SPIRIT LAKES PLANNING GRANT REPORT

PHASE I
INVENTORY
&
RECOMMENDATIONS

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Completed by

Spirit Lakes Improvement Association, Inc.

&

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In Cooperation with

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INTRODUCTION

Background

North and Little Spirit Lakes limnological characteristics vary considerably. They are connected by a narrow channel in which the main tributary stream enters and flows through Little Spirit. Little Spirit's outlet, the Spirit River, is impounded with a dam with an approximate2 foot head.

North Spirit is a 214 acre a steeply- sloped shoreline lake oriented in a north-south direction. It consist of three long bays with all littoral areas of 90% gravel that quickly falling to limnetic areas of muck. Each bay has one or several deep areas at 20-24 feet. Direct drainage from the immediate shoreline with it's steep terrain is only .88 square miles. Additional drainage of approximately 1.1 square miles enters from a very small tributary entering the south bay. Other surface drainage occurs through attached bog wetlands north of the NE and NW bays and south of the South Bay. In the past 30 years North or Big Spirit has experienced winter kill conditions several times. Aeration devices have been installed to help alleviate these conditions. Summer conditions bring mass algae blooms with summer seechi disc readings averaging 5 feet.

Little Spirit is a 126 acre impoundment which receives water from North Spirit, a main North Tributary, and Olson Creek. Little Spirit is a shallow impoundment with a maximum depth of 9 feet. The littoral areas consists of 65% gravel, 20% muck, and 15% sand. Deeper water areas are 100% muck. Little Spirit is also subject to winter kill conditions and an aeration system has been installed to help alleviate these conditions. Summer months are also subject to periodic mass algae blooms with summer secch disc readings averaging less than two feet in the past.

With the placement of the aeration systems combined with recent mild winters fish losses have been avoided in both lakes. This has lead to the development of a game and panfish fishery supported by extensive stocking of game fish.

The Spirit Lakes Improvement Association was incorporated in 1985. Their objectives are to address the water quality and resource problems of the that face the Spirit Lakes' community.

Goals & Methods

The goals of this planning grant were to inventory and interpret the existing conditions of the Spirit Lakes and their watesheds. The methods used to achieve these goals were:

1.) to gather information on present conditions in the lake and watershed,
2.) to gather all past recorded resource data available on the lakes,
3.) and, to understand and clarify this information to develop a long range management plan.

The inventory included assessment of current physical,biological,and chemical conditions of the water resources and watershed. It also included compiling a complete recording of man induced changes in the Spirit Lakes from water level changes, fish stocking, and resource uses and development. Past assessements of the fisheries and water quality reports are also recorded as part of this document.

Interpretations of the above inventory are made throughout the report. The viewpoint used by the consultant, Aquatic Resources, to interpret the inventory was ecologically based in that the chemical, physical, and biological resources of the land and water are all connected and interact with one another.

The conclusions and recommendations at the end of the report are the results of this ecological interpretation to solve the water quality problems of the Spirit Lakes.

ACKNOWLEDGEMENTS

A special thanks to the Spirit Lakes Improvement Association who have taken the lead and effort in understanding the resources of there lake's community. MIKE KOLECHECK's patience and guidance was important in carrying out all aspects of the planning grant process. GLORA MAY and MARLIN KRAUS were always there to keep the bookkeeping straight and provide information on the operation of the aeration systems. BERNARD STROBACH , NEAL OLKIVES, and more recently, CLYDE SCHULZ are the "eyes" on the lake who made the secchi disc observations that were so important to understanding how the lake changes from year to year. Thank you DENNIS RADTKE and GARY BECKER and all other association members for asking the questions and charging forward to answer them.

Another thanks must go to the Wisconsin Lakes Planning Grant folks and Department of Natural Resource personnel for considering and accepting this plan. Thanks, JIM LEALOS, DNR senior fish manager for the fisheries and dissolved oxygen reports from his files. Thank you Price and Taylor Soil Conservation and Zoning personnel for providing watershed,zoning, and soils information.

LAND RESOURCES OF THE SPIRIT LAKES WATERSHED

GEOLOGY AND WATERSHED CHARACTERISTICS

The largest area of the watershed extends north and west from the Spirit Lakes (See watershed delineation map- Figure 1.). This area of the watershed includes several subwatersheds of several smaller lakes including Stone, Hultman, Fickle, and several unnamed lakes. A smaller area of the watershed extends to the south and southeast.

The topography of this area was formed during the last glacial advance. One advance of the Wisconsin Glacier formed what is known as the Perkinstown Moraine. This terminal or end moraine was formed when two mile-high massive lobes of the Wisconsin Glacier - The Chippewa and Wisconsin Valley lobes - ended and stopped advancing. The Perkinstown Moraine was formed by melting ice at the common inside edges near the end of these two lobes. This melting process released sand, silt, cobbles, and boulders from the glacier to form the high ridges of this watershed area. As the mountains of ice melted on the southeast edge of the Perkinstown Moraine watershed lakes and rivers were formed. Water entering these lakes and rivers combine to create the river that enters between Big & Little Spirit Lakes.

Most of the watershed soils have developed over this glacial material called till. Till is an unsorted, unstratified, mixture of earth, sand, gravel, and boulders transported and deposited or dropped directly by glacier ice. In the Perkinstown Moraine area of Spirit Lake's watershed this till in places is over 200 feet thick - thicker than any other area of Price county. It is this deposited till that trapped water to form the lakes and swamps as well as created the high hill areas including Timm's Hill. Glacial deposits to the immediate south and east and northeast of Spirit lakes are only 100 feet thick and most of the soils have developed over glacial till that has been deposited on the bedrock beneath.

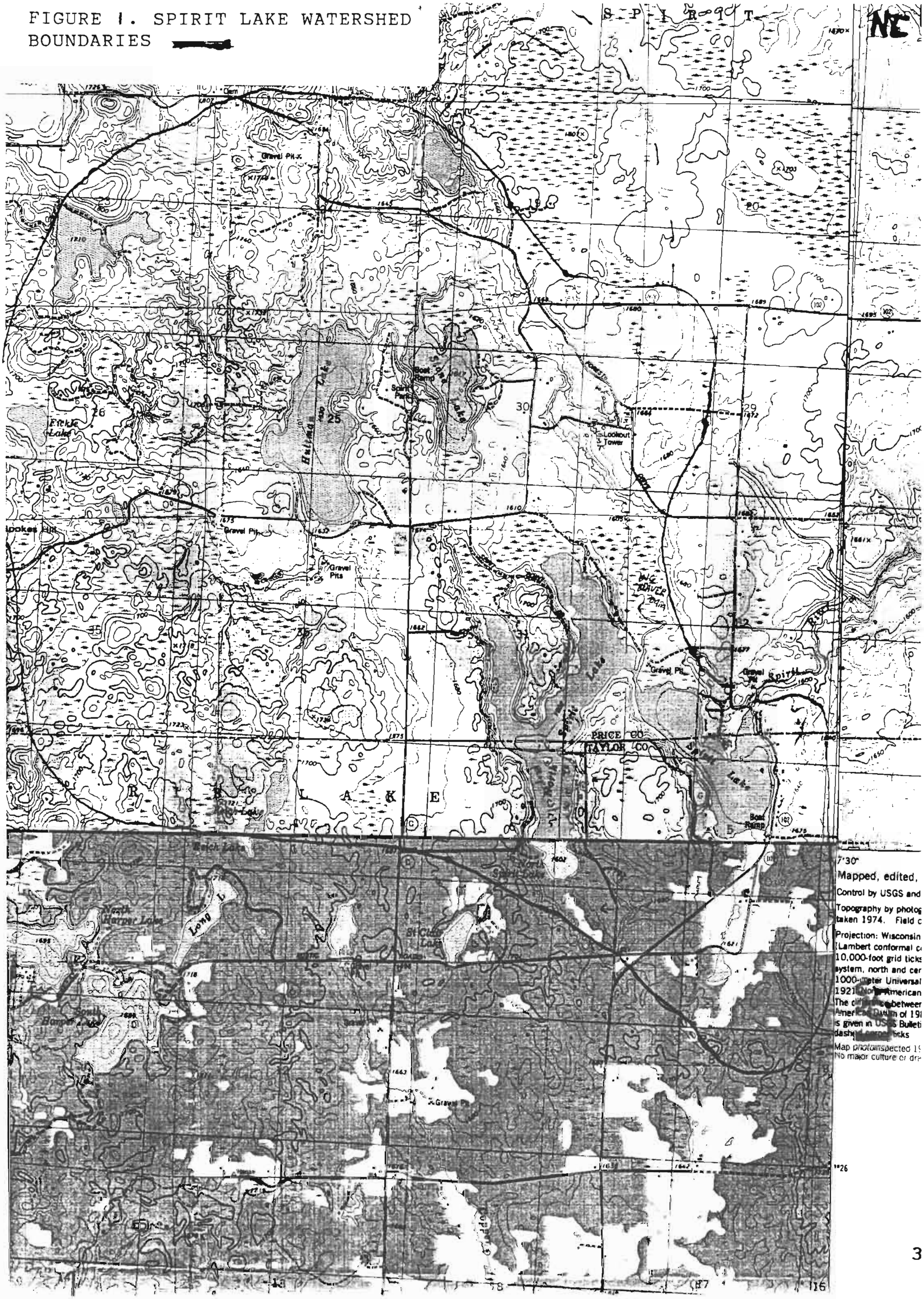
What is different about the Perkinstown Moraine and most of the Spirit lake's watershed to the north and northwest is that most of moraines soils have developed over glacial outwash. Glacial outwash is layered or stratified sand, gravel, or cobblestone deposited by moving water. The largest glacial outwash area known as a stream terrace can be found immediately north of Big Spirit Lake. A stream terrace is a flat plain area deposited by a glacial stream. This glacial stream outwash area extends north of the wetlands connected to the northwest and northeast bays of Big Spirit Lake to the east side of Stone Lake. This area can be found on both sides if CTH C and extends north of the east-west stretch of CTH C to where the stream from Stone Lake crosses this same road.

Other sandy and gravelly outwash areas are found beneath and at the base of the till ridges in this part of the watershed. It is at the gravelly-sandy bases of these till ridges that the waterways that connect the watershed lakes and ponds to the Spirit lakes are found. Organic soils have developed over the gravel and sand substratum creating marshy areas adjacent to the streams and lakes.

Water quickly infiltrates the well drained soils in the morrainic hills of the north and northwest part of the watershed and perculates through this outwash material to low areas of streams and lakes. This hydrologic process proceeds quickly in this watershed and spring or groundwater flows are common in low lying areas of lakes and streams and/or at the base of high hills and steep slopes. Any obstruction in these areas can decrease the amount of flow from these areas or create changes in the physical and chemical makeup of the water when exposed to organic soils of these low lying areas.

The rest of the watershed to the west, south and east are made up of glacial till soils deposited by the Wisconsin Valley Lobe of the Wisconsin glacial advance or soils that developed over this till. Heavy silt loam soils are more common but sandy loam soils are still predominant. The dominate sandy loam soils is mixed with stones and gravel from till glacial deposits. The topography is more rolling and only one waterway enters Little Spirit from the south. Large wetland areas are found close to the lakes and small wetlands can be found where ponding has occurred on the heavy silt soils.

FIGURE 1. SPIRIT LAKE WATERSHED BOUNDARIES



SOILS AND LAND USE

The soils and land use of the Spirit Lakes watershed are reflective of the glacial deposits described above. The glacial deposits resulted in sandy tills and steep relief in most upland areas that are not suitable for agriculture use because of erosion or excessive drainage. A few farms exist in the watershed but are limited to sandy silt loam soils on level to rolling hill areas. Many farms have stopped dairy production and the cleared land is used mainly for hay or alfalfa production. Most of the upland of the watershed is forested and protected by second growth northern hardwoods. These forests provide forest products and recreational opportunity.

Residential development is found close to some of these lakes and other residents are scattered throughout the forested watershed. Limited road development and access in this hilly region has limited further residential or cottage development .

The soils found in the steep hills of the Perkinstown Moraine southeast drainage to Spirit Lakes are well-drained to lakes and streams that intersect this area of the watershed. Low areas include bogs and other wetlands areas adjacent to lakes and waterways. The more isolated bogs areas have organic surface soils over sandy and till loams. The waterways contain mostly silty/ loamy soils at the surface from glacial and upland stream deposits underlain by stony deposits from glacial outwash. These waterways vary in width from wide shallow valleys to narrow steep-sided valleys where well- drained adjacent hillside create spring seepage areas. See Soils in TABLE 2.

TABLE 2. SOILS OF THE SPIRIT LAKES WATERSHED IN THE PERKINSTOWN MORAINE DRAINAGE

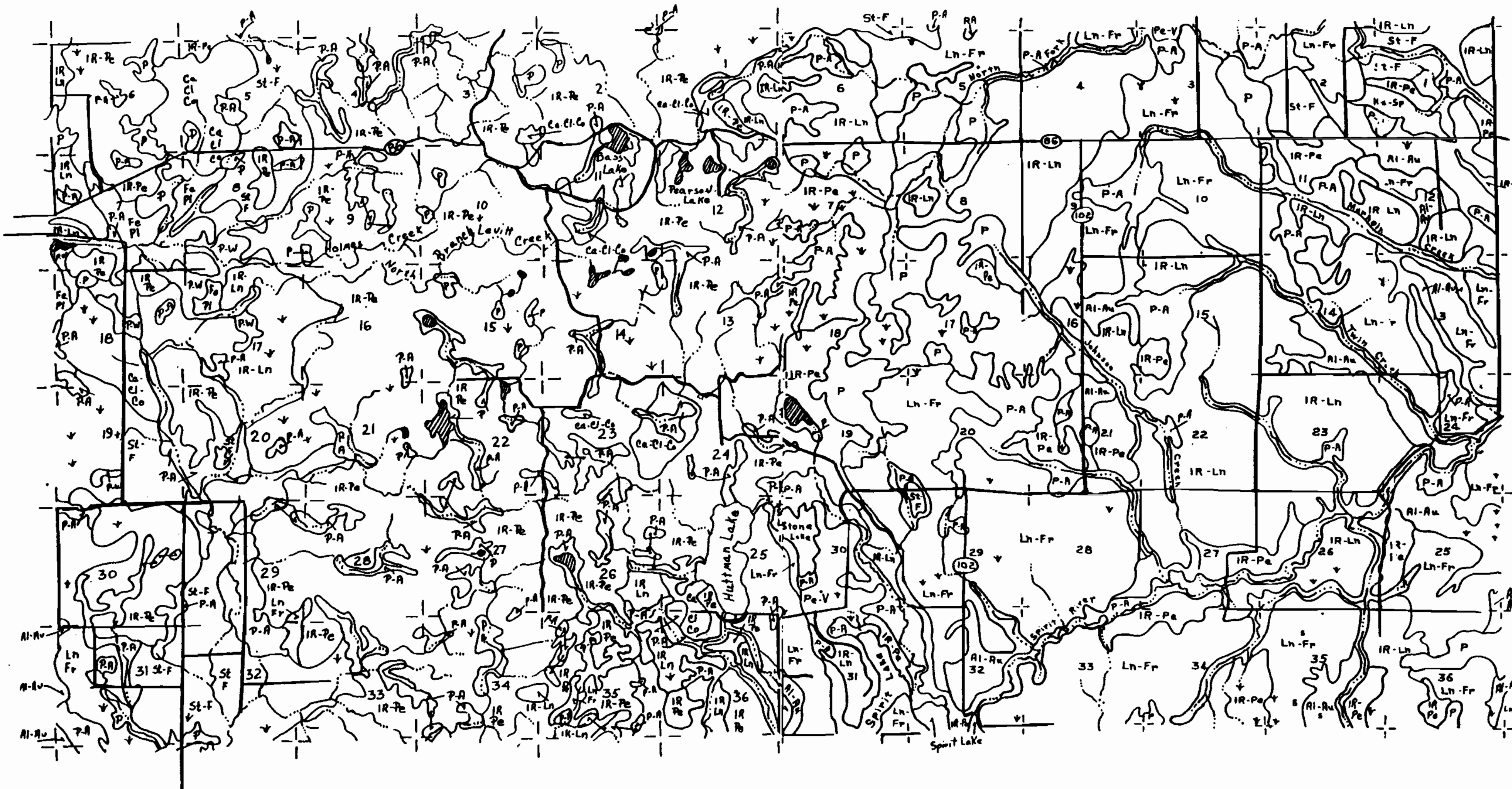
SOIL NAME:	IRON RIVER	PENCE	ADOLPH	PEAT
SOIL DESCRIPTION:				
SURFACE	SILTY/LOAMY	LOAMY	30-50" SILT	<42" ORGANIC
SUBSOIL	SANDY LOAMY TILL	SAND/GRAVEL OUTWASH	SANDY LOAM/ LOAMY TILL	SANDY LOAM/ LOAMY TILL
SUBSOIL(2NDARY)			W/ALLUVIAL	
SUBSTRATUM	SANDY LOAMY TILL	SAND/GRAVEL OUTWASH	STONY	SANDY LOAM/ LOAMY TILL
SLOPE	5-30%		0-5%	0-1%
LOCATION:	KNOLLS & RIDGES	STREAM TERRACES &LOWER FOOT SLOPES	WATERWAYS	LOW AREAS

Beaver and other aquatic wildlife are abundant in these areas for the hunter, trapper, and fisherman. A large mink and fox rearing facility was located on the hillsides adjacent to a tributary stream that enters the larger stream approximately one mile above the Spirit lakes. In recent years the facility has curtailed production.

Soils found in the remaining watershed that drain from the west , south, and east are mainly sandy loam soils with hilltop areas of silt loams (See Watershed Soils-FIGURE 2). The sandy loams are well-drained to excessively drained and are highly erodable. The silt loams on hilltops and the adjacent rolling hills are mostly highly erodable except in a few level areas near the hilltops. A few of these silt loams have high water capacities and are subject to ponding. These areas if not drained have developed small wetland areas in the watershed. Land use in the past included dairy operations that included tillage for grain crops and alfalfa and pasture. Most of the active dairy farms have been replaced by hay and forage crop production.

Several upland drainage ways enter Big Spirit Lake direct or through attached wetlands (See Figure 1, Page 3). Olson Creek enters Little Spirit Lake through a wetland at the south end east of the boat landing after traveling through a large culvert under STH 102. This drainage way originates from field and forested sandy and silt loam soils. This drainage then passes through several ponds before entering Little Spirit. This drainage way with it's small base flow also passes through peat and muck soils through most of it's watercourse.

FIGURE 2. SOIL MAP OF THE SPIRIT LAKE WATERSHED



GENERAL SOILS MAP
SHEET 34 of 35

HILL TOWNSHIP
T34N-R2E

GENERAL SOILS MAP
SHEET 35 of 35

SPIRIT TOWNSHIP
T34N-R3E

SHORELINE SOILS

Soils of the immediate shoreline of Big and Little Spirit lakes are described in the soil surveys in each county. Price county's soil survey only includes a general soils map soil associations where Taylor County has recently prepared more specific soil descriptions. The soils are listed as follows:

BIG SPIRIT

SHORELINE	SOIL DESCRIPTION
West (Price Co)	Lynne-Freer Association
West(Taylor Co)	Pellisser Gravelly Sandy Loam or Newot Sand Loam
NW Bay East & NE Bay West	Iron River-Lynne Association
NE Bay West	Iron River-Pence Association
S Bay East(Price Co)	Lynne-Freer Association
S Bay East(Taylor Co)	Pellisser Gravelly Sandy Loam or Newot Sand Loam
South	Lupton, Cathro, Tawas Muck
N NE & NW Bays	Peat-Adolf Association

LITTLE SPIRIT

SHORELINE	SOIL DESCRIPTION
Northwest (Price Co)	Lynne-Freer Association
West(Taylor Co)	Pellisser Gravelly Sandy Loam or Newot Sand Loam
Northeast(Price Co)	Iron River-Lynne Association
South	Lupton, Cathro, Tawas Muck
Southeast	Maplehurst Silt Loam
Northeast & North	Pellisser Gravelly Sandy Loam or Newot Sand Loam

If the Lynn-Freer Association soils were analyzed further in Price County the Taylor County description of either being a Pellissser Gravelly Loam or Newot Sand Loamwould describe these soils. These soils are very stony, are well drained to excessively drained, and highly erodable. These soils make up the majority of the areas that shoreline development has occurred in both Big and Little Spirit lakes. Wastewater treatment systems on these steep slopes and soils are not effective in treating waste and effluent will seep to the surface. These soils on more level ground(<10% slope) may very in characteristics that could support a drain field.

Iron River-Lynne association soils found on peninsula between NW & NE bays of Big Spirit Lake and the North Shore of Little Spirit in Price County as well as the Iron River-Pence Association soils on the east shore of the northeast Bay of Big Spirit have the same soil limitations in regards to sewage disposal as the Lynn-Freer Association soils above. Most of the soils and topographies of the Spirit Lakes shoreline limits wastewater system design,construction, use, and maintenance. These soil conditions can easily contribute phosphorus, various nitrogen compounds, sodium, and chloride from septic systems.

WATER RESOURCE HISTORY OF SPIRIT LAKES

Early History & Lake Use

History notes that Chippewa Indians at one time harvested wild rice growing in shallow waters near the channel and south shores. These historical facts are probably accurate as ideal conditions for wild rice are shallow waters that are from a few inches in depth to 2 or 3 feet, sufficient water movement to prevent substrate stagnation with no appreciable amounts of alkali in the water, and a muck bottom. In addition, wild rice, like most water plants, will not grow where there is much variation in the water level. At one time all these conditions occurred on the south shores of both Big and Little Spirit Lakes where water enters through muck substrates. The channel between the lakes also has this substrate, depth, and a flow from the stream that enters there. The increased depths in both lakes caused by the placement of a permanent dam at the outlet was enough to upset these requirements for wild rice. Early history also noted the abundance of Canada geese and ducks that utilized the lakes. Other emergent and floating aquatic plants were probably abundant that would draw these waterfowl to the area. Fish were also abundant in the lake. Grouse and snowshoe hares were noted as abundant game species that utilized the vast undisturbed wetlands and conifer habitat found in the watershed to the north.

Logging of the white pine in the area in the 1880's brought the first manmade changes in the lake. A dam was placed near the outlet of the lake to store and release water to float pine logs stored in the Spirit River below. Water levels would be raised in the lakes and at the proper time the gates of the dam would be opened so the extra water flow would reach the logs in the morning and carry them down river. It was noted that a large number of fish would leave when the stored water was released. Many were suckers entering the river to spawn. Large harvest of suckers were made by the local residents during those early pioneer days. Placement of a permanent dam stopped this upstream and downstream migration of fish.

From this early history the vegetation that lined the shores of the Spirit Lakes can also be noted. In the late 1800's a large area of wild ginseng was discovered and picked on the south bank of the channel between the two lakes. This steep hillside was also noted as having an abundance of wild apple trees. A camp for peeling hemlock was established on Spirit Point from 1908 to 1912. The frozen lake was used to provide a road through the channel and Little Spirit to connect with another road that took the bark to the tannery in Rib Lake. The peeled hemlock logs were brought to the shoreline of Big Spirit Lake in the winter time. At ice out the logs were floated through the channel with boom and motor launch and sent down the Spirit River.

A sawmill once existed next to Olson Creek. Sawdust from this mill was disposed of by placement in the creek and water flow carried it into the lake.

In 1910 a double arch stone bridge was constructed that replace the ford at the outlet of Little Spirit Lake. This opened the area up to cottage development and provides traffic from both the north and south to support the early service industries.

By 1941 the old wooden dam had deteriated and a severe storm created high water that carried the remains of the dam downstream.

Water Level & Lake Changes

The data on the water resource history of the Spirit Lakes until recent years was generally limited to fish management activities of inventory and stocking. Water level history that is tied to a known elevation can be traced to 1948. The water level history is traced below to understand just how much and when water levels were changed. From this the impacts of the changed water levels on the ecology of the lake can be assessed.

In a 1948 Public Service Commission hearing it was documented that a "natural obstruction between Big Spirit Lake and Little Spirit Lake which with the present obstruction causes a 1/10-foot higher elevation in Big Spirit Lake than in Little Spirit Lake". It was also stated that the previous dam had been out for some 25 years. The proposal was to raise the water level on Little Spirit Lake 18 inches. Due to an objection raised by a riparian owner on Big Spirit Lake the lake was raised only 6 inches above the October 6, 1948 water level of 92.6 to an elevation of 93.1 (assumed elevation of 100.00 feet from top of concrete on the east side of the bridge at the center).

In the spring of 1951 the dike at the right of the spillway failed and was repaired with brush and earth. It was proposed that a section of the dike was to be paved. Legal benchmarks were set on bridge(100.00) and a maple tree(100.35) 75 feet SE of upstream retaining wall of highway bridge & 20 feet from the highway. On July 9, 1951 the following elevations tied to the above benchmarks were recorded:

July 9,1951	
Lake Level:	93.15 feet
Water Below Dam:	91.10 feet
Crest of Spillway,Right Side(41' long)	93.05 feet
Crest of Spillway, Center	93.02 feet
Crest of Spillway, Left End	93.12 feet
Top of Left Dike	96.05 feet

On August 18, 1958 benchmark on Bridge had been destroyed and another was created with a spike on the north side of a 10" poplar (98.34)approximately 37 feet south of concrete structure.

The elevations that tied into this new benchmark and the maple bench mark above were recorded as:

August 18, 1958

Lake Level:	93.77 feet
High Water Mark Observed:	93.87 feet
Water Level Below Dam	90.75 feet
Crest of Spillway, Left End(43' Long)	90.08 feet
Crest of Spillway, 9' from Left End	93.96 feet
Crest of Spillway, 15' from Left End	93.55 feet
Crest of Spillway, 22' from Left End	93.18 feet
Crest of Spillway, 29' from Left End	93.60 feet
Crest of Spillway, 33' from Left End	93.93 feet
Crest of Spillway, Right End	94.05 feet
Top of Concrete in Pipe in Left Abutment of Dam	94.81 feet

October 26, 1959

Lake Level:	93.93 feet

In a 1960 Public Service Commission hearing it was documented that the the Rib Lake Fish and Game Association in 1957 capped the 22 foot concrete spillway of the dam to have a triangular overflow section with a center notch raised 1" with bulkheads on either side with elevations 12 inches above the present dam. The purpose of the cap was to protect the earthen embankments at the sides of the spillway and provide a passageway for fish. It was order that the cap be removed at that time. This new dam was capable of passing about 21 cfs with a pool elevation of 93.95 but before it was capped the this same amount of flow would create a pool level of 93.39 feet. A minimum level of 93.1 and a maximum level of 93.6. It was granted flash boards could be placed at each end of the dam during low flows but could not raise the water over the maximum.

In review of the above historical data it appears that the lake's water elevations were changed beginning in the late 1880's with periodic raising of water levels in the spring to float logs. Apparently this practice took place until at least 1912 when hemlock logs from Big Spirit tanning bark camp were sent downstream. From the elevations of the old dikes the maximum head created during this period was probably a maximum of about 2 1/2 feet. That would give the dike a safety freeboard of about 1 foot below the dikes and send water through the dam gates. This is assumed from using the first recorded elevations of the Little Spirit of 92.6 feet on October 6, 1948 (w/ Big Spirit being 1/10 foot higher) and the left dike was measured at an elevation of 96.05 on July 9, 1951. This also assumes the destructive flood of 1941 did not scour the outlet of Little Spirit out- but if this was the case the elevation between the two lakes would of created the 1/10 foot difference in the two lakes recorded in 1948 hearing.

If this practice of raising and lowering of the Spirit Lakes occurred in April through June with fish being released from the the lake with each periodic draw down; and fish were also restricted from entering of reentering the Spirit Lakes by the structure or gates the rest of the year the fish population could have been severely altered at this time. It is during the periods of May through June when both game and forage fish enter rivers to spawn. Minnows species would especially be effected with their small size and inability to overcome elevation obstructions.

Other impacts on the Spirit Lakes were also occurring. A increase in water levels of up to 2 1/2 feet would also flood open marshes and tamarack/ spruce bogs in the bays and inlets as well as the shallow water vegetation around the edges of the lakes. Eventually with water level fluctuations over this 25 to 30 year period the aquatic plant community y important for fish and aquatic organisms for cover and food were lost .

During this same period increased runoff from the steep uplands as a result of the canopy removal associated with the virgin timber removal was occurring. Highly acidic organic nutrients were released from the wetlands and bogs and minerals were released from the hilly erodable steep slopes that border the lake. These increased nutrient loads brought changes in the water chemistry that in return increased plankton productivity.

In the streams and marshes of the watershed above organic silt and dissolved muck were transported downstream while the mineral soils washing off the hillsides took their place. These materials settled out where ever the water slowed or was impounded as in Little Spirit Lake.

During the next 30 to 40 years (from 1916 to 1951) as the dam was no longer operated and slowly deteriated the water levels slowly returned to the original levels. During this period the watershed tree canopy was replaced by other trees decreasing upland erosion and the lake's fishery and aquatic plant community probably began rebounding from the effects of dam obstructions.

Fish stocking began in 1933 when largemouth bass were stocked. More largemouth and bluegill were introduced to the lake in 1935 and muskellunge in 1936. Brown trout were stocked in the river in 1935 also. This time period corresponded to increased road access to the area and recreational development. In 1941 a severe flood removed what remained of the dam.

About 1949 the a dam was created increasing Spirit Lakes depth approximately 6 inches over fall water levels. In 1957 this water level was raised approximately 16" above earliest known water levels. The effects of these early water levels changes on the aquatic community were never documented.

FISH AND AQUATIC COMMUNITY HISTORY

The first recorded assessment of the fishery occurred two years after the dam at the outlet raised the water level approximately 16 inches (Table 2). It also occurred 23-24 years after largemouth bass, bluegill, and muskellunge were recorded as stocked into the Spirit lakes. The first inventory of the Spirit lakes fishery was conducted with a boom shocker on May 27, 1959. One half of the shoreline was covered in a 7 hour period. Muskellunge, northern pike,largemouth bass, black crappie, bluegill, pumpkinseed, yellow perch, bullhead, were the fish species collected. Only one sucker was measured but it was listed as common in the survey.

TABLE 2. FISHERIES SURVEY RESULTS ON MAY 27, 1959

	# COLLECTED	SIZE RANGE inches	AVERAGE inches
GAME FISH			
MUSKY	16	9.3 - 21.3	14
NORTHERN PIKE	4	14.2- 40.0	23.5
LM BASS	16	6.2-15.5	9.6
PANFISH			
BL.CRAPPIE	116	4.7-9.3	6.9
BLUE GILL	111	3.4-7.6	6
PUMPKINSEED	106	3.8-6.4	5.4
YELLOW PERCH	86	5.2-10.3	7.1
BULLHEAD	83	6.8-13.8	11.3
SUCKER	COMMON 1	8	8

It was during this first spring fish survey in 1959 that the first documentation of aquatic plants of the Spirit lakes occurred. Water lilies, cattails, and the submergent aquatic plants of the pondweed family and coontail were noted. It was not noted in which lake these plants were observed. Aquatic plant observations again made in 1964,1968, and after the first winter kill of 1970 in North Spirit Lake. Two plants were noted in 1970 in Little Spirit. The submerged plants identified in these observations show a progression from 1964 to 1968 to 1970 to plants more tolerant of reduced light and more able to utilize abundant organic nutrients dissolved in the water.

In 1965 it was noted that reproduction of natural muskellunge was not occurring in the Spirit lakes. Muskellunge were again stocked in 1968 and again in 1970 after the first recorded winter fish kill occurred. On May 29 that spring 75,600 muskellunge fry were stocked (Table 3).

1970 was the beginning of a series of winter kills. Winter kills were noted in North Spirit in 1972 and 1979 and in Lower Spirit in 1972 and 1973. Mass algae blooms began occurring after the 1972 winter kill in North Spirit.

Stocking of fish in North and Lower Spirit have occurred annually from 1982 to the present time(See Table 3). Walleye have been stocked as 2.6-3.6" fingerlings from mid July to early August in North Spirit over this time except for a single stocking of 50,000 fry stocked on May 9, 1986. Muskellunge are usually stocked either in late summer as 9" fingerlings or in September / October as 9 - 13" fingerlings in either lake.

Largemouth bass have been mainly stocked from July to October as 3-5" fish. 50,000 1" largemouth bass post- larval fingerlings were stocked in North Spirit on July 20, 1988 and another 40,000 1" in Lower Spirit.

TABLE 3. STOCKING HISTORY OF SPIRIT LAKES

DATE	LOCATION	SPECIES	NUMBER	SIZE	COMMENT
1933	?	LARGEMOUTH	?	?	
1935	?	LARGEMOUTH	?	?	
1935	?	BLUEGILL	?	?	
1935	SPIRIT RIVER	BROWN TROUT	?	?	
1968	?	MUSKELLUNGE	?	?	
May 29, 1970	N. SPIRIT	MUSKELLUNGE	75600	FRY	
Sep 16, 1982	N. SPIRIT	MUSKELLUNGE	100	11"	
Aug 9, 1983	N. SPIRIT	MUSKELLUNGE	213	9"	
Oct 12, 1983	L. SPIRIT	MUSKELLUNGE	126	9"	

SPIRIT LAKES STOCKING HISTORY (CONTINUED)

Jul 24, 1984	N. SPIRIT	WALLEYE	10120	3"	
Jul 27, 1984	L. SPIRIT	LARGEMOUTH	12000	3"	
Oct 16, 1984	L. SPIRIT	LARGEMOUTH	960	3.5"	
Sept 19, 1985	N. SPIRIT	MUSKELLUNGE	426	11"	LV CLIP
Oct 7, 1985	L.SPIRIT	MUSKELLUNGE	125	9"	
May 9, 1986	N. SPIRIT	WALLEYE	50000	FRY	
Aug 15, 1986	N. SPIRIT	WALLEYE	10011	3"	
Sep 20,1986	L. SPIRIT	LARGEMOUTH	12600	3"	
Oct 13,1986	N. SPIRIT	MUSKELLUNGE	369	8-11.9" 200RV COOP	
Aug 11, 1987	N.SPIRIT	MUSKELLUNGE	426	9"	
Aug 11, 1987	L. SPIRIT	MUSKELLUNGE	252	9"	
Oct 5, 1987	L. SPIRIT	MUSKELLUNGE	56	9"	
Oct 5, 1987	N. SPIRIT	MUSKELLUNGE	341	9-11" COOP	
Jun 9, 1988	L. SPIRIT	LARGEMOUTH	12600	3"	
Jul 20,1988	N. SPIRIT	WALLEYE	10710	3"	
Jul 20,1988	N. SPIRIT	LARGEMOUTH	50000	1"	
Sep 22, 1988	L. SPIRIT	LARGEMOUTH	12000	3"	
Oct 12, 1988	N. SPIRIT	MUSKELLUNGE	95	12" COOP	
Jul 17, 1989	N. SPIRIT	WALLEYE	10625	3"	
Aug 15,1989	L. SPIRIT	MUSKELLUNGE	252	8"	
Oct 18, 1989	N. SPIRIT	WALLEYE	2130	3" LV	
May 30, 1990	L. SPIRIT	LARGEMOUTH	40000	1" POST LARVAL	
Jul 24, 1990	N. SPIRIT	WALLEYE	10650	3"	
Oct 18, 1990	L. SPIRIT	MUSKELLUNGE	373	11" COOP/M INC.	
Oct 30, 1990	L. SPIRIT	MUSKELLUNGE	115	13"	
Oct 30, 1990	N. SPIRIT	MUSKELLUNGE	57	13" PVT	
Jul 18, 1991	N. SPIRIT	WALLEYE	5325	3"	
Aug 7, 1991	N. SPIRIT	MUSKELLUNGE	250	9"	
Oct ?	N. SPIRIT	MUSKELLUNGE	43	13" PVT M INC.	
July 21, 1992	N. SPIRIT	WALLEYE	21420	2.9"	
Sep 4, 1992	L. SPIRIT	LARGEMOUTH	1000	4.6"	
Jul 26, 1993	N. SPIRIT	WALLEYE	20538	3.6"	
Sep 4, 1993	L. SPIRIT	MUSKELLUNGE	250	9.6"	
Oct 16, 1993	N. SPIRIT	MUSKELLUNGE	100	12" PVT M INC.	
Oct 16, 1993	L. SPIRIT	MUSKELLUNGE	277	9.0"	
Oct 17, 1993	L.SPIRIT	MUSKELLUNGE	50	12"	
Aug 11, 1994	N. SPIRIT	WALLEYE	22000	2.6"	
Aug 4, 1995	N. SPIRIT	WALLEYE	21894	2.6"	
Sep 12, 1995	L. SPIRIT	LARGEMOUTH	3150	3.9"	

Fisheries surveys did not occur again until 1988 after intensive stocking efforts began in 1982. Since this date surveys have occurred in 1992, 1994, and 1995 (Tables 4 -9).

TABLE 4. FISHERIES SURVEY RESULTS 1988

BIG SPIRIT 1988 HOT

	# COLLECTED	SIZE RANGE(in)	AVERAGE(in) # COLLECTEDSIZE
GAME FISH			
MUSKY	91	10.0-42.9	MISSED 40-45"
NORTHERN PIKE	48	4.5-37.4	
LM BASS	21	3.0-13	
PANFISH			
BL.CRAPPIE	526	2.4-11.4	MOST 6.4
BLUE GILL	144	2.3- 8.2	
PUMPKINSEED	156	2.3- 6.4	MOST 6.4, 7.4 2ND
YELLOW PERCH	360	2.4-10.4	

LITTLE SPIRIT 1988

GAME FISH			
MUSKY	53	MAX. 37"	
NORTHERN PIKE	63	MAX. 37"	
LM BASS	46	MAX. 17.9"	
PANFISH			
BL.CRAPPIE	861	2.4-12.5	5.4-7.4
BLUE GILL	157	2.4- 8.4	
PUMPKINSEED	362	2.4- 6.4	
YELLOW PERCH	218	2.4- 9.4	

OTHER SPECIES	
WHITE SUCKER	COMMON
GOLDEN SHINER	COMMON
COMMON SHINER	PRESENT
SUCKER MOUTH MINNOW	COMMON
RUSTY CRAYFISH	

TABLE 5. FISHERIES SURVEY RESULTS 1992

NORTH SPIRIT - SPRING 1992

	AGE	# COLLECTED	SIZE RANGE	AVERAGE
GAMEFISH				
MUSKY				
	AGE 1	3	11.5-12.0	11.7
	AGE 2	18	11.5-19.8	15.9
	AGE 3	12	16.7-24.6	19.9
	AGE 4	7	20.2-30.8	25
	AGE 5	13	22.1-33.3	30.2
	AGE 6	14	28.5-35.5	32.6
	AGE 7	9	32.0-38.0	36.6
	AGE 8	1	38	38
	AGE 9	1	41	41
TOTALS		78	11.5-41.0	
NORTHERN PIKE				
	AGE 4	2	19.7-23.8	21.8
	AGE 5	3	22.7-23.1	22.9
	AGE 6	3	28.6-32.4	30.3
TOTALS		8	19.7-32.4	
LM BASS				
	AGE 1	2	5.5-5.6	5.6
	AGE 2	5	5.4-8.0	7.4
	AGE 3	1	8.2	8.2
	AGE 4	7	11.6-13.3	12.6
	AGE 5	19	12.2-16.6	13.7
	AGE 6	10	13.1-16.6	13.9
	AGE 7	1	16.1	16.1
	AGE 8	1	16.6	16.6
TOTALS		46	5.5-16.6	
WALLEYE				
	AGE 1	16	5.5- 8.2	6.6
	AGE 2	15	6.9-11.5	10.4
	AGE 3	10	12.1-14.2	13.0
	AGE 4	61	12.6-20.8	16.5
	AGE 5	18	13.7-20.5	16.8
	AGE 6	1	15.1	15.1
TOTALS		121	5.5-20.6	

TABLE 6. FISHERIES SURVEY APRIL 1994

NORTH SPIRIT 4/23/94

	# COLLECTED	SIZE RANGE	AVERAGE
<u>GAME FISH</u>			
MUSKY			
TOTALS	23	9.5-36.1	
NORTHERN PIKE			
TOTALS	4	8.0-14.4	
LM BASS			
TOTALS	13	10.5-15.9	
WALLEYE			
TOTALS	198	5.0-25.4	
<u>OTHER SPECIES</u>			
YELLOW PERCH	1	10.5"	
WHITE SUCKER	C		

NOTE: PANFISH NOT COLLECTED

TABLE 7. FISHERIES SURVEY SEPTEMBER 1994

N. SPIRIT 9/27/94	# COLLECTED	SIZE RANGE
GAME FISH		
MUSKY		
TOTALS	30	5.5-41.0
NORTHERN PIKE		
TOTALS	14	11.5-18.9
LM BASS		
TOTALS	80	3.0-17.9
WALLEYE		
TOTALS	535	3.3-24.9
PANFISH		
BL. CRAPPIE	204	1.7-11.4
BLUEGILL	29	1.5- 8.4
YELLOW PERCH	27	2.0-11.9
Y. BULLHEAD	11	1.8-12.3
OTHER SPECIES:		
WHITE SUCKER	18	9.5-17.4
BURBOT	1	10.0
BG X PS	4	4.6-7.1
SCULPIN	COMMON	
JOHNNY DARTER	COMMON	
GOLDEN SHINER	PRESENT	
IOWA DARTER	PRESENT	
RUSTY CRAYFISH	PRESENT	

TABLE 8 . NORTH SPIRIT FISHERIES SURVEY APRIL-1995

N. SPIRIT APRIL 28 1995

	AGE	YOY	# COLLECTED	SIZE RANGE INCHES	MODAL SIZES INCHES	CATCH/HR
GAME FISH						
MUSKY						
TOTALS			15	10.5-34.3		11.5
NORTHERN PIKE						
TOTALS			2	10.0-15.9		1.5
LM BASS						
TOTALS			19	3.0-16.9		14.6
WALLEYE						
	AGE 1	94	30	<5.4	3.9	
	AGE 2	93	74	11.0-12.9	11.9	
	AGE 3	92	27	13.0-14.4	13.5	
	AGE 4	91	45	14.5-16.4	15.4	
	AGE 5	90				
	AGE 6	89				
TOTALS			187	3.1-21.7		143.8
PANFISH						
BL. CRAPPIE			48	2.5-10.8	3.0 , 9.3, 9.8	36.9
WHITE SUCKER			5	10.0-11.9		3.8
BLUEGILL			6	2.4-7.8		4.6
PUMPKINSEED			2	6.6-6.8		1.5
YELLOW PERCH			24	2.6-8.0		18.5
Y. BULLHEAD			0			
BG X PS			0			
OTHER SPECIES						
SCULPIN:			P			
JOHNNY DARTER			P			
GOLDEN SHINER			C			
IOWA DARTER			P			
N. RED BELLY DACE			P			
RUSTY CRAYFISH			A			

TABLE 9. FISHERIES SURVEY LITTLE SPIRIT APRIL-1995

LITTLE SPIRIT APRIL 28 1995

	AGE	YOY	# COLLECTED	SIZE RANGE INCHES	MODAL SIZES INCHES	CATCH/HR
GAME FISH						
MUSKY						
HYBRIDS			2	13.1-14.4		
TOTALS			15	13.1-34.9	14.0, 17.9	21.4
NORTHERN PIKE						
TOTALS			22	8.5-28.4	11.5, 19.9	31.4
LM BASS						
TOTALS			30	6.0-19.9	13.4	42.9
WALLEYE						
	AGE 1	94				
	AGE 2	93				
	AGE 3	92				
	AGE 4	91				
	AGE 5	90				
	AGE 6	89				
TOTALS			27	4.5-18.3	13.4	38.6
PANFISH						
BL. CRAPPIE			55	2.7-11.9	8.0, 9.3	137.5
WHITE SUCKER			12	6.0-13.9		17.1
BLUEGILL			31	4.2- 8.5	7.2	77.5
PUMPKINSEED			18	5.2-7.0	5.4, 5.9	45
YELLOW PERCH			43	2.3-9.1	6.7, 8.1	107.5
Y. PERCH AGE 1			ABUNDANT	2-3"		
B. BULLHEAD			2	11.5-12.5		5
OTHER FISH						
SCULPIN			P			
JOHNNY DARTER			P			
GOLDEN SHINER			C			

Aeration began in the south bay of North Spirit in 1989 and in Lower Spirit in the winter of 1992-93. The aeration effects on maintaining winter oxygen is documented in the water quality assessment below. The aeration system in the south bay of North Spirit operated from freeze up in the winter of 1988-89 until the end of August in 1989.

Lake management information gathering efforts began in 1986 when Neal Olkives began volunteer secchi disc/ water clarity observation on Big Spirit Lake. Two years later in 1988 Bernard Strohbach began taking these same observations on Little Spirit. These recordings are documented and evaluated as part of the water quality assessment that follows.

WATER QUALITY OF SPIRIT LAKES
APPRAISAL AND ANALYSIS

Inventories of the physical water quality characteristics of the Spirit Lakes were made through oxygen/temperature profiling, secchi disc readings, and general observations. The information gathered above was combined with chemical and biological sampling so ecological interpretations and assessments could be made.

The observations and testing made by the consultant were combined with other current secchi disc readings made by Self Help Volunteers during the study period. Secchi disc information from 1986 to 1995 was also evaluated to understand the physical changes in the lakes over time. Temperature/oxygen profiles and early water chemistry data from Park Falls Fish Management files were also included in the evaluation.

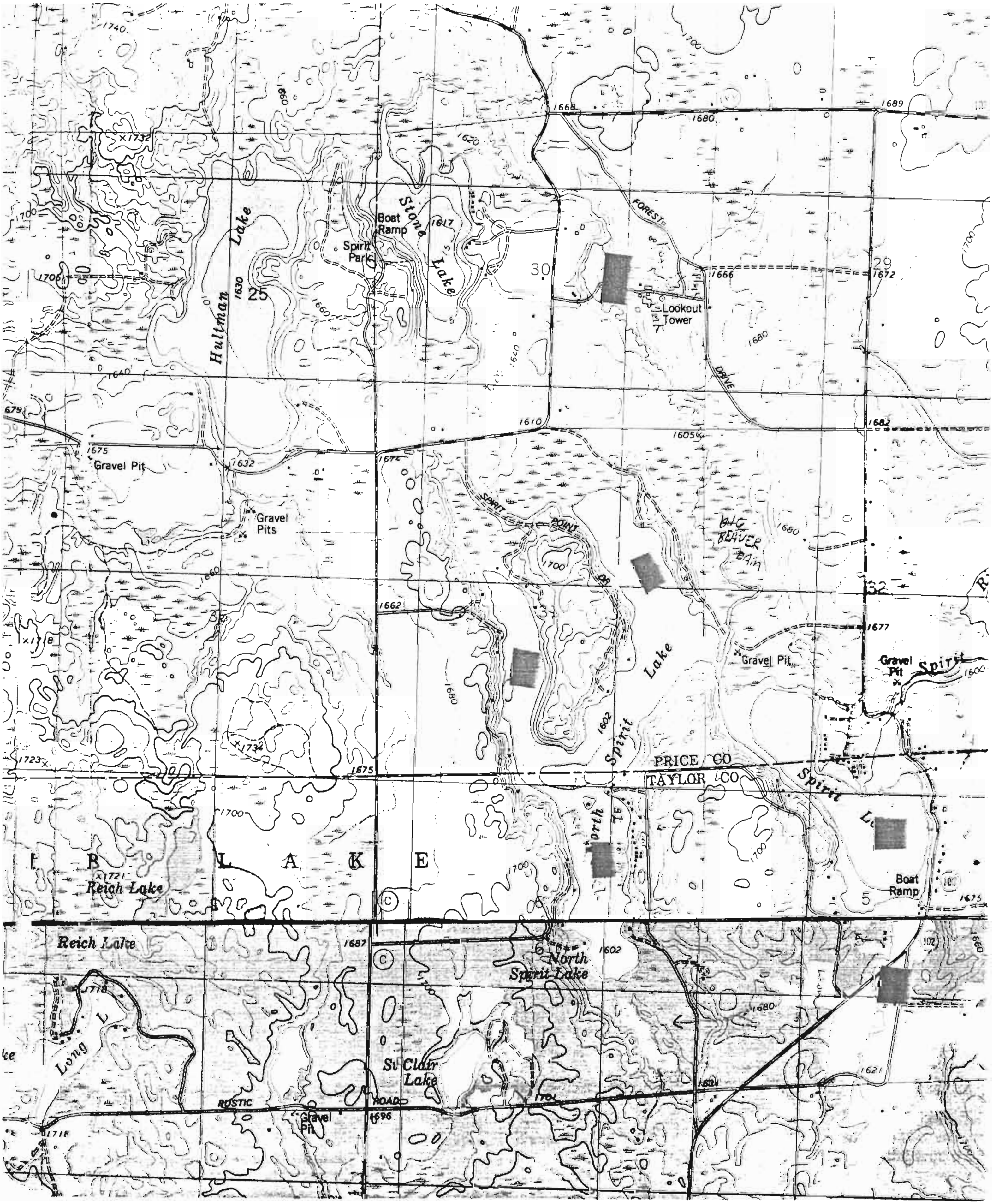
PROCEDURE

Monthly physical, chemical, and biological sampling began under the ice on February 18, 1994 and continued until October 13, 1994. Three deep water locations were chosen for sampling in Big Spirit Lake that corresponded to deep holes in each of the three bays - South, Northwest, and Northeast. One deep water sampling location was chosen in Lower Spirit . Sampling parameters varied to analyze certain conditions and at the same time keep lab analysis cost down.

Oxygen and temperatures were taken in the streams entering the lakes. The stream entering between the two lakes was sampled approximately one linear mile upstream where a town road between CTH C and Forest Drive crosses the stream. Periodic sampling also occurred in this stream approximately 100 yards upstream from where it enters the channel separating the Spirit Lakes. Olson Creek, that enters Little Spirit from the south, was sampled immediately above the culvert beneath STH 102. Outlet temperatures at the bridge just above the outlet dam were also taken on occasion. See FIGURE 3 for sampling locations.

Weather conditions were closely watched to assess effects of wind, rain, and temperature. Sampling corresponded as close as possible to season changes that effect the physical parameters of the Spirit Lakes. Biological and chemical sampling dates were also correlated to match the physical sampling dates.

FIGURE 3. SPIRIT LAKE WATER QUALITY SAMPLING LOCATIONS

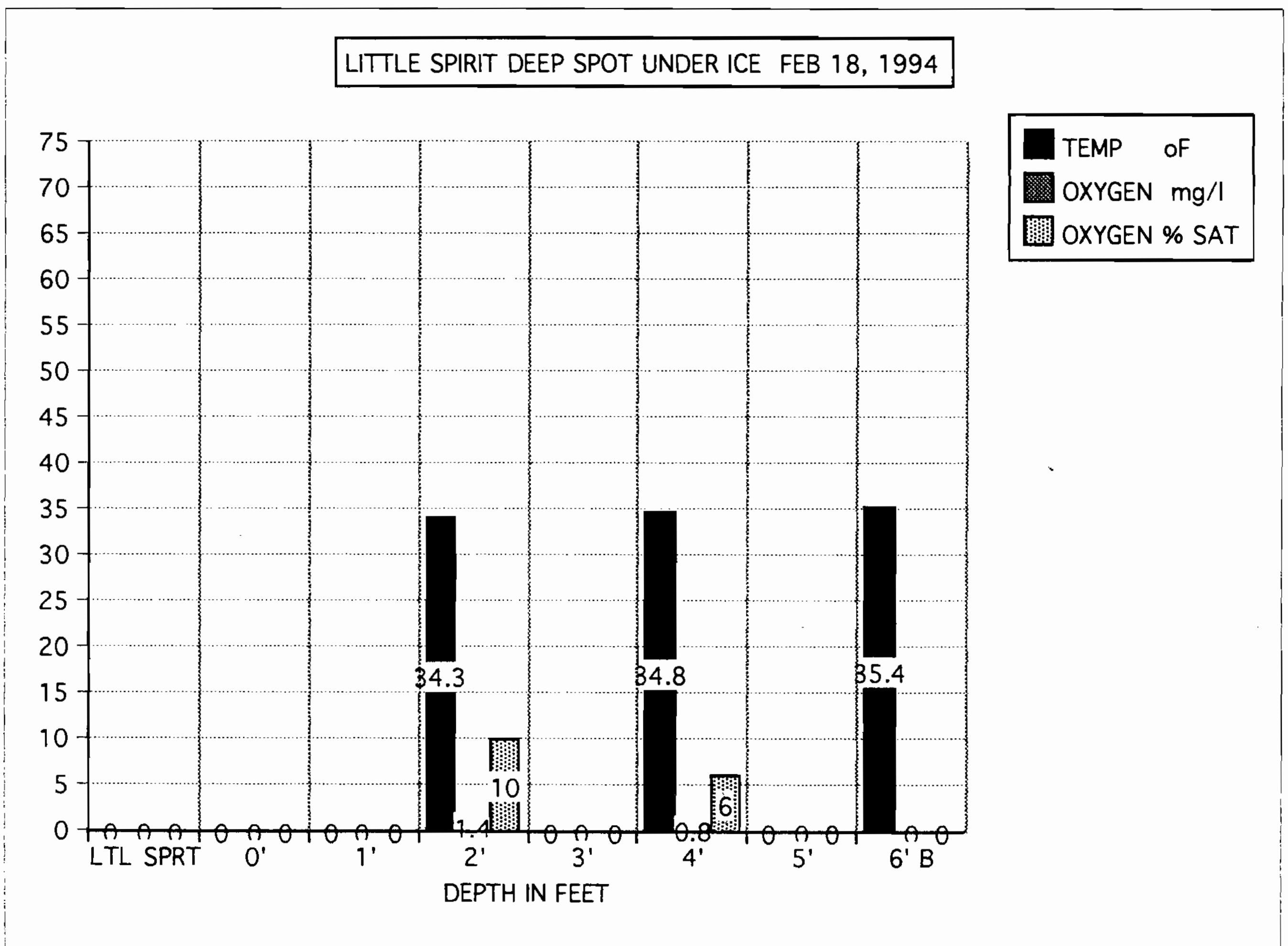


RESULTS AND DISCUSSION

February 18, 1994 Little Spirit Lake was sampled approximately 200 yards southeast of the open water aeration field located along the north central shoreline.
14" of ice and 5" of snow covered the lake at this location. Water temperature varied only 1.2 degrees through the 6 foot depth from 34.3 oF below the ice to 35.4 near the bottom . Very low oxygen and saturatution levels were found (See Figure 4). Large zooplankton were observed in sampling hole.

FIGURE 4. LITTLE SPIRIT OXYGEN/TEMPERATURE PROFILE FEB 18, 1994.

Feb 18, 1994	TEMP oF	OXYGEN mg/l	OXYGEN % SAT	OTHER DATA:
LTL SPRT				SAMPLE LOCATION: APRX. 200 YARDS SE OF
0'	14" ICE 5" SNOW			AERATION FIELD, DEEP HOLE
1'				LARGE ZOOPLANKTON UNDER ICE
2'	34.3	1.4	10	
3'				
4'	34.8	0.8	6	
5'				
6' B	35.4	0	0	



These low oxygen condition in Little Spirit Lake correspond to DNR fish management files reporting similar low oxygen conditions in Little Spirit in 1989 and 1990 in mid winter before the aeration system was installed (Table 10). The 1995 oxygen sampling closer to the aeration field indicates good oxygen being maintained at least locally near the aeration field. Temperatures in the six foot bottom profile depth are fairly consistent with or without aeration.

TABLE 10. LITTLE SPIRIT UNDER THE ICE 1989, 1990, & 1995

DEPTH	Jan 25, 1989 OXYGEN(mg/l)	Feb 14, 1989 OXYGEN(mg/l)	Mar 1, 1989 OXYGEN(mg/l)
1'	3.2	2.6	2.6
2'	3.2	2.6	2.6
3'	3.0	2.1	2.2
4'	2.6	1.9	2.0
5'	2.4	1.9	1.8
6'	1.4	1.0	1.1

	Feb 2, 1990 OXYGEN(mg/l)
1'	0.5
2'	0.5
3'	0.5
4'	0.5
5'	0.5
6'	0.5

	Jan 6, 1995 oF/02/%Sat	Jan 25, 1995 oF/02/%Sat	Feb 7, 1995 oF/02/%Sat	Feb 21,1995 oF/02/%Sat
1'	32.4/11.2/77	32.2/8.5/58	32/10.4/71	- - -
2'	34.1/9.2/66	33.8/7.0/49	33.3/8.6/65	33.3/6.9/48
3'	34.8/8.0/58	34.5/6.4/47	34.3/6.4/46	34.1/5.8/41
4'	37.9/7.6/55	34.8/6.0/43	34.5/6.3/45	34.3/5.6/40
5'	36.9/6.0/44	35.3/5.5/40	35.1/5.0/36	34.5/5.5/40
6'	39.2/1.5/11	37.4/3.0/23	37.8/5.0/37	36.0/3.6/26
Time:	1:45 PM	1:15 PM	12:30 PM	1:30 PM
Conditions:	Snow1"Ice 11"	Snow2"Ice16"	Snow1"Ice19.5"	Snow2"Ice22"
Comments:	Aerator On	Aerator On	Aerator On	Aerator On

FIGURE 5. BIG SPIRIT OXYGEN -TEMPERATURE PROFILES UNDER THE ICE ON FEBRUARY 18, 1994.

