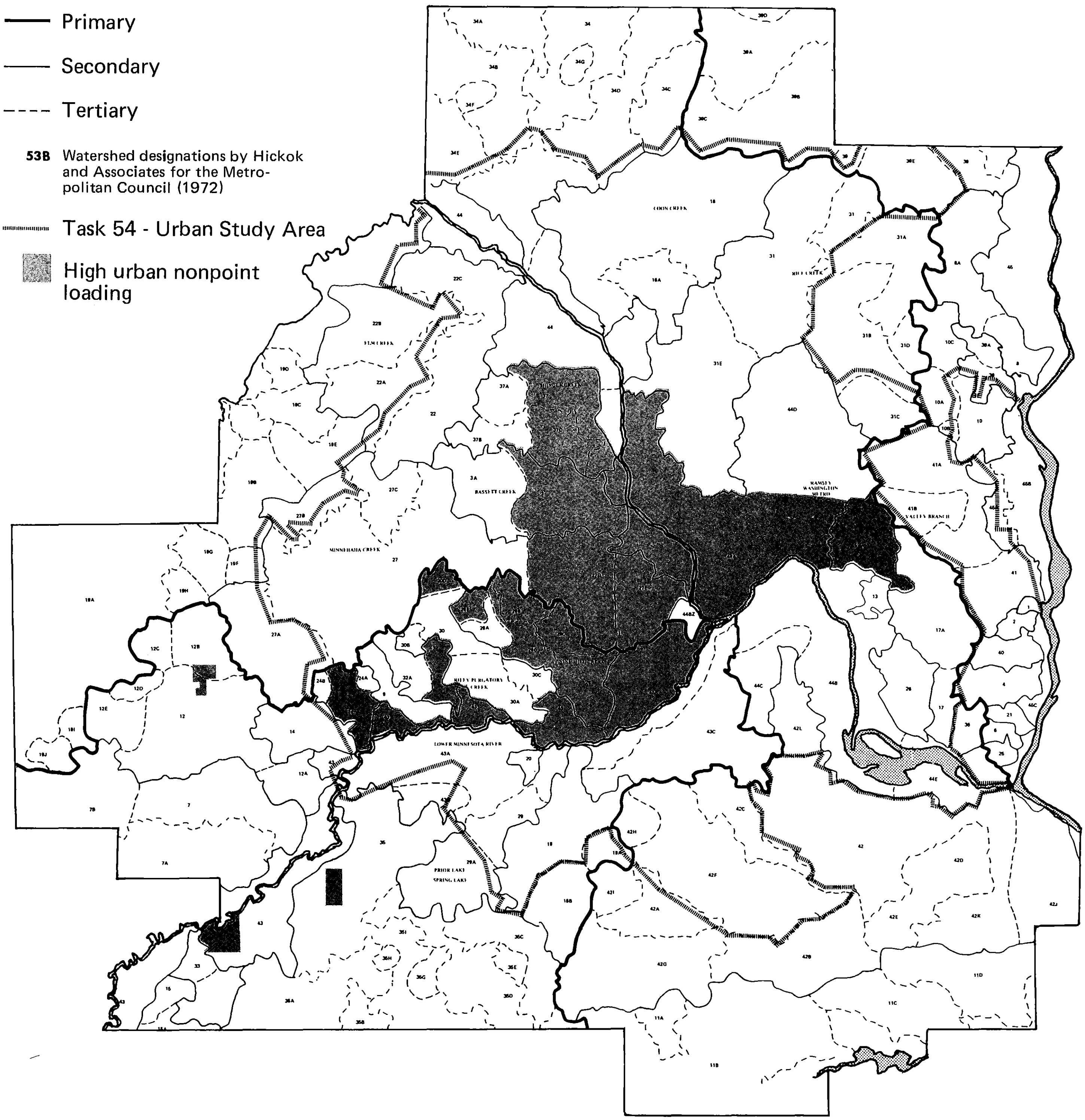
High urban nonpoint loading



figures for the largest contributing subwatersheds in each pollutant category.

Comparison With Routine Monitoring

Routine river quality monitoring for Rice and Purgatory Creeks was obtained from 1976 to grossly determine what portion of the total load of pollutants is accounted for in routine monitoring. United States Geological Survey (U.S.G.S.) and Riley-Purgatory Creek Watershed District monitoring data were used. The ratios of the calculated nonpoint source stormwater runoff to the routinely monitored water quality for equivalent units (pounds/acre/year) ranged from 1.14:1 to 9.6:1 for various parameters. Trends were reversed for some nitrogen, however, with most being accounted for by simple routine monitoring.

These results are gross and should serve as magnitude estimates rather than definitive numbers. The results indicate the likelihood that the routine monitoring programs have been sampling only basal flow and concentrations, and have not reflected a significant amount of the pollutant loading to streams. With the possible exception of nutrients, it appears that loading could be highly underestimated if conclusions are drawn on the basis of routine monitoring. It is suggested that those conducting routine sampling programs embark on a program that would also collect event-related samples, sampling across the runoff water charts from several types of storms throughout the year (including snow melt). Flow data is essential at the time of sampling if loading is to be adequately quantified.

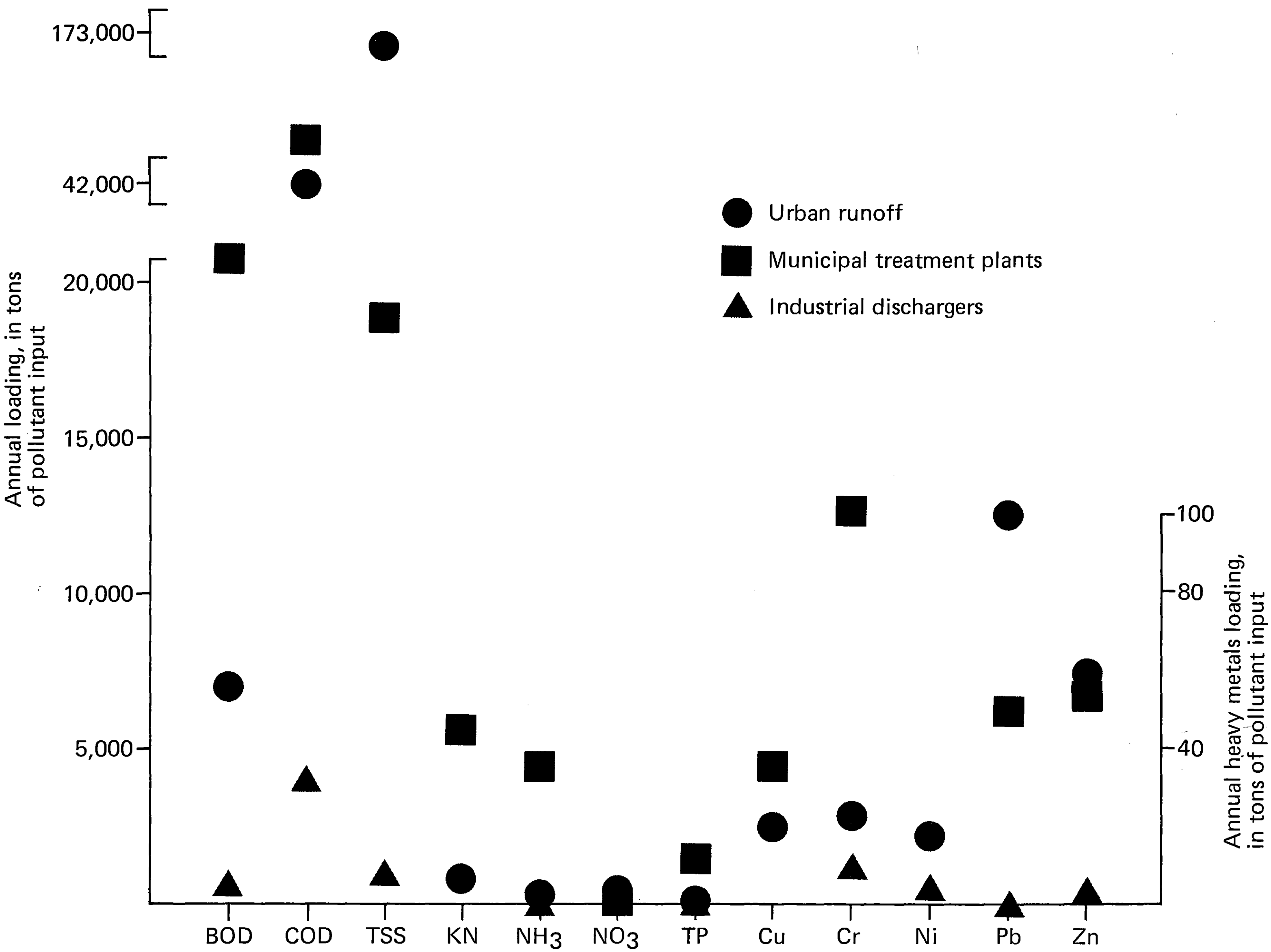
Comparison With Municipal and Industrial Dischargers

A comparison of pollutants resulting from urban stormwater runoff with pollutants from urban area point dischargers will help place the runoff problem in perspective. Historically, water quality improvement efforts in the Metropolitan Area have been concentrated on abatement of pollution from point dischargers, with the result that dischargers have generally improved, but water quality standards are still not being met. EPA in many reports has questioned the rationale of spending millions of dollars to upgrade treatment systems before the urban stormwater nonpoint situation is analyzed.

A compilation of 1976 municipal treatment plant discharges within the urban study area was made (Appendix Table 3.5) for purposes of comparison with nonpoint urban loading. Similarly, Appendix Table 3.6 is a compilation of annual pollution loading from industries in the Metropolitan Area discharging more than 0.5 million gallons per day (mgd). The following mathematical representations and Figure 15 will help to explain the results of the point versus urban nonpoint comparison (where UR is urban runoff, MTP is municipal treatment plants, and IND is industry):

$$
\begin{array}{llllll}
BOD: & UR & = & 0.33\ MTP & = & 9.78\ IND \\
COD: & UR & = & 0.66\ MTP & = & 13.13\ IND \\
TSS: & UR & = & 9.20\ MTP & = & 152\ IND \\
KN: & UR & = & 0.15\ MTP & & \\
NH_3: & UR & = & 0.08\ MTP & = & 1.21\ IND \\
NO_3: & UR & = & 1.40\ MTP & &
\end{array}
$$

Figure 15
COMPARISON OF ANNUAL LOADINGS FROM URBAN STORMWATER RUNOFF, MUNICIPAL TREATMENT PLANTS, AND INDUSTRIAL DISCHARGERS



TP:	UR	=	0.14 MTP	=	101	IND
Cu:	UR	=	0.58 MTP			
Cr:	UR	=	0.23 MTP	=	2.50	IND
Ni:	UR			=	3.91	IND
Pb:	UR	=	3.36 MTP	=	316	IND
Zn:	UR	=	1.08 MTP	=	15.40	IND

Using Biochemical oxygen demand (BOD) as an example, annual urban runoff loading is only one-third that of municipal wastewater treatment facilities, but is 9.78 times that of industrial dischargers. Urban stormwater runoff loading exceeded that of 1976 municipal treatment plants in TSS, NO_3, Pb and Zn, and exceeded industrial dischargers in every monitored parameter.

If it is assumed that the Metro Plant at Pig's Eye, the largest single discharger, will reach 25 mg/l BOD and 30 mg/l TSS (secondary treatment) by 1985 at a design flow of 290 mgd, the above figures will change accordingly and the proportion of urban stormwater runoff loading to total pollution loading in the Metropolitan Area will increase. Assuming urban runoff inputs remain constant, the new mathematical relationships replacing those indicated above would be:

BOD:	UR	=	0.57 MTP
TSS:	UR	=	12.17 MTP

This would mean that urban loading for BOD relative to treatment plants would rise from one-third to one-half, and for TSS would rise from 9.2 to 12.17.

To put stormwater discharges into further perspective, the loading figures presented in Appendix Table 3.3 were divided by 57, the annual average number of precipitation events over 0.10 inches (Appendix Table 3.1). This figure was compared in Table 3 with daily discharge figures of the point discharges to get an idea of what the gross effects are of a single precipitation event. The events used for comparison are assumed to occur over a 24-hour period, thus giving a conservative element since the events generally occur within about four hours.

The significant findings of this table are that a single event occurring over a hypothetical 24-hour period will add 56 times as much TSS, 4 times as much COD, and 1.32 to 25 times as much heavy metals as average daily municipal and industrial discharges occurring at the same time. As noted previously, most nutrient inputs from point sources do exceed urban nonpoint inputs on an event basis, but a significant amount of nutrient loading does result from urban stormwater runoff loading.

U.S. EPA (Athayde and Waldo, 1977) has prepared a graphical representation of future projected proportional loads from urban runoff, industrial point, and municipal point. Figure 16 is a reproduction of the EPA figure.

This figure shows that urban runoff will become increasingly large relative to other sources of pollution and that management decisions must be made keeping in mind that the unrecorded sources of pollution are significant contributors to the total pollutant picture.

TABLE 3. COMPARISON OF AVERAGE SINGLE EVENT STORMWATER RUNOFF LOADING WITH AVERAGE DAILY LOADINGS FROM MUNICIPAL TREATMENT PLANTS AND INDUSTRIAL DISCHARGES FOR 1976

	Multiplier to Arrive at Stormwater Load		
Parameter	Treatment Plant	Industrial	Total Point Source
BOD	2.1	63	2.04
COD	4.2	84	4.0
TSS	59.0	975	56
KN	0.96	-	0.96
NH_3	0.51	7.7	0.47
NO_3	9.0	-	9.0
TP	0.91	649	0.90
Cu	3.74	-	3.74
Cr	1.44	16	1.32
Ni	-	25	25
Pb	21.5	1,971	21
Zn	6.9	98	6.5

Potential Lake Degradation

A cursory evaluation was done on lake degradation resulting from urban stormwater input. The problem immediately identifiable in the Metropolitan Area is that impervious surfaces have been drained into the closest and most convenient course available, which in most cases is either a lake or a water course that drains into a lake. Of principal concern are the nutrients that contribute to eutrophication of the lake.

The assumptions made to reduce the number of lakes considered to a workable number were: choosing only lakes with no septic tanks so their input could not contribute; eliminating lakes less than 100 acres unless they have been identified as large-scale recreation lakes; and not considering lakes that are nothing more than large marshes.

MPCA's Clean Lakes Information File (CLIF) was searched, as well as additional sources of lake quality information. Several public agencies were contacted and their opinions solicited as to lakes degraded from urban runoff. The results of this cursory examination are listed in Appendix Table 3.7. The county, lake and nature of problem are identified for the 63 lakes that remained in the study.

The study analysis shows that 36 of the lakes evaluated are most likely directly degraded as a result of urban runoff, with an additional eight undergoing a certain degree of degradation from urban runoff. These lakes should establish future priorities for rehabilitating urban lakes degraded by urban runoff.

Deicing in the Metropolitan Area

According to a survey conducted as part of this study, more than 120,000 tons of salt were applied in the winter of 1976 in the urban area by 35 large municipalities, the seven counties and the two State Department of Transportation districts. Salt applied by municipalities is generally at a ratio of one part salt (sodium chloride) to five parts sand. Calcium chloride is frequently used when temperatures drop below 20°F. In extremely icy conditions, 100 percent salt is sometimes used in dangerous driving locations.

The survey showed that it is uncommon in the Metropolitan Area for public maintenance departments to dispose of relocated, deiced snow directly into a stream or lake, but the study was unable to ascertain what private snow removal contractors do. Public agencies do, however, continue to deposit removed snow onto areas lying within floodplains or on higher land draining directly to a watercourse. Several dump sites and uncovered stockpiles may result in leachate runoff causing degradation of ground and surface waters.

Several adverse environmental impacts are addressed in the technical report,[8] including biological, physical and chemical effects. The report does not advocate abandoning salt use for maintaining safe roads, but neither does it advocate overuse to maintain bare pavement. Common sense use and education of those applying deicing material could reduce the adverse environmental consequences of road salt.

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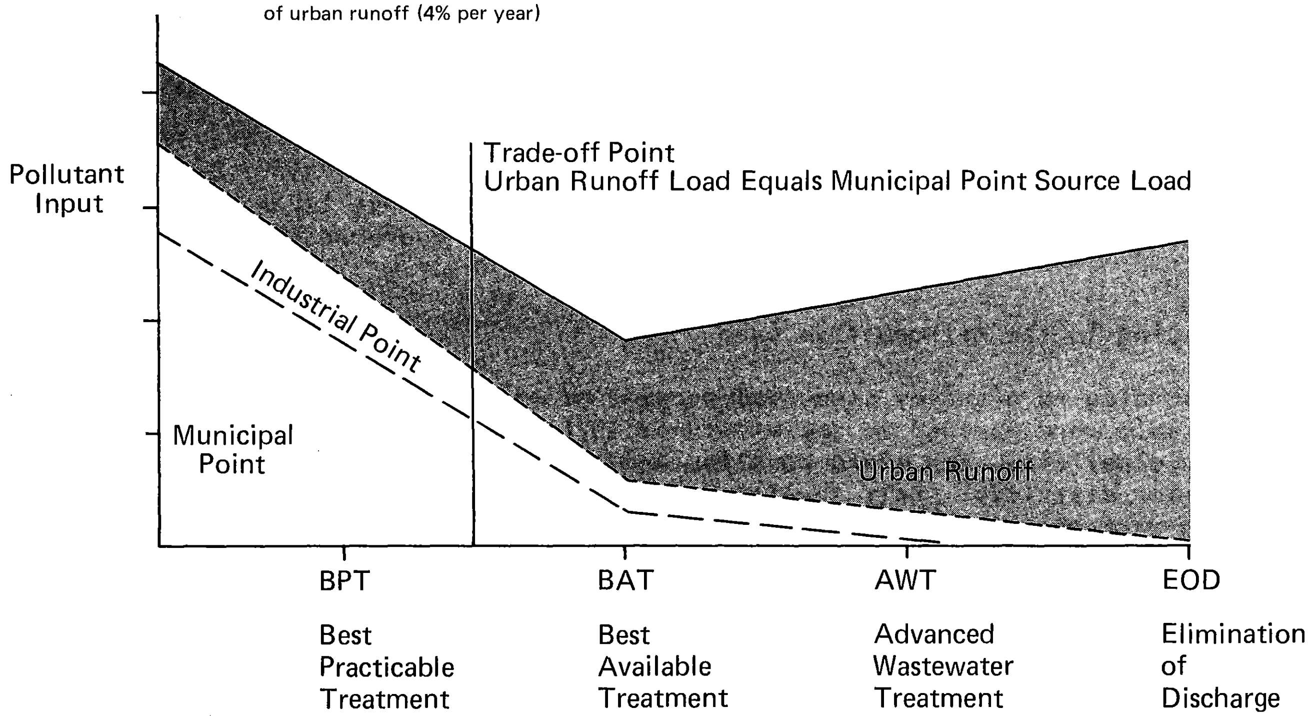
8 Water Pollution From Urban Runoff. March 1978. Metropolitan Council

Figure 16
URBAN RUNOFF COMPARED WITH POINT SOURCE TREATMENT LEVELS, FROM ATHAYDE AND WALDO (1977)

Note: Growth included in calculation of urban runoff (4% per year)



Stormwater Planning

Control of pollutant loading from urban stormwater runoff does not occur on a large scale in the Metropolitan Area. A small survey of 70 large and developing communities was conducted to determine the status of long-range stormwater plans. Results show that much confusion exists over what comprises a truly 'comprehensive' plan. Although most communities address stormwater handling in some manner, only about half actually have comprehensive stormwater plans. The problem that arises with this sporadic coverage is that degree of stormwater planning changes as municipal borders are crossed, resulting in a piecemeal approach to comprehensive stormwater management.

Conclusions

1. Urban stormwater runoff pollution is potentially a significant portion of total annual loading for the Metropolitan Area. Further water pollution abatement programs must consider this source of pollutant input and change to a balanced approach from the historic practice of considering only point sources of pollution if future water quality goals are to be reached. Future upgrading of municipal treatment plants and industrial dischargers should be viewed in light of potential large capital expenditures for treatment structures versus reduced expenditures for minimum-structural or source control of nonpoint sources of pollution.

2. The ten subwatersheds that consistently rank among the largest in total and on a per acre unit basis loading for most of the expected pollutants are: central Mississippi River through the urban core, lower Minnehaha Creek, Waconia FGC, lower Bassett Creek, Chain of Lakes drainage and central Minnehaha Creek in Minneapolis, Shady Oak Lake tributaries, Twin Lake tributaries, north tributary to Nine Mile Creek, Belle Plaine FGC and lower Minnesota River.

3. 1976 loadings from municipal treatment plants and industrial dischargers show that annual urban stormwater pollutant loading exceeded municipal plants in TSS, NO_3, Pb and Zn, and exceeded industrial dischargers in every monitored parameter. The majority of point sources are released into the Mississippi and Minnesota Rivers, whereas the urban nonpoint loadings also occur on the secondary and tertiary streams, many of which flow directly into lakes.

Recommendations

1. Based on the findings of this study, abatement of nonpoint pollution from urban runoff should receive high priority in future water pollution programs.

2. A Phase II study proposal should contain an urban runoff element that would address management techniques, water quality sampling to verify Phase I conclusions, modeling of urban runoff, costs and financing of management, implementation techniques and alternatives selection.

STREAM CHANNEL EROSION

Background

Stream channel erosion occurs from both natural and human causes. Some channel erosion is part of a normal process of change in landform, caused by streambank slumping, bank washing, mass wasting and other activities as the stream tends to reach an equilibrium. Urbanization and human use of a watershed may further cause a stream channel to erode. Increase in the peak of runoff, uncontrolled concentrated storm discharges, urbanization of streambanks and use of the banks for recreational purposes or for grazing animals are all causes of stream channel erosion.

In 1977, the Metropolitan Council conducted a survey of channel erosion on streams in the Metropolitan Area. This was accomplished through a Section 208 contract with the Association of Metropolitan Soil and Water Conservation Districts, which subcontracted to the USDA-Soil Conservation Service. While many field personnel reported instances where obvious disturbance was the cause of channel erosion, generally the survey does not permit differentiation between natural and "accelerated" channel erosion.

Stream Channel Erosion Pollutants and Pollution Process

The major pollutant by volume contributed to water by channel erosion is the soil eroded away from the banks or bottom of the channel. There might be some concern over the contribution of nutrients through the natural fertility of soils eroded, the organic matter such as grass, trees and shrubs and other organic litter dropping into the water through mass wasting or bank washing. These associated pollutants are, however, most probably inconsequential.

Erosion occurs when the water in a channel or entering a channel detaches soil particles on the banks or undermines channel banks, which then slump in; or when the water digs a deeper channel. Streams are constantly tending to an equilibrium, which is reached when channel slope, size of the bed, direction of flow, velocity and loading of the water have reached a balance. Once equilibrium has been reached, little if any natural channel erosion occurs. However, other factors influence channel erosion. In urbanizing watersheds, land use changes cause a different relationship between runoff and stream channel size. Increases in peak runoff, larger short-term volume flows, smaller base flows and concentrated storm sewer discharges are usual occurences in urbanizing and urbanized watersheds.

Urban development and the accompanying storm sewer system have resulted in substantial enlargement of stream channels receiving urban runoff (Coughlin and Hammer, 1973). Most soil loss from channel erosion is caused during the process of stream enlargement and the subsequent period when the stream tends toward an equilibrium.

Geomorphic Regions and Their Streams

The Metropolitan Area is drained principally by the Mississippi, Minnesota and St. Croix Rivers. About 40 large and small streams, in addition to developing streams, contribute to these three major rivers. The valleys and channels of these streams present considerable geomorphic differences as they are part of 12 different geomorphic regions (Figure 17). These geomorphic differences and land use differences in each of the watersheds influence the amount of erosion taking place in the channel or on the confining walls of the river.

Streams in the Anoka Sand Plain area generally have very little channel erosion. When natural erosion occurs it is due to a change in the stream channel slope, normally within the last reach before discharging to another river, such as the Mississippi or Rum Rivers. Urban development close to the banks, disturbance of banks by cattle or by human recreational activities also causes erosion.

Streams in the Mississippi Valley Outwash, the Mississippi and Vermillion Rivers, have few channel erosion problems. The Vermillion has very few problems. Mississippi River problems exist on its northern reach, caused primarily by fluctuating water levels, ice jams and storm sewer outfalls. A few erosion problems also occur on the steep banks of the Mississippi at its confluence with the Minnesota River.

The Cannon River lying in the Cannon Valley Outwash geomorphic region has had considerable streambank erosion; however, a large portion of the erosion sites are now inactive. Some active erosion is occurring at river bends.

The Minnesota Valley Outwash consists primarily of the Minnesota River. A considerable amount of erosion occurs in the river channel, especially at the outside curves of the meandering river channel. However, the major areas of active erosion are the bluffs or steep banks of the river valley. These banks, 100 to 200 feet high, are extremely susceptible to gullying.

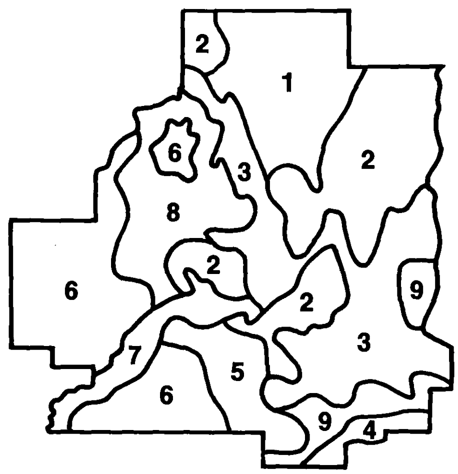
The major watersheds of the Twin Cities Formation geomorphic region are Rice Creek, Brown's Creek, Big Marine Lake and Marine on St. Croix. Little channel erosion occurs in these watersheds, with the exception of an area of steep gradient on Rice Creek prior to reaching the Mississippi River, and some severe gully problems along the St. Croix in the Marine on St. Croix Watershed.

In the Waconia-Waseca moraine geomorphic region, streams generally are not presenting serious erosion problems. However, most of these streams flow to the Minnesota River, whose bed is at places about 200 feet below the upland bed of these streams. As a result, the last few miles of the channel of each stream in this geomorphic region exhibit a steep slope and have steep banks subject to severe erosion problems. These streams include Carver Creek, Silver Creek, Bevens Creek, Chaska Creek, Robert Creek, Belle Plaine, Ravenna Stream, Porter Creek and Sand Creek. All of these streams, except for Chaska Creek and a portion of Belle Plaine, are in agricultural use and present additional moderate erosion problems on their meandering courses.

The Credit River is the only major stream in the Prior Lake Moraine geomorphic area. The meandering channel has many eroding areas, some of which are particularly severe. Severe bank erosion also occurs in the last reach of the river as it flows to the Minnesota River.

Figure 17
MAJOR GEOMORPHIC REGIONS

1. Anoka Sand Plain
2. Twin Cities Formation
3. Mississippi Valley Outwash
4. Cannon Valley Outwash
5. Prior Lake Moraine
6. Waconia-Waseca Moraine
7. Minnesota Valley Outwash
8. Prior Lake, Emmons-Faribault, Hayward-Owatonna Moraines
9. Kenyon-Taopi Plain



Pollution Potential from Stream Channel Erosion

Survey information was used to assess the location and extent of stream channel erosion in the Region. Only sediments were evaluated and no in-field analysis other than spot-checking was done. Further information on the methodology used to assess stream channel erosion can be found in Appendix A.4.

It is estimated that more than 570,000 tons of soil are eroded annually from streambanks in major actively eroding areas. This occurs over 1.3 million feet of eroded channel. Wide differences exist among the watersheds. Several watersheds have less than 100 feet of eroded channel per square mile of drainage basin and produce less than 10 tons of soil per square mile, while several other watersheds have more than 2,000 feet of eroded channel and produce 2,000 tons of sediment per square mile. Figure 18 and Appendix Table 4.1 show the variability in stream channel erosion in the Metropolitan Area.

The Minnesota River Valley is a major contributor of sediment with the 150 to 200 feet high bluffs of the valley walls producing an estimated 350,000 tons of soils annually. The Minnesota River loading is significant; it represents 60 percent of the total annual metropolitan load from stream channel erosion.

Eight other watersheds are significant sources of sediment. On the average, for every square mile of watershed a quarter of a mile or more of the stream channel is eroding. All eight streams have cut deep ravines into the slopes of the Minnesota River and are discharging to the Minnesota River. These streams contribute an estimated additional 120,000 tons of soils from noted bank erosion areas annually. Thus, approximately 85 percent of the annual soil losses from noted stream channel erosion areas is discharged to the Minnesota River. Severe erosion problems in the Silver Creek, Bevens Creek, Bluff Creek, Robert Creek, Sand Creek, Chaska Creek and the Belle Plaine watersheds result from the last two to four miles of each creek having a very steep gradient through the steep slopes and bluffs walling the Minnesota River. In addition, serious gullies are forming in the steep banks of these streams as a result of disturbance of vegetation by cattle, recreational vehicles, or excavation for sand or construction aggregate. On such steep slopes, especially those facing south and thus drier, gullies are extremely difficult to heal.

While total soil losses and length of eroded channel are good indicators of watersheds with channel erosion problems, neither indicator is sufficient to identify the severity of the problem. To obtain an indication of the problem on an overall watershed basis, an index was developed using the ratio of soil loss in tons over eroded channel in feet. The range of this index is depicted on Figure 19 and the computed values are reported in Appendix Table 4.1.

Conclusions

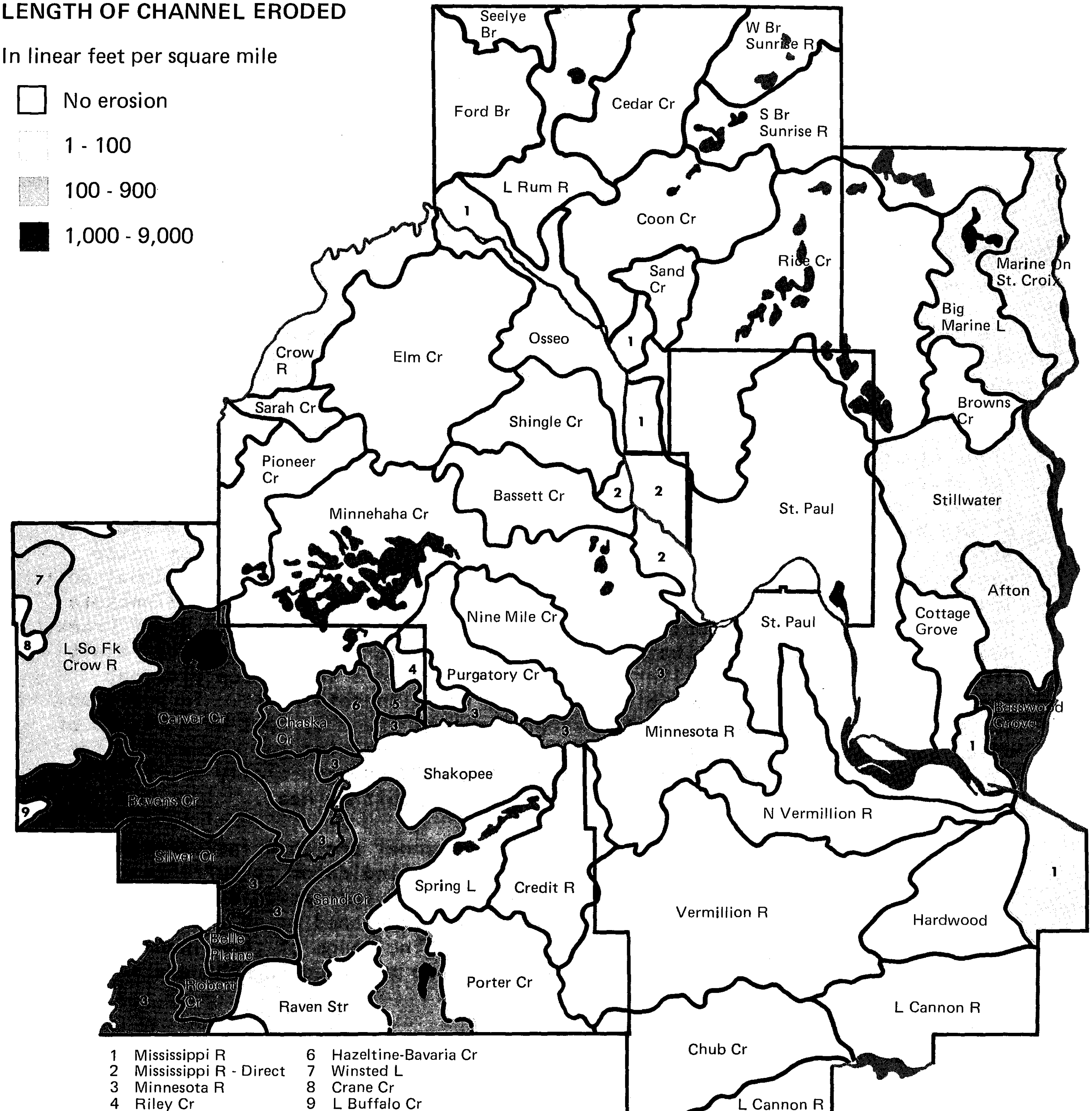
1. Stream channel and gully erosion in the Metropolitan Area contribute annually over 570,000 tons of sediments to water.

2. Stream channel and gully erosion in the Metropolitan Area are major contributors of sediment to streams.

Figure 18
METROPOLITAN AREA STREAM CHANNEL SURVEY – ESTIMATED LENGTH OF CHANNEL ERODED

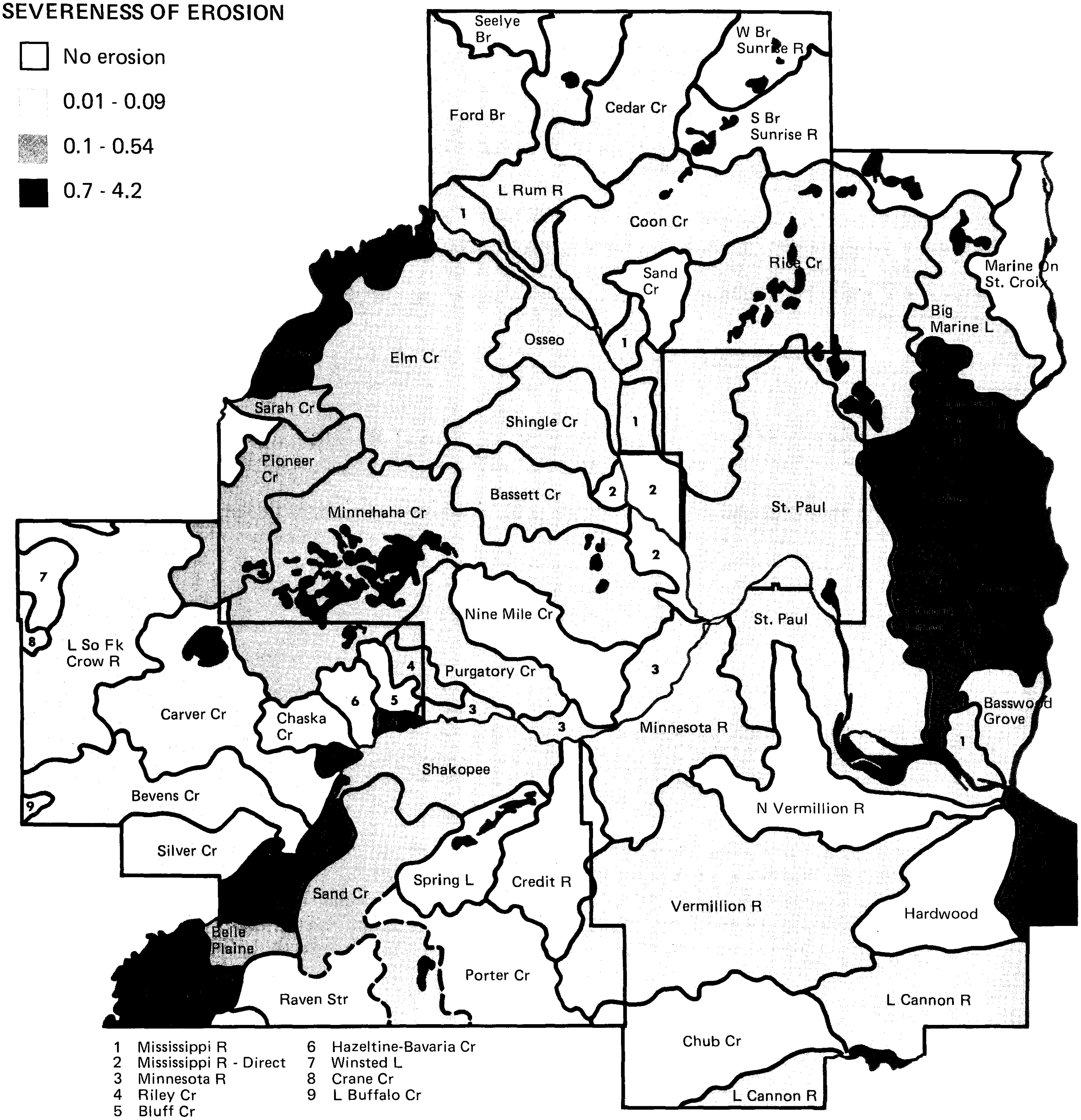
In linear feet per square mile

No erosion
1 - 100
100 - 900
1,000 - 9,000



1 Mississippi R
2 Mississippi R - Direct
3 Minnesota R
4 Riley Cr
5 Bluff Cr
6 Hazeltine-Bavaria Cr
7 Winsted L
8 Crane Cr
9 L Buffalo Cr

Figure 19
METROPOLITAN AREA STREAM CHANNEL SURVEY – INDEX OF SEVERENESS OF EROSION



3. Sixty percent of sediments from channel and gully erosion are generated from the Minnesota River Valley banks and bluffs.

4. Twenty-five percent of the sediments from channel and gully erosion are discharged into the Minnesota River by eight watersheds where drainage channels cut through the bluffs and steep slopes of the river valley.

5. Eighty-five percent of the sediments generated annually by channel erosion in the Metropolitan Area are being discharged into the Minnesota River.

6. Serious erosion problems on stream channels appeared to be caused by streams with steep gradients trying to reach an equilibrium, and by human activities such as stormwater discharges, cattle or human activities on fragile steep banks, or agricultural or urban use of steep valley walls.

Recommendations

1. Based on these findings, curtailment of unnatural stream channel erosion should receive high priority in future water pollution programs.

2. A Phase II study proposal should contain a stream channel erosion element that would address the natural versus unnatural character of stream channel erosion, management techniques and financing costs and control alternatives for curtailing unnatural stream channel erosion.

LANDFILL LEACHATES

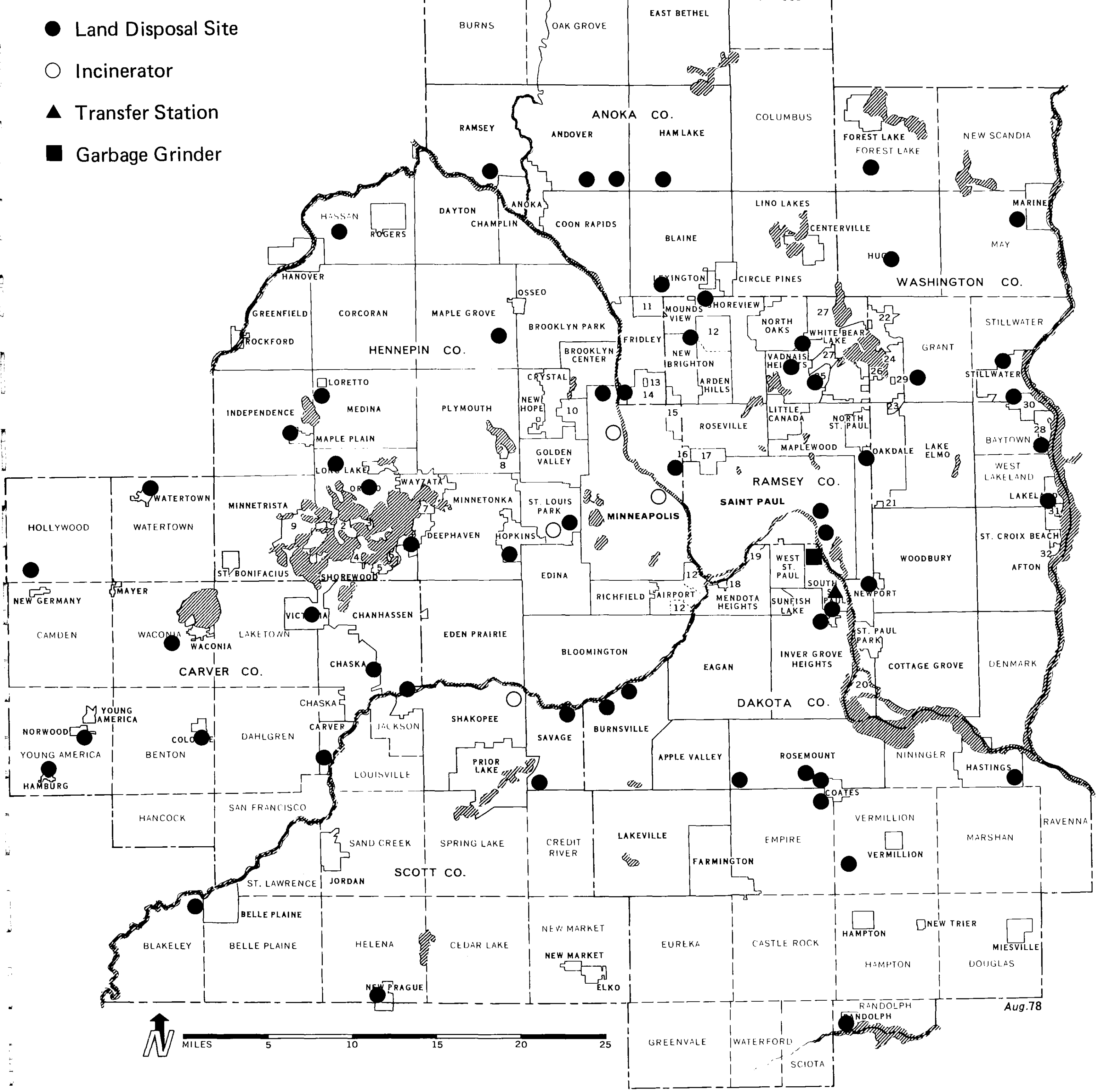
This part of the report summarizes a technical study that reviewed available information on currently operating and closed landfills in the Metropolitan Area and provides an estimate of leachate generation. Leachate is the contaminated water that seeps beyond the physical limits of a landfill; contamination is a result of the water picking up chemical and biological pollutants from the solid waste refuse. The focus of this study is on the potential pollution generated by the flow of water through material in sanitary landfills and dumps. Findings can serve as a basis for further study of actual pollution problems, for re-evaluating the role of sanitary landfills in the Region's solid waste disposal system and for reviewing the safeguards necessary to minimize pollution from landfills, whatever their future role in the system.

