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environmental status report

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Florida Power
CORPORATION

TO: RECIPIENTS OF THE ENVIRONMENTAL STATUS REPORT

Florida Power Corporation is pleased to present to you its Quarterly Environmental Status Report covering the period July-September, 1972. Happily, we are back on a quarterly schedule.

Included is discussion and technical information regarding environmental work at the Crystal River Nuclear Plant site, the Anclote Plant site, and the Weedon Island Plant site during the July-September quarter, together with a brief description of the supporting and associated activities during that same period.

We trust that this report will continue to be useful in supplementing your understanding of our environmental efforts, and we encourage you to contact us should you have any questions concerning the scope or direction of these activities.

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Assistant Vice President

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florida power corporation

QUARTERLY ENVIRONMENTAL STATUS REPORT

GENERAL

The publication of this issue of the Environmental Status Report incorporates the environmental activities of Florida Power Corporation from July to September, 1972. Several new programs were initiated earlier this year and a report of findings to date for each of them is included in the Appendices.

The following is a summarization of the Company's supporting and associated activities from July 1, 1972, to September 30, 1972. This work has been contributed to by many in the Company and has been coordinated as a principal responsibility of the Generation Environmental and Regulatory Affairs Department.

A. Environmental Affairs

In the realm of environmental affairs, Florida Power Corporation is continuing to interface with its research projects, with governmental agencies and conservation groups and to assess any environmental impact resulting from its various power plants either those now in operation or those proposed.

During the past quarter, efforts were directed principally at the following concerns:

1. Finalization of the *Anclote Environmental Report (Operating License Stage)*. Submission to the U.S. Army Corps of Engineers is planned for November of this year.

2. Completion of an erosion study at Anclote. This was initiated after both Florida Power Corporation and the University of South Florida, Marine Science Institute expressed concern over possible impact on the seagrasses from erosion of the intake and discharge canals as currently designed.

3. Continued generation of responses to the AEC's concerns about the environmental impact of Crystal River Unit #3.

4. Surveillance of the dredging operation at the P. L. Bartow Plant to ascertain and assess possible environmental impact.

5. Formulation of plans for the Fifth Semi-Annual Review of Environmental Research Programs at Crystal River. The conference is scheduled for November 17, 1972.

Finally, the *Anclote Environmental Project Report* for 1971, prepared by the University of South Florida, Marine Science Institute was published.

Miss Karen Ann Wilson (who joined the company in January as an Associate Ecologist) presented a paper at the 25th meeting of the American Institute of Biological Sciences held in Minneapolis on August 31, 1972. Her paper was entitled, "Distribution and Taxonomy of Luminous Bacteria in the Eastern Gulf of Mexico." Research for the paper was carried out in 1970-71 at the University of South Florida, Marine Science Institute while Karen was completing her master's degree in marine science.

B. Licensing and Regulatory Affairs

The environmental licensing activities of the Company include the preparation, review and submission of all environmental permit applications to regulatory agencies. In addition, liaison is effected with these agencies as an ongoing responsibility to provide design engineering with environmental parameters.

During the past quarter, the following project permit applications were prepared, submitted, or acted upon by the respective regulatory agencies:

1. Anclote Dredging Project: Receipt of Permits from Florida Department of Pollution Control and Board of Trustees of the Internal Improvement Trust Fund; submission of application to the U.S. Army Corps of Engineers.

2. Anclote Thermal Monitoring System: Receipt of Federal Communications Commission frequency permit applications.

3. Anclote Pipeline: Prepared applications for all crossings of navigable waters for submission to the Pinellas County Water and Navigation Control Authority.

4. Crystal River: Preparation of permit to U.S. Army Corps of Engineers to discharge liquid wastes into navigable waters.

5. Bartow Maintenance Dredging: Submission of supporting information to local, state, and federal agencies for compliance of permit provisos.

6. Bartow Channel Markers: Preparation of letters of no objection to Pinellas County, Trustees of the Internal Improvement Trust Fund, and U. S. Army Corps of Engineers; permit application to U. S. Coast Guard.

7. Bayboro Maintenance Dredging: Obtained permit to dredge from Pinellas County Water and Navigation Control Authority; prepare applications for submission to the Florida Department of Pollution Control and Trustees of the Internal Improvement Trust Fund.

8. Bayboro Seawall Construction: Obtained permission for construction of a seawall behind the mean high water line from the Florida Department of Pollution Control, Trustees of the Internal Improvement Trust Fund and U. S. Army Corps of Engineers.

9. System: Preparation of permit applications to the Florida Department of Pollution Control to construct chemical-industrial waste treatment facilities for Bartow, Crystal River, Higgins, Turner, Avon Park, and Suwanee Plants.

C. Nuclear Affairs

Major Company efforts for this period involved coordination of activities related to completion of the Atomic Energy Commission's (AEC) environmental review of Crystal River and presentation of information the AEC requires in its safety analysis review of Crystal River. Resolution of items requiring additional information by the AEC is one of the requirements necessary prior to issuance of an Operating Permit. Related to the above, the following major tasks were accomplished:

1. In July, representatives of the Atomic Energy Commission visited Florida Power Corporation General Headquarters Complex in conjuction with their environmental review of Crystal River. Assumptions in the thermal plume modeling studies being performed by the Marine Science Institute were discussed.

2. On August 30, 1972, Amendment #22 to the Crystal River Application was filed with the Atomic Energy Commission. The Amendment consisted of Volume #5 to the Crystal River Environmental Report. Contained in this volume were responses to the *AEC Guide for Submission of Information on Costs and Benefits of Environmentally Related Alternative Designs for Defined Classes of Completed and Partially Completed Nuclear Facilities*. Also included was the report—*Water Oriented Activities at Crystal River.*

3. In September, after an approximate six-month review and preparation process the AEC issued its Draft Environmental Impact Statement on the Crystal River Unit #3. This is a requirement of the National Environmental Policy Act. Currently, the Draft Statement is being reviewed by federal and state agencies and other interested parties. A Final Statement is to be issued by the end of the year.

4. On September 13, 1972, Florida Power Corporation submitted comments to the AEC on its proposed *Guide to the Preparation of Environmental Reports*. As a result, representatives of Florida Power Corporation were invited along with other interested industry representatives to a public meeting in October in Washington, D.C., to discuss the proposed Guide.

In conclusion, continuing discussions are being held with representatives of Florida Power Corporation and the Atomic Energy Commission to resolve items relating to the nuclear safety of the Crystal River facility. Resolution of major items is expected by the end of the year.

II SITE METEOROLOGY PROGRAM (CRYSTAL RIVER)

Acquisition of meteorological data continues as a requirement of the research programs at the site as well as for use by the Atomic Energy Commission in the licensing of the Crystal River Nuclear Unit #3.

Wind data recovery rates for both the 35 and the 150 foot levels has exceeded 95% during this period. For the past year, the average data recovery rate has exceeded 95% for both levels.

III BENTHIC MARINE ECOLOGY PROGRAM (CRYSTAL RIVER)

The first progress report of this new program is presented in Appendix B. Current objectives and prognosis for fulfilling them are discussed. Results obtained to date, especially with regard to the supplementary faunal entrapment study are also given.

IV MARINE THERMAL PLUME PROGRAM

The University of South Florida, Marine Science Institute, is continuing to document and analyze the thermal plume characteristics at Crystal River. Meteorological, current, tide, and dye diffusion data as well as aerial photography are being used for calibration of the hydraulic and thermal dispersion models. Incorporated in Appendix A is the progress report which covers the time period July to September, 1972.

V PRE-OPERATIONAL RADIOLOGICAL SURVEY

A. Florida Department of Health and Rehabilitative Services

The Department of Health and Rehabilitative Services is continuing to document the background radioactivity around the Crystal River site. Analysis and comparison of radiological data results are presented in Appendix E. Effective July 1, 1972, changes have been made in the analytical scheme—specific isotopic analysis has been substituted, where possible, for gross radioactive analysis.

B. University of Florida, Department of Environmental Engineering

A report of the last quarter's activities is presented in Appendix D. Since a third contract year is beginning, a review of the primary objectives of the contract, together with an evaluation of the degree to which these objectives have been achieved are included. In addition, goals for the new contract year are set forth.

VI CHLORINATION STUDY

The final report of the University of Florida's chlorination study at Crystal River is presented in Appendix C. A review of the results obtained during the study, together with conclusions and a recommendation to Florida Power Corporation are included.

VII ZOOPLANKTON SURVEY

The first report of the University of Florida's zooplankton survey at Crystal River is presented in Appendix G. This report is chiefly concerned with procedures that will be employed throughout the year, since sufficient data have not been processed at this time to allow for presentation in this issue of the **Status Report.**

VIII BENTHIC MARINE ECOLOGY PROGRAM (WEEDON ISLAND, TAMPA BAY)

The first six months of the University of South Florida's benthic marine ecology program at Florida Power Corporation's P.L. Bartow Plant in Tampa Bay will be devoted primarily to recruiting and equipment purchasing with the first surveys to be conducted in late September. Therefore, the report presented in Appendix H is primarily the result of a preliminary examination of the area conducted in the Summer of 1972.

IX ANCLOTE ESTUARINE ECOLOGY STUDY

The Marine Science Institute of the University of South Florida is continuing its study of the Anclote estuary and adjacent Gulf of Mexico in order to provide Florida Power Corporation with a complete ecological characterization of an estuarine area adjacent to a newly created power plant site. A report of activities from July to September, 1972, is presented in Appendix I.

x| appendices

appendix a

data report

NO. 007

INDEPENDENT ENVIRONMENTAL STUDY OF THERMAL EFFECTS OF POWER PLANT DISCHARGE

by

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INTRODUCTION

Meteorological, current, tide, and dye diffusion data have been taken in the discharge basin of the Crystal River power plant of Florida Power Corporation. This data is being used for calibration of the hydraulic and thermal dispersion models developed by the Marine Science Institute, as well as for defining functions for water sources and sinks at the boundaries and determining friction and eddy diffusion coefficients. Aerial photography was used to provide boundary and bathymetry refinements as well as descriptive circulation and biological information.

RHODAMINE DYE SURVEY NO. 4

The two-dimensional equation which describes the fate of a conservative pollutant introduced into an estuary in terms of its lateral and longitudinal transport as given by Sverdrup (1942) is

$$\frac{\partial c}{\partial t} = \frac{\partial}{\partial x}\left(Kx\frac{\partial c}{\partial x}\right) + \frac{\partial}{\partial y}\left(Ky\frac{\partial c}{\partial y}\right) - \left[\frac{\partial (uc)}{\partial t} + \frac{\partial (vc)}{\partial t}\right] = 0$$

where:

c = Concentration of a given substance in water
x = Distance measured along the x-axis
y = Distance measured along the y-axis
u = Velocity along the x-axis
v = Velocity along the y-axis
t = Time

and

Kx, Ky = eddy diffusion coefficient in the x and y directions, respectively.

It is important to note that models derived from this equation calculate a solution in terms of the eddy diffusion coefficient which is arbitrary and cannot be determined *a priori* except by field measurements. Analytical predictive equations have been developed for pipes and open channels, but these have little applicability to estuarine systems. If the model is being applied to an area with no previous documented field tests, the only resort is to dye tracers to determine Kx and Ky.

To gain knowledge of the use of dye and to develop a set of techniques for measurement, for the first field experiments the method used by Ross (1971) in Tampa Bay was used. The simplifications are as follows:

1) Kx = Ky = K

2) Diffusion is assumed circular regardless of skew and an average diameter is used to determine area of spread.

3) The change in area of spread with respect to time, $\frac{\Delta L^2}{\Delta t}$ (L = distance), is calculated from recorded time intervals and $K = \frac{\Delta L^2}{\Delta t}$.

The dye (200 ml) was released as point sources at three points throughout the basin. This was accomplished by pouring the dye into the water from a beaker. The diameter of each dye patch was determined by visual comparison with a twelve-foot measured pole floating centrally in the dye.

The results of the three drops are shown in Tables 1, 2, and 3* as dye drops 4A, 4B, and 4C. The location of the dye releases are shown in Figure 2. The "x axis" runs east-west and the "y axis" north-south. These are the model reference axes and are used here to facilitate translation of field data to the model.

CONCLUSIONS

Under the conditions and limitations of this field analysis, values for the eddy diffusion coefficient K ranged from 0.47 ft^2/s on the low to 7.85 ft^2/s on the high. The average value was 2.03 ft^2/s.

The wide variability of K and the non-circular behavior of the dye makes the results questionable. A paper by Carter and Okubo (1970) describes their method using a Turner Fluorometer. This device has been used by our research group at Crystal River to determine flow patterns. The method is superior in that it determines Kx and Ky and uses a detection method for the dye which is sensitive to one part per billion. K is determined by the relationship

*Tables and Figures are shown on pp. 23 through 45.

$$K = \frac{1}{2} \frac{d\sigma_s^2}{dt}$$

where σ_s^2 is the variance of the concentration distribution in the s-direction. This method will be used in future analyses, and longer observation periods will be attempted.

RHODAMINE DYE SURVEY NO. 5

A. Dye was released as the tide turned from ebb to flood on September 10, 1972. The drop zone was located at Station 5A, Figure 2. The time of the 200 ml dye release for Station A was 1103 and a current meter (see description) was anchored in the same location at 1106. Photographs were taken of the dye diffusion at three-minute intervals beginning at 1106 and ending at 1118, a total duration of twelve minutes.

The dye remained at the drop zone, dispersing slightly in all directions, and drifting approximately 10-15 feet toward the southwest. At 1109 the mass of dye began advecting northward, toward Lutrell Island, with a gradual turn to the east. By 1115 the dye had moved approximately 80 feet to the northeast of the original position. The current velocity during this time fluxuated from 0 cm/sec to a maximum of 5 cm/sec to the east (Figure 3).

The flow pattern in this particular section of the basin is quite regular. It has a general northeast-southwest oscillatory type of movement, approaching perpendicular to shore.

B. Dye Station 5B was located between the tip of the discharge spoil and the oyster bar to the west (Figure 2). The current meter was anchored at 1136 and the 200 ml of dye was released at 1140, thirty-one minutes into flood. Photographs were taken at 1141 and 1143, followed by three-minute intervals between exposures until 1152, a total duration of eleven minutes.

The dye initially moved directly north with little dispersion. It continued on this northerly course until it reached the north side of the discharge channel at 1149. The dye then began moving eastward, parallel to the north edge of the discharge channel as shown in Figure 2. Although well dispersed, the dye remained a single mass as it entered the discharge channel and continued moving eastward. The current velocities at 5B ranged from 29.5 cm/sec to 32.5 cm/sec and were directed to the north (Figure 3).

C. Dye was released at Station 5C one hour and twelve minutes into flood tide. The release zone is shown in Figure 2. The current meter was anchored at 1210 and 200 ml of dye was released at 1216. Photographs were taken at 1217 and 1219 followed by three-minute intervals between exposures until 1228. Another photograph was taken at 1251 making the total duration of photographs thirty-five minutes.

The dye moved to the north from the release zone with a gradual curving to the east. At 1228 the dye divided into two masses with the northern one being the smaller of the two. However they both continued to move north, toward the barge canal. The current flow for this station was monotonically increasing, beginning at 12 cm/sec and increasing to 14 cm/sec, with generally a northerly direction (Figure 2).

The flow pattern in this section of the basin is exceptionally stable compared to adjacent regions. This is easily explained by smooth bathymetric features which yield little or no obstruction to the current flow.

HIGH-TIDE PROFILES

During STD Survey 11, on August 12, 1972 high-tide channel profiles for salinity and temperature were made of the discharge channel and Cross-Florida Barge Canal. The data points were surveyed for the barge canal between 1425 EDT and 1520 EDT at the late flood stage of the tides. The station locations are shown in Figure 4. The data points for the discharge channel were surveyed between 1651 EDT and 1715 EDT, the early ebb tidal stage. Station locations are shown in Figure 7.

Tide Data: August 12, 1972

EDT	ft.
0424	3.5
1113	0.9
1636	3.7
2336	1.0

The Cross-Florida Barge Canal cross section (Figure 5) for late flood tide was taken within one hour of maximum flow; therefore a good representation of flood conditions was obtained. The temperature in the canal ranged from 32-.5°C to 31.5°C and had little effect on the density of the water. The salinity section, however, showed definite wedging characteristics, with the more saline Gulf of Mexico water undercutting the less dense Withlacoochee River water, as it moved eastward up the barge canal. A lens of less saline river water was suspended in a pocket approximately in the middle of the profile. This seemed to be a remnant of the pattern which was produced earlier in the tidal cycle and then was severed from water of similar salinity due to the dynamic upwelling of saline gulf water as it entered the mouth of the barge canal spoil banks. A deeper lens of fresh water from the barge canal was found under the upwelling at the spoil banks. An explanation of this will be forthcoming as more data in this area is compiled. It is possible that this pattern is formed due to an excessively large flow (990 cfs on 9/12/72, also see "Cross-Florida Barge Canal Flow Data" section, this report) from the barge canal and patterns previously established during an ebb tide.

The early ebb tide profile for the discharge channel (Figure 6) was made just after high water. The temperatures ranged from 34.0°C at Biological Marker 4 (see Figure 7) to a maximum of 39°C at the plant outfall. Temperature patterns indicated that a homogeneous mass of water was moving west in the channel until it reached Biological Marker 3 (see Figure 7). At this point high horizontal temperature gradients occurred similar to those discussed in Carder (1970a). Salinity profiles for flood tide are related to temperature from the discharge to approximately Biological Markers 3 and 5 where contact with less saline water of Withlacoochee origin produced a region of mixing. The sections indicate that the warm, saline plume water began to dive under the fresher, cooler Withlacoochee water at about Biological Marker 3.

LOW-TIDE PROFILES

During STD Survey 12, on August 13, 1972 low-tide channel profiles for salinity and temperature were made of the discharge channel and Cross-Florida Barge Canal. The data points for the barge canal were surveyed between 1320 EDT and 1340 EDT. The data points for the discharge channel were surveyed between 1050 EDT and 1120 EDT.

Tide Data: August 13, 1972

EDT	ft.
0446	3.6
1149	0.8
1716	3.5
2356	1.3

The Cross-Florida Barge Canal cross section (Figure 8) for low-tide was taken approximately two hours into flood tide, and is therefore more representative of an early flood tide. The temperatures in the canal ranged from 31-.5°C to 31.0°C and had little effect on density of the water. The salinities showed a wedging phenomenon similar to that of the late flood tide profile except in an earlier stage. The lower salinities are on the surface but have not been severed by an upwelling of saline water entering from the gulf. The lower lens of less saline water is present here in the same configuration as in the flood tide profile.

The low-tide profile for the discharge channel (Figure 9) is only complete from Biological Marker 3 to Biological Marker 5. The patterns represented for both the salinity and temperatures are not complete enough to draw accurate conclusions.

STD SURVEY NO. 11 (HIGH-TIDE)
STD SURVEY NO. 12 (LOW-TIDE)

Two STD (salinity, temperature, depth) surveys were run on August 12 and 13, 1972, near high and low tides respectively. The tidal range for each day was greater than four feet, representing a wider range than usual for this location. The thermal plume submergence phenomenon mentioned in Carder (1970a) is apparent from

Figures 12-16 where the warm, saline plume water has wedged below the cool, fresh water of Withlacoochee River origin. At high tide the saline thermal plume has been pushed north of the discharge canal into the shallows, and at ebb tide, it has been extended westward.

The difference between thermal plume areas at high and low tides is due to the increased depths found in the western part of the discharge basin. This increases the volume of water found beneath a given contoured area as well as decreases the water column temperature rise due to solar radiation. Since most measurements have been taken near mid-day, solar radiation has enlarged the apparent thermal plume size more in the shallows than in the deeper portions of the basin.

AERIAL PHOTOGRAPHIC SURVEY NO. 1

The concept of using aerial photography in the collection of data had never been attempted before by the Marine Science Institute at Crystal River. Photographs will hopefully lead to the understanding of some of the past as well as present physical processes of the discharge basin and surrounding areas.

On Friday, September 8, 1972 at 1000 EDT photography of the Crystal River basin commenced from a 2000 foot altitude. A 35 mm single-lens reflex camera was used with a combination of filters which will be mentioned in the description of films. The first twenty exposures were on a high speed infrared black and white negative film. This particular film was exposed at ASA 50, f2.8 with a shutter speed of 1/250 of a second. The lens was covered by one U.V. filter, one number 25 red filter, and one Polaroid filter. The next one hundred exposures were taken on Infrared Ektachrome colorpositive film. This film was exposed at ASA 100, f4.0 with a shutter speed of 1/1000 of a second. The lens was filtered with one U.V. filter, one number 12 yellow filter, and one Polaroid filter. The next thirty-six exposures were on High Speed Ektachrome color-positive film. This film was exposed at ASA 160, f4.8, with a shutter speed of 1/1000 of a second. The filters employed were one U.V. filter and one Polaroid filter.

The general discussion included here is only designed to bring to light some of the more obvious features observed as well as which films produced the best results for our work requirements.

The High Speed Infrared (Kodak) film produced very poor results in all instances. Due to its short length (20 exposures) and its high sensitivity to light (must be loaded and unloaded in total darkness) it is utterly impossible to unload the camera while in flight without light leakage. This means that if more than 20 exposures of this film, or a combination of this film and others are required, a blackout bag must be carried in flight for loading and unloading. The photographs that were received had poor resolution, and distinction between land and marine features (bars, turbid areas, etc.) was difficult if not impossible to distinguish.

The High Speed Ektachrome slides had good resolution, but show little in the way of vegetation differences in both marine and terrestrial environments. Differences in turbidity although seen, were not distinct. Land features as well as marine features could be separated and mapped from these photographs if necessary, but Infrared Ektachrome produced better results for this operation.

The Infrared Ektachrome slides produced the best resolution and excellent distinction between different types of marine and terrestrial vegetation. Turbid areas were quite distinct, and submarine topographic features were revealed despite enormous turbidity. Some of the more noticeable features observed in the photographs are as follows:

1. Migrating sand (quartz) bars in the two inland tidal channels north of Point A (figure 7).

2. Oxbow steam patterns in all of the inland tidal channels, but somewhat subdued in the two channels north of Point A.

3. Flood tide flow patterns through the gaps in the oyster bars were obvious from turbidity patterns both in direction and flow volume.

4. Bars uncharted from previous black-and-white aerials were more noticeable, one of which had been unobserved until the field survey on

October 7 and 8, 1972.

5. Areas of outcropping Inglis limestone can be seen on photographs along the discharge channel and south of the intake spoil.

6. Infrared reflectance (pink implies exposed vegetation) is greater on exposed oyster bars in the discharge basin than on those outside of it, indicating some type of photosynthesis is occuring on the bars in the discharge basin.

7. Massive kills of sable palms in certain restricted locations indicate the effects of possible changes in flow patterns since the erection of discharge channel spoil banks (see "Palms" Figure 7).

8. Turbidity was extremely high in the barge canal, Withlacoochee River entrance, and the northern and western parts of the discharge basin. Extensive dredging in this area and other parameters probably lead to this relocation of fine particles.

9. The maximum extent of the ebb tide pattern of the plume was quite noticeable because it was only fifteen minutes into flood tide when the photographs were taken. However, because of poor visibility (3-5 miles) a low altitude was used and the plume was not totally contained in a single exposure.

These are just a few of details which were recovered from the photographic survey. In future aerial surveys the High Speed Infrared film will be dropped and fewer High Speed Ektachrome slides will be taken. An extensive recharting of bars is now under way as well as a charting of the possible approaches of a flood tide, with much of the data for both being obtained from the Infrared Ektachrome aerial photographs. Studies of the tidal channels north of Point A will also begin within the next quarter.

CROSS-FLORIDA BARGE CANAL FLOW DATA

After the study and consideration of numerous STD surveys, barge canal profiles, and the observation of excessive amounts of fresh or low saline water in the discharge basin it was an obvious necessity to obtain volume discharge data for the barge canal. The information collected was obtained from Malcolm Johnson, employed by the Southwest Florida Water Management District in Tampa, Florida. The volumes/second of flow are based on flow measurement through the Inglis Lock on the barge canal, maintained by the Army Corps of Engineers.

Maximum Discharge 3980 cfs July 26, 1966
Maximum Discharge 100-30 cfs
Average 65 cfs
(this variance is due to leakage at the lock during a total damping of water flow)
990 cfs August 12, 1972

Flow data for the Inglis Lock has been maintained since 1964.

CURRENT METER DESCRIPTION

Two film-recording subsurface current meters (General Oceanics Model Number 2010) have been purchased and used in the collection of data for the Current Surveys and Dye Survey #5. The results produced are quite promising for future work to be done at Crystal River.

The Model 2010 Film Recording Current Meter consists of a buoyant, cylindrical housing containing a directional inclinometer and a Super 8 cartridge camera which sense and record the inclination and compass heading of the instrument. It is designed to be tethered to a ballast weight for bottom current measurements. A large vane is affixed to the housing to assist orientation and stabilization within the current stream. The data recording camera is triggered to photograph the directional inclinometer at regular intervals (1, 5, 10, 15, 30, or 60 minutes) by a solid-state electronic clock. The self-contained battery supply and camera film capacity enable approximately 3500 data records to be taken over an operating period of up to five months.

Crystal River Units 1 and 2 Condenser Temperatures

	August 12, 1972				August 13, 1972			
	Unit 1		Unit 2		Unit 1		Unit 2	
	Inlet °F	Outlet °F	Inlet °F	Outlet °F	Inlet °F	Outlet °F	Inlet °F	Outlet °F
0101	86.4	100.5	88.1	94.2	86.4	100.5	87.6	93.0
0201	86.4	99.9	88.5	93.4	86.3	100.4	87.6	93.2
0301	86.3	99.8	88.2	93.1	86.3	100.5	87.5	93.1
0401	86.0	99.4	87.8	92.6	86.3	100.4	87.4	94.5
0501	86.0	99.4	87.8	92.7	86.1	98.1	86.7	94.1
0601	85.9	99.3	87.8	92.6	86.1	98.1	86.8	94.8
0701	85.9	99.2	87.8	92.6	85.8	98.0	86.4	94.3
0801	86.3	100.3	87.8	96.8	86.0	98.9	87.2	91.7
0901	86.2	100.2	87.7	95.1	86.3	100.4	87.1	97.1
1001	86.2	100.4	87.8	96.5	86.5	100.6	87.2	100.6
1101	86.4	100.5	87.9	99.3	86.8	100.9	87.7	101.2
1201	86.5	100.6	88.3	101.4	86.7	100.9	88.2	101.5
1301	86.7	100.8	88.6	101.7	86.8	101.0	88.2	101.5
1401	87.0	101.1	88.8	101.9	86.9	101.0	88.4	101.8
1501	87.0	101.2	89.0	102.1	86.9	101.1	88.6	102.0
1601	87.2	101.3	89.1	102.4	87.0	101.2	88.7	102.2
1701	87.3	101.4	89.0	102.5	87.0	101.2	88.7	102.2
1801	87.1	101.2	89.0	102.5	86.9	101.1	88.6	102.2
1901	87.2	101.3	88.8	102.3	86.7	100.9	88.5	102.1
2001	86.6	100.7	88.6	102.1	86.5	100.7	88.3	101.9
2101	86.6	100.7	88.3	101.9	86.6	100.0	88.2	101.5
2201	86.5	100.6	88.5	102.2	86.5	99.9	88.0	101.2
2301	86.4	100.5	88.1	99.1	86.3	99.7	87.9	101.0
2401	86.3	100.4	88.1	94.6	86.3	96.3	87.7	100.8

It will be noted that in past reports gross generation was reported. Since this is not directly convertable into added temperature Florida Power made arrangements to supply condenser rise in the form of inlet and outlet temperatures. This will be of great benefit to the modeling effort since the 11°F rise is not constant as can be seen from the figures above.

Plume Acreages

8-12-72

Surface: Temperature °C	Acres	Three Feet: Temperature °C	Acres
>38	3.19	>38	4.56
37-38	5.02	37-38	3.65
36-37	3.92	36-37	4.56
35-36	1.09	35-36	5.47
34-35	26.00	34-35	39.41
33-34	101.09	33-34	83.94

Ambient (condenser intake) 85.9-89.1°F or 29.9-31.7°C

8-13-72

Surface: Temperature °C	Acres	Three Feet: Temperature °C	Acres
>36	0.91	>36	1.09
35-36	2.74	35-36	6.57
34-35	24.63	34-35	44.70
33-34	126.54	33-34	37.68

Ambient (condenser intake) 85.8-88.7°F or 29.9-31.5°C

THERMAL BUDGET

The Thermal Dispersion Model has been enlarged to include a budget of heat sources and sinks indigenous to the area surrounding the discharge basin.

Although the thermal budget was not originally considered in the research, it was quickly recognized that the usefulness of the results of the model would be greatly enhanced by its addition. The model can predict which grids will contain thermal addition from the plant, but in the field it is impossible to separate power plant heated water from naturally heated water. As the resultant flood plume figures show, much of the water included in summer flood plumes is naturally heated diurnally by incoming radiation during daylight hours when our measurements are made.

The calculations are those of Callaway *et al.*, (1969) with the basic equation:

$$T_{new} = T_{old} + \frac{q_H \, \Delta t}{\rho_w \, C_p \, D}$$

where:

$$q_H = q_{net} + q_e + q_c$$

q_{net} =total incoming and outgoing radiation (kcal/m²/sec) (+ incoming,—outgoing)

D=depth of water column (m)

C_p =specific heat of water at constant pressure (kcal/kgm/°C)

$q_e = \rho_w$ E (HV), evaporative heat flux (kcal/m²/sec)

ρ_w =water density (1000 kg/m³)

E =N·U($e_s - e_a$)=rate of water loss due to evaporation (kgm/sec)

and

N=empirical constant (MB^{-1})

U=wind speed(m/sec) (if u $\leq$ .05 set u=.05)

e_s=2.1718x10⁸exp (-4157.0/(239.09+T_s)) pressure of saturated water vapor (MB)

e_a=2.1718x10⁸ exp. (−4157.0/(239.09+T_{wb})) − AP($T_a - T_{wb}$) (6.6x10⁻⁴+7.59x10⁻⁷(T_{wb})) pressure of water vapor in ambient air(MB)

AP=air pressure(MB)

HV=597−.57 T_s, latent heat of vaporization (kcal/kgm)

q_c=BR·q_e, convective heat exchange (kcal/m²/sec)

BR=6.1x10⁻⁴(AP) $\frac{T_a - T_s}{e_s - e_a}$, Bowen Ratio

T_{wb}=wet bulb temperature (°C)

T_a=dry bulb temperature (°C)

T_s=water surface temperature (°C)

A visual presentation of the processes described by these equations is presented in Figure 18. The drawing is after R. Geiger, "The Climate Near the Ground," p. 7, Harvard University Press, Cambridge, Mass. 1957.

The results for the days of the STD surveys contained herein (August 12 and 13, 1972) are shown in Figures 19 and 20. Figure 19 shows the raw meteorological data. All of the data except net radiation were taken from the data records from the Environmental Data Acquisition (Buoy) System, whose meteorological station is now fully operational.

The center chart on Figure 20 shows the theoretical temperature change of a stationary packet of water two meters deep, unaffected by the thermal plume but subjected to natural environmental changes. A range of 3.8°F is noted caused by natural effects over a one-day cycle. In one meter of water the effect is doubled (ignoring the effect of increased evaporation).

The lower chart on Figure 20 shows the surface sensor on Buoy OD which is furthest from the plume over the same forty-eight hour period. The good correlation indicates that the heat budget program is ready to be transferred to the thermal model program, and that Buoy OD is apparently unaffected by the plume.

TIDE SURVEY

On September 9 and 10, 1972, a detailed analysis of the tidal wave characteristics at the Crystal River discharge area was made. Tide gauges were placed at the locations marked in Figure

21. The objective was measurement of the amplitude damping factor and phase lag factor. It can be shown (Ippen, 1966) that the time of high water at some fixed point in the basin (with time=0 at a fixed point at the basin entrance) depends only on the phase lag factor which is constant for the basin and independent of the wave characteristics, and that the amplitude ratio between these points is completely consistant. This method has been established by researchers on the Bay of Fundy and the Delaware Estuary as valid and accurate. Once these factors are established and refined from field data the same geographic locations can be located in the model and the same numeric indicators isolated. The bottom friction and blockage friction can then be adjusted to give a good match.

The results of the analysis are shown in Figures 22, 23, 24, and 25. By superimposing Figure 22 of Tide Station 026 on any of the others the amplitude damping factor and phase lag factor can be determined. It was noted that despite the flow obstacles and shallow reaches between the basin opening to the west, the phase lag and amplitude damping factors were very small and will require further refinement.

As determined from the results of this survey:

			026-028	026-029	026-027
K	sec	high	.462	.610	0
	grid	low	.793	.488	.686
N	ft	high	.026	.026	.029
	grid	low	.091	.095	.058

where:

N=amplitude damping factor or the height the amplitude of the tide wave loses in traveling through each 485 foot grid.

K=phase lag factor or the amount of delay the tide wave accumulates in traveling through each 485 foot grid.

The constants will be checked and rechecked by further studies to be sure all anomolous behavior and field errors are removed. The model will then be adjusted to fit these parameters.

CURRENT SURVEY

On September 9 and 10, 1972, a current survey of the discharge basin was performed. This is the second in a long series which will be used to check the results from the mathematical computer model of the basin. Particular attention will be focused on:

1. Leakages or inputs/outputs in the north and south boundaries which are not solid.
2. Current magnitude and direction in shallow, roughbottomed areas to check friction factor for this case.
3. Current magnitude and direction in deep, smoothbottomed areas to check friction factor for this case.

The upper current trace in Figure 26 is the recorded current at the location marker "Unit A" in Figure 21. This was the location identified in Withlacoochee Input Curent Survey No. 1 (Pyle *et al.*, 1971c) as the major source of fresh Withlacoochee River water entering the basin. This fresh water is apparent from salinity surveys made in the basin and causes density layering apparent in the field temperature surveys. Because of this pronounced effect it is important to correctly identify the nature of the flow in a manner compatible with the computer model so that it can be accurately reproduced.

In the first boundry current survey, mentioned previously, it was determined that the flow through the pass (identified in Figure 21 as the placement of the Unit A current meter) was southward during maximum ebb flow and nonexistent during low water, maximum flood flow, and high water. The problem remained to quantify this flow.

The original measurements were made with a current vane, a kite-shaped device on a line which when immersed assumes an angle with the plumb line proportional to the current speed. The present measurements are being made with a General Oceanics Film-Recording Current Meter with measurements taken every five minutes. The results are shown as the upper current trace in Figure 26. As can be seen, the same qualitative pattern of flow is evident as noted previously with flow into the basin occurring only at the time of maximum ebb slow. Quantitative values from this study will be fed into the computer model as time dependent current magnitude and direction (upper arrows in Figure 26 represent direction with north towards top of paper and increasing angle clockwise) as a half-rectified sine wave 45° out of phase with the tidal forcing function. This technique will be checked by inputting a salinity depression at this geographic point in the dispersion program and matching patterns of low salinity with past field results.

THERMISTOR BUOY DATA

Although direct computer access to data from the ECI Environmental Data Acquisition System (see Colbert and Carder, 1971) is not yet available, short series of data have been punched for preliminary computer messaging. An example of such is being provided to demonstrate some of the capabilities of an automated data acquisition system for use in conjunction with thermal effluent research. Although there are twelve thermistor buoys and a weather station active in the system, only short data records from a few sensors will be displayed until direct computer access can be made to the buoy data (recorded on magnetic tape).

Figure 7 is a chart of the discharge basin at the Crystal River plant with the locations of three ECI buoys indicated by the letters A, E, and G. They telemeter temperatures (hourly from depths of one, four, seven, and eleven feet) back to the Base Station located in power generation Unit No. 1. Only data from the surface sensors will be treated this time.

Figures 27, 28, and 29 are computer plots of hourly temperature data from Buoys A, G, and E, respectively. The records begin at 1500 hrs. on February 29, 1972, and end at 0900 hrs. on March 7, 1972. These data were processed using the Autocovariance and Power Spectral Analysis Program BMDO2T, developed by Health Sciences Computing Facility, UCLA.

Power spectra for these data appear in Figures 30, 31, and 32. Note that the ordinate is plotted on a natural log scale of power, and the abscissa is plotted in frequency (cycles/hour). Each of these spectra have prominent peaks near the frequencies 0.006, 0.044, and 0.081 cycles/hour which correspond to periods of 166.7, 22.7 and 12.3 hours, respectively. These periods correspond roughly to the weekly heating and cooling trends seen in Figures 27 to 29, to diurnal, and to semi-diurnal components. The diurnal components could be due to a number of phenomena. Power plant loading (i.e., outfall temperature) has strong 24 hour periodicity (see Carder and Klausewitz, 1972), tides have secondary diurnal components, and solar radiation has a 24 hour cycle. The 12.3 hour period corresponds closely to the primary M_2 component of the tides. Each of these periods can be better approximated by the use of longer data records in the future.

A comparison of the power spectra of Figures 27, 28 and 29 indicates a trend observed visually by Carder and Klausewitz (1972) from early data: the closer the observation point is to the plant outfall, the more predominant the effects of plant loading are as compared to those of the tide. The ratios of diurnal power to semi-diurnal power for Buoys A, G, and E are 4.50, 4.02, and 1.76, respectively, demonstrating as was expected that tidal effects become much more important in the discharge basin than in the canal in affecting the periodicity of a temperature record. This, of course, assumes that the sensor location is in the path of the plume at least part of the time. The temperature record from a region not affected by the plume would have a significant solar heating effect having a predominant diurnal periodicity (see Figure 20).

Figure 33 is a graph of the cross-covariance function between the records from Buoy A and Buoy G. The interesting thing to notice is the temperature phase difference between the two locations represented by the position of the central maximum. Its phase lag is between two and three hours, indicating that the average time that it takes a parcel of water of a certain temperature to travel from Buoy A to Buoy G is approximately 2½ hours. Since their spatial separation is 6500 ft., the mean current speed in the discharge canal is 0.49 mph to the west.

This value is centered within the range of current measurements made at various stages of the tide on previous field trips.

CONCLUDING REMARKS

Significant progress has been made during the previous six months time both in the availability and use of new instrumentation and in model calibration advances.

The addition of meteorological (Weather Station) parameters to the ECI Environmental Data Acquisition System is providing hourly information critical to the calibration of the heat budget portion of the Thermal Dispersion Model. Comparison of theoretically predicted temperatures with naturally occurring ambient (unaffected by the thermal plume) temperature has demonstrated the accuracy of the heat budget subroutine for use in the Crystal River plant discharge basin.

Calibration of the hydraulic (circulation) program is nearing completion with the use of five portable tide gauges and two buoyed current meters for check of tidal amplitudes, phases, and currents. This information is being used to modify friction and blockage factors discussed previously. The current meters have also been used to measure boundary water sources (Withlacoochee River and Cross-Florida Barge Canal) to define all major flows into and out of the dischange basin.

Dye diffusion studies are continuing in order to adjust eddy diffusion coefficients from sub-basin to sub-basin. Aerial photography has provided information for boundary and depth refinements to the model as well as descriptive circulation and biological information.

Model calibration efforts will continue during the next six months. The Thermal Dispersion Program will be run without any power loading from the plant involved to determine what the ambient background temperature distribution would be if the plant were turned off. This will allow a true assessment to be made of the temperature contribution made by the plant without the high meteorological (increase for summer days/decrease for winter nights) effects apparent in field data from the shallows.

REFERENCES

Callaway, R.J., K.V. Byram, and G.R. Ditsworth, 1969. Mathematical model of the Columbia River from the Pacific Ocean to the Bonneville Dam. Fed. Water Pollution Control Admin., Corvallis, Oregon.

Carder, K.L., 1970a. Independent environmental study of thermal effects of power plant discharge. Data Report No. 001, Environmental Status Report, Florida Power Corporation, St. Petersburg, Florida, July, August September.

Carder, K.L., 1970b. Independent environmental study of thermal effects of power plant discharge. Data Report No. 002, Environmental Status Report, Florida Power Corporation, St. Petersburg, Florida, October, November, December.

Carder, K.L., 1971a. Independent environmental study of thermal effects of power plant discharge. Data Report No. 003, Environmental Status Report, Florida Power Corporation, St. Petersburg, Florida, January, February, March.

Carder, K.L., 1971b. Independent environmental study of thermal effects of power plant discharge. Data Report No. 004, Environmental Status Report, Florida Power Corporation, St. Petersburg, Florida, April, May, June.

Carder, K.L. and R.H. Klausewitz, 1972. Independent environmental study of thermal effects of power plant discharge. Data Report No. 006, Environmental Status Report, Florida Power Corporation, St. Petersburg, Florida, January-June.

Carter, H.H., and A. Okubo, 1970. Longitudinal dispersion in non-union flow, Technical Report 68, Chesapeake Bay Institute, Johns Hopkins University, November.

Colbert, D.C. and K.L. Carder, 1971. Environmental data acquisition telemetry system, Proc.

of the IEEE International Conference of Engineering in the Ocean Environment, San Diego, 373-376.

Ippen, A.T., 1966. Estuary and coastline hydrodynamics. McGraw-Hill, New York, 743 pp.

Pyle, T.E., R.H. Klausewitz, and K.L. Carder, 1971c. Independent environmental study of thermal effects of power plant discharge. Data Report No. 005, Environmental Status Report, Florida Power Corporation, St. Petersburg, Florida, July-December.

Ross, Bernard E., 1971. Personal communication.

Sverdrup, H.V., M.W. Johnson, and R.H. Flemming, 1942. The Oceans. Prentice-Hall, New York, 1087 pp.

Table 1

Dye Drop 4A — 8/12/72 — 18:00 — Depth $\doteq$ 6 ft.

Elapsed time sec.	Dye shape	Dye size ft.	Predominant Axis	$(\frac{ft^2}{s})\ \frac{\Delta x^2}{\Delta t} \doteq K$
0	circle	1	none	—
5	circle	2	none	0.47
10	circle	3	none	0.79
15	circle	5	none	2.50
20	ellipse	7x5	x	1.57
30	ellipse	10x6	x	0.66
60	ellipse	15x8	x	0.78
120	ellipse	20x10	x	1.05
180	ellipse	40x20	x	7.85

Total K for 180 sec. = 3.49 ft^2/s

Table 2

Dye Drop 4B 8/12/72 18:30 Depth $\doteq$ 21 ft.

Elapsed time sec.	Dye shape	Dye size ft.	Predominant Axis	$\frac{\Delta x^2}{\Delta t} \doteq K$
1	circle	1	none	–
5	circle	5	none	3.[illegible]7
25	ellipse	12x5	x	1.38
60	ellipse	20x5	x	0.90

Total K for 60 sec. = 1.31 ft^2/s

Table 3

Dye Drop 4C 8/13/72 14:30 Depth $\doteq$ 8 ft.