Feb 18, 1994	TEMP oF	OXYGEN mg/l	OXYGEN % SAT	OTHER DATA
BS S. BAY				
0'	14" ICE , 4" SNOW			
2'	34	3.3	23	
4'	34.8	2	14	
6'	35.1	2.2	16	
8'	35.4	2.4	18	
10'	35.4	0.5	6	
12'	36.6	0.1	1	
14'	37.6	0	0	
16'	38.1	0	0	
18'	38.5	0	0	
19'				
20'	38.9	0	0	
21'B	38.9	0	0	

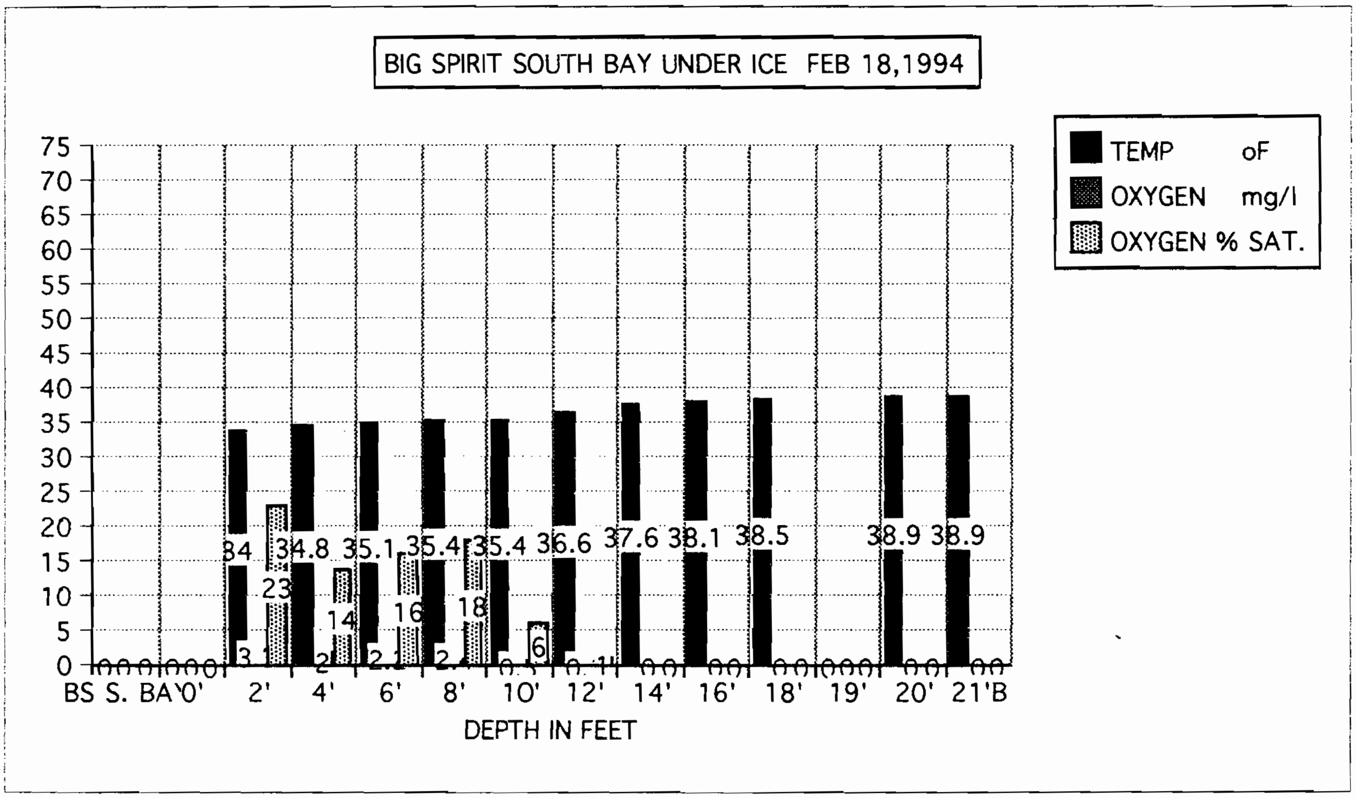
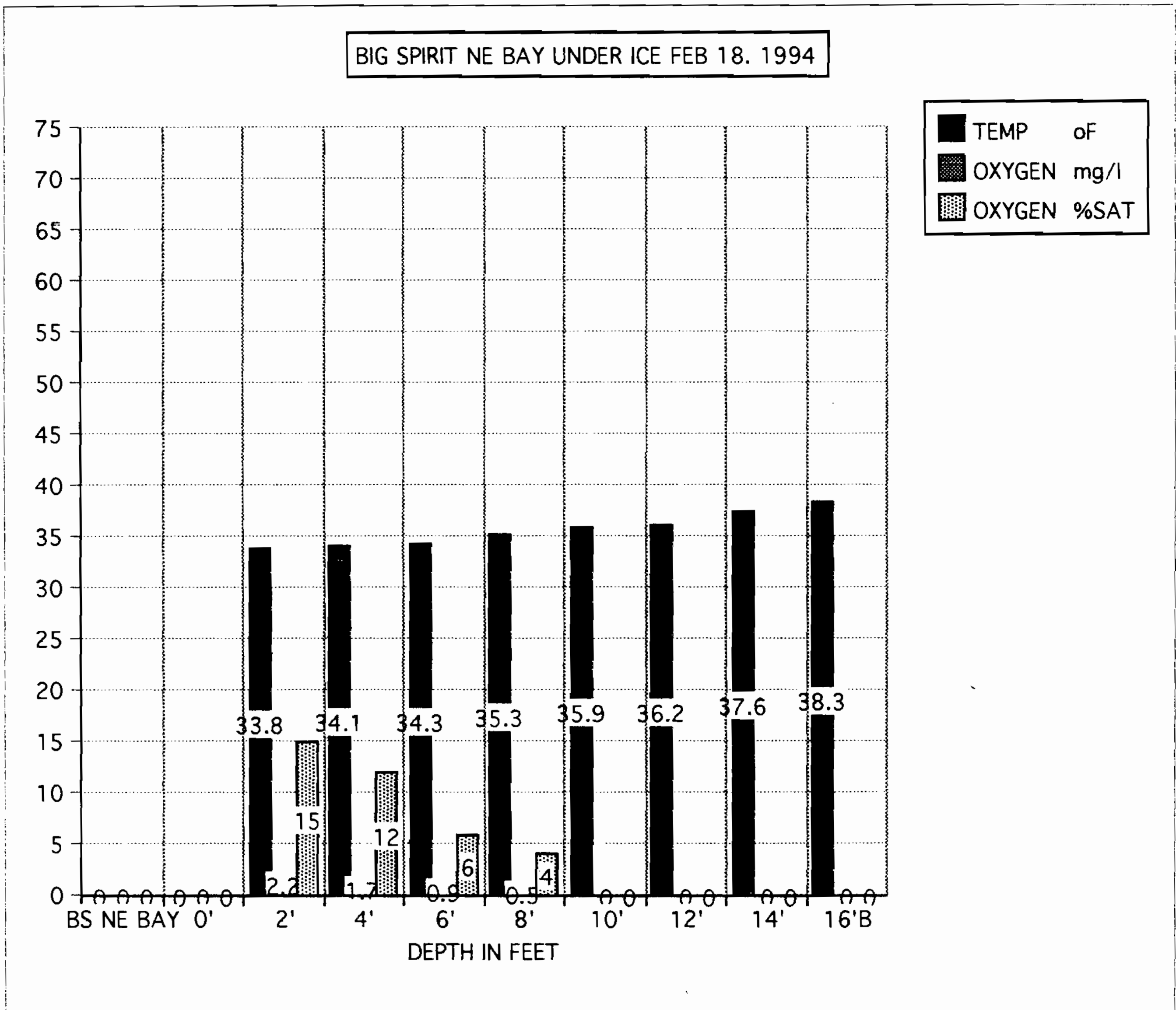


FIGURE 6. BIG SPIRIT NE BAY OXYGEN TEMPERATURE PROFILE ON FEB 18, 1994.

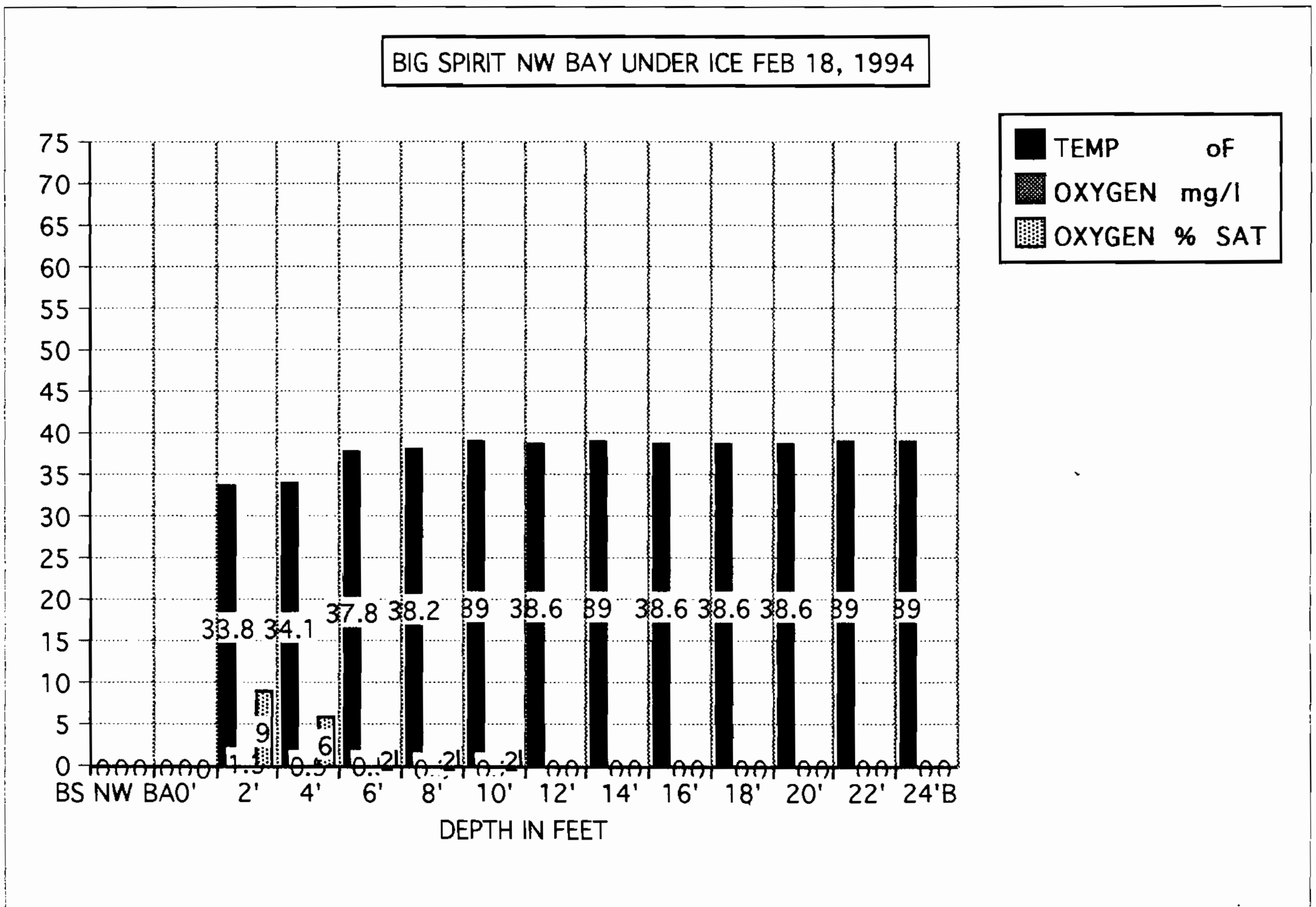
Feb 18, 1994 BS NE BAY	TEMP oF	OXYGEN mg/l	OXYGEN %SAT	OTHER DATA:
0'	14" ICE 4" SNOW			
2'	33.8	2.2	15	
4'	34.1	1.7	12	
6'	34.3	0.9	6	
8'	35.3	0.5	4	
10'	35.9	0	0	
12'	36.2	0	0	
14'	37.6	0	0	
16'B	38.3	0	0	



No oxygen at all was found below the 8' depth in NE bay, the 10' depth in the NW bay, and the 12' depth in the south bay. Temperature stratifications were similar at all three locations. This indicated the aeration near the south sampling point was probably increasing the saturation levels in the top ten feet of water but not impacting water density/ temperature profiles.

FIGURE 7. BIG SPIRIT NW BAY OXYGEN TEMPERATURE PROFILE ON FEB 18,1994.

Feb 18, 1994	TEMP oF	OXYGEN mg/l	OXYGEN % SA	OTHER DATA:
BS NW BAY				
0'	14" ICE 4" SNOW			
2'	33.8	1.3	9	
4'	34.1	0.9	6	
6'	37.8	0.5	2	
8'	38.2	0.3	2	
10'	39	0.2	2	
12'	38.6	0	0	
14'	39	0	0	
16'	38.6	0	0	
18'	38.6	0	0	
20'	38.6	0	0	

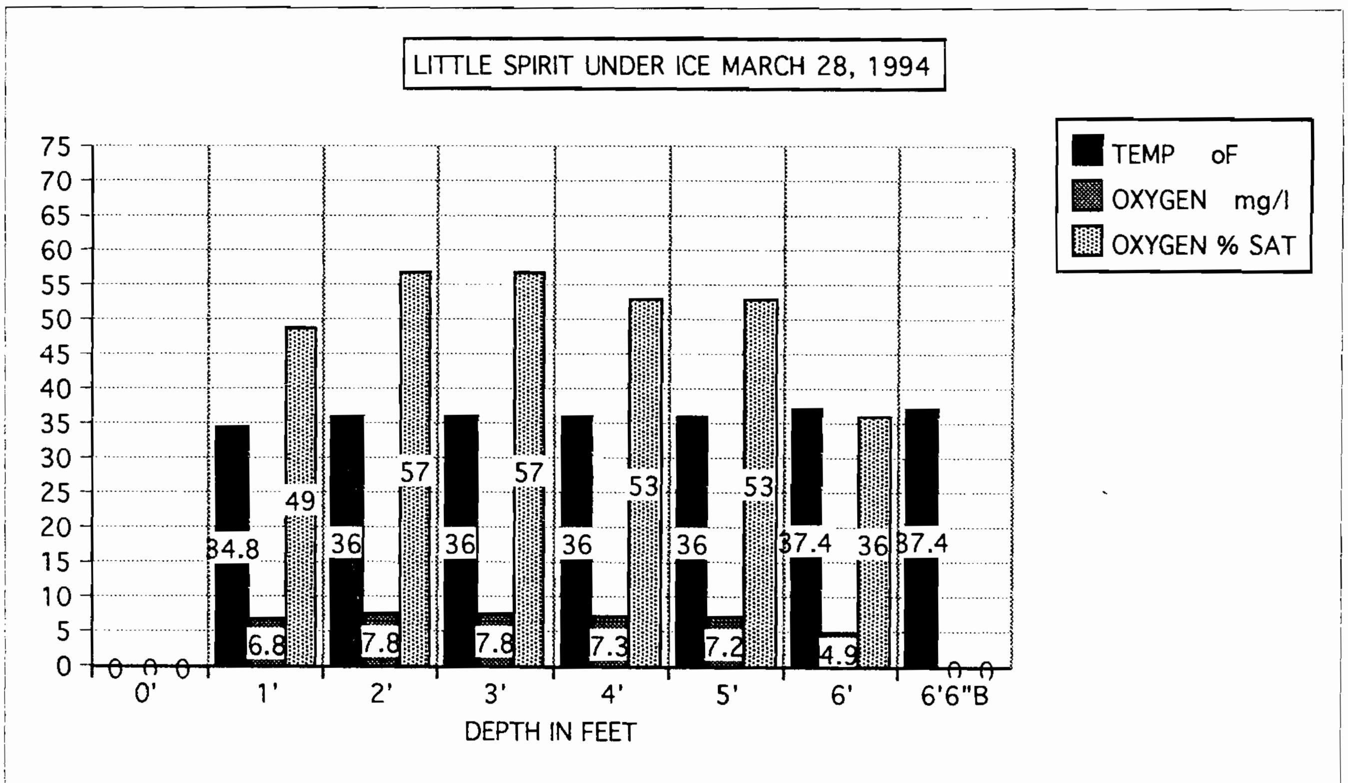


March 28, 1994   A March thaw with sunny skies brought drastic changes to the Spirit Lakes. The ice was found to be nearly crystal clear with no snow cover until the morning of the sampling. Oxygen levels increased in Little Spirit and the NE and NW bays of North Spirit but did not increase at the south bay sampling site.

Little Spirit Lake oxygen levels rebounded more than in North Spirit Lake. Oxygen levels increased to above the 5 mg/l or 5 ppm stress threshhold level. Low oxygens were only found at the bottom interface with the sediment (SEE FIGURE 8 BELOW).

FIGURE 8. LITTLE SPIRIT OXYGEN-TEMPERATURE PROFILE ON MAR 28, 1994

Mar 28, 1994	TEMP oF	OXYGEN mg/l	OXYGEN % SAT	OTHER DATA
0'	R ICE 1" SNOW IN NIGHT			RIVER ABOVE: UNNAMED TRIB. FROM STONE L.
1'	34.8	6.8	49	-AT MINK FARM BRIDGE, TEMP 36.1 oF
2'	36	7.8	57	OXYGEN 7.8 mg/l
3'	36	7.8	57	
4'	36	7.3	53	RIVER BELOW: SPIRIT RIVER
5'	36	7.2	53	-AT STH 102 BRIDGE, TEMP 37.4 oF,
6'	37.4	4.9	36	OXYGEN 8.3 mg/l
6'6"B	37.4	0	0	



Nutrient sampling taken under the ice and near the bottom of Little Spirit Lake sampling location indicated higher levels of organic nitrogen, ammonia-N and phosphorus beneath the ice than near the bottom. At the same time 5- day Biochemical Oxygen Demand just below the ice was higher than near the top than near the bottom (See Figures 9 & 10). Oxygen levels had improved from the February 18 sampling and water temperatures had risen slightly.

FIGURE 9. LITTLE SPIRIT NITROGEN-PHOSPHORUS LEVELS SURFACE AND BOTTOM UNDER THE ICE ON MARCH 28, 1994.

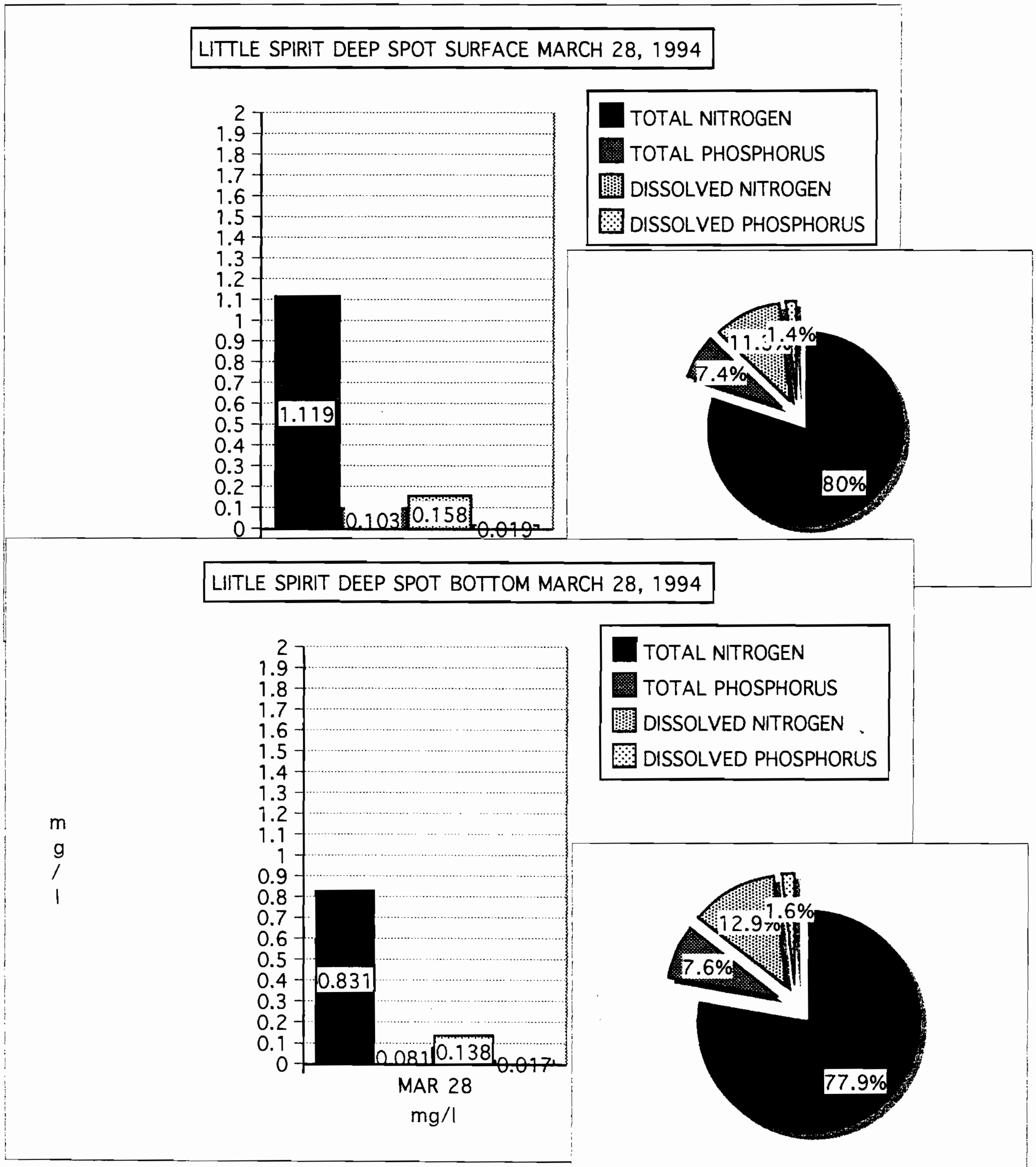
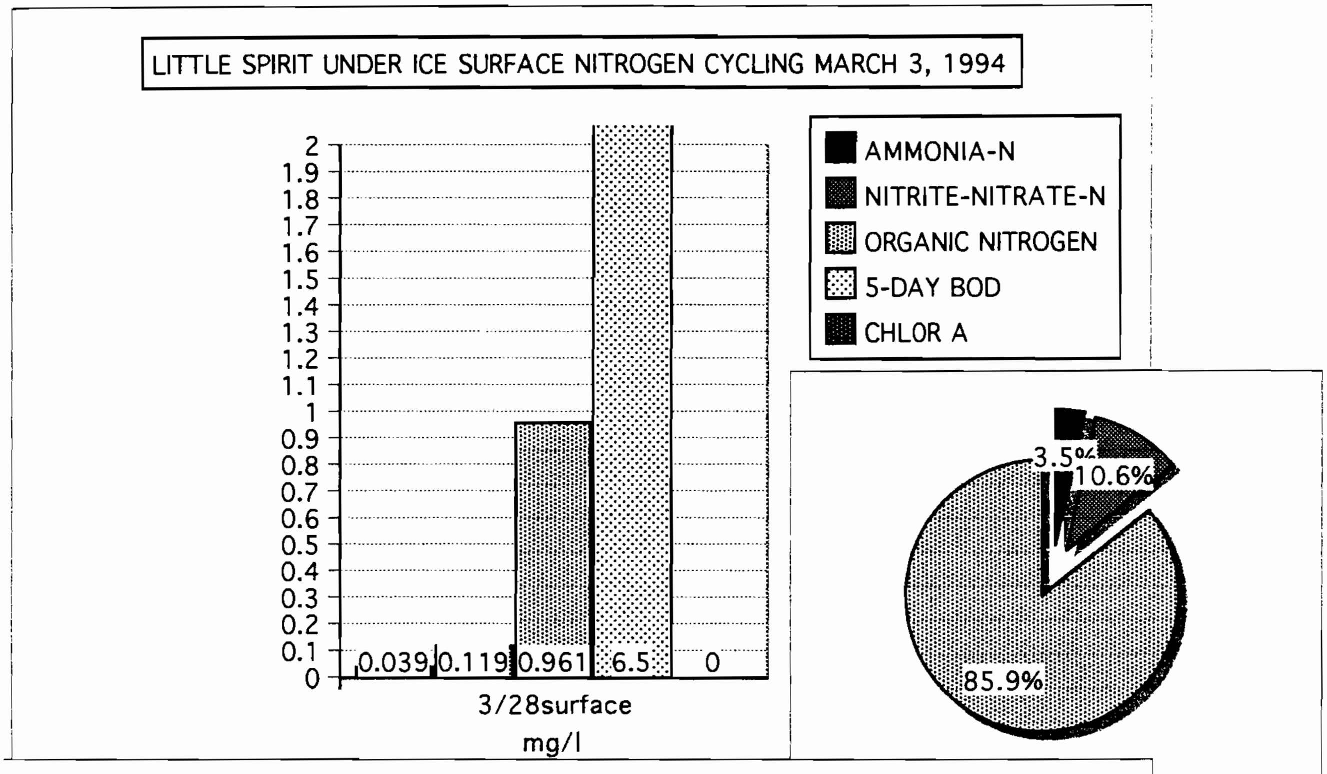
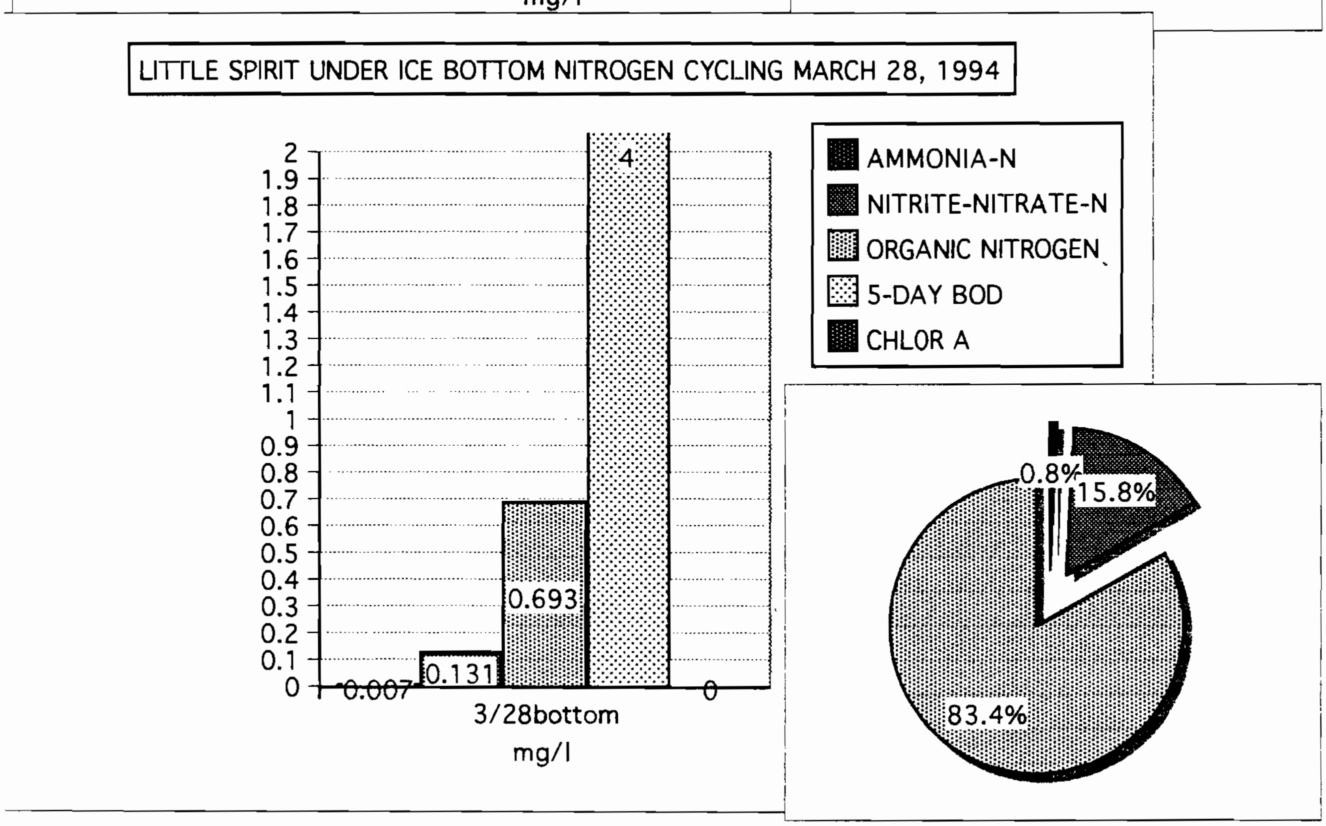


FIGURE 10. LITTLE SPIRIT NUTRIENT CYCLING UNDER ICE ON MARCH 28, 1994

LITTLE SPIRIT UNDER ICE

MO/DAY 94	AMMONIA-N	NITRITE-NITRA	ORGANIC NITRO	5-DAY BOD	CHLOR A	OXYGEN/TEMP
3/28surface	0.039	0.119	0.961	6.5		6.8 mg/l / 36o
MO/DAY 94	AMMONIA-N	NITRITE-NITRA	ORGANIC NITRO	5-DAY BOD	CHLOR A	OXYGEN/TEMP
3/28bottom	0.007	0.131	0.693	4		7.2 mg/l / 36(





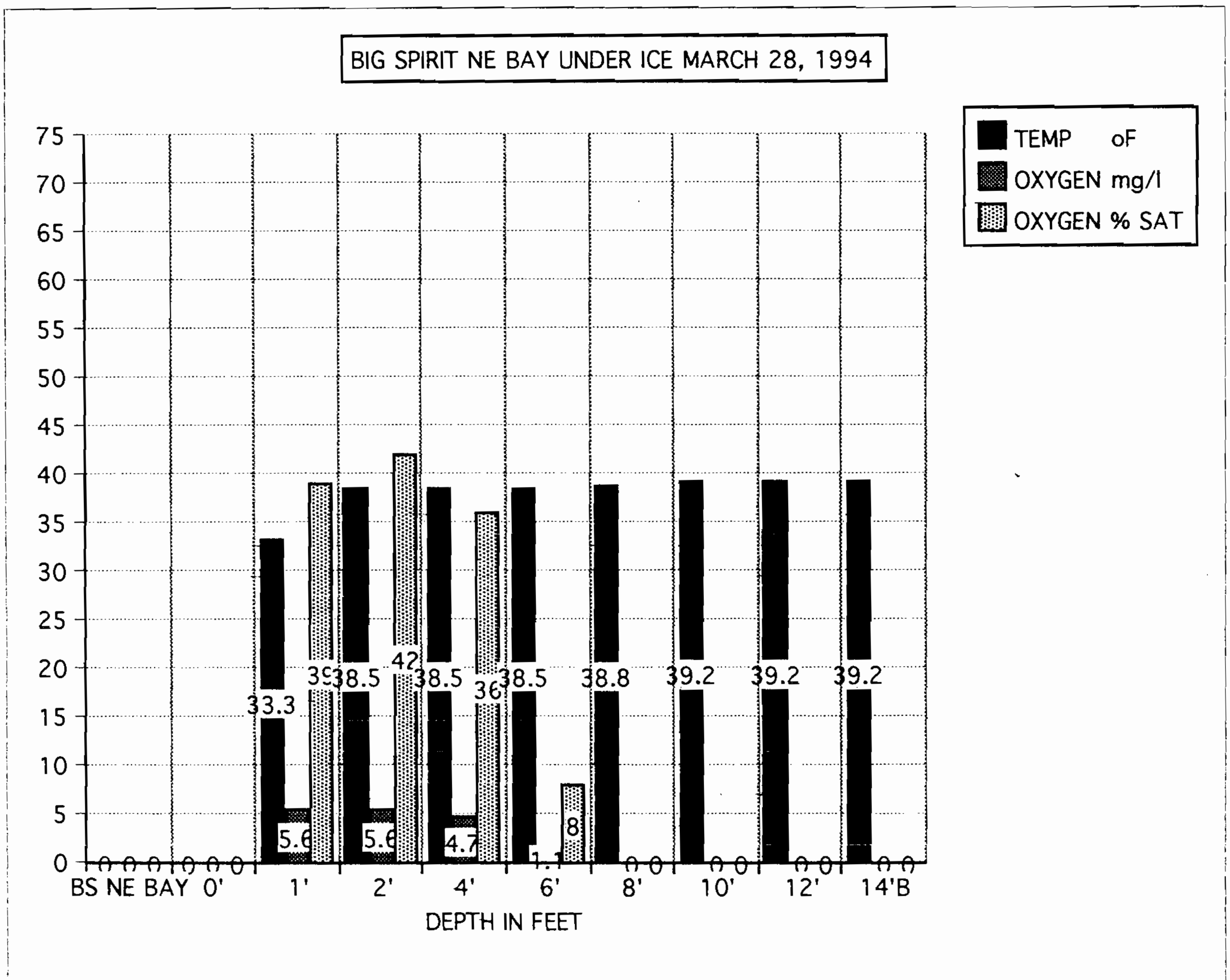
Oxygen and temperatures were taken on the river upstream at the mink farm bridge and at the Little Spirit outlet at the bridge. High oxygen levels and temperature above in the stream corresponded to mid depth readings in Little Spirit . At the 102 bridge temperatures were identical to the 6' readings in the lake and oxygen's slightly higher than at the mid water depths.

The quality of the river water entering the channel between the lake is important to the water quality of Little Spirit under the ice. The organic and ammonia load was added to the river as it passed a large wetland area above Little Spirit Lake. During the critical times of midwinter ice cover aeration of the stream as it flow through Little Spirit contributes more oxygen to areas in contact with the moving water of the stream but not in non contact areas. The oxygen demand of organic material on the bottom outside these stream contact areas in Little Spirit depletes the oxygen until increased water flows during periodic winter and spring thaws widen the stream currents under the ice to reach these oxygen devoid areas. This same stream current that adds oxygen also carries an increased organic and phosphorus load from the wetland above in the stream as indicated by the nutrient sampling.

North Spirit Lake oxygen level increases in March were not as substantial as those found in Little Spirit but increased in two areas of the lake above stressful low levels. The clear ice combined with nearly identical water temperature/ density conditions from surface to bottom were recorded in the NE and NW bay sampling points (Figures 11 &12). Phytoplankton activity was observed at both of these sampling points.

FIGURE 11. BIG SPIRIT NE BAY TEMPERATURE OXYGEN PROFILES UNDER THI ICE ON MARCH 28,1994.

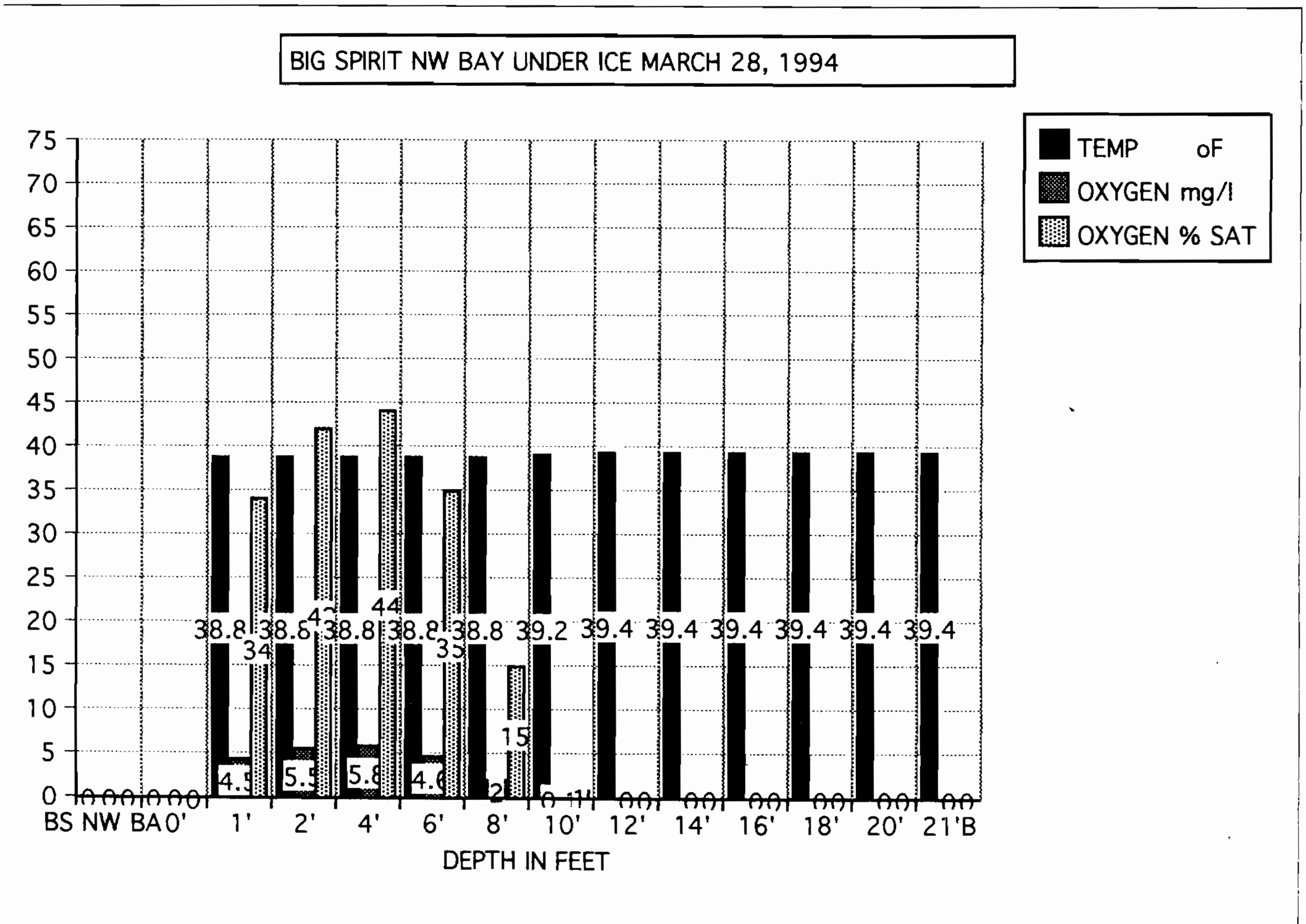
Mar 28, 1994	TEMP oF	OXYGEN mg/l	OXYGEN % SAT	OTHER DATA:
BS NE BAY				PHYTOPLANKTON OBSERVED
0'	11" ICE 2" SNOW IN NIGHT			
1'	33.3	5.6	39	
2'	38.5	5.6	42	
4'	38.5	4.7	36	
6'	38.5	1.1	8	
8'	38.8	0	0	
10'	39.2	0	0	
12'	39.2	0	0	
14'B	39.2	0	0	



Temperatures in the NE an NW bays vared less than one degree from 2 feet below the ice to the bottom . Oxygen and oxygen saturation profiles in the NW and NE bays were comparible to each other and near 5.0 ppm or mg/l in the top 6 feet of water. Oxygen completely disappeared between the 6-8 foot depth in the NE bay and at the 10-12 foot depth in the NW bay.

FIGURE 12. BIG SPIRIT NW BAY OXYGEN-TEMPERATURE PROFILE UNDER THE ICE ON MARCH 28, 1994

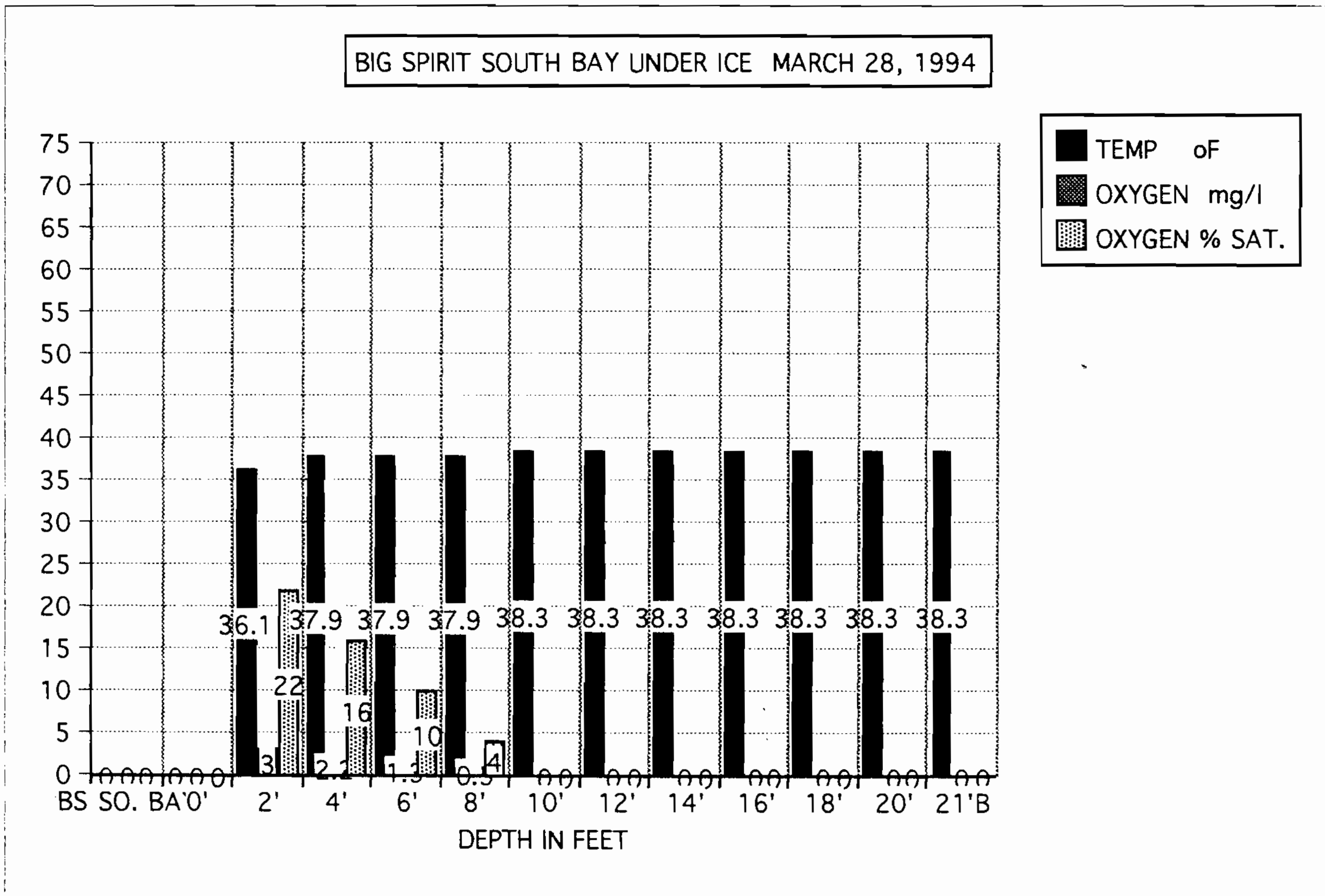
Mar 28, 1994	TEMP oF	OXYGEN mg/l	OXYGEN % SAT	OTHER DATA:
BS NW BAY				PHYTOPLANKTON OBSERVED
0'	9" ICE 1" SNOW IN NIGHT			
1'	38.8	4.5	34	
2'	38.8	5.5	42	
4'	38.8	5.8	44	
6'	38.8	4.6	35	
8'	38.8	2	15	
10'	39.2	0.1	1	
12'	39.4	0	0	
14'	39.4	0	0	
16'	39.4	0	0	
18'	39.4	0	0	
20'	39.4	0	0	
21'B	39.4	0	0	



The sampling results from the south bay of Big Spirit, located 200 yards north of the open aeration field, when compared to the NE and NW bay sampling results were considerably different. At the south bay sampling site colder water was found and temperature just under the ice to the bottom had a much larger range. In comparison, the south bay oxygen completely disappeared at the 10-12 foot depth and had less oxygen and oxygen saturation percentages than the North bay location. It is apparent that the circulation caused by the diffused oxygen system to the south effected the south bay sampling point (Figure 13). Several parameters to identify the differences are discussed below.

FIGURE 13. SPIRIT LAKE SOUTH BAY OXYGEN-TEMERATURE PROFILE UNDER THE ICE ON MARCH 28, 1994.

	TEMP oF	OXYGEN mg/l	OXYGEN % SAT	OTHER DATA
BS SO. BAY				-H2O SAMPLE
0'	12" CLEAR ICE, 1" SNOW IN NIGHT			TOP & BOTTOM
2'	36.1	3	22	
4'	37.9	2.2	16	
6'	37.9	1.3	10	
8'	37.9	0.5	4	
10'	38.3	0	0	
12'	38.3	0	0	
14'	38.3	0	0	
16'	38.3	0	0	
18'	38.3	0	0	
20'	38.3	0	0	



Water chemistry samplings of the water near the bottom and below the ice at the NW bay and south bay locations were made to further explain the temperature/ oxygen profile differences (Figures 14 THRU 17).

FIGURE 14. BIG SPIRIT NW BAY NITROGEN-PHOSPHORUS UNDER THE ICE ON MARCH 28, 1994.

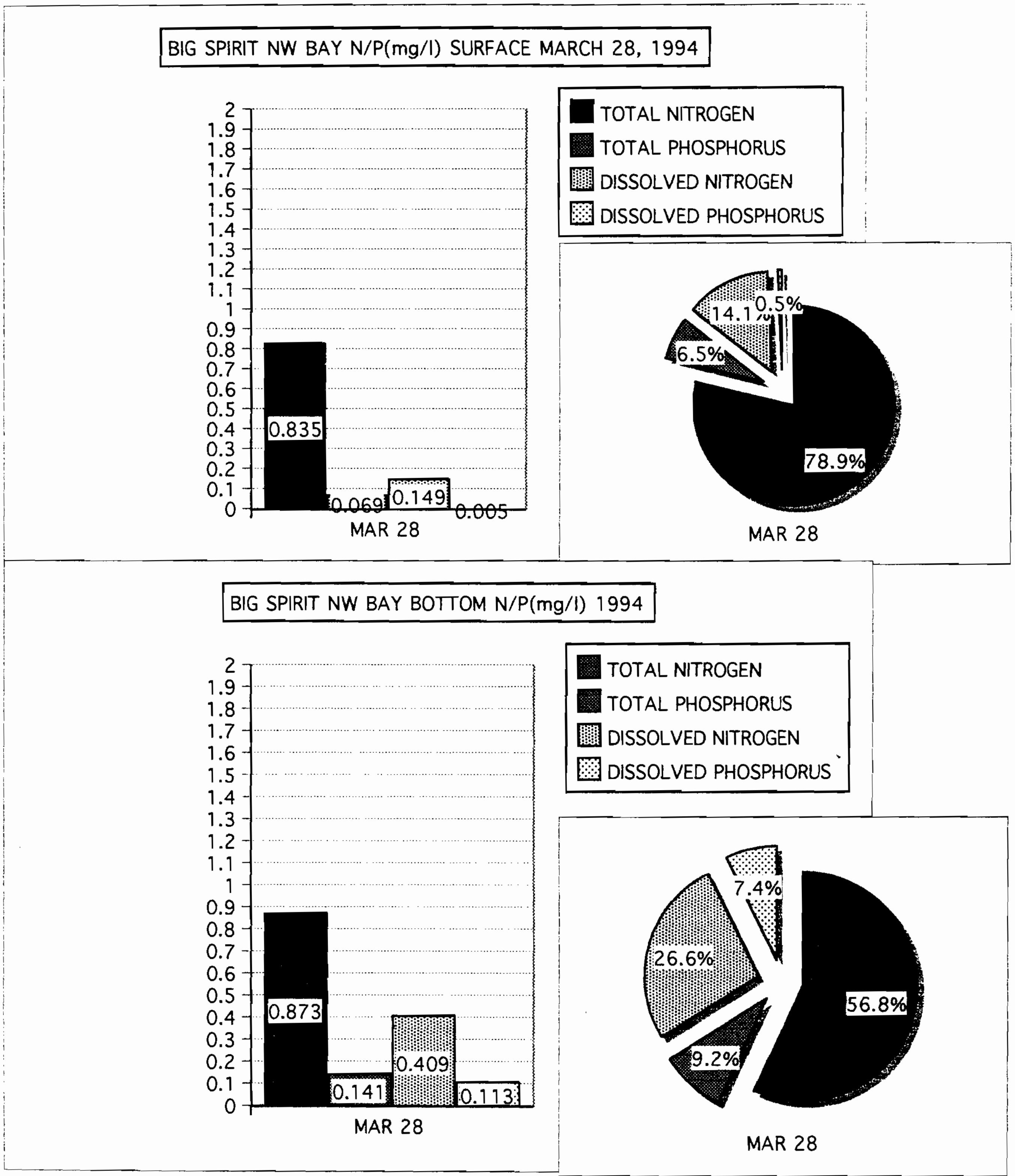
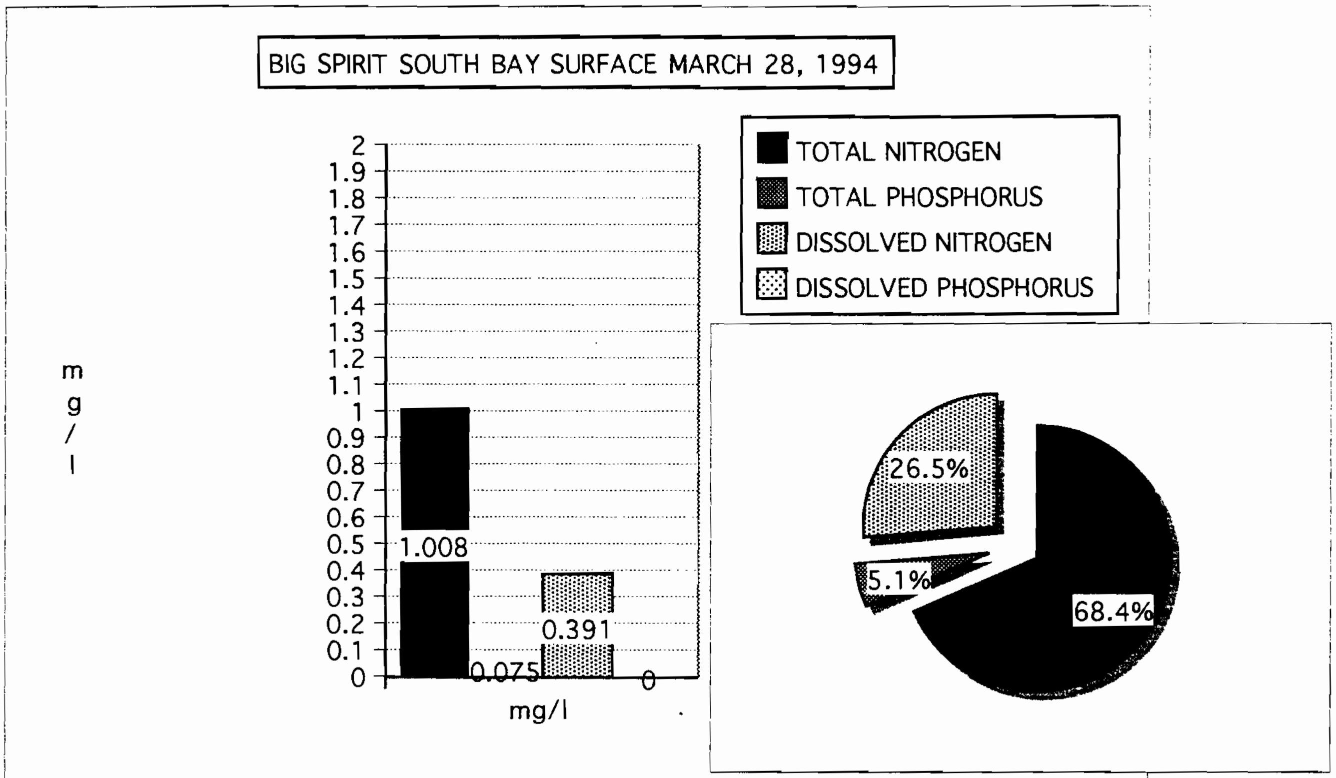


FIGURE 15. BIG SPIRIT SOUTH BAY NITROGEN-PHOSPHORUS UNDER THE ICE ON MARCH 28, 1994.

BIG SPIRIT SOUTH BAY

MO/DAY	94	TOTAL NITROGE	TOTAL PHOSPH	DISSOLVED NITI	DISSOLVED PHOSPHORUS
MAR 28		1.008	0.075	0.391	CONTAMINATED ?
MO/DAY	94	TOTAL NITROGE	TOTAL PHOSPH	DISSOLVED NITI	DISSOLVED PHOSPHORUS
MAR 28		1.226	0.24	0.604	0.022



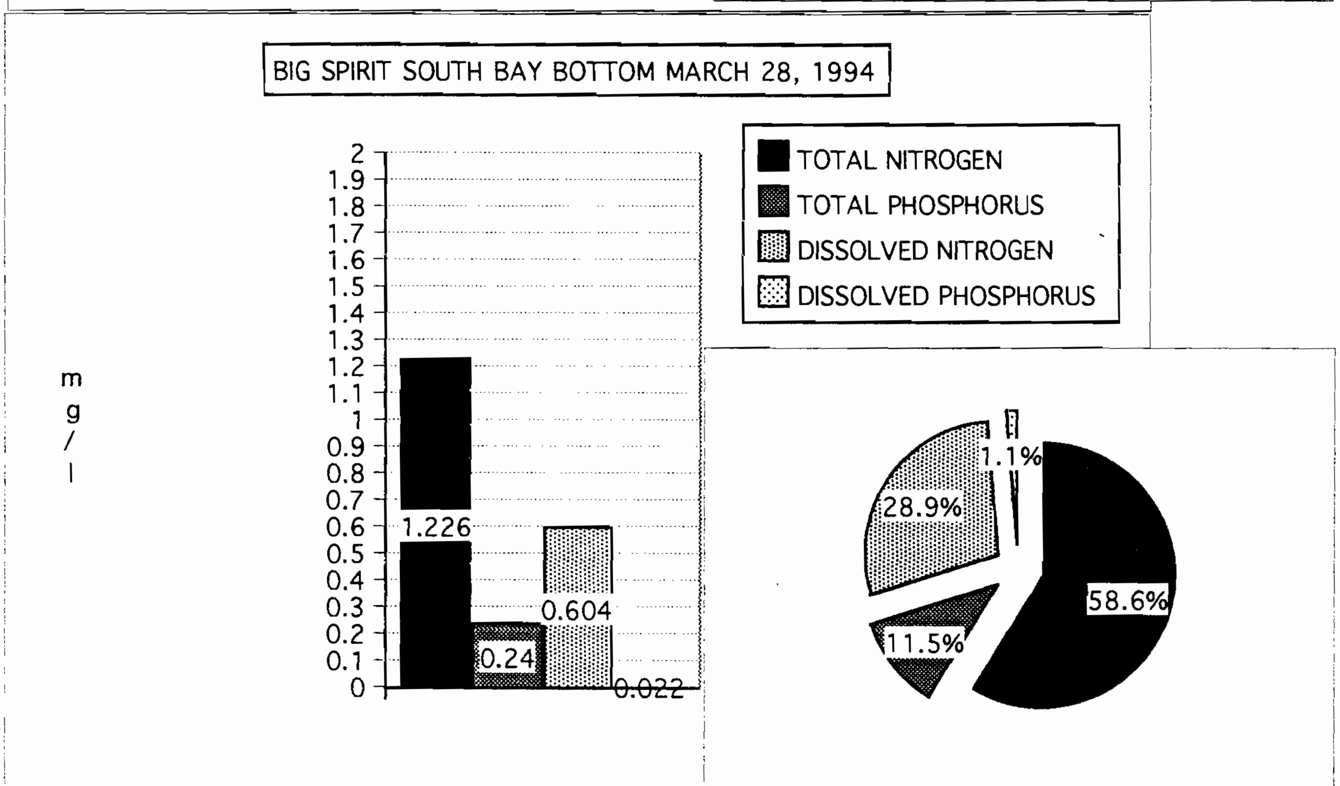


FIGURE 16. BIG SPIRIT NW BAY NITROGEN CYCLING UNDER ICE ON MARCH 28,1994.

