WATER QUALITY AND LAND USE RELATIONSHIPS
IN THE
SOUTH NATION RIVER BASIN

A Report Prepared For

Water Quality Branch

Inland Waters Directorate

Environment Canada

Burlington, Ontario

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selected stations, and for which a reasonable number of observations have been made were selected for study (Table 3.2). Mercury and aluminium, for which data were available primarily from the Lower sub-basin, were evaluated only for Trend Analysis.

Individual station observations have been plotted over the period of study (1980-1988) rather than mean or median values because of a number of inherent limitations associated with the information. These include:

1) the data are not normally distributed and include significant gaps in the data base.

2) data is frequently collected (or reported) inconsistently during the year with the result that the data collection is skewed;

3) collections are taken monthly at approximately the same time. Data may therefore be "event" influenced during certain sampling periods but not others. This is a particular concern for sediment-associated variables such as turbidity or phosphorous which are significantly influenced by stormfall events, floods, industrial discharges etc.;

On the basis of this assessment, trends at the sub-basin level were identified industrial lagoon discharges in Winchester;

2) the Cassleman impoundment during fall emptying of the industrial lagoons in Winchester; and

3) the Crysler impoundment due to continuous summer discharges from an industrial source in Chesterville.

The SNRCA has estimated that approximately 4% (SNRCA 1983) of the total phosphorous loading and 0.5% of the total nitrogen loading results from these point source contributors.

5.0 WATER QUALITY CHARACTERISTICS

Water quality in the river and its tributaries is typically poor throughout the year with high phosphorous and bacteria concentrations frequently resulting in unpotable water (SNRCA 1983). There are several contributing factors including, extremely low flows during summer and fall months, and sedimentation resulting from erosion along streams and ditches. Runoff from agricultural cropland and livestock activities contribute phosphorous and bacteria that impair water quality. Fall discharges of effluent from municipal and industrial lagoons, as well as sanitary and storm sewage outfalls, also contribute to poor water quality in the main river and its tributaries (SNRCA 1983).

Ten water quality variables which have been monitored at each of the four

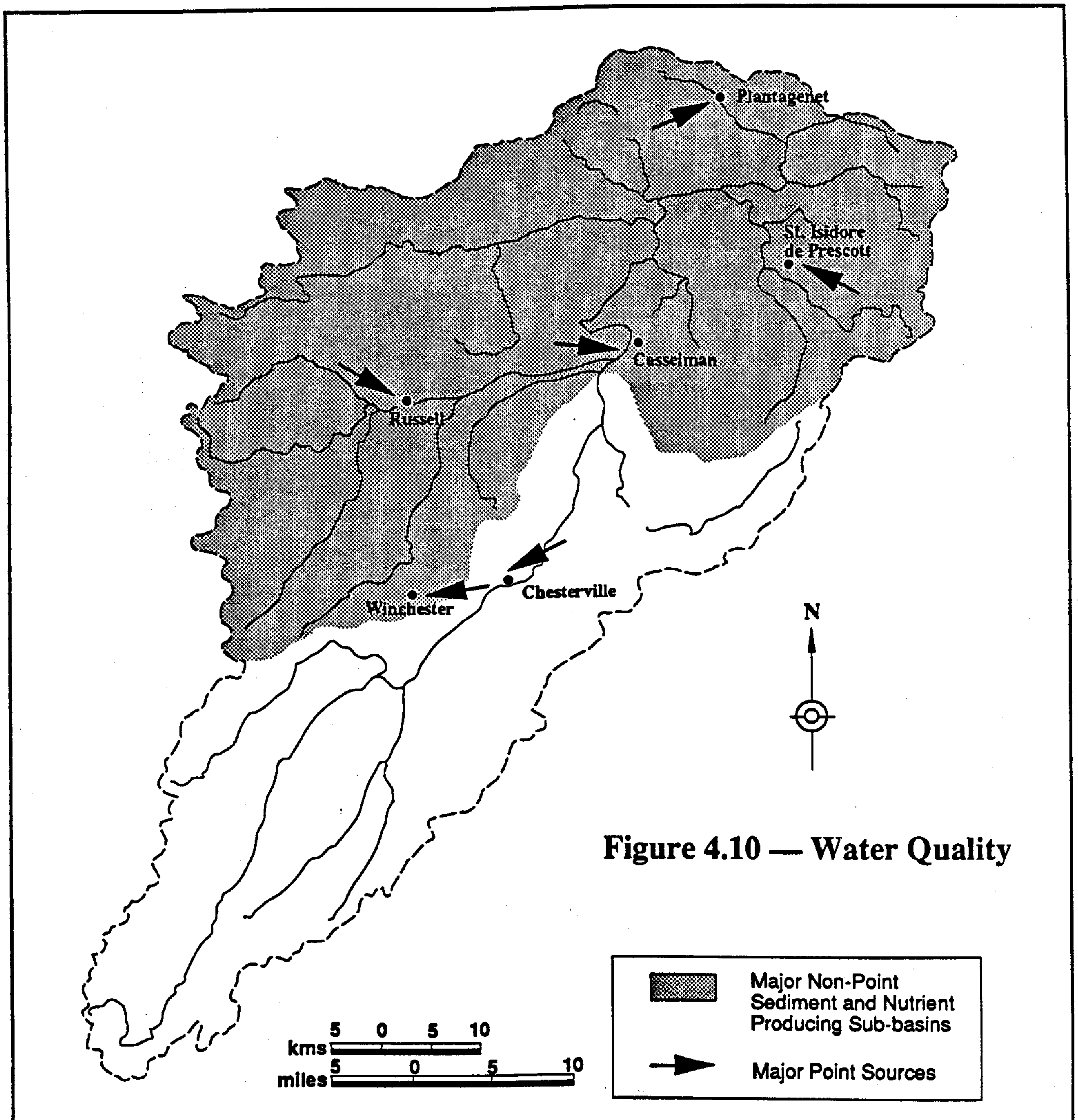


Figure 4.10 — Water Quality

of erosion is the dominant type in the basin due to the extensive areas of clay, the high percentage of row cropping (corn), and the extent to which these areas are subject to flooding. Although most of the flooding, hence erosion and sediment loadings, occurs during the spring melt, periodic flooding occurs during the summer and fall months, heavy rainfall events at most times of the year stimulate erosion and sediment events.

Outlet drains (excavated ditches) are also extensively used in the basin and contribute significantly to sediment loadings through bank erosion. Drains in the northern part of the watershed (Lower sub-basin) which are typically constructed in the marine clays are particularly important in this regard.

4.2.3 Industrial and Municipal Discharges

Although point source discharges are not important on a basin scale, they may be important locally. The point sources in the basin, include 2 industrial lagoon discharges and 6 municipal lagoon discharges. Major point source discharges in the basin are shown on Figure 4.10.

Modelling carried out by the SNRCA (MacLaren Plansearch 1982), suggested that potentially unacceptable dissolved oxygen concentrations downstream of specific point sources could occur as a result of low flow conditions. These locations include:

1) the East Castor River during late summer continuous

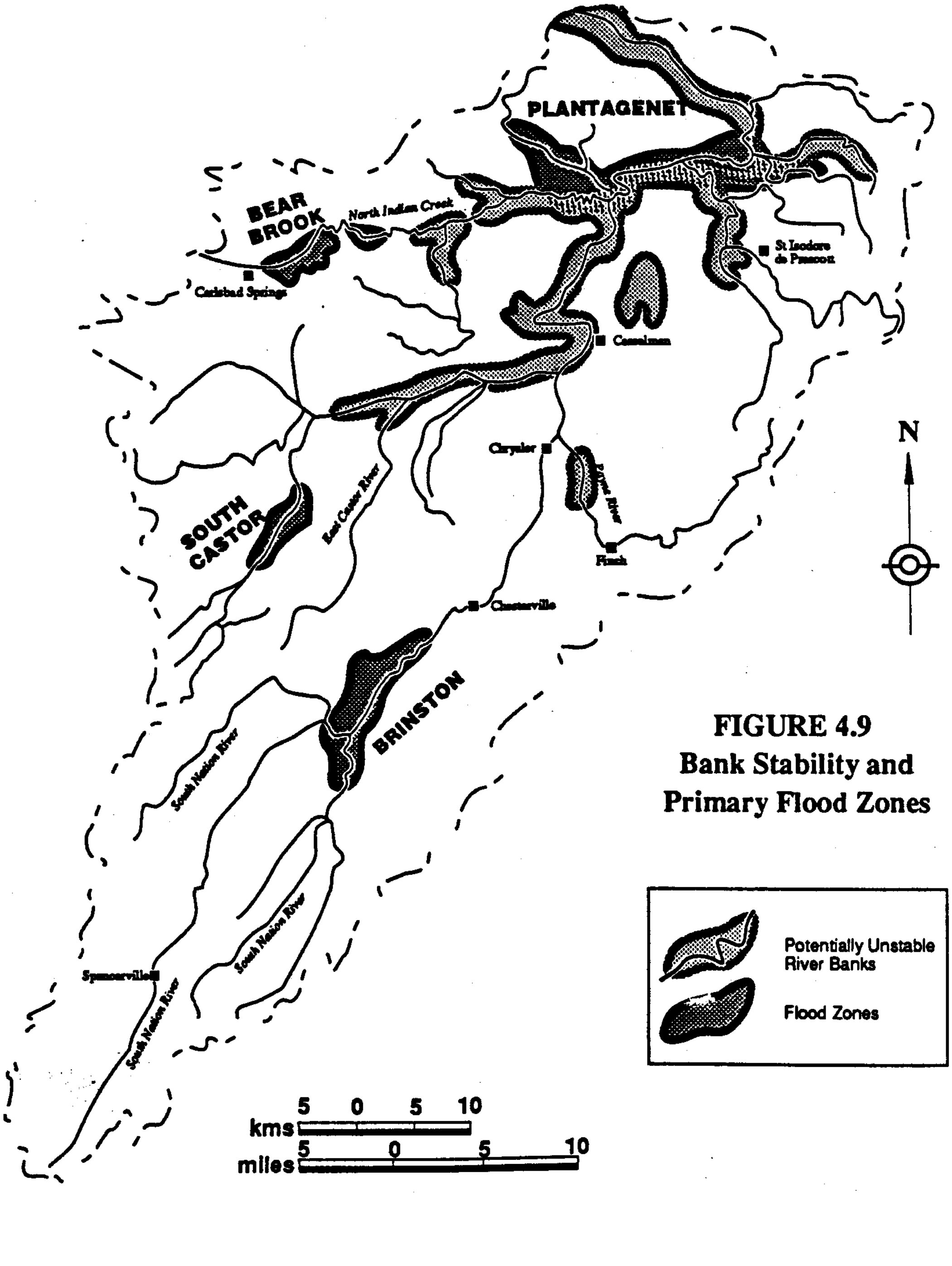


FIGURE 4.9
Bank Stability and Primary Flood Zones

rates of 0.100 - 0.499 kg/ha. Use of this latter herbicide in the Upper sub-basin is less (0.050 - 0.099 kg/ha) reflecting the higher acreages of unimproved land in this part of the basin.

4.2.2 Land Erosion

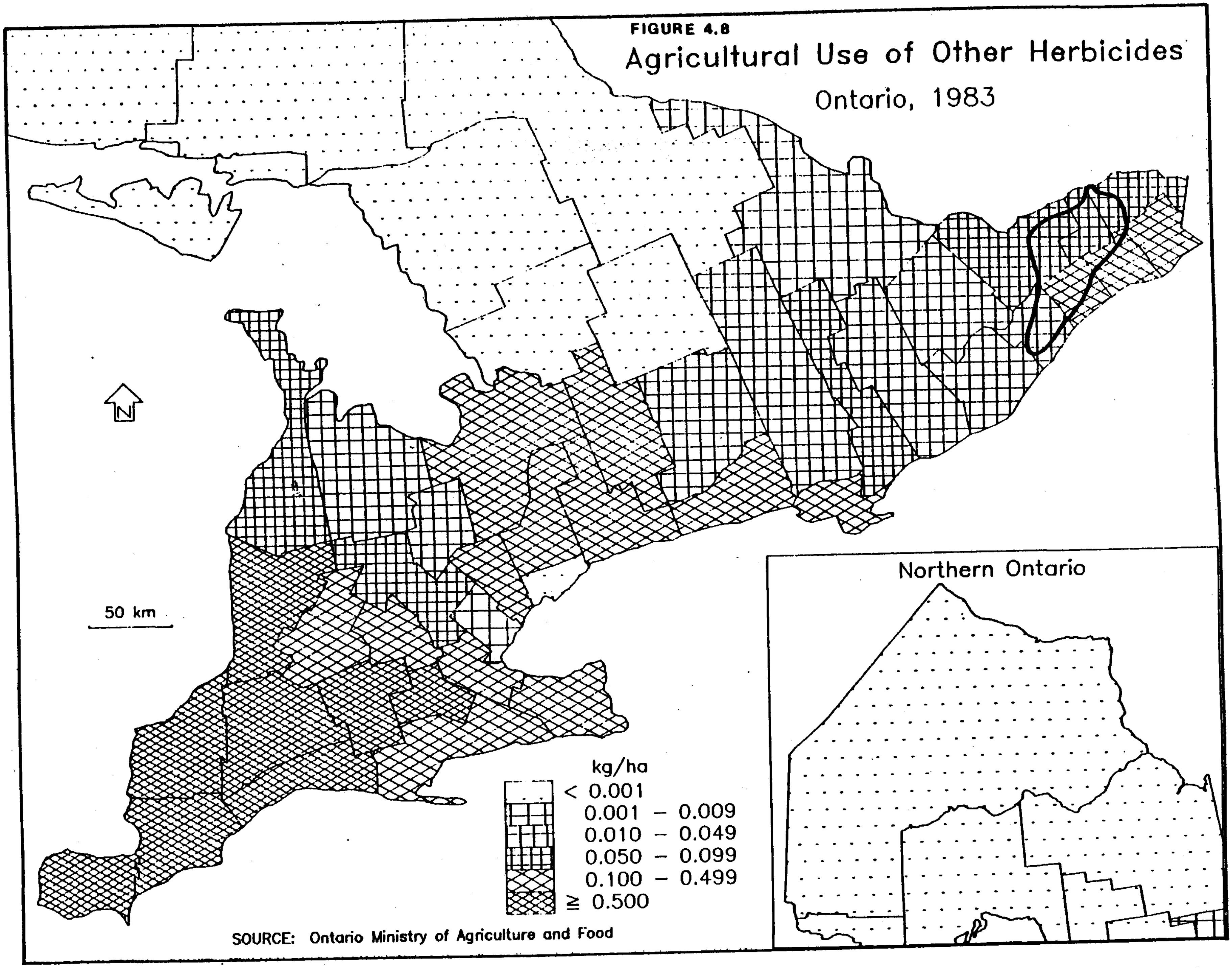
Although soil erosion on agricultural land is not generally perceived to be a major problem in the basin, a number of locations, particularly along the Castor, Bear Brook, Scotch and lower South Nation Rivers are highly susceptible to instability and landslides. This instability is associated with the finer textured silts and clays into which these rivers have cut channels. The areas most susceptible to instability are delineated on Figure 4.9.
Sediment loads result primarily from bank instability and erosion along the South Nation river and several of its tributaries (Figure 4.9). A smaller percentage of erosion occurs over the flat-laying agricultural lands in the Lower and Bear Brook sub-basins during periods of flood in late spring or early summer. Soil loss is general lower due to the flat laying nature of the land which reduces gully and rill erosion commonly associated with more rolling or undulating terrain.

THe importance of soil erosion for surface water quality was highlighted by the PLUARG studies which identified the significance of soil particle size in controlling loadings from agricultural land. The implication being that while soil loss itself may be low, nutrient losses could be significant due to their solubility, and close association with clay colloids. It is likely that this type

