Donald C. Cook Nuclear Plant • Units 1 & 2

Annual Environmental Operating Report

January 1, Through December 31, 1986

Indiana & Michigan Electric Company
Bridgman, Michigan

Docket Nos. 50-315 & 50-316
License Nos. DPR-58 & DPR-74

AMERICAN ELECTRIC
AEP
POWER SYSTEM

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List of Appendices

I. INTRODUCTION

Environmental Technical Specifications, Appendix A, Section 6.9.1.6 and Appendix B, Part II, Section 5.4.1 require that an annual report be submitted to the Nuclear Regulatory Commission which details the results and findings of ongoing environmental radiological and non-radiological surveillance programs. This report serves to fulfill these requirements and represents the Annual Environmental Operating Report for Units 1 and 2 of the Donald C. Cook Nuclear Plant for the operating period from January 1, 1986 till December 31, 1986.

During 1986, based on the monthly operating reports for Unit 1 and Unit 2, the yearly gross electrical generation, average unit service and capacity factors were:

	Unit 1	Unit 2
Gross electrical generation (MWe)	6,918,330	4,335,567
Unit service factor (%)	85.2	61.5
Unit capacity factor MDC Net (%)	74.4	46.7

The Semi-Annual Radioactive Effluent Release Reports for 1986 reporting year indicated that there were no adverse effects to the environment and general public due to the operation of the Donald C. Cook Nuclear Plant.

II. CHANGES TO THE ENVIRONMENTAL TECHNICAL SPECIFICATIONS

There were no changes made to the Non-radiological Environmental Technical Specifications during 1986. A change was requested to the National Pollution Discharge Elimination System (NPDES) permit MI0005827 in which the applicant requested permission to reroute Makeup Plant prefilter backwash to Lake Michigan. For further information, see Appendix 1.1 to this document.

There was one change made to the Radiological Technical Specifications during 1986. Amendment no. 94 to Donald C. Cook Unit 1 and Amendment no. 80 to the Unit 2 Appendix A Technical Specifications were issued on April 22, 1986 and deleted the requirement to sample the New Buffalo drinking water intake. No other changes were made in these Technical Specifications during 1986.

III

NON-RADIOLOGICAL ENVIRONMENTAL OPERATING REPORT

Environmental Protection Plan (EPP)

III.A.1 Plant Design and Operation

There were no changes in station design, tests or experiments performed which constituted an unreviewed environmental question.

The construction activities performed in 1986 which led to hook-up of the Lake Township water supply, office extension and associated sewage treatment expansion, and training/simulator facility reported in the environmental evaluations in the 1985 Annual Environmental Operating Report resulted in no adverse environmental impact.

One environmental evaluation was conducted to determine whether construction activities associated with the upgrade and temporary use of the beach access road which is included as Appendix 1.2 to this document. Based on this evaluation, it was concluded that with proper mitigation practices there would be no adverse environmental impact arising from the proposed activity.

III.A.2 Reporting Related to the NPDES Permit and State Certification

Notifications made to the Michigan Department of Natural Resources regarding the NPDES Permit are listed under Nonroutine Reports which comprises Appendix 1.3 to

this document.

III.B. Environmental Monitoring

III.B.1 Herbicide Application

Krovar I and Oust were used for bare ground weed control in the areas and concentrations specified in the attached letter from L. A. Shepard to H. E. Brooks (Appendix 1.4). A total of 303 pounds of Krovar I and 2.6 pounds of Oust were applied to approximately forty (40) acres within the owner controlled area in 1986.

There were no applications of the herbicide Torden 101R as there was no transmission line right-of-way maintenance performed within the owner controlled area in 1986.

III.C Aquatic Studies

During 1986 three aquatic studies were performed for the Donald C. Cook Nuclear Plant.

III.C.1 *Corbicula* Monitoring Program

As part of the *Corbicula* Monitoring Program, performed in accordance with our response to the NRC IE Bulletin 81-03; entrainment, diver-collected sand and gravel samples, and beach areas at the Donald C. Cook Nuclear Plant were examined for the presence of the Asiatic clam, *Corbicula fluminea*. No veligers, small or adult clams, or empty shells were detected in any of the sampling.

To date, inspections of lake water systems for biofouling, conducted by Environmental Section personnel have indicated no evidence of *Corbicula*.

The Cook Plant *Corbicula* Monitoring Program conducted by the University of Michigan will continue in 1987, as well as in-house inspections of lake water systems.

For further information concerning the *Corbicula* Monitoring Program results for 1986, please refer to Appendix 1.5.

III.C.2 Diver Assessment of the Inshore Southeastern Lake Michigan Environment Near the D. C. Cook Nuclear Plant, 1973-1982

This report is a summary and analysis of observations made by divers in southeastern Lake Michigan near the D. C. Cook Nuclear Plant from 1970 to 1982. This investigation was one component of a multi-disciplinary environmental impact study conducted by the Great Lakes Research Division, University of Michigan, for the Donald C. Cook Nuclear Plant. Overall scope of work included: physical studies - hydrology, sediments, shore erosion, ice effects; chemical studies - standard water chemistry, nutrients, trace metals; and biological studies - psammo-littoral organisms, periphyton, algae, zooplankton, benthos, and fish. In addition, studies by other agencies included radiological work, weather and currents, thermal plume mapping, terrestrial flora and fauna, and other environmental, sociological, and economic assessments associated with plant site selection and preconstruction activities. In 1986, the various studies conducted by the Great Lakes Research Division were integrated into an overview of the aquatic environment of the study area.

The purpose of the underwater assessment program was to gather data via direct observation or analysis of hand-collected samples. Information amassed through these efforts was used to collaborate or augment other studies at the Cook Plant and to provide a unique assessment of the aquatic environment, its ecology, and plantinduced effects.

For further information on this report, please refer to Appendix 1.6 of this document.

III.C.3 Interactive Data Base Management System for Ecological Studies Related to the Donald C. Cook Nuclear Power Plant

This report documents in detail the procedures used and the programs written in establishing the data base management system for the D. C. Cook ecological study and describes the data contained in the data base as well as the way in which these data can be accessed. This documentation can be used as a reference when accessing the data base and to clarify questions that arise during the use of this system.

For further information concerning this report, please refer to Appendix 1.7 of this document.

IV

RADIOLOGICAL ENVIRONMENTAL MONITORING PROGRAM (REMP)

IV.A Changes or Control to the REMP

As discussed above, the D. C. Cook Nuclear Plant Unit 1 and Unit 2 Technical Specifications were changed in 1986 to remove New Buffalo as a drinking water sample location.

Two new milk farms were added to the REMP during 1986 on November 21, 1986. These were the Zelmer and The Warmbien Milk Farms.

During 1986, Controls for Environmental Pollution, Inc. (CEP) has conducted the REMP sample analysis, except for surface and drinking water samples. Up until March of 1986, plant chemistry personnel were performing the radiological analysis for the surface and drinking water requirements. During the review of the data for the 1985 Annual Environmental Operating Report, it was discovered that the counting methodology used by the plant personnel was unable to meet the Technical Specification 4-12.1 Lower Limits of Detectability requirements without using excessively large sample volumes and extremely long count times. To correct this problem, surface and drinking water samples were sent to our REMP contractor for analysis beginning in April of 1986. This matter was discussed in more detail in the special report which was submitted to the NRC Region III office on May 1, 1986.

During 1986 sampling for the Radiological Environmental Monitoring Program was accomplished by both plant and contractor personnel. Up until November of 1986, contractor personnel were responsible for the all REMP samples except for drinking and surface water samples, and for fish samples. On November 1, 1986 plant personnel took over responsibility for collection of these samples. In addition, plant personnel have had continuous responsibility for the collection of drinking and surface water samples as well as fish sample collection.

In general, the Annual Environmental Operating Report shows no observable effect on the surrounding environment from the operation of the Donald C. Cook Nuclear Plant, Units 1 and 2.

For further information concerning the Radiological Environmental Monitoring Program, please see Appendices 2.1 and 2.2 which contain the results of the contractor and plant performed analysis on environmental samples.

IV.B Special Sample Collection Program Report

On September 10, 1986, a report was issued to the NRC in response to NRC IE Information Notice 86-32, "Request for Collection of Licensee Radioactivity Measurements Attributed to the Chernobyl Nuclear Plant Accident." The enhanced sample collection and analysis program was initiated on May 3, 1986 and continued through July 3, 1986 by which time the levels of observed activity had returned to background levels. The purpose of this enhanced monitoring program was to evaluate the levels of radioactive fallout resulting from the Chernobyl Nuclear Plant accident and to assure that any activity detected in our environmental program was properly identified as to the source. Concurrent with and upon completion of the enhanced environmental sample collection and analysis program, our routine radiological environmental sample collection and analysis program continued uninterrupted. The results of the routine REMP results are contained in Appendix 2.1 of this Report and the results of the enhanced sampling and analysis program are reported in Appendix 2.3 to this report.

IV.C. Land Use Census

IV.C.1 Annual Milk Farm Survey

The annual milk farm survey for 1986 was completed on September 12, 1986, using the updated Milk Farm List from the Michigan Department of Agriculture and the previous year's milk farm survey map. We also contacted Berrien County farmers by phone in performing this survey. A new milk farm survey map and list were completed according to the appropriate Plant procedure. Changes were identified from the previous year for the closest milk farm in the nine land covering meteorological sectors within the five (5) mile emergency planning zone. The comparison results

between the reporting year (1986) and the prior year (1985) are shown in Appendix 2.4 to this report.

Two (2) new milk farms were added to our sampling program as a result of the findings of the 1986 annual milk farm survey. On November 21, 1986, the Zelmer Farm (4.75 miles SSE, Sector H) and the Warmbien Farm (7.8 miles S, Sector J) were initiated into the routine milk farm sampling program. In addition to these two farms added to the program, two (2) farms in Sector F were contacted for possible inclusion in the sampling program, but they indicated that they did not wish to participate in the program.

IV.C.2 Annual Residential Land Use Survey

The 1986 Residential Land Use Survey was completed on August 20, 1986 using the updated list of new building permits from Lake Township and the previous year's survey map. There were no new residences having a new building permit and which were located closer than the previous year's closest residence in each of the nine (9) land covering meteorological sectors within the five mile emergency planning zone. The comparison results of the residential land use survey for 1985 and 1986 are found in Appendix 2.5 to this Report.

IV.D Condition Reports

In 1986, four (4) condition reports were issued with respect to the REMP. They are identified below and are more fully documented in Appendix 2.6 of this Report. The four condition reports issued:

1)	12-04-86-388	Special report for violation of T/S Table 4.12-1 LLD limits for drinking and surface water samples.
2)	2-04-86-474	Xe-138 LLD limit in excess of T/S limit for Upper Containment Purge.
3)	12-10-86-1165	Unplanned partial release of gas decay tank.
4)	12-11-86-1347	Violation of allowable interval for collection of environmental air samples.

Appendix 1.1

REQUESTED CHANGE TO NPDES PERMIT MI0005827

ATTACHMENT 8

INDIANA & MICHIGAN ELECTRIC COMPANY

P.O. BOX 16631
COLUMBUS, OHIO 43216

January 22, 1987

AEP:NRC:0170C
10 CFR 50.36 (b)

Donald C. Cook Nuclear Plant Unit Nos. 1 and 2
Docket Nos. 50-315 and 50-316
License Nos. DPR-58 and DPR-74
NATIONAL POLLUTANT DISCHARGE ELIMINATION
SYSTEM (NPDES) PERMIT

Nuclear Regulatory Commission
Attn: Document Control Desk
Washington, D.C. 20555

Dear Sirs:

In accordance with Section 3.2 of Appendix B (Environmental Protection Plan) of the Donald C. Cook Nuclear Plant Unit Nos. 1 and 2 Facility Operating License, attached is a copy of an application to the State of Michigan Department of Natural Resources for modification of the D. C. Cook NPDES Permit No. MI 0005827. This application is for your information only and has been submitted to the State of Michigan for approval of a facility change which would allow discharge of make-up plant prefilter backwash water to Lake Michigan.

This document has been prepared following Corporate procedures which incorporate a reasonable set of controls to insure its accuracy and completeness prior to signature by the undersigned.

Very truly yours,

M. P. Alexich
Vice President

RBK
1/22/87

cm

Attachment

cc: John E. Dolan
W. G. Smith, Jr. - Bridgman
R. C. Callen
G. Bruchmann
G. Charnoff
NRC Resident Inspector - Bridgman
J. G. Keppler - Region III

bc: J. G. Feinstein/M. W. Evarts
S. H. Horowitz/T. O. Argenta/R. C. Carruth
J. J. Markowsky/S. H. Steinhart/P. G. Schoepf/G. S. Wright
R. W. Jurgensen
R. F. Kroeger
M. L. Horvath - Bridgman
E. A. Morse - Bridgman
C. A. Erikson
J. B. Shinnock
J. A. Druckemiller
J. Fryer/D. Fitzgerald-Stuart
D. L. Wigginton, NRC - Washington, D.C.
AEP:NRC:0170C
DC-N-6015.1

ATTACHMENT B

ATTACHMENT TO AEP:NRC:0170C

NPDES PERMIT APPLICATION

LETTER FROM JACK A. DRUCKEMILLER (I&MECo)

TO PAUL D. ZUGGER (MICHIGAN DEPARTMENT OF NATURAL RESOURCES),

DATED DECEMBER 23, 1986

Attachment to AEP:NRC:0170C

ATTACHMENT 8

INDIANA & MICHIGAN ELECTRIC COMPANY
ONE SUMMIT SQUARE, P.O. BOX 60, FORT WAYNE, IN 46801
Telephone (219) 425-2111

December 23, 1986

Paul D. Zugger, Executive Secretary
Water Resources Commission
Department of Natural Resources
P. O. Box 30028
Lansing, Michigan 48909

Dear Mr. Zugger:

RE: Donald C. Cook Nuclear Plant
NPDES Permit No. MI0005827

Enclosed is a revised Industrial and Commercial Wastewater Discharge Application for the Donald C. Cook Nuclear Plant. This application is submitted for approval of a facility change.

The facility change involves rerouting of Makeup Plant Prefilter backwash water to Lake Michigan via outfalls 001 or 002 (Unit 1 and Unit 2 discharges). The filter backwash water is currently discharged to the Plant's Turbine Room Sump, which subsequently discharges to an onsite Absorption Pond. The ability to discharge this effluent to Lake Michigan would aid us in performing repairs to the sump and would allow us to reduce the volume of groundwater discharges. Screening data for this waste stream is provided in the enclosed application.

Note that the line diagram flowsheet for Section 1, Item 6 is as proposed, reflecting the planned rerouting of the filter backwash water.

Your timely consideration of the request for facility modification is appreciated since repairs of the Turbine Room Sump are scheduled for early 1987. Please call me if you require information or have any questions regarding the information provided. We would be happy to meet with the people responsible for drafting the permit modification.

Very truly yours,

Jack A. Druckemiller
Manager of Environmental Affairs

JAD/df
Enclosure

c: W. G. Smith, Jr.

ATTACHMENT B

SECTION I

SEE INSTRUCTIONS ON REVERSE SIDE

EPA I.D. NUMBER: MID098647621

PERMIT NUMBER → MI0005827

APPLICATION FOR DISCHARGE PERMIT IS: MODIFICATION [X] EXISTING [ ] NEW [ ] INCREASED USE [ ] REISSUANCE [ ]

ITEM 1 — PHYSICAL LOCATION ADDRESS AND INFORMATION

A. PARENT COMPANY/DEPT./OWNER: INDIANA & MICHIGAN ELECTRIC
B. DIV./BUREAU: NA
C. PLANT OR FACILITY: D C COOK PLANT
D. TYPE OF FACILITY: STM ELECTRIC GEN
E. STANDARD INDUSTRIAL CLASSIFICATION (REFER TO TABLE II): 4911
F. STREET NUMBER: NA
G. STREET NAME: RED ARROW HIGHWAY
H. CITY NAME: BRIDGMAN — MI
I. ZIP CODE: 49106
J. TOWNSHIP: LAKE
K. COUNTY (REFER TO TABLE I): CO. NAME BERRIEN — CO. NUMBER 11
L. NAME OF AUTHORIZED CONTACT PERSON: JACK A DRUCKEMILLER
M. TITLE: MGR ENV AFFAIRS
N. TELEPHONE NUMBER: 219 425 2118
O. ADDRESS (IF DIFFERENT FROM ABOVE): PO BOX 60
P. CITY NAME: FORT WAYNE
Q. STATE: IN
R. ZIP CODE: 46801
S. TYPE OF TREATMENT FACILITY (REFER TO TABLE II): IL 5A 4G 5P
T. PROGRAM FOR EFFECTIVE RESIDUALS MANAGEMENT — YES [ ] NO [ ] N.A. [X] DATE SUBMITTED ___ DATE IMPLEMENTED ___
U. BACK-UP POWER SOURCE: YES [X] NO [ ] N.A. [ ]
V. POLLUTION INCIDENT PREVENTION PLAN: YES [X] NO [ ] N.A. [ ] DATE SUBMITTED 6/12/80 DATE IMPLEMENTED 6/82
W. NUMBER OF EMPLOYEES: 587
X. TYPE OF DISCHARGE: GROUNDWATER [ ] SURFACE WATER [ ] BOTH [X]
Y. DO YOU HAVE A CERTIFIED OPERATOR? YES [X] NO [ ]
OPERATOR'S NAME D. Fitzgerald-Stuart # 309 70 4802
FACILITY # 1110514 CERTIFICATION # W0002 8613

ITEM 2 — MAILING ADDRESS OF APPLICANT

A. NAME: RICHARD C MENGE
B. NAME: INDIANA & MICHIGAN ELECTRIC CO
C. STREET ADDRESS OR POST OFFICE BOX: PO BOX 60
D. CITY NAME: FORT WAYNE
E. STATE: IN
F. ZIP CODE: 46801

REQUIRED SIGNATURE

I, the applicant, certify under penalty of law that I have personally examined and am familiar with the information submitted in this application and all attachments and that, based on my inquiry of those individuals immediately responsible for obtaining the information, I believe that the information is true, accurate and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment.

SIGNATURE OF APPLICANT
SIGNATURE: R.C. Menge DATE: 12/23/86
NAME: R. C. Menge TITLE: Vice President

SIGNATURE OF LOCAL GOVERNMENTAL REPRESENTATIVE (SEE NOTE ON REVERSE SIDE)
SIGNATURE: ___ DATE: ___
NAME: ___ TITLE: ___

ATTACHMENT 8

SECTION I

SEE INSTRUCTIONS ON REVERSE SIDE

PERMIT NUMBER → MI0005827

ITEM			
ITEM 3 SOURCE OF WATER SUPPLY	A. MUNICIPAL	NAME	
		QUANTITY (MAX.)	GALLONS/DAY
	B. SURFACE WATER INTAKE	NAME OF WATERWAY	
		QUANTITY (MAX.)	GALLONS/DAY
	C. PRIVATE WELL	QUANTITY (MAX.)	GALLONS/DAY
	D. OTHER	SPECIFY	
		QUANTITY (MAX.)	GALLONS/DAY
ITEM 4 FACILITY WATER USAGE	A. PROCESS WATER (INCLUDING CONTACT COOLING WATER)	QUANTITY (MAX.)	GALLONS/DAY
	B. NONCONTACT COOLING WATER	QUANTITY (MAX.)	GALLONS/DAY
	C. SANITARY WATER	QUANTITY (MAX.)	GALLONS/DAY
	D. OTHER	SPECIFY	
		QUANTITY (MAX.)	GALLONS/DAY
ITEM 5 CRITICAL MATERIALS & PRIORITY POLLUTANTS USED • STORED • PRODUCED	MATERIAL 1	NAME OF SUBSTANCE	
		PARAMETER NUMBER	
		QUANTITY	UNITS /YEAR
	MATERIAL 2	NAME OF SUBSTANCE	
		PARAMETER NUMBER	
		QUANTITY	UNITS /YEAR
	MATERIAL 3	NAME OF SUBSTANCE	
		PARAMETER NUMBER	
		QUANTITY	UNITS /YEAR
REFER TO TABLES IV & V	MATERIAL 4	NAME OF SUBSTANCE	
		PARAMETER NUMBER	
		QUANTITY	UNITS /YEAR
UNITS CODE: 1 POUNDS, 2 GALLONS, 3 CUBIC YARDS, 4 TONS	MATERIAL 5	NAME OF SUBSTANCE	
		PARAMETER NUMBER	
		QUANTITY	UNITS /YEAR
	MATERIAL 6	NAME OF SUBSTANCE	
		PARAMETER NUMBER	
		QUANTITY	UNITS /YEAR
	MATERIAL 7	NAME OF SUBSTANCE	
		PARAMETER NUMBER	
		QUANTITY	UNITS /YEAR

No change from information previously provided.

ATTACHMENT 8

SEE INSTRUCTIONS ON REVERSE SIDE

SECTION I

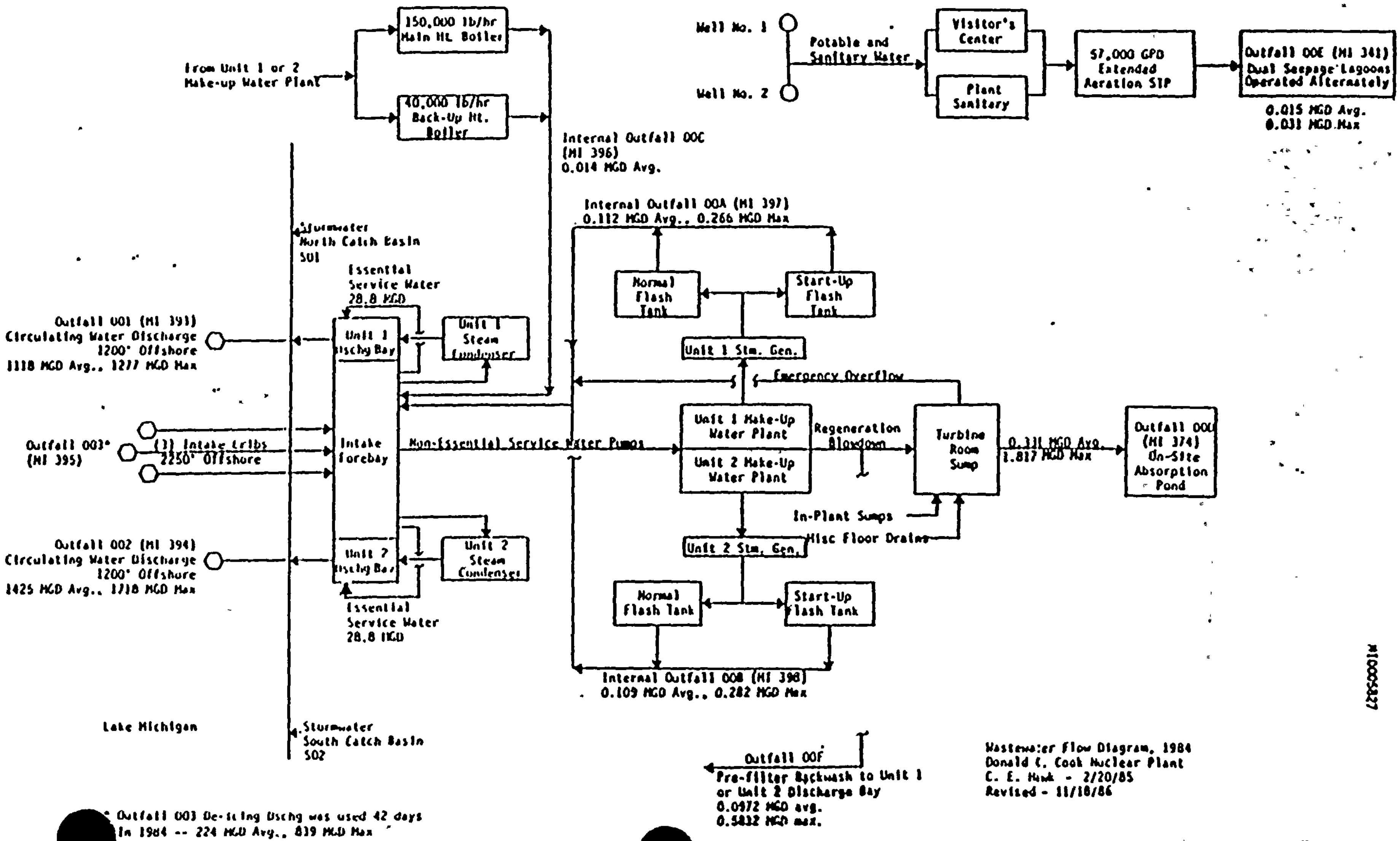
PERMIT NUMBER → MI0005827

ITEM 6

DESCRIPTION AND DIAGRAM

A. PROVIDE A BRIEF DESCRIPTION AND LINE DIAGRAM SHOWING THE WATER FLOW THROUGH YOUR FACILITY FROM INTAKE TO DISCHARGE. SHOW ALL OPERATIONS CONTRIBUTING WASTEWATER, INCLUDING PROCESS AND PRODUCTION AREAS, SANITARY FLOWS, COOLING WATER, AND STORMWATER RUNOFF. YOU MAY GROUP SIMILAR OPERATIONS INTO A SINGLE UNIT. THE WATER BALANCE SHOULD SHOW AVERAGE FLOWS. SHOW ALL SIGNIFICANT LOSSES OF WATER TO PRODUCTS, ATMOSPHERE, AND DISCHARGE. YOU SHOULD USE ACTUAL MEASUREMENTS WHENEVER AVAILABLE; OTHERWISE USE YOUR BEST ESTIMATE.

See line diagram on following page.



ATTACHMENT B

Section I, Item 6, cont'd.
Outfall Descriptions

Outfall 00F - Pre-Filter Backwash

Make-up water of ultra-high purity is required for the steam generators. The first step in treating intake lake water is solids removal using multi-media filters. The filters are called pre-filters since they are the initial step in the treatment process.

Alum (aluminum sulfate) is injected into the water supply upstream of the pre-filters to act as a coagulant on the filter media. When the pre-filters are saturated with solids removed from the lake water, the pre-filters are backwashed with additional lake water, and the solids are flushed to the turbine room sump then discharged to an on-site absorption pond.

The proposed plant modification would reroute the pre-filter backwash to Lake Michigan. There would be a small net increase in the amount of solids returned to Lake MIchigan as a result of the alum added during treatment. The design maximum amount of alum which could be used is 624 lb alum per day which would cause a net increase of 0.05 ppm solids when discharged through Outfall 001 or 0.04 ppm solids when discharged through Outfall 002. The attached screening data show that the typical pre-filter backwash contains only 1.7 μg/l aluminum and 25 μg/l sulfate.

ATTACHMENT B

SECTION I

PERMIT NUMBER → MI0005827

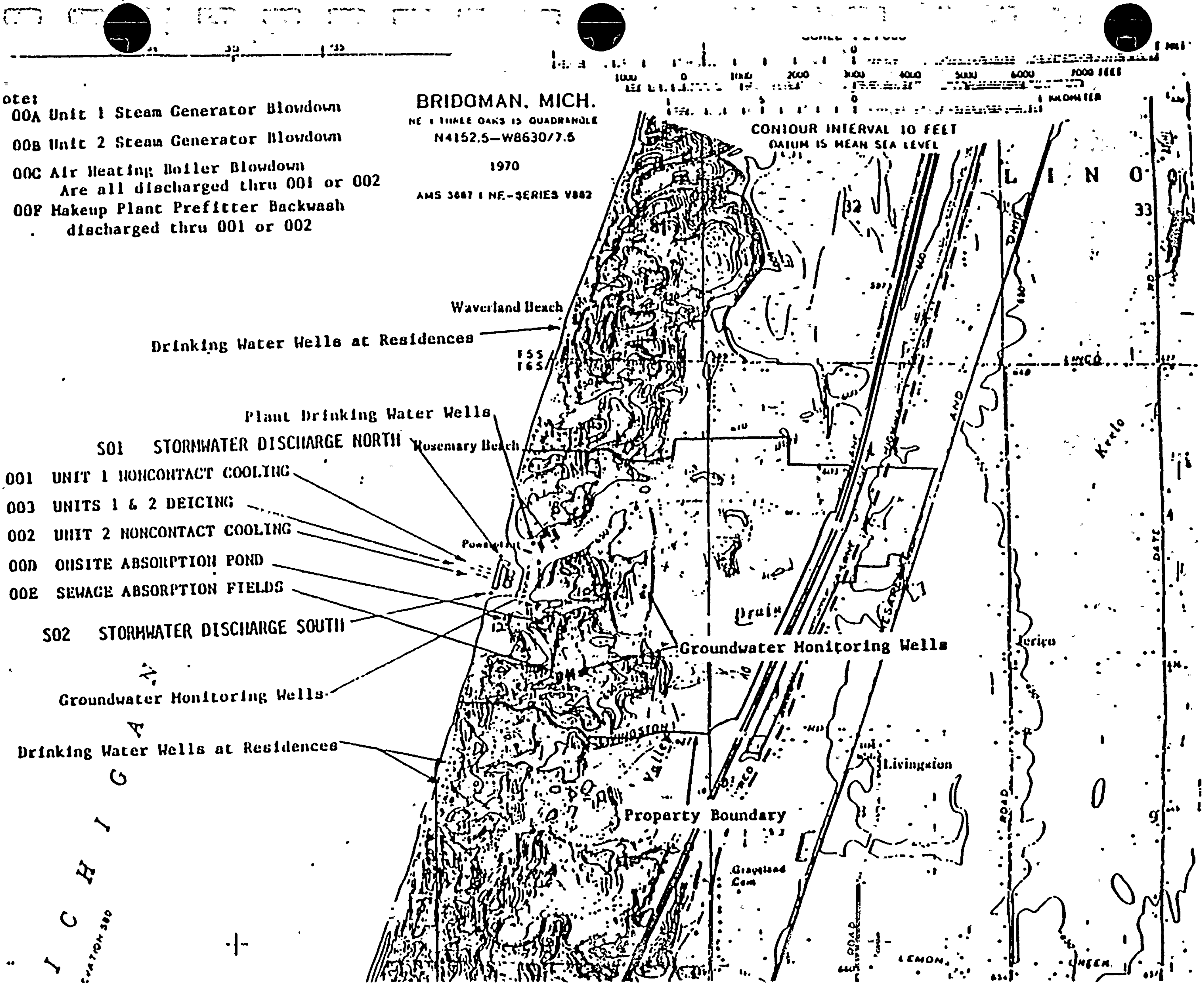
SEE INSTRUCTIONS ON REVERSE SIDE

ITEM 7

LOCATION MAP

A. PROVIDE A MAP OF THE TREATMENT FACILITY LOCATION, SHOWING THE LOCATION OF THE DISCHARGE POINT(S) AND OTHER INFORMATION REQUESTED ON REVERSE SIDE OF PAGE.

See topo map on following page.



ATTACHMENT 8

ATTACHMENT 8

SECTION I

PERMIT NUMBER → MI0005827

SEE INSTRUCTIONS ON REVERSE SIDE

ITEM 8 CONCENTRATED ANIMAL FEEDING OPERATION	A. DO YOU OPERATE A CONCENTRATED ANIMAL FEEDING FACILITY? (IF NO CONTINUE TO ITEM 10)	☐ YES ☒ NO
	B. NUMBER OF ACRES USED FOR CONFINEMENT FEEDING?	___ . ___ ACRES
	C. IF THERE IS OPEN CONFINEMENT, HAS A RUNOFF DIVERSION AND CONTROL SYSTEM BEEN CONSTRUCTED? (IF NO, CONTINUE TO ITEM 9)	☐ YES ☐ NO
	D. WHAT IS THE DESIGN BASIS FOR THE CONTROL SYSTEM? CHECK ONE OF THE FOLLOWING AND ENTER NUMBER OF INCHES OF RAIN?	☐ 10 YEAR, 24 HOUR STORM ___ . ___ INCHES ☐ 25 YEAR, 24 HOUR STORM ___ . ___ INCHES ☐ OTHER (SPECIFY) ___ . ___ INCHES
	TYPE	
	E. WHAT IS THE NUMBER OF ACRES OF CONTRIBUTING DRAINAGE?	___ . ___ ACRES
	F. WHAT IS THE DESIGN SAFETY FACTOR FOR THIS CONTROL SYSTEM?	___ . ___
ITEM 9 TYPE & NUMBER OF ANIMALS IN OPEN AND HOUSED CONFINEMENT	TYPE 1 A. LIST TYPE OF ANIMAL.	
	B. GIVE THE NUMBER OF THIS TYPE OF ANIMAL IN OPEN CONFINEMENT.	
	C. GIVE THE NUMBER OF THIS TYPE OF ANIMAL IN HOUSED CONFINEMENT.	
	TYPE 2 A. LIST TYPE OF ANIMAL.	
	B. GIVE THE NUMBER OF THIS TYPE OF ANIMAL IN OPEN CONFINEMENT.	
	C. GIVE THE NUMBER OF THIS TYPE OF ANIMAL IN HOUSED CONFINEMENT.	
	TYPE 3 A. LIST TYPE OF ANIMAL.	
	B. GIVE THE NUMBER OF THIS TYPE OF ANIMAL IN OPEN CONFINEMENT.	
	C. GIVE THE NUMBER OF THIS TYPE OF ANIMAL IN HOUSED CONFINEMENT.	
	TYPE 4 A. LIST TYPE OF ANIMAL.	
	B. GIVE THE NUMBER OF THIS TYPE OF ANIMAL IN OPEN CONFINEMENT.	
	C. GIVE THE NUMBER OF THIS TYPE OF ANIMAL IN HOUSED CONFINEMENT.	
	TYPE 5 A. LIST TYPE OF ANIMAL.	
	B. GIVE THE NUMBER OF THIS TYPE OF ANIMAL IN OPEN CONFINEMENT.	
	C. GIVE THE NUMBER OF THIS TYPE OF ANIMAL IN HOUSED CONFINEMENT.	
	TYPE 6 A. LIST TYPE OF ANIMAL.	
	B. GIVE THE NUMBER OF THIS TYPE OF ANIMAL IN OPEN CONFINEMENT.	
	C. GIVE THE NUMBER OF THIS TYPE OF ANIMAL IN HOUSED CONFINEMENT.	
	TYPE 7 A. LIST TYPE OF ANIMAL.	
	B. GIVE THE NUMBER OF THIS TYPE OF ANIMAL IN OPEN CONFINEMENT.	
	C. GIVE THE NUMBER OF THIS TYPE OF ANIMAL IN HOUSED CONFINEMENT.	
	TYPE 8 A. LIST TYPE OF ANIMAL.	
	B. GIVE THE NUMBER OF THIS TYPE OF ANIMAL IN OPEN CONFINEMENT.	
	C. GIVE THE NUMBER OF THIS TYPE OF ANIMAL IN HOUSED CONFINEMENT.	

SECTION I

PERMIT NUMBER → MI0005827

SEE INSTRUCTIONS ON REVERSE SIDE

ITEM 10 — AQUATIC ANIMAL PRODUCTION FACILITY

A.	DO YOU OPERATE AN AQUATIC ANIMAL PRODUCTION FACILITY? (IF NO, CONTINUE TO ITEM 12)	☐ YES ☒ NO
B.	INDICATE THE TOTAL NUMBER OF PONDS, RACEWAYS AND SIMILAR STRUCTURES AT YOUR FACILITY. SPECIFY ______	____ . PONDS ____ . RACEWAYS ____ . OTHER
C.	INDICATE IN WHICH CALENDAR MONTH MAXIMUM FEEDING OCCURS.	______
D.	ENTER THE TOTAL NUMBER OF POUNDS OF FOOD FED DURING THIS MONTH?	______ POUNDS

ITEM 11 — SPECIES OF AQUATIC ANIMALS PRODUCED AT THIS FACILITY

SPECIES 1	A.	IS THIS SPECIE A WARM OR COLD WATER SPECIE?	☐ WARM ☐ COLD
	B.	GIVE THE NAME OF THIS SPECIE.	______
	C.	ENTER THE TOTAL HARVESTABLE WEIGHT OF THIS SPECIE PRODUCED BY THIS FACILITY PER YEAR IN POUNDS.	______ POUNDS
	D.	ENTER THE MAXIMUM WEIGHT PRESENT FOR THIS SPECIE WHICH WOULD REPRESENT YOUR NORMAL OPERATION.	______ POUNDS
SPECIES 2	A.	IS THIS SPECIE A WARM OR COLD WATER SPECIE?	☐ WARM ☐ COLD
	B.	GIVE THE NAME OF THIS SPECIE.	______
	C.	ENTER THE TOTAL HARVESTABLE WEIGHT OF THIS SPECIE PRODUCED BY THIS FACILITY PER YEAR IN POUNDS.	______ POUNDS
	D.	ENTER THE MAXIMUM WEIGHT PRESENT FOR THIS SPECIE WHICH WOULD REPRESENT YOUR NORMAL OPERATION.	______ POUNDS
SPECIES 3	A.	IS THIS SPECIE A WARM OR COLD WATER SPECIE?	☐ WARM ☐ COLD
	B.	GIVE THE NAME OF THIS SPECIE.	______
	C.	ENTER THE TOTAL HARVESTABLE WEIGHT OF THIS SPECIE PRODUCED BY THIS FACILITY PER YEAR IN POUNDS.	______ POUNDS
	D.	ENTER THE MAXIMUM WEIGHT PRESENT FOR THIS SPECIE WHICH WOULD REPRESENT YOUR NORMAL OPERATION.	______ POUNDS
SPECIES 4	A.	IS THIS SPECIE A WARM OR COLD WATER SPECIE?	☐ WARM ☐ COLD
	B.	GIVE THE NAME OF THIS SPECIE.	______
	C.	ENTER THE TOTAL HARVESTABLE WEIGHT OF THIS SPECIE PRODUCED BY THIS FACILITY PER YEAR IN POUNDS.	______ POUNDS
	D.	ENTER THE MAXIMUM WEIGHT PRESENT FOR THIS SPECIE WHICH WOULD REPRESENT YOUR NORMAL OPERATION.	______ POUNDS
SPECIES 5	A.	IS THIS SPECIE A WARM OR COLD WATER SPECIE?	☐ WARM ☐ COLD
	B.	GIVE THE NAME OF THIS SPECIE.	______
	C.	ENTER THE TOTAL HARVESTABLE WEIGHT OF THIS SPECIE PRODUCED BY THIS FACILITY PER YEAR IN POUNDS.	______ POUNDS
	D.	ENTER THE MAXIMUM WEIGHT PRESENT FOR THIS SPECIE WHICH WOULD REPRESENT YOUR NORMAL OPERATION.	______ POUNDS
SPECIES 6	A.	IS THIS SPECIE A WARM OR COLD WATER SPECIE?	☐ WARM ☐ POUNDS
	B.	GIVE THE NAME OF THIS SPECIE.	______
	C.	ENTER THE TOTAL HARVESTABLE WEIGHT OF THIS SPECIE PRODUCED BY THIS FACILITY PER YEAR IN POUNDS.	______ POUNDS
	D.	ENTER THE MAXIMUM WEIGHT PRESENT FOR THIS SPECIE WHICH WOULD REPRESENT YOUR NORMAL OPERATION.	______ POUNDS

SECTION I

PERMIT NUMBER → MI0005827

LIST NAME AND MAILING ADDRESS OF ALL PROPERTY OWNERS ADJACENT TO THE TREATMENT FACILITY AND OR DISCHARGE/DISPOSAL AREA.

ITEM 12

MAILING LIST OF ADJACENT PROPERTY OWNERS

No change from information previously provided.

ATTACHMENT B

SECTION II

PERMIT NUMBER → MI0005827

SEE INSTRUCTIONS ON REVERSE SIDE

ITEM 1

DISCHARGE LOCATION • SCHEDULE • FLOW RATE

WASTEWATER TYPE CODE
1 CONTACT COOLING
2 NONCONTACT COOLING
3 PROCESS
4 SANITARY
5 STORMWATER

UNIT CODE
1 MGY
2 MGD
3 GPD

OUTFALL NUMBER	00F
A. LOCATION OF DISCHARGE	NW ¼ SW ¼ SECTION 06, TOWN 06S, RANGE 19W
B. NAME OF RECEIVING WATER (IE. GROUNDWATER OR NAME OF SURFACE WATER)	LAKE MICHIGAN
C. DO YOU DISCHARGE SEASONALLY? (IF NO, CONTINUE TO E)	☐ YES ☒ NO
D. IF YES, LIST DISCHARGE PERIODS NA	MO. / DAY THROUGH MO. / DAY
E. LAND APPLICATION RATE NA	IN./HR. . HR./DAY . IN./WK. .
F. TYPE OF WASTEWATER DISCHARGE	WASTEWATER TYPE CODE 3
G. DISCHARGE SCHEDULE (YEARLY AVERAGE)	HOURS/DAY 02 DAY/YEAR 365
H. DISCHARGE FLOW RATE	TOTAL YEARLY 50 UNIT CODE 1; DAILY MINIMUM 0.0972 UNIT CODE 2; DAILY MAXIMUM 0.5832 UNIT CODE 2
I. THE MAXIMUM DISCHARGE FLOW RATE TO BE AUTHORIZED IN PERMIT.	AUTHORIZED 0.5832 UNIT CODE 2
J. MAXIMUM DESIGN DISCHARGE FLOW RATE.	DESIGN 0.5832 UNIT CODE 2

ITEM 2

WATER TREATMENT ADDITIVES

UNITS CODE
1 Mg/l
2 Ug/l

A. DO YOU USE WATER TREATMENT ADDITIVES TO TREAT YOUR DISCHARGE? (IF NO, CONTINUE TO ITEM 3)	☐ YES ☒ NO
B. NAME, FUNCTION, AND CHEMICAL COMPOSITION OF THESE ADDITIVES.	NAME / FUNCTION
C. NAME AND ADDRESS OF MANUFACTURERS OF THESE ADDITIVES.	

D. EXPECTED DISCHARGE CONCENTRATION OF ADDITIVES.	MINIMUM	UNITS CODE	AVERAGE	UNITS CODE	MAXIMUM	UNITS CODE
ADDITIVE NAME						
ADDITIVE NAME						
ADDITIVE NAME						

E. DO YOU TREAT THE DISCHARGE TO REMOVE ADDITIVES? ☐ YES ☒ NO

F. WHAT IS THE REMOVAL EFFICIENCY AND DISCHARGE FREQUENCY?	% REMOVAL	DISCHARGE FREQUENCY HRS./DAY	DAYS/WK.
ADDITIVE NAME			
ADDITIVE NAME			
ADDITIVE NAME			

G. AS AN ATTACHMENT TO THIS APPLICATION PROVIDE SPECIFIC MAMMALIAN OR AQUATIC TOXICOLOGICAL DATA OR REFERENCE WHICH ARE AVAILABLE AND INFORMATION ON THE RATE OF DEGRADATION OF THE PRODUCTS FOR EACH ADDITIVE.

ATTACHMENT 8

SECTION II

SEE INSTRUCTIONS ON REVERSE SIDE

PERMIT NUMBER → MI0005827

ITEM 3

PROCESS STREAMS CONTRIBUTING TO OUTFALL DISCHARGE

OUTFALL NUMBER		0 0 F

PROCESS 1

A. NAME OF PROCESS CONTRIBUTING TO THE DISCHARGE THROUGH THIS OUTFALL, AND SIC CODE		FILTER BACKWSH — SIC 4[illegible]
B. PROCESS SCHEDULE (YEARLY AVERAGE)	HOURS/DAY 01-2	DAYS/YEAR 365
C. PROCESS VOLUME FLOW RATE		UNIT CODE
	TOTAL YEARLY 50	5
	DAILY MINIMUM 0.0972	6
	DAILY MAXIMUM 0.5832	6
D. PROCESS PRODUCTION RATE	NA	UNITS / TIME

PROCESS 2

A. NAME OF PROCESS CONTRIBUTING TO THE DISCHARGE THROUGH THIS OUTFALL, AND SIC CODE		
B. PROCESS SCHEDULE (YEARLY AVERAGE)	HOURS/DAY	DAYS/YEAR
C. PROCESS VOLUME FLOW RATE		UNIT CODE
	TOTAL YEARLY	
	DAILY MINIMUM	
	DAILY MAXIMUM	
D. PROCESS PRODUCTION RATE		UNITS / TIME

PROCESS 3

A. NAME OF PROCESS CONTRIBUTING TO THE DISCHARGE THROUGH THIS OUTFALL, AND SIC CODE		
B. PROCESS SCHEDULE (YEARLY AVERAGE)	HOURS/DAY	DAYS/YEAR
C. PROCESS VOLUME FLOW RATE		UNIT CODE
	TOTAL YEARLY	
	DAILY MINIMUM	
	DAILY MAXIMUM	
D. PROCESS PRODUCTION RATE		UNITS / TIME

PROCESS 4

A. NAME OF PROCESS CONTRIBUTING TO THE DISCHARGE THROUGH THIS OUTFALL, AND SIC CODE		
B. PROCESS SCHEDULE (YEARLY AVERAGE)	HOURS/DAY	DAYS/YEAR
C. PROCESS VOLUME FLOW RATE		UNIT CODE
	TOTAL YEARLY	
	DAILY MINIMUM	
	DAILY MAXIMUM	
D. PROCESS PRODUCTION RATE		UNITS / TIME

PROCESS 5

A. NAME OF PROCESS CONTRIBUTING TO THE DISCHARGE THROUGH THIS OUTFALL, AND SIC CODE		
B. PROCESS SCHEDULE (YEARLY AVERAGE)	HOURS/DAY	DAYS/YEAR
C. PROCESS VOLUME FLOW RATE		UNIT CODE
	TOTAL YEARLY	
	DAILY MINIMUM	
	DAILY MAXIMUM	
D. PROCESS PRODUCTION RATE		UNITS / TIME

UNITS CODE

1 POUNDS
2 GALLONS
3 CUBIC YARDS
4 TONS
5 MGY
6 MGD
7 GPD

TIME

1 HOUR
2 DAY
3 WEEK
4 MONTH
5 YEAR

ATTACHMENT B

SECTION II

SEE INSTRUCTIONS ON REVERSE SIDE

PERMIT NUMBER: MI0005827

ITEM 4 — GROUNDWATER DISCHARGE INFORMATION

OUTFALL NUMBER: 0 0 1 F

Question	Yes	No
A. IS THE DISCHARGE FROM THIS OUTFALL DIRECTED TO THE GROUND OR GROUNDWATERS? (IF NO, CONTINUE TO ITEM 5)	☐	☒
B. HAS A HYDROGEOLOGICAL STUDY OR ITS EQUIVALENT BEEN PERFORMED OR IS THERE SUFFICIENT CURRENT HYDROGEOLOGICAL INFORMATION AVAILABLE AS REQUIRED BY THE WATER RESOURCES COMMISSION PART 22 GROUNDWATER RULES OF AUGUST 14, 1980 R.323.2207 (PAGE 45) FOR THIS EXISTING OR PROPOSED DISCHARGE? IF YES ATTACH A COPY OF THE REPORT.	☐	☐
C. ARE YOU REQUESTING AN EXEMPTION FROM SUBMITTING A HYDROGEOLOGICAL REPORT UNDER RULE R.323.2207 (2) (PAGE 45) OR FROM GROUNDWATER MONITORING REQUIREMENTS UNDER RULE R.323.2223 (5) (PAGE 47) OF THE PART 22 RULES. IF "YES" ATTACH DOCUMENTS AND EXPLANATION TO DEMONSTRATE THAT YOUR DISCHARGE WOULD QUALIFY FOR AN EXEMPTION.	☐	☐
D. ARE YOU REQUESTING A VARIANCE FROM RULE 323.2205 (PAGE 45) (NONDEGRADATION) OF THE WATER RESOURCES COMMISSION PART 22 GROUNDWATER RULES? IF YES, ATTACH SUCH DOCUMENTS AS NECESSARY TO DEMONSTRATE THE NEED FOR A VARIANCE IN TERMS OF THE CRITERIA SPECIFIED IN RULE 323.2210 (PAGE 47) OF THE PART 22 RULES.	☐	☐

E. LIST ALL CHEMICAL SUBSTANCES WHICH ARE IN MICHIGAN'S CRITICAL MATERIALS REGISTER TABLE IV (PAGE 5) AND/OR U.S. EPA'S PRIORITY POLLUTANT LIST TABLE V (PAGE 7) OR ANY OTHER SUBSTANCES WHICH ARE OR MAY BECOME INJURIOUS TO THE DESIGNATED USES OF THE GROUNDWATER OR TO THE PUBLIC HEALTH THAT ARE DISCHARGED OR EXPECTED TO BE DISCHARGED TO THE GROUNDWATER BY THIS FACILITY. ESTIMATE THE FINAL EFFLUENT CONCENTRATION AND RECORD ALL DATA IN ITEM 7 OF SECTION II IN THIS BOOKLET.

THE APPLICANT MAY BE REQUIRED TO DO ADDITIONAL WASTE ANALYSES.

☐ NOT APPLICABLE/BELIEVED ABSENT

☐ PRESENT, DATA PROVIDED IN ITEM 7

ITEM 5 — EXPECTED WASTEWATER CHARACTERISTICS

A. DISCHARGE CHARACTERISTICS

Parameter	Concentration AVE	Concentration MAX	Units Code	# Analyses	Sample Type Code
*BOD5 (FIVE DAY BIOLOGICAL OXYGEN DEMAND)			1		
*COD (CHEMICAL OXYGEN DEMAND)			1		
*TOC (TOTAL ORGANIC CARBON)			1		
*AMMONIA NITROGEN (AS N)			1		
*TOTAL SUSPENDED SOLIDS			1		
TOTAL PHOSPHORUS (AS P)			1		
TOTAL RESIDUAL CHLORINE			1		
DISSOLVED OXYGEN	MIN		1		
*PH			4		
FECAL COLIFORM BACTERIA			3		
*TEMPERATURE (SUMMER)			5		
*TEMPERATURE (WINTER)			5		

B. OTHER WASTEWATER CHARACTERISTICS

Parameter	Concentration AVE	Concentration MAX	Units Code	# Analyses	Sample Type Code
OIL & GREASE					

UNITS CODE
1 Mg/l
2 Ug/l
3 COUNTS/100 ml
4 S.U.
5 °F
6 LBS/DAY

SAMPLE TYPE
1 GRAB
2 24 HOUR COMPOSITE

See attached sheets for data.

ATTACHMENT B

SECTION II

SEE INSTRUCTIONS ON REVERSE SIDE

PERMIT NUMBER → MI0005827.

ITEM 6

PRIORITY POLLUTANTS AND ADDITIONAL INFORMATION FOR SURFACE WATER DISCHARGE ONLY

OUTFALL NUMBER	0 0 1 F
THE FOLLOWING REQUESTED INFORMATION SHALL BE ADDRESSED BY ALL SURFACE WATER DISCHARGERS. NOTE! NEW USE DISCHARGERS SHALL PROVIDE EXPECTED VALUES FOR THE QUANTITATIVE AND QUALITATIVE INFORMATION REQUESTED BELOW.	
A. IS THIS FACILITY A PRIMARY INDUSTRY? (REFER TO TABLE IA PAGE 41) (IF NO, GO TO E) (IF YES, GO TO B)	[X] YES [ ] NO
B. INDICATE TYPE OF PRIMARY INDUSTRY AS LISTED IN TABLE IA PAGE 41. (CONTINUE WITH C.)	S T M L E L E C T P W R
C. DOES THIS OUTFALL DISCHARGE CONTAIN ANY PROCESS WASTEWATER? (IF NO, GO TO E) (IF YES, GO TO D)	[X] YES [ ] NO
D. INDICATE WHICH GC/MS FRACTIONS MUST BE TESTED FOR. (REFER TO TABLE IA PAGE 41) NOTE! FOR EACH GC/MS FRACTION CHECKED, EACH SPECIFIC ORGANIC TOXIC POLLUTANT WITHIN EACH FRACTION MUST BE ANALYZED FOR (SEE TABLE IIA PAGE 42. IN ADDITION, ALL PRIMARY INDUSTRY APPLICANTS WITH A PROCESS WASTEWATER DISCHARGE MUST PROVIDE QUANTITATIVE DATA FOR EACH TOXIC POLLUTANT IN TABLE IIIA PAGE 43). RECORD ALL DATA ON FORMS PROVIDED (ITEM 7) IN THIS BOOKLET. (CONTINUE WITH E-K BELOW)	[X] VOLATILE [X] BASE/NEUTRAL [X] ACID [ ] PESTICIDE
E. IF ANY SURFACE WATER DISCHARGE APPLICANT (PRIMARY OR SECONDARY INDUSTRY), REGARDLESS OF THE TYPE OF DISCHARGE, KNOWS OR HAS REASON TO BELIEVE THAT ANY POLLUTANT LISTED IN TABLES IIA AND IVA PAGES 42-43 IS DISCHARGED FROM ANY OUTFALL, THE QUANTITATIVE MUST BE PROVIDED. RECORD ALL DATA ON FORMS PROVIDED (ITEM 7) IN THIS BOOKLET.	[ ] NOT APPLICABLE/BELIEVED ABSENT [X] PRESENT/DATA IS ATTACHED
F. IF ANY SURFACE WATER DISCHARGE APPLICANT (PRIMARY OR SECONDARY INDUSTRY), REGARDLESS OF TYPE OF DISCHARGE, KNOWS OR HAS REASON TO BELIEVE ANY POLLUTANTS LISTED IN TABLE VA PAGE 43 ARE DISCHARGED FROM ANY OUTFALL, THE APPLICANT MUST DESCRIBE REASONS FOR THE POLLUTANT BEING PRESENT AND PROVIDE ANY AVAILABLE QUANTITATIVE DATA. RECORD ALL DATA ON FORMS PROVIDED (ITEM 7) IN THIS BOOKLET.	[X] NOT APPLICABLE/BELIEVED ABSENT [ ] PRESENT/DATA IS ATTACHED
G. ALL SURFACE WATER DISCHARGE APPLICANTS (PRIMARY AND SECONDARY INDUSTRIES) WHO: USES OR MANUFACTURES 2, 4, 5 - TRICHLOROPHENOXY ACETIC ACID (2, 4, 5-T); 2-(2, 4, 5-TRICHLOROPHENOXY) PROPANOIC ACID (SILVEX, 2, 4, 5, TP); 2-(2, 4, 5-TRICHLOROPHENOXY) ETHYL 2, 2-DICHLOROPROPIONATE (ERBON); O, O-DIMETHYL O-(2, 4, 5-TRICHLOROPHENYL) PHOSPHOROTHIOATE (RONNEL); 2, 4, 5-TRICHLOROPHENOL (TCP); OR HEXACHLOROPHENE (HCP); (ALL DATA FOR THE ABOVE MUST BE GENERATED USING STANDARD ANALYTICAL CALIBRATION PROCEDURES) OR KNOWS OR HAS REASON TO BELIEVE THAT TCDD IS OR MAY BE PRESENT IN THEIR DISCHARGE, MUST REPORT QUALITATIVE DATA, GENERATED WHICH USED A SCREENING PROCEDURE NOT CALIBRATED WITH ANALYTICAL STANDARDS, FOR 2, 3, 7, 8, - TETRACHLORODIBENZO-P-DIOXIN (TCDD). RECORD ALL DATA ON FORMS PROVIDED (ITEM 7) IN THIS BOOKLET.	[X] NOT APPLICABLE/BELIEVED ABS [ ] PRESENT/DATA IS ATTACHED
J. IF THE SURFACE WATER DISCHARGE APPLICANT KNOWS OR HAS REASON TO BELIEVE THAT BIOLOGICAL TOXICITY TESTS WERE MADE IN THE LAST THREE (3) YEARS ON ANY OF THE APPLICANT'S DISCHARGES OR ON A RECEIVING WATER IN RELATION TO A DISCHARGE, PROVIDE THIS INFORMATION AS AN ATTACHMENT TO THIS APPLICATION.	[X] NOT APPLICABLE [ ] APPLICABLE/SEE ATTACHED
K. IF A CONTRACT LABORATORY OR CONSULTING FIRM PERFORMED ANY OF THE ANALYSES REQUIRED BY THIS APPLICATION, PROVIDE THE NAME AND ADDRESS OF EACH LABORATORY OR FIRM AND THE ANALYSES PERFORMED AS AN ATTACHMENT OF THIS APPLICATION.	[ ] NOT APPLICABLE [X] APPLICABLE/SEE ~~ATTACHED~~ BELOW
L. DO YOU DISCHARGE ANY OTHER TOXIC OR INJURIOUS CHEMICAL SUBSTANCES NOT LISTED IN TABLES IV PAGE 0 AND IIA THROUGH VA PAGES 42-43. IF YES, THEN IDENTIFY THE CHEMICAL SUBSTANCES AND ESTIMATE THE FINAL EFFLUENT CONCENTRATIONS. SUBMIT THIS INFORMATION AS AN ATTACHMENT TO THIS APPLICATION.	[X] NOT APPLICABLE [ ] APPLICABLE/SEE ATTACHED

K. NUS Corporation
Laboratory Services Division
5350 Campbells Run Road
Pittsburgh, PA 15205

ATTACHMENT 8

SECTION II

SEE INSTRUCTIONS ON REVERSE SIDE

PERMIT NUMBER → MI0005827

ITEM 7

CRITICAL MATERIALS • TOXIC POLLUTANTS • HAZARDOUS SUBSTANCES IN DISCHARGE

OUTFALL NUMBER: 00F

A. USE THIS DATA SHEET TO RECORD INFORMATION AS REQUIRED IN: (CHECK APPROPRIATE BOX FOR WHICH INFORMATION THIS DATA SHEET REPRESENTS.)

- [ ] 1. SECTION II, ITEM 4-E, GROUNDWATER DISCHARGE INFORMATION (PAGE 35)
- [X] 2. SECTION II, ITEM 6, PRIORITY POLLUTANTS IN SURFACE WATER DISCHARGE (PAGE 37) See attached data sheets.
- [ ] 3. B. BELOW: CRITICAL MATERIALS (TABLE IV) IN SURFACE WATER DISCHARGE (PAGE 39)

B. LIST ANY CRITICAL MATERIAL (TABLE IV PAGE 6) NOT ADDRESSED IN SECTION II ITEM 6 PRIORITY POLLUTANTS WHICH YOU KNOW OR HAVE REASON TO BELIEVE TO BE PRESENT IN THE DISCHARGE. SEE REVERSE SIDE OF THIS PAGE FOR FURTHER DIRECTIONS.

- [X] NOT APPLICABLE
- [ ] APPLICABLE (SEE BELOW)

Material	Item	Value
MATERIAL 1	A. NAME OF CRITICAL MATERIAL OR PRIORITY POLLUTANT	
	B. AVERAGE CONCENTRATION; SAMPLE TYPE; # OF ANALYSES	UNIT CODE / SAMPLE TYPE / # OF ANALYSES
	C. MAXIMUM CONCENTRATION AND MASS	UNIT CODE / UNIT CODE
MATERIAL 2	A. NAME OF CRITICAL MATERIAL OR PRIORITY POLLUTANT	
	B. AVERAGE CONCENTRATION; SAMPLE TYPE; # OF ANALYSES	UNIT CODE / SAMPLE TYPE / # OF ANALYSES
	C. MAXIMUM CONCENTRATION AND MASS	UNIT CODE / UNIT CODE
MATERIAL 3	A. NAME OF CRITICAL MATERIAL OR PRIORITY POLLUTANT	
	B. AVERAGE CONCENTRATION; SAMPLE TYPE; # OF ANALYSES	UNIT CODE / SAMPLE TYPE / # OF ANALYSES
	C. MAXIMUM CONCENTRATION AND MASS	UNIT CODE / UNIT CODE
MATERIAL 4	A. NAME OF CRITICAL MATERIAL OR PRIORITY POLLUTANT	
	B. AVERAGE CONCENTRATION; SAMPLE TYPE; # OF ANALYSES	UNIT CODE / SAMPLE TYPE / # OF ANALYSES
	C. MAXIMUM CONCENTRATION AND MASS	UNIT CODE / UNIT CODE
MATERIAL 5	A. NAME OF CRITICAL MATERIAL OR PRIORITY POLLUTANT	
	B. AVERAGE CONCENTRATION; SAMPLE TYPE; # OF ANALYSES	UNIT CODE / SAMPLE TYPE / # OF ANALYSES
	C. MAXIMUM CONCENTRATION AND MASS	UNIT CODE / UNIT CODE
MATERIAL 6	A. NAME OF CRITICAL MATERIAL OR PRIORITY POLLUTANT	
	B. AVERAGE CONCENTRATION; SAMPLE TYPE; # OF ANALYSES	UNIT CODE / SAMPLE TYPE / # OF ANALYSES
	C. MAXIMUM CONCENTRATION AND MASS	UNIT CODE / UNIT CODE
MATERIAL 7	A. NAME OF CRITICAL MATERIAL OR PRIORITY POLLUTANT	
	B. AVERAGE CONCENTRATION; SAMPLE TYPE; # OF ANALYSES	UNIT CODE / SAMPLE TYPE / # OF ANALYSES
	C. MAXIMUM CONCENTRATION AND MASS	UNIT CODE / UNIT CODE
MATERIAL 8	A. NAME OF CRITICAL MATERIAL OR PRIORITY POLLUTANT	
	B. AVERAGE CONCENTRATION; SAMPLE TYPE; # OF ANALYSES	UNIT CODE / SAMPLE TYPE / # OF ANALYSES
	C. MAXIMUM CONCENTRATION AND MASS	UNIT CODE / UNIT CODE

UNITS CODE

1. Mg/l
2. Ug/l
3. LBS/DAY
4. KG/DAY

SAMPLE TYPE

1. GRAB
2. 24 HR.COMP.

ADDITIONAL PAGES OF THIS ITEM 7 ARE ATTACHED FOR THE REST OF THE CRITICAL MATERIALS AND/OR PRIORITY POLLUTANTS REQUIRED TO BE REPORTED.

- [ ] YES
- [X] NO

ATTACHMENT B

NUS CORPORATION

Laboratory Services Division
5350 Campbells Run Road
Pittsburgh, PA 15205
412-788-1080

REPORT TO:
Park West Two
Cliff Mine Road
Pittsburgh, PA 1527

LAB ANALYSIS REPORT

CLIENT NAME: INDIANA & MICHIGAN ELECTRIC CO.
ADDRESS: P.O. BOX 312/D.C. COOK PLANT
BRIDGEMAN, MI 49106
REPORT DATE: 08/29/86
ATTENTION: B FITZGERALD/STEWART

NUS CLIENT NO: 010904
NUS SAMPLE NO: 16080400
VENDOR NO: 05411000
WORK ORDER NO: 55830
DATE RECEIVED: 08/08/86

SAMPLE IDENTIFICATION: MAKEUP PLANT PREFILTER BACKWASH COMP 08/06 0930

TEST	DETERMINATION	RESULTS	UNITS
N360	NPDES PART V-A REQUIRED		
N032	Ammonia as N (distillation)	< 0.1	mg/l
N050	BOD, 5-day (O2)	2	mg/l
N116	Organic Carbon(non-purgeable)	3.8	mg/l
N120	COD (O2)	10	mg/l
N490	pH	7.9	
N610	Solids, suspended at 103 C	16	mg/l
N361	NPDES PART V-B		
N010	Aluminum (Al)	1.7	mg/l
N040	Barium (Ba)	< 0.1	mg/l
N150	Cobalt (Co)	< 0.01	mg/l
N190	Iron,total (Fe)	0.08	mg/l
N230	Magnesium (Mg)	9.9	mg/l
N240	Manganese (Mn)	< 0.01	mg/l
N260	Molybdenum (Mo)	< 0.03	mg/l
N340	Tin (Sn)	< 1	mg/l
N350	Titanium (Ti)	< 0.5	mg/l
N055	Boron (B)	< 0.2	mg/l
N060	Bromide (Br)	< 2.0	mg/l
N225	Color, True	5	Pt-Co
N310	Fluoride, total (F)	2.7	mg/l
N390	Nitrate (N)	0.3	mg/l
N410	Nitrite (N)	< 0.01	mg/l
N435	Nitrogen, Kjeldahl (N)	0.4	mg/l
N440	Nitrogen, Organic (N)	0.4	mg/l
N540	Phosphorus, total (P)	0.34	mg/l
N730	Sulfate, turbidimetric (SO4)	25	mg/l
N740	Sulfide (S)	< 0.1	mg/l
N760	Sulfite (SO3)	< 1	mg/l
N770	Surfactants (MBAS)	< 0.05	mg/l
N362	NPDES PART V-C TOXIC METALS		
N020	Antimony (Sb)	< 0.1	mg/l

NUS CORPORATION

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5350 Campbells Run Road
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LAB ANALYSIS REPORT

CLIENT NAME: INDIANA & MICHIGAN ELECTRIC CO.
ADDRESS: P.O. BOX 312/D.C. COOK PLANT
BRIDGEMAN, MI 49106

REPORT DATE: 08/29/86

ATTENTION: B FITZGERALD/STEWART

NUS CLIENT NO: 010904
NUS SAMPLE NO: 16080400
VENDOR NO: 05411000
WORK ORDER NO: 55830
DATE RECEIVED: 08/08/86

SAMPLE IDENTIFICATION: MAKEUP PLANT PREFILTER BACKWASH COMP 08/06 0930

TEST	DETERMINATION	RESULTS	UNITS
M030	Arsenic (As)	0.002	mg/l
M050	Beryllium (Be)	< 0.002	mg/l
M090	Cadmium (Cd)	< 0.005	mg/l
M140	Chromium (Cr)	< 0.01	mg/l
M160	Copper (Cu)	< 0.01	mg/l
M200	Lead (Pb)	< 0.03	mg/l
M250	Mercury (Hg)	< 0.0002	mg/l
M270	Nickel (Ni)	< 0.03	mg/l
M290	Selenium (Se)	< 0.004	mg/l
M300	Silver (Ag)	< 0.01	mg/l
M330	Thallium (Tl)	< 0.1	mg/l
M390	Zinc (Zn)	0.07	mg/l
W270	Cyanide, total (CN)	< 0.005	mg/l
W500	Phenolics	< 0.02	mg/l
0110	VOLATILES-PP IN WATER		
OV01	Acrolein	< 100	ug/l
OV02	Acrylonitrile	< 100	ug/l
OV03	Benzene	< 5	ug/l
OV05	Bromoform	< 5	ug/l
OV06	Carbon Tetrachloride	< 5	ug/l
OV07	Chlorobenzene	< 5	ug/l
OV08	Chlorodibromomethane	< 5	ug/l
OV09	Chloroethane	< 10	ug/l
OV10	2-Chloroethylvinyl Ether	< 10	ug/l
OV11	Chloroform	< 5	ug/l
OV12	Dichlorobromomethane	< 5	ug/l
OV14	1,1-Dichloroethane	< 5	ug/l
OV15	1,2-Dichloroethane	< 5	ug/l
OV16	1,1-Dichloroethylene	< 5	ug/l
OV17	1,2-Dichloropropane	< 5	ug/l
OV18	1,3-Dichloropropylene	< 5	ug/l
OV19	Ethylbenzene	< 5	ug/l

CLIENT ORIGINAL

NUS CORPORATION

Laboratory Services Division
5350 Campbells Run Road
Pittsburgh, PA 15205

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412-788-1080

LAB ANALYSIS REPORT

CLIENT NAME: INDIANA & MICHIGAN ELECTRIC CO.
ADDRESS: P.O. BOX 312/D.C. COOK PLANT
BRIDGEMAN, MI 49106

REPORT DATE: 08/29/86

ATTENTION: B FITZGERALD/STEWART

NUS CLIENT NO: 010904
NUS SAMPLE NO: 16080400
VENDOR NO: 05411009
WORK ORDER NO: 55330
DATE RECEIVED: 08/08/86

SAMPLE IDENTIFICATION: MAKEUP PLANT PREFILTER BACKWASH COMP 08/06 0930

TEST	DETERMINATION	RESULTS	UNITS
0V20	Methyl Bromide	< 10	ug/l
0V21	Methyl Chloride	< 10	ug/l
0V22	Methylene Chloride	38	ug/l
0V23	1,1,2,2-Tetrachloroethane	< 5	ug/l
0V24	Tetrachloroethylene(Perchloro)	< 5	ug/l
0V25	Toluene	< 5	ug/l
0V26	1,2-Trans-Dichloroethylene	< 5	ug/l
0V27	1,1,1-Trichloroethane	< 5	ug/l
0V28	1,1,2-Trichloroethane	< 5	ug/l
0V29	Trichloroethylene	< 5	ug/l
0V30	Trichlorofluoromethane	< 5	ug/l
0V31	Vinyl chloride	< 10	ug/l
0120	ACIDS - PP IN WATER		
0A01	2-Chlorophenol	< 10	ug/l
0A02	2,4-Dichlorophenol	< 10	ug/l
0A03	2,4-Dimethylphenol	< 10	ug/l
0A04	4,6-Dinitro-o-cresol	< 50	ug/l
0A05	2,4-Dinitrophenol	< 50	ug/l
0A06	2-Nitrophenol	< 10	ug/l
0A07	4-Nitrophenol	< 50	ug/l
0A08	p-Chloro-m-cresol	< 10	ug/l
0A09	Pentachlorophenol	< 50	ug/l
0A10	Phenol	< 10	ug/l
0A11	2,4,6-Trichlorophenol	< 10	ug/l
0E30	Acid Extraction-Water		
0130	BASE NEUTRALS - PP IN WATER		
0B01	Acenaphthene	< 10	ug/l
0B02	Acenaphthylene	< 10	ug/l
0B03	Anthracene	< 10	ug/l
0B04	Benzidine	< 50	ug/l
0B05	Benzo(a)Anthracene	< 10	ug/l
0B06	Benzo(a)Pyrene	< 10	ug/l

See attache data sheet 11/7/86. Rete indicates than dete le methylene chl

ATTACHMENT B

NUS CORPORATION

Laboratory Services Division
5350 Campbells Run Road
Pittsburgh, PA 15205

REMIT TO:
Park West Two
Cliff Mine Road
Pittsburgh, PA 15275

412-788-1080

LAB ANALYSIS REPORT

CLIENT NAME: INDIANA & MICHIGAN ELECTRIC CO.
ADDRESS: P.O. BOX 3127D.C. COOK PLANT
BRIDGEMAN, MI. 49106
ATTENTION: J FITZGERALD/STEWART

REPORT DATE: 08/29/86

NUS CLIENT NO: 010904
NUS SAMPLE NO: 16080400
VENDOR NO: 05411600
WORK ORDER NO: 55830
DATE RECEIVED: 08/08/86

SAMPLE IDENTIFICATION: MAKEUP PLANT PREFILTER BACKWASH COMP 08/06 0930

TEST	DETERMINATION	RESULTS	UNITS
0307	3,4-Benzofluoranthene	< 10	ug/l
0308	Benzo(ghi)Perylene	< 10	ug/l
0309	Benzo(k)Fluoranthene	< 10	ug/l
0310	Bis(2-Chloroethoxy)Methane	< 10	ug/l
0311	Bis(2-Chloroethyl)Ether	< 10	ug/l
0312	Bis(2-Chloroisopropyl)Ether	< 10	ug/l
0313	Bis(2-Ethylhexyl)Phthalate	< 10	ug/l
0314	4-Bromophenyl Phenyl Ether	< 10	ug/l
0315	Butyl Benzyl Phthalate	< 10	ug/l
0316	2-Chloronaphthalene	< 10	ug/l
0317	4-Chlorophenyl Phenyl Ether	< 10	ug/l
0318	Chrysene	< 10	ug/l
0319	Dibenzo(a,h)Anthracene	< 10	ug/l
0320	1,2-Dichlorobenzene	< 10	ug/l
0321	1,3-Dichlorobenzene	< 10	ug/l
0322	1,4-Dichlorobenzene	< 10	ug/l
0323	3,3'-Dichlorobenzidine	< 20	ug/l
0324	Diethyl Phthalate	< 10	ug/l
0325	Dimethyl Phthalate	< 10	ug/l
0326	Di-N-Butyl Phthalate	< 10	ug/l
0327	2,4-Dinitrotoluene	< 10	ug/l
0328	2,6-Dinitrotoluene	< 10	ug/l
0329	Di-N-Octyl Phthalate	< 10	ug/l
0330	1,2-Diphenylhydrazine(Azobz)	< 20	ug/l
0331	Fluoranthene	< 10	ug/l
0332	Fluorene	< 10	ug/l
0333	Hexachlorbenzene	< 10	ug/l
0334	Hexachlorobutadiene	< 10	ug/l
0335	Hexachloro-cyclopentadiene	< 10	ug/l
0336	Hexachloroethane	< 10	ug/l
0337	Indeno(1,2,3 cd)Pyrene	< 10	ug/l
0338	Isophorone	< 10	ug/l

A Halliburton Company

CLIENT ORIGINAL

ATTACHMENT 8

NUS CORPORATION

Laboratory Services Division
5350 Campbells Run Road
Pittsburgh, PA 15205
412-788-1080

REMIT TO:
Park West Two
Cliff Mine Road
Pittsburgh, PA 15275

LAB ANALYSIS REPORT

CLIENT NAME: INDIANA & MICHIGAN ELECTRIC CO.
ADDRESS: P.O. BOX 312/D.C. COOK PLANT
BRIDGEMAN, MI 49106
REPORT DATE: 08/29/86
ATTENTION: B FITZGERALD/STEWART

NUS CLIENT NO: 010904
NUS SAMPLE NO: 14080400
VENDOR NO: 05411000
WORK ORDER NO: 55830
DATE RECEIVED: 08/08/86

SAMPLE IDENTIFICATION: MAKEUP PLANT PREFILTER BACKWASH COMP 08/06 0930

TEST	DETERMINATION	RESULTS	UNITS
0B39	Naphthalene	< 10	ug/l
0B40	Nitrobenzene	< 10	ug/l
0B41	N-Nitrosodimethylamine	< 10	ug/l
0B42	N-Nitrosodi-N-Propylamine	< 10	ug/l
0B43	N-Nitrosodiphenylamine	< 10	ug/l
0B44	Phenanthrene	< 10	ug/l
0B45	Pyrene	< 10	ug/l
0B46	1,2,4-Trichlorobenzene	< 10	ug/l
0E25	Base Neutral Extraction-Water		
0142	PESTICIDES/PCB'S - PP IN WATER		
0E10	Pesticide/PCB Extraction-Water		
0P01	Aldrin	< 0.05	ug/l
0P02	alpha BHC	< 0.05	ug/l
0P03	beta BHC	< 0.05	ug/l
0P04	delta BHC	< 0.05	ug/l
0P05	gamma BHC (Lindane)	< 0.05	ug/l
0P06	Chlordane	< 0.50	ug/l
0P07	4-4'DDD	< 0.10	ug/l
0P08	4-4'DDE	< 0.10	ug/l
0P09	4-4'DDT	< 0.10	ug/l
0P10	Dieldrin	< 0.10	ug/l
0P11	Endosulfan I	< 0.05	ug/l
0P12	Endosulfan II	< 0.10	ug/l
0P13	Endosulfan Sulfate	< 0.10	ug/l
0P14	Endrin	< 0.10	ug/l
0P15	Endrin Aldehyde	< 0.10	ug/l
0P16	Heptachlor	< 0.05	ug/l
0P17	Heptachlor Epoxide	< 0.05	ug/l
0P18	Toxaphene	< 1.0	ug/l
0P19	PCB-1016	< 0.5	ug/l
0P20	PCB-1221	< 0.5	ug/l
0P21	PCB-1232	< 0.5	ug/l

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ATTACHMENT B

NUS CORPORATION

Laboratory Services Division
5350 Campbells Run Road
Pittsburgh, PA 15205
412-788-1080

REMIT TO:
Park West Two
Cliff Mine Road
Pittsburgh, PA 15275

LAB ANALYSIS REPORT

CLIENT NAME: INDIANA & MICHIGAN ELECTRIC CO.
ADDRESS: P.O. BOX 312/D.C. COOK PLANT
BRIDGMAN, MI 49106
ATTENTION: B FITZGERALD/STEWART

NUS CLIENT NO: 010904
NUS SAMPLE NO: 16060400
VENDOR NO: 05411000
REPORT DATE: 08/29/86
WORK ORDER NO: 55830
DATE RECEIVED: 08/08/86

SAMPLE IDENTIFICATION: MAKEUP PLANT PREFILTER BACKWASH COMP 08/06 0930

TEST	DETERMINATION	RESULTS	UNITS
OP22	PCB-1242	< 0.5	ug/l
OP23	PCB-1248	< 0.5	ug/l
OP24	PCB-1254	< 1.0	ug/l
OP25	PCB-1260	< 1.0	ug/l
R450	RADIUM 226 AND 228		
R804	Radium-226	< 0.5	pCi/l
R805	Radium-228	< 3	pCi/l
R800	Gross Alpha	< 4	pCi/l
R801	Gross Beta	< 6	pCi/l
W150	Chlorine, Total Res DPD (Cl2)	< 0.1	mg/l

COMMENTS:

Reviewed and Approved by: A Halliburton Company

CLIENT ORIGINAL

ATTACHMENT B

NUS CORPORATION

Laboratory Services Division
5350 Campbells Run Road
Pittsburgh, PA 15205
412-788-1080

REMIT TO:
Park West Two
Cliff Mine Road
Pittsburgh, PA 15275

LAB ANALYSIS REPORT

CLIENT NAME: INDIANA & MICHIGAN ELECTRIC CO.
ADDRESS: P.O. BOX 312/D.C. COOK PLANT
BRIDGMAN, MI 49106
ATTENTION: D FITZGERALD/STEWART

REPORT DATE: 08/29/86

NUS CLIENT NO: 010904
NUS SAMPLE NO: 16069403
VENDOR NO: 05411000
WORK ORDER NO: 55330
DATE RECEIVED: 08/08/86

SAMPLE IDENTIFICATION: MAKEUP PLANT PREFILTER BACKWASH-GRAB III 08/06 0300

TEST	DETERMINATION	RESULTS	UNITS
3A34	Fecal Coliform (MPN)	43	col/100ml
M682	Oil,extraction-gravimetric(3)	< 3.0	mg/l

COMMENTS:

Reviewed and Approved by:

ATTACHMENT B

NUS CORPORATION

Laboratory Services Division
5350 Campbells Run Road
Pittsburgh, PA 15205
412-788-1080

REPORT TO:
Park West Two
Cliff Mine Road
Pittsburgh, PA 15275

LAB ANALYSIS REPORT

CLIENT NAME: INDIANA & MICHIGAN ELECTRIC CO.
ADDRESS: P.O. BOX 312/D.C. COOK PLANT
BRIDGMAN, MI 49106

NUS CLIENT NO: 010904
NUS SAMPLE NO: 16000404
VENDOR NO: 05411000
REPORT DATE: 08/29/86
WORK ORDER NO: 55830
ATTENTION: D FITZGERALD/STEWART
DATE RECEIVED: 08/08/86

SAMPLE IDENTIFICATION: MAKEUP PLANT PREFILTER BACKWASH-GRAB IV 08/06 0920

TEST	DETERMINATION	RESULTS	UNITS
BA33	Fecal Coliform (MPN)4	23	col/100ml
N683	Oil, extraction-gravimetric(4)	< 3.0	mg/l

COMMENTS:

Reviewed and Approved by: A Halliburton Company

CLIENT ORIGINAL

ATTACHMENT B

NUS CORPORATION

Laboratory Services Division
5350 Campbells Run Road
Pittsburgh, PA 15205
412-788-1080

REMIT TO:
Park West Two
Cliff Mine Road
Pittsburgh, PA 15275

LAB ANALYSIS REPORT

CLIENT NAME: INDIANA & MICHIGAN ELECTRIC CO.
ADDRESS: P.O. BOX 312/D.C. COOK PLANT
BRIDGMAN, MI 49106
ATTENTION: B FITZGERALD/STEWART

REPORT DATE: 08/29/86

NUS CLIENT NO: 010904
NUS SAMPLE NO: 14080402
VENDOR NO: 05411000
WORK ORDER NO: 55830
DATE RECEIVED: 08/08/86

SAMPLE IDENTIFICATION: MAKEUP PLANT PREFILTER BACKWASH-GRAB II 08/05 1645

TEST	DETERMINATION	RESULTS	UNITS
8A33	Fecal Coliform (MPN) 2	< 3	col/100ml
N681	Oil,extraction-gravimetric(2)	3.4	mg/l

COMMENTS:

Reviewed and Approved by: A Halliburton Company

CLIENT ORIGINAL

ATTACHMENT 8

NUS CORPORATION

Laboratory Services Division
5350 Campbells Run Road
Pittsburgh, PA 15205
412-788-1080

REPORT TO:
Park West Two
Cliff Mine Road
Pittsburgh, PA 15275

LAB ANALYSIS REPORT

CLIENT NAME: INDIANA & MICHIGAN ELECTRIC CO.
ADDRESS: P.O. BOX 312/D.C. COOK PLANT
BRIDGMAN, MI 49106
REPORT DATE: 08/29/86
ATTENTION: J FITZGERALD/STEWART

NUS CLIENT NO: 010994
NUS SAMPLE NO: 16090401
VENDOR NO: 05411000
WORK ORDER NO: 53030
DATE RECEIVED: 08/08/86

SAMPLE IDENTIFICATION: MAKEUP PLANT PREFILTER BACKWASH-GRAB 1 08/05 1125

TEST	DETERMINATION	RESULTS	UNITS
BA32	Fecal Coliform - MPN	< 3	col/100ml
M680	Oil, extraction-gravimetric	< 3.0	mg/l

COMMENTS:

Reviewed and Approved by: NUS A Halliburton Company

CLIENT ORIGINAL

NUS CORPORATION

ATTACHMENT B

Laboratory Services Division
5350 Campbells Run Road
Pittsburgh, PA 15205
412-788-1080

REMIT TO:
Park West Two
Cliff Mine Road
Pittsburgh, PA 15275

LAB ANALYSIS REPORT

CLIENT NAME: INDIANA & MICHIGAN ELECTRIC CO.
ADDRESS: P.O. BOX 312/D.C. COOK PLANT
BRIDGMAN, MI 49106
ATTENTION: B FITZGERALD/STEWART

REPORT DATE: 11/07/86

NUS CLIENT NO: 010904
NUS SAMPLE NO: 16101256
VENDOR NO: 05411000
WORK ORDER NO: 55030
DATE RECEIVED: 10/17/86

SAMPLE IDENTIFICATION: MAKEUP PLANT PRE-FILTER BACKWASH COMP 10/13-14

TEST	DETERMINATION	RESULTS	UNITS
0119	VOLATILES-PP IN WATER		
0V01	Acrolein	< 100	ug/l
0V02	Acrylonitrile	< 100	ug/l
0V03	Benzene	< 5	ug/l
0V05	Bromoform	< 5	ug/l
0V06	Carbon Tetrachloride	< 5	ug/l
0V07	Chlorobenzene	< 5	ug/l
0V08	Chlorodibromomethane	< 5	ug/l
0V09	Chloroethane	< 10	ug/l
0V10	2-Chloroethylvinyl Ether	< 10	ug/l
0V11	Chloroform	< 5	ug/l
0V12	Dichlorobromomethane	< 5	ug/l
0V14	1,1-Dichloroethane	< 5	ug/l
0V15	1,2-Dichloroethane	< 5	ug/l
0V16	1,1-Dichloroethylene	< 5	ug/l
0V17	1,2-Dichloropropane	< 5	ug/l
0V18	1,3-Dichloropropylene	< 5	ug/l
0V19	Ethylbenzene	< 5	ug/l
0V20	Methyl Bromide	< 10	ug/l
0V21	Methyl Chloride	< 10	ug/l
0V22	Methylene Chloride	< 5	ug/l
0V23	1,1,2,2-Tetrachloroethane	< 5	ug/l
0V24	Tetrachloroethylene(Perchloro)	< 5	ug/l
0V25	Toluene	< 5	ug/l
0V26	1,2-Trans-Dichloroethylene	< 5	ug/l
0V27	1,1,1-Trichloroethane	< 5	ug/l
0V28	1,1,2-Trichloroethane	< 5	ug/l
0V29	Trichloroethylene	< 5	ug/l
0V30	Trichlorofluoromethane	< 5	ug/l
0V31	Vinyl chloride	< 10	ug/l

COMMENTS:

Reviewed and Approved by: JRC

Appendix 1.2

ENVIRONMENTAL EVALUATION

Donald C. Cook Nuclear Plant
Upgrade and Temporary Use of Beach Access Road

INDIANA & MICHIGAN ELECTRIC COMPANY

DONALD C. COOK NUCLEAR PLANT

ENVIRONMENTAL EVALUATION

FOR

UPGRADE AND TEMPORARY USE

OF THE

BEACH ACCESS ROAD

Prepared by: ______________________________
T. G. Harshbarger, Radiological Support Section

Approved by: ______________________________
S. J. Brewer-Manager, Radiological Support Section

Concurred by: ______________________________
J. Fryer, Environmental Coordinator

TABLE OF CONTENTS

I. <u>Executive Summary</u>

This Environmental Evaluation was conducted to determine if the upgrade and temporary use of the D. C. Cook beach access road constitutes an unreviewed environmental question pursuant to Part II, Section 3.1 of the Donald C. Cook Technical Specifications.

Due to the installation of water and sewage lines at the plant site normal access to the current training facility will be unavailable. Therefore, the beach access road, which connects to Livingston Road, will be used on a temporary basis to provide access to the training facility.

Based on this Environmental Evaluation it is concluded that the upgrade and use of the beach access road is not an unreviewed environmental question. Therefore, it will not be necessary to obtain approval from the Nuclear Regulatory Commission prior to the start of the road upgrade and use.

II. Purpose of this Environmental Evaluation

The purpose of this Environmental Evaluation is to determine if the proposed upgrade and use of the Donald C. Cook beach access road constitutes an unreviewed environmental question as defined by Part II, Section 3.1 of the Donald C. Cook Plant Technical Specifications.

As stated in Part II, Section 3.1 of the Donald C. Cook Plant Environmental Technical Specifications, "A proposed change, test or experiment shall be deemed to involve an unreviewed environmental question if it concerns (1) a matter which may result in a significant increase in any adverse environmental impact previously evaluated in the final environmental statement (FES) as modified by staff's testimony to the Atomic Safety and Licensing Board, supplements to the FES, environmental impact appraisals, or in any decisions of the Atomic Safety and Licensing Board; or (2) a significant change in effluents or power level [in accordance with 10 CFR Part 51.5(b)(2)] or (3) a matter not previously reviewed and evaluated in the documents specified in (1) of the Subsection, which may have a significant adverse environmental impact."

III. Description of the Activity and the Affected Area

The Indiana & Michigan Electric Company (I&M) is installing new water and sewage lines to support the Donald C. Cook Nuclear Plant. During a short period of the installation (approximately 8 weeks) the normal access to the current training facility will be unavailable for use.

This training facility is utilized by 75-100 plant personnel each day to meet Nuclear Regulatory Commission and Institute of Nuclear Power Operations training commitments. In addition 60 plant employees work out of the training facility on permanent basis. In order to maintain access to the training facility and thus keep the training facility operational it is proposed to upgrade and use the existing beach access road.

The existing beach access road was used as a site access during the construction of the plant and is currently used by plant security to conduct security inspections of the beach front. The route that is being proposed for upgrade and use exits the training facility parking lot to the north and immediately turns west to run adjacent to the south edge of the plant protected area for approximately 300 feet. The road then turns south and runs parallel to the Lake Michigan shoreline for approximately 1700 feet before it intersects Livingston Road. Only the 1700 feet of access road that runs parallel to the shoreline requires upgrading. This upgrading would involve adding 480 cubic yards of 22A gravel and crushed stone to this section of the road. The gravel would be added to make the road surface smooth and to fill in wash outs. This upgrade would be an average of 3 inches of stone over the 1700 feet length of the road, 20 feet wide. The total cost of the upgrade is estimated at approximately $8,000 for material and labor.

A discussion of the Geology and Soils, Groundwater and Surface Water, Biological Resources, and Cultural Resources in the area of the beach access road can be found in the "Indiana & Michigan Electric Company Donald C. Cook Nuclear Plant Environmental Evaluation for the Proposed Drinking Water Hookup to the Lake Township Water Supply".

IV. Environmental Impacts

A. Geological and Soils

Since the beach access road was previously used for site access during the construction of the plant and is now used for periodic security patrols compaction of the soils beneath the road has already occurred. Use of the road by cars and light trucks is not expected to cause further compaction of the soils in this area. In addition, no excavation will occur as the result of the road upgrade and use. Therefore, there will be no impact to the geological formations and soils in area of the beach access road.

B. Surface Water and Groundwater

The upgrade and use of the beach access road will not have any impact on either the watertable or surface water in the area of the beach access road.

C. Biological Resources

1. Terrestrial Ecology

There will be no impacts to the terrestrial ecology as the result of the upgrade and use of the beach access road for the following reasons.

a. No habitat will be removed as a result of the upgrade and temporary use of the beach access road.

b. Since the beach access road is already subjected to the intrusion of man and machinery (i.e. recreational use of the beach adjacent to access road, periodic security patrols, and existing security lights) animals residing in the areas adjacent to the construction should not be disturbed by the increased activity.

2. Aquatic Ecology

There will be no impact to the aquatic ecology in the area as the result of the road upgrade and use.

D. Cultural Resources

There will be no change in land use as the result of the upgrade and temporary use of the beach access road. No archaeological resources are known to exist in the area based on previous construction excavations.

E. Noise

Noise levels generated by the increased flow of traffic (approximately 100 vehicles per day) on Livingston Road and the beach access road could be considered a nuisance by individuals using the adjacent beach and lake area and by individuals residing along Livingston Road. However, this is a temporary impact that will last for only 8 weeks.

V. Environmental Controls

The following environmental controls shall be utilized to minimize impact to the environment resulting from the upgrade and use of the beach access road. These environmental controls shall be reviewed and enforced by the D. C. Cook Environmental Section.

A. Noise

As stated, the impact of noise in the surrounding community is a temporary impact (approximately 8 weeks). If use of the beach access road is required beyond the scheduled eight weeks, written authorization to do so must be obtained from the D. C. Cook Environmental Section.

B. Environmental Observations

The D. C. Cook Environmental Section will inspect Livingston Road and the beach access road once a week to determine if use of the access road is causing any adverse impacts. The D. C. Cook Environmental Section will take appropriate actions to mitigate any observed impacts.

C. Permits

It has been determined through discussions with township and county authorities that no permits are required to use the Livingston Road/Beach Access Route to the training facilities.

VI. Conclusion

It is concluded that with proper mitigation practices as outlined in the Environmental Controls Section of this evaluation no significant adverse environmental impact will result from the proposed activity.

It is further concluded that the upgrade and temporary use of the beach access road does not involve an unreviewed environmental question. Therefore, it will not be necessary to obtain approval from the Nuclear Regulatory Commission to upgrade and use the beach access road.

However, it should be noted that this Environmental Evaluation shall be included as part of the 1986 Annual Environmental Operating Report.

Appendix 1.3

NPDES Non-Routine Reports - 1986

NONROUTINE REPORTS

EVENT DATE	C/R NUMBER	DESCRIPTION
5/28/86	12-06-86-0634	Heating boiler blowdown - total suspended solids concentration exceed NPDES Permit limit.
6/16/86	02-06-86-0708	Steam generator blowdown - total suspended solids concentration exceeded NPDES Permit limit.
6/29/86	02-07-86-0816	Steam generator blowdown - total suspended solids sample was missed.
6/30/86	12-06-86-0759	Turbine Room Sump discharge pipe ruptured. While making repairs to pipe on 7/16/86 and 7/17/86, the sump overflowed to Lake Michigan.
9/3/86	12-09-86-1043	Turbine Room Sump overflowed to Lake Michigan.
10/31/86	12-11-86-1281	Turbine Room Sump discharge pipe was broken.
11/7/85 to 11/10/86	1-11-86-1303	Unit 1 intake and discharge temperature readings were missed.

Appendix 1.4

Herbicide Application Program - 1986

ATTACHMENT C

INDIANA & MICHIGAN ELECTRIC COMPANY

AMERICAN ELECTRIC AEP POWER SYSTEM

DATE: March 26, 1987

SUBJECT: 1986 Herbicide Spray Report - D. C. Cook Plant

FROM: L. A. Shepherd

TO: H. E. Brooks

SUMMARY OF PROGRAM

A. During April and May, Benton Harbor Division Spraying Crew used a mixture of Krovar I (K-I) and Oust to control grass and weed growth on the plant site. Locations treated included: KV yards, roadways, parking lots, perimeters of the sewage ponds and controlled/uncontrolled areas inside the plant fence. A total of 303 lbs. of K-I and 2.6 lbs. of Oust were used. (See Attachment 1) .

B. This year no applications of Tordon 101R (Dow Chemical) were made to tree stumps because there was no trimming of trees by Goshen Tree Crew.

C. Major Areas covered and Observations (See Attachment 1).

1. Sewage Pond: Very good weed control around ponds and on road, very few weeds found.

2. Absorption Pond: Roadway here has some weed growth started through the stones.

3. U-1 Main Transformer: Excellent control, no weeds.

4. U-2 Main Transformer: 3 weeds discovered along west side of the middle single phase transformer catch basin at the concrete/sand interface.

5. U-1 Diesel Fuel Oil Tank Unloading Area: Excellent Control, no weeds.

6. U-2 Diesel Fuel Oil Tank Unloading Area: Sparse grasses inside basin. Two clumps of weeds discovered on south side of turbine building at building/sand interface.

7. Chlorine Building, Cimco & AEPSC Site Design Office Trailers: Excellent weed control, no weeds discovered.

8. Hydrogen and Nitrogen Storage Tank Area (near 609' East Aux. Cranebay): Excellent control, no weeds found.

9. East Perimeter Fence, Ice Crew/Westinghouse/ANR/Computer Office Trailers: Excellent control, 2 weeds observed in whole area.

10. South Perimeter Fence: Excellent control, no weeds present.

11. West Perimeter Fence: Asphalt area, no weeds.

12. North Perimeter Fence: Excellent control, no weeds.

13. Six Trailers South Side (Cimco, STA and Firewatch Trailers): Area around trailers clear, clumps of weeds around base of nearby poles.

14. U-2 Start-up Transformer: Several patches of weeds under base of transformer.

15. Hydro-Nuclear Office (U-2 West End of Turbine Bldg.): Patches of weeds at building/sand interface, no weeds under trailer.

16. U-2 Outside Trash Basket Area: Excellent control, no weeds.

17. U-1 Spent Resin and Charcoal Dumping Area (near screenhouse roll-up door): Clumps of weeds in sand area.

18. Heating Boiler Fuel Oil Tank Unloading Area: Excellent Control, no weeds present.

19. Gas Cylinder Storage Area (South Side of Old Office Bldg.): Excellent control, no weeds discovered.

20. Employee Picnic Lunch Area: Excellent Control, no weeds.

21. Vehicle Entry Control Area: Excellent Control, no weeds.

22. New Office Bldg. Construction Area: Excellent Control, no weeds.

23. Construction & Security Office Building and Guard Island: Excellent control, no weeds found.

24. Westinghouse, ANR Trailers: No weed growth under trailers.

25. Unit #1 Containment and RWST, CST and PWST, Storage Tank Areas: No weed growth around Unit 1 RWST. Grass growing on North and East sides of Unit 1 CST Storage Tank concrete base and sand interface. Small clumps of grass on north side of Brown-Boveri transformer. Grass and weed noticed on north and east side of Unit 1 PWST tank concrete base and sand interface. Excellent weed control around and under trailers in this area.

26. Unit #2 Containment and RWST, CST and PWST Storage Tank Areas:

    Clumps of grass outside southwest corner of single phase transformer ASEA pad.

    10 X 20 ft. sparse patch of weeds and grass on the northside of Unit 2 CST and RWST Storage Tanks.

    Small clumps of grass on north side of Unit 2 PWST Storage Tank at concrete pad and sand interface.

    Small clumps of grass on the north, east, and south sides of Unit 2 CST at concrete pad and sand interface.

    Very sparse clumps of grass near fence east of Unit 2 PWST and CST Storage Tanks.

    Sparse patch (10 ft X 3 ft.) of grass noticed where railroad tracks come into fenced area on southeast side.

    Weed control around HNS Laundry trailer excellent; no weeds.

27. 345 KV Switchgear Yard: Spot of clover discovered along south fence. One small patch of grass in southwest corner near transformer berm. Small patches of chickweeds along north fence.

28. 765 KV Switchgear Yard: Grass present on the southeast, northeast and northwest sides of yard near fence.

29. Dayco Building: Good weed control, a few weeds around building.

30. Craft Employees Parking Lot: Excellent weed control; no weeds.

31. I&M Employees Parking Lot: Excellent weed control; no weeds.

32. Visitors Parking Lot: Excellent weed control; no weeds.

33. Construction Storeroom Parking Lot: Good weed control, two clumps of grass by Alltel parking space.

34. Contractor Supervisor's Parking Lot: Chickweed and grass along temporary fence. Good weed control in parking lot.

35. Sewage Plant & 69/KV Switchgear Station: Clumps of grass on south side of sewage plant. Excellent weed control in 69 to 4 KV Switchgear yard. No weeds.

36. Training Center: A few dandelions on east side of the main training center near the railroad ties used for parking stops. Grass noticed in the vicinity of parking stops in the east side of the parking lot. No weeds in center of lot. No weeds around New Sewage Plant.

37. Plant Manager's Lot, Auditors Office and Construction Storeroom Office: Good weed control around parking stops and lot in general. No weeds. Two clumps of grass on south side of QA auditor's office. Excellent weed control around Construction Storeroom Office. No weeds.

38. 69/4KV lines: Pines do not seem to be resprouting but oaks are resprouting at the base of their stumps and some resprouting of sassafras is apparent. Maximum height of resprouting 6-8 ft.

39. 765 KV lines: Large stumps show no signs of resprouting - appear to be dead.

40. 345 KV lines: Large stumps show no signs of resprouting - appear to be dead.

The observations made in November and December clearly indicate that the thorough spraying program continues to control encroaching vegetation resulting in a reduction of maintenance costs and an increase in overall plant-site visibility. The one exception to this seems to be the resprouting of oaks and sassafras near 69/4 KV lines.

If you have questions or require further information please contact me at Ext. 1326.

Linda Shepherd
L. A. Shepherd

LAS/js

cc: W. G. Smith, Jr./A. A. Blind/L. S. Gibson/J. E. Rutkowski
T. A. Kriesel
J. E. Fryer
E. C. Mallen
D. Fitzgerald-Stuart
C. R. Mort

D. C. COOK NUCLEAR PLANT
HERBICIDE APPLICATION DATA
1986

Weed Spray Application by: B. H. Division
I & M Electric

Name: Dennis Runkel
Greg Myers

Date	Lbs. KROVAR I	Rate #/Acre	Gallons	OUST 1 oz/acre	Acres	Location
4/18/86	18	6	300	3.0	3.0	765 KV yard
4/22/86	18	6	300	3.0	3.0	765 KV yard
4/22/86	15	6	250	2.5	2.5	69/4 KV yard
4/23/86	18	6	300	3.0	3.0	765 KV yard
4/24/86	27	6	450	4.5	4.5	765 KV yard
4/25/86	18	6	300	3.0	3.0	765 KV yard
4/28/86	9	6	150	1.5	1.5	765 KV yard
4/28/86	18	6	300	3.0	3.0	345 KV yard
4/29/86	18	6	300	3.0	3.0	345 KV yard
5/2/86	18	6	300	3.0	3.0	345 KV yard
5/2/86	22	10	220	2.2	2.2	Plant perimeter
5/5/86	22	10	220	2.2	2.2	Plant perimeter
5/6/86	8	10	80	0.8	0.8	Plant perimeter
5/6/86	4	10	40	0.4	0.4	Sewage Ponds A/B
5/7/86	34	10	340	3.4	3.4	Micro 69/4 KV yard Parking Areas
5/8/86	30	10	300	3.0	3.0	Cook Parking Lots
5/9/86	6	10	60	0.6	0.6	Cook Parking Lots
	303 lbs.		3960 gals	42.1 oz.	39.6 acres	

Summary: Used 303 lbs. Krovar I applied to approx. 40 acres
ie.177# @ 6#/acre - outer yards
126# @ 10#/acre - inner yards
2.6 lbs. OUST - all areas

ATTACHMENT C

INDIANA & MICHIGAN ELECTRIC COMPANY

AMERICAN ELECTRIC POWER SYSTEM

DATE: March 19, 1987

SUBJECT: Right-of-Way Maintenance Herbicide Use

FROM: H. E. Brooks

TO: E. C. Mallen

This will confirm our phone conversation of today.

There was no right-of-way maintenance performed on the bus ties or exit lines on Cook Plant lands in 1986.

Accordingly, no herbicides were used in 1986.

Ed

H. E. Brooks

HEB:et

cc: J. A. Druckemiller
J. L. Pawlisch
R. E. Gifford

INTRA-SYSTEM

Appendix 1.5

Corbicula Monitoring Program - 1986

ATTACHMENT A

A Technical Report To:

The D. C. Cook Nuclear Plant

American Electric Power Service Corporation

Indiana and Michigan Electric Company

RESULTS OF THE 1986 MONITORING PROGRAM (WITH A SUMMARY OF 1982-1985 RESULTS) TO DETECT THE ASIATIC CLAM (CORBICULA) IN THE VICINITY OF THE D. C. COOK NUCLEAR POWER PLANT

By

David S. White
Great Lakes Research Division
Benthos Laboratory
1061 North University Building
University of Michigan
Ann Arbor, MI 48109
(313) 764-7486

DRDA Contract

No. 83-1766-P1

December 9, 1986

SUMMARY

Entrainment, diver collected sand and gravel samples, and beach areas at the D. C. Cook nuclear power plant were examined for the presence of the Asiatic clam *Corbicula fluminea* in mid-June, mid-July, and mid-August 1986. No veligers, small or adult clams, or empty shells were detected in any of the sampling. There is only one confirmed report of the species (a single empty shell in 1984) being collected from any site in Lake Michigan in the immediate vicinity of the D. C. Cook plant. Live *Corbicula* were collected in Lake Michigan near the J. H. Campbell power plant (White et al. 1984) north of the D. C. Cook power plant in November 1983. We have no further data to show if that population still exists. Thus, it is concluded that no population has become established nor were there any reproducing individuals detected at D. C. Cook. At present, *Corbicula* does not appear to be a threat to operations of the water systems at the power plant.

INTRODUCTION

Corbicula fluminea (Mullèr) (=*Corbicula manilensis*) was introduced into the Columbia River of Washington State in the late 1930s and since has spread eastward throughout the Mississippi River drainage and most recently (1980-1981) into Lake Erie. For Lake Michigan, a small population was detected near the J. H. Campbell power plant (southeastern Lake Michigan) in November 1983 (White et al. 1984), and a single intact, empty shell was found in diver collected sand and gravel, 22 May 1984, from the water intake at D. C. Cook.

Biofouling of power plant service water systems by Corbicula in the Mississippi and southern drainages and now western Lake Erie has prompted monitoring of all Great Lakes power plants to allow for early detection and creation of control procedures. A monitoring program specifically for Corbicula was initiated at the D. C. Cook power plant in 1982. In that year, three 24 hr entrainment samples were examined for veligers (planktonic larvae) and small clams. Dates of sampling in 1982 were late May, mid-August, and early October (Table 1). Entrainment samples were supplemented by collections of clam shells washed onto the beach in front of the power plant and near the mouth of the St. Joseph River. Beach walks were conducted in late September and late October 1982 (Table 1). The St. Joseph River site was chosen as a possible point of entry of Corbicula into Lake Michigan. No Corbicula veligers or small clams were detected in entrainment samples nor were specimens found in the more than 400 shells (primarily fingernail clams in the family Pisidiidae) collected in beach walks. Shells of Corbicula are much more sturdy than are shells of pisidiids; thus, if present in the lake, they should wash ashore (White 1979). Further, no Corbicula had been collected in lake benthos sampling programs from 1970 through April 1982 or in previous entrainment studies nor had there been any validated reports of Corbicula being collected from Lake Michigan or its drainage (Mackie et al. 1981, Zdeba and White 1985).

Entrainment samples, beach collections, and gravel samples were again examined in 1983, 1984, 1985, and 1986. Sampling periods were moved to mid-June, mid-July, and mid-August based upon life cycle data gathered for western Lake Erie by Scott-Wasilk et al. (1983) (See Table 1 for sampling dates). No specimens of Corbicula were found in thorough examination of entrainment samples. Several hundred Pisidiidae (fingernail clams) were collected in the beach walks each year, but no Corbicula were located either at D. C. Cook or at the mouth of the St. Joseph River.

From a November 1983 diver collected sample near the J. C. Campbell power plant, we identified 10 live Corbicula (White et al. 1984) which we assumed were in their first year of growth. We do not know if that population has survived. On 7 January 1985, I confirmed a single whole shell of Corbicula from diver collected sand and gravel collected 22 May 1984 from the water intake of D. C. Cook. It was my opinion that the specimen was quite recent because it was intact, and it appeared to be of the same cohort as the specimens collected near J. C. Campbell. In the summer of 1985, I examined a similar sample from the D. C. Cook water intake but found only naturally occurring Pisidiidae. To date, the only verified specimen of Corbicula fluminea collected in the vicinity of the D. C. Cook nuclear power plant was that found in the 1984 sand and gravel collection.

CONCLUSIONS

No Corbicula veligers or small clams were collected in the 1986 samplings. Only a single empty shell has been collected

TABLE 1

Sampling dates, sample type, and numbers of <u>Corbicula</u> collected from 1982 through 1986 at the D. C. Cook nuclear power plant.

Date	Sample Type		
	Entrainment	Beach Walk	Sand and Gravel
1982			
25-26 May	none	-	-
18-19 Aug	none	-	-
21 Sep	-	none	-
5-6 Oct	none	-	-
26 Oct	-	none	-
1983			
15-16 Jun	none	none	-
13-14 Jul	none	none	-
17-18 Aug	none	none	-
1984			
22 May	-	-	1*
14-15 Jun	none	none	-
12-13 Jul	none	none	-
16-17 Aug	none	none	-
1985			
13-14 Jun	none	none	-
July	-	-	none
12-13 Jul	none	none	none
15-16 Aug	none	none	none
1986			
16-17 Jun	none	none	-
14-15 Jul	none	none	-
18-19 Aug	none	none	-

* intact empty shell

(1983) over the past 17 years of monitoring (1970-1986). From these data, it is concluded that individuals of <u>Corbicula</u> have occurred in the vicinity of the D. C. Cook nuclear power plant; however, at this time, there are no established populations along the southeastern shoreline of Lake Michigan, particularly in the nearshore areas at or adjacent to D. C. Cook.

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Appendix 1.6

Diver Assessment of the Inshore Southeastern Lake Michigan Environment Near the D. C. Cook Nuclear Plant 1973 - 1982

Special Report No. 120

Great Lakes Research Division

University of Michigan

THE UNIVERSITY OF MICHIGAN

Diver Assessment of the Inshore Southeastern Lake Michigan Environment Near the D. C. Cook Nuclear Plant, 1973-1982

JOHN A. DORR III
and
DAVID J. JUDE

Special Report No. 120 of the
Great Lakes Research Division

DIVER ASSESSMENT OF THE INSHORE SOUTHEASTERN LAKE MICHIGAN ENVIRONMENT NEAR THE D. C. COOK NUCLEAR PLANT, 1973-82

John A. Dorr III

and

David J. Jude

Under contract with

American Electric Power Service Corporation
Indiana & Michigan Electric Company

Ronald Rossmann, Project Director

Special Report No. 120

Great Lakes Research Division

The University of Michigan

Ann Arbor, Michigan 48109

1986

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ACKNOWLEDGMENTS

We would like to thank the present project director Ronald Rossmann and past directors John Ayers and Erwin Seibel for their support, guidance, and editorial acumen. Valuable on-site assistance and practical expertise were provided to us by past and present Indiana & Michigan Power Company staff members Jon Barnes, Tom Kriesel, and Eric Mallen. We would like to recognize our colleagues Jim Barres and Laurie Feldt for their efforts to identify the periphyton collected during the study. Thanks are extended to Sam Ritter who drafted the figures found in this report, and to Beverly McClellan and Marion Luckhardt who assisted in the technical preparation of the report. Many useful suggestions for improvement of the text were provided by Jim Bowers.

We would like to recognize and gratefully acknowledge the extensive time, effort, and dedication of Lee Somers who has supervised and guided the development of diving activities at The University of Michigan and without whose support and assistance this study could not have been conducted. Finally, our deepest appreciation is extended to the many divers whose efforts, dedication, and sacrifices contributed during the many hours of physically and mentally demanding work made this study possible.

This project was funded by a grant from the Indiana & Michigan Power Company, a subsidiary of the American Electric Power Service Corporation. We thank Alan Gaulke for his liaison work throughout the study.

INTRODUCTION

This report is a summary and analysis of observations made by divers in southeastern Lake Michigan near the D. C. Cook Nuclear Plant, 1973-1982. This investigation was one component of a multi-disciplinary environmental impact study conducted by the Great Lakes Research Division, University of Michigan, for the Donald C. Cook Nuclear Plant from 1970 through 1982. Overall scope of work included: physical studies - hydrology, sediments, shore erosion, ice effects; chemical studies - standard water chemistry, nutrients, trace metals; and biological studies - psammo-littoral organisms, periphyton, algae, zooplankton, benthos, and fish. In addition, studies by other agencies included radiological work, weather and currents, thermal plume mapping, terrestrial flora and fauna, and other environmental, sociological, and economic assessments associated with plant site selection and pre-construction activities. In 1986, the various studies conducted by Great Lakes Research Division were integrated into an overview of the aquatic environment in the study area.

The purpose of the underwater assessment program was to gather data via direct observation or analysis of hand-collected samples. Information amassed through these efforts was used to collaborate or augment other studies at the Cook Plant and to provide a unique assessment of the aquatic environment, its ecology, and plant-induced effects.

The D. C. Cook Nuclear Plant is located in Berrien County on the shore of southeastern Lake Michigan near Bridgman, Michigan. The plant site was purchased in 1959 and pre-construction activities began in the 1960s. Construction of the two-unit, 2,200 megawatt plant began in the late 1960s. Placement of in-lake structures (intake and discharge pipes and structures, and riprap field) was completed in late 1972. Unit 1 achieved "on-line" status during 1975, following a prior startup period in 1974. Unit 2 went on-line during 1977. Great Lakes Research Division studies began at the Cook Plant in 1970 and were divided into two general phases: preoperational and operational. Underwater studies were conducted during 1973-1982 and included 10 annual periods of observation from April through October during most years. In accordance with the plant construction schedule, the preoperational study period began in 1970 and extended through 1974 when Unit 1 went on-line. Therefore, the preoperational database for diving observations encompassed the 2-yr period from 1973 to 1974. Operational studies were conducted from 1975 through 1982, although full operational status was not attained until late in the study.

An important feature of Cook Plant structure and operation regarding its potential effects on the lake was the presence of in-lake structures and once-through circulation of water to cool the plant reactors. At peak operation, 6.1 million liters per minute (1.6 million gpm) of water are drawn through a system of three water intakes located 223 m (2,250 ft) offshore in 9 m of water, circulated once through the plant, and returned to the lake via two discharge structures located 109 m (1,100 ft) offshore in 6 m of water. Aquatic biota entrained in the cooling water are exposed to physical and thermal effects, as is the environment immediately surrounding the discharge area. Also, the presence of in-lake plant structures (intakes and riprap) creates a physical environment that is atypical of the surrounding area.

Nearshore surficial sediments in the study area are typically composed of coarse- to medium-sized grained sand (1.0-0.25-mm diameter) with fine- to very fine-sized sand (0.25-0.06-mm diameter) becoming predominant offshore (Davis and McGeary 1965, Hawley and Judge 1969). A distinct change in sediment composition that occurs offshore at about 24 m is a function of depth and severity of nearshore physical processes (Seibel et al. 1974, Rossmann and Seibel 1977). An accumulation of 1-10 mm of fine particulate material consisting of sediment, periphyton, organic detritus, and diatom tests often covers the bottom (Dorr and Jude 1980a, b). Inshore surficial sediments are unstable, and topography can be attributed to nearshore physical processes including waves and currents. Typical manifestations in the study area are an inner and outer bar and a gentle slope of 1:100 or less beyond a depth of 4 m (Davis and McGeary 1965). Thus most areas of the bottom exhibit only little relief and provide minimal to no surficial shelter or protection for macroscopic biota, e.g., fish, crustaceans, and molluscs. In contrast, substrate surrounding the intake and discharge structures and sub-surface water circulation pipes consists of crushed limestone riprap (0.1-1.0 m in diameter). It was installed during plant construction to reduce scour by plant discharge water on in-lake, cooling-water structures. In its central area, the riprap bed is mounded 1-2 m above bottom, and the structures rise an additional 3 m above the riprap. Consequently, the surface profile in the water intake and discharge areas is considerably more rugose than the surrounding natural environment.

The focus of our underwater studies was to examine selected features of this man-made environment and to compare and contrast them with those of the surrounding area. Through these observations, a better understanding of the aquatic environment in the vicinity of the plant was achieved, as well as of the plant impact on that environment. Patterns of colonization of aquatic biota were also delineated.

Within the report, Cook plant data and findings are integrated with other underwater studies conducted in Lake Michigan. Changes in the ecology of the Cook Plant area related to the impact of the plant are also discussed.

The knowledge gained through the underwater assessment study has provided unique insight into the inshore southeastern Lake Michigan environment. This insight augments that obtained from other components of the Cook Plant environmental study. Our results should help guide future similar studies, as well as add to the understanding of physical and biological processes in the Great Lakes and elsewhere.

METHODS

The underwater assessment study at the Cook Plant is unique to the Great Lakes in two respects: its duration, which encompassed 10 separate field seasons, and its design. Diving began in 1973 and continued through 1982. During this period, 281 (221 day, 60 night) dives were performed in the study area (Table 1), and more than 161 h of underwater time were amassed. The area was examined by divers each month, April-October, for 8-10 seasons.

The second unique aspect of this study was the extent to which observational techniques, effort, and sampling were standardized. During 1973-1974, diving and underwater assessment techniques were developed for the study area and were incorporated into the Cook Plant environmental monitoring scheme for plant operation as required by the Nuclear Regulatory Commission and the Michigan Department of Natural Resources. These environmental technical specifications (U.S. Atomic Energy Commission 1975) were in effect from 1975 through completion of our field studies in 1982, and stringently defined baseline study objectives and sampling regimes for all sections of the Cook Plant environmental survey including underwater studies. Strict adherence to these specifications resulted in a sampling program that was both rigorous and relatively inflexible with regard to modifications. However, it had the advantage of generating a continuum of data that permitted identification and analysis of ecological patterns, changes, and plant impacts on the environment over a period of years.

Environmental technical specifications stipulated that visual observations would be conducted at least once per month, April through October, at five specified locations, including two dives (one day, one night) in the area of the intake structures, one day dive in the area of the

Table 1. Summary of day (D) and night (N) dives performed during 1973-1982 in southeastern Lake Michigan in the vicinity of the D. C. Cook Nuclear Plant near Bridgman, Michigan. Diving was not conducted during January, November, and December.

Month	1973		1974		1975		1976		1977		1978		1979		1980		1981		1982	
	D	N	D	N	D	N	D	N	D	N	D	N	D	N	D	N	D	N	D	N
Feb									1	1										
Mar																				
Apr			3			1	4	1	3	1	4		1		3	1	4	1	3	1
May			2	1	3	1	5	1	7	1	4	1	9	2	3	1	4	1	3	1
Jun	3	1	6	1	2	2	4	1	6	1	4	1	4	1	4	1	5	1	1	1
Jul			2		5	1	4	1	4	1	4	1	4	1	4	1	4	1	2	1
Aug	3				4	1	4	1	3	1	5	1	8	2	5	1	3	1	2	1
Sep	4		1		3	1	3	1	1	1	4	1	3	1	3	1	3	1	1	1
Oct			1	1	4	1		1			3		3	1	5	1	3	1	1	1
Total Dives	10	1	15	3	21	8	24	7	25	7	28	5	32	8	27	7	26	7	13	7
Time (min)	445	71	576	220	949	369	907	428	1,035	275	799	249	718	315	647	3.0	708	225	266	180

discharge structures, and two day dives in reference areas (one north and one south of the plant) (Fig. 1). Station names were abbreviated as follows: south intake station - SI, middle intake station - MI, north intake station - NI, south discharge station - SD, north discharge station - ND, south reference station III - SR-III, south reference station II - SR II, south reference station I - SR-I, north reference station III - NR-III, north reference station II - NR-II, and north reference station I - NR-I.

Dives were separated into two categories: standard series dives (those which were performed to satisfy technical specifications) and supplemental dives. Standard series dives were conducted according to fixed procedures which described the area examined by divers, observational and sampling techniques, and recording of data. The formats for supplemental dives were flexible in response to the objectives of the dive.

During standard series dives, two divers equipped with scuba swam side-by-side and either 1 or 2 m apart. Divers made observations and collected samples at the intake structure stations by swimming around the top (61 m in circumference) and base (78 m in circumference) of the structure. While swimming, each diver examined a plot of 2 m in width; the areas examined on top and around the base of the structures were approximately 244 m^2 and 312 m^2, respectively. In addition, divers swam a 10-m transect along the north side of the south intake structure base following an anchored line placed there for the duration of the study. While swimming a transect along this line, each diver examined adjacent plots 1 m in width, resulting in observations collected from 1 x 10 m (10 m^2) plots. These observational efforts in measured areas provided a quantified data base. Swims and observations at the discharge stations were conducted in exactly the same

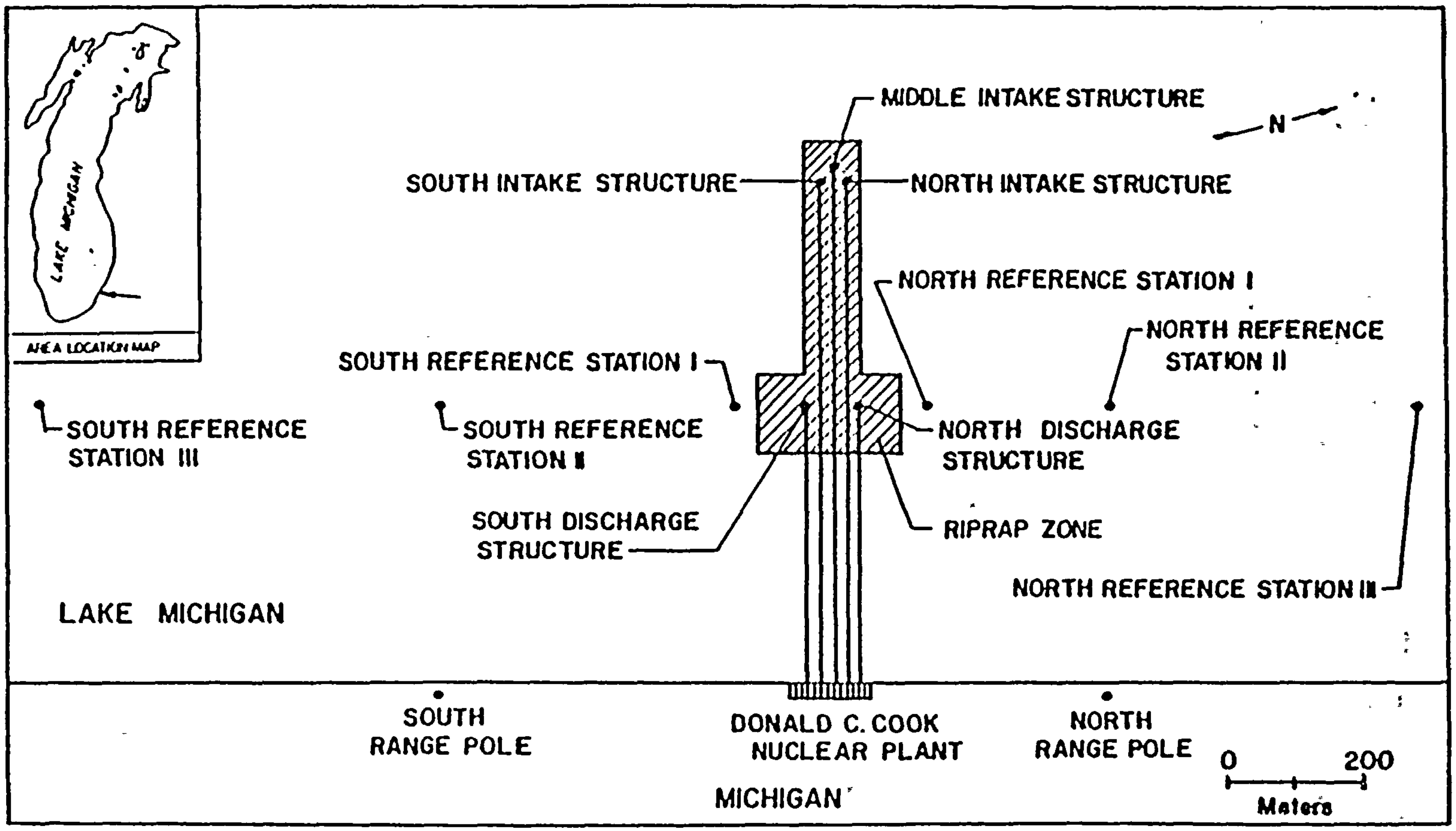

Fig. 1. Scheme of the Cook Plant study area in southeastern Lake Michigan, 1973-1982, showing locations of the scuba-monitored intake, discharge, and reference structures and stations. Stippled area represents approximate dimensions of riprap zone. Depths at intake, discharge, and reference stations were 9 m, 6 m, and 6 m, respectively.

manner as described for the intake structure stations. Areas examined on top ($213 m^2$) and around the base ($256 m^2$) of the discharge structures differed slightly in size from areas examined at the intake structures; however, transect swims along anchored lines at the two locations were conducted identically. Often, but not always, areas in addition to those described were examined during a dive. This was done to increase the total area examined in the vicinity of the plant structures.

At reference stations north and south of the Cook Plant (outside riprap zone in Fig. 1), two 1 x 10 m ($10 m^2$), side-by-side transects were swum parallel to shore in line with the discharge structures. At each reference station, a 10-m line was temporarily anchored for the duration of the transect swim and divers swam out to the full extent of the anchored line. In addition to the two 10-m^2 plots examined at a reference station, a 5- to 10-min swim was conducted parallel to shore and toward the discharge structures, following completion of each 10-m transect swim. The 10-m transect swims at the reference stations provided quantified data to compare with those obtained within the plant-structure area (stippled zone in Fig. 1). The 5-10-m swims increased the area examined at the reference stations.

The previously described stations and observational methods comprised our monthly standard series sampling effort. Whenever possible, this complete standard series effort was conducted April through October, 1975-1982.

Occasionally, bad weather or other unsafe diving conditions forced a reduction in this standard series sampling effort, particularly at the beginning and end of the field season. Also, over the duration of the study several basic alterations occurred in the standard series diving effort. As noted earlier, 1973-1974 diving preceded the environmental monitoring specifications and slight differences occurred in diving efforts and techniques. During mid-1977, two-unit operation was achieved and water was discharged from both structures. Consequently, this area became unsafe for divers to enter and the standard series dive at this location was eliminated. Occasionally after this, when water was not being discharged from one of the structures, supplementary dives were made in this area. Finally, in June 1982, the technical specifications for environmental monitoring were altered and the monthly standard series diving was reduced to one day and one night dive in the vicinity of the south intake structure.

Observations were made following a prescribed format (Fig. 2) and were recorded underwater on water-resistant paper. Occasionally, observations were committed to memory and transcribed at the surface or dictated in a tape recorder for later reference. Observations made by both divers during non-transect swims (e.g., swims around the top and base of the structures, 5→ 10-min swims at reference stations, and during supplementary dives) were pooled and discussed as total observations, observations per unit area (m^2), or as subjective descriptions of abundance. Transect observations were pooled and a mean and standard error (SE) calculated. For most data, numbers were expressed as numbers per 10 m, 100 m, or 1,000 m to avoid fractional units.

Although data were collected in both a qualitative (descriptions or numerical estimations) and quantitative (counts) manner, suspected violations of assumptions associated with normal-based statistical analyses precluded reliable parametric analysis (see Dorr and Jude 1980a for a discussion of these violations as they pertain to underwater observations and studies). Therefore, analytical procedures were limited to subjective interpretation of data, and development and interpretation of ranked orders of abundance.

Observer ______ Location ______ Depth (ft) ______

Temp: Sur ______ Bot ______ Swell action (bottom): NO YES Visib ______

Turbid: V LOW LOW MED HI V HI Current: NO YES: From ______ Speed ______

Bottom Comp (%): Silt ______ Sand ______ Gravel ______ Rock ______ Floc (mm) ______

Organic debries (Num/Den): ALGAE ____/____ DUNE GRASS ____/____ CHIPS ____/____

TERR. PLANTS ____/____ BARK ____/____ LEAVES ____/____ TWIGS ____/____

BRANCHES ____/____ TRUNKS ____/____ STUMPS ____/____ CLAM SHELLS ____/____

UNID PLANT ____/____ UNID ANIML ____/____ OTHER ____/____

Inorganic debris (Item, Num, Den): ______

Ripple marks: From: ______ Ht ______ Wdth ______ Len ______ Scour: NO YES ______

Loose algae: NO YES; Color ______ Size ______ Num/Den ______

Descr: ______

Periphyton: NO YES; Color ______ Len ______ % Coverage ______

Descr: SPARSE MED LUXURIANT ______

Gastropods: Num Shells ______; Live: NO YES; Num/Den ______

Descr (location, behav) ______

Clams: Num Shells ______; Trails: NO YES (Descr) ______

Live: NO YES; Num/Den ______ Descr ______

Crayfish: Dead; NO YES (Num) ______ Live: NO YES Num/Den ______

Descr (size, location, behav) ______

Fish eggs: NO YES; Location ______ Substrate ______

Num/Den ______ Rel. size ______ Color ______

% Clear ______ % Opaque ______ % Fungus ______ Other ______

Misc invert. (sponge, hydra, bryozoa, insects, crustaceans) ______

Fish	Number	Density	Size	larv YOY juv adt.	Location	Behavior
SS						
JD						
AL						
YP						

Numerical estimating code: Actual count or: Few (F) = 1–10 Many (M) = 11–50 Numerous (N) = 50–100 Abundant (A) = 100+ Very abundant (T) = 1000+

Comments:

Fig. 2. Prescribed format in which observations and measurements were recorded underwater on water-resistant paper during dives in southeastern Lake Michigan near the D. C. Cook Nuclear Plant, 1973-1982.

Observations and findings presented are based on objective and subjective analysis of quantified data, tempered by our qualitative data, general knowledge of the study area, and interpretation of the literature.

Dorr and Jude (1980a) discussed limitations associated with underwater visual assessments which include equipment and personnel training limitations and physical and psychological stress, all of which serve to reduce the accuracy and precision of observational data. Under conditions of limited visibility (often less than 3 m in the study area), abundance of pelagic organisms is usually underestimated by divers, particularly for highly mobile animals such as large fish. Where substrate is uneven, abundance of demersal or cryptozoic organisms may also be underestimated. Through standardization of our observational techniques, we attempted to obtain at least consistently biased (underestimated) parameter estimates where the error was proportional to the true population size.

Finally, Miller (1956) described the plateau effect which is related to perceptual handling of simultaneously presented stimuli. Shaw (1975) discussed implications of this plateau effect related to fish schooling and "flash expansion" of schools to present multiple moving targets and promote predator avoidance. In a sense, a diver is also a predator subjected to the confusing effect of these avoidance responses. Experience has shown that the visual plateau for divers ranges from 8 to 15 targets when present simultaneously, depending on visibility and duration of the observation period. As a consequence, we developed a standardized code for estimating numbers of objects in a consistent manner. They included: few = 1-10, many = 10-50; numerous = 50-100, abundant = >100. When pooling data (counts) such as these, estimates could be averaged (e.g., few + many = 1-10 + 10-50, or 5 + 30

= 35) or lower (1 + 10 = 11) and upper (10 + 50 = 60) limits placed on parameter estimates. Small aggregations of animals or objects were estimated or counted in total, large aggregations were visually partitioned and the number of items in a single partition counted or estimated and multiplied by the number of partitions to obtain an estimate of total number. These estimates were used during subjective evaluation of fish abundance based upon combined counted and estimated numbers.