BIG SPIRIT NW BAY UNDER ICE

MO/DAY 94	AMMONIA-N	NITRITE-NITRA'	ORGANIC NITRO	5-DAY BOD	CHLOR A	OXYGEN/TEMP
3/28 Surface	0.014	0.135	0.686	3.8		5.5mg/l /38oF
MO/DAY 94	AMMONIA-N	NITRITE-NITRA'	ORGANIC NITRO	5-DAY BOD	CHLOR A	OXYGEN/TEMP
3/28 Bottom	0.236	0.173	0.464	1.7		0.0mg/l /39oF

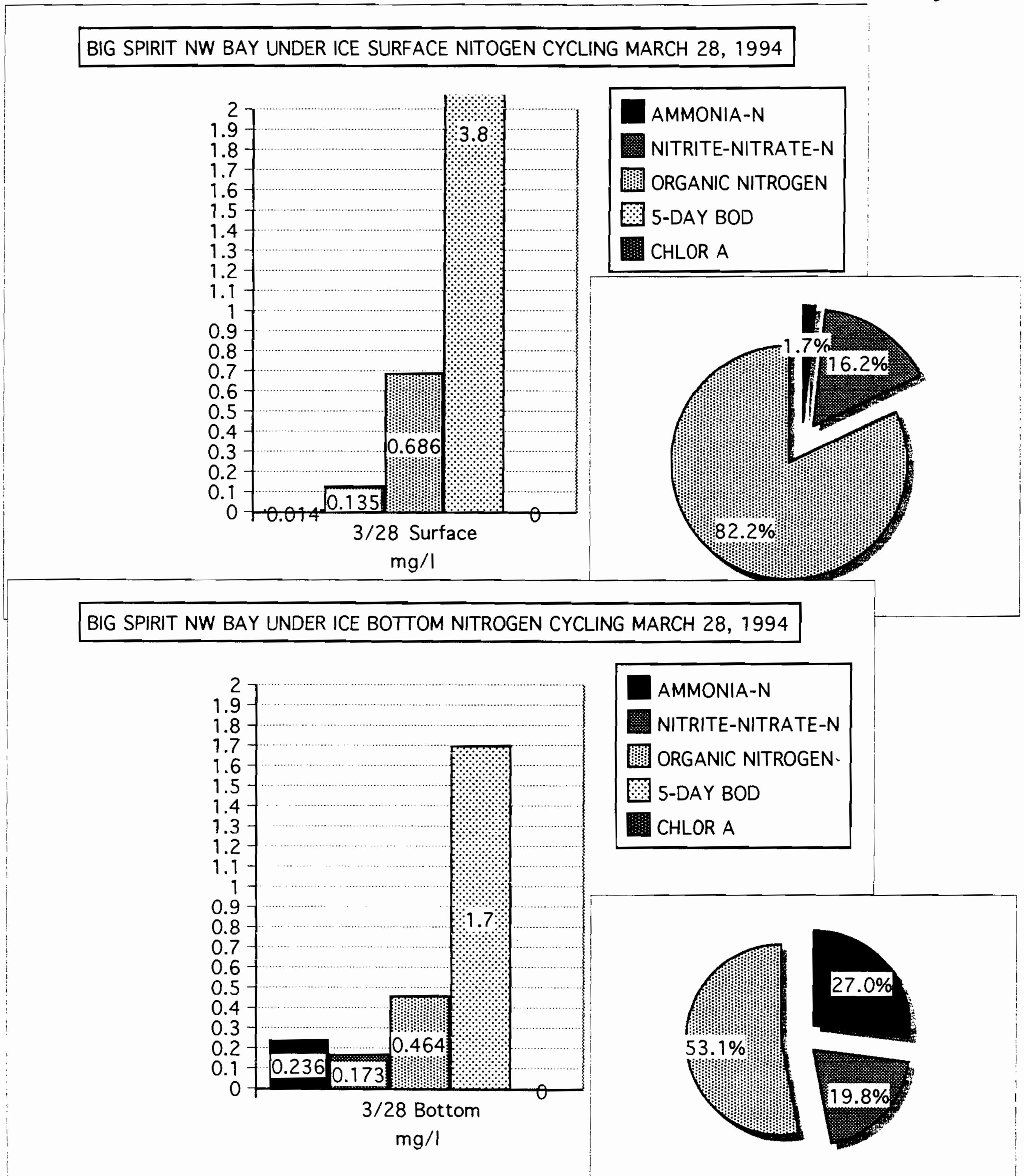
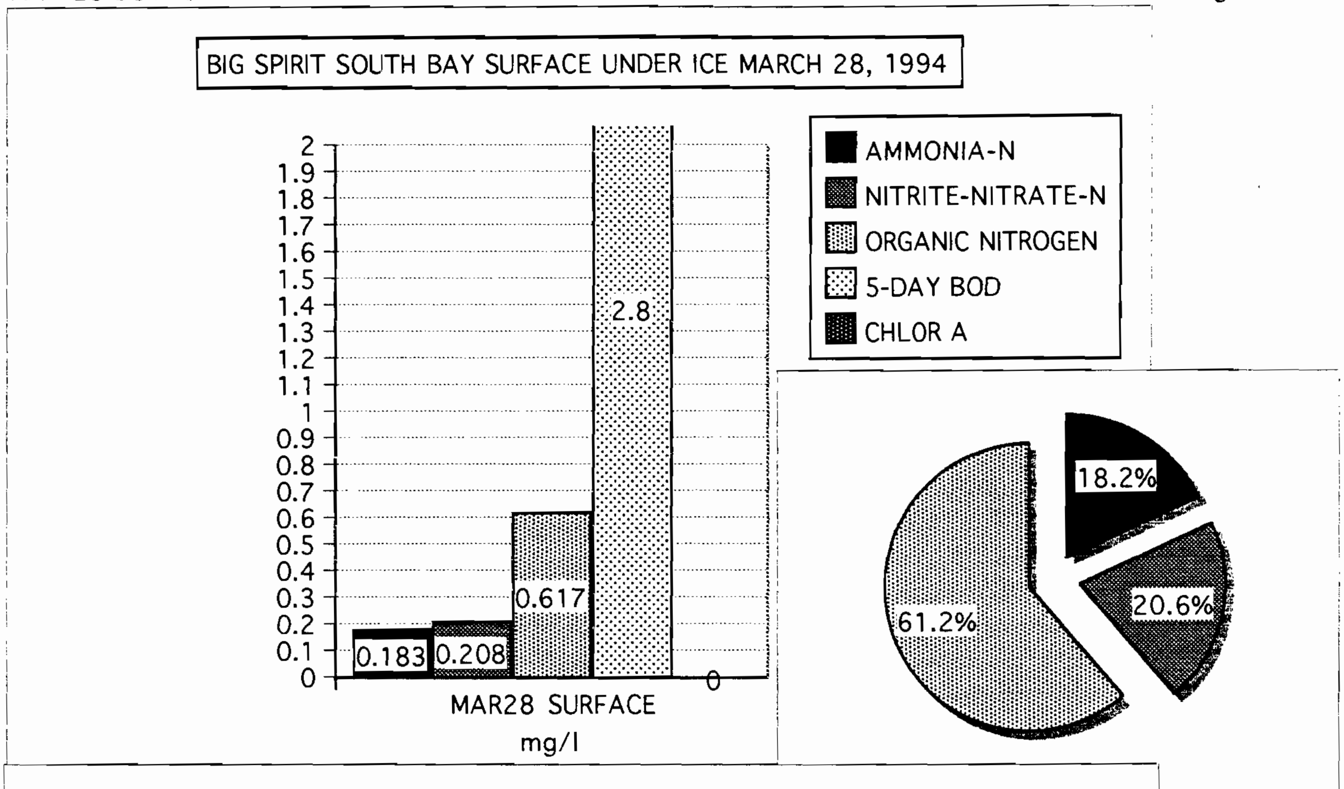
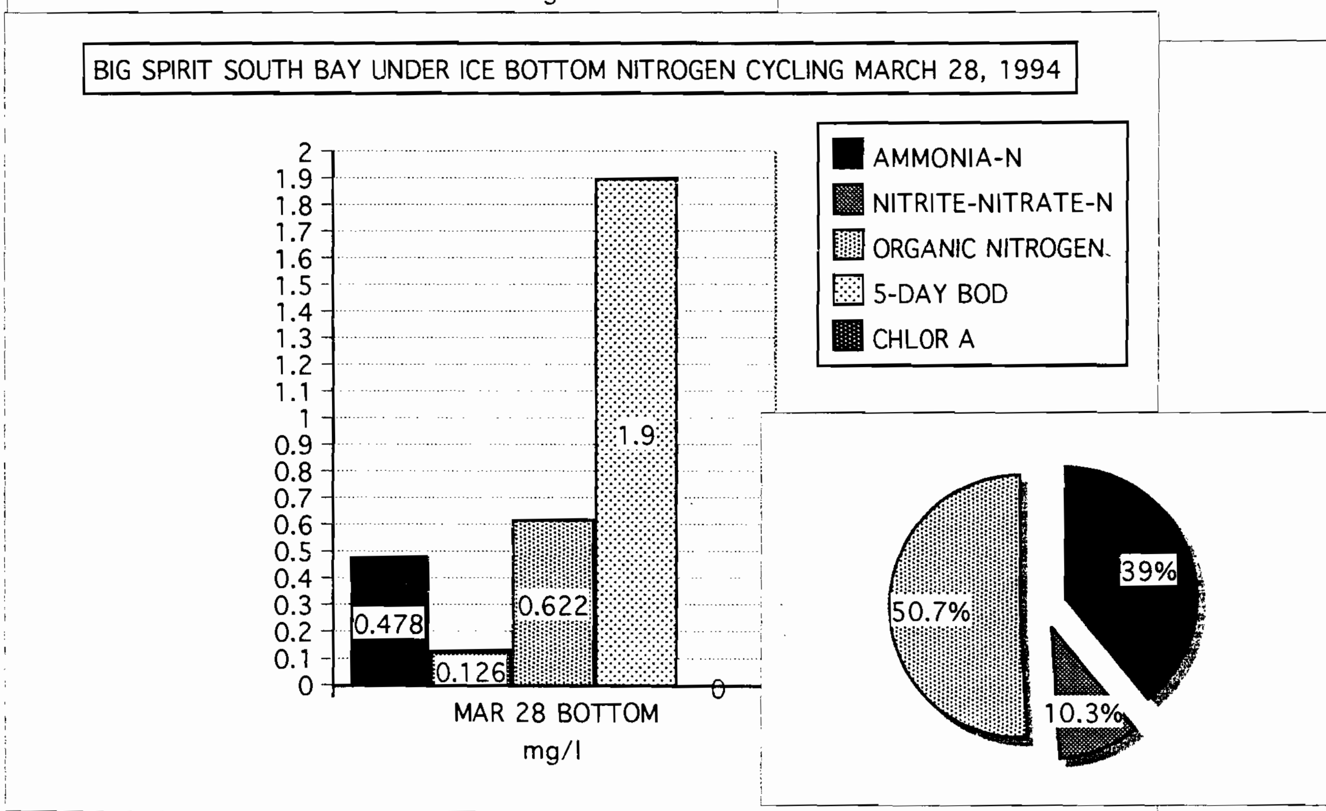


FIGURE 17. BIG SPIRIT SOUTH BAY NITROGEN CYCLING UNDER THE ICE ON MARCH 28, 1994

BIG SPIRIT SOUTH BAY SURFACE MARCH 3, 1994

MO/DAY 94	AMMONIA-N	NITRITE-NITRA	ORGANIC NITRO	5-DAY BOD	CHLOR A	OXYGEN/TEMP
MAR28 SURFA(	0.183	0.208	0.617	2.8		3mg/l / 36oF
MO/DAY 94	AMMONIA-N	NITRITE-NITRA	ORGANIC NITRO	5-DAY BOD	CHLOR A	OXYGEN/TEMP
MAR 28 BOTTO	0.478	0.126	0.622	1.9		0 mg/l / 39oF





When ammonia-N levels near the surface were compared, south bay reading were over 13 times greater than the NW bay. The lower oxygen and temperatures at the south bay surface than at the NW bay surface could account for the higher ammonia reading as ammonia-N conversion to nitrite-nitrate-N does not as readily occur at lower oxygen levels and at lower temperatures. Nitrite-nitrate-N levels were also higher in the south bay. At the same time dissolved nitrogen, total nitrogen, and total phosphorus levels near the south bay's surface under the ice were all higher than in the NW bay.

When nutrient levels of near bottom water samples were compared ammonia- N at the south bay sampling site were twice the concentration of the NW bay sight. A corresponding higher nitrite-nitrate-N level was found in the NW bay bottom. Total and dissolved nitrogens and total phosphorus were all proportionally higher in the south bay bottom waters than the NW bay bottom waters. Only the dissolved phosphorus levels were much higher in the NW bottom sample.

The aeration plume south of the south bay sampling location is probably circulating nutrient - rich sediments from the bottom near the diffusers to the surface. Here the water is cooled by the contact with the cold air at the surface and the water plume then extends under the ice away from the open water area. This would explain the colder and nutrient-laden water at the south sample point when compared to the north bays. The lower oxygen would be a result of the oxygen demand associated with the suspended and dissolved organic matter. The Biochemical Oxygen Demand of the near surface water was higher in the NW bay than the south bay does not support this, but the presence of phytoplankton in the NW sample and not in the South bay sample would explain the higher the 5 day- BOD reading. The differences in bottom water nutrients maybe from the precipitation of suspended nutrients from the aeration plume at the south sample.

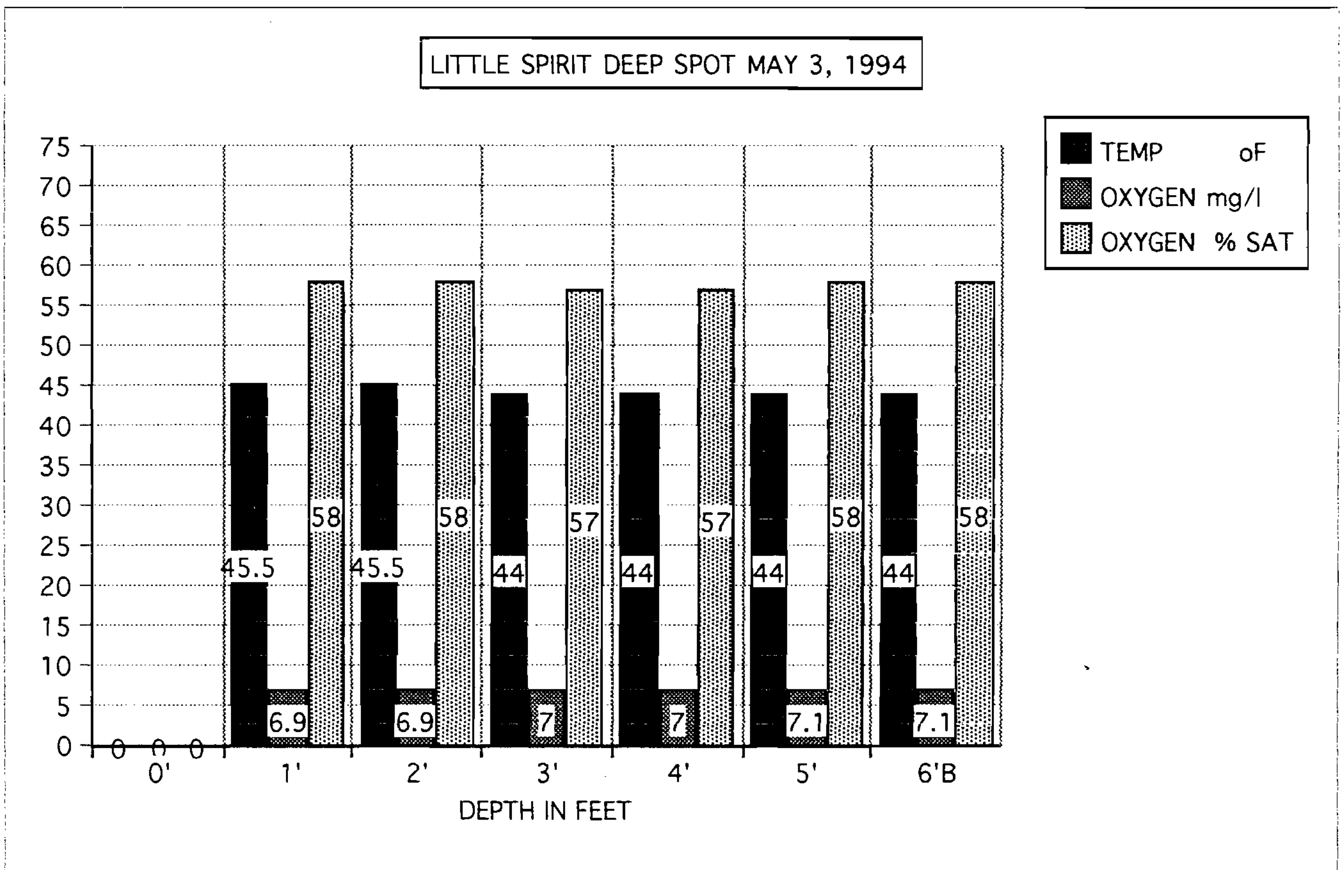
The presence of phytoplankton at the NW and NE bay sampling sights would account for the increased oxygen in the surface water under the ice from the February sampling. Quantitative assessment by chlor a and plankton identification sampling would have helped clarified the differences between North and South Spirit sampling points. Did the increased nutrients at the surface inhibit algae growth in the south bay or were the nutrients and conditions necessary for phytoplankton growth in the north bays more ideal?

<u>May 3, 1994</u> Warm spring winds mixed the waters of Big Spirit to it's deepest depths. Winds and stream flows from Olson Creek and the north tributary mixed and warmed Little Spirit. Oxygen/ Temperature profiles, nutrient and mineral sampling were completed to assess the water quality of the entering streams and in-lake conditions. Sampling at this time is important to assess the nutrients available for plankton and plant production in the upcoming growing season.

Little Spirit Lake surface water temperatures were 4 to 5 degrees higher than the surface waters of Big Spirit Lake (Figures 18). Temperatures of the tributary streams entering Little Spirit were also warmer than either lake but were taken later in the day - temperatures of the streams are more closer to those found in Little Spirit.

FIGURE 18. LITTLE SPIRIT LAKE & TRIBUTARIES OXYGEN-TEMPERATURES ON MAY 3, 1994.

May 3, 1994	TEMP oF	OXYGEN mg/l	OXYGEN%SA`	OTHER DATA:
0'				RIVER ABOVE: UNNAMED TRIB. FROM STONE L.
1'	45.5	6.9	58	-AT MINK FARM BRIDGE, TEMP 46 oF,
2'	45.5	6.9	58	OXYGEN 9.2 mg/l
3'	44	7	57	TRIBUTARY: OLSON CREEK
4'	44	7	57	-AT 102 CULVERT , TEMP 48 oF
5'	44	7.1	58	OXYGEN 8.1 mg/l
6'B	44	7.1	58	SECCHI: 3'0"
LOCATION : DEEP SPOT				PLANKTON SAMPLED



Water temperatures in Little Spirit below the 2 foot depth to the bottom were 44 oF. Dissolved oxygen levels throughout the Little Spirit water column were near 7.0 mg/l but the percent oxygen saturation at this low temperature was only 57-58%. In the tributary streams oxygen saturation were much higher. Olson Creek's dissolved oxygen level was at 8.1mg/l at 48 oF with a oxygen saturation of 77%. The north tributary at the mink farm road crossing oxygen levels was at 9.2 at 46oF with an oxygen saturation of 11.9 %.

When these oxygen levels are compared with nutrient sampling in Little Spirit and the streams several parameters of water quality could be interpreted. Total Nitrogen levels in the surface water of Little Spirit were at 0.800 mg/l of which 97 % (0.772mg/l) is from Organic Nitrogen (Figures 19 & 20). Organic or biomass nitrogen is fine plant and animal matter suspended in the water column. Dissolved nitrogen in the form of ammonia-N was also present in the surface water and had not been converted to nitrite-nitrate-N because of the low temperatures. A fairly high 5-day Biochemical Oxygen Demand, a low chlor A reading, and a Secchi depth of only 3' accompanied this high organic surface water. There was no wind to stir up bottom sediments that according to the oxygen meter reading had little oxygen demand. It is evident that the organic matter was originating in the stream above and not from bottom sediments.

Phosphorus levels in the Little Spirit and the tributary streams also indicate nutrients entering Little Spirit from both tributary streams (Figure 21). Total phosphorus includes the plant and animal fragments suspended in the water. Dissolved phosphorus is soluble and can easily be taken up by plants - both plankton & macrophytes. Dissolved phosphorus should be 0.010 mg/l or less in the spring to prevent summer algae blooms. Total phosphorus concentrations below 0.030 should be maintained to prevent nuisant algae blooms.

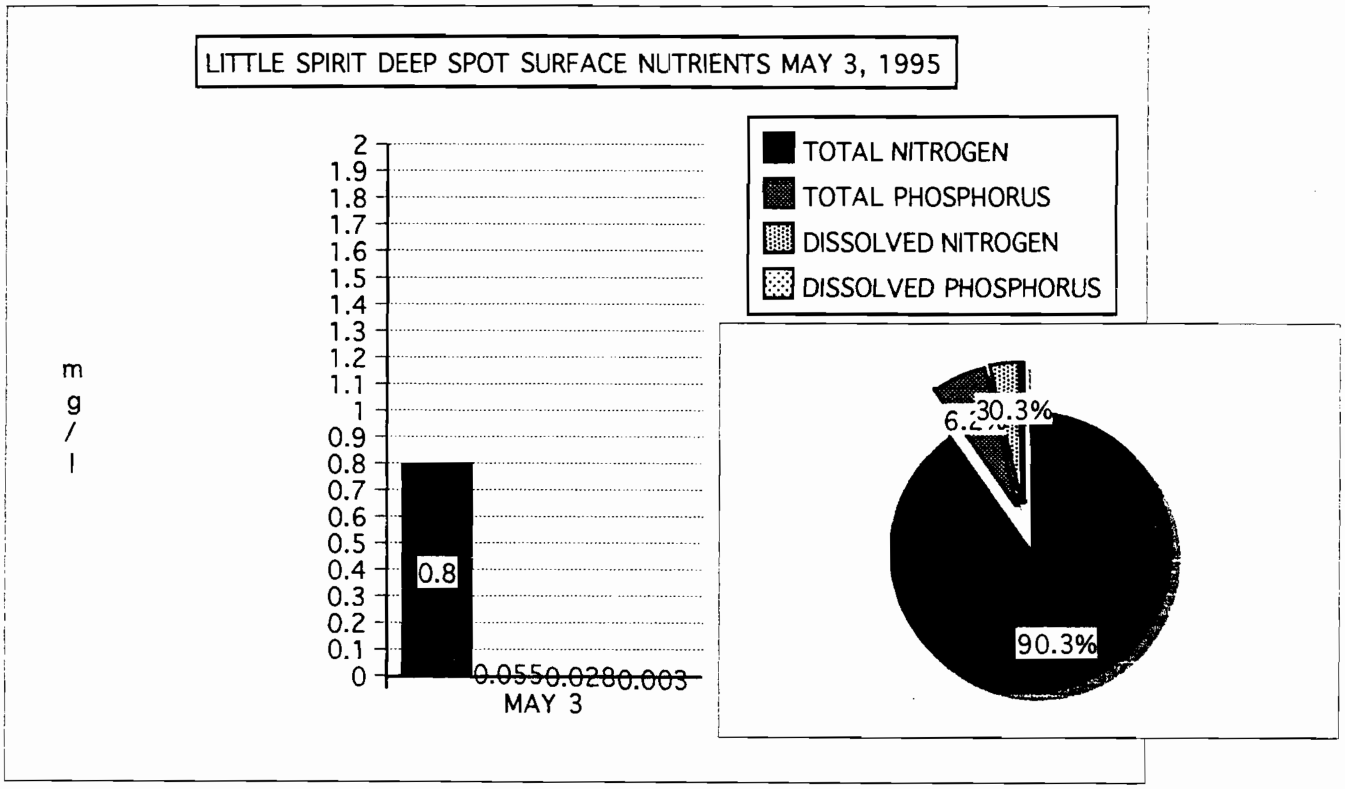
Little Spirit and its tributaries exceed these spring total phosphorus levels. It must be remembered that the north tributary travels through organic soils of stream side wetlands above the sampling point and a large wetland and flood beaver dam marsh after the sampling point. Organic soils, marsh areas, and shallow ponds are also found upstream from the Olson Creek sampling location. Water volumes and watershed drainage areas draining into the North tributary are much greater than those of Olson Creek but the upland soils in the small Olson Creek watershed are much more fertile.

FIGURE 19. LITTLE SPIRIT NITROGEN- PHOSPHORUS ON SURFACE AND BOTTOM ON MAY 3, 1994.

LITTLE SPIRIT-DEEP SPOT

MO/DAY 94	TOTAL NITROGE	TOTAL PHOSPH	DISSOLVED NITI	DISSOLVED PHOSPHORUS
MAY 3	0.8	0.055	0.028	0.003

MO/DAY 94	TOTAL PHOSPH	DISSOLVED PHOSPHORUS
MAY 3	0.059	0.003



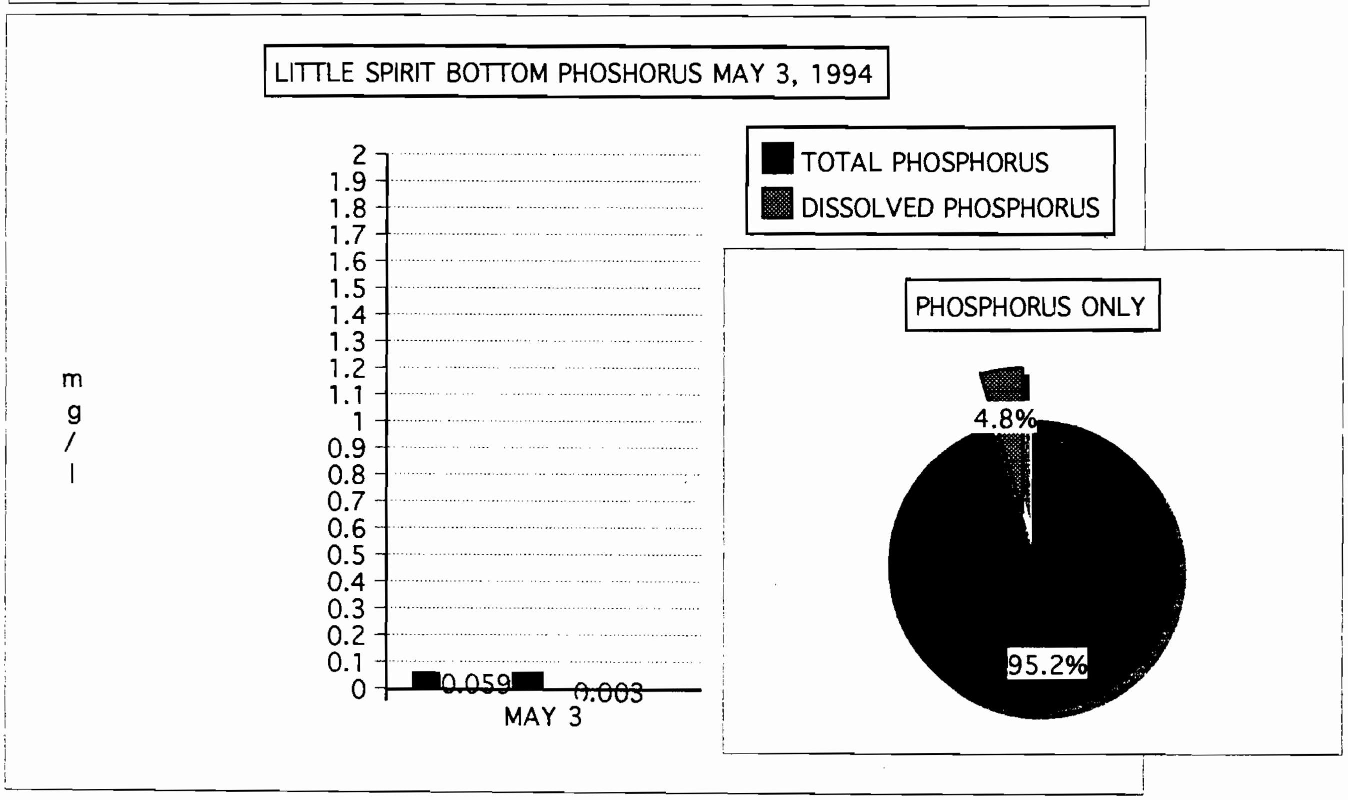


FIGURE 20. LITTLE SPIRIT NITROGEN CYCLING ON MAY 3, 1994

LITTLE SPIRIT SPRING TURNOVER

MO/DAY 94	AMMONIA-N	NITRITE-NITRA	ORGANIC NITRO	CHLOR A	5 DAY BOD	OXYGEN/TEMP
MAY 3 Surface	0.028	0.007	0.772	0.0217	2.9	6.9mg/l45.5oF
MO/DAY 94						OXYGEN/TEMP
MAY 3 Bottom						7.0mg/l 44oF

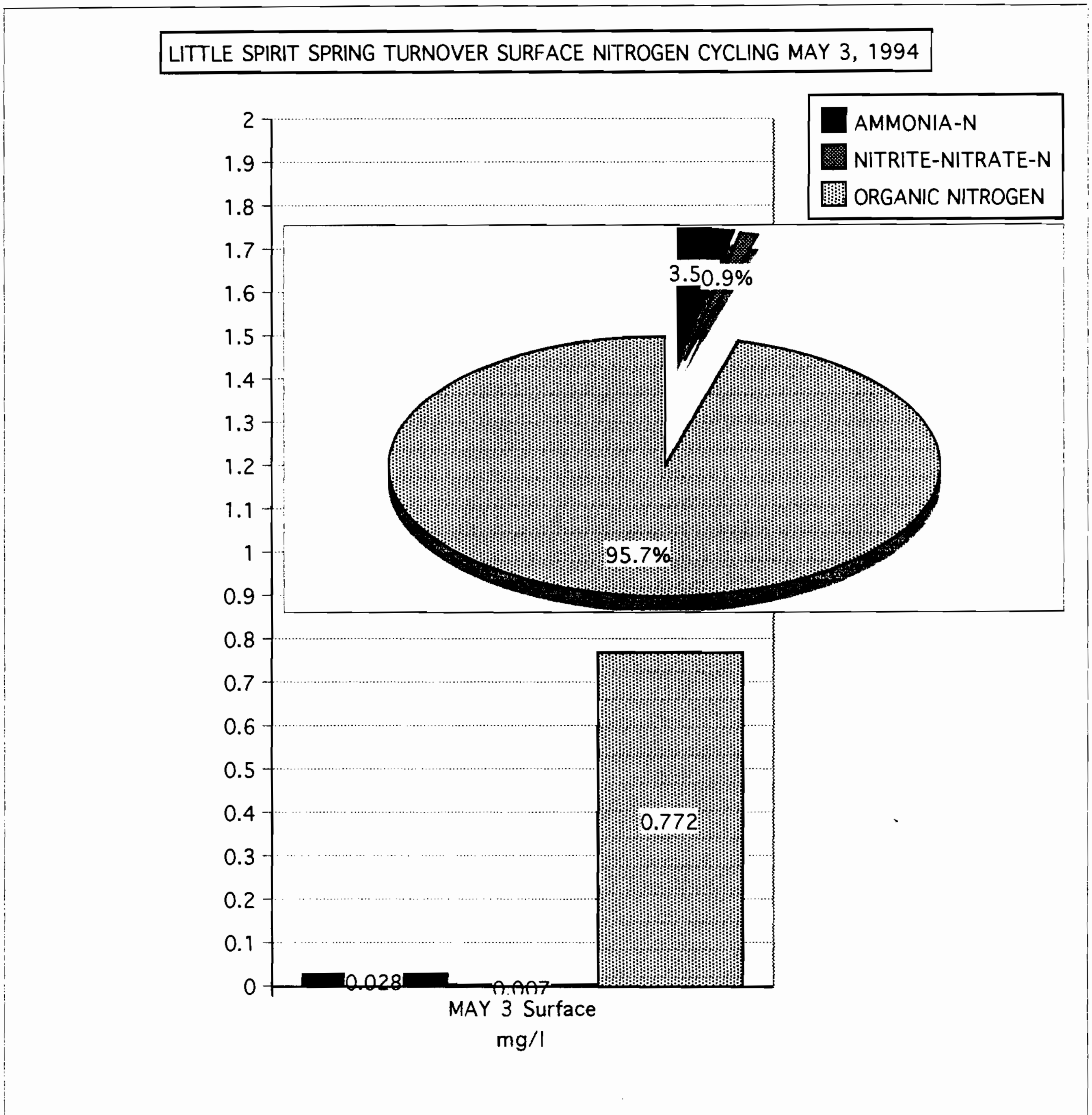
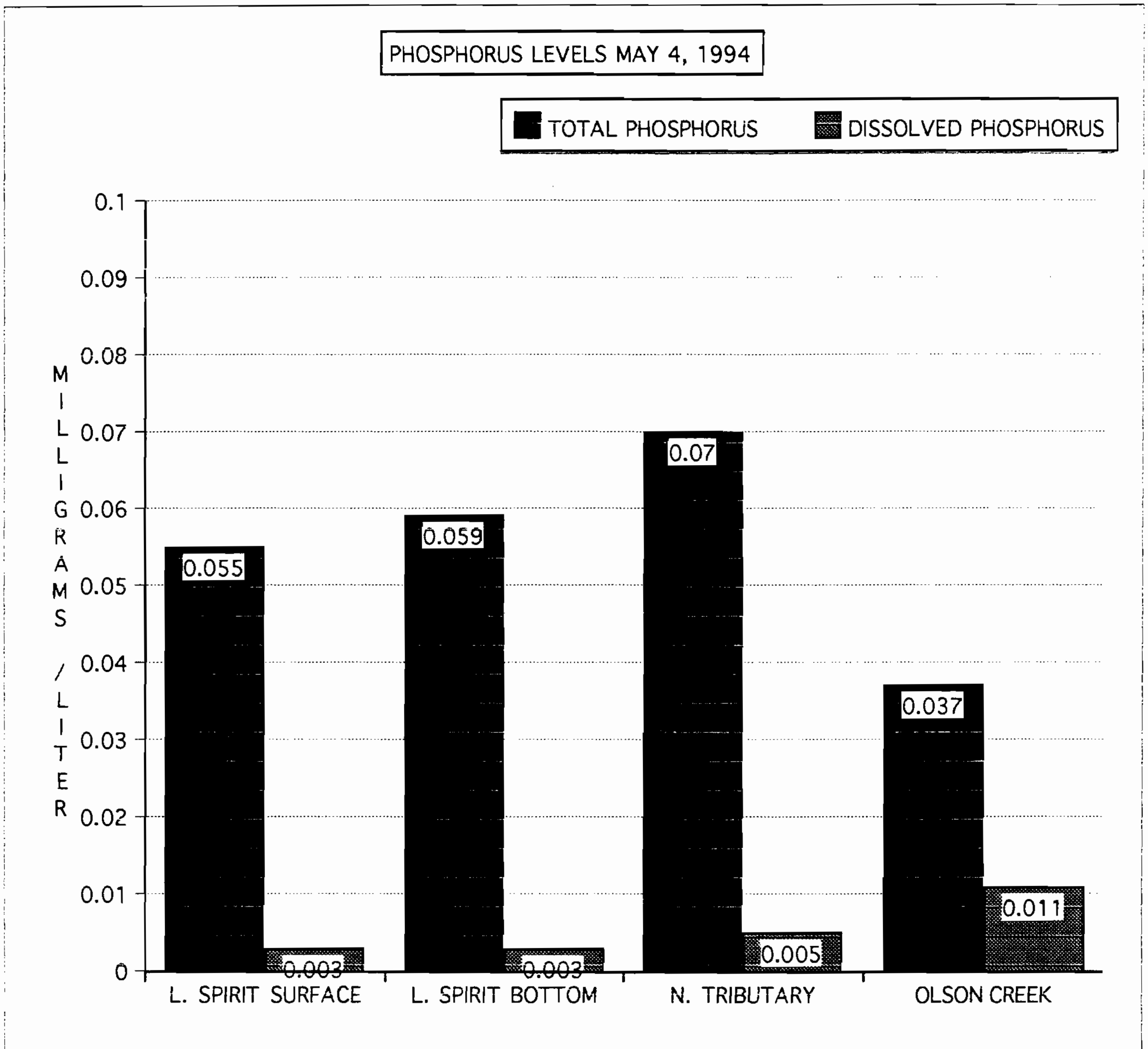


FIGURE 21. SPRING PHOSPHORUS LEVELS OF LITTLE SPIRIT & TRIBUTARIES ON MAY 3, 1994.

	TOTAL PHOSPH	DISSOLVED PHOSPHORUS
L. SPIRIT SURF/	0.055	0.003
L. SPIRIT BOTT	0.059	0.003
N. TRIBUTARY	0.07	0.005
OLSON CREEK	0.037	0.011



Big Spirit Lake water temperatures at spring turnover sampling were found to be from 39 to 41.5 throught the water column. Oxygen ranged from 9.8 to 10.3 through the entire column including bottom readings (Figure 22 thru 24). Oxygen saturation levels ranged from 78 to 80 % - much higher than the waters of Little Spirit.

FIGURE 22. BIG SPIRIT NE BAY AT TEMPERATURE - OXYGEN PROFILE AT SPRING TURNOVER ON MAY 3, 1994.

May 3, 1994 TEMP	oF OXYGEN	mg/lOXYGEN	%S. OTHER DATA:
BS NE BAY			
0'	41.5	10.1	80
2'	41.5	10.2	81
4'	41	10	78 -SECCHI: 6.0'
6'	41.5	10.2	80
8'	41.5	10.2	80
10'	41	10.3	80
12'	41	10.2	80
14'	41	10	78
16'	41.5	10	79
18'B	40	10	77

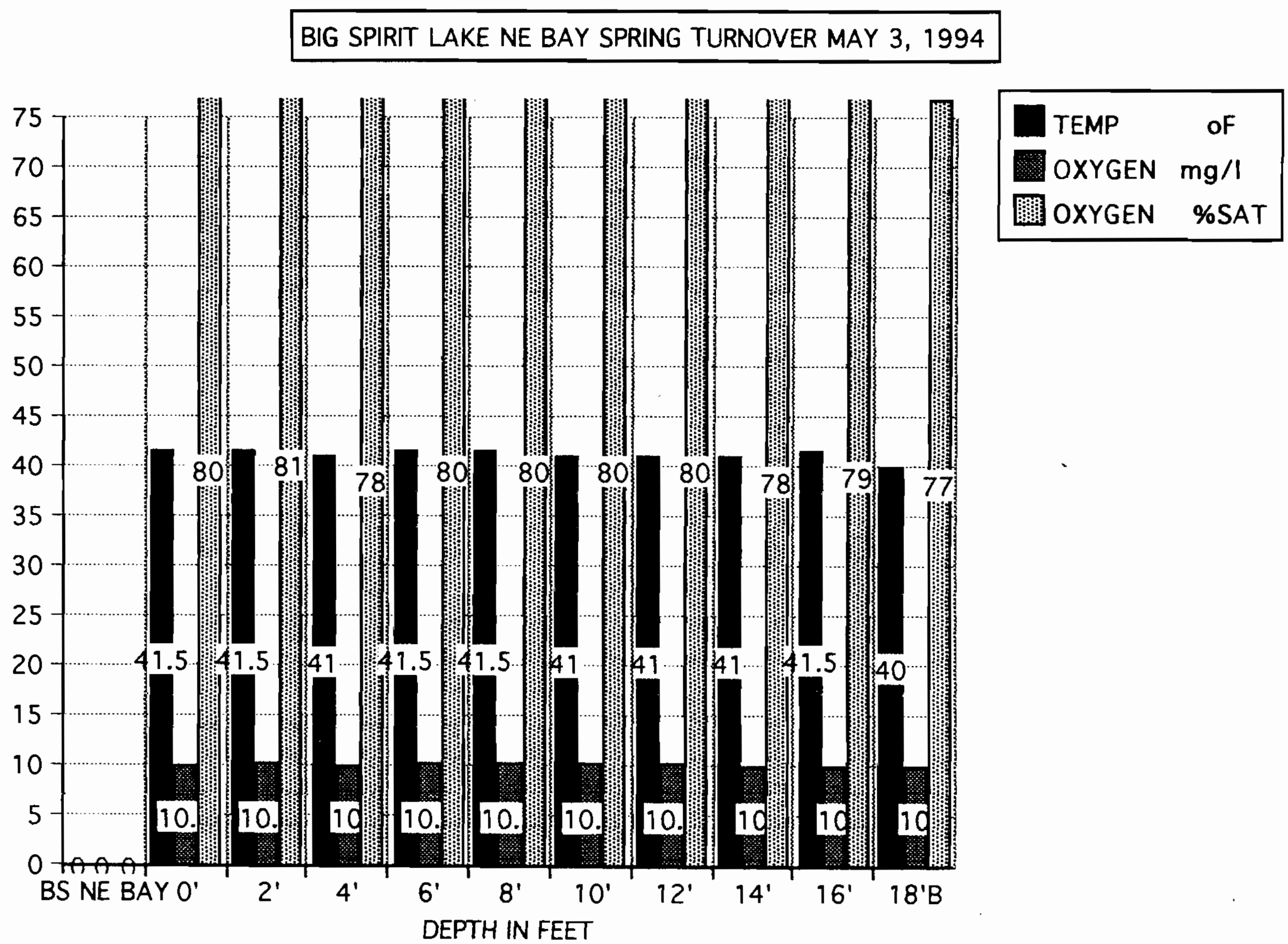


FIGURE 23. BIG SPIRIT SOUTH BAY OXYGEN -TEMPERATURE PROFILE AT SPRING TURNOVER ON MAY 3, 1994.

May 3, 1994	TEMP oC	OXYGEN mg/l	OXYGEN % SAT	OTHER DATA:
BS S.BAY				SECCHI DEPTH 6.0 FEET
0'	41	10	78	PLANKTON SAMPLED
2'	41	10.1	79	SHALLOWS: 43oF, 10.2 mg/l
4'	41	10.1	79	
6'	41	10	78	WEATHER:
8'	41	10	78	AIR TEMP: 50oF
10'	41	10	78	SUNNY
12'	39	9.8	75	CALM
14'	41	10	78	
16'	41	10	78	
18'	41	10	78	
20'	41	10	78	
21'B	39	0	0	

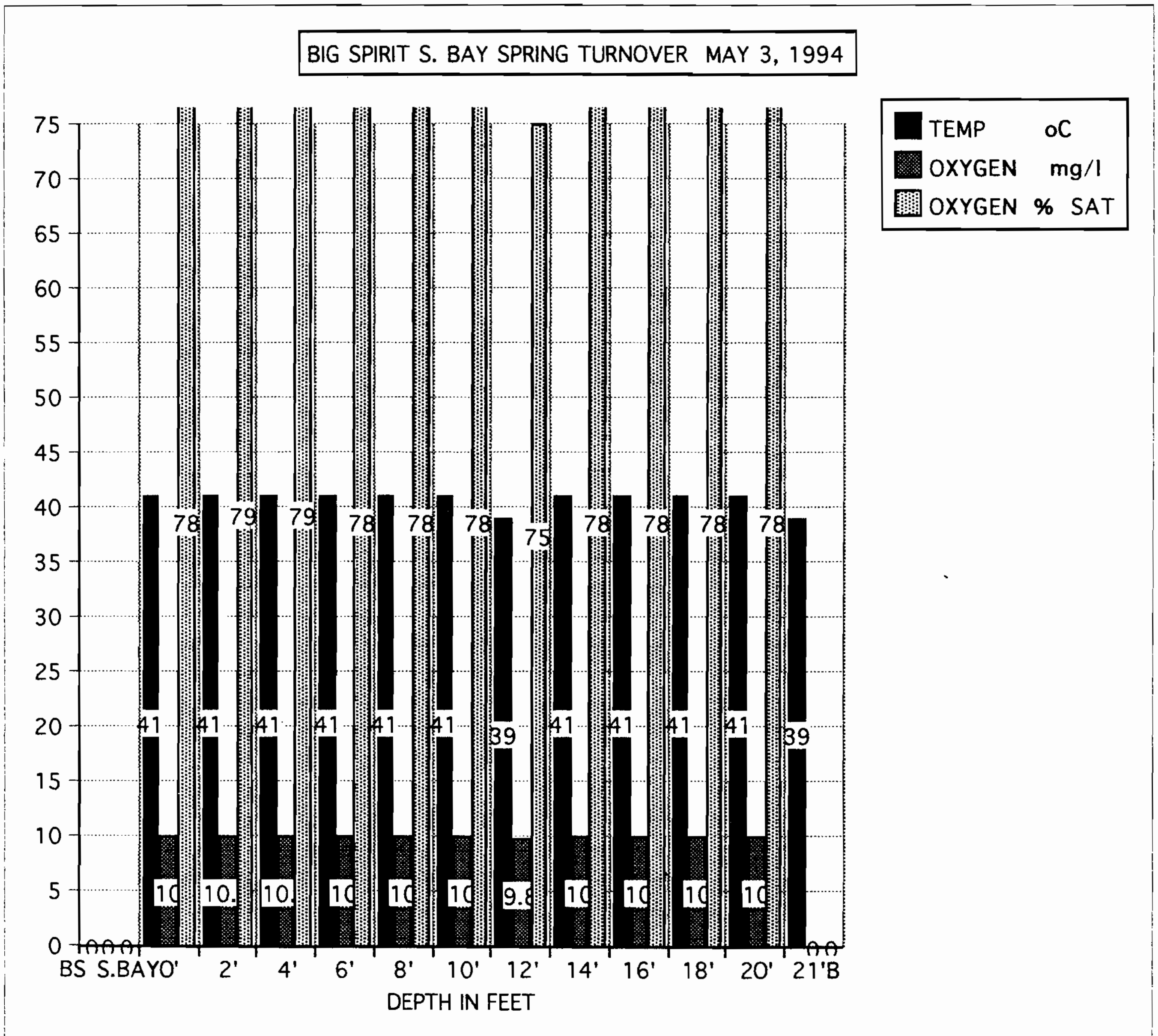
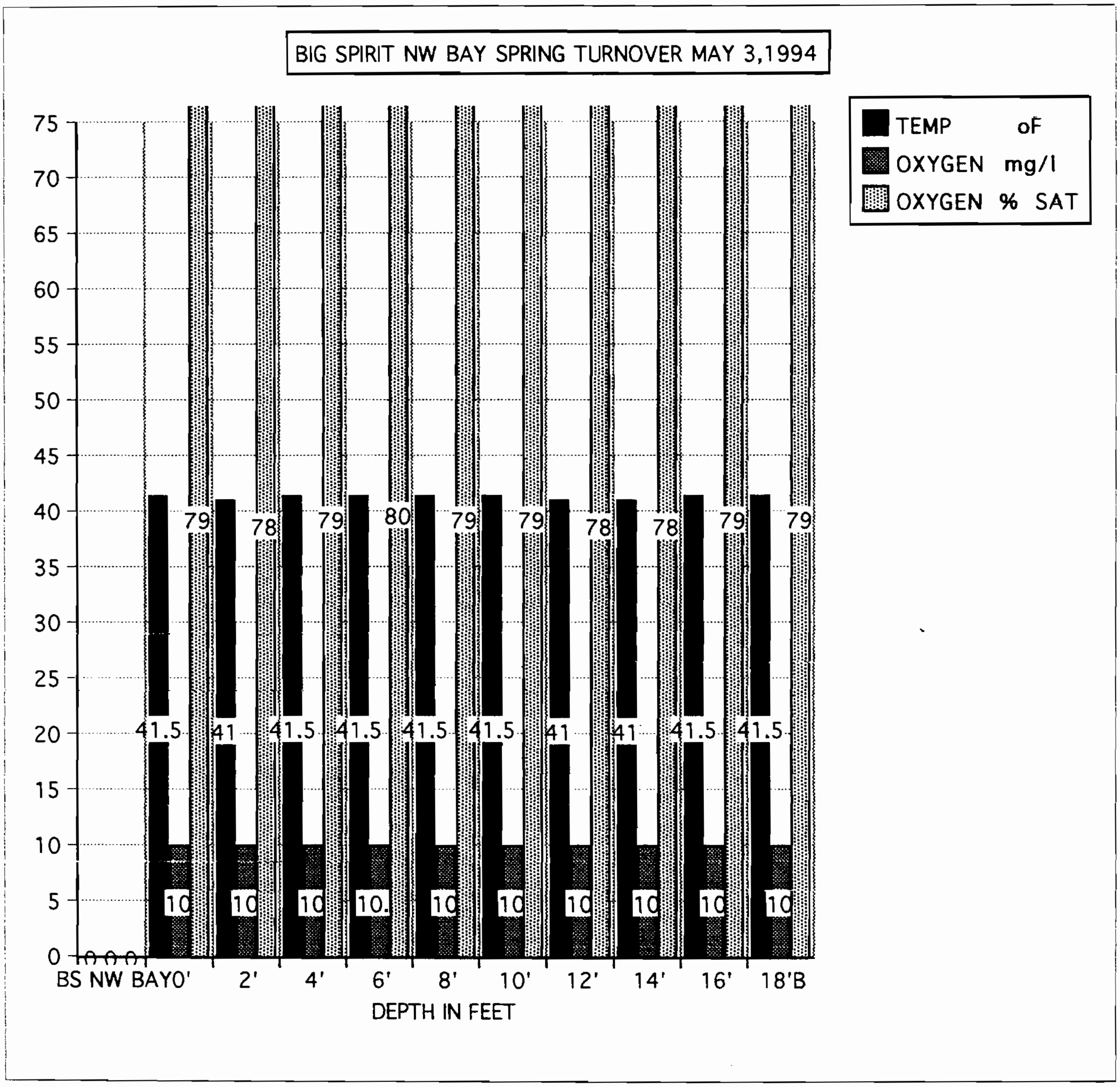


FIGURE 24. BIG SPIRIT NE BAY TEMPERATURE - OXYGEN PROFILE AT SPRING TURNOVER ON MAY 3, 1994

MAY 3,1994	TEMP oF	OXYGEN mg/l	OXYGEN % S.	OTHER DATA
BS NW BAY				
0'	41.5	10	79	-H20 SAMPLE
2'	41	10	78	TOP & BOTTOM
4'	41.5	10	79	-SECCHI 6.0'
6'	41.5	10.1	80	-PLANKTON SAMPLED
8'	41.5	10	79	-SHALLOWS 43.5oF, 10.2mg/l
10'	41.5	10	79	
12'	41	10	78	
14'	41	10	78	
16'	41.5	10	79	
18'B	41.5	10	79	



Nutrient levels were sampled in the northwest and south bays of Big Spirit near the surface and bottom. Total nitrogen levels at the surface of both locations were the same; but Dissolved nitrogen levels at the in the south bay surface were double those in the NW bay. See Figures 25 & 26 below.

Both total phosphorus and dissolved phosphorus were higher in the surface and bottom waters of the South Bay than the NW Bay during this spring mixing period. Dissolved phosphorus was the same at the surface and bottom in the NW bay. In the South Bay dissolved phosphorus was slightly higher on the bottom than the top. Total phosphorus levels were higher on the bottom than the top at both sampling sites but the South Bay sampling site the different concentration from top to bottom was much greater.

FIGURE 25. BIG SPIRIT SOUTH BAY NITROGEN AND PHOSPHORUS AT SPRING TURNOVER ON MAY 3, 1994.

BIG SPIRIT SOUTH BAY

MO/DAY 94	TOTAL NITROGE	TOTAL PHOSPH	DISSOLVED NITI	DISSOLVED PHOSPHORUS SURFACE
MAY 3 S	0.6	0.053	0.083	0.009

MO/DAY 94	TOTAL NITROGE	TOTAL PHOSPH	DISSOLVED PHOSPHORUS BOTTOM
MAY 3 B		0.071	0.011

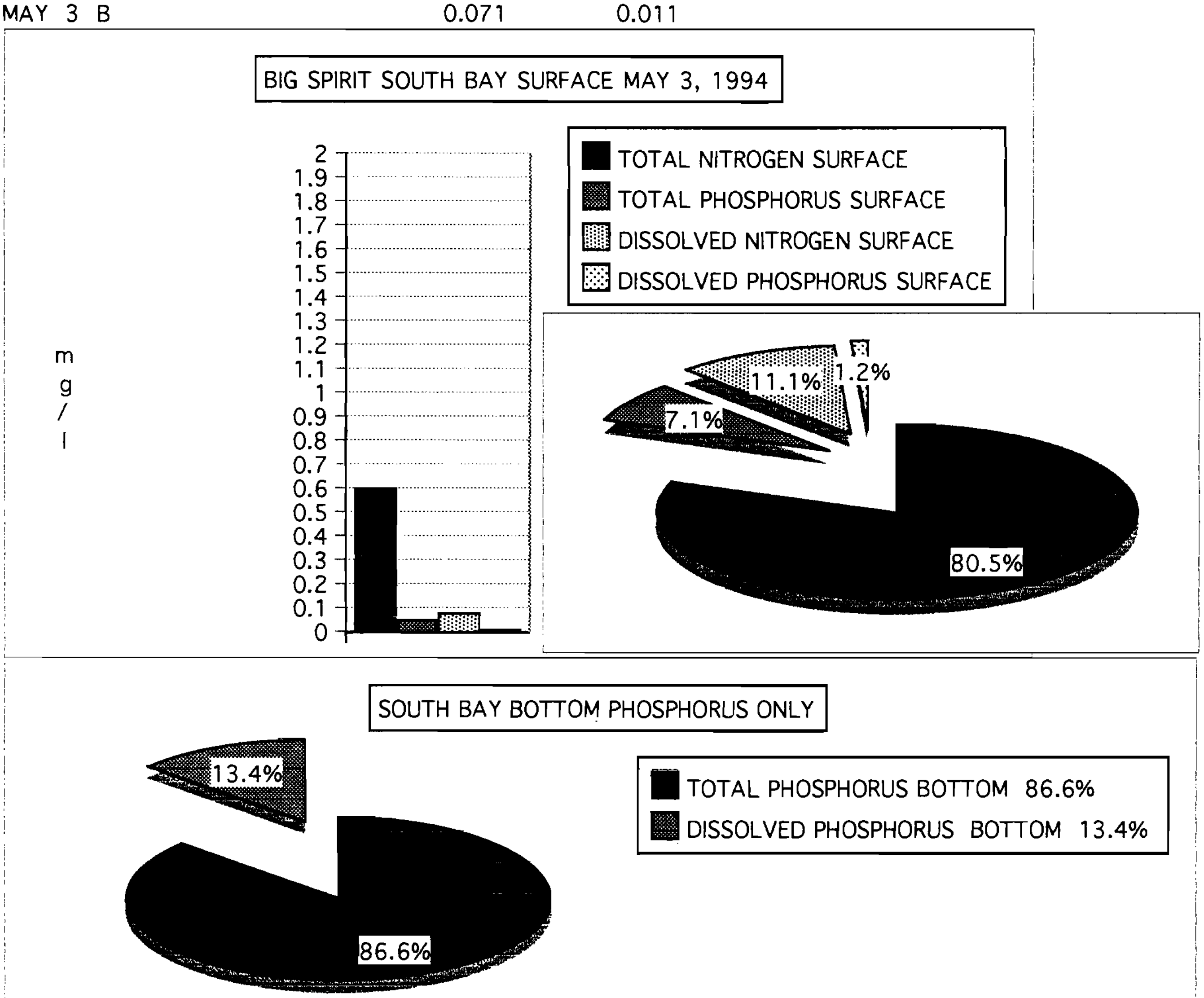
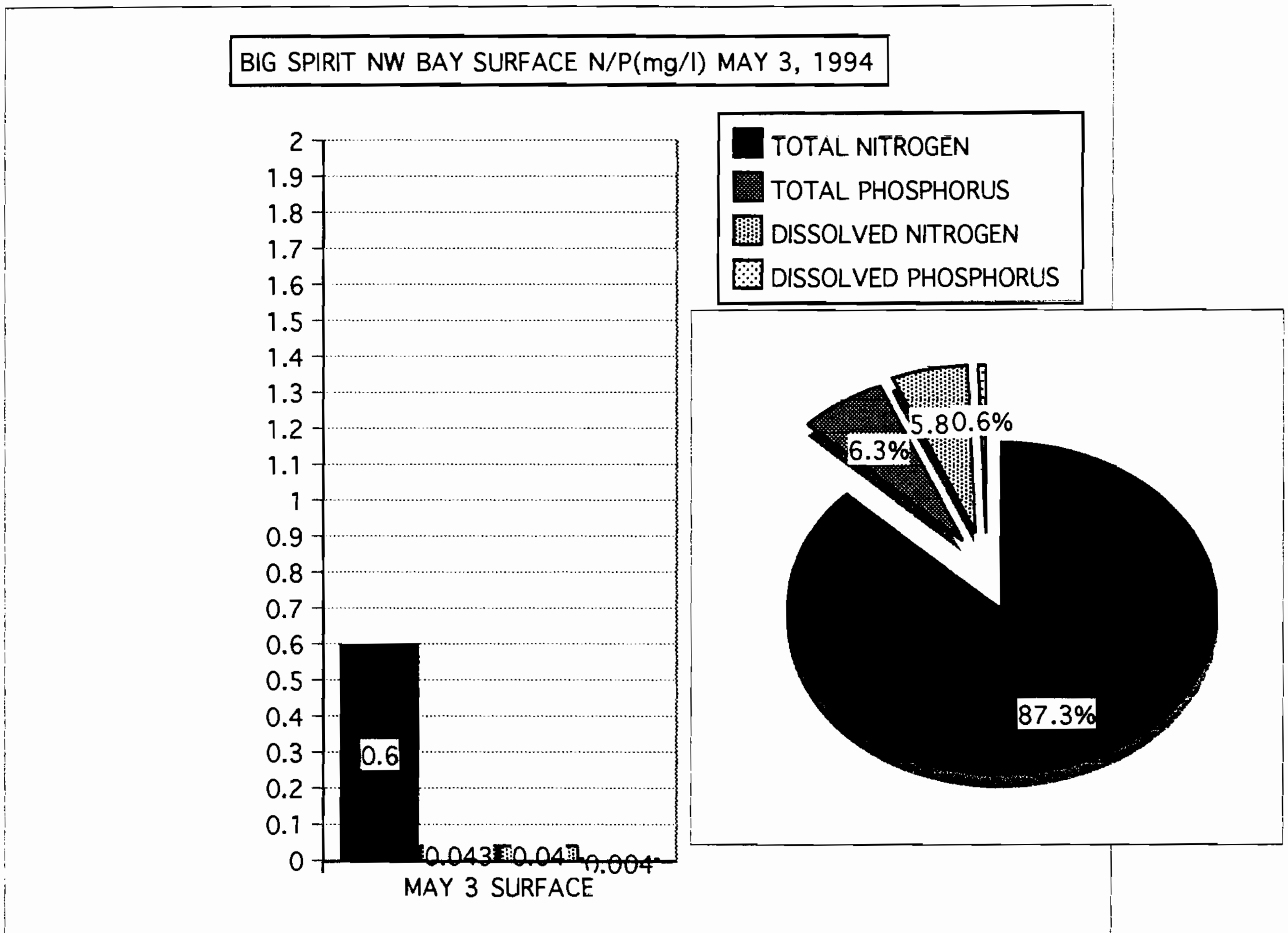


FIGURE 26. BIG SPIRIT NW BAY NITROGEN - PHOSPHORUS LEVELS AT SPRING TURNOVER ON MAY 3, 1994.