FIGURE 4.8

Agricultural Use of Other Herbicides

Ontario, 1983

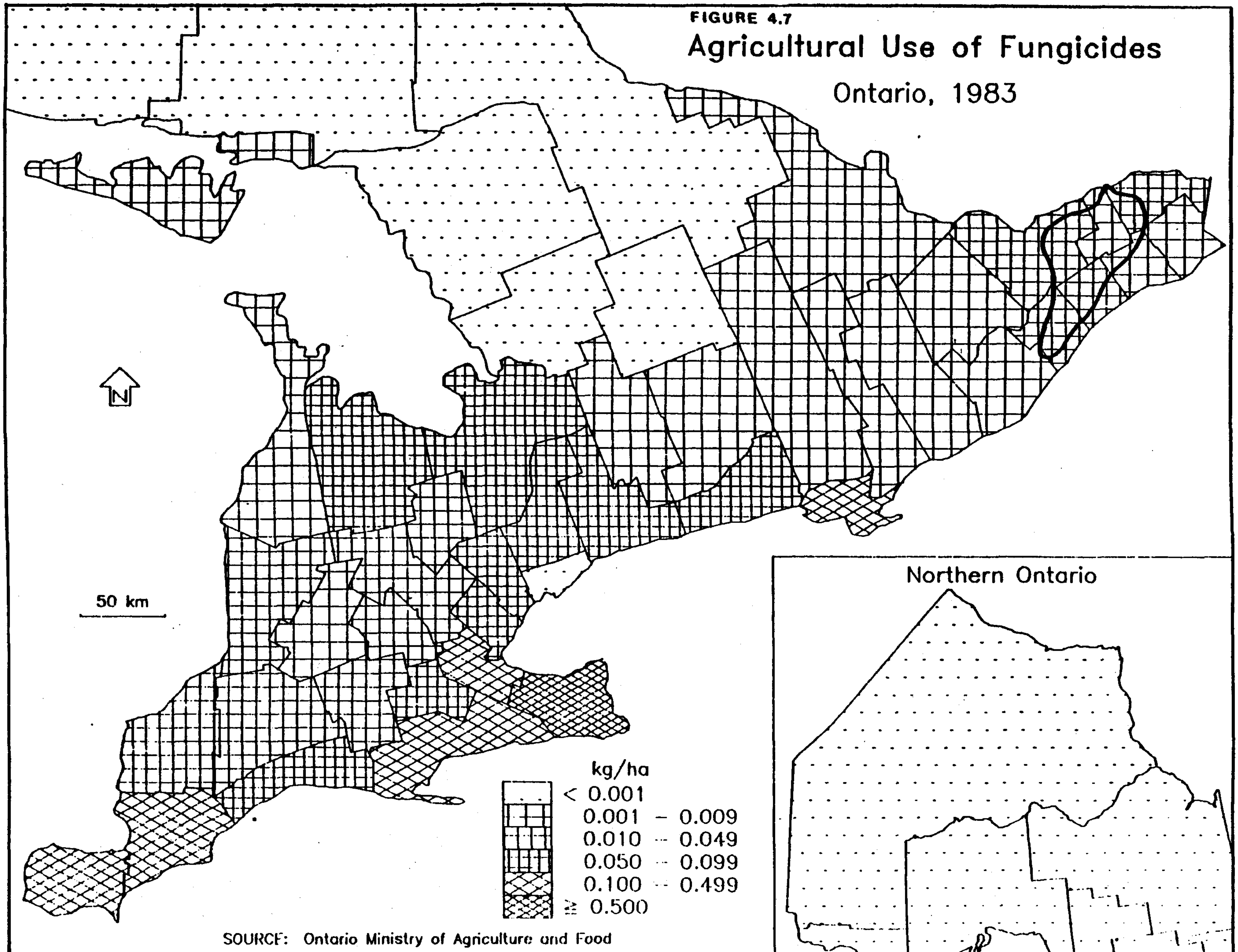


SOURCE: Ontario Ministry of Agriculture and Food

FIGURE 4.7

Agricultural Use of Fungicides

Ontario, 1983

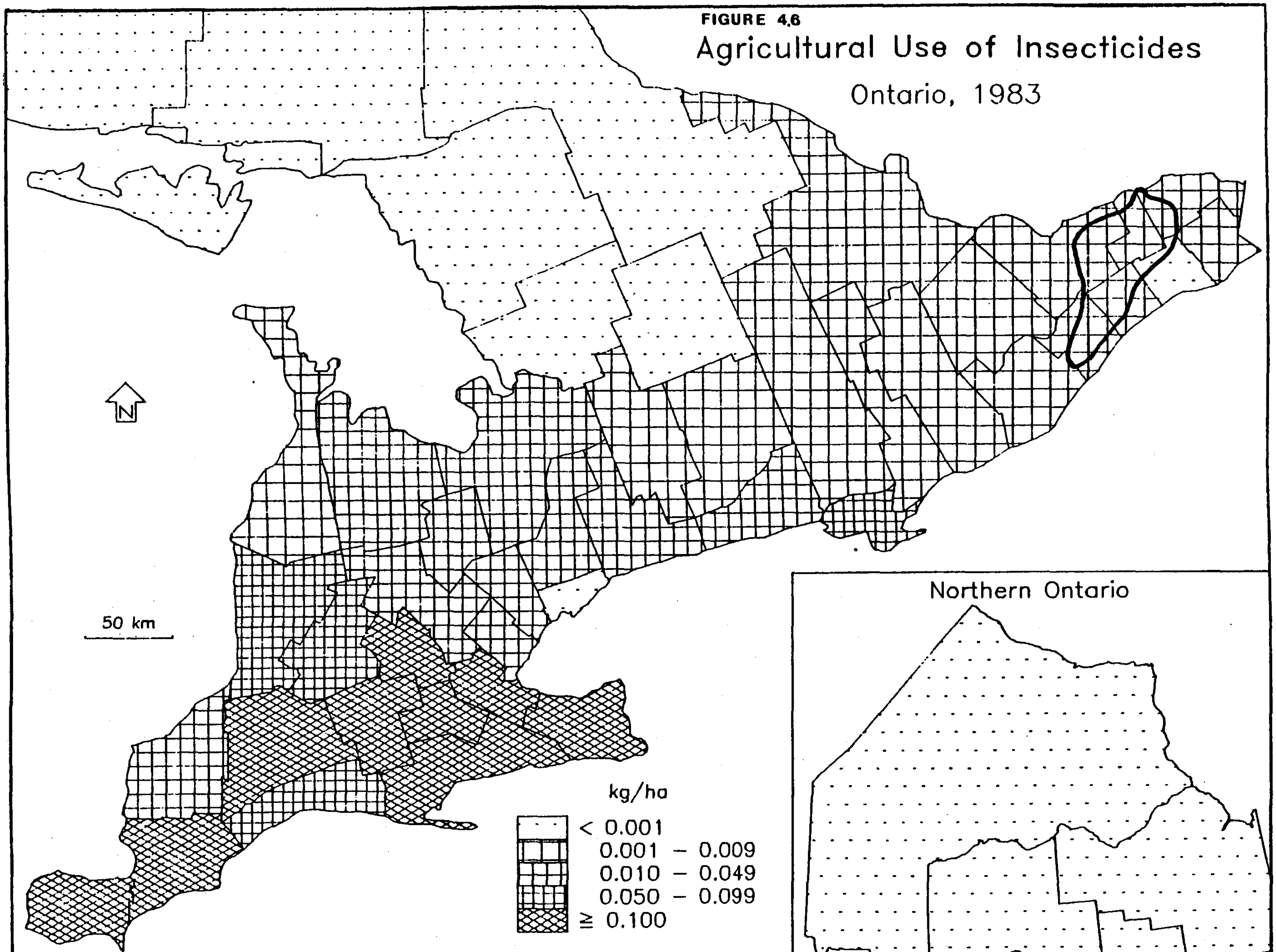


SOURCE: Ontario Ministry of Agriculture and Food

FIGURE 4.6

Agricultural Use of Insecticides

Ontario, 1983

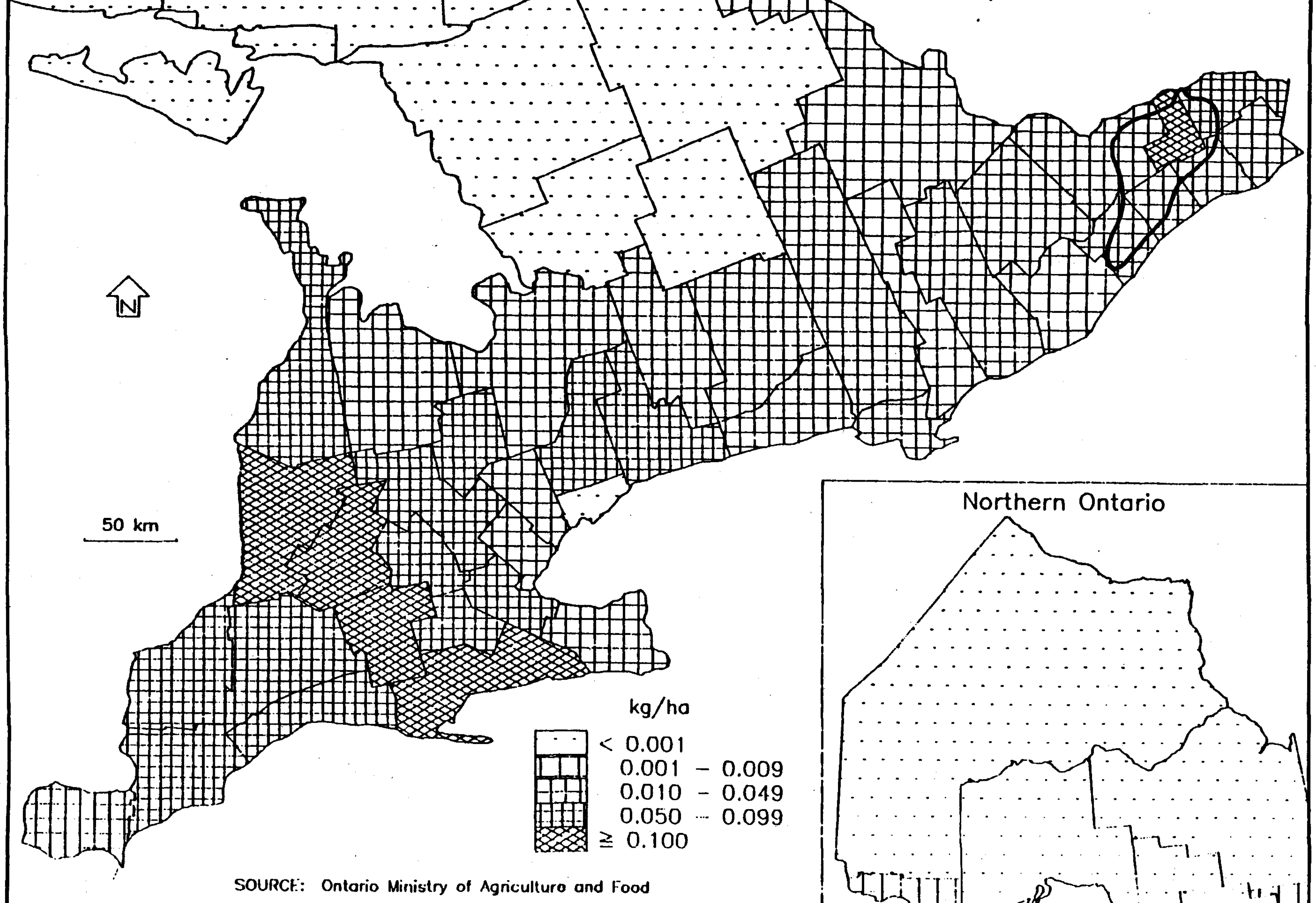


SOURCE: Ontario Ministry of Agriculture and Food

FIGURE 4.5

Agricultural Use of Phenoxy Herbicides

Ontario, 1983

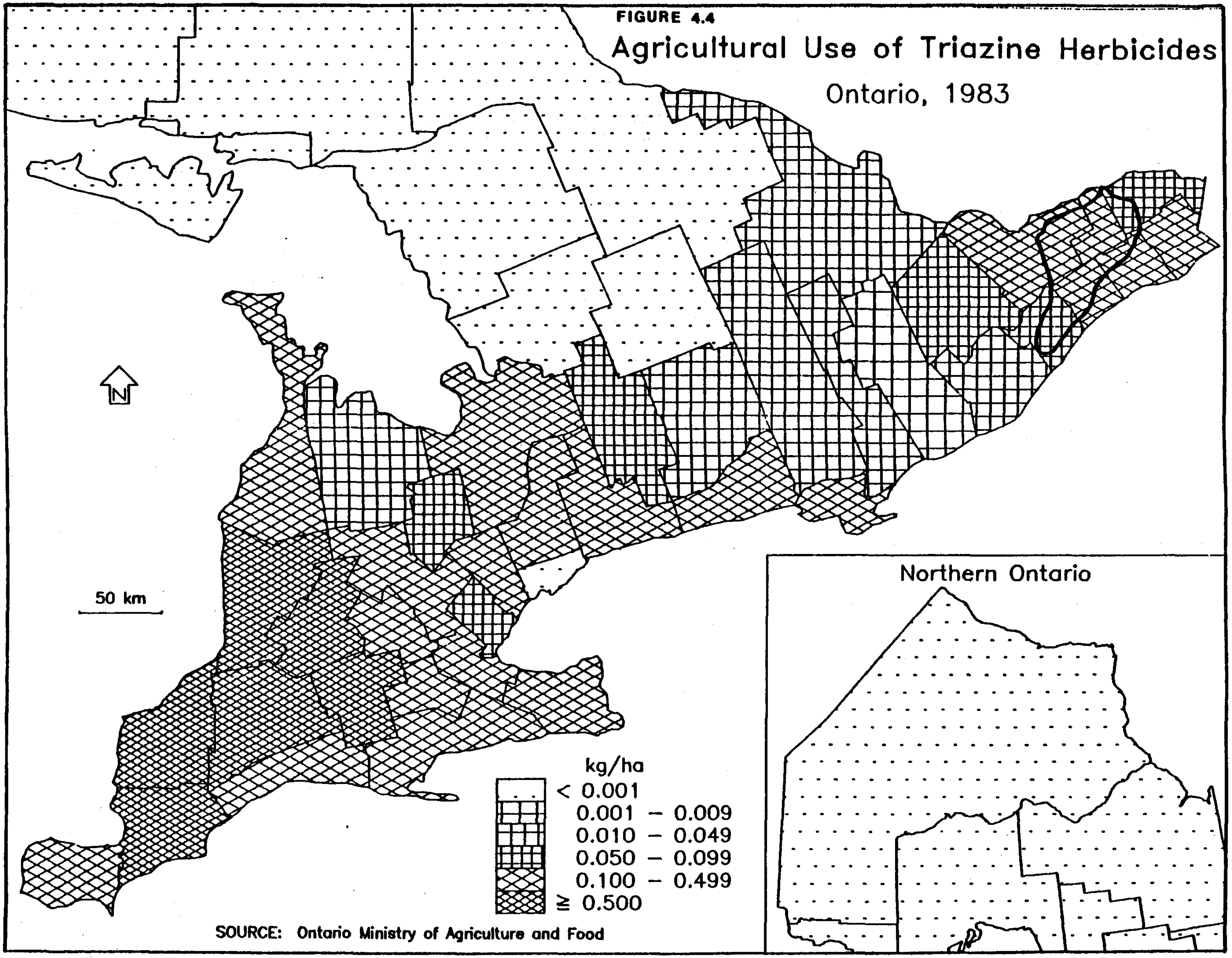


SOURCE: Ontario Ministry of Agriculture and Food

FIGURE 4.4

Agricultural Use of Triazine Herbicides

Ontario, 1983



SOURCE: Ontario Ministry of Agriculture and Food

typically medium (10-20 ppm) and require inputs of phosphorous for maximum crop production. Potassium values are considered medium (61-120 ppm) to high (121-150 ppm) and would, at medium levels require potassium inputs. Soil pH ranges from 6.1 to 7.0 and does not require liming for crop production. Nitrogen is also applied, with rates dependent on crops being grown and manure applications.

Within the basin, nitrogen is applied in such forms as urea, anhydrous ammonia, ammonium nitrate and liquid nitrogen. Phosphate is supplied through superphosphate and monoammonium or diammonium phosphate. Potash (K2O) is mainly applied through muriate of potash (Graham and Associates 1981).

Livestock manure is also an important source of organic nitrogen with approximately 8,000 tons of nitrogen produced in the basin each year through this source (Graham and Associates 1981).

Pesticide Use

Pesticide use in the basin has shown a steady increase since 1971 (Graham and Associates 1981; McGee 1984). Figures 4.4 to 4.8 show the agricultural use of various pesticides throughout the basin in 1983. Similar information for 1988 is currently being prepared but was not available in time for this study.

In general, herbicide use is moderately high to high in the basin with Phenoxy acid herbicide use being very high (> 0.500 kg/ha) in the lower part of the basin. Triazine herbicides are also used extensively in the basin at application

Table 4.5. Estimate of fertilizer use (Tons) for the County area that lies in the SNRB for the years 1971, 1979 and 1980.

Counties	1971	1979	1980
Ottawa-Carleton	1,498	1,947	1,713
Russell	6,073	7,894	6,946
Prescott	2,955	3,841	3,380
Grenville	1,377	1,790	1,575
Dundas	2,459	3,197	2,813
Stormont	1,220	1,586	1,396
Glengarry	520	676	595
Totals	16,102	20,931	18,418

Source: Agricultural Component Background Study, Report No.4. South Nation River Conservation Authority, 1981.

it can be seen that fertilizer use is typically low throughout the basin (approximately 72 lbs/improved acre), with the highest applications occuring in northern parts of the basin. Most fertilizer applications are to corn.

Soil samples tested in the basin indicate that levels of phosphorous are

Table 4.4. Livestock populations in the SNRB during the period 1971-1980.

Livestock	1971	1976	1980
Cattle	151,154	146,815	138,000
Milk Cows	79,638	71,790	56,500
Pigs	35,842	24,026	60,000
Sheep	2,171	4,646	7,500

Source: South Nation River Basin Water Management Study. Main Report. 1983.

Fertilizer Use

Comprehensive data on fertilizer use in the basin is limited. The most recent data, summarized from information maintained by the Fertilizer Institute of Ontario, is presented in Graham and Associates (1981) (Table 4.5). On the basis of this information showing the physiographic units of the basin, shows the drainage to be concentrated on the Winchester Clay Plain and drainage concentrated in the lower portion of the Upper sub-basin, the upper portion of the Lower sub-basin and the Scotch sub-basin.

Livestock Operations

Production of milk is the single most important agricultural activity in the basin, with most crops (e.g. corn, hay, etc.) grown to support this activity. Beef production is not as important in the basin compared to dairy operations although there has been some shifting to this type of operation and its relative importance is increasing (Graham and Associates 1981). Few feed lots are found in the basin. A summary of livestock population for 1971, 1976 and 1980 are provided in Table 4.4. These statistics are based on a special run done for the Basin Management Study in 1980, by Statistics Canada.

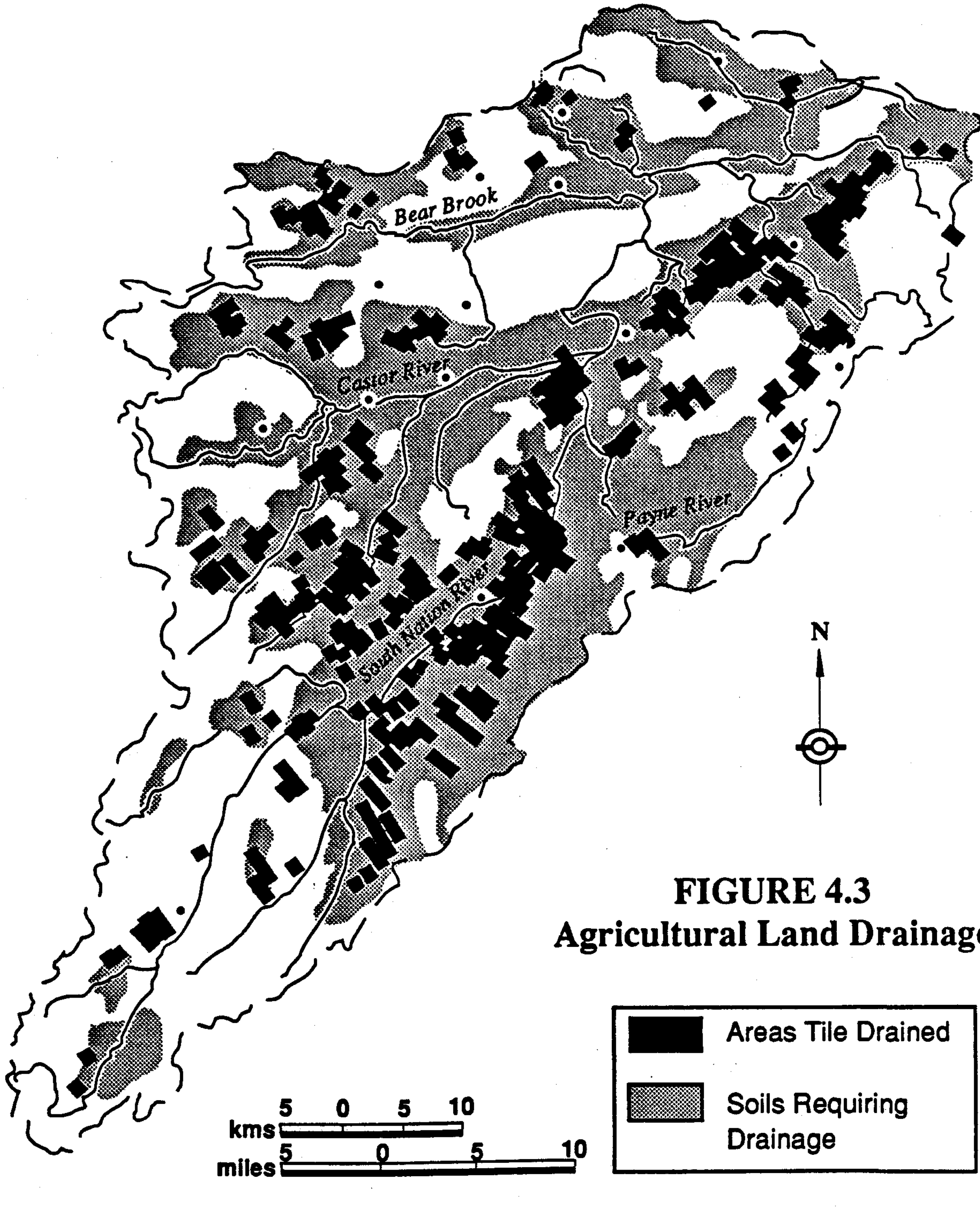


FIGURE 4.3
Agricultural Land Drainage

marginal type lands.

Market gardening systems occur throughout the basin, and although have shown some increase in area since 1983, still occupy a limited land area (< 1%).

Much of the remaining area in the basin is "unimproved" land with the greatest proportion in woodland. The Upper sub-basin has the highest percentage of land in this category (28%), while the Castor sub-basin has approximately 16%. Idle land is also greatest in the upper sub-basin (12%), and lowest in the Scotch sub-basin (4%).

Wetlands occupy a small (2.5%) yet significant percentage of the basin. Included in this class are major portions of the Alfred bog, the Moose Creek bog, Winchester bog, and the Spencerville bog.

Agricultural Drainage

Although the basin is characterized by extensive useable lands, the most significant limitation results from poor natural drainage. As noted earlier, and as illustrated in Table 4.3, almost two-thirds of the land base in the four sub-basins is comprised of silts and clays. The Scotch sub-basin has the largest percentage (83%) of these finer textured materials. To improve the agricultural capabilities of the land base, extensive areas throughout the basin have been tile drained (Figure 4.3). A comparison of the area tile drained with Figure 4.1

Table 4.3. Land use and major soil textures in the six sub-basins of the South Nation River watershed.

SUB-BASIN	LAND USE PCMH %	HGG %	MG %	IDLE %	FOREST %	URBAN %	WETLAND %	SOIL TEXTURE SAND %	SI/C %	ORGANIC %
Lower South Nation	59	5.7	0.05	6.8	22.7	0.7	3.5	27	62	11
Upper South Nation	47	7.8	0.25	12.4	28.9	0.6	2.5	26	67	9
Castor	59	7.2	0.07	9.6	16.4	1.9	3.4	29	61	10
Scotch	65	4.7	0.03	4.2	24.9	0.6	0.1	9	83	8
Bear Brook*	38	8.2	0.5	8.3	38.1	2.2	0.3	52	48	2
Payne*	53	4.7	0.2	9.7	30.5	0.6	0.2	10	88	2

PCMH: monoculture, corn system, mixed system, hay system

HGG: pasture system, grazing system

MG: market gardening

*: general estimate only for soil texture

Table 4.2. Agricultural Land Use Systems used to characterized land use throughout Ontario.

Symbol	Land Use System	Description
P	Monoculture	A contiguous arrangement of four or more fields, or a minimum of 16 ha. of corn or small grains.
C	Corn System	A contiguous arrangement of four or more fields of uniform size. 40-75% of the area is corn, the remainder is a mixture of hay, pasture and sometimes grain.
M	Mixed System	A contiguous arrangement of four or more fields of uniform size. There must be some corn, but less than 40% of the area. The remainder is a mixture of hay, grain and pasture.
H	Hay System	A contiguous arrangement of four or more fields with a mixyure of hay, grain, and pasture, the largest portion being hay.
HG	Pasture System	A contiguous arrangement of two or more fields with a mixture of hay and pasture, about equal quanitites of each.
G	Grazing System	A contiguous arrangement of four or more fields or a minimum of 16 ha with no field separation of either permanent pasture or native grass pasture, or a combination. It may have minor amounts (< 10%) of hay.
A1	Idle Agricultural	Land idle for 1-10 years and in a state of reversion Land to natural vegetation.
A2	Idle Agricultural Land	Land idle for more than 10 years and supporting native vegetation.
Z	Woodland	Forest cover with a minimum of 45% crown closure density and not less than half a hectare in area.
Zp	Pastured Woodland	Woodlands that are grazed by livestock.
Zr	Reforestation	Land supporting a stand of artificially stocked trees.
B	Built up	Urban related land uses.
X	Swamp, Marsh	Supports vegetation characteristic of a poorly drained area.
E1	Extraction	Sand and gravel pits and quarries.
E2	Extraction	Topsoil removal.
T	Sod Farms	Public or commercial sales.
R	Recreation	Parks, golf courses, campgrounds, etc.
K	Specialty Agriculture	Orchards, market gardens, etc.
W	Water	Rivers, streams, etc.

Table 4.2 describes the Land Use Systems classification as applied in the SNRB as well as throughout most of southern Ontario. Table 4.3 summarizes Land Use Systems as well as major soil textures for each of the four sub-basins examined during this study.