Background

From now until 1980, the Metropolitan Area will produce an estimated average of 5,000 tons per day of municipal solid waste. This rate translates into a daily average of 4.5 pounds for every person in the Seven-County Metropolitan Area.

Before 1971, the Region disposed of its solid waste in 68 dumps and landfills (Figure 20) subject to little regulation and control. In 1971, landfill permits were issued under a state-mandated regulatory and review process in which

Figure 20
LOCATION OF DISPOSAL FACILITIES, 1968



private operators, the seven counties, the Metropolitan Council and the MPCA all play roles. The goal was to ensure the efficient disposal of solid waste consistent with environmental safeguards. The process is called "sanitary landfilling," a systematic method of locating landfill sites in suitable locations, preparing the site to minimize environmental impacts and operating the landfill consistent with sanitary and environmental standards. The original 60 solid waste disposal sites have been reduced to 14 sanitary landfills, 12 are now licenced to operate in the Metropolitan Area (Figure 21).

Landfill Leachate Pollutants and Pollution Processes

Sanitary landfilling is supposed to minimize environmental damage by spreading wastes in thin layers, compacting them to the smallest practical volume and covering them with clean earth at the end of each operating day. As the solid wastes decompose, they produce large amounts of carbon dioxide, which reacts with water in contact with the solid waste to produce a weak acid. The water's acidity increases its ability to dissolve or leach chemicals from solid waste, increasing the dissolved solids present in the water. The resulting contaminated water is called leachate.

The principal contaminants of concern in landfill leachates are heavy metals, BOD and COD, alkalinity, total dissolved solids, chlorides, microorganisms, hardness and organic compounds such as oil and phenols. Determining the pollution potential of a landfill requires a determination of whether leachate will be produced, the nature of the leachate, the annual volume of leachate produced and the surface or subsurface pathways allowing leachate movement out of the site.

The principal source of water for leachate production is rain that infiltrates solid waste, or groundwater or surface water which has risen, flowed laterally, or flowed over a landfill site. Leachate composition varies with the amount of water in the landfill, the composition and age of the solid waste, the thickness and compaction of the refuse and the processing and cover over the refuse. Composition of the waste itself is the most important factor, because it determines the presence of heavy metals, toxic organic compounds and harmful microorganisms that cause health hazards, as well as other objectionable qualities such as odor, color and turbidity.

Table 4 compares some characteristics of landfill leachates with those of raw sewage (Oleckno, 1976), and Table 5 compares mean leachate composition of 123 Illinois leachate analyses (Clark and Piskin, 1977) with current Minnesota Department of Health (Mn/DOH) drinking water standards.

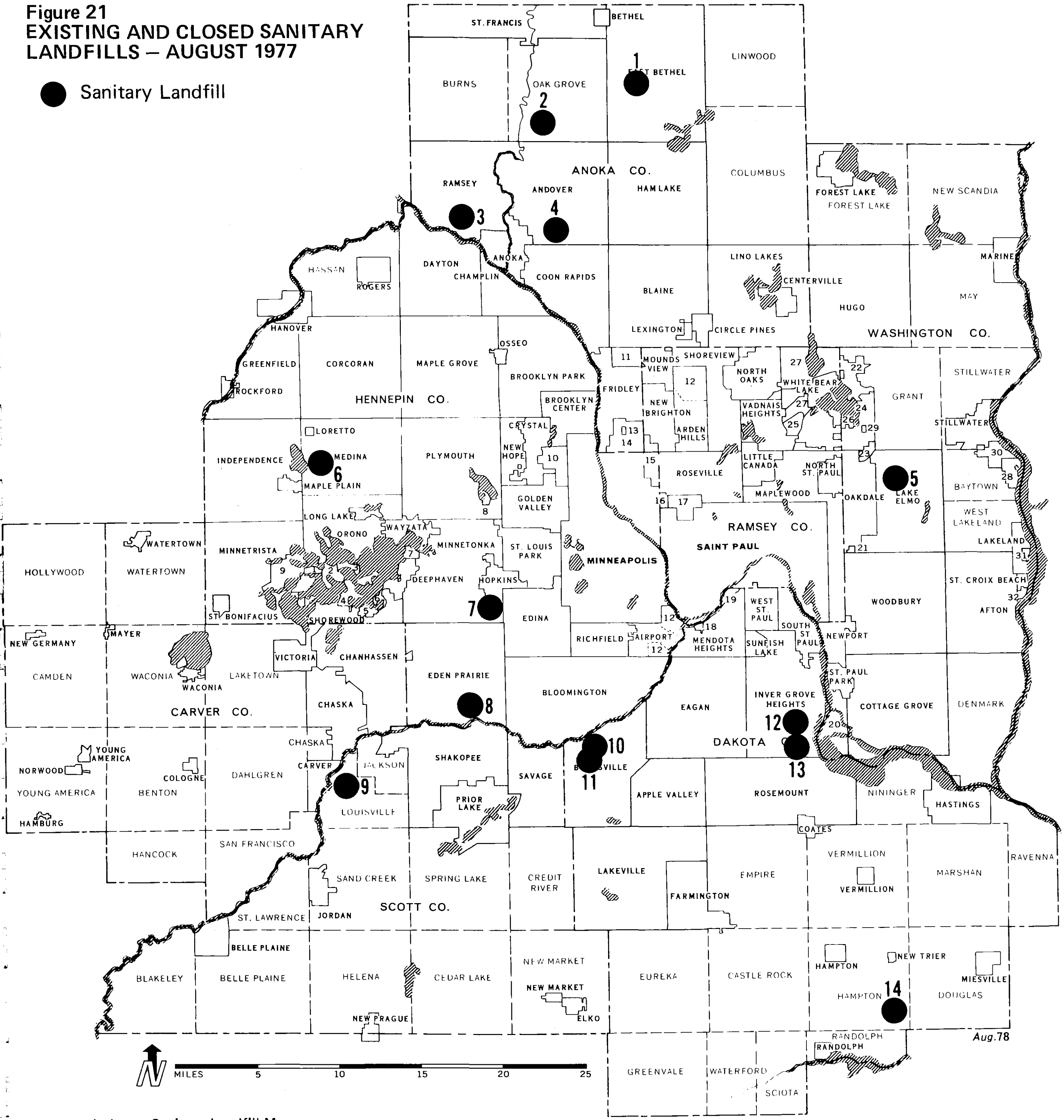
Table 4

Comparison of Leachate to Raw Sewage (Oleckno, 1976)

Constituent	Leachate	Raw Sewage
pH	6.9	7.1
Alkalinity (mg/l)	2,867	125
BOD_5 (mg/l)	1,987	205
Chlorides (Cl)	2,406	94

Figure 21
EXISTING AND CLOSED SANITARY LANDFILLS – AUGUST 1977

● Sanitary Landfill



Index to Sanitary Landfill Map

1. East Bethel Sanitary Landfill
2. Oak Grove Sanitary Landfill
3. Anoka Municipal Sanitary Landfill
4. Waste Disposal Engineering Sanitary Landfill
5. Washington County East Oakdale Sanitary Landfill (closed)
6. Woodlake Sanitary Landfill
7. Hopkins Sanitary Landfill
8. Flying Cloud Sanitary Landfill
9. Louisville Sanitary Landfill
10. Freeway Sanitary Landfill
11. Burnsville Sanitary Landfill
12. American Systems Inver Grove Heights Sanitary Landfill (closed)
13. Pine Bend Sanitary Landfill
14. Dakhue Sanitary Landfill

TABLE 5

COMPARISON OF MEAN LEACHATE COMPOSITION WITH CURRENT MINNESOTA DEPARTMENT OF HEALTH (Mn/DOH) STANDARDS*

(milligrams/liter unless other units are given)

Parameter	Mean Leachate	Mn/DOH Standards
Alk ($CaCO_3$)	2,062	-
NH_3-N	158	-
As	1.09	0.01
Ba	3.05	1.0
BOD	2,281	-
B	9.0	1.0
Cd	0.10	0.01
Ca	635	-
COD	7,996	-
Cl	773	250
Cr^{+6}	0.004	0.05
Cr (total)	0.58	-
Cu	25.2	1.0
CN	0.030	0.01
F	0.5	1.5
Hdns ($CaCO_3$)	2,332	-
Fe	697	0.3
Pb	0.43	0.05
Mg	260	-
Mn	27.5	0.05
Hg (ppb)	1.2	-
Ni	0.3	-
NO_3	0.46	10
Oil	24	-
pH (units)	6.8	6.5 - 8.5
Phenol	1.94	0.001
PO_4	5.16	-
K	270	-
Se	(undetected)	0.01
SiO_2	30	-
Ag	0.03	0.05
Na	276	-
SC (mmhos/cm)	20,540	700
SO_4	1,204	250
TDS	20,240	500
TSS	915	-
Zn	12.1	5

* All values are for Class A drinking water standards except for pH which is the standard for surface water containing aquatic life, and SC which is the standard for irrigation water.

Both Tables 4 and 5 show the amount of contaminants potentially available for release and movement if conditions are right.

The other characteristics of landfills --- thickness, compaction, milling and cover --- determine the field capacity or the amount of water the refuse can hold against gravitational force. They also determine how much surface rainwater enters the waste and flows or percolates into the groundwater. These parameters can be estimated or averaged. A study of the movement or transport of contaminants to sensitive receptors, such as individual or community wells, would be needed to determine the impact of landfill leachates on public health.

Landfilling in the Metropolitan Area

Fourteen sanitary landfills in the Metropolitan Area were evaluated; two are presently closed. Figure 21 indicates the location of the 14 landfill sites.

Additionally, there were 68 dumps that formerly operated in the Metropolitan Area. In 1968, a study was done by Black and Veatch that mapped all of the existing disposal sites, identified each facility, listed the type of each facility, indicated which sites accepted hazardous wastes, described the landscape around the site and estimated the solid waste volume of each site. Figure 20 is a copy of the map used in the Black and Veatch report.

This report and the technical study upon which it is based have excluded from consideration transfer stations, incinerators, garbage grinders, ash dumps and demolition fills. The facilities remaining for evaluation are dumps, landfills and sanitary landfills.

Regulation of Activity

All solid waste landfilling activities in the Metropolitan Area are now regulated by the MPCA, with preliminary approval or disapproval by the Metropolitan Council. All permit applications to MPCA are sent to the Council for review. If the Council disapproves a permit, MPCA will not issue one; if the Council approves a permit, MPCA still has the approval/disapproval option.

Additionally, all counties with solid waste sites have a permitting procedure. The Metropolitan Waste Control Commission (MWCC) has authorities with respect to disposal of hazardous waste, including waste sludge from treatment processes.

Potential Pollution from Landfill Leachates

A water balance method was used to approximate the volume that might enter a sanitary landfill, percolate downward, saturate fill material and leave the landfill as contaminated leachate. Details on the water balance method and various assumptions associated with it can be found in Appendix A.5. Existing data show that seven of the 14 landfills presently may be having leachate problems.

The results of this analysis (Appendix Table 5.2) show that the remaining seven landfills might begin to have problems in several years. The preliminary review indicates that the Pine Bend Landfill can potentially produce 24 million gallons of leachate annually; followed by Waste Disposal Engineering (Anoka County) at 16 million gallons and Flying Cloud (Hennepin County) and East Bethel (Anoka County) at 11 million gallons. These figures are rough approximations used only to assess magnitude and do not represent documented, in-field measurements.

Fifty-six of the 68 old dumps were evaluated in a cursory manner to indicate pollution potential. Twelve were not considered because they were transfer stations, incinerators, garbage grinders, ash dumps or demolition fills. The results of this evaluation (Appendix Table 5.3) indicate that 22 sites have a high or medium high potential for leachate percolation. Further study, including a determination of exact location, has to be done on these old sites.

An additional brief study was conducted to determine physical conditions least likely to result in leachate generation. It was found that the main factors controlling leachate production from percolating water are the properties of the final cover material, with largest leachate production occurring under coarse-grained cover.

Conclusions

1. There is a high potential for water pollution from sanitary landfills and closed dumps in the Metropolitan Area. Half of the sanitary landfills presently have leachate problems, and other landfills with highly permeable cover materials may begin to have leachate problems in several years.

2. The main factors controlling leachate production from percolating rainwater are the properties of the final cover materials. Large leachate volumes result from all highly permeable cover materials, such as sand and gravel. Cover materials that may result in low leachate volumes include clay, peat and lime sludge. Increasing the slope of a landfill does not appear to affect percolation as much as properties of the cover material.

3. Of the seven sanitary landfills in the study that have leachate problems, four are located in wetlands; one is located in a floodplain; one is located in a low area adjacent to a stream; and one is located in an abandoned gravel pit. Of the old dumps and landfills, seven are in wetlands; nine are in floodplains; and three are in abandoned gravel pits. These locations are unacceptable and are most likely resulting in the production of large leachate volumes.

4. Some field and laboratory analyses are necessary to substantiate these 'desk technique' conclusions. The report does not answer questions concerning the length of time a landfill may remain a potential problem, the rates of leachate movement in groundwater, the exact volumes of leachate presently being produced, the possible effects of leachate contamination of biologic communities, or the uses of groundwater downgradient from the disposal sites.

Recommendations

1. Based on these findings, abatement of pollution from percolation of water through landfills and dumps should receive a high priority in future water pollution programs.

2. A Phase II study proposal should contain a landfill leachate element that would address in greater detail the old dumps, effectiveness of landfill cover materials, groundwater monitoring systems, wells down-gradient from landfill sites and the development of better management techniques, regulatory guidance and monitoring systems.

MINING ACTIVITIES

Background

Sand, gravel and crushed stone aggregates are among the most important natural resources of the Seven-County Metropolitan Area. These products are the only major mineral resources mined in the Area. Because the demand for aggregate products is expected to increase, the water quality effects of mining this resource are being assessed as part of the Section 208 nonpoint program.

There are approximately 600 small to large-scale mining operations in the Seven-County Area. Activity at many of these sites is limited or sporadic, but potential pollution generating activities merit attention at the remaining sites.

A technical study was done to assess the type and amount of surface and groundwater pollution occurring in the Area as a result of mining and related activities. Existing mining operations were surveyed for location, type of operation and watershed containment. An inventory of regulated mining and processing operations was made and gross sediment resulting from mining was determined for dischargers with permits and land-disturbing activities. A proposal has been made regarding the need for further management efforts. The technical report is summarized here.

Mining Pollutants and Pollution Process

Mining of sand, gravel and crushed stone aggregate deposits involves several phases of activity. Each phase involves potential pollution generating activities. The pollutant of principal concern is sediment, although toxic and organic pollutants also cause concern.

Sediments are released through several excavation and processing steps. One source of sediment is overburden, the material on top of the aggregate deposit to be mined. In the Metropolitan Area, the overburden is usually an organic top soil and/or unsorted glacial till composed of fairly fine-grained, easily mobilized particles. When overburden is stripped and stockpiled near the removal site, land is disturbed and drainage patterns are altered, often resulting in erosion of exposed soils and stockpiled material.

The second phase of mining is extraction of the aggregates. During this phase the land is disturbed by truck and heavy machinery, and by actual traffic removal of large volumes of aggregate material. In crushed stone operations, the bedrock is rendered workable by blasting with explosives. All this activity generates dust and mobilizes fine-grained soil material, leaving it available for movement in the event of rain or strong winds.

The final two mining phases, transport and processing, involve movement of large quantities of aggregate material. Crushing of the material can occur before or after transport, depending on the type of operation and the physical constraints. The raw material is generally washed and sorted and the wastewater is either discharged to a receiving water body (by permit), recycled, or discharged to a seepage pond where the water returns to the groundwater system leaving the suspended soil behind.

If the sediment generated by any of these activities leaves the site, it is by permitted discharge (MPCA) or by overland runoff in suspension. Most material does not leave the site, but is collected in designed holding ponds or is captured by depressions within the excavation and processing site.

The toxic pollutants resulting from mining operations are heavy metals, oil and grease and pesticides. They can be introduced by leakage from vehicles and machinery, pesticide application to control rodents, and decomposition of derelict equipment. Organic pollution can result from sanitary facilities that discharge wastes improperly and from inducing changes in groundwater flow (septic tank effluent or contaminated river water) by altering flow patterns.

Migration of both toxic and organic materials could occur in overland runoff waters. Runoff would dissolve or suspend pollutants and move them to receiving water bodies (which could be collection ponds). Movement of organic pollutants into groundwater could potentially occur from careless sanitary practices or from altering groundwater flow conditions and inducing flow of contaminated material to new areas.

Mining in the Metropolitan Area

The Metropolitan Area is located in one of the best sand and gravel areas of the state because of the surficial glacial geology. Two glacial lakes influenced the area more than 9,500 years ago, leaving behind a wealth of valuable naturally sorted deposits. The Metropolitan Area leads the state in aggregate production due to a combination of readily available resources and high demand. Figure 22 is a surficial geology and geomorphic map adapted from Hogberg (1971) which shows the principal areas of concentrated mining activity. Crushed stone is also a valuable resource derived principally from the readily accessible Prairie du Chien group of limestones and dolomites.

The U.S. Department of the Interior, Bureau of Mines (USDI-BOM), annually gathers voluntary information on production of mined resources. Although this information is not required of a producer, USDI-BOM believes it is a very close indication of areawide production. Table 6 is a compilation of the past five production years. The "W" in some entries indicates that the information has been withheld for confidential reasons. Most of the material included in Table 6 goes directly into construction of roads and buildings.

The major mining operations in the Metropolitan Area occur near Hopkins, Edina, Osseo, Shakopee, Savage, Burnsville, Inver Grove Heights, Newport, St. Paul

Figure 22
SURFICIAL GEOLOGIC AND GEOMORPHIC MAP ADAPTED FROM HOGBERG (1971)

- Sand dune area
- Concentration of mining activity
- Alluvium
  Post-Des Moines Lake river terrace and alluvial deposits

Deposits related to the Des Moines Lake - Grantsburg Sublake

- Till
- Outwash
- Lake Deposits

Deposits related to Superior Lake

- Till
- Outwash

Deposits older than Superior Lake

- Drift, thinly covering bedrock

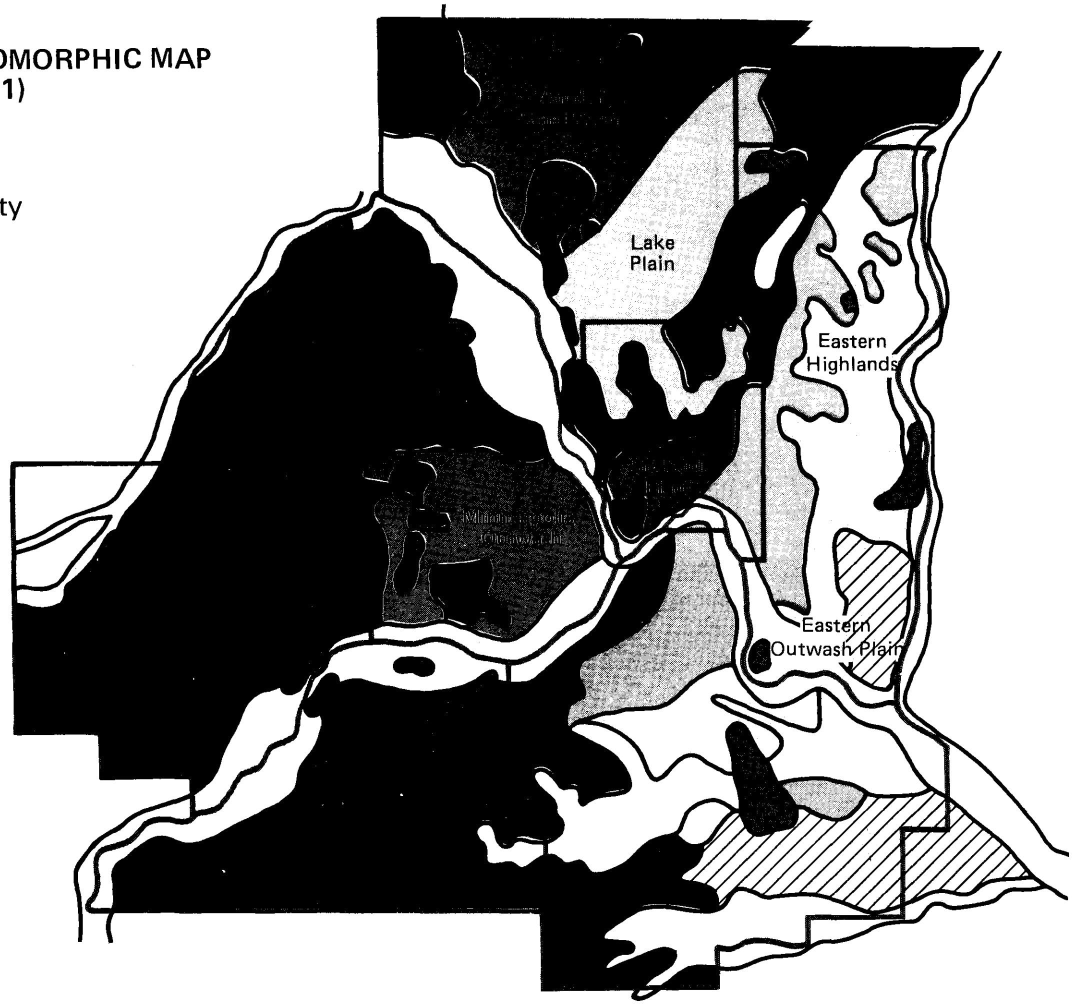


TABLE 6. SAND, GRAVEL AND CRUSHED STONE PRODUCTION FOR THE METROPOLITAN AREA, IN THOUSANDS OF SHORT TONS. SOURCE, UNITED STATES DEPARTMENT OF INTERIOR, BUREAU OF MINES (PERSONAL COMMUNICATION).

	Sand and Gravel					Crushed Stone				
County	Year: 1972	1973	1974	1975	1976	Year 1972	1973	1974	1975	1976
Anoka	W	W	W	W	311	-	-	-	-	-
Carver	639	W	396	326	W	-	61	-	-	-
Dakota	3,141	3,479	2,820	2,554	2,389	W	W	W	W	W
Hennepin	5,100	5,035	4,206	3,578	3,583	31	1	5	-	-
Ramsey	W	W	W	W	W	-	-	.5	-	-
Scott	279	610	519	640	518	770	1,019	1,122	920	1,025
Washington	2,559	2,928	2,852	2,501	2,596	W	W	W	W	892
TOTAL	W	13,170	11,807	W	W	2,190	2,605	2,621	W	W

- = no production W = withheld

Park and Grey Cloud Island, with major reserves in the Rosemount-Farmington area and Grey Cloud Island area, and smaller, lower quality deposits at Osseo, Anoka County (sand), northern Washington County (gravel), and mid-Washington County. An inventory by secondary watershed is given in Table 7, which presents figures for sand and gravel, crushed stone, and undifferentiated borrow pits. Almost all are small Minnesota Department of Transportation (Mn/DOT) or local highway maintenance 'borrow pits', established as a local supply of aggregate for routine road maintenance.

TABLE 7. INVENTORY OF MINING OPERATIONS

Primary Basin	Secondary Basin	Number of Mining Sites		
		Sand & Gravel	Crushed stone	Undifferentiated
Mississippi River	Direct discharge	70	5	13
	Cannon River	25	1	0
	Vermillion River	74	3	2
	Battle Creek	0	0	0
	Minnehaha Creek	28	0	3
	Bassett Creek	6	0	3
	Shingle Creek	15	0	1
	Rice Creek	18	0	5
	Coon Creek	4	0	14
	Elm Creek	1	0	3
	Rum River	7	0	0
	Crow River	48	0	0
Minnesota River	Direct discharge	55	8	23
	Nine Mile Creek	12	0	11
	Credit River	12	0	0
	Eagle Creek	1	0	0
	Purgatory Creek	3	0	1
	Riley Creek	0	0	0
	Bluff Creek	0	0	1
	Hazeltine-Bavaria Creek	4	0	2
	Chaska Creek	5	0	1
	Carver Creek	12	0	0
	Sand Creek	16	2	0
	Bevens Creek	11	0	0
	Robert Creek	13	0	0
St. Croix River	Direct discharge	30	2	1
	Sunrise River	22	0	0
	Silver Creek	5	0	0
	Browns Creek	6	0	1
	Valley Branch	24	0	3
	Trout Brook	1	0	0
	(637)	528	21	88

Table 7 shows that 55 percent of all Metropolitan Area sand and gravel operations are contained in watersheds directly discharging to the Mississippi, Vermillion, Minnesota or St. Croix Rivers. The Crow River and Valley Branch watersheds also contain a relatively high number of sand and gravel operations. These occurrences are directly related to the alluvial and outwash material abundant in the mined areas.

Regulation of Mining Activity

The location and type of a mining operation dictates whether it is subject to regulation under a local or county ordinance, a MPCA discharge permit, a Minnesota Department of Natural Resources (Mn/DNR) water appropriation permit, or no regulation whatsoever. Carver, Scott and Washington Counties have conditional or special use permits, while the other counties have placed control with local communities.

Mn/DNR has issued 23 active permits for water appropriation to mining operations that use water for processing or pump water to drain active pits. MPCA has issued 12 permits for discharge of wastewater or for operation of a recycling system that reuses water or discharges by seepage. Because of overlapping permits, the total number of state regulated operations in the Metropolitan Area is 26, or 4.1 percent of the total number (637) occurring. It is assumed that most activity that could generate considerable amounts of pollution would be associated with one of these 26 operations. The remaining operations are either very small or use no water in their excavation and processing, so they pose very little soil erosion or sedimentation threat to water quality.

Pollution Potential from Mining Activities

This element of the nonpoint source overview study assessed land-disturbing mining activity to see if it presented a pollution threat to area waters. Literature values on erosion from land-disturbing activity were combined with known acreage disturbed to arrive at erosion figures. Additional methodology information is contained in Appendix A.6.

The results of the mining study show that about 116 acres of new land are disturbed annually by mining ventures in the Metropolitan Area. This activity results in approximately 7,772 tons of erosion, with 50 percent, or 3,887 tons per year, reaching area water bodies. An additional 327 tons of sediment are contributed to water bodies through discharges permitted by MPCA under the State or National Pollution Discharge Elimination System (NPDES) permit system.

Conclusions

1. Fifty-five percent of Metropolitan Area sand and gravel operations are contained in watersheds directly discharging to the Mississippi, Vermillion, Minnesota, or St. Croix Rivers, with high concentrations also in the Crow River and Valley Branch watersheds.

2. Mining operations in the Metropolitan Area are not a major contributor to water pollution problems. All dischargers with permits are well under MPCA's relatively stringent standards, yielding an annual maximum of only 327 tons total suspended solids. A maximum gross annual loading figure of 3,887 tons of sediment from 116 acres of earth-moving activities can be approximated by making various assumptions and using literature figures.

3. The Metropolitan Area streams receiving the largest estimated annual sediment loads from mining operations are the Minnesota River (1,997

tons), the Mississippi River (796 tons) and the Vermillion River (704 tons). For comparison, a 50-acre subdivision, on a gently sloping site with moderately erodible soils and no erosion control would theoretically generate approximately 2,250 tons of sediment under the delivery conditions assumed in this report.

4. Minimal water quality degradation is expected from any other sources of pollution associated with mining.

5. The aggregate industry has responded well to the need to improve the quality of water resources, but further efforts are needed in the areas of water recycling and land reclamation.

Recommendation

Because of the lack of impact of mining on the water quality of the Metropolitan Area, a low priority should be assigned to any further investigations related to mining activities.

BARGE WASHWATER DISCHARGES

Background

According to a recent study by the Metropolitan Council, commodity movement by barges in the Metropolitan Area increased from 2 million to 10 million tons a year between 1953 and 1973 (Cheeney, 1976). The same study reports a movement of more than 5,800 barges to and from the Twin Cities in 1971. Barge navigation comes to a stop during December through early March as a result of ice conditions on the river. Peak months for barge movements are July through September (Appendix Figure 7.1).

The most frequently transported commodities are coal on the northbound trip to the Twin Cities and grain on the southbound trip (Appendix Figures 7.2 and 7.3). The economics of barge operations makes it necessary for operators to have the barge loaded during both the northbound and southbound trips. For this reason it becomes necessary to clean a barge that carried coal in order that it may return with a load of grain. A survey of barge washing facilities in the Metropolitan Area was undertaken to determine the impact of barge washing on water quality in the Area.

Pollutants and Pollution Process

All barge companies interviewed agreed that the barges they most often send for a wash are those carrying coal on the northbound trip and scheduled to carry grain on the southbound trip. Pollutants to be expected in barge wash-water and the bilge and ballast waters are coal dust residues and fuel oil. These products, if released to the stream, would result in biochemical oxygen demand and could also affect both the pH and turbidity of the water.

Water used for barge washing is pumped from the river and used to hose down the barge. The wash-water is then pumped out of the barge and one of two things happen. It is either released to the Mississippi River after going through a settling basin or it goes through a process of settling in a series of tanks and the water is released to the metropolitan sewer system for treatment at a wastewater treatment plant. Bilge and ballast waters pumped from towboats are also either released to the river or go to the wastewater treatment plant. Foreign matter such as coal residues and oils, if not removed before discharge, are allowed to enter the water.

Level of Washing Activity

It is estimated that in recent years 300 to 330 barges have been washed each month of the barging season. All the barges washed, with the exception of about six, are taken to two companies providing washing services. The first company washes approximately 180 barges a month. While in past years it had a permit to discharge wash-water to the river, more recently it has found it more economical to discharge the water to the sanitary sewer system for treatment at a metropolitan wastewater treatment plant, after some secondary settling treatment has been provided to the wash-water primarily to remove the coal residues. These residues are then sold to a power company as a fuel. The second company, which washes approximately 150 barges a month, is said to discharge wastewater and pumped bilge and ballast water to the river without adequate treatment. The lack of adequate treatment is a point of contention between the MPCA and the company.

A third company provides some washing of about six barge tanks transporting molasses or fertilizers. It discharges wash-waters to a metropolitan treatment plant.

Pollution Potential from Barge Washing

The MPCA, the regulatory agency responsible for the issuing of a permit for this type of activities, has set minimum standards for discharges of barge wash-waters to the river. The consolidation of barge-washing operations and the further elimination of all the discharges to the river but one have not warranted an extensive collection of data on the impact of washing activities on water quality. The survey has shown that the regulatory agency is in the process of bringing the remaining discharger into compliance with the standards, and that a minimal pollution potential exists.

Conclusion

Consolidation of barge washing into three commercial operations, the further elimination of all the discharges but one and the compliance program being set by the regulatory agency for that discharger indicate the potential pollution by barge wash-water to be minimal.

Recommendation

Because of the lack of impact of barge washing on the water quality of the Metropolitan Area, a low priority should be assigned to any further investigations related to the subject.

RIVER DREDGING

Background

In accordance with a congressional mandate, the U.S. Army Corps of Engineers (U.S.COE), Saint Paul District, annually maintains a navigation channel within the Metropolitan Area on the Mississippi, Minnesota and St. Croix Rivers. Much discussion has occurred concerning the water quality damage potentially resulting from the dredging activity associated with keeping these channels open. The nine-foot Channel Project in the Metropolitan Area extends from Mississippi River Mile (RM) 806.1 above the confluence with the Ohio River to RM 857.6 in Minneapolis; on the Minnesota River from the mouth to Savage (RM 14.7); and on the St. Croix River from the mouth to Stillwater (RM 24.5). Additionally, a nine-foot channel is maintained on the Minnesota River by the Peavey Company to RM 21.8 and a four-foot channel is maintained by the COE from RM 21.8 to 25.6 at Shakopee. A three-foot channel from Stillwater to Taylors Falls (RM 51.8) is authorized for COE maintenance, with recent activities limited to clearing and snagging due to the Wild and Scenic River status it has received.

The COE is responsible for spoils disposal site selection except in the Upper St. Anthony Falls (SAF) pool and the lower Minnesota River, where enabling legislation gives this responsibility to the City of Minneapolis and the Lower Minnesota River Watershed District, respectively. The Great River Environmental Action Team (GREAT) was established to review the environmental impact of dredging activities. GREAT is an interagency cooperative effort between COE, U.S. Fish and Wildlife Service, MPCA, EPA, U.S. Coast Guard, U.S. Geological Survey (USGS) and concerned local parties.

The maintenance of a navigation channel within the Twin Cities Metropolitan Area provides for an economical downstream interchange of a tremendous amount of grain and fuel products through a system of locks and dams operated by the COE. Barge traffic is expected to increase over the next 25 years.

The purpose of this report is to identify the types and amounts of pollution occurring within the Metropolitan Area as a result of maintenance dredging. The report analyzes the GREAT effort and presents a management recommendation.

Pollutants and Pollution Process

The major pollutants of concern in dredging activities are sediment and toxic materials, with nutrients, oxygen-demanding substances, oil and grease and bacteria also of interest. Suspended sediment and turbidity result from all of the bottom-disturbing activities associated with dredging and spoils disposal. The degree to which harm is done as a result of dredging is the subject of much research by COE, GREAT and the Dredged Material Research Program (DMRP) of COE. Possible ill effects include decrease in light penetration, river bottom covering, inhibition of proper oxygen exchange in fish, flocculation of planktonic algae, depletion of oxygen resources and potential release of associated toxic material.

Toxic materials such as heavy metals, pesticides and PCB's adhere to sediment and may be released if conditions are proper at the time of sediment disturbance. The release of toxic material from sediment depends on oxygen conditions, pH conditions, sorptive capabilities of the sediment and organic matter,and physical conditions at the disturbed site.

Nutrients (nitrogen and phosphorus) are also released according to the geochemical and biochemical nature of the sediment and water at the time of disturbance. An oxygen demand is immediately exerted at the time of sediment disturbance and generally lasts for a short time. Oil and grease and bacteria are of concern locally where accumulations may be re-suspended in large quantities upon sediment disturbance.

Sediment and associated pollutants are first introduced as potential pollution problems at the time material is actually dredged. Hydraulic dredges employ a pump to lift material from the bottom and transport it by boat or pipeline to a disposal site where a slurry of 20-30 percent solids is discharged, again presenting a pollution opportunity. Mechanical dredges use a clamshell crane to remove up to four cubic yards of sediment at one lifting. Next, this material is placed in bulk into a dump scow and moved to a disposal site where the sediment is dropped in six feet of water to be cast on shore by another crane and spread by bulldozer. During all phases of the mechanical dredging process, pollutants are potentially available for release and transport.

The principal secondary process of pollution generation is propellor-wash from tenders, tows and recreational boats. Dredge tenders are large turbidity generators, particularly at shallow water operations.

Materials introduced through any of these disturbances will travel until gravity allows them to settle or until biological or chemical processes occur to take the pollutant from the transport system. The water quality effects of dredging activities are discussed on the next page.

Dredging in the Metropolitan Area

The following figures represent the approximate yearly amounts of material dredged in the Metropolitan Area since the late 1950's:

Minnesota River	-	13,000 cubic yards
St. Croix River	-	42,000 cubic yards
Upper and Lower SAF Pools	-	23,000 cubic yards
Pool No. 1	-	126,000 cubic yards
Pool No. 2	-	180,000 cubic yards

For reference, the Mississippi River is divided into a series of pools with Upper SAF Pool from RM 857.6 to RM 853.8; Lower SAF Pool to RM 853.3; Pool No. 1 to RM 847.6; Pool No. 2 to RM 815.3; and Upper Pool No. 3 to the point where the Mississippi River leaves the Metropolitan Area at RM 806.1. The Saint Paul Barge Terminal (RM 837.45) is the single largest location needing routine maintenance dredging, with a 58 percent frequency of dredging and an annual volume removed equal to 82,000 cubic yards.

Table 8 gives the amount of material annually dredged in each pool from 1973 to 1976. Information on the location of dredging activity is included in Appendix A.8.

Table 8

VOLUME OF MATERIAL DREDGED, 1973-1976, IN THOUSAND CUBIC YARDS

Year	SAF Pools	Pool No. 1	Pool No. 2	Minnesota River	St. Croix River
1976	115.7	17.1	191.5	63.8	0
1975	0	28.4	26.6	0	0
1974	134.4	0	522.3	0	183.0
1973	28.2	82.6	312.2	62.9	0

Most of the material dredging in the Metropolitan Area is done by the Dredge Wm. A. Thompson or by the Derrickbarge Hauser. The Thompson is a large hydraulic dredge equipped with a 22 inch intake, 20 inch discharge and 1,800 horsepower diesel driven pump; manned by a crew of 56-66; and capable of moving approximately 17,000 cubic yards of material per day. Spoils from the Thompson can be transported 4,700 feet by pipeline over water and 2,000 feet over land. The Hauser is a 66 foot by 45 foot barge with a deck-mounted four cubic yard crane, powered by a 317 horsepower diesel engine with a lifting capacity of 55,000 pounds at a 25 foot radius. The Hauser is attended by five tenders, six dumpscows, a cranebarge, two bulldozers and four barges, all operating to transport spoils up to 7-1/2 miles from the dredging location. The Hauser is capable of moving approximately 3,600 cubic yards of material per day. In some instances, private dredging contractors or smaller pieces of government equipment are used in place of larger equipment.

Appendix Table 8.1 lists the location and average annual dredged volume of the Region's most frequently dredged channels. Following the table in Appendix A.8 is a brief description of each of the pools indicated in the table.

Pollution Potential from River Dredging

This element of the nonpoint source pollution overview was designed to assess the threat that annual river dredging presents to water quality. Frequently dredged channels were identified (Appendix Table 8.1) and literature values of the water quality effects of dredging were reviewed and compared to the conditions within the Region.

The results of the study indicated that a pollution potential of dredging does exist, but that under the usual conditions the effects will be short-term and local. Sediment will usually fall out of suspension within one mile of dredging disposal and will tend to carry with it any pollutants that were released upon disturbance due to dredging.

It was further found that the COE, MPCA, EPA and others are studying the dredging and disposal problem under the auspices of the GREAT and through the disposal permit procedure. The Metropolitan Council probably could not contribute further to mitigation of the problem.

Conclusions

1. Most pollution resulting from dredging and disposal is short-term and localized, with no major degradation generally occurring.

2. The biochemistry and geochemistry of sediment-water reactions determine to a principal extent the nature of the pollutant behavior.

3. In most cases, MPCA water quality standards will be exceeded for only a short duration, if at all.

4. Under oxic conditions most pollutants will settle out of the water column and remain immobile in the bottom sediments.

5. Significant amounts of toxic material are not released into the solution phase during dredging and disposal operations, but monitoring should continue to determine if any long-term effects exist.

6. Because pollutants exist especially in bottom sediments downstream from major dischargers, dredging efforts should be minimized downstream of major outfalls during periods of low flow.

7. The current efforts of GREAT and COE have been effective in defining and alleviating environmental problems associated with dredging.

