A Critical Evaluation of the Nonradiological Environmental Technical Specifications

Vol. 3 Peach Bottom Atomic Power Station Units 2 and 3

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Prepared for the U.S. Nuclear Regulatory Commission
Office of Nuclear Regulatory Research
Under Interagency Agreement ERDA 40-550-75

OAK RIDGE NATIONAL LABORATORY

OPERATED BY UNION CARBIDE CORPORATION FOR THE ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

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Printed in the United States of America. Available from
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road, Springfield, Virginia 22161
Price: Printed Copy \$7.50; Microfiche \$3.00

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Contract No. W-7405-eng-26

ENERGY DIVISION

A CRITICAL EVALUATION OF THE NONRADIOLOGICAL
ENVIRONMENTAL TECHNICAL SPECIFICATIONS

VOLUME 3

PEACH BOTTOM ATOMIC POWER STATION UNITS 2 AND 3

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Manuscript Completed: August 10, 1976
Date Published: April 1977

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MASTER

FOREWORD

Under the sponsorship of the Office of Regulatory Research of the U.S. Nuclear Regulatory Commission, Argonne National Laboratory, Battelle Northwest Laboratory, and Oak Ridge National Laboratory have collaborated in conducting a one-year study on the evaluation of the nonradiological environmental monitoring programs and Technical Specifications requirements at various operating nuclear power plants. As a result of this work, a series of reports is being prepared by the three laboratories. The titles of these reports are given below.

Argonne National Laboratory

The following reports were prepared by Argonne National Laboratory scientists:

<u>Report Title</u>	<u>Report Number</u>
An Evaluation of Environmental Data Relating to the Kewaunee Nuclear Power Plant Site	ANL/EIS-1
An Evaluation of Environmental Data Relating to the Quad Cities Nuclear Power Station	ANL/EIS-2
An Evaluation of Environmental Data Relating to the Duane Arnold Energy Center	ANL/EIS-3
An Evaluation of Environmental Data Relating to the Three Mile Island Site	ANL/EIS-4
An Evaluation of Environmental Data Relating to the Zion Nuclear Power Plant	ANL/EIS-5
An Evaluation of Environmental Data Relating to the Prairie Island Site	ANL/EIS-6
An Evaluation of Environmental Data Relating to the Nine Mile Point - 1	ANL/EIS-7
An Evaluation of Environmental Data Conclusions and Recommendations for Nonradiological Environmental Monitoring	ANL/EIS-8

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Battelle Northwest Laboratory

The following reports were prepared by Battelle Northwest Laboratory scientists:

<u>Report Title</u>	<u>Report Number</u>
Evaluation of Monticello Nuclear Power Plant Environmental Impact Prediction, Based on Monitoring Program	BNWL-1250
Evaluation of Haddam Neck (Connecticut Yankee) Nuclear Power Plant Environmental Impact Prediction, Based on Monitoring Program	BNWL-1251
Evaluation of Millstone Nuclear Power Plant, Unit 1, Environmental Impact Prediction, Based on Monitoring Program	BNWL-1252
Evaluation of Three Nuclear Power Plants, Environmental Prediction, Based on Monitoring Program. A Summary Report	BNWL-1253

Oak Ridge National Laboratory

The following reports were prepared by Oak Ridge National Laboratory scientists:

<u>Report Title</u>	<u>Report Number</u>
A Critical Evaluation of the Nonradiological Environmental Technical Specifications: Conclusions and Recommendations	ORNL/NUREG/TM-69
A Critical Evaluation of the Nonradiological Environmental Technical Specifications: Surry Power Plant Units 1 and 2	ORNL/NUREG/TM-70
A Critical Evaluation of the Nonradiological Environmental Technical Specifications: Peach Bottom Atomic Power Station Units 2 and 3	ORNL/NUREG/TM-71
A Critical Evaluation of the Nonradiological Environmental Technical Specifications: San Onofre Nuclear Generating Station Unit 1	ORNL/NUREG/TM-72

ABSTRACT

A comprehensive study of the data collected as part of the environmental Technical Specifications program for Units 2 and 3 of the Peach Bottom Nuclear Power Plant was conducted for the Office of Regulatory Research of the U.S. Nuclear Regulatory Commission. The program included an analysis of both the hydrothermal and ecological monitoring data collected from 1967 through 1976.

The hydrothermal analysis includes a discussion of models used in plume predictions prior to plant operation and an evaluation of the present hydrothermal monitoring program. The two primary methods used for temperature monitoring employ a fixed-thermograph network and boat measurements. Analysis of the boat survey data provides a fine resolution for defining the extent of the thermal plume, while the thermograph data provide adequate information to establish significant temporal effects. However, it is not possible to adequately verify or disprove the validity of the various Peach Bottom plume predictions based on the Technical Specifications data.

The ecological analysis includes validation of impacts predicted in the Final Environmental Statement using the operational monitoring data. Chlorophyll *a* and other plant pigment measurements were used to monitor changes in the primary producers. Densities of consumers (i.e., zooplankton, benthos, and fish) were used to monitor changes in these trophic groups. Models based on operating data were constructed to determine whether changes were occurring at each trophic level. Analysis of the monitoring data suggests that the thermal discharges at Peach Bottom are not having a significant effect on the primary producers, zooplankton or benthos. Fish population densities increased in the discharge area during summer months, but not during winter months.

Specific recommendations are made for improving both the present hydrothermal and ecological monitoring programs. Hydrothermal monitoring would be improved by more complete reporting of in-plant operating parameters. In addition, the present boat surveys could be discontinued, and monitoring efforts could be directed toward expanding the present thermograph network. Ecological monitoring programs were judged to be of high quality because standardized collection techniques, consistent reporting formats, and statistical analyses were performed on all of the data and were presented in an annual report. Sampling for all trophic groups was adequate for the purposes of assessing power plant induced perturbations. Considering the extensive period of preoperational data (six years) and operational data (three years) available for analysis, consideration could be given to reducing monitoring effort after data have been collected for a period when both units are operating at full capacity. In this way, an assessment of the potential ecological impact of the Peach Bottom facility can be made under conditions of maximum plant induced perturbations.

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1. PLANT DESIGN AND CHARACTERISTICS¹⁻³

Peach Bottom Atomic Power Station (PBAPS) is operated by Philadelphia Electric Company (PECO) and consists of three reactors, the first of which is now decommissioned. Unit 1 was an experimental high-temperature gas-cooled reactor (HTGR) that used once-through cooling. It had a core thermal power of 115 MW(t), a net electrical output of 40 MW(e), and a heat rejection rate of 75 MW(t). Unit 1 began operation in March 1966 and was permanently shut down in November 1974.

The engineer-constructor for Units 2 and 3 was Bechtel Corporation. Each consists of a General Electric boiling-water reactor (BWR) with a rated core thermal power of 3293 MW(t) and a design core thermal power of 3440 MW(t). Each unit has rated net electrical output of 1065 MW(e) and a design net electrical output of 1100 MW(e). Consequently, the total heat rejected to the environment (aquatic and atmospheric) by both units is 4456 MW(t) at rated conditions and 4680 MW(t) at design conditions.

This heat is rejected using a once-through cooling system with optional helper cooling towers. Figure 3.1 illustrates the layout of the PBAPS site. The flow of cooling water through Units 2 and 3 is shown in Fig. 3.2. At full operation, 3342 cfs are drawn from Conowingo Pond through an intake structure oriented parallel to the shoreline. There are about 487 ft of trash racks with open spaces 3.25 in. wide. About 40 ft behind the trash racks are 24 vertical traveling screens of conventional design. These screens have 3/8-in. square openings, and at the lowest pond elevation normally attained (104.5 ft Conowingo Datum = 105.2 USC&G Datum), the velocity through these openings is 0.75 fps. Cooling water then flows 700 ft through separate intake basins to the pumphouse located at the shoreline. The pumphouse contains six circulating water pumps (three per reactor), each rated at 557 cfs. Each pump is protected by a conventional traveling screen with 3/8-in. square openings. At rated conditions, the cooling water experiences a 19.9°F temperature rise in passing through the condensers. The temperature rise at design conditions is 20.8°F. The heated water is discharged into a common intermediate pond.

Part of this flow proceeds directly into a 4700-ft-long discharge canal, which ranges in width from 300 to 400 ft and parallels the shoreline. The Unit 1 intake and discharge structures are located on this canal, and Rock Run Creek empties into it. At the end of the discharge canal is the discharge control structure shown in Fig. 3.3. This structure consists of spaces for four sluice gates arranged in a rectangular pattern. One of the gates is permanently open, and the position of the other three is automatically controlled to maintain a discharge velocity of 5 to 8 fps parallel to the shoreline. A spillway is provided to handle unusually high flows.

Approximately 58% (1950 cfs) of the condenser effluent can be diverted from the intermediate basin through mechanical-draft helper towers before entering the discharge canal. There are three banks of cross-flow

ORNL DWG 76-12552

Fig. 3.1. Peach Bottom - Plan view of Peach Bottom Complex.

Source: Directorate of Licensing, U.S. Atomic Energy Commission, Final Environmental Statement - Peach Bottom Atomic Power Station Units 2 and 3, Docket Nos. 50-277 and 50-278 (April 1973).

ORNL DWG 76-12553

Fig. 3.2. Peach Bottom — Path of cooling water from Conowingo Pond through the Peach Bottom Station. Source: Philadelphia Electric Company, 316(a) *Demonstration for PBAPS Units 2 and 3 on Conowingo Pond (July 1975).*

Fig. 3.3. Peach Bottom — Submerged discharge structure, with details of movable gates. Source: Directorate of Licensing, U.S. Atomic Energy Commission, *Final Environmental Statement — Peach Bottom Atomic Power Station Units 2 and 3*, Docket Nos. 50-277 and 50-278 (April 1973).

towers, each containing 11 cells, which operate in parallel. Because the performance of the cooling towers depends on meteorological conditions, their effectiveness in reducing the temperature rise seen by the pond (discharge ΔT) is subject to wide variations from day to day. Table 3.1 shows that, on the average, the towers are far more effective during the summer months. At design conditions, the monthly average discharge ΔT ranges from a low of 12.9°F in August to a high of 18.2°F in December. On an annual basis, the towers can reduce the heat load of Conowingo Pond by 25%. Operation of the towers results in the evaporation of up to 25 cfs and the loss of an estimated 3.9 cfs as drift. Because there is no recirculation of the cooling water, there is no appreciable buildup of dissolved solids in this drift.

Table 3.1. Peach Bottom - Performance of PBAPS Units 2 and 3 cooling system at design conditions with three helper towers^a

Month	Intake water temperature (°F)	Condenser ΔT (°F)	Cooling tower range (°F)	Discharge ΔT (°F)	Heat rejected to pond [MW(t)]
January	35.0	20.8	6.0	17.3	3811
February	36.0	20.8	5.0	17.9	3928
March	39.5	20.8	5.5	17.5	3840
April	48.5	20.9	6.0	17.3	3811
May	64.0	20.8	9.5	15.2	3342
June	72.5	20.8	10.5	14.7	3225
July	80.0	20.8	13.0	13.0	2873
August	79.5	20.8	13.5	12.9	2814
September	70.5	20.8	10.5	14.7	3225
October	60.0	20.8	8.5	15.8	3459
November	45.0	20.8	6.0	17.2	3782
December	35.5	20.8	4.5	18.2	4016
Annual average				16.0	3518
Without cooling towers				20.8	4680

^aBased on average monthly meteorological conditions.

Source: Philadelphia Electric Company, 316(a) Demonstration for PBAPS Units 2 and 3 on Conowingo Pond (July 1975).

Figure 3.4 and Table 3.2 illustrate the transit time for water to flow through PBAPS by various paths at full power. Water bypassing the cooling towers is discharged in about 88 min, while water flowing through the second cooling tower bank takes about 109 min to reach the discharge structure.

ES-2903

ORNL DMG 76-12555 RI

CONDENSER

Fig. 3.4. Peach Bottom — Path of cooling water from Conowingo Pond through the Peach Bottom Station. Transit times are given in Table 3.2. Source: Directorate of Licensing, U.S. Atomic Energy Commission, *Final Environmental Statement — Peach Bottom Atomic Power Station Units 2 and 3*, Docket Nos. 50-277 and 50-278 (April 1973).

Table 3.2. Peach Bottom — Circulating water transit time through plant cooling system

Flow distance ^a	Description	Flow directly to discharge canal	Flow through cooling tower system
1-2	Retention in intake structure	24.3 min	24.3 min
2-3	Circulating water piping to condenser	0.7 min	0.7 min
3-4	Condenser	14 sec	14 sec
4-5	Condenser to cooling tower pond	1.3 min	1.3 min
5-6	First cooling tower pond		24.3 min
6-7	Second cooling tower pond		16.3 min
7-8	Piping from pond to cooling tower		22 sec
8-9	Retention in cooling tower		64 sec
9-10	Cooling tower discharge to canal		87.5 sec
10-11	Transit in discharge canal	38.9 min	38.9 min
5-10	Bypassing of cooling tower, time in discharge canal	22.6 min	
Total		88 min	109 min

^aPoints 1 through 10 are labeled on Fig.3.4.

Source: Directorate of Licensing, U.S. Atomic Energy Commission, *Final Environmental Statement—Peach Bottom Atomic Power Station Units 2 and 3*, Docket Nos. 50-277 and 50-278 (April 1973).

II. PLANT SITE CHARACTERISTICS

A. HYDROLOGY¹⁻³

The Peach Bottom Atomic Power Station is located in southeastern Pennsylvania on the west bank of Conowingo Pond, an impounded reach of the Susquehanna River. Figure 3.5 shows Peach Bottom in relation to the hydroelectric dams of the lower Susquehanna. The upstream boundary of Conowingo Pond is Holtwood Dam, which is in Pennsylvania, while the downstream boundary is Conowingo Dam in Maryland.

Conowingo Pond is 14 miles long and varies in width from 0.5 to 1.5 miles. PBAPS is located about 6 miles downstream of Holtwood Dam, 3 miles upstream of the Pennsylvania-Maryland state line, and 8 miles upstream of Conowingo Dam. The width at the site is about 1.3 miles. Conowingo Pond has a surface area of 13.5 sq miles and a volume that varies between 240,000 and 322,000 acre-ft. Normal depths are 10 to 20 ft in the region from Holtwood Dam to the state line; the pond then slopes to a depth of about 90 ft at the base of Conowingo Dam. The silting rate has been about 7 ft in 20 years.