In each of the basins the dominant Land Use Systems are associated with Field Crop systems which include monoculture, corn system, mixed system and hay system (PCMH in Table 4.3). The monoculture system is essentially a non-rotational cropping system of the same crop year after year. In the SNRB this is predominantly corn. The corn system is predominantly corn, but reflects a rotational pattern with hay and pasture and some grains. In the basin approximately 60% of this system would be in corn, either for silage or grain (Graham and Associates, 1981). The mixed agricultural land use system (Table 4.2) reflects a more mixed aspect of the rotational pattern with less extensive corn however and more hay. The hay system includes predominantly hay with some cereals and corn. These various land use systems for the most part support the primary agricultural pursuit of the basin which is dairy-livestock operations.
The Scotch sub-basin is dominated by these row crop land use systems (i.e. corn, corn with hay, and hay) with 65% of the sub-basin characterized as such. The Upper sub-basin has the smallest percentage (47%) dedicated to field crops, reflecting the fact that this area has the least area of "improved" lands of the basin.

The hay/grazing systems (HGG in Table 4.3) are characteristic of the Upper sub-basin and are associated with extensive livestock operations and often with

Land Use System Classification

Agricultural Land Use Systems have been used as the basis for describing land use within each of the sub-basins examined during this study.

Land Use Systems have been developed to improve the nature of rural land use analyses. Based on work done in the Ottawa-Carleton region six systems, using the farm as the basic unit of analyses, were identified. These systems were Monoculture, Corn System, Mixed System, Hay System, and Grazing System. Each of these Systems are relatively stable through time, i.e. annual rotational changes in crop cover do not affect their classification. Real changes in land use however, such as occurs when a mixed farm moves to a livestock operation, are readily detected. This system was subsequently applied to various areas throughout southern and eastern Ontario, including those counties within the South Nation River basin. Although the Agricultural Land Use Systems maps were based on a 1979 survey, the nature of Land Use Systems are such that not only are classes relevant for a longer period of time, but the type of information is more easily related (qualitatively) to water quality information than is the more traditionally used crop summary information (OMAF 1987). In this latter case information is provided on a crop by crop, field by field basis and as such is frequently out of date by the following year because of crop rotation. Further, there are difficulties analysing several years data as it is difficult to determine whether a change in crop cover is simply a rotational change or a real change in land use. This type of information however, is available annually through OMAF and although not used for this study, could be used for those basins where Land Use Systems information is not available.

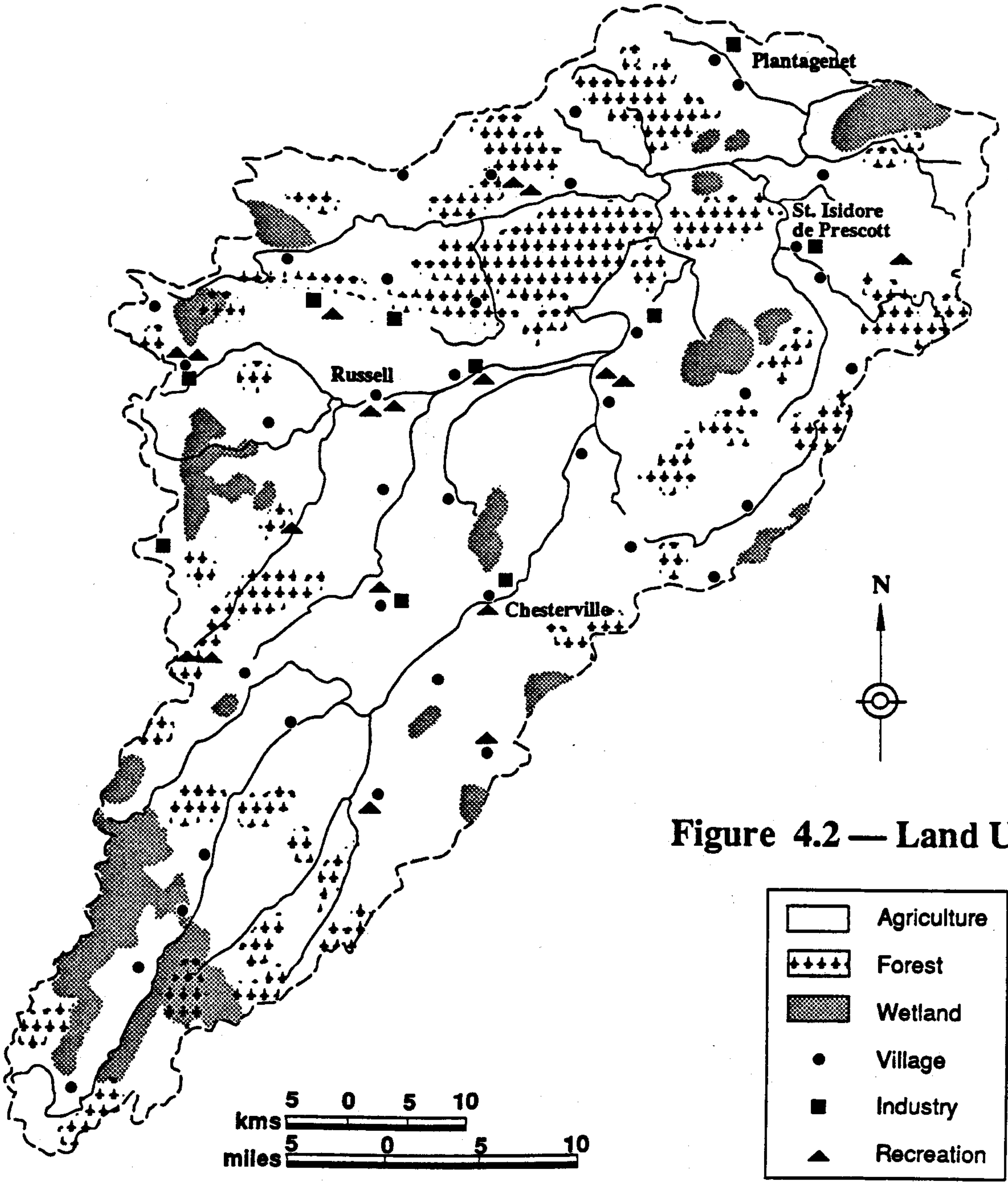


Figure 4.2 — Land Use

4.2 Land Use Characteristics

4.2.1 Agriculture

Land use in the Basin is dominated by agriculture with approximately 60% of the land base in this activity (Table 4.1).

Figure 4.2 shows generalized land use throughout the basin.

Table 4.1. Distribution of land use in the South Nation River Basin.

Land Use	Hectares	Proportion
Agriculture	237,000	60%
Woodlands	90,000	23%
Wetlands	9,000	2%
Forest Plantation	2,000	1%
Idle Land	34,000	9%
Urban & Other	19,000	5%
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Total	391,000	100%

Source: South Nation River Basin Water Management Study. Main Report. 1983.

clay lacustrine and marine sediments and organic (peat and muck) deposits.

Clay and clay loam textured soils dominate much of the basin (Figure 4.1), and were laid down during the Champlain Sea period. Extensive areas of sands, and loamy sands also occur particularly in the extreme northern and southern portions of the basin. Organic deposits of muck and peat occupy as much as 10% of the basin and are scattered throughout occupying poorly drained depressions, abandoned stream channels and along drainage divides. Relief is very low throughout the basin and this, together with the fine textured soils are primarily responsible for many of the water management issues in the basin.

4.1.2 Hydrology

The dominant hydrological feature of the Basin is the South Nation River whose headwaters rise near Brockville in the southern part of the basin, and flow in a northeasterly direction to its confluence with the Ottawa River, approximately 40 km east of Ottawa.

Along much of its length, the river flows through the Winchester and Ottawa Valley Clay Plains. In the southern and northern parts of the basin, reaches of the river flow through sand plains which overlay a clay substrate. A number of smaller rivers or creeks drain several sub-basins including the Bear Brook Creek, and the Castor, Scotch and Payne Rivers. In this study the Upper and Lower South Nation, the Castor and Scotch River sub-basins were examined.

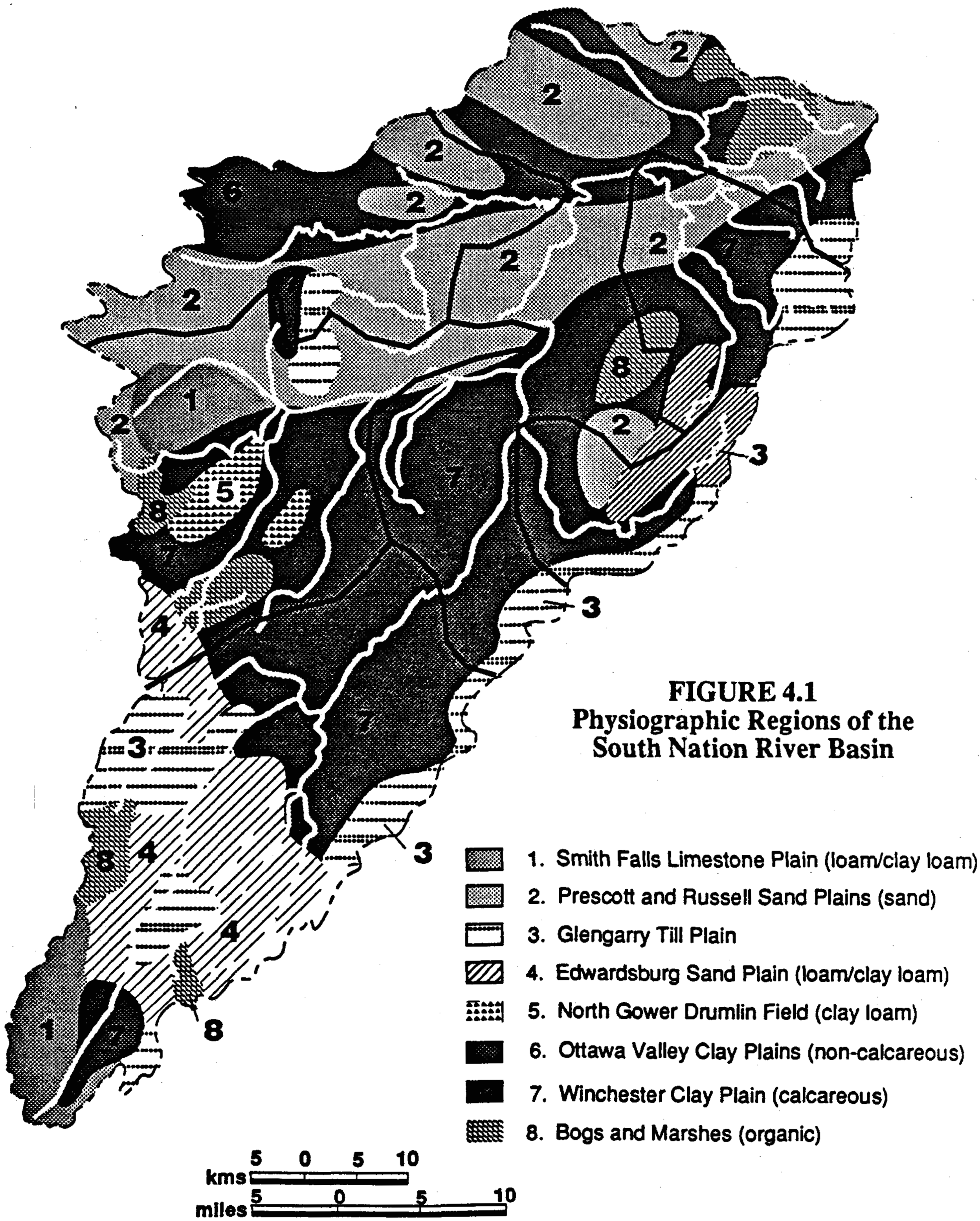

FIGURE 4.1
Physiographic Regions of the South Nation River Basin

basins. The Payne and Bear Brook sub-basins are not currently monitored. The Upper sub-basin is represented by the monitoring station at Chesterville, the Castor sub-basin by the station downstream from Russell (conc. 5 Russell Twp.), the Scotch sub-basin downstream from St. Isidore (Scotch River East Conc. 17) and the Lower sub-basin at Plantagenet (Hwy. 17).

The Plantagenet station also represents the final monitoring point prior to export from the basin, and integrates all water quality information from the entire South Nation River Basin. The station at Casselman (on the South Nation River) was not used since it integrates non-point and point source contributions from several sub-basins.

4.0 PHYSICAL AND LAND USE CHARACTERISTICS

4.1 Physical Characteristics

4.1.1 Surficial Deposits

Surficial materials in the South Nation River Basin are associated with a range of physiographic conditions (Figure 4.1) related to the Late Wisconsin glacial period, and subsequent post-glacial inundation of the area by the Champlain Sea. These marine deposits were in turn modified following recession of the sea by fluvial activity associated with the Ottawa River. Features formed during each of these phases include fine textured (clay loam) till plains, sandy and gravelly glacio-fluvial outwash deposits, sandy lacustrine deltaic and fluvial deposits,

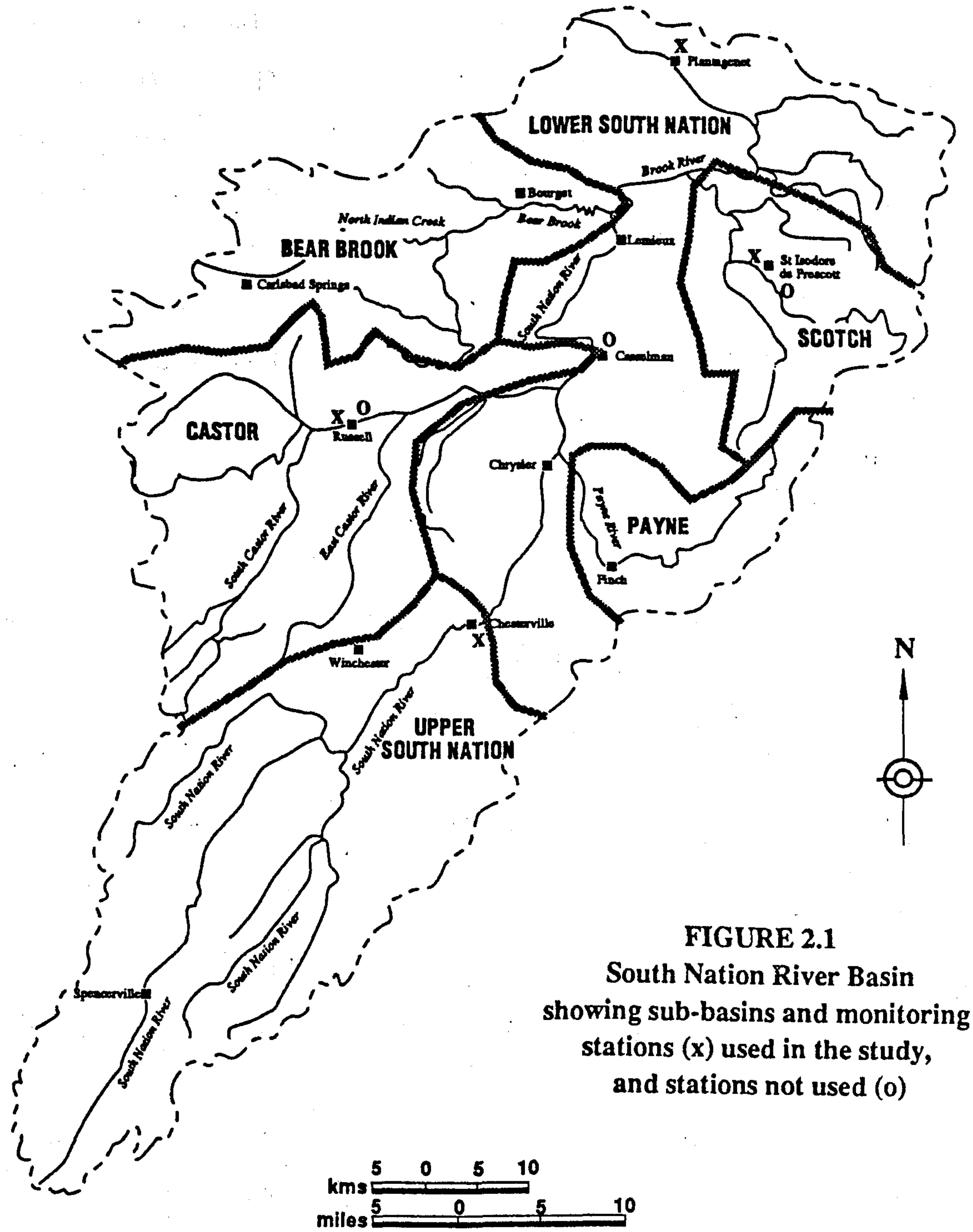

FIGURE 2.1
South Nation River Basin showing sub-basins and monitoring stations (x) used in the study, and stations not used (o)

3.1.3 Sub-basin Partitioning and Current MOE Monitoring Stations

In order to analyse water quality data and water quality / land use relationships effectively, it is important to work within a common spatial framework. The watershed or river basin provides this ecologically significant spatial framework. Within the South Nation River Basin there are 6 major sub-basins (Figure 3.1) including:

a) Upper South Nation sub-basin which includes all drainage area above the Chesterville Dam;

b) Castor River sub-basin;

c) Bear Brook sub-basin;

d) Payne River sub-basin;

e) Scotch River sub-basin; and

f) Lower South Nation sub-basin which includes all drainage area not included in the 5 previously defined sub-basins.

Although there are seven water quality monitoring stations within the basin, only four of the basins are effectively monitored through the existing network. These include: the Upper South Nation, Castor, Scotch and Lower South Nation sub-

Summary information on the location of all waste disposal sites within the basin was obtained through MOE (1988).

South Nation River Basin Water Management Study

A valuable source of land use and other resource description information for the basin was the South Nation River Basin Water Management Study conducted during the early 1980's. In 1980/81 sixteen detailed studies were carried out through the Canada-Ontario Eastern Ontario Subsidiary Agreement, to provide detailed background information relating to water management issues within the basin. These studies provide detailed technical information on resources such as agriculture, fish and wildlife, forestry, idle land, residential and commercial activities, water resources and erosion. Information contained in these reports was particularly useful when examining water quality/land use relationships, and in the evaluation of water quality trends. Information on tile drainage, livestock operations and major non-point sediment and nutrient producing areas and important point sources were obtained through these reports.

SNRCA staff were helpful in identifying significant trends in land use in the basin since the early 1980's, and in relating these to possible trends in water quality.

Data Format and Analysis

Data was received from MOE as an ASCII file and reformatted into LOTUS 1-2-3 relational database format. The data were then sub-divided into smaller files (i.e. nutrients, major ions, metals and others) to speed processing time in both LOTUS and the statistical analysis programs. Tabular summaries of the data were created in LOTUS. The data were then downloaded into STATGRAPHICS (STSC, Inc. 1987), a PC based statistical software package. All analyses were carried out using the STATGRAPHICS software on an IBM PS/2 286 with math co-processor. Time Series Analysis, Trend Analysis and Regression Analysis were carried out on selected variables as appropriate.

3.1.2 Land Use Data

Data Sources

Land Use data were acquired through several sources including: 1) the South Nation River Conservation Authority (SNRCA), 2) the Ontario Ministry of Agriculture and Food (OMAF), and 3) MOE. Agricultural Land Use System maps (1979) prepared by OMAF, provided the most useful information regarding the nature and distribution of land use in the basin. Statistical summaries by township, of the major Land Use System classes were also provided through OMAF. Land Use Systems information, which is reported on a County or Township basis, was converted to the sub-basin framework through proportional allocation of each of the major land use classes.

Spatial and temporal availability of data for each of the parameters is highly variable. The most intensively sampled location is the lower sub-basin of the watershed near Plantagenet, while the least sampled location is in the upper basin at Chesterville. In the latter case, data is available primarily for 1987 and 1988.

Sampling frequency for each parameter is also variable. Only the Plantagenet station is sampled regularly. As a result, a sub-set of the entire data base was selected for analysis (Table 3.2). Water quality information on Organic parameters i.e. to examine herbicide and pesticide residues, was not available, although general information on herbicide and pesticide use in the basin was obtained through OMAF (McGee 1984).

Table 3.2. Parameters selected for analysis in the South Nation River Basin study.

Chloride	Alkalinity	Conductivity
Total Nitrogen	Copper	Total Phosphorous
Turbidity	Lead	Mercury
Dissolved Oxygen	NH3-N	Aluminium

Table 3.1. Water quality parameters included in the PWQMN and data availability.
Only those monitoring stations used in this study are included.

Monitoring Station	ALK	AL	BOD	CA	CD	CL	COND	CR	CU	DO	DOC	FE	HG	K	MG	MN	NA	PH	PHENOLS	TOTALP	SE	SO4	TURB	Z:
Plantagenet	X	O	O	O	O	O	X	O	X	X	O	X	O	O	O	O	O	X	O	X	O	O	X	
St. Isidore	X		X	-	-	X	X	O	X	X			R	O				X	R	X			X	[illegible]
Russell	X			R	R	R	X	R	X	X			R	R				X	X	X			X	[illegible]
Chesterville	R		R	R	R	R	R	R	R	R		R	R	R				R	R	R			R	[illegible]

Available 1980/81 to 1988: 'X'
Available 1984-1988: 'O'
Available 1987-1988: 'R'
Available sporadically: '-'

3.1 Data Collection and Literature Review

3.1.1 Water Quality Data

Data Source

Water quality data for the South Nation River Basin for the period 1980-1988 was obtained through the Ministry of Environment, Hydrology and Networks Unit, Water Resources Branch. Seven monitoring stations for which data was available are located within the basin (Figure 2.1) and include:

- o Castor River at Conc. Rd. No. 5 Russell Twp.
- o Castor River at Conc. Rd. No. 3 Russell Twp.
- o Scotch River East at Conc. 17 downstream St. Isidore
- o Scotch River East at Conc. 19 upstream St. isidore
- o S. Nation River Hwy. 17 Plantagenet
- o S. Nation River at dam downstream Casselman
- o S. Nation River at dam Chesterville

Data on water quality parameters for each of the stations was downloaded from the MOE data base onto 5 1/4" floppy disks and made available to Wickware & Associates. Water quality parameters and data availability for those stations used in this study are listed in Table 3.1.

