Nitrogen losses from Midwestern watersheds: Implications for nitrogen management policies

by

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CHAPTER 1: LITERATURE REVIEW

Increasing concerns about the role of agriculture in nonpoint source pollution has prompted studies to quantify the losses of nutrients from various agricultural systems. Concerns about the increased amounts of nutrients in rivers, streams, and lakes has led many reports and articles to be written about the causes and effects of nutrients in the coastal waters off the United States. Hypoxia is the state of low dissolved oxygen in coastal waters (Carey et al., 1999). To be considered low, these waters have oxygen concentrations between 2 or 3 milligrams (mg) per liter (L) or less (Goolsby et al., 1999). The largest zone of hypoxia in the coastal waters of the United States is at the mouth of the Mississippi River in the Gulf of Mexico, this is also the largest in the western Atlantic Ocean (CENR, 2000). With a recent article published in The Des Moines Register, public concern about hypoxia and its economic and ecological implications has grown as a federal task force has encouraged landowners and others in the Mississippi River Valley (MRV) to decrease the use of nitrogen by one-third (Beeman, 2000). Coastal waters have been the focus since the Gulf of Mexico has had an increase in the size of the hypoxic waters in the last few years (Rabalais et al., 1999). The hypoxic zone is about the size of New Jersey (CENR, 2000). The size of the seasonal hypoxia has grown as large as 18,000 km^2 (Brezonik, 1999). The extent of the Gulf hypoxia has ranged between 8,000-9,000 km^2 in mid-summer of 1985-92, where as in the years 1993-1997 the size reached 16,000-18,000 km^2 (Rabalais et al., 1999). The 1998 maximum size was 12,480 km^2 (Rabalais et al., 1999).

Hypoxia that occurs in saltwater is a result of two conditions, water column stratification and decomposition of organic matter. Water column stratification occurs when the coastal water has a lack of mixing and the bottom water is isolated from the surface oxygen supplies. This also occurs when the freshwater discharge does not mix with the saltwater already present in the coastal region. Water column stratification reaches a maximum during the spring and summer when a high flux of freshwater promotes the stratification. Because the warmer, less dense freshwater covers the colder, denser saltwater, hypoxia increases as stratification hinders the replenishment of oxygen. The second condition is when the decomposition of organic matter which consumes the available oxygen in the water. Nutrients, such as N, increase the production of algae on the surface and the organic material from the algae settles to the bottom. Bacteria that in turn consume oxygen decompose organic matter derived from the algae. Lack of oxygen in the coastal region can either cause fish evacuation or kills. In 1998, Congress passed the Harmful Algal Bloom and Hypoxia Research and Control Act. This law requires an "integrated assessment of hypoxia in the northern Gulf of Mexico that examines: the distribution, dynamics and causes; ecological and economic consequences; sources and loads of nutrients transported by the Mississippi River to the Gulf of Mexico; effects of reducing nutrient loads; methods of reducing nutrient loads; and the social and economic benefits of such methods" (P.L. 105-383, 1998).

The purpose of this study is to examine the levels of N in the rivers throughout the Upper Midwest that may have led to these increased levels of hypoxia in the Gulf of Mexico. There are other nutrients that may contribute to the formation of hypoxic areas, such as phosphorus (CENR, 2000).

Studies conducted on the hypoxia problem in the Gulf of Mexico show that P loads have not changed significantly since the 1970's (CENR, 2000). Excess P can be harmful when excessive levels are present in water. P has effects on freshwater streams and lakes as well as saltwater. P can cause overenrichment of the waters and cause algae blooms that use up the oxygen in the water and can lead to hypoxia. The limiting element can change depending on whether the overenrichment is in freshwater or saltwater. The term limiting element is when a plant and bacterial growth in an aquatic system would become limited by the availability of an essential element (Correll, 1998). This is where it deems important to figure out what is the limiting element as once a limiting element is discovered, the inputs of that nutrient can be managed and reduced to limit the eutrophication or hypoxia.

This focus only on N reduction is based on evidence between nitrate-nitrogen increases and increases in the size of the hypoxic zone in the Gulf of Mexico (Mitsch et al., 1999). It is also based on the understanding that coastal waters are N limiting (Rabalais et al., 1999). Although P is important, when looking at estuarine and marine areas, N is seen as the more dominant element for coastal waters (e.g., D'Elia et al., 1986; Harris, 1986; Valiela, 1984).

Sources of P include animal food and manure, fertilizers, and human waste. Commercial and organic fertilizer (manure) contains N, P, potassium, secondary nutrients, and micronutrients. The fertilizer can be found in liquid or dry forms. Industrial and municipal treatment plants effluent and sludge can release P into rivers. According to the EPA, 71% of the non-point source P pollution results from agricultural activities (EPA draft, 1998). But most scientists agree that the principal cause of the hypoxic zone in the Northern Gulf of Mexico is NO_3-N discharge from the Mississippi River (News & Views, 1999). Some of the conservation practices described in Chapter 3 can be used to decrease the amount of P loads.

A current opinion in aquatic science is that phytoplankton in marine and estuarine environments tend to be N limited and freshwater phytoplankton tend to show P limitations (Hecky, 1988). The amount of fertilizer use reflects this as P fertilizer use stabilized in 1980 and then dropped slightly (Turner and Rabalais, 1991).

P isn't significant for this study is that the Upper Mississippi River Basin only contributes 6% of the P that is found in the Gulf of Mexico (Goolsby et al., 1999). Even though the Gulf has not seen an increase in P loads in the last few decades, it still could have some effect on hypoxia and therefore is important to know that it can exist. For the basis of the Federal Task Force to examine hypoxia and its issues, P is not seen as the limiting element.

Statistics show that as much as 15 % of the N in fertilizer applied to crops in the MRV can be found in the Gulf of Mexico (Diaz, 1999). The N contributing to the hypoxic area in the Gulf of Mexico is linked to nonpoint source pollution from agriculture, which is the most significant source of ground and surface water pollution seen in the U.S. (Contant et al., 1993). The annual total N flux to the Gulf of Mexico is 89 % from nonpoint source pollution (Goolsby, 2000). This is significant as 58% of the MRV is cropland (Goolsby, 2000).

The study region was narrowed to the Upper Midwest area. The use of this land is primarily crops; therefore, requiring more N fertilizer added to the soils. N is applied in a variety of different forms. It accounts for about one-half of the fertilizers applied to harvested acres (Kellogg et al., 1992). The inorganic N fertilizers that are applied in conventional systems provide only 50-70% of the N requirements, when applied at planting (Keeney, 1982). The problem develops when farmers compensate for this loss by applying 30-50% more N than is recommended (Norris and Shabana, 1988). The excess nitrates can then move through the soils or into subsurface drainage runoff into nearby streams through baseflow. It is assumed that a reduction in N application can be made without an economic impact (Doering et al., 1999)

The study area narrows the Midwest region into individual watersheds. These are analyzed by the amount of area and the amount of harvested cropland. The source of nutrient contamination in the Gulf of Mexico has been linked to an overuse of nutrients in the MRV (Fig. 1) (CAST, 1999). The Upper Midwest region includes the states of Iowa, Illinois, Missouri, Minnesota, and Wisconsin. These five states are the Midwestern crop producing states and are all located in the Mississippi River Valley. These states were chosen, as they are the focus in the Contaminants in the Mississippi River, 1987-92 Circular by the USGS. The USGS states that 51 % of the nitrates in the Mississippi River are attributed to the Upper Mississippi River (Antweiler, 1995). A major portion of the nitrates that are in the Mississippi River are coming from the tributaries that run through farmed regions in Illinois, Iowa, and Minnesota (Meade and Leenheer, 1995).

Previous research has been done on N loadings in the MRV (Mitsch et al., 1999). Unfortunately, little synthesis of N loading is available for the tributaries of the Mississippi River. Along with the tributaries, an examination at the individual watersheds within the MRV hasn't been undertaken. An assumption is that the trends found for the Mississippi River are true for the tributaries. This assumption then becomes the basis for policy decisions.

Unfortunately, from a scientific point-of-view, no evidence has been published to show N loading across watersheds and within streams other than on a large scale for the MRV. An examination of the smaller scale and amount of N loading throughout the Upper Midwest MRV is needed before a policy decision can be made on agriculture nonpoint source pollution because of implementation of practices within fields. This evidence is critical to convince producers of the need to adopt alternative N management practices.

When forming agriculture policies the responsibility of the government is to consider that farms need to be sustainable in their production while protecting the environment (Haruvy et al., 1996). By using past trends and loadings in the MRV, the N loads can be reduced by using watershed-scale policies. These watershed-scale policies are policies set

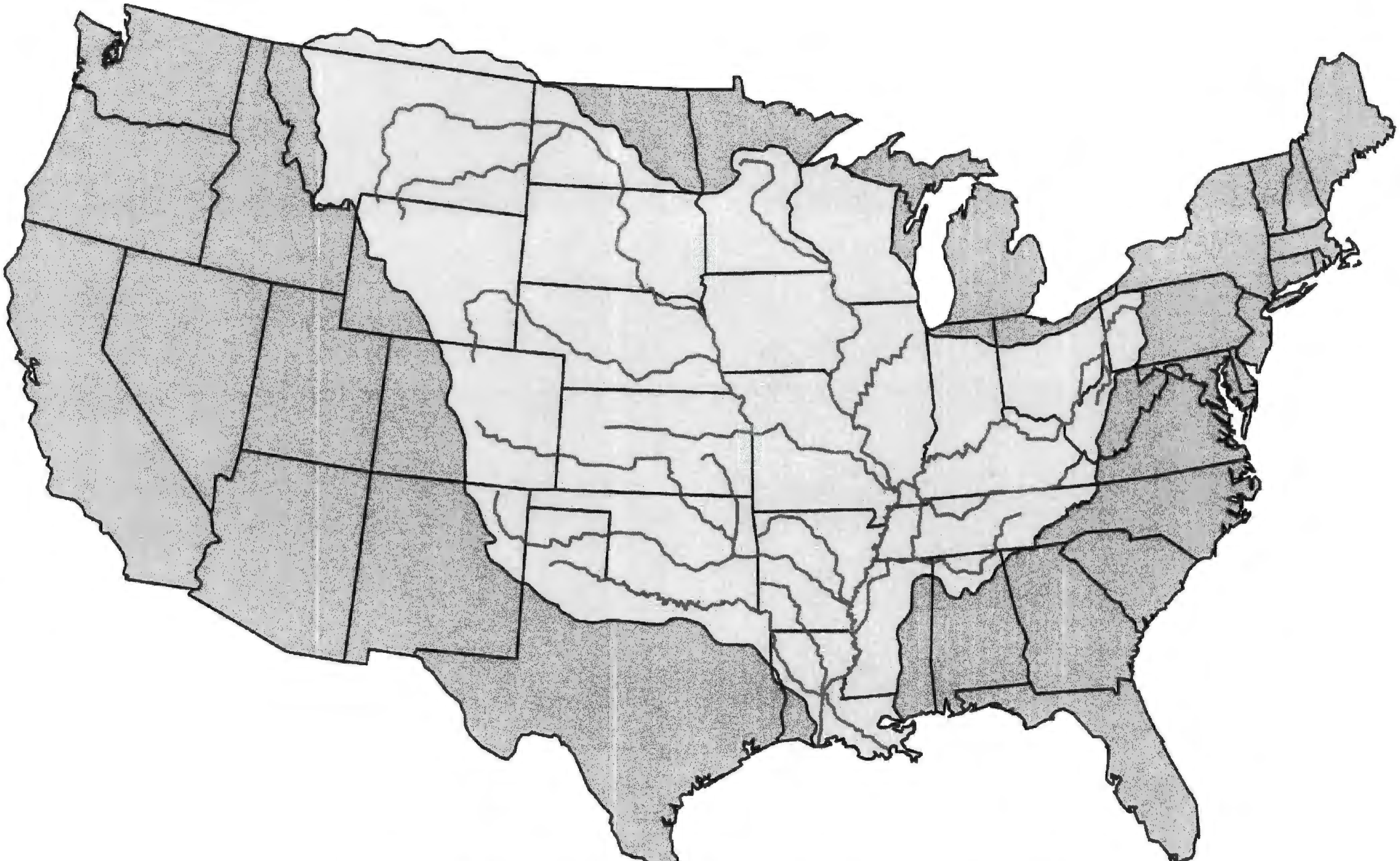


Figure 1. The Mississippi River Valley Drainage Basin. (CAST, 1999)

around a watershed. By doing this, the amount of N can be controlled by conditions that are relatively similar. The conditions that should be considered when setting policies is soil type, elevation, slope, topography, weather, and cover (Randhir and Lee, 2000). Using these conditions the watershed can be divided into sub-regions to make the watershed better represented with policy decisions based on the amount of fertilizer that is used. The sub-regions can be used to set policies that also are beneficial with the use of site-specific impacts of these policies (Qiu and Prato, 1999).

A higher quality of life is maintained while goals of profit and water quality are met when the landowner uses site-specific information with a resource management plan (EPA draft, 1998). Implementing the watershed-scale research that has been done on resource management plans and by combining these efforts to reduce the amount of N, a reduction in hypoxia can be achieved.

Four primary questions evolved as guides for this study:

- What is the variation of nitrogen load among small watersheds within the Upper Mississippi River Valley?
- What is the year to year variation in flow from individual watersheds?
- What is the year to year variation in N fertilizer and harvested land area in agricultural watersheds within the Upper Mississippi River Valley?
- Are the variations among watersheds consistent enough to allow for the development of management policies for improved water quality?

CHAPTER 2: NITROGEN'S CONTRIBUTIONS

According to the Committee on Environment and Natural Resources, "A 40 percent reduction in total nitrogen flux to the Gulf is necessary to return loads comparable to those during 1955-70" (CENR, 2000). This is a significant amount of N that needs to be reduced in the Midwest. For example, in Iowa this would amount to an annual reduction of 600 Gg or 67 % of the current application load. Midwestern states apply a large amount of N to harvested cropland each year. To understand the role of N in hypoxia and also the potential significance of a reduction of application, this study will discuss N as a nutrient and how it pertains to the environment. In addition to N application, the pathways to water, and sources will be examined.

The N cycle as shown in Figure 2, shows the overall cycle of N in the environment. N is an essential element that occurs naturally and is critical to the growth of plants and crop production. For the most part it is absorbed in the form of nitrates for use in plant growth (Tisdale and Nelson, 1975). Plants also use other forms of N as the ammonium ion and urea, but in smaller quantities (Tisdale and Nelson, 1975).

Nitrogen sources include fertilizer, mineralized soil nitrogen, legume N-fixation, manure, atmospheric deposition, municipal point sources, and urban nonpoint sources. There are also many different types of N fertilizer used in crop production and can be applied as a dry fertilizer or liquid. Liquid applications of anhydrous or aqua ammonia are the most widely used types of fertilizer (Burkart and James, 1999). The amount of N fertilizer applied has increased by fourfold from the years 1960-1977 (Legg and Meisinger, 1982). This increase is due to an increase in federally funded programs for fertilizer use and the production of inexpensive synthetic N fertilizers (Tisdale and Nelson, 1975). The largest

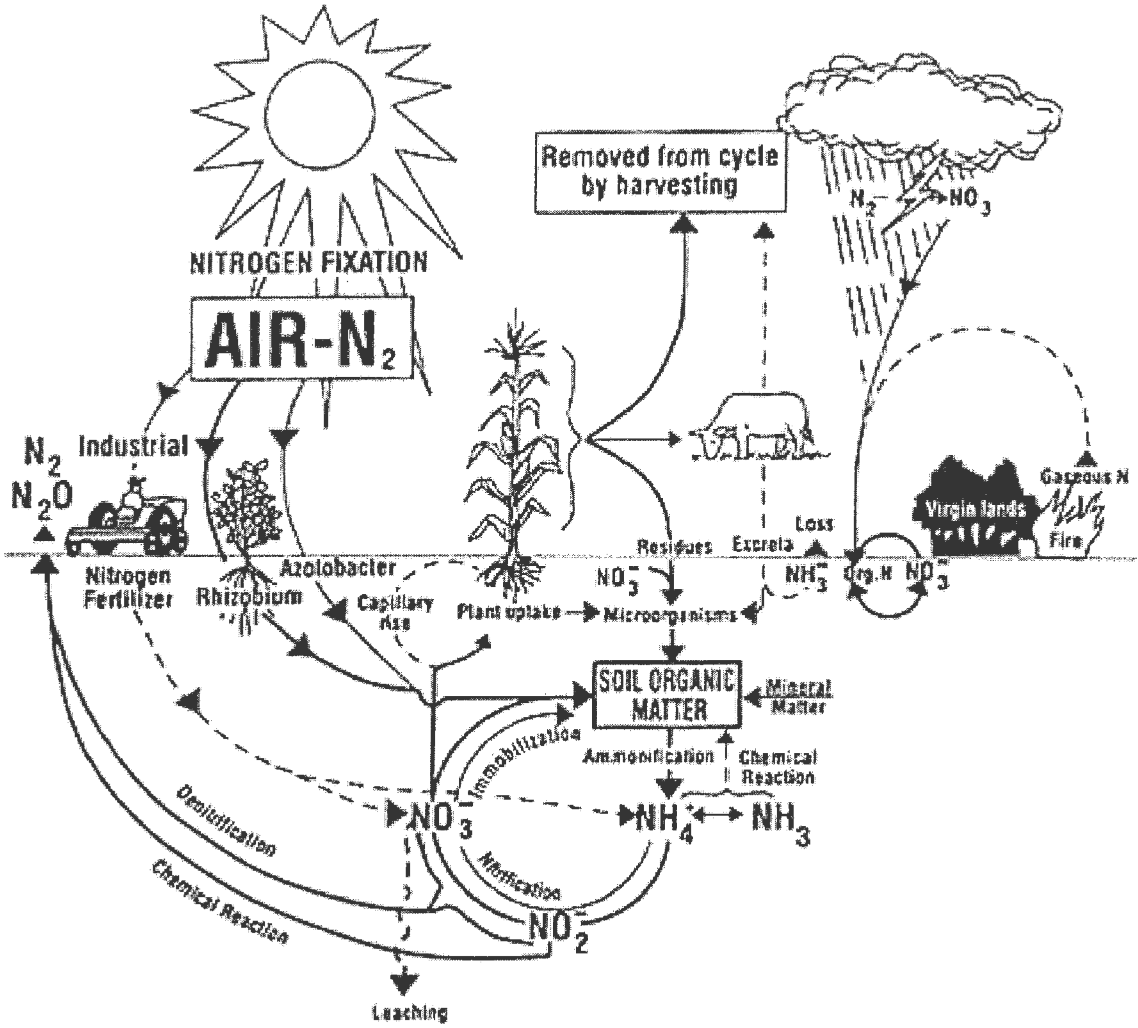


Figure 2. The Nitrogen Cycle in Soil (The Ohio State University Extension, 2000).

use of N fertilizer is in corn production and accounts for approximately 39% of N fertilizer in 1977. The amount of N fertilizer sold has increased since the 70's. The increase in the 1960's is typical of the 5 Midwestern states. Nitrogen fertilizer application accounts of roughly 29% of the total N sources in the Upper Midwest (Fig. 3). The other source of N in the soil is N mineralization. N mineralization is the formation of N from the organic to the inorganic state of NH_4 or NH_3 (Jansson & Persson, 1982). Mineralization occurs when soil organisms use N as an energy source. Mineralization increases as the organic matter increases in the soil. Organic matter is highest in the Upper Midwest and therefore has the potential to produce large amounts of available N in the soil profile. Legume-N fixation is also a source of N and can contribute to N loadings in rivers. Legumes provide N through crop rotation with grain crops (NRC, 1989). N is released throughout the legume growing season by microbial decomposition. The overall contributions of N depend on several factors, such as the management system, soil characteristics, water availability, and climate (NRC, 1989). Soybeans, for example, can contribute 0-310 kilograms per hectare depending upon these factors (NRC, 1989). This N can be used as a credit when applying N fertilizer to grain crops as corn.

In the Midwest an important cropping system is a corn-soybean rotation. This rotation allows for excess N to be used by the corn after the legumes are harvested the previous year. If a rotation is not used legumes can produce excess N that it leaches to groundwater or to surface waters through subsurface drains. In a Minnesota study, four years of continuous soybean (2820 kg/ha) contributed two/thirds as much N as heavily fertilized corn (10347 kg/ha) (Randall, 1997). The amount of N that is available through legumes could be significant enough to have enough N available using a corn-soybean rotation without the use of fertilizers (NRC, 1989). Manure contributes N to crop production

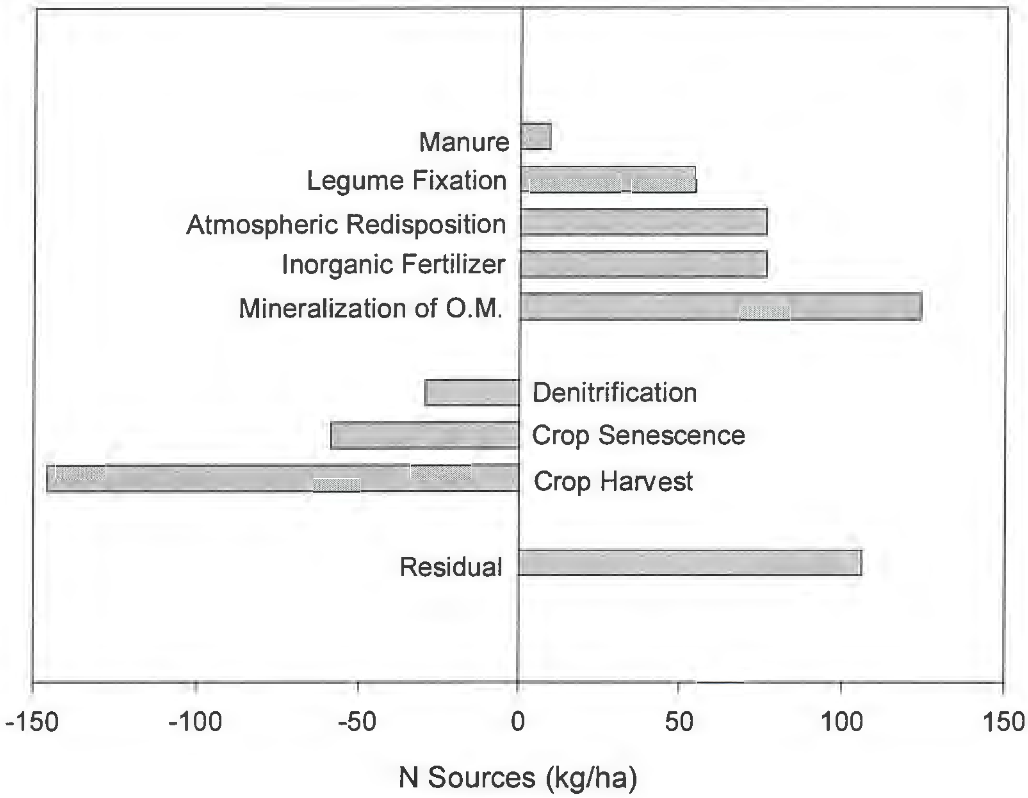


Figure 3. Total nitrogen sources and losses for the Mississippi River Basin (Personal Communication, 2000, M.R. Burkart).

and non-point source pollution. Since 1978, an increase in the amount of livestock operations has seen a high amount of manure being produced and not enough crop area to apply it on (Lander et al., 1998). This increase has led to 1.2 million metric tons of N excreted from animals as manure (Lander et al., 1998). N is deposited from the atmosphere through rain or wet atmospheric deposition. Atmospheric deposition accounts for 15% of the N in the Mississippi River Basin (CAST, 1999). Most of the N in the atmosphere is in the form of N_2 (Willrich and Smith, 1970). The N that is in found in atmospheric deposition is from a variety of sources which include industrial air pollution, fertilizer use, soil N fixation, manure, and automobiles. Municipal and urban runoff account for 5% of the N sources of the Mississippi River Basin (CAST, 1999).

N can enter the water in different pathways that lead to overenrichment. These pathways include tile drains, leaching from the soil, and atmospheric deposition. In tile drains, N can be carried into surface drains and streams with runoff from the fields where fertilizer is being applied.

In relation to hypoxia the discussion leads to 1) Which nutrients are the most frequent cause of hypoxia in the Northern Gulf of Mexico? 2) What nutrient concentrations are acceptable to the public? and 3) Can we control hypoxia by limiting a key nutrient?

CHAPTER 3: AGRICULTURAL PRACTICES

Agricultural practices are defined as farming operations in the field to improve crop production efficiency. These practices range from tillage practices to the timing of nutrient or chemical applications. Practices differ among regions, farmers, and fields. Agricultural practices can promote or reduce runoff and environmental effects of crop production. Upper Midwestern states have different types and adoption of practices. The role of conservation agricultural practices in N reduction and management is discussed. The future of these practices and how they are used can achieve the reduction in N loading required to meet environmental quality objectives.

Agricultural practices vary due to climate, soils, water availability, crop, and farmer preference. Tillage, fertilizers applied, and crop rotation are the primary practices that affect nitrogen in the environment.

Tillage can modify the amount of nitrate that leaches, runs off, or volatilizes into the atmosphere. Tillage ranges in intensity from conventional to no-till. Conventional tillage refers to the operations that are most commonly used in a region that prepares the soil for crop production following the previous crop. With conventional tillage a small amount of residue, less than 30%, is left on the soil surface (MPS, 1992). Crop residue can help decrease the loss of N from a field due to less soil erosion and runoff. No-till leaves the soil surface undisturbed after harvest and the only disturbance is when the seed is planted. This type of practice leaves the crop residue from the previous harvest to allow for more organic material to be in the soil.

The type, timing, and application rate of fertilizers are important in the use of N fertilizers. The type of fertilizer can change the amount of N that is applied. Anhydrous ammonia represents about 85% of applied N fertilizer (ERS, 1997). The N composition for anhydrous ammonia is 82.2% (Tisdale and Nelson, 1975). There is also a number of methods that fertilizer can be placed in the soil, which can also lead to different amounts of N loss. Some of these types are ground and air broadcast, banded, chemigation, and injected. Broadcast is where the fertilizer is applied evenly over the soil surface before planting. Ground broadcast is the principal method of fertilizer application (ERS, 1997). Banded application is when the fertilizer is applied in strips or bands along the sides of the rows of crops. Chemigation is when irrigation systems are used for application of the fertilizer by fertilizer combining with the irrigation water. The last method of fertilizer application that is used is injection or knifing the fertilizer in the soil. This is the second most used method next to ground broadcast (ERS, 1997). The timing of the fertilizer application is important in the amount of fertilizer that is taken up by the plant and the amount of fertilizer that is lost. Timing is significant as the crops can use the fertilizer better if it is applied in a proper manner (NRC, 1989). Unused N is lost to the environment by being immobilized, denitrified, washed into streams or lakes, or leached from the soil into groundwater. Corn production in the Midwest uses spring application of N fertilizer on about 54% of treated acres (ERS, 1997). The rates of applications also effect the amount of N that is lost to the environment. According to the Economic Research Service, 98% of the corn area in the Midwest have N fertilizer applied (ERS, 1997). In the last decade the Midwest states of Illinois, Iowa, and Wisconsin have stayed relatively constant in their N fertilizer application rates (Figure 4, 5 and 6). However, Missouri and Minnesota have had an increase in the last decade (Figure 7 and 8). This increase could be explained by an increase in the amount of agriculturally related land.

Crop rotation is another significant agricultural practice in controlling N losses. Nitrogen that legumes produce benefit corn the following year. Iowa, Illinois, and Minnesota

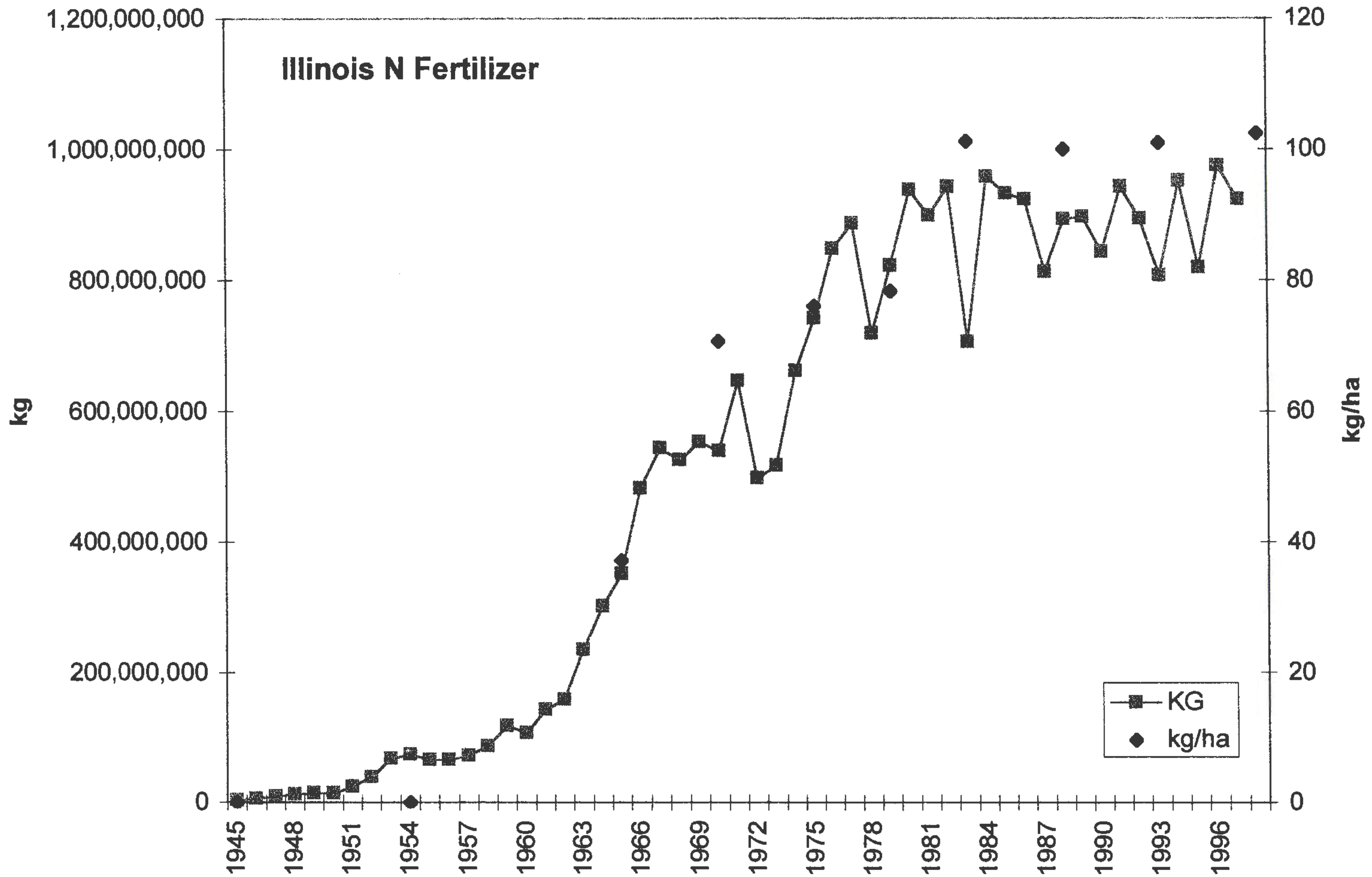


Figure 4. Nitrogen fertilizer applied annually and per harvested hectares in Illinois from 1945-1997.

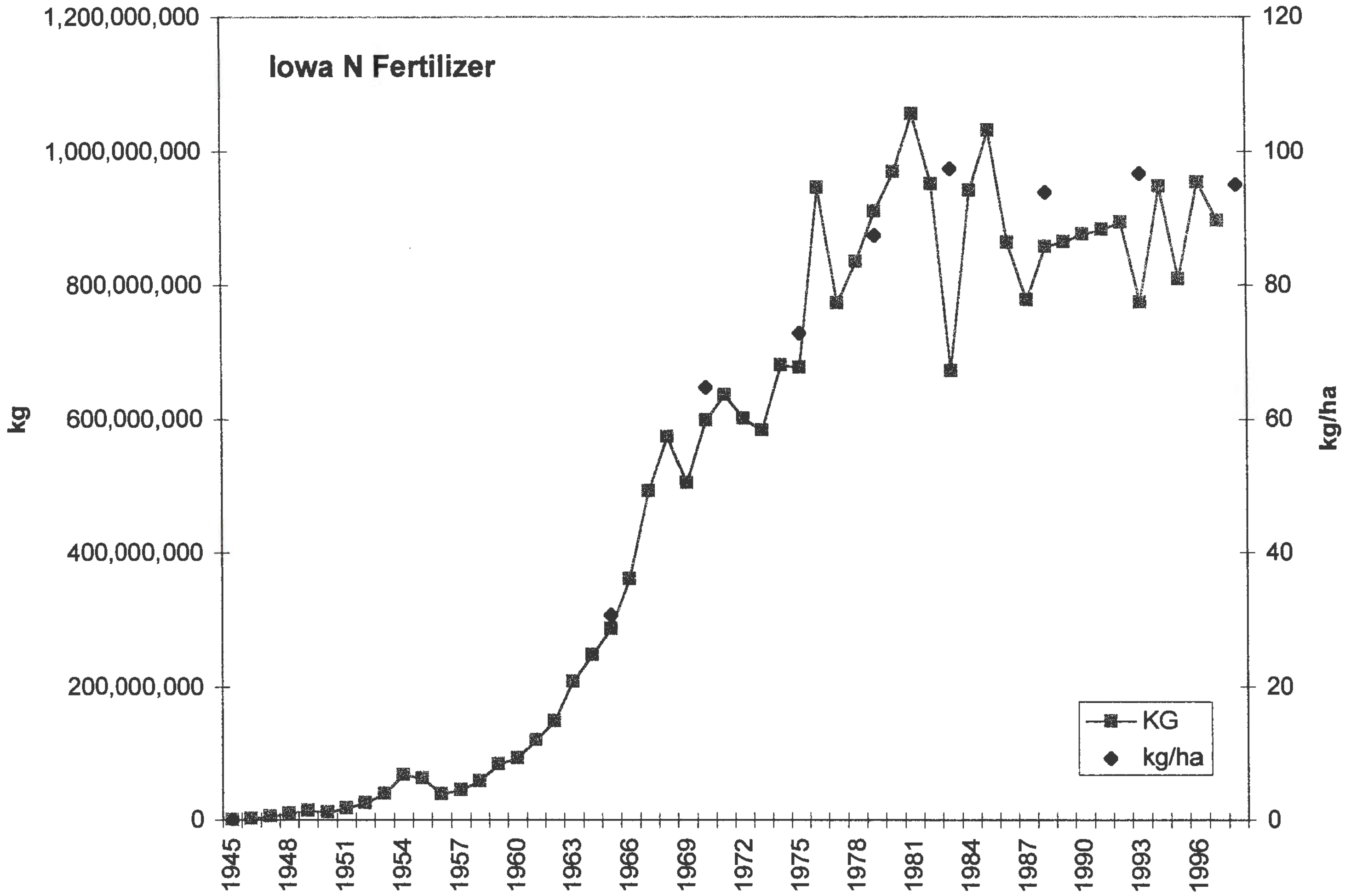


Figure 5. Nitrogen fertilizer applied annually and per harvested hectares in Iowa from 1945-1997.

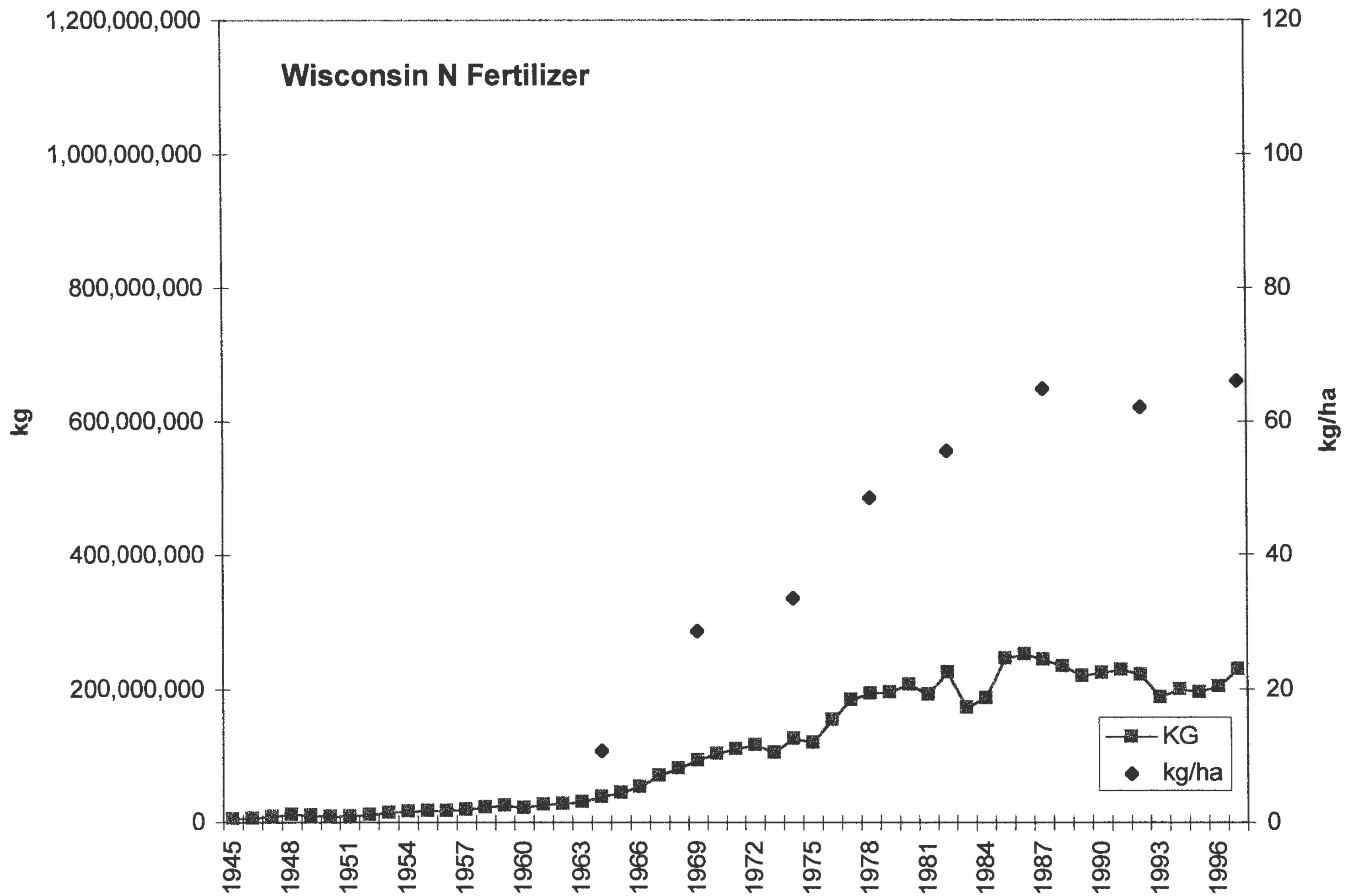


Figure 6. Nitrogen fertilizer applied annually and per harvested hectares in Wisconsin from 1945-1997.

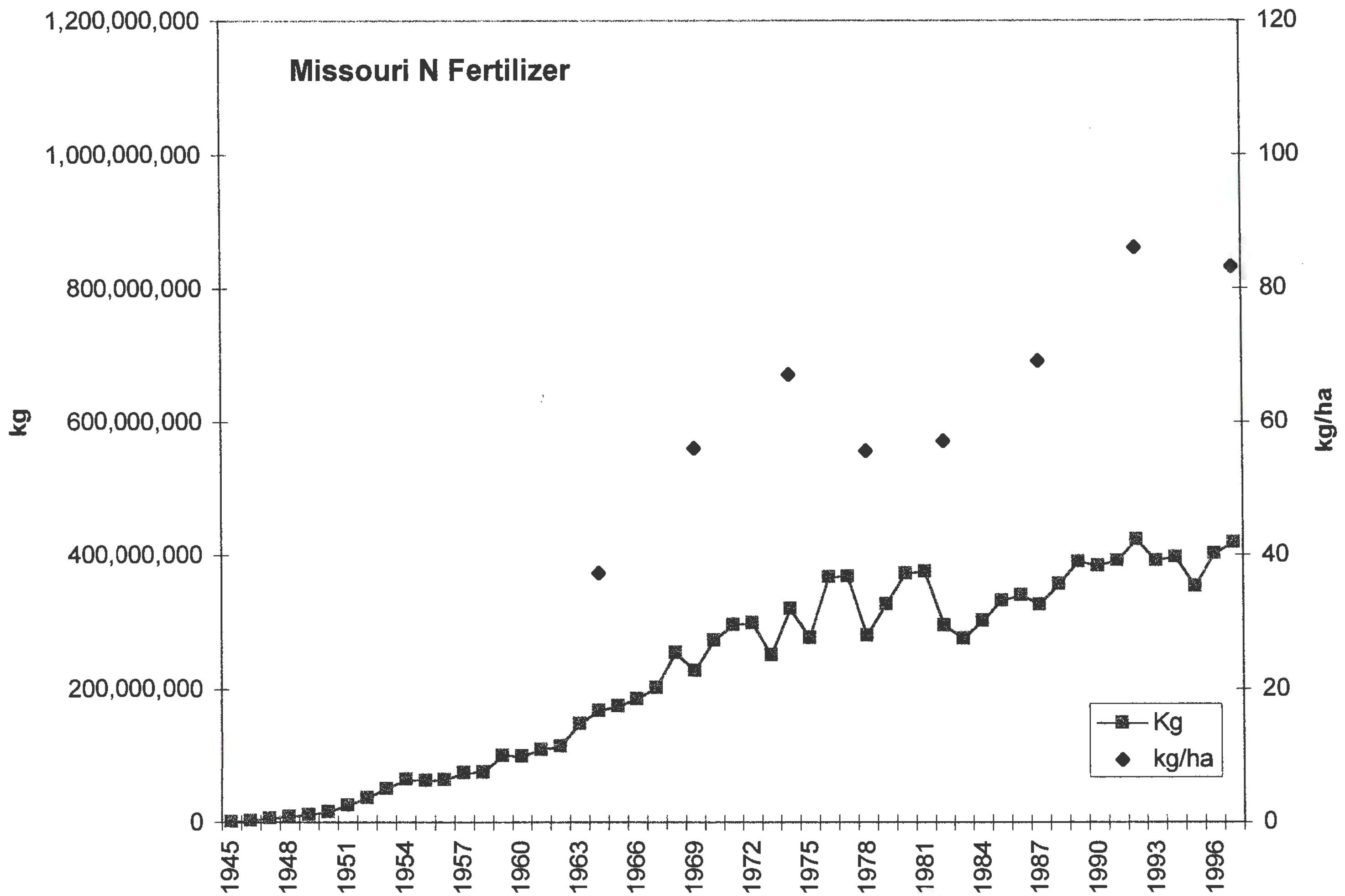


Figure 7. Nitrogen fertilizer applied annually and per harvested hectares in Missouri from 1945-1997.

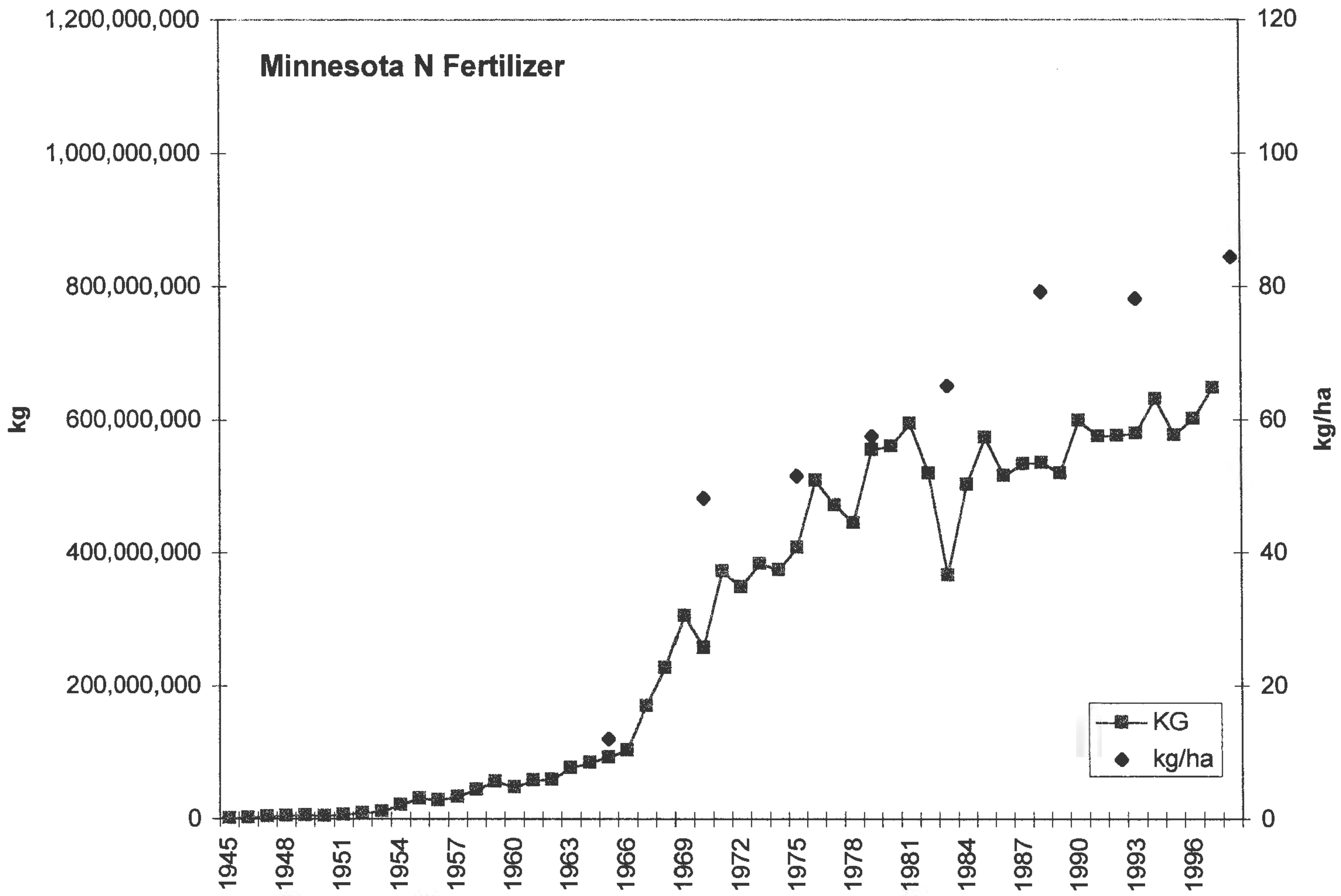


Figure 8. Nitrogen fertilizer applied annually and per harvested hectares in Minnesota from 1945-1997.

Table 1. Cropping patterns in Midwest States, 1995 (ERS).

Cropping Patterns[1]	Illinois	Iowa	Minnesota	Missouri	Wisconsin
		Million Hectares Planted			
	4.13	4.74	2.71	0.67	1.48
		Percent of hectares			
Continuous Corn	14	17	9	18	21
Rotations with Soybeans[2]	64	67	64	41	17
Other Row Crops[3]	13	13	12	29	11
Row Crops & Small Grains	1	*	5	nr	2
Idle or Fallow	3	1	1	8	6
Hay, Pasture, Other	1	*	1	3	24
All Other Patterns[4]	4	1	8	1	12

nr=Not Reported *=less than 1
[1]Based on crops planted in spring/summer 1993 through spring/summer 1995.
[2]Alternating corn and soybeans
[3]All other continuous row crop rotations except alternating corn and soybeans, ex. soybeans-corn-corn
[4]Specfic rotation data not available

have the highest percentage of crop rotation in their acres planted, but Iowa has the most acres planted in a corn-soybean rotation (Table 1).

Throughout the Upper Midwest watersheds different patterns of rotation are seen in these places, but there is also a similarity in the types of practices used and the use of these practices in conservation (Table 2). Tillage can be used to conserve the amount of crop residue that is left on the soil and help in reducing soil erosion. Fertilizer can be used in an economic and environmental more efficient way by reducing application rate to what is desired by the crop and not adding the extra 'insurance'. The timing methods can be used to apply fertilizer in the most efficient way. Crop rotation is already being used in most of these Midwestern states, so that could be increased to being used for all corn production.

Table 2. Nutrient use and practice on selected crops for Midwest states, 1996 (ERS).

Practice	Fall Corn	North Soybeans	Spring Wheat
		Thousand hectares	
Planted hectares	24888	17159	6617
		Percent of Planted Hectares[1]	
Livestock manure applied	17	NA	NA
Commercial fertilizers applied	98	32	89
Nitrogen	98	16	89
Phosphate	86	23	79
Both chemical and manure applied	16	NA	NA
Nitrogen timing:		Percent of Treated Hectares	
Fall before planting	22	20	22
Spring before planting	54	50	45
At planting	43	18	77
After planting	33	14	1
Fertilizer appl. Method:			
Broadcast (ground)	73	91	28
Broadcast (air)	1	1	NR
Chemigation	2	1	NR
Banded	40	7	78
Foliar	1	@	NR
Injected (knifed in)	54	4	48
Average application rates		Kilograms per Treated Hectares	
Nitrogen:			
Annual	152	27	75
Fall before planting	119	24	96
Spring before planting	132	34	80
At planting	38	13	22
After planting	116	18	57
Nitrogen:			
Broadcast (ground)	102	21	78
Broadcast (air)	64	NR	NR
Chemigation	90	3	NR
Banded	31	10	16
Foliar	112	6	NR
Injected (knifed in)	146	106	87

@'= less than 0.5 percent NR= None reported NA= Not applicable

[1]Percents in a column may add to over 100 since a ha can be treated more than once

[2]Percent of soil-tested ha tested for nitrogen

[3]Percent of nitrogen-tested ha

Fall Corn= IL, IN, IA,MI, MN, MO,NE, OH, SD, and WI

North Soybeans= IL, IN, IA, MN, MO, NE, and OH

Spring Wheat= MN, MT, and ND

Source: USDA, ERS, based on 1996 Agricultural Management Study

N management can be used in combination with these conservation practices. The Federal Task Force that is researching hypoxia lists several practices that can be implemented on the farm in conjunction with N management. These result in changing farm practices by reducing 'insurance' rates of applied N fertilizer, using manure properly, using a credit system for legumes, soil, and manure, improving soil testing, and finally by introducing alternative cropping systems (Mitsch et al., 1999). These changes could result in 10-15% reduction in N in the Mississippi River Basin (Mitsch et al., 1999). The most significant reduction of N in the Mississippi River Basin would be seen with a 20% reduction in N fertilizer use (Mitsch et al., 1999).

CHAPTER 4: APPLICATION OF NITROGEN FERTILIZER

N fertilizer is applied at different rates and types throughout the Upper Midwest. The amount of fertilizer applied depends on the crops grown, climate, and soils. The states of Iowa and Illinois are comparable but Minnesota, Missouri and Wisconsin are not alike. Each state is different in some way and also similar. Chapter 3 detailed the importance of N management through agricultural practices and the importance of application rates to reduce N loss. Application of fertilizer is considered an important practice relating to crop production and also in controlling N runoff.

Certain factors can change and effect the application of fertilizer. These factors are N credits, climate, and the type of crop. The application rates discussed in Chapter 3 show that there is more N applied in the corn states than in the soybean or wheat states. The type of crop is important when discussing N credits. If a producer uses a corn-soybean rotation then the N that is fixed by the legume leaves a portion of N in the field. This amount should be credited towards the subsequent fertilizer application. The climate can also affect the amount of N that is applied and/or credited. Areas prone to drought may not utilize all of N fertilizer applied. N can be deposited through the rain. If an area experiences heavy rainfall then the amount of N can be added into the N equation and apply less chemical fertilizer.

Fertilizer has been used in crop production since the early 20th century. Throughout the last 80 years the amount of fertilizer that has been applied has been increasing due to a number of factors. In the 1960's fertilizer use increased dramatically with the development of synthetic fertilizers.

The U.S. Geological Survey has complied reports on the use of fertilizer in the United States. Individual states report fertilizer amounts to the National Fertilizer and Environmental Research Center of the Tennessee Valley Authority and the USGS complies them annually. These are reported on a 1945-1985 basis and 1985-1991 basis. The 1945-1985 county level data were estimated through separating the state-level fertilizer use in proportional amounts of state fertilized acres reported in counties (Alexander and Smith, 1990). The 1985-1997 data are the fertilizer amounts as tonnage reports that the state reports as amounts that counties' sell in tons per year of fertilizer (Battaglin and Goolsby, 1994). The fertilizer is assumed to be applied on a per county basis and is in kilograms of N in all fertilizers that is reported by the state. The fertilizer is graphed on a per county level throughout the 52 years. These years show increased usage beginning in the 1960's when fertilizer became readily available. Since N fertilizer is the target for the hypoxic zone in the Northern Gulf of Mexico, the amount of N fertilizer applied could be related to the size of the zone.

CHAPTER 5: NITROGEN LOADS IN UPPER MIDWEST WATERSHEDS

The scope of this chapter is to examine the role of N in the Upper Midwest agricultural watersheds. This chapter details the amount of N potentially influencing Gulf of Mexico Hypoxia. These loads are important as the amount of fertilizer applied could be related to the amount of fertilizer that is lost.

5.1 Data Sources

Data from several different sources were used in this study. The data for the water gauging stations, which included N concentrations and flow, were collected by state or federal agencies and entered into an information management system for water monitoring data called STORET (EPA, 2000). The Environmental Protection Agency maintains this database and extensive amount of data exists for the U.S., but not in the regularity of collection sites. The data is sporadic and doesn't include every U.S. river system. The STORET data were made available by John Olson, Iowa Department of Natural Resources.

The Illinois EPA provided the Illinois state data. The data used was in a document prepared by Short (1999). These databases contain the amount of N, P, and sediments in the Illinois river system from the ambient monitoring program. The ambient water quality monitoring network runs the Illinois collection stations. This network was established through Illinois state agencies but operated by the Illinois EPA. The files that were available included N concentrations, flow, and Arc View shape files for the watersheds.

Census of Agriculture data for the years of 1987, 1992, and 1997 were used to determine the amount of total land area and harvested land each county within a given state (Census of Agriculture, 1997).

Arc View data including watershed boundaries for Iowa, Missouri, Minnesota, and Wisconsin coverage's came from USGS files (ESRI, 1999).

Annual precipitation state data came from the cooperative station network of the National Climatic Data Center in Asheville, NC. The stations for data collection were located as close to the end of the watershed as possible. Which would account for the gauging station where the samples were taken, but does not represent an average of the whole watershed.

Annual sold fertilizer data was located on the USGS web site (http://water.usgs.gov/pubs/ofr/ofr90130/data.html) and is in an Arc View format. Sources of fertilizer data were described in Chapter 4.

5.2 Criteria for Data Selection

The criteria for the selection of locations throughout the Upper Midwest used the STORET and EPA data sets that included N concentration and flow. Illinois had over 200 stations listed in STORET with data collected at least once during the 50 year period of data. To narrow this down, the stations were eliminated if there was missing flow or N data. Next, the watershed stations were chosen if there was more than six months of data available per year from 1980 to 1997. The next step was to limit locations to only one watershed per major river. The last step was to plot the locations on a map and choose sites located throughout the Mississippi River Drainage Valley. This same process was used for all states but not all the steps were needed, as some states did not have a regular basis for collecting data.

5.3 Watershed Locations

5.3.1 Illinois

Illinois is the eastern most state that is included for the upper Midwest Mississippi River Valley. The western border of Illinois is the Mississippi River. This makes the amount of nutrients that flow through the state important as the nutrients have a direct route to the Gulf coast. The base for Illinois was prepared by Matt Short, Illinois EPA, in November of 1999 (Short, 1999). The Illinois watersheds selected were: North Fork Embarras River, Little Wabash River, Cache River, Edwards River, Indian Creek, Spoon River, Sangamon River, Salt Creek, La Moine River, Macoupin Creek, Cahokia Creek, Kaskaskia Creek, Richland Creek, and Casey Fork. The total area for these 14 watersheds is 2,199,978 hectares. The watershed area calculations were made using Arc View 3.2 shapefiles. The data were collected and used to determine the areas of the 14 watersheds. These 14 watersheds were chosen on their location and on the amount of data available on each collection station and encompass 54 counties (Fig. 9). The watersheds were then separated into different categories: high, low flow; high, low concentration; and then an overall average watershed. The watersheds chosen to represent these criteria were Casey Fork, Edwards River, Salt Creek, Kaskaskia River, and Indian Creek. Casey Fork was chosen for it's low concentration or low load. The Edwards River watershed was chosen to represent the average watershed in Illinois as it's flow, area, and concentrations were typical. Salt Creek represents high concentration or load. The Kaskaskia River was chosen as the high flow watershed for Illinois. Finally, Indian Creek is representative of the low flow for Illinois.

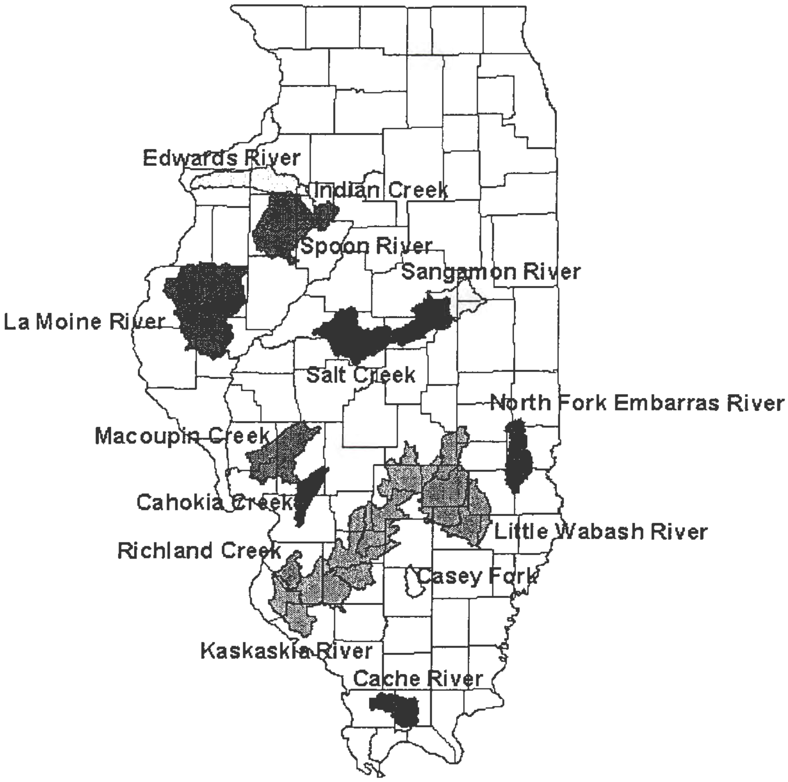


Figure 9. Illinois study area of watersheds.