Daily average flows at Conowingo Dam have ranged from 1400 cfs during the drought of 1964 to 972,000 cfs as a result of Hurricane Agnes in June 1972. The mean daily average flow at Conowingo Dam is 36,080 cfs. Figure 3.6 presents monthly and annual flow duration curves based on data recorded at Conowingo Dam between 1929 and 1969. Maximum flows generally occur in March or April, and minimum flows are expected during August and September. Daily average flows exceed 7000 cfs about 90% of the time.

Natural river flows in the lower Susquehanna are based on measurements at the U.S. Geological Survey gauge in Harrisburg, which is in the last unregulated reach of the river. Based on predicted flows at Harrisburg, the operation of the Conowingo Hydro Plant is scheduled so that Conowingo Pond will be full on Monday morning and will be lowered by intermittent operation during the week to such a level that it can be refilled over the weekend. During an average week, the pond level may decline by 3 to 3.5 ft.

The flow patterns in Conowingo Pond are directly influenced by the following regulated in and out flows.

- (a) The inflow through the Holtwood Hydroelectric Plant may vary from 0 to 32,000 cfs. Higher flows pass over the spillway.
- (b) The Muddy Run Pumped Storage Station pumps water out of the pond at a rate of up to 27,120 cfs during off-peak hours. During peak demand hours, the station generates up to 880 MW(e) by returning flows of up to 34,000 cfs to the pond.
- (c) The cities of Chester and Baltimore withdraw flows of up to 50 and 230 cfs, respectively, for their municipal water supplies. The Baltimore withdrawal is expected to increase to 460 cfs.

Fig. 3.5. Peach Bottom — Hydraulic facilities on the lower Susquehanna River. Source: Directorate of Licensing, U.S. Atomic Energy Commission, *Final Environmental Statement — Peach Bottom Atomic Power Station Units 2 and 3*, Docket Nos. 50-277 and 50-278 (April 1973).

ORNL DMG NO 76-12557

PERIOD: 1929-1969

Fig. 3.6. Peach Bottom — Flow duration curves of the Susquehanna River at Conowingo Dam. Source: Philadelphia Electric Company, 316(a) Demonstration for PBAPS Units 2 and 3 on Conowingo Pond (July 1975).

- (d) Outflows through the Conowingo Hydro Plant vary from 0 to 85,000 cfs. Higher flows pass over the spillway.

Because of their relatively small size, the water supply intakes have little influence on pond-wide circulation. The contribution of direct runoff and creek inflow is also assumed to be small. Circulation patterns are largely dominated by Holtwood, Muddy Run, Conowingo Dam, and the natural river flow rate.

Figure 3.7 shows graphically a normal seven-day cycling operation of the Muddy Run Plant, the Holtwood Dam, and Conowingo Dam. This figure illustrates the operations in late summer when river flow is relatively low (assumed to be 2500 cfs in the graph). The Muddy Run Plant pumps into the Muddy Run Reservoir during the early morning hours and generates electricity during the hours of peak demand. The Holtwood and Conowingo Hydroelectric Plants essentially counterbalance each other with respect to the net rate of water input and discharge from Conowingo Pond. Figures 3.8 and 3.9 show the cyclic behavior at representative river flows of 5000 and 15,000 cfs respectively. The operation of these three plants is altered markedly during the Saturday and Sunday periods when demands for electrical power are low. At a low river flow of 2500 cfs (Fig. 3.7), the Muddy Run Plant is the major determinant in dictating a flow pattern, whereas at high river flows (15,000 cfs), the periodic withdrawal of water through the Conowingo Plant becomes a major determinant of flow pattern (Fig. 3.9). The Holtwood Plant under high-flow conditions provides an almost continuous input to Conowingo Pond, whereas the effect of the cyclic behavior of the Muddy Run Plant is diminished.

In addition to PBAPS, heat of artificial origin is added to Conowingo Pond by the Holtwood Steam Generating Station. This is a coal-fired plant that rejects 198 MW(t) directly upstream of Holtwood Dam. At steady low-flow conditions, it might be expected that this plume could raise the intake temperature at Peach Bottom by 0.5°F. In fact, the operation of Muddy Run serves to reduce this effect. During the pumping phase at low-river flows, the flow in Conowingo Pond is upstream from Peach Bottom to Muddy Run, thus preventing the Holtwood plume from progressing downstream. During generation, the effective dilution is many times the natural flow.

The maximum surface temperature measured during the preoperational period was 94°F, and the maximum bottom temperature was 85.2°F. Surface temperatures of 32°F may be inferred because the pond usually has ice cover during January and February. During the 1966 through 1974 period, the ice usually lasted for less than four consecutive weeks.

Figure 3.10 shows the monthly average of daily mean and extreme river temperatures observed at Safe Harbor Hydro Station from 1936 through 1966. Table 3.3 is a joint probability distribution for seven-day average flows measured at Harrisburg and seven-day average temperatures measured at Safe Harbor Hydro Station from 1936 through 1966. This table indicates

ORNL DWG 76-12558

Fig. 3.7. Peach Bottom - Major weekly inflows and discharges of Conowingo Pond at a natural river flow of 2500 cfs. Source: Directorate of Licensing, U.S. Atomic Energy Commission, *Final Environmental Statement - Peach Bottom Atomic Power Station Units 2 and 3*, Docket Nos. 50-277 and 50-278 (April 1973).

Fig. 3.8. Peach Bottom — Major weekly inflows and discharges of Conowingo Pond at a natural river flow of 5000 cfs. Source: Directorate of Licensing, U.S. Atomic Energy Commission, *Final Environmental Statement — Peach Bottom Atomic Power Station Units 2 and 3*, Docket Nos. 50-277 and 50-278 (April 1973).

ORNL DMG 76-12560

Fig. 3.9. Peach Bottom — Major weekly inflows and discharges of Conowingo Pond at a natural river flow of 15,000 cfs. Source: Directorate of Licensing, U.S. Atomic Energy Commission, *Final Environmental Statement — Peach Bottom Atomic Power Station Units 2 and 3*, Docket Nos. 50-277 and 50-278 (April 1973).

ORNL DWG NO 76-12570

Fig. 3.10. Peach Bottom — Range of average daily river temperatures, Susquehanna River at Safe Harbor Hydro Station (1936-1966). Source: Philadelphia Electric Company, 316(a) *Demonstration for PBAPS Units 2 and 3 on Conowingo Pond* (July 1975).

Table 3.3. Peach Bottom — Joint probability distribution
for seven-day average flows and temperatures,^a Susquehanna River

River flow (cfs)	Temperature (°F)							Seven-day average flow distribution (%)
	30-39	40-49	50-59	60-69	70-79	80-85	>85	
<2,500	0	.309	.451	.283	.371	.044	0	1.458
2,500-4,999	.080	.582	1.175	2.165	5.276	1.856	.177	11.321
5,000-9,999	2.589	1.688	2.033	2.307	5.647	3.889	.247	18.400
10,000-14,999	4.216	1.441	.831	.954	4.278	1.621	.283	13.824
15,000-19,999	3.818	.919	.486	1.025	2.846	.725	.009	9.829
20,000-29,999	4.940	1.865	1.131	2.165	2.430	.327	0	12.856
30,000-39,999	3.526	1.494	.981	1.821	1.087	.018	0	8.927
40,000-49,999	2.333	1.370	1.228	.999	.362	0	0	6.292
50,000-74,999	4.030	2.961	2.678	1.326	.194	0	0	11.189
≥75,000	2.015	1.298	.972	.583	.027	0	0	5.895
Seven-day average temperature distribution, %	27.547	14.537	11.966	13.628	22.518	8.662	.716	

^aBased on average daily U.S. Geological Survey river flows for Harrisburg and average daily temperatures at Safe Harbor Hydro Station (1936 through 1966).

Source: Philadelphia Electric Company, 316(a) Demonstration for PBAPS Units 2 and 3 on Conowingo Pond (July 1975).

that although temperatures greater than 80°F occurred 9.4% of the time, they were coincident with river flows below 2500 cfs only 0.04% of the time.

B. METEOROLOGY¹⁻⁴

The climate at Peach Bottom is relatively mild and humid, with an annual temperature range from 5°F to 90°F expected in a typical year. Monthly average values of dry-bulb temperature, relative humidity, wet-bulb temperature, wind speed, and solar radiation are presented in Table 3.4. These averages are derived from onsite measurements made between August 1967 and March 1972, except for the solar radiation values taken from the *Climatic Atlas of the United States*.⁵ The valley exerts a definite channeling influence on winds, with wind from the WNW occurring about 40% of the time. Onsite precipitation data from August 1967 through July 1971 showed an annual average of 30.2 in. (water equivalent). August was the wettest month (4.75 in.), while January was the driest (0.8 in.). Severe ice storms occur about every three years, usually between December and February.

Table 3.4. Peach Bottom – Units 2 and 3 monthly meteorological data

Month	Occurrence	Dry-bulb temperature (°F)	Relative humidity (%)	Wet-bulb temperature (°F)	Wind speed (mph)		Solar radiation (Langley/day)
					50 ft	25 ft	
January	Average	27.0	75.0	25	8.5	6.7	160
	50%			30			
	5%			40			
February	Average	30.0	70.2	27	7.6	6.0	225
	50%			30			
	5%			44			
March	Average	38.1	68.5	34.5	8.2	6.5	315
	50%			35			
	5%			51			
April	Average	50.0	67.9	45	8.3	6.6	400
	50%			45			
	5%			62			
May	Average	60.0	76.2	56	6.7	5.3	480
	50%			55			
	5%			68			
June	Average	70.9	81.8	67	6.3	5.0	525
	50%			65			
	5%			73			
July	Average	75.3	82.1	71	5.5	4.3	510
	50%			69			
	5%			74		3.4	610
August	Average	71.2	84.1	68	4.5	3.5	450
	50%			68			
	5%			74			
September	Average	62.8	86.7	60.5	5.1	4.0	380
	50%			61			
	5%			73			
October	Average	54.3	84.4	52	5.7	4.5	270
	50%			50			
	5%			65			
November	Average	42.9	81.5	40.5	6.0	4.7	180
	50%			40			
	5%			56			
December	Average	34.9	78.5	32.5	8.2	6.5	130
	50%			30			
	5%			47			

Source: Philadelphia Electric Company, 316(a) Demonstration for PBAPS Units 2 and 3 on Conowingo Pond (July 1975).

III. OPERATING HISTORY

Peach Bottom Unit 1 reached initial criticality in March 1966 and was shut down for decommissioning in November 1974. Table 3.5 lists the annual average plant capacity factors (PCFs) for Unit 1 from 1967 through 1974.⁶

Table 3.5. Peach Bottom - Unit 1
annual average plant
capacity factors^a

Year	Plant capacity factor (%)
1967	42.2
1968	37.4
1969	39.1
1970	42.0
1971	60.0
1972	32.8
1973	56.2
1974	59.4

^aPCF = (net electric energy generated)
(100) / (maximum dependable capacity)
(gross hr).

Construction permits for Units 2 and 3 were issued in January 1968. Unit 2 achieved initial criticality in September 1973 and began commercial operation in May 1974. Unit 3 achieved initial criticality in August 1974 and started commercial service in December 1974.

Because of a generic BWR design problem involving vibration of in-core monitoring devices, the authorized operating levels of Units 2 and 3 were restricted during the latter part of 1975. A 50% power limitation was imposed on Unit 3 on June 2 and on Unit 2 on June 21. On July 23, the limit was raised to 55% for both units, with permission to operate at higher levels for brief periods in order to explore the nature of the vibration problem. Unit 2 was repaired during November, and its restriction was lifted as of December 1, 1975.

Figure 3.11 shows the monthly average heat rejection rates for the combined station for 1974 and 1975. This is the total heat rejected to the atmosphere and to Conowingo Pond. Although heat was rejected in each month, only in March and April 1975 did the station approach rated capacity. The 1974 annual average heat rejection rate was 1583 MW(t), and the 1975 average was 2627 MW(t). The data for the first three months of 1974 were obtained by planimetry of graphs in the *Monthly Reports of the Thermal and Biological Monitoring Programs*⁷ and do not include the

Fig. 3.11. Peach Bottom — Monthly average heat rejection rate (to air and water).

contributions of Unit 1. The values for the other months were obtained from the *Operating Plants Status Reports*⁸ and do include all units. During the preoperational period from September through December 1973, Unit 2 rejected an average of 81 MW(t) for 35 days.

As may be inferred from the above discussion, heat rejection data in a form suitable for statistical analysis are not easily obtained. The Semiannual Operating Reports⁹ usually contain only a six-month summary table. The best sources of monthly data after April 1974 are the *Operating Plants Status Reports*.⁸ The *Monthly Reports of the Thermal and Biological Monitoring Programs*⁷ contain continuous graphs of thermal and electrical output (such as Fig. 3.12). These are of value in interpreting plume maps but are difficult to use in further analysis. The only way to determine the proportion of heat rejected to the pond is to back-calculate using the temperature rise between intake and discharge and the circulating water flow rate. As will be discussed in Sect. IV.A.2.a, this technique is awkward to use and leads to uncertain results due to the nature of the temperature measurements. Analysis would be simplified if monthly tables were reported in which the average heat rejected to the atmosphere and to Conowingo Pond are distinguished.

Further discussion of temperature and flow-rate measurements and cooling tower performance will be found in Sect. IV.A.2.a.

PEACH BOTTOM ATOMIC POWER STATION OPERATIONS
UNITS 2 and 3
JUNE 24 TO JULY 22, 1974

Fig. 3.12. Peach Bottom - Typical thermal and electrical output data, June 24 to July 22, 1974. Source: Philadelphia Electric Company, *Peach Bottom Atomic Power Station, Thermal and Biological Monitoring Program Monthly Reports*, No. 1 (July 1973) through No. 31 (January 1976).

IV. CONFIRMATORY ASSESSMENT

A. HYDROTHERMAL MONITORING

1. Predicted hydrothermal impactsa. Philadelphia Electric Company (PECO) hydrothermal predictions^{10,11}

Philadelphia Electric Company (PECO) based its preoperational predictions of the Peach Bottom thermal plume on a physical model study conducted at Alden Research Laboratories. The objectives of the study were to design an efficient discharge system and to provide predictions of the thermal plume under various power levels, hydraulic regimes, and meteorological conditions. No reports were issued covering the design phase of the study.

The physical model is a scaled-down replica of the entire Conowingo Pond, contained in a 274- by 50-ft building. The horizontal length scale is 1/300, and the vertical scale is 1/30. This gives a vertical distortion of 1/10. The time-scale ratio is 1/54.8. The density ratio is 1/1.