2) Analyze water quality data collected from the South Nation River basin between 1980 and 1988 to determine relationships between water quality changes and land use practices in the basin during that time.

3) Prepare a report which defines chemical differences between different reaches of the South Nation River and its tributaries, and relate such differences to specific issues such as eutrophication, pesticide use and urban development. Where possible, ascribe cause to the observed differences by examining specific mechanisms which could account for the observations.

3.0 STUDY METHODS

Work on the study was undertaken in three phases: 1) acquisition and review of all available water quality and land use data for the basin; 2) statistical analysis of water quality data and evaluation of water quality/land use relationships; and 3) preparation of report and recommendations regarding use of the data as part of a national water quality monitoring network. A brief outline of the methods associated with each phase of the project follows.

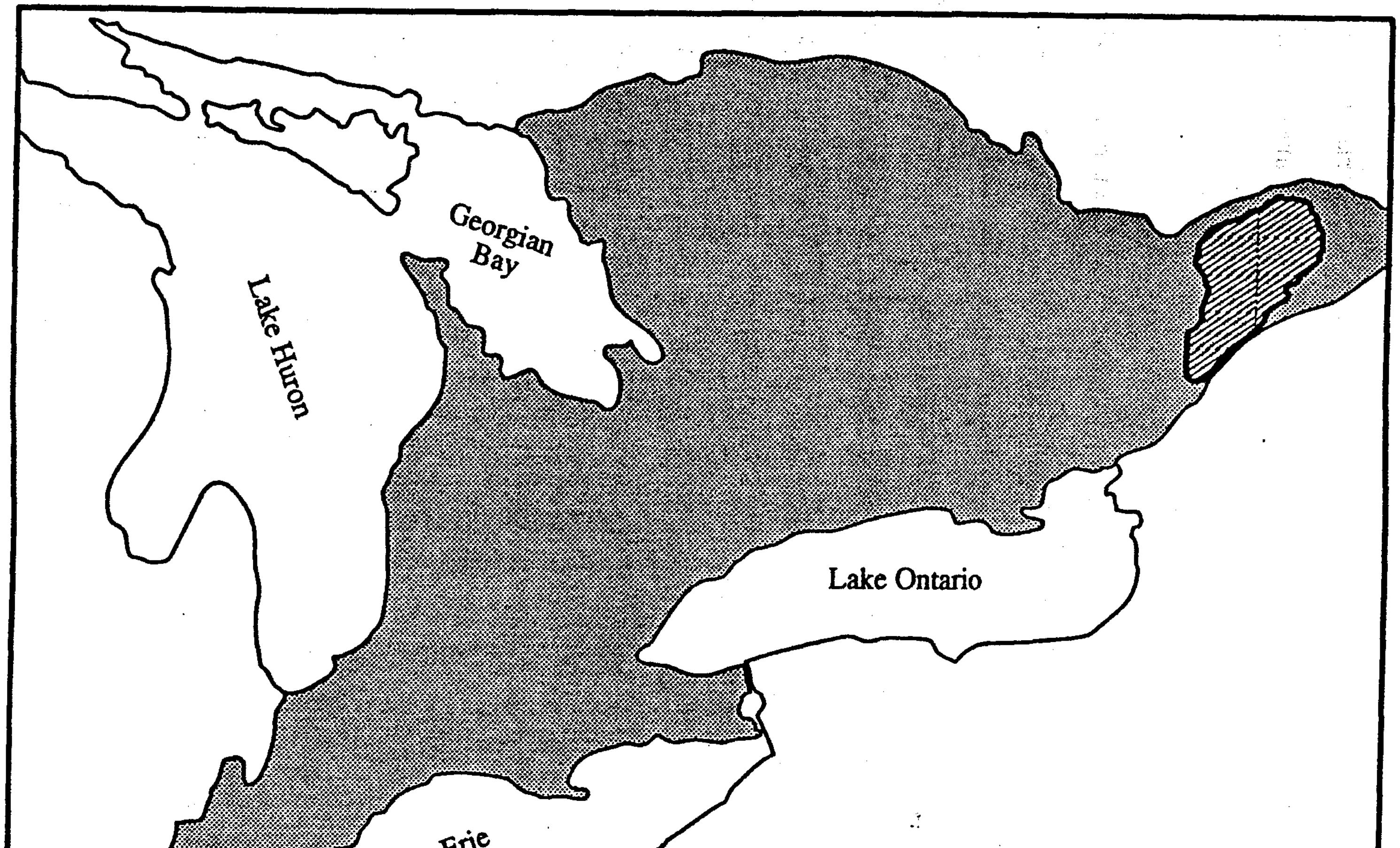

FIGURE 1.1 — Location of the South Nation River Basin in Eastern Ontario

suggested to better address federal needs.

The purpose of this pilot study is to examine existing MOE water quality data for the South Nation River Basin, particularly in relation to existing land use practices in the basin. The data will be evaluated in terms of its adequacy in addressing specific national water quality issues which are of concern in this river basin.

The South Nation River is one of eastern Ontario's largest rivers with a drainage basin of approximately 3900 km2 (Figure 1.1). The basin includes parts of the Counties of Leeds and Grenville, Stormont, Dundas and Glengarry, Prescott and Russell, and the Regional Municipality of Ottawa-Carleton. Although there are no major urban centres in the basin, most communities are within commuting distance of one of four large municipalities: the Town of Hawksbury; the City of Cornwall; the City of Brockville, or the City of Ottawa. The river basin has unique physical characteristics which cause continuing problems for natural resource management in general and water management in particular (SNRCA 1983).

2.0 STUDY OBJECTIVES

The following objectives for the study were defined:

1) Conduct a literature review of water quality and land use publications relevant to the issues of pesticides, eutrophication and baseline information in the South Nation River basin.

on the water quality of Ontario's lakes and rivers. Sampling stations in the PWQMN have been selected to measure water quality at strategic geographic locations and to monitor the effects of point source waste water discharges and the effects of nonpoint source land uses.

An extensive water quality data base has been assembled through the PWQMN. To date however, there have been few attempts to analyze this information on a watershed or basin level, or to investigate relationships between water quality and land use.

The Inland Waters Directorate of the federal Department of Environment (DOE), through the Canada-Ontario water quality agreement is interested in establishing a national network of water quality monitoring stations to meet the data needs of both federal and provincial governments in several Ontario river basins. The purpose of this network is to develop and maintain a coordinated, comparable, nationwide inventory of water quality information, which will enable the Inland Waters Directorate (IWD) to effectively address and respond to important national water quality issues.

As a first step in this process, an evaluation of current water quality information being collected through the PWQMN (e.g. sampling locations, frequency of sampling, parameters being sampled) is required. This data is being examined in terms of its adequacy for addressing national water quality issues in each river basin. Following this assessment, IWD will be better able to evaluate the effectiveness of the existing sampling regime relative to federal information requirements. Based on this evaluation, alternative sampling strategies can be

1.0 INTRODUCTION

A series of studies of nonpoint source pollution to the Great lakes Basin, undertaken as part of the Pollution from Land Use Activities Reference Group (PLUARG) during the 1970's, served to document and highlight the relationship between land use activities, and surface water quality (IJC 1980).

The PLUARG studies found that the Great Lakes were being polluted from land use activities by phosphorous, sediments, industrial compounds, pesticides, and certain heavy metals. Within the Great Lakes Basin, intensive agricultural operations were identified as the major nonpoint source of phosphorous; erosion from crop production on fine textured soils and from urbanizing areas were identified as primary sources of sediment; and urban runoff and atmospheric deposition were found to be the main sources of toxic substances.

The most important land related factors affecting nonpoint loadings included soil type, land use intensity, and materials usage. For example intensive row cropping (corn, soybeans) on fine textured soils (silts and clays) contributed the highest amounts of phosphorous.

Since 1964, the Ontario Water Resources Commission, and more recently the Ministry of the Environment (MOE), have operated a Provincial Water Quality Monitoring Network (PWQMN). This network was established to provide information

Table 5.1. Statistical summary for each of the variables examined during the 1980-1988 study period. Median concentrations for each variable are presented for each of the sub-basins examined.

SUB-BASIN	ALKALINITY (mg/l)	CHLORIDE (mg/l)	NH3-N (mg/l)	TKN (mg/l)	TOTAL P (mg/l)	COPPER (mg/l)	LEAD (mg/l)	SULPHATE (mg/l)	TURBIDITY (FTU)	DO (mg/l)	COND (mg/l)
Plantagenet	171	32	0.07	0.98	0.10	0.007	0.003	41.6	21.5	11.0	506
Russell	214	28	0.05	0.65	0.07	0.005	0.003	N/A	15.0	9.0	579
St. Isidore	197	25	0.04	1.05	0.18	0.007	0.003	N/A	52.0	9.0	511
Chesterville	199	18	0.05	1.02	0.06	0.007	0.003	N/A	11.3	8.0	481

using individual values, rather than using annual or seasonal mean values because it was felt that the data could be better compared with the land use information on a sub-basin level.

To assist in sub-basin comparisons and evaluation of trends in surface water quality, a general summary of the information was prepared (using median concentration values) and results presented in Table 5.1.

5.1 Total Phosphorous

Concentrations of total phosphorous in each of the sub-basins are shown on Figure 5.1. Median phosphorous concentrations for each of the sub-basins during the study period are presented in Figure 5.2. Although observations are sporadic for the upper sub-basin (Chesterville), the less intensive agricultural nature of the sub-basin (47% row crops, 28% forested and 12% idle land) is reflected in the lowest concentrations of phosphorous (0.04-0.2 mg/l). The highest concentrations of total P occur in the Scotch sub-basin (0.1-1.0 mg/l) and reflect three factors: 1) the sub-basin has the highest intensity of row crops of all sub-basins (65%); 2) a significant portion of the west branch of the Scotch River is susceptible to bank instablity; and 3) a significant portion of the sub-basin has been tile drained or ditched (83% of the basin has fine-textured silt and clay soils).

The Castor sub-basin also exhibits relatively high concentrations of phosphorous, again reflecting the high percentage of fine-textured soils, intensive agriculture, and significant reaches of the River which are susceptible to

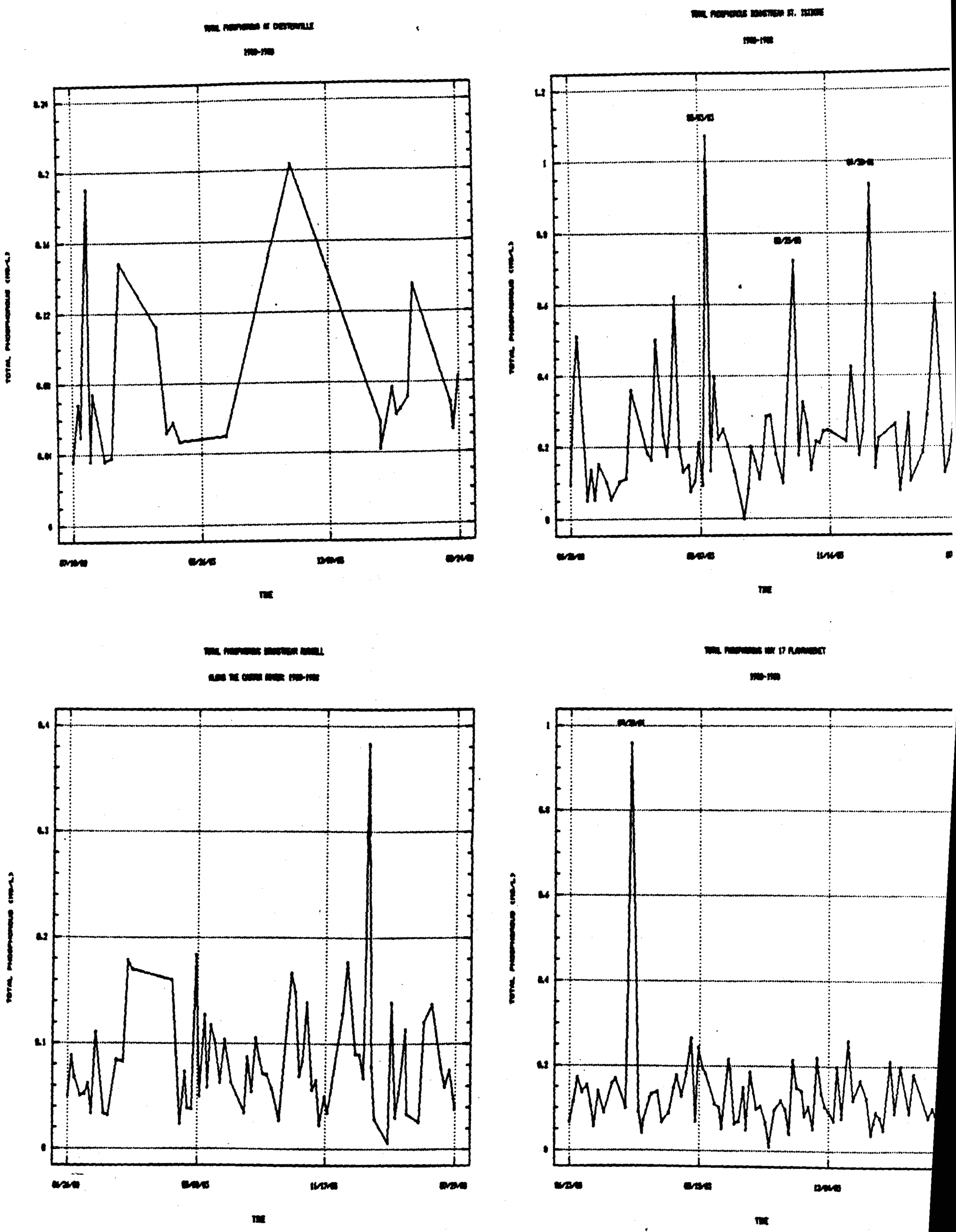

Figure 5.1. Total Phosphorous concentrations in each of the four major sub-basins of the South Nation River.

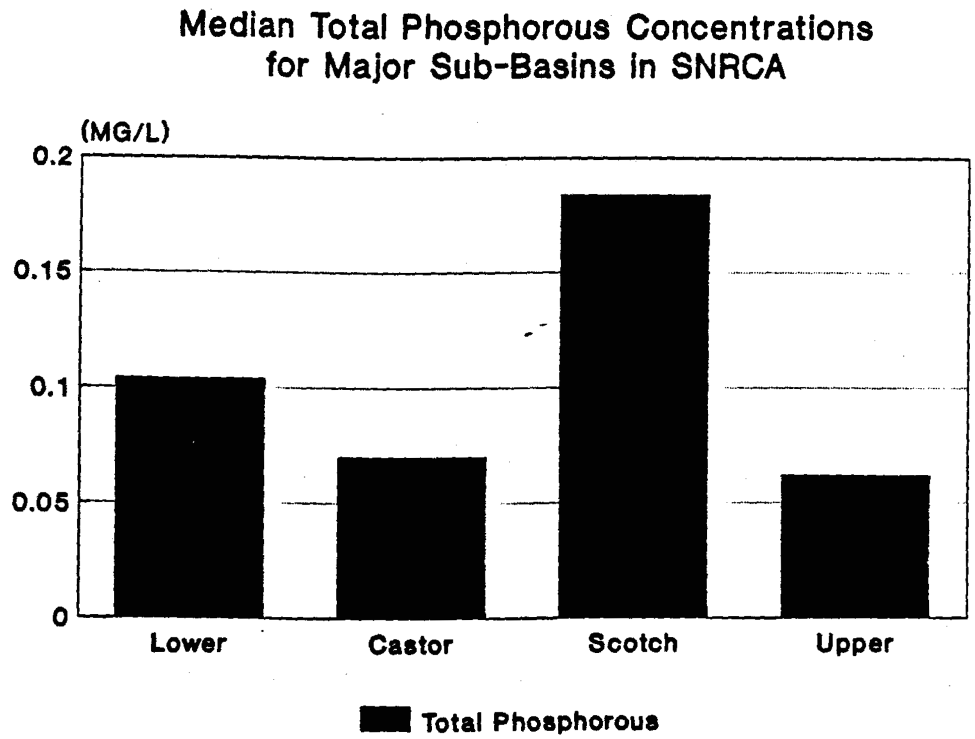

Figure 5.2. Median concentrations for Total Phosphorous in each of the four major sub-basins of the South Nation River.

erosion (instability) and flooding. With the exception of one observation, (which may represent analytical error or a major storm event response), phosphorous concentrations at Plantagenet in the Lower sub-basin are less variable and do not exhibit the wide fluctuations associated with the other sub-basins. More stable stream flow in the Lower basin likely contributes to this condition.

Trend analysis (Figure 5.3) suggests that Total Phosphorous concentrations have increased in all but the downstream basin of the South Nation River watershed throughout the 1980's. Expected improvements in phosphorous concentrations resulting from various water management programs initiated in the basin following intensive studies during the early 1980's (SNRCA 1983) have not been observed except at the Plantagenet station. Here, a decline of about 35% in total phosphorous concentration (from 16 to 11 mg/l) values is observed in the Lower sub-basin. The reason for this change in the Lower sub-basin is not clear but may be related in part to higher flow conditions associated with this part of the watershed, or better point source control in this part of the watershed.

Phosphorous concentrations consistently exceed the canadian water quality guidelines of 0.030 mg/l in all sub-basins for which data is available. Guidelines are exceeded 99% of the time in the Lower sub-basin, 98.5% of the time in the Scotch sub-basin and 86.7% of the time in the Castor sub-basin. Approximately 95% of phosphorous losses in the basin originate with non-point (i.e. agricultural) sources (MacLaren Plansearch 1982). The remaining losses are attributed to point source discharges such as the 2 industrial and 6 municipal lagoon discharge sources.

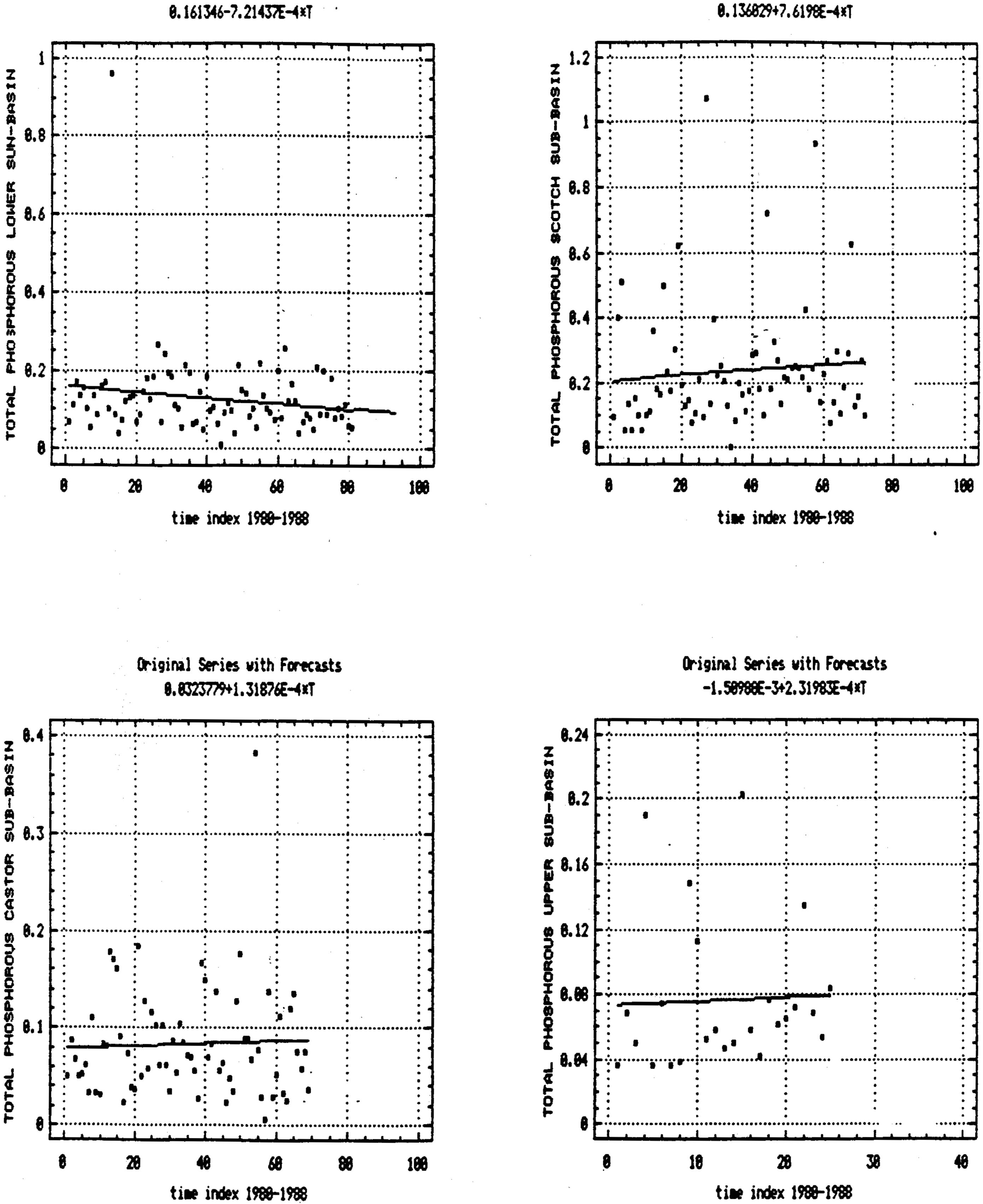

Figure 5.3. Trends in Total Phosphorous concentrations in each of the four major sub-basins of the South Nation River.