5.3.2 Iowa

Iowa is the western most state of the upper Midwest Mississippi River Valley and has two major rivers bordering the state. The eastern border is the Mississippi River and the western border is the Missouri River. Since the Mississippi River directly transports nutrients that flow into the Gulf coast, the amount of nutrients that is lost from Iowa is important in the role of Hypoxia in the Gulf of Mexico. The Iowa watersheds were chosen based upon STORET data. The parameters of total N, flow, and date were examined and narrowed down based on monthly collections. These were then narrowed to 16 watersheds based on these three parameters (Fig. 10). The watersheds that represent Iowa are: North Fork Maquoketa River, Volga River, Upper Iowa River, Iowa River, English River, Cedar River, West Fork Cedar River, Cedar Creek, South Skunk River, North River, East Fork Des Moines River, North Raccoon River, Chariton River, East Nishnabotna River, Solider River, and Floyd River. The total area for the 16 watersheds is 3,852,494 hectares and encompasses 83 counties.

5.3.3 Missouri

Missouri is the southern most state in the Upper Midwest. Missouri is important because the Mississippi River travels the east border of the state and the Missouri is the northwestern border. These two rivers converge in St. Louis. The agriculture of Missouri is not as extensive as Iowa or Illinois but it is equally important as the Missouri and Mississippi River are part of the state. The Missouri watersheds were chosen from the STORET database. Missouri had a lesser amount of data available so sites were chosen that had a good representation of collected data. With the same criteria used with the other states the stations were narrowed down to seven (Fig. 11). Watersheds representing Missouri are: Current River, Big Piney River, Meramec River near Sullivan, Meramec River near Paulina

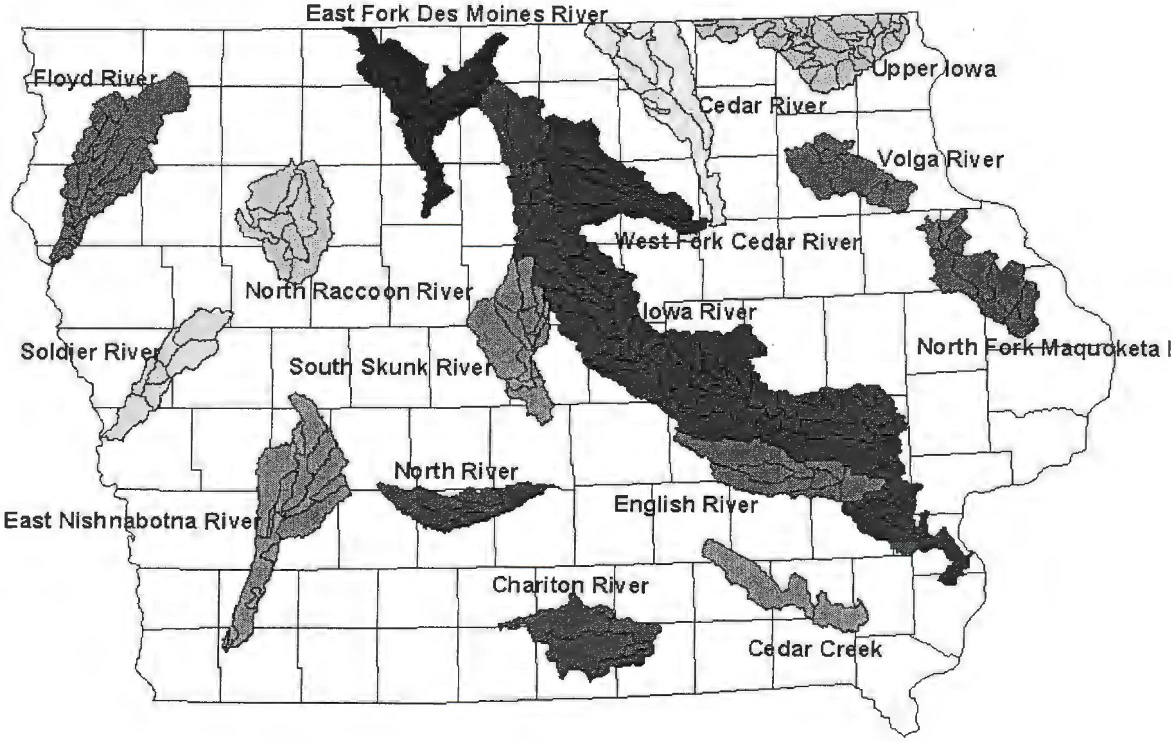


Figure 10. Iowa study area watersheds.

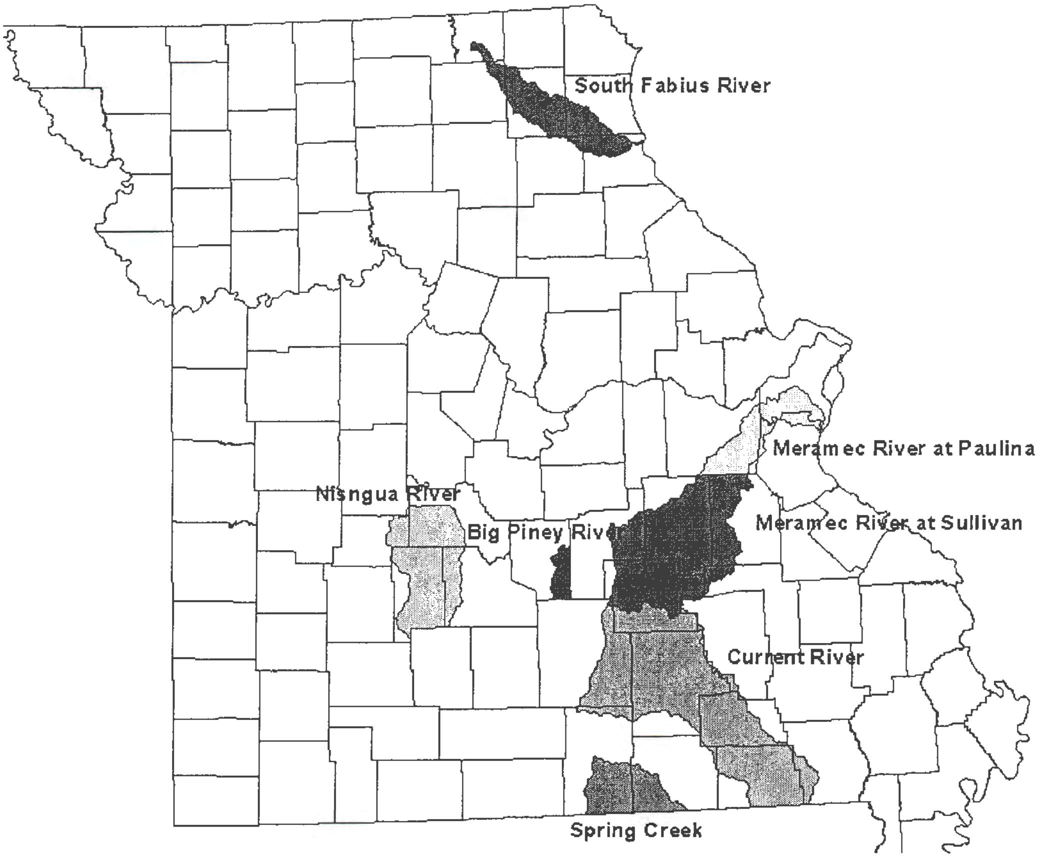


Figure 11. Missouri study area watersheds.

Hills, Nisngua River, South Fabius River, and Spring Creek. The watersheds total 1,865,648 hectares within 29 counties.

5.3.4 Minnesota

Minnesota's data in the STORET database were not available in a form that could be used in this study. Some sites had data collected every week for a year, then data collections would skip several years. A few watersheds were chosen to just show the N concentration that is present in Minnesota rivers (Figs. 12-15). Minnesota data were missing flow for many stations, which prevented load from being calculated. Without the watershed data, the map for locations was not created.

5.3.5 Wisconsin

Wisconsin wasn't used because the few stations that had both key elements for this study were not tributaries of the Mississippi River or were the Mississippi River watersheds themselves. The purpose of this study was to look at the watersheds that contribute to the Mississippi River since the Mississippi has been studied for the last few years on it's N concentrations. Wisconsin was primarily used as a reference point in comparing concentrations, since data was lacking for a complete analysis of nitrate load.

5.4 Data Processing

Layouts of the rivers along with the county lines were used with the polygon shapes of the watersheds, which were categorized as USGS HUC 11 digit watersheds. The collection stations were located on a state map by directions given by STORET. After the stations were located on a state map they were then located using the township theme in Arc View 3.2. Next, the rivers were located by using the query function on Arc View, which finds and selects the river chosen. Then the selected polygons or 11 digit HUC watersheds

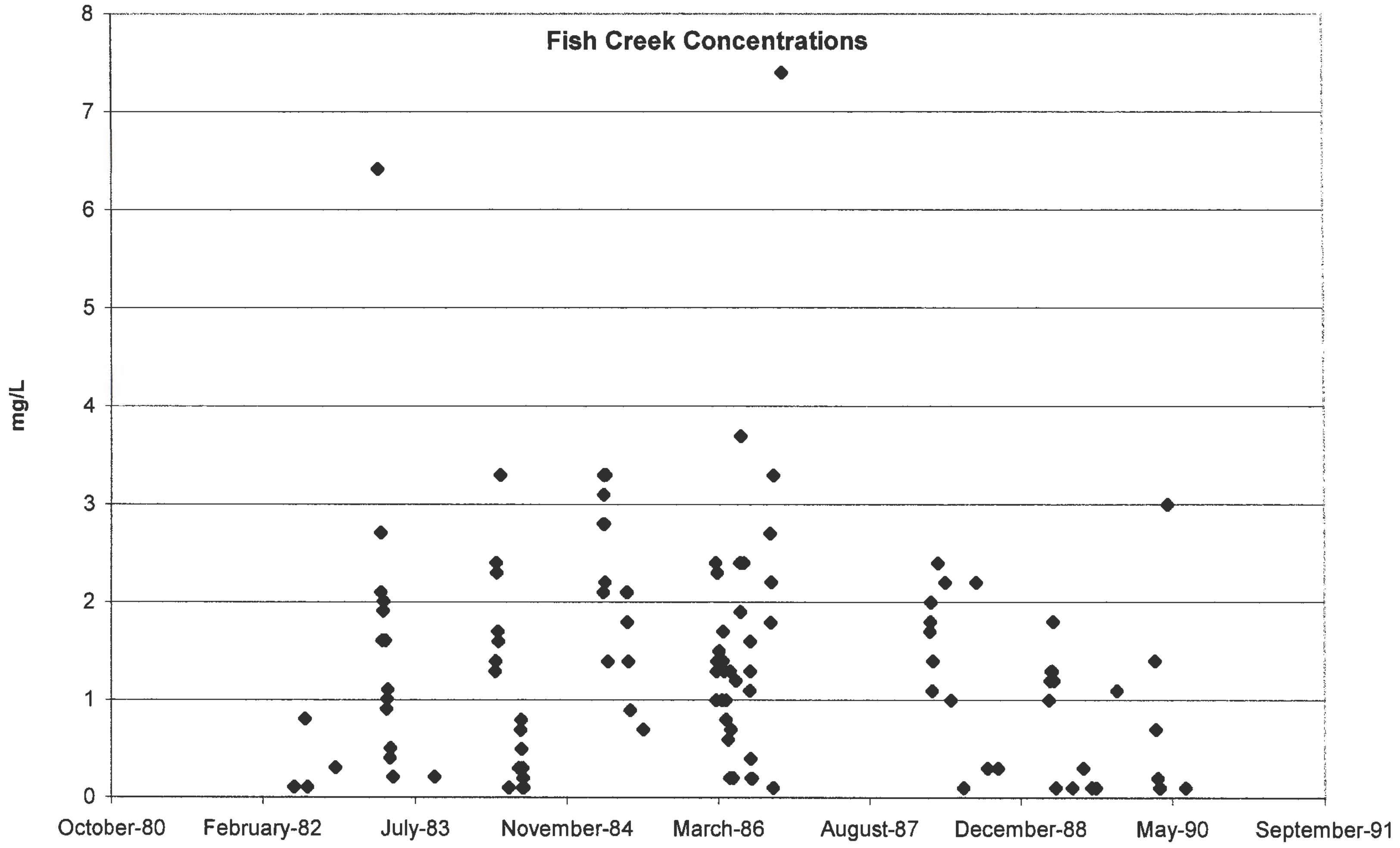


Figure 12. Nitrogen concentrations in Fish Creek, Minnesota.

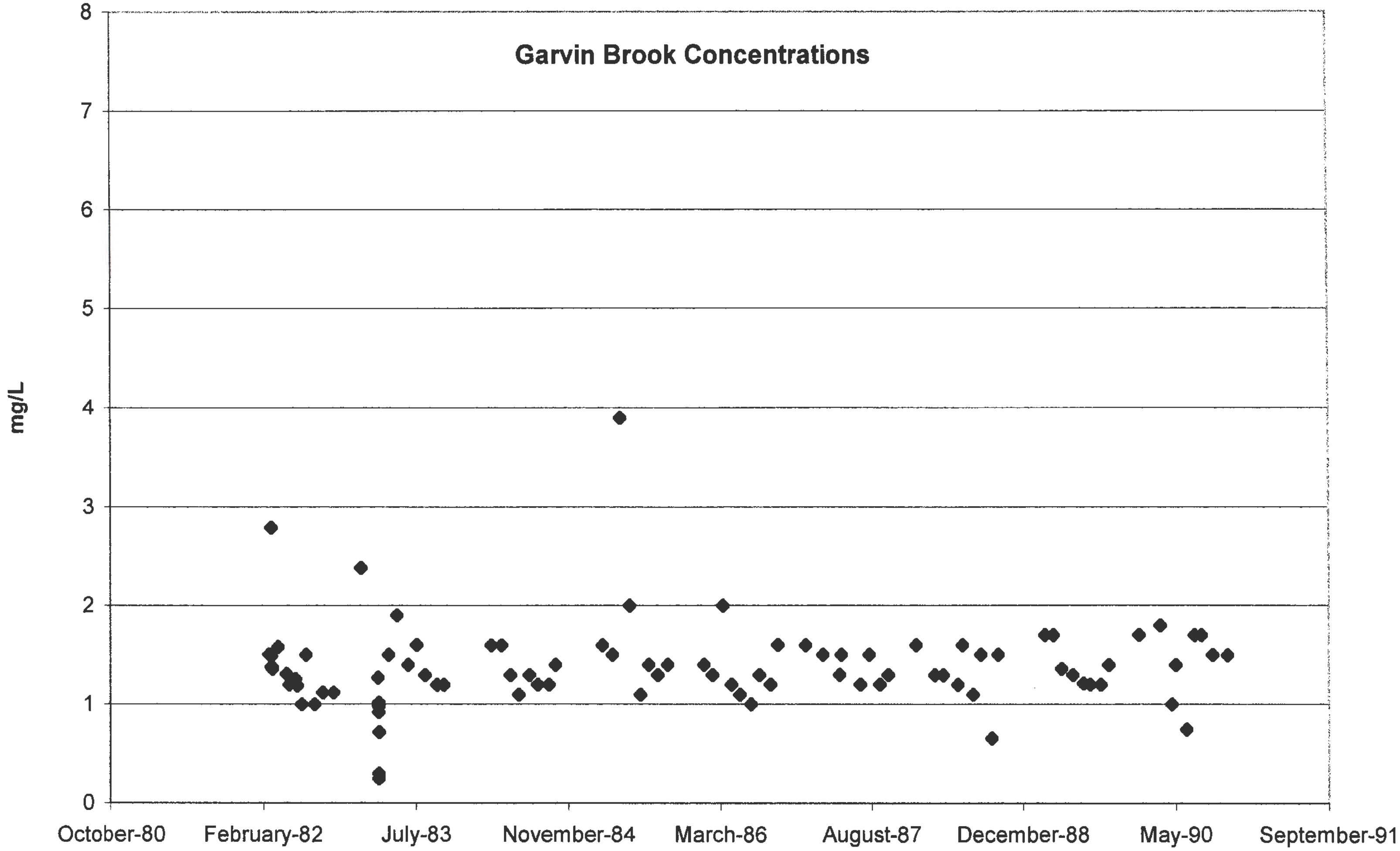


Figure 13. Nitrogen concentrations in Garvin Brook, Minnesota.

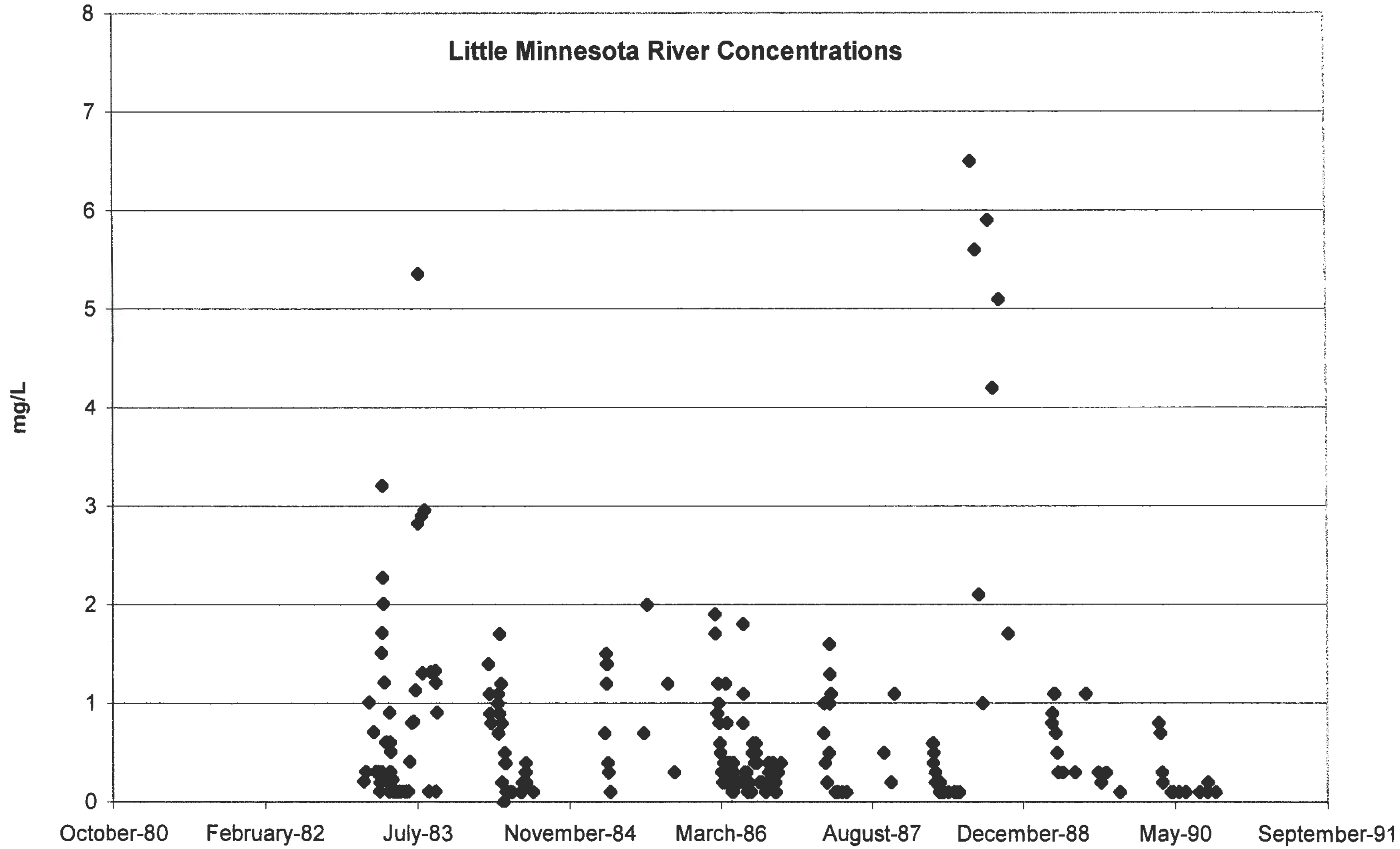


Figure 14. Nitrogen concentrations in Little Minnesota River, Minnesota.

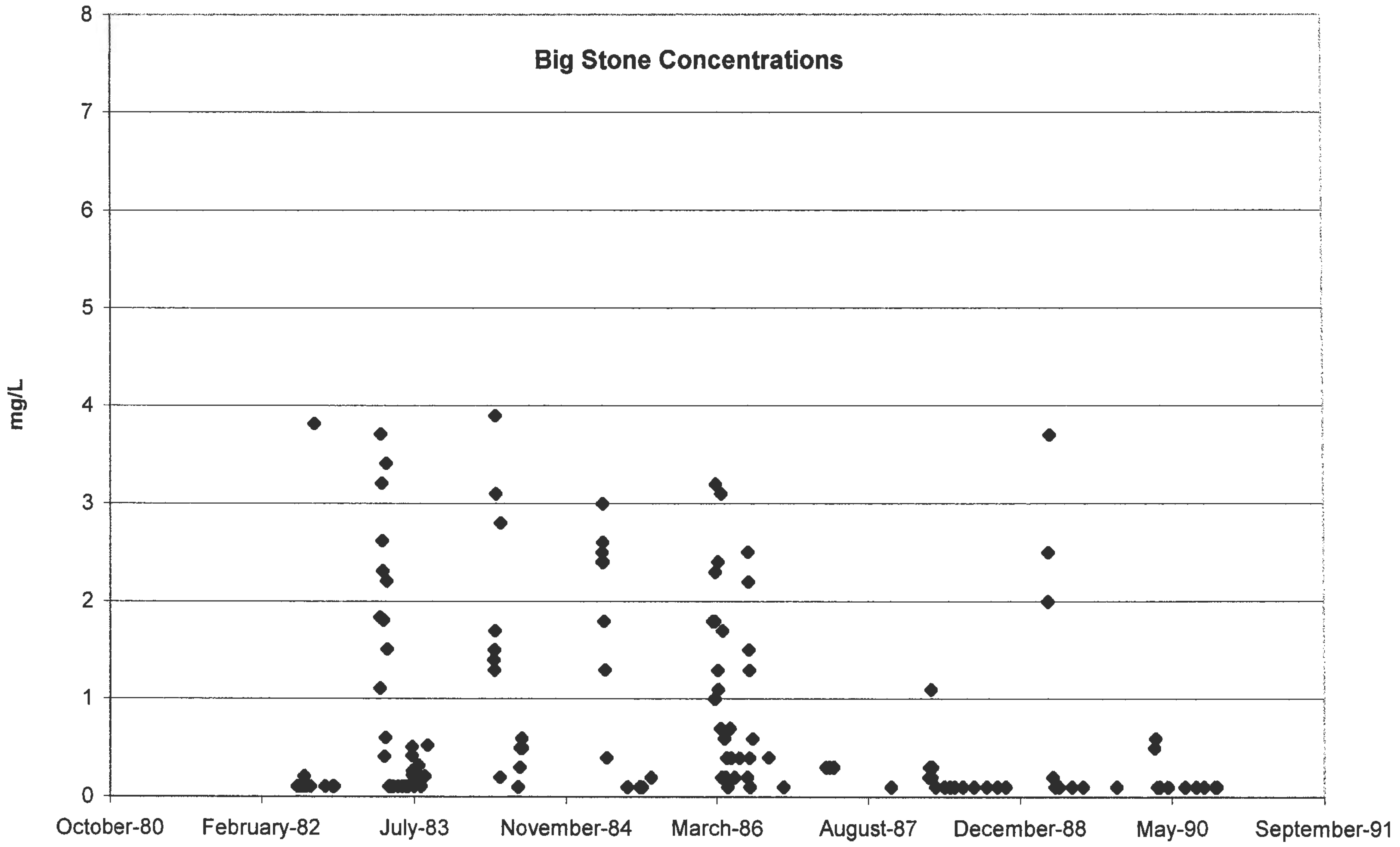


Figure 15. Nitrogen concentrations in Big Stone River, Minnesota.

that are located around the river are chosen for the drainage pattern within a particular river.

The final selection is then considered to be the watershed for that river and collection station. These features were then created into a shape file and named for the river. This was completed for all stations in Iowa, Missouri, and since these watershed delineation was complete for Illinois and then county data was incorporated into the layout.

The geoprocessing wizard in Arc View was used to isolate watersheds based on county lines. This was done by selecting the watershed and the county themes so that both were active. The final step created a shapefile with a new name and attributes. These steps were completed for Illinois, Iowa, and Missouri watersheds and areas are shown in Table 3. Combining the watershed area per county with the harvested land area provided a better estimate of fertilizer applied to the watersheds. Fertilizer data, harvested area, and boundaries for the watersheds were combined to estimate the fertilizer applied to each county and each watershed. The land data from the Census of Agriculture for 1987, 1992, and 1997 allowed three years of comparison of applied fertilizer amounts to runoff loads. Harvested land per county was determined on a watershed basis, dividing the total harvested land area by the total land area. Percentage of total cropland area and harvested land was taken and multiplied by the watershed area per county. The fertilizer amounts from 1987, 1992, and 1997 crop years were used to determine the amount of fertilizer added to the watershed on a county and watershed level. After the watersheds were divided into counties the amount of N applied to the counties in the given year was divided by the amount of harvested area for that country based upon the Census of Agriculture to generate the application load (kg/ha) for each watershed. This value was multiplied by the amount of cropland in that watershed for the individual county to estimate the load (kg) applied per watershed.

Table 3. Watershed areas by state.

Illinois Watersheds	Area (HA)
Cache River	62514
Cahokia Creek	52895
Casey Fork	22442
Edwards River	114131
Indian Creek	16206
Kaskaskia River	542326
La Moine River	332002
Little Wabash River	289640
Macoupin Creek	144114
North Fork Embarras River	81515
Richland Creek	32914
Salt Creek	242809
Sangamon River	61500
Spoon River	204970

Iowa Watersheds	Area (HA)
Cedar Creek	102587
Cedar River	217063
Chariton River	162504
East Fork Des Moines River	218861
East Nishnabotna River	255379
English River	165773
Floyd River	237457
Iowa River	1216284
North Fork Maquoketa River	152702
North Raccoon River	180183
North River	103651
Solider River	117105
South Skunk River	179742
Upper Iowa	202652
Volga River	117588
West Fork Cedar River	222963

Missouri Watersheds	Area (HA)
Big Piney River	28724
Current River	366410
Meramec River/PH	504048
Meramec River/S	423096
Nisngua River	242990
South Fabius River	162661
Spring Creek	124436

5.5 Data Presentation

The data were presented in N concentration, as NO_2 and NO_3-N in mg/L. This was used to have a better understanding of nitrogen concentrations found in Midwest streams. Annual concentrations were derived from the daily concentrations and then multiplied by the number of days in the collection interval. Monthly concentrations were then used to calculate the annual N concentration. The N concentration was also used to compare results across the Mississippi River Basin. Data expressed as load (kg/ha) provides a measure of the contribution of the land area within a watershed to nitrate movement. Concentration and load were equally important throughout the study. The harvested cropland data was presented as hectares so that this amount of lost N could be compared with annual amounts of applied N fertilizer. Data were presented on the same scale within a data type to allow for a direct comparison among watersheds and states.

5.6 Results

The N concentrations in the watersheds located through the Upper Midwest vary from amounts such as 22 mg/L found in the North River watershed in Iowa during 1991 to 0.01 mg/L. These low amounts were found throughout a number of the watersheds. Complete data set of N loads is given in Appendix A. Concentrations for Illinois, Iowa, and Missouri watersheds show a higher amount of N than in the Northern Midwestern states of Minnesota and Wisconsin. Even though these states were not used in the study the amounts of concentration was regarded to compare a slight difference in concentrations. But since the load couldn't be calculated without flow and flow was missing the watersheds were not used extensively.

5.6.1 Illinois

Flow across 6 years from the 14 watersheds in Illinois showed a large variation among years (Fig. 16). The flow was highest in 1993 and lowest during 1980, 1987, and 1992. The water flow from these tributaries affected the N load potentially transported to the Gulf, as the N load increases with flow. Loads for a few select watersheds are shown to demonstrate the variability among watersheds. Casey Fork is shown as having a low concentration compared to the other stations. Edwards River was chosen as a most representative of the Illinois watersheds. The highest concentrations were observed from the Salt Creek watershed. Kaskaskia River and Indian Creek watersheds were chosen to represent the range of high and low flow. Details on the concentrations, flow, and N load are described in detail for each of these watersheds in the following sections.

5.6.1.1 Casey Fork

The Casey Fork watershed covers 22,442 hectares in Marion and Jefferson counties. Harvested area in both counties is less than 50% with Marion County at 48% and Jefferson at 38%. Within the watershed 8,621 hectares are harvested cropland to which N fertilizer is applied during a two year period based on a corn-soybean rotation. Concentration from the watershed displayed no concentrations above 10 mg/L during the 17 year record (Fig. 17). Flow volumes revealed a large variation among years with 1986 being the highest flow on record (Fig. 18). However, when these two accounts are combined to produce an estimate of N load these valued are low across all years (Fig. 19).

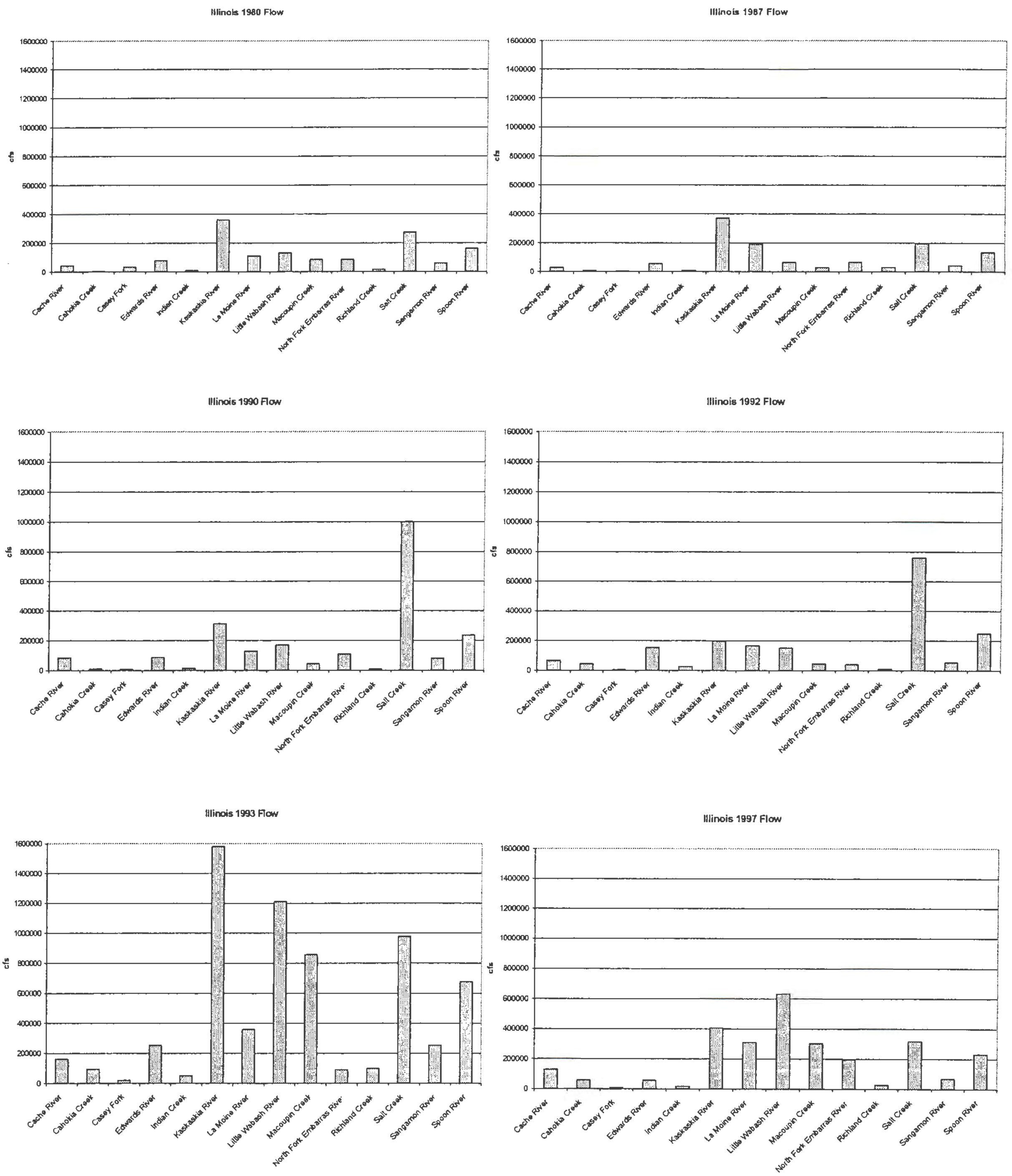


Figure 16. Water flow in Illinois watersheds for selected years.

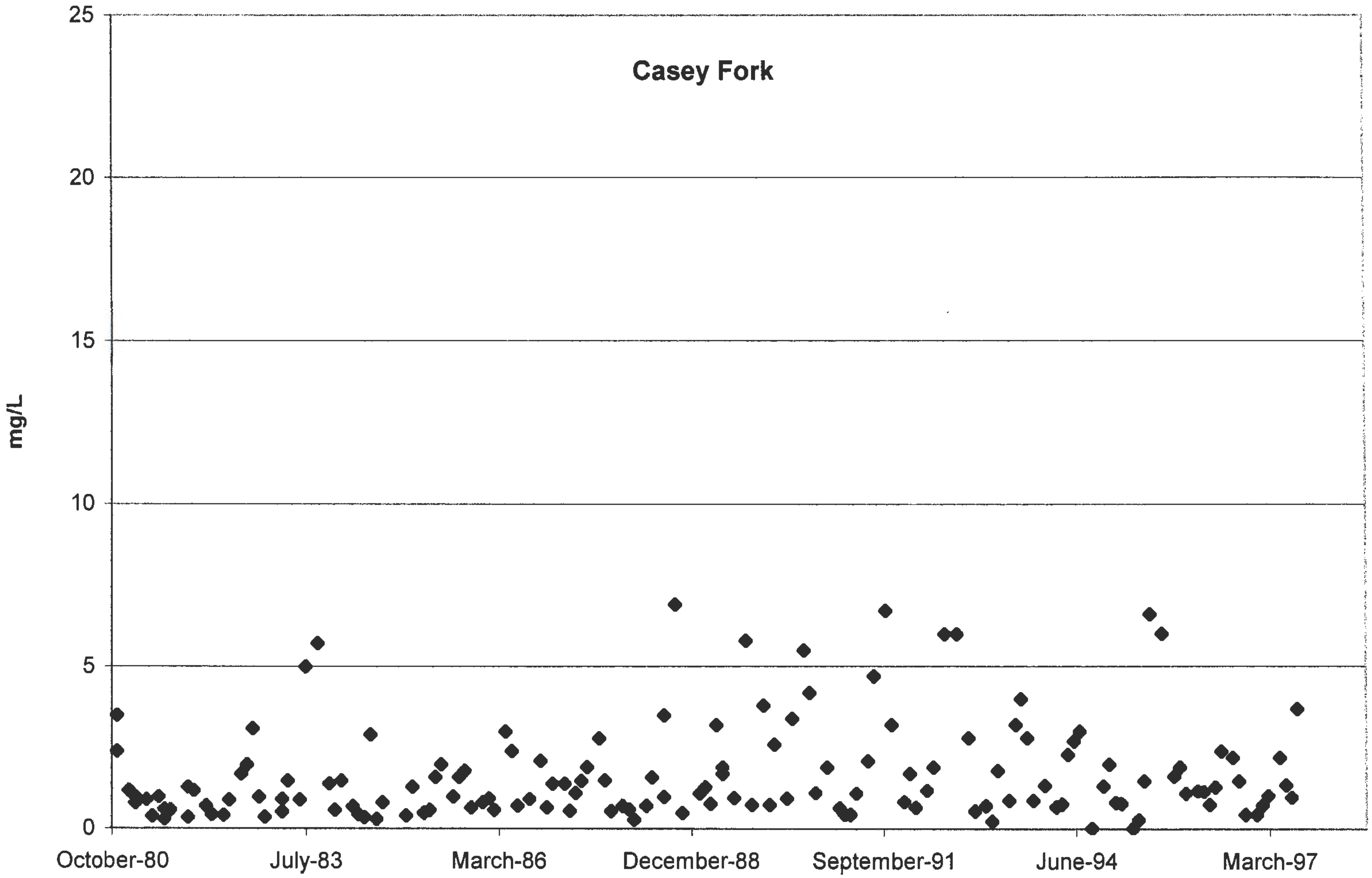


Figure 17. Nitrogen concentrations for Casey Fork, Illinois from 1980-1997.

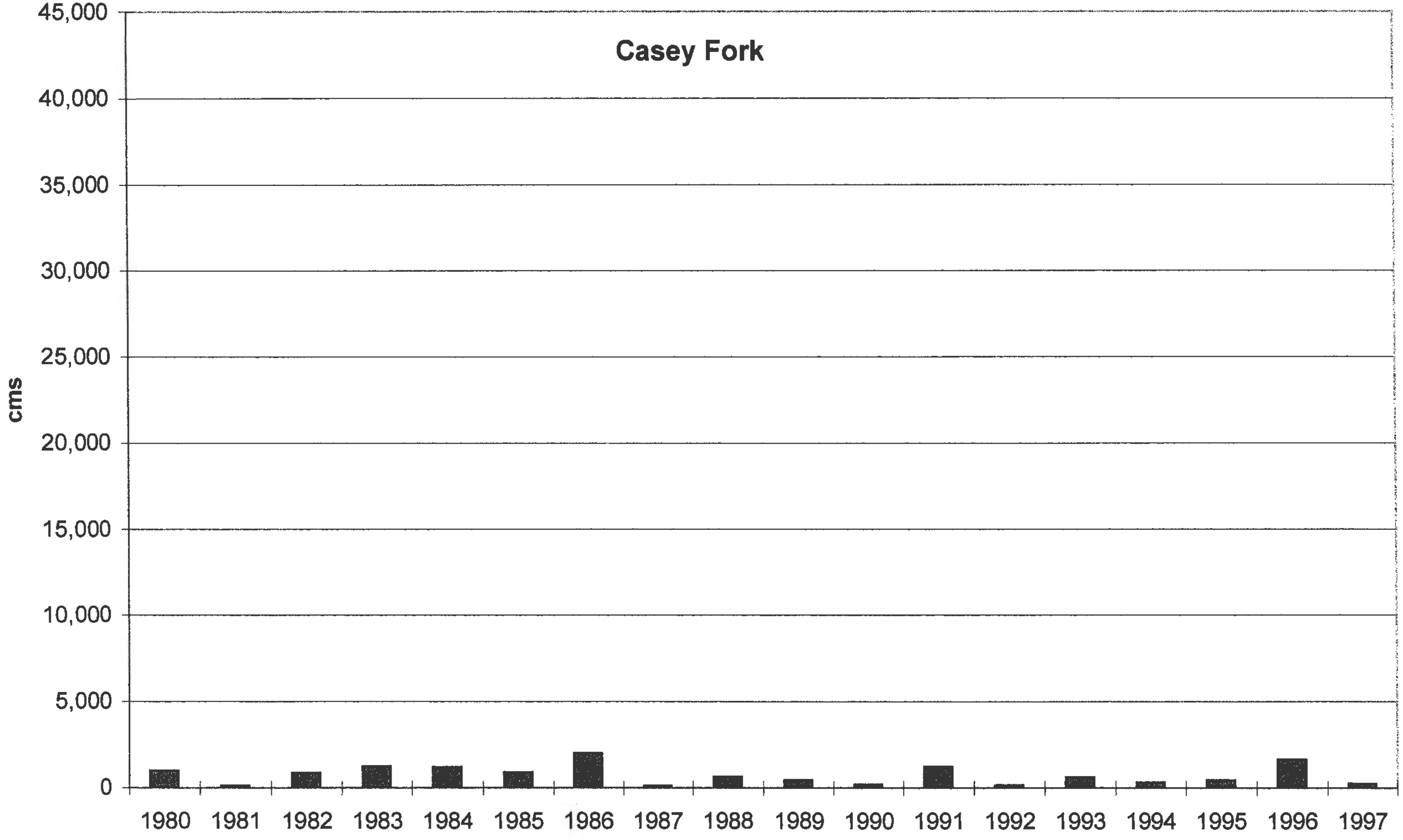


Figure 18. Flow for Casey Fork, Illinois from 1980-1997.

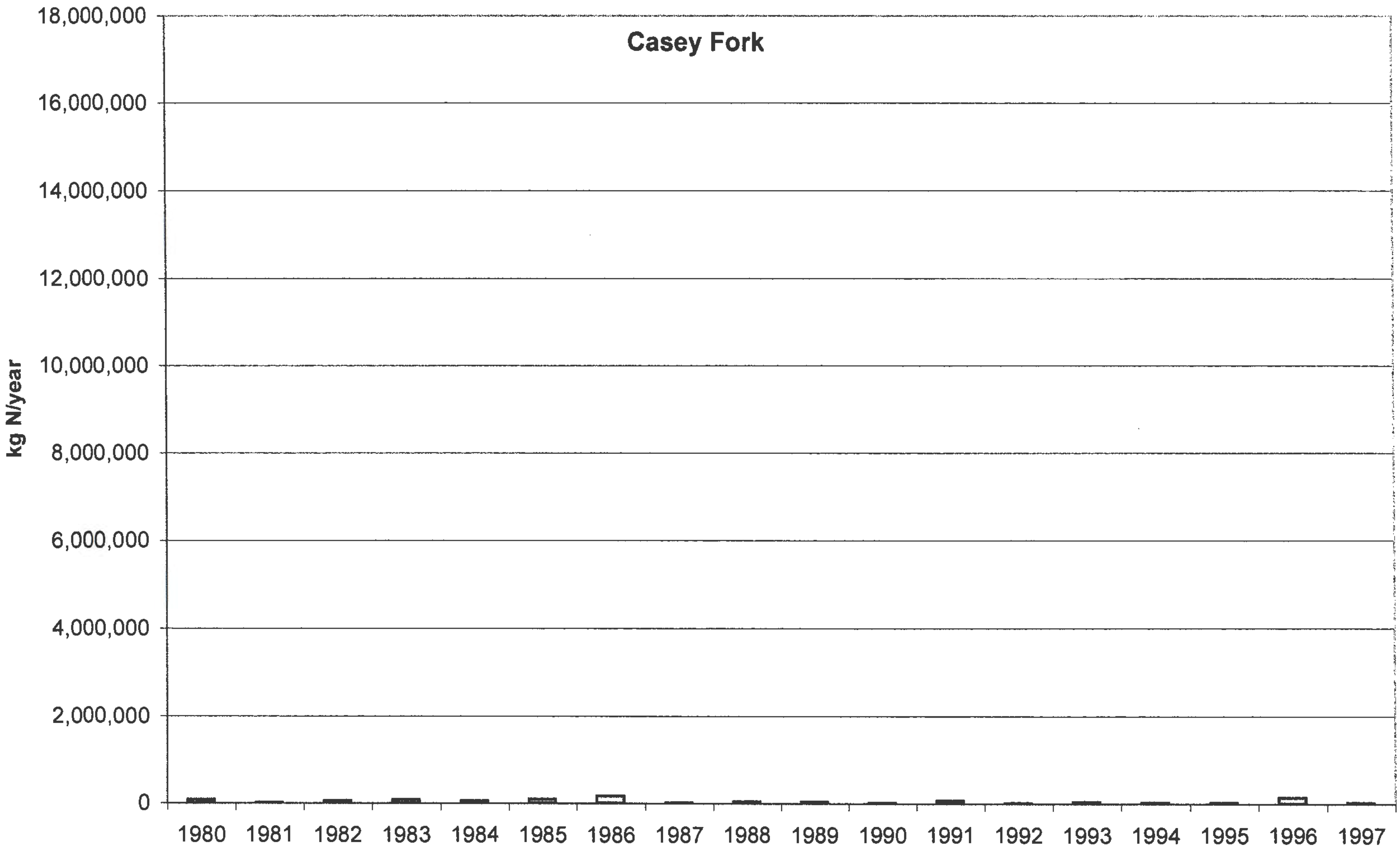


Figure 19. Nitrogen kg/ha/year for Casey Fork, Illinois from 1980-1997.

5.6.1.2 Edwards River

Edwards River is an average watershed for Illinois with 114,131 hectares. Henry, Mercer, and Rock Island are the counties that encompass the Edwards River watershed. Harvested cropland is 78%, 73%, and 50% respectively, which equals 86,439 hectares of the watershed. The N concentrations are higher for this watershed with 22 months over 10 mg/L (Fig. 20). This combined with a high flow could impact the Gulf of Mexico. The average concentration for the 17 year data record is around 7 mg/L. The highest load (Fig. 21) was in 1982 and 1994, which is the same years that a high flow was recorded (Fig. 22). The Edwards River watershed shows a pattern of increased load when the flow is increased but not as much when the concentrations are increased. These years of increased flow are not reflecting higher than normal precipitation either.

5.6.1.3 Salt Creek

Salt Creek has a relatively higher flow for it's 242,809 hectares. The watershed covers eight counties: Tazewell, Mason, Logan, Dewitt, Menard, Sangamon, McLean, and Piatt. These counties have 71%, 71%, 88%, 76%, 71%, 75%, 86%, and 86% harvested cropland, respectively. This amount of harvested cropland is higher and leads to more N applied over its 200,795 hectares of harvested cropland. In 1990, the flow and load were the highest recorded in this data record (Figs. 23 and 24). The concentration in 1990 was above 10 mg/L (Fig. 25). The Salt Creek shows a pattern of higher load when the precipitation is at a high. Even though the load is increased, the concentrations have remained low throughout the 17 years of data recorded.

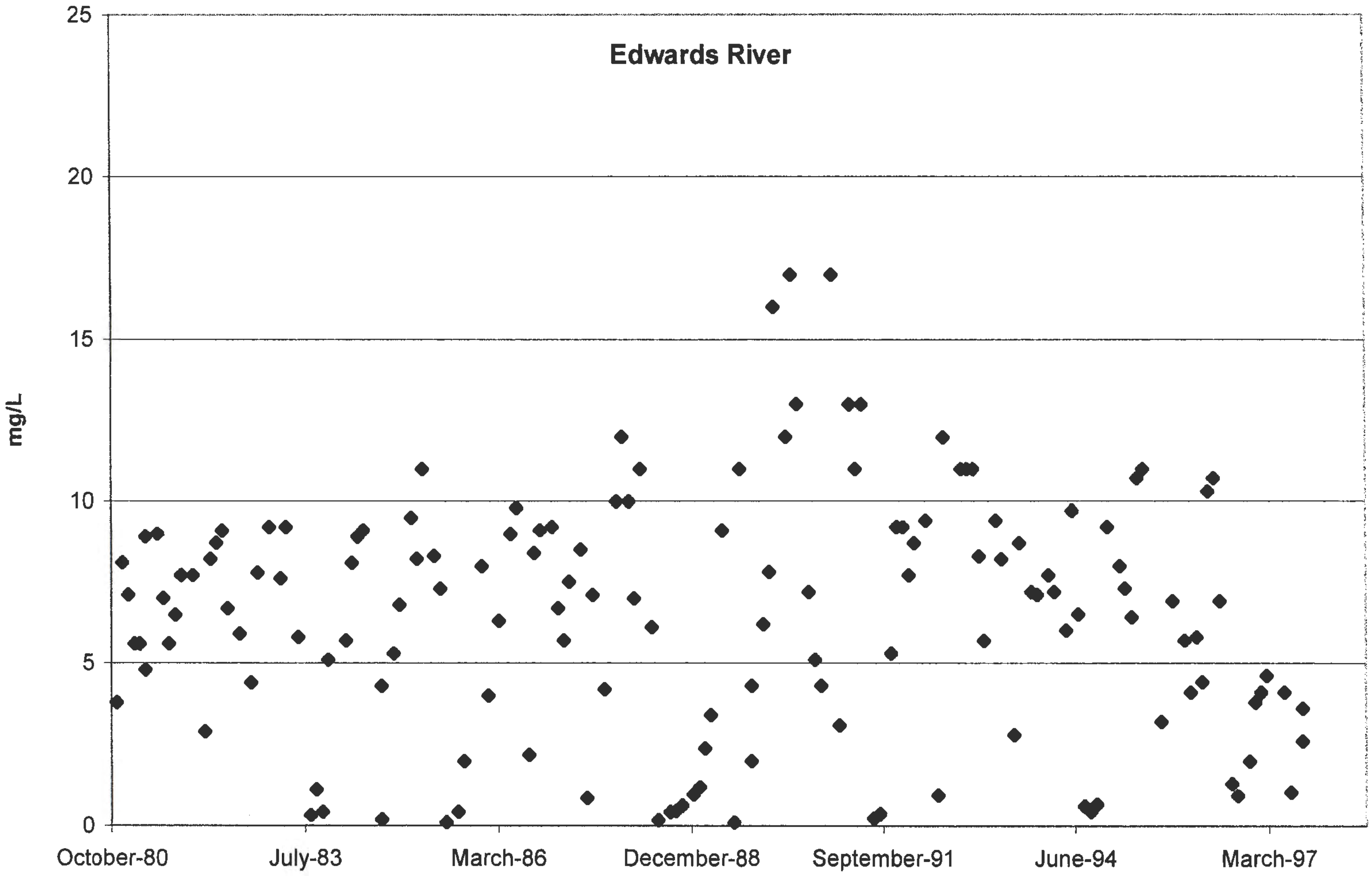


Figure 20. Nitrogen concentrations for Edwards River, Illinois from 1980-1997.

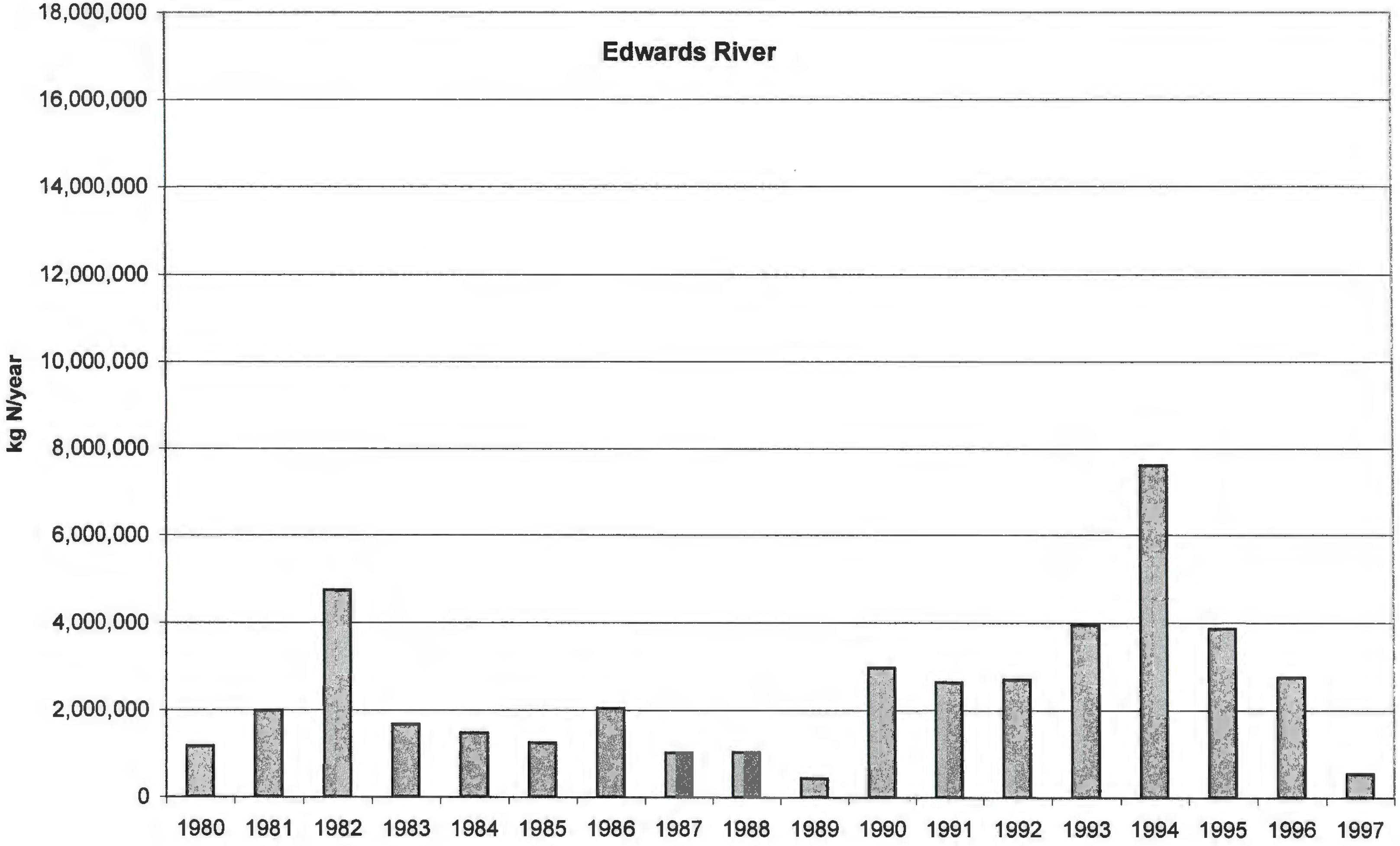


Figure 21. Nitrogen kg/ha/year for Edwards River, Illinois from 1980-1997.

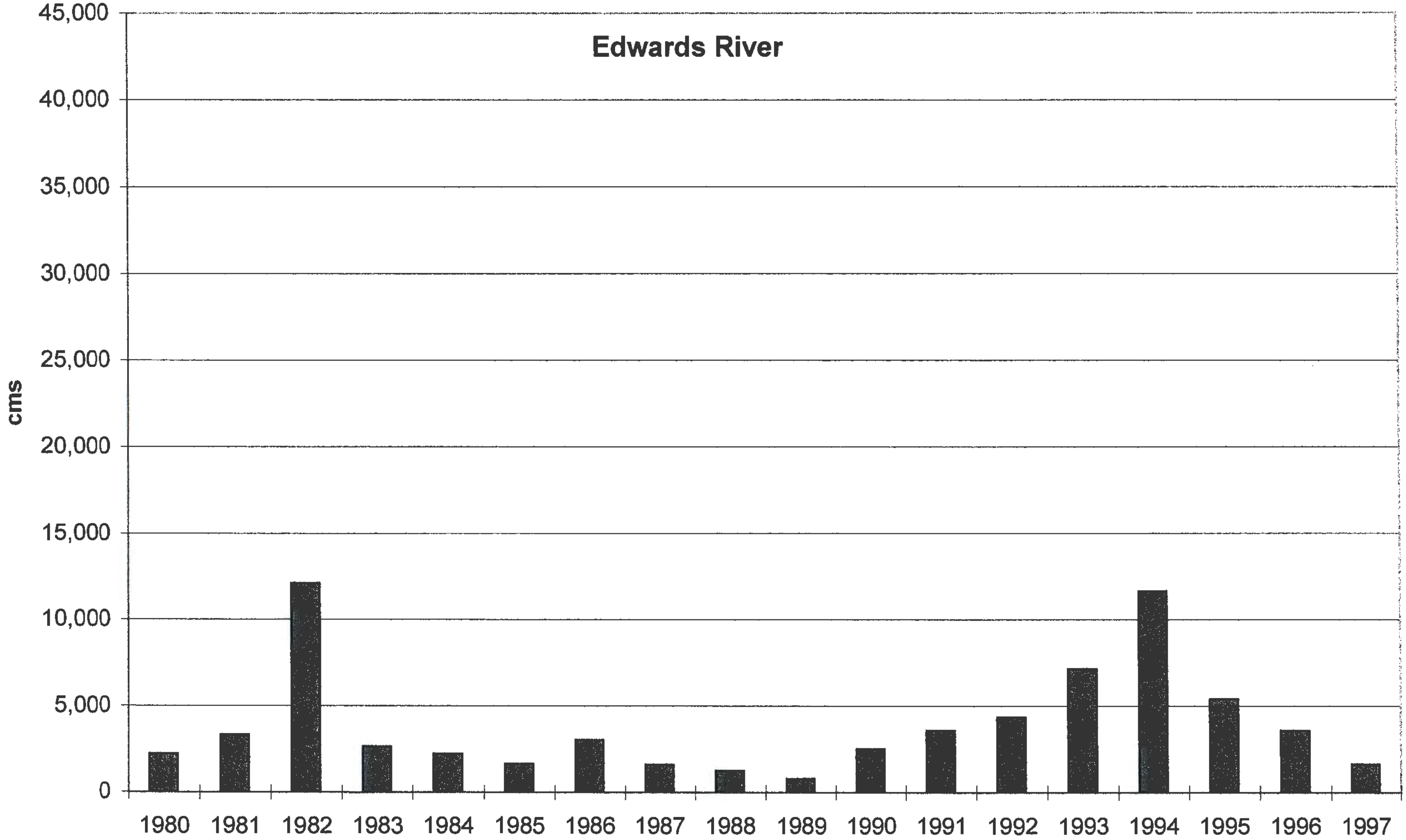


Figure 22. Flow of Edwards River, Illinois from 1980-1997.