Wooden templates derived from contour maps of the river bottom from Conowingo to Holtwood were placed every 5 ft in the model; these placements represented a spacing of approximately every 1500 ft in the prototype (Conowingo Pond). Areas in the immediate vicinity of the Peach Bottom site were provided with extra templates for a more accurate description of the topography at the inlet and discharge points. All templates were back-filled with compacted sand, and the final surface of the model was plastered with cement grout to the finished top edges of the templates. Flows were provided to correspond to the time-dependent inputs to and discharges from Conowingo Pond, with the exception of the two intakes for the cities of Chester and Baltimore.

The model was constructed so that water from the Peach Bottom model intake could be passed through a boiler and heated to produce the same net plant temperature rise that exists in the prototype. Flows corresponding to summer conditions in the river, where an ambient river temperature approaching 85°F may occur together with a rise of 13°F within the plant, could be modeled. During the winter months, cold water from the local stream at Alden Laboratories was used to duplicate conditions corresponding to near-freezing in the prototype. A heating unit was installed to help maintain constant river temperatures. Exhaust fans and heating units were provided to help maintain constant model atmospheric conditions during each test run.

During the 1967-1968 testing program, temperature measurements were made with 250 copper-constantan thermocouples located at different positions, and these temperatures were recorded automatically every 48 sec for each thermocouple. This 48-sec period corresponded to approximately 44 min in the prototype. More frequent measurements were also made when these were thought to be necessary.

Because heat transfer to the atmosphere cannot be correctly simulated in a physical model, corrections must be applied to the measurements in order to obtain predictions of prototype results. In the report on the 1967-1968 phase of this study,¹⁰ heat transfer to the atmosphere was erroneously related to the difference between water temperature and wet-bulb temperature. This led to gross underpredictions of the thermal plume, as pointed out in the FES.¹ Consequently, further tests were conducted, and a more accurate method of accounting for heat transfer to the atmosphere was employed.

Later, model tests were run to maintain the model equilibrium temperature approximately equal to those expected in the prototype. Investigations indicated that the prototype average monthly equilibrium temperatures were essentially equal to the ambient river temperatures. The equilibrium temperature is the ambient water surface temperature at which the net rate of heat transfer across the water surface is zero for a given atmospheric condition. The model equilibrium temperature was estimated by use of three shallow insulated boxes at different locations in the model building. The boxes were kept filled with water to a depth of about 1.5 in., and their temperature was monitored continuously during each test run. The heating units and exhaust fans in the building were used to maintain the model equilibrium temperature generally within 0.5°F of the model river temperature.

During each test, wet- and dry-bulb and equilibrium temperatures were monitored. Surface heat exchange coefficients were also estimated using insulated waterboxes. A known heat input was imposed on the water in the box, and the surface temperature at steady-state conditions was recorded. Data were collected for several imposed heat loads during each test.

Temperature measurements in the model were made with copper-constantan thermocouples. Three hundred thermocouple probes were used, and about 90 sec were required to record temperatures for all probes. This corresponds roughly to about 1 hr 20 min in the prototype for the model scales used. The thermocouples were distributed throughout the model to provide definition of vertical and horizontal temperature patterns and to monitor the temperature of all flows into and out of the model.

The test program in the model was governed by the consideration of the effects of various flow conditions at Holtwood, Muddy Run, Conowingo, and Peach Bottom on the reservoir itself. The daily and weekly operations of the three hydro units result in unsteady flow conditions in Conowingo Pond. The flow patterns may repeat themselves on a weekly cycle if river flow conditions permit. Each model test was conducted using the appropriate operating schedule for the river flow rate under consideration.

Tests were normally run for the equivalent of three prototype weeks. The first week was used to establish the flow patterns in the model and the second week for obtaining the basic temperature distribution. Where appropriate, the third week of data included the effects of an instantaneous complete shutdown of the plant.

In the Bechtel report,¹¹ heat transfer to the atmosphere was correctly related to excess temperature above equilibrium temperature. To correct for the difference in surface heat transfer characteristics between model and prototype, the following technique was used. A prototype pond heat balance was performed equating heat input from the plant to heat output by pond outflow and transfer to the atmosphere. This was then equated to a similar model heat balance. A model surface temperature correction factor was determined that would result in a heat balance between model and prototype. This factor was then used to correct the model data to the specified prototype conditions. This correction is applicable in the area somewhat outside the jet mixing zone. Jet mixing is not adequately simulated in a distorted model, and therefore, a model prototype correction factor cannot be determined for this area. Most of the heat load imposed on the pond is dissipated to the atmosphere. However, under high through-flow conditions, a substantial portion of the imposed heat load may be advected by flows through the Conowingo Dam.

The results of the conversion of model to prototype temperature distributions for Conowingo Pond are presented as isotherms of the temperature rise above the ambient incoming water temperature. For each case analyzed, isotherms are presented on a plan view of the pond at depths of 1, 5, and 13 ft for three times during a weekly cycle. Usually the results are presented for Tuesday AM, Thursday PM, and either Sunday PM or Monday AM. The Tuesday and Thursday results represent typical isotherm patterns after Muddy Run pumping and generating cycles respectively. The late Sunday or early Monday isotherm patterns represent times when the thermal plume approaches its greatest upstream extent due to the prolonged Muddy Run pumping cycle over the weekend.

In addition to the above, vertical temperature-rise profiles at four locations in the pond are shown. The Alden Research Laboratories model test used for each case is identified, as are the basic plant, pond, and atmospheric conditions. A pond operational schedule is shown for the river flow under consideration, and the average surface heat exchange coefficient is given.

Table 3.6 lists all the two-unit cases presented, including pertinent river and plant operating conditions. The results provide a range of predicted temperature distributions under various expected operating conditions. Once-in-ten-year minimum average seven-day low flow or lower data are presented. So that these data will be considered in terms of their probable occurrence, Table 3.6 shows the recurrence interval for each low-flow test. A similar set of results for one-unit operation was also presented.

Table 3.6. Peach Bottom — Units 2 and 3 model test analysis
for prediction of pond isotherms (data summary)

Month	River flow ^a (cfs)	River temperature ^b (°F)	Wet-bulb temperature ^c (°F)	Modeled river flow (cfs)	Recurrence ^d interval (years)	Discharge to pond (cfs)	ΔT pond ^e (°F)	Number of towers
January	8,000 (28,000)	35	25	5,000 25,000	36	3,350 3,350	17.3 17.3	3 3
March	15,800 (66,000)	40	34.5	15,000 25,000	12	3,350 3,350	17.5 17.5	3 3
May	12,500 (33,500)	64	56	10,000	30	3,350	15.2	3
July	3,800 (12,500)	80	71	2,500 10,000	>50	3,350 3,350	13.0 13.0	3 3
		85	78 ^f	2,500	>50	3,350	13.0	3
November	4,000 (19,000)	45	40.5	2,500 25,000	30	3,350 3,350	17.2 17.2	3 3

^aOnce-in-ten year minimum average seven-day low flow, Susquehanna River, computed natural flow entering Safe Harbor; numbers in parenthesis represent median monthly flows.

^bAverage monthly river temperature measured at Safe Harbor.

^cAverage monthly wet-bulb temperature measured at site (Weather Station No. 1), except as noted.

^dSeven-day average river flow.

^eΔT pond = temperature of discharge to pond minus the intake water temperature.

^fWet-bulb temperature equaled or exceeded approximately 1% of time in month.

Source: R. A. Elder, F. H. Wend, A. R. Bird, and F. M. Al-Kazily, *Predicted Prototype Temperature Distributions in Conowingo Pond, Summary Report*, Bechtel Inc. (July 1973).

Figure 3.13 shows one of the largest plumes observed in the model study. In this severe January case, which is expected to occur once in 36 years, almost the entire pond below Peach Bottom shows a 9°F temperature increase.

For the pond as a whole, predicted rates of temperature change following reactor shutdown are of the same magnitude as those occurring during normal operation.

b. Oak Ridge National Laboratory (ORNL) hydrothermal predictions¹

ORNL checked the PECO physical model study results by an energy balance to see if the average surface temperature was adequate to transfer the imposed heat load to the atmosphere. This calculation revealed a serious error in the reduction of the physical model data and led to a complete reconsideration of the thermal impact of Peach Bottom on Conowingo Pond.

Near-field isotherms were also calculated using a steady-state, vertically mixed integral model developed especially for this problem. The model assumes a jet discharge into a co-flowing uniform channel. Cross-channel velocities are not allowed. Entrainment and bottom friction act to slow the jet to the ambient velocity; the calculated velocity pattern is used to determine the temperature field. The temperature of the ambient fluid is taken to be the fully mixed pond temperature appropriate to the conditions being considered. In this way, a crude matching of near and far fields is obtained. Surface heat transfer to the atmosphere is included.

Figure 3.14 shows predictions for two summer cases. In both predictions, two reactors are operating with a condenser temperature rise of 13°F and a discharge velocity of 6 fps. In both cases, the surface heat transfer coefficient is $5.8 \text{ Btu ft}^{-2} \text{ hr}^{-1}$. The isotherms represent temperature rise above natural pond temperature. In Case 1, the pond flow rate is 2500 cfs, and the fully mixed pond temperature rise is 3.8°F. In Case 2, the pond flow rate is 10,400 cfs, and the fully mixed pond temperature rise is 2.3°F. ORNL concluded that the maximum far-shore temperature rise would be 4°F under summer low-flow conditions while Muddy Run was discharging and that higher near-field temperatures should occur during other phases of Muddy Run operation.

2. Observed hydrothermal impacts

a. Hydrothermal monitoring program

Since December 1971, an integrated program of hydrothermal monitoring has been carried out for PECO by Environmental Devices Corporation (ENDECO). The program consists of two major ongoing components: continuous monitoring by fixed thermographs and periodic boat surveys of the vertical temperature profile at selected stations. A number of ancilliary projects have also been carried out, including a current survey of the pond and detailed studies of the discharge jet.

Fig. 3.14. Peach Bottom — ORNL estimate of isotherms resulting from two-unit operation for summer low-flow (Case 1) and summer average-flow (Case 2) conditions. Muddy Run assumed to be in discharge phase. Source: Directorate of Licensing, U.S. Atomic Energy Commission, *Final Environmental Statement - Peach Bottom Atomic Power Station Units 2 and 3*, Docket Nos. 50-277 and 50-278 (April 1973).

The early phase of the monitoring program is summarized in a preoperational report¹² covering 1972 and the first half of 1973. Since then, monthly reports⁸ have been issued. Because these are intended to satisfy all regulatory agencies, they go beyond what NRC requires. Although there have been some changes in their contents from time to time (with a major upgrade in July 1974), it is helpful to examine the list of contents in a typical Monthly Report, Number 30, covering December 1975. (Actually, the reports cover the one-month periods between thermograph film magazine retrievals, rather than calendar months.) Table 3.7 lists the tables and Table 3.8 lists the illustrations contained in the hydrothermal section of Monthly Report Number 30.

The fixed monitors are ENDECO Type 109 recording thermographs, which take 1-hr time exposure photographs of a liquid-in-glass thermometer each hour. These thermographs have an accuracy of $\pm 0.4^{\circ}\text{F}$ and a time constant of 10 min. They have proven to be very reliable in service at Peach Bottom, with 100% data retrieval not uncommon. Figure 3.15 shows the locations at which thermographs were positioned in July 1975. During 1972 and 1973, there were 18 locations monitored by thermographs. This number was increased to 35 in January 1974 but was reduced to 26 in December 1974. With a few exceptions, these locations have since remained unchanged. Most of the thermographs have their sensors mounted at a depth of 1 ft, but there are several near-bottom sensors. In order to provide on-line information to the reactor operators, radio telemetering thermal sensors are located at Holtwood Dam and at the Pennsylvania-Maryland state line. There is also a hard-wire telemetering system at the state line.

Figure 3.15 also shows the vertical profiling stations used in the fine-grain thermal boat surveys. During the first half of 1972, 44 stations were sampled. This was increased to 55 in July 1972 and to the present 72 in July 1974. Temperature readings at 1, 5, and 10 ft are made at each location using an ENDECO Type 133 Digital Thermometer. This device has an accuracy of $\pm 0.4^{\circ}\text{F}$ and a time constant of 3.6 sec. Sensor depth is determined by markings on the probe cable.

More than 184 fine-grain thermal surveys have been made since the start of monitoring. The number reported has varied from 1 to 23 per month, with 6 being a typical number. Figure 3.16 shows the usual manner in which the results of these boat surveys are presented. Horizontal isotherm plots are prepared for each depth, and a vertical profile down the Pond axis is also presented. These maps are accompanied by a rather complete list of environmental parameters. The only major omission is the number of cooling towers in operation. The particular survey shown took about 4 hr to complete, which is a typical duration (although 7 hr is not uncommon). The question of how much distortion is introduced by this time lag has not been addressed.

Table 3.7. Peach Bottom - Hydrothermal tables contained in Monthly Report Number 30

Table number	Title
2.3-1	Daily Meteorological Summary, December 1975
2.4-1 ^a	Percent Acres of Conowingo Pond, at or above 5°F for December
2.4-2 ^a	Percent area above each isotherm for individual surveys, Conowingo Pond (December 1972, 1973, 1974, 1975)
2.4-3 ^a	Percent of Area vs Occurrence Surface Isotherms: Conowingo Pond (December 1972, 1973, 1974, 1975)
2.5-1	Conowingo Pond, Thermograph Statistics by Station (18 instruments), December 1975
2.5-2 ^a	Conowingo Pond, Thermograph Statistics, 16 surface/18 stations, December 1975
2.6-1 through 2.6-4 ^a	Rate of Change of Temperature (DT/Dt), (18 thermograph stations), December 1972, 1973, 1974, 1975)

^aEliminated starting with Monthly Report Number 31.

Source: Philadelphia Electric Company, Peach Bottom Atomic Power Station, Thermal and Biological Monitoring Program Monthly Reports, No.1 (July 1973) through No.31 (January 1976).

Table 3.8. Peach Bottom - Hydrothermal illustrations contained in Monthly Report Number 30

Figure number	Title
2.1-1	Instrument and survey locations, Conowingo Pond
2.2-1	Water Flow; Natural River, Muddy Run, December 1975
2.2-2	Water Flow; Holtwood, Conowingo, December 1975
2.2-3	PBAPS Operations: Unit 2, December 1975
2.2-4	PBAPS Operations: Unit 3, December 1975
2.4-1 through 2.4-3 ^a	Center Line Axis Predicted Ambient, Conowingo Pond, December 1975
2.4-2 through 2.4-10	Isotherm Plots, Conowingo Pond, December 1975
2.5-1	Instrument Operation, Conowingo Pond
2.5-2 ^a	Vertical Temperature Differential (ΔT) at Thermograph Station 16; Mean Surface Temperature
2.5-3	Temperature Comparisons, PBAPS Vicinity, December 1975

^aEliminated starting with Monthly Report Number 31.