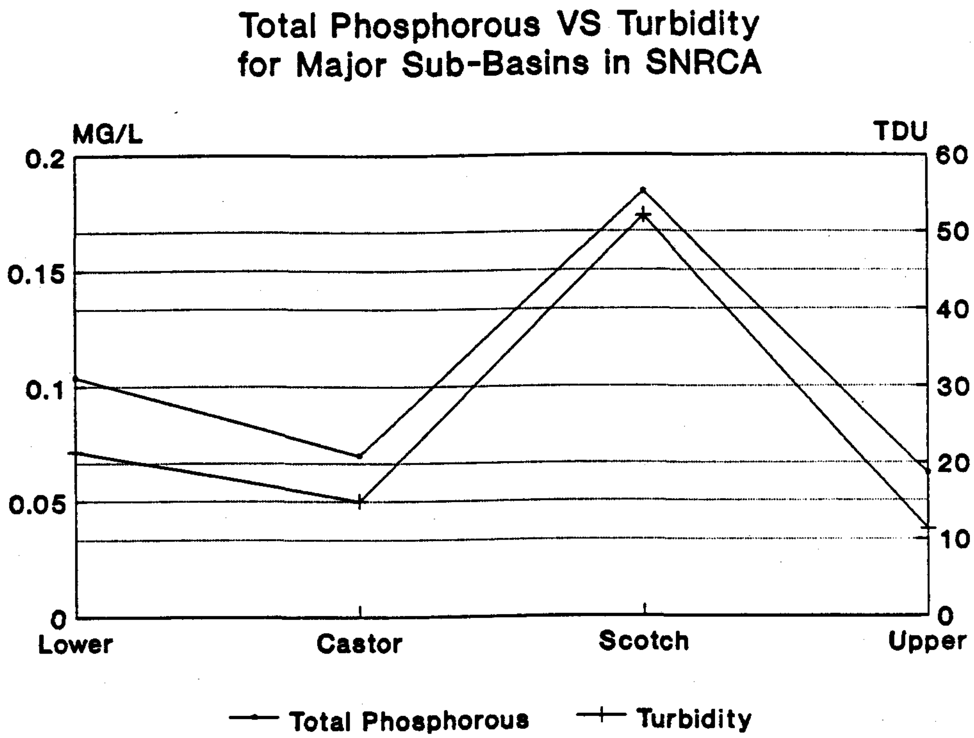

Figure 5.4. Relationship between Total Phosphorous and Turbidity in each of the four major sub-basins of the South Nation River.

The importance of erosion control is highlighted in Figure 5.4 which shows the relationship between phosphorous concentrations and turbidity in each of the sub-basins. The analysis suggests that until erosion control measures, particularly those affecting open drains and streambank instability are effectively instituted, improvements in phosphorous concentrations cannot be expected.

5.2 Total Nitrogen

Total nitrogen (Kjeldahl) concentrations for each of the four sub-basins are shown in Figure 5.5. Observations are sporadic, except in the Lower sub-basin at Plantagenet where sampling has been consistent on a monthly basis since 1984. Figure 5.6 presents median TKN concentrations over the study period for each of the sub-basins. Concentrations range from 0.7 mg/l in the Castor sub-basin to 1.05 mg/l in the Scotch sub-basin. All TKN values are less than the drinking water quality guideline of 10 mg/l. Figure 5.5 suggests that total nitrogen concentration in the Lower sub-basin have increased over the study period. The reason for this is not clear, however it is consistent with data reported elsewhere. Possible causal factors would include increased use of nitrogen based fertilizers and increased drainage activity in the basin.

5.3 NH3-N (Total Ammonia)

Ammonia sources in the basin are associated primarily with low level applications of fertilizers used in the production of row crops such as corn and from

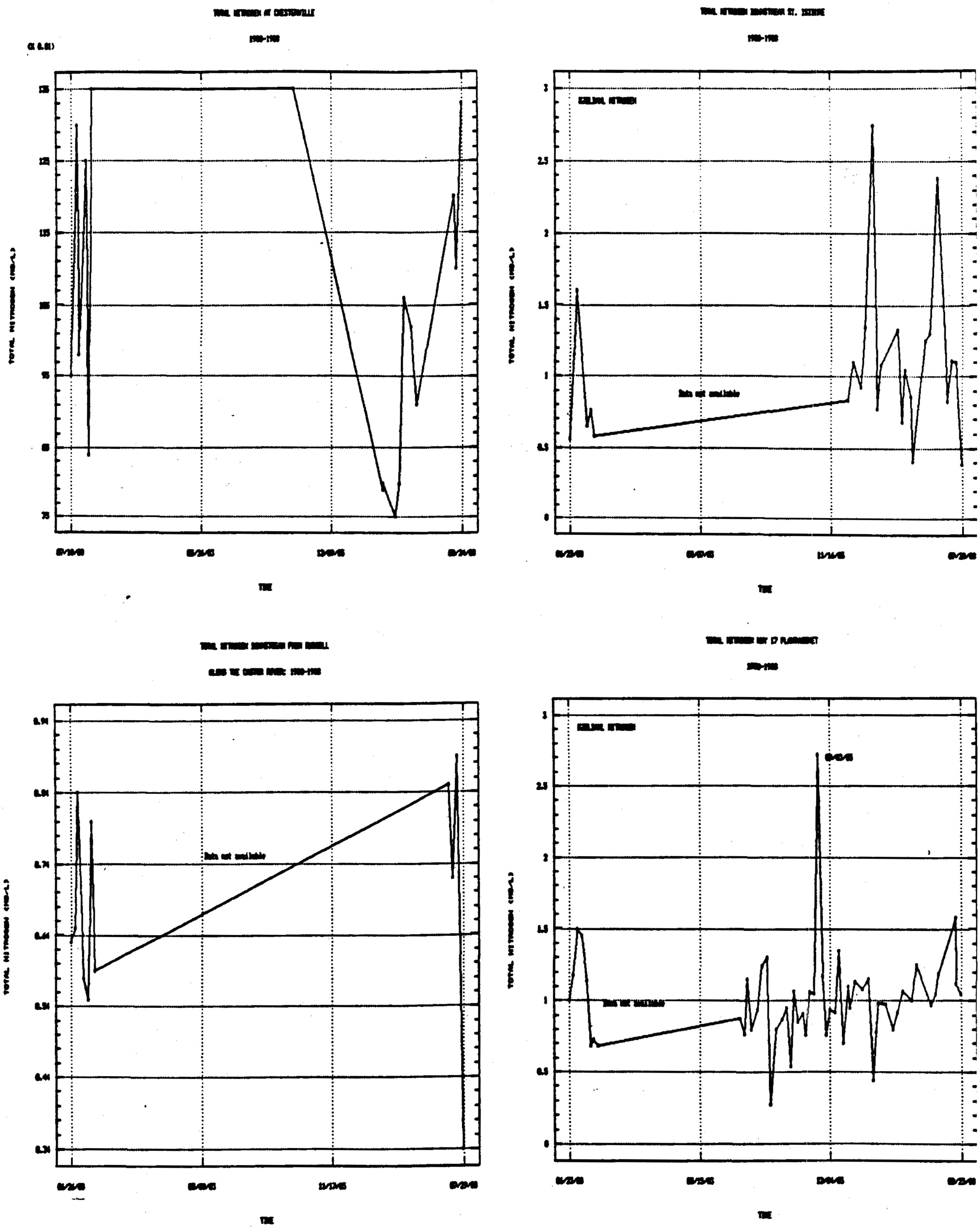

Figure 5.5. Total Kjeldahl Nitrogen (TKN) concentrations in each of the four major sub-basins of the South Nation River.

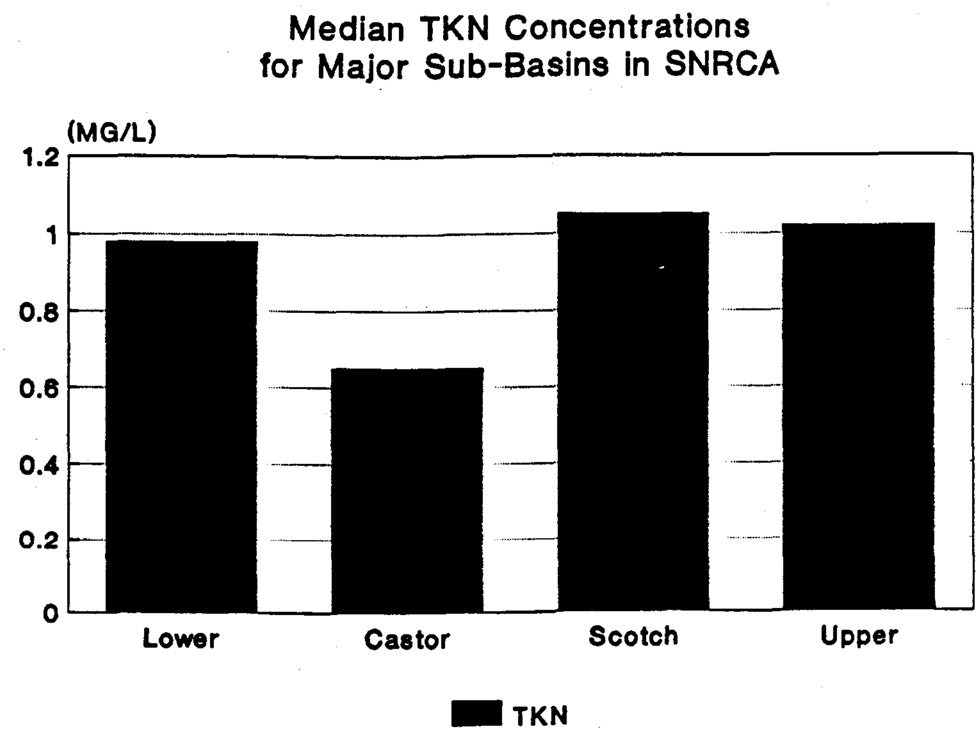

Figure 5.6. Median concentrations of TKN in each of the four major sub-basins of the South Nation River.

livestock activities such as manure application and cattle access to stream courses. Ammonia concentrations for each of the sub-basins is shown in Figure 5.7. Observations from the Upper sub-basin and the Castor sub-basin are limited and little further comment is possible. Median concentrations of ammonia for each of the sub-basins over the study period are shown in Figure 5.8. In the Scotch River sub-basin concentrations range from 0.99 mg/l to 0.002 mg/l with large seasonal fluxes clearly evident. Median concentration in the sub-basin is 0.04 mg/l. Concentrations in the Lower sub-basin range from 1.45 mg/l to 0.002 mg/l with a median concentration of 0.07 mg/l (Table 5.1). Water quality guidelines for aquatic life are consistently met in both sub-basins.

5.4 Turbidity

Turbidity concentrations for each of the sub-basins is shown in Figure 5.9. Median concentrations for each of the sub-basins over the study period are shown in Figure 5.10. Highest concentrations are associated with the Scotch River sub-basin, a basin dominated by fine-textured soils, row cropping and land drainage. The median turbidity value for this sub-basin (52.0 FTU) is over twice that of the Lower sub-basin (21.5 FTU).

Figure 5.11 shows an increasing trend in turbidity in all of the sub-basins throughout the 1980's reflecting in particular the increase in land drainage. The Scotch sub-basin shows the greatest relative increase and is currently the largest (of those sub-basins studied) sediment-contributing sub-basin in the South Nation River Basin. Turbidity is lowest in the Upper sub-basin, where fine-

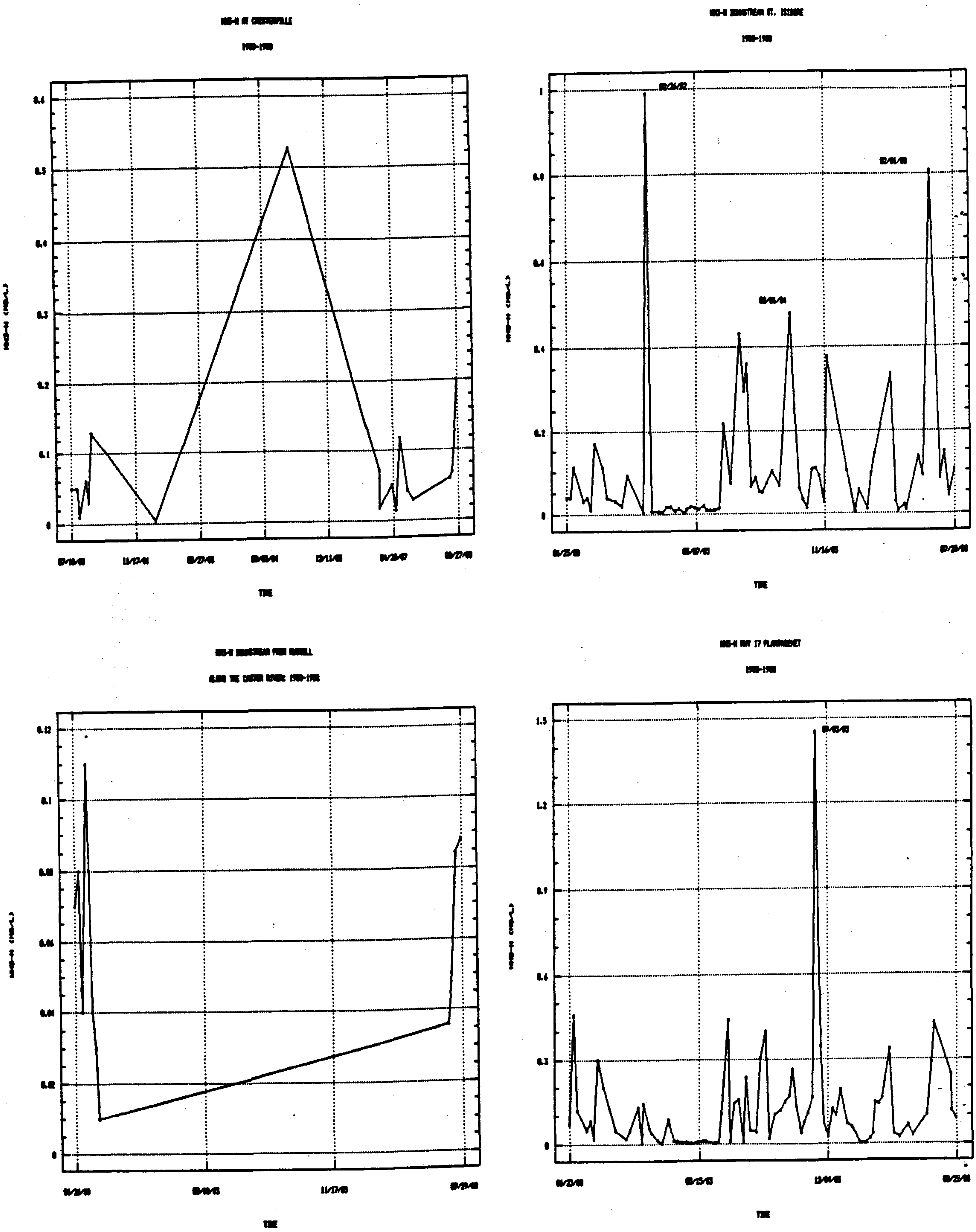

Figure 5.7. NH3-N concentrations in each of the four major sub-basins of the South Nation River.

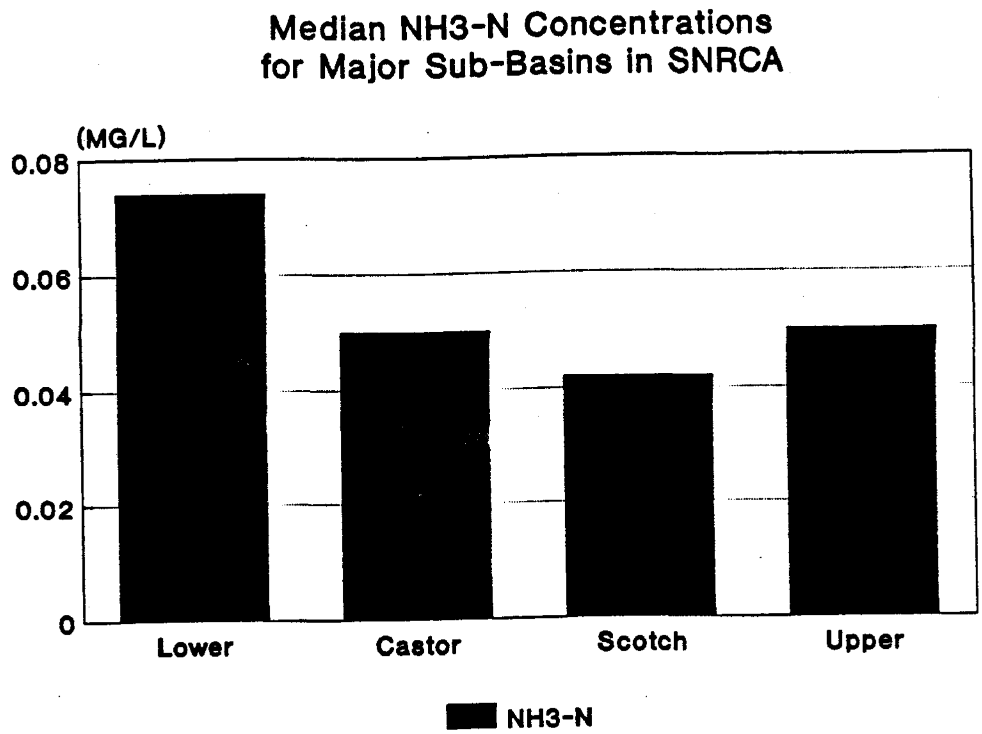

Figure 5.8. Median concentrations of NH3-N in each of the four major sub-basins of the South Nation River.

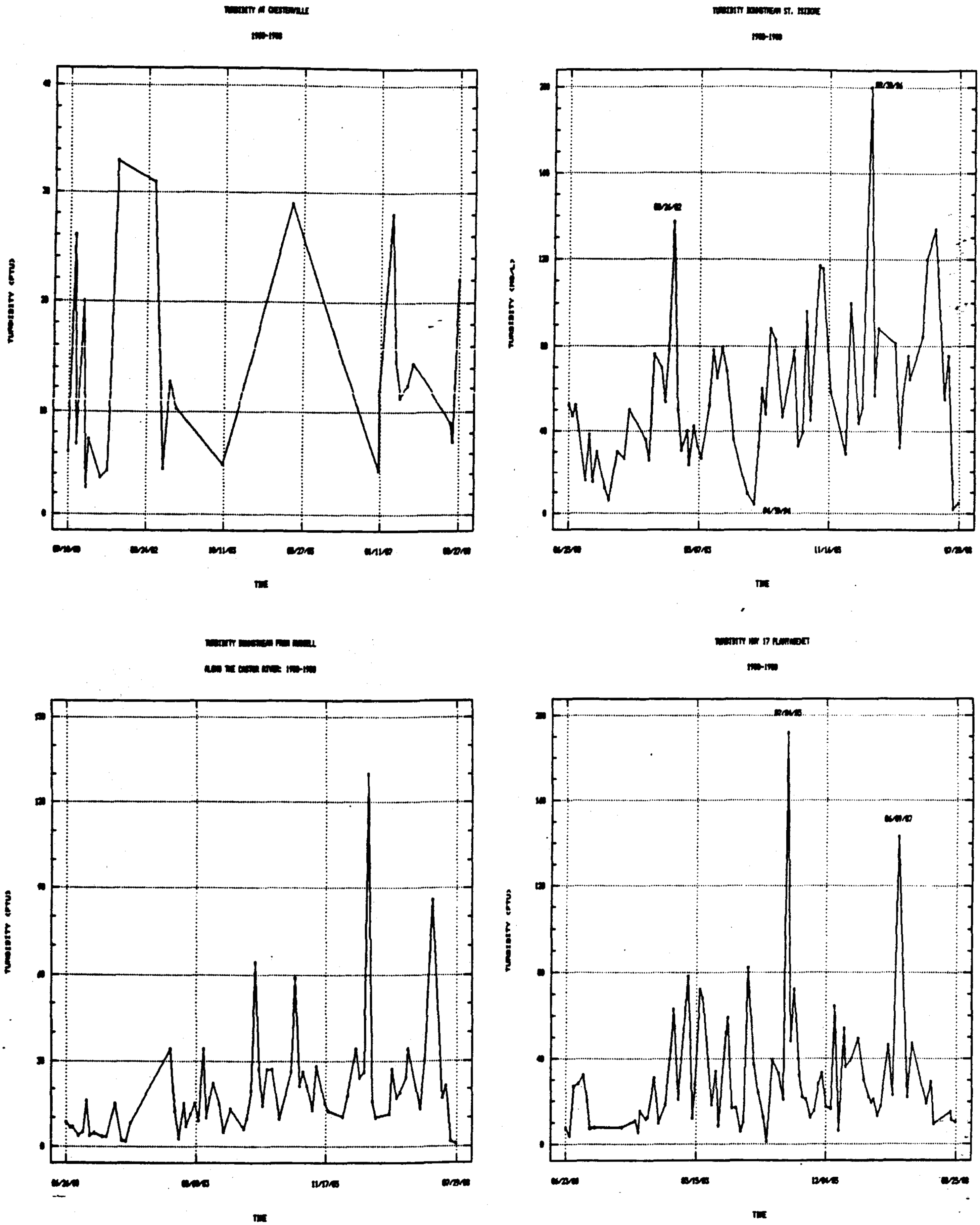

Figure 5.9. Turbidity concentrations in each of the four major sub-basins of the South Nation River.