Elapsed time sec.	Dye shape	Dye size ft.	Predominant Axis	$\frac{\Delta x^2}{\Delta t} \doteq K$
0	circle	1	none	—
5	ellipse	5x4	x	2.99
15	ellipse	12x6	x	4.08
45	ellipse	20x7	x	1.78
90	ellipse	25x8	x	1.05
180	ellipse	30x10	x	0.87

Total K for 180 sec. = 1.31 ft^2/s

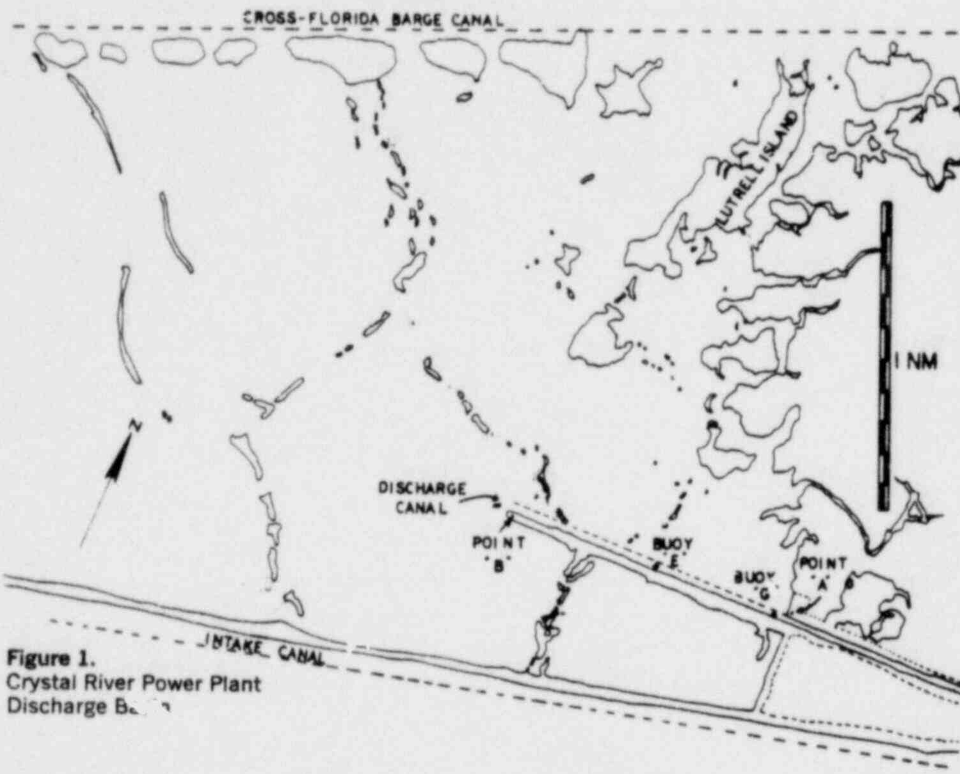


Figure 1.
Crystal River Power Plant
Discharge Ba[illegible]

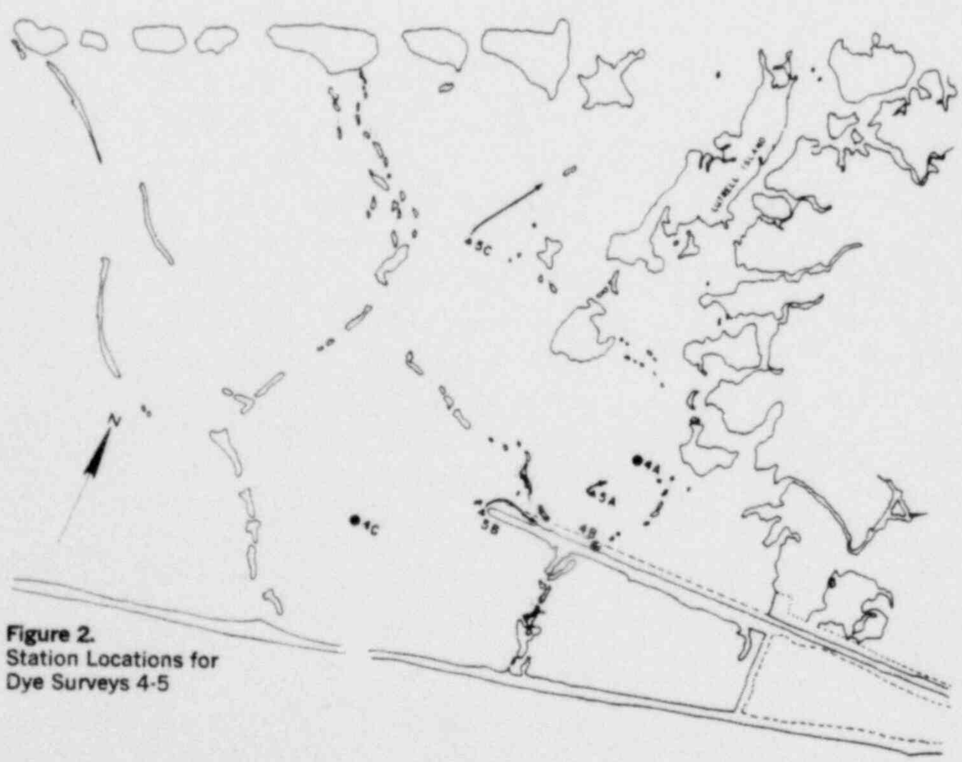


Figure 2.
Station Locations for
Dye Surveys 4-5

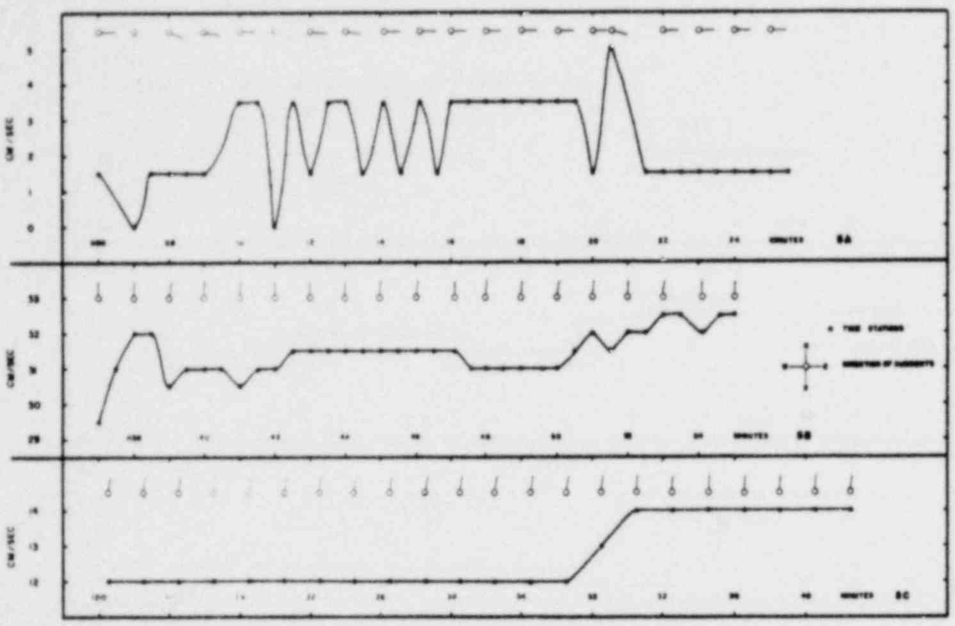


Figure 3. Current Velocities for Dye Surveys 5A, 5B, 5C

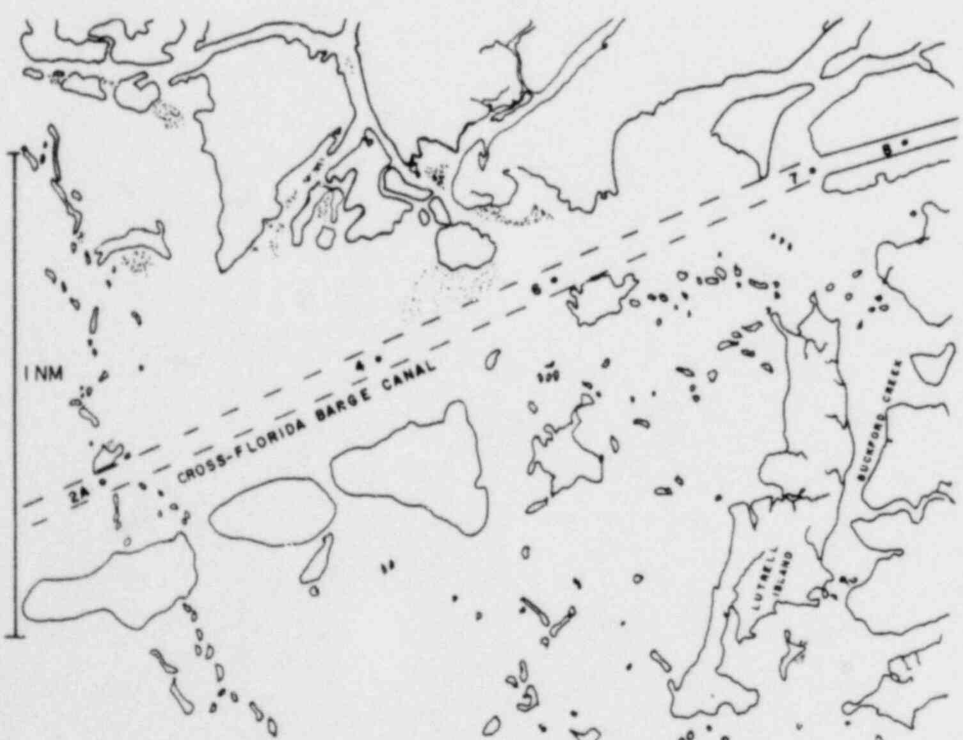


Figure 4. Station Locations on the Cross-Florida Barge Canal

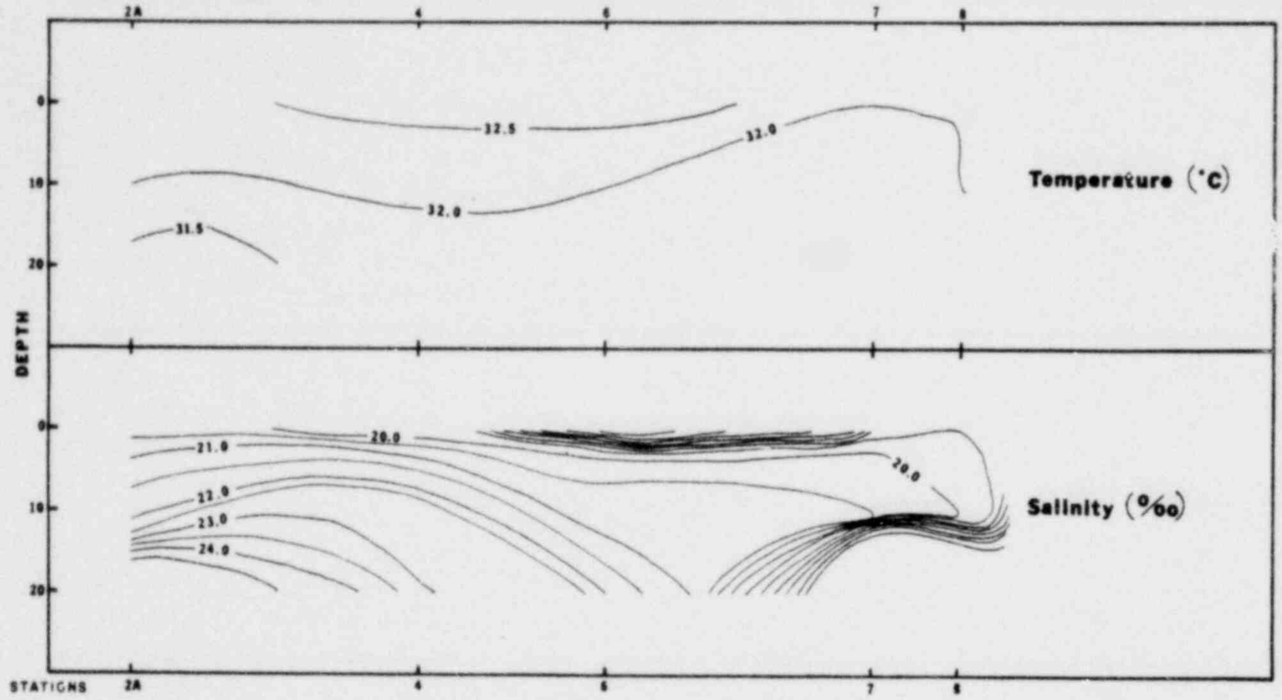


Figure 5. Late High-Tide Profile—Barge Canal

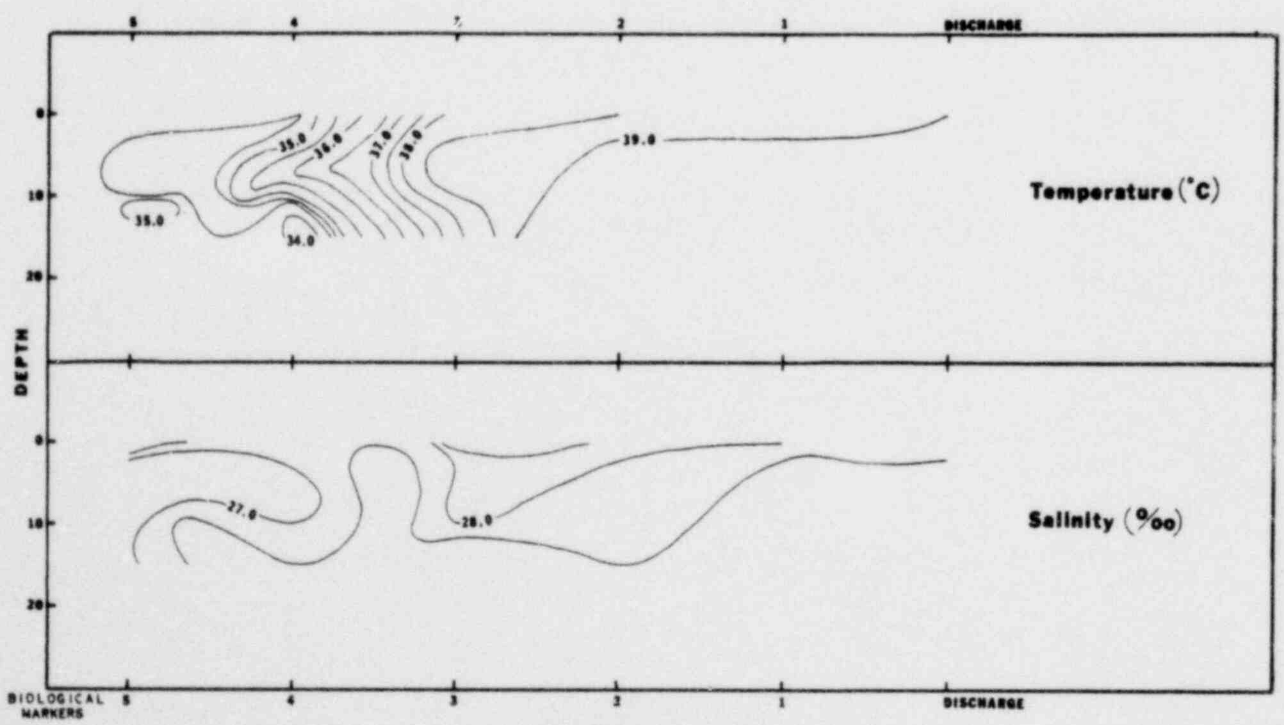


Figure 6. Late High-Tide Profile—Discharge Canal

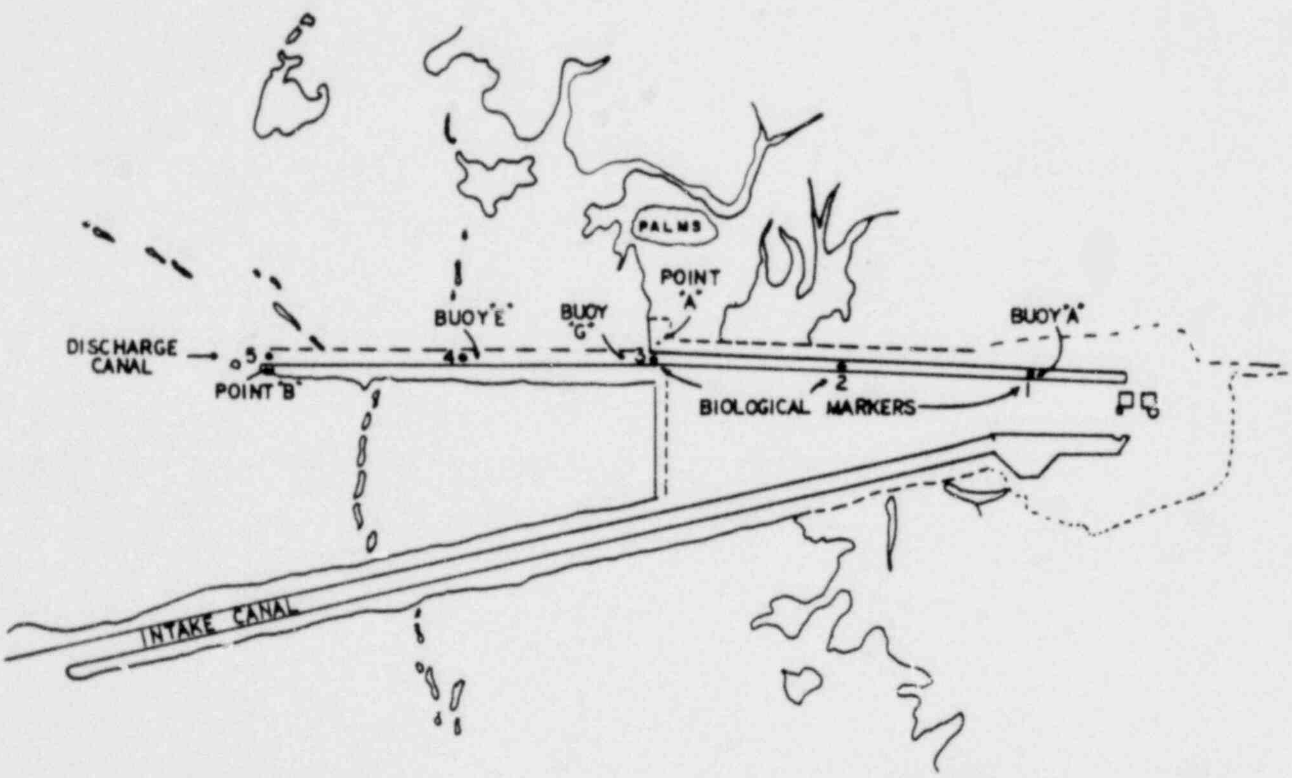


Figure 7. Crystal River Plant Site and Immediate Surroundings with Biological Markers

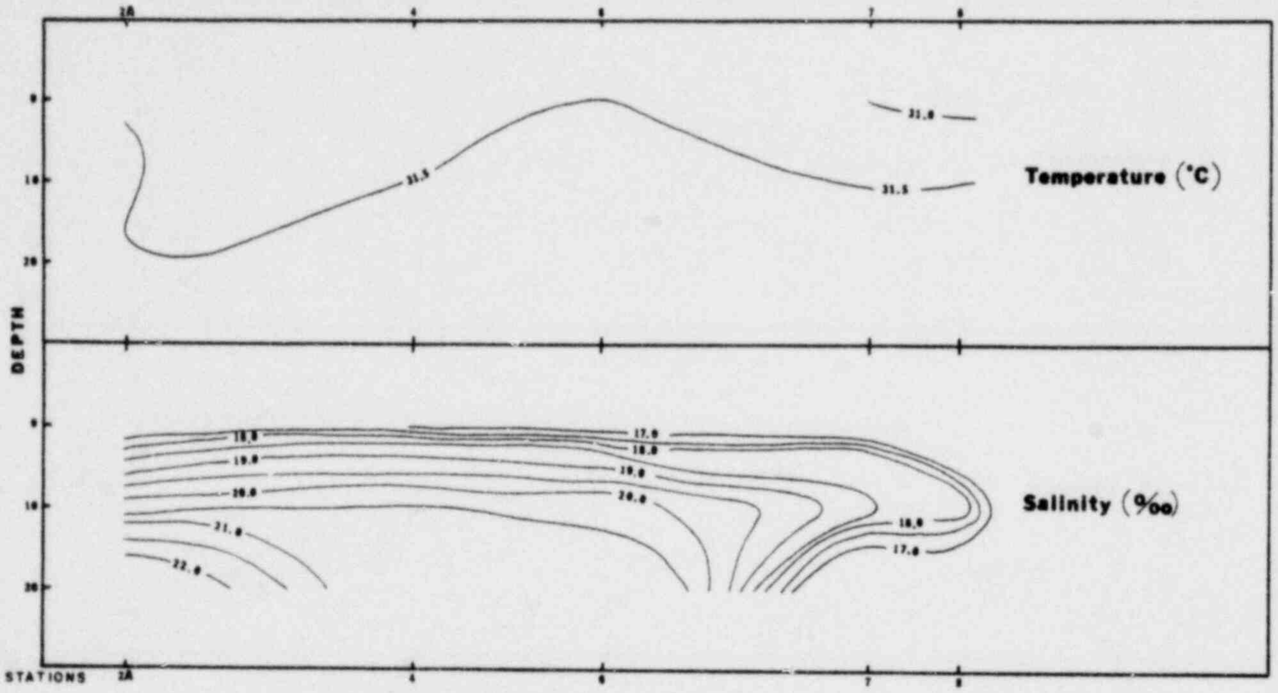


Figure 8. Low-Tide Profile—Barge Canal

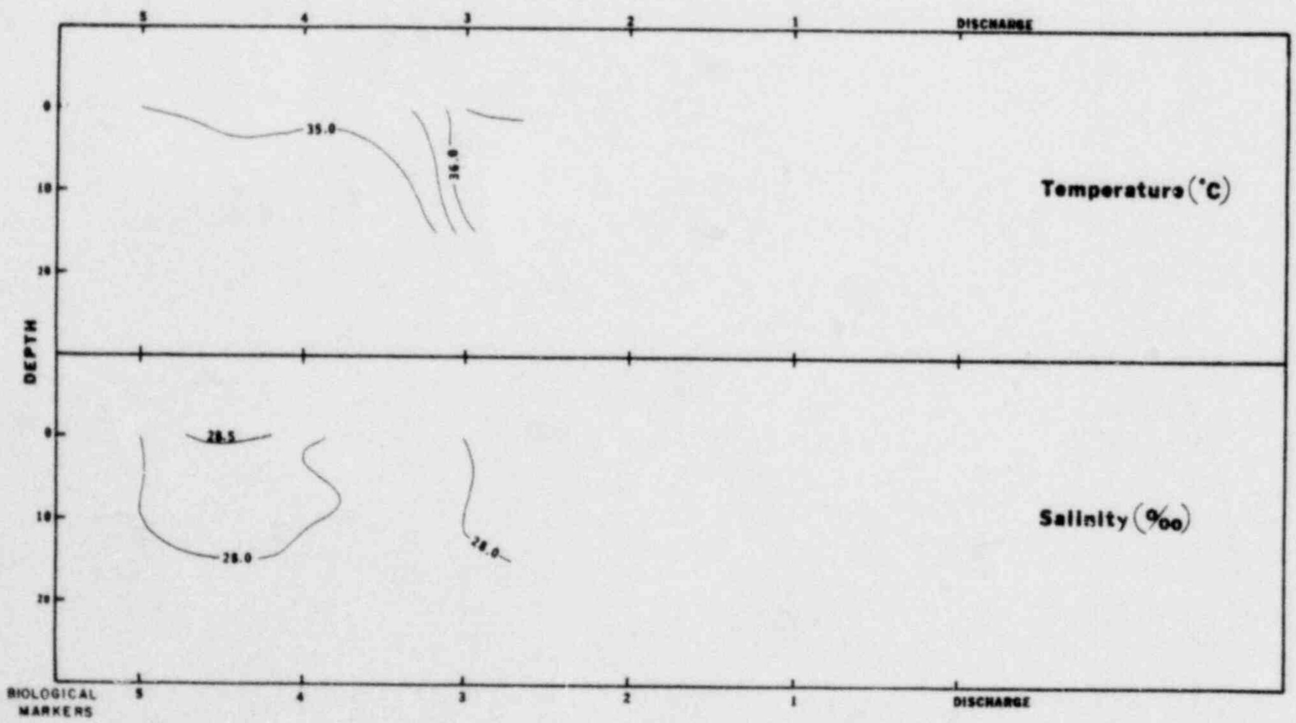


Figure 9. Low-Tide Profile—Discharge Basin

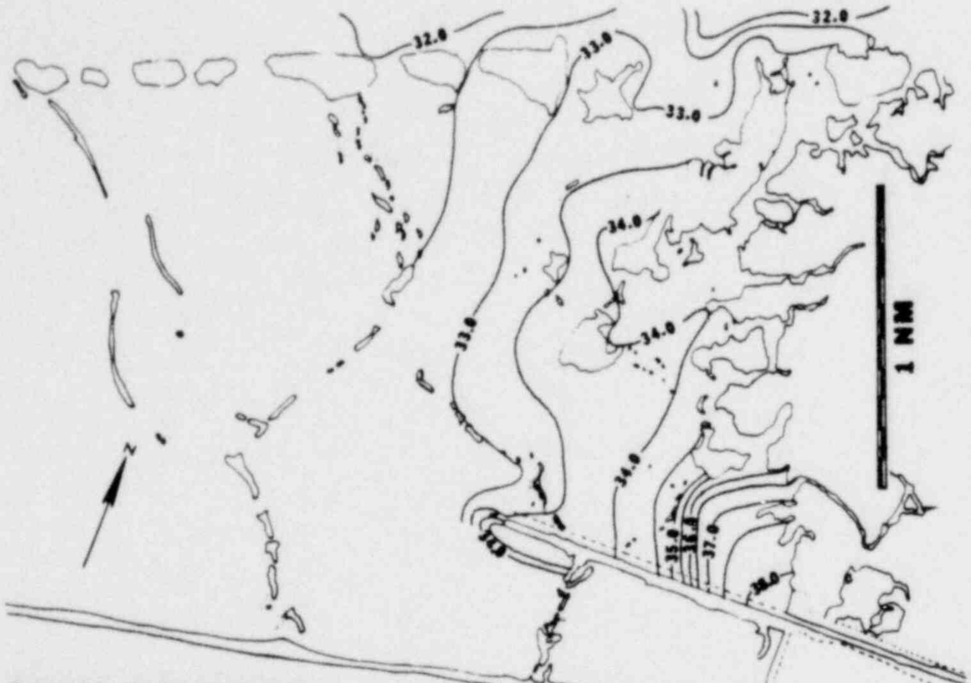


Figure 10. Surface Temperature
August 12, 1972
Flood Tide
Contour Interval 0.5°C

Figure 11. Three Foot Temperature
August 12, 1972
Flood Tide
Contour Interval 0.5°C

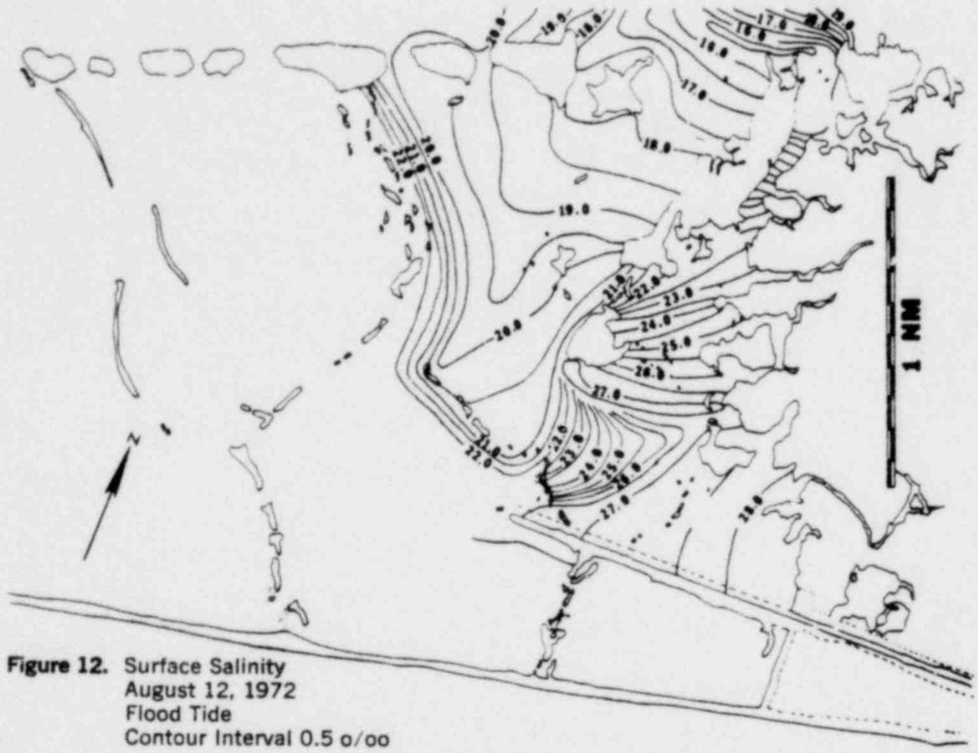


Figure 12. Surface Salinity
August 12, 1972
Flood Tide
Contour Interval 0.5 o/oo

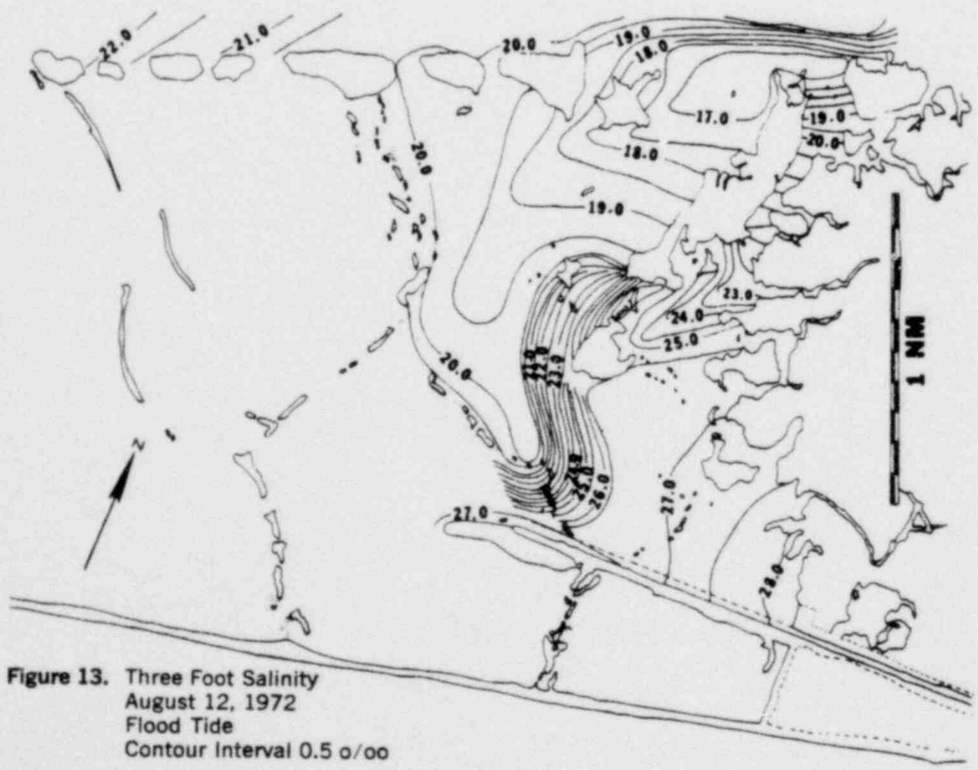


Figure 13. Three Foot Salinity
August 12, 1972
Flood Tide
Contour Interval 0.5 o/oo

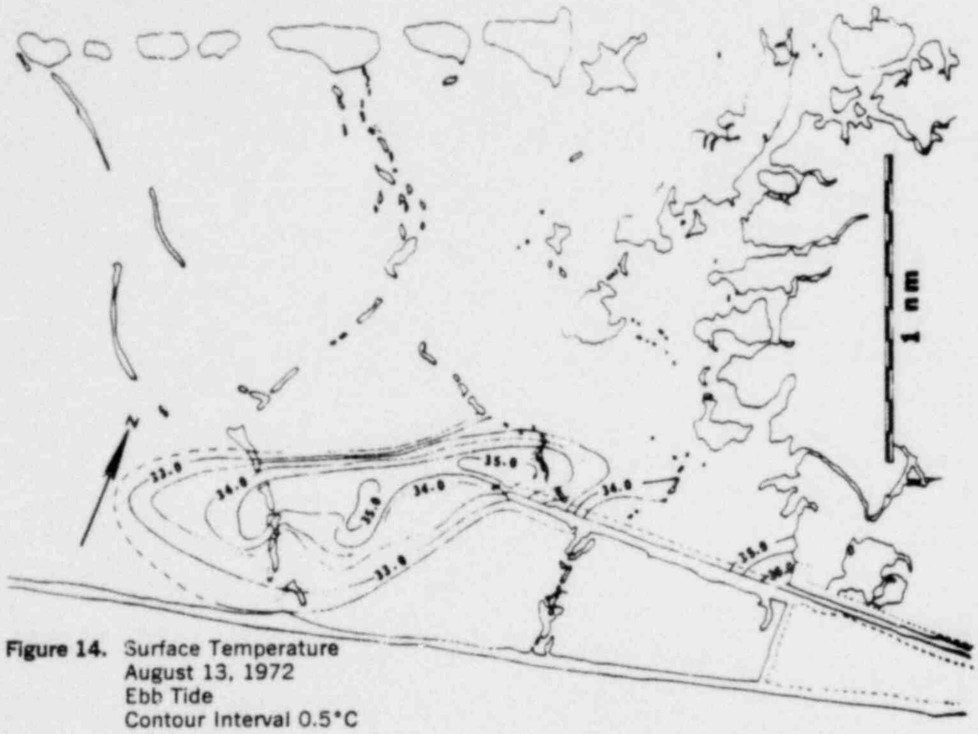


Figure 14. Surface Temperature
August 13, 1972
Ebb Tide
Contour Interval 0.5°C

Figure 15. Three Foot Temperature
August 13, 1972
Ebb Tide
Contour Interval 0.5°C

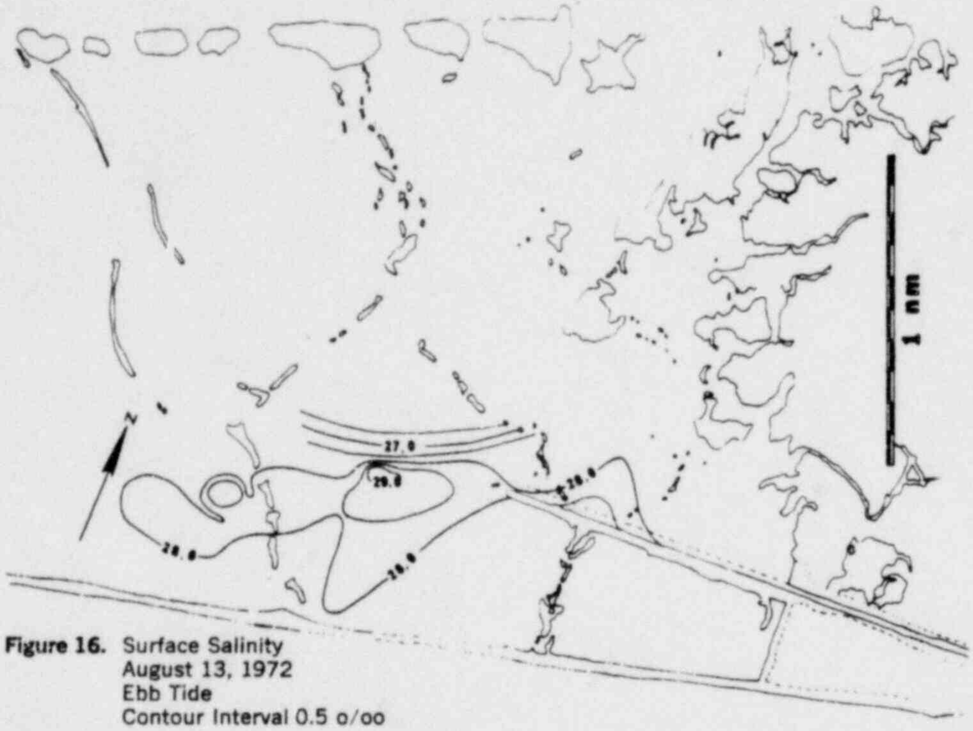


Figure 16. Surface Salinity
August 13, 1972
Ebb Tide
Contour Interval 0.5 o/oo

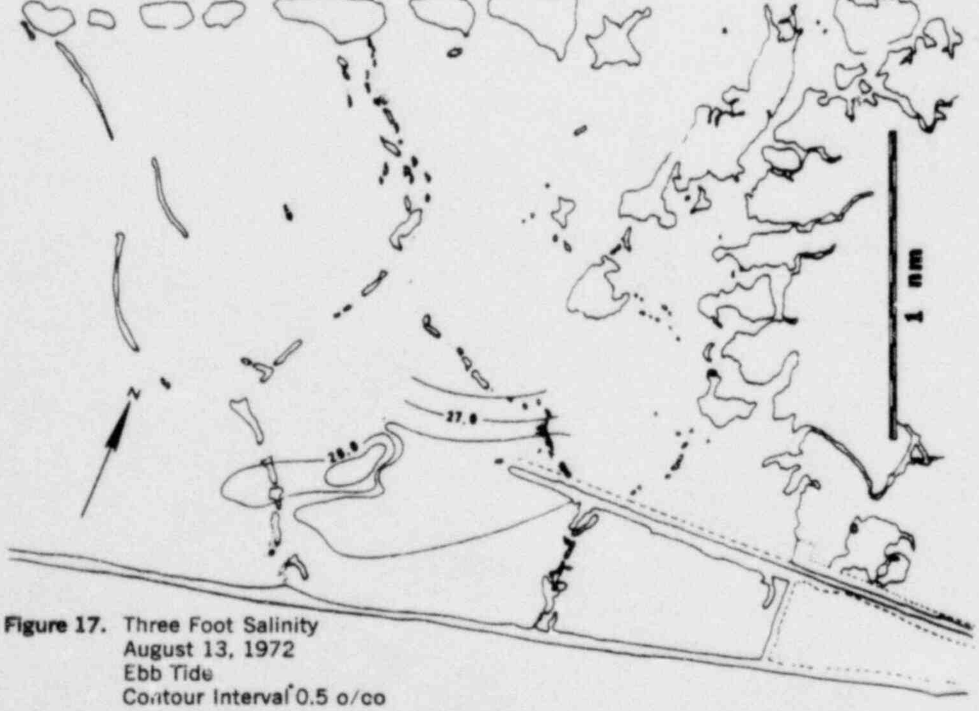
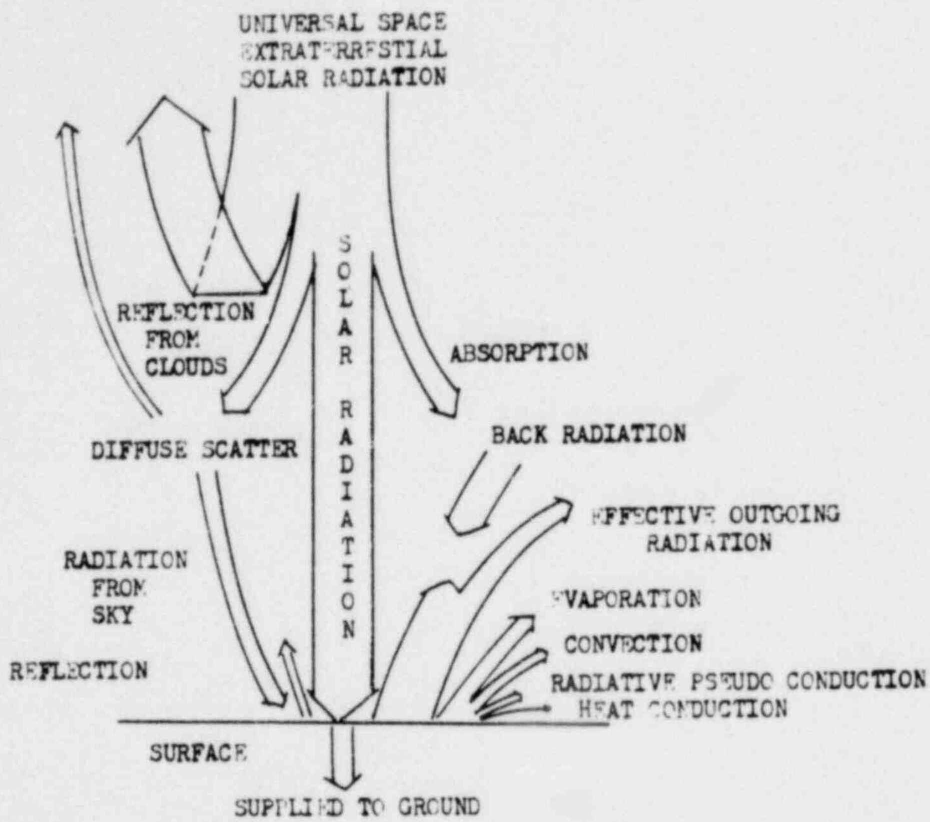
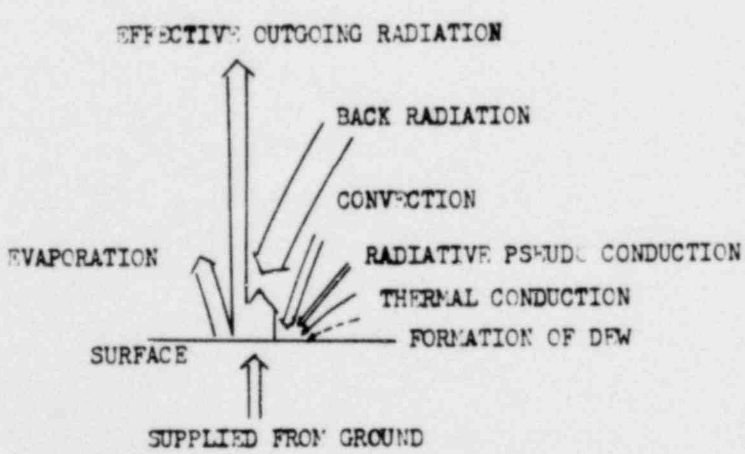


Figure 17. Three Foot Salinity
August 13, 1972
Ebb Tide
Contour Interval 0.5 o/co



ENERGY BALANCE AT NOON ON A SUNNY DAY. ARROW WIDTH PROPORTIONAL TO ENERGY.