Recommendation

Based on the findings of the dredging element of this report, it is recommended that the Metropolitan Council monitor the progress of dredging operations, but formalize no management program that would overlap with ongoing GREAT and COE efforts. If at some time the Council finds that the Metropolitan Area interests are not being adequately addressed, it should be prepared to petition COE and GREAT as to their reasons for not addressing such issues.

OTHER SOURCES OF POLLUTION

Background

In 1977, The Metropolitan Council contracted with the Association of Metropolitan Soil and Water Conservation Districts to conduct a general survey of small-scale sources of pollution which were not being addressed by the Council in other studies or for which additional unrecorded data might be available. The contract required information on pollution resulting from the following sources:

- Large-scale septic tank system failures;
- Excessive highway/street sanding;
- Open sand/gravel/black dirt borrow pits;
- Poorly constructed storm sewers causing erosion;

- Landfills/dumps causing a problem;
- Heavily polluted runoff; and
- Other pollution sources.

Other Pollution Sources

The survey recorded approximately 70 specific problem areas. These problems fall into four categories: 1) sediments from storm sewers, open borrow pits and street sanding; 2) nutrients from septic tank failures or drainage from residential lawns, and sanitary sewer seepage; 3) landfill leachates; and 4) industrial wastes spillage or runoff from industrial sites.

Half the reported problems are sediments entering a water body, mostly the result of poor storm sewer construction causing erosion, although a few borrow pits and street sanding were also noted as problem areas. The estimated magnitude of each of the problems indicates that while these problems might be cause for concern for some local residents, the degree of magnitude of the pollution problems is very slight and could be taken care of locally without much effort.

One-third of the reported problems are nutrients entering a lake or other water bodies. Most of the identified problems are the result of numerous failing septic tank systems draining to a lake.

A few of the problems are also the result of sanitary sewers leaking to wetlands adjacent to lakes. A large-scale study of failing septic tank systems is being conducted in the Region by the MWCC under Section 201 of the Federal Water Pollution Control Act. Alternative systems will be proposed to solve existing problems and prevent future problems.

The Metropolitan Council is developing an institutional structure and a management program to resolve the problem of water pollution through failing septic tank systems. This effort is part of the point source section of the water quality management plan being prepared by the Council under Section 208 of the Federal Water Pollution Control Act. The two programs should adequately deal with these problems in the near future. Leaking sanitary sewers will be repaired as part of the normal maintenance program for sanitary sewer systems.

The survey reported that seven landfills are causing water pollution through leaching. A desk study of all the landfills in the Metropolitan Area has already indicated that landfills present a serious potential for polluting groundwater (pages 62-63). A more detailed study on nonpoint source pollution in the Metropolitan Area will further assess the magnitude of the potential problems and recommend a management program and an institutional structure to implement the program.

In addition, a few cases of industrial wastes polluting waters were cited. The most notorious and serious case in the metropolitan Area is located within the City of St. Louis Park. Industrial wastes in the form of coal-tar derivatives were dumped on the ground several years ago by a company no longer using the site. Studies of the soils and of the groundwater at the site[10] have shown that the chemicals are finding their way into the upper aquifers and are threatening the local water supply. The MPCA, Mn/DOH and the Minnesota Environmental Quality Board (EQB) are aware of this serious problem and working to develop some solution.

Conclusion

The results of the survey of small-scale pollution problems caused by various diffuse sources have shown that there appear to be no additional problems beyond those identified in the studies of pollution from agricultural urban runoff, stream channel erosion, construction activities, dredging, barge washing, mining and landfills, related to this overview report.

Recommendation

Based on these findings, no further regional action is believed necessary to address sources of pollution other than the priorities identified in this report.

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10 Barr Engineering, 1977

SECTION IV COMPARISON OF NONPOINT SOURCE CONTRIBUTIONS

This section compares the findings from studies of nine nonpoint sources of pollution and establishes priorities for future water quality management efforts. Significant pollutants are examined to determine their relative importance.

Study results were that five nonpoint sources present major water pollution potential, and four others present less significant potential. Major water pollution potential was found to exist as a result of agricultural runoff, construction erosion, urban runoff, stream channel erosion and landfill leachates. Mining, barge cleaning, dredging and miscellaneous nonpoint sources were found to have less significant pollution potential.

Major findings for each individual study are summarized in Section I and details of each study are given in Section III of this report. Results of the entire study must be kept in perspective, because all analyses were performed using existing data and information. The point source information included in this section is based on 1976 discharge figures.

POLLUTANT COMPARISONS BY WATERSHED

The pollutant information determined for the five major nonpoint contributors was tabulated and compared by watershed. The U.S.D.A.-Soil Conservation Service (SCS) Conservation Needs Inventory (CNI) watershed designations were used. The Hickok watershed delineations used in the urban runoff study are converted to CNI watersheds in Appendix B.

Table 9 is a matrix of pollutant percentage versus type of nonpoint source contributor. Major municipal and industrial point discharges occurring within the watershed were included for comparison purposes. Landfill leachates, although a potential major pollution contributor, were not included in this watershed analysis because the tabulation contains pollutants generally not associated with leachates. In this table, a solid line (-) indicates that no determination was made and a zero (0) indicates that no pollutant contribution comes from this source. No BOD/COD determinations were made for agricultural runoff and no chemical pollutant figures were generated for construction and stream channel erosion because of the limited scope of this report.

In Table 9, the acreage noted in the 'Drainage Area' column within a watershed is distributed among several land uses. To put acreages in perspective, the following figures represent total Metropolitan Area land occurring within each of the major land use categories that were analyzed. The total acreage included below shows more acreage than exists in the Region because some overlap occurred between the open space urban category and the agricultural category. This overlap is due primarily to the 'idle' land on the urban fringe that is not intensively farmed.

- Agricultural - 1,300,000 acres
- Construction - 3,000 acres
- Urban - 861,000 acres
  - (open space 603,000)
  - (lakes 65,000)
  - (residential, commercial, industrial 193,000)
- Stream channel - 250 channel miles
- Sanitary landfills (14) 1,000 acres

Urban land use was broken down to show that much of the urban acreage is in open space and lakes. The focus of urban runoff pollution discussion will be on the 193,000 acres of residential and commercial/industrial use. Some of the urban open space also overlaps with the agricultural use category.

Table 10 is a listing of those watersheds that experience relatively significant water pollution from the various land uses evaluated. These watersheds will provide focal points for future management efforts.

Several of the watersheds listed in Table 10 occur in more than one category. These watersheds exhibit a diversity of nonpoint pollution problems largely resulting from varying land uses. Many of the agriculturally-related watersheds are the same for each subcategory of pollutant type.

Watersheds that commonly appear in the agriculture categories are located in Carver County, western Hennepin County, southern Scott and Dakota Counties, and northern Washington County. Exceptions to this are the Saint Paul Watershed and Rice Creek large watersheds with quite variable land uses.

TABLE 9. ESTIMATED LOADING PERCENTAGES BY WATERSHED (Twin Cities Metropolitan Area)

WATERSHED Name	Number	Drainage Area (Acres)	CONSTITUENTS	Agricultural	Urban	Construction	Streambank and Gully Erosion	Municipal	Industrial
Mississippi River (Upper and Osseo)	0-81 0-83 (Combined for Assessment)	42,048	TSS	57	17	0	26	0	1
			BOD**	--*	84	--	--	16	0
			TP	2	17	--	--	61	0
			TN	26	38	--	--	36	0
			COD	--	85	--	--	15	--
Elm Creek	0-82	67,520	TSS	92	4	2	2	1	0
			BOD	--	98	--	--	2	0
			TP	85	13	--	--	2	0
			TN	78	22	--	--	0	0
			COD	--	99	--	--	1	0
Sand Creek	0-84	9,280	TSS	29	71	0	0	0	0
			BOD	--	100	--	--	0	0
			TP	33	67	--	--	0	0
			TN	19	81	--	--	0	0
Coon Creek	0-85	45,568	TSS	76	21	0	3	0	0
			BOD	--	100	--	--	0	0
			TP	63	37	--	--	0	0
			TN	46	54	--	--	0	0
Rice Creek	0-86	121,856	TSS	82	14	3	1	0	0
			BOD	--	100	--	--	0	0
			TP	71	29	--	--	0	0
			TN	63	37	--	--	0	0
Shingle Creek	0-87	25,728	TSS	62	31	4	3	0	0
			BOD	--	100	--	--	0	0
			TP	25	75	--	--	0	0
			TN	26	74	--	--	0	0
Mississippi River (St. Paul and Direct)	0-88 0-91 0-96 (Combined for Assessment)	198,720	TSS	44	31	9	6	10	1
			BOD	--	12	--	--	86	2
			TP	3	5	--	--	92	0
			TN	4	9	--	--	83	4
			COD	--	18	--	--	78	4
Basset Creek	0-89	27,264	TSS	56	37	6	1	0	0
			BOD	--	100	--	--	0	0
			TP	25	75	--	--	0	0
			TN	24	76	--	--	0	0

* (--) Means not determined
**Percentages will not include BOD from agricultural uses

TABLE 9 (continued)

WATERSHED Name	Number	Drainage Area (Acres)	CONSTITUENTS	PERCENTAGE OF TOTAL DETERMINED WATERSHED LOADING Agricultural	Urban	Construction	Streambank and Gully Erosion	Municipal	Industrial
Minnehaha Creek	0-90	113,600	TSS	77	18	3	1	1	0
			BOD	--	98	--	--	2	0
			TP	45	49	--	--	6	0
			TN	46	52	--	--	2	0
			COD	--	99	--	--	1	0
Cottage Grove	0-92	17,024	TSS	92	4	0	4	0	0
			BOD	--	100	--	--	0	0
			TP	88	12	--	--	0	0
			TN	75	25	--	--	0	0
North Vermillion River	0-93	40,064	TSS	90	10	1	0	1	0
			BOD	--	91	--	--	9	0
			TP	80	20	--	--	0	0
			TN	60	30	--	--	10	0
Hardwood (Vermillion)	0-94	33,280	TSS	100	0	0	0	0	0
			BOD	--	0	--	--	0	0
			TP	100	0	--	--	0	0
			TN	100	0	--	--	0	0
Vermillion River	0-95	112,960	TSS	95	2	2	1	1	1
			BOD	--	62	--	--	31	7
			TP	63	5	--	--	32	0
			TN	76	11	--	--	13	0
			COD	--	78	--	--	22	--
Mississippi River (East Dakota County)	0-97	18,304	TSS	86	0	0	14	0	0
			BOD	--	0	--	--	0	0
			TP	100	0	--	--	0	0
			TN	100	0	--	--	0	0
Sarah Creek	6-01	6,336	TSS	97	0	0	3	1	0
			BOD	--	0	--	--	100	0
			TP	100	0	--	--	0	0
			TN	100	0	--	--	0	0
Crow River	6-03	21,376	TSS	95	0	0	5	1	0
			BOD	--	0	--	--	100	0
			TP	100	0	--	--	0	0
			TN	100	0	--	--	0	0
Louzers L. Outlet	6A-15	960	TSS	100	0	0	0	0	0
			BOD	--	0	--	--	0	0
			TP	100	0	--	--	0	0
			TN	100	0	--	--	0	0
L. Buffalo Creek	6B-08	1,088	TSS	100	0	0	0	0	0
			BOD	--	0	--	--	0	0
			TP	100	0	--	--	0	0
			TN	100	0	--	--	0	0

TABLE 9 (continued)

WATERSHED Name	Number	Drainage Area (Acres)	CONSTITUENTS	PERCENTAGE OF TOTAL DETERMINED WATERSHED LOADING: Agricultural	Urban	Construction	Streambank and Gully Erosion	Municipal	Industrial
Crane Creek	6B-09	1,792	TSS	100	0	0	0	0	0
			BOD	--	0	--	--	0	0
			TP	100	0	--	--	0	0
			TN	100	0	--	--	0	0
Winsted Lake	6B-10	7,232	TSS	99	0	0	1	0	0
			BOD	--	0	--	--	0	0
			TP	100	0	--	--	0	0
			TN	100	0	--	--	0	0
Pioneer Creek	6B-11	33,664	TSS	99	0	0	1	0	0
			BOD	--	0	--	--	0	0
			TP	100	0	--	--	0	0
			TN	100	0	--	--	0	0
L. South Fork Crow River	6B-12	63,168	TSS	95	0	3	2	1	0
			BOD	--	0	--	--	100	0
			TP	100	0	--	--	0	0
			TN	100	0	--	--	0	0
L. Rum River	7-15	34,112	TSS	80	4	0	16	1	0
			BOD	--	89	--	--	11	0
			TP	85	15	--	--	0	0
			TN	75	25	--	--	0	0
Seelye Brook	7-16	8,960	TSS	100	0	0	0	0	0
			BOD	--	0	--	--	0	0
			TP	100	0	--	--	0	0
			TN	100	0	--	--	0	0
Cedar Creek	7-17	36,480	TSS	99	0	1	1	0	0
			BOD	--	0	--	--	0	0
			TP	100	0	--	--	0	0
			TN	100	0	--	--	0	0
Ford Brook	7-18	29,760	TSS	100	0	0	1	0	0
			BOD	--	0	--	--	0	0
			TP	100	0	--	--	0	0
			TN	100	0	--	--	0	0
Forest Prairie Creek	8-114	1,472	TSS	100	0	0	0	0	0
			BOD	--	0	--	--	0	0
			TP	100	0	--	--	0	0
			TN	100	0	--	--	0	0
Minnesota River (Upper, Shakopee, Belle Plaine)	8-122	74,752	TSS	24	2	1	74	1	1
	8-125		BOD	--	46	--	--	43	11
	8-126		TP	36	8	--	--	56	--
	8-136		TN	48	18	--	--	34	--
	(Combined for Assessment)		COD	--	66	--	--	34	--

TABLE 9 (continued)

WATERSHED Name	Number	Drainage Area (Acres)	CONSTITUENTS	PERCENTAGE OF TOTAL DETERMINED WATERSHED LOADING Agricultural	Urban	Construction	Streambank and Gully Erosion	Municipal	Industrial
Robert Creek	8-124	9,728	TSS	26	0	0	74	0	0
			BOD	--	0	--	--	0	0
			TP	100	0	--	--	0	0
			TN	100	0	--	--	0	0
Silver Creek	8-127	17,600	TSS	95	0	0	5	0	0
			BOD	--	0	--	--	0	0
			TP	100	0	--	--	0	0
			TN	100	0	--	--	0	0
Beven's Creek	8-128	36,672	TSS	96	0	0	4	1	0
			BOD	--	0	--	--	100	0
			TP	100	0	--	--	0	0
			TN	100	0	--	--	0	0
Sand Creek	8-129	45,504	TSS	64	1	0	36	1	0
			BOD	--	20	--	--	80	0
			TP	97	3	--	--	--	0
			TN	98	2	--	--	--	0
Porter Creek	8-129-1	30,400	TSS	98	0	2	1	0	0
			BOD	--	0	--	--	0	0
			TP	100	0	--	--	0	0
			TN	100	0	--	--	0	0
Raven Stream	8-129-2	22,848	TSS	98	0	0	2	0	0
			BOD	--	0	--	--	0	0
			TP	100	0	--	--	0	0
			TN	100	0	--	--	0	0
Carver Creek	8-130	51,328	TSS	96	1	0	3	1	1
			BOD	--	36	--	--	46	18
			TP	85	3	--	--	8	4
			TN	93	2	--	--	5	0
			COD	--	52	--	--	48	--
Chaska Creek	8-131	8,576	TSS	94	0	0	6	0	0
			BOD	--	0	--	--	0	0
			TP	100	0	--	--	0	0
			TN	100	0	--	--	0	0
Hazeltine-Bavaria Creek	8-132	8,000	TSS	78	8	5	8	1	0
			BOD	--	45	--	--	55	0
			TP	50	17	--	--	33	0
			TN	46	28	--	--	26	0
			COD	--	68	--	--	32	0
Bluff Creek	8-133	4,480	TSS	88	4	0	8	0	0
			BOD	--	100	--	--	0	0
			TP	83	17	--	--	0	0
			TN	76	24	--	--	0	0

TABLE 9 (continued)

WATERSHED			CONSTITUENTS	PERCENTAGE OF TOTAL DETERMINED WATERSHED LOADING					
Name	Number	Drainage Area (Acres)		Agricultural	Urban	Construction	Streambank and Gully Erosion	Municipal	Industrial
Riley Creek	8-134	6,720	TSS	94	6	0	0	0	0
			BOD	--	100	--	--	0	0
			TP	67	33	--	--	0	0
			TN	66	34	--	--	0	0
Spring Lake	8-135	20,032	TSS	95	3	1	1	1	0
			BOD	--	76	--	--	24	0
			TP	63	11	--	--	26	0
			TN	75	17	--	--	8	0
			COD	--	86	--	--	14	0
Credit River	8-137	31,999	TSS	96	3	0	1	1	0
			BOD	--	79	--	--	21	0
			TP	78	10	--	--	12	0
			TN	62	34	--	--	4	0
			COD	--	91	--	--	9	0
Purgatory Creek	8-139	23,296	TSS	76	9	10	5	0	0
			BOD	--	100	--	--	0	0
			TP	62	38	--	--	0	0
			TN	55	45	--	--	0	0
Nine Mile Creek	8-140	28,544	TSS	0	66	34	1	0	0
			BOD	0	100	--	--	0	0
			TP	0	100	--	--	0	0
			TN	0	100	--	--	0	0
Lower Minnesota River	8-141 8-138	41,280	TSS	47	20	21	12	1	1
			BOD	--	52	--	--	30	18
			TP	12	10	--	--	78	0
			TN	15	20	--	--	75	0
			COD	--	67	--	--	23	--
South Branch Sunrise River	9-21	44,032	TSS	97	2	0	1	0	0
			BOD	--	100	--	--	0	0
			TP	92	8	--	--	0	0
			TN	85	15	--	--	0	0
West Branch Sunrise River	9-22	19,456	TSS	99	0	1	0	0	0
			BOD	--	0	--	--	0	0
			TP	100	0	--	--	0	0
			TN	100	0	--	--	0	0
Marine on St. Croix	9-34	24,128	TSS	100	0	0	1	0	0
			BOD	--	0	--	--	0	0
			TP	100	0	--	--	0	0
			TN	100	0	--	--	0	0
Big Marine Lake	9-36	30,272	TSS	99	0	0	1	0	0
			BOD	--	0	--	--	0	0
			TP	100	0	--	--	0	0
			TN	100	0	--	--	0	0

TABLE 9 (continued)

WATERSHED			CONSTITUENTS	PERCENTAGE OF TOTAL DETERMINED WATERSHED LOADING					
Name	Number	Drainage Area (Acres)		Agricultural	Urban	Construction	Streambank and Gully Erosion	Municipal	Industrial
Brown Creek	9-37	12,992	TSS	88	7	1	5	0	0
			BOD	--	100	--	--	0	0
			TP	86	14	--	--	0	0
			TN	69	31	--	--	0	0
Stillwater (St. Croix)	9-39	52,992	TSS	87	2	1	9	1	0
			BOD	--	56	--	--	44	0
			TP	86	7	--	--	7	0
			TN	67	8	--	--	25	0
			COD	--	68	--	--	32	--
Afton (St. Croix)	9-41	20,480	TSS	58	0	0	42	0	0
			BOD	--	0	--	--	0	0
			TP	100	0	--	--	0	0
			TN	100	0	--	--	0	0
Basswood Grove	9-42	14,080	TSS	83	0	0	17	0	0
			BOD	--	0	--	--	0	0
			TP	100	0	--	--	0	0
			TN	100	0	--	--	0	0
Chub Creek	10-09	48,448	TSS	98	0	0	2	0	0
			BOD	--	0	--	--	0	0
			TP	100	0	--	--	0	0
			TN	100	0	--	--	0	0
L. Cannon River	10-13	51,200	TSS	99	0	0	1	1	0
			BOD	--	0	--	--	100	0
			TP	100	0	--	--	0	0
			TN	100	0	--	--	0	0
Total Metropolitan Area			TSS	74	5	2	18	1	1
			BOD	--	24	--	--	74	2
			TP	34	8	--	--	58	0
			TN	40	14	--	--	44	2
			COD	--	38	--	--	59	3
			Cr	--	17	--	--	76	7
			Cu	--	37	--	--	63	0
			Ni	--	78	--	--	0	22
			Pb	--	77	--	--	23	0
			Zn	--	50	--	--	46	4

TABLE 10. WATERSHEDS DEMONSTRATING HIGH RELATIVE POTENTIAL LOADINGS FROM VARIOUS NONPOINT SOURCES IN THE TWIN CITIES METROPOLITAN AREA

Nonpoint Source and estimated loadings	Watersheds with high relative loading
Agricultural:	Stillwater Watershed
	Big Marine Lake *
Sediments (greater than 50,000 tons per year)	Marine on St. Croix *
	Porter Creek *
	Sand Creek (Scott County)
	Elm Creek
	Lower Cannon River
	Minnehaha Creek *
	Carver Creek *
	Bevens Creek *
	Lower South Fork Crow River
	Pioneer Creek *
	Credit River *
	Vermillion River
	Chub Creek
	St. Paul Watershed
	Basswood Grove *
	(* - greater than 2.5 tons/acre)
Agricultural:	
Nutrients (greater than 300,000 lbs N per year)	Rice Creek
	St. Paul Watershed
	Minnehaha Creek *
	Carver Creek *
	Bevens Creek
	Minnesota River (8-122)
	Lower South Fork Crow River
	Porter Creek *
	Pioneer Creek *
	Credit River *
	Vermillion River
	Chub Creek
	Lower Cannon River *
	Elm Creek
	Sand Creek (Scott County) *
	Stillwater Watershed
	(* - greater than 10 lbs N/acre)
Agricultural:	
Feedlots (density of greater than 175 animal units per square mile)	Carver Creek
	Bevens Creek
	Silver Creek (Carver County)

Table 10 (continued)

Nonpoint Source and estimated loadings	Watersheds with high relative loading
Agricultural:	
Feedlots (density of greater than 175 animal units per square mile) (continued)	Chaska Creek Winsted Lake Watershed Chub Creek Robert Creek
Construction Erosion: (greater than 2,000 tons per year)	Minnesota River (8-141) * Elm Creek Rice Creek Bassett Creek * Minnehaha Creek St. Paul Watershed * Vermillion River * Hazeltine-Bavaria Creek * Purgatory Creek Nine Mile Creek * Stillwater Watershed * Lower Sourth Fork Crow River * (* - greater than 50 tons/acre of developing land)
Urban Runoff: (watersheds with consistent high loadings for several pollutants)	St. Paul Watershed Mississippi River (0-88, 81) Minnehaha Creek Waconia, Belle Plaine, Jordan FGC's Bluff Creek Minnesota River (8-138, 141) Nine Mile Creek Bassett Creek Shingle Creek Chaska Creek Riley Creek

Table 10 (continued)

Nonpoint Source and estimated loadings	Watersheds with high relative loading
Stream Channel Erosion:	
(greater than 1,000 feet of erosion per square mile)	Minnesota River (8-122*, 126*, 138) Hazeltine-Bavaria Creek Silver Creek Bevens Creek Bluff Creek * Carver Creek Chaska Creek Robert Creek * Belle Plaine (Minnesota River) Sand Creek (Scott County) Basswood Grove (* - greater than 3,000 feet erosion/sq. mile)
Landfill Leachates:	
(greater than 11 million gallons of leachate produced per year)	St. Paul Watershed Coon Creek Minnesota River (8-141, 138) Cedar Creek

Many of the watersheds identified as problems from stream channel erosion also occur as agriculturally-related problems. Most significant stream channel erosion occurs in the Minnesota River drainage basin of Carver and Scott Counties. The one noticeable exception to this is Basswood Grove, which drains a bluff area with rock outcroppings within the St. Croix River Valley.

Similarities exist quite often between the watersheds with construction problems and those with urban stormwater problems. Commonly appearing problem watersheds or portions of watersheds occur in the central cities and in the developing ring around the central cities. Following the construction/urbanization phase, many of the watersheds identified in the construction problem category will have urban runoff problems if proper management does not occur.

Several watersheds exist in apparently unrelated categories in Table 10. Minnehaha Creek and the Saint Paul Watershed, because of their large size and varying land uses, occur in agricultural, urban and construction categories. Chaska Creek is agricultural in the upper watershed and developed in the lower watershed and hence appears in two categories. Elm Creek and the Vermillion River appear in both construction and agricultural problem listings because they are undergoing a certain amount of urbanization; a similar statement can be made for the Stillwater Watershed and the Lower South Fork Crow River.

Municipal and industrial point sources add large amounts of pollutants in the Mississippi River (Table 9 numbers 0-81, 83 and 0-88, 91, 96) and Minnesota River (8-122, 125, 126, 136 and 8-138, 141) drainage basins. In these watersheds, nonpoint sources add the majority of sediments while point sources add most of the nutrient and oxygen-demanding substances.

The final entry in Table 10, total percentages for the Metropolitan Area, will be discussed in the following subsection.

CONTRIBUTIONS TO EACH POLLUTANT CONSTITUENT

This section evaluates the various nonpoint source inputs to each pollutant. Each of these evaluations will help decide future management paths that should be pursued to abate nonpoint pollution.

Sediment

Table 11 was compiled to illustrate the various sources of sediment loading for each of the major watersheds in the Metropolitan Area. Figure 23 was similarly developed to visually compare sediment inputs from all of the subwatersheds studied. The values show that agricultural-related sediment loading accounts for 74 percent of the total; stream channel erosion for 18 percent; urban runoff for 5 percent; construction erosion for 2 percent; and point sources for 1 percent.

Agriculturally-related activities account for an overwhelming percentage of the total estimated sediment loading, but the total acreage (over 1.3 million acres) is also considerably higher than any of the other contributing sources. Sediment

TABLE 11 Estimated Annual Sediment Loads from Various Sources
Twin Cities Metropolitan Area

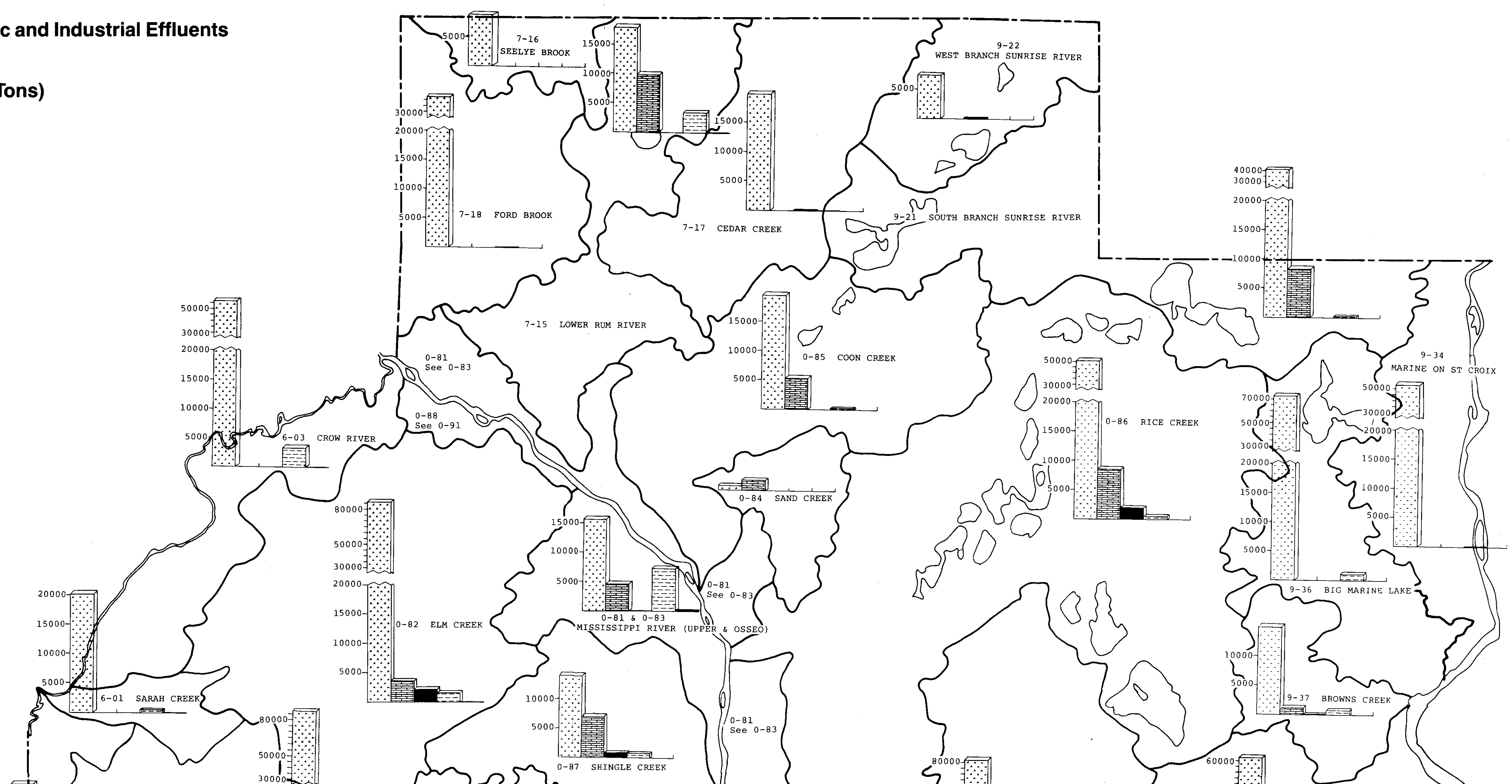
Estimated Annual Sediment Loads (tons)						
Primary Watershed	Agriculture	Urban Runoff	Construction	Stream Channel	Point Source	
Mississippi River (0)	642,209	126,073	28,728	31,045	18,768	
Crow River (6)	238,749	0	1,864	6,288	29	
Rum River (7)	89,421	980	164	3,510	4	
Minnesota River (8)	822,594	42,109	22,924	485,650	1,230	
St. Croix River (9)	335,085	3,397	1,063	43,080	38	
Cannon River (10)	182,548	0	0	2,529	75	
TOTAL	2,310,606	172,559	54,743	572,102	20,144	3,130, 154
Percent of Total Sediment Load	74	5	2	18	1	100%

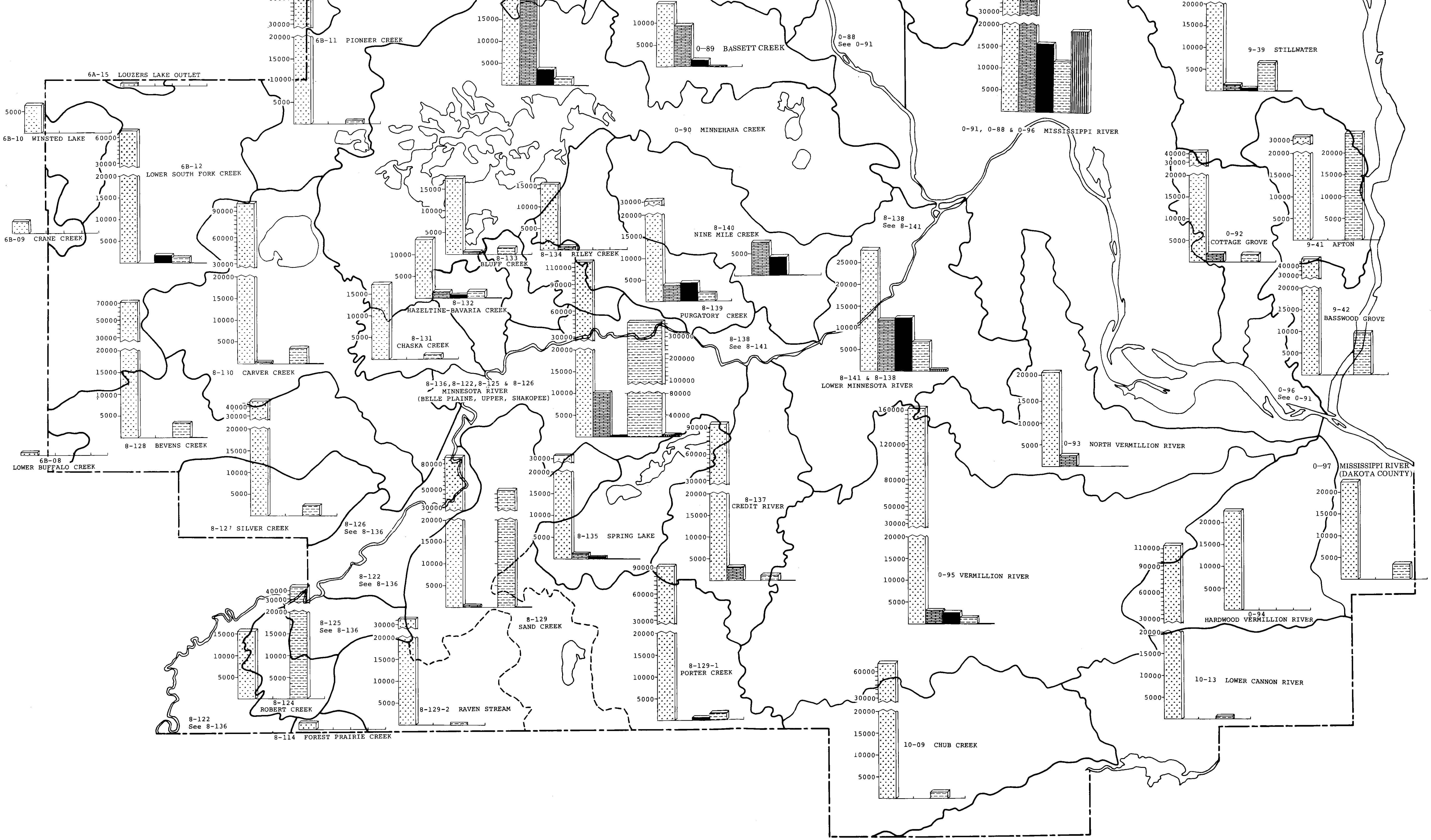
Figure 23
Source Comparison of Estimated Annual Sediment Loads

Sources of Sediment

- Agricultural Runoff
- Urban Runoff
- Construction Sites
- Stream Channel Erosion
- Domestic and Industrial Effluents

(Quantities in Tons)




6B-11 PIONEER CREEK
6A-15 LOUZERS LAKE OUTLET
6B-10 WINSTED LAKE
6B-12 LOWER SOUTH FORK CREEK
6B-09 CRANE CREEK
6B-08 LOWER BUFFALO CREEK
8-130 CARVER CREEK
8-128 BEVENS CREEK
8-127 SILVER CREEK
8-126 See 8-136
8-122 See 8-136
8-125 See 8-136
8-124 ROBERT CREEK
8-114 FOREST PRAIRIE CREEK
8-129-2 RAVEN STREAM
8-129 SAND CREEK
8-131 CHASKA CREEK
8-132 HAZELTINE-BAVARIA CREEK
8-133 BLUFF CREEK
8-134 RILEY CREEK
8-136, 8-122, 8-125 & 8-126 MINNESOTA RIVER (BELLE PLAINE, UPPER, SHAKOPEE)
8-135 SPRING LAKE
8-129-1 PORTER CREEK
8-137 CREDIT RIVER
8-140 NINE MILE CREEK
8-139 PURGATORY CREEK
8-138 See 8-141
8-141 & 8-138 LOWER MINNESOTA RIVER
0-89 BASSETT CREEK
0-88 See 0-91
0-90 MINNEHAHA CREEK
0-91, 0-88 & 0-96 MISSISSIPPI RIVER
9-39 STILLWATER
0-92 COTTAGE GROVE
9-41 AFTON
9-42 BASSWOOD GROVE
0-96 See 0-91
0-93 NORTH VERMILLION RIVER
0-95 VERMILLION RIVER
0-97 MISSISSIPPI RIVER (DAKOTA COUNTY)
0-94 HARDWOOD VERMILLION RIVER
10-13 LOWER CANNON RIVER
10-09 CHUB CREEK

loading from agriculture results primarily from precipitation and melt-water-runoff picking up and moving particles of sediment beyond the limits of the small-scale field. The largest agricultural sediment loading comes from the Minnesota River drainage basin, followed closely by the Mississippi Basin.

These figures, coupled with the relatively large input from the Crow River Basin, show that most of the Region's sediment loading comes from the agriculturally active areas of Carver County, Scott County and southern Dakota County.

Particularly high per acre sediment loading (greater than 2.5 tons/acre/year) occurs for several subwatersheds, including Big Marine Lake, Marine on St. Croix, Porter Creek, Minnehaha Creek, Bevens Creek, Pioneer Creek, Credit River and Basswood Grove. Per acre gross erosion (movement of soil within a particular field) levels exceed the value (4 t/A/yr) recommended to maintain soil productivity for 40 of the 60 watersheds evaluated in this study. The appendix details the various subwatershed loadings.

Stream channel erosion accounts for 18 percent of the sediment loading in the Metropolitan Area. The Minnesota River basin contributes by far the greatest amount of sediment from channel erosion. Totaling only 11 percent of the watershed areas experiencing channel erosion, the Minnesota River basin contributes 85 percent of the sediment due to stream channel erosion. High relative levels of channel erosion also occur in the Lower Rum River, Mississippi River (0-81, 97), Saint Paul, Crow River, Stillwater, Cottage Grove, Brown Creek and Afton Watersheds. Particularly high stream channel erosion occurs on the Minnesota River Valley bluffs as tributary streams attempt to reach equilibrium by cutting through the steep slopes. Activities of people, including agriculture and recreation, tend to accelerate this phenomenon and promote erosion.

Perspective on the seriousness of the stream channel erosion problem can be gained by realizing that 18 percent of total estimated sediment generation in the Metropolitan Area comes from 250 eroding channel miles. This figure represents material eroded from only one side of the channel, i.e., 100 feet of channel eroding on both sides would be recorded as 200 feet of erosion.

Five percent of the total estimated sediment loading in the Metropolitan Area comes from urban stormwater runoff. Urban runoff inputs are concentrated in the central cities and the immediate ring around the cities. Highest per acre loading figures occur from approximately 193,000 urban acres located in the geographic center of the Metropolitan Area plus three outlying Freestanding Growth Centers. These 193,000 acres comprise 22.4 percent of the land area evaluated for urban runoff and are estimated to contribute 50.3 percent of the total urban generated sediments. Approximately 92,000 of the 193,000 acres are occupied by open space and lakes, which contribute relatively small amounts of sediment loading compared with residential and commercial/industrial uses.

The watersheds yielding the highest per acre urban sediment volumes are the Saint Paul, lower Minnehaha Creek, Mississippi River (0-81, 88), Bassett Creek, Shingle Creek, Minnesota River (8-138), Nine Mile Creek, Riley Creek, Hazeltine-Bavaria Creek Watersheds, and Jordan, Waconia, and Belle Plaine Freestanding Growth Centers. Per acre sediment yields for these watersheds range from 0.17 to 0.67 tons per year. This sediment comes from atmospheric fallout, grit applied to prevent skidding, urban erosion and organic particles from vegetation within the urban areas. The urban runoff contribution may be the easiest to manage because it is generally concentrated in residential and commercial/industrial areas, the sources of pollution and methods of clean-up are fairly well defined, and the institutional arrangements to manage it may currently exist.

Construction is an urban-related activity that accounts for 2 percent of the total Metropolitan Area sediment loading although it occurs over an approximate annual average of only 3,000 acres. The average per acre sediment yield from this erosion is 18 tons per year, while the annual average erosion (movement of soil on-site) is 47 tons per acre per year. These figures exemplify the extremely disproportionate contribution that construction makes to sediment loading. Although it accounts for only 2 percent of the total regional loading, construction erosion is estimated to be the largest major per acre contributor of sediment.

Most of the 3,000 acres of construction in 1976 occurred in the area surrounding the urban core of the Metropolitan Area. The principal watersheds within which construction is estimated to contribute large amounts of sediment are the Lower South Fork Crow River, Stillwater Watershed, Minnesota River (8-141), Nine Mile Creek, Rice Creek, Bassett Creek, Purgatory Creek, Vermillion River, Saint Paul Watershed, Hazeltine-Bavaria Creek, Minnehaha Creek and Elm Creek. These watersheds contribute 95 percent of the construction-related sediment while containing 81 percent of the construction activity. Further perspective on the importance of construction erosion can be realized by noting that the construction season for a particular area generally only lasts from three to six months, so the sediment added to a receiving body will be many times that normally occurring without construction activity.

Included in the Section III discussion of construction erosion is a roadside erosion survey conducted in 1972 by the Minnesota Chapter of the Soil Conservation Society of America. The survey of 5,375 miles of roadway showed that 106,000 tons of soil were lost from roadside erosion for an average of 20 tons per mile or 85 tons per erosion site. Severe soil losses from roadways were reported for Chanhassen and Benton Townships in Carver County; Eden Prairie and Minnetrista in Hennepin County; east central Ramsey County; Jackson/Louisville and Sand Creek Townships in Scott County; Afton and Forest Lake Townships in Washington County. Erosion on county roads seems to be slightly more severe than on state or township roads.