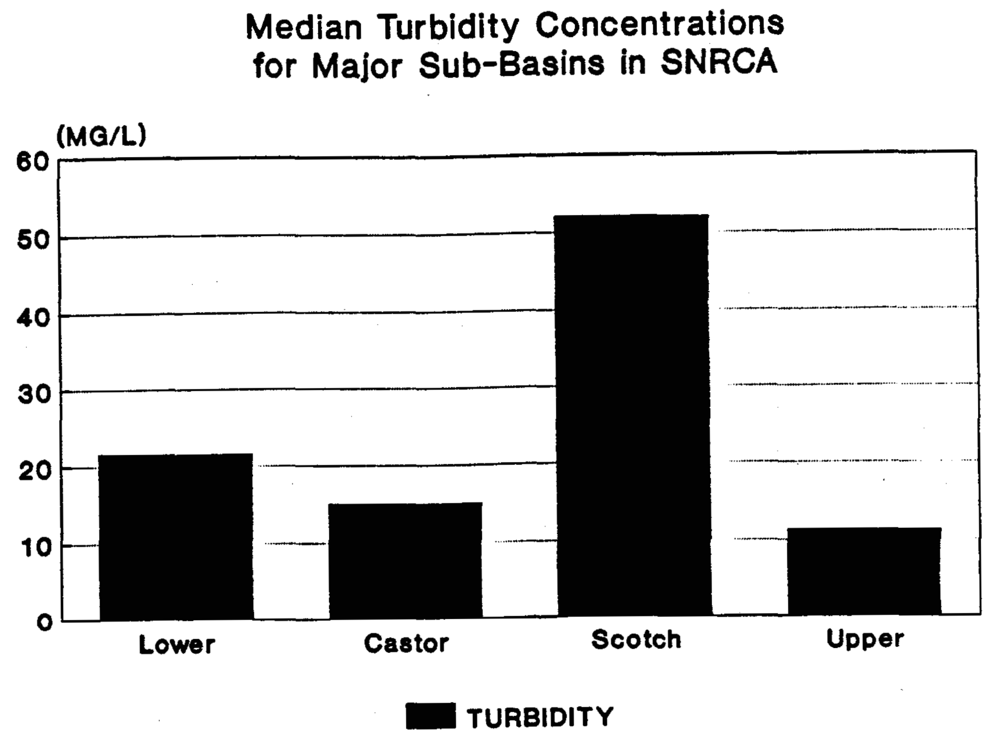

Figure 5.10. Median Turbidity concentrations in each of the four major sub-basins of the South Nation River.

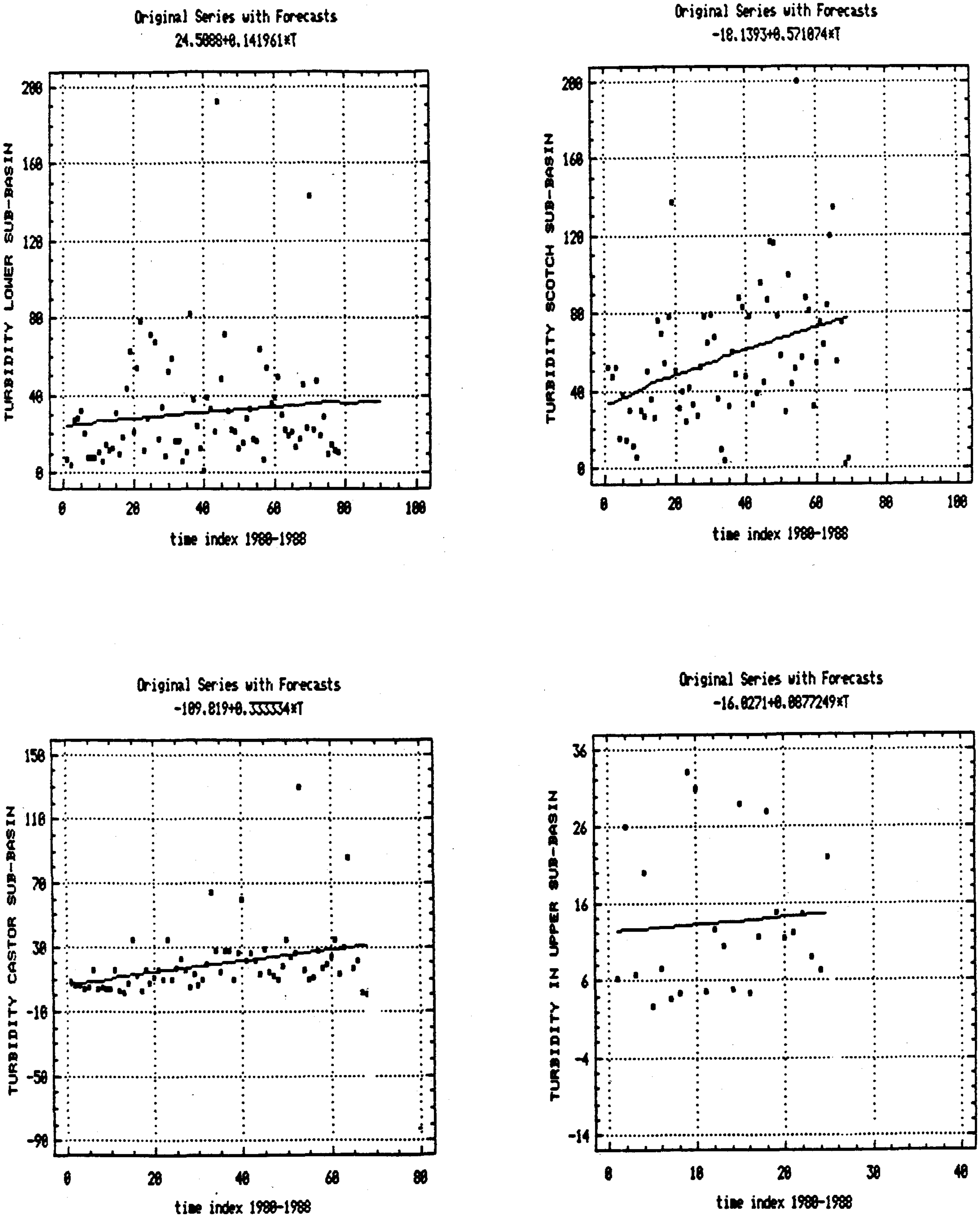

Figure 5.11. Trends in Turbidity concentrations in each of the four major sub-basins of the South Nation River.

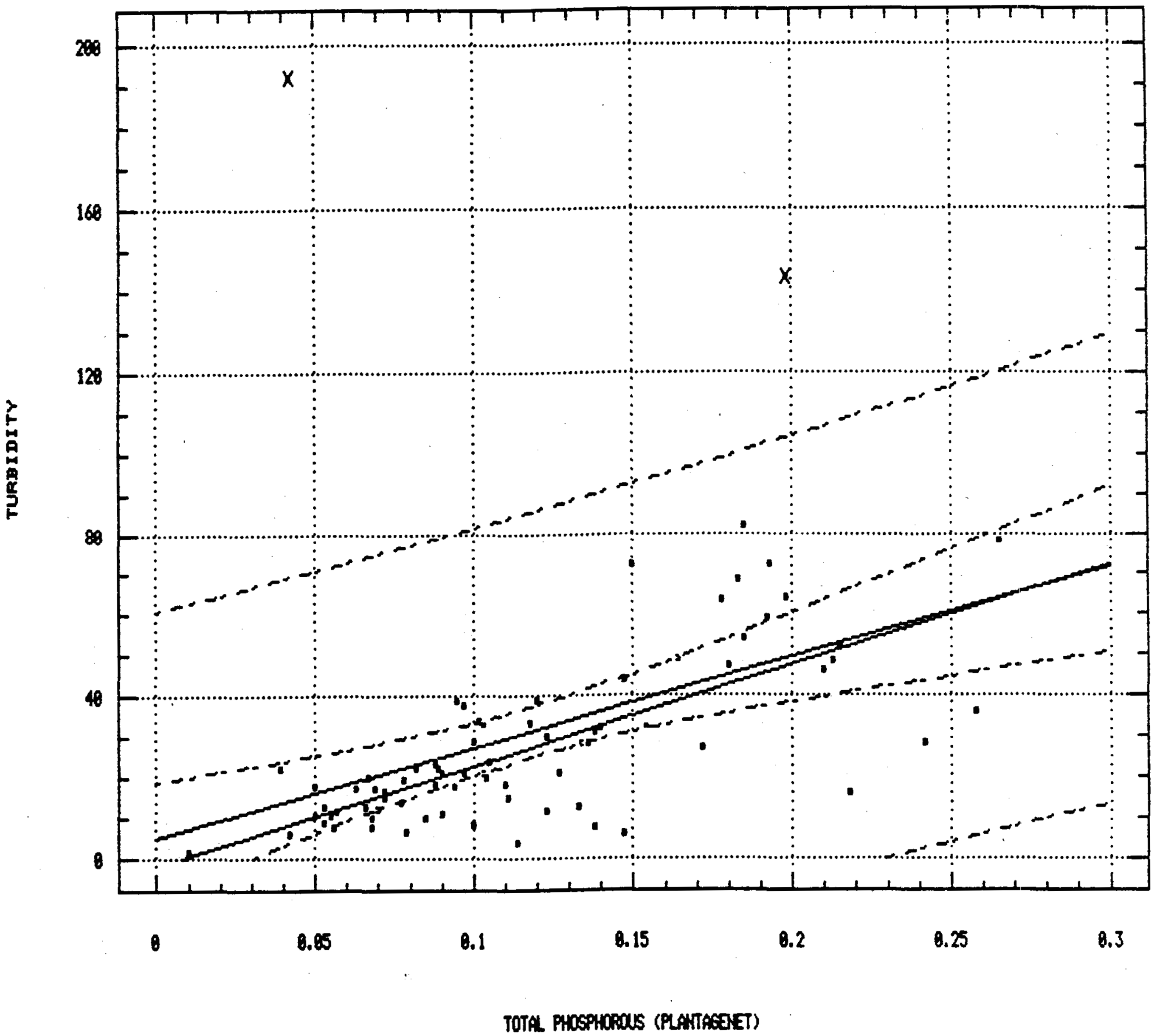

Figure 5.12. Total Phosphorous vs Turbidity in the Lower sub-basin of the South Nation River: a regession model.

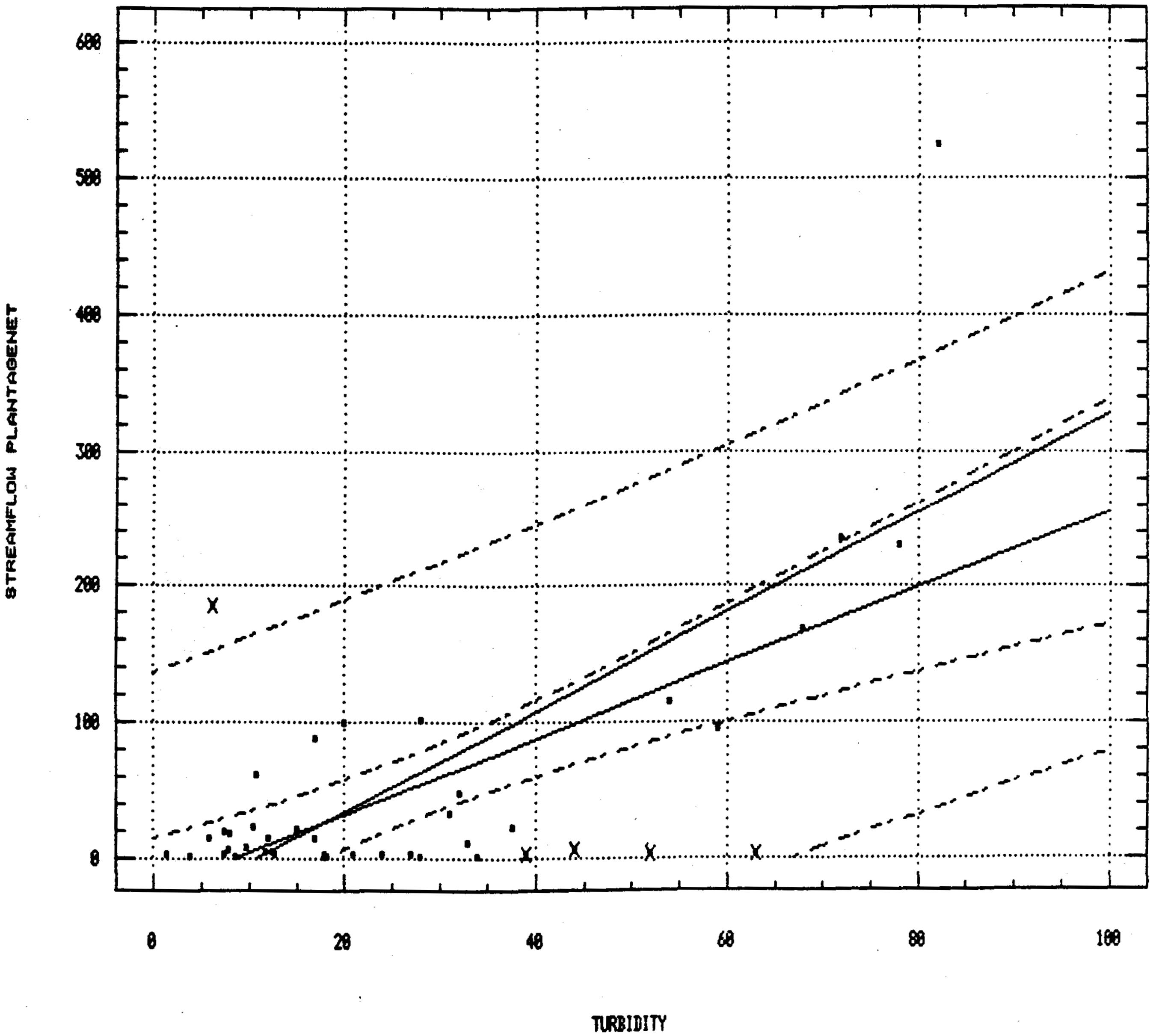

Figure 5.13. Turbidity vs Streamflow in the Lower sub-basin of the South Nation River: a regression model.

textured soils, land drainage and row cropping are not as dominant.

Statistically derived relationships between turbidity and various other water quality parameters have been established in studies such as those carried out by PLUARG with varying degrees of success. Similar relationships were explored during this study also with limited success.

The general relationship between turbidity and phosphorous has been discussed in section 4.1 and was explored further using regression analysis for the Lower sub-basin (Figure 5.12.). The close relationship (R= 0.71887) between the two variables is again indicated. Figure 5.13 shows the relationship between turbidity and streamflow (R= 0.79705) for the Lower sub-basin.

5.5 Dissolved Oxygen

Dissolved oxygen concentrations for the four sub-basins are shown in Figure 5.14. Median concentration values for each of the sub-basins are shown in Table 5.1 and graphed in Figure 5.15 for ease of comparison. Observations for the Upper Sub-basin have been sporadic thereby making it difficult to observe trends. In general, concentrations range between 3.0 mg/l and 16.0 mg/l throughout the basin, with mean values of 9.1 mg/l in the Scotch sub-basin, 9.5 mg/l in the Castor sub-basin, and 11.2 mg/l in the Lower sub-basin.

Figure 5.16 shows dissolved oxygen trends in each of the sub-basins. The analysis suggests that improvements in dissolved oxygen over the study period have

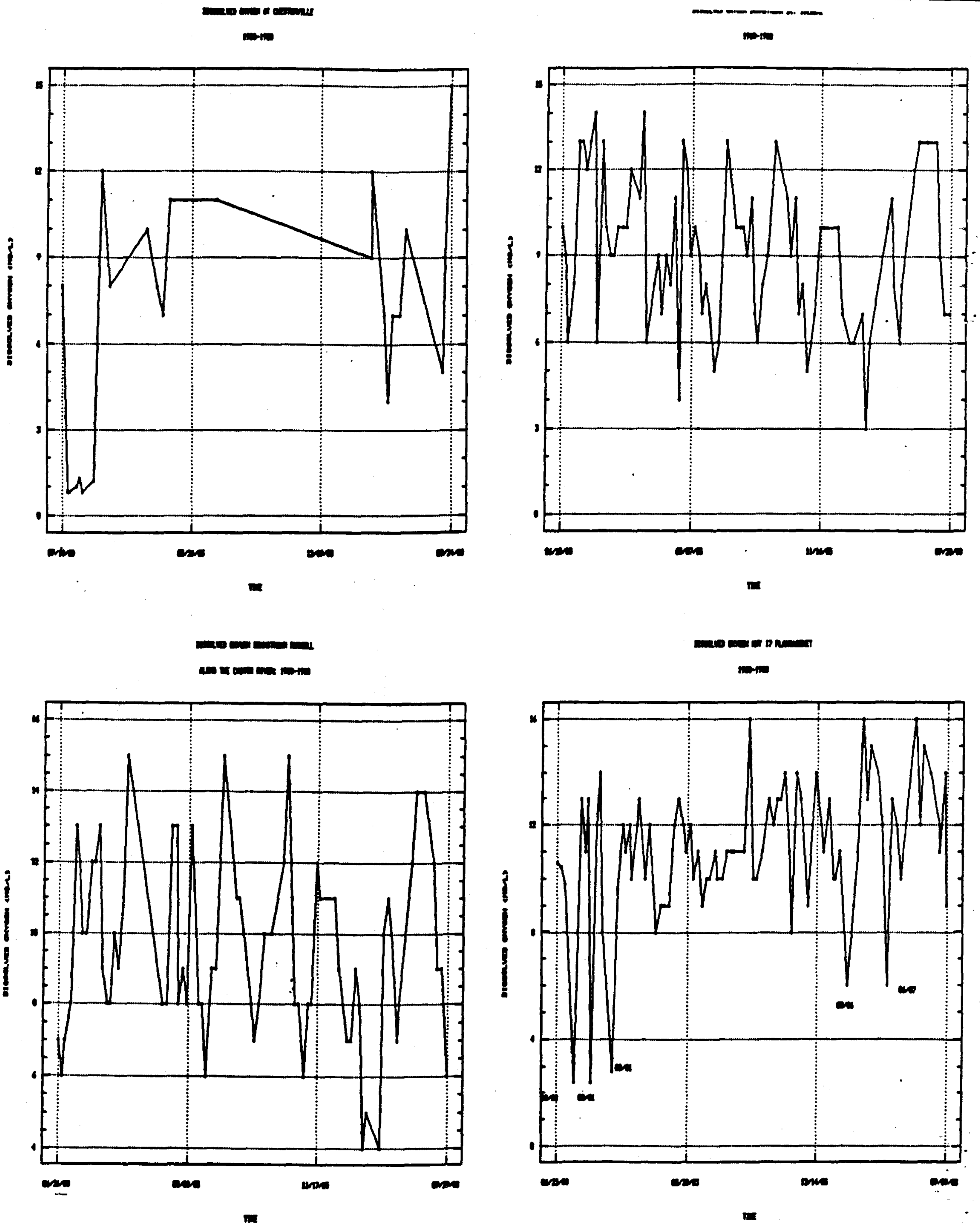

Figure 5.14. Dissolved Oxygen concentrations in each of the four major sub-basins of the South Nation River.

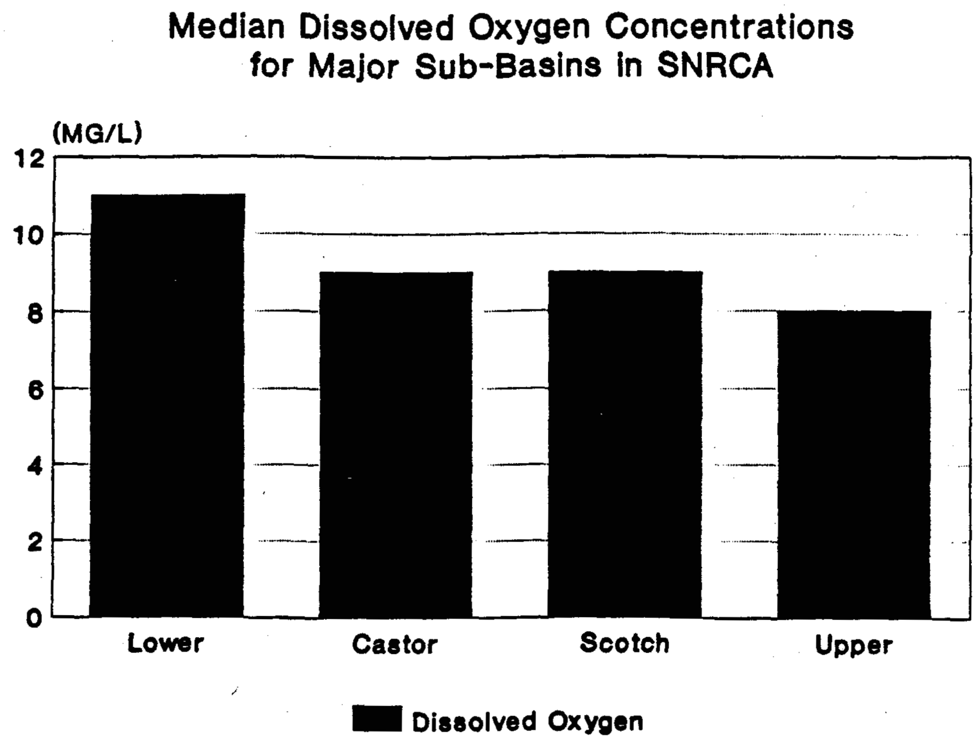

Figure 5.15. Median concentrations of Dissolved Oxygen in each of the four major sub-basins of the South Nation River.