ENERGY BALANCE AT NIGHT DRAWN TO THE SAME SCALE AS ABOVE

Figure 18.
Energy Balance Terms

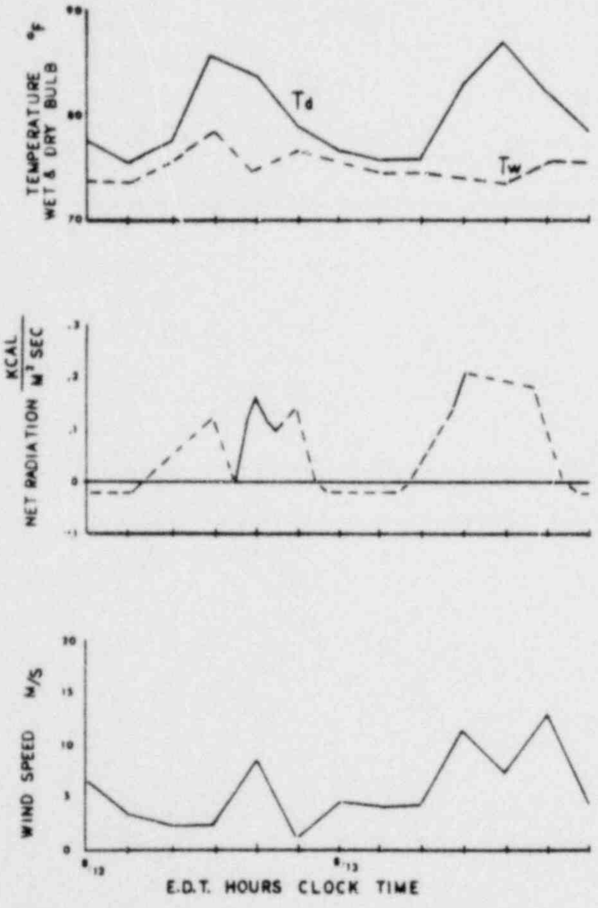


Figure 19.
Meteorological Data — August 12 and 13, 1972

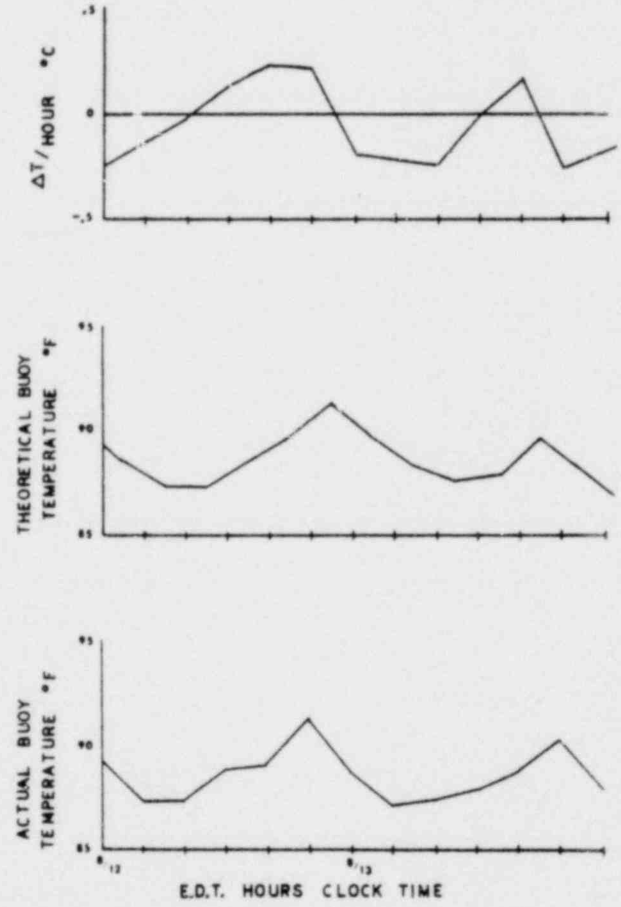


Figure 20.
Results of Thermal Budget compared with Buoy Data

Figure 21. Tide and Current Meter Locations September 9 and 10, 1972

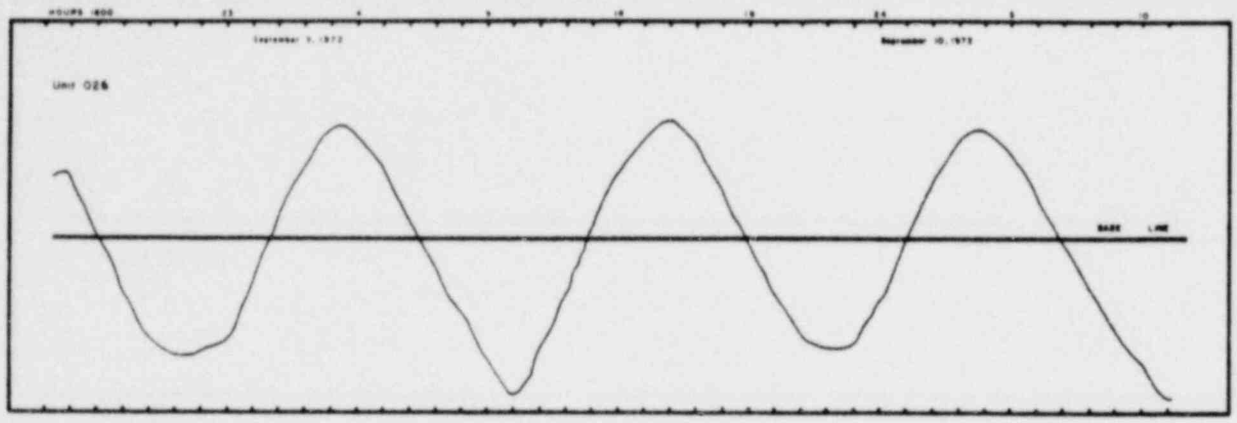


Figure 22. Tide Station 026

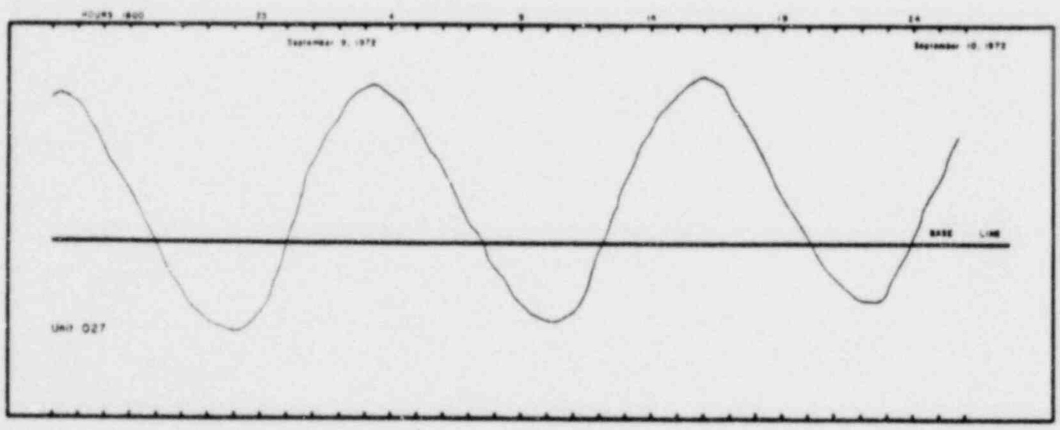


Figure 23. Tide Station 027

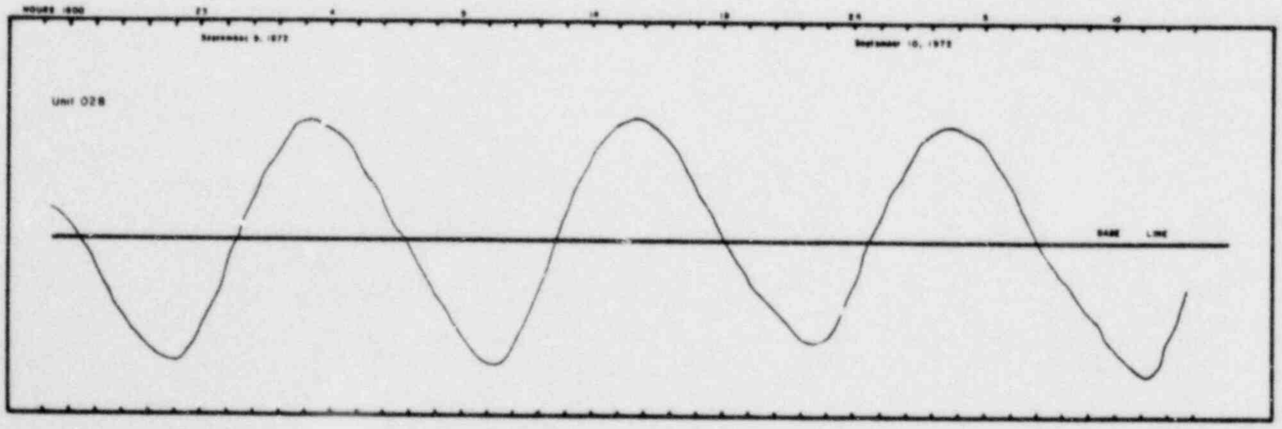


Figure 24. Tide Station 028

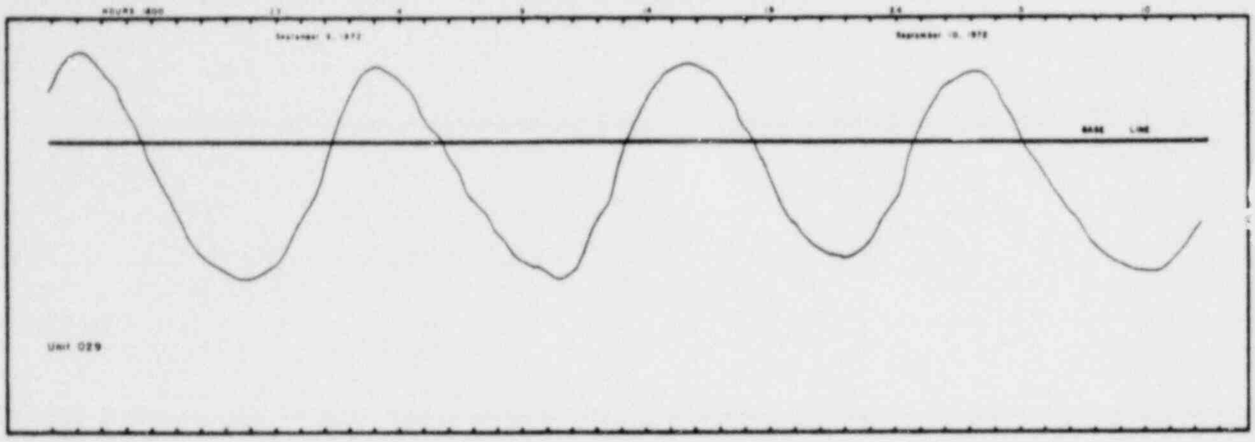


Figure 25. Tide Station 029

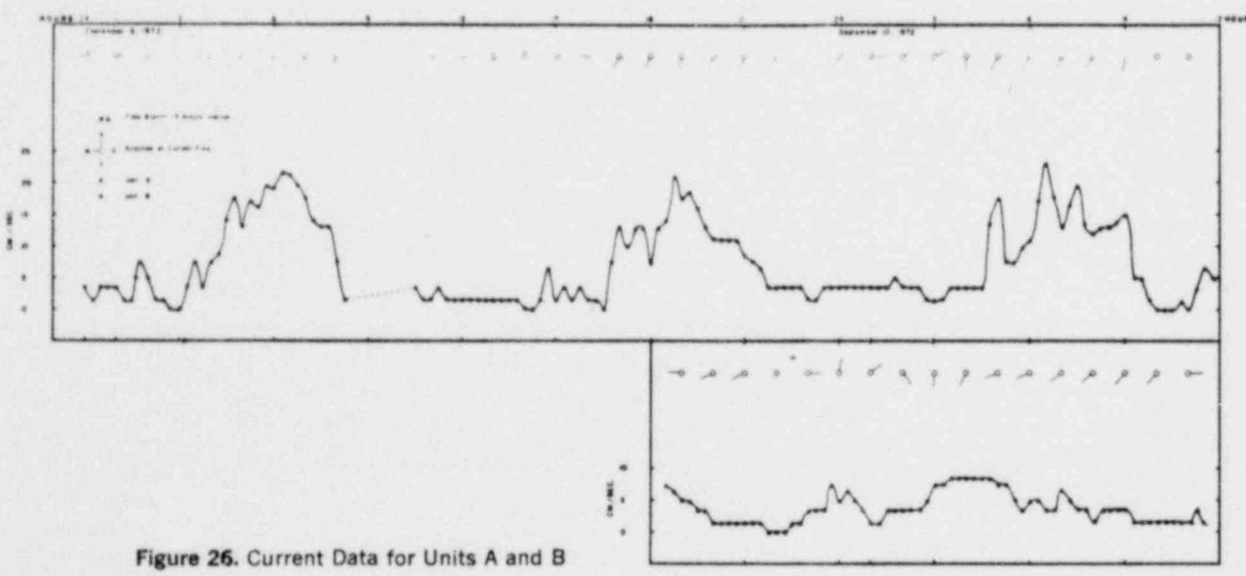


Figure 26. Current Data for Units A and B

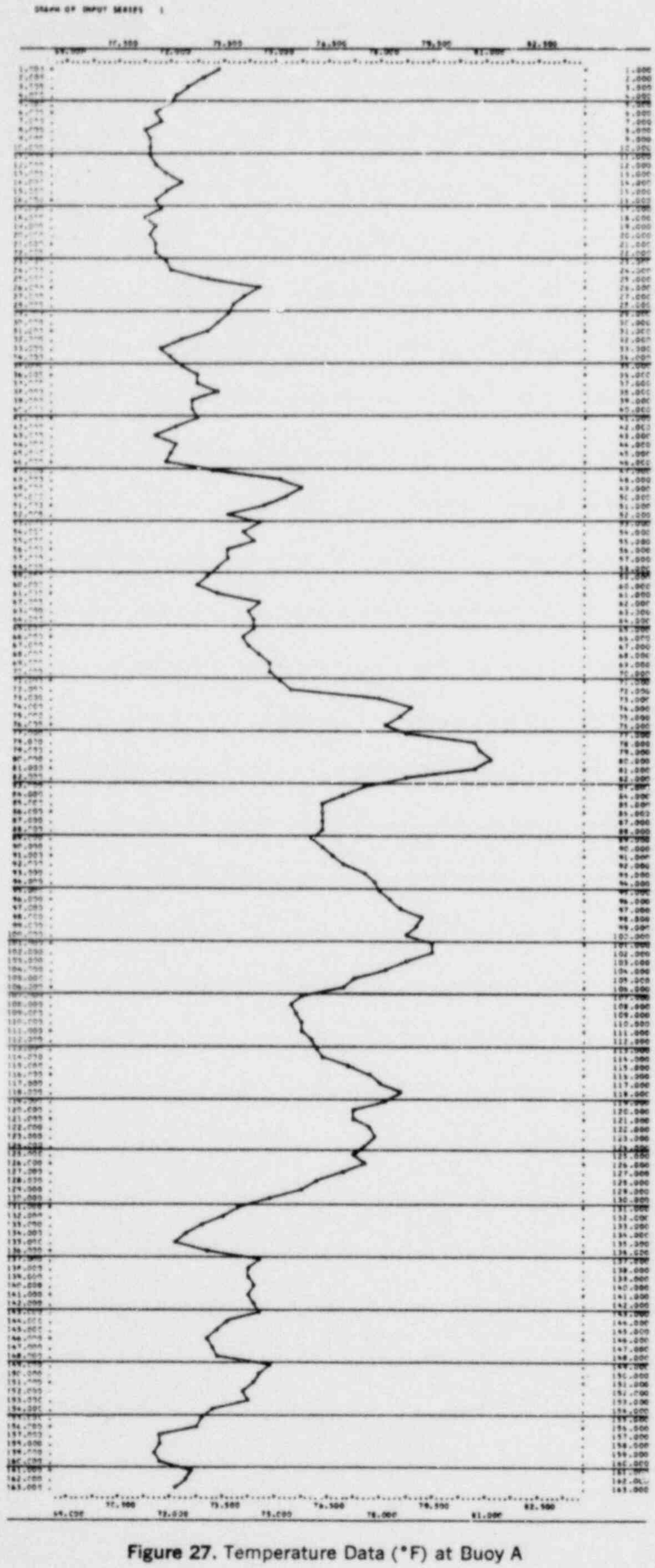


Figure 27. Temperature Data (°F) at Buoy A

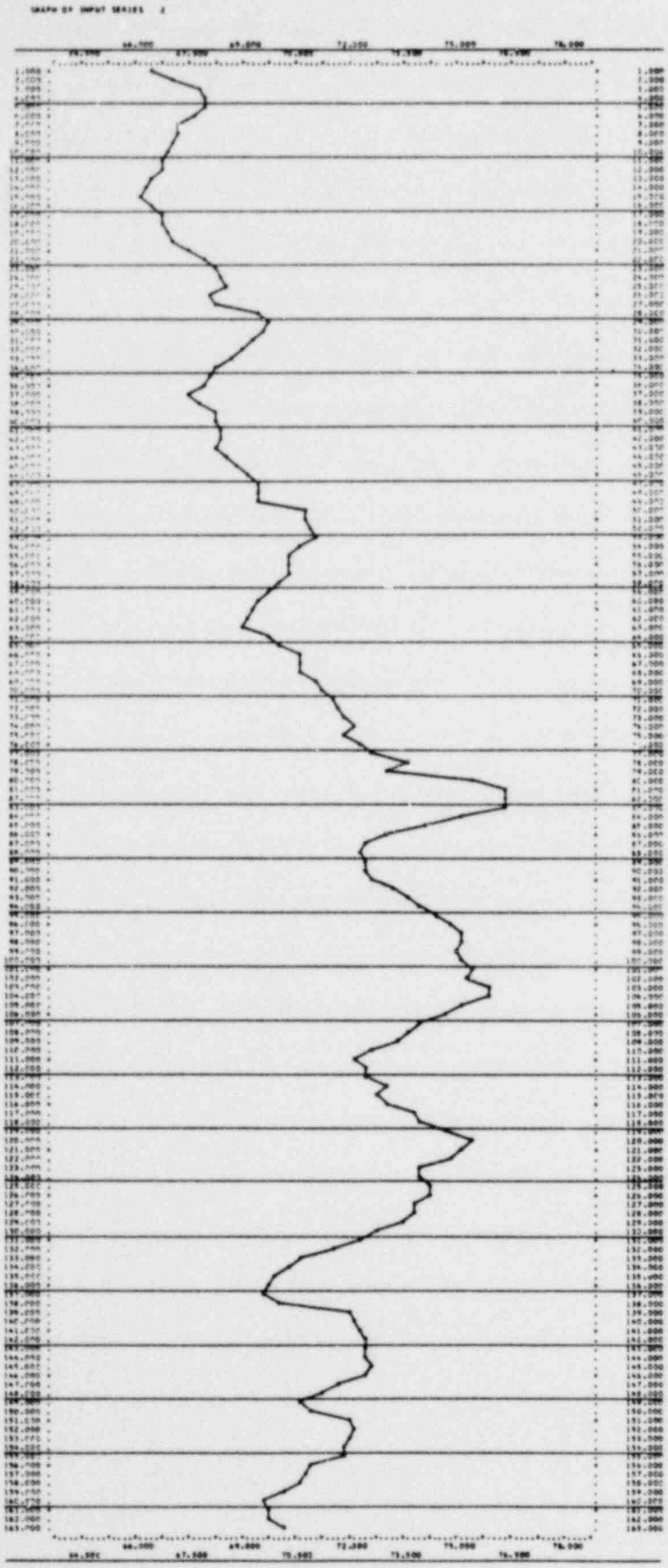


Figure 28. Temperature Data (°F) at Bouy E

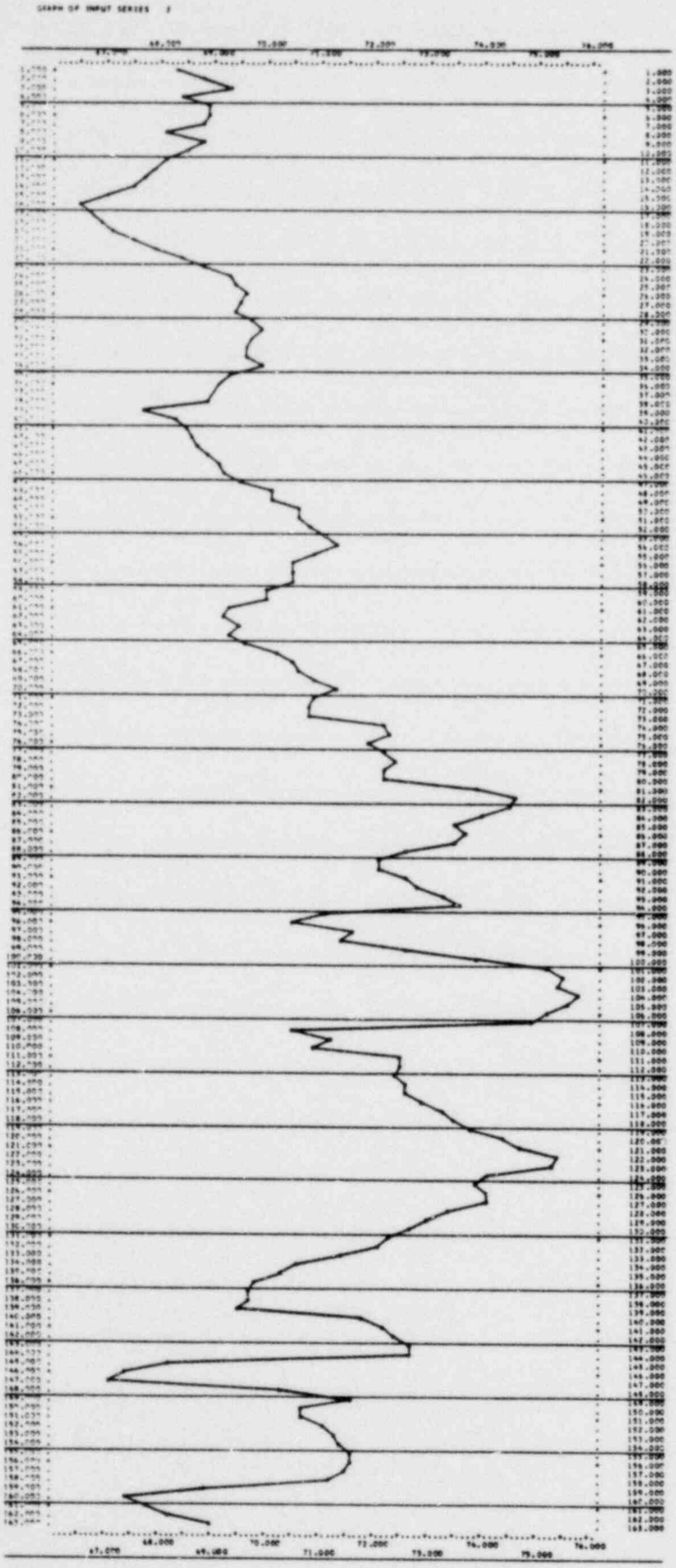


Figure 29. Temperature Data (°F) at Buoy G

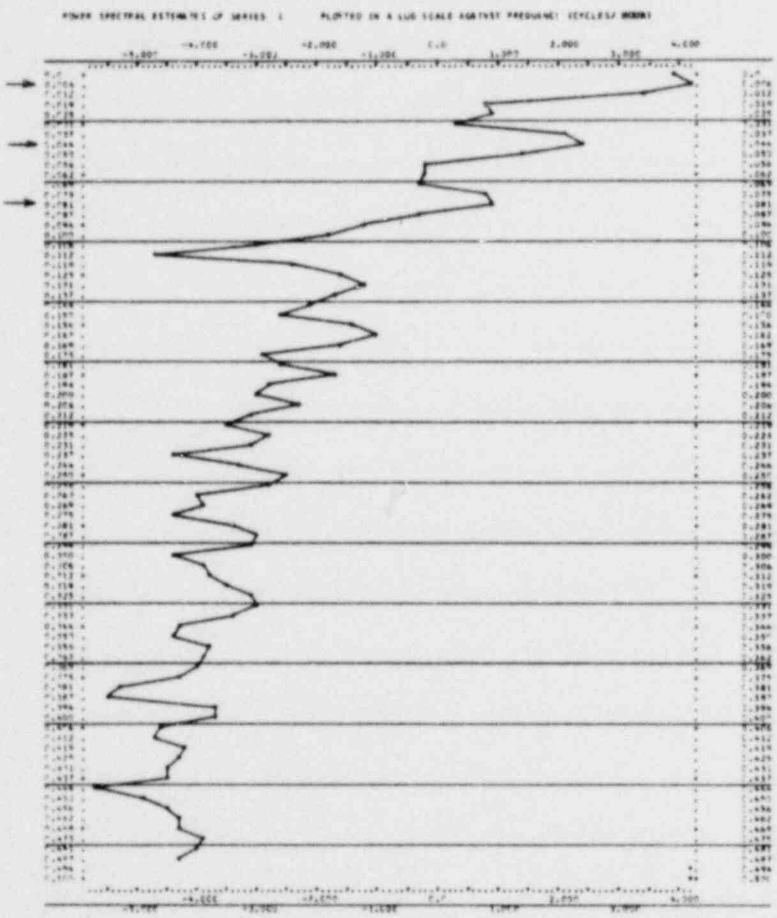


Figure 30. Power Spectral Estimates of Temperature Data from Buoy A

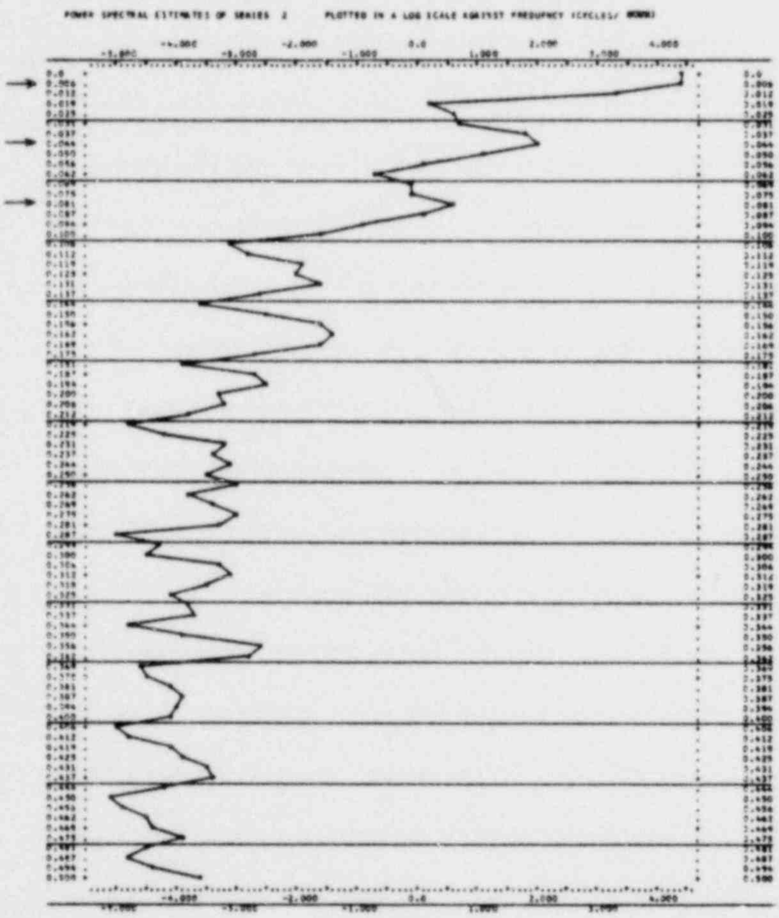


Figure 31. Power Spectral Estimates of Temperature Data from Buoy E

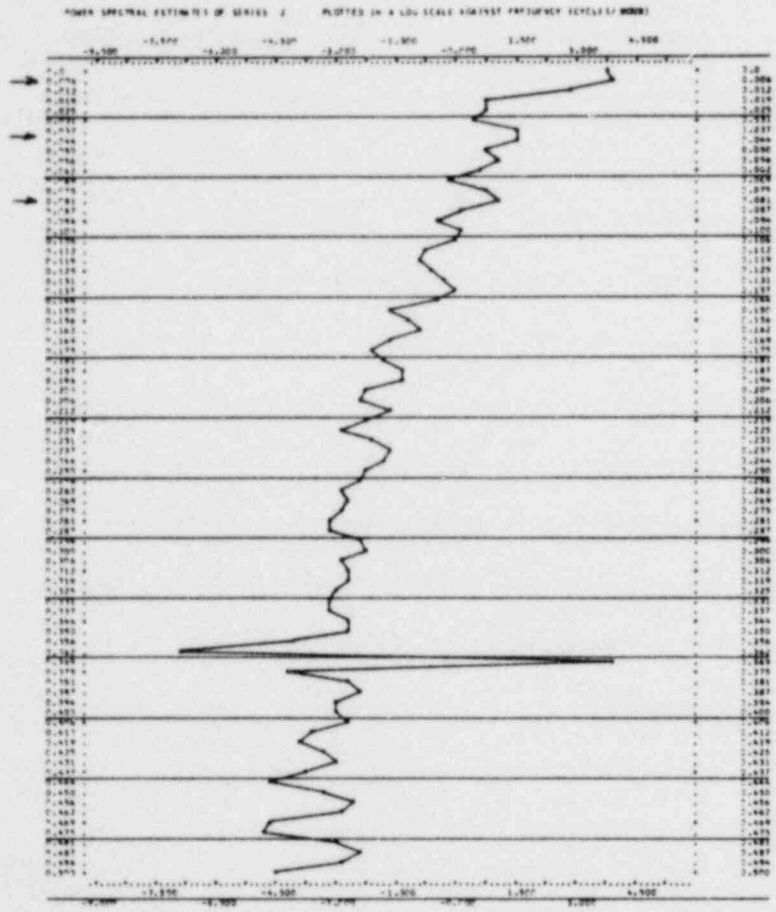


Figure 32. Power Spectral Estimates of Temperature Data from Buoy G

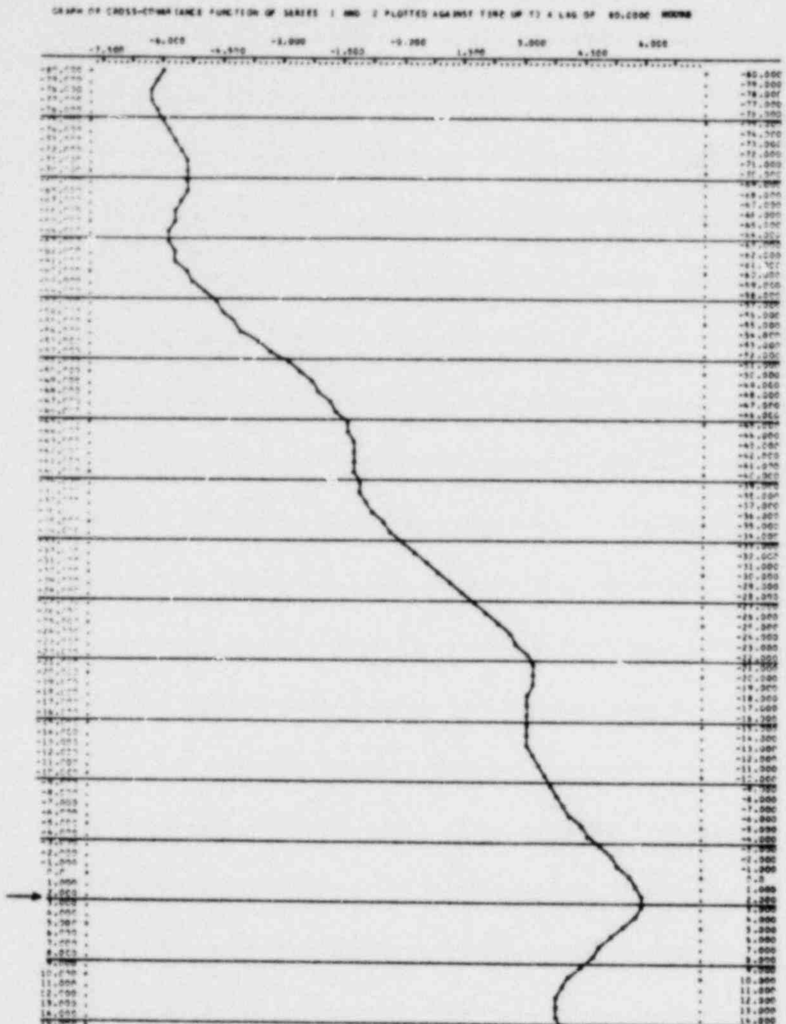


Figure 33. Cross-Covariance of Temperature Series from Buoys A and E

appendix b

SEMI ANNUAL progress report

EVALUATION OF THE MARINE ECOSYSTEM DEVELOPING WITHIN, AND ADJACENT TO, THE THERMAL PLUME OF THE POWER GENERATION UNITS AT CRYSTAL RIVER, FLORIDA

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INTRODUCTION

Power Generation at Crystal River

The Crystal River electrical power generation capacity is currently provided by two fossil-fueled conventional generating plants. Plant Units 1 and 2 have a combined output of 897 megawatts electrical and rely on once-through cooling with a combined flow of 640,000 gpm of seawater. These units have a designed, maximum condenser temperature rise of 6.1 C (11 F) at the above pumping rate. Both units are oil fired and have been in operation since July, 1966 (Unit 1) and November, 1969 (Unit 2).

A nuclear power plant (Unit 3) is currently under construction and is scheduled for fuel loading in late 1972 and commercial operation in 1973. Unit 3 is a Babcock and Wilcox pressurized water reactor having an output of 855 megawatts electrical. Once-through cooling will involve a pumping rate of 700,000 gpm of seawater with a maximum condenser rise of 9.4 C (17 F).

The Physical Environment at Crystal River

The plant site, in Citrus County, Florida, is situated 12 km (7.5 miles) north of Crystal River on a low-energy coastline characterized by a relatively flat topography. The plant sits at the landward edge of a *Juncus* sp. (with *Spartina* sp.) dominated tidal saltmarsh through which two canals cycle marine waters for cooling. The south canal is 8.3 km (5.2 miles) long and serves both as a cooling intake and deep water channel for oil barges. The 2.3 km (1.4 miles) north canal discharges the warm cooling-water into the coastal estuarine area adjacent the salt marsh. At low tide the effluent is confined to the canal and discharged at the terminus. At high tide the plume is encompassed within the water mass flooding the nearshore areas. The spatial and physical characteristics of the plume have been described elsewhere.

The shallow-sloping estuarine bottom (46.4 km to the 5 fa contour) is generally coincident with the drowned karst topography of this portion of west central Florida. Variations in bottom relief are due to oyster bars and the cutting and filling actions of currents. Fresh water sources in the general area include: (1) precipitation (1397 mm, 50% of which falls between June and September), (2) local surface runoff and subsurface drainage, (3) the Crystal River, 4.8 km to the south (mean flow, 269 M gpm), (4) the Withlacoochee River, 6.4 km to the north (mean flow, 817 M gpm), and (5) the Cross Florida Barge Canal, 5.8 km to the north (a portion of the Withlacoochee River flow is diverted through the canal).

Natural and man-made features may be viewed from any of several perspectives or points of view. In this project, the power plant is considered to be an interacting component of a much larger system (Figure 1).* An objective of this project is to fully describe and document the characteristics of one of the mechanisms of interaction; the thermal cooling-water discharge.

RESEARCH OVERVIEW

This report describes certain aspects of the progress made leading to an Evaluation of the Marine Ecosystem Developing Within, and Adjacent to, the Thermal Plume of the Power Generation Units at Crystal River, Florida. Some examples of the results are given to lend emphasis to the progress on certain topics. Other topics are described in terms of the current objectives and prognosis for fulfilling them. With the exception of the screen-wash entrapment study, each of the work units is expected to serve two general purposes. One is a quantitive description of the local environment and the changes which occur among selcted components in response to normal and man-induced perturbations. By including with this, measurements of ecosystem activity and function, the response of the entire system can be described. This progress report addresses both of these purposes.

MAPPING

Many phases of this project require a base map delineating the boundaries of the major eco-

*Figures and Tables are shown on pp. 55 through 66.

systems and subsystems in the area of interest. Through the use of overlays, quantitative information relating to species abundance, diversity, biomass, productivity, etc., may be graphically shown for consecutive periods during the course of the year. To generate this base map an airborne remote-sensing survey is to be flown by MAPCO, Inc. during the week of 23-27 October. The survey is to consist of four flights along a single flight line approximately two miles long and roughly parallel with the coastline at the plant site. Two flights, one at 5,000 feet (negative scale, 1:10,000) and the second at 2,500 feet (negative scale, 1:5,000) will utilize Eastman Kodak Aero-Neg film 2445. The resulting photographs, 9"x9" color contacts and a 36"x36" color enlargement, used in conjunction with the appropriate ground truth control, is expected to yield a highly accurate base map. To assist in the photo interpretation, the third and fourth flights are to be flown at 5,000 and 2,500 feet utilizing Eastman Kodak Infrared Aerochrome film 2443.

Whereas, the major singular objective of these overflights is the generation of a base map, the photos may also be expected to yield much additional information of value to the project. For instance, the infrared shots may reveal the limits of intrusion of the thermal plume into the saltmarsh as might be detected by elevated temperatures in the surface sediments. Also, with the assistance of MAPCO, Inc., specific image patterns and qualities may be correlated with observed characteristics in the various benthic subsystems. Should the correlations prove to be of interest and meaningful to the project, future overflights will be made on a quarterly basis to monitor seasonal variations in these subsystems.

It should be noted that this mapping task applies also to the control areas to the north and south of the thermal study area.

MODELS FOR GUIDING RESEARCH AND PREDICTION

Along with initial measurements on the estuary, preliminary models have been generated which organize available information, including especially the principal stocks and variables, pertinent to an understanding of the interactions of the thermal plume within the estuarine ecosystem. The fairly complex models which are generated, first guide our research measurements, and then as we come to recognize which are the principal pathways, the models are simplified, the coefficients evaluated, and computer simulations run. Two of the five models in the preliminary stage are presented in this report (Figures 2 and 3).

The estuarine area that receives the outfall water at Crystal River has the following divisions which are recognized for the purposes of measurement and prediction. These divisions, as well as the major benthic subunits, are to be mapped using the described airborne remote-sensing procedures. The persons leading the effort on the key work units under H.T. Odum are indicated:

1. Saltmarsh subsystem which borders the estuary on the landward side—D. Young.
2. Inner bay, 5 feet or less in depth, composed of a mixture of grassy bottoms, oyster associations, algal bottoms, and areas of sand and mud—W. Smith. (see Figure 8)
3. Oyster bar subsystems which form networks across the area exposed at low tide—M. Lehman.
4. Deeper outer basin in which the planktonic ecosystem becomes as important as the bottom ecosystems—H. McKellar. (see Figure 8)

In support of the above work units and for the purpose of monitoring quantitative changes in the benthic subsystems and animal stocks, are three additional work units supervised by S.C. Snedaker:

1. Benthic grass and algal subsystems which are distributed throughout the estuary and adjacent control areas—R. van Tine.
2. Benthic infauna including vertebrates and the macro-invertebrates—W. Seaman.
3. Pathways of energy flow through the resident and migratory fish populations—C. Adams.

Also in progress, is a model for understanding the role environmental adaptation has in the power system's service to the region. A model that includes the estuary, and power system and the main driving forces on the region is being developed by H.T. Odum, C. Nichol and others.

EVALUATION OF PROCESSES WITHIN THE PLUME RECEIVING ECOSYSTEM

As shown in Figure 2, the main metabolism of the estuarine ecosystem involves the production of organic matter and oxygen by photosynthesis and their consumption in respiration by the consumers. The rates of these processes provide a measure of the overall activity and well being of the prevailing ecosystem. The shifts in pH due to utilization of carbon dioxide in the daytime photosynthesis and the release of carbon at night from respiration also describe the metabolism. The role of phosphorus as a plant nutrient and the fact that it is often limiting, reflects, through the uptake and release of this element, the total activity of the living components. Thus, if one simultaneously monitors pH, oxygen and phosphorus, it is possible to estimate some of the rates of metabolism of the whole estuarine system, providing one can also estimate the amounts of these substances entering and leaving the bay through tidal advection, diffusions, and inflow from land.

Since June, the main effort of this task group has been directed toward determining the overall estuarine metabolism using these measures conducted over 24 hour periods in the area receiving the plume and in areas to the north and south not affected by the plume (Figure 1). Generally, 8 to 10 stations were monitored in each erea with data being taken every 3 to 4 hours at each station when feasible. Feasibility is usually dictated by the low tides which prevent access to shallow or exposed areas.

Oxygen

For each station a diurnal metabolism graph was constructed. Figure 4 is an example using data from a station in the plume-affected area. In this graph the record of oxygen-per-volume is given along with temperature, salinity, and depth from which percent saturation was calculated. Multiplying oxygen-per-volume by depth gives oxygen-per-area. From the oxygen-per-area graph an oxygen rate-of-change curve was calculated. On the rate-of-change graph, the oxygen which was removed by tidal advection was added back and oxygen which was gained was subtracted out. These exchanges were estimated for each hour from the change in depth and oxygen concentration measured at the same time in that area or in the advection source area. Finally, the diffusion of oxygen across the sea surface was estimated using a floating plastic dome filled with nitrogen gas which was allowed to regain oxygen from the water under the normal conditions of underwater circulation in the field. A field oxygen probe was used to monitor the return rate of oxygen to the air space under the plastic dome. This rate was used to correct for the oxygen gained or lost by diffusion. The final result is an oxygen rate-of-change graph showing the rise in oxygen due to photosynthesis during the day and decrease due to respiration at night. Gross production and total respiration of the community are calculated from the corrected graph. An example of the diurnal oxygen analysis steps is presented in Figure 4.

The measurements during the summer showed general similarity in the rise and fall of oxygen at all stations on the same day suggesting that lateral mixing was among areas of similar metabolism. The values of metabolism, determined thus far, are within the range of those known for estuaries elsewhere in the Gulf of Mexico. The calculations are tedious and not all of the summer runs have been completed.

The diurnal oxygen assay of estuary function is scheduled for each season. The method will also be used for the study of localized zones such as the oyster bar subsystems.

pH-Carbon dioxide

With the help of Dr. Robert Beyers of the University of Georgia, who participated in the project in June, an apparatus for determining carbon-dioxide metabolism from pH shifts was prepared and pH curves were taken accompanying the oxygen. The range of pH was from 0.3

to 1.0 pH unit per day, rising with daytime photosynthesis and decreasing at night. Since pH equipment can be established for long-term recording more readily than oxygen probes, this method may be used for continuous monitoring of metabolism in the center of the ecosystem receiving the plume and in, at least, one area outside of the plume-affected estuary. Arrangements are being made for adding the pH buoy to the Crystal River telemetering system in order that this index of total ecosystem function may be recorded continuously. Figure 5 is an example of the similarity between oxygen and pH. Both may be used to calculate metabolism.

Light transmission
Vertical records of light transmission, as part of the monitoring of the estuarine metabolism, were made using a submarine photometer. Representative graphs are given in Figures 6 and 7. Although the waters, like many estuaries, are relatively turbid, the depth is so shallow at the average high tide that a high proportion of the incident light reaches the benthic communities of algae and grassy vegetation. The divergence among percent-transmission readings at depths greater than 1 m suggests the presence of dissimilar water masses on the two study days.

Phosphorus
Some measurements of phosphorus have been made to establish the magnitudes of concentration of this nutrient in its various forms (dissolved, particulate, organic, inorganic, etc.) in the bay and canals. For this preliminary work and as the basis of the continuing effort, sampling stations were located in the inner and outer bays and in the intake and discharge canals. In addition to phosphorus, samples were also taken for assays of chlorophyll-a and pheopigments.

On September 10, eight surface samples were taken in the intake and discharge canals as shows in Figure 8. The distributions of temperature, phosphorus fractions, and chlorophyll-a are plotted in Figure 9 along with concentrations found at similar stations taken on 12 August. Using the 10 September data, the relative percentage of phosphorus fractions with respect to the total phosphorus in the water column was plotted in Figure 10. This analysis indicated a relatively constant ratio among phosphorus fractions both in the intake and discharge canals; total phosphorus was approximately 49% particulate, 34% dissolved organic, and 17% dissolved inorganic. Table 1 lists the absolute phosphorus and chlorophyll concentrations as stations in the bay area.

CHLOROPHYLL AND CAROTENOID ANALYSES

Surface water samples were collected during the summer (6-7, 13-14, 27-28 July and 10-11 August, 1972) in the inner bay (see Figure 8), the control areas, and in the saltmarsh, for the purpose of comparing the respective concentrations of chlorophylls a, b and c and the carotenoids. Ffforts on each occasion were made to take samples simultaneously at a minimum of 6 stations in two areas of interest at 3-hour intervals for 24 hours. Whereas an adequate number of samples were taken for statistical comparisons, the lack of adequate lab facilities permitted only 118 samples to be analyzed. Thus, a statistical comparison at this time is not possible and only example data are presented here (Table 2). The comparative study is scheduled to be re-initiated this November and will include benthic macorphytes. The samples reported in Table 2 are for chlorophyll-a from a diurnal sampling run on 10 August in the north control area. As the stations are fixed points, the major variation in the results is probably due to sampling from different water masses. Missing data is the result of either station inaccessibility due to tides and darkness or contaminated samples which were discarded.

ENERGY FLOW IN *JUNCUS* SALTMARSHES AND IMPACT OF THERMAL ADDITION

The saltmarshes at Crystal River are dominated by two principle species, *Juncus roemerianus* and *Spartina alterniflora*, and work to date has concentrated on determining temporal changes in the standing crop or biomass of these two defined compartments. Comparisons are being made between the marsh just north of the discharge canal, which may be receiving thermal effluent in significant quantities of water, and nearby marshes receiving ambient-temperature nearshore waters. In addition, plots of marsh vegetation have been planted on the intake and discharge canals to further isolate temperature as the environmental variable. Monitoring of these transplant sites and sampling in the parent marshes will continue through the Spring of 1973. It is hoped at that time statements about marsh response to temperature changes can be made.

Figures 11 and 12 summarize seasonal trends in biomass of *Juncus* and *Spartina* observed at Crystal River. Data from other regions of the southeastern United States are included for comparison. Our studies to date indicate that the saltmarsh receiving hot water is continuing to grow and the heat addition, at its present level, is not acting as a chronic stress prohibiting growth. Figure 3 shows the result of one month's sampling comparing *Spartina* stem densities (stems/m^2) in the marsh receiving hot water and in a similar marsh located south of the intake canal and receiving no hot water. These data indicate a statistically significant difference (95% confidence level) in mean stem density in the discharge marsh. Further sampling will be carried out to determine if such a difference exists throughout the year.

SCREEN-WASH ENTRAPMENT

The screen-wash entrapment study is designed to quantify in terms of numbers, size/age class and biomass, the animal species which become entrapped on the screen-wash at the cooling water intake pumps. In addition to absolute quantities, the study is also designed to allow for the partitioning of variation due to season, time of day, tide and general climatic conditions. This is achieved by making hourly collections of the sluice effluent for 24 consecutive hours once a week. The study began on 13/14 August, 1972, and is to be continued through mid-September, 1973, to provide a full year's record with a one-month overlap.

Procedure

In front of the cooling-water intake pumps is a set of vertical travelling screens which serve to filter the incoming water. When the screens become clogged they are moved past a water spray which dislodges the material and carries it into a free-running sluice. The sluice is double ended and the collections are made at the west end. (The hypothesis that 50% of the entrapped material is carried to each end is to be statistically tested on a quarterly basis.) Collections are made by trapping all of the material on a sample screen. The 24 hourly collections are kept separate throughout the subsequent lab processing procedure. The processing includes identification and sorting by species, recording length and freshweight for each individual and the preservation of sample material for dry weight and ash-free dry weight conversion and ancillary studies as may be necessary. The data are logged by day and hour of collection and tidal stage. Other pertinent information such as climatic conditions and sea state will be included in the statistical analysis.

As the travelling screens are washed only when they become clogged, there are periods during the 24-hour diurnal collections when no collections are made. It is assumed, however, that since the material was entrapped during the intervening period since the previous wash the data could be interpreted either according to time of collection or period of entrapment. In the final analysis of this study, both considerations will be taken into account.

Results

To date, the collections have yielded 60 species of fish and macroinvertebrates in widely varying quantities. The results tentatively suggest that most organisms, in terms of numbers, become entrapped on the rising tide irrespective of time of day. The data also indicate that the major contribution to the total entrapped biomass is attributable to bottom feeders (catfish, batfish, rays, blue crabs, etc.) that are able to get under the woven curtains in front of the screen-wash assembly. These and similar questions should be fully answered and documented by the end of the study.

Table 3 and the example graphs in Figures 14 and 15 summarize the work to date. The total calculated entrapment (vertebrates, fresh weight) for the 42-day sample period was 408 kg of which 314 kg (77%) was contributed by a single species, the polka-dot batfish, *Ogcocephalus radiatus*. These results cannot be fully interpreted, however, until the one-year sampling schedule is completed, and until we are able to estimate the population sizes of the species from which the entrapped material is drawn.

BENTHIC STUDIES

At the time of preparation of this report, insufficient data were available for presenting results on the benthic studies. This is due primarily to the inordinate delays in acquiring equipment and an on-site sample processing facility. However, some of the preliminary work has been initiated and is briefly described.

Sediment analyses
To assist in the mapping and the benthic studies, core samples have been taken of the sediments in the study area of the estuary. The samples will be described according to their composition in terms of gravel, sand, coarse silt, fine silt and clay fractions. Coorelations between these mechanical properties and benthic community components will be attempted.

Sedimentation rates
A set of 30 sediment traps are to be stationed in the study area and control areas to determine rates of sedimentation and if possible, composition of the material. Traps will be analyzed at two-month intervals.

Benthic macrophytes
Benthic macrophytes are harvested from 1 m^2 sample areas in the major benthic communities using a frame and small hand-operated dredge on the bottom. The macrophytes, collected whole, are described in terms of numbers per species, density, general vigor, and ash-free dry weight biomass.

Benthic infauna
Benthic vertebrates and macro-invertebrates are sampled using a 16m^2 drop net from which all organisms are removed by successive sweeping with a 1/16th mesh seine. The organisms are sorted to species, counted and ash-free dry weights determined. Three drop-net collections are made per benthic community type per quarter.