The final contributors to sediment loading in the Metropolitan Area are municipal and industrial point source dischargers, which contribute only 1 percent of the total sediment load. Most point sources discharge to the Mississippi River basin, with a small amount also to several other basins. The primary ill-effect of these point sources is that they discharge every day, as opposed to the nonpoint additions only during precipitation or melt events. This daily loading provides a continual degradation factor to area streams, particularly the Mississippi River which receives 93 percent of the point sediments.

In summary, agriculture is thought to contribute the largest total load of sediments, but construction and urban activity may contribute larger per acre loadings. Eighty-five percent of all the stream channel erosion in the Metropolitan Area occurs within the Minnesota River basin.

Nutrients

Total nitrogen (TN) and total phosphorus (TP) analyses were performed for agricultural, urban and point sources of pollution. Nutrient contributions were not quantified for other pollution sources because of the limited scope of this report.

Tables 12 and 13 and Figures 24 and 25 were prepared to illustrate the nutrient loadings and percentages from the different sources that were determined in each major watershed. Details of the information in the tables and figures are presented in the respective sections of the text.

Point sources (predominantly municipal discharges) of pollution add 46 percent and 58 percent respectively, of the TN and TP loading determined in the Metropolitan Area. Approximately 85 percent of both nutrients are discharged to the Mississippi River basin, with the only other major discharges going to the Minnesota River basin. As with sediment, the primary problem with these discharges is that they occur every day and provide a continued pollutant input. As these point sources come into compliance with discharge standards and move toward reducing nutrient loads, nonpoint contributions of nutrients will become increasingly large relative to point source loadings and will eventually dominate the loading regime.

The second largest nutrient loading source in the Region is agricultural activity. Agriculture is estimated to contribute 40 percent and 34 percent, respectively, of the total determined TN and TP loads for the Metropolitan Area from slightly over 1.3 million acres of land. TN losses from this land range from 2.50 to 18.0 pounds per acre per year and TP losses range from 0.40 to 2.80 pounds per acre per year. Tables 12 and 13 show that agricultural nutrient losses are fairly well distributed over the major watersheds of the Region, with the highest values coming from the agricultural areas of Carver, Scott, southern Dakota, Anoka, northern Ramsey, western Hennepin and northern Washington Counties.

The watersheds that contribute the greatest nutrient loads are Rice Creek, Saint Paul Watershed, Minnehaha Creek, Carver Creek, Bevens Creek, Minnesota River (8-122, 126), Lower South Fork Crow River, Porter Creek, Pioneer Creek, Credit River, Vermillion River, Chub Creek, Lower Cannon River, Elm Creek, Sand Creek and Stillwater Watershed. Most of these watersheds are the same ones identified as primary contributors to sediment loading from agriculturally-related activities. Nutrient sources within these watersheds are applied fertilizer, animal wastes, crop residue and decomposed minerals. Both soluble and sediment-related loading contributions were determined. Future management efforts will need to address the various practices available and the effectiveness of these practices relative to abating soluble and sediment nutrient transport.

An inventory of feedlots and animal units was also undertaken as part of this task. More than 3,400 feedlots and 220,000 animal units were found to exist in the seven counties. Largest animal densities are found in Carver Creek, Bevens Creek, Silver Creek (Carver County), Chaska Creek, Winsted Lake Watershed, Lower Buffalo Creek, Chub Creek, Lower South Fork Crow River, Robert Creek, and Louzers Lake Outlet. Nutrients from these feedlots are estimated to contribute 30 million pounds of TN and 10 million pounds of TP annually, but

TABLE 12. ESTIMATED ANNUAL TOTAL NITROGEN LOADS FROM VARIOUS SOURCES TWIN CITIES METROPOLITAN AREA

Watershed	(No.)	Estimated Annual TN Loads (tons) Agriculture	Urban Runoff	Point Source	
Mississippi River	(0)	1,624	1,312	5,481	
Crow River	(6)	525	0	0	
Rum River	(7)	200	15	0	
Minnesota River	(8)	2,014	578	739	
St. Croix River	(9)	739	46	57	
Cannon River	(10)	424	0	0	
TOTAL		5,526	1,951	6,297	13,774
Percent of Total TN Load		40%	14%	46%	100%

TABLE 13. ESTIMATED ANNUAL TOTAL PHOSPHORUS LOADS FROM VARIOUS SOURCES TWIN CITIES METROPOLITAN AREA

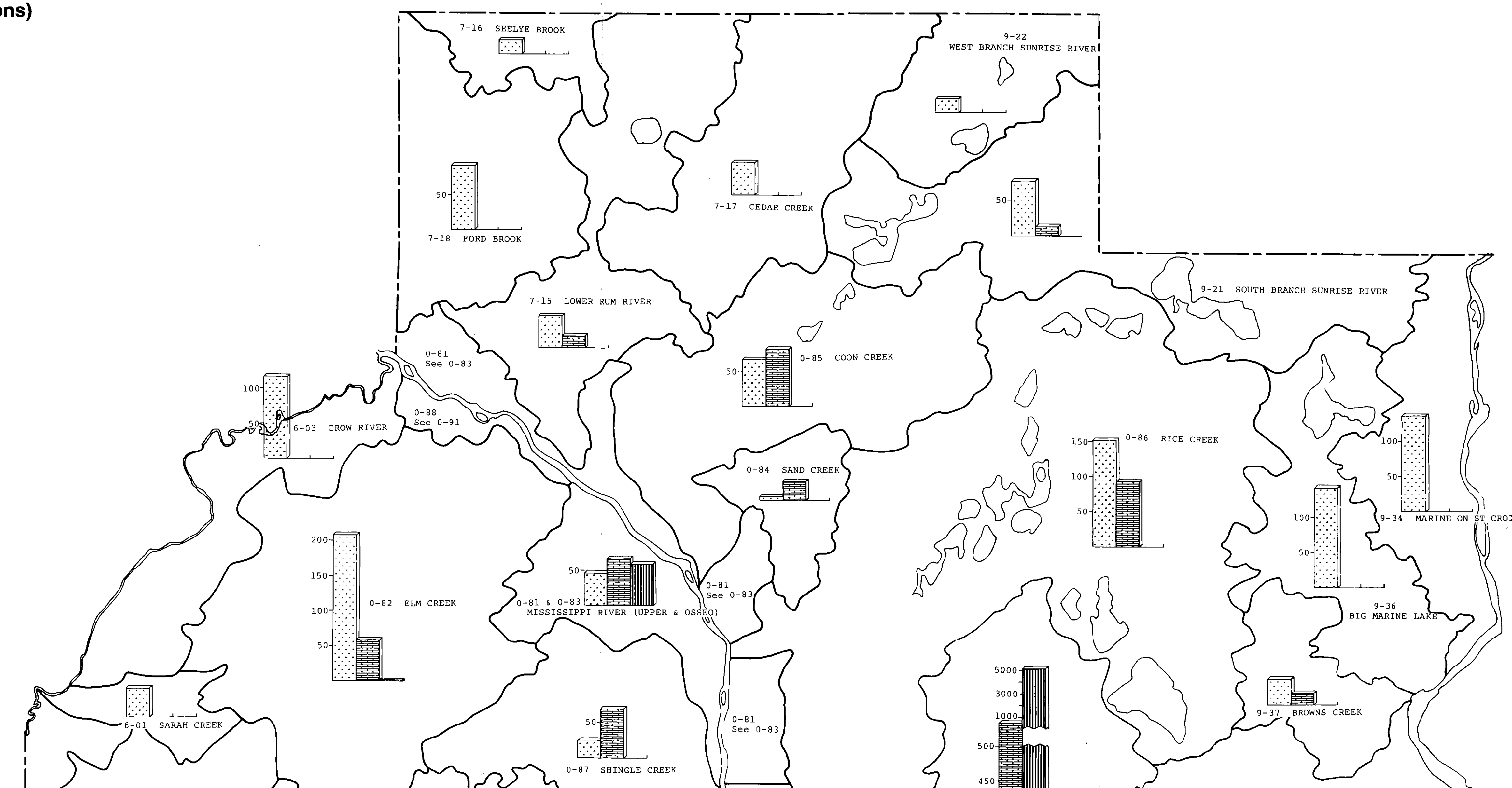
Watershed		Estimated Annual TP Loads (tons) Agriculture	Urban Runoff	Point Source	
Mississippi River	(0)	272	162	1,336	
Crow River	(6)	80	0	0	
Rum River	(7)	32	1	0	
Minnesota River	(8)	333	54	231	
St. Croix River	(9)	118	4	2	
Cannon River	(10)	70	0	0	
TOTAL		905	221	1,569	2,695
Percent of Total TP Load		34%	8%	58%	100%

Figure 24
Source Comparison of Estimated Annual Total Nitrogen Loads

Sources of Nitrogen

- Agricultural Runoff
- Urban Runoff
- Domestic and Industrial Effluents

(Quantities in Tons)



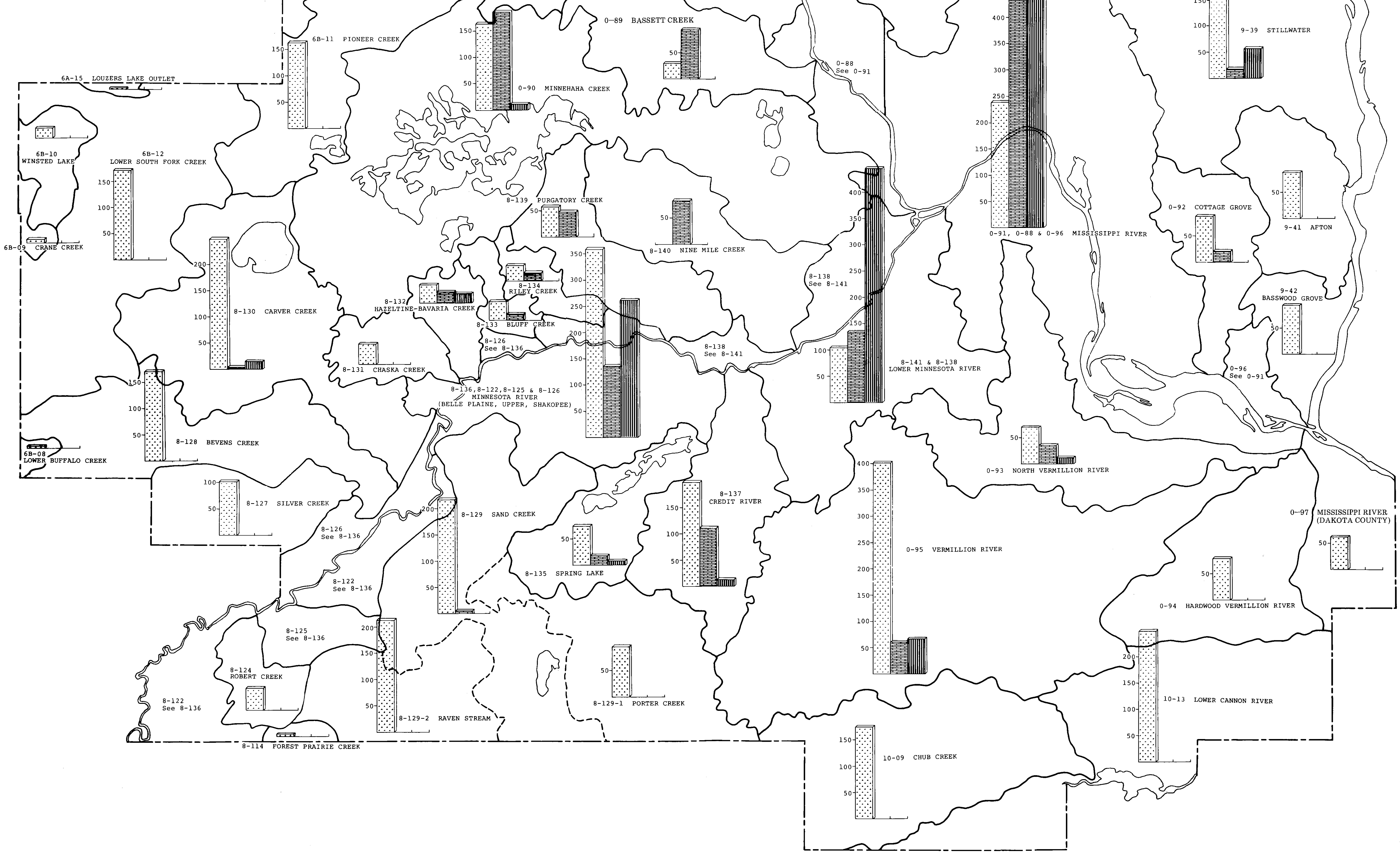
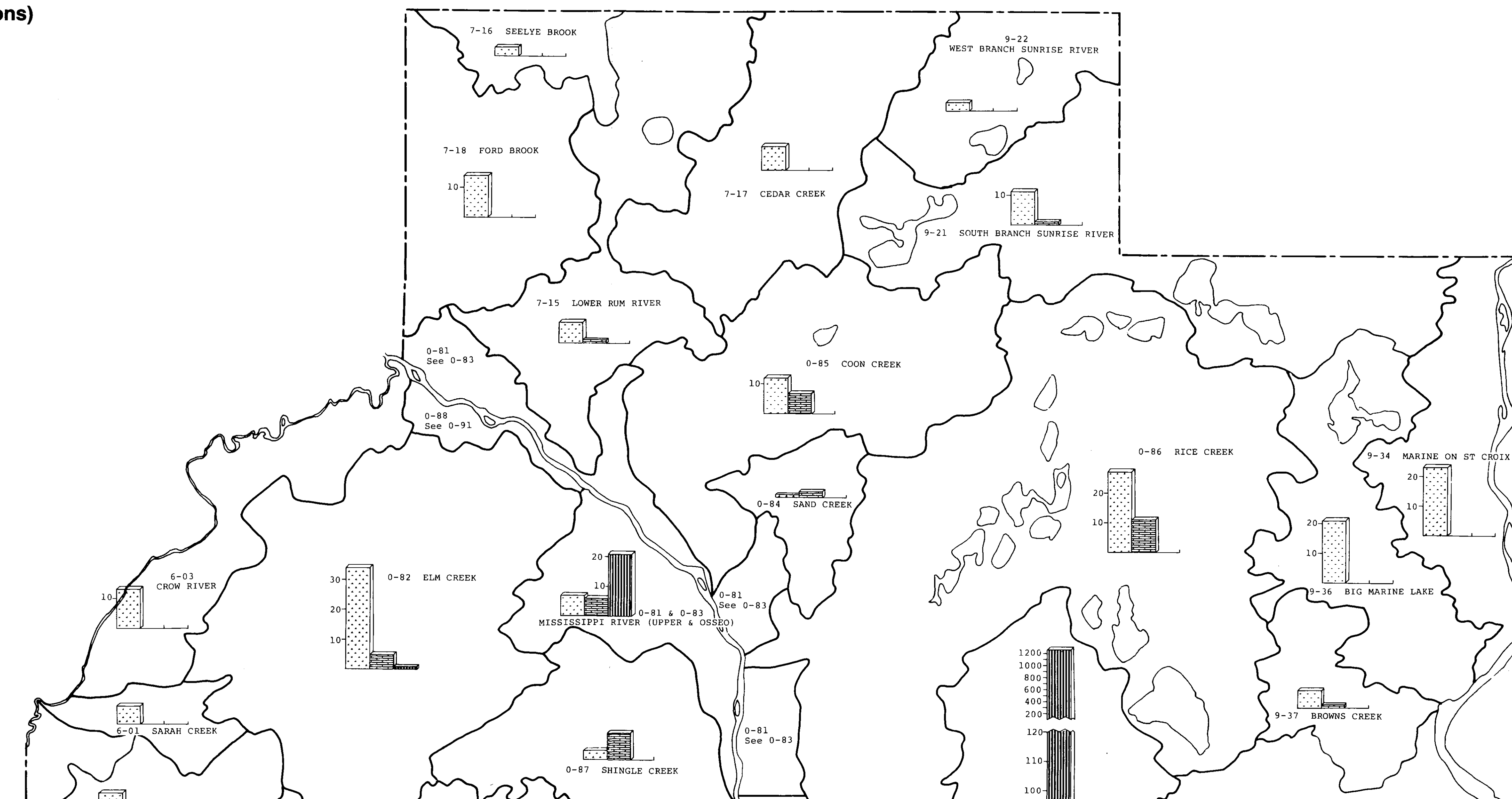

6B-11 PIONEER CREEK
0-90 MINNEHAHA CREEK
0-89 BASSETT CREEK
0-88 See 0-91
9-39 STILLWATER
6A-15 LOUZERS LAKE OUTLET
6B-10 WINSTED LAKE
6B-12 LOWER SOUTH FORK CREEK
6B-09 CRANE CREEK
8-139 PURGATORY CREEK
8-140 NINE MILE CREEK
0-91, 0-88 & 0-96 MISSISSIPPI RIVER
0-92 COTTAGE GROVE
9-41 AFTON
8-130 CARVER CREEK
8-134 RILEY CREEK
8-132 HAZELTINE-BAVARIA CREEK
8-133 BLUFF CREEK
8-126 See 8-136
8-138 See 8-141
9-42 BASSWOOD GROVE
8-131 CHASKA CREEK
8-141 & 8-138 LOWER MINNESOTA RIVER
0-96 See 0-91
8-136, 8-122, 8-125 & 8-126 MINNESOTA RIVER (BELLE PLAINE, UPPER, SHAKOPEE)
8-128 BEVENS CREEK
6B-08 LOWER BUFFALO CREEK
0-93 NORTH VERMILLION RIVER
8-127 SILVER CREEK
8-129 SAND CREEK
8-137 CREDIT RIVER
0-97 MISSISSIPPI RIVER (DAKOTA COUNTY)
8-126 See 8-136
0-95 VERMILLION RIVER
8-135 SPRING LAKE
8-122 See 8-136
0-94 HARDWOOD VERMILLION RIVER
8-125 See 8-136
8-124 ROBERT CREEK
8-122 See 8-136
8-129-1 PORTER CREEK
8-129-2 RAVEN STREAM
10-13 LOWER CANNON RIVER
8-114 FOREST PRAIRIE CREEK
10-09 CHUB CREEK

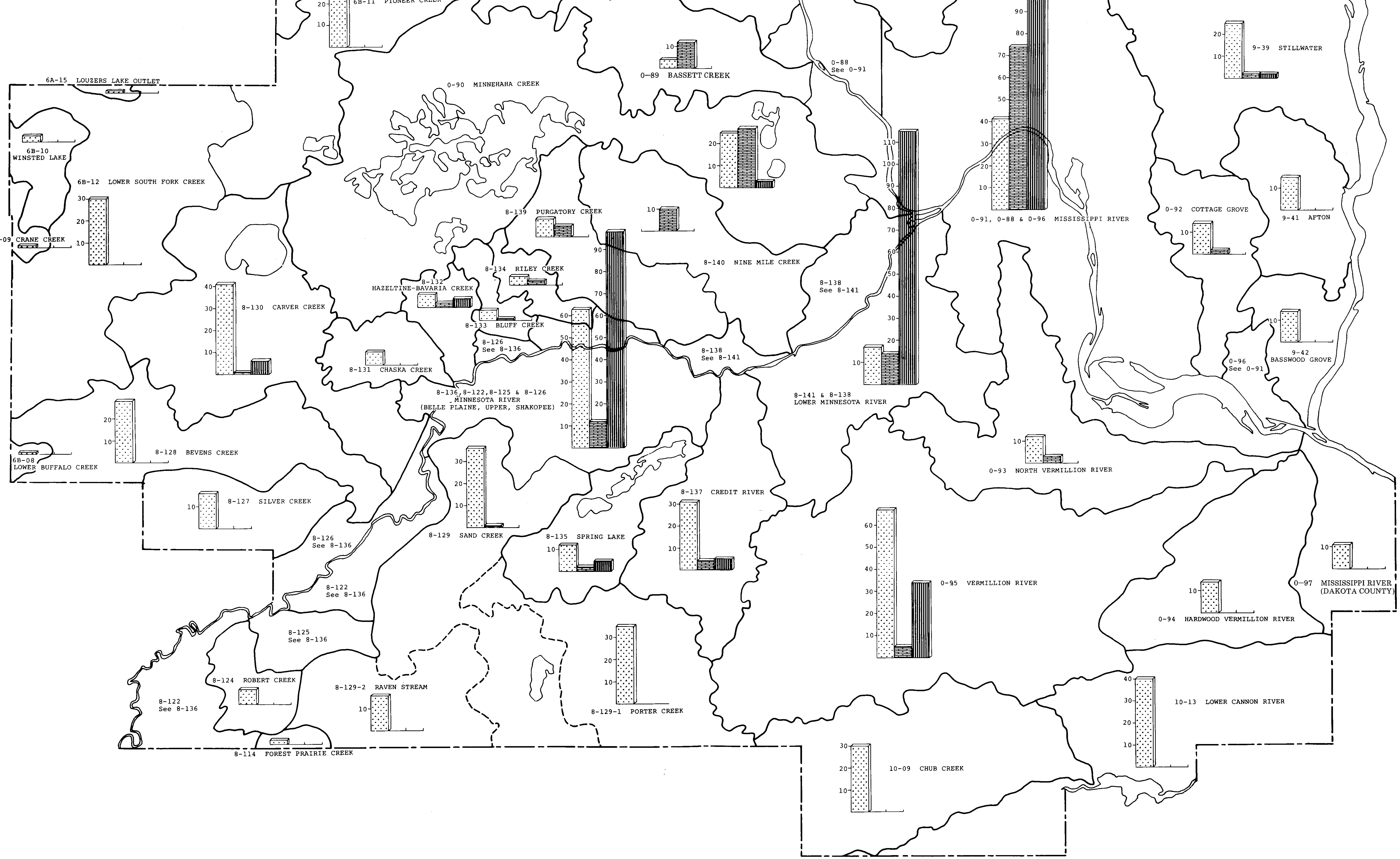
Figure 25
Source Comparison of Estimated Annual Total Phosphorus Loads

Sources of Phosphorus

- Agricultural Runoff
- Urban Runoff
- Domestic and Industrial Effluents

(Quantities in Tons)




6B-11 PIONEER CREEK
0-89 BASSETT CREEK
0-88
See 0-91
9-39 STILLWATER
6A-15 LOUZERS LAKE OUTLET
0-90 MINNEHAHA CREEK
6B-10
WINSTED LAKE
6B-12 LOWER SOUTH FORK CREEK
6B-09 CRANE CREEK
0-91, 0-88 & 0-96 MISSISSIPPI RIVER
0-92 COTTAGE GROVE
9-41 AFTON
8-139 PURGATORY CREEK
8-140 NINE MILE CREEK
8-134 RILEY CREEK
8-132
HAZELTINE-BAVARIA CREEK
8-138
See 8-141
8-130 CARVER CREEK
8-133 BLUFF CREEK
8-126
See 8-136
8-131 CHASKA CREEK
8-138
See 8-141
9-42
BASSWOOD GROVE
0-96
See 0-91
8-136, 8-122, 8-125 & 8-126
MINNESOTA RIVER
(BELLE PLAINE, UPPER, SHAKOPEE)
8-141 & 8-138
LOWER MINNESOTA RIVER
6B-08
LOWER BUFFALO CREEK
8-128 BEVENS CREEK
0-93 NORTH VERMILLION RIVER
8-127 SILVER CREEK
8-137 CREDIT RIVER
8-129 SAND CREEK
8-135 SPRING LAKE
8-126
See 8-136
0-95 VERMILLION RIVER
0-97 MISSISSIPPI RIVER
(DAKOTA COUNTY)
8-122
See 8-136
0-94 HARDWOOD VERMILLION RIVER
8-125
See 8-136
8-124 ROBERT CREEK
8-129-2 RAVEN STREAM
8-129-1 PORTER CREEK
10-13 LOWER CANNON RIVER
8-122
See 8-136
8-114 FOREST PRAIRIE CREEK
10-09 CHUB CREEK

these figures were not added to Tables 12 and 13 because not enough information was available to make assumptions on the amount of nutrients reaching the water bodies.

Urban runoff accounts for 14 percent and 8 percent, respectively, of the total determined TN and TP loading for the Metropolitan Area. Although this contribution seems minor, it occurs only during precipitation and melt events and because it is diffuse it enriches essentially every receiving water body in the urban area. Nutrient sources include decayed vegetation, animal droppings, chemical additives and applied lawn fertilizers. Loading values for TN in urban areas range from 0.10 to 11.0 pounds per acre per year and for TP from 0.10 to 1.9 pounds per acre per year.

An analysis (Section III) of 1976 discharges from major municipal and industrial sources versus urban stormwater runoff shows that urban runoff contributes 0.14 times as much TP as municipal dischargers and 100 times as much TP as industrial dischargers. On a storm event basis, the urban runoff would account for 0.90 as much TP as municipal sources and 650 times as much as industrial sources. Similar values are expected for TN based on the analysis done in Chapter 3 for Kjeldahl nitrogen (KN). These figures clearly show that although municipal dischargers are responsible for more nutrient loading, urban nonpoint runoff far surpasses industrial nutrient input and contributes a significant volume of nutrients to receiving waters spread throughout the urban area.

The watersheds primarily responsible for urban runoff nutrient loading are the same ones contained within the 193,000 acre area discussed in the sediment evaluation (Section III). This 22.4 percent of the urban area studied is responsible for 40 percent and 52 percent, respectively, of the TN and TP loading resulting from urban runoff.

In summary, point sources of pollution may contribute the largest percentage of nutrient loading to the Metropolitan Area, but as point source dischargers come under water pollution compliance, nonpoint source dischargers will become an increasingly larger percentage of the total loading. Nutrient input from agriculturally-related activities accounts for a large sum of total loading because of the more than 1.3 million acres currently under agricultural use in the Region. Urban stormwater runoff accounts for a lower amount of nutrient loading, but also occupies a smaller amount of land than agriculture.

Oxygen-Demanding Substances

Biochemical oxygen demand (BOD) and chemical oxygen demand (COD) were determined for urban runoff and point sources of pollution. Although a considerable amount of BOD likely results from agricultural activities, values were not determined because to use the literature available would have required far more detailed analysis than fits within the scope of this overview report. Both BOD and COD were determined because urban runoff is dominated by COD loading while point source loading is dominated by BOD loading.

Table 14 was prepared to illustrate the BOD and COD loading that occurred in the Metropolitan Area in 1976. Seventy-six percent of the determined BOD loading comes from point sources (mostly municipal treatment plants) and 24 percent comes from urban runoff. Of the total BOD load from point sources, 95 percent occurs in the Mississippi River and approximately 97 percent of this

TABLE 14. ESTIMATED ANNUAL OXYGEN-DEMANDING SUBSTANCES FROM URBAN RUNOFF AND POINT SOURCES

TWIN CITIES METROPOLITAN AREA

Watershed	Estimated Annual Oxygen-Demanding Substances (tons)			
	BOD		COD	
	Urban	Point Source	Urban	Point Source
Mississippi River (0)	5,339	20,674	30,837	64,076
Crow River (6)	0	25	0	0
Rum River (7)	25	3	238	0
Minnesota River (8)	1,401	942	10,153	2,987
St. Croix (9)	104	36	818	159
Cannon River (10)	0	63	0	0
TOTAL	6,869	21,743	42,046	67,222 *
Percent of Total Oxygen-Demanding Substance Load	24%	76%	38%	62%

* 60,000 of this from Metro Plant.

is from the Metro Plant at Pig's Eye. This discharge is largely responsible for the degraded condition of the Mississippi River downstream from the plant discharge. Urban runoff BOD loading, however, occurs over an 860,000 acre area and contributes to essentially every receiving water body in the Region. The same 193,000 acre area discussed in the previous sections contributes the largest amount of BOD loading.

Sixty-two percent of the determined COD loading comes from point sources and 38 comes from urban runoff. Similar to BOD, 95 percent of the COD point source loading occurs on the Mississippi River, with essentially all of this from the Metro Plant. Also, similar to BOD, the highest COD loads come from the 193,000 acre portion of the urban area; this 22.4 percent of the urban area accounts for 51 percent of the total urban runoff COD load, largely because it has the highest concentration of high density residential and commercial/industrial uses.

It is quite obvious that as soon as the Metro Plant reduces its BOD and COD discharges to acceptable levels, urban runoff will dominate the oxygen-demanding substance loading situation in the Metropolitan Area. Urban runoff in 1976 contributed 0.33 times and 9.78 times, respectively, as much BOD as municipal and industrial sources and 0.66 times and 13.1 times as much COD as these sources. If it is assumed that the Metro Plant (as the largest single discharger) will reach 25 mg/l BOD and 100 mg/l COD (arbitrarily used here because a secondary treatment standard for COD does not presently exist) by 1985 at a design flow of 290 MGD, the above figures for municipal dischargers will change accordingly and the proportion of urban stormwater runoff loading to total municipal loading will increase. Assuming urban runoff inputs remain constant, the new mathematical relationships would have urban runoff contributing 0.57 times as much BOD and 0.87 times as much COD as municipal dischargers. For treatment levels of 10 mg/l BOD and 50 mg/l COD, the figures for urban stormwater would go to 1.3 times as much BOD and 1.6 times as much COD. On an event basis in 1976, urban runoff contributed 2.1 and 6.3 times as much BOD, respectively, as daily municipal and industrial dischargers and 4.2 and 84 times as much COD. Clearly, nonpoint additives of BOD and COD contribute significantly to the degradation of our area waters.

The urban runoff analysis in the nonpoint overview study did not consider the large amount of oxygen-demand of combined sewage by-passed by the Minneapolis, Saint Paul and South Saint Paul combined sewer systems. This subject is being addressed in a Section 201 (PL 92-500) project being conducted by the Metropolitan Waste Control Commission (MWCC).

Landfill Leachate

Leachate resulting from landfills and dumps does not lend itself to comparison with the other nonpoint sources of pollution. A discussion of landfill leachates occurs in Section III of this overview report.

Leachate is the contaminated water that seeps beyond the physical limits of a landfill; contamination is a result of the water picking up chemical and biological pollutants from the solid waste refuse. The principal contaminants of concern in the leachate are heavy metals, BOD and COD, alkalinity, total dissolved solids, chlorides, micro-organisms, hardness and organic compounds such as oil and phenols. These contaminants present the single largest threat to groundwater quality in the Metropolitan Area.

Appendix Table 5.2 indicates that six of the 14 sanitary landfills in the Metropolitan Area present threats to surface water quality; six present threats to groundwater laterally; and four present threats to groundwater vertically. Additionally, the table indicates that of the 68 abandoned dumps grossly evaluated, 19 threaten surface water, 24 threaten groundwater laterally and seven threaten groundwater vertically.

Half of the sanitary landfills now operating in the Region presently have leachate problems and landfills having highly permeable cover materials may begin to have leachate problems in several years. Proper design and phasing-out of landfills could minimize leachate problems by minimizing contact with percolating water.

Heavy Metals

The final contaminants evaluated are the heavy metals, specifically, chromium (Cr), copper (Cu), nickel (Ni), lead (Pb) and zinc (Zn). These metals were analyzed only for the main contributing sources - urban runoff and point source dischargers.

Table 9 indicated that urban runoff was the dominant contributor for Ni and Pb; point sources were dominant for Cr and Cu; and 50 percent of Zn came from each source. A large percentage of the point source metal loading is from the municipal treatment plant at Pig's Eye (Metro Plant), with small additions from the Anoka Plant and several industrial dischargers. Again, elimination of the large loading from the Metro Plant would thrust urban runoff into the dominant position relative to metals loading in the Metropolitan Area.

The same 193,000 acre area identified in previous sections is largely responsible for the metal loading from urban areas. This 22.4 percent of the total urban study area contributes, for example, 60 percent of the total urban Pb loading. Most of this Pb loading results from combustion of fossil fuels associated with automobiles. Other sources of heavy metal contamination are primarily industrial conbustion and processing, fluid spills and leaks, and urban litter.

Perhaps the largest problem associated with heavy metals is that they tend to accumulate in quiescent waters, often reaching levels toxic to biologic organisms. This effect does exist downstream from the cities of Minneapolis and Saint Paul, where Spring Lake provides an opportunity for river velocities to decrease and the waters to drop their suspended load. This problem is compounded by the fact that the Metro Plant discharges just upstream of Spring Lake, adding 22 to 83 percent of the various metal loadings. Again, reduction of the Metro Plant metals discharges in the future will increase the relative importance of the urban nonpoint metals loading.

Other Pollutants

The only other pollutants evaluated in this overview report were discussed in relation to urban stormwater runoff. The pollutants for which estimates are made include chlorides (Cl), volatile suspended solids (VSS), total solids (TS), dissolved phosphorus (DP), nitrates (NO_3), ammonia (NH_3), Kjeldahl nitrogen (KN), organic nitrogen (ON) and fecal coliform. Information on these pollutants and their estimated loadings resulting from urban runoff can be found in Section III. Discussion does not occur in this section because either the pollutant is contained within another evaluated pollutant (nitrogen) or insufficient information was available to allow for comparison.

SELECTION OF PRIORITIES FOR FUTURE PROGRAMS

The information presented in this section leads to the selection of nonpoint water quality pollution sources that merit further attention in subsequent studies. The priority items that resulted from this analysis are clearly urban runoff, construction erosion, agricultural runoff, landfill leachate, and stream channel erosion. Dredging, mining, barge washing, and the catalogue of miscellaneous sources did not indicate further emphasis.

High Priority Items

Urban Runoff and Construction Erosion

Highest priority in future management efforts should go to the urban-related sources of nonpoint pollution, those being runoff from urban surfaces and erosion from construction activities. Although these two categories did not yield extremely large percentages of loading, the contributions were from a relatively small total area at a high per acre loading rate. Major reductions in sediment, COD and heavy metals loading could be realized by curtailment of urban-related nonpoint pollution. Significant reductions in BOD and nutrients could also result. Future emphasis should be placed on: verifying the data presented in the two technical reports and parts of this overview; identifying of 'best-management practices' applicable and effective for the Twin Cities area; evaluating of simulation techniques; assessing costs and financing for a remedial program; recommending legal and institutional approaches to solving urban-related problems; assessing a recommended management program relative to Metropolitan Council development policies; and providing a public information system.

Agricultural Runoff and Landfill Leachate

The next highest level of priority should go to agricultural runoff and landfill leachate. Significant reductions can be made in sediment and nutrient export from agricultural areas by implementing various management techniques to keep sediment from migrating and to prevent soluble and sediment nutrients from leaving the fields and feedlots. The MPCA is devoting a great deal of its Section 208 grant to developing management techniques and approaches to agricultural-related nonpoint source pollution. This activity should build a firm base upon which to develop Metropolitan Area programs for the affected 1.3 million acres of agricultural land. Future Council efforts should include: verifying the data presented in the technical reports and Section III; evaluating and incorporating the results of MPCA's agricultural program; studying the implementation mechanisms available to the Council for the Metropolitan Area; providing technical information to the public for use in addressing techniques; and assessing the same legal, institutional, and financial questions mentioned in the urban-related topic.

Landfill leachates are of equal priority to agricultural runoff. Essentially no documented evidence exists to allow the Council to state definitively that leachates are seeping from the landfill sites. Answers to questions regarding rates of seepage, nature of escaping leachate, effectiveness of cover materials, and site locations have to be found before a second generation of landfill planning can occur. Future efforts should include: verifying the results of the leachate technical report; surveying closed dumps for water quality concerns; working with MPCA to develop an effective monitoring system for landfills; studying the physical conditions within which landfills could be best located; and developing better landfilling management practices and regulatory guidance.

Stream Channel Erosion

The final high priority item for future study is stream channel erosion. This was included because the magnitude and nature of the problem raise several issues pertaining to the effectiveness of management programs, such as the validity of trying to stop nature's attempt to reach equilibrium, the tremendous cost of any management program, and the validity of categorizing a segment of channel erosion as 'natural' or 'human-induced.' Undoubtedly, some level of management activity should be included in future efforts so that cultural factors such as urbanization, intensive recreation and agriculture are minimized on unstable streambanks. Future management efforts, therefore, should include: definition of locale and factors that foster stream channel erosion; evaluation of cost-effective management techniques; and assessment of the legal and institutional requirements for a remedial program.

Low Priority Items

Dredging

Dredging is assigned a low priority because of the on-going efforts to minimize the pollution associated with dredging and disposal activity. The interagency Great River Environmental Review Team (GREAT) and the U.S. Army Corps of Engineers (COE) have developed a review mechanism that has been effective to date in defining the water quality and environmental concerns involved in dredging. Continued surveillance should, however, be maintained over the COE dredging activities to assure that environmental concerns are addressed. Active Metropolitan Council participation in a management program would only overlap with GREAT and COE programs.

In addition, it was found through a literature review of available data that the water quality problems associated with dredging and disposal are localized and short-term. Water quality standards are commonly violated, but effects of dredging activities are usually not experienced beyond the vicinity of the project.

Mining

Sand and gravel and aggregate mining is a low priority item because very small amounts of sediment are generated annually by mining operations in the Metropolitan Area. Only 3,900 tons of sediment from 116 acres of earth-moving activity and 330 tons from permitted discharges occur in the Seven-County Region. The coarse nature of the material being mined allows for rapid settling of material moving off-site.

Barge Washing

Barge washing was given a low priority for future efforts because the MPCA regulates this activity and is pursuing a schedule to bring the one remaining discharger to the Mississippi River into compliance with discharge standards. Two other barge washing operations discharge to sanitary treatment facilities.

Miscellaneous Catalogue

None of the sources identified under this category were placed on high priority because they all appear to be addressed in other sections of the Metropolitan Council's Section 208 program or in programs of other agencies. Particular concern, however, is raised that the MPCA, Department of Health and Environmental Quality Board develop solutions to industrial spill problems such as the one within the City of Saint Louis Park.

APPENDIX A: SURVEY GRAPHICS AND METHODOLOGY FOR ESTIMATING IMPACTS OF POLLUTANTS

This section of the appendix presents additional graphic material and outlines the methodology used to arrive at the results in Section III of the report. Combining information in Section III and Appendix A will give the reader a complete picture of the studies that were performed for this overview report.

AGRICULTURAL RUNOFF

Table 1.1 shows the income distribution for different forms of agriculture in the Metropolitan Area. This shows the variability in farming activity within the Seven-County Region.

Methodology for Estimating Sediment Loads from Agricultural Land Use

Sediment yields resulting from gross soil losses due to the use of land for agriculture have been estimated for the Twin Cities Metropolitan Area.[11] The Metropolitan Area was divided into some 60 major watersheds as delineated on maps of the Conservation Needs Inventory (CNI) of the Soil Conservation Service (SCS) of the U.S. Department of Agriculture.

Estimates of average annual gross soil loss, annual sediment production, and annual net sediment export were prepared under a Section 208 contract with the Metropolitan Council. These estimates were based on the knowledge of the seven metropolitan SCS conservationists on the types of crop cultivated in each watershed, the methods of land cultivation in use and intimate knowledge of the soil types and geomorphology of the district. No actual soil loss data were collected in the field. This study is only concerned with sediments derived from sheet and rill erosion from agricultural land including farmed and idle rural land.

A few terms must be defined for this study:

- Gross Soil Loss is soil loss from sheet and rill erosion, as caused by rainfall and overland runoff, within a particular watershed; here computed as a total average annual loss.

- Sediment Production is that part of the soil loss, as defined above, reaching a body of water (lake, stream, wetland); here computed as a total average annual volume.

- Net Sediment Export is the volume of sediment leaving a watershed by stream transport; here computed as a total annual volume.

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11 Association of Metropolitan Soil & Water Conservation Districts, 1977.

TABLE 1.1 COUNTY DISTRIBUTION OF INCOME FROM VARIOUS SECTORS OF FARMING AS A PERCENTAGE OF TOTAL METROPOLITAN FARMING INCOME - 1970 DATA TWIN CITIES METROPOLITAN AREA

County	Fruits & Berries	Vegetables	Horticulture	Major Crops	Dairy Products	Poultry	Other Livestock
Anoka	1	34	7	5	4	31	6
Carver	3	1	0	14	35	11	16
Dakota	3	28	5	33	18	12	37
Hennepin	19	25	48	19	14	17	10
Ramsey	0	2	12	0	0	0	0
Scott	4	5	2	14	18	8	16
Washington	70	5	27	14	11	20	16
TOTAL	100	100	101 *	99 *	100	99 *	101 *

* Due to rounding off numbers

The total average annual gross soil loss for each watershed was computed using values derived from the universal soil loss equation [12] and multiplied by the acreage of agricultural land in each geographical sub-unit of each of the 60 watersheds, as defined on the Soil Conservation Service CNI maps of the Metropolitan Area.