Source: Philadelphia Electric Company, Peach Bottom Atomic Power Station, Thermal and Biological Monitoring Program Monthly Reports, No.1 (July 1973) through No.31 (January 1976).

Fig. 3.15. Peach Bottom — ENDECO temperature monitoring locations in Conowingo Pond. Source: Philadelphia Electric Company, Peach Bottom Atomic Power Station Monthly Report No. 21 (July 1975), Fig. 2.1-1.

Fig. 3.16. Peach Bottom — Results of a typical small-boat thermal survey. Source: Philadelphia Electric Company, *Peach Bottom Atomic Power Station, Thermal and Biological Monitoring Program Monthly Reports*, No. 1 (July 1973) through No. 31 (January 1976).

KEY TO FIG. 3.16

DATE: Tuesday December 9 1975
day month date yearTIME: Survey Start: 1345 Hours (EST)
State Line: 1535 Hours (EST)
Survey Finish: 1740 Hours (EST)HYDRAULIC DATAPond Elevation Start: 107.87 FeetFinish: 107.67 Feet

Average (24 Hour) Flows:

Natural River 27,400 CFSConowingo Inflow 26,325 CFSConowingo Dam Draft 29,025 CFSPBAPS POWER OUTPUTUnit 2: Thermal 2810 MegawattsElectrical 920 MegawattsUnit 3: Thermal 1800 MegawattsElectrical 600 MegawattsMETEOROLOGICAL DATATime: 1330-1345 ESTAir Temperature: 45 °FRelative Humidity: 93 PercentBOAT SURVEY SUMMARYWATER TEMPERATURE (THERMOGRAPH)Daily Mean: Holtwood 3.7 °C (38.7 °F)Muddy Run 3.7 °C (38.7 °F)Mid Survey: Holtwood 3.7 °C (38.7 °F)Muddy Run 3.9 °C (39.0 °F)WATER TEMPERATURE (SURVEY)PBAPS: Discharge 9.3 °C (48.7 °F)Intake 3.4 °C (38.1 °F) ΔT 5.9 °C (10.6 °F)

Pond Surface:

Station

Maximum 9.3 °C (48.7 °F) 9Minimum 3.4 °C (38.1 °F) 59,69

Pond Bottom:

Maximum 9.3 °C (48.7 °F) 9Minimum 3.4 °C (38.1 °F) 59,69Precipitation: 0.05 Inches
(24 Hour Total)Wind Speed: 8.4 MPHCloud Cover: Low CoverLocation: Boat Station 7Wind Direction: Southeast

Comment:

b. Hydrothermal monitoring required by Technical Specifications

The hydrothermal monitoring requirements imposed on PBAPS by NRC are contained in Sects. 2.1, 3.1, and 6.3a of Appendix B to the Peach Bottom Operating License.¹³

Sections 2.1 and 3.1 are parallel sections establishing operating limits and monitoring requirements on the maximum discharge temperature. In the initial issuance (July 1973), these sections imposed no requirements because Unit 2 was restricted to power levels under 329 MW(t) and because Unit 3 was not yet operating. The October 1973 revision of Sect. 2.1 required that as soon as the cooling towers were completed, all three towers should be used whenever Unit 2 exceeded 20% rated thermal power. (When the cooling system was designed, it was intended that the towers be used only during the summer.) A cooling tower was defined to be operable if its lift pump and 10 of its 11 fans were operable. Cooling tower inoperability was defined to be an Environmental Deviation (subject to special reporting as specified in Sect. 7.4.2) if (1) more than one tower is affected, (2) the average daily calculated flow of the Susquehanna River through Conowingo Pond is less than 10,000 cfs, or (3) full operation of all towers is not regained within 48 hr. The 48-hr period is intended to allow maintenance to be performed. Section 3.1 requires that the condenser inlet and discharge canal outlet temperatures be continuously monitored in the control room. This system is allowed to be inoperable for seven days for maintenance before an Environmental Deviation occurs. There is no reporting requirement associated with these measurements.

Requiring three cooling towers to be in operation whenever either unit exceeds 20% power is somewhat rigid. Presumably, three towers are adequate to ensure that no ecological damage results when both units are at 100% power. Therefore, it seems reasonable to require tower operation only as needed to limit the heat rejection rate in Conowingo Pond to that which would result from both units operating at full power with three towers. It would also seem reasonable to require that the towers be turned off during periods when the wet-bulb temperature exceeds the discharge temperature; otherwise, the towers will tend to increase the heat load on Conowingo Pond.

Section 7.4.2 requires that Environmental Deviations be reported orally to the NRC within 24 hr and that a written report be submitted within 10 days. Table 3.9 lists the 25 Environmental Deviations reported during 1974 and 1975 involving the cooling towers. Eleven of these involved 2 of 11 fans on a single tower being inoperative. Five of these reports dealt with deviations lasting 2 hr or less.

Table 3.9. Peach Bottom - Environmental Deviations involving cooling towers

Environmental deviation number	Docket number	Reporting date	Problem	Duration	River flow (cfs)	Plant power level (%)
74-2	50277-286	7-15-74	2 of 11 fans on Tower B inoperative	72 hr		90
74-5			Tower B inoperative	38 days <		
74-6	-338	12-9-74	2 of 11 fans on Tower C inoperative	<48 hr		100
74-7	-345	12-12-74	Tower A inoperative	1 hr	25,000 <	100
75-1	-369	2-3-75	2 of 11 fans on Tower C inoperative Tower A inoperative	<4 days		35
75-2	-365	2-7-75	2 of 11 fans on Tower A inoperative	<11 days		95
75-3	-377	2-21-75	2 of 11 fans on Tower C inoperative	<10 days	25,000 <	100
75-6	-384	3-11-75	2 of 11 fans on Tower C inoperative	5 days	70,000 <	200
75-7	-393	4-4-75	2 of 11 fans on Tower C inoperative	<11 days	76,000 <	200
75-8	-408	4-28-75	2 of 11 fans on Tower C inoperative	<12 days	32,000 <	200
75-10	-422	5-23-75	2 of 11 fans on Tower B inoperative	<10 days	60,000 <	
75-11	-436	6-27-75	Tower A and Tower C inoperative	30 min	45,000 <	
75-12	-463	6-27-75	Tower A and Tower B inoperative	16 hr	36,000 <	
75-13	-467	7-25-75	2 of 11 fans on Tower B inoperative Tower C inoperative	1 hr		100
75-14	-483	8-21-75	Tower A and Tower B inoperative	20 min	10,700	117
75-16	-485	9-8-75	Tower B inoperative	2 hr	7,800	110
75-17	-494	9-10-75	Tower A inoperative	15 days <	<10,000	110
75-18	-500	9-24-75	2 of 11 fans on Tower C inoperative	30 min		110
75-19	-506	9-26-75	Tower C inoperable	2 hr		110
75-20	-518	10-3-75	2 of 11 fans on Tower C inoperative	3 days	20,000 <	57
75-21	-519	10-6-75	All Towers shut down during high river flows	3 days	200,000 <	100
75-22	-515	10-10-75	2 of 11 fans on Tower C inoperative	11 days		110
75-23	-540	10-24-75	Tower A and Tower C inoperative	15 hr	28,000	110
75-24	-530	10-29-75	All Towers shut down during high river flows	3 days	100,000 <	110
75-26	-564	11-26-75	Tower A and Tower C inoperative	10 days	38,000 <	55

Section 6.3a is called "Thermal Plume Mapping" and has remained unchanged since the October 1973 revision. It reads as follows:¹³

Objective

To determine the extent of the thermal plume in the Conowingo Pond and in the discharge canal resulting from the heated circulating water discharge and to select a representative measurement that will accurately predict pond conditions.

Specification

A thermal monitoring program will be conducted essentially as described in Supplement No. 2 to "Applicant's Environmental Report-Operating License Stage"¹⁴ in the answer to Question 24. Isothermal plots of the receiving waters shall be produced at 1°F intervals to show the results of plant operations under various conditions of load, stream flow, operations of hydro-electric plants, meteorological conditions, and ambient stream temperatures. Such plots shall indicate both surface and depth temperature distribution and shall be determined by model tests and prototype monitoring. A minimum number of continuously monitoring temperature sensors shall be determined to accurately predict pond conditions. Twice a month, weather conditions permitting, data will be collected utilizing a motor-boat-mounted temperature recorder.

Discharge canal water temperatures shall be monitored monthly using the temperature measurement points at the outlet of the discharge pond into the discharge canal, at the discharge point of each cooling tower, and at the discharge point to Conowingo Pond.

Bases

Hydraulic model tests have been completed to predict the extent of the thermal plume. However, the model does not account for the effect of meteorological conditions and other phenomena occurring in the prototype. Thermal mapping of the prototype will be performed with one- and two-unit operation.

The results shall be reported to the Commonwealth of Pennsylvania Department of Environmental Resources as required under the Industrial Waste Permit No. 5681011. The results shall be reported to the AEC as per Section 7.4, except that reporting shall be on a monthly basis.

The monitoring program described in the answer to Question 24 is that conducted by ENDECO.

Once the plant is in operation, plume studies should be based on the prototype.

The monthly measurements in the discharge canal are not very helpful. If these measurements are to be of value, they should be continuous. Indeed, there are thermographs where the discharge pond empties into the discharge canal (thermograph 31) and at the end of the discharge canal (thermograph 32). In the monthly reports, the excess of these temperatures over those measured by thermograph 30 (located behind the intake screens) is plotted. The difference between the reading of thermograph 31 and thermograph 30 is not a reliable indicator of condenser temperature rise, however. For example, on July 10, 1974, the plant was rejecting a total of 2250 MW(t) and the circulating water flow rate was 2500 cfs. The calculated condenser temperature rise was 13.7°F, but the measured difference (between thermographs 31 and 30) was 6°F. Because conditions were steady, this anomaly cannot be dismissed as a time-lag effect. Spot checks in different months revealed a high percentage of such discrepancies, so instrument malfunction is not a likely cause. Apparently, thermograph 31 is being influenced by the discharge from the first cooling tower. To eliminate such ambiguities, temperatures could be monitored at the station intake, the entrance and exit of the condensers, the exit of the discharge pond, the entrance and exit of each tower, and the exit of the discharge canal. After a detailed study of these data, some of these measurements may be eliminated.

c. ORNL analysis

An important aspect in assessing the thermal impact resulting from an operating power plant is determining the extent of the thermal plume. The high spatial resolution obtained by the boat surveys in Cconwingo Pond provides adequate data for defining the plume produced by the discharge from Peach Bottom Atomic Power Station Units 2 and 3. The heated effluent is discharged parallel to the west bank and gives rise to a classical plume hugging the shore to the south of the discharge point. This plume is evident in Fig. 3.17, which is a typical temperature map obtained from a boat survey. Many features that frequently appear in boat survey results can be seen in Fig. 3.17. Perhaps the most striking feature is the downstream extent of the plume. While the plume is close to shore, it is in a region characterized by relatively weak flow and eddies. However, at the state line, the west bank of the pond recedes relative to the centerline of the plume. Beyond this point, the plume trajectory is toward the centerline of the pond. This is reinforced by the inflow from Michael's Run. As the plume moves away from the shore, it is diluted and distorted by stronger flows until a point is reached where the plume has lost its identity and becomes a nebulous mass of warm water. This mechanism serves to reduce the possible extent of larger excess temperatures (well-defined plume). By virtue of mixing, it also makes regions of relatively low excess temperatures difficult to identify.

Fig. 3.17. Peach Bottom — Horizontal isotherms and thermal profile of Conowingo Pond. Source: Philadelphia Electric Company, *Peach Bottom Atomic Power Station Monthly Report No. 25* (July 1975), Fig. 2.4-5.

For the purposes of this study, determination of the downstream penetration of excess temperature from the discharge is necessary. Figure 3.17 shows an approximate 5°F (2.8°C) temperature difference between the farthest upstream (northern) isotherm and the region near Conowingo Dam. At first glance, this temperature difference might be singularly attributed to the thermal discharge; however, the effect is not quite this simple. A second mechanism becomes evident when inspecting the vertical cross-section along the centerline of Conowingo Pond, shown at the bottom of Fig. 3.17. The significant feature here is the tilting of the isotherms toward the deep portion of the basin near Conowingo Dam. This is caused by the hypolimnetic withdrawal of water from the pond, through the dam. This selective withdrawal of cold water causes the lower portion of Conowingo Pond to be a heat sink for all thermal sources (such as insolation), and not just the thermal effluent from PBAPS. This conclusion is easily verified by viewing the boat survey data collected during the preoperational period. An example of such data is provided in Fig. 3.18. A significant temperature rise can clearly be seen between the upper (north) and lower (south) portions of the pond.

It must be established whether any of the apparent excess temperature in the lower portion of Conowingo Pond can be attributed to the power plant operation. To accomplish this, monthly averaged temperature differences based on an upstream and a downstream location were computed using all the boat survey data for a preoperational year. This procedure was then repeated for a postoperational year. The results of both the calculations are plotted in Fig. 3.19. For both cases, an annual cycle in horizontal temperature variation can be seen. Based on the selective withdrawal hypothesis, this confirms the expected behavior that the maximum temperature differential occurs during the warmer months when stratification is strongest, while the minimum temperature differential occurs during the winter when conditions are near isothermal. Beyond this, it is immediately apparent that the postoperational curve is consistently higher than the preoperational one, with a mean difference of 1.7°F (0.9°C) and a maximum difference of 3.7°F (2.0°C). This result strongly suggests that the thermal output from PBAPS produces an increase in temperature in Conowingo Pond, which frequently can be detected downstream at Conowingo Dam.

While the boat survey data provide high spatial resolution, the synopticity must be questioned. Whether or not significant changes occur in the actual temperature distribution in Conowingo Pond during the course of a given boat survey must be established. Factors that could affect such changes are variations in the following parameters: PBAPS thermal output and circulating-water flow rate, inflow through Holtwood Dam, outflow through Conowingo Dam, operation of Muddy Run Pumped Storage Station, and meteorological variables. In general, meteorological time scales are typically large and should not influence the boat survey data. The exception to this is a case of an extreme localized weather event such as a thunderstorm, which is of short duration. However, during such conditions, boat operations would likely be suspended. The other parameters are provided in PBAPS monthly reports in strip-chart form. Although these plots are somewhat coarse, they do indicate that characteristic large amplitude

DATE: July 10, 1973
TIME 1015-1330 EST

Fig. 3.18. Peach Bottom - ENDECO preoperational boat survey at Conowingo Pond. Source: Philadelphia Electric Company, *Peach Bottom Atomic Power Station Monthly Reports*, July 1973 through January 1974.