Feeding studies and gut-clearance rates
Results from the benthic species biomass determinations describe the areal abundance of certain food items. Gravimetric analyses of the stomach contents of local consumers and gut-clearance rates indicate the rate at which the food items are being consumed per kilo of consumer. By matching food availability with consumption patterns and rates it may be possible to describe, in quantitative terms, the dependence of selected consumers on specific benthic communities. This information may also be of value in the modeling.

Standing stocks of pelagic fishes
To fully quantify and describe the dependence of a fish species on a specific food resource, it is necessary to also know the biomass-per-unit-area of the consumer larger than can be sampled using the drop net. In cooperation with the Environmental Protection Agency and the Florida Game and Fresh Water Fish Commission, a technique for the non-destructive sampling of a large area (1 acre) has been developed. It involves the successive seining within a block net to establish a diminishing-returns curve for selected species from which the parent population size in the enclosure can be calculated. Seine samples can be counted and measured on site and returned to the water. Should the necessary equipment become available, the technique will be tried at Crystal River.

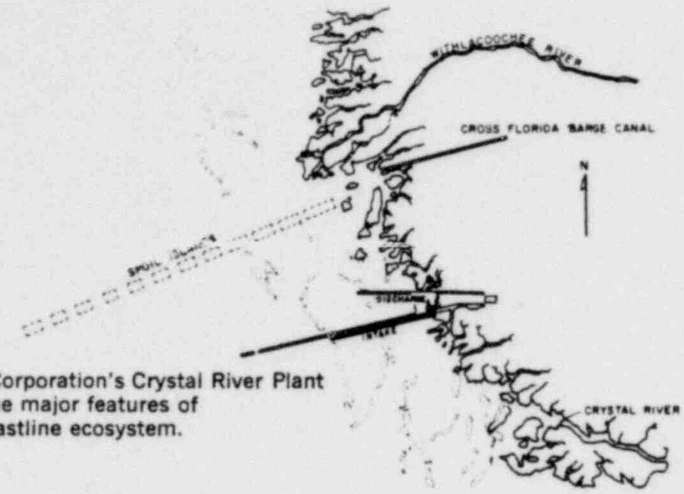


Figure 1.
Florida Power Corporation's Crystal River Plant in relation to the major features of the regional coastline ecosystem.

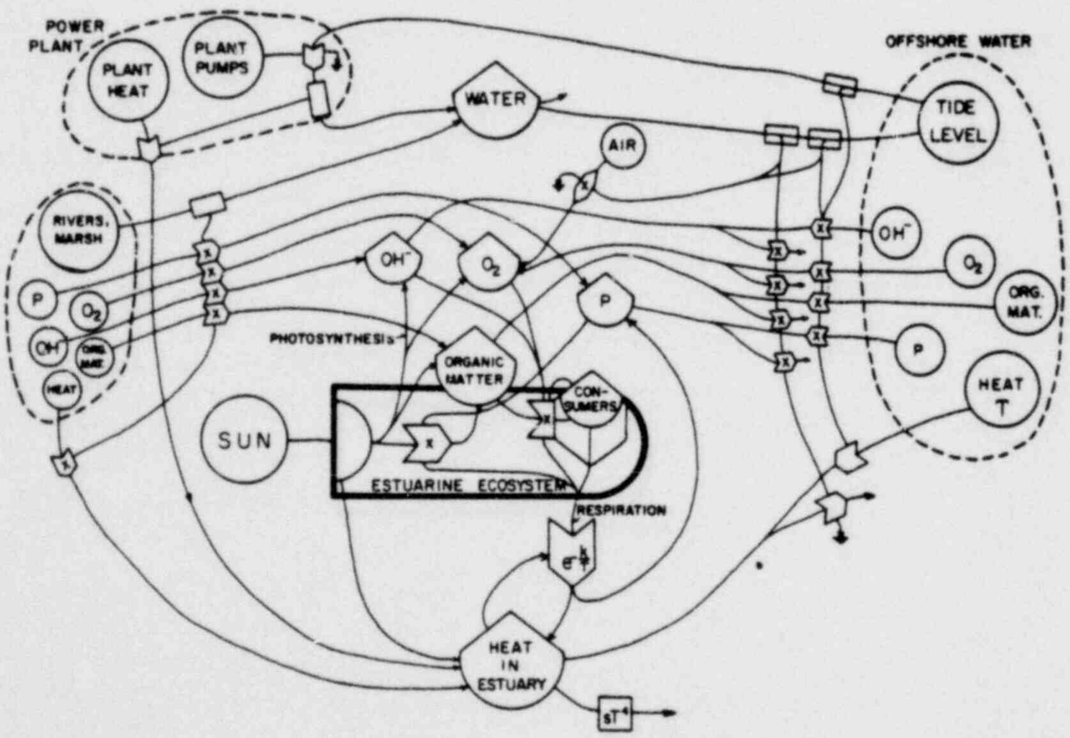


Figure 2. Preliminary model (drawn with energy circuit symbols) of the overall metabolism of the ecological system receiving hot water. Each symbol may be interpreted in a qualitative visual way, but each also has a characteristic mathematical expression. Thus, the networks illustrated here and in Figure 3, each constitute a system of equations. The circles and tanks, respectively, represent overall forcing functions and metabolic variables. Multiplicative interactions are shown with pointed blocks marked "X". Figure 1 has the main pathways of system function and these are the flows measured in the summer work just completed.

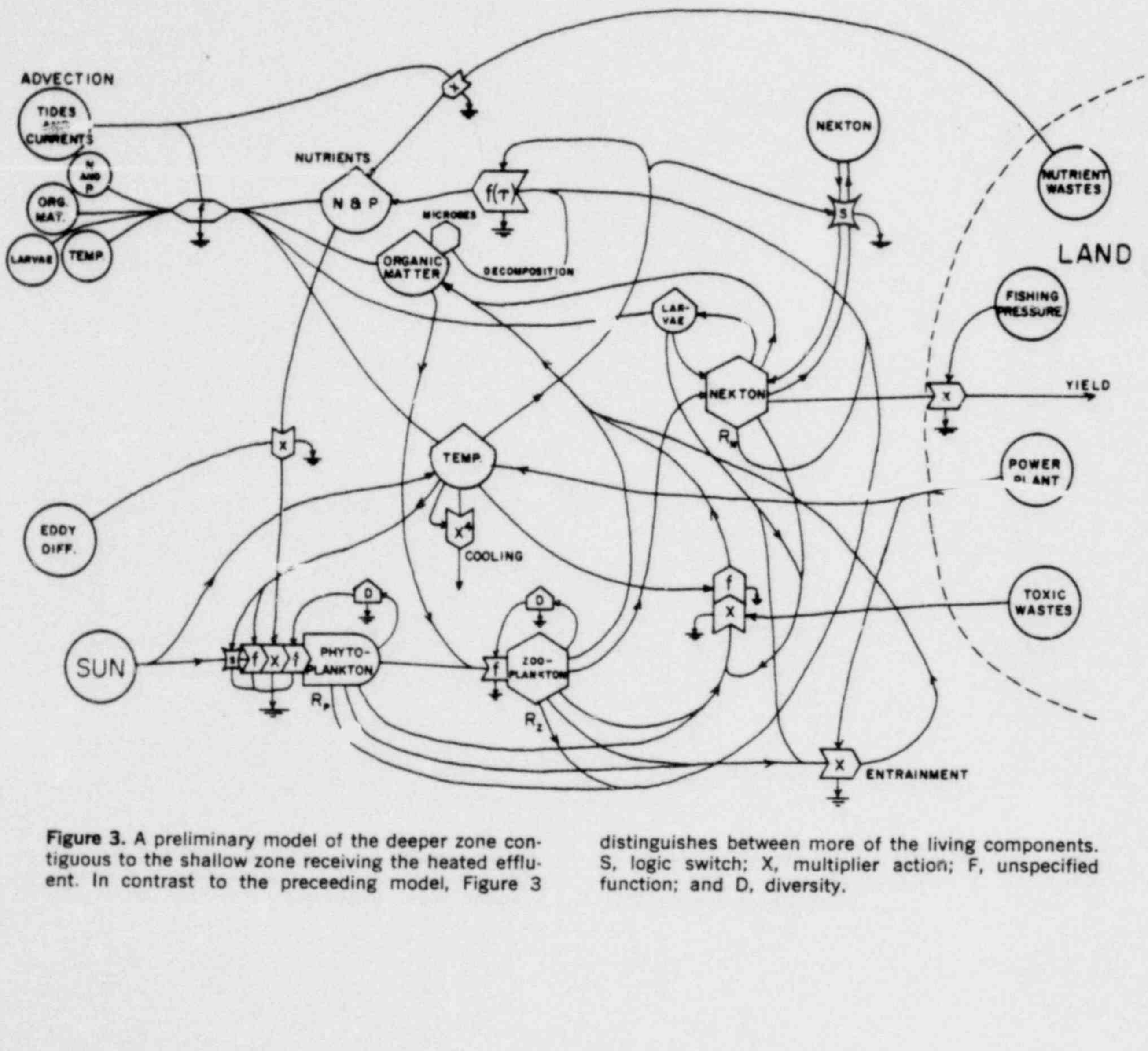


Figure 3. A preliminary model of the deeper zone contiguous to the shallow zone receiving the heated effluent. In contrast to the preceeding model, Figure 3 distinguishes between more of the living components. S, logic switch; X, multiplier action; F, unspecified function; and D, diversity.

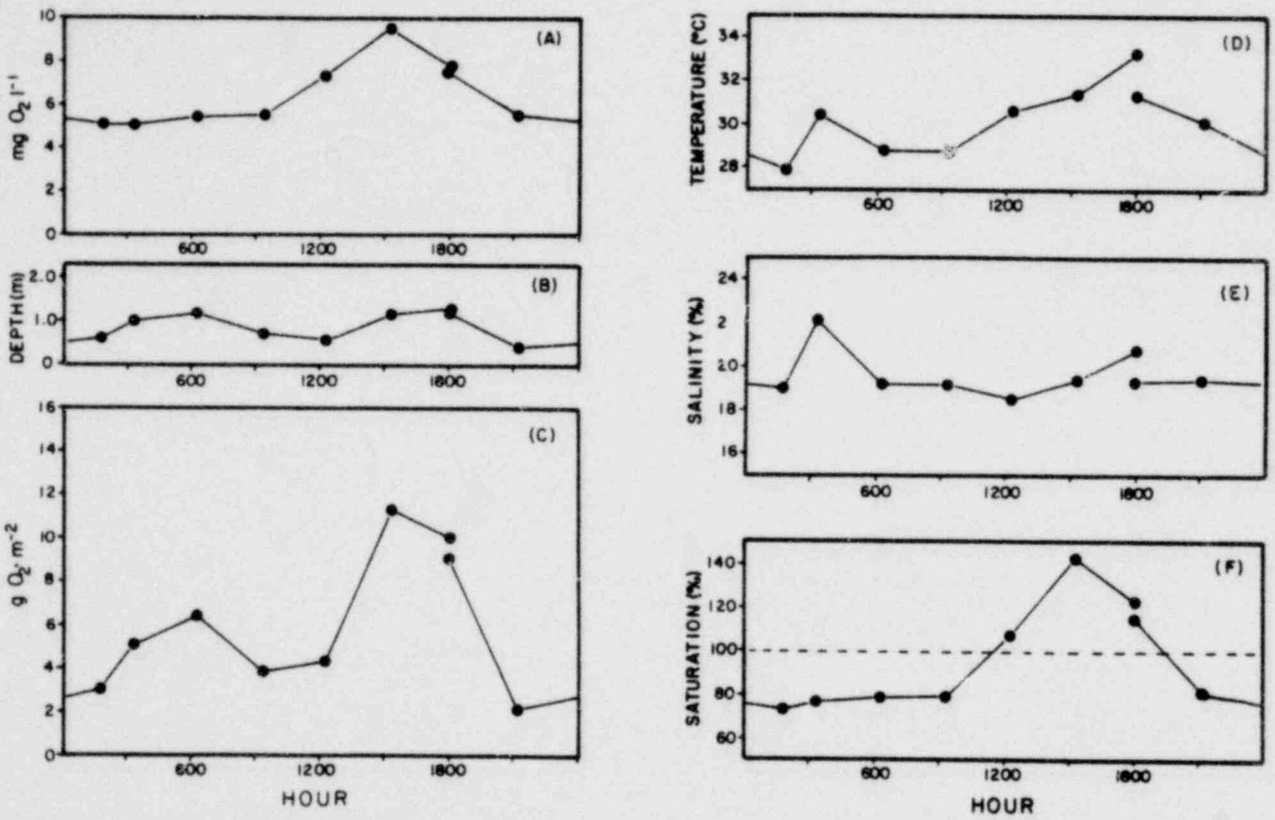
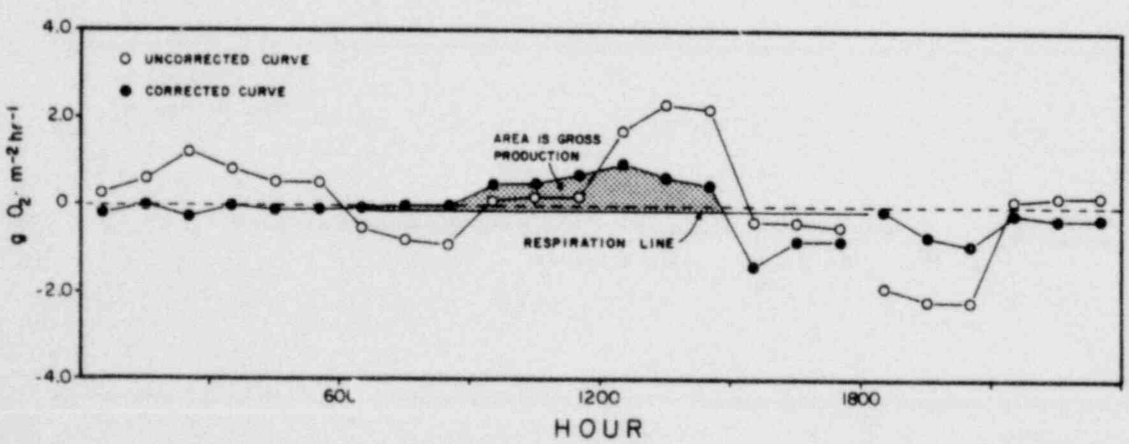


Figure 4. Example of the steps in a diurnal oxygen analysis. dissolved oxygen concentration (A) and water depth (B) are measured at approximate 3 hour intervals along with temperature (D) and salinity (E) from which percent saturation (F) and oxygen-per-area (C) are calculated. The rate-of-change in oxygen (G) is corrected for gains and losses through diffusion and advection. Total diurnal gross production equals the shaded area under the curve in (G).



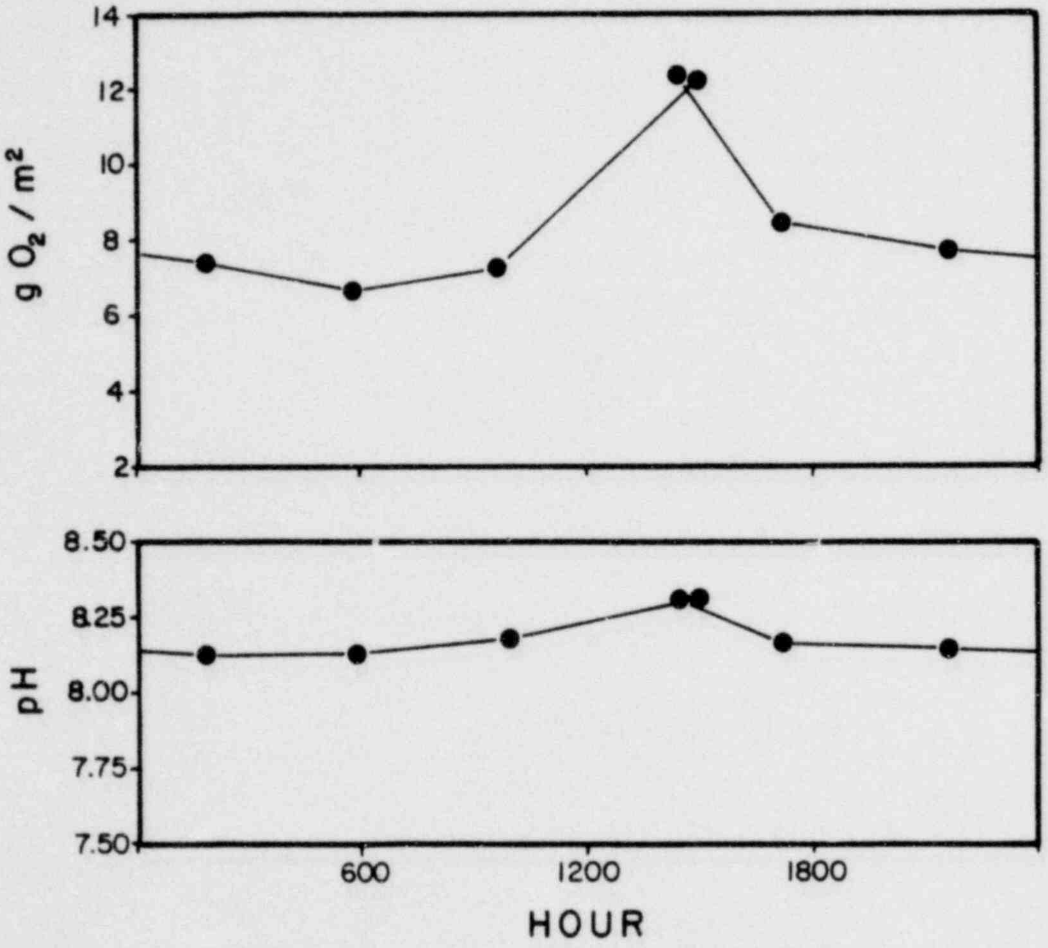


Figure 5. The similarity between dissolved oxygen and pH from a diurnal sampling. During daytime photosynthesis, carbon dioxide is utilized and oxygen produced. The loss of carbon dioxide from the water raises the pH.

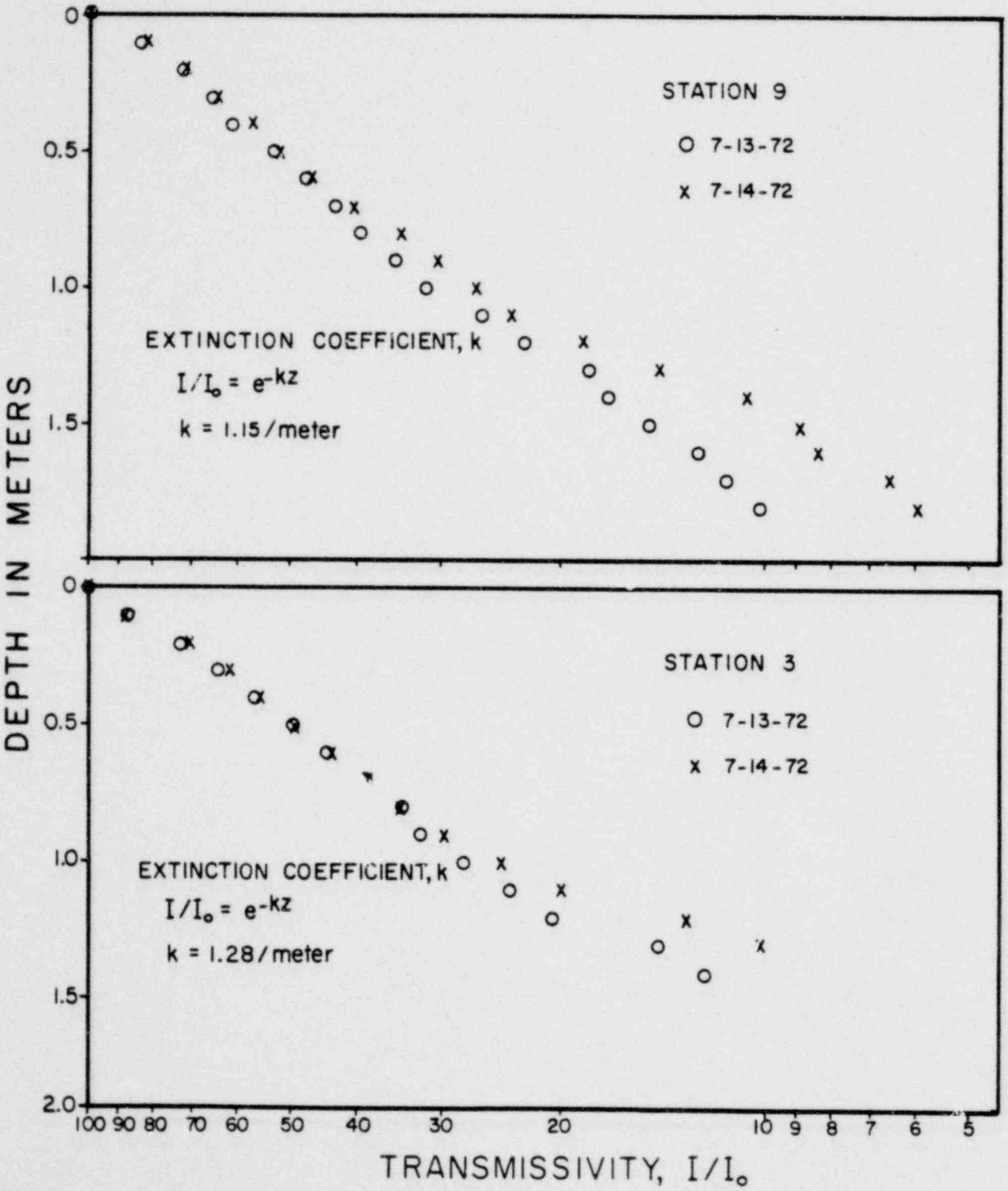


Figure 6. (top) Percent light transmission through the water column in the inner bay area northwest of the discharge canal. Data were taken on 13, 14 July 1972 at high tide.

Figure 7. (bottom) Percent light transmission through the water column in the outer bay between two large oyster bar systems northwest of the discharge canal. Data were taken on 13, 14 July 1972 at high tide.

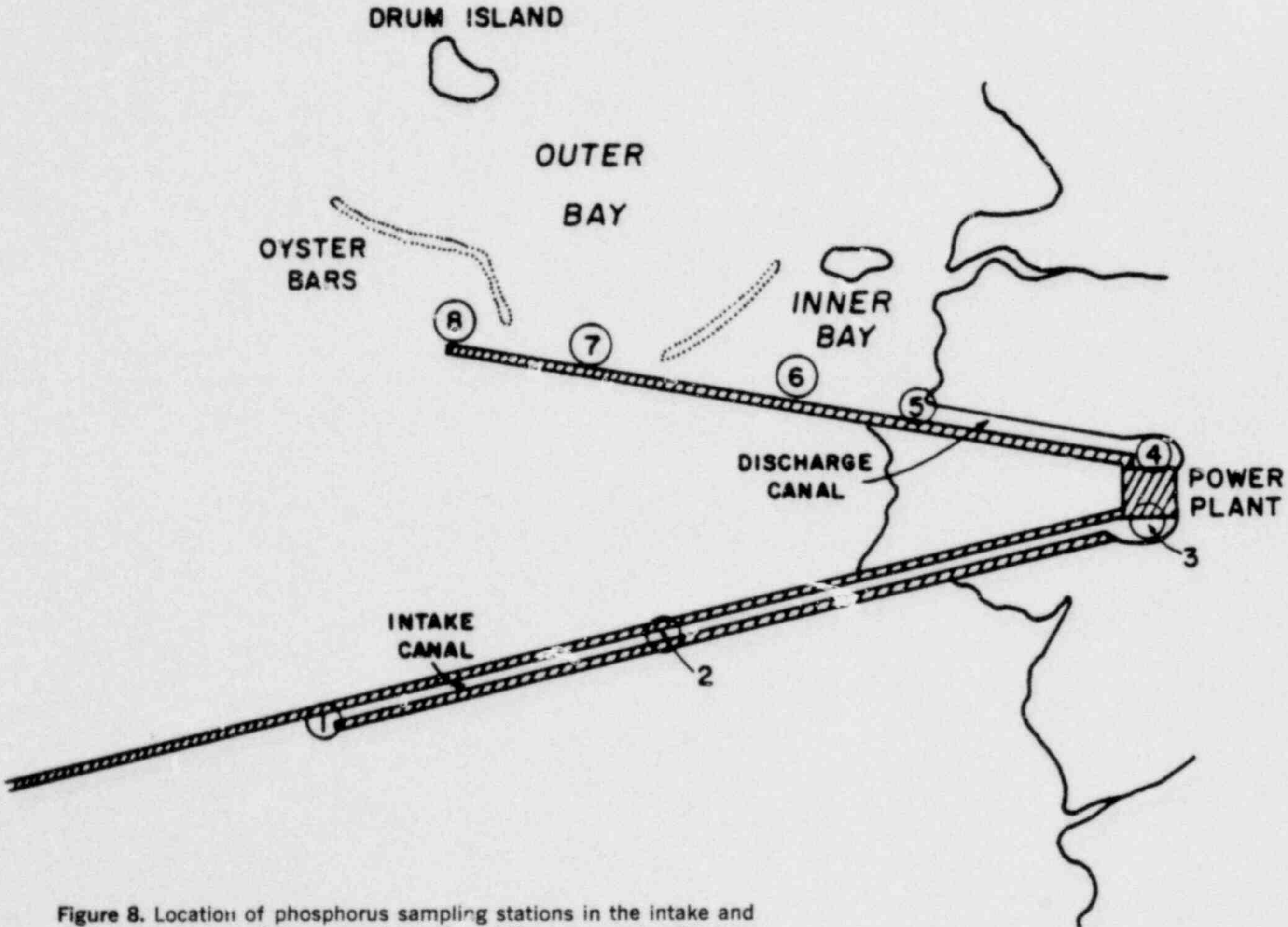


Figure 8. Location of phosphorus sampling stations in the intake and discharge canals and the general location of the inner and outer bay.

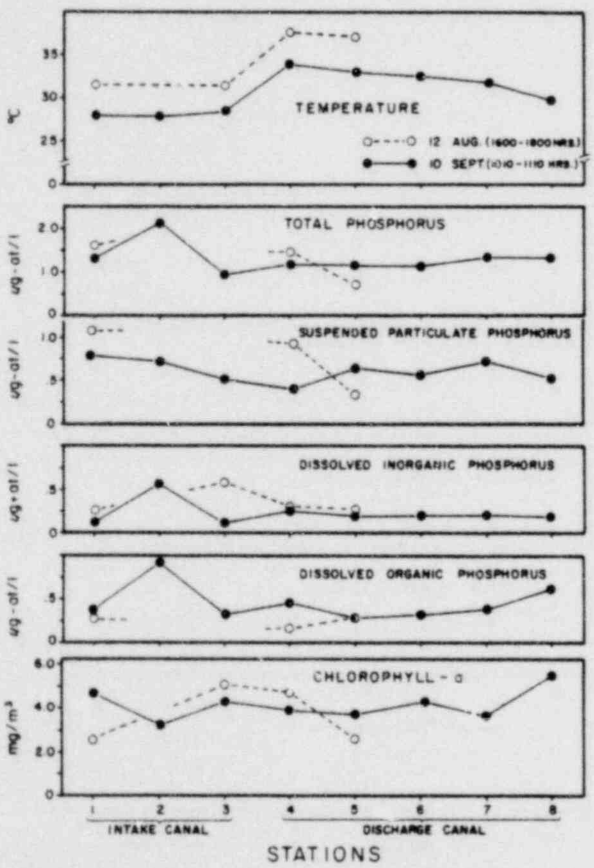


Figure 9. Temperature and the concentrations of phosphorus fractions and chlorophyll-a in the intake and discharge canals. (Stations indicated in Figure 8)

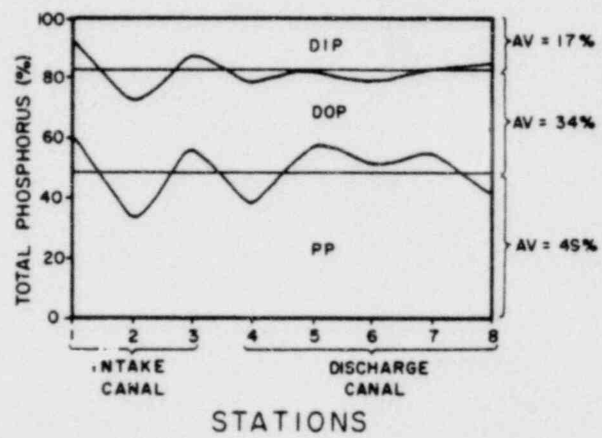


Figure 10. Relative percentages of the phosphorus fractions in the intake and discharge canals. (Stations indicated in Figure 8)

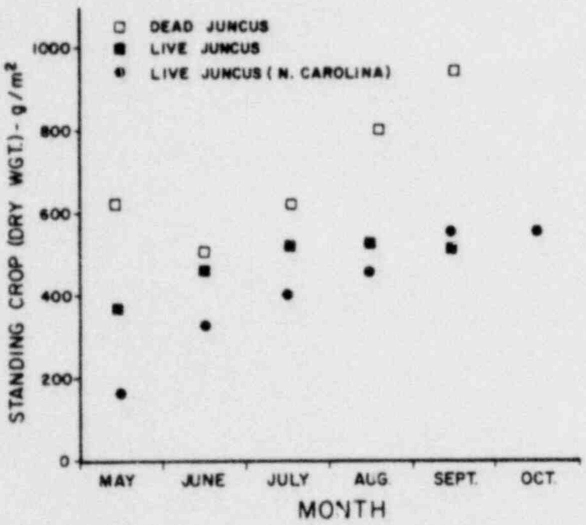


Figure 11. Changes in the above-ground living and attached-dead standing crop of *Juncus roemerianus* during a 5 month period. Data from a North Carolina marsh is included for comparison.

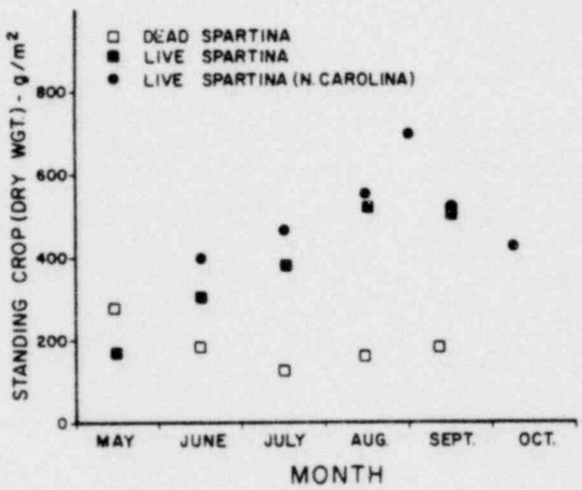


Figure 12. Changes in the above-ground living and attached-dead standing crop of *Spartina alterniflora* during a 5 month period. Data from a North Carolina marsh is included for comparison.

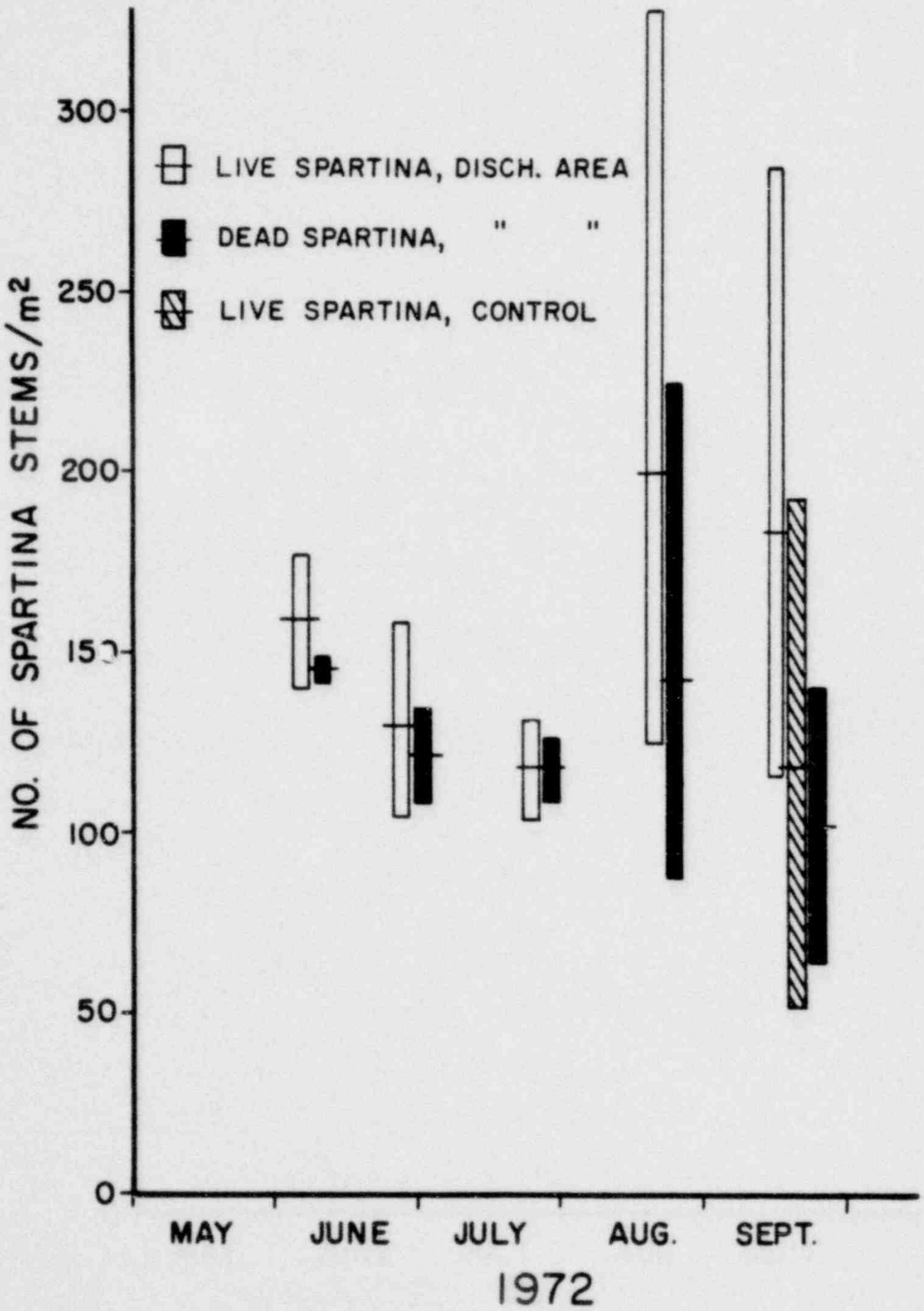


Figure 13. A comparison of the number of live *Spartina* stems per-unit-area in the thermal discharge area and in a similar control area south of the intake canal. The base data are from the monthly surveys and the comparison is for the month of September, 1972.

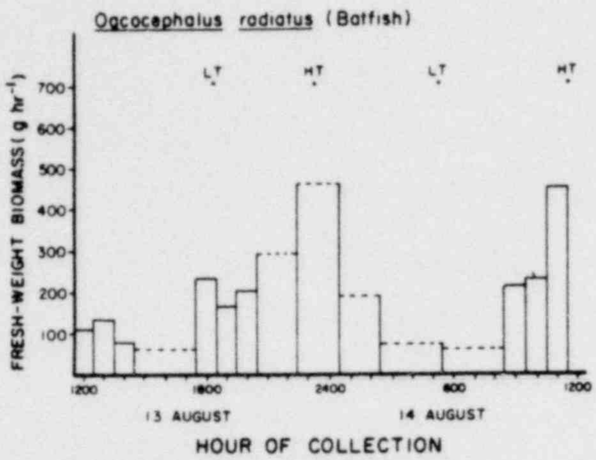


Figure 14. A diurnal record of the entrapment of batfish *(Ogcocephalus radiatus)* on the screen-wash assembly, expressed in fresh weight biomass (grams) per hour. Dotted lines indicate that the biomass trapped during 1 hour was prorated back over the total period of entrapment. LT and HT refer to the respective times of low tide and high tide, during the diurnal sampling.

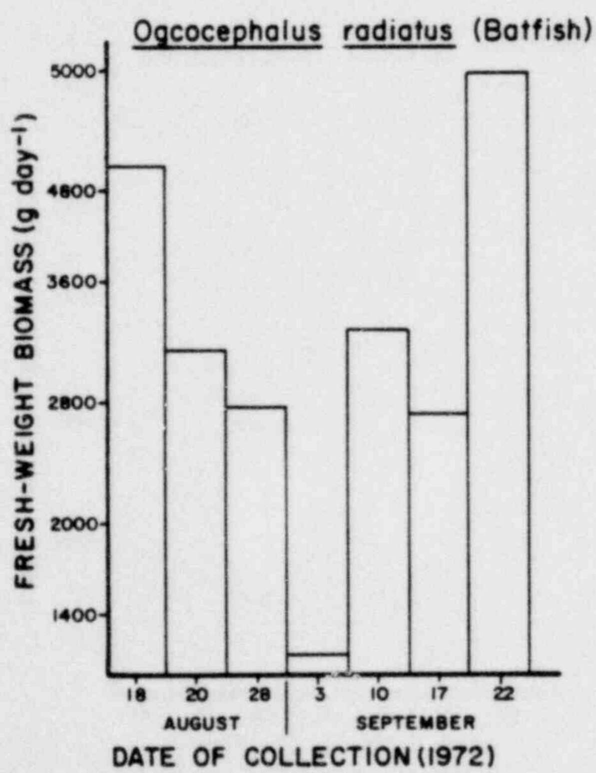


Figure 15. The total fresh weight biomass of batfish *(Ogcocephalus radiatus)* entrapped during the sampling days in 7 consecutive weeks.

Table 1
Phosphorus fractions and chlorophyll-a in the discharge bay area
(12 August 1972)

	μg-At/1				mg/m³
	TP	PP	DIP	DOP	CHl-a
Inner Bay	—	—	0.21	—	3.01
	.69	0.25	0.17	.27	4.29
Outer Bay	1.04	0.43	0.11	.50	3.93
	1.50	0.68	0.54	.28	3.60

Table 2.
Chlorophyll-a values (mg m^{-3}) for Hodges Island control area,
10 August, 1972

	Station Number									
TIME	1	2	3	4	5	6	7	8	9	10
1615-1825	9.22	13.96	21.1	15.5	8.78	9.04	10.69	8.61	6.68	9.57
2000-2205	17.4	15.9	19.8	10.2	9.5	9.7	16.2	11.6	15.5	—
2350-0320	21.73	9.87	11.92	27.84	19.0	9.2	6.3	—	—	10.4
0350-0505	14.3	10.1	11.5	—	14.1	12.5	12.6	11.9	—	9.9
0640-0755	10.9	10.5	11.3	10.6	12.9	14.5	11.3	13.8	—	14.9
0920-1045	10.9	8.9	10.9	—	14.8	18.3	10.3	14.1	—	23.0
1300-1410	10.8	7.8	12.1	13.8	7.4	8.54	9.4	8.2	—	10.4
1620-1755	11.9	8.0	10.6	8.6	8.98	7.4	4	32.7	—	10.1

Table 3.
SCREEN-WASH VERTEBRATE ENTRAPMENT SUMMARY
for the Period 13 August-22 September 1972

Genus species . . . vernacular	TOTAL BIOMASS (grams, fresh wt.) 6 sample days	42 day rate[1]
Ogcocephalus radiatus . . . polka-dot batfish	22,431.1	314,035.
Eucinostomus argenteus . . . spotfin mojarra	18.1	253.
Monacanthus hispidus . . . planehead filefish	27.9	391.
Syngnathus louisianae . . . chain pipefish	1.3	18.2
Strongylura notata . . . redfin needlefish	0.9	12.6
Selene vomer . . . lookdown	38.2	535.
Chloroscombrus chrysurus . . . Atlantic bumper	17.7	248.
Anchoa hepsetus . . . striped anchovy	18.2	255.
Oligoplites saurus . . . leatherjacket	20.9	293.
Anchoa mitchilli . . . bay anchovy	17.5	245.
Strongylura marina . . . Atlantic needlefish	216.6	3,032.
Gymnura micrura . . . smooth butterfly ray	368.5	5,159.
Opisthonema oglinum . . . Atlantic thread herring	11.0	154.
Lagodon rhomboides . . . pinfish	394.4	5,522.
Eucinostomus gula . . . silver jenny	7.1	99.4
Dasyatis sabina . . . Atlantic stingray	987.2	13,821.
Synodus foetens . . . inshore lizardfish	75.9	1,063.
Chilomycterus schoepfi . . . striped burrfish	1,060.6	14,848.
Myrophis punctatus . . . speckled worm eel	46.9	657.
Brevoortia patronus . . . gulf menhaden	51.0	714.
Caranx hippos . . . crevalle jack	876.9	12,277.
Lactophrys quadricornis . . . scrawled cowfish	227.4	3,184.
Calamus arctifrons . . . grass porgy	586.3	8,208.
Cynoscion nebulosus . . . spotted seatrout	554.7	7,766.
Centropristis striata . . . black sea bass	489.4	6,852.
Trinectes maculatus . . . hogchocker	46.3	648.
Micrognathus crinigerus . . . fringed pipefish	0.2	2.8
Arius felis . . . sea catfish	424.5	5,943
Hyporhamphus unifasciatus . . . halfbeak	16.2	227.
Haemulon plumieri . . . white grunt	21.6	302.
Cynoscion arenarius . . . sand seatrout	0.3	4.2
Anchoay sp. . . . anchovy	4.0	56.0
Bairdiella chrysura . . . silver perch	8.8	123.
Mugil cephalus . . . striped mullet	N/A	N/A
Achirus lineatus . . . lined sole	27.2	381.
Syngnathus floridae . . . dusky pipefish	4.5	63.
Hippocampus sp. . . . seahorse	2.1	29.4
Blennius sp. & Chasmodes sp. . . . blenny	2.8	39.2
Lutjanus griseus . . . gray snapper	1.8	25.2
Orthopristis chrysoptera . . . pigfish	11.2	157.
Menticirrhus americanus . . . southern kingfish	1.2	16.8
Scomberomorus sp. . . . mackerel	10.2	143.
Sphoeroides sp. . . . puffer	13.0	182.
	29,141.6 g	407,984.8 g

appendix C

EFFECTS OF POWER PLANT chlorination ON MARINE MICROBIOTA

FINAL REPORT

April 28, 1971-April 28, 1972

Department of Environmental Engineering Sciences

University of Florida

Gainesville, Florida

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CHAPTER I. INTRODUCTION

Over the past few years, scientists have become increasingly concerned about the types and amounts of wastes being discharged into the waters of the world. The immediate and long-range effects of these effluents upon the biota of the various aquatic communities is being vigorously examined.

One of the problems of major concern is that of "thermal pollution," i.e. the discharge of heated effluents into rivers, lakes, and seas. There are those who feel that such a procedure is having a catastrophic effect on the population of fishes and other organisms that live in these waters. Others, who prefer the term "calefaction" or warming, feel that deleterious biological effects are minimal. Some even go so far as to say that the levels of heating being encountered may turn out to have beneficial long-range results.

The steam-electric industry uses huge quantities of natural water as a heat transfer medium. Trembley (1965) has predicted that the electricity needs of the United States will double every ten years and in six years in some areas. Picton (1960) predicted that by 1980 one-fifth to one-sixth of the total freshwater runoff of the United States would be used as cooling water. The cooling water used by electric plants is passed through condenser tubes and normally results in a significant increase in the temperature of the water at the discharge point.

The continuous passage of productive estuarine water through the condenser tubes of steam-electric plants has presented a unique problem to the generating plants. As the water passes through the tubes, organisms attach to the walls, causing two major problems: reduction in heat transfer and biological pitting. Both effects have obvious and serious economic implications.

In order to remove the fouling organisms, a technique known as "condenser tube shooting" has been used. Solid plugs of various materials, such as plastic or rubber, are forced through the tubes using air pressure. While this procedure is temporarily effective, the organisms adhering tightly to the tube walls are not removed completely and act as seed for regrowth. The technique does very little to stop pitting. Furthermore, in order to "shoot" the tubes, the operation of the generating unit must be curtailed.

To successfully remove the organisms from the condenser tubes, they must be killed or prevented from settling and growing on the tubes. For this reason, chlorine, a disinfectant, is added to the cooling water before it enters the plant. In most cases, chlorine is added as a sodium hypochlorite solution. Such a system of control, combined with periodic "condenser shooting," has been shown to effectively control the growth of marine fouling organisms.

The obvious question which should be asked regarding such a procedure is, "What effects will the chlorine have on the marine environment?" The toxicity of chlorine to a wide variety of organisms is well known. The environmental implications of large amounts of chlorine on marine and freshwater ecosystems, however, is not. In a recent article in *Science*, Brook and Baker (1972) state "We can find nowhere in the literature a presentation of the direct relationship between chlorine concentration and productivity of phytoplankton, nearly all emphasis having been placed on heating and sudden thermal shock." Florida Power Corporation's steam-electric generating plant located near Crystal River, Florida has been using chlorine to check marine growth since June, 1971.

Objectives

The specific objectives of this study were to determine, by using various parameters, the direct and indirect effects of chlorinated cooling water of a steam-electric plant on the microbiota of the receiving waters.

Physical Characteristics of the Study Area

The plant site is located 70 miles north of Tampa, Florida and 7.5 miles northwest of Crystal River, Florida at latitude 23°57′ and longitude 82°45′ (Figure 1)*. The plant is bordered on the west by the Gulf of Mexico and the terrain throughout the area is relatively flat marshland. Two canals have been dug through this marsh (Figure 2). The south canal serves as both an intake for cooling water and as a channel for oil barges supplying the plant. The north canal carries the effluent back into the Gulf.