The preceding discussion underscores our efforts to develop a continuous and consistent data base. Sampling locations were examined in a spatially and temporally consistent manner. Observational targets (Fig. 2) and efforts were standardized. Subjective descriptions (Fig. 2) and numerical estimation techniques were also standardized and learned by divers. Finally, to reduce variation associated with differences in personal diving techniques and capabilities, the senior author performed all but two months of diving during the entire study. Therefore, about one half of the observational data base included no diver-to-diver variation.

The operational and observational diving techniques used during this study were developed over a 10-yr period 1973-1982. Many of these techniques are described in other underwater studies that we have conducted in the Great Lakes, the results of which are often related to this study. They include: Dorr (1982), Dorr and Jude (1980a, 1980b), Dorr et al. (1981a, 1981b), Jude et al. (1981a, 1982), Rutecki et al. (1983, 1985), Schneeberger (1982), and Schneeberger et al. (1982).

During June 1974, and April-October 1975-1981, divers collected samples of periphyton from the top of the south intake structure and riprap surrounding the base of the structure. Periphyton was scraped from the structure with a putty knife into a plastic mason jar. Efforts were directed toward collection of an adequate-sized sample; no attempt was made to sample a quantified or consistently-sized area. A small piece of riprap about 4 cm in diameter which supported a noticeable amount of periphyton was selected and placed in a second jar. These samples were preserved in 10% formaldehyde for laboratory analysis, but because of time constraints, only the samples collected from the intake structure were examined. In the laboratory, the sample of scrapings was stirred thoroughly, and a subsample was removed for wet-mounting in water. Algal identifications were made at 400-600X using a Leitz-Wetzlar Ortholux microscope. Taxa identified in these wet-mounts became the yearly lists of periphyton collected from the Cook Plant area.

Data used for comparison with diving observations were derived from companion studies on impinged fish (Thurber and Jude 1984, 1985) and field-collected fish (Tesar et al. 1985, Tesar and Jude 1985). Impinged fish were collected and processed every day during 1975 and every fourth day during 1976-1982. Fish were sampled in Lake Michigan using seines, trawls, and gill nets at a variety of stations from April-November, 1973-1982.

RESULTS AND DISCUSSION

PHYSICAL FEATURES

Waves and Currents

Surface Waves

The fetch of Lake Michigan ranges from about 100 km west to about 350 km north. For large lakes such as this, the maximum wave height (h) is related to the fetch (x) of the lake as follows: $h = 0.105x$ (Mortimer 1975, Wetzel 1975). Based on this, maximum wave heights at the study site would range from 3:3 m from the west to 6.2 m from the north.

We observed storm waves with a cycloid diameter or height (trough-to-crest distance) in excess of 4 m, while wave heights of 1-2 m were common during periods of onshore winds. However, it was unsafe for us to dive when wave heights exceeded 1.5 m; therefore, our observations were biased toward conditions extant during quiescent periods in the lake.

Wetzel (1975, p. 94) stated that for travelling surface waves with a cycloid cross-sectional path, "the decrease of vertical movement (of the water) with increasing depth can be approximately described as a halfing of the cycloid diameter for every depth increase of $\lambda/9$", where λ is the wavelength measured as crest-to-crest distance. Wetzel further stated that the ratio of amplitude to wavelength is highly variable from 1:100 to 1:10, but that except at shallow beach areas, wave lengths of short surface waves are less than the depth. Given this, the wavelength of a wave 1.5 m high should not exceed 10 m when water depth is less than 10 m. For a wave with a height of 1.5 m and and a wavelength of 9 m (as might have occurred during our dives at the 9-m stations), the vertical displacement of water on the bottom should be about 3 mm. On top of the Cook Plant intake structures, which are about 4 m below the surface, the vertical displacement of water should be about 90 mm. These calculations are in agreement with conditions that we observed during dives in the study area. If surface waves exceeded 1 m in height, some water displacement was noticeable on the bottom at all 6- and 9-m stations. Water displacement was usually evidenced by a swaying of the periphyton or sloshing movements of surficial floc. On top of the intake or discharge structures this movement was greatly accentuated relative to conditions on the bottom. Because the riprap was mounded from lake bottom level at its periphery to several meters off bottom at the base of the intake and discharge structures, the movement of water caused by surface wave action attenuated as divers swam from the structures across the riprap and down to level bottom. Movement of water on the bottom at <9 m occurred when surface waves were less than 1 m high, but the effects were unnoticeable to divers.

These observations suggest that circulation of water and resuspension of surficial sediment and flocculent organic material occurs through surface wave action. The threshold for these effects probably occurs when wave heights are between 0.5-1.0 m; effects increase rapidly with increasing wave height. Evidence that the riprap traps sediment will be presented later. This factor in combination with surface wave action probably contributed to the increased levels of suspended materials observed by divers near bottom in riprapped areas relative to the surrounding sand areas, when lake surface conditions were rough. Barres et al. (1984) noted elevated levels of particulates in phytoplankton samples collected from the Cook Plant forebay during periods of stormy weather and nearshore turbulence. As discussed later, plant intake water was often noted by divers to be drawn from the bottom of the water column at the base of the intake structures. The resuspension of surficial material noted by divers during and immediately after periods of rough lake conditions may account for the elevated levels of particulates noted in these samples. Rossmann et al. (1982) suggested that elevated concentrations of orthophosphate and dissolved silica in water samples collected in the study area may also have resulted from storm-induced turbulence.

These observations indicate that surface wave action increased the amount of suspended material in the riprap areas, relative to surrounding areas. Attached algae and invertebrates (sponge, bryozoans, Hydra); benthic invertebrates, such as worms, insect larvae, snails, and crayfish; and fish with demersal life stages concentrated in the riprap areas were exposed to effects of this increased suspension. Such effects may have included increased siltation and impairment of filter feeding. Surface wave action undoubtedly promoted circulation of water in and around the riprap. The rise of the riprap off bottom in combination with its many interstices permitted surface wave action to more effectively perfuse this substrate. This in turn would improve the availability of oxygen and exchange of gases, while serving to continually remove floc from the surface of the substrate.

Currents

Wind friction and atmospheric pressure changes result in seiches, differential heating of the lake, diffusion of dissolved materials from the sediments, influx and outflow of water, and geostrophic (e.g., Coriolis) effects (Mortimer 1975). In Lake Michigan, surface currents often circulate in large swirls or gyres (Ayers et al. 1958) which in turn are subject to modifications by standing wave motions. Lake basin morphometry also influences direction and speed of surface water currents. Although general current patterns may be established in large bodies of water such as the southern basin of Lake Michigan, current velocity at any given point may vary with local conditions. This is particularly true for the inshore region where local effects such as presence of offshore winds or sand bars may influence current flow.

Studies on currents were conducted in 1975 and 1978 (Indiana & Michigan Power Company 1975, 1976; ETA 1980) at locations about 600 m north and south of the Cook Plant at the 3- and 6-m depth contours. Generally, current speeds measured during 1975 ranged from 6 to 12 cm/s (0.2-0.4 fps) with a maximum speed approaching 60 cm/s (2 fps). Currents tended to flow to the north, although considerable day-to-day variation occurred. These data suggest that considerable variability existed in both current speed and direction in space and time. Mortimer (1975) has found that current vectors nearshore are predominantly shore-parallel, while offshore, the clockwise rotating current vectors of Poincáre waves dominate the lake.

Efforts by divers to establish general current direction and speed at a given location were unsuccessful. Considerable variability was measured among locations separated by only 200 m as well as differences at various depths in the water column. Consequently, no attempt was made by divers to assess current velocities, although effects of currents were recorded when observed.

Absence or presence of currents was best observed by the horizontal transport of suspended material past a stationary diver. When surface waves exceeded 0.5 m in height, vertical displacement of the water obscured the horizontal movement of suspended material at depths less than 3 m. When currents were present, horizontal movement of suspended material could be discerned within 1 m of the bottom at 6 m and 9 m, regardless of wave heights at the surface. This was the result of the rapid attenuation of vertical displacement of water with increasing depth. In areas where sediment accumulated, such as localized depressions in the sand observed at the reference station or at the periphery of the riprap field, both current and surface waves acted to resuspend sediment.

In general, current flow and direction appeared to be influenced by proximity to the intake and discharge structures at the surface and on the bottom. Strong currents were encountered throughout the water column at stations 100 m north and south of the respective discharge structure during discharge of water. As best as could be determined, the direction of flow was always away from the structure. Strong eddy currents were encountered during dives at a station located in line with, and mid-way between, the two discharge structures. But at the reference stations located 900 m north and 1200 m south of the Cook Plant, no effect of plant water discharge on local water current was discerned.

Within the riprap area, pronounced currents associated with plant water circulation obscured any general current patterns noticeable to divers. Large differences in the force of the intake current could be felt at different points around the base of each structure. These differences ranged from currents that were almost undetectable to those that were difficult to swim against. The direction and speed of the natural lake current and the recirculation patterns established between the intake and discharge structures influenced the direction and strength of the intake current and the withdrawal of water from various levels of the water column.

In both riprap areas and on open lake bottom increased rugosity of the bottom profile acted to reduce current speed within a few centimeters of the bottom. This observation is in keeping with the existence of a boundary layer of slack water known to exist as a function of vertical relief dimensions variability and of current force and direction. Both riprap and large ripple marks would contribute to variability in vertical relief and current flow at the water-sediment interface.

Thermal Effects

Water temperature regimes encountered during our underwater studies paralleled those characteristic of southern Lake Michigan. Water temperatures were 4-8°C during April and increased rapidly during May-June. Temperatures less than 10°C were rarely encountered during June-September. During fall, temperatures declined and reached 10°C during late October-early November as determined from other dive studies in the region (Dorr and Jude 1980a, Dorr et al. 1981b).

Divers experienced three major thermal effects. The first was vertical thermal stratification during June-August. It was common to encounter a 1- thick layer of very warm water at the surface, particularly when the lake surface was calm. An abrupt drop in water temperature could be felt on exposed skin as divers descended through this layer. Temperatures in the adjoining layer remained nearly constant until 1-2 m off bottom. At this point, a second abrupt thermal decline was noticed. This layer of cold water on the bottom was often more turbid than overlying water, and contained higher amounts of suspended particles. It was believed that these were relatively distinct thermal layers and that mixing of water among layers was reduced relative to homothermal conditions. Observation of the distinct cold nepheloid layer on bottom supports this contention.

The second effect experienced by divers was that of horizontal thermal stratification. This condition was again encountered during the warm-water months and was particularly noticeable during the 5-min swims at reference stations. Divers often swam through water masses of different temperatures; thermal interfaces were usually distinct and only a few meters thick. Because all swims were conducted on the bottom at 6 m little is known of conditions in mid-water. It is possible that isolated masses of cooler water were present on the bottom and surrounded by warmer water, perhaps as a result of uneven development or breakdown of vertical stratification following a change in lake conditions (e.g., surface waves, currents, upwelling).

The final thermal effect encountered by divers was summer upwelling of cold water inshore following periods of strong offshore winds. Unusually cold water was occasionally encountered during typically warm-water periods, i.e., July or August. On some occasions, water temperatures declined considerably during diving which occurred over a 2-day period. Again, cold-water upwellings were often accompanied by increased turbidity and pronounced decreases in underwater visibility.

Because of lake size and its gentle sloping bottom, the major thermocline between the epilimnion and the hypolimnion lay well offshore of the study area during the period of maximum vertical thermal stratification. During occasional dives in deep water (>12 m), a distinct thermocline was encountered along with a large difference in temperature between the epilimnion and hypolimnion.

Surficial Features.

Presence of riprap and in-lake plant structures created artificial features and atypical habitat. Most of the lake bottom in inshore southeastern Lake Michigan is composed of coarse- to fine-grained sand with occasional areas of pebbles, and presents a flat, unbroken profile. Only isolated rocks and an occasional log or branch were encountered during our studies. Dorr (1982), Dorr and Jude (1980b), and Jude et al. (1978) conducted extensive diver surveys of areas containing rough substrate of natural (moraines, clay banks) and artificial (reefs, utility structures, harbor breakwalls) origin from Muskegon, Michigan, south to Michigan City, Indiana. Areas of rough substrate were isolated within the total inshore system and represented only a small portion (<1%) of the total inshore area.

Ripple marks and occasional large depressions were observed at the reference stations and during swims along the 6-m contour. The dimensions and direction of ripple marks observed 1000 m north (Station III) and 1200 m south (station III) of the plant were measured and recorded during 1973-1982 (Table 2). Most often, ripple marks were generated from a westerly-to-northerly direction (quadrant IV - 270-360°). This was the situation during 84% of the dives at the north station, and 74% of the dives at the south station. The slight reduction (10%) in frequency of generation from the fourth quadrant observed at the south station was probably created by the riprap north of the south station. This hypothesis is supported by our observations that ripple marks were consistently smallest at the south reference station (station I) closest to the riprap. Discharge of water in a north and westerly direction combined with the "reef-like" barrier that the riprap and discharge structures presented, undoubtedly acted to diminish the

Table 2. Direction of generation (quadrant), height (trough-to-crest), and width (crest-to-crest) of ripple marks observed by divers in reference areas north and south of the D. C. Cook Nuclear Plant, during some months from 1973 to 1982. Quadrant: I = north to east (0-90°); II = east to south (90-180°); III = south to west (180-270°); IV = west to north (270-360°); Asym = asymmetric (no clear direction of generation). Dimensions are in cm. Blanks indicate no data.

	North Reference Areas			South Reference Areas		
Month	Quadrant	Height	Width	Quadrant	Height	Width
1973						
Sep	IV	17	61			
1974						
Apr	IV	3	15			
Jun				IV	3	18
Jul				IV	4	10
1975						
May	IV	5	15	IV	4	17
Jun	III	1	11			
Jul	III	4	10	III	5	31
Aug	I	3	9	III	4	13
Sep	IV	6	20			
Oct	I	5	9	IV	4	19
1976						
Apr	III	11	75	II	2	5
May	III	4	15	III	4	14
Jun	IV	5	16	IV	4	5
Jul	IV	2	8	IV	4	6
Aug	I	6	15	IV	2	6
Sep	IV	6	8			
1977						
Apr	IV	13	100			
May	IV	2	18	IV	2	11
Jun	IV	4	10	Asym	1	6
Jul	IV	3	10	IV	2	5
Aug	IV	2	5	IV	3	15

(Continued).

Table 2. Continued.

	North Reference Areas			South Reference Areas		
Month	Quadrant	Height	Width	Quadrant	Height	Width
<u>1978</u>						
Apr				III	5	15
May	III	4	20	Asym	<1	<1
Jun	IV	6	25	III	5	20
Jul	IV	5	18	IV	2	10
Aug	IV	3	15	IV	3	15
Sep	IV	25	50	IV	2	5
Oct	IV	3	10			
<u>1979</u>						
May	IV	4	20	IV	4	20
Jun	IV	5	15	IV	4	12
Jul	IV	3	10	IV	5	150
Aug	IV	5	20	IV	5	18
Oct	IV	3	15	IV	2	6
<u>1980</u>						
Apr	IV	4	12	IV	6	20
May	IV	14	90	Asym	2	10
Jun	IV	5	15	IV	3	15
Jul	IV	15	60	IV	5	8
Aug	IV	4	12	IV	4	15
Sep	IV	4	6	IV	2	10
Oct	IV	3	5	IV	2	6
<u>1981</u>						
Apr	IV	50	100	IV	3	6
May	IV	2	6	IV	2	6
Jun	IV	20	60	IV	2	6
Jul	IV	3	10	IV	2	6
Aug	IV	2	6	IV	2	6
Sep	IV	6	10	IV	4	8
Oct	IV	4	8	I	4	6
<u>1982</u>						
Apr	IV	8	10	IV	6	6
May	IV	12	15	Asym	4	10

strength of waves and currents approaching from that direction, which is the prevailing direction of approach at this location on the lake. In general, ripple marks were smallest and most asymmetrically developed at reference stations (stations I and II) closest to the riprap and discharge area.

Very large ripple marks with amplitudes (heights) exceeding 10 cm were occasionally observed at the two most northerly reference stations. These marks often had wavelengths of 50-100 cm, and extended for 10 m or more along the bottom. They were always generated from the 270-360° quadrant (quadrant IV - west-north), and were never observed at south reference stations. These large marks usually occurred in isolated patches along the 6-m contour and were separated by extensive areas containing much smaller ripple marks. Often these smaller marks were generated from a different direction and cross-hatched the large marks. Most likely, these large ripple marks were the remnants of marks generated during conditions of high winds and large surface waves coming from a westerly to northerly direction. Large marks were never observed at the north reference station (station I) closest to the discharge area, again probably a result of the disruptive effect of the north-westerly directed discharge current on incoming waves. In fact, the disruption of surface waves by the plant's water discharge is observable from shore.

The other surficial feature of the bottom observed in the vicinity of the reference stations was the presence of localized depressions in the lake bottom. These depressions were only observed during swims parallel to shore between north reference station II and station III. During the 5-10-min swims, divers occasionally encountered depressions about 1 m deep and 5-10 m across; because the third dimension was not measured, the actual shape of these depressions is not known. We suspect that they may have been roughly oval in shape with the long axis oriented more closely perpendicular to sho[illegible] than the short axis. These depressions were surficial features of the bottom that were distinctly different from the major troughs that were located between the major sand bars. One possibility is that these depressions were trenches or cuts across these major bars and that the depressions connected adjoining troughs. Another possibility is that the depressions were remnants of old troughs that had been mostly filled in during the relocation of a bar. These features are not unique to the Cook Plant area, since we observed them during other underwater studies in inshore southeastern Lake Michigan.

Sediment

Qualitative microscopic analysis of the flocculent ("floc") layer of material overlying the riprap and sand revealed it to be composed primarily of sediment, diatom tests, and some organic detritus (primarily algae). The thickness of this layer ranged from complete absence to about 10 mm; a layer 2-3 mm thick was typical of the area (Table 3).

When present, similar amounts of floc were observed in both reference areas and on the riprap. However, only once, in April 1982, was floc totally absent from the riprap surrounding the intake structures, whereas, complete absence of floc in reference areas was more common (8 occurrences at north reference station III, 11 occurrences at south reference station III). Observations of floc deeper than 10 mm were made on two occasions north of the plant and once south of it. The floc layer on the riprap was never thicker than 6 mm between 1975 and 1982.

We attribute the more continuous presence of floc on riprap compared with sand to be the result of the better trapping action of the riprap surface.

Table 3. Depth (mm) of flocculent surficial sediment measured on riprap surrounding the D. C. Cook Nuclear Plant intake structures and at reference stations north and south of the plant, 1973-1982. T (trace) = detectable, but unmeasurable. Blanks indicate no measurements made.

Month	Area: Intake	N. Reference	S. Reference
1973			
Jun			<5
Aug	<5		
Sep	<5	<5	
1974			
Apr	>10	5-10	
May	5-10		
Jun	<5		
Oct	5		
1975			
May	6	<5	
Jun	<5	T	
Jul	4	2	
Aug	3	T	0
Sep	3	0	
Oct	2	0	0
1976			
Apr	2	2	2
May	3	20	3
Jun	2	1	1
Jul	3	2	2
Aug	2	0	5
Sep	2	2	
Oct	4		
1977			
Apr	3	15	
May	3	2	0
Jun		2	0
Jul	3	0	0
Aug	4	T	0
Sep	2		

(Continued).

Table 3. Continued.

Month	Area		
	Intake	N. Reference	S. Reference
1978			
Apr	5	4	0
May	3	3	3
Jun	2	3	2
Jul		8	4
Aug	1	2	2
Sep	2		4
Oct	3	1	
1979			
Apr	1		
May	2	3	5
Jun	3	8	3
Jul	T	1	3
Aug	4	2	2
Sep	1	0	0
Oct	1	2	0
1980			
Apr	2	2	2
May		3	4
Jun	1	2	2
Jul		0	0
Aug		2	3
Sep	2	0	20
Oct	2	2	2
1981			
Apr	2	2	4
May	2	5	4
Jun	2	2	5
Jul	2	0	2
Aug	4	2	2
Sep	2	3	4
Oct	1	1	0
1982			
Apr	0	8	6
May	3	2	3
Aug	4		
Oct	2		

The uneven surface of individual clasts and the presence of periphyton caused floc to be retained more effectively than on the smooth surface of the sand bottom. Two general observations support this contention: (1) floc accumulated in the troughs of the ripple marks, and not on the sides or crests, and (2) surface wave action often caused movement of floc on the sand bottom but not on the riprap. Rarely did floc accumulate on the sides or crests of ripple marks. Most often, it was carried into the troughs by water movement. It was noted earlier that surface wave action could be felt on the bottom at 6 m when waves exceeded 1 m in height. Also, the threshold for noticeable water movement occurred when waves were 0.5-1.0 m in height. When surface waves were 1 m, a slight oscillation or movement of the floc in the troughs of ripple marks was apparent. Under these same conditions, the periphyton on riprap was observed to sway, but no movement of the floc could be seen.

Additional evidence that uneven surfaces trapped sediment more effectively that smooth surfaces was provided by the occasional deep accumulations of floc in depressions observed in the sand bottom in the north reference area (see previous section - Surficial Features). Floc 10-20 cm deep was measured in some of these depressions (Table 3). Suspended material, transported along the bottom, probably encountered these depressions where water velocities were reduced resulting in this material being deposited in thick layers. In a sense, these large depressions were analogous to small pockets or interstices in the surface of the riprap. A small trough (1-2 m wide and less than 1 m deep) in the sand bottom adjacent to the riprap often formed along the perimeter of the riprap. Quite often, floc accumulated in this restricted area to depths of 10-20 mm. Most likely, this was the result of a small area of stagnant water created by the barrier which the riprap imposed as it rose off the bottom at this point. Observations made during studies of other areas of naturally formed sand (Jude et al. 1978, Dorr and Jude 1980b), rock or clay bottom (Dorr 1982), and artificial substrates (Dorr et al. 1981b, Dorr 1982) confirm that rugose surfaces trap sediment more effectively than smooth surfaces.

There appeared to be a direct relationship between absence or presence of floc and water depth. In this study and others (Dorr 1974, Dorr and Miller 1975, Dorr 1982), floc was rarely observed at depths less than 6 m. However, it was always present at 12 m or more. Seibel et al. (1974) and Rossmann and Seibel (1977) noted a distinct demarcation at 24 m where finer-grained sediment predominated. Its occurrence was a function of depth and severity of nearshore physical processes, including wave action and currents. Our observations, combined with the calculated attenuation of even the largest surface waves observed during any period of several years, suggest that at depths greater than 12 m, the movement of water is not sufficient to sweep even smooth bottom clear of flocculent material, much less rugose surfaces. This observation has significant implications regarding the depth location of structures such as artificial reefs or natural lake trout spawning reefs, where the removal or absence of floc from the surfaces or interstices of the substrate by natural movements of the water is desired.

In a 1977 experiment, we positioned several vertical sediment-collecting tubes 1 m off bottom over Cook Plant intake riprap. Following a 21-day period (25 May-16 June), 74 mm of material was collected in the 3.8-cm diameter tubes. The tubes were constructed to permit diffusion of formaldehyde from an attached reservoir into the collection chamber, thereby preserving the material from decomposition. About 90% of the floc collected was sediment;

the remaining portion was composed of diatom tests and organic detritus. This experiment confirmed the potential for rapid deposition and accumulation of sediment in inshore depressions.

Flocculent material may change the circulation of water, dissolved gas exchange, and sediment oxygen demand (SOD) in microhabitats such as surfaces and interstices of substrates, which might adversely impact biological entities such as incubating lake trout eggs.

Transparency

Water transparency, the maximum distance between two divers at which they remained visible, was measured on the bottom with a line marked at 0.5-m intervals; values were relatively comparable among riprap and reference stations (Table 4). Highest visibility recorded was 6.8 m at the 9-m intake station, while the lowest was 0.6 m at a north reference station. Typical values were 2-3 m at all stations.

Visibility tended to be highest during summer months (June-August). This was probably the result of summer thermal stratification, followed by depletion of nutrients, and reduced plankton productivity. Also, fewer severe storms and reduced turbulence during summer permitted suspended material to settle. Highest visibilities occurred following a period of one to two weeks of calm lake conditions.

Several patterns were noted in the visibility among stations. Visibilities were usually lower at the two stations closest to the discharge structures (NR-1, SR-1) than at other reference or riprap stations. Also, there was a noticeable decrease in visibility from surface to bottom (6 m) at these two stations. The reduction in visibility at these locations was the

Table 4. Horizontal visibility (m) as measured by divers on the bottom near Cook Plant intake structures (9 m) and in reference areas (6 m) north and south of the plant, 1973-1982. Asterisk (*) shows months when measurements were not made on the same day at intake and reference stations. Measurements at reference stations were always made on the same day for any given month. Omitted months and blanks indicate no measurements made.

	Area		
Month	Intake	N. Reference	S. Reference
1973			
Jun*	2.0		2.0
Aug	4.5		
Sep	1.2		1.8
1974			
Apr*	1.0	0.6	
May	3.8		
Jun	3.3		3.3
Jul			1.7
Oct	1.2		
1975			
May*	2.1	2.0	
Jun	7.6	6.1	
Jul	4.5	4.0	4.5
Aug*	3.0	3.0	1.5
Sep	2.7	2.7	
Oct	2.7	2.0	2.5
1976			
Apr*	2.5	1.8	1.0
May*	2.0	1.8	1.2
Jun	4.0	4.5	3.0
Jul	1.5	1.5	2.0
Aug*	3.0	3.0	3.0
Sep	2.0	1.5	
Oct	3.0		
1977			
May	3.0		
Jun	6.8	6.1	6.0
Jul*	5.0	3.0	4.5
Aug	6.0	4.0	4.0
Sep	2.5	2.0	2.0

(Continued).

Table 4. Continued.

Month	Area		
	Intake	N. Reference	S. Reference
1978			
Apr	1.0	1.0	1.0
May	1.0	2.0	2.0
Jun	3.0	3.0	3.0
Jul*	2.0	3.0	3.0
Aug	2.5	2.5	3.0
Sep	2.0	2.0	2.0
Oct	1.0	3.0	
1979			
Apr	2.0		
May	2.0	2.5	2.0
Jun	2.0	2.0	2.0
Jul	4.5	4.0	4.0
Aug	3.0	3.0	3.0
Sep	3.0		
Oct*	1.3	2.0	2.0
1980			
Apr	2.0	3.0	2.0
May		3.0	2.5
Jun	3.0	3.0	3.0
Jul	1.0	2.5	1.5
Aug*	2.0	2.0	2.0
Sep*	2.0	2.5	2.5
Oct*	2.5	2.0	2.5
1981			
Apr	1.5	1.5	2.0
May	2.0	2.0	2.0
Jun	3.0	3.0	3.0
Jul	2.0	3.0	1.0
Aug	3.0	4.0	3.0
Sep	3.0	2.5	2.0
Oct	1.5	1.0	2.0
1982			
Apr	1.5	1.0	1.0
May*	3.0	3.0	3.0
Jun	4.0		
Jul	4.0		
Aug	4.0		
Sep	3.0		
Oct	3.0		

result of increased turbulence and suspension of sediment near the point of water discharge. No effect of plant-induced turbulence and reduced visibility was noted at reference stations farthest from the discharge structures.

On several occasions (Table 4), visibility at intake structures was greater than at reference stations. This situation occurred during summer months when a slight thermal stratification developed inshore (see previous section - Thermal Effects). A warm, clear layer of water occasionally overlaid a narrow band (1-2 m thick) of colder, more turbid water adjacent to the bottom. At reference stations where these layers were undisturbed, visibility was markedly reduced by one-half or more compared to the intake area. The overlying water layer was often drawn down into the lower layer at the intake structures, thus displacing the cooler, more turbid water and accounting for lower visibilities at reference stations. While diving on the bottom around the base of the intake structures, divers often swam in and out of these two water masses. This probably occurred because the water was not drawn evenly from both layers at all points around the structures.

Our studies in other inshore areas of southeastern Lake Michigan revealed that water transparency, measured as underwater visibility, did not vary consistently among locations. Underwater visibilities recorded at the Cook Plant were typical of the area. But, in another study (Dorr 1982) south of the plant near New Buffalo, Michigan, we found visibility on the bottom (6-12 m) in an isolated area of clay substrate and extensive submarine trenches to be consistently lower than the surrounding area, including that of the Cook Plant. This was the result of erosion of the clay substrate combined with relatively stagnant water contained in trenches. The water was usually much more transparent several meters above bottom.

Observations at the Cook Plant and elsewhere in the area suggest that inshore visibility (transparency) is largely a function of water movements or currents that suspend sediment off bottom. During quiescent periods, this material settles and transparency increases significantly. Presence of accumulations of sediment or erodable material such as clay may reduce visibility locally.

Inorganic Debris

We distinguished between inorganic debris observed in the study area and organic material which was termed detritus. Two general types of debris were noted: that which was deposited during initial construction and subsequent repair of in-lake plant structures, and debris which accumulated as a result of activities unrelated to plant construction and maintenance operations.

A variety of materials was deposited on the riprap during construction including: steel girders and plates, metal pipe, plastic, steel cable, and tires. For the most part, heavy objects remained in place for the duration of the study. Subsequent repair work on these structures (e.g., replacement of broken ice guards on the structures, addition of riprap or cement scour pads, etc.) resulted in accumulation of debris which remained in the area. However, some transport of lighter materials (plastic, tires, containers, etc.) from the area occurred during major storms.

In contrast with the riprap area, debris from plant construction was never observed on the surrounding sand bottom. If such debris were deposited in this area, lighter materials were probably rapidly transported from the area, while heavy objects sank into the bottom and were covered over by sand. The end result was that plant construction debris did not remain exposed in sand bottom areas for an extended time. In contrast, inorganic debris and organic detritus deposited on the riprap could not sink into the substrate, but snagged on the projections and in the crevices of the rugose substrate and was held in place. This debris served to expand the variety of substrates and habitats available to local biota.

The other general type of debris that was noted in the area was that which resulted from the dumping of trash into the lake. Some of this material (beverage containers, clothing, fishing tackle, household items, etc.) was dumped directly into the area by people fishing from small boats. It was not uncommon to count 20 or more small boats over the riprap area on a summer day. The other source of this trash came from refuse dumped in surrounding areas of the lake or eroded from the beach.

In general, the bulk of this trash was composed of lighter items which were eventually transported from the area. Trash was less abundant in the early spring following the prolonged absence of fishermen from the area coupled with the intense fall and spring storms which swept trash from the area. Evidence of such transport was provided by the occasional observation of such trash at all reference stations. Our observations during this and other studies reveal that while most trash is washed onshore or buried and eventually degraded in the substrate, considerable amounts of litter must be exposed and washed along the bottom of the lake at any given time. We base this observation on consideration of the relatively small areas of the lake bottom observed by divers, and the fairly high frequency at which trash was observed. With the exception of the riprap area itself, accumulations and observations of trash near the Cook Plant were similar to those noted elsewhere in the lake.

While plant construction materials that remained in place on the riprap provided expanded substrate and habitat, the trash did not. Trash was an inevitable result of the intensive use of a small area of the lake by the fishing populace.

BIOLOGICAL FEATURES

Organic Detritus

Organic detritus observed in the study area by divers was classified into two groups: microscopic and macroscopic. Microscopic organic detritus was defined as organic material whose original form could not be discerned by the unaided eye. These materials included remains of planktonic organisms or parts of larger organisms that were finely divided, such as shredded plants or decomposed animal tissue. Macroscopic organic detritus included dead algae, parts of plants (e.g., grasses, bark, twigs, limbs, trunks), and dead animals (e.g., crayfish and fish).

Accumulations of sediment greater than 10 mm thick were uncommon but amounts less than 5 mm thick were frequently observed in the study area. No diver-collected samples were analyzed for loss of organic material upon ignition, at which time organic material would be oxidized to carbon dioxide and water. However, in a separate study, analysis of 34 samples collected at depths less than 18 m in the vicinity of the study area showed a mean loss in sample weight upon ignition of 4.3% with a standard deviation of 4.1% (Rossmann and Seibel 1977). Combined with diving observations, these results suggest that both the total accumulation of surficial sediment and its organic component are variable in inshore southeastern Lake Michigan. Typical values for thickness and organic content of inshore surficial sediment are 3-5 mm and

4.3% total weight, respectively. These observations also suggest that small amounts of microscopic organic material are consistently available to benthic detritivores including epibenthic zooplankton, sponges, bryozoans, Hydra, snails, clams, crayfish, insect larvae, and fish. Not surprisingly, all of these organisms were found in the study area, although they were unevenly distributed.

Presence of macroscopic organic detritus was recorded in one of several categories contained in the prescribed record format (Figure 2). Some of these groups were later combined and summarized in six general categories of macroscopic material: algae (A), dune grass (B), shreds or chips of wood (C), twigs and branches (D), tree trunks and stumps (E), and fish (F) (Table 5). Other materials such as mollusc shells, insect larvae exuviae, crayfish, and fish feces were seen on occasion, but not often enough to warrant inclusion in the general summarization of observations. It was not possible to discern or count individual detrital objects. Therefore, only presence (or absence) of detritus within the various categories was noted and summarized as frequency of occurrence (%) among stations and years (Table 5).

Most types of organic detritus were observed at one time or another at all stations. Twigs and branches were most common and were seen at all stations at least once in all years. Clumps of loose algae were seen during 22% and 26% of all dives at the north- and south-reference stations, respectively. Dune grass was noted more often at the reference stations than at the intake or discharge stations. Shreds and chips of wood were consistently seen at all stations, but were observed more frequently in reference areas. The smooth, flat bottom at the reference stations facilitated diver observation of small detrital objects such as algae, dune

Table 5. Frequency of observation (%) of organic detritus on the bottom of southeastern Lake Michigan during standard series dives in the vicinity of the D.C. Cook Nuclear Plant, 1973-1982.[1] Observations of fish (F) are expressed in absolute numbers of fish counted during dives.

Year and station[2]	No. of dives	Category[3] A	B	C	D	E	F
1973							
NR	1			100			
SR	1						10 AL
I	4	25	25	25	25		
D	3	33	33		33		1 YP
1974							
NR	1		100	100	100		
SR	3	100		33			5 AL
I	9						
D	6		33	50	50	67	1 SS, 1 YP, 1 XX
1975							
NR	6	50		67	33		1 AL
SR	4	50		50			4 AL, 1 YP
I	11				27		1 AL
D	7	14		14	100	43	
1976							
NR	6		17	67	50		1 AL
SR	5		20	40			1 AL
I	12				17		1 AL
D	6			33	100	33	7 AL
1977							
NR	5	60	20	20			4 AL, 1 SP
SR	4	75					2 AL, 1 SM
I	12	8		8	17		
D	4	25		50	75		9 AL, 1 CP, 1 SS
1978							
NR	7	29			14		2 AL
SR	6	17		17			1 CC, 1 XX
I	12	8			8	8	
D							
1979							
NR	7	14		29	14		2 AL
SR	7	14	14	43	29		
I	14	14		14	14		
D	5				80		

(Continued).

Table 5. Continued.

Year and station[2]	No. of dives	Category[3] A	B	C	D	E	F
1980							
NR	7			14	43		4 AL
SR	7			14	14		2 AL
I	14				14	7	2 AL, 1 YP
D	3						
1981							
NR	7	29		43	71		3 JD
SR	7	29		14	57		32 AL, 2 YP
I	14			7	7		9 AL
D	3			33	33		
1982							
NR	2		50				
SR	2		100			50	1 AL
I	14				7		
D	2						
All years							
NR	49	22	6	35	35		14 AL, 3 JD, 1 SP
SR	46	26	9	24	15	2	57 AL, 3 YP, 1 CC, 1 XX
I	116	4	<1	4	13	2	13 AL, 1 YP
D	46	7	7	20	54	20	16 AL, 2 YP, 2 SS, 1 CP, 1 XX
Total	257	14	4	16	25	5	100 AL, 6 YP, 3 JD, 2 SS, 1 CC, 1 CP, 1 SM, 1 SP, 2 XX

1 Frequency of observation (%) = $\frac{No}{Nt} \times 100$
where:
No = no. dives at station when observed,
Nt = total no. of yearly dives at station.

2 NR = north reference stations, SR = south reference stations, I = intake station, D = discharge station.

3 A = loose algae, B = dune grass, C = shreds or chips of wood, D = twigs and branches, E = trunks and stumps, F = fish (AL = alewife, CC = channel catfish, CP = common carp, JD = johnny darter, SM = rainbow smelt, SP = spottail shiner, SS = sculpin, YP = yellow perch, XX = unidentified fish).

grass, and shreds or chips of wood.. At the intake and discharge stations, the uneven surface of riprap and abundance of interstices made observation of these small objects more difficult than at reference stations.

Tree stumps and trunks were observed infrequently (5% of total dives) and only once at a reference station. Stumps and trunks were most often observed at the discharge station. Their projections snagged on the uneven substrate. The solid foundation formed by the riprap also prevented the heavy stumps and trunks from sinking into the substrate. Water discharge currents from the Cook Plant kept these objects washed free of sediment that might otherwise have eventually covered them. On several occasions (1974-1976), divers observed tree trunks which were adjacent to the discharge structures and remained in place for several months, including winter.

In areas of sand substrate, moderately heavy objects resting on the bottom sank into the substrate and were rapidly covered by sediment. We observed many large chunks of wood, logs, and stumps during excavation of the lake bottom for placement of plant intake and discharge pipes. A portion of an excavated stump was examined and thought to have been buried along the shoreline during a previous low-level stage of the lake; possibly during the Chippewa (5,000-6,000 years ago) or Nipissing (4,000-5,000 years ago) stages (Hough 1958; personal communication, C. I. Smith, Department of Geology, University of Michigan)..

Shells of snails and sphaeriid clams were observed occasionally, most often in troughs of large ripple marks or in shallow, flat-bottomed depressions in the riprap. These shells were often fragmented and many were severely eroded. This suggests that the shells were transported by waves and currents and accumulated in these areas of slack water. Divers often encountered shells or fragments when sifting through coarse sand, but rarely when examining fine sand. Again, this was probably the result of the sorting of sediments by water movement; shell fragments contained in the fine sand were too small to be observed by the unaided eye.

Fish feces were commonly observed at reference stations. Alewife feces were most abundant during May-June when these fish concentrated in the area. Following commencement of heated water discharge from the plant during 1975, common carp began to be attracted to the area and feces of this fish were often found in abundance at reference stations closest to the discharge structures. The feces of these alewives and common carp undoubtedly increased the supply of organic material to detritivores and recycled nutrients to algae in the local area, but the significance of this contribution is unknown.

On a few occasions, dead crayfish were observed in the riprap zone but no pattern was detected in their occurrence. However, crayfish are often used by fishermen as bait for yellow perch that congregate over the riprap. Some of the dead crayfish seen by divers may have been discarded by these local fishermen.

Dead insect larvae and shells were observed occasionally but never in large numbers. Larvae of mayflies, water bugs, caddisflies, and water beetles were seen at both sand and riprap stations.

The preceding observations indicate that a spectrum of plant and animal material is available to detritivores inhabiting the inshore region of southeastern Lake Michigan. The role that detrital-feeding organisms play in lake ecology is discussed in more detail later in this report (see ECOLOGY).

Large accumulations of dead fish were never observed during dives in the vicinity of the Cook Plant (Table 6). The largest number of dead fish

Table 6. Record of dead fish observed during all dives in the vicinity of the D. C. Cook Nuclear Plant, southeastern Lake Michigan, 1973-1982. Blanks indicate no data.

Date	Time	Water temp. (°C) Surface	Bottom	Fish observed Species[1]	Dead	Live[2]
				North reference stations		
25 Jun 75	1945	19.0	19.0	AL	1	
13 May 76	1333	13.0	12.0	AL	1	
9 Jun 76	1730	21.7	16.2	AL	1	75-100
19 May 77	1530	19.0	16.0	AL	4	1
13 Jul 77	1745	23.7	21.6	SP	1	
28 Jun 78	1515	20.5	16.5	AL	2	
25 Jun 79	1605	13.5	9.5	AL	2	
24 Jun 80	1605	19.0	17.4	AL	5	
26 May 81	1615	14.8	12.3	JD	3	
				South reference stations		
18 Jun 73	1717	22.0	18.0	AL	10	1
22 Jul 74	1945	15.6	10.0	AL	1	
23 Jul 74	1445	15.6	7.8	AL	4	
17 Jul 75	1450	25.0	22.8	AL	5	
				YP	1	
15 Jul 76	1910	23.5	22.7	AL	1	>1,000
19 May 77	1630	19.5	16.5	AL	2	25-30
				SM	1	
28 Jun 78	1620	20.5	19.5	CC	1	
18 Jul 78	1556	18.0	15.0	XX	1	
28 May 80	1804	13.6	11.9	AL	2	
26 May 81	1635	14.5	12.5	AL	1	
23 Jun 81	1835	17.4	16.0	AL	30	
				YP	1	
1 Jul 81	1630			AL	1	20
				YP	1	
19 May 82	1722	19.0	17.0	AL	1	>100
				Intake station		
16 Jul 75	1425	22.2	22.2	AL	1	1
8 Jun 76	2145	19.0	16.2	AL	1	>1,000
15 Jul 76	1705	23.5	22.6	SS	1	2
28 May 80	1559	13.0	10.5	AL	2	1
28 Jul 80	0400	18.0	12.5	YP	1	
26 May 81	1720	15.5	12.0	AL	5	60
23 Jun 81	1900	18.0	16.5	AL	3	7
1 Jul 81	1730	18.0	13.0	AL	1	30

(Continued).

Table 6. Continued.

Date	Time	Water temp. (°C) Surface	Bottom	Fish observed Species[1]	Dead	Live[2]
			Discharge station			
16 Aug 73	1103	21.1	17.8	YP	1	
22 May 74	1150	12.0	11.0	SS	1	
				YP	1	
				XX	1	
12 May 76	1540	14.4	11.8	AL	11	
19 May 77	1330	19.6	15.4	AL	1	
				SS	1	1
				CP	2	18
16 Jun 77	1920	19.0	16.2	AL	8	>100

1 AL = alewife, YP = yellow perch, SS = sculpin (C. cognatus or C. bairdi), JD = johnny darter, CC = channel catfish, CP = common carp, SM = rainbow smelt, SP = spottail shiner, XX = unidentified fish. See Appendix 3 for scientific names.

2 Number of live fish of same species observed during same dive.

observed during a single dive was 30 alewives, which were seen during a dive in June 1981 at a south reference station. Observation of more than 5 dead fish during a dive was rare, and of the 281 dives made in the vicinity of the Cook Plant during 1973-1982 (Table 1), dead fish were observed on only 35 occasions (12% of the dives).

During the 281 dives made near the Cook Plant, 125 dead fish were counted. Of this total, 107 or 86% of the fish were alewives (see Appendix 3 for scientific names); the remainder was comprised of yellow perch (5), slimy sculpin and johnny darter (3 each), common carp (2), spottail shiner (1), channel catfish (1), rainbow smelt (1), and 2 unidentified fish. All of these fish species were abundant in the study area (Tesar and Jude 1985) and were commonly observed by divers, with the exception of channel catfish.

No particular pattern or trend was detected in numbers of dead fish observed among stations or years. However, 71% of the dives during which dead fish were seen were conducted during May-June. This observation was not surprising because of the high percentage (86%) of dead fish that were alewives. Annual dieoffs of alewives have typically occurred during May-June in southeastern Lake Michigan since the late 1960s (Brown 1968, Jude et al. 1979). In fact, considering the thousands of dead fish occasionally seen floating on the surface of the lake above the divers and washed up directly onshore, the small number of carcasses seen on bottom was unexpected. An unquantified but probably small proportion of the alewife carcasses that sank to the bottom may have been eaten or decayed, but severely eroded or decayed fish were seldom seen. Most dead alewives seen inshore of the 10-m depth contour of the lake probably floated on the surface or bottom until they eventually washed up onshore. The continuous exposure of this inshore region of the lake to waves and currents undoubtedly quickened the transport of dead fish to the beach.

Dead fish were never observed during April, September, and October. Inshore water temperatures were lower during these months than in May-August, and adult alewife and yellow perch remained farther offshore. The few dead yellow perch (5) observed during the underwater study were probably caught and discarded by local fishermen fishing from boats above the riprap and in-lake plant structures. Observations of all other species of dead fish were incidental and showed no pattern or particular significance.

Periphyton

Installation of the Cook Plant intake structures and associated riprap field was completed in late 1972. The surfaces of these objects then underwent a rapid sequence of initial rusting (of metallic surfaces), accumulation of sediment and organic detritus, and formation of bacterial slime. Much of this occurred in 1972-1973.

As the inshore water warmed during spring 1973, the surfaces of the structures and riprap began to be colonized by periphyton (attached algae), associated zooplankton, and other microscopic invertebrates. Macroscopic attached invertebrates such as sponges, bryozoans, and Hydra also appeared in small numbers on these surfaces.

The structures and riprap field were first examined by divers in June 1973. From 1973-1982, the length of periphyton on the top of the south intake structure and on riprap surrounding its base was measured by divers during most monthly dives (Appendix 1). Extensive colonization and growth of periphyton on the top of the intake structure occurred during its first year in the lake because the periphyton was already 3.7 cm long when first examined in June 1973. Periphyton 0.5 cm in length also appeared on the upper surfaces of riprap surrounding the structure at this time. Periphyton grew rapidly on top of the structure during late spring and attained peak lengths during mid-summer. This was followed by sloughing of the algae during late summer and over-wintering at minimal lengths (Fig. 3). Although the pattern of growth for periphyton on top of the structure was similar for all years, peak length attained each year varied. This was primarily the result of mechanical abrasion by ropes tied to buoys surrounding the structure and diver-construction activities during some years. Periphyton attained greatest lengths on protected portions of the structure (e.g., crevices, flanges, etc.) and along the top edges of the structure.

Periphyton growth on riprap surrounding the base of the south intake structure followed an annual pattern that paralleled that on top of the structure. Peak lengths were usually less than those attained on top of the structure, except during years of abrasion to the top of the structure. The primary reason for reduced growth of periphyton on the riprap was the increased depth (an additional 3 m) and commensurate reduction in light.

Some basic patterns in periphyton growth on the structure or surrounding riprap were detected during the 10 seasons that the area was examined (Fig. 1). Periphyton growth was most luxuriant at the edges of the structure top and within 5 m of the base of the structure, probably the result of maximal water currents which occurred at these locations. The movement of water kept the periphyton free of sediment and increased exchange of gases and nutrients. Periphyton growth was limited on vertical surfaces and non-

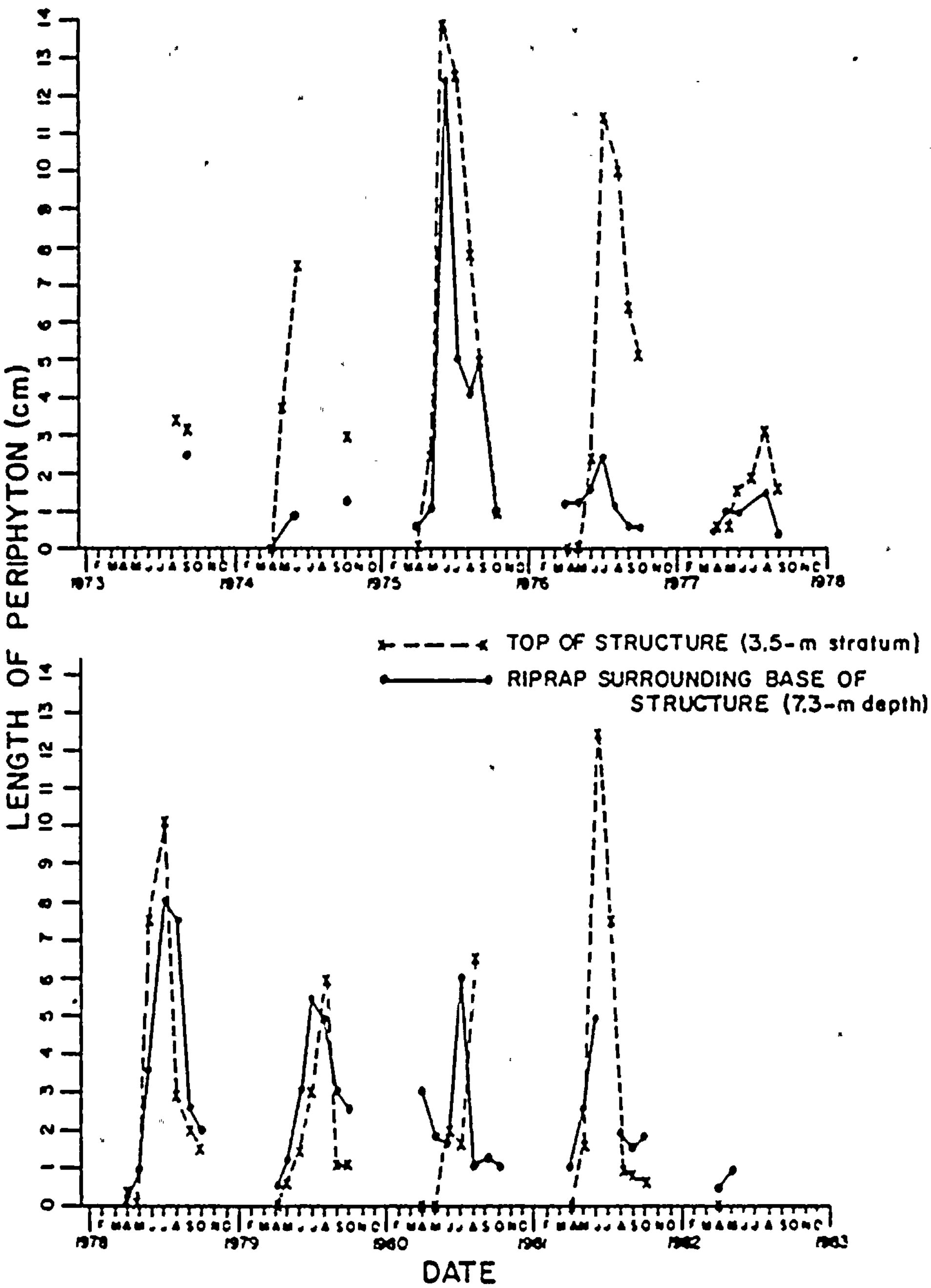

Fig. 3. Length of periphyton (mm) on top of the south intake structure (at the 3-m depth stratum) and on the upper surfaces of riprap (at the 7.4-m depth stratum) adjacent to the base of the structure. Measurements were made during dives in southeastern Lake Michigan near the D. C. Cook Nuclear Plant, 1973-1982.

existent on the undersides of the structure, riprap, and other unlighted surfaces at all depths.

The rapid attenuation of light with increasing depth also limited growth of periphytic algae. Periphyton growth at depths exceeding 10 m was minimal in comparison with that which occurred at lesser depths. A similar observation was made during our underwater examinations in 1978-1981 of fine-mesh screens, intake structures, and riprap at the J. H. Campbell Power Plant at Port Sheldon, Michigan, located 100 km north of the Cook Plant (Jude et al. 1982). Periphyton growth on all objects was depauperate in comparison with that observed on the upper surfaces of the Cook Plant structures and riprap. However, depths at the Cook Plant ranged from 4 to 9 m, while those at the Campbell Plant exceeded 10 m. At Hamilton Reef, located near Muskegon, Michigan, about 140 km north of the Cook Plant, periphyton was very sparse and _Cladophora_ was absent (Cornelius 1984). The minimum depth of this reef is 8.3 m. Observations on the Campbell and Hamilton reefs suggest that periphyton growth is limited at depths greater than 7-8 m in eastern Lake Michigan.

These observations also suggest that, given the general light, temperature, and water transparency regime in southeastern Lake Michigan, clogging of water intake structures by periphytic algae should be limited to horizontal surfaces exposed to direct sunlight at depths less than 8 m. However, clogging of structures by attached invertebrates such as sponges, bryozoans, and _Hydra_ would not necessarily be eliminated by increasing depth, and in fact these organisms became very dense on the Campbell Plant intake screens (Rutecki et al. 1985, Jude et al. 1982).

For several years prior to 1975, periphyton samples were collected from artificial substrates placed in the lake. Analysis of these samples provided baseline information on the taxonomic composition of periphyton in the study area. Preliminary studies in 1974 and full sampling efforts occurred from 1975 through 1981. During this time, the sampling program was altered so that samples of periphyton were collected from the top of the south intake structure and surrounding riprap by divers. Comparison of the 1974-1981 diver-collected samples with those collected earlier from the artificial substrates revealed that direct sampling of periphyton from the structures and riprap to qualitatively assess colonization and growth of periphytic algae on these objects was preferable to use of hand-placed artificial substrates.

A distinct trend occurred toward increasing numbers of taxa, or taxonomic diversity, with time (Fig. 4; Table 7). Total numbers of taxa increased from 97 in 1975 to 189 in 1981. Numbers of previously unrecorded taxa followed a trend similar to that observed for total taxa but was less pronounced. This trend was mostly the result of an increasingly diverse diatom flora. The fraction diatom (Bacillariophyta) taxa made of total taxa increased every ye (except 1980) from 58% in 1975 to 75% in 1981 (Table 8); data from 1974 were considered inconclusive because they were based on analysis of only one sample from June. The percentage of the total that green algae (Chlorophyta) comprised decreased by 14% during the same period. Percent composition of blue-green algae (Cyanophyta) remained relatively stable and varied from 4% in 1976 to 9% in 1978 (range = 5%). Other algae (Chrysophyta, Euglenophyta, Pyrrophyta, and Rhodophyta) comprised from 1% (1979) to 8% (1975) by number of the total taxa recorded for each year.

The increase in algal taxonomic diversity was accompanied by a decrease in numbers of dominant forms. In 1977, 8 of 97 taxa occurred in all samples; in 1978, 3 of 117 taxa were present in all samples; in 1979, no taxon was

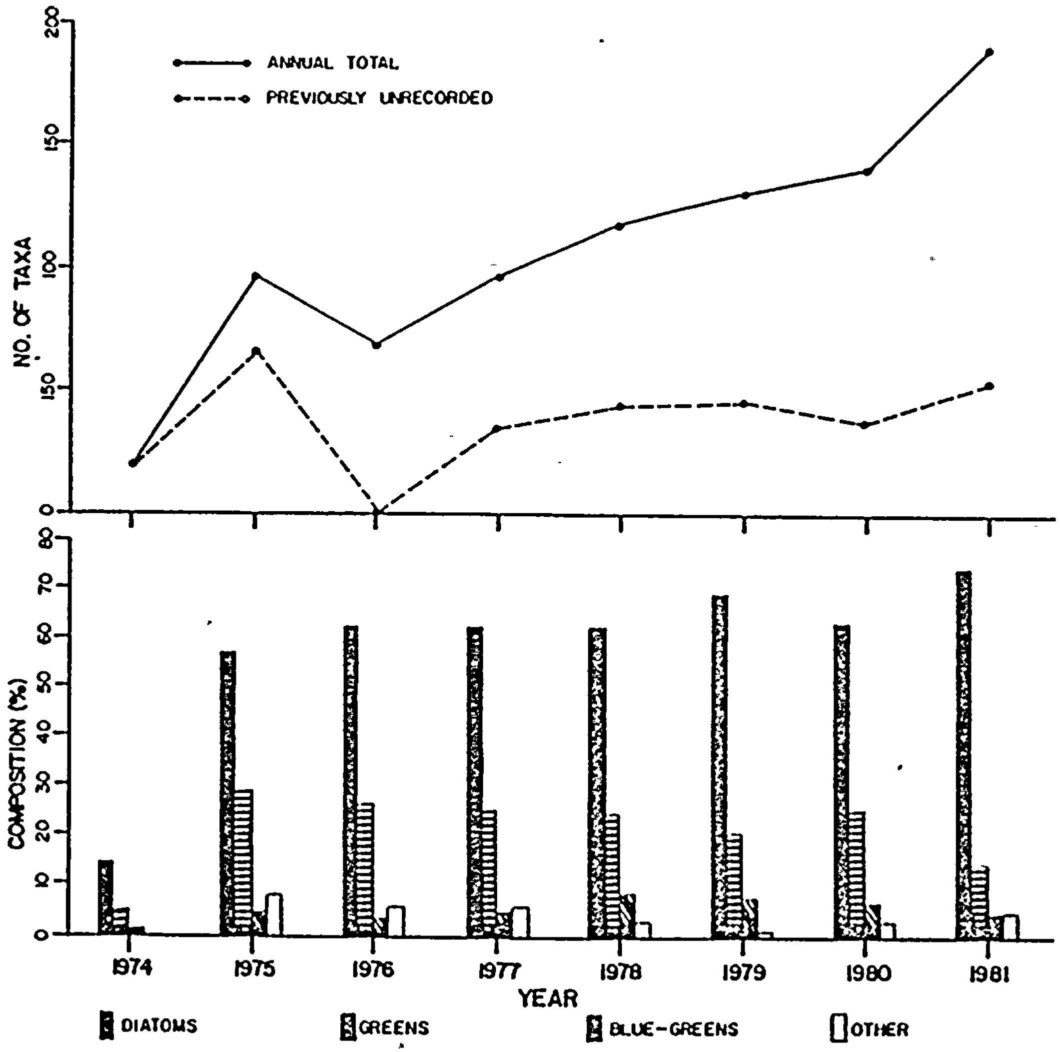

Fig. 4. Total number and percent composition by major groups of periphytic algae collected by divers from the top of the south intake structure of the D. C. Cook Nuclear Plant, located at the 3-m strata of the 9-m contour in southeastern Lake Michigan. One sample was collected each month, April-October, 1974-1981, in most years. A wet-mounted subsample was qualitatively analyzed under a microscope, and algae were identified to lowest recognizable taxon. Total number of samples analyzed each year was: 1974 = 1, 1975 = 5, 1976 = 6, 1977 = 4, 1978 = 7, 1979 = 7, 1980 = 7, 1981 = 7.

Table 7. Total number and number of previously unrecorded taxa of periphyton identified in diver-collected samples scraped from the top of the south intake structure of the D. C. Cook Nuclear Plant, 1974-1981. One sample per month, April-October, was collected each year with the exception of 1974 (all months but June omitted), 1975 (April and September omitted), 1976 (October omitted), and 1977 (April, May, and October omitted). Fraction (%) of total periphyton taxa that were also identified in samples of entrained phytoplankton collected from the plant forebay is also listed. Blanks indicate no samples collected.

Year	No. of samples	Total no. of taxa	No. (%) taxa previously unrecorded	Percentage of taxa entrained
1974	1	21	21 (100)	
1975	5	97	66 (68)	
1976	6	67	1 (1)	
1977	4	97	34 (35)	74
1978	7	117	43 (37)	81
1979	7	131	45 (34)	79
1980	7	141	38 (27)	78
1981	7	189	54 (29)	78

Table 8. Composition by number (and percent) of the number of taxa found in diver-collected periphyton samples scraped from the top of the D. C. Cook Nuclear Plant south intake structure during 1974-1981. One sample per month, April-October, was collected each year with the exception of 1974 (all months but June omitted), 1975 (April and September omitted), 1976 (October omitted), and 1977 (April, May, and October omitted). Algae were categorized as follows: diatoms = Bacillariophyta, green algae = Chlorophyta, blue-green algae = Cyanophyta, golden-brown algae = Chrysophyta, red algae = Rhodophyta, and other algae = Euglenophyta and Pyrrophyta.

Year	Diatoms	Green algae	Blue-green algae	Golden-brown algae	Red algae	Other algae
1974	15 (71)	5 (24)	1 (5)	0	0	0
1975	56 (58)	28 (29)	5 (5)	5 (5)	1 (1)	2 (2)
1976	44 (63)	19 (27)	3 (4)	3 (4)	1 (2)	0
1977	61 (63)	25 (26)	5 (5)	2 (2)	1 (1)	3 (3)
1978	75 (63)	29 (25)	10 (9)	1 (1)	0	2 (2)
1979	101 (70)	31 (21)	11 (8)	1 (1)	0	0
1980	91 (64)	37 (26)	11 (7)	1 (1)	1 (1)	1 (1)
1981	142 (75)	29 (15)	9 (5)	4 (2)	0	5 (3)

present in all samples; in 1980 and 1981, one taxon was present in all samples. During the period 1975-1980, the dominant green algae on the structure were species of Cladophora. During 1979-1981, length and density of Cladophora filaments growing on the structure were reduced relative to earlier years. Oscillatoria spp. were the dominant blue-green algae during all years expect 1981 when Anacystis incerta was most abundant. Diatoms of the genera Asterionella, Cymbella, Fragilaria, Melosira, Navicula, Nitzschia, Stephanodiscus, and Tabellaria were common in nearly all years. The golden-brown algae Dinobryon sp. was commonly recorded in samples, while red algae, flagellates, and euglenoids were occasionally noted.

Successive comparison of total numbers of taxa identified annually in the periphyton samples revealed: 54 taxa were present in 1981 only; 48 taxa were present in 2 of the 7 years; 23 taxa were present in 3 of the 7 years; 17 taxa were present in 4 of the 7 years; 10 taxa were present in 5 of the 7 years; 17 taxa were present in 6 of the 7 years; and 37 taxa were present in all years.

The fraction of periphyton taxa observed in samples of entrained phytoplankton collected from the Cook Plant forebay was consistently high, varying from 74% to 81% during 1977-1981 (Table 7). This observation suggests that considerable sloughing of periphyton occurs each year. Most likely, sloughing rates are highest during late summer and early fall as decreasing light levels and water temperatures result in die-off of much of the periphyton. Comparison between taxonomic lists of algae collected by divers and those collected in entrainment samples pumped from the plant forebay, suggests that entrainment sampling is an effective method for qualitatively assessing the diversity of periphyton attached to in-lake power plant structures during months when diving is not possible.

Several conclusions may be drawn from the observations presented in this section. Almost immediately upon their placement in the lake, underwater structures were colonized by periphyton, and considerable taxonomic diversity was achieved during the first year. However, there was a steady increase in the total number of taxa recorded each year, which was accompanied by a decline in number of dominant forms noted. A substantial number of rare taxa was recorded each year, and long-term dominant taxa were few in number. The largest number of previously unrecorded taxa was identified in 1981 samples, during the fifth and final year of the periphyton study. This suggests that ecological succession continued to occur 7 years after the structures and riprap had been placed in the lake, and that the taxonomic composition and relative abundance of periphyton had not yet stabilized at the end of this period. Evidence (Fig. 4) also indicated that periphytic succession would continue and that taxonomic stabilization was not imminent.

The decline in abundance of Cladophora during 1979-1981 was significant because, prior to that, these algae comprised most of the mass of periphyton seen and sampled from the area. Reasons for this decline are not known, but reduced abundance of Cladophora is related to declining phosphorus levels in Lake Michigan due to the phosphate ban in 1977 and reduced discharges at Chicago and Waukegan, Illinois. Presence (or absence) of Cladophora on substrates was shown to affect the distribution of some invertebrates (Lauritsen and White 1981).

Attached Macroinvertebrates

Several taxa of invertebrates having one or more sessile stages during which they must attach to a substrate were observed by divers and included:

freshwater sponge, bryozoans, and Hydra spp. Observations of these animals were generally incidental relative to those of other invertebrates (snails and crayfish), but a few patterns emerged from the limited data (Appendix 1). Attached invertebrates were only observed on substrates in the riprap zone. Attached invertebrates were not observed in reference areas because of the absence of stable substrate.

Branched or multi-filamentous Hydra were first observed during September 1973 and were attached to riprap surrounding the intake structures. They were not observed again until 1978 when they were seen during standard series diving in October. Hydra were subsequently observed twice in 1979, and once in 1980 and 1982. These data are somewhat misleading in that they suggest the abundance of Hydra was low in the study area. When observed, Hydra occurred in tremendous numbers and often completely covered the upper surfaces of the riprap. During February 1977, a supplemental dive was made in the Cook Plant forebay where mats of Hydra 1-2 cm thick and more than 10 m in diameter were seen attached to the forebay walls. Commercial divers noted similar occurrences of Hydra during inspection of the interior walls of the plant intake and discharge pipes (personal communication, A. Sebrechts, Bridgman, Mich.). The abundance of Hydra on the intake structures and pipe explains its consistent occurrence in large numbers in entrainment samples.

In the open lake, Hydra were seen only during May and August-October, suggesting that conditions (e.g., water temperature, availability of specific planktonic prey) during June-July were not conducive to Hydra growth. Another possibility is that Hydra competed for substrate with algal periphyton which attained maximum growth during June-July. This hypothesis is consistent with diver observations that Hydra were concentrated on the lateral and undersides of the riprap and plant structures where periphyton was absent.

The long-term distribution of Hydra showed a distinct pattern of initial colonization within one year of placement of substrates in the lake, followed by an extended period (1974-1977) of gradual expansion in distribution and density on these substrates. Peak abundance was achieved during 1978-1980, although Hydra continued to be observed throughout the duration of the study.

Bryozoans were observed during monthly dives once in 1974, three times in 1976, once in 1977, 1978, and 1980, and twice in 1981. Colonies were isolated and generally small, never exceeding a centimeter in diameter. No seasonal or temporal pattern in the abundance or distribution of this organism was detected during this study. Colonization of the structure and riprap by bryozoans occurred during the first two years that these substrates were in the lake.

Freshwater sponges were not observed in the study area until 1975, when they were seen during two monthly dives. Subsequently, they were seen during 3 mo in 1976, all months in 1977, 4 mo in 1978, 3 mo in 1979, 1 mo in 1980, 4 mo in 1981, and 1 mo in 1982. Both its seasonal and temporal distributions were more continuous than that of Hydra or bryozoans.

About two years were required for sponges to colonize the plant structures and riprap in sufficient numbers to be noticed by divers. It is possible that colonization of these substrates may have occurred more slowly than for Hydra or bryozoans, although this cannot be substantiated by our data. Numbers of sponge colonies appeared to stabilize during 1976-1978 and remained at similar levels of abundance through the remainder of the study.

Both the structures and riprap served as substrates for attachment of sponges, although they were observed most frequently on the riprap.

Sponges were not observed during dives in early spring (April-May) except in 1977. Generally, colonies were first observed during June, continued to increase in numbers throughout the summer, and remained abundant during the fall (September-October). In late summer, sponges were often bright green in color, a result of the inclusion of algal cells in the sponge matrix. Colonies usually appeared as flattened disks up to 1 cm in thickness and 10 cm in diameter, but occasionally formed finger-like outgrowths 2-3 cm in length. During late fall, sponge colonies became flattened and tan or white in color as the algal cells died, and a reduction or die-off of sponge was suspected to occur during the winter. Winter die-off and dormancy of most living cells contained in upper strata of the underlying skeletal matrix is typical of temperate freshwater sponges (Pennak 1953).

The general pattern of colonization of Cook Plant substrates by attached invertebrates was one of early appearance followed by slow expansion to available substrates. Riprap appeared to provide a more suitable substrate than did the metal structures, perhaps because rusting and sloughing of the metal surface occurred throughout the study, although the rate at which this process occurred declined in later years of the study. Peak abundance of attached macroinvertebrates occurred four to six years after placement of substrates in the lake. During the last several years of the study, the abundance of *Hydra* and bryozoans declined, while numbers of sponge colonies continued to fluctuate and showed no particular pattern or trend. Availability of substrate combined with moving (plant-circulated) water and presence of surficial sediment, organic detritus, and periphyton combined to provide a hospitable but isolated micro-environment that was atypical of the surrounding inshore environment.

Underwater observations at both the Campbell Plant reef near Port Sheldon, Michigan (Jude et al. 1982) and Hamilton Reef near Muskegon, Michigan (Cornelius 1984) documented the colonization of riprap by sponges within one to two years of substrate placement in Lake Michigan. At the Campbell Plant, sponge colonies attached to wedge-wire intake screens in addition to the riprap, eventually necessitated cleaning of these screens. Farther north of the Campbell Plant at Hamilton Reef, sponges and unidentified fungi were common in diver-collected samples of invertebrates attached to the riprap (Cornelius 1984).

Free-living Macroinvertebrates

Diver observation of unattached or free-living macroinvertebrates in the study area included aquatic stages of insect larvae, molluscs (clams and snails), and crustaceans (crayfish). These observations are summarized in Appendices 1-2.

Within and outside the riprap zone, divers observed larvae of Diptera (Chironomidae - true midges), Ephemeroptera (mayflies), and Trichoptera (caddisflies). Observations of these larvae were infrequent with no clear pattern. However, insect larvae were observed only during mid-spring (April-May) in the study area.

Other invertebrates observed in the area included the crustaceans *Mysis* (opossum shrimp) and *Pontoporeia* (scuds), and an adult of the insect family Notonectidae (back swimmers). *Pontoporeia* were observed only during late summer and fall (August-October) and never during spring or early summer.

Sightings of the above invertebrates were generally limited to the riprap zone. Often, these organisms were seen clinging to the sides or undersurfaces of stones. These animals were rarely seen in areas north or south of the plant. Most likely, invertebrates living in such areas of shifting sand substrate either buried themselves in the upper layers of the sediment and were not visible to the divers or were quickly eaten by fish.

Molluscs observed during the study included Sphaeriidae (fingernail clam) and Gastropoda (snails). Live sphaeriids were not observed because they were buried in the sediment. However, large numbers of empty shells were commonly seen at all stations. Sphaeriid shells accumulated in the troughs of ripple marks and in open depressions among the riprap. These accumulations were often several centimeters thick and several meters in length or diameter and attested to the abundance of these organisms in the study area. On one occasion one valve of a large pocketbook clam (*Lampsilis ventricosa*) was found at 6 m at the most northerly reference station (Fig. 2). Whether the specimen came from Lake Michigan or was transported from a connected inland lake was not known. However, we found lampsilid clams in abundance in the Grand Mere Lakes, a chain of shallow bar lakes located about 3 km north of the Cook Plant and which connect to Lake Michigan via an intermittent outlet.

Gastropods (snails) observed in the area during 1973-1982 included *Physa*, *Goniobasis*, and *Lymnaea*. *Lymnaea* were easily recognized by the high, sharp spire of their shell. Only shells of this snail were seen on a few occasions, and live specimens were never observed. *Physa* and *Goniobasis* were distinguished underwater by differences in the coil of their shell (sinistral and dextral, respectively). Laboratory identification of snails collected over a period of several years revealed that most specimens were *Physa integra* and documented this snail to be the predominant gastropod inhabiting the Cook Plant riprap.

Gastropod speciation at the J. H. Campbell Plant differed considerably from that observed for the Cook Plant. The Campbell Plant riprap was initially colonized by Valvata which were later displaced by Lymnaea, and Physa were never observed at the Campbell Plant (Rutecki et al. 1985). Interestingly, Valvata were seen in great abundance during a pre-construction underwater survey of the site in 1977 (Jude et al. 1978) and were the most abundant gastropod in Ponar grab samples of sediment collected during 1977-1979 from areas north and south of the plant (Winnell and Jude 1981).

The difference in species distribution of gastropods between the Cook and Campbell reefs was probably related to differences in physical and biological conditions at the two reefs. The increased size of the riprap and interstitial spaces, combined with greater depth and subsequently reduced storm-generated water turbulence, less periphyton, and absence of Cladophora on the Campbell Plant reef, may have favored or excluded certain species of snails. Pennak (1953) noted that Physa occurs in greatest abundance where there is a moderate amount of aquatic vegetation but is rare in areas where there are dense mats of vegetation. This may, in part, explain why Physa initially colonized the Cook riprap but disappeared in later years as periphyton became more abundant on the reef. Absence of periphyton or other vegetation on the Campbell riprap may have discouraged colonization of this reef by Physa. On the other hand, Lymnaea is found in a wide variety of habitats (Pennak 1953). This snail was abundant on the Campbell reef and its shells were occasionally collected at the Cook reef. No exact explanation could be made for the presence of Valvata on the Campbell reef and its absence on the Cook reef. However, there is a major anatomical and physiological difference in the respiratory mechanism of the Valvatidae when compared with the Physidae and Lymnaeidae. The Valvatidae have external plumose gills; whereas, the Physidae and Lymnaeidae have a "lung" or pulmonary cavity. Also, most pulmonate snails come to the surface to breathe (although a large number do not) and therefore generally tend to inhabitat shallow water. The increased depth of the Campbell reef along with absence of periphyton that might interfere with external gills may have favored the valvatid snails.

Numbers of snails (primarily Physa) at the Cook Plant did not show any strong pattern of seasonal abundance during April-October, except that they tended to be most abundant during April-June and August-October and were never abundant during July (Fig. 5). However, a clear pattern of temporal abundance emerged during the study. Snails were observed in large numbers during 1973-1975 and peaked in abundance during May 1975 when 30-100 snails/m^2 were counted during dives at the south intake station. These numbers include only snails immediately visible to divers without disturbing the riprap. In actuality, the density of snails was probably several times greater than 30-100/m^2, because they were abundant on the sides and undersurfaces of the riprap as well as on stones beneath the surficial layer of riprap. Following 1975, a precipitous decline in snail abundance occurred during 1976-1978. No snails were observed in the study area from 1979 through 1982.

The riprap was colonized by snails during its first year in the lake and supported large populations of Physa for about three years. At that point, habitat conditions or some other ecological effect occurred that rendered the riprap unsuitable for Physa. As previously noted, it is possible that after several years, the accumulation of sediment and periphyton on the surface of

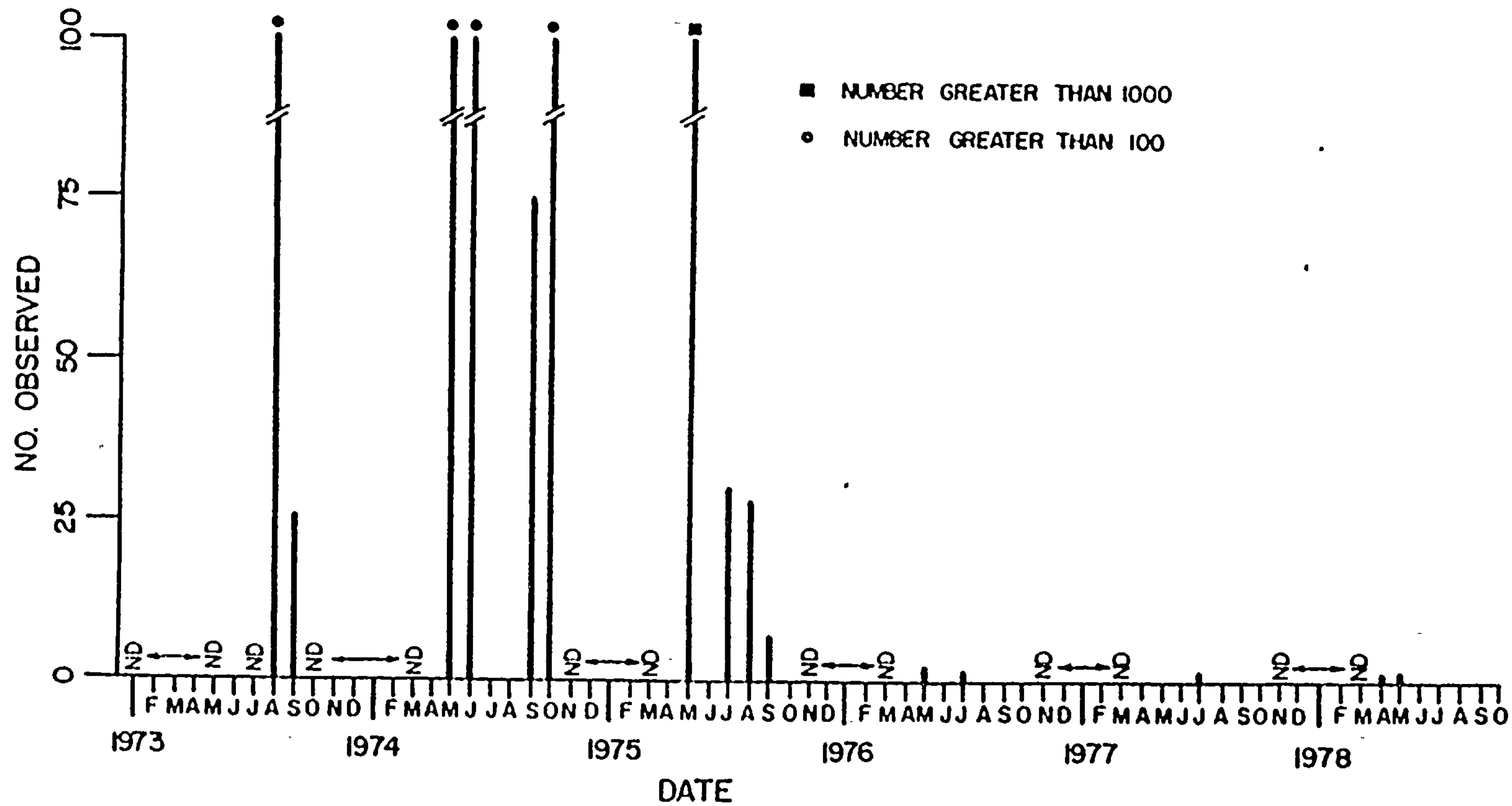

Fig. 5. Numbers of snails observed by divers in southeastern Lake Michigan near the D. C. Cook Nuclear Plant, 1973-1982. Snails were seen only at stations within the riprap zone and none was observed after 1978. ND = no diving that month.

the riprap reached a point at which it interfered with the respiration or movement of the snails. Another possibility is that composition of microscopic flora and fauna that snails fed upon was altered through the accumulation of sediment and periphyton, and eventually the riprap surfaces no longer provided suitable food for the snails. Yet another possibility is based on the observation that snail egg cases were commonly observed during the first few years of diving but not in later years. Perhaps as the surface of the riprap aged and accumulated material, it was no longer sufficiently clean to serve as substrate for the attachment and incubation of these eggs.

On a few occasions, live snails were seen on the metal surfaces of the intake and discharge structures. However, only isolated animals were observed and densities never exceeded one snail per several square meters. The surface of the structures was always covered with either periphyton and sediment, or, when periphyton was absent, rust. The snails may have avoided all such surfaces. Also, snails were quite obvious on the flat surface of the structure and may have been more susceptible to predation by fish.

In contrast to sightings of Valvata in areas surrounding the Campbell reef, live snails were never observed by divers in sand-substrate areas surrounding the Cook Plant riprap zone. No explanation can be offered for this difference. However, snails were observed in areas of natural (clay, cobble) rough substrate north and south of the Cook Plant (Dorr 1982). These isolated areas of naturally occurring, stable substrate probably served as preserves on the lake bottom where snails, along with crayfish and attached invertebrates could survive and emigrate to areas of newly placed artificial substrate.

Information on the abundance and distribution of decapods (crayfish) in the study area originated from two sources: diving observations made during 1973-1982 and records of their impingement from 1975 through 1981 on Cook Plant traveling screens (Fig. 6). Three species of crayfish were present in impingement samples; Orconectes propinquus, O. virilis, and Cambarus diogenes diogenes. Only isolated specimens of the latter two species were collected, representing only a fraction of a percent (0.08%) of all crayfish collected (Winnell 1984). Crayfish were observed during all years of the underwater study, although their abundance fluctuated during this period. It was assumed that most crayfish observed by divers were O. propinquus, based on the predominance of that species in impingement samples.

Crayfish were observed more frequently at night than during the day (Fig. 7). This was in accordance with the generally nocturnal habits of this animal which remains hidden in burrows or under substrate during the daytime (Pennak 1953). At the Cook Plant, crayfish could be found during daytime by excavating some of the riprap. At night, crayfish emerged and rested on top of the stones or among the interstices.

Comparison of total numbers of crayfish observed by divers each month with numbers of crayfish impinged documented a general pattern of initial low abundance, followed by rapid population growth, and then by a decline to about one-tenth of peak abundance. Crayfish were observed in 1973 and had therefore colonized the reef within one year of its placement in the lake. During 1979-1982, numbers of crayfish observed and impinged fluctuated but remained within the same general upper and lower limits during the period.

During April-October, 1975-1982, day and night observations were made at two side-by-side, 1 x 10 m transects adjacent to the base of the south intake

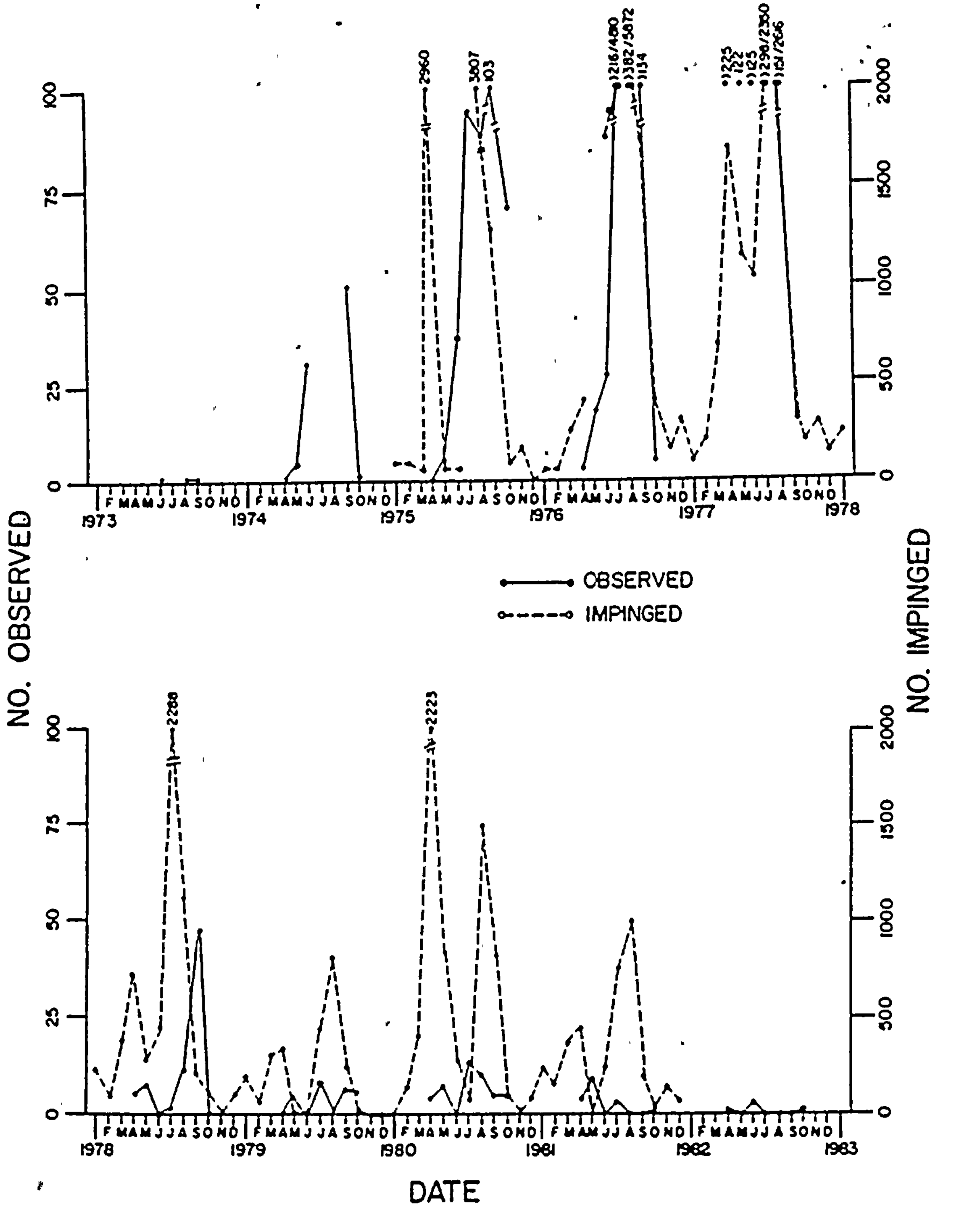

Fig. 6. Numbers of crayfish observed by divers (1973-1982) and impinged on traveling screens (1975-1981) at the D. C. Cook Nuclear Plant, 1975-1981, southeastern Lake Michigan.

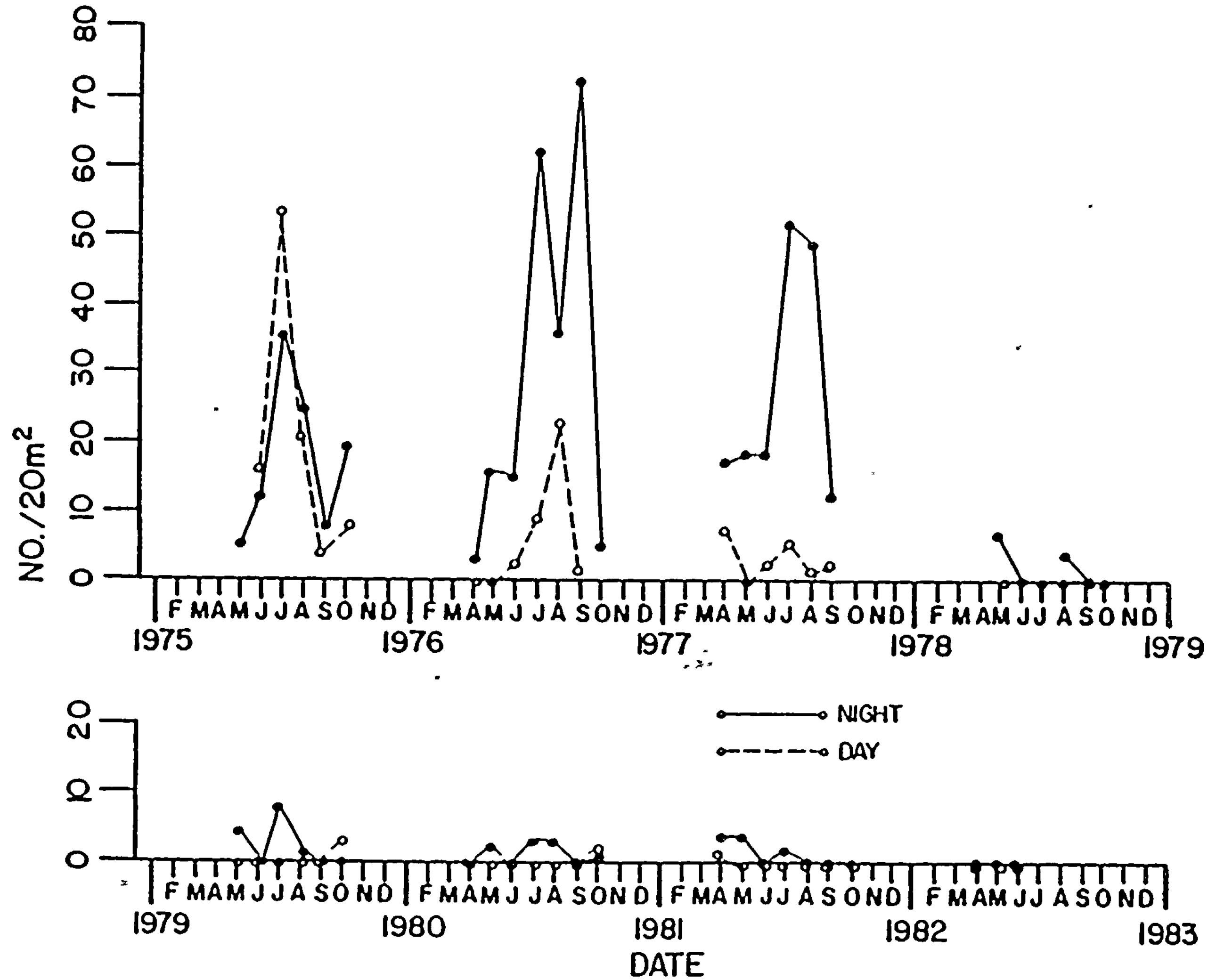

Fig. 7. Total numbers of crayfish seen by divers during day and night swims over two adjacent 1 x 10 m transects (20 m^2 total area) along the base of the south intake structure of the D. C. Cook Nuclear Plant, southeastern Lake Michigan, 1975-1982.

structure. These observations were pooled to yield numbers of crayfish (and other organisms) observed per 20 m^2. These quantified observations were based on standardized methodology and constituted the most reliable database from which conclusions could be drawn based on underwater observations. Comparison of transect observations of crayfish (Fig. 7) with total numbers of crayfish observed and impinged in the study area (Fig. 6) revealed a corroborating pattern of temporal abundance. As with total numbers of crayfish observed and impinged, peak abundance of crayfish recorded during transect observations (72/20 m^2) also occurred during 1976, although more were seen during September than August. Transect observations also support the conclusion that crayfish were most abundant on the Cook Plant riprap during 1975-1977 and that their abundance declined precipitously during 1978. They continued to be observed in small numbers through 1981 but none was seen in 1982.

The reason for the abrupt decline in abundance of crayfish in 1978 is unknown. Peak numbers of crayfish impinged during 1978 approached 1977 levels but sustained impingement during 1978 was clearly less than that of 1977. Total and transect observations of crayfish declined by a factor of 10 during the period 1977-1978. It appears that some environmental factor or ecological relationship changed during the period fall 1977-spring 1978 and caused a rapid decline in abundance of crayfish on the Cook Plant riprap. A similar decline in abundance of snails was discussed earlier, although it occurred during 1976, about two years in advance of the crayfish population decline.

Peak abundance of crayfish recorded during transect observations (September 1976 - Fig. 7) was 72/20 m^2 or about 4/m^2. However, this number included only those animals visible to the divers who did not displace the riprap during transect swims. Based on non-transect observations during which the riprip was overturned, it is possible that actual abundance of crayfish may have peaked at 8-10/m^2. Based on numbers and weights of crayfish impinged during the same month, the average weight of these crayfish was 5.1 g. This extrapolates to an observed abundance of 20.4 g/m^2 (162 lbs/acre) and an estimated abundance of 41-51 g/m^2 (364-445 lbs/acre). Pennak (1953) noted that pond populations of crayfish generally do not exceed 100 lbs/acre but in exceptional cases may attain 500-1,500 lbs/acre. These data suggest that at peak abundance, the riprap supported a relatively dense population of crayfish. It is possible that within two to three years the carrying capacity of the habitat may have been exceeded which resulted in the subsequent decline in crayfish abundance observed during later years of the study.

Unlike the Cook Plant reef, no crayfish were observed during four years of diving (1978-1981) on the Campbell Plant reef. Rutecki et al. (1985) attributed this disparity to differences in reef composition and configuration. Surficial riprap surrounding the Cook Plant intakes was composed of stone ranging from about 0.1-0.6 m in diameter and weighing about 1-50 kg. Campbell Plant riprap was considerably larger than Cook Plant riprap, usually exceeding 1 m in diameter and weighing 225-900 kg. The interstices among the Campbell riprap were much larger than those of the Cook Plant and may have provided crayfish with less protection from fish predation (e.g., slimy sculpin, yellow perch), especially during the egg and juvenile stages.

Another possible explanation for the absence of crayfish on the Campbell reef is that, in contrast to the Cook riprap, periphyton was extremely depauperate on the Campbell riprap and Cladophora was absent. Prince et al. (1975) found that in Smith Mountain Lake, crayfish were abundant in areas supporting luxuriant Cladophora and absent from areas with little or no growth of this alga. Crayfish are omnivorous and are known to eat aquatic vegetation (Pennak 1953). It is possible that Cladophora constituted an important component of the diet of crayfish at the Cook Plant and that absence of this or other aquatic vegetation on the Campbell riprap resulted in an inadequate supply of food. Lauritsen and White (1981) found that the seasonal abundance of some predacious and filter-feeding zoobenthos was correlated with the the luxuriance of Cladophora on the Cook Plant riprap. These zoobenthos may have served as prey for crayfish, thus providing a trophic link through which the abundance of Cladophora could affect the abundance of crayfish on the reef.

These observations correspond with those of Cornelius (1984) for Hamilton Reef near Muskegon, Michigan. This artificial reef is similar in composition and location to the Campbell reef, although its configuration is somewhat different in that the riprap is separated into numerous piles several meters apart which are interspersed by areas of sand. Like the Campbell reef, periphyton was scarce on the Muskegon reef, Cladophora was absent, and crayfish were not observed during three field seasons of diving. Elsewhere in the area, Dorr (1982) documented the presence of crayfish in areas of naturally occurring cobble substrate located near Saugatuck and South Haven, Mich., between the Campbell and Cook Plants. These substrates also supported periphyton, although growths were never as luxuriant as those seen at the Cook Plant. However, abundance of crayfish was also lower at these locations than at the Cook Plant. The above observations argue for the existence of a relationship between abundance of periphyton, Cladophora in particular, and that of crayfish on inshore reefs in eastern Lake Michigan.

During 10 years of diving at the Cook Plant, only one crayfish was seen in an area of sand substrate outside the riprap zone. This attests to the critical role that substrate plays as a limiting factor in the life history and distribution of crayfish, particularly in such a harsh environment as occurs inshore in eastern Lake Michigan.

Fish Spawning

Spawning by numerous species of fish has been inferred from catches of male and female fish with ripe-running gonads in the inshore region of Lake Michigan near the Cook Plant (Jude et al. 1979, Tesar et al. 1985). Occurrence of newly hatched yolk-sac larvae in plankton net hauls in the lake and entrainment samples collected from the plant forebay (Bimber et al. 1984, Noguchi et al. 1985) supports this inference. More direct evidence of fish spawning in the immediate vicinity of the Cook Plant was provided by *in situ* observation of eggs of five fish species: alewife, spottail shiner, yellow perch, johnny darter, and slimy sculpin.

Fish eggs were observed during all years of the study except 1982 (Appendix 1). Eggs were observed exclusively during May-August (Fig. 8). Duration of occurrence for a given species ranged from about 3 weeks for yellow perch and sculpin to about 10 weeks for alewife.

The line graphs in Figure 8 must be interpreted with care because they present information on different components of the reproductive cycle. The basic progression of events during reproduction should be the appearance of ripe-running fish in the area followed (or paralleled) by spawning and deposition of eggs. Next would come a period of egg incubation during which

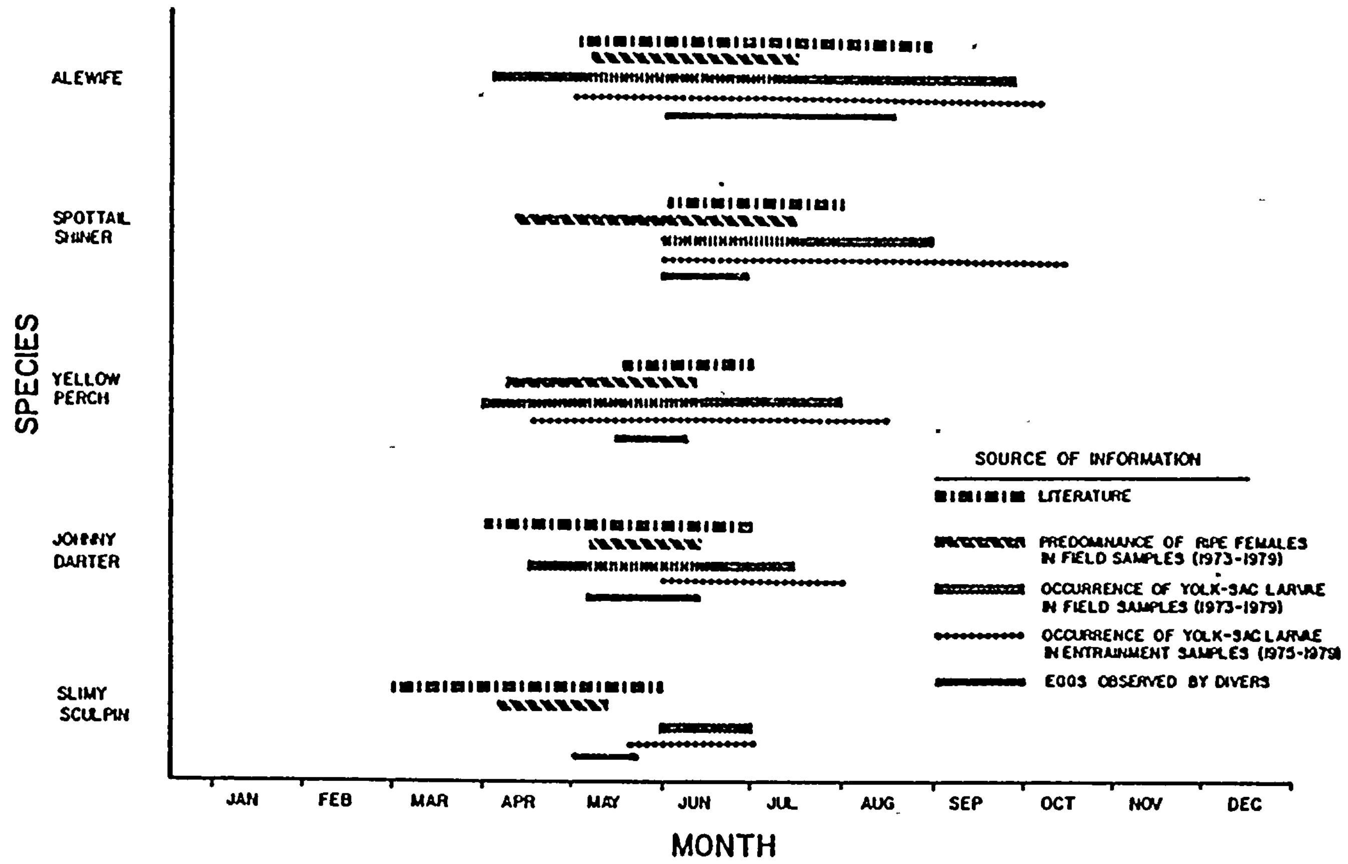

Fig. 8. Chronology of maturation, spawning, egg incubation, and hatching of alewife, spottail shiner, yellow perch, johnny darter, and slimy sculpin, in southeastern Lake Michigan near the D. C. Cook Nuclear Plant. Spawning periods were cited from Auer (1982); all other data were compiled during 1973-1982 studies at the Cook Plant.

eggs might be observed *in situ* followed by hatching and appearance of yolk-sac larvae in the area.

Most data presented in Figure 8 were compiled exclusively from diving observations and concurrent studies of adult and larval fish at the Cook Plant, with the exception of the literature survey. Therefore, some disparity between reported spawning periods and the timing of other events in the reproductive cycle shown in Fig 8. was expected. This occurred because the literature survey included habitats other than the Cook Plant where environmental conditions might elicit spawning at other times of the year. For example, temperature-dependent spawning of fish may occur earlier in the year in a shallow inland lake where the water warms more rapidly in spring than in Lake Michigan.

Another cause for the disparity among events depicted in Figure 8 may be that these data summarize the findings from several years of study. Some variability occurred among years in the timing of reproductive events (e.g., maturation of gonads, deposition of eggs, and hatching of larvae). Therefore, for any given year, the duration of reproductive events was probably shorter than the periods shown.

Alewife showed the most protracted period of reproductive activity among the five species. Over a 4-6-yr period, yolk-sac larvae were taken in field samples as early as April and appeared in both field and entrainment samples until the beginning of October. Occurrence of ripe adults (early May-mid-July) and observation of eggs (June-mid-August) were in close agreement in terms of the sequence of these reproductive events. The spawning period reported in the literature for alewife was longer than that suggested by adult fish studies and diving observations but agreed with the occurrence of yolk-sac larvae late in the summer. The appearance of yolk-sac larvae in field and entrainment samples during April was difficult to explain in terms of the data presented in Figure 8 but may have resulted from exceptionally early spawning by a few fish. Yolk-sac larvae were never captured in large numbers during April or early May. The period from mid-May through July appeared to encompass the bulk of alewife spawning and egg incubation in the study area. Most eggs observed during late July and August were either opaque or fungused, indicating that they were no longer viable.

Of these five fish, alewife, spottail shiner, yellow perch, johnny darter, and slimy sculpin, only alewife has pelagic eggs that are randomly broadcast during spawning; the other four species have demersal eggs that adhere to the substrate. Also, only alewife eggs were observed in areas outside the riprap zone. The eggs often accumulated and formed a thin layer in the troughs of the ripple marks at the sand-substrate reference stations north and south of the plant. Alewife eggs were commonly observed on top of the riprap and plant structures, trapped among the filaments of periphyton. Eggs were seen in about equal abundance in the riprap zone and at reference stations. No indication of area- or substrate-selective spawning was noted.

During 1973-1982 adult fish studies near the D. C. Cook Nuclear Plant, several thousand yellow perch stomachs were examined. Many were found to contain alewife eggs, thereby documenting predation by yellow perch on these eggs (unpublished data, Great Lakes Res. Div., Univ. Mich., Ann Arbor, Mich.). These studies and those of Dorr (1982) showed extensive yellow perch predation on young-of-the-year and adult alewife as well. Yellow perch predation on large larval alewives was suspected, but larvae were not found in the stomachs of yellow perch, probably because of the rapid rate at which this material was digested beyond recognition. The Cook Plant adult fish studies also documented a dramatic increase in abundance of yellow perch in the area and a concurrent decline in abundance of alewife (Tesar and Jude 1985, Jude and Tesar 1985). The recent decline in abundance of alewife in Lake Michigan probably resulted from salmonine predation. Increased abundance and predation of yellow perch on eggs, larvae, juveniles, and adult alewife combined with that from stocked salmonids may cause a possible future collapse of alewife stocks in Lake Michigan.

Spottail shiners were observed spawning on top of the south intake structure during a night dive in 1973. As the eggs were broadcast over the mat of periphyton that covered the surface of the structure, they settled into the periphyton and adhered to the algal filaments. Spawning was not observed on the riprap. On several occasions during later years, a few eggs were collected from the top of the structure and incubated in the laboratory, and the newly hatched larvae were identified as spottail shiners.

The chronology of reproductive events observed for spottail shiners in the study area (Fig. 8) closely paralleled the expected timing of events. Ripe fish were caught during mid-April-mid-July. Spawning and eggs were observed during June. Yolk-sac larvae appeared in field samples from June through mid-August and in entrainment samples from June through mid-October. The bulk of spottail shiner spawning, egg incubation, and hatching occurred during June-mid-July in the study area. The only unexplained component of the data (Fig. 8) was the observation of yolk-sac larvae in entrainment samples during September and October, one to two months after ripe fish ceased to be collected in the area. The spawning period reported in the literature for spottail shiners was in close agreement with that which would have been predicted from field study data.

Spottail shiner eggs were occasionally seen on the riprap but never at reference stations. This is probably due to the more nearshore distribution (≤3 m) of their eggs.

Maturation, spawning, egg incubation, and hatching of yellow perch in the study area was examined in detail by Dorr (1982). He documented that spawning and incubation of yellow perch eggs was limited to areas of rough (natural or artificial) substrate. Yellow perch egg masses were never observed on sand substrate during nearly 500 dives in the study area which encompassed 10 spawning seasons (Dorr and Jude 1980a,b; Dorr 1982). These findings concur with those reported in the literature and clearly establish that in southeastern Lake Michigan yellow perch spawned selectively on stable, rugose substrate. These substrates probably serve to anchor the eggs and suspend them slightly above bottom, thereby reducing settling of eggs into the substrate or transport to areas with conditions less favorable to survival, e.g., the turbulent beach zone.

In addition to the Cook Plant reef, evidence of yellow perch spawning on two other artificial reefs in eastern Lake Michigan has been compiled. Although yellow perch egg masses were never observed on the Campbell Plant reef (Rutecki et al. 1985), the high abundance of ripe fish and yolk-sac larvae in field samples and predominance of yellow perch larvae in entrainment samples (Jude et.al. 1982) suggest that perch spawned on this reef. Yellow perch eggs were usually observed in situ for no more than 2 weeks (Dorr 1982); most likely, the timing and intensity of diving on the Campbell reef was inadequate to permit observation of eggs. Biener (1982) reported aggregation and spawning of yellow perch on Hamilton Reef near Muskegon, Michigan, in 1981.

Yellow perch egg masses were also observed in areas of natural rough substrate by Dorr (1982). Masses were seen at 6-9 m on cobble substrate near Saugatuck and South Haven, Michigan, and on rugose clay substrate 3 km north of the Cook Plant and on New Buffalo shoals south of the plant. Egg masses have also been seen on clay substrate near Michigan City, Indiana (personal communication, G. McDonald, Ball State Univ., Muncie, Indiana).

Capture of ripe yellow perch during early April-early June and observation of eggs during mid-May-early June corresponded with the expected timing of these events. Occurrence of yolk-sac larvae in field and entrainment samples during mid-May-July corresponded with maturation and spawning. The occurrence of yolk-sac larvae in the study area during April and early May has been attributed to riverine input of larvae spawned in inland waters that warm to spawning temperatures earlier in the spring than inshore Lake Michigan waters (Wells 1973; Jude et al. 1979, 1981a; Dorr 1982; Perrone et al. 1983). Appearance of yolk-sac larvae in August entrainment samples may have been the result of some isolated late spawning or unusually slow maturation of larvae.

The spawning period (mid-May to mid-June) reported for yellow perch in southern Lake Michigan corresponded closely with that predicted from Cook Plant fish and underwater studies. Lake Michigan yellow perch have a short reproductive season relative to other fish species, and the bulk of spawning, incubation, and hatching occurs during a 3-4-week period from mid-May through early June in this area of the lake.

Johnny darter eggs were found on two occasions in 1977, during May and June. In May, one cluster of eggs was found attached to the underside of a fiberglass washtub and another was attached to the underside of a swim fin. Both of these objects had been lost from the dive boat during the previous month. In June, two more clusters of eggs were found attached to the underside of a flat slab of wood. The female darter often lays her eggs in several clusters each containing 20-200 eggs (Scott and Crossman 1973); the two clusters of eggs found on the wood slab may have been spawned by a single fish. The clusters were 2-3 cm in diameter and were composed of several hundred eggs packed closely together in a single layer. The eggs were collected, hatched in the laboratory, and larvae verified as johnny darters.

The concurrent appearance of ripe fish in field samples and observation of eggs during mid-May to mid-June (Fig. 8) defined a short spawning period for johnny darters in the study area. The occurrence of yolk-sac larvae in field and entrainment samples during mid-May-July was in general accord with the timing of spawning and incubation of eggs, as was the spawning period reported in the literature. But, like the other species, both early and late occurrences of yolk-sac larvae were noted. These data suggest that the bulk of johnny darter spawning, incubation, and hatching occurs from mid-May through late June in the study area.

Sculpin eggs were found on two occasions, in May of 1974 and 1978. In both instances, the eggs occurred as a flattened mass attached on the underside of a piece of riprap. These masses were similar in appearance to the johnny darter egg clusters except that both the individual sculpin eggs and size of the egg mass were larger than those of the darter. On both occasions, the collected eggs were incubated in the laboratory until the larvae hatched and were identified as slimy sculpin (Cottus cognatus).

The chronology of reproductive events documented for slimy sculpin by Cook Plant fish and diving studies was nearly perfect, in biological terms. Ripe adults were caught during April-mid-May, and eggs were observed during the first three weeks of May. Yolk-sac larvae appeared in entrainment samples from mid-May through June and in field samples during June. Larvae appeared in entrainment samples about two weeks earlier than in field samples, because sculpin spawning was concentrated in the riprap zone where field net tows were not conducted. Netting was conducted north and south of the riprap, and some time probably elapsed before the newly hatched larvae migrated from their nests in the riprap zone to surrounding areas of the lake where they were subsequently netted. The spawning period reported in the literature generally agreed with that predicted from Cook Plant data. Again, spawning reported during March-early April probably occurred in inland waters that warm to spawning temperatures more rapidly than inshore Lake Michigan. These data (Fig. 8) indicate spawning, egg incubation, and hatching of sculpins occurs during a relative brief period, with the bulk of this activity taking place during late April-late May.

Several conclusions may be drawn from the preceding discussion on reproductive activity of fish in the study area. Two general modes of spawning were noted: fish that broadcast their eggs at random without regard to substrate type and fish with substrate-specific spawning requirements. Alewife was a primary example of the first category of spawner. Its eggs were pelagic and ubiquitously distributed. Examples of the other spawning mode included spottail shiner, yellow perch, johnny darter, and slimy sculpin. Spottail shiner eggs were demersal and adhesive and were found attached to a variety of stable substrates. It appeared that while this species selects stable substrates for spawning, the composition and configuration of that substrate is not a critical factor in the selection process. Johnny darter and slimy sculpin were more selective in that eggs were laid on the flat, clean undersides of riprap and inorganic or organic debris. As in other studies in the area (Biener 1982, Dorr 1982, Rutecki et al. 1985), yellow perch were found to have rather specific substrate requirements that focused on substrate configuration and rugosity. Finally, related studies (Dorr and Jude 1981a, Dorr et al. 1981b, Jude et al. 1981b) in the area have compiled evidence that some species such as lake trout have extremely specific spawning-substrate requirements that include characteristics such as composition, configuration, rugosity, and interstitial dimensions.

With the exception of alewife and spottail shiner, spawning was concentrated in the riprap zone, and much of the reproduction of the species discussed occurred during May-June. During this period, survival and growth of these fish populations could be affected by perturbations of specific events (spawning, incubation, hatching and early survival) in their reproductive cycle. Populations of pelagic spawners such as alewife that broadcast their eggs randomly over a wide area are less likely to be affected by a point ecological impact than populations of fish which concentrate their spawning in the area of the impact. With regard to johnny darters, slimy sculpins, and to a small degree spottail shiners, an ecological trade-off exists between reproduction and plant operation. These species concentrate around and spawn on in-lake plant structures, thus increasing their vulnerability to impingement, entrainment, and physical (heat) and chemical (chlorine) discharges. But at the same time, populations of these fish have been enhanced by the creation of this artificial substrate and would not exi[st] in such abundance if the plant structure were not present.

Juvenile and Adult Fish

Twenty-two taxa encompassing 24 species of fish were observed by divers during the study and were grouped according to frequency of observation (Table 9) from data presented in Appendix 1. Frequently observed species included alewife, yellow perch, sculpins (slimy sculpin and mottled sculpin), johnny darter, and spottail shiner. All of these fish were seen at least once during each year of the study. Commonly observed species included trout-perch, common carp, rainbow smelt, burbot, and white sucker. These fish were seen during seven to nine years of the study. Uncommonly observed species included largemouth bass, lake trout, channel catfish, black bullhead, smallmouth bass, and longnose sucker. These fish were seen in more than one year but less than half of all study years. Species that were rarely observe[d] and were seen during only one year included emerald shiner, brown trout, quillback, walleye, coregonids (bloater and lake herring), and shorthead redhorse. The 10 taxa that were frequently or commonly observed composed the bulk of the observations of fish. The remaining 12 taxa were seen too infrequently to make detailed inferences based on underwater observations.

A total of 72 species of fish were identified among the 1.1 million fish collected during 1973-1982 field studies near the Cook Plant (Tesar and Jude 1985) and 5.8 million fish impinged on its traveling screens during 1975-1982 (Thurber and Jude 1985). Therefore, about one third (31%) of the species documented in the study area by Cook Plant studies were observed by divers. These observations suggest that a large number of the species that occurred in

Table 9. Annual relative ranked abundance of fish observed during all diving in southeastern Lake Michigan near the D. C. Cook Nuclear Plant, 1973-1982. Fish were grouped according to frequency of observation. Blanks indicate no observation. Common names of fish assigned according to Robins et al. (1980).

Species	No. yrs observed	Year									
		73	74	75	76	77	78	79	80	81	82
<u>Frequent</u>											
Alewife	10	2	6	1	1	1	1	1	1	1	1
Yellow perch	10	3	4	3	4	3	3	2	4	2	2
Cottus spp.[1]	10	5	1	2	2	5	4	5	5	5	4
Johnny darter	10	6	3	4	3	2	4	4	6	4	6
Spottail shiner	10	1	2	5	6	7	7	3	3	7	5
<u>Common</u>											
Trout-perch	9	4	5	6	7		8	8	8	3	7
Common carp	9		7	7	5	6	6	6	7	6	3
Rainbow smelt	8			8	8	4	2	7	2	8	7
Burbot	7		8	9	9	9		9	9		9
White sucker	7			9	10	9	10		10	9	9
<u>Uncommon</u>											
Largemouth bass	3			9		8					9
Lake trout	3		8						10	9	
Channel catfish	2		8								9
Black bullhead	2		8						10		
Smallmouth bass	2			9	10						
Longnose sucker	2						9	10			
<u>Rare</u>											
Emerald shiner	1		8								
Brown trout	1								10		
Quillback	1							10			
Walleye	1						10				
Coregonus spp.[2]	1										9
Shorthead redhorse	1										9
Total taxa		6	12	12	11	10	11	11	13	10	14

[1] Includes both *C. cognatus* (slimy sculpin) and *C. bairdi* (mottled sculpin).

[2] Includes both *C. artedii* (cisco or lake herring) and *C. hoyi* (bloater).

the area were rare and that diver observations of fish were limited to the more abundant species. The 5 fish taxa most frequently observed by divers were also among the 10 fish taxa most frequently collected in field and impingement samples.

Total number of fish taxa observed each year varied from 6 to 14 (Table 9). If 1973 data are ignored (both the diving methodology and schedule were incomplete that year), numbers of fish taxa observed ranged from 10 to 14, annually. Considering that 11 taxa were seen at least 7 out of 10 years, and 5 taxa were seen every year, the diversity of species regularly observed by divers was low in comparison with total number of species occurring in the area. However, the most abundant species in field and impingement samples were nearly always observed by the divers. These observations suggest that diving is effective for documenting the presence of abundant species but ineffective for studying rare species.

Fish species observed by divers could be divided into two categories based on their behavior and response to the presence of the Cook Plant. The first category described orientation of fish in the water column - pelagic or demersal. The second category was related to the response of fish to the physical presence or aspects of plant operation - attracted or indifferent (species repelled by the plant were not discerned by this study) (see Tesar and Jude 1985). Four combinations of these behavior-response categories were represented in the observational data base: pelagic fish that were attracted to the plant (pelagic-attracted), pelagic fish that were indifferent to the plant (pelagic-indifferent), demersal fish that were attracted to the plant (demersal-attracted), and demersal fish that were indifferent to the plant (demersal-indifferent).

Pelagic fish that appeared to be attracted to the in-lake structures or operation of the plant included yellow perch and common carp and possibly largemouth bass, smallmouth bass, and walleye. Pelagic species that appeared generally indifferent to the in-lake presence or operation of the plant included alewife, spottail shiner, trout-perch, rainbow smelt, lake trout, emerald shiner, brown trout, and coregonids. Demersal fish that appeared to be attracted to the in-lake presence or operation of the plant included sculpins, burbot, channel catfish, and black bullhead. Demersal fish that appeared indifferent to the in-lake presence or operation of the plant included johnny darter, white sucker, longnose sucker, quillback, and shorthead redhorse.

Inspection of relative ranked abundance of fish within and among years revealed that in most years alewife was most abundant. Yellow perch always attained one of the next three ranks (second-fourth). Alewife, yellow perch, johnny darter, spottail shiner, and sculpins always comprised at least four of the top five ranks each year.

Relative ranked abundance of fish species observed during transect swims along the base of the south intake structure (Table 10) generally paralleled that established for total dives (Table 9). Total number of fish species observed each year ranged from five to nine. Number of species observed during transect dives was always less than the total number observed for any given year, primarily because the observational effort for transect swims was much less than for total dives. However, during transect swims, observations were focused on the bottom and did not extend above bottom beyond the range of visibility, which was usually between 2 and 3 m (Table 4). Consequently, a slightly higher percentage (44%) of those species classified as demersal was

Table 10. Annual relative ranked abundance of fish observed during duplicate observations made during transect swims in southeastern Lake Michigan, 1975-1982. Observations were made by two divers swimming side-by-side for 10 m along the base of the south intake structure of the D. C. Cook Nuclear Plant. Each diver examined an area 1 m wide; observations were summed and then ranked for the total area (20 m^2) examined. Fish were grouped according to frequency of observation. Blanks indicate no observation. Common names of fish assigned according to Robins et al. (1980).

Species	No. yrs observed	Year							
		75	76	77	78	79	80	81	82
<u>Frequent</u>									
Alewife	8	1	1	1	1	1	4	6	2
Yellow perch	8	3	4	4	2	2	3	4	1
<u>Cottus</u> spp.[1]	8	2	2	3	5	3	2	1	3
<u>Common</u>									
Johnny darter	7	4	3	2	3	5	6	3	
Spottail shiner	7	5	5		4	4	5	4	4
Rainbow smelt	5		6	5	6		1	2	
Trout-perch	4		8			6	7	7	
<u>Uncommon</u>									
Burbot	3		6			6	7		
<u>Rare</u>									
Black bullhead	1						7		
Total taxa		5	8	5	6	7	9	7	4

[1] Includes both <u>C</u>. <u>cognatus</u> (slimy sculpin) and <u>C</u>. <u>bairdi</u> (mottled sculpin).

seen than of those classified as pelagic (38%). Of those species frequently or commonly observed during the total diving effort, only burbot and white sucker did not appear in these same observational frequency categories during transect dives. These two species were not abundant and never attained a rank higher than ninth in total dives conducted after 1974.

As with total dives, alewife was the most frequently observed fish species during transect dives. Sculpins displaced yellow perch as the second-most abundant fish species observed during transect swims. This was not unexpected considering the generally high abundance and demersal behavior of sculpin. Yellow perch was generally the third-most abundant species seen during transect swims. Johnny darter and spottail shiner occupied a lower frequency category for transect dives than for total dives. However, the significance of this shift was relatively inconsequential considering the overall abundance of these two species in the study area. No pelagic species classified as uncommon or rare among total diving observations (Table 9) were observed during transect swims (Table 10).

In addition to total diving observations (summarized from Appendix 1) and transect observations (summarized from Appendix 2), summary data are presented from standard series field sampling (Tesar and Jude 1985) and studies on impingement of fish on the Cook Plant traveling screens (Thurber and Jude 1984, 1985) for 10 species of fish: yellow perch, common carp, alewife, spottail shiner, trout-perch, rainbow smelt, sculpins, burbot, johnny darter, and white sucker. The remaining 12 species of fish observed during underwater studies at the Cook plant were seen too infrequently to permit meaningful analyses based on observational data. Species discussions are grouped according to the four behavioral categories noted earlier: pelagic-attracted, pelagic-indifferent, demersal-attracted, and demersal-indifferent.

Pelagic-Attracted --

The species complex of diver-observed pelagic fish that appeared to be attracted to the in-lake structures or plant operation included yellow perch, common carp, and possibly largemouth bass, smallmouth bass, and walleye. Sufficient evidence (Tables 9, 10) was compiled during the study to infer the attraction of yellow perch and common carp to the plant. The attraction of the other three species to the plant was hypothesized more from general knowledge of the species and their habits than from empirical data.

Yellow perch was usually the second- or third-most abundant species observed during all dives and transect swims and was never lower than fourth (Fig. 9). It was also among the five most abundant species in field and impingement samples. During 1973-1977, the relative ranked abundance of yellow perch fluctuated among the four sampling categories. A distinct decline in abundance occurred in field and impingement samples between 1977 and 1978 and was followed by a steady increase in relative abundance. Although this pattern was not reflected in diving observations, yellow perch were frequently observed during 1978-1982 underwater studies.

The disparity in trends of relative ranked abundance between field and impingement sampling and all dives and transect swims may be explained by the documented affinity that yellow perch have for rough substrate in the generally smooth, sandy-bottom areas of inshore eastern Lake Michigan (Dorr 1982, Rutecki et al. 1985). The attraction of yellow perch to the riprap zone, established through underwater observations, elevated their local

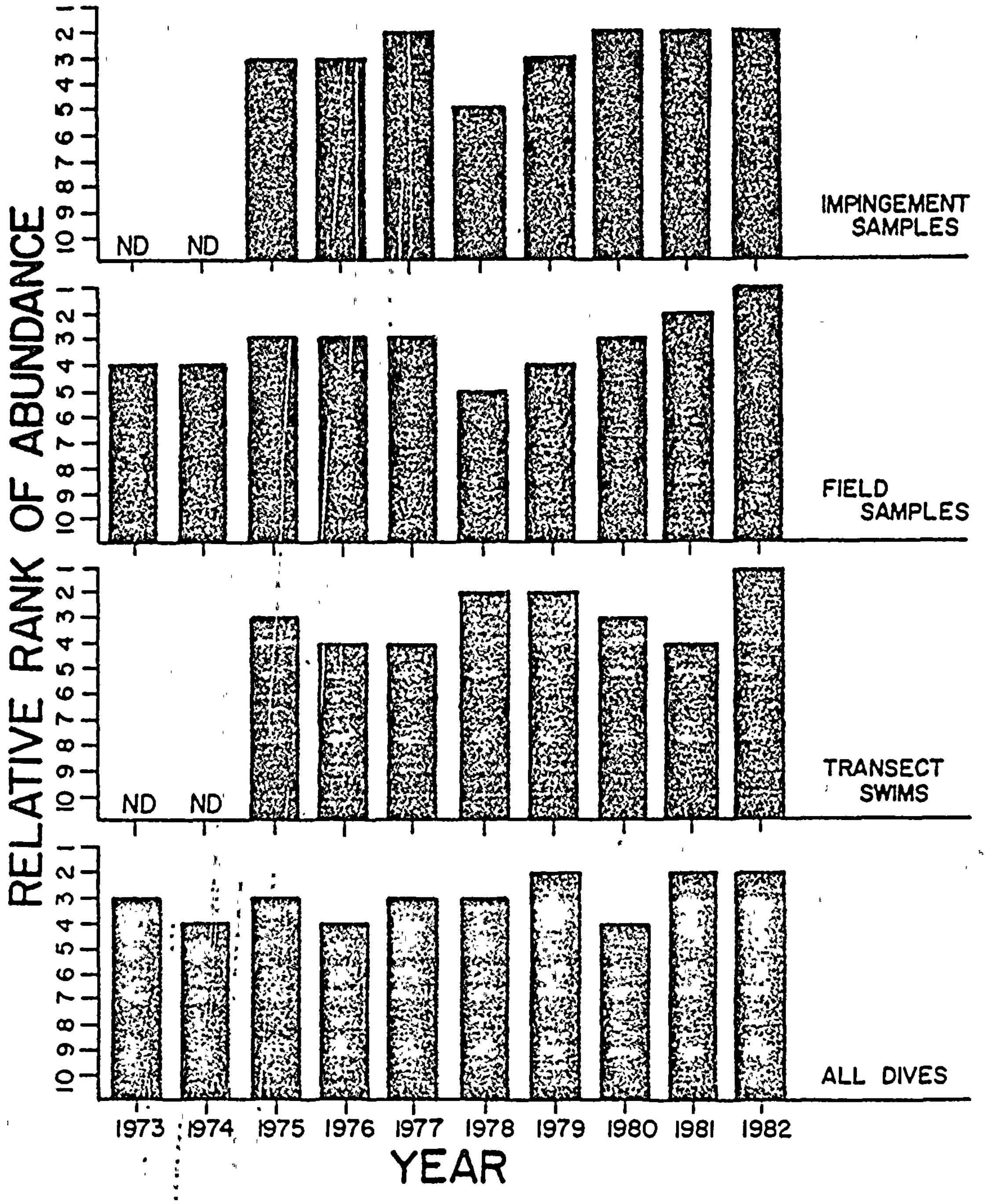

Fig. 9. Comparison of relative ranked abundance of yellow perch observed by divers during all dives (1973-1982) and transect swims (1975-1982), collected in standard series field samples (1973-1982), and impinged (1975-1982) at the D. C. Cook Nuclear Plant, southeastern Lake Michigan. Ordinate scale is inverted and extends from lowest to highest rank of relative abundance. Blanks indicate zero observations or catch; ND = no diving or sampling.

abundance in comparison with field sampling, which was conducted only in areas of sand substrate (Fig. 9). The parallel in ranked abundance of yellow perch in impingement samples with that of field samples suggests that rate of impingement was related more closely to their general field abundance than their attraction to the riprap zone.

Most yellow perch observed by divers were adults; juveniles were seldom seen, although they were abundant in field and impingement samples. A distinct pattern in the temporal distribution of yellow perch was noted. Adult fish moved inshore into the study area during April. This movement appeared to be more closely related to inshore spawning than initial feeding, because most fish did not eat until spawning was completed (Dorr 1982). Spawning occurred in the study area during late May, and yellow perch remained concentrated in the riprap zone throughout the summer. Feeding commenced shortly after spawning was completed. During fall, yellow perch moved offshore and were seldom seen by divers during October dives. Largest numbers of adult fish were collected in field samples during May-August. Young-of-the-year were collected in trawl and seine hauls during late summer and fall and in impingement samples during fall and winter.

At least two patterns in the spatial distribution of yellow perch were discerned by this and related studies. The first pattern was the seasonal inshore migration of adults in spring and an offshore migration during fall. These movements were documented by underwater observations, field studies (Tesar and Jude 1985), and impingement studies at the Cook Plant (Thurber and Jude 1984, 1985). Juvenile yellow perch inhabited the inshore area throughout fall and winter, as evidenced by their impingement at the Cook Plant during these months. The second pattern in spatial distribution was the concentration of adult fish in areas of rough substrate. As water temperatures increased in spring, adult fish moved inshore and onto natural and artificial reefs present in the area. Although Dorr (1982) compiled some evidence that limited movement off the reefs occurred after spawning, the bulk of the fish appeared to remain close to areas of rough substrate. Yellow perch were never observed at smooth-bottomed reference stations; however, they were commonly collected there during summer months in trawls and gill nets (Tesar and Jude 1985).

Adult yellow perch were distinctly day-active and at night rested on the bottom, often in crevices formed by the riprap. As further evidence of yellow perch nocturnal inactivity, divers were able to grasp fish at night. During the day, fish on several occasions were fed crayfish by divers. Fish formed loose schools composed of various sizes of fish with a length range often exceeding 100 mm. Random swimming or "milling" was typical; closely coordinated group movements were not observed. Both solitary fish and schools remained within 1-3 m of the bottom or the plant structures.

Common carp was the sixth or seventh most commonly observed fish in the study area; they were seen during all years except 1973. Field sampling and impingement of common carp at the plant suggested that the overall abundance of this species in the study area was relatively constant during the study period (Fig. 10). However, several patterns and changes in the temporal and spatial distribution of common carp were evidenced by underwater observations and other studies of adult and larval fish.