The universal soil loss equation was used to predict soil loss from sheet and rill erosion on agricultural lands. The equation is used to compute long-term average annual soil losses for specific combinations of physical and management conditions. While it was essentially designed to predict soil losses from specific fields, it can be used to compute estimates of soil losses from sheet and rill erosion within a particular watershed.[13]

The following formula was used to compute gross soil losses:

$$Y\ (L) = \sum_{i=1}^{n} \left[A_i \cdot (R.K.LS.C.P.)_i \right]$$

Where:

$Y\ (L)$ = gross soil loss in tons per year
n = number of sub-areas in the watershed
A_i = acreage of sub-area $_i$, in acres

Universal soil loss equation factors:

R = erosion potential of average annual rainfall
K = soil erodibility factor
LS = a slope length and steepness factor
C = soil cover factor
P = erosion control practice factor

The result of the erosion study for the Metropolitan Area indicates that, given the average annual rainfall for the Metropolitan Region, the types and acreages of crop grown in 1976, and the methods of cultivation and soil conservation in use in each watershed, at the time of the study, some 6,247,100 tons of soil are potentially lost annually, as a direct result of the agricultural use of the land in the Metropolitan Area. This can be translated to a soil loss of 4.60 tons per year per acre in agricultural use.

Per area unit loss of soil is dependent on many variables. Therefore, it can be expected that the estimated average annual soil loss varies with each watershed. Table 1.2 shows a wide range in the per acre annual soil loss by watersheds with estimates ranging from about one third of a ton per acre per year to approximately 16 tons per acre per year.

More than 40 watersheds or county portions of a watershed are estimated to

12 Wischmeier and Smith, 1965.
13 Wischmeier, 1976.

TABLE 1.2 AGRICULTURAL LAND USE - ESTIMATED SEDIMENT PRODUCTION BY WATERSHEDS

NO.	SUBWATERSHED	RURAL AREA ACRES	GROSS EROSION IN TONS	SEDIMENT PRODUCTION TOTAL-TONS	SEDIMENT PRODUCTION TONS/AC	SEDIMENT EXPORT TOTAL-TON	PERCENTAGE OF RURAL LAND ADEQUATELY PROTECTED
7-16	Seelye Brook	8,263	15,085	8,750	1.06	3,017	70
7-18	Ford Brook	25,992	85,809	42,905	1.65	13,129	70
7-15	Lower Rum River	24,489	39,809	17,914	0.73	5,753	73
7-17	Cedar Creek	29,800	44,115	19,852	0.67	4,868	69
9-22	West Branch Sunrise River	14,119	16,314	7,341	0.52	1,370	73
9-21	South Branch Sunrise River	32,968	95,975	41,739	1.27	2,735	55
0-85	Coon Creek	36,356	55,647	19,476	0.54	4,514	74
0-84	Sand Creek	3,228	1,515	758	0.23	199	69
0-86	Rice Creek	81,418	92,107	50,627	0.62	6,664	52
0-91	St. Paul	58,373	187,212	69,179	1.18	43,036	68
0-81	Mississippi River	5,454	23,070	8,700	1.60	1,490	80
0-90	Minnehaha Creek	26,734	240,216	87,615	3.27	3,507	52
8-130	Carver Creek	44,819	221,994	99,127	2.21	38,787	33
8-128	Bevens Creek	35,499	157,567	70,905	2.00	64,843	33
8-127	Silver Creek	17,468	102,627	46,182	2.64	21,546	33
8-131	Chaska Creek	8,419	42,930	17,172	2.04	10,700	33
8-132	Hazeltine-Bavaria Creek	6,480	35,775	13,237	2.04	8,700	33

TABLE 1.2 (continued)

NO.	SUBWATERSHED	RURAL AREA ACRES	GROSS EROSION IN TONS	SEDIMENT PRODUCTION TOTAL-TONS	SEDIMENT PRODUCTION TONS/AC	SEDIMENT EXPORT TOTAL-TON	PERCENTAGE OF RURAL LAND ADEQUATELY PROTECTED
8-133	Bluff Creek	4,480	34,928	17,464	3.90	10,500	33
8-134	Riley Creek	4,416	37,560	15,153	3.43	5,887	35
8-139	Purgatory Creek	3,887	89,474	31,201	2.04	6,846	50
8-122	Minnesota River	19,249	79,894	33,200	1.71	22,687	35
8-126	Minnesota River	12,480	47,173	21,228	1.70	13,180	33
6A-15	Louzers Lake Outlet	960	1,267	748	0.78	507	33
6B-12	Lower South Fork Creek	60,222	158,232	67,446	1.2	22,310	35
6B-10	Winsted Lake	7,000	13,813	6,216	0.89	3,600	33
6B-11	Pioneer Creek	29,103	221,993	83,802	2.88	16,728	72
6B-09	Crane Creek	1,792	4,849	2,764	1.54	1,746	33
6B-06	Silver Creek	64	144	123	1.92	-	33
6B-08	Lower Buffalo Creek	1,088	1,057	793	0.73	423	33
8-141	Minnesota River	22,371	77,734	27,728	1.24	13,076	36
8-137	Credit River	28,185	269.249	94,857	3.36	50,326	32
0-97	Mississippi Direct	17,060	60,300	22,311	1.31	12,663	27
0-93	North Vermillion	31,423	57,429	21,566	0.68	11,078	31
0-95	Vermillion River	102,657	443,643	162,642	1.58	73,146	27
0-94	Hardwood	32,699	65,001	22,750	0.70	11,700	27
10-09	Chub Creek	47,537	178,411	67,796	1.43	29,309	20

TABLE 1.2 (continued)

NO.	SUBWATERSHED	RURAL AREA ACRES	GROSS EROSION IN TONS	SEDIMENT PRODUCTION TOTAL-TONS	SEDIMENT PRODUCTION TONS/AC	SEDIMENT EXPORT TOTAL-TON	PERCENTAGE OF RURAL LAND ADEQUATELY PROTECTED
10-13	Lower Cannon River	47,877	382,508	114,752	2.40	57,376	20
6-01	Sarah Creek	5,550	60,800	20,064	3.62	3,610	55
6.03	Crow River Direct	20,284	158,000	56,916	2.81	10,810	60
0-82	Elm Creek	55,721	259,400	85,602	1.54	11,050	65
0-83	Osseo	8,704	20,250	6,885	0.79	3,020	82
0-87	Shingle Creek	1,050	38,700	13,932	0.93	100	77
0-89	Bassett Creek	3,240	43,100	14,654	4.52	3,370	66
8-125	Belle Plaine	7,430	55,272	16,582	2.23	6,080	50
8-136	Shakopee	28,828	133,788	46,826	1.62	24,584	31
8-124	Robert Creek	9,728	41,153	15,638	1.61	10,686	61
8-124	Forest Prairie Creek	1,472	4,319	1,857	1.26	975	56
8-135	Spring Lake	13,978	91,658	34,830	2.49	18,286	42
9-129	Sand Creek	42,640	232,411	88,316	2.07	60,439	46
8-129-1	Porter Creek	29,672	243,427	92,502	3.12	63,210	37
8-129-2	Raven Stream	22,158	96,234	36,569	1.65	22,673	62
9-34	Marine on St. Croix	20,598	124,279	53,440	2.59	36,040	35
9-36	Big Marine Lake	24,975	168,738	72,557	2.91	19,771	35
9-37	Brown's Creek	9,474	34,170	14,693	1.55	7,860	35

TABLE 1.2 (continued)

NO.	SUBWATERSHED	RURAL AREA ACRES	GROSS EROSION IN TONS	SEDIMENT PRODUCTION		SEDIMENT EXPORT TOTAL-TON	PERCENTAGE OF RURAL LAND ADEQUATELY PROTECTED
				TOTAL-TONS	TONS/AC		
9-39	Stillwater	36,449	145,082	62,408	1.71	21,748	35
9-41	Afton	17,604	79,229	34,068	1.93	22,180	35
9-42	Basswood Grove	11,160	113,346	48,739	4.37	26,070	35
00-92	Cottage Grove	16,364	98,558	42,380	2.59	19,495	35
00-96	Mississippi River	6,260	29,840	12,831	2.05	8,060	35
TOTAL		1,327,768	6,247,100	2,308,308		998,063	

exceed the generally accepted 4-5 tons per acre soil loss standard for soil conservation. The worst 10 watersheds or portions of watersheds are as follows:

Pioneer Creek (Hennepin County) 8.2 tons
Porter Creek (Scott County)8.2 tons
Basswood Grove (Washington County) 10.1 tons
Credit River (Scott County) 10.4 tons
Vermillion River (Scott County) 11.9 tons
Chub Creek (Scott County) 12 tons
Bassett Creek (Hennepin County) 13.3 tons
Minnesota River (Hennepin County) 15.5 tons
Carver Creek (Hennepin County) 15.6 tons

This study also indicates a very wide range in the percentage of land in agricultural use subjected to adequate control measures to prevent soil loss or maintain soil losses within limits necessary for continued crop production. On a county basis, estimates of the percentage of land adequately protected vary from 27 percent to 86 percent, with the range even greater when the data are compared on a watershed basis. The phrase "adequately treated or protected" applies to land on which soil conservation measures are taken to maintain the productivity of the land. The phrase does not mean that the volume of erosion contributed is not causing water pollution problems. Table 1.2 and Text Figure 5 indicate the amount and percentage of agricultural land in each watershed with adequate treatment.

Sediment production is dependent on erosion of soil and on the transport of the eroded soil to the receiving waters. The amount of eroded soil reaching a body of water can be estimated by the use of the sediment delivery ratio.[14]

Studies of sediment yield indicate that the magnitude of the sediment yield is mainly related to the size of the drainage area. However, several factors may influence the delivery ratio.[15]

- Proximity of the sources of sediment to the receiving water;
- Size and density of sediment sources;
- Characteristics of the sediment transport system;
- Texture of eroded material;
- Availability of deposition areas;
- Topography of the watershed.

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14 Roehl, 1962.
15 Shelton, 1977.

TABLE 1.3

AGRICULTURAL LAND USE - ESTIMATED LAND PROTECTION - 1976
Twin Cities Metropolitan Area

County	Acres in County	Acres in Agricultural Use (1)	Percent of Agri. Land With Adequate Protection(2)	Percentage of County in Agricultural Use(3)
Anoka	283,520	203,030	69	36
Carver	239,360	217,755	33	82
Dakota	376,320	307,250	27	72
Hennepin	389,760	147,603	68.5	33
Ramsey	109,440	27,643	86	5
Scott	232,960	214,290	42.6	74
Washington	268,160	209,960	35.4	50
TOTAL	1,899,520	1,327,531	44.2	55

(1) Also includes idle land.

(2) Also includes idle land.

(3) Percentage of land as reported in Minnesota agricultural statistics, 1977 - does not include idle land not part of a farm income.

By plotting yield figures versus drainage areas in relation to sediment losses calculated by the universal soil loss equation, a delivery ratio can be obtained (Figure 1.1).

The total average annual volume of sediments produced in each of the 60 metropolitan watersheds was obtained by the use of the delivery ratio method and estimating the trapping efficiency of sub-units within these watersheds.

The sediment production can be represented as follows:

$$Y\ (S) = \sum_{i=1}^{n} [A_i \cdot (R.K.LS.C.P.Sd)_i]$$

Where:

Y (S)	=	sediment production, in tons per year
n	=	number of sub-areas in the watershed
A_i	=	acreage of sub-area i; in acres
R,K,LS,C,P	=	variables of the universal soil loss equation
Sd	=	sediment delivery ratio, dimensionless. This value is obtained for the sediment yield curve in Figure 1.1.

The Metropolitan Area study indicates that approximately 2.3 million tons of sediments are received annually into water bodies and streams at an average rate of 1.8 tons per acre in agricultural use and per year.

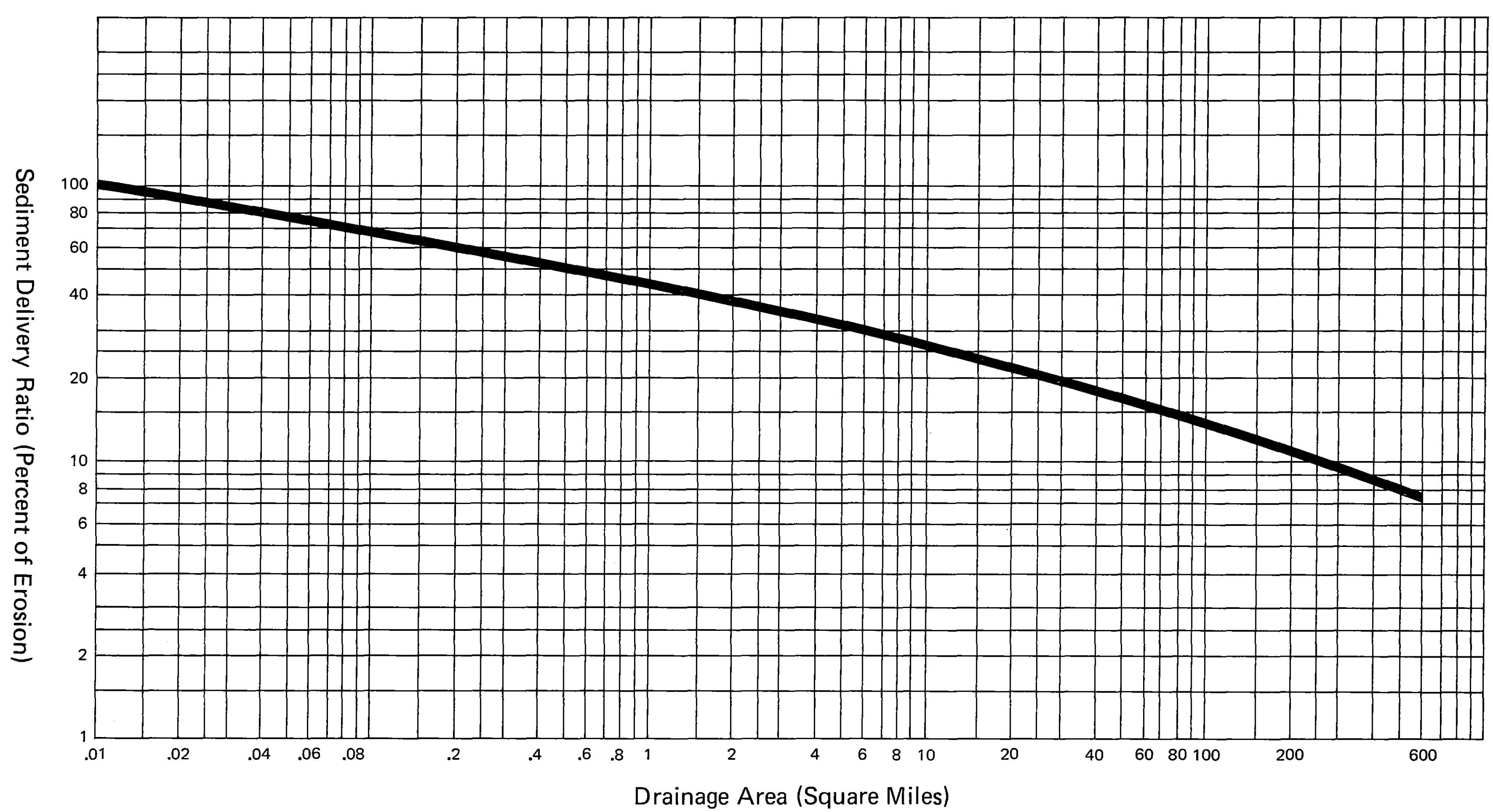
Sediment production varies with each of the metropolitan watersheds. Estimate values range from 0.2 tons per acre to 5.5 tons per acre per year (Text Figure 6 and Table 1.2). Ten watersheds have annual average sediment production exceeding 3.5 tons per acre per year. These are:

in Carver County, Bluff Creek 3.9 tons
in Hennepin County, Sarah Creek 3.6 tons
in Hennepin County, Bassett Creek 4.5 tons
in Hennepin County, Carver Creek 5.2 tons
in Hennepin County, Minnesota River, 5.2 tons
in Scott County, Credit River 3.6 tons
in Scott County, Vermillion River 4.5 tons
in Scott County, Chub Creek 4.6 tons
in Washington County, Basswood Grove 4.4 tons

The sediment production equation estimates the volume of soil reaching a body of water. When this soil has reached a lake or a stream, some of the soil is deposited at the bottom or at the edge of the water; the rest is then transported downstream to the next watershed. The deposited soils may be picked up again by faster or larger flows and transported downstream.

While the study of pollution problems from agricultural land uses is basically interested in the figures on sediment production, a knowledge of the volume of

Figure 1.1
SEDIMENT YIELD CURVE



sediment exported outside the watershed would be useful as it provides an indication of the cummulative effects on larger or primary watersheds.

The Net Sediment Export figure for each of the 60 watersheds was obtained using the sediment yield ratio curve see figure 1.1 above, but using the entire larger watershed to determine the size of the watershed. The range of estimated net sediment export values varies from less than one tenth of a ton per acre per year to about 3 tons per acre per year. Table 1.2 relates the net sediment export from one watershed to the next.

Methodology for Estimating Nutrient Loading From Agricultural Land Use

Agricultural fertilizers, natural fertility of soils and animal wastes have long been suspected of causing serious water pollution problems. In recent years, with an increased interest in studying the impact of diffuse sources of pollution on water quality, several research efforts have demonstrated the seriousness of the adverse impact of land fertilization and feedlot runoff on water quality. As a result, water quality management plans prepared under Section 208 of the Federal Water Pollution Control Act of 1972 must identify agriculture related pollution problems and demonstrate how these problems will be eliminated over time to satisfy national water quality goals.

The study for nutrient loads from Twin Cities agriculture, reported here, was undertaken for the sole purpose of indicating the order of magnitude with which agricultural fertilizers and feedlots are contributing to water quality degradation. The results identified in the tables or on the maps that follow should not be used to point to any specific source of pollution. No data were collected for this study and to this date no study of pollution from agriculture has been conducted to obtain specific field information for the Twin Cities Metropolitan Area. An estimate of the order of magnitude of the generation of nutrients by agriculture was made on the basis of a desk study using figures derived by reseachers for other parts of the United States exhibiting physical features similar to the Twin Cities Area. As with the sediment analysis, the Metropolitan Area was divided into 60 major watersheds as delineated on maps of the Conservation Needs Inventory (CNI) of the Soil Conservation Service of the U.S. Department of Agriculture.

The results reported here for loads of nitrogen (N) and phosphorus (P) generated from agricultural land use in each of 60 watersheds of the Metropolitan Area were obtained as follows:

1. Estimates of agricultural related sediment production for each watershed were obtained using the universal soil loss equation and sediment delivery ratios and sediment yield curves.

2. Estimates of average annual runoff for each watershed were determined using runoff coefficients developed in "Stormwater Impact Investigation for the Metropolitan Council" (1973). These were modified as required by the difference in watershed delineation used in the 1973 study and the Soil Conservation Service (SCS), Conservation Needs Inventory Watersheds (Appendix C).

3. The literature was searched to identify values for soluble nitrogen, soluble soluble phosphorus, nitrogen and phosphorus associated with sediments. Several criteria were used to identify which research results might be transferrable to the Metropolitan Area. These criteria are as follows:

- Runoff values should be within the range for this region (4 to 6 inches per year);

- Considerable snowfall (44 inches a year) should occur;

- Soil losses should be within the range for this region; and

- The total nitrogen and phosphorus losses, on a per acre annual basis, should be reasonably close to results reported by Johnson and Straub (1971) for a study of a 20 square mile watershed just outside the Metropolitan Area.

A considerable amount of research has been undertaken throughout the United States to identify the quantities of nitrogen and phosphorus released from agricultural land to water bodies. Several conclusions can be reached from a survey of the literature:

1. Losses of nitrogen and phosphorus are quite variable; many factors are involved including crop types, planting practices, land management practices, quantities of fertilizers and manure applied and timing of applications, soil types, climatological conditions, and others.

2. There is general agreement that most of the nitrogen and phosphorus losses are associated with sediments though the percentages diminish for nitrogen when crop residues are left on the land for soil erosion and runoff control purposes.

3. In areas where spring thaw results in large volume of surface runoff, melt waters and spring rain runoff carry in the order of 75 percent of the total nutrient loading to the stream. This was also evidenced in the Johnson and Straub study for the New Prague Watershed, cited above.

On the basis of the criteria identified above, the following general values were chosen for nitrogen and phosphorus loadings:

• Soluble nitrogen	0.64 lbs. per in. of runoff per acre
• Sediment nitrogen	3.20 lbs. per ton of sediment per acre
• Soluble phosphorus	0.14 lbs. per in. of runoff per acre
• Sediment phosphorus	0.44 lbs. per ton of sediment per acre

On the basis of an average annual runoff of 5 inches and 4.8 tons of eroded soil per acre for the Metropolitan Area, and an average delivery ratio of 0.4, nitrogen loading would be 11 pounds per acre average for the Metropolitan Area. Total phosphorus loading would then be 1.3 lbs. per acre, again average for the entire rural area of the Metropolitan Area.

Obviously, as can be expected, there are great variations in nitrogen and phosphorus loadings between all the watersheds. The Anoka Sand Plain with sandy soil highly permeable and thus producing little runoff, and low sheet erosion would contribute only 2.5 to 6 pounds of nitrogen per acre and 0.4 to 0.7 pounds of phosphorus per acre. For comparison, Hazeltine-Bavaria Creek Watershed and Bluff Creek Watershed, two generally steeply sloping watersheds with high runoff and high sheet soil erosion would contribute 14 to 15 pounds of nitrogen per acre and 2 to 2.4 pounds of phosphorus per acre. Table 1.4 and Text Figures 7 and 8 show the estimated annual nutrient losses from each watershed with agricultural land.

The estimated total annual delivery of nitrogen and phosphorus from agricultural land use to water bodies in the Metropolitan Area is 11 million pounds and 1.8 million pounds respectively. As related in the literature for example (Johnson and Straub, 1971) approximately 90 percent of the total annual loading of nitrogen and 75 percent of the total annual loading of phosphorus are delivered to the water bodies with the spring runoff during March, April and May. It is conceivable then that land in agricultural use contributes 10 million and 1.4 million pounds of nitrogen and phosphorus, respectively, over a period of 2 to 3 months in the spring. Obviously such sudden loading of streams has serious implications for the development of a nutrient control program.

Methodology for Inventorying Feedlots in the Metropolitan Area

Feedlots, when improperly located with respect to water resources, and improperly managed to prevent runoff from entering a lake or stream, can seriously downgrade water quality. Several researchers have investigated the use of vegetated strips of land to treat feedlot runoff. While this method of treatment might be very promising, two factors must still be of concern. First, runoff must be spread overland and not allowed to find its way through a channel to a stream; second, the degree of treatment of the feedlot runoff is still far from being adequate, though a tremendous improvement.

For this Section 208 study, a survey of the number, location and size of feedlots was undertaken for the entire Metropolitan Area. Aerial photographs and interviews were used to identify each feedlot and obtain information on its size. Since many different types of animals are confined to feedlots in the Metropolitan Area it is difficult to compare one feedlot to the next. So the size of each lot has been reported in animal units (Table 1.5). The Minnesota Pollution Control Agency's (MPCA's) table of animal equivalents was used for the purpose (MPCA, 1974).

The Metro-wide survey of feedlots indicated that there are over 3,400 feedlots in the Metropolitan Area with a total of over 220,000 animal units. Table 1.5 shows the number of feedlots and animal units and animal densities within each of the metropolitan watersheds.

Moore (1969) published a study on management of livestock wastes to control pollution. Using his published values for nitrogen and phosphorus produced by cattle of 0.36 pounds per day and 0.115 pounds per day respectively, the farm animal population of the Metropolitan Area is producing over 30 million pounds of nitrogen and 10 million pounds of phosphorus per year. However, the information is lacking to make any reasonable estimate of how much of this nitrogen and phosphorus finds its way to a stream or lake. The survey of feedlots indicated that from 35 percent to 90 percent of the feedlots on a

TABLE 1.4 ESTIMATED ANNUAL NUTRIENT LOSSES FROM AGRICULTURAL LAND USE

WATERSHED NAME		ANNUAL SEDIMENTS YIELD IN TONS	ANNUAL RUNOFF IN INCHES	TOTAL ANNUAL NITROGEN LOSSES IN POUNDS	NITROGEN LOSS - POUNDS PER ACRE PER YEAR	TOTAL ANNUAL PHOSPHORUS LOSSES IN POUNDS	PHOSPHORUS LOSSES - POUNDS PER ACRE PER YEAR
Seelye Brook	7-16	8,750	1.94	38,260	4.63	6,095	0.74
Ford Brook	7-18	42,905	2.64	181,212	6.97	28,484	1.10
Lower Rum River	7-15	17,914	1.94	87,730	3.58	14,533	0.59
Cedar Creek	7-17	19,852	1.54	92,896	3.11	15,159	0.51
West Branch Sunrise River	9-22	7,341	1.28	35,056	2.48	5,760	0.41
South Branch Sunrise River	9-21	41,739	0.90	152,554	4.63	22,519	0.68
Coon Creek	0-85	19,476	2.90	129,799	3.57	23,330	0.64
Sand Creek	0-84	758	4.90	12,548	3.88	2,547	0.79
Rice Creek	0-86	50,627	2.74	304,781	3.74	53,506	0.68
St. Paul	0-91	69,179	5.15	413,769	7.09	72,525	1.24
Mississippi River	0-81	8,700	5.60	45,272	8.30	7,954	1.46
Minnehaha Creek	0-90	87,615	2.80	328,275	12.28	49,030	1.83
Carver Creek	8-130	99,127	6.16	493,900	11.02	82,266	1.84
Bevens Creek	8-128	70,905	4.90	338,220	9.53	55,550	1.56
Silver Creek	8-127	46,182	4.81	202,073	11.57	32,083	1.84
Chaska Creek	8-131	17,172	4.08	76,934	9.14	12,366	1.47

TABLE 1.4 (continued)

WATERSHED NAME		ANNUAL SEDIMENTS YIELD IN TONS	ANNUAL RUNOFF IN INCHES	TOTAL ANNUAL NITROGEN LOSSES IN POUNDS	NITROGEN LOSS - POUNDS PER ACRE PER YEAR	TOTAL ANNUAL PHOSPHORUS LOSSES IN POUNDS	PHOSPHORUS LOSSES - POUNDS PER ACRE PER YEAR
Hazeltine-Bavaria Creek	8-132	13,237	6.24	68,236	10.53	11,484	1.77
Bluff Creek	8-133	17,464	4.51	68,815	15.36	10,512	2.35
Riley Creek	8-134	15,133	3.36	57,986	13.13	8,744	1.98
Purgatory Creek	8-139	31,201	5.45	113,400	5.60	16,693	0.85
Minnesota River	8-122	33,200	10.18	231,651	12.03	42,041	2.18
Minnesota River	8-126	21,228	10.18	149,240	11.96	27,127	2.17
Louzers Lake Outlet	6A-15	748	3.64	4,630	4.82	819	0.85
Lower South Fork Crow R.	6B-12	67,446	3.64	356,120	5.91	60,366	1.00
Winsted Lake	6B-10	6,216	3.64	36,198	5.17	6,302	0.90
Pioneer Creek	6B-11	83,802	3.08	325,533	11.18	49,423	1.70
Crane Creek	6B-09	2,964	3.64	13,020	7.27	2,129	1.18
Silver Creek	6B-06	123	3.64	544	8.5	86	1.34
Lower Buffalo Creek	6B-08	793	4.72	5,072	4.66	904	0.83
Minnesota River	8-141	27,728	4.44	208,329	9.31	33,811	1.51
Credit River	8-137	94,857	5.15	396,439	14.07	62,058	2.20
Mississippi River	0-97	22,311	5.84	123,366	7.23	21,185	0.95

TABLE 1.4 (continued)

WATERSHED NAME		ANNUAL SEDIMENTS YIELD IN TONS	ANNUAL RUNOFF IN INCHES	TOTAL ANNUAL NITROGEN LOSSES IN POUNDS	NITROGEN LOSS - POUNDS PER ACRE PER YEAR	TOTAL ANNUAL PHOSPHORUS LOSSES IN POUNDS	PHOSPHORUS LOSSES - POUNDS PER ACRE PER YEAR
N. Vermillion River	0-93	21,566	3.34	136,180	4.33	24,182	0.77
Vermillion River	0-95	162,642	4.29	802,314	7.81	133,219	1.30
Hardwood Creek	0-94	22,750	3.92	154,835	4.73	27,955	0.85
Chub Creek	10-09	67,796	4.39	350,506	7.37	59,046	1.24
Lower Cannon River	10-13	114,752	4.26	497,737	10.40	79,045	1.65
Sarah Creek	6-01	20,064	3.82	77,772	14.01	11,796	2.12
Crow River	6-03	56,916	3.72	230,423	11.39	35,607	1.75
Elm Creek	0-82	85,602	3.92	416,931	7.48	68,686	1.23
Osseo	0-83	6,885	3.17	39,690	4.56	6,891	0.79
Shingle Creek	0-87	13,932	5.32	48,157	3.23	6,912	0.46
Bassett Creek	0-89	14,654	5.59	58,484	18.05	8,982	2.77
Belle Plaine	8-125	16,582	5.55	79,453	10.69	13,069	1.76
Shakopee	8-136	46,826	5.77	256,299	8.89	43,890	1.52
Robert Creek	8-124	15,638	5.21	82,478	8.48	13,975	1.44
Forest Prairie Creek	8-114	1,857	5.12	10,765	7.31	1,872	1.27
Spring Lake	8-135	34,830	4.07	147,865	10.58	23,289	1.67
Sand Creek	8-129	88,316	5.55	434,068	10.18	71,990	1.69

TABLE 1.4 (continued)

WATERSHED NAME		ANNUAL SEDIMENTS YIELD IN TONS	ANNUAL RUNOFF IN INCHES	TOTAL ANNUAL NITROGEN LOSSES IN POUNDS	NITROGEN LOSS - POUNDS PER ACRE PER YEAR	TOTAL ANNUAL PHOSPHORUS LOSSES IN POUNDS	PHOSPHORUS LOSSES - POUNDS PER ACRE PER YEAR
Porter Creek	8-129-1	92,502	6.83	425,708	14.35	69,073	2.33
Raven Stream	8-129-2	36,569	5.12	189,627	8.56	31,973	1.44
Marine on St. Croix	9-34	53,440	7.75	273,174	13.26	45,862	2.23
Big Maine Lake	9-36	72,557	3.08	281,412	11.27	42,694	1.71
Browns Creek	9-37	14,693	4.06	71,634	7.56	11,850	1.25
Stillwater	9-39	62,408	4.37	301,645	8.28	49,760	1.36
Afton	9-41	34,068	5.74	173,688	9.87	29,137	1.66
Basswood Grove	9-42	48,739	4.26	186,391	16.70	28,101	2.52
Cottage Grove	00-92	42,380	3.81	175,518	10.73	27,376	1.67
Mississippi River	00-96	12,831	4.76	60,129	9.60	9,818	1.57
TOTALS		2,308,308		11,054,741		1,813,441	

TABLE 1.5 ESTIMATED NUMBER OF ANIMAL FEEDLOTS AND ANIMAL UNIT DENSITY

Watershed Name	Number of Feedlots	Number of Animal Units	Density of Animal Mile/Square
Seelye Brook	3	394	28
Ford Brook	23	2,654	57
Lower Rum River	7	2,717	51
Cedar Creek	14	1,083	19
W. Branch Sunrise River	9	1,270	42
S. Branch Sunrise River	35	6,645	97
Coon Creek	13	1,380	19
Sand Creek	1	90	6
Rice Creek	38	1,730	9
St. Paul	11	2,794	16
Mississippi River 0-81	9	1,257	28
Minnehaha Creek	127	6,787	38
Carver Creek	328	15,803	197
Bevens Creek	233	11,100	194
Silver Creek	118	5,620	204
Chaska Creek	65	3,100	231
Hazeltine-Bavaria Creek	23	1,100	88
Bluff Creek	10	475	68
Riley Creek	12	837	80
Purgatory Creek	3	450	12
Minnesota River	96	5,799	112
Louzers Lake Outlet	5	240	160
Winsted Lake	56	2,670	236
Pioneer Creek	109	7,078	135
Crane Creek	8	380	136
Silver Creek	4	190	190 *
Lower Buffalo Creek	6	290	171
Minnesota River	3	500	5
Mississippi River	6	1,575	55
N. Vermillion River	34	940	19
Vermillion River	227	28,886	164
Hardwood Creek	47	2,130	41
Chub Creek	204	19,091	252
Lower Cannon River	114	3,300	41
Lower S. Fork Crow River	439	21,757	216
Sarah Creek	14	510	52
Crow River Direct	54	3,768	113
Elm Creek	126	12,101	115
Osseo	0	0	0
Shingle Creek	0	0	0
Bassett Creek	2	490	11
Nine Mile Creek	1	410	9
Belle Plaine	28	1,355	105
Shakopee	50	2,854	55
Robert Creek	43	2,631	173
Forest Prairie Creek	4	303	132
Sand Creek	190	9,730	137

TABLE 1.5 (continued)

Watershed Name	Number of Feedlots	Number of Animal Units	Density of Animal Mile/Square
Porter Creek	101	5,044	106
Raven Stream	93	5,336	149
Spring Lake	43	1,652	53
Credit River	64	3,346	67
Marine on St. Croix	24	4,192	111
Big Marine Lake	40	2,830	60
Brown's Creek	12	394	19
Stillwater	33	1,647	20
Afton	23	1,647	51
Basswood Grove	25	1,130	51
Cottage Grove	32	220	8
Mississippi River	5	460	45
TOTAL	3,447	224,162	

* This watershed is only a fraction of a square mile; animal density has not been normalized to the square mile basis.

county basis are presenting a potential for pollution and in need of some better manure management system to prevent water pollution.

Methodology for Assessing Pesticide Use in the Metropolitan Area

There are no readily available statistics on the use of pesticides (herbicides, insecticides, fungicides) by farmers in the Metropolitan Area. Some information on pesticide use is reported by the Minnesota Crops and Livestocks Reporting Service as a total use for the entire state. Considering that the crops grown in the Metropolitan Area and that the farming techniques are no different from those crops and techniques in the remainder of the state, pesticide use in the region should be causing problems no different from the rest of the state. A review of available water quality data for lakes and streams has provided no reason to believe that pesticide use on agricultural land is causing any serious problems in the region. However, the lack of specific data is a serious hindrance to making a valid determination of a lack of problem.

A considerable amount of research on the quantity of pesticides transported by runoff from treated areas has been undertaken over the last several years, as a result of a growing concern over the impacts of pesticides on both water quality and the flora and fauna of the United States. Several remarks can be made on the basis of a literature review:

- The total amount of various pesticides lost from areas sprayed varies widely.
- The losses, while varying for different pesticides, are influenced by the characteristics of the land.
- While different pesticides behave in different ways, the largest amount of pesticides moved away from the treated field are associated with the runoff. However, this depends highly on the water solubility of the pesticide and the degree and strength of its adsorption on soils.
- Concentration of pesticide in the runoff is generally the highest when a rainfall occurs soon after the application of the pesticide.
- Several studies have shown that for several pesticides the concentration in the runoff can be reduced by grassways or untreated grass areas receiving the runoff.
- The quantity and the concentration of the pesticide in the runoff is related to the rate of application in the field, and the topography, itensity and duration of rainfall and the timing after application, soil erodibility and land management practices.

Text Table 2 shows the percentage of applied pesticides lost in runoff (in dissolved form and absorbed on sediments) as reported in the literature. The lack of data on the use of pesticides in the region and on the quantities in streams or lakes in itself warrants a research effort to ascertain the lack of apparent problem.

SEDIMENT FROM CONSTRUCTION ACTIVITIES

Methodology for Estimating Sediment Loading from Construction Activities

Each minor civil division of the Metropolitan Area was surveyed to identify where construction had taken place in 1976 and obtain data on the size of the projects. The local units of governments were also asked about their use and implementation of erosion/sedimentation control measures.[16]

The total average annual gross soil loss for each construction site was computed using the universal soil loss equation. Data for slope, soil erodibility, and management practices were obtained from published soil data. Management practices were established based on the local requirements for erosion/sedimentation control. Soil losses from the various sites within one watershed were added up to obtain the soil loss for that watershed.

The following formula (Universal Soil Loss Equation, USLE) was used to compute gross soil losses:

$$Y\ (L) = \sum_{i=1}^{n} [A_i \cdot (R.K.LS.C.P.)_i]$$

Where:

Y (L)	=	gross soil loss in tons per year
n	=	number of sub-areas in the watershed
A_i	=	acreage of sub-area "i", in acres

USLE factors:

R	=	erosion potential of average annual rainfall (rainfall factor)
K	=	soil erodibility factor
LS	=	a slope length and steepness factor
C	=	soil cover factor
P	=	erosion control practice factor

The result of the erosion study for the Metropolitan Area indicates that, given the average annual rainfall for the Metropolitan Region, the existing level of implementation of erosion/sedimentation controls, and the 1976 acreage of land developed, some 140,000 tons of soil are lost annually as a direct result of land development in the Region.

As can be expected there are great variations in the amount of soil eroded

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16 Association of Metropolitan Soil & Water Conservation Districts, 1977.

from each site when normalized on a per acre basis (Table 2.1). The estimated values for sites developed in 1976 ranged from 0.5 tons per acre per year (or 1,300 tons per square mile) on the fairly flat Anoka sand plain in the Cedar Creek Watershed to 203 tons per acre per year (or 130,000 tons per square mile) for a development on the slopes of the Minnesota River where little in preventative erosion measures were put in place. The average soil loss for developments in the Metropolitan Area is estimated at over 47 tons per acre per year (or 30,000 tons per square mile).

On the basis of the volume eroded material on a per acre unit the following were the worst watersheds in the Metropolitan Area in 1976:

Hazeltine-Bavaria (Carver County), 203 tons per acre;
Porter Creek (Scott County), 73 tons per acre;
Nine Mile Creek (Hennepin County), 65 tons per acre;
Minnesota River 141 (Dakota County), 64 tons per acre
Bassett Creek (Hennepin County), 56 tons per acre;
Stillwater (Washington County), 55 tons per acre;
Lower South Fork Crow River (Hennepin County), 55 tons per acre;
Vermillion River (Dakota County), 53 tons per acre;
St. Paul (Ramsey County), 53 tons per acre; and
Shakopee (Scott County), 51 tons per acre.

Sediment Production is dependent on erosion of soil as the sediment source, and on the transport of the eroded soil to the receiving waters. The amount of eroded soil reaching a body of water can be estimated by the use of the sediment delivery ratio (Roehl, 1962) shown previously in Figure 1.1

Studies of sediment yield indicate that the magnitude of the sediment yield is mainly related to the size of the drainage area. However, the following factors may influence the delivery ratio:[17]

- Proximity of the sources of sediment to the receiving water;
- Size and density of sediment sources;
- Characteristics of the sediment transport system;
- Texture of eroded material;
- Availability of deposition areas; and
- Topography of the watershed.

By plotting yield figures versus drainage areas in relation to sediment losses calculated by the universal soil loss equation, a delivery ratio can be obtained.

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17 Shelton, 1977.

TABLE 2.1

TWIN CITIES METROPOLITAN AREA 1976.
CONSTRUCTION ACTIVITIES - ESTIMATED EROSION
AND SEDIMENT GENERATION

Watershed Name		Disturbed Acreage	Erosion in Tons	Erosion in Tons/Acre/Yr.	Sediment in Tons	Sediment Export - In Tons
Elm Creek	0-82	170	4,906	28.90	2,047	409
Osseo	0-83	20	100	5.00	90	90
Rice Creek	0-86	172	3,389	19.70	1,977	395
Shingle Creek	0-87	190	996	5.25	826	165
Bassett Creek	0-89	56	3,129	55.90	1,642	328
Minnehaha	0-90	154	5,862	38.00	3,624	544
St. Paul	0-91	590	31,221	52.90	15,766	2,365
N. Vermillion	0-93	45	405	9.00	41	8
Vermillion	0-95	115	6,069	52.80	2,796	560
Lower S. Fork Crow	6B-12	38	2,071	54.50	1,864	932
Cedar Creek	7-17	125	243	1.95	164	28
Porter Creek	8-129-1	20	1,466	73.30	733	110
Hazeltine	8-132	20	4,060	203.00	812	365
Spring Lake	8-135	30	952	31.70	541	162
Shakopee	8-136	10	510	51.00	255	43
Purgatory Creek	8-139	268	10,030	37.40	4,240	848
Nine Mile Creek	8-140	125	8,172	65.40	4,074	815
Minnesota River	8-141	635	53,504	64.30	12,269	2,454
W. Branch Sunrise River	9-22	40	192	4.80	96	22
Stillwater	9-39	55	3,040	55.30	912	228
Browns Creek	9-37	65	183	2.80	55	17
TOTAL		2,943	140,500	47.60	54,824	10,888

The total average annual volume of sediments produced in each of the 60 metropolitan watersheds was obtained by the use of the delivery ratio method and estimating the trapping of sub-units within these watersheds.