BIG SPIRIT NW BAY

MO/DAY	94	TOTAL NITROGE	TOTAL PHOSPH	DISSOLVED NITI	DISSOLVED PHOSPHORUS
MAY 3 SURFAC		0.6	0.043	0.04	0.004

MO/DAY	94	TOTAL NITROGE	TOTAL PHOSPH	DISSOLVED PHOSPHORUS
MAY 3 BOTTOM			0.051	0.004



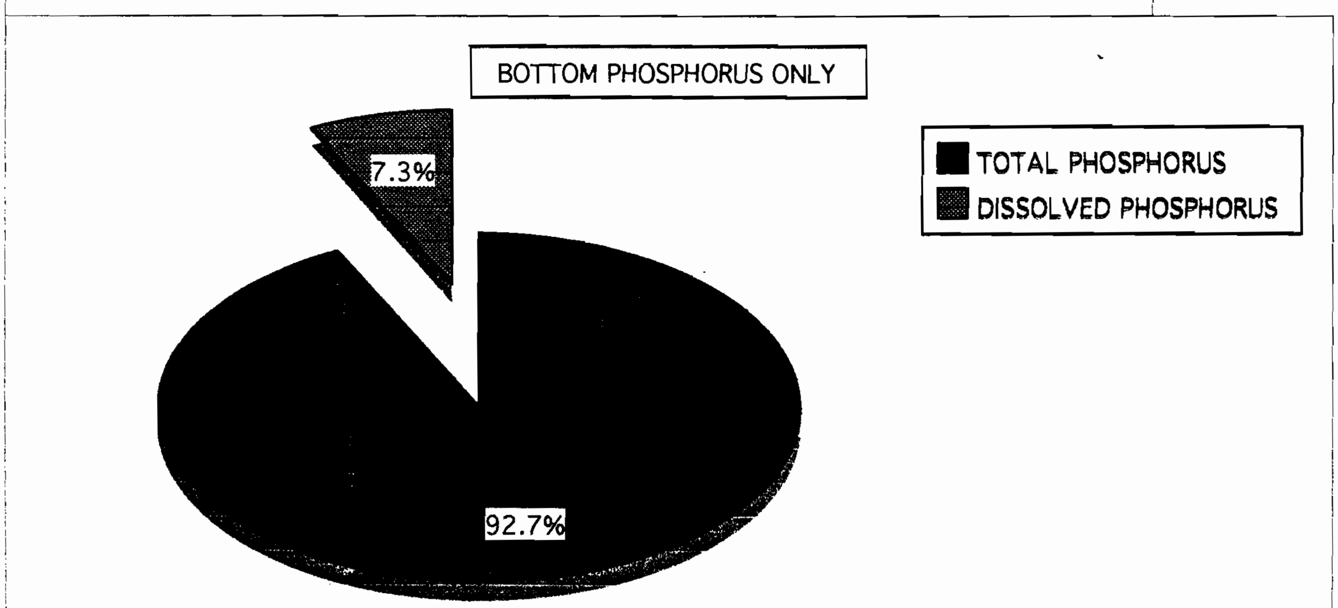
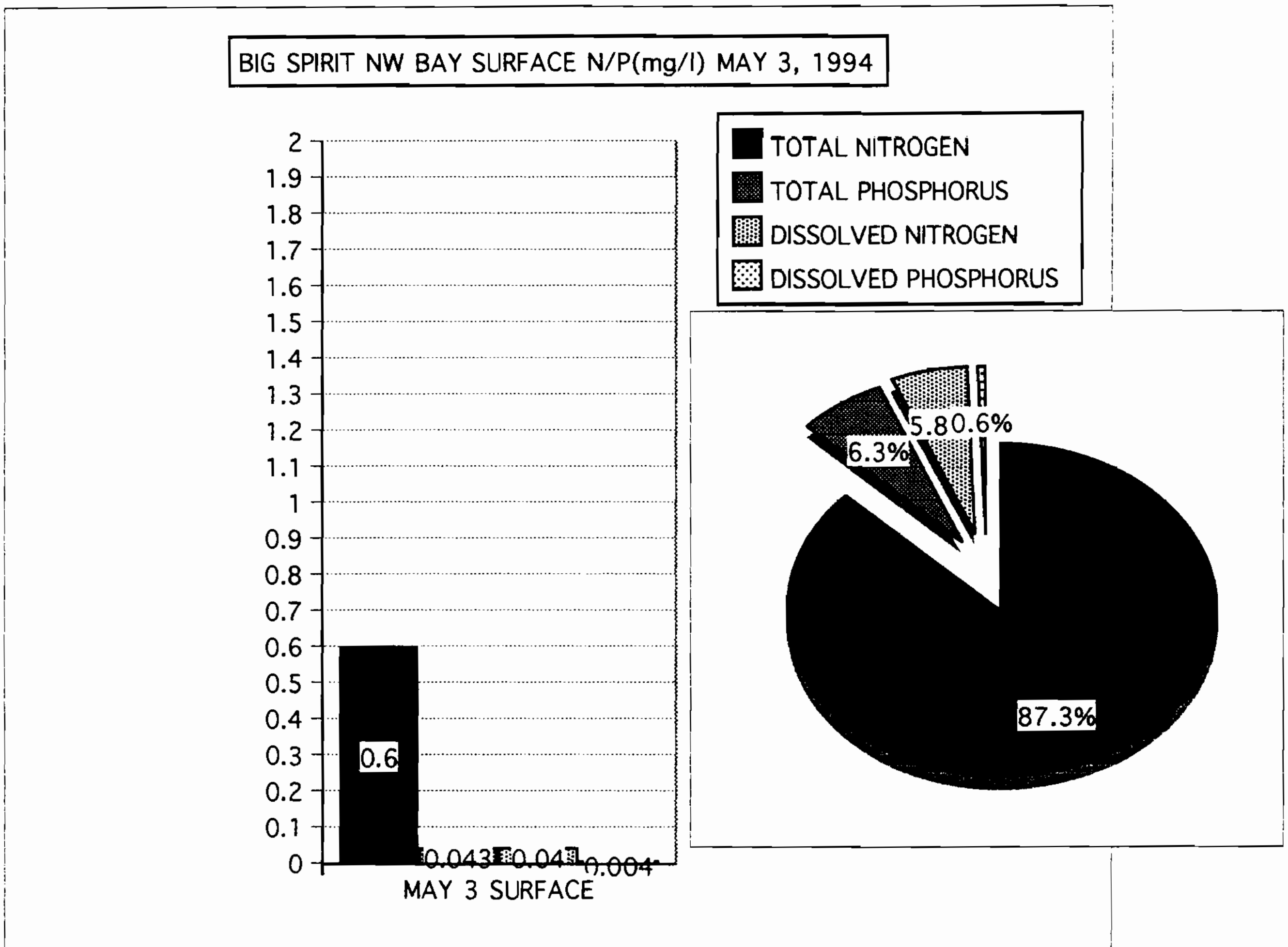


FIGURE 27. BIG SPIRIT NW BAY NITROGEN - PHOSPHORUS LEVELS AT SPRING TURNOVER ON MAY 3, 1994.

BIG SPIRIT NW BAY

MO/DAY 94	TOTAL NITROGE	TOTAL PHOSPH	DISSOLVED NITI	DISSOLVED PHOSPHORUS
MAY 3 SURFAC	0.6	0.043	0.04	0.004
MO/DAY 94	TOTAL NITROGE	TOTAL PHOSPH	DISSOLVED PHOSPHORUS	
MAY 3 BOTTOM		0.051	0.004	



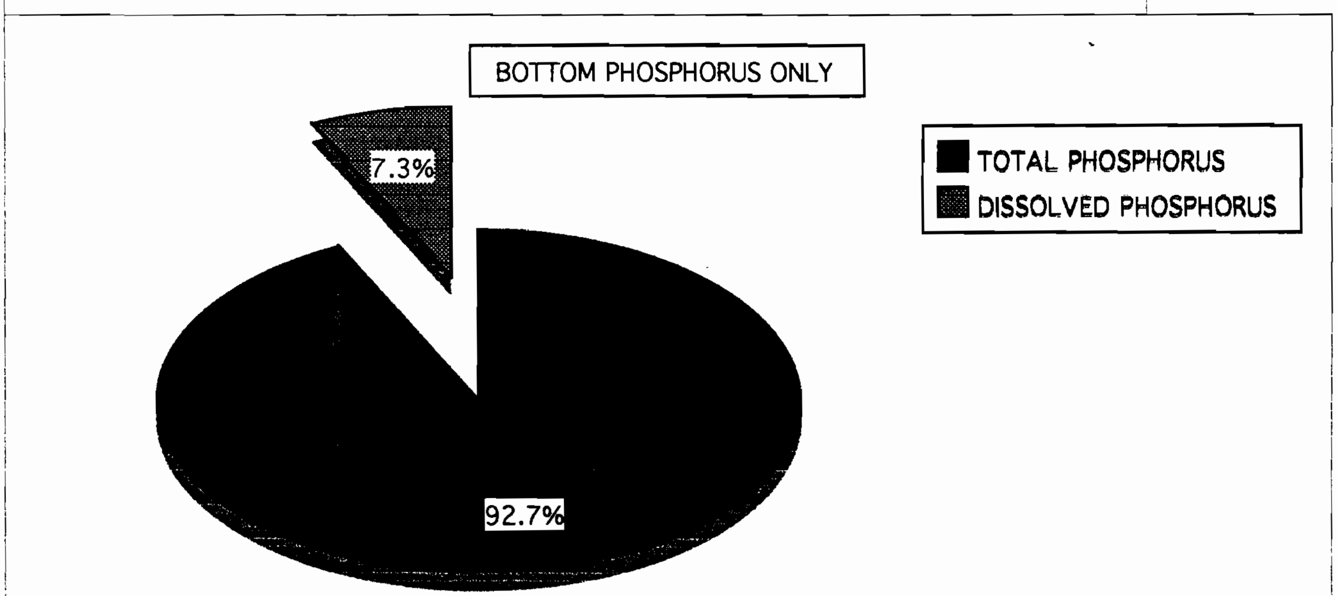
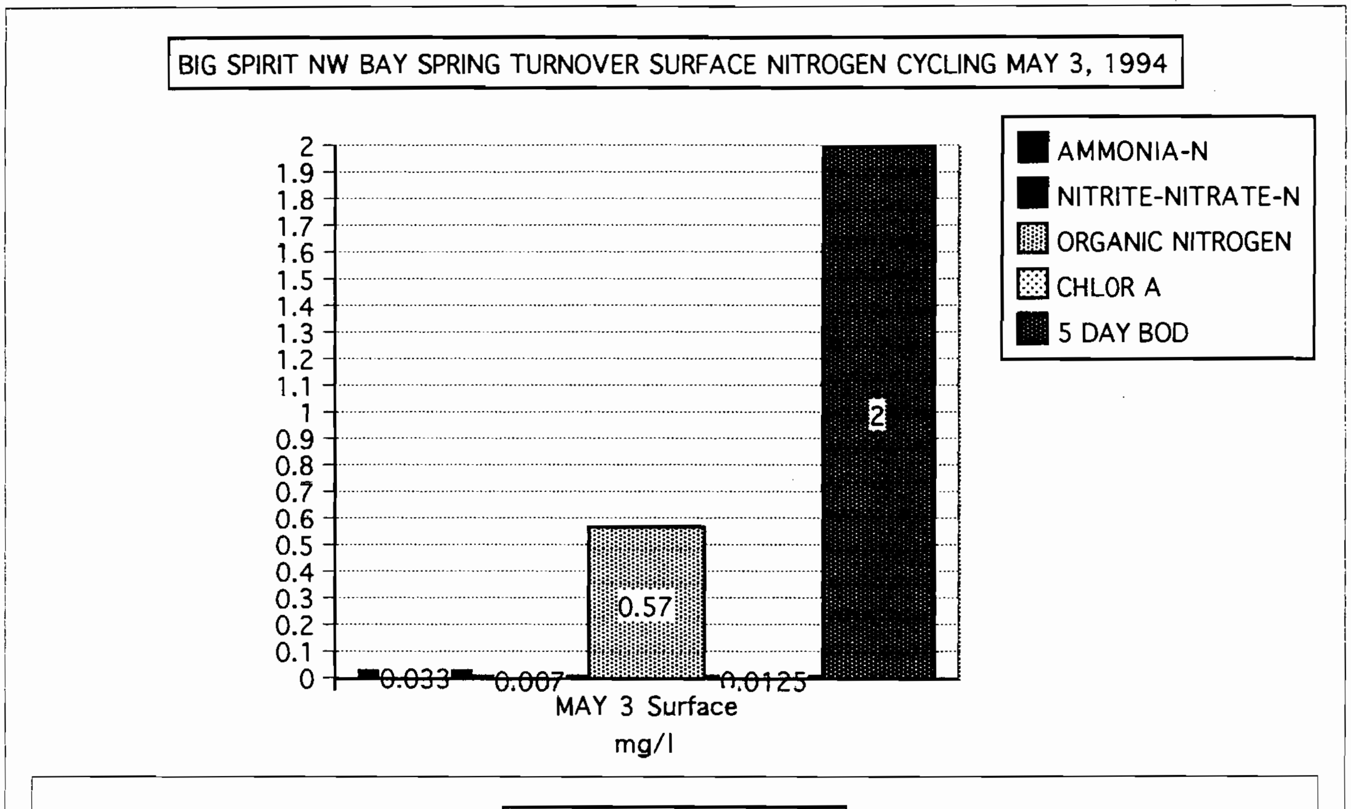
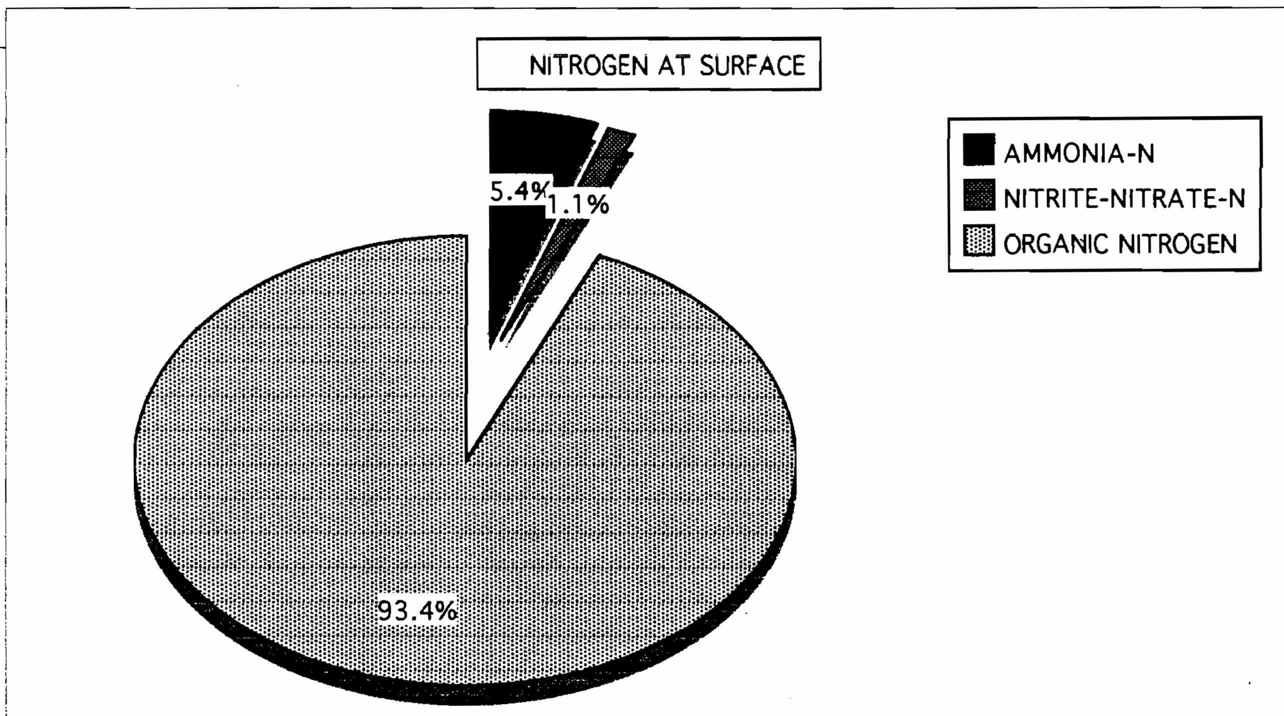


FIGURE 28. BIG SPIRIT NW BAY SURFACE NITROGEN CYCLING AT SPRING TURNOVER ON MAY 3, 1994.

BIG SPIRIT NW BAY SPRING TURNOVER

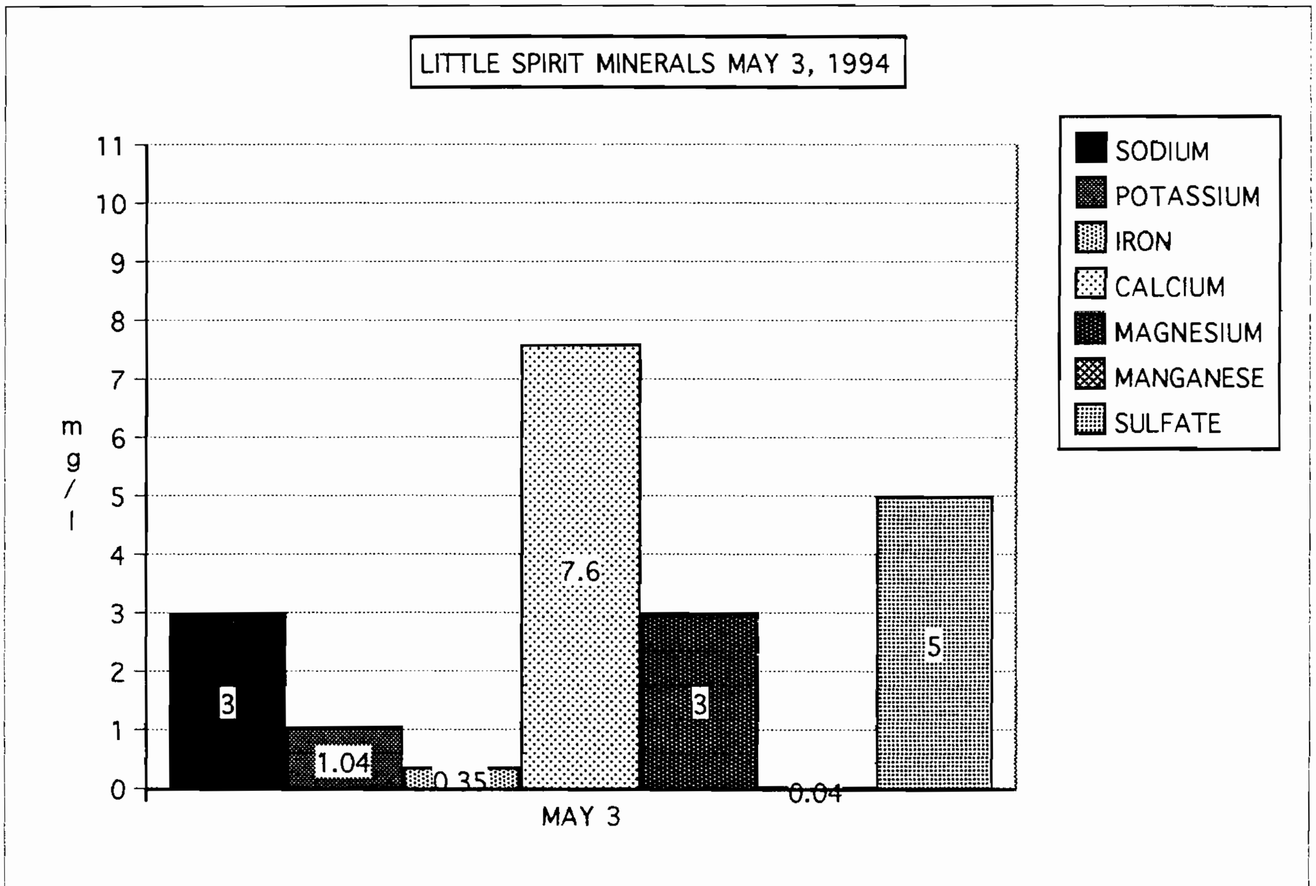
MO/DAY 94	AMMONIA-N	NITRITE-NITRA	ORGANIC NITRO	CHLOR A	5 DAY BOD	OXYGEN/TEMP
MAY 3 Surface	0.033	0.007	0.57	0.0125	2	10.0mg/l 41oF
MO/DAY 94						OXYGEN/TEMP
MAY 3 Bottom						10.0mg/l 41.5

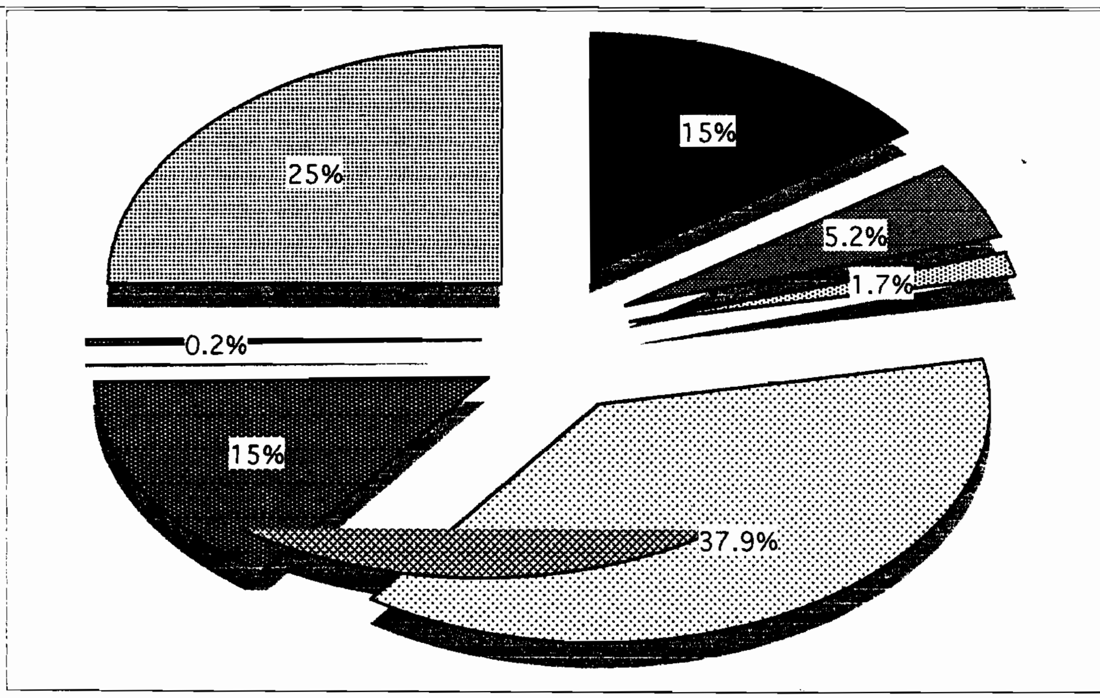




Minerals and trace element levels were comparible for both the NW Bay and South Bay surface waters of Big Spirit Lake but were quite different for some elements when compared to Little Spiri (Figures 29,30 & 31).

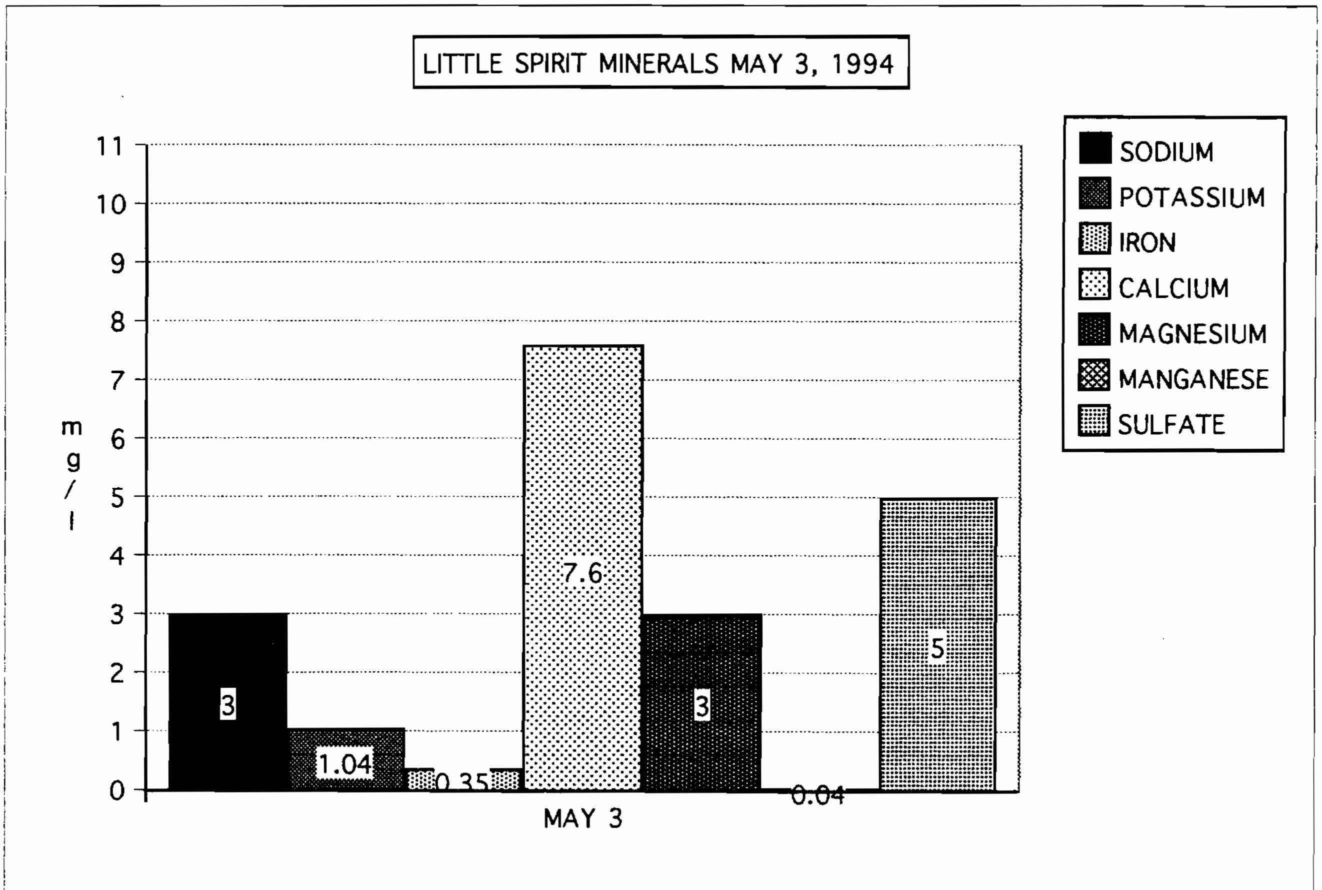
FIGURE 29. LITTLE SPIRIT MINERALS AND TRACE ELEMENTS ON MAY 3, 1994.

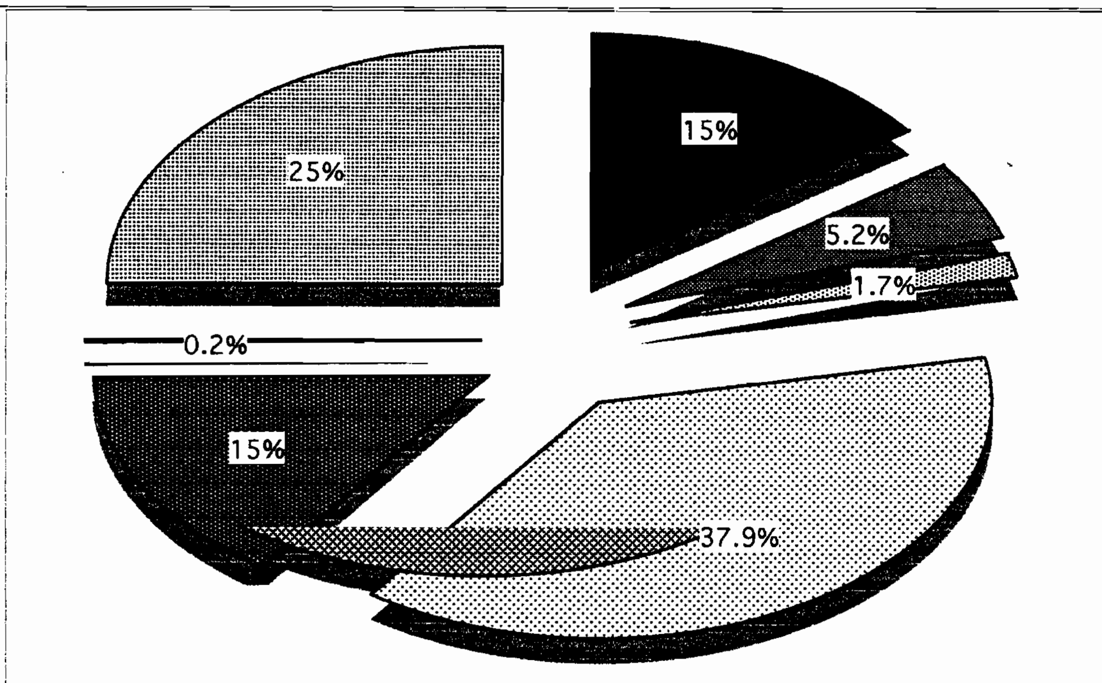




Minerals and trace element levels were comparible for both the NW Bay and South Bay surface waters of Big Spirit Lake but were quite different for some elements when compared to Little Spiri (Figures 30,31 & 32).

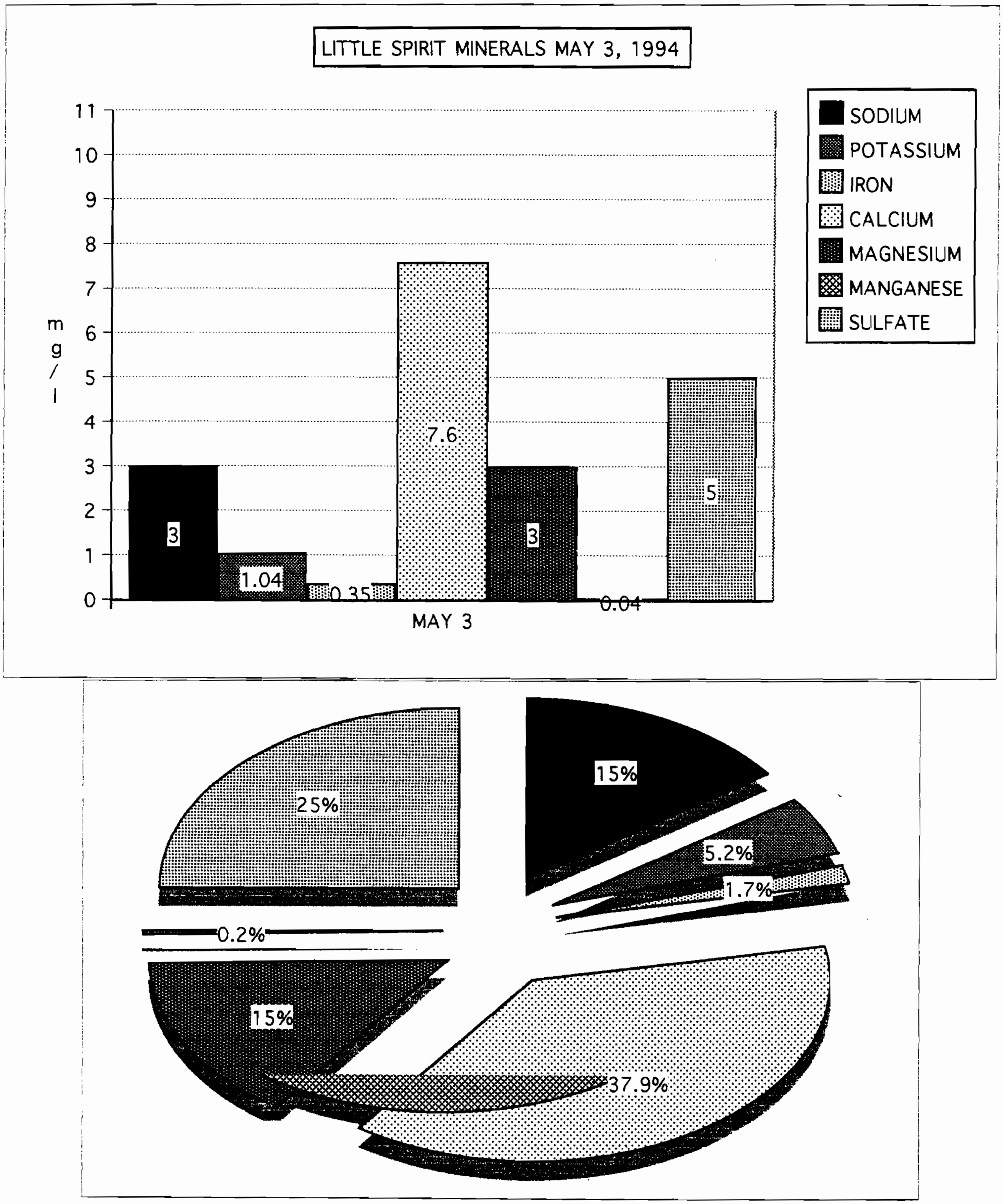
FIGURE 30. LITTLE SPIRIT MINERALS AND TRACE ELEMENTS ON MAY 3, 1994.





Minerals and trace element levels were comparible for both the NW Bay and South Bay surface waters of Big Spirit Lake but were quite different for some elements when compared to Little Spiri (Figures 30,31 & 32).

FIGURE 31. LITTLE SPIRIT MINERALS AND TRACE ELEMENTS ON MAY 3, 1994.



Iron, manganese, and sulfate were all slightly higher in the South Bay than in the NW Bay. Potassium was 37% higher in Little Spirit than in Big Spirit. Iron was nearly double the concentration in Little Spirit than in Big Spirit. Manganese was the opposite with concentrations in Little Spirit about one half of those found in Big Spirit.

Potassium levels found in soils and water are very low. Their presence in Little Spirit Lake may indicate pollution caused by human activity. Potassium is a key component in potash fertilizer and is abundant in animal waste. The mink farm located on the north tributary streams could be a possible source of this element in the spring runoff sample.

Total iron concentrations are usually in the order of 0.05 to 0.2 mg/l in natural surface waters. Both South Spirit and Little Spirit exceeded the 0.2 mg/l concentration during spring ice-out conditions. The iron found in these waters were released under low to zero oxygen under the ice conditions at the bottom of Big Spirit and in the large marsh area that the upper tributary from Stone Lake flows through. The higher iron concentration corresponded to the high organic loads in both locations.

Iron in the form of ferric hydroxide or as a colloidal iron-organic complex originating from the above areas can be suspended in the water or attach to organic particles suspended in the water. These particles could be seen in the water when sampling and reduced water clarity in Little Spirit to one foot and in Big Spirit to less than 6 feet. Manganese and iron have similar electron bonding characteristics.

Sulfate can also be liberated from bottom and decaying matter under anaerobic (without oxygen) conditions just as iron does. Sulfate can be reduced to hydrogen sulfide under low or zero oxygen conditions. Hydrogen sulfide smells like rotten eggs and can be harmful to fish.

JUNE 30, 1994 June's warm weather increased water temperatures and brought excellent water quality conditions to both North and Lower Spirit. Oxygen/ temperature profiling and surface phosphorus sampling of Little Spirit , NW and south bays of Big Spirit, and the two rivers entering were completed on this date. Phytoplankton samples were also taken in all lake locations except the NE Bay of Big Spirit.

Temperature stratification was occurring on North Spirit as temperatures at the surface in all bays were at 74 to 75 degrees at midday with partial cloud cover and light south breeze. Temperatures dropped to 71 to 72 degrees at the 12 to 14 foot water depth. Water to this depth was well oxygenated in the all the bays.

Supersaturated levels were found within the top 4 feet of the surface in the south bay and down to 12 feet in the NW bay. Phytoplankton blooms were evident in all bays to create these near saturation to supersaturated levels to the 14 foot depth. From 12 -14 feet to the bottom total oxygen depletion was already occurring in the NW and south bay of Big Spirit. The NE bay complete oxygen depletion had not yet occurred. See Figures 32, 33, and 34 .

FIGURE 32. BIG SPIRIT NE BAY TEMPERATURE - OXYGEN PROFILE ON JUNE 30, 1994

JUNE 30. 1994 TEMP	oF OXYGEN	mg/lOXYGEN	%SA OTHER	DATA:
BS NE BAY				
0'	74	7.7	90	-PLANKTON SAME AS NW BAY
2'	74	7.8	90	-SECCHI 5.0'
4'	72	7.7	89	
6'	72	7.8	90	
8'	72	7.7	89	
10'	72	7.8	90	
12'	71	6.2	70	
14'	71	4.2	47	
16'	68	0.8	9	
18'B	68	0.3	3	

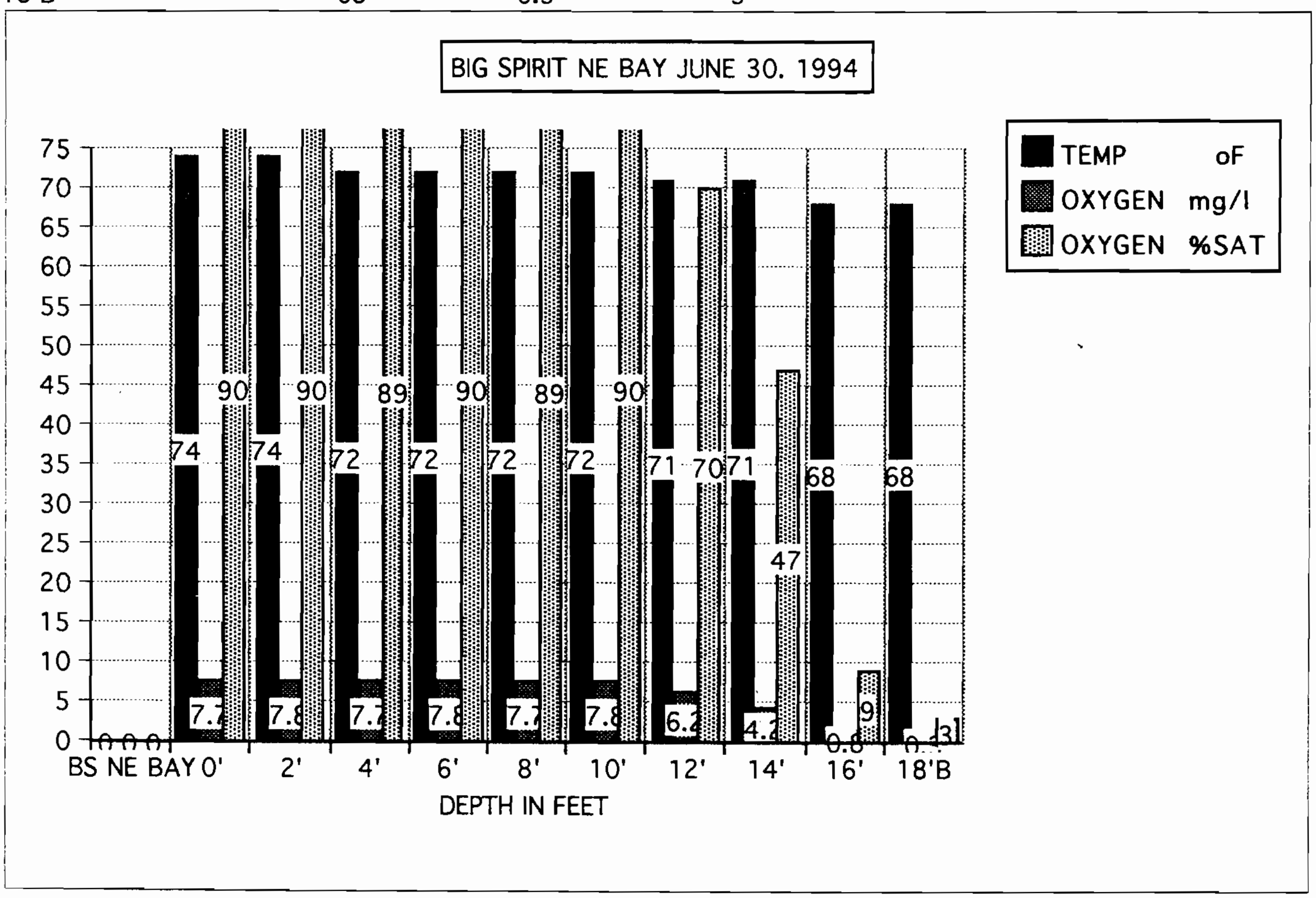


FIGURE 33. BIG SPIRIT SOUTH BAY OXYGEN - TEMPERATURE PROFILES ON JUNE 30, 1994.

June 30, 1994 BS S. BAY	TEMP oF	OXYGEN mg/l	OXYGEN % S.	OTHER DATA:
				-SECCHI DISC 6.0'
0'	75	8.7	104	-PLANKTON SAMPLED
2'	74	8.8	104	
4'	74	8.8	104	WEATHER:
6'	73	8.2	95	AIR TEMP 73oF
8'	72	8.2	94	WIND S 5-10
10'	72	8.2	94	70% CLOUD COVER
12'	72	7.2	83	
14'	72	0.8	9	
16'	70	0.4	4	
18'	69	0.2	2	
20'	69	0	0	
22'B	69	0	0	

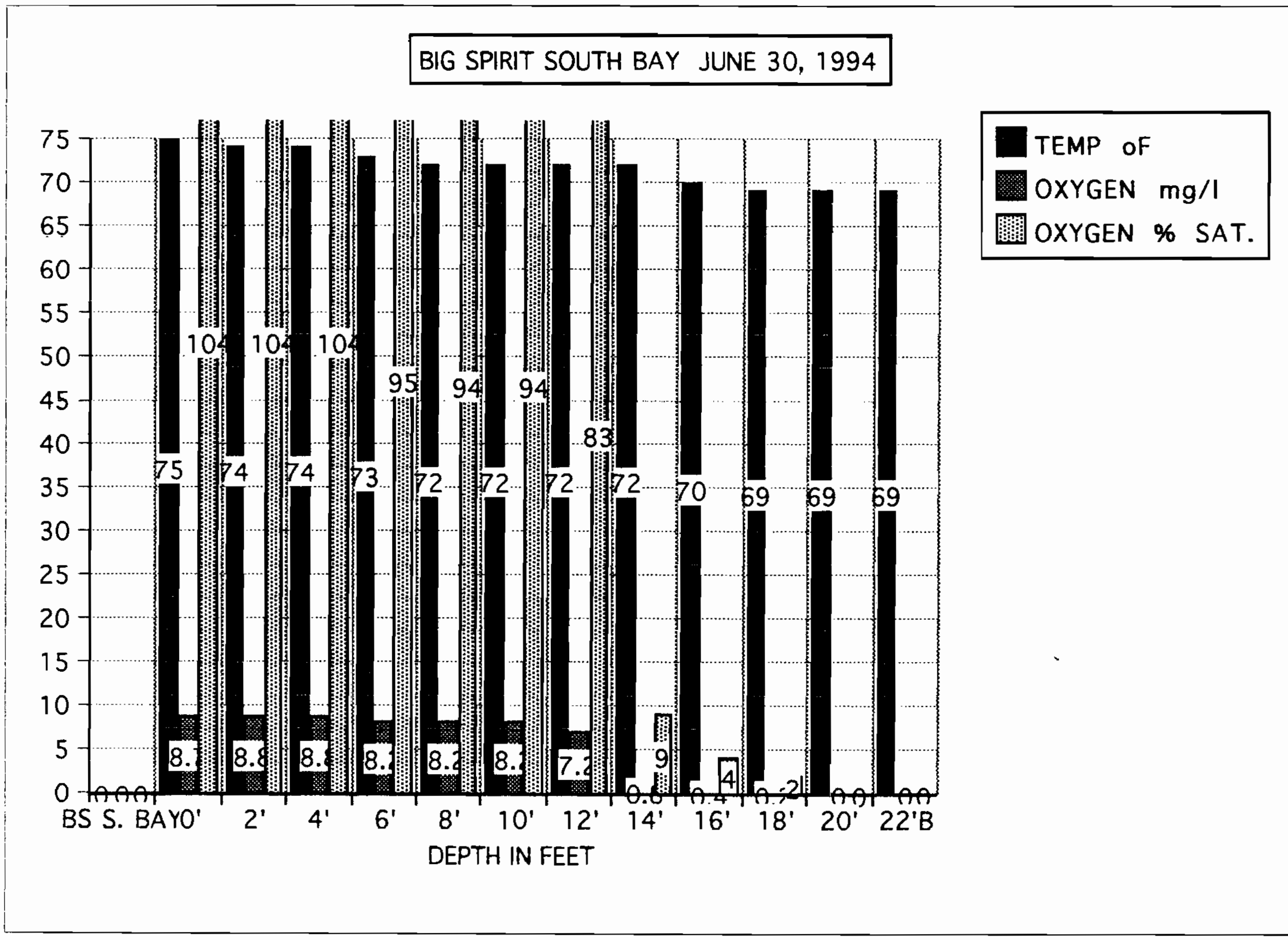
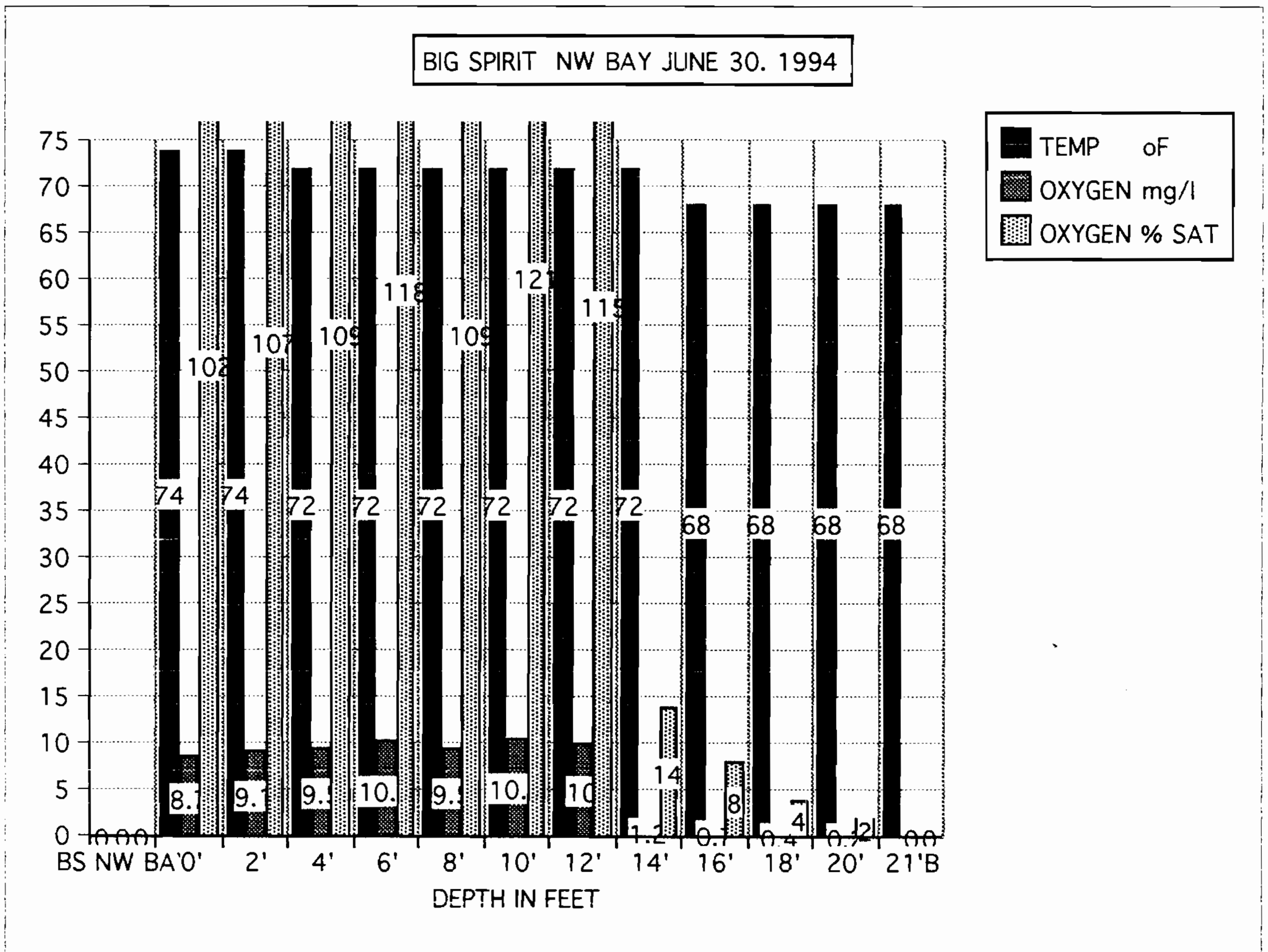


FIGURE 34. BIG SPIRIT NW BAY TEMPERATURE - OXYGEN PROFILE ON JUNE 30, 1994.

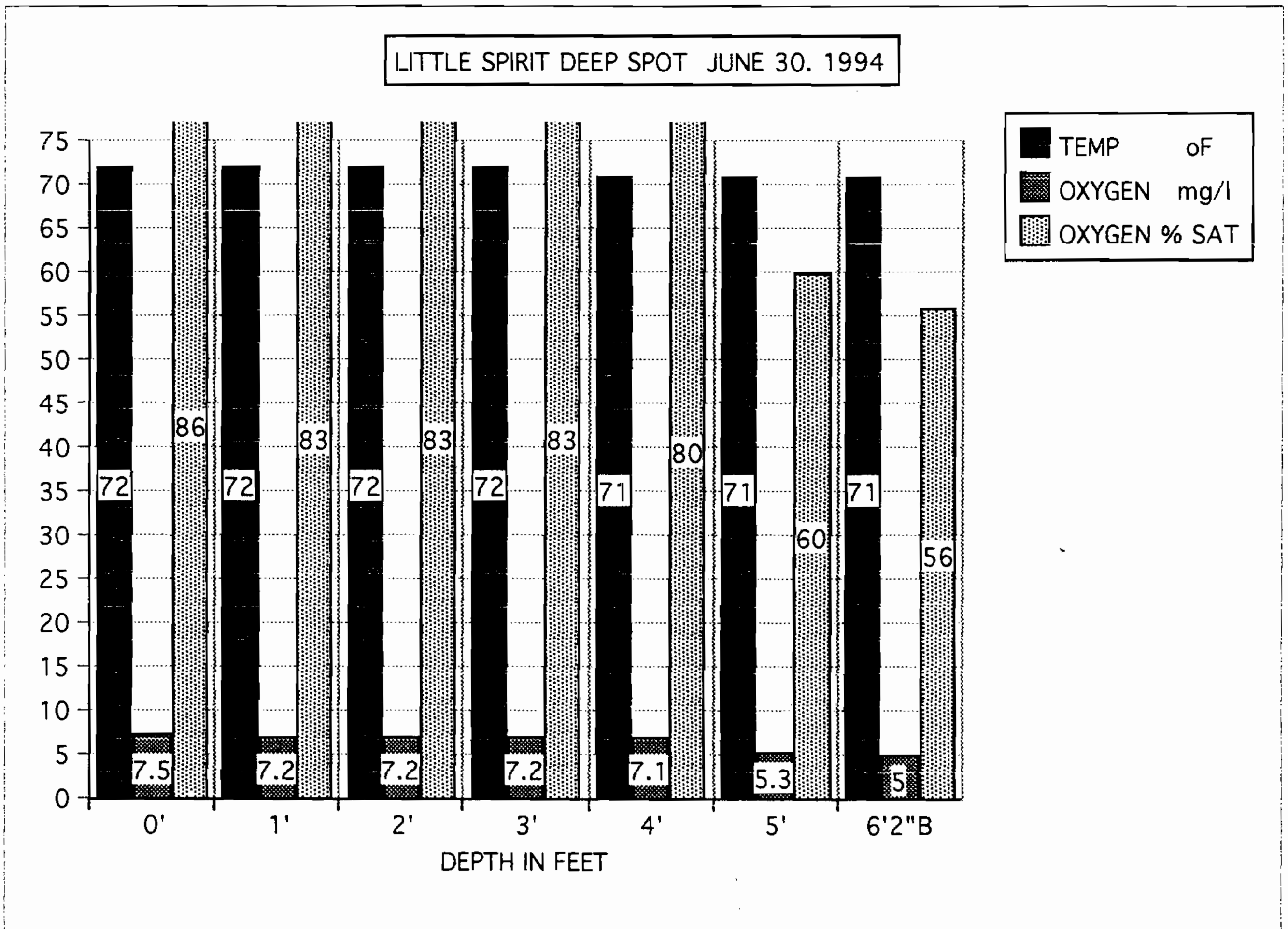
JUNE 30. 1994	TEMP oF	OXYGEN mg/l	OXYGEN % SAT	OTHER DATA:
BS NW BAY				-PLANKTON SAMPLED
0'	74	8.7	102	-PHYTO SMLER THAN S. BAY
2'	74	9.1	107	-CRAYFISH OBSERVED
4'	72	9.5	109	-SECCHI 7.0'
6'	72	10.3	118	
8'	72	9.5	109	
10'	72	10.5	121	
12'	72	10	115	
14'	72	1.2	14	
16'	68	0.7	8	
18'	68	0.4	4	
20'	68	0.2	2	
21'B	68	0	0	



In Little Spirit Lake the temperature was 72 oF from the surface to 3 feet and 71 from 3 feet to the 6 foot bottom. Oxygen saturation was a near the 80% level at the top 4 feet but dropped to near 60% in the bottom 2 feet as the bottom sediment appeared to exibit an oxygen demand. All oxygen readings were above 5 mg/l- even in the near the bottom - adequate to support a variety of aquatic life.

FIGURE 35. LITTLE SPIRIT OXYGEN - TEMPERATURE PROFILE ON JUNE 30, 1994.

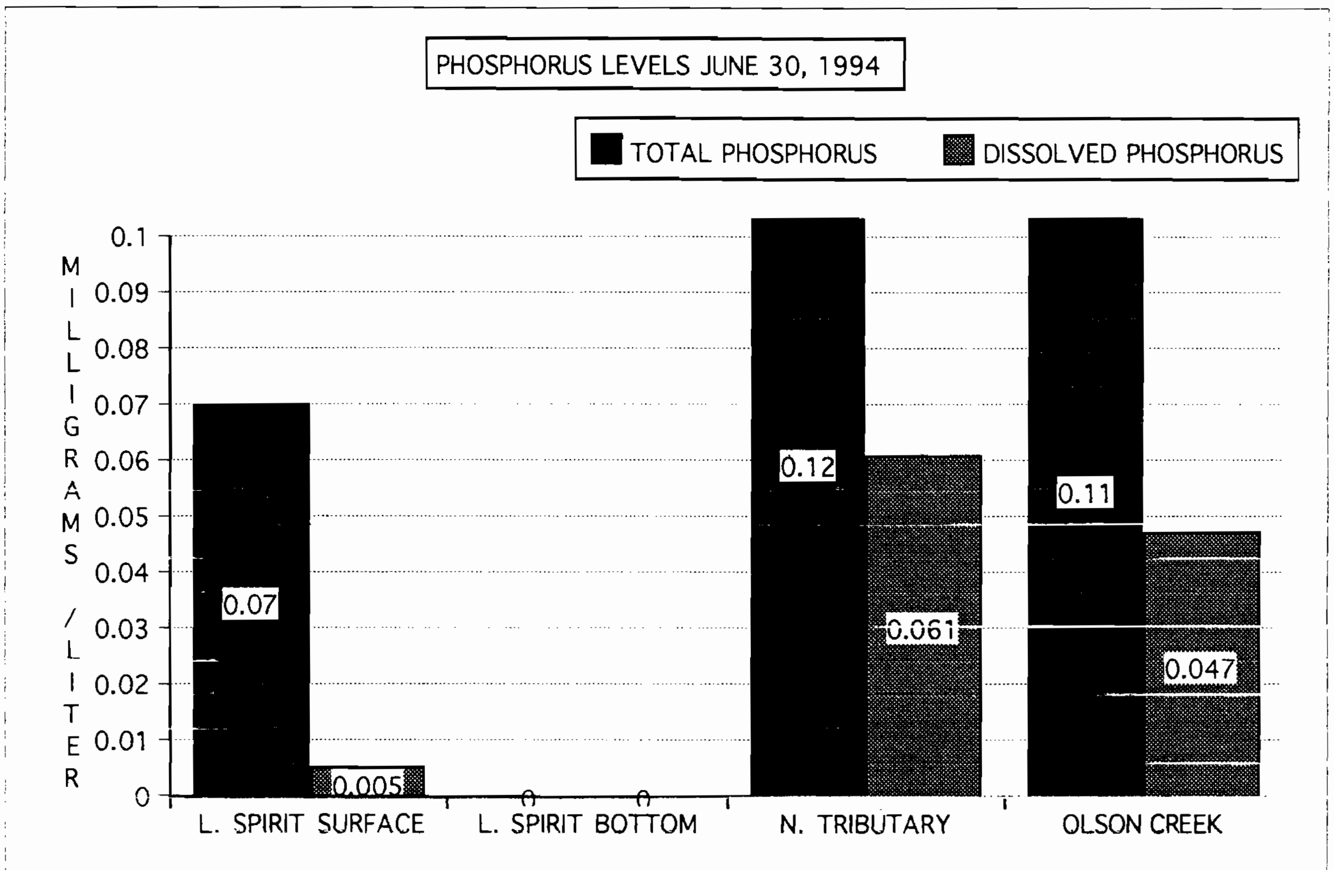
JUN 30. 1994	TEMP oF	OXYGEN mg/l	OXYGEN % SAT	OTHER DATA:
0'	72	7.5	86	RIVER ABOVE: UNNAMED TRIB. FROM STONE L.
1'	72	7.2	83	-AT MINK FARM BRIDGE, TEMP 72 oF
2'	72	7.2	83	OXYGEN 6.8 mg/l
3'	72	7.2	83	TRIBUTARY: OLSON CREEK
4'	71	7.1	80	-AT 102 CULVERT, TEMP 74oF
5'	71	5.3	60	OXYGEN 7.5 mg/l
6'2"B	71	5	56	SECCHI : 3.0'
LOCATION: DEEP SPOT				PLANKTON SAMPLED



Total phosphorus and dissolved phosphorus levels of Little Spirit were slightly higher than those found in North Spirit. Chlor a (level of planktonic algae production) was at 17.6 micrograms in Little Spirit - similar to the NW bay of Big Spirit and less than the May 3 reading. Secchi disc reading was only 3 feet . Organic suspension of bottom sediments and phytoplankton were observed that would limit water clarity. The phytoplankton community was dominated by a single specie of green algae and a single specie of bluegreen algae - both were abundant. Diatoms and protozoans were common. See Table 11 above.