Diving observations documented a distinct increase in abundance of these fish near the plant following the start-up of warm-water discharge. This local increase was paralleled in field study catches (Tesar and Jude 1985). Of

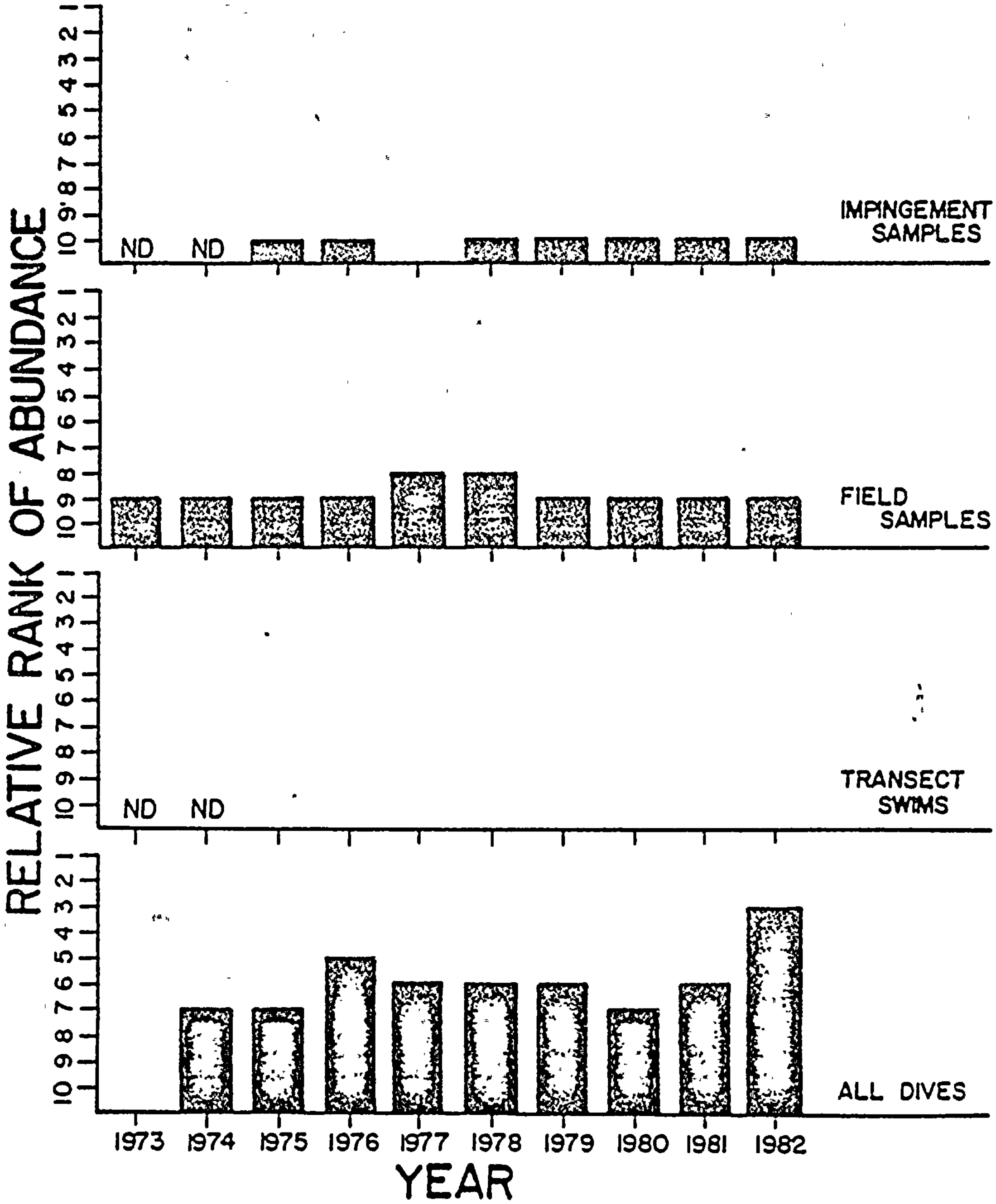

Fig. 10. Comparison of relative ranked abundance of common carp observed by divers during all dives (1973-1982) and transect swims (1975-1982), collected in standard series field samples (1973-1982), and impinged (1975-1982) at the D. C. Cook Nuclear Plant, southeastern Lake Michigan. Ordinate scale is inverted and extends from lowest to highest rank of relative abundance. Blanks indicate zero observations or catch; ND = no diving or sampling.

the more than 460 common carp observed during the study, none was seen in 1973, and only two were seen in 1974, preoperational years. Nine fish were seen in 1975. From 1976 to 1982, numbers of fish observed annually varied from 14 to more than 200 (Appendix 1) and averaged about 40. Larval common carp were never collected in preoperational years 1973-1974 at the Cook Plant but were collected and entrained at the plant during its first operational year (1975) and in most later years of the study (Noguchi et al. 1985). Larval common carp were not collected during 1973-1979 at reference stations located 7 km south of the Cook Plant near Warren Dunes State Park, but a few larvae were taken at these reference stations during the last years of the study. Bimber et al. (1984) attributed this uneven distribution of larval common carp to spawning in the warm-water plume of the plant. Although common carp were attracted to the plant, annual impingement was low and ranged from zero to 34 fish between 1975 and 1982 (Thurber and Jude 1985). This suggests that the fish were not particularly susceptible to entrapment at the intake structures, probably because they concentrated near the discharge area.

Further evidence of attraction of common carp to the warm-water plume was that of the more than 460 fish observed by divers, only 12 were seen at the intakes and none was seen at reference stations. All other observations were made in the vicinity of the discharge stations. On several occasions during late spring and summer, divers in boats and on shore observed schools of common carp swimming in the vicinity of the discharge structures; none was seen in the vicinity of the intake structures.

Divers observed common carp in greatest abundance during the period May-August. Most fish taken in field samples were collected during the same period. However, the impingement of common carp did not show any temporal pattern, probably because their susceptibility was low even when they were abundant in the vicinity of the discharge.

Common carp were day-active and seldom seen at night. The few fish that were observed during night dives were on the bottom, solitary, and inactive. Most often, common carp were seen in groups rather than individually. Most diver-observed fish were swimming randomly in the vicinity of the discharge structures. They often approached the divers closely and on several occasions swam into the divers. As noted earlier, their feces were often abundant at the closest reference station north of the discharges (north reference station I - Fig. 1) but were rarely seen at other diving stations.

Largemouth bass, smallmouth bass, and walleye were seen three times, twice, and once, respectively, during the study (Table 9) and never during transect swims (Table 10) or at reference stations. In all instances, the fish were seen in close proximity to the intake or discharge structures. It is believed that these fish were attracted to the structures and not just the surrounding rough substrate, perhaps because of the elevated profile that the structures presented. All fish were seen during the warm-water months (May-September) and during the day. Only solitary fish were observed.

Pelagic-Indifferent --

The species complex of diver-observed pelagic fish indifferent to the in-lake structures or plant operation included alewife, spottail shiner, trout-perch, rainbow smelt, lake trout, emerald shiner, brown trout, and unidentified coregonids (bloater or lake herring). Sufficient observational data were compiled on the first four species to permit meaningful discussion and inferences. The remaining fish species were seen infrequently and little can be concluded based on these sightings.

Alewife was generally the most abundant species observed and collected in the study area. Comparison of summary data (Fig. 11) revealed few fluctuations in annual relative ranked abundance within each of the four data categories. Field sampling data and other evidence indicated that the abundance of alewife in the study area declined during 1980-1982 relative to previous years (Jude and Tesar 1985). This decline was paralleled by transect swim data where annual observational effort was standardized. The decline was not reflected in data compiled from all dives. It is possible that the small annual variation in total diving effort that occurred during 1975-82 may have obscured this decline, although more dives were conducted annually during 1975-1979 (17-19 dives yearly) than during 1980-1982 (15-17 dives yearly). Another explanation may be that large schools of alewives were rarely encountered during transect swims; whereas, they were frequently encountered during non-transect diving. Also, estimation of these large schools of fish (often containing more than 1,000 individuals) may have smoothed and obscured yearly variations in abundance. Nonetheless, alewife were the most abundant and ubiquitously distributed fish in the study area.

No patterns or trends were observed in the spatial distribution of alewife during the underwater study. Individual and schooling fish were observed at both riprap and reference stations.

A distinct temporal pattern was noted in the abundance of alewife. Alewife were rarely observed during April but were usually seen in great abundance during May-June, and the impingement of alewives usually peaked during the same period. Adult fish were collected in field samples in

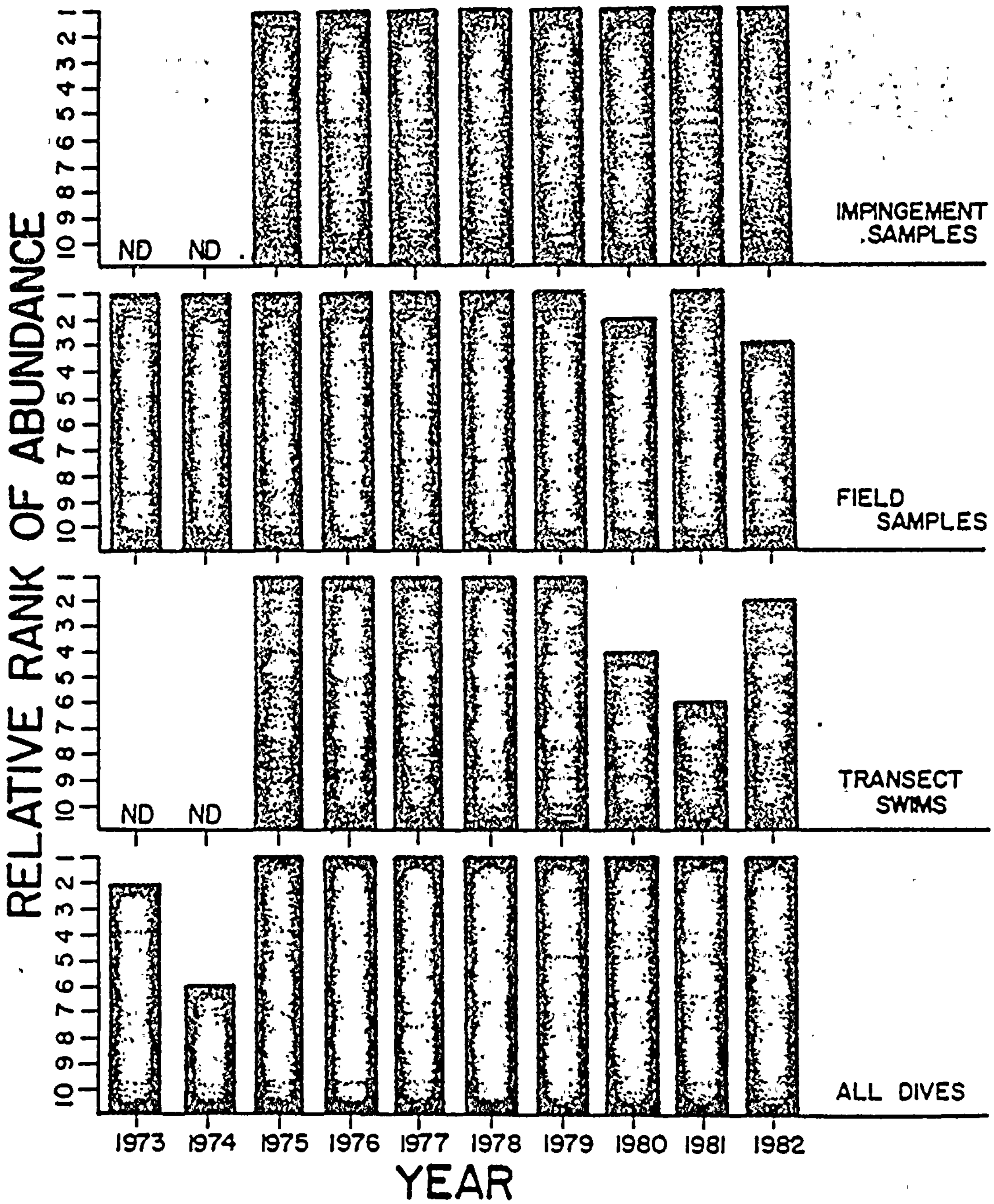

Fig. 11. Comparison of relative ranked abundance of alewives observed by divers during all dives (1973-1982) and transect swims (1975-1982), collected in standard series field samples (1973-1982), and impinged (1975-1982) at the D. C. Cook Nuclear Plant, southeastern Lake Michigan. Ordinate scale is inverted and extends from lowest to highest rank of relative abundance. Blanks indicate zero observations or catch; ND = no diving or sampling.

greatest abundance during the same period. The abundance of alewife in the study area during this period corresponded with their spring migration from offshore areas of the lake to the more rapidly warming inshore waters where they subsequently spawned during late May-August. Adult fish continued to be observed throughout the summer, although numbers of fish observed were reduced from peak levels that occurred during May-June. Numbers of adult fish seen during October were always low and corresponded with the fall migration of fish to offshore areas.

Young-of-the-year (YOY) alewives were usually first observed by divers during August or September and large schools were often seen during September-October. This fall pattern was paralleled by an increase in impingement of YOY alewives, which by this time were large enough (>50 mm) to be retained by the traveling screens (Thurber and Jude 1984, 1985). Young-of-the-year fish were often seined in great abundance during August-September.

When observed, schools of both adult and YOY alewives were distributed throughout the water column. Schooling of adult fish was observed only during the day. Movements of individual fish were rarely coordinated into simultaneous group movements and considerable "milling" of fish occurred. Solitary fish were commonly seen. At night, fish often occurred in groups or clustered at various locations around the intake structure. Although the fish were active at night, swimming appeared undirected, and fish could often be approached closely or touched by divers. Schools of YOY alewife were only observed at night and were closer to the surface than the bottom. On several occasions, adult fish were observed to group near the intake structure and face into the oncoming current. Some individuals made snapping or sucking (not coughing) movements with their mouth and may have been ingesting zooplankton in the water.

Spottail shiner was included among the group of frequently observed species; they were seen during all years of the study. It was also included among the five most-abundant species in field and impingement samples. The relative ranked abundance of spottail shiners in impingement catches fluctuated somewhat among years but remained nearly constant for field samples (Fig. 12). A nearly constant level of relative abundance was also reflected in transect-swim data. Pooled observations from all dives suggested that the relative abundance of spottail shiners declined during the late 1970s, but this decline was not reflected among the other three data bases. Therefore, it was concluded that the relative ranked abundance of spottail shiners remained relatively unchanged during the study.

Spottail shiners were not observed at reference stations, but field and impingement studies did not indicate any notable differences in spatial distribution. However, diving was more extensive in the riprap area and the small size of the fish made them difficult to see off bottom, particularly when visibility was low. No other evidence of substrate-selective behavior or attraction to plant structures or operation was compiled during the underwater studies.

A distinct temporal pattern was noted in the seasonal distribution of spottail shiners as observed by divers. Fish were rarely seen in the study area in April and October and were most often observed during June-August. A similar pattern of seasonal abundance was reflected in field catches of spottail shiner (Tesar and Jude 1985). This temporal pattern of abundance resulted from movement of fish into the inshore area of the lake during June-

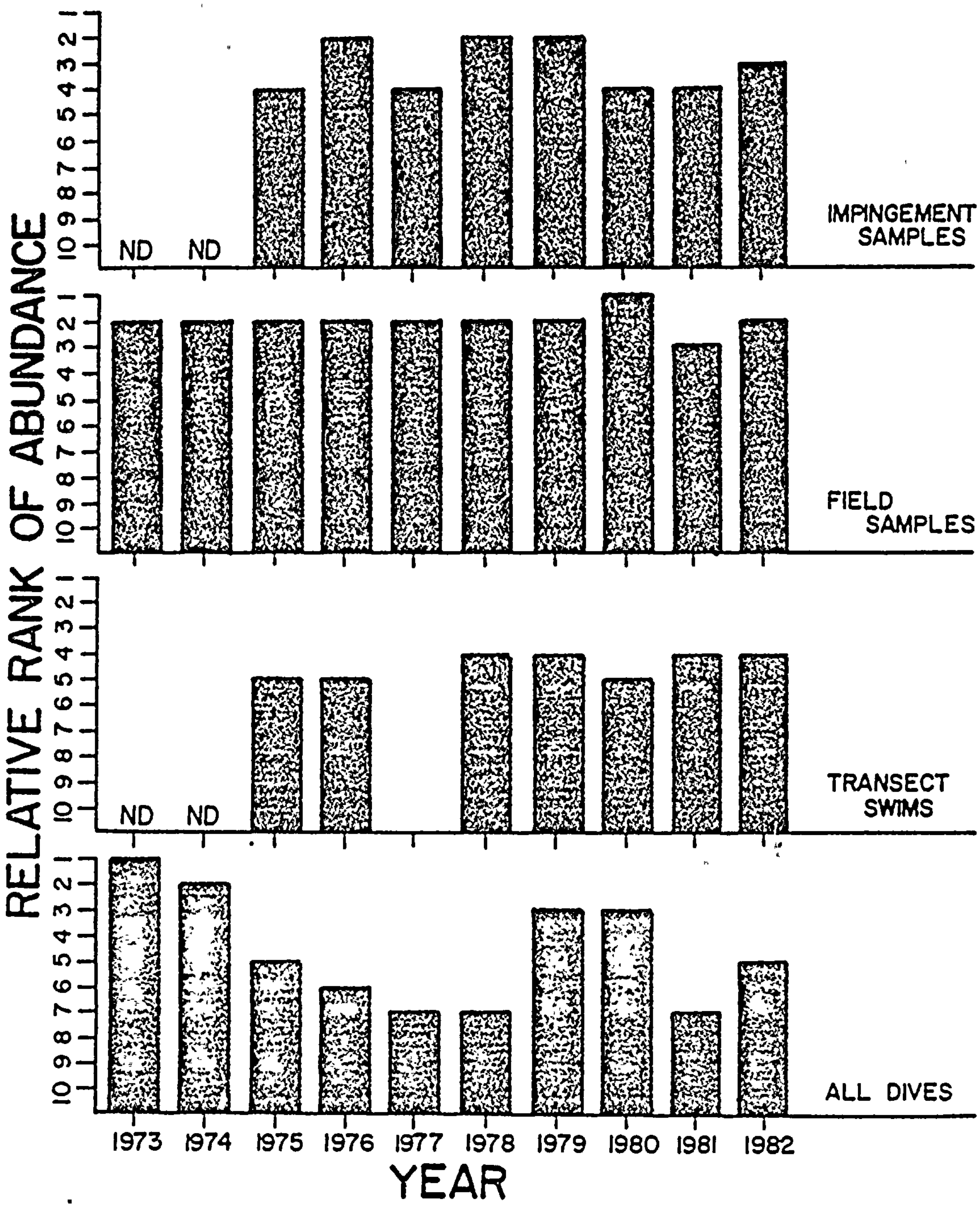

Fig. 12. Comparison of relative ranked abundance of spottail shiners observed by divers during all dives (1973-1982) and transect swims (1975-1982), collected in standard series field samples (1973-1982), and impinged (1975-1982) at the D. C. Cook Nuclear Plant, southeastern Lake Michigan. Ordinate scale is inverted and extends from lowest to highest rank of relative abundance. Blanks indicate zero observations or catch; ND = no diving or sampling.

August when spawning and feeding occurred. During fall, fish moved offshore. Although peak impingement of spottail shiners usually occurred during May-August, fish were often impinged in large numbers throughout the year. The relatively high impingement of fish during periods of low field abundance may have resulted from their seeking shelter near the structures during fall and winter storms or from their general disorientation and increased susceptibility to entrapment during these periods of severe inshore turbulence.

Spottail shiners were more commonly observed at night than during the day, but this was believed to be more the result of increased vulnerability to approach and observation at night because of reduced light than to actual increases in nocturnal activity. This belief was based on the observed similarity between daytime and nighttime behavior, including levels of activity and alertness.

Most spottail shiners seen by divers were adults; juveniles and YOY fish were rarely observed. Although schooling probably occurs for this species (Nursall 1973), it was not observed by divers. No differences in diel activity were noted. Fish were seen throughout the water column and did not appear attracted to the structures or riprap.

During a 1973 night dive on the south intake structure, several thousand spottail shiners were observed, some of which were seen to broadcast their eggs over the periphyton growing on top of the structure. Spawning was not observed in subsequent years, but spottail shiners were usually seen in considerable abundance during June night dives in the vicinity of the structures. The fish are abundant and widely distributed in Lake Michigan, and no evidence supporting substrate-selective spawning was compiled during this study. Spottail shiner eggs are demersal, adhesive, and probably randomly broadcast without regard to substrate configuration or composition. Most spawning occurs in the <3 m depth zone (Tesar and Jude 1985, Noguchi et al. 1985).

Trout-perch were seen during 9 of the 10 study years (Table 9) but usually not in great abundance, i.e., more than 60 fish during any set of monthly dives (Appendix 1). Trout-perch were never seen in abundance during transect swims along the base of the south intake structure (Table 10). This was attributed to their tendency to remain off-bottom during the day, which encompassed half of the transect diving effort. The relative ranked abundance of trout-perch remained similar among years for impingement and field samples and transect swims (Fig. 13). A decline in relative ranked abundance occurred in data summarized from all dives, but this decline was not reflected in the other three data sets.

Although trout-perch were never seen at reference stations, no evidence was compiled during field sampling and impingement studies to suggest that they were attracted to the plant structures or riprap or by plant operation. A seasonal pattern was evident in the temporal distribution of the fish. Generally, trout-perch were seen most frequently during May-August; sightings during other months were rare. Both field and impingement catches of trout-perch were largest during May-September and small during the winter. No pattern was noted in the diel distribution of fish as observed by divers.

All fish observed were solitary. During the day, trout-perch were alert and active and were difficult to approach. At night, most fish were seen within 1-2 m of the bottom, and although they were active, swimming was

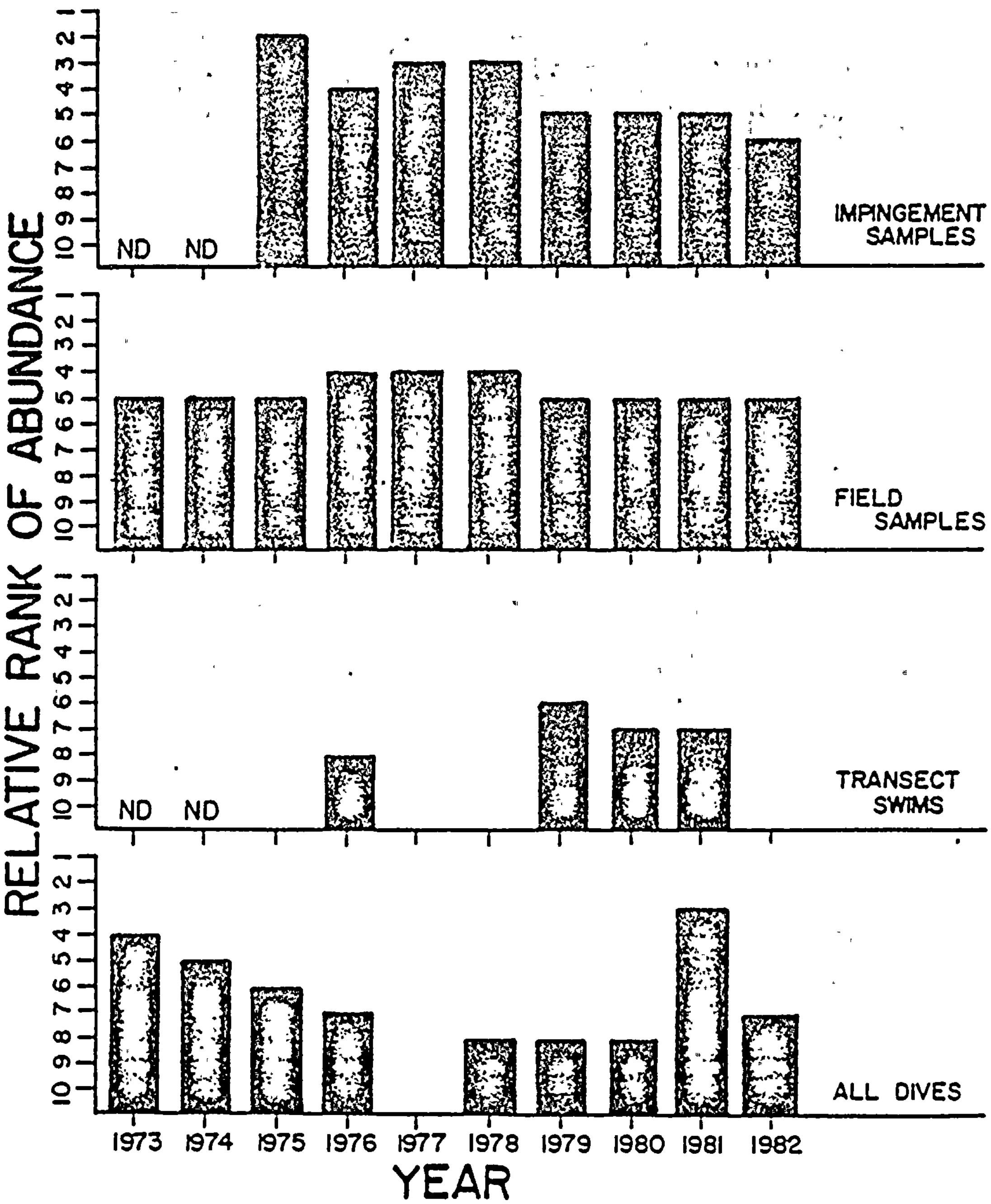

Fig. 13. Comparison of relative ranked abundance of trout-perch observed by divers during all dives (1973-1982) and transect swims (1975-1982), collected in standard series field samples (1973-1982), and impinged (1975-1982) at the D. C. Cook Nuclear Plant, southeastern Lake Michigan. Ordinate scale is inverted and extends from lowest to highest rank of relative abundance. Blanks indicate zero observations or catch; ND = no diving or sampling.

undirected and sporadic, and the fish appeared disoriented and often darted against the bottom when approached.

Rainbow smelt were seen during 8 of the 10 study years. Adult fish were never seen in abundance although schools of YOY fish were occasionally observed during September and October. The relative ranked abundance of rainbow smelt remained similar among years for field samples but varied among impingement samples, transect swims, and overall diving observations (Fig. 14).

A pronounced seasonal pattern was noted in the temporal distribution of rainbow smelt. Fish were most commonly collected in field and impingement samples during the early spring when the fish moved inshore to spawn and during fall after the lake water cooled. Exceptions to this pattern occurred during summer when upwellings brought fish associated with offshore cold-water masses into the study area. Much of the variability among years for diving observations was attributed to the sporadic occurrence of upwellings inshore during summer months and the association of rainbow smelt with these masses of cold water. Rainbow smelt were not observed at reference stations, but no pattern or differences in spatial abundance of fish were established during the underwater studies. Quite likely, fish avoided the warm-water discharge area and plume, but this was undoubtedly a local effect and had negligible impact on the overall inshore distribution or abundance of rainbow smelt.

Adult fish were seen more often at night than during the day. Fish were solitary, active, and alert. They were usually seen off-bottom and did not exhibit any affinity for the structures or riprap. Schooling was not observed for adult fish, but small schools of YOY fish were seen during some night dives in September and October.

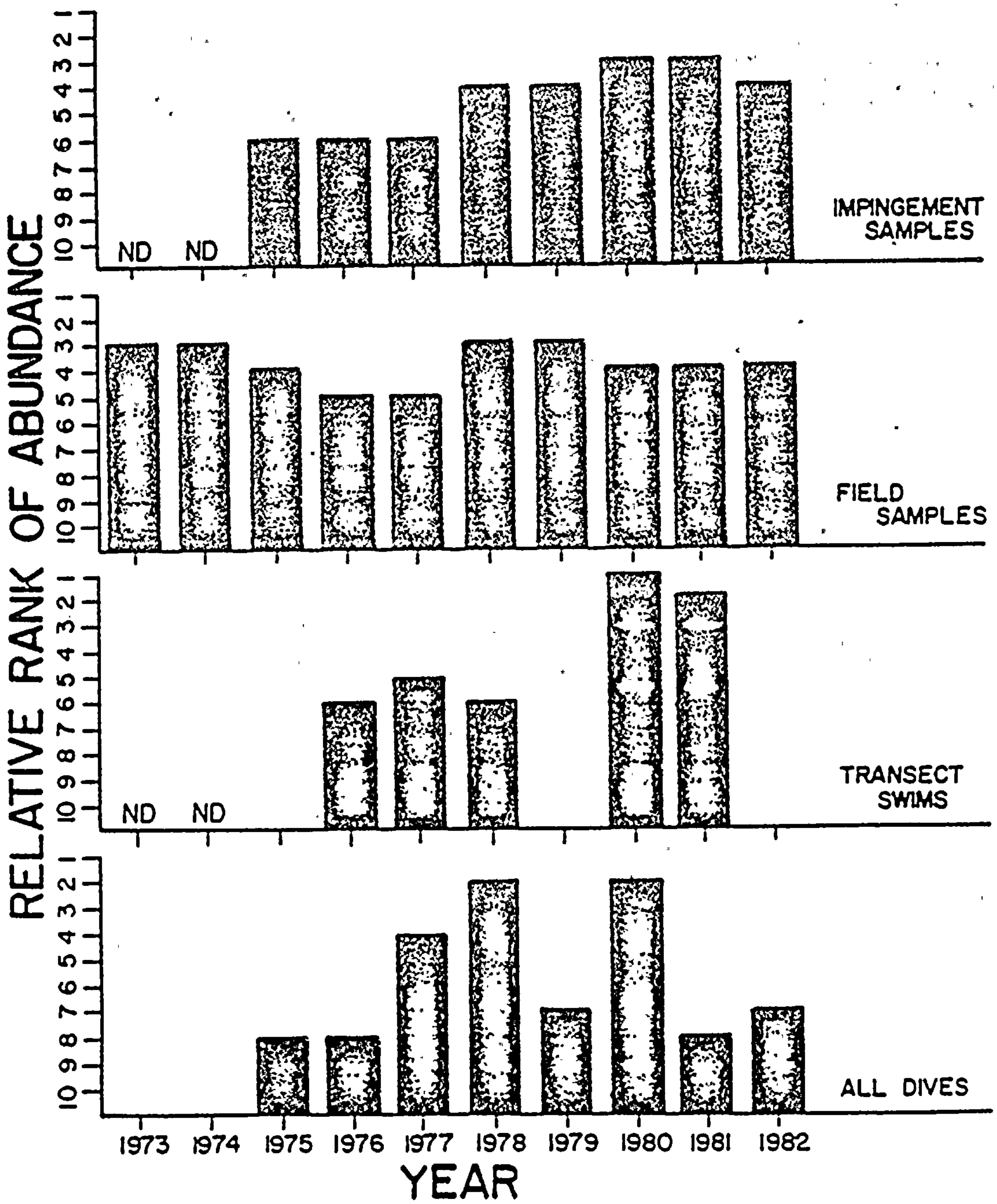

Fig. 14. Comparison of relative ranked abundance of rainbow smelt observed by divers during all dives (1973-1982) and transect swims (1975-1982), collected in standard series field samples (1973-1982), and impinged (1975-1982) at the D. C. Cook Nuclear Plant, southeastern Lake Michigan. Ordinate scale is inverted and extends from lowest to highest rank of relative abundance. Blanks indicate zero observations or catch; ND = no diving or sampling.

Lake trout were seen during three of the study years, and emerald shiner, brown trout, and unidentified coregonids (bloaters or lake herring) were seen during one year. Brown trout, emerald shiner, and unidentified coregonids were seen too infrequently to permit meaningful inferences regarding these fish. However, no evidence was compiled during the underwater studies which indicated that any of these four species of fish were attracted or repelled by presence of in-lake structures or riprap or by operation of the plant.

In a separate study, lake trout were seen in abundance in the Cook Plant intake area and at 6 m in an area of rough clay substrate 5 km north of the Cook Plant off the Grand Mere Lakes during night dives conducted on 14 November 1977. The fish were active, alert, and occurred in groups, but spawning was not observed. The substrate was examined closely, but no eggs were found (unpublished data, Great Lakes Research Division, University of Michigan, Ann Arbor, Michigan). The only other observations of lake trout were incidental sightings of solitary fish made primarily at night. During 9-10 November 1975, an intense storm passed through the Great Lakes region, and thousands of windrowed lake trout eggs were observed along the beach at the Cook Plant (personal communication, J. Barnes, Indiana & Michigan Power Company, Bridgman, Mich.) as well as near Charlevoix, Michigan (personal communication, T. Stauffer, Marquette Fisheries Research Station, Marquette, Michigan). However, lake trout eggs were never observed by divers or taken in entrainment samples pumped from the plant forebay. On a few occasions, salmonid eggs were found in the stomachs of slimy sculpins impinged at the Cook Plant, but the species and location where the eggs were spawned and eaten were not established. During 10 years of study, no evidence was compiled to suggest that lake trout spawned on the Cook Plant riprap.

Demersal-Attracted --

The species complex of diver-observed demersal fish that appeared to be attracted to the in-lake structures or plant operation included sculpin (Cottus cognatus or C. bairdi), burbot, channel catfish, and black bullhead. We believe sculpins and burbot were attracted to the plant area. The attraction of channel catfish and black bullhead to the plant area was hypothesized more from general knowledge of the species and their habits than from empirical data.

Three species of sculpin were found in field and impingement samples collected in the study area: Cottus cognatus or slimy sculpin, C. bairdi or mottled sculpin, and Myoxocephalus thompsoni or deepwater sculpin. Deepwater sculpins were rarely collected and are excluded from this discussion. Both slimy sculpins and mottled sculpins were identified in field and impingement catches made in the study area (Tesar and Jude 1985; Thurber and Jude 1984, 1985). There was some evidence that mottled sculpin were more abundant inshore during summer than slimy sculpin. However, it was not possible for divers to distinguish between the two species; therefore, they are treated as a single group and referred to collectively as sculpins.

Sculpins were seen during every year of the study for both total standard series dives (Table 9) and transect swims along the base of the south intake structure (Table 10). Overall, it ranked as the fourth- or fifth-most abundant fish species seen by divers during the study. Comparison of the relative ranked abundance of sculpins observed during all dives and transect swims with their ranked abundance in impingement and field samples indicated the attraction of this fish to the plant area (Fig. 15). Sculpins ranked as only the sixth- to ninth-most abundant fish in field samples that were

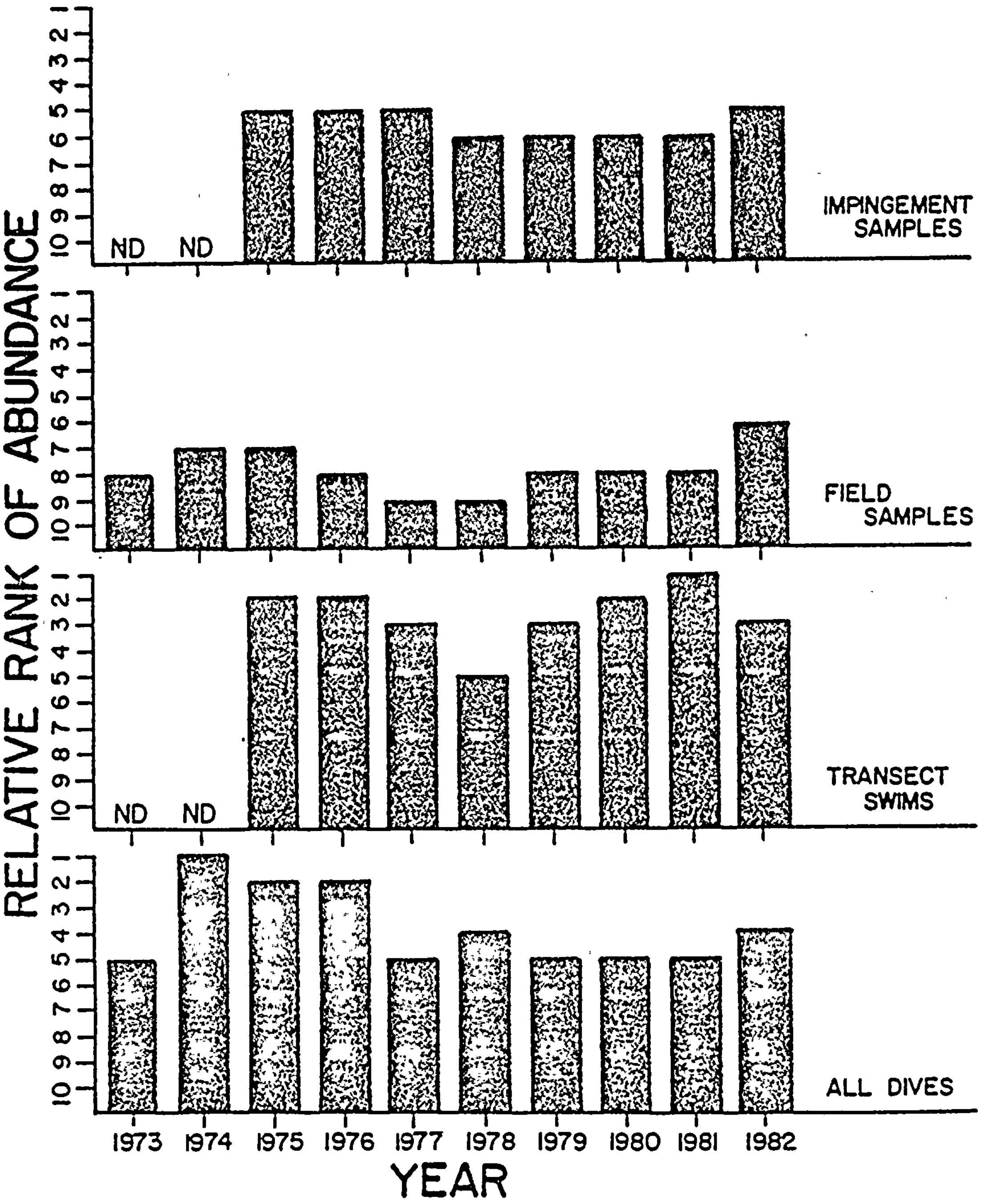

Fig. 15. Comparison of relative ranked abundance of slimy sculpins (*Cottus cognatus* or *C. bairdi*) observed by divers during all dives (1973-1982) and transect swims (1975-1982), collected in standard series field samples (1973-1982), and impinged (1975-1982) at the D. C. Cook Nuclear Plant, southeastern Lake Michigan. Ordinate scale is inverted and extends from lowest to highest rank of relative abundance. Blanks indicate zero observations or catch; ND = no diving or sampling.

collected exclusively in sand-bottom areas. But in impingement samples, they ranked as the fifth to sixth most abundant species and were always among the first five most abundant species in transect and total diving observations. Sculpins are cryptozoic in their behavior which is reflected in their preference for rugose substrate (Scott and Crossman 1973). The interstices among the riprap provided ideal shelter and habitat for these fish. Sculpins were probably attracted to the riprap and the protection it afforded rather than to any specific factor associated with plant operation (e.g., circulation, heated-water discharge, turbulence, suspension of sediments and locally elevated turbidity, etc.)

Evaluation of the temporal abundance of sculpins as reflected in their relative abundance among years showed that a decline occurred during 1976-1977, which was followed by a gradual recovery during 1978-1982 (Fig. 15). This decline and recovery was noted in both field and impingement collections as well as in diver observations of sculpins. No explanation can be offered for these changes in annual abundance. Of all fish observed by divers, sculpins were the most evenly distributed throughout the observational period (April-October). Unlike most other fish, sculpins were frequently observed in the study area during April-May and September-October. Although sculpins were impinged during most months, numbers of fish taken during April-May usually peaked at levels 10-fold higher than during other months (Thurber and Jude 1984, 1985). This was probably related to higher levels of activity and movement associated with spawning in riprap areas surrounding the intakes and subsequently, increased vulnerability to impingement. Elsewhere in the area, sculpins were found to move shoreward in early spring to spawn but generally avoided the warm inshore waters during summer (Tesar and Jude 1985).

Comparison of diving observations and impingement catches with the field distribution of sculpins underlines the attraction and concentration of fish in the riprap zone during periods (summer) when the overall abundance in the inshore area was low.

The uneven spatial distribution of sculpins reflects their preference for rough substrate and their attraction to the riprap. Sculpins were rarely observed in sand-bottom areas surrounding the riprap, although small numbers of fish were trawled and seined from these areas (Tesar and Jude 1985). Sculpins were also observed during other underwater studies in areas of natural rough substrate north and south of the Cook Plant (unpublished data, Great Lakes Research Division, Univ. Mich., Ann Arbor, Mich.).

All sculpins observed by divers were solitary. Most fish were adults, but juveniles were occasionally seen during late summer. Sculpins showed a distinctly nocturnal activity pattern which was reflected in the large number of fish observed during night transect swims (Appendix 2). During the day, fish remained hidden below the top layer of riprap and were less frequently observed. At night, they moved onto the upper surfaces of the stones where they remained active and alert. None was ever seen swimming off bottom, and only an occasional fish was sighted at night on top of the intake structures.

Burbot were commonly observed in the riprap area and were seen during 7 of the 10 study years. They were consistently the ninth-most abundant fish observed during all dives (Table 10) but were among the least frequently observed fish species seen during transect swims (Table 10). Similar to sculpins, burbot were relatively less abundant in field samples collected outside the riprap area than in impingement catches and diver observations which sampled the population on the riprap (Fig. 16). These data suggest that burbot concentrated in the riprap area. The attraction was probably related to the increased protection that the more rugose substrate provided and not to some aspect of plant operation.

Diving observations revealed no temporal pattern in the seasonal inshore abundance or distribution of burbot, although field sampling and impingement catches indicated that the fish left the inshore area during summer months. Underwater observations of burbot revealed a clear pattern in their diel distribution. Nearly all fish were seen at night, and they remained out of sight during the day. As with sculpins, all burbot observed were solitary, alert, and active, although they could usually be approached and grasped by divers. They were always seen on the bottom and were usually entwined among the riprap.

Despite the relatively low abundance of burbot in the area, on one occasion a specimen was found lodged headdown inside a 7-cm diameter tube that had been suspended perpendicular to and 1 m off the bottom for three weeks to collect suspended sediment. This attested to the active exploration of the area by this particular species.

Burbot were never observed at reference stations, and their spatial distribution reflected their attraction and concentration in the riprap area. The relatively frequent impingement of burbot in relation to their low field abundance also reflected their concentration in the area. Construction divers working inside the intake and discharge pipes and plant forebay reported seeing burbot in high abundance relative to the riprap area (personal communication, A. Sebrechts, Sebrechts Inc., Bridgman, Michigan). Quite possibly,

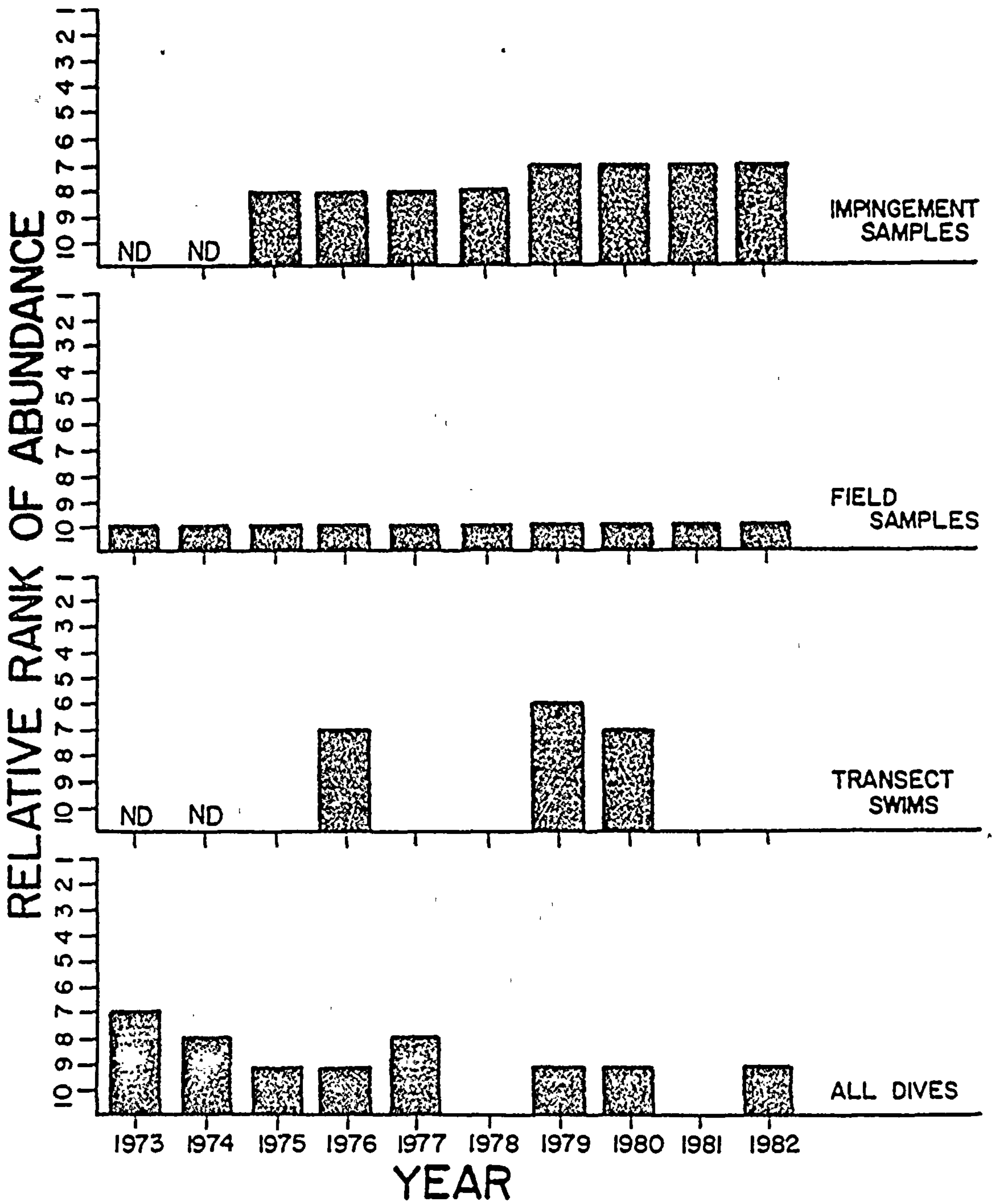

Fig. 16. Comparison of relative ranked abundance of burbot observed by divers during all dives (1973-1982) and transect swims (1975-1982), collected in standard series field samples (1973-1982), and impinged (1975-1982) at the D. C. Cook Nuclear Plant, southeastern Lake Michigan. Ordinate scale is inverted and extends from lowest to highest rank of relative abundance. Blanks indicate zero observations or catch; ND = no diving or sampling.

the fish were attracted to the dark interior of these structures, and ended up being impinged as a result.

Channel catfish and black bullheads were seen during two years of the study (Table 9), and a black bullhead was seen once during a night transect swim along the base of the south intake structure (Table 10). These fish were never observed at reference stations and were not seen in abundance on the reef. Most sightings occurred at night; fish were solitary and alert. No fish were seen swimming off bottom, and they were usually found in the interstices among the riprap rather than on top of it.

Demersal-Indifferent --

The species complex of diver-observed demersal fish that appeared to be indifferent to the in-lake structures or plant operation included johnny darter, white sucker, longnose sucker, quillback, and shorthead redhorse. The composite of diving observations, field studies, and impingement sampling indicated that these fish were distributed throughout the study area and did not appear to congregate in the riprap area.

Johnny darters were observed during all study years (Table 9) and during transect dives in all but the last year of diving (Table 10). They were typically about the fourth-most frequently observed species of fish. Although johnny darters were observed in abundance in the riprap area, they were also frequently seined in the beach zone and trawled at 6- and 9-m stations during field studies of fish (Tesar et al. 1985, Tesar and Jude 1985). Comparison of the relative ranked abundance of johnny darters showed that they were the sixth- to eighth-most frequently collected species in field sampling and the seventh- to ninth-most frequently impinged species (Fig. 17). The difference

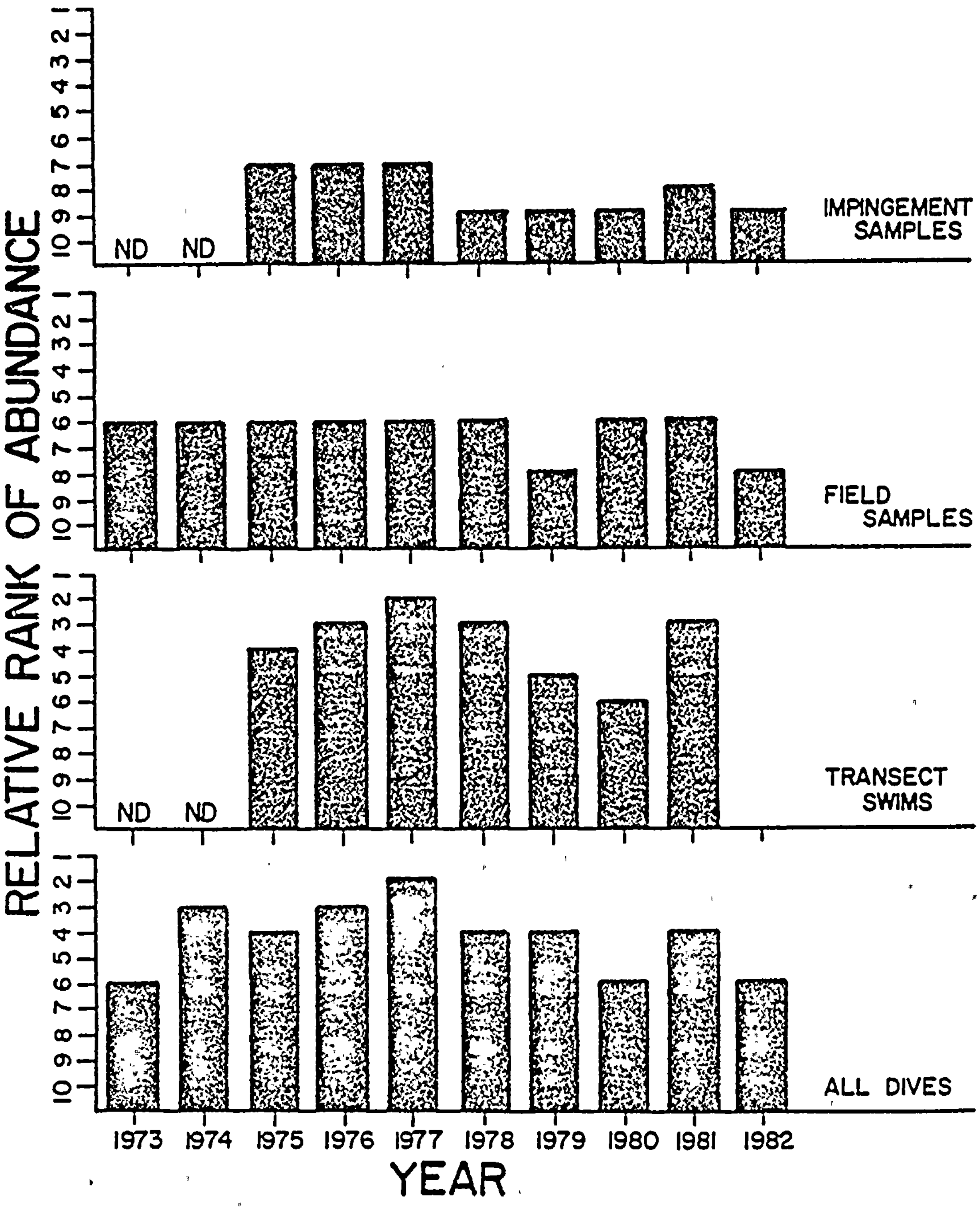

Fig. 17. Comparison of relative ranked abundance of johnny darters observed by divers during all dives (1973-1982) and transect swims (1975-1982), collected in standard series field samples (1973-1982), and impinged (1975-1982) at the D. C. Cook Nuclear Plant, southeastern Lake Michigan. Ordinate scale is inverted and extends from lowest to highest rank of relative abundance. Blanks indicate zero observations or catch; ND = no diving or sampling.

in absolute value of annual rank between these data sets never exceeded three and was often only one. These differences were probably not significant and did not suggest an unusually high rate of impingement of fish in relation to their general field abundance. Johnny darters were occasionally observed at dive study reference stations, although they were seen in far greater abundance on the riprap. The relative ranked abundance of johnny darters observed during transect swims and for all dives differed slightly in absolute value but followed nearly identical patterns in terms of annual variation. The close similarity in these patterns of abundance was attributed to the abundance, demersal behavior, and rather even distribution of johnny darters on the riprap. As a result, the small areas of riprap examined during transect swims served well as representative samples of the abundance of johnny darters.

Several patterns appeared in the temporal abundance and distribution of johnny darters. Diver observations and field and impingement catches suggested that the abundance of johnny darters relative to other species declined after 1977 and then fluctuated at lower levels during remaining years of study. The rebound in relative abundance was more apparent in field samples than in impingement samples or diver observations. This suggests that the decline was more pronounced in the riprap area relative to the surrounding area and that recovery to former levels of relative abundance was slower. Quantitative substantiation and explanation for a differential decline and recovery in abundance of johnny darter between the riprap and surrounding sand area are lacking.

Secondly, johnny darters were absent from the area during April and October, in contrast with their high abundance and widespread distribution during warm-water months (May-September). Monthly peaks in numbers of fish observed, impinged, and collected in field samples often occurred in May and coincided with the spawning period for these fish (Fig. 8).

A final temporal pattern occurred in diel abundance. Although johnny darters were commonly seen during the day, numbers observed during transect swims were consistently higher at night (Appendix 2).

As noted earlier, although johnny darters were seen in much greater abundance at riprap stations than at reference stations, no overall patterns or differences in the spatial distribution of this species were supported among the three general studies (diving, field, impingement). While johnny darters may prefer rough substrate, particularly for spawning, they appear to be widely distributed inshore during spring, summer, and fall. The decline in rate of impingement of johnny darters during winter suggested that either the fish moved offshore, or their activity and susceptibility to impingement were lower during this period.

Nearly all johnny darters seen were adult fish, which were solitary, alert, and active during day and night. All fish were seen on the bottom and often rested on the upper surfaces of the riprap. Occasionally, a fish was observed on top of the intake structure.

White suckers were seen during 7 of the 10 study years and ranked as the ninth- or tenth-most frequently observed species of fish (Table 9). White suckers were never observed during transect swims, primarily because of their low abundance in the area. The relative ranked abundance of white suckers in field samples remained the same (seventh) for all but two years, when it declined by one rank (Fig. 18). Relative ranked abundance of white suckers in impingement samples fluctuated slightly but showed no strong patterns or

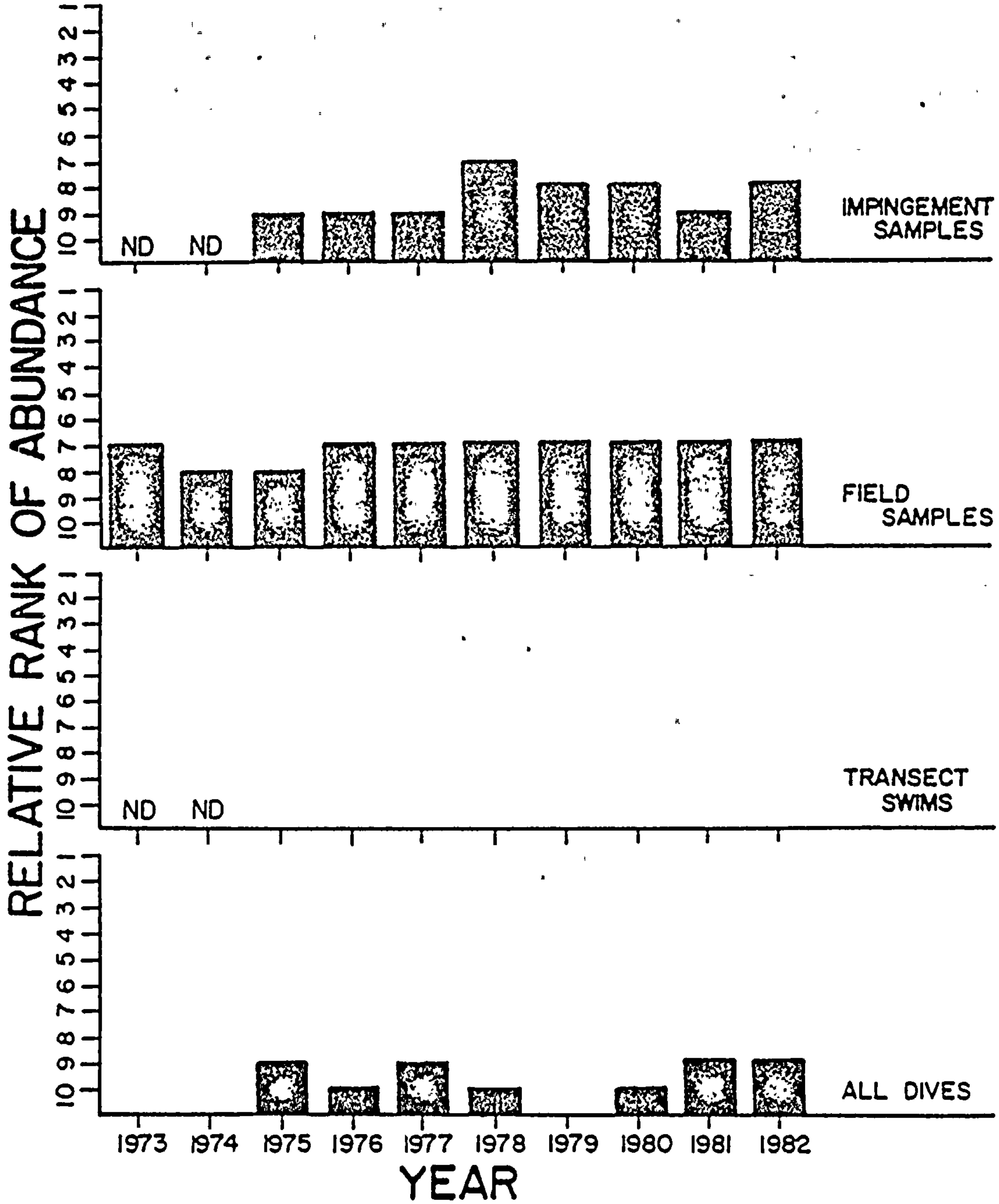

Fig. 18. Comparison of relative ranked abundance of white suckers observed by divers during all dives (1973-1982) and transect swims (1975-1982), collected in standard series field samples (1973-1982), and impinged (1975-1982) at the D. C. Cook Nuclear Plant, southeastern Lake Michigan. Ordinate scale is inverted and extends from lowest to highest rank of relative abundance. Blanks indicate zero observations or catch; ND = no diving or sampling.

trends. White suckers were observed consistently but in low numbers during most years of the underwater study.

A seasonal pattern in the temporal abundance of white suckers appeared in both underwater observations and field catch of this species. Fish were observed exclusively during May-August except on one occasion in September; most collected in field samples were also taken during May-August. Impingement of these fish tended to be greater in summer, but white suckers were impinged during most months and occasionally in relatively high numbers during winter. These data suggest that white suckers are generally more abundant inshore during warm-water months. It is possible that they move offshore during winter or some fish may have sought shelter from storms and ice inside the intake structures and pipes, thus accounting for the relatively high impingement during winter when field abundance was relatively low. White suckers were most often seen at night when they were solitary, alert, and active. Tesar and Jude (1985) found that this species moved shoreward at night in the study area.

Although white suckers were not observed at reference stations, there was no evidence that they were attracted to the plant structures or riprap or that operational factors affected their distribution. In fact, analysis of gill net data revealed that white suckers were significantly less abundant near the Cook Plant than at a reference station located 11 km south off Warren Dunes State Park, Michigan (Tesar and Jude 1985). These data indicate that white suckers may actually have avoided the Cook Plant area, perhaps in response to some operational factor such as discharge of heated water. A similar pattern of avoidance was noted at the J. H. Campbell Plant located north of the Cook Plant (Jude et al. 1982).

Longnose suckers were seen on several occasions during the study. Quillback and shorthead redhorse were each observed on one occasion. All of these fish were observed in the riprap zone, but attraction of these species to the area was not established.

The overall abundance and distribution of most fish observed by divers were influenced by several factors. One factor was the annual water temperature regime. Fish abundance, diversity, and levels of activity as observed by divers were generally highest during the warm-water months (May-September), with lowest levels of abundance, diversity, and activity occurring during April.

Abundance and diversity of fish observed by divers was generally higher at night than during the day. Part of this was because many fish were less wary at night and did not flee the area as divers approached. Also, many species of fish seen were nocturnal or showed no clear pattern of diel activity. Those species that were day-active often remained on bottom at night where they were readily visible to the divers.

Inshore turbulence associated with storms and surface waves appeared to cause many fish to retreat from the area. Offshore movements were most likely, but some fish (alewife and yellow perch) in the immediate vicinity of the Cook Plant appeared to seek shelter in the lee of the intake structures and were consequently more vulnerable to impingement during these periods. This response to storms was also documented by Lifton and Storr (1977).

Finally, for many of the species of fish observed during this underwater study, their onshore movements and peak abundance in the study area were often directly correlated with spawning activities. This was true for species that were attracted to the plant area for spawning substrate (e.g., yellow perch, sculpins, johnny darter) or an operational factor (common carp) and for species that appeared indifferent to the presence or operation of the Cook plant (e.g., alewife, spottail shiner, rainbow smelt).

The spatial and temporal abundance of Lake Michigan fish found in the study area appears to be strongly influenced by environmental factors (substrate conditions, water temperature, storms, turbulence, ice, diel period) acting in concert with physiological needs of the fish (maturation, spawning, feeding, survival, growth) and the distribution of other aquatic biota (predators and prey). Our studies also indicate that the level of influence that these factors assert on fish abundance, distribution, and behavior changes as fish pass through various stages in their life history and physiological needs.

ECOLOGY

Given some annual variation, most of the physical, chemical, and biological features of the study area remained basically unchanged during preoperational and operational phases of the Cook Plant (Rossmann 1986). Such factors included composition and configuration of surficial sediments, presence of lake currents and occasional occurrence of storms, annual water temperature regime, nutrient cycling, and the seasonal appearance of various animal populations in the area. These factors along with many others comprise the environment and dictate the growth and survival of plants and animals in the area. In most instances, these environmental interrelations and responses are complex and difficult to isolate or explain.

However, construction and operation of the Cook Plant resulted in some gross alterations in local environmental conditions which could be identified and explored. The placement of plant structures and riprap in the lake created a small, isolated benthic environment that was atypical of the surrounding area. Subsequent operation of the plant which included withdrawal of water, circulation and warming of water inside the plant, and discharge of water back into the lake further affected both the benthic and pelagic environment in the immediate vicinity. Two basic themes underlie the initial discussion in this section: the first is an evaluation of the response of selected biota to the introduction of new habitat or sets of environmental conditions. The second theme is the response of these biota to habitat aging and changes in environmental conditions. The discussion is limited to observations and inferences that are derived from this underwater study.

The inshore physical environment in this region of the lake is variable in comparison with many other aquatic environments. Waves, currents, shifting surficial sediments, exposure to ice scour, and widely fluctuating water temperatures contribute to the set of conditions that stress plants and animals living in the area. The riprap and in-lake plant structures provided a stable substrate that afforded increased protection for mobile benthic organisms and a surface for attachment of sessile biota. This was reflected in the rapid colonization of this habitat by organisms not found in the surrounding environment, (e.g., periphyton and attached invertebrates) or which normally occurred in lesser abundance (e.g., snails, crayfish, and some fish).

Following placement of the structures and riprap in the lake, aging of their surfaces commenced and altered the conditions of this micro-environment. The structure surfaces first rusted and then accumulated bacterial slime, fine sediment, and particulate organic material. Bacterial slime grew on the surface of the riprap while the holes and crevices, particularly those in its upper surfaces, trapped sediment and organic matter.

Periphyton rapidly colonized the exposed, upper surfaces of the structures and riprap, and Cladophora was often abundant. Snails appeared on the riprap within a year and attached invertebrates (Hydra, bryozoans, and sponges) colonized the substrate in the first few years. Crayfish also appeared on the reef within the first several years. Abundance of snails, crayfish, and some invertebrates peaked during the first three to five years and then declined to varying degrees. Snails disappeared completely from the riprap by the sixth year, and numbers of crayfish observed and impinged declined dramatically by the seventh year. The abundance of most attached invertebrates declined in later years of the study, but these organisms continued to be observed throughout the 10-yr study period. Interestingly, fluctuations occurred in the abundance of fish that were attracted to the area, but clear patterns or trends in their abundance were not evident. The reason for this may be that those factors which attracted the fish (e.g., shelter, circulating water, etc.) were not altered as much during the study as the micro-environment on the surface of the riprap. This in turn suggests that attraction of fish to the area may have been more a response to the physical configuration of the reef than to biological factors such as availability of prey (e.g., sculpin feeding on snails or perch feeding on crayfish).

In a stable environment, associated physical, chemical, and biological conditions often achieve some balance with each other. Patterns, trends, and random variations in these conditions are expected to occur during long periods of observation, but radical changes are either atypical (e.g., damage or destruction of the structures) or at least predictable (upwellings). When existing habitat is altered or new habitat is introduced, the extant environmental conditions change and a new set of physical, chemical, and biological conditions begin to appear. Usually, some period of time is required to reform a stable and relatively predictable balance with this new set of conditions. The response of individual organisms to these environmental changes varies but is eventually reflected in population abundance and diversity. Populations may increase or decrease in numbers, and the rate at which this occurs may also vary. However, several basic patterns are known, and some occurred at the Cook Plant.

One pattern, shown by snails at the Cook Plant, is where population density follows a J-shaped curve over time. Initially, a positive acceleration phase occurs, followed by a logarithmic growth phase. Eventually, population density peaks and is then followed by a logarithmic decrease in population density and later, a negative acceleration phase (Knight 1965). Colonization, rapid population increase, peak abundance, and population decline of snails took place within a 4-yr period; over the next two years the population trailed off into extinction on the reef. The primary factor which initially encouraged population growth was most likely the appearance of clean, stable substrate. The major factor which eventually caused the extinction of snails on the reef may have been the accumulation of a thick coating of material (sediment, organic detritus, and algae) on the surface of the substrate. This material may have interfered with snail movement, ventilation, or incubation of eggs attached to the substrate. Changes may also have occurred in the composition of the detrital material upon which snails fed.

A second population density curve which develops in response to changing environmental conditions is the sigmoid curve. In this instance, the ascending limb and peak of the curve are followed by a series of oscillations which may be cyclic or nonperiodic and show trends and patterns or totally random changes in population abundance over time. Attached invertebrates and crayfish followed this general form of population density curve. Given time and eventual stabilization of environmental conditions on the reef, the population density curves of these organisms might eventually flatten or show some periodicity or trend. But the duration and intensity of sampling conducted during this study were insufficient to reveal such features in these population curves. The seasonal growth of Cladophora followed a variation of this curve where the length and density of the alga showed cyclic fluctuations according to season (maximum in summer, minimum in winter). However, no long-term trend superimposed on these cyclic oscillations was identified during the study.

Changes in surficial substrate conditions suspected to have affected snails probably also affected attached invertebrates and crayfish. Evidence indicated that Cladophora may have had a direct effect on these animals. In studies of artificial substrates placed on the Cook Plant riprap, Lauritsen and White (1981) found that Cladophora increased space available for clinging invertebrates such as Naididae, Oligochaeta, water mites, and amphipods. With the disappearance of most Cladophora in the fall, the total number of benthic invertebrates decreased, and filter feeders dominated the fauna. Prince et al. (1975) found that at Smith Mountain Lake, Virginia, crayfish were most abundant in areas of luxuriant Cladophora growth and absent from areas of the reef with little or no Cladophora growth. These observations combined with those of the present study (see Free-living Macroinvertebrates) suggest that a direct relationship exists between the presence of Cladophora (or factors which promote growth of the alga) and the abundance of invertebrates at the Cook Plant. The population growth of snails may have been repressed by luxuriant Cladophora growth; whereas, the population growth of crayfish may have been enhanced. Attached invertebrates may have had to compete with the alga for substrate, and some of the aquatic insect larvae observed during the study may have fed on organisms living in association with Cladophora.

Another population density curve is asymptotic in shape. Unlike the J-shaped curve, no clear peak density is achieved but rather an asymptotic or flat, linear phase is established. Some possible examples of this curve were the population densities of yellow perch, sculpin, johnny darter, and burbot that were attracted to the rough substrate. Unfortunately, diving was not conducted before and immediately after placement of the substrate in the lake. Therefore, the initial increase in density which occurred as fish located and colonized the area was not recorded and the ascending limb of the curve was not reflected in the data. However, the relative ranked abundance of many of these fish underwent only minor fluctuations following colonization, and the actual abundance of these reef fish may have stabilized. As noted earlier, the attraction of these fish to the reef may have been more a response to its gross physical configuration and stability which remained nearly unchanged during the study, than to reef organisms (algae or invertebrates) that served as prey, or to micro-environmental conditions on the surface of the riprap. Interestingly, lake trout, which appear to have extremely specific requirements regarding spawning-substrate conditions, were never found to utilize the Cook Reef for spawning; whereas, other fish (yellow perch, slimy sculpin, johnny darter, spottail shiner, and alewife) with less stringent spawning-substrate requirements spawned extensively on the reef. In contrast, lake trout did spawn on the newly-placed large riprap at the Campbell Plant (Jude et al. 1981b).

The population density curves of periphytic algae at the Cook Plant reef followed a pattern typical for colonial algae but unique in comparison with curves previously discussed. In general, abundance of individual algal forms peaked soon after colonization and then decreased slowly, thus defining asymmetric population density curves that were skewed to the right. However, as individual population densities decreased and more stability was attained, total diversity of forms increased almost linearly throughout the study. These opposing processes may have been the result of aging and increased stability of surficial substrate conditions acting in concert with the large number of rare forms present in the lake.

Most organisms studied during this investigation exhibited both temporal and spatial variation in their abundance and distribution. The three most obvious environmental effects were substrate conditions, water temperature, and photic conditions. Pronounced effects of substrate were found on the distribution of periphyton, attached invertebrates, snails, and crayfish and on the distribution and spawning of some fish. For all animals studied, presence of stable, rugose substrate attracted and concentrated biota that were less abundant in the surrounding environment of flat, exposed, shifting-sand bottom. Most organisms not attracted to the riprap zone (e.g., pelagic fish) were distributed in the area in a manner similar to that of the surrounding environment. However, the faunal distributions of some organisms that would undoubtedly have been reduced by the presence of hard substrate, such as those of burrowing invertebrates, including sphaeriid clams or worms, were not studied.

Although short-term fluctuations in water temperature, such as upwellings, were encountered, their effects on the abundance and distribution of local biota were difficult to discern through diver observations. However, seasonal changes in water temperature had obvious effects on both plants and animals. In general, abundance and diversity of most organisms observed by divers were far greater during months of warm water than during early spring (April) or late fall (October). Part of this reduction was likely the result of reduced metabolic activity and movements as a function of lower water temperatures. But, frequent storm-generated turbulence and scouring of the bottom by ice made the inshore area considerably more inhospitable during the cold-weather period of the year.

The diel distribution of some animals was a direct result of phototrophic responses. Crayfish were distinctly more active at night as were sculpin and YOY alewives. Yellow perch and common carp were active during the day and inactive at night. While abundance of adult alewives appeared unaffected by photoperiod, schooling was a distinctly daytime activity. In general, most fish were less alert and more approachable by divers at night than during the day. Also, orientation of fish to the structures and riprap was often clearly obvious during the day and obscure or absent at night.

Finally, a distinct process of colonization and succession of biota on the Cook Plant structures and riprap was documented during this study. Although specific population density curves have been discussed, the overall pattern was one of initial location of habitat by extant biota, explosive population growth which peaked during the first few years of the reef's existence, and a decline in population abundance to lower levels of fluctuating population abundance or extinction. This general pattern was most strikingly exhibited by sessile biota, perhaps because they were more directly affected by changes in substrate conditions than were motile organisms such as fish. These changes probably included shifts in micro-habitat conditions such as circulation of water and exchange of gases and nutrients at the substrate/water interface. The physical occlusion of the substrate surface, pores, cracks, and interstices by an accumulation of algae, sediment, and organic detritus probably influenced these micro-habitat conditions and dictated the response of organisms to that habitat.

Generally, artificial reefs are used throughout the world to increase local biological productivity (Rutecki et al. 1985). Such increases are achieved by expanding the variety and abundance of habitat available to biota. These conditions favor the survival and growth of individual organisms and promote local population increases. The Cook Plant structures and riprap have provided just such an environment which through its physical presence and modification of extant environmental conditions acting in combination with effects of plant operation have had a distinct impact on the local ecology. From the standpoint of diver-observed effects, this impact appears limited almost exclusively to the reef itself and has not influenced the ecology of the surrounding area to any noticeable extent.

PLANT EFFECTS

Physical Presence

The physical presence of Cook Plant in-lake structures and riprap appeared to have several effects on the local environment that were not related to plant operation (e.g., circulation or discharge of heated water). These effects were generally related to an expansion of habitat which provided increased substrate for attachment, shelter, or reproduction of biota.

The structures and riprap provided stable substrate for the attachment and growth of periphytic algae and attached invertebrates including *Hydra*, bryozoans, and freshwater sponges. These animals were not found on shifting-sand substrate in the surrounding area.

Snails were attracted to the clean, stable substrate that provided a surface on which they could move about and lay their eggs. Crayfish may have fed on *Cladophora* or other periphyton attached to the riprap but also used the interstices among the stones for shelter and protection.

Several species of fish were attracted to the structures and riprap. Yellow perch congregated in the area in the late spring and remained more concentrated in the riprap zone than the surrounding area throughout the summer. Although alewives did not show any particular attraction to the area based on diver observations, impingement records indicated that fish clustered near the structure during storms and were thereby more vulnerable to entrapment (Thurber and Jude 1984, 1985). Demersal fish including sculpins, burbot, johnny darter, black bullheads, and catfish were attracted to the riprap probably as a result of their cryptozoic behavior. In all cases, the presence of the structures and riprap increased the amount of protected habitat available to these fish. Therefore, strictly from the standpoint of their physical presence, the structures and riprap enhanced and expanded local populations of some fish species in a manner that would not have occurred in the absence of this habitat. However, this enhancement must be balanced against the operation of the plant which often contributed to mortality of fish occurring in the area.

The riprap served as spawning substrate for yellow perch, slimy sculpin, and johnny darter, and through this process may have enhanced the growth of local populations of these fish. Spottail shiners were observed to spawn on periphyton growing on top of the south intake structure, which provided an additional but probably insignificant amount of spawning habitat.

In overview, the physical presence of in-lake plant structures and riprap created an atypical, more sheltered, and more diverse habitat as compared to the surrounding area. These factors served to attract and concentrate biota which normally would be absent from the area or occur in considerably reduced numbers. In most instances, the presence of this habitat enhanced local populations of some plants and animals, while others (e.g., those of burrowing animals) were likely reduced. But, the attraction and enhancement of these populations must be balanced against their increased vulnerability to operational effects of the Cook Plant and plant-induced mortality.

Operational Effects

The entrainment of organisms during intake of plant cooling water and discharge of heated water and currents associated with the withdrawal and discharge of water were the major effects of plant operation that were noted by divers. Some of the physical impacts from plant operation have already been described and are summarized here. A shallow surface layer of warm water was occasionally encountered by divers at reference stations closest to the discharge structures. Warm water was also encountered when diving in the discharge area during one-unit plant operation. Elevated turbidity was occasionally encountered at the north reference station nearest the plant, and on one dive, debris was flushed from the north discharge during cleaning of the plant forebay. Intake and discharge of water modified lake currents and waves in the immediate vicinity of the plant. We observed changes in ripple mark patterns on the bottom, encountered eddy currents at the discharge, and detected water masses of clearly differing temperature and transparency in the stratified intake water. Although the riprap trapped sediment and organic debris, some of these materials were re-suspended by plant-generated water currents.

Although the pelagic life stages of attached organisms were vulnerable to entrainment and possible plant-induced mortality, sessile adult organisms were considerably less susceptible to operational effects of the plant. Diver observations revealed that portions of the intake structures most directly exposed to intake water currents often supported the most luxuriant periphyton growth.

Crayfish were attracted to the riprap. However, intake currents strong enough to dislodge these animals from the substrate and result in their subsequent impingement in the plant were never encountered. Crayfish, which show pronounced negative phototatic behavior (Pennak 1953), most likely were attracted to the dark interior of the intake structures and pipes and eventually entered or were entrained into the the plant forebay and impinged on the traveling screens. The same process may have occurred for sculpins which concentrated in the riprap area; sculpins are also nocturnally active.

Diver-observed effects of plant operation on fish were limited to attraction of common carp to the heated discharge water and a general responsiveness of some species to currents at the intake structures. Although common carp spawned in the warm water as evidenced by the concentration of newly hatched larvae at sampling stations nearest the thermal plume (Bimber et al. 1984), they may have been attracted to the plume for other reasons. No evidence was compiled to indicate that common carp would have been attracted to the area strictly in response to the physical presence of plant structures or riprap. Several species of fish, including yellow perch, alewives, and spottail shiners, were observed to exhibit positive rheotaxis and some position-holding in the area of strong intake currents. On occasion, some of these fish were observed to selectively congregate at various locations around the intake where the incoming water was warmer or less turbid than at other points. Cook Plant impingement records and other studies suggest that both alewives and yellow perch may have concentrated near the intake structures during storms and periods of extreme inshore turbulence, perhaps in search of shelter in the lee of the structures (Lifton and Storr 1977; Thurber and Jude 1984, 1985). Such concentrations, combined with the increased activity of fish during storms and possible disorienting effects of extreme turbulence, may have resulted in increased impingement of fish during and immediately following severe inshore turbulence.

Pelagic fish, including juvenile and adult alewife, spottail shiner, and yellow perch, were observed to swim in and out of the intake structures. This observation suggests that water intake currents outside the structures and at many points within the structures were not so strong as to over-power the fish. Rough measurements of current speed made by divers at the intake screens of the structures by timing the transport of suspended material along a measured distance indicated that intake currents at the screens were usually less than 0.5 m/sec. During seven-pump plant operation, currents at the intake screens occasionally approached 1 m/sec at points along the structure which faced directly into the oncoming lake current. Commercial divers repairing the intake structures reported that there were specific locations within the structures where intake currents would suddenly increase (personal communication, A. Sebrechts, Sebrechts Inc., Bridgman, Mich.). These locations varied with the number of pumps operating, direction and speed of lake currents and surface waves, and eddy currents caused by recirculation of discharge water.

Review of fish swimming performance, summarized by Hocutt and Edinger (1980), indicates that water velocity at the Cook Plant intake screens is considerably less than the "burst" swimming speeds of most pelagic and juvenile fish found in the study area and does not exceed the "sustained" swimming speed for species such as alewife and yellow perch. They also reported that alewife demonstrate a countercurrent orientation in streams and prefer high velocity flow; whereas, yellow perch are inconsistent in their orientation to current.

We theorize that at the Cook Plant most fish voluntarily enter the structure and then may be unexpectedly subjected to strong currents occurring at varying locations within the structure. Upon entering the structure and suddenly encountering these currents, many fish probably retreat to areas of reduced current within or outside the structure; this scenario may be repeated many times before the fish eventually leave the area or are entrapped. Intake currents inside the pipes may approach 1.8 m/sec (6 ft/sec) during seven-pump operation, which would be 10 body lengths/sec for a 180 mm fish. Based on fish swimming performances cited in Hocutt and Edinger (1980), this value (10 lengths/sec) probably exceeds the "burst" swimming speed for many of the species of fish commonly impinged at the Cook Plant, particularly small fish.

Hocutt and Edinger noted that swimming performance is also related to the rate of velocity increase. Therefore, if a fish unexpectedly encounters a strong intake current inside the Cook Plant structure, escape may be difficult, particularly if the fish has been drawn through the structure and down into the intake pipe. If fish congregated near the structures for shelter during storms, the increase in turbulence could well disorient them or mask the intake current so that the fish might have increased difficulty sensing the sudden increases in intake current flow inside the structure. The end result would be that more fish would be entrained and impinged during storms, which was exactly what was observed at the Cook Plant.

Divers noted plant effects that were the result of the simple physical presence of the structures and riprap and some that were a function of plant operation. Most of these effects served to enhance local population densities of organisms attracted to the area. Negative effects (e.g., primarily entrainment and impingement) appeared to be limited more to plant operation than the physical presence of the structures and riprap in the lake and were inferred from other aspects of the Cook Plant studies. Barring a large change in the in-lake structure of the Cook Plant or its operation, future diver observation of additional major or significant ecological changes or plant impacts are not anticipated.

SUMMARY

The physical, chemical, and biological features of the inshore environment surrounding the Cook Plant in-lake intake and discharge structures and riprap defined a harsh regime of environmental conditions relative to many other aquatic environments. A spectrum of flora and fauna existed in this

environment, but the abundance and distribution of most organisms appeared to be rather strictly dictated by the environmental conditions they encountered. The inshore Lake Michigan environment evaluated during this underwater study appeared relatively homogeneous, and considerable opportunity existed for the mobile life stages of flora and fauna to migrate and colonize new habitat.

Inshore surface waves may attain 4 m in the study area during intense storms, which contribute to the harsh nature of the environment. Effects of waves 0.5-1.0 m could be felt on the bottom by divers at depths less than 10 m. Lake currents were occasionally encountered by divers, but their effects were masked in areas where plant-generated currents could be felt. Both uni-directional and eddy currents were detectable throughout the water column within 100 m of the discharges; at stations more than 300 m from the discharges, weak plant-generated currents were noted occasionally, but lake currents appeared to predominate. Variable current speeds were encountered at the intake structures, but distinct differences often occurred at various points around the structures. Currents were strongest during seven-pump operation, and presence of warm water drawn into the shoreward sides of the structures suggested some recirculation of discharge water.

Thermal effects encountered during diving included seasonal large-scale changes in water temperature, short-term processes, including upwellings, and temperature stratification within the water column. A thin layer of naturally warmed water was occasionally found at the surface. Plant effects included presence of warm water near the discharge area and recirculation of discharge water.

The bottom profile of the inshore Lake Michigan environment was typically flat and unbroken. Sediments were composed of coarse- and fine-grained shifting sand. Occasional "islands" of rock or clay substrate occurred in the inshore area of eastern Lake Michigan but were extremely limited in number and areal extent. These islands included habitat and environmental conditions more dissimilar to the surrounding area than to the physical conditions created by the Cook Plant in-lake structures and riprap.

Accumulations of surficial flocculent material typically ranged from 1 to 5 mm thick. Occasionally, large (10-m diameter, 1 m deep) depressions containing 20-40 mm of floc were encountered at reference stations. The riprap trapped sediment along with other inorganic and organic materials.

Water transparency ranged from less than 1 m to more than 6 m and was reduced during periods of inshore turbulence. High transparency was usually associated with extended periods (days to weeks) of stable weather and calm lake conditions. Transparency was occasionally reduced in the vicinity of the discharges and at specific points around the intake structure. These reductions were attributed to discharge turbulence and withdrawal of water from discrete water masses of differing turbidity.

Inorganic debris and organic detritus were more commonly observed in the riprap zone than at reference stations. This was believed to be primarily a function of the increased trapping action of the more rugose surface of the riprap. Inorganic trash accumulated as a result of plant construction and items discarded by fishermen angling over the reef. Organic debris was composed primarily of terrestrial plant material.

Periphyton colonized the structures and riprap within a year of placement in the lake. Seasonal growth patterns were clearly obvious, with algal length, density, and taxonomic diversity peaking during summer months. Most algae sloughed from the substrate during winter. Cladophora was abundant and was suspected to have affected the abundance of other organisms on the reef, including attached or clinging invertebrates, crayfish, and possibly snails. No long-term pattern in length or luxuriance of periphyton growing on the plant structures or riprap was identified. However, taxonomic diversity and number of new forms recorded each year increased almost linearly throughout the study. These observations documented a pattern of colonization and succession that was typical for periphytic algae and also attested to the large number of rare forms present in the lake.

Attached invertebrates observed during the study included *Hydra*, bryozoans, and freshwater sponges. *Hydra* colonized the structure and riprap during its first year in the lake, as did bryozoans. Freshwater sponges appeared to require about two years to colonize the substrate. Peak abundance of these invertebrates on the reef occurred four to six years after placement in the lake. During the last several years of the study, abundance of *Hydra* and bryozoans declined, while numbers of sponge colonies continued to fluctuate and showed no particular pattern or trend. Riprap appeared to provide a more suitable substrate than did the metal structure, although large mats of *Hydra* were observed on the interior walls of the intake pipes and plant forebay.

Snails and crayfish colonized the riprap within its first year in the lake. Abundance of snails (*Physa*) peaked during the third year of the reef and then declined rapidly. No snails were observed during the last four years of the study. Extinction was believed to have been caused primarily by changes in the surface of the substrate as it aged and accumulated sediment, bacterial slime, periphyton, and organic detritus. Crayfish abundance peaked one year after that of snails. A rapid decline in abundance then occurred, but unlike snails, crayfish continued to be observed in low numbers throughout the duration of the study. Decline in crayfish abundance was believed to be related to changes on the reef substrate surface operating in combination with initial overpopulation of the habitat. For both snails and crayfish, predation on eggs, juveniles, and adults by other crayfish and fish may have contributed to the decline in abundance of these invertebrates.

Several species of fish including yellow perch, slimy sculpin, and johnny darter spawned on the reef in preference to the surrounding sand-bottom area. Spottail shiners were observed to spawn over periphyton growing on top of an intake structure. Alewife eggs were seen in abundance but were about equally distributed over riprap and sand substrate, indicating that this species broadcasts its eggs at random without regard to substrate composition. Observation of fish eggs was limited to May-August, and spawning activity of the above species appeared to be concentrated in May-June.

Twenty-two taxa, encompassing 24 species of fish, were observed by divers during the study and were grouped according to frequency of observation. Frequently observed species included alewife, yellow perch, sculpins, johnny darter, and spottail shiner. All of these fish were seen at least once during every year of the study. Commonly observed species included trout-perch, common carp, rainbow smelt, burbot, and white sucker. These fish were seen during seven to nine years of the 10-year study. Uncommonly observed species included largemouth bass, lake trout, channel catfish, black bullhead, smallmouth bass, and longnose sucker. These fish were seen in more than one but less than half of the study years. Species that were rarely observed and were seen during only one year included emerald shiner, brown trout, quillback, walleye, unidentified coregonids, and shorthead redhorse.

Pelagic fish that appeared to be attracted to the in-lake presence or operation of the plant included yellow perch and common carp and possibly largemouth bass, smallmouth bass, and walleye. Pelagic species that appeared generally indifferent to the in-lake presence or operation of the plant included alewife, spottail shiner, trout-perch, rainbow smelt, lake trout, emerald shiner, brown trout, and coregonids. Demersal fish that appeared to be attracted to the in-lake presence or operation of the plant included slimy sculpin, burbot, channel catfish, and black bullhead. Demersal fish that appeared indifferent to the in-lake presence or operation of the plant included johnny darter, white sucker, longnose sucker, quillback, and shorthead redhorse.

Several generalizations related to fish behavior may be made based on this study. Species diversity and overall abundance of fish were higher during the warm-water months (June-August) than in the spring or late fall and higher at night than during the day. Day-active fish included yellow perch, common carp, and johnny darter. Nocturnally active fish included sculpins and burbot. Alewife, spottail shiner, trout-perch, and rainbow smelt showed no obvious pattern in diel activity. Daytime schooling was observed among adult alewife (500-1,000/school), yellow perch (10-50/school), and common carp (5-20/school), although aggregations tended to be loose and often included fish of widely differing sizes. Schooling among YOY fish was observed for alewife, yellow perch, and rainbow smelt. For all species that were active at night, swimming was more undirected and slower, and fish were more easily approached by divers than during the day.

Schools of YOY alewife were observed in September and October during most years. Schools of YOY yellow perch were occasionally seen in August.

Observation of these YOY fish coincided with their appearance inshore at this time of the year and was further documented in field and impingement catches.

Fish abundance and diversity were greater in the riprap area than in the surrounding area of sand substrate. Yellow perch, slimy sculpins, johnny darter, burbot, channel catfish, and black bullheads were probably attracted to the vertical relief and protection that the rugose substrate offered. Common carp appeared to be attracted to the warm-water discharge. Largemouth bass, smallmouth bass, and walleye were seen in close association with the structures and may have been attracted to the vertical relief that these objects presented. Alewives were seen in abundance in all of the study area but may have sought shelter near the structures during periods of inshore turbulence. Spottail shiners, rainbow smelt, and trout-perch did not appear attracted or repelled by the physical presence of the reef or operation of the plant. Excluding the operational effects of entrainment and impingement on fish at various life stages, the physical presence of the structures and riprap appeared to enhance fish populations by providing additional habitat for spawning, feeding, and protection from predation and harsh inshore lake conditions.

The seasonal abundance of fish observed by divers in the study area was often directly correlated with their spawning activities. This was true for species that were attracted to the plant area for spawning substrate (e.g., yellow perch, sculpins, johnny darter) or by an operational factor (common carp), as well as for species that appeared indifferent to the presence or operation of the Cook Plant (e.g., alewife, spottail shiner, rainbow smelt).

The spatial and temporal abundance of Lake Michigan fish found in the study area appeared to be strongly influenced by environmental factors (substrate conditions, water temperature, storms, turbulence, ice, diel period) acting in concert with physiological needs of the fish (maturation, spawning, feeding, survival, growth) and presence of other lake biota (predators and prey). Our studies also indicated that the level of influence that these factors assert on fish abundance, distribution, and behavior changes as fish pass through various stages in their life history and physiological needs.

The Cook Plant structures and riprap have created habitat atypical of the surrounding environment. Through its physical presence and modification of extant environmental conditions acting in combination with effects of plant operation, it has had a distinct impact on the local ecology. Population increases for some organisms, including periphytic algae, attached and free-living invertebrates, and pelagic and demersal fish, have been achieved through the expansion of substrate to provide increased shelter and a more diversified habitat relative to the surrounding environment. Environmental conditions on the reef have favored the survival and growth of individual organisms and resulted in local population increases. From the standpoint of diver observations, effects of these changes appeared limited almost exclusively to the reef itself and have not influenced the ecology of the surrounding area to any noticeable extent.

Presence of the riprap served to enhance local population densities of organisms attracted to the area. The attraction and enhancement of these populations must be balanced against their increased vulnerability to operational effects of the Cook Plant and plant-induced mortality. Negative effects (e.g., primarily entrainment and impingement) appeared to be limited more to plant operation than the physical presence of the plant structures and riprap in the lake and were inferred more from other components of the Cook Plant studies than from diver observations. Barring major modifications to the in-lake structures or operation of the Cook Plant, future diver observation of additional large or significant ecological changes or plant impacts are not anticipated.

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Appendix 1. Summary of observations made during dives on riprap substrate surrounding the D. C. Cook Nuclear Plant intake and discharge structures in southeastern Lake Michigan, 1973-1982.

Category	Apr	May	Jun	Jul	Aug	Sep	Oct
				1973			
No. of dives[1]			3		3	3	
Periphyton[2]							
Structure			3.7		3.7	3.2	
Riprap			0.5		2.0	2.5	
Invertebrates[3]							
Crayfish			1		1	1	
Snails					>100	26	
Hydra						X	
Bryozoans							
Sponge							
Other							
Fish[4]							
YP			95				
JD			12		3		
SS			10		5	6	
TP			50				
SP			>1,000				
AL			>200		50		
BR							
CC							
CP							
ES							
BB							
LT							
WS							
SB							
SM							
LB							
BT							
LS							
QB							
SR							
XC							
WL							
Fish eggs[5]							
Riprap			SP				
Sand							

(Continued).

Appendix 1. Continued.

Category	Apr	May	Jun	Jul	Aug	Sep	Oct.
				1974			
No. of dives[1]	2	3	3			1	2
Periphyton[2]							
Structure	0	3.8	7.5				3.0
Riprap	0	0.5	1.0				1.3
Invertebrates[3]							
Crayfish	1	5	30			50	1
Snails	0	100	>100			75	>100
Hydra							
Bryozoans							X
Sponge							
Other							P
Fish[4]							
YP		25	45				
JD		39	60			2	
SS		>100	2			75	72
TP			50				
SP			>100				
AL			35				2
BR		1					
CC		1					
CP		1*	1				
ES		1					
BB		1					
LT							1
WS							
SB							
SM							
LB							
BT							
LS							
QB							
SR							
XC							
WL							
Fish eggs[5]							
Riprap		SS	SP				
Sand				AL			

(Continued).

Appendix 1. Continued.

Category	Apr	May	Jun	Jul	Aug	Sep	Oct
				1975			
No. of dives[1]	1	2	3	3	3	3	3
Periphyton[2]							
Structure	0	2.5	13.8	12.5	7.5	5.0	1.0
Riprap	0.5	1.0	12.5	5.0	4.0	5.0	1.0
Invertebrates[3]							
Crayfish		5	37	95	89	103	70
Snails		>1,000		30	28	7	
Hydra							
Bryozoans							
Sponge						X	X
Other							
Fish[4]							
YP		5	>100	67	54		
JD		4	4	62	>133	15	
SS		19	>100	>100	>128	51	32
TP			1	60			
SP			>100				
AL		4	>1,000	>1,000	>1,000	>1,000	>1,000
BR				1			
CC							
CP			1	3+1*	2	2	
ES							
BB							
LT							
WS				1			
SB				1			
SM					2		
LB						1	
BT							
LS							
QB							
SR							
XC							
WL							
Fish eggs[5]							
Riprap			AL,SP,YP	AL			
Sand							

(Continued).

Appendix 1. Continued.

Category	Apr	May	Jun	Jul	Aug	Sep	Oct
				1976			
No. of dives[1]	3	3	3	3	3	3	1
Periphyton[2]							
Structure	0	0	2.5	11.5	10.0	6.3	5.0
Riprap	1.2	1.2	1.5	2.5	1.0	0.5	0.5
Invertebrates[3]							
Crayfish	3	18	27	>216	>382	>134	5
Snails		2		1			
Hydra							
Bryozoans			X			X	X
Sponge					X	X	X
Other	T	E		N			
Fish[4]							
YP	2	1	107	13	8	1	
JD		>119	24	11			
SS	13	79	89	59	135	9	8
TP			1		3		
SP		2	2	7	2	3	
AL	1	2	>1,000	>100	>243	>1,000	108
BR			1		1		
CC							
CP		1	2	8	7	30	
ES							
BB							
LT							
WS				1			
SB				1			
SM	1	1			1		
LB							
BT							
LS							
QB							
SR							
XC							
WL							
Fish eggs[5]							
Riprap			SP,AL	AL	AL		
Sand			AL	AL			

(Continued).

Appendix 1. Continued.

Category	Apr	May	Jun	Jul	Aug	Sep	Oct
				1977			
No. of dives[1]	3	3	3	3	3	2	
Periphyton[2]							
Structure	0.5	0.5	1.5	1.8	3.0	1.5	
Riprap	0.4	1.0	1.0	1.2	1.5	0.3	
Invertebrates[3]							
Crayfish	>225	122	>125	>298	>151	15	
Snails				1			
Hydra							
Bryozoans					X		
Sponge	X	X	X	X	X	X	
Other							
Fish[4]							
YP	7	43	14	187	13		
JD	1	200	50	28	11		
SS	21	42	8		7		
TP							
SP		5					
AL	1	39	>1,000	16	>1,000	1	
BR		1					
CC							
CP	5	13	31	14			
ES							
BB							
LT							
WS		1					
SB							
SM	2				>102		
LB		2					
BT							
LS							
QB							
SR							
XC							
WL							
Fish eggs[5]							
Riprap		JD,YP	JD,YP,AL	AL			
Sand			AL	AL			

(Continued).

Appendix 1. Continued.

Category	Apr	May	Jun	Jul	Aug	Sep	Oct
				1978			
No. of dives[1]	2	3	3	3	3	3	2
Periphyton[2]							
Structure	0.3	0.1	7.5	10.0	3.0	2.0	1.7
Riprap	0	1.0	3.5	8.0	7.5	2.5	2.0
Invertebrates[3]							
Crayfish	5	7		1	11	47	
Snails	1	1					
Hydra							X
Bryozoans					X		
Sponge			X		X	X	X
Other		M,C					
Fish[4]							
YP		11	13	25	1		
JD		7	6	15	5	5	
SS	5	14			8	10	1
TP			8			3	
SP			2		11	2	
AL			>360	>1,000	3	>100	>1,000
BR							
CC							
CP		2	5	25			5
ES							
BB							
LT							
WS					1		
SB							
SM		50			5		
LB							
BT							
LS			4				
QB							
SR							
XC							
WL				1			
Fish eggs[5]							
Riprap		SS	AL,SP	AL			
Sand				AL			

(Continued).

Appendix 1. Continued.

Category	Apr	May	Jun	Jul	Aug	Sep	Oct
				1979			
No. of dives[1]	3	3	3	3	3	2	2
Periphyton[2]							
Structure	0	0.5	1.5	3.0	6.0	1.0	1.0
Riprap	0.5	1.2	3.0	5.5	5.0	3.0	2.5
Invertebrates[3]							
Crayfish		4		8	1	6	5
Snails							
Hydra					X	X	
Bryozoans							
Sponge			X		X	X	
Other							
Fish[4]							
YP		99	1	170	36		2
JD		8	5	9	9		
SS		3	3	8	1		
TP		1		2		1	2
SP		2		36		8	3
AL				8	>1,000	327	>1,000
BR		3		1	1		
CC							
CP		8		4	1	1*	
ES							
BB							
LT							
WS							
SB							
SM		5	3				
LB							
BT							
LS			1				
QB						1	
SR							
XC							
WL							
Fish eggs[5]							
Riprap		YP		AL			
Sand				AL			

(Continued).

Appendix 1. Continued.

Category	Apr	May	Jun	Jul	Aug	Sep	Oct
				1980			
No. of dives[1]	2	2	3	3	2	2	3
Periphyton[2]							
Structure	0	0	2.0	1.6	6.5		1.0
Riprap	3.0	1.8	1.5	6.0	1.0	1.3	1.0
Invertebrates[3]							
Crayfish	4	7		13	10	5	5
Snails							
Hydra		X					
Bryozoans		X					
Sponge						X	
Other							
Fish[4]							
YP		15	114		7	7	
JD		2	10	3	3	31	
SS		53	38			27	
TP	5	1		1			
SP			>106			7	
AL	79	1	15	40	50	>103	
BR		1	1				
CC							
CP			30				
ES							
BB			1				
LT				1			
WS					1		
SB							
SM		2	6	41	5	210	
LB							
BT	1						
LS							
QB							
SR							
XC							
WL							
Fish eggs[5]							
Riprap			AL				
Sand			AL				

(Continued).

Appendix 1. Continued.

Category	Apr	May	Jun	Jul	Aug	Sep	Oct
				1981			
No. of dives[1]	3	2	3	3	2	2	2
Periphyton[2]							
Structure	0	1.5	12.5	7.5	1.0	0.8	0.7
Riprap	1.0	2.5	5.0		2.0	1.5	1.8
Invertebrates[3]							
Crayfish	4	9		3			1
Snails							
Hydra							
Bryozoans					X	X	
Sponge				X	X	X	X
Other					P	P	
Fish[4]							
YP		>110		9	>243		
JD	2	>109	28	5	4	1	
SS	21	89	11	1	3	22	
TP	1		>175	30	3	1	
SP	5	7	31	1	1		
AL	4	60	15	40	2	>1,000	4
BR							
CC							
CP	18		30				
ES							
BB							
LT							1
WS						1	
SB							
SM			11	15			
LB							
BT							
LS							
QB							
SR							
XC							
WL							
Fish eggs[5]							
Riprap		YP					
Sand							

(Continued).

Appendix 1. Continued.

Category	Apr	May	Jun	Jul	Aug	Sep	Oct.
				1982			
No. of dives[1]	1	2	2	3	3	2	2
Periphyton[2]							
Structure	0						
Riprap	0.5	1.0			4.0		
Invertebrates[3]							
Crayfish			3				1
Snails							
Hydra					X		
Bryozoans							
Sponge					X		
Other							
Fish[4]							
YP		12	44	>765	>131		
JD		5			7	1	
SS		84	1	1	34	5	3
TP			1			2	
SP			2		1	12	
AL		1	>178	1	>170	>114	>1,000
BR					1		
CC				1			
CP		3*		>100	>100+6*		
ES							
BB							
LT							
WS				1			
SB							
SM						3	
LB					1		
BT							
LS							
QB							
SR						1	
XC							1
WL							
Fish eggs[5]							
Riprap							
Sand							

1 Total number of standard series dives (usually three) made in the ripraped area surrounding the plant intake and discharge structures. From August 1977 to May 1982, diving in the area was reduced to only those occasions when water was not being discharged from one of the structures. During June 1982, the technical specifications for monitoring were reduced to two dives per month in the intake area only.

2 Length (cm) of periphyton on top of the structure and on riprap adjacent to the base of the structure as measured by divers.

3 Numbers of crayfish and snails were counted by divers. Values showing the greater than (>) symbol are totals which included open-ended estimates of 100+ or 1,000+ (see Fig. 2 and Methods). Presence of other invertebrates was noted (X) but animals were not enumerated. C = Chironomid (midge) larvae, E = Ephemeropterid (mayfly) larvae, M = Mysis, N = Notonectid (back swimmer), P = Pontoporeia, T = Trichoptera (caddisfly) larvae.

4 See Appendix 3 for scientific and common names, and abbreviations for fish. * = observed at intake stations.

5 Denotes observation of eggs of the fish species indicated during standard series dives on riprap substrate or during dives at reference stations north and south of the plant in areas of sand substrate.

Appendix 2. Duplicate observations made during transect swims in southeastern Lake Michigan, April through October, 1975-1982. Observations were made by two divers swimming side-by-side for 10 m along the base of the south intake structure of the D. C. Cook Nuclear Plant. Each diver examined an area 1 m wide. Total area of each transect was 10 m^2. Omitted swims are indicated by an asterisk (*). D = day, N = night.

	Apr		May		Jun		Jul		Aug		Sep		Oct	
	N	D	N	D	N	D	N	D	N	D	N	D	N	D
							1975							
Invertebrates														
Crayfish	*	*	5,0	*	8,4	16,0	6,30	54,0	18,7	13,8	5,3	3,1	14,6	6,2
Snails	*	*	30,100	*	0,0	0,0	1,0	5,0	2,0	3,1	1,2	0,0	0,0	0,0
Fish														
Yellow perch	*	*	4,0	*	30,0	0,0	2,1	0,0	8,7	0,0	0,0	0,0	0,0	0,0
Alewife	*	*	1,0	*	35,80	0,0	50,21	0,0	7,100,7,100	0,0	7,100,7,100	0,0	0,0	7,100,7,100
Johnny darter	*	*	4,0	*	0,0	0,0	15,3	23,0	9,4	2,4	0,0	4,0	0,0	0,0
Sculpin	*	*	50,100	*	6,0	15,0	5,17	16,0	7,4	2,0	3,2	3,0	4,8	1,3
Spottail shiner	*	*	0,0	*	50,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
							1976							
Invertebrates														
Crayfish	3,0	0,0	10,6	0,0	11,4	2,0	40,23	3,6	32,4	15,8	50,22	1,0	2,3	0,0
Snails	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Fish														
Yellow perch	2,0	0,0	1,0	0,0	4,5	0,0	4,1	0,0	0,0	0,0	1,0	0,0	0,0	0,0
Alewife	0,0	0,0		0,0	12,10	30,0	2,0	0,0	>100,30	0,0	2,18	0,0	0,0	0,0
Johnny darter	0,0	0,0	2,0.	4,6	8,4	4,3	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0
Sculpin	3,1	1,0	17,8	2,5	16,17	2,3	5,6	1,0	14,1	1,4	1,6	1,0	2,4	0,0
Spottail shiner	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	1,0	0,0	1,0	0,0	0,0	0,0
Rainbow smelt	1,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Burbot	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0
Trout-perch	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0

(Continued).

Appendix 2. (Continued).

	Apr		May		Jun		Jul		Aug		Sep		Oct	
	N	D	N	D	N	D	N	D	N	D	N	D	N	D
1977														
Invertebrates														
Crayfish	10,8	5,2	8,11	0,0	13,6	2,0	17,35	5,0	23,26	1,0	9,4	2,0	*	*
Snails	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	*	*
Fish														
Yellow perch	0,0	0,0	2,6	1,0	1,1	2,1	6,3	0,0	0,0	0,0	0,0	0,0	*	*
Alewife	0,0	0,0	0,0	1,0	15,8	50,25	1,0	0,0	1,1	0,0	1,0	0,0	*	*
Johnny darter	0,0	0,0	7,6	4,7	4,6	1,2	0,0	2,0	0,0	4,1	0,0	0,0	*	*
Sculpin	3,2	4,2	4,6	0,0	3,1	3,0	0,0	0,0	4,1	0,0	0,0	0,0	*	*
Rainbow smelt	2,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	*	*
1978														
Invertebrates														
Crayfish	*	*	2,5	0,0	0,0	0,0	*	0,0	1,3	0,0	0,0	0,0	*	0,0
Snails	*	*	0,0	1,0	0,0	0,0	*	0,0	0,0	0,0	0,0	0,0	*	0,0
Fish														
Yellow perch	*	*	1,0	0,0	2,8	8,0	*	0,0	0,0	0,0	0,0	0,0	*	0,0
Alewife	*	*	0,0	0,0	2,5	30,30	*	0,0	1,0	0,0	0,0	0,0	*	>1,000,>1,000
Johnny darter	*	*	0,0	0,0	1,0	1,3	*	3,5	1,0	0,0	1,0	0,0	*	0,0
Sculpin	*	*	0,0	0,0	1,0	0,0	*	1,0	1,0	0,0	0,0	0,0	*	1,0
Spottail shiner	*	*	0,0	0,0	1,0	0,0	*	0,0	2,2	0,0	0,0	0,0	*	0,0
Rainbow smelt	*	*	2,1	0,0	0,0	0,0	*	0,0	0,0	0,0	0,0	0,0	*	0,0

(Continued).

Appendix 2. (Continued).

	Apr		May		Jun		Jul		Aug		Sep		Oct	
	N	D	N	D	N	D	N	D	N	D	N	D	N	D
							1979							
Invertebrates														
Crayfish	*	*	3,1	0,0	0,0	0,0	8,0	0,0	1,0	0,0	0,0	0,0	0,0	3,0
Fish														
Yellow perch	*	*	6,6	0,0	0,0	0,0	5,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0
Alewife	*	*	0,0	0,0	0,0	0,0	5,0	0,0	0,0 >1,000,>1,000		2,0	0,0	5,0	0,0
Johnny darter	*	*	0,0	1,0	1,0	0,0	5,0	3,0	0,0	0,0	0,0	0,0	0,0	0,0
Sculpin	*	*	0,0	0,0	0,0	0,0	8,10	0,0	1,01	0,0	2,2	0,0	1,0	1,0
Spottail shiner	*	*	0,0	0,0	0,0	0,0	1,10	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Burbot	*	*	2,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Trout-perch	*	*	0,0	0,0	0,0	0,0	2,0	6,0	0,0	0,0	0,0	0,0	0,0	0,0
							1980							
Invertebrates														
Crayfish	0,0	0,0	1,1	0,0	0,0	0,0	3,0	0,0	2,1	0,0	0,0	0,0	1,0	2,0
Fish														
Yellow perch	0,0	0,0	2,0	0,0	2,0	0,0	0,0	0,0	2,5	0,0	1,0	0,0	0,0	0,0
Alewife	0,0	0,0	0,0	0,0	1,3	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Johnny darter	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0
Sculpin	0,0	0,0	6,4	0,0	3,0	0,0	0,0	0,0	1,3	0,0	1,0	0,0	1,0	0,0
Spottail shiner	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	2,0	0,0	0,0	0,0
Rainbow smelt	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	5,0	0,0	30,20	0,0	0,0	0,0
Burbot	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Trout-perch	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0

(Continued).

Appendix 2. (Concluded).

	Apr		May		Jun		Jul		Aug		Sep		Oct	
	N	D	N	D	N	D	N	D	N	D	N	D	N	D
1981														
Invertebrates														
Crayfish	4,0	1,0	4,0	0,0	0,0	0,0	1,1	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Fish														
Yellow perch	0,0	0,0	8,0	0,0	2,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Alewife	4,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	2,0	0,0	2,0	0,0	0,0	0,0
Johnny darter	2,0	0,0	0,0	3,1	2,0	4,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Sculpin	20,0	0,0	2,0	2,0	3,3	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0
Spottail shiner	5,0	0,0	5,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	2,1	0,0	0,0	0,0
Rainbow smelt	0,0	0,0	0,0	0,0	6,5	0,0	5,10	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Trout-perch	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
1982														
Fish														
Yellow perch	0,0	0,0	2,0	5,0	1,12	0,0	*	*	*	*	*	*	*	*
Alewife	0,0	0,0	0,0	0,0	2,5	30,30	*	*	*	*	*	*	*	*
Sculpin	0,0	0,0	0,0	0,0	1,0	0,0	*	*	*	*	*	*	*	*
Spottail shiner	0,0	0,0	0,0	0,0	1,0	0,0	*	*	*	*	*	*	*	*

Appendix 3. Scientific name, common name, and abbreviations for species of fish observed by divers in southeastern Lake Michigan near the D. C. Cook Nuclear Plant, 1973-1982. Names were assigned according to Robins et al. (1980).

Scientific name	Common name	Abbreviation
Alosa pseudoharengus (Wilson)	alewife	AL
Carpiodes cyprinus (Lesueur)	quillback	QL
Catostomus catostomus (Forster)	longnose sucker	LS
Catostomus commersoni (Lacepede)	white sucker.	WS
Coregonus spp.[1]	unident. coregonid	XC
Cottus spp.[2]	unident. cottid	SS
Cyprinus carpio Linnaeus	common carp	CP
Etheostoma nigrum Rafinesque	johnny darter	JD
Ictalurus melas (Rafinesque)	black bullhead	BB
Ictalurus punctatus (Rafinesque)	channel catfish	CC
Lota lota (Linnaeus)	burbot	BR
Micropterus dolomieui Lacepede	smallmouth bass	SB
Micropterus salmoides (Lacepede)	largemouth bass	LB
Moxostoma macrolepidotum (Lesueur)	shorthead redhorse	SR
Notropis atherinoides Rafinesque	emerald shiner	ES
Notropis hudsonius (Clinton)	spottail shiner	SP
Osmerus mordax (Mitchill)	rainbow smelt	SM
Perca flavescens (Mitchill)	yellow perch	YP
Percopsis omiscomaycus (Walbaum)	trout-perch	TP
Salmo trutta Linnaeus	brown trout	BT
Salvelinus namaycush (Walbaum)	lake trout	LT
Stizostedion vitreum vitreum (Mitchill)	walleye	WL

1 May include both Coregonus artedii Lesueur (lake herring or cisco) and Coregonus hoyi (Gill) (bloater) because divers could not distinguish between these species while underwater.

2 May include both Cottus cognatus Richardson (slimy sculpin) and Cottus bairdi Girard (mottled sculpin) because divers could not distinguish between these species while underwater.

Appendix 1.7

Interactive Data Base Management System

for

Ecological Studies

Related

to the

Donald C. Cook Nuclear Power Plant

Special Report No. 119

Great Lakes Research Division

University of Michigan

THE UNIVERSITY OF MICHIGAN

Interactive Data Base Management System for Ecological Studies Related to the Donald C. Cook Nuclear Power Plant

WILLIAM Y. B. CHANG
and
MARYAM S. SHAHRARAY

Special Report No. 119 of the
Great Lakes Research Division

Interactive Data Base Management System for Ecological Studies Related to the Donald C. Cook Nuclear Power Plant

by

William Y. B. Chang

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Great Lakes and Marine Waters Center
The University of Michigan
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Ann Arbor, MI 48109

1986

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INTRODUCTION

Ecological studies related to the Donald C. Cook Nuclear Plant are unique. They differ from most environmental impact research in the extent of their coverage and the great length of the research period. This investigation included studies of bacteria, phytoplankton ecology, zooplankton ecology, benthic macroinvertebrate populations, fisheries, water chemistry, and physical limnology (winds, currents, ice, sediments). This study can serve as a valuable example for future environmental monitoring and is a great source of information for the enhancement of our understanding of the long-term dynamics in the near-shore region of a large lake. Accumulated data can be used for future power plant site planning and siting on the Great Lakes coastline.

The data base was begun in 1970 and has since grown rapidly in size. Although data archiving has been maintained continuously by each section, the archived information does not interface easily and cannot be used readily by a person without computer training. Furthermore, due to the rapid expansion of the data base, few individuals can maintain complete awareness of all available data and utilize pertinent information when analyzing a problem. The result is inefficiency in report writing and data interpretation. To improve this situation, a project to devise an interactive data base management system was initiated. This data system can improve efficiency in data retrieval and storage and house in one place all information from the studies related to the D. C. Cook Nuclear Power Plant. The latter provides a safeguard for access to these data by other interested persons for their research on Great Lakes ecosystems after the completion of the project. This data base encompasses 13 individual studies and is summarized in Table 1. The total includes more than

TABLE 1. Summary of data sets.

Sub-project	Sample Type	Years Archived
Phytoplankton	Lake Samples	1970-1982
	Entrainment Samples	1975-1982
Zooplankton	Lake Samples	1970-1982
	Entrainment Samples	1975-1982
Benthos	Lake Samples	1970-1982
	Entrainment Samples	1975-1982
	Impingement Samples	1975-1981
Field-caught Fish	Summary Statistics	1973-1982
	Lake Samples	1973-1982
	Impingement Samples	1973-1982
Larval Fish	Lake Samples	1973-1982
	Entrainment Samples	1975-1982
Nutrient and Anion	Entrainment and Lake Samples	1974-1982
Lake Water Chemistry	Lake Samples	1973-1982
Sediments	Lake Samples	1973-1977

one-half million cases of biological, chemical, and physical information on the nearshore of southeastern Lake Michigan.

The data base management program used is Taxir, which is an information storage and retrieval program and has general purpose features for keeping track of large organized data sets. The capability and benefits of such a system extend far beyond this and include the following items:

1. It offers a centralized data source and can be controlled and monitored effectively.
2. It allows for multiple users.
3. It reduces the data redundancy and increases efficiency in data retrieval and storage.
4. It can enhance data integrity, consistency, and accuracy and can provide security while greatly reducing efforts needed for generating reports and tables.

For this study, a general procedure was followed. The first step was to reorganize "raw data" in a form compatible with the Taxir data program. Comments were then solicited from each sub-project leader with respect to the appropriateness and adequacy of the information. If important parameters should be included but were not yet included in the data base, efforts were made to incorporate such information. Data verification was then performed, and errors were corrected. Because it was our intent that the data base be accessible to all interested persons, an interactive user program was written which was designed to improve user access and ease of operation.

This report documents in detail the procedures used and the programs written for establishing the data base management system for the D. C. Cook ecological study and describes the data contained in the data base as well as the ways in which these data can be accessed. An overview of each chapter is given below.

Chapter 1 is a review of Data Base Management Systems (DBMS) and their importance in scientific research, as well as the elements that need to be considered when selecting a DBMS program.

Chapter 2 is an introduction to available (DBMS) programs from the Michigan Terminal System (MTS) of The University of Michigan along with the characteristics of each DBMS program. Comparisons between these systems are made. The reasons for choosing the Taxir program for this task are discussed.

Chapter 3 is an introduction to data organization and how Taxir handles data structure. It also describes major terms and notations used in association with the establishment of the data base.

Chapter 4 is a description of the procedures and the flow diagram for establishing a data base for each sub-project. Details are given regarding the structures of different data sets, which include formats, parameters, ranges, software programs, and methods. All procedures and software programs used are described and documented. Explanations of how to access the data sets are also given.

Chapter 5 includes a presentation of the Interactive Computer Program, which is written in FORTRAN and can be interfaced with Taxir. This program is intended to improve user access and can help persons with little experience in accessing data with computers.

CHAPTER 1

DATA BASE MANAGEMENT SYSTEMS

Data Base Management Systems (DBMS) is a term that refers to the computer technology necessary for data collection, organization, storage, retrieval, and manipulation. A data base system (DBS) deals with record-keeping and making the computer function as a super filing system.

A Data Management System (DMS) works with the smallest unit of data, which is usually called a data <u>item</u>. A collection of items is called a <u>record</u>, and an organized collection of records constitutes a <u>file</u>. The occurrences of the records in a file are associated by means of a specified relationship.

The generally-accepted requirements for a DBMS include the capability to create, revise, add, and delete records from a file; retrieve records; sort; perform limited computations; and generate reports.

ADVANTAGES OF USING A DBMS

The advantages of working with a DBMS rather than a non-computer filing system are that the data can be accessed in a greater variety of ways, searched quickly, and changed more easily; and auxiliary programs can be applied to the data in the DBMS to produce reports, copies of the data, and other outputs. In non-computer filing systems, such outputs usually must be produced manually, a process which is time-consuming, subject to transcribing errors, and inefficient.

The advantages of Data Base (DB) technology in areas other than data filing can include:

- data independence,
- data shareability,
- non-redundancy of stored data,
- reliability,
- integrity,
- access flexibility,
- security,
- efficient performance (especially in view of large-size files), and
- greater administrative control.

These advantages are essential for developing and supporting modern integrated information systems, which bring together a variety of data and interrelate it for a variety of users, not just for one or for a limited few. The ability to share or use these data also minimizes the amount of redundant storage.

DATA BASE DESIGN

Data base design is the most important attribute of a data base management system and shows how the data items are classified and interrelated. In designing non-computer filing systems, an office-clerical typically invents a number of filing categories and decides which files are in which categories and what kinds of things are sorted in each file. The same design decisions must be made when computer systems analysts set up data bases.

TYPES OF COMPUTER DATA BASE MODELS

Technically, data base designs can be grouped according to their logical characteristics. One data base design may have many file categories with files within each category, another may allow each file to belong to several categories at once, and so on.

Each DBMS has certain capabilities and restrictions regarding the data base designs that it will support. The set of rules that determines which data base designs a given DBMS can support is called the "data model" of the DBMS. The term "data model" is used because the data base design rules for each DBMS constitute a set of assumptions about how a filing system generally behaves.

Because most data base management systems are expected to be general-purpose computing tools, it is the goal of most data models to be as general and as simple as possible. There are three major kinds of data models that are common: hierarchical, network, and relational. Of these, only the relational model maintains the logical simplicity of so-called flat files. A brief description of these models follows.

Hierarchical Model

The hierarchical model keeps data in a form resembling the following outline. For example, suppose there is a need to keep records of university students who are being used as subjects in psychology experiments. A hierarchical system would organize the data like this:

I.	Researcher	:Dr. Know
	Address	:Medical Bldg.
	Experiment Type	:Attention
	A. Subject	:John
	Telephone	:665-9988
	Major	:Computer Science
	Sex	:Male
	B.	:
	C.	:
II.	Researcher	:

The basic idea of the hierarchical model is that the data are organized into groups (in our example, researchers) which have subgroups (individual subjects in this instance); in turn, they can have subgroups, and so on, to the required degree of complexity.

It is important to note that each group in a hierarchical data base may have many subgroups, but each subgroup is in one and only one group. This is an example of what is called a "1-N" relation between groups and subgroups.

The major failing of this model is that few data base management problems remain strictly hierarchical. For example, if one person serves as a subject for two different reseachers, then the data would no longer behave in a strictly hierarchical manner.

Network Model

The network model could be considered an extension of the hierarchical data model. A network data model is simply a model that allows more or less arbitrarily complex relationships. Thus, in our example not only can the records of one researcher be related to those of many subjects, but also one subject record can be related to many researcher records. This is called a many-many relationship. The following relationships can serve as an example:

Researcher Dr. Know		Researcher Dr. Best	
Subject John	Subject Mary	Subject Bob	Subject Nancy

The biggest problem with the network data model is that the data base can become excessively complicated.

Relational Data Model

The relational data model is the most modern of all the data models. This is actually an extension of the flat-file data model (see Chapter 3). The flat-file data model treats data as a single collection of ordered items, each with the same format. For example, the following flat file contains the information about the subjects in our previous example,

Subject	Telephone	Major	Sex
John	665-9988	Computer Science	Male
.	.	.	.
.	.	.	.
.	.	.	.

while the following flat file keeps track of researchers:

Researcher	Address	Experiment Type
Dr. Know	Medical Bldg.	Attention
.	.	.
.	.	.
.	.	.

Then if we need to store the information about the relationship between researchers and subjects, there will be another flat file such as the one below:

Researcher	Subject	Date Assigned
Dr. Know	John	4/1/82
'	'	'
'	'	'
'	'	'

In order to have a practical records system using these flat files, we would need some data base management capable not only of storing them but also of manipulating them to retrieve and update the stored information. This data base management system would have to extract and combine information from the flat files in various ways, but the relational model has a flexibility that the flat-file data model cannot attain.

In general, any data base design that can be represented in the hierarchical or the network models can also be represented as a set of relations in the relational model. While it is true that the relational model is conceptually simple, there still remains a good deal of work to make that simplicity available to users at low cost.

AVAILABILITY OF DBM

The commercial products associated with data bases and data management systems have changed dramatically in the last several years, especially because of new hardware and software technologies. In the 1970s there were no more than two dozen widely marketed DBMS product lines; today there are hundreds. Major data management systems differ primarily in language utilized, file organization, and access method and level of system users.

Language Utilized

This deals with the difference between what are called self-contained and host-contained systems. The former usually provide a language designed for the non-programmers, whereas the latter are tied to such languages as COBOL, PL/1, ALGOL, and FORTRAN, and are especially for the application programmers who use these languages. Self-contained systems provide their own language, which is user-oriented and designed to be used by managers and others with minimal knowledge of programming.

It is important to note that self-contained languages are usually machine dependent. Few systems can operate effectively on more than one type of computer equipment.

File Organization

In examining data management systems, one must separate logical and physical file organization. A study of logical organization will show whether user requirements can be satisfied. A study of physical file organization indicates the handling procedures, file maintenance, retrieval capability, output, and similar operational features of the data management system.

Access Method and Level of System Users

A data management system makes it possible for various users to work with a common data base when the data base is an interrelated set of organization files. Three levels can be defined within the system users:

1. Systems Designers determine long-range objectives.
2. Middle Management oversees the daily operations of a company.
3. General Users need to have no knowledge of programming, and/or self-contained system language.

CRITERIA FOR SELECTING A DBMS

Too often, decisions on the selection of a DBMS are based on incomplete and inaccurate factors that can result in revisions and costly long-range repercussions. Selection of a DBMS should be done carefully in order to avoid a loss of time and money in the long run. In selecting a data base management system, four criteria should be considered:

1. suitability of the DBMS to the specific characteristics of the data to be handled,
2. simplicity of the system used,
3. time and cost involved, and
4. future needs.

A good DBMS should offer: 1) data independence, 2) data dictionary to define and control the data environment, 3) good query language to allow access to the data base, 4) good report-generating features, and 5) a simple high-level user language.

The time dedicated to an analysis and evaluation of the user's requirements and limitations, as well as the evaluations of the assets and limitations of the various DBMS available, can be the time most valuably spent. The planning time, carefully spent, can make the installation and use of a DBMS a profitable experience in both financial and managerial terms.

CHAPTER 2

DBMS SUPPORTED BY MTS

MICHIGAN TERMINAL SYSTEM

The Michigan Terminal System (MTS) is a very powerful operating system supported by the University of Michigan Computing Center. Like most large computer installations, it prohibits direct operation of the equipment by anyone but professional operators. The computer is under the combined control of its human operators and a master program called the operating system, which coordinates the jobs of the various users and provides them with a variety of auxiliary computing services.

MTS permits its users to operate in either interactive mode or batch mode. In interactive mode, a large number of users at remote terminals are able to use the computer concurrently and independently. The user in interactive mode usually types a message (e.g., command, statement, query) on his terminal keyboard and sees a response from the computer before typing the next statement, which may be a modification of the first one.

For jobs running in batch mode, the operating system is the same, but no dialogue is possible between the user and the computer. The user submits his entire job at once (in the form of a card deck) and waits for the entire output of the job. Batch mode is useful when there is no need for human-computer interaction. In both modes, the user appears, from his own point of view, to have the entire computer to himself.

DBMS ON MTS SUPPORTED BY THE COMPUTING CENTER

The computing center supports the Taxir and SPIRES data base management systems. Both systems are used primarily for academic applications, although they have been applied to a few administrative projects.

Taxir

Taxir is a generalized information storage and retrieval system which can be used at any computer installation within the MTS operating system. It is written and supported by the University of Michigan Computing Center. It is a completely self-contained system that provides facilities for defining, searching, and managing data bases that can be implemented as flat-file data bases.

Taxir is the simplest data base management system available on MTS at The University of Michigan and is the easiest system to learn and use. In general, Taxir is very inexpensive to use. It stores data in a highly compressed form, which reduces the cost of storage; and it retrieves data very rapidly, thereby reducing computer processing costs.

Taxir can be run in both interactive and batch mode. It provides a number of features that make it an attractive data base management system for many data base applications. It has a single high-level language, somewhat resembling English, that provides simple commands for defining, manipulating, updating, and querying data bases. The system has flexible report-generation facilities, which allow users to produce ordered, labeled, formatted outputs. Taxir provides an interface with MIDAS, a powerful statistical analysis program available to compensate for Taxir's few facilities for statistical features. In addition, it can be called through standard FORTRAN-calling conventions. In general, Taxir can best be used for data base applications in which 1) the data are represented in a flat-file structure, 2) the application requires a cheap, easy-to-use system, 3) users want to search on any field or combination of fields, and 4) MTS security facilities are sufficient.

SPIRES

The Stanford Public Information Retrieval System (SPIRES) was written at Stanford University. It is an on-line general-purpose information and retrieval system available in the MTS operating system and supported by the Computing Center at The University of Michigan. It is a completely self-contained DBMS that provides extensive facilities for defining, searching, updating, and managing data bases. SPIRES is based on the hierarchical data model, but it also provides some network capabilities (see Chapter 1).

Although SPIRES is a general-purpose system, it has special features for efficiently and conveniently storing and retrieving text or character data. Any application that requires storage of lengthy textual material is a strong candidate for SPIRES. For example, designers of bibliographic data bases would probably find SPIRES the most appropriate data base management system on MTS.

Output formats and other special SPIRES features can be used to generate reports, construct tables, sort data, and display data in a variety of formats. Because SPIRES is so flexible, it is also very complex. This means that it is more costly and often more difficult to use than the other DBMS available on MTS. It is true that searching an existing SPIRES data base is not difficult, but defining a new data base usually is not a simple task. Some programming background is often required for a better understanding of this language.
In general, one should consider SPIRES for data bases when the data 1) involve lengthy textual materials such as characters or strings, 2) require many

repeating fields, 3) can best be stored hierarchically, 4) are very large in number, and 5) require extensive DBM facilities.

OTHER DBMS

Other units at The University of Michigan also support some DBMS on MTS, which may be used by anyone with a computing center account. The major ones are MICRO, MIDAS, OSIRIS, ADBMS, ARCH:MODEL, and Relational Management System (RIM). A brief description of each system follows.

MICRO

The MICRO information management system, which operates only on MTS, is written and supported by the Institute of Labor and Industrial Relations, a joint institute of The University of Michigan and Wayne State University. MICRO is a self-contained information, storage, and retrieval system. It is based on the relational data model.

MICRO permits non-programmers to define, enter, interrogate, manipulate, and update user-defined collections of data in a relatively unstructured and unconstrained environment. It has general applicability to a wide variety of educational, administrative, and research data processing activities. Its capabilities lie roughly between those of Taxir and SPIRES. It is designed to be run interactively from computer terminals, but caution is required when trying to run a batch job.

MICRO is very powerful in terms of the programming language because of its English-like grammer, which makes it easy to learn and use. Predetermined procedures can be easily executed in MICRO to deal with complex reporting and retrieval problems. It has limited facilities for character string (text) data. It can be interfaced to MIDAS (the statistical package on MTS) for any statistical analysis.

MIDAS and OSIRIS

These are both statistical analysis packages which provide some data management capabilities. MIDAS is supported by the Statistical Research Laboratory. OSIRIS is supported by the Survey Research Center of the Institute for Social Research. They both work in interactive and batch modes.

ADBMS

This is a host-language-dependent DBMS based on the network data model. Users must write their own "interface" program to use ADBMS. It is written in FORTRAN but can be called from programs written in FORTRAN, COBOL, and PL/1 on MTS. ADBMS is particularly useful when one is faced with complex structures and when access and reporting requirements are algorithmic in nature. It also can be used with many different operating systems and computers.

ADBMS is written and supported by a Research Project of the Information System Design Optimization Society (ISDOS) in the department of Industrial and Operations Engineering (IOE), the College of Engineering at The University of Michigan.

ARCH:MODEL

ARCH:MODEL is a DBMS designed for applications involving geometric modeling, such as computer-aided architectural design. It is supported by the Architectural Research Laboratory of the College of Architecture and Urban Planning at The University of Michigan.

Relational Management System (RIM)

This is a self-contained system based on the relational model. It provides features for combining and manipulating flat files. Data can include real and integer vectors and also matrices. It has extensive on-line documentation and help facilities. It is supported by the Architectural Research Laboratory but is available to all in the University community.

CRITERIA FOR A SUITABLE SELF-ORIENTED DBMS

In choosing a good self-contained high-level language, one should consider the following properties:

1) A substantial number of prospective users of the language must exist;
2) The language must solve a substantial portion of the problems confronting the intended users;
3) It should not be needlessly difficult to learn;
4) It should be natural to write programs in the language which are easy to understand;
5) Any limitation of the language should be clearly justified (e.g., learning ease, processing efficiency, available capacity); and
6) The language should provide the users with appropriate access to facilities for effective communication with the environment.

JUSTIFICATION FOR SELECTION OF TAXIR

After careful study and comparison of the available DBMS on MTS, Taxir was chosen for this project. Comparisons were done mainly between Taxir, SPIRES, and MICRO. All three are general-purpose DBMS and are simpler and stronger than the others. Although SPIRES has many good features, running SPIRES programs is costly and time consuming. Furthermore, the advantage which SPIRES has in dealing with bibliographic features is not of interest here. Because of the complexity involved in the design of a new SPIRES data base, it has been recommended that, when possible, one should use Taxir or MICRO instead of SPIRES.