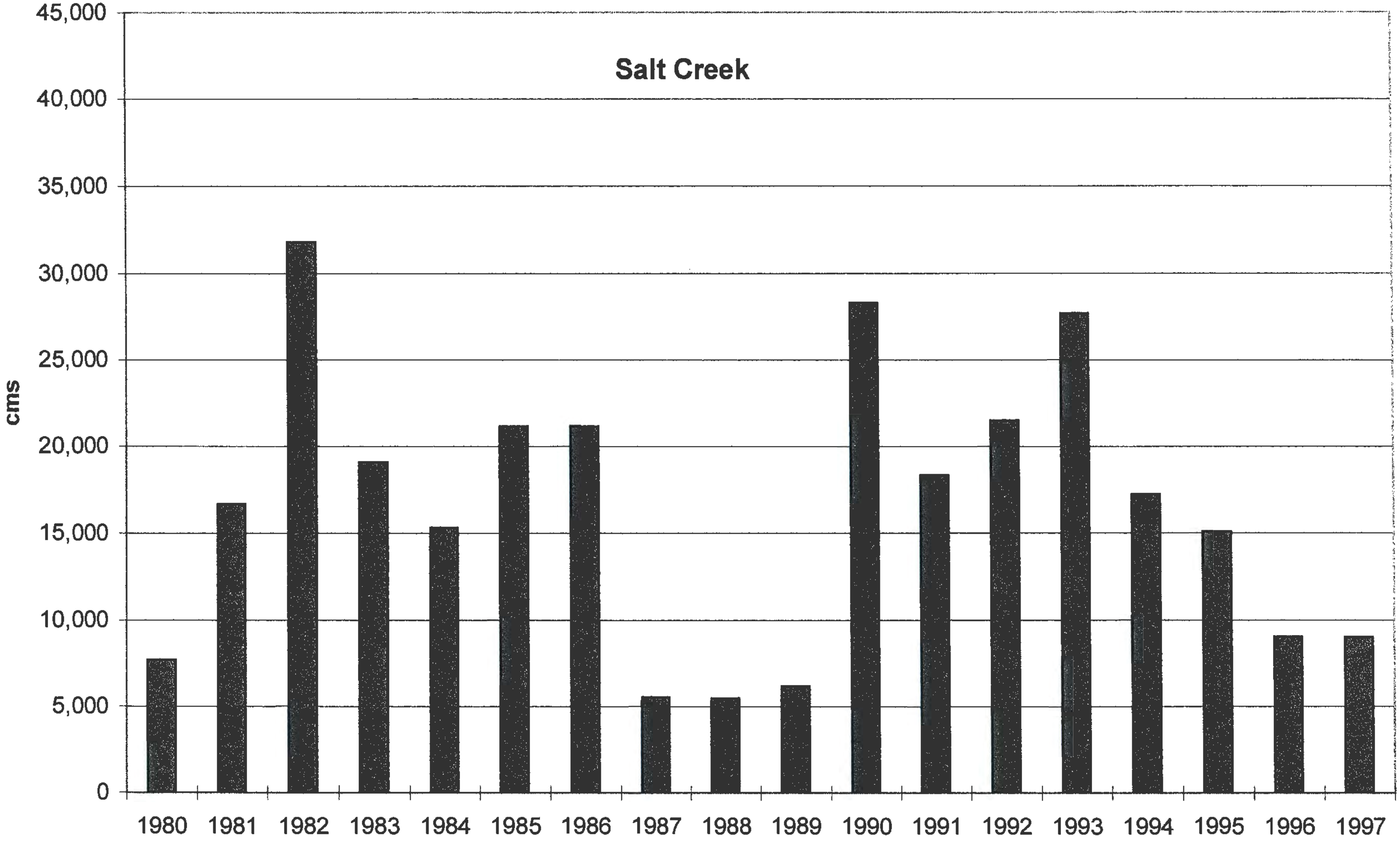


Figure 23. Flow of Salt Creek, Illinois from 1980-1997.

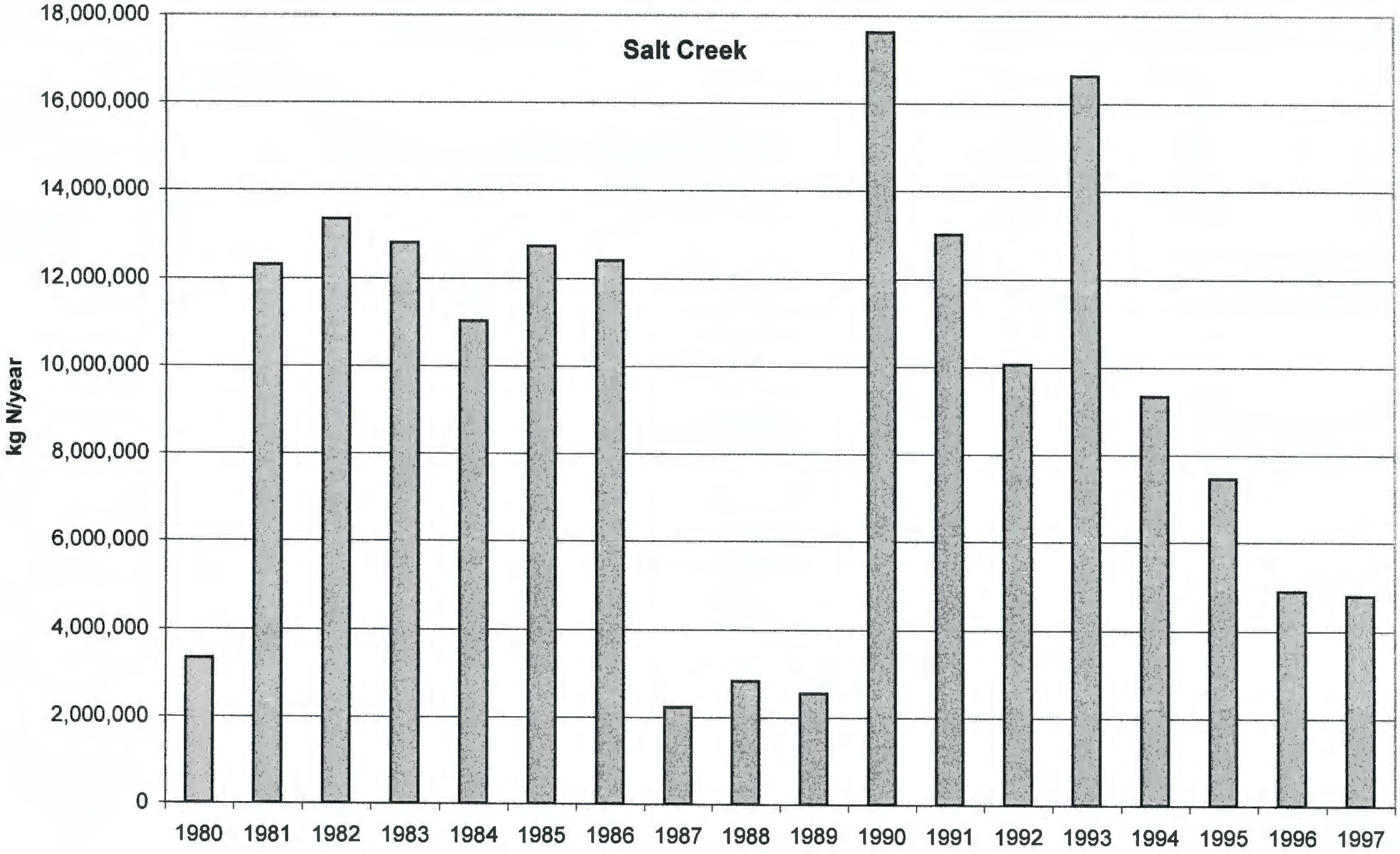


Figure 24. Nitrogen kg/ha/year for Salt Creek, Illinois from 1980-1997.

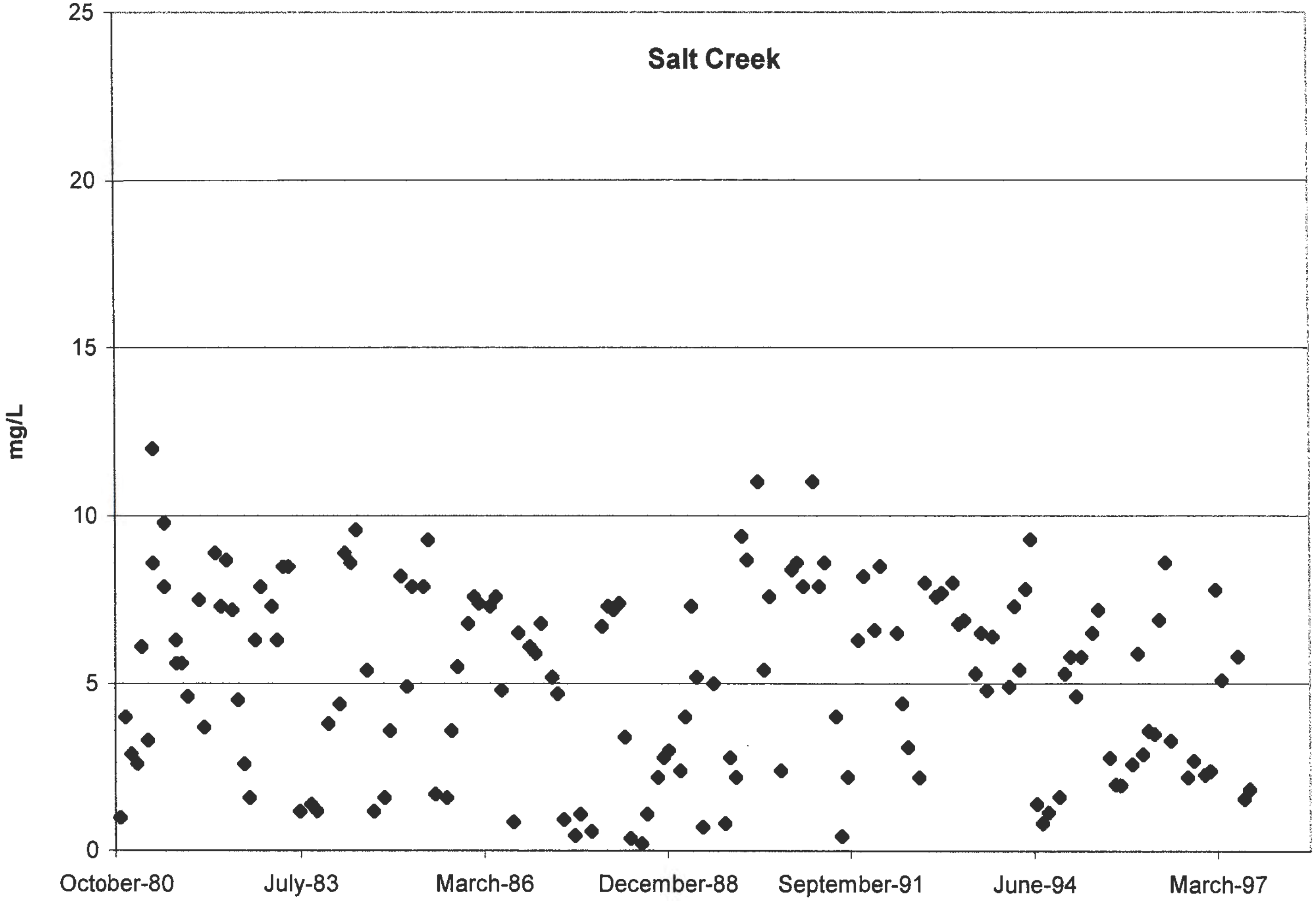


Figure 25. Nitrogen concentrations for Salt Creek, Illinois from 1980-1997.

5.6.1.4 Kaskaskia River

The Kaskaskia River is one of the larger watersheds in this study with a drainage area of 542,326 hectares. This watershed represents 12 counties: Shelby, Montgomery, Effingham, Fayette, Bond, Marion, Clinton, St. Clair, Monroe, Washington, Randolph, and Perry. Kaskaskia watershed has an average of 60% harvested cropland with 341,347 hectares of cropland. This watershed has the highest flow for the Illinois watersheds and its concentrations are lower so that leads to a lower load (Figs. 26, 27, and 28). Again the relationship is shown between flow, concentration, and load. Kaskaskia River watershed's flow stays consistent except in the higher rainfall years. This is a significant pattern and shows that even through no definite N concentration change and an average flow, the load in this river is variable.

5.6.1.5 Indian Creek

Indian Creek is the smallest Illinois watershed studied with an area of 16,206 hectares. The counties that are included in this watershed are Stark and Henry. The watershed has a total of 13,469 hectares of harvested cropland with an average of 83% being harvested cropland. Flow for this area is very small (Fig. 29), but the N concentrations are higher with 3 months over 15 mg/L (Fig. 30). The average concentration is around 10 mg/L. The load is then average or slightly lower since the flow is so small (Fig. 31). Indian Creek is a smaller scale watershed and does not have a high discharge. This also shows that the load has not changed throughout the last 20 years and that the factors that influence N river load are not quite as important in a small-scale watershed.

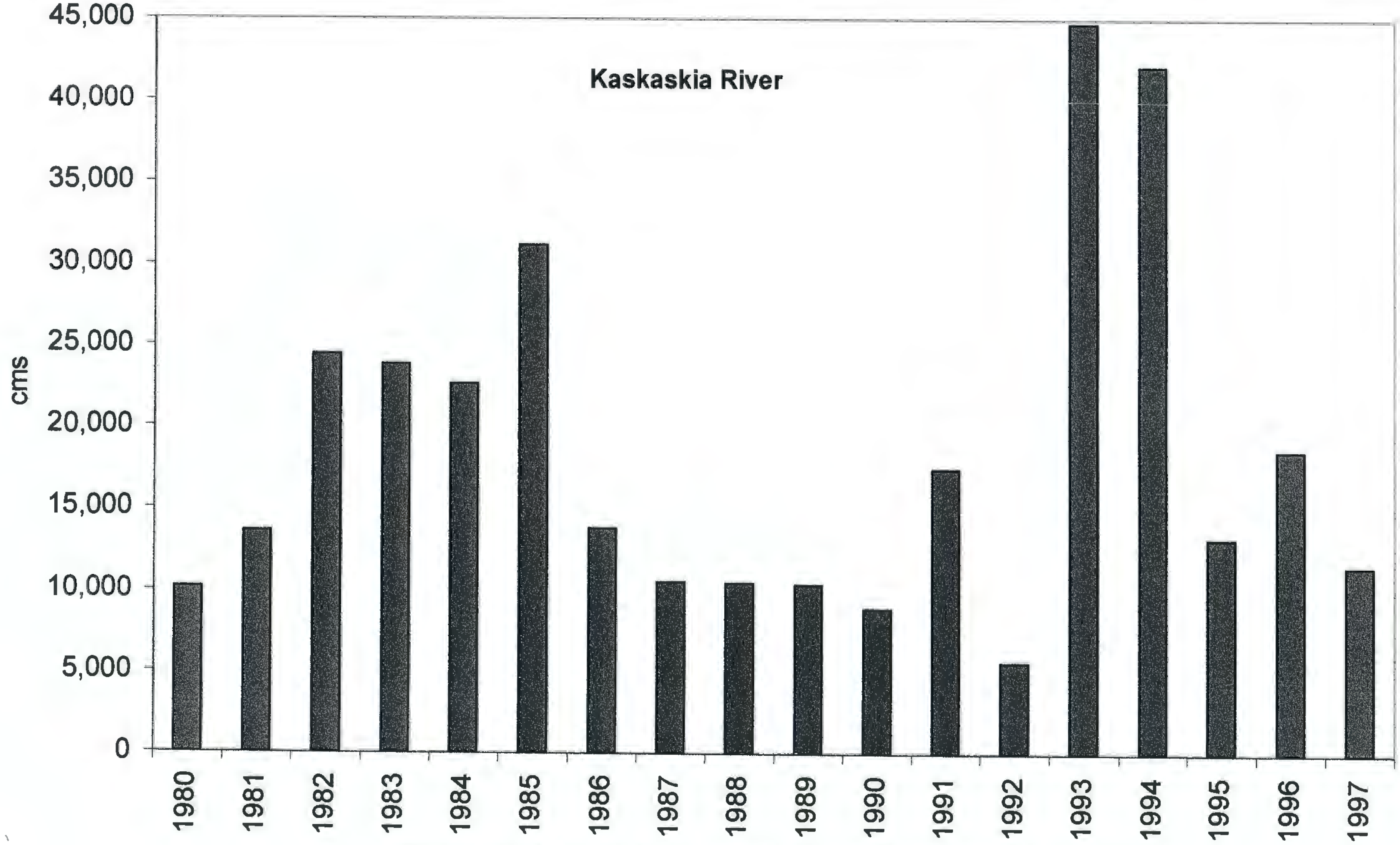


Figure 26. Flow for the Kaskaskia River, Illinois from 1980-1997.

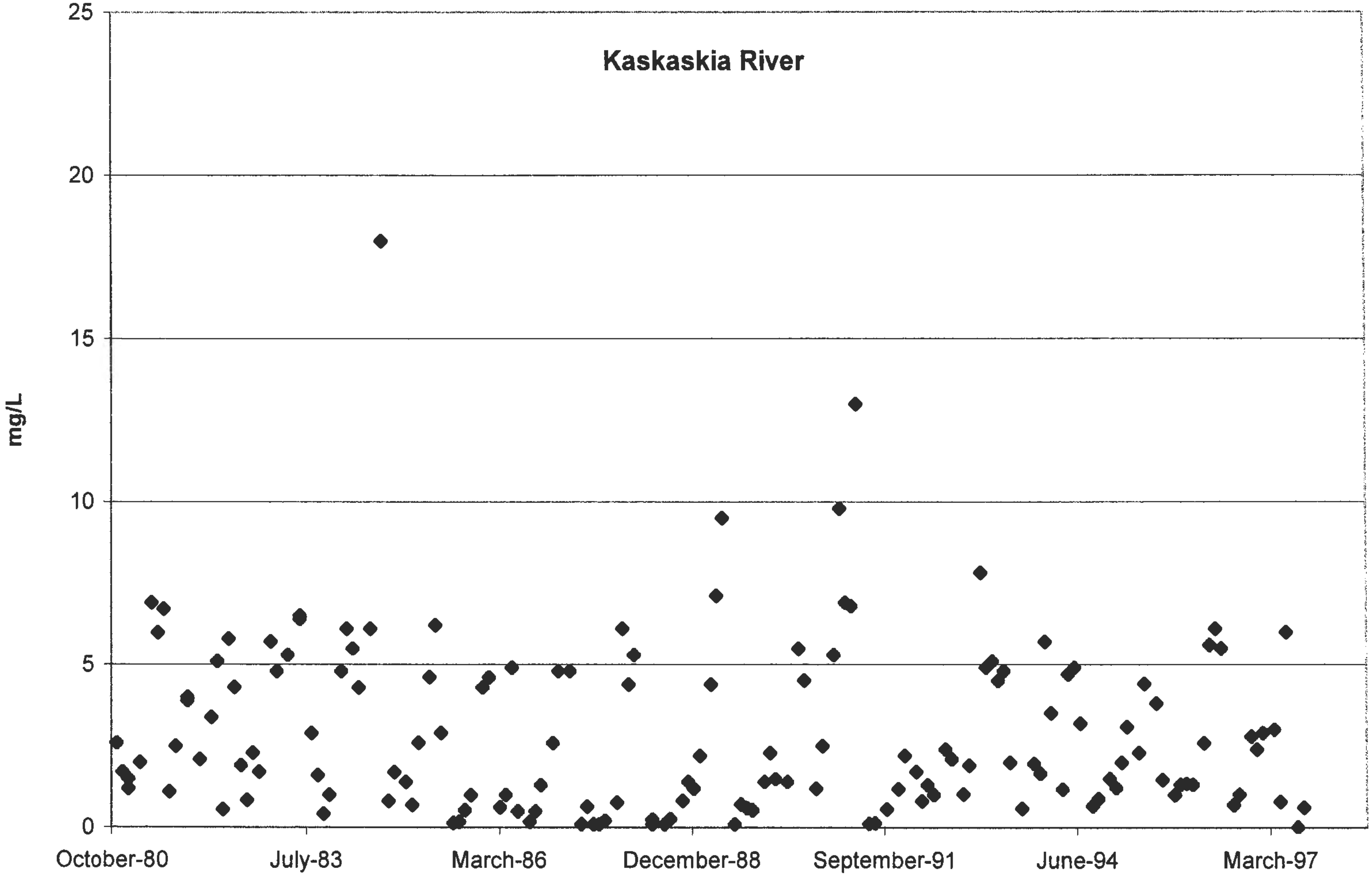


Figure 27. Nitrogen concentrations for the Kaskaskia River, Illinois from 1980-1997.

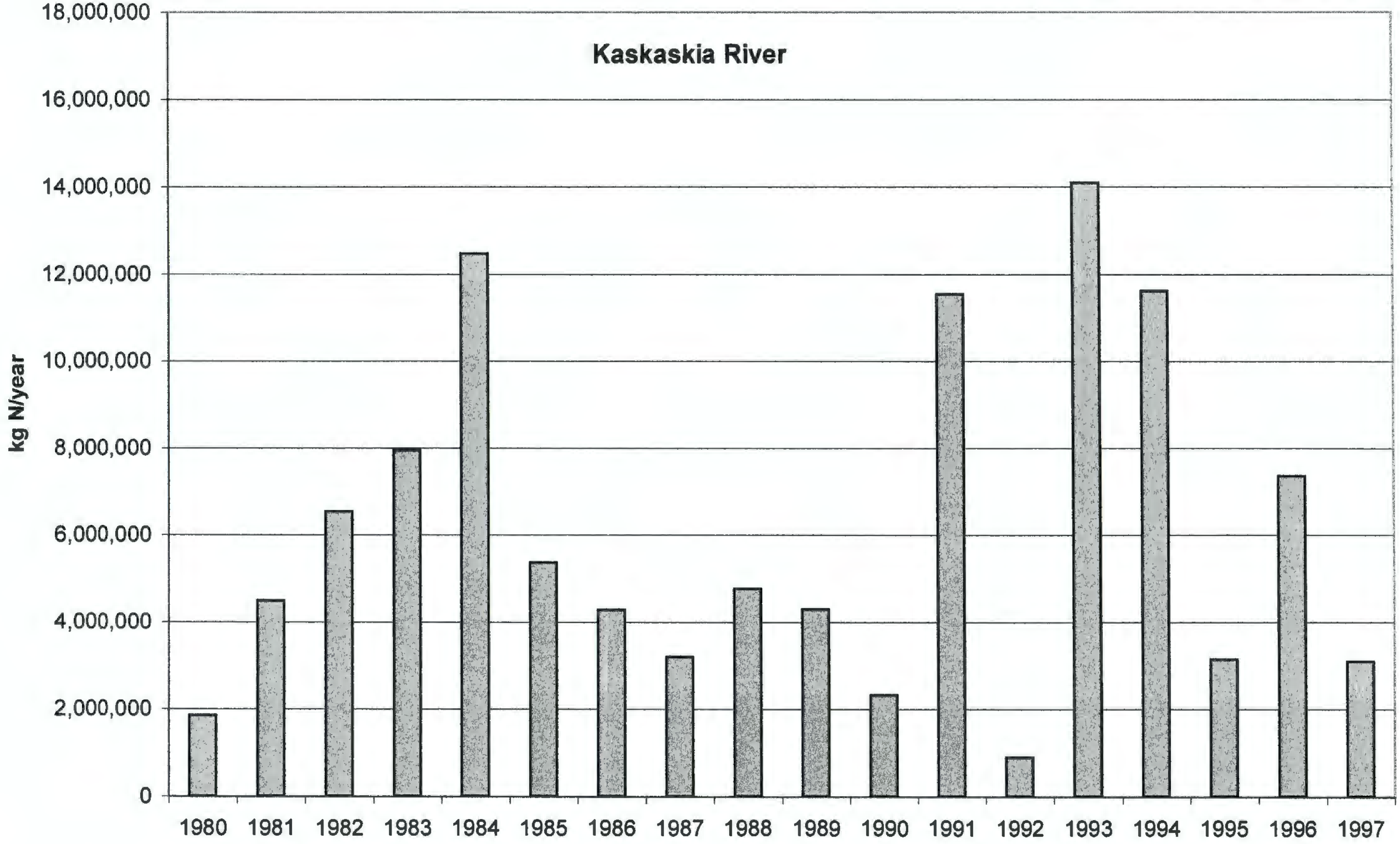


Figure 28. Nitrogen kg/ha/year for the Kaskaskia River, Illinois from 1980-1997.

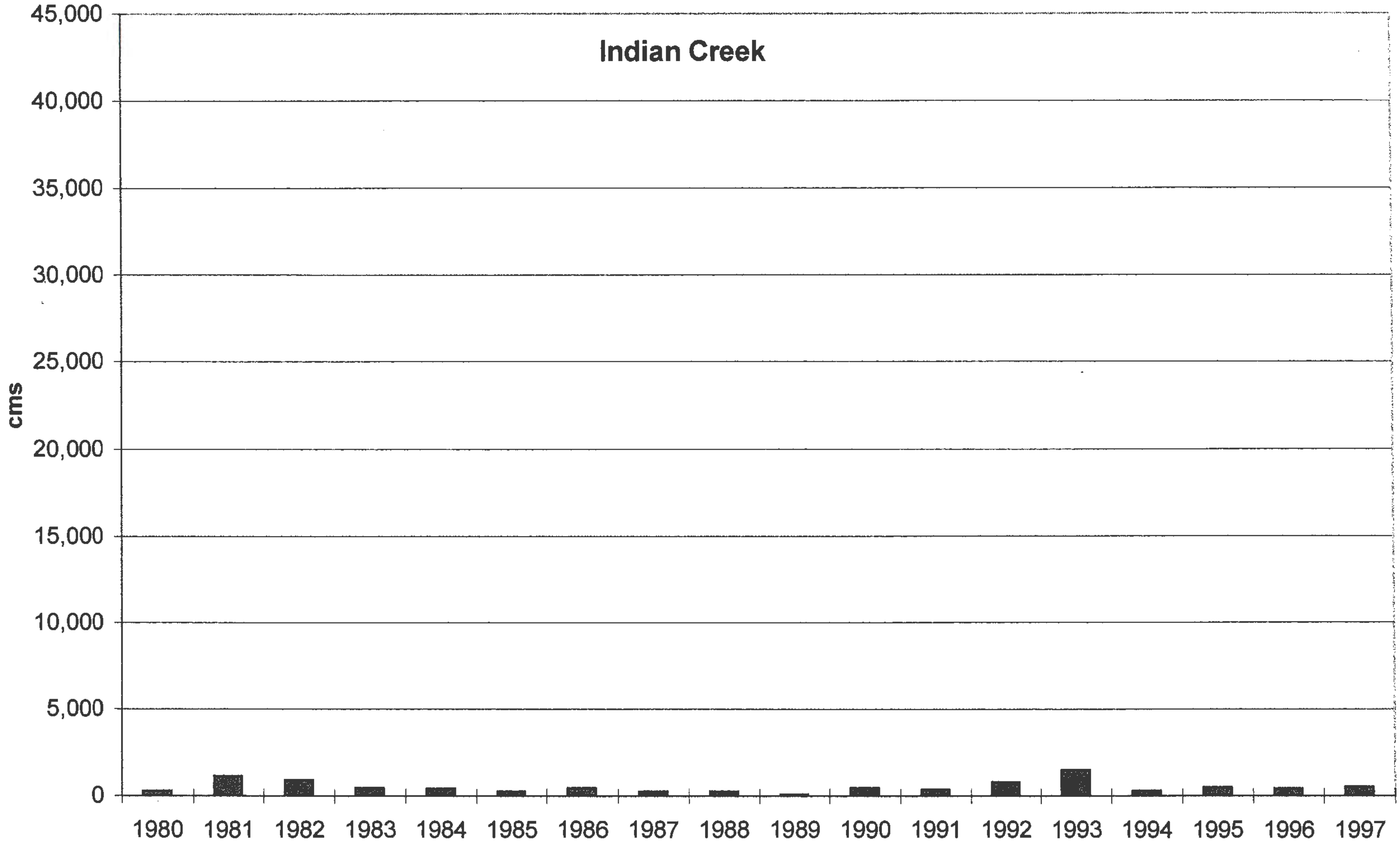


Figure 29. Flow for Indian Creek, Illinois from 1980-1997.

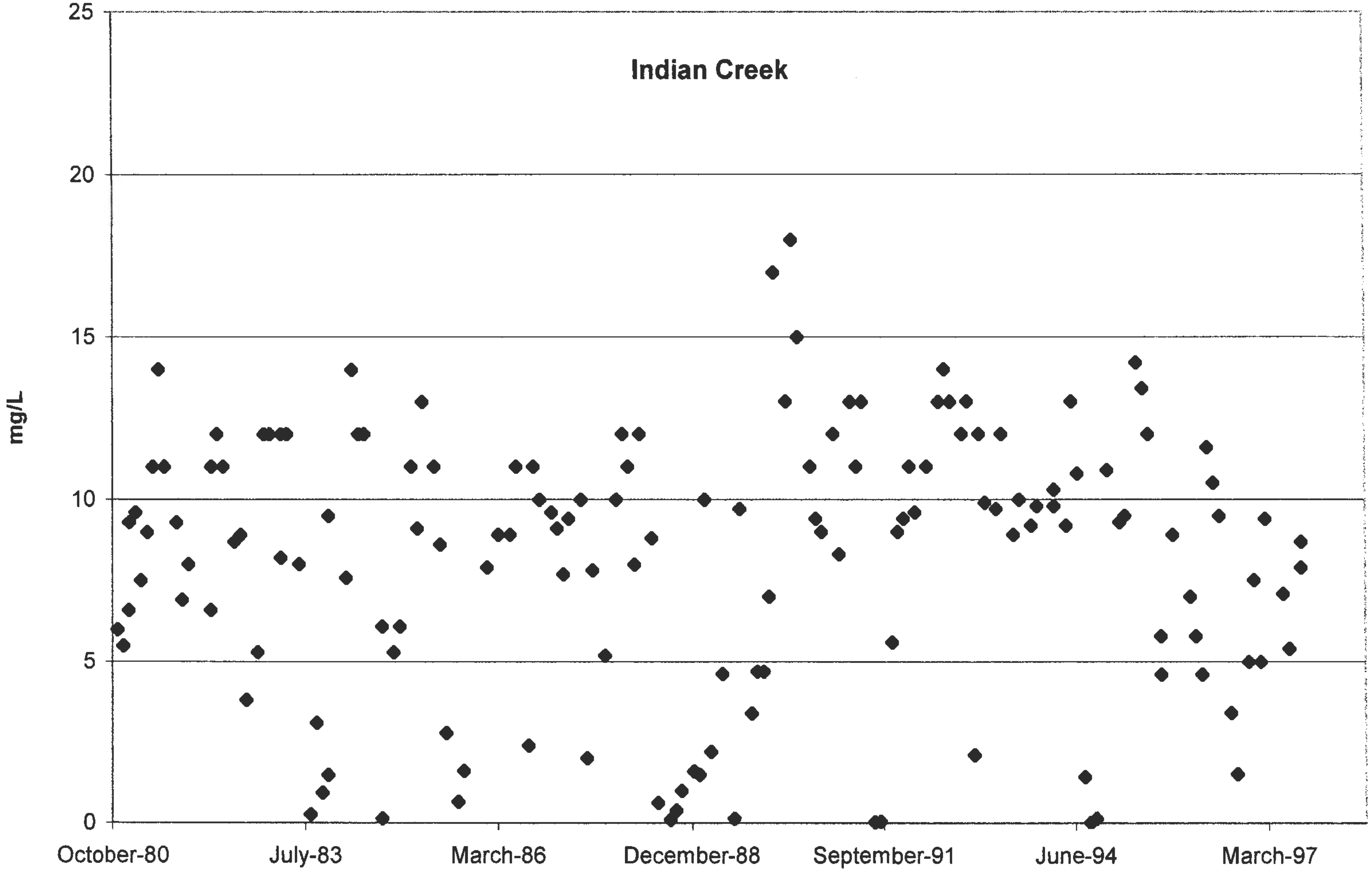


Figure 30. Nitrogen concentrations for Indian Creek, Illinois from 1980-1997.

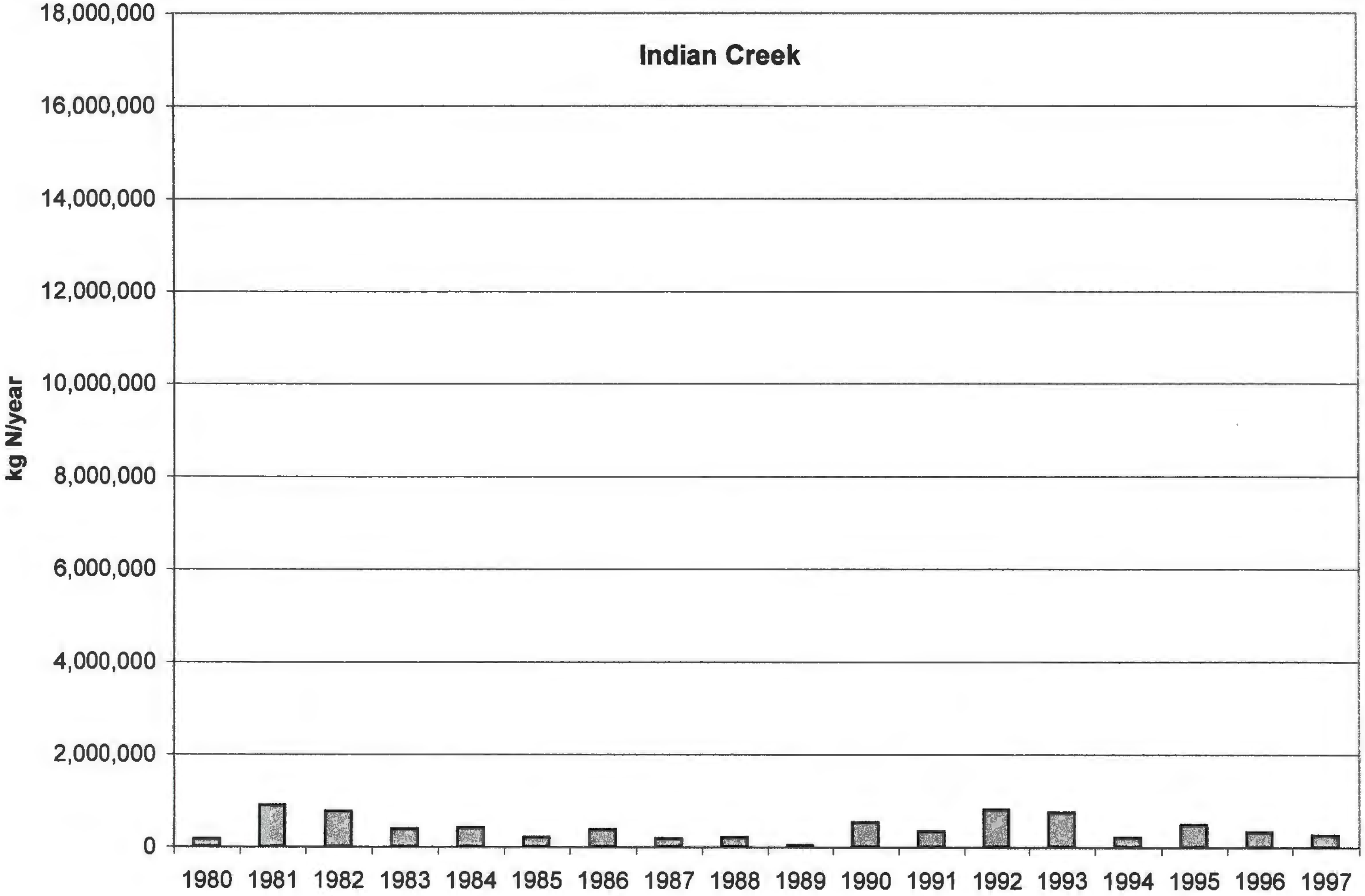


Figure 31. Nitrogen kg/ha/year for Indian Creek, Illinois from 1980-1997.

5.6.1.6 N Balance

Variations across the watersheds can be attributed to many factors. Examination of these factors that could affect the load revealed the following. The fertilizer use hasn't varied too much in the period from 1980-1997 (Fig. 4). Annual precipitation varies across years (Fig. 32) and the harvested areas have not changed significantly throughout the studied years (Fig. 33). The annual precipitation for this time period does show occasionally above average rainfall but for the most part the rainfall has stayed average (Fig. 32). The amount of N detected in the rivers of Illinois is the loss of N from all sources within the watershed. The N load lost for each watershed is expressed in kg/ha. To evaluate the loss relative to harvested cropland area data were compared for 1987, 1992, and 1997 across individual watersheds load varies among these three years. These loads vary from almost no loss (Cahokia Creek watershed in 1987) to over 60 kg/ha in 1992 (Indian Creek watershed). The amount of N that is found in the Illinois rivers depends on the size of the watershed. The smaller the watershed and the lesser amount of harvested cropland show that there is a lesser amount of N in the water. When the area load is calculated the watershed size is not related to the amount of load. The amount of N lost in relationship to N fertilizer applied is shown in Figures 34, 35, and 36 for 1987, 1992, and 1997. The first chart is the year 1987 and this shows the amount of fertilizer that was applied and the amount of N that is found in the watersheds. In 1987 lost N was not higher than 20 kg/ha except for the Sangamon River watershed. For some watersheds the loss is not that significant of a change. Then the next chart is 1992 and throughout this year the amount of fertilizer applied increased, which shows that there was a higher amount lost, especially in the Indian Creek watershed with almost 70 kg/ha. Then five years later in 1997 the amount

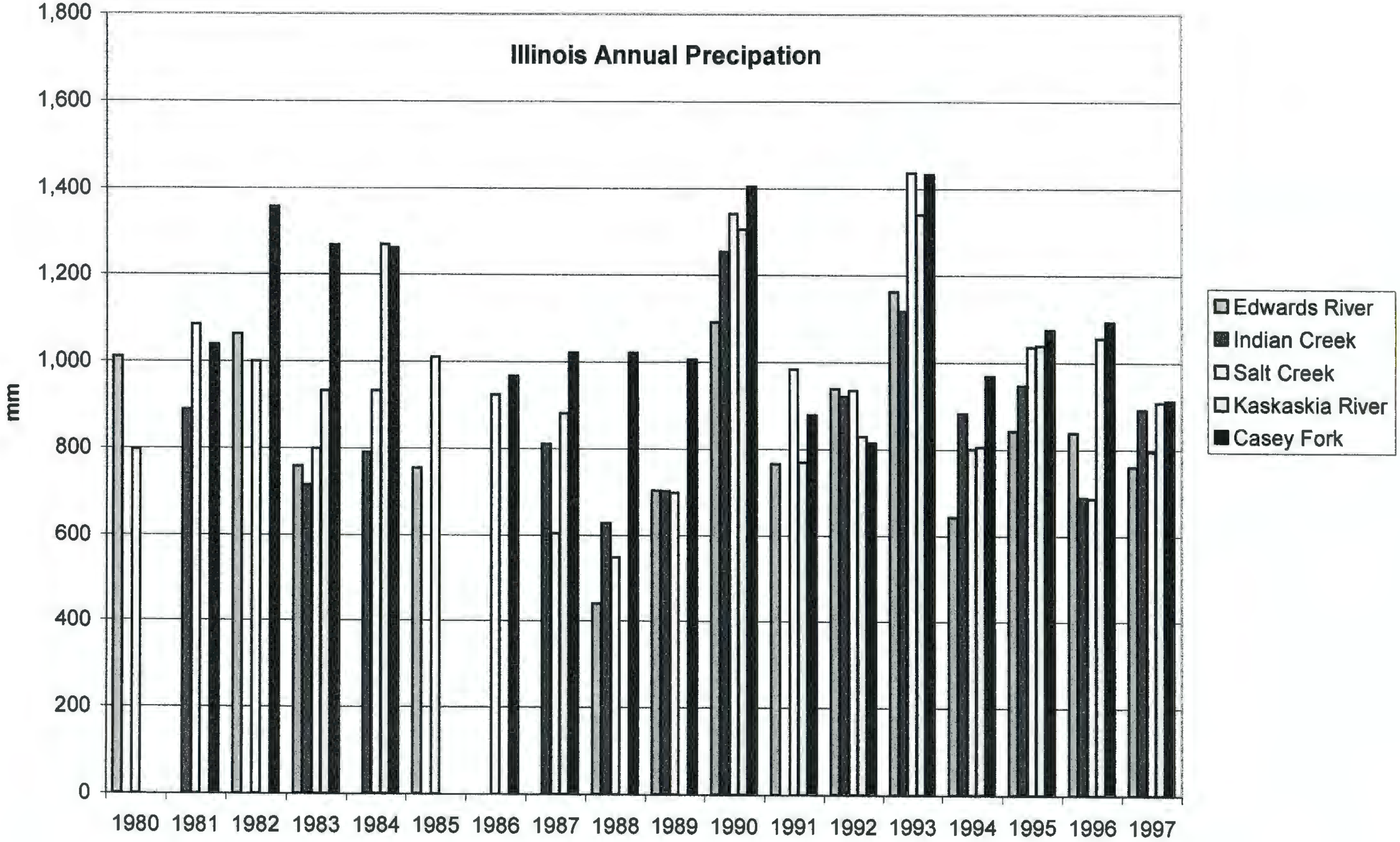


Figure 32. Annual precipitation for Illinois watersheds from 1980-1997.

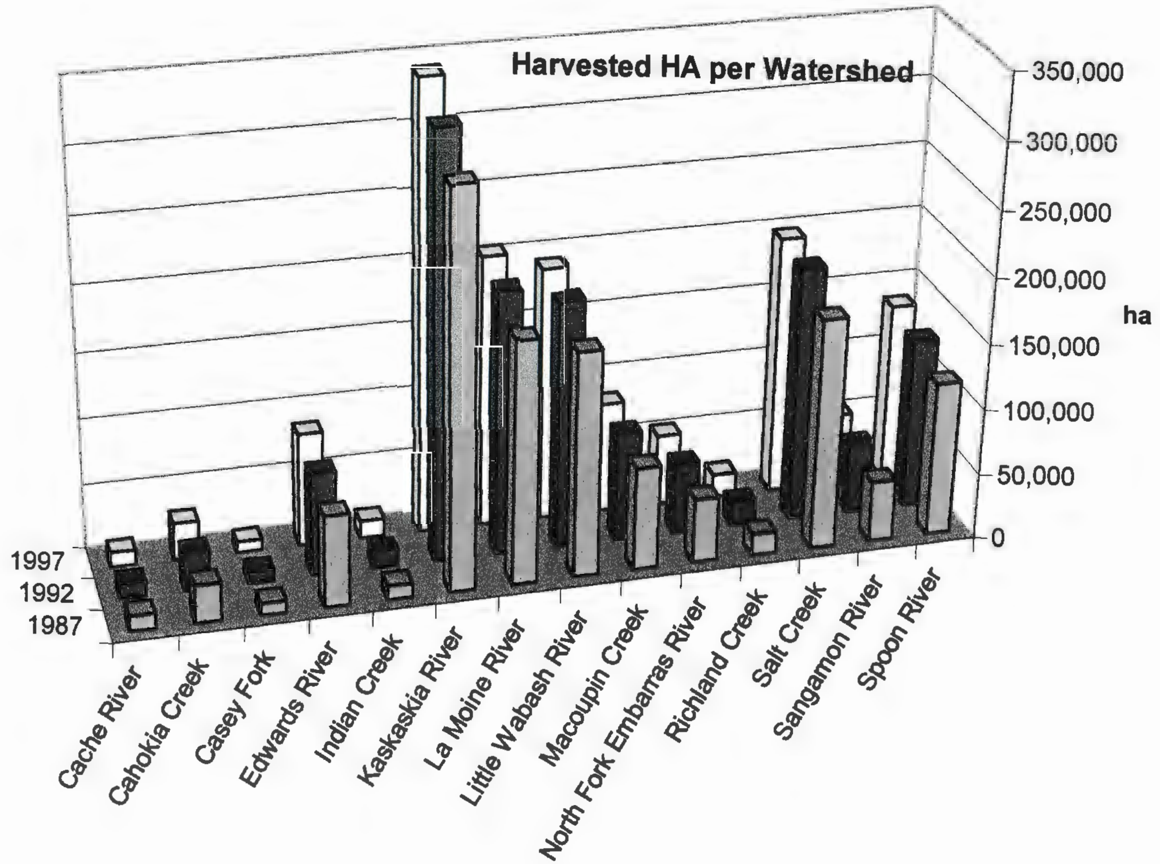


Figure 33. Illinois watersheds based on amount of harvested hectares for 1987, 1992, and 1997.

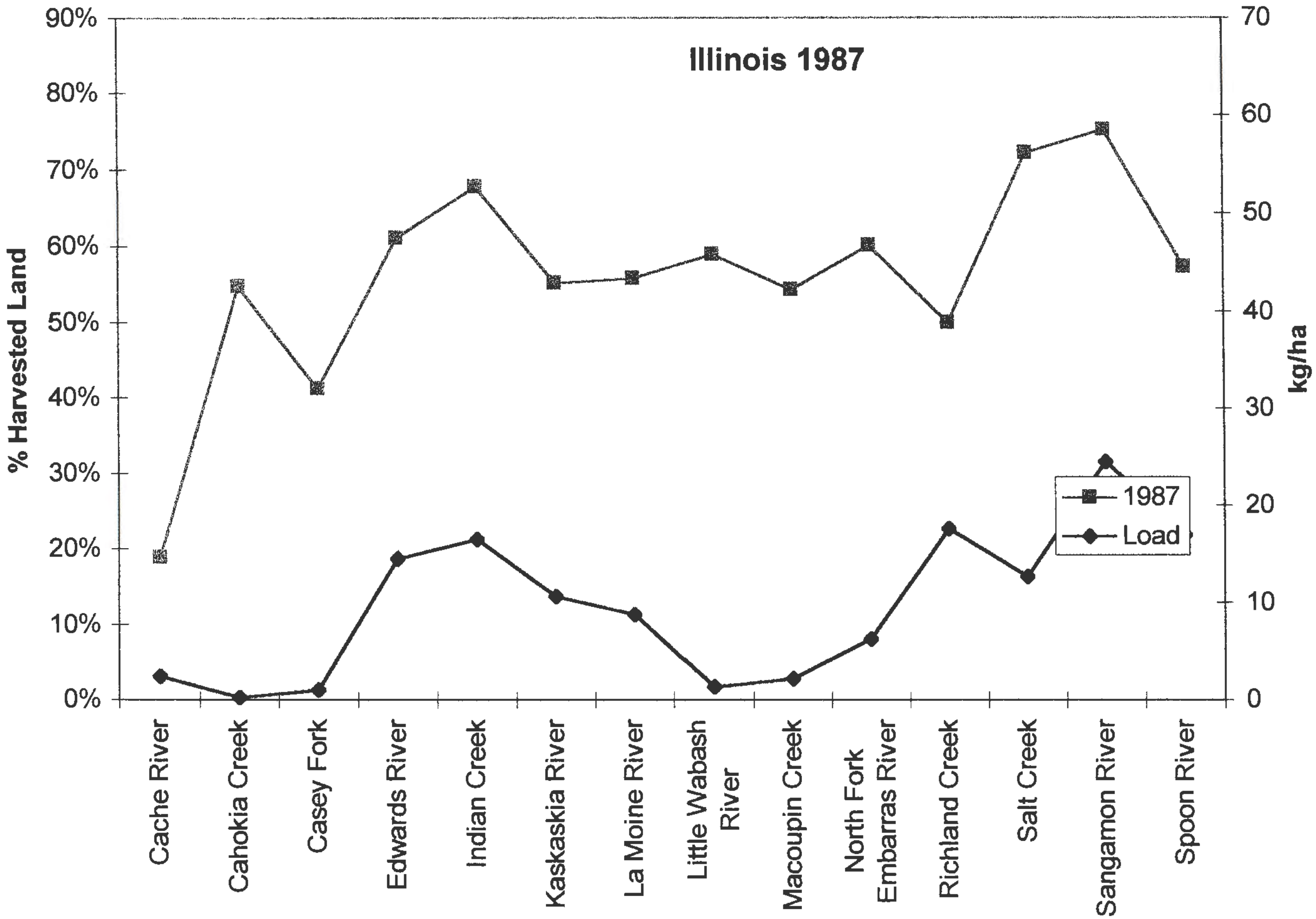


Figure 34. An Illinois comparison of the percent harvested land to the amount of N that was lost in 1987.

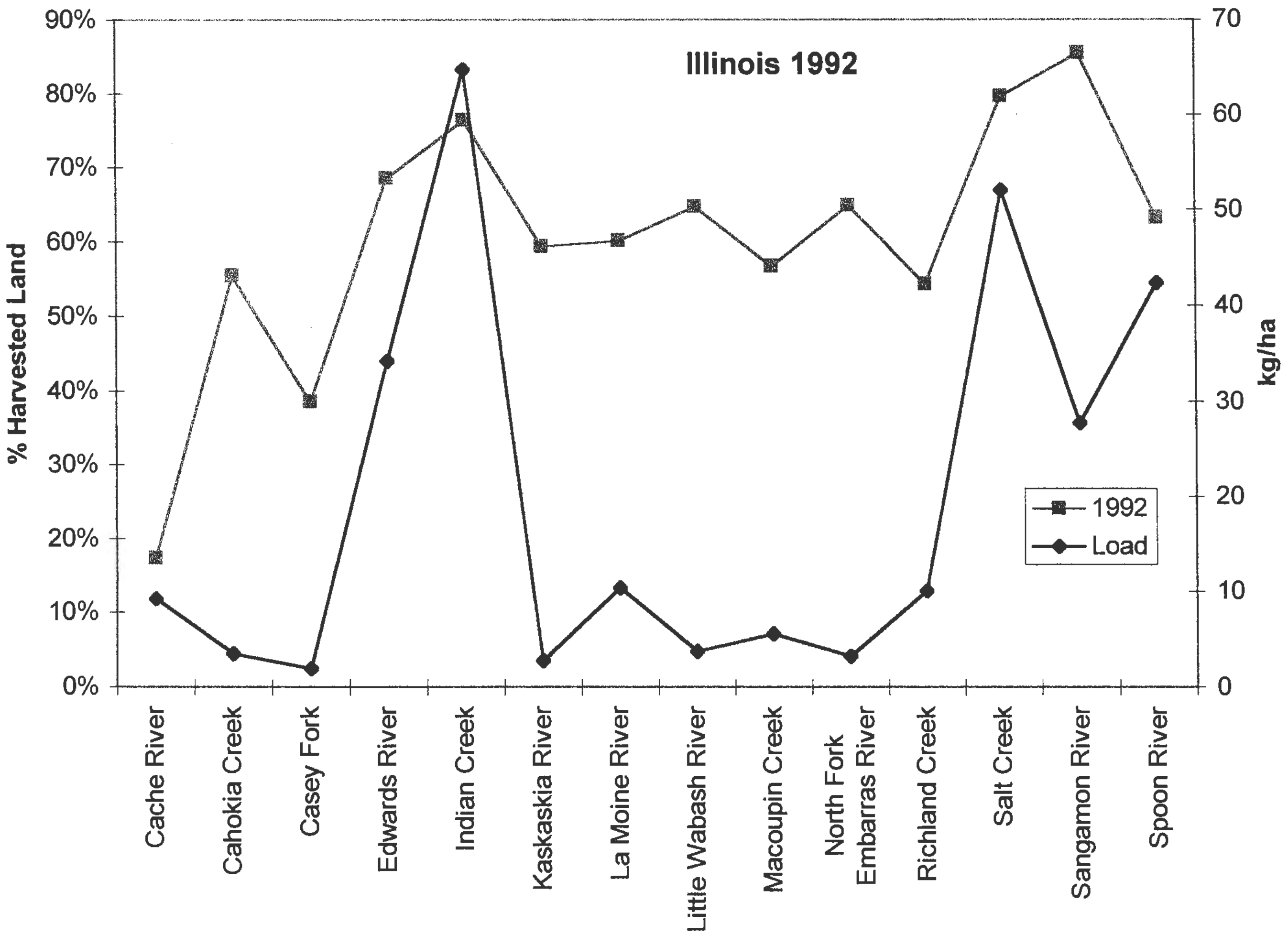


Figure 35. An Illinois comparison of the percent harvested land to the amount of N that was lost in 1992.

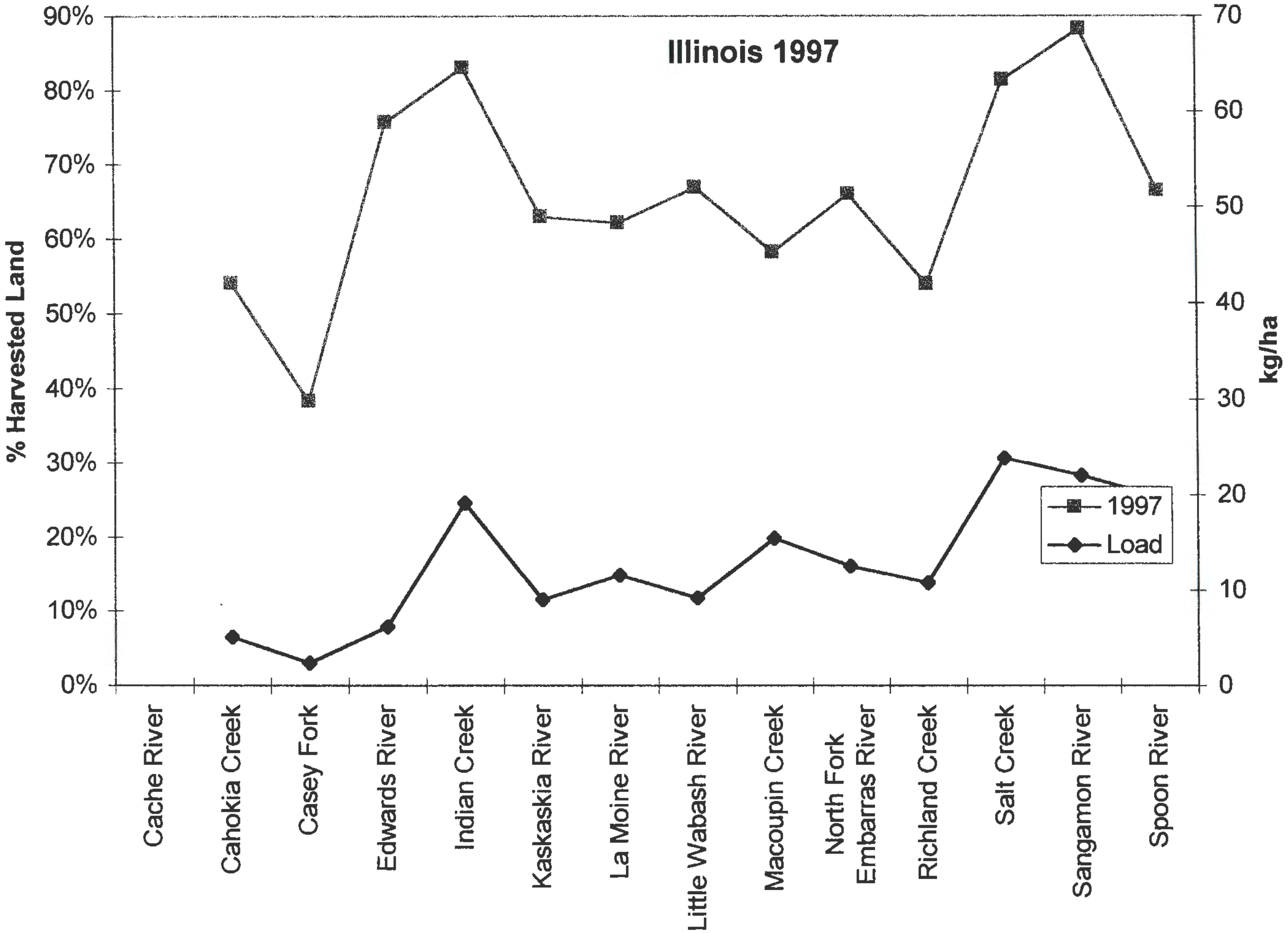


Figure 36. An Illinois comparison of the percent harvested land to the amount of N that was lost in 1997.

of N applied was less with the same lost as in 1987. This change for no particular reason is important to realize that without a connection to one of the variables the amount of loss can not be categorized. This is important for policymaking in Illinois because blanket regulations would not be successful throughout the state of Illinois.

Illinois' state average for N fertilizer application has averaged 100 kg/ha throughout all harvested lands (Fig. 4). There is a large variation in fertilizer application to corn production. Watersheds vary on the amount applied (Fig. 37). The percent fertilizer lost is the ratio of the amount of fertilizer applied and the load found in the rivers. This graph shows that 1992 had a higher difference among watersheds. This could be due to a rotation or other factor that would effect the amount of fertilizer applied. In most of the watersheds a trend is seen that 1997 had the highest percent of lost fertilizer. According to the amount of fertilizer sold in Illinois, 1996 and 1997 were the highest amounts to date. The important realization is that the amount of fertilizer lost is not dependent on the size of the land. Indian Creek which is fairly small had an almost 60% loss in 1992.

5.6.2 Iowa

Flow data across all 16 watersheds in Iowa showed a large variation among years (Fig. 38). These 16 watersheds were narrowed down to 4 on a basis of high, low flow; high, low concentrations; and an average representation. These 4 watersheds include the Chariton River, Iowa River, North River, and Upper Iowa. The Chariton is considered to have a low concentration, where as the Iowa River has a high concentration. The North River represents the low flow compared to the Iowa River with a high annual flow. The average watershed is the Upper Iowa River, this watershed has an average flow, area, and concentration compared to the other 15 watersheds. Data from the remaining 12 watershed are in the Appendix .