Higher concentrations of phosphorus were found in the tributary streams above Little Spirit than in Little Spirit. No precipitation had occurred for several days prior to sampling. Total phosphorus for the North Tributary and the Olson creek were comparable, at 0.120 and 0.110 mg/l , respectively. Dissolved phosphorus was at 0.061mg/l in the North Tributary and 0.047 in Olson Creek. Organic soils and wetlands are found upstream from both sample sights.

FIGURE 36. PHOSPHORUS LEVELS OF LITTLE SPIRIT LAKE AND IT'S TRIBUTARIES ON JUNE 30, 1994.



Temperature of the North Tributary at the mink farm culvert crossing was 72 oF and oxygen was at 6.8 mg/l (78% saturation). Temperature of Olson Creek above the STH 102 Culvert was at 74 oF with dissolved oxygen reading at 7.5 mg/l (saturation 87%).

Phosphorus levels at the surface of South and NW bays of North Spirit were identical. Total phosphorus was at 0.04 mg/l and Dissolved Phosphorus were below detectible limits.

Biological activity in the form of zooplankton and phytoplankton appeared to be utilizing all the soluble phosphorus. Phytoplankton in the south bay appeared larger than in the NW bay and Chlor a concentrations in the south bay were higher, 23.2 to 17.7 micrograms/ liter, respectively.

Corespondently, secchi disc readings in the south bay were also slightly less than in the NW bay. The phytoplankton community was dominated by a variety of green algaes. See Table 11 below.

TABLE 11. 1994 PLANKTON OF BIG & LITTLE SPIRIT LAKES

June 30, 1994	B.SPIRIT	L.SPIRIT
PROTOZOA		
Mallomonas	C	
Pandorina	C	
DIATOMS		
Synedra	C	
ALGAE-GREEN		
Draparnaldia		A
Oedogonium	A	
Chaetophora	A	
Mougeotia	A	
Ankistrodesmus	C	
ALGAE-BLUEGREEN		
Aphanizomenon		A
ZOOPLANKTON		
Daphnia pulex	A	
Cyclops bicuspidatus	A	
Polyphemus sp.	A	
Anisogammerus sp.	A	

July 26, 1994	B.SPIRIT	L.SPIRIT
PROTOZOA		
DIATOMS		
Synedra	A	S
ALGAE-GREEN		
Ankistrodesmus	A	
ALGAE-BLUEGREEN		
Spirulina sp.	S	
ZOOPLANKTON		
Bosmina sp.		S
Daphnia sp.(small)		S
Diaptomus sp.	A	
Canthocamptus sp.	S	
Daphnia pulex	C	
Daphnia galeata	C	
Epischura sp.	C	
Diaphanosoma sp.	C	

Aug 30, 1994	B.SPR	L.SPIRIT
PROTOZOA		
DIATOMS		
Synedra		A
DESMID		
Closterium	C	S
ALGAE-GREEN		
Oedogonium		A
Ankistrodesmu:	A	
Ophiocytium	S	
ALGAE-BLUEGREEN		
Spirulina sp.	C	A
Aphanizomenon	S	
Coelosphaerium	C	C
Phormidium	A	
(chloroplasts)	C	
ZOOPLANKTON		
Diaphanosoma sp.		C
Diaptomus sp.	A	C
Cyclops sp.		S
Daphnia dubea	S	

July 26, 1994 Summer brought heavy planktonic algae blooms to Big Spirit Lake that created secchi disc reading of less than 3 feet. Temperature stratification from the surfaces waters to the bottom in the South and NE bays in July only varied a few degrees from 73 to 70 oF. Oxygen quickly dissappeared below 12 feet in the south and NE bays.

In the NW bay of Big Spirit temperatures were 75 oF in the top 6 feet, with a thermcline from 8 to 10'(73-to 71 oF), and colder, low oxygen water from 11' to the 18' bottom. The intensity of the phytoplankton blooms brought supersaturated oxygen reading to the top 5 feet in the South bay and the top 8 feet in the NW and NE bays. See Figures 37,38, & 39.

FIGURE 37. BIG SPIRIT NE BAY TEMPERATURE - OXYGEN PROFILE ON JULY 26, 1994.

July 26, 1994 TEMP	oF	OXYGEN mg/l	OXYGEN %SA	OTHER DATA:
BS NE BAY				
0'	70	10.1	113	-SECCHI: 2.3'
2'	71	10.4	130	-SO2 IN BOTTOM SAMPLE
4'	71	10.5	121	-COLD RAIN SHOWER PRIOR
6'	72	10.8	124	
8'	73	10.4	121	
10'	73	8.6	100	
12'	72	3.2	37	
14'	71	0	0	
16'	71	0	0	
18'B	71	0	0	

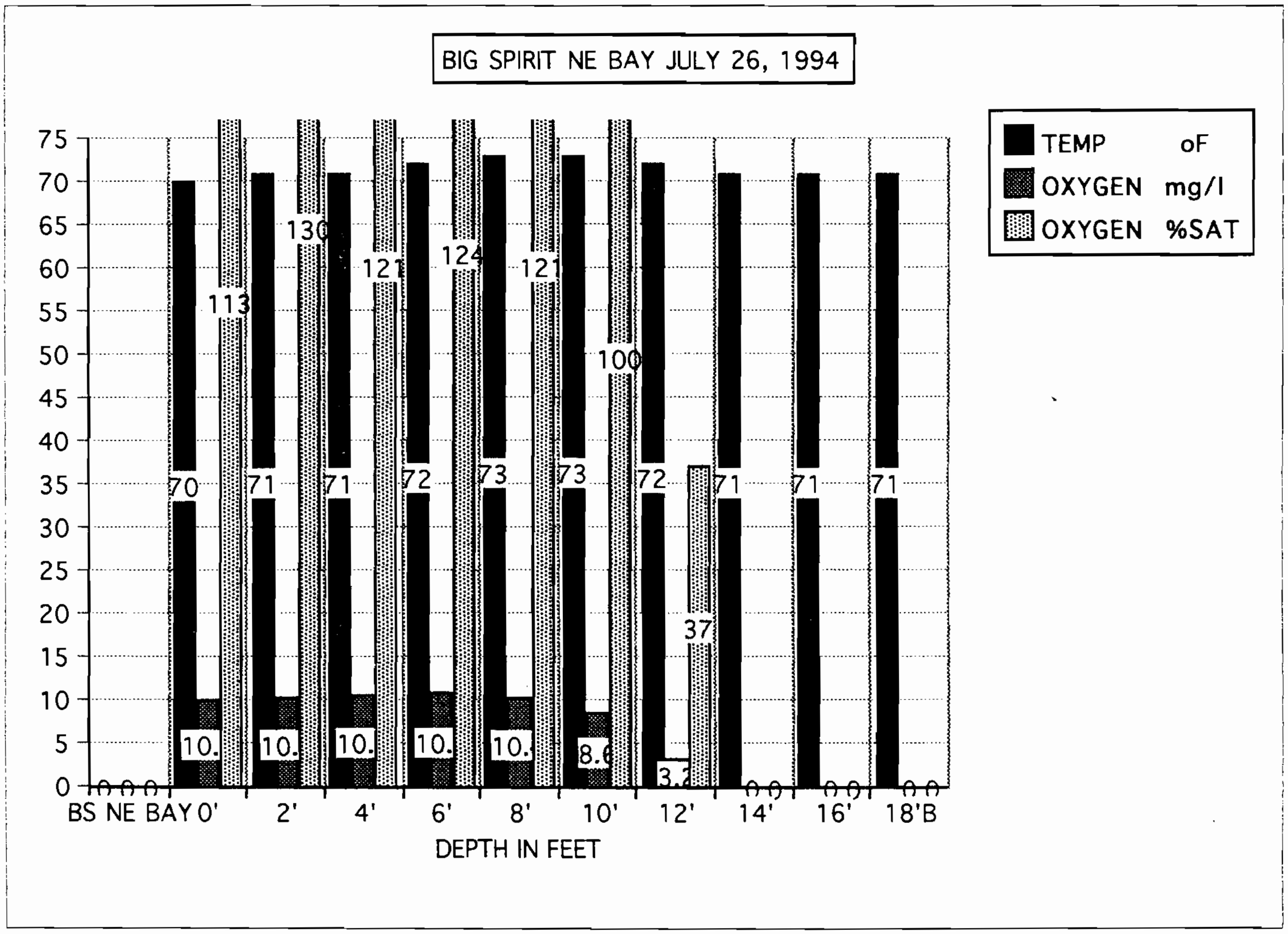


FIGURE 38. BIG SPIRIT SOUTH BAY OXYGEN - TEMPERATURE PROFILES ON JULY 26, 1994.

July 26, 1994	TEMP oF	OXYGEN mg/l	OXYGEN % SAT	OTHER DATA:
0'	73	11.4	133	SECCHI DISC 2.3'
2'	73	11.1	129	HEAVY PHYTOPLANKTON BLOOM
4'	73	11.2	130	
6'	73	11.5	134	WEATHER:
8'	72.5	7	81	AIR TEMP 72oF
10'	72	6.7	77	W. WIND AT 5
12'	72	6	69	100% CLOUD COVER
14'	71.5	3.5	40	
16'	71	0.3	3	
18'	71	0.1	1	
20'	71	0.1	1	
22'B	70	0	0	

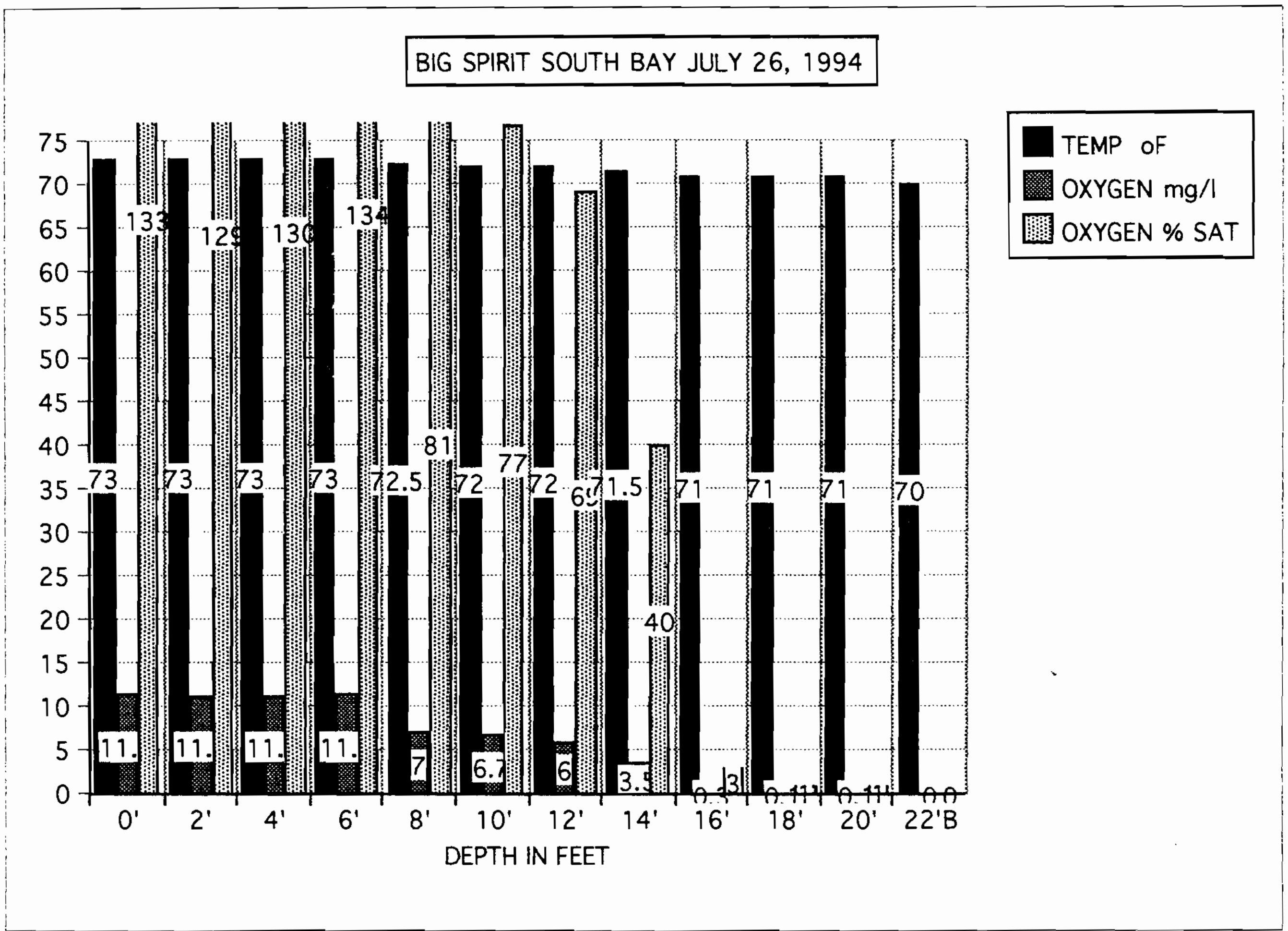
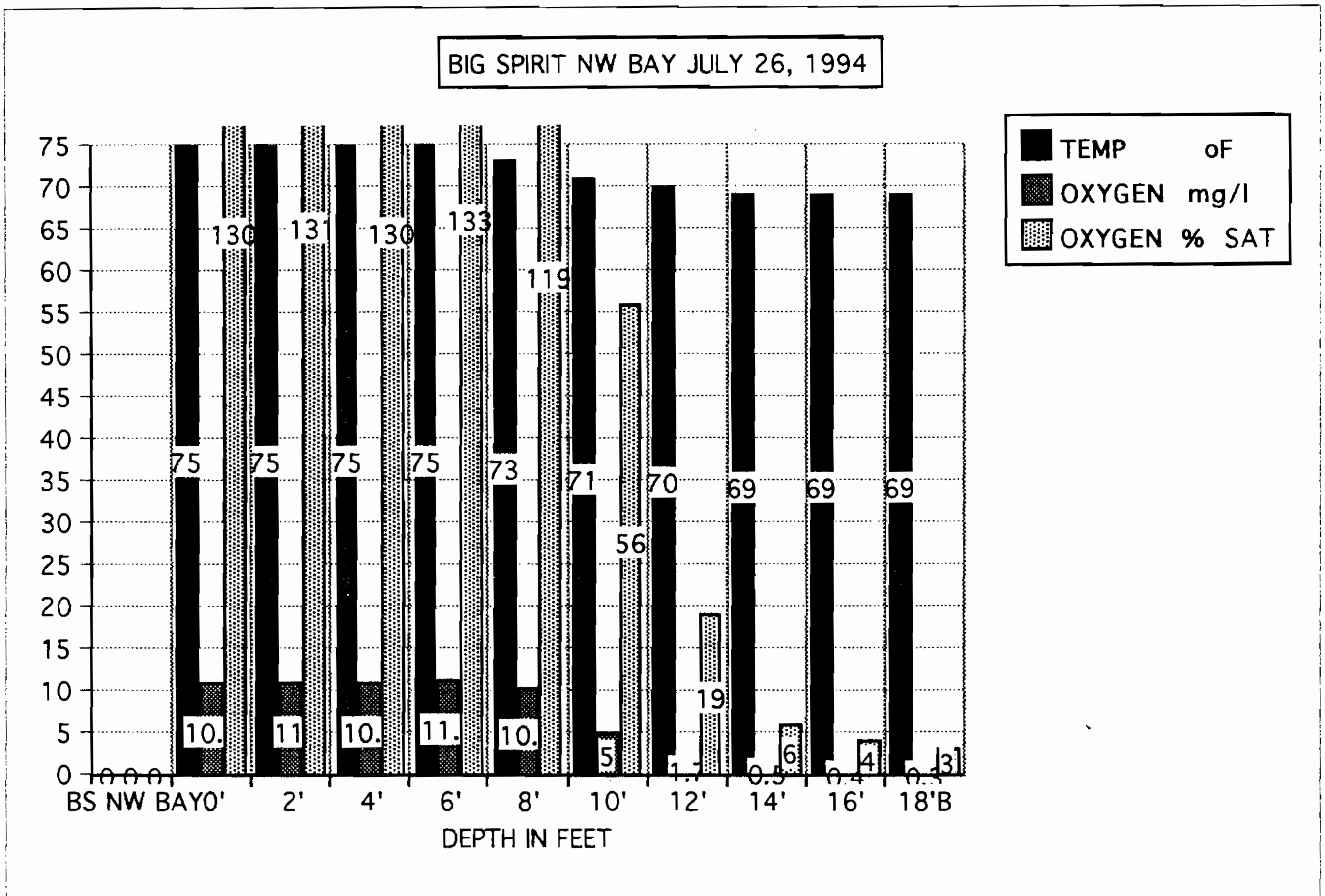


FIGURE 39. BIG SPIRIT NW BAY OXYGEN - TEMPERATURE PROFILES ON JULY 26, 1994.

July 26, 1994 TEMP	oF	OXYGEN mg/l	OXYGEN % S.	OTHER DATA:
BS NW BAY				-PLANKTON SAMPLED
0'	75	10.9	130	-SECCHI : 2.95'
2'	75	11	131	-SO2 IN BOTTOM SMPL
4'	75	10.9	130	-HVY PHYTOPLANKTON BLOOM
6'	75	11.2	133	
8'	73	10.2	119	
10'	71	5	56	
12'	70	1.7	19	
14'	69	0.5	6	
16'	69	0.4	4	
18'B	69	0.3	3	



Secchi disc readings corresponded to these readings with a south bay reading of 2.3 feet , and NW bay reading of 2.95 feet, and the NE bay 2.3 feet. A cold rain shower occurred just prior to the NW bay sampling and the NE sampling occurred approximately a hour later.

Chlor a reading in the south bay was 92.4 micrograms and in the NW bay was 149.0 micrograms. The phytoplankton community was dominated by a single specie of green algae, and a single specie of blue-green algae was now present. Eight species of zooplankton were identified. Diatoms were now abundant and provided food along with the green algae for the variety of zooplankton present(See Table 11, Page 62). Bluegreen algae was not causing this intense algae bloom.

Total Phosphorus samples were taken from the 1' from the surface and 2 ' from the bottom in the south and NW bays of Big Spirit. Total Phosphorus at the surface in both locations were comparable but bottom samples in the south bay had considerably higher total phosphorus levels than the NW bay bottom. See Figures 40 & 41 below.

This would correspond to the anaerobic (no oxygen) conditions found on the south bay bottom that would release phosphorus from the bottom sediment; where in the NW bay bottom some oxygen was still present and not as much phosphorus was being released.

Both sulfur dioxide and a ferrous iron odor were given off the near bottom samples collected in the NE and NW bays of North Spirit. This same odor was present on the anchor pulled from the NE bay of Big Spirit when sampling oxygen conditions. This is an indicator that anaerobic bacterial activityis releasing phosphorus and nutrient salts.

FIGURE 40. BIG SPIRIT SOUTH BAY SURFACE AND BOTTOM TOTAL PHOSPHORUS ON JULY 26, 1994.

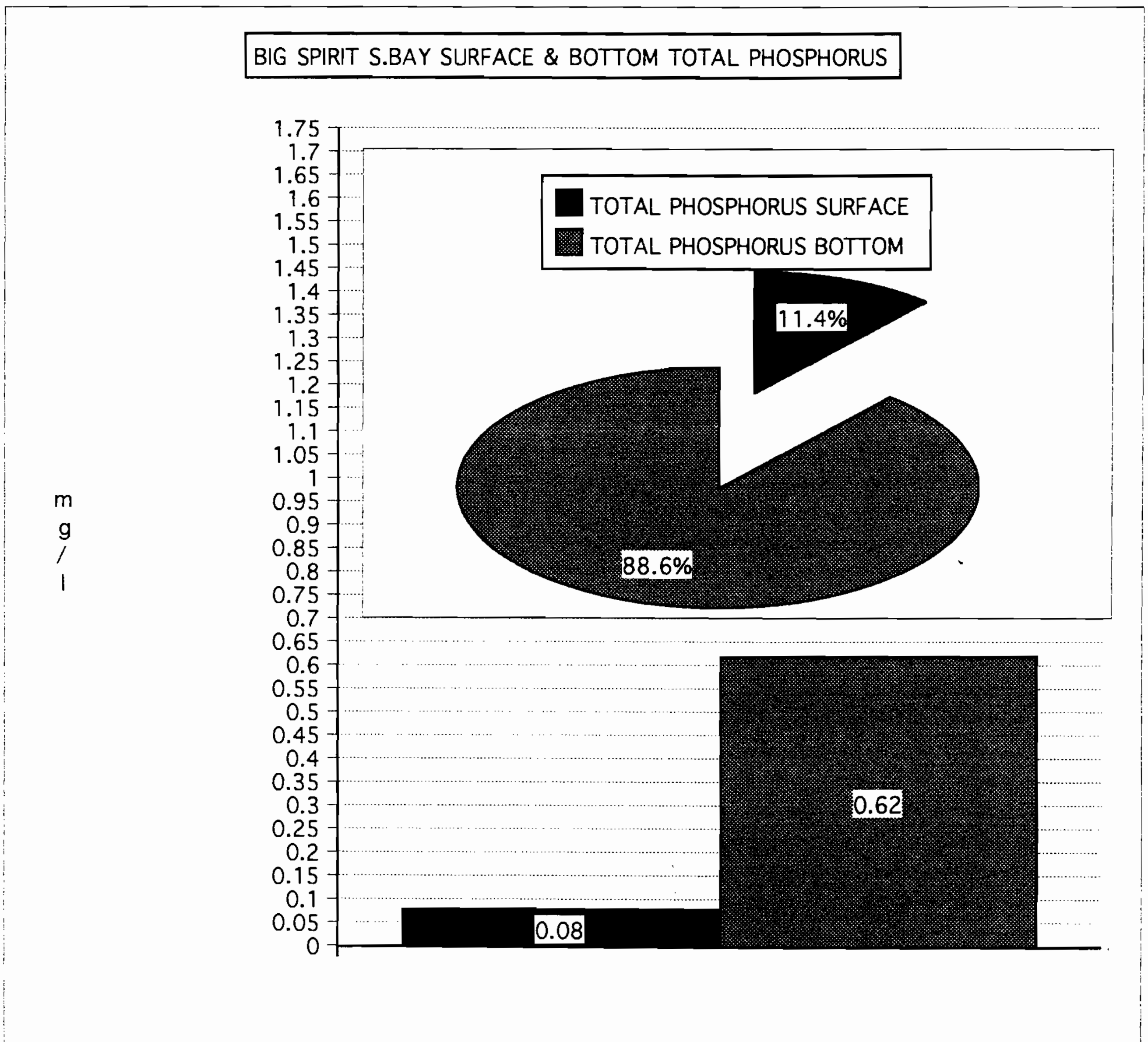
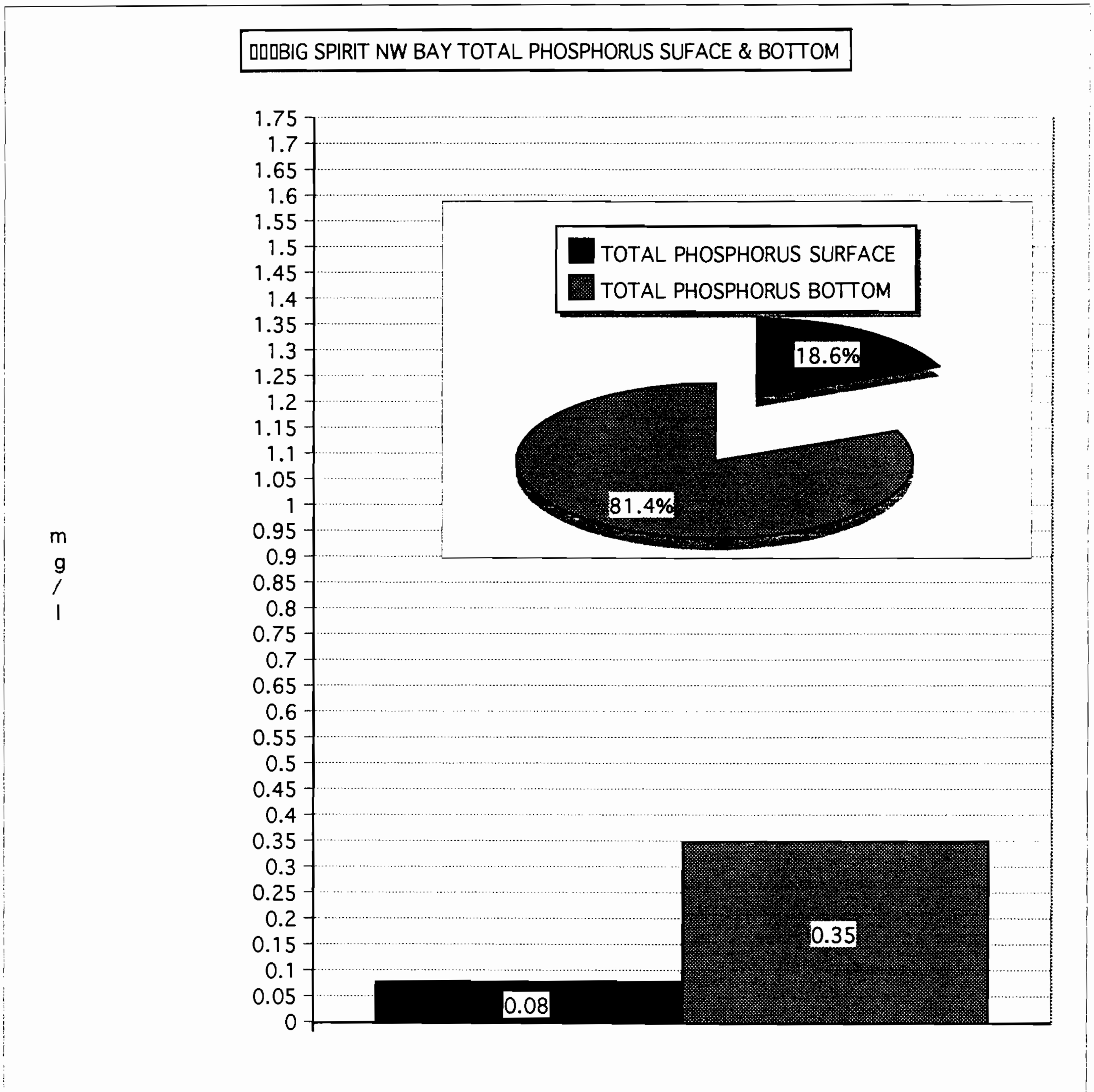


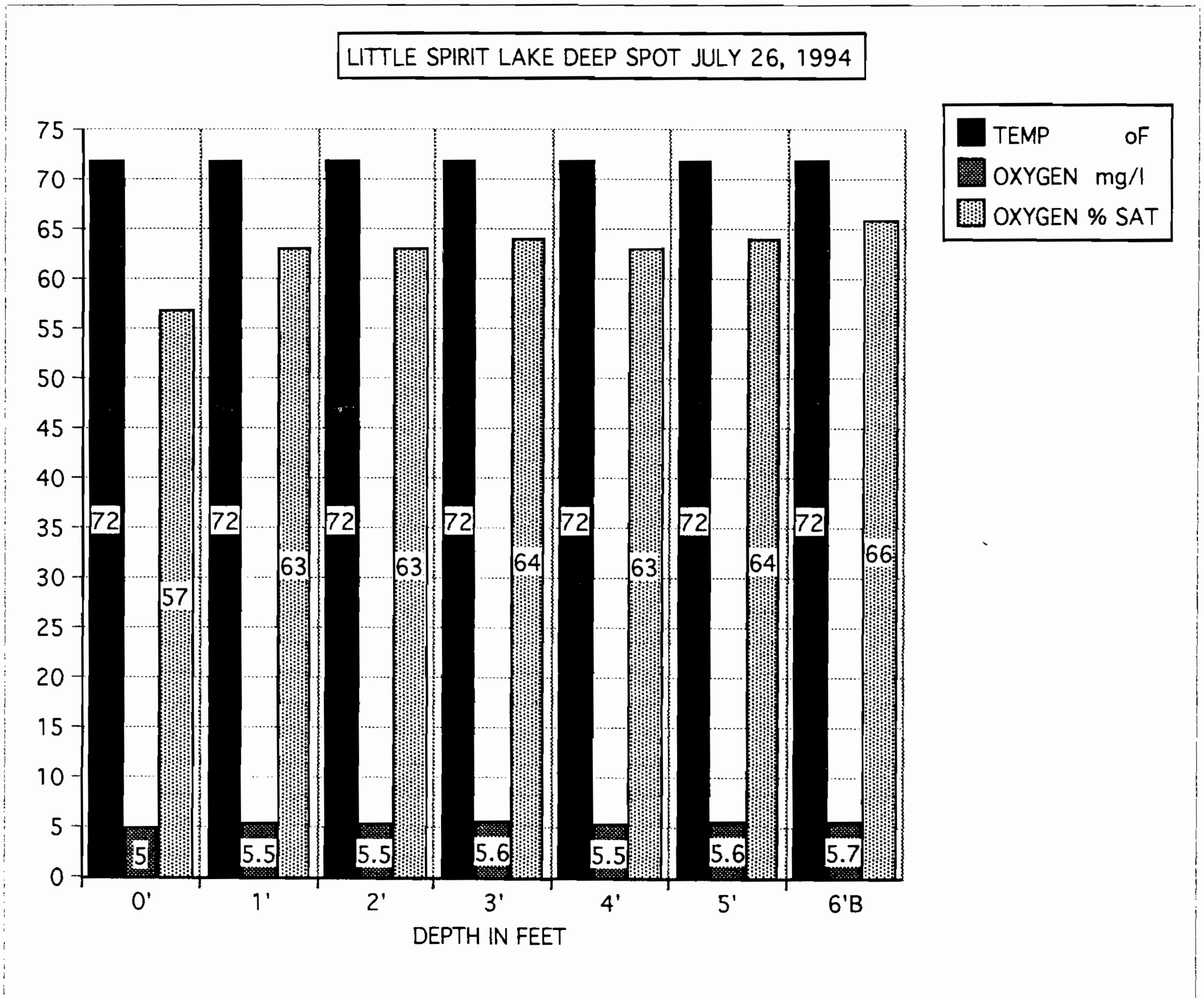
FIGURE 41. BIG SPIRIT NW BAY TOTAL PHOSPHORUS SURFACE & BOTTOM ON JULY 26, 1994.



In Little Spirit lake water temperatures were a constant 72 oF from top to bottom. Oxygen levels were from 5 to 5.7 mg/l (with a saturation levels increasing slightly 57-66%) from top to bottom. Secchi disc reading extended to within 6 inches of the bottom where flocculent soft sediments could be seen (Figure 42).

FIGURE 42. LITTLE SPIRIT OXYGEN TEMPERATURE PROFILE ON JULY 26, 1994

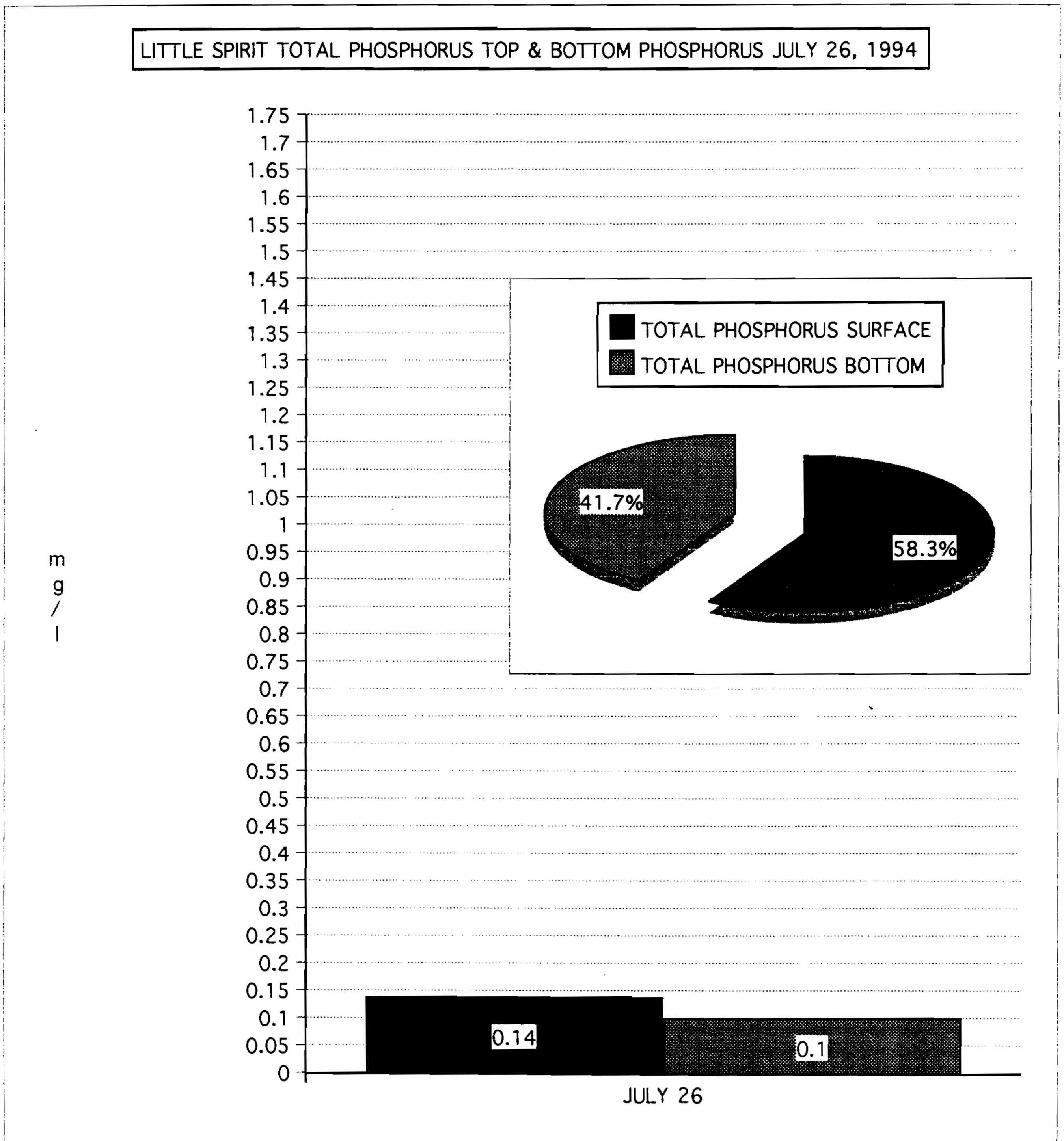
July 26, 1994 TEMP	oF	OXYGEN mg/l	OXYGEN % SAT	OTHER DATA:
0'	72	5	57	RIVER ABOVE:UNNAMED TRIB. FROM STONE L.
1'	72	5.5	63	-AT MINK FARM BRIDGE, TEMP 68 oF
2'	72	5.5	63	OXYGEN 5.2 mg/l
3'	72	5.6	64	-PLANKTON IN CHANNEL BETW LAKES BUT NOT
4'	72	5.5	63	IN RIVER
5'	72	5.6	64	TRIBUTARY: OLSON CREEK
6'B	72	5.7	66	- AT 102 CULVERT, TEMP 68oF OXYGEN 6 mg/l
LOCATION: DEEP SPOT				SECCHI 5'6" RAIN SHOWER BEFORE RDINGS



Chlor a reading in Little Spirit was at 13.9 microliters. Only diatoms and two small zooplankton were identified in the plankton sample. Phytoplankton was abundant in the channel between the lakes but not in the river or in little Spirit. Water temperatures and dissolved oxygen at the mink farm crossing of the north tributary was at 68 oF and 5.2 mg/l.

Olson Creek above the STH 102 culvert was at 68 oF and 6 mg/l oxygen. Phosphorus reading at the top and bottom of Little Spirit were 0.140 and 0.100 mg/l,respectively. See Figure 43.

FIGURE 43. LITTLE SPIRIT TOTAL PHOSPHORUS SURFACE AND BOTTOM ON JULY 26, 1994.



August 30, 1994 Late summer brought extremes in temperatures that ushered in hot muggy days, frequent cooling thunderstorms with wind. Temperature/ oxygen profiling and nutrient sampling continued so changes in North and Little Spirit Lake's water quality and chemistry could be documented.

Temperatures in the top 10 feet of North Spirit dropped 5 to 7 oF since the late July sampling to the mid to upper 60's. Waters deeper than 10 feet also cooled 5 to 7 degrees the mid 60's. See Figures 44,45, & 46.

FIGURE 44. BIG SPIRIT NE BAY OXYGEN- TEMPERATURE PROFILES ON AUGUST 30, 1994.

Aug 30, 1994 TEMP	oF	OXYGEN mg/l	OXYGEN % SAT	OTHER DATA:
BS NE BAY				-PHYTOPLANKTON THICK
0'	65	6.5	69	-SO2 ODOR IN BOTTOM SAMPLE
2'	67.5	6.5	71	-SECCHI: 3.0'
4'	68	6.5	71	-ELODEA &FRAGRANT WATER
6'	68	6.7	74	LILYIN N. BAY IN 2' H20
8'	68	6.7	74	-COOL RAIN IN AM
10'	68	6	66	-8/27/94 RAISED W.L.
12'	67.5	3.25	36	
14'	67	0	0	
16'	65	0	0	
18'	64	0	0	
19'B	63	4	37	

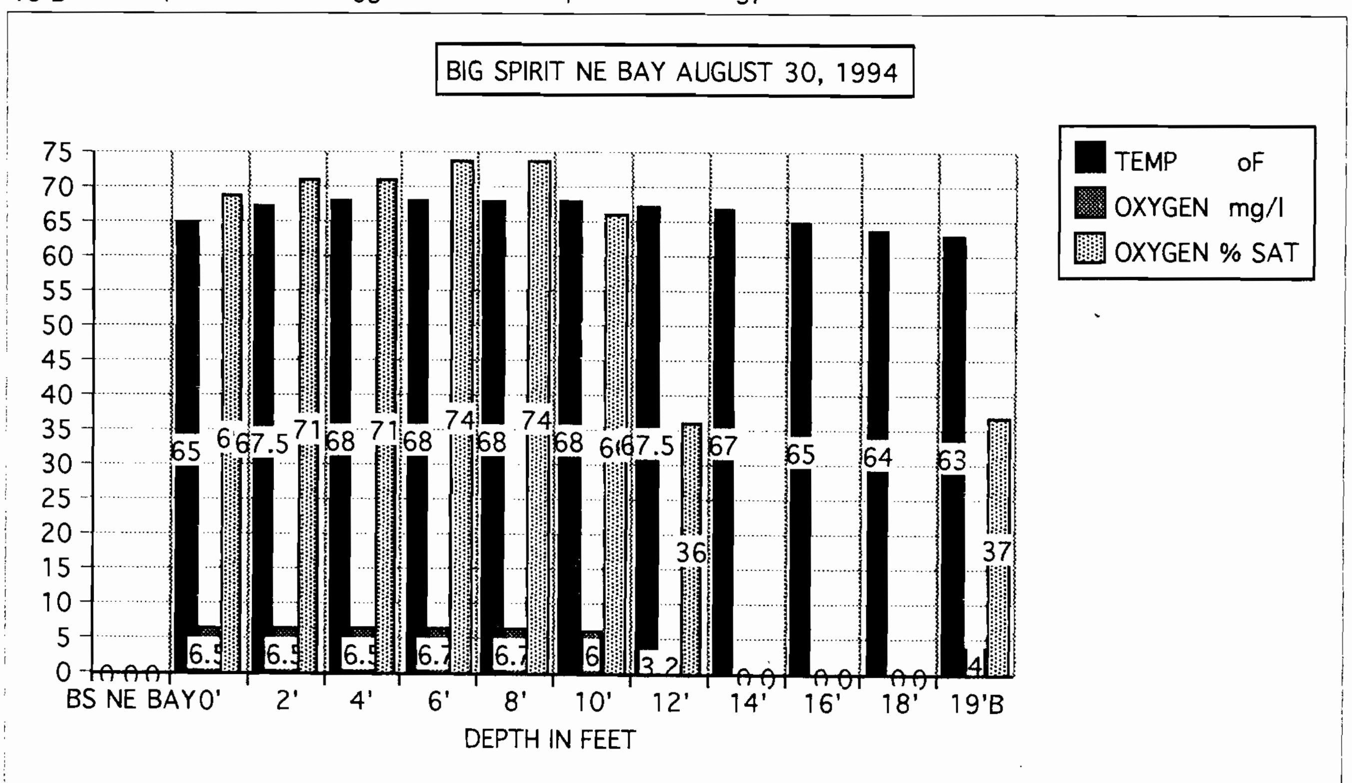


FIGURE 45. BIG SPIRIT SOUTH BAY OXYGEN - TEMPERATURE PROFILE ON AUGUST 30, 1994.

Aug 30, 1994	TEMP oF	OXYGEN mg/l	OXYGEN % SAT	OTHER DATA:
BS S. BAY				-SECCHI DISC 4.5'
0'	67	7.25	79	-DIATOMS 2' OFF BOTTOM
2'	68	7.5	82	IN WATER SAMPLE
4'	68	7.2	79	-PLANKTON SAMPLED
6'	68	7.2	79	
8'	68	6.9	76	WEATHER:
10'	68	5.3	58	AIR TEMP 60oF
12'	67	0	0	RAIN AM
14'	66.5	0	0	SUNNY & COOL PM
16'	65	4	43	
18'	65	4	43	
20'B	65	4	43	

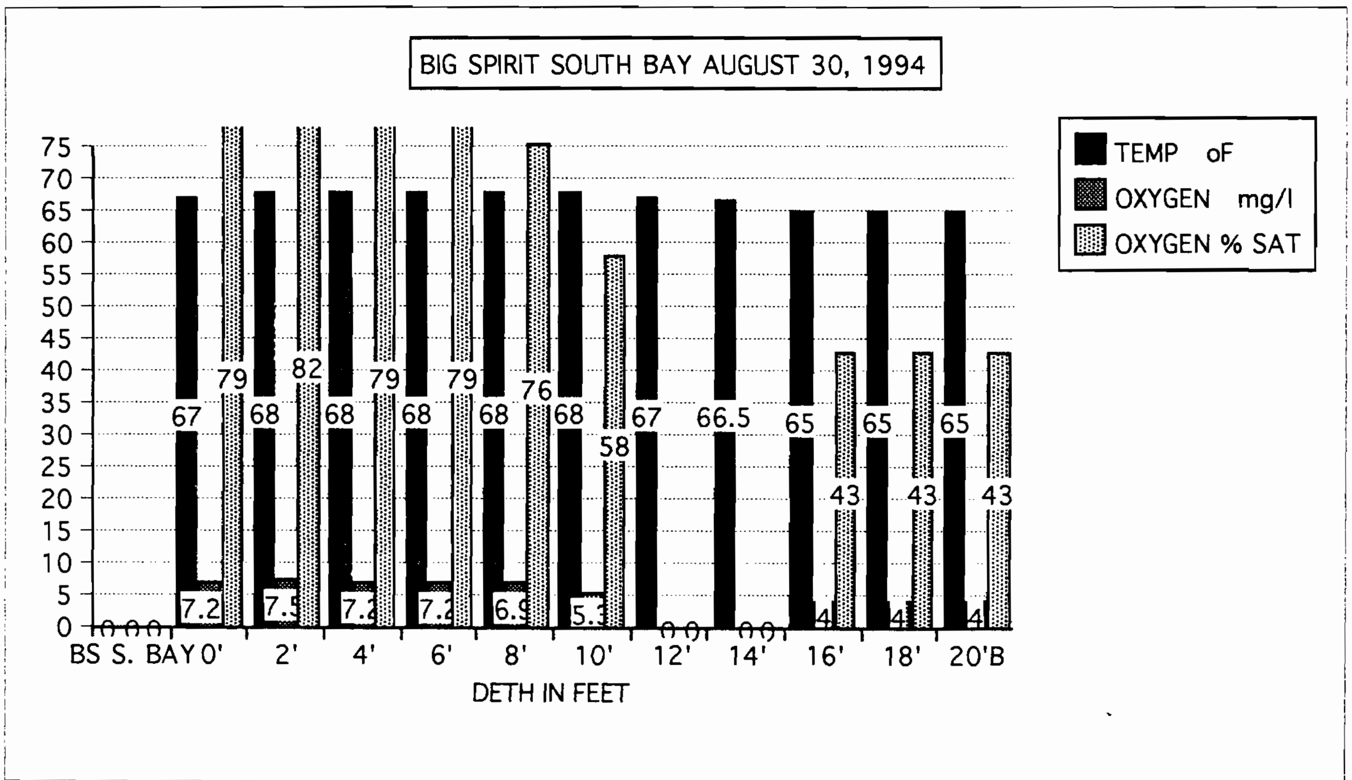
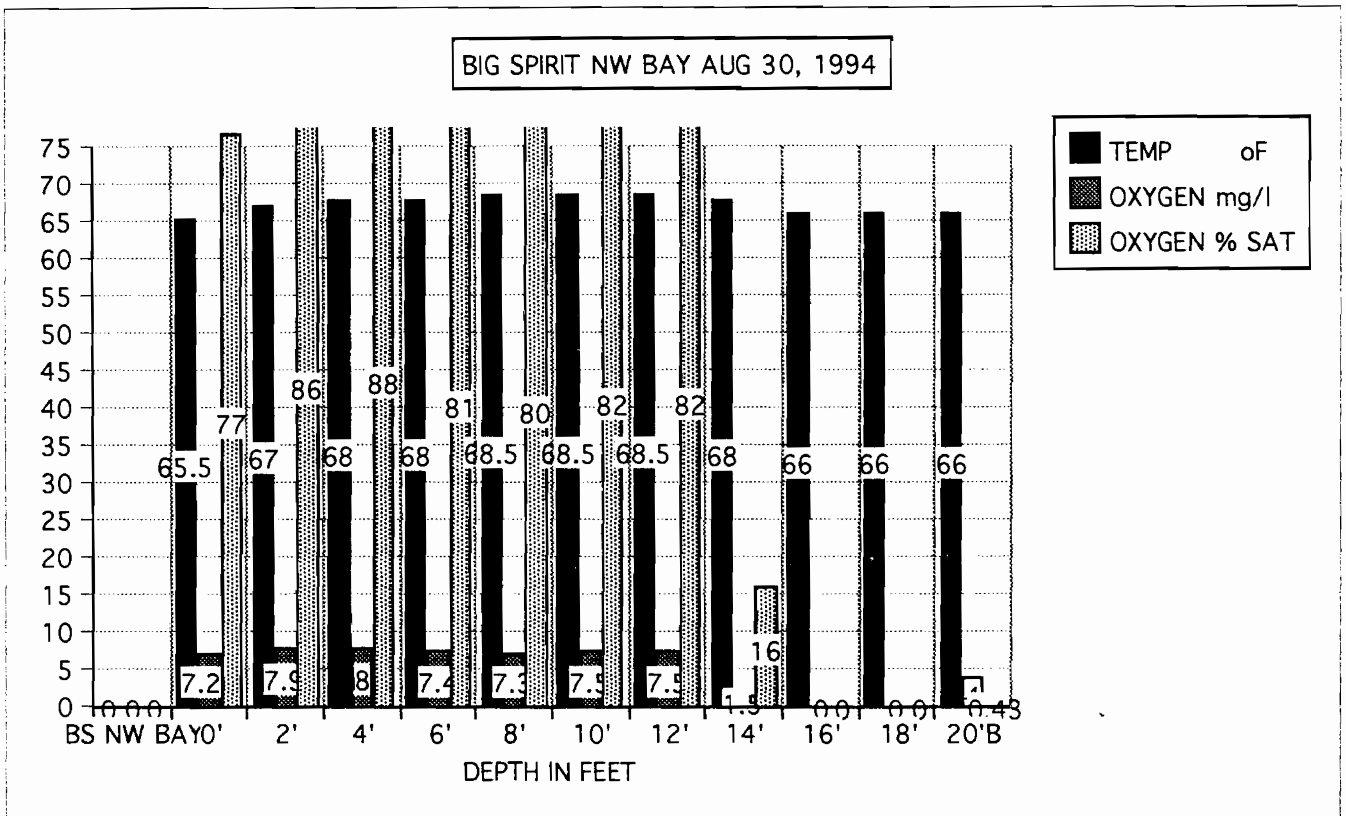


FIGURE 46. BIG SPIRIT NW BAY TEMPERATURE - OXYGEN PROFILES ON AUGUST 30, 1994.

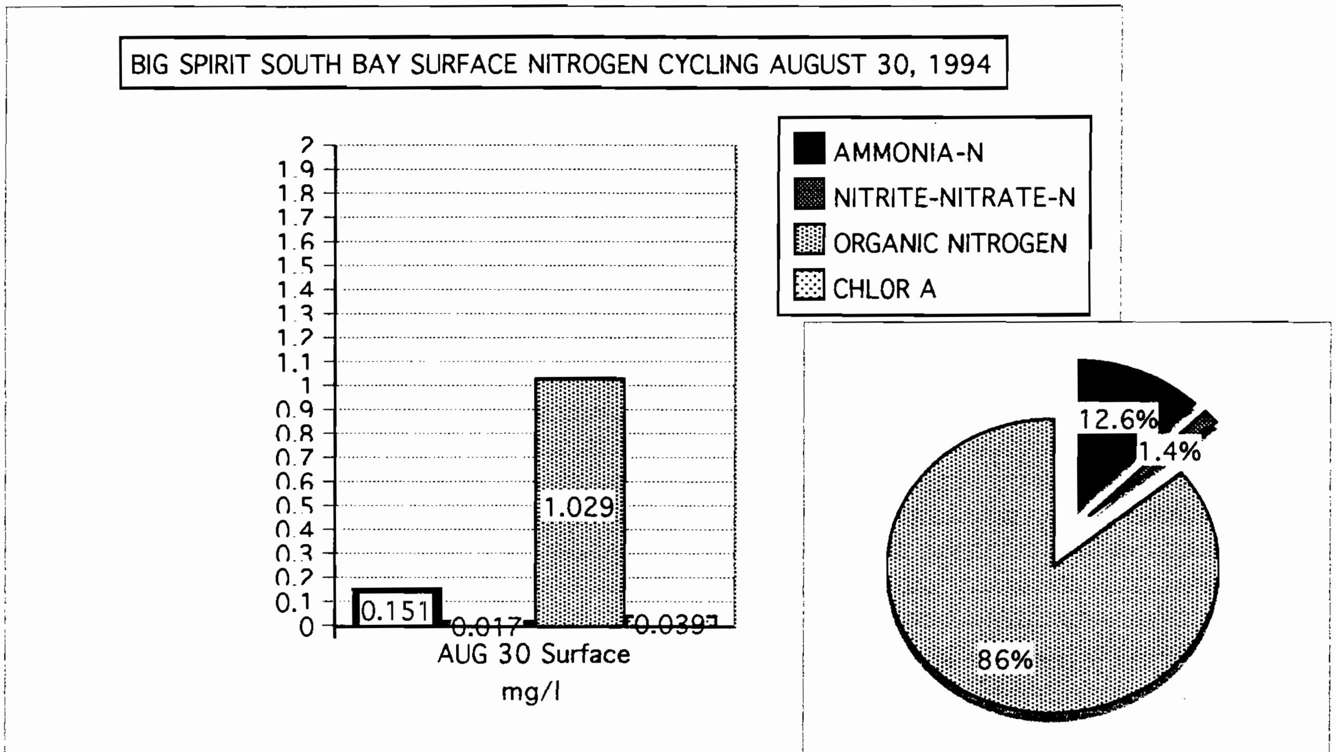
Aug 30, 1994 TEMP	oF	OXYGEN mg/l	OXYGEN % SAT	OTHER DATA:
BS NW BAY				-PLANKTEN WINDROWED
0'	65.5	7.25	77	ON EAST SHORE
2'	67	7.9	86	-SM PHYTPLTN ON BOTTOM
4'	68	8	88	- SECHHI 3.7'
6'	68	7.4	81	-SULFUR-IRON SMELL ON BTM
8'	68.5	7.3	80	
10'	68.5	7.5	82	
12'	68.5	7.5	82	
14'	68	1.5	16	
16'	66	0	0	
18'	66	0	0	
20'B	66	4	0.43	

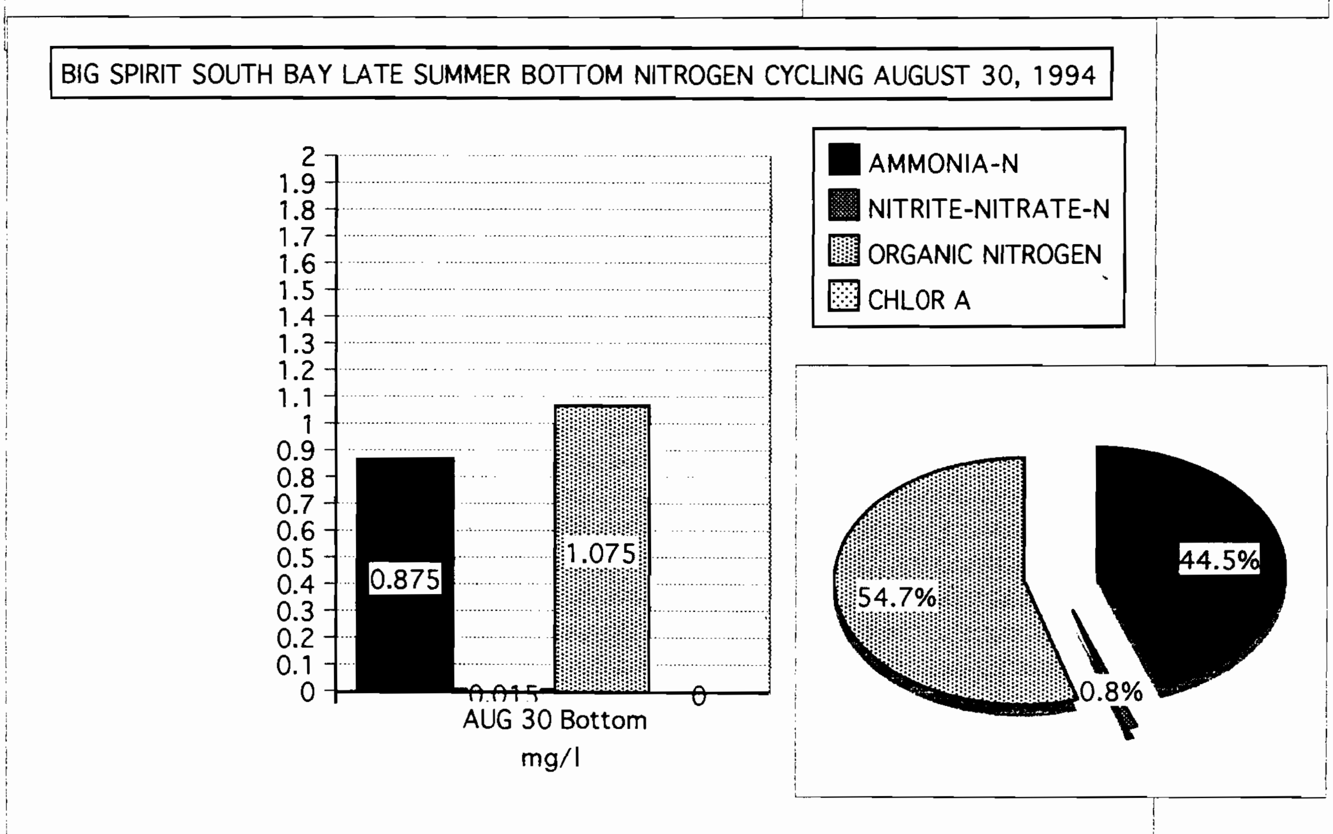


Oxygen depletion below 10- 12 feet continued except low oxygen was now appearing in the bottom few feet. Small phytoplankton and diatom silica encasements were found in the water chemistry samples brought from the bottom at these bottom oxygen sites. It is assumed that phytoplankton from the surface waters had recently " rained" down and produced the low oxygen levels found near the bottom. Cool showers occurred in the morning before the sampling and the difference in the temperatures from the surface to the bottom was now so slight density differences that formally held phytoplankton at the surface no longer existed.