The sediment production can be represented as follows:

$$Y(S) = \sum_{i=1}^{n} [A_i \cdot (R.K.LS.C.P.Sd)_i]$$

Where:

Y (S)	=	sediment production; in tons per year
n	=	number of sub-areas in the watershed
A_i	=	acreage of sub-area i; in acres
R,K,LS,C,P	=	variables of the universal soil loss equation
Sd	=	sediment delivery ratio, dimensionless. This value is obtained for the sediment yield curve in Figure 1.1).

The Metropolitan Area survey indicates that approximately 55,000 tons of construction-related sediments are received annually into water bodies and streams. Sediment production varies with each of the metropolitan watersheds, as shown in Text Figure 11.

The sediment production equation estimates the volume of soil reaching a body of water. When this soil has reached a lake or a stream some of the soil is deposited at the bottom or at the edge of the water; the rest is then transported downstream to the next watershed. The deposited soils may be picked up again by faster or larger flows and transported to downstream lakes.

The Net Sediment Export figure for each of the watersheds was obtained using the sediment yield ratio curve, but using the entire larger watershed to determine the size of the watershed. Table 2.1 indicates the net sediment export from one watershed to the next.

Methodology for Study of Pollution Loads from Roadside Erosion

A survey group* was formed for each of the seven metropolitan counties for the purpose of field surveying over 5,300 miles of state, county, township and major private roads and recording the location of eroding areas, the volume of material eroding and the erosion factors including: the road design (cut, fill, and grade), the location of the erosion site (ditch, inslope, backslope, or adjacent area), the type of erosion (slide or gravity, washing by water, blowout by wind) and the cause (disturbance, inadequate design or other).

The information was recorded on a form designed for the survey and on plat books and aerial photographs. Individual reports have been or are being prepared for each of the counties.

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* Under the leadership of Minnesota Department of Transportation

The survey shows that over 106,000 tons of soil were lost from roadside erosion for an average of 20 tons per mile or 85 tons per erosion site. As can be seen from Table 2.2, there are variations among the counties with Anoka County having the smallest soil loss on a per road mile basis with 3.5 tons per mile and Scott County having the greatest with 37 tons per mile. Severe soil losses from roadways were reported for:

Chanhassen Township (4,119 tons and Benton Township (3,040 tons) in Carver County;

Eden Prairie (16,674 tons) and Minnetrista (3,039 tons) in Hennepin County;

East Central Ramsey County (7,880 tons),

Jackson/Louisville Townships (8,560 tons), and Sand Creek Township (5,780 tons) in Scott County;

Afton Township (5,438 tons) and Forest Lake (3,690 tons) in Washington County.

A disaggregation of the data on the number of erosion sites and volume of soil losses into township, county and state road classes does not show any striking differences between the categories of road ownership. Township and county roads account for 42 and 41 percent of the erosion sites, respectively, whereas state roads account for 15 percent of the sites. Soil losses on township roads contributed 36,000 tons or 35 percent of the total loss, county roads contributed over 49,000 tons or 46 percent and state roads 16,000 tons or 15 percent of the total roadside soil losses.

TABLE 2.2 SURVEY OF ESTIMATED ROADSIDE EROSION IN THE METROPOLITAN AREA

County	Roadway Mileage	Number of Erosion Sites	Number of Sites per Mile	Soil Loss in Tons	Soil Loss in Tons per Site	Soil Loss in Tons per Mile
Anoka	780	84	0.11	2,857	34	3.75
Carver	721	319	0.44	15,375	48	21
Dakota	1,039	137	0.13	9,535	70	9
Hennepin	868	75	0.09	23,846	318	29
Ramsey	472	220	0.47	11,330	51	24
Scott	698	206	0.30	25,670	125	37
Washington	796	231	0.29	17,815	77	22
Metro-Wide	5,374	1,272	0.23	106,428	84	20

Source: Roadside Erosion Survey, sponsored by Minnesota Chapter Soil Conservation Society of America

POLLUTION FROM URBAN STORMWATER RUNOFF

Methodology for Assessing Pollution Potential from Urban Runoff

Pollutant loadings for the urban sub-watersheds are determined as gross average annual input on a normalized and on a total input basis. The average annual loading rates for the Metropolitan Area will indicate the magnitude and locations of the problem; event detail was not attempted because of insufficient time and funds. The reported loading is on a long-term annual basis, derived from the rainfall figures, summarized in Table 3.1.

TABLE 3.1 1967-1976 PRECIPITATION INFORMATION* (NOAA, U.S. DEPT. OF COMMERCE, LOCAL DATA)

YEAR	AMOUNT OF PRECIPITATION OCCURRING IN EVENT OVER .10" (E)	TOTAL YEARLY (T) PRECIPITATION	E/T	NUMBER OF EVENTS OVER 0.10"
1967	23.15 inches	25.44 inches	.91	55
1968	36.33 "	37.95 "	.95	64
1969	17.84 "	19.39 "	.92	51
1970	28.89 "	30.53 "	.95	64
1971	26.95 "	29.44 "	.92	69
1972	20.92 "	23.77 "	.88	58
1973	19.25 "	21.13 "	.91	56
1974	17.46 "	19.11 "	.91	53
1975	32.89 "	34.89 "	.94	56
1976	15.05 "	16.5 "	.91	40
		MEAN	.92	57

* Minneapolis-St. Paul International Airport

To determine average annual loading, the factors required are annual rainfall (P), watershed runoff percentage (C), area of specific land uses (A), and pollutant concentration expected from a specific land use (j). These factors are used in the following formula to derive loading:

$$M_j = \sum_{a}^{n} [k \quad (PxC)ja \quad Aa] \qquad (1)$$

Where M_j = pounds of pollutant j annually generated for the entire watershed

k = conversion factor = 0.23

P = annual precipitation, inches/year

C = coefficient of runoff, dimensionless percentage

A = area of land use type a

j = pollutant concentration

a = land use type

Equation 1 reduces to:

$$M_j = \sum_{a}^{n} 0.23 \quad (Qxja) \quad Aa \qquad (2)$$

Where Q = P x C

Pollutant Concentrations

All of the factors involved in equations 1 and 2 were known except for 'j', pollutant concentration expected for each type of land use. Because the program did not allow for sampling, an attempt was made to analyze all available literature in terms of using results for the Metropolitan Area. Studies of areas with physical characteristics similar to the Metropolitan Area and studies that excelled in technique and in deriving definite conclusions were chosen as input to loading determinations. Pollutant parameters were chosen on the basis of importance to the overall pollution problem, but were seletively excluded if good data did not exist to substantiate reported values. The values used were evaluated and compiled into specific land use concentrations and placed in Table 3.2. These concentrations were then placed in equation 2 to determine pollutant loadings.

A note of caution should be introduced at this point about the limitations of using these concentrations. Because most of these figures were derived from studies conducted in geographical areas outside of the Metropolitan Area and because methodologies were not always similar in conducting each of these studies, interpretation of the results derived by using Table 3.2 should be limited to perceiving the magnitude of the problem only.

Sub-watershed Loading

Loading calculations (equation 2) were performed for all of the urban study area sub-watersheds and the three additional freestanding growth centers. Table 3.3 reports these figures in two ways: as total tons per year so that watershed loading magnitude can be ascertained, and as pounds per acre per year so that all of the watersheds can be normalized to identify those that contribute a disproportionately high amount of pollution. The purpose of reporting these two figures is to compare watersheds because the large size of a particular watershed may result in high total loadings, whereas an adjacent smaller watershed may have a per unit loading rate several times that of the larger watershed. The implication of a finding such as this is that the 208 management agency must decide whether priority should be placed on managing an entire, large watershed to minimize a widely occurring problem, or whether it should first attempt to control watersheds with a proportionately higher per unit contribution.

Table 3.4 is a compilation of the two largest total loading and per acre loading sub-watersheds for each pollutant parameter. Examination of Table 3.4 reveals that for very many of the pollutants, the sub-watersheds with the largest or second largest loadings are the same sub-watersheds with large per unit loads. The ten sub-watersheds that consistently rank among the largest in total and normalized loading for most of the expected pollutants are (in approximate ranking):

- 44A - Mississippi River central; essentially all of Saint Paul, north Minneapolis, and smaller communities northwest of St. Paul.
- 27E - Lower Minnehaha Creek; south Minneapolis and east Richfield
- Waconia FGC - Located in sub-watersheds 12 and 12B in upper Carver Creek
- 3 - Lower Bassett Creek: Golden Valley and northwest Minneapolis.
- 27D - Chain of lakes drainage in Minneapolis and central portion of Minnehaha Creek; southeast Minneapolis, west Richfield, St. Louis Park, north Edina.
- 28E - Shady Oak Lake tributary; south Minnetonka
- 37C - Twin Lakes tributary, Shingle Creek; Crystal and New Hope

Table 3.2

DATA USED FOR INPUT TO LOADING EQUATIONS (j)

Land Use	BOD	COD	TSS	VSS	TS	TP	DP	NO_3-N	NH_3-N	KN	ON	TN	C1	Fecal Coliform MPN/100 ml	Cr	Cu	Ni	Pb	Zn
	mg/1														ug/1				
HDR-m	36	135	436	106	624	0.75	0.67	0.75	0.92	1.29	2.07	3.52	35	402	140	115	115	473	225
sd	32	105	199	27	252	0.25	0.03	0.43	0.23	1.46	1.23	1.67	—	194	14	7.1	35	378	7.1
n	7	6	7	5	6	4	2	2	2	7	MDR**	2	I	2	2	2	MDR	3	2
MDR-m	29.1	150	577	99	697	0.80	0.65	1.06	0.76	1.16	2.07	3.66	19.5	9,100	137	143	115	448	433
sd	20.8	83	579	55	444	9.18	0.20	0.65	0.56	0.94	1.23	0.20	10.6	10,800	101	12	35	330	163
n	10	10	12	10	10	5	8	6	5	8	3	2	2	4	3	3	2	4	3
LDR-m	16.2	78	420	75	631	0.65	0.50	0.36	0.63	1.6	2.07	3.8	24	9,600	134	122	115	175	376
sd	13.7	16	262	19	152	0.40	0.21	0.08	0.18	1.16	1.23	—	6	13,260	5	30	35	134	79
n	4	4	5	3	4	3	2	2	2	5	MDR	1	2	2	2	2	MDR	2	2
C/I-m	23.7	119	634	101	744	0.6	0.54	1.33	0.8	1.02	1.25	3.52	56	562	116	107	80	453	338
sd	25	52	654	78	556	0.3	0.35	0.65	0.42	0.7	0.35	1.67	25	819	77	45	50	237	148
n	12	12	15	12	13	6	4	5	3	12	2	2	2	4	6	6	4	7	6
OS-m	5.7	58	234	206	616	0.29		0.18	0.63	1.93	2.07	3.8	67	4,200	—	—	—	70	—
sd	7	64	301	—	34	—		—	0.18	1.37	1.23	—	—	—				—	
n	2	2	2	1	2	1		1	LDR	2	MDR	LDR	1	1				1	
Compilation-m	31.8	158	596	—	—	0.73	—	—	—	—	—	2.34	—	274,000	—	—	—	—	—
sd	11	42	51			0.2						0.17		211,000					
n	4	4	3			3						3		3					

*HDR — High Density Residential
MDR — Medium Density Residential
LDR — Low Density Residential
C/I — Commercial/Industrial
OS — Open Space
m — Mean
sd — Standard Deviation
n — Number of sample inputs

**Figure from similar land use utilized due to lack of sufficient data.

TABLE 3.3. LOADING FIGURES* FROM URBAN NONPOINT SOURCES (lbs./acre/year) tons/year

WATERSHED # AND NAME	P	C	Q	BOD	COD	TSS	VSS	TS	TP	DP	NO_3-N	NH_3-N	KN	ON	TN	Cl	AVERAGE FECAL COLIFORM MPN/100 ml	Cr	Cu	Ni	Pb	Zn
3, Bassett	29.5	.3510	10.35	289	1,495	6,209	1,762	8,982	7.9	5.8	11	10	18	25	49	595	4,282	1.2	1.2	.97	4.5	3.3
Creek				50	260	1,078	306	1,559	1.4	1.0	1.9	1.7	3.2	4.4	8.5	103		.21	.20	.17	.78	.58
3A, Upper Bassett	30.5	.2076	6.33	105	797	3,298	2,118	7,121	4.1	1.2	3.8	7.4	20	23	43	694	4,141	.25	.24	.20	1.5	.73
Creek				13	97	403	258	869	.5	.14	.46	.9	2.5	2.8	5.2	49		.03	.03	.02	.18	.09
5, Battle	30.5	.2828	8.62	139	794	3,333	1,315	5,560	4.2	2.5	5.2	6	13	16	31	445	4,026	.53	.5	.41	2.1	1.4
Creek				31	180	755	298	1,259	.94	.56	1.2	1.4	3	3.7	7.1	101		.12	.11	.09	.48	.32
9, Bluff	29.5	.1734	5.12	20	183	754	605	1,867	.92	.08	.68	1.9	6	6.1	11	199	3,625	.02	.02	.01	.26	.05
Creek				6.8	63	259	208	641	.32	.02	.23	.66	2	2.1	3.9	68		.006	.005	.004	.09	.02
10, Browns	28.5	.1517	4.32	34	276	1,164	783	2,589	1.4	.34	1.3	2.7	8	8.3	16	258	4,241	.07	.07	.06	.48	.22
Creek				8.1	65	273	184	608	.33	.08	.3	.63	1.8	1.9	3.6	61		.02	.02	.01	.11	.05
13, Fish	30.5	.1605	4.90	13	90	387	209	756	.46	.18	.51	.79	2	2.3	4.4	71	4,065	.04	.04	.03	.19	.12
Creek				12	82	355	192	695	.42	.16	.47	.72	1.9	2.1	4	65		.04	.03	.03	.18	.11
16, Coon	30.5	.1107	3.38	146	1,269	5,237	3,929	12,539	6.6	1.10	4.7	13	40	42	77	1,274	4,495	.26	.25	.22	1.9	.75
Creek				5.5	48	198	149	474	.25	.41	.18	.49	1.4	1.6	2.9	48		.01	.01	.009	.07	.03
16A, E.Trib. Coon	30.5	.1886	5.75	56	446	1,875	1,294	4,273	2.4	.55	1.8	4.4	13	14	26	426	4,442	.13	.12	.10	.74	.36
Creek				11	86	362	250	824	.46	.11	.36	.85	2.4	2.7	5.0	82		.02	.02	.02	.14	.07
17, Cottage Grove	27.5	.1595	4.39	14	122	523	373	1,204	.62	.11	.55	1.2	3.5	3.8	7.2	125	3,920	.02	.02	.02	.20	.07
Ravine				7.4	63	268	191	617	.32	.06	.28	.63	1.8	2.0	3.7	64		.01	.01	.009	.10	.04
17A, Upper Cottage Gr.	28.5	.1394	3.97	34	343	1,393	1,198	3,615	1.7	.04	1.1	3.7	11	12	22	390	4,139	.01	.01	.01	.43	.03
Ravine				5.2	52	212	183	551	.26	.006	.17	.56	1.7	1.8	3.4	60		.001	.001	.001	.06	.004
18, Credit	27.0	.1981	5.35	70	639	2,648	2,076	6,504	3.3	.38	2.3	6.6	20	22	40	672	4,263	.09	.09	.08	.90	.27
River				8.8	73	301	236	739	.38	.04	.26	.76	2.2	2.4	4.5	76		.01	.01	.01	.10	.03
18A, E.Trib.	27.5	.1380	3.80	16	122	513	341	1,148	.66	.17	.50	1.2	3.4	3.8	69	112	4,354	.04	.04	.03	.41	.11
Credit River				7.0	54	229	152	513	.29	.08	.22	.53	1.5	1.7	3.1	50		.02	.02	.02	.09	.05
20, Eagle	27.0	.0830	2.24	2.5	23	96	79	238	.17	.01	.09	.24	.72	.78	1.4	25	4,106	.002	.002	.002	.03	.01
Creek				3.4	32	131	104	323	.16	.01	.12	.33	.98	1.0	2.0	34		.003	.003	.002	.04	.01
22, Elm	30.0	.1305	3.92	74	549	2,262	1,826	5,653	2.8	.24	1.9	5.8	17	19	35	596	4,166	.06	.06	.05	.74	.17
Creek				7.0	52	214	173	535	.27	.02	.18	.55	1.6	1.8	3.3	56		.006	.005	.004	.07	.02
22C, W.Trib.	29.5	.1635	4.82	40	369	1,536	1,219	3,810	1.9	.20	1.3	3.9	12	13	23	398	3,991	.05	.05	.04	.50	.15
Elm Creek				6.5	60	249	197	617	.31	.03	.20	.63	1.9	2.0	3.8	64		.01	.007	.007	.08	.02
24, Hazel-tine-Bavaria	29.5	.2425	7.15	37	306	1,280	917	2,977	1.6	.32	1.2	3.1	8.8	9.7	18	302	4,290	.08	.07	.06	.49	.20
Creek				13	105	440	315	1,022	.55	.11	.42	1.1	3.0	3.3	6.2	104		.03	.02	.02	.17	.07
24A, Hazel-tine Lake	30.0	.0812	2.44	1.6	16	65	56	169	.08	.003	.05	.17	.53	.57	1.0	18	3,482	.001	.001	.001	.002	.002
Trib.				2.7	26	107	92	278	.13	.005	.08	.28	.87	.93	1.7	30		.001	.001	.001	.003	.004
24B, Lake	30.0	.1067	3.20	4.7	23	95	77	239	.12	.01	.07	.24	.74	.80	1.6	25	3,694	.003	.003	.002	.03	.008
Bavaria Trib.				7.3	36	149	120	374	.19	.02	.12	.38	1.2	1.2	2.3	39		.005	.004	.004	.05	.01
26, Unnamed	30.0	.1592	4.78	25	215	894	661	2,116	1.1	.19	.84	2.2	6.3	7.0	13	216	4,366	.04	.04	.03	.33	.12
Miss.R.Trib.				8.1	69	288	213	682	.36	.06	.27	.70	2.0	2.2	4.1	70		.01	.01	.01	.11	.04
27, Minne-	30.5	.1059	3.23	94	1,003	4,128	2,332	8,338	5.3	2.1	5.0	8.8	23	26	49	811	3,055	.46	.43	.37	2.1	1.2
haha Creek				2.1	38	158	89	319	.20	.08	.19	.34	.88	1.0	1.9	31		.02	.02	.01	.08	.05
27C, Trib.to	30.5	.1133	3.46	24	195	805	581	1,877	1.0	.2	.78	1.9	5.6	6.2	11	189	4,173	.04	.04	.04	.31	.13
Tanager Lake				5.9	49	201	145	469	.25	.05	.19	.48	1.4	1.5	2.8	47		.01	.01	.01	.08	.03
27D, Chain of Lakes	29.0	.3360	9.74	418	2,166	8,774	2,400	12,462	11	8.4	15	14	25	36	68	745	4,705	1.8	1.7	1.4	6.4	5.0
Drainage				47	244	990	271	1,406	1.3	.95	1.7	1.6	2.8	4.0	7.6	84		.20	.20	.16	.73	.56
27E, Lower Minnehaha	28.0	.4910	13.75	427	1,845	6,807	2,029	10,249	10	7.9	12	13	22	31	57	707	1,718	1.7	1.4	1.3	6.0	3.2
Creek				80	347	1,281	382	1,928	1.9	1.5	2.2	2.5	4.2	5.8	11	133		.31	.27	.25	1.1	.61

TABLE 3.3 (continued)

WATERSHED # AND NAME	P	C	Q	BOD	COD	TSS	VSS	TS	TP	DP	NO_3-N	NH_3-N	KN	ON	TN	Cl	AVERAGE FECAL COLIFORM MPN/100 ml	Cr	Cu	Ni	Pb	Zn
28, Nine	28.0	.2774	7.77	62	500	1,946	961	3,640	2.6	1.3	2.6	4.0	9.5	12	21	300	4,694	.28	.27	.23	1.2	.74
Mile Creek				18	149	579	286	1,083	.78	.39	.78	1.2	2.8	3.5	6.3	89		.08	.08	.07	.35	.22
28A, Bryant	29.5	.1663	4.90	12	85	345	205	713	.44	.16	.42	.75	2.0	2.3	4.2	66	3,856	.03	.03	.03	.17	.09
Lake Trib.				10	72	291	173	602	.37	.13	.35	.63	1.7	1.9	3.6	56		.03	.03	.02	.14	.08
28B, N.Trib.	29.5	.3283	9.68	70	399	1,664	627	2,405	2.1	1.3	2.6	3.0	6.3	7.9	15	210	4,250	.27	.26	.22	1.1	.76
Nine Mile Cr.				40	215	897	338	1,296	1.1	.69	1.4	1.6	3.4	4.3	8.2	113		.15	.14	.12	.58	.41
28C, N.E.																						
Trib. Nine	29.0	.2182	6.33	57	349	1,408	646	2,526	1.8	.94	2.0	2.7	6.4	7.8	15	205	4,857	.20	.20	.16	.84	.57
Mile Creek				21	128	518	238	928	.67	.35	.74	.99	2.4	2.9	5.4	75		.07	.07	.06	.31	.21
28D, Upper	29.0	.3092	8.97	50	413	1,520	870	3,062	1.8	.65	2.0	3.8	8.3	9.4	18	291	4,110	.14	.13	.11	.75	.41
Nine Mile Cr.				21	174	642	367	1,292	.80	.27	.82	1.6	3.5	4.0	7.6	12		.06	.06	.04	.31	.17
28E, Shady	30.0	.3078	9.23	61	257	976	242	1,411	1.5	1.2	1.6	1.8	3.0	4.3	8.0	98	2,509	.27	.23	.22	.84	.55
Oak Lake Trib.				54	227	862	213	1,245	1.3	1.1	1.4	1.6	2.6	3.8	7.0	87		.24	.20	.19	.74	.49
29, Prior	27.0	.1740	4.70	39	306	1,257	836	2,791	1.6	.43	1.3	2.9	8.1	9.1	17	269	4,174	.10	.09	.08	.53	.28
Lake Trib.				8.4	65	267	178	593	.34	.09	.28	.61	1.7	1.9	3.6	57		.02	.02	.02	.11	.06
30, Upper	30.0	.2247	6.74	35	308	1,294	904	2,975	1.6	.37	1.2	3.1	8.8	9.7	18	297	4,423	.09	.08	.07	.50	.24
Purgatory Cr.				11	99	417	291	958	.53	.14	.40	.99	2.8	3.1	5.8	96		.03	.03	.02	.16	.08
30A, Lower	28.5	.2186	6.23	41	348	1,460	1,043	3,363	1.8	.33	1.5	3.5	9.9	11	20	345	4,027	.07	.07	.05	.58	.21
Purgatory Cr.				11	90	377	269	868	.46	.08	.39	.89	2.6	2.8	5.2	89		.02	.02	.01	.15	.05
30B, W.Trib.	30.0	.1096	3.29	3.9	30	121	78	261	.15	.04	.14	.27	.75	.85	1.6	25	3,836	.01	.01	.01	.05	.03
Purgatory Cr.				5.8	44	180	116	389	.23	.06	.20	.40	1.1	1.3	2.3	37		.01	.01	.01	.08	.04
30C, Trib.to	29.5	.1150	3.39	8.8	65	261	161	551	.39	.11	.30	.57	1.6	1.8	3.3	51	3,967	.02	.02	.02	.12	.07
Anderson Lks.				6.1	45	181	112	383	.24	.08	.21	.40	1.1	.61	2.3	35		.02	.02	.01	.09	.05
30D, N.Trib.	30.5	.2239	6.83	31	184	734	293	1,239	.99	.57	1.1	1.3	3.0	3.9	4.0	88	5,951	.12	.12	.10	.45	.37
Purgatory Cr.				26	151	604	241	1,019	.81	.47	.87	1.1	2.5	3.2	3.3	72		.10	.10	.09	.37	.30
31, Upper	29.0	-.0321	-.93	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Rice Cr.																						
31C, Trib.to	28.5	.0094	.27	2.2	14	58	26	103	.07	.04	.08	.11	.26	.32	.59	8.4	2,914	.008	.008	.007	.03	.02
White Bear Lk.				.48	3.0	13	5.7	23	.16	.01	.02	.02	.06	.07	.13	1.8		.002	.002	.001	.007	.005
31E, Lower	29.0	.2189	6.35	324	2,015	8,402	4,056	15,532	11	5.2	12	17	40	47	90	1,350	4,037	1.1	1.1	.88	4.8	3.0
Rice Creek				18	115	479	231	886	.60	.29	.66	.95	2.3	2.7	5.1	77		.06	.06	.05	.27	.17
32, Riley	29.0	.1994	5.78	15	136	584	436	1,373	1.3	.09	.49	1.4	4.2	4.6	8.4	142	4,225	.02	.02	.02	.19	.06
Creek				8.6	77	332	247	780	.76	.05	.28	.80	2.4	2.6	4.8	81		.01	.01	.01	.11	.04
32A, Upper	29.5	.1208	3.56	10	98	397	333	1,012	.49	.02	.33	1.0	3.1	3.4	6.2	109	3,610	.005	.005	.004	.13	.01
Riley Cr.				4.3	42	170	142	433	.21	.01	.14	.44	1.3	1.4	2.7	46		.002	.002	.002	.05	.006
34, Rum	29.5	.0704	2.08	25	238	980	802	2,467	1.2	.08	.83	2.5	7.6	8.2	15	262	4,201	.02	.02	.02	.32	.06
River				3.0	28	117	96	294	.14	.01	.10	.30	.90	.98	1.8	31		.002	.002	.002	.04	.007
37, Shingle	30.5	.2832	8.64	106	582	2,420	841	3,849	3.1	2.7	4.0	4.2	8.7	11	21	284	3,861	.43	.41	.34	1.6	1.2
Creek				32	174	722	251	1,149	.92	.81	1.2	1.3	2.6	3.3	6.4	85		.13	.12	.10	.48	.36
37A, Trib.	30.5	.1292	3.94	11	41	417	319	1,004	.52	.07	.39	1.0	3.0	3.3	6.1	104	3,750	.02	.02	.01	.15	.05
to Eagle Lk.				5.5	49	202	155	487	.25	.03	.19	.50	1.5	1.6	3.0	51		.008	.007	.006	.07	.02
37B, S.W.																						
Trib.Shingle	30.5	.2062	6.29	26	222	934	673	2,178	1.2	.21	.96	2.2	6.5	7.1	13	222	4,137	.05	.05	.04	.35	.14
Creek				10	88	369	266	861	.46	.08	.38	.88	2.6	2.8	5.2	88		.02	.02	.02	.14	.06
37C, Twin																						
Lakes Trib.	30.5	.3155	9.62	137	753	3,144	1,032	4,831	4.0	2.7	5.1	5.3	11	14	27	338	4,810	.72	.55	.45	2.1	1.6
Shingle Cr.				41	224	936	307	1,438	1.2	.79	1.5	1.6	3.2	4.2	8.0	101		.21	.16	.14	.63	.48
39E, Trib.																						
to Forest	27.5	.0912	2.51	24	211	883	672	2,124	1.1	.14	.82	2.2	6.4	6.9	13	222	4,076	.03	.03	.02	.31	.10
Lake				3.9	35	145	111	349	.18	.02	.14	.36	1.1	1.1	2.1	37		.005	.005	.004	.05	.02
42C, Trib.																						
to Upper	29.0	.1364	3.96	33	281	1,176	850	2,756	1.5	.28	1.1	2.8	8.3	9.1	17	278	4,503	.07	.06	.06	.43	.20
Vermillion				6.8	57	239	172	559	.30	.06	.22	.57	1.7	1.8	3.4	56		.01	.01	.01	.09	.04
River																						

TABLE 3.3 (continued)

WATERSHED # AND NAME	P	C	Q	BOD	COD	TSS	VSS	TS	TP	DP	NO_3-N	NH_3-N	KN	ON	TN	Cl	AVERAGE FECAL COLIFORM MPN/1oo ml	Cr	Cu	Ni	Pb	Zn
42F, Upper Vermillion River	29.5	.1387	4.09	104	969	3,870	3,098	9,703	4.9	.61	3.6	10	29	32	59	1,016	4,192	.14	.13	.11	1.4	.38
				6.2	58	231	185	1,969	.29	.04	.22	.60	1.8	1.9	3.5	61		.008	.008	.006	.09	.02
42H, Crystal Lake Drainage	28.0	.1782	4.99	17	128	453	366	1,155	.67	.21	.61	1.2	3.3	3.7	6.9	110	4,172	.05	.05	.04	.24	.14
				9.6	73	308	191	656	.38	.12	.35	.68	1.9	2.1	3.9	63		.03	.03	.02	.13	.08
42L, N.Trib. Upper Ver-million River	30.0	.1669	5.01	39	305	1,269	856	2,824	1.6	.38	1.4	2.9	8.2	9.0	17	284	4,004	.08	.08	.06	.55	.22
				10	78	322	218	717	.40	.10	.36	.75	2.1	2.3	4.3	72		.02	.02	.02	.14	.06
43, Lower Minnesota River	27.5	.3642	10.02	46	404	1,664	1,263	3,980	2.0	.28	1.6	4.1	12	13	24	413	4,263	.06	.06	.05	.62	.19
				16	149	596	452	1,426	.74	.10	.57	1.5	4.3	4.7	8.7	148		.02	.02	.02	.22	.07
43A, Lower Minnesota River	27.5	.2247	6.18	178	1,569	6,579	4,954	15,631	7.8	1.0	6.6	16	47	50	95	1,648	3,793	.22	.21	.16	2.5	.64
				9.6	85	356	268	847	.43	.06	.36	.87	2.5	2.7	5.1	89		.01	.01	.009	.13	.03
43B, Lower Minnesota River	27.0	.2827	7.63	340	2,115	9,052	4,234	16,460	11	5.5	13	18	42	49	95	1,445	3,701	1.2	1.1	.93	5.1	3.3
				21	133	570	267	1,037	.70	.35	.81	1.1	2.6	3.1	6.0	91		.08	.07	.06	.32	.21
43C, Lower Minnesota River	27.5	.1646	4.53	68	561	2,308	1,654	5,323	2.7	.55	2.4	5.5	16	17	32	543	4,140	.12	.11	.09	.94	.33
				8.1	67	274	197	633	.33	.07	.29	.65	1.9	2.0	3.8	65		.014	.013	.011	.11	.04
44, Miss-issippi River, N.W.	29.5	.1292	3.81	162	1,085	4,635	3,089	10,409	5.9	1.5	4.5	11	31	34	63	1,013	4,702	.37	.35	.31	1.8	1.1
				8.5	57	243	162	546	.31	.08	.23	.56	1.6	1.8	3.3	53		.02	.02	.02	.09	.06
44A, Miss-issippi River, Central	28.0	.4833	13.53	1,859	8,803	35,276	11,380	54,322	47	34	60	65	118	155	300	4,122	2,234	7.2	6.3	5.6	28	16
				69	328	1,315	424	2,022	1.7	1.3	2.2	2.4	4.4	5.8	11	154		.27	.24	.21	1.0	.59
44B, Miss-issippi River, S. Central	30.0	.1864	5.59	312	1,969	8,303	4,037	15,360	10	4.7	12	16	40	46	89	1,360	3,221	1.0	1.0	.53	4.7	2.9
				13	84	353	172	653	.43	.20	.50	.70	1.7	2.0	3.8	58		.04	.04	.02	.20	.12
44C, Miss-issippi River, South	29.5	.1731	5.11	33	294	1,202	945	2,938	1.5	.16	1.1	3.0	8.9	9.7	18	308	3,842	.04	.04	.03	.43	.10
				7.9	71	291	229	712	.36	.04	.27	.73	2.2	2.3	4.3	75		.008	.008	.007	.10	.03
44D, Miss-issippi River, North of St. Paul	28.5	.2107	6.00	261	1,558	6,498	2,742	11,213	8.2	4.6	9.6	12	28	34	64	902	4,096	.98	.95	.78	3.9	2.8
				18	110	457	193	789	.58	.32	.68	.85	1.9	2.4	4.5	63		.07	.07	.06	.28	.20
44E, Miss-issippi River, S.E.	27.5	.1331	3.66	32	248	1,008	677	2,241	1.3	.33	1.1	2.3	6.5	7.3	13	219	3,776	.07	.07	.06	.44	.21
				6.3	48	197	132	438	.25	.07	.21	.45	1.3	1.4	2.6	43		.014	.014	.012	.09	.04
45B, St. Croix near Stillwater	28.5	.1526	4.35	46	331	1,400	798	2,843	1.8	.64	1.7	2.9	7.9	9.0	17	261	4,815	.14	.14	.12	.66	.43
				10	74	313	178	635	.39	.14	.37	.66	1.8	2.0	3.8	58		.03	.03	.03	.15	.10
Waconia FGC	30.0	.3960	11.88	21	114	465	124	650	.60	.43	.81	.70	1.3	1.9	3.5	37	6,480	.09	.09	.07	.33	.28
				59	326	1,330	355	1,858	1.7	1.2	2.3	2.0	3.7	5.3	10	105		.26	.26	.21	.93	.81
Jordan FGC	28.5	.2870	8.18	18	107	465	192	791	.55	.31	.71	.97	1.9	2.3	4.5	67	3,979	.07	.06	.05	.28	.19
				27	165	718	297	1,222	.86	.47	1.1	1.5	2.9	3.5	6.9	103		.10	.10	.08	.43	.29
Belle Plaine FGC	28.5	.3260	9.29	65	365	1,705	518	2,570	2.0	1.4	2.8	2.9	5.6	6.9	14	191	4,318	.30	.29	.23	1.0	.88
				36	201	939	285	1,414	1.1	.74	1.5	1.6	3.1	3.8	7.7	105		.17	.16	.13	.57	.49
TOTAL LOADING IN TONS/YEAR				6,869	42,046	172,559	85,893	351,765	221	107	239	354	863	1,003	1,951	28,796		23.1	21.2	17.8	101.0	58.5

* PARAMETER ABBREVIATIONS:

BOD - Biochemical Oxygen Demand
COD - Chemical Oxygen Demand
TSS - Total Suspended Solids
VSS - Volatile Suspended Solids
TS - Total Solids
TP - Total Phosphorus
DP - Dissolved Phosphorus
NO_3-N - Nitrate Nitrogen
NH_3-N - Ammonia Nitrogen
KN - Kjeldahl Nitrogen
ON - Organic Nitrogen
TN - Total Nitrogen
Cl - Chlorides
Cr - Chromium
Cu - Copper
Ni - Nickel
Pb - Lead
Zn - Zinc

TABLE 3.4. Loading Figures for Largest Contributing Subwatersheds

Parameter	Total Loading, t/A		Normalized Loading, lb/A/yr.	
	Value	Subwatershed	Value	Subwatershed
BOD	1,859	44A	80	27E
	427	27E	69	44A
COD	8,803	44A	347	27E
	2,166	27D	328	44A
TSS	35,276	44A	1,330	Waconia FGC*
	9,052	43B	1,315	44A
VSS	11,380	44A	452	43
	4,954	43A	424	44A
TS	54,322	44A	2,022	44A
	16,460	43B	1,969	42F
TP	47	44A	1.9	27E
	11	43B, 31E, 27D	1.7	44A, Waconia FGC
DP	34	44A	1.5	27E
	8.4	27D	1.3	44A
NO_3	60	44A	2.3	Waconia FGC
	15.3	27D	2,2	2.2 44A, 27E
NH_3	65	44A	2.5	27E
	18	43B	2,4	44A
KN	118	44A	4.4	44A
	42	43B	4.3	43
ON	155	44A	5.8	27E, 44A Waconia FGC
TN	300	44A	11	27E, 44A Waconia FGC
Cl	4,122	44A	154	44A
	1,648	43A	148	43
Fecal Coliform	6,480	Waconia FGC		
	5,951	30D		
Cr	7.2	44A	0.31	27E
	1.8	27D	0.27	44A
Cu	6.3	44A	0.27	27E
	1.7	27D	0.24	44A
Ni	5.6	44A	0.25	27E
	1.4	27D	0.21	44A, Waconia FGC
Pb	28	44A	1.1	27E
	6.4	27D	1.0	44A
Zn	16	44A	0.81	Waconia FGC
	5	27D	0.61	27E

* FGC - Freestanding Growth Center

28E - North tributary to Nine Mile Creek; south Hopkins, northwest Edina and southeast Minnetonka

Belle Plaine FGC - Located in sub-watershed 43 tributary to the Minnesota River

43 - Lower Minnesota River; west Bloomington, south Eden Prairie, and south Chaska-Chanhassen.

Other sub-watersheds that contribute relatively large per unit area loadings are 5, 37, 30D, Jordan FGC, 28, 28D, 43B, 28C, 24, and 32. Figure 3.1 displays the location of these major and minor contributing watersheds.

The findings of this section lead to a recommendation that future management priority should be placed on sub-watersheds that contribute the largest per acre loading. In so doing, it is believed that the sub-watersheds that also contribute the largest total loadings will be included.

The two sub-watersheds (44A and 27E) contributing the greatest amount of pollutants happen to occur in the combined sewer service areas of St. Paul and Minneapolis. As such, the 208 management effort in the future will address methods for minimizing pollutant input in the combined system, but the 201 efforts of the Metropolitan Waste Control Commission (MWCC) will address remedial measures required once the surface materials are mobilized and enter the sewer.

Some of the sub-watersheds undergoing rapid but spotty urbanization did not necessarily show up in Table 3.3 as the largest contributors to the pollution totals because such development averaged over the entire acreage of the sub-watershed resulted in decreased per unit loading values.

Additional Information

Table 3.5 is a listing of the 1976 loading from study area municipal treatment plants. This information was used in the text of this report to analyze the point source versus urban nonpoint source pollutant loading. Table 3.6 is a similar listing for major industrial discharges.

Table 3.7 is a listing of lakes in the study area that are potentially degraded from stormwater runoff. Discussion of the results of this table occurs in the text of this report.