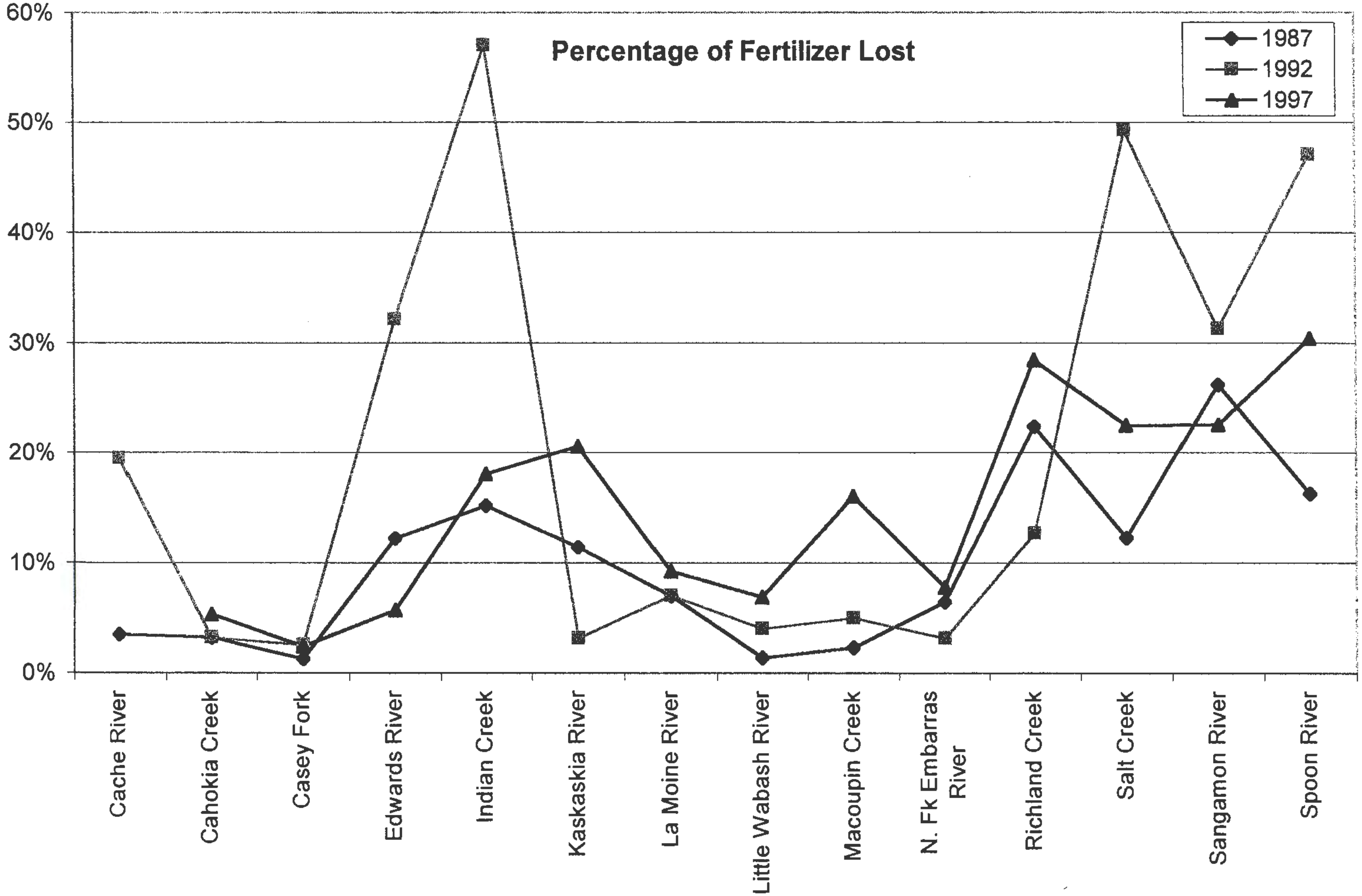


Figure 37. The percentage of nitrogen fertilizer that was lost throughout the Illinois watersheds.

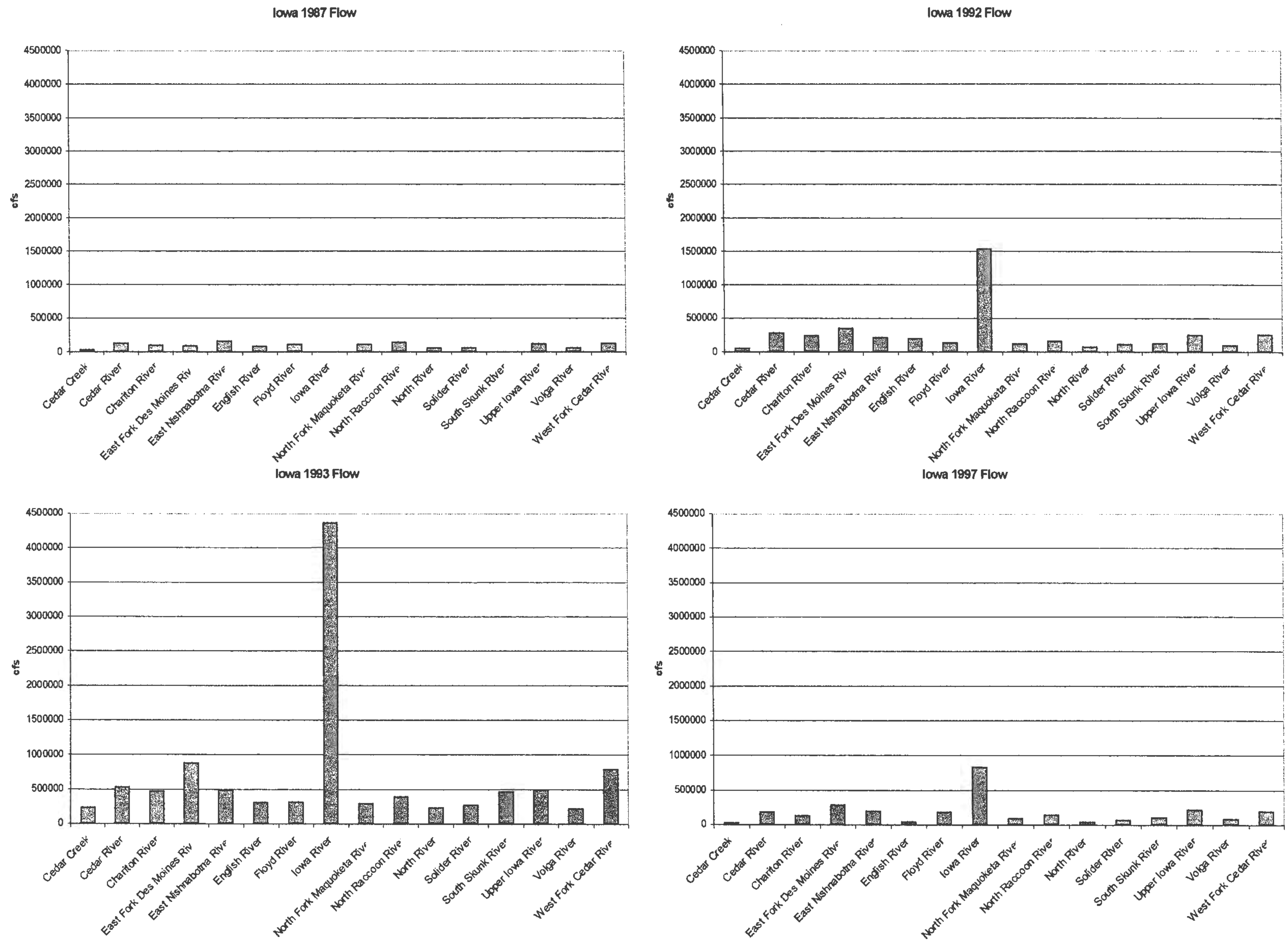


Figure 38. Water flow in Iowa watersheds for selected years.

5.6.2.1 North River

The North River is an averaged sized watershed with an area of 103,651 hectares. The watershed includes the counties of Adair, Dallas, Guthrie, Madison, Polk, and Warren. This watershed averaged 49,710 hectares of harvested cropland in 1997. The North River was chosen as it has a rather low flow and can demonstrate that even with a low flow the load can be higher as the N concentrations in the North River are high. The concentrations have seen up to 22 mg/L and average around 10 mg/L. This is significant to note that a high concentration and a low flow can add as much N to the Gulf of Mexico as a low concentration and high flow. The load (Fig. 39) for the North River watershed follows the pattern of the flow (Fig. 40) throughout the 10 years of data. The load does not change significantly when the N concentration increased to above 20 mg/L in the period from 1988 to 1990. In fact in 1989 the load was rather low even though the amount of N concentration was increased (Fig. 41). The most significant impact on the watershed was flow and rainfall.

5.6.2.2 Iowa River

The Iowa River represents both a high flow and load. This has been unique for the other states as one watershed did not demonstrate these characteristics. The Iowa River watershed is also unique because the drainage area is large with 1,216,284 hectares and a harvested cropland total of 823,368 hectares throughout 24 counties. The Iowa River saw a tremendous amount of water in 1993 with the Midwest floods (Fig. 42). This high flow throughout the state caused a high flux of N into the Mississippi River. The annual concentrations have averaged around 5 mg/L (Fig. 43). The Iowa River is not as consistent as some of the other watersheds in Iowa. As the amount of load (Fig. 44) does not reflect the change in the variables. In 1989 it was an average year for rainfall and it still had a lower flow than the other years. This is also unique because in 1988 the annual

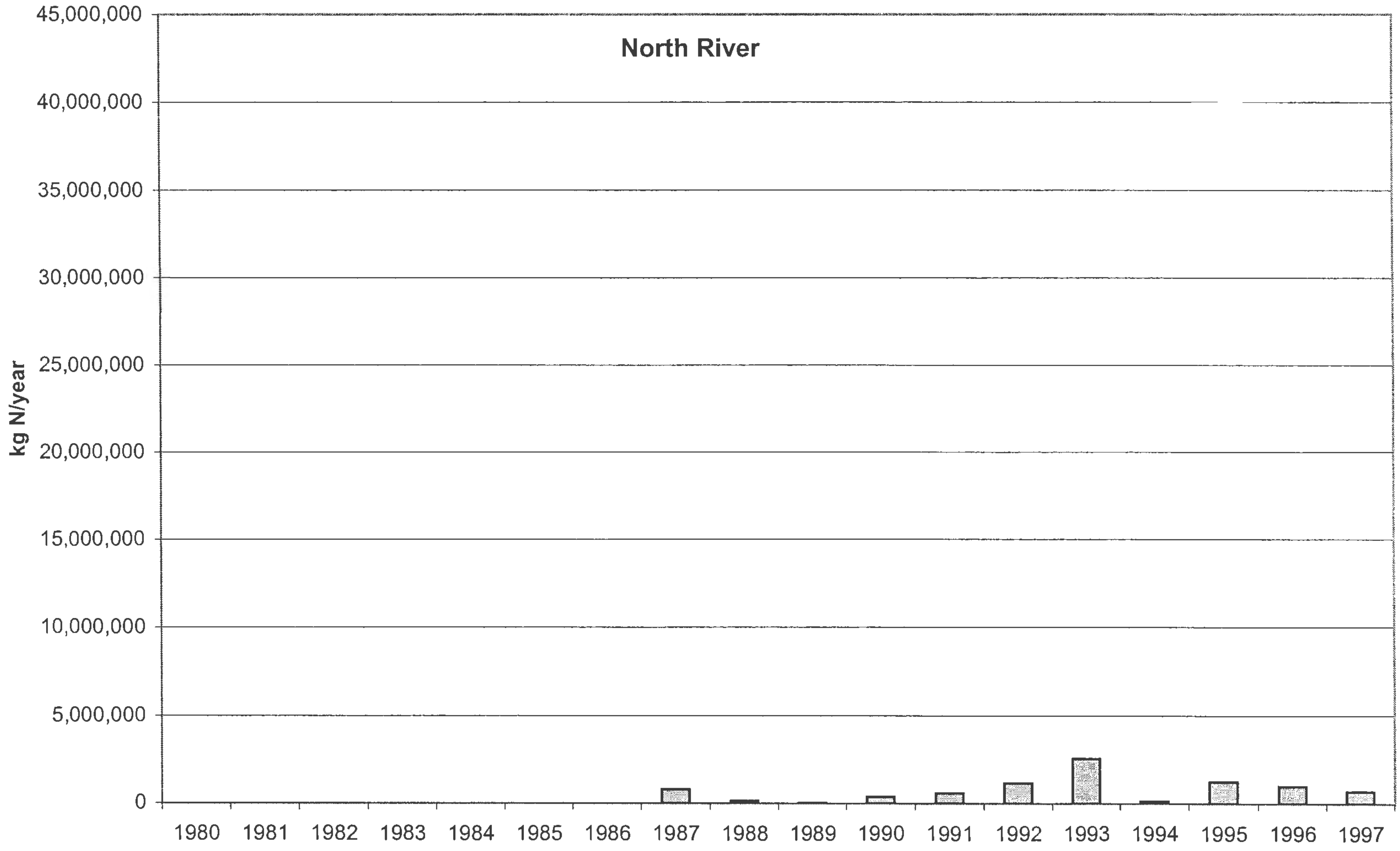


Figure 39. Nitrogen kg/ha/year for the North River, Iowa from 1980-1997.

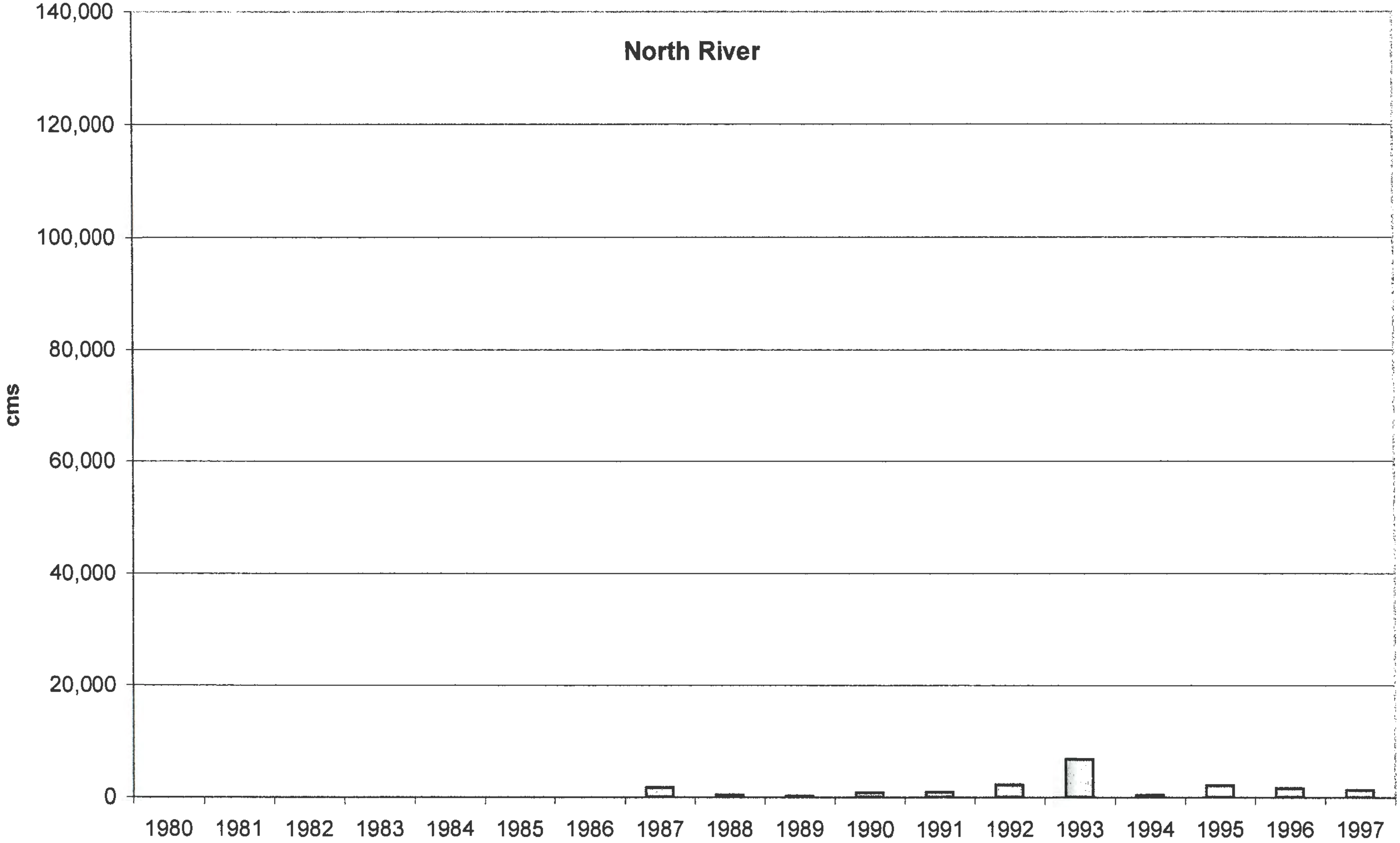


Figure 40. Flow for the North River, Iowa from 1980-1997.

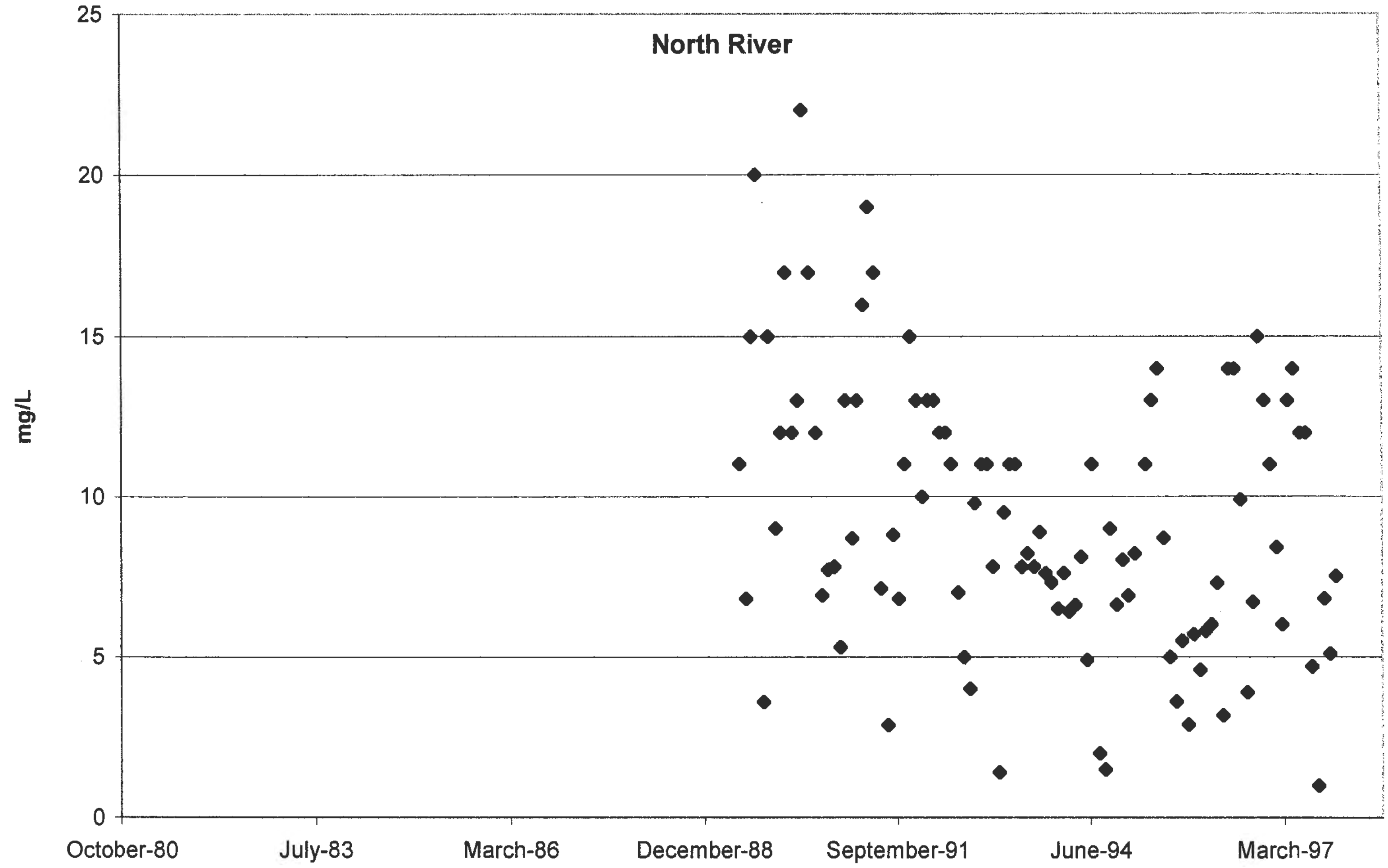


Figure 41. Nitrogen concentrations for the North River, Iowa from 1980-1997.

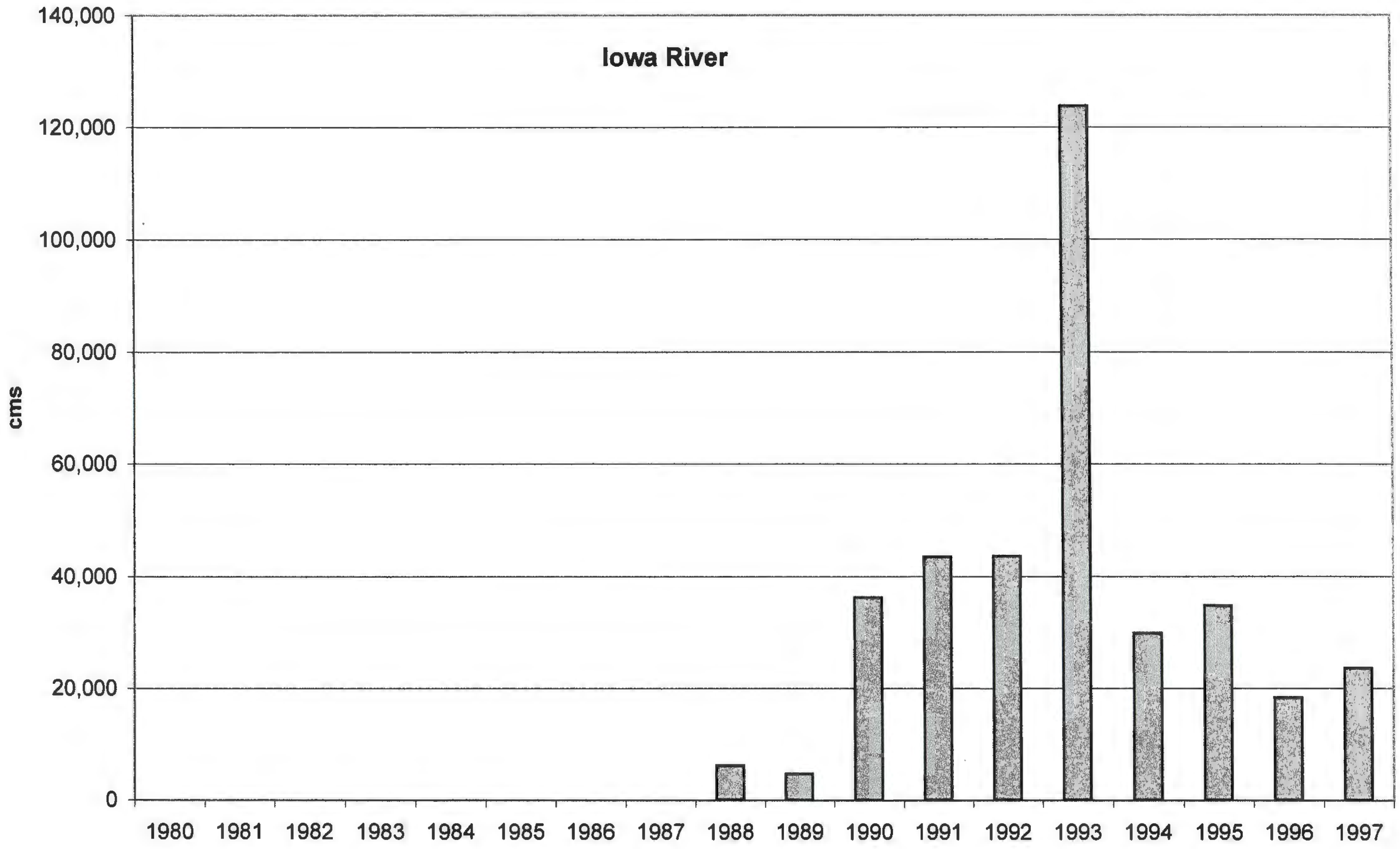


Figure 42. Flow for the Iowa River, Iowa from 1988-1997.

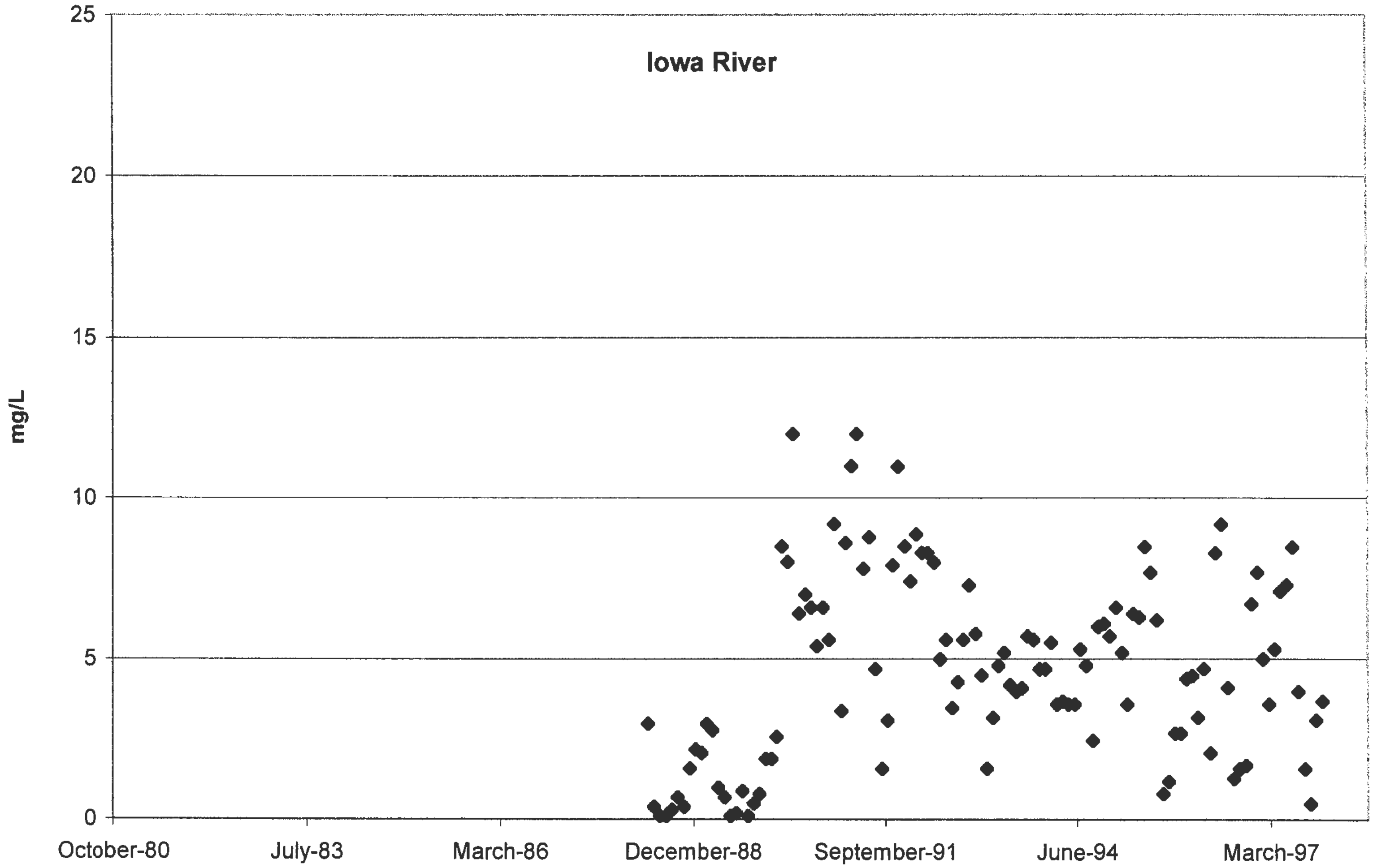


Figure 43. Nitrogen concentrations for the Iowa River, Iowa from 1988-1997.

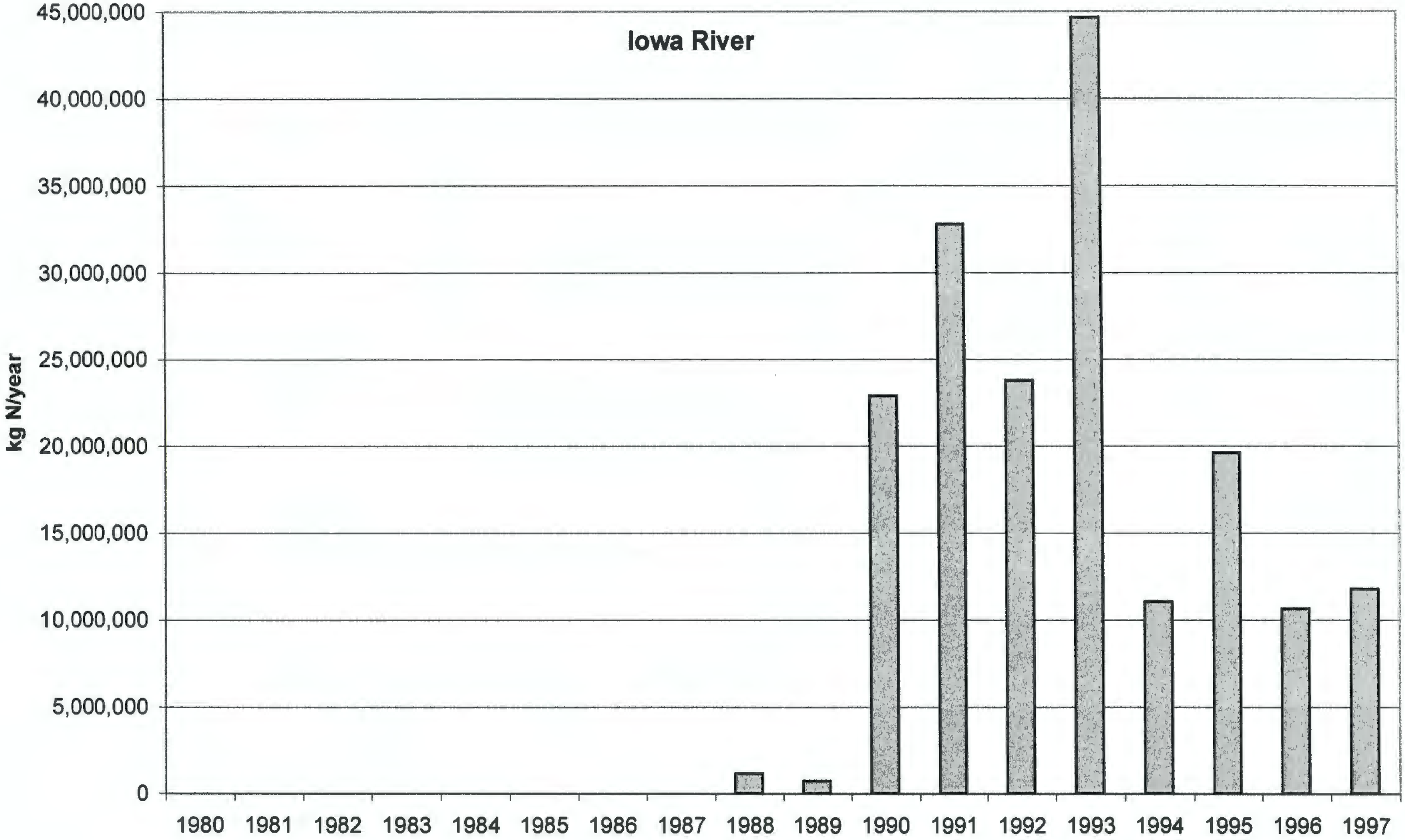


Figure 44. Nitrogen kg/ha/year for the Iowa River, Iowa from 1988-1997.

precipitation was lower but the flow was higher. Another example is between 1990 and 1993 when annual load was the highest for these years and rainfall was not higher than normal rainfall until 1993. The change in concentration was not that different either.

5.6.2.3 Chariton River

This watershed has a very low load due to a lower flow and very low N concentration (Fig. 45). The average is around 2 mg/L for the 1980's and 1990's. This watershed has a smaller drainage area with 162,504 hectares. This area includes the counties of Appanoose, Clarke, Decatur, Lucas, Monroe, and Wayne. The counties average 30% of the amount of harvested cropland throughout the watershed. The Chariton River has a link that is not seen with the other watersheds. There seems to be a consistency with this watershed that was not seen with other Iowa watersheds. With a low rainfall in 1988 and 1989 the N concentration, load (Fig. 46), and flow (Fig. 47) were lower than the other years. Since the concentrations are lower in this study site the load stays lower except in the years with a high rainfall that causes a higher amount of water flux in the watershed. This watershed does have the lowest load for the Iowa watersheds and the amount of N fertilizer applied is lower this watershed (table 4). 5.6.2.4 Upper Iowa

The Upper Iowa River at New Albin has a drainage basin of 202,652 hectares. This is another smaller watershed but has a larger impact because it drains into the Mississippi River. This watershed includes the counties of Allamakee, Howard, Mitchell, and Winneshiek. The counties average 50% of harvested cropland. The Upper Iowa River has an average amount of flow in the stream and also a N concentration of around 5 mg/L. This concentration seems average for most rivers. The Upper Iowa River watershed represents an average Iowa watershed. The area, flow, and load are average of the studied Iowa

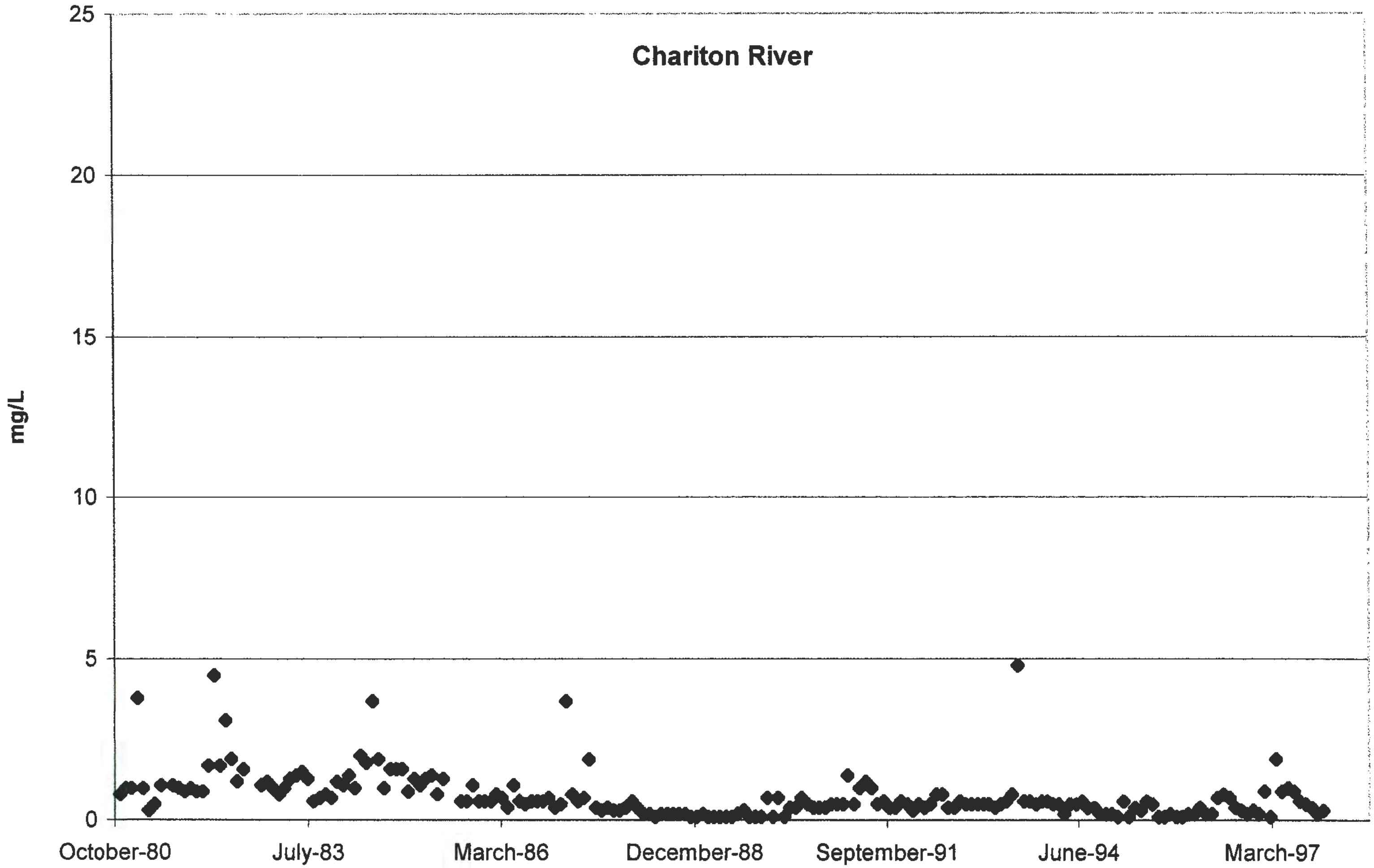


Figure 45. Nitrogen concentrations for the Chariton River, Iowa from 1980-1997.

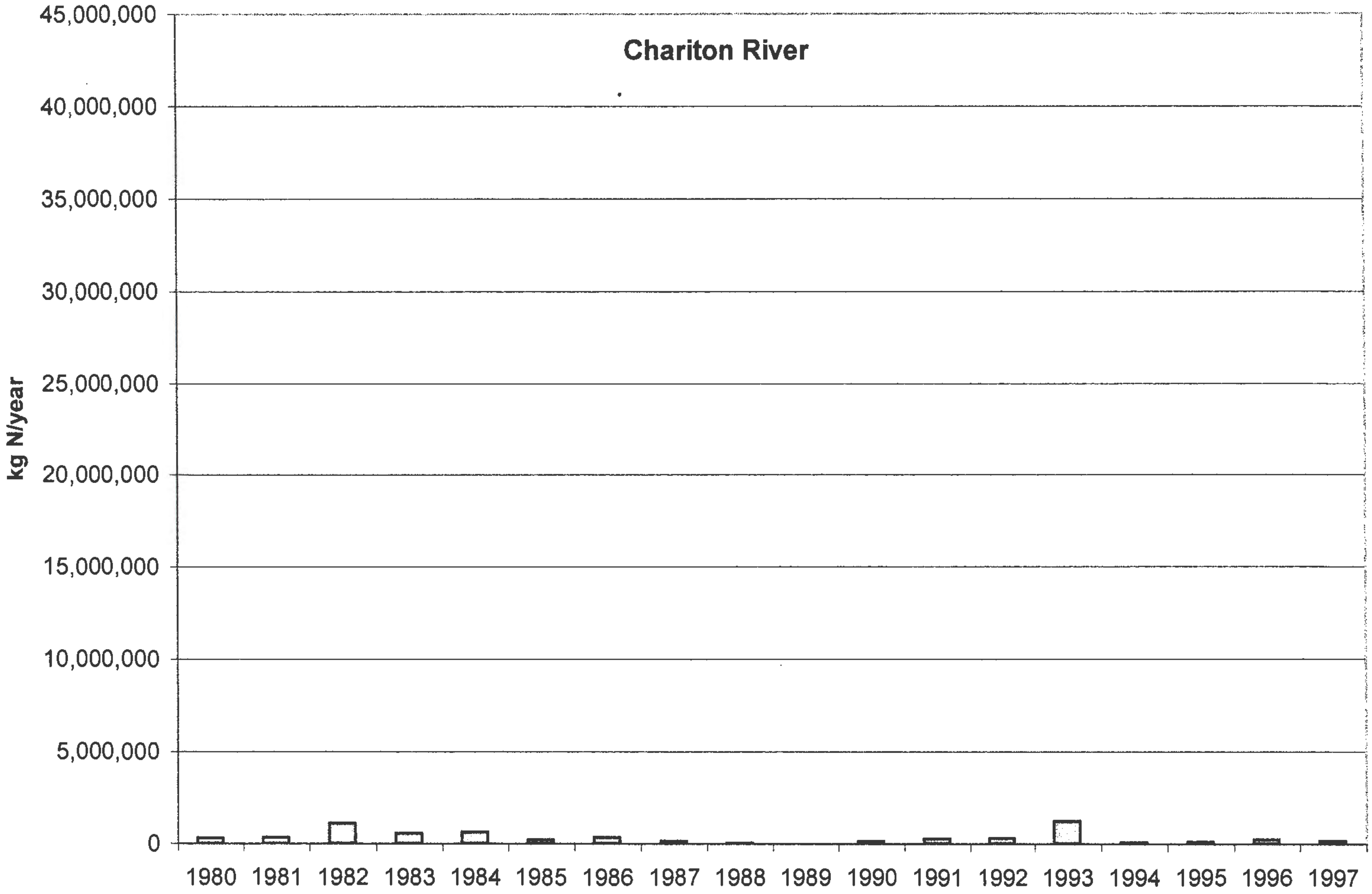


Figure 46. Nitrogen kg/ha/year for the Chariton River, Iowa from 1980-1997.

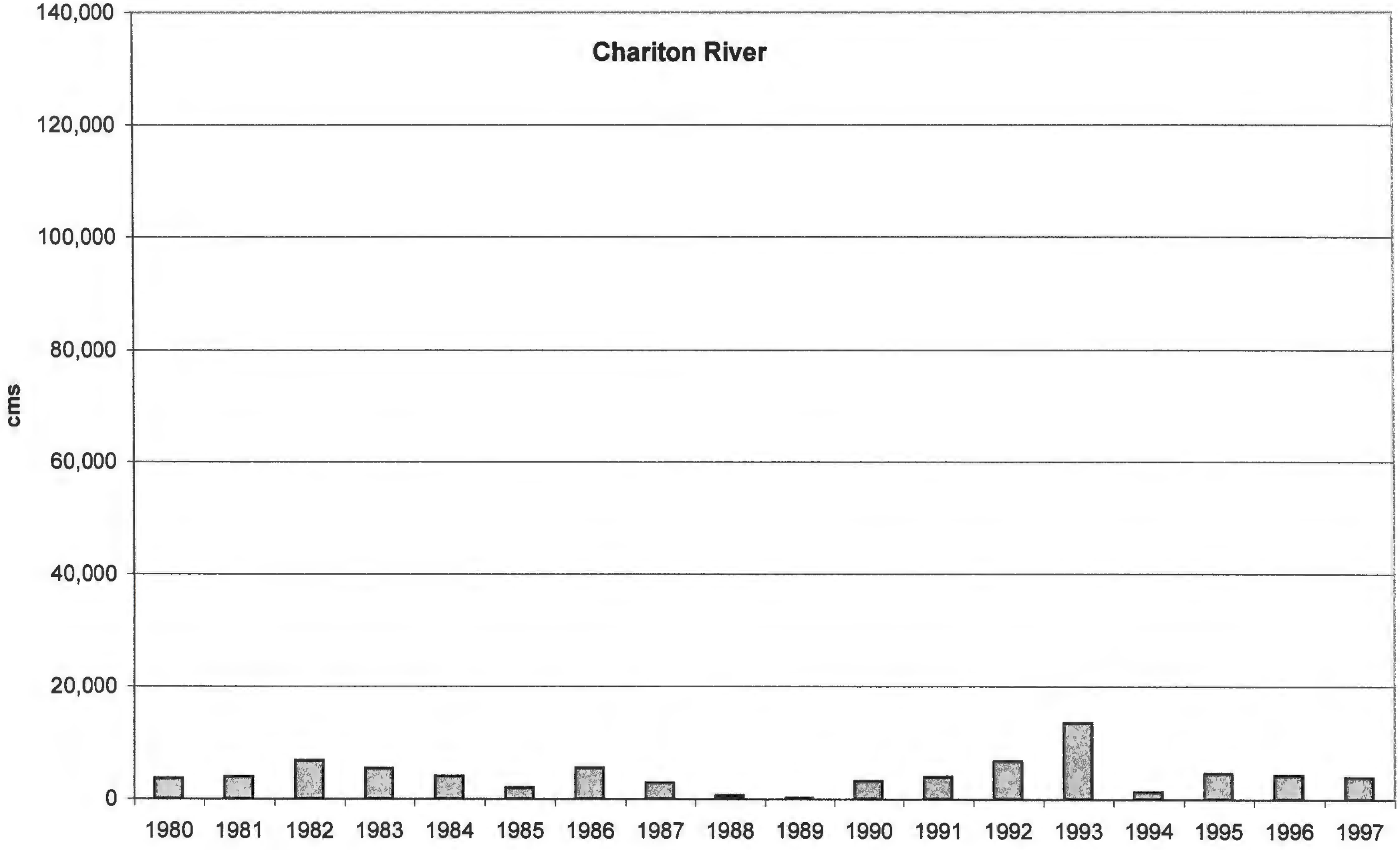


Figure 47. Flow for the Chariton River, Iowa from 1980-1997.

Table 4. Amount of nitrogen fertilizer applied in kg/ha per watershed and county.

Watershed Name	County Name	1987	1992	1997
North Fork Maquoketa River		**115.3**	**114**	**111.7**
	Clayton	106.9	109.6	112.6
	Delaware	125	149.1	118
	Dubuque	110	80.1	100.4
	Jackson	107.4	97.2	100.8
	Jones	125.5	125.2	121.6
Volga River		**113.9**	**124.1**	**109.2**
	Clayton	106.9	109.6	112.6
	Delaware	125	149.1	118
	Fayette	110.2	115.1	99.2
Upper Iowa		**93.7**	**89.8**	**93.9**
	Allamakee	90.4	98.2	69.3
	Howard	100	89.9	59.6
	Mitchell	90.8	94.5	99.6
	Winneshiek	93.3	89.4	135
Iowa River		**98.7**	**99.6**	**105**
	Benton	107.2	92.5	83.8
	Cerro Gordo	96.2	117.3	147.9
	Des Moines	99	77.5	105.8
	Franklin	99	76.2	98.3
	Grundy	102.3	101.1	83
	Hamilton	81.5	97.5	88.1
	Hancock	99.6	91.3	75.9
	Hardin	98.8	163.3	161
	Henry	106.3	152	148.5
	Iowa	104.3	111.3	185.7
	Jasper	93.2	109.9	105.1
	Johnson	105.5	77.2	93
	Keokuk	127.7	135.8	144.5
	Linn	100.4	68.6	77.8
	Louisa	109	100.8	96.6
	Mahaska	95.4	97	83.2
	Marshall	90.7	75.4	130.6
	Muscatine	110.3	106.3	79.4
	Poweshiek	93.4	60	41.6
	Story	87.8	109.8	103.1
	Tama	101.5	86.1	102.7
	Washington	102.8	83	65
	Winnebago	87.2	132.1	146.1
	Wright	85.8	89	102.8

Table 4. Continued.

English River	**104.7**		**93**		**100**	
Johnson		104.3		111.3		185.7
Keokuk		127.7		135.8		144.5
Iowa		127.7		135.7		144.5
Mahaska		95.4		97		83.2
Poweshiek		93.7		60		41.6
Washington		102.8		83		65
Cedar River	**102.4**		**109.4**		**83.8**	
Black Hawk		99.4		95.8		109.6
Bremer		116.7		125.4		50.4
Butler		107.3		140		95.7
Chickasaw		121		108.9		99.7
Floyd		88.3		93.9		71.7
Mitchell		90.8		94.5		99.6
Worth		95.7		118.6		47.5
West Fork Cedar River	**102.3**		**105.9**		**97.6**	
Black Hawk		99.4		95.8		109.6
Bremer		116.7		125.4		50.4
Butler		107.3		140		95.7
Cerro Gordo		96.2		117.3		147.9
Franklin		99		76.2		98.3
Hancock		99.6		91.3		75.9
Cedar Creek	**105.1**		**102.6**		**94.4**	
Henry		106.3		152		148.5
Jefferson		111.7		77.1		51.2
Keokuk		127.7		135.8		144.5
Mahaska		95.4		97		83.2
Van Buren		95.1		32.8		45.4
Wapello		84		85.8		56.3
South Skunk River	**91.2**		**105.3**		**103.1**	
Boone		89.1		49.7		50.1
Hancock		99.6		91.3		75.9
Hardin		98.8		163.3		161
Polk		102.9		101.3		76.9
Story		87.8		109.8		103.1
Webster		76.4		113.2		131.9
North River	**84.9**		**94.4**		**70.9**	
Adair		89.1		94.4		77.7
Dallas		81.8		93.3		66
Guthrie		80.6		113.9		58.9
Madison		79.4		77.2		81.2
Polk		102.9		101.3		76.9
Warren		74		80.4		66.9

Table 4. Continued.

East Fork Des Moines River	**90.3**		**94.1**		**94.8**	
Emmet		85.9		79.7		114
Hancock		99.6		91.3		75.9
Humboldt		80.7		87.4		100.1
Kossuth		91.5		92.4		71.2
Palo Alto		91.8		89.3		103.2
Winnebago		87.2		132.1		146.1
North Raccoon River	**84**		**91.4**		**99.9**	
Buena Vista		84.1		111.4		109.2
Calhoun		82.3		129.7		142.2
Clay		85		68.2		86.6
Palo Alto		91.8		89.3		103.2
Pocahontas		81.5		60.9		77.5
Sac		79.9		87.7		79.1
Chariton River	**84.1**		**79.4**		**66.2**	
Appanoose		73.9		64.6		47.8
Clarke		79		66.6		76.3
Decatur		87.7		89.8		55.5
Lucas		89.8		35		27.7
Monroe		103.6		64		45.4
Wayne		76.7		128		117.3
East Nishnabotna River	**89**		**107**		**101.3**	
Adair		89.1		94.4		77.7
Audubon		98.8		50.2		54.4
Carroll		84.8		149.2		161.5
Cass		78.8		105.8		112.2
Guthrie		80.6		113.9		58.9
Montgomery		88.8		88.4		72.6
Page		70.5		79.5		62.9
Pottawattamie		102.3		84.8		109.5
Shelby		99.5		170		142.5
Solider River	**102.8**		**98.2**		**98.2**	
Crawford		123.5		85.4		77.4
Harrison		92.9		83.1		100.7
Ida		92		95		122.1
Monona		98.3		129		102.3
Floyd River	**92.2**		**83.3**		**77.5**	
Cherokee		82.4		81.3		63.7
O'Brien		102.9		82		103.7
Osceloa		76.4		71.2		66
Plymouth		81.2		78.9		67.6
Sioux		99.5		69.8		66.7
Woodbury		105.1		118.8		95.4

watersheds. The annual precipitation interacts with the flow (Fig. 48) as the flow is high when the rainfall is higher than average as typified by 1993. In 1990 we see a lower flow than excepted given the rainfall amounts. Concentration (Fig. 49) does not change significantly in 1990 to account for this reduced load (Fig. 50).

5.6.2.5 N Balance

The Iowa watersheds are not as comparable as Illinois, as the Iowa watersheds are not uniformly distributed among the state. The variables for this equation are inconsistent also. Since the 1980's the amount of N fertilizer has gone down (Fig. 5). Annual precipitation over Iowa for the watersheds have shown yearly variations, however, relative differences among the watersheds is minimum (Fig. 51). Precipitation in 1982 and 1993 was the highest. The years 1988 and 1994 rank as the lowest precipitation amounts during this time period. The harvested areas for these watersheds have not changed significantly in the 10 years of data (Fig. 52). Without a change in the variables involved there hasn't been a pattern seen for the recent change in the size of the amount of N located in the Mississippi River Valley.

The Chariton is an example of a low harvested area and a low N load. In all the years that are shown in Figure 53, 54, and 55, the amount of load in the rivers corresponds with the amount of harvested land. An exception is seen in 1992 with a few of the watersheds having a high load even though the harvested area did not change. In 1997 the amount of applied fertilizer for Iowa was around 95 kg/ha (Fig. 5). This amount is significant for Iowa because the amount of fertilizer lost is shown as a percentage (Fig. 56). This graph shows no relationship among the years for the amount of lost N. For example, in the Chariton River the amount of lost N was consistently less than 10%, but when the Upper Iowa is compared it shows a loss of 11% for 1987 and up to over 40% in 1992. This is

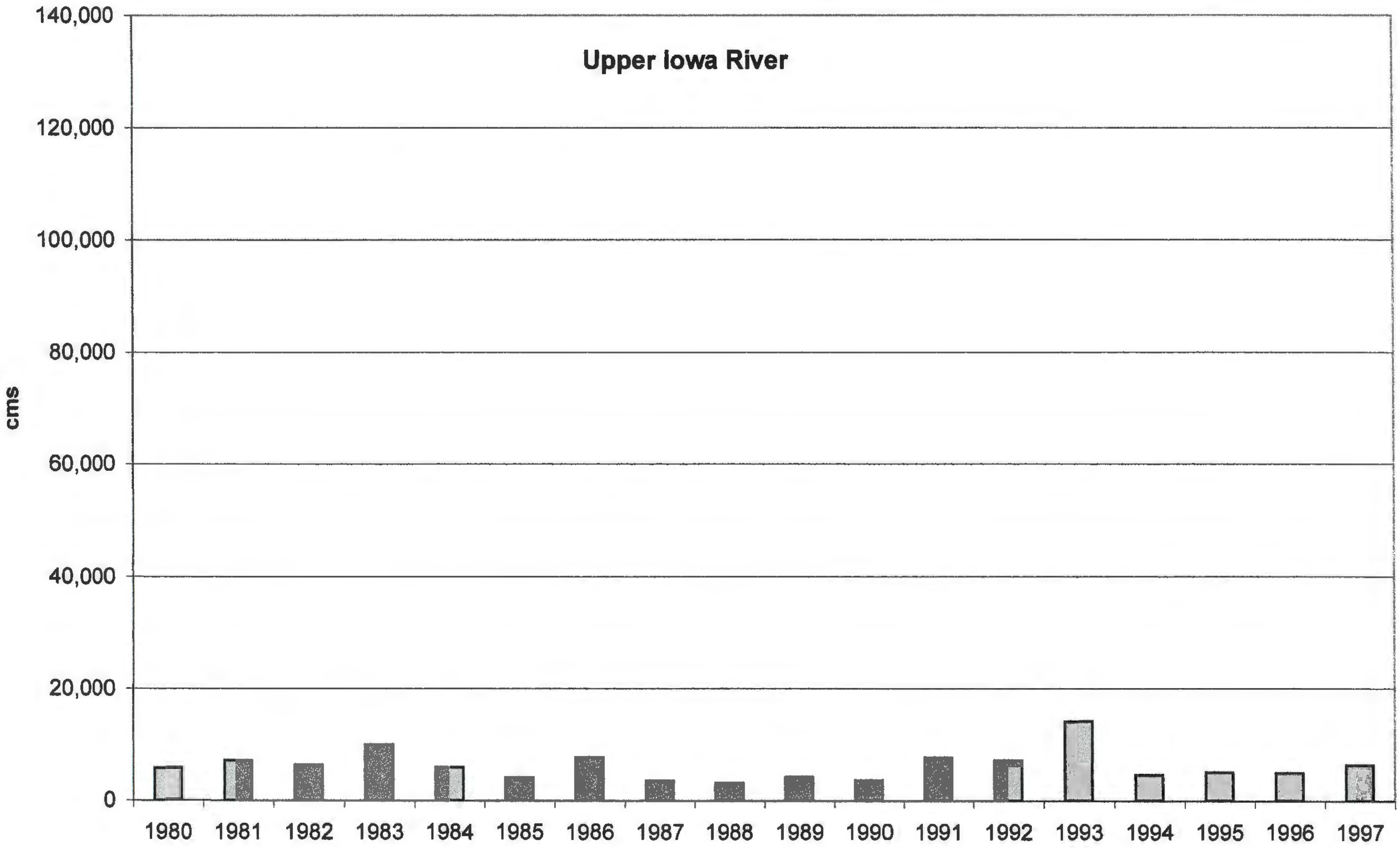


Figure 48. Flow for the Upper Iowa River, Iowa from 1980-1997.

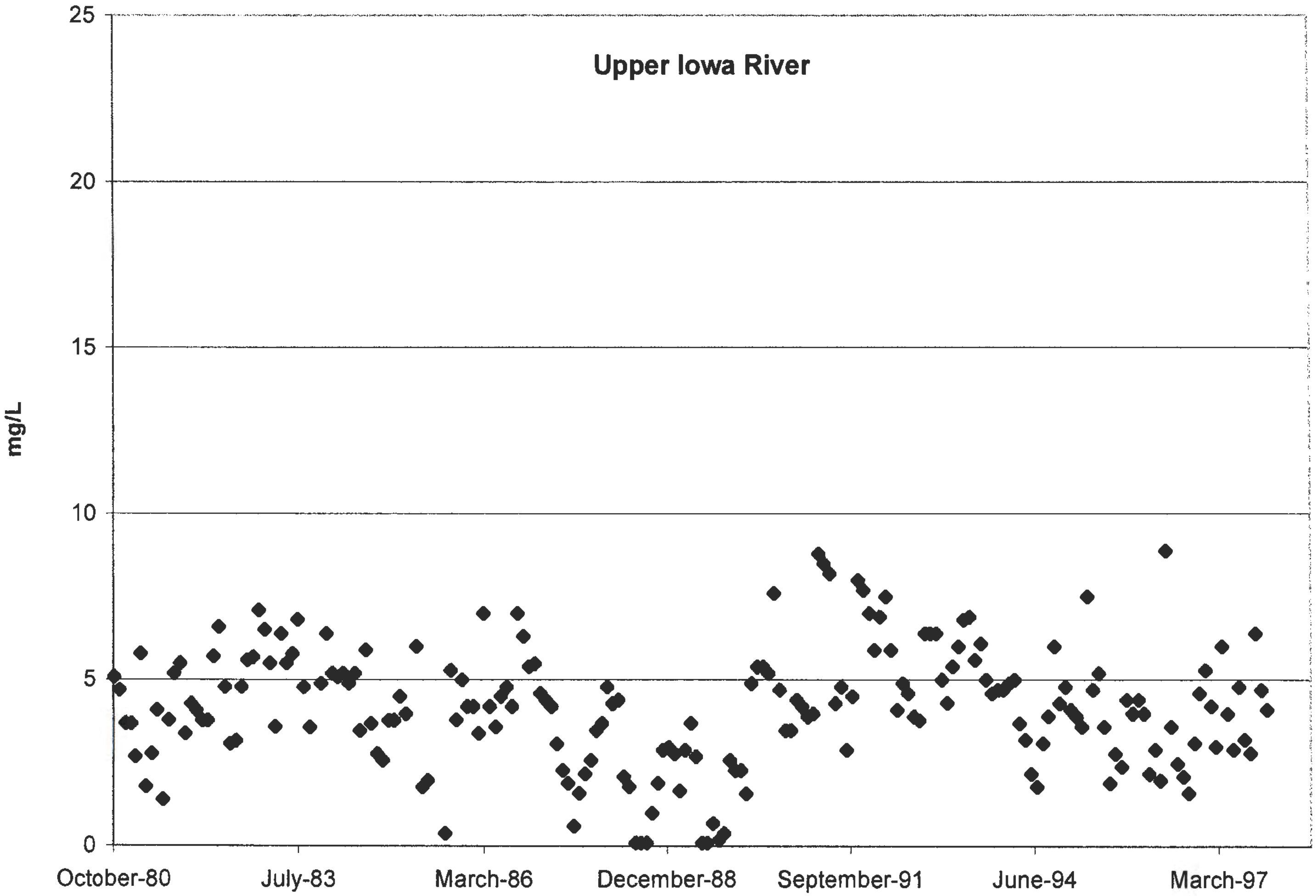


Figure 49. Nitrogen concentrations for the Upper Iowa River, Iowa from 1980-1997.