Because in this study data sets are represented in forms of flat files, the final comparisons were done between MICRO and Taxir. Although MICRO can work with several data sets simultaneously and has rather good on-line documentation, Taxir has the following advantages:

1) Taxir is written, supported, and maintained by the Computing Center of The University of Michigan;
2) Taxir is the simplest DBMS to learn and use;
3) It is cheaper to run a Taxir program;
4) Taxir stores data in a highly compressed form (less memory space is needed);
5) Information retrieval is faster with Taxir;
6) Taxir has flexible querying and display features;
7) It is possible to call Taxir from a FORTRAN program for further applications; and
8) Taxir can be run safely in both interactive and batch modes.

These advantages determined the choice of Taxir for the DBMS for the D. C. Cook environmental impact study.

CHAPTER 3

TAXIR ORGANIZATION

TAXIR DATA BASE

A Taxir data bank is a collection of items, each of which contains data belonging to information categories called descriptors containing all the relevant information about some entity being described by the data bank. For example, a phytoplankton data bank would contain one item for each species on the list. Each item in that data bank would consist of several pieces of information about one presented species, such as day, month, year, location, major group, cell number, and so on.

Each descriptor represents an attribute of the entities being described by the data bank. For example, a phytoplankton data bank could have the descriptors such as day, month, year, location, major group, cell numbers, etc. That is, each item in a data bank is associated with a series of data values (descriptors). There should be one value for each descriptor. Thus a Taxir data bank may be thought of as a two-dimensional matrix in which each row corresponds to an item and each column corresponds to a descriptor. This data organization is called a flat-file structure (discussed in next section). Every Taxir data bank has the following structure:

	Descriptor 1	Descriptor 2	Descriptor 3............	Descriptor N
Item 1				
Item 2				
.	States	States	States	States
.				
.				
.				
Item M				

The range of values allowed for a descriptor in a data bank is called a descriptor state, which may be integer/real numbers or strings of characters. This concept is identical to that of range for a parameter. For example, if the descriptor state for years is 1971 to 1973, then the descriptor year could have the states 1971, 1972, and 1973.

FLAT-FILE DATA MODEL

As was mentioned in Chapter 1, the relational model is the extension of the flat-file data model. The flat-file data model is the simplest and the oldest data model. A flat-file DBMS keeps data in the form of a flat file, (e.g., mailing list data bank). Each item in the flat file is called a record. Each record corresponds to a single complete entry in the file. Records are composed of data elements.

A data element is basically an irreducible data component. Each data element has a name or a value. Data elements are sometimes called fields. Every record in the flat-file data base has the same number of elements, and each record has data values that represent one object in the real world.

FLAT-FILE NATURE OF TAXIR DATA BANK

The way in which Taxir organizes and manipulates data is based on a simple notion of set theory using a flat-file data model. In general, if the information can be stored as a single flat file, then the data base can be stored as a Taxir data bank. In each Taxir data bank, each item has one and only one state for each descriptor. That is, each item in a Taxir data bank corresponds to a record in a flat-file data base, each descriptor corresponds to a field, and each descriptor-state corresponds to a value. Furthermore, like other flat-file DBMS, Taxir does not allow structure fields (i.e., descriptors may not consist of other descriptors); and it provides no direct access to the items in one data bank based on information stored in another data bank.

DESIGN OF THE DATA BANK

Before using Taxir, one needs to consider the following for the design of a data bank:

1) Number of data banks needed
2) Item(s) in each data bank
3) List of the descriptors for each item
4) List of states for each descriptor
5) Kind of queries (questions) expected
6) Nature of information flow and work flow
7) Cost and time involved

In most cases, planning and time will be needed to decide upon these points, but it is essential to study all the constraints in order to design and create a data bank that meets all the requirements.

TYPE OF DATA SUPPORTED BY TAXIR

Associated with each descriptor in a Taxir data bank is a descriptor type which specifies what data values may be used as states for that descriptor. Taxir permits three descriptor types: from-to, order, and name, which provide the capability to store numerical (integer/real values), codified (categorical), and general character-string (words) data, respectively. Taxir also provides some features for handling missing data for each of these descriptor types identified as unknown states. The descriptor types are specified by the designer of a data bank when the data bank is defined.

The thing to consider here is that Taxir automatically assigns code numbers for both descriptors and their states to a data bank. Thus a user can have the choice of typing either the name of the descriptors and their states or the codes for both of them when communicating with Taxir.

RUNNING TAXIR

There are three ways to use Taxir: 1) as an interactive system from a terminal; 2) as a non-interactive system in batch mode, and 3) as a subroutine by calling it from a user program. In each case, user inputs to Taxir must be in the form of Taxir statements, MTS commands, or input data. Each Taxir statement is a request for Taxir to do some data processing or to modify the Taxir environment. Each statement begins with a statement name, known as a statement type. Most statements also include additional information, which further specifies what the user wants Taxir to do. The system reads and executes each statement before treating the next statement. There are no facilities for conditional jumps; hence, no program branching or looping. In other words, the execution of the Taxir statements is sequential.

DATA ENTRY AND DATA COMPRESSION

Taxir provides the following data entry capabilities:

1) Data can be entered in batch mode or in interactive mode.

2) Data can be entered directly from punch cards, MTS disk files, or terminals, and indirectly from magnetic tapes and other available machine-readable forms.

3) Data to be entered can be in a variety of user-specified fixed or free formats.

4) Taxir assigns a default state for any missing values.

5) Taxir does some data validation on all data.

6) Data are automatically stored in a highly compressed form.

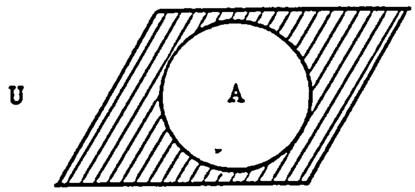
This last capability of Taxir is particularly important in saving memory space. The compression process is completely automatic and unseen by Taxir users who cannot (need not) control it.

RETRIEVING DATA AND BOOLEAN EXPRESSIONS

The power to retrieve information selectively from a data bank is the power to name subsets of interest from the total bank. For this purpose, Taxir applies the language of boolean algebra.

A boolean expression which defines the subset of items from the data bank consists of a series of operators and operands. A set of rules defines how the operators act on the operands to yield a result. These operators are complement (NOT), intersection (AND), and union (OR).

The operands are sets, as are the results. The figures below explain these concepts graphically:



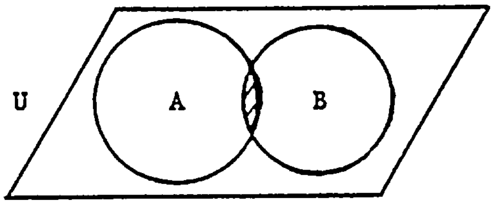
(1)

Complement,

if U = all the students in the class and

A = those with hats,

then NOT A = those without hats (shaded area).



(2)

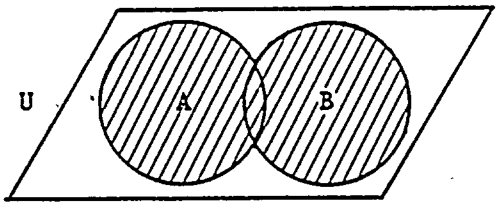
Intersection,

if U = all the students in the class and

A = those with hats and

B = those with coats,

then A AND B = those with both hats and coats (shaded area).



(3)

Union,

if U = all the students in the class and

A = those with hats and

B = those with coats,

then A OR B = those with hats or coats or both (shaded area).

Taxir boolean expressions provide simple, flexible ways for users to select items by specifying simple or complex search criteria involving any or all of the descriptors in a data bank. The retrieving statements enable Taxir users to:

1) Find out how many items meet some user specified criteria, prior to displaying, deleting, or updating them.
2) Retrieve and immediately display some user-specified set of items.
3) Retrieve items based on the states of any descriptor in a data bank.
4) Issue complex search requests involving any combination of descriptors.
5) Narrow a search result before displaying or updating the items in it.

DISPLAYING DATA IN TAXIR

Taxir display facilities include features for:

1) Displaying some or all of the descriptor-state for selected items.
2) Displaying data in a variety of formats.
3) Sorting output in terms of any descriptor.
4) Generating a report, including subtotals and totals.

(Note that Taxir can interface with MIDAS for further statistical computations.)

CHAPTER 4

PROGRAMMING PROCEDURES FOR ESTABLISHING THE COOK DATA BASE

DESCRIPTION OF THE COOK DATA BASE

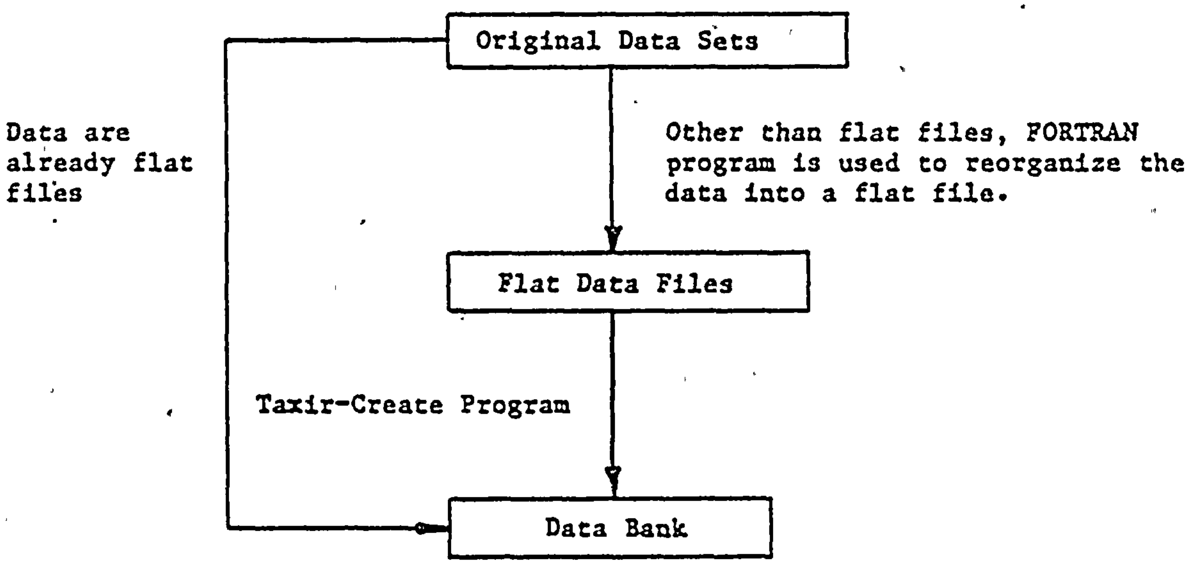
The methods used to establish the Cook Project data base are discussed in this chapter. This data base includes 15 data banks which are shown below:

Group	Data Type		Name of Data Bank
Phytoplankton	Lake Samples	1.	Lake.Phytoplankton
	Entrainment Samples	2.	Entrained.Phytoplankton
Zooplankton	Lake Samples	3.	Lake.Zooplankton
	Entrainment Samples	4.	Entrained.Zooplankton
Benthos	Lake Samples	5.	Lake.Benthos
	Entrainment Samples	6.	Entrained.Benthos
	Impingement Samples	7.	Impinged.Benthos
Field-Caught Fish	Summary Statistics	8.	Adult.Fish.Summary.Statistics
	Lake Samples	9.	Lake.Adult.Fish
	Impingement Samples	10.	Impinged.Adult.Fish
Larval Fish	Lake Samples	11.	Lake.Larvae
	Entrainment Samples	12.	Entrained.Larvae
Nutrient and Anion	Lake and Entrainment Samples	13.	Nutrients
Lake Water Chemistry	Lake Samples	14.	Lakewater
Sediments	Lake Samples	15.	Sediments

The explanations for the methods used along with the lists of the programs, the examples, and other helpful comments are provided in the sections which follow. It is hoped that this information can facilitate users in accessing data of interest, retrieving the needed information, and using the provided methods for establishing a similar data base in the future.

GENERAL PROCEDURES

To establish a data base using Taxir, the data must be in flat-file form. Once they are in that form, a Taxir program is used to enter these data to the computer data base program. Because most of the Cook data were not in the form of flat files, FORTRAN programs were written to reorganize these data into the flat-file forms. The general procedures involved in this operation are shown in the following flow chart.



For each data set, the FORTRAN program and the programs to create a Taxir data base for this data set are presented along with the flow chart diagram. It is noted that the FORTRAN programs written for this project are used not only to reformat the data sets but also in some cases to combine the parameters of interest from several data sets into a single flat file.

LAKE PHYTOPLANKTON

The Lake.Phytoplankton data bank is one of the largest data banks created for this project. It contains 13 descriptors and 90,076 items. The descriptors and their codes are listed below:

1-DAY

2-MONTH

3-YEAR

4-LOCATION

5-NAME

6-TEMPERATURE

7-SPECIES CODES

8-MAJOR GROUPS

9-CELLS

10-FRACTION

11-TOTAL CELLS

12-DIVERSITY

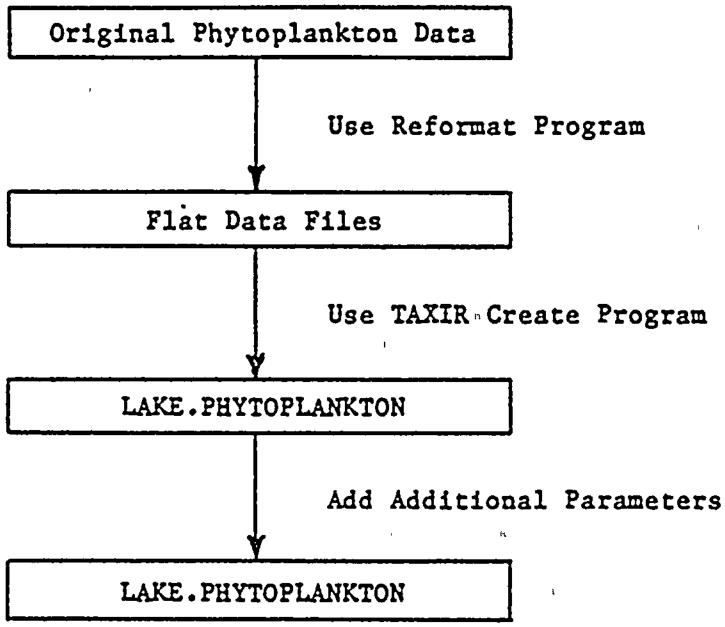
13-REDUNDANCY

The monthly number of phytoplankton items collected since November 1970 is listed in Table 4.1.

TABLE 4.1. The number of data items in the Lake Phytoplankton data bank for the D. C. Cook Plant data.

Year	Month	Total # of Items	Year	Month	Total # of Items	Year	Month	Total # of Items
70	NOV	(1,179)	76	APR	(2,105)	79	APR	(2,302)
71	APR	(988)		MAY	(735)		MAY	(674)
	JUL	(1,799)		JUN	(545)		JUN	(736)
	SEP	(1,589)		JUL	(1,925)		JUL	(1,516)
	NOV	(985)		AUG	(504)		AUG	(690)
72	APR	(1,078)		SEP	(880)		SEP	(491)
	JUL	(758)		OCT	(2,441)		OCT	(2,045)
	OCT	(1,607)	77	APR	(2,405)		NOV	(724)
73	APR	(1,621)		MAY	(602)	80	APR	(2,108)
	JUL	(1,321)		JUN	(598)		MAY	(696)
	OCT	(1,495)		JUL	(1,861)		JUN	(653)
74	APR	(1,628)		AUG	(708)		JUL	(1,919)
	MAY	(513)		SEP	(991)		AUG	(850)
	JUN	(498)		OCT	(2,390)		SEP	(725)
	JUL	(1,654)		NOV	(590)		OCT	(2,180)
	AUG	(393)	78	APR	(2,432)		NOV	(555)
	SEP	(338)		MAY	(852)	81	APR	(1,705)
	OCT	(2,190)		JUN	(989)		MAY	(695)
75	APR	(1,727)		JUL	(2,897)		JUN	(371)
	MAY	(393)		AUG	(638)		JUL	(1,248)
	JUN	(685)		SEP	(671)		AUG	(571)
	JUL	(1,461)		OCT	(2,610)		SEP	(762)
	AUG	(455)		NOV	(743)		OCT	(2,080)
	SEP	(643)					NOV	(655)
	OCT	(2,839)				82	APR	(1,749)
							MAY	(429)

The flow chart representing the stages in the creation of the Lake.Phytoplankton data bank is as follows:



Phytoplankton Data Files and the Reformat Programs

The original phytoplankton data files are stored in the files: RDmonthyear (for example, RDNOV70). The data between November 1970 and December 1980 are saved on the tape "Phyto," the 1981 and 1982 data files can be found on the "Phyto2" tape. Because there are some differences in the data structures in these files, especially in the formats of the headlines, different reformat programs are needed to handle these forms of the data structures. The following is a list of the names of the reformat programs for different sets of the data.

Reformat Program	Data Set
REFORMAT1	All months of 1971, 1972, 1973; and May, June, August, September in 1974.
REFORMAT2	November 1970; all months of 1975; and April, May, July, October in 1976.
REFORMAT3	April, July, October in 1974.
REFORMAT4	June, August, September in 1976; and all months of 1977, 1978, 1979, 1980, 1981, and 1982.

These reformat programs are listed in Tables 4.2-4.5.

Taxir Create Program

Reformat programs discussed in the last section were used to provide the phytoplankton data in the form of flat files. The Taxir Create program PLTAXIRCR was then used to create the LAKE.PHYTOPLANKTON data bank. The contents of the PLTAXIRCR program are given in Table 4.6.

TABLE 4.2. Program REFORMAT1.

```
C PROGRAM  REFORMAT1  IS RUN TO REORGANIZE LAKE PHYTOPLANKTON RAW DATA
C FILES.  THIS PROGRAM IS USED FOR ALL MONTHS OF 1971, 1972, 1973; AND
C MAY, JUNE, AUGUST, SEPTEMBER IN 1974.
C UNIT 5 IS ASSIGNED TO INPUT FILE. (RAW DATA FILE).
C UNIT 6 IS ASSIGNED TO OUTPUT FILE. (REFORMATTED DATA FILE).
C UNIT 7 IS ASSIGNED TO ANOTHER OUTPUT FILE FOR THE VALUES OF DL & SW.
C
C
C
C
C*******
C*******        INITIALIZE VARIABLES.
C*******
C
      LOGICAL*1 CODE(9,200)
      REAL CTS(200),FRAC(200),H(16)
C
      CONST=-1./ALOG(2.)
C
C*******
C*******        READ THE HEADLINES.
C*******
C
 1    READ(5,100,END=99) (H(I),I=1,16),IDL,ISW
 100  FORMAT(16A4,I2,1X,I3)
      WRITE(7,200) IDL,ISW
 200  FORMAT(I2,1X,I3)
C
      SUM=0.
      NS=1
C
C*******
C*******        READ THE DATA LINES.
C*******
C
 5    READ(5,300,END=10) (CODE(J,NS),J=1,9),CTS(NS)
 300  FORMAT(9A1,F7.0)
      IF(CTS(NS).LT.1.) GO TO 10
      CTS(NS)=CTS(NS)/1000.
      SUM=SUM+CTS(NS)
      NS=NS+1
      GO TO 5
C
 10   DIV=0.
      NS=NS-1
C
C*******
C*******        CORRECT THE FRACTION AND DIVERSITY VALUES.
C*******
C
      DO 15 I=1,NS
      FRAC(I)=CTS(I)/SUM
      DIV=DIV+FRAC(I)*ALOG(FRAC(I))*CONST
 15   FRAC(I)=FRAC(I)*100.
C
C*******
C*******        WRITE THE CORRECT VALUES.
C*******
C
      DO 20 I=1,NS
 20   WRITE(6,400) (H(K),K=2,9),H(10),(CODE(J,I),J=1,9),
     1CTS(I),FRAC(I),SUM,DIV
 400  FORMAT(8A4,6X,A4,2X,9A1,F8.1,F7.2,F8.1,F6.2)
C
      GO TO 1
C
 99   STOP
      END
```

TABLE 4.3. Program REFORMAT2.

```
C PROGRAM REFORMAT2 IS RUN TO REORGANIZE LAKE PHYTOPLANKTON RAW DATA
C FILES.  THIS PROGRAM IS USED FOR NOVEMBER 1970:. ALL MONTHS OF 1975:
C AND APRIL, MAY, JULY, OCTOBER IN 1976.
C UNIT 5 IS ASSIGNED TO INPUT FILE, (RAW DATA FILE).
C UNIT 6 IS ASSIGNED TO OUTPUT FILE, (REFORMATTED DATA FILE).
C UNIT 7 IS ASSIGNED TO ANOTHER OUTPUT FILE FOR THE VALUES OF DL & SW.
C
C
C
C
C*******
C*******        INITIALIZE VARIABLES.
C*******
C
      LOGICAL*1 CODE(9,200)
      REAL CTS(200),FRAC(200),H(16)
C
      CONST=-1./ALOG(2.)
C
C*******
C*******        READ THE HEADLINES.
C*******
C
 1    READ(5,100,END=99) (H(I),I=1,16),IDL,ISW
 100  FORMAT(16A4,I2,1X,I3)
      WRITE(7,200) IDL,ISW
 200  FORMAT(I2,1X,I3)
C
      CF=(IDL+1.)*41.4516/ISW
      SUM=0.
      NS=1
C
C*******
C*******        READ THE DATA LINES.
C*******
C
 5    READ(5,300,END=10) (CODE(J,NS),J=1,9),CTS(NS)
 300  FORMAT(9A1,F7.0)
      IF(CTS(NS).LT.1.) GO TO 10
      CTS(NS)=CTS(NS)*CF
      SUM=SUM+CTS(NS)
      NS=NS+1
      GO TO 5
C
 10   DIV=0.
      NS=NS-1
C
C*******
C*******        CORRECT THE FRACTION AND DIVERSITY VALUES.
C*******
C
      DO 15 I=1,NS
      FRAC(I)=CTS(I)/SUM
      DIV=DIV+FRAC(I)*ALOG(FRAC(I))*CONST
 15   FRAC(I)=FRAC(I)*100.
C
 *******
 *******        WRITE THE CORRECT VALUES.
 *******

      DO 20 I=1,NS
 20   WRITE(6,400) (H(K),K=2,9),H(10),(CODE(J,I),J=1,9),
     1CTS(I),FRAC(I),SUM,DIV
 400  FORMAT(8A4,6X,A4,2X,9A1,F8.1,F7.2,F8.1,F6.2)
C
      GO TO 1
C
 99   STOP
      END
```

TABLE 4.4. Program REFORMAT3.

```
C PROGRAM  REFORMAT3  IS RUN TO REORGANIZE LAKE PHYTOPLANKTON RAW DATA
C FILES. THIS PROGRAM IS USED FOR APRIL, JULY, OCTOBER IN 1974.
C UNIT 5 IS ASSIGNED TO INPUT FILE, (RAW DATA FILE).
C UNIT 6 IS ASSIGNED TO OUTPUT FILE, (REFORMATTED DATA FILE).
C UNIT 7 IS ASSIGNED TO ANOTHER OUTPUT FILE FOR THE VALUES OF DL & SW.
C
C
C
C
C*******
C*******        INITIALIZE VARIABLES.
C*******
C
      LOGICAL*1 CODE(9,200)
      REAL CTS(200),FRAC(200),H(16)
C
      CONST=-1./ALOG(2.)
C
C*******
C*******        READ THE HEADLINES.
C*******
C
 1    READ(5,100,END=99) (H(I),I=1,16),IDL,ISW
 100  FORMAT(16A4,I2,1X,I3)
      WRITE(7,200) IDL,ISW
 200  FORMAT(I2,1X,I3)
C
      IF((IDL.EQ.0).AND.(ISW.EQ.0)) CF=1
      IF((IDL.NE.0).OR.(ISW.NE.0)) CF=(IDL+1.)*41.4516/ISW
      SUM=0.
      NS=1
C
C*******
C*******        READ THE DATA LINES.
C*******
C
 5    READ(5,300,END=10) (CODE(J,NS),J=1,9),CTS(NS)
 300  FORMAT(9A1,F7.0)
      IF(CTS(NS).LT.1.) GO TO 10
      CTS(NS)=(CTS(NS)/1000.)*CF
      SUM=SUM+CTS(NS)
      NS=NS+1
      GO TO 5
C
 10   DIV=0.
      NS=NS-1
C
C*******
C*******        CORRECT THE FRACTION AND DIVERSITY VALUES.
C*******
C
      DO 15 I=1,NS
      FRAC(I)=CTS(I)/SUM
      DIV=DIV+FRAC(I)*ALOG(FRAC(I))*CONST
 15   FRAC(I)=FRAC(I)*100.
C
C*******
C*******        WRITE THE CORRECT VALUES.
C*******
C
      DO 20 I=1,NS
 20   WRITE(6,400) (H(K),K=2,9),H(10),(CODE(J,I),J=1,9),
     1CTS(I),FRAC(I),SUM,DIV
 400  FORMAT(8A4,6X,A4,2X,9A1,F8.1,F7.2,F8.1,F6.2)
C
      GO TO 1
C
 99   STOP
      END
```

TABLE 4.5. Program REFORMAT4.

```
C PROGRAM  REFORMAT4  IS RUN TO REORGANIZE LAKE PHYTOPLANKTON RAW DATA
C FILES. THIS PROGRAM IS USED FOR JUNE, AUGUST, SEPTEMBER IN 1976; AND
C ALL MONTHS OF 1977, 1978, 1979, 1980, 1981, 1982.
C UNIT 5 IS ASSIGNED TO INPUT FILE. (RAW DATA FILE).
C UNIT 6 IS ASSIGNED TO OUTPUT FILE. (REFORMATTED DATA FILE).
C UNIT 7 IS ASSIGNED TO ANOTHER OUTPUT FILE FOR THE VALUES OF DL & SW.
C
C
C
C
C*******
C*******        INITIALIZE VARIABLES.
C*******
C
      LOGICAL*1 CODE(9,200)
      REAL CTS(200),FRAC(200),H(13)
C
      CONST=-1./ALOG(2.)
C
C*******
C*******        READ THE HEADLINES.
C*******
C
 1    READ(5,100,END=99) (H(I),I=1,13),DL,SW
 100  FORMAT(13A4,1X,2F4.2)
      IDL=DL
      ISW=SW
      WRITE(7,200) IDL,ISW
 200  FORMAT(I2,1X,I3)
C
      CF=(IDL+1.)*41.4516/ISW
      SUM=0.
      NS=1
C
C*******
C*******        READ THE DATA LINES.
C*******
C
 5    READ(5,300,END=10) (CODE(J,NS),J=1,9),CTS(NS)
 300  FORMAT(9A1,F7.0)
      IF(CTS(NS).LT.1.) GO TO 10
      CTS(NS)=CTS(NS)*CF
      SUM=SUM+CTS(NS)
      NS=NS+1
      GO TO 5
C
 10   DIV=0.
      NS=NS-1
C
C*******
C*******        CORRECT THE FRACTION AND DIVERSITY VALUES.
C*******
C
      DO 15 I=1,NS
      FRAC(I)=CTS(I)/SUM
      DIV=DIV+FRAC(I)*ALOG(FRAC(I))*CONST
 15   FRAC(I)=FRAC(I)*100.
C
C*******
C*******        WRITE THE CORRECT VALUES.
C*******
C
      DO 20 I=1,NS
 20   WRITE(6,400) (H(K),K=2,9),H(12),(CODE(J,I),J=1,9),
     1CTS(I),FRAC(I),SUM,DIV
 400  FORMAT(8A4,6X,A4,2X,9A1,F8.1,F7.2,F8.1,F6.2)
C
      GO TO 1
C
 99   STOP
      END
```

TABLE 4.6. Program PLTAXIRCR.

```
RUN *TAXIR
CREATE LAKE.PHYTOPLANKTON,
DAY(FROM 1 TO 31),
MONTH(ORDER,JAN,FEB,MAR,APR,MAY,JUN,JUL,AUG,SEP,OCT,NOV,DEC),
YEAR(FROM 70 TO 85),
LOCATION(NAME),
NAME(NAME),
TEMPERATURE(FROM .1 TO 40.0),
CODE(NAME),
GROUP(ORDER,C,D,F,G,H,O,P,R,S),
CELLS(FROM .1 TO 9999.9),
FRAC(FROM .01 TO 100.00),
TOTALCELLS(FROM .1 TO 100000.0),
DIVERSITY(FROM .01 TO 6.00)*
ENTER DATA LOCATION=LREFORM, FORMAT=FIXED,
DAY<5-6>,
MONTH<8-10>,
YEAR<12-13>,
LOCATION<14-25>,
NAME<27-30>,
TEMPERATURE<39-42>,
CODE<45-52>,
GROUP<53>,
CELLS<55-61>,
FRAC<63-68>,
TOTALCELLS<69-76>,
DIVERSITY<79-82>*
SAVE
STOP
```

Added Parameters

When the Lake.Phytoplankton data bank was first created, it contained 12 descriptors but did not include redundancy indexes. It was later felt that there was a need to add such indexes; a 13th descriptor called REDUNDANCY was created, and its values were added to the data bank. Because the values needed to calculate redundancy were not available, they were derived as follows:

Step 1: Use Redundancy program (Table 4.7) to assemble the values corresponding to the numbers of forms, diversities, and total cells from the phytoplankton tables.

Step 2: Use Predundancy program (Table 4.8) to compute redundancy indexes from these values assembled from the phytoplankton tables.

The newly created descriptor REDUNDANCY was then added to the Lake.Phytoplankton data bank by first using the Taxir Statement of Define More Descriptor which is shown as follows:

```
DMD REDUNDANCY (FROM 0.000 to 1.0000)
```

Then, Correction Statement was used to enter the values of the descriptor into the data base. An example of this procedure is shown later.

Data Tape and Taxir Table

The complete Lake.Phytoplankton data bank is saved on tape with volume name COOK and ID Code COOK, beginning at first position.

An example of the use of the Taxir program to generate a table for reports is shown in Table 4.9.

TABLE 4.7. Program REDUNDANCY.

```
C PROGRAM REDUNDANCY PROVIDES THE VALUES CORRESPONDING TO THE
C NUMBERS OF FORMS, DIVERSITIES AND TOTAL CELLS .
C UNIT 5 IS INPUT FILE, (PHYTOPLANKTON TABLES).
C UNIT 6 IS ASSIGNED TO OUTPUT FILE.
C
C
C
C
C*******
C*******       INITIALIZE VARIABLES.
C*******
C
      LOGICAL*4 UNDL/'----'/,UNDL1,TITLE/'Tota'/,T1
      LOGICAL*1 DATE(9),CODE(9),EQUC,TOTAL(9)
C
C*******
C*******       READ THE LOOP.
C*******
C
 1    READ(5,100,END=99) UNDL1
 100  FORMAT(3X,A4)
      IF(EQUC(UNDL,UNDL1)) GO TO 2
C
      GO TO 1
C
 2    CALL SKIP(0,2,5)
      READ(5,101) DATE,CODE,N,DIV
 101  FORMAT(2X,9A1,9X,9A1,55X,I4,34X,F6.2)
      N1=(N+1)/2+5
C
      CALL SKIP(0,N1,5)
      READ(5,102) T1,TOTAL
 102  FORMAT(101X,A4,4X,9A1)
      IF(EQUC(T1,TITLE)) GO TO 4
C
      DO 5 I=1,N1
      READ(5,102) T1,TOTAL
      IF(EQUC(T1,TITLE)) GO TO 4
 5    CONTINUE
C
C*******
C*******       CHECK THE ERRORS.
C*******
C
      WRITE(6,104) CODE,DATE
 104  FORMAT('***ERROR*** TOTAL NOT FOUND FOR STATION: ',9A1,1X,
     & 'ON DATE: ',9A1)
      STOP 99
C
C*******
C*******       WRITE THE CORRECT VALUES.
C*******
C
 4    WRITE(6,103) DATE,CODE,N,TOTAL,DIV
 103  FORMAT(1X,9A1,1X,9A1,1X,I4,1X,9A1,1X,F6.2)
C
      GO TO 1
C
 99   STOP
      END
```

TABLE 4.8. Program PREDUNDANCY.

```
C PROGRAM PREDUNDANCY READS IN STATISTICS ON PHYTOPLANKTON CATCHES
C FROM UNIT 5,  COMPUTES A REDUNDANCY INDEX  AND WRITES THE OUTPUT
C TO UNIT 6.
C
C
C
C
C*******
C*******       INITIALIZE VARIABLES.
C*******
C
      LOGICAL*1 DATE(9),CODE(9)
C
C*******
C*******       READ THE STATISTICS.
C*******
C
 3    READ(5,1,END=4) DATE,CODE,N,A,DIV
 1    FORMAT(1X,9A1,1X,9A1,1X,I4,1X,F9.1,1X,F6.2)
C
C*******
C*******       COMPUTE THE REDUNDANCY INDEX.
C*******
C
      B=2*A*3.1416
      B=SQRT(B)
      B=ALOG10(B)
      C=A/2.71828
      C=A*ALOG10(C)
      D=2*3.1416*(A/N)
      D=SQRT(D)
      D=ALOG10(D)
      E=(A/N)/2.71828
      E=(A/N)*ALOG10(E)
      F=(B+C)
      G=(D+E)*N
      DMAX=(3.3219/A)*(F-G)
      T=2*3.1416*(A-(N-1.))
      U=(A-(N-1.))/2.71828
      T=SQRT(T)
      T=ALOG10(T)
      V=(A-(N-1.))
      U=V*ALOG10(U)
      U=U+T
      DMIN=(3.3219/A)*(F-U)
      RI=(DMAX-DIV)/(DMAX-DMIN)
C
C*******
C*******       WRITE THE OUTPUT.
C*******
C
      WRITE(6,2) DATE,CODE,RI
 2    FORMAT('0',9A1,1X,9A1,'REDUNDANCY = ',E10.3)
C
      GO TO 3
C
 4    STOP
      END
```

TABLE 4.9. An example of generating tables using Taxir program.

```
RUN *TAXIR
GET LAKE.PHYTOPLANKTON
O '+------------------------------------------------------------+',
'| YEAR | MONTH | LOCATION |    CODE    | GROUP |   CELLS   |'<P1>,
'|------------------------------------------------------------|'<P1>,
('|'<P1,A>, YEAR<P4>, '|'<P9,A>, MONTH<P13>, '|'<P18,A>, LOCATION<P22>,
'|'<P31,A>, CODE<P34>, '|'<P44,A>, GROUP<P49>, '|'<P54,A>, CELLS<P57>,
'|'<P65,A>) FOR ITEMS WITH FRAC>50.0*
```

No. of items in query response: 167
No. of items in data bank: 90078
Percentage of response/total data bank: 0.19%

YEAR	MONTH	LOCATION	CODE	GROUP	CELLS
70	NOV	DC-2	OCSPECAA	F	131.3
		DC-3			125.3
		DC-5			137.7
		NDC.21			157.5
		NDC.50			104.6
		NDC.51			169.0
		NDC1-1			158.0
		NDC2-0	CGSPECAA		420.0
		SDC.21	OCSPECAA		61.7
		SDC.50			41.9
		SDC1-0			178.2
		SDC2-4	CGSPECAA		155.7
		SDC4-0			348.2
		SDC7-2			300.3
		SDC7-3			327.9
71	JUL	DC-2	GLSPECAA	G	1118.3
		DC-4			1208.7
		DC-5			357.3
		NDC7-1			2793.7
		NDC7-2			1194.8
		NDC7-3			1894.6
	SEP	NDC.52			169.4
		NDC2-4			167.0
		NDC4-0	MESPECAA	C	803.7
		SDC.52	GLSPECAA	G	126.7
		SDC.53			216.7
		SDC1-2			125.7
		SDC1-3			187.0
		SDC4-3			172.1
		SDC4-4			121.1
72	JUL	NDC1-2	TAFENEST	P	63.1
		NDC4-3	FRCROTON		165.2
		NDC7-5	CGSPECAA	F	39.9
		SDC.52	TAFENEST	P	104.4
	OCT	DC-6	CHLIMNET	R	460.3
		NDC1-0	MEGRANUL	C	834.8
		NDC1-1			1400.4
		NDC2-0			1105.6
		NDC2-1			1500.6
		NDC4-0			1254.0
		NDC4-1			3964.1
		NDC4-4	CHLIMNET	R	415.3
		NDC7-1	MEGRANUL	C	3984.5
		NDC7-3			756.8
		SDC1-0			2919.8
		SDC1-1			1736.3
		SDC2-0			897.8
		SDC4-1			1098.8
		SDC4-4	CHLIMNET	R	368.9
73	JUL	DC-3	CYSTELLI	C	311.4
		SDC4-3			827.5

An Example for Preparing the Phytoplankton Computer Data Base

In order to add a new data file which we call "RDJUN82" and its redundancy index to the established data base, the following procedure is followed:

```
#SIG XXXX                                   (signon MTS)
#XXX                                        (Password)
(The following statements reformat the data set.)
#RUN *FTN SCARDS=REFORMAT4 SPUNCH=FOR.OBJ
#RUN FOR.OBJ 5=RDJUN82 6=REFORMJUN82
(To run the Taxir program to enter the data into the data bank)
#RUN *TAXIR
GET LAKE.PHYTOPLANKTON
ENTER DATA LOCATION=LREFORMJUN82 FORMAT=FIXED,
DAY<5-6>,
   .
   .
   .
   .     Same as in PLTAXIRCR
   .
   .
   .
SAVE
STOP
(To compute the redundancy index)
#RUN *FTN SCARDS=REDUNDANCY SPUNCH=RED.OBJ
#RUN RED.OBJ 5=PHYTOJUN82 6=RJUN82
#RUN *FTN SCARDS=PREDUNDANCY SPUNCH=PRED.OBJ
#RUN PRED.OBJ 5=RJUN82 6=PRJUN82
(Run Taxir program to enter redundancy index into the data bank.)
```

```
#RUN *TAXIR

GET LAKE.PHYTOPLANKTON

CORRECTION (REDUNDANCY=*.***) *MONTH=JUN AND YEAR=82 AND LOCATION=DC-0*
   '
   '
   ' (entering redundancy values for different locations of month of June)
   '
   '
   '

CORRECTION (REDUNDANCY=*.***) *MONTH=JUN AND YEAR=82 AND LOCATION=NDC7-5*

SAVE

STOP

#SIG$ (sign off MTS)
```

*

ENTRAINED PHYTOPLANKTON

The Entrained.Phytoplankton data bank contains 63,748 items and 21 descriptors. The descriptors are listed as follows:

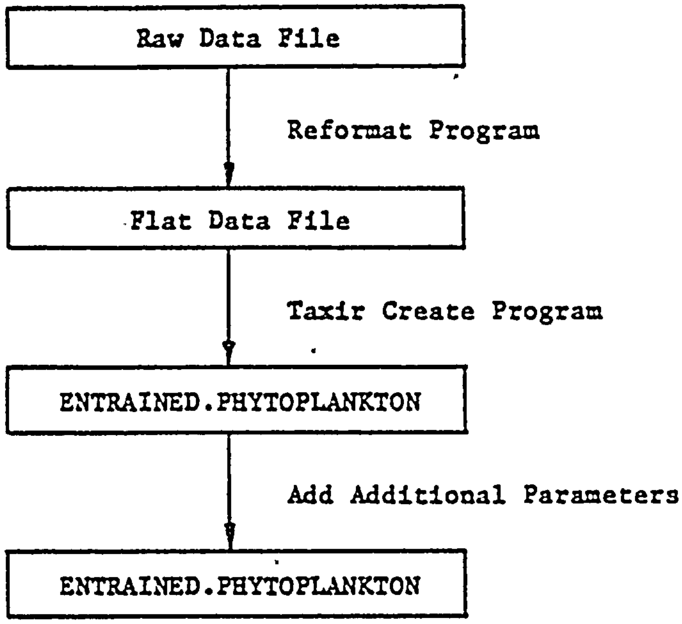
1-DAY
2-MONTH
3-YEAR
4-LOCATION
5-TIME
6-SPECIES CODES
7-MAJOR GROUPS
8-CELLS
9-FRACTION
10-DIVERSITY
11-TEMPERATURE
12-REDUNDANCY
13-CHLOROPHYLL A
14-CHLOROPHYLL B
15-CHLOROPHYLL C
16-PHAEOPHIN
17-CHLOROPHYLL A INCUBATED
18-CHLOROPHYLL B INCUBATED
19-CHLOROPHYLL C INCUBATED
20-PHAEOPHIN
21-HOURS INCUBATED

The number of data items collected for Entrained.Phytoplankton data bank beginning in 1975 is listed in Table 4.10.

TABLE 4.10. The number of data items in Entrained.Phytoplankton data bank.

Year	Month	Total # of Items	Year	Month	Total # of Items	Year	Month	Total # of Items
75	FEB	(460)	78	JAN	(692)	80	JAN	(795)
	MAR	(465)		FEB	(587)		FEB	(788)
	APR	(290)		MAR	(483)		MAR	(795)
	MAY	(237)		APR	(661)		APR	(870)
	JUN	(590)		MAY	(983)		MAY	(793)
	JUL	(619)		JUN	(1,023)		JUN	(638)
	AUG	(534)		JUL	(1,254)		JUL	(487)
	SEP	(441)		AUG	(899)		AUG	(1,099)
	OCT	(659)		SEP	(1,208)		SEP	(1,259)
	NOV	(604)		OCT	(1,408)		OCT	(1,047)
	DEC	(559)		NOV	(871)		NOV	(634)
76	JAN	(653)		DEC	(991)		DEC	(617)
	FEB	(687)	79	JAN	(1,074)	81	JAN	(879)
	MAR	(711)		FEB	(838)		FEB	(811)
	APR	(673)		MAR	(1,021)		MAR	(797)
	MAY	(723)		APR	(537)		APR	(742)
	JUN	(789)		MAY	(465)		MAY	(793)
	JUL	(1,054)		JUL	(384)		JUN	(513)
	AUG	(641)		AUG	(870)		JUL	(475)
	SEP	(1,017)		SEP	(1,033)		AUG	(865)
	OCT	(706)		OCT	(1,210)		SEP	(1,174)
	NOV	(686)		NOV	(678)		OCT	(632)
	DEC	(678)		DEC	(732)		NOV	(754)
77	MAR	(635)					DEC	(792)
	APR	(666)				82	JAN	(911)
	MAY	(557)					FEB	(624)
	JUN	(769)					MAR	(888)
	JUL	(692)					APR	(723)
	AUG	(563)					MAY	(706)
	SEP	(724)						
	OCT	(627)						
	NOV	(559)						
	DEC	(677)						

The steps for creating the Entrained.Phytoplankton data bank were similar to the ones that were described for the Lake.Phytoplankton data bank. They are shown as follows:



Original Data and Reformat Program

Original data are stored on the computer tape in a file such as RDENTXXXXX, where the first XXX is a code for month and the second XX is a code for the year (for example, RDENTAPR82). The entrainment data files prior to 1980 are stored on a tape called PHYTO. The 1980, 1981, and 1982 data files can be found on a tape called PHYTO2.

The Reformat Program for entrained phytoplankton is called EREFORMAT. This program is very similar to that used for lake phytoplankton. A listing of this program is given in Table 4.11.

TABLE 4.11. Program EREFORMAT.

```
C PROGRAM EREFORMAT IS USED TO REORGANIZE ENTRAINMENT PHYTOPLANKTON
C RAW DATA FILES.
C UNIT 5 IS ASSIGNED TO INPUT FILE. (RAW DATA FILE).
C UNIT 6 IS ASSIGNED TO OUTPUT FILE. (REFORMATTED DATA FILE).
C UNIT 7 IS ANOTHER OUTPUT FILE FOR THE VALUES OF DL AND  SW.
C
C
C
C
C*******
C*******       INITIALIZE VARIABLES.
C*******
C
      LOGICAL*1 CODE(9,200)
      REAL CTS(200),FRAC(200),H(13)
C
      CONST=-1./ALOG(2.)
C
C*******
C*******       READ THE HEADLINES.
C*******
C
 1    READ(5,100,END=99) (H(I),I=1,13),DL,SW
 100  FORMAT(13A4,1X,2F4.2)
      IDL=DL
      ISW=SW
      WRITE(7,200) IDL,ISW
 200  FORMAT(I2,1X,I3)
      CF=(IDL+1.)*41.4516/ISW
C
      SUM=0.
      NS=1
C
C*******
C*******       READ THE DATA LINES.
C*******
C
 5    READ(5,300,END=10) (CODE(J,NS),J=1,9),CTS(NS)
 300  FORMAT(9A1,F7.0)
      IF(CTS(NS).LT.1.) GO TO 10
      CTS(NS)=CTS(NS)*CF
      SUM=SUM+CTS(NS)
      NS=NS+1
      GO TO 5
C
 10   DIV=0.
      NS=NS-1
C
C*******
C*******       CORRECT THE FRACTION AND DIVERSITY VALUES.
C*******
C
      DO 15 I=1,NS
      FRAC(I)=CTS(I)/SUM
      DIV=DIV+FRAC(I)*ALOG(FRAC(I))*CONST
 15   FRAC(I)=FRAC(I)*100.
C
C*******
C*******       WRITE THE CORRECT VALUES.
C*******
C
      DO 20 I=1,NS
 20   WRITE(6,400) (H(K),K=2,9),(CODE(J,I),J=1,9),
     1CTS(I),FRAC(I),SUM,DIV,H(12)
 400  FORMAT(8A4,2X,9A1,F8.1,F7.2,F8.1,F6.2,2X,A4)
C
      GO TO 1
C
 99   STOP
      END
```

Taxir Create Program for Entrained Phytoplankton

To establish the Entrained.Phytoplankton data bank, a Taxir Create program PETAXIRCR (Table 4.12) is used. This program uses the entrained phytoplankton data in flat-file form to store them in a Taxir data bank called Entrained.Phytoplankton.

Added Parameters

Additional descriptors were added to the Entrained.Phytoplankton data bank. These descriptors are Chlorophyll a, Chlorophyll b, Chlorophyll c, Phaeophin, Chlorophyll a Incubated, Chlorophyll b Incubated, Chlorophyll c Incubated, Phaeophin Incubated, Hours Incubated, and Redundancy Index. The values for Chlorophyll and Phaeophin are obtained by using the computer program ORGANTABLE (Table 4.13). This program selects the parameter information from the chlorophyll and phaeophin tables. Running the above program results in the output data files corresponding to these parameters which are in a form such that Taxir Statement CORRECTION can be applied. In this way, these additional descriptors are stored in the already established Entrained.Phytoplankton data bank.

In order to merge the additional descriptors with appropriate cases of entrained phytoplankton, identification codes (ID codes) of YEAR, MONTH, DAY, LOCATION, and TIME were used. Because the specific times of collection are different at each sampling but the periods basically correspond to morning, noon, and evening periods, these periods were used in place of actual sampling time for ID codes. These periods are shown as follows:

Morning	2-8:30 a.m.
Noon	8:30-14:00 p.m.
Evening	18:00-24:00 p.m.

TABLE 4.12. Program PETAXIRCR.

```
RUN *TAXIR
CREATE ENTRAINED.PHYTOPLANKTON,
DAY(FROM 1 TO 31),
MONTH(ORDER,JAN,FEB,MAR,APR,MAY,JUN,JUL,AUG,SEP,OCT,NOV,DEC),
YEAR(FROM 70 TO 85),
LOCATION(NAME),
TIME(FROM 1 TO 2400),
CODE(NAME),
GROUP(ORDER,C,D,F,G,H,O,P,R,S),
CELLS(FROM .1 TO 9999.9),
FRAC(FROM .01 TO 100.00),
DIVERSITY(FROM .01 TO 6.00),
TEMPERATURE(FROM 0.0 TO 100.0)*
ENTER DATA LOCATION=EREFORM, FORMAT=FIXED,
DAY<7-8>,
MONTH<10-12>,
YEAR<14-15>,
LOCATION<18-20>,
TIME<22-25>,
CODE<35-42>,
GROUP<43>,
CELLS<46-51>,
FRAC<53-58>,
DIVERSITY<69-72>,
TEMPERATURE<74-78>*
SAVE
STOP
```

TABLE 4.13. Program ORGANTABLE.

```
C PROGRAM ORGANTABLE IS FOR REORGANIZING THE CHLOROPHYLL AND PHAEOPHIN
C VALUES FROM THEIR TABLES. THE INPUT FILES ARE:
C UNIT 4: CHLOROPHYLL A TABLE.
C UNIT 5: CHLOROPHYLL B TABLE.
C UNIT 6: CHLOROPHYLL C TABLE.
C UNIT 7: PHAEOPHYTIN TABLE.
C THE OUTPUT FILE  IS  UNIT  8  WHICH  CONTAINS  THE  TAXIR CORRECTION
C STATEMENTS. LATER BY  SETTING  THE SOURCE FILE  EQUAL  TO THE OUTPUT
C FILE THE UNKNOWN  CHLOROPHYLL  AND  PHAEOPHIN VALUES CAN BE ADDED TO
C ENTRAINED.PHYTOPLANKTON DATA BANK.
C
C
C
C
C*******
C*******       INITIALIZE VARIABLES.
C*******
C
      REAL LOCTON,MEANA,MEANB,MEANC,MEANP
      INTEGER MONTH,DAY,YEAR,TIME,HRSINC
C
C*******
C*******       READ THE MEAN VALUES. (ONE AT A TIME).
C*******
C
 100  READ(4,1,END=99) MONTH,DAY,YEAR,TIME,LOCTON,HRSINC,MEANA
      READ(5,2) MEANB
      READ(6,2) MEANC
      READ(7,2) MEANP
 1    FORMAT(11X,3(I2,1X),I4,1X,A2,1X,I2,9X,E10.3)
 2    FORMAT(39X,E10.3)
C
C*******
C*******       CHECK THE TOTAL HOURS OF INCUBATION FOR EACH SAMPLE
C*******       AND CONSTRUCT TAXIR CORRECTION STATEMENTS.
C*******
C
      IF(HRSINC.EQ.0) GO TO 10
      IF((TIME.GE.200).AND.(TIME.LE.830)) GO TO 20
      IF((TIME.GT.830).AND.(TIME.LE.1400)) GO TO 30
      WRITE(8,3) MEANA,MEANB,MEANC,MEANP,HRSINC,YEAR,MONTH,DAY,LOCTON
 3    FORMAT(1X,'C (17=',F8.4,')',1X,'(18=',F8.4,')',1X,
     1'(19=',F8.4,')','(20=',F8.4,')',1X,'(21=',I2,')',1X,'*3=',
     1I2,' & 2=',I2,' & 1=',I2,' & 4=',A2,' & 5>1800 & 5<2400*')
      GO TO 100
C
 20   WRITE(8,4) MEANA,MEANB,MEANC,MEANP,HRSINC,YEAR,MONTH,DAY,LOCTON
 4    FORMAT(1X,'C (17=',F8.4,')',1X,'(18=',F8.4,')',1X,
     1'(19=',F8.4,')','(20=',F8.4,')',1X,'(21=',I2,')',1X,'*3=',
     1I2,' & 2=',I2,' & 1=',I2,' & 4=',A2,' & 5>200 & 5<830*')
      GO TO 100
C
 30   WRITE(8,5) MEANA,MEANB,MEANC,MEANP,HRSINC,YEAR,MONTH,DAY,LOCTON
 5    FORMAT(1X,'C (17=',F8.4,')',1X,'(18=',F8.4,')',1X,
     1'(19=',F8.4,')','(20=',F8.4,')',1X,'(21=',I2,')',1X,'*3=',
     1I2,' & 2=',I2,' & 1=',I2,' & 4=',A2,' & 5>830 & 5<1400*')
      GO TO 100
C
 10   IF((TIME.GE.200).AND.(TIME.LE.830)) GO TO 40
      IF((TIME.GT.830).AND.(TIME.LE.1400)) GO TO 50
      WRITE(8,6) MEANA,MEANB,MEANC,MEANP,HRSINC,YEAR,MONTH,DAY,LOCTON
 6    FORMAT(1X,'C (13=',F8.4,')',1X,'(14=',F8.4,')',1X,
     1'(15=',F8.4,')','(16=',F8.4,')',1X,'(21=',I2,')',1X,'*3=',
     1I2,' & 2=',I2,' & 1=',I2,' & 4=',A2,' & 5>1800 & 5<2400*')
      GO TO 100
C
```

Continued on next page.

TABLE 4.13. (Continued).

```
 40    WRITE(8,7) MEANA,MEANB,MEANC,MEANP,HRSINC,YEAR,MONTH,DAY,LOCTON
 7     FORMAT(1X,'C (13=',F8.4,')',1X,'(14=',F8.4,')',1X,
      1'(15=',F8.4,')','(16=',F8.4,')',1X,'(21=',I2,')',1X,'=3=',
      1I2,' & 2=',I2,' & 1=',I2,' & 4=',A2,' & 5>200 & 5<830=')
       GO TO 100
C
 50    WRITE(8,8) MEANA,MEANB,MEANC,MEANP,HRSINC,YEAR,MONTH,DAY,LOCTON
 8     FORMAT(1X,'C (13=',F8.4,')',1X,'(14=',F8.4,')',1X,
      1'(15=',F8.4,')','(16=',F8.4,')',1X,'(21=',I2,')',1X,'=3=',
      1I2,' & 2=',I2,' & 1=',I2,' & 4=',A2,' & 5>830 & 5<1400=')
       GO TO 100
C
 99    STOP
       END
```

Computer commands used in this process are shown below:

```
#RUN *FIN SCARDS=ORGANTABLE SPUNCH=-LOAD
#RUN -LOAD 4=CHLORAXX
           5=CHLORBXX
           6=CHLORCXX          (XX=YEAR)
           7=PHAXX             (4,5,6,7)=INPUT FILES
           8=CHLPHAXX          8=OUTPUT FILE
#SOURCE CHLPHAXX
```

<u>Data Tape</u>

The complete Entrained Phytoplankton data bank with 21 descriptors is saved on the tape called COOK beginning at the 2nd position.

LAKE ZOOPLANKTON

The Lake.Zooplankton data bank contains 32,113 items and 10 descriptors. The descriptors are:

1-STATION

2-MONTH

3-YEAR

4-DEPTH

5-TAXON #

6-COUNT

7-PCCOMP

8-TAXON

9-TEMPERATURE

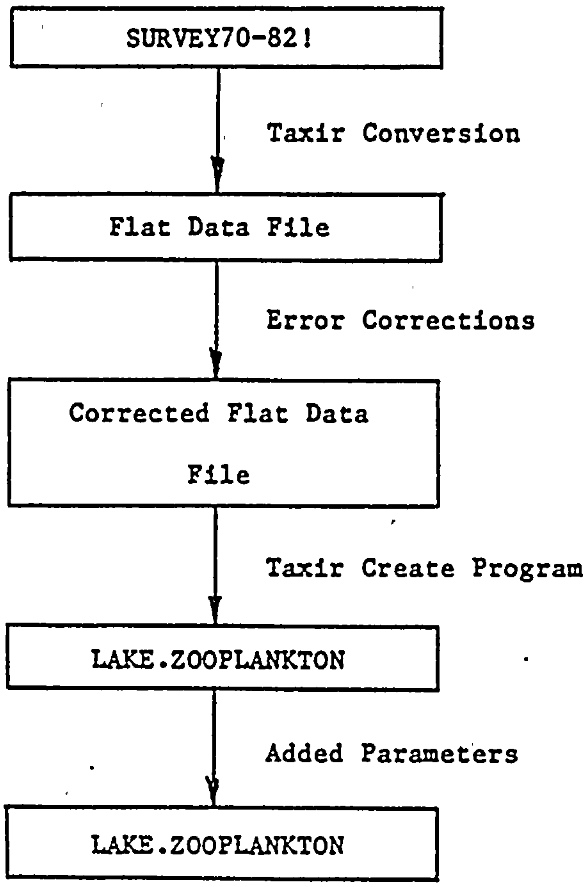
10-SECCHI DISC

The monthly number of data items collected for lake zooplankton beginning in July 1970 is listed in Table 4.14.

TABLE 4.14. The number of data items in Lake.Zooplankton data bank.

Year	Month	Total # of Items	Year	Month	Total # of Items	Year	Month	Total # of Items
70	JUL	(459)	75	APR	(441)	79	APR	(431)
	SEP	(508)		MAY	(228)		MAY	(211)
	NOV	(461)		JUN	(312)		JUN	(204)
71	APR	(189)		JUL	(630)		JUL	(582)
	JUL	(464)		AUG	(718)		AUG	(298)
	SEP	(603)		SEP	(322)		SEP	(280)
	NOV	(402)		OCT	(611)		OCT	(677)
72	APR	(421)		DEC	(281)		NOV	(296)
	MAY	(90)	76	APR	(391)	80	APR	(488)
	JUN	(104)		MAY	(488)		MAY	(253)
	JUL	(353)		JUN	(260)		JUN	(262)
	AUG	(121)		JUL	(637)		JUL	(489)
	SEP	(116)		AUG	(336)		AUG	(299)
	OCT	(393)		SEP	(323)		SEP	(342)
	NOV	(115)		OCT	(593)		OCT	(625)
73	APR	(417)	77	APR	(442)		NOV	(251)
	MAY	(134)		MAY	(215)	81	APR	(401)
	JUN	(167)		JUN	(250)		MAY	(243)
	JUL	(566)		JUL	(635)		JUN	(214)
	AUG	(173)		AUG	(318)		JUL	(456)
	SEP	(171)		SEP	(321)		AUG	(305)
	OCT	(582)		OCT	(660)		SEP	(312)
74	APR	(389)		NOV	(288)		OCT	(547)
	MAY	(223)		DEC	(238)		NOV	(290)
	JUN	(247)	78	APR	(454)	82	APR	(416)
	JUL	(511)		MAY	(260)		MAY	(186)
	AUG	(307)		JUN	(282)			
	SEP	(307)		JUL	(570)			
	OCT	(606)		AUG	(304)			
				SEP	(337)			
				OCT	(702)			
				NOV	(309)			

The steps for constructing this data bank follow the flow diagram shown below:



Lake.Zooplankton Data Bank

The Lake.Zooplankton data bank was established using the steps listed above. These steps are the same as those taken for the establishment of the phytoplankton data bank, except that the length for each descriptor name was reduced to six characters, which is the maximum number of labeling characters that MIDAS permits. Two descriptors, TEMPERATURE and SECCHI DISC, were also added to this data set. These additions were made using the Taxir Statement CORRECTION. Both the steps for adding additional parameters and procedures which were used to create the Lake.Zooplankton data bank are shown below:

1) Convert the SURVEY70-82! to a line file.

```
#RUN *TAXIR
GET SURVEY70-82!
Q<DATA, SURVEY> ALL *ALL*
STOP
```

2) Correct the errors in the SURVEY data file.

```
#Ed SURVEY
:A@A /F ;JANUARY;JANbbbb;
:    '      '
     '      '
     '      '
     '      '
     '      '
:A@A /F ;DECEMBER;DECbbbbb;
:A@A /F ;DC-0-0;DC-0bb;
:    '      '
     '      '
     '      '
     '      '
     '      '
:A@A /F ;NDC-7-5;NDC 7-5b;
:STOP
#SOURCE ZLTAXIRCR
```

3) (Add values of SECCHI DISC and TEMPERATURE to the data bank.

```
CORRECTION (SECCHIDISC=....) AND (TEMPERATURE=....)
```

```
*MONTH=.... AND YEAR=.... AND STATION=....*
     '
     '
     '
     '
     '
SAVE
STOP
```

ZLTAXIRCR is presented in Table 4.15.

Data Tape

The final version of the Lake.Zooplankton data bank is saved on the tape called COOK at the 3rd position.

TABLE 4.15. Program ZLTAXIRCR.

```
RUN *TAXIR
CREATE LAKE.ZOOPLANKTON,
STATION(NAME),
MONTH(ORDER,JAN,FEB,MAR,APR,MAY,JUN,JUL,AUG,SEP,OCT,NOV,DEC),
YEAR(FROM 69 TO 85),
DEPTH(FROM 0 TO 60),
TAXON #(FROM 10001 TO 99999),
COUNT(FROM 0 TO 1000000),
PCCOMP(FROM 0.00 TO 100.00),
TAXON(NAME),
TEMPERATURE(FROM 0.1 TO 40.0),
SECCHI DISC(FROM 0.00 TO 100.00)*
ENTER DATA LOCATION=SURVEY, FORMAT=FIXED,
STATION<1-8>,
MONTH<10-18>,
YEAR<20-21>,
DEPTH<23-24>,
TAXON #<26-30>,
COUNT<32-38>,
PCCOMP<40-45>,
TAXON<47-81>,
TEMPERATURE<83-86>,
SECCHI DISC<88-93>*
SAVE
STOP
```

ENTRAINED ZOOPLANKTON

The Entrained.Zooplankton data bank consists of 19,703 items and 11 descriptors. The descriptors are listed below:

1-TYPE

2-GRATE

3-MONTH

4-DAY

5-YEAR

6-TIME

7-TAXON #

8-COUNT

9-PCCOMP

10-TAXON

11-TEMPERATURE

The monthly number of data items collected for entrained zooplankton beginning in 1975 is listed in Table 4.16.

TABLE 4.16. The number of data items in Entrained Zooplankton data bank.

Year	Month	Total # of Items	Year	Month	Total # of Items	Year	Month	Total # of Items
75	JAN	(30)	78	JAN	(165)	80	JAN	(304)
	FEB	(149)		FEB	(95)		FEB	(170)
	MAR	(118)		MAR	(88)		MAR	(151)
	APR	(126)		APR	(120)		APR	(185)
	MAY	(121)		MAY	(184)		MAY	(224)
	JUN	(166)		JUN	(336)		JUN	(163)
	JUL	(204)		JUL	(523)		JUL	(146)
	AUG	(218)		AUG	(550)		AUG	(266)
	SEP	(222)		SEP	(355)		SEP	(330)
	OCT	(203)		OCT	(445)		OCT	(276)
	NOV	(182)		NOV	(197)		NOV	(169)
	DEC	(142)		DEC	(401)		DEC	(155)
76	JAN	(153)	79	JAN	(235)	81	JAN	(203)
	FEB	(101)		FEB	(179)		FEB	(134)
	MAR	(101)		MAR	(210)		MAR	(150)
	APR	(109)		APR	(151)		APR	(119)
	MAY	(156)		MAY	(191)		MAY	(216)
	JUN	(258)		JUN	(166)		JUN	(117)
	JUL	(312)		JUL	(396)		JUL	(152)
	AUG	(509)		AUG	(535)		AUG	(326)
	SEP	(192)		SEP	(436)		SEP	(417)
	OCT	(189)		OCT	(383)		OCT	(138)
	NOV	(184)		NOV	(273)		NOV	(158)
	DEC	(173)		DEC	(266)		DEC	(258)
77	FEB	(33)				82	JAN	(220)
	MAR	(187)					FEB	(128)
	APR	(160)					MAR	(213)
	MAY	(138)					APR	(179)
	JUN	(175)					MAY	(171)
	JUL	(436)						
	AUG	(598)						
	SEP	(312)						
	OCT	(290)						
	NOV	(174)						
	DEC	(164)						

Entrained.Zooplankton Data Bank

The Entrained.Zooplankton data bank contains 11 descriptors; the last of which, TEMPERATURE, was added to this data base after it was created by the Taxir program. The final version of the Entrained.Zooplankton data bank is stored on the tape COOK at the 4th position.

LAKE BENTHOS

The Lake.Benthos data bank has 72,504 items and 16 descriptors. The descriptors are:

1-YEAR

2-MONTH

3-REGION

4-ZONE

5-DEPTH

6-CON.FACT

7-AREA

8-STATION

9-GROUP

10-CODE

11-CELLS

12-PRIM SED

13-SEC SED

14-TERT SED

15-QUAT SED

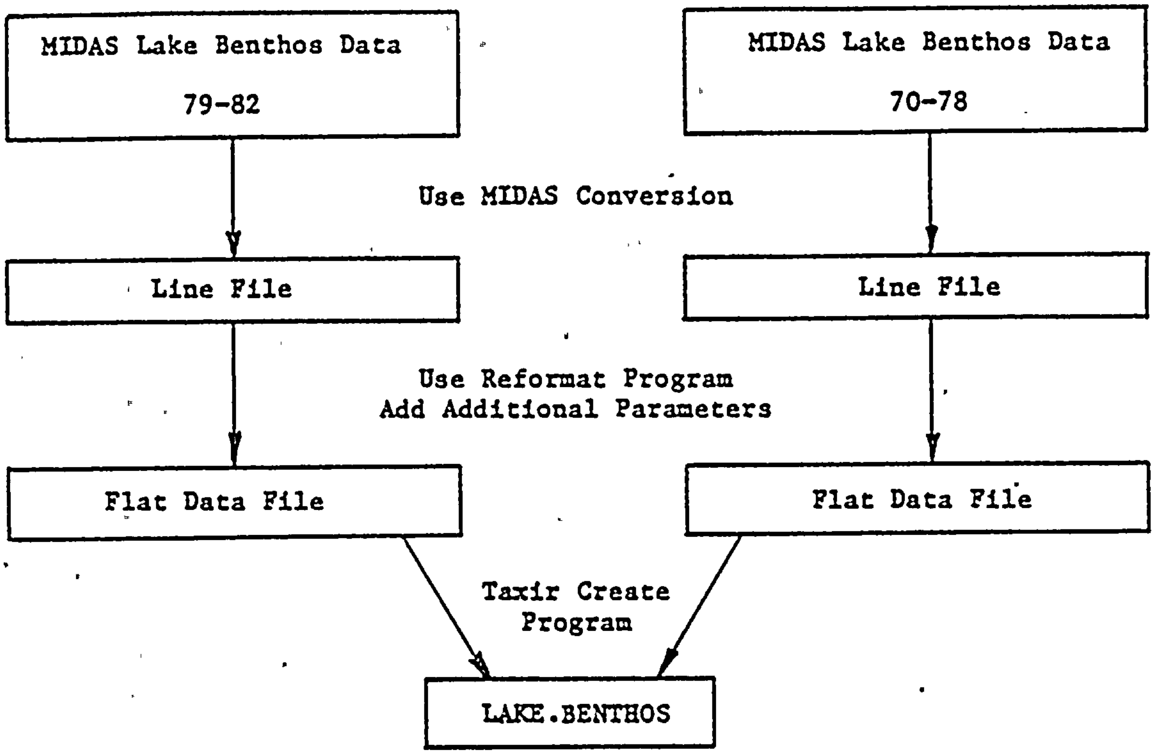
16-VOLUME

The number of data items collected for the Lake.Benthos data bank is shown by months in Table 4.17.

TABLE 4.17. The number of data items in Lake.Benthos data bank.

Year	Month	Total # of Items	Year	Month	Total # of Items	Year	Month	Total # of Items
70	7	(595)	75	4	(1,065)	78	4	(980)
	11	(817)		5	(696)		5	(482)
71	4	(702)		6	(784)		6	(564)
	7	(857)		7	(1,862)		7	(1,881)
	11	(610)		8	(1,030)		8	(585)
72	4	(898)		9	(934)		9	(652)
	5	(318)		10	(1,301)		10	(1,572)
	6	(363)		12	(561)		11	(599)
	7	(1,970)	76	4	(1,081)	79	4	(698)
	8	(371)		5	(667)		5	(556)
	9	(294)		6	(434)		6	(627)
	10	(1,996)		7	(1,360)		7	(949)
	11	(335)		8	(536)		8	(576)
73	4	(1,774)		9	(495)		9	(531)
	5	(222)		10	(1,036)		10	(911)
	6	(440)	77	4	(1,153)		11	(545)
	7	(3,074)		5	(533)	80	4	(625)
	8	(448)		6	(515)		5	(570)
	9	(486)		7	(1,884)		6	(539)
	10	(2,173)		8	(565)		7	(922)
74	4	(2,030)		9	(614)		8	(582)
	5	(600)		10	(1,373)		9	(625)
	6	(753)		11	(642)		10	(882)
	7	(1,629)		12	(543)		11	(445)
	8	(879)				81	4	(701)
	9	(844)					5	(478)
	10	(1,327)					6	(532)
							7	(839)
							8	(586)
							9	(598)
							10	(881)
							11	(490)
						82	4	(556)
							5	(476)

Procedures for establishing the Lake.Benthos data bank are shown by the following flow diagram:



Lake.Benthos Data Bank

The original Lake Benthos data were stored in MIDAS internal files COOKMERGE and COOK79-82. The former houses the data between 1970 and 1978, and the latter contains the data between 1979 and 1982. The procedures for establishing this data base are: (1) to change these MIDAS internal files to line files, then (2) to change the line files to flat files, and (3) to use a Taxir Create program to create the Lake.Benthos data bank.

To accomplish the first step, we used the following computer statements to convert COOKMERGE to a line file:

```
(while in MTS mode)
#RUN STAT:MIDAS
?READ INTERNAL FILE=COOKMERGE VARIABLE=ALL
(writing the variables of interest in the required order in the file
LINVMIDAS, an MTS line file)
?WRITE VARIABLE=1-5,9,155-156,10-147,150-154,200-205,300-303,400-406,500-510
FILE=LINVMIDAS CASES=ALL FORMAT=(2(F3.0,2X),2(F2.0,2X),F4.1,2X,F5.2,2X,F2.0,2X,
F4.0,2X,166(F10.2,2X),4(F2.0,2X),F4.1)
?FINISH
```

Note that the order of the variables in the file LINVMIDAS follows the sequence of variables, YEAR, MONTH, REGION, ZONE, DEPTH, CON.FACT, AREA, STATION, 166 SPECIES VALUES, PRIMSED, SECSED, TERTSED, QUATSED, and VOLUME.

With a slight change, the above statements were applied to change COOK7982 to a line file. The complete statements are as follows:

```
#RUN STAT:MIDAS
?READ INTERNAL FILE=COOK7982 VARIABLE=ALL
?WRITE VARIABLE=1-31,34-61 FILE=MCOOK7982 CASES=ALL
FORMAT=(2(F3.0,2X),F2.0,2X,2(F2.0,2X),F4.1,2X,F5.2,2X,4(F2.0,2X),F4.1,2X,46(F10.
2,2X),F4.0)
?FINISH
```

The order of the variables in file MCOOK7982 is different from that in the LINVMIDAS and is shown as follows: YEAR, MONTH, AREA, REGION, ZONE, DEPTH, CON.FACT, PRIMSED, SECSED, TERTSED, QUATSED, VOLUME, 46 SPECIES VALUES, and STATION.

Reformat Programs

Each benthos species in the BLINVMIDAS is treated as a parameter. There are 166 species included in this file, but only 46 species occur frequently. A large amount of space in the file is, therefore, occupied by species occurring only rarely; this represents an inefficient utilization of space. We decided to change the form of data storage so as to make more efficient use of file space. Programs BLARRAN1 and BLARRAN2 were written for this purpose. These programs ignore those species with counts of 0.0; the remaining species are placed in a flat-file form with one species per line. The program BLARRAN1 is used for restructuring the 1970-1978 data while BLARRAN2 is used for rearranging the 1978-1982 data. The results of these programs are stored in files REMCOOK7982 and BLREMIDAS. The command statements for using these programs are listed below:

```
#RUN *FTN SCARDS=BLARRAN1 SPUNCH=OBJ1
#RUN *FTN SCARDS=BLARRAN2 SPUNCH=OBJ2
#RUN OBJ1 5=BLINVMIDAS 6=BLREMIDAS
#RUN OBJ2 5=MCOOK7982 6=REMCOOK7982
```

The contents of these programs are listed in Tables 4.18 and 4.19.

TABLE 4.18. Program BLARRAN1.

```
C PROGRAM BLARRAN1 IS USED TO ORGANIZE LAKE BENTHOS DATA SETS FOR
C THE PERIOD OF 1970 TO 1978.  THE  OUTPUT FILE IS IN THE FORM OF
C FLAT FILE  WHICH  LATER CAN BE ADDED TO LAKE.BENTHOS DATA BANK.
C UNIT 5 IS THE INPUT FILE.
C UNIT 6 IS ASSIGNED TO OUTPUT FILE. (FLAT FILE).
C
C
C
C
C*******
C*******         INITIALIZE VARIABLES.
C*******
C
      REAL YEAR,MONTH,REGIN,ZONE,DEPTH,CONFAC,AREA,STAT,PRSD,
     1SESD,TESD,QUSD,VOLUME,SPCONT(166)
      REAL*8 SPNAME(166)
      INTEGER    IYEAR,IMONTH,IREGIN,IZONE,IAREA,ISTAT,IPRSD,
     1ISESD,ITESD,IQUSD
      LOGICAL*1 GROUPN(166)
C
C*******
C*******         INITIALIZE DATA.
C*******
C
      DATA SPNAME/8H  C.FLUV,8H C.ANTHR,8HCHIRNMUS,8H   CLADO,
     18H C.ROLLI,8HCRYPTO 1,8HCRYPTO 2,8HCRYPTO 3,8H  CRICOT,
     18HDEMICRYP,8HH.CHANGI,8H  H.OLIV,8H  HYDROB,8H  MICROP,
     18H   M.TUB,8H P.ABORT,8HP.NEREIS,8HP.UNDINE,8HP.CAMPTO,
     18H  P.WINN,8H P.FALLX,8H  P.SCAL,8H  POLY 2,8H  P.LONG,
     18H PROCLAD,8H P.SIMUL,8HRHEOTANY,8H  R.DEMJ,8H S.TYLUS,
     18H TANYTAR,8HTHIEN GR,8H O. CHIR,8H  A.LEYD,8HA.LOMOND,
     18H C.DIAPH,8H  C.DIAS,8HC.SETOSU,8H    DERO,8H  N.PARD,
     18HN.PSEUDO,8H   N.VAR,8H  N.SIMP,8H   P.LIT,8HP.SIMPLX,
     18H  P.MICH,8HP.FORELI,8HP.LONGIS,8HP.OSBORN,8HS.APPEND,
     18H S.JOSIN,8H S.LACUS,8H U.UNCIN,8H V.INTER,8HIM WO HC,
     18H IM W HC,8HL.ANGUST,8H  L.CLAP,8HL.CERVIX,8H  L.HOFF,
     18H  L.PROF,8H  L.SPIR,8H  L.UDEK,8H P.FREYI,8H PELO MM,
     18H PELO ML,8H P.SUPER,8HP.BEDOTI,8H  P.MOLD,8H   P.VEJ,
     18H  A.AMER,8H A.LIMNO,8H  A.PLUR,8H  I.TEMP,8HT.TUBIFX,
     18H  R.COCC,8H   V.SIN,8H   V.TRI,8HAMNICOLA,8HBYTHINIA,
     18H  SOMATO,8H LYMNAEA,8H   PHYSA,8HO. GASTR,8H S.NITID,
     18H S.STRIA,8H S.TRANS,8H S.CORN,8HP.ADAMSI,8H P.CASER,
     18H  P.COMP,8H  P.CONV,8H  P.FALL,8H  P.FERR,8H  P.HENS,
     18H P.IDAHO,8H P.LILLJ,8H  P.MILL,8H   P.NIT,8H  P.PAUP,
     18H P.SUPIN,8H   P.SUB,8H   P.VAR,8H  P.WALK,8H  H.STAG,
     18H D.PARVA,8H  N.OBSC,8H  G.COMP,8HO. HIRUD,8HO INSECT,
     18HP.HOYI 1,8HP.HOYI 2,8HP.HOYI 3,8HP.HOYI 4,8HP.HOYI G,
     18HP.HOYI S,8HP.HOYI M,8H  TPONTO,8H  TMYSIS,8H   TGAMM,
     18H  THYALL,8H   TCHIR,8H   TNAID,8H  TTUBIF,8H  TENCHY,
     18H  TSTYLO,8H  TOLIGO,8H TGASTRO,8H TSPHAER,8H  TPISIP,
     18H TPELECY,8H THYDRAC,8H  THIRUD,8H  THYDRA,8HTTURBELL,
     18H  TOTHER,8H TANIMAL,8H TAEOLOS,8H ASELLUS,8H O. NAID,
     18H  O.SERP,8H  N.COMM,8H P.FRICI,8HN.BRETSC,8HN.BEHNGI,
     18HO. TUBIF,8H P.VARIG,8H  P.HAMM,8H   A.PIG,8HM. PISID,
     18HU. PISID,8H S.RHOMB,8H P.AMNIC,8H S.SECUR,8HO. SPHAE,
     18HP.VENTRI,8H M. CHIR,8H   KIEFF,8H  C.HALO,8HPARACLAD,
     18HHARNISCH,8H PHAENOP,8H   DICRO,8H  GLYPTO,8HPARATANY,
     18HRHEOTANY,8H  STICTO/
C
      DATA    GROUPN/32*1HC,21*1HN,22*1HT,8*1HG,4*1HS,16*1HP,
     15*1HH,1HO,8*1HA,1HO,2*1HA,1HC,1HN,1HT,3*1HO,1HG,1HS,1HP,
     12*1HO,1HH,6*1HO,6*1HN,4*1HT,2*1HP,1HS,1HP,2*1HS,1HP,11*1HC/
C
C*******
C*******         READ DATA LINES CONTAINING 166 SPECIES COUNTS.
C*******
C
```

Continued on next page.

TABLE 4.18. (Continued).

```
 100  READ(5,10,END=99) YEAR,MONTH,REGIN,ZONE,DEPTH,CONFAC,AREA,
     1STAT,(SPCONT(J),J=1,166),PRSD,SESD,TESD,QUSD,VOLUME
  10  FORMAT(2(F3.0,2X),2(F2.0,2X),F4.1,2X,F5.2,2X,F2.0,2X,F4.0,
     12X,166(F10.2,2X),4(F2.0,2X),F4.1)
C
      IYEAR=YEAR
      IMONTH=MONTH
      IREGIN=REGIN
      IZONE=ZONE
      IAREA=AREA
      ISTAT=STAT
      IPRSD=PRSD
      ISESD=SESD
      ITESD=TESD
      IQUSD=QUSD
C
C*******
C*******       WRITE THE FLAT FILE WITH THE SPECIFICATIONS
C*******       OF ONE SPECIES AT EACH LINE.
C*******
C
      DO 20 I=1,166
      IF(SPCONT(I).LE.0.) GO TO 20
      WRITE(6,30) IYEAR,IMONTH,IREGIN,IZONE,DEPTH,CONFAC,IAREA,
     1ISTAT,GROUPN(I),SPNAME(I),SPCONT(I),IPRSD,ISESD,ITESD,
     1IQUSD,VOLUME
  30  FORMAT(2(I3,3X),2(I2,3X),F4.1,3X,F5.2,3X,I2,3X,I4,3X,A1,
     13X,A8,3X,F10.2,3X,4(I2,3X),F4.1)
  20  CONTINUE
C
      GO TO 100
C
  99  STOP
      END
```

TABLE 4.19. Program BLARRAN2.

```
C PROGRAM BLARRAN2 IS USED TO ORGANIZE LAKE BENTHOS DATA SETS FOR
C THE PERIOD OF 1979 TO 1982.  THE OUTPUT FILE IS IN THE FORM OF
C FLAT FILE  WHICH  LATER CAN BE ADDED TO LAKE.BENTHOS DATA BANK.
C UNIT 5 IS THE INPUT FILE.
C UNIT 6 IS ASSIGNED TO OUTPUT FILE. (FLAT FILE).
C
C
C
C
C*******
C*******       INITIALIZE VARIABLES.
C*******
C
       REAL YEAR,MONTH,AREA,REGIN,ZONE,DEPTH,CONFAC,PRSD,SESD,
      1TESD,OUSD,VOLUME,SPCONT(46),STAT
       REAL*8 SPNAME(46)
       INTEGER    IYEAR,IMONTH,IAREA,IREGIN,IZONE,IPRSD,ISESD,
      1ITESD,IOUSD,ISTAT
       LOGICAL*1 GROUPN(46)
C
C*******
C*******       INITIALIZE DATA.
C*******
C
       DATA SPNAME/8HP.HOYI 1,8HP.HOYI 2,8HP.HOYI 3,8HP.HOYI 4,
      18HP.HOYI G,8HP.HOYI S,8HP.HOYI M,8H  TPONTO,8H  TMYSIS,
      18H   TGAMM,8H  THYALL,8H ASELLUS,8HV.LEWISI,8H   V.SIN,
      18HAMNICOLA,8HBYTHINIA,8H  SOMATO,8H LYMNAEA,8H   PHYSA,
      18H TGASTRO,8H  TPISID,8HS.MARGIN,8H S.NITID,8HS.SIMILE,
      18H S.STRIA,8H S.TRANS,8H TSPHAER,8H TPELECY,8H   TCHIR,
      18H  TSTYLO,8H   TNAID,8H  TTUBIF,8H  TENCHY,8H  TOLIGO,
      18HGLOSSOPH,8H  H.STAG,8H D.PARVA,8H  N.OBSC,8HO. HIRUD,
      18H  THIRUD,8H THYDRAC,8H  THYDRA,8HTTURBELL,8H  TOTHER,
      18HO INSECT,8H TANIMAL/
C
       DATA    GROUPN/8*1HA,1HO,2*1HA,1HO,8*1HG,1HP,6*1HS,1HO,
      11HC,1HO,1HN,1HT,2*1HO,6*1HH,G*1HO/
C
C*******
C*******       READ DATA LINES CONTAINING 46 SPECIES COUNTS.
C*******
C
 100   READ(5,10,END=99) YEAR,MONTH,AREA,REGIN,ZONE,DEPTH,
      1CONFAC,PRSD,SESD,TESD,OUSD,VOLUME,(SPCONT(J),J=1,46),STAT
 10    FORMAT(2(F3.0,2X),F2.0,2X,2(F2.0,2X),F4.1,2X,
      1F5.2,2X,4(F2.0,2X),F4.1,2X,46(F10.2,2X),F4.0)
C
       IYEAR=YEAR
       IMONTH=MONTH
       IAREA=AREA
       IREGIN=REGIN
       IZONE=ZONE
       IPRSD=PRSD
       ISESD=SESD
       ITESD=TESD
       IOUSD=OUSD
       ISTAT=STAT
C
       IF(IYEAR.EQ.10) IYEAR=79
       IF(IYEAR.EQ.11) IYEAR=80
       IF(IYEAR.EQ.12) IYEAR=81
       IF(IYEAR.EQ.13) IYEAR=82
C
       IF(CONFAC.EQ.1.) CONFAC=60.60
       IF(CONFAC.EQ.2.) CONFAC=20.40
       IF(CONFAC.EQ.3.) CONFAC=30.30
```

Continued on next page.

TABLE 4.19. (Continued).

```
C
C********
C********       WRITE THE FLAT FILE WITH THE SPECIFICATIONS
C********       OF ONE SPECIES AT EACH LINE.
C********
C
      DO 20 I=1,46
      IF(SPCONT(I).LE.0.) GO TO 20
      WRITE(6,30) IYEAR,IMONTH,IREGIN,IZONE,DEPTH,CONFAC,
     1IAREA,ISTAT,GROUPN(I),SPNAME(I),SPCONT(I),IPRSD,
     1ISESD,ITESD,IQUSD,VOLUME
 30   FORMAT(2(I3,3X),2(I2,3X),F4.1,3X,F5.2,3X,I2,3X,I4,
     13X,A1,3X,A8,3X,F10.2,3X,4(I2,3X),F4.1)
 20   CONTINUE
C
      GO TO 100
C
 99   STOP
      END
```

Taxir Create Program

Program BLTAXIRCR is a Taxir Create program for establishing the Lake.Benthos data bank. This Create program uses the result of the reformat programs establishing a Taxir data base, LAKE.BENTHOS, which is saved on the COOK tape at position 5. The Taxir Create program for the Lake.Benthos data bank is shown in Table 4.20.

TABLE 4.20. Program BLTAXIRCR.

```
RUN *TAXIR
CREATE LAKE.BENTHOS,
YEAR(FROM 70 TO 85),
MONTH(FROM -0 TO 12),
REGION(FROM -0 TO 9),
ZONE(FROM -0 TO 9),
DEPTH(FROM -0.0 TO 99.9),
CON.FACT(FROM -0.00 TO 99.99),
AREA(FROM -0 TO 9),
STATION(FROM -0 TO 999),
GROUP(ORDER,A,C,G,H,N,O,P,S,T),
CODE(NAME),
CELLS(FROM 0.01 TO 1000000.99),
PRIM SED(FROM -0 TO 9),
SEC SED(FROM -0 TO 9),
TERT SED(FROM -0 TO 9),
QUAT SED(FROM -0 TO 9),
VOLUME(FROM -0.0 TO 99.9)*
ENTER DATA LOCATION=BLREMIDAS, FORMAT=FIXED,
YEAR<1-3>,
MONTH<7-9>,
REGION<13-14>,
ZONE<18-19>,
DEPTH<23-26>,
CON.FACT<30-34>,
AREA<38-39>,
STATION<43-46>,
GROUP<50>,
CODE<54-61>,
CELLS<65-74>,
PRIM SED<78-79>,
SEC SED<83-84>,
TERT SED<88-89>,
QUAT SED<93-94>,
VOLUME<98-101>*
SAVE
STOP
```

ENTRAINED BENTHOS

The Entrained.Benthos data bank contains 11 descriptors and 7,911 items. The descriptors are:

1-SAMPLE

2-YEAR

3-MONTH

4-WEEK

5-PERIOD

6-PUMP

7-REPLICATION

8-CUBIC.METER

9-GROUP

10-CODE

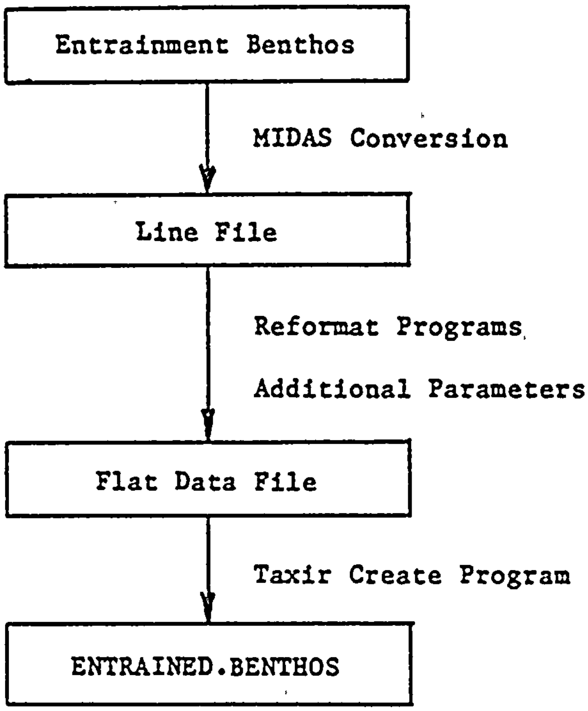
11-CELLS

The monthly number of data items stored in the Entrained.Benthos data bank is shown in Table 4.21.

TABLE 4.21. The number of data items in Entrained.Benthos data bank.

Year	Month	Total # of Items	Year	Month	Total # of Items	Year	Month	Total # of Items
75	1	(54)	78	1	(75)	81	1	(62)
	2	(94)		2	(22)		2	(42)
	3	(25)		3	(21)		3	(79)
	4	(48)		4	(46)		4	(59)
	5	(47)		5	(98)		5	(131)
	6	(65)		6	(195)		6	(281)
	7	(69)		7	(159)		7	(185)
	8	(109)		8	(189)		8	(200)
	9	(83)		9	(96)		9	(99)
	10	(39)		10	(86)		10	(131)
	11	(61)		11	(112)		11	(105)
	12	(125)		12	(119)		12	(184)
76	1	(66)	79	1	(50)	82	1	(29)
	2	(31)		2	(32)		2	(21)
	3	(95)		3	(20)		3	(9)
	4	(68)		4	(109)		4	(29)
	5	(79)		5	(100)		5	(5)
	6	(97)		6	(178)			
	7	(135)		7	(134)			
	8	(70)		8	(183)			
	9	(77)		9	(80)			
	10	(45)		10	(97)			
	11	(6)		11	(117)			
	12	(24)		12	(99)			
77	3	(26)	80	1	(131)			
	4	(51)		2	(43)			
	5	(5)		3	(29)			
	6	(123)		4	(50)			
	7	(67)		5	(75)			
	8	(222)		6	(235)			
	9	(90)		7	(142)			
	10	(136)		8	(207)			
	11	(23)		9	(102)			
	12	(150)		10	(107)			
				11	(108)			
				12	(109)			

The steps used to create the Entrained.Benthos data bank are shown in the following flow diagram:



Entrained.Benthos Data Bank

The original entrained benthos data are stored in an internal MIDAS file as ENTRAINMENT-REV. This file was first converted to an MTS line file and then changed to a flat file. The detailed procedures for creating a line file from an internal MIDAS file was discussed previously. The similar procedures for creating a line file for entrained benthos are shown below:

```
$RUN STAT:MIDAS
(reading all the variables)
?READ INTERNAL FILE=ENTRAINMENT-REV VARIABLE=ALL
(writing the required variables with the desired order)
?WRITE VARIABLE=1-7,9-16,18-22,24-25 FILE=EINVMIDAS CASES=ALL
```

```
FORMAT=(F4.0,1X,6(F3.0,1X),F6.2,1X,34(F10.5,1X))
?FINISH
```

The order of the parameters in the EINVMIDAS is as follows: YEAR, MONTH, WEEK, PERIOD, PUMP, REPLIC, CUBICM, and 34 parameters for species.

Reformat Program

Each species in the entrained benthos file EINVMIDAS is treated as a parameter in the same way as that in the lake benthos file. The program BEARRAN was written for the same purposes as those for the lake benthos data, to reduce the space reserved for those species that show no counts and to rearrange the data by placing one species per line in a flat file. The content of this program is listed in Table 4.22. The result from program BEARRAN was saved in a file named BEREMIDAS.

Taxir Create Program

A Taxir Create program, BETAXIRCR, was used to create the Entrained Benthos data bank. This computer data bank is saved at position 6 of the COOK tape. The contents of BETAXIRCR are listed in Table 4.23.

TABLE 4.22. Program BEARRAN.

```
C PROGRAM BEARRAN IS USED TO ORGANIZE  ENTRAINMENT BENTHOS DATA SETS
C FOR THE PERIOD OF 1975 TO 1982.  THE OUTPUT FILE IS IN THE FORM OF
C FLAT FILE WHICH LATER CAN BE ADDED TO ENTRAINED.BENTHOS DATA BANK.
C UNIT 5 IS THE INPUT FILE.
C UNIT 6 IS THE OUTPUT FILE. (FLAT FILE).
C
C
C
C
C*******
C*******        INITIALIZE VARIABLES.
C*******
C
      REAL SAMP,YEAR,MONTH,WEEK,PERID,PUMP,REP,CUBICM,SPCONT(34)
      REAL*8 SPNAME(34)
      INTEGER ISAMP,IYEAR,IMONTH,IWEEK,IPERID,IPUMP,IREP
      INTEGER*2 GROUPN(34)
C
C*******
C*******        INITIALIZE DATA.
C*******
C
      DATA SPNAME/8H P.HOYI1,8H P.HOYI2,8H P.HOYI3,8H P.HOYI4,
     18HP.HOYI G,8HP.HOYI S,8HP.HOYI M,8H T MYSIS,8H  T GAMM,
     18H T HYALL,8HCRANGONX,8H T ASELL,8H  T CHIR,8H  T NAID,
     18H T TUBIF,8H T STYLO,8H T ENCHY,8H T HIRUD,8H TGASTRO,
     18HT SPHAER,8H T PISID,8HT HYDRAC,8H T HYDRA,8H  T TURB,
     18HCRAYFISH,8H  OTHERS,8H TRICHOP,8H   EPHEM,8H ODONATA,
     18H COLEOPT,8H CHAOBOR,8H CULICID,8HSIMULIID,8HOINSECTA/
      DATA   GROUPN/7*2HAM,2HMY,3*2HAM,2HAS,2HCH,4*2HOL,2HHI,
     12HGA,2HSP,2HPI,3*2HOT,2HCR,2HOT,8*2HOI/
C
C*******
C*******        READ DATA LINES CONTAINING 34 SPECIES COUNTS.
C*******
C
 100  READ(5,10,END=99) SAMP,YEAR,MONTH,WEEK,PERID,PUMP,REP,
     1CUBICM,(SPCONT(I),I=1,34)
 10   FORMAT(F4.0,1X,6(F3.0,1X),F6.2,1X,34(F10.5,1X))
      ISAMP=SAMP
      IYEAR=YEAR
      IMONTH=MONTH
      IWEEK=WEEK
      IPERID=PERID
      IPUMP=PUMP
      IREP=REP
C
C*******
C*******        CHANGE YEAR CODES. (EX: CHANGE 1 TO 75).
C*******
C
      IF(IYEAR.EQ.1) IYEAR=75
      IF(IYEAR.EQ.2) IYEAR=76
      IF(IYEAR.EQ.3) IYEAR=77
      IF(IYEAR.EQ.4) IYEAR=78
      IF(IYEAR.EQ.5) IYEAR=79
      IF(IYEAR.EQ.6) IYEAR=80
      IF(IYEAR.EQ.7) IYEAR=81
      IF(IYEAR.EQ.8) IYEAR=82
C
C*******
C*******        WRITE THE FLAT FILE WITH THE SPECIFICATIONS
C*******        OF ONE SPECIES AT EACH LINE.
C*******
C
      DO 20 I=1,34
      IF(SPCONT(I).LE.0.0) GO TO 20
      WRITE(6,30) ISAMP,IYEAR,IMONTH,IWEEK,IPERID,IPUMP,
     1IREP,CUBICM,GROUPN(I),SPNAME(I),SPCONT(I)
 30   FORMAT(I3,3X,6(I2,3X),F6.2,3X,A2,3X,A8,3X,F10.5)
 20   CONTINUE
      GO TO 100
C
 99   STOP
      END
```

TABLE 4.23. Program BETAXIRCR.

```
RUN *TAXIR
CREATE ENTRAINED.BENTHOS,
SAMPLE(FROM 100 TO 999),
YEAR(FROM 70 TO 85),
MONTH(FROM 1 TO 12),
WEEK(FROM 1 TO 5),
PERIOD(FROM 1 TO 9),
PUMP(FROM 1 TO 2),
REPLIC(FROM 1 TO 2),
CUBIC M(FROM 0.00 TO 999.99),
GROUP(ORDER,AM,AS,CH,CR,GA,HI,OI,OL,OT,MY,PI,SP),
CODE(NAME),
CELLS(FROM 0.00000 TO 9999.99999)*
ENTER DATA LOCATION=BEREMIDAS, FORMAT=FIXED,
SAMPLE<1-3>,
YEAR<7-8>,
MONTH<12-13>,
WEEK<17-18>,
PERIOD<22-23>,
PUMP<27-28>,
REPLIC<32-33>,
CUBIC M<37-42>,
GROUP<46-47>,
CODE<51-58>,
CELLS<62-71>*
SAVE
STOP
```

IMPINGED BENTHOS

The Impinged.Benthos data bank contains 4,103 items and 11 descriptors, which are listed below:

1-YEAR

2-MONTH

3-PERIOD

4-CASE

5-NAME

6-SEX

7-REPRODUCTION

8-SIZE

9-NUMBER

10-TOTAL NUMBER

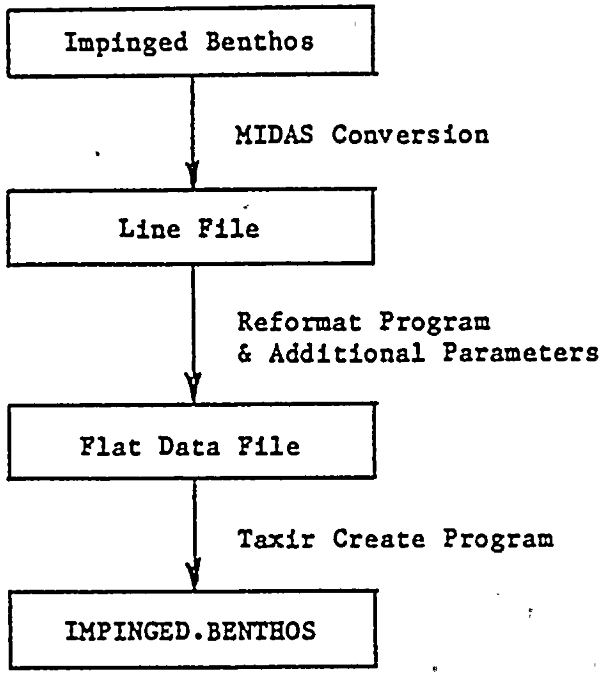
11-TOTAL WEIGHT

The monthly number of data items stored in the Impinged.Benthos data bank is shown in Table 4.24.

TABLE 4.24. The number of data items in Impinged.Benthos data bank.

Year	Month	Total # of Items	Year	Month	Total # of Items	Year	Month	Total # of Items
75	1	(13)	78	1	(27)	81	1	(34)
	2	(26)		2	(19)		2	(12)
	3	(51)		3	(26)		3	(40)
	4	(104)		4	(53)		4	(34)
	5	(101)		5	(10)		6	(10)
	6	(46)		6	(17)		7	(56)
	7	(18)		7	(28)		8	(49)
	8	(638)		8	(47)		9	(14)
	9	(525)		9	(17)		10	(11)
	10	(150)		10	(19)		11	(15)
	11	(120)		11	(19)		12	(14)
	12	(39)		12	(4)			
76	1	(57)	79	1	(4)			
	2	(30)		2	(4)			
	3	(36)		3	(18)			
	4	(57)		4	(9)			
	5	(22)		5	(2)			
	6	(48)		7	(41)			
	7	(102)		8	(49)			
	8	(102)		9	(32)			
	9	(81)		10	(16)			
	10	(41)		11	(16)			
	11	(38)		12	(2)			
	12	(33)	80	2	(16)			
77	1	(11)		3	(38)			
	2	(9)		4	(59)			
	3	(39)		5	(66)			
	4	(94)		6	(12)			
	5	(56)		7	(15)			
	6	(69)		8	(63)			
	7	(110)		9	(31)			
	8	(45)		10	(21)			
	9	(29)		11	(2)			
	10	(24)		12	(13)			
	11	(18)						
	12	(50)						

The steps for establishing this data bank are shown in the following flow diagram:



<u>Impinged.Benthos Data Bank</u>

The data for impinged benthos are also in an internal MIDAS file. The same MTS procedures used for both lake and entrained benthos are used here. The computer statements for the operations are listed below:

```
#RUN STAT:MIDAS
(read all the variables)
?READ INTERNAL FILE=IMPINGE VARIABLE=ALL
(write the required parameters)
?WRITE VARIABLE=1-44,46-49 FILE=IINVMIDAS CASES=ALL
FORMAT=(3(F3.0,1X),45(F7.1,1X))
?FINISH
```

The order of the original variables in IINVMIDAS is as follows: YEAR, MONTH, REPRODUCTION, SPECIES (the parameters of 43 species), TOTAL NUMBER, TOTAL WEIGHT.

Reformat Program

The reformat program BIARRAN was used to reduce the space occupied by those impinged benthos species that show no counts and to rearrange the data so that each species is in the form of one species per line in a flat file. The contents of BIARRAN are listed in Table 4.25.

Taxir Create Program

The Taxir Create program BITAXIRCR was used to create the Impinged.Benthos data bank. The complete Impinged.Benthos data bank is stored on tape COOK at position 7. The contents of the program are listed in Table 4.26.

TABLE 4.25. Program BIARRAN.

```
C PROGRAM BIARRAN IS USED TO ORGANIZE IMPINGEMENT BENTHOS DATA SETS
C FOR THE PERIOD OF 1975 TO 1981. THE OUTPUT FILE IS IN THE FORM OF
C FLAT FILE WHICH LATER CAN BE ADDED TO IMPINGED.BENTHOS DATA BANK.
C UNIT 5 IS ASSIGNED TO INPUT FILE.
C UNIT 6 IS THE OUTPUT FILE. (FLAT FILE).
C
C
C
C
C********
C********       INITIALIZE VARIABLES.
C********
C
      REAL YEAR(815),MONTH(815),PERIOD(815),SPCONT(815,43),
     1TOTALN(815),TOTALW(815)
      REAL*8 NAME(43)
      INTEGER IYEAR(815),IMONTH(815),IPERID(815)
      INTEGER*2 SEX(43),REPROD(43),SIZE(43)
C
C********
C********       INITIALIZE DATA.
C********
C
      DATA NAME/41*8HORC PROP,8HMUTILATE,8HOTHER SP/
      DATA  SEX/2*2H F,2HM1,2HM2,2*2H F,2HM1,2HM2,2*2H F,
     12HM1,2HM2,2*2H F,2HM1,2HM2,2*2H F,2HM1,2HM2,2*2H F,
     12HM1,2HM2,2*2H F,2HM1,2HM2,2*2H F,2HM1,2HM2,2*2H F,
     12HM1,2HM2,2*2H F,2HM1,2HM2,2H M,2*2H  /
C
      DATA REPROD/2H R,2HNR,2*2H  ,2H R,2HNR,2*2H  ,2H R,
     12HNR,2*2H  ,2H R,2HNR,2*2H  ,2H R,2HNR,2*2H  ,2H R,
     12HNR,2*2H  ,2H R,2HNR,2*2H  ,2H R,2HNR,2*2H  ,2H R,
     12HNR,2*2H  ,2H R,2HNR,5*2H  /
      DATA SIZE/4*2H 1,4*2H 2,4*2H 3,4*2H 4,4*2H 5,4*2H 6,
     14*2H 7,4*2H 8,4*2H 9,4*2H10,3*2H  /
C
C********
C********       READ DATA LINES CONTAINING 43 SPECIES COUNTS.
C********
C
      DO 10 I=1,815
      READ(5,20) YEAR(I),MONTH(I),PERIOD(I),(SPCONT(I,J),J=1,43),
     1TOTALN(I),TOTALW(I)
 20   FORMAT(3(F3.0,1X),45(F7.1,1X))
      IYEAR(I)=YEAR(I)
      IMONTH(I)=MONTH(I)
      IPERID(I)=PERIOD(I)
C
C********
C********       CHANGE YEAR CODES. (EX: CHANGE 1 TO 75).
C********
C
      IF(IYEAR(I).EQ.1) IYEAR(I)=75
      IF(IYEAR(I).EQ.2) IYEAR(I)=76
      IF(IYEAR(I).EQ.3) IYEAR(I)=77
      IF(IYEAR(I).EQ.4) IYEAR(I)=78
      IF(IYEAR(I).EQ.5) IYEAR(I)=79
      IF(IYEAR(I).EQ.6) IYEAR(I)=80
      IF(IYEAR(I).EQ.7) IYEAR(I)=81
C
C********
C********       WRITE THE FLAT FILE WITH THE SPECIFICATIONS
C********       OF ONE SPECIES AT EACH LINE.
C********
C
      DO 30 K=1,43
      IF(SPCONT(I,K).LE.0.) GO TO 30
      WRITE(6,40) IYEAR(I),IMONTH(I),IPERID(I),I,NAME(K),
     1SEX(K),REPROD(K),SIZE(K),SPCONT(I,K),TOTALN(I),TOTALW(I)
 40   FORMAT(3(I2,3X),I3,3X,A8,3(3X,A2),3(3X,F7.1))
 30   CONTINUE
 10   CONTINUE
C
      STOP
      END
```

TABLE 4.26. Program BITAXIRCR.

```
RUN *TAXIR
CREATE IMPINGED.BENTHOS,
YEAR(FROM 70 TO 85),
MONTH(FROM 1 TO 12),
PERIOD(FROM 1 TO 9),
CASE(FROM 1 TO 999),
NAME(NAME),
SEX(NAME),
REPROD(NAME),
SIZE(FROM 1 TO 10),
NUMBER(FROM 0.0 TO 99999.9),
TOTALN(FROM 0.0 TO 99999.9),
TOTALW(FROM 0.0 TO 99999.9)*
ENTER DATA LOCATION=BIREMIDAS, FORMAT=FIXED,
YEAR<1-2>,
MONTH<6-7>,
PERIOD<11-12>,
CASE<16-18>,
NAME<22-29>,
SEX<33-34>,
REPROD<38-39>,
SIZE<43-44>,
NUMBER<48-54>,
TOTALN<58-64>,
TOTALW<68-74>*
SAVE
STOP
```

SUMMARY STATISTICS FOR ADULT LAKE AND IMPINGED FISH

This Adult.Fish.Summary.Statistics data bank is one of the largest in the Cook project. It consists of 102,238 items and 10 descriptors. The descriptors are listed below:

1-SPECIES

2-MONTH

3-YEAR

4-GEAR

5-STATION

6-SERIES

7-TEMPERATURE

8-INTERVAL

9-TOTAL NUMBER

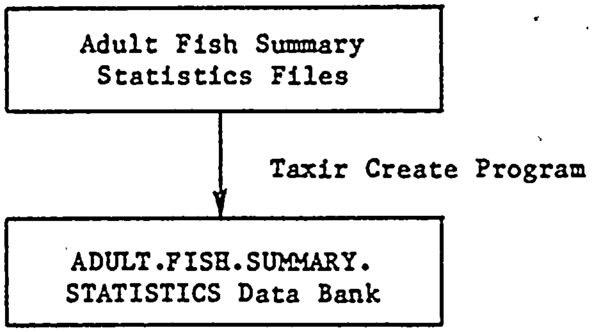
10-TOTAL WEIGHT

The monthly number of data items stored in the Adult.Fish.Summary.Statistics data bank is listed in Table 4.27.

TABLE 4.27. The number of data items in the Adult.Fish.Summary.Statistics data bank.

Year	Month	Total # of Items	Year	Month	Total # of Items	Year	Month	Total # of Items
73	1	(25)	76	1	(992)	79	1	(261)
	2	(127)		2	(728)		2	(87)
	3	(282)		3	(569)		3	(267)
	4	(847)		4	(1,125)		4	(1,227)
	5	(922)		5	(1,314)		5	(788)
	6	(1,257)		6	(997)		6	(1,042)
	7	(891)		7	(1,652)		7	(1,131)
	8	(1,126)		8	(1,006)		8	(1,177)
	9	(792)		9	(1,016)		9	(1,445)
	10	(870)		10	(761)		10	(1,000)
	11	(145)		11	(316)		11	(752)
	12	(68)		12	(233)		12	(112)
74	1	(114)	77	1	(51)	80	1	(62)
	2	(21)		2	(67)		2	(149)
	3	(445)		3	(257)		3	(185)
	4	(805)		4	(507)		4	(669)
	5	(1,160)		5	(936)		5	(1,562)
	6	(867)		6	(951)		6	(1,681)
	7	(1,564)		7	(1,115)		7	(1,006)
	8	(1,097)		8	(891)		8	(1,141)
	9	(725)		9	(1,088)		9	(1,496)
	10	(584)		10	(936)		10	(1,288)
	11	(326)		11	(748)		11	(730)
	12	(165)		12	(179)		12	(491)
75	1	(285)	78	1	(150)	81	1	(307)
	2	(215)		2	(56)		2	(143)
	3	(791)		3	(141)		3	(123)
	4	(2,843)		4	(412)		4	(959)
	5	(2,698)		5	(718)		5	(1,562)
	6	(3,286)		6	(1,128)		6	(1,722)
	7	(1,872)		7	(1,359)		7	(1,617)
	8	(1,875)		8	(1,368)		8	(840)
	9	(1,580)		9	(1,140)		9	(966)
	10	(1,682)		10	(1,373)		10	(1,176)
	11	(2,279)		11	(724)		11	(1,233)
	12	(2,102)		12	(222)		12	(550)
						82	1	(250)
							2	(90)
							3	(128)
							4	(1,147)
							5	(908)
							6	(1,131)
							7	(875)
							8	(709)
							9	(817)
							10	(584)
							11	(602)
							12	(91)

The procedures for establishing this data bank are shown as follows:



Adult.Fish.Summary.Statistics Data Bank

The original data for adult lake and impinged fish summary statistics are stored in flat-file form; therefore, no procedure is necessary to rearrange this data format. A Taxir Create program was used to create the Adult.Fish. Summary.Statistics data bank directly from the original data files. These computer data are stored on tape COOK at position 8. The Taxir Create program AFSSTAXIRCR is shown in Table 4.28.

TABLE 4.28. Program AFSSTAXIRCR.

```
RUN *TAXIR
CREATE ADULT.FISH.SUMMARY.STATISTICS.
SPECIES(FROM 0 TO 99),
MONTH(FROM 1 TO 12),
YEAR(FROM 70 TO 85),
GEAR(FROM 0 TO 99),
STATION(FROM 0 TO 99),
SERIES(FROM 0 TO 99),
TEMPERATURE(FROM 0.0 TO 99.9),
INTERVAL(FROM 0 TO 999),
TOTALNUMBER(FROM 0 TO 999999),
TOTALWEIGHT(FROM 0.0 TO 99999999.9)*
ENTER DATA LOCATION=MASTERFILE, FORMAT=FIXED,
SPECIES<1-2>,
MONTH<3-4>,
YEAR<5-6>,
GEAR<7-8>,
STATION<9-10>,
SERIES<11-12>,
TEMPERATURE<13-16>,
INTERVAL<17-19>,
TOTALNUMBER<20-25>,
TOTALWEIGHT<26-35>*
SAVE
STOP
```

FIELD-CAUGHT AND IMPINGED FISH

The data for field-caught and impinged fish constitute the largest data set in the Cook project. Because the data are too extensive to be held in a single file, the data were divided into two files. The first one contains the raw data on adult lake fish stored in computer data base Lake.Adult.Fish; the second one includes the raw data on impinged adult fish stored in the computer data base Impinged.Adult.Fish. Both data banks have 22 descriptors:

1-MONTH	12-SPECIES
2-DAY	13-FISH NO.
3-YEAR	14-LENGTH
4-TIME	15-WEIGHT
5-GEAR	16-SEX
6-SERIES	17-GONAD COND.
7-STATIC	18-GILLNET HR.
8-WATER TEMP.	19-GILLNET MIN.
9-FISHUSE	20-FOOD PRESENT
10-BIOL.COND.	21-SUBSAMPLE
11-PHY.COND.	22-TWNONSUB

The Lake.Adult.Fish data bank has 181,156 items, and the Impinged.Adult. Fish data bank includes 110,843 items. The numbers of data items stored in the data banks are shown in Tables 4.29 and 4.30.

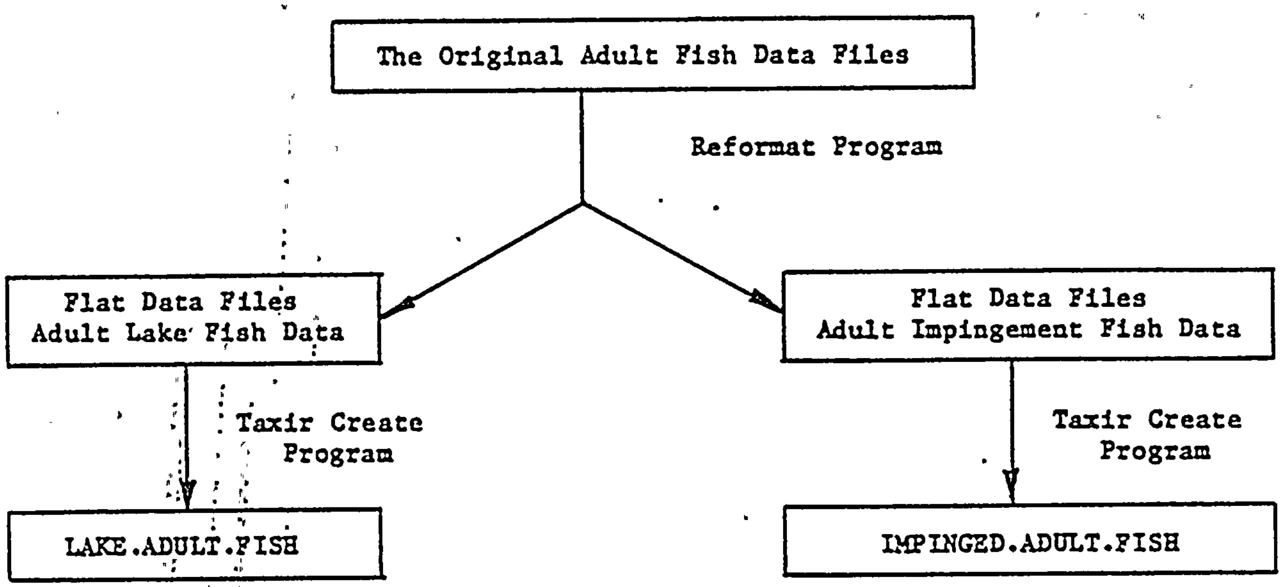
TABLE 4.29. The number of data items in Lake.Adult.Fish data bank.

Year	Month	Total # of Items	Year	Month	Total # of Items	Year	Month	Total # of Items
73	2	(80)	76	2	(143)	80	4	(953)
	3	(830)		3	(205)		5	(4,508)
	4	(2,611)		4	(2,146)		6	(3,819)
	5	(2,445)		5	(2,700)		7	(2,957)
	6	(3,746)		6	(2,008)		8	(2,411)
	7	(2,219)		7	(3,302)		9	(3,738)
	8	(3,130)		8	(2,117)		10	(2,887)
	9	(1,568)		9	(2,153)		11	(1,725)
	10	(2,263)		10	(1,448)	81	4	(2,324)
	11	(211)		11	(326)		5	(2,973)
	12	(7)	77	3	(206)		6	(4,264)
74	1	(82)		4	(413)		7	(4,443)
	3	(419)		5	(2,057)		8	(1,275)
	4	(1,866)		6	(1,947)		9	(1,769)
	5	(3,516)		7	(2,554)		10	(2,418)
	6	(2,448)		8	(2,205)		11	(2,099)
	7	(3,177)		9	(2,646)	82	4	(1,663)
	8	(2,256)		10	(2,063)		5	(1,711)
	9	(1,526)		11	(1,494)		6	(2,128)
	10	(1,284)		12	(40)		7	(1,433)
	11	(567)	78	4	(434)		8	(1,621)
	12	(91)		5	(1,313)		9	(2,258)
75	1	(94)		6	(2,854)		10	(896)
	3	(376)		7	(3,417)		11	(1,186)
	4	(703)		8	(2,976)			
	5	(2,319)		9	(2,175)			
	6	(3,156)		10	(3,227)			
	7	(2,055)		11	(1,313)			
	8	(1,753)	79	4	(2,399)			
	9	(2,495)		5	(1,934)			
	10	(1,541)		6	(3,004)			
	11	(1,208)		7	(2,967)			
	12	(917)		8	(2,647)			
				9	(3,509)			
				10	(2,677)			
				11	(1,719)			

TABLE 4.30. The number of data items in the Impinged.Adult.Fish data bank.

Year	Month	Total # of Items	Year	Month	Total # of Items	Year	Month	Total # of Items
73	1	(33)	77	1	(68)	80	1	(132)
	2	(157)		2	(118)		2	(383)
	3	(11)		3	(456)		3	(572)
	4	(99)		4	(588)		4	(2,667)
	10	(2)		5	(337)		5	(1,667)
	11	(6)		6	(325)		6	(2,159)
	12	(140)		7	(521)		7	(488)
74	1	(98)		8	(80)		8	(1,384)
	2	(30)		9	(148)		9	(2,260)
	3	(745)		10	(622)		10	(1,530)
	4	(255)		11	(326)		11	(51)
	5	(173)		12	(316)		12	(1,294)
	6	(38)	78	1	(305)	81	1	(1,247)
	7	(1,193)		2	(73)		2	(284)
	8	(767)		3	(376)		3	(256)
	9	(276)		4	(333)		4	(708)
	10	(52)		5	(470)		5	(3,466)
	11	(122)		6	(408)		6	(2,231)
	12	(205)		7	(1,235)		7	(1,326)
75	1	(467)		8	(1,286)		8	(983)
	2	(424)		9	(468)		9	(519)
	3	(1,063)		10	(628)		10	(997)
	4	(8,084)		11	(388)		11	(1,754)
	5	(4,853)		12	(484)		12	(2,606)
	6	(6,153)	79	1	(719)	82	1	(565)
	7	(2,097)		2	(130)		2	(206)
	8	(1,735)		3	(514)		3	(262)
	9	(1,344)		4	(661)		4	(2,140)
	10	(3,879)		5	(45)		5	(1,575)
	11	(4,189)		6	(5)		6	(1,872)
	12	(3,697)		7	(1,053)		7	(1,032)
76	1	(2,626)		8	(1,027)		8	(296)
	2	(1,249)		9	(1,359)		9	(134)
	3	(1,611)		10	(814)		10	(384)
	4	(574)		11	(124)		11	(562)
	5	(759)		12	(276)		12	(228)
	6	(616)						
	7	(1,099)						
	8	(548)						
	9	(575)						
	10	(593)						
	11	(378)						
	12	(522)						

The procedures for creating these two data banks are shown in the flow diagram below:



Reformat Program

The program CHNGFRMT was used to reorganize the data for the adult lake and impinged fish which are stored in a file named TRANSREC. It separates lake fish data from the impingement data and enters the results of this program in flat-file forms stored in REFTRANFIE and REFTRANIMP, where the former contains the lake data and the latter houses the impingement data. These procedures are shown below:

```
#RUN *FTN SCARDS=CHNGFRMT SPUNCH=C.OBJ
#RUN C.OBJ 5=TRANSREC 6=REFTRANFIE 7=REFTRANIMP
```

(Table 4.31 is a copy of program CHNGFRMT)

TABLE 4.31. Program CHNGFRMT.

```
C PROGRAM CHNGFRMT  IS USED TO SEPARATE FIELD RECORDS FROM THE IMPINGEMENT
C RECORDS IN THE TRANSREC FILES. THE OUTPUT FILES PROVIDED BY THIS PROGRAM
C ARE IN THE FORM OF FLAT FILES.
C UNIT 5 IS THE INPUT FILE. (TRANSREC FILES).
C UNIT 6 IS THE OUTPUT FILE FOR IMPINGEMENT RECORDS.
C UNIT 7 IS THE OUTPUT FILE FOR FIELD RECORDS.
C
C
C
C
C*******
C*******      INITIALIZE VARIABLES.
C*******
C
      INTEGER AB
      REAL D,E,H
      LOGICAL*1 A(13),AC(7),B(20),C(18)
C
C*******
C*******      READ THE DATA LINES FROM TRANSREC FILES.
C*******
C
 100  READ(5,1,END=99) A,AB,AC,D,B,E,C,H
 1    FORMAT(13A1,I1,7A1,F4.1,20A1,F5.0,18A1,F7.0)
C
C*******
C*******      CHECK THE TYPE OF THE RECORD. (IMPINGEMENT OR FIELD).
C*******
C
      IF(H.EQ.0.0) GO TO 10
      IF(AB.EQ.1) GO TO 20
C
C*******
C*******      WRITE THE IMPINGEMENT AND FIELD RECORDS.
C*******
C
      WRITE(6,2) A,AB,AC,D,B,E,C,H
 2    FORMAT(13A1,I1,7A1,F4.1,20A1,F8.2,18A1,F9.1)
      GO TO 100
C
 20   WRITE(7,2) A,AB,AC,D,B,E,C,H
      GO TO 100
C
 10   IF(AB.EQ.1) GO TO 30
      WRITE(6,3) A,AB,AC,D,B,E,C
 3    FORMAT(13A1,I1,7A1,F4.1,20A1,F8.2,18A1)
      GO TO 100
C
 30   WRITE(7,3) A,AB,AC,D,B,E,C
      GO TO 100
C
 99   STOP
      END
```

Taxir Create Program

The Taxir Create program AFTAXIRCR (Table 4.32) was used to create adult lake and impinged fish data banks from the flat files REFTRANFIE and REFTRANIMP. The results of the Taxir Create program are saved in the Lake.Adult.Fish and Impinged.Adult.Fish data banks. The final version of Lake.Adult.Fish is saved on tape COOK at position 9, and that for Impinged.Adult.Fish is stored on the same tape at position 10.

TABLE 4.32. Program AFTAXIRCR.

```
RUN *TAXIR
CREATE IMPINGED.ADULT.FISH,
MONTH(FROM 1 TO 12),
DAY(FROM 1 TO 31),
YEAR(FROM 70 TO 85),
TIME(FROM 0 TO 2400),
GEAR(FROM 0 TO 9),
SERIES(FROM 0 TO 99),
STATION(FROM 0 TO 9),
WATERTEMP.(FROM 0.0 TO 99.9),
FISHUSE(FROM 0 TO 9),
BIOL.COND.(FROM 0 TO 9),
PHY.COND.(FROM 0 TO 9),
SPECIES(FROM 0 TO 99),
FISHNO.(FROM 0 TO 999999),
LENGTH(FROM 0 TO 9999),
WEIGHT(FROM 0.00 TO 99999.99),
SEX(FROM 0 TO 9),
GONADCOND.(FROM 0 TO 9),
GILLNETHR.(FROM 0 TO 99),
GILLNETMIN.(FROM 0 TO 99),
FOODPRESENT(FROM 0 TO 9),
SUBSAMPLE(FROM 0 TO 99),
TWNONSUB(FROM 0.0 TO 9999999.9)*
ENTER DATA LOCATION=REFTRANIMP, FORMAT=FIXED,
MONTH<1-2>,
DAY<3-4>,
YEAR<5-6>,
TIME<9-12>,
GEAR<14>,
SERIES<15-16>,
STATION<19>,
WATERTEMP.<22-25>,
FISHUSE<29>,
BIOL.COND.<30>,
PHY.COND.<31>,
SPECIES<32-33>,
FISHNO.<34-39>,
LENGTH<41-44>,
WEIGHT<46-53>,
SEX<56>,
GONADCOND.<59>,
GILLNETHR.<60-61>,
GILLNETMIN.<62-63>,
FOODPRESENT<64>,
SUBSAMPLE<68-69>,
TWNONSUB<72-80>*
SAVE
STOP
```

FIELD: LARVAL FISH

The Lake.Larvae data bank contains 20 descriptors and 14,110 items. The descriptors are as follows:

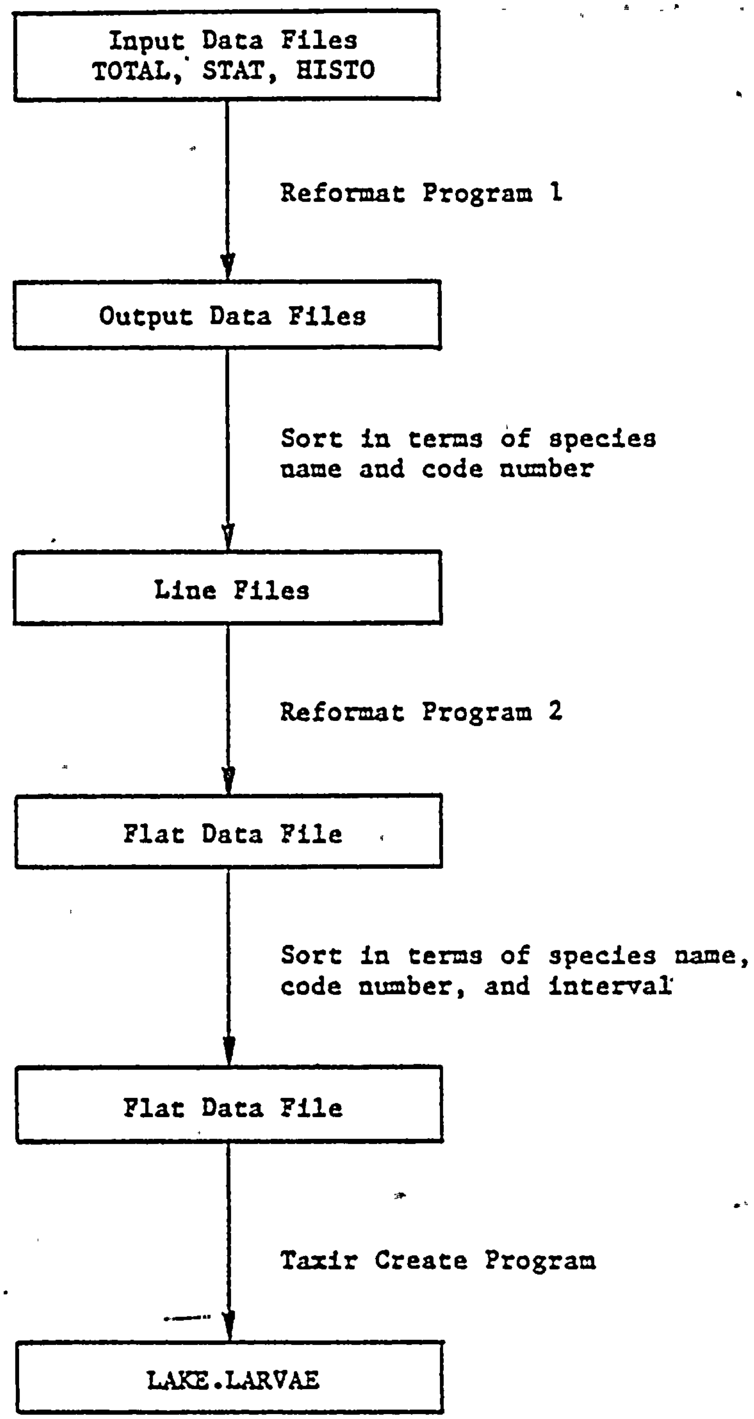
1-CODE NO.	11-GRATE
2-SAMPLE NO.	12-STATION
3-PERIOD	13-TEMPERATURE
4-MONTH	14-REVOLATION
5-DAY	15-SPECIES NAME
6-YEAR	16-SPECIES DENSITY
7-DIAL	17-INTERVAL
8-TIME	18-NUMBER
9-GEAR	19-SUM LENGTH
10-TOW DEPTH	20-SUM SQUARE LENGTH

The monthly number of data items stored in the Lake.Larvae data bank is listed in Table 4.33.

TABLE 4.33. The number of data items in Lake.Larvae data bank.

Year	Month	Total # of Items	Year	Month	Total # of Items	Year	Month	Total # of Items
73	3	(8)	77	4	(56)	81	4	(77)
	4	(80)		5	(56)		5	(139)
	5	(55)		6	(213)		6	(239)
	6	(404)		7	(398)		7	(184)
	7	(372)		8	(311)		8	(480)
	8	(151)		9	(91)		9	(111)
	9	(45)		10	(17)		10	(12)
	10	(52)		11	(17)		11	(12)
	11	(10)	78	4	(78)	82	4	(76)
74	1	(4)		5	(86)		5	(106)
	3	(12)		6	(150)		6	(483)
	4	(58)		7	(121)		7	(492)
	5	(171)		8	(237)		8	(466)
	6	(395)		9	(74)		9	(12)
	7	(463)		10	(19)		10	(12)
	8	(336)		11	(13)		11	(12)
	9	(155)	79	4	(72)			
	10	(58)		5	(88)			
	11	(30)		6	(125)			
75	4	(74)		7	(507)			
	5	(120)		8	(358)			
	6	(300)		9	(122)			
	7	(521)		10	(34)			
	8	(419)		11	(12)			
	9	(102)	80	4	(73)			
	10	(80)		5	(169)			
	11	(68)		6	(124)			
76	2	(8)		7	(743)			
	4	(73)		8	(207)			
	5	(79)		9	(96)			
	6	(299)		10	(14)			
	7	(930)		11	(13)			
	8	(439)						
	9	(73)						
	10	(47)						
	11	(12)						

The flow chart below shows the different stages involved in the creation of the Lake.Larvae data bank.



The purpose of this operation is to combine the data in various formats in three files into one single flat file, which is then entered into the Taxir data base management program to create a data base management file. The original data are contained in three files called HISTOYR, STATYR, and TOTALYR, where "YR" indicates the year when the data were collected. Both the open lake and the nearshore beach data are included in these files. The HISTOYR file contains the following parameters: CODE NO., SAMPLE NO., PERIOD, DATE, DIAL, TIME, GEAR, TOW DEPTH, GRATE, STATION, TEMPERATURE, REVOLATION, SPECIES NAME, and 51 different density intervals. The first 12 parameters of the STATYR file are the same as those in HISTOYR file but the parameters which follow are SPECIES CODES and statistical values of TOTAL NUMBER, SUM, and SUM OF SQUARE for 20 species. The first 12 parameters of the TOTALYR file are also the same as those in the HISTOYR file, but are followed by the single parameter, total egg counts.