Figure 3.1
SUBWATERSHEDS CONSISTENTLY HIGH IN URBAN NONPOINT LOADING

Watersheds

—— Primary

—— Secondary

---- Tertiary

53B Watershed designations by Hickok and Associates for the Metropolitan Council (1972)

Task 54 - Urban Study Area

High urban nonpoint loading

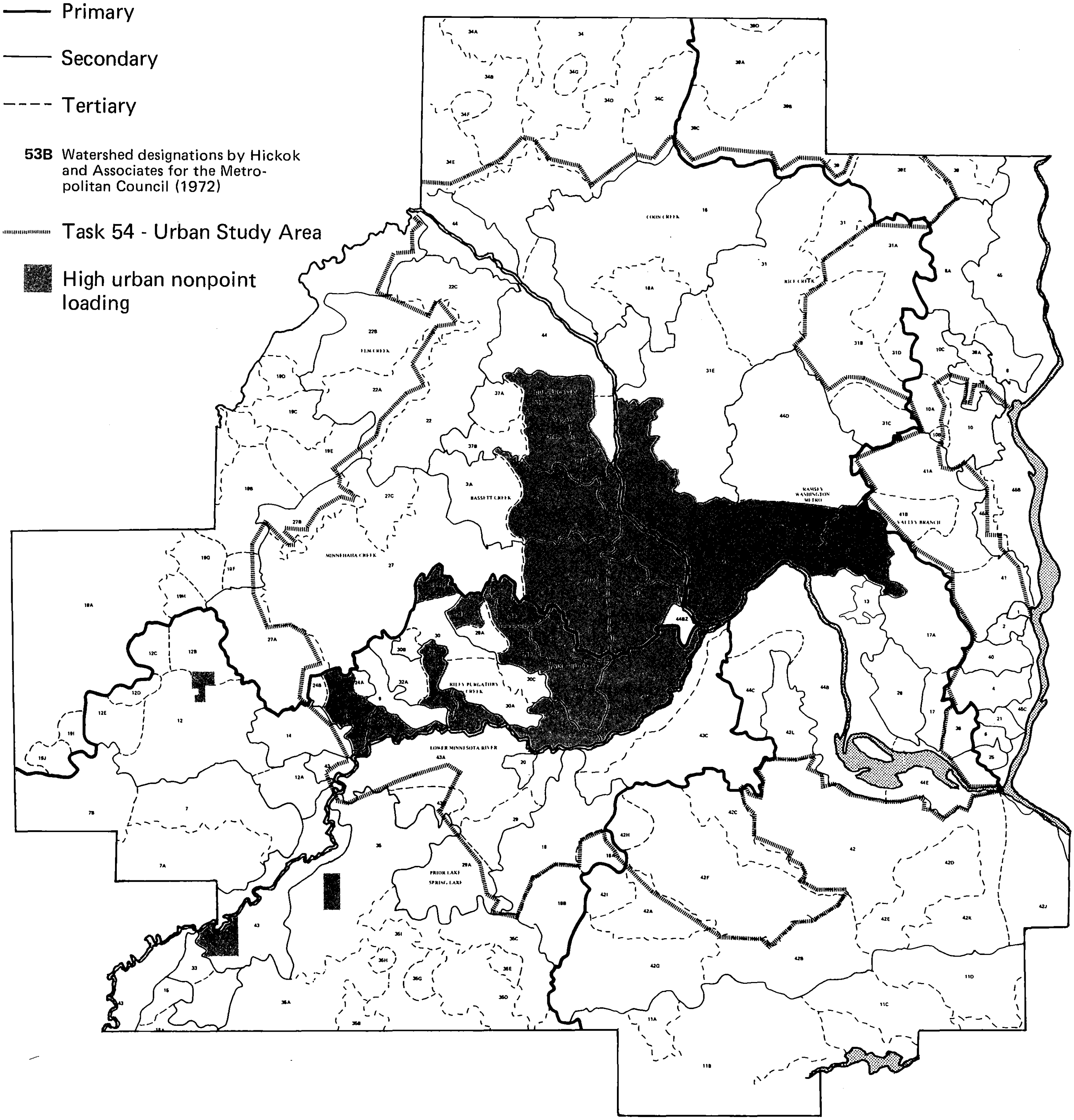


TABLE 3.5 1976 LOADING FOR STUDY AREA
MUNICIPAL TREATMENT PLANTS (in thousand pounds per year)

PLANT	WATERSHED	BOD	COD	TSS	KJN	NH_3	NO_3- NO_2	TP	Cu	Cr	Pb	Zn
Anoka	44	59.3	376.6	80.8	77.6	67.9	37.8	42.6	0.96	0.96	0.54	0.64
Apple Valley	42F	31.1	244.4	22.2	89.3	83.5	5.3	36.4				
Bayport	45B	21.3	80.7	12.2	9.6	7.5	4.3	0.6				
Blue Lake	43A	412.3	2,419.0	522.3	395.8	335.4	121.3	192.4				
Chaska	24	103.6	310.7	135.6	37.0	29.6	1.6	8.1				
Cottage Grove	44E	152.4	332.4	69.3	75.9	65.4	14.8	29.6				
Farmington	42F	32.7	132.9	25.9	19.4	15.4	1.3	24.9				
Hastings	44E	47.5	328.5	83.1	68.9	60.9	22.5	24.5				
Lakeville	42A	39.3	163.1	45.1	13.2	9.0	2.6	5.2				
Long Lake	27C	23.7	83.3	27.8	11.7	9.2	0.2	3.6				
Medina	22	3.0	13.2	3.2	3.5	3.1	0.5	1.3				
Metro	44B	39,975.0	120,000.0	35,800.0	9,670.0	7,339.0	226.7	2,500.0	71.8	204.0	59.6	107.4
Orono	27	7.6	52.8	16.1	5.1	3.0	2.8	3.0				
Prior Lake	18	46.9	150.0	37.5	25.6	22.4	1.0	9.4				
Rosemount	42	10.2	27.8	2.2	20.9	19.4	0.3	0.6				
Savage	29	23.1	99.5	11.6	14.6	11.0	1.5	9.5				
Seneca	43B	493.6	2,764.0	493.6	875.3	809.5	14.8	230.3				
Stillwater	45B	51.1	236.5	63.9	97.8	93.3	1.8	3.2				
Waconia FGC*	12B	49.0	209.7	41.9	26.8	20.7	3.3	7.8				
Jordan FGC	35	85.5		76.2								
Belle Plaine FGC	43	134.4		124.6								
TOTAL (10^3lbs/yr)		41,800.0	128,025	37,690.0	11,540.0	9,000.0	464.4	3,140.0	72.76	204.96	60.4	108.04
(tons/yr)		20,900.0	64,013	18,845.0	5,771.0	4,504.0	232.3	1,568.0	36.38	102.48	30.07	54.02

* Freestanding Growth Center

TABLE 3.6. 1976 LOADING FOR STUDY AREA

INDUSTRIAL DISCHARGES* (in thousand pounds per year)

PERMITTEE	BOD	COD	TSS	METALS	OTHER
Bongards Creamery	21.9		21.9		TP 4.4
M.A. Gedney Co.	152.2		182.6		
Koch Refinery	213.2	4,545.3	255.9	Cr 10.4	NH4-N 355.1
E. Kraemer & Sons			118.7		
Metro Airport Commission	283.9		337.6	Pb 0.65	
Mid-America Dairymen	22.8		22.8		
3-M Chemolite	380.5		456.6	Cr 3.8 Ni 9.1 Fe 15.2 Zn 7.6	
Northwest Refinery	219.0	1,873.9	214.6	Cr 4.3	NH4-N 146.4
J.L. Shiely-Shakopee			277.9		
J.L.Shiely-Grey Cloud			255.7		
St. Paul Ammonia	43.8		52.5		NH4-N 87.5
Vy-Facto North.	67.9		81.5		
TOTAL 10^3 lb/yr.	1,405	6,419	2,278	Cr 18.5 Pb 0.65 Ni 9.1 Fe 15.2 Zn 7.6	NH4-N 589.0 TP 4.4
tons/yr.	702.6	3,209	1,139	Cr 9.25 Pb 0.32 Ni 4.55 Fe 7.6 Zn 3.8	NH4-N 294.5 TP 2.2

* Major Industrial Discharges Over 0.5 mgd

TABLE 3.7 URBAN LAKES POTENTIALLY DEGRADED FROM STORMWATER RUNOFF

County	Lake (Nature of Problem *)			
Anoka	Reshanau	(3)		
	Golden	(5)		
	Wood (Spring)	(3)		
Carver	Virginia	(2)		
Dakota	Crystal	(1)		
Hennepin	Penn	(1)	Harriet	(1)
	Powderhorn	(1)	Hiawatha	(1)
	Nokomis	(1)	Round	(4)
	Calhoun	(2)	Starling	(2)
	Crystal	(1)	Shady Oak	(2)
	Sweeny-Twin	(1)	Gleason	(3)
	Wirth	(2)	Parker	(1)
	Brownie	(1)	Eagle	(1)
	Cedar	(1)	Weaver	(1)
	Lake of the Isles	(1)	Christmas	(1)
	Twin	(1)	Dutch	(4)
	Palmer	(2)	Langdon	(4)
	Bryant	(1)		
Ramsey	Silver	(2)	Turtle	(1)
	Gervais	(1)	Long	(1)
	Keller	(1)	Pike	(1)
	Phalen	(1)	Round	(3)
	Beaver	(2)	Snail	(1)
	Lilydale (Birch)	(1)	Grass	(3)
	Goose	(5)	Island	(3)
	Sucker	(1)	Johanna	(1)
	Como	(1)	Wabasso	(1)
	Owasso	(1)	Silver	(1)
	Josephine	(1)		
Scott	Lower Prior	(1)	Crystal	(1)
Washington	Lily	(1)	Tanners	(1)

* MPCA assistance was sought in identifying causes for lake degradation and in developing the following categories for nature of the problem:

1. Urban runoff confirmed as a problem;
2. Some urban runoff; shallow morphometry;
3. No significant urban runoff; shallow morphometry;
4. Information lacking;
5. Drainage ditch; shallow morphometry.

SEDIMENT FROM STREAM CHANNEL EROSION

Estimates of average annual gross soil loss from stream channel erosion were prepared on the basis of data obtained by Soil Conservation Service (SCS) personnel under a 208 subcontract with the Metropolitan Council. It was assumed that gross soil losses from the channel and sediment yields would be the same since in almost all instances eroded materials fall directly into the stream to be carried away as bedload or suspended material.

Methodology for Estimating Erosion from Stream Channels

Sediment yields resulting from stream channel erosion and gullies were estimated for the Metropolitan Area. For this purpose the Metropolitan Area was divided into 60 major watersheds as delineated on maps of the Conservation Needs Inventory (CNI) (1975) of the SCS of the U.S. Department of Agriculture.

Each watershed was inventoried by the County Soil Conservationist for existing channel and gully erosion problems. Erosion problems were detected on aerial photographs; the length of eroding channel, and the annual rate of channel bank recession were also noted for each erosion site. The information was then checked through a field survey during which other information on soil type, height of bank, and cause of the problem was recorded.

Each eroding area was classified as either active (eroding) or inactive (bare area but no longer eroding) and placed into one of three classes representing the severeness of the problem: "slight erosion", less than 50 tons of sediments per year; "moderate", 50 - 100 tons of sediments per year; or "severe", losses greater than 100 tons per year. A summary was prepared for each of the 60 watersheds briefly stating the geomorphologic and land use characteristics of the watershed as well as indicating the magnitude of channel erosion problems. It should be noted that no actual soil loss data were actually collected.

On the basis of the information recorded by the SCS personnel, the Council estimated soil losses, and length of eroded channel for each watershed and developed an index of the severeness of the erosion problem for each watershed (Table 4.1). This 'index of severeness' is simply the ratio of weight of soil losses to length of eroded channel.

TABLE 4.1 STREAM CHANNEL EROSION

WATERSHED NAME		SIZE IN SQUARE MILES	TOTAL EROSION-TONS PER YEAR	LENGTH OF ERODED CHANNEL-IN FEET	SOIL LOSS PER YR./SQ. MILE IN TONS	LENGTH OF CHANNEL ERODED/ SQ. MILE IN FEET	INDEX OF SEVERITY *
Lower Rum River	7-15	53.3	3,480	7,250	65.0	136	0.48
Cedar Creek	7-17	57.0	8	60	0.10	1	0.10
Coon Creek	0-85	71.2	387	3,100	5.5	43.5	0.13
Rice Creek	0-86	189.8	525	2,800	3.00	15.00	0.20
Ford Brook	7-18	46.5	22	150	0.40	3.00	0.13
Mississippi River	0-81	38.4	7,022	13,000	183	339	0.54
Minnesota River	8-126	21.1	134,443	188,200	6,371	8,920	0.71
Lower South Fork Crow River	6b-12	97.5	1,373	35,300	14	362	0.04
Hazeltine-Bavaria	8-132	12.5	1,420	36,025	113	2,882	0.04
Silver Creek	8-127	27.5	2,356	69,450	80	2,525	0.03
Bevens Creek	8-128	57.3	3,220	110,400	56	1,927	0.03
Winsted Lake	6b-10	11.3	79	3,700	7	327	0.02
Bluff Creek	8-133	7.0	1,620	24,400	231	3,485	0.07
Carver Creek	8-130	79.5	3,488	94,750	44	1,192	0.04
Chaska Creek	8-131	13.4	1,030	27,450	77	2,048	0.04
Pioneer Creek	6b-11	52.6	931	4,200	18	80	0.22
Purgatory & Riley Creeks	8-139,134	46.9	1,940	9,850	41	210	0.20
Minnehaha Creek	00-90	177.5	1,439	9,200	8	52	0.15
Minnesota River	8-141	64.5	3,171	8,100	49	126	0.39

Table 4.1 (contd.)

WATERSHED NAME		SIZE IN SQUARE MILES	TOTAL EROSION-TONS PER YEAR	LENGTH OF ERODED CHANNEL-IN FEET	SOIL LOSS PER YR./SQ. MILE IN TONS	LENGTH OF CHANNEL ERODED/ SQ. MILE IN FEET	INDEX OF SEVERITY
Mississippi River	0-97	28.6	3,543	3,400	123	119	1.03
St. Paul	0-91	232.9	10,419	20,110	45	86	0.52
Vermillion River	0-95	176.5	1,556	13,975	9	80	0.11
Chub Creek	10-09	75.7	1,648	23,500	22	310	0.07
Lower Cannor River	10-13	80.0	881	5,400	11	68	0.16
Elm Creek	0-82	105.5	1,710	8,900	16	84	0.19
Sarah Creek	6-01	9.9	627	3,250	63	328	0.19
Shingle Creek	0-87	40.2	764	4,000	19	100	0.19
Nine Mile Creek	8-140	44.6	37	2,600	1	58	0.02
Mississippi River	0-83	38.2	366	5,650	10	148	0.07
Bassett Creek	0-89	42.6	207	700	5	16	0.31
Crow River	6-03	33.4	3,278	3,800	98	114	0.86
Minnesota River	8-138	28.8	3,737	32,500	130	1,128	0.12
Minnesota River	8-122	30.9	219,230	174,150	7,095	5,636	1.26
Shakopee	8-136	51.9	6,354	45,700	122	883	0.14
Robert Creek	8-124	15.2	44,271	54,700	2,913	3,599	0.81
Spring Lake	8-135	31.3	62	1,550	2	50	0.04
Porter Creek	8-129-1	47.5	1,504	29,200	32	615	0.05
Raven Stream	8-129-2	35.7	653	18,100	18	507	0.04
Belle Plaine	8-125	12.9	6,660	30,600	516	2,372	0.22

Table 4.1 (contd.)

WATERSHED NAME		SIZE IN SQUARE MILES	TOTAL EROSION-TONS PER YEAR	LENGTH OF ERODED CHANNEL-IN FEET	SOIL LOSS PER YR./SQ. MILE IN TONS	LENGTH OF CHANNEL ERODED/ SQ. MILE IN FEET	INDEX OF SEVERITY
Credit River	8-137	50.0	1,202	16,500	24	330	0.07
Sand Creek	8-129	71.1	49,252	98,500	693	1,385	0.50
Stillwater	9-39	82.3	6,596	9,400	80	114	0.70
Basswood Grove	9-42	22	9,665	23,850	439	1,084	0.40
Mississippi River	0-96	10.2	1,305	4,400	128	431	0.30
Cottage Grove	0-92	26.6	1,802	1,800	68	68	1
Brown Creek	9-37	20.3	855	200	42	10	4.2
Big Marine Lake	9-36	47.3	1,060	4,800	22	101	0.22
Marine on St.Croix	9-34	37.7	135	5,100	4	135	0.03
Afton	9-41	32	24,474	19,500	765	609	1.26
South Branch Sunrise River	9-21	68.8	295	3,100	4	45	0.09
Metropolitan Area		2,755.4	572,102	1,316,320	207	477	0.43

* Soil loss in tons over eroded channel in feet.

LANDFILL LEACHATES

Methodology for Assessing the Pollution Potential from Landfill Leachates

The water balance method was used in the technical study of landfill leachates to determine the amount of precipitation occurring on the landfill surface, the amount lost from the landfill surface, and the amount entering the landfill surface. The basic parameters of the equation are illustrated in Figure 5.1, and the definitions of the parameters and the methods of calculating them follow.

Precipitation (P) is the amount of rain that falls on a landfill area. Contour maps (Kuehnast et al., 1975) of the mean monthly precipitation from 1959 to 1972 were used to estimate monthly precipitation at each landfill. These values vary considerably yielding final leachate volumes that must be considered as gross rather than definite volumes.

Surface Runoff (RO) is the portion of rainfall that runs off of a landfill surface without seeping into the cover soil. The amount of runoff is dependent on the land surface cover, slope, soil moisture, soil type, and rainfall intensity. Two methods of estimating runoff were used, the USDA-SCS curve number method and the rational runoff method. The Soil Conservation Service (U.S. Department of Agriculture, 1972) or "curve number" method uses a hydrologic soil grouping and ground cover parameters to determine a runoff curve number that allows runoff to be determined from a graph based on precipitation.

The "rational runoff method" is based on the fact that runoff equals rainfall intensity multiplied by a coefficient of runoff. Coefficiencies of runoff are unitless fractions derived from experiments which combine slope, vegetation, and soil conditions into one constant. Detailed discussion on selection of runoff parameters is contained in the technical study.

Infiltration (Inf.) is the amount of rainfall that may enter the surface of the soil cover. The amount of infiltration varies considerably through the year, depending upon the degree of soil moisture. The initial infiltration, before any losses to evaporation or plants have occurred, is determined by subtracting the amount of runoff from the amount of precipitation.

Evapotranspiration (ET) is a term that simply means the loss of water to the atmosphere by evaporation and transpiration (plant usage).

Potential Evapotranspiration (PET) is the amount of evapotranspiration that will occur if there is a continuous supply of moisture throughout the year. Evaluation of the factors that go into the equation (Thornthwaite formula) to determine PET is given in detail in the text. The various factors affecting PET are heat energy received on the soil surface, air temperature, latitudes and moisture availability.

Determination of Leachate Movement

After PET, Inf., and Δ ST are known, ET can be determined. Water not lost to runoff, changes in soil moisture storage, or evapotranspiration will then flow through the soil cover and enter the solid waste in a landfill. The amount of water that flows through the soil cover is called percolation (Perc.). The basic water balance equation that relates percolation to precipitation is:

$$\text{Perc} = P - RO - \Delta\ ST - ET.$$

Water that percolates through the soil cover into the solid waste will eventually cause the refuse to reach field capacity and begin producing leachate. The amount of water that solid waste can absorb before producing leachate depends upon initial moisture content and field capacity of the refuse.

Solid waste has an ability to absorb a very grossly determined average of 0.15 inches of water per inch of refuse. This figure multiplied by the depth of the refuse, then divided by the percolation rate will give the length of time required for the refuse to reach field capacity. The annual percolation rate multiplied by the areal square footage of the landfill will then indicate the annual volume of leachate moving out of the refuse once it has reached field capacity.

Figures derived by this method should serve only to assess the nature of the problem. Many assumptions are made that limit the use of the figures to gross estimates. When the average annual leachate values are compared with single yearly leachate values, it is observed that single yearly values of leachate production can vary plus or minus 50 percent, with the yearly variation coinciding with precipitation variations. Additionally, the figures derived by this method and presented in Table 5.2 represent the time required for maximum leachate production to begin. However, leachate movement may begin very soon after landfill construction because of channeling effects or movement of fluids (leachate) through available channels in the refuse and fill material.

Flow of Leachate

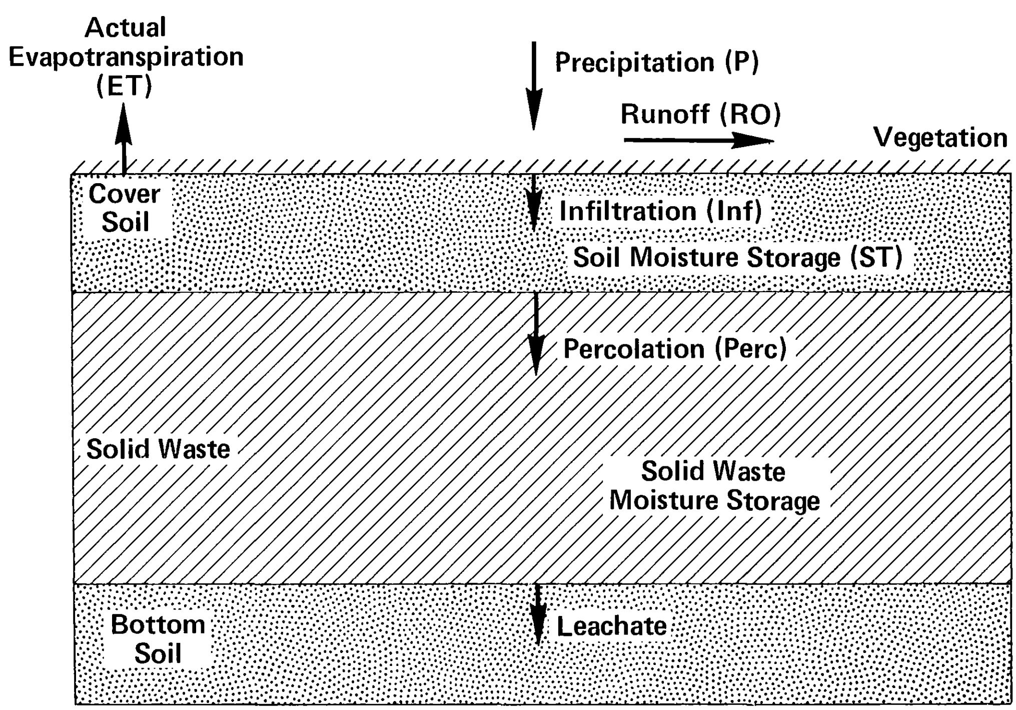
Once leachate reaches the base of a landfill, it will come into contact with soil that separates the landfill from the groundwater. In this soil zone, the strength of the leachate begins to be reduced or attenuated by adsorption, ion exchange, chemical precipitation, oxidation-reduction, and biological activity. In general, substances present in landfill leachate in large concentrations are attenuated by chemical precipitation; substances present in small concentrations are attenuated by adsorption of oxidation-reduction reactions. All of the processess involved are at least partially reversible, and it may be possible for soil underneath a landfill to become a weak source of pollution long after the more concentrated leachate has passed.

Field Capacity is a condition existing when a soil contains the maximum amount of water that it can hold against the force of gravity. Once field capacity is reached, additional volumes of water from precipitation or infiltration will result in movement of leachate out of the confines of the landfill site, i.e., leachate-generated pollution. Field capacities are tabulated in the Irrigation Guide for Minnesota (1976).

Changes in Soil Moisture Storage (Δ ST) must be determined to know the behavior of water as it infiltrates into the cover material. Soil moisture retention tables are used to determine the amount of water that will remain in a soil after certain amounts of evapotranspiration have occurred.

FIGURE 5.1

PARAMETERS OF THE WATER BALANCE



(Fenn et al., 1975, p. 9)

In general, clays (due to large particle surface area) have the highest attenuation capacibilites; silts have moderate capabilities; and sands have little capability. Fractured bedrock and highly porous gravels do not attenuate leachate in most instances. If the soil below a landfill does not allow leachate to flow through the pores in the soil, then leachate will collect underneath the landfill until it flows from the edges creating a surface water problem or until it seeps over the impervious layer into the groundwater. If the soil underneath the landfill allows leachate to flow through the pores in the soil, the leachate will be attenuated to some degree within the soil, but leachate will percolate through the soil until it reaches the groundwater. At this point, unsaturated flow or percolation ceases, and saturated or groundwater flow begins.

In most cases, groundwater is contained in the pore spaces between grains of soil or rock or in fractures of consolidated rocks. Any subsurface strate of rock that will yield water is called an aquifer. The upper surface of the zone of saturation is called the water table; it will most likely follow the land surface contour in upper, unconsolidated soil layers. If an aquifer is confined by impermeable layers, it will be under pressure; the height to which water rises in a well placed into one of these artesian aquifers defines the piezometric surface. An aquifer resting on top of an impervious layer above the groundwater table is called a perched aquifer. Figure 5.2 shows the relationship of these three aquifer types.

Flow velocities within an aquifer can be determined if the physical characteristics of the aquifer are known. The direction of flow in an aquifer is from regions of high hydraulic head to regions of low hydraulic head. Flow velocities may be on the order of a few feet to several feet per year, and flow direction may be vertical or lateral.

When leachate enters groundwater, it begins to be affected by the velocity and direction of flow and the physical nature of the material through which it flows. The velocity of flow and nature of the material will determine the extent to which the leachate is diluted and attenuated. Leachate will generally spread out in a "plume" or irregular pattern. Studies have found that there is a tendancy for a groundwater mound to form beneath or inside a sanitary landfill, the concern being that goundwater will "back-up" and become highly enriched with respect to leachate.

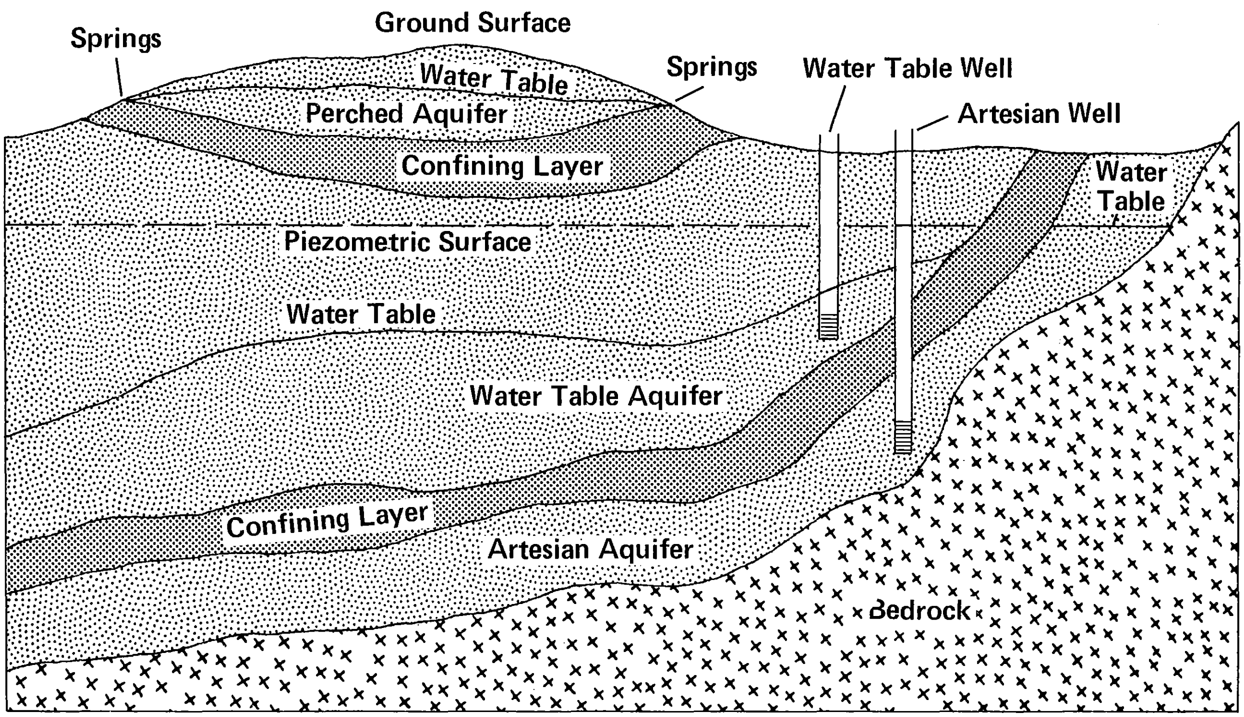
After leachate has entered groundwater and has begun to move with it, the contaiminated water may flow to the surface and pollute lakes or streams, or it may be intercepted by a pumping well and contaminate domestic or municipal water supplies. Contaminated water may also continue to find its way to other rock or aquifer systems and move surprisingly deep and far.

Geology and Aquifers of the Metropolitan Area

The primary aquifers are the Prairie du Chien-Jordan Groups, the St. Peter Sandstone, and the Mount Simon-Hinckley Sandstones. Bedrock formations in the area are in a general bowl shape (Twin Cities Basin), with the formations likely subcropping beneath glacial drift in the periphery of the Metropolitan Area. Figure 5.3 is a west-to-east geologic cross-section through the center of the Metropolitan Area. Groundwater may readily discharge

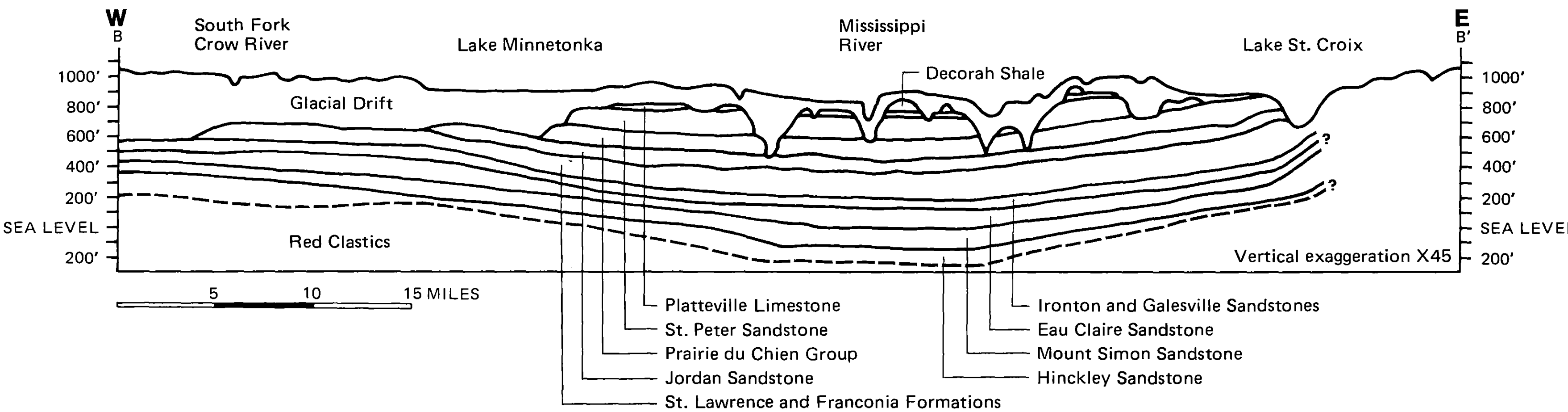
FIGURE 5.2

TYPES OF WELLS AND AQUIFERS



(Gibson and Singer, 1969, p. 11)

Figure 5.3
GENERALIZED GEOLOGIC CROSS SECTION OF THE METROPOLITAN AREA



or recharge at subcroppings. Glacial drift varies from extremely permeable sands to highly impermeable clays.

Buried bedrock valleys, cut during earlier glacial times, have been mapped to some extent in the Area. No definite work exists to determine whether these valleys are discharge or recharge areas.

Although the configuration of the various bedrock units has been mapped with some degree of accuracy, the highly variable character of the overlying glacial drift and the added complication of buried bedrock valleys suggest that no general assumptions can be made concerning the potential for groundwater contamination by sanitary landfills and dumps located in the Metropolitan Area. Therefore, the study proceeded on a site-by-site basis, with intensive examination of the sanitary landfills and less emphasis on the closed dumps.

Pollution Potential for Landfill Leachate Movement

Sanitary Landfills

Text Figure 21 displays the 14 sanitary landfill sites evaluated. Two of the sites are not operating at this time.

A general determination of the possibility that a landfill may be a pollution problem required devising a system to rank the landfills. Some of the parameters and their ranges are given in Table 5.1. Each parameter is ranked low (L), moderately low or moderately high (ML or MH), moderate (M), or high (H) according to the ability of each parameter to cause or transmit leachate. Each parameter relates to the production of pollution by percolation; the flow of pollution into groundwater; and the flow of pollution into surface water.

Leachate production from percolation is related to the infiltration capacity of the cover material, the soil moisture of the cover material, and the area of the landfill site. The 'hydrologic soil group' (Table 5.1, where A is high infiltration and D is high runoff) appears to be one of the main indicators. Site volumes, site areas, and annual leachate values were all ranked and it appears that the cover soil material may be the main indicator of potential leachate production from percolation.

The potential of a site to pollute surface water is related to a site's flooding possibilities, the volume of the surface water available for dilution, the ability of the surface water to flush itself, and the nearness of surface water to the landfill site. The potential of a site to contaminate groundwater is related to the potential attenuation of leachate by surrounding soils and the location of a site relative to groundwater. Contamination of groundwater in the vertical direction is related to the existence of impermeable layers at some depth beneath the site and to the location of the site relative to groundwater.

Table 5.1
RANKING OF PARAMETERS FOR SANITARY LANDFILLS

Parameter	Low (L)	Moderately Low (ML)	Modeate (M)	Moderately High (MH)	High (H)
Hydrologic Group of Cover Soil	C and D		I— — — — — — — — ——B— — — — — — — — — —I		A
Soil Moisture (ins./in.)	Greater than 0.13		I— — — — — —Between 0.13 and 0.10 — — — — I		Less than .10
Avg. Annual Perc. (gals./cu. ft.)	Less than 2	Between 2 and 3		Between 3 and 4	Greater than or equal to 4
Site Area (millions of sq. ft.)	Less than or equal to 1.5		I— — — — — — Between 1.5 and 3.0— — — — — I		Greater than 3.0
Site Vol. (millions of cu. ft.)	Less than 1.0	Between 1.0 and 2.0		Between 2.0 and 4.5	Greater than 4.5
Avg. Annual Leachate Vol. (millions of gals.)	Less than 5.0	Between 5.0 and 10.0		Between 10.0 and 15.0	Greater than or equal to 15.0
Type of Surface Water	Large streams	Small streams and large lakes with outlets		Large lakes and with no outlets and small lakes with outlets	Small lakes with no outlets
Proximity to Surface Water (ft.)	4,000 or more		I— — — More than 300 but less than 4,000 — — — I		300 or less
Potential of Soils to Tranmit Leachate	Clays	Silts and clayey sands		Sands	Gravel and frctured bedrock
Area of ground water Available (ft.)	300 or less to discharge		More than 300 but less than 5,000 to discharge		5,000 or more to points of discharge

Table 5.2
TABULATING AND RANKING OF DATA FOR SANITARY LANDFILLS

Sanitary Landfill Name	Leachate Production from Percolation: Average Annual Precipitation (ins.)	Hydrologic Group of Cover Soil	Soil Moisture (in. per in)	Average Annual Percolation (Gal. per cu. ft)	Site Area (millions of sq. ft.)	Site Volume (millions of cu. yds.)	Average Annual Leachate Volume (millions of gals.)	Potential Surface Water Polution: Is the site subject to flooding?	Type of Surface Water	Nearness of Surface Water (in. ft.)	Potential Ground Water Pollution: Is the ground-water table in contact with the solid waste?	Potential of soils to transmit leachate laterally	Area of ground-water available	General Pollution Potential: Surface water	Ground water (lateral)	Ground water (vertical)	Time required for maximum leachate production (yrs.)
Anoka Co.	28.85	D	0.19	1.53	2.0	3.7	3	No	Small Lake no outlet	300	No	MH	L	MH	ML	L	51
Anoka Municipal		L	L	L	M	MH	L		H	H							
East Bethel	29.20	A	0.09	4.11	2.6	1.6	11.0	No	Large Lake with outlet	1000	Yes	MH	M	MH	MH	L	4.6
		H	H	H	M	ML	MH		ML	M							
Oak Grove	28.40	A	0.09	4.00	1.1	1.6	4	No	Small Stream	1500	Yes	MH	M	ML	MH	L	11
		H	H	H	L	ML	L		ML	M							
Waste Disposal Engineering	29.80	A	0.09	4.57	3.5	1.8	16	No	Small Stream	300	No	MH	L	MH	ML	H	3.5
		H	H	H	H	ML	H		ML	H							
Dakota Co. American Systems Inver Grove Heights	29.60	B	0.12	3.52	1.2	0.9	4	No	Large Stream	5000	Yes*	MH	H	L	ML	ML	6
		M	M	MH	L	L	L		L	L							
Pine Bend	29.60	B	0.13	2.11	11.3	11.6	24	No	Large Stream	5000	No	MH	M	L	H	MH	25
		M	M	ML	H	H	H		L	L							
Burnsville	26.45	B	0.28	1.66	2.6	4.9	4	Yes	Large Stream	300	No	H	L	MH	L	L	34
		M	L	L	M	H	L		L	H							

*Recent soil borings indicate that the American Systems site is in contact with a perched water table.

Table 5.2
TABULATION AND RANKING OF DATA FOR SANITARY LANDFILLS (CONTINUED)

Sanitary Landfill Name	Leachate Production from Percolation							Potential Surface Water Pollution			Potential Ground Water Pollution			General Pollution Potential			
	Average Annual Precipitation (ins.)	Hydrologic Group of Cover Soil	Soil Moisture (in. per in)	Average Annual Percolation (Gal. per cu. ft)	Site Area (millions of sq. ft.)	Site Volume (millions of cu. yds.)	Average Annual Leachate Volume millions of gals.)	Is the site subject to flooding?	Type of Surface Water	Nearness of Surface Water (in. ft.)	Is the ground-water table in contact with the solid waste?	Potential of soils to transmit leachate laterally	Area of ground-water available	Surface water	Ground water (lateral)	Ground water (vertical)	Time required for maximum leachate production (yrs.)
Freeway	26.45	B M	0.28 L	1.66 L	5.6 H	4.2 MH	9 ML	Yes	Large Stream L	300 H	Yes	H	L	H	L	L	14
Dakhue	28.50	B M	0.13 M	3.37 MH	1.1 L	0.8 L	4 L	No	Small Stream ML	6000 L	No	MH	H	L	MH	MH	7
Hennepin Co. Flying Cloud	28.20	B M	0.12 M	2.90 ML	3.9 H	5.1 H	11 MH	No	Large Stream L	1000 M	No	MH	M	MH	ML	L	14
Hopkins	31.70	B M	0.09 H	4.32 H	1.6 M	1.2 ML	7 ML	No	Small Stream ML	1000 M	Yes	MH	M	ML	MH	ML	5
Woodlake	29.80	C L	0.18 L	2.16 L	2.2 M	3.0 MH	5 ML	No	Small Stream ML	1000 M	Yes	L	M	L	ML	L	19
Scott Co. Louisville	27.7	A H	0.04 H	4.08 H	2.3 M	2.9 MH	9 ML	No	Large Lake with outlet ML	1000 M	No	MH	M	ML	ML	L	10
Washington Co. Wash. Co. East Oakdale	29.9	B M	0.20 L	3.83 MH	1.5 L	1.7 ML	5 ML	No	Small Lake no outlet H	6000 L	Yes	ML	H	ML	H	MH	10

*Recent soil borings indicate that the American Systems site is in contact with a perched water table.

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All of the parameters were compared in Table 5.2 to obtain an indication of each site's pollution potential. These indicators must be considered as first approximations only.

Old Dumps and Landfills

Text Figure 20 displays the 68 old dumps and landfills that were considered in this section of the study. A decision was made to evaluate only dumps, landfills and sanitary landfills, thus excluding transfer stations, incinerators, garbage grinders, ash dumps, and demolition fills. The total number has therefore been decreased to 56.

Soil properties of the sites were estimated by using USDA-SCS soil surveys, the Minnesota Hydrology Guide (1977), and the Irrigation Guide for Minnesota (1976). Information concerning surface water was determined from U.S. Geological Survey (USGS) topographic maps. Data on subsurface geology was obtained from Minnesota Geological Survey (MGS) well logs.

The data for each facility was compiled in the same manner as that for the sanitary landfills, and comparisons and rankings were made using Table 5.1. Table 5.3 is a compilation of the data on the 56 sites, giving a general indication of the potential percolation, surface water pollution, lateral groundwater pollution, and vertical groundwater pollution. Because precise locations are not available, the data in Table 5.3 should be viewed accordingly. It is hoped that future studies will be better able to define locations and subsurface data.

Table 5.3

DATA ON 1968 DISPOSAL FACILITIES IN THE METROPOLITAN AREA

Facility No. on Map	Name	Location	Type of Facility	Type of Site	Volume of Site (Millions of cu. yds.)	Hydrologic Group of Cover Soil	Cover Soil Names	Cover Soil Moisture (Ins./in.)	Nearness to Surface Water (In ft.)	Type of Surface Water
	Anoka Co.									
1	Anoka City Landfill	Sec. 22 & 27, T32N,R25W	San. Fill*	Rolling	1.94	D	Lime Sludge	0.19	300	Small Lake No outlet
2	Johnson Landfill	Sec. 27, T32N,R24W	Fill*	Rolling	1.61	A	Sartell	0.09	300	Small Stream
3	Hendscran Inc.	Sec. 32, T31N,R23W	Fill	Level	0.56	A/B	Isanti Lino	0.09	> 5,000	None
4	St. Francis Dump	Sec. 31, T34N,R24W	Dump	Rolling	0.24	A	Nymore	0.06	1,500	Large Stream
5	Bethel Dump	Sec. 36, T34N,R24W	Dump	Level	0.32	A/B	Isanti Lino	0.09	400	Small Stream
6	Lee Johnson Landfill	Sec. 31, T32N,R23W	Dump	Rolling	0.08	A	Zimmerman Isanti	0.09	1,500	Small Stream
7	Carter Dump	Sec. 32, T34N,R23W	Dump	Marsh	0.02	B	Peat	0.28	> 5,000	Small Stream
8	Peterson Inc.	Sec. 5, T31N,R23W	Fill	Level	0.97	A	Zimmerman	0.09	1,000	Small Stream
	Carver Co.									
10	Carver Village Dump	Sec. 19, T115N,R23W	Dump	Floodplain	0.24	A	Salida	0.03	300	Small Stream
11	Victoria Dump	Sec. 13, T116N,R24W	Dump	Hillside	0.02	B	LeSueur Lester	0.19	2,500	Large Lake No outlet
12	Watertown Village Dump	Sec. 3, R117N,R25W	Dump	Floodplain	0.02	B/A	Terril Hayden Hubbard	0.15	300	Large Stream
13	Cologne Dump	Sec. 13, T115N,R24W	Dump	Level	0.32	B	Hayden	0.19	> 5,000	Small Stream
14	Hamburg Dump	Sec. 28, T115N,R26W	Dump	Marsh	0.13	B	Peat	0.28	2,500	Small Stream
15	Norwood Dump	Sec. 13, T115N,R26W	Dump	Level	0.13	B	Lester	0.19	1,000	Small Stream

*Hazardous waste disposal permitted.