There are two rivers which empty near the plant's canals and which influence the area. These are the Withlacoochee, which enters the Gulf approximately four miles northwest of the plant, and the Crystal, which enters approximately three miles southeast.

The Gulf waters around the plant are shallow, the bottom sloping gradually for a distance of 25.6 nautical miles to the five fathom contour. The bottom composition varies from hard sand to rock covered with mud near the natural shoreline.

Description of Generating Facilities

The steam electric generating complex at Crystal River is presently composed of two fossil-fueled units. Unit 1, in operation since July of 1966, is oil fired (converted from coal in March, 1970) with a 387 Mw generating capacity. It is designed to have a maximum condenser temperature rise of 6.1°C (11°F) with a cooling water pumping rate of 300 thousand gal/min. Unit 2, in operation since November, 1969, is also oil fired and has a generating capacity of 510 Mw with a maximum condenser rise of 6.1°C (11°F) and a pumping rate of 340 thousand gal/min. A third unit, presently under construction and sheduled for completion in late 1972, will be nuclear-fueled. This unit will have a generating capacity of 825 Mw with a water pumping rate of 700 thousand gal/min and a maximum condenser temperature rise of 9.4°C (17°F).

*Figures and Tables are shown on pp. 81 through 87.

Chlorination Procedure

Figure 3 is a schematic diagram showing one of the eight condenser units and the path of flow of both the water and the chlorine through the system. The chlorination procedure used by Florida Power is an important factor in determining the amount of chlorine which can be expected in the discharge canal.

There are eight intake pipes, one for each condenser unit, as shown in Figure 3 (four each for Units 1 and 2). The waters of the pipes do not mix after passage through the screens. Chlorine, in the form of a sodium hypochlorite solution, is added to each tube. Only one tube is chlorinated at a time. A storage drum (approximately 1100 gallons) is filled with the solution and 25 gallons drained into a smaller drum and finally into one intake pipe. After the smaller drum has been emptied (approximately 15 minutes), it is filled again (30 seconds) and the procedure repeated for the remaining seven pipes. As the chlorinated water from each condenser unit passes into the outflow canal, it is diluted by the unchlorinated water of the seven other pipes. The entire process takes from one and a half to two hours to complete.

The chlorination procedure was begun 21 June 1971 and has continued to date. The process is run once each morning. Personnel employed by Florida Power Corporation have been monitoring the chlorine residuals immediately prior to discharge before and after addition of the sodium hypochlorite solution. Since chlorination has been initiated, residuals of 0.1-1.0 ppm have been found in the condenser unit being chlorinated just before discharge and subsequent dilution with unchlorinated water from the other seven condenser units. The average chlorine residual found was 0.64 ppm. An effort is being made to keep the residual below 1 ppm, preferably around 0.8-0.9 ppm.

CHAPTER II. LITERATURE REVIEW

In order to separate thermal from chlorine induced effects, it was necessary to determine the effects of a sudden temperature rise on the microbiota of the cooling water.

Papers which have dealt with the problems of thermal modification appear in a number of recent comprehensive bibliographies. A few of these are: Raney and Menzel (1969); Krenkel and Parker (1969); Kennedy and Mihursky (1967, 1969); Naylor (1965); and Coutant (1969).

Although many of the studies have been done in different geographical areas, mention of a few will give an indication of some of the responses that may be expected.

In one of the earliest studies conducted on a number of power stations in England, Markowski (1959) concluded that passage through the condensers of these stations, which were both coastal and freshwater, had "no detrimental effect on the organisms found."

Warriner and Brehmer (1966), from their field investigations made at the Virgina Electric and Power Company at Yorktown, Virginia, found that the primary production of the natural phytoplankton communities of the York River is enhanced by the artificial increase in water temperature during the winter months. However, if the temperature of the river water was above 15°C, they found that a temperature rise of 5.5°C always depressed primary production significantly. Using the redundancy index developed by Margalef (1956) to express benthic community diversity, the authors also showed that during the winter months increased community diversity occurred nearer the point of discharge. Diversity data for summer indicated a reversal of the winter situation.

In a study conducted at a power plant located at Chalk Point, on the Patuxent River estuary, Maryland, Morgan and Stross (1969) found that the phytosynthesis of algae passing through the cooling system of the power plant was inhibited by an 8°C rise if the natural water was 23°C or warmer. Photosynthesis was stimulated, however, by the same input of heat if the ambient water temperature was 16°C or cooler.

In a tropical environment, Mayer (1914) reported average ambient water temperatures to be 29°C and that temperatures of 33-38°C caused high mortalities of such organisms as mollusks, corals, and small fish. Acclimating eight representative marine organisms, Mayer found their death points ranged from 35°C to 46.3°C. He concluded that tropical marine animals live within 5°C of their maximum metabolic activity and 10 to 15°C of their thermal death point.

Merriman (1970) is presently participating in a long-term study which is designed to determine the biological consequences of the heated effluent of the Connecticut Yankee Atomic Power Company on the Connecticut River. After five years of study, he has concluded that "industrial heating in a major river of the northeastern U.S. has so far had no drastic biological consequences." He further feels that the levels of heating being experienced may even have beneficial long-range results.

In studying the effects of heated effluent discharge on fishes around seven power stations in Great Britain, Alabaster (1963) found that heated effluents caused temperature increases between 6.3 and 10.4°C and maximum temperatures of up to 30°C. He found that such heated effluents could be lethal to caged fishes in the summer but that winter fish populations increased. Alabaster concluded that the chances for fish kills in the areas studied were low but could possibly occur where organic and thermal pollution might act synergistically. Jones (1964), another British researcher, agreed with Alabaster in that he also felt that thermal addition would not cause significant fish kills. Jones further stated that fish tend to disappear from thermal discharge areas in the summer and congregate in such areas in the winter.

While innumerable studies have dealt with the effects of thermal effluents, the ecological effects of chlorine addition have not been extensively documented.

In a recent study at Chalk Point (Patuxent River, Maryland) by Hamilton *et al.* (1970), investigators showed that the primary production of cooling water may be reduced by as much as 91 percent by chlorination. They also found that bacterial densities and concentrations of chlorophyll were reduced. In the absence of chlorination, he found that productivity was sometimes stimulated.

In an effort to determine the mortality rate of copepods passing through condenser pipes at the Chalk Point power plant, Heinle (1969) noted that on one date when no copepod mortalities were observed, chlorine was being applied at relatively high rates. He stated that "one cannot conclude that chlorination alone was responsible for the copepod mortalities."

In a study mentioned earlier, Markowski (1959) collected material from the inflowing and outflowing cooling water for both qualitative and quantitative studies. Markowski listed the total number of animals from nine freshwater and ten marine animal groups, including protozoans, nematodes, crustaceans, rotifers, annelids, and molluscs. He found that these species mentioned, which had been exposed to a rise of chlorination, were found not only alive but able to reproduce. He further stated, however, that chlorine does have a harmful effect on sedentary non-planktonic organisms when exposed to relatively high concentrations for long continuous periods of time.

In an experimental investigation, Hirayama and Hirano (1970) cultured two marine phytoplankters, *Chlamydomonas sp.* and *Skeletonema costatum*, and exposed each to various concentrations of chlorine in culture media for exactly five and ten minutes. By daily measurements of the optical density of the culture, the growth rate of the organisms treated with chlorine was compared with that of the control. The investigators found that *S. costatum* is so severely damaged by a chlorine concentration of 1.5 to 2.3 ppm when exposed for five to ten minutes that its growth could not recommence even on the 30th day after treatment. *Chlamydomonas sp.*, on the other hand, can survive chlorine concentrations of 20 ppm or more. After nine days of exposure at this concentration, *Chlamydomonas sp.* can regrow.

Nicholas Holmes (1970) feels that low level continuous chlorination is a very effective way of controlling mussel fouling in cooling systems and that the low concentrations of the residual chlorine at outfall culvert (less than 0.1 mg/1) have a minimal effect on the environment. W.G. James (1967) has expressed the most optimistic opinion concerning the effects of power plant chlorination. He states that at Carmarthen Bay Power Station, where warm effluent water is being used to propagate sea fish, no deleterious effects of chlorinated water on fish have been found. Furthermore, the growth rates of the fish have been found to be greater than expected and it has been thought that the chlorine kills certain bacteria which have a retarding effect on fish growth.

CHAPTER III. MATERIALS AND METHODS

The majority of past workers have attempted to determine the "shock" effect of the increased temperature upon various organisms as they pass through condenser tubes by examining the influent and discharge water only. Unfortunately, it is difficult to determine the viability of the organisms visually. For this reason, the three parameters were chosen in an effort to determine, both directly and indirectly, the viability of the organisms and any changes in their metabolic rate and biomass.

Sampling stations were chosen in an effort to determine not only the immediate effects of the addition of chlorine on the organisms but also the changes which may occur as the organisms are flowing down the effluent canal.

Figure 4 shows the sampling stations. Station 1 is in the center of the intake canal just south of the cyclone screen. Station 2 is in the center of the discharge canal and slightly west of the Unit 1 discharge. This station was chosen as being representative of the thoroughly mixed discharge water from both units. Stations 3, 4, and 5 are located at one-half mile intervals down the discharge canal. Station 6 is located one-half mile to the north of the navigational light on the end of the south bank of the discharge canal. This station was chosen as being representative of shallow, estuarine water. Also, from previous studies of currents in the area (Carder, unpublished), water from the discharge canal has been shown to reach this point during ebb tide only.

Since this study proposes to show not only the "shock" effects of chlorine addition, but also any recovery which may occur as the organisms pass out the discharge canal, the same water had to be sampled at all stations. Urinine dye was added to the water at Station 1 and when the colored water had passed through the condenser tubes and out to Station 2, the time was recorded. Since the time required was approximately eight minutes, Station 2 was sampled eight minutes after Station 1.

While sampling Station 2, two drogues were placed in the water. As the drogues passed each of the remaining stations, samples were taken. Since samples were taken during both ebb and flood tides, flow rates in the canal varied. The procedure described assured that the same water was tested in each case.

Since Station 6 is in an open area of the Gulf, whether or not the sample water passing Station 5 also passed Station 6 depended on the tidal stage. Because of this, only general trends in any changes of water quality at Station 6 will be evaluated.

In order to separate thermal effects from changes due to chlorine addition, two baseline studies were performed before chlorination was initiated. Five studies were performed after the plant had begun the addition of chlorine. Table 1 shows the study dates, the number of sample runs performed, and the times of each run.

Each run consisted of sampling Stations 1 through 6. In order to make more than one run in a day, some time overlap was necessary. As previously noted, chlorination was applied **only in the mornings** of the chlorination studies. At the time the afternoon runs were made on those days, no chlorine was being added to the discharge canal. Such a procedure allowed for the comparison of data on morning runs, when chlorine was presented, and afternoons (no chlorine) of the same day. This eliminated day to day variations which could normally be expected.

Analyses were performed at three locations: (1) on board the sampling vessel; (2) in the trailer-laboratory at the plant site; and (3) in the Department of Environmental Engineering Sciences laboratories at Gainesville. In the following sections, the collection methods and analytical techniques for the parameters used are described. The purpose for choosing a parameter is also explained.

The parameters are as follows:

1. Temperature and Dissolved Oxygen: These were measured on board using an instrument (YSI) equipped with an electronic oxygen probe and a thermistor thermometer. Temperatures were taken at a depth of 1 foot. Occasionally, deeper recordings were taken to see if wide variations occurred with depth. They did not. Since oxygen is less soluble at higher temperatures, measurements were made to ascertain whether or not dissolved oxygen was sufficient to support marine life.

2. Chlorophyll a: Chlorophyll **a** is the green pigment common to almost all photosynthetic plants, including algae. Chlorophyll measurements are used to estimate biomass and also give an indication of the relative viability of phytoplankton populations. For the analysis of chlorophyll, 750 ml of sea water was collected in a one liter plastic bottle and returned to the trailer laboratory. There, the sample was millipore filtered. The filters were placed in a desiccator and returned to Gainesville, where the chlorophyll was extracted with 90 percent acetone. Spectrophotometric readings were made at 665, 645, and 630 millimicrons. The formulae of Parsons and Strickland (1963) were used to calculate the amount of chlorophyll **a.** This method yielded relative standard deviations of less than six percent (Browne, 1971).

3. Primary Productivity: This procedure measures the rate of photosynthesis of planktonic populations. The carbon-14 method of Strickland and Parsons (1960) was used.*

*Total alkalinity and pH necessary supporting parameters for the determination of primary production were also performed according to the methodology of Strickland and Parsons (1960).

Basically, this method consists of adding five microcuries of C-14 labeled sodium bicarbonate, obtained from the International Chemical and Nuclear Corp., to 300 ml of sea water. Two bottles are used: one clear and one taped to exclude sunlight. The two bottles were filled with water, injected with C-14 and suspended on buoyed polyvinyl rods at each station for approximately three and one-half hours. During phytosynthesis in the light bottle, algae take up labeled bicarbonate. In the dark bottle, organisms other than algae may do the same. Algae do not photosynthesize in the dark. After incubation, the bottles are returned to the trailer laboratory, where a 50 ml aliquot from each are millipore filtered and placed in a dessicator. Upon their return to Gainesville, the beta emissions of the filters are counted on a Geiger-Mueller counter and the counts converted to milligrams carbon fixed per cubic meter of water per hour. Dark bottle counts are subtracted from light bottle counts to correct for non-algal carbon fixation. This method gives a relative standard deviation less than eight percent (Moyer, 1971; Strickland and Parsons, 1960).

A recording pyrheliograph (Belfort Instrument Company) was ordered to measure variations in the amount of sunlight energy available for photosynthesis, but did not arrive until after the two baseline studies had been run. By using the gm-cal/cm² striking the water surface, one can determine any variations in the productivity of the sample due to increased energy availability.

4. Adenosine Triphosphate (ATP): ATP is an energy yielding compound present in all living organisms. It yields the energy for aerobic and anaerobic cellular activity and dissipates rapidly upon the death of the organism. ATP is used as an indicator of both viability and biomass. McElroy (1947) found that fireflies have absolute requirements for ATP for their production of luminescence. Hastings (1968) has reviewed the biochemistry of the luminescence reactions in detail. The first reaction which ultimately leads to light emission involves the reaction between luciferin and ATP, catalyzed by the enzyme "luciferase" (Equation 1).

$$LH_2 + ATP + E \overset{Mg^{++}}{\quad\quad} E-LH_2-AMP+PP_1 \quad (1)$$

$$E-LH_2-AMP+O_2 \quad E-L-O^* + \text{Product} \quad (2)$$

$$E-L-O^* \quad E-L-O^- + h\nu \quad (3)$$

The enzyme-luciferin-adenosine monophosphate product is oxidized to oxyluciferyl-adenylate (Equation 2). The inorganic pyrophosphate (PP_i) of Equation 1 is a by product. Since the oxyluciferyl-adenylate compound is in an excited state, a quantum of light is released immediately upon its formation (Equation 3). If one mixes a known concentration of firefly lantern extract (which contains the luciferase enzyme) with a solution containing a known amount of ATP, a certain amount of light will be emitted. The more ATP present, the greater will be the quantum of light emitted. After the initial burst of light, the luminescence declines rapidly. To avoid this rapid decline, magnesium arsenate buffer is added to the extracts of the firefly lanterns. By making known solutions of varying concentrations of ATP, standard curves can be drawn from which values for unknown samples can be obtained.

Lyophilized aqueous extracts of firefly lanterns were obtained commercially (Sigma Chemical Co., Stock FLE-50) and stored at −20°C until ready for use, at which time each vial was rehydrated with 37.5 ml of deionized water, allowed to stand for one hour, and filtered. Standard solutions of ATP, usually 10, 20, 40, 60, 100, and 150 ug/1, were made by diluting a test tube of stock solution of ATP with tris buffer. Samples of water were collected from each station and brought back to the trailer laboratory where a 750 ml sample was filtered through a millipore filter (pore size of 0.8 microns). The filters were then immediately immersed in 40 ml of boiling tris buffer and boiled until a volume of less than ten ml was reached. This procedure kills the organisms present and extracts the ATP quantitatively. The solutions were then frozen. Upon returning to Gainesville, the bottles were brought up to a volume of ten ml. After thorough mixing, aliquots were centrifuged to bring down all debris and the supernatant poured into a test tube.

A liquid scintillation spectrometer (Packard Tri-Carb Model 2002) was used to measure light emission caused by the addition of 1.5 ml of the enzyme preparation to 0.5 ml of the ATP standards and 0.5 ml of the sample. Photon emissions were recorded and the amount of ATP in each sample was converted to micrograms per liter using the standard curve. A relative standard deviation of less than five percent can be expected by such a technique.

5. Total Bacterial Populations: A 75 ml sterilized screw-top test tube was used to collect about 35 ml of water just below the water surface. A sterile glove was used to avoid contamination from the hand. In the trailer laboratory, the sample was serially diluted and millipore filtered. The filter was placed on a pad soaked with a medium consisting of Bacto gelatin, BBL phytone, yeast extract, and ½ strength artificial sea water. The composition of artificial sea water is as follows:

$NaCl - 1.2\%$
$KCl - 0.035\%$
$MgCl_2 \cdot 6H_2O - 0.265\%$
$MgSO_4 \cdot 7H_2O - 0.35\%$

The filters were returned to Gainesville, incubated at room temperature, and counted at 48 and 96 hours. Spread plates were also made using the same medium described plus agar for solidification. Incubation times and temperature were identical. Bacterial counts were determined because it was felt that these organisms would be among the most sensitive to chlorine additions.

6. Weights: One liter of surface water was collected in a plastic bottle and returned to Gainesville. There, total solids were determined by evaporation of 50 ml and suspended solids by filtration of 500 ml with a Reeve Angel glass fiber filter (Grade 934AH).

7. Secchi Disc: The Secchi disc is a flat, circular piece of metal or weighted wood attached to a metered line. The surface is divided into black and white quadrants. To read, the disc is lowered until it disappears from view. A measurement is made at this point. It is then raised until it becomes visible. The reading made at this point is averaged with the previous reading for a final value. Secchi disc readings give a rough estimate of turbidity.

8. Chlorine: The orthotolidine-arsenite standard method A.P.H.A., 1971) was used to measure residual chlorine. A 48 ml sample was mixed with two ml of orthotolidine and allowed to set for three minutes. The yellow color was measured using a Klett-Summerson colorimeter. Concentrations were then read from a previously made standard curve. Such a procedure can detect residual chlorine levels as low as 0.005 ppm.

CHAPTER IV. RESULTS AND DISCUSSION

In order to facilitate interpretation and discussion, most of the data is presented in summary form, usually as average values for all runs. The reader is referred to previous progress reports for raw data not presented here.

TOTAL CHLORINE RESIDUAL RESULTS

Chlorine analyses were run in the morning since that was the only time of application. The results showed that by the time the chlorinated water from one condenser unit mixed with the unchlorinated water from the seven other units and reached Station 2, no residual chlorine was measurable. Sea water has a fairly large chlorine demand and active chlorine disappears from the system rapidly. Chlorine and its products are readily adsorbed and absorbed by suspended particles and by dissolved sulphides and organic matter. As the water from the outfall culverts mixes with the ambient sea water with its fresh supplies of suspended materials, any remaining chlorine rapidly disappears.

PHYSICAL RESULTS

The large points on Figures 5 and 6 show the average temperature changes found at each of the other five stations relative to Station 1. Figure 5 shows the morning changes and Figure 6 the afternoon changes. The small dots are individual data points. The average increase in temperature from Stations 1 to 2 was 5.7°C in the mornings and 4.8°C in the afternoons.

Figures 7 (morning data) and 8 (afternoon data) show the exact temperatures recorded at Stations 1 and 2 during each of the seven studies. It is felt that the larger Δ T in the mornings occurred because of increased plant load during this period. Since organisms experience a greater temperature change when passing from Stations 1 to 2 in the mornings, one might expect harmful effects to be greatest at that time. However, another factor, that of the thermal death limit, is involved in considering the afternoon results. Organisms in tropical and sub-tropical climates have been shown to be living close to their thermal death point. Since organisms in the effluent canal are likely to experience higher maximum temperatures in the afternoons, deleterious effects may be greater at this time. It was thought, therefore, that the most profound changes would be apparent in the afternoons during the summer months. How close the various organisms in the Gulf waters around the plant are living to their thermal death limit was not determined by direct experimentation. However, some general conclusions regarding such a matter can be inferred from the results of the other parameters used.

As the heated water passed out the discharge canal (Figures 5 and 6), minor temperature variations occurred. In analyzing the data, no pattern became obvious. In no instance, however, was the water temperature at Station 5 cooler than Station 1. The minor variations in temperature throughout the canal depend on a number of factors, including state of tidal cycle, amount of cloud cover, air temperature, salinity of Gulf water, wind velocity and direction and amount of groundwater influx.

As the water entered the open, shallow area of the Gulf, it began to cool. Temperatures recorded at Station 6 were generally cooler than those at Station 5 (the one exception was the B run of July 9th when a 1.0°C rise was recorded). The average drop was 3.15°C with a maximum of 4.0°C and a minimum of 0.7°C. In no instance was the water temperature at Station 6 any cooler than the intake water temperature recorded during the same run. During two runs, the temperature returned to within one degree of the intake temperature and in one instance equaled the Station 1 value.

The fact that Station 6 temperatures were always higher than Station 1 values is due to several factors, including diurnal temperature increases, the constant discharge of heated effluent and the shallowness of the Gulf at Station 6.

Dissolved Oxygen. A summary of the dissolved oxygen values obtained during the study are shown in Figures 9 (A.M.) and 10 (P.M.). Again, the larger points represent the average annual values and the smaller the actual readings obtained.

During six of the seven runs, D.O. values were lower in the morning than in the afternoon. One would expect this because of the normal diurnal fluctuations in any body of water. Changes in D.O. from Station 1 to 2 were minimal, increasing only slightly in the morning and decreasing in the afternoon. The positive changes are due to reaeration caused by the turbulence of the effluent while the negative changes are due to the decreased solubility of oxygen in water at higher temperatures.

Of prime importance is the fact that at no sampling station during any of the runs did the surface D.O. reach dangerously low levels — the minimum value being 5.9 ppm on November 15 at Station A-1. From the data, it appears that if there are any adverse effects caused by heat and/or chlorine, they are not due to depressed oxygen levels or expressed as such.

Solids Determinations and Secchi Disc Readings. The results of the weight determinations and Secchi Disc readings are shown in Table 2.

It is difficult to distinguish any obvious trends in the solids data; only general trends can be noted. The force of the water as it leaves the condenser units plays an important factor in the results of not only the weight determinations, but also the other parameters tested. This force causes the water to be quite turbulent at the start of the discharge canal. Material is constantly being eroded from the banks and bottom of the canal. In general, total solids increased by Station 2 (whether chlorinating or not) and this increase is likely due to the added turbulence of the water at this point. When decreases did occur, they were slight (always less than 250 mg/1). The same trend was apparent in the suspended solid results. Volatile solids (when analyzed) showed extreme variability and no trends were evident.

Both total and suspended solids exhibited little change as the water mass passed Stations 3, 4 and 5. Only minor changes due to expected variations within the water were observed. For this reason, the test was eliminated at Stations 3, 4 and 6 during the final three studies.

Of the eight times weight analyses were performed at Station 6, total solids were markedly lower than Station 5 in seven instances. The largest drops occurred during the A and B runs (43 and 47 percent respectively) of the same day (September 13th). The water at Station 6 is not being mixed as thoroughly as the water in the effluent canal and is likely the cause of the decreasing solids at this point.

The Secchi Disc readings were consistently lower at Station 2 than at Station 1 (with one exception on the afternoon of September 13th). The decrease averaged 0.34. Again, this is due to the increased turbidity of the water at this point.

It is interesting to note that the two largest increases in total solids from Stations 1 to 2 occurred during two of the mornings while chlorine addition was in progress. The increase of 2,348 mg/1 of July 9th and 1,760 mg/1 of January 12th may be a result of slime material being loosened from condenser tube walls by the toxic chlorinated water. This would be the only manner by which chlorine would be expected to alter the solids characteristics of the water as it passed from Stations 1 to 2.

BIOLOGICAL RESULTS

Primary Productivity. The average productivity value obtained at each station during the year's study and the values for each of the individual runs are shown in Figures 11 and 12.

Figure 11 shows values obtained on runs when chlorination was not in progress (runs A and B of the baseline study and the B runs of the chlorination studies) while Figure 12 represents results obtained during the A runs when chlorine was being added to the cooling water. To view these tables with some perspective, it is necessary to consider the baseline studies, which were made before chlorination began. On the afternoons of April 28th and June 4th, productivity values from Stations 1 to 2 dropped 20.5 and 21.3 percent respectively.

Comparable morning data showed an 8.19 percent increase in April and a 13.8 percent drop in June. This data shows that thermal effects alone are more pronounced in the afternoon.

With chlorine addition, the trend is reversed. Drops in primary production from Stations 1 to 2 are greater in the morning. Primary productivity values decreased as a result of condenser tube passage four out of five times during chlonination. The average drop was 53 percent—the maximum being 65 and 67 percent during the summer runs (July and September). In none of the non-chlorinating runs did the percentage decrease come close to these values. In no instance did the productivity drop as much in the afternoons when chlorination had stopped as in the mornings during chlorination. In two instances, productivity showed an increase from Stations 1 to 2 in the afternoon. It thus appears that the chlorine is having a definite negative effect on the photosynthetic ability of the organisms.

Productivity values fluctuated down the effluent canal, but a definite trend is apparent from the graphs. In 86 percent of the cases, the productivity of the water at Station 5 was significantly higher than the Station 2 value of the same run. One insignificant decrease was noted and in two cases the values were the same as Station 2. The one instance of productivity being below the Station 2 value by the end of the canal occurred on a day (June 4) when the temperature of the water at Station 5 was still 1.5°C warmer than the temperature recorded at Station 2. In general, however, the productivity exhibited recovery by Station 5. Recovery was greater in the mornings. In fact, during the chlorination run, the productivity value was higher at Station 4 than at Station 2 in every instance. This phenomenon occurred in less than one-half of the non-chlorinating runs. It is possible that organisms affected by chlorination in the effluent canal serve as a nutrient source for the hardier organisms which survived condenser tube passage. This may cause the much higher productivity values recorded at Station 4 and especially Station 5 during chlorination.

Whether chlorinating or not, Station 6 productivity values were higher than Station 1 values in 12 of the 14 total runs made. The only decreases, 5.0 and 3.2 percent, were slight Again, a number of variables prevail which will affect the water mass as it passes out into the shallow areas of the Gulf. In general, diurnal variations due to the later time of sampling Station 6, would tend to make productivity higher at this point. Because of these variables, it is difficult to know what direct or indirect effects the heated and chlorinated water are having at this point.

Chlorophyll a. The chlorophyll data are presented in summary form in Figures 13 and 14. Definite trends were not apparent. The percentage changes at each of the stations (using Station 1 as the basis for comparison) were positive on some runs and negative on others. When not chlorinating, chlorophylll **a** values at Station 2 decreased five times (average 6.6 percent) and increased four times (average 13.4 percent); during chlorination, values increased two times (27.9 percent average) and decreased three times (22.6 percent average). Values fluctuated a great deal as the water passed the other stations in the discharge canal.

It is generally quite difficult to estimate the standing biomass of water based on chlorophyll results. The turbulence within a body of water in an estuary, caused by waves, can cause a natural patchiness of the phytoplankton. The turbulence of the discharge canal, plus the fact that the concentration in intake water changes constantly throughout the day, would tend to increase the variation present. Flemer *et al.* (1968) observed such variations from an anchored station in the upper Chesapeake Bay. He found that chlorophyll **a** concentrations in five meters of water varied from 24 to 44 mg/m^3 during two tidal cycles. In open ocean work, chlorophyll **a** concentrations have shown marked diurnal variation (Yentsch and Ryther, 1957). Such variations are evident in the chlorophyll **a** data. Flemer (1969) feels that phytoplankton are able to synthesize their pigment at different rates over a 24-hour period. Sampling problems are associated even within the same water mass. For these reasons, the value of the chlorophyll **a** data is considered minimal and was deleted during the later sampling runs.

Bacteria. The largest response to increased temperature and/or chlorine is evident in the bacterial populations. In the following discussion, the figures cited will be the results of the Millipore membrane filter using a 96-hour incubation period. This method was chosen because of the greater chance of contamination in the spread plate procedure. Figures 15 and 16 show the bacterial results. March 24th data are not included due to plate contamination.

The number of bacteria per ml varied considerably throughout the year. The lowest count was 41/ml at Station 1 during the A run of September while the highest count (1,040/ml) was at Station 2, Run B, on April 28th. In general, the counts were in the range of 100-300/ml. When comparing the two figures, one can plainly see that the average rise in bacteria from Stations 1 to 2 was much greater when chlorine was not being added (Figure 15). Increases were as high as 550 percent (afternoon, April 28th) and averaged 152 percent above the Station 1 value. These increases are likely due to bacteria washing off the condenser pipes, bacterial reproduction and a larger number of bacteria naturally present in the discharge canal. Many are washed from the banks and flushed from the bottom. When chlorinating, however, the largest increase was only 26.8 percent and averaged 17.2 percent. These increases were the lowest recorded at Station 2 of all runs made. Since chlorine was present during these runs, it is concluded that the growth pattern of the bacteria had been hindered by the presence of chlorine.

In both instances (whether chlorinating or not), bacterial populations by Station 5 were higher than Station 1 during 10 of the 12 runs made. From these results, the most profound effects of chlorine are apparent at Station 2 and by Station 3 or 4 are almost negligible.

Adenosine Triphosphate. Figures 17 and 18 show the results of the ATP determinations. Values ranged from 0.15 to 2.75 μg/1, with the majority of values between 0.5 and 2.0 μg/1. Seasonal variations were present, with the lowest readings occurring during the winter months and the highest in the summer.

During chlorination (Figure 18), ATP dropped in every instance from Stations 1 to 2. The average drop was 43 percent. This was the most consistent result obtained. At no station within the discharge canal during chlorination did the ATP concentration return to the value recorded at Station 1. This finding is in direct contrast to the primary productivity, chlorophyll and bacterial data, which clearly showed a rebound by Station 4. Since the amount of ATP represents the viability of all the organisms collected in the sample, it is possible that deaths of organisms not reflected by bacterial counts, chlorophyll or primary production are responsible for the long-lasting depressed ATP values. The most obvious organisms would be the zooplankton, which include a broad assemblage of forms. This supposition can only be proven or disproven by further research.

In the absence of chlorine, ATP values showed a slight rise at Station 2, possibly due to the presence of condenser tube organism washout and the organisms being eroded from the bottom and banks of the receiving canal. The drop at Station 5 could be real or due to experimental variation.

CHAPTER V. CONCLUSIONS

The Florida Power Corporation presently chlorinates Gulf of Mexico cooling water daily. The purpose is to control fouling and pitting of the condenser tube walls. From the data presented in this report, it appears that chlorination is exerting adverse effects on the microbiota in the cooling water. These adverse effects are most apparent in the immediate vicinity of the effluent and, in most cases, are not demonstrable at the end of the discharge canal. The ATP findings are an exception and have been discussed earlier.

The ecological ramifications of decreased levels of many of the parameters studied are difficult to assess. From the information gathered during this study, however, we feel that the total biological impact of chlorinating Gulf of Mexico water is minimal. If the receiving body of water were a small lake or reservoir, the effects might be quite serious. The regenerative or assimilative capacity of the Gulf, however, is more than adequate to receive Florida Power's effluent. As mentioned before, most parameters return to normal levels by the end of the effluent canal.

From the baseline data, it appears that deleterious thermal effects, while minimal, are more pronounced in the afternoon. For that reason, Florida Power should continue their practice of chlorinating in the morning.

BIBLIOGRAPHY

Alabaster, J.S. 1963. The effects of heated effluents on fish, Int. J. of Air and Water Pollut., 7:541-63.

American Public Health Association, 1971. Standard methods for the examination of water and wastewater (Thirteenth Edition). A.P.H.A., Inc., New York. 769 p.

Brooks, A.J. and A.L. Baker, 1972. Chlorination of power plants: impact on phytoplankton productivity. Science. 176 (4042) pp. 1414-1415.

Browne, F.X. 1971. ATP measurements in laboratory cultures and field populations of phytoplankton. Ph.D. Thesis, University of Florida.

Carder, K.L., 1971. Independent environmental study of thermal effects of power plant discharge, Data Report No. 004. University of South Florida Marine Science Institute. 22 p.

Coutant, C.C. 1969. Thermal pollution—biological effects. A review of the literature of 1968. Battelle Mem. Inst. Pacific Northwest Lab., Richland, Wash. 43 p.

Flemer, D.A., W.L. Dovei, H.T. Pfitzenmeyer, and D.E. Ritchie, Jr. 1968. Biological effects of spoil disposal in Chesapeake Bay. J. Sanit. Eng. Div., Proc. Amer. Soc. Civil Eng. SA4, 94:683-706.

Flemer, D.A. 1969. Chlorophyll analysis as a method of evaluating the standing crop phytoplankton and primary productivity. Ches. Sci. 10(3,4):301-306.

Hamilton, D.H., Jr, D.A. Flemer, J.W. Keefe, and J.A. Mikursky. 1970. Power plants: effects of chlorination on estuarine primary production. Sci. 169:197-98.

Hastings, J.W. 1968. Ann. Rev. Biochemistry, 37:603-608.

Heinle, D.R. 1969. Temperature and zooplankton. Ches. Sci. 10(3,4):186-209.

Hirayama, K. and R. Hirano. 1970. Influences of high temperature and residual chlorine on marine phytoplankton. Mar. Bio. 7:205-213.

Holmes, N. 1970. Marine fouling in power stations. Mar. Poll. Bull., 7:105-106.

James, W.G. 1967. Mussel fouling and use of exmotive chlorination. Chem and Ind. p. 994-996.

Jones, J.R.E. 1964. Thermal pollution: the effects of heated effluents. In Fish and River Pollution, p. 153-68.

Kennedy, V.S. and J.A. Mihursky. 1967. A bibliography of the effects of temperature in the aquatic environment. Nat Res. Inst., Univ. Md., Contrib. No. 326:89 p.

Kennedy, V.S. and J.A. Mihursky. 1969. Addendum to: bibliography on the effects of temperature in the aquatic environment. Nat. Res. Inst., Md., Ref. No. 69-9:18 p.

Krenkel, P.A. and F.L. Parker (Ed.). 1969. Biological aspects of thermal pollution. Vanderbilt Univ. Press, 407 p.

Margalef, R. 1956. Informacion de diversidad especifica en las communidades des organismos. Invest. Pesquera, 3:99-106.

Markowski, S. 1959. The cooling water of power stations: a new factor in the environment of marine and freshwater invertebrates. J. Anim. Ecol. 28, 243-58.

Mayer, A.G. 1914. The effects of temperature upon tropical marine animals. Pap. Fortugas Lab., 6(1):1-24.

McElroy, W.D. 1947. Proct. Nat. Aca'd. Sci. U.S. 21:435-443.

Merriman, D. 1970. The calefaction of a river. Sci. Amer. 222(5):42-52.

Morgan, R.P. and R.G. Stross. 1969. Destruction of phytoplankton in the cooling water supply of a steam electric station. Ches. Sci. 10 (3,4):165-71.

Moyer, M.S. 1971. Effects of power plant chloination on marine microbiota. M.S. Thesis. U. of Florida. 75 p.

Naylor, E. 1965. Effects of heated effluents upon marine and estuarine organisms. Adv. Mar. Biol., 3:63-103.

Parsons, T.R. and J.D.H. Strickland, 1963. Discussion of spectrophotometric determination of marine-plant pigments, with revised equations for ascertaining chlorophylls and carotenoids. J. of Mar. Res., 21(3):155-72.

Picton, W.L. 1960. Water use in the United States, 1900-1980. Bus. Def. Serv. Adm., U.S. Dept. Comm.

Raney, E.C. and B.W. Menzel. 1969. Heated effluents and effects on aquatic life, with emphasis on fishes. A bibliography. Cornell Univ. Water Res. Mar. Sci. Cent., Phila. Electr. Co., and Ichthyol Assoc., Bull. No. 2:470 p.

Strickland, J.D.H. and T.R. Parsons. 1960. A manual of seawater analysis. Bull. Fish. Res. Brd. Com., 125:153-63.

Trembley, F.J. 1965. Effects of cooling water from steam-electric power plants on stream biota. In Biological Problems in Water Pollution, 3rd Seminar. P.H.S. Publ. 99-WP-25, p. 334-346.

Warinner, J.E. and M.L. Brehmer. 1966. Effects of thermal effluents on marine organisms. Int. J. Air and Wat. Pollut., 10:277-289.

Yentsch, C.S. and J.H. Ryther. 1957. Short-term variations in phytoplankton chlorophyll and their significance. Limnol. Oceanogr. 2:140-142.

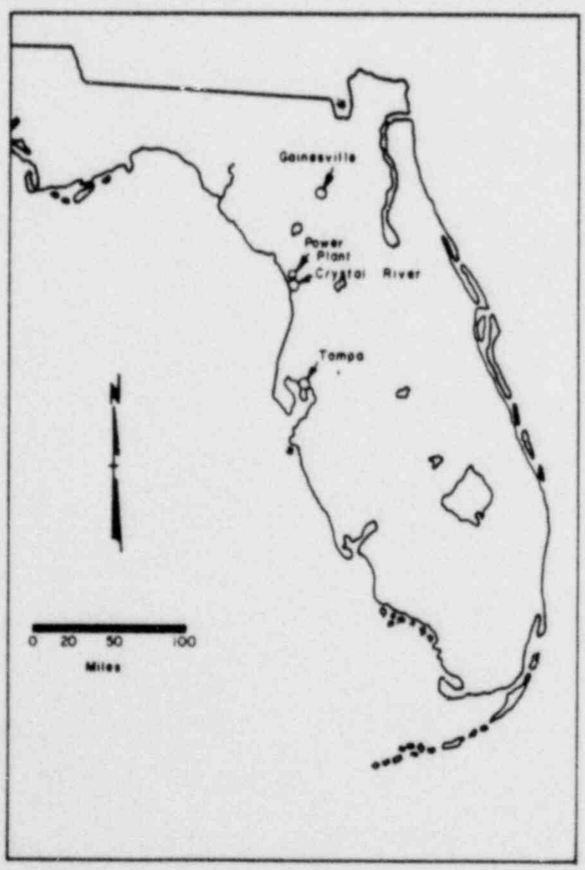

Figure 1.
Geographical Location of Florida Power Corporation's Crystal River Plant.

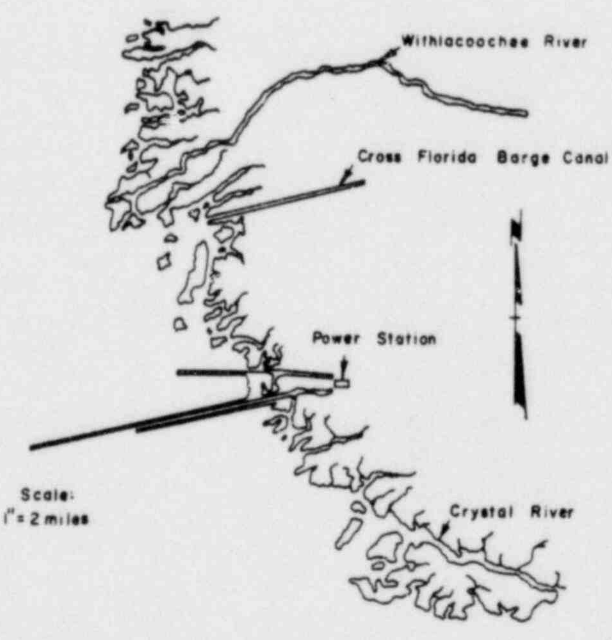

Figure 2.
Location of Plant Site.

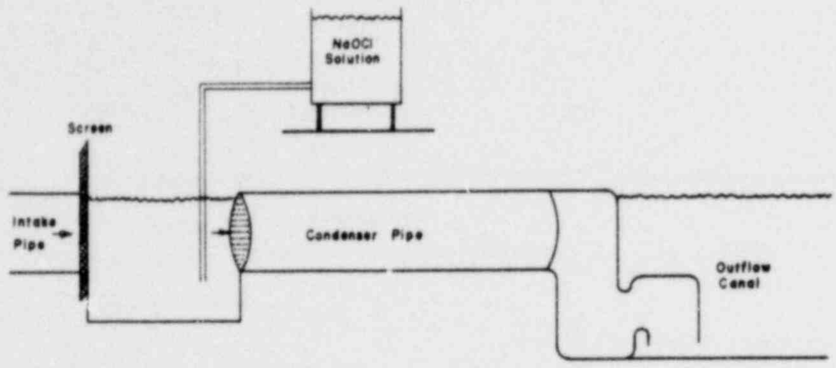

Figure 3. Schematic Diagram Showing Path of Water Through Plant.

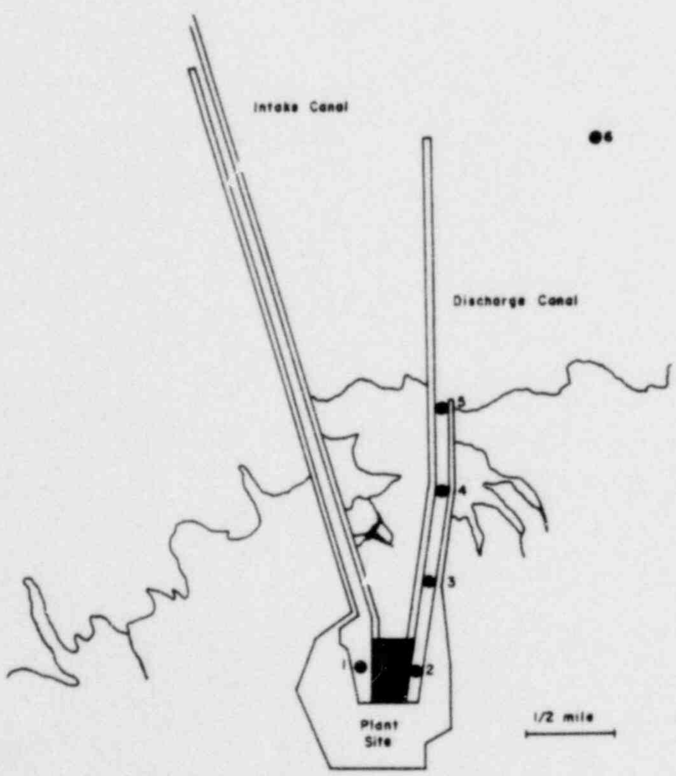

Figure 4. Station Locations

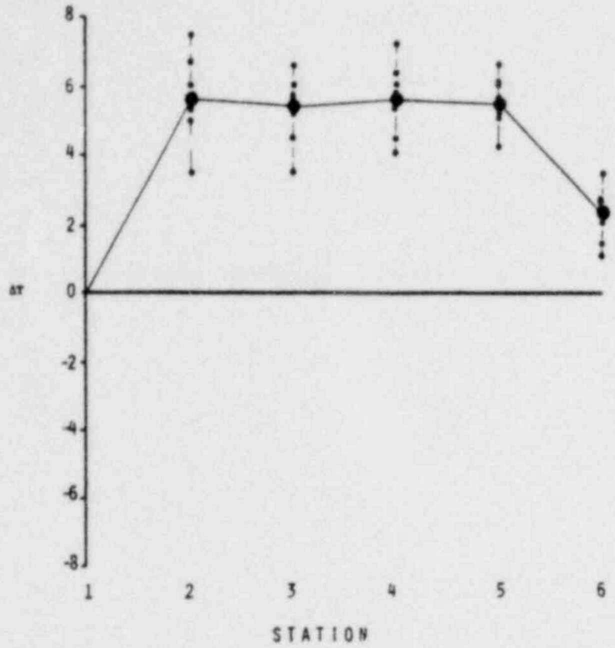

Figure 5. Summary and Average of Morning Water Temperature Changes. All Points Represent Changes from Intake (Station 1) Temperature.

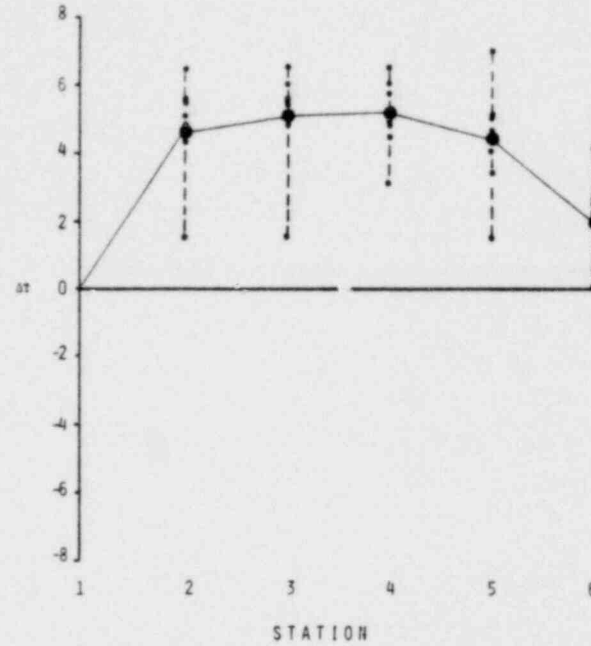

Figure 6. Summary and Average of Afternoon Water Temperature Changes. All Points Represent Changes from Intake (Station 1) Temperature.