Fig. 3.19. Peach Bottom - Monthly-averaged temperature difference between an upstream and a downstream location in Conowingo Pond during a preoperational and an operational period.

variations occur with periods of 12 to 24 hr. Because the boat surveys require about 3 or 4 hr for completion, some distortion might be expected. To verify this, "instantaneous" data from the thermographs deployed in Conowingo Pond have been compared with the results from a boat survey. Figure 3.20 shows surface isotherms based on a boat survey carried out on August 8, 1975, between 10:00 and 15:30 hr. Along with this, the temperatures recorded by 15 of the thermographs on the same day at 12:00 hr are given. While the agreement is quite good in some areas, differences of 1.5°F (0.8°C) appear in other areas. This comparison does seem to indicate the presence of distortion during the course of a boat survey. However, this result is inconclusive because of the poor spatial resolution of the thermograph data.

The boat survey data have provided valuable information about the thermal loading of Conowingo Pond; however, the relatively low sampling frequency, as well as the manner of presentation, makes this information semi-qualitative in nature. Such information would not seem adequate to permit the assessment of the ecological impact of the thermal discharge. At the expense of a great deal of time, the best that could be hoped for from the boat survey data is annual or monthly averaged, mean, maximum, and minimum temperature distributions. This is not the case with the fixed thermograph data. Although these data are lacking in spatial resolution, the frequency of observations makes the data well suited for an ecological analysis.

Thermograph data were obtained from PECO in the form of a magnetic tape, through the cooperation of Mr. George Zaimis. This tape contained hourly surface temperature readings for 18 stations located in Conowingo Pond beginning January 1, 1972, and extending into June 1976. The locations of these thermograph stations are shown in Fig. 3.15 as Stations 1 through 18. The most useful result that could be gleaned from these data is the specific time-temperature datum which could be directly related to exposure times of particular species to a given temperature elevation. To this end, a probability analysis was applied to the thermograph data. The most difficult aspect of this task was establishing an adequate definition of ambient temperature, which is an obvious prerequisite to the calculation of excess temperature. This complication is a direct result of the natural horizontal temperature variations that exist in Conowingo Pond. The most direct method for establishing an ambient temperature is to take an extreme upstream station and assume it is beyond the influence of the thermal plume. The observed temperature at this control station can then be subtracted from the observed temperature at the other stations to establish a set of excess temperatures. Recalling the earlier discussion of horizontal temperature variations and the implications of the preoperational curve in Fig. 3.19, such a definition of ambient temperature would obviously result in unrealistically high values for the excess temperature. In fact, the maximum error could be in excess of 5°F (2.8°C).

A more consistent technique was adopted for the determination of the ambient temperature. The assumption is still that an upstream control station exists; however, a regression is performed on the preoperational

Fig. 3.20. Peach Bottom -- Comparison of surface isotherms from a boat survey with the temperatures recorded at fixed stations in Conowingo Pond on August 8, 1975.

data to provide a system of algebraic equations for predicting the ambient temperature at each station based on the observed temperature at the control station. The accuracy of any curve-fitting technique is proportional to the order of the equation used. The restriction here is that the number of data points required for the regression is also proportional to the order. In the case of Conowingo Pond, this could lead to diminishing returns. By considering a long data record, a higher order equation can be obtained. On the other hand, the use of a longer period of data introduces complicating effects, such as seasonal variations, which must be resolved by the predictive equations. For this reason, using a second order (quadratic) regression on monthly segments of the preoperational data seemed most efficient.

The first task of this procedure was to select a control station. Based on the isotherm maps of the boat survey data, Station 1 was chosen for the control (see Fig. 3.15). Stations 17 and 18 were not used at all in this analysis because they were not located in the pond proper. Following this, the preoperational data were scrutinized to determine which 12-month period had the fewest missing data. The period beginning in July 1, 1973, and ending June 30, 1974, was found to best serve this purpose. During the latter part of this period, there was some thermal discharge from PBAPS; however, the plant's output was low, and no significant bias in the regression was expected. Using the designated data and using Station 1 as a control, three coefficient arrays were generated based on the predictive equation

$$T_i = A_{ij} + B_{ij} (T_1) + C_{ij} (T_1)^2$$

where i indicates the station number, T_i is the temperature at Station i , T_1 is the temperature at Station 1, and j is a monthly index. An example of this monthly curve fit is given for Station 2 in Fig. 3.21. These coefficients can be used to predict the ambient as a function of time for Stations 2 through 16 during all postoperational periods having data available from Station 1.

A probability analysis was done on one year of postoperational data beginning July 1, 1975. This period was selected because it generally has the most complete data, particularly at Station 1. Excess temperatures were computed for each hourly temperature measurement at all 15 stations. Excess temperatures at every station were grouped into 0.5°F (0.28°C) slots extending over the entire range. The number of observations in each slot were counted and then normalized with the total number of observations made at that particular station. This provides an estimate of the probability distribution as a function of excess temperature. These probability distributions are plotted for every station in Fig. 3.22.

To better understand the meaning of these distributions, it is necessary to again consider the prediction of the ambient temperatures. The regression analysis provides a "best fit" through the data; an actual ambient temperature could, with equal probability, be greater or less than the predicted ambient. Furthermore, if the prediction is meaningful, the standard deviation should be small. Therefore, if a station is unaffected by the thermal discharge, its probability distribution should be characterized by a sharp symmetric peak centered at zero excess temperature.

Fig. 3.21. Peach Bottom - Monthly predictive curves for the ambient temperature ($^{\circ}\text{F}$) at Station 2 as determined by the regression analysis. The observed data at Station 2 plotted against the observed data at Station 1 are also shown.

Fig. 3.21a

Fig. 3.21b

Fig. 3.21c

Fig. 3.21d

Fig. 3.21e

Fig. 3.21f

Fig. 3.21g

Fig. 3.21h

Fig. 3.211

Fig. 3.21j

Fig. 3.21k

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Fig. 3.22a. Peach Bottom - Probability vs excess temperature for Stations 2 through 16.

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Fig. 3.22b

Fig. 3.22c

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Fig. 3.22d

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Fig. 3.22e

Returning to Fig. 3.22, it is apparent that a number of stations fall into this category. In particular, Stations 2, 4, 5, and 12 show little evidence of excess temperature. Stations influenced by the thermal discharge should have probability distributions characterized by lower, but broader, curves displaced in the positive direction along the excess temperature axis. Good examples of such distributions are shown at Stations 6, 7, 10, and 11 (Fig. 3.22). Station 6 shows the strongest positive shift because it is the nearest station to the discharge. The distribution also shows that excess temperatures of 2.0°F (1.1°C) to 10°F (5.6°C) can occur at Station 6 with about the same likelihood. These variations are probably a direct result of variations in the thermal output of PRAPS and also appear in the mean monthly excess temperatures given in Fig. 3.23. Some thermograph stations show only slight temperature rises. These can be identified in Fig. 3.22 as curves having maximums at excess temperatures slightly greater than zero and sloping more steeply on the negative side than the positive side. This situation can be seen at Stations 13 and 15.

Some unusual events also appear in these results. The probability distribution for Station 3 is typical of a thermograph showing no influence of the thermal plume, but the curve exhibits a secondary peak center at 3.5°F (1.9°C). Station 3 is situated near the mouth of Caesar's Run, and this peak could be a result of periodic warm water inflows from this small tributary. The probability curve for Station 16 is quite irregular. Part of this problem can be attributed to curve fitting for the ambient temperature at this station. There is so much scatter in these data [the standard deviation is 11.5°F (6.4°C)] that the ambient prediction technique must be deemed worthless for this particular station. An example of this scatter is given in Fig. 3.24. Other complications must exist at this station because this inaccuracy alone could not totally account for the 50°F (27.8°C) excess temperatures that appeared. In light of this, the thermograph data taken at Station 16 in subsequent analyses were discarded.

The results of these probability distributions are best used for a station-by-station analysis. A more useful result for viewing the pond as a whole, particularly when exposure times are of interest, is the cumulative distribution function (CDF). The cumulative distribution function, $F_T(X)$, is a functional representation of the probability of event T being less than X. For example, $F_{\Delta T}(3.0) = 0.75$ means that the probability of the excess temperature, ΔT , being less than 3.0°F (1.7°C) is 75%. The CDF can be obtained quite simply from the probability distributions. Once again, the entire range of excess temperatures are divided into 0.5°F (0.28°C) intervals, with probabilities calculated for each interval. The CDF for a given interval is approximately the sum of the probabilities of all the lower intervals inclusively. In this manner, the CDFs for Stations 2 and 6 are shown in Fig. 3.25. These curves necessarily contain the same information as the probability distributions, merely presented in a different manner. The CDF for Station 2 shows a 43% probability of the excess temperature being less than 0.0°F (0.0°C), while there is only an 8% probability of the excess temperature being greater than 1.0°F (0.6°C). This is indicative of an area relatively free from thermal loading. Conversely, the CDF for Station 6 shows only

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Fig. 3.23. Peach Bottom - Monthly-averaged excess temperature at Station 6. The ambient temperature is determined by the regression analysis.

Fig. 3.24. Peach Bottom - Ambient temperature prediction curve ($^{\circ}\text{F}$) for Station 16 during July. This is typical of the degree of scatter in the thermograph data from this station.

Fig. 3.25a. Peach Bottom — Cumulative distribution function estimate for the excess temperature at thermograph Station 2. DTN is the normalized excess temperature, defined as the actual excess temperature divided by the maximum excess temperature [4.5°F (2.5°C)]. The ambient temperature is determined by the regression analysis.

Fig. 3.25b. Peach Bottom - Cumulative distribution function estimate for the excess temperature at thermograph Station 6. DTN is the normalized excess temperature, defined as the actual excess temperature divided by the maximum excess temperature [28.5°F (15.8°C)]. The ambient temperature is determined by the regression analysis.

an 8% probability of the excess temperature being negative, while the probability of the excess temperature being greater than 3.0°F (1.7°C) is 77%. This station is clearly in the thermal plume.

The best way to present these CDF results is to plot on a map of Conowingo Pond the excess temperature at each station for a fixed frequency of occurrence. Based on these values, isotherms have been drawn by hand. Because of the low spatial resolution, considerable imagination was needed to accomplish this; however, the contours should be reasonably realistic because they were drawn with the knowledge of the boat survey maps. Plots of this kind were prepared for occurrence frequencies of 100%, 90%, 75%, 50%, 25%, and 0%. Some of these are shown in Fig. 3.26. The 25% and 0% occurrence levels are not included in this figure because they show predominately negative temperatures and therefore are not particularly informative. This is a result of the technique employed in calculating the ambient temperature. These plots provide bounding values for the indicated temperature excess at a particular occurrence frequency. For example, the 100% occurrence level (Fig. 3.26a) shows that a 6°F (3.3°C) excess temperature of 15°F (8.3°C) is totally contained in an area that never reaches Stations 11 or 13. A similar region bounds the 4°F (2.2°C) isotherm 90% of the time (Fig. 3.26b) and bounds the 1.0°F (0.5°C) isotherm 50% of the time.

An alternate method of viewing these plots is to superimpose them and draw contours of constant probability of occurrence for a fixed value of excess temperature. This was done to generate Fig. 3.27. This technique has the potential for conveying the maximum information regarding exposure time.

Unfortunately, the small number of thermograph stations result in quite sparse contours in some plots of Fig. 3.27. This figure shows that excess temperatures are most frequently observed in a well-defined thermal plume region, which lies along the west shore of Conowingo Pond extending from the PBAPS discharge to Station 13. Other definitive remarks about these results are difficult to make because of the poor spatial resolution. However, the centerline of the pond below PBAPS appears to act as an approximate boundary for the 0.5°F (0.3°C) excess temperature 50% of the time (Fig. 3.27a), the 1.0°F (0.6°C) excess temperature 75% of the time (Fig. 3.27b), the 3°F (1.7°C) excess temperature 90% of the time (Fig. 3.27c), and the 10.0°F (5.5°C) excess temperature 100% of the time (Fig. 3.27f).

In an effort to obtain more information from the thermograph data, the probability analysis was reapplied to Stations 2 through 16 over the same period using a different definition of ambient temperature. Temperature data at each thermograph station were scanned on a monthly basis. The ten lowest readings during each month were averaged, and the resulting value was considered the ambient temperature during that month at that particular station. This was because the thermal output from PBAPS Units 2 and 3 was sporadic and there could be short periods when the total thermal output was low during each month. If so, the average of the ten lowest temperatures during each month should be representative of the ambient

Fig. 3.26a. Peach Bottom — Surface excess temperature estimates (°F) in Conowingo Pond for occurrence frequency levels: (a) 100%, (b) 90%, (c) 75%, and (d) 50%.

Fig. 3.26b

Fig. 3.26c

Fig. 3.26d

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Fig. 3.27a. Peach Bottom — Surface excess temperature extent contours for excess temperatures of (a) 0.5°F (0.28°C), (b) 1.0°F (0.6°C), (c) 2.0°F (1.1°C), (d) 3.0°F (1.7°C), (e) 5.0°F (2.8°C), and (f) 10.0°F (5.6°C).

Fig. 3.27b

fig. 3.27c

FIG. 3.27d

Fig. 3.27e

Fig. 3.27f

temperature at each station, with the possible exception of Stations 6, 7, and 10. The CDFs for these 16 stations were plotted; surprisingly, the curves for all stations were remarkably similar. This can be seen in Fig. 3.28, which shows the CDF for Stations 2 and 6. These can be compared with the CDF for the same stations using the ambient temperature prediction based on the regression analysis (shown in Fig. 3.25). Frequency of occurrence plots similar to Fig. 3.26 were prepared for the 100%, 90%, 75%, 50%, 25%, and 0% occurrence levels. These are shown in Fig. 3.29. The striking feature in this figure is the spatial homogeneity of the excess temperature. As a result of this homogeneity, no attempt was made to draw isotherms. Although these results did not confirm the previous analyses, they unexpectedly showed a very important feature of the thermal loading in Conowingo Pond. When considering this definition of ambient temperature, it becomes apparent that the CDF analysis actually represents a statistical description of the observed monthly temperature variations in Conowingo Pond. Figure 3.29 then shows that the temperature variation for any occurrence frequency differs very little from station to station. It can now be concluded from this that although the exposure temperature of an aquatic organism will vary with position, the temperature range will not vary.