Table 5.3 (continued)

Map #	Potential of Soils to Transmit Leachate: Laterally	Potential of Soils to Transmit Leachate: Vertically	Area of Ground Water Available	Potential Percolation	Surface Water Pollution Potential	Lateral Ground Water Pollution Potential	Vertical Ground Water Pollution Potential
1	MH	L	L	L	H	ML	L
2	MH	L	L	H	MH	ML	L
3	MH	L	H	MH	L	MH	L
4	L	L	M	H	ML	ML	L
5	MH	L	L	MH	MH	ML	L
6	MH	ML	M	H	ML	MH	ML
7	MH	L	H	ML	L	MH	L
8	MH	L	M	H	ML	MH	L
10	MH	L	L	H	H	ML	L
11	L	L	M	ML	ML	L	L
12	L	L	L	MH	MH	L	L
13	L	L	H	ML	ML	ML	L
14	L	L	M	ML	ML	ML	L
15	L	L	M	ML	ML	ML	L

*Hazardous waste disposal permitted.

Table 5.3 (continued)

Facility No. on Map	Name	Location	Type of Facility	Type of Site	Volume of Site (Millions of cu. yds.)	Hydrologic Group of Cover Soil	Cover Soil Names	Cover Soil Moisture (Ins./in.)	Nearness to Surface Water (In ft.)	Type of Surface Water
16	New Germany	Sec. 33, T117N,R26W	Dump	Rolling	0.02	B	LeSueur	0.19	2,500	Small Stream
17	Chaska City Dump	SW¼ of Sec, 3, T115N,R23W	Dump	Floodplain	0.23	A	Alluvium	0.03	300	Large Stream
18	Waconia City Dump	Sec. 22, T116N,R25W	Dump	Level	0.19	B	Lester Hayden	0.19	5,000	Large Lake No outlet
	Dakota Co.									
19	Freeway Landfill	SE¼ of Sec. 28, T27N,R25W	Fill	Floodplain	0.97	B	Peat	0.28	300	Large Stream
20	Burnsville San. Landfill	Sec. 32, T27N,R24W	Fill	Floodplain	3.23	B	Peat	0.28	300	Large Stream
22	So. St. Paul Landfill	Sec. 34, T28N,R22W	Fill	Floodplain	0.05	B	Hubbard Dakota	0.12	2,500	Large Stream
23	Rosemount Twp. Dump	Sec. 1, T114N,R19W	Dump*	Ditch	0.03	B	Waukegan	0.20	5,000	Small Stream
24	Ag. Experiment Station Dump	Sec. 34, T115N,R19W	Dump	Pothole	0.03	B	Waukegan Estherville	0.16	None	None
25	Rosemount Research Ctr.	SW¼ of Sec. 35, T115N,R19W	Dump	Pothole	0.02	B	Waukegan Dakota	0.19	None	None
26	Rosemount City Dump	Sec. 31, T115N,R19W	Dump*	Pothole	0.06	B	Waukegan Estherville Dakota	0.17	None	None
27	Empire Landfill	Sec. 29, T114N,R18W	Dump*	Rolling	0.06	B	Rockton Hubbard	0.12	1,000	Small Stream
28	Randolph Village Dump	Sec. 7, T112N,R18W	Dump*	Creek bank	0.03	B	Estherville	0.12	1,500	Large Stream
29	Hastings Dump	Sec. 36, T115N,R17W	Dump*	Gully	0.11	B	Dakota	0.18	300	Small Stream

*Hazardous waste disposal permitted.

Table 5.3 (continued)

Map #	Potential of Soils to Transmit Leachate: Laterally	Potential of Soils to Transmit Leachate: Vertically	Area of Ground Water Available	Potential Percolation	Surface Water Pollution Potential	Lateral Ground Water Pollution Potential	Vertical Ground Water Pollution Potential
16	L	L	M	ML	ML	ML	L
17	MH	L	L	H	H	L	L
18	L	L	H	ML	ML	L	L
19	H	L	L	ML	H	L	L
20	H	L	L	ML	H	L	L
22	H	L	M	MH	MH	MH	L
23	ML	L	H	ML	ML	ML	L
24	MH	L	H	ML	L	ML	L
25	MH	L	H	ML	L	ML	L
26	MH	MH	H	ML	L	MH	MH
27	MH	L	M	MH	ML	MH	L
28	MH	MH	M	MH	ML	ML	MH
29	MH	ML	L	ML	MH	ML	ML

*Hazardous waste disposal permitted.

Table 5.3 (continued)

Facility No. on Map	Name	Location	Type of Facility	Type of Site	Volume of Site (Millions of cu. yds.)	Hydrologic Group of Cover Soil	Cover Soil Names	Cover Soil Moisture (Ins./in.)	Nearness to Surface Water (In ft.)	Type of Surface Water
30	Rubbish Ranch	Sec. 33, T28N,R22W	Dump*	Kettle	0.16	B	Burnsville, Hayden, Kingsley	0.13	> 5,000	None
	Hennepin Co.									
32	Bass Lake Landfill	Sec. 6, T28N,R24W	Dump	Marsh	0.11	B	Peat	0.28	4,500	Large Lake with outlet
34	Boyer San.	N½ of Sec. 8, T118N,R23W	San. fill	Rolling	1.29	C	Hamel, Lerdal	0.18	1,000	Small Stream
35	Maple Plain Dump	Sec. 23, T118N,R24W	Dump	Marsh	0.97	B	Peat	0.28	300	Small Stream
36	Smith Dump	Sec. 3, T117N,R23W	Dump	Marsh	0.11	B	Peat	0.28	2,500	Large Lake with outlet
37	Eisinger Dump	Sec. 32, T118N,R23W	Fill	Marsh	0.73	B	Peat	0.28	1,000	Small Stream
38	Hopkins San. Landfill	SW¼ of Sec. 25, T117N,R22W	Fill	Rolling	1.16	B	Hayden	0.19	1,000	Small Stream
41	Osseo-Maple Grove Pay Dump	Sec. 24, T119N,R22W	Dump*	Gravel pit	0.24	B	Heyder	0.09	> 5,000	Large Lake
42	Deephaven Dump	Sec. 25, T117N,R23W	Dump*	Pothole	0.05	B	Heyder	0.09	4,500	Large Lake
45	Hassan Dump	Sec. 29, T120N,R23W	Dump	Pothole	0.02	B	Peat	0.28	5,000	Large Stream
	Ramsey Co.									
46	Pigs Eye Landfill	NW¼ of Sec. 10, T28N,R22W	Fill	Floodplain	8.23	B	Alluvium and Topsoil	0.09	300	Large Stream
47	Fish Hatchery	NW¼ of Sec. 3, T28N,R22W	Fill	Floodplain	0.97	A	Alluvium	0.06	300	Large Stream
48	Maplewood Dump	Sec. 24, T29N,R22W	Fill*	Level	0.13	B	Kingsley Rosholt	0.11	2,000	Small Stream
49	Vadnais Heights Landfill	Sec. 29, T30N,R22W	Dump*	Marsh	0.05	B	Peat	0.28	300	Small Stream

*Hazardous waste disposal permitted.

Table 5.3 (continued)

Map #	Potential of Soils to Transmit Leachate: Laterally	Potential of Soils to Transmit Leachate: Vertically	Area of Ground Water Available	Potential Percolation	Surface Water Pollution Potential	Lateral Ground Water Pollution Potential	Vertical Ground Water Pollution Potential
30	MH	L	H	MH	ML	MH	H
32	MH	L	M	ML	ML	MH	L
34	L	L	M	L	MH	ML	L
35	ML	L	L	ML	H	ML	L
36	L	L	M	ML	ML	ML	L
37	ML	L	M	ML	MH	ML	L
38	MH	L	M	ML	MH	MH	L
41	MH	L	H	MH	MH	MH	L
42	MH	L	M	MH	ML	MH	L
45	MH	L	H	ML	ML	MH	L
46	L	L	L	MH	H	L	L
47	L	L	L	H	H	L	L
48	MH	L	M	MH	ML	MH	L
49	L	L	L	ML	MH	L	L

*Hazardous waste dispcsal permitted.

Table 5.3 (continued)

Facility No. on Map	Name	Location	Type of Facility	Type of Site	Volume of Site (Millions of cu. yds.)	Hydrologic Group of Cover Soil	Cover Soil Names	Cover Soil Moisture (Ins./in.)	Nearness to Surface Water (In ft.)	Type of Surface Water
50	Township Dump	Sec. 16, T30N,R22W	Dump*	Pothole	0.15	B	Kingsley	0.09	300	Small Lake No outlet
53	University of Minn. Landfill	Sec. 3, T30N,R23W	San. Fill	Rolling	0.81	A	Zimmerman	0.09	1,000	Small Stream
	Scott Co.									
54	Minn. Valley San. Landfill	Sec. 9, T115N,R21W	Fill	Floodplain	0.97	B	Dakota	0.18	300	Large Stream
55	Shakopee Pay Dump	Sec. 1, T115N,R23W	Dump*	Pothole	0.03	B/C	Dakota Oshawa	0.18	300	Large Stream
56	Prior Lake Pay Dump	SE¼ of Sec. 31, T115N,R21W	Dump	Gravel pit	0.11	B	Hayden	0.19	> 5,000	Large Lake With outlet
57	Belle Plain Dump	NE¼ of Sec. 2, T113N,R25W	Dump*	Gravel pit	0.16	A	Hubbard	0.06	1,000	Large Stream
58	New Prague Dump	Sec. 33, T113N,R23W	Dump*	Valley	0.40	B	Waukegan LeSueur Lester	0.19	1,000	Small Stream
	Wash. Co.									
60	Bayport Dump	Sec. 15, T29N,R20W	Fill*	Gully	0.65	B	Waukegan	0.20	> 5,000	Large Lake With outlet
61	Stillwater City Dump	Sec. 20, T30N,R20W	Dump*	Level	0.24	B/C	Milaca Santiago	0.16	2,500	Small Lake With outlet
62	Bellaire Sanitation	Sec. 28, T30N,R21W	Dump*	Level	0.03	B	Antigo	0.20	> 5,000	Large Lake With outlet
63	Lakeland Dump	Sec. 35, T29N,R20W	Dump*	Pothole	0.02	B	Waukegan Langdon Bayport	0.20	4,000	Large Lake With outlet
64	Forest Lake Twp. Dump	Sec. 28, T32N,R21W	Dump	Level	0.08	B/C/D	Hayden Bluffton	0.19	> 5,000	Small Stream
65	Oneka Twp. Dump	NE¼ of Sec. 15, T31N,R21W	Fill*	Hillside	0.03	A	Zimmerman Isanti	0.09	> 5,000	Small Stream
66	Marine Dump	SW¼ of Sec. 1, T31N,R20W	Dump	Gully	0.03	B	Antigo	0.20	> 5,000	Large Stream
68	Newport Dump	NE¼ of Sec. 25, T28N,R22W	Dump*	Hillside	0.37	B/C	Milaca Santiago	0.16	> 5,000	Large Stream

*Hazardous waste disposal permitted.

Table 5.3 (continued)

Map #	Potential of Soils to Transmit Leachate: Laterally	Potential of Soils to Transmit Leachate: Vertically	Area of Ground Water Available	Potential Percolation	Surface Water Pollution Potential	Lateral Ground Water Pollution Potential	Vertical Ground Water Pollution Potential
50	MH	L	L	MH	H	L	L
53	MH	L	M	H	MH	MH	L
54	H	L	L	ML	H	ML	L
55	H	L	L	ML	ML	ML	L
56	MH	L	H	ML	ML	MH	L
57	MH	L	M	H	ML	MH	L
58	Unknown	Unknown	M	ML	ML to MH	Unknown	Unknown
60	H	H	H	ML	ML	H	H
61	MH	ML	M	ML	MH	MH	ML
62	MH	L	H	ML	ML	MH	L
63	H	H	H	ML	ML	MH	MH
64	L	L	H	ML	ML	ML	ML
65	MH	L	H	H	ML	MH	ML
66	MH	MH	H	ML	ML	MH	MH
68	ML	ML	H	ML	ML	MH	MH

*Hazardous waste disposal permitted.

MINING

Methodology for Determining Pollution from Mining Activity

Sediment pollution was evaluated with respect to runoff from land-disturbing activity and discharge from permitted outlets. Literature values on land-disturbing activity such as construction were used because documentation could not be found on the amount of sediment leaving a site disturbed by mining of aggregates.

Literature values ranged from 7-200 tons/acre/year, with average values of 33-189 tons/acre/year. Approximately 116 acres of new overburden are disturbed annually, with an average soil loss based on available figures of 67 tons/acre/year; this leads to the conclusions that 7,772 tons of sediment move on-site every year. Based on U.S.D.A. - Soil Conservation Service (SCS) delivery ratios, approximately 50 percent of this sediment can be expected to reach receiving streams and move off-site, yielding a soil loss of 3,887 tons/year as a result of mine-related land-disturbing activities. This figure serves only to estimate an order of magnitude and has not been verified by field monitoring. On the basis of the small amount of land disturbed annually and the scattered locations of the disturbed sites, it is concluded that these operations do not present a major threat to the water quality of the Metropolitan Area.

An additional small increment of sediment loading comes from MPCA permitted dischargers. MPCA regulates all discharges and has set daily average total suspended solids discharge standards based on equivalent secondary treatment at 20-30 mg/l with a maximum daily allowable discharge of 30-50 mg/l. Additionally, all dischargers meet turbidity standards of 25 JTU and a pH range of 6.5-8.5. An analysis of the average total suspended solids loading for eight months (normal mining year) under MPCA regulation shows that a total of 327 tons will be discharged in a typical year. This figure is in all likelihood quite high because almost all dischargers stay well below the established discharge standards. As with sediment from runoff, this amount of sediment input is not judged significant to the Metropolitan Area.

Total annual suspended solids loading in the Metropolitan Area from mining and associated activities is grossly determined to be 4,214 tons. Suspended solids input from land-disturbing activity exceeds those from permitted dischargers by a ratio of 12:1.

Loading figures for oil and grease, heavy metals, and pesticides are not available from mining sites, but problems are not expected to be generated from these sources. MPCA routine monitoring of waters in the vicinity of mining sites has not detected any noticeable amount of toxicant input from mining operations.

Concern has been raised that pumping large volumes of water for purposes of dewatering a quarry may result in septic tank effluent migration beyond its previous limits of migration of polluted river water toward the dewatered areas.

There is no documentation of this problem in the Metropolitan Area, but the Township of Grey Cloud Island will monitor the groundwater hydrology of the island as mining progresses below the elevation of the Mississippi River to keep aware of the influence of mining operations on the local groundwater.

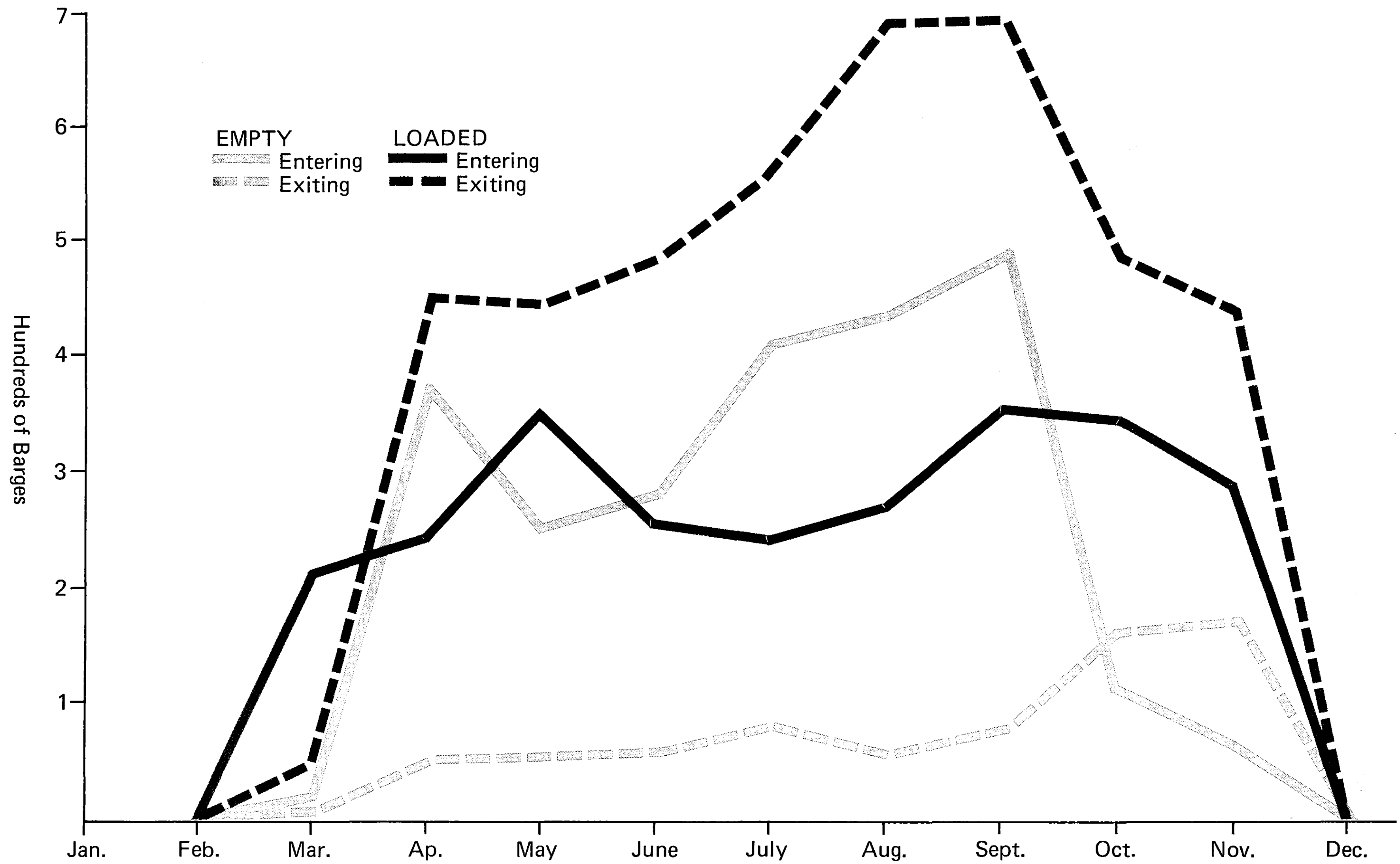
BARGE WASHWATER DISCHARGES

Methodology for Assessing Pollution Potential from Barge Washwater

In 1977, the Metropolitan Council staff interviewed all major barge companies operating in the Metropolitan Area to determine their barge washing practices. Companies providing barge washing services were also interviewed. All federal and state agencies which might have some permitting authority with respect to this kind of operation were also contacted for permitting requirements, permit information and data on water quality problems associated with barge washing activities. Minimal pollution potential was found likely to occur.

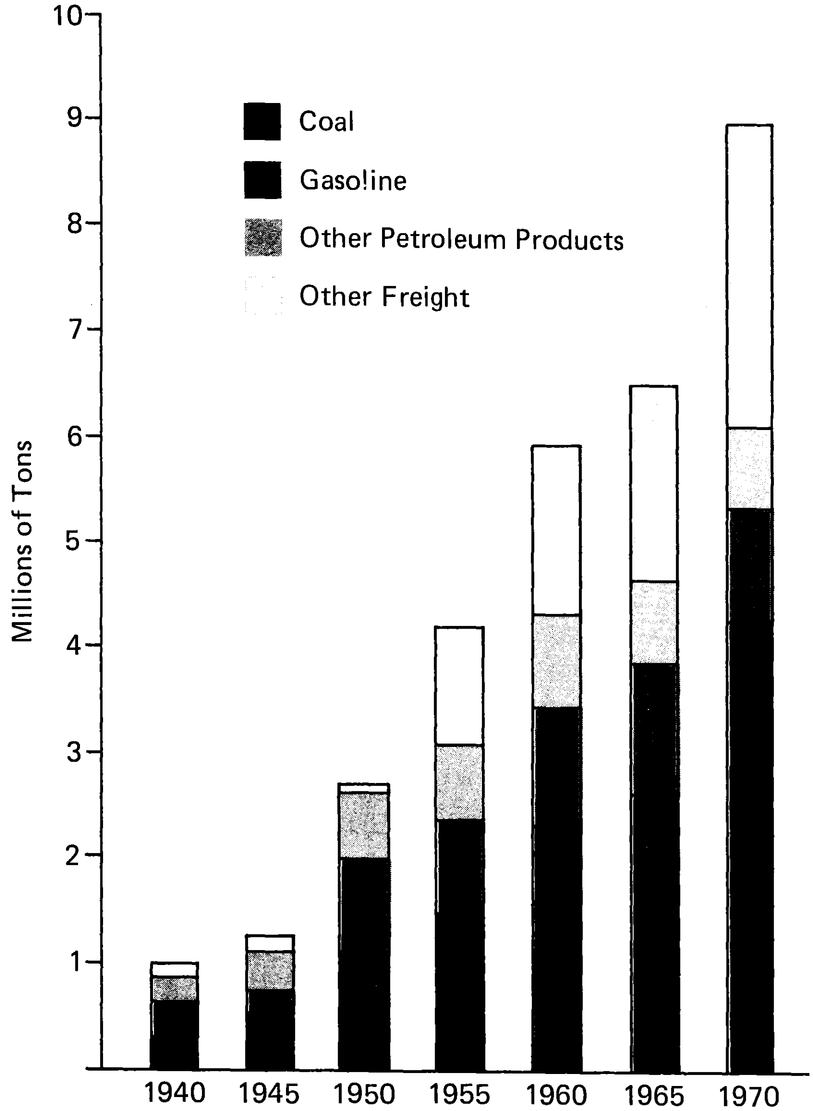
Additional information: Figures 7.1 through 7.3 graphically display barging activity in the Metropolitan Area.

Figure 7.1
1975 BARGE TRAFFIC IN THE METROPOLITAN AREA



Source: Various Data Compilation

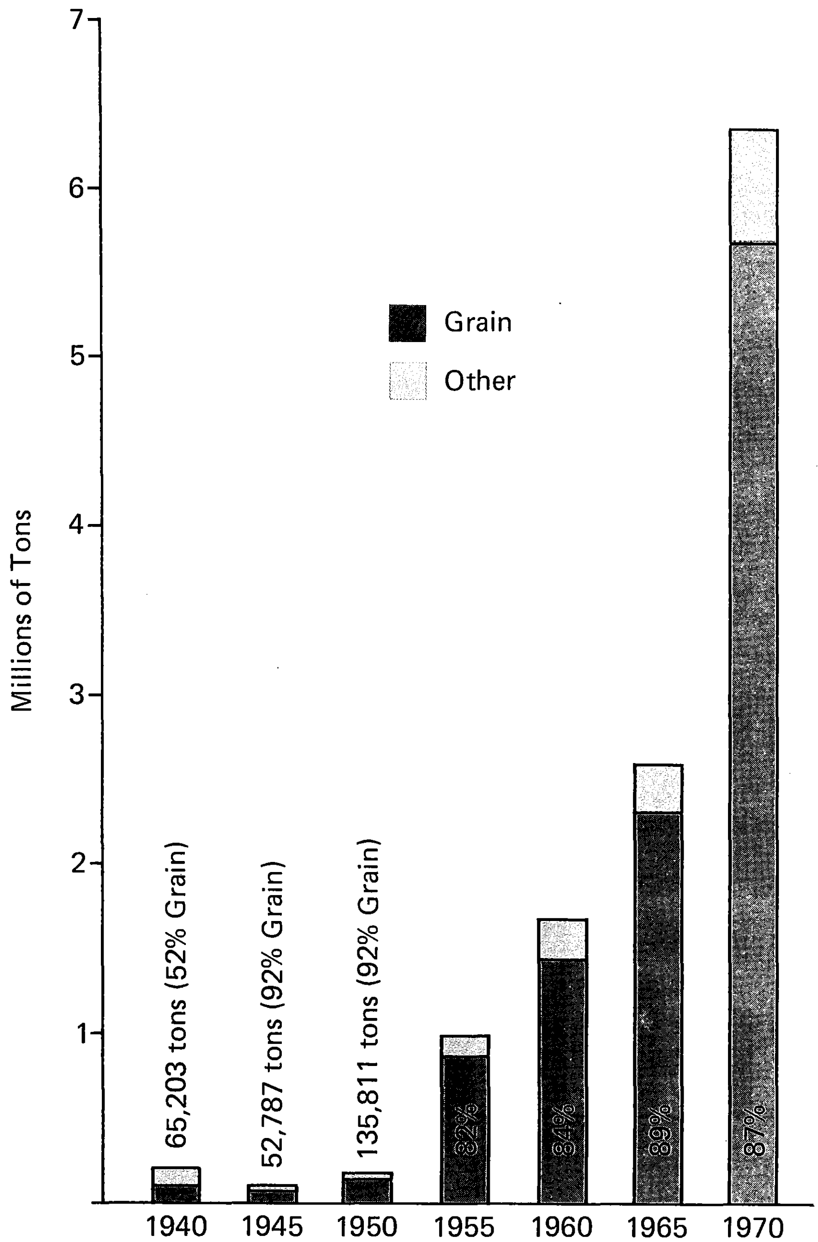
Figure 7.2
RECEIPTS OF MAJOR COMMODITIES – ALL PORTS
ST. PAUL DISTRICT*



Source: U.S. Army Corps of Engineers

*Note that the St. Paul District of the Army Corps of Engineers is much larger than the Metropolitan Area.

Figure 7.3
SHIPMENTS OUT OF THE ST. PAUL DISTRICT



Source: U.S. Army Corps of Engineers

RIVER DREDGING

Table 8.1 is a compilation of dredging locations identified by the Corps of Engineers (COE) as frequently in need of dredging. The most frequently dreged areas are Pool 2 above and below Smith Avenue Bridge, Upper St. Anthony Falls Pool above and below the Broadway Avenue and Plymouth Avenue Bridges, and Pool 2 at the St. Paul Barge Terminal. Reference to the table will show average annual volume dreged.

Following are brief descriptions of each of the pools in the Metropolitan Area. These descriptions provide background information on the nature of the pool and on dredged material disposal within the pool.

The SAF pools are located in the highly urbanized area of Minneapolis. The pools occur in a narrow valley with steep banks, limiting the amount of available disposal sites. Until 1976, the spoil material was placed on the channel banks at approximately RM 855.4 (the Broadway Avenue Bridge). In 1976, the Carl Bolander and Sons Construction Company (RM 854.9) of Minneapolis received the entire spoil load for the season and made it available for beneficial use outside of the floodplain. The amount of dredging has increased in recent years in the SAF pools, and has been concentrated in the vicinity of the railroad bridges and the Lowry, Plymouth, and Broadway Avenue Bridges.

Pool No. 1 is similar to the SAF pools in that it occurs in an urbanized area and flows through a narrow channel with no floodplain. This pool has the highest per mile dredge volumes (22,042 yds^3/mile) in the entire St. Paul District of the COE, most likely due to the redredging of material washed back into the channel during high flows. All of the material dredged in 1976 went to the old municipal coal terminal (RM 853.0) and was made available for beneficial use outside of the floodplain. Recent heavily used disposal sites in Pool No. 1 have been on the east bank below the Franklin Avenue Bridge (RM 850.9) and on the west bank below the Lake Street Bridge (RM 849.3). Most dredging activity occurs in the vicinity of the Lake Street and Franklin Avenue Bridges or in the approach to Lock and Dam No. 1.

Pool No. 2 is the largest reach of dredged channel in the area, passing through several differing land uses. Industrial and commercial use of Pool No. 2 is the highest of any other St. Paul District pool. As such, Pool No. 2 has the largest annual average volume of material dredged (179,931 yds^3) in the Metropolitan Area. In 1976, spoil material was accepted by the Port Authority for fill at Holman Airport and by the City of St. Paul near the High Bridge (RM 841) for beneficial use by the city. Additionally, two channel bank dumps were made so that GREAT could study the water quality effects of disposal activities. In the past, disposal sites have been identified as near to the dredging site as possible. The most frequently dredged site in Pool No. 2 is the St. Paul Barge Terminal (RM837.2), with other dredging frequently occurring at Boulanger Bend (RM 821.0), the Pine Bend Footlight (RM 824.5) and near the High Bridge (Smith Avenue, RM 840.5).

Table 8.1

DREDGING LOCATIONS IDENTIFIED BY CORPS OF ENGINEERS AS FREQUENTLY NEEDING DREDGING

Pool	River Mile	Site Name	Length of Site (Mile)	Average Annual Volume Dredged (1,000 yd^3)	1956-74 Frequency of Dredging (%)
USAF	857.2	Below M. St. P. and S. Ste. Marie RR Bridge	0.8	15.2	41
USAF	856.0	Above and Below Lowry Ave. Bridge	0.9	11.8	50
USAF	855.0	Above and Below Broadway Ave. and Plymouth Ave. Bridges	1.6	6.0	59
#1	851.95	Above Franklin Ave. Bridge	0.9	20.0	52
#1	851.1	Below Franklin Ave. Bridge	0.8	20.0	47
#1	850.3	Above Lake Street Bridge	0.8	20.2	52
#1	849.4	Below Lake Street Bridge	1.0	16.2	52
#1	848.6	Below St. Paul Daymark 849.1	0.6	2.4	26
#1	847.95	Upper Approach to L/D No. 1	0.7	9.06	31

Table 8.1 (continued)

Pool	River Mile	Site Name	Length of Site (Mile)	Average Annual Volume Dredged (1,000 yd^3)	1956-74 Frequency of Dredging (%)
#2	847.5	Lower Approach to L/D No. 1	0.3	2.0	47
#2	840.4	Above and Below Smith Avenue Bridge	0.4	9.4	74
#2	839.45	Harriet Island	0.5	4.64	31
#2	837.45	St. Paul Barge Terminal	1.5	82.5	58
#2	827.8	Grey Cloud Slough	1.0	8.9	21
#2	823.55	Pine Bend Foot Light	0.5	13.3	31
#3	815.0	Lower Approach L/D #2	0.4	2.58	16
#3	811.1	Prescott, Wisconsin	1.0	10.0	31
#3	808.5	Truedale Slough	0.5	7.0	52
#3	807.7	Four Mile Island	1.8	15.2	31
St. Croix	6.4	Kinnikinnic Barge	0.3	17.0	36
Minn.	11.4	Below Peterson's Bar	0.4	1.9	14

Table 8.1 (continued

Pool	River Mile	Site Name	Length of Site (Mile)	Average Annual Volume Dredged (1,000 yd^3)	1956-74 Frequency of Dredging (%)
Minn.	12.0	Peterson's Bar	0.4	5.9	28
Minn.	12.8	Cargill Slip Area	0.4	1.0	14
Minn.	14.5	Above Savage	0.4	1.9	14
Minn.	4.0	Four-Mile Cutoff	0.4	3.4	10
Minn.	0.0	Mouth	0.4	5.0	30

The Minnesota River flows through a moderately urbanized section of the Metropolitan Area. Most of the commercial grain traffic in the Metropolitan Area originates along the Minnesota River banks. Dredging in the Minnesota River has occurred at the lowest annual long-term volume (13,000 yds^3) of any stretch of area stream. The Lower Minnesota River Watershed District is responsible for providing general disposal sites as they are needed by the COE projects, with detail site selection a joint effort of all parties affected by the disposal activity. Spoils in 1976 were deposited in an excavated pit on the Edward Kraemer and Sons property; as fill by Cargill, Inc.; and as fill at a 'one-time-only' site owned by the Watershed District. Recent activity in the river prior to 1976 has been limited, with no dredging in 1974 and 1975 and deposition of spoils material in 1973 on the banks at RM's 14.5 and 12.0. Most recent dredging has occurred at Peterson's Bar (RM 12.0) and at Savage (RM 14.7).

Because some of the St. Croix River has been designated by Congress as a Wild and Scenic River, the COE is minimizing its maintenance activities, performing only clearing and snagging operations in 1976. From 1965 to 1976, the St. Croix River was dredged only four times. Disposal is a problem because of the steep slopes and lack of a floodplain. Spoil material in the valley has been primarily used for beach and island nourishment or development, with all of the 1974 spoils going to island development near Hudson. Most of the recent dredging requirements for the St. Croix have been at the mouth of the Wisconsin Kinnickinick River (RM 6.0), with additional increments at Hudson and at Catfish Bar (RM 11.7).

Methodology for Assessing Pollution Potential from Dredging and Disposal

Only within the past ten years have environmental issues managed to displace economics as the principal consideration in dredging and disposal operations. The primary environmental results of dredging and disposal include: 1. disturbance of sediments with resultant water quality deterioration from turbidity and decreased light penetration, dissolved oxygen depletion, resuspension of contamination material, release of nutrients and toxicants, and creation of floating scum and debris; 2. alteration of channel configuration and bottom habitat changing the hydraulic character of the channel and resulting in such things as increased velocity and altered sediment distribution; 3. disturbance and destruction of in-stream and on-shore aquatic wildlife organisms and habitat; 4. closing off of backwater areas and creation of stagnant, eutrophic pools; and 5. a variety of secondary effects such as increased recreation resulting from beach nourishment and wind erosion blowing spoil material. Spoil deposition is almost entirely on land, with open water disposal occurring only in emergencies or in conjunction with a water quality study.

An extensive environmental review scheme has been established under the auspices of GREAT. Every dredging project is reviewed on-site by the team and by local interested parties. The COE will then in most cases follow the consensus of the review team in pursuing its dreding activities avoiding environmentally sensitive areas and making every attempt to find an upland disposal site.

The GREAT Water Quality Work Group has also conducted several research projects to monitor the water quality effects of dredging and disposal activities.

Sediments

The processes responsible for placing sediment in suspension are outlined in the text of this report. Research reports prepared by GREAT, MPCA, COE, and the Dredged Material Research Program (COE) were reviewed with respect to water quality degradation. All of the researchers found that the sediment and turbidity generated by dredging activities is local and short-term in nature and that it is unavoidable in any dredging situation. The COE makes every attempt to remain within MPCA - established water quality standards. In most cases the river where dredging or disposal occurs will return to ambient conditions within one mile downstream of the activity. Sediment pollution from dredging activities is not a major factor in water quality deterioration.

Heavy Metals

Dredging presents an opportunity for heavy metals accumulated in sediment to come in contact with water and be resuspended or solubilized. Geochemical and biochemical reactions differ for each chemical parameter and are dependent upon the oxygen condition of the aquatic environment. Most metals will be released in anoxic (reducing) environments, but will be reprecipitated when oxic (oxidizing) conditions return. Additionally, most metals will readily adsorb (attach) to fine silts and clays and organic material. After initital release upon sediment disturbance, dilution and aeration return a disturbed area to oxic conditions and metals become insoluble, are scavenged by iron oxides, or adhere to settling sediment or organic matter. Levels of release upon disturbance are generally in the low-to-sub-ppm range, lasting for only a short amount of time. Release of significant amounts of toxic materials generally does not occur and in most cases MPCA - established standards for heavy metals are not violated. Long-term results need to be further explored by researchers. Heavy metal release was not found to be a signigicant water pollution contributor.

Chlorinated Hydrocarbon Pesticides and PCB's

These pollutants are addressed together because of their similar traits and bahavior. Both pollutants tend to adhere to sediment and organic matter and accumulate in bottom material. Pesticides and PCB's are released dependent upon conditions similar to heavy metals. Dredging activity will usually release very little pesticides or PCB's because of their strong sorption tendancy; if any material is released, it will be for only a short-term because it will be scavenged by sediments, by organics, or by iron oxides as they precipitate upon dilution. Any released pesticides or PCB's are usually at a level close to the limit of detection. Pesticide and PCB release was not found significant.

Nutrient (nitrogen-N and phosphorus-P) Release

This pollutant is similar to the two previous pollutants in that it is dependent to a great extent upon the dissolved oxygen conditions. Ammonia (NH_3), organic N, and ortho-phosphate (PO_4) are well released under anoxic conditions but are readily oxidized when dilution returns conditions to oxic. The released nutrient will adsorb to sediment and organics, be used by organisms, or be scavenged by an iron oxide. Major nutrient released do not occur during dredging operations.

The other contaminants considered during the dredging study were oxygen-demanding substances, oil and grease, and coliform bacteria. All of these pollutants were found to be locally important, but insignificant and short term in their overall effect. None were considered to degrade water quality in a significant manner.

OTHER POTENTIAL SOURCES OF POLLUTION

Methodology for Assessing the Pollution Potential of Other Sources

The Association of Metropolitan Soil and Water Conservation Districts (1977) under contract to the Metropolitan Council surveyed each of the counties of the Metropolitan Area for known cases of pollution from the sources identified in the text. The survey was conducted through personal interviews with personnel from each of the Metropolitan Soil and Water Conservation Districts, the Soil Conservation Service of the U.S. Department of Agriculture, Minnesota Department of Natural Resources, and the engineer and planner for each of the metropolitan counties.

In each instance, the location of the problem, the cause of the problem, the type of pollutant generated, an estimate of the magnitude of the pollution problem, as well as what was being done to remedy it were noted on a form for the record. No attempt was made to sample or monitor the pollution sources. The estimate of the magnitude of each problem is based upon the best professional judgement of the professional personnel interviewed.

APPENDIX B: SELECTED BIBLIOGRAPHY

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APPENDIX C

CORRESPONDING U.S.D.A. - SOIL CONSERVATION SERVICE (SCS) AND HICKOK AND ASSOCIATES WATERSHEDS

SCS		HICKOK NUMBER
0-81, 83	Upper Mississippi River and Osseo	44
0-82	Elm Creek	22, A, B, C
0-84	Sand Creek	16A
0-85	Coon Creek	16
0-86	Rice Creek	31, A, B, C, D, E
0-87	Shingle Creek	37, A, B, C
0-88, 91, and 96	Mississippi River, St. Paul and Direct	5, 13, 26, 36, 44A, 44B, 44C, 44D, 44E, 442
0-89	Bassett Creek	3, A
0-90	Minnehaha Creek	27, A, B, C, D, E
0-92	Cottage Grove	17, A
0-93	North Vermillion River	42, C, L
0-94	Hardwood (Vermillion)	42E, 42D, 42K
0-95	Vermillion River (main)	42A, 42B, 42F, 42G, 42I
0-97	Mississippi River (lower)	42J
6-01	Sarah Creek	19C
6-03	Crow River	19, D
6A-15	Louzers Lake Outlet	not included
6B-08	Lower Buffalo Creek	not included
6B-09	Crane Creek	not included
6B-10	Winsted Lake	not included
6B-11	Pioneer Creek	19B, 19E, 19F, 19G, 19H
6B-12	Lower So. Fork Crow River	19A, 19I, 19J

Appendix C (continued)

	SCS		HICKOK NUMBER
•	7-15	Lower Rum River	34, G
•	7-16	Seelye Brook	34A
•	7-17	Cedar Creek	34D, 34G
•	7-18	Ford Brook	34B, 34E, 34F
•	8-114	Forest Prairie Creek	not included
•	8-122, 125, 126, 136	Minnesota River (Upper, Shakopee, Belle Plaine)	15, 20, 43, A, D, Belle Plaine
•	8-124	Robert Creek	33
•	8-127	Silver Creek	7A
•	8-128	Bevens Creek	7, B
•	8-129	Snad Creek	35, B, G, H, I, Jordan
•	8-129-1	Porter Creek	35C, 35D, 35E, 35F
•	8-129-2	Raven Stream	35A
•	8-130	Carver Creek	12, A, B, C, D, E, Waconia
•	8-131	Chaska Creek	14
•	8-132	Hazeltine-Bavaria Creek	24, A, B,
•	8-133	Bluff Creek	9
•	8-134	Riley Creek	32, A
•	8-135	Spring Lake	29, A
•	8-137	Credit River	18, A, B
•	8-139	Purgatory Creek	30, A, B, C, D
•	8-140	Nine Mile Creek	28, A, B, C, D, E
•	0-141, 138	Minnesota River (lower)	43B, 43C, 42H
•	9-21	So. Branch Sunrise River	39, B, C, E
•	9-22	West Branch Sunrise River	39A
•	9-34	Maine on the St. Croix	45

Chlorides. Chloride resulting primarily from road deicing has two pollution effects. First, it is quite soluble and can migrate as salt (NaCl) into ground and surface water supplies and result in salty drinking water. Additionally, chlorides that concentrate in lakes can inhibit the normal "overturning" function of lakes that occurs in the spring and fall. In addition, plants and other water inhabiting organisms have varying levels of tolerance to chlorides. Some plants and organisms may be eliminated at fairly low levels.

Fecal Coliform. Fecal coliforms are bacteria that serve as easily identified indicators of microbial contamination such as bacteria, viruses, protozoa and fungi. Fecal coliforms in themselves are not really pollutants.

Chlorinated Pesticides and PCB's. Both of these chlorinated hydro-carbons have similar traits and behavior. They are very slow to degrade and can be toxic if allowed to accumulate to a sufficiently high concentration. These pollutants can be quite mobile because of their strong ability to adsorb to fine-grained sediment and organic matter.

In addition to the above pollutant definitions, the following terms relating to soil erosion are defined:

Gross Soil Loss. Soil loss from sheet and rill erosion, as caused by rainfall and overland runoff, within a particular watershed; here computed as a total average annual loss.

Sediment Production. That part of the soil loss, as defined above, reaching a body of water (lake, stream, wetland); here computed as a total average annual volume.

Net Sediment Export. Volume of sediments leaving a watershed by stream transport; here computed as a total annual volume.