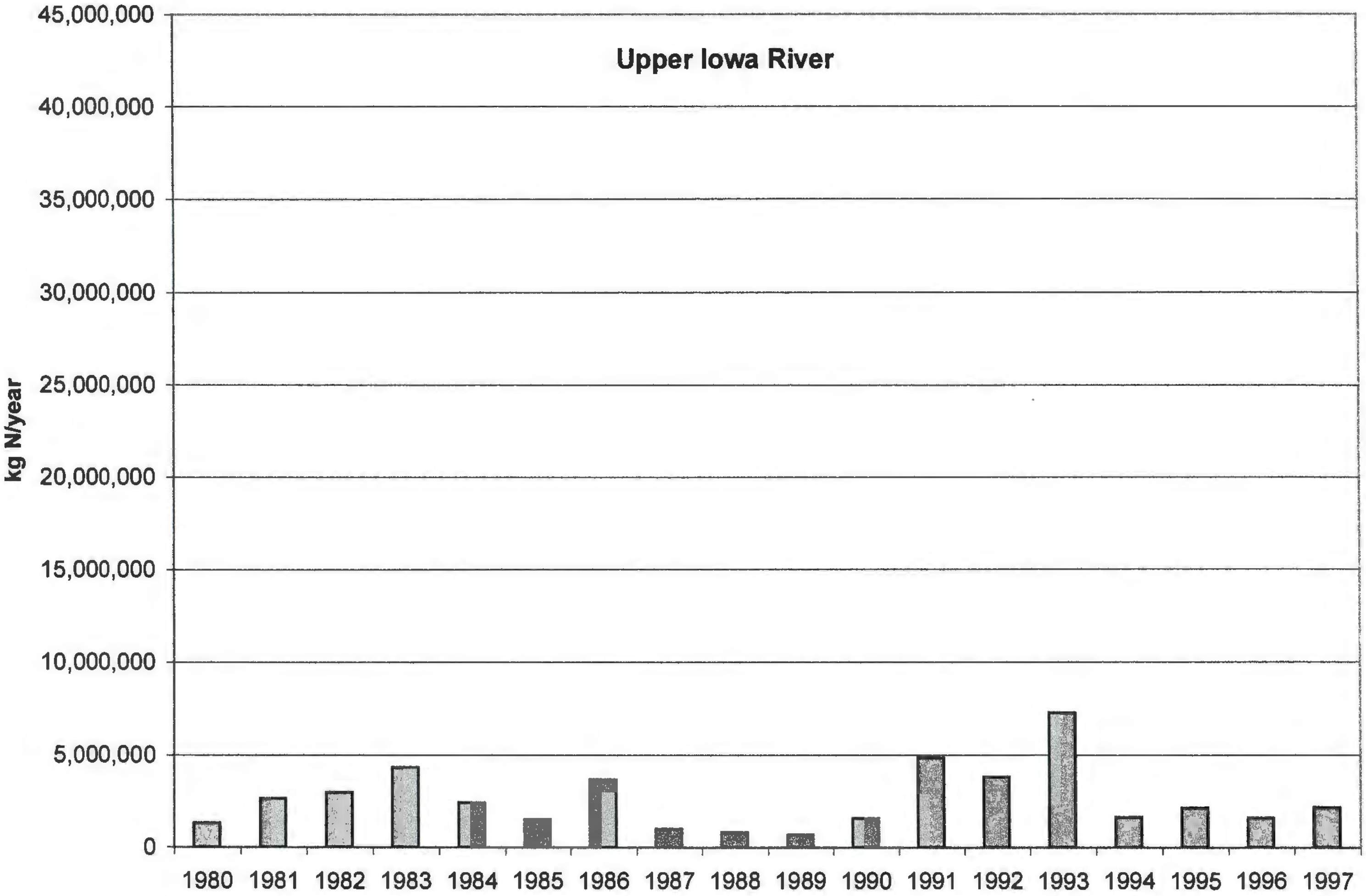


Figure 50. Nitrogen kg/ha/year for the Upper Iowa River, Iowa from 1980-1997.

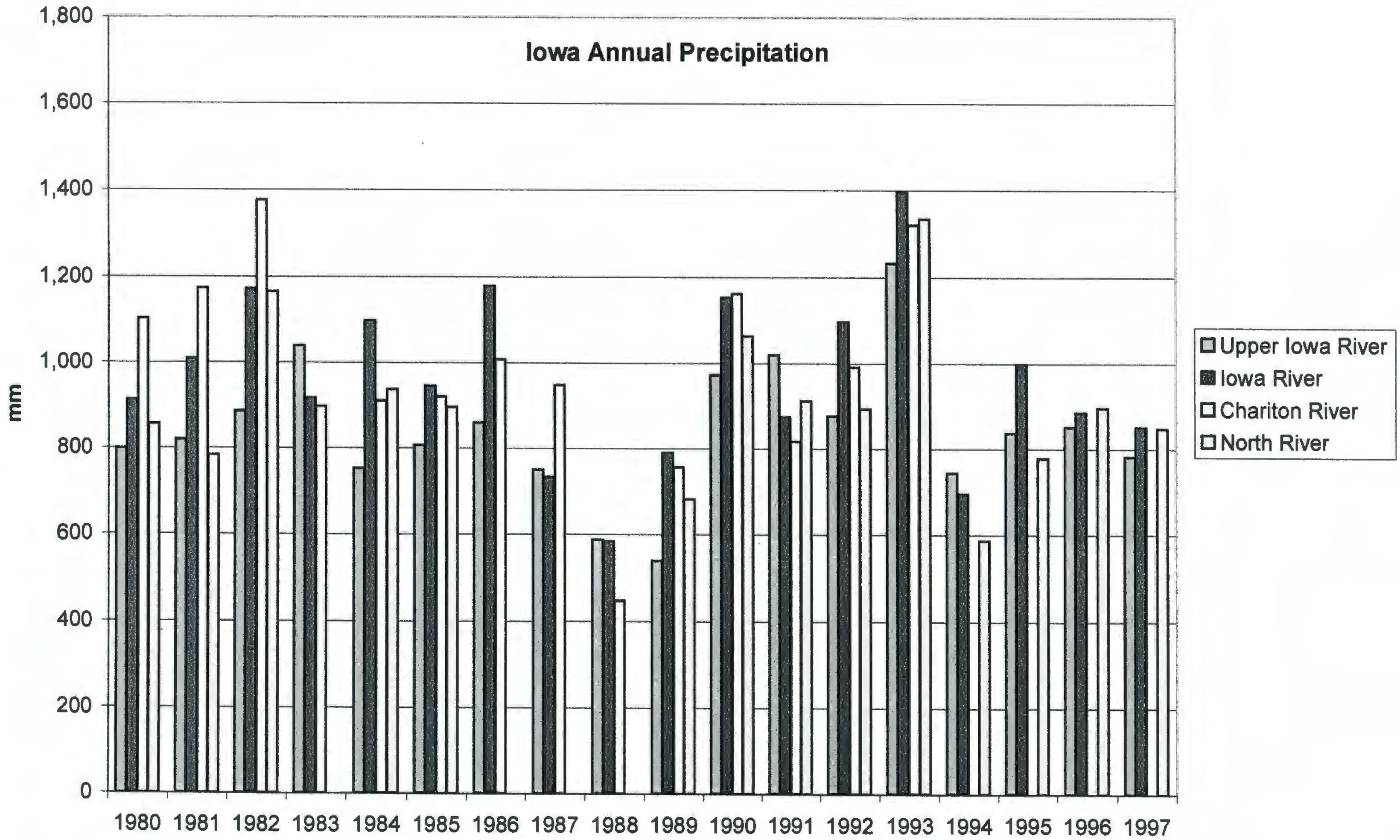


Figure 51. Annual precipitation for Iowa watersheds from 1980-1997.

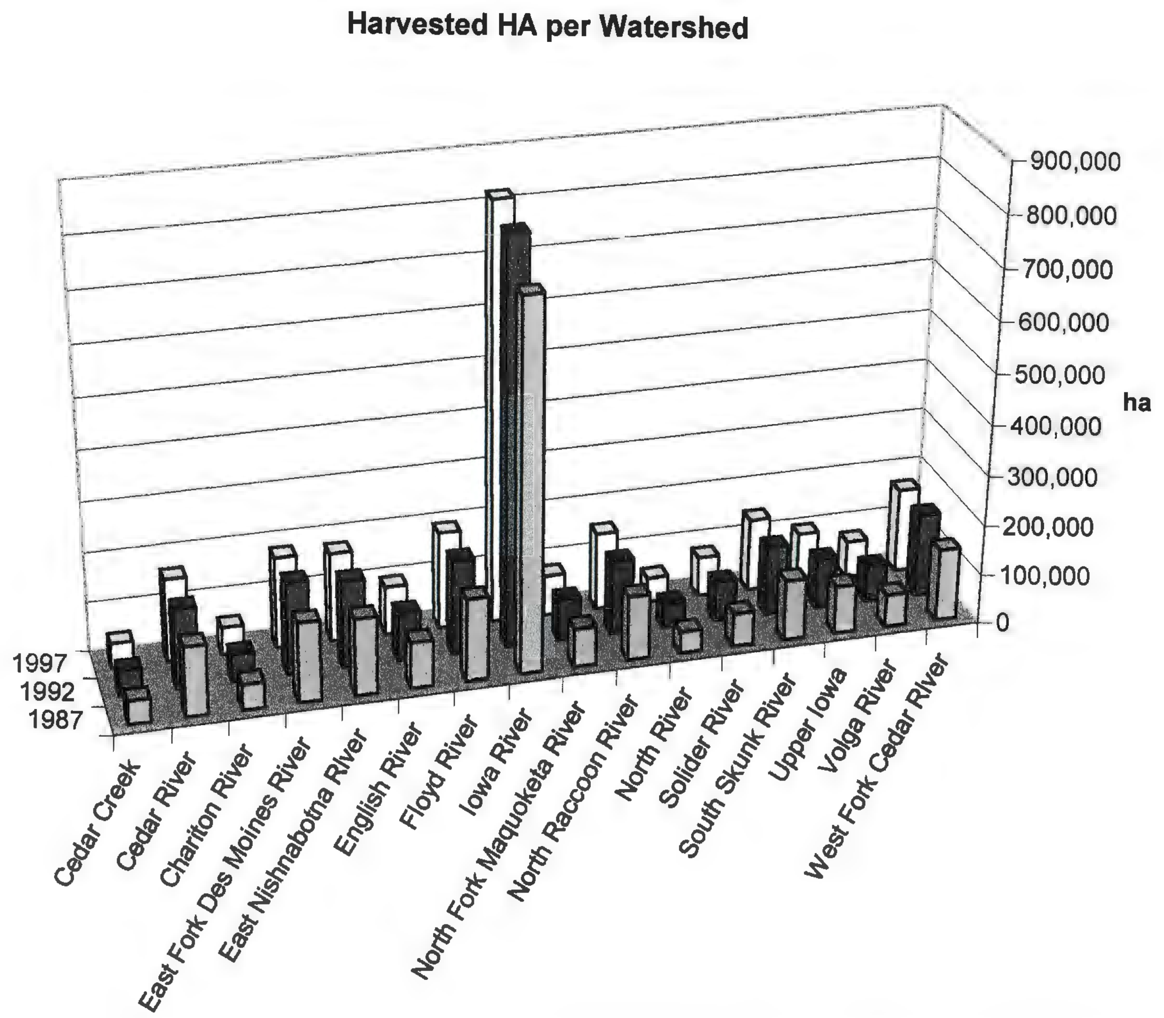


Figure 52. Iowa watersheds based on the amount of harvested hectares for 1987, 1992, and 1997.

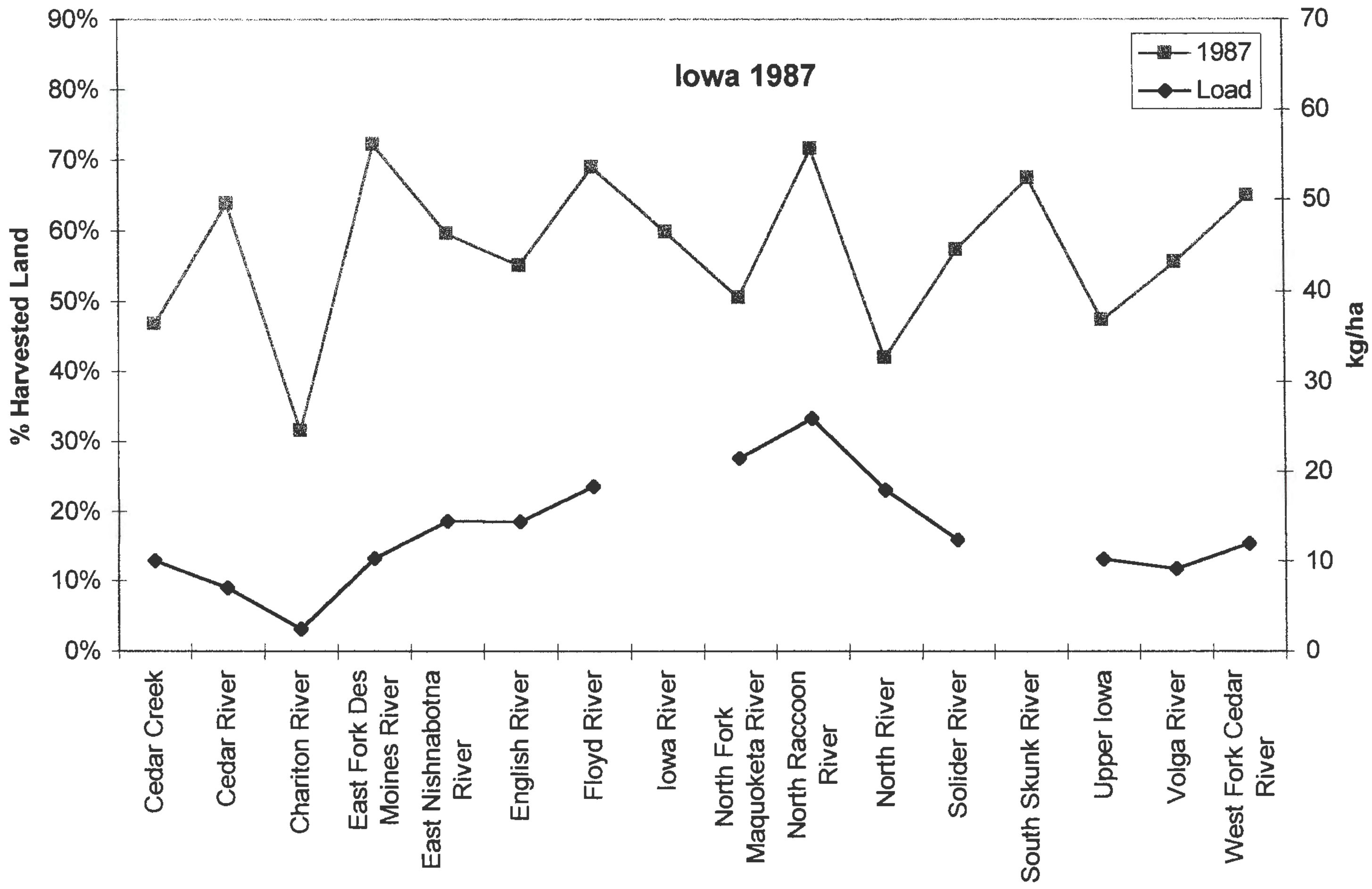


Figure 53. An Iowa comparison of the percent harvested land to the amount of N that was lost in 1987.

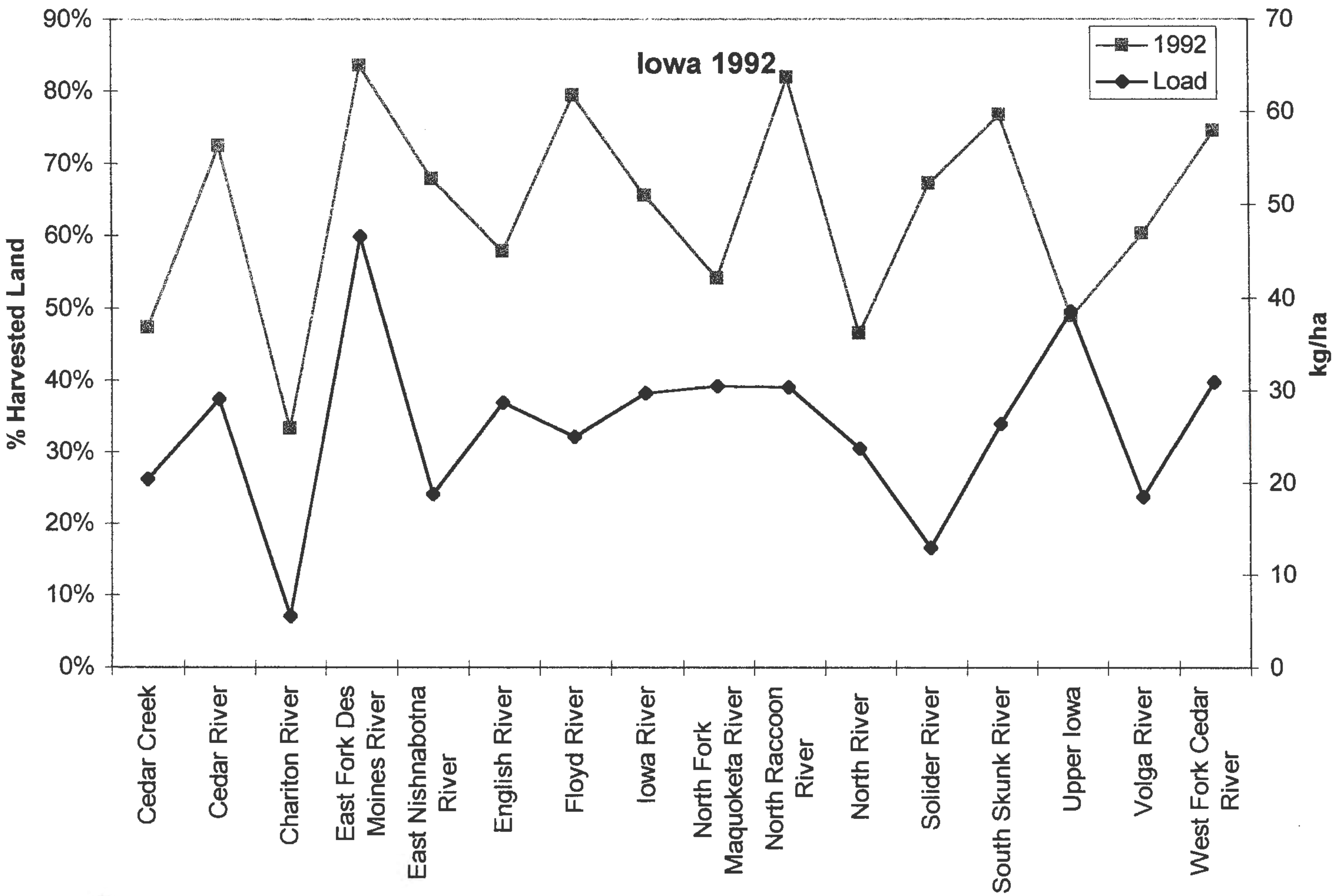


Figure 54. An Iowa comparison of the percent harvested land to the amount of N that was lost in 1992.

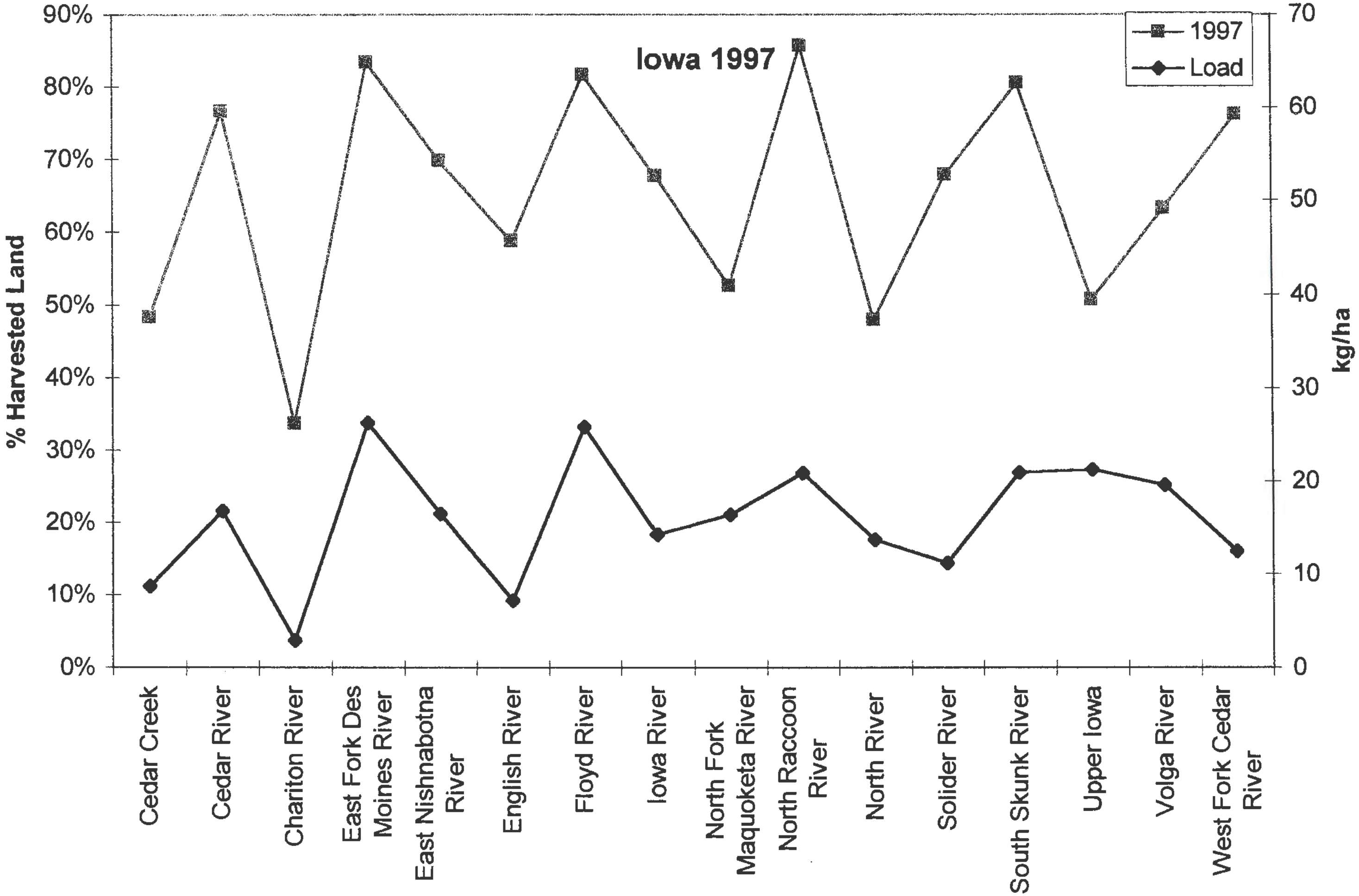


Figure 55. An Iowa comparison of the percent harvested land to the amount of N that was lost in 1997.

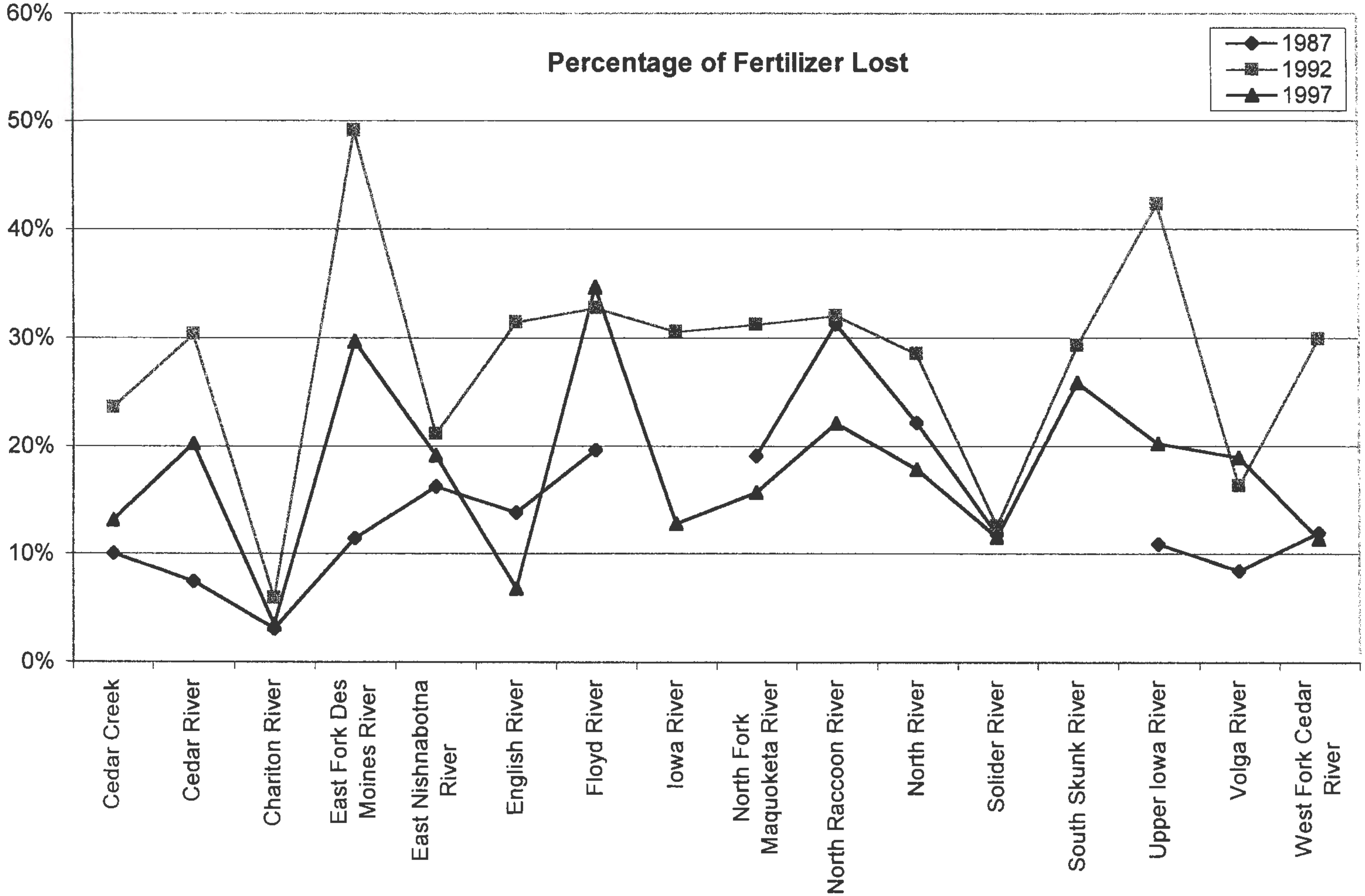


Figure 56. The percentage of nitrogen fertilizer that was lost throughout the Iowa watersheds.

significant because there wasn't a change in any of the variables for this to be happening. This inconsistency is important when referring to policymaking.

The amount of fertilizer applied also corresponds with the amount of N found in the Iowa watersheds. Figure 57, 58, and 59 illustrates the amount of fertilizer applied compared with the load of fertilizer in the rivers, 1987 and 1997 are equivalent years and 1992 has a higher application rate and also a higher amount that is lost. The balance between the amount applied and the amount lost is not achieved. One major reason that the change in N could be different in 1992 is that it could have been a cropping year where more N was applied such as a corn-soybean rotation where more corn was planted.

5.6.3 Missouri

In Figure 60, the flow of 7 watersheds in Missouri is compared for two different years. An average year is represented by 1987 and is compared with 1993 which was an above normal year. Missouri was narrowed to 4 watersheds using the same criteria as Illinois and Iowa. The selected watersheds are the Meramec River at Paulina Hills, Current River, Spring Creek, and South Fabius River. The remaining 3 watersheds are located in Appendix.

5.6.3.1 Meramec River at Paulina Hills

The Meramec River runs through the central section of Missouri and enters St. Louis where the Missouri and Mississippi River converge. This river is important in its location as a tributary for the Mississippi River. The drainage area is unlike Iowa and Illinois due to a lower percentage of harvested land. The total area for the Meramec River is 511,172 hectares but the harvested cropland area is 47,772 hectares. This is a lower percentage than the other two states with about 10% of the land harvested. The concentrations of N are lower in this watershed than in others due to the lower quantity of harvested land. This

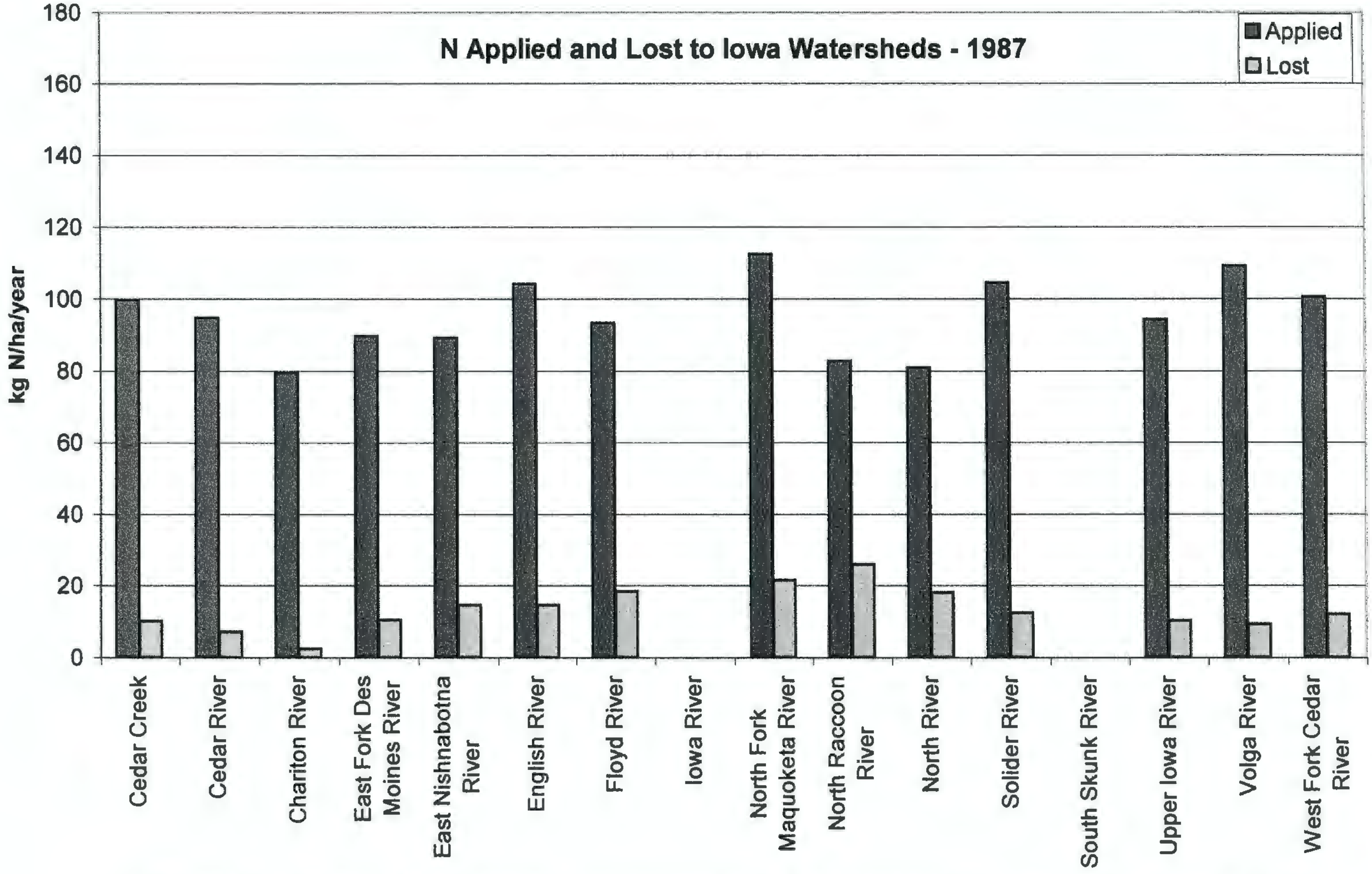


Figure 57. Nitrogen fertilzier applied compared with the amount of nitrogen lost for Iowa in 1987.

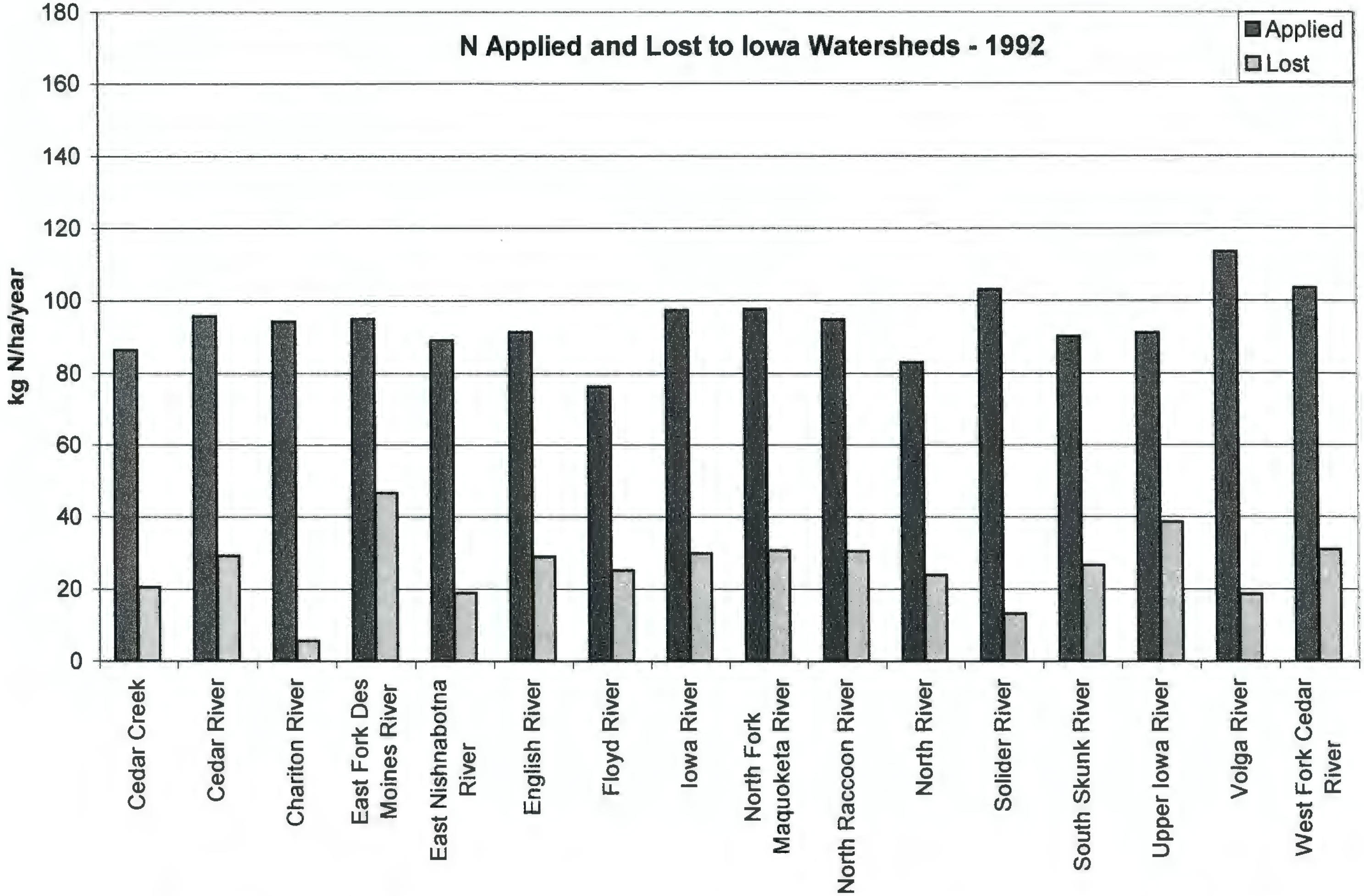


Figure 58. Nitrogen fertilzier applied compared with the amount of nitrogen lost for Iowa in 1992.

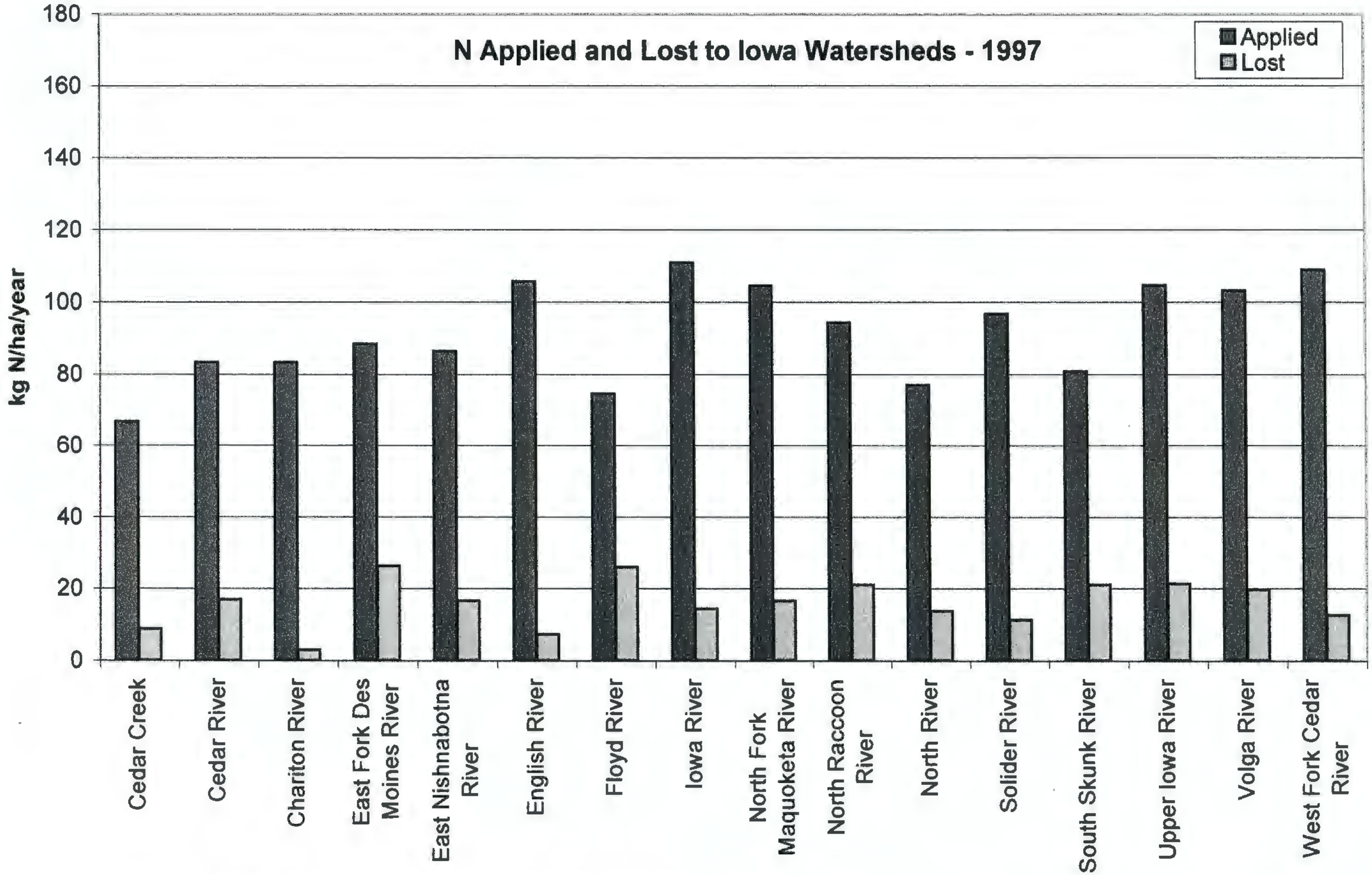


Figure 59. Nitrogen fertilizer applied compared with the amount of nitrogen lost for Iowa in 1997.

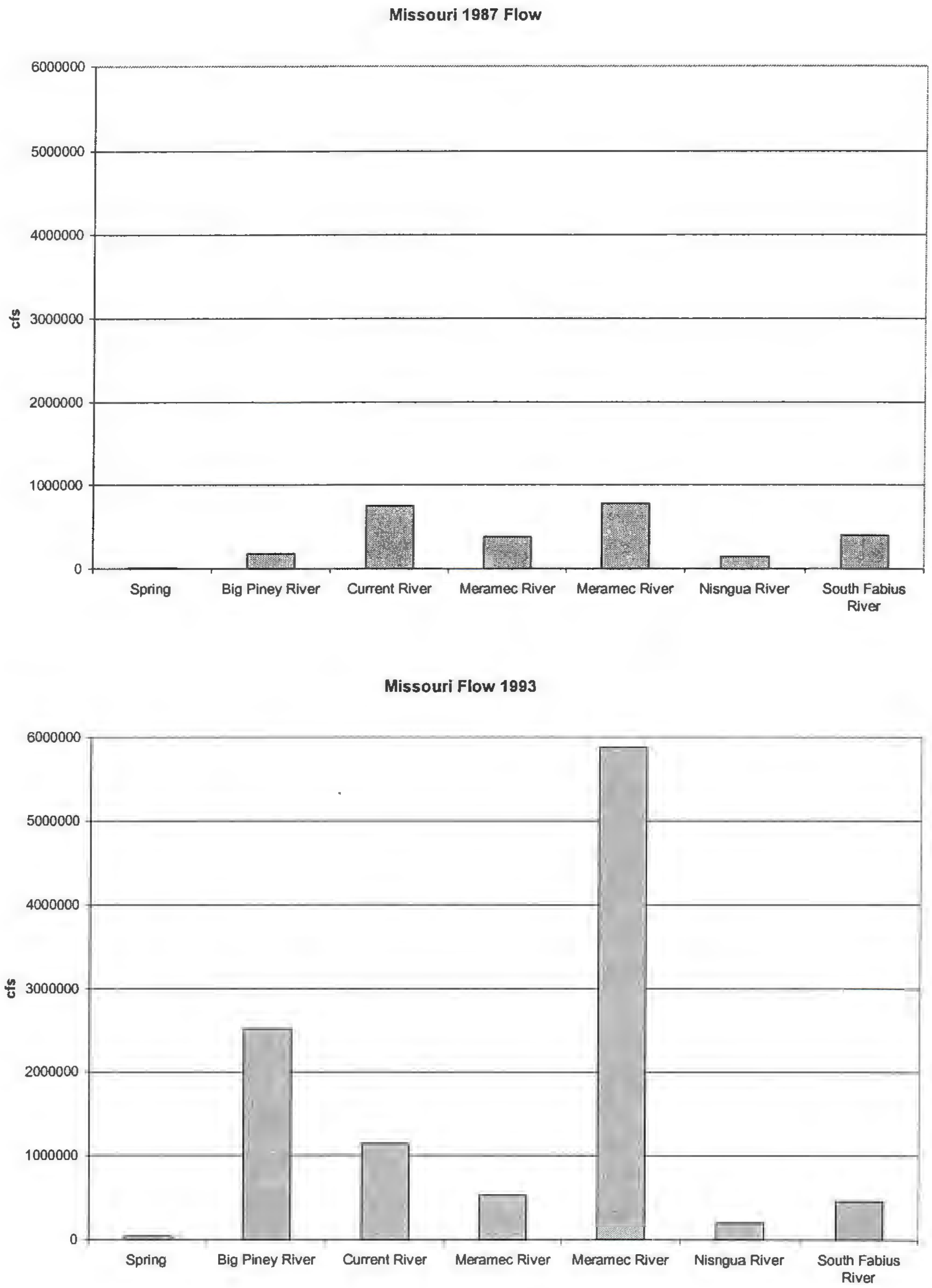


Figure 60. Water flow in Missouri for selected years.

watershed does not seem to have a pattern as the amount of rainfall has not affected the amount of flow (Fig. 61), except in 1993. The N load (Fig. 62) exhibits a pattern that mimics the flow. However, concentrations (Fig. 63) have not changed although the flow and load were changed. The only significant response in this watershed is that flow is a tremendous aid to the amount of N load found in the rivers.

5.6.3.2 Current River

The Current River is located south of the Meramec River and the drainage area large with a small percentage of cropland. This area is mostly forest with about 12% of the area harvested cropland. The drainage area is 372,569 hectares with only 44,782 hectares of cropland. The Current River does have a higher flow (Fig. 64), which leads to a higher load even with a small N concentration of around .5 mg/L on an average annual basis. The Current River watershed does not show a pattern of low rainfall and the flow stays steady throughout the late 80's. This watershed is missing some of the data as STORET wasn't complete for this river. The load is the highest for this state as the kg of N that is detected in the stream is high (Fig. 65). The unsettling factor here is that the concentration are low in fact under 1 mg/L (Fig. 66). With these factors remaining unchanged a high load does not fit in this picture.

5.6.3.3 Spring Creek

Spring Creek represents a low load due to a low flow (even in 1993) and an average concentration of around 0.75 mg/L. This watershed also has a low percentage of cropland. The drainage area includes 124,436 hectares, but only 9,734 hectares of harvested cropland. This accounts for only 8% of the area, which leads the rest to be considered forests. The flow (Fig. 67) in the Spring Creek watershed is low for the other sites and also throughout the years it shows barely an increase in the amount of rain. The precipitation

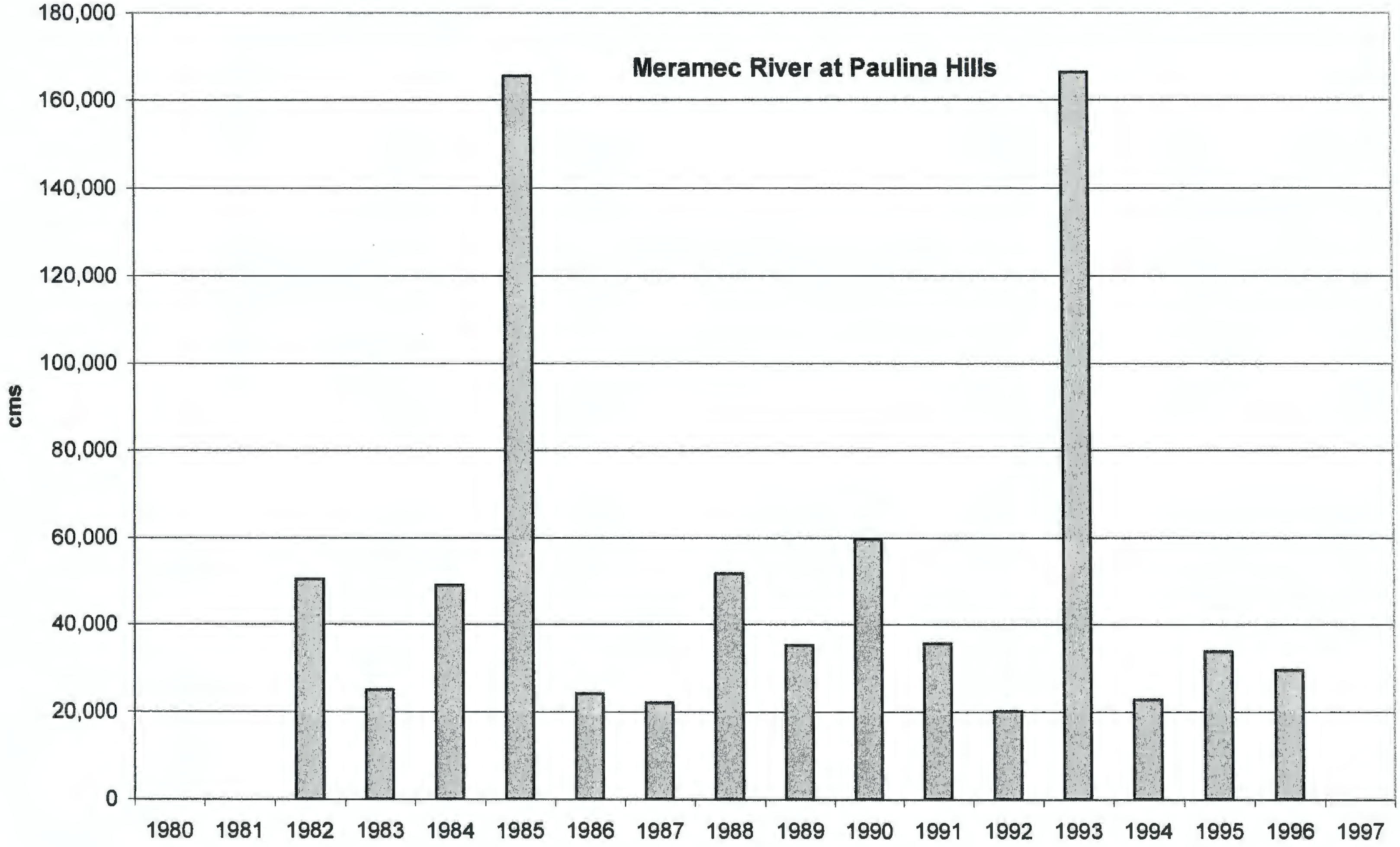


Figure 61. Flow for the Meramec River at Paulina Hills, Missouri from 1982-1996.

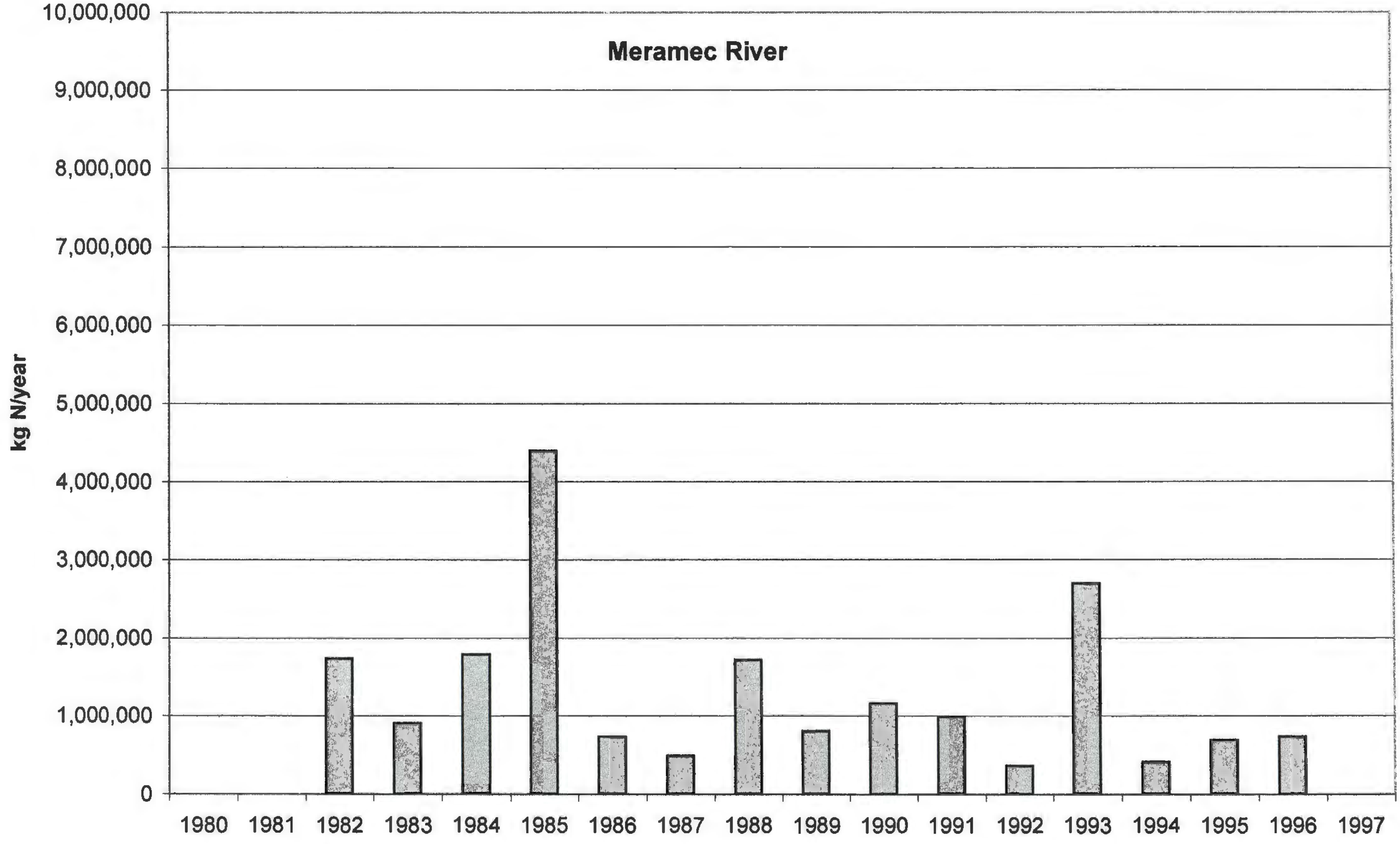


Figure 62. Nitrogen kg/ha/year for the Meramec River at Paulina Hills, Missouri from 1982-1996.

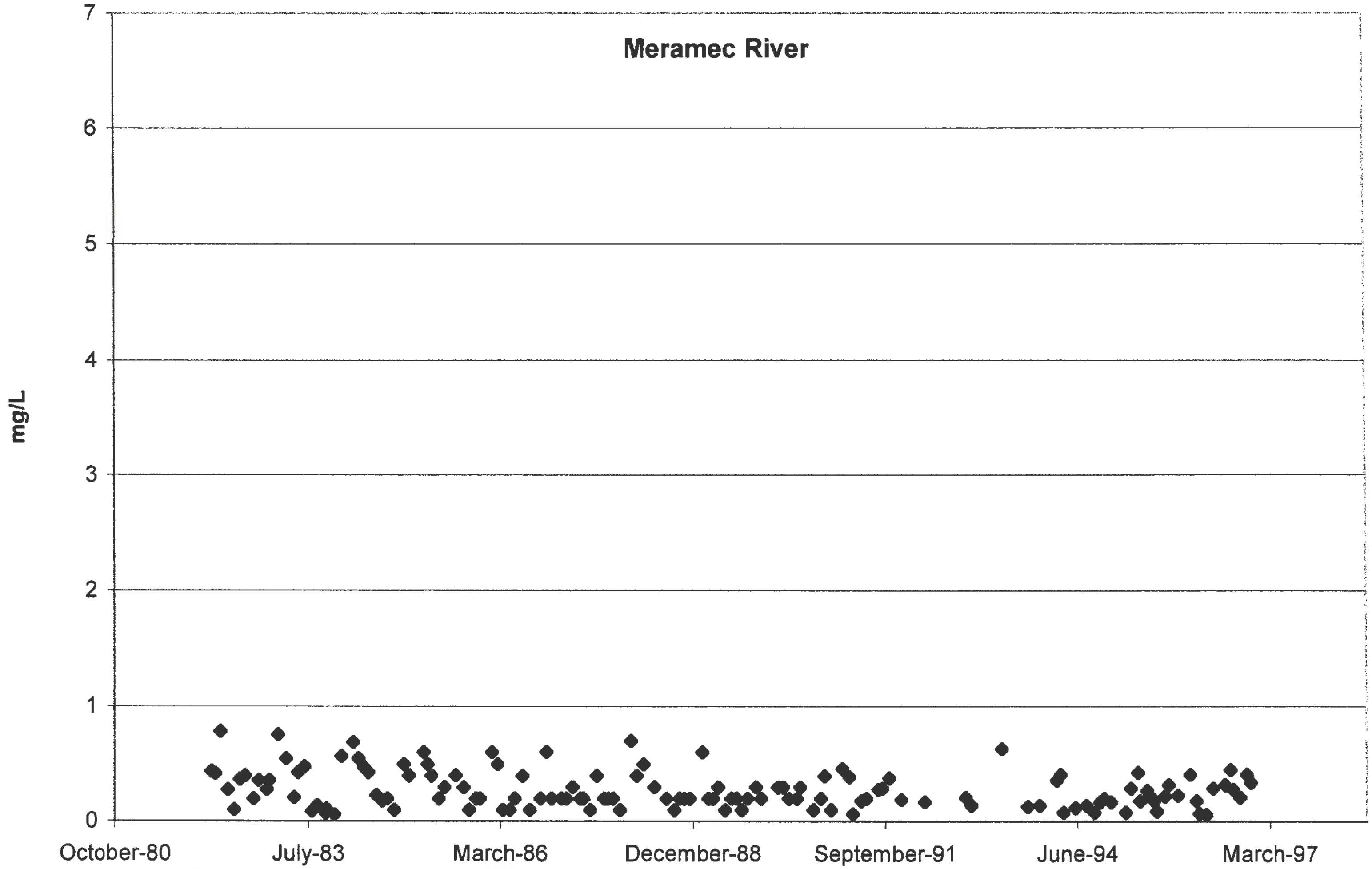


Figure 63. Nitrogen concentrations for the Meramec River at Paulina Hills, Missouri from 1982-1996.