These high concentrations accompanied a chlor a concentrations of 58.4 microgram/l and secchi disc reading of 3.6 feet in the NW bay. These readings were higher than in the south bay where chlor a was at 39.0 and the secchi disc indicated water clarity to 4.4 feet. See Figures 48 & 49.

FIGURE 48. BIG SPIRIT SOUTH BAY NITROGEN CYCLING SURFACE AND BOTTOM ON AUGUST 30, 1994.





Organic nitrogen levels were also high as a result of the plankton activity at the surface. Ammonia-N was also present and dominated the dissolved nitrogen at the surface indicating that plankton was dying and decaying at a fast rate and oxygen was not converting it to nitrite-nitrate-N fast enough. Ammonia-N levels at the surface were higher in the South bay than in the NW bay and oxygen saturation levels also corresponded to this ammonia condition . There was little or no dissolved phosphorus available at the surface at this time.

At this same time nutrients on the bottom were at much higher concentrations than at the surface. Total nitrogen levels were over 60% higher on the bottom than on the surface in both the NW and south bays of North Spirit. Total phosphorus levels on the bottom were over 3 times greater than found on the surface at both North Spirit Lake locations.

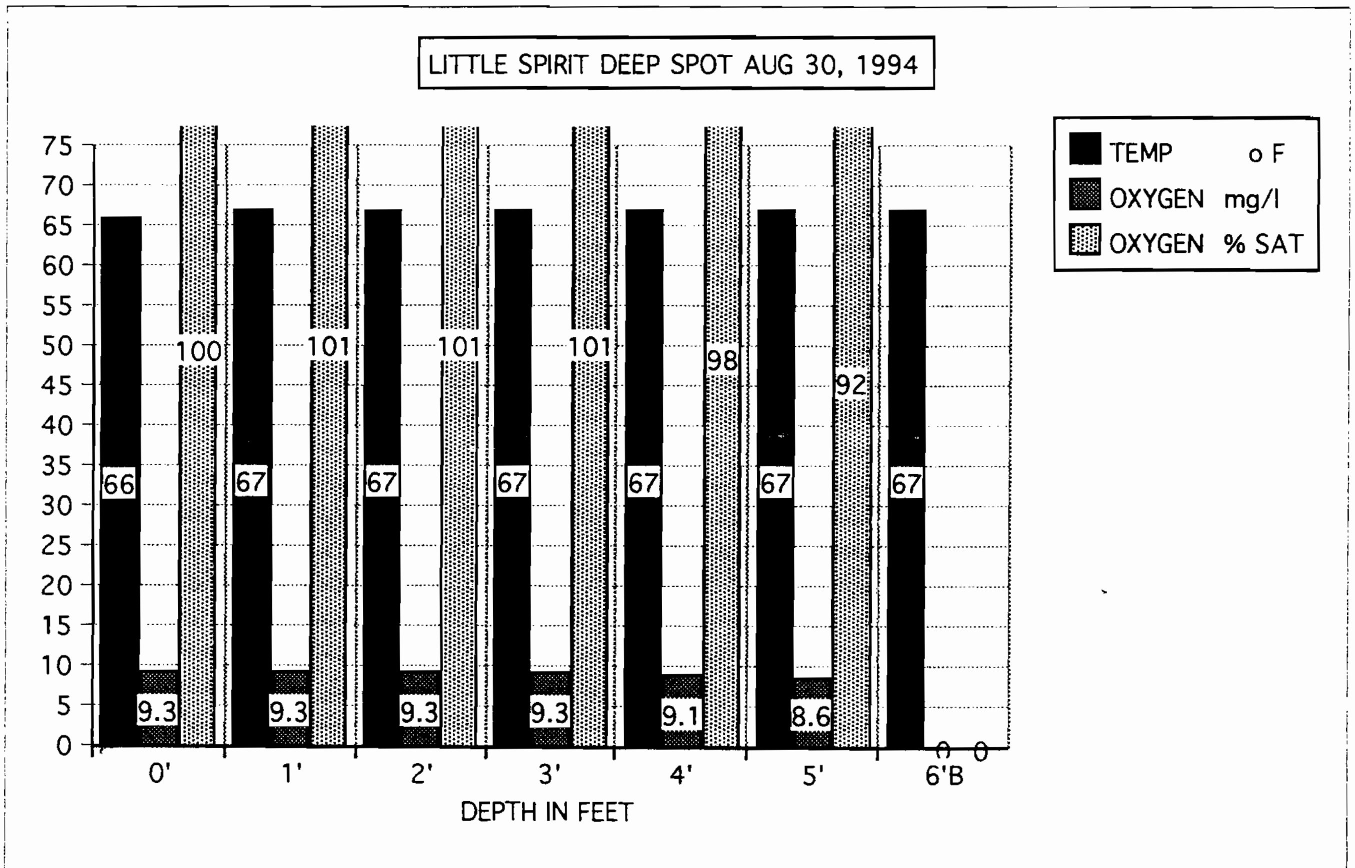
Dissolved nitrogen was at the same time 5 times greater on the bottom than on top in the south bay and 9 times greater in the NW bay. Ammonia-N accounted for most of the dissolved nitrogen which was being released from the decaying phytoplankton and very little was being converted to nitrite-nitrate-N. As at the surface higher concentrations of ammonia-N were found at the bottom of the NW bay than at the bottom of the south bay of North Spirit. Organic nitrogen levels found at the bottom was close to those levels found near the surface at both locations. It is apparent that plankton was dying and falling to the bottom from the surface and dissolved phosphorus was also accumulating and being released from the decaying organic matter and the bottom sediments.

These nutrient activities corresponded to a change in plankton from July 26 to August 30. A single green algae and a single diatom dominated on July 26 and only a few blue-green algae of a single specie was present. An abundance and variety of zooplankton were present in late July feeding on the abundant green algae and diatoms. On August 30, the same green algae was still abundant, a second one appeared, the diatom that had been present since spring disappeared. Five blue-green algae were added and the zooplankton population dropped to two large species. The blue- green algae bloom had begun. See Table 11 on Page 62.

In Little Spirit Lake water temperatures were a constant 67 degrees from 1 foot below the surface to the bottom at 6 feet. The surface was only 1 degree warmer. Oxygen was near 100% saturation from top to 5 feet with oxygen levels falling to 0 in the bottom substrate at 6 feet. See Figure 50.

FIGURE 50. LITTLE SPIRIT OXYGEN - TEMPERATURE PROFILES ON AUGUST 30, 1994.

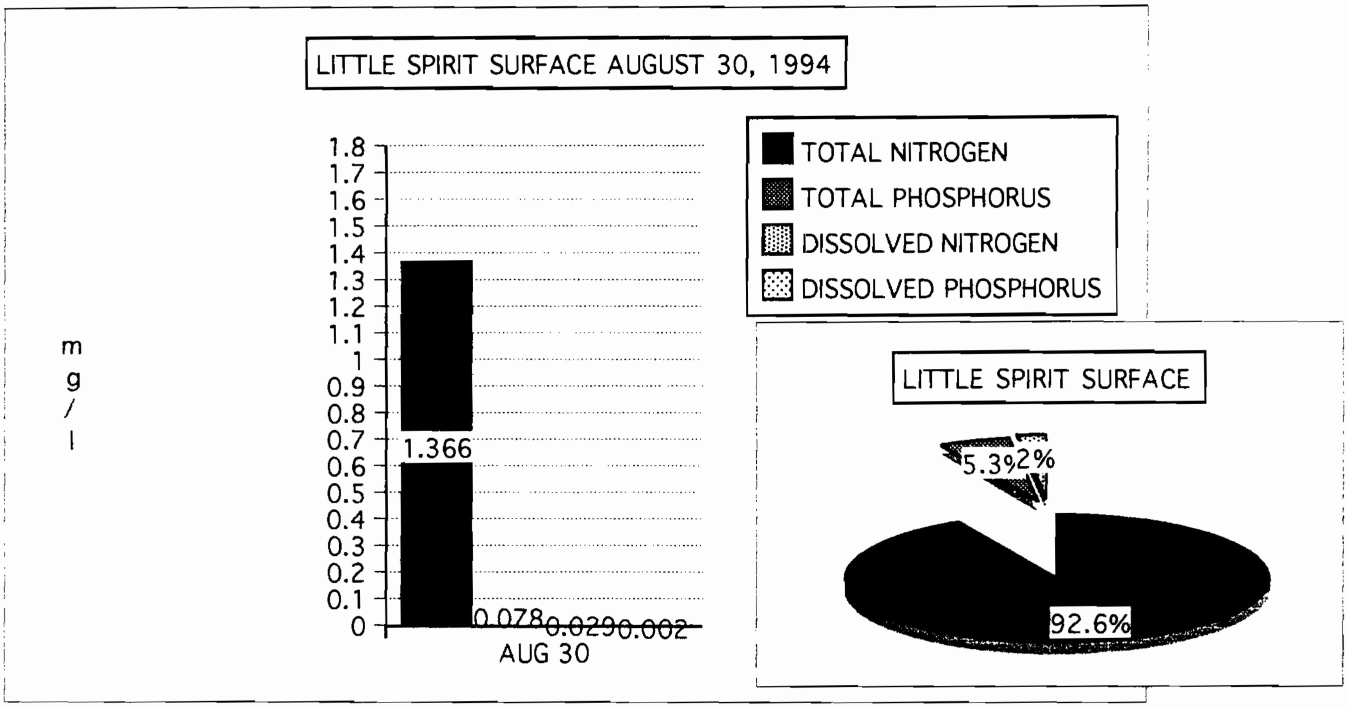
Aug 30, 1994 TEMP	o F	OXYGEN mg/l	OXYGEN % SAT	OTHER DATA:
0'	66	9.3	100	SEECHI: 3' 4"
1'	67	9.3	101	LRG & THICK PHYTOPLANKTON IN H2O COLUMN
2'	67	9.3	101	FILAMENTOUS ALGAE(HYDRODICTON) PRESENT
3'	67	9.3	101	TINY CLAMS ON COONTAIL END BUDS
4'	67	9.1	98	LGR CLAMS ALSO PRESENT
5'	67	8.6	92	RAIN IN AM, SUNNY & COOL PM
6'B	67	0	0	
LOCATION: DEEP SPOT				

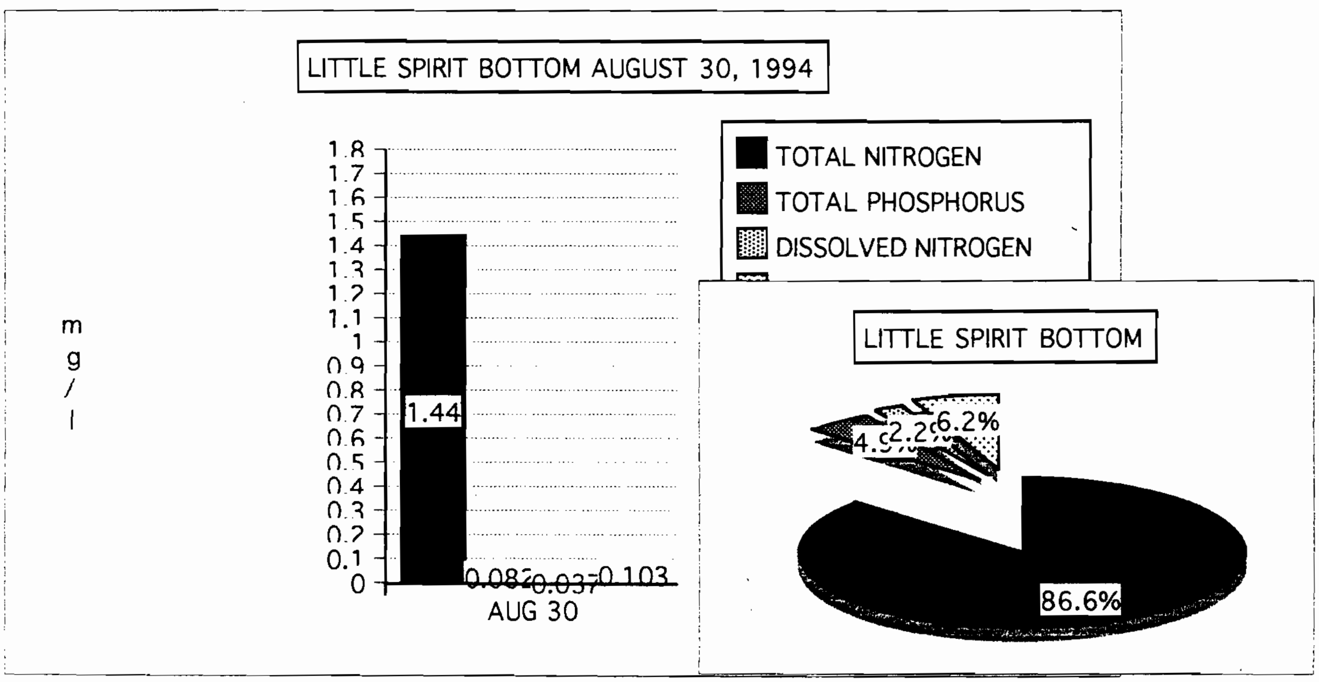


The secchi reading was at only 3' 4" as large and thick phytoplankton were evident in the water column. The aquatic plant, coontail, was found on the bottom with the filamentous algae growing from it's decaying terminal buds. Tiny clams were hanging on to both plants. Larger clams were found near the base. These clams were filtering the organic detritus carried by the current and wave action that was slowed by the coontail and filamentous algae.

The plankton community in Little Spirit on August 30, 1994 was found to be diverse and quite different from Big Spirit. Diatoms that had disappeared from Big Spirit remained abundant in Little Spirit. One green algae and one blue-green algae were also abundant. One other blue-green algae was sparse. Two large zooplankton were common and one small one was sparse. Only two blue-green algae were present where in North Spirit five were present.

FIGURE 51. LITTLE SPIRIT NITROGEN- PHOSPHORUS LEVELS OF LATE SUMMER ON AUGUST 30, 1994.

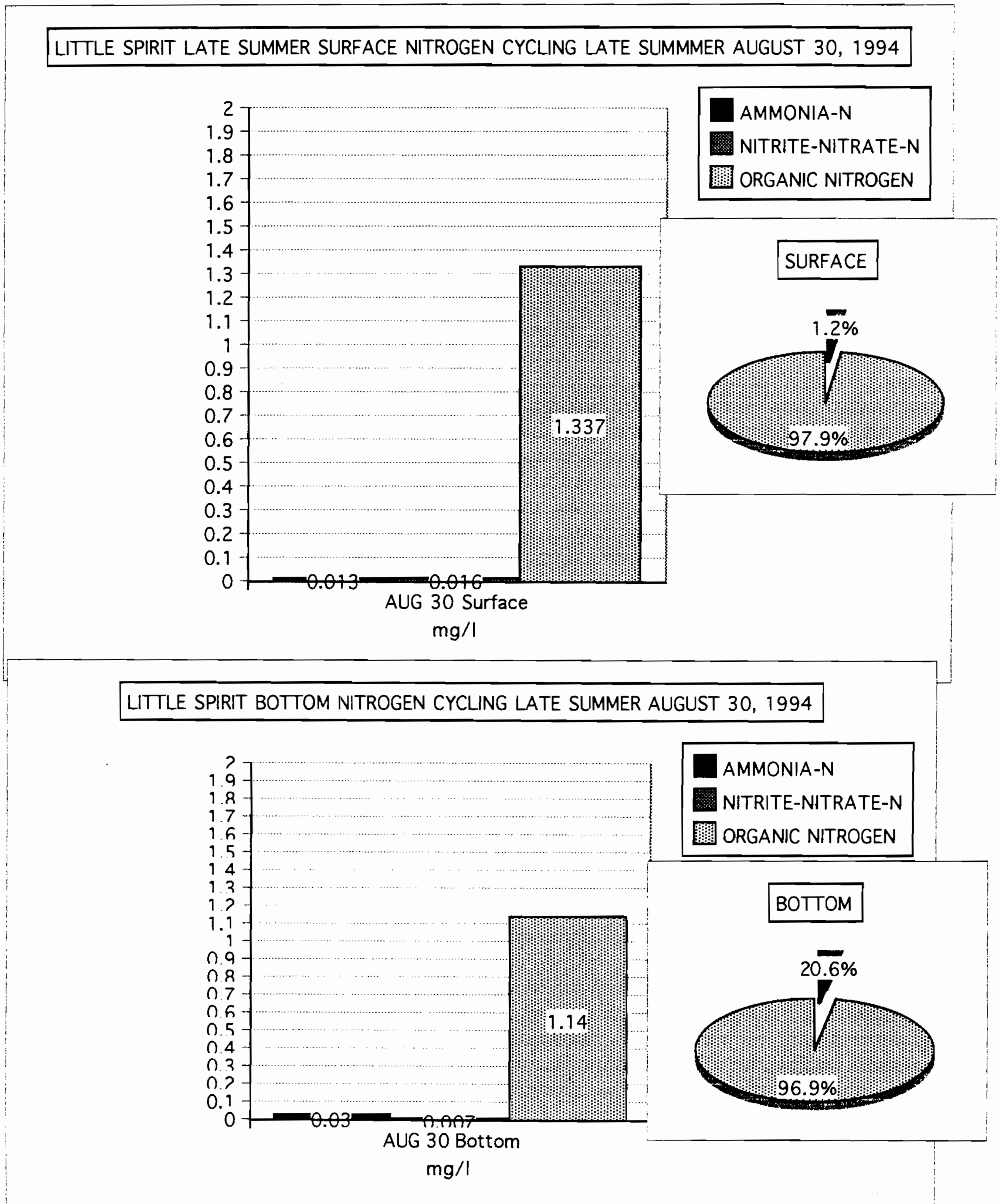




Total Nitrogen levels of Little Spirit samplings were 1.366 mg/l one foot below the surface and 1.44 mg/l one foot off the bottom (Figure 51 Above).

These total nitrogen readings were comparable to those found at the surface of the NW bay of Big Spirit . As in Big Spirit organic nitrogen made up most of the total nitrogen but the ammonia build up that was occurring in Big Spirit was not occurring in Little Spirit (Figure 52).

FIGURE 52. LITTLE SPIRIT LAKE NITROGEN CYCLING OM AUGUST 30, 1994.



The plankton community in Little Spirit on August 30, 1994 was found to be diverse and quite different from Big Spirit. Diatoms that had dissappeared from Big Spirit remained abundant in Little Spirit. One green algae and one blue-green algae were also abundant. One other blue-green algae was sparse. Two large zooplankton were common and one small one was sparse. Only two blue-green algae were present where in North Spirit five were present.

September 9, 1994 A quick oxygen/temperature profile in the south bay of North Spirit was taken on this date to document the effects of an intense blue-green algae bloom on the physical aquatic environment. The sampling date and three days prior were very sunny, hot, calm days. Strong NW winds created heavy wave action for three days prior to these calm days (Figure 53 below).

Water temperatures were at 74 degrees with an oxygen reading of 15.5 mg/l as phytoplankton was wind rowing on the east shoreline of the south bay. Percent saturation of oxygen was at over 182%. In 12 feet of water 150 feet from shore a secchi disc reading of 3 feet was recorded. The top 2 to three feet also had supersaturated oxygen conditions that were lethal to fish and other aquatic organisms.

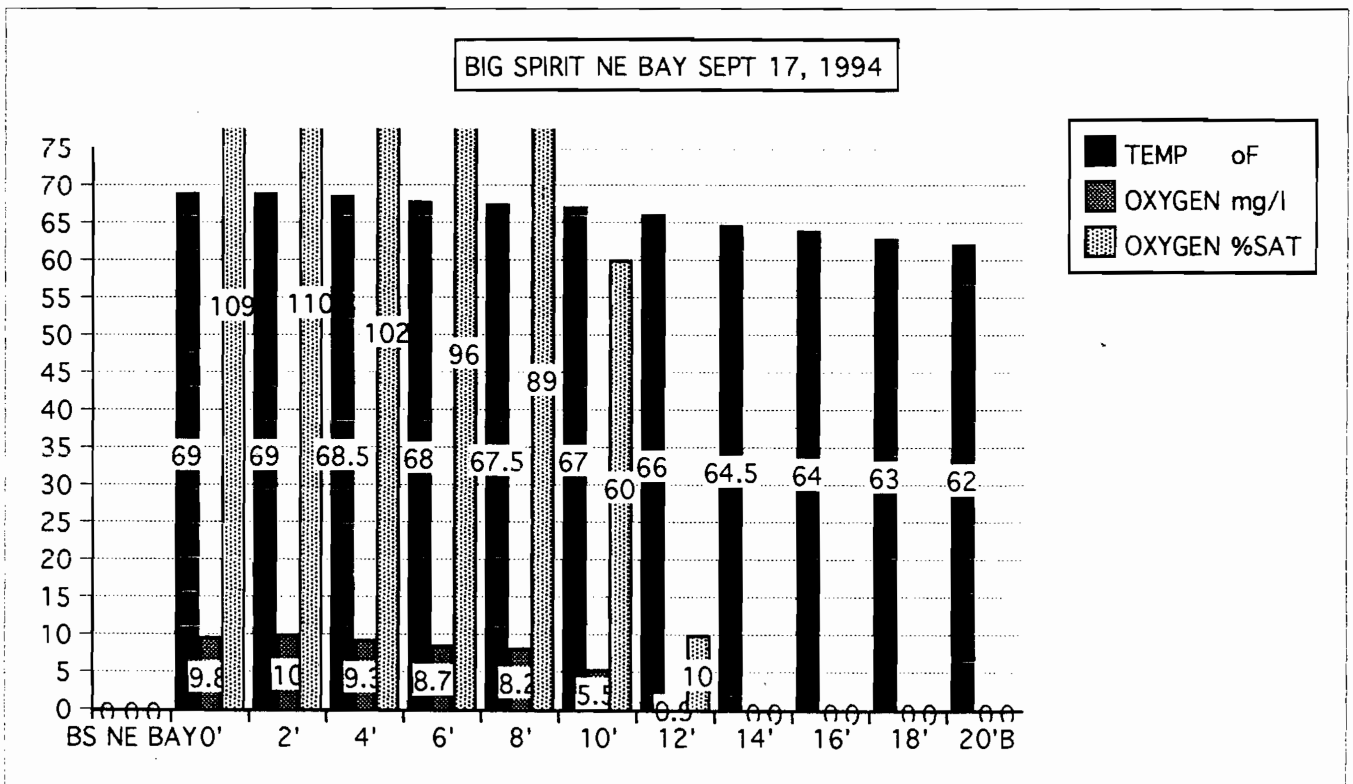
At 3-5 feet suitable oxygen was present but from 5 feet to the bottom very low oxygen conditions were found Conditions were ideal for a summer fish kill that could possibly occur during the early morning hours if cloudy skies and night time respiration of the phytoplankton depleted the oxygen levels.

September 17, 1994 A second oxygen/ temperature profiling of the conditions of all bays of North Spirit and of Little Spirit and it's tributaries was made on this date. Hot humid days continued for seven days prior to the profiles. Thunder showers and easterly winds occurred each day from September 14 through 16.

Near saturation levels of oxygen and temperatures of 67 to 69 to the 6 to 8 foot depth were found in the NE and South bay of Big Spirit. Temperatures dropped steadily to 62 degrees from this depth to the bottom. Oxygen levels in this deep zone were at zero. See Figures 54 & 55.

FIGURE 54. BIG SPIRIT NE BAY TEMPERATURE - OXYGEN PROFILE ON SEPTEMBER 17, 1994.

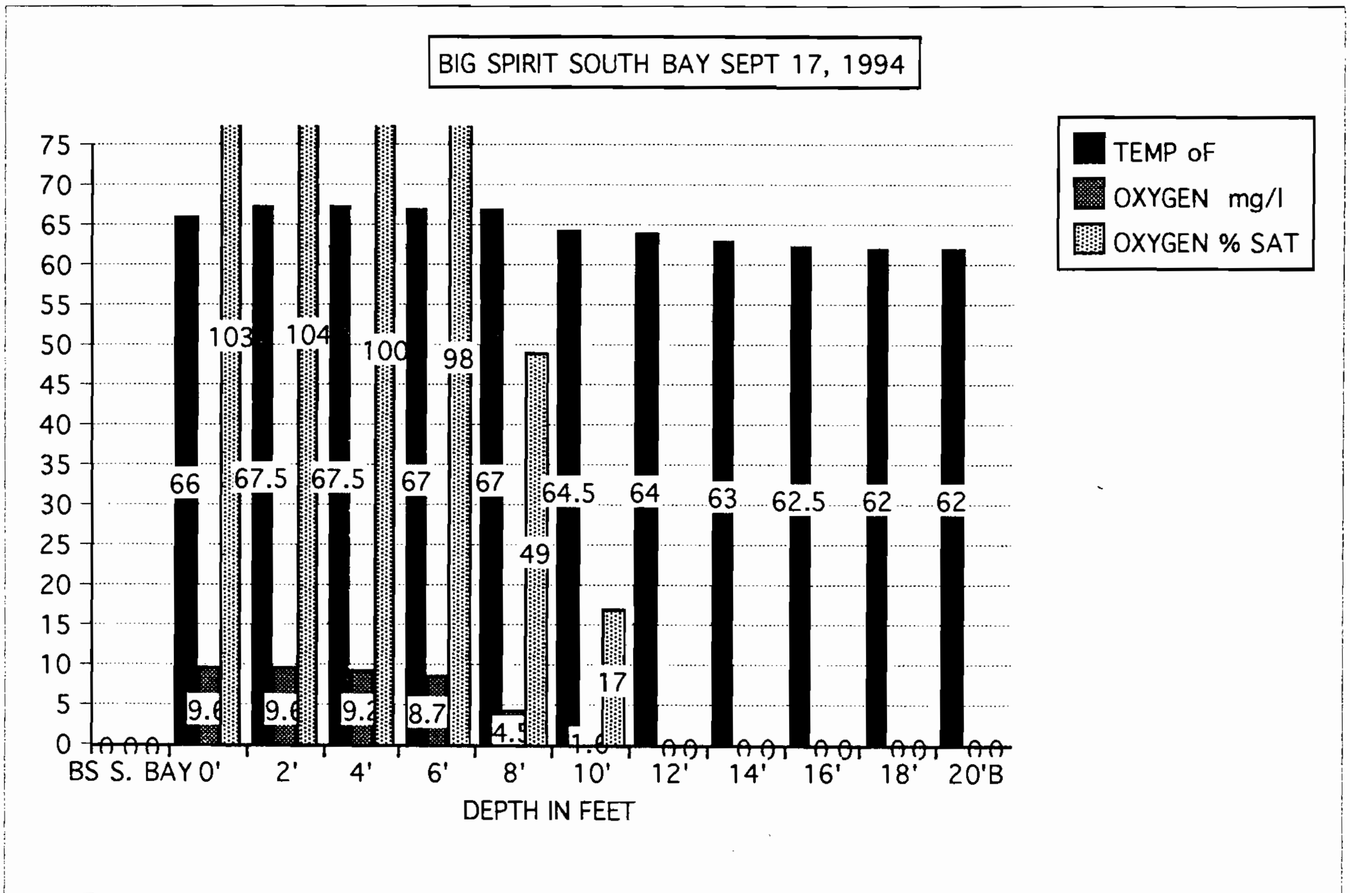
Sep 17, 1994 TEMP	oF	OXYGEN mg/l	OXYGEN %SAT	OTHER DATA:
BS NE BAY				-PHYTO PLANKTON BLOOM
0'	69	9.8	109	-SECCHI: 1.0'
2'	69	10	110	
4'	68.5	9.3	102	
6'	68	8.75	96	
8'	67.5	8.2	89	
10'	67	5.5	60	
12'	66	0.9	10	
14'	64.5	0	0	
16'	64	0	0	
18'	63	0	0	
20'B	62	0	0	



Seechi readings in the south bay were at 4'4" and in the NE bay were at 1'0". Winds changed from SW at 10-15 mph at 1:30 pm to NW at 5-10 mph at 2:30 when Big Spirit profiles and secchi disc readings were taken. It is these wind conditions that probably induced the difference in seechi profiles in these two locations as the south bay sampling was completed first, the NW bay second, and the NE bay last.

FIGURE 55. BIG SPIRIT SOUTH BAY OXYGEN - TEMPERATURE PROFILES ON SEPTEMBER 17, 1994.

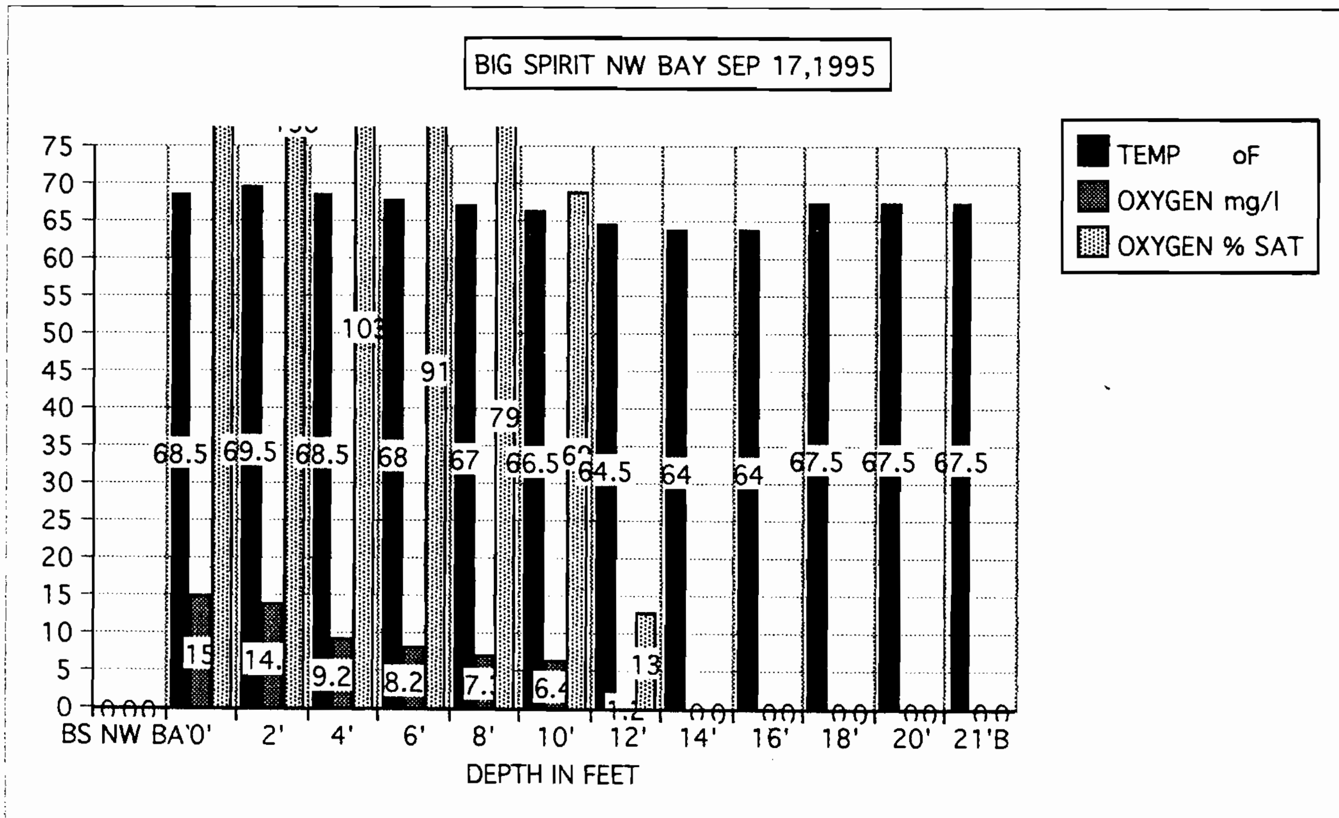
SEPT 17, 1994	TEMP oF	OXYGEN mg/l	OXYGEN % SAT	OTHER DATA:
BS S. BAY				SECCHI DISC 4'4"
0'	66	9.6	103	PHYTOPLANKTON BLOOM
2'	67.5	9.6	104	
4'	67.5	9.2	100	
6'	67	8.75	98	WEATHER:
8'	67	4.5	49	AM WIND SW 10-15, SUNNY
10'	64.5	1.6	17	PM WIND N -NW 5-10, CLOUDY
12'	64	0	0	
14'	63	0	0	FOR 7 DAYS PRIOR HOT HUMID DAYS
16'	62.5	0	0	THUNDER SHOWERS 9-14 THROUGH 9-16
18'	62	0	0	
20'B	62	0	0	



Conditions in the protected NW bay were somewhat different. this bay had supersaturated conditions caused by phytoplankton in the surface 3 feet with good oxygen conditions below the phtoplankton from 3 to 10 feet. Oxygen completely dissappeared below the 12' depth. Secchi depth was restricted to 2 feet at this location (Figure 56 below). This long narrow bay of North Spirit is protected from wind from nearly every direction- adjacent steep terrain and the south edge of Spirit Point protects most of this bay except winds from the NNW and SSE.

FIGURE 56. BIG SPIRIT NW BAY TEMPERATURE - OXYGEN PROFILE ON SEPTEMBER 17, 1994.

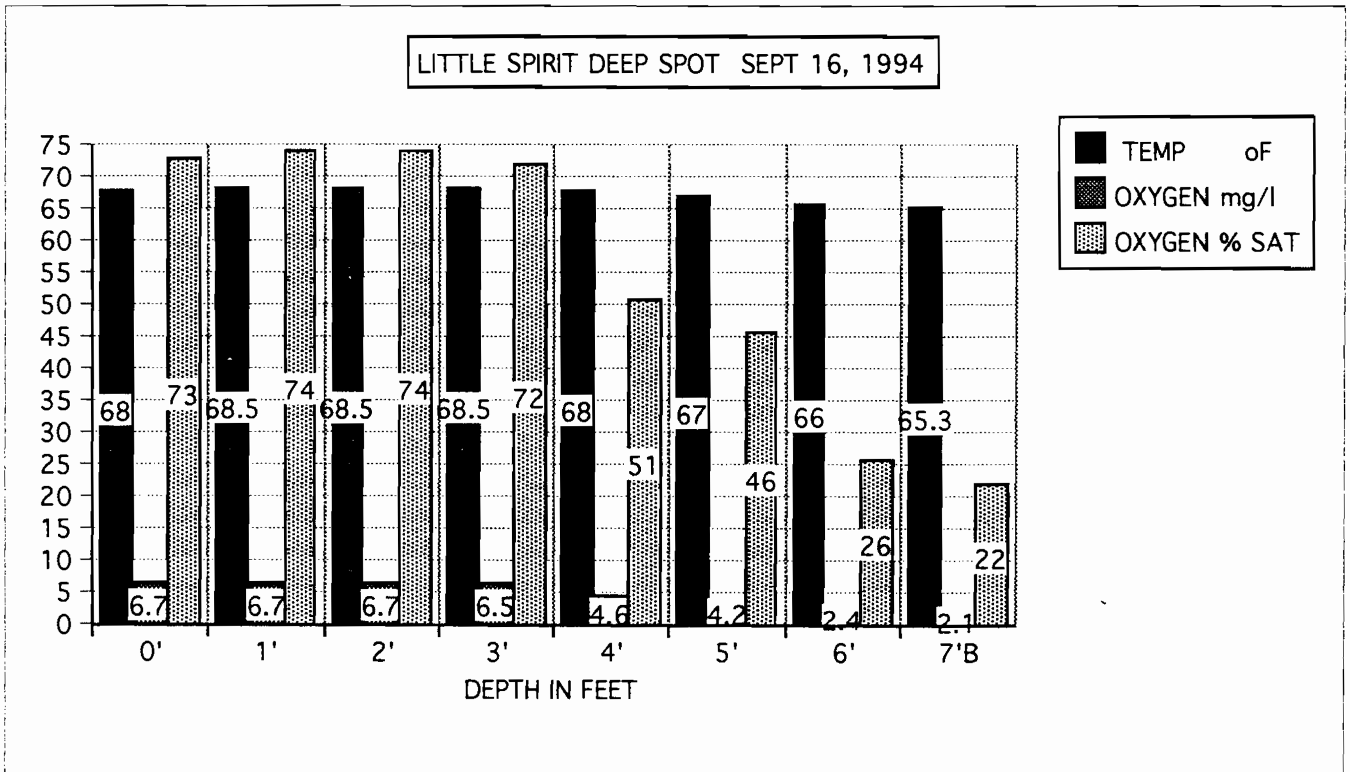
SEP 17,1995	TEMP oF	OXYGEN mg/l	OXYGEN % SAT	OTHER DATA:
BS NW BAY				-PHYTOPLANKTON BLOOM
0'	68.5	15	167	-SECCHI 2.0'
2'	69.5	14.1	158	
4'	68.5	9.25	103	
6'	68	8.25	91	
8'	67	7.3	79	
10'	66.5	6.4	69	
12'	64.5	1.2	13	
14'	64	0	0	
16'	64	0	0	
18'	67.5	0	0	
20'	67.5	0	0	
21'B	67.5	0	0	



In Little Spirit Lake and the tributaries water temperatures had warmed from two weeks prior. In Little Spirit\ oxygen levels dropped below the 5.0 mg/l level to 2.1 mg/l in 5 to 7 feet of water. Duckweed now appeared on the surface and coontail and the filamentous algae, <u>Hydrodicton,</u> were still present on the bottom. Secchi disc depth reading in Little Spirit was 3'11" corresponding to the depth where oxygen levels and temperatures began to decline. See Figure 57 below.

FIGURE 57. LITTLE SPIRIT LAKE AND N. TRIBUTARY TEMPERATURE-OXYGEN PROFILING ON SEPTEMBER 17, 1994.

SEPT 16, 1994	TEMP oF	OXYGEN mg/l	OXYGEN % SAT	OTHER DATA:
0'	68	6.7	73	SECCHI: 3'11", DUCKWEED SPARCE,COONTAIL
1'	68.5	6.7	74	& FILAM. ALGAE(HYDRODICTON) ON BOTTOM
2'	68.5	6.7	74	CHANNEL BETWEEN BIG & LITTLE SPIRIT 2':
3'	68.5	6.5	72	IN RIVER 100 YDS UPSTREAM IN CURRENT:
4'	68	4.6	51	TEMP 64oF, OXYGEN 3 mg/l
5'	67	4.2	46	W.OF RIVER BY BUOYS TEMP 66 oF,O2 7.5 mg/l
6'	66	2.4	26	MID CHANNEL E. OF RIVER:
7'B	65.3	2.1	22	TEMP 64 oF,O2 3 mg/l,DUCKWEED THICK



Observations of the north tributary stream as it entered the channel between two lakes wer made. It was during these observations that the wind shifted from SW to NW. Temperature and oxygen readings in the current approximately 100 yards north and upstream from connecting channels were 64 oF and 3.0 mg/l, respectively. The effects of flooded wetlands and oxygen demands from organic sediment washed from the recent rains in the stream above was evident. Oxygen and temperature readings west near the channel marker buoys were 66 oF and 7.5 mg/l. In the mid channel east of river the oxygen and temperatures were the same as the river 100 yarc upstream even with the presence of a strong west wind pushing water from North Spirit. Duckwe was thick among decaying pickerel plants on south side of the channel.

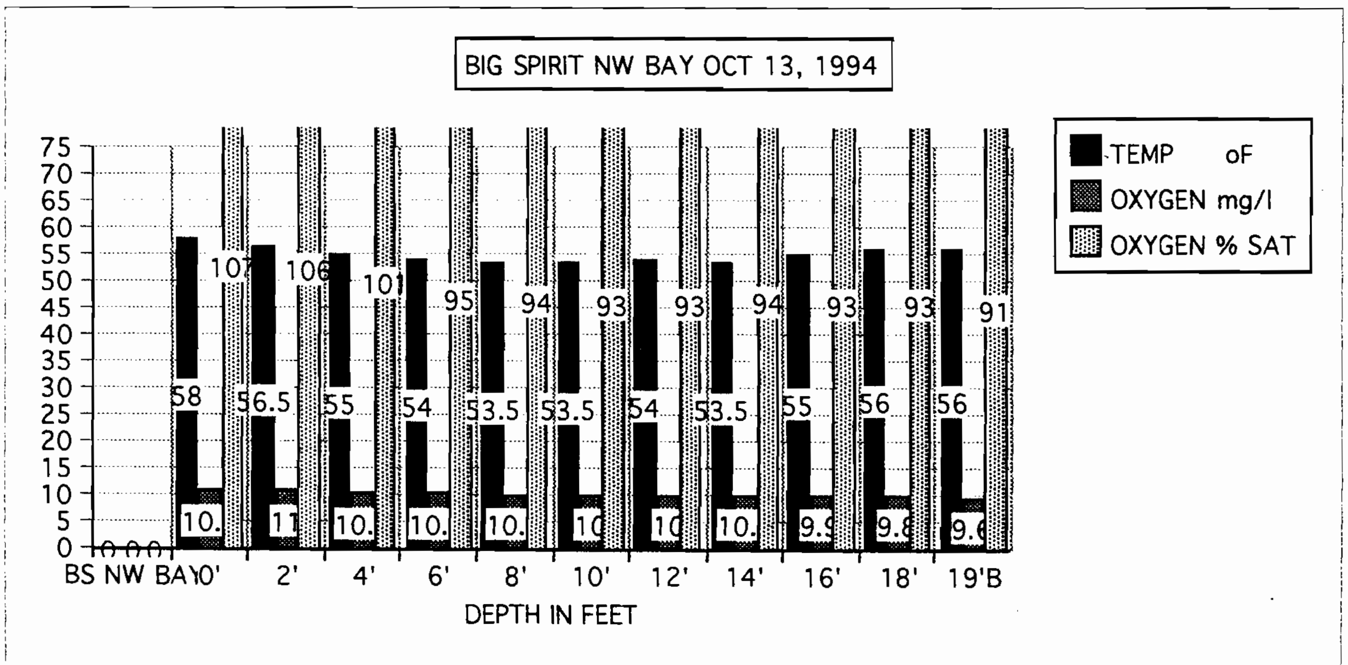
October 13, 1994 Fall turnover conditions were documented on this date. Five inches of rain had fallen since the first of October. Oxygen/ temperature profiles were made at all locations and water chemistry for nutrients and minerals in Little Spirit and the south bay of Big Spirit. The weather on the sampling date was sunny and calm with an air temperature of 54 oF.

In all bays of North Spirit temperatures from surface to the bottom were found to be in the mid 50 oF 's and oxygen was restored to the bottom sediments. There was variation in the fall mixing conditions from bay to bay. Phytoplankton was still blooming in the NW and NE bays but was not as thick or as noticable in the south bay. Chlor a was at 14.3 microgram/l in the south bay down from 39.0 on August 30. Secchi disc readings in all bay were at 3.6 feet.

In the NW bay surface waters were 3 oF warmer than the 3 feet below the surface. A layer of warm water was also found in the bottom 2-3 feet (See Figure 58). Oxygen was near saturation throughout the water column except slightly lower oxygens on the bottom. Was phytoplankton "raining" from the surface and warming bottom water temperatures?

FIGURE 58. BIG SPIRIT NW BAY TEMPERATURE - OXYGEN PROFILE ON OCTOBER 13, 1994.

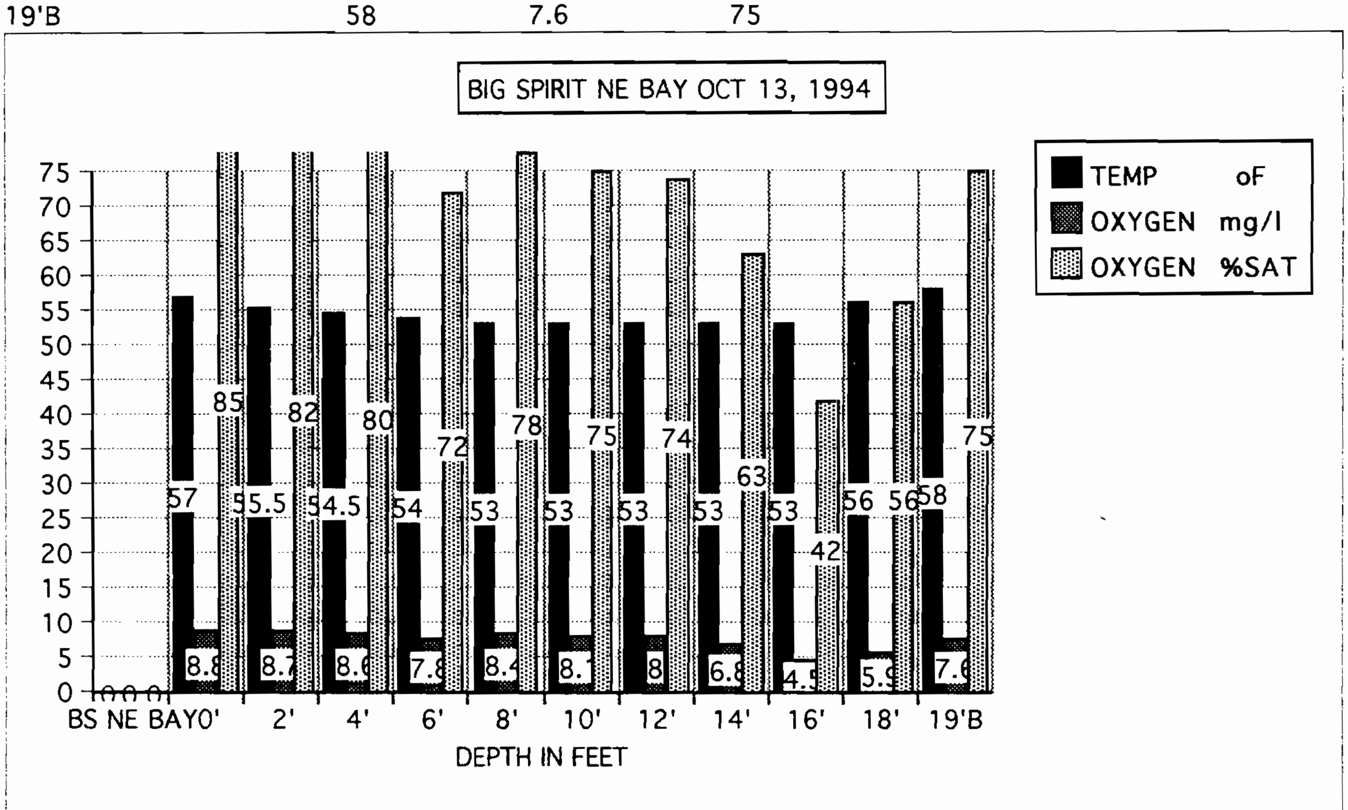
Oct 13, 1994	TEMP oF	OXYGEN mg/l	OXYGEN % SAT	OTHER DATA:
BS NW BAY				-PHYTOPLANKTON WINDROWED
0'	58	10.9	107	ON SHORE
2'	56.5	11	106	- SECCHI 4.6'
4'	55	10.6	101	
6'	54	10.3	95	
8'	53.5	10.2	94	
10'	53.5	10	93	
12'	54	10	93	
14'	53.5	10.1	94	
16'	55	9.9	93	
18'	56	9.8	93	
19'B	56	9.6	91	



In the NE bay surface waters were again 3 oF higher than water 3-4 feet below the surface (Figure 59). A layer of same temperature water was also found from 16' to the bottom which had lower oxygen levels than the cooler water immediately above it. There the bottom foot however was warmest and had higher oxygen levels. Again, periodic "raining" of phytoplankton would explain this.

FIGURE 59. BIG SPIRIT NE BAY TEMPERATURE - OXYGEN PROFILE ON OCTOBER 13, 1994.

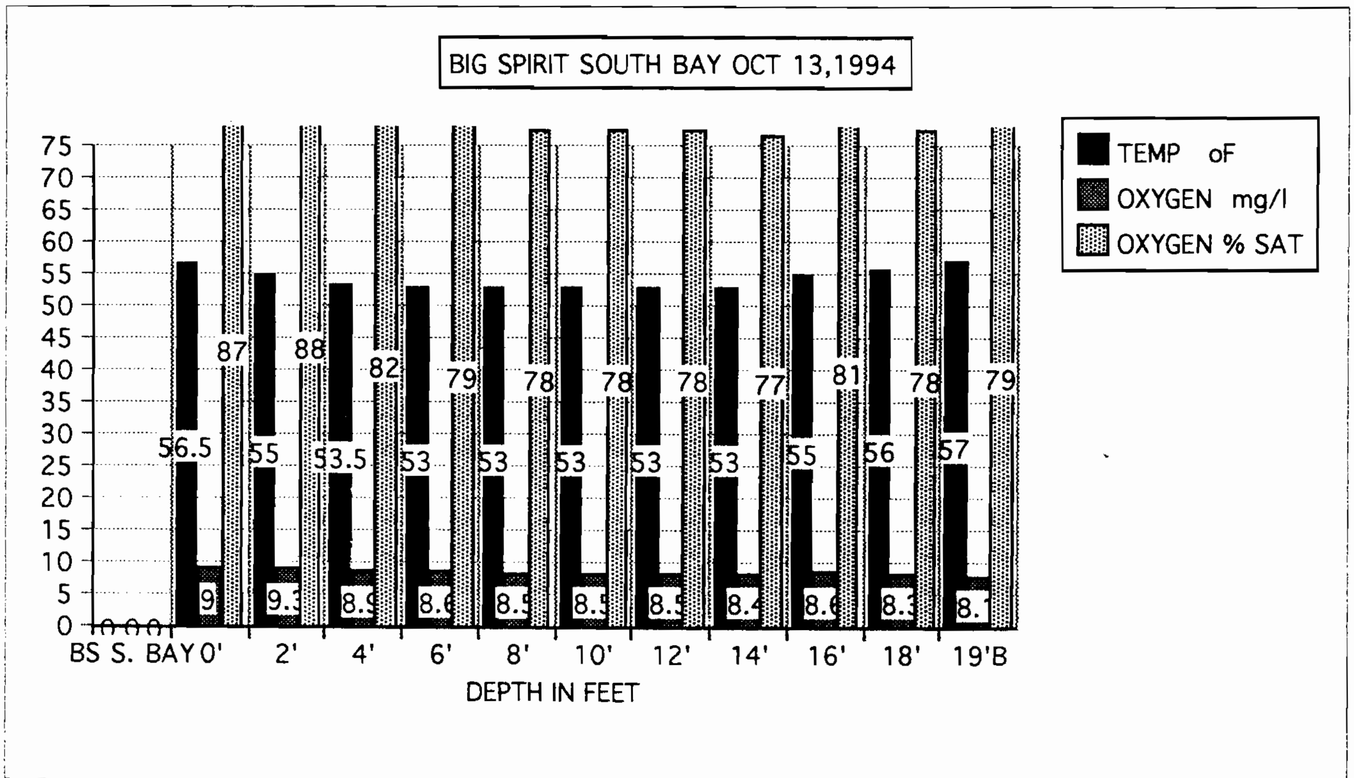
Oct 13, 1994	TEMP oF	OXYGEN mg/l	OXYGEN %SA	OTHER DATA:
BS NE BAY				-PHYTOPLANKTON THICK
0'	57	8.8	85	-SECCHI: 4.6'
2'	55.5	8.7	82	
4'	54.5	8.6	80	
6'	54	7.8	72	
8'	53	8.4	78	
10'	53	8.1	75	
12'	53	8	74	
14'	53	6.8	63	
16'	53	4.5	42	
18'	56	5.9	56	
19'B	58	7.6	75	



In the South bay the temperature stratification followed the same pattern as the NW and NE bays but surface waters were slightly cooler (Figure 60). The south bay is more exposed to the west and northwest winds and this would account for the cooler surface temperature alone; but phytoplankton concentrated at the surface also has the abiltily to retain heat. Fall turnover nutrient sampling was conducted at this site.

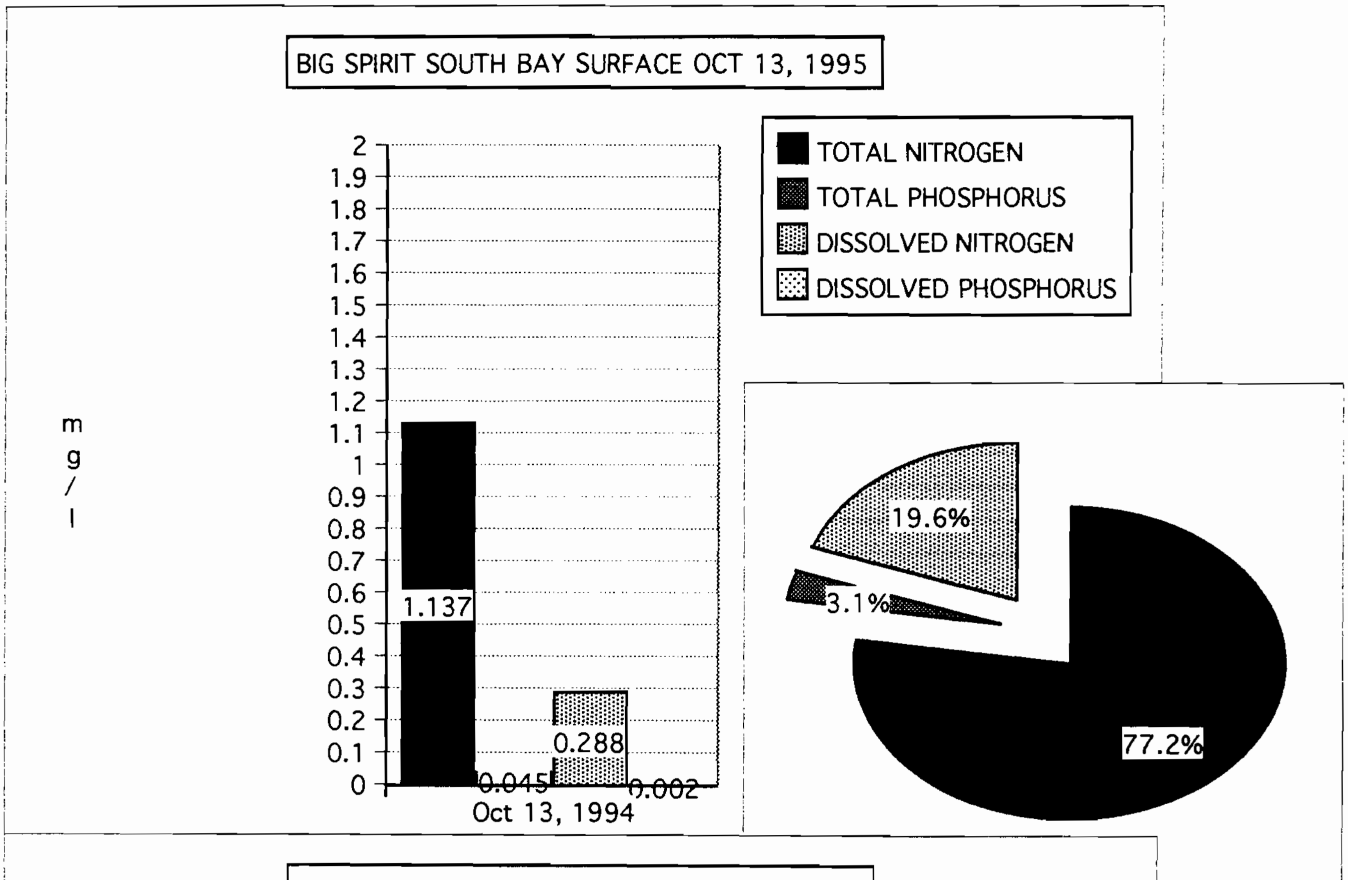
FIGURE 60. BIG SPIRIT SOUTH BAY OXYGEN - TEMPERATURE PROFILES ON OCTOBER 13, 1994.