The final analysis performed on the thermograph data was a correlation study. Such a study was hoped to provide information quantifying the influence of various factors on the position of the thermal plume. The contributory factors considered were the thermal output from PBAPS Units 2 and 3, the circulating-water flow rate, flow through Holtwood and Conowingo Dams, the natural river flow, and the operation of Muddy Run Pumped Storage Station. Unfortunately, the only data available for these parameters are in the form of strip charts from the PBAPS monthly reports, such as the one shown in Fig. 3.12. Due to the extreme time required for digitizing such data, only a three-month data set could be prepared for each of the seven parameters. The three-month period considered begins July 27, 1975, and ends October 27, 1975. A Fourier transform technique was used to correlate these data with the temperature data from a number of thermograph stations. The major difficulty in this analysis was the frequent gaps that appeared in the thermograph data. To ignore such gaps in a correlation study renders it meaningless. Consequently, separate analyses must be performed on each full section of data between these gaps. Furthermore, for the results to be meaningful in a statistical sense, there must be a large number of data points in each of these sections. The data from all thermograph stations were inspected to find those with the longest record lengths, as well as the fewest gaps, for the selected three-month period. The stations that best met this criterion were selected for use in this analysis. These are Stations 2, 3, 10, 14, and 15.

The results of the initial correlation studies were so disappointing that further computer runs were suspended. In all cases, no consistently strong correlations were observed. This was a particularly surprising result for the correlation between the PBAPS thermal output and the temperature at a station near the discharge. An example of such a case is given in Fig. 3.30. This correlation of the thermal output from

Fig. 3.28a. Peach Bottom — Cumulative distribution function estimate for the excess temperature at thermograph Station 2. DTN is the normalized excess temperature, defined as the actual excess temperature divided by the maximum excess temperature [23.0°F (12.8°C)]. The ambient temperature is defined as the average of the ten lowest readings at this station during each month.

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Fig. 3.28b. Peach Bottom - Cumulative distribution function estimate for the excess temperature at thermograph Station 6. DTN is the normalized excess temperature, defined as the actual excess temperature divided by the maximum excess temperature [31.1°F (17.3°C)]. The ambient temperature is defined as the average of the ten lowest readings at this station during each month.

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PEACH BOTTOM ATOMIC
POWER STATION

Fig. 3.29a. Peach Bottom - Surface excess temperature estimates (°F) in Conowingo Pond for occurrence frequency levels of (a) 100%, (b) 90%, (c) 75%, (d) 50%, (e) 25%, and (f) 0%. The ambient temperature is defined as the average of the ten lowest readings during each month at each station.

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FIG. 3.29b

FIG. 3.29c

Fig. 3.29d

Fig. 3.29e

Fig. 3.29f

Fig. 3.30a, d, and g. Peach Bottom - Thermal output from Peach Bottom Atomic Power Station Unit 3 (generalized amplitude) vs time (hr), (Fig. 3.30b, e, and h) temperature at Station 10 (generalized amplitude) vs time (hr), and (Fig. 3.30c, f, and i) cross-correlation coefficient vs time lag (hr) for the three segments of thermograph data.

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TEMPERATURE - THERMOGRAPH STATION 40

Fig. 3.30b

Fig. 3.30c

Fig. 3.30d

Fig. 3.30e

Fig. 3.30f

Fig. 3.30g

TEMPERATURE - THERMOGRAPH STATION 10

Fig. 3.30h

Fig. 3.30f

Unit 3 with the temperature at Station 10 represents the best results obtained. During the three-month period, there were three sections of unbroken data from Station 10. Figure 3.30 represents a plot of the correlation coefficient vs time lag for each section, as well as plots of the temperature and thermal output data. Comparing both data sets in the first segment (Fig. 3.30a), it can be seen that the large changes in the output from Unit 3 are strongly reflected in the observed temperature at thermograph Station 10. This effect appears as a strong cross correlation (0.55) at zero time lag. If similar correlations appeared in the other two sections of data, this result would be significant. However, the cross correlation for the second section of data (Fig. 3.30b) shows a negative coefficient at zero time lag. This means that the temperature at Station 10 decreases in response to increases in the thermal output from Unit 3, or vice versa. The strongest positive correlation appears in these data at a time lag of 160 hr. The third section of data is totally different from the first two sections. No significant cross correlation (Fig. 3.30c), positive or negative, is evident here. Such inconsistent results are typical of the correlation study.

Although the results of the correlation analysis proved worthless, it is an attractive method for the analysis of future Peach Bottom data. The study performed here was plagued with handicaps that could be avoided in the future. The worst of these is the absence of long data sets free from gaps. If correlation studies are planned, data could be taken more carefully. Another factor that contributed to the demise of this technique was that certain data had to be digitized from strip charts. Data generated in this way are not believed to be of sufficiently high quality for the Fourier transform methods that were used.

B. ECOLOGICAL EVALUATION

1. Thermal effects

The analyses of the effects of thermal effluent additions from Peach Bottom Units 2 and 3 on the biota of Conowingo Pond, a mainstream freshwater impoundment between the Holtwood and Conowingo Dams on the lower Susquehanna River, have been performed within the following framework. The first few years of the preoperational monitoring program (1967 through 1971) are characterized by infrequent sampling intervals, particularly during winter months, and by the small number of stations that are consistently sampled. However, preoperational data for chlorophyll *a*, zooplankton, and benthos improved greatly from 1972 through 1973.

All 11 stations in Conowingo Pond were sampled intensively for at least one to two years prior to commercial operations; no stations were deleted or added during the sampling period. Thus, an adequate comparison of a preoperational period (1967-1973) and an operational period (1974-1975) is possible. This analysis will concentrate on near-field effects of the thermal additions within a designated discharge area. Analysis of the impingement data at Peach Bottom was performed using data from November 1973 through June 1975 (20 months) exclusively.

a. Assessment of monitoring methods

(i) Chlorophyll a

Primary production at Peach Bottom was monitored by determining the concentrations of chlorophyll *a* (both total and active), *b*, *c*, phaeopigments, and carotenoids in water samples collected biweekly with a Van Doren bottle from the surface, 5 ft, 10 ft, and bottom depths at five stations (601, 604, 605, 607, and 611) in Conowingo Pond (Fig. 3.31). Only surface sample data for chlorophyll *a* were used in our analysis. An in-depth analysis of results of data on all pigments collected at all depths in Conowingo Pond is discussed by McClellan.⁹ Stations 630 and 640, located at the Holtwood and Conowingo Dams, respectively, were also sampled; however, results from these stations were not included in the thermal analysis.

The plant pigment determinations were made using wavelengths of 7500, 6650, 6450, 6300, and 4800 Å and a light beam of 5 cm. All sampling results were expressed as milligrams per cubic meter. In 1970, a time lag of several days occurred between collection and analysis; however, beginning in 1971, all samples were analyzed within 15 to 24 hr after collection.

The annual frequency of sampling for chlorophyll at the five monitoring stations in Conowingo Pond is presented in Table 3.10. The sampling program for 1970 and 1971 concentrated sampling operations from July through December, but beginning in 1972, a more consistent and more intensive program evolved.

Table 3.10. Peach Bottom - Yearly sampling frequency at plant pigment monitoring stations in Conowingo Pond

Year	Station				
	601	604	605	607	611
1970	9	0	10	0	10
1971	14	0	18	5	15
1972	20	19	20	0	20
1973	20	20	20	20	20
1974	21	21	21	21	21
1975	22	22	22	22	22

ORNL DMG 76-12512

Fig. 3.31. Peach Bottom - Location of limnological (zooplankton, phytoplankton, benthos) sampling stations, Conowingo Pond. Source: Philadelphia Electric Company, Peach Bottom Atomic Power Station, Thermal and Biological Monitoring Program Monthly Reports, No. 1 (July 1973).

**Table 3.11. Peach Bottom—Comparison of monthly and annual mean river flow^a at Holtwood Dam,
January 1967 through December 1975^b**

Year	January	February	March	April	May	June	July	August	September	October	November	December	Annual mean
Preoperational													
1967	20.5	30.8	82.6	64.4	66.0	19.2	15.4	21.3	10.6	27.2	44.2	48.4	37.6
1968	18.7	40.2	56.9	34.7	49.6	54.1	18.9	6.5	14.0	7.0	43.9	34.3	31.5
1969	23.0	28.6	28.7	59.6	34.5	20.4	15.8	18.9	6.7	5.2	27.3	32.3	25.1
1970	19.1	69.5	52.4	136.9	42.5	21.2	21.1	10.9	8.7	18.1	58.5	42.6	41.8
1971	27.7	74.5	103.8	62.7	45.4	15.3	7.6	14.5	11.1	11.1	18.5	59.7	37.7
1972	46.9	31.8	113.1	91.1	72.3	178.0	58.2	12.8	7.5	7.5	55.5	105.5	65.0
1973	51.3	62.8	64.9	80.8	60.5	37.3	21.9	14.6	16.1	13.8	27.0	89.8	45.1
Mean	29.5	48.3	71.8	75.7	53.0	49.4	22.7	14.2	10.7	12.8	39.3	58.9	40.5
Operational													
1974	72.7	47.6	61.4	92.4	39.7	19.4	21.4	10.6	21.2	11.8	23.0	53.5	39.6
1975	54.4	84.9	81.9	49.9	58.2	43.5	20.2	10.0	83.4	66.7	42.0	37.2	52.7
Mean	63.6	66.2	71.6	71.2	49.0	31.4	20.8	10.3	52.3	39.2	32.5	45.4	46.1

^aAnnual mean river flow = flow (as shown) X 10³ cfs.

^bData supplied by Pennsylvania Power and Light Company.

The FES for Peach Bottom predicted that a possible reduction in phytoplankton production, as well as a change in species composition, might occur due to thermal additions. This would result in a decline in diatom and green species and an increase in the more tolerant blue-green species. Because total cell counts and identification of phytoplankton species within Conowingo Pond were not performed, no quantitative evaluation of the predicted species shift in the phytoplankton community can be made.

Temporal variations in the chlorophyll *a* concentrations attained during a yearly growth cycle are shown in Fig. 3.32 (a-e) for five stations in Conowingo Pond. Beginning in late March, a rapid rise in chlorophyll *a* concentrations occurred, and peak concentrations were generally attained by May. After the spring peak, there was a minor summer decline in chlorophyll *a* concentrations, followed by a secondary fall (September-November) peak which occurred before the winter decline. This seasonal pattern for changes in chlorophyll *a* concentrations was typical of the response observed at all stations in Conowingo Pond, suggesting the homogeneous nature of this system.

An excellent example of the similarity of response of the primary producers (chlorophyll *a* concentrations) at all stations in Conowingo Pond can be seen during the latter portion of 1975. In all years, the spring peak in chlorophyll *a* concentrations occurred in May, declined slightly during June and July, and then began to increase again to a fall peak, which occurred from late September through early November. In 1975, however, chlorophyll *a* concentrations declined sharply after day 270 (September 25) to concentrations below those of the two preceding years. This decline is likely to have been mediated in part by Hurricane Eloise because river flows increased from 34,500 cfs on September 24 to 361,000 cfs on September 26.⁹ Increased flow rates are clearly evident during September and October of 1975 when flow rates were five to eight times higher than mean flows reported for the same months during preoperational years (Table 3.11). Chlorophyll *a* concentrations at all stations in Conowingo Pond responded similarly to this natural perturbation in the environment. No recovery of the chlorophyll *a* concentrations occurred in the latter half of 1975 because conditions conducive to phytoplankton growth would not occur until the following spring.

ORNL DWG 76-12522 R1

Fig. 3.32a. Peach Bottom - Temporal variation in total chlorophyll *a* concentrations (milligrams/cubic meter) at five stations in Conowingo Pond during 1973 through 1975.

Fig. 3.32b

Fig. 3.32c

Fig. 3.32d

Fig. 3.32e

Variations in the mean annual chlorophyll a concentrations are presented in Fig. 3.33 for each station. At all stations, chlorophyll a concentrations increased from 1972 to a peak in 1974 and then declined in 1975. A similar plot is presented in Fig. 3.34; however, the annual means include only data from April through September. Monthly data from October through March were not included because concentrations of chlorophyll a were extremely low in the winter months.

Several major points may be gleaned from comparing the mean annual chlorophyll a concentration data at each station with the location of the station in Conowingo Pond.

1. Station 601 (control) exhibited the lowest chlorophyll a concentrations, except for Station 611. Station 611 is near the Conowingo Dam, and the physical characteristics of this station in relation to the dam (i.e., higher water temperature, greater water depth, and point of hypolimnetic withdrawal) create conditions distinct from all others in Conowingo Pond.
2. Chlorophyll a concentrations at Station 604 (a station outside influence of the plume) were comparable to the control.
3. Chlorophyll a concentrations at the discharge (Station 605) were higher than most stations, possibly due to the beneficial effect of the heated plume on primary production, particularly during winter months.
4. Station 607 had consistently higher chlorophyll concentrations than all other stations; however, this may be due to the proximity of this station to the mouth of Peters Creek, a possible source of additional nutrients that could stimulate phytoplankton production.

(ii) Zooplankton

Zooplankton samples were collected biweekly at all stations in Conowingo Pond using a Clarke-Bumpus quantitative sampler equipped with a #20-mesh nylon net. The sampler was towed in a circular oblique path from a maximum depth of 20 ft. A calibrated flow meter attached to the sampler was used to determine the volume of water filtered. Zooplankton samples at the Holtwood and Conowingo Dams were collected by straining a measured volume of water through a #20-mesh plankton net. One sample per station was collected in 1967 through 1969, 1973, and 1974. Triplicate samples were collected at each station during 1970 through 1972 and 1975, but these were not reported as such in the Semiannual Operating Reports.

Zooplankton samples were preserved in 40% isopropyl alcohol and were diluted or concentrated to a volume that yielded an estimated 200 to 300 organisms/ml before identification and counting were performed. From 1970 through 1972, three 1-ml subsamples from each replicate were counted on a Sedgewick-Rafter chamber. Only one 1-ml sample was examined from each sample collected in 1967 through 1969, 1973, and 1974. All zooplankters were counted when fewer than 150 to 200 animals per sample were present.

ORNL DWG 76-12519 R1

Fig. 3.33. Peach Bottom - Variations in the mean annual chlorophyll a (milligrams/cubic meter) concentrations at five stations in Conowingo Pond.

ORNL DWG 76-12520R1

Fig. 3.34. Peach Bottom - Variations in the mean annual chlorophyll *a* (milligrams/cubic meter) concentrations at five stations in Conowingo Pond. (Annual means include only data from April through September.)

The zooplankton monitoring data were reported as the total number of organisms per liter or as biomass (milligrams of dry weight per liter). Biomass was determined from a known volume of concentrated sample that had been dried to a constant weight in a 40°C oven and then weighed to the nearest 0.0001 gram. Samples containing excessive detritus were not weighed. For this reason, only zooplankton densities were used to assess population responses to thermal additions in this study.