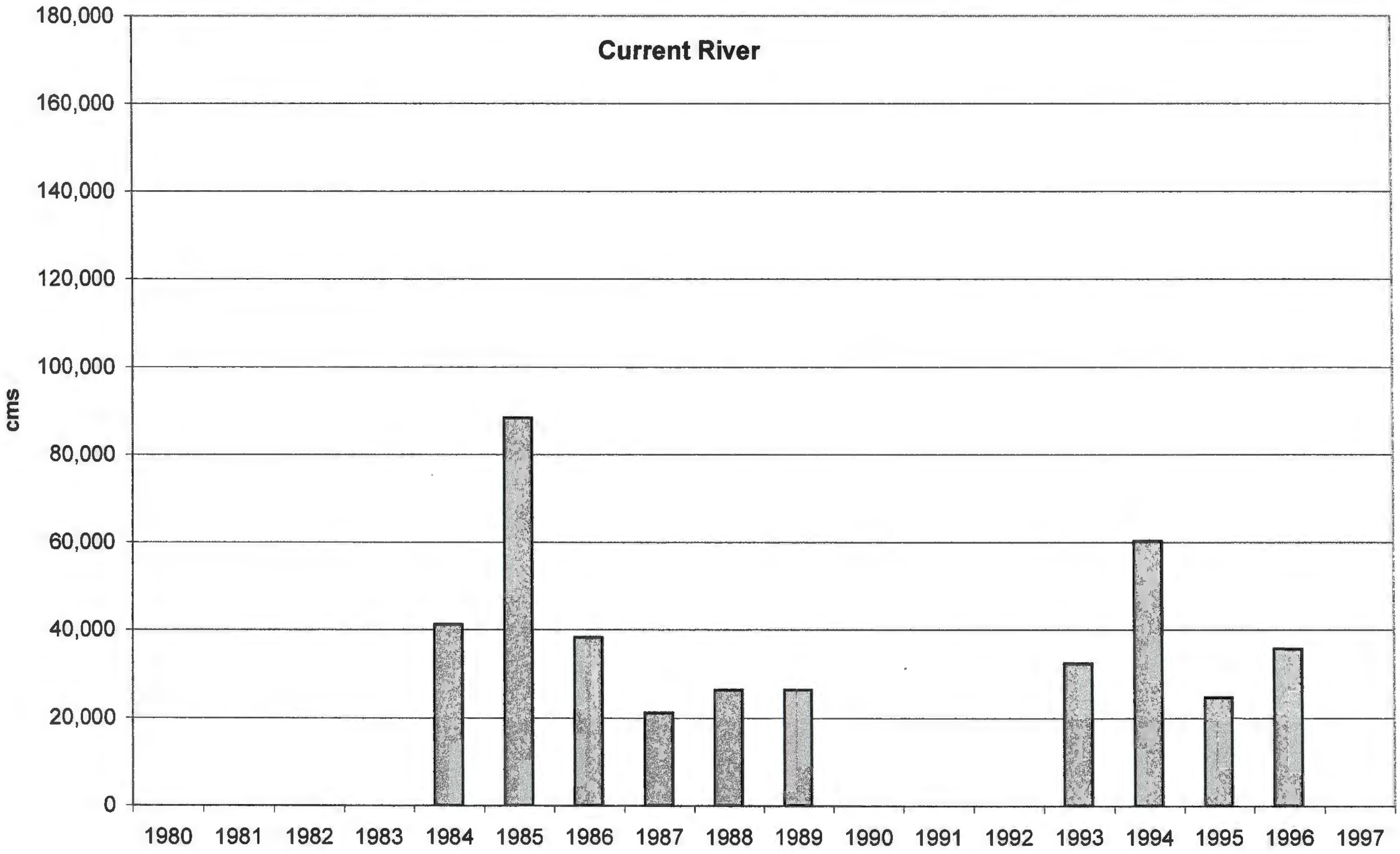


Figure 64. Flow for the Current River, Missouri from 1984-1989 and 1993-1996.

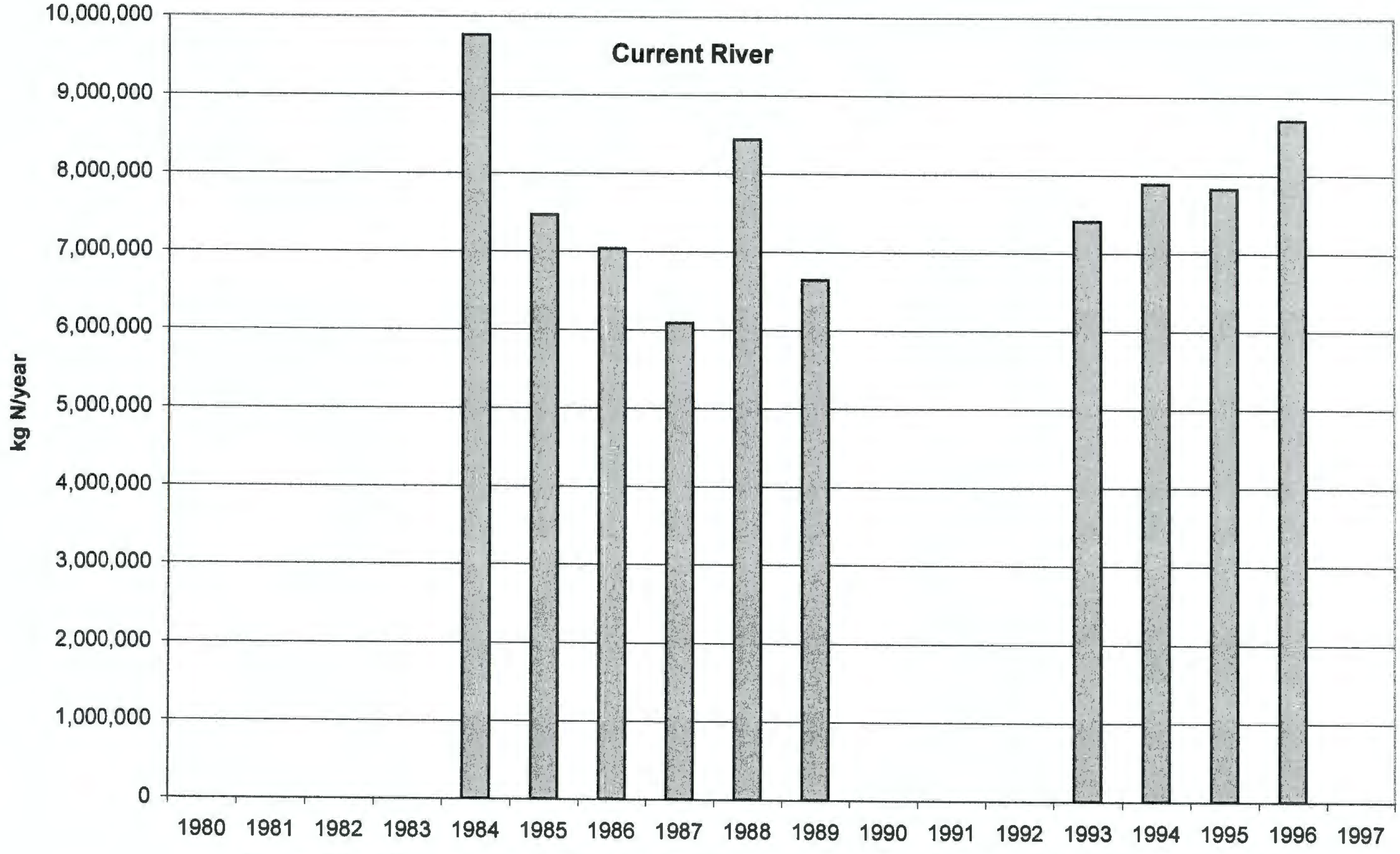


Figure 65. Nitrogen kg/hayear for the Current River, Missouri from 1984-1989 and 1993-1996.

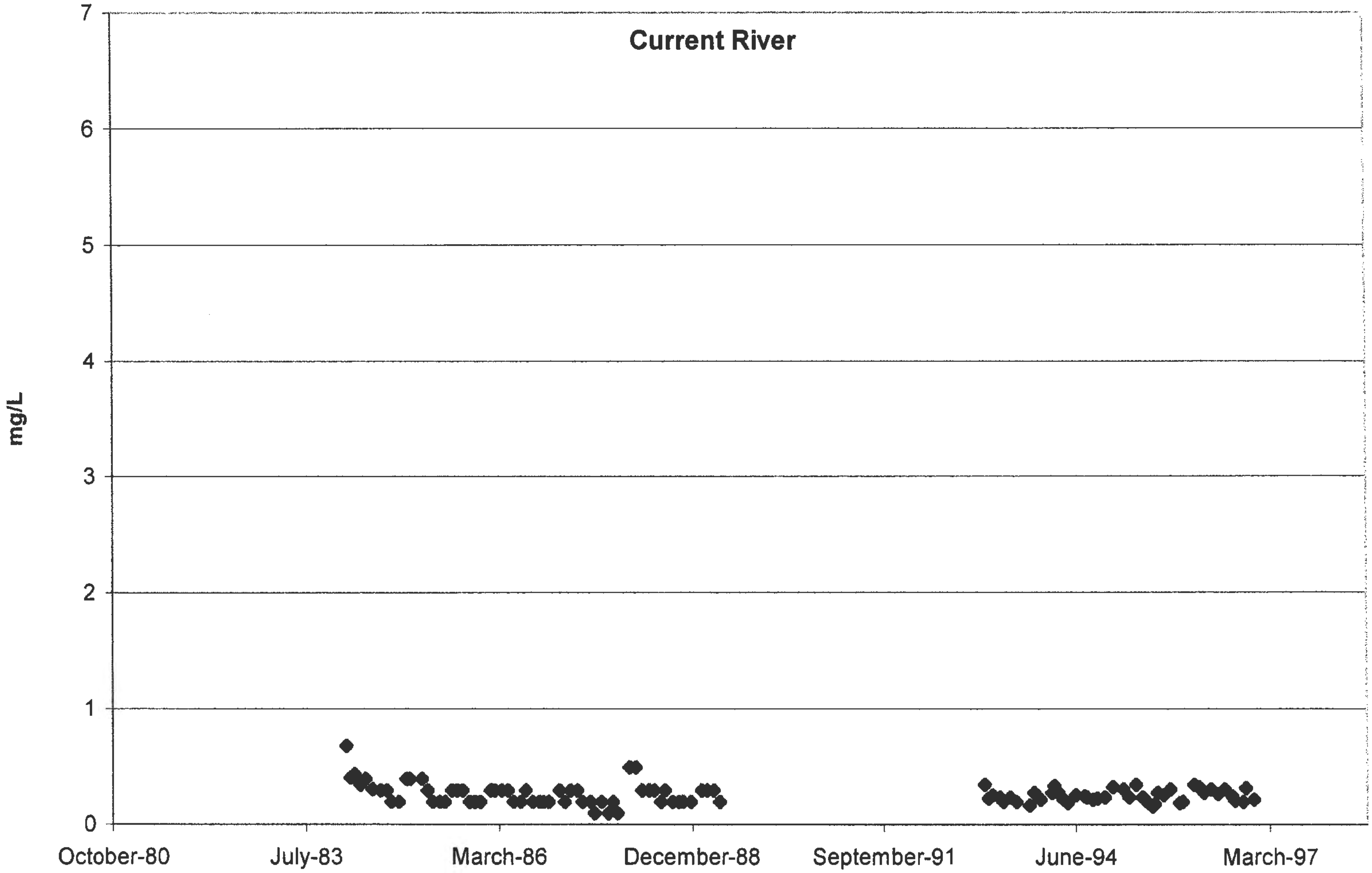


Figure 66. Nitrogen concentrations for the Current River, Missouri from 1984-1989 and 1993-1996.

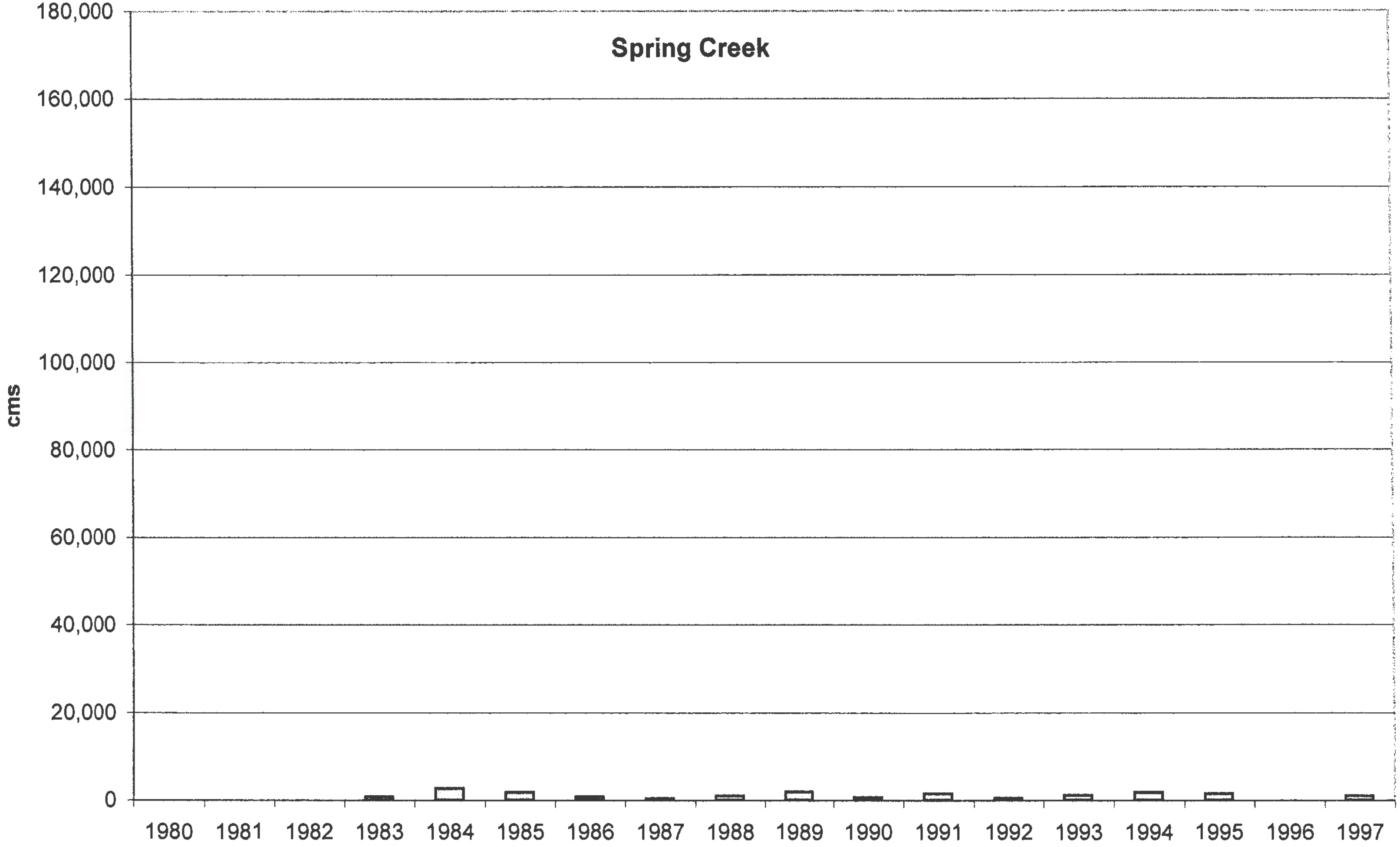


Figure 67. Flow for Spring Creek, Missouri from 1983-1997.

has increased throughout the years but the graph does not reflect. For a small watershed with a low percentage of harvested acres the river is true to it's size and doesn't show a high flux of N load (Fig. 68). The concentrations are low in this watershed also as the 15 year period show only three times that the river had a higher than 1 mg/L of N (Fig. 69). Since all the data stays on a normal flux it is easy to conclude that this watershed has a normal change in N load.

5.6.3.4 South Fabius River

This river system is important to study, as the river is located in Northern Missouri and drains into the Mississippi River. Compared with the other watersheds in the Missouri study area, the South Fabius has the largest proportion of cropland in the watershed. The drainage area sits within the counties of Scotland, Schuyler, Adair, Knox, Lewis, Marion, and Shelby and has an average of 39% harvested cropland. This watershed area is 162,661 hectares with 63,161 hectares of harvested cropland. The river has had a higher load (Fig. 70) due to high flow (Fig. 71) compared with the other Missouri watersheds. But still the N concentrations remain rather low with an average of 0.5 mg/L (Fig. 72). The flow of the South Fabius River reflects the years that have high rainfall also have a higher flow. Then in turn this reflects with the amount of river load. The higher the years for flow the higher the amount of N load. The concentrations do not seem to have a reflection in this picture as in 1983 there was a higher amount of N but the river does not have a higher load that year.

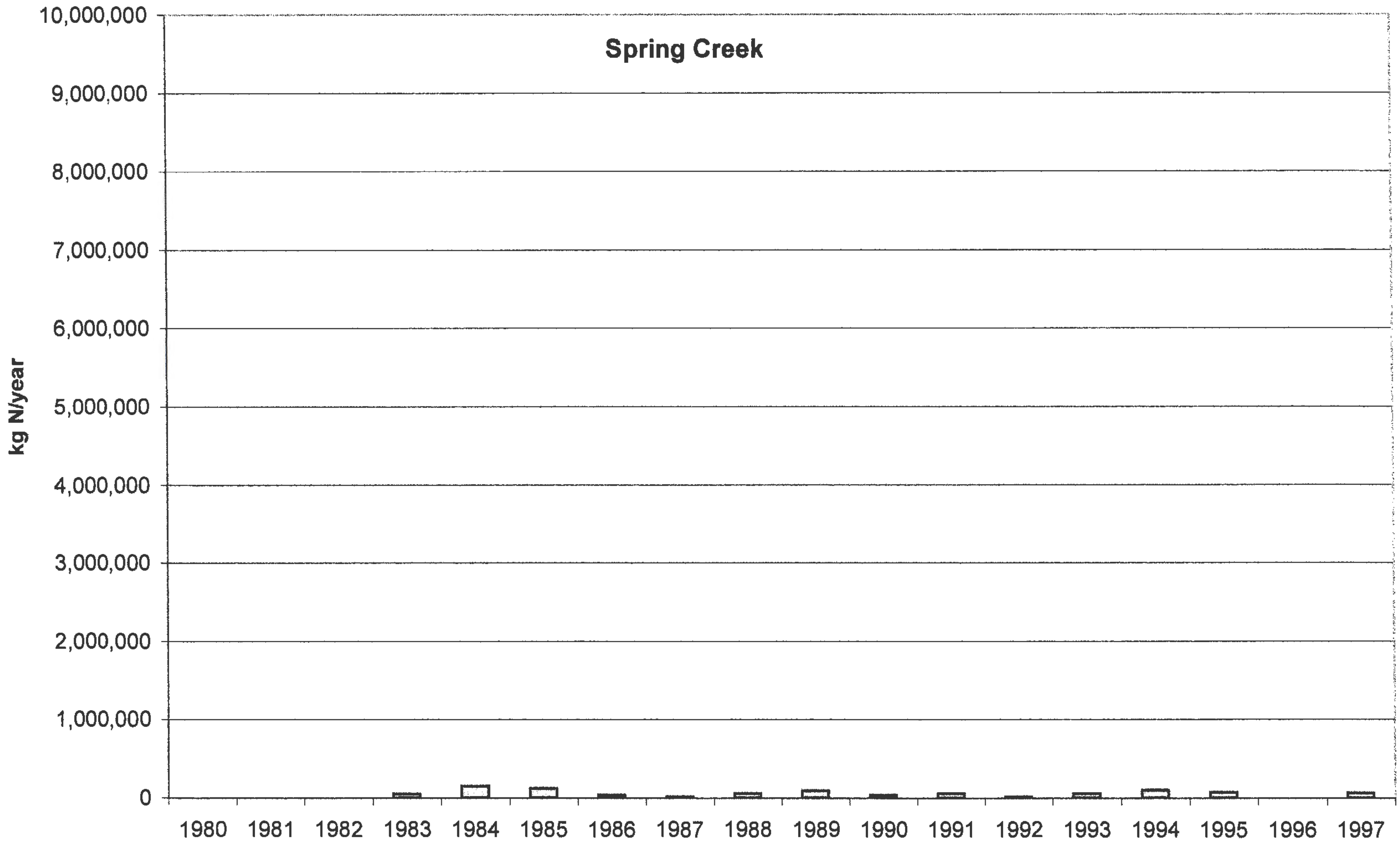


Figure 68. Nitrogen kg/ha/year for Spring Creek, Missouri from 1983-1997.

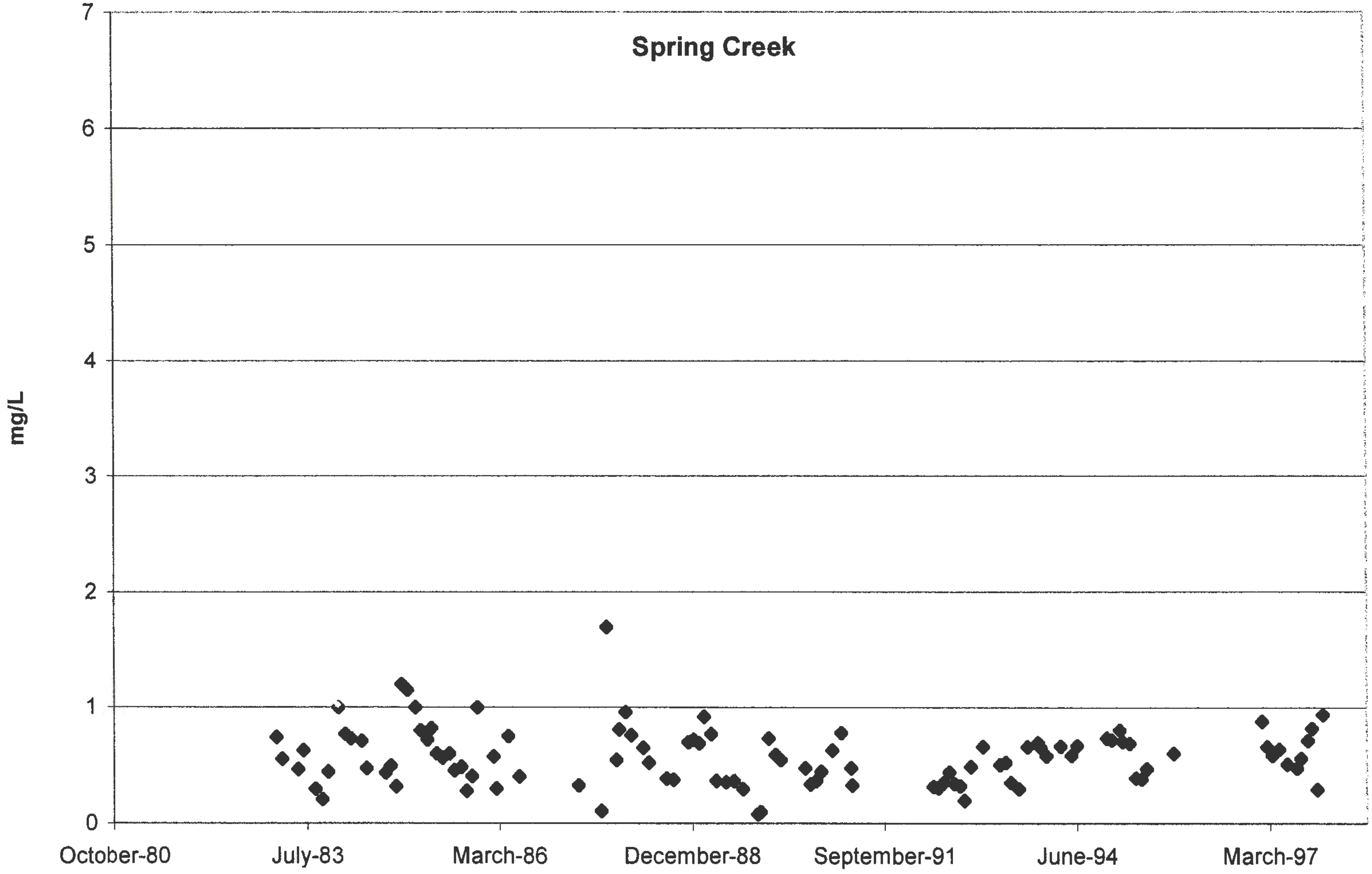


Figure 69. Nitrogen concentrations for Spring Creek, Missouri from 1983-1997.

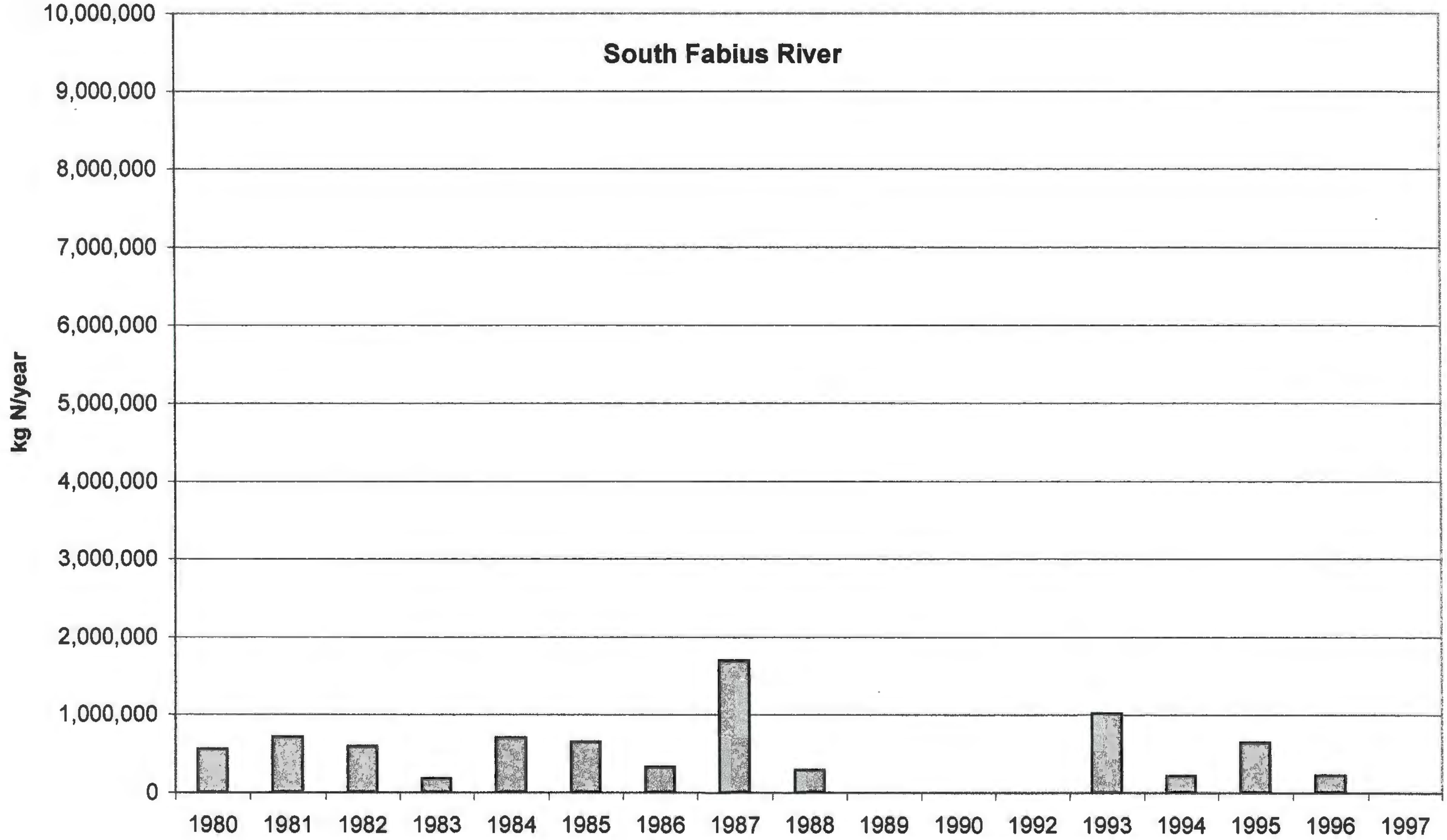


Figure 70. Nitrogen kg/ha/year for the South Fabius River, Missouri from 1980-1988 and 1993-1996.

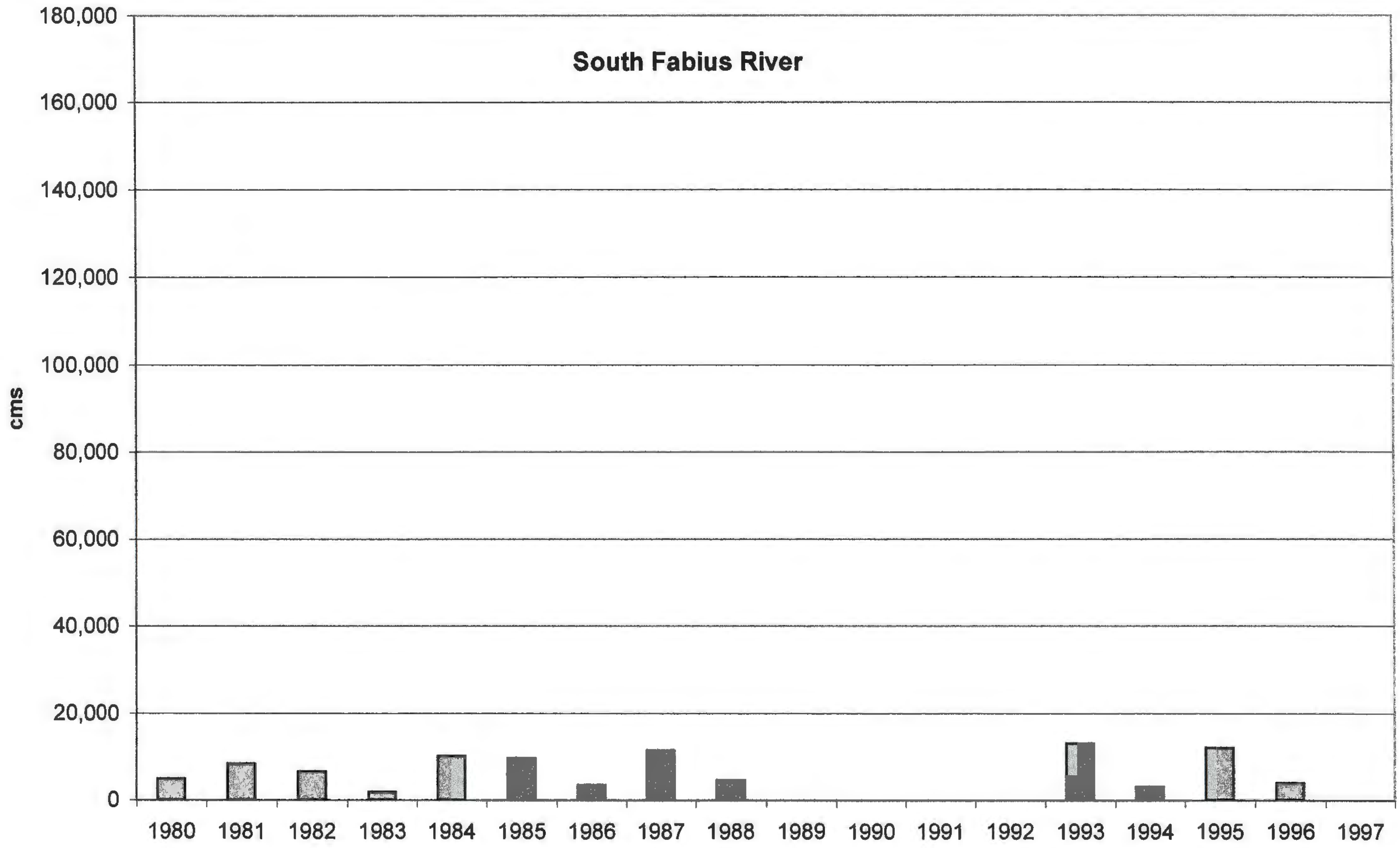


Figure 71. Flow for the South Fabius River, Missouri from 1980-1988 and 1993-1996.

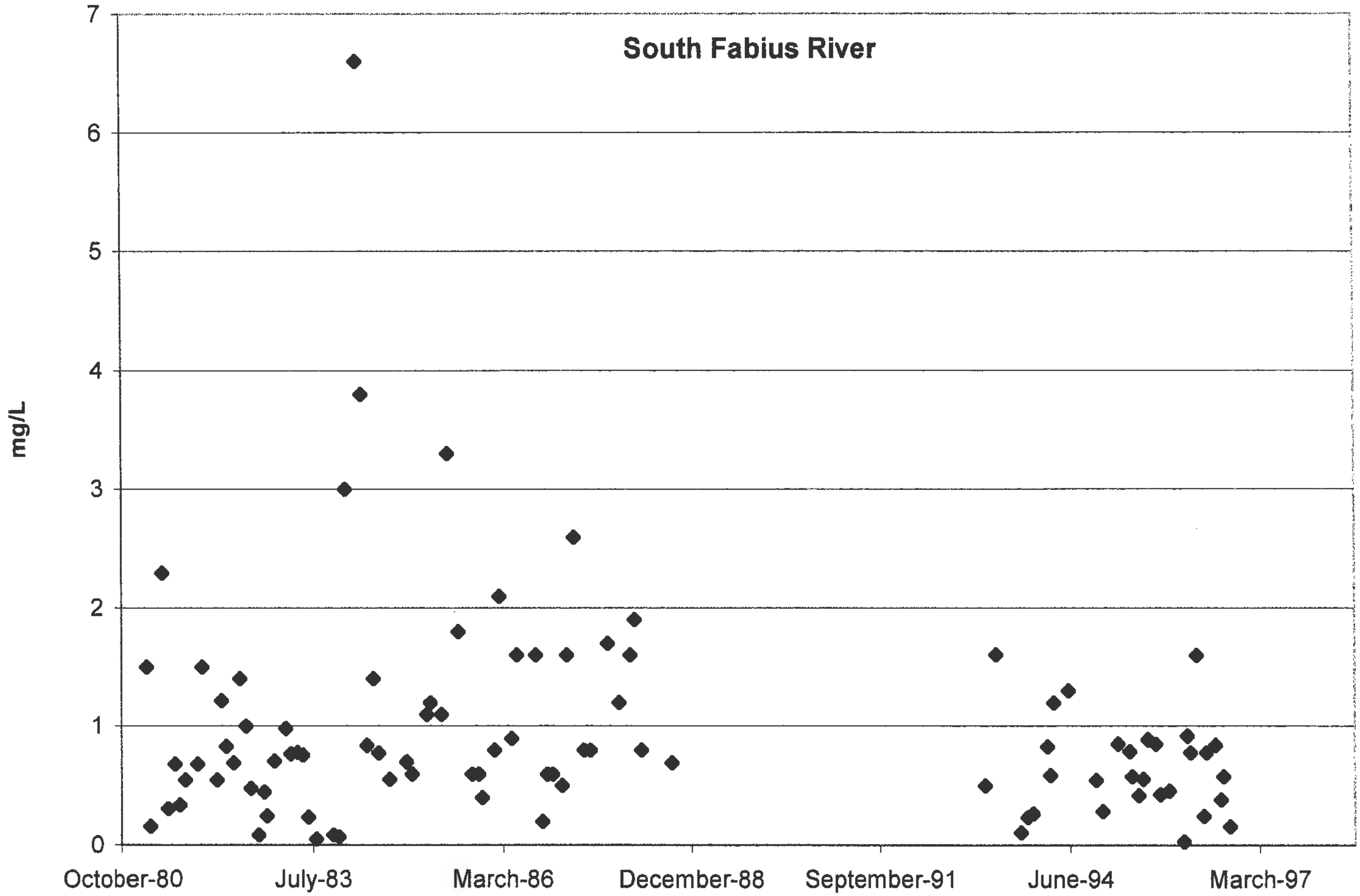


Figure 72. Nitrogen concentrations for the South Fabius River, Missouri from 1980-1988 and 1993-1996.

5.6.3.5 N Balance

The watersheds in Missouri exhibit a number of differences from Illinois and Iowa. The amount of harvested acres is less than Iowa or Illinois (Fig. 73). This should also mean a lesser amount of N fertilizer applied to the watersheds. The application rates are lower with an average annual rate of 80 kg/ha (Fig. 7). The rainfall amounts are higher which could possibly cause a higher flow in some of the rivers (Fig. 74). In some of the years Missouri has exceeded 60 inches of rain throughout some watersheds in years 1982,1985, 1990, and 1993. These years are expecting to have higher amounts of N loads in those watersheds. Missouri has some interesting data that shows a higher amount of loss in some streams, e.g., as much as 170 kg/ha in the Current River. This is a very high amount of N in this watershed. This is repeated in another watershed that has not been discussed but the trend is there in the Big Piney watershed with a loss of 150 kg/ha. When one looks at the other watersheds in Figure 75 the trend isn't there for 1987 with five other watersheds having a loss of less than 20 kg/ha. The state is hard to compare with the fertilizer applications. With an average application rate under 100 kg/ha and a watershed that has lost 180% of the N that is applied this definitely shows an inconsistency. The average rate of fertilizer application was less in 1997 than in 1987 but Missouri's data is less than complete (Fig. 76). So an accurate theory on why this has happened isn't available. With a sparse amount of available data the balance is not achieved in this state. With two watersheds losing more N than what is added in N fertilizer and also with five other watersheds with an average loss of 20%. Figure 77 and 78 show this relationship with the Missouri watersheds based on the amount of N that is applied and the amount of N that is lost.

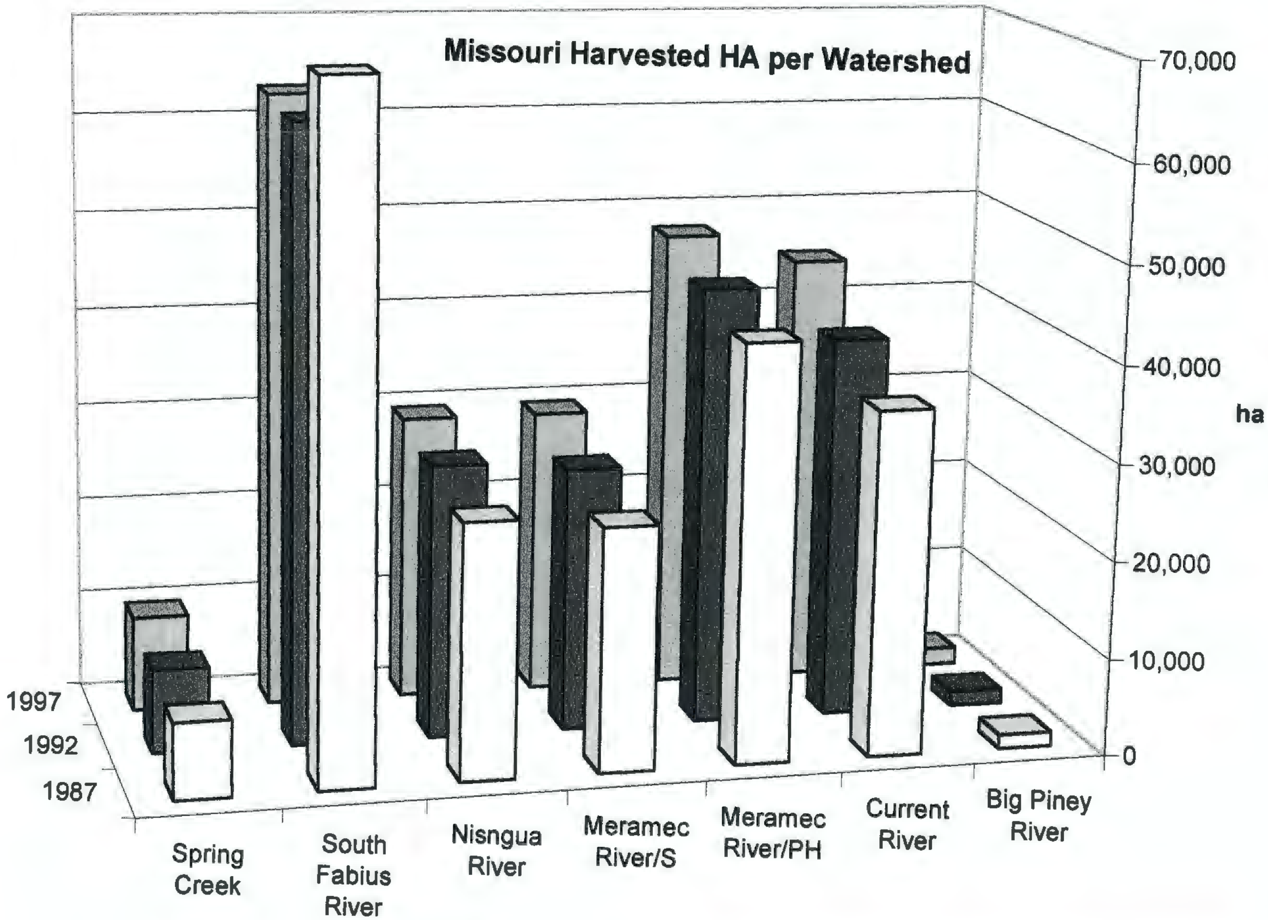


Figure 73. Missouri watersheds based on the amount of harvested hectares for 1987, 1992, and 1997.

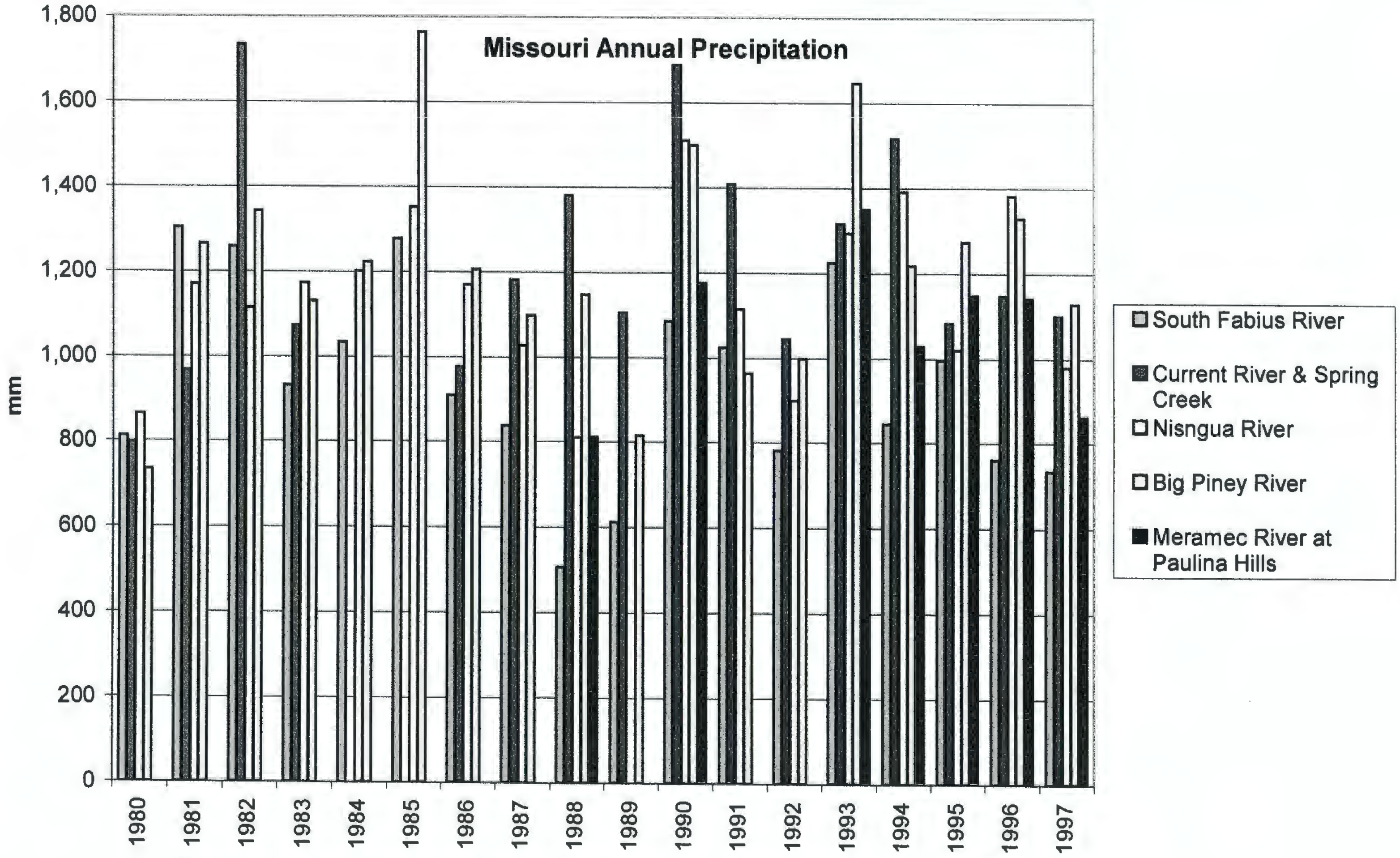


Figure 74. Annual precipitation for Missouri watersheds from 1980-1997.

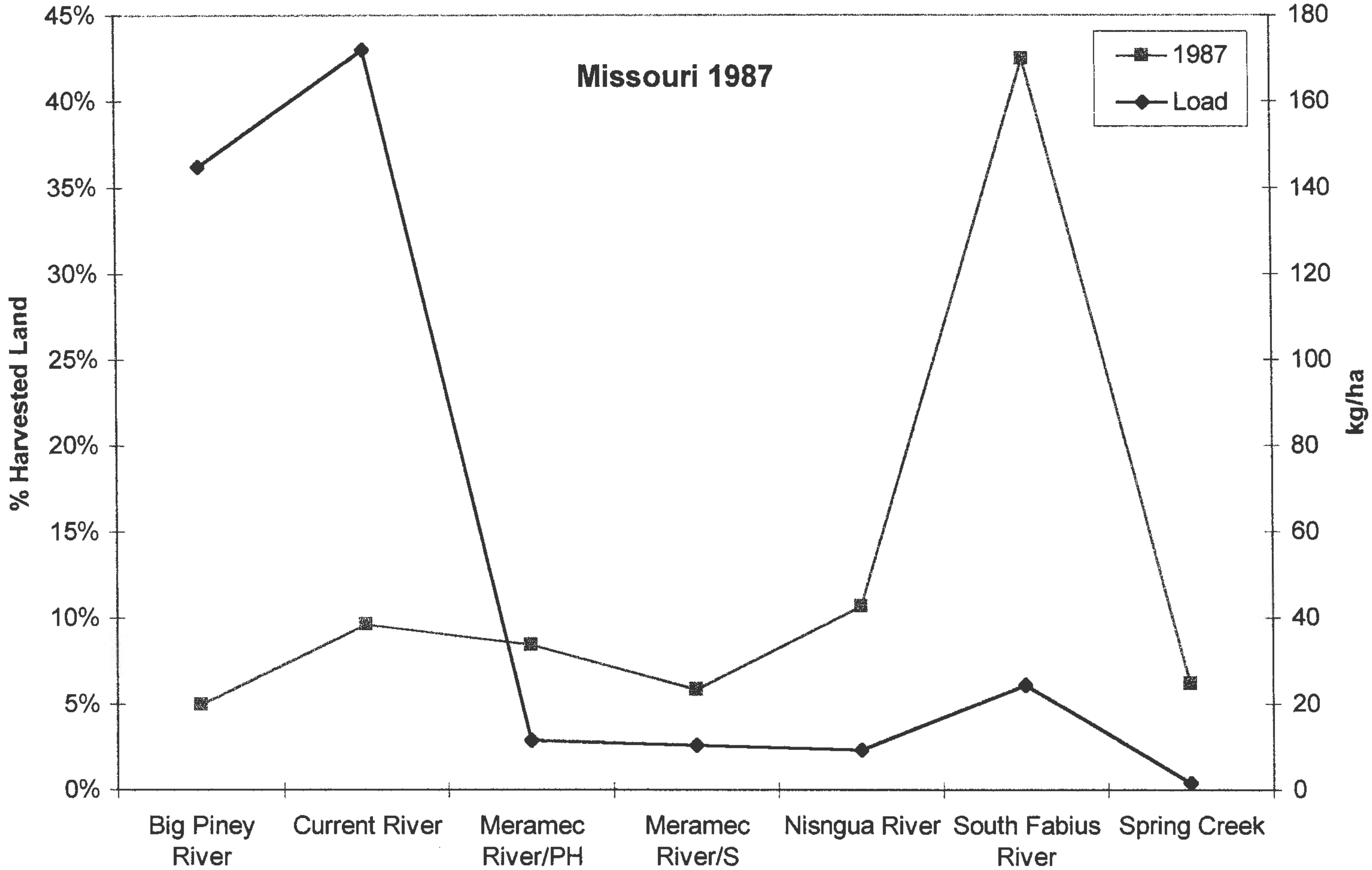


Figure 75. A Missouri comparison of the percent harvested land to the amount of N that was lost in 1987.

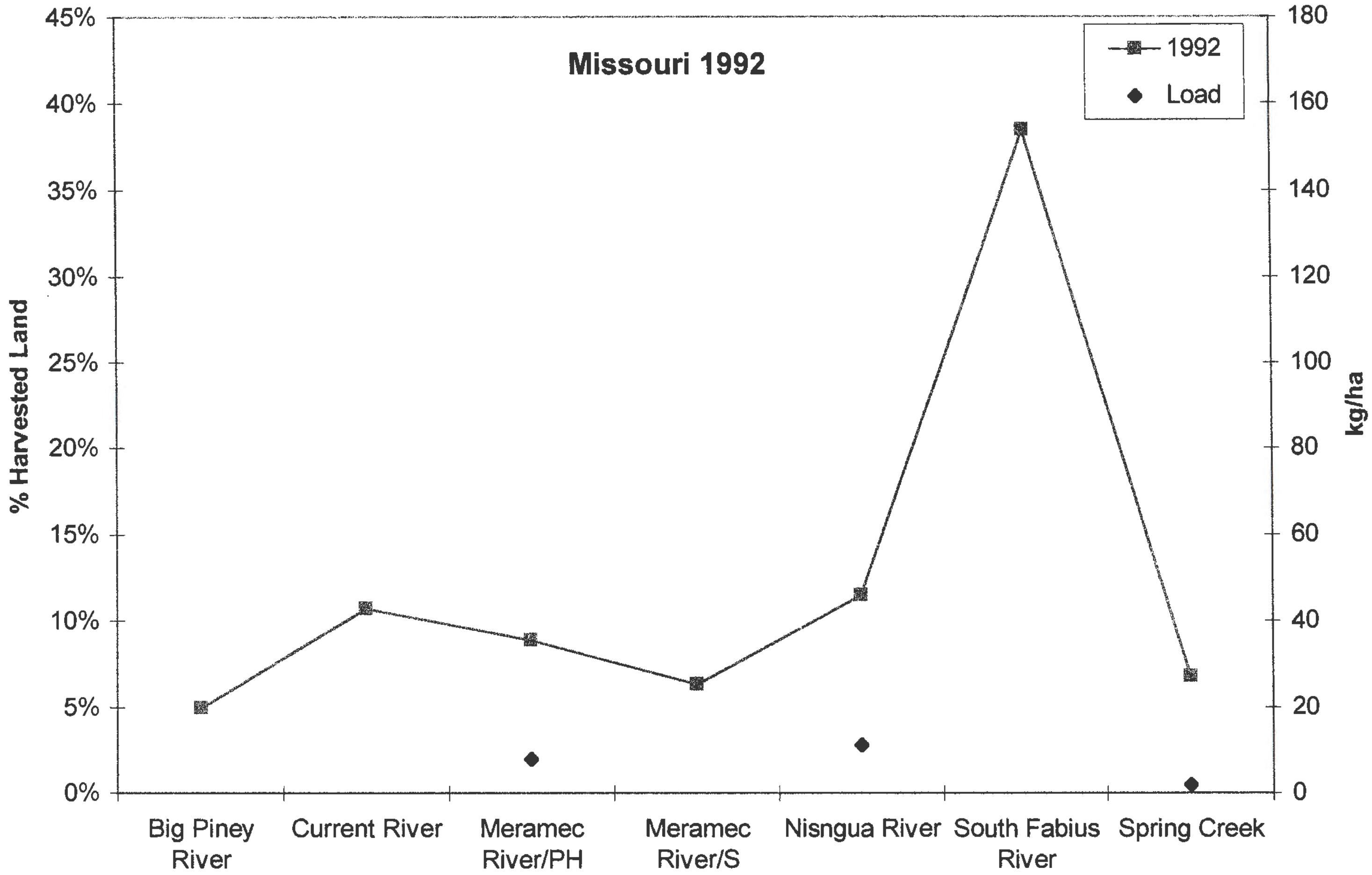


Figure 76. A Missouri comparison of the percent harvested land to the amount of N that was lost in 1992.

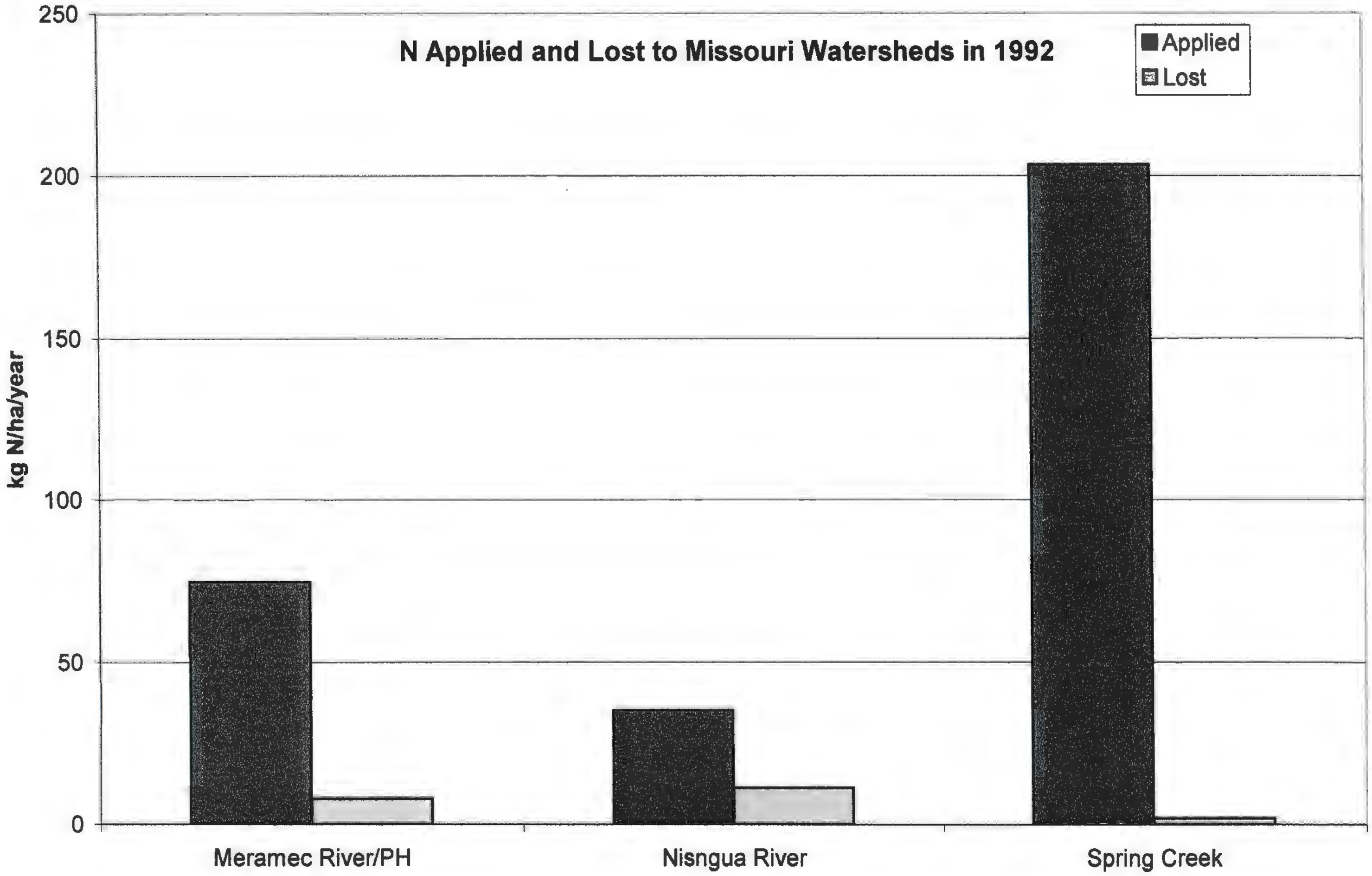


Figure 77. Nitrogen fertilizer applied compared with the amount of nitrogen lost for Missouri in 1992.

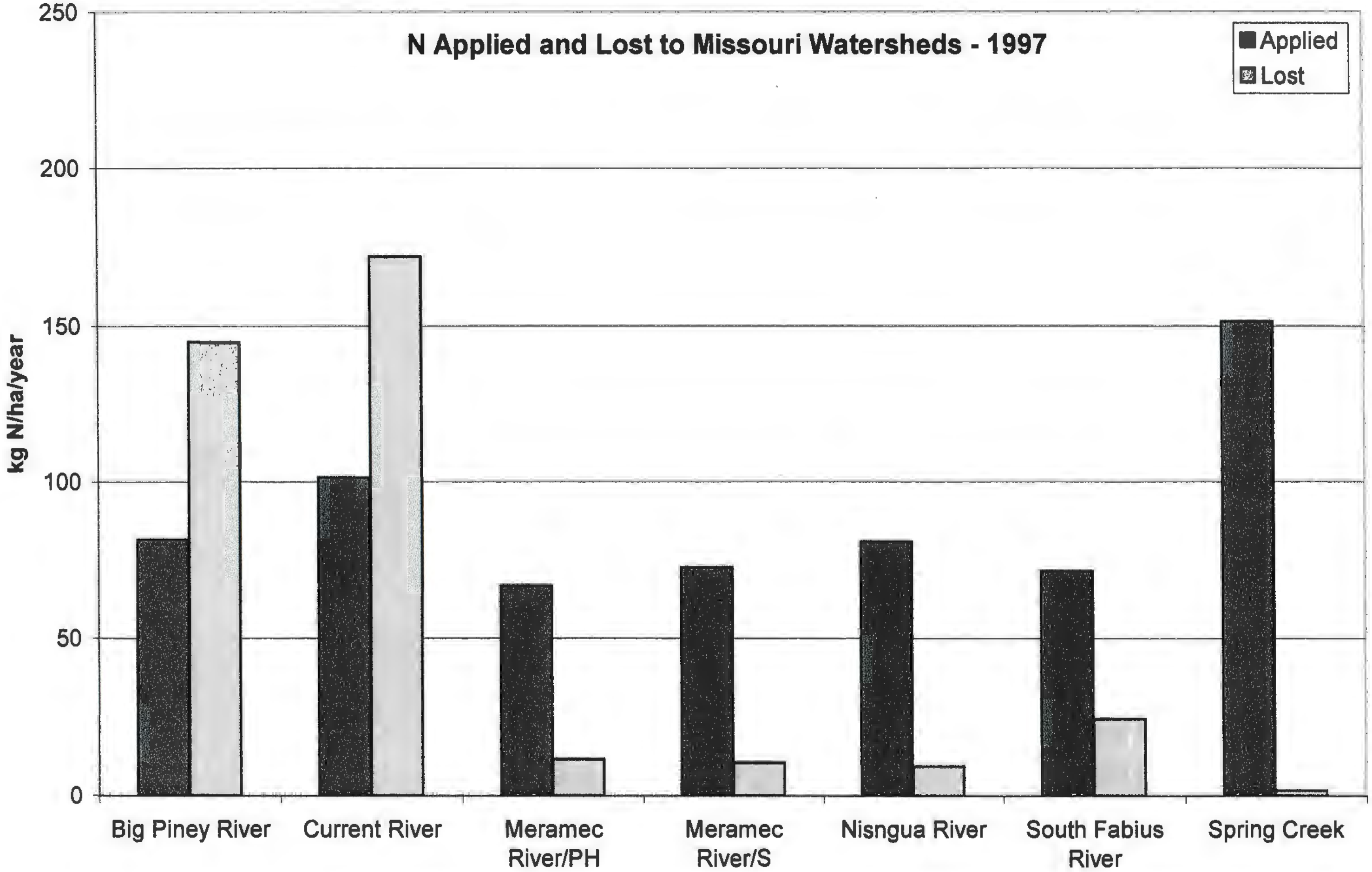


Figure 78. Nitrogen fertilizer applied compared with the amount of nitrogen lost for Missouri in 1997.