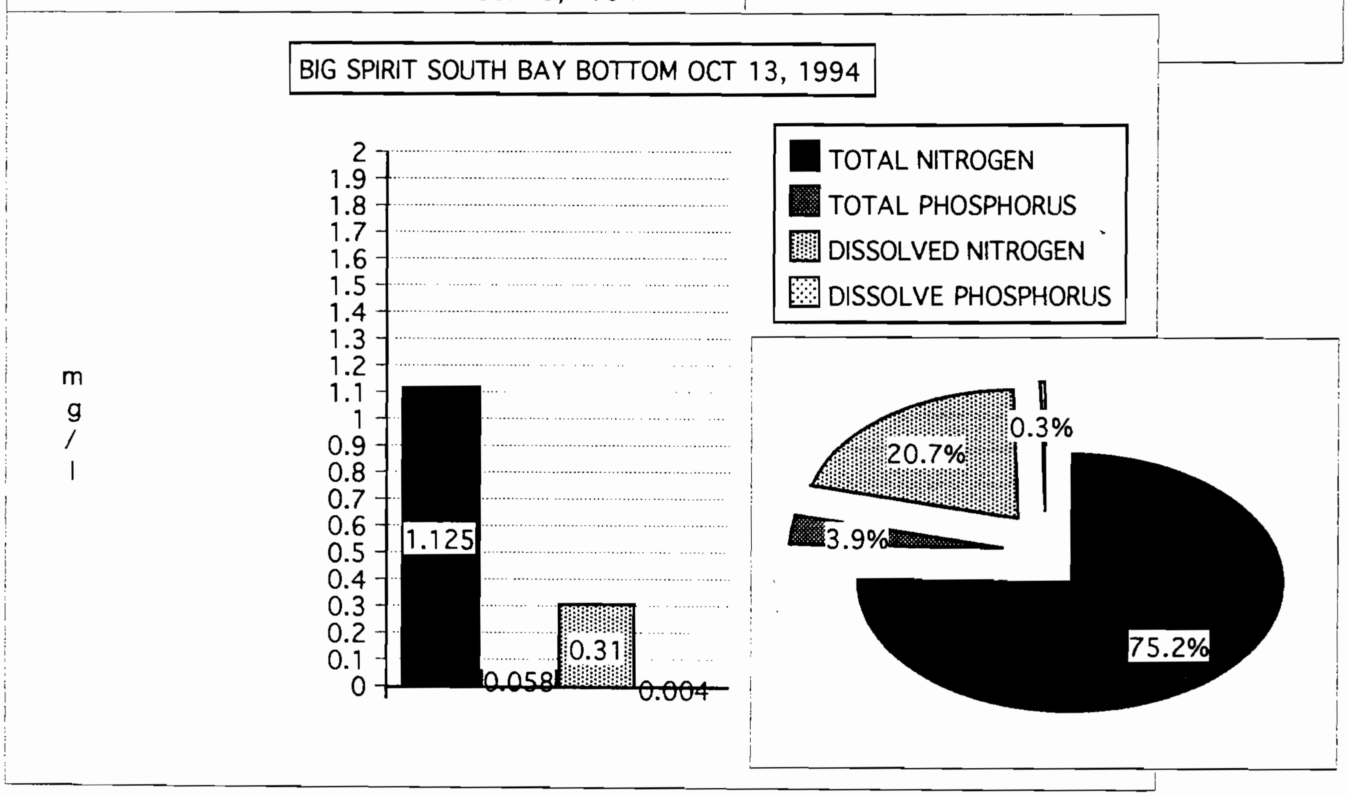
Oct 13, 1994	TEMP oF	OXYGEN mg/l	OXYGEN % SAT	OTHER DATA:
BS S. BAY				-SECCHI 4.6'
0'	56.5	9	87	-PLANKTON SAMPLED
2'	55	9.3	88	
4'	53.5	8.9	82	WEATHER:
6'	53	8.6	79	AIR TEMP 54oF
8'	53	8.5	78	WIND CALM
10'	53	8.5	78	SUNNY
12'	53	8.5	78	
14'	53	8.4	77	
16'	55	8.6	81	
18'	56	8.3	78	
19'B	57	8.1	79	



Total nitrogen and dissolved nitrogen at just below the surface and 2 feet off the bottom were comparible during this spring mixing the South bay of Big Spirit. See Figure61 below.

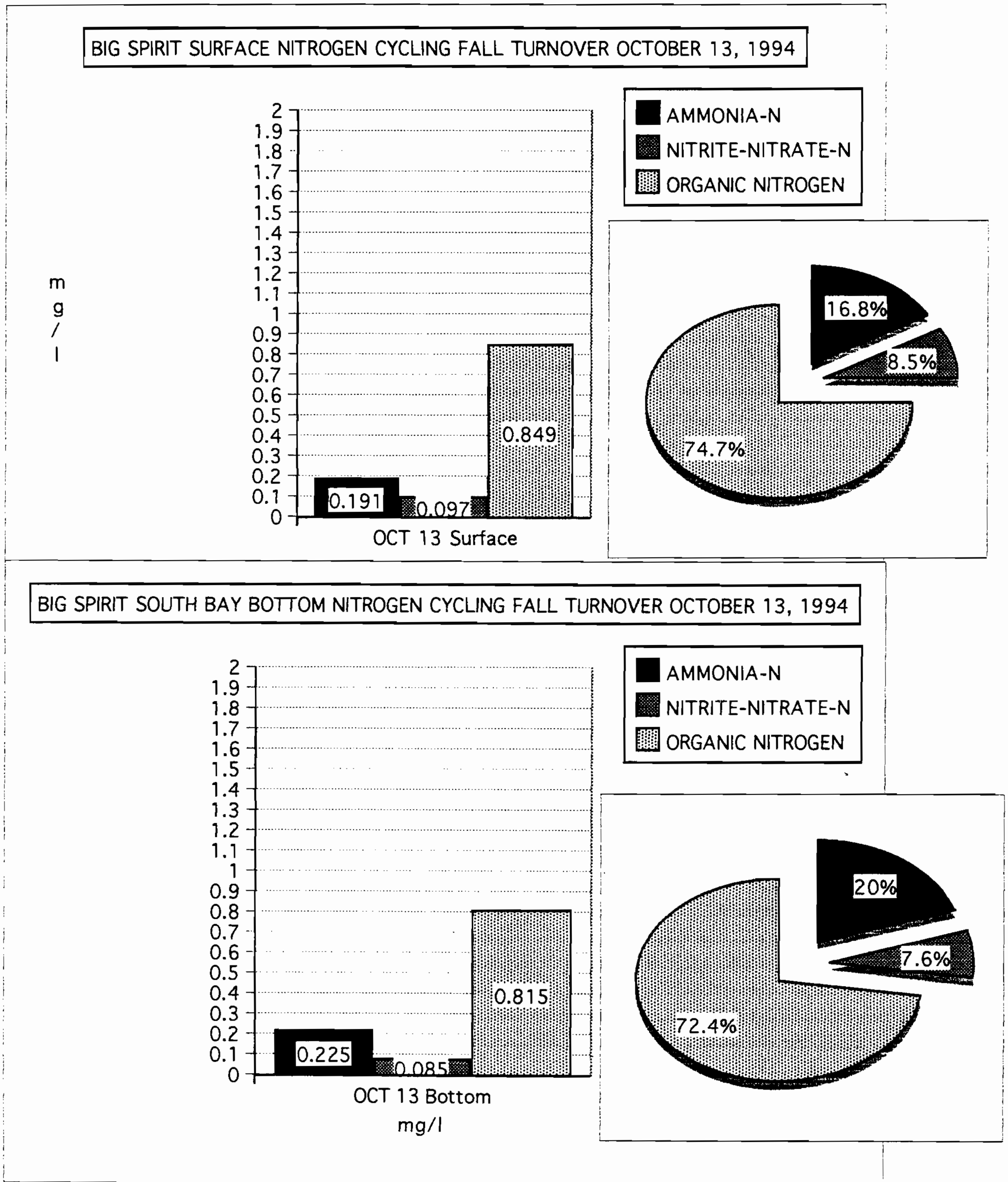
FIGURE 61. BIG SPIRIT SOUTH BAY NITROGEN PHOSPHORUS LEVELS ON OCTOBER 13, 1994.





A closer look reveals that most of the total nitrogen at the surface and bottom is in the form of organic nitrogen making up 72 to 74%. Ammonia nitrogen is second in concentration both at the surface and at the bottom with 17 to 2% of the total nitrogen.
Nitrite-nitrate-N has the lowest concentration at both the surface and bottom with 7.6-8.5% of the total nitrogen (Figure 52).

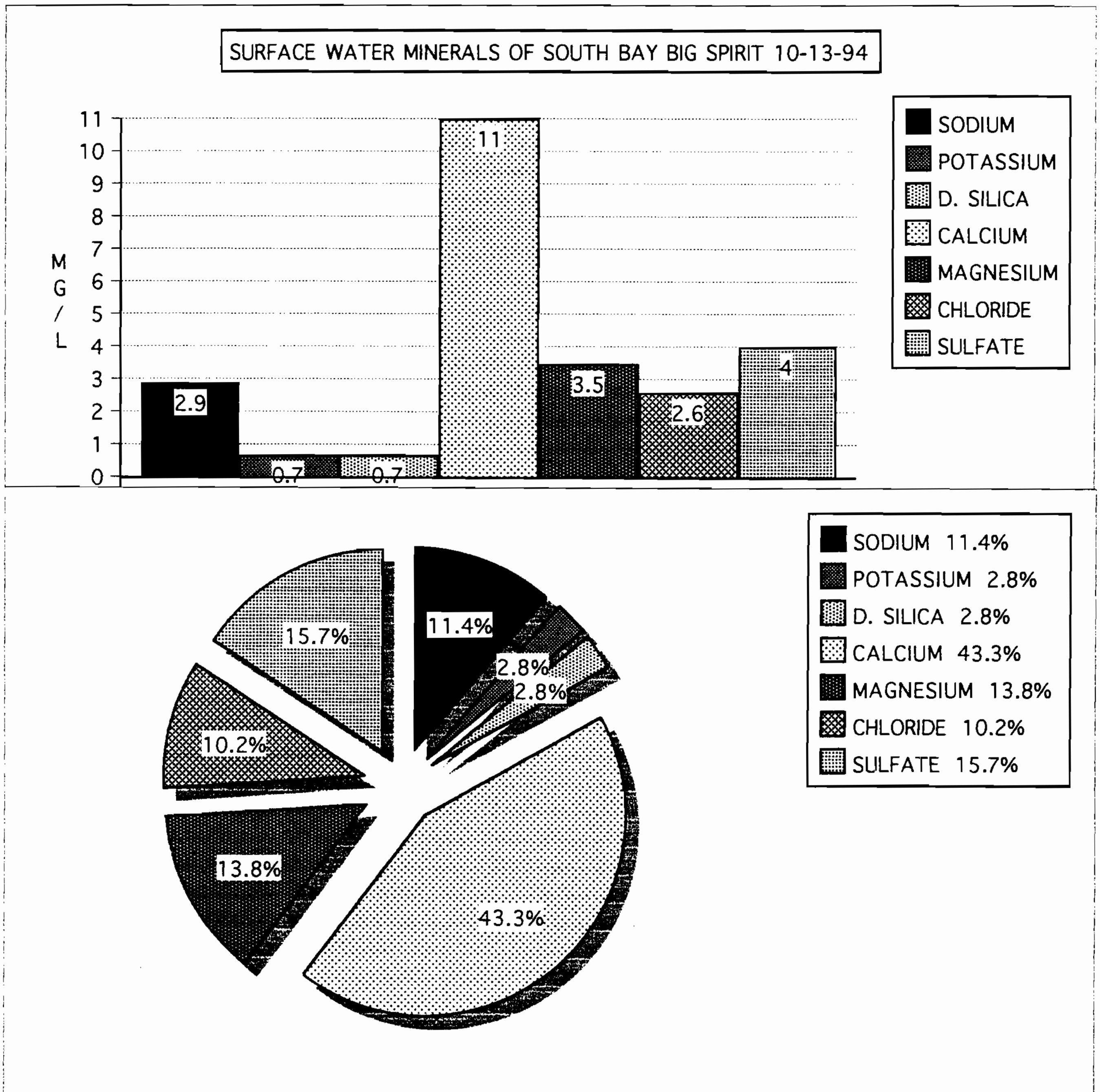
FIGURE 52. BIG SPIRIT SOUTH BAY NUTRIENT CYCLING ON OCT 13, 1994.



It is apparent that the lake is mixing well. Higher oxygen saturations and slightly higher temperatures at the surface are converting ammonia nitrogen to nitrite-nitrate-N than at the bottom.

Total phosphorus levels were slightly higher on the bottom than on surface. Little dissolved phosphorus was available either near the surface or near the bottom. The main biomass of organic nitrogen in North Spirit appears to be plankton that quickly decomposes in the presence of oxygen with the resulting inorganic forms quickly being recycled back into the algae. Mineral content in the South Bay was comparable at fall mixing to those found during spring mixing(Figure 63).

FIGURE 63. BIG SPIRIT SOUTH BAY MINERALS AT FALL TURNOVER ON OCTOBER 13, 1994.

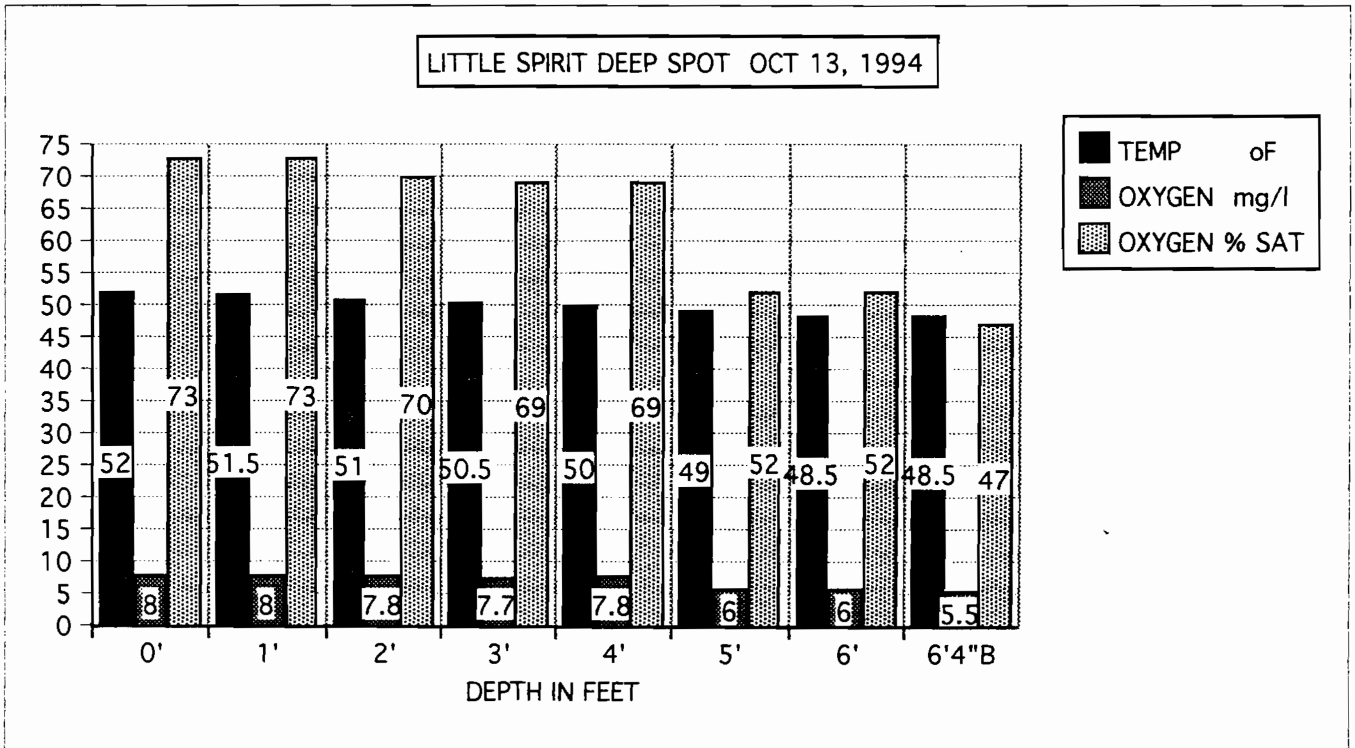


In Little Spirit surface water temperatures were at least 4 oF cooler than any surface water of North Spirit. Bottom temperatures were 6 oF cooler in Little Spirit than in North Spirit. Oxygen saturations in the surface 4 feet were near 70% but dropped to 50 % at depths below this (Figure 64). Secchi depth was at 3.6 feet and chlor a readings indicated phytoplankton activity was very low. Filamentous algae was now growing from the bottom. Oxygen in the north tributary appproximately 100 yards upstream of connecting channel was at 8.4 mg/l.

FIGURE 64. LITTLE SPIRIT OXYGEN - TEMPERATURE PROFILE ON OCTOBER 13, 1994.

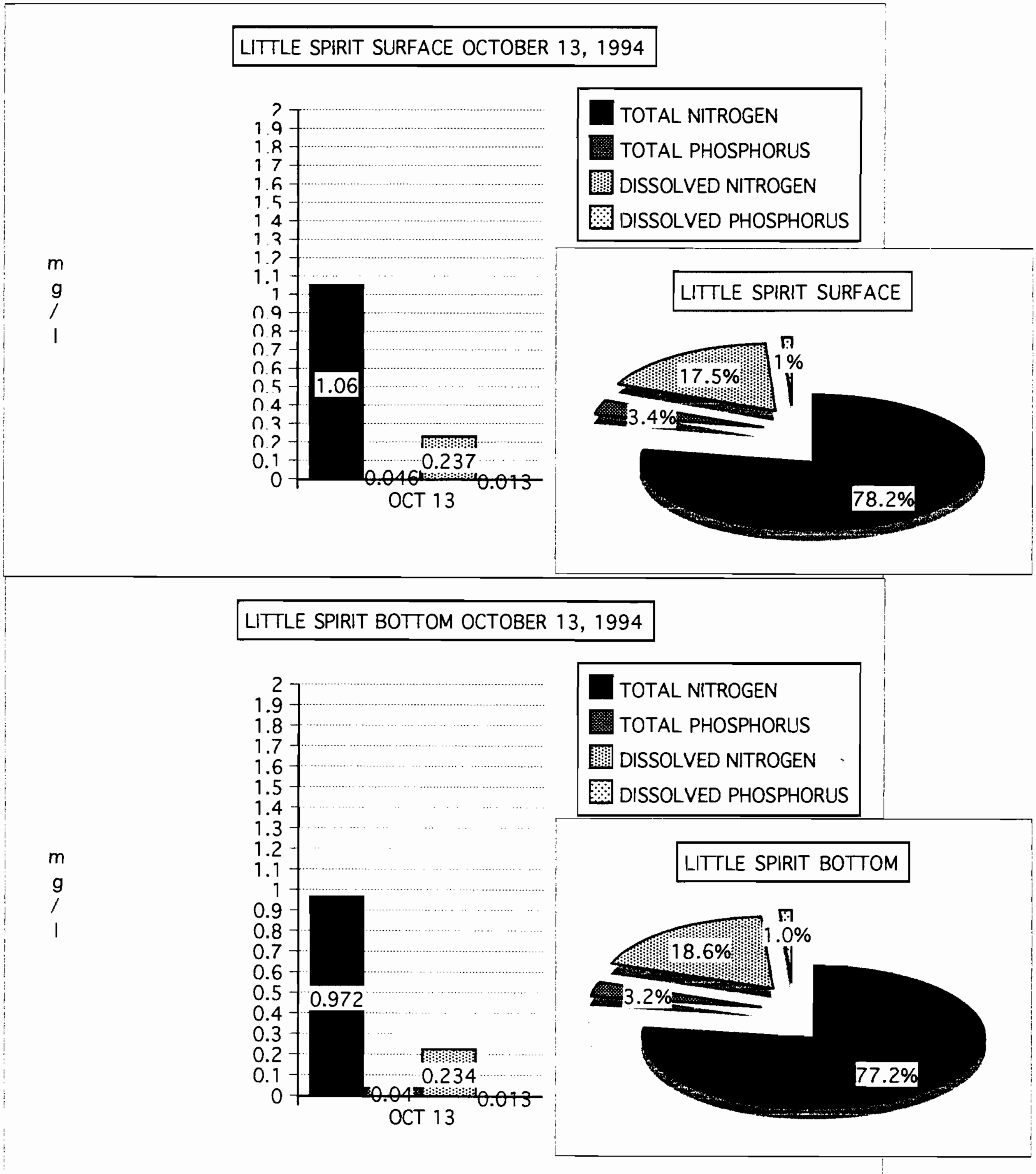
Oct 13, 1994	TEMP oF	OXYGEN mg/l	OXYGEN % SAT	OTHER DATA:
0'	52	8	73	SECCHI: 3'6", FILAMENTOUS ALGAE
1'	51.5	8	73	(HYDRODICTON)ON ANCHOR
2'	51	7.8	70	UNNAMED TRIBUTARY FROM STONE LAKE:
3'	50.5	7.7	69	100 YDS UPSTREAM IN CURRENT:
4'	50	7.8	69	AT 1' depth TEMP 50oF, OXYGEN 8.4 mg/l
5'	49	6	52	At 3' depth TEMP 48 oF, OXYGEN 8.4 MG/L
6'	48.5	6	52	WEATHER : SUNNY , CALM, 54oF
6'4"B	48.5	5.5	47	

SAMPLE LOCATION: DEEP SPOT



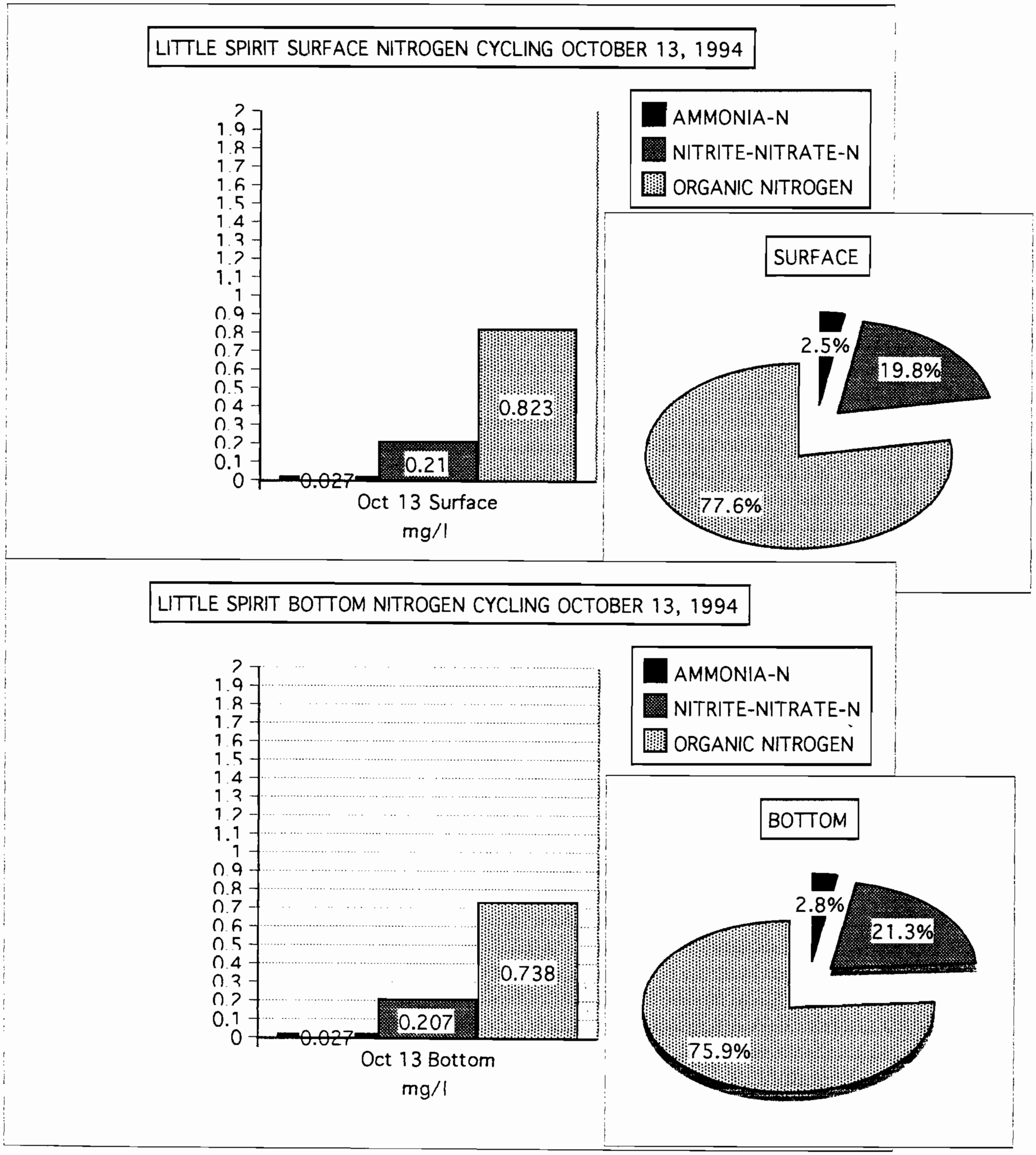
Nutrient sampling near the surface and two feet from the bottom indicated high but comparable levels of total and dissolved nitrogen at both the surface and bottom.
Dissolved phosphorus levels were at 13 micrograms/liter at both surface and near the bottom. Total phosphorus levels were also nearly the same at the surface and bottom (Figure 65).

FIGURE 65. LITTLE SPIRIT NITROGEN - PHOSPHORUS LEVELS ON OCTOBER 13, 1994.



Organic nitrogen, as in Big Spirit, made up most of the total nitrogen found. However, the organic nitrogen at the surface is not from plankton but from detritus carried by the current. Ammonia levels were low as it was quickly being converted to nitrite-nitrate by the oxygenated-moving water or utilized by the filamentous algae. Phosphorus was readily available for assimulation by the filamentous algae which grows well under cool water conditions. Organic sediments of plant matter and detritus were more evident in Little Spirit than Big Spirit (Figure 66).

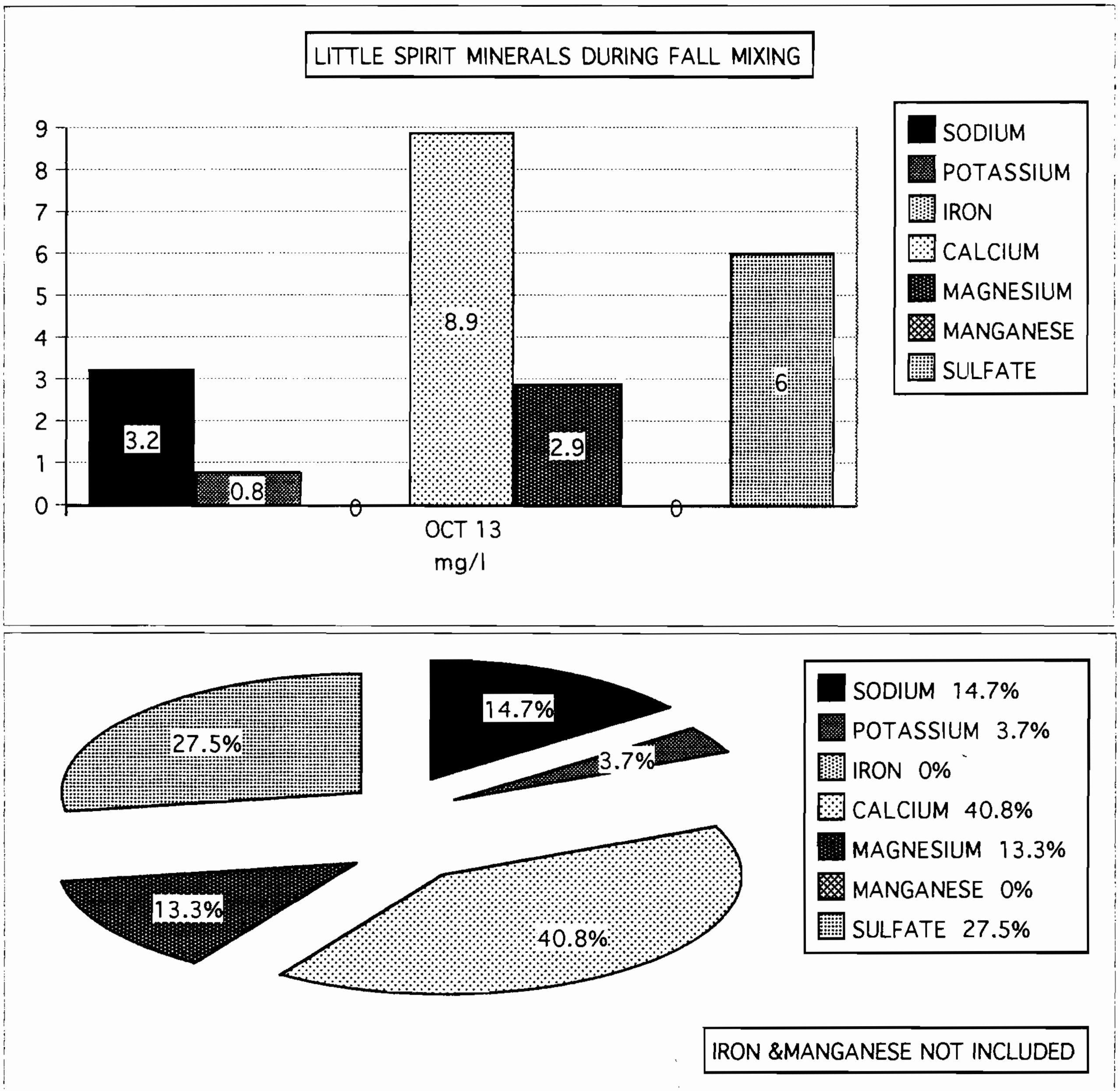
FIGURE 66. LITTLE SPIRIT NITROGEN CYCLING ON OCTOBER 13, 1994.



Fall mineral levels found in Little Spirit Lake were similar to those found during spring sampling except for an increase in calcium and a decrease in potassium (Figure 67). Potassium levels in Little Spirit were comparable to those found in Big Spirit.

Calcium levels in Little Spirit were found to be almost 13 times higher than that found in Big Spirit. Calcium entering Little Spirit from the larger watershed that drains into the North Tributary would provide more calcium to Little Spirit. A large clam population was also noted in Little Spirit. Clams need large amount of calcium for shell production and can provide a source for calcium storage and recycling of this important mineral.

FIGURE 67. LITTLE SPIRIT FALL MIXING MINERALS ON OCTOBER 13, 1994.



SECCHI DISC HISTORY INTERPRETATIONS

PROCEDURE

Secchi disc readings and corresponding observations of water color, water levels, presence of algae, and weather began in 1986 and have continued to the present day. The lake volunteers made excellent observations spanning the open water periods which has document changes in the lake from one year to the next.

A general graphic representation of these observations can be found in Appendix 1 & 2. The graphs found in the appendices combine secchi depth readings with water color observations. When algae was described it was placed in one of three categories: 1) green phytoplankton, small, 2) green phytoplankton, large, and 3) filamentous algae. These algae observation were then "stacked" in the graph with water color observations. When this "stacking" occurs the lowest "X" represents the observed secchi depth. Though secchi disc readings and observations are date specific the graphs depict a time frame of conditions from one observation to the next which enables easier interpretation of the observations.

The interpretation of these graphs that follows identifies general patterns of water color and clarity changes as well as algae succession. In general it also interprets weather effects on these patterns. In 1994, volunteer secchi disc readings were combined with the planning grant activities of the assessment of water quality described above for further interpretation and comparison to past years.

RESULTS AND DISCUSSION

Spirit Lake's water color and clarity are effected by the brown color associated with drainage through and from adjacent bogs. If there was no visible suspended matter or turbidity and high secchi reading the volunteer marked the "clear/blue"(BL on graphs). If there was a lower secchi disc reading due to the tannic acid coloration of the water without apparent suspended matter the volunteer marked "clear" and "brown" which is designated BL/BR on the graphs. If there was any type of algae activity that gave a green appearance to the water "green" was marked accompanied by a description of what was causing the green appearance. A "brown" designation noted suspended matter and turbidity (BR on the graphs).

BIG SPIRIT

1986 During this first year of observations the ice out date was not recorded. Both spring and fall water clarity readings depths from 4.5 to 8 feet were similar with no turbidity or suspended matter noted. Phytoplankton activity was noted from Jun 14 to September 22 with the lowest secchi disc reading occurring on July 28 and the highest on June 14 when the presence of algae was first noted. July 28, Sept, and October water level readings noted high water levels that would correspond to precipitation periods.

1987 Ice out occurred on April 15 and the first secchi disc reading on this date noted "Brown" appearance to the water with a low secchi disc reading of 2.5 feet indicating lake turnover after ice out. The May 5 reading recorded "clear/blue" with water levels being 2" low corresponding to little spring precipitation - the drought had begun. June and July observations noted the presence of both phytoplankton and filamentous algae with a secchi disc reading on Jun 15 of 6 feet and normal water levels. By July 21 the "bloom" had reduced secchi disc visibility to two feet with the same water level observation. By the end of August the algae had disappeared and water color was described as BL/BR with water clarity to 7 feet. Water on this date was again 2" low. By September 21 the water was now clear and BL with a secchi disc reading of 7.5 feet.

1988 Ice out was not recorded but four secchi disc readings from April 22 to June 9 indicated BL/BR water color with secchi disc readings varying from 4 to 10 feet. Water levels were observed to be normal during this period. As in 1987, from June 26 to August 8 phytoplankton and filamentous algae were present with secchi disc readings decreasing from 5 feet on June 26 to 2.5 feet on August 8. Water levels were recorded to be 1 to 2" low through this period. In September and October the water color cleared and secchi disc conditions extended to 10.5 feet. Nearly the same conditions were found on the lake during the dry years of 1987 and 1988.

1989 In this year ice out occurred on April 20. On April 27 and May 13 secchi depth clarity was still reduced by suspended organic matter to 3 to 3.5 feet. The aeration system continued to operate until the end of July in an attempt to reduce the algae problems of the last two summers. On July 20 secchi disc water clarity was at 3.5 feet from both filamentous and green algae. Rain had raised the water level about an inch.

On August 8 the filamentous algae was disappearing as the green algae bloom continued to give secchi readings of 3.75 feet. By August 24 rain again raised the water level and plankton that looked like"blades of grass" limited secchi disc readings to 3.75 feet. This "blade of grass" was probably the green algae, Ankistrodesmus, that was identified in the 1994 phytoplankton community during the entire season.

As fall approached filamentous algae matted on the surface and limited secchi disc water clarity to 2 feet on October 13 and 3.5 feet on November 11. Water was noted to be low on October 13 but returned to normal on November 11. The summer aeration and mixing appeared to sustain and intensify both the filamentous and phytoplankton bloom noted by lower and constant secchi disc readings. The injection type aerator was replaced with a compressor diffused system after this season.

1990 Ice out occurred on April 9. The three year drought was now ending and heavy rains often occurred throughout the year. On April 22 water levels were normal but water clarity was only at 4 feet from tannic coloration. Secchi depth improved to 10 feet on May 7 after rains raised the water level 2 inches - tannic acid still tinted the water color enough to be noted as Bl/BR. By May 23 small phytoplankton gave Big Spirit a green tinge with water clarity to 7 feet. Heavy rains in June raised the water level 6 inches with water clarity staying the same at 7 feet but without the algae but with the brown tannic color. By July 27, the water level returned to normal with small green phytoplankton appearing again but in heavier concentrations as secchi disc was limited to 4 feet. In August and September, heavy rains raised water levels, stopping the algae bloom, leaving the water brown with organic suspended matter and secchi disc depths of 4 feet on August 22 and 5 feet on October 2.

1991 Ice out occurred on April 7. A week later secchi disc readings were at 4 feet with organic matter giving the water a brown appearance. Water levels were only up slightly. By May 9 the water had cleared to 9 feet with light tannic water color. Warm weather in late May and early June lead to small phytoplankton appearing on June 4 giving a green tinge to the water and a secchi disc reading of 5 feet. Three weeks later on June 27 the phytoplankton tinge was now gone and the tannic brown tinge remained to keep secchi disc depth at 5 feet.

July brought rain showers and a 1" increase in water level. This was accompanied by the beginning of a phytoplankton bloom that was noted on July 23 with a secchi depth of 4 feet. This bloom again had the"short blades of grass algae", (Ankistrodesmus) that dominated the bloom in the summer of 1989 and 1994. The bloom continued through last secchi disc reading of 2.5 feet on October 19. Water was low at the August 22 observation date when the bloom was most intense with a secchi reading of 2 feet at noon. Water levels were normal in September and October as this Ankistrodesmus dominated phytoplankton bloom continued with low secchi disc readings. In both 1989 and in 1991 rain triggered the bloom with this dominating algae, but in 1989 this bloom was replaced by filamentous algae under the low water conditions in October. It was high water levels and rain that also accompanied the sustained phytoplankton bloom in the fall of 1994 but in this bloom Ankistrodesmus was partnered with several blue-green free- floating algae in the study. These same free-floating blue-green algae may or may not have been present in 1989 and 1991.

1992 The ice went out on the late date of April 25 precluding what became the "year without a summer". Air temperatures that summer were mainly in the 60's and seldom reached in to the 70's. This cool summer effected Spirit Lakes dramatically.

On May 18 the secchi disc visibility reading was at 6 feet and water was brown as 2" of rain fell the day before. On May 26 the water was clear to 8 feet and by Jun 5 water cleared to 8.5 feet. The water level was low on June 20 and secchi depth was reduced to 3.5' with organic matter and phytoplankton algae. Light rains began in late June with the water levels returning to normal .

Phytoplankton diminished on July 2 as water clarity increased to 5 feet and the suspended organic matter disappeared. Filamentous algae appeared briefly at this time but by July 16 a larger phytoplankton could be observed in the water but was described as clear BL with a secchi depth of 7 feet.

The phytoplankton increased slight by July 30 decreasing the water clarity by only one foot. August was dry but cool and cloudy and water levels dropped. On August 24 the water was clear to 7 feet. Light rain followed by a few sunny days at the beginning of September brought a minor phytoplankton pulse decreasing secchi depth to 6 feet. Cloudy weather and rain raised the water level on September 22 two inches and cleared the water of algae. Rain continued as winds moved to the NW in October. The last secchi disc reading of 8 feet was on October 15 with tannic brown staining of the water evident. The water level was 2" high. The lake was still open in the third week in November that year.

1993 Ice out as in 1992 was later- occurring on April 29. Heavy rains fell from May through July. Water color was described as clear / blue from April 8 to July 29. Secchi depths were 7 to 8 feet until July 29 when the reading fell to 6 feet.
By August 22 Big Spirit water level dropped and an algae bloom and high organic suspended solids reduced the secchi disc reading to 3 feet. Filamentous algae was combined with Ankistrodesmus and other large phytoplankton by September 15 to reduce the secchi depth to 5 feet. The bloom of large phytoplankton continued into late fall(Nov 15) after the lake turnover. The filamentous algae disappeared as the water levels returned to normal in October and November and as the phytoplankton bloom became more intense.

1994 Ice out occurred the third week of April. This was the year of the planning grant study, therefore, more secchi disc readings were taken to correspond to water chemistry and plankton sampling.

Spring rains in late April created high water levels on May 3 & 4. These high water levels corresponded to secchi clarity of 6 to 7.5 feet with clear blue water color. By May 25 the water level had returned to normal and algae was appearing in warm water shore areas and was giving a faint green color in deep water areas - water clarity was to 8 feet. By June 6 the first phytoplankton pulse was intensifying, decreasing secchi visibility to 6 feet as water levels appeared normal even with rain the day prior. A week later,on June 12, the first algae bloom was fading as secchi disc water clarity increased to 7.5 feet. Despite thunderstorms and rain the day before the water levels dropped. By June 21 and June 26 few phytoplankton could be seen and the tannic water color brown was evident as secchi clarity increased to 9.5 feet and 8.0 feet, respectively. This corresponded to low water levels.

On June 30, when plankton and water chemistry were sampled, a second phytoplankton pulse was starting as secchi disc disc in the South Bay dropped to 6.0 feet. Secchi disc reading in the NW Bay was at 7.0 feet and the phytoplankton appeared smaller. In the NE bay the secchi clarity dropped to 5.0 feet and the plankton were small as noted in the NW bay. By July 5 the water levels were still low. Warm temperatures brought thundershowers in night and the morning of sampling. Phytoplankton decreased secchi clarity to 5.5 feet. By July 14 a major algae bloom was underway dropping secchi disc visibility to 2.5 feet. This intense bloom remained through July 26. Multiply thundershowers in mid July raised the low water levels of July 14 to normal levels on July 24. This pulse of the phytoplankton bloom lessen the first two week in August as secchi disc clarity increased to 4 feet on August 6 and 5 feet on August 15.

On August 30 a third increase in phytoplankton was occurring and secchi disc readings dropped to 4.5 feet. During water chemistry sampling diatoms were found near the bottom and a cool rain shower had occurred that morning. Plankton sampling indicated a blue-green algae was now codominating the phytoplankton community with the " blades of grass" green algae, Ankistrodesmus. Water levels had increased the week before.

A hot, humid, weather pattern with no wind followed and a spot check on September 9 found the third bloom to reduce secchi transparency to 3.0 feet. Phytoplankton was accumulating in the near shore areas. Thundershowers began occurring in the weeks to follow as this weather pattern continued. Secchi disc clarity was found to be 3 to 4 feet on September 17 .

Weather began to cool as winds switched to the NW. By October 13 the lake had turned over and the bloom was winding down increasing secchi clarity to 4.5 to 5.5 feet. Plankton was found dying and wind rowing on the down wind shoreline. Ice cover the lake on November 23.

1995 Ice out occurred on April 17. The first secchi observation on May 11 found the lake color brown and a water clarity of 6.0 feet. Water level was found to be normal and spring winds were light out of the NW. A week later on May 17 water was still brown in color and with a light NW wind as secchi disc clarity increased to 6.5 feet. One half inch of rain two days prior did not raise water levels above normal.

Air and water temperatures increased and after a weekend of rain phytoplankton created a green tinge in the water with secchi disc transparency to 8.5 feet on June 1. By June 8, after continued spring rains the phytoplankton bloom decreased secchi depth to 7 feet. By June 17 the phytoplankton was blooming reducing secchi depth to 5.75 feet. Water levels were now below normal.

The aeration system was started about this time to try to dispel the phytoplankton bloom. By June 24 filamentous algae was found floating at surface of aeration mixing plume. Rain fell on June 25 and the June 26 secchi reading decreased to 5 feet as the phytoplankton bloom continued. Water levels were still below normal. On July 7 the aeration system was turned off at noon and secchi transparency was still at 5.0 feet at 3:OO pm. Water level was still below normal.

The next secchi disc observation was made on August 31. Water transparency was only 4.0 feet and the water was with plankton despite $.5 inches of rain that had fallen in the previous week. Water levels was now high and air temperatures were now cooling. On September 17 water level returned to normal and algae was blooming decreasing secchi visibility to 3.5 feet.

A month later , on October 15, the bloom was over and very little phytoplankton was visible in water. Fall rains, cool NW winds, cooled the water and raised the water level to above normal. Organic suspended particles and tannic acid coloring limited secchi depth to 3.5 feet. On November 4 - five days before freeze up on November 9- no algae could be seen as water clarity increased to 5 feet but tannic brown water color under high water conditions were still present.

Little Spirit

1988 Ice out occurred on April 9 and the secchi disc reading on April 10 was 4.5 feet but did not hit bottom. Water color was indicated as being clear. The next secchi disc reading on April 23 also had a 4.5 foot reading but the water color was now brown indicating suspended organic matter from spring rains and runoff. Water clarity decreased somewhat in May as tannic acid contributed to a darker water color as water levels dropped. By the end of May water became brown again reducing the secchi clarity to 3.5 feet again.

On June 15 phytoplankton could be seen in the water with suspended organic matter reducing the secchi disc reading to 2 feet. This bloom corresponded with low water levels and followed two weeks of warm weather. By June 27 the phytoplankton bloom turned the water green reducing the water clarity to 1.5 feet as the water remained low. Phytoplankton and filamentous algae at this same time were reducing water clarity to 5 feet in Big Spirit Lake.

By July 3 the algae changed to include blue-green and filamentous algae. The blue-green algae, Spirulina , was described as well as the green algae, Ankistrodesmus. A slime mass near shore that was purple was also described. This was probably one of the following blue-green algae: Nostic, Anaebaena, or Aphanizomen. This algae bloom included filamentous algae near shore. Secchi disc clarity from July 3 through the 21 was 1.5 feet. This drought year produced little rain in July and water levels remained low.

On August 9, after a few rains, the water level rose 2" and water color changed to a green- brown. Filamentous algae was observed near the shoreline and the secchi disc water clarity increased to 2.5 feet. By September 1 some algae still could be seen but the water was now brown with organic matter from runoff limiting secchi disc clarity to 3 feet.

By September 15 the weather began to cool and fall rains kept the water brown and limited light penetration to 2.5 feet. At this time in Big Spirit the water was clear with excellent secchi disc readings. Organic matter was entering Little Spirit from the North Tributary.

These conditions were still present on October 6 as rains kept the lake level above normal, the water was still brown, but water clarity increased to 4 feet. By October 15 the water cleared to 5 feet but the bottom could not be seen because of the organic matter suspended.

By November 9 the water clarity increased to 6 feet and the bottom could be seen. Ice appeared on October 30 prior to this reading but was off by November 9 when the secchi disc sampling occurred.

1989 Ice out occurred on April 22, two days after Big Spirit. Secchi disc readings were 3.5 feet on April 26 and 4 feet on May 13. In Big Spirit the water clarity was nearly the same on April 27 and May 3 with the aeration system running. The water was described as brown but clear but the bottom could not be observed.
On May 26, after a 4" rain the day before, the secchi disc reading was at 4 feet with brown/clear water color. Secchi clarity dropped to 3.5 feet a week later on June 2 and to 3.0 feet by June 20 as the water was still clear for recreational enjoyment but described as brown.

By July 3 hot weather brought the beginning of an algae bloom. Secchi water clarity dropped to 2.0 feet but water color was described as brown. By July 13 phytoplankton was wind rowing near shore with filamentous algae appearing in other near shore areas. By July 28 the phytoplankton bloom increased further reducing water clarity y to 1.75 feet. Filamentous and other blue-green algae grew thick and formed large masses on the shoreline surface. Rain occurred between July 13 and 28 raising water levels. The same phytoplankton and filamentous algae blooms were occurring in Big Spirit south bay where the aeration system was operating.

Little changed from the July 28 reading until September 12. The water remained green with algae and water clarity dropped to 1.25 feet on August 12, 1.75 feet on September 1, and 1.9 feet on September 12. Rain in mid August had raised water levels. Secchi disc readings during this same period in Big Spirit Lake were 3.5 feet and the same algae blooms were occurring there. The September 12 observation included the presence of a "green scum" on the water which was probably the same filamentous algae that was matting big Spirit.

On September 29 the water clarity increased to 2.5 feet and the water was described as brown but not quite clear. By October 11, thick filamentous algae returned under low water levels but the water color was described as brown. Just as all year- the bottom could not be seen.

On October 25 and November 3 with the water low the water cleared to its tannic brown; and the bottom could be seen at 6.1 and 7 feet, respectively.

1990 Heavy rains occurred throughout the open water period of 1990. On April 17 and 24 secchi water clarity was at 3.5 and 3 feet , respectively. Water color was brown and organic matter near the bottom prevented the secchi disc from being observed on the bottom. Weather was warm and breezy on April 17 and warm and windy on April 24. Very little rain fell near these dates and water levels were normal. April 22 secchi disc reading in Big Spirit was 4 feet from tannic acid tinting of the water.

Heavy rains fell the first week of May which raised the water levels 2 inches. On May 13 the water clarity was described as cloudy brown in Little Spirit and the secchi reading was 4 feet. On May 31 the water was described as brown and secchi depth was 3.75 feet. During this same period, Big Spirit water cleared after the rains and was followed by a plankton pulse on May 23. No plankton pulse was described on Little Spirit.

Heavy rains in June brought high water levels to both lakes. Big Spirit water cleared while Little Spirit secchi disc readings dropped to 3.0 feet on June 15 and 2.75 on June 27. Water was described as brown during this time but on June 27 algae was now appearing dropping the recreational enjoyment to level 3.

In July the water level returned to normal and a phytoplankton restricted secchi clarity to 1.5 feet on July 23. This same bloom reduced secchi depth to 4 feet in big Spirit on July 27.

August and September brought heavy rains and raised water levels on the Spirit Lakes. By August 27 the green of Little Spirit was brown with organic sediment and secchi dropped to 2.0 feet. By September 12 water levels were very high and suspended organic matter combined with phytoplankton to reduce secchi depth to 2.5 feet. On September 21 algae was disappearing suspended organic matter limited secchi depth to two feet.

October brought more rain and continued high water levels. The water cleared of organic matter but a deep tannic color gave the water a brown color. Secchi disc readings on October 12 and 23 were 3.5 feet and 3.35 feet, respectively.

1991 April brought spring shower runoff that suspended organic matter and combined with a tannic brown tinge to limited secchi clarity to 3.5 feet on April 20 and 3.0 feet on May 3. The water stayed brown but secchi reading improved to 4.0 feet in May. Water clarity also increased in Big Spirit in May. On May 28, even with 1 1/8 inch of rain the night before the secchi clarity was at 4 feet, but a week later on June 3 the secchi depth dropped to 3.25.

By June 18 the water was still brown but a plankton bloom was starting and secchi depth dropped to 2 feet. By June 28 the water was brown with suspended organic matter with filamentous algae floating on the surface. A rain shower occurred in the afternoon on this date. Was it this rain shower that triggered the phytoplankton blooms that followed?

In July the open water phytoplankton contained the "blades of grass plankton", Ankistrodesmus, and filamentous algae was thick near shore. Secchi disc transparency was now at 1.75 feet on July 9. This condition continued through September 10 with secchi disc readings ranging from 1.75 to 2.25 feet. This bloom continued - just as it did in Big Spirit - through the last secchi disc reading on October 30. Organic matter gave a brown color to the water through this entire period. Water levels were normal during the period. Duckweed appeared on the September 23 observations apparently as a result of the heavy organic load suspended in the water.

1992 A late ice-off occurred on April 28, three days after Big Spirit. This year is known as the " year without summer" as temperatures seldom got above 70 oF as cloudy skies and rain dominated the open water periods.

Rains and high river flows through Little Spirit increased summer secchi depths in absence of any major algae blooms. The small algae pulse that occurred in Big Spirit in late July corresponded to the only phytoplankton noted in Little Spirit the entire year.

Secchi disc depth when ice still covered two thirds of Little Spirit was 4.5 feet on April 23. A week after ice out the secchi visibility dropped to 3.5 feet. During both of the above samplings the water color was described as brown and the secchi disc did not touch bottom. On May 17 after 2" of rain the water cleared and the secchi clarity improved to 4.0 feet. By May 29 the secchi depth decreased slightly to 3.75 feet. At this time filamentous algae appeared near the shoreline.

On June 9 the water clarity dropped to 3 feet and by June 27 a phytoplankton pulse was observed. Rain accompanied this plankton pulse and water clarity increased to 4.0 feet. Rain continued into July as water clarity increased to 5 feet on July 11. On July 28 rain fell overnight and NW winds apparently suspended sediments reducing secchi disc clarity to 3.0 feet.

In August and early September the cool weather, clouds, and wind limited secchi visibility to 2-2 1/2 feet. September rains cleared the lake as secchi depths increased to 5 feet on September 9 and 5.5 feet on September 21.

In October and November despite NW winds secchi readings increased even further. Secchi depths of 6 or 7 feet were recorded three times in October. On November 11 the secchi disc depth was on the lake bottom at 7 feet. This occurred after a thin sheet of ice covered the lake on November 7, the aeration system was turned on November 8, and the thin ice layer melted on November 10.

1993 Time of ice-out on Little Spirit was not recorded was not recorded but Big Spirit ice out was on April 29, two days before the first secchi reading on May 1. This was the second year in a row of late ice-out. It was also the second year of heavy rainfall from May thru July.

The May 1 secchi disc clarity was 4.0 feet under cloudy,rainy, 48 oF air temperatures. Water was tannic brown stained but clear of organic suspension. As the May rains continued water conditions were found the same on May 23 with identical secchi and color. Weather conditions were also similar except air temperature was now 60 oF. By June 14 secchi depth was still at 4.0 feet and water color had not changed and lake was approximately 2" high.

On June 22 after 2.5 inches of rain the secchi reading dropped to 3.0 feet and water levels were noted to be 12" high. By July 8 there were no changes in secchi but light rain and wind continued as the lakes dropped to normal water levels. On July 27 Little Spirit's secchi depth increased to 4 feet with normal water levels and sunny conditions.

Finally, on August 16 a green phytoplankton pulse was noted with a 3.0 foot secchi disc reading. Water color was noted as brown in Little Spirit. In Big Spirit during the entire month of August suspended organic matter and a phytoplankton bloom limited secchi disc to the 3 feet. On August 16 filamentous algae appeared in Little and Big Spirit. Secchi disc clarity dropped 1.75 feet and water levels were recorded as being 2" low.

The sunny and warm weather continued into September as blue-green algae and free-floating phytoplankton bloomed in both lakes. This month's water levels were recorded as being at normal levels. Secchi disc transparency on September 6th & 12th were at 2.5 feet in Little Spirit.

In late September the secchi reading depths in Little Spirit increased to 5.5 feet as the phytoplankton and filamentous algae disappeared with the cool fall weather. By October 6 Little Spirit cleared even further and the secchi disc hit bottom and could be seen at 8 feet.

By October 31 the tannic stained-tinged water was clear enough to find the secchi disc in 8.25 feet of water. A thin layer of ice was forming near shore and the channel between the two lakes had a half inch of ice. The aeration system in Little Spirit was started on November 1.

Big Spirit during this same time continued it's bloom of large phytoplankton well into November after fall turnover. Secchi disc readings were at 4.0 feet in October and November.

1994 This was the year of the lake planning study, therefore, secchi disc readings were completed more often. These extra observations were combined with water chemistry and phytoplankton sampling.

Little Spirit's ice was half out on April 17 about the time when Big Spirit's ice out was noted. Total ice-out did not occur until April 19. Water color was brown with tannic stain but clear with the ice half off and on April 26. Secchi depths on both dates were 3.5 feet.

On May 6 the water level was recorded as high and there was a corresponding organic loading that darkened the clear brown water color. At the same time secchi clarity increased to 4.5 feet. Water clarity also increased in Big Spirit but the water color was noted as clear and blue.

Late May brought unseasonably warm weather and by May 26 the first phytoplankton pulse was beginning in Little Spirit and secchi depth decreased to 4 feet. This same pulse timing was noted on Big Spirit.

On June 7 the water clarity of Little Spirit increased to 5.5 feet after rain the day before. Rain was recorded again on June 12 as hot days were creating thundershowers. On June 16 the secchi transparency dropped to 4.0 feet as phytoplankton could be seen in the water. The small phytoplankton pulse continued into mid June in both lakes; but began to decline as water levels dropped and the water color darkened. Secchi disc transparencies decreased in Little Spirit and increased in Big Spirit in Late June as the this first pulse ended in both lakes.

Early July brought rain dampening the algae in Little Spirit as a major plankton pulse was occurring in Big Spirit. June 29 and July 6&8 secchi disc readings were all at 4.0 in Little Spirit. On July 11 and July 25 secchi disc reading in Little Spirit decreased to 3.5 feet in Little Spirit with light phytoplankton. In Big Spirit the plankton was much thicker with small phytoplankton. Water levels were normal with no recorded precipitation in late July.

In early August the phytoplankton decreased in Little Spirit as secchi disc clarity increased to 4.0 feet on August 3 and 4.5 feet on August 15. Water levels were normal as the phytoplankton decreased in Little Spirit. A corresponding decrease in phytoplankton and increase in secchi transparency occurred in Big Spirit. Then in late August - under hot and humid conditions - the water level dropped and a blue-green phytoplankton bloom began a strong third pulse. The water clarity was reduced to 2 .0 feet by the plankton on August 26 but rebounded to 3.0 feet two days later on August 30 as the water level on the lake was raised on August 27.

By the first week in September the blue-green free floating phytoplankton in Little Spirit was diminishing and secchi depths increased t 5 feet on the 5th and 7th of September. Hot humid weather at the same time continued the bloom on Big Spirit Lake.

On September 14 the hot humid weather broke with a 3" rain storm increasing water levels. Secchi disc transparency increased to 6 feet after the rain as the water color was brown but clear. Fall rains kept up with water color changing to a deep dark brown color. Secchi transparency at the same time dropped to 3 to 3.5 feet during the rainy period that lasted from September 14 to October 12.

On October 19 the water level had dropped and secchi depths increased to 4.0 feet. In Big Spirit Lake fall turnover had occurred and the blue-green phytoplankton bloom was winding down as the water cooled. The water color in Little Spirit Lake remained deep dark brown until freeze up. Secchi transparency increased from 4 feet on October 27 to 4.5 feet on November 3 & 8. On November 15 - the last secchi reading was 5 feet.

1995 Ice-off occurred on April 20 with an east wind blowing at 10-20 mph. The water was tannic brown but clear to 4.5 feet. Big Spirit ice-off was 3 days prior on April 17. On April 27 the secchi reading dropped to 4 feet with a NW wind blowing at 20 mph.

By May 9 there was very little change in the secchi depth as it increased to 4.5 feet but the water turned to a darker brown. Wind was now blowing out of the southeast. By March 19 the secchi visibility dropped to 4 feet again with the wind blowing out of the NW at 10-20 mph. The wind had been blowing from the NW for 5 days. The water color was still dark brown. Only two inches of rain had fallen since ice-out and the weather had remained cool and windy during this this first month .

On May 28 rain was falling but secchi depth increased to 4.5 feet with a SW wind blowing at 20 mph. Rain continued the next few days bringing warm weather and an increase in water levels on June 1. On this date the first plankton pulse of the year was evident on Big Spirit and but it was not apparent Little Spirit . Little Spirit did notice a change in water quality but secchi disc remained at 4.5 feet and water was noted as tannic stained brown. The change was probably from rain runoff entering from the North tributary.

Rain and cool weather followed the week after June 1. Water levels rose and the water cleared. The Secchi depth increased to 5 feet by June 12 with water quality slightly degraded by suspended matter. The weather then cleared, temperatures warmed, and water levels dropped to below normal. This spurred an algae pulse on Little Spirit on June 16 - two weeks after Big Spirit. Air temperatures increased to the 90's and aquatic plants began to appear on the lake. Even with increasing phytoplankton and the water color turning green the secchi disc clarity reached 5.5 feet on June 23. The presence of plants appeared to be improving water clarity.

By July 2 the plankton bloom intensified decreasing the secchi disc reading to 1.5 feet. On July 5 as south winds and hot weather prevailed and secchi depth was still at 1.5 feet. Rain came on July 6 bringing cool weather that day; but warm and sunny weather followed the next two weeks. Secchi clarity on July 14 was 2 feet with a west wind and dropped back to 1.5 feet on July 29 with a NW wind.

August brought many rain and raised water levels. The plankton bloom continued but water clarity improved to 2 feet on August 3 and 2.5 feet on August 11 and 17th. On August 17 some filamentous algae could be seen near shore and water color changed from green to brown. During the last week in August 4.5 inches of rain was recorded. By August 27 the water levels increased further, secchi depth increased to 2.75 feet, and the water remained brown in color. The phytoplankton bloom had ended.