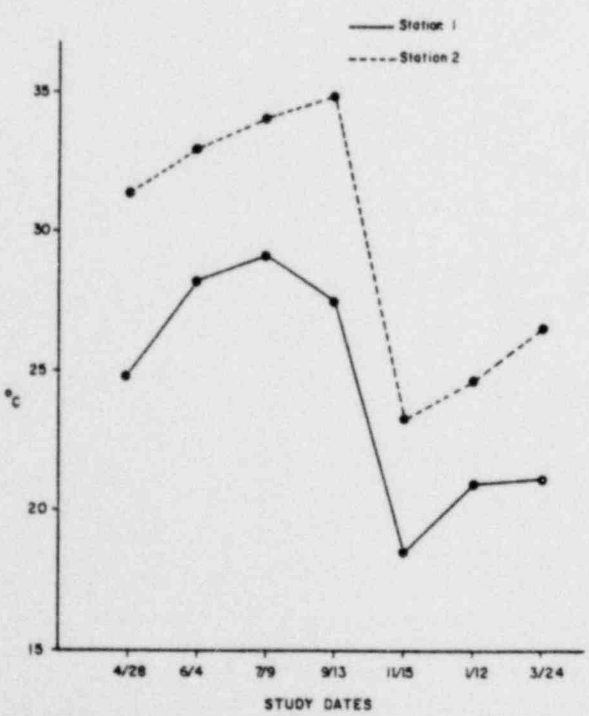

Figure 7.
Temperature Summary for Stations 1 and 2.
Morning Readings.

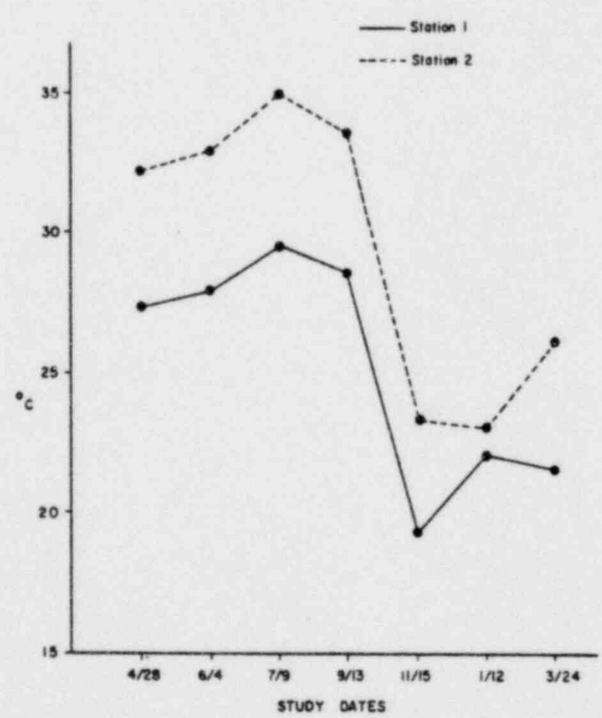

Figure 8.
Temperature Summary for Stations 1 and 2.
Afternoon Readings.

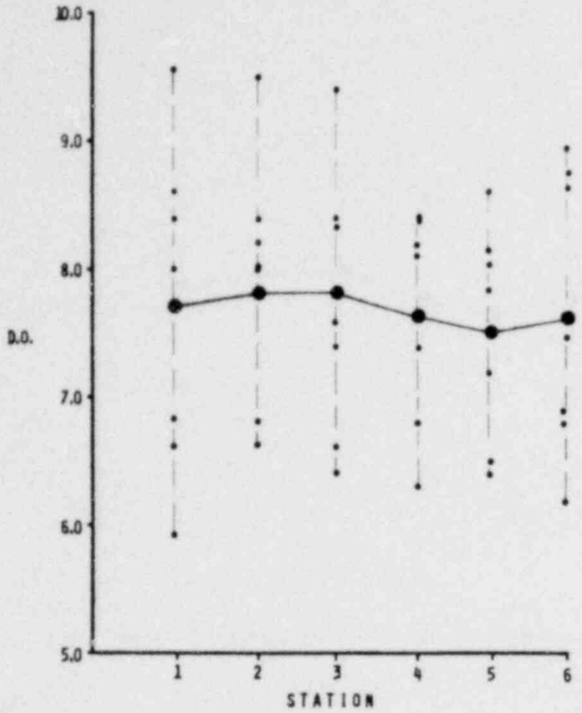

Figure 9. Summary and Average of Morning Dissolved Oxygen Values.

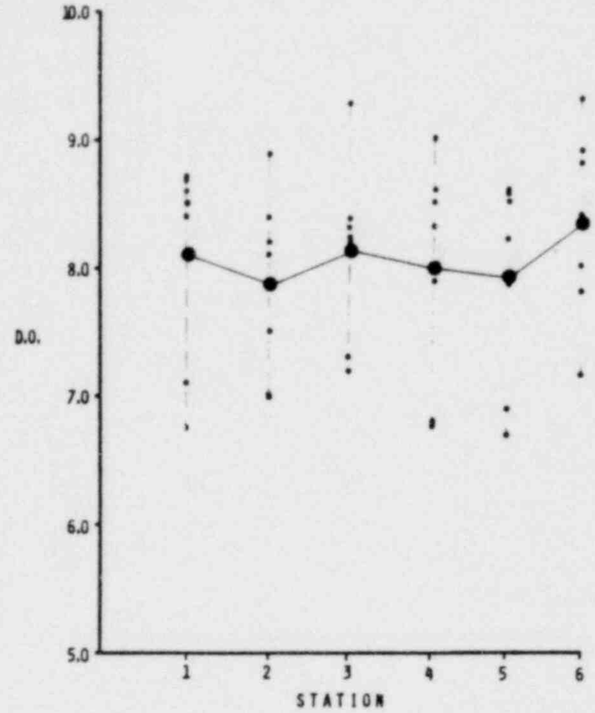

Figure 10. Summary and Average of Afternoon Dissolved Oxygen Values.

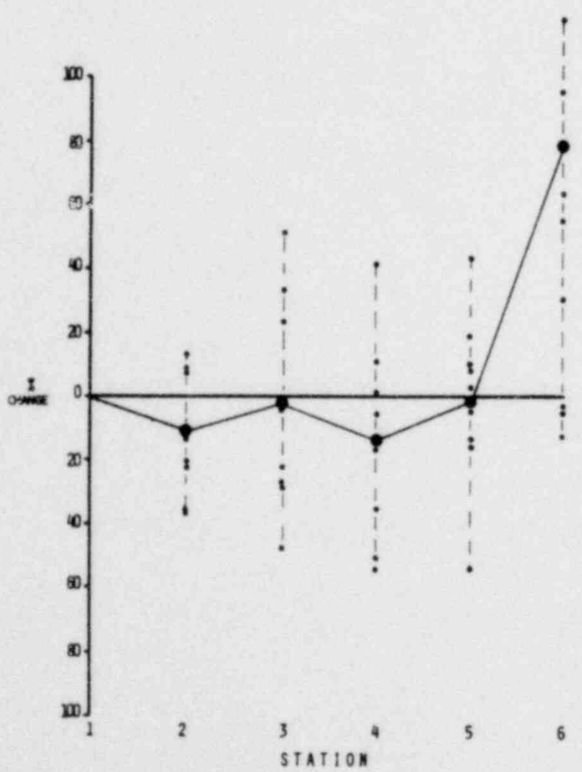

Figure 11. Summary and Average of Primary Productivity Percentage Deviations from Station 1 when Not Chlorinating.

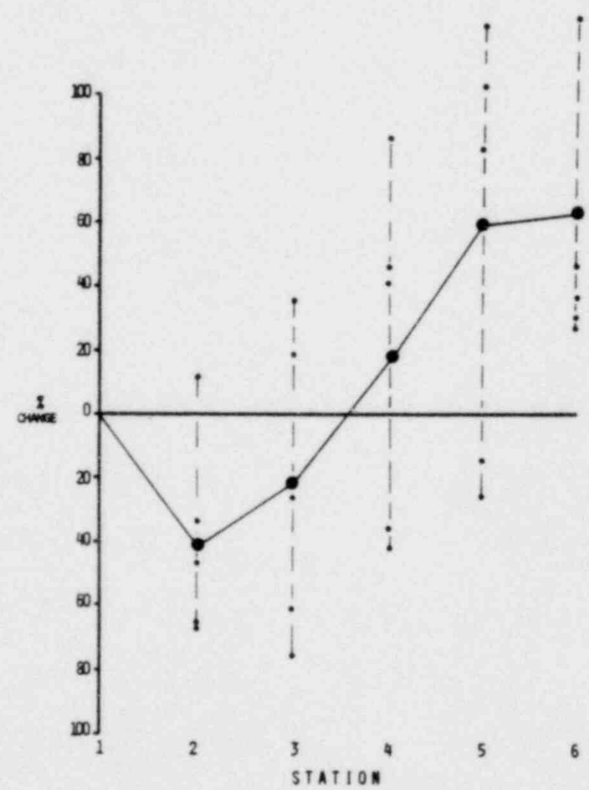

Figure 12. Summary and Average of Primary Productivity Percentage Deviations from Station 1 During Chlorination.

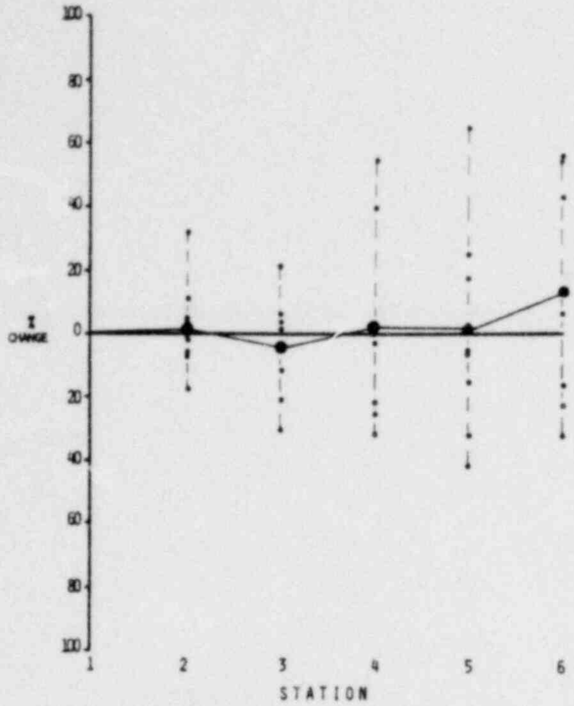

Figure 13.
Summary and Average of Chlorophyll a Percentage Deviations from Station 1 when Not Chlorinating.

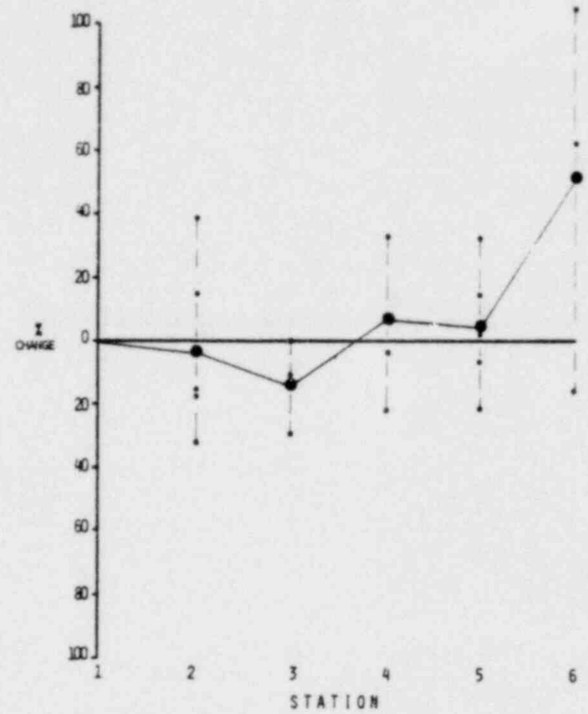

Figure 14.
Summary and Average of Chlorophyll a Percentage Deviations from Station 1 During Chlorination.

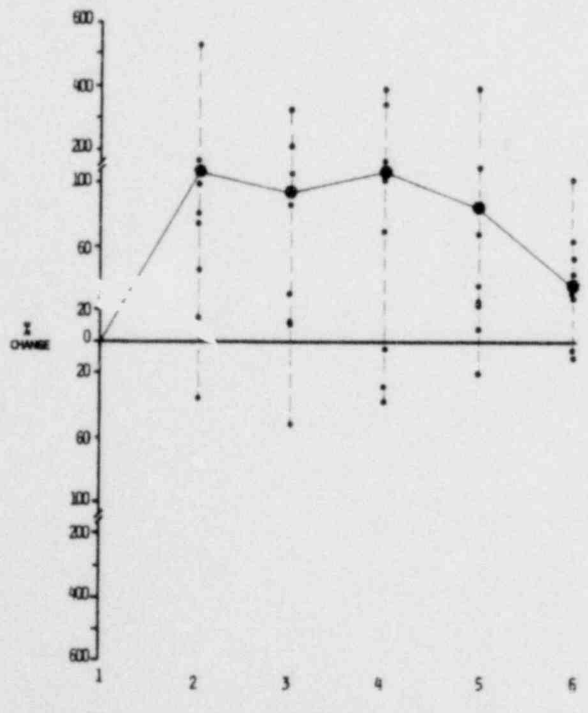

Figure 15.
Summary and Average of Bacteria Percentage Deviations from Station 1 when Not Chlorinating.

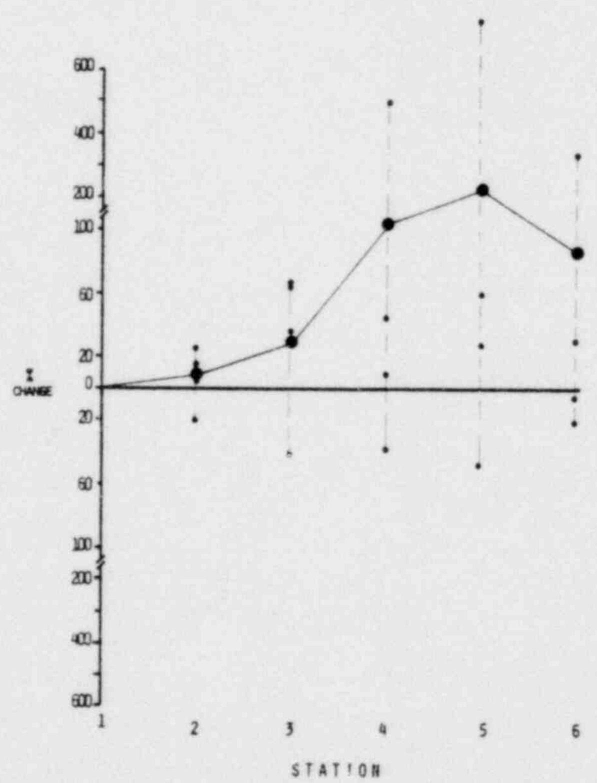

Figure 16.
Summary and Average of Bacteria Percentage Deviations from Station 1 During Chlorination.

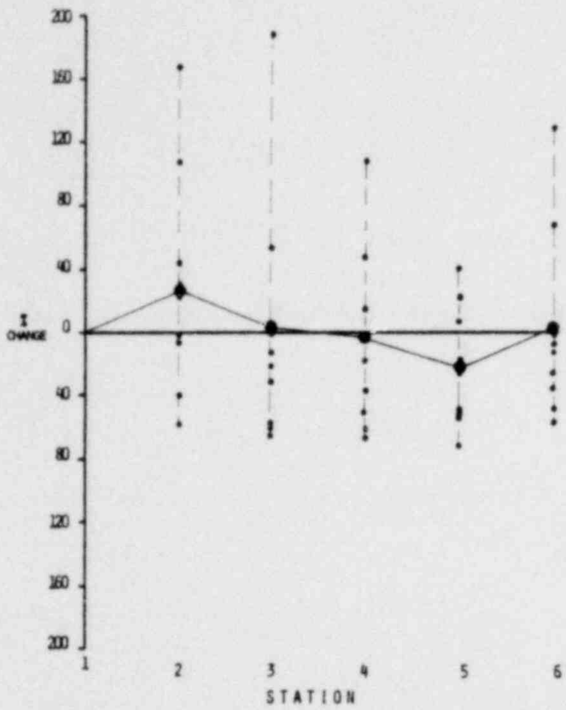

Figure 17.
Summary and Average of ATP Percentage Deviations from Station 1 when Not Chlorinating.

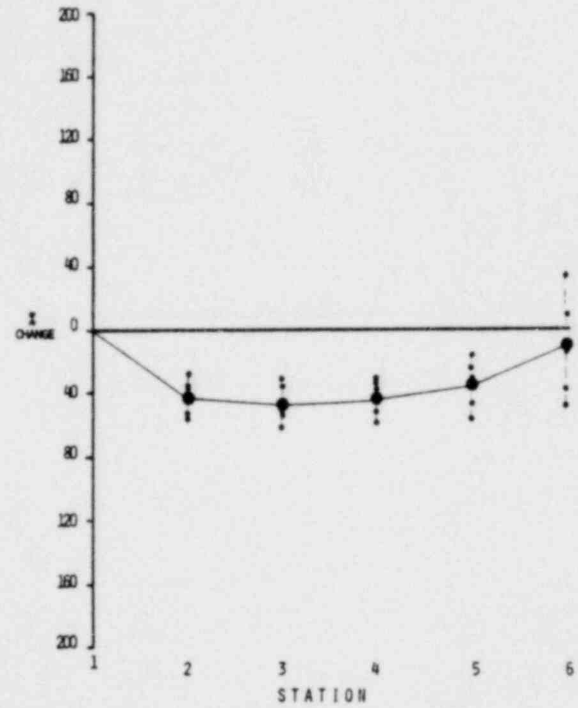

Figure 18.
Summary and Average of ATP Percentage Deviations from Station 1 During Chlorination.

Table 1
STUDIES PERFORMED

	Sample Runs	Time
Baseline Studies		
April 28	A	9:00 A.M. — 12:15 P.M.
	B	1:30 P.M. — 3:15 P.M.
	C	4:55 P.M. — 6:40 P.M.
June 4	A	8:25 A.M. — 11:20 A.M.
	B	12:30 P.M. — 5:05 P.M.
Chlorination Studies		
July 9	A	8:40 A.M. — 1:30 P.M.
	B	2:40 P.M. — 4:45 P.M.
September 13	A	9:18 A.M. — 1:10 P.M.
	B	12:10 A.M. — 3:54 P.M.
November 15	A	8:20 A.M. — 11:30 A.M.
	B	11:57 A.M. — 2:30 P.M.
January 12	A	8:15 A.M. — 11:45 A.M.
	B	12:30 P.M. — 2:13 P.M.
March 24	A	8:30 A.M. — 11:15 A.M.
	B	12:05 A.M. — 2:16 P.M.

Table 2
WEIGHT DETERMINATIONS AND SECCHI DISC READINGS

Date	Station	Total Solids (mg/1)	Suspended Solids (mg/1)	Volatile Solids (mg/1)	Secchi Disc (meters)
July 9	A-1	24,692	9.4	0.6	1.6
	A-2	27,050	10.6	0.4	1.5
	A-3	27,154	12.8	1.0	1.4
	A-4	27,200	11.4	1.4	1.3
	A-5	26,396	18.6	3.6	1.0
	A-6	24,868	8.2	0.4	1.3
	B-1	25,644	6.4	0.8	—
	B-2	26,694	13.2	0.8	1.05
	B-3	27,736	14.4	2.8	1.0
	B-4	27,110	19.0	2.6	1.1
	B-5	27,786	19.0	3.8	1.1
	B-6	23,870	10.0	1.4	—
Sept. 13	A-1	23,812	3.6	2.2	2.2
	A-2	24,580	3.8	0.8	1.6
	A-3	24,952	3.0	0.6	1.85
	A-4	24,284	7.2	4.0	1.3
	A-5	24,750	4.4	2.0	1.1
	A-6	14,072	4.8	1.2	1.0
	B-1	24,804	13.8	2.8	0.6
	B-2	24,592	10.6	3.0	1.0
	B-3	24,960	11.4	3.6	1.9
	B-4	24,846	11.4	4.8	1.0
	B-5	24,646	7.2	1.8	0.8
	B-6	12,924	5.4	2.0	0.7
Nov. 15	A-1	27,965	26.2	9.2	1.5
	A-2	27,948	22.8	5.8	1.25
	A-5	27,500	19.0	2.8	1.0
	B-1	28,118	14.8	3.0	1.75
	B-2	28,140	15.8	4.0	1.0
	B-5	28,213	25.5	7.0	1.0
Jan. 12	A-1	25,926	11.6	7.8	2.3
	A-2	27,686	11.8	3.8	2.0
	A-5	29,298	13.6	6.0	1.8
	B-1	32,408	11.2	4.6	1.8
	B-2	32,406	12.0	5.0	1.5
	B-5	33,160	14.2	6.6	1.8
Mar. 24	A-1	26,980	7.3	0.75	1.3
	A-2	26,754	15.5	6.25	1.0
	A-5	27,186	10.8	1.00	1.1
	B-1	26,514	12.5	3.00	1.2
	B-2	26,946	7.8	1.25	1.0
	B-5	26,624	17.3	5.50	1.1

appendix d

environmental

SURVEILLANCE FOR RADIOACTIVITY IN THE VICINITY OF THE CRYSTAL RIVER NUCLEAR POWER PLANT: AN ECOLOGICAL APPROACH

University of Florida

Department of Environmental Engineering

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I. INTRODUCTION

This report covers the period of the beginning of the third contract year. It is important therefore, to review the primary objectives of the contract, to evaluate the degree to which these objectives have been achieved, and to set forth goals for the coming contract year.

It was recently announced that Crystal River Unit #3 will not be expected to be operational until October, 1974. Also, it should be noted that Crystal River Unit #4 has been cancelled. These announcements have considerable impact upon the nature of the preoperational activities in environmental surveillance for radioactivity. Two full years of background data are generally considered to be the minimum requirements. There is less agreement in the literature on the need for the two years to **immediately precede** the operational phase. This research effort intends to proceed under the assumption that two years of intensive data need not be collected for the two years just prior to fuel loading. Any two-year period reasonably near start-up can be justified as a suitable indication of the levels of radioactivity and trends in those levels. Limited data in the immediate intervening preoperational period will be useful in confirming these established levels and/or trends. Continuity of the program is important.

Research and development times for each phase of the sampling program varied considerably. Marine sampling was begun within a few months of the initial contract date. Items such as the air particulate sampler underwent research, design, procurement, construction, field placement, and testing before becoming operational. At this date, therefore, each phase or network has completed a different fraction of the two-year intensive data collection program. Many will extend well into the 3rd contract year, however, none are expected to extend into the 4th contract year.

II. OBJECTIVES

The broad objectives of the original contract were as follows:

1. To gather extensive and accurate information on the pre-operational levels of radiation and radioactivity existing in the environment. This information is essential in interpreting the operational surveys after the start-up of the power plant.

2. To obtain information on the critical nuclides, critical pathways and critical biological groups associated with uptake of radioactivity into the human food chain. This information is helpful in designing the operational survey. It will also provide a basis from which project personnel can interpret the results in terms of the actual or potential exposure to man. To the extent possible, exposure levels will be estimated.

3. To test and exercise the methods and procedures that will be used in later operational radiological surveys.

4. To gather baseline data that will provide a basis for comparison with future levels of radioactivity in the environment in the event that claims are filed against the plant as a result of suspected or real contamination.

5. An often-overlooked objective of a preoperational surveillance program is improved public relations. Early reporting of complete, factual and comprehensive data will serve to gain public confidence.

6. A final objective is to provide the personnel of the power company with experience, training and confidence in the area of environmental monitoring.

The original objective #2 contained some reference to "exposure to man." In the 1971-72 proposal, a seventh objective was added in order to strengthen the attention to dose calculations. Objective 7 was as follows:

7. Develop and estimate the maximum possible dosage, as a consequence of all liquid effluents, that may be rendered to individuals at the boundary of the site and within a low population zone during situations of normal operation and 1% failed fuel. This is pursuant to Florida Power Corporation demonstrating satisfactory compliance with the provisions of the proposed amendment to the AEC codes 10CFR50 with respect to radiation doses to the public.

III. STATUS OF COMPLETION OF OBJECTIVES

Figure 1, page 93, summarizes the project objectives and status of completion for each objective during the past contract years and indicates percentage effort for the current contract year. Detailed discussion of the objectives is presented below:

1. Extensive information on the pre-operational levels of radiation and radioactivity existing in the environment has been gathered. Each phase of the program, however, is currently on a different time scale due to the research and development effort put into the phase. The two years of intensive sampling for the marine organisms is over 90% complete. The other phases range in percent completion down to about 50% complete for the deposition samples, which was the last equipment package to be placed in the field.

2. Detailed pathway information and extensive ecological data have been obtained. The entire program was conceived and designed to apply as many ecological principles as possible to the surveillance programs. As a consequence, the study and understanding of the ecology of the area — whether marine, marshland, freshwater or terrestrial — has been a major effort. It should be noted that this ecological approach was proposed about a year and a half **before** the Calvert Cliffs' Decision and its subsequent effect upon ecological requirements in Impact Statements.

With the exception of the exposure level estimates implied, this activity is about 80% complete. The terrestrial sampling will be a major effort in the coming year. The design and implementation of dose models may draw attention to missing or incomplete data. To this extent, therefore, the estimated completion percentage for ecological data is subject to change.

3. Methods, procedures and equipment have been thoroughly tested and this objective is essentially complete. However, there still exists the possibility of statistical tests of the data uncovering anomalies that may be attributable to instrument design. Lower limits of detection yield better resolution of unknowns and interfering radionuclides and less statistical error on concentrations just above detectable. Therefore, new techniques and instrumentation are continually investigated.

4. Whether or not baseline data is sufficient for comparison with future levels of radioactivity in the environment in order to detect suspected or real contamination by the plant is dependent upon the variability of the baseline data. Statistical tests are used to determine whether the differences are real or random. In the pre-operational phase it is possible to test for differences between sites, species, season, etc. Adequate data will be available for this objective at the end of each two-year segment of intensive sampling. In this regard, this objective has hardly begun to be complete, however, it was not intended to be completed.

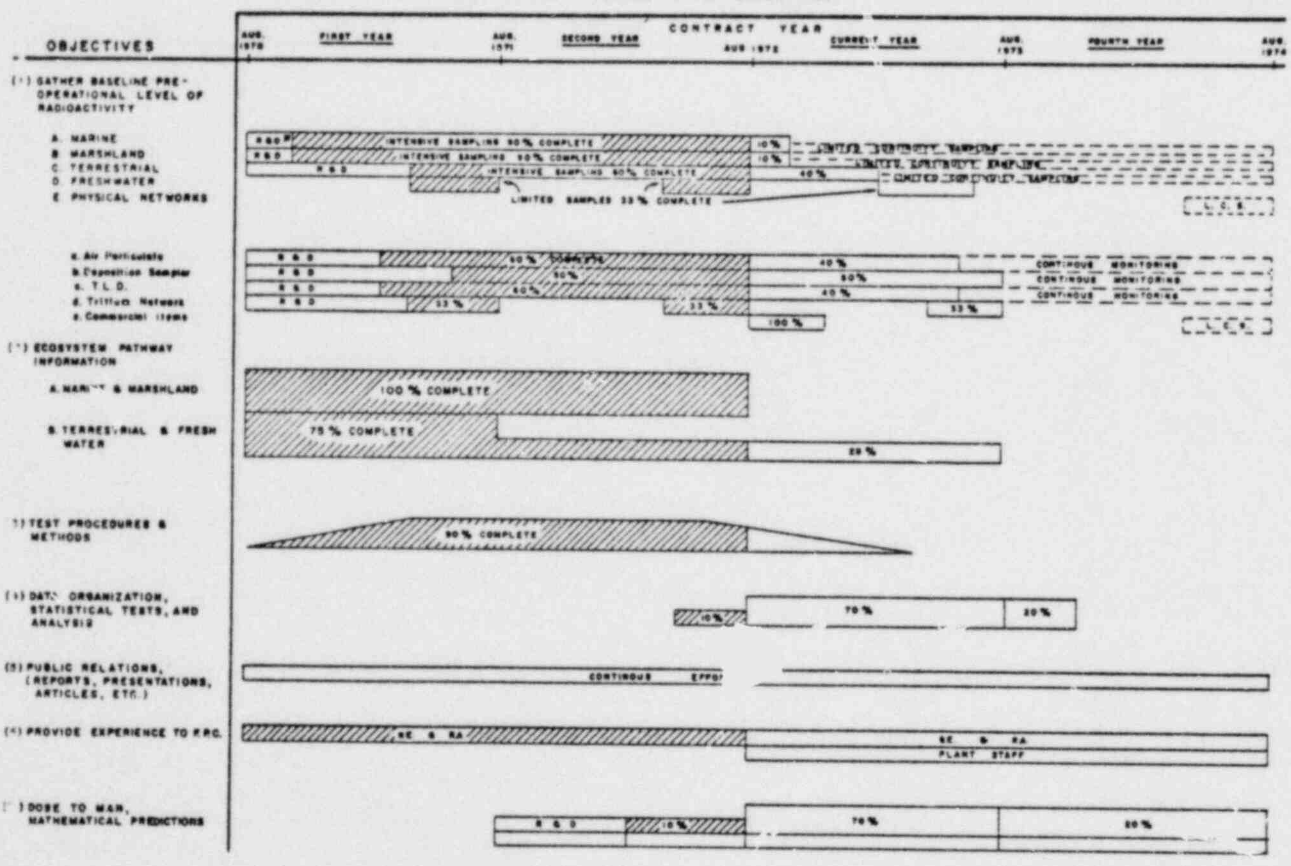
5. The objective of improved public relations has been very successful. All faculty investigators and students have taken every opportunity to publish or present papers on the various phases of the program. The list of publications includes, University of Florida theses, papers in national journals, articles in news media and contributions to the FPC Quarterly Status Reports. Presentations have been made at meetings of national organizations, of regional groups, and FPC semi-annual research reviews.

6. The objective of providing FPC personnel with experience, training and confidence in the area of environmental monitoring has been successful. FPC personnel in the Environmental and Regulatory Affairs Department have been deeply involved in the research program. The interchange of ideas and knowledge has been beneficial to both the University and FPC. Plant personnel will become more involved in the research program during the coming year. Rescheduling of the completion date for Crystal River Unit #3 will make this possible. Additionally, every effort will be made to make plant management and the radiation and protection personnel aware of the goals and conduct of this research.

7. In the area of dose prediction and path-

way models, some work in both the terrestrial and marine environments has been accomplished. The type of model used in the terrestrial ecosystem has been described in quarterly progress reports. A preliminary report on the specific activity approach model in the marine environment has been submitted to FPC during the second contract year. Work in this area will be a major emphasis in the coming contract year since the overall understanding of the ecosystems has progressed under objective 2 during previous contract years.

STATUS OF COMPLETION OF OBJECTIVES



* R & D = RESEARCH AND DEVELOPMENT, DESIGN OF SAMPLING SCHEDULE, PURCHASE OF EQUIPMENT, SITE SELECTING ETC.

Figure 1

appendix e

pre-operational

SURVEILLANCE OF THE NUCLEAR POWER PLANT SITE

OF THE FLORIDA POWER CORPORATION,

CRYSTAL RIVER SITE

July 1-September 30, 1972

STATE OF FLORIDA

DEPARTMENT OF HEALTH AND REHABILITATIVE SERVICES

Radiological and Occupational Health Section
Bureau of Preventable Diseases
Division of Health

Emmett Roberts, Secretary
Department of Health and Rehabilitative Services

Dr. Chester L. Nayfield, Administrator
Radiological and Occupational Health Section

Orlando Staff
Wallace B. Johnson
Benjamin P. Prewitt
Jerry C. Eakins
James Matarrese
Robert G. Orth
Henry Thur
M. Melinda Geda
Lucille Fisher

PRE-OPERATIONAL RADIOLOGICAL SURVEILLANCE — CRYSTAL RIVER

The report included herein constitutes the radiological surveillance conducted at Crystal River during the period July 1 to September 30, 1972. During this period the following samples were collected and analyzed :

Vector	No. Sites Sampled	No. Samples May 31 to Sept. 30*
Vegetation	10	29
Food Crops	1	1
Soil	11	11
Milk	1	1
Marine Biota	4	5
Seawater	6	11
Surface Water	3	6
Drinking Water	6	12
TLD	5	19
Air Particulates	5	30
Air Iodines	5	30
Silt	4	8
Precipitation	2	12
Algae	3	3
		178

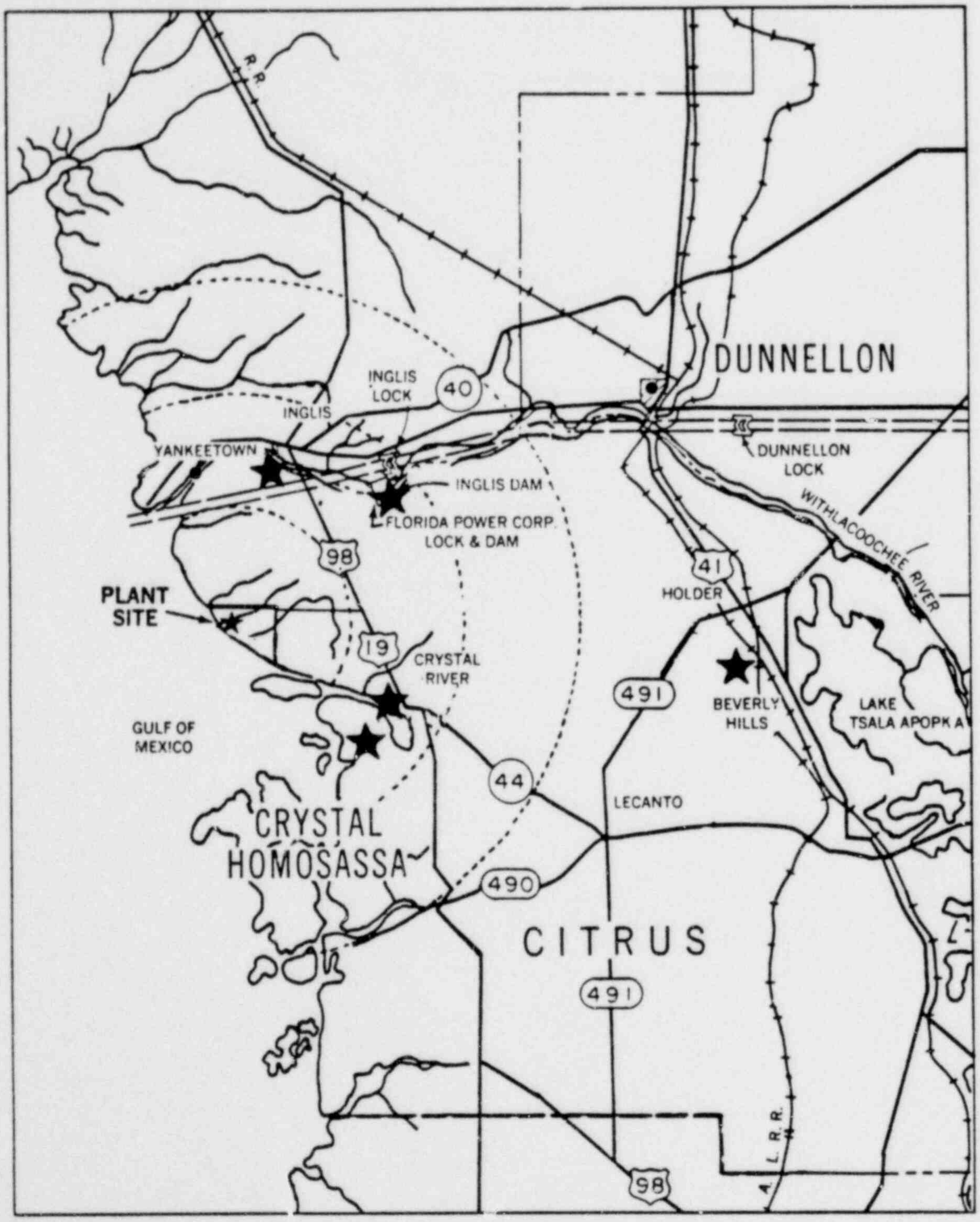
*Does not include September gamma samples

CRYSTAL RIVER SAMPLING AND ANALYTICAL SCHEME

Effective July 1, 1972

	Sites	Frequency		Analysis	
Biota					
Oysters	7	Q	Gamma	Sr 90	
Fish	4	Q	Gamma	Sr 90	
Crabs	1	Q	Gamma	Sr 90	
Soil	10	SA	Gamma	Sr 90	
Silt	4	Q	Gamma	Sr 90	
Marine Algae	4	Q	Gamma	Sr 90	
Citrus	1	Q	Gamma	Sr 90	
Palmetto	10	Q#	Gamma	Gross Beta	
Seawater	4	Q	Gamma	Sr 90	H 3
Public Water Supply	4	Q	Gamma	Gross Beta	H 3
Surface Water	4	Q	Gamma	Gross Beta	H 3
Ground Water	2	Q	Gamma	Gross Beta	H 3
Milk	1	Q	Gamma	Sr 90	
Air Particulates	5	Bi-Weekly		Gross Beta	
Air Iodines	5	Bi-Weekly	Gamma	—	
Precipitation	2	M	Gamma	Gross Beta	H 3
TLD	5	M			

#Change from monthly frequency



THERMOLUMINESCENT DOSIMETER LOCATIONS AND AIR PARTICULATE SAMPLERS

GAMMA BACKGROUND AND ACTIVITY IN AIR PARTICULATES

AIR PARTICULATES to 9-30-72

Sampling Site	5-19-72*	6-02-72	6-20-72	7-6-72	7-19-72	8-2-72	8-23-72	9-7-72	9-21-72
C 04	<1 pCi/m³	<1 pCi/m³	Motor failure	Motor failure	Motor failure	NA	<1 pCi/m³	<1 pCi/m³	<1 pCi/m³
C 07	"	"	<1 pCi/m³	"	<1 pCi/m³	<1 pCi/m³	"	"	"
C 08	"	"	Motor failure	NA	"	"	"	"	"
C 18	"	"	<1 pCi/m³	<1 pCi/m³	Motor failure	"	"	"	"
C 26	"	"	Motor failure	NA	<1 pCi/m³	"	"	"	"

AIR IODINES# to 9-30-72

Site	5-19-72*	6-02-72	6-20-72	7-6-72	7-19-72	8-2-72	8-23-72	9-7-72	9-21-72
C 04	ND	ND	Motor failure	Motor failure	Motor failure	Motor failure	ND	ND	ND
C 07	ND	ND	ND	"	ND	ND	ND	ND	ND
C 08	ND	ND	Motor failure	"	ND	ND	ND	ND	ND
C 18	ND	ND	ND	ND	Motor failure	ND	ND	ND	ND
C 26	ND	ND	Motor failure	Motor failure	ND	ND	ND	ND	ND

*Previously reported
#Installed new samplers on 8-23-72

GAMMA BACKGROUND to 9-30-72
TLD (mrem/hour)

Site	6-21-72	7-7-72	8-25-72	9-22-72	Mean
C 04	.020	.022	.018	.019	.020
C 07	.023	.021	No sample	.021	.022
C 08	.024	.021	.023	.018	.021
C 18	.019	.025	.018	.022	.021
C 26	.023	.021	.022	.033	.025
Mean	.022	.022	.020	.023	

PRECIPITATION — Gross Beta
pCi/1 Dissolved Solids

Site	4-14-72	5-2-72	6-20-72	7-6-72	8-23-72	9-21-72
C 07	6	9	ND	15*	ND	NA
C 18	ND	13	ND	12	NA	NA

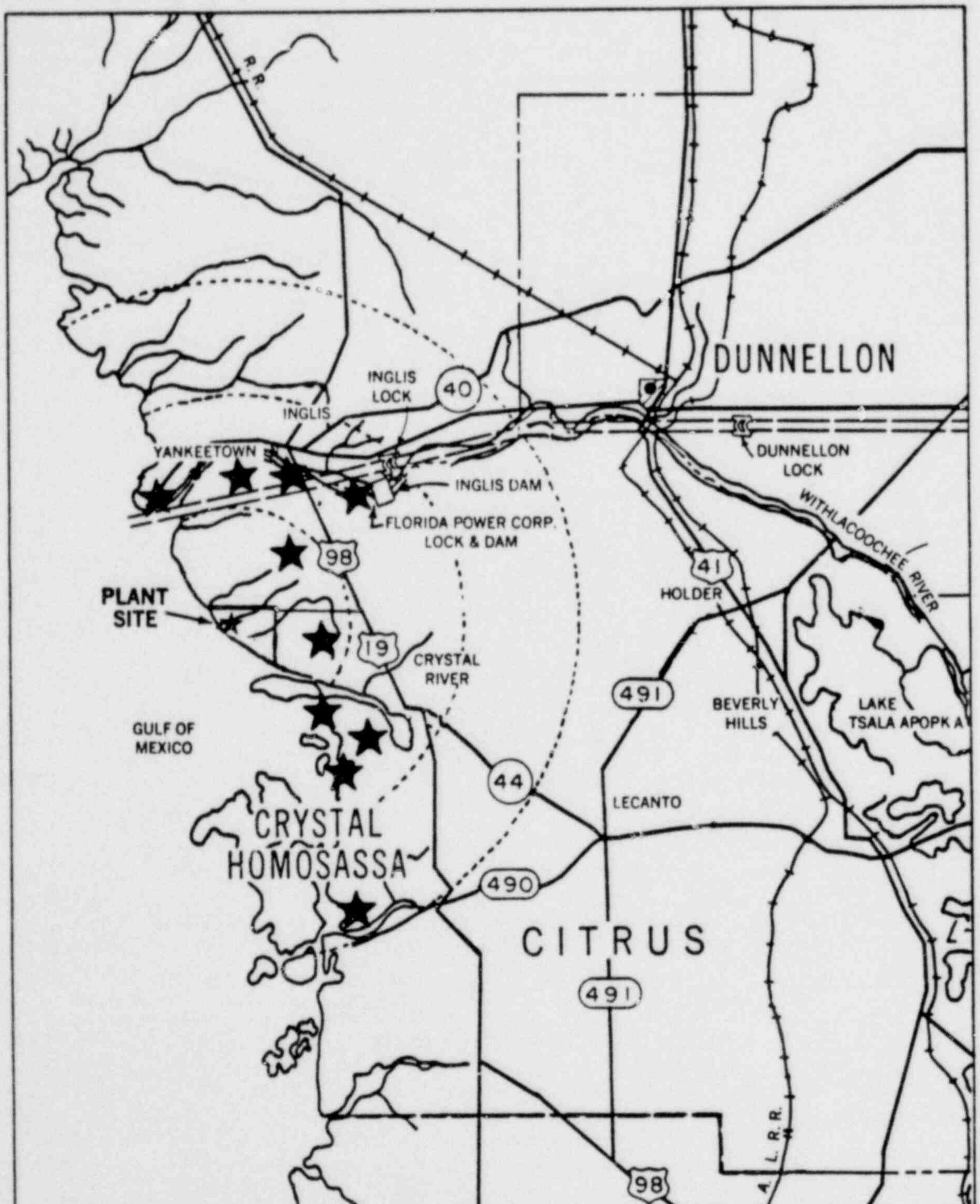
* 18 pCi/1 undissolved solids
NA Analysis not completed

PRECIPITATION — Tritium

Site	5-2-72	8-23-72
C 07	<200 pCi/1	<200 pCi/1
C 18	<200 pCi/1	<200 pCi/1

PRECIPITATION — Gamma Scan

Site	4-14-72	5-2-72	6-20-72	7-6-72	8-23-72	9-21-72
C 07	ND	ND	ND	ND	ND	NA
C 18	ND	ND	ND	ND	ND	NA



SOIL AND VEGETATION

VEGETATION AND SILT

Note: Data reported which are obtained from gamma spectroscopy have been calculated utilizing the new "least squares" program. This program is still under development and these data are subject to review and revision.