Reformat Programs

All three files are identical in the first 12 parameters but are different in the parameters which follow. Reformat programs are needed to rearrange these files, so that all parameters can be merged into one single flat file. Two reformat programs were used. The first reformat program is called LLARVARR, as shown in Table 4.34. The major functions of this program are 1) to change STATYR file from 20 species per line to one species per line, 2) to delete those lines with no density values in the HISTOYR file, and 3) to add the character "EG" to each line in TOTALYR file to indicate that these data are for fish eggs.

TABLE 4.34. Program LLARVARR.

```
C PROGRAM LLARVARR HAS THREE FUNCTIONS. IT CHANGES STAT FILE INTO A FLAT
C FILE. DELETES THE DATA LINES WITH NO HISTOGRAM VALUES FROM HISTO FILE.
C AND FINALLY IT ADDS CHARACTER 'EG' TO EACH LINE OF TOTAL FILE.
C UNITS 2, 4, AND 6 ARE THE INPUT FILES.
C UNITS 3, 5, AND 7 ARE THE OUTPUT FILES.
C
C
C
C
C*******
C*******       INITIALIZE VARIABLES.
C*******
C
      INTEGER SPN(20),NUMI(20),SAMPNO,PRO,DATE,DIEL,TIME,GEAR,
     1TOWDEP,GRATE,STATN,SPECN,IREV,EGGCON
      REAL SUMI(20),SUMSI(20),TEMP,REV,ROUNDC(51),SPCON(20)
      REAL*8 CODENO
C
C*******
C*******       DELETE THE DATA LINES FROM STAT FILE WITH NO STATISTICS,
C*******       MAKE STAT FILE FLAT.
C*******
C
 100  READ(2,10,END=99) CODENO,(SPN(I),NUMI(I),SUMI(I),
     1SUMSI(I),I=1,20)
  10  FORMAT(A5,42X,20(1X,A2,1X,I4,1X,F9.1,1X,F11.1))
C
      IF(NUMI(1).EQ.0) GO TO 100
C
      DO 20 I=1,20
      IF(NUMI(I).EQ.0.) GO TO 20
      WRITE(3,30) CODENO,SPN(I),NUMI(I),SUMI(I),SUMSI(I)
  30  FORMAT(A5,1X,A2,1X,I4,1X,F9.1,1X,F11.2)
  20  CONTINUE
C
      GO TO 100
C
C*******
C*******       DELETE DATA LINES FROM HISTO FILE WITH NO HISTOGRAM VALUES.
C*******
C
  99  READ(4,11,END=999) CODENO,SAMPNO,PRO,DATE,DIEL,TIME,
     1GEAR,TOWDEP,GRATE,STATN,TEMP,REV,SPECN,(ROUNDC(I),I=1,51)
  11  FORMAT(A5,1X,A4,1X,I2,1X,I6,1X,I1,1X,I4,1X,A1,1X,
     1A2,A1,A2,1X,F4.1,1X,F6.0,1X,A2,51F6.0)
C
      DO 21 I=1,51
      IF(ROUNDC(I).EQ.0.) GO TO 21
      GO TO 101
  21  CONTINUE
C
      GO TO 99
C
 101  WRITE(5,11) CODENO,SAMPNO,PRO,DATE,DIEL,TIME,GEAR,
     1TOWDEP,GRATE,STATN,TEMP,REV,SPECN,(ROUNDC(I),I=1,51)
C
      GO TO 99
C
C*******
C*******       ADD CHARACTER 'EG' TO EACH LINE OF TOTAL FILE.
C*******
C
 999  READ(6,12,END=9999) CODENO,SAMPNO,PRO,DATE,DIEL,TIME,
     1GEAR,TOWDEP,GRATE,STATN,TEMP,REV,EGGCON
  12  FORMAT(A5,1X,A4,1X,I2,1X,I6,1X,I1,1X,I4,1X,A1,1X,A2,A1,
     1A2,1X,F4.1,1X,F6.0,6X,I9)
      IREV=REV
      WRITE(7,31) CODENO,SAMPNO,PRO,DATE,DIEL,TIME,GEAR,
     1TOWDEP,GRATE,STATN,TEMP,IREV,EGGCON
  31  FORMAT(A5,1X,A4,1X,I2,1X,I6,1X,I1,1X,I4,1X,A1,1X,A2,
     1A1,A2,1X,F4.1,1X,I6,1X,'EG',1X,I9)
      GO TO 999
C
 9999 STOP
      END
```

The second reformat program is called MERGE, as shown in Table 4.35. This program merges the three output files provided by the LLARVARR program. In order to use this program, the output files were first sorted by species name and code number. The sorted data were stored in files SRSTATYR, SRHISTOYR, and SRTOTALYR, respectively. The MERGE program was then used, first to copy the SRTOTALYR at the beginning of a new file, and then to combine every pair of lines (one each from SRHISTOYR and SRSTATYR) into a single line of parameters in the new file. The 51 density intervals, however, were changed to a single density interval per line. Thus, the new file is flat, containing all information for fish species with their statistical values and one density interval per line. The new file, called MERGEYR, was sorted again at the end of the operation.

This final sorted flat file named SMERGEYR was set as input to a Taxir Create program. The computer commands and statements used in this process for the 1981 field larval fish data are shown below:

```
#RUN *FIN SCARDS=LLARVARR SPUNCH=LLARV.OBJ
#RUN LLARV.OBJ 2=STAT81 4=HISTO81 6=TOTAL81
               3=RSTAT81 5=RHISTO81 7=RTOTAL81
(to sort the output files in terms of species name and code number)
#RUN *SORT PAR=SORT=CH,A,1,5,CH,A,7,2
INPUT=RSTAT81,U,35,35 OUTPUT=SRSTAT81,U,35,35 END
#RUN *SORT PAR=SORT=CH,A,1,5,CH,A,49,2
INPUT=RHISTO81,U,356,356 OUTPUT=SRHISTO81,U,356,356 END
#RUN *SORT PAR=SORT=CH,A,1,5
INPUT=RTOTAL81,U,64,64 OUTPUT=SRTOTAL81,U,64,64 END
```

TABLE 4.35. Program MERGE.

```
C PROGRAM MERGE IS USED TO MERGE SRSTAT AND SRHISTO FILE. THE OUTPUT
C OF THIS PROGRAM IS IN THE FORM OF FLAT FILE.
C UNITS 3, 5, AND 7 ARE THE INPUT FILES.
C UNIT 9 IS THE OUTPUT FILE. (FLAT FILE).
C
C
C
C
C*******
C*******       INITIALIZE VARIABLES.
C*******
C
      INTEGER NUMI,SAMPNO,PRO,DATE,DIEL,TIME,GEAR,TOWDEP,
     1GRATE,STATN,IREV,SPN,IROUND(51)
      REAL SUMI,SUMSI,TEMP,REV,ROUNDC(51)
      REAL*8 CODENO
C
C*******
C*******       WRITE THE SRTOTAL FILE IN THE BEGINNING OF THE
C*******       OUTPUT FILE.
C*******
C
      READ(3,10,END=99) CODENO,SAMPNO,PRO,DATE,DIEL,TIME,GEAR,
     1TOWDEP,GRATE,STATN,TEMP,IREV,SPN,EGGCON
   10 FORMAT(A5,1X,A4,1X,I2,1X,I6,1X,I1,1X,I4,1X,A1,1X,A2,A1,
     1A2,1X,F4.1,1X,I6,1X,A2,1X,I9)
      WRITE(9,10) CODENO,SAMPNO,PRO,DATE,DIEL,TIME,GEAR,TOWDEP,
     1GRATE,STATN,TEMP,IREV,SPN,EGGCON
C
C*******
C*******       READ ONE LINE FROM SRSTAT FILE AND ONE LINE
C*******       FROM SRHISTO FILE AT A TIME.
C*******
C
   99 READ(5,20,END=999) NUMI,SUMI,SUMSI
   20 FORMAT(9X,I4,1X,F9.1,1X,F11.2)
      READ(7,30,END=999) CODENO,SAMPNO,PRO,DATE,DIEL,TIME,
     1GEAR,TOWDEP,GRATE,STATN,TEMP,REV,SPN,(ROUNDC(I),I=1,51)
   30 FORMAT(A5,1X,A4,1X,I2,1X,I6,1X,I1,1X,I4,1X,A1,1X,A2,A1,
     1A2,1X,F4.1,1X,F6.0,1X,A2,51F6.0)
      IREV=REV
C
C*******
C*******       WRITE THE MERGED LINES.
C*******
C
      DO 40 I=1,51
      IF(ROUNDC(I).EQ.0.) GO TO 40
      IROUND(I)=ROUNDC(I)
      WRITE(9,50) CODENO,SAMPNO,PRO,DATE,DIEL,TIME,GEAR,
     1TOWDEP,GRATE,STATN,TEMP,IREV,SPN,IROUND(I),I,
     1NUMI,SUMI,SUMSI
   50 FORMAT(A5,1X,A4,1X,I2,1X,I6,1X,I1,1X,I4,1X,A1,1X,A2,A1,A2,
     11X,F4.1,1X,I6,1X,A2,4X,I6,1X,I2,1X,I4,1X,F9.1,1X,F11.2)
   40 CONTINUE
C
      GO TO 99
C
  999 STOP
      END
```

(to produce MERGE81)

```
#RUN *FTN SCARDS=MERGE SPUNCH=MER.OBJ

#RUN MER.OBJ 3=SRSTAT81 5=SRHISTO81 7=SRTOTAL81 9=MERGE81
```

(to sort MERGE81 in terms of species name, code number, and Intervals)

```
#RUN *SORT PAR=SORT=CH,A,1,5,CH,A,49,2,CH,A,62,2 INPUT=MERGE81,U,90,90 OUTPUT=
SMERGE81,U,90,90 END
```

Taxir Create Program

A Taxir Create program FLTAXIRCR is used to create the Lake.Larvae data bank from SMERGEYR files. This data bank is stored on the tape COOK at position 11. The contents of FLTAXIRCR are presented in Table 4.36.

TABLE 4.36. Program FLTAXIRCR.

```
R *TAXIR
CREATE  LAKE.LARVAE,
CODENO(NAME),
SAMPNO(NAME),
PERIOD(FROM 0 TO 99),
MONTH(FROM 1 TO 12),
DAY(FROM 1 TO 31),
YEAR(FROM 70 TO 85),
DIEL(FROM 0 TO 9),
TIME(FROM 0 TO 9999),
GEAR(NAME),
TOWDEP(NAME),
GRATE(NAME),
STATN(NAME),
TEMP(FROM 0.0 TO 99.9),
REV(FROM 0 TO 999999),
SPECN(NAME),
SPECDEN(FROM 0 TO 999999),
INTERVAL(FROM 0 TO 99),
NUM(FROM 0 TO 9999),
SUMLEN(FROM 0.0 TO 9999999.9),
SUMSLEN(FROM 0.00 TO 9999999.99)*
ENTER DATA LOCATION=SMERGE, FORMAT=FIXED,
CODENO<1-5>,
SAMPNO<7-10>,
PERIOD<12-13>,
MONTH<15-16>,
DAY<17-18>,
YEAR<19-20>,
DIEL<22>,
TIME<24-27>,
GEAR<29>,
TOWDEP<31-32>,
GRATE<33>,
STATN<34-35>,
TEMP<37-40>,
REV<42-47>,
SPECN<49-50>,
SPECDEN<55-60>,
INTERVAL<62-63>,
NUM<65-68>,
SUMLEN<70-78>,
SUMSLEN<80-90>*
SAVE
STOP
```

ENTRAINMENT: LARVAL FISH

The Entrained.Larvae data bank contains 12,111 items and 25 descriptors. The descriptors in this data bank are shown below:

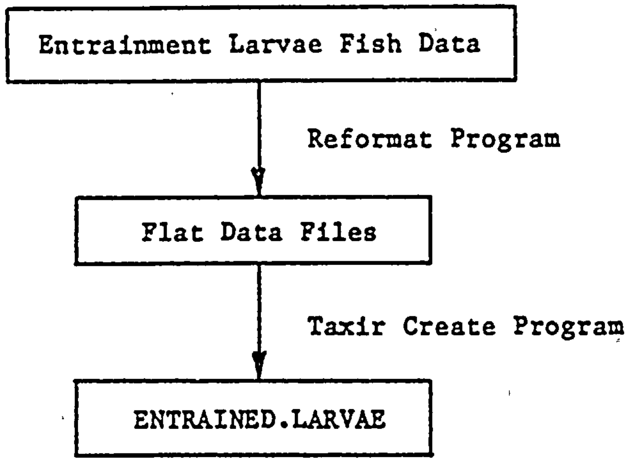
1-CASE
2-CODE
3-SAMPLE NUMBER
4-MONTH
5-DAY
6-YEAR
7-J DAY
8-MONTHPD
9-GEAR
10-SERIES
11-GRATE
12-NORTH/SOUTH
13-INTAKE/DISCHARGE
14-DEPTH
15-STARTH
16-STARTM
17-STOPH
18-STOPM
19-TTIME
20-DIEL
21-TEMP
22-REVS
23-SPEC
24-SPDEN
25-INTERVAL

The monthly number of data items stored in the Entrained.Larvae data bank is listed in Table 4.37.

TABLE 4.37. The number of data items stored in the Entrained Larvae data bank.

Year	Month	Total # of Items	Year	Month	Total # of Items	Year	Month	Total # of Items
75	1	(8)	78	1	(27)	81	1	(32)
	2	(8)		2	(31)		2	(32)
	3	(8)		3	(34)		3	(31)
	4	(17)		4	(28)		4	(33)
	5	(72)		5	(45)		5	(73)
	6	(423)		6	(109)		6	(721)
	7	(603)		7	(192)		7	(380)
	8	(201)		8	(154)		8	(679)
	9	(22)		9	(58)		9	(42)
	10	(21)		10	(56)		10	(32)
	11	(22)		11	(34)		11	(32)
	12	(34)		12	(31)		12	(31)
76	1	(21)	79	1	(28)	82	1	(32)
	2	(25)		2	(32)		2	(32)
	3	(25)		3	(29)		3	(32)
	4	(50)		4	(32)		4	(32)
	5	(44)		5	(66)		5	(93)
	6	(191)		6	(242)		6	(1,070)
	7	(761)		7	(482)		7	(1,024)
	8	(306)		8	(384)		8	(143)
	9	(33)		9	(54)		9	(40)
	10	(34)		10	(43)		10	(40)
	11	(33)		11	(32)		11	(32)
	12	(40)		12	(32)		12	(32)
77	3	(32)	80	1	(34)			
	4	(40)		2	(32)			
	5	(46)		3	(31)			
	6	(489)		4	(36)			
	7	(311)		5	(62)			
	8	(210)		6	(208)			
	9	(42)		7	(238)			
	10	(32)		8	(108)			
	11	(16)		9	(38)			
	12	(32)		10	(33)			
				11	(32)			
				12	(32)			

The procedures for establishing this data bank are as follows:



Reformat Program

The original entrainment larvae fish data were stored in the file ENTXXHISTDEN, where XX indicates the year when the data were collected. The reformat program ELARVARR was then used to convert the entrained larval fish data into a flat-file form and to abbreviate the codes for the species names. These codes are shown in the reformat program (Table 4.38). It is noted that eggs are considered as one category for larvae and are coded as "EG." The computer control statements used are shown below:

```
#RUN *FTN SCARDS=ELARVARR SPUNCH=EL.OBJ
#RUN EL.OBJ 5=ENTXXHISTDEN 6=REFENTXXHDEN
```

Taxir Create Program

A Taxir Create program ELTAXIRCR was used to create the Entrained.Larvae data bank. The data bank is saved on the COOK tape at position 12. The program ELTAXIRCR is presented in Table 4.39.

TABLE 4.38. Program ELARVARR.

```
C PROGRAM ELARVARR IS USED TO CONVERT THE ENTRAINMENT LARVAE FISH DATA INTO
C A FLAT FILE FORM AND TO ABBREVIATE THE CODES FOR THE SPECIES NAMES.
C UNIT 5 IS THE INPUT FILE.
C UNIT 6 IS THE OUTPUT FILE, (FLAT FILE).
C
C
C
C
C*******
C*******       INITIALIZE VARIABLES.
C*******
C
      INTEGER CASE,CARD,CODE,SNO,MO,DAY
      INTEGER YR,JDAY,MOPD,IGEAR
      INTEGER SERIES,GRATE,NS,IID,DEPTH
      INTEGER STARTH,STARTM,STOPH,STOPM
      INTEGER TTIME,DIEL,REVS,EGGS,C80
      INTEGER CC80,SP,SPDEN(51)
      INTEGER*2 SPEC
      REAL TEMP
      DIMENSION  SPEC(19)
C
C*******
C*******       INITIALIZE DATA.
C*******
C
      DATA SPEC/2HAL,2HSP,2HSM,2HYP,2HTP,2HJD,2HXP,2HSS,2HMS,
     12HCP,2HNS,2HFS,2HQL,2HBR,2HUC,2HXM,2HXC,2HXE,2HXX/
C
C*******
C*******       ICHTHYOPLANKTON SPECIES AND GROUP ENTRAINED AT THE
C*******       D.C. COOK PLANT.
C*******
C
C  ************************************************************************
C  *  CODE  *  COMMON NAME OR CATEGORY  *  SCIENTIFIC NAME OR CATEGORY    *
C  ************************************************************************
C  *(1)  AL *  ALEWIFE                  *  ALOSA PSEUDOHARENGUS (WILSON)   *
C  *(2)  SP *  SPOTTAIL SHINER          *  NOTROPIS HUDSONIUS (CLINTON)    *
C  *(3)  SM *  RAINBOW SMELT            *  OSMERUS MORDAX (MITCHILL)       *
C  *(4)  YP *  YELLOW PERCH             *  PERCA FLAVESCENS (MITCHILL)     *
C  *(5)  TP *  TROUT-PERCH              *  PERCOPSIS OMISCOMAYCUS (WALBAUM)*
C  *(6)  JD *  JOHNNY DARTER            *  ETHEOSTOMA NIGRUM (RAFINESQUE)  *
C  *(7)  XP *  UNIDENTIFIED FISH LARVAE *                                  *
C  *        *    AS A RESULT OF POOR    *                                  *
C  *        *    CONDITION              *                                  *
C  *(8)  SS *  SLIMY SCULPIN            *  COTTUS COGNATUS (RICHARDSON)    *
C  *(9)  MS *  MOTTLED SCULPIN          *  COTTUS BAIRDI (GIRARD)          *
C  *(10) CP *  COMMON CARP              *  CYPRINUS CARPIO (LINNAEUS)      *
C  *(11) NS *  NINESPINE STICKLEBACK    *  PUNGITIUS PUNGITIUS (LINNAEUS)  *
C  *(12) FS *  DEEPWATER SCULPIN        *  MYOXOCEPHALUS THOMPSONI (GIRARD)*
C  *(13) QL *  QUILLBACK                *  CARPIODES CYPRINUS (LESUEUR)    *
C  *(14) BR *  BURBOT                   *  LOTA LOTA (LINNAEUS)            *
C  *(15) UC *  UNIDENTIFIED SCULPINS    *  COTTUS SPP.                     *
C  *(16) XM *  UNIDENTIFIED MINNOWS     *  CYPRINIDAE                      *
C  *(17) XC *  UNIDENTIFIED COREGONIDS  *  COREGONUS SPP.                  *
C  *(18) XE *  UNIDENTIFIED DARTERS     *  ETHEOSTOMA SPP.                 *
C  *(19) XX *  UNIDENTIFIED FISH LARVAE *                                  *
C  *     EG *  EGGS                     *                                  *
C  ************************************************************************
```

TABLE 4.38. (Continued).

```
C
C*******
C*******       READ THE FIRST DATA LINE FROM THE TRANSREC FILE.
C*******
C
100  READ(5,10,END=999) CASE,CARD,CODE,SNO,MO,DAY,YR,JDAY,
    1MOPD,IGEAR,SERIES,GRATE,NS,IID,DEPTH,STARTH,STARTM,
    1STOPH,STOPM,TTIME,DIEL,TEMP,REVS,EGGS,C80
10   FORMAT(I4,I1,1X,I4,1X,I4,1X,3I2,1X,I3,1X,I2,1X,2I1,1X,2I1,
    11X,I1,I2,1X,2I2,1X,2I2,1X,I4,1X,I1,1X,F4.1,1X,I5,2X,I10,I1)
C
C*******
C*******       WRITE THE FIRST RECORD WHEN THERE ARE NO
C*******       HISTOGRAM VALUES EXISTED.
C*******
C
     WRITE(6,20) CASE,CODE,SNO,MO,DAY,YR,JDAY,MOPD,IGEAR,SERIES,
    1GRATE,NS,IID,DEPTH,STARTH,STARTM,STOPH,STOPM,TTIME,DIEL,
    1TEMP,REVS,EGGS
20   FORMAT(I4,2X,I4,1X,I4,1X,3I2,1X,I3,1X,I2,1X,2I1,1X,2I1,1X,
    1I1,I2,1X,2I2,1X,2I2,1X,I4,1X,I1,1X,F4.1,1X,I5,2X,'EG',2X,I10)
C
     IF(C80.EQ.0) GO TO 100
C
C*******
C*******       READ THE SECOND DATA LINE.
C*******
C
200  READ(5,30,END=999) SP,(SPDEN(L),L=1,51),CC80
30   FORMAT(' ',10X,52I5,5X,I5)
C
C*******
C*******       COMBINE THE FIRST AND SECOND RECORDS WHEN THERE ARE
C*******       MORE THAN ONE HISTOGRAM VALUES.
C*******
C
     DO 40 I=1,51
     IF(SPDEN(I).EQ.0) GO TO 40
     WRITE(6,50)   CASE,CODE,SNO,MO,DAY,YR,JDAY,MOPD,IGEAR,SERIES,
    1GRATE,NS,IID,DEPTH,STARTH,STARTM,STOPH,STOPM,TTIME,DIEL,TEMP,
    1REVS,SPEC(SP),SPDEN(I),I
50   FORMAT(I4,2X,I4,1X,I4,1X,3I2,1X,I3,1X,I2,1X,2I1,1X,2I1,
    11X,I1,I2,1X,2I2,1X,2I2,1X,I4,1X,I1,1X,F4.1,1X,I5,2X,A2,
    12X,I10,2X,I2)
40   CONTINUE
C
     IF(CC80.EQ.0) GO TO 100
     GO TO 200
C
999  STOP
     END
```

TABLE 4.39. Program ELTAXIRCR.

```
RUN *TAXIR
CREATE ENTRAINED.LARVAE,
CASE(FROM 0 TO 9999),
CODE(FROM 0 TO 9999),
SAMPLENO(FROM 0 TO 9999),
MONTH(FROM 1 TO 12),
DAY(FROM 1 TO 31),
YEAR(FROM 75 TO 85),
JDAY(FROM 0 TO 999),
MONTHPD(FROM 0 TO 99),
GEAR(FROM 0 TO 9),
SERIES(FROM 0 TO 9),
GRATE(FROM 0 TO 9),
NOR/SOU(FROM 0 TO 9),
INT/DIS(FROM 0 TO 9),
DEPTH(FROM 0 TO 99),
STARTH(FROM 0 TO 99),
STARTM(FROM 0 TO 99),
STOPH(FROM 0 TO 99),
STOPM(FROM 0 TO 99),
TTIME(FROM 0 TO 9999),
DIEL(FROM 0 TO 9),
TEMP(FROM 0.0 TO 99.9),
REVS(FROM 0 TO 99999),
SPEC(NAME),
SPDEN(FROM 0 TO 999999999),
INTERVAL(FROM 0 TO 99)*
ENTER DATA LOCATION=REFENTHIST, FORMAT=FIXED,
CASE<1-4>,
CODE<7-10>,
SAMPLENO<12-15>,
MONTH<17-18>,
DAY<19-20>,
YEAR<21-22>,
JDAY<24-26>,
MONTHPD<28-29>,
GEAR<31>,
SERIES<32>,
GRATE<34>,
NOR/SOU<35>,
INT/DIS<37>,
DEPTH<38-39>,
STARTH<41-42>,
STARTM<43-44>,
STOPH<46-47>,
STOPM<48-49>,
TTIME<51-54>,
DIEL<56>,
TEMP<58-61>,
REVS<63-67>,
SPEC<70-71>,
SPDEN<74-83>,
INTERVAL<86-87>*
SAVE
STOP
```

NUTRIENT AND ANION

The Nutrients data bank contains 12 descriptors and 10 items. It includes the data from both entrainment and lake samples. The descriptors for this data bank are:

1-STATION
2-MONTH
3-YEAR
4-TOTAL P
5-ORTHOPHOSPHATE P
6-DISSOLVED SILICA SiO_2
7-TEMPERATURE
8-NITRATE N
9-NITRITE N
10-CHLORIDE
11-SULFATE
12-OXYGEN SATURATION

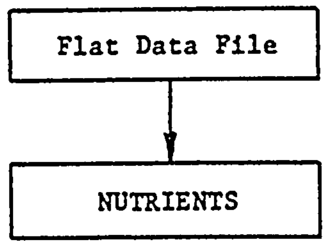
Total P and orthophosphate P are in units of ppb while dissolved silica SiO_2, nitrate N, nitrite N, chloride, and sulfate are in units of ppm.

The number of data items stored in the Nutrients data bank is shown in Table 4.40.

TABLE 4.40. The number of data items in the Nutrients data bank.

Year	Month	Total # of Items	Year	Month	Total # of Items	Year	Month	Total # of Items
74	4	(18)	78	1		81	1	
	5	(23)		2			2	
	6	(18)		3			3	
	7	(25)		4	(31)		4	(31)
	8	(25)		5			5	
	9	(11)		6			6	
	10	(15)		7	(31)		7	(31)
75	4	(24)		8			8	
	7	(30)		9			9	
	10	(18)		10	(31)		10	(31)
76	1			11			11	
	2			12			12	
	3		79	1		82	1	
	4	(19)		2			2	
	5			3			3	
	6			4	(31)		4	(31)
	7	(31)		5			5	
	8			6				
	9			7	(31)			
	10			8				
	11			9				
	12			10	(31)			
77	3			11				
	4	(31)		12				
	5		80	1				
	6			2				
	7	(31)		3				
	8			4	(31)			
	9			5				
	10	(31)		6				
	11			7	(31)			
	12			8				
				9				
				10	(31)			
				11				
				12				

The steps for establishing the Nutrients data bank are shown on the diagram below:



<u>Taxir Create Program</u>

A Taxir Create program NUTTAXIRCR was used to create the Nutrients data bank which is stored as NUTRIENTS on tape COOK at position 14. The contents of NUTTAXIRCR are shown in Table 4.41.

TABLE 4.41. Program NUTTAXIRCR.

```
R *TAXIR
CREATE NUTRIENTS,
STATION(NAME),
MONTH(FROM 1 TO 12),
YEAR(FROM 74 TO 82),
TOTAL P(FROM 0.000 TO 9999.999),
ORTHOPHOSPHATE P(FROM 0.000 TO 9999.999),
DISSOLVED SILICA SIO2(FROM 0.000 TO 9999.999),
TEMPERATURE C(FROM 0.00 TO 100.00),
NITRATE N(FROM 0.000 TO 9999.999),
NITRITE N(FROM 0.000 TO 9999.999),
CHLORIDE(FROM 0.000 TO 9999.999),
SULFATE(FROM 0.000 TO 9999.999),
OXYGEN SATURATION(FROM 0.000 TO 9999.999)*
ENTER DATA LOCATION=REFREM, FORMAT=FIXED,
STATION<1-20>,
MONTH<21-30>,
YEAR<31-40>,
TOTAL P<41-50>,
ORTHOPHOSPHATE P<51-60>,
DISSOLVED SILICA SIO2<61-70>,
TEMPERATURE C<71-80>,
NITRATE N<81-90>,
NITRITE N<91-100>,
CHLORIDE<101-110>,
SULFATE<111-120>,
OXYGEN SATURATION<121-130>*
SAVE
STOP
```

LAKE WATER CHEMISTRY

The Lakewater data bank contains 48 descriptors and 735 items. The data are solely from lake samples. The descriptors for this data bank are:

1-STATION
2-MONTH
3-YEAR
4-TOTAL PHOSPHORUS-PPB
5-ORTHOPHOSPHORUS-PPB
6-DISSOLVED SILICA-PPM
7-TEMPERATURE-DEGREES C
8-NITRATE-PPM N
9-NITRITE-PPM N
10-CHLORIDE-PPM
11-SULFATE-PPM
12-OXYGEN SATURATION PERCENT
13-ALKALINITY-MEQ/L
14-DISSOLVED BARIUM-PPB
15-DISSOLVED CALCIUM-PPM
16-DISSOLVED CADMIUM-PPM
17-DISSOLVED COBALT-PPB
18-DISSOLVED CHROMIUM-PPB
19-DISSOLVED COPPER-PPB
20-DISSOLVED IRON-PPB
21-DISSOLVED POTASSIUM-PPM
22-DISSOLVED MAGNESIUM-PPM
23-DISSOLVED MANGANESE-PPB
24-DISSOLVED MOLYBDENUM-PPB
25-DISSOLVED SODIUM-PPM
26-DISSOLVED NICKEL-PPB
27-DISSOLVED LEAD-PPB
28-DISSOLVED STRONTIUM-PPB
29-DISSOLVED ZINC-PPB
30-PH
31-SECCHI DISK-M
32-EH-MV
33-CONDUCTIVITY-UMHOS
34-SAMPLE DEPTH-M
35-PARTICULATE BARIUM-PPM
36-PARTICULATE CALCIUM-PPM
37-PARTICULATE COBALT-PPM
38-PARTICULATE CHROMIUM-PPM
39-PARTICULATE COPPER-PPM
40-PARTICULATE IRON-PPM
41-PARTICULATE POTASSIUM-PPM
42-PARTICULATE MAGNESIUM-PPM
43-PARTICULATE MANGANESE-PPM
44-PARTICULATE MOLYBDENUM-PPM
45-PARTICULATE SODIUM-PPM
46-PARTICULATE NICKEL-PPM
47-PARTICULATE STRONTIUM-PPM
48-PARTICULATE ZINC-PPM

The unit for each descriptor is indicated in the descriptors after the sign "-". The number of data items stored in the Lakewater data bank is shown in Table 4.42.

TABLE 4.42. The number of data items in the Lakewater data bank.

Year	Month	Total # of Items	Year	Month	Total # of Items	Year	Month	Total # of Items
74	4	(18)	76	4	(18)	80	4	(30)
	5	(23)		7	(30)		7	(30)
	6	(18)	77	4	(30)		10	(30)
	7	(25)		7	(30)	81	4	(30)
	8	(25)		10	(30)		7	(30)
	9	(11)	78	4	(30)		10	(30)
	10	(15)		7	(30)	82	4	(30)
75	4	(24)		10	(30)			
	7	(24)	79	4	(30)			
	8	(6)		7	(30)			
	10	(18)		10	(30)			

Taxir Create Program

A Taxir Create program TAXSOURCEWAT was used to create the Lakewater data bank which is stored as LAKEWATER on tape COOK at position 15. The content of TAXSOURCEWAT is shown in Table 4.43. The line file from which the Taxir data base was created is named COOKWATER.

TABLE 4.43. Program TAXSOURCENAT.

```
RUN *TAXIR
CREATE LAKEWATER,
STATION(NAME),
MONTH(FROM 1 TO 12),
YEAR(FROM 73 TO 85),
TOTAL PHOSPHORUS-PPB(FROM 0.00 TO 3300.00),
ORTHOPHOSPHORUS-PPB(FROM 0.00 TO 1500.00);
DISSOLVED SILICA-PPM SIO2(FROM 0.00 TO 12.30),
TEMPERATURE-DEGREES C (FROM 0.0 TO 30.0),
NITRATE-PPM N (FROM 0.00 TO 1.50),
NITRITE-PPM N (FROM 0.000 TO 0.100),
CHLORIDE-PPM (FROM 1.00 TO 110.00),
SULFATE-PPM (FROM 6.00 TO 70.00),
OXYGEN SATURATION PERCENT (FROM 0.0 TO 160.0),
ALKALINITY-MEQ/L (FROM 1.00 TO 5.00),
DISSOLVED BARIUM-PPB (FROM 10.0 TO 130.0),
DISSOLVED CALCIUM-PPM (FROM 20.0 TO 80.0),
DISSOLVED CADMIUM-PPM (FROM 0.120 TO 0.250),
DISSOLVED COBALT-PPB (FROM 0.050 TO 5.000),
DISSOLVED CHROMIUM-PPB (FROM 0.500 TO 3.700),
DISSOLVED COPPER-PPB (FROM 0.900 TO 10.600),
DISSOLVED IRON-PPB (FROM 1.50 TO 460.00),
DISSOLVED POTASSIUM-PPM (FROM 0.700 TO 7.100),
DISSOLVED MAGNESIUM-PPM (FROM 7.40 TO 32.00),
DISSOLVED MANGANESE-PPB (FROM 0.050 TO 184.000),
DISSOLVED MOLYBDENUM-PPB (FROM 2.20 TO 41.50),
DISSOLVED SODIUM-PPM (FROM 2.80 TO 69.50),
DISSOLVED NICKEL-PPB (FROM 2.00 TO 54.50),
DISSOLVED LEAD-PPB (FROM 0.600 TO 0.680),
DISSOLVED STRONTIUM-PPB (FROM 40.0 TO 190.0),
DISSOLVED ZINC-PPB (FROM 0.30 TO 97.00),
PH (FROM 7.40 TO 8.85),
SECCHI DISK-M (FROM 0.65 TO 12.50),
EH-MV (FROM 370 TO 640),
CONDUCTIVITY-UMHOS (FROM 212 TO 672),
SAMPLE DEPTH-M (FROM 0.0 TO 30.0),
PARTICULATE BARIUM-PPM (FROM 0.0000 TO 0.0160),
PARTICULATE CALCIUM-PPM (FROM 0.00 TO 2.32),
PARTICULATE COBALT-PPM (FROM 0.00 TO 0.01),
PARTICULATE CHROMIUM-PPM (FROM 0.0000 TO 0.0110),
PARTICULATE COPPER-PPM (FROM 0.00000 TO 0.00930),
PARTICULATE IRON-PPM (FROM 0.000 TO 1.000),
PARTICULATE POTASSIUM-PPM (FROM 0.000 TO 0.380),
PARTICULATE MAGNESIUM-PPM (FROM 0.000 TO 1.000),
PARTICULATE MANGANESE-PPM (FROM 0.000 TO 0.120),
PARTICULATE MOLYBDENUM-PPM (FROM 0.00000 TO 0.00570),
PARTICULATE SODIUM-PPM (FROM 0.0250 TO 5.8000),
PARTICULATE NICKEL-PPM (FROM 0.00000 TO 0.00270),
PARTICULATE STRONTIUM-PPM (FROM 0.00000 TO 0.00260),
PARTICULATE ZINC-PPM (FROM 0.0000 TO 0.2200)*
ENTER DATA LOCATION=WATER, FORMAT=FIXED,
STATION <1-20>,
MONTH <21-23>,
YEAR <24-26>,
TOTAL PHOSPHORUS-PPB <27-38>,
ORTHOPHOSPHORUS-PPB <39-50>,
DISSOLVED SILICA-PPM SIO2 <51-62>,
TEMPERATURE-DEGREES C <63-74>,
NITRATE-PPM N <75-86>,
NITRITE-PPM N <87-98>,
```

TABLE 4.43. (Continued).

```
CHLORIDE-PPM <99-110>,
SULFATE-PPM <111-122>,
OXYGEN SATURATION PERCENT <123-134>,
ALKALINITY-MEQ/L <135-146>,
DISSOLVED BARIUM-PPB <147-158>,
DISSOLVED CALCIUM-PPM <159-170>,
DISSOLVED CADMIUM-PPM <171-182>,
DISSOLVED COBALT-PPB <183-194>,
DISSOLVED CHROMIUM-PPB <195-206>,
DISSOLVED COPPER-PPB <207-218>,
DISSOLVED IRON-PPB <219-230>,
DISSOLVED POTASSIUM-PPM <231-242>,
DISSOLVED MAGNESIUM-PPM <243-254>,
DISSOLVED MANGANESE-PPB <255-266>,
DISSOLVED MOLYBDENUM-PPB <267-278>,
DISSOLVED SODIUM-PPM <279-290>,
DISSOLVED NICKEL-PPB <291-302>,
DISSOLVED LEAD-PPB <303-314>,
DISSOLVED STRONTIUM-PPB <315-326>,
DISSOLVED ZINC-PPB <327-338>,
PH <339-350>,
SECCHI DISK-M <351-362>,
EH-MV <363-374>,
CONDUCTIVITY-UMHOS <375-386>,
SAMPLE DEPTH-M <387-398>,
PARTICULATE BARIUM-PPM <399-410>,
PARTICULATE CALCIUM-PPM <411-422>,
PARTICULATE COBALT-PPM <423-434>,
PARTICULATE CHROMIUM-PPM <435-446>,
PARTICULATE COPPER-PPM <447-458>,
PARTICULATE IRON-PPM <459-470>,
PARTICULATE POTASSIUM-PPM <471-482>,
PARTICULATE MAGNESIUM-PPM <483-494>,
PARTICULATE MANGANESE-PPM <495-506>,
PARTICULATE MOLYBDENUM-PPM <507-518>,
PARTICULATE SODIUM-PPM <519-530>,
PARTICULATE NICKEL-PPM <531-542>,
PARTICULATE STRONTIUM-PPM <543-554>,
PARTICULATE ZINC-PPM <555-566>.
SAVE
STOP
```

SEDIMENT TEXTURE AND CHEMISTRY

The Sediments data bank contains 52 descriptors and 430 items. The data are from lake samples. The descriptors for this data bank are:

1-STATION	27-STANDARD DEVIATION OF MEAN GRAIN SIZE-PHI
2-YEAR	28-KURTOSIS OF GRAIN SIZE
3-STATION DEPTH-M	29-SKEWNESS OF GRAIN SIZE
4-STATION NUMBER	30-INSOLUBLE FRACTION-%
5-SAMPLE DEPTH-CM	31-BARIUM-%
6-LOSS ON IGNITION-%	32-TOTAL CARBON-%
7-WATER CONTENT-%	33-INORGANIC CARBON-%
8--3 PHI-%	34-ORGANIC CARBON-%
9--2 PHI-%	35-CALCIUM-%
10--1 PHI-%	36-COBALT-%
11-0 PHI-%	37-CHROMIUM-%
12-1 PHI-%	38-COPPER-%
13-2 PHI-%	39-IRON-%
14-3 PHI-%	40-POTASSIUM-%
15-4 PHI-%	41-MAGNESIUM-%
16-5 PHI-%	42-MANGANESE-%
17-6 PHI-%	43-MOLYBDENUM-%
18-7 PHI-%	44-SODIUM-%
19-8 PHI-%	45-NICKEL-%
20-9 PHI-%	46-LEAD-%
21-10 PHI-%	47-STRONTIUM-%
22-GRAVEL-%	48-ZINC-%
23-SAND-%	49-EH-MV
24-SILT-%	50-PH
25-CLAY-%	51-X-LOCATION
26-MEAN GRAIN SIZE-PHI	52-Y-LOCATION

The number of data items stored in the Sediments data bank is shown in Table 4.44.

TABLE 4.44. The number of data items in the Sediments data bank.

Year	Total Number of Items
1973	(158)
1975	(160)
1977	(112)

Taxir Create Program

A Taxir Create program TAXSOURCESED was used to create the Sediments data bank which is stored as SEDIMENTS on tape COOK at position 16. The content of TAXSOURCESED is shown in Table 4.45. The line file from which the Taxir data base was created is named COOKSEDIMENT.

TABLE 4.45. Program TAXSOURCESED.

```
RUN *TAXIR
CREATE SEDIMENTS,
STATION(NAME),
YEAR(FROM 1973 TO 1977),
STATION DEPTH-M (FROM 4.5 TO 61.5),
STATION NUMBER (FROM 1. TO 233.),
SAMPLE DEPTH-CM (FROM 0.5 TO 62.5),
LOSS ON IGNITION-% (FROM 0.7 TO 60.4),
WATER CONTENT-% (FROM 14.4 TO 95.3),
-3 PHI-% (FROM 0.00 TO 8.47),
-2 PHI-% (FROM 0.00 TO 20.71),
-1 PHI-% (FROM 0.00 TO 42.38),
0 PHI-% (FROM 0.00 TO 57.15),
1 PHI-% (FROM 0.00 TO 65.41),
2 PHI-% (FROM 0.00 TO 82.51),
3 PHI-% (FROM 0.00 TO 81.01),
4 PHI-% (FROM 0.00 TO 85.70),
5 PHI-% (FROM 0.00 TO 39.40),
6 PHI-% (FROM 0.00 TO 26.86),
7 PHI-% (FROM 0.00 TO 64.76),
8 PHI-% (FROM 0.00 TO 23.58),
9 PHI-% (FROM 0.00 TO 9.36),
10 PHI-% (FROM 0.00 TO 19.62),
GRAVEL-% (FROM 0.00 TO 63.10),
SAND-% (FROM 15.60 TO 102.00),
SILT-% (FROM 0.00 TO 62.30),
CLAY-% (FROM 0.00 TO 47.90),
MEAN GRAIN SIZE-PHI (FROM -1.300 TO 6.100),
STANDARD DEVIATION OF MEAN GRAIN SIZE-PHI (FROM 0.130 TO 2.900),
KURTOSIS OF GRAIN SIZE (FROM -5.600 TO 2.500),
SKEWNESS OF GRAIN SIZE (FROM -3.000 TO 35.000),
INSOLUBLE FRACTION-% (FROM 6.00 TO 99.00),
BARIUM-% (FROM 0.000000 TO 0.019000),
TOTAL CARBON-% (FROM 0.15 TO 7.45),
INORGANIC CARBON-% (FROM 0.00 TO 5.30),
ORGANIC CARBON-% (FROM 0.00 TO 5.30),
CALCIUM-% (FROM 0.000 TO 11.700),
COBALT-% (FROM 0.000140 TO 0.004200),
CHROMIUM-% (FROM 0.000018 TO 0.025000),
COPPER-% (FROM 0.000020 TO 0.005000),
IRON-% (FROM 0.120 TO 9.200),
POTASSIUM-% (FROM 0.035 TO 0.760),
MAGNESIUM-% (FROM 0.000 TO 8.740),
MANGANESE-% (FROM 0.000730 TO 0.095000),
MOLYBDENUM-% (FROM 0.000000 TO 0.003580),
SODIUM-% (FROM 0.0100 TO 0.0860),
NICKEL-% (FROM 0.000000 TO 0.010300),
LEAD-% (FROM 0.000094 TO 0.001090),
STRONTIUM-% (FROM 0.000380 TO 0.010700),
ZINC-% (FROM 0.00100 TO 0.03000),
EH-MV (FROM -70.0 TO 485.0),
PH (FROM 6.95 TO 8.55),
X-LOCATION (FROM 1.00 TO 18.00),
Y-LOCATION (FROM 0.75 TO 10.00)*
ENTER DATA LOCATION=COOKSEDIMENT, FORMAT=FIXED,
STATION <1-16>,
YEAR <17-21>,
STATION DEPTH-M <22-31>,
STATION NUMBER <32-41>,
SAMPLE DEPTH-CM <42-51>,
```

TABLE 4.45. (Continued).

```
LOSS ON IGNITION-% <52-61>,
WATER CONTENT-% <62-71>,
-3 PHI-% <72-81>,
-2 PHI-% <82-91>,
-1 PHI-% <92-101>,
0 PHI-% <102-111>,
1 PHI-% <112-121>,
2 PHI-% <122-131>,
3 PHI-% <132-141>,
4 PHI-% <142-151>,
5 PHI-% <152-161>,
6 PHI-% <162-171>,
7 PHI-% <172-181>,
8 PHI-% <182-191>,
9 PHI-% <192-201>,
10 PHI-% <202-211>,
GRAVEL-% <212-221>,
SAND-% <222-231>,
SILT-% <232-241>,
CLAY-% <242-251>,
MEAN GRAIN SIZE-PHI <252-261>,
STANDARD DEVIATION OF MEAN GRAIN SIZE-PHI <262-271>,
KURTOSIS OF GRAIN SIZE <272-281>,
SKEWNESS OF GRAIN SIZE <282-291>,
INSOLUBLE FRACTION-% <292-301>,
BARIUM-% <302-311>,
TOTAL CARBON-% <312-321>,
INORGANIC CARBON-% <322-331>,
ORGANIC CARBON-% <332-341>,
CALCIUM-% <342-351>,
COBALT-% <352-361>,
CHROMIUM-% <362-371>,
COPPER-% <372-381>,
IRON-% <382-391>,
POTASSIUM-% <392-401>,
MAGNESIUM-% <402-411>,
MANGANESE-% <412-421>,
MOLYBDENUM-% <422-431>,
SODIUM-% <432-441>,
NICKEL-% <442-451>,
LEAD-% <452-461>,
STRONTIUM-% <462-471>,
ZINC-% <472-481>,
EH-MV <482-491>,
PH <492-501>,
X-LOCATION <502-511>,
Y-LOCATION <512-521>*
SAVE
STOP
```

CHAPTER 5

INTERACTIVE PROGRAM

PROGRAM INTERACT

The program INTERACT (Table 5.1) is an interactive computer program which is written to provide on-line instructions to users wishing to access the Cook water quality data base. It is hoped that this interactive program can facilitate the use of this data base by users with little or no knowledge of computer programming, MTS, or Taxir. The program INTERACT consists of seven major commands for accessing the data base. A brief description of these commands is given below.

1. "H" = HELP

   This program offers a HELP file (Table 5.2) which users can request at any point in the data accessing process. By simply typing in the command "H," users are provided with a complete explanation of other commands used in connection with the data base.

2. "S" = SELECT DATA BANK

   Any one of the 13 data banks contained in the data base system can be selected using this command. Since it is impossible to keep all 13 data banks on line at all times, an additional program has been written to access those data which are stored on a computer tape. This FORTRAN program is called LINK (Table 5.3). It will select and restore information from a tape whenever a file restoration request is made. When the job is completed, the computer will return to this main program INTERACT.

3. "O" = SELECT OUTPUT OPTION

This command provides three possible options for output: terminal screen, temporary or permanent line file, and MTS line or page printer.

4. "V" = VARIABLE DESCRIPTION

The list and types of descriptors in this data base management system can be obtained using this command.

5. "P" = PERCENTAGE OF TOTAL DATA ITEMS

The percentage of total data items can be obtained by applying this command.

6. "Q" = QUERY

This is an important command for retrieving data. By typing "Q," users can query the needed information and generate necessary tables and reports with requested data.

7. "T" = TERMINATE THE PROGRAM

Entering "T" results in the termination of the execution of the program.

In the following presentation of the computer programs INTERACT and LINK, boxes have been used to provide information and explanations of the different stages of operations, as well as the assignments for the input and output units and devices.

INTERFACE WITH TAXIR USING INTERACT

INTERACT is a FORTRAN-based interactive program. It acts as an intermediary between the users and Taxir by asking the users a series of questions

TABLE 5.1. Program INTERACT.

```
C THIS  INTERACTIVE  PROGRAM INTERFACES WITH TAXIR TO  RETRIEVE DATA
C FROM THE  13  DATA BANKS  CREATED FOR COOK PROJECT. TO WORK WITH A
C PARTICULAR  DATA BANK,  THE DATA SHOULD BE  AVAILABLE ON LINE IN A
C TEMPORARY OR  PERMANENT FILE.  HOWEVER, THIS PROGRAM HAS AN OPTION
C TO RESTORE THE DATA BANKS FROM A TAPE.
C
C TO RUN THIS PROGRAM TYPE: "SOURCE INTERACTIVE"
C
C IN THE RUN COMMAND UNITS ARE ASSIGNED AS FOLLOW:
C UNIT 5 IS ASSIGNED TO *MSOURCE* TO READ THE INPUT FROM THE SCREEN.
C UNIT 6 IS ASSIGNED TO *SINK* TO PRINT THE  MESSAGES ON THE SCREEN.
C TAXIR  MESSAGES ARE  WRITTEN ON SERCOM. IN THIS  PROGRAM SERCOM IS
C ASSIGNED TO A TEMPORARY FILE CALLED "-CHECK".
C UNIT 7 IS ALSO ASSIGNED TO "-CHECK" TO CHECK TAXIR MESSAGES.
C
C
C
C      ***********************************************
C      *                                             *
C      *         MAIN PROGRAM TO INITIALIZE & CALL   *
C      *         SYSTEM SUBROUTINES.                 *
C      *                                             *
C      ***********************************************
C
C
C
      LOGICAL*1    RESP
      LOGICAL      EQUC
C
C
      CALL  INITLZ
      WRITE(6,1)
1     FORMAT(//,'ARE YOU ALREADY FAMILIAR WITH THE PROGRAM?'/,
     1'TYPE "Y" FOR YES TO SKIP THE DESCRIPTION OF THE COMMANDS.'/,
     1'TYPE "N" IF YOU NEED HELP.')
C
C
      CALL FREAD(5,'STRING:',RESP,1)
      IF(EQUC('Y',RESP).OR.EQUC('y',RESP)) GO TO 1000
      CALL HELP(0)
C
C
1000  CALL CMDNOE('$EM -CHECK',10)
      WRITE(6,4)
4     FORMAT(//,'SELECT NEXT COMMAND: (H,S,O,V,P,Q,T)')
C
C*******
C*******        ACCEPT A COMMAND AND DECODE IT.
C*******
C
      CALL DECODE(NCOMND)
      GO TO (10,20,30,40,50,60,70), NCOMND
C
10    CALL HELP(1)
      GO TO 1000
C
20    CALL SELDB
      GO TO 1000
C
30    CALL OUTOP
```

TABLE 5.1. (Continued).

```
      GO TO 1000
C
40    CALL VOCAB
      GO TO 1000
C
50    CALL PERCNT
      GO TO 1000
C
60    CALL QUERY
      GO TO 1000
C
70    CALL TERMIN
      GO TO 1000
C
C
      END
      SUBROUTINE INITLZ
C
C
C
C       ************************************************************
C       *                                                          *
C       *     SUBROUTINE INITLZ; TO INITIALIZE TAXIR PROGRAM.      *
C       *                                                          *
C       ************************************************************
C
C
C
      CALL TAXIR('DUMMY',0)
      CALL FREAD(-2,'LENGTH',.TRUE.)
      CALL FREAD(-2,'DELIMITERS','/%¢/;/')
C
C
      RETURN
      END
      SUBROUTINE  DECODE(NCOMND)
C
C
C
C       ******************************************************
C       *                                                    *
C       *     SUBROUTINE DECODE; TO RECEIVE THE COMMAND &    *
C       *     DECODE IT.                                     *
C       *                                                    *
C       ******************************************************
C
C
C
      LOGICAL*1 RESP
      LOGICAL EQUC
C
C
      NERR=0
10    NCOMND=0
      LEN=1
      CALL FREAD(5,'STRING:',RESP,LEN)
      IF(EQUC('H',RESP).OR.EQUC('h',RESP)) NCOMND=1
      IF(EQUC('S',RESP).OR.EQUC('s',RESP)) NCOMND=2
      IF(EQUC('O',RESP).OR.EQUC('o',RESP)) NCOMND=3
      IF(EQUC('V',RESP).OR.EQUC('v',RESP)) NCOMND=4
```

TABLE 5.1. (Continued).

```
      IF(EQUC('P',RESP).OR.EQUC('p',RESP)) NCOMND=5
      IF(EQUC('Q',RESP).OR.EQUC('q',RESP)) NCOMND=6
      IF(EQUC('T',RESP).OR.EQUC('t',RESP)) NCOMND=7
C
C
      IF(NCOMND.GT.0) RETURN
C
C
      NERR=NERR+1
      IF(NERR.GE.2) GO TO 20
C
      WRITE(6,1)
1     FORMAT(//,'INVALID COMMAND, TRY AGAIN.')
      GO TO 10
C
C*******
C*******        PRINT THE LIST OF COMMANDS.
C*******
C
20    WRITE(6,2)
2     FORMAT(//,'INVALID COMMAND! THE COMMANDS ARE:'//,
     1'H     HELP'/,
     1'S     SELECT DATA BANK'/,
     1'O     SELECT OUTPUT OPTION'/,
     1'V     VARIABLE DESCRIPTION'/,
     1'P     PERCENTAGE OF TOTAL DATA ITEMS'/,
     1'Q     QUERY'/,
     1'T     TERMINATE THE PROGRAM!')
C
C
      NERR=0
      GO TO 10
C
C
      END
      SUBROUTINE  HELP(I)
C
C
C
C       *************************************************************
C       *                                                           *
C       *       SUBROUTINE HELP ; THIS ROUTINE IS USED TO HELP      *
C       *       THE USER TO UNDERSTAND THE QUERY COMMANDS USED      *
C       *       IN THE PROGRAM. THE PROGRAM CONTENTS ARE READ       *
C       *       FROM THE MTS LINE FILE "SDLS:HELP".                 *
C       *                                                           *
C       *************************************************************
C
C
C
C
      IF(I.NE.0) GO TO 5
      CALL CMDNOE('$COPY SDLS:HELP(001,071) TO *SINK*@SP ',38)
      RETURN
C
C
5     WRITE(6,1)
1     FORMAT(//,'HELP: SELECT THE COMMAND THAT YOU WANT TO '/,
     1'BE EXPLAINED: (H,S,O,V,P,Q,T)')
C
C
```

```
      CALL DECODE(NCOMND)
C
      GO TO(10,20,30,40,50,60,70), NCOMND
C
10    CALL CMDNOE('$COPY SDLS:HELP(072,089) TO *SINK*@SP ',38)
      RETURN
C
20    CALL CMDNOE('$COPY SDLS:HELP(090,104) TO *SINK*@SP ',38)
      RETURN
C
30    CALL CMDNOE('$COPY SDLS:HELP(105,120) TO *SINK*@SP ',38)
      RETURN
C
40    CALL CMDNOE('$COPY SDLS:HELP(121,135) TO *SINK*@SP ',38)
      RETURN
C
50    CALL CMDNOE('$COPY SDLS:HELP(136,151) TO *SINK*@SP ',38)
      RETURN
C
60    CALL CMDNOE('$COPY SDLS:HELP(152,166) TO *SINK*@SP ',38)
      RETURN
C
70    CALL CMDNOE('$COPY SDLS:HELP(167,181) TO *SINK*@SP ',38)
C
C
      RETURN
      END
      SUBROUTINE SELDB
C
C
C
C        *******************************************************
C        *                                                     *
C        *        SUBROUTINE SELDB; TO SELECT A SPECIFIC       *
C        *        DATA BANK.                                   *
C        *                                                     *
C        *******************************************************
C
C
C
      INTEGER ERRNUM
      LOGICAL*1  RESP
      LOGICAL    EQUC
C
C*******
C*******       PRINT THE LIST OF DATA BANKS.
C*******
C
10    WRITE(6,2)
2     FORMAT(//,'THE DATA BANKS AND THEIR CODE NUMBERS ARE;',
     1//,
     1'LAKE.PHYTOPLANKTON                  OR   1'/,
     1'ENTRAINED.PHYTOPLANKTON             OR   2'/,
     1'LAKE.ZOOPLANKTON                    OR   3'/,
     1'ENTRAINED.ZOOPLANKTON               OR   4'/,
     1'LAKE.BENTHOS                        OR   5'/,
     1'ENTRAINED.BENTHOS                   OR   6'/,
     1'IMPINGED.BENTHOS                    OR   7'/,
     1'ADULT.FISH.SUMMARY.STATISTICS       OR   8'/,
     1'LAKE.ADULT.FISH                     OR   9'/,
```

TABLE 5.1. (Continued).

```
     1'IMPINGED.ADULT.FISH              OR   10'/,
     1'LAKE.LARVAE                      OR   11'/,
     1'ENTRAINED.LARVAE                 OR   12'/,
     1'NUTRIENT.AND.ANION               OR   13'/,
     1'LAKEWATER.CHEMISTRY              OR   14'/,
     1'SEDIMENTS                        OR   15')
C
C*******
C*******        CHECK THE AVAILABILITY OF THE DATA BANK(S).
C*******
C
20    WRITE(6,3)
3     FORMAT(//,'THE DATA SHOULD BE AVAILABLE ON LINE.'/,
     1'IS THE DATA BANK OF YOUR INTEREST AVAILABLE ON LINE?'/,
     1'PLEASE ANSWER "Y" OR "N".')
C
C
      LEN=1
      CALL FREAD(5,'STRING:',RESP,LEN)
      IF(EQUC('Y',RESP).OR.EQUC('y',RESP)) GO TO 30
      CALL CMDNOE('SOURCE RESTORE',14)
      STOP
C
C
30    WRITE(6,4)
4     FORMAT(//,'TO PLACE THE REQUESTED DATA BANK IN THE TAXIR PROGRAM,'/,
     1'ENTER THE DATA BANK CODE NUMBER:'/,
     1'(EX: ENTER 1 FOR LAKE.PHYTOPLANKTON)')
C
C
      CALL FREAD(5,'I:',IC)
      GO TO (110,120,130,140,150,160,170,180,190,200,210,220,230,240,250),IC
C
C
      WRITE(6,5)
5     FORMAT(//,'BAD OPTION!')
      GO TO 10
C
C*******
C*******        TAXIR INTERFACE WITH THE DATA BASE.
C*******
C
110   CALL TAXIR('GET LAKE.PHYTOPLANKTON',22)
      CALL ERRCHK(ERRNUM)
      IF(ERRNUM.EQ.0) RETURN
      CALL TAXIR('DUMMY',-1)
      CALL CMDNOE('$EM -CHECK',10)
      CALL TAXIR('GET -LAKE.PHYTO',15)
      CALL ERRCHK(ERRNUM)
      IF(ERRNUM.EQ.0) RETURN
      GO TO 300
C
120   CALL TAXIR('GET ENTRAINED.PHYTOPLANKTON',27)
      CALL ERRCHK(ERRNUM)
      IF(ERRNUM.EQ.0) RETURN
      CALL TAXIR('DUMMY',-1)
      CALL CMDNOE('$EM -CHECK',10)
      CALL TAXIR('GET -ENT.PHYTO',14)
      CALL ERRCHK(ERRNUM)
      IF(ERRNUM.EQ.0) RETURN
```

TABLE 5.1. (Continued).

```
      GO TO 300
C
130   CALL TAXIR('GET LAKE.ZOOPLANKTON',20)
      CALL ERRCHK(ERRNUM)
      IF(ERRNUM.EQ.0) RETURN
      CALL TAXIR('DUMMY',-1)
      CALL CMDNOE('$EM -CHECK',10)
      CALL TAXIR('GET -LAKE.ZOO',13)
      CALL ERRCHK(ERRNUM)
      IF(ERRNUM.EQ.0) RETURN
      GO TO 300
C
140   CALL TAXIR('GET ENTRAINED.ZOOPLANKTON',25)
      CALL ERRCHK(ERRNUM)
      IF(ERRNUM.EQ.0) RETURN
      CALL TAXIR('DUMMY',-1)
      CALL CMDNOE('$EM -CHECK',10)
      CALL TAXIR('GET -ENT.ZOO',12)
      CALL ERRCHK(ERRNUM)
      IF(ERRNUM.EQ.0) RETURN
      GO TO 300
C
150   CALL TAXIR('GET LAKE.BENTHOS',16)
      CALL ERRCHK(ERRNUM)
      IF(ERRNUM.EQ.0) RETURN
      CALL TAXIR('DUMMY',-1)
      CALL CMDNOE('$EM -CHECK',10)
      CALL TAXIR('GET -LAKE.BEN',13)
      CALL ERRCHK(ERRNUM)
      IF(ERRNUM.EQ.0) RETURN
      GO TO 300
C
160   CALL TAXIR('GET ENTRAINED.BENTHOS',21)
      CALL ERRCHK(ERRNUM)
      IF(ERRNUM.EQ.0) RETURN
      CALL TAXIR('DUMMY',-1)
      CALL CMDNOE('$EM -CHECK',10)
      CALL TAXIR('GET -ENT.BEN',12)
      CALL ERRCHK(ERRNUM)
      IF(ERRNUM.EQ.0) RETURN
      GO TO 300
C
170   CALL TAXIR('GET IMPINGED.BENTHOS',20)
      CALL ERRCHK(ERRNUM)
      IF(ERRNUM.EQ.0) RETURN
      CALL TAXIR('DUMMY',-1)
      CALL CMDNOE('$EM -CHECK',10)
      CALL TAXIR('GET -IMP.BEN',12)
      CALL ERRCHK(ERRNUM)
      IF(ERRNUM.EQ.0) RETURN
      GO TO 300
C
180   CALL TAXIR('GET ADULT.FISH.SUMMARY.STATISTICS',33)
      CALL ERRCHK(ERRNUM)
      IF(ERRNUM.EQ.0) RETURN
      CALL TAXIR('DUMMY',-1)
      CALL CMDNOE('$EM -CHECK',10)
      CALL TAXIR('GET -AD.FISH.S.S',16)
      CALL ERRCHK(ERRNUM)
      IF(ERRNUM.EQ.0) RETURN
```

TABLE 5.1. (Continued).

```
      GO TO 300
C
190   CALL TAXIR('GET LAKE.ADULT.FISH',19)
      CALL ERRCHK(ERRNUM)
      IF(ERRNUM.EQ.0) RETURN
      CALL TAXIR('DUMMY',-1)
      CALL CMDNOE('$EM -CHECK',10)
      CALL TAXIR('GET -L.AD.FISH',14)
      CALL ERRCHK(ERRNUM)
      IF(ERRNUM.EQ.0) RETURN
      GO TO 300
C
200   CALL TAXIR('GET IMPINGED.ADULT.FISH',23)
      CALL ERRCHK(ERRNUM)
      IF(ERRNUM.EQ.0) RETURN
      CALL TAXIR('DUMMY',-1)
      CALL CMDNOE('$EM -CHECK',10)
      CALL TAXIR('GET -I.AD.FISH',14)
      CALL ERRCHK(ERRNUM)
      IF(ERRNUM.EQ.0) RETURN
      GO TO 300
C
210   CALL TAXIR('GET LAKE.LARVAE',15)
      CALL ERRCHK(ERRNUM)
      IF(ERRNUM.EQ.0) RETURN
      CALL.TAXIR('DUMMY',-1)
      CALL CMDNOE('$EM -CHECK',10)
      CALL TAXIR('GET -L.LARVAE',13)
      CALL ERRCHK(ERRNUM)
      IF(ERRNUM.EQ.0) RETURN
      GO TO 300
C
220   CALL TAXIR('GET ENTRAINED.LARVAE',20)
      CALL ERRCHK(ERRNUM)
      IF(ERRNUM.EQ.0) RETURN
      CALL TAXIR('DUMMY',-1)
      CALL CMDNOE('$EM -CHECK',10)
      CALL TAXIR('GET -E.LARVAE',13)
      CALL ERRCHK(ERRNUM)
      IF(ERRNUM.EQ.0) RETURN
      GO TO 300
C
230   CALL TAXIR('GET NUTRIENTS',13)
      CALL ERRCHK(ERRNUM)
      IF(ERRNUM.EQ.0) RETURN
      CALL TAXIR('DUMMY',-1)
      CALL CMDNOE('$EM -CHECK',10)
      CALL TAXIR('GET -NUTRIENTS',14)
      CALL ERRCHK(ERRNUM)
      IF(ERRNUM.EQ.0) RETURN
      GO TO 300
240   CALL TAXIR('GET LAKEWATER',13)
      CALL ERRCHK(ERRNUM)
      IF(ERRNUM.EQ.0) RETURN
      CALL TAXIR('DUMMY',-1)
      CALL CMDNOE('$EM -CHECK',10)
      CALL TAXIR('GET -LAKEWATER',14)
      CALL ERRCHK(ERRNUM)
      IF(ERRNUM.EQ.0) RETURN
      GO TO 300
```

```
250  CALL TAXIR('GET SEDIMENTS',12)
     CALL ERRCHK(ERRNUM)
     IF(ERRNUM.EQ.0) RETURN
     CALL TAXIR('DUMMY',-1)
     CALL CMDNOE('$EM -CHECK',10)
     CALL TAXIR('GET -SEDIMENTS',14)
     CALL ERRCHK(ERRNUM)
     IF(ERRNUM.EQ.0) RETURN
C
C*******
C*******        CHECK TAXIR MESSAGES.
C*******
C
300  CALL TAXIR('DUMMY',-1)
     CALL CMDNOE('$EM -CHECK',10)
     WRITE(6,6)
6    FORMAT(//,'REQUESTED DATA BANK IS NOT AVAILABLE.'/,
    1'DO YOU WANT TO SELECT ANOTHER DATA BANK?'/,
    1'ENTER "Y" FOR YES, "N" FOR NO.')
     CALL FREAD(5,'STRING:',RESP,LEN)
     IF(EQUC('Y',RESP).OR.EQUC('y',RESP)) GO TO 20
C
C
     RETURN
     END
     SUBROUTINE OUTOP
C
C
C
C      ************************************************
C      *                                              *
C      *       SUBROUTINE OUTOP; TO SELECT AN OUTPUT  *
C      *       FILE OR DEVICE.                        *
C      *                                              *
C      ************************************************
C
C
C
     LOGICAL*1  LINE(29)
C
C
     DATA LINE(1),LINE(2),LINE(3),LINE(4),LINE(5),LINE(6),
    1LINE(7)/1HS,1HE,1HT,1H ,1HO,1HU,1HT/
     DATA LINE(8),LINE(9),LINE(10),LINE(11)/1HP,1HU,1HT,1H=/
C
C*******
C*******        OUTPUT FILE/DEVICE OPTIONS.
C*******
C
5    WRITE(6,1)
1    FORMAT(//,'SELECT OUTPUT FILE/DEVICE, TYPE:'//,
    13X,'1  TERMINAL'/,
    13X,'2  LINE PRINTER'/,
    13X,'3  OUTPUT FILE NAME')
C
C
     CALL FREAD(5,'I:',IC)
     IF(IC.EQ.1) GO TO 10
     IF(IC.EQ.2) GO TO 20
     IF(IC.EQ.3) GO TO 30
```

TABLE 5.1. (Continued).

```
C
C
      WRITE(6,2)
2     FORMAT(//,'BAD OPTION!')
      GO TO 5
C
C*******
C*******       INTERFACE WITH TAXIR.
C*******
C
10    CALL TAXIR('SET OUTPUT=*MSINK*',18)
      RETURN
C
20    CALL TAXIR('SET OUTPUT=*PRINT*',18)
      RETURN
C
30    WRITE(6,3)
3     FORMAT(//,'ENTER NAME OF THE OUTPUT FILE.')
C
C*******
C*******       INTERFACE WITH TAXIR.
C*******
C
      LEN=18
      CALL FREAD(5,'STRING:',LINE(12),LEN)
      LEN=LEN+11
      CALL TAXIR(LINE,LEN)
C
C
      RETURN
      END
      SUBROUTINE VOCAB
C
C
C
C       ****************************************************************
C       *                                                              *
C       *       SUBROUTINE VOCAB;  TO PROVIDE THE USER WITH THE        *
C       *       LIST OF DESCRIPTORS FOR THE SELECTED DATA BANK.        *
C       *                                                              *
C       ****************************************************************
C
C
C
      INTEGER ERRNUM
      LOGICAL*1 LINE(87),ASTRIS,RESP
      LOGICAL   EQUC
C
C
      DATA ASTRIS/1H*/
      DATA LINE(1),LINE(2),LINE(3),LINE(4)/1HS,1HH,1HO,1HW/
      DATA LINE(5)/1H /
C
C*******
C*******       OBTAIN DICTIONARY INFORMATION.
C*******
C
      WRITE(6,1)
1     FORMAT(//,'ARE YOU FAMILIAR WITH ALL THE OPTIONS FOR OBTAINING'/,
     1'INFORMATION ABOUT DATA DESCRIPTORS?'/,
```

```
     1'TYPE "Y" FOR YES TO SKIP THE DESCRIPTIONS.'/,
     1'TYPE "N" IF YOU NEED THE DESCRIPTIONS.')
C
C
      CALL FREAD(5,'STRING:',RESP,1)
      IF(EQUC('Y',RESP).OR.EQUC('y',RESP)) GO TO 10
C
C
40    WRITE(6,2)
2     FORMAT(//,'THE OPTIONS ARE LISTED BELOW:'///,
     1'OPTION 1:  TYPE "SUM" TO GET THE DATA SUMMARY FOR THE'/,
     1'             SELECTED DATA BANK.')
      WRITE(6,3)
3     FORMAT(//,'OPTION 2:  TO OBTAIN INFORMATION ON DESCRIPTORS,',
     1' TYPE'/,
     1'             THE NAMES  OR  CODES  OF THE  DESCRIPTORS,'/,
     1'             (SEPARATED BY ,).'/,
     1'             ENTER "ALL" FOR ALL THE DESCRIPTORS.'/,
     1'             (EX: 1,2,3 OR MONTH,DAY OR ALL)')
      WRITE(6,4)
4     FORMAT(//,'OPTION 3:  FOR LISTINGS OF BOTH DESCRIPTORS AND',
     1' THEIR'/,
     1'             STATES, TYPE  "F"  FOLLOWING  A  PARAMETER'/,
     1'             NAME OR CODE AS IN THE EXAMPLE BELOW.'/,
     1'             (EX: 1 F,2 F,3 F OR MONTH F,DAY F OR ALL F)')
      WRITE(6,5)
5     FORMAT(//,'OPTION 4:  TO OBTAIN THE LIST OF THE CODE(S) AND',
     1' NAME'/,
     1'             (S)  OF DESCRIPTOR  STATE(S) THAT CONTAINS'/,
     1'             OR BEGINS WITH A PARTICULAR  STRING;  TYPE'/,
     1'             THE  DESCRIPTOR  NAME OR CODE  ALONG  WITH'/,
     1'             THE WORDS  "BEGINS" OR "CONTAINS"  AND THE'/,
     1'             SPECIFIED STRING.'/,
     1'             (EX: NAME CONTAINS MARY OR NAME BEGINS M)'/,
     1'            *NOTE  THAT FOR THIS OPTION THE  DESCRIPTOR'/,
     1'             TYPE SHOULD BE NAME OR ORDER.')
C
C
10    WRITE(6,6)
6     FORMAT(//,'ENTER THE DESCRIPTOR NAME(S) OR CODE(S) ALONG WITH'/,
     1'THE REQUIRED STRING (IF ANY).')
C
C*******
C*******       TAXIR INTERFACE WITH THE DATA BASE.
C*******
C
      LEN=80
      CALL FREAD(5,'STRING:',LINE(6),LEN)
      LEN=LEN+6
      LINE(LEN)=ASTRIS
C
C
      CALL TAXIR(LINE,LEN)
C
C*******
C*******       CHECK TAXIR MESSAGES.
C*******
C
      CALL ERRCHK(ERRNUM)
      IF(ERRNUM.EQ.0) GO TO 20
```

TABLE 5.1. (Continued).

```
      CALL TAXIR('DUMMY',-1)
      CALL CMDNOE('$EM -CHECK',10)
      WRITE(6,7)
7     FORMAT(//,'THE INFORMATION YOU ASKED CAN NOT BE LISTED.'/,
     1'THE STATEMENT YOU HAVE TYPED CONTAINS ERROR(S).'/,
     1'DO YOU WANT TO TRY AGAIN? (Y/N)')
C
C
      CALL FREAD(5,'STRING:',RESP,1)
      IF(EQUC('Y',RESP).OR.EQUC('y',RESP)) GO TO 30
      GO TO 20
C
C
30    WRITE(6,8)
8     FORMAT(//,'DO YOU NEED HELP TO CONSTRUCT YOUR QUESTION? (Y/N)!)
      CALL FREAD(5,'STRING:',RESP,1)
      IF(EQUC('Y',RESP).OR.EQUC('y',RESP)) GO TO 40
      GO TO 10
C
C
20    RETURN
      END
      SUBROUTINE PERCNT
C
C
C
C       ***********************************************************
C       *                                                         *
C       *       SUBROUTINE PERCNT; TO PRODUCE STATISTICS IN       *
C       *       TERMS OF PERCENTAGES FOR A DATA BANK.             *
C       *                                                         *
C       ***********************************************************
C
C
C
      INTEGER ERRNUM
      LOGICAL*1  LINE(86),ASTRIS,RESP
      LOGICAL EQUC
C
C
      DATA LINE(1),LINE(2),LINE(3),LINE(4),LINE(5)/1HH,1HM,1H ,1H*,1H /
      DATA ASTRIS/1H*/
C
C*******
C*******        INSTRUCTIONS TO OBTAIN THE NECESSARY STATISTICS.
C*******
C
30    WRITE(6,1)
1     FORMAT(//,'DO YOU NEED HELP TO CONSTRUCT YOUR QUESTION? (Y/N)')
C
C
      CALL FREAD(5,'STRING:',RESP,1)
      IF(EQUC('Y',RESP).OR.EQUC('y',RESP)) GO TO 10
      GO TO 20
C
C
10    WRITE(6,2)
2     FORMAT(//,'TO SPECIFY YOUR QUESTION YOU SHOULD ENTER THE',
     1' NAME'/, 'OR CODE OF THE  DESCRIPTOR  ALONG  WITH ITS  TYPE,'/,
     1'(SEPARATED BY ,).'/,
```

TABLE 5.1. (Continued).

```
     1'(EX: DAY,31 OR YEAR,80)'//,
     1'TO COMBINE THE DESCRIPTORS USE LOGICAL  STATEMENTS'/,
     1'"AND/OR". YOU CAN ALSO USE PARENTHESES TO NAME THE'/,
     1'SUBSET OF INTEREST FROM THE TOTAL BANK.'/,
     1'EX: YEAR,80 AND MONTH,MAY'/,
     1'      YEAR,80 OR  MONTH,MAY'/,
     1'      (YEAR,80 AND MONTH,MAY) OR DAY,31')
C
C
20    WRITE(6,3)
3     FORMAT(//,'ENTER THE QUESTION.')
C
C*******
C*******          TAXIR INTERFACE WITH THE DATA BASE.
C*******
C
      LEN=80
      CALL FREAD(5,'STRING:',LINE(6),LEN)
      LEN=LEN+6
      LINE(LEN)=ASTRIS
C
C
      CALL TAXIR(LINE,LEN)
C
C*******
C*******          CHECK TAXIR MESSAGES.
C*******
C
      CALL ERRCHK(ERRNUM)
      IF(ERRNUM.EQ.0) GO TO 40
      CALL TAXIR('DUMMY',-1)
      CALL CMDNOE('$EM -CHECK',10)
      WRITE(6,4)
4     FORMAT(//,'THE PERCENTAGE CAN NOT BE COMPUTED.'/,
     1'THE STATEMENT YOU HAVE TYPED CONTAINS ERROR(S).'/,
     1'DO YOU WANT TO TRY AGAIN? (Y/N)')
C
C
      CALL FREAD(5,'STRING:',RESP,1)
      IF(EQUC('Y',RESP).OR.EQUC('y',RESP)) GO TO 30
C
C
40    RETURN
      END
      SUBROUTINE QUERY
C
C
C
C        **********************************************************
C        *                                                        *
C        *        SUBROUTINE QUERY; TO RETRIEVE INFORMATION       *
C        *        FROM THE SELECTED DATA BANK.                    *
C        *                                                        *
C        **********************************************************
C
C
C
      INTEGER ERRNUM
      LOGICAL*1  LINE(166),ASTRIS,RESP
      LOGICAL EQUC
```

TABLE 5.1. (Continued).

```
C
C
      DATA  ASTRIS/1H*/
      DATA  LINE(1),LINE(2)/1HQ,1H /
C
C*******
C*******        INSTRUCTIONS TO CONSTRUCT THE QUERIES.
C*******
C
40    WRITE(6,1)
1     FORMAT(//,'DO YOU NEED THE INSTRUCTIONS TO MAKE YOUR QUERY? (Y/N)')
C
C
      CALL FREAD(5,'STRING:',RESP,1)
      IF(EQUC('Y',RESP).OR.EQUC('y',RESP)) GO TO 10
      GO TO 20
C
C
10    WRITE(6,2)
2     FORMAT(//,'THE QUERY "Q" COMMAND IS THE MOST POWERFUL RETRIEVAL',
     1' TOOL'/,'IN THIS PROGRAM.  THE  CONSTRUCTION OF A  QUERY',
     1' STATEMENT'/,'CONSISTS OF TWO PARTS:'///,
     1'I.  THE SPECIFICATION OF THE  DESCRIPTOR(S) WHICH MUST BE'/,
     1'      LISTED IN THE DATA OUTPUT. THERE ARE FIVE OPTIONS FOR'/,
     1'      THIS PART AS SHOWN BELOW:'//,
     1'      1.  THE NAME(S)  OR  CODE(S) OF THE DESCRIPTOR(S) CAN'/,
     1'          BE ENCLOSED IN PARENTHESES, (SEPARATED BY ,).'/,
     1'          TYPING  AN  "A"  IN ENCLOSED ANGLE BRACKETS  "<>"'/,
     1'          FOLLOWING DESCRIPTOR CODE OR NAME WILL  RESULT IN'/,
     1'          A PRINT OF DUPLICATE STATES.'/,
     1'          EX: (YEAR,MONTH,DAY)'/,
     1'              (YEAR<A>,MONTH<A>,DAY<A>)'//,
     1'      2.  TYPING  "ALL"  RESULTS IN THE LIST FOR ALL OF THE'/,
     1'          DESCRIPTORS.'/,
     1'          EX: (ALL)')
      WRITE(6,3)
3     FORMAT(/,'      3.  A TOTAL OR SUBTOTAL OF NUMERICAL  DESCRIPTORS CAN'/,
     1'          BE OBTAINED BY TYPING A  "TN"  IN A PAIR OF ANGLE'/,
     1'          BRACKETS,  WHERE N INDICATES THE SUBTOTAL FOR THE'/,
     1'          NTH  DESCRIPTOR.  IF N  IS  ZERO,  THEN THE GRAND'/,
     1'          TOTAL IS PRINTED.  AN  EXAMPLE  IS SHOWN BELOW IN'/,
     1'          WHICH T0 IS THE GRAND TOTAL AND T1 AND T2 ARE THE'/,
     1'          SUBTOTALS FOR DESCRIPTORS 1 AND 2.'/,
     1'          EX: (YEAR,MONTH,SPCONT<T0,T1,T2>)'//,
     1'      4.  IF THE OUTPUT IS DESIGNED TO SERVE AS AN INPUT TO'/,
     1'          MIDAS  FOR   FURTHER   STATISTICAL  ANALYSIS  THE'/,
     1'          STATEMENT  "<STAT,FN>" SHOULD BE TYPED BEFORE THE'/,
     1'          DESCRIPTOR LIST,  WHERE  "FN"  IS THE NAME OF THE'/,
     1'          OUTPUT FILE PROVIDED BY THE "O" COMMAND.'/,
     1'          EX: <STAT,RESULT> (YEAR,MONTH,DAY,SPCONT)'//,
     1'      5.  IF THE  WORD  "TAB"  IS  USED IN  A PAIR OF ANGLE'/,
     1'          BRACKETS   BEFORE   THE   DESCRIPTOR   LIST,  THE'/,
     1'          PERCENTAGE  OF  DATA  ITEMS  FOR  EACH CELL IN AN'/,
     1'          N-WAY TABULATION IS PRINTED.'/,
     1'          EX: <TAB> (YEAR,MONTH,SPCONTS)')
      WRITE(6,4)
4     FORMAT(//,'II. THE BOOLEAN EXPRESSION,  WHICH  DEFINES THE SUBSET OF'/,
     1'    ITEMS FROM THE DATA BANK,  WHICH MUST  BE  RETRIEVED.'/,
     1'    TO COMPLETE THIS,  THE NAME OR CODE OF THE DESCRIPTOR'/,
     1'    AND ITS TYPE SHOULD BE ENTERED, (SEPARATED BY ,).'/,
```

```
     1'      EX: YEAR,80'/,
     1'          MONTH,MAY'//,
     1'      THIS   SUBSET   MAY   CONSIST  OF  A  COMBINATION  OF'/,
     1'      DESCRIPTORS.  IN  THIS  CASE THE  LOGICAL  STATEMENTS'/,
     1'      "AND/OR" AND PARENTHESES  "()"  CAN BE USED TO SELECT'/,
     1'      THE  SUBSET.  IF  "ALL"  IS  ENTERED  THE  SUBSET  OF'/,
     1'      INTEREST IS EQUAL TO THE WHOLE DATA BANK.'/,
     1'      EX: YEAR,80 AND MONTH,MAY'/,
     1'          YEAR,80 OR MONTH,MAY'/,
     1'          (YEAR,80 AND MONTH,MAY) OR DAY,31'/,
     1'          ALL')
C
C
20    ICOUNT=3
      WRITE(6,5)
5     FORMAT(//,'ENTER THE DESCRIPTOR LIST AND THE NECESSARY KEYWORDS.'/,
     1'EX: (YEAR<A>,MONTH<A>,SPCONT<A>)'/,
     1'      (YEAR,SPCONT<T0,T1>)'/,
     1'      <STAT,RESULT> (YEAR,MONTH,SPCONT)'/,
     1'      <TAB> (YEAR,SPCONT>')
      LEN=80
      CALL FREAD(5,'STRING:',LINE(ICOUNT),LEN)
      ICOUNT=ICOUNT+LEN+1
      LINE(ICOUNT)=ASTRIS
      ICOUNT=ICOUNT+1
C
C
      WRITE(6,6)
6     FORMAT(//,'ENTER THE BOOLEAN  EXPRESSION  TO NAME THE',
     1' SUBSET OF'/,'INTEREST FROM THE TOTAL BANK.'/,
     1'EX: YEAR,80 AND MONTH,MAY')
C
C
C
C*******
C*******       TAXIR INTERFACE WITH THE DATA BASE.
C*******
C
      LEN=80
      CALL FREAD(5,'STRING:',LINE(ICOUNT),LEN)
      ICOUNT=ICOUNT+LEN+1
      LINE(ICOUNT)=ASTRIS
C
C
      CALL TAXIR(LINE,ICOUNT)
C
C*******
C*******       CHECK TAXIR MESSAGES.
C*******
C
      CALL ERRCHK(ERRNUM)
      IF(ERRNUM.EQ.0) GO TO 30
      CALL TAXIR('DUMMY',-1)
      CALL CMDNOE('$EM -CHECK',10)
      WRITE(6,7)
7     FORMAT(//,'THE LIST CAN NOT BE PRINTED.'/,
     1'THE STATEMENT YOU HAVE TYPED CONTAINS ERROR(S).'/,
     1'DO YOU WANT TO TRY AGAIN? (Y/N)')
C
C
```

TABLE 5.1. (Continued).

```
      CALL FREAD(5,'STRING:',RESP,1)
      IF(EQUC('Y',RESP).OR.EQUC('y',RESP)) GO TO 40
C
C
30    RETURN
      END
      SUBROUTINE TERMIN
C
C
C
C       **************************************************************
C       *                                                            *
C       *         SUBROUTINE TERMIN; TO TERMINATE THE EXECUTION      *
C       *         OF THE PROGRAM.                                    *
C       *                                                            *
C       **************************************************************
C
C
C
      LOGICAL   EQUC
C
C
      WRITE(6,1)
1     FORMAT(//,'DO YOU WANT TO END THE EXECUTION OF THE PROGRAM? (Y/N)')
C
C
      CALL FREAD(5,'STRING:',RESP,1)
      IF(EQUC('Y',RESP).OR.EQUC('y',RESP))  STOP
C
C
      WRITE(6,2)
2     FORMAT('COMMAND IGNORED.')
C
C
      RETURN
      END
      SUBROUTINE ERRCHK(ERRFLG)
C
C
C
C       **************************************************************
C       *                                                            *
C       *         SUBROUTINE ERRCHK; TO CHECK THE ERROR MESSAGES     *
C       *         PRODUCED BY TAXIR PROGRAM.                         *
C       *                                                            *
C       **************************************************************
C
C
C
      INTEGER ERRFLG
      LOGICAL*1 ERROR(6)
      LOGICAL EQUC
C
C*******
C*******          READ TAXIR MESSAGES FROM THE FILES ASSIGNED TO SERCOM, WHICH
C*******          CONTAINS ERROR MESSAGES RECOGNIZED AT THIS POINT.
C*******
C
      READ(7,1) ERROR
1     FORMAT(6A1)
```

TABLE 5.1. (Continued).

```
      CALL CMDNOE('$EM -CHECK',10)
      ERRFLG=1
      IF(EQUC('0READY',ERROR)) ERRFLG=0
C
C
      RETURN
      END
```

TABLE 5.2. File HELP.

```
     **THIS IS AN INTERACTIVE PROGRAM**

IF YOU  ARE NOT NOW  USING THE  "UPPER CASE"
OPTION, PLEASE DO SO. SINCE THIS PROGRAM CAN
WORK ONLY WITH THE "UPPER CASE" OPTION.


THE GOAL OF THIS  PROGRAM  IS TO HELP YOU TO
RETRIEVE THE  INFORMATION YOU  NEED FROM ANY
OF THE 13  EXISTING  DATA  BANKS,  WHICH ARE
LISTED AS FOLLOW:

LAKE.PHYTOPLANKTON                OR    1
ENTRAINED.PHYTOPLANKTON           OR    2
LAKE.ZOOPLANKTON                  OR    3
ENTRAINED.ZOOPLANKTON             OR    4
LAKE.BENTHOS                      OR    5
ENTRAINED.BENTHOS                 OR    6
IMPINGED.BENTHOS                  OR    7
ADULT.FISH.SUMMARY.STATISTICS     OR    8
LAKE.ADULT.FISH                   OR    9
IMPINGED.ADULT.FISH               OR   10
LAKE.LARVAE                       OR   11
ENTRAINED.LARVAE                  OR   12
NUTRIENT.AND.ANION                OR   13
LAKEWATER.CHEMISTRY               OR   14
SEDIMENTS                         OR   15

THERE ARE SEVEN COMMANDS IN THIS PROGRAM;

HELP                                 H
SELECT DATA BANK                     S
SELECT OUTPUT OPTION                 O
VARIABLE DESCRIPTION                 V
PERCENTAGE OF TOTAL DATA ITEMS       P
QUERY                                Q
TERMINATE THE PROGRAM                T


HINTS:  FOR DATA  RETRIEVAL, THE SEQUENCE OF
OPERATIONS LISTED BELOW IS USUALLY FOLLOWED;

(1)  FIRST  YOU  SHOULD SELECT THE DATA BASE
     OF INTEREST.
(2)  ONCE THAT IS DONE,  YOU SHOULD TELL THE
     COMPUTER WHAT  DEVICE YOU ARE USING AND
     HOW YOU WANT YOUR INFORMATION  PRINTED.
     THIS CAN BE ACCOMPLISHED BY  TYPING "O"
     AND RESPONDING TO THE  QUESTIONS  WHICH
     APPEAR AFTER THE COMMAND "O".
(3)  THREE TYPES OF  INFORMATION CAN THEN BE
     ACCESSED;  IF YOU  NEED THE  VARIABLES
     CONTAINED IN THE DATA BASE, TYPE "V".
     IF YOU WANT TO KNOW THE  PERCENTAGE OF
     DATA ITEMS IN THE DATA QUERY TYPE "P".
     IF YOU NEED THE  ACTUAL DATA FOR ALL OR
     PART OF THE DATA BASE, TYPE "Q".

PLEASE ANSWER TO ALL OF THE QUESTIONS, WHICH
APPEAR AFTER YOU TYPE THE COMMAND.
```

TABLE 5.2. (Continued).

(4) FINALLY, WHEN YOU DO NOT WANT TO PROCEED FURTHER, "T" WILL TERMINATE THE RETRIEVAL OPERATIONS AND RETURN YOU TO MTS.

TO GET THE DESCRIPTION OF THE COMMANDS TYPE "H" FOR HELP, THEN TYPE THE FIRST LETTER OF EACH COMMAND WHILE YOU ARE IN HELP MODE, (EX: S, FOR SELECT DATA BANK).

HELP "H"

FUNCTION:	TO EXPLAIN ONE OR MORE COMMANDS FOR THE USER.
HOW TO CALL:	PRESS "H" TO GET A LIST OF ALL THE EXISTING COMMANDS. IF YOU ARE INTERESTED IN A SPECIFIC COMMAND ENTER THE FIRST LETTER OF THAT COMMAND, (H,S,O,V,P,Q,T).

SELECT DATA BANK "S"

FUNCTION:	TO SELECT ONE OF THE EXISTING DATA BANKS.
HOW TO CALL:	PRESS "S" TO CHOOSE A DATA BANK AND TO GET A LIST OF EXISTING DATA BANKS.

SELECT OUTPUT OPTION "O"

FUNCTION:	TO CHOOSE AN OUTPUT FILE/DEVICE THAT OUTPUTS GET PRINTED ON, (EX: TERMINAL SCREEN, LINE PRINTER, LINE FILE).
HOW TO CALL:	PRESS "O" TO SELECT THE OUTPUT FILE/DEVICE.

TABLE 5.2. (Continued).

VOCABULARY "V"

FUNCTION:	TO GET THE VOCABULARY LIST FOR SOME OR ALL OF THE DESCRIPTORS.
HOW TO CALL:	PRESS "V" TO GET THE VOCABULARY LIST.

PERCENTAGE "P"

FUNCTION:	TO PROVIDE THE USER WITH THE PERCENTAGE OF ITEMS IN THE TOTAL DATA BANK BELONGING TO THE SUBSET OF INTEREST.
HOW TO CALL:	PRESS "P" TO GET THE PERCENTAGE.

QUERY "Q"

FUNCTION:	TO RETRIEVE INFORMATION FROM THE SELECTED DATA BANK.
HOW TO CALL:	PRESS "Q" TO RETRIEVE THE ACTUAL DATA FOR ALL OR PART OF THE SELECTED DATA BASE.

TERMINATE THE PROGRAM "T"

FUNCTION:	TO TERMINATE THE EXECUTION OF THE PROGRAM.
HOW TO CALL:	PRESS "T" TO END THE PROGRAM.

TABLE 5.3. Program LINK.

```
C RUN PROGRAM LINK RESULTS IN CREATION OF TEMPORARY FILE -F,
C WHERE "F" INDICATES THE NAME OF THE FILE WHICH CONTAINS THE
C COMMANDS NECESSARY FOR RESTORATION OF THE DATA BASES FROM A
C *FS TAPE.
C UNIT 5 IS ASSIGNED TO *MSOURCE* TO READ THE CODE NUMBER(S)
C OF THE DATA BANK(S) WHICH NEED TO BE RESTORED.
C UNIT 6 IS  ASSIGNED TO *SINK* TO PRINT THE  MESSAGES ON THE
C TERMINAL.
C UNIT 7 IS ASSIGNED TO FILE "-G" FOR *FS USE.
C UNIT 8 IS  ASSIGNED TO FILE "-F" FOR  RESTORATION COMMANDS.
C
C
C
C       ************************************************
C       *                                              *
C       *       PROGRAM LINK; TO RESTORE THE DATA      *
C       *       BASES FROM THE TAPE.                   *
C       *                                              *
C       ************************************************
C
C
C
      INTEGER IARR(15),NUM,N
      LOGICAL*1 RESP
      LOGICAL EQUC
C
C*******
C*******       ENTER THE CODE NUMBER(S) OF THE DATA BANK(S).
C*******
C
30    WRITE(6,1)
1     FORMAT(//,'ENTER THE CODE NUMBER(S) OF THE DATA BANK(S)  WHICH YOU'/,
     1'LIKE TO WORK WITH DURING THE EXECUTION OF THIS PROGRAM.'/,
     1'THESE DATA BANKS WILL BE RESTORED FROM THE TAPE AND CAN'/,
     1'BE ACCESSED LATER ONE AT A TIME. CODE NUMBERS SHOULD BE'/,
     1'SEPARATED BY A ",". (EX: 1,2,3,4)')
C
      N=FREAD(5,'INTEGER VECTOR:',IARR,15)
      IF(N.NE.0) GO TO 10
      WRITE(6,2)
2     FORMAT(//,'NO ENTRY!'/,
     1'DO YOU NEED THE LIST OF THE DATA BANKS? (Y/N)')
C
      CALL FREAD(5,'STRING:',RESP,1)
      IF(EQUC('Y',RESP).OR.EQUC('y',RESP)) GO TO 20
      GO TO 30
C
C*******
C*******       PRINT THE LIST OF DATA BANKS IF NEEDED.
C*******
C
20    WRITE(6,3)
3     FORMAT(//,'THE DATA BANKS AND THEIR CODE NUMBERS ARE;',
     1//,
     1'LAKE.PHYTOPLANKTON               OR   1'/,
     1'ENTRAINED.PHYTOPLANKTON          OR   2'/,
     1'LAKE.ZOOPLANKTON                 OR   3'/,
     1'ENTRAINED.ZOOPLANKTON            OR   4'/,
     1'LAKE.BENTHOS                     OR   5'/,
     1'ENTRAINED.BENTHOS                OR   6'/,
```

TABLE 5.3. (Continued).

```
     1'IMPINGED.BENTHOS                 OR    7'/,
     1'ADULT.FISH.SUMMARY.STATISTICS    OR    8'/,
     1'LAKE.ADULT.FISH                  OR    9'/,
     1'IMPINGED.ADULT.FISH              OR   10'/,
     1'LAKE.LARVAE                      OR   11'/,
     1'ENTRAINED.LARVAE                 OR   12'/,
     1'NUTRIENT.AND.ANION               OR   13'/,
     1'LAKEWATER.CHEMISTRY              OR   14'/,
     1'SEDIMENTS                        OR   15')
C
      GO TO 30
C
C*******
C*******      CHECK THE ENTERED CODE NUMBER(S).
C*******
C
10    J=0
      DO 40 I=1,N
      IF((IARR(I).NE.0).AND.(IARR(I).LT.16)) GO TO 40
      J=J+1
40    CONTINUE
C
      IF(J.EQ.N) GO TO 50
      IF((J.NE.0).AND.(J.LT.N)) GO TO 60
      GO TO 70
C
50    WRITE(6,4)
4     FORMAT(//,'THE ENTERED CODE NUMBER(S) ARE NOT ACCEPTABLE.')
80    WRITE(6,5)
5     FORMAT(//,'DO YOU NEED THE LIST OF THE DATA BANKS? (Y/N)')
      CALL FREAD(5,'STRING:',RESP,1)
      IF(EQUC('Y',RESP).OR.EQUC('y',RESP)) GO TO 20
      GO TO 30
C
60    WRITE(6,6) J
6     FORMAT(//,I5,1X,'WRONG CODE NUMBER(S).'/,
     1'DO YOU WISH TO REENTER THE LINE? (Y/N)')
      CALL FREAD(5,'STRING:',RESP,1)
      IF(EQUC('Y',RESP).OR.EQUC('y',RESP)) GO TO 80
C
C*******
C*******      CREATION OF FILE "-G".
C*******
C
70    WRITE(7,7)
7     FORMAT('RESPONDS')
C
      CALL CMDNOE('$EM -G',6)
C
      DO 90 I=1,N
      WRITE(7,8)
8     FORMAT('Y')
90    CONTINUE
C
C*******
C*******      CREATION OF FILE "-F".
C*******
C
      WRITE(8,9)
9     FORMAT('COMMANDS')
```

```
C
      CALL CMDNOE('$EM -F',6)
C
      DO 100 I=1,N
      NUM=IARR(I)
      GO TO (120,130,140,150,160,170,180,190,210,220,230,240,250,260,270),NUM
C
      WRITE(6,11) NUM
11    FORMAT(//,I5,1X,'NOT AN ACCEPTABLE CODE NUMBER.')
      GO TO 100
C
120   WRITE(8,12)
12    FORMAT('RESTORE LAKE.PHYTOPLANKTON -LAKE.PHYTO')
      GO TO 100
C
130   WRITE(8,13)
13    FORMAT('RESTORE ENTRAINED.PHYTOPLANKTON -ENT.PHYTO')
      GO TO 100
C
140   WRITE(8,14)
14    FORMAT('RESTORE LAKE.ZOOPLANKTON -LAKE.ZOO')
      GO TO 100
C
150   WRITE(8,15)
15    FORMAT('RESTORE ENTRAINED.ZOOPLANKTON -ENT.ZOO')
      GO TO 100
C
160   WRITE(8,16)
16    FORMAT('RESTORE LAKE.BENTHOS -LAKE.BEN')
      GO TO 100
C
170   WRITE(8,17)
17    FORMAT('RESTORE ENTRAINED.BENTHOS -ENT.BEN')
      GO TO 100
C
180   WRITE(8,18)
18    FORMAT('RESTORE IMPINGED.BENTHOS -IMP.BEN')
      GO TO 100
C
190   WRITE(8,19)
19    FORMAT('RESTORE ADULT.FISH.SUMMARY.STATISTICS -AD.FISH.S.S')
      GO TO 100
C
210   WRITE(8,21)
21    FORMAT('RESTORE LAKE.ADULT.FISH -L.AD.FISH')
      GO TO 100
C
220   WRITE(8,22)
22    FORMAT('RESTORE IMPINGED.ADULT.FISH -I.AD.FISH')
      GO TO 100
C
230   WRITE(8,23)
23    FORMAT('RESTORE LAKE.LARVAE -L.LARVAE')
      GO TO 100
C
240   WRITE(8,24)
24    FORMAT('RESTORE ENTRAINED.LARVAE -E.LARVAE')
      GO TO 100
C
250   WRITE(8,25)
```

TABLE 5.3. (Continued).

```
25    FORMAT('RESTORE NUTRIENTS -NUTRIENTS')
      GO TO 100
C
260   WRITE(8,26)
26    FORMAT('RESTORE LAKEWATER -LAKEWATER')
      GO TO 100
C
270   WRITE(8,27)
27    FORMAT('RESTORE SEDIMENTS -SEDIMENTS')
100   CONTINUE
C
C*******
C*******        END OF THE *FS COMMANDS IN FILE "-F".
C*******
C
      WRITE(8,28)
28    FORMAT('STOP')
C
      WRITE(6,29)
29    FORMAT(//,'AT THIS POINT THE TAPE IS BEING MOUNTED AND THE REQUESTED'/,
     1'DATA BANK(S)  ARE  BEING  RESTORED.  COMPLETION OF THIS'/,
     1'PROCESS WILL TAKE A FEW MINUTES. PLEASE STAND BY!')
C
C
      STOP
      END
```

and then passing their responses on to the Taxir program. This program is made possible by the fact that Taxir can be loaded and run as a subroutine of a larger program. Using this feature in programming, two programs can be loaded together, and control commands can be passed to each other without unloading the first program. This allows both programs to remain loaded and maintain an updated value of their variables. However, if a program is loaded along with the initialization of the variables by using an ordinary run command, problems can occur when a second run command is issued. This results in loading the new program and unloading of the first program, and can lead to the loss of the updated values for the parameters of the first program.

The program INTERACT, using a Taxir FORTRAN callable subroutine, stores the necessary commands (statements) in an array of characters and passes them to Taxir as an argument of the subroutine, as shown in the following form:

```
CALL TAXIR (ARRAY,LENGTH)
```

ARRAY is the first calling argument containing the Taxir command, and LENGTH is the 2nd calling argument representing the length in characters of the command. The LENGTH argument is important because at each call Taxir should look only at the meaningful characters stored in the array at that time so as to avoid problems which can be caused by the characters left by the previous commands of greater length. As an example, the Taxir call (as seen in various uses in program INTERACT) can be:

```
CALL TAXIR ('SET OUTPUT=*MSINK*',18)
```

Here, 18 is the number of the characters in this command, and this call could be made when the terminal screen is to be selected as the output device.

The above explanations show how, in general, different Taxir commands are passed by INTERACT (or any other FORTRAN program) to Taxir. However, Taxir can be called from INTERACT in two other special forms for two specific purposes. On these two calls, the LENGTH arguments have definite values, but the ARRAY arguments can be ignored and replaced by dummy parameters. These two calls are explained as follows:

1. LENGTH=0 CALL TAXIR ('DUMMY',0)

   This call initializes Taxir and is equivalent to invoking Taxir with the $RUN *TAXIR command. This call is made only once in the beginning of the program INTERACT.

2. LENGTH=-1 CALL TAXIR ('DUMMY',-1)

   This is equivalent to pressing the return key (in case Taxir is running by itself) to cancel a statement or a data item. This call is used in INTERACT whenever an error in the statement (command) passed to Taxir is detected.

PROGRAM LINK

There are 15 different data banks contained in the Cook data base. Some of these data banks are very large and occupy a large memory space. As a result, it is not economical to keep all the data on-line. Our approach is to save these data banks on magnetic tape and to restore them in temporary files when they are needed.

The program LINK (shown in Table 5.3) is designed to accomplish this task. This program can be called by INTERACT whenever the request is made to restore some or all of the data base. When users respond to the computer query as to the names of data banks to be restored, the restoration of these data banks will be made in temporary files. This process, however, often takes considerable time, especially during peak computer use periods.

PROCEDURES FOR OPERATING INTERACT AND LINK

To run the program INTERACT, the user should first sign on to MTS. This is done by entering the computer center account ID (CCID) and the password for that account shown as follows:

```
#SIGNON XXXX (account ID)
?XXXX        (Password)
```

Then enter the command:

```
#SOURCE INTERACTIVE
```

This statement will start the execution of the program INTERACT. The communication from this point on is interactive; the users simply respond to the questions asked by the program. To ensure the success of the data retrieval, it is important to respond to all the questions asked by the program. However, during the execution of the program if there is a need to select a data bank, which may or may not be on-line, the program will first check whether the data bank being requested is on-line. If the file is not on-line, the program LINK will be run automatically to restore part or all of the requested data. The flow-diagram in Figure 5.1 represents the major steps in the above operations.

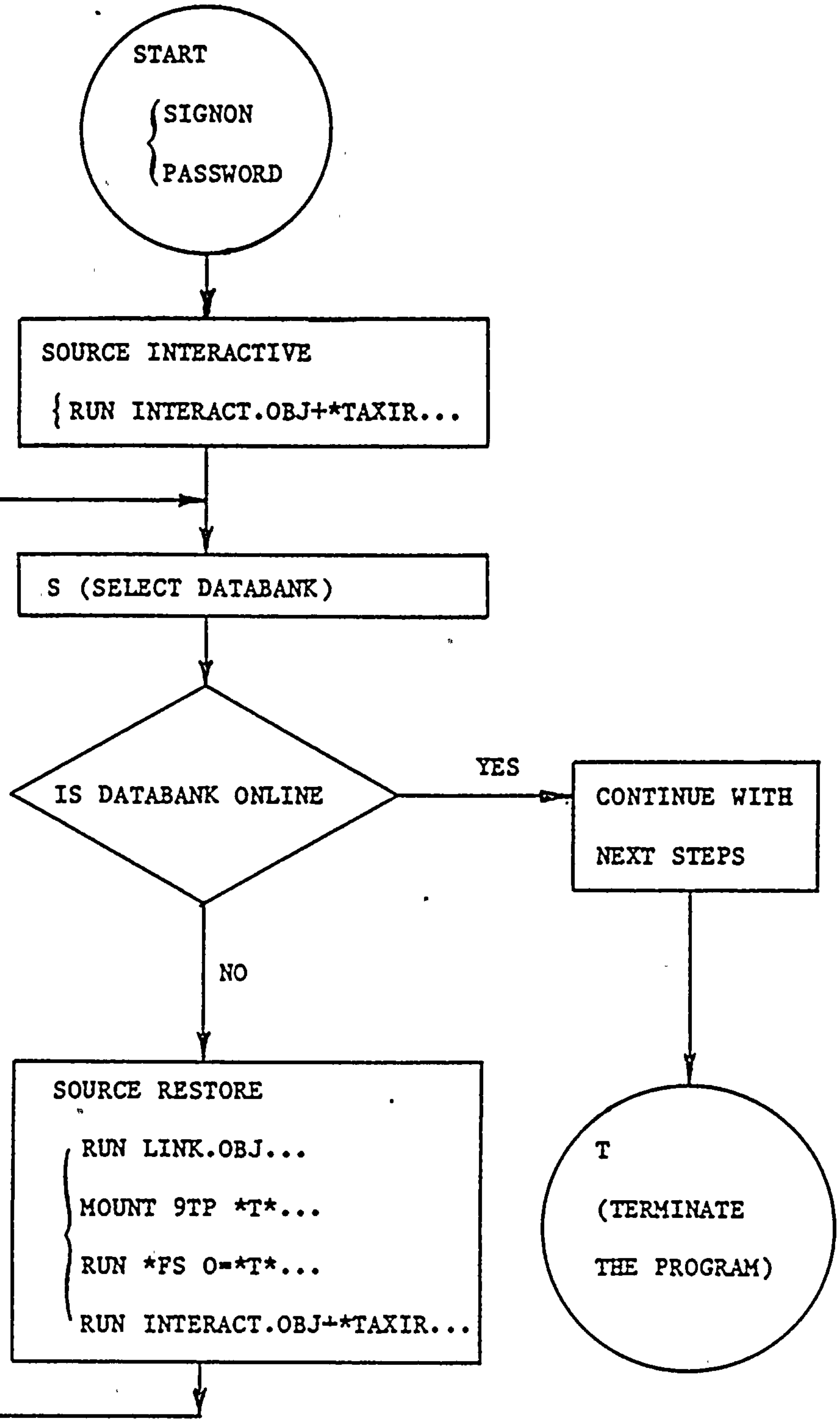


Figure 5.1. Flow-chart representation of stages involved in operations of INTERACT and LINK.

UNIT ASSIGNMENTS FOR PROGRAMS INTERACT AND LINK

Any CCID which is used to run the interactive program will have access to the following four files:

File I: INTERACT.OBJ

This file contains the object codes for the INTERACT program.

File II: LINK.OBJ

The object codes for the LINK program are in this file.

File III: INTERACTIVE

This file consists of the following RUN command:

RUN INTERACT.OBJ+*TAXIR 5=*MSOURCE* 6=*SINK* 7=-CHECK SERCOM=-CHECK

This run command invokes Taxir and INTERACT simultaneously. Units 5 and 6 are assigned to the terminal screen to serve as interactive input/output devices. Taxir error messages are written on a device called SERCOM. SERCOM and Unit 7 are assigned to the temporary file -CHECK. This file is used to detect and control typing errors made by the user.

File IV: RESTORE

There are four commands in this file:

Command A:

RUN LINK.OBJ 5=*MSOURCE* 6=*SINK* 7=-G 8=-F

Unit 8 is assigned to file -F. File -F contains the restoration commands. Units 5 and 6 are assigned to the terminal screen as explained in III. Unit 7 is assigned to -G to be used later in MTS file saving program (*FS).

Command B:

MOUNT C0073A 9TP *T* VOL=COOK 'COOK'

This line of file RESTORE specifies that the 9-track computer tape should be mounted.

Command C:

RUN *FS 0=*T* SCARDS=-F GUSER=-G SERCOM=-S SPRINT=-SP

Running the *FS program will result in restoration of the requested databanks. SCARDS is assigned to -F for input commands. GUSER is assigned to -G which is created by Command A for the source of responses to *FS prompting messages. SERCOM is assigned to -S for the error messages and SPRINT is assigned to -SP for saving other messages from *FS.

Command D:

RUN INTERACT.OBJ+*TAXIR 5=*MSOURCE* 6=*SINK* 7=-CHECK SERCOM=-CHECK

Finally, this last line of file RESTORE is the same run command as in Command A. This identical run command will restart the program INTERACT. At this point, the file restoration is complete and data retrieval can be continued.

CHAPTER 6

DISCUSSION

This report documents in detail the procedures used and the programs written in establishing the data base management system for the D. C. Cook ecological study and describes the data contained in the data base as well as the way in which these data can be accessed. This documentation can be used as a reference when accessing the data base and to clarify questions that arise during the use of this system.

A computer data base management system is essential for a large project because it can increase efficiency in report writing, data analyses, and data interpretation. It can also enhance data exchange and utilization; provide an efficient way to archive the data; and act as a safeguard for access to and centralized management of the data.

The Cook computer data base encompasses 15 individual data banks. The total includes more than one-half million cases of biological, chemical, and physical information on the nearshore of southeastern Lake Michigan. This data base is considered one of the largest water quality information bases for the southeastern portion of the lake. Considerable experience has been gained from the establishment of this data base. This experience can be useful for establishing a computer data system for other projects and is discussed in the paragraphs which follow.

Any sizable research project should have a computerized data base management system. Such a system should be established at the onset of the research project, beginning at the same time as the beginning of data collection. When one is still in the research planning phase, considerations should be given to

1) the type of data which will be collected, 2) the kind of analysis and report format which will be needed, 3) the type of access which is expected, and 4) the type of information retrieval which will be used frequently. These considerations are critical to ensure that the computerized data base meets the needs of the users. Once the answers for these questions are provided, a uniform data reporting format should be used. This can reduce the time and effort needed to establish a data base management system.

One needs to know what DBMS programs are available from the main frame of the computer and at what cost for data entry and subsequently updating. One should also know the capabilities and limitations of the available DBMS programs, whether the capabilities of a DBMS program meet the basic needs for a project, and whether the limitations would impose a serious restriction on the operation and use of the data base. Considerations of DBMS should also cover the maintenance and expansion of a data base and the degree of difficulty for a person to use and operate the data base management system.

The discussion thus far has assumed that the state of computer technology and data base management has remained unchanged. It is important to realize that is not the case, that a DBMS which serves you today will certainly differ greatly at some time in the future. We have observed rapid progress in the use and operation of computers in the past 10 years. We can expect that similar even faster progress may be made in the time to come. For example, it would not be unthinkable that one could simply speak to a computer receiver to retrieve needed information from a DBMS in the near future, as voice recognition and natural language queries become components of data base management systems. As computers become more powerful and able to store large amounts of data less expensively, a DBMS could include graphics or instant results of statistical analyses with a few simple commands. Simplified protocol can make the use of DBMS an easy task and will enable the user to access many on-line information services without learning specialized techniques or command languages for each one. Accessing an ecological data base in this case would not differ too much from getting cash from your bank account by using a computer terminal. By then, DBMS will truly be an integral part of our daily life. The tedious task of data selection and analyses for aquatic studies can be accomplished in a matter of a few minutes.

While dreaming of possible future directions in computer technology for data base management systems, we hope and believe that the Cook data base management system represents the state of the art for the present and can facilitate the use and access of ecological data for southeastern Lake Michigan.

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Appendix 2.1

1986 Annual Report

Radiological Environmental Monitoring Program

Donald C. Cook Nuclear Plant

Units 1 and 2

Controls for Environmental Pollution, Inc.

AMERICAN ELECTRIC POWER SERVICE CORPORATION

DONALD C. COOK NUCLEAR PLANT

RADIOLOGICAL ENVIRONMENTAL MONITORING PROGRAM ANNUAL REPORT FOR 1986

SUBMITTED BY:

CONTROLS FOR ENVIRONMENTAL POLLUTION, INC.

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Bob Bates, Contract Manager

Approved By: [signature]
James J. Mueller, President

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Abstract

Controls for Environmental Pollution, Inc (CEP) has conducted a operational radiological environmental monitoring program for American Electric Power Service Corporation (AEPSC), Donald C. Cook Nuclear Plant, Units 1 and 2, starting October 1, 1985. This annual report presents data for 1986.

Analytical results are presented and discussed along with other pertinent information. Possible trends and anomalous results, as interpreted by CEP, are discussed.

1.0 Introduction

This report presents an analysis of the results of the Radiological Environmental Monitoring Program conducted during 1986 for American Electric Power Service Corporation, Donald C. Cook Nuclear Plant, Units 1 and 2.

In compliance with federal and state regulations and in its concern to maintain the quality of the local environment, AEPSC began its radiological monitoring program in 1973.

The objectives of the radiological environmental monitoring program are as follows: 1) to establish baseline radiation levels in the environs prior to reactor operations; 2) to monitor potential critical pathways of radioeffluent to man; 3) to determine radiological impact on the environment caused by the operation of the D.C. Cook Nuclear Plant.

A number of techniques are being used to distinguish Cook Plant effects from other sources during the operational phase, including application of established background levels. Operational radiation levels measured in the vicinity of the Cook Plant will be compared with the pre-operational measurements at each of the sampling locations. In addition, results of the monitoring program will help to evaluate sources of elevated levels of radiation during reactor operation in the environment, e.g., atmospheric fallout or abnormal plant releases.

The Donald C. Cook Nuclear Plant is located on the shore of Lake Michigan approximately one mile northwest of Bridgman, Michigan. The Plant consists of two pressurized water reactors, Unit 1, 1030 MWE and Unit 2, 1100 MWE. Unit 1 achieved initial criticality on January 18, 1975 and Unit 2 achieved initial criticality on March 10, 1978.

During the weekend of April 26, 1986, a Soviet Union (USSR) Nuclear reactor located at Chernobyl (north of Kiev) suffered a major accident, resulting in a significant release of radioactivity. Due to the easterly flow of the upper air, the radioactive plume drifted over the Asian continent and the Pacific Ocean before arriving on the west coast of the United States. D.C. Cook first detected contamination from the plume in the air particulate samples collected on 05/13/86. Other sample matrixes indicated increases in activity during the second quarter 1986. All elevated levels of activity can be directly attributable to the Chernobyl accident and the resulting radioactive plume.

Changes to the monitoring program during 1986 are as follows:

1. November 21, 1986 - Two new milk farms are added to the REMP.
2. November 1, 1986 - The D.C. Cook plant personnel began collecting all environmental samples, taking the place of the CEP hired sample collector.
3. September 8, 1986 - Air samples are collected on Monday's versus Tuesdays.
4. May 15, 1986 - New Buffalo drinking station is deleted by Technical specification (Amendment 94 for Unit #1 and Amendment 80 for Unit #2).
5. January 14, 1986 - All air samples began to be collected on the same day of the week. This replaces the old system where on-site samples were collected on a different day than the offsite samples.

2.0 Description of the Monitoring Program

American Electric Power Service Corporation has contracted with Controls for Environmental Pollution, Inc. starting October 1, 1985, to determine the radiation levels existing in and around the Donald C. Cook Nuclear Plant area.

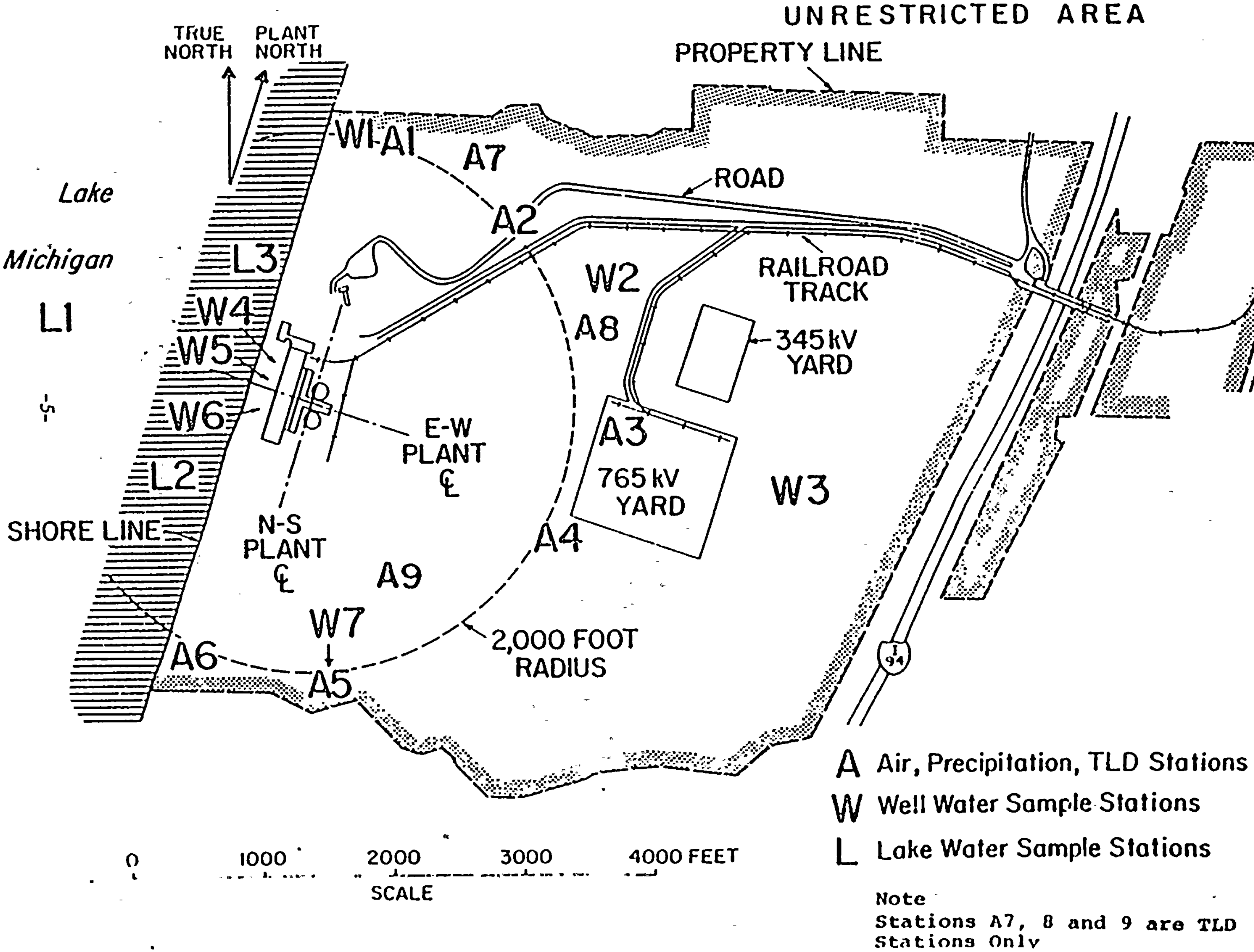
From January 1, 1986 to December 31, 1986, CEP and Cook Plant personnel have collected the samples and shipped them to CEP for analysis. The type of samples collected during 1986 were: milk, airborne particulates, airborne radioiodine, direct radiation (TLD), groundwater, food products, fish, bottom sediment, drinking water and surface water.

Locations of the monitoring sites are shown in Figures 1 and 2. Table I presents monitoring sites and the respective samples collected. Sample collection frequency for each of the monitoring locations is depicted in Table II.

Meanings of sample type codes used in Table I are as follows:

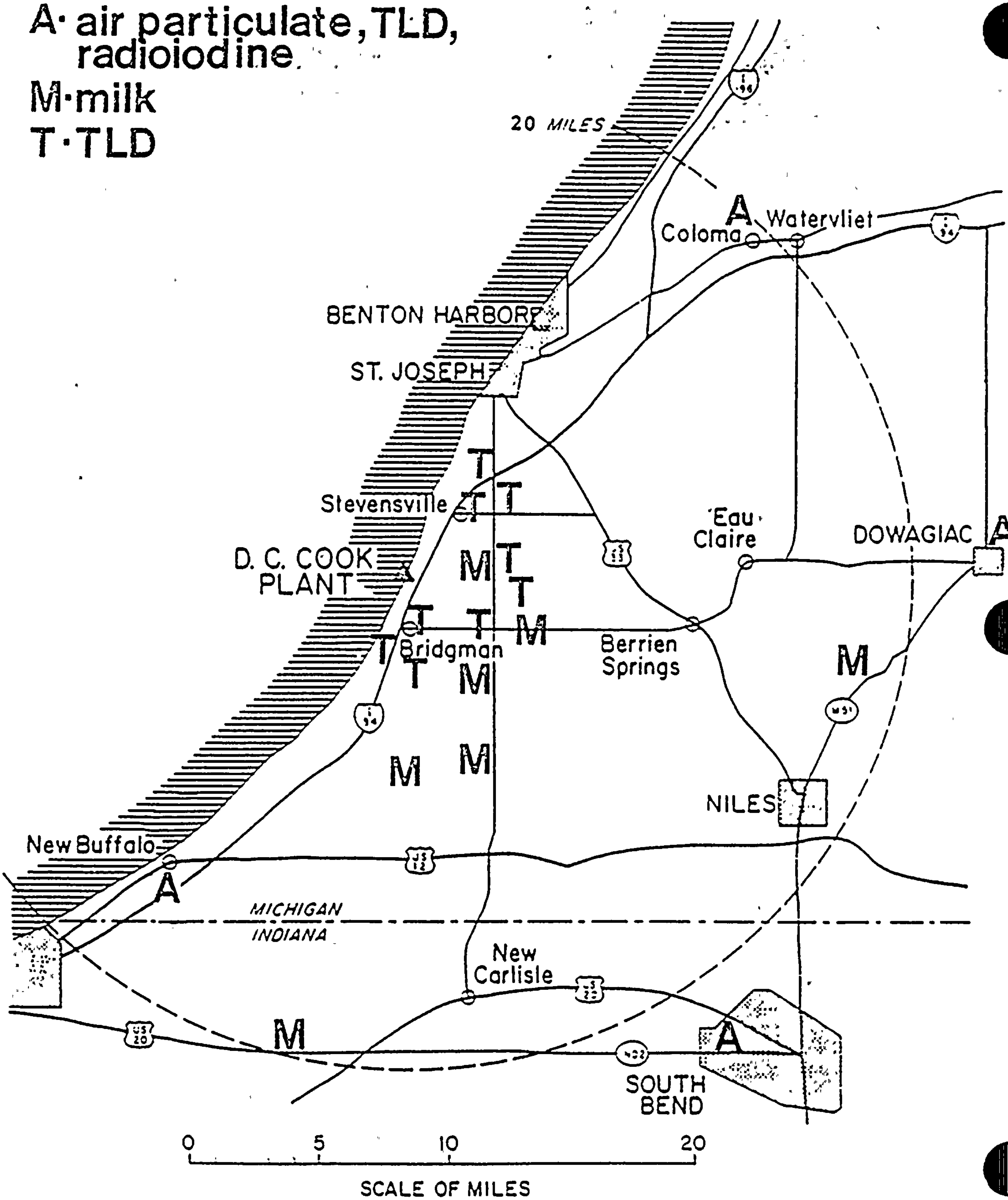
CODE	MEANING
ONS	On Site Location
NBF	New Buffalo, MI Location
SBN	South Bend, IN Location
DOW	Dowagiac, MI Location
COL	Coloma, MI Location
OFS	Off Site
LS	Lake Sediment

Figure 1


UNRESTRICTED AREA
PROPERTY LINE
TRUE NORTH
PLANT NORTH
Lake Michigan
L1
L3
L2
W1
A1
A7
A2
ROAD
RAILROAD TRACK
W2
A8
W4
W5
W6
345 kV YARD
A3
765 kV YARD
W3
E-W PLANT ℄
SHORE LINE
N-S PLANT ℄
A4
A9
W7
A6
A5
2,000 FOOT RADIUS
I 94
A Air, Precipitation, TLD Stations
W Well Water Sample Stations
L Lake Water Sample Stations
0
1000
2000
3000
4000 FEET
SCALE
Note
Stations A7, 8 and 9 are TLD Stations Only

-5-

Figure 2



A· air particulate, TLD, radioiodine.
M·milk
T·TLD
20 MILES
Coloma
Watervliet
BENTON HARBOR
ST. JOSEPH
Stevensville
D. C. COOK PLANT
Eau Claire
DOWAGIAC
Bridgman
Berrien Springs
NILES
New Buffalo
MICHIGAN
INDIANA
New Carlisle
SOUTH BEND
0
5
10
20
SCALE OF MILES

TABLE I

SAMPLING LOCATIONS

LOCATION CODE	DESCRIPTION*	SAMPLE TYPES
ONS-1 (A1)	0.4 mi NNE, Meteorological Tower	Air, TLD
ONS-2 (A2)	0.4 mi NE, Visitors Center road	Air, TLD
ONS-3 (A3)	0.5 mi ENE, 765 KV Yard	Air, TLD
ONS-4 (A4)	0.4 mi ESE, Onsite	Air, TLD
ONS-5 (A5)	0.4 mi SW, Onsite	Air, TLD
ONS-6 (A6)	0.4 mi SSW, Shoreline and Fence Line Junction	Air, TLD
NBF	16.0 mi SSW, Town of New Buffalo, MI	Air, TLD
SBN	24.0 mi SE, City of South Bend ID	Air, TLD
DOW	26.0 mi ENE, Town of Dowagiac, MI	Air, TLD
COL	20.0 mi NNE, Town of Coloma, MI	Air, TLD
ONS-7 (A7)	0.4 mi NNE, Onsite	TLD
ONS-8 (A8)	0.4 mi ENE, Onsite	TLD
ONS-9 (A9)	0.3 mi SSE, Onsite	TLD
OFS-1	3.5 mi NNE, Intersection of Red Arrow Highway and Marquette Woods Road, Pole // B294-44	TLD
OFS-2	3.0 mi NNE, Stevensville Substation	TLD
OFS-3	4.0 mi NE, Pole //B296-13	TLD
OFS-4	3.2 mi ENE, Pole // B350-72	TLD
OFS-5	3.2 mi ESE, Intersection of Shawnee and Cleveland, Pole // B387-32	TLD
OFS-6	3.5 mi SE, Intersection of Snow Road and Holden Pole // B426-70	TLD
OFS-7	2.0 mi S, Bridgman Substation	TLD
OFS-8	3.0 mi SSE, California Road, Pole // B424-20	TLD

TABLE I (Continued)
SAMPLING LOCATIONS

LOCATION CODE	DESCRIPTION*	SAMPLE TYPES
OFS-9	3.25 mi E, Riggles Road, Pole # B369-214	TLD
OFS-10	2.6 mi SSW, Intersection of Red Arrow Highway and Hildebrant Road, Pole # B422-152	TLD
W1	0.4 mi NNE, Rosemary Beach	Well Water
W2	0.5 mi NE, Scrapyard	Well Water
W3	0.7 mi ENE, MSU Trailer	Well Water
W4	0.01 mi NW, Onsite	Well Water
W5	0.01 mi W, Onsite	Well Water
W6	0.01 mi SSW, Onsite	Well Water
W7	0.4 mi S, Livingston Beach	Well Water
Totzke	4.5 mi ENE, Totzke Farm, STV (M)	Milk
Wyant	18.0 mi E, Wyant Farm, DOW (M)	Milk
Lozmack	9.0 mi SSE, Lozmack Farm, TOK (M)	Milk
Schuler	4.25 mi SE, Schuler Farm, BRD (M)	Milk
Livinghouse	20 mi S, Livinghouse Farm, LPT (M)	Milk
Warmbien	7.8 S, Warmbien Farm, TKS (M)	Milk
Zelmer	4.75 mi SSE, Zelmer Farm, BDG (M)	Milk
ONS-S	0.5 mi S (maximum), Lake Michigan	Fish
ONS-N	0.5 mi N (maximum), Lake Michigan	Fish
OFS-S	0.5 mi S (minimum), Lake Michigan	Fish
OFS-N	0.5 mi N (minimum), Lake Michigan	Fish
LS-2	0.25 mi N, North Shoreline, Lake Michigan	Sediment
LS-3	0.25 mi S, South Shoreline, Lake Michigan	Sediment
L1	Circulating intake	Circulating

Supplemental #1
04/20/87

TABLE I (Continued)

SAMPLING LOCATIONS

LOCATION CODE	DESCRIPTION*	SAMPLE TYPES
L2	0.1 mi SSW, from point of discharge (South Lake)	Surface Water
L3	0.1 mi NNE, from point of discharge (North Lake)	Surface Water
V1	Onsite	Vegetation
V2	Onsite	Vegetation
STJ (D)	St. Joseph Station	Drinking Water
LTW (D)	Lake Township Station	Drinking Water
NBF (D)**	New Buffalo Station	Drinking Water

*All distances are measured from the center line between Unit 1 and Unit 2.

**Deleted from REMP on May 15, 1986, as per Technical Specification change 3.12.1, Table 3.12-1, Item 3C (Amendment No. 94 for Unit #1 and Amendment No. 80 for Unit #2).