The annual frequency of sampling for zooplankton monitoring stations in Conowingo Pond is presented in Table 3.12. The zooplankton sampling program for 1967 through 1971 did not include sampling during the first five months of the year, and many stations were not consistently sampled each year. Beginning in 1972, all stations were regularly sampled during all months of the year. At Peach Bottom, sampling during the coldest winter months was often hindered by ice formation and rough water on Conowingo Pond.

Table 3.12. Peach Bottom - Yearly sampling frequency at zooplankton monitoring stations in Conowingo Pond

Year	Station									
	601	602	603	604	605	606	607	608	609	610
1967	6	7	7	7	8	8	8	9	0	0
1968	8	7	8	8	0	0	0	0	9	9
1969	8	12	11	0	11	11	15	6	8	8
1970	18	18	18	18	20	20	20	18	18	18
1971	13	13	13	13	13	13	13	13	14	13
1972	19	19	19	19	19	19	19	19	0	19
1973	21	21	21	20	21	21	21	21	21	21
1974	21	21	21	21	21	21	21	21	21	21
1975	19	48	20	20	48	20	20	48	48	20

The zooplankton community in Conowingo Pond is represented by two groups, cladocerans and copepods. The cladoceran genera include *Bosmina*, *Daphnia*, *Ceriodaphnia*, *Moina*, *Alona*, *Ilyocryptus*, *Diaphanosoma*, and *Leptodora*, while copepod genera include *Cyclops*, *Mesocyclops*, and *Diaptomus*.

The temporal variations in zooplankton densities occurring during a typical seasonal growth cycle are shown in Fig. 3.35 (a-h) for all stations in Conowingo Pond. Zooplankton concentrations were very low during the colder months of November through April, but attained high concentrations from May through September. The temporal fluctuations in zooplankton concentrations correspond to changes in the total chlorophyll *a* concentrations (chlorophyll *a* being an indicator of primary production).

ORNL DWG. 76-12526

Fig. 3.35a. Peach Bottom - Temporal variations in the density of zooplankton (numbers/100 liters) at eight stations in Conowingo Pond during 1973 through 1975.

Fig. 3.35b

ORNL DWG. 76-12528

Fig. 3.35c

Fig. 3.35d

ORNL DWG. 76-12530

Fig. 3.35e

Fig. 3.35f

ORNL DWG. 76-12532

Fig. 3.35g

Fig. 3.35h

Annual zooplankton fluctuations in Conowingo Pond were observed to be bimodal. The first peak in zooplankton densities generally occurred in late June or early July, with a second smaller peak occurring in late August or September.³ After the two periods of peak production, zooplankton concentrations rapidly declined to near-zero concentrations during the winter months. Primary production also declined during this same winter period, which is characterized by reduced water temperatures and occasional ice cover.

During 1975, a slightly different pattern of zooplankton growth was observed. The first peak occurred in early July, but densities were lower than in the two preceding years. In addition, the second peak in zooplankton concentrations did not occur because concentrations declined after the first peak was attained. Two possible explanations can be given for the response of the zooplankton. First, a strong-year class of the gizzard shad, *Dorosoma cepedianum*, was produced in 1975, and these fishes feed primarily on zooplankton.¹⁵⁻¹⁸ Increases in the young-of-the-year gizzard shad, which occurred at the site,⁹ may have resulted in severe predation pressure on the zooplankton. Secondly, Hurricane Eloise, which struck on September 25, 1975, (during the period when a second peak in zooplankton would have been expected) may have greatly affected zooplankton production. As discussed earlier, river flows increased from five to eight times above the mean flows generally present at the site. No recovery of the zooplankton populations at any station in Conowingo Pond occurred in the remaining months of 1975. An in-depth discussion on those physical and biological factors which may have influenced population fluctuations at the Peach Bottom site can be found in SOR-5.⁹

The mean annual variation in zooplankton concentrations from 1972 through 1975 are shown for two discharge stations (605 and 608), two periphery stations (609 and 610) and a control (601) in Fig. 3.35. Except for the control station, the mean annual concentrations of zooplankton increased from 1972 to a peak in 1974, and thereafter declined. The computed mean annual densities in Fig. 3.36 include only the months of April through September because zooplankton concentrations in all of the winter months were extremely low. Three major points concerning zooplankton population growth are important.

1. The pattern of annual zooplankton density increases over the years was very similar to the pattern exhibited in the chlorophyll *a* data. During years of highest primary production, the herbivorous zooplankton display their greatest population densities. Similarly, when primary production sharply declined, as occurred from 1974 through 1975, zooplankton concentrations also declined.
2. There was a consistent increase in zooplankton densities downstream from the Peach Bottom facility. Station 601 has the lowest zooplankton concentrations during all years (except 1972). The densities at the discharge stations (605 and 608) were generally higher, while Stations 609 and 610 exhibited the highest densities from 1972 through 1975. Two possible

ORNL DWG 76-125MR1

Fig. 3.36. Peach Bottom - Variations in the mean annual zooplankton densities (numbers/100 liters) from April through September for five stations in Conowingo Pond.

explanations for the increase in zooplankton densities downstream from the plant may be related to the thermal effects mediated by the nuclear facility or physical parameters associated with the entrainment of water behind the Conowingo Dam.

3. Relatively consistent and parallel changes in mean densities among stations occurred over the years. Density of zooplankton at all stations increased at a similar rate from 1972 to 1974 and then decreased at a similar rate from 1974 to 1975. This may be interpreted to mean that the physical, chemical, or ecological processes affecting the zooplankton at any one station equally affect zooplankton at all other stations.

(iii) Benthos

At Peach Bottom, the benthic sampling program changed drastically from 1967 through 1975. Benthic samples were collected from 1967 through 1972 using an 81-in.² Ekman dredge and from 1973 through 1975 using an 81-in.² Ponar dredge. In addition, benthos collected from 1967 through 1970 were wet sieved through a #20 U.S. screen. A #50 U.S. screen was used from 1971 to 1972, and a #30 U.S. screen was used from 1973 through 1975. After washing, the samples were either preserved in 10% formalin or were sorted and stored in 40% isopropyl alcohol. Samples were counted and identified to the lowest possible taxon. Chironomid larvae were first boiled in 5% KOH solution to clear head capsules before identification. All benthic data were reported as density (number of organisms per 81 in.²) or as biomass (milligrams of dry weight per 81 in.²). Biomass was determined by drying a subsample of each taxon at 40°C and weighing them to the nearest 0.001 mg. For this analysis, only the biomass data were used.

The inconsistency in the sieve pore size creates serious problems in using these data for interyear comparisons. Intra-year comparisons of temporal changes in the benthic community, however, are not invalidated by the sampling gear changes. The report by Purdy, Hansell, and Silver,¹⁹ titled *Analysis of Benthos Densities and Biomass in Conowingo Pond*, does not address the problems associated with sampling gear changes; thus, results and conclusions drawn from this study are subject to criticism.

The frequency of yearly sampling for monitoring stations in Conowingo Pond is presented in Table 3.13. From 1967 through 1969, benthic samples were not consistently collected at all 11 stations, and sampling was not performed during the first three to five months or the last one to two months of each year. Beginning in 1974, samples were generally collected on a biweekly basis at all 11 stations. Sampling during the colder winter months was often hampered by a rough water state and the formation of an ice cover.

The Peach Bottom benthic community was predominated by oligochaetes and aquatic insects. The six most abundant species include the oligochaetes *Limnodrilus hoffmeisteri* and *Ilyodrilus templetoni* and the dipterans *Chironomus attenuatus*, *Procladius* sp. (complex), *Chaoborus punctipennis*, and *Coelotanypus concinnus*.

The temporal variations in the benthic standing crop from 1973 through 1975 at all stations in Conowingo Pond are shown in Fig. 3.37 (a-k). Benthic standing crops at all stations (601 through 608) are generally greater during the cooler months of each year than standing crops observed during the summer months. This pattern is less pronounced at Stations 609 and 610; at Station 611, the deep-water station at the Conowingo Dam, benthic standing crops are relatively constant during a seasonal growth cycle. Because the depressions in benthic standing crop occur at both the control station and several discharge stations, these declines would seem to be mediated by natural conditions in Conowingo Pond, rather than as a result of power plant perturbations. The summer depressions in the biomass could be a result of higher ambient summer water temperatures that might inhibit growth, the emergence of aquatic insect larvae,⁹ or a result of cropping of the benthic community by fish. The latter explanation, however, may be of minor importance because summer fish populations are dominated by young-of-the-year (predominantly catfish), and these juveniles feed primarily on zooplankton. In addition, benthos are probably not of major importance in the fish food chain of Conowingo Pond because of their low biomass.

Table 3.13. Peach Bottom — Yearly sampling frequency at benthic monitoring stations in Conowingo Pond

Year	Station										
	601	602	603	604	605	606	607	608	609	610	611
1967	10	11	11	11	11	11	10	9	0	0	0
1968	12	11	10	10	9	9	9	8	8	7	5
1969	8	9	9	1	2	9	11	4	7	8	0
1970	18	18	17	16	19	19	20	13	18	16	18
1971	13	13	13	13	12	13	13	12	13	13	11
1972	22	21	21	22	21	21	21	21	21	21	21
1973	21	21	21	21	21	21	21	21	21	21	21
1974	21	21	21	21	21	21	21	21	21	21	21
1975	23	23	20	21	22	20	21	21	20	22	22

A prominent feature of the benthic community is the decline in the benthic standing crops during the latter portion of 1975. This decline is not typical of the system patterns, since benthic biomass increased during September and October in the two preceding years. However, Hurricane Eloise may have mediated the changes in the typical annual growth pattern of the benthic community because it perturbed the system at a time when the benthic biomass generally began to increase after the summer depression in the standing crop. This decline in the benthos is less severe at the thermally affected stations (605 and 608) than at the control and peripheral stations. Perhaps the thermal plume in these areas enhanced growth, slightly counteracting the effects of Hurricane Eloise. The overall annual decline in the benthic standing crops at all stations in 1975 was probably due to effects of Hurricane Eloise rather than to power plant-induced perturbations, since all stations exhibit a similar parallel decline in benthic biomass around day 270. As with the other two trophic groups, the benthic community was unable to recover from the effects of the hurricane during the remaining months of 1975.

Fig. 3.37a. Peach Bottom - Temporal variations in the biomass of benthos (mg/81 in.²) at eleven stations in Conowingo Pond during 1973 through 1975.

Fig. 3.37b

Fig. 3.37c

Fig. 3.37d

Fig. 3.37e

Fig. 3.37f

Fig. 3.37g

Fig. 3.37h

Fig. 3.371

Fig. 3.37j

Fig. 3.37k

(iv) Fish

Fish in Conowingo Pond were sampled using four methods: trawls, seines, trap nets, and meter nets. The monitoring stations for each sampling year were located on the basis of available habitat type and physical constraints imposed by topography. Stations were located upstream of the power plant and in areas expected to be within the heated plume. Twelve trap net stations, 18 trawl zone stations, 13 trawl transect stations, 12 seine stations, and 13 ichthyoplankton meter-net stations were sampled biweekly. Beginning in July 1974, an additional seven trawl stations were established inside and outside the thermal plume, and these were sampled three times a week. All trap net, trawling, and seining data were presented in the semiannual operating reports in summarized form that was not amenable to statistical analysis. The data were either combined by six-month periods (January through June or July through December) or by stations. However, weekly catch per unit effort (CPE) data for the seven trawl stations shown in Fig. 3.38 were presented in the monthly reports beginning in July 1974; only these data were used in our analysis of power plant effects on resident fish populations. Analysis of other fish monitoring data was made by Mathur et al.²⁰

Trawling was conducted with a 16-ft semi-balloon trawl for 10 min at a constant boat speed. Weekly data were presented as CPE at each station, along with corresponding ΔT values. No preoperational trawl data are available; consequently, no interyear comparisons could be made.

The fish community in Conowingo Pond is, for the most part, dominated by warm water species, the spotfin shiner (*Notropis spilopterus*), bluegill (*Lepomis macrochirus*), pumpkinseed (*Lepomis gibbosus*), bluntnose minnow (*Pimephales notatus*), and spottail shiner (*Notropis hudsonius*), which are the common forage fishes. The white crappie (*Pomoxis annularis*) and channel catfish (*Ictalurus punctatus*) are the most important game fishes, with smallmouth (*Micropterus dolomieu*), largemouth bass (*Micropterus salmoides*), yellow perch (*Perca flavescens*), and walleye (*Stizostedion vitreum*) being less important.

The temporal variations in CPE at Stations 451 and 470 (discharge stations), Stations 452, 472, 473, and 474 (periphery stations), and Station 453 (control station) are shown in Fig. 3.39 (a-g). Station 451, directly off the end of the discharge canal, was subjected to the highest ΔT s and the highest water discharge velocities of any station (see Fig. 3.37).

Several trends in the fish catch data collected from July 1974 to December 1975 are evident. First, the CPE is generally higher in the last half of 1974 than in the last half of 1975. Primary production, zooplankton densities, and benthic biomass all exhibited a similar reduction in the last half of 1975 as compared with 1974. The decline in the fish catch during 1975 may be related to the perturbations induced by high river flows after Hurricane Eloise and the corresponding declines in other trophic levels within Conowingo Pond. For example, because zooplankton are the preferred food for several species of the larval fish in Conowingo Pond, a decline in these organisms might influence the standing crop of fishes.

Fig. 3.38. Peach Bottom — Location of trawl stations inside and outside the thermal plume of Peach Bottom Atomic Power Station in Conowingo Pond. Source: Philadelphia Electric Company, *Peach Bottom Atomic Power Station, Semiannual Operating Reports*, No. 3 (July 1, 1974, through December 31, 1974).

Fig. 3.39a. Peach Bottom — Temporal variations in the fish catch per unit effort collected at seven stations in Conowingo Pond from July-December 1974 and January-December 1975.

Fig. 3.39b

Fig. 3.39c

Fig. 3.39d

Fig. 3.39e

Fig. 3.39f

Fig. 3.398

Fish catches at control Station 453 exhibited two peaks during 1975, in March through April and in August through September. Though this station has been designated as the control, it is in close proximity to the discharge canal. Although this station is not affected by the plume, the physical structure of the canal itself may have affected this area by altering current patterns or creating quiet water areas. Stations 472 and 474, which are downstream and offshore, exhibited fish catch peaks similar to those seen in the control. During 1975, the highest CPE at this station occurred in May and August.

The two stations nearest the mouth of the discharge canal, 451 and 452, exhibited highly variable CPE over the year. The high degree of variability in the fish catches may be a result of fluctuations in the discharge temperature and velocity associated with fluctuations in power production from Units 2 and 3. The peak catch periods at 451 occurred in March and May; at Station 453, they occurred in June and September. Five out of the seven stations sampled exhibit a peak fish catch during May (Table 3.14).