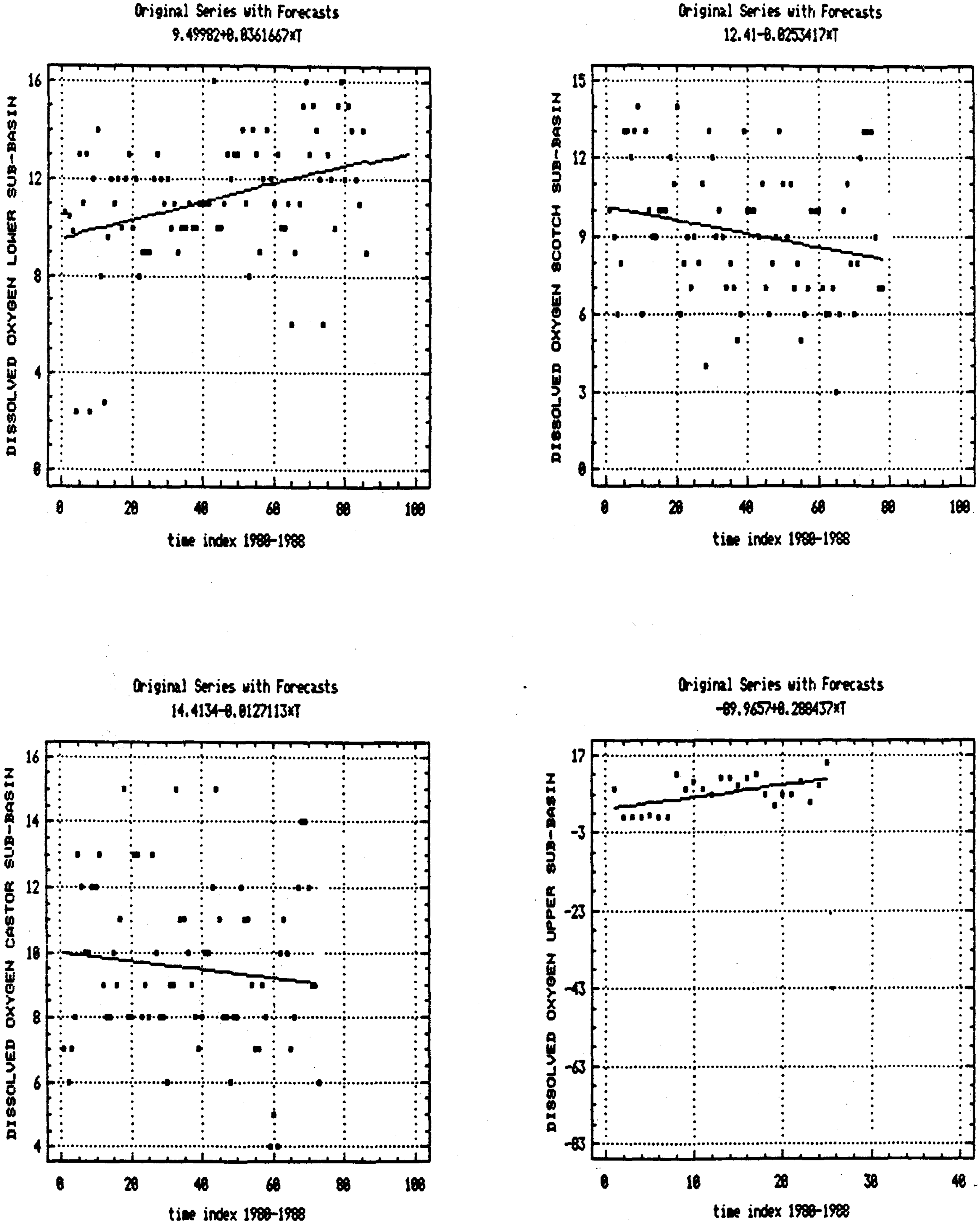

Figure 5.16. Trends in Dissolved Oxygen in each of the four major sub-basins of the South Nation River.

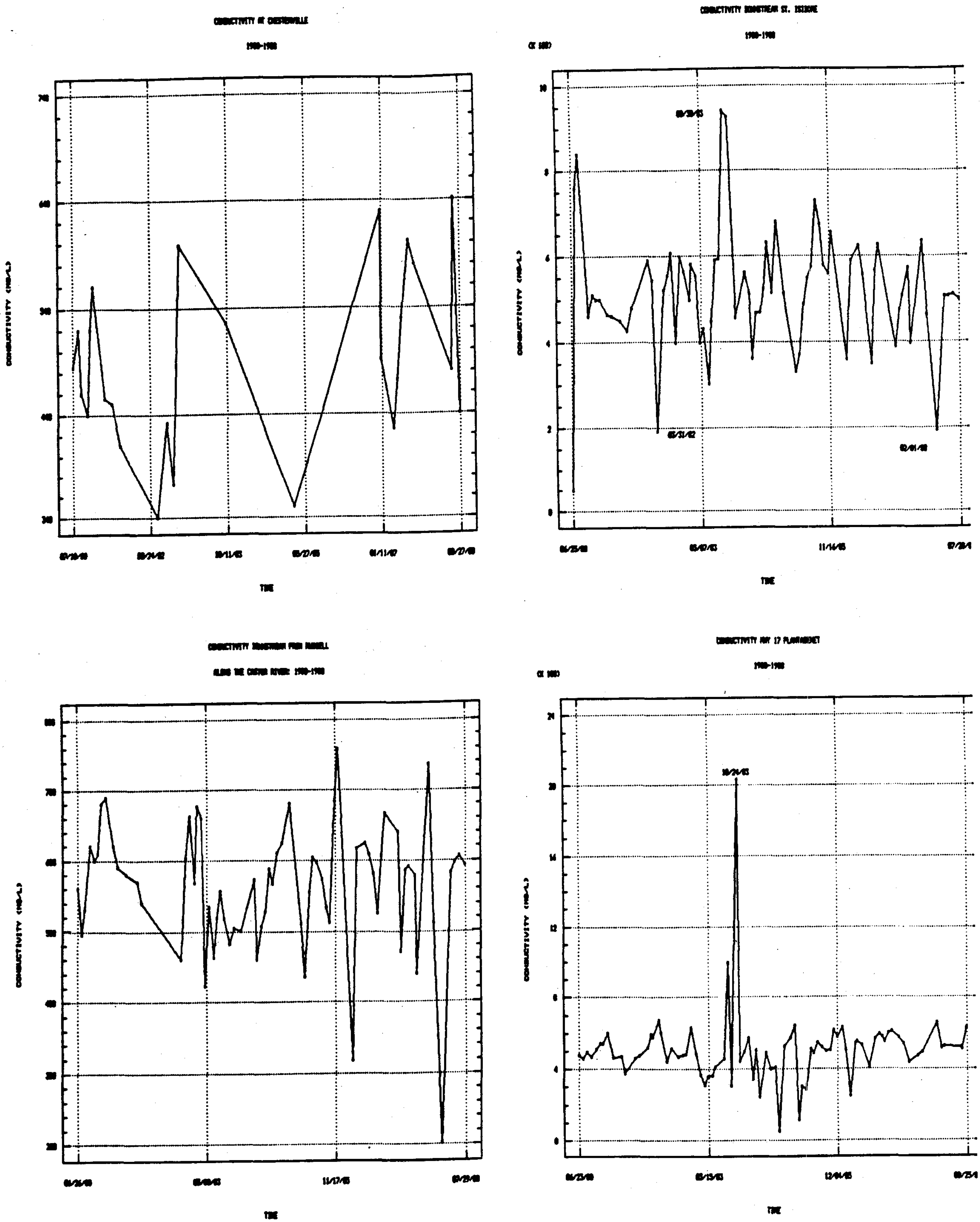

Figure 5.17. Conductivity in each of the four major sub-basins of the South Nation River.

occurred in the Upper and Lower sub-basins, while deteriorating conditions are observed in the Castor and Scotch sub-basins. These latter trends in dissolved oxygen conditions are not entirely unexpected as both sub-basins are intensively row cropped, subject to considerable erosion, and have experienced significant increases in land drainage over the study period.

In general, dissolved oxygen concentrations satisfy the water quality guidelines for aquatic life (6.5 mg/l) in each of the sub-basins.

5.6 Conductivity

Conductivity concentrations for the four sub-basins are shown in Figure 5.17. Median concentrations for each of the sub-basins over the study period are shown in Table 5.1. Highest median concentrations are observed in the Castor sub-basin (579.5 mg/l), and lowest concentrations in the Upper sub-basin (481 mg/l), reflecting the dominance of fine-textured soils and slope instability associated with the Castor sub-basin.

5.7 Alkalinity

Alkalinity concentrations for the four sub-basins are shown in Figure 5.18. Median concentrations for each of the sub-basins is presented in Table 5.1. Sporadic observations only have been made for the Upper sub-basin. In general,

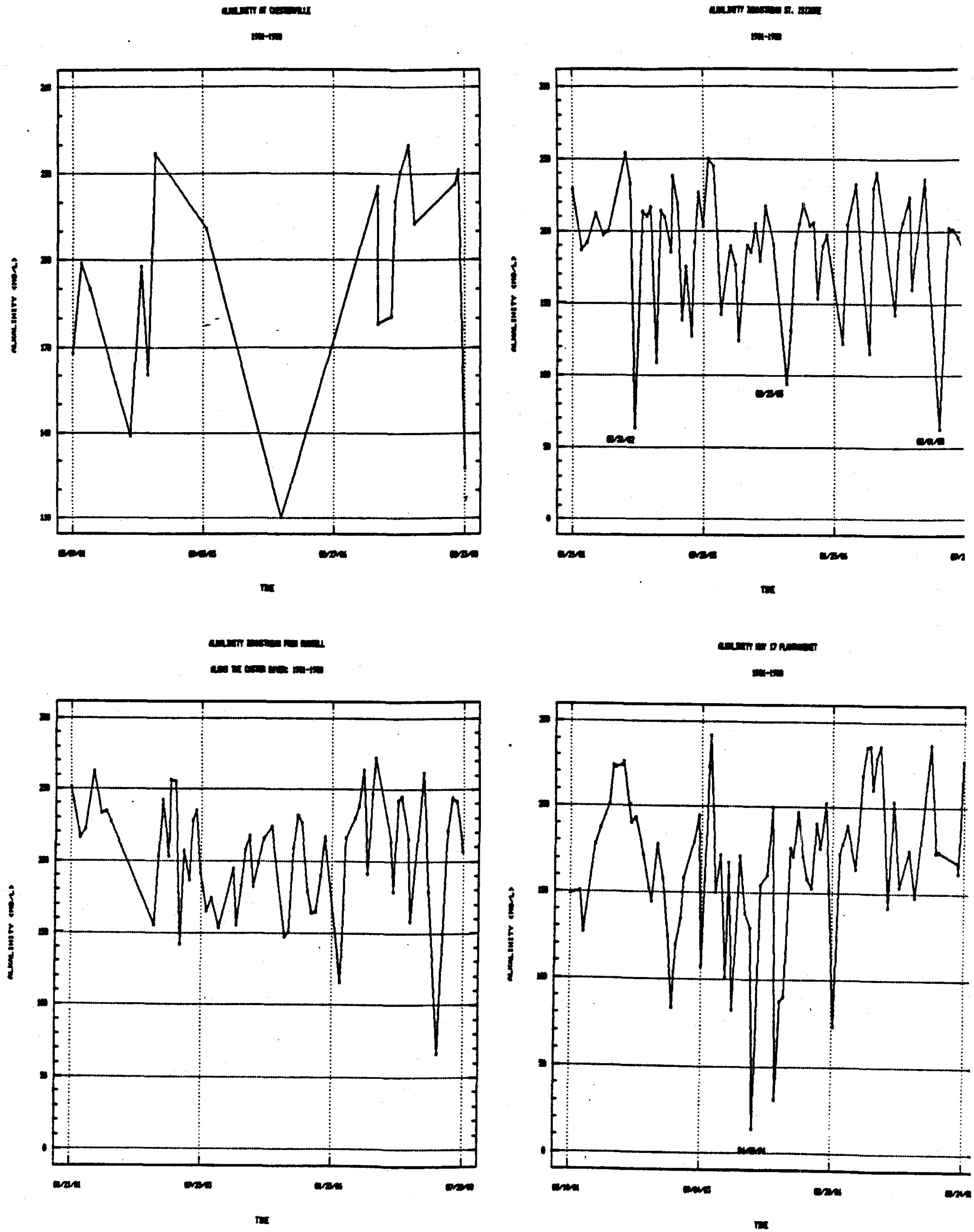

Figure 5.18. Alkalinity concentrations in each of the four major sub-basins of the South Nation River.

the various sub-basins are well buffered, with alkalinity concentrations ranging from a median of 214.35 mg/l in the Castor sub-basin to 171.8 mg/l in the Lower sub-basin. Concentrations have been relatively stable over the study period.

5.8 Chloride

Chloride concentrations for the four sub-basins are shown in Figure 5.19. Median concentrations are shown in Table 5.1 and Figure 5.20. From Figure 5.19 it can be seen that few observations are available for the Upper or Castor sub-basins hence interpretation is limited. In general, median concentrations increase downstream in the basin with concentrations in the Lower sub-basin of 32.1 mg/l. Concentrations in all sub-basins are within the guidelines for Canadian drinking water quality of 250 mg/l.

5.9 Trace Metals (Lead, Copper, Mercury, Aluminium)

Lead and copper concentrations (totals) for each of the sub-basins are shown in Figures 5.21 and 5.22. Mean concentrations are shown in Table 5.1. Data for other trace metals such as mercury and aluminium are available only for the Lower sub-basin. Trends for all four trace metals in the Lower sub-basin are shown in Figure 5.23. In general, trace metal data has been interpreted cautiously given the uncertainty associated with analytical results. Changing analytical techniques, detection levels and ease of sample contamination combine to create this uncertainty.

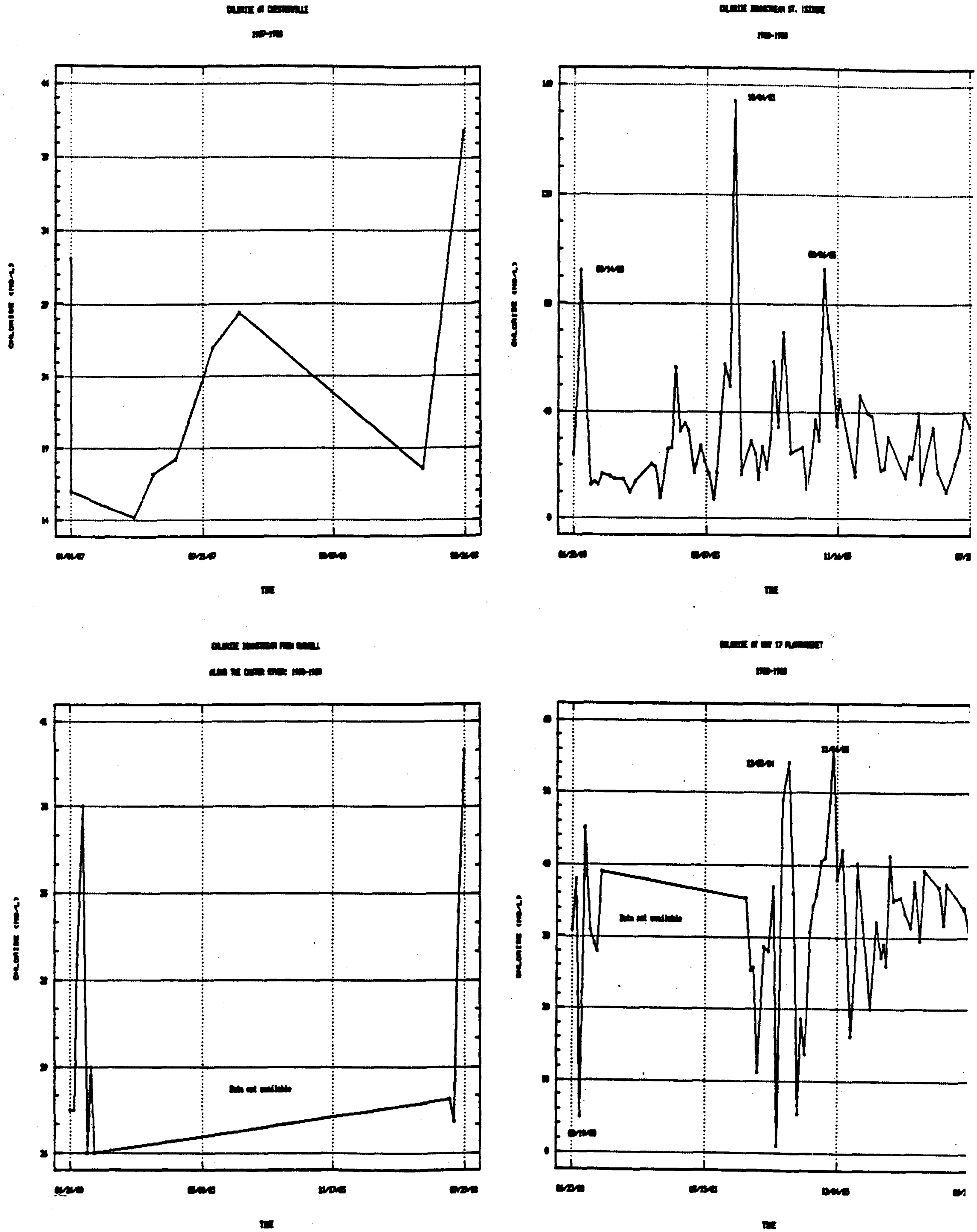

Figure 5.19. Chloride concentrations in each of the four major sub-basins of the South Nation River.

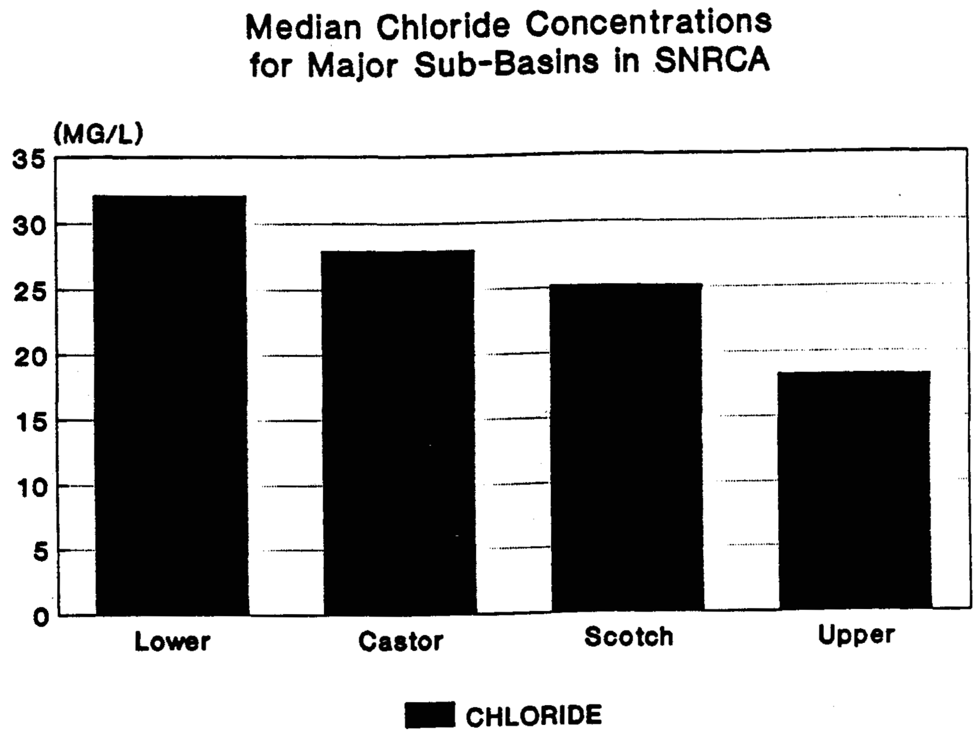

Figure 5.20. Median concentrations of Chloride in each of the four major sub-basins of the South Nation River.

Lead concentrations are low throughout the basin, typically at the detection level. Occasional spikes are observed and were discussed with staff of the SNRCA (Preston Pers. Com.), but no particular reason relating to land use, municipal or industrial lagoon discharge could be identified. Sample contamination is a highly likely cause of the extreme values. The Scotch sub-basin shows the highest tendancy for lead concentrations although levels, as in all other sub-basins have been relatively stable over the study period and within the Canadian guidelines for drinking water of 0.05 mg/l.

Copper concentrations are similar to those for lead, with levels in the Scotch sub-basin typically exhibiting most significant fluxes. Concentrations of copper in the Scotch sub-basin range from 0.027 mg/l to 0.001 mg/l. Sampling frequency has declined since 1986 and may account for the more apparently stable trend since that time. Changes in analytical techniques may also be responsible for this trend (see paragraph below).

In the Lower sub-basin, copper concentrations were in significantly greater flux prior to 1985 than since. Reasons for this trend are not immediately apparent, although MOE analytical techniques changed around this time and may account for the trend (Logan Pers. Com.). SNRCA staff (Preston Pers. Com.) could not suggest other land activity reasons for the trend. Regardless, it should be noted that concentrations are within the Canadian drinking water guidelines of 1.0 mg/l or the guideline of 0.04 mg/l for aquatic life.