5.7 Comparison Among Midwestern States

The objective is to examine the levels of N in the rivers throughout the Upper Midwest that may have led to increased levels of hypoxia in the Gulf of Mexico. Iowa and Illinois contribute large N loads into the river, which can be explained by the large amount of cropland and a high fertilizer application rate. Missouri has a lower application rate but still has a relative large amount of N load in these watersheds. Even though Minnesota and Wisconsin were not intensively evaluated in this study, there is a pattern of lower N fertilizer use and lower N concentrations in the rivers. If we examine watersheds on a state by state basis, no consistent pattern emerges from the percent of N found in the rivers and streams. This could be accounted for by little change in the fertilizer applied. There are four factors that influence the amount of N in water: precipitation, flow, harvested area, and applied fertilizer. The amount of change throughout these watersheds and states exhibits no consistent relationship among any of the factors (Fig. 79 and Fig. 80). This cloud of data illustrates that there is not a relationship between harvested land area or the amount of applied fertilizer with N load loss from the watersheds. Consistent patterns and relationships are needed to help policymakers understand the potential impact of N management plans. The lack of consistency among the relationships of all the factors involved, a policy that incorporated all of them would be necessary to develop best management practices for these watershed areas. With nutrient management plans, all these factors are considered. As one sees, reducing one factor is not going to reduce the amount of N found in the waters. The final objectives of this study will examine the action that needs to be taken on N management that could lead to more consistent reduction in N loads.

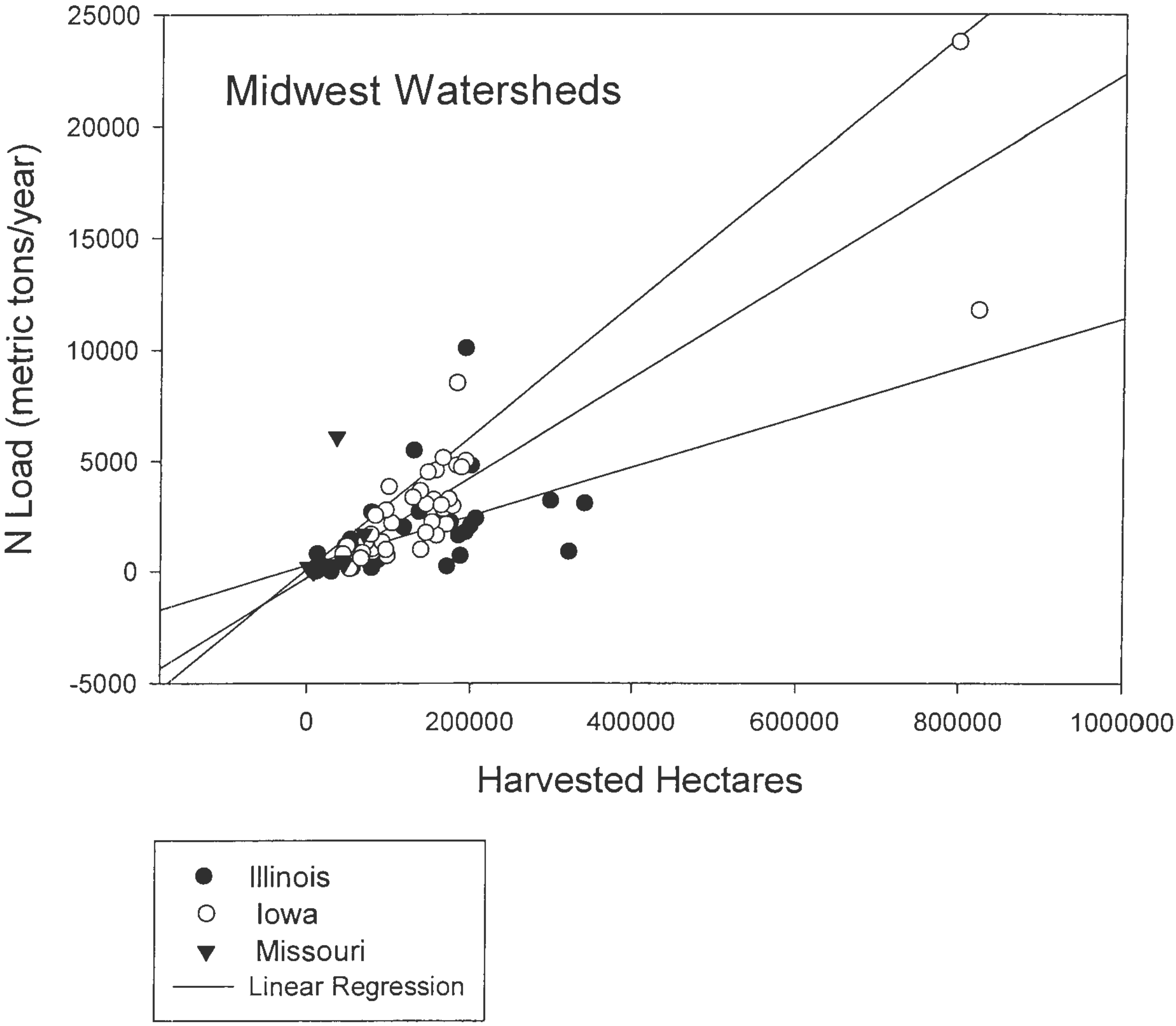


Figure 79. Linear regression of Illinois, Iowa, and Missouri's watersheds with a comparison of harvested hectares to the amount of N load.

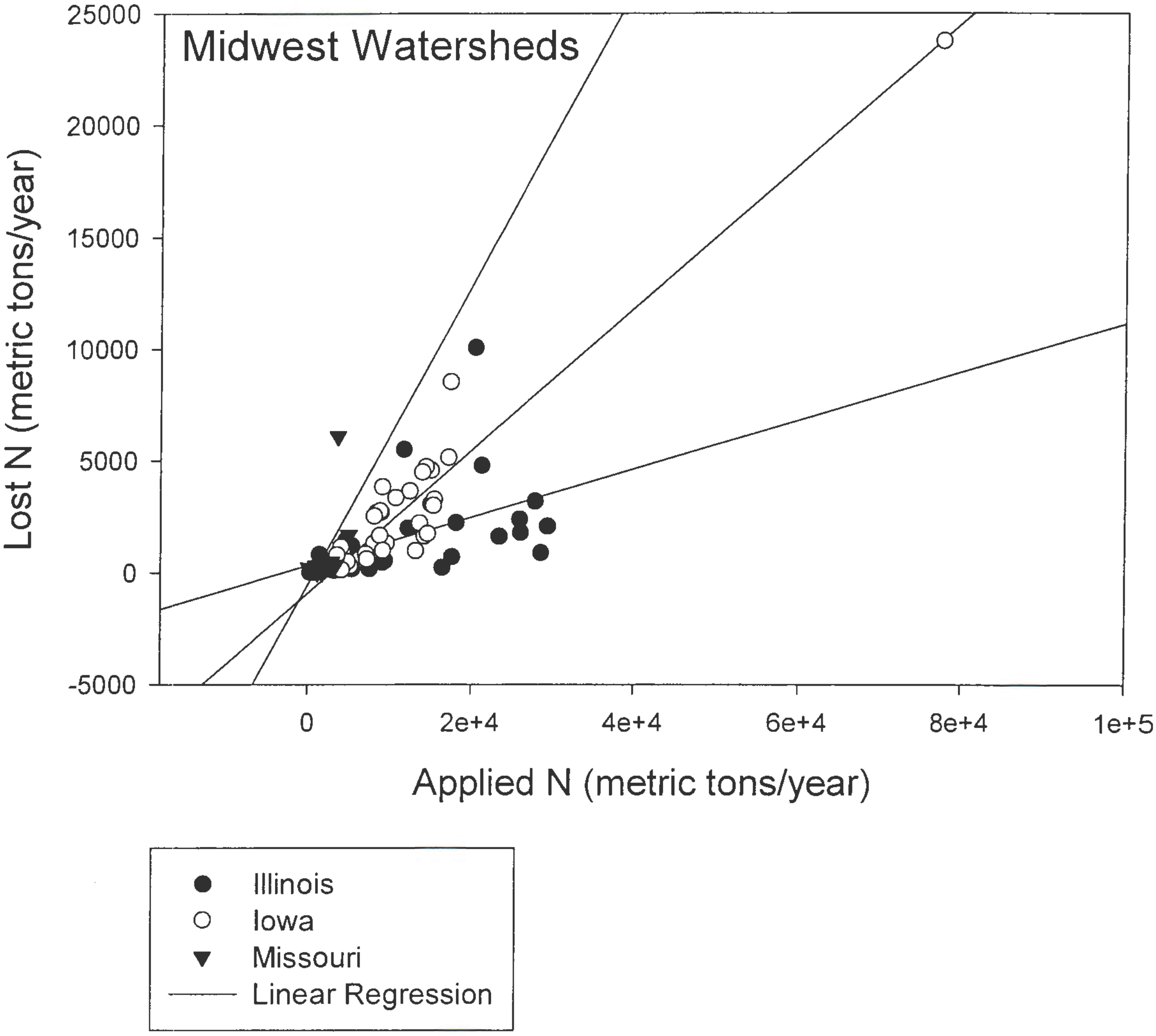


Figure 80. Linear regression of Illinois, Iowa, and Missouri's watersheds with a comparison of applied N fertilizer to the amount of N load.

CHAPTER 6: CURRENT FEDERAL AND OTHER STATES REGULATIONS

The purpose of this chapter is to compare Iowa's policies and programs with those of other states. This chapter will also discuss the Federal programs and regulations that have been tried in the past and current regulations.

6.1 Federal Programs ~ Voluntary

The U.S. government also offers voluntary programs to the producers along with the state programs. Most of these plans have financial assistance for those producers that implement best management plans. The Rural Clean Water Program, which was established under the Clean Water Act of 1977, allows for financial assistance to landowners to control the movement of agricultural chemicals.

6.2 Federal Regulations ~ Involuntary

The federal government does not have direct regulations on fertilizer use. There has been an indirect attempt for nonpoint source pollution regulations. Such as the Clean Water Act of 1987 added a section requiring individual states to complete an assessment of nonpoint source pollution areas. In Iowa this has been completed by the DNR.

Another program that is being established is the National Strategy for the Development of Regional Nutrient Criteria. This is being implemented by the Environmental Protection Agency (EPA). The goal is to have every state adopt criteria for the amount of nutrients that are allowed in the water by 2003 (EPA, 1998). This type of regulation is dependent on the loss of N not on the regulation of the amount applied.

6.3 Other States

There have been attempts by the states to adopt nutrient management plans for N. These states have had these plans for a few short years so the data is not out of whether these involuntary plans are reducing the amount of N that is detected in water bodies.

6.3.1 Maryland

The state of Maryland adopted the Water Quality Improvement Act of 1998 on May 12. The state has required that anyone who operates a farm and uses a chemical fertilizer must have N and phosphorus based plan by December 2001. The producer then has until December of 2002 to implement the nutrient management plan (NMP). In Maryland a farm is considered any agricultural operation that has $2500 gross annual income or eight animal units. These NMP have to be developed by a management consultant certified through the Maryland Department of Agriculture. The state does allow for some cost-share programs to implement the plans.

6.3.2 Pennsylvania

In the spring of 1993 the state of Pennsylvania passed their Nutrient Management Act. This law requires a regulatory examination of farm-level nutrient plans. The Pennsylvania State Conservation Commission oversees and regulates the Nutrient Management Act. This act was prompted to manage manure nutrient application.

6.3.3 Delaware

In June of 1999, Delaware passed the Nutrient Management Program. Crop producers are effected if they apply fertilizer to more than 10 acres of land. The goal of Delaware's Nutrient Management Program was to obtain the maximum economic return from nutrient resources while protecting the environment. Starting this past July the plans were to be reviewed and the act is to be fully implemented by 2007.

6.4 Nutrient Management Plans

The concept of NMP is not new nor does it relate entirely to hypoxia. NMP are plans that are established by a certified person according to the state. Each plan can be established to fit the state needs. Generally, a plan can include:

- Soil erosion control
- Minimum distance from chemicals and manure storage and handling areas to water sources
- Soil testing
- Manure testing
- Yield goals for the land receiving nutrients
- A timetable for implementing the plan

These examples are from the Maine Nutrient Management Act (State of Maine, 1997). Every plan can be different to meet the differences in the watersheds. NMP may also have sections that consider other conservation agricultural practices. The benefits are to the producer, society and to the environment when NMP are establish on a state level. The question that raises is whether these are feasible in Iowa. Iowa is a different state than eastern states and it seems all that is being done in the heavily cropped areas relates to manure use not commercial fertilizer use. It is possible for these states with high N losses to implement nutrient management strategies to benefit the Midwest agricultural areas.

CHAPTER 7: CURRENT IOWA POLICIES AND PROGRAMS

The purpose of this chapter is to look at what the state of Iowa has done or is doing for N reduction in relationship to Hypoxia in the Northern Gulf of Mexico. After analyzing the amount of N that is found in the rivers a need for reduction is seen. This reduction can be done in many ways. The first is to examine the current regulations and programs for N reduction.

7.1 Current Regulations for Iowa

There are currently no regulations regarding N fertilizer use, but efforts have been made through education to encourage voluntary best management practices.

7.2 Programs that are Statewide

With the no limitation on the amount of N fertilizer applied throughout Iowa, there have been state agencies that have introduced programs that might reduce the amount of N that is being lost.

7.2.1 NRCS

The Natural Resource Conservation Society (NRCS) has produced many pamphlets and handouts to aid producers in N reduction in water sources. Some of these are general programs as is grass waterways, wetlands, and better soil testing. These programs have been in effect for years but we are still seeing a high amount of N in the rivers throughout Iowa.

7.2.2 Department of Natural Resources

The Iowa Department of Natural Resources has also had N management aid throughout Iowa similar to the NRCS. One program that is unique to the DNR is the

Nonpoint Source Program through the DNR's Water Quality Bureau. The objective of this DNR program is to assess the waters of Iowa for areas with nonpoint source pollution problems. There is a list available with these areas listed and also brochures that explain the issue. This program also sets up a voluntary state cost-share program. It uses up to 85% of the cost-share appropriation each year to pay for up to 50% of the installation costs of permanent soil and water conservation practices.

7.2.3 Private Industry Programs

Programs are being developed by private industry throughout Iowa to foster nutrient management. One newly formed group called Agriculture's Clean Water Alliance (ACWA) was organized to promote more efficient nutrient use and prevent nutrient loss from the Raccoon River watershed. This organization is a combination of farmers and businesses working together throughout this organization to help reduce N loss without the use of regulations.

The Iowa Farm Bureau, American Agrinsurance and IGF as insurance companies and the Iowa Department of Economic Development formed an insurance consortium to evaluate a program. The goal would be for N fertilizer reduction that could be beneficial to the field as well as to the producer. This N deficit insurance policy could aid producers to reduce the amount of N that is and this would reduce the amount of N that is lost to rivers throughout Iowa.

7.3 Nitrogen Reduction at the State Level

Throughout the state of Iowa there has been efforts made for N management. This can be done through a reduction in loss or a reduction in the amount that is used. The different state agencies have shown that they can come together to help reduce this increasing problem without regulations. The N loss problem will be easier dealt with if the states will adopt these voluntary methods.

CHAPTER 8: POTENTIAL FOR IOWA

The scope of this chapter is to look at the implications for N reduction in Iowa. The idea of a nutrient management plan will also be investigated. Iowa was narrowed down from the other states as the target for nutrient management because of the focus of the Gulf of Mexico hypoxic area. If Iowa implemented NMP it would be a driving force for other agricultural areas to adopt mandatory NMP.

8.1 View from Iowa

There have been several surveys conducted throughout the Midwest to examine N loss and reduction. The Iowa Environmental Council commissioned a poll based on the public attitudes towards water quality. According to this survey of Iowans, 67% of the people surveyed agreed that more should be done to regulate water quality (Lasley and Padgitt, 1997a). This same survey, 40% of Iowans showed concern that agricultural use of fertilizers was the source of a great deal of water pollution (Lasley and Padgitt, 1997b). The survey was done in 1996 and 1986 this gave a comparison of 10 years. In 1996 the people's opinion for favoring restrictions on farm fertilizers was 78% (Lasley and Padgitt, 1997c).

8.1.1 Agro-Oceanic Nutrient Flux Center

Iowa State University through the leadership of Professor John Downing has submitted a proposal for the Agro-Oceanic Nutrient Flux Center. This center would be established as a joint effort from Iowa State University, Louisiana State University, and the Louisiana Universities Marine Consortium, if the funding becomes available. The goals of the center would be to summarize the knowledge on the nutrient flux issue, identify and fill research gaps, and listen to stakeholders to help implement effective and efficient nutrient management methods.

As a part of the proposal for this center a survey was conducted by Professors Steve Padgitt and John Downing. They surveyed the people of the Mississippi River Basin and individual states. The basin-wide survey results are as follows. When asked "if water pollution from agricultural sources is a problem," 54% of those surveyed said that is was somewhat serious of a problem and 26% said it was a very serious problem (Downing and Padgitt, 1998). Of the Iowans surveyed 58% said it was a somewhat serious problem and 29% said that it was a very serious problem (Downing and Padgitt, 1998). When asked "if they had ever heard of Hypoxia," 11% of the Basin-wide surveyed responded yes and 13% of Iowa responded yes (Downing and Padgitt, 1998). After explaining Hypoxia the people were asked "how important they felt this problem was," 67% in both the Iowa and basin-wide survey said it was very important (Downing and Padgitt, 1998). The survey also asked "what possible steps should be taken to address this issue." When asked if "education to teach farmers about Hypoxia would be effective," 88% of the basin-wide surveyed said it would be effective with 89% of Iowans surveyed saying that education would be effective (Downing and Padgitt, 1998). Another possible solution that was addressed was limiting the amount of fertilizer used on farms and 67% of the basin and 72% of the Iowans agreed that it would be effective (Downing and Padgitt, 1998).

8.2 Past Experience with Voluntary Programs

Producers have been implementing voluntary programs for years. The most important idea is whether this past experience with voluntary programs worked. There is a higher usage of fertilizer now, producers are implementing some programs, but there is still a high amount of N detected in the waters of Iowa. It is hard to say if these voluntary actions have reduced the amount of N that is lost. Voluntary programs have not reduced the amount of fertilizer applied as the current programs target the amount of runoff.

8.3 Past Experience with Regulations

Regulations are seen to be the basis of life in America. The question here is whether this is right or if a reduction can be seen without adding new regulations. There have not been any past regulations on the amount of fertilizers that can be applied. This is seen as trouble because the regulation of nonpoint source pollution is nonexistent. It is hard to compare new regulations to old when there has not been any. Comparing to the point source pollution regulations then there could be a possible reduction in the amount of fertilizer applied, but does that necessarily mean a reduction in N concentrations in rivers.

8.4 Potential for Iowa to Implement a NMP

Throughout the surveys conducted with Iowans, it shows that Nutrient Management is needed as people are establishing this as an issue that needs attention. There seems to be support of nutrient management planning on a voluntary basis not through regulations as other states have done. The implementation of a NMP through voluntary actions would be beneficial to see if a reduction of N in the surface water will occur before a regulation is based upon NMP.

CHAPTER 9: CONCLUSION: WHAT THE FUTURE HOLDS

Modifying N load in water will require modification of current nutrient management practices. These results of N loadings and the aspects of regulating chemical fertilizers will aid in policy decision making.

9.1 NMP = N Reduction

This is extremely important as the concept of NMP for reducing N loss and hypoxia is studied. If a NMP becomes standard for producers in the coming years, will it lead to N reduction? This is vital to making regulations. A further study of the states that have implemented a NMP would be beneficial to see if a N reduction has occurred in those states. The time frame for N reduction could take years to see a difference in the amount of N concentration that is found in the waters of the U.S. Along with this is the point that not all states have N management regulations so a decrease in the N used in areas that share other water supplies where only one state has regulation will not cause a change in the amount of N detected.

9.2 Feasible Alternative to N Reduction

NMP are an alternative to N loss but are they a feasible alternative to the producer? The Iowans that have been surveyed have said that they believe we should protect our water from these nutrients (Downing and Padgitt, 1998). At this point the question is not if we should do something but what should be done. Our society believes that something needs done and that is where the policymakers are coming into the picture. If a NMP is the future of crop production then the best nutrient planning needs should be assessed. Since N loads are not uniform across watersheds and surely not across states then nutrient management planning need be done at the local level. The watershed is the largest area that could be managed as a whole. This way a blanket regulation is not applied throughout every state. Blanket regulations would lead to many producers over applying in watersheds that have too much and other that can not apply very much where needed.

There are two categories of nutrient management. The first is to control the nutrients on-site as the nutrient in being used. The other way is to manage the nutrient off-site before it reaches the water body. Some examples of on-site management that can be incorporated into a NMP is nutrient use reduction, reducing leaching, better timing of application, and reducing nutrient loss by using cover crops. Examples of off-site management include wetlands and buffer strips. By combining these practices with NMP a reduction in the nutrient loss could be seen and producers will also benefit by having the reduced risk of lost nutrients.

9.3 Iowa Nutrient Management Plan

The ideals and thoughts that have presented themselves throughout the research over the N loads into the Mississippi River Valley led the decision on NMP to be enforced as to the reduction of N loads. The ideal Iowa plan would be a state enforced Act that oversees producers who apply commercial and organic fertilizer to more than 25 acres. This would be based on other statewide implementation programs. An Iowa NMP would be best set on a watershed scale, using the 8 digit HUC's as the basis for the policy. These watersheds then would be decided by the Iowa DNR whether they were N sensitive areas. If an area has a N load excess already present in the water bodies a N reduction plan would be implemented by the producers of this watershed. However, if a watershed were not deemed N sensitive then the producers would need to plan for their use of chemicals, organic and inorganic.

Iowa's NMP would be certified by a NMP advisor that would oversee the implementation of these plans for Iowa. Specific areas of both types of plans would include soil testing – fall and spring, application and timing of fertilizers, topography, water bodies located in watershed and around individual fields, and also a list of management practices that are currently being used. The two plans would differ, as a N reduction plan would require a lesser amount of be used in these areas. However, the non-sensitive areas would have a plan in effect that would use management practices to reduce the amount N entering in the water body.

The costs of NMP would be fully supported by the State of Iowa legislature. NMP advisors would be trained at local educational meetings and could be producers or other technical staff in state agencies.

9.4 Future of an Iowa NMP

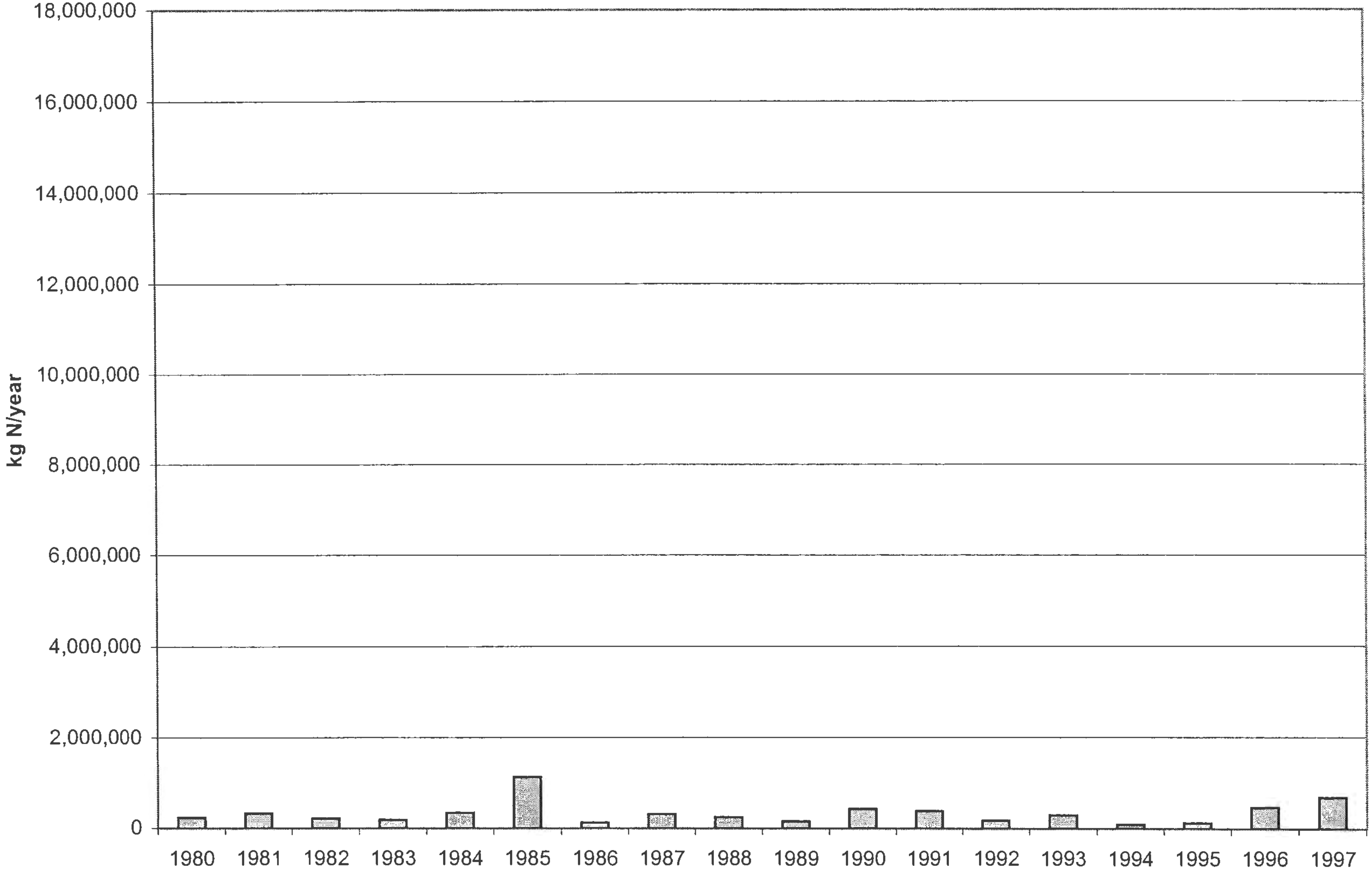
The implications of an Iowa NMP would follow the same lines that were discussed in earlier sections. By examining the factors that could effect the amount of N load in the MRV, a lack of consistency is the final result. This will in turn effect the implications of a plan. If the wrong factor were targeted then the amount of N reduction would be limited. However, if all factors are targeted the amount of N could foresee a reduction. The future of a NMP for Iowa revolves around these factors and thoughts.

A year to year variation throughout Iowa watersheds saw patterns in some watersheds where in some years if the majority of the factors were the same then the watershed stayed consistent. Looking across watersheds, the patterns become different as the amount of harvested land, type of land use, and applied N are variable. This is where the idea of a watershed scale base policy is helpful to target these watersheds that are different. Iowa's NMP, if targeting all these factors, would in effect see a reduction in the amount of nutrients in the water of the state and then reduce the nutrient levels downstream.

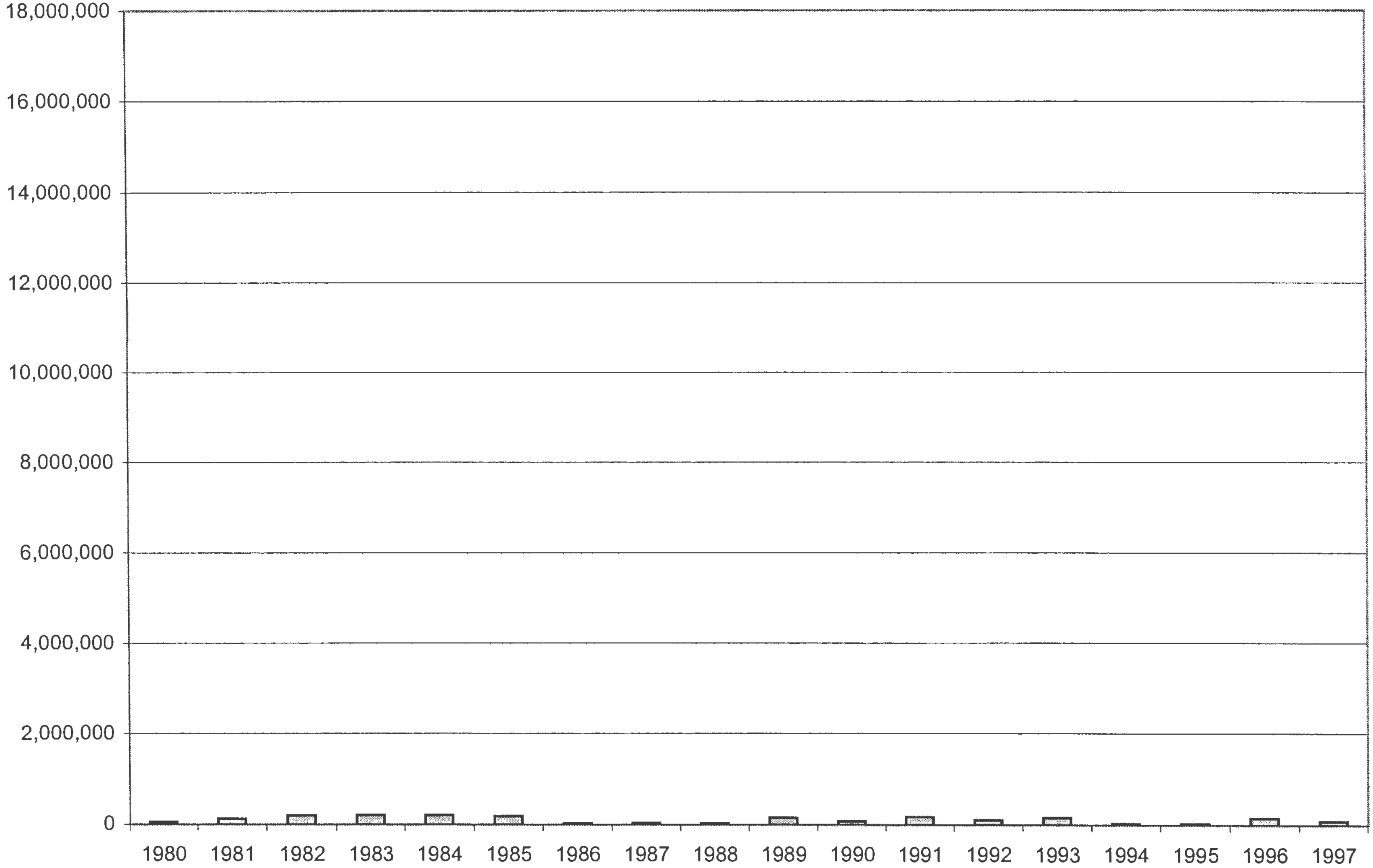
APPENDIX:

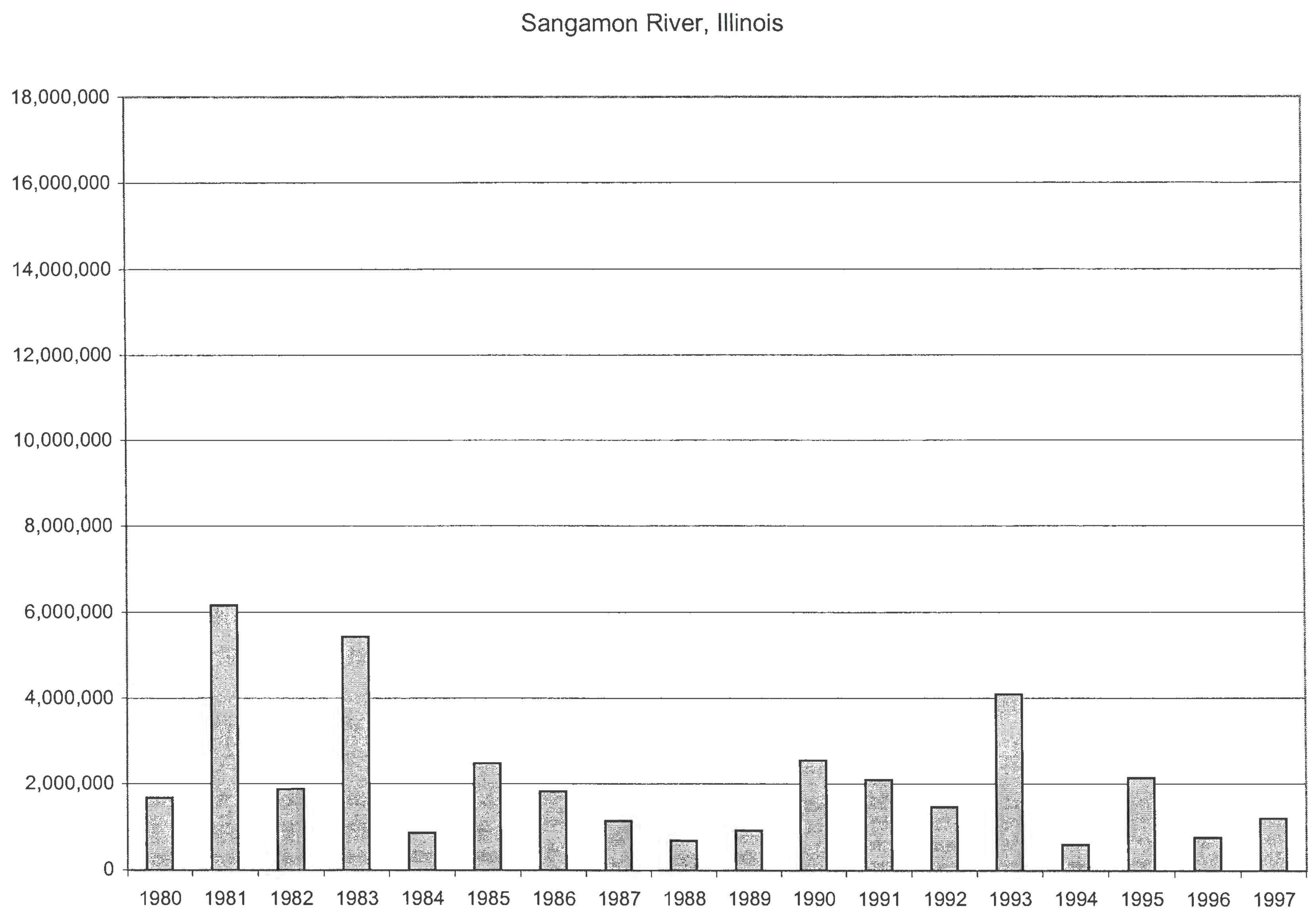
GRAPHS OF NITROGEN LOADS FOR WATERSHEDS STUDIED IN ILLINOIS, IOWA, AND MISSOURI

North Fork Embarras River, Illinois



Cache River, Illinois




Sangamon River, Illinois
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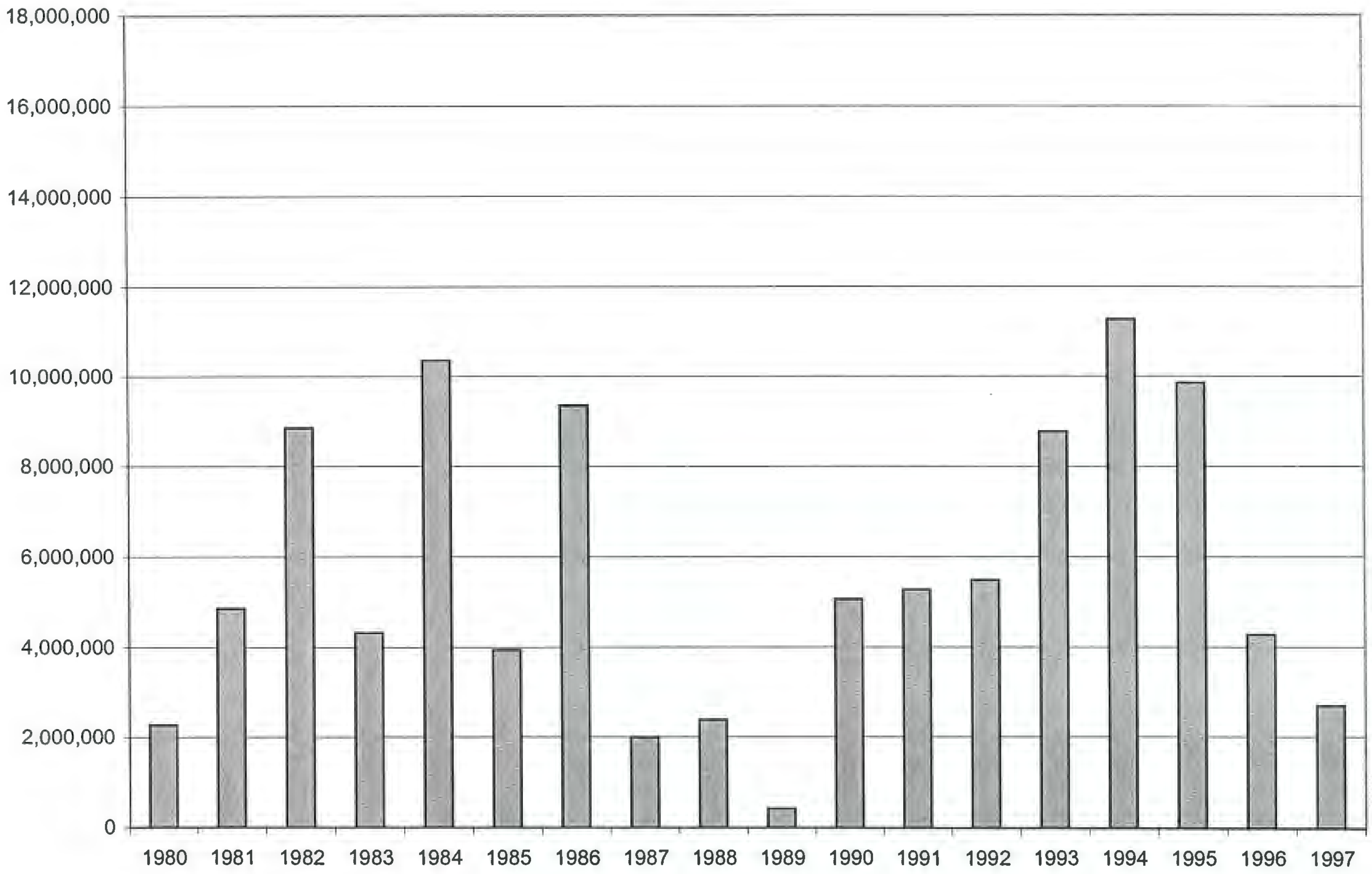
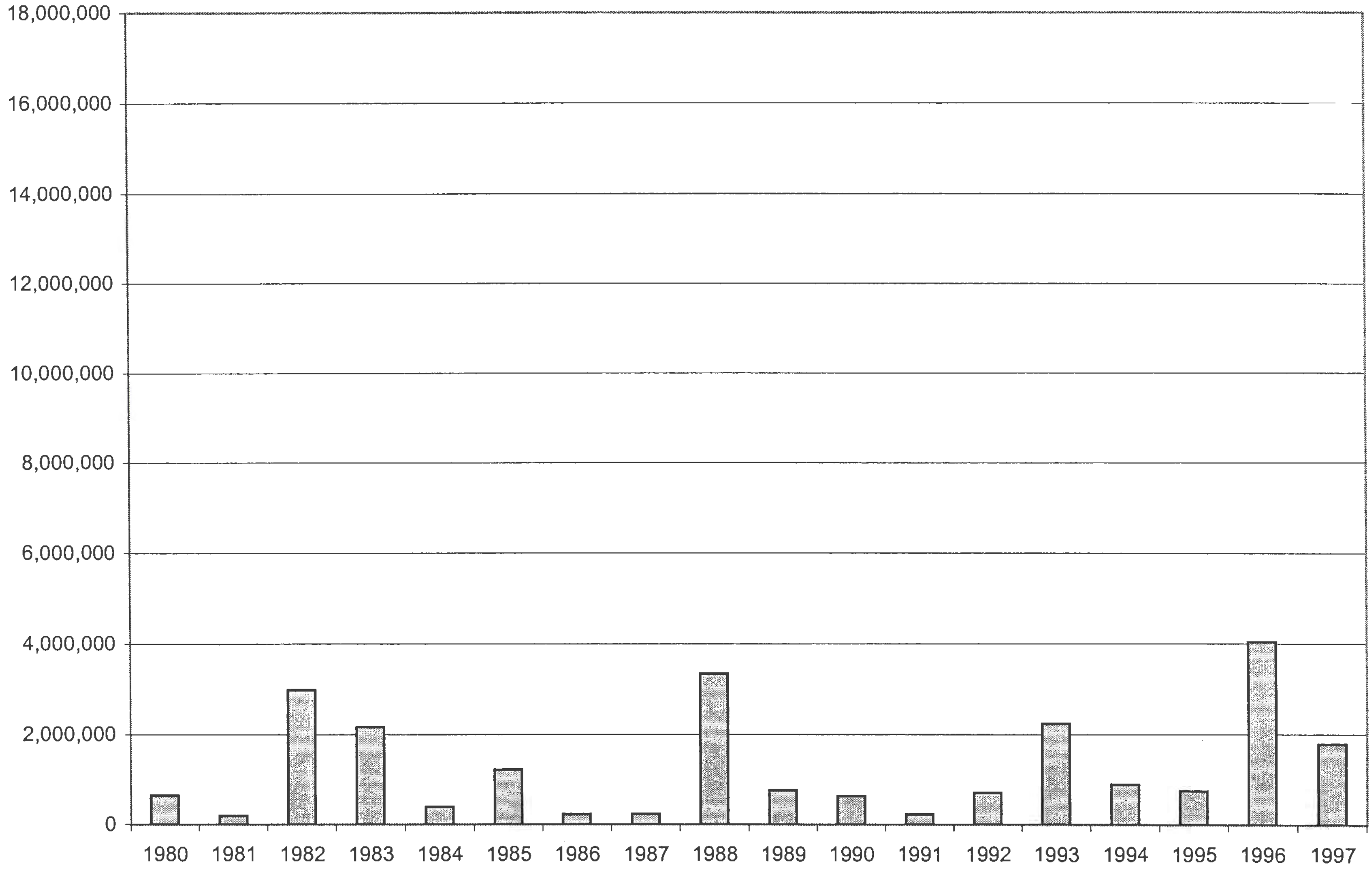
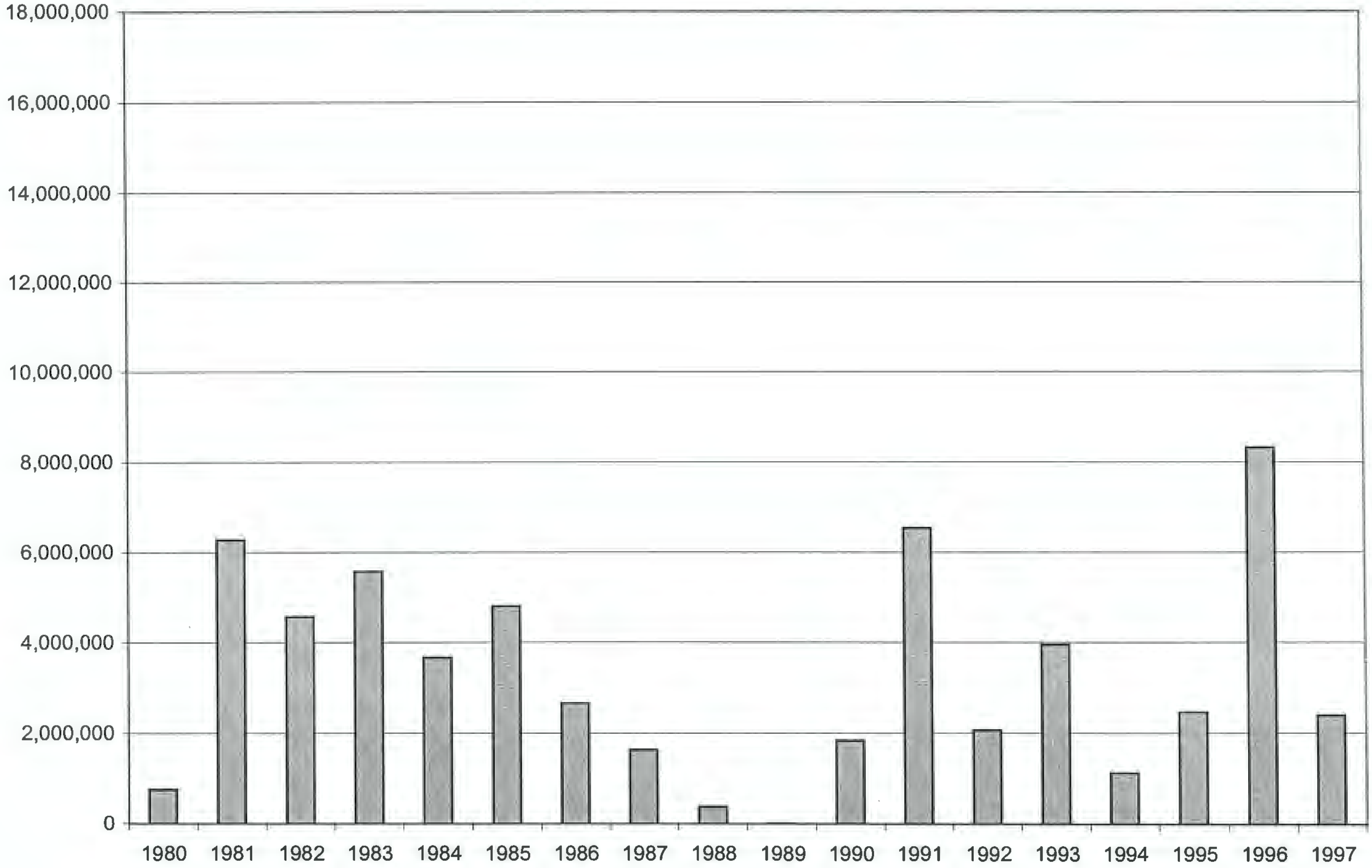
Spoon River, Illinois

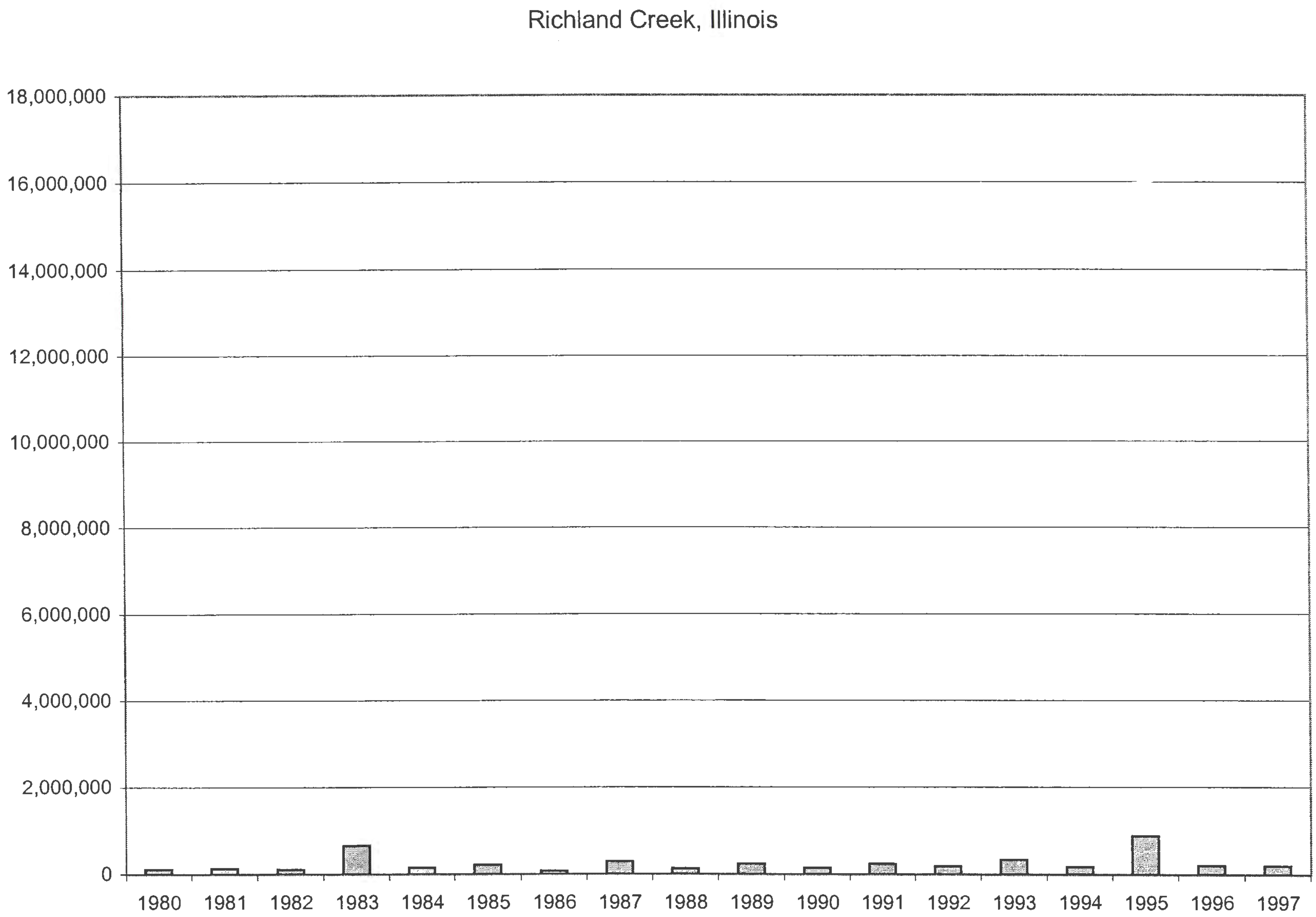


Little Wabash River, Illinois



La Moine River, Illinois




Richland Creek, Illinois
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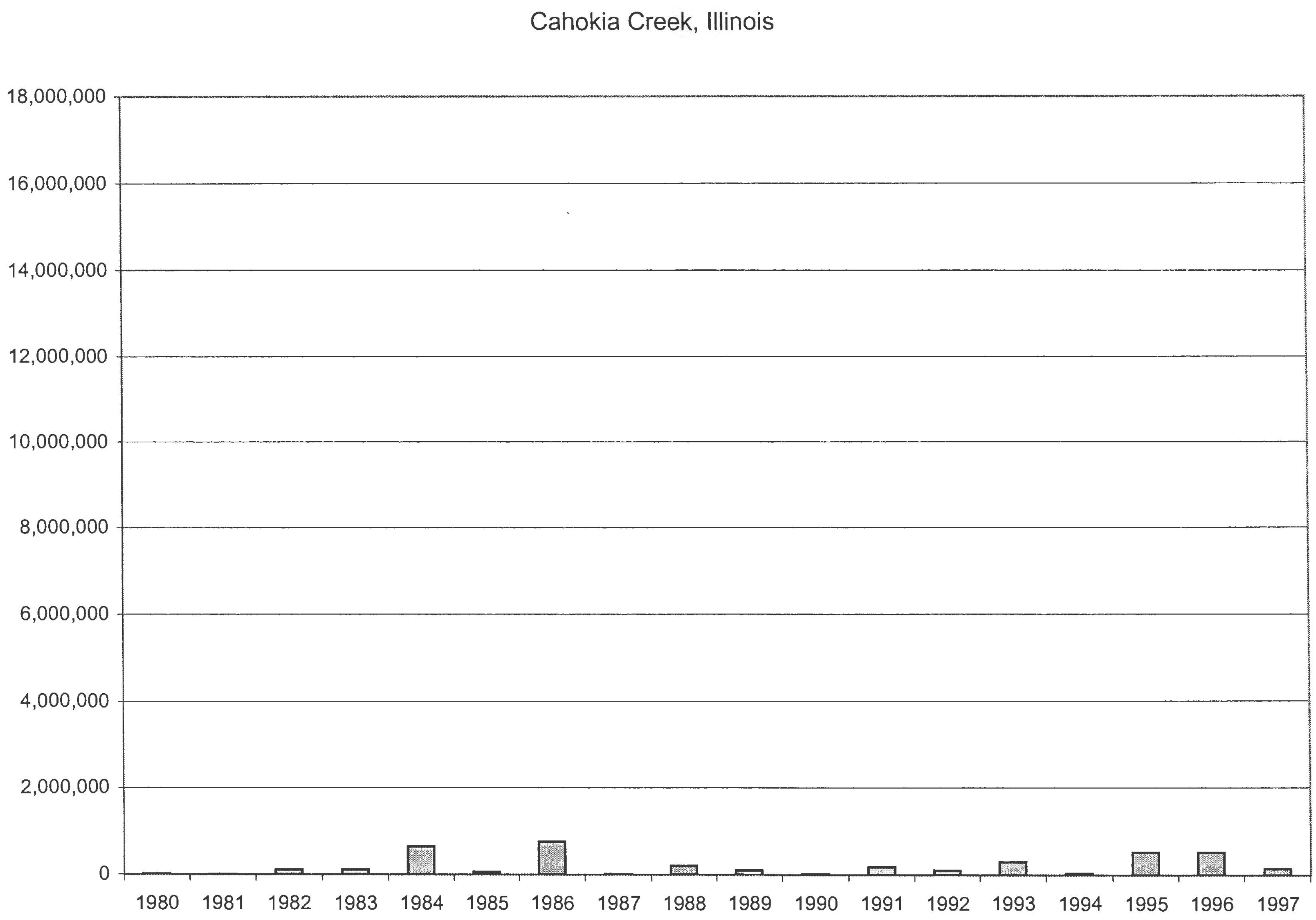
Cahokia Creek, Illinois
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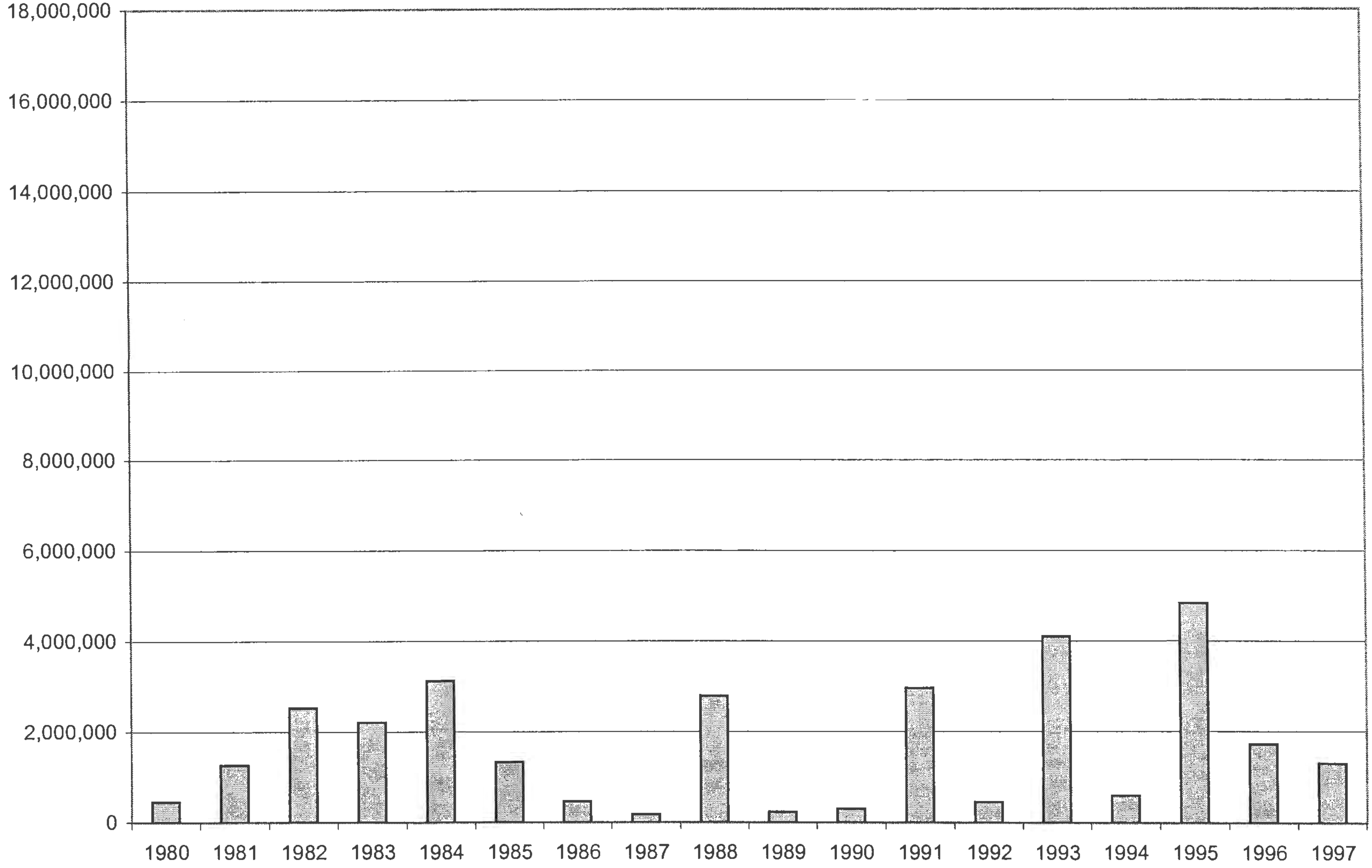
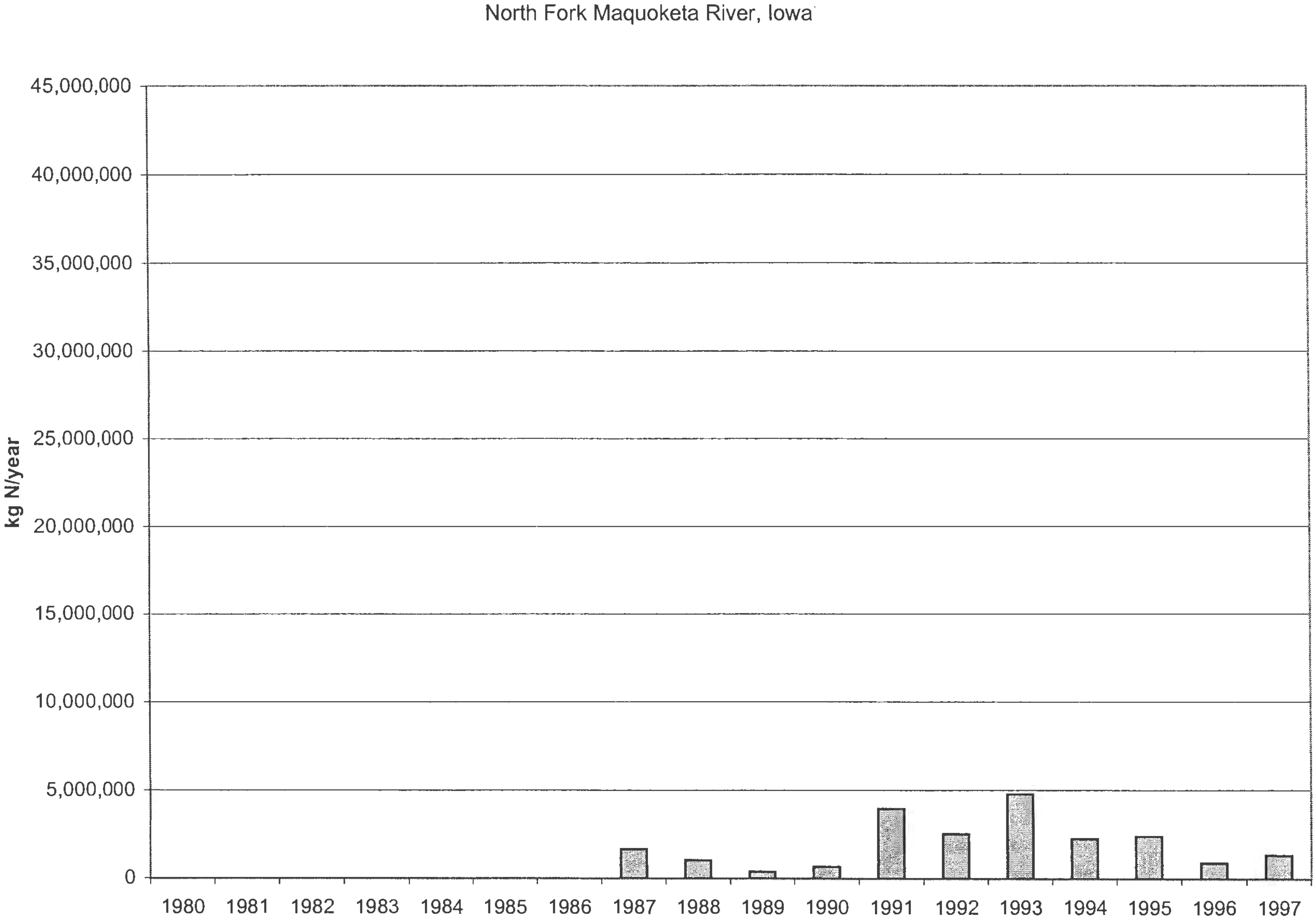
Macoupin Creek, Illinois