During the winter months, there is no evidence of large congregations of fish at any of the stations, with the exception of 470. Higher winter fish catches at this station may be related to the location of the station at the mouth of a major creek, which may provide an area of greater food availability. The CPE during other months (April through October) is also higher at 470 than all other stations (Table 3.14). Station 470 is affected by thermal additions from the Peach Bottom discharge. The high CPE at this station during the warmer months may be related to the temperature preference of the channel catfish, the dominant species at the site. Ichthyological Associates research staff found that channel catfish acclimated to temperatures ranging from 71 to 85°F, preferred temperatures up to 95°F.²⁰

In summary, the following general conclusions can be made related to the fish in the vicinity of Peach Bottom:

1. Stations 453 (control), 472, 473, and 474 had similar patterns of fish CPE during 1975.
2. Station 451 (discharge), which was exposed to both high-water velocity and elevated temperatures (Fig. 3.23), exhibited high CPE from March through June but did not exhibit high CPE in the winter, as predicted in the FES.
3. The highest CPE was recorded at Station 470. This may be related to the direct effects of increased river flow associated with Hurricane Eloise and the coinciding decline in primary production, zooplankton densities, and benthic biomass at the site.
5. Overall, the effect of the operation of the Peach Bottom facility on the fish populations in Conowingo Pond cannot be properly assessed due to the relatively short period of time (18 months) these data were collected. Additional fish trawl data are needed for adequate assessment.

Table 3.14. Peach Bottom — Mean catch per unit effort at each of the fish trawling stations during 1975

Station	January	February	March	April	May	June	July	August	September	October	November	December	Total number of trawls
451	6.9	0.5	181.4	25.5	56.0	62.0	2.4	0.6	5.3	1.2	0.4	0.3	44
452	2.3	0.1	0.24	6.1	12.1	21.8	8.2	3.0	7.2	0.7	0.2	0.3	46
453	14.1	2.0	3.0	19.4	76.4	49.0	12.6	104.3	55.4	0.3	0.1	1.5	46
470	32.5	0.2	17.9	42.0	102.2	197.1	345.2	71.2	138.3	31.6	5.4	3.3	46
472	3.1	0.1	0.2	10.1	54.4	39.7	8.7	74.5	32.9	6.1	0.3	0.8	46
473	21.9	0.2	0.7	5.9	40.3	3.7	37.6	28.2	1.2	1.4	4.1	0.2	46
474	17.3	0.2	0.1	16.2	44.5	19.7	10.3	132.1	27.8	5.4	1.2	0.2	46

b. Data analysis and evaluation

To determine whether the operation of the Peach Bottom Plant has had any measurable effect on the major trophic groups of Conowingo Pond, the preoperational data were compared with the operational data.

(i) Chlorophyll a (total)

Chlorophyll a concentrations were monitored at five stations during the years 1972 through 1975. The preoperational years were considered to be 1972 and 1973, while the operational years included 1974 and 1975 (Units 2 and 3 began commercial operation in May and December 1974 respectively).

Using Station 601, the following structural equation was hypothesized for each station X :

$$Z(X) = BZ(601) ,$$

where $Z(X) = \log_{10} [(\text{chlorophyll at station } X) + 1]$.

The results of the models developed for comparison of chlorophyll a concentrations are summarized in Table 3.15. The slopes of the regression lines (B_p and B_o) are comparable for all stations in Conowingo Pond. One can then conclude that the concentrations of chlorophyll a are not significantly different between Station 601 and the other four stations (B values) either in the preoperational or the operational years (B_p/B_o).

Table 3.15. Peach Bottom - Statistical comparison of chlorophyll^a concentrations at various stations

Station	Plant status	Number of monthly samples	$\bar{X}$ 601	$\bar{X}$ Station X^a	B	S_B	R^2
604	Operational	22	0.99	1.01	1.012	0.038	97.2
604	Preoperational	22	0.88	0.91	1.030	0.022	99.1
605	Operational	22	0.99	1.03	1.015	0.041	96.8
605	Preoperational	22	0.88	0.90	1.015	0.027	98.5
607	Operational	22	0.99	1.03	1.020	0.041	96.8
607	Preoperational	12	0.88	0.90	1.016	0.041	98.3
611	Operational	22	0.99	0.92	0.913	0.039	96.3
611	Preoperational	22	0.88	0.83	0.926	0.039	96.4

^aStation X is the station in the first column to which 601 is being compared.

In Table 3.16, the B values calculated from the combined chlorophyll a data of the preoperational and operational years are given for the stations. Data for the preoperational and operational years were combined because there were no significant differences in the slopes of the preoperational and operational periods. Observe that the estimated values of B for Stations 604, 605, and 607 are the same, while that of Station 611 is slightly smaller. Using the approximate confidence intervals of Table 3.16, one can conclude tentatively that Stations 601, 604, 605, and 607 are relatively homogeneous, while Station 611 is different. As discussed previously, Station 611 is distinctly different in water temperature and depths from all other stations in Conowingo Pond.

In summary, it appears that the operation of the Peach Bottom plant has had no significant effect on the concentrations of chlorophyll a observed at the four stations investigated.

(ii) Zooplankton

Eleven stations were sampled for zooplankton during the years 1967 through 1975, although only nine stations were used in this analysis. Station 607 was excluded because of its location at the mouth of Peters Creek, and Station 611 (near the dam) was excluded because of its distinct physical characteristics. The preoperational period included 1967 through 1973, and the operational period included 1974 and 1975.

Table 3.16. Peach Bottom — Confidence intervals (95%) for B for the discharge stations^a

Station	N	B	S_B	R^2	Lower limit ^b	Upper limit ^b
604	44	1.02	0.02	98.0	0.98	1.06
605	44	1.02	0.03	97.5	0.97	1.07
607	34	1.02	0.03	97.2	0.96	1.08
611	44	0.92	0.03	96.3	0.86	0.97

^a B was calculated from the combined chlorophyll a data of the preoperational (1972-1973) and operational (1974-1975) periods.

^bLower and upper limits based on 95% confidence interval.

The same type of statistical model discussed for chlorophyll *a* was developed for zooplankton. Using Station 601 as a control, the following model for each station during the preoperational and operational periods was estimated:

$$Z(\text{station } X) = EZ(601) ,$$

where $Z(\text{station } X) = \log_{10} [\text{zooplankton} + 1 \text{ (of any station)}]$.

The same relationships that exist in the statistical models for the chlorophyll *a* model also exist for this model.

In Table 3.17, the B_o and B_p values are given for all stations. Only Stations 605 and 603 are considered stressed stations. The ratio of $B_p:B_o$, given in Table 3.17 indicates that no major changes in zooplankton concentrations occurred at the stressed stations after Units 2 and 3 became operational. The two stations exhibiting the largest differences were Stations 602 and 603, which were not affected by the thermal plume. Except for Station 603, all stations exhibited a $B_p:B_o$ value greater than 1.0. The slopes were tested for equality; for preoperational and operational years, slopes for the discharge Stations 605 and 608 are equivalent.

Table 3.17. Peach Bottom - Statistical comparison of the average density of zooplankton at various stations

Station	Plant status	Number of monthly samples	$\bar{X}$ 601	$\bar{X}$ station X ^a	B	S _B	R ²	B_p/B_o
602	Operational	22	0.56	0.46	0.83	0.04	95.2	1.14
602	Preoperational	47	0.52	0.48	0.95	0.03	95.9	
603	Operational	22	0.56	0.68	1.17	0.04	97.6	0.87
603	Preoperational	47	0.52	0.51	1.02	0.03	96.1	
605	Operational	22	0.56	0.58	1.01	0.04	97.0	1.06
605	Preoperational	41	0.53	0.55	1.07	0.03	96.7	
606	Operational	22	0.56	0.64	1.08	0.05	95.1	1.03
606	Preoperational	42	0.52	0.54	1.05	0.03	96.0	
608	Operational	22	0.56	0.59	1.01	0.04	96.7	1.05
608	Preoperational	38	0.53	0.56	1.06	0.04	95.9	
609	Operational	22	0.56	0.66	1.10	0.06	94.1	1.10
609	Preoperational	29	0.51	0.61	1.21	0.05	94.7	
610	Operational	22	0.56	0.79	1.31	0.08	92.9	1.08
610	Preoperational	29	0.51	0.75	1.41	0.07	94.3	
611	Operational	11	0.46	0.60	1.03	0.18	75.9	-
611	Preoperational							

^aStation X is the station in the first column to which station 601 is being compared.

Therefore, the data for the preoperational and operational years may be combined for each station to obtain the coefficients shown in Table 3.18. By obtaining the 95% confidence intervals for the B values of each station (Table 3.18), it is evident that we are justified in combining Stations 605 and 608. Stations 609 and 610 are distinct; they are located closer to the middle of the river than 605 and 608.

The above analysis indicates that the thermal additions of Peach Bottom are producing no significant effect on the zooplankton densities at the most thermally stressed stations (605 and 608).

(iii) Benthos

Only benthic data collected from 1973 through 1975 were used in this analysis. Benthic sampling methods prior to 1973 (as described earlier) involved the use of several different size sieving screens and two different bottom dredges; thus, benthic biomass values could not be compared. The same type of statistical model used for evaluation of the chlorophyll a concentrations and zooplankton densities was also employed in evaluation of the benthos.

Mean benthic biomass values for Stations 601 through 608 for the preoperational period (1973) and operational period (1974 and 1975) are presented in Table 3.19. Again, there is no significant difference between the slopes of any of the linear regression lines. The $B_p:B_o$ ratio for the two thermally stressed stations (605 and 608) indicates that benthic biomass relative to Station 601 was slightly reduced in the operational years; however, reduction in the benthic biomass also occurred at Stations 602 and 603, which were not thermally stressed. Examination of the annual mean biomass values for each station during the two periods shows that the average biomass has increased at each station since the plant became operational. Because the control areas seem to exhibit a similar response

Table 3.18. Peach Bottom - Confidence intervals (95%) of B for the discharge stations^a

Station	N	B	S_B	R^2	Lower limit ^b	Upper limit ^b
605	63	1.042	0.02	96.8	0.994	1.09
608	60	1.041	0.03	96.2	0.987	1.10
609	51	1.153	0.04	94.2	1.069	1.24
610	51	1.361	0.05	93.5	1.261	1.46

^a B was calculated from the combined zooplankton data of the preoperational (1972-1973) and operational (1974-1975) periods.

^b Lower and upper limits based on 95% confidence interval.

Table 3.19. Peach Bottom - Statistical comparison of the biomass of benthos at various stations

Station	Plant status	Monthly samples	$\bar{X}$ 601	$\bar{X}$ station X^a	B	S _B	R ²	B _p /B _o
602	Operational	40	0.99	1.05	0.90	0.06	88.7	0.84
	Preoperational	21	0.73	0.71	0.82	0.11	73.4	
603	Operational	37	1.06	0.91	0.87	0.04	92.6	0.75
	Preoperational	21	0.73	0.56	0.65	0.10	68.4	
604	Operational	38	1.04	1.22	1.11	0.05	93.1	1.05
	Preoperational	21	0.73	0.97	1.17	0.11	85.1	
605	Operational	39	0.99	1.04	0.92	0.07	82.3	0.96
	Preoperational	21	0.73	0.74	0.88	0.12	80.0	
606	Operational	37	1.05	0.87	0.80	0.05	89.6	1.05
	Preoperational	21	0.73	0.68	0.84	0.09	79.8	
607	Operational	38	1.03	1.06	1.00	0.05	92.4	1.04
	Preoperational	21	0.73	0.87	1.04	0.10	83.9	
608	Operational	38	1.03	1.27	1.10	0.06	90.4	0.85
	Preoperational	21	0.73	0.87	0.94	0.11	78.1	
609	Operational	37	1.06	1.23	1.09	0.05	92.8	0.94
	Preoperational	21	0.73	0.86	1.02	0.09	82.2	
610	Operational	22	0.85	1.07	1.13	0.09	88.6	
	Preoperational							
611	Operational	22	0.85	1.43	1.40	0.13	85.1	
	Preoperational							

^aStation X is the station in the first column to which station 601 is being compared.

to the thermally stressed areas, any effect that the operation of the nuclear power plant had on the benthos is not separable from natural variation.

2. Impingement

Cooling water for Units 2 and 3 is withdrawn directly from Conowingo Pond by six pumps with a capacity of 5.68×10^6 liters/min. The intake portal contains 32 sets of vertical steel trash racks that prevent heavy debris and ice from contacting the 24 traveling screens set 40 ft behind the intake portals. The total intake area was designed to be large enough to maintain a velocity of 0.75 fps or less through the screens at the lowest pond level normally attained. The screens automatically rotate vertically past a jet water spray, dislodging the debris and carrying it into a sluiceway. Under normal operating conditions, the screens rotate only when a specified pressure gradient is reached. However, the screens can be washed continuously when large amounts of trash accumulate or in the winter months to eliminate ice. The trash and fishes are dewatered as they pass over a vibrating screen at the end of the sluiceway and are collected in a trash bin.

Impingement samples at Unit 2 were collected twice a week from November 1973 through December 1975; from July through September 1974, sampling frequency was increased to four times a week. At Unit 3, sampling was initiated in December 1974, and impinged fishes were surveyed during two successive 12-hr periods per week (day and night). A removable aluminum basket was placed in an outer trash bin at the start of the sampling. Fishes that accumulated in the basket at the end of 12 hr constituted a sample.

Impingement samples were evaluated for the period November 1973 to June 1975 (data from July through December 1975 were not available at the time this analysis was performed). During this time, approximately 15,500 fish representing 33 species were impinged. The sampling time was calculated to be 12% of the total 20-month period from November 1973 to June 1975. Since the numbers were not corrected to number of fish collected per week, the total impinged was estimated for the 20-month period to be approximately 134,000 fish. For convenience, only raw numbers were used in this report. Prior to the start-up of Unit 3 (December 1974), Unit 2 was estimated to average 137 fish impinged per day. But with the operation of Unit 3, the total estimated population of fish impinged increased over 200% to 417 fish per day; Unit 3 impinged 72% of this number. Actually, the daily rate of impingement at Unit 2 dropped 17% after Unit 3 began operation. The Technical Specifications required monitoring at Unit 2 for a period of only three months beginning at the start of commercial operation. However, the utility's consultants have continued collecting monitoring data on both Units 2 and 3 from November 1973 through the present time.

Of the 33 species impinged at the Peach Bottom station, not all occurred in any one single year, and four species comprised 94% of the total collected for the 20-month period (Table 3.20). The four dominant species were channel catfish (*Ictalurus punctatus*), white crappie (*