SOIL

GAMMA ANALYSIS

Site	Type	Date	I 131	Ba 140	Cs 137	K 40	Ce 144	Ru 106	Zr 95	Mn 54	Th 232	Zn 65	Ra 226	Cs 134	Co 58	Co 60
C 01	Soil	8-23-72									180 (53)		1200 (188)			
C 02	Soil	8-23-72											1100 (123)			
C 03	Soil	8-23-72			370 (21)						250 (70)		1100 (245)			
C 04	Soil	8-22-72			1100 (28)						200 (46)		550 (146)			
C 05	Soil	8-23-72			270 (21)				150 (47)		270 (70)		1600 (246)			
C 06	Soil	8-23-72			1600 (38)						210 (62)		1100 (197)			
C 08	Soil	8-23-72									300 (51)		1300 (183)			
C 09	Soil	8-23-72									150 (33)		680 (104)			
C 11	Soil	8-23-72							60 (27)		200 (40)		730 (124)			
C 12	Soil	8-23-72			120 (19)				130 (42)		280 (63)		1400 (224)			

SILT

GAMMA ANALYSIS

Site	Type	Date	I 131	Ba 140	Cs 137	K 40	Ce 144	Ru 106	Zr 95	Mn 54	Th 232	Zn 65	Ra 226	Cs 134	Co 58	Co 60	Gross Beta
C 01	Silt	5-2-72											520 (54)				ND
		8-23-72									260 (47)		1400 (167)				NA
C 09	Silt	5-2-72											500 (82)				ND
		8-23-72									300 (48)		1300 (170)				NA
C 13	Silt	5-2-72							120 (53)		400 (78)		2800 (285)				ND
		8-24-72											3300 (278)				NA
C 14	Silt	5-2-72									270 (86)		2400 (219)				ND
		8-24-72											1200 (174)				NA

( ) Calculation error

VEGETATION

GAMMA ANALYSIS

Site	Type	Date	I 131	Ba 140	Cs 137	K 40	Ce 144	Ru 106	Zr 95	Mn 54	Th 232	Zn 65	Ra 226	Cs 134	Co 58	Gross Beta
C 01	Cabbage Palm	4-14-72				6900 (593)			720 (113)							7206
		5-2-72				3900 (1378)			2200 (273)							
C 02	Cabbage Palm	4-14-72			1300 (49)	7700 (840)			680 (160)							7625
		5-2-72			1300 (70)	7500 (1144)			1300 (230)							NA
		8-23-72			880 (42)	5200 (705)										NA
C 03	Cabbage Palm	4-14-72			250 (9)											5176
		5-2-72			560 (90)	3400 (1552)			2500 (296)							NA
		8-23-72			260 (44)	5700 (710)										NA
C 04	Cabbage Palm	4-14-72			3500 (106)	5700 (1707)			590 (360)							7428
		5-2-72			2200 (79)	4100 (1280)	790 (254)		2400 (258)							NA
		8-22-72			670 (37)	5700 (626)			430 (115)				460 (105)			NA
C 05	Cabbage Palm	4-14-72			1800 (47)	3600 (794)			620 (152)							4370
		5-2-72			1500 (60)	5600 (1019)			2100 (1858)							NA
		8-23-72			1300 (56)	6600 (906)			350 (189)							NA
C 06	Cabbage Palm	4-14-72			6900 (162)	9600 (2613)			680 (550)							5698
		5-2-72			4500 (109)	7900 (1747)			840 (353)							NA
		8-23-72			450 (45)	3300 (783)			1200 (148)							NA
C 08	Cabbage Palm	4-14-72			2200 (77)	10,000 (1322)			1400 (251)							5945
		5-2-72				5200 (971)			2100 (183)							NA
		8-23-72			110 (46)	4800 (746)			560 (156)							NA
C 09	Cabbage Palm	4-14-72			210 (70)	7300 (1143)			2000 (247)							6282
		5-2-72			120 (48)	6000 (831)			1300 (154)							NA
		8-23-72			110 (39)	7900 (684)			510 (128)				370 (113)			NA
C 11	Cabbage Palm	4-14-72			190 (40)	5200 (701)			260 (133)							4823
		5-2-72			160 (70)	6400 (1146)	1000 (227)		2400 (449)							NA
		8-23-72				5000 (867)			1500 (189)							NA
C 12	Cabbage Palm	4-14-72			330 (80)	8400 (1295)			1600 (275)							7717
		5-3-72			350 (49)	4900 (857)			7100 (155)				400 (143)			NA
		8-23-72			530 (41)	7400 (705)			260 (132)				360 (116)			NA

( ) Calculation error

MILK

GAMMA ANALYSIS

Site	Type	Date	I 131	Ba 140	Cs 137	K 40	Ce 144	Ru 106	Zr 95	Mn 54	Th 232	Zn 65	Ra 226	Cs 134	Co 58	Co 60
C 25	Milk	8-24-72				1200 (180)										

FOOD CROP

GAMMA ANALYSIS

Site	Type	Date	I 131	Ba 140	Cs 137	K 40	Ce 144	Ru 106	Zr 95	Mn 54	Th 232	Zn 65	Ra 226	Cs 134	Co 58	Sr 90
C 19	Oranges	5-3-72				3000 (215)										105.2

BIOTA

GAMMA ANALYSIS

Site	Type	Date	I 131	Ba 140	Cs 137	K 40	Ce 144	Ru 106	Zr 95	Mn 54	Th 232	Zn 65	Ra 226	Cs 134	Co 58	Sr 90	Gross Beta
C 08	Fiddler Crab	5-3-72				1900 (546)			130 (36)		240 (54)		1500 (195)			380.3	4828
C 12	Blue Crab	5-3-72				1600 (313)							830 (94)			NA	3732
C 13	Hard-Tail Jack	5-4-72				2900 (187)										NA	3611
	" " "	8-24-72				2900 (1282)							1200 (447)				
C 14	Hard-Tail Jack	5-4-72				3200 (208)										2.58	4092

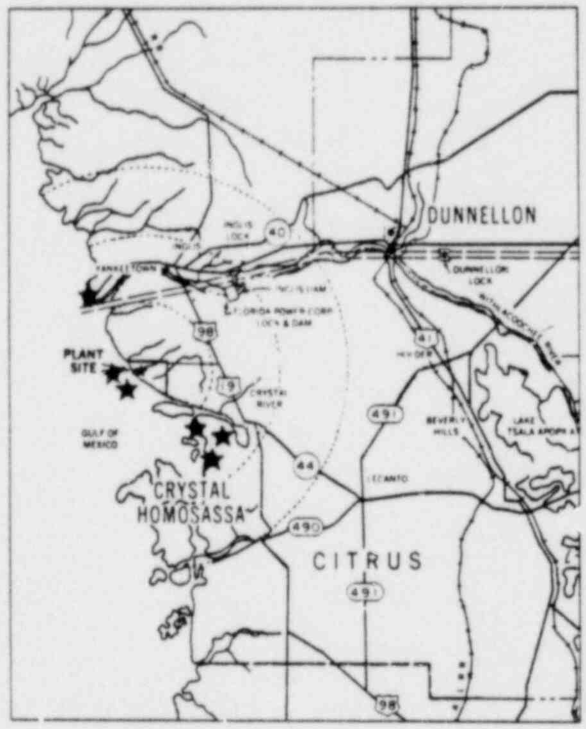
ALGAE

GAMMA ANALYSIS

Site	Type	Date	I 131	Ba 140	Cs 137	K 40	Ce 144	Ru 106	Zr 95	Mn 54	Th 232	Zn 65	Ra 226	Cs 134	Co 58	Co 60	Gross Beta
C 01	Turtle Grass	8-23-72							300 (154)								
C 13	Turtle Grass	8-24-72				5300 (663)											
C 14	Turtle Grass	8-24-72							720 (219)								

( ) Calculation error

DRINKING WATER



SEAWATER SAMPLING

WATER

GAMMA ANALYSIS

Site	Type	Date	I 131	Ba 140	Cs 137	K 40	Ce 144	Ru 106	Zr 95	Mn 54	Th 232	Zn 65	Ra 226	Cs 134	Co 58	H 3	Gross Beta
C 07	Well	5-2-72														<200	
		8-24-72														<200	
C 08	Seawater	5-3-72														<200	39
		8-23-72														<200	
C 09	Seawater	5-3-72														<200	124
C 10	Well	5-3-72														<200	ND
		8-23-72														<200	
C 11	Seawater	5-3-72														<200	212
		8-23-72				360 (174)										<200	
C 12	Seawater	5-3-72														<200	19
		8-23-72														<200	
C 13	Seawater	5-4-72														<200	287
		8-24-72				350 (153)										<200	
C 14	Seawater	5-4-72														<200	246
		8-24-72				400 (110)										<200	
C 15	Surface	5-2-72														<200	ND
		8-23-72														<200	
C 16	Surface	5-2-72														<200	ND
		8-23-72														<200	
C 17	Surface	5-2-72														<200	ND
		8-23-72														<200	
C 18	Well	5-2-72														<200	26
		8-23-72														<200	
C 22	Well	5-2-72														<200	ND
		8-22-72				340 (156)										<200	
C 23	Well	5-2-72														<200	ND
		8-22-72														<200	
C 24	Well	5-4-72														<200	ND
		8-24-72														<200	

( ) Calculation error

appendix f

radiation

SURVEILLANCE REPORT

PINELLAS COUNTY HEALTH DEPARTMENT

George R. McCall

Staff

Mrs. Russell Hobbs

The following data are a summary of air monitoring results and rainfall collections taken in St. Petersburg, Florida for the period June-September, 1972.

The approximate air volume on which the determinations are based was 2100 cubic meters for the 48-hour sampling periods and 3100 cubic meters for 72-hour periods. The counting equipment consists of a thin end window (2mg/cm^2) Geiger-Mueller tube coupled with a Packard Mod.410A scaler-timer system. On each occasion, the instrument is standardized against a 32,000 pci Strontium-90 calibration source of dimensions identical to the air filters.

PINELLAS COUNTY HEALTH DEPARTMENT

RADIATION SURVEILLANCE QUARTERLY REPORT

JULY 1 — SEPT. 30, 1972

DATE (1971)	AIR Gross Beta Activity (pCi/m^3)	RAINFALL (mm)	REMARKS
7/4	0.195	0	
7/5	0.275	17.95 mm	
7/7	0.174	0	
7/10	0.132	0	
7/12	0.141	0	
7/14	0.103	20.35 mm	
7/17	0.089	0	
7/19	0.0926	2.825 mm	
7/21	0.087	4.4 mm	
7/24	0.129	0	
7/26	0.0605	0	
7/28	0.178	0	
7/31	0.098	7.45 mm	
8/2	0.081	0	
8/4	0.181	0	
8/7	0.108	2.225 mm	
8/9	0.144	0	
8/11	0.099	2.35 mm	
8/14	0.078	0	
8/16	0.051	15.32 mm	
8/18	0.112	46.40 mm	
8/21	0.16	0	
8/23	0.00989	60.96 mm	
8/25	0.044	25.9 mm	
8/28	0.04	66.61 mm	
8/30	0.0225	0	
9/1	0.103	9.8 mm	
9/4	0.0157	0	
9/6	0.127	0	
9/8	0.109	16.85 mm	
9/11	0.090	0	
9/13	0.105	0	
9/15	0.053	0	
9/18	0.204	0	
9/20	0.229	5.0 mm	
9/22	0.170	0	
9/25	0.069	0	
9/27	0.0903	14.50 mm	
9/29	0.094	0	

George R. McCall

George R. McCall
Public Health Physicist, Division of
Radiological & Occupational Health

appendix g

A SUPPLEMENTARY ZOOPLANKTON SURVEY AT THE CRYSTAL RIVER PLANT SITE

University of Florida

Department of Zoology

Principal Investigator
Dr. Frank J.S. Maturo, Jr.

Graduate Assistant
John W. Caldwell

INTRODUCTION

This project was initiated to: 1) determine the presence of major food chain species and the planktonic forms of commercially important finfish and shellfish in the area adjacent to the Crystal River plant site; 2) qualitatively assess the occurrence of these organisms within the intake area of Units 1 and 2 as a means of evaluating the entrainment potential of these organisms.

REVIEW OF ACTIVITIES

Four sampling areas were established as a result of a preliminary survey made shortly after project funding in mid-July (Fig. 1, page 114). Station 1 is located inshore south of the intake canal. The station is within 25 yards of the coastal marsh, the depth being 2 ft. at MLW. The bottom substrates in this area consist of attached *Sargassum* and sandy patches between limestone outcrops. The salinity is noticeably influenced by the freshwater drainage from the Crystal River and adjacent marshes (Fig. 2).

Station 2 is also south of the intake canal and is located midway between Station 1 and the canal opening, a distance of 1.2 nautical miles offshore. The substrate in this area is sand and shell between prominent oyster bars. The depth is 4 ft. at MLW. The salinity is consistently higher than that at Station 1 (Fig. 2).

Station 3 is southwest of the intake canal opening in an area which appears to be the source of the entrained water. The depth is 7 ft. at MLW; the substrate is hard sand. The salinity is slightly but consistently higher than Station 2 (Fig. 2).

Station 4 is located just in front of the intake screens of Units 1 and 2. The depth is 15 ft. at MLW. The substrate appears to be a fine coal dust sediment. The salinity is essentially the same as that of Station 3 (Fig. 2).

Initially, 10 minute plankton tows were made using 50cm. dia. nets with 202 micron and 80 micron mesh. Because of the high level of suspended matter, the nets clogged quickly and prevented accurate metering of the water column sampled. After several trials, the best tow duration was found to be 1 minute. Use of the 80 micron mesh net was discontinued because of the clogging effect of the suspended matter.

The sampling regime established for each station consists of two 1-minute horizontal surface tows at biweekly intervals. Samples are preserved in buffered formalin and returned to the laboratory.

The following procedures are employed for examination of each sample. The two samples from each station are pooled prior to splitting. One half of the total sample is separated in a sieve series with standard mesh sizes of Nos. 10, 20, 30, 60 and 120. Five 7 ml. aliquots are removed from each mesh size screen for qualitative and quantitative determinations of organisms.

Qualitative determinations are made by use of the following categories:

- Copepods:
  - Calanoid
  - Harpacticoid
- Mollusc veligers:
  - gastropods
  - bivalves
    - Oyster *(Crassostrea)* (if possible)
    - others
- Barnacle larvae
- Shrimps
- *Penaeus*
  - others (mysids, etc.)
- Crab larvae
  - stone crab *(Menippe)* (if possible)
  - blue crab *(Callinectes)* (if possible)
  - others
- Lobster larvae
- Other Crustaceans
  - (subdivided, if found pertinent)
- Polychaetes
- Echinoderms
- Chaetognaths
- Tunicates
- Medusae (including siphonophores)
- Miscellaneous invertebrates
- Eggs
- Fish eggs
- Fish larvae

Biomass determinations are made based on the sieve separation scheme. The method provides a more accurate estimation than the traditional procedures. This gravimetric procedure, devised by Mr. Clay Adams (Masters Thesis, UF 1972), involves mechanically separating zooplankton using a set of paleontological sieves, making a random sample of the individual fractions; determining the percent composition of each fraction by recording counts per zooplankton type divided by the total count of all zooplankton in the fraction sample; vacuum filtering each sieve fraction onto a preweighed Whatman No. 42 filter disc; oven-drying loaded discs and weighing each to determine the dry weight of fraction; and finally compiling the weights and percentages of the several sieve fractions to determine the dry-weight percentage composition of the zooplankton types.

The sieve separation facilitates counting procedures because it sorts organisms to size and reduces the number of species per sample.

The sampling program was begun July 24, 1972 and continues at biweekly intervals. Because the project is in its first quarter, we do not have sufficient data processed for presentation at this time.

GOALS FOR THE FOLLOWING QUARTER

The sampling program will be continued as described above. As familiarity with species types develops, we plan to catch up on the backlog of samples. As data accumulates, statistical analyses will be applied.

LITERATURE CITED

Adams, C.A. 1972

Food Habits of Juvenile Pinfish *(Lagodon rhomboides)*. Silver Perch *(Bairdiella chrysura)*, and spotted Seatrout *(Cynoscion nebulosus)* of the Estuarine Zone near Crystal River, Fl. Unpublished Masters Thesis, Graduate School, University of Florida.

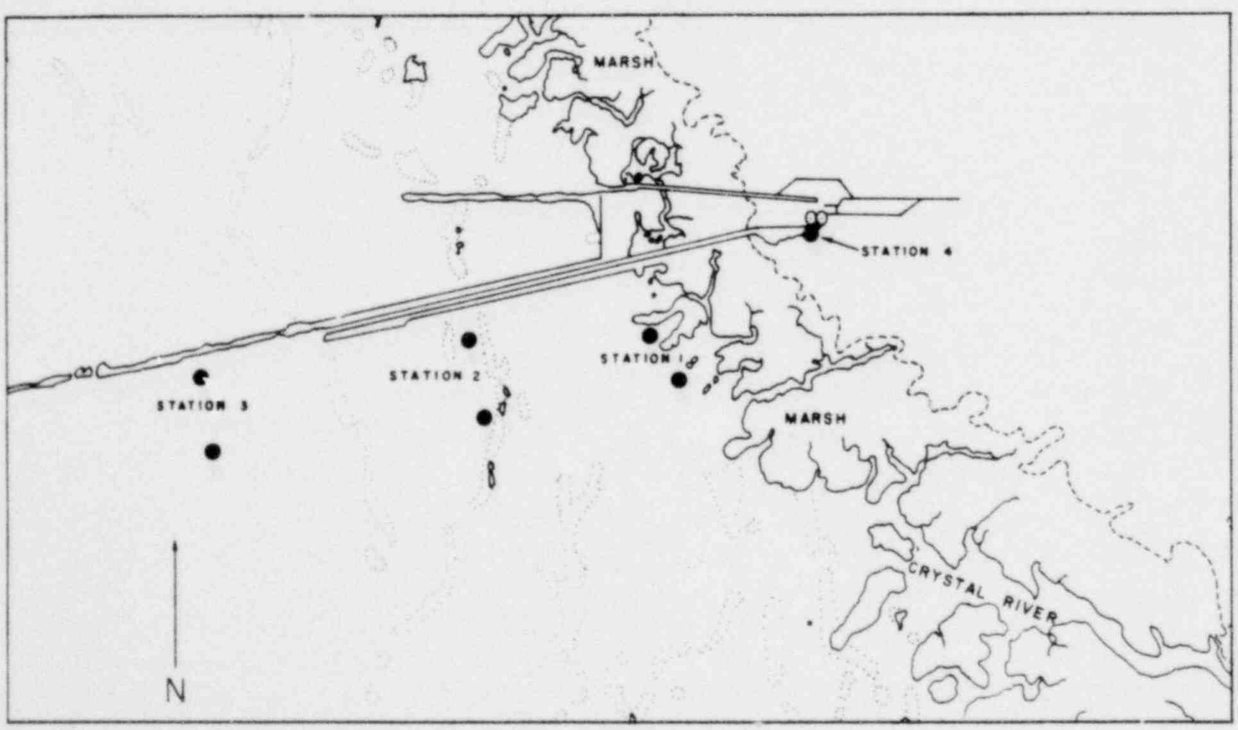


Figure 1. Map of Crystal River area showing collecting stations.

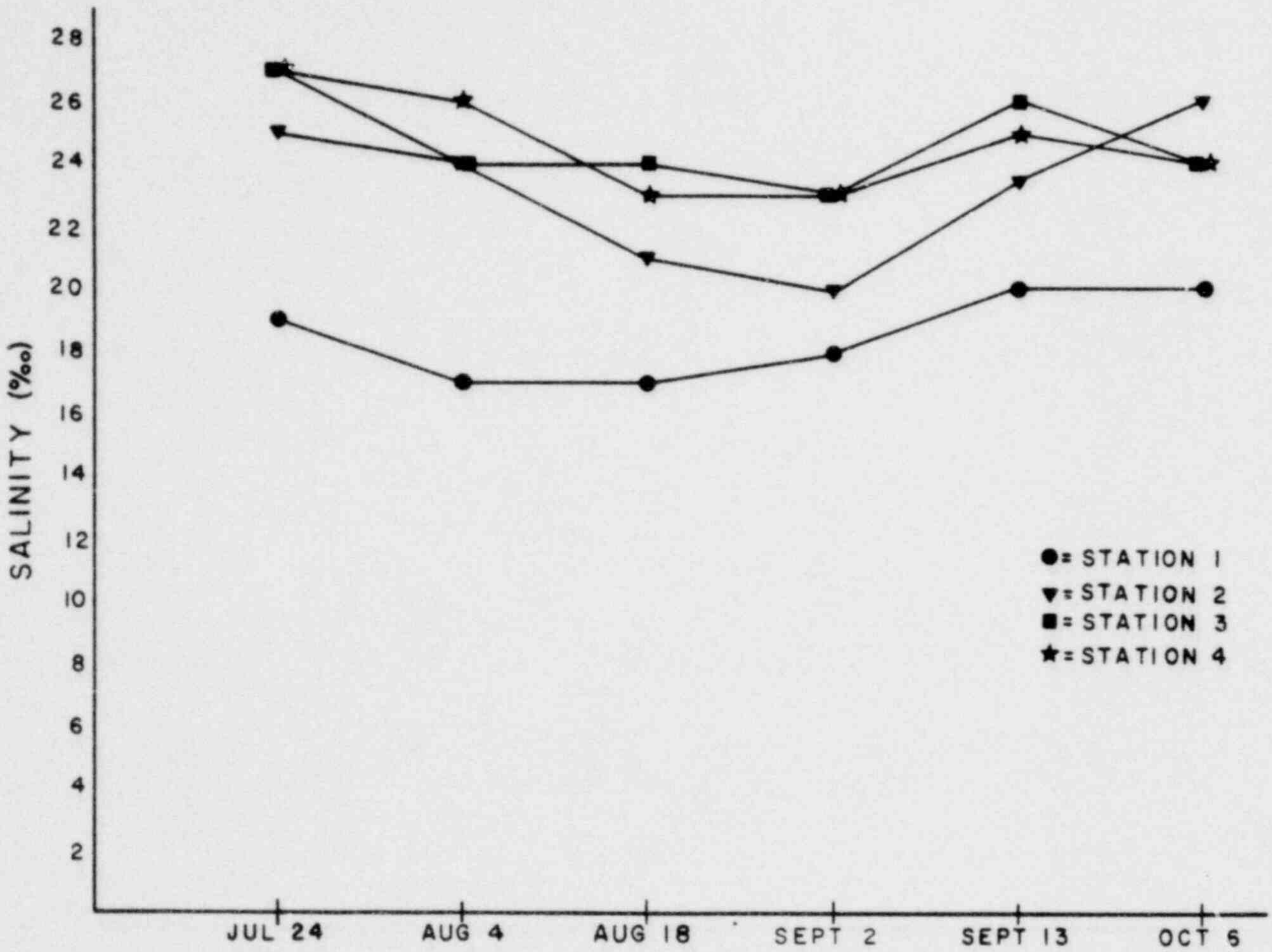


Figure 2. Salinity at the collecting stations on the sampling dates.

appendix h

THE BENTHIC invertebrate COMMUNITY ADJACENT TO WEEDON ISLAND, TAMPA BAY, FLORIDA

Progress Report

April-September 1972

Thomas E. Pyle
Norman J. Blake
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James Seagle
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Technical Report no. 13
September 1972

INTRODUCTION

The study of the marine environment adjacent to Florida Power Corporation's P.L. Bartow generating plant on Weedon Island officially began in April of 1972. Under the contract, the first six months were to be devoted primarily to recruiting and equipment purchasing with the first surveys to be conducted in late September. Therefore, the report which follows is primarily the result of a preliminary examination of the area conducted in the summer of 1972.

PRELIMINARY RESULTS

Seagrass mapping

The study was initiated with an aerial reconnaissance and photographic overflight in May 1972. Using techniques developed for the Anclote project (Feigl *et al.*, 1972), false color IR photographs were taken for the purpose of mapping seagrass beds and other bottom types adjacent to the power plant. This work is not complete, but the photographs have been used to plan the positions of the first bottom sampling transects.

Benthic survey

An investigation of the sea bottom community north and east of the P.L. Bartow power station was begun on June 15, 1972. The study included the establishment of a preliminary sampling program to determine the size and number of bottom samples needed to represent a valid sample of the benthic fauna and to obtain baseline information on the types of organisms and their relative abundance.

Two transects were established on the east side of the plant: one north and one south of the intake channel (Figure 1). Both transects run due east from shore, approximately 75 meters north (transect 1) and south (transect 2) of the turning basin, across the grass flats and into the deeper sand area toward the end of the channel. Each transect extends a distance of approximately 600 meters.

Both transects were examined with skindiving gear and the bottom was characterized according to areal percentage of sand and seagrass. At each significant change in the bottom type, water depth and distance from shore was recorded. From this information, bottom profiles for the two transects were drawn (Figures 2 and 3). The mapping of a third transect was also undertaken (Figure 4). This transect was located on the north side of the intake canal running due east from the middle of the northern boundary of the turning basin. The third transect was not considered sufficiently different to warrant sampling during this preliminary survey.

Detailed visual observations along these transects and spot observations in other areas have been combined with information from aerial photographs to produce a preliminary map of bottom types adjacent to the plant site (Figure 5).

Six stations were occupied along transects I and II (Figure 1) in order to sample the major habitats with regard to depth and bottom type (Table 1). A total of 18 samples were taken from each of the 12 stations. Fourteen of the samples (81 cm^2 plugs) were taken with a 9 x 9 cm bottom sampler which is similar to the one being utilized in the Anclote benthic survey (see Anclote Annual Report 1971, Baird *et al.*, 1972). These samples will be compared to 4 samples (225 cm^2 plugs) taken with a 15x15 cm sampler. All of the above mentioned sampling has been completed and the samples are now being sorted.

Transect selection along the northwestern flat has been delayed by innumerable equipment malfunctions and logistical problems. Prior to the establishment of sampling stations in this area, STD readings at various tidal stages are required to obtain an estimate of the extent of the thermal plume. Thermographs ordered for this purpose have not been received.

Although definitive temperature data are not presently available, release of dye in conjunction with aerial photography on September 14, 1972 indicates that the plume may not follow the outfall channel. The position of the dye plume approximately 15 minutes after release is shown in Figure 5.

Figures and Table 1 are shown on pp. 120-123.

REFERENCES

Baird, R.C. *et al.* 1972. Anclote Environmental Project Report 1971. Mar. Sci. Inst., U. of South Florida. 251 pp.

Feigl, J., T.E. Pyle, R. Clingan and R. Zimmerman. 1972. Aerial mapping of seagrass beds. Abstract. Quarterly Jour. Fla. Acad. Sci., 35 (1):32.

Table 1. Descriptions of sampling stations

Transect	Station	Distance from shore (meters)	Description	Depth (cm)
I	A	15	Sand — 100%	63
I	B	70	*Syringodium* — 25% *Thalassia* — 75%	133
I	C	290	Sand — 25% *Diplanthera* — 5% *Syringodium* — 70%	127
I	D	585	*Diplanthera* — 100%	119
I	E	600	*Syringodium* — 100%	91
I	F	620	Sand — 100%	155
II	A	15	Sand — 100%	70
II	B	215	Sand — 20% *Syringodium* — 10% *Diplanthera* — 70%	103
II	C	500	*Diplanthera* — 100%	116
II	D	510	*Thalassia* — 50% *Diplanthera* — 50%	126
II	E	530	*Syringodium* — 100%	122
II	F	595	Sand — 100%	142

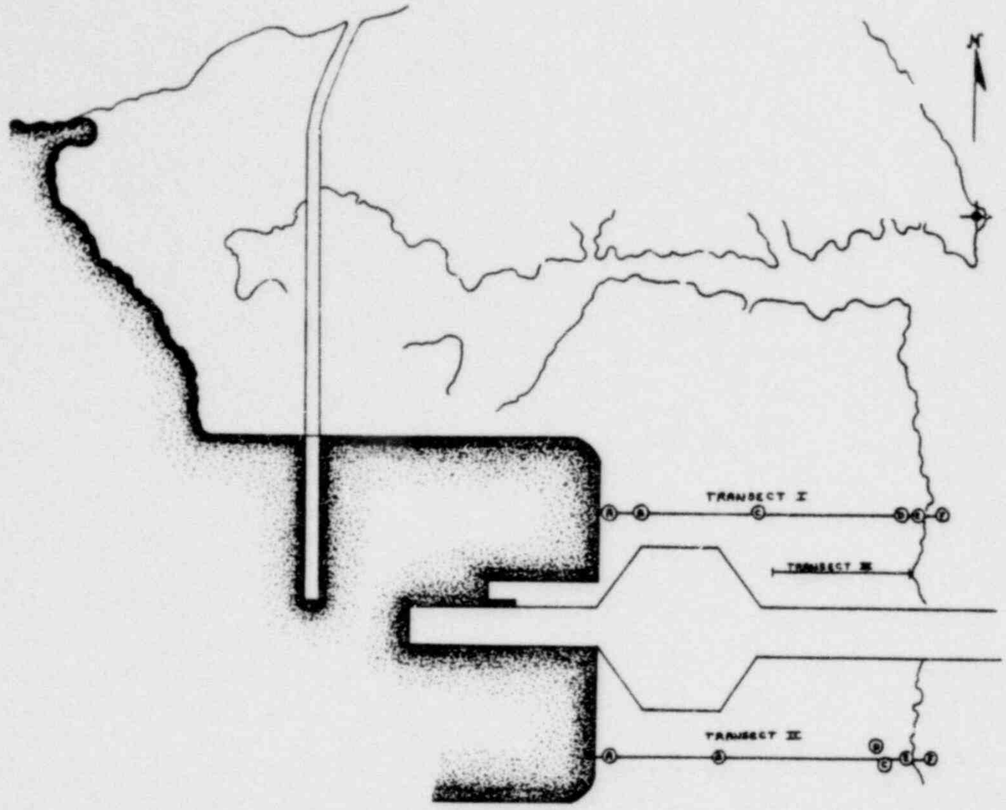
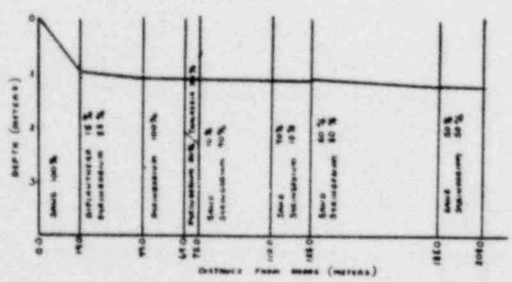
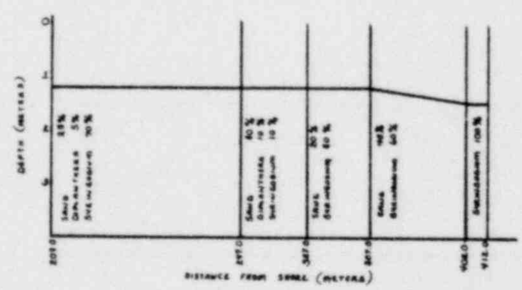


Figure 1. Location of transects and sampling stations in the area adjacent to the Bartow power plant

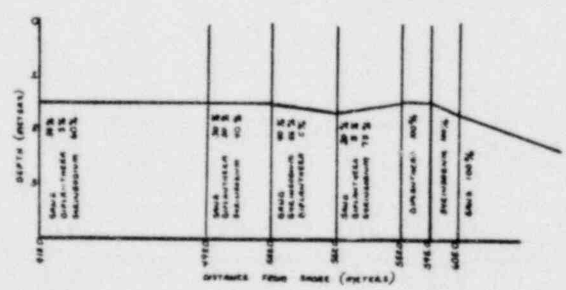


A



B

Figure 2A-C. Transect I — bottom profile.



C

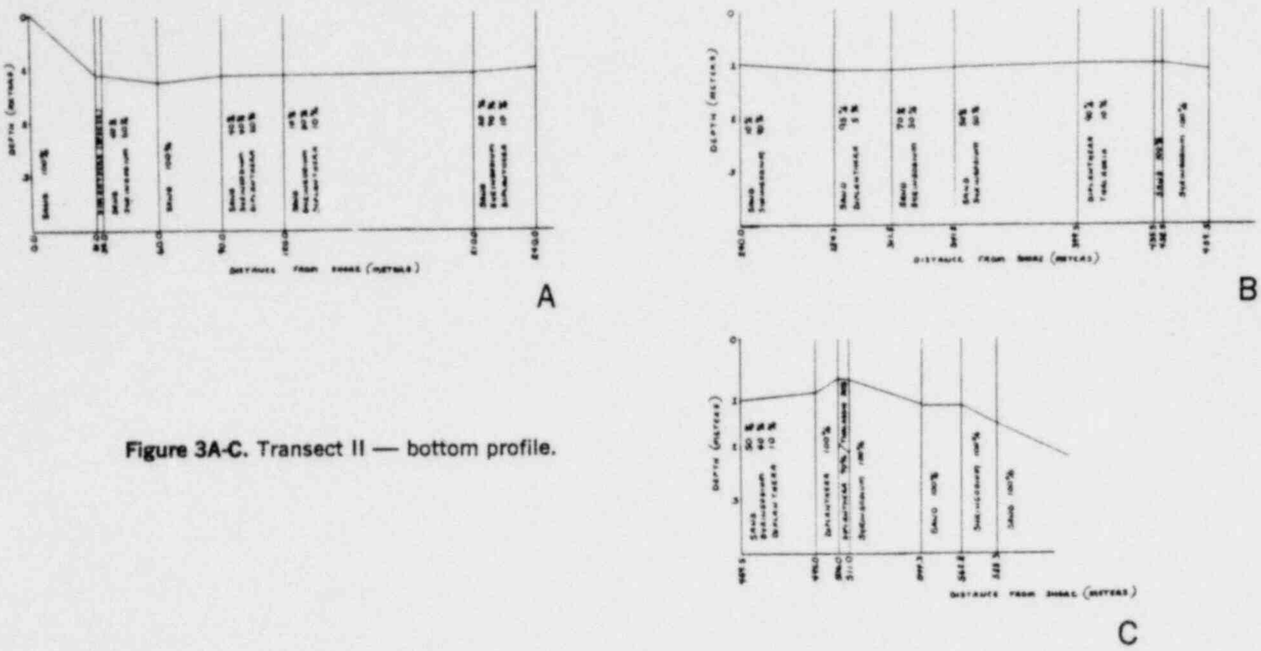


Figure 3A-C. Transect II — bottom profile.

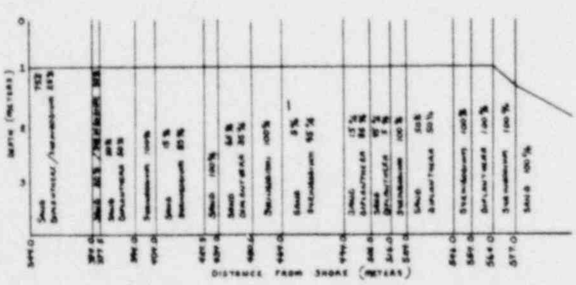


Figure 4. Transect III — bottom profile.

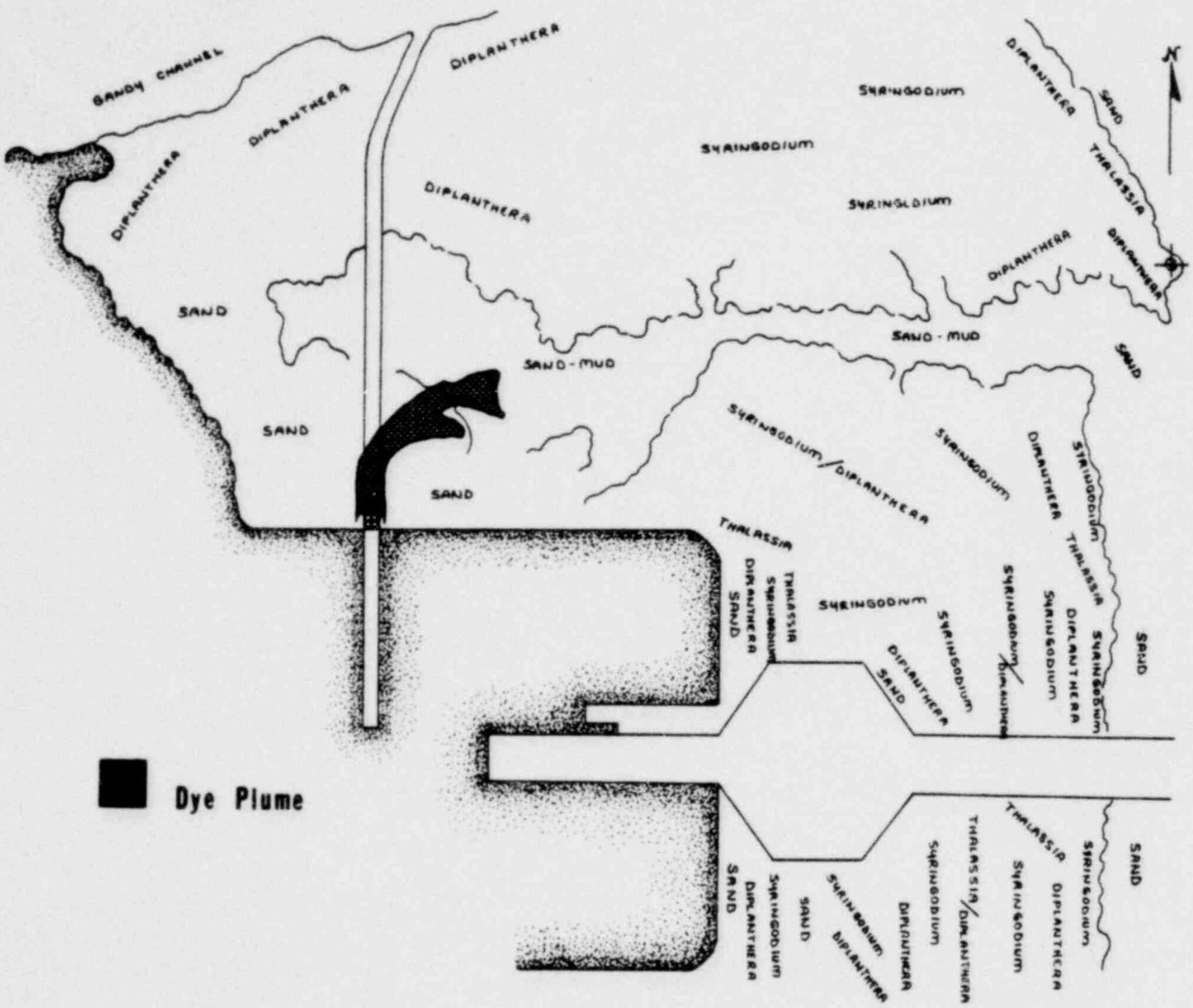


Figure 5. Preliminary map of the distribution of seagrasses in the area adjacent to the Bartow power plant.

appendix i

anclote

ENVIRONMENTAL PROJECT

PROGRESS REPORT

October 1972

Prepared for:
FLORIDA POWER CORPORATION

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INTRODUCTION

The Anclote Environmental Report for 1971 has now been published and is available to all interested in an assessment of the marine environment near the Anclote Power generating facility. This report contains under one cover as much detailed environmental information as can be found for a similar area of the west coast of Central Florida and should be of interest to all concerned.

Of particular interest is the completion of two technical reports. One concerns plankton studies at Anclote while the other is an annotated bibliography of seagrasses. The second report is considered a major contribution to an assessment of seagrass beds and related research at Anclote in view of the extent and known biological importance of seagrass beds in the Anclote region. Both of these reports are included in this progress report.

The proposed monitoring and surveillance system at Anclote is in the final planning stages. The system will measure temperature, light, and current at various key locations in the Anchorage. This system provides critical input for many aspects of the Anclote project. The system would provide:

a) unbiased consistent documentation of the actual changes which occur in the anchorage in the parameters measured;

b) a measure of the variability and rates of change which occur over short spans of time;

c) a level of data input consistent with the synopticity and microhabitat coverage required for appreciation of difference in the habitats and importantly for accurate modeling;

d) a data base from which unbiased accurate estimates of "background" values could be established in relation to regulatory policy (e.g., thermal addition, JTU's for controlled dredging);

e) a data base in order to develop a more comprehensive and fundamental understanding of the interactions of light, currents, temperature, and substrate on the distribution of marine organisms particularly the seagrasses.

1) Biological sampling including examination of seagrass growth parameters will be centered around the fixed recording stations.

2) Sedimentological analyses and other physical and chemical measurements will be taken at these stations and correlation of these parameters with distribution of organisms (seagrasses particularly) can be made and changes documented.

3) Additional funds for support of controlled experiments (submitted to N.S.F.) on seagrass growth, light requirements, and physiological compensation would provide a theoretical basis for correlating actual field observations of grasses and measurements taken from the instruments.

SUB-DISCIPLINE REPORTS

Geological: A simultaneous bottom sampling program with the benthic ecology group was completed during the summer. Emphasis was placed on obtaining samples in the seagrass beds especially those adjacent to the planned discharge canal. Analyses of benthic organisms will be correlated with sediment properties.

Aerial observation and photography continued at a somewhat reduced frequency. A paper presenting the economical techniques developed for the Anclote project is being prepared for publication by T. Pyle and J. Feigl. Surprisingly, requests for details of our simple technique have even come from workers at NASA.

Transmissometer measurements have also continued at a reduced pace. A paper discussing these data is being prepared by T. Pyle and J. McCarthy. Preliminary data from two surveys are included with this progress report. More intensive surveys in the immediate vicinity of the discharge channel will commence shortly and will be coordinated with measurements from the buoys as soon as they are installed.

Also included with this report (see enclosure) are brief descriptions of the results of two surveys of suspended sediments in waters above the grass beds adjacent to the discharge channel site. The data for June 21, 1972 are extremely interesting because they were obtained soon after the passage of Hurricane

Agnes. This was obviously the time of highest turbulence in the Anclote area during the preconstruction phase of our study.

Physical: The physical section has been involved with the hydrological model at Anclote. The initial computer runs are now being made and results will appear in the Anclote Environmental Report for 1972. **Plankton** (see enclosed Technical Report #12)

Seagrasses and Algae (see enclosed Technical Report #14): A study of the non-epiphytic algae has been initiated and reports on the systematics and ecology of seagrasses will appear in the Environmental Project for 1972.

Benthic Invertebrates: Dr. Norman Blake, a new faculty appointee will supervise the benthic effort at Anclote. At present the major effort has been involved with sorting the considerable backlog of samples collected over the past year.

Fish: This winter will complete a full year of systematic sampling of the fishes at Anclote. A series of experimental trawling and seining experiments have been initiated to better assess sampling bias and improve methodology. A detailed investigation of the Fyke net study is well along and results will appear in the Project Report for 1972.

Light Transmissivity

May 2, 1972 (0740-1003 D.S.T.)
Tides: H) 0334 D.S.T.
L) 0801 D.S.T.
H) 1407 D.S.T.

Transmissivity in Anclote Anchorage ranged between 64 and 89% T/10cm. With the exception of one possibly erroneous point (68% T), observed in the data between markers 3 and 6 (in Anchorage), the lowest values were recorded in the river channel between markers 3 and 7x (64-72% T/10cm), the highest values 87-89% T/10cm) were recorded off Bailey's Bluff, as in the majority of previous surveys.

A surface slick of undetermined dimensions was encountered west of marker 3 approaching the south end of Dutchman Key. It was aligned approximately NNE-SSW, paralleling Anclote Key, and was outlined by floating seagrasses. Turbidity measurements increased slightly west of marker 3 (80-84% T/10cm), but dropped off to 75% after crossing the western boundary of the slick.

Position	Time (D.S.T.)
RCMrk 13	0741
RCMrk 1	0806
Mrk 10	0814
Mrk 74	0821

Light Transmissivity

September 15, 1972 (0735-1214 E.S.T.)
Tides: H) 0303 E.S.T.
L) 1049 E.S.T.
H) 1834 E.S.T.

Transmissivity in Anclote Anchorage ranged between 50 and 75% T/10cm. The lowest values were recorded between Rabbit Key and Howard Park (43-50% T/10cm), while the highest values were observed just south of Anchorage marker 6 (68-72% T/10cm).

In the area between Rabbit Key and Howard Park, where the lowest readings were obtained, a foam line and numerous floating dead fish were observed.

Position	Time (E.S.T.)
RCMrk 17	0742
RCMrk 3	0806
AMrk 3	0821
Radar Station	0836
AMrk 6	0902
Bailey's Bluff	0931
AMrk 1	0957
AMrk 6	1015
So. Dutch. Key	1035
AMrk 3	1051
AMrk 7x	1114
Rabbit Key	1134
Howard Park	1143
ICMrk 40	1200
RCMrk 1	1214

Suspended Sediment
June 21, 1972

Tides:
H) 0722 Sampling Time: 1130-1230
Middle of ebb tide
L) 1536 Seas 4-6 ft.

Range of Total Suspended Load
(TSL):3.6-63.6 mg/1
Highest TSL at station 3 (grid #15156)
Lowest TSL at station 10 (grid #18071)
Range of Inorganic Fraction
(IOF):0.8-36.4 mg/1
Highest IOF at Station 3 (grid #15156)
Lowest IOF at station 10 (grid #18071)
Range of Percent Inorganic Fraction
in TSL:11.4-57.2%
Highest % inorganic at station 3 (grid #15156)
Lowest % inorganic at station 7 (grid #16106)
Range of Turbidity in JTU's:4.1-46
Highest JTU at station 3 (grid #15156)
Lowest JTU at station 11 (grid #18103)

Suspended Sediment
August 30, 1972

Tides:
H) 1718 Sampling Time: 1130-1230
End of ebb tide
L) 1041 Seas calm

Range of Total Suspended Load
(TSL):3.45-12.30 mg/1
Highest TSL at station 3 (grid #15156)
Lowest TSL at station 9 (grid #17083)
Range of Inorganic Fraction
(IOF):0.60-6.30 mg/1
Highest IOF at station 3 (grid #15156)
Lowest IOF at station 11 (grid #18103)
Range of Percent Inorganic Fraction
in TSL:16.67-59.89%
Highest % inorganic at station 4 (17148)
Lowest % inorganic at station 11 (18103)
Range of Turbidity in JTU's:2.5-7.9
Highest JTU at station 4 (grid #17148)
Lowest JTU at station 11 (grid #18103)

There appears to be a general trend of high inorganic values in Area III and low inorganic values in Area II. The influence of river discharge is greatest in Area III and this may be the dominant source of inorganic material on days with calm seas (August 30). On days with high seas (June 21) wave action is probably the dominant factor with river discharge secondary. A wide natural range of TSL and other parameters under natural conditions can also be seen with the exceptions of stations 1, 10 and 13. These three stations have relatively narrow ranges possibly due to a sort of "sheltering effect" from the river channel at station 1 and broad grass beds underlying the nearshore stations 10 and 13.