TABLE II

COLLECTION SCHEDULE

Collection Site	Air Particulates	Air Radioiodine	Well Water	Lake Water	Drinking Water	Sediment	Fish	Milk	Vegetation	TLD
ONS-1 (A1)	W	W								Q
ONS-2 (A2)	W	W								Q
ONS-3 (A3)	W	W								Q
ONS-4 (A4)	W	W								Q
ONS-5 (A5)	W	W								Q
ONS-6 (A6)	W	W								Q
ONS-7 (A7)										Q
ONS-8 (A8)										Q
ONS-9 (A9)										Q
OFS-1										Q
OFS-2										Q
OFS-3										Q
OFS-4										Q
OFS-5										Q
OFS-6										Q
OFS-7										Q
OFS-8										Q
OFS-9										Q
OFS-10										Q
NBF	W	W								
SBN	W	W								
DOW	W	W								
COL	W	W								
W-1			Q							
W-2			Q							
[illegible]			Q							

TABLE II (Continued)

COLLECTION SCHEDULE

Collection Site	Air Particulates	Air Radioiodine	Well Water	Lake Water	Drinking Water	Sediment	Fish	Milk	Vegetation	TLD
W-4			Q							
W-5			Q							
W-6			Q							
W-7			Q							
BDG (M)								M(2)*		
STV (M)								M(2)*		
TKS (M)								M(2)*		
DOW (M)								M(2)*		
LPT (M)								M(2)*		
TOK (M)								M(2)*		
BRD (M)								M(2)*		
ONS-S							SA(2)**			
ONS-N							SA(2)**			
OFS-S							SA(2)**			
OFS-N							SA(2)**			
LS-2						SA(2)**				
LS-3						SA(2)**				
L1				M						
L2				M						
L3				M						
V1									Y	
V2									Y	
STJ (D)					M(2)*					
LTW (D)					M(2)*					
NBF (D)					M(2)*					

*Twice a month

SA = Semi Annual W = Weekly Q = Quarterly Y = Yearly M = Monthly

3.0 Analytical Procedures

The analytical procedures discussed in this report are those routinely used by CEP to analyze samples.

3.1 Fresh Milk

3.1.1 Iodine-131

Two liters of milk containing standardized Iodine carrier are stirred with Dowex 1 X 8 anion exchange resin for one hour. The Iodine is stripped from the resin with sodium perchlorate ($NaClO_4$) and precipitated with silver nitrate ($AgNO_3$). The precipitate is filtered onto a tared glass fiber filter, and dried. The dried precipitate is weighed for percent recovery and counted for Iodine-131 in a thin window, gas flow, proportional counter.

3.1.2 Gamma Spectrometry

A suitable aliquot of sample is placed in a marinelli beaker and counted with a multichannel analyzer equipped with an intrinsic Germanium detector which is coupled to a 4096 channel, computer based, multi-channel analyzer (Tracor Northern TN4500).

3.2 Vegetation (Food Products)

3.2.1 Gamma Spectrometry

Refer to Milk Subsection 3.1.2.

3.3 Surface Water, Ground Water, and Drinking Water

3.3.1 Gamma Spectrometry

Refer to Milk Subsection 3.1.2.

3.3.2 Gross Beta

A one liter aliquot of sample is evaporated to dryness and transferred to a stainless steel planchet. The Gross Beta radioactivity is measured by counting the planchet in an internal gas flow, simultaneous proportional, low background counter.

3.3.3 Tritium

Three milliliters of the sample are mixed with Packard Optifluor cocktail. The mixture is nineteen percent sample in a clear gel type aquasol. The vials are then counted for Tritium in a Beckman Model LS-5801 Liquid Scintillation System for 400 minutes.

3.4 Air Particulate

3.4.1 Gross Beta

The filter is placed in a stainless steel planchet and counted for Gross Beta activity using a low background, internal gas flow, simultaneous proportional counter.

3.4.2 Gamma Spectrometry

The air filters are sealed in small, plastic Marinelli beakers and counted utilizing the method described in Milk Subsection 3.1.2.

3.5 Airborne Radioiodine (Alkaline Leach Method)

Radioiodine is removed from activated charcoal along with a standardized iodine carrier using concentrated ammonium hydroxide (NH_4OH) and hydrogen peroxide (H_2O_2). The charcoal is filtered and the remaining solution is acidified with nitric acid (HNO_3) and extracted with carbon tetrachloride (CCl_4). A 0.2% hydrazine solution supplies futher purification and an aqueous media for precipitation. Iodine is precipitated with silver nitrate ($AgNO_3$) and filtered onto a tared glass fiber filter as silver iodide (AgI). The dried precipitate is weighed for recovery and counted for Iodine-131 in a thin window, gas flow, proportional counter.

3.6 Sediment (Shoreline) - Gamma Spectrometry

Refer to Milk Subsection 3.1.2.

3.7 Fish - Gamma Spectrometry

Refer to Milk Subsection 3.1.2.

4.0 Major Instrumentation

4.1 Beckman Liquid Scintillation Counting System

A Beckman LS-5801 Liquid Scintillation System will be used for all Tritium determinations. The system has a tritium counting efficiency of sixty percent in a wide open window.

4.2 Tracor Northern Computer Based Gamma Spectrometer

The Gamma Spectrometer consists of a Tracor Northern TN-4500 Multichannel Analyzer equipped with: 1) a DEC LS1-11/23 microprocessor; b) a DEC RT-11 version IV operating system; c) a free standing console consisting of a full ASCII keyboard; d) a comprehensive MCA Control Section and e) two solid state Ge(Li) detectors and three intrinsic detectors having 2.8 KeV, 3.0 KeV, 2.07 KeV, 2.20 KeV and 1.85 KeV resolutions and respective efficiencies of 16.1%, 8.9%, 22.6%, 30.6% and 25.1%.

The Computer Based Tracor Northern Gamma Spectrometry System is used for all Gamma Counting. The system uses Tracor Northern developed software (automatic isotope analysis) to search and identify, as well as quantize the peaks of interest.

4.3 Beckman Wide Beta II Low Background Gas Proportional System

The Beckman Wide Beta II two-inch detector counting system has an average of 2.5 cpm Beta background and 0.1 cpm Alpha background. The system can also be set up with a one-inch detector. The system capacity is one hundred samples. The detector has an efficiency of 60% for Strontium-90 and 40% for Plutonium-239.

4.4 Beckman Wide Beta II Low Background Gas Proportional System (Simultaneous)

The Beckman Wide Beta II two-inch planchet counting system has an average of 2.5 cpm Beta background and 0.1 cpm Alpha background. The detector has a sixty percent efficiency for Strontium-90 and forty percent for Plutonium-239. This system has been designed for simultaneous Alpha and Beta counting. The system sample capacity is one hundred samples.

4.5 Beckman Low Beta II Low Background Beta System

The Beckman Low Beta II Gas proportional one-inch detector counting system has an average of 1.5 cpm Beta background and 0.1 cpm Alpha background and detector efficiency of sixty percent for Strontium-90 and forty percent for Plutonium-239. The system capacity is one hundred samples. The system can also be set up with a two-inch detector having 2.5 cpm Beta background and 0.1 cpm Alpha background.

4.6 Tennelec LB5100 System

The Tennelec LB5100 System has two-inch planchet counting system and has an average of 2 cpm Beta background and 0.1 cpm Alpha backgorund. This system has been designed for simultaneous Alpha and Beta counting. The system sample capacity is fifty samples. The system efficiency for Alpha (Plutonium-239) is twenty-one percent, while the Beta (Strontium-90) efficiency is fifty-one percent.

4.7 Berthold-10-Channel Low-Level Planchet Counting System

The Berthold LB770 is capable of simultaneously counting 10 planchets for Gross Alpha and Gross Beta activities alternately with proportional gas flow detectors. The system has an average background count rate of less than 1 count per minute for Beta and less than 0.05 count per minute for Alpha. The instrument has an Alpha efficiency of thirty-three percent for Plutonium-239 and Beta efficiencies of forty-five percent for Strontium-Yttrium-90, and forty-three percent for

Cesium-137. The system is connected to a computer to calculate samples as pCi/unit volume.

5.0 Isotopic Detection Limits and Activity Determinations

Analytical Detection limits are governed by a number of factors including:

5.1 Sample Size

The sample size taken is based on the numerical data one wishes to obtain which can describe a particular situation and can be interpreted as a basis for possible action. The sample size has to be representative and provide for accurate analysis or the entire process is invalid (Table III).

5.2 Counting Efficiency

The fundamental quality in the measurement of a radioactive substance is the number of disintegrations per unit time. As with most physical measurements in analytical chemistry, it is seldom possible to make an absolute measurement of the disintegration rate but rather it is necessary to compare the sample with one or more standards. The standards determine the counter efficiency which may then be used to convert sample counts per minute (cpm) to disintegrations per minute (dpm).

5.3 Background Count Rate

Any counter will show a certain counting rate without a sample in position. This background counting rate comes from several sources: 1) natural environmental radiation from the surroundings; 2) cosmic radiation; and 3) the natural radioactivity in the counter material itself. The background counting rate will depend on the amount of these types of radiation and the sensitivity of the counter to the radiation.

5.4 Background and Sample Counting Time

The amount of time devoted to counting background depends on the level of activity being measured. In general, with low level samples, this time should be about equal to that devoted to counting a sample (Table V).

5.5 Time Interval Between Sample Collection and Counting

Decay measurements are useful in identifying certain short-lived isotopes. The disintegration constant, or its related quantity, the half-life, is one of the basic characteristics of a specific radionuclide and is readily determined if the half-life is sufficiently short.

5.6 Chemical Recovery of the Analytical Procedures

Most radiochemical analyses are carried out in such a way that losses occur during the separations. These losses occur due to a large number of contaminants that may be present and interfere during chemical separations. Thus it is necessary to include a technique for estimating these losses in the development of the analytical procedure.

The Lower Limits of detection are calculated using the following formula:

$$LLD = \frac{4.66\ s_b}{E \cdot V \cdot 2.22 \cdot Y \cdot \exp(-\lambda \Delta t)}$$

WHERE:

LLD = "A priori" lower limit of detection as defined above (as pCi per unit mass or volume).

s_b = Standard deviation of the background counting rate or of the counting rate of a blank sample as appropriate (as counts per minute).

E = Counting efficieny (as counts per disintegration).

V = Sample size (in units of mass or volume).

2.22 = Number of disintegrations per minute per picocurie.

Y = Fractional radiochemical yield (when applicable).

λ = Radioactive decay constant for the particular radioisotope.

Δt = Elapsed time between sample collection (or end of the sample collection period) and time of counting.

The value of s_b used in the calculation of the LLD for a particular measurement system is based on the actual observed variance of the background counting rate, or, of the counting rate of the blank sample, (as appropriate), rather than on an unverified theoretically predicated variance.

In calculating the LLD for a radionuclide determined by gamma-ray spectrometry, the background included the typical contributions of other nuclides normally present in the samples.

The activities per unit sample mass or volume are determined using the following formula:

$$A = \frac{C-B}{(2.22)(V)(R)(E)(e^{-\lambda t})} \pm \frac{1.96\left[\frac{C+B}{T^2}\right]^{1/2}}{(2.22)(V)(R)(E)(e^{-\lambda t})}$$

WHERE:

- A = Activity as pCi per units sample mass or volume.
- C = Sample count rate in counts per minute.
- B = Background counts per minute.
- V = Sample volume or mass analyzed.
- E = Counter efficiency as cpm/dpm.
- 2.22 = Numerical constant to convert disintegrations per minute to picocuries.
- $(e^{-\lambda t})$ = Decay factor to correct the activity to time of collection.
- T = Counting time in minutes.
- 1.96 = Statistical constant for the 95% confidence level.
- R = Chemical recovery or photon yield.

6.0 Quality Control Program

CEP employs a mutli-faceted Quality Control Program designed to maintain high performance of its laboratory. The overall objectives of the program are to:

1. Verify that work procedures are adequate to meet specifications of AEPSC.
2. Coordinate an in-house quality control program independent of external programs, to assure that CEP is operating at maximum efficiency.

Objectives are met by a variety of procedures that oversee areas of sample receipt and handling, analysis and data review. These procedures include standard operating procedures, known and unknown spike analysis, blank analysis, reagent, carrier and nuclide standardization as well as participation in the U.S. Environmental Protection Agency's Interlaboratory Cross-check Program. (See Appendix A for EPA Radiological Cross-check results).

TABLE III
ALIQUOT USED FOR DETECTION LIMIT CALCULATION AND ACTUAL ANALYSIS

Sample Type	Gross Beta	Gamma Spec	Iodine-131	Tritium
Air Particulates	265 m^3	265 m^3		
Airborne Radioiodine			265 m^3	
Milk		1000 ml	2000 ml	
Vegetation (Food Products)		500 g		
Surface Water		1000 ml		3 ml
Ground Water		1000 ml		3 ml
Drinking Water	1000 ml	1000 ml		3 ml
Sediment (Shoreline)		200 g		
Fish		200 g		

TABLE IV

DETECTION LIMITS BY OTHER THAN GAMMA SPECTROMETRY

Sample Type	Gross Beta	Iodine-131	Tritium
Air Particulates	0.004 pCi/m^3		
Airborne Radioiodine		0.005 pCi/m^3	
Milk		0.4 pCi/l	
Surface Water	2.0 pCi/l	0.5 pCi/l	300 pCi/l
Ground Water	2.0 pCi/l	0.5 pCi/l	300 pCi/l
Drinking Water	2.0 pCi/l	0.5 pCi/l	300 pCi/l

TABLE V
SAMPLE COUNTING TIMES

Sample Type	Gross Beta	Gamma Spec	Iodine-131	Tritium
Air Particulates	100 min	8 hrs		
Airborne Radioiodine			100 min	
Milk		8 hrs	100 min	
Vegetation (Food Products)		8 hrs		
Surface Water	100 min	8 hrs		400 min
Ground Water	100 min	8 hrs		400 min
Drinking Water	100 min	8 hrs		400 min
Sediment (Shoreline)		8 hrs		
Fish		8 hrs		

TABLE VI

DETECTION LIMITS BY GAMMA SPECTROMETRY

Isotope	Vegetation pCi/Kg (wet)	Water pCi/l	Milk pCi/l	Air Filter pCi/m^3	Fish pCi/Kg (wet)	Soil pCi/Kg (dry)
Cerium-144	121	17	10	0.005	80	80
Barium-La-140	75	4	4	0.030	40	40
Cesium-134	29	7	5	0.023	40	70
Ru, Rh-106	143	2	2	0.001	40	40
Cesium-137	40	2	4	0.001	40	40
Zr, Nb-95	66	5	8	0.026	80	40
Manganese-54	21	2	2	0.001	60	80
Iron-59	21	3	3	0.006	100	30
Zinc-65	60	15	16	0.045	100	100
Cobalt-60	63	5	5	0.019	30	80
Cobalt-58		5	3		60	
Iodine-131	30	1	[illegible]	0.02*		

*Charcoal Trap

7.0 Data Interpretation and Conclusions

Interpretations and conclusions regarding all types of samples analyzed during 1986 are discussed in the following sections. For the calculation of means the detection limit value is used for all samples with activities below the detection limit.

7.1 Air Particulates

Air particulate samples were collected from each of the ten monitoring sites on a weekly basis during 1986. During the year, four samples could not be reported due to the following reasons:

Date	Station	Reason
01/21/86	ONS6	Malfunctioning meter
02/04/86	ONS4	Lost during shipment
03/11/86	NBF	Sample missing at site
07/22/86	ONS5	Power off at station

Air filters were analyzed for Gross Beta activity. Gamma Spectralanalysis of the air filters is done on the individual station composites on a quarterly basis. Table VII presents the Gross Beta activities observed during the first quarter of 1986. Levels ranged from a low of less than 0.004 pCi/m^3 to a high of 0.038$\pm$0.003 pCi/m^3 at Station ONS3 (02/18/86). Mean weekly activities ranged from less than 0.004 pCi/m^3 at the offsite collection locations, to 0.022$\pm$0.016 pCi/m^3 at the onsite collection locations on 02/18/86. This data is consistent with preoperational data.

Table VIII presents the Gross Beta activities observed during the second quarter of 1986. Levels ranged from a low of less than 0.004 pCi/m^3 to a high of 0.155$\pm$0.005 pCi/m^3 at Station SBN (05/27/86). Mean weekly activities ranged from 0.005$\pm$0.001 pCi/m at the offsite collection locations on 04/15/86 to 0.135$\pm$0.024 pCi/m at the offsite collection sites on 05/27/86.

Gamma spectralanalysis of the second quarter composites indicated the following activity due to the Chernobyl accident (See Section 1.0).

GAMMA SPECTRALANALYSIS
SECOND QUARTER 1986 COMPOSITE
04/01/86 - 07/01/86

Location	CS-134 0.023*	CS-137 0.001*	RU-103 0.001*	RU-106 0.001*
ONS1	0.008±0.002	0.013±0.002	0.045±0.011	**
ONS2	**	0.009±0.002	**	**
ONS3	**	0.010±0.002	**	0.054±0.027
ONS4	**	0.008±0.002	0.031±0.010	**
ONS5	**	**	**	**
ONS6	**	0.012±0.002	0.040±0.014	0.041±0.020
COL	**	0.010±0.002	0.022±0.010	**
DOW	**	0.005±0.002	**	**
NBF	0.011±0.001	0.016±0.002	0.062±0.010	**
SBN	**	0.006±0.002	0.023±0.011	0.040±0.016

*Lower limit of detection
**Less than lower limit of detection

Table IX presents the Gross Beta activities observed during the third quarter of 1986. Levels ranged from a low of less than 0.004 pCi/m^3 at several locations to a high of 0.063±0.004 pCi/m^3 at station ONS2 (09/02/96). Mean weekly activity ranged from 0.014±0.005 pCi/m^3 at the onsite collection locations on 09/29/86, to 0.033±0.023 pCi/m at the offsite collection locations on 08/19/86. This data is consistent with previous quarters (excluding the second quarter of 1986).

Table X presents the Gross Beta activity observed during the fourth quarter of 1986. Levels ranged from a low of less than 0.004 pCi/m^3 at location SBN (12/22/86) to a high of 0.059±0.003 pCi/m^3 at station COL (12/29/86).

Mean weekly activity ranged from 0.009±0.003 pCi/m^3 at the onsite collection locations on 10/06/86, to 0.052±0.007 pCi/m^3 at the offsite collection locations on 12/29/86.

Table XI contains the mean Gross Beta activities by sampling station. Mean quarterly and mean annual activities are calculated using all weekly activities except those marked invalid. If a particular sample was below the detection limit, the detection limit is used for that sample when calculating means. Mean activity for each quarter ranged from a low of 0.006±0.004 pCi/m^3 at Station ONS1 during the first quarter to a high of 0.057±0.059 pCi/m^3 at Station SBN during the second quarter.

Table XII contains the mean Gross Beta activities by station for 1986. Annual mean activities compare well to one another and range from 0.024±0.025 pCi/m^3 at station DOW to 0.030±0.030 pCi/m^3 at station ONS5. The annual mean activity for onsite stations was 0.028±0.027 pCi/m^3 during 1986. The offsite station's annual mean activity was 0.026±0.028 pCi/m^3. Mean activities seen during 1986 are elevated due to the activity from Chernobyl being detected during the second quarter.

Man-made Gamma-emitting Nuclides were less than detection limit in all of the quarterly composite air filter samples during 1986, except as noted during the second quarter.

TABLE VII

GROSS BETA IN AIR PARTICULATES (pCi/m^3)

FIRST QUARTER

1986

Collection Date	ONS1	ONS2	ONS3	ONS4	ONS5	ONS6	Weekly Mean Gross Beta Activities ±Standard Deviation of the Mean
01/07/86	*	*	0.011±0.002	0.013±0.002	0.011±0.002	0.006±0.002	0.008±0.004
01/14/86	*	0.006±0.002	0.014±0.002	0.013±0.002	0.004±0.002	*	0.008±0.005
01/21/86	*	0.013±0.002	0.016±0.002	0.016±0.002	0.015±0.004	a	0.013±0.005
01/28/86	*	*	0.013±0.002	0.004±0.001	0.028±0.005	0.017±0.002	0.012±0.010
02/04/86	0.004±0.001	0.008±0.002	0.018±0.002	b	0.012±0.003	0.015±0.002	0.011±0.006
02/11/86	*	0.024±0.003	0.023±0.002	0.023±0.002	0.004±0.002	0.019±0.002	0.016±0.010
02/18/86	*	*	0.038±0.003	0.036±0.003	0.016±0.002	0.036±0.002	0.022±0.016
02/25/86	0.004±0.003	0.019±0.004	*	0.025±0.003	0.012±0.003	0.026±0.002	0.015±0.010
03/04/86	0.008±0.003	0.024±0.004	0.024±0.003	0.017±0.002	0.022±0.003	0.025±0.002	0.020±0.007
03/11/86	*	*	0.012±0.005	0.018±0.002	0.026±0.004	0.023±0.002	0.015±0.009
03/18/86	*	*	0.017±0.003	0.014±0.002	0.010±0.004	*	0.009±0.006
03/25/86	0.009±0.002	0.008±0.002	0.012±0.002	0.011±0.002	0.006±0.001	0.017±0.002	0.011±0.004
04/01/86	0.018±0.002	0.020±0.001	0.023±0.002	0.013±0.002	0.018±0.002	0.021±0.002	0.019±0.003
Mean Gross Beta Activity ± Standard Deviation of the Mean	0.006±0.004	0.011±0.008	0.017±0.008	0.017±0.008	0.014±0.008	0.018±0.010	

*Less than lower limit of detection (0.004 pCi/m^3)
[a]Invalid sample (malfunctioning meter)
[b]Sample lost during shipping

TABLE VII (Continued)

GROSS BETA IN AIR PARTICULATES (pCi/m^3)

FIRST QUARTER

1986

Collection Date	NBF	SBN	DOW	COL	Weekly Mean Gross Beta Activities ±Standard Deviation of the Mean
01/04/86	*	*	0.009±0.001	*	0.005±0.002
01/14/86	*	*	*	*	*
01/21/86	*	*	*	*	*
01/28/86	*	*	0.008±0.002	*	0.005±0.002
02/04/86	0.005±0.001	0.009±0.007	0.013±0.002	0.020±0.006	0.012±0.006
02/11/86	0.019±0.002	0.006±0.002	0.005±0.003	0.004±0.003	0.009±0.007
02/18/86	*	*	*	0.011±0.003	0.006±0.004
02/25/86	0.004±0.002	0.004±0.002	0.018±0.004	*	0.008±0.007
03/04/86	*	0.005±0.003	0.012±0.003	0.008±0.005	0.007±0.004
03/11/86	a	*	*	*	*
03/18/86	*	*	*	*	*
03/25/86	0.008±0.002	0.007±0.002	*	0.005±0.002	0.006±0.002
04/01/86	0.014±0.002	0.021±0.002	0.010±0.002	0.015±0.002	0.015±0.005
Mean Gross Beta Activity ± Standard Deviation of the Mean	0.006±0.005	0.006±0.005	0.008±0.005	0.007±0.005	

*Less than lower limit of detection (0.004 pCi/m^3)
[a]Sample missing at site

TABLE VIII

GROSS BETA IN AIR PARTICULATES (pCi/m^3)

SECOND QUARTER

1986

Collection Date	ONS1	ONS2	ONS3	ONS4	ONS5	ONS6	Weekly Mean Gross Beta Activity ± Standard Deviation of the Mean
04/08/86	0.014±0.002	0.013±0.002	0.013±0.002	0.013±0.002	0.011±0.002	0.016±0.002	0.013±0.002
04/15/86	0.005±0.001	0.005±0.001	0.005±0.001	0.005±0.001	0.004±0.001	0.006±0.001	0.005±0.001
04/22/86	0.010±0.001	0.008±0.001	0.015±0.002	0.009±0.002	0.011±0.002	0.012±0.001	0.011±0.003
04/29/86	0.028±0.003	0.030±0.002	0.025±0.003	0.020±0.002	0.020±0.002	0.032±0.003	0.026±0.005
05/06/86	0.028±0.003	0.020±0.002	0.018±0.002	0.015±0.002	0.016±0.002	0.018±0.002	0.019±0.005
05/13/86	0.131±0.005	0.132±0.004	0.131±0.005	0.093±0.004	0.131±0.004	0.120±0.004	0.123±0.015
05/20/86	0.122±0.004	0.128±0.004	0.106±0.004	0.113±0.004	0.118±0.004	0.016±0.003	0.101±0.042
05/27/86	0.142±0.005	0.127±0.004	0.142±0.004	0.131±0.005	0.127±0.004	0.094±0.005	0.127±0.018
06/03/86	0.093±0.004	0.083±0.003	0.111±0.004	0.087±0.005	0.104±0.004	0.104±0.007	0.097±0.011
06/10/86	0.103±0.004	0.067±0.004	0.068±0.003	0.051±0.003	0.069±0.003	0.085±0.006	0.074±0.018
06/17/86	0.017±0.002	0.020±0.003	0.021±0.002	0.015±0.002	0.023±0.002	0.019±0.002	0.019±0.003
06/24/86	0.025±0.003	0.019±0.002	0.024±0.002	0.021±0.003	0.024±0.002	0.026±0.002	0.023±0.003
07/01/86	0.011±0.002	0.007±0.002	0.008±0.002	*	0.012±0.002	0.013±0.002	0.009±0.003
Mean Gross Beta Activity ± Standard Deviation the Mean	0.056±0.053	0.051±0.050	0.053±0.051	0.045±0.045	0.052±0.050	0.043±0.041	

*Less than lower limit of detection (0.004 pCi/m^3)

TABLE VIII (Continued)

GROSS BETA IN AIR PARTICULATES (pCi/m^3)

SECOND QUARTER

1986

Collection Date	NBF	SBN	DOW	COL	Weekly Mean Gross Beta Activities ±Standard Deviation of the Mean
04/08/86	0.013±0.002	0.014±0.002	0.009±0.002	0.012±0.002	0.012±0.002
04/15/86	*	0.005±0.001	*	0.005±0.001	0.005±0.001
04/22/86	0.011±0.002	0.012±0.002	0.011±0.002	0.012±0.002	0.012±0.001
04/29/86	0.019±0.002	0.016±0.002	0.036±0.003	0.021±0.002	0.023±0.009
05/06/86	0.015±0.002	0.019±0.002	0.011±0.002	0.016±0.002	0.015±0.003
05/13/86	0.105±0.004	0.166±0.005	0.117±0.004	0.134±0.005	0.131±0.027
05/20/86	0.102±0.004	0.107±0.004	0.078±0.004	0.108±0.004	0.099±0.014
05/27/86	0.154±0.005	0.155±0.005	0.122±0.005	0.107±0.004	0.135±0.024
06/03/86	0.101±0.004	0.120±0.005	0.058±0.004	0.077±0.004	0.089±0.027
06/10/86	0.048±0.003	0.067±0.004	0.057±0.003	0.055±0.003	0.057±0.008
06/17/86	0.018±0.002	0.022±0.002	0.024±0.002	0.015±0.002	0.020±0.004
06/24/86	0.029±0.002	0.026±0.003	0.020±0.002	0.017±0.002	0.023±0.006
07/01/86	0.011±0.002	0.009±0.002	0.009±0.002	0.009±0.002	0.010±0.001
Mean Gross Beta Activity ± Standard Deviation of the Mean	0.048±0.049	0.057±0.059	0.043±0.041	0.045±0.046	

*Less than lower limit of detection (0.004 pCi/m^3)

TABLE IX

GROSS BETA IN AIR PARTICULATES (pCi/m^3)

THIRD QUARTER

1986

Collection Date	ONS1	ONS2	ONS3	ONS4	ONS5	ONS6	Weekly Mean Gross Beta Activity ± Standard Deviation of the Mean
07/08/86	0.020±0.002	0.015±0.002	0.023±0.002	0.026±0.007	0.024±0.002	0.040±0.003	0.025±0.008
07/15/86	0.011±0.002	0.016±0.003	0.017±0.002	0.021±0.005	0.019±0.002	0.025±0.002	0.018±0.005
07/22/86	0.014±0.003	0.014±0.003	0.016±0.003	0.013±0.003	a	0.035±0.003	0.018±0.009
07/29/86	0.018±0.002	0.018±0.004	0.024±0.003	0.018±0.003	0.017±0.003	0.029±0.003	0.021±0.005
08/05/86	0.025±0.002	0.017±0.003	0.018±0.003	0.018±0.003	0.026±0.003	0.024±0.002	0.021±0.004
08/12/86	0.020±0.003	0.036±0.005	0.020±0.002	0.014±0.002	0.026±0.003	0.042±0.003	0.026±0.011
08/19/86	0.024±0.003	0.032±0.003	0.026±0.003	0.024±0.002	0.030±0.003	0.040±0.005	0.029±0.006
08/26/86	0.026±0.003	0.007±0.002	0.039±0.003	0.042±0.003	0.027±0.003	0.023±0.002	0.027±0.013
09/02/86	0.033±0.002	0.063±0.004	0.020±0.002	0.015±0.002	0.022±0.003	0.020±0.002	0.029±0.018
09/08/86	0.023±0.003	0.022±0.003	0.021±0.003	0.031±0.003	0.026±0.003	0.017±0.003	0.023±0.005
09/15/86	0.029±0.002	0.063±0.003	0.022±0.002	0.017±0.002	0.027±0.003	0.022±0.002	0.030±0.017
09/22/86	0.016±0.002	0.020±0.002	0.021±0.002	0.028±0.002	0.053±0.003	0.018±0.002	0.026±0.014
09/29/86	0.011±0.002	0.014±0.002	0.019±0.005	0.017±0.002	0.006±0.002	0.016±0.002	0.014±0.005
Mean Gross Beta Activity ± Standard Deviation the Mean	0.021±0.007	0.026±0.018	0.022±0.006	0.022±0.008	0.025±0.011	0.027±0.009	

[a]Invalid sample - power off at station

TABLE IX (Continued)

GROSS BETA IN AIR PARTICULATES (pCi/m^3)

THIRD QUARTER

1986

Collection Date	NBF	SBN	DOW	COL	Weekly Mean Gross Beta Activities ±Standard Deviation of the Mean
07/08/86	0.023±0.003	0.021±0.003	0.019±0.002	0.021±0.003	0.021±0.002
07/15/86	0.031±0.003	0.021±0.002	0.016±0.002	0.017±0.002	0.021±0.007
07/22/86	0.017±0.003	0.017±0.003	0.013±0.003	0.017±0.003	0.016±0.002
07/29/86	0.023±0.002	0.021±0.003	0.033±0.003	0.018±0.003	0.024±0.007
08/05/86	0.019±0.002	0.021±0.002	0.010±0.002	0.048±0.003	0.025±0.016
08/12/86	0.022±0.002	0.025±0.003	0.013±0.002	0.023±0.003	0.021±0.005
08/19/86	0.040±0.003	0.060±0.003	0.024±0.003	0.006±0.002	0.033±0.023
08/26/86	0.024±0.003	0.030±0.003	0.026±0.003	0.035±0.003	0.029±0.005
09/02/86	0.019±0.002	0.020±0.002	0.020±0.002	0.033±0.003	0.023±0.007
09/08/86	0.023±0.003	0.026±0.003	0.027±0.003	0.023±0.003	0.025±0.002
09/15/86	0.024±0.003	0.018±0.002	0.023±0.003	0.037±0.003	0.026±0.008
09/22/86	0.015±0.002	0.013±0.002	0.014±0.002	0.018±0.02	0.015±0.002
09/29/86	0.011±0.002	0.015±0.002	0.019±0.003	0.018±0.002	0.016±0.004
Mean Gross Beta Activity ± Standard Deviation of the Mean	0.022±0.007	0.024±0.012	0.020±0.007	0.024±0.011	

TABLE X

GROSS BETA IN AIR PARTICULATES (pCi/m^3)

FOURTH QUARTER

1986

Collection Date	ONS1	ONS2	ONS3	ONS4	ONS5	ONS6	Weekly Mean Gross Beta Activity ± Standard Deviation of the Mean
10/06/86	0.008±0.002	0.009±0.002	0.010±0.002	0.009±0.002	0.004±0.002	0.012±0.002	0.009±0.003
10/13/86	0.015±0.002	0.018±0.002	0.016±0.002	0.015±0.002	0.029±0.003	0.023±0.003	0.019±0.006
10/20/86	0.014±0.002	0.012±0.002	0.012±0.002	0.011±0.002	0.014±0.002	0.019±0.002	0.014±0.003
10/25/86	0.035±0.003	0.035±0.003	0.040±0.003	0.040±0.003	0.044±0.003	0.048±0.003	0.040±0.005
11/03/86	0.020±0.003	0.021±0.002	0.023±0.002	0.021±0.003	0.035±0.003	0.022±0.003	0.024±0.006
11/10/86	0.019±0.002	0.024±0.003	0.019±0.002	0.020±0.002	0.020±0.002	0.019±0.002	0.020±0.002
11/17/86	0.024±0.002	0.026±0.003	0.028±0.003	0.025±0.003	0.029±0.003	0.032±0.003	0.027±0.003
11/24/86	0.030±0.002	0.036±0.003	0.041±0.003	0.032±0.003	0.039±0.003	0.038±0.003	0.036±0.004
12/01/86	0.020±0.003	0.025±0.003	0.024±0.003	0.022±0.003	0.027±0.003	0.026±0.003	0.024±0.003
12/08/86	0.020±0.002	0.021±0.002	0.022±0.002	0.021±0.003	0.023±0.002	0.024±0.003	0.022±0.002
12/15/86	0.020±0.002	0.024±0.003	0.024±0.003	0.022±0.002	0.028±0.003	0.026±0.003	0.024±0.003
12/22/86	0.014±0.003	0.018±0.003	0.017±0.003	0.012±0.003	0.023±0.003	0.033±0.003	0.020±0.008
12/29/86	0.042±0.003	0.051±0.003	0.048±0.003	0.046±0.003	0.053±0.003	0.051±0.003	0.049±0.004
Mean Gross Beta Activity ± Standard Deviation the Mean	0.022±0.009	0.025±0.011	0.025±0.012	0.023±0.011	0.028±0.013	0.029±0.011	

TABLE X (Continued)

GROSS BETA IN AIR PARTICULATES (pCi/m^3)

FOURTH QUARTER

1986

Collection Date	NBF	SBN	DOW	COL	Weekly Mean Gross Beta Activities ±Standard Deviation of the Mean
10/06/86	0.011±0.002	0.010±0.002	0.017±0.002	0.007±0.001	0.011±0.004
10/13/86	0.016±0.002	0.017±0.002	0.019±0.003	0.020±0.002	0.018±0.002
10/20/86	0.013±0.002	0.014±0.002	0.012±0.002	0.012±0.002	0.013±0.001
10/25/86	0.040±0.003	0.043±0.003	0.047±0.003	0.044±0.003	0.044±0.003
11/03/86	0.020±0.002	0.025±0.003	0.021±0.003	0.024±0.003	0.023±0.002
11/10/86	0.019±0.002	0.023±0.002	0.022±0.002	0.022±0.002	0.022±0.002
11/17/86	0.015±0.007	0.029±0.003	0.027±0.003	0.029±0.003	0.025±0.007
11/24/86	0.030±0.003	0.034±0.003	0.033±0.003	0.035±0.003	0.033±0.002
12/01/86	0.021±0.002	0.027±0.003	0.027±0.003	0.024±0.003	0.025±0.003
12/08/86	0.018±0.002	0.018±0.002	0.018±0.002	0.024±0.003	0.020±0.003
12/15/86	0.024±0.002	0.023±0.002	0.027±0.003	0.025±0.003	0.025±0.002
12/22/86	0.013±0.003	*	0.019±0.003	0.020±0.003	0.014±0.007
12/29/86	0.043±0.003	0.052±0.003	0.052±0.003	0.059±0.003	0.052±0.007
Mean Gross Beta Activity ± Standard Deviation of the Mean	0.022±0.010	0.025±0.013	0.026±0.012	0.027±0.013	

*Less than lower limit of detection (0.004 pCi/m^3)

TABLE XI

GROSS BETA IN AIR PARTICULATES (pCi/m^3)

QUARTERLY STATISTICAL SUMMARY

1986

	ONS1	ONS2	ONS3	ONS4	ONS5	ONS6
FIRST QUARTER	0.006±0.004	0.011±0.008	0.017±0.008	0.017±0.008	0.014±0.008	0.018±0.010
SECOND QUARTER	0.056±0.053	0.051±0.050	0.053±0.051	0.045±0.045	0.052±0.050	0.043±0.041
THIRD QUARTER	0.021±0.007	0.026±0.018	0.022±0.006	0.022±0.008	0.025±0.011	0.027±0.009
FOURTH QUARTER	0.022±0.009	0.025±0.011	0.025±0.012	0.023±0.011	0.028±0.013	0.029±0.011

	NBF	SBN	DOW	COL
FIRST QUARTER	0.006±0.005	0.006±0.005	0.008±0.005	0.007±0.005
SECOND QUARTER	0.048±0.049	0.057±0.059	0.043±0.041	0.045±0.046
THIRD QUARTER	0.022±0.007	0.024±0.012	0.020±0.007	0.024±0.011
FOURTH QUARTER	0.022±0.010	0.025±0.013	0.026±0.012	0.027±0.013

TABLE XII

GROSS BETA IN AIR PARTICULATES (pCi/m^3)

ANNUAL STATISTICAL SUMMARY

1986

Station	Mean	1986 Range Low Value	1986 Range High Value
ONS1	0.026±0.032	< 0.004	0.142±0.005
ONS2	0.028±0.030	< 0.004	0.132±0.004
ONS3	0.029±0.030	< 0.004	0.142±0.004
ONS4	0.027±0.026	< 0.004	0.131±0.005
ONS5	0.030±0.030	< 0.004	0.131±0.004
ONS6	0.029±0.024	< 0.004	0.120±0.004
Onsite Stations Mean	0.028±0.027		
NBF	0.025±0.029	< 0.004	0.154±0.005
SBN	0.028±0.035	< 0.004	0.166±0.005
DOW	0.024±0.025	< 0.004	0.122±0.005
COL	0.026±0.027	< 0.004	0.134±0.005
Offsite Stations Mean	0.026±0.028		

Figure 3
GROSS BETA IN AIR PARTICULATES
WEEKLY ACTIVITY–STATION ONS1
1986

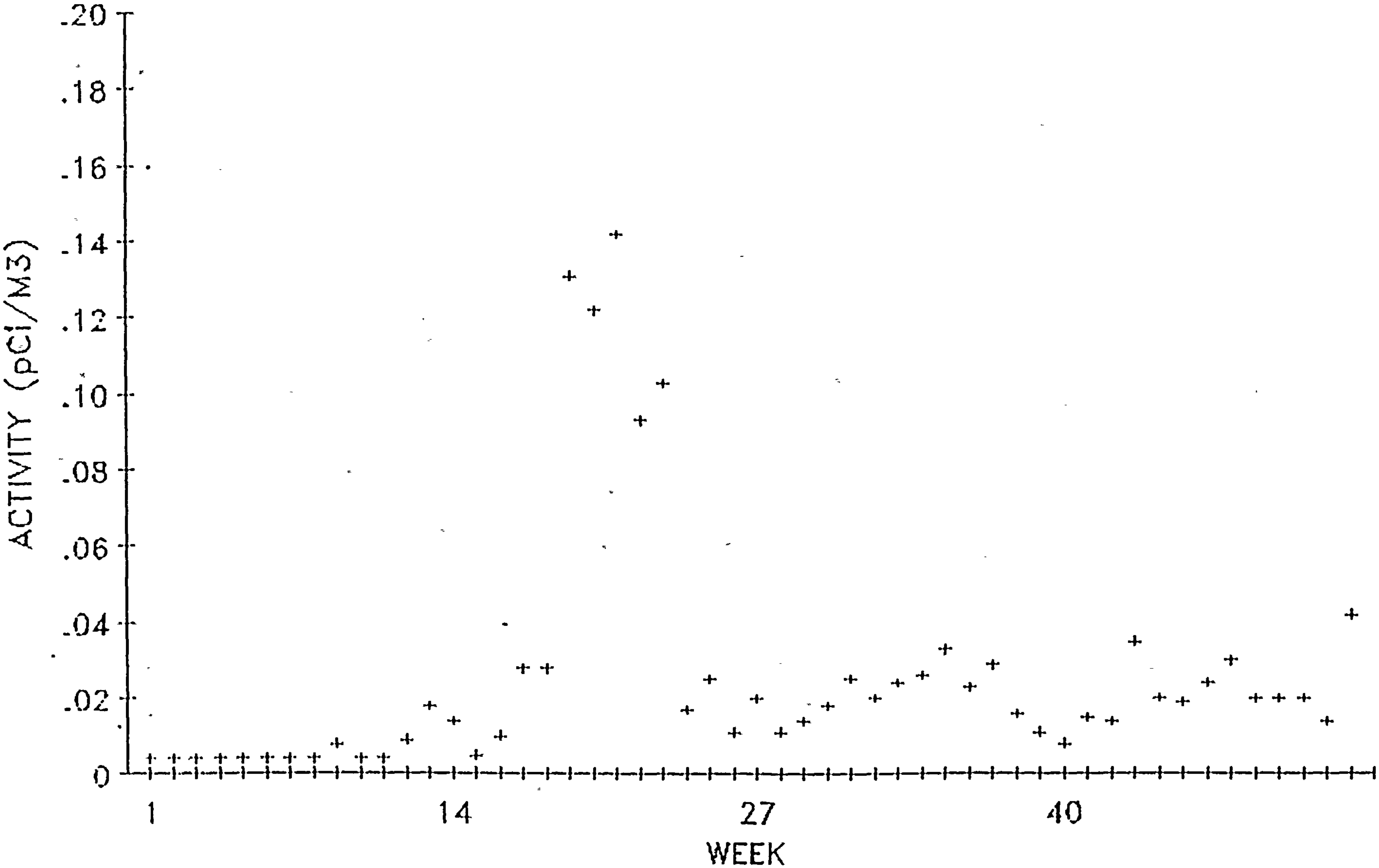


Figure 4
GROSS BETA IN AIR PARTICULATES
WEEKLY ACTIVITY-STATION ONS2
1986

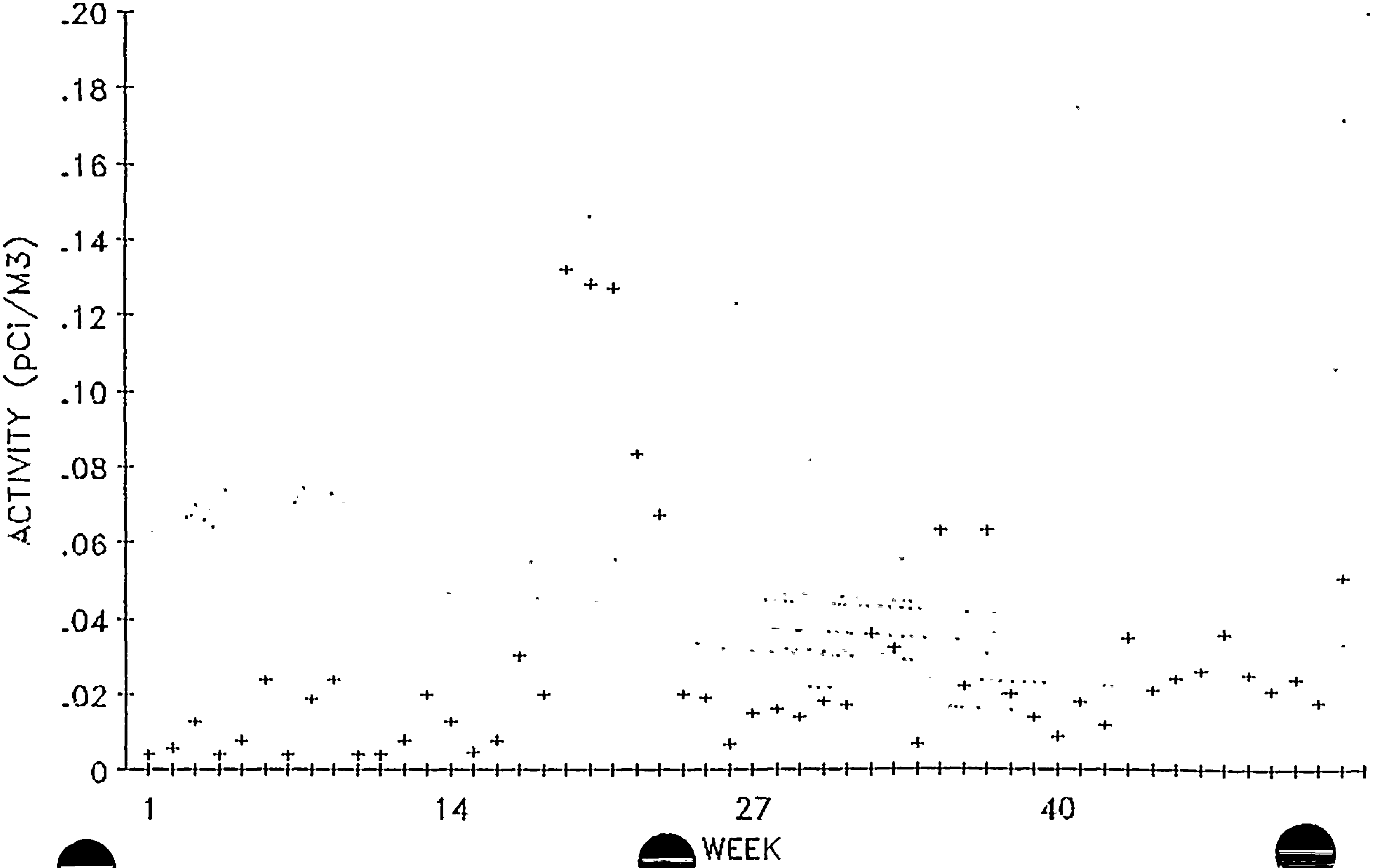


Figure 5
GROSS BETA IN AIR PARTICULATES
WEEKLY ACTIVITY–STATION ONS3
1986

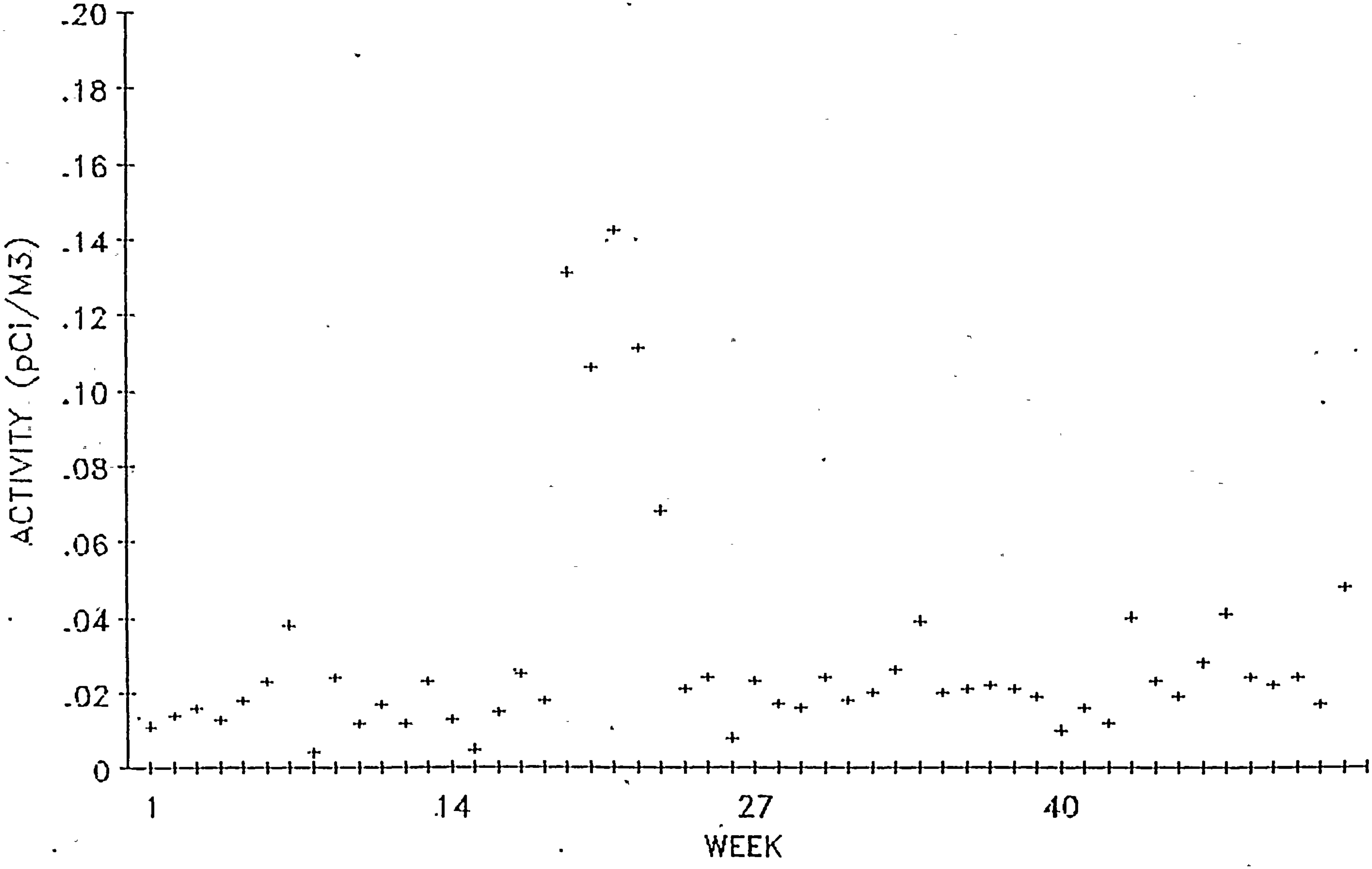


Figure 6
GROSS BETA IN AIR PARTICULATES
WEEKLY ACTIVITY–STATION ONS4
1986

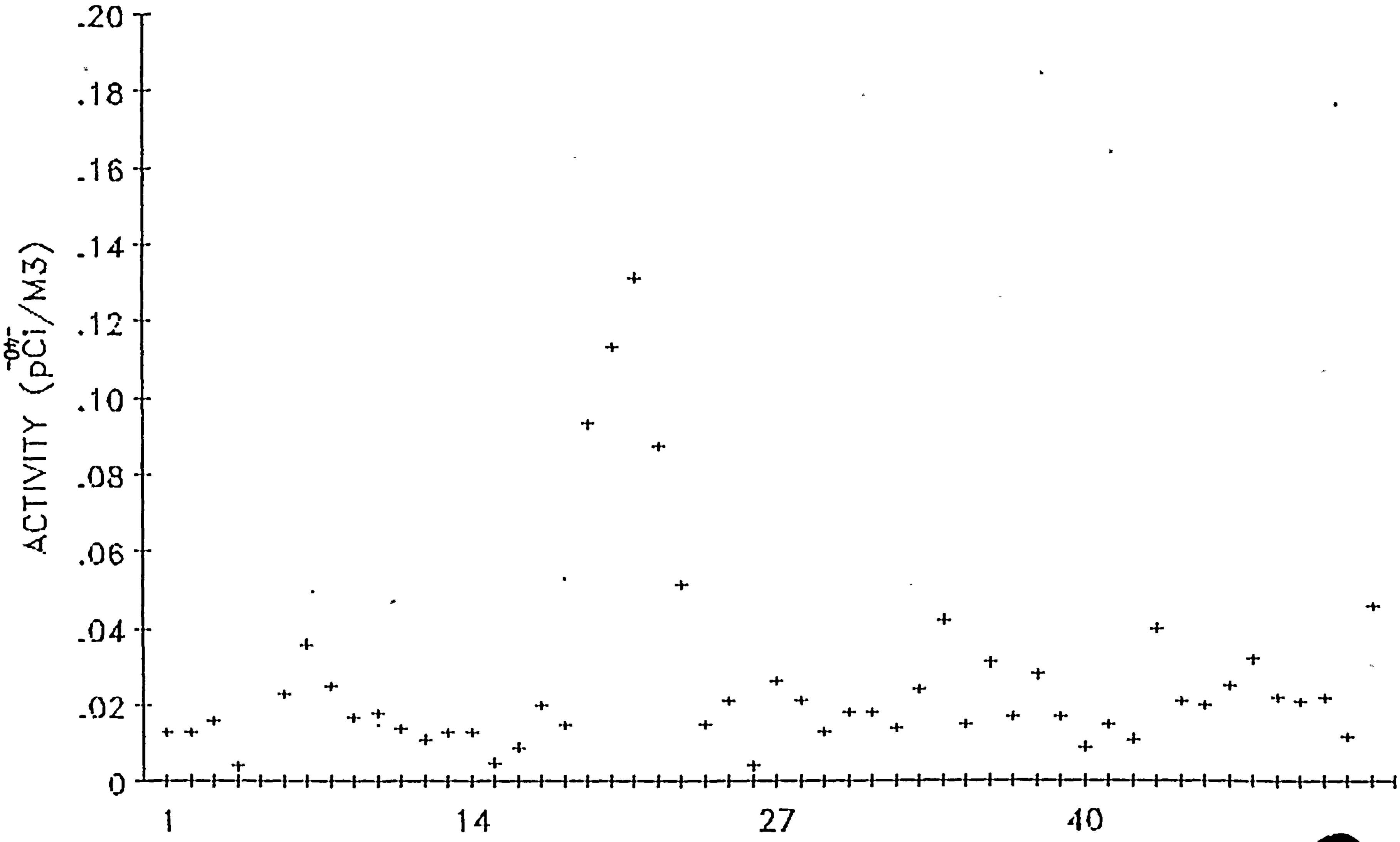


Figure 7
GROSS BETA IN AIR PARTICULATES
WEEKLY ACTIVITY–STATION ONS5
1986

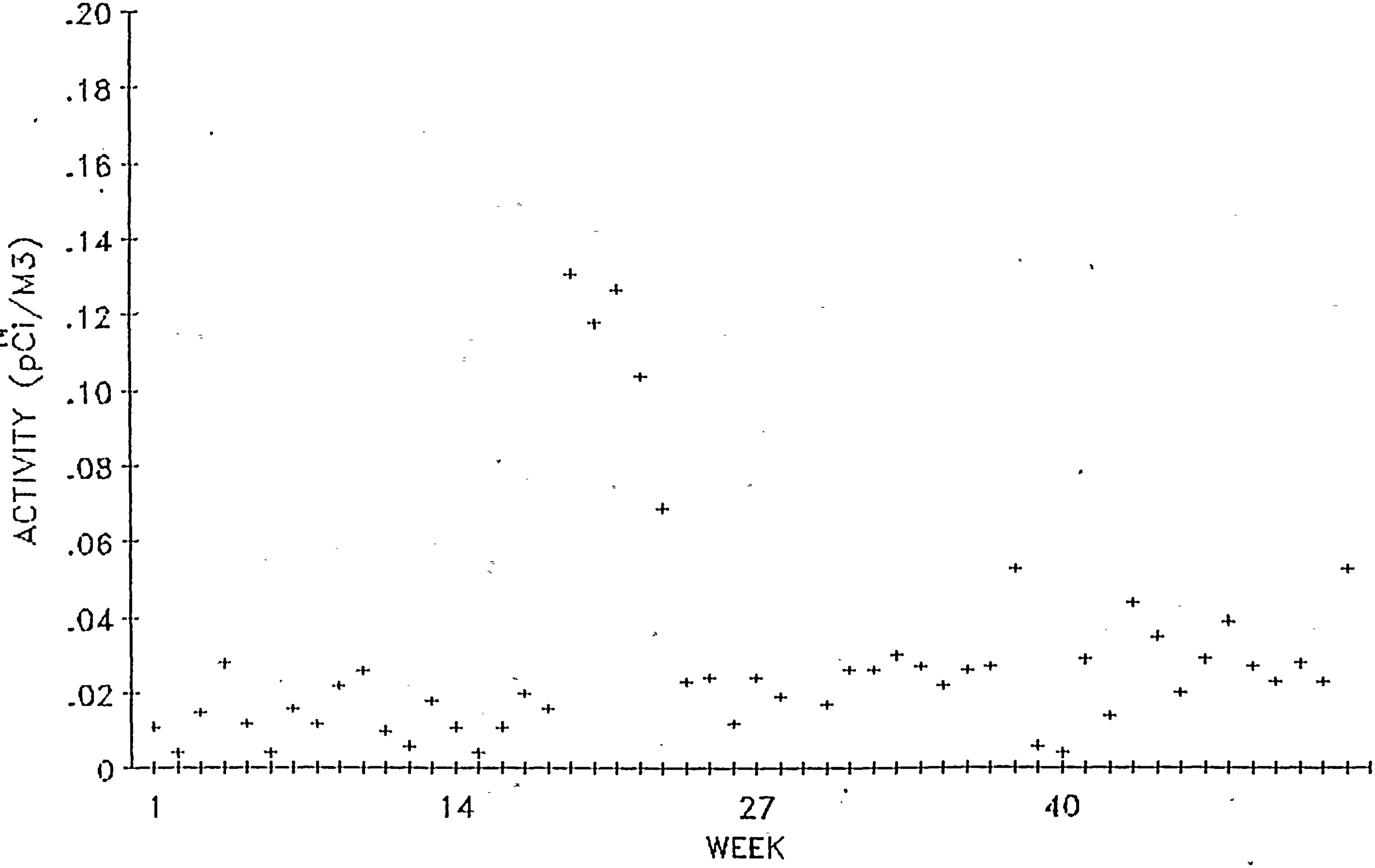


Figure 8
GROSS BETA IN AIR PARTICULATES
WEEKLY ACTIVITY-STATION.ONS6
1986

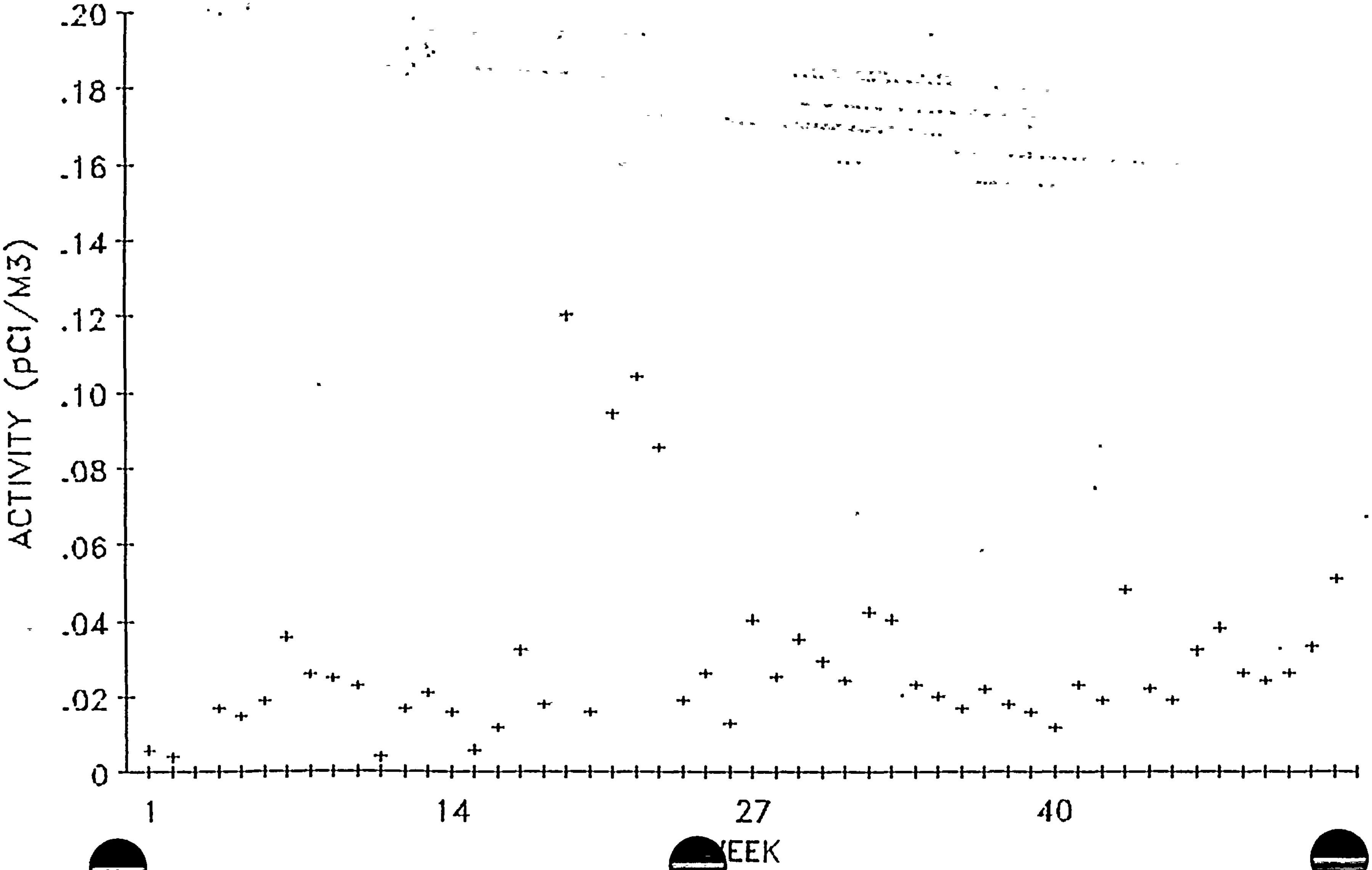


Figure 9
GROSS BETA IN AIR PARTICULATES
WEEKLY ACTIVITY—STATION NBF
1986

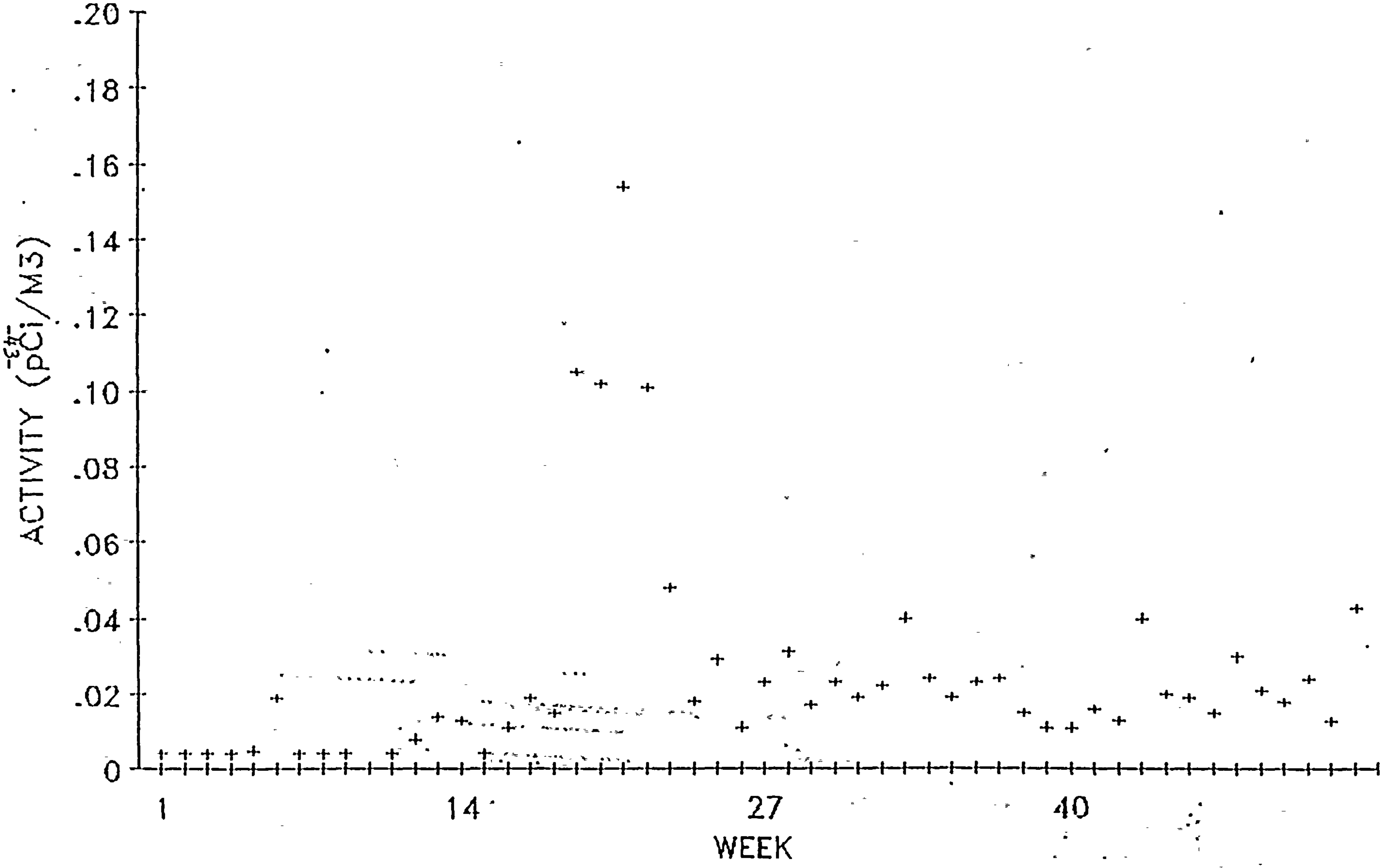


Figure 10
GROSS BETA IN AIR PARTICULATES
WEEKLY ACTIVITY-STATION SBN
1986

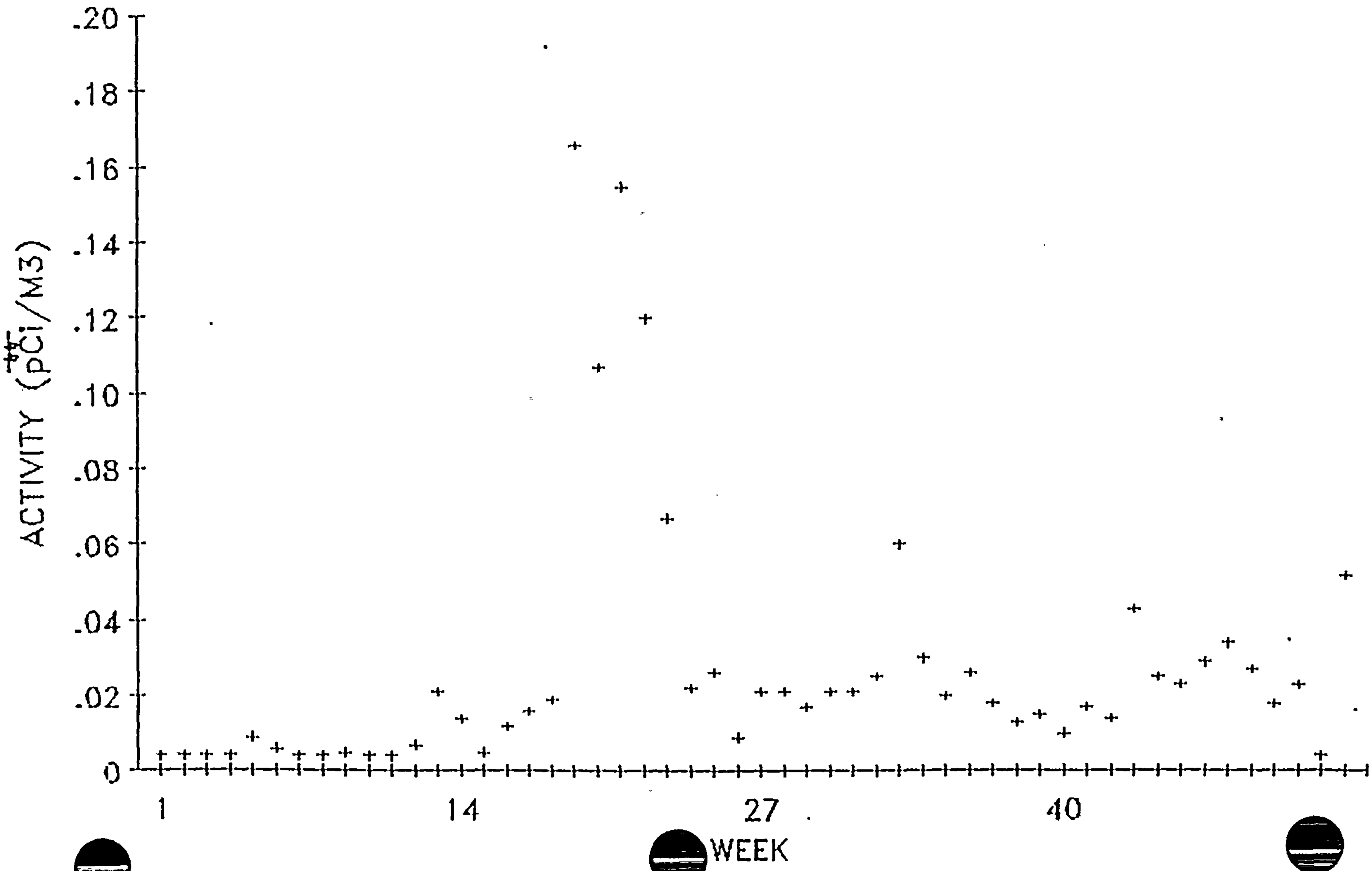


Figure 11
GROSS BETA IN AIR PARTICULATES
WEEKLY ACTIVITY-STATION DOW
1986

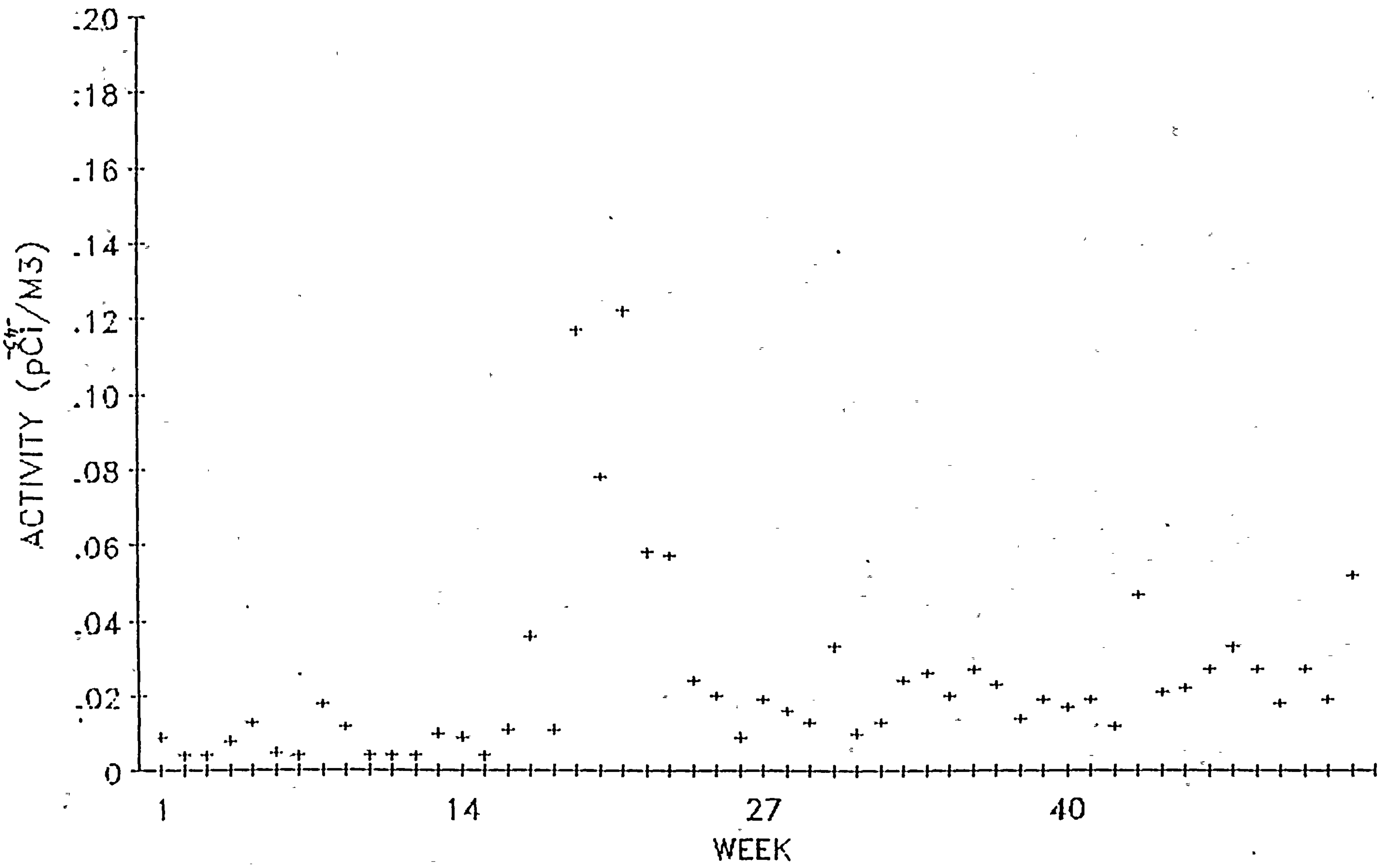


Figure 12
GROSS BETA IN AIR PARTICULATES
WEEKLY ACTIVITY–STATION COL
1986

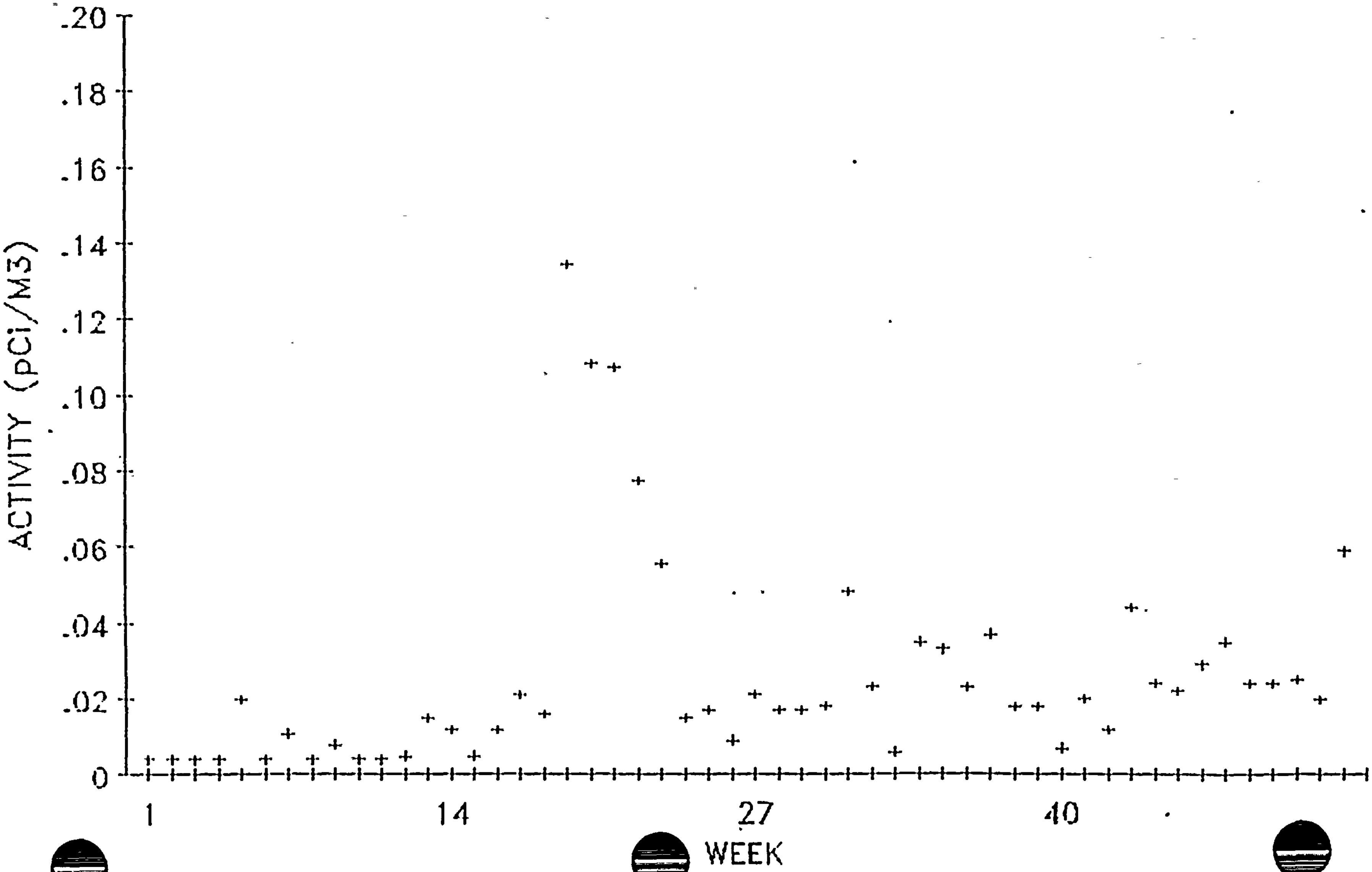
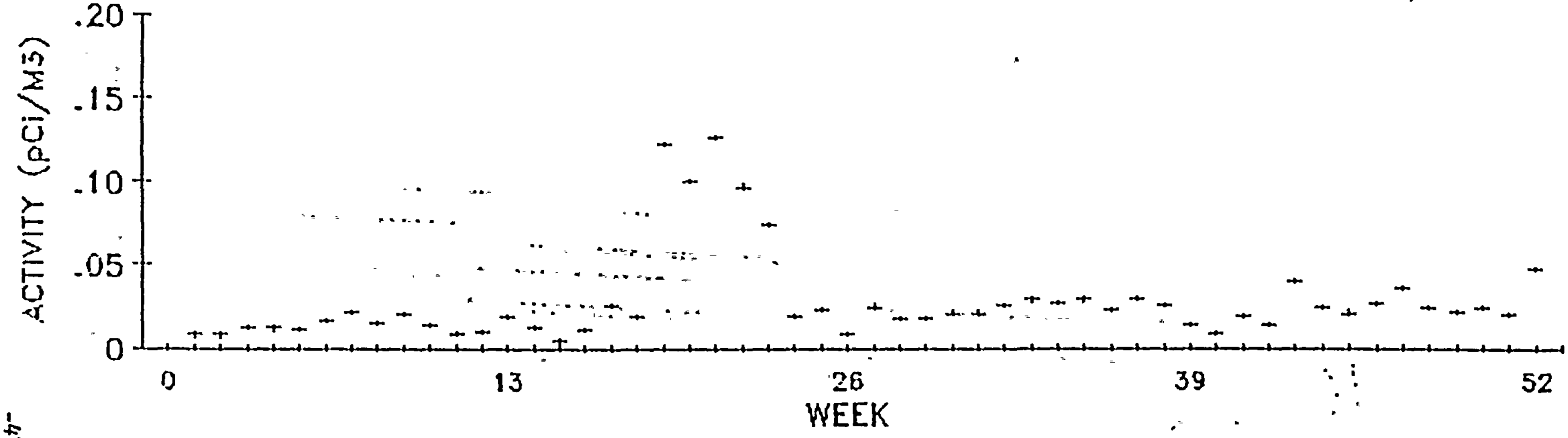
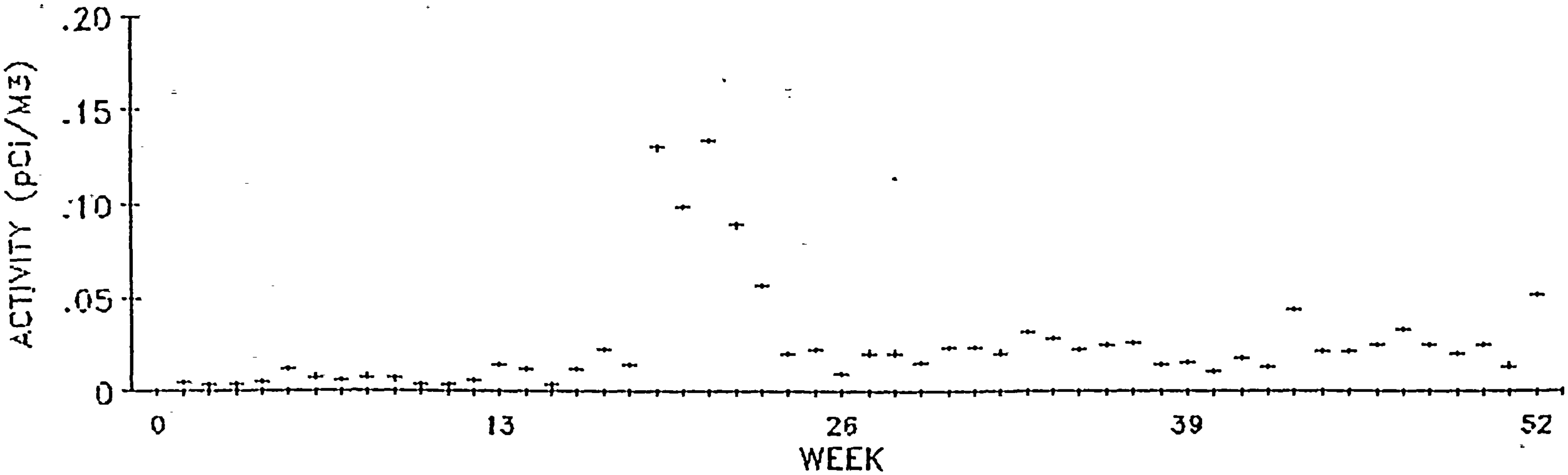


Figure 13
GROSS BETA IN AIR PARTICULATES
MEAN WEEKLY ACTIVITY–ON SITE COLLECTION
1986



GROSS BETA IN AIR PARTICULATES
MEAN WEEKLY ACTIVITY–OFF SITE COLLECTION
1986



7.2 Airborne Radioiodine

Samples for airborne radioiodine were collected concurrently with the air particulate samples from the ten monitoring stations. These samples were collected in charcoal cartridges and analyzed for I-131.

Airborne radioiodine levels for the four quarters of 1986 can be seen in Tables XIII through XVI. As noted, elevated levels of radioiodine were detected during the second quarter and are directly attributable to the Chernobyl accident.

The detected levels of radioiodine during the first, third, and fourth quarters were less than the plant Technical Specification detection limit (7E-2 pCi/m^3) of table 4.12-1.

TABLE XIII

AIRBORNE RADIOIODINE (pCi/m³)

FIRST QUARTER

1986

Collection Date	ONS1	ONS2	ONS3	ONS4	ONS5	ONS6
01/07/86	*	*	*	*	*	*
01/14/86	*	*	*	*	*	*
01/21/86	*	*	*	*	*	a
01/28/86	*	*	*	*	*	*
02/04/86	*	*	*	b	*	*
02/11/86	*	*	*	*	*	*
02/18/86	*	*	*	*	*	*
02/25/86	*	*	*	*	*	*
03/04/86	*	*	*	*	*	*
03/11/86	*	*	*	*	*	*
03/18/86	*	*	*	*	*	*
03/25/86	*	*	*	*	*	*
04/01/86	*	*	*	*	*	0.009 ± 0.007

*Less than lower limit of detection (0.005 pCi/m³)
[a]Invalid Sample (meter problem)
[b]Sample lost during shipping

TABLE XIII (Continued)

AIRBORNE RADIOIODINE (pCi/m^3)

FIRST QUARTER

1986

Collection Date	NBF	SBN	DOW	COL
01/04/86	*	*	*	*
01/14/86	*	*	*	*
01/21/86	*	*	*	*
01/28/86	*	*	*	*
02/04/86	*	*	*	*
02/11/86	*	*	*	*
02/18/86	*	*	*	*
02/25/86	*	*	*	*
03/04/86	*	*	*	*
03/11/86	a	*	*	*
03/18/86	*	*	*	*
03/25/86	*	*	*	*
04/01/86	*	*	*	*

*Less than lower limit of detection (0.005 pCi/m^3)

[a]Sample missing at site

TABLE XIV

AIRBORNE RADIOIODINE (pCi/m^3)

SECOND QUARTER

1986

Collection Date	ONS1	ONS2	ONS3	ONS4	ONS5	ONS6
04/08/86	*	*	*	*	*	*
04/15/86	*	*	*	*	*	*
04/22/86	*	*	*	*	*	*
04/29/86	*	*	*	*	*	*
05/06/86	*	*	*	*	0.011±0.006	*
05/13/86	0.061±0.009	0.115±0.009	0.093±0.010	0.073±0.009	0.088±0.010	0.081±0.009
05/20/86	0.122±0.009	0.096±0.006	0.098±0.008	0.087±0.007	0.093±0.007	0.018±0.006
05/27/86	0.044±0.007	0.070±0.006	0.050±0.006	0.048±0.009	0.055±0.007	0.048±0.010
06/03/86	*	0.060±0.008	*	*	*	*
06/10/86	0.009±0.007	0.027±0.008	0.014±0.006	0.008±0.006	0.008±0.005	0.013±0.010
06/17/86	*	*	*	0.020±0.005	0.013±0.004	*
06/24/86	0.010±0.006	0.008±0.006	*	0.013±0.007	0.016±0.005	*
07/01/86	*	*	*	*	*	*

*Less than lower limit of detection (0.005 pCi/m^3)

TABLE XIV (Continued)
AIRBORNE RADIOIODINE (pCi/m^3)
SECOND QUARTER
1986

Collection Date	NBF	SBN	DOW	COL
04/08/86	*	*	*	*
04/15/86	*	*	*	*
04/22/86	*	*	*	*
04/29/86	*	*	*	*
05/06/86	*	*	*	*
05/13/86	0.081±0.009	0.097±0.010	0.092±0.011	0.064±0.010
05/20/86	0.088±0.007	0.109±0.008	0.075±0.007	0.107±0.008
05/27/86	0.054±0.007	*	0.046±0.008	*
06/03/86	0.025±0.010	*	*	0.038±0.011
06/10/86	0.012±0.006	*	*	*
06/17/86	*	*	*	0.010±0.004
06/24/86	0.008±0.005	0.007±0.006	*	0.018±0.007
07/01/86	*	*	*	*

*Less than lower limit of detection (0.005 pCi/m^3)

TABLE XV
AIRBORNE RADIOIODINE (pCi/m^3)
THIRD QUARTER
1986

Collection Date	ONS1	ONS2	ONS3	ONS4	ONS5	ONS6
07/08/86	*	*	*	*	*	*
07/15/86	*	*	*	*	*	*
07/22/86	*	*	*	*	a	*
07/29/86	*	*	*	*	*	*
08/05/86	*	*	*	*	0.012±0.005	*
08/12/86	*	*	*	*	*	*
08/19/86	*	*	*	*	*	*
08/26/86	*	*	*	*	*	*
09/02/86	*	*	*	*	*	*
09/08/86	*	*	*	*	*	*
09/15/86	*	*	*	*	*	*
09/22/86	*	*	*	*	*	*
09/29/86	*	*	*	*	*	*

*Less than lower limit of detection (0.005 pCi/m^3)

[a]Invalid sample - power off at station

TABLE XV (Continued)

AIRBORNE RADIOIODINE (pCi/m^3)

THIRD QUARTER

1986

Collection Date	NBF	SBN	DOW	COL
07/08/86	*	*	*	*
07/15/86	*	*	*	*
07/22/86	*	*	*	*
07/29/86	*	*	*	*
08/05/86	*	*	*	0.024±0.008
08/05/86	*	*	*	0.009±0.004
08/12/86	*	*	*	*
08/19/86	*	*	*	*
08/26/86	*	*	*	*
09/02/86	*	*	*	*
09/08/86	*	*	*	*
09/15/86	*	*	*	*
09/22/86	*	*	*	*
09/29/86	*	*	*	*

Less than lower limit of detection (0.005 pCi/m^3)

TABLE XVI

AIRBORNE RADIOIODINE (pCi/m^3)

FOURTH QUARTER

1986

Collection Date	ONS1	ONS2	ONS3	ONS4	ONS5	ONS6
10/06/86	*	*	*	*	*	*
10/13/86	*	*	*	*	*	*
10/20/86	*	*	*	*	*	*
10/25/86	*	*	*	*	*	*
11/03/86	*	*	*	*	*	*
11/10/86	*	*	*	*	*	*
11/17/86	*	*	*	*	*	*
11/24/86	*	*	*	*	*	*
12/01/86	*	*	*	*	*	*
12/08/86	*	*	*	*	*	*
12/15/86	*	*	*	*	*	*
12/22/86	*	*	*	*	*	*
12/29/86	*	*	*	*	*	*

*Less than lower limit of detection (0.005 pCi/m^3)

TABLE XVI (CONTINUED)
AIRBORNE RADIOIODINE (pCi/m^3)
FOURTH QUARTER
1986

Collection Date	NBF	SBN	DOW	COL
10/06/86	*	*	*	*
10/13/86	*	*	*	*
10/20/86	0.017±0.014	*	*	*
10/25/86	*	*	*	*
11/03/86	*	*	*	*
11/10/86	*	*	*	*
11/17/86	*	*	*	*
11/24/86	*	*	*	*
12/01/86	*	*	*	*
12/08/86	*	*	*	*
12/15/86	*	*	*	*
12/22/86	*	*	*	*
12/29/86	*	*	*	*

*Less than lower limit of detection (0.005 pCi/m^3)

7.3 Thermoluminescent Dosimetry

Thermoluminescent Dosimetry (TLD) was employed to determine direct radiation in and around the Donald C. Cook Nuclear Plant. The TLD's were placed at 23 locations and exchanged quarterly. Listed below are the mean quarterly readings in mR/week for all TLD's.

	mR/week		
	Onsite	Offsite	Background
First Quarter	1.19 ± 0.49	1.02 ± 0.24	0.80 ± 0.37
Second Quarter	0.75 ± 0.09	0.71 ± 0.10	0.76 ± 0.12
Third Quarter	1.09 ± 0.16	1.13 ± 0.07	1.00 ± 0.06
Fourth Quarter	1.16 ± 0.16	1.29 ± 0.20	1.26 ± 0.09
Annual	1.05 ± 0.32	1.06 ± 0.27	0.95 ± 0.27

Figures 14 through 36 present the mR/week values obtained for each TLD station collected during each quarter of 1986.

The highest reading for Onsite stations was seen at Station ONS-7 during the first quarter with a value of 2.07 mR/week. The highest reading for Offsite stations was at Station OFS-5 (1.65 mR/week) in the fourth quarter. Background stations had a high value of 1.36 mR/week during the fourth quarter at Station SBN.

TABLE XVII

THERMOLUMINESCENT DOSIMETRY (mR/week)

1986

Station Location	First Quarter 01/01/86 - 04/06/86	Second Quarter 04/06/86 - 07/07/86	Third Quarter 07/07/86 - 10/04/86	Fourth Quarter 10/04/86 - 01/05/87
ONS-1	0.96	0.69	1.14	1.18
ONS-2	0.74	0.83	1.26	1.18
ONS-3	0.59	0.86	0.90	1.40
ONS-4	1.18	0.76	1.09	0.80
ONS-5	1.18	0.65	0.96	1.18
ONS-6	0.89	0.89	0.98	1.24
ONS-7	2.07	0.63	1.35	1.11
ONS-8	1.85	0.72	1.22	1.16
ONS-9	1.26	0.72	0.92	1.18
Mean TLD ± Standard Deviation Of the Mean	1.19±0.49	0.75±0.09	1.09±0.16	1.16±0.16
OFS-1	1.11	0.66	1.15	1.26
OFS-2	1.33	Missing	1.29	1.36
OFS-3	0.89	0.78	1.10	1.22
OFS-4	0.89	0.73	1.03	1.23
OFS-5	0.81	0.78	1.11	1.65
OFS-6	1.18	0.63	1.14	1.44
OFS-7	0.71	0.55	1.09	1.27
OFS-8	Missing	Missing	1.21	1.32
OFS-9	1.41	0.67	1.15	0.86
OFS-10	0.89	0.85	1.06	1.32
Mean TLD ± Standard Deviation Of the Mean	1.02±0.24	0.71±0.10	1.13±0.08	1.29±0.20
NBF	0.37	0.76	1.02	1.30
SBN	1.26	0.68	0.98	1.36
DOW	0.74	0.66	1.07	1.20
COL	0.81	0.92	0.92	1.16
Mean TLD ± Standard Deviation Of the Mean	0.80±0.37	0.76±0.12	1.00±0.06	1.26±0.09