During September temperatures cooled, more rain fell the first two weeks, and water levels were high during this period. Water color remained brown though secchi clarity improved from 2.0 feet on September 3, to 3 feet on the 15th. As water levels returned to normal secchi depth increased to 3.75 feet on the September 25th and 4.0 feet on October 4. On this date filamentous algae was observed in shallow water again but the water color remained brown as it had been all month.

Heavy rains then began to fall in October. Five inches of rain fell by October 13 raising water levels and dropping water clarity to 3.0 feet . More rain fell the last two weeks of October as temperatures dropped from the 60's to the 30's. Secchi depths increased to 3.75 feet on October 23 and 4.0 feet on October 28 and water levels remained high. In Big Spirit the phytoplankton bloom had ended some time before October 15.

CONCLUSIONS & RECOMMENDATIONS

BACKGROUND

Summer algae blooms can be traced back to 1972 and corresponded to winter kill and freezeouts that occurred in 1970,72, and 73. The summer algae blooms eventually shaded out the submerged vegetation that was still abundant in 1978.

Secchi disc observations from 1986 to the present have told us alot about the intensity, timing, and climatic conditions that effect the algae blooms. The focus of this planning grant study was to understand the complicated relationships of the lake and watershed ecosystems that caused the initial algae bloom and those that continue to effect the lake.

The 1994-95 study of the Spirit Lakes and it's watershed resource evaluation was extremely important in evaluating the problems associated with the algae blooms. Basically the secchi disc history combined with this study tells us - depending on the weather -various forms of algae can cause problems in either lake from late May to November.

Filamentous algae(slimy,stringy, and glob forming)) in Big Spirit was a problem mainly in the drought-low water years of 1987 and 88 and when the aerator was ran most of the summer in 1989. This algae was a problem in Little Spirit those same years. It is also a problem in Little Spirit during heavy rainfall & cool conditions that increase water clarity and wash an abundance of organic matter through the lake.

Blue-green algae(free-floating & big) - using 1994 sampling as a basis and comparing it with other secchi disc observations - is generally associated with both lakes later in the summer into fall. It is at this time the secchi disc clarity is ussually the lowest and these free-floating algae begin windrowing on the shorelines causing more problems.

The green algae and diatoms(the GOOD algae) dominate the early and mid summer phytoplankton community. These usually smaller phytoplankton can be eaten by a large list of aquatic animals more readily than the above forms of algae. It is the cropping of this algae that is one component in reducing the phytoplankton bloom problems.

The abundance of all of these algae are now causing problems with the health of the Spirit Lakes. Especially in Big Spirit where the "rain" of plankton the last 100 years has combined with organic material released from the flooded bogs at the end of each bay to accumulate bottom muck. This bottom muck has nutrient compounds and bacteria that use up oxygen that is needed by the all water born, air breathing animals.

By March of each year the oxygen demand by the bacteria,sediment, and air breathing animals utilize most of the available oxygen under the ice in Big and Little Spirt except where aeration and river or spring flows add oxygen. A few weeks after spring mixing the oxygen demand begins to increase again as the water warms the bottom and typically by mid June low or no oxygen is found below 10 feet in Big Spirit and near the bottom in Little Spirit (depending on the weather it could be earlier or later).

On the surface the algae use the dissolved nutrients to grow, reproduce, and eventually cause blooms. They produce oxygen when the sunshines or provides light; but at night and during heavy cloud cover the algae use up the oxygen they produce. In addition these blooms shade out bottom substate areas that could produce attached plants that are more stable and healthy for the lake.

At times, as on September 9, 1994 when hot humid still conditions lasted for days, algae produces too much oxygen in the surface3 feet. Oxygen demand from the bottom extended to within 6 feet of the surface leaving only a narrow layer of water adequate to support aquatic animals - ideal conditions for summer kill.

This layer of water at present keeps most bottom nutrients from reaching the surface and feeding the algae found there during the growing season (generallyJune to August). The nutrients at the surface are recycled (and added to by rain and runnoff) from one algae to the next all summer . This is evident from 1994 sampling and secchi disc observations that included water levels and rain recordings.

The goals of the following recommendations are either to utilize excess algae (and nutrients) or prevent these nutrients from reaching the algae.

FISH & AQUATIC RESTORATION

In review of the resource data that is available on the circumstances that lead up to the first algae blooms of the early 1970's several factors probably played an important role in the change of the lake. The series of winter fish kills started a chain of events that have lead to where we are today. Several winterkills this close together can cause high mortality of larger aquatic organisms from game fish to minnows, from snails to clams, from crayfish to aquatic insect larval. Smaller insect larva and many of the other aquatic invertebrates listed above may recover within a year or two but the fish species from gamefish to minnows may take decades. This is evident in the effort that has gone into fish stocking and the current results.

This stocking - except for the 1970 muskellunge stocking of fry and postlarval largemouth bass in 1990 - has centered around gamefish of large enough size that plankton are not important in the diets of these fish when stocked(See Stocking Records- Page 14 & 15).

The size of game fish stocked in the past and at present are dependent on the food organisms such as minnows, clams, crayfish, snails, and aquatic insects. Are these fish predators keeping prey population of these animals at such low levels they cannot themselves fully utilize the algae available.

These fish and panfish now produce offspring that utilize zooplankton as an important part of their diet each spring and summer. Are these young of the year fish over cropping the zooplankton that feed on the algae?

The above listed aquatic animals that are dominant in game and panfish diets are the lake community residents that feed directlly and indirectly on the algae that causes the algae blooms. Most of these aquatic animals need well-oxygenated bottom habitat to survive and reproduce.

This habitat is limited during the growing season and under the ice in the Spirit Lakes as documented by the 1994 oxygen-temperature profiles. Build up of dying and decaying algae as it windrows in shallow wave-aerated shorelines further decreases the available habitat for these organisms.

<u>Recommendation #1</u> Habitat suspended off the bottom such as brush and aquatic plants that are important for minnows,clams,crayfish, snails, and aquatic insects are also limited in both lakes especially in Big Spirit. This suspended substrate is also important for floating yellow perch egg ribbons to attach to avoid falling to the bottom and suffocating. Young perch, because of their slender body form are favorate prey of the game and large panfish. Increases in their population would also take predator pressure off plankton and algae feeding minnows and other organisms.

The placement of **brush bundles** at summer oxygenated water depths (5-10 feet) in North Spirit would provide cover, food substrate, and predator cover for these organisms. Securing these bundles at these depths will avoid navigation conflicts. In Little Spirit a few bundles could be placed in the deep water holes but it's shallow depth limits safe placement locations.

Currently phytoplankton blooms limit light penetration that is necessary for submergent aquatic plant growth in Big Spirit Lake. Sand and gravel substrate combined with wind and wave action also limit suitable substrate for plant growth. **Wild Celery** is an excellent plant for surviving on sandy moderately wind and wave swept shorelines.

Planting of several thousand of these plants roots in selective areas for several years should eventually establish a population. Wild celery reproduces by seed and by a rhizome root system. These roots are loved by muskrats and ducks so this must be considered when planting them. Wild Celery could utilize the detritus that is now building up from the windrowing decaying algae.

<u>Recommendation #2</u> Increasing the **forage minnow base** in the Spirit Lakes is also a sound strategy in solving the algae bloom problem. Six minnow species have been listed during various fish surveys over the past thirty years.

How were the population of these species affected by the several winter kill in the early 1970's? If several of these species were lost in the series of fish kills the Lower Spirit Dam and upstream beaver dams(or a plunge pool below an improperly placed or maintained culvert) would limit recruitment and population establishment of these species. Many of these species migrate to river habitat to spawn- these obstuctions would also limit this ability. Three of the minnows listed host larva of clams on their gills - if these species were lost by the winter fish kills did we loose these clam species that filter plankton too.

Currently game and panfish populations are thriving and reproducing in both Spirit Lakes. What predator pressures are these abundant levels of fish placing on the forage minnow base under the above conditions?

The stocking of minnows should be considered at this time. The preferred species that should be stocked in the **northern redbelly dace**. This minnow is an exclusive plant eater that feeds on algae and decomposing algae and other plant ooze. Other minnows feed on zooplankton that in return feed on the algae and diatoms. These minnows make good bait but are not a commonly available from minnow dealers. If a supply of these minnows can be found they should be stocked not only in the lake but possibly stocked and reared if possible in several areas ponds whether connected or not connected by rivers and streams to the Spirit Lakes. This minnow may also be abundant in these pond already as their preferred habitat is detritus filled beaver ponds, bog ponds, and small lakes that are tannic stained - these water bodies are abundant in the Spirit Lake watershed to the North. This minnow also spawns on mats of filamentus algae. An intial lake stocking should be completed in spring or early summer to utilize the initial green algae pulse and provide first year spawning opportunities.

Another forage minnow that is also native to the Spirit Lakes that should be the second choice to stock or raise would be the **common shiner**. This minnow is a running water spawner that also hybridizes with the northern redbelly dace above. It feeds on both plant and animal matter.

All other native minnows that can be trapped below or above the present fish barriers should be stocked to compensate for recruitment and reproduction lost because of these barriers. Removal of these barriers, if possible, would be even be more beneficial to the lakes.

Option #1. Phosphorus and other nutrients released and recycling from bottom sediments at spring turnover provides algae at the surface with the it's need elements for growth and reproduction. Phosphorus inactivation is a technique to achieve long-term control of phosphorus release from lake sediments by adding as much aluminum sulfate(alum) to the lake as safely possible.

This procedure has proven to be highly effective and long-lasting in thermally stratified lakes as in North Spirit. Successful treatment could last 5 to 10 years. This could greatly increase transparency and improve conditions for submerged aqautic palnt growth that was previously found in the lake. A potential negative impact is a considerable drop in pH as the alkalinity levels in Big Spirit that would buffer this drop are borderline adequate. Application would have to be closely monitored and possible buffers would be needed to be added to prevent the pH drop. Cost could be prohibitive on all of Spirit Lake and one bay treatment such as the NE bay that is isolated might be feasible but at the same time limit the effectiveness.

WATERSHED RESTORATION & PROTECTION

The watershed of the Spirit Lakes at the present time is fairly undeveloped and protected by relatively undisturbed terrain. Nutrient imputs from rainfall and seepage effect both of the lakes plankton community. Little Spirit small retention time and stream flow inputs from a large watershed can change water quality fairly quickly when flows are adequate. North Spirit is effected more by seepage and groundwater water flows. Nutrients or fresh water entering theNorth Spirit are slowed by adjacent unflooded wetlands or filtering by the effects of perculated soil. It's large volume to surface acre ratio protects it from sudden changes induced but heavy rains.

The steep terrain combined with light soils that surrounding the Spirit Lakes increases the erodibility of the soils without a canopy or ground cover. Any shoreline development, road building, or septic fields on this terrain will release soil nutrients or human waste substances to the lakes.

Recommendation #3 At the present there are only about 24 dwelling on the Big Spirit shoreline and development is sparce. Shoreline development on Little Spirit is more limited by the number of building sites available as much of the shoreline is already developed. The lake association should encourage enforcement of county shoreline and residential zoning restrictions and/or create more stringent local shoreline development ordinances to protect water quality and aesthetics of the shoreline. These can be done through town ordinances or by the creation of a legal lake district if developmental pressures on the shoreline or steep adjacent hillsides develops. Owners of existing private sewage systems should be informed of the proper maintainence and service they require as well as explained the effects of failed systems on water quality.

Water quality of the Spirit Lakes is effected by the organic nutrients that wash from organic and peat soils that have developed over thousands of years in watershed wetlands and drainage ways. Many of these nutrients are normally "tied up" in a peat and sphagnum moss materials and their oxygen devoided bog environments that inactivate these nutrients. Beaver dams or other structures that constrict or channel normal or storm water event flows can raise water elevations or direct flows through these bog areas and release these stored nutrients and suspended organic matter to the stream and eventually to the Spirit Lakes. This is quite evident in the water quality changes in Little Spirit during spring runnoff and heavy or sustained rains.

Recommendation #4 An evaluation of watershed drainageways for beaver activity that floods peat soils should be periodically completed. Flooded impoundments can raise water temperatures of the stream, reduce oxygen levels, and increase dissolved nutrients of the impounded stream. Evaporation rates increase leaving less water in the stream. All these factors can effect algae and water quality in the stream below.

Most of the peat and organic soils in the drainage ways and rivers in the watershed are underlaid by sand and gravel glacial outwash materials. None impounded free- flowing water through these sub layers pick up essential minerals that are needed for healthy aquatic plants and animals in the Spirit Lakes below.

An evaluation of culverts and road crossings of the waterways in the Spirit Lake watershed should also be made for the same reasons discussed above. These obstructions should also be evaluate for restrictions to minnow and fish movements.

WATER LEVEL OPTIONS

The changes and fluctuations in the water levels of the Spirit Lakes over the last century has changed the physical, chemical, and biological characteristics of the Spirit Lakes. These changes happen slowly over a number of years and through wet and dry periods so the effects are rarely noticed or documented.

The watersheild along part of the east shore of Little Spirit is an example. Watersheild can always found where there is any kind of fluctuation in water level and a loose organic substrate. This plant has a spiral (spring-loaded) stem on its leaves and fruiting flower that can go up and down with the water level where other lily pads or other emergent vegetation do not have the abilty to do this. Therefore, after several years or decades this plant would eventually dominate over other floating or emergent vegetation. Wild rice is another plant that has dissappeared from changes in water elevation.

Increasing or decreasing water elevations of only a few feet can increase or decrease head pressure on springs entering the bottom of the both lakes - especially North Spirit - in turn increasing and decreasing water flows. The drought years of 1987 and 1988 may have been an example of where lack of rain, lowered water tables, and decreased flows from the pressure from the small dam head were enough to concentrate nutrients and change the process of organic decomposition on the bottom releasing nitrogen gas to form the filamentous algae blooms that the lakes had. In 1989 the running of the aeration system did not help to change this process. When rains returned and more water added to the hydrologic system the lake recovered. Bog wetlands in all bays of North Spirit and at the river entrances to Little Spirit have been flooded by the raising of the dam releasing "tied up" nutrients just as beaver dams and obstructions in the watershed do.

The differences between North and Little Spirit are significant as mineral alkalinity and pH vary considerably between the two lakes. Currently, small amount of nutrient inputs changes from lack of rain or substantial storm events were observed in the water chemistry sampling that induced changed in the water clarity and eventually density and composition of algae species. The effects of the dam on the ecology and water quality is evident but hard to prove without extensive study and records.

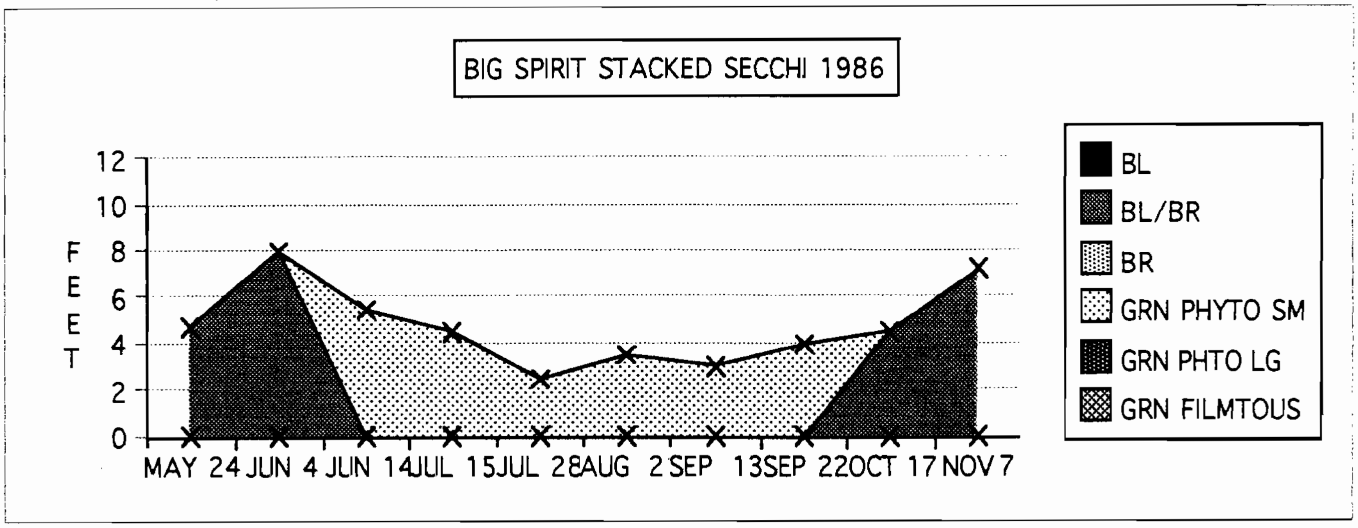
<u>Option # 2</u> This option may not be feasible or acceptable but must be brought forward as an alternative to restore the lake if all of the recommendations are not successful in bringing about water quality restoration to the 1960's levels. The removal of the dam combined with some other projects to make the loss in water depth more acceptable is the just of this option.

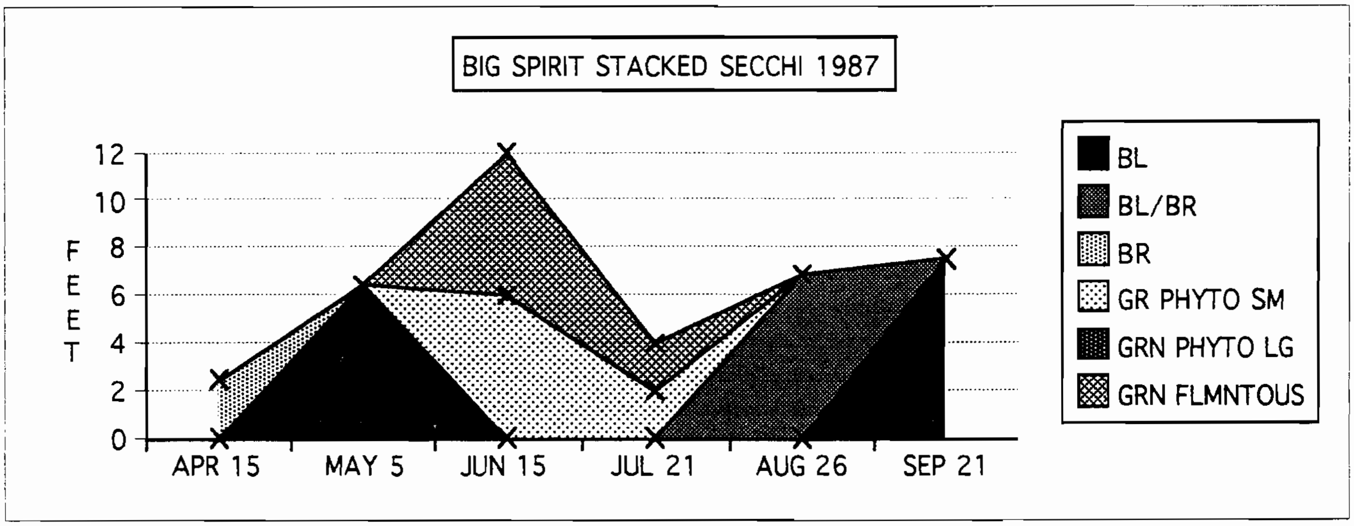
In 1948 before any "recent" dam was placed at the outlet of Little Spirit an investigation of the Public Service Commission found that "a natural obstruction between Big Spirit Lake and Little Spirit Lake which with present obstruction causes a 1/10-foot higer elevation in Big Spirit Lake than in Little Spirit Lake". If the lake was drawn down and removed some type of dredging project would have to be done to connect the two lakes. Permits, plans, and spoil site locations for the dredged materials would be part of the process.

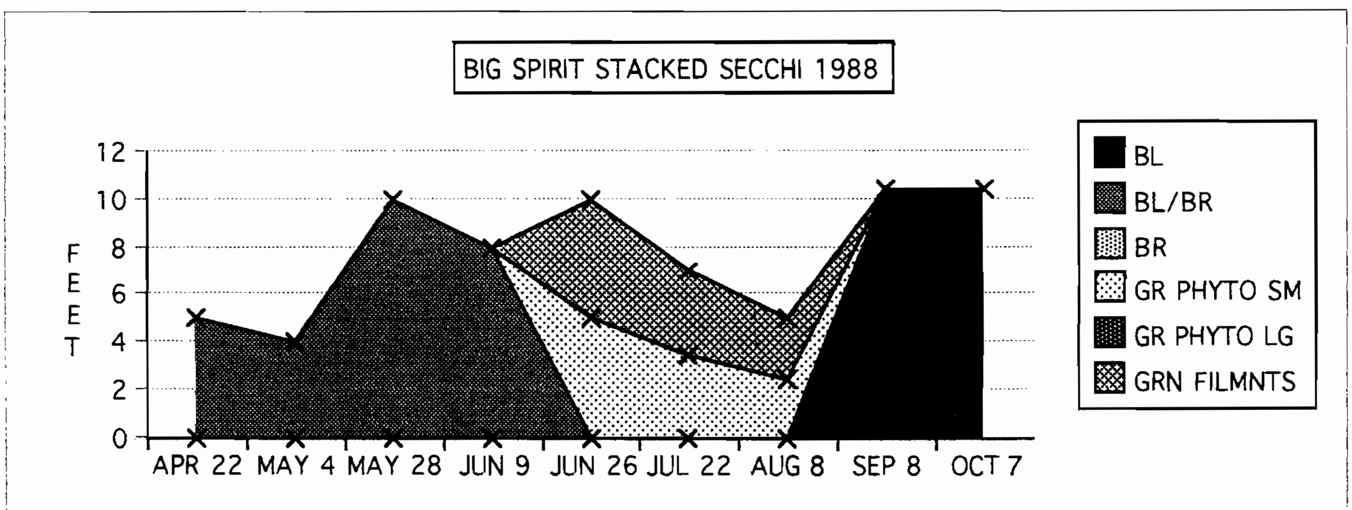
The shoreline residents on Upper Spirit would be effected the least by the dam removal as their steep shorelines would not change the physical appearance or recreational access to the lake significantly. Residents of Little Spirit would see a significant change as to the shallowness of the lake. Extension of the pier would be a hardship on many. Little Spirit would change drastically as much of the stored and accumulated organic matter would be washed down stream. The lake would resemble a large river that meanders and changes it shorelines periodically when major storm events occur. Some dredging in Little Spirit would be necessary to alleviate some of property owners problems and the problem created with the current with public access.

It is very important that if the dam is not removed that a structure is built and maintained that is capable of limiting fluctuations in water level as much as possible. A fish passageway would also benefit the fisheries of the Spirit Lakes.

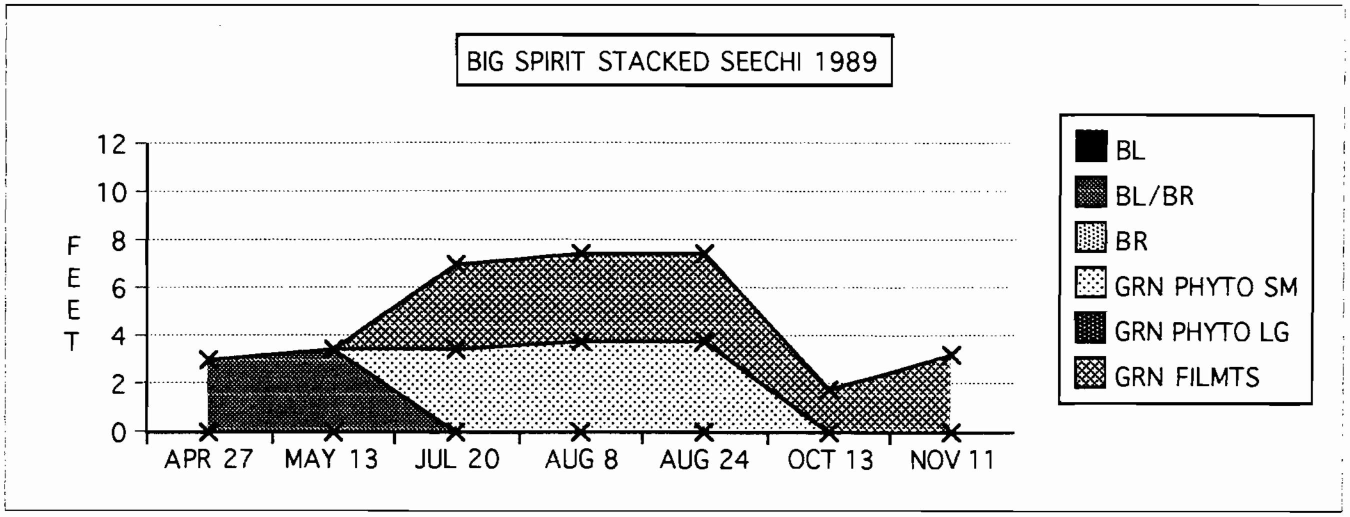
APPENDIX I. BIG SPIRIT SECCHI DISC HISTORY 1986-1988.

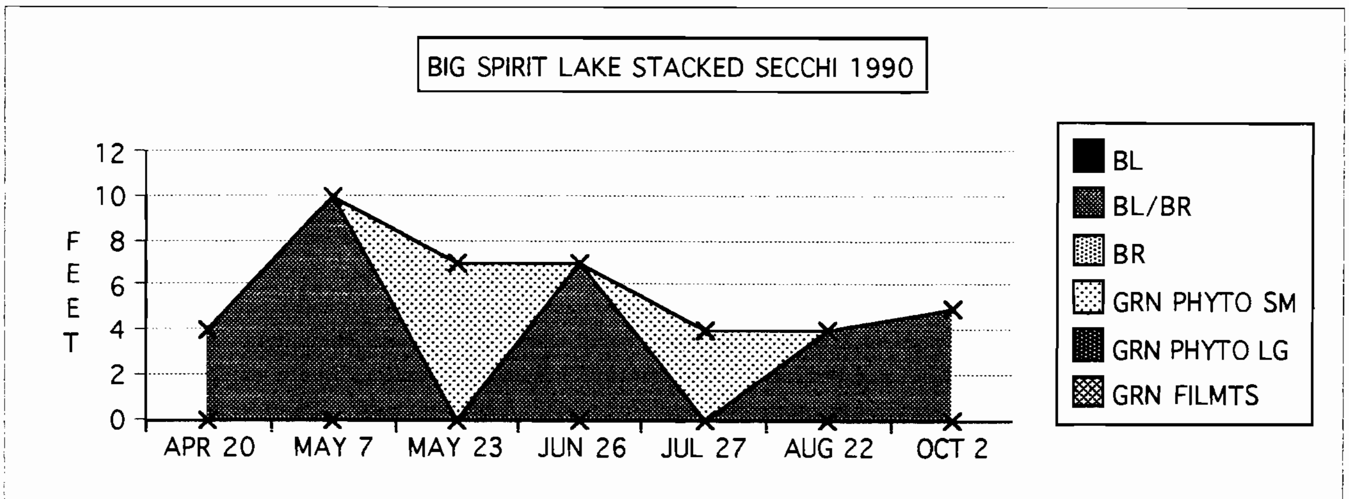


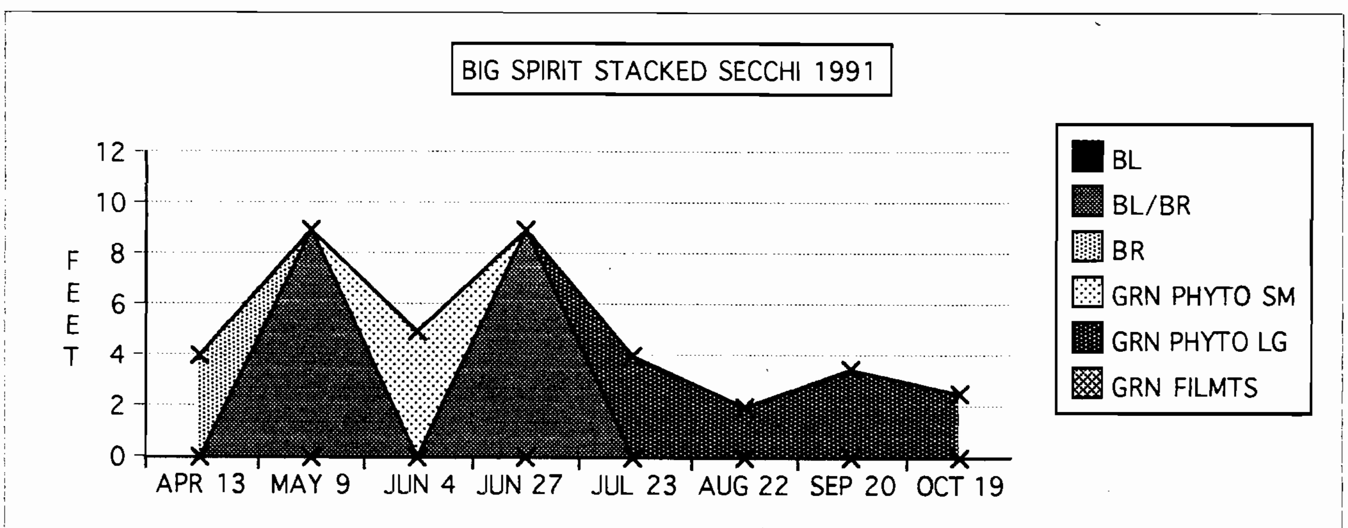




APPENDIX 1.(CONT) BIG SPIRIT SECCHI DISC HISTORY 1989-1991.







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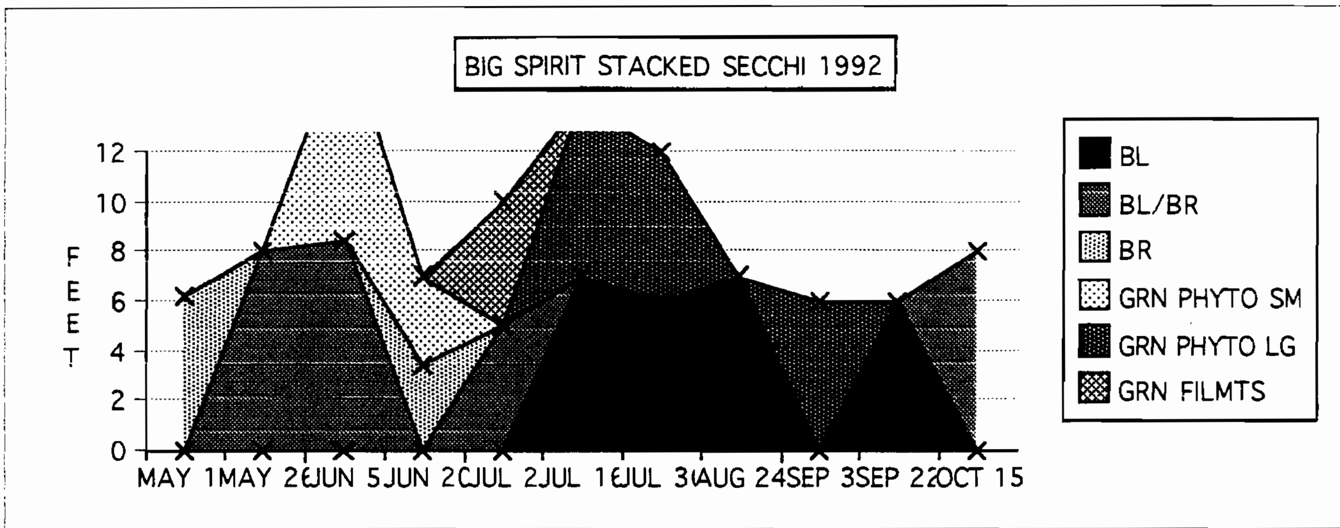
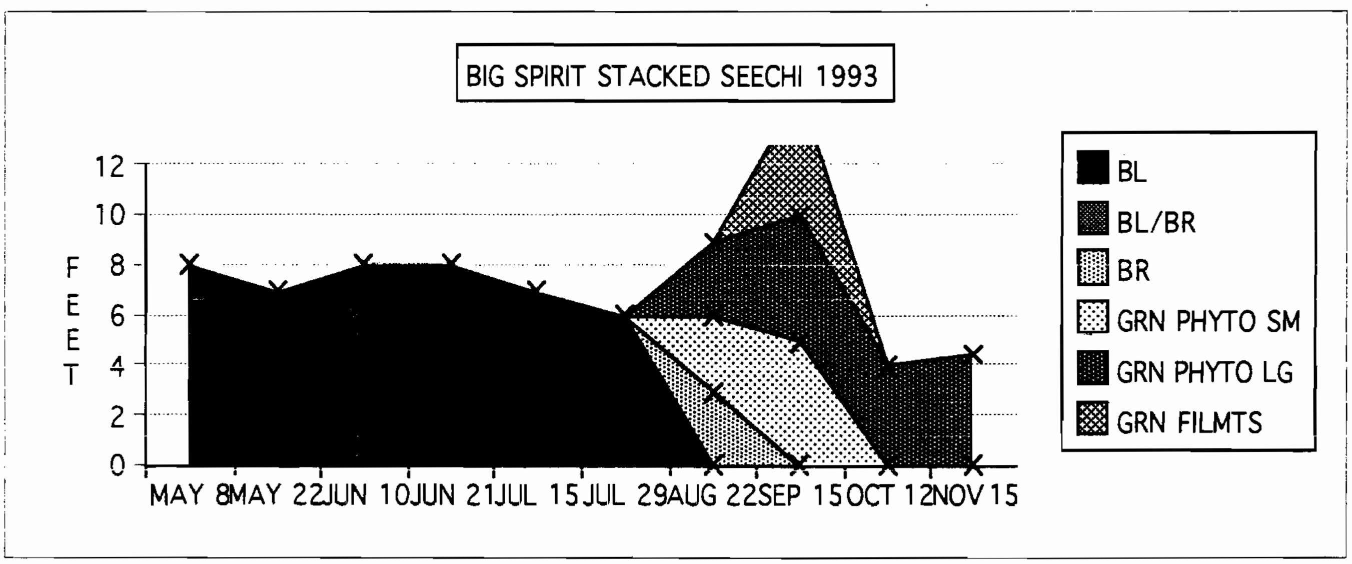
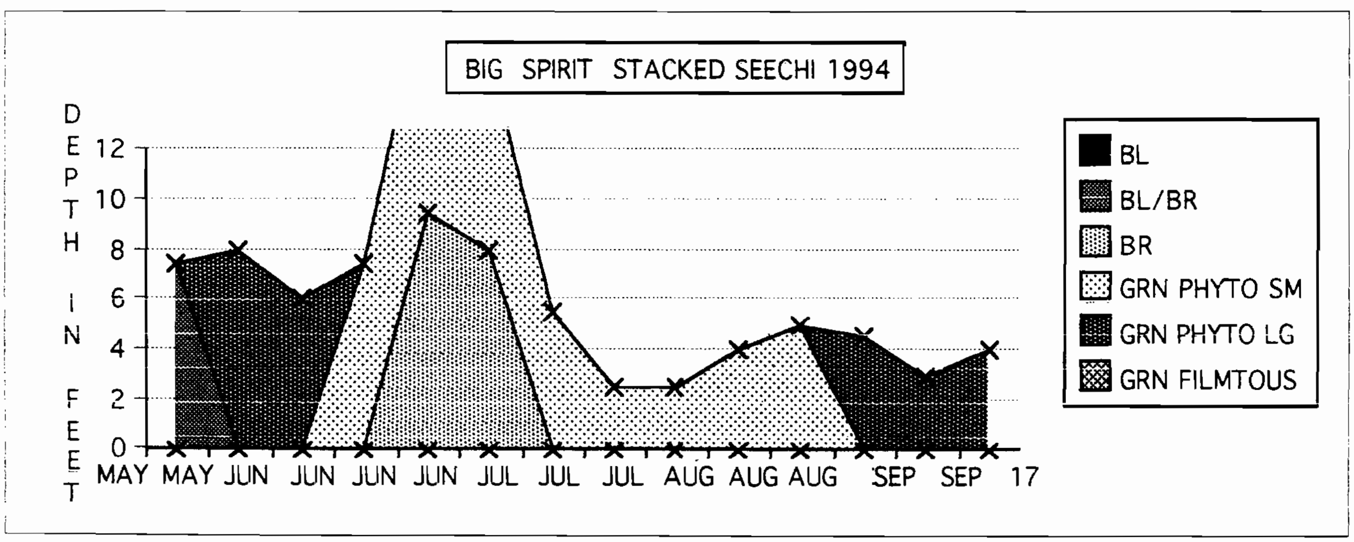
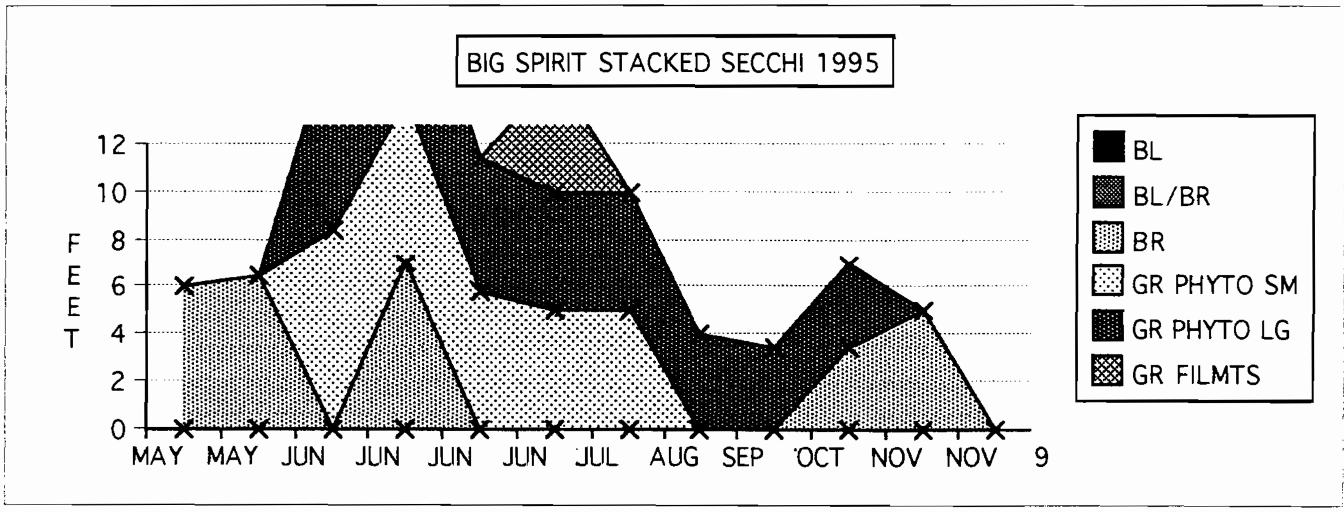






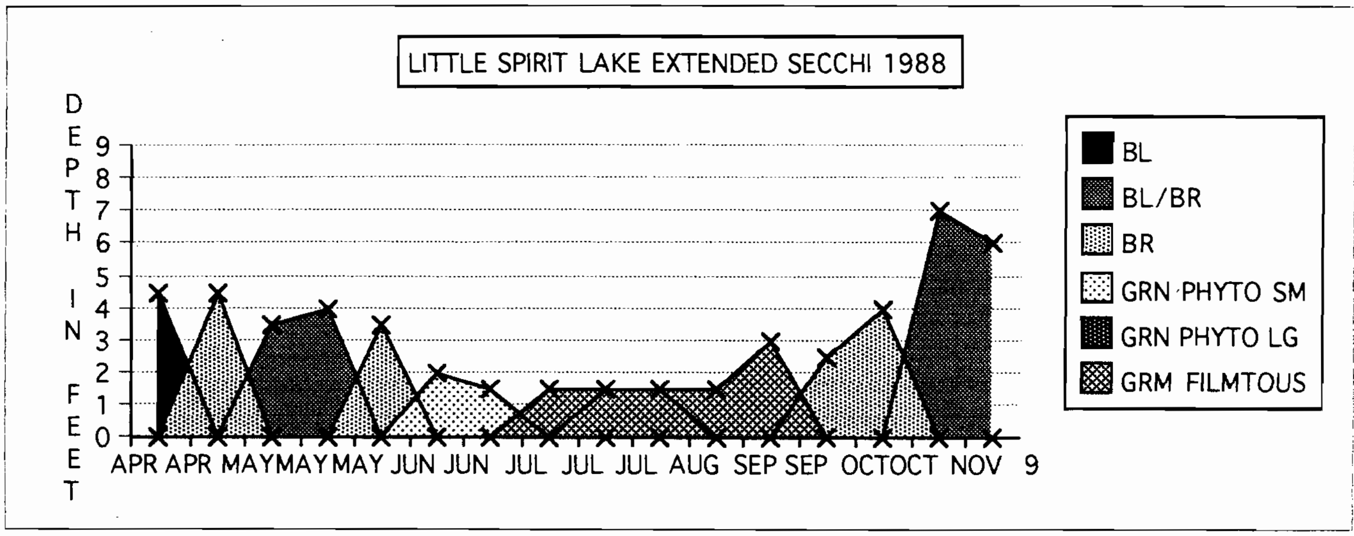
APPENDIX 1. BIG SPIRIT SECCHI HISTORY 1995.

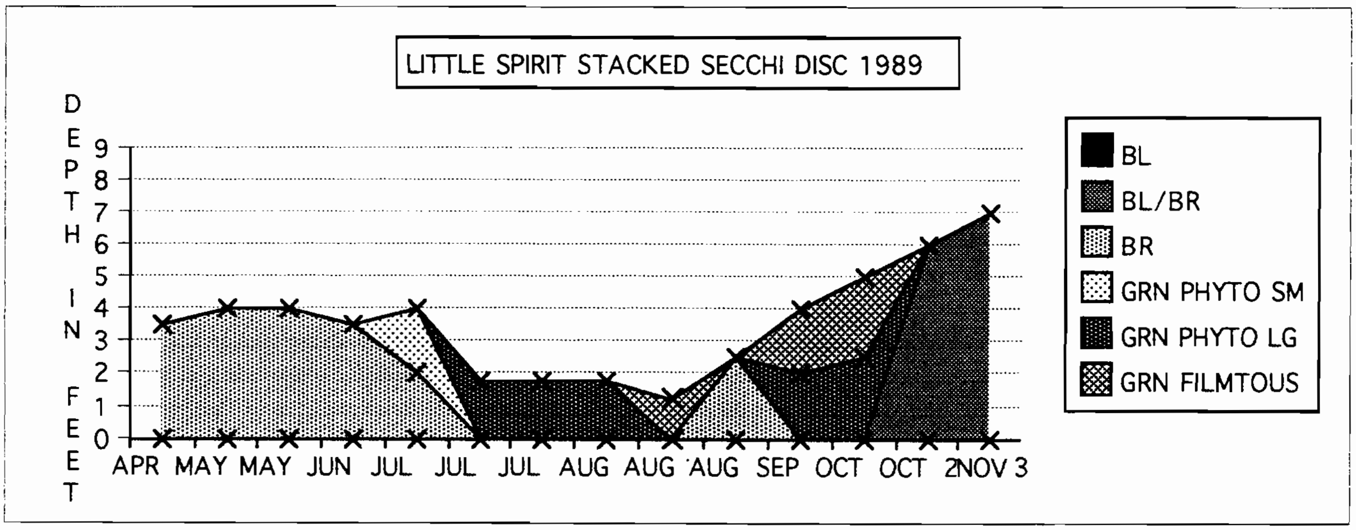


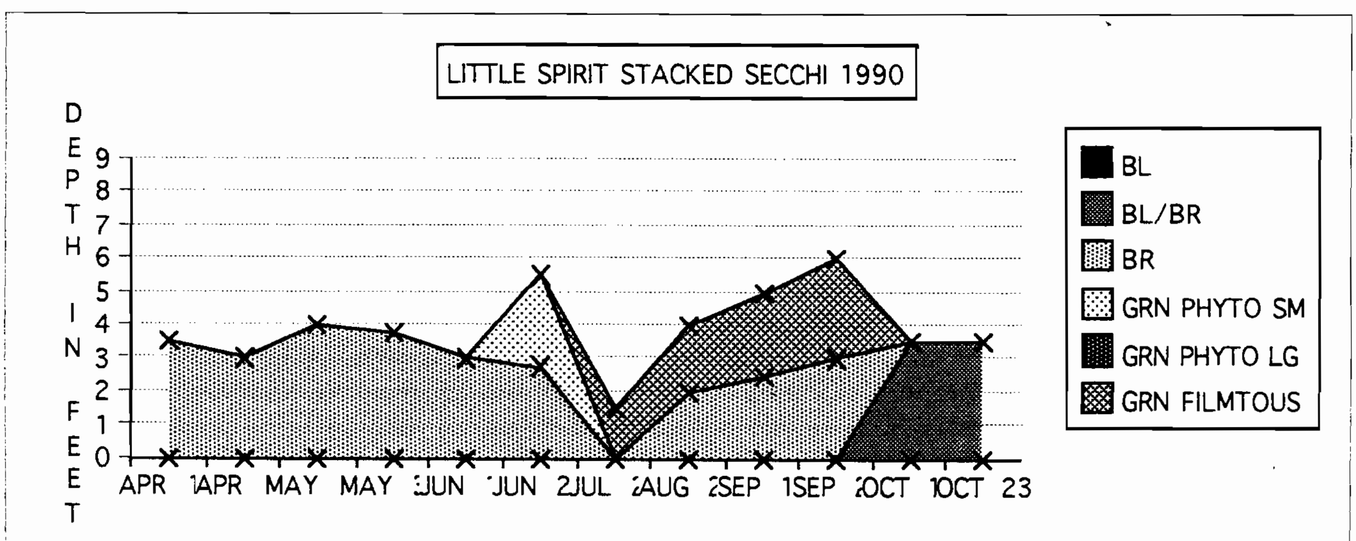
BIG SPIRIT STACKED SECCHI 1996

BIG SPIRIT STACKED SECCHI 1997

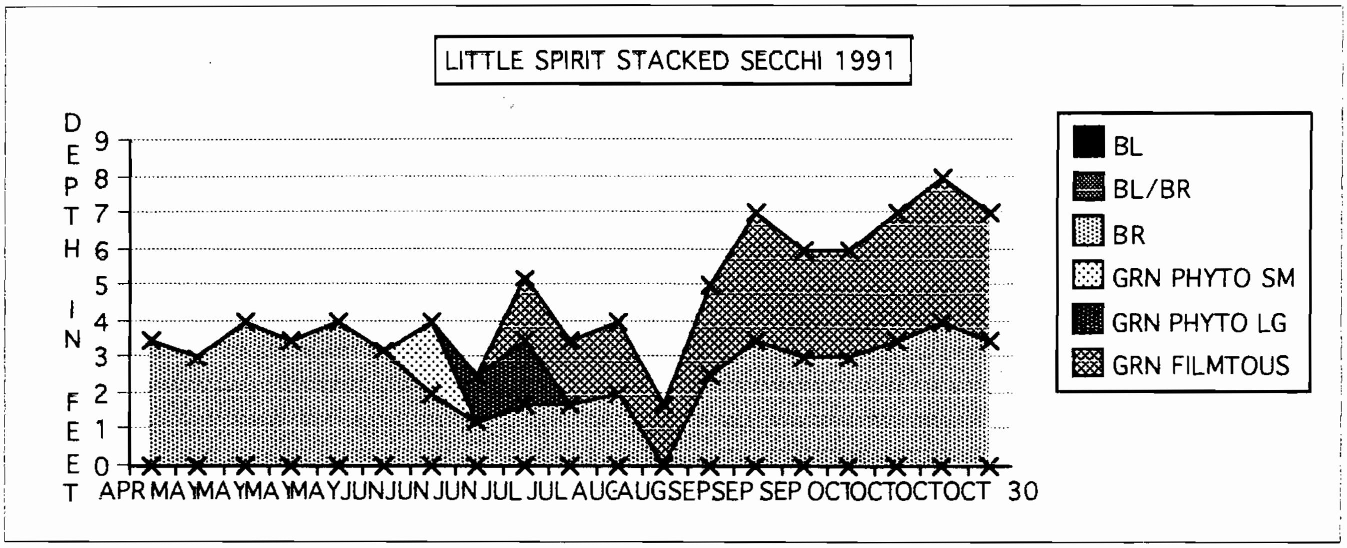
APPENDIX II. LITTLE SPIRIT SECCHI HISTORY 1988- 1990

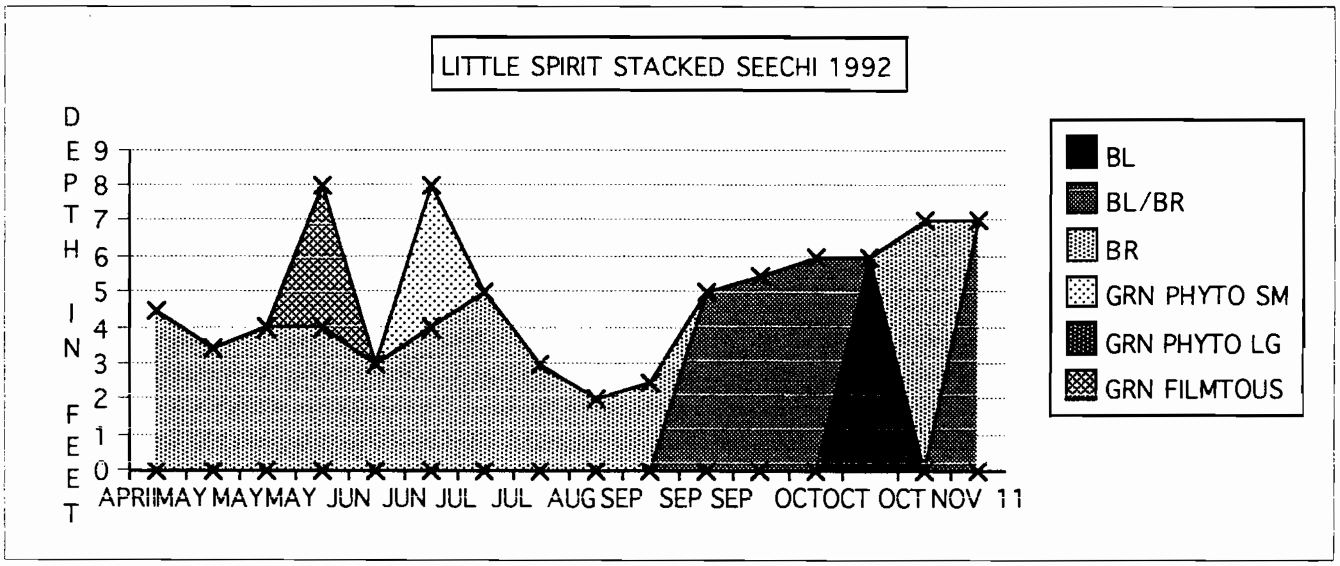


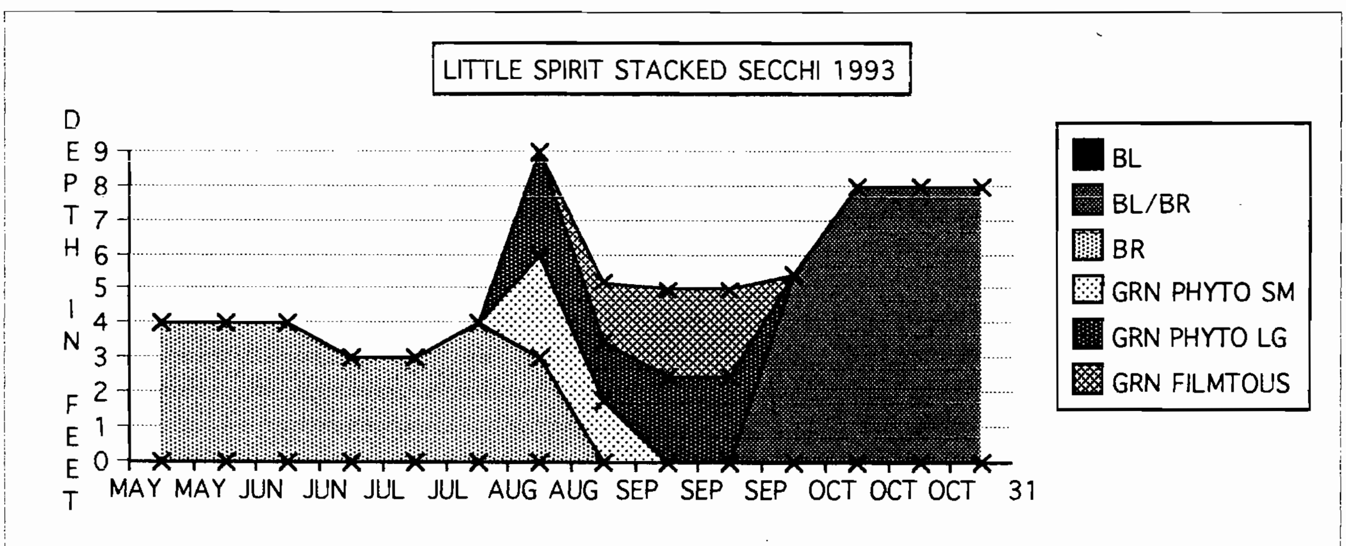




APPPENDIX II (CONT). LITTLE SPIRIT SEECHI HISTORY 1991-1993.







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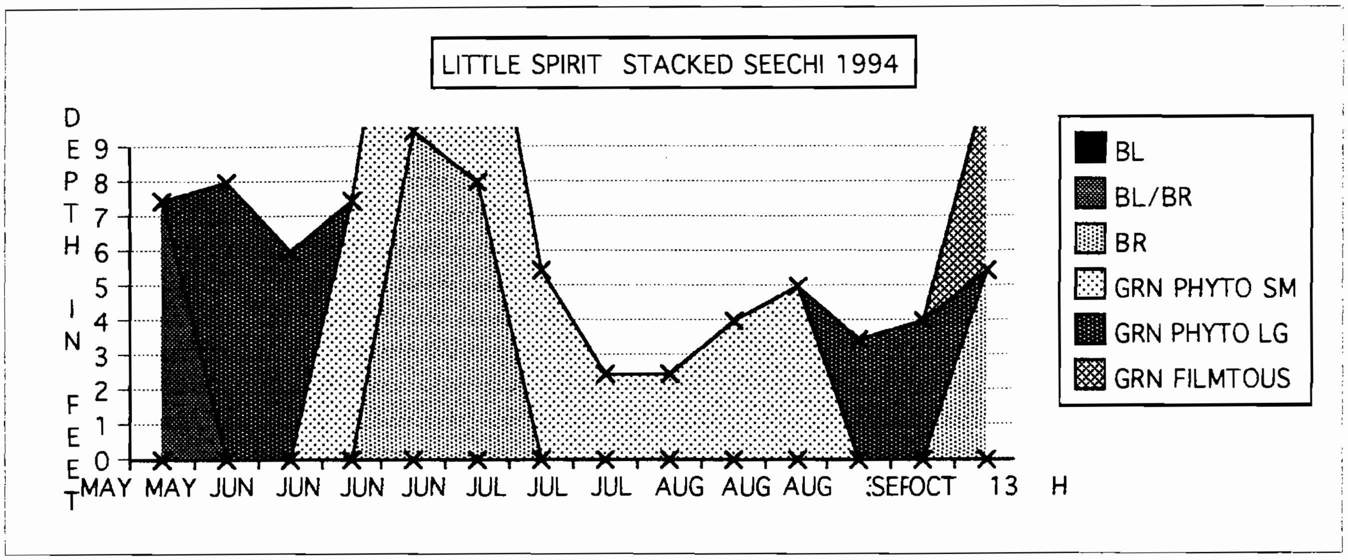

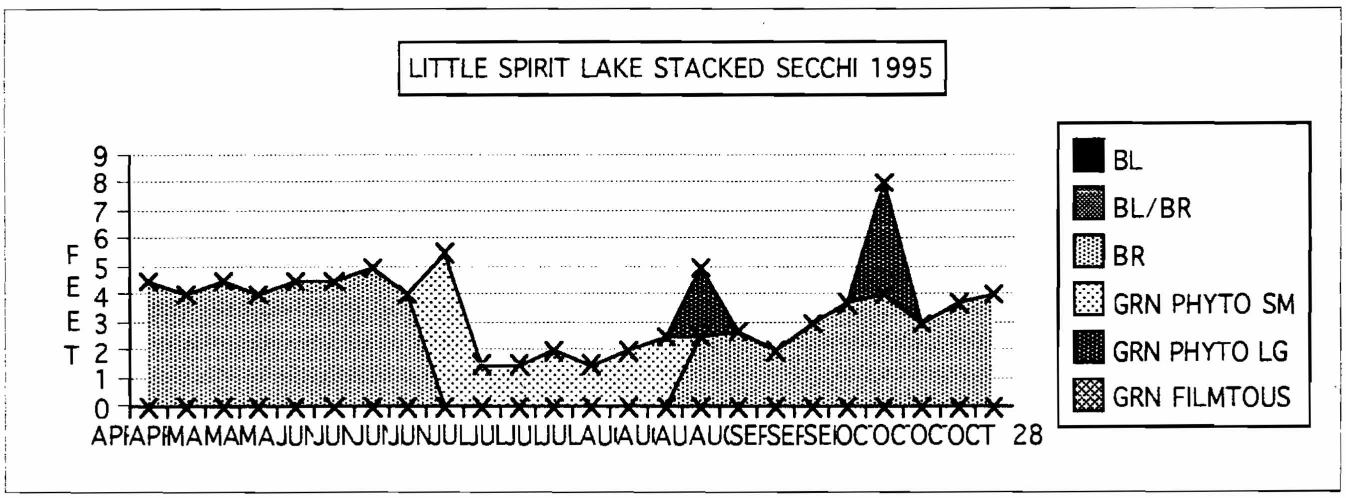

LITTLE SPIRIT SEECI 1996