Turbidity readings were obtained by the use of a Hach 2100A Turbidimeter and are expressed in Jackson Turbidity Units. These readings tend to be higher in Area III than in Area II, thus lending support to the above conclusions.

ANCLOTE ENVIRONMENTAL PROJECT

Technical Report No. 12

PRELIMINARY REPORT OF THE ZOOPLANKTON OF THE ANCLOTE RIVER ESTUARY

by
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August 1972

Zooplankton program for the Anclote Environmental project was initiated September, 1970. Fourteen stations were established (sampled monthly) throughout the study area including locations near the proposed intake and discharge canals. Zooplankton was collected by sieving 50 1 of surface water through 62 micron mesh gauze.

A list of species identified thus far is in Table 1 (page 143). Community structure was found to vary with changes in salinity and season, copepod nauplii being dominant in all samples. Copepod adults ranked second in abundance. Dominant copepods during this time were *Oithona brevicornis, Paracalanus crassirostris,* and *Acartia tonsa,* species typically prevalent in estuarines of the southeastern United States (Gillespie, 1971; McIlwain, 1968; Hopkins, 1966; Woodmansee, 1958; Simmons, 1957). Benthic invertebrate larvae are also important as has been found in other Gulf coast estuaries (Gillespie, 1971; Kelly and Dragovich, 1967; Hopkins, 1966). The principal types were pelecypod and gastropod veligers and polychaete larvae, as Hopkins (1966) found in St. Andrews Bay, Florida. The appendicularians *Oikopleura dioica* and *Oikopleura longicauda* contributed significantly to zooplankton numbers, the dominant species depending on salinity. *Sagitta tenuis* was found to be the major chaetognath species with importance depending also on season and salinity. Fish eggs and larvae were found only occasionally and were scarce when encountered. Zooplankton numbers decreased during the winter months with the most conspicuous decline in both numbers and diversity being recorded in January, 1971. Numbers and diversity increased in the spring with a peak occuring in May, 1971.

Further research is planned to investigate diurnal vertical variations and fluctuations at selected sampling points over a tidal cycle of zooplankton abundance. Effects of plankton patchiness on sampling methods will also be assayed.

LITERATURE CITED

Gillespie, M.C. 1971. Analysis and treatment of zooplankton of estuarine waters of Louisiana. In *Cooperative Gulf of Mexico Estuarine Inventory and Study, Louisiana.* Louisiana Wild Life and Fisheries Commission.

Hopkins, T.L. 1966. Plankton of the St. Andrew Bay System of Florida. Publ. Inst. Mar. Sci. Univ. Tex., 11:1?-64.

Kelly, J.A. and A. Dragovich. 1967. Occurrence of macrozooplankton in Tampa Bay, Florida and the adjacent Gulf of Mexico. Fish. Bull. 66(2): 209-221.

McIlwain, T.D. 1968. Seasonal occurrence of the pelagic Copepoda in Mississippi Sound. Gulf Research Reports 2(3):257-270.

Simmons, E.G. 1957. An ecological survey of the Upper Laguna Madre of Texas. Publ. Inst. Mar. Sci. Univ. Tex., 4(2):156-200.

Woodmansee, R.A. 1958. The seasonal distribution of the zooplankton off Chicken Key in Biscayne Bay, Florida. Ecology, 39(2):247-262.

ANCLOTE ENVIRONMENTAL PROJECT

Technical Report No. 14

AN ANNOTATED BIBLIOGRAPHY OF THE SEAGRASSES OF THE GULF OF MEXICO

by
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October 1972

INTRODUCTION

The following bibliography is intended for any-one interested in the ecology of seagrass communities in the Gulf of Mexico. All major publications of direct interest to the area are included, as are selected papers pertaining to various localities in the Gulf. Where particularly useful, papers from other areas are included, as are those which pertain primarily to investigative techniques and to biotic communities associated with seagrass beds. Taxonomic and anatomical works are also included for reference. While this bibliography is not intended to be complete, it is considered a good review of present state of knowledge of these plants as well as a reasonably comprehensive introduction to the literature.

Anderson, R.R., 1969. Temperature and rooted aquatic plants. *Chesapeake Sc.* 10(3&4):157-164.

Respirometer techniques were used to determine effects of heat on respiration and photosynthesis of *Ruppia maritima* and *Potamogeton perfoliatus*. Oxygen consumption increased with temperature until the thermal death point, ca. 45°C.

Arber, A., 1920. Water Plants — A Study of Aquatic Angiosperms. *Cambridge U. Press*, 436 pp.

A general survey of the taxonomy and morphology of aquatic angiosperms, marine and fresh water.

Baird, R.C., K.L. Carder, T.L. Hopkins, T.E. Pyle, and H.J. Humm, 1972. *Anclote Environmental Project Report 1971*. Marine Science Inst., Univ. South Fla., St. Petersburg, 251 pp.

A progress report on an environmental impact study for a power plant. Contains discussions of grass bed mapping by aerial photography and seagrass zonation in addition to physical, chemical, geological, and zoological reports.

Barbour, M.G., 1970. Is any angiosperm an obligate halophyte? *Am. Mid. Nat.* 84(1):105-120.

A discussion and partial literature review on the question of obligate halophytism. He concludes that none are obligate halophytes. The most attention is given to salt marsh plants and species which grow in inland saline areas. Very little attention is given to the seagrasses.

Bauersfield, P., R.R. Kifer, N.W. Durrant, and J.E. Sykes, 1969. Nutrient content of turtle grass *(Thalassia testudinum)*. *6th International Seaweed Symposium*, pp. 637-645.

Data are given on the proximate composition, mineral spectrum, and carbohydrate and amino acid composition. The effects of washing with fresh water are an increase in available protein, and a reduction in ash and sodium chloride equivalent.

As sheep fodder, *Thalassia* is inadequate alone but was very significant in promoting growth which added to a diet of alfalfa and corn.

Bernatowicz, A.J., 1952. Marine monocotyledonous plants of Bermuda. *Bull. Mar. Sc. Gulf Carib.* 2(1):338-345.

The species of seagrasses found in Bermuda are given, including an uncertain record of *Zostera*. The apparent relationship of seagrasses to sediment and bottom types is discussed, as is the role of *Thalassia* in trapping and binding sediment and the production of certain types of bottom features.

Britton, N.L. and C.F. Millspaugh, 1920. *The Bahama Flora*. Publ. by the authors, N. Y.

A floristic study of the Bahama Islands, including marine algae (by M.A. Howe), and land plants as well as seagrasses.

Buesa, R.J., 1972. Produccion primaria de las praderas de *Thalassia testudinum* de la plataforma noroccidental de Cuba. I.N.P. Centre de Investigaciones Pesqueras, Reunion Bal. Trab. 3:101-143.

Maximum productivity of *Thalassia* on the northwest platform of Cuba occurs at a depth of about one meter where visible light provides .19 gram calories per square centimeter per day. This productivity takes place from 7:30 a.m. until 6:30 p.m. The compensation point is at about 11 meters depth where the illumination is about 2 Klux and the energy total about .011 gram calories per square centimeter per day.

Burkholder, P.R., L.M. Burkholder, and J. Rivero, undated. *Thalassia* in Puerto Rico. Mimeo.

Standing crop of a *Thalassia* bed was measured and the plants were analyzed for chemical content. A study of the bacteria associated with *Thalassia* was made. Different biomass and root-rhizome/leaf ratios were found for different sediment types.

Burkholder, P.R., L.M. Burkholder, and J. Rivero, undated. Chlorophyll *a* in some corals and marine plants. Mimeo.

Chlorophyll *a* was determined for 28 animal and 20 plant species by acetone extraction and optical density readings.

Burkholder, P.R., L.M. Burkholder, and J. Rivero, 1959. Some chemical constituents of turtle grass, *Thalassia testudinum*. *Bull. Torr. Bot. Cl.* 86:88-93.

Thalassia from Puerto Rico was found to contain 13% protein, 15% fiber, and 36% carbohydrate. The food value of *Thalassia* in the ecosystem is discussed.

Diaz-Piferrer, M., 1967. Las Algas Superiors y Fanerogamas Marinas. In: R. Margalef (ed.) *Ecologia Marina*. Fundacion Le Salle de Cieneia Natureles, pp. 273-307.

A review of non-plankton algae and marine angiosperms (in Spanish).

Edwards, P., 1970. Seaweeds and seagrasses in the vicinity of Port Aransas, Texas. *Contrib. Mar. Sc.* 15 (suppl.).

A general survey and illustrated key to the marine algae and seagrasses of the area.

Fenchel, T., 1970. Studies on the decomposition of organic detritus derived from the turtle grass *Thalassia testudinum*. *Limnol. Oceanog.* 15(1): 14-20.

The microbial communities associated with detrital particles are enumerated and their oxygen consumption measured. The feeding habits of a detritus-consuming amphipod and its effect on the detritus and the microbial community are discussed.

Fuss, C.M., and J.A. Kelly, 1969. Survival and growth of seagrasses transplanted under artificial conditions. *Bull Mar. Sc.* 19(2):351-365.

Thalassia testudinum and *Diplanthera wrightii* were grown in aquaria and in flow-through sea water systems. Aquaria were found unsuitable. *Thalassia* survived and produced new growth in flow-through systems, but *Diplanthera* lost weight and only a few plants survived.

Gessner, F., 1968. Die Zellwand mariner Phanerogamen. *Mar. Biol.* 1(3):191-200.

Studies are reported on the drying and water reabsorption of the leaves of four seagrass species. It is found that seagrasses have very thick epidermal cell walls which absorb large amounts of water. Staining indicates large amounts of pectic substances. This is compared to terrestrial and fresh water vascular plants and to marine algae. The situation in the seagrasses most closely resembles that of the marine algae.

Gessner, F., 1971. The water economy of the seagrass *Thalassia testudinum*. *Mar. Biol.* 19 (3): 258-260.

The cuticle of *Thalassia* was examined under the electron microscope and was found to be very thin and highly perforate. Thus water is easily lost through the surface when the plant is exposed. He found that the plant can survive a 65% water loss. Some biomass data for different areas is given.

Ginsburg, R.N. and H.A. Lowenstam, 1958. Influence of marine communities on the depositional environment of sediments. *J. Geol.* 66 (3):310-318.

While physical forces and bottom topography determine the type, size, and distribution of bottom sediments some bottom communities vary these conditions sufficiently to make a distinct change in the sediment types. The effects of coral reefs, blue-green algal mats, and seagrass beds are described.

Glynn, P.W., L. Almadovar, and J.G. Gonzales, 1964. Effects of hurricane Edith on marine life in La Parguera, Puerto Rico. *Carib. J. Sc.* 4:335-345.

A review of the disruption of all types of marine life by the hurricane, and accompanying changes in topography. Among the seagrasses, *Syringodium* was heavily damaged but *Thalassia* was not.

Hamm. , L., 1968. Salzgehalt und Photosynthese bei marinen Pflanzen. *Mar. Biol.* 1:185-190.

Photosynthesis of several seagrasses and marine algae is measured in response to salinity. She concludes that salinity may affect photosynthesis by affecting the carbon supply or by causing exosmosis.

Hartman, R.T. and D.L. Brown, 1967. Changes in internal atmosphere of submersed vascular hydrophytes in relation to photosynthesis. *Ecology* 48(2):252-258.

Gas was extracted from the lacunal system of two species of fresh water vascular plants closely related to *Thalassia*. They found a lag in peak O_2 and CO_2 concentrations between the lacunae and the surrounding water. The volume of extractable gas varied diurnally. It is concluded that the lacunal system serves as a reservoir for metabolic gases and that as a result changes in dissolved oxygen should not be the sole criteria for productivity measurements with plants of this type.

Hartog, C. den, 1960. New seagrasses from Pacific Central America. Pacif. Nat. 1(15):1-8.

Three species of *Diplanthera* are described, including *D. beaudettii*, which den Hartog says in a later publication is the species (as *Halodule*) which occurs in the Gulf of Mexico. *Halophila baillonis* is reported for the area.

Hartog, C. den, 1964. An approach to the taxonomy of the seagrass genus *Halodule* Endl. (Potamogetonaceae). *Blumea*, 12:289-312.

A taxonomic treatment of the genus *Halodule* (=*Diplanthera*). The taxonomic value of certain morphological characters and geographic distribution are discussed. An evolutionary sequence is suggested and a key to the species is given.

Hartog, C. den. 1970. *The Seagrasses of the World.* North-Holland Publ. Co., London, 276 pp. + 31 pls.

A taxonomic review of all known seagrass species, with some notes on ecology and distribution of each.

Hoese, H.D., 1960. Juvenile penaeid shrimp in the shallow Gulf of Mexico. *Ecology* 41(3):592-593.

The presence of juvenile shrimp is attributed to the presence of benthic vegetation, especially seagrasses, rather than to the low salinity waters of bays and estuaries.

Hoese, H.D. and R.S. Jones, 1963. Seasonality of larger animals in a Texas turtle grass community. *Publ. Inst. Mar. Sc. Univ. Tex.* 9:37-47.

A one year study of fish and macroinvertebrates in the grass flats of Redfish Bay, Texas. The community was found similar to that of Florida West Coast Bays. Annual salinity range is 22-41 o/oo. Most of the bay bottom is covered with *Thalassia*, which is replaced in shallow water by *Diplanthera*. The abundance and seasonality of the animals is described.

Hopper, B.E. and S.P. Meyers, 1967. Population studies on benthic nematodes within a subtropical seagrass community. *Mar. Biol.* 1(2): 85-96.

About 100 species of marine nematodes were found in the surface sediments of *Thalassia* bed. Four species comprised 87-95% of all animals collected. Maximum peaks of population density are correlated with physiographic alterations in the environment. It is concluded that the ratio of nematode species are useful indicators of biological and physical changes in the environment.

Hopper, B.E. and S.P. Meyers, 1967. Foliicolous marine nematodes on turtle grass, *Thalassia testudinum* Koenig, in Biscayne Bay, Florida. *Bull. Mar. Sc.* 17(2):471-517.

A taxonomic survey of the leaf-dwelling marine nematodes found on *Thalassia*. A key to the most common species is included. Four new species are described.

The abundance and distribution of species at four sites in Biscayne Bay is described.

Howard, J.F., D.L. Kissling, and J.A. Lineback, 1970. Sedimentary facies and distribution of biota in Coupon Bight, lower Florida Keys. *Geol. Soc. Am. Bull.* 81(7):1929-1946.

A study of sediments and sedimentation processes in a small bay. The role of *Thalassia* in building mud-banks and the effect of bedrock topography on *Thalassia* distribution are described.

Humm, H.J., 1956. Seagrasses of the northern Gulf coast. *Bull. Mar. Sc. Gulf Carib.* 6(4):305-308.

An annotated species list for Mississippi Sound is given with a key to the species. Five species are assumed to be of essentially continuous distribution around the Bay, interrupted only by shifting sediments and river mouths. The importance of seagrasses as producers is pointed out.

Humm, H.J., 1964. Epiphytes of the seagrass, *Thalassia testudinum*, in Florida. *Bull. Mar. Sc. Gulf Carib.* 14(2):306-341.

An annotated species list and a key to the algal epiphytes (Cyanophyta, Chlorophyta, Phaeophyta, Rhodophyta) found on *Thalassia* is given.

Humm, H.J., R.C. Baird, K.L. Carder, T.L. Hopkins, and T.E. Pyle, 1971. *Anclote Environmental Project Annual Report 1970*. Marine Science Inst., Univ. South Fla., St. Petersburg, 134 pp.

A report of the biota collected and the physical data taken in the Anclote River, St. Joseph Sound, and adjacent Gulf of Mexico. The seagrass species are reported and their general distribution in the area is discussed.

Jones, J.A., 1968. Primary productivity of the tropical marine turtle grass. *Thalassia testudinum* Koenig, and its epiphytes. Ph.D. Diss., Univ. Miami, Coral Gables, 196 pp.

This is a report of a field study on primary production as a function of temperature and illuminance of *Thalassia* and its epiphytic algae.

Kelly, J.A., C.M. Fuss and J.R. Hall, 1971. The transplantation and survival of turtle grass, *Thalassia testudinum*, in Boca Ciega Bay, Florida. *U.S. Fish. Wildl. Serv. Bull.* 69(2):273-280.

Fourteen methods for transplanting *Thalassia* were tested. The most clearly effective was to detach the short shoots from the rhizome, treat them with napthalene acetic acid, and fix them to rods stuck in the bottom to prevent their being washed away. All six of the plants tested in this manner survived.

Kissling, D.L., 1965. Coral distribution on a shoal in Spanish Harbor, Florida Keys. *Bull. Mar. Sc.* 15(3):599-611.

The occurrence and zonation of *Thalassia* in the area are described. There is some discussion of its association with animal communities.

Land, L.S., 1970. Carbonate mud production by epibiont growth on *Thalassia testudinum*. *J. Sed. Petrol.* 40(4):1361-1363.

The rate of calcium carbonate production by coralline red algae and serpulid worms living on *Thalassia* is measured. From estimates of the total leaf area produced per year, the conclusion is drawn that the rate of production is equal to the rate of accumulation of ancient platform carbonates.

Lawrence, G.H.M., 1951. *Taxonomy of Vascular Plants*. MacMillan & Co., New York, xii+823 pp.

A general taxonomic work which includes the seagrasses and discusses their taxonomic position.

Margalef, R., 1968. *Perspectives in Ecological*

Theory. Univ. Chicago Press, Chicago, 111 pp.

A general review of ecological theory containing discussions of some techniques useful in the study of seagrasses.

Margalef, R. and J.A. Rivero, undated. Succession and composition of the *Thalassia* community. Mimeo.

Stages in the succession leading from bare sand to a dense *Thalassia* bed are reported. The commoner species in each stage are given (both plants and animals) and this succession is compared to that known for *Posidonia* meadows in the Mediterranean.

Marmelstein, A.D., P.W. Morgan and W.E. Pequegnat, 1968. Photoperiodism and related ecology in *Thalassia testudinum. Bot. Gaz.* 129 (1):63-67.

Beds of *Thalassia* at Miami and at St. Andrew Bay on the northwestern Gulf Coast were compared for time of flowering. Flowering was found to be seasonal and responded to water depth and clarity. *Thalassia* plants were also grown under controlled conditions and were found to have a marked response to intermediate daylengths.

Maurer, L.G. and P.L. Parker, 1967. Fatty acids in seagrasses and marsh plants. *Contrib. Mar. Sc.* 12:113-119.

The fatty acid composition of some marine vascular plants, including five seagrass species, was determined. They differed little from the fatty acid patterns of terrestrial plants, but there was a definite difference between the plant parts. Roots and rhizomes have less extractable lipid than leaves. 18:1 and 18:2 acids are concentrated in underground parts while 18:3 is concentrated in the leaves. No significance of this is known.

McMahan, C.A., 1968. Biomass and salinity tolerance of shoal grass and manatee grass in lower Laguna Madre, Texas. *J. Wildlife Mgmt.* 32(3):501-506.

Three different *Diplanthera* and *Syringodium* beds were sampled for plant biomass. *Diplanthera* shows seasonal variation in biomass, *Syringodium* does not. *Diplanthera* survived 9.0-52.5 o/oo in culture. *Syringodium* died at 52.5 o/oo. Salinities less than 35 o/oo were not tested for *Syringodium.* Biomass data are given but are not correlated with salinity.

McMillan, C. and F.N. Moseley, 1967. Salinity tolerances of five marine spermatophytes of Redfish Bay, Texas. *Ecology* 48(3):503-506.

Five seagrass species were grown in outdoor concrete pools and in controlled environment chambers and the effects of increasing salinity on growth rate and chlorophyll content were measured. It was found that the distribution of these species in Redfish Bay was partially correlated to their salinity tolerances.

McNulty, J.K., 1961. Ecological effects of sewage pollution in Biscayne Bay, Florida: sediments and the distribution of benthic and fouling macro-organisms. *Bull. Mar. Sc. Gulf Carib.* 11(3):394-447.

Both harmful and fertilizing effects are observed in a polluted area of Biscayne Bay. The dominant benthic plants in highly polluted areas were red algae. *Diplanthera wrightii* and/or *Halophia baillonis* are dominant in less polluted area. *Halophila* was more tolerant. *Thalassia* occurred well away from the pollution source.

Menzel, R.W., 1956. Annotated checklist of the marine fauna and flora of the St. George's Sound-Apalachee Bay region, Florida Gulf Coast. Oceanog. Inst., Fla. St. Univ. Contrib. No. 61, 78 pp. Mimeo.

A checklist with notes on abundance, bottom type, etc., for each species.

Menzies, R.J., J.S. Zaneveld, and R.M. Pratt, 1967. Transported turtle grass as a source of organic enrichment of abyssal sediments off North Carolina. *Deep Sea Res.* 14:111-112.

Floating detached *Thalassia* is carried by the Gulf Stream and deposited in deep water off North Carolina. The grass floats while the tissue is alive and healthy but sinks when dead.

Meyers, S.P., P.A. Orpurt, J. Simms, and L.L. Boral, 1965. *Thalassiomycetes* VII. Observations on fungal infestation of turtle grass, *Thalassia testudinum* Koenig. *Bull. Mar. Sc.* 15(3): 548-563.

The fungi infesting *Thalassia* are divided into three groups based on abundance and frequency of isolation. Most frequent were *Labyrinthula, Lindra thalassiae* (ascomycete), and three deuteromycetes. Seasonal changes are reported. Infestation may be quite variable. Differences between foliicolons and lignicolons species are discussed.

Moore, D.R., 1963. Distribution of the seagrass, *Thalassia*, in the United States. *Bull. Mar. Sc. Gulf Carib.* 13(2):329-342.

The distribution of *Thalassia testudinum* along the coasts of the United States is given. Literature on the ecological ranges of *Thalassia* is reviewed and the gaps in its distribution are explained on this basis.

Muenscher, W.C., 1944. *Aquatic Plants of the United States*. Comstock Publ. Co., Ithaca, New York, 374 pp.

A general floristic review and key to marine and fresh water vascular plants of the U.S.

Odum, H.T., 1963. Productivity measurements in Texas turtle grass and the effects of dredging an intracoastal channel. *Publ. Inst. Mar. Sc. Univ. Tex.* 9:47-58.

Chlorophyll a and O_2 concentration measurements were made in a bed of *Thalassia* and *Diplanthera* prior to, immediately after, and year after the dredging of a channel. Values declined immediately after dredging and remained low for the rest of the year. The following year, however, the values were much higher than before the dredging. Apparently dredging has no permanent effect on adjacent seagrass beds not removed or buried under spoil or heavy silt. Release of nutrients while not measured, may have been a factor.

O'Gower, A.K. and J.W. Wacasey, 1967. Animal communities associated with *Thalassia, Diplanthera*, and sand beds in Biscayne Bay. I. Analysis of communities in relation to water movements. *Bull. Mar. Sc.* 17(1):175-201.

Samples of the benthic animal communities were collected from *Thalassia, Diplanthera*, and sand beds at two locations in Biscayne Bay which differed in the rate of tidal flow. The data were statistically analyzed and showed some similarities and other dissimilarities between the three enironments.

Orpurt, P.A., and L.L. Boral, 1964. The flowers, fruits, and seeds of *Thalassia testudinum* Koenig. *Bull. Mar. Sc. Gulf Carib.* 14(2):296-302.

The flowers and fruits of *Thalassia* which had been improperly described from old herbarium material are redescribed and the anatomy and germination of the seed are described for the first time.

Orpurt, P.A., S.P. Meyers, L.L. Boral, and J. Sims, 1964. *Thalassiomycetes* V. A new species of *Lindra* from turtle grass, *Thalassia testudinum* Koenig. *Bull. Mar. Sc. Gulf Carib.* 14(3):405-417.

Lindra thalassiae n.sp. is described. It is a scolecosporous pyrenomycete. The species is euryhaline, the spores germinating in 0-200% seawater. It is present all year, but fruiting is seasonal.

Patriquin, D.G., 1972. The origin of nitrogen and phosphorous for growth of the marine angiosperm *Thalassia testudinum*. *Mar. Biol.* 15(1):35-46.

A *Thalassia* bed was sampled for nutrient content of leaves and rhizomes and for nutrient content of sediments. Large amounts of phosphate and virtually all nitrogen are obtained by the plant from the sediments. Reducing conditions are required, possibly for the activity of N_2-fixing bacteria.

Phillips, R.C., 1958. Extension of distribution of *Ruppia maritima* var. *obliqua* (Schur.) Ascher. and Grabn. *Quart J. Fla. Acad. Sc.* 21 (2):185-186.

A range extension for this variety, pre-

viously known only from Maine and further north. A brief discussion of varieties and their distribution is given.

Phillips, R.C., 1959. Notes on the marine flora of the Marquesa Keys, Florida. *Quart. J. Fla. Acad. Sc.* 22(3):155-162.

A general description of the vegetation, depth, and bottom type at six stations. Of particular note is the unusual occurrence of *Thalassia* beds in a bottom composed mostly of *Halimeda* segments.

Phillips, R.C., 1960. Observations on the ecology and distribution of the Florida seagrasses. Fla. St. Bd. Conserv. Mar. Lab., Prof. Pap. Ser., No. 2:1-72.

A review of the anatomy and ecological requirements of the Florida seagrasses. There is an extensive review of the literature to date and experiments and field observations on growth and development are reported. Experimental work was situated in Tampa Bay and vicinity. The distribution of seagrasses is discussed.

Phillips, R.C., 1960. The ecology of marine plants of Crystal Bay, Florida. *Quart. J. Fla. Acad. Sc.* 23(4):328-337.

Abundance and distribution of marine algae and seagrasses at six stations in Crystal Bay are reported. Three samples were taken at each station at three different times. Physical data for each collection is given.

Phillips, R.C., 1960. Environmental effect on leaves of *Diplanthera* du Petit-Thouars. *Bull. Mar. Sc. Gulf Carib.* 10(3):346-353.

Diplanthera was collected from three tidal zones and found to have a morphology peculiar to each. Leaf length and width, and rhizome thickness and internode length were found to vary environmentally. Further, the leaf tips and internal anatomy varied with environment, thus making *D. wrightii* and *D. uninervis* indistinguishable when sterile.

Phillips, R.C., 1962. Distribution of seagrasses in Tampa Bay, Florida. Sp. Sc. Rpt. No. 6, Fla. St. Bd. Conserv. Mar. Lab., St. Petersburg, Fla., pp. 1-12.

A survey of a number of localities around the shores of Tampa Bay indicates that seagrasses in the bay are limited to depths of less than one fathom. In most areas two zones exist: *Diplanthera* or *Ruppia* inshore in the intertidal zone, with *Syringodium* from ELWS to one fathom depth. *Ruppia* occupies the shoreward zone when salinity is low. *Thalassia* is sparse in the bay. In areas of very low salinity only *Ruppia* is found.

Phillips, R.C., 1967. On the species of the seagrass, *Halodule*, in Florida. *Bull. Mar. Sc.* 17 (3):672-676.

The author reports the three vegetative leaf characters used to separate species of *Halodule (Diplanthera)* to vary on the same plant and in plants from different environments, to such a degree that they cannot be used as species characters. He concludes that all Florida plants are *H. wrightii.*

Phillips, R.C. and R.M. Ingle, 1960. Report on the marine plants, bottom types and hydrography of the St. Lucie estuary and adjacent Indian River, Florida. Sp. Sc. Rpt. No. 4, Fla. Bd. Conserv. Mar. Lab., St. Petersburg, Fla.

A report of four trips to the St. Lucie estuary and Indian River to study seagrasses and algae. During the rainy season fresh water is released into the area from Lake Okeechobee via the St. Lucie Canal. Dense beds of *Syringodium* and *Diplanthera* occurred in the Indian River, short sparse patches of *Diplanthera* and *Ruppia* in St. Lucie River. Hydrographic and bottom sample data are given along with a species list of algae and seagrasses with notes on abundance. The data demonstrate a decrease in seagrass abundance with decreasing salinity.

Phillips, R.C. and V.G. Springer, 1960. Report on the hydrography and marine plants of the Caloosahatchee River and adjacent waters, Florida. Sp. Sc. Rpt. No. 5, Fla. Bd. Conserv., Mar. Lab. St. Petersburg, 34 pp.

The Caloosahatchee River is used as a drainage channel for Lake Okeechobee during the wet season of the year. Two collections were made, one during fresh water release the other not. Of the seagrasses only *Ruppia* and *Diplanthera* were found in the river at any time. Fresh water runoff did not seem to effect them. During fresh water release *Valisneria americana* invaded the seagrass area, but it was killed back when the salt water again advanced up the river. Marine algae, which were mostly small filamentous forms growing as epiphytes or on shells were killed by the fresh water but reinvaded when the fresh water release into the river was stopped. Hydrographic data for the two trips are given.

Pomeroy, L.R., 1960. Primary productivity of Boca Ciega Bay, Florida. *Bull. Mar. Sc. Gulf Carib.* 10(1):1-10.

Dissolved oxygen determinations indicate that seagrasses (primarily *Thalassia*), benthic microflora, and phytoplankton are of equal importance in primary productivity in water of less than 2 m depth. Only phytoplankton are important at greater depths.

Randall, J.E., 1965. Grazing effect on seagrasses by herbivorous reef fishes in the West Indies. *Ecology* 46(3):255-260.

A band of bare sand is usually found between seagrass beds and reefs in the West Indies. This is explained by the parrot fish and surgeon fish which live around the reef and which do not move far from it to avoid predators. Other consumers of seagrasses are discussed.

Randall, J.E., 1967. Food habits of reef fishes of the West Indies. *Stud. Trop. Oceanog.* 5:665-847.

Stomach contents of 212 species of inshore and reef fishes were analyzed. The species were divided into groups according to preferred food sources. Seventeen species and four entire families are listed as plant and detritus feeders. Nine additional species, omnivores, feed heavily on plant material. Most of the sessile animal feeders consume considerable plant material also. Notes on preferred food species are given.

Scoffin, T.P., 1970. The trapping and binding of subtidal carbonate sediments by marine vegetation in Bimini Lagoon, Bahamas. *J. Sed. Petrol.* 40(1):249-273.

A discussion of the effects of marine plants on sediment deposition. Mangroves, *Thalassia*, and algae are considered. The current strength necessary to erode a *Thalassia* bed is discussed.

Sculthorpe, D.C., 1967. *The Biology of Aquatic Vascular Plants* Edward Arnold, Ltd., London, 610 pp.

A general text and reference book on aquatic vascular plants, both marine and fresh water. Taxonomic, anatomical, and ecological aspects of aquatic plants in general are discussed in detail. Little attention is given to any particular species.

Stephens, W.M., 1968. The turtle grass community. *Nat. Hist.* 77(2):50-57.

An introductory account of the occurrence and importance of tropical seagrass beds. For the non-specialist.

Strawn, K., 1961. Factors affecting the zonation of submerged monocotyledons at Cedar Key, Florida. *J. Wildlife Mgmt.* 25(2):178-189.

The zonation of five species of seagrasses is determined by tide level. This zonation is modified by tide pools and drainage channels. Zonation changes from areas with diurnal tides to those with semidiurnal tides. The stiffer leaved plants required deeper water.

Tabb, D.C. and R.B. Manning, 1962. A checklist of flora and fauna of northern Florida Bay and adjacent brackish waters of the Florida mainland collected during the period July, 1957 through September, 1960. *Bull. Mar. Sc. Gulf Carib.* 11(4):552-649.

An annotated list of the plant and animal species collected. In brackish water, *Ruppia* is usually dominant, but is replaced in *Diplanthera* if the salinity rises to 15-20 o/oo. If the salinity falls below 10 o/oo *Ruppia* is replaced by *Chara*.

Thomas, L.P., D.R. Moore, and R.C. Work, 1961. Effects of hurricane Donna on the turtle grass beds of Biscayne Bay, Florida. *Bull. Mar. Sc.* 11:191-197.

A review of the various agents of destruction for *Thalassia* with special reference to Hurricane Donna. The amount of *Thalassia* blades torn loose by the hurricane is estimated at almost 1.5 million kg dry weight. Wet weight is estimated at 5 times dry weight. Nevertheless, they conclude that damage to the beds was light and was quickly repaired.

Thorhaug, A., 1971. Seagrasses and macroalgae. In: Bader, R.G. and M.A. Roessler, An Ecological Study of South Biscayne Bay and Card Sound. Progress Rpt. to U.S. Atomic Energy Comm. and Fla. Power and Light Co.

A report of observations on benthic plants in a thermally stressed area.

Thorhaug, A. and R.D. Stearns, 1972. (in press) An ecological study of *Thalassia testudinum* in unstressed and thermally stressed estuaries.

Productivity of *Thalassia* in leaf production was as great as 37 grams dry weight per square meter per day during warmer months of the year in the best beds in Card Sound, Biscayne Bay, in an unstressed area. Peak productivity occurred in the spring with a slight decrease during summer months.

In an area stressed by heated water from a power plant, there was a progressive amount of productivity with each degree rise in temperature above ambient during summer months. Where the temperature rise was 5° or more, *Thalassia* tended to die out.

In an area where sediments are sufficiently deep and where the organic matter content of sediments is favorable, *Thalassia* communities are comparable in productivity to Ryther's average productivity of areas of upwelling in the open sea.

Thorne, R.F., 1954. Flowering plants of the waters and shores of the Gulf of Mexico. Fish. Bull., U. S. 89:193-202.

A general review of the literature and species present of all types of flowering plants, including seagrasses, mangroves, salt marshes, and sand-strand vegetation.

Tomlinson, P.B., 1969a. On the morphology and anatomy of turtle grass, *Thalassia testudinum* (Hydrocharitaceae). II. Anatomy and development of the root in relation to function. *Bull. Mar. Sc.* 19(1):57-71.

Thalassia roots have no water conducting tissues except close to their insertion and apparently are not significant in water absorption. However, there are histological features which suggest that the root is a site of selective absorption. The differentiation of various root tissues is described.

Tomlinson, P.B., 1969b. On the morphology and anatomy of turtle grass, *Thalassia testudinum* (Hydrocharitaceae). III. Floral morphology and anatomy. *Bull. Mar. Sc.* 19(2):286-305.

The morphology and histology of the flowers of *Thalassia* are described and flowering periodicity is discussed.

Tomlinson, P.B., 1972. On the morphology and anatomy of turtle grass, *Thalassia testudinum* (Hydrocharitaceae). IV. Leaf anatomy and development. *Bull. Mar. Sc.* 22(1):75-93.

The two types of leaves found in *Thalassia* are established as homologs. Their production by the apical meristem and subsequent development are discussed and the anatomy of mature leaves is described.

Tomlinson, P.B. and G.W. Bailey, 1972. Vegetative branching in *Thalassia testudinum* (Hydrocharitaceae)—A correction. *Bot. Gaz.* 133(1): 43-50.

It is established that the production of erect branches in *Thalassia* is truly lateral, not the result of a dichotomous division of the rhizome apex, as had been shown for two other monocotyledens. Although the branch and rhizome are the same size for a while and appear dichotomous, the branch meristem is produced

in a lateral, leaf-opposed position. The subsequent growth of the rhizome displaced the branch into a truly lateral position.

Tomlinson, P.B. and G.D. Vargo, 1966. On the morphology and anatomy of turtle grass, *Thalassia testudinum* (Hydrocharitaceae). I. Vegetative morphology. *Bull. Mar. Sc.* 16(4):748-761.

A general description of the external vegetative morphology of *Thalassia*, and a discussion of the mode of growth and development.

Van Breedveld, J., 1966. Preliminary study of seagrass as a source of fertilizer. Spec. Sc. Rpt. No. 9, Fla. Bd. Conserv., Mar. Lab., St. Petersburg, 23 pp.

Syringodium was tested as a source of fertilizer for tomatoes and strawberries. It was found to compare favorably with compost and commercial fertilizer for cultivation of these plants.

Voss, G.L. and N.A. Voss, 1955. An ecological survey of Soldier Key, Biscayne Bay, Florida. *Bull. Mar. Sc. Gulf Carib.* 5:203-237.

A description of ecological zonation in the area. *Thalassia* forms a zone between *Porites* coral and Alcyonarians. The fauna of the *Thalassia* beds are discussed.

Wood, E.J.F. and J.C. Zieman, 1969. The effects of temperature on estuarine plant communities. *Chesapeake Sc.* 10(3&4):172-174.

A preliminary report of thermal pollution studies on benthic plants. This paper contains general information which is treated in more detail in subsequent papers.

Zieman, J.C., 1968. A study of the growth and decomposition of the seagrass, *Thalassia*. M.S. thesis, Univ. Miami, Coral Gables, Fla. 50 pp.

A descriptive account of the growth and decomposition of *Thalassia*. Apparently breakage of the cuticle is necessary for the entrance of decay organisms. Techniques are discussed and preliminary experimental data are presented.

Zieman, J.C., 1970. The effects of a thermal effluent stress on the seagrasses and macro algae in the vicinity of Turkey Point, Biscayne Bay, Florida. Ph.D. Diss., Univ. Miami, Coral Gables, Fla.

A description of the genesis of *Thalassia* beds and their distribution in Biscayne Bay. The effects of thermal effluents on grass beds are described. It is concluded that *Thalassia* is not killed directly at the temperatures encountered, but that respiration exceeds photosynthesis.

Additional References of Possible Interest

Breuer, J.P., 1962. An ecological survey of the lower Laguna Madre of Texas, 1953-1959. *Pub. Inst. Mar. Sc. Univ. Texas*, Aransas, 8:153-183.

Hartog, C. den, 1967. The structural aspect in the ecology of seagrass communities. *Helg. Wissen. Meersunter.* 15:648-659.

McRoy, C.P. and R.J. Baradate, 1970. Phosphate absorption in eel grass. *Limnol. Oceanog.* 15(1):6-13.

Odum, H.T., 1956. Primary production measurements in eleven Florida springs and a marine turtle grass community. *Limnol. Oceanog.* 2: 85-97.

Odum, H.T., P.R. Burkholder, and J. Rivero, 1959. Measurements of productivity of turtle grass flats, reefs, and the Bahia Fosforescente of southern Puerto Rico. *Publ. Inst. Mar. Sc. Univ. Texas* 6:159-170.

Patriquin, D.G., in press. Estimation of growth rate, production and age of the marine angiosperm *Thalassia testudinum* Koenig *Carib. J. Sc.* 13.

Quasim, S.Z., 1971. Primary production of seagrasses. *Hydrobiology* 38:79-88.

Reyes-Vasquez, G., 1965. Studies on the diatom flora living on *Thalassia testudinum* Koenig in Biscayne Bay. M.S. thesis, Univ. Miami, Coral

Gables, Fla., 81 pp.

Simmons, E.G., 1957. An ecological survey of the upper Laguna Madre of Texas. *Publ. Inst. Mar. Sc. Univ. Texas* 4(2):156-200.
Stearns, R.D. and A. Thorhaug, in press. Preliminary field observations on the sexual stages of *Thalassia testudinum* in south Biscayne Bay and Card Sound, Florida. *Bull. Mar. Sc.*

Tabb, D.C., D.L. Dubrow, and R.B. Manning, 1962. The ecology of northern Florida Bay and adjacent estuaries. Tech. Ser. No. 39, Fla. Bd. Conserv., 81 pp.

Taylor, W.R., 1928. The marine algae of Florida, with special reference to the Dry Tortugas. Carnegie Inst. Wash. Pub. 379, Papers Tortugas Lab., 25:i-v & 1-219, 3 figs., 37 pls.

Thorhaug, A., and R. Stearns, 1971. A field study of the marine angiosperm *Thalassia testudinum* in a tropical marine estuary. *Am. J. Bot.* 58(4):14-15.

Welch, B.L., 1965a. Gross productivity of seral stages in the *Thalassia* community, including an accelerating stage of *Porites*. *Ocean Science and Engineering*, 1 & 2:296.

Welch, B.L., 1965b. Succession in the Caribbean *Thalassia* community. *Ocean Science and Engineering*, 1 & 2:297.

Wolf, D.A., G.W. Thayer, and R. B. Williams, in press. Ecological effects of man's activities on temperate estuarine eelgrass communities. *In* B. Ketchum (ed.), *Critical Problems of the Coastal Zone. M.I.T. Press*, Cambridge, Mass.

Wood, E.J.F., W.E. Odum, and J.C. Zieman, 1969. Influence of seagrasses on the productivity of coastal lagoons. Laguna Costeras, Un Simposio. Mam. Simp. Intern. Lagunas Costeras Nov. 28-30, 1967. Mex. D. F.:495-502, 2 figs.

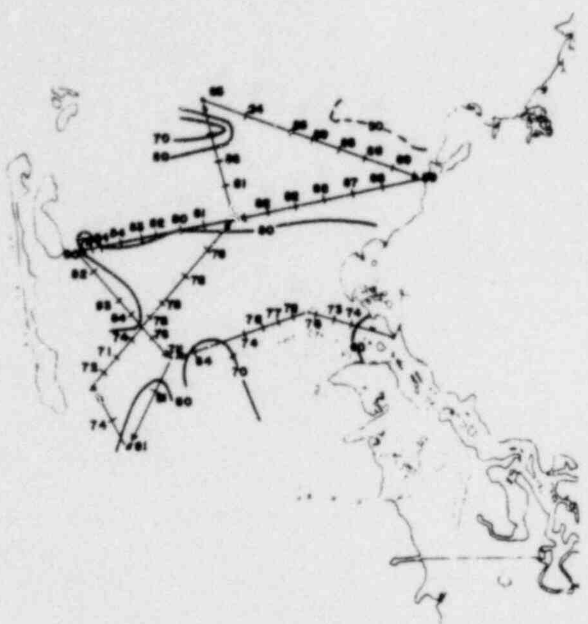

Figure 1. % T/10 cm. May 2, 1972.

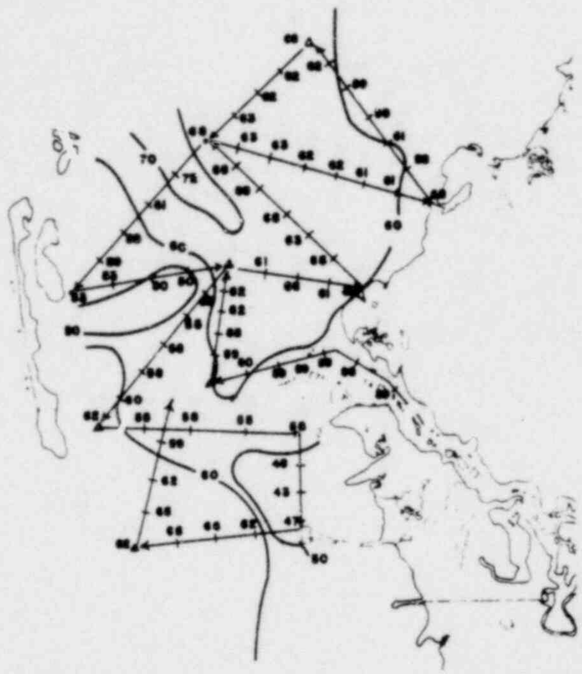

Figure 2. % T/10 cm. September 15, 1972.

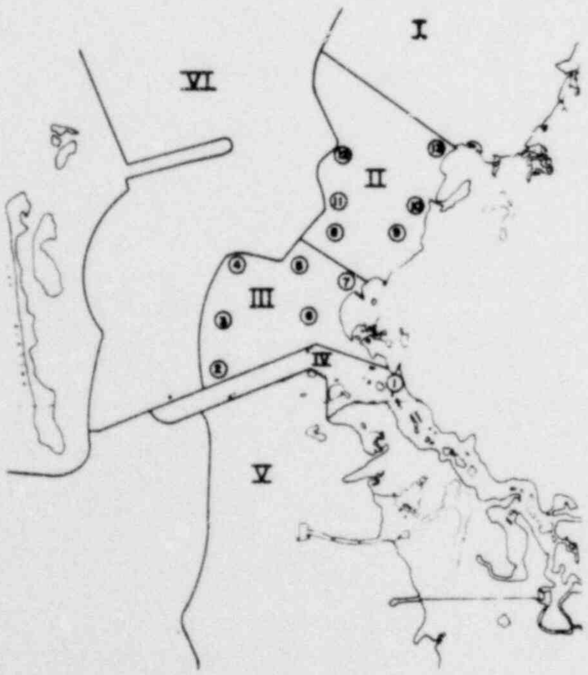

Figure 3. Suspended Sediment Sampling Stations with Geologic Subdivisions of Anclote Area.

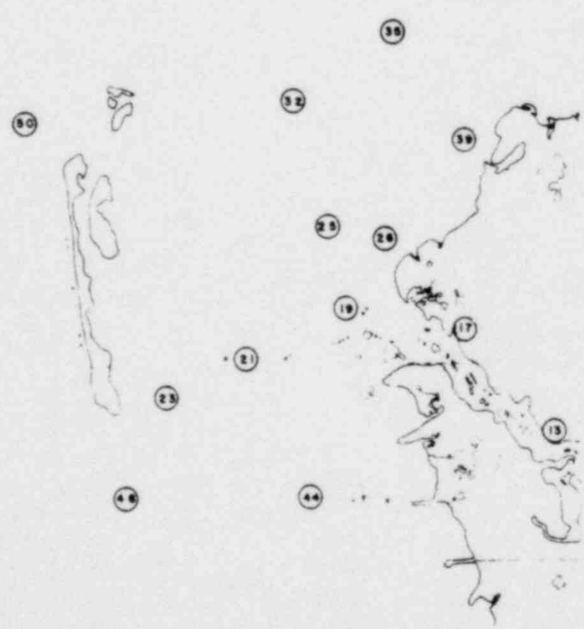

Figure 4. Zooplankton Sampling Stations.