Figure 14
QUARTERLY THERMOLUMINESCENT DOSIMETRY
LOCATION ONS-1
1986

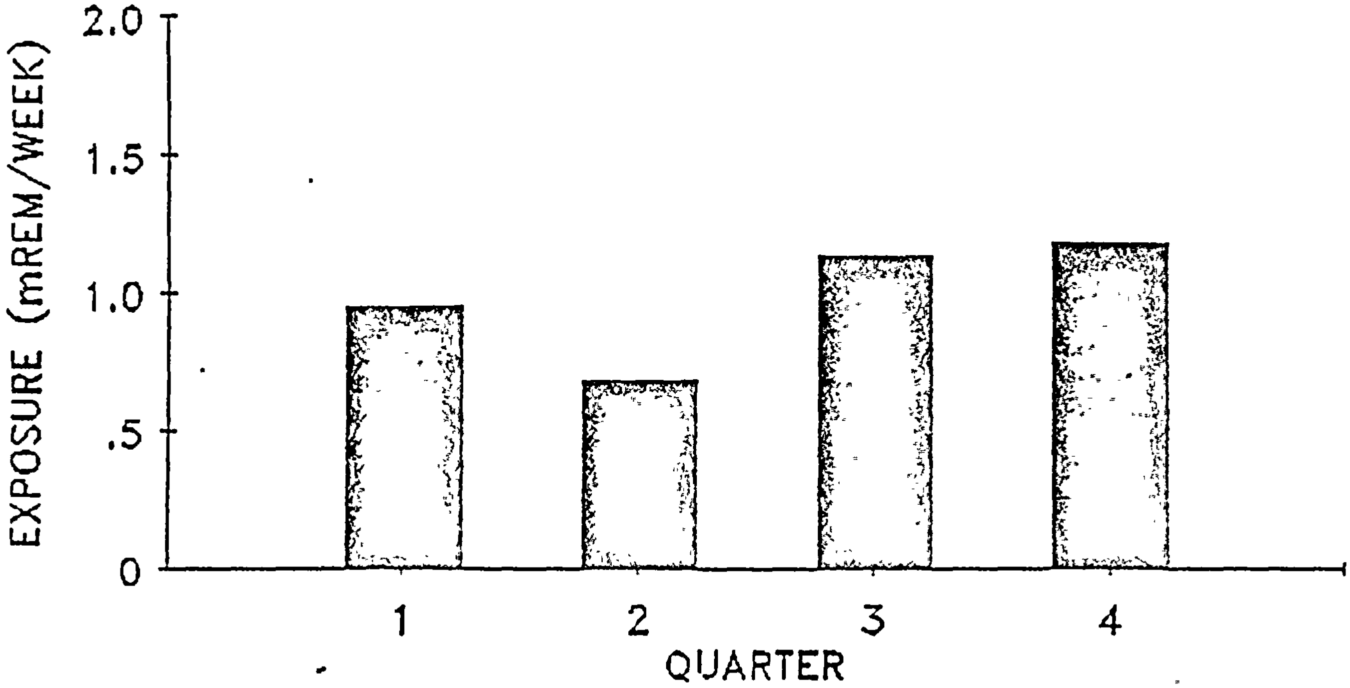


Figure 15
QUARTERLY THERMOLUMINESCENT DOSIMETRY
LOCATION ONS-2
1986

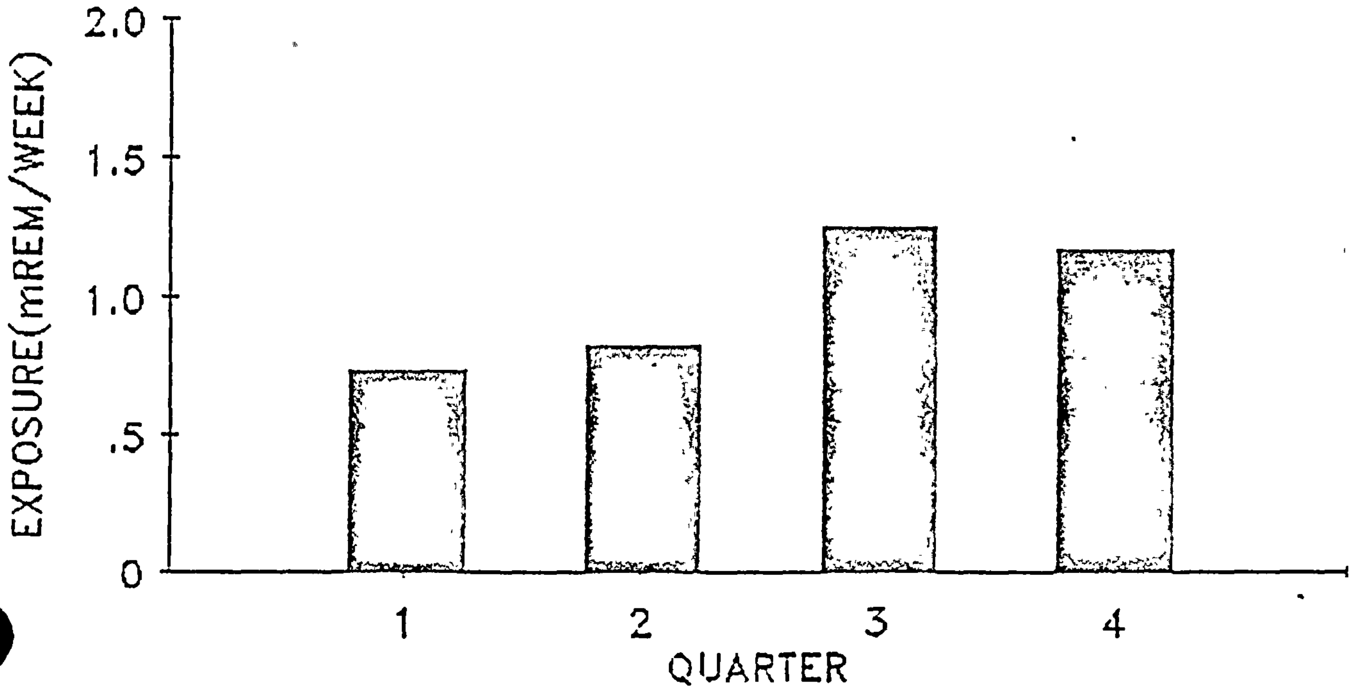


Figure 16
QUARTERLY THERMOLUMINESCENT DOSIMETRY
LOCATION ONS-3
1986

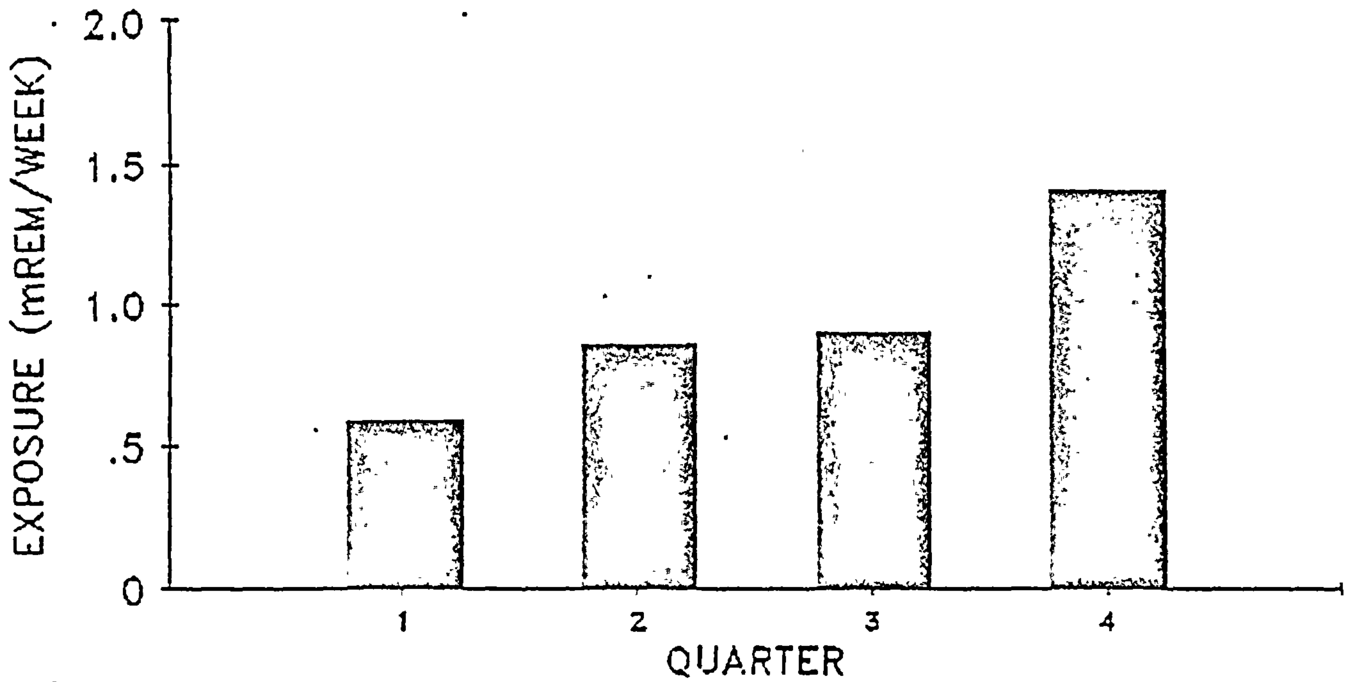


Figure 17.
QUARTERLY THERMOLUMINESCENT DOSIMETRY
LOCATION ONS-4
1986

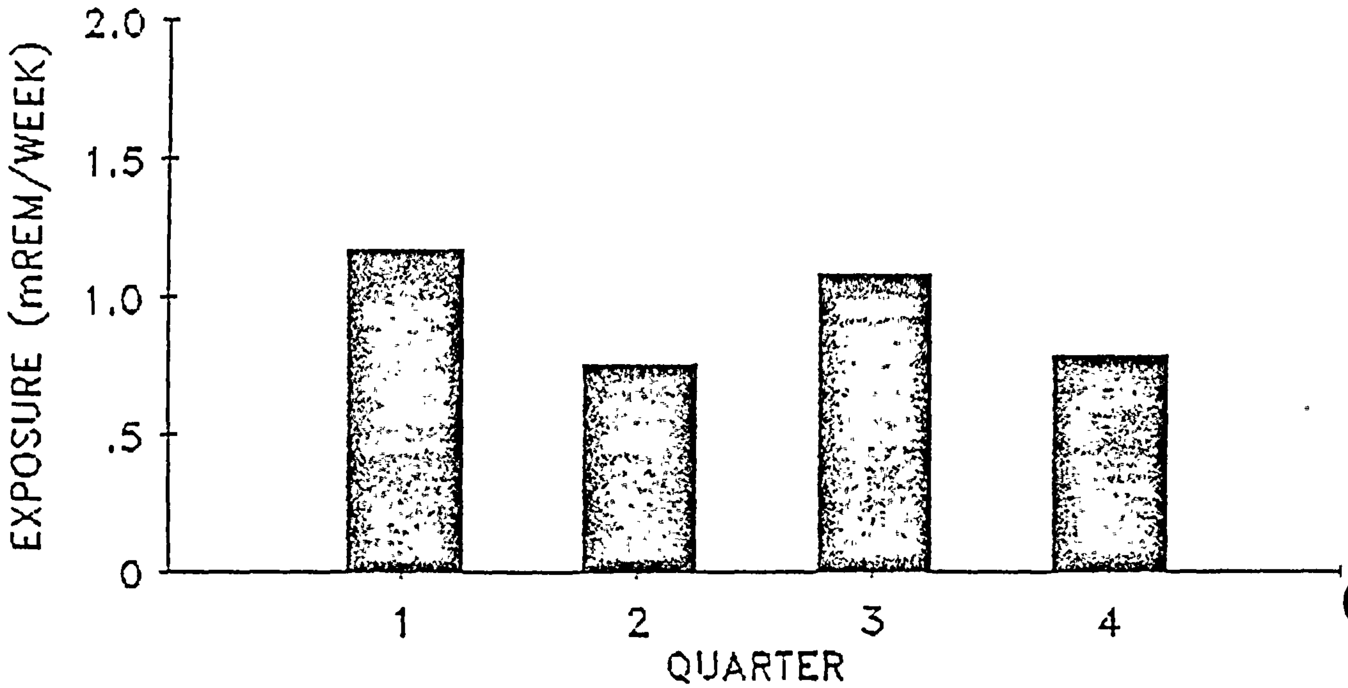


Figure 18
QUARTERLY THERMOLUMINESCENT DOSIMETRY
LOCATION ONS-5
1986

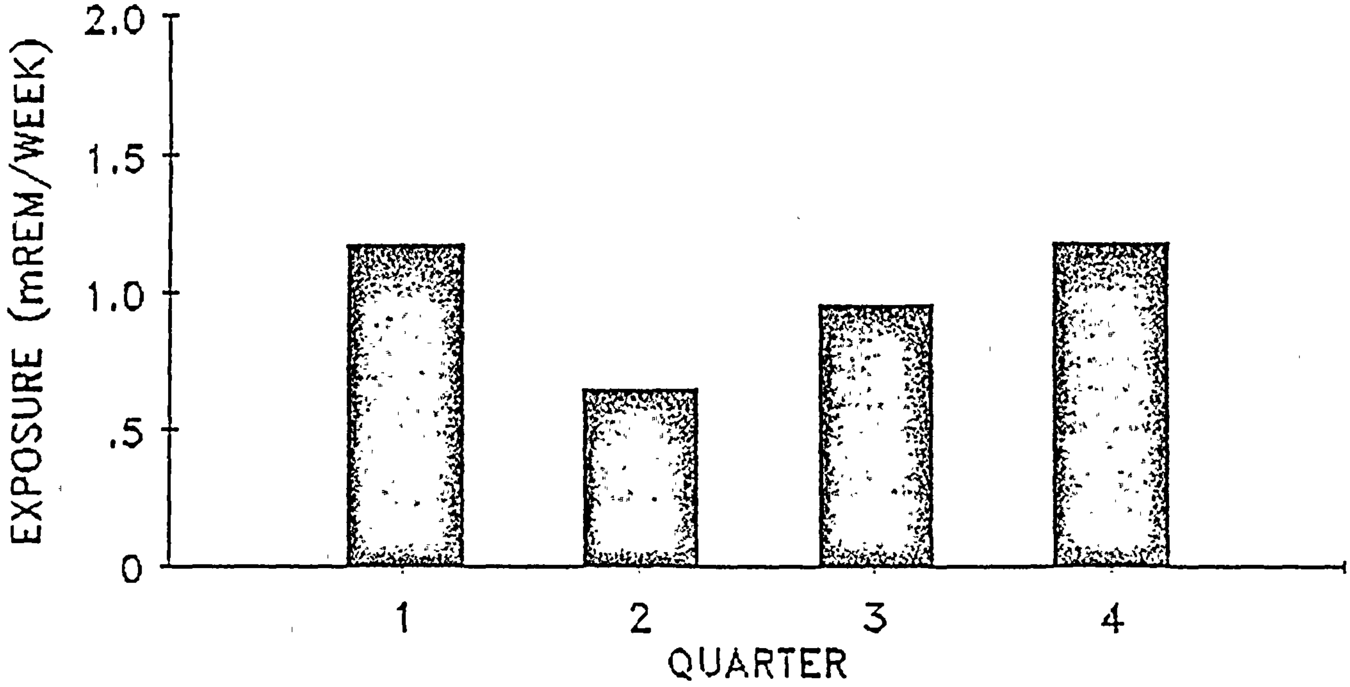


Figure 19
QUARTERLY THERMOLUMINESCENT DOSIMETRY
LOCATION ONS-6
1986

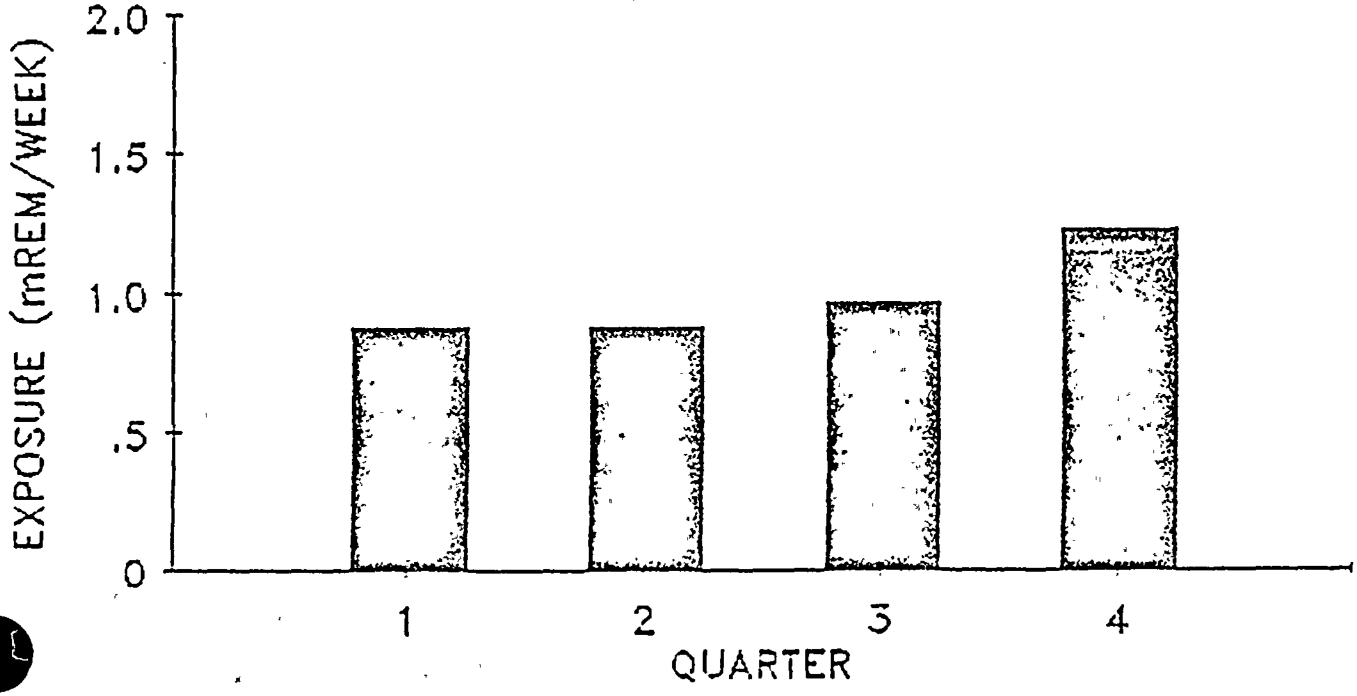


Figure 20
QUARTERLY THERMOLUMINESCENT DOSIMETRY
LOCATION ONS-7
1986

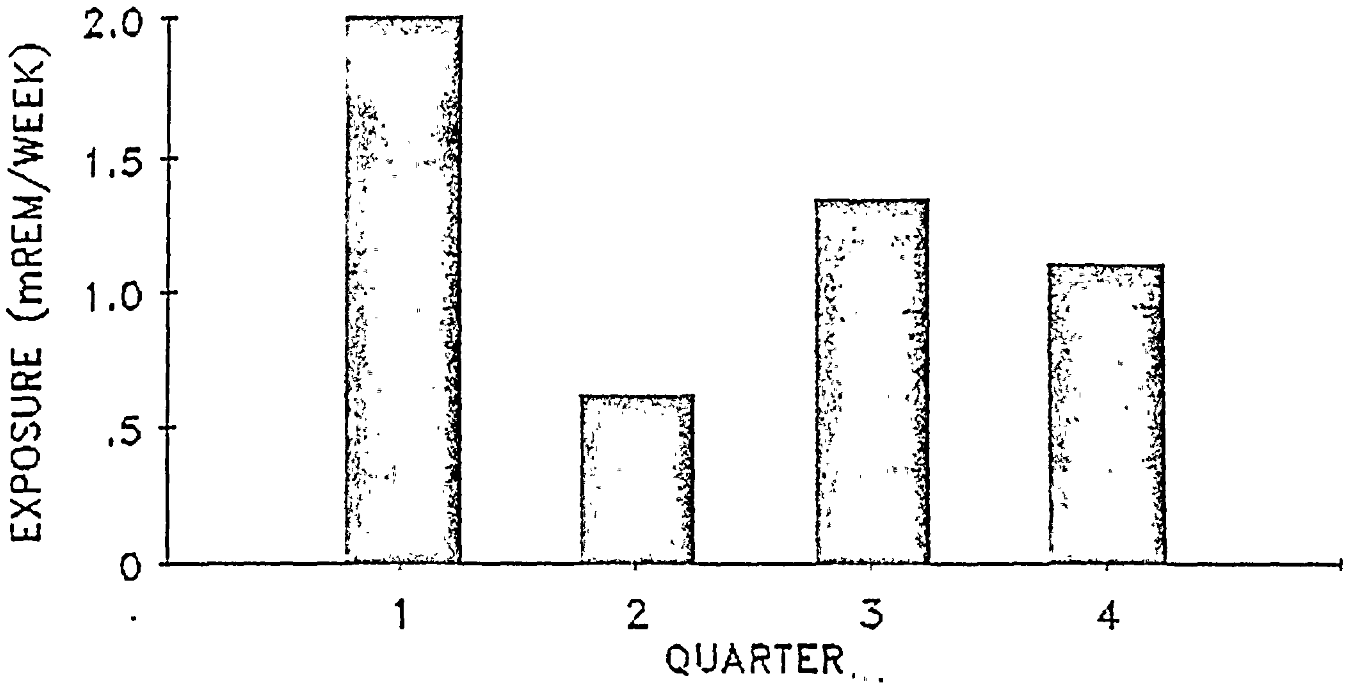


Figure 21
QUARTERLY THERMOLUMINESCENT DOSIMETRY
LOCATION ONS-8
1986

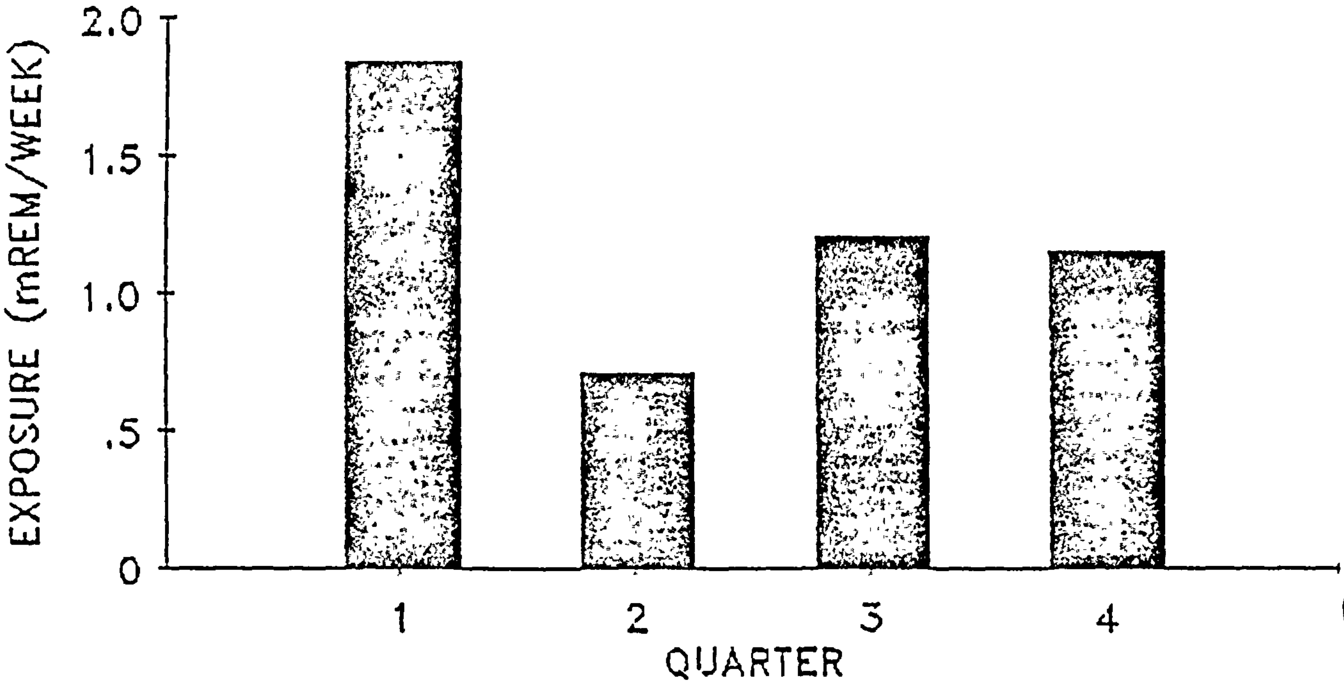


Figure 22
QUARTERLY THERMOLUMINESCENT DOSIMETRY
LOCATION ONS-9
1986

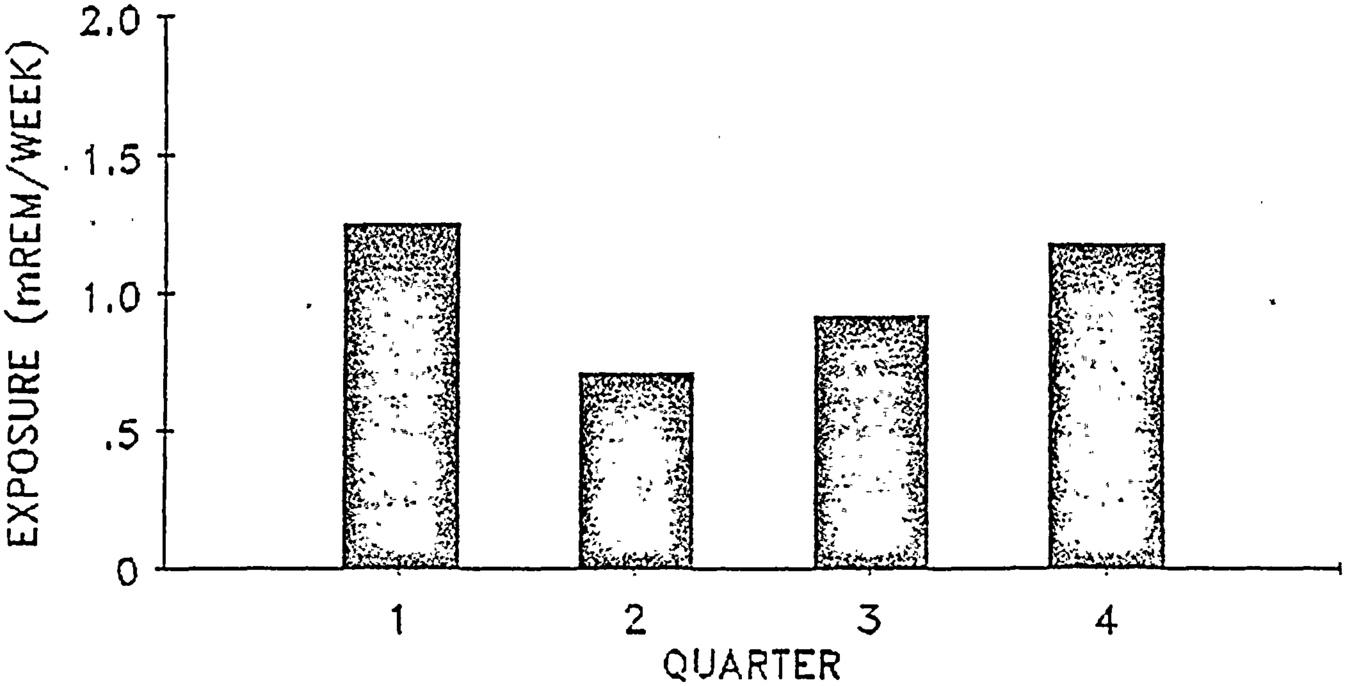


Figure 23
QUARTERLY THERMOLUMINESCENT DOSIMETRY
LOCATION OFS-1
1986

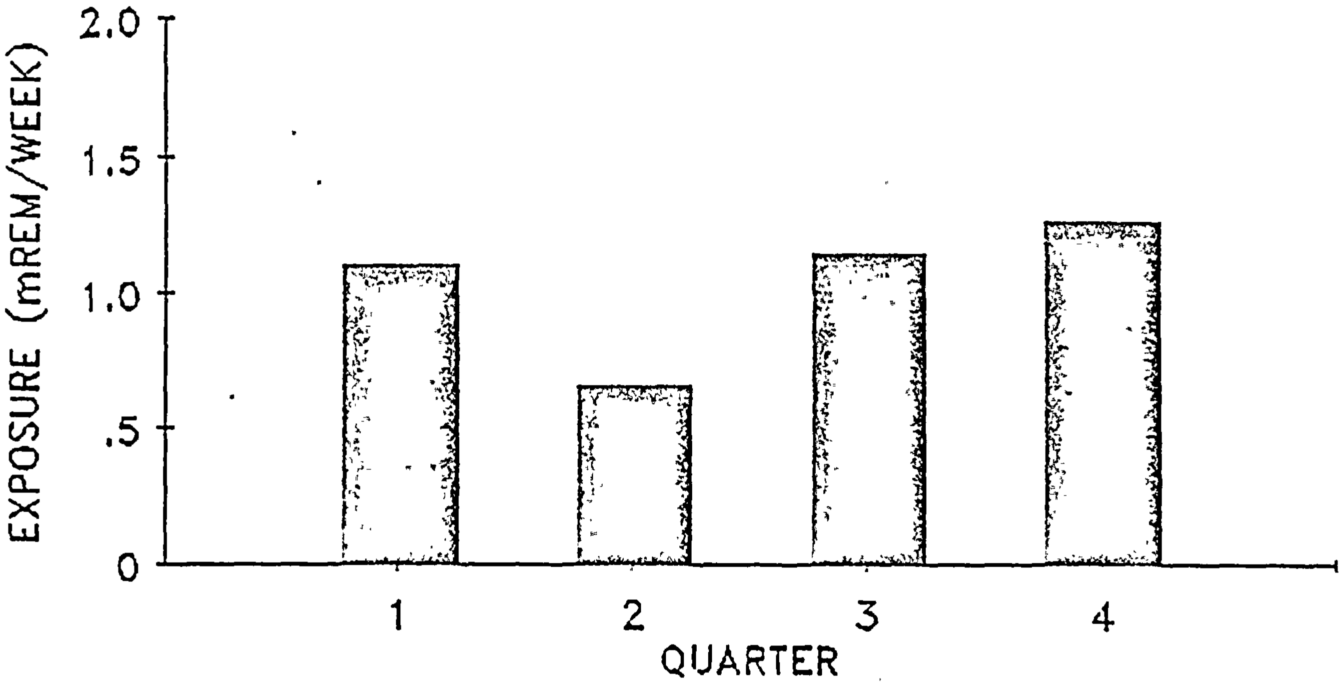


Figure 24
QUARTERLY THERMOLUMINESCENT DOSIMETRY
LOCATION OFS-2
1986

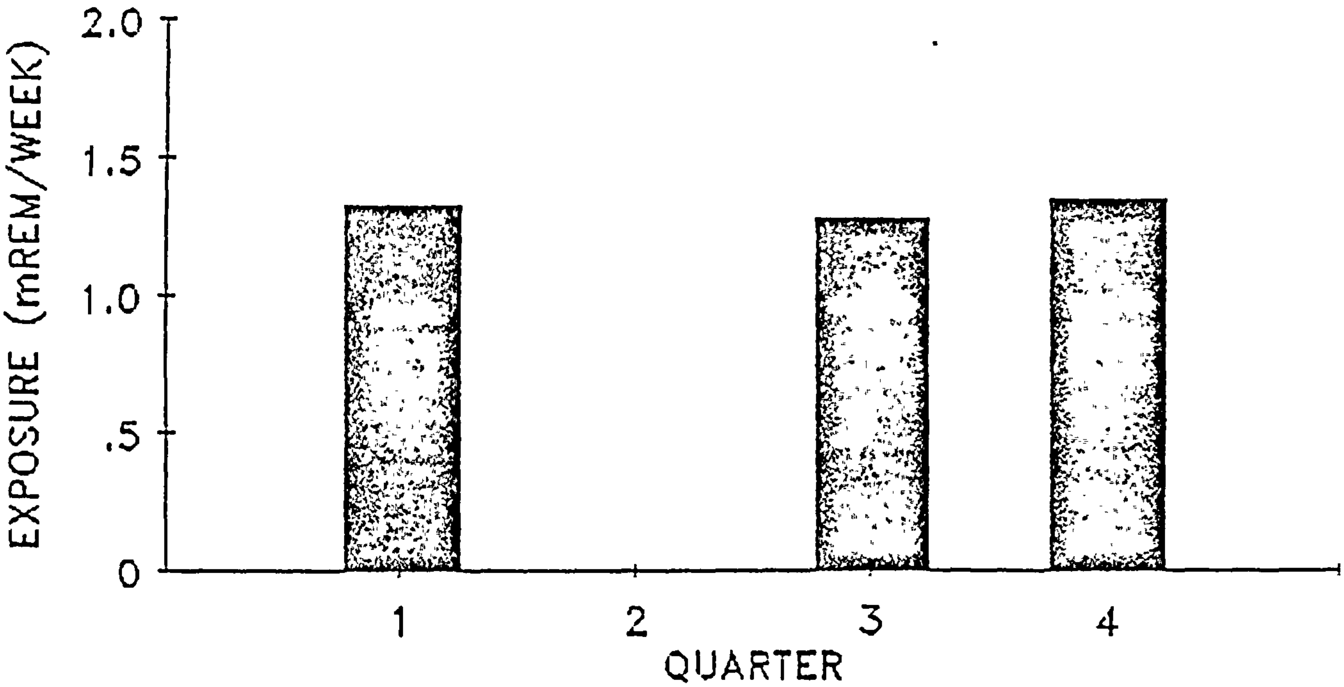


Figure 25
QUARTERLY THERMOLUMINESCENT DOSIMETRY
LOCATION OFS-3
1986

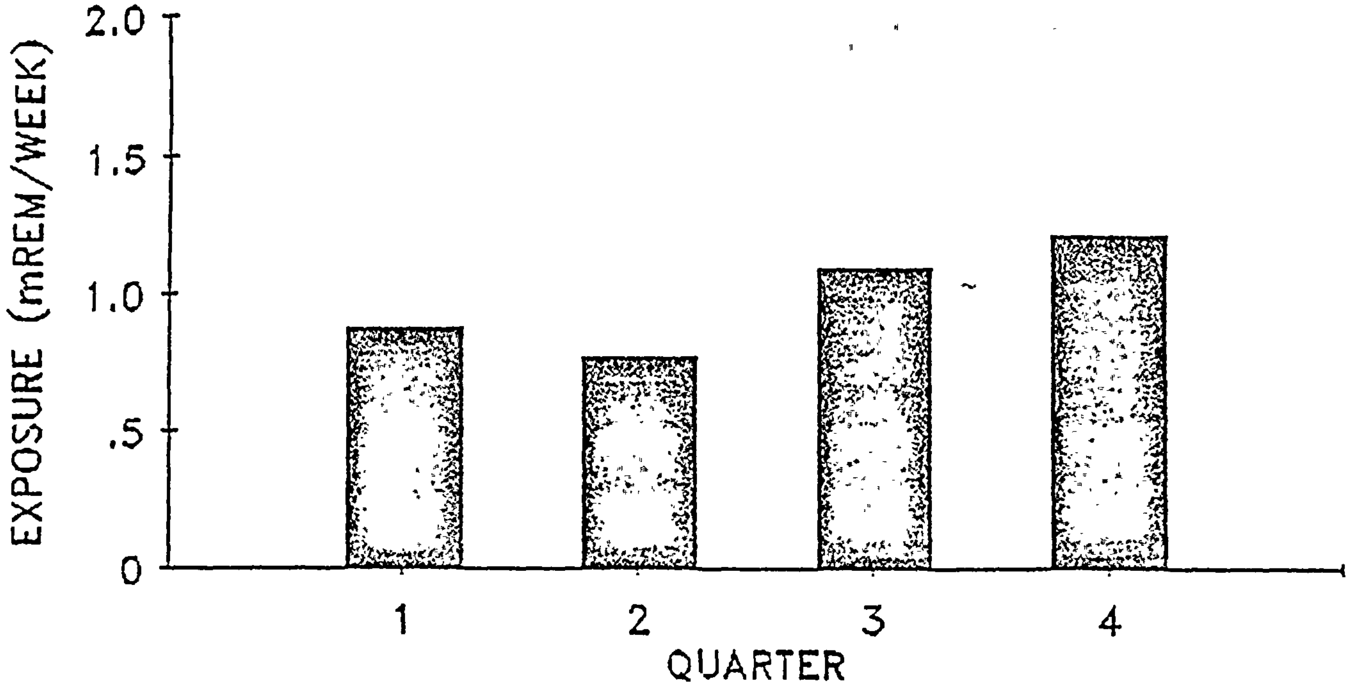


Figure 26
QUARTERLY THERMOLUMINESCENT DOSIMETRY
LOCATION OFS-4
1986

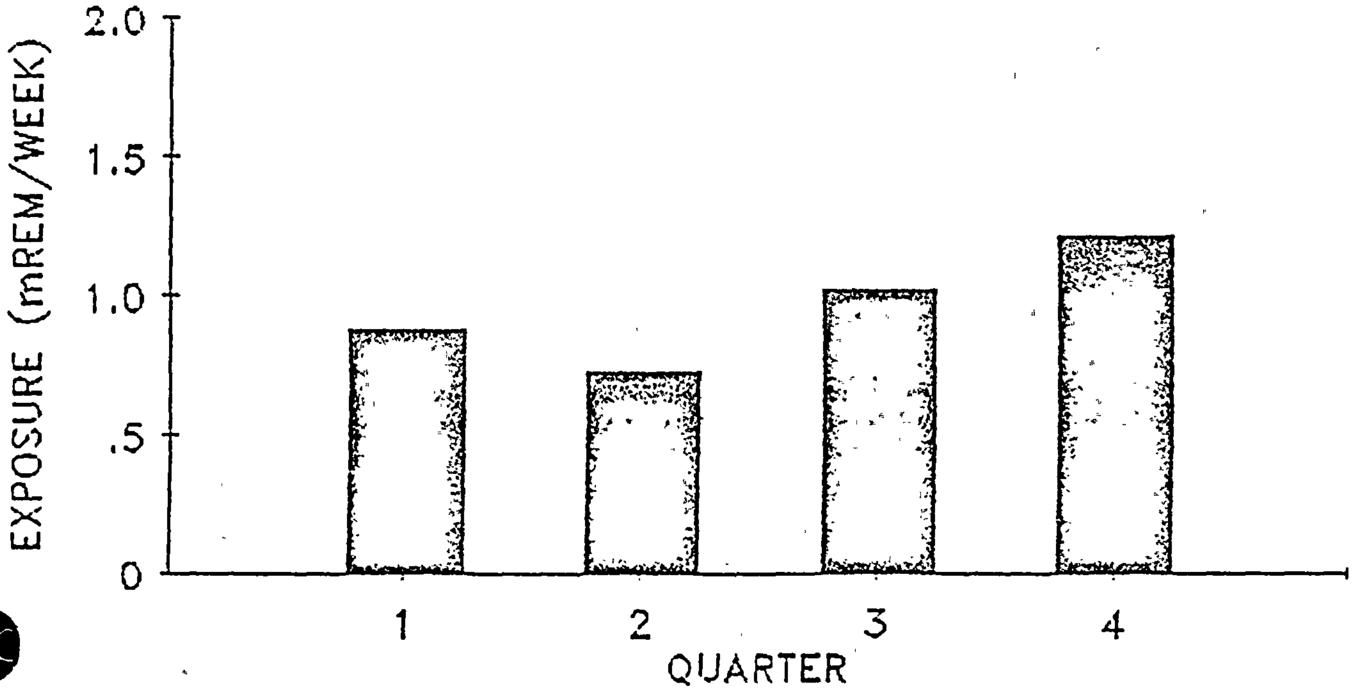


Figure 27
QUARTERLY THERMOLUMINESCENT DOSIMETRY
LOCATION OFS-5
1986

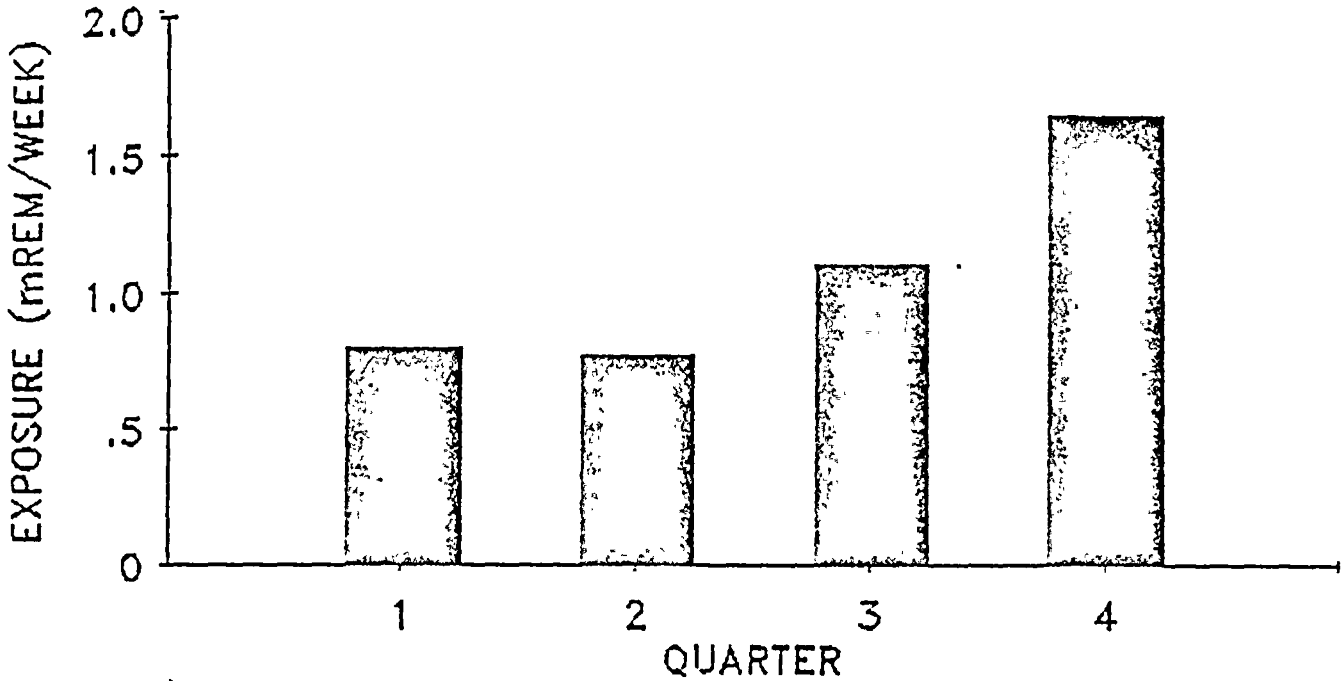


Figure 28
QUARTERLY THERMOLUMINESCENT DOSIMETRY
LOCATION OFS-6
1986

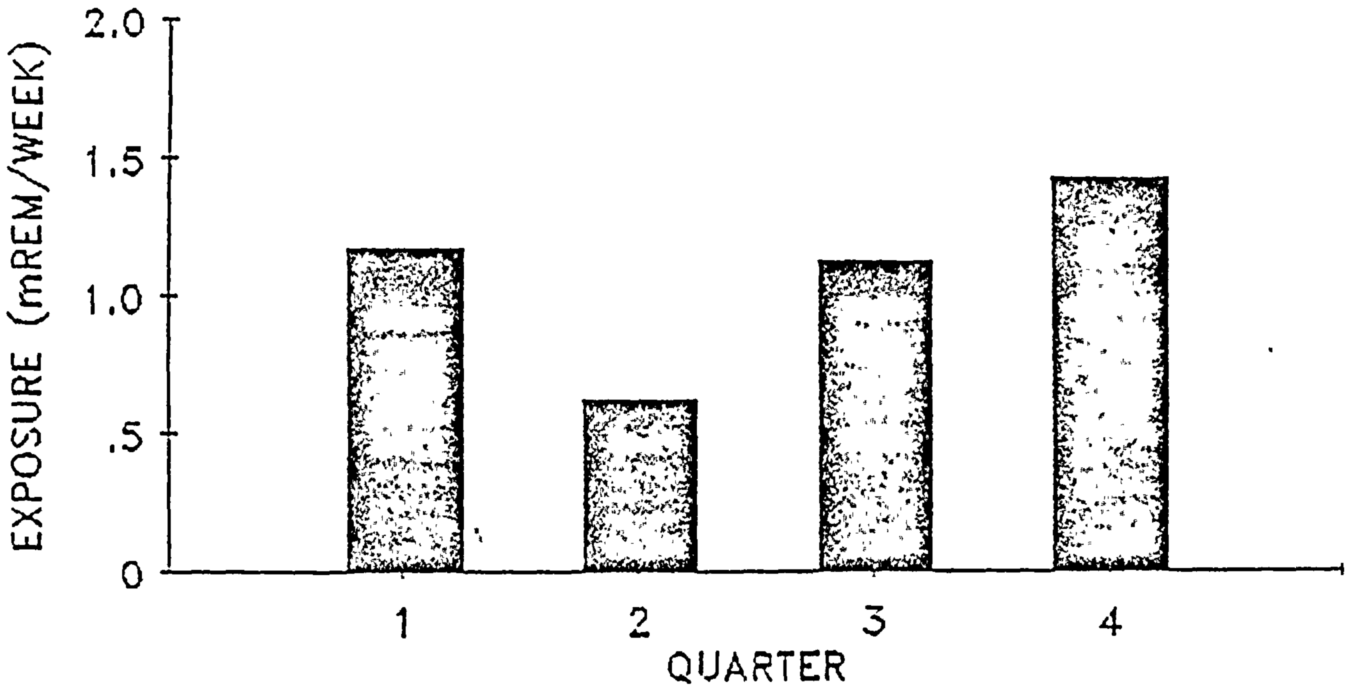


Figure 29
QUARTERLY THERMOLUMINESCENT DOSIMETRY
LOCATION OFS-7
1986

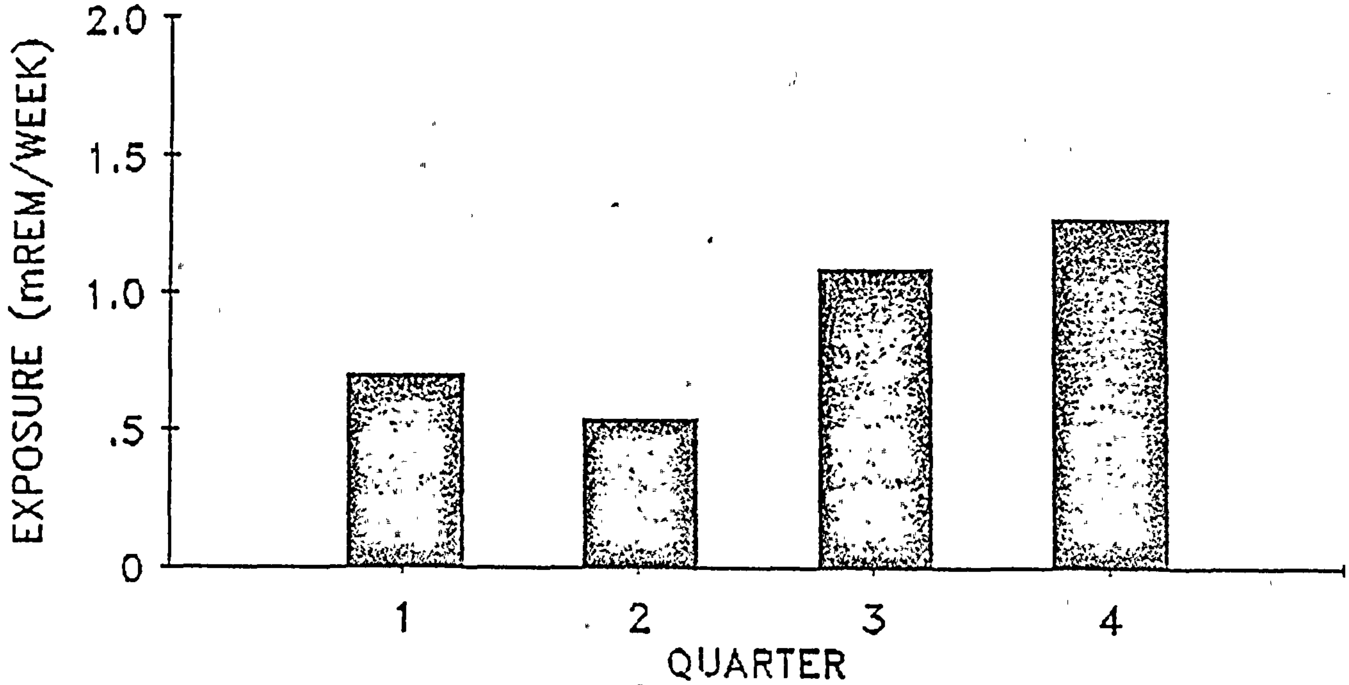


Figure 30
QUARTERLY THERMOLUMINESCENT DOSIMETRY
LOCATION OFS-8
1986

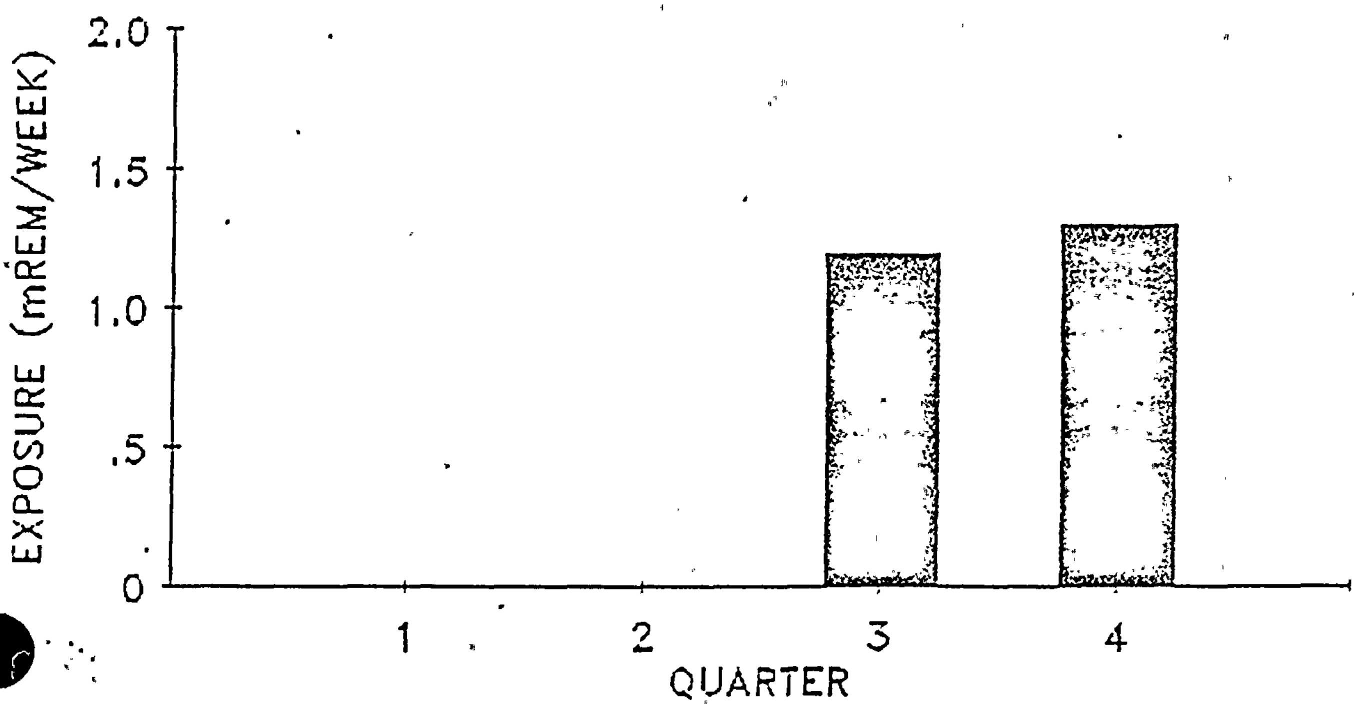


Figure 31
QUARTERLY THERMOLUMINESCENT DOSIMETRY
LOCATION OFS-9
1986

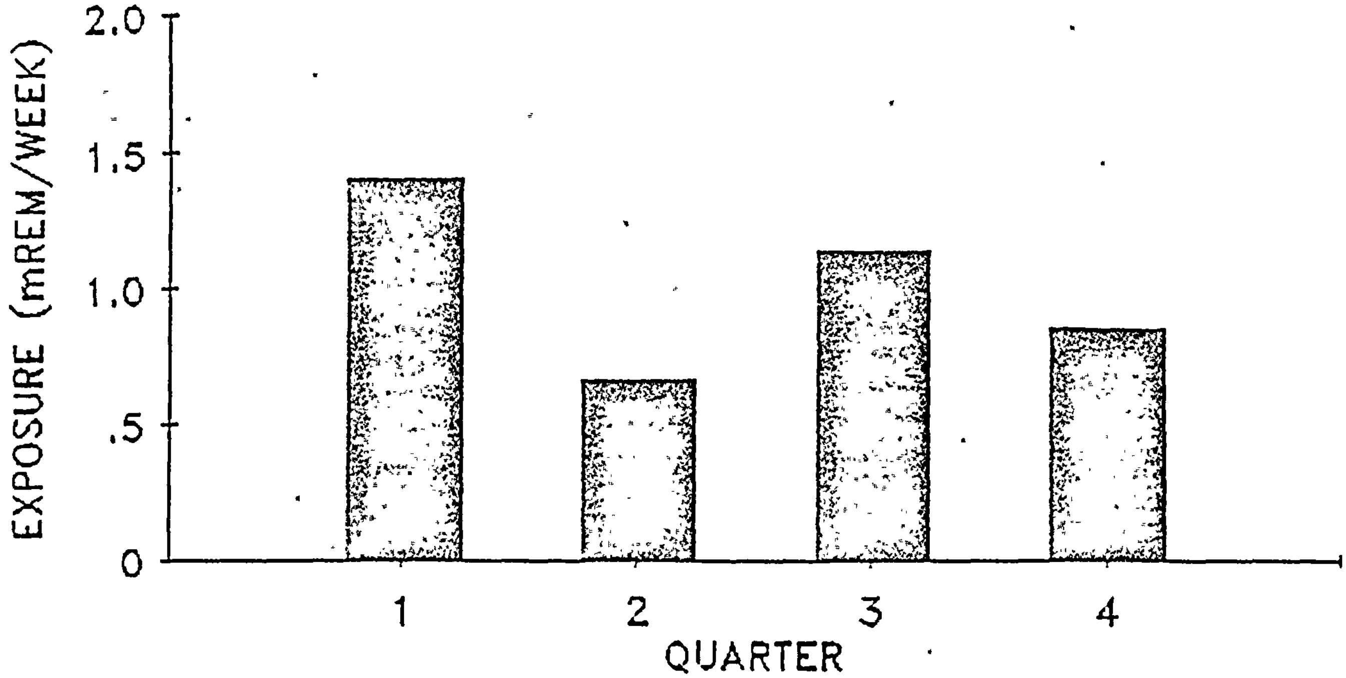


Figure 32
QUARTERLY THERMOLUMINESCENT DOSIMETRY
LOCATION OFS-10
1986

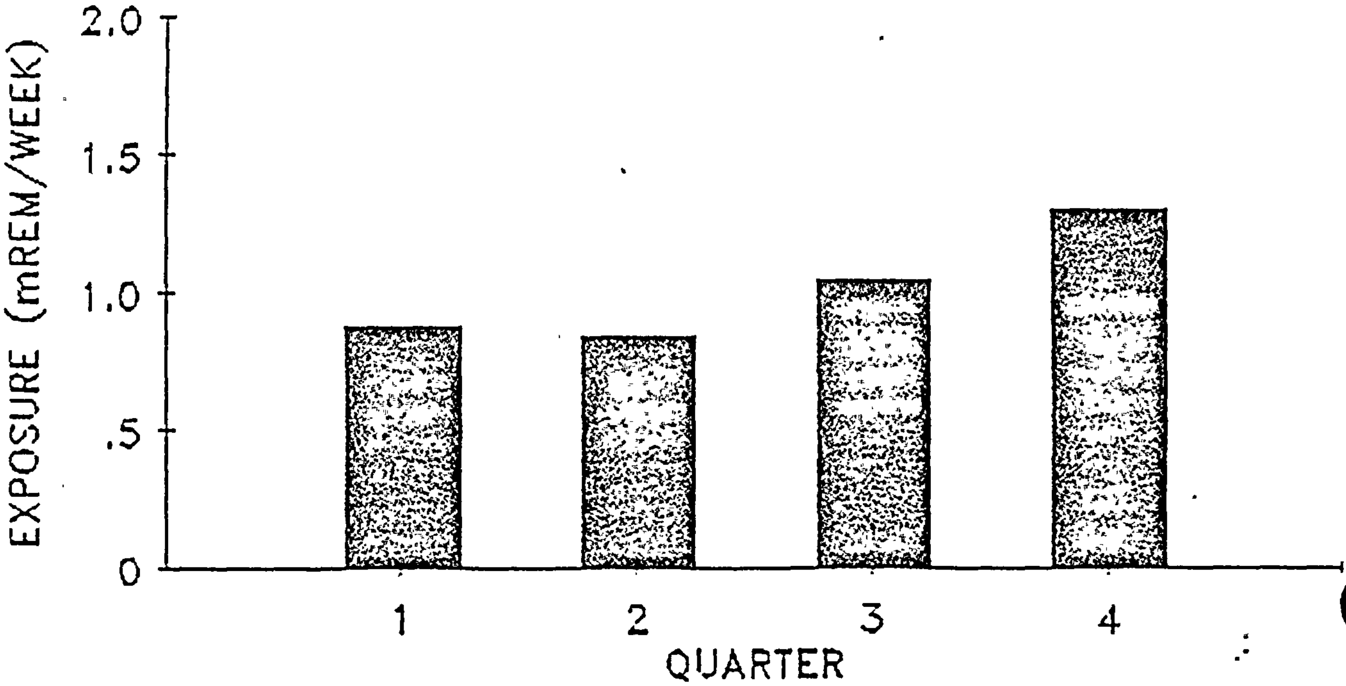


Figure 33
QUARTERLY THERMOLUMINESCENT DOSIMETRY
LOCATION NBF
1986

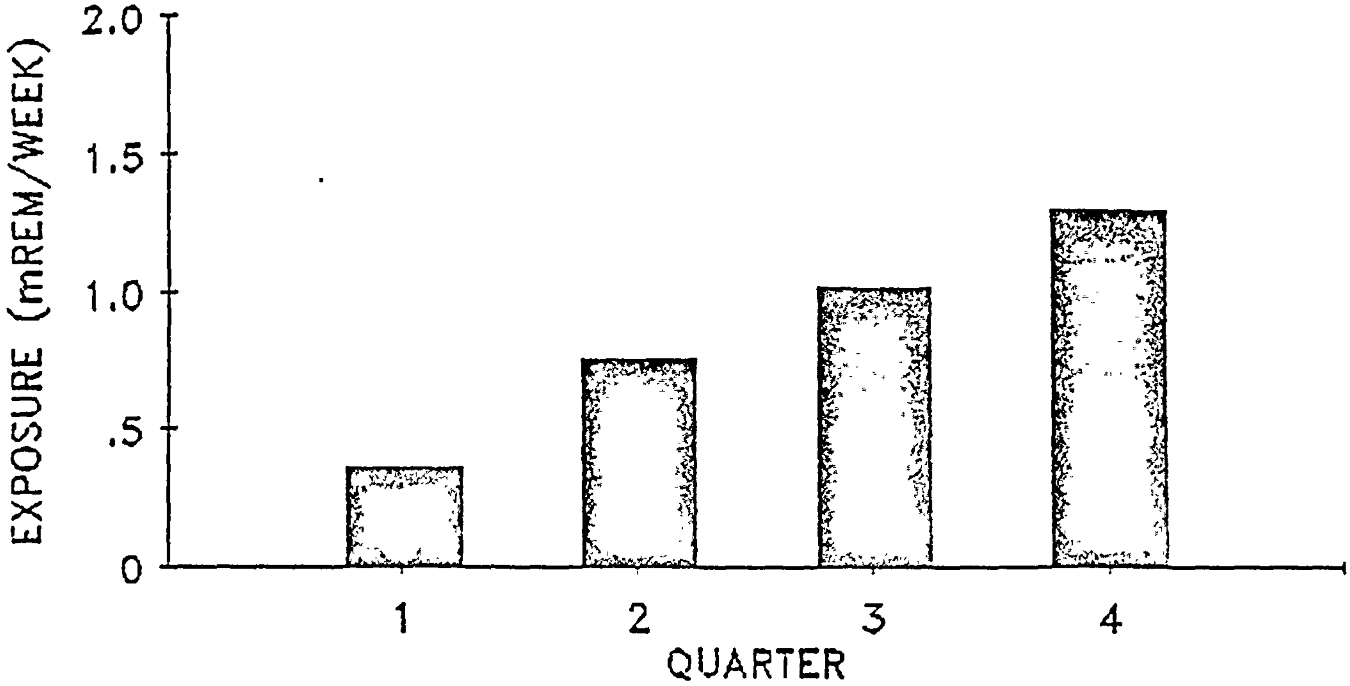


Figure 34
QUARTERLY THERMOLUMINESCENT DOSIMETRY
LOCATION SBN
1986

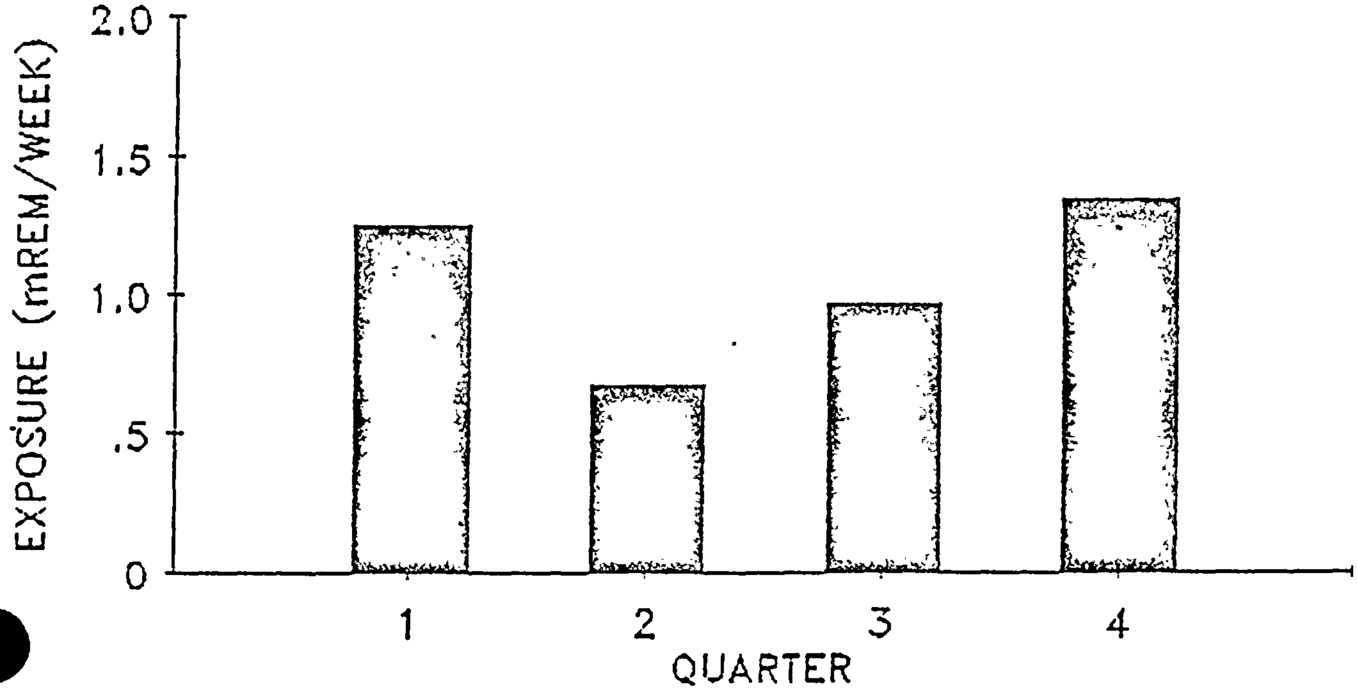


Figure 35
QUARTERLY THERMOLUMINESCENT DOSIMETRY
LOCATION DOW
1986

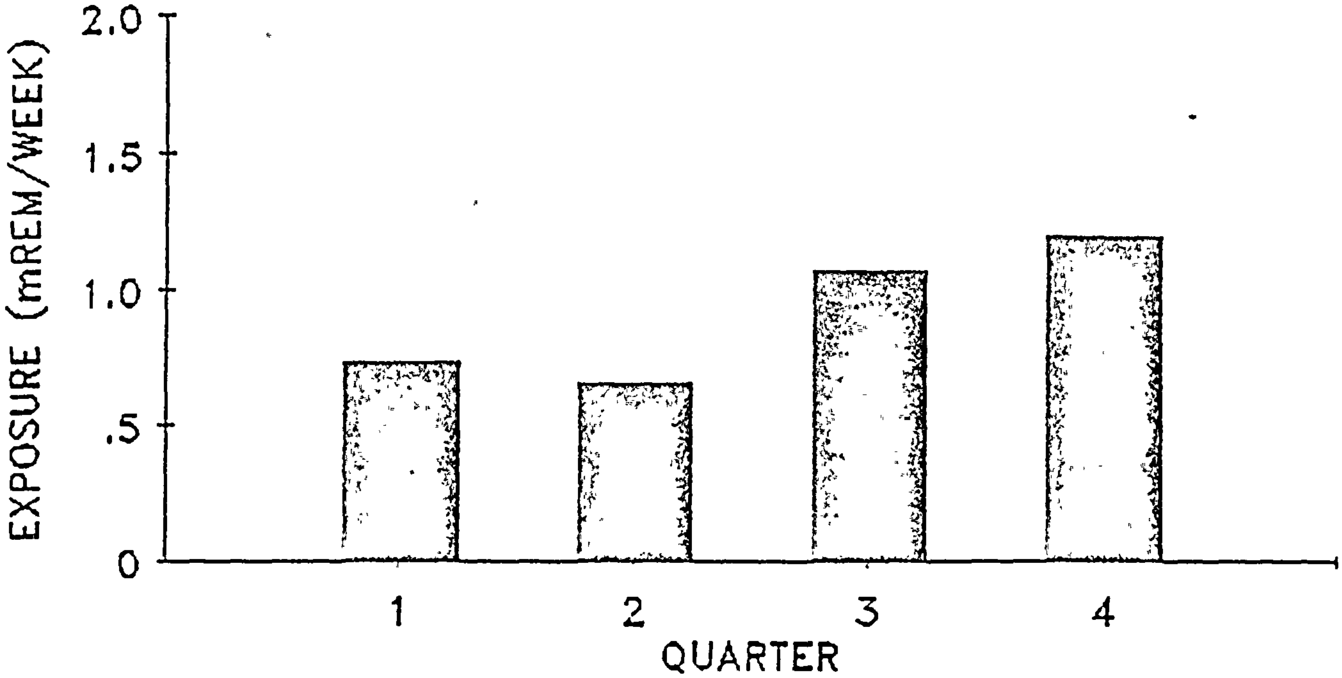
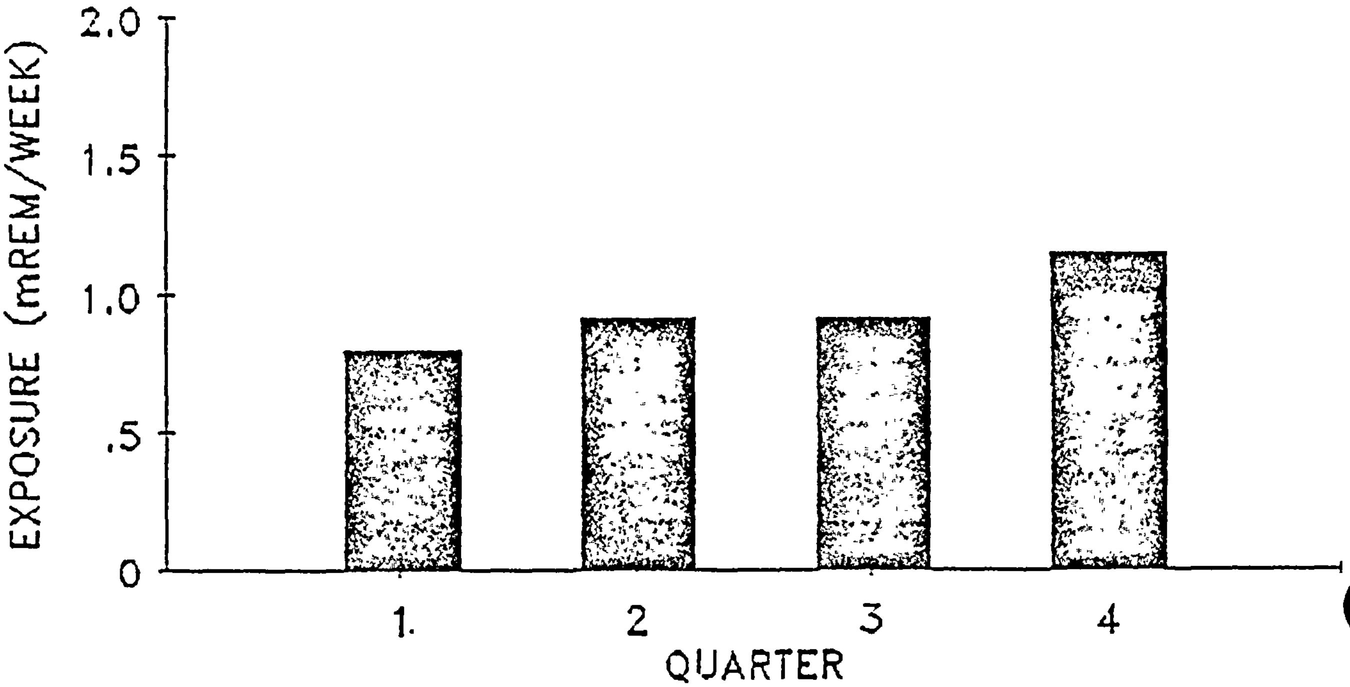


Figure 36
QUARTERLY THERMOLUMINESCENT DOSIMETRY
LOCATION COL
1986



7.4 Milk (Fresh)

Fresh milk samples were collected on a twice monthly basis during 1986 from the following locations:

1. Schuler Farm
2. Totzke Farm
3. Lozmack Farm
4. Wyant Farm
5. Livinghouse Farm

Beginning November 21, 1986, two new milk sampling locations were added to the program. These are the Zelmer Farm and the Warmbien Farm.

All milk samples were analyzed for Iodine-131 and Gamma-emitting nuclides. Results of these analyses are presented in Table XVIII through XXXI.

Iodine-131 was detected in the milk samples during the period 05/24/86-06/21/86; activity which is directly attributable to the radioactive plume caused by the Chernobyl accident. Activity during that period ranged from less than the lower limit of detection (0.4 pCi/l) at the Totzke Farm (06/07/86) to a high of 22.2 pCi/l at the Wyant Farm (05/24/86). All other samples during 1986 were less than the lower limit of detection.

Gamma-emitting nuclides of interest remain below the level of detection for all milk samples collected in 1986, with the exception of one sample. The sample was collected at the Lozmack Farm on 08/16/86 and indicated Cesium-137 activity of 11.3 $\pm$ 4.7 pCi/l, but it is less than the detection limit (18 pCi/l) of Cook Plant Technical specification 3.12.1, Table 4.12-1.

TABLE XVIII
FRESH MILK

Sample Location	Collection Date	Radiochemical (pCi/l) I-131
Schuler Farm	01/11/86	< 0.4
	01/18/86	< 0.4
	02/01/86	< 0.4
	02/15/86	< 0.4
	03/01/86	< 0.4
	03/15/86	< 0.4
	03/29/86	< 0.4
	04/12/86	< 0.4
	04/26/86	< 0.4
	05/10/86	< 0.4
	05/24/86	5.7 ± 0.9
	06/07/86	1.1 ± 0.8
	06/21/86	0.7 ± 0.5
	07/05/86	< 0.4
	07/19/86	< 0.4
	08/02/86	< 0.4
	08/16/86	< 0.4
	09/02/86	< 0.4
	09/13/86	< 0.4
	09/27/86	< 0.4
	10/11/86	< 0.4
	10/25/86	< 0.4
	11/07/86	< 0.4
	11/21/86	< 0.4
	12/05/86	< 0.4
	12/19/86	< 0.4

TABLE XIX
FRESH MILK
GAMMA SPECTROMETRY

Sample Location	Collection Date	pCi/l Cs-134 5*	Cs-137 4*	Mn-54 2*	Co-58 3*	Co-60 5*	Zr,Nb-95 8*	Fe-59 3*	Zn-65 16*	Ba,La-140 4*
Schuler Farm	01/11/86									
	01/18/86									
	02/01/86									
	02/15/86									
	03/01/86									
	03/29/86									
	04/12/86									
	04/26/86									
	05/10/86									
	05/24/86									
	06/07/86	LESS THAN LOWER LIMIT OF DETECTION								
	06/21/86									
	07/05/86									
	07/19/86									
	08/02/86									
	08/16/86									
	09/02/86									
	09/13/86									
	09/27/86									
	10/11/86									
	10/25/86									
	11/07/86									
	11/21/86									
	12/05/86									
	12/19/86									

*Lower limit of detection

TABLE XX
FRESH MILK

Sample Location	Collection Date	Radiochemical (pCi/l) I-131
Totzke Farm	01/11/86	< 0.4
	01/18/86	< 0.4
	02/01/86	< 0.4
	02/15/86	< 0.4
	03/01/86	< 0.4
	03/15/86	< 0.4
	03/29/86	< 0.4
	04/12/86	< 0.4
	04/26/86	< 0.4
	05/10/86	< 0.4
	05/24/86	0.8 ± 0.7
	06/07/86	< 0.4
	06/21/86	1.6 ± 0.7
	07/05/86	< 0.4
	07/19/86	< 0.4
	08/02/86	< 0.4
	08/16/86	< 0.4
	09/02/86	< 0.4
	09/13/86	< 0.4
	09/27/86	< 0.4
	10/11/86	< 0.4
	10/25/86	< 0.4
	11/07/86	< 0.4
	11/21/86	< 0.4
	12/05/86	< 0.4
	12/19/86	< 0.4

TABLE XXI

FRESH MILK

GAMMA SPECTROMETRY

Sample Location	Collection Date	Cs-134 5*	Cs-137 4*	Mn-54 2*	Co-58 3*	Co-60 5*	Zr,Nb-95 8*	Fe-59 3*	Zn-65 16*	Ba,La-140 4*
		pCi/l								
Totzke Farm	01/11/86									
	01/18/86									
	02/01/86									
	02/15/86									
	03/01/86									
	03/29/86									
	04/12/86									
	04/26/86									
	05/10/86									
	05/24/86									
	06/07/86	LESS THAN LOWER LIMIT OF DETECTION								
	06/21/86									
	07/05/86									
	07/19/86									
	08/02/86									
	08/16/86									
	09/02/86									
	09/13/86									
	09/27/86									
	10/11/86									
	10/25/86									
	11/07/86									
	11/21/86									
	12/05/86									
	12/19/86									

*Lower limit of detection

TABLE XXII

FRESH MILK

Sample Location	Collection Date	Radiochemical (pCi/l) I-131
Lozmack Farm	01/11/86	< 0.4
	01/19/86	< 0.4
	02/02/86	< 0.4
	02/16/86	< 0.4
	03/03/86	< 0.4
	03/15/86	< 0.4
	03/29/86	< 0.4
	04/13/86	< 0.4
	04/26/86	< 0.4
	05/11/86	< 0.4
	05/25/86	1.3 ± 0.7
	06/07/86	2.4 ± 0.8
	06/21/86	1.2 ± 0.7
	07/05/86	< 0.4
	07/19/86	< 0.4
	08/02/86	< 0.4
	08/16/86	< 0.4
	09/02/86	< 0.4
	09/13/86	< 0.4
	09/27/86	< 0.4
	10/11/86	< 0.4
	10/25/86	< 0.4
	11/07/86	< 0.4
	11/21/86	< 0.4
	12/05/86	< 0.4
	12/19/86	< 0.4

TABLE XXIII

FRESH MILK

GAMMA SPECTROMETRY

Sample Location	Collection Date	Cs-134 5*	Cs-137 4*	Mn-54 2*	Co-58 3*	Co-60 5*	Zr,Nb-95 8*	Fe-59 3*	Zn-65 16*	Ba,La-140 4*
		pCi/l								
Lozinack Farm	01/11/86	**	**	**	**	**	**	**	**	**
	01/19/86	**	**	**	**	**	**	**	**	**
	02/02/86	**	**	**	**	**	**	**	**	**
	02/16/86	**	**	**	**	**	**	**	**	**
	03/03/86	**	**	**	**	**	**	**	**	**
	03/15/86	**	**	**	**	**	**	**	**	**
	03/29/86	**	**	**	**	**	**	**	**	**
	04/13/86	**	**	**	**	**	**	**	**	**
	04/26/86	**	**	**	**	**	**	**	**	**
	05/11/86	**	**	**	**	**	**	**	**	**
	05/25/86	**	**	**	**	**	**	**	**	**
	06/07/86	**	**	**	**	**	**	**	**	**
	06/21/86	**	**	**	**	**	**	**	**	**
	07/05/86	**	**	**	**	**	**	**	**	**
	07/19/86	**	**	**	**	**	**	**	**	**
	08/02/86	**	**	**	**	**	**	**	**	**
	08/16/86	**	11.3±4.7	**	**	**	**	**	**	**
	09/02/86	**	**	**	**	**	**	**	**	**
	09/13/86	**	**	**	**	**	**	**	**	**
	09/27/86	**	**	**	**	**	**	**	**	**
	10/11/86	**	**	**	**	**	**	**	**	**
	10/25/86	**	**	**	**	**	**	**	**	**
	11/07/86	**	**	**	**	**	**	**	**	**
	11/21/86	**	**	**	**	**	**	**	**	**
	12/05/86	**	**	**	**	**	**	**	**	**
	12/19/86	**	**	**	**	**	**	**	**	**

*Lower limit of detection
**Less than lower limit of detection

TABLE XXIV

FRESH MILK

Sample Location	Collection Date	Radiochemical (pCi/l) I-131
Wyant Farm	01/11/86	< 0.4
	01/18/86	< 0.4
	02/01/86	< 0.4
	02/15/86	< 0.4
	03/01/86	< 0.4
	03/15/86	< 0.4
	03/29/86	< 0.4
	04/12/86	< 0.4
	04/26/86	< 0.4
	05/10/86	< 0.4
	05/24/86	22.2 ± 1.3
	06/07/86	22.1 ± 1.3
	06/21/86	2.5 ± 0.7
	07/05/86	< 0.4
	07/19/86	< 0.4
	08/02/86	< 0.4
	08/16/86	< 0.4
	09/02/86	< 0.4
	09/13/86	< 0.4
	09/27/86	< 0.4
	10/11/86	< 0.4
	10/25/86	< 0.4
	11/07/86	< 0.4
	11/21/86	< 0.4
	12/05/86	< 0.4
	12/19/86	< 0.4

TABLE XXV

FRESH MILK

GAMMA SPECTROMETRY

Sample Location	Collection Date	pCi/l Cs-134 5*	Cs-137 4*	Mn-54 2*	Co-58 3*	Co-60 5*	Zr,Nb-95 8*	Fe-59 3*	Zn-65 16*	Ba,La-140 4*
Wyant Farm	01/11/86									
	01/18/86									
	02/01/86									
	02/15/86									
	03/01/86									
	03/15/86									
	03/29/86									
	04/12/86									
	04/26/86									
	05/10/86									
	05/24/86									
	06/07/86	LESS THAN LOWER LIMIT OF DETECTION								
	06/21/86									
	07/05/86									
	07/19/86									
	08/02/86									
	08/16/86									
	09/02/86									
	09/13/86									
	09/27/86									
	10/11/86									
	10/25/86									
	11/07/86									
	11/21/86									
	12/05/86									
	12/19/86									

*Lower limit of detection

TABLE XXVI

FRESH MILK

Sample Location	Collection Date	Radiochemical (pCi/l) I-131
Livinghouse Farm	01/11/86	< 0.4
	01/18/86	< 0.4
	02/01/86	< 0.4
	02/15/86	< 0.4
	03/01/86	< 0.4
	03/15/86	< 0.4
	03/29/86	< 0.4
	04/12/86	< 0.4
	04/26/86	< 0.4
	05/10/86	< 0.4
	05/25/86	2.9 ± 0.8
	06/07/86	11.0 ± 1.1
	06/21/86	2.3 ± 0.7
	07/05/86	< 0.4
	07/19/86	< 0.4
	08/02/86	< 0.4
	08/16/86	< 0.4
	09/02/86	< 0.4
	09/13/86	< 0.4
	09/27/86	< 0.4
	10/11/86	< 0.4
	10/25/86	< 0.4
	11/07/86	< 0.4
	11/21/86	< 0.4
	12/05/86	< 0.4
	12/19/86	< 0.4

TABLE XXVII

FRESH MILK

GAMMA SPECTROMETRY

Sample Location	Collection Date	pCi/l Cs-134 5*	Cs-137 4*	Mn-54 2*	Co-58 3*	Co-60 5*	Zr,Nb-95 8*	Fe-59 3*	Zn-65 16*	Ba,La-140 4*
Livinghouse Farm	01/11/86									
	01/18/86									
	02/01/86									
	02/15/86									
	03/01/86									
	03/15/86									
	03/29/86									
	04/12/86									
	04/26/86									
	05/10/86									
	05/25/86									
	06/07/86	LESS THAN LOWER LIMIT OF DETECTION								
	06/21/86									
	07/05/86									
	07/19/86									
	08/02/86									
	08/16/86									
	09/02/86									
	09/13/86									
	09/27/86									
	10/11/86									
	10/25/86									
	11/07/86									
	11/21/86									
	12/05/86									
	12/19/86									

*Lower limit of detection

TABLE XXVIII

FRESH MILK

Sample Location	Collection Date	Radiochemical (pCi/l) I-131
Zelmer Farm	11/21/86*	< 0.4
	12/05/86	< 0.4
	12/19/86	< 0.4

*First collection date

TABLE XXIX

FRESH MILK

GAMMA SPECTROMETRY

Sample Location	Collection Date	pCi/l								
		Cs-134 5*	Cs-137 4*	Mn-54 2*	Co-58 3*	Co-60 5*	Zr,Nb-95 8*	Fe-59 3*	Zn-65 16*	Ba,La-140 4*
Zelmer Farm	11/21/86									
	12/05/86									
	12/19/86									

LESS THAN LOWER LIMIT OF DETECTION

*Lower limit of detection

TABLE XXX
FRESH MILK

Sample Location	Collection Date	Radiochemical (pCi/l) I-131
Warmbien Farm	11/21/86*	< 0.4
	12/05/86	< 0.4
	12/19/86	< 0.4

*First collection date

TABLE XXXI

FRESH MILK

GAMMA SPECTROMETRY

Sample Location	Collection Date	Cs-134 5*	Cs-137 4*	Mn-54 2*	Co-58 3*	Co-60 5*	Zr,Nb-95 8*	Fe-59 3*	Zn-65 16*	Ba,La-140 4*
		pCi/l								
Warmbien Farm	11/21/86									
	12/05/86									
	12/19/86									

LESS THAN LOWER LIMIT OF DETECTION

*Lower limit of detection

7.5 Groundwater

Quarterly groundwater samples were collected from seven wells. All groundwater samples were analyzed for Tritium and Gamma-emitting nuclides. Results obtained from the analysis of the samples is presented in Tables XXXII and XXXIII.

Four groundwater sites; Well No. 4 - Onsite, Well No. 5 - Onsite, Well No. 6 - Onsite and Well No. 7 -Livingston Beach exhibited tritium activity during 1986. These sites had activity ranging from 449±274 pCi/l at Well No. 7 - Livingston Beach (03/06/86) to 3012±300 pCi/l at Well No. 5 - Onsite (08/15/86). Well No. 5 was resampled on 08/21/86 and indicated tritium activity of 4734 ± 302 pCi/l. Well numbers 1, 2, and 3 had no tritium activity above the lower limit of detection (300 pCi/l) during 1986.

Gamma spectralanalysis of the groundwater samples revealed no gamma-emitting isotopes of interest.

TABLE XXXII

GROUNDWATER

Sample Location	Collection Date	Radiochemical (pCi/l) Tritium pCi/l
Well No. 1 - Rosemary Beach	03/06/86	< 300
	06/06/86	< 300
	08/15/86	< 300
	10/09/86	< 300
Well No. 2 - Scrapyard	03/06/86	< 300
	06/06/86	< 300
	08/15/86	< 300
	10/09/86	< 300
Well No. 3 - MSU Trailer	03/06/86	< 300
	06/06/86	< 300
	08/15/86	< 300
	10/09/86	< 300
Well No. 4 - Onsite	03/06/86	< 300
	06/06/86	1249±207*
	08/15/86	2500±295*
	10/09/86	2274±320*
Well No. 5 - Onsite	03/06/86	< 300
	06/06/86	1466±210*
	08/15/86	3012±300*
	08/21/86	4734±302*
	10/09/86	2167±370*
Well No. 6 - Onsite	03/06/86	< 300
	06/06/86	< 300
	08/15/86	965±280*
	10/09/86	< 300
Well No. 7 - Livingston Beach	03/06/86	449±274*
	06/06/86	717±205*
	08/15/86	1530±288
	10/09/86	2412±300*

*Verified by reanalysis

TABLE XXXIII

GROUNDWATER

GAMMA SPECTROMETRY

Sample Location	Collection Date	pCi/l								
		Cs-134 7*	Cs-137 2*	Mn-54 2*	Co-58 5*	Co-60 5*	Zr,Nb-95 5*	Fe-59 3*	Zn-65 15*	Ba,La-140 4*
Well No. 1 Rosemary Beach	03/06/86									
	06/06/86									
	08/15/86									
	10/09/86									
Well No. 2 Scrapyard	03/06/86									
	06/06/86									
	08/15/86									
	10/09/86	LESS THAN LOWER LIMIT OF DETECTION								
Well No. 3 MSU Trailer	03/06/86									
	06/06/86									
	08/15/86									
	10/09/86									
Well No. 4 Onsite	03/06/86									
	06/06/86									
	08/15/86									
	10/09/86									
Well No. 5 Onsite	03/06/86									
	06/06/86									
	08/15/86									
	10/09/86									

*Lower limit of detection

TABLE XXXIII (Continued)

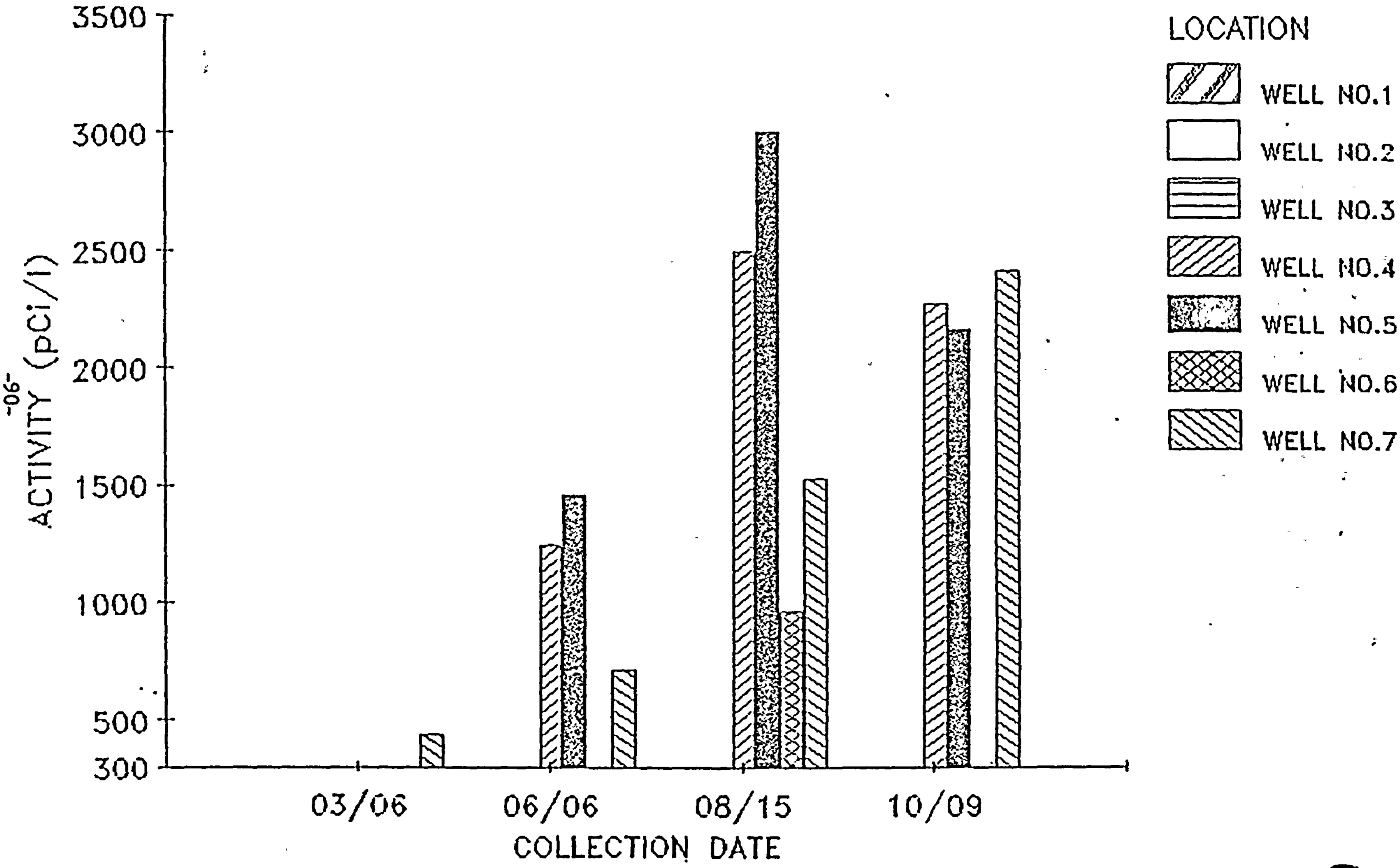
GROUNDWATER

GAMMA SPECTROMETRY

Sample Location	Collection Date	pCi/l Cs-134 7*	Cs-137 2*	Mn-54 2*	Co-58 5*	Co-60 5*	Zr,Nb-95 5*	Fe-59 3*	Zn-65 15*	Ba,La-140 4*
Well No. 6 Onsite	03/06/86									
	06/06/86									
	08/15/86									
	10/09/86									
Well No. 7 Livingston Beach	03/06/86	LESS THAN LOWER LIMIT OF DETECTION								
	06/06/86									
	08/15/86									
	10/09/86									

*Lower limit of detection

Figure 37
TRITIUM IN GROUNDWATER
1986



LLD=3 i/l

7.6 Vegetation

Five vegetation samples were collected from two sectors during 1986. All samples were analyzed for man-made gamma-emitting isotopes.

Table XXXIV presents the results of the gamma spectralanalysis of the vegetation samples. Gamma-emitting nuclides of interest were less than lower limit of detection.

TABLE XXXIV

VEGETATION

GAMMA SPECTROMETRY

Sample Identification	Date Collected	pCi/Kg (wet) Cs-134 60*	Cs-137 80*
Sector D			
Broad Leaf	08/13/86		
Grapes	08/20/86		
Grape Leaves	08/20/86	LESS THAN LOWER LIMIT OF DETECTION	
Sector B			
Grapes	08/20/86		
Grape Leaves	08/20/86		

*Lower limit of detection

7.7 Fish

Fish samples were collected from four locations on a twice yearly basis. Species of fish collected during 1986 include coho salmon, brown trout, white sucker, lake trout, and longnose sucker. Gamma spectralanalysis was performed on all fish samples. All results are in terms of pCi/Kg (wet). Table XXXV lists the results of analysis.

All samples collected on 05/15/86 indicated the presence of Cesium-137. Activity ranged from 48 ± 8 pCi/kg at the onsite - south sample point (Coho Salmon) to 291 ± 48 pCi/kg at the offsite - south sample point (brown trout/white sucker).

Two samples collected 09/17/86 indicated the presence of Cesium-137. The lake trout sample (ONS-S) had an activity of 32 ± 9 pCi/kg and the other lake trout sample (OFS-N) had an activity of 62 ± 8 pCi/kg.

All other gamma-emitting nuclides of interest were less than the lower limit of detection in the 1986 fish samples.

TABLE XXXV

FISH

GAMMA SPECTROMETRY

Location	Identification	Collection Date	pci/Kg (wet) Cs-134 40*	Cs-137 40*	Mn-54 60*	Co-58 60*	Co-60 30*	Fe-59 100*	Zn-65 100*
ONS-S	Coho Salmon	05/15/86	**	48±8	**	**	**	**	**
OFS-S	Brown Trout/ White Sucker	05/15/86	**	291±48	**	**	**	**	**
OFS-N	Coho Salmon	05/15/86	**	84±8	**	**	**	**	**
ONS-N	Coho Salmon	05/15/86	**	85±11	**	**	**	**	**
ONS-S	Lake Trout	09/17/86	**	32±9	**	**	**	**	**
OFS-S	Longnose Sucker/ White Sucker	09/17/86	**	**	**	**	**	**	**
OFS-N	Lake Trout	09/17/86	**	62±8	**	**	**	**	**
ONS-N	Longnose Sucker	09/17/86	**	**	**	**	**	**	**

*Lower limit of detection
**Less than lower limit of detection

Not[illegible] Cook Plant tech, spec. detection limit for Cs-137 is [illegible] pCi/kg (wet) and reportable level is 2,000 pCi/kg (wet).

7.8 Bottom Sediment

Bottom sediment samples were collected twice from two locations of Lake Michigan in 1986. Samples were analyzed for gamma-emitting nuclides. Table XXXVI lists the results of the gamma spectralanalysis.

One sample, LS-3 (05/30/86) indicated a Cesium-137 activity of 73±23 pCi/Kg, but it is less than the detection limit of 180 pCi/kg (dry) as per Cook Plant technical specification 3.12.1, Table 4.12-1.

All other gamma-emitting nuclides of interest were less than the lower limit of detection in the bottom sediment samples.

TABLE XXXVI

BOTTOM SEDIMENT

GAMMA SPECTROMETRY

		pCi/Kg (dry)							
Location	Collection Date	Cs-134 70*	Cs-137 40*	Mn-54 80*	Co-60 80*	Zr,Nb-95 40*	Fe-59 30*	Zn-65 100*	Ba,La-140 40*
LS-2	05/30/86	**	**	**	**	**	**	**	**
LS-3	05/30/86	**	73±23	**	**	**	**	**	**
LS-2	10/20/86	**	**	**	**	**	**	**	**
LS-3	10/20/86	**	**	**	**	**	**	**	**

*Lower limit of detection

**Less than lower limit of detection

7.9 Water

Three types of water samples are collected. Drinking water samples were collected from Lake Township, St. Joseph, and New Buffalo during 1986. Surface water samples were collected from North Lake and South Lake. Circulating water samples were also collected during 1986.

Tables XXXVII to XXXXII list the results of the analyses of the drinking water samples. Gross Beta activity for 1986 ranged from less than the lower limit of detection (2.0 pCi/l) to a high of 125 ± 3 pCi/l in the New Buffalo sample of 05/15/86. This sample indicated Cobalt-60 activity of 144 ± 10 pCi/l when analyzed by gamma spectrometry. This is the only anomalous sample from New Buffalo during 1986. All samples before and after 05/15/86 were routine and the composite sample that included the time-frame of the anomalous sample was routine.

Tritium analysis of the drinking water samples indicated activity in two samples during 1986. Lake Township (09/25/86) was 520 ± 349 pCi/l and St. Joseph (08/21/86) was 454 ± 268 pCi/l. All other samples were less than the lower limit of detection (300 pCi/l). Gamma spectranalysis of the drinking water samples indicated that no gamma-emitting isotopes of interest were above the lower limit of detection. The exception is the New Buffalo sample (05/15/86).

Tables XXXXIII to XXXXVI list the results of the analyses of the surface water samples. Gross Beta activity for 1986 ranged from less than the lower limit of detection (2.0 pCi/l) to a high of 24.5 ± 1.6 pCi/l in the South Lake sample of 12/18/86. Tritium analysis of the surface water samples indicated activity in three samples during 1986. North Lake (06/11/86) was 415 ± 265 pCi/l, North Lake (08/14/86) was 466 ± 266 pCi/l and South Lake (07/17/86) was 650 ± 271 pCi/l. All other samples were less than the lower limit of detection (300 pCi/l). Gamma spectralanalysis of the surface water samples indicated that no gamma emitting isotopes of interest were above the lower limit of detection.

Tables XXXXVII and XXXXVIII list the results of the analyses of the circulating water samples. Gross Beta activity ranged from less than the lower limit of detection (2.0 pCi/l) to a high of 20.2 ± 2.8 pCi/l (12/18/86). Tritium analysis indicated all samples less than the lower limit of detection (300 pCi/l). No gamma-emitting isotopes of interest were detected in any of the circulating water samples during 1986.

TABLE XXXVII

DRINKING WATER

1986

Sample Location	Collection Date	Radiochemical (pCi/l)	
		Gross Beta 2.0*	Tritium 300*
Lake Township	02/27/86	< 2.0	<300
	03/13/86	< 2.0	<300
	03/27/86	2.5±1.1	<300
	04/10/86	< 2.0	<300
	04/24/86	< 2.0	<300
	04/25/86	< 2.0	<300
	05/08/86	2.1±0.9	<300
	05/22/86	< 2.0	<300
	06/05/86	5.5±1.0	<300
	06/19/86	< 2.0	<300
	07/03/86	3.4±1.2	<300
	07/31/86	2.8±1.0	<300
	08/14/86	2.7±1.1	<300
	08/28/86	3.0±1.1	<300
	09/11/86	5.7±1.0	<300
	09/25/86	**	520±349[a]
	10/09/86	< 2.0	<300
	10/23/86	2.3±1.5	<300
	11/06/86	**	<300
	11/20/86	< 2.0	<300
	12/04/86	< 2.0	<300
	12/18/86	3.3±0.9	<300
	12/31/86	6.4±1.8	<300

*Lower limit of detection (LLD)
**Quantity not sufficient for analysis
[a]Value is lower than the tech. spec. LLD of 2000 pCi/l

TABLE XXVIII
DRINKING WATER
GAMMA SPECTROMETRY

Sample Location	Collection Date	pCi/l I-131 1*	Cs-134 7*	Cs-137 2*	Mn-54 2*	Co-58 5*	Co-60 5*	Zr,Nb-95 5*	Fe-59 3*	Zn-65 15*	Ba,La-140 4*
Lake Township	02/27/86										
	03/13/86										
	03/27/86										
	04/10/86										
	04/24/86										
	04/25/86										
	05/08/86										
	05/22/86										
	06/05/86										
	06/19/86										
	07/03/86										
	07/31/86	LESS THAN LOWER LIMIT OF DETECTION									
	08/14/86										
	08/28/86										
	09/11/86										
	09/25/86										
	10/09/86										
	10/23/86										
	11/06/86										
	11/20/86										
	12/04/86										
	12/18/86										
	12/31/86										

*Lower limit of detection

Supplemental #1
04/20/87

TABLE XXXIX

DRINKING WATER

1986

Sample Location	Collection Date	Radiochemical (pCi/l) Gross Beta 2.0*	Tritium 300*
St. Joseph	02/27/86	< 2.0	< 300
	03/13/86	2.9±0.5	< 300
	03/27/86	4.3±1.1	< 300
	04/10/86	< 2.0	< 300
	04/24/86	< 2.0	< 300
	04/25/86	< 2.0	< 300
	05/08/86	< 2.0	< 300
	05/22/86	2.7±1.0	< 300
	06/05/86	2.0±0.9	< 300
	06/19/86	< 2.0	< 300
	07/03/86	< 2.0	< 300
	07/31/86	< 2.0	< 300
	08/14/86	3.2±1.1	< 300
	08/28/86	< 2.0	454±268
	09/11/86	6.3±1.0	< 300
	09/25/86	**	< 300
	10/09/86	< 2.0	< 300
	10/23/86	2.5±1.5	< 300
	11/06/86	**	< 300
	11/20/86	3.0±0.5	< 300
	12/04/86	< 2.0	< 300
	12/18/86	< 2.0	< 300
	12/31/86	4.0±0.9	< 300

*Lower limit of detection
**Quantity not sufficient for analysis

TABLE XXXX

DRINKING WATER

GAMMA SPECTROMETRY

Sample Location	Collection Date	I-131 1*	Cs-134 5*	Cs-137 4*	Mn-54 2*	Co-58 3*	Co-60 5*	Zr,Nb-95 8*	Fe-59 3*	Zn-65 16*	Ba,La-140 4*
		pCi/l									
St. Joseph	02/27/86	**	**	**	**	**	**	**	**	**	**
	03/13/86	**	**	**	**	**	**	**	**	**	**
	03/27/86	**	**	**	**	**	**	**	**	**	**
	04/10/86	**	**	**	**	**	**	**	**	**	**
	04/24/86	**	**	**	**	**	**	**	**	**	**
	04/25/86	a	a	a	a	a	a	a	a	a	a
	05/08/86	**	**	**	**	**	**	**	**	**	**
	05/22/86	**	**	**	**	**	**	**	**	**	**
	06/05/86	**	**	**	**	**	**	**	**	**	**
	06/19/86	**	**	**	**	**	**	**	**	**	**
	07/03/86	**	**	**	**	**	**	**	**	**	**
	07/31/86	**	**	**	**	**	**	**	**	**	**
	08/14/86	**	**	**	**	**	**	**	**	**	**
	08/28/86	**	**	**	**	**	**	**	**	**	**
	09/11/86	**	**	**	**	**	**	**	**	**	**
	09/25/86	**	**	**	**	**	**	**	**	**	**
	10/09/86	**	**	**	**	**	**	**	**	**	**
	10/23/86	**	**	**	**	**	**	**	**	**	**
	11/06/86	**	**	**	**	**	**	**	**	**	**
	11/20/86	**	**	**	**	**	**	**	**	**	**
	12/04/86	**	**	**	**	**	**	**	**	**	**
	12/18/86	**	**	**	**	**	**	**	**	**	**
	12/31/86	**	**	**	**	**	**	**	**	**	**

*[illegible]r limit of detection
**[illegible] than lower limit of detection
[illegible] not [illegible]icie[illegible] or a[illegible]sis

TABLE XXXXI
DRINKING WATER
1986

Sample Location	Collection Date	Radiochemical (pCi/l) Gross Beta 2.0*	Tritium 300*
New Buffalo	02/27/86	< 2.0	< 300
	03/13/86	2.8±0.9	< 300
	03/27/86	2.1±1.0	< 300
	04/10/86	< 2.0	< 300
	04/24/86	2.5±0.9	< 300
	04/25/86	7.8±1.2	< 300
	05/08/86	< 2.0	< 300
	05/22/86[c]	125±3**	< 300
	08/29/86	2.2±1.8	a
	10/17/86	< 2.0	< 300
	10/23/86	2.5±1.5	< 300
	10/31/86[b]	d	< 300
	11/06/86[b]	d	< 300

*Lower limit of detection
**Verified by reanalysis
[a]Special sampling to check Gross Beta/Gamma
[b]Dip sample
[c] This is the last data required by tech. specs. Station deleted by tech. spec. change (Amendment #94 for Unit #1 and Amendment #80 for Unit #2).
[d]Quantity not sufficient for analysis

TABLE XXXXII

DRINKING WATER

GAMMA SPECTROMETRY

Sample Location	Collection Date	I-131 1*	Cs-134 5*	Cs-137 4*	Mn-54 2*	Co-58 3*	Co-60 5*	Zr,Nb-95 8*	Fe-59 3*	Zn-65 16*	Ba,La-140 4*
		pCi/l									
New Buffalo	02/27/86	**	**	**	**	**	**	**	**	**	**
	03/13/86	**	**	**	**	**	**	**	**	**	**
	03/27/86	**	**	**	**	**	**	**	**	**	**
	04/10/86	**	**	**	**	**	**	**	**	**	**
	04/24/86	**	**	**	**	**	**	**	**	**	**
	04/25/86	**	**	**	**	**	**	**	**	**	**
	05/08/86	**	**	**	**	**	**	**	**	**	**
	05/22/86[c]	**	**	**	**	**	144 ± 10	**	**	**	**
	08/29/86[a]	**	**	**	**	**	**	**	**	**	**
	10/17/86	**	**	**	**	**	**	**	**	**	**
	10/23/86	**	**	**	**	**	**	**	**	**	**
	10/31/86[b]	**	**	**	**	**	**	**	**	**	**
	11/06/86[b]	**	**	**	**	**	**	**	**	**	**

*Lower limit of detection
**Less than lower limit of detection
[a]Special sampling
[b]Dip Sample
[c]Del[illegible] from tech, spec. and no longer required to be sampl[illegible]

Suppl[illegible]tal #1
04/2[illegible]

TABLE XXXXIII

SURFACE WATER

1986

Sample Location	Collection Date	Radiochemical (pCi/l) Gross Beta 2.0*	Tritium 300*
North Lake (L3)	04/10/86	2.2±0.5	< 300
	04/25/86	< 2.0	415±265
	05/15/86	3.2±1.0	< 300
	06/12/86	3.6±1.0	< 300
	07/03/86	< 2.0	< 300
	07/31/86	2.4±1.0	< 300
	08/28/86	3.5±1.1	466±266
	09/25/86	**	< 300
	10/23/86	**	< 300
	11/20/86	< 2.0	< 300
	12/18/86	17.4±1.4	< 300

*Lower limit of detection
**Quantity not sufficient for analysis

TABLE XXXXIV

SURFACE WATER

GAMMA SPECTROMETRY

		pCi/l									
Sample Location	Collection Date	I-131 1*	Cs-134 7*	Cs-137 2*	Mn-54 2*	Co-58 5*	Co-60 5*	Zr,Nb-95 5*	Fe-59 3*	Zn-65 15*	Ba,La-140 4*
North Lake (L3)	04/10/86										
	04/25/86										
	05/15/86										
	06/12/86										
	07/03/86										
	07/31/86										
	08/28/86										
	09/25/86	LESS THAN LOWER LIMIT OF DETECTION									
	10/23/86										
	11/20/86										
	12/18/86										

*Lower limit of detection

Supplemental #1
04/20/87

TABLE XXXXV
SURFACE WATER
1986

Sample Location	Collection Date	Radiochemical (pCi/l) Gross Beta 2.0*	Tritium 300*
South Lake (L2)	04/10/86	2.6±0.5	< 300
	04/25/86	< 2.0	< 300
	05/15/86	3.4±1.0	< 300
	06/12/86	3.0±1.0	< 300
	07/03/86	< 2.0	< 300
	07/31/86	< 2.0	650±271
	08/28/86	< 2.0	< 300
	09/25/86	a	< 300
	10/23/86	a	< 300
	11/20/86	a	< 300
	12/18/86	24.5±1.6**	< 300

*Lower Limit of detection
**Verified by reanalysis
aQuantity not sufficient for analysis

TABLE XXXXVI

SURFACE WATER

GAMMA SPECTROMETRY

Sample Location	Collection Date	pCi/l I-131 1*	Cs-134 7*	Cs-137 2*	Mn-54 2*	Co-58 5*	Co-60 5*	Zr,Nb-95 5*	Fe-59 3*	Zn-65 15*	Ba,La-140 4*
South Lake (L2)	04/10/86										
	04/25/86										
	05/15/86										
	06/12/86										
	07/03/86										
	07/31/86										
	08/28/86										
	09/25/86	LESS THAN LOWER LIMIT OF DETECTION									
	10/23/86										
	11/20/86										
	12/18/86										

*Lower limit of detection

Supplemental #1
04/20/87

TABLE XXXXVII

CIRCULATING WATER

1986

Sample Location	Sample #	Collection Date	Radiochemical (pci/l)) Gross Beta 2.0*	Tritium 300*
Circulating Intake (L1)	#1	04/10/86	< 2.0	< 300
	#2	04/10/86	< 2.0	< 300
	#1	04/25/86	3.6±1.1	< 300
	#2	04/25/86	5.3±1.1	< 300
	#1	05/15/86	2.1±0.9	< 300
	#2	05/15/86	< 2.0	< 300
	#1	06/12/86	3.1±1.0	< 300
	#1	07/03/86	2.5±1.2	< 300
	#2	07/03/86	< 2.0	< 300
		07/31/86	< 2.0	< 300
		08/28/86	< 2.0	< 300
		09/25/86	a	< 300
		10/23/86	< 2.0	< 300
		11/20/86	< 2.0	< 300
		12/18/86	20.2±2.8**	< 300

*Lower limit of detection
**Verified by reanalysis
[a]Quantity not sufficient for analysis

TABLE XXXXVIII

CIRCULATING WATER

GAMMA SPECTROMETRY

Sample Location		Collection Date	pCi/l Cs-134 7*	Cs-137 2*	Mn-54 2*	Co-58 5*	Co-60 5*	Zr,Nb-95 5*	Fe-59 3*	Zn-65 15*	Ba,La-140 4*
Circulating Intake	#1	04/10/86									
	#2	04/10/86									
	#1	04/25/86									
	#2	04/25/86									
	#1	05/15/86									
	#2	05/15/86									
	#1	06/12/86									
	#1	07/03/86									
	#2	07/03/86									
		07/31/86									
		08/28/86	LESS THAN LOWER LIMIT OF DETECTION								
		09/25/86									
		10/23/86									
		12/18/86									

*[illegible]r limit of detection

8.0 Missing Samples

Sample Type	Location	Required Collection Date	Reason
Air particulate/radioiodine	ONS-6	01/21/86	Malfunctioning meter
Air particulate	ONS-4	02/04/86	Lost in shipment
Radioiodine	COL	02/11/86	Lost in shipment
Air particulate	NBF	03/11/86	Missing at site
TLD	OFS-8	04/06/86	Missing at site
TLD	OFS-2	07/07/86	Missing at site
TLD	OFS-8	07/07/86	Missing at site
Drinking Water	Lake Township	07/10/86	Lost in shipment
Drinking Water	St. Joseph	07/10/86	Lost in shipment
Air particulate/radioiodine	ONS-5	07/22/86	Power off at station

APPENDIX A

Results of the EPA Cross-Check Program

1986

For

Controls for Environmental Pollution, Inc.

EPA CROSS-CHECK PROGRAM
1986

Gross Alpha/Beta In Water

Date	Parameter	EPA Known Value pCi/l ± 1σ	CEP Reported Value pCi/l ± 2 σ
1/86	Gross Alpha	3 ± 5	5 ± 1 6 ± 1 7 ± 1
	Gross Beta	7 ± 5	7 ± 1 9 ± 1 10 ± 1
3/86	Gross Alpha	15 ± 5	13 ± 3 15 ± 3 16 ± 3
	Gross Beta	8 ± 5	15 ± 3 16 ± 3 17 ± 3
7/86	Gross Alpha	6 ± 5	5 ± 1 6 ± 1 6 ± 1
	Gross Beta	18 ± 5	15 ± 3 16 ± 3 18 ± 3
9/86	Gross Alpha	15 ± 5	12 ± 2 12 ± 2 14 ± 2
	Gross Beta	8 ± 5	17 ± 4 18 ± 3 20 ± 3

EPA CROSS-CHECK PROGRAM

1986

Gamma In Water

Date	Parameter	EPA Known Value pCi/l ± 1 σ	CEP Reported Value pCi/l ± 2 σ
2/86	Cesium-134	30 ± 5	29 ± 4 24 ± 4 33 ± 5
	Cesium-137	22 ± 5	18 ± 4 16 ± 4 21 ± 4
	Cobalt-60	18 ± 5	25 ± 2 29 ± 4 21 ± 3
	Zinc-65*	40 ± 5	57 ± 15 56 ± 12 56 ± 12
6/86	Cesium-137	10 ± 5	9 ± 2 12 ± 2 10 ± 2
	Zinc-65	86 ± 5	87 ± 8 84 ± 8 90 ± 8
10/86	Ruthenium-106	74 ± 5	65 ± 21 67 ± 6 71 ± 23
	Cesium-134	28 ± 5	22 ± 2 26 ± 2 28 ± 2

*Spike sample was reanalyzed and a value of 41 ±14 pCi/l was obtained

Supplemental #1
04/20/87

EPA CROSS-CHECK PROGRAM

1986

Gamma In Water (Continued)

Date	Parameter	EPA Known Value pCi/l ± 1σ	CEP Reported Value pCi/l ± 2σ
10/86	Cesium-137	44 ± 5	42 ± 4 43 ± 1 48 ± 3
	Cobalt-60	31 ± 5	28 ± 4 29 ± 4 29 ± 4
	Zinc-65	85 ± 5	77 ± 7 78 ± 7 79 ± 7

EPA CROSS-CHECK PROGRAM

1986

Tritium in Water

Date	Parameter	EPA Known Value pCi/l ± 1 σ	CEP Reported Value pCi/l ± 2 σ
2/86	Tritium	5227 ± 523	4100 ± 410 4590 ± 459 4190 ± 419
6/86	Tritium*	3125 ± 360	2290 ± 230 2170 ± 220 2050 ± 210
10/86	Tritium	5973 ± 597	5462 ± 600 5257 ± 600 5880 ± 600

*Spike sample was reanalyzed with the LS-5801 and a value of 3533 ± 565 pCi/l was obtained

Supplemental #1
04/20/87

EPA CROSS-CHECK PROGRAM

1986

Iodine-131 In Water

Date	Parameter	EPA Known Value pCi/l ± 1σ	CEP Reported Value pCi/l ± 2σ
4/86	Low Level	9 ± 6	9 ± 4 7 ± 4 7 ± 4
8/86	High Level*	45 ± 6	30 ± 4 33 ± 4 39 ± 4

*Spike sample was reanalyzed and a value of 40 ± 4 pCi/l was obtained

Supplemental #1
04/20/87

EPA CROSS-CHECK PROGRAM

1986

Radionuclides In Milk

Date	Parameter	EPA Known Value pCi/l± 1 σ	CEP Reported Value pCi/l± 2 σ
6/86	Iodine-131	41 ± 6	36 ± 6 32 ± 4 40 ± 7
	Cesium-137	31 ± 5	34 ± 5 26 ± 4 28 ± 4
10/86	Iodine-131	49 ± 6	43 ± 3 33 ± 9 37 ± 4
	Cesium-137*	39 ± 5	53 ± 25 58 ± 22 48 ± 20

*Spike sample was reanalyzed and a value of 34 ± 5 pCi/l was obtained

Supplemental #1
04/20/87

EPA CROSS-CHECK PROGRAM

1986

Iodine-131 In Milk

Date	Parameter	EPA Known Value pCi/l± 1 σ	CEP Reported Value pCi/l± 2 σ
2/86	Low Level	9 ± 6	9 ± 1 9 ± 1 10 ± 1

EPA CROSS-CHECK PROGRAM

1986

Radionuclides in Air Filters

Date	Parameter	EPA Known Value pCi/filter ± 1σ	CEP Reported Value pCi/filter ± 2 σ
4/86	Gross Alpha	15 ± 5	15 ± 3 15 ± 3 16 ± 3
	Gross Beta	47 ± 5	56 ± 6 57 ± 6 58 ± 6
	Cesium-137	10 ± 5	8 ± 3 9 ± 3 9 ± 3
9/86	Gross Alpha	22 ± 5	23 ± 2 22 ± 2 26 ± 2
	Gross Beta	66 ± 5	64 ± 2 63 ± 2 66 ± 2
	Cesium-137	22 ± 5	23 ± 3 25 ± 3 22 ± 3

EPA CROSS-CHECK PROGRAM

1986

Radionuclides In Food

Date	Parameter	EPA Known Value pCi/kg± 1 σ	CEP Reported Value pCi/kg± 2 σ
1/31	Iodine-131	20 ± 6	20 ± 5 21 ± 7 22 ± 7
	Cesium-137	15 ± 5	15 ± 5 16 ± 5 17 ± 5
	Potassium	950 ± 143	910 ± 91 950 ± 95 940 ± 94

APPENDIX B

TLD CROSS CHECK DATA

FIFTH INTERNATIONAL ENVIRONMENTAL DOSIMETER INTERCOMPARISON PROJECT

Organizers:
T F. Gesell
University of Texas
School of Public Health
P.O. Box 20186
Houston, Texas 77025
(713) 792-4376

G. de Planque
U.S. Department of Energy
Environmental
Measurements Laboratory
376 Hudson St.
New York, N.Y. 10014
(212) 620-3635 Commercial
(212) 660-3635 FTS

Sponsors:
U.S. Department of Energy

University of Texas
School of Public Health

August 03, 1981

Fifth International Intercomparison of Environmental Dosimeters

Dear Participant:

Enclosed is an individual data record for each dosimeter which you entered in the intercomparison, an explanation of the coding used for the individual data record, and a few preliminary summary statistics. The individual data record has been generated directly from the data that we have in our computer file. Please check each entry carefully for accuracy and report any discrepencies to me as soon as possible. This computer file will be used for further, detailed analyses so the accuracy of the input data which you provide is extremely important. Please note that we do not computerize all the data which you provide so blank spaces do not imply missing data. Where data is missing, a field of 9's appears. Please supply missing data if possible.

Table 1-3 provide summary statistics for the three exposure conditions and the corresponding figures provide the distribution. In general, there was very good agreement between the average of all participants and independently measured values.

After a reasonable period of time is allowed for corrections to the data file to be received, and noted, we will perform a more detailed analysis and forward the results to you.

Sincerely,

Thomas F. Gesell, Ph.D.
Associate Professor of Health Physics

TG:ls
Enc: 1. Individual data record(s)
2. Explanation of the individual data record
3. Summary statistics and figures for the intercomparison

EXPLANATION OF THE INDIVIDUAL DATA

The serial number appears in the second line of the record. Please check to see that it corresponds to the serial number(s) of your dosimeter set(s).

The sections labeled "I total exposure measured" and "II estimated exposures, participant's results" should exactly reflect the corresponding information which you provided on your response forms. The corrections are coded as follows:

- 0 no corrections
- 1 analytical correction
- 2 physical correction
- 3 both analytical and physical corrections
- 9 no information supplied

The section labeled "II estimated exposures, author's results" reflect our calculation of the estimated exposures based upon sure data from section I. Where a discrepency of more than 0.1 mR occurs we plan to use the author's results in the subsequent analyses unless you contact us.

Section IIIB should be equal to the sum of the estimated storage exposures which you provided under item IIIB of the response form.

Item IIIc gives the estimated transit exposure which you calculated as well as the author's calculation. As with the lab and field data, where a discrepency occurs we intend to use the author's result unless you notify us.

The remainder of the individual data record should be self explainatory except for the codes which are given below:

IV A. READER TYPE

1 Eberline TLR-5, TLR-6
2 EG & G (all)
3 Harshaw 2000
4 Harshaw 4000
5 Harshaw 2271
6 Harshaw CP-1112/PD
7 Teledyne 7100
8 Teledyne 7300
9 Teledyne 8300
10 Teledyne UD-505A
11 Victoreen 2600
12 Krackow 748
13 Conrad 5100 A and B
14 Harshaw 3000
15 RDC MKIV,1000
16 Victoreen 2800
17 LDT-20
18 National and Panasonic UD 505A
19 Atomic Energy of Canada AEP 5256A
20 TNO Automatic
21 Kyokko 1200
22 Matsushita National UD 502B
23 Aloka 202
24 Teledyne 9100
25 Pitman Toledo
26 Studsvik Auto 1313A
27 Victoreen 2810
28 Panasonic 710 A
30 Non-Commercial TLD
31 Non-Commercial TSEE
32 Densitometer (all)
33 Toshiba FGD 6

34 Therados AB, Uppsula
35 Panasonic UD 702A
36 RDL 78
37 TLD-04
38 X-Rite Model 301

IV. B DOSIMETER MATERIAL

TLD
1 BeO
2 CaF_2:Dy
3 CaF_2:Mn
4 CaF_2:natural
5 $CaSO_4$:Dy
6 $CaSO_4$:Tm
7 LiF:Mg,Ti
8 LiB,LiF in combination
9 Mg_2 SiO_4: Tb
13 $CaSO_4$: in Lif
14 LiF:Mg,Cu,P
15 Al_2O_3

TSEE
20 BeO

FILM

30 All

RADIOPHOTOLUMINESCENCE
40 $AgPO_3$

99 Not reported

IV. E LEVEL OF PERFORMANCE

1. Routine
2. Best Effort
3. Experimental system not used in routine monitoring
9. Not reported

V. CALIBRATION INFORMATION

Calibration isotope

60	cobalt 60
90	strontium 90
137	cesium 137
226	radium - 226
238	uranium - 238
500	x-rays
999	not reported

Calibration geometry

1. collimated beam
2. point source in free air
3. other
9. not reported

V. C. PACKAGING DURING CALIBRATION

1. same as intercomparison dosimeters
2. different from intercomparison dosimeters
3. other
9. not reported

V.D. CALIBRATION DURING OR BEFORE READOUT

1. during readout
2. before readout
3. other
9. not reported

V.E. CALIBRATION METHOD

1. individually
2. by the batch
3. by the batch with individual corrections
4. other
9. not reported

V.F. CALIBRATION EXPOSURE DETERMINATION

1. calculation from source strength
2. measurement
3. other
9. not reported

PREVIOUS PARTICIPATION

0. did not participate in any previous intercomparison
1. participated in one previous intercomparison
2. participated in two previous intercomparisons
3. participated in three previous intercomparisons
4. participated in four previous intercomparisons

TYPE OF ORGANIZATION

United States Participants

1. Manufacturers and consultants
2. Government agencies and national laboratories
3. Universities
4. Utilities

Participants outside the United States

5. All

FIFTH INTERNATIONAL INTERCOMPARISON OF ENVIRONMENTAL DOSIMETERS

INDIVIDUAL DATA RECORD FOR SERIAL NUMBER 0660

I TOTAL EXPOSURE MEASURED	EXPOSURE(MR)	ERROR(MR)	CORRECTIONS FADING	ENERGY	DIRECTIONAL	SELF IRRADIATION
FIELD DOSIMETER 1	39.0					
FIELD DOSIMETER 2	39.0					
BEGINNING LAB DOSIMETER 1	95.0					
BEGINNING LAB DOSIMETER 2	100.0					
END LAB DOSIMETER 1	111.0					
END LAB DOSIMETER 2	115.0					
CONTROL DOSIMETER 1	19.0					
CONTROL DOSIMETER 2	19.0					
II ESTIMATED EXPOSURES						
PARTICIPANT'S RESULTS						
FIELD EXPOSURE	26.0	1.0	0	0	0	0
BEGINNING LAB EXPOSURE	79.6	3.2	0	0	0	0
END LAB EXPOSURE	94.0	3.8	0	0	0	0
AUTHOR'S RESULTS						
FIELD EXPOSURE	26.0					
BEGINNING LAB EXPOSURE	78.5					
END LAB EXPOSURE	94.0					
IIIA ESTIMATED STORAGE EXPOSURE	0.0					
IIIC ESTIMATED TRANSIT EXPOSURE						
PARTICIPANT'S RESULTS	13.0	.5				
AUTHOR'S RESULT	13.0					

****

	CODE
IV GENERAL INFORMATION -	
A READER TYPE	03
B DOSIMETER MATERIAL	02
E LEVEL OF PERFORMANCE	3
V CALIBRATION INFORMATION	
A FIRST CALIBRATION ISOTOPE	137
SECOND CALIBRATION	999
CALIBRATION GEOMETRY	2
C PACKAGING DURING CALIBRATION	1
D CALIBRATION DURING OR BEFORE READOUT	1
E CALIBRATION METHOD (INDIVIDUAL, BATCH,ETC.)	1
F CALIBRATION EXPOSURE DETERMINATION	1
G ESTIMATED CALIBRATION ERROR IN PERCENT	999.9
PREVIOUS PARTICIPATION	0
TYPE ORGANIZATION	1

Appendix 2.2

Surface and Drinking Water Results

January - March, 1986

Donald C. Cook Nuclear Plant

Units 1 and 2

Note: Drinking and Surface water sample results for the remainder of 1986 are to be found in Appendix 2.1 of this report.

TABLE I
DONALD C. COOK NUCLEAR PLANT
WATERBORNE, SURFACE
TRITIUM, QUARTERLY COMPOSITE

(LLD = 2000 pCi/ℓ)
Concentrations in pCi/ℓ

	1st QTR	2nd QTR	3rd QTR	4th QTR
L1	<LLD			
L2	*			
L3	*			

* SAMPLE COULD NOT BE TAKEN DUE TO ICE ON LAKE

TABLE II
DONALD C. COOK NUCLEAR PLANT
WATERBORNE, SURFACE
GAMMA ISOTOPIC, MONTLHY COMPOSITE

Concentrations in pCi/ℓ

Cs-137 (LLD = 18 pCi/ℓ)

SAMPLE LOCATION: COLLECTION DATE	L1	L2	L3
1-16-86	<LLD	*	*
2-13-86	<LLD	*	*
3-13-86	<LLD	*	*

Cs-134 (LLD = 15 pCi/ℓ)

COLLECTION DATE	L1	L2	L3
1-16-86	<LLD	*	*
2-13-86	<LLD	*	*
3-13-86	<LLD	*	*

* SAMPLE COULD NOT BE TAKEN DUE TO ICE ON LAKE

TABLE II
DONALD C. COOK NUCLEAR PLANT
WATERBORNE, SURFACE
GAMMA ISOTOPIC, MONTLHY COMPOSITE

Concentrations in pCi/ℓ

Co 60 (LLD = 15 pCi/ℓ)

SAMPLE LOCATION:	L1	L2	L3
COLLECTION DATE			
1-16-86	<LLD	*	*
2-13-86	<LLD	*	*
3-13-86	<LLD	*	*

La 140 (LLD = 15 pCi/ℓ)

COLLECTION DATE	L1	L2	L3
1-16-86	<LLD	*	*
2-13-86	<LLD	*	*
3-13-86	<LLD	*	*

* SAMPLE COULD NOT BE TAKEN DUE TO ICE ON LAKE

TABLE II
DONALD C. COOK NUCLEAR PLANT
WATERBORNE, SURFACE
GAMMA ISOTOPIC, MONTLEY COMPOSITE

Concentrations in pCi/ℓ

Fe 59 (LLD = 30 pCi/ℓ)

SAMPLE LOCATION:	L1	L2	L3
COLLECTION DATE			
1-16-86	<LLD	*	*
2-13-86	<LLD	*	*
3-13-86	<LLD	*	*

Zn 65 (LLD = 30 pCi/ℓ)

1-16-86	<LLD	*	–
2-13-86	<LLD	*	*
3-13-86	<LLD	*	*

* SAMPLE COULD NOT BE TAKEN DUE TO ICE ON LAKE

TABLE II
DONALD C. COOK NUCLEAR PLANT
WATERBORNE, SURFACE
GAMMA ISOTOPIC, MONTLHY COMPOSITE

Concentrations in pCi/ℓ

Co 58 (LLD = 15 pCi/ℓ)

SAMPLE LOCATION:	L1	L2	L3
COLLECTION DATE			
1-16-86	<LLD	*	*
2-13 86	<LLD	*	*
3-13-86	<LLD	*	*

MN 54 (LLD = 15 pCi/ℓ)

1-16-86	<LLD	*	*
2-13-86	<LLD	*	*
3-13-86	<LLD	*	*

* SAMPLE COULD NOT BE TAKEN DUE TO ICE ON LAKE

TABLE II
DONALD C. COOK NUCLEAR PLANT
WATERBORNE, SURFACE
GAMMA ISOTOPIC, MONTLHY COMPOSITE

Concentrations in pCi/ℓ

Zr 95 (LLD = 30 pCi/ℓ)

SAMPLE LOCATION: COLLECTION DATE	L1	L2	L3
1-16-86	<LLD	*	*
2-13-86	<LLD	*	*
3-13-86	<LLD	*	*

Nb-95 (LLD = 15 pCi/ℓ)

COLLECTION DATE	L1	L2	L3
1-16-86	<LLD	*	*
2-13-86	<LLD	*	*
3-13-86	<LLD	*	*

* SAMPLE COULD NOT BE TAKEN DUE TO ICE ON LAKE

TABLE II
DONALD C. COOK NUCLEAR PLANT
WATERBORNE, SURFACE
GAMMA ISOTOPIC, MONTLHY COMPOSITE

Concentrations in pCi/ℓ

I-131 (LLD = 1 pCi/ℓ)

SAMPLE LOCATION: COLLECTION DATE	L1	L2	L3
1-16-86	<LLD	*	*
2-13-86	<LLD	*	*
3-13-86	<LLD	*	*

BA-140 (LLD = 60 pCi/ℓ)

COLLECTION DATE	L1	L2	L3
1-16-86	<LLD	*	*
2-13-86	<LLD	*	*
3-13-86	<LLD	*	*

* SAMPLE COULD NOT BE TAKEN DUE TO ICE ON LAKE

TABLE III
DONALD C. COOK NUCLEAR PLANT
WATERBORNE, DRINKING
TRITIUM, QUARTERLY COMPOSITE

(LLD = 2000 pCi/ℓ)

Concentrations in pCi/ℓ

	1st QTR	2nd QTR	3rd QTR	4th QTR
St. Joseph	<LLD			
Lake Township	<LLD			
New Buffalo	<LLD			

TABLE IV
DONALD C. COOK NUCLEAR PLANT
WATERBORNE, DRINKING
GROSS BETA, MONTHLY COMPOSITE

(LLD = 4 pCi/ℓ)

Concentrations in pCi/ℓ

SAMPLE LOCATION:	ST. JOSEPH	LAKE TOWNSHIP	NEW BUFFALO
SAMPLE DATE:			
1-2-86	<2.54	<2.80	<2.54
1-16-86	<2.53	<2.78	<2.78
1-30-86	<2.49	-2.49	<2.49
2-13-86	<2.89	<2.75	-2.89

TABLE V
DONALD C. COOK NUCLEAR PLANT
WATERBORNE, DRINKING
GAMMA ISOTOPIC, MONTHLY COMPOSITE

Concentrations in pCi/ℓ

Cs-137 (LLD = 18 pCi/ℓ)

SAMPLE LOCATION: SAMPLE DATE	ST. JOSEPH	LAKE TOWNSHIP	NEW BUFFALO
1-2-86	<LLD	<LLD	<LLD
1-16-86	<LLD	<LLD	<LLD
1-30-86	<LLD	<LLD	<LLD
2-13-86	<LLD	<LLD	<LLD

Cs-134 (LLD = 15 pCi/ℓ)

SAMPLE DATE	ST. JOSEPH	LAKE TOWNSHIP	NEW BUFFALO
1-2-86	<LLD	<LLD	<LLD
1-16-86	<LLD	<LLD	<LLD
1-30-86	<LLD	<LLD	<LLD
2-13-86	<LLD	<LLD	<LLD

TABLE V
DONALD C. COOK NUCLEAR PLANT
WATERBORNE, DRINKING
GAMMA ISOTOPIC, MONTHLY COMPOSITE

Concentrations in pCi/ℓ

I-131 (LLD = 1 pCi/ℓ)

SAMPLE LOCATION: SAMPLE DATE	ST. JOSEPH	LAKE TOWNSHIP	NEW BUFFALO
1-2-86	<LLD	<LLD	<LLD
1-16-86	<LLD	<LLD	<LLD
1-30-86	<LLD	<LLD	<LLD
2-13-86	<LLD	<LLD	<LLD

BA-140 (LLD = 60 pCi/ℓ)

SAMPLE DATE	ST. JOSEPH	LAKE TOWNSHIP	NEW BUFFALO
1-2-86	<LLD	<LLD	<LLD
1-16-86	<LLD	<LLD	<LLD
1-30-86	<LLD	<LLD	<LLD
2-13-86	<LLD	<LLD	<LLD

TABLE V
DONALD C. COOK NUCLEAR PLANT
WATERBORNE, DRINKING
GAMMA ISOTOPIC, MONTHLY COMPOSITE

Concentrations in pCi/ℓ

ZR-95 (LLD = 30 pCi/ℓ)

SAMPLE LOCATION: SAMPLE DATE	ST. JOSEPH	LAKE TOWNSHIP	NEW BUFFALO
1-2-86	<LLD	<LLD	<LLD
1-16-86	<LLD	<LLD	<LLD
1-30-86	<LLD	<LLD	<LLD
2-13-86	<LLD	<LLD	<LLD

NB-95 (LLD = 15 pCi/ℓ)

SAMPLE DATE	ST. JOSEPH	LAKE TOWNSHIP	NEW BUFFALO
1-2-86	<LLD	<LLD	<LLD
1-16-86	<LLD	<LLD	<LLD
1-30-86	<LLD	<LLD	<LLD
2-13-86	<LLD	<LLD	<LLD

TABLE V
DONALD C. COOK NUCLEAR PLANT
WATERBORNE, DRINKING
GAMMA ISOTOPIC, MONTHLY COMPOSITE

Concentrations in pCi/ℓ

CO-58 (LLD = 15 pCi/ℓ)

SAMPLE LOCATION: SAMPLE DATE	ST. JOSEPH	LAKE TOWNSHIP	NEW BUFFALO
1-2-86	<LLD	<LLD	<LLD
1-16-86	<LLD	<LLD	<LLD
1-30-86	<LLD	<LLD	<LLD
2-13-86	<LLD	<LLD	<LLD

MN-54 (LLD = 15 pCi/ℓ)

SAMPLE DATE	ST. JOSEPH	LAKE TOWNSHIP	NEW BUFFALO
1-2-86	<LLD	<LLD	<LLD
1-16-86	<LLD	<LLD	<LLD
1-30-86	<LLD	<LLD	<LLD
2-13-86	<LLD	<LLD	<LLD

TABLE V
DONALD C. COOK NUCLEAR PLANT
WATERBORNE, DRINKING
GAMMA ISOTOPIC, MONTHLY COMPOSITE

Concentrations in pCi/ℓ

FE-59 (LLD = 30 pCi/ℓ)

SAMPLE LOCATION: SAMPLE DATE	ST. JOSEPH	LAKE TOWNSHIP	NEW BUFFALO
1-2-86	<LLD	<LLD	<LLD
1-16-86	<LLD	<LLD	<LLD
1-30-86	<LLD	<LLD	<LLD
2-13-86	<LLD	<LLD	<LLD

ZN-65 (LLD = 30 pCi/ℓ)

SAMPLE DATE	ST. JOSEPH	LAKE TOWNSHIP	NEW BUFFALO
1-2-86	<LLD	<LLD	<LLD
1-16-86	<LLD	<LLD	<LLD
1-30-86	<LLD	<LLD	<LLD
2-13-86	<LLD	<LLD	<LLD

TABLE V
DONALD C. COOK NUCLEAR PLANT
WATERBORNE, DRINKING
GAMMA ISOTOPIC, MONTHLY COMPOSITE

Concentrations in pCi/ℓ

Co-60(LLD = 15 pCi/ℓ)

SAMPLE LOCATION: SAMPLE DATE	ST. JOSEPH	LAKE TOWNSHIP	NEW BUFFALO
1-2-86	<LLD	<LLD	<LLD
1-16-86	<LLD	<LLD	<LLD
1-30-86	<LLD	<LLD	<LLD
2-13-86	<LLD	<LLD	<LLD

LA-140(LLD = 15.pCi/ℓ)

SAMPLE DATE	ST. JOSEPH	LAKE TOWNSHIP	NEW BUFFALO
1-2-86	<LLD	<LLD	<LLD
1-16-86	<LLD	<LLD	<LLD
1-30-86	<LLD	<LLD	<LLD
2-13-86	<LLD	<LLD	<LLD

Appendix 2.3

Enhanced Radiological Environmental Monitoring Program Results

Arising from the Accident

at the

Chernobyl Nuclear Power Station

AR# 1317

TECHNICAL - PHYSICAL SCIENCES DEPARTMENT ACTION REQUEST

TO: R. J. Clendenning SECTION: Radiation Protection

Action Request due to Department Head on ~~8/9/86~~ ~~7/9/86~~ 9/9/86. This date has been chosen to allow for adequate review and preparation of supplemental responses.

Recommendations/Assignment:

Review I. E. Information Notice 86-32: Request for Collection of Licensee Radioactivity Measurements attributed to the Chernobyl Nuclear Plant accident and address the plant manager's comments.

Reference Document: I. E. Information Notice 86-32

Additional Response Due To: QC Due Date: N/A

A. C. C. Lisa G. Holmes

Technical/Physical Sciences Superintendent [signature] 5/19/86 Date Issued

Response:

See attached report and graphs

Completed By: [signature] Date: 9/9/86

Technical/Physical Sciences Superintendent [signature] 9/10/86 Date

Extension dates may be obtained from Technical - Physical Sciences Superintendent for those items with no responses due outside the Department. All AR's with responses due outside the Department are expected to be completed on time.

[redacted]

Fmm...

W. G. SMITH, JR.

RECEIVED
MAY 13 1986
Technical Dept.

B

AGi / ~~[illegible]~~ / Randy

Aside from whatever we're doing on the IEN, would like to have a brief chronology of our actions (sampling frequency, additional samples, etc) & graphical representation of environmental activity for ~1 wk prior to accident through time everything is normal (or stable). Just keep a file with this for closure.

[redacted]

PRIORITY ATTENTION REQUESTED

SSINS No.: 6835
IN 86-32 8605028GA
PW05028GA

UNITED STATES
NUCLEAR REGULATORY COMMISSION
OFFICE OF INSPECTION AND ENFORCEMENT
WASHINGTON, D.C. 20555

May 2, 1986

IE INFORMATION NOTICE NO. 86-32: REQUEST FOR COLLECTION OF LICENSEE RADIOACTIVITY MEASUREMENTS ATTRIBUTED TO THE CHERNOBYL NUCLEAR PLANT ACCIDENT

Addressees:

All nuclear power reactor facility licensees holding an operating license (OL) or construction permit (CP).

Purpose:

The purpose of this information notice is to update licensees of the recent Chernobyl nuclear power plant accident and to request voluntary reporting of any licensee environmental radioactivity measurement data probably caused by that event.

In order to enhance the Federal and state monitoring programs, all nuclear power reactor facilities with on-going environmental monitoring programs are requested to consider the NRC request to report confirmed anomalous environmental radioactivity measurements probably caused by radioactive material released in the accident at the Chernobyl nuclear power plant in the U.S.S.R. It is requested that recipients review the attached information and provide the environmental data discussed herein.

Description of Circumstances:

Information issued by the Environmental Protection Agency (EPA) concerning the recent reactor accident in Chernobyl, USSR is contained in Attachments 1, 2 and 3.

In the week following the accident at Chernobyl, elevated levels of radioactivity have been detected in air, rainwater, soil and food in many European countries. The radionuclides that have been detected in air in these countries include: I-131, Cs-137, Cs-134, Te-132, Ru-103, Mo-99, Np-239, and Nb-95. Although estimates of plume arrival time and location of entry into the continental United States are highly uncertain at this time, the plume may arrive in the Pacific Northwest United States during May 7-10, 1986.

Discussion:

It appears likely that radioactive material from the Chernobyl accident may arrive within the continental U.S. in concentrations that are readily detectable. In order to enhance nationwide environmental surveillance, the EPA (and some states) have increased the airborne monitoring sampling frequencies to be better able to detect any traces of the plume. In order to supplement and reinforce this state and federal nationwide surveillance program, the NRC licensees [as

DCC: 24*03*10
72*40*C3*C2
99*02*05*31

8605020492

Environmental Protection Agency

Washington DC 20460

Attachment 1
IN 86-32
May 2, 1986

EPA

Soviet Nuclear Accident

FOR RELEASE: 2:00 P.M., THURSDAY, MAY 1, 1986

A Task Force Report

CONTACT: DAVE COHEN
(202) 382-4355

On Tuesday, the Environmental Protection Agency, which maintains the nation's radiation monitoring network, increased its sampling frequency for airborne radioactivity to daily. Results obtained thus far show no increase in radioactivity above normal background levels. The Canadian air monitoring network has also increased its sampling frequency to daily. Results there show no increase in radioactivity.

The air mass containing the radioactivity from the initial Chernobyl nuclear event is now widely dispersed throughout northern Europe and Polar regions. Portions of radioactivity off the northwest Norwegian coast yesterday morning should continue to disperse with possible movement toward the east in the next several days. Other portions of the radioactive air mass may move east through the Soviet Union and through the Polar regions over the coming week.

The Soviets have reported they have smothered the fire. From our information it is not clear whether the fire is out or not. We also cannot confirm news reports of damage at a second reactor, but the second hot spot seen in the LANDSAT photos is not a reactor.

The U.S. Government has offered to provide technical assistance to the Soviet Government to deal with the accident. On Wednesday afternoon, a senior Soviet official from their Embassy in Washington delivered a note to the Department of State expressing appreciation for our offer of assistance and stating that for the time being, assistance is not needed.

At the present time, the U.S. Government has no data on radiation levels or contamination levels at any location within the Soviet Union. We also have no firm information concerning the number of casualties from the accident.

(more)

Attachment 2
IN 86-32
May 2, 1986

TALKING POINTS
CHERNOBYL NUCLEAR ACCIDENT
April 30, 1986

o Late Friday, April 25, or early Saturday, April 26, a serious accident occurred at the Chernobyl nuclear facility near Kiev in the Soviet Union. As a result of an apparent loss of reactor coolant, the facility experienced a core meltdown, explosion, and fire. Causes of the accident are not known.

o The explosion and resulting fire released a plume of radioactive materials to the atmosphere. So long as the reactor core fire continues, radioactive gases will be given off.

o The facility involved is a graphite-moderated, boiling-water-cooled, pressure-tube unit. It is one of four such units at Chernobyl. To our knowledge, only this one unit, known as Unit #4, is involved in the accident.

o The initial plume traveled in a northwest direction toward Scandanavia. Predictions now suggest it will move in an eastward direction. Radiation levels above normal background have been detected in Scandanavian countries. However, these levels pose no significant risk to human health or the environment.

o The U.S. government has made an offer of technical assistance to the Soviets. This good faith offer was made out of genuine concern for the health and safety of the Soviet people. The Soviet government responded April 30 that no foreign assistance is needed.

o We have also requested specific information on the accident. To date, we have not received a full response to that request. This is also a matter of great concern to the United States.

o The radiation plume emitted as a result of the Chernobyl accident will disperse over time throughout the Northern Hemisphere. Eventually, some radioactive contamination will reach the United States. However, based on the limited information we now have, there is no reason to believe that levels reaching this country will pose any significant risk to human health or the environment. Please see the accompanying fact sheet on radiation health effects for basic information on exposure.

Attachment 3
IN 86-31
May 2, 1986

Fact Sheet-Chernobyl
SOVIET NUCLEAR
ACCIDENT

FOR RELEASE: 2:00 P.M., FRIDAY, MAY 2, 1986

CONTACT: DAVE COHEN (202) 382-4355

Radiation monitoring networks in the United States and Canada are continuing to analyze for airborne radioactivity daily. No increases in radioactivity above normal background levels have been detected in either country. Canadian officials intend to increase the sampling frequency of their milk monitoring network, which consists of 16 stations near population centers in southern Canada, to weekly beginning next week.

It is believed that air containing radioactivity now covers much of Europe and a large part of the Soviet Union. The distribution of radioactivity is likely to be patchy. Air containing radioactivity detected by aircraft at 5000 feet about 400 miles west of northern Norway is believed to have moved westward and now appears to be heading south or southeastward perhaps to return to western Europe. There is no independent confirmation of the radioactivity in the air moving eastward across Asia.

(A weather map should be attached to today's Task Force Report. If you do not have a copy, it can be picked up in the EPA press office, room 311, West Tower, 401 M St., S.W. (202) 382-4355.)

Environmental monitoring data have been provided by the Swedish government for the Stockholm area for April 28-30. Extrapolations of those data suggest that radiation exposure levels at the Chernobyl site would have been in a range from 20 rem to hundreds of rem whole-body for the two-day period over which most of the radiation release probably took place. Radiation doses for the thyroid gland have been estimated to be in a range from 200 rem to thousands of rem for the same period. These doses are sufficient to produce severe physical trauma including death. It should be emphasized that these are estimates subject to considerable uncertainty. The U.S. has as yet no information from the Soviet Union as to actual radiation levels experienced at the accident site.

The White House has established an Interagency Task Force to coordinate the Government's response to the nuclear reactor accident in Chernobyl. The Task Force is under the direction of Lee M. Thomas, Administrator of the Environmental Protection Agency, with representatives from the White House, Department of State, EPA, Department of Energy, Nuclear Regulatory Commission, National Oceanic and Atmospheric Administration, U.S. Air Force, Department of Agriculture, Food and Drug Administration, Federal Emergency Management Agency, Department of Interior, Federal Aviation Administration, the U.S. Public Health Service, and other agencies.

# # #

PLEASE NOTE: THE EPA PRESS OFFICE WILL BE OPEN OVER THE WEEKEND FOR UPDATING. HOURS WILL BE FROM 10am TO 2PM. 202-382-4355.

cc: M. P. Alexich
T. O. Argenta
S. J. Brewer
J. M. Cleveland
C. A. Erikson
J. G. Feinstein
R. F. Kreeger
J. J. Markowsky
J. B. Shinnock
D. H. Williams, Jr.
John E. Dolan

SSINS No.: 6835
IN 86-32, Supplement 1

UNITED STATES
NUCLEAR REGULATORY COMMISSION
OFFICE OF INSPECTION AND ENFORCEMENT
WASHINGTON, D.C. 20555

June 6, 1986

JUN 1 6 1986

IE INFORMATION NOTICE NO. 86-32, SUPPLEMENT 1: REQUEST FOR COLLECTION OF LICENSEE RADIOACTIVITY MEASUREMENTS ATTRIBUTED TO THE CHERNOBYL NUCLEAR PLANT ACCIDENT

Addressees:

All nuclear power reactor facilities holding an operating license (OL) or a construction permit (CP).

Purpose:

The purpose of this supplement is to provide an update on the response to Information Notice 86-32 and to inform the licensees that the reporting of environmental monitoring data attributable to Chernobyl (within 24 hours) is no longer needed.

Discussion:

Information Notice (IN) 86-32 issued May 2, 1986 requested that reactor licensees report within 24 hours any environmental data collected at their facility attributable to the Chernobyl reactor incident. To date over 46 licensees have responded by reporting evaluated levels of fission products around their facility. All licensees responding to IN 86-32 reported I-131 in rain water and air samples. Measurable levels of Cs-134, Cs-137, Ru-103, Ba-140, La-140, and Te-132 also were frequently reported in air samples. Many of the I-131 concentrations reported in air, milk, and food product (leafy vegetables) samples, although low, were above the special reporting levels listed in Table 3.12-2 of the standard Radiological Effluent Technical Specifications (RETS).

Responses to IN 86-32 were entirely on a voluntary basis. The NRC appreciates the cooperation received on this effort. The licensees' data were provided to the Federal Interagency Task Force established to deal with the Chernobyl accident. The Environmental Protection Agency has indicated that "the environmental radiation data supplied by NRC licensees were instrumental in understanding particular aspects of the U.S. radiological situation and in answering concerns of U.S. citizens relative to gaseous radioiodine in the air".

8606040003

AMERICAN ELECTRIC
AEP
POWER SYSTEM

INDIANA & MICHIGAN ELECTRIC COMPANY

September 9, 1986 #807

SUBJECT: IE Information Notice 86-32
Request for Collection of Licensee Radioactivity Measurement attributed to the Chernobyl Nuclear Plant Accident.

FROM: S. R. Khalil

TO: R. J. Clendenning

In response to the Chernobyl reactor accident on April 26, 1986, we started a special sample collection and analysis program to evaluate the levels of radioactivity resulted from this accident and to assure that the detected materials are properly identified as to source (e.g. either plant operations or the Chernobyl event). Three sample stations were selected, two on-site stations (ONS-2 and ONS-4) and one off-site station (Coloma). Airborne samples were collected from these stations three times per week (i.e. Tuesday, Thursday and Saturday). The enhanced sample collection program starts on May 3, 1986 and was completed on July 3, 1986. The results of airborne radioiodines and airborne particulates (gross beta) samples are presented in Figures 1 and 4. Samples were also collected in a routine basis according to our plant REMP every seven days from six on-site stations and four off-site stations. The results of the weekly routine samples from these ten stations during second quarter of 1986 are shown in Figures 2,3, 5 and 6.

On May 10, 1986, the iodine levels showed a very slight increase in all three stations, followed by a sharp increase for both airborne particulate and iodine levels on May 13, 1986. During the second half of the month of May 1986, Figure 1 shows that three radioiodines levels were detected on May 15, May 22,, and May 31, 1986 which indicate two decay periods for the I-131 radioactivities in our plant area. Also, Figure 4 shows that three peaks of the airborne particulate activity during May 13 throught June 5, 1986 period. Following this time, the radioiodines and particulates activities were decreased to normal background levels during the month of June until the enhanced sampling program was discontinued. Our routine sampling program continued without interruption as scheduled and indicates that these observed levels was due to the Chernobyl event, not from D.C. Cook Plant.

A rain sample was obtained on May 20, 1986 from Coloma station and the gamma spec. analysis indicated no detectable activity in this sample. The analysis of our routine milk samples collected every 14 days during the second quarter of 1986 are presented in Figure 7 for five milk farm stations. Milk samples collected on May 24 and June 7 shows a I-131 level increased, specially from Wyant station samples in Dowagiac, MI. On June 21, 1986 the iodine radioactivity level was decreased in all stations.