Aluminium has been measured consistently in the Lower sub-basin since 1984, and

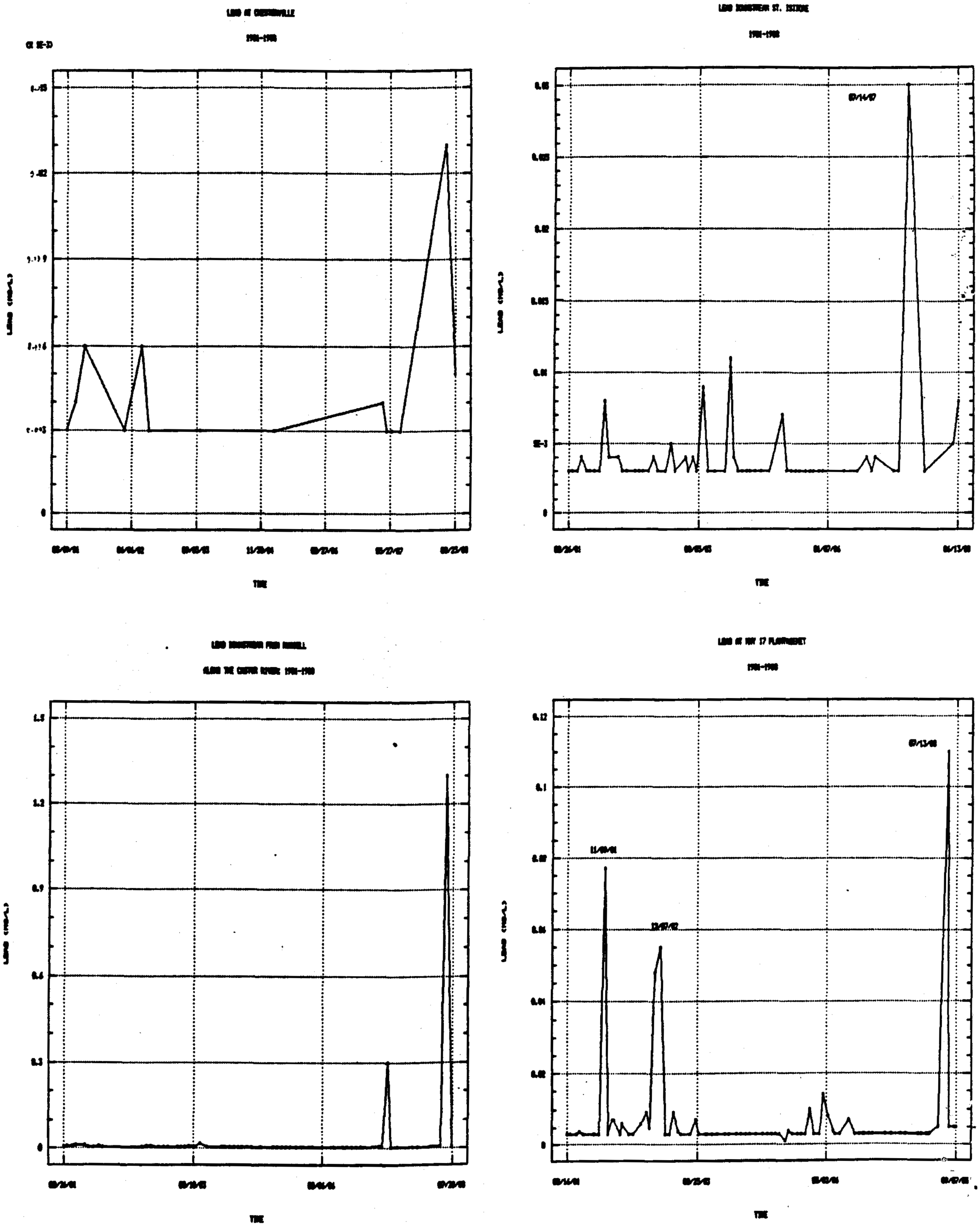

Figure 5.21. Lead concentrations in each of the four major sub-basins of the South Nation River.

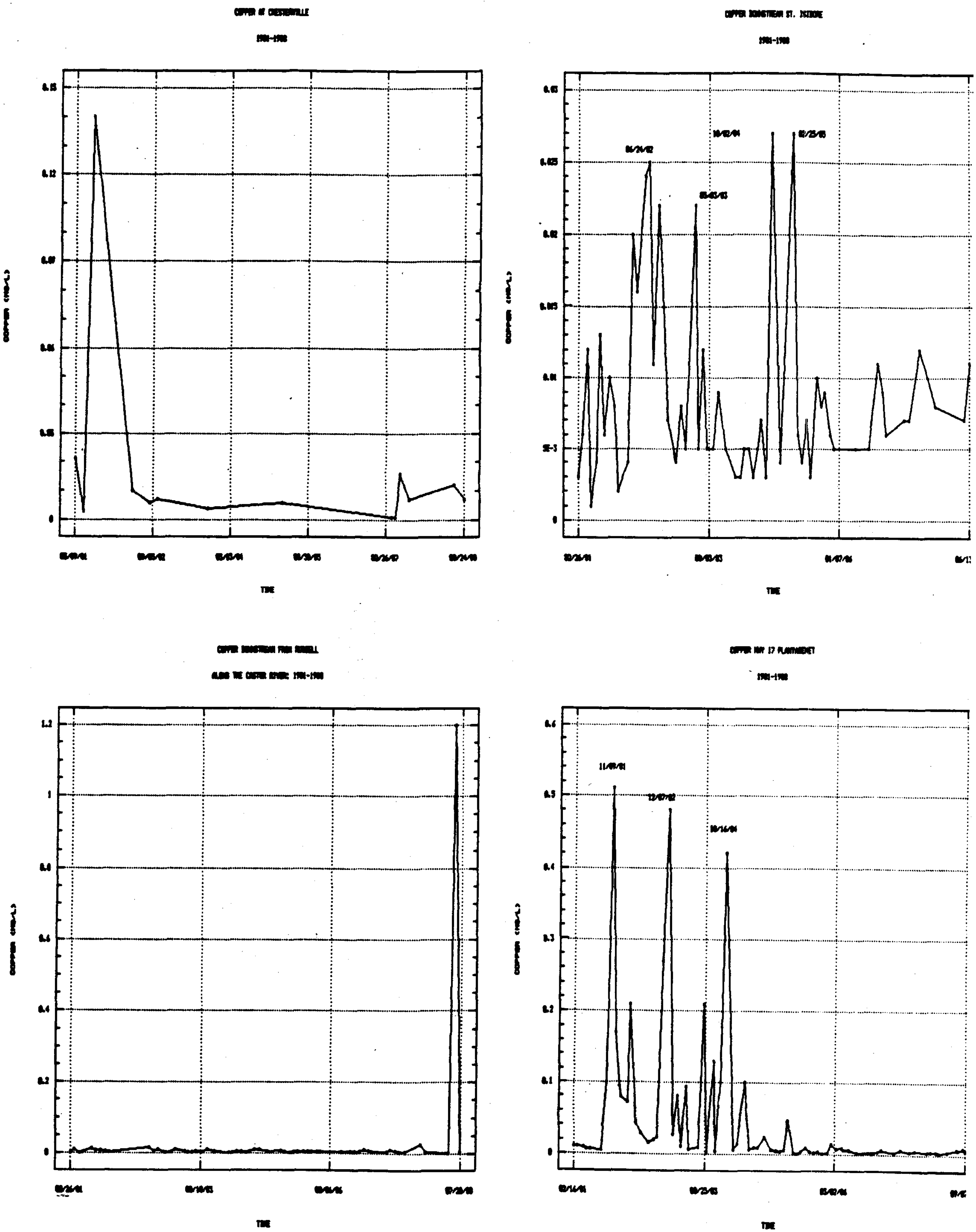

Figure 5.22. Copper concentrations in each of the four major sub-basins of the South Nation River.

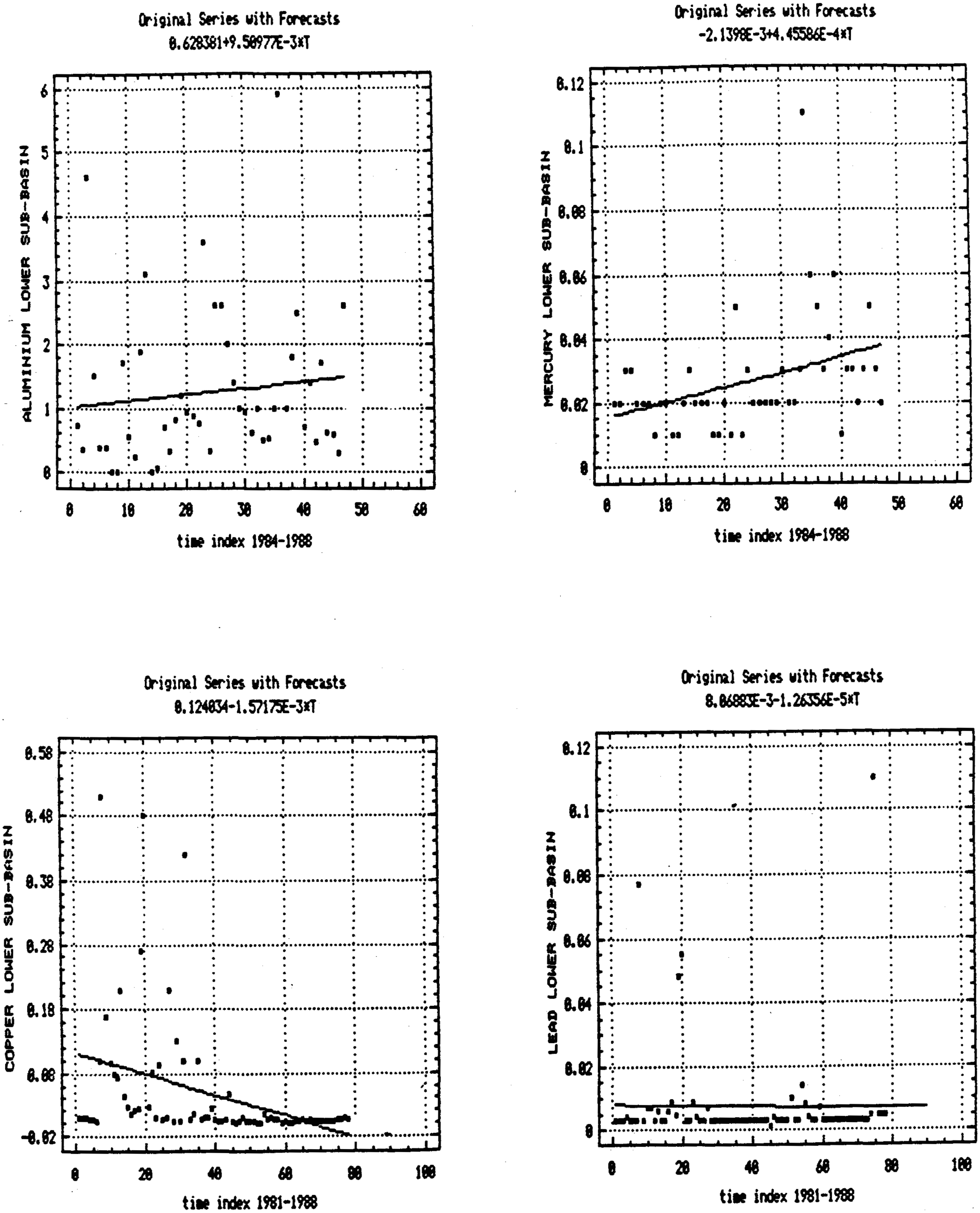

Figure 5.23. Trends in trace metals in the Lower sub-basin of the South Nation River.

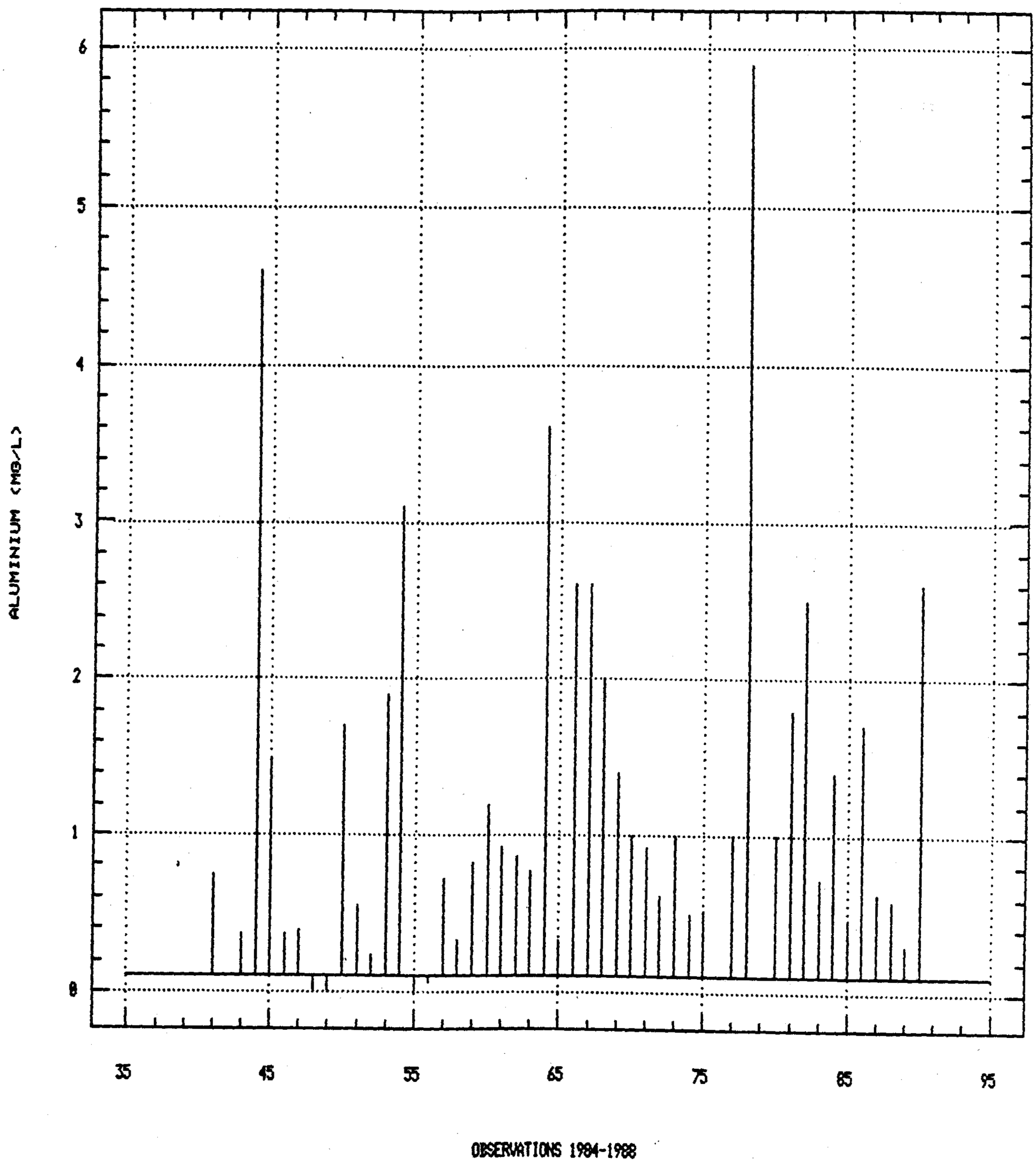

Figure 5.24. Aluminium concentrations in the Lower sub-basin relative to Canadian drinking water quality guidelines.

concentrations range from 5.9 mg/l to 0.009 mg/l with a median concentration of 1.2 mg/l. Figure 5.23 shows the trend (increasing) in aluminium concentrations over the study period, while Figure 5.24 shows its concentration relative to the Canadian guideline for aquatic life of 0.1 mg/l. In almost all cases, the guideline is exceeded. Land use activity which might be contributing to these levels is not immediately apparent. Lack of monitoring for aluminium in other sub-basins makes it difficult to identify potential area sources, however flux levels for lead and copper in the Scotch sub-basin suggest that this sub-basin be investigated further.

6.0 SUMMARY AND RECOMMENDATIONS

The South Nation River Basin is one of eastern Ontario's largest rivers with a drainage basin of approximately 3900 km2. Within the basin, clay and clay loam textured soils dominate a typically flat, low laying physiographic plain. The South Nation River and its tributaries are characterized by low gradients and insufficient channel size to accomodate peak flows during spring and summer periods. As a result, water management issues revolve around spring and summer floods, availability of good drinking water, low summer flows which constrain waste assimilation and recreational opportunities, and the need for land drainage to improve agricultural land capability.

Land use in the basin is predominantly agriculture with approximately 60% of the land base devoted to this activity. The primary agricultural pursuit in the basin is dairy-livestock operation, with extensive areas of row cropping (primarily corn) devoted to supporting this activity. The Lower or northern half of watershed is the most intensively cropped and most heavily drained area.

Water quality in the basin reflects its agricultural nature, and is generally described as being of poor quality (SNRCA 1983). On the basis of this analysis water quality issues such as high phosphorous and turbidity levels remain similar to those identified earlier in the decade by the SNRCA (1983). Phosphorous concentrations consistently exceed the 0.030 mg/l guideline and result primarily from non-point sources such as eroded stream bank material, livestock activities, and land drainage. The majority of phosphorous loss occurs during the spring period, and is highest in the northern part of the basin where streams are most susceptible to erosion, livestock densities are highest, and drainage for row cropping activities is most intensive. Dissolved oxygen is also of concern particularly during periods of low flow. Although aluminium in the Lower sub-basin consistently exceeds the guidelines for aquatic life most of the aluminium is associated with clay and silt colloids and biologically unavailable. Specific mechanisms resulting in increased aluminium and mercury concentrations have not been identified but appear to be associated with the Scotch sub-basin.

Trends for most parameters examined during the study indicate that water quality in the basin is not improving. The Scotch sub-basin in particular shows increasing problems relating to phosphorous and turbidity. Increasing concentrations of mercury and aluminium in the Lower sub-basin is also evident and should continue to be monitored.

The discontinous nature of observations makes it difficult to undertake statistically rigorous analyses. Observations may be unintentionally seasonally or event biased and result in misleading trends or estimates of annual water quality. Mean annual concentrations for various parameters were therefore eschewed in this study in favor of using the entire water quality database over the nine year study period favoring the assumption that errors of ommission and commission over the longer time period would tend to balance the sampling inconsistencies and provide some indication of overall trends in water quality.

Relating water quality to land use activities requires that a common spatial or geographic framework be used. The drainage basin provide such a framework. Unfortunately land use information is rarely collected using this framework and typically needs to be converted from a county or township base. This inevitably results in errors in estimating land use activity since this conversion typically assumes that land use is evenly distributed over these politically defined units. The use of Agricultural Land Use Systems is a significant step forward in ameliorating this problem since land use maps are available and can be used to more effectively allocate the information. Land Use Systems by their nature, are also useful over a longer timeframe than annual crop census data.

For general long term water quality monitoring, the location of monitoring stations is important and of course dependent on the water quality monitoring program objectives. If, for example, the objective of a program is to provide overall basin and/or sub-basin level information, it would seem appropriate that stations be located in the lower reaches of each sub-basin and be sampled on a regular monthly/seasonal/annual basis. Stations should be designed to monitor specific parameters associated with known issues of concern within each sub-basin as required. Sampling techniques need to be refined so that large data sets such as the trace metal data can be used rather than rejected. Sampling frequency and sample collection must be made more consistent in order to ensure data sets can be analysed with greater confidence than is currently the case.

At the present time not all basins in the watershed are being monitored. Of particular concern is the lack of data for the Bear Brook sub-basin. The Bear Brook drains a developing area of the watershed, and an area susceptible to significant erosion. This sub-basin should be considered in any future monitoring station design.

The integration of a Geographic Information System (GIS) into the analysis of water quality/land use analyis would also represent a significant step forward. GIS would provide a basis for integrating more effectively on a watershed basis, point source as well as non-point source water quality and land use data. A recent study by O'Neill and Hanna (1988) wherein GIS was used to examine toxic contaminants in water in Atlantic Canada and relate their distribution to land use and water quality illustrates the potential for this important technology.

6.0 REFERENCES

Environment Canada. 1987. Canadian water quality guidelines. Report to: Canadian Council of Resource and Environment Ministers. Water Quality Br. Ottawa, Ontario.

Graham and Associates. 1981. Agricultural component background study. Report No.4. South Nation River Conservation Authority, Berwick, Ontario.

International Joint Commission. 1980. Pollution in the Great Lakes Basin from land use activities. An IJC report to the governments of the U.S. and Canada. Windsor, Ontario, 1980.

MacLaren Plansearch. 1982. Water resources study component of the South Nation River Basin. Report to the SNRCA, Berwick, Ontario, 1982.

McGee, B. 1984. Survey of pesticide use in Ontario, 1983. Economics and Policy Coordination Branch, OMAF. Toronto, 1984.

Ministry of Environment. 1988. Waste disposal site inventory. MOE, Toronto, 1988.

O'Neill, H.J. and W.B. Hanna. 1988. An application of SPANS technology to toxic contaminant monitoring in the Atlantic Region. Inland Waters Directorate, Atlantic Region, Water Quality Branch, Moncton, New Brunswick.

Ontario Ministry of Agriculture and Food. 1987. Agricultural statistics for Ontario, 1987. Statistical Services Unit, Economics and Policy Coordination Branch, August 1988. Publication 20. Toronto, Ontario.

SNRCA. 1983. South Nation River basin water management study, main report. South Nation River Consevation Authority, Berwick, Ontario.