North Fork Maquoketa River, Iowa
kg N/year
45,000,000
40,000,000
35,000,000
30,000,000
25,000,000
20,000,000
15,000,000
10,000,000
5,000,000
0
1980
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1982
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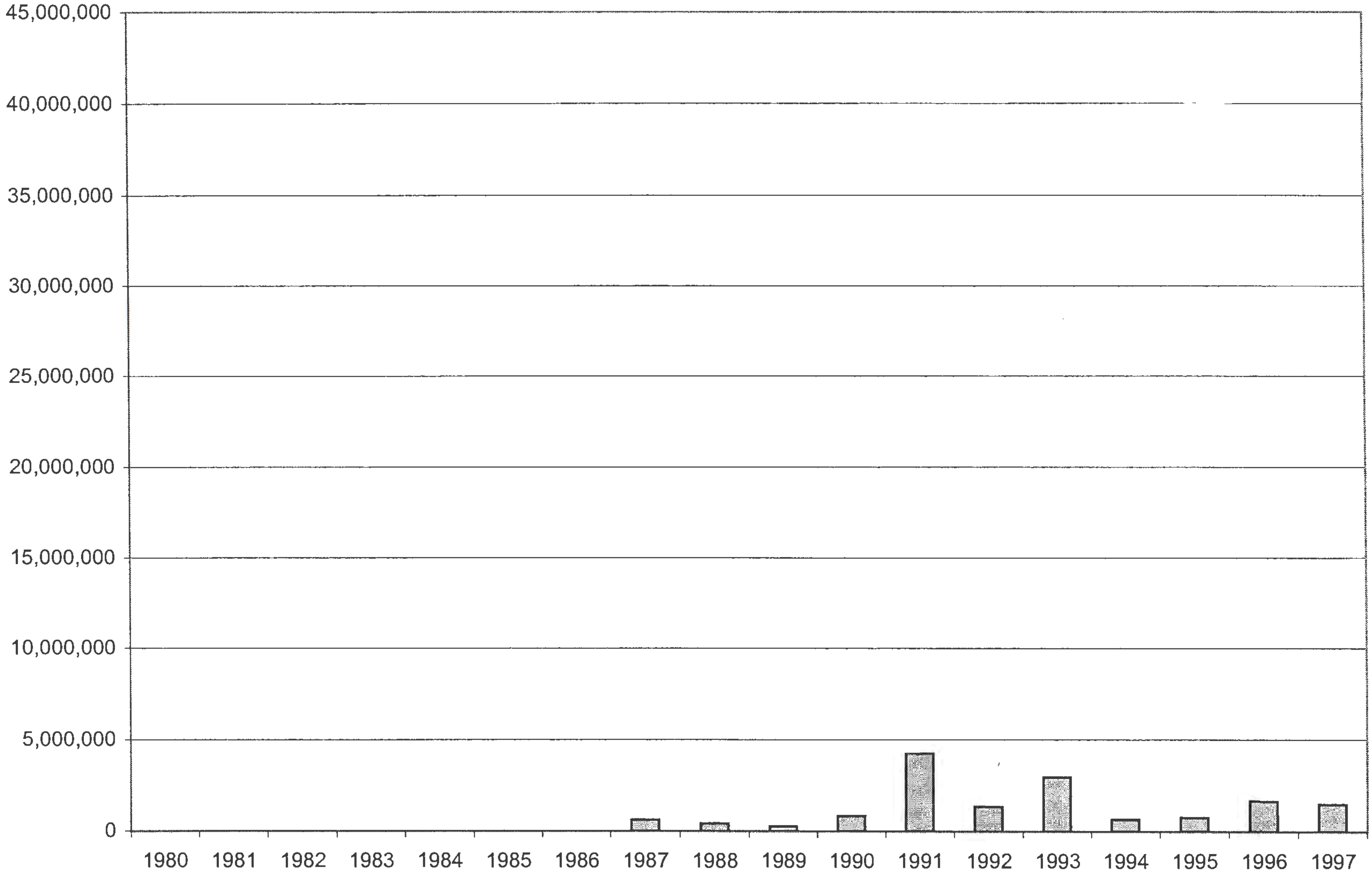
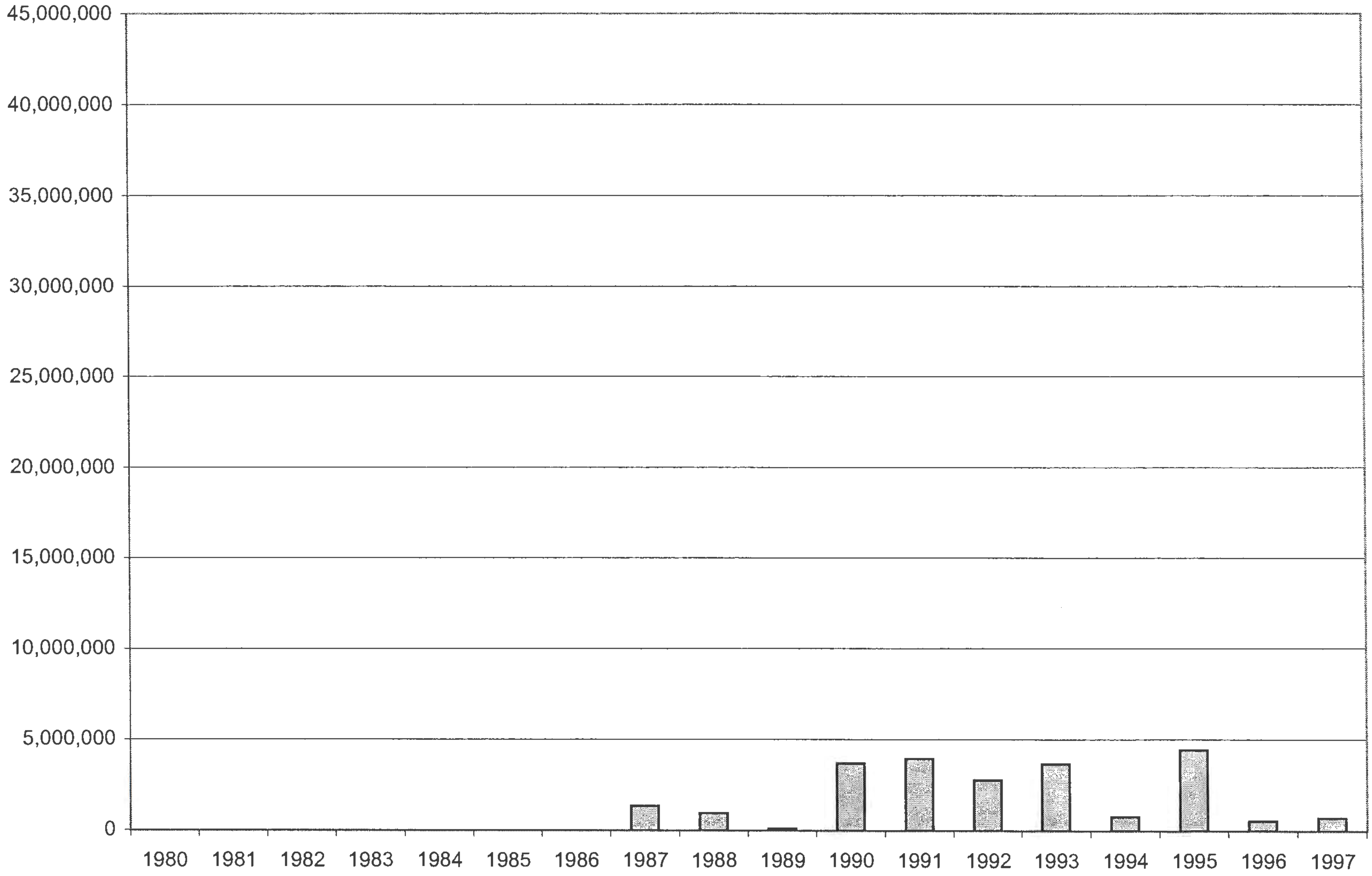
1991
1992
1993
1994
1995
1996
1997

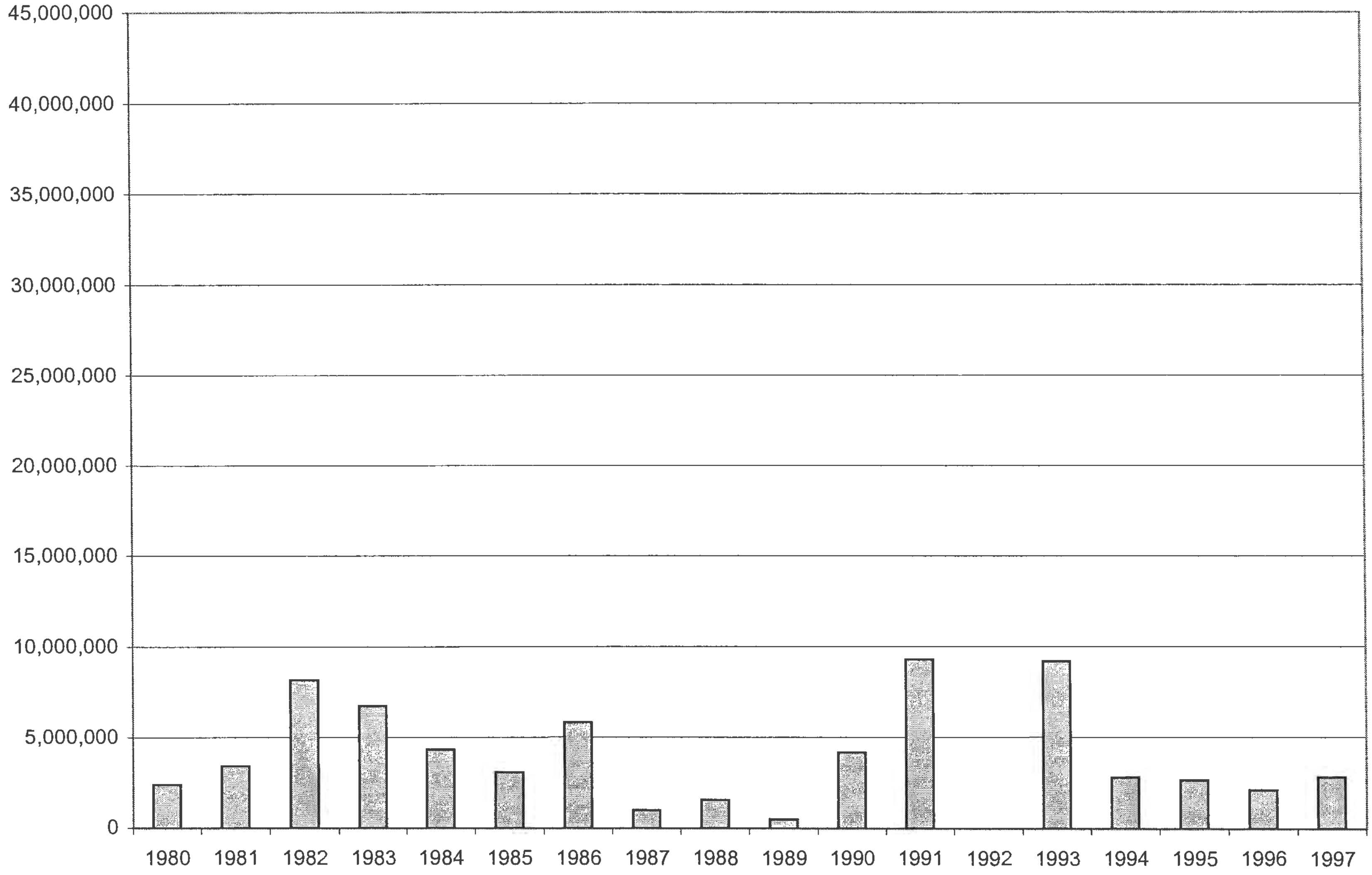
Volga River, Iowa



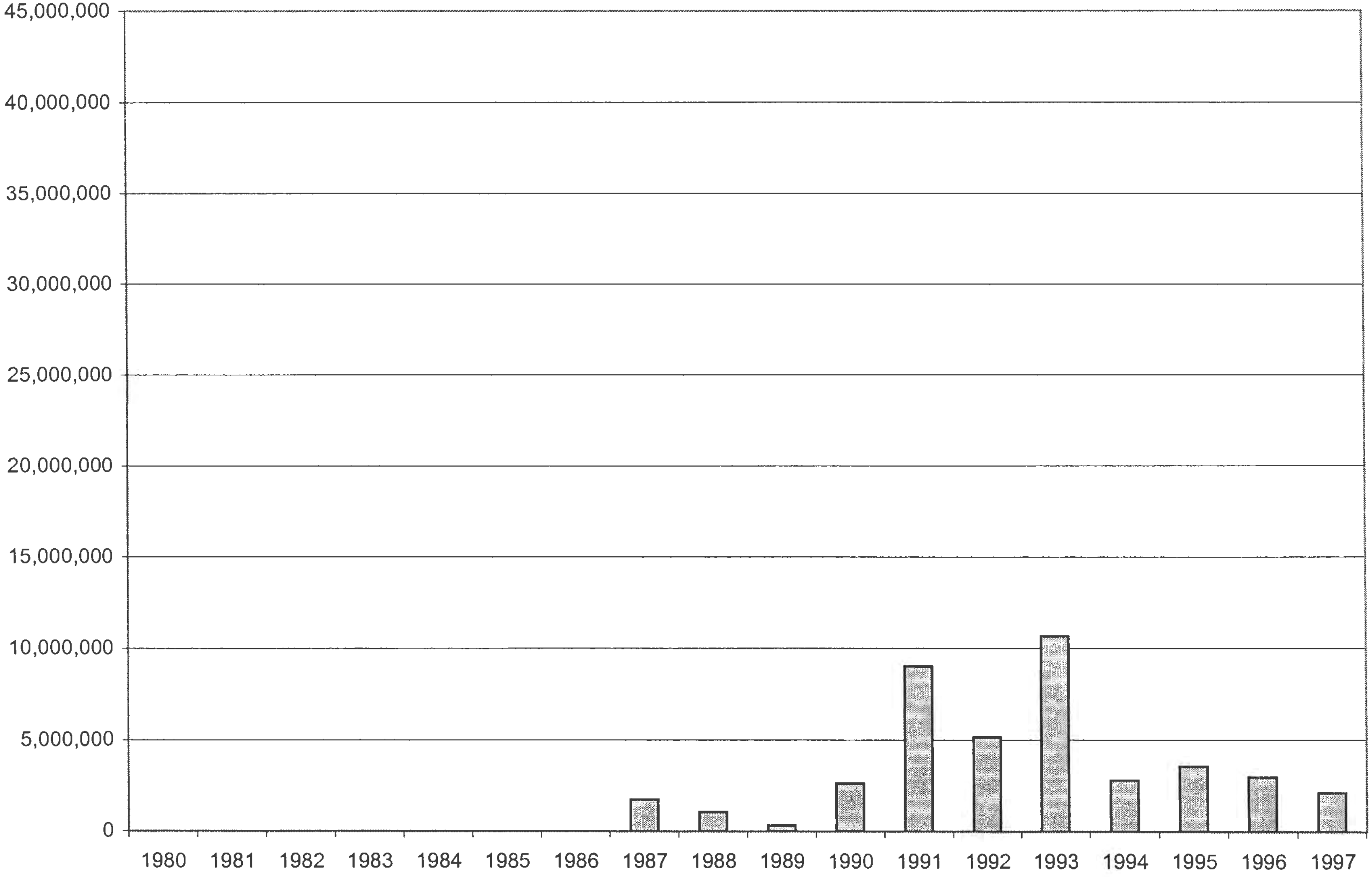
English River, Iowa



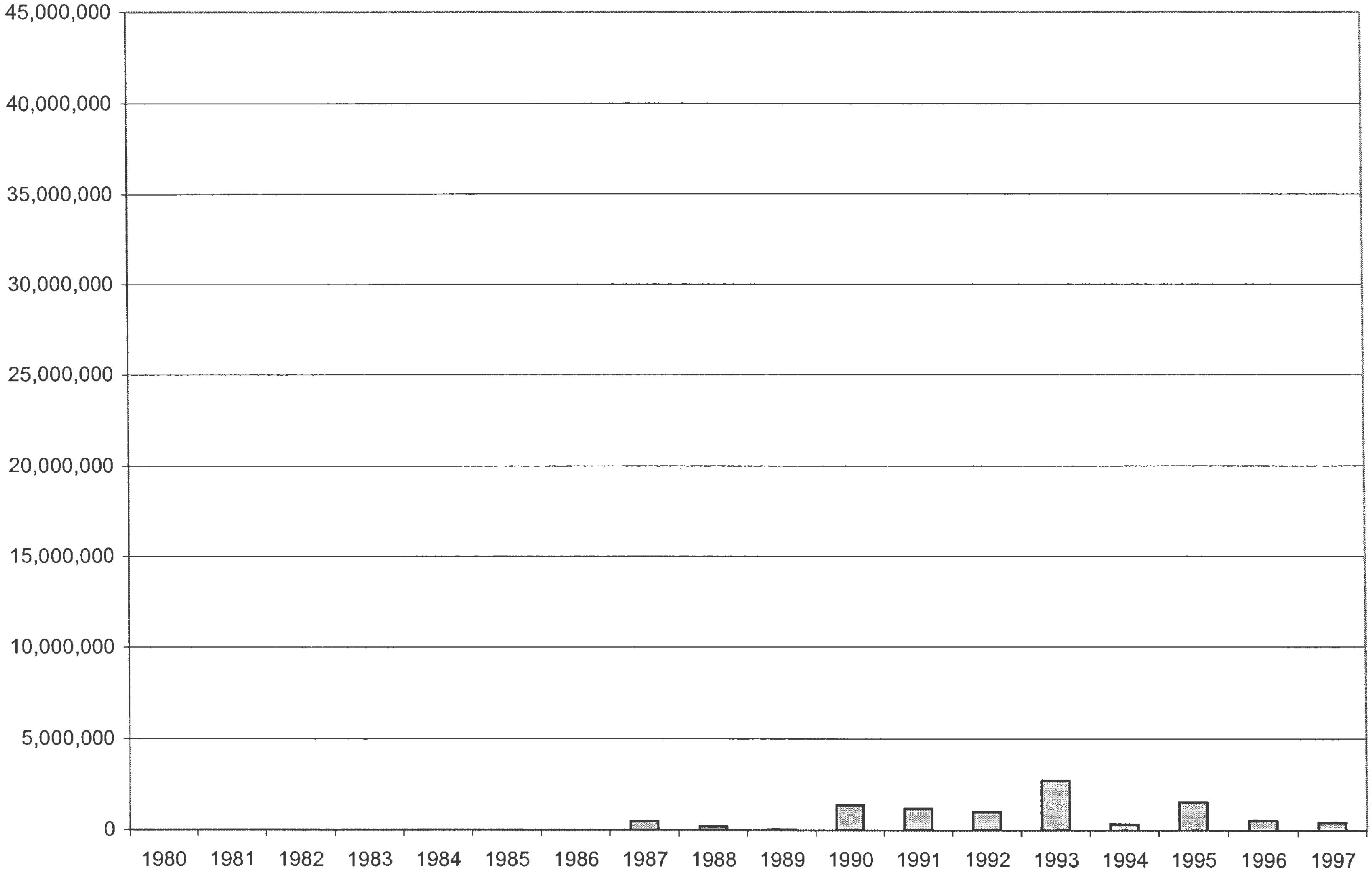
Cedar River, Iowa



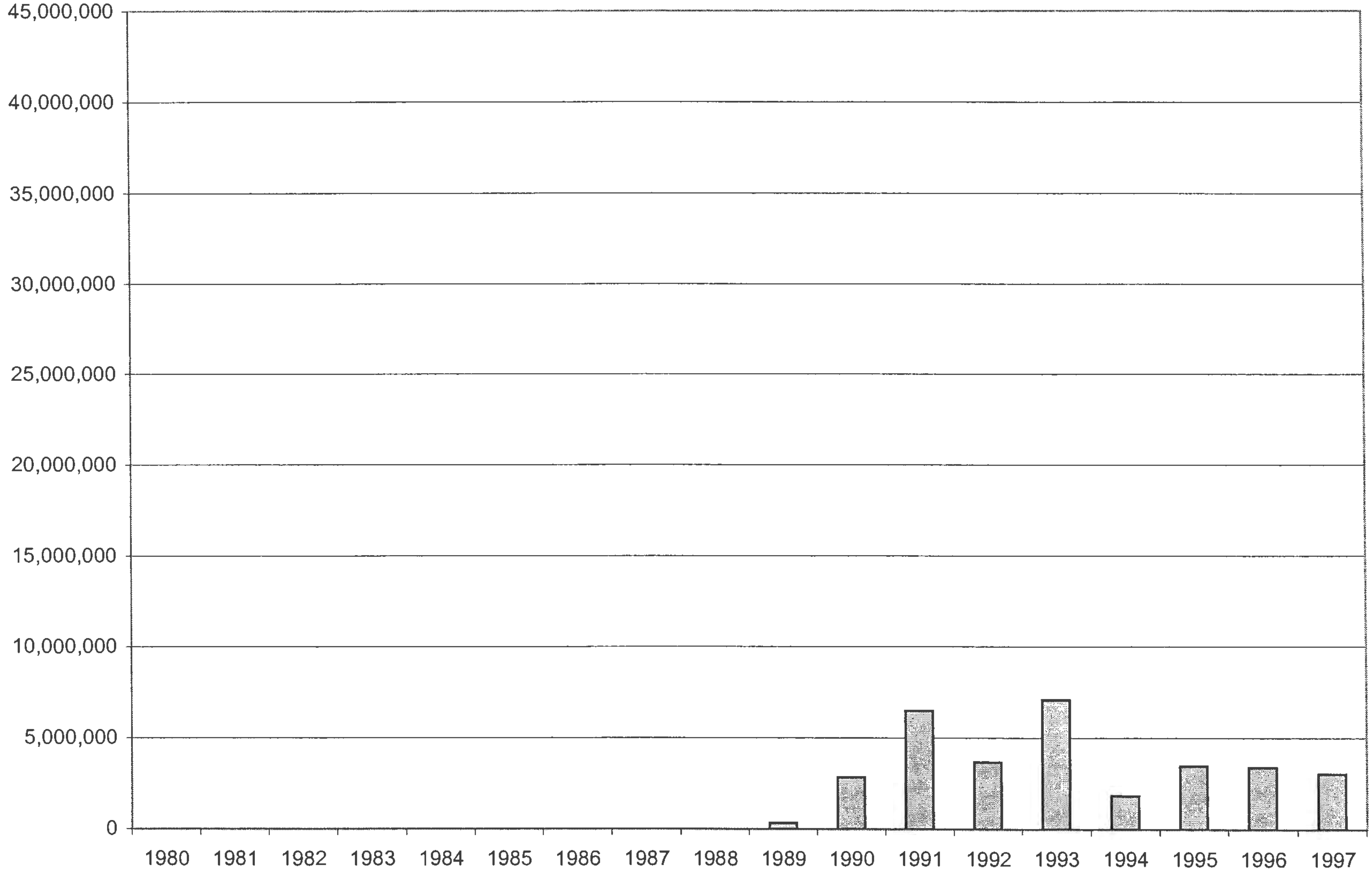
West Fork Cedar River, Iowa



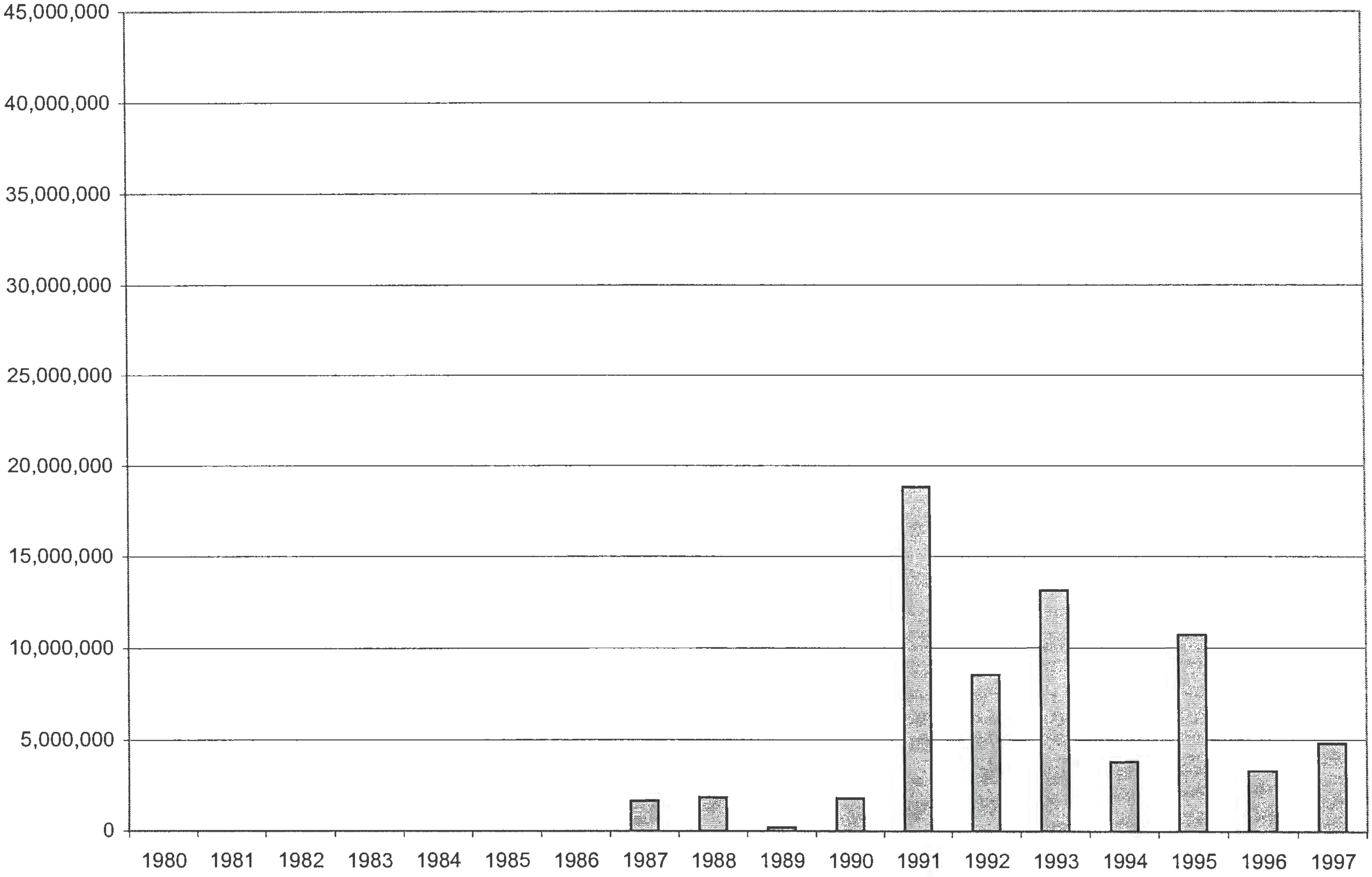
Cedar Creek, Iowa



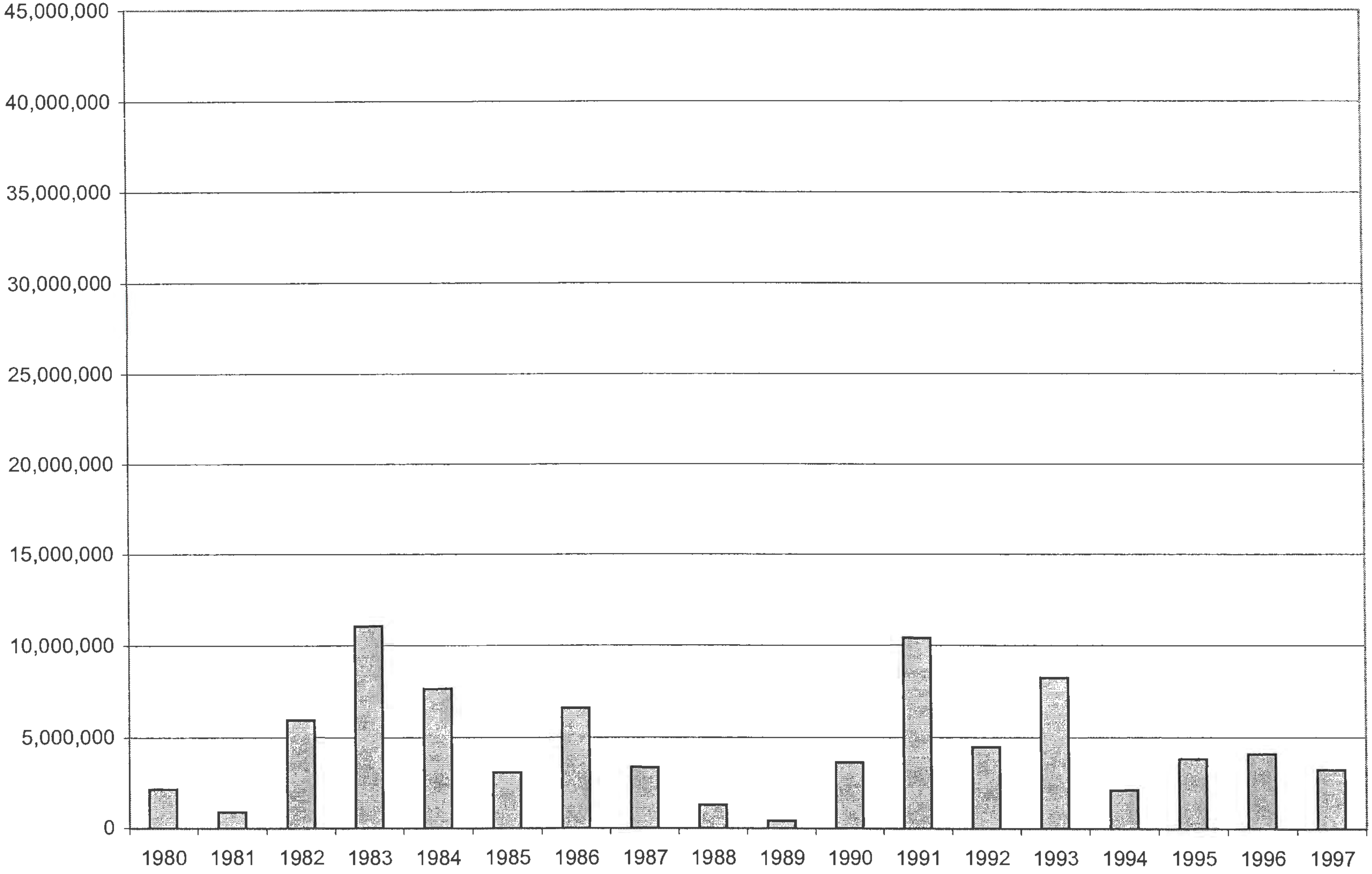
South Skunk River, Iowa

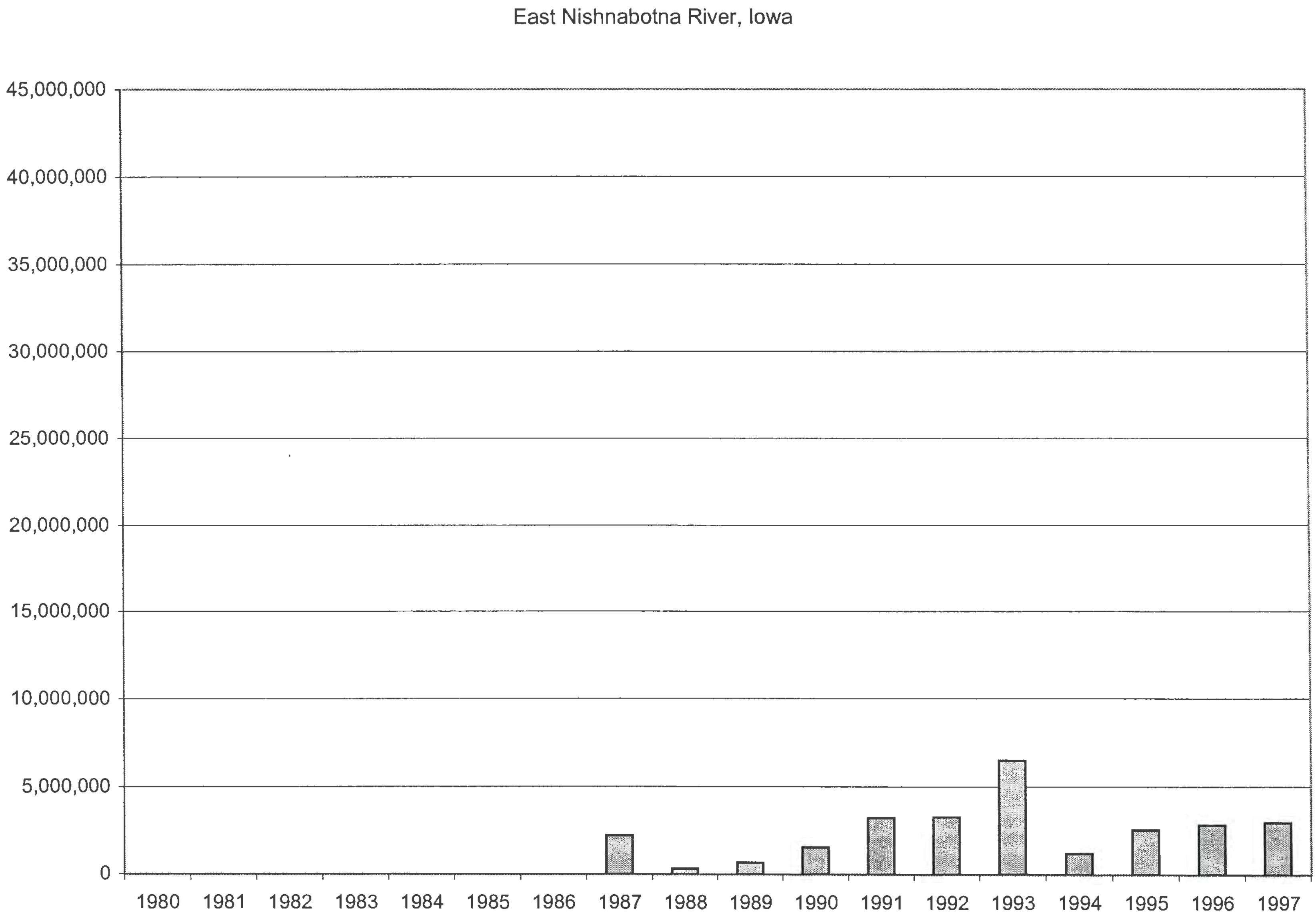


East Fork Des Moines River, Iowa



North Raccoon River, Iowa




East Nishnabotna River, Iowa
45,000,000
40,000,000
35,000,000
30,000,000
25,000,000
20,000,000
15,000,000
10,000,000
5,000,000
0
1980
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1995
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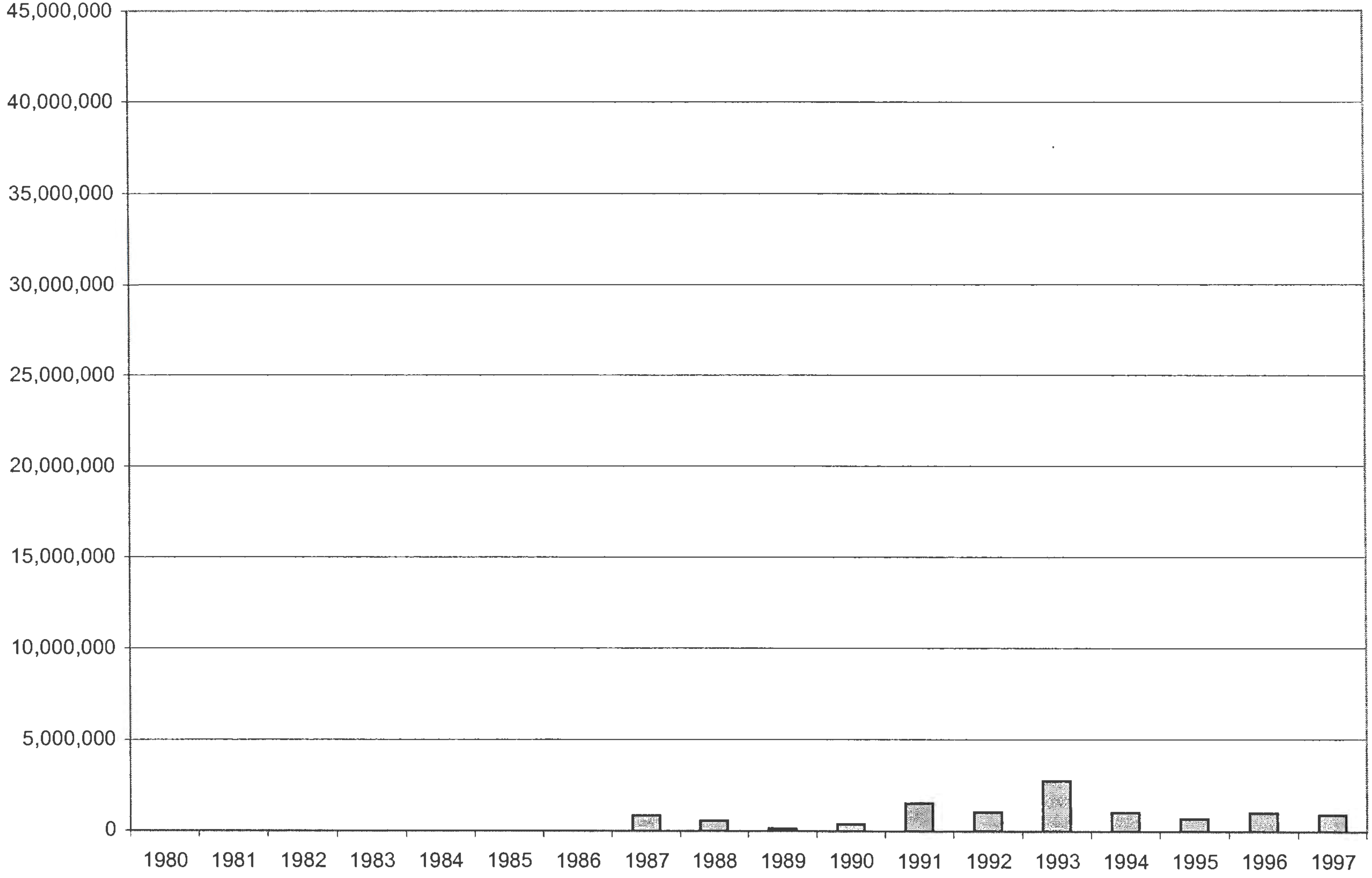
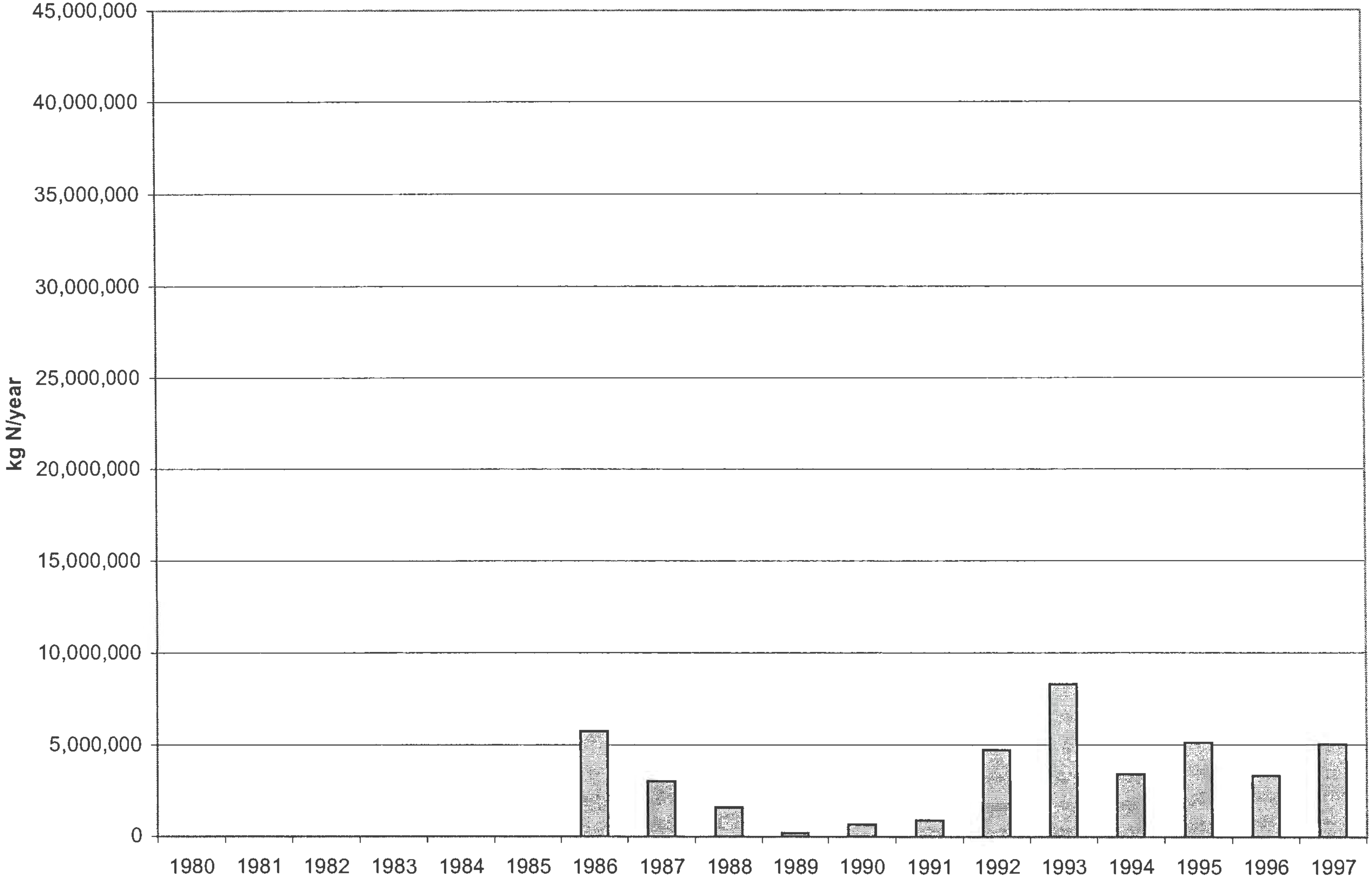
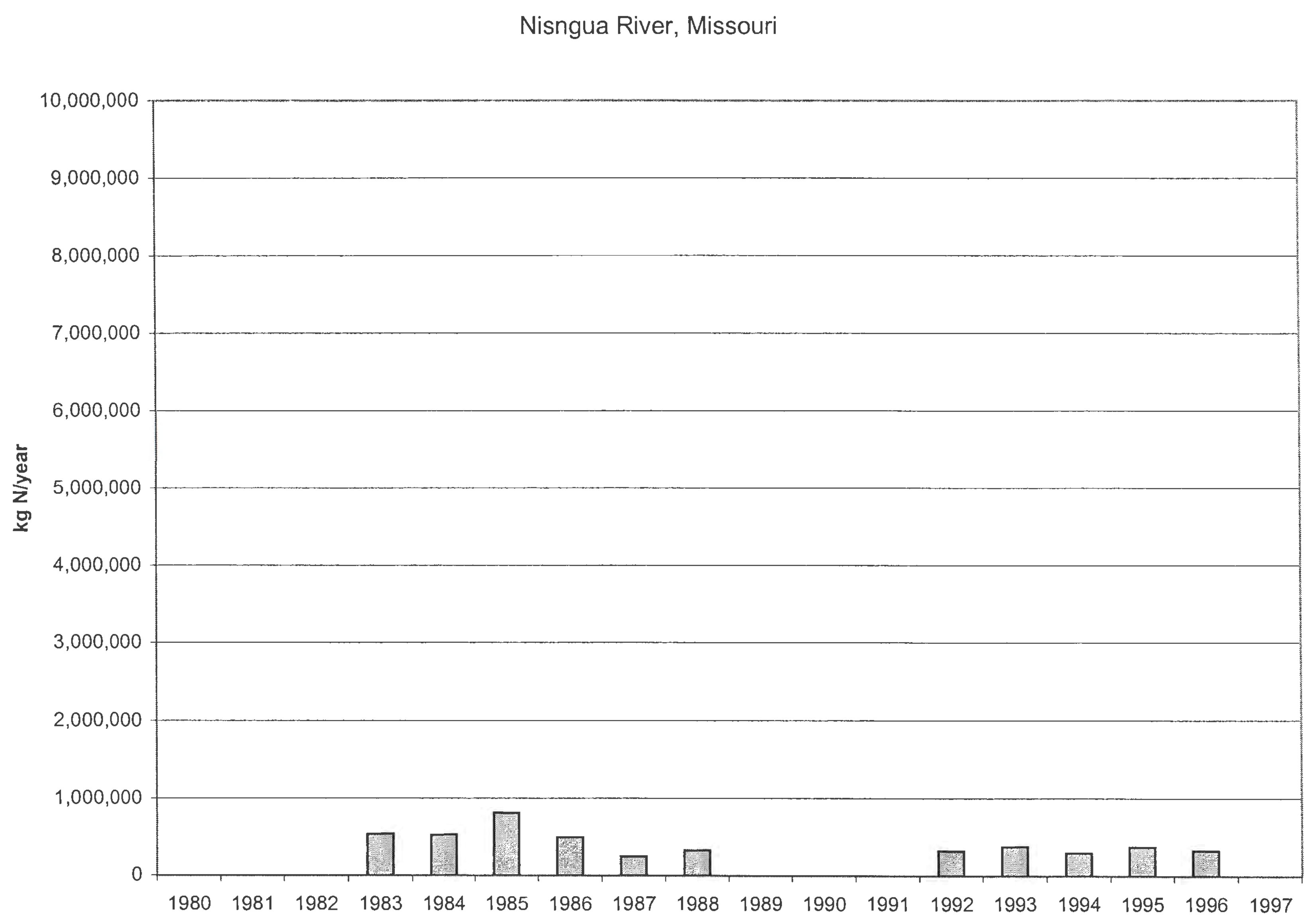
1997

Solider River, Iowa



Floyd River, Iowa




Nisngua River, Missouri
kg N/year
10,000,000
9,000,000
8,000,000
7,000,000
6,000,000
5,000,000
4,000,000
3,000,000
2,000,000
1,000,000
0
1980
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1990
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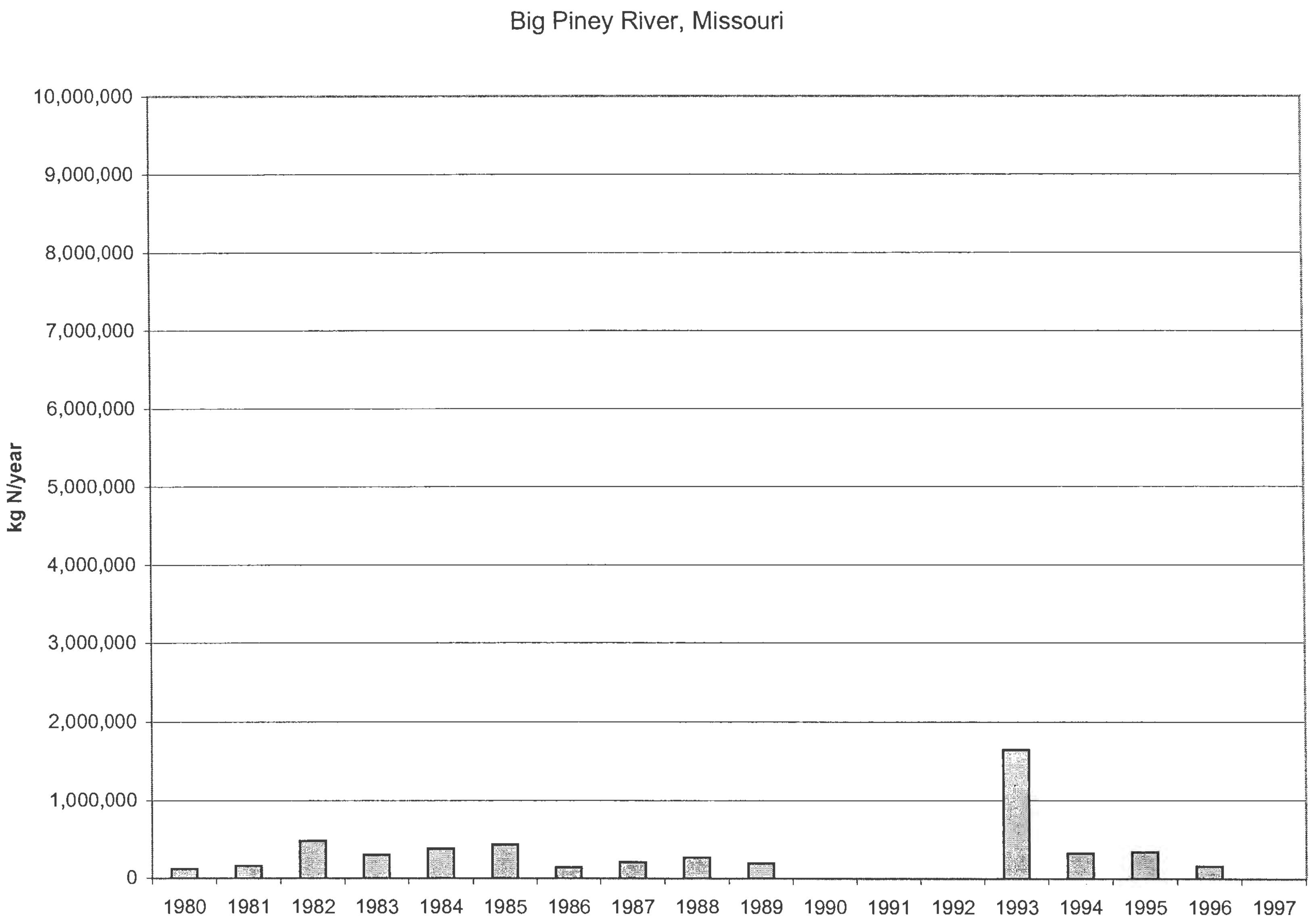
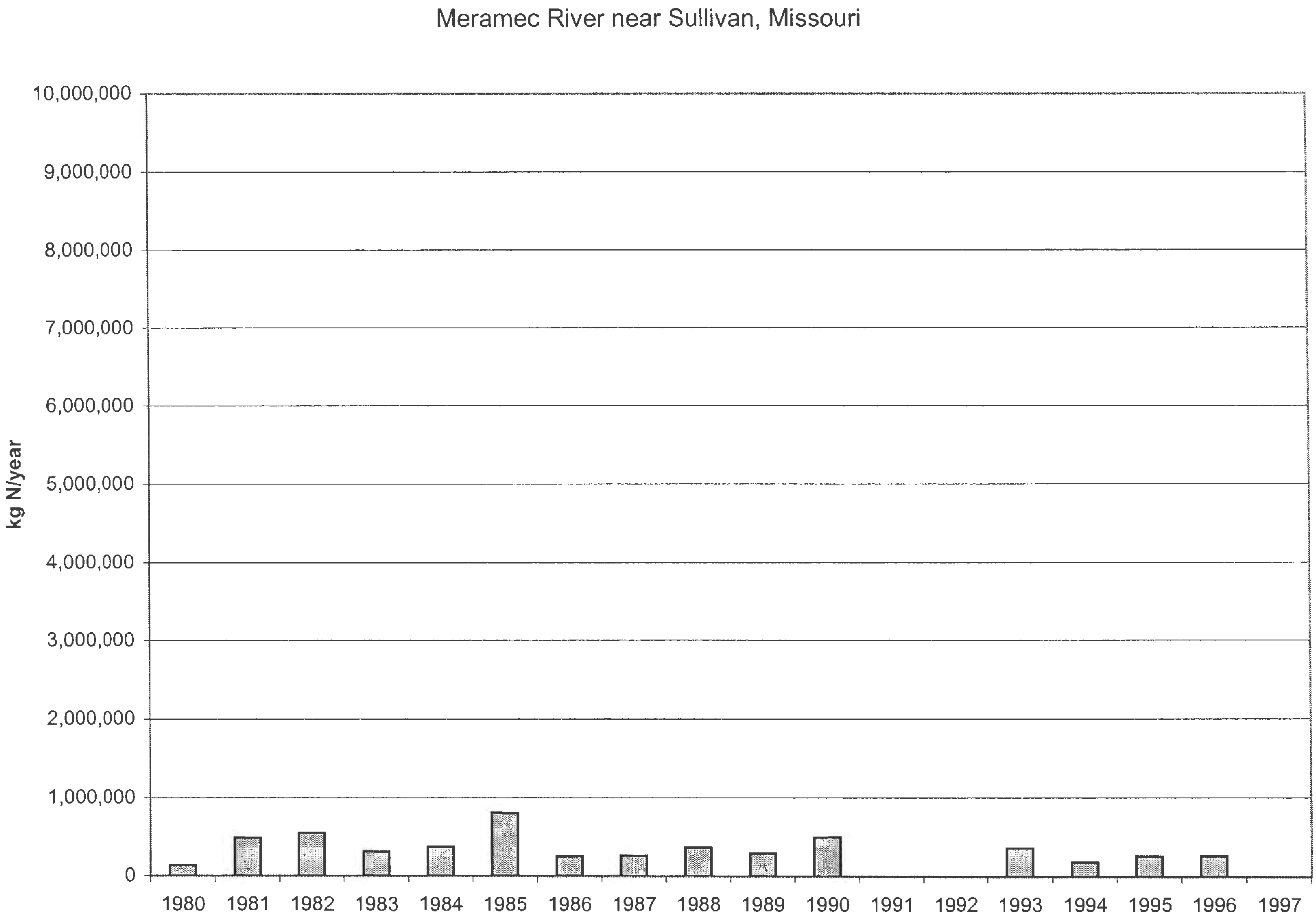
1993
1994
1995
1996
1997



Big Piney River, Missouri
10,000,000
9,000,000
8,000,000
7,000,000
6,000,000
5,000,000
4,000,000
3,000,000
2,000,000
1,000,000
0
kg N/year
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997


Meramec River near Sullivan, Missouri
kg N/year
10,000,000
9,000,000
8,000,000
7,000,000
6,000,000
5,000,000
4,000,000
3,000,000
2,000,000
1,000,000
0
1980
1981
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1997

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