Samir Khalil
S. R. Khalil
/lg

cc: AR#1317

INTRA-SYSTEM

Special Airborne Samples (pCi/m3 x10-3)

:E	ONS2 [I131]	[illegible] [I131]	COLOMA [I131]	ONS2 [BETA]	ONS4 [BETA]	COLOMA [BETA]
APR29	x10-3 < 5	< 5	< 5	30	20	21
MAY3	< 5	< 5	< 5	19	18	14
MAY6	< 5	< 5	< 5	20	15	16
MAY8	< 5	< 8	< 5	9	8	9
MAY10	67	54	49	27	20	23
MAY13	185	182	202	318	314	313
MAY15	206	209	222	333	303	318
MAY17	131	110	80	128	112	77
MAY20	65	58	55	46	42	24
MAY22	94	88	113	300	374	338
MAY24	39	47	36	99	99	17
MAY27	30	41	27	69	67	69
MAY29	15	19	41	53	33	47
MAY31	63	34	45	74	81	93
JUN3	< 5	11	13	183	173	196
JUN5	36	28	23	510	188	153
JUN7	< 5	< 5	20	42	39	40
JUN10	27	8	< 5	67	51	55
JUN12	< 5	< 5	32	20	28	26
JUN14	< 5	< 5	< 5	33	16	25
JUN17	< 5	20	10	20	15	15
JUN19	< 5	47	< 5	31	32	38
JUN21	< 5	18	< 5	42	40	38
JUN24	< 5	10	27	17	11	12
JUN26	< 5	< 5	< 5	8	7	11
JUN28	< 5	< 5	< 5	22	20	16
JUL1	< 5	< 5	< 5	10	8	12
JUL3	< 5	< 5	< 5	11	9	8

MILK IODINE RESULTS PCi/Liter

MILK	TOTZKE	SCHULER	LOZMACK	LIVINGHOU	WYANT
APRIL12	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4
APRIL26	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4
MAY10	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4
MAY24	0.8	5.7	1.3	2.9	22.1
JUNE7	0.5	1.1	2.4	11	22.1
JUNE21	1.6	0.7	1.2	2.3	2.5

AIRBORNE IODINE RESULTS PCi/M3

Routine Airborne Samples
Iodine, [illegible] pCi/m3

	ONS1	ONS2	ONS3	ONS4	ONS5	ONS6	NBF	SBN
[illegible]R8	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
APR15	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
APR22	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
APR29	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
MAY6	<0.005	<0.005	<0.005	<0.005	0.011	<0.005	<0.005	<0.005
MAY13	0.061	0.115	0.093	0.073	0.088	0.081	0.081	0.097
MAY20	0.122	0.096	0.098	0.087	0.093	0.018	0.088	0.109
MAY27	0.044	0.07	~0.05	0.048	0.055	0.048	0.054	<0.005
JUN3	<0.005	0.06	<0.005	<0.005	<0.005	<0.005	0.025	<0.005
JUN10	0.009	0.027	0.014	0.008	0.008	0.013	0.012	<0.005
JUN17	<0.005	<0.005	<0.005	0.02	0.013	<0.005	<0.005	<0.005
JUN24	0.01	0.008	<0.005	0.013	0.016	<0.005	0.008	0.007
JUL1	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005

AIRBORNE PARTICULATES PCi/M3

	ONS1	ONS2	ONS3	ONS4	ONS5	ONS6	NBF	SBN
APR8	0.014	0.013	0.013	0.013	0.011	0.016	0.013	0.014
APR15	<0.005	<0.005	<0.005	<0.005	<0.004	0.006	<0.004	<0.005
APR22	0.01	0.008	0.015	0.009	0.011	0.012	0.011	0.012
[illegible]PR29	0.028	0.03	0.025	0.02	0.02	0.032	0.019	0.016
[illegible]Y6	0.028	0.02	0.018	0.015	0.016	0.018	0.015	0.019
[illegible]Y13	0.131	0.132	0.131	0.093	0.131	0.12	0.105	0.166
MAY20	0.122	0.128	0.106	0.113	0.118	0.016	0.102	0.107
MAY27	0.142	0.127	0.142	0.131	0.127	0.094	0.154	0.155
JUN3	0.093	0.083	0.111	0.087	0.104	0.104	0.101	0.12
JUN10	0.103	0.067	0.068	0.051	0.069	0.085	0.048	0.067
JUN17	0.017	0.02	0.021	0.015	0.023	0.019	0.018	0.022
JUN24	0.025	0.019	0.024	0.021	0.024	0.026	0.029	0.026
JUL1	0.011	0.007	0.008	<0.005	0.012	0.013	0.009	0.009

DOW	COL
< 0.005	<0.005
< 0.005	<0.005
<0.005	<0.005
< 0.005	<0.005
<0.005	<0.005
0.092	0.064
0.075	0.107
0.046	<0.005
<0.005	0.038
< 0.005	< 0.005
<0.005	0.01
<0.005	0.018
<0.005	<0.005

DOW	COL
0.009	0.012
0.004	< 0.005
0.011	0.012
0.036	0.021
0.011	0.016
0.117	0.134
0.078	0.108
0.122	0.107
0.058	0.077
0.057	0.055
0.024	0.015
0.02	0.017
0.011	0.009

ENHANCED AI.BORNE RESULT

D.C.COOK PLANT (REMP)

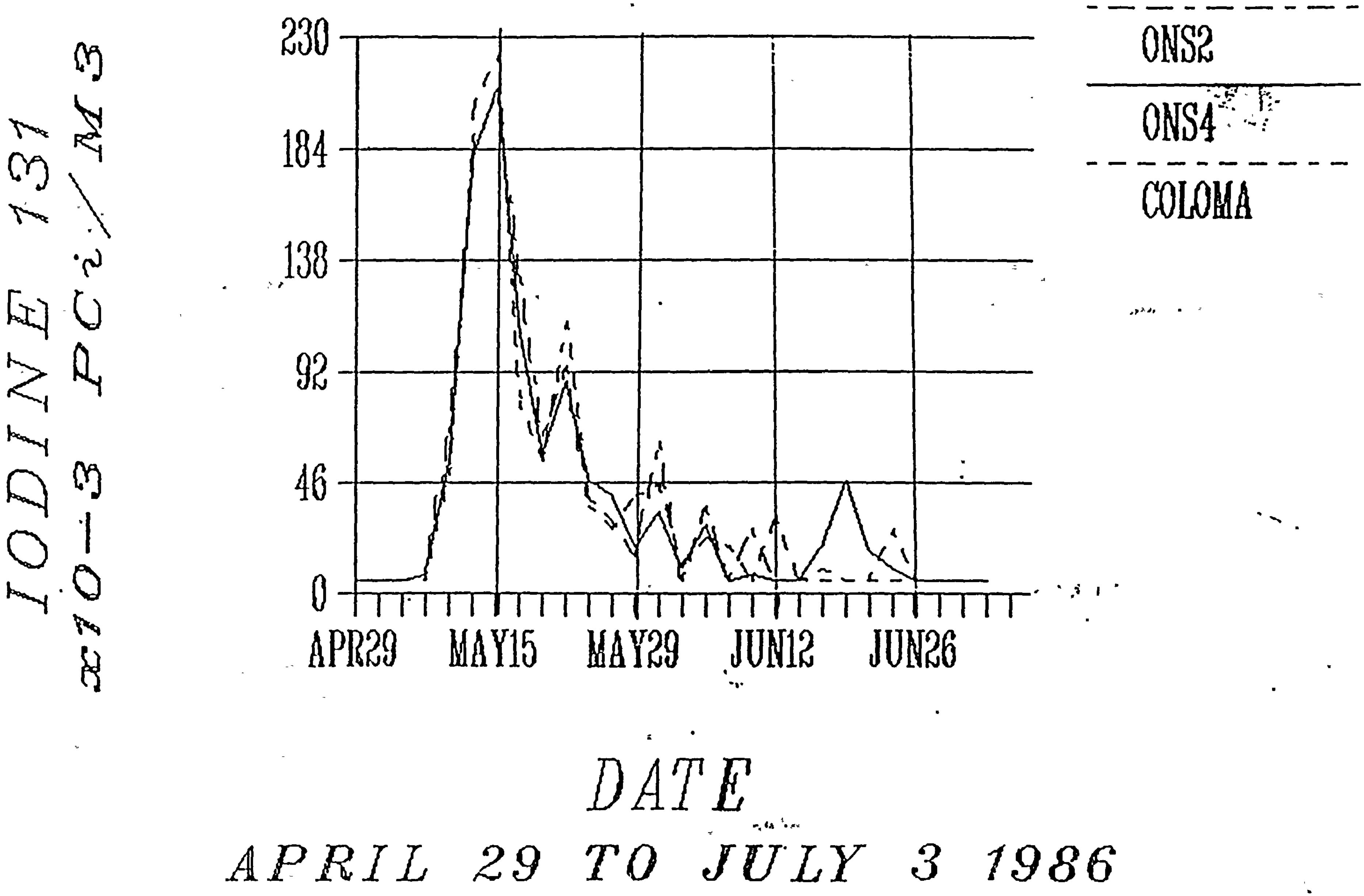
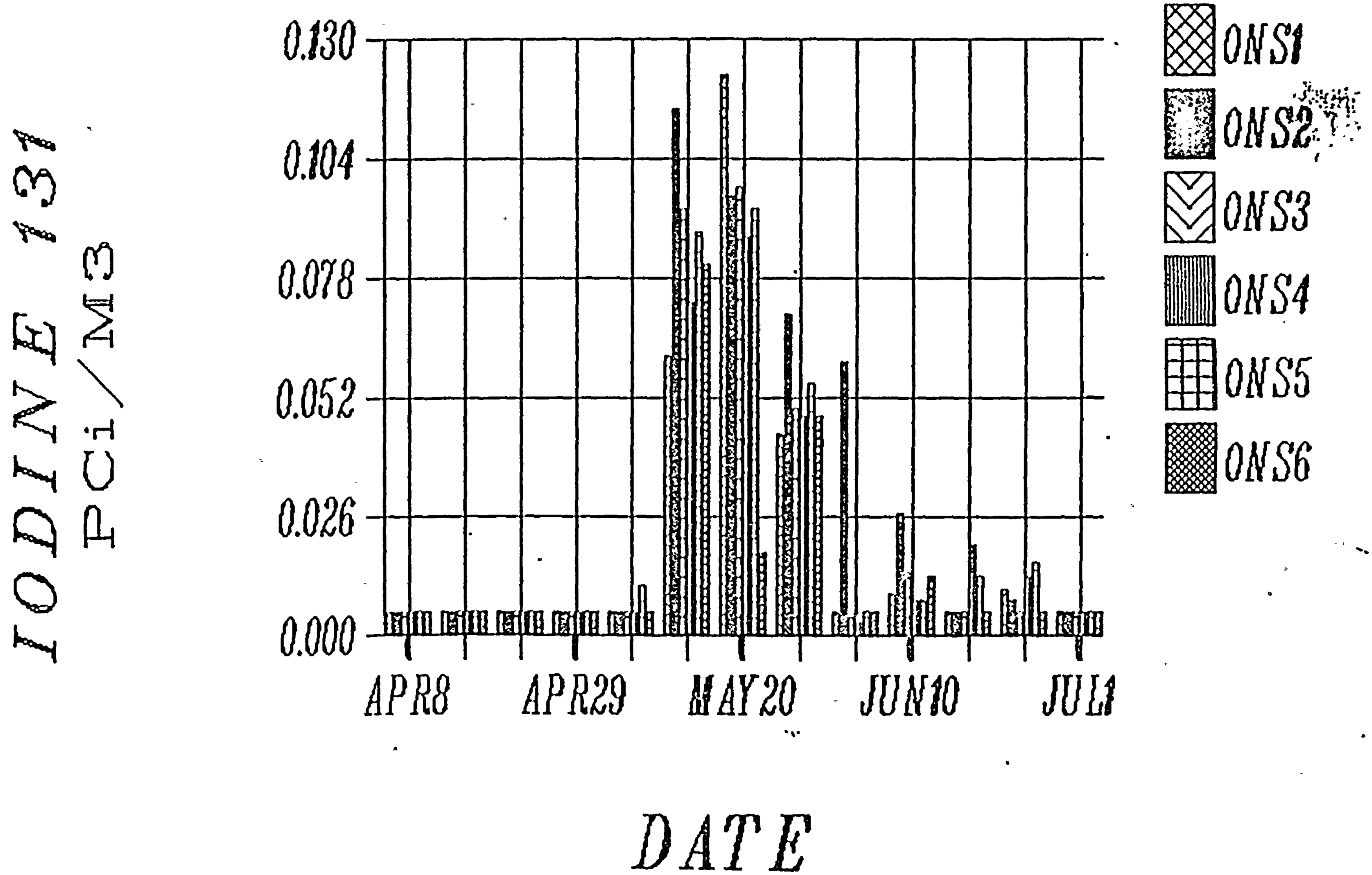


Figure (1)

AIRBORNE IODINE RESULTS

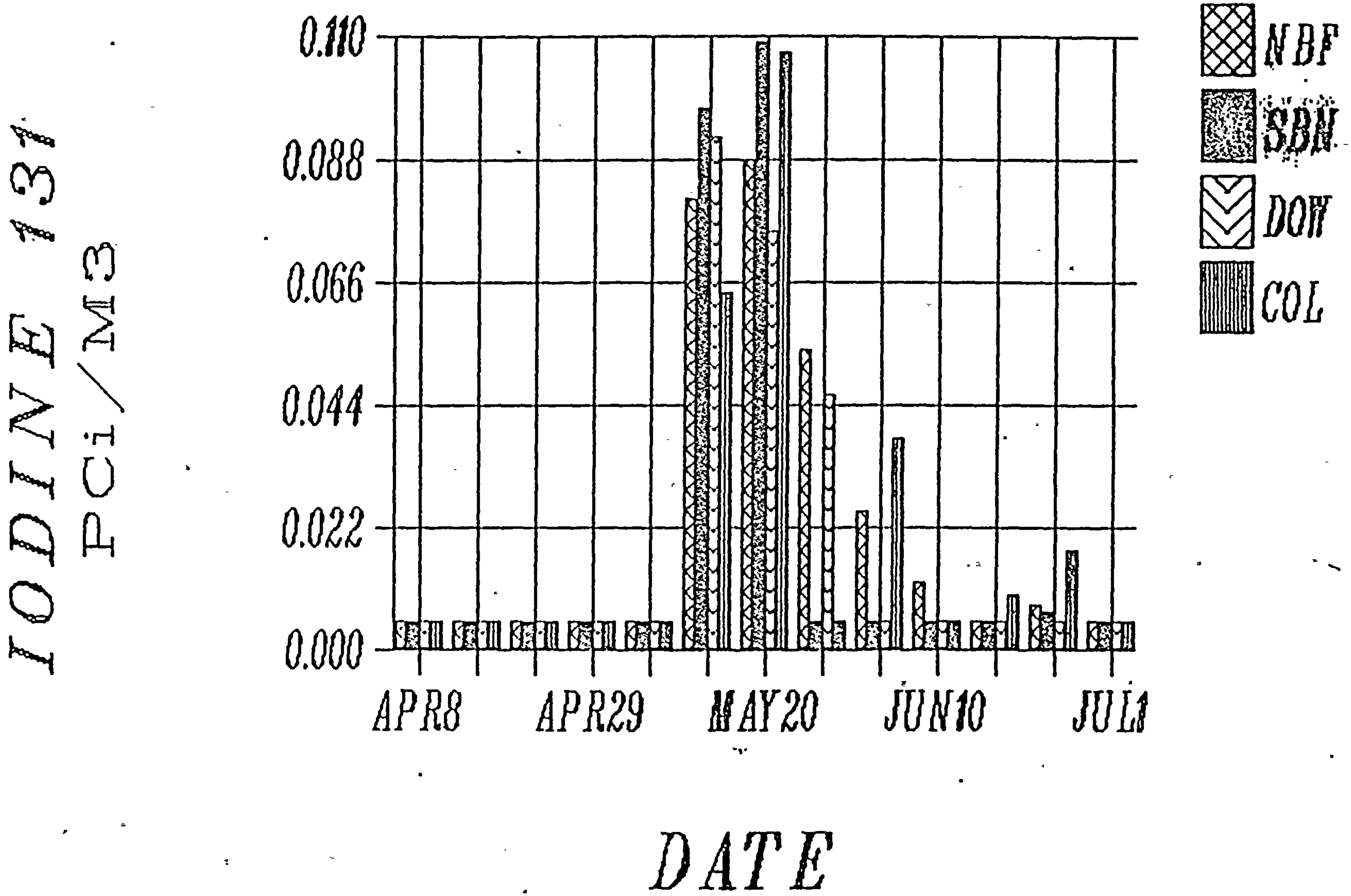
D.C. COOK PLANT (REMP)



APRIL 8 TO JULY 1 1986

AIRBORNE IODINE RESULTS

D.C. COOK PLANT (REMP)

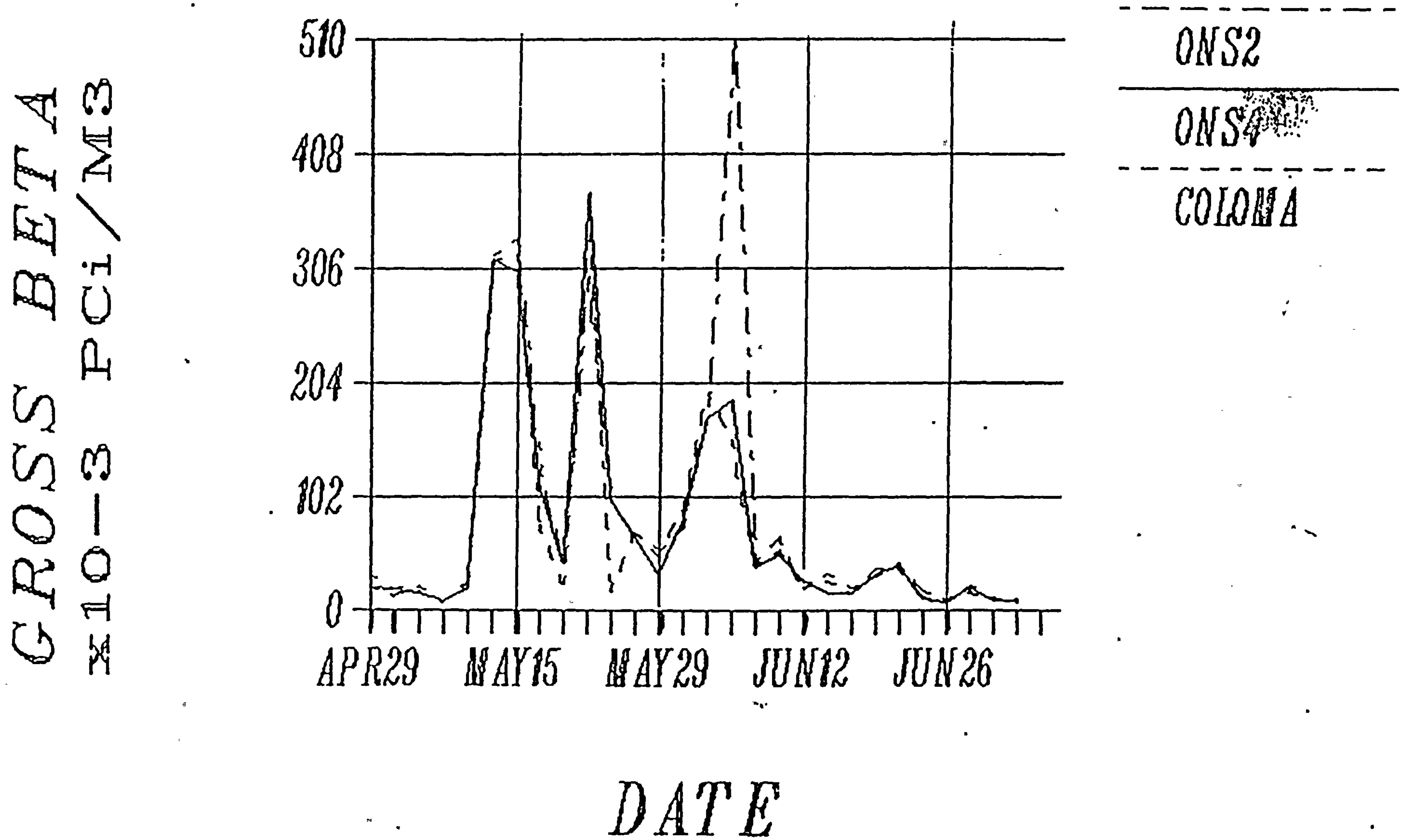


APRIL 8 TO JULY 1 1986

Figure (1)

ENHANCED AI.BORNE RESULT

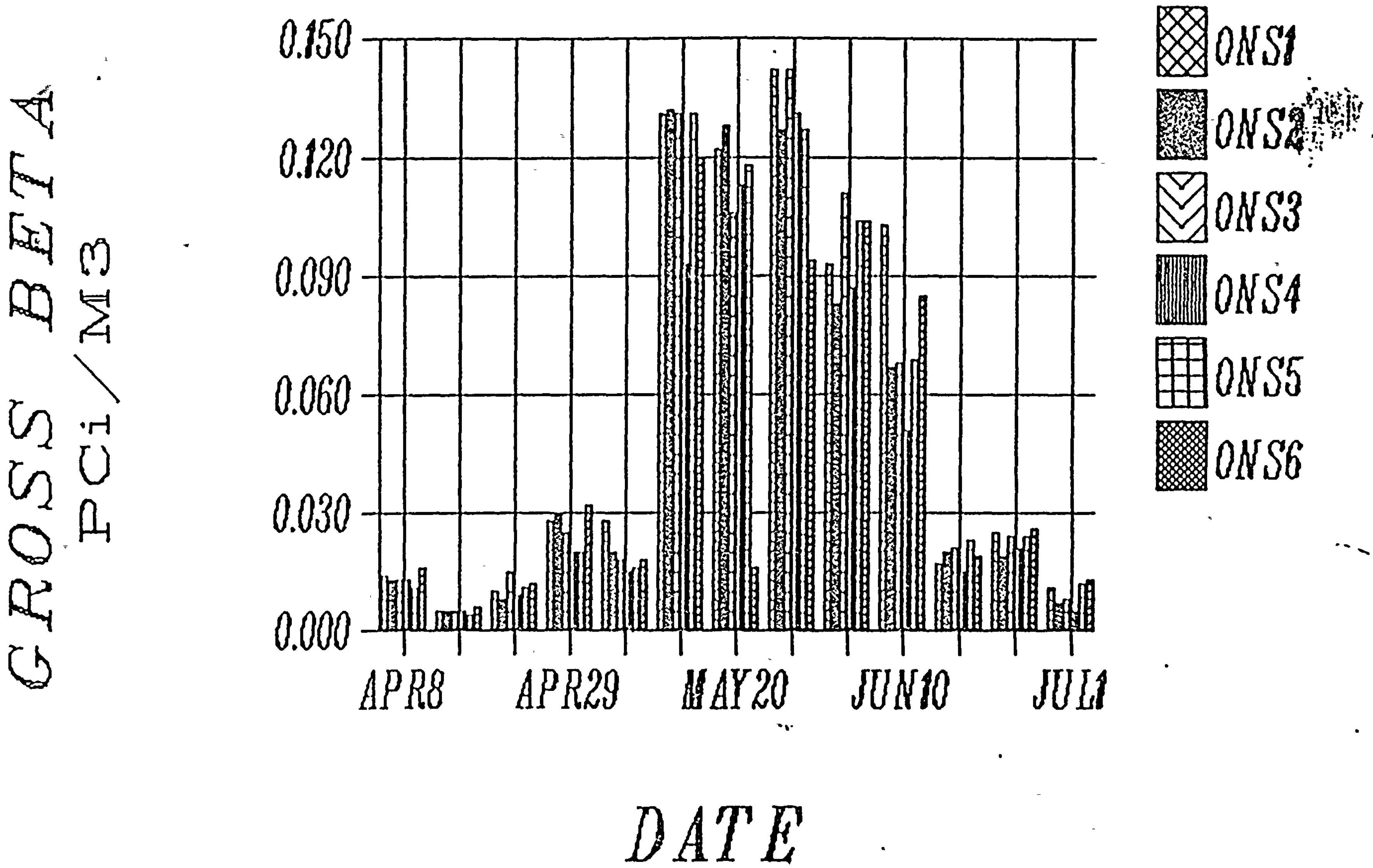
D.C. COOK PLANT (REMP)



APRIL 29 TO JULY 3 1986

AIRBORNE PARTICULATES

D.C. COOK PLANT (REMP)

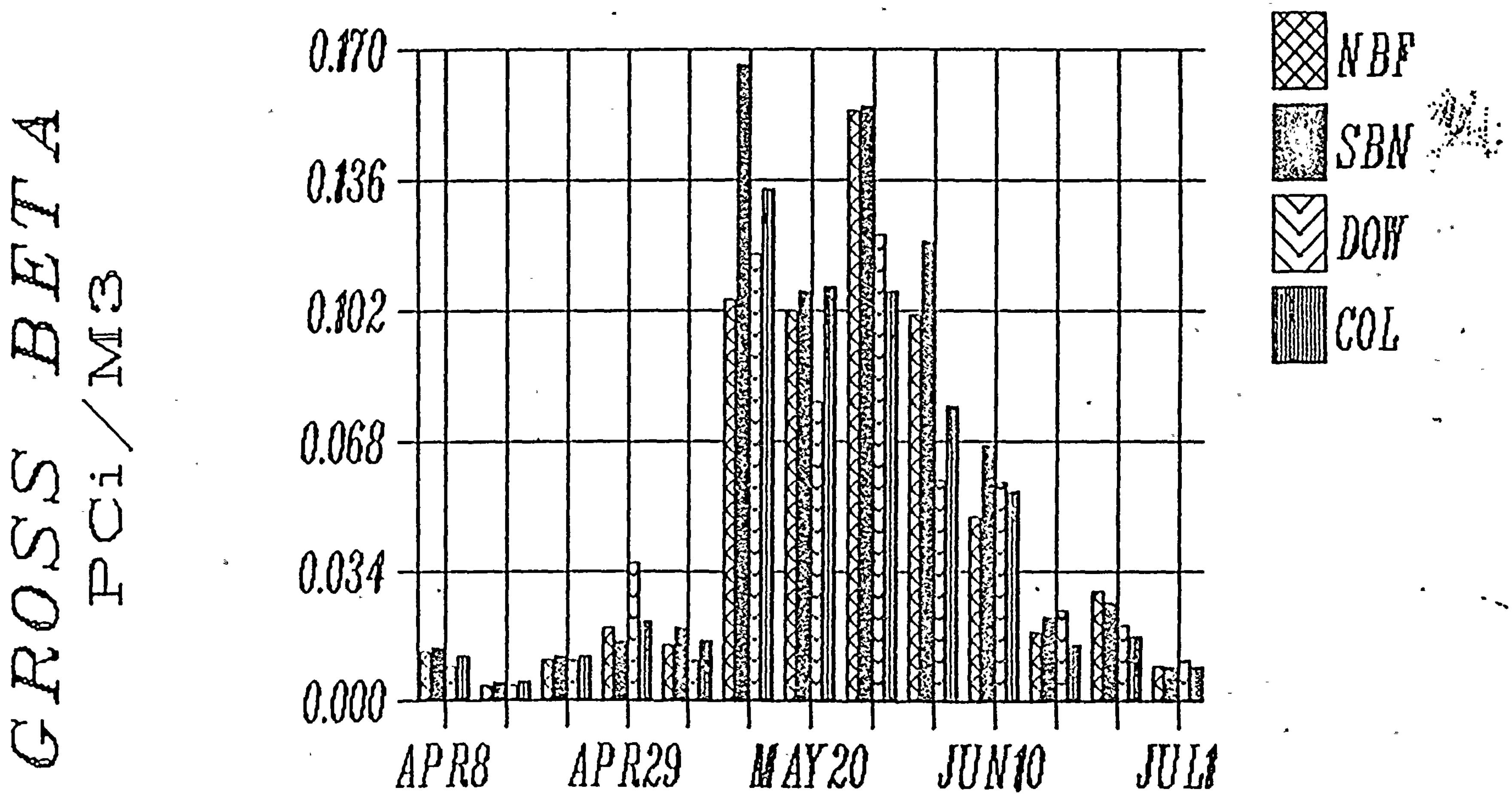


APRIL 8 TO JULY 1 1986

Figure (5)

AIRBORNE PARTICULATES

D.C. COOK PLANT (REMP)

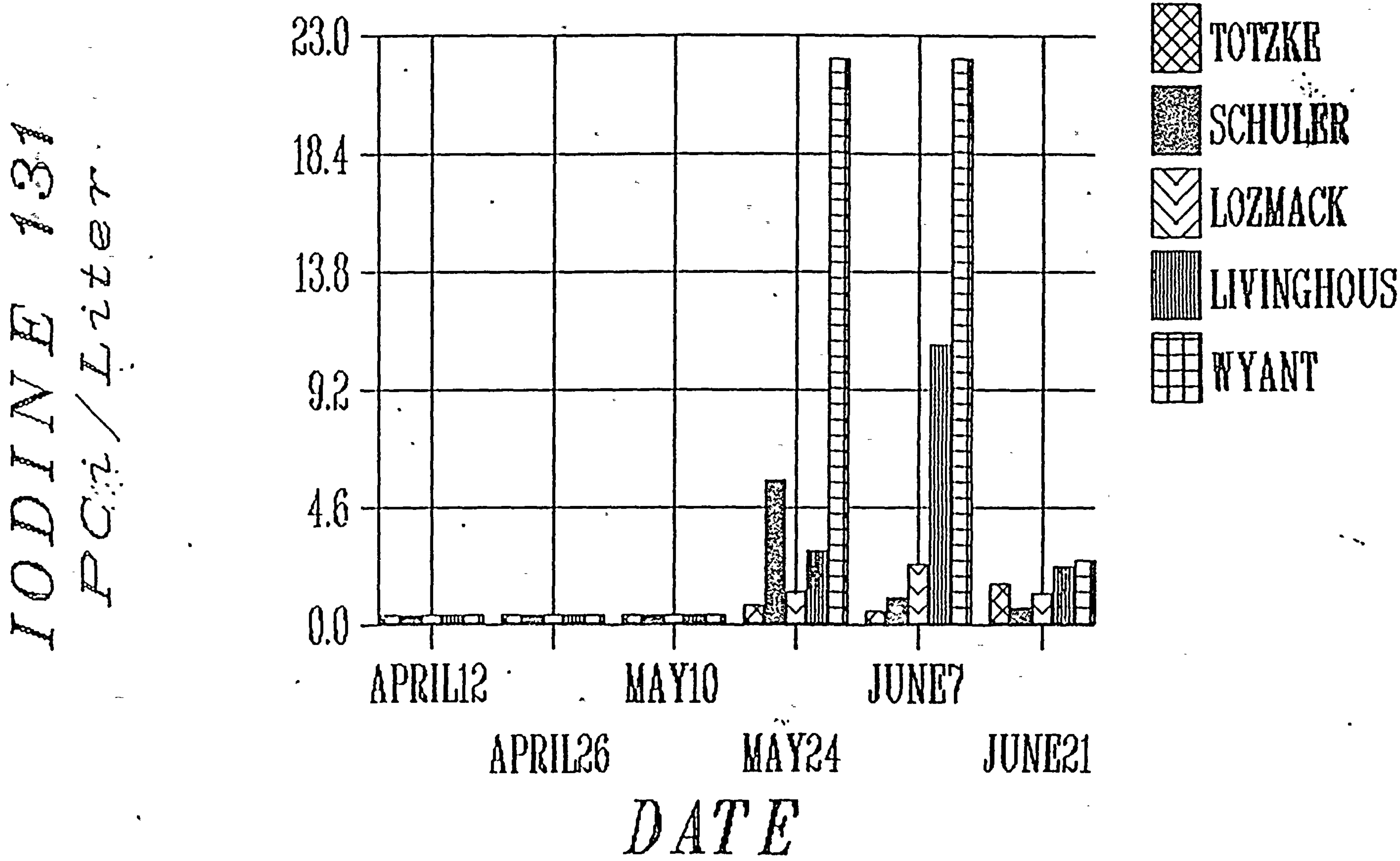


DATE

APRIL 8 TO JULY 1 1986

MILK SAMPLES RESULTS

D.C.COOK PLANT (REMP)



APRIL TO JUNE 1986

INDIANA & MICHIGAN ELECTRIC COMPANY

AMERICAN ELECTRIC POWER SYSTEM

September 9, 1986 #808

SUBJECT: IE Information Notice 86-32

FROM: S. R. Khalil

TO: R. J. Clendenning

I reviewed the Radiological Support Section, AEPSC Report, which was prepared by H. Jones on June 23, 1986. The following are some incorrect information in Mr. Jone's report:

a) Sample results for May 31 and June 5, 1986, are not listed in this report's table.

b) Graph presents only results for May 3 through May 29, 1986, and neglecting the rest of the data.

c) This report was dated June 23, 1986, inspite of it contains results up to July 3, 1986.

d) It contains a misleading statement that the normal sampling routine was resumed when the enhanced sampling program was discontinued. Routine sampling was never stopped and no violation to Technical Specification 3/4.12.1 requirements as Mr. Jone's statement could be interpreted.

e) It contains an incorrect statement for no activity detected in milk samples. Samples collected on May 24 and June 7, 1986, showed increased and detectable I-131 level.

S. R. Khalil

S. R. Khalil

jm

cc: AR #1317

INTRA-SYSTEM

AMERICAN ELECTRIC POWER SERVICE CORPORATION

AMERICAN ELECTRIC AEP POWER SYSTEM

DATE: June 23, 1986

SUBJECT: NRC IE Information Notice 86-32 - Request for Collection of Licensee Radioactivity Measurements Attributed to the Chernobyl Nuclear Plant Accident Close-Out Information Summary.

FROM: H. W. Jones

TO: AEP:NRC:9455

Following the Chernobyl reactor accident and the resulting release of radioactive material to the atmosphere, the Nuclear Regulatory Commission issued NRC IE Information Notice 86-32 in which they requested licensees to report any anomalous findings in their radiological environmental monitoring program which would reasonably be attributed to the Chernobyl plume. Consequently the D. C. Cook Plant's Radiation Protection Section requested that Controls for Environmental Pollution, Inc. (CEP) begin an enhanced sample collection and analysis regime on air-borne particulate and air-borne radioiodine samples. A total to three (3) sample stations were selected for this regime, two on-site (ONS-2 and ONS-4) and one off-site (Coloma) stations which were sampled three times a week (Tuesday, Thursday, and Saturday). The results of this sampling regime are attached in both tabular and graphical form to this report, and is summarized below. All three air sample stations showed background levels of airborne particulates (i.e. gross beta) and I-131 up until May 8, 1986. At which time only one of the on-site sample stations showed a very slight increase in I-131. From this time until May 15, 1986; both the airborne particulates and I-131 levels steadily increased. After this date, the radioactivity levels decreased gradually except for those samples which showed an increase in both airborne particulates and I-131 levels collected on May 22, 1986. This transitory increase is hypothesized to have occurred because of a change in the direction of the upper atmospheric jet stream prior to sample collection.

The noted decrease in activity levels continued to approach normal background levels, until such times as increased sampling was discontinued and the normal sampling routine was resumed. In addition to these airborne particulate and iodine samples, a special rain sample was obtained on May 20, 1986; no detectable activity was observed. In addition to these samples, routine milk samples collected during this time were found to have no measurable levels of activity noted. Per a discussion with a member of the Radiation Protection Section (on May 30, 1986) have been reported to the NRC. On June 6, the NRC issued Supplement 1 to NRC IE Information Notice 86-32, notifying Licensees that such enhanced environmental sample analysis regimes are no longer required, and the Plant Radiation Protection Section was subsequently notified on June 17, 1986.

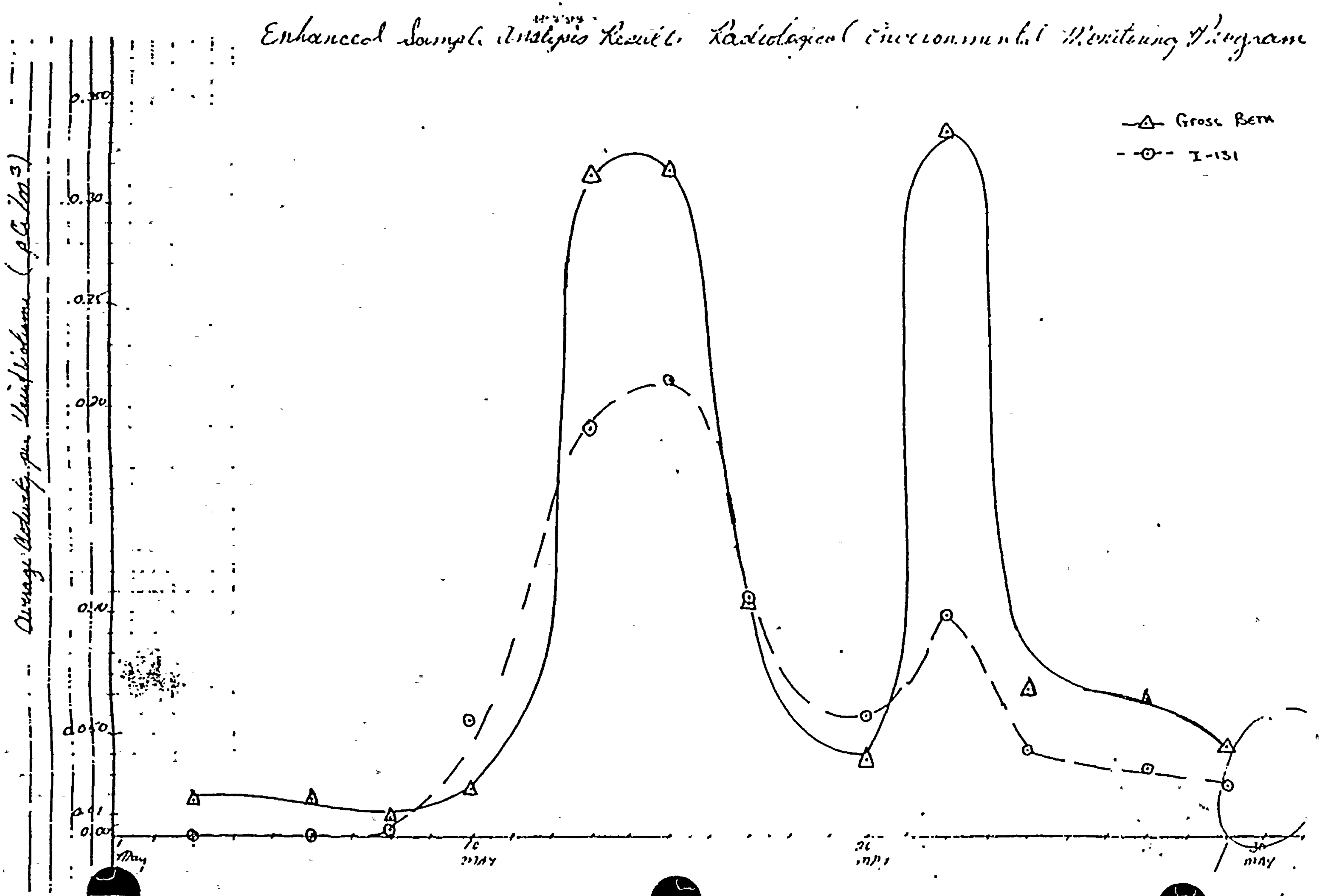
If you have any questions concerning any information found in this memo, please contact me at extension 2024.

H. W. Jones

edg

Attachments

cc: S. J. Brewer
M. P. Alexich
R. W. Jurgensen
D. V. Shaller
T. A. Kriesel, w/o att.
R. J. Clendenning, w/o att.
S. R. Khalil, w/o att.
D. Allen, w/o att.
J. Kambach, w/o att.



Enhanced Sample Analysis Results Radiological Environmental Monitoring Program
Gross Beta
I-131
Average Activity per Unit Volume (pCi/m³)
0.30
0.25
0.20
0.10
0.050
0.01
0.001
1 May
10 May
20 May
30 May

Radiological Environmental Monitoring Program

Enhanced Sample Analysis Results

DATE	I-131 (10^{-3} pCi/m^3) ONS-2	I-131 ONS-4	I-131 COLOMA	Gross Beta (10^{-3} pCi/m^3) ONS-2	Gross Beta ONS-4	Gross Beta COLOMA
[illegible]	<5	<5	<6	20±2	[illegible]	[illegible]
-3-86	< 5	< 5	< 5	19±6	18±4	14±4
-6-86	< 5	< 5	< 5	20±2	15±2	16±2
-8-86	< 5	8±3	< 5	9±2	8±1	9±1
-10-86	67±16	54±14	49±11	27±4	20±3	23±3
-13-86	185±14	182±14	202±16	318±7	314±7	313±7
-15-86	206±17	209±17	222±18	333±9	303±9	318±9
5-17-86	131±19	110±15	80±12	128±6	112±5	77±4
5-20-86	65±7	58±7	55±7	46±3	42±3	24±2
5-22-86	94±12	88±12	113±15	300±8	374±9	338±9
5-24-86	39±9	47±10	36±9	99±5	99±5	17±3
5-27-86	30±8	41±8	27±7	69±4	67±4	69±4
5-29-86	15±8	19±9	41±10	53±5	33±4	47±5
5-31-86	63 ± 5	39 ± 9	45 ± 5	79 ± 5	87 ± 5	92 ± 5
6-3-86	< 5	11±7	13±9	183±5	173±5	196±5
6-5-86	36 ± 8	28 ± 10	23 ± 10	510 ± 17	188 ± 7	153 ± 6
6-7-86	< 5	< 5	20±11	42±5	39±4	40±4
6-10-86*	27±8	8±6	< 5	67±4	51±3	55±3
6-12-86	< 5	< 5	32±11	20±4	28±4	26±4
6-14-86	< 5	< 5	< 5	33±4	16±3	25±3
6-17-86 *	< 5	20±5	10±4	20±3	15±2	15±2
6-19-86	< 5	47±12	< 5	31±4	32±4	38±4
6-21-86	< 5	18±7	< 5	42±4	40±4	38±4
6-24-86	< 5	10±7	27±9	17±2	11±2	12±2
6-26-86	< 5	< 5	< 5	8±3	7±3	11±3
6-28-86	< 5	< 5	< 5	22±4	20±4	16±4
7-1-86	< 5	< 5	< 5	10±3	8±2	12±2
[illegible]-86	< 5	< 5	< 5	11±4	9±4	8±4

*Duplicate Samples

NA NA

Radiological Environmental Monitoring Program

Enhanced Sample Analysis Results

GAMMA SPECTROSCOPY ANALYSIS
Composite Particulate Samples

DATE	MAN-MADE RADIONUCLIDES (10^{-3} pCi/m^3) Cs-134	Cs-137	I-131	Ru-103	
5-22-86	90 ± 13	166 ± 13	86 ± 34	299 ± 19	

Remarks

Appendix 2.4

Milk Farm Census - 1986

TABLE VIII
DONALD C. COOK NUCLEAR PLANT

MILK ANIMAL SURVEY TABLE

SECTOR	SURVEY YEAR	DISTANCE (MILES)	NAME	ADDRESS
B	a	N/A	N/A	N/A
	b	N/A	N/A	N/A
C	a	N/A	N/A	N/A
	b	21.25	ROBERT SONNENBERG	RT 2, WATERVLIET, MICH
D	a	4.5	GERALD TOTZKE	RT 1, BARODA
	b	4.5	GERALD TOTZKE	RT 1, BARODA
E	a	13.0	ANDREWS UNIV.	BERRIEN SPRINGS
	b	13.0	ANDREWS UNIV.	BERRIEN SPRINGS
F	a	7.0	LEE NELSON	RT 1, BOX 390A, SNOW RD. BARODA
	b	7.0	LEE NELSON	RT 1, BOX 390A, SNOW RD. BARODA
G	a	4.25	G.G. SHULER + SONS	RT 1 SNOW RD BARODA
	b	4.25	G.G. SHULER + SONS	RT 1 SNOW RD. BARODA
H	a	4.75	NORMAN ZELMER	11701 S. GAST RD BRIDGMAN
	b	4.75	NORMAN ZELMER	11701 S. GAST RD BRIDGMAN
J	a	7.8	WILLIE WARMBIEN	AVERY RD. THREE OAKS
	b	8.25	JOHN WARMBIEN	BOX 184 AVERY RD. THREE OAKS
K	a	12.0	KENNETH TAPPAN	RT 2. THREE OAKS
	b	11.0	GEORGE MICHELL	SPRING CREEK RD. THREE OAKS.

All other sectors are over water.

[a]Reporting Year = 1986

[b]Year Prior to Reporting Year = 1985

Appendix 2.5

Residential Land Use Census - 1986

TABLE VII
DONALD C. COOK NUCLEAR PLANT

RESIDENTIAL LAND USE SURVEY TABLE

SECTOR	SURVEY YEAR	HOUSE#[1]	DISTANCE IN FEET	LOT#
B	a	2	2700	6-4.1
	b	2	2700	6-4.1
C	a	3	3300	6-6800-28
	b	3	3300	6-800-28
D	a	4	6150	5-36
	b	4	6150	5-36
E	a	5	6150	5-25.5
	b	5	6150	5-25.5
F	a	6	6000	8-10.3
	b	6	6000	8-10.3
G	a	7	4650	7-4
	a	7	4650	7-4
H	a	8	4950	7-8600-7.8
	b	8	4950	7-8600-7.8
J	a	9	3450	7-10.3
	b	9	3450	7-10.3
K	a	10	3300	7-10.3
	b	10	3300	7-10.3

All other sectors are over water.

[1]House# indicated is not address but reference number used on map when obtaining the raw field data.

[a]Reporting Year = 1986

[b]Year Prior to Reporting Year = 1985

Appendix 2.6

Condition Reports - REMP

American Electric Power System
INDIANA & MICHIGAN ELECTRIC COMPANY
DONALD C. COOK NUCLEAR PLANT
P.O. Box 458, Bridgman, Michigan 49106
(616) 465-5901

May 1, 1986

Donald C. Cook Nuclear Plant Unit Nos. 1 and 2
Docket Nos. 50-315 and 50-316
License Nos. DPR-58 and DPR-74

Mr. J. G. Keppler, Regional Administrator
United States Nuclear Regulatory Commission
Office of Inspection and Enforcement
Region III
799 Roosevelt Road
Glen Ellyn, IL 60137

Dear Mr. Keppler,

In accordance with Technical Specification 3.12.1 we are submitting this special report to advise you that the minimum lower limits of detectability in the lake water sampling stations and the drinking water stations exceeded the limits of Table 4-12.1.

During 1985 samples of water from Lake Michigan were composited by three (3) indicator and three (3) background stations. Samples collected throughout the year for the three (3) background stations were composited on a monthly basis and analyzed for gamma emitters and gross beta. Samples for the three (3) indicator stations were composited on a bi-monthly basis and analyzed for gamma emitters and gross beta. The results were included in the Annual Environmental Operations Report for 1985 which was submitted on May 1, 1986.

It was identified by plant personnel that the radiochemistry counting equipment was unable to meet the required technical specification Lower Limits of Detection (LLD of T/S 4-12.1) and that the Minimum Detectable Activity (MDA) in some cases exceeded the reporting values as specified in T/S 3.12.1. The LLD is defined as the detection capability for the instrument only using the equation in T/S Table 4.12-1 and the MDA, as the detection capability for a given instrument, procedure and type of sample. This was not previously identified because the LLD values were never compared to the maximum values for LLD in Table 4.12-1 or the reporting levels required by T/S 3.12.1. We do not have the data to prove compliance with the LLD values required by T/S 4.12-1 since April 15, 1983 when the Radiological Environmental Technical Specifications went into effect. However, the system backgrounds would have increased with time and efficiency reduced, both of which we believe, would generate LLD values equal to or lower than those presently obtainable. Prior to this date, no maximum values for LLD were required.

In two instances for Cs-134 and I-131 the MDA values obtained exceeded the reporting levels in Technical Specification Table 3.12-2. The following is a comparison of the D. C. Cook Plant MDA, the Technical Specifications maximum value for the LLD (Table 4.12-1), Cook LLD limits, and the reporting levels required by Table 3.12.2.

RADIONUCLIDE	MAXIMUM LLD pCi/l (T/S TABLE 4.12-1)	COOK MDA VALUE pCi/l	COOK LLD LIMITS pCi/l	REPORTING LE[illegible]Ci/l (T/S TABLE 3.[illegible]2)
Gross Beta	4	2700 - 3540	2700 - 3540	N/A
H-3	2000	500 - 610	500 - 610	20,000
Mn-54	15	29	2.8	1,000
Fe-59	30	57	15.4	400
Co-58, 60	15	58, 49	15.8, 18.6	1,000 - 300
Zn-65	30	40	15.6	300
Zr-95	30	75	10.6	400
Nb-95	15	75	10.7	400
* I-131	1	48	4.9	2
° Cs-134	15	50	8.4	30
Cs-137	18	45	12.8	50
Ba-140	60	196	12.6	200
La-140	15	196	21.8	20[illegible]

* LLD > Reporting Level
° MDA > Reporting Level

In addition to the cases of Cs-134 and I-131 MDA values exceeding the reporting level, there was one instance where although the LLD value was less than the reporting level, the quarterly average concentration exceeded the reporting level. This occurred during the first quarter of 1985 for the lake water sample station L1 for Cs-137. The cause of this occurrence has been determined to be the elevated MDA values for two (2) months of the quarter when combined with the somewhat higher results for the third month of the quarter.

No elevated releases which would have been expected to increase the environmental sampling radioactivity levels above the maximum LLD were made at anytime. It is believed that the MDA being over the required reporting level is an analytical problem and not a result of plant operations. These findings are summarized below:

RADIONUCLIDE	SAMPLE STATION	CALENDAR QUARTER	CAUSE
Cs-134, I-131	L1, L2, L3	1, 2, 3, 4	MDA > Reporting Level
	St. Joseph	1, 2, 3, 4	MDA > Reporting Level
	Lake Township	1, 2, 3, 4	MDA > Reporting Level
	New Buffalo	1, 2, 3, 4	MDA > Reporting Level
Cs-137	L1	1	Elevated MDA caused aver[illegible] quarterly concentration t[illegible] exceed reporting level.

To prevent recurrence we have started and will continue sending the lake and drinking water samples to the radiological environmental monitoring program contractor, Controls for Environmental Pollution, Inc. (CEP), or another qualified laboratory with the capability to reach the required limits.

In addition, a plant procedure now directs the review and comparison of the Radiological Environmental Monitoring Program Data to Technical Specification requirements.

The required LLD values currently achievable by CEP are summarized below:

RADIONUCLIDE	CEP DETECTION LIMITS - pCi/l	MAXIMUM LLD - pCi/l (T/S TABLE 4.12-1)
Gross Beta	3	4
H-3	500	2000
Mn-54	2	15
Fe-59	3	30
Co-58, 60	5	15
Zn-65	15	30
Zr-95	5	30
Nb-95	5	15
I-131	1	1
Cs-134	7	15
Cs-137	2	18
Ba-140	4	60
La-140	4	15

Sincerely,

A. Olan Blind for

W. G. Smith, Jr.
Plant Manager

/sg

cc: John E. Dolan
M. P. Alexich
R. F. Kroeger
C. A. Erikson
R. W. Jurgensen
J. F. Stietzel
R. C. Callen, EPSC
G. Charnoff, Esq.
D. Hahn
INPO
PNSRC
S. R. Brewer
B. A. Svensson
A. A. Blind
Dottie Sherman, ANI Library
T. A. Kriesel
R. J. Clendenning
NRC Resident Inspector

8

MANAGEMENT REVIEW

PMI-7030
ATTACHMENT NO. 1

WEA

DONALD C. COOK NUCLEAR PLANT
CONDITION REPORT

Page 1 of ___

C/R Category: (A) B C (D) E F

C/R No.: 12-04-86-388

Classified By: ______ / 4/2/86

LER No.: ______

Offsite Notification:

( ) NRC-ENS ( ) NRC-Res. ( ) AEPSC ( ) I&M ( ) EIC-PA

Completed By: ______ ______ ______ ______ ______

Date/Time: ______ ______ ______ ______ ______

Investigation Assigned To: T. Kriese

LER Assigned To: T. Kriese (special report) PNSRC 4-15-87 NRC 5-1-87

Condition Report Due Date: ______

LER Due Date: PNSRC 4-19-86 NRC 4-30-86

PNSRC Review Date: ______ Mtg. No.: ______ PNSRC Signature: ______

S S S S S S S S S S S S S S S S S S S S S S S S S S S S S S S S S S

C/R Initiated (Date): April 1, 1986

Unit Affected: 1 & 2

Date of Event: April 1, 1986

Time of Event: 1:30 PM

Plant Conditions at Time of Event: U-1 Mode 1 Power Level 90

U-2 Mode 6 Power Level 0

Item Reported On: Lower limits of Detection (LLD) for waterborne (Surface and Drinking) Samples

Event Description: when compiling the lake water results of 1985 for the Annual Environmental Operating Report, as per procedure 12 THP 6010 RAD.050, Rev. 0 it became apparent that several radionuclides results do not reach the required LLD limits of the Tech. Spec. Table 4.12.1. The lake samples were collected and analyzed by the plant chemistry section.

Reported By: SAMIR KHALIL

Immediate Actions: None.

(see attached investigation and preventive action. No further action is required)

Job Order No.: ______

Action Taken By: SAMIR R. KHALIL

CATEGORY A,C,D,E INITIAL DISTRIBUTION: Plant Manager, PNSRC Secretary, Originator, QC Superintendent, AEPSC QA Supervisor, NRC Resident Inspector, Originating Department Head, Others: ______

CONDITION REPORT INITIATOR

TAK

DETERMINATION OF SIGNIFICANT EVENTS

The evaluators are to review each event description to determine if this event warrants PNSRC review of investigation and closeout actions. If any question is answered "Yes", the event is significant and requires PNSRC review for closeout. If the answer to all questions is "No", the event is not significant enough to warrant PNSRC review of the investigation and the event is to be evaluated and dispositioned by the assigned Department Head in accordance with paragraph 5.5.1.

- [x] Yes [ ] No - Does the event constitute a violation of applicable codes, regulations, license requirements or Technical Specifications (an LCO/Action Statement not met)?

- [ ] Yes [x] No - If the event involves Technical Specification/safety related equipment, is additional followup warranted other than Job Order completion or drawing revision/review (consideration for Part 21 reporting)?

- [ ] Yes [x] No - Is the event of generic interest which should be entered as an operating experience on the Nuclear NETWORK System? (Requires Distribution to STAs)

- [ ] Yes [x] No - Is this a repetitious occurrence which requires resolution beyond the specific corrective action? (e.g., adverse trend from frequency of occurrence.)

NOTE: 1) If "Yes" box is checked, the investigation and closeout of this event must be reviewed by PNSRC.

2) Other events may be designated for PNSRC closeout review at the discretion of the evaluators.

Lead Reviewer [signature] Date 4/2/96

IND. & MICH. ELECT. CO.
RECEIVED
APR 2 1996
DONALD C. COOK PLANT
Q. C. DEPARTMENT

CONDITION REPORT NO.: 12-04-86-388

Investigation Report: A month ago, it was found that I-131 results does not meet the LLD limit as per Table 4.12-1 of our Tech. Spec. Action has been taken by the plant chemistry section to send the Lake water samples to offsite laboratory, Control for Environmental Pollution Inc. (CEP) which has the capability to reach the required limit. The attached information is being prepared to be submitted in the Annual Environmental Operating Report for 1985 which is due to NRC prior to May 1, 1986. No further action is req...

Cause of Event:
- ☐ Personnel Error
- ☐ Defective Procedure
- ☐ External Cause
- ☐ Component Failure
- ☐ Design, Manufacturing, Construction/Installation
- ☐ Environmental Qualification
- ☐ Electrical Component Aging
- ☒ Unknown
- ☒ Other: the plant counting equipment capability limit.

Should this Event be Considered For:

	Yes	No
10CFR21	☐	☑
Is the Corrective/Preventive Action applicable to other equipment/unit?	☐	☑

Preventive Action Taken: waterborne (surface and drinking) samples are and will be, sent to Control for Environmental Pollution Inc. (CEP) for all required analysis as per Tech. Spec. 3/4.12-1 Table 3.12-1 items 3a and 3c. Analysis will be performed for I-131, Gross Beta, Tritium and gamma isotopic analysis of each composite sample.

Investigation Completed By: Samir R. Khalil Date: 4/1/86

Preventive Action Taken By: [signatures] Date: 4/1/86

Department Head Approval: [signature] Date: 4-1-86

C/R 12-04-86-388 Review Report

Description of Condition:

During preparation of the Annual Environmental Operating Report for 1985 as per 12 THP 6010.RAD.050, it appears to us that the waterborne (surface and drinking) results do not meet the Technical Specification, Table 4.12-1 LLD limits for all reported radionuclides, except tritium. These results have been reviewed in accordance with 12 THP 6010.RAD.052. The average concentration for calendar quarter was calculated for any sample result equal to or greater than the reported LLD value, and compared to the Technical Specification, Table 3.12-2.

Technical Specification Review:

Technical Specification 3/4.12.1, Table 3.12-2 and 4.12-1 were reviewed for the reporting level concentration and LLD concentration for all reported radionuclides. It was found that the LLD values for all radionuclides, except tritium, are higher than the LLD limits of Table 4.12-1. Also, the average concentration per calendar quarter for Cs-134 (Lake Township Station - 2nd quarter and L1 Station - 1st quarter) and Cs-137 (L1 Station - 1st quarter) are higher than the reporting level concentrations of Technical Specification, Table 3.12-2.

Cause of Occurrence:

This event was caused due to the Chemistry Section counting equipment was not able to reach the required lower limits of detention without using large volume samples and extremely long count times. The reporting level concentration for Cs-134 and Cs-137 exceeded the Technical Specification, Table 3.12-2 because of the uncertain LLD reported values for these two isotopes.

Corrective Action:

Action has been taken to send the waterborne (surface and drinking) samples to Control for Environmental Pollution, Inc., (CEP), the current contractor for our Radiological Environmental Monitoring Program. The CEP Laboratory has the capability to reach the required Technical Specification LLD limits for all radionuclides (see attachment).

Preventive Action:

The waterborne sample results will be reported as part of the current contractor's monthly report for the Radiological Environmental Monitoring Program.

SAMK
4/7/86

7

DONALD C. COOK NUCLEAR PLANT
CONDITION REPORT — ANNUAL REPORT

Page 1 of 5

MANAGEMENT REVIEW

C/R Category: A B C (D) E F

C/R No.: 2-04-86-474

Classified By: 3AB / JKJB

LER No.: N/A

Offsite Notification: N/A

( ) NRC-ENS ( ) NRC-Res. ( ) AEPSC ( ) I&M ( ) EIC-PA

Completed By: ______

Date/Time: ______

Investigation Assigned To: T. A. KRIESEL

LER Assigned To: N/A

Condition Report Due Date: ______ LER Due Date: N/A

PNSRC Review Date: 11/20/86 Mtg. No.: 1986 PNSRC Signature: PNSRC 4-15-8 NRC 5-1-87

S S S S S S S S S S S S S S S S S S S S S S S S S S S S S S S S S S S S S S

CONDITION REPORT INITIATOR

C/R Initiated (Date): 4/24/86 Unit Affected: 2

Date of Event: 3/1/86 Time of Event: 2200

Plant Conditions at Time of Event: U-1 Mode 1 Power Level 90

U-2 Mode 3 Power Level 0

Item Reported On: Upper Containment Purge - Gas Sample

Event Description: The LLD determined for Xe-138 did not meet the Tech. Spec. LLD of <1 E-4. The concentration determined was <1.95 E-3.

Reported By: Russ [signature]

Immediate Actions: None Taken

Job Order No.: N/A Action Taken By: N/A

CATEGORY A,C,D,E INITIAL DISTRIBUTION: Plant Manager, PNSRC Secretary, Originator, QC Superintendent, AEPSC QA Supervisor, NRC Resident Inspector, Originating Department Head, Others: ______

TAK

PMI-7030
ATTACHMENT NO. 1

.474
2 of 5

DETERMINATION OF SIGNIFICANT EVENTS

The evaluators are to review each event description to determine if this event warrants PNSRC review of investigation and closeout actions. If any question is answered "Yes", the event is significant and requires PNSRC review for closeout. If the answer to all questions is "No", the event is not significant enough to warrant PNSRC review of the investigation and the event is to be evaluated and dispositioned by the assigned Department Head in accordance with paragraph 5.5.1.

Annual Report entry required

- [x] Yes [ ] No - Does the event constitute a violation of applicable codes, regulations, license requirements or Technical Specifications (an LCO/Action Statement not met)?

- [x] Yes [ ] No - If the event involves Technical Specification/safety related equipment, is additional followup warranted other than Job Order completion or drawing revision/review (consideration for Part 21 reporting)?

- [ ] Yes [x] No - Is the event of generic interest which should be entered as an operating experience on the Nuclear NETWORK System? (Requires Distribution to STAs)

- [ ] Yes [x] No - Is this a repetitious occurrence which requires resolution beyond the specific corrective action? (e.g., adverse trend from frequency of occurrence.)

NOTE:
1) If "Yes" box is checked, the investigation and closeout of this event must be reviewed by PNSRC.
2) Other events may be designated for PNSRC closeout review at the discretion of the evaluators.

Lead Reviewer [signature] Date 4/26/86

CONDITION REPORT NO.: 2-04-86-474

Page ~~1A~~ 3 of ~~3~~ 5

Investigation Report: see attached

Cause of Event:
- [ ] Personnel Error
- [ ] Defective Procedure
- [ ] External Cause
- [ ] Component Failure
- [ ] Design, Manufacturing, Construction/Installation
- [ ] Environmental Qualification
- [ ] Electrical Component Aging
- [ ] Unknown
- [X] Other: Procedural Inadequacy

Should this Event be Considered For:

10CFR21 Yes [ ] No [X]

Is the Corrective/Preventive Action applicable to other equipment/unit? Yes [ ] No [X]

Preventive Action Taken: Information provided which requires noble gas counting within 3.5 min of sample collection.

Investigation Completed By: Russ Looker Date: 5/9/86

Preventive Action Taken By: Russ Looker Date: 5/9/86

Department Head Approval: [signature] Date: 5/14/86

C/R 2-04-86-474

A. Technical Specification 4.11.2.1.1 was violated in that the Lower Limit of detectability determined for Xenon-138 exceeded the allowable lower limit of detectability. This violation will be reported in the Annual Radiological Environmental Operating Report for 1986 to be submitted May 1, 1987

B. For purge, three samples are taken: Upper Containment, Lower Containment, and Instrument Room. There is only one counting system, in the counting room, for analyzing these gas samples. The count time for each gas sample is 4000 seconds (66.67 minutes). By the time the Upper Containment gas sample could be counted, the Xenon-138 activity had decayed off enough so that we could not achieve the Tech. Spec. Lower Level of Detectability.

C. No corrective action was taken.

D. Chemical Section Update ~~#287~~ 290 was issued directing that no more than ~~45~~ 35 minutes elapse between sample time and count time.

E. No previous occurrences are known to the investigator.

F. No previous commitments are known to the investigator.

Page 3 of 3

INDIANA & MICHIGAN ELECTRIC COMPANY
Chemical Section Update No. 290

AMERICAN ELECTRIC POWER SYSTEM

DATE: May 13, 1986

SUBJECT: Time Limit for Counting Gas Marinelli's

FROM: Russ Looker

TO: All Chemical Section Personnel

In order to achieve the Tech. Spec. LLD required on a gas sample, the gas marinelli must be counted within 35 minutes after sampling. This time limit is to insure we meet the T.S. LLD for the Xenon/Krypton (Xe133, Xe133m, Xe135, Xe138, Kr87, Kr88) isotopes. The determining isotope is Xe138, which has a half life of 17 minutes.

This will mean that gas marinelli samples on the CAEJ, GSE, GDT's, Vent Stacks, and purge samples cannot be drawn together. In the case of the purge samples, we will try to get R.P. to stagger the samples by at least 1½ hours, and we may have to count them at the ECF. For the CAEJ, GSE, GDT's, and Vent Stacks, they will have to be drawn approx. 1½ hours apart.

The T.S. LLD for the GDT's and purge samples, for gases, is 1×10^{-4} µCi/ml. The T.S. LLD for the CAEJ, GSE, and Vent Stack is 1×10^{-6} µCi/ml. Upon completion of analysis, if these LLD's are not met, a new sample will have to be taken and analyzed.

This Chemical Section Update supercedes Update #287.

Russ

Russ Looker

RL:bw

cc: J. T. Wojcik
Chemical Section Files (1)

INDIANA & MICHIGAN ELECTRIC COMPANY

DATE: December 18, 1986

SUBJECT: Condition Reports PNSRC

FROM: R. A. Palmer/L. G. Holmes

TO: PNSRC

The Condition Report(s) listed below have been completed and the data is ready for your review and approval.

12-10-86-1165

Lisa G. Holmes

Technical ACC

dp

attachment

cc: STA Section

ATTACHMENT NO.

CONDITION REPORT No. 12-10-86-1165 PAGE 1 OF 25

CATEGORY A B C D (E) F

PART 1 - CONDITION IDENTIFICATION AND DESCRIPTION

Description of Condition/Finding: UNPLANNED PARTIAL RELEASE OF #1 GDT

Continuation Sheet: ☐

Method of Discovery: SS NOTIFIED BY MAINTENANCE PERSONNEL WORKING ON VALVE IN SYSTEM.

Reported by: S.J. Chesler

Immediate Action Taken: #1 GAS DECAY TANK WAS PUMPED TO CVCS HOLD UP TKS VIA RECYCLE HEADER. WHEN #1 GDT WAS ~25 PSIG, STOPPED VENTING TO CVCS HOLDUP TANKS & STARTED PUMPING TO #5 GDT. WHEN #1 GDT WAS AT ~5 PSIG, BLED N2 INTO #1 GDT FOR ~2 MIN THEN PUMPED DOWN #1 GDT

Continuation Sheet: ☒ Action Taken by: M. GALLAGHER.

PART 2 - OFF-SITE NOTIFICATION

☐ AEPSC/Person Contacted: ______ By: ______ Date: ______ Time: ______

☐ I&M/Person Contacted: ______ By: ______ Date: ______ Time: ______

☐ NRC/ENS Person Contacted: ______ By: ______ Date: ______ Time: ______

☐ Initial STA Investigation By: S.J. Chesler Date: 10/4/86

☐ Michigan/Person Contacted: ______ By: ______ Date: ______ Time: ______

☐ Not Applicable/Determined by: S.J. Chesler Date 10/4/86 Time: 1310

☐ NRC Resident Inspector Contacted By: ______ Date: ______ Time: ______

PART 3 - PAG REVIEW

☐ LER Due to: PNSRC by: / / NRC by: / /
Assigned to: ______ Dept: ______

☐ Other Reports Due to: PNSRC by: / /
to: NRC, or other outside agency by: / /
Assigned to: ______ Dept: ______

☐ Part 21: Transfer to Columbus PAG, Date: / /
Date Transferred to AEPSC/QA: / /
Part 21 Determination Due By: / /

☑ Problem: Problem Report Number: ______
Investigation Assigned to: T. A. KRIESEL Dept: ______
Investigation Due By: 11 / 18 / 86

☐ AEPSC Assistance Required From: ______ Due By: / /

☐ SIGNIFICANT PROBLEM (PNSRC Review Required): No ☑ To Be Determined ☐

☐ Condition Report

☐ Return to Originator: ______ Dept: ______
Response Required By: / /
Remarks: ______

PAG Review By: [signature] Date: 10 / 6 / 86

TRENDING/TRACKING DATA

Condition Report Date: 10/4
Date of Condition: 10/4/86
Time of Condition: C 1100

Unit Affected: ☐ 1 ☐ 2 ☒ Both

Unit 1 Mode: 1
Power Level: 90 %
Reactor Trip: ☐ Yes ☒ No
ESF Actuation: ☐ Yes ☒ No
Action Statement Entered: ☐ Yes ☒ No

Unit 2 Mode: 2
Power Level: 58 %
Reactor Trip: ☐ Yes ☒ No
ESF Actuation: ☐ Yes ☒ No
Action Statement Entered: ☐ Yes ☒ No

Component ID Number: ______

QA/QC/CQC Report Number: ______

Finding No. ______

NRC Inspection Report/Finding No.
315/ ______
316/ ______

AEP:NRC: Letter No. ______

REFERENCE DOCUMENTS

Tech. Spec. Reference: ______

Tech. Spec. Table Reference: ______

Tech Spec. Equipment Inoperable ☐ Yes ☒ No

Tech Spec. Instrument Inoperable ☐ Yes ☒ No

Drawing Number: ______ Rev. ______
OP-12-5139 Rev. 3
______ Rev. ______

Procedure Number: ______ Rev. ______

Specification Number:
DCC ______ QC ______ Rev. ______
DCC ______ QC ______ Rev. ______

Reference PM Number ______ PM ______ Rev. ______

Code/Standard Reference: ______

Reference PO Number: ______

Reference RPC Number: ______

Reference JO Number: ______

cc: NRC Resident Inspector, Plant Manager, QA Supervisor, QC Superintendent, PNSRC Secretary, ~~Trends Coordinator~~ R.L. Simms

DETERMINATION OF SIGNIFICANT EVENTS

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☐ Yes ☑ No - Does the event constitute a violation of applicable codes, regulations, license requirements or Technical Specifications (an LCO/Action Statement not met)?

☑ Yes ☐ No - If the event involves Technical Specification/safety related equipment, is additional followup warranted other than Job Order completion or drawing revision/review (consideration for Part 21 reporting)?

☐ Yes ☑ No - Is the event of generic interest which should be entered as an operating experience on the Nuclear NETWORK System? (Requires Distribution to STAs)

☐ Yes ☑ No - Is this a repetitious occurrence which requires resolution beyond the specific corrective action? (e.g., adverse trend from frequency of occurrence.)

NOTE: 1) If "Yes" box is checked, the investigation and closeout of this event must be reviewed by PNSRC.

2) Other events may be designated for PNSRC closeout review at the discretion of the evaluators.

Lead Reviewer B A Sumner Date 10/6/86

GHC /78

PROBLEM REPORT No. 2-10-86-1165

ATTACHMENT NO.
PAGE 2 OF

CCCX
8131.117-SCAAP50

INVESTIGATION

Investigation: THE WORK WAS COVERED BY CLEARENCE PERMIT #105149. A CUT WAS MADE IN THE LINE BETWEEN WD-228-1 AND BRV-311. THE ISOLATION VALVE FOR THE #1 GDT (WD-229-1) LEAKED THRU ALLOWING GAS TO VENT FROM THE #1 GDT INTO THE AUXILIARY BUILDING VIA THE PIPE CUT.

Continuation Sheet: ☒

CAUSE DESCRIPTION

Description of Cause: ISOLATION VALVE WD-229-1 LEAKED THRU PERMITTING GAS TO ESCAPE INTO THE AUXILIARY BUILDING

Continuation Sheet: ☐

CORRECTIVE ACTION

CORRECTIVE ACTION: OPERATIONS PERSONNEL MITIGATED THE CONDITION AND VALVE WD-229-1 WAS REPAIRED

Continuation Sheet: ☐

PREVENTIVE ACTION

PREVENTIVE ACTION to Preclude Recurrence: NONE REQUIRED

Continuation Sheet: ☐

Evaluator: [signature] Date: 30 OCT 86

Are Corrective/Preventive Actions:

☐ To be implemented before a mode change? NO

☐ To be implemented by the end of next refueling outage? NO

DEPARTMENT HEAD/ORIGINATOR APPROVAL

☒ Y ☐ N 1. Investigation is Sufficient to Determine Root Cause

☒ Y ☐ N 2. CORRECTIVE ACTIONS Remedy Symptoms of Problem

☐ Y ☒ N 3. PREVENTIVE ACTIONS Preclude Recurrence of Cause

☐ Y ☒ N 4. Investigation Reveals Outside Agency Notification Required

☐ Y ☒ N 5. SIGNIFICANT PROBLEM (PNSRC Review Required)

☒ Y ☐ N 6. Forms Are Filled Out Completely

☒ Y ☐ N 7. Documentation is Complete

☐ Y ☐ N 8. Investigation Report Returned for Further Action To:

Date Forwarded: ______ Due Date: ______

Comments:

Approved By: Department Head [signature] Date: 11/7/86

Approved By: QA/NSDRC ______ Date: ______

PNSRC REVIEW

Comments:

______ PNSRC Meeting No. ______ Date: __/__/__

TRENDING/TRACKING DATA

Part 21 Package No. ______

Plant System Code: [illegible]

Safety System Inoperable: ☐ Yes ☒ No

Action Statement(s) Met: ☐ Yes ☒ No

Building Location Code: [illegible]

Floor Elevation : [illegible]

Room Code : [illegible]

Department Involved* : [illegible]

CAUSE CODES

__.__ Human Factors

2.4 Design, Manufacturing, Construction/Installation

__.__ External Cause

__.__ Defective Procedure

__.__ Management/Quality Assurance Deficiency

__.__ Other

CORRECTIVE ACTION CODES

__.__ Human Factors Correction

__.__ Activity Correction

__.__ External Correction

__.__ Procedure Correction

__.__ Programmatic Correction

6.1 Other

CLOSE OUT DOCUMENTS

LER No.	Dept.	Due	Compl.

J.O. No.	Dept.	Due	Compl.
004795	MAI		10-15-86

Procedure	Dept.	Due	Compl.

Drawing	Dept.	Due	Compl.

RFC No.	Dept.	Due	Compl.

PM No.	Dept.	Due	Compl.

Spec. No.	Dept.	Due	Compl.

P.O. No.	Dept.	Due	Compl.

AEP:NRC No.	Dept.	Due	Compl.

Other	Dept.	Due	Compl.

cc: Originating Department Head/Originator, IRC (Original), QA Supervisor, STA Section, NSDRC Subcommittee on Corporate and Plant Occurrences

CONTINUATION SHEET

CR No. 12-10-86-1165

PR NO.

Description of Condition/Finding:

Method of Discovery:

Immediate Action Taken: AND REPAIRED VALVE WD-229-1 UNDER JOB ORDER 004795

Investigation: AFTER NOTIFICATION BY THE MAINTENANCE PERSONNEL, THE SHIFT SUPERVISOR NOTIFIED RP TO OBTAIN SAMPLES FOR ANALYSIS FOR AIRBORNE RADIOACTIVITY AND EXPLOSIVE MIXTURE. BOTH SAMPLES WERE NEGATIVE. THE ON DUTY STA PERFORMED ANALYSIS FOR BOTH EMERGENCY PLAN CONDITIONS AND ANALYSIS OF UNPLANNED RELEASES. IT WAS DETERMINED THAT THE PLANT WAS NOT IN AN EMERGENCY PLAN CONDITION AND THAT NO OFFSITE NOTIFICATION WAS REQUIRED. QUANTIFICATION OF THE RELEASE, ASSUMING THE ENTIRE TANK WAS RELEASED, RESULTED IN THE RELEASE OF 0.928 CURIES OF ACTIVITY (ALL NOBLE GAS). THIS UNPLANNED RELEASE WILL BE REPORTED IN THE SEMI-ANNUAL EFFLUENT RELEASE REPORT FOR THE PERIOD OF 1 JULY 86 THRU DEC 31, 1986

INVESTIGATION COMPLETE 24 OCT 86

Description of Cause:

CORRECTIVE ACTION Taken:

PREVENTIVE ACTION Taken To Preclude Recurrence:

[illegible] #1 GDT

- 10:00 #1 GDT [illegible]

[illegible]

PK1 311). The [illegible]

was leaking.

RP took samples for radiation & explosive mixtures, both of which showed nothing. Plant vent 1505 increased slightly ≈3×10⁻⁷ to ≈1.7×10⁻⁶ uc/cc.

It was decided to dump the #1 GDT to CVCS hold up tk via the recycle header. When #1 GDT was ≈ 25 psig we stopped venting to CVCS HUT's & commenced pumping to [illegible] GDT. When #1 GDT was at ≈ 5 psig we bled N2 into [illegible] [illegible] [illegible] #1 GDT and [illegible] WO 239-1.

The [illegible] [illegible] WO 239-1 [illegible].

[illegible] C. [illegible]

CR 12-10-86-1165
PAGE 7 OF 25

SATURDAYS (10/4/86)
UNPLANNED GDT #1 RELEASE

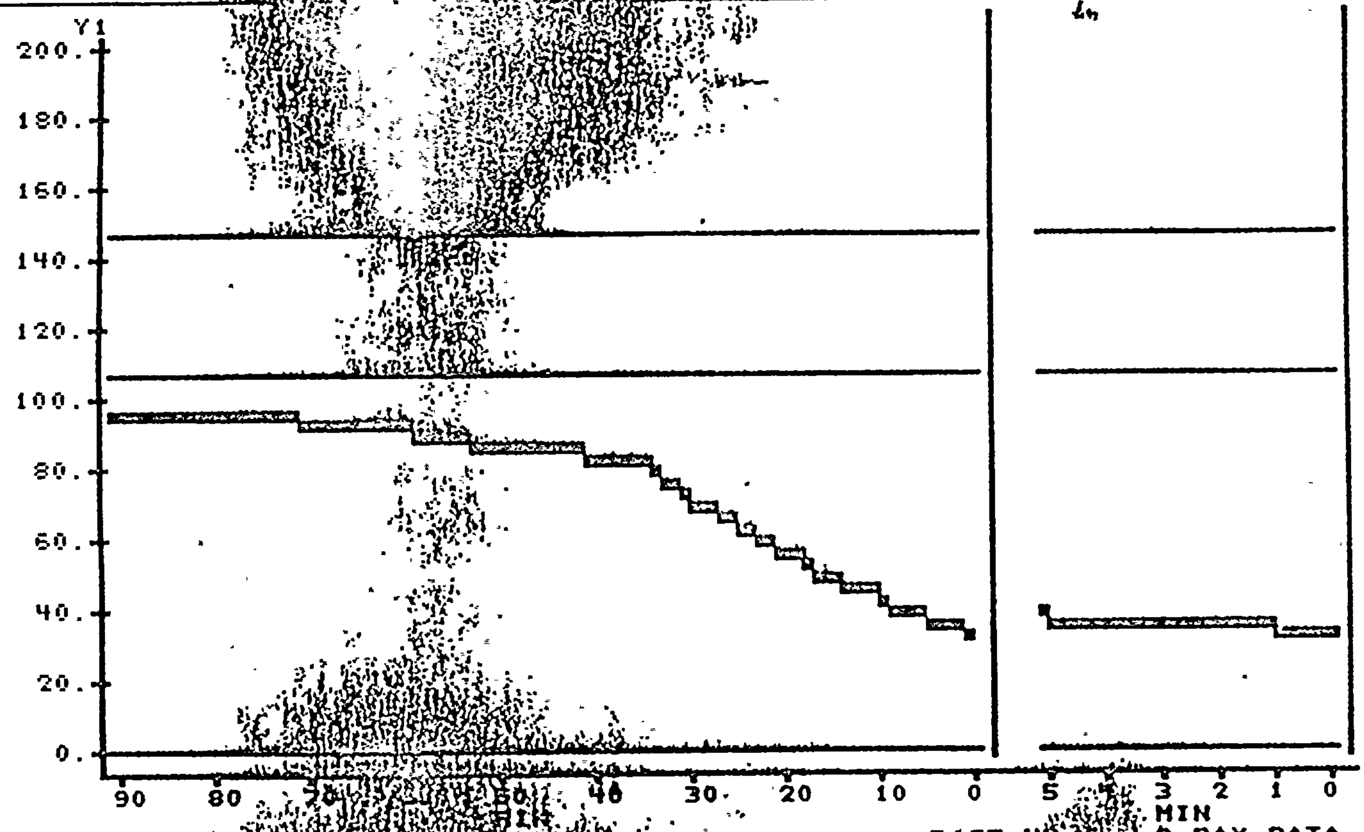
STANDARD TIME

90 MIN TREND PL

04 OCT 86 11:07:51

CR IS ON DAYLIGHT TIME

Y1 GAS DECAY TANK 67 PSIG RPC-310
LOLO = 0.00 110.00 HIHI = 150.00



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CURRENT VALUES

PAGE UP 2 DAY DATA

Y1 =
Y2 =

TREND PLOT MENU
RANGE CHANGE

DISPLAY 2 3 4 5 6

PAGE 8 OF 25

2 HR TREND PLOT   UTSC D. C. COOK UNIT 1   04 OCT 86 11:17:36

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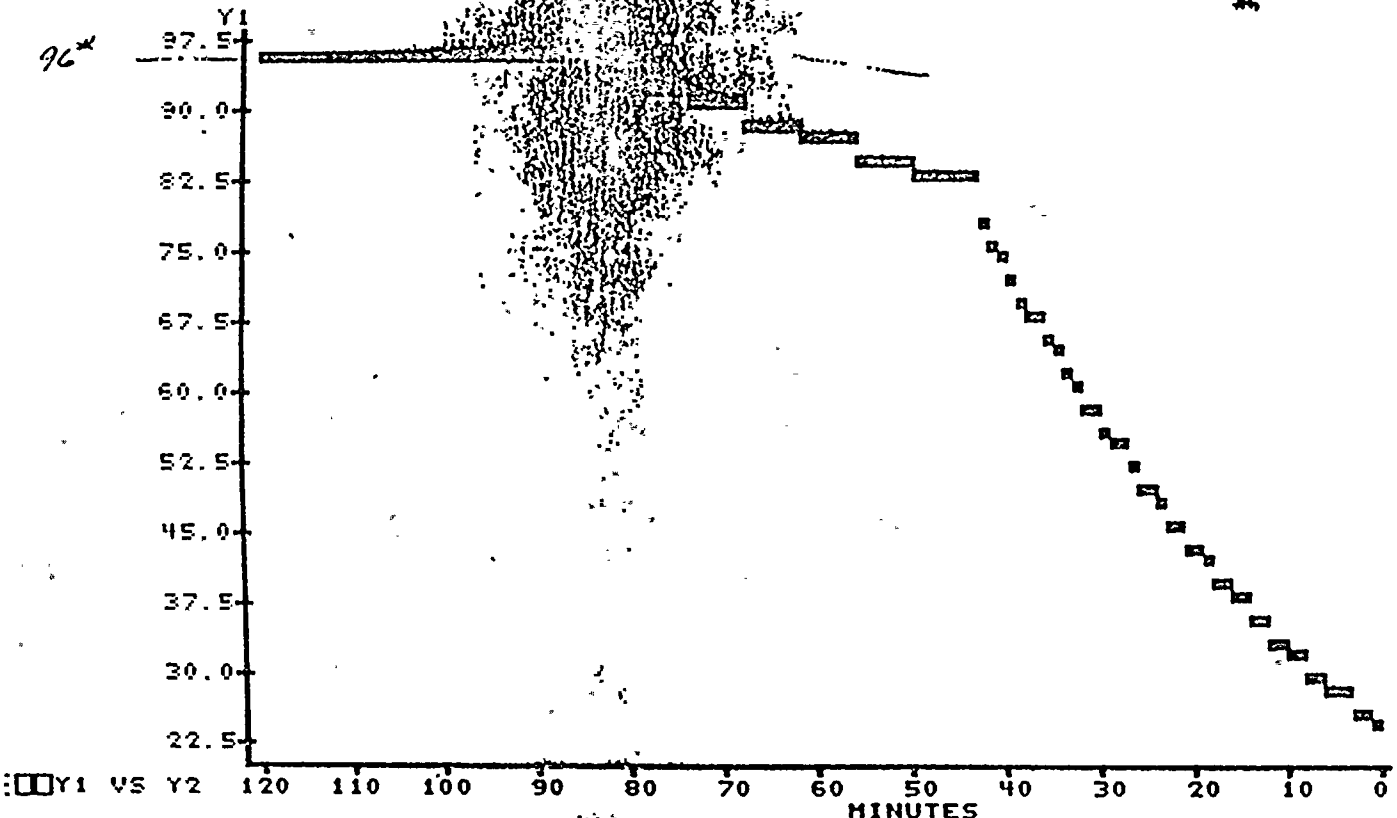

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LIMIT LINES ARE CURRENT VALUES

Y1 =
Y2 =

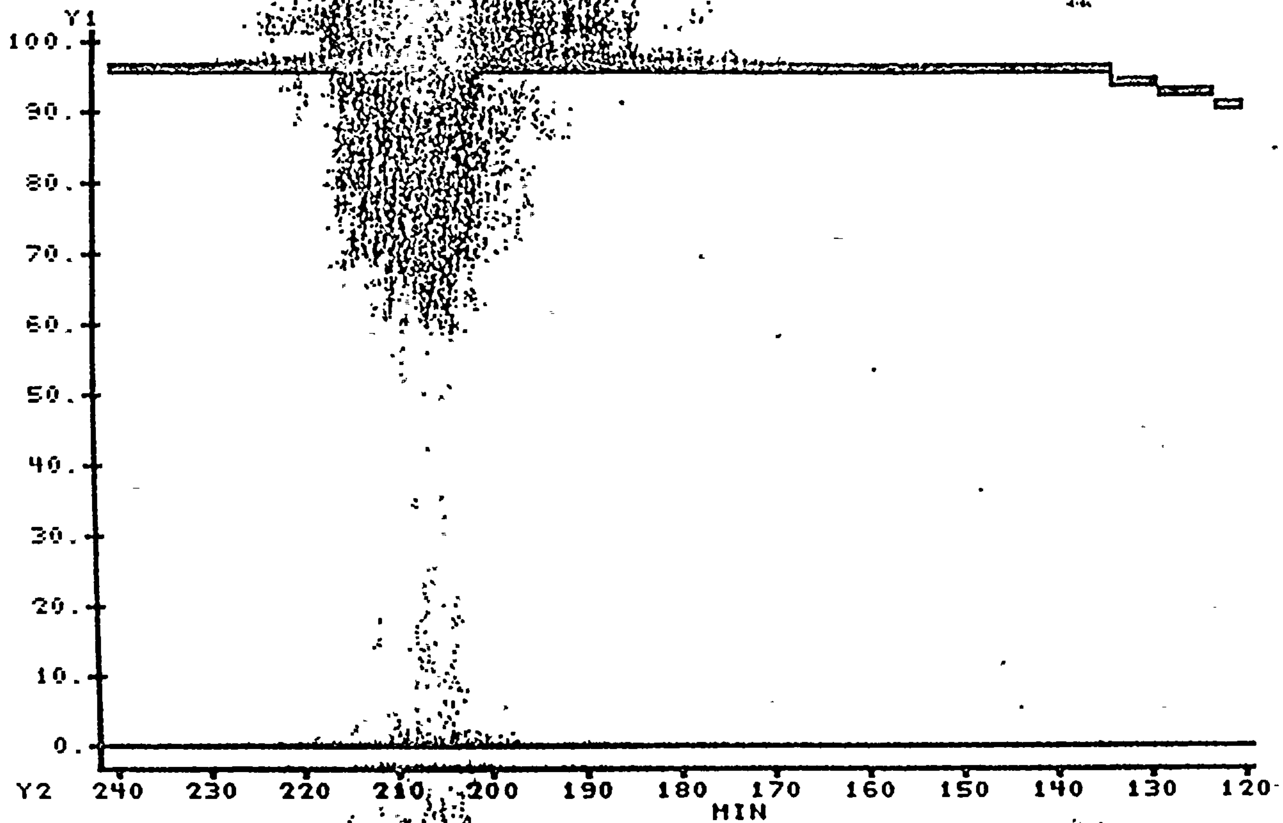
TREND PLOT MENU
RANGE CHANGE

DISPLAY TREND PLOT NO.-> 1   2   3   4   5   6

CR 12-10-86-1165
PAGE 9 OF 25

2 HR TREND PLOT [illegible] OTSE D. C. COOK UNIT 1 04 OCT 86 12:06:50

Y1 GAS DECAY TANK 1 PRES[illegible] 6.07 PSIG RPC-310
LOLO = 0.00 LO [illegible] HI = 110.00 HIHI = 150.00



Y1 VS Y2

PAGE RIGHT FOR NEXT 120 MINUTES
LAST PAGE DISPLAYED

Y1 =
Y2 =

TREND PLOT MENU
RANGE CHANGE

DISPLAY TREND PL[illegible] --> 1 2 3 4 5 6

2 HR TREND PLOT   OTSC D C COOK UNIT 1   04 OCT 86 12:05:06

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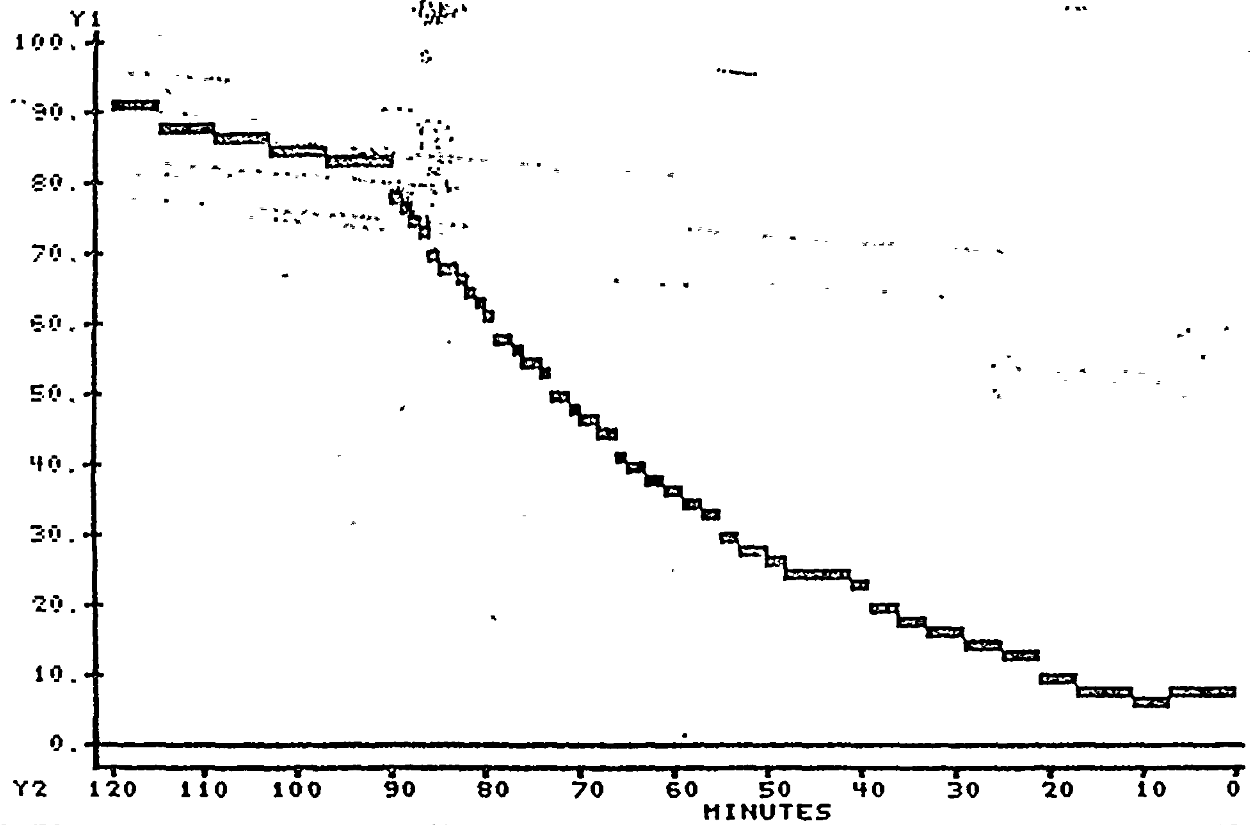


Y1 VS Y2

PAGE LEFT FOR PREVIOUS 120 MINUTES   PAGE RIGHT FOR 90 MINUTES

LIMIT LINES ARE CURRENT VALUES

Y1 =
Y2 =

TREND PLOT MENU
RANGE CHANGE

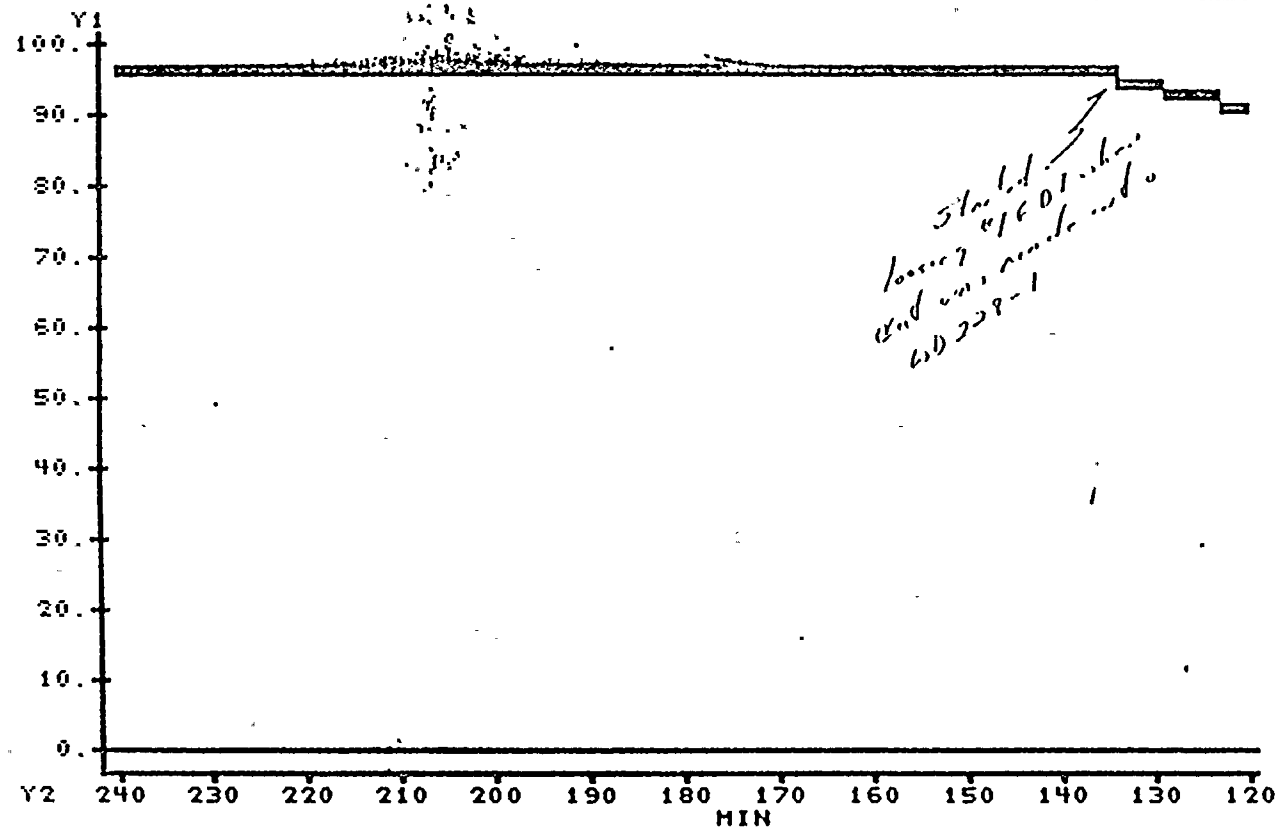
DISPLAY TREND PLOT NO.-> 1 2 3 4 5 6

CR 12-10-86-1165

PAGE 11 OF 25

2 HR TREND PLOT   OTSC D C COOK UNIT 1   04 OCT 86 12:06:03

Y1	GAS DECAY TANK 1 PRESS			6.07 PSIG		RPC-310	
LOLO =	0.00	LO =	0.00	HI =	110.00	HIHI =	150.00



Y1 VS Y2

PAGE RIGHT FOR NEXT 120 MINUTES

LAST PAGE DISPLAYED

Y1 =
Y2 =

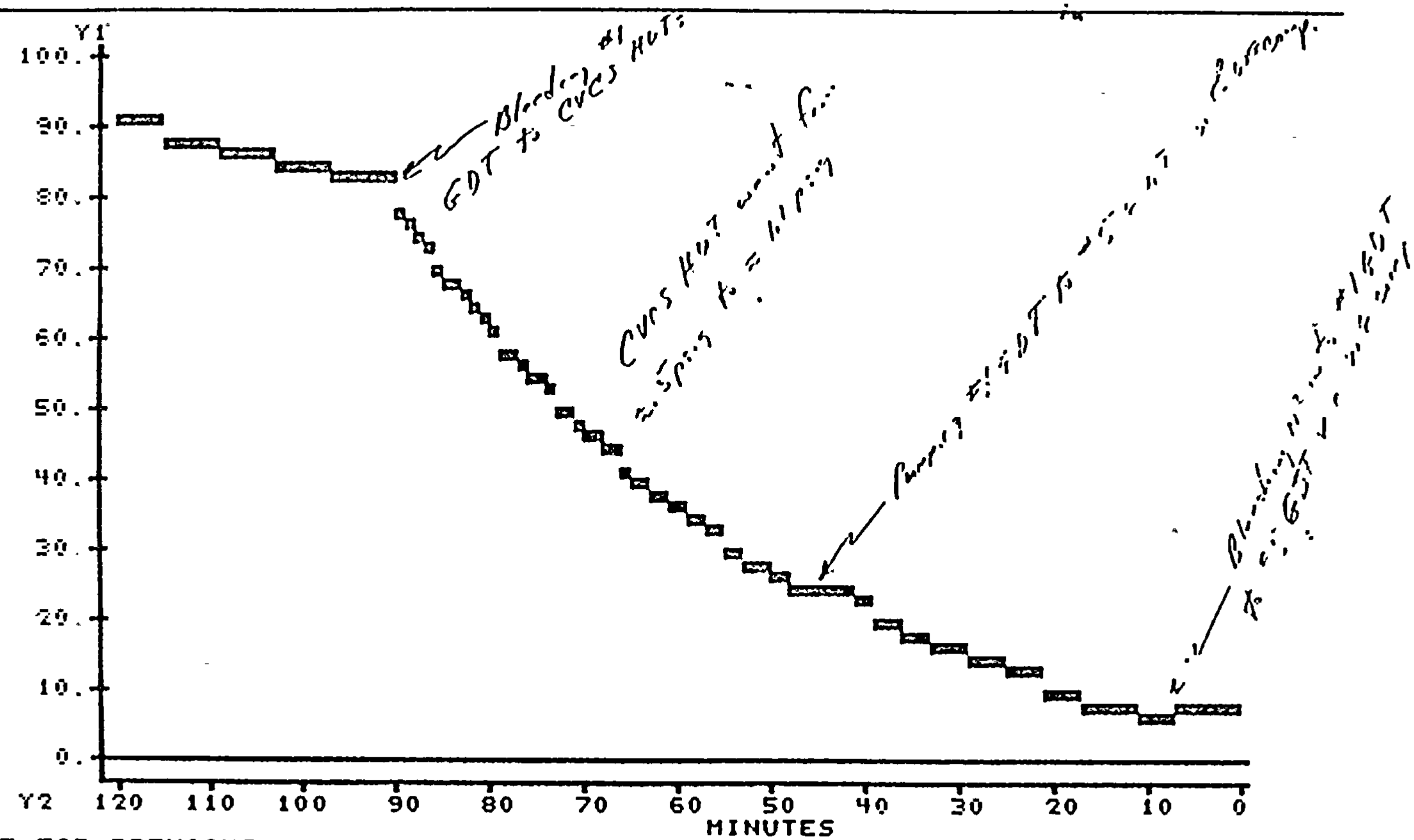
TREND PLOT MENU
RANGE CHANGE

DISPLAY TREND PLOT NO. -> 1 2 3 4 5 6

F/R 12-10-86-1165
PAGE 12 OF 25

2 HR TREND PLOT OTSC D C COOK UNIT 1 04 OCT 86 12:04:46

Y1	GAS DECAY TANK 1 PRESS				6.07 PSIG		RPC-310	
	LOLO =	0.00	LO =	0.00	HI =	110.00	HIHI =	150.00



Y1 VS Y2

PAGE LEFT FOR PREVIOUS 120 MINUTES

PAGE RIGHT FOR 90 MINUTES

LIMIT LINES ARE CURRENT VALUES

Y1 =
Y2 =

TREND PLOT MENU
RANGE CHANGE

DISPLAY TREND PLOT NO.-> 1 2 3 4 5 6

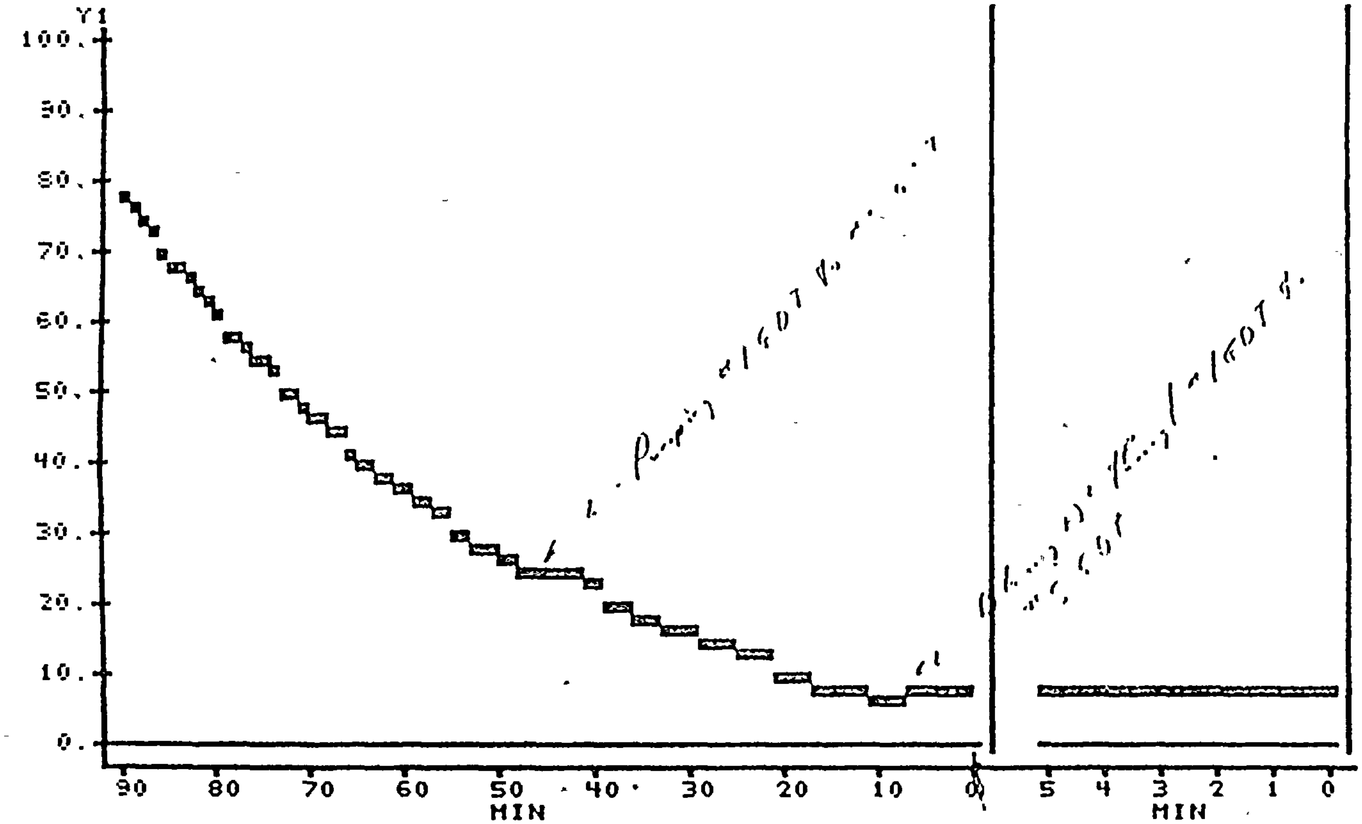
C/R 12-10-86-1165

PAGE 13 OF 25

90 MIN TREND PLOT OTSC D C COOK UNIT 1 04 OCT 86 12:03:34

Y1 GAS DECAY TANK 1 PRESS 7.99 PSIG RPC-310

LOLO = 0.00 LO = 0.00 HI = 110.00 HIHI = 150.00



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LIMIT LINES ARE CURRENT VALUES

Y1 =
Y2 =

TREND PLOT MENU
RANGE CHANGE

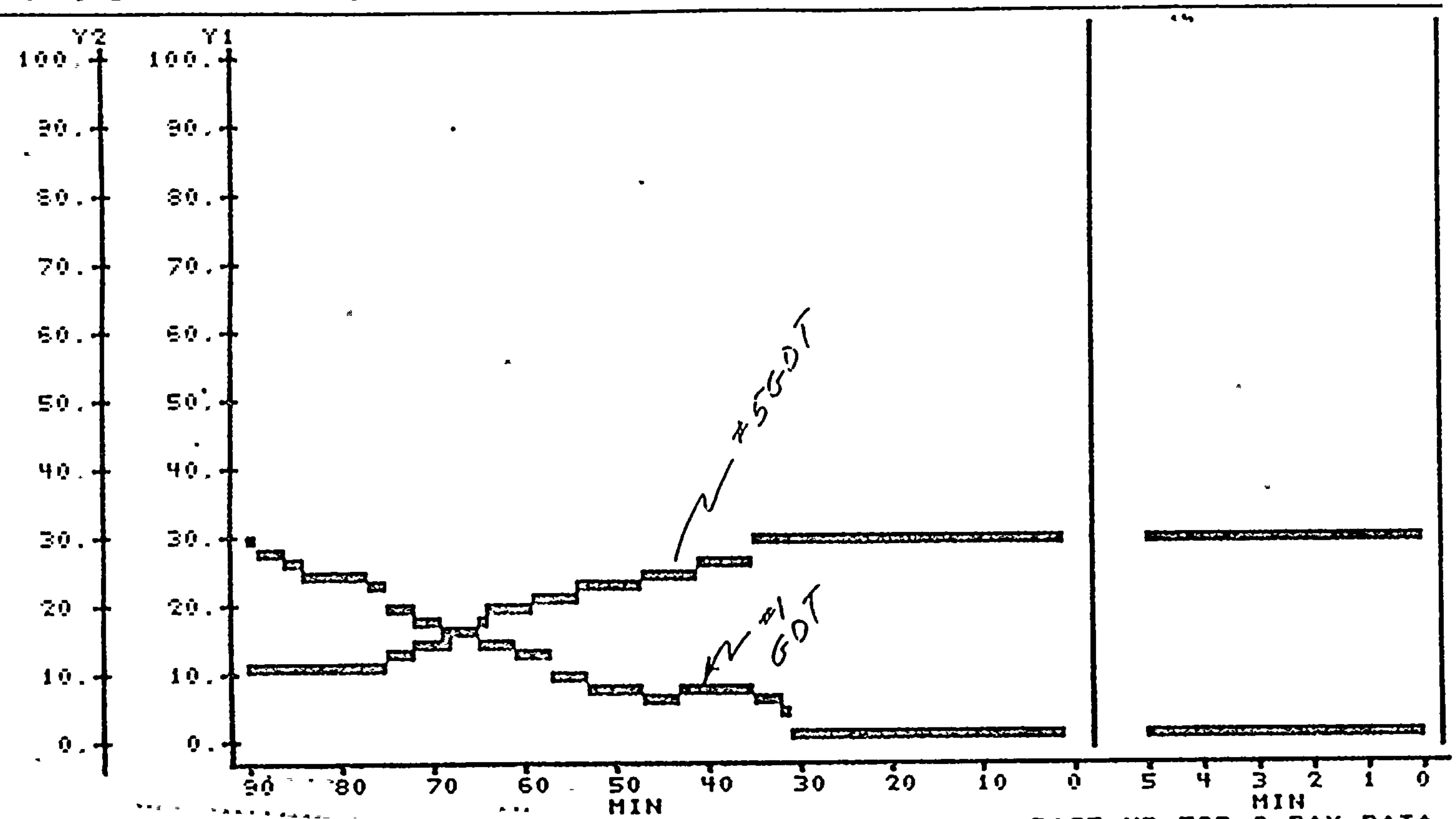
DISPLAY TREND PLOT NO. -> 1 2 3 4 5 6

C/R 12-10-86-1165

PAGE 14 OF 25

90 MIN TREND PLOT   OTSC D C COOK UNIT 1   04 OCT 86 12:39:52

Y1	GAS DECAY TANK 1 PRESS	1.59	PSIG	RPC-310
Y2	GAS DECAY TANK 5 PRESS	28.39	PSIG	RPC-350



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EXECUTE COMPLETE

Y1 =
Y2 =

TREND PLOT MENU
RANGE CHANGE

DISPLAY TREND PLOT NO. -> 1 2 3 4 5 6

At approx 12:00 EDT I was in U1 Control Room when Mike Gallagher (SS) came in and informed us that, during repair of a valve near/associated with the waste gas system, gas was noted to be flowing out of the valve. He also indicated the gas did not appear to be radioactive as determined by a sample. At that time, the gas decay tank system was called up on the CR OTSC screen and vent monitor readings for U1 and U2 were checked. The OTSC trend feature was used and it was determined that the #1 GDT was bleeding down. Since no release ~~out SJC~~ or other activities were in progress to account for this it (the leakage) was attributed to an isolated (tagged out) manual isolation valve leaking by the work area. Operations personnel then proceeded to vent the #1GDT to the CVCS HU Tanks to minimize further releases. About 12:30 I calculated that we were not in Emergency Plan ECC-13 conditions and @ 1310 completed offsite dose projections ~~per [illegible] FMP 2000EP.006~~ SJC. These projections were far below the E-plan levels for entry into an NUE. So no immediate reportability exists. Operations subsequently purged #1 GDT with N_2 and used the Radwaste gas compressor to pump the remaining contents to another gas decay tank. Also, after the leak was 1st noted personnel checked the gas for flammability, and determined it not to be flammable or explosive, so E-plan NUE (per ECC-9) was not applicable.

S. J. Cherba 10-4-86

NOTE – Times shown on OTSC graphs are EST whereas plant is on EDT. Also the diaphragm on one of the tagged isolation valves was found to be defective and replaced (WD 229-1 ~~[illegible]~~). Chem was requested to sample the #1 GDT & CVCS HU Tanks for N.G. / Iodine / & Particulate. S. Cherba 10-4-86

6.2.2.2 Enter concentrations and flows for the following as applicable:

	CONCENTRATION	RELEASE POINT	FLOW*(CFM)
1505	1.49×10^{-6} µci/cc	Unit 1 Unit Vent	9.05×10^4 CFM
2505	8.37×10^{-7} µci/cc	Unit 2 Unit Vent	5.76×10^4 CFM
1105	8.13×10^{-7} µci/cc	Unit 1 GSLO	1.14×10^3 CFM
2805	9.42×10^{-7} µci/cc	Unit 2 GSLO	1.12×10^3 CFM
1905	1.54×10^{-5} µci/cc	Unit 1 SJAE	1 CFM
2905	1.45×10^{-5} µci/cc	Unit 2 SJAE	1 CFM

*Read vent flow from 1, 2-MR-54 or from the monitors flow channel.

6.2.2.3 See PMP 2080 EPP.001-ECC-13 to determine if an Emergency Condition Classification has been entered based on the RMS readings. (One-hour NRC notification if the Emergency Plan is entered.) ~ 9×10^{1} µCi/min TOTAL

NO NO

6.2.2.4 See PMP 2080 EPP.006 to determine the site boundary dose rate using existing weather conditions. (One-hour NRC notification if the Emergency Plan is entered.)

6 M/h 50 ft WIND & VELOCITY DIR 120°

180 ft TEMP − 30 ft TEMP −1°C CAT E

6.2.2.5 Quantify the release (assuming Xe-133) using the following equation for each release point, as applicable:

____µci/cc X ____CFM X ____MIN(RELEASE* DURATION) X 2.83E-2 = ____ CURIES RELEASED

RELEASE DUR 0947 EST → 1310 EST

*The release duration is defined as the time from the first indication of release (high alarm) to whenever the monitor returns to normal or to the present time if the release has not been terminated.

VRS 1505 1.49×10^{-6} (9.05×10^4) (~~113~~ 198) $\times 2.83 \times 10^{-2}$ = ~~.4212~~ Ci .7556 Ci

VRS 2505 8.37×10^{-7} (5.76×10^4) (~~113~~ 198) $\times 2.83 \times 10^{-2}$ = ~~.1636~~ Ci .2691 Ci

(1117 → 1310 HRS) +85 MIN on 10-4-86 → 198

TOTAL — 1.0364 Ci

SJAE GSLO

6.2.3 Estimation of the Percent of the Technical Specification Whole Body Dose Rate.

6.2.3.1 The release rate limit of ≤500 mrem per year to an individual at or beyond the site boundary is provided to insure that the dose rate from gaseous effluents from both units on the site will be within the annual dose limits of 10 CFR Part 20 for unrestricted areas. The annual dose limits are the doses associated with the concentrations of 10 CFR Part 20, Appendix B, Table II.

6.2.3.2 Using the concentrations and flows from 6.2.2.2, convert to release rate.

MAX 10 MIN AVERAGE →

Unit 1 Unit Vent	1.49×10^{-6} µci/cc	X	9.05×10^{4} CFM	X	4.72E+2	=	63.6 µci/sec
Unit 2 Unit Vent	8.37×10^{-7} µci/cc	X	5.76×10^{4} CFM	X	4.72E+2	=	22.8 µci/sec
Unit 1 GSLO	8.73×10^{-7} µci/cc	X	1.14×10^{3} CFM	X	4.72E+2	=	.5 µci/sec
Unit 2 GSLO	9.47×10^{-7} µci/cc	X	1.12×10^{3} CFM	X	4.72E+2	=	.5 µci/sec
Unit 1 SJAE	1.54×10^{-5} µci/cc	X	1 CFM	X	4.72E+2	=	~0 µci/sec
Unit 2 SJAE	1.45×10^{-5} µci/cc	X	1 CFM	X	4.72E+2	=	~0 µci/sec

87.4 X 60 =
5244 µci/min
5.244×10^{3} µCi/min

If the release rate in µci/min exceeds 4.25E+6, when averaged over 1 hour, then 2 times the 10 CFR 20 concentrations have been exceeded and the NRC must be notified within 4 hours. See PMSO.034.

6.2.3.3. Using the release rate, the whole body dose rate can be calculated, using the whole body dose rate factor for Xe-133 (2.94 E+2) and the average annual X/Q (8.44E-6).

Unit 1 Unit Vent 63.6 µci/sec X 2.48E-3 = .1577 mrem/yr

Unit 2 Unit Vent 22.8 µci/sec X 2.48E-3 = .0565 mrem/yr

Unit 1 GSLO .5 µci/sec X 2.48E-3 = .0006 mrem/yr

Unit 2 GSLO .5 µci/sec X 2.48E-3 = .0006 mrem/yr

Unit 1 SJAE ~0 µci/sec X 2.48E-3 = 0 mrem/yr

Unit 2 SJAE ~0 µci/sec X 2.48E-3 = 0 mrem/yr

The sum of the dose rates from all release points divided by 500 (the whole body dose rate limit) multiplied by 100 is equal to the percent of the Technical Specification limit.

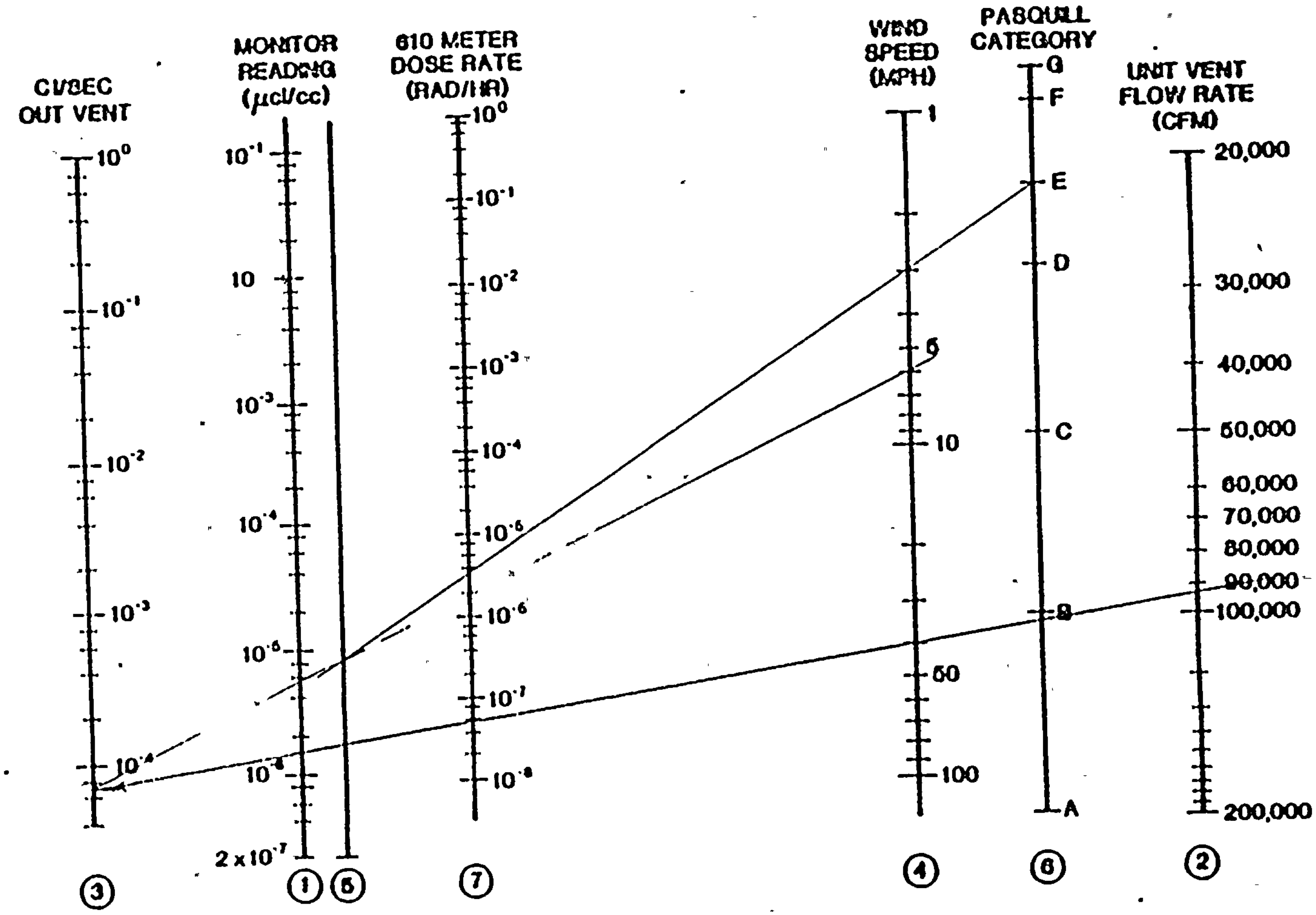
$\frac{.2155}{500}$ mrem/year X 100 = .043 % of the Tech. Spec. Limit

6.2.4 After the total release and percent of the Technical Specifications has been calculated, issue a Condition Report with all data included and follow PMI-7030 instructions.

6.2.5 A thirty-day written report is required if any airborne radioactive release exceeds 2 times the applicable concentrations of the limits specified in 10 CFR 20, Appendix B in unrestricted areas, when averaged over one hour.

6.2.6 Ensure that data generated by the use of this procedure is forwarded to the Environmental Section.
The total quantity released is required to be included in the Semi-Annual Radioactive Effluent Release Report.
Off-site doses due to unplanned gaseous releases will be included in the quarterly and yearly dose calculations.

UNIT VENT EFFLUENT MONITOR
(VRS 1505/2505)



Wind from 120° (SE)

Wind towards 300° (NW) TOWARDS LAKE

610 Dose Rate 4X10^-5 RAD/HR

(Site Boundary Dose Rate) 4X10^-2 mRad/HR

Date/Time 1310

By S Clerba

6 mph

-1°C Pasq E

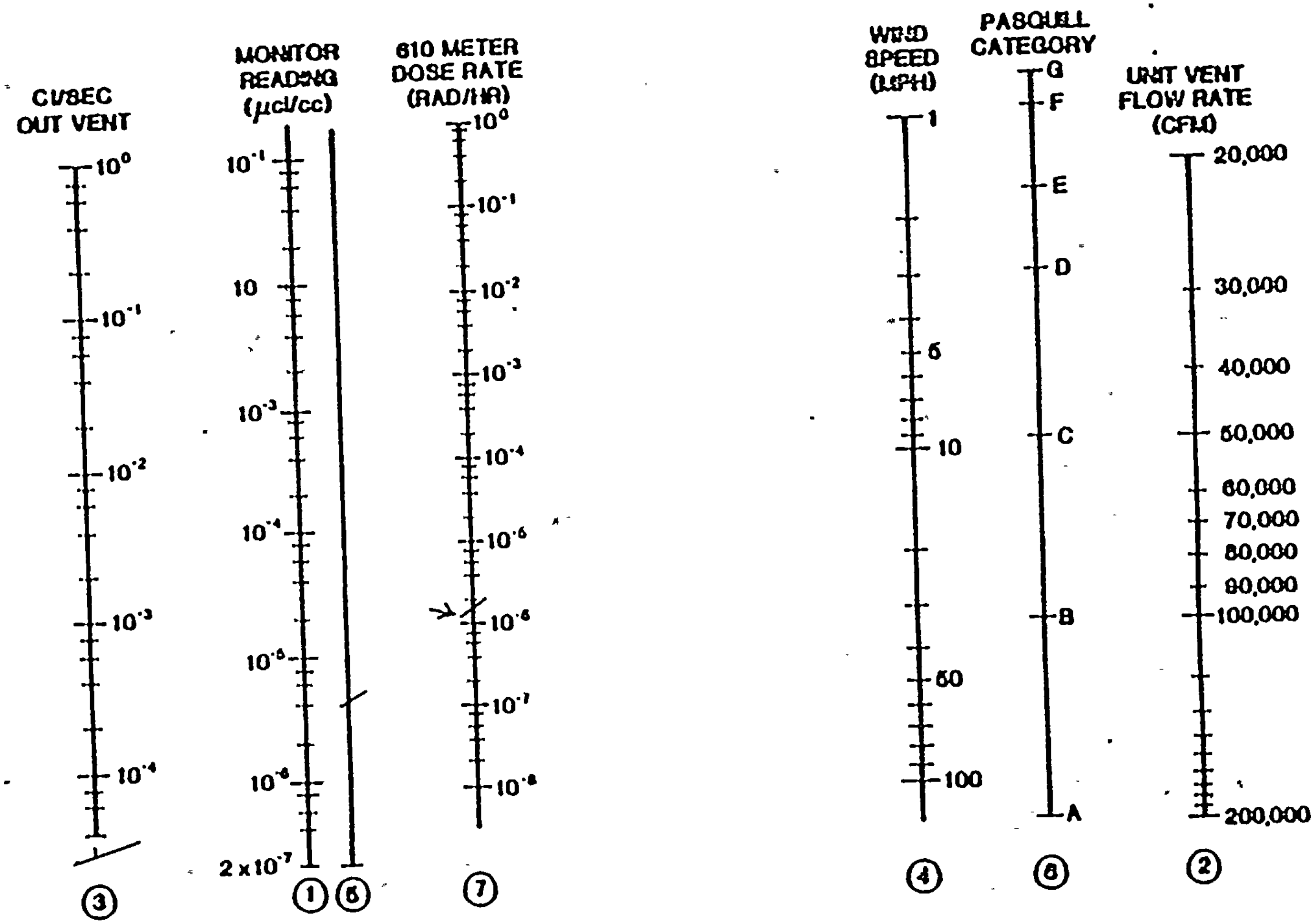
Page 1 of 2
Rev. 5

PMP 2080 EPP.006
EXHIBIT J

PAGE 2 OF 25

C/R 12-10-36-1165

UNIT VENT EFFLUENT MONITOR
(VRS 1505/2505)



Wind from 120° (SE)
Wind towards 300° (NW)

610 Dose Rate 1.7×10^{-6} RAD/HR
(Site Boundary Dose Rate)
1.7×10^{-3} mRAD/HR

Date/Time 1310
By [signature]

C/R 12-10-86-116S
PAGE 21 OF 23

C/R 12-10-86-1165 ~~RG-220-F25~~

Potter	Main	10-4-86	004795
ORIGINATOR	DEPARTMENT	DATE	JOB ORDER NUMBER

☐ UNIT 1 ☐ UNIT 2 ☒ SHARED — DESIGN CHANGE NO. ☑ N/A

NOSEX14
ME-VKD-12-WD-229-1
FILE DESIGNATOR (OF DEPT. PERFORMING JOB)

☐ TURBINE ☒ AUXILIARY ☐ SCREENHOUSE ☐ CONTAINMENT

☐ SERVICE ☐ SERVICE EXT. ☐ OFFICE ☐ OTHER: ______ 587 ELEVATION

LOCATION DESCRIPTION: GDT WEST HALLWAY, N.E. AREA OF ROOM, ON EAST WALL.

PROBLEM DESCRIPTION: WD-229-1 LEAKS BY SEAT.

UNCONTROLLED DOCUMENT

COMPLETED BY ORIGINATING DEPARTMENT

BLUE JOB ORDER TAG HUNG? ☐ YES ☑ NO

☐ EMERGENCY ☐ REGULAR ☑ EXPEDITE ______ HOURS / DAYS / EVENTS

TECH SPEC RELATED? ☐ YES IF "YES", ATTACH FORM PMI-2290-3 ☑ NO

WILL COMPLETION OF THIS JOB ELIMINATE A PERSONNEL SAFETY HAZARD? ☐ YES ☑ NO

JOB ORDER ASSIGNED TO:
☑ MAINT. ☐ TECH. P.S. ☐ TECH. ENGR.
☐ OPS. ☐ QC ☐ CONST. ☐ OTHER ______

ADDITIONAL INFORMATION ______

D Potter	10-4-86	D Potter	10-4-86
REVIEWED BY	DATE	DEPT. HEAD APPROVAL	DATE

COMPLETED BY DEPARTMENT RESPONSIBLE FOR JOB

FURTHER EVALUATION OF JOB SCOPE REQUIRED ☑ YES IF "YES", FILL IN "SCOPE OF WORK" SECTION BELOW ☐ NO

SAFETY RELATED OR SAFETY INTERFACE ☑ YES IF "YES", ATTACH FORM PMI 2290-3 ☐ NO

SCOPE OF WORK: Replace diaphragm on 12-WD-229-1.

TECH. SPEC. RELATED? ☐ YES IF "YES", ATTACH FORM PMI 2290-3 IF NOT ALREADY ATTACHED ☑ NO

PROCEDURES REQUIRED (OTHER THAN FOR POST-MAINT TESTING) ☑ YES ☐ NO

DRAWING REFERENCES
FLOW DIAGRAM 12-5139
ELECTRICAL N/A
OTHER N/A

PROCEDURE NO. 12 MHP 5021.001.023

PLANT CONDITIONS REQUIRED
☑ REGULAR ☐ LOAD REDUCTION ☐ OUTAGE ☐ OTHER ______

D Potter	10-4-86	R E J [signature]	10-4-86
REVIEWED BY	DATE	APPROVED BY	DATE

1 2

CR 12-10-80-1165 PAGE 23 OF 25

ISSUED TO Ruff	US/ASS/SS APPROVAL	... START WORK ☐ YES ☑ NO	004745 JOB ORDER NUMBER

PERMITS REQUIRED

CLEARANCE: ☑ YES ☐ NO NO. 105949

RWP: ☑ YES ☐ NO NO. 4882

OTHER: ☐ YES ☑ NO NO. N/A

CLEANLINESS RATING PER PMI-2220 ☐ 1 ☐ 2 ☑ 3 ☐ N/A

ADDITIONAL INFORMATION

ACCT / W.O. / 530390000

APPROVAL TO START ☑ N/A ______ US/ASS/SS ______ DATE

DESCRIPTION OF WORK DONE

REPLACE 1" DIAPHAM IN 12-WD-229-1

LEAK STOPPED

UNCONTROLLED DOCUMENT

SYSTEM INTERNAL CLEANLINESS

INSPECTION BY ☐ N/A Kolosowsky + [illegible] INDIVIDUAL PERFORMING WORK 10-4-86 DATE

VERIFIED BY ☑ N/A ______ CLEANLINESS INSPECTOR ______ DATE

WORK PERFORMED BY Kolosowsky + ZIELKE

DATE COMPLETED: 10-4-86

OPERATORS NOTIFIED ☑ N/A ______ US/ASS/SS ______ DATE

BLUE TAG REMOVED ☐ YES ☑ N/A

WORK AND WORK AREA INSPECTED BY Gerald Ruff INSPECTOR SIGNATURE 10-4-86 DATE

ADDITIONAL INFORMATION

PARTS / MATERIAL DESCRIPTION	M&E NUMBER	A-TAG NO.	QTY. OBTAINED	QTY. USED
1" DIAPHAM	23-483105	255G5	1	1

DOCUMENTATION REVIEWED AND ACCEPTED BY Gerald Ruff SUPERVISOR 10-4-86 DATE [illegible] Potter FINAL REVIEWER 10-6-86 DATE

CR 1240-86-1165 PAGE 24 OF 25

TECHNI... ... FORM

JOB ORDER NUMBER 004795

TECH. SPEC. REFERENCE(s): N/A

...ION STATEMENT ALREADY ENTERED ☐ YES ☑ N..

SS NOTIFIED BY N/A (NAME) N/A (DATE) N/A (TIME)

ACTION STATEMENT WILL BE ENTERED IF WORK IS NOT COMPLETED BY: N/A (DATE / TIME OR OPERATIONAL MODE) ☐ YES ☑ NO

ACTION STATEMENT ENTRY REQUIRED TO PERFORM WORK ☐ YES ☑ NO

BRIEF DESCRIPTION OF MOST LIMITING "ACTION STATEMENT" REQUIREMENTS: N/A

UNCONTROLLED DOCUMENT

APPLICABILITY: N/A

DETERMINATION PERFORMED BY: POTTER (NAME (PLEASE PRINT))

SURVEILLANCE AND MAINTENANCE OF ENVIRONMENTALLY QUALIFIED, SAFETY RELATED ELECTRICAL EQUIPMENT (REFER TO PMI 5025) ☐ YES ☑ NO

TEST OR INSPECTION REQUIRED (PROCEDURE NUMBER, JOB ORDER NUMBER OR DESCRIPTION)	DEPT.	PERSON TO CONTACT	RESULTS ACCEPTABLE YES	RESULTS ACCEPTABLE NO	VERIFIED BY	DATE

...MARKS: Nuke Safety Related - No test.

ALL REQUIRED TESTS AND INSPECTIONS VERIFIED SIGNED OFF: Gerald Ruff (SUPERVISOR SIGNATURE) 10-6-86 (DATE)

FROM LAB SAMPLE RESULTS.

From #1 GDT analysis: assuming initial pressure @ 90 psig and release entire contents:

Xe-133	7.46^{-4}
Kr-85	4.28^{-1}
	4.29^{-1}

from MCVCS

Xe-133	1.56^{-1}
Kr-85	7.67^{-1}
Xe-135	3.37^{-4}
H-3	1.00^{-5}
Xe-131m	4.02^{-3}
Xe-133m	5.70^{-4}
	9.28 [illegible] $^{-1}$

N/D

9.28^{-1} Ci

INDIANA & MICHIGAN ELECTRIC COMPANY

AMERICAN ELECTRIC POWER SYSTEM AEP

December 4, 1986

#964

SUBJECT: Condition Report #12-11-86-1347

FROM: D. M. Allen

TO: S. J. Brewer/H. W. Jones

According to Radiation Protection procedure #12 THP 6010.RAD.052, Revision 0, a condition report was issued for a violation of the Cook Plant Technical Specification 3/4-12.1 concerning air sample collection frequency. Please find attached a copy of this condition report which should be included in the NRC submittal of the Annual Environmental Operating Report for 1986.

D. M. Allen

D. M. Allen

jm

attachment

cc: W. G. Smith, Jr./L. S. Gibson
T. A. Kriesel
R. J. Clendenning

INTRA-SYSTEM

✓✓ [illegible]-7030

ATTACHMENT NO. 1

CONDITION REPORT No. 12-11-86-1347

COOK
[illegible] -86XAP50

PART 1 - CONDITION IDENTIFICATION AND DESCRIPTION

Description of Condition/Finding: THE OFFSITE ENVIRONMENTAL AIR STATION SAMPLES WERE COLLECTED ON 14JAN86. THIS WAS 10 DAYS AFTER THE PREVIOUS COLLECTION ON 04JAN86, WHICH IS MORE THAN THE 4th 7±2 days ALLOWED IN TECH SPEC - 3/4.0.2.

Continuation Sheet: ☐

Method of Discovery: DURING REVIEW USING RAD.052

Reported by: Tim Leckenet (signature)

Immediate Action Taken: VERIFIED THAT REMAINING SAMPLES WERE NOT IN VIOLATION ALSO. ACTION ITEM 3/4.12-1a. REQUIRES A REPORT BE SUBMITTED TO THE COMMISSION IN THE ANNUAL RAD OPERATING REPORT. THIS CONDITION REPORT RESPONSE CAN SERVE AS THAT RESPONSE TO THE COMMISSION.

Continuation Sheet: ☐ Action Taken by: Tim Leckenet (signature)

PART 2 - OFF-SITE NOTIFICATION

☐ AEPSC/Person Contacted: ______ By: ______
Date: ______ Time: ______

☐ I&M/Person Contacted: ______ By: ______
Date: ______ Time: ______

☐ NRC/ENS Person Contacted: ______ By: ______
Date: ______ Time: ______

☐ NRC Resident Inspector Contacted By: ______
Date: ______ Time: ______

☐ Michigan/Person Contacted: ______ By: ______
Date: ______ Time: ______

☐ Not Applicable/Determined by: ______
Date: ______ Time: ______

☐ Initial STA Investigation By: William [illegible] (signature) Date: 11/17/86

PART 3 - PAG REVIEW

☐ Return to Originator: ______ (PAG Member) Date: __/__/__

Classification and Investigation

☐ Condition Report

☒ Problem: Problem Report Number: 86-137

☐ Significant Problem (PNSRC Review Required); To Be Determined ☐ TPS

Investigation Assigned To: ? KRIESEL Dept. ☐☐☐

Investigation Due By: 1/1/87

☐ AEPSC Assistance Required: From: ______, Due By: __/__/__

☐ To Be Entered on Network System (Due to Generic Interest)

☐ Part 21: Transfer to Columbus PAG, Date: __/__/__

Date Transferred to AEPSC QA: __/__/__

Part 21 Determination Due By: __/__/__

Offsite Reportability 11/20/86 GK

☒ LER Required, Assigned To: KRIESEL NO LER REQUIRED TPS Dept. ☐☐☐

Due To: LERC By: 12/3/86 NRC By: 12/13/86

☐ Other Reports Required, Assigned To: ______ Dept. ☐☐☐

Type of Report: ______

Due To: PNSRC By: ?/__/__

NRC or Other Outside Agency By: __/__/__

PAG Review By: [signature] Date: 11/18/86

TRENDING/TRACKING DATA

Condition Report Date: 11/15/8[illegible]

Date of Condition: 1/14/8[illegible]

Time of Condition: 0000

Unit Affected
☐ 1 ☐ 2 ☒ Both

Unit 1 Mode: ______

Power Level: ______ %

Reactor Trip: ☐ Yes ☒ No

ESF Actuation: ☐ Yes ☒ No

Action Statement Entered: ☒ Yes ☐ No

Unit 2 Mode: ______

Power Level: ______ %

Reactor Trip: ☐ Yes ☒ No

ESF Actuation: ☐ Yes ☒ No

Action Statement Entered: ☒ Yes ☐ No

Component ID Number: ______

QA/QC/NSDRC Report Number: ______

Finding No. ______

NRC Inspection Report/Finding No.
315/ ______
316/ ______

AEP:NRC: Letter No. ______

REFERENCE DOCUMENTS

Tech. Spec. Reference: 3/4.0.2

Tech. Spec. Table Reference: ______

Tech Spec. Equipment Inoperable ☐ Yes ☒ No

Tech Spec. Instrument Inoperable ☐ Yes ☒ No

Drawing Number: ______ Rev. ______
______ Rev. ______
______ Rev. ______

Procedure Number: 12THP6010 RAD.001 Rev. 4
______ Rev. ______

Specification Number:
DCC ______ QC __ Rev. ______
DCC ______ QC __ Rev. ______

Reference PM Number
__ __ PM __ __ __ __ Rev. ______

Code/Standard Reference: ______

Reference PO Number: ______

Reference RFC Number: ______

Reference JO Number: ______

cc: NRC Resident Inspector, Plant Manager, QA Supervisor, PNSRC Secretary, STA Section, Assigned Dept. (Original), Originator, IRC(File Copy)

PROBLEM REPORT No. 12-11-86-1347 ATTACHMENT NO.

COCK 6151.1(7-86)AP50

INVESTIGATION

Investigation: THROUGH INVESTIGATING ALL OTHER ENVIRONMENTAL AIR SAMPLES DATES IT WAS DISCOVERED THAT TECH SPEC. 3/4.0.2 WAS NOT VIOLATED AGAIN. FOR THE REST OF 1986 TO DATE. A letter was written to corporate to assure this is included in 1986 Annual Report.

Continuation Sheet: ☐

CAUSE DESCRIPTION

Description of Cause: THE TIME PRIOR TO THE VIOLATION THE SAMPLE COLLECTING WAS SPLIT INTO TWO PARTS ONSITE AND OFFSITE. THE OFFSITE AIR SAMPLES WERE COLLECTED ON 04JAN86. THE ONSITE AIR SAMPLES WERE COLLECTED ON 07JAN86 BOTH ONSITE AND OFFSITE WERE THEN COLLECTED ON 14JAN86. THIS MADE IT 10 days BETWEEN THE 04JAN86 AND THE 14JAN86 SAMPLE THUS VIOLATING THE 7±2 days STATED IN TECH SPEC 3/4.0.2

Continuation Sheet: ☐

CORRECTIVE ACTION

CORRECTIVE ACTION: ALL ENVIRONMENTAL AIR SAMPLING DATES WERE CHECKED FOR THE REST OF THE YEAR AND NO further TECH SPEC'S WERE VIOLATED.

Continuation Sheet: ☐

PREVENTIVE ACTION

PREVENTIVE ACTION to Preclude Recurrence: ON 01NOV86 ONSITE PLANT PERSONNEL TOOK OVER SAMPLE COLLECTING OF ALL ENVIRONMENTAL SAMPLING. THIS WAS PREVIOUSLY PERFORMED BY A LOCAL CONTRACTOR. TO ENSURE THIS PROBLEM WILL NOT OCCUR AGAIN PERSONNEL PERFORMING SAMPLING MUST PERFORM COMPUTER SIGN OFF/UPDATES, TICKLER

Continuation Sheet: ☒

Evaluator: Tim Leckenet D. Allen Date: 12/3/86

Are Corrective/Preventive Actions:

- ☐ To be implemented before a mode change?
- ☐ To be implemented by the end of next refueling outage?

DEPARTMENT HEAD/ORIGINATOR APPROVAL

- ☐ Y ☐ N 1. Investigation is Sufficient to Determine Root Cause
- ☐ Y ☐ N 2. CORRECTIVE ACTIONS Remedy Symptoms of Problem
- ☐ Y ☐ N 3. PREVENTIVE ACTIONS Preclude Recurrence of Cause
- ☐ Y ☐ N 4. Investigation Reveals Outside Agency Notification Required
- ☐ Y ☐ N 5. SIGNIFICANT PROBLEM (PNSRC Review Required)
- ☐ Y ☐ N 6. Forms Are Filled Out Completely
- ☐ Y ☐ N 7. Documentation is Complete
- ☐ Y ☐ N 8. Investigation Report Returned for Further Action To: ____

Date Forwarded: ____ Due Date: ____

Comments: ____

Approved By: Department Head ____ Date: ____

Approved By: QA/NSDRC ____ Date: ____

PNSRC REVIEW

Comments: ____

____ PNSRC Meeting No. ____ Date: __/__/__

TRENDING/TRACKING DATA

Part 21 Package No. ____

Plant System Code: ☐☐☐☐☐

Safety System Inoperable: ☐ Yes ☐ No

Action Statement(s) Met: ☐ Yes ☐ No

Building Location Code: ☐

Floor Elevation: ☐

Room Code: ☐

Department Involved: ☐

CAUSE CODES

- 1 . 2 Human Factor
- __ . __ Design, Manufacture/Construction/Installation
- __ . __ External Cause
- __ . __ Defective Procedure
- __ . __ Management/Quality Assurance
- __ . __ Other

CORRECTIVE ACTION CODES

- __ . __ Human Factors Correction
- 2 . 6 Activity Correction
- __ . __ External Correction
- __ . __ Procedure Correction
- __ . __ Programmatic Correction
- __ . __ Other

CLOSE OUT DOCUMENTS

	Dept.	Due	Compl.
LER No.			
J.O. No.			
Procedure			
Drawing			
RFC No.			
PM No.			
Spec. No.			
P.O. No.			
AEP:NRC No.			
Other			

cc: Originating Department Head/Originator, IRC (Original), QA Supervisor, STA Section, NSDRC Subcommittee on Corporate and Plant Occurrences

PNL-7050
ATTACHMENT NO. 1

CONTINUATION SHEET

CR No. 12-11-86-1347

PR NO. ____

Description of Condition/Finding:

Method of Discovery:

Immediate Action Taken:

Investigation:

Description of Cause:

CORRECTIVE ACTION Taken:

PREVENTIVE ACTION Taken To Preclude Recurrence: FILE UPDATES AND CONTROL ROOM (BOTH U1 & U2) SIGN OFFS FOR EACH INDIVIDUAL TYPE OF SAMPLING.

INDIANA & MICHIGAN ELECTRIC COMPANY

AMERICAN ELECTRIC AEP POWER SYSTEM

DATE: November 24, 1986

SUBJECT: Condition Report Investigation Assignment

12-11-86-1347

FROM: R. A. Palmer/L. G. Holmes

TO: K. J. Clendenning

The attached Condition Report has been assigned to your section for investigation. Please complete the investigation and return to the Technical Superintendent by 12/15/86.

Upon completion of the Condition Report investigation, insure that copies of any Job Orders which resulted either from the original occurrence or any which were generated as a result of your investigation are attached to the Condition Report.

If the Condition Report investigation cannot be completed within the time period specified above, please forward a xeroxed copy of the Condition Report to the Technical ACC, stating your estimated date of completion, prior to the completion date shown on the Condition Report cover letter.

If you have any questions concerning Condition Reports, feel free to call.

Lisa Holmes

Technical ACC

/sg

Attachment

INTRA-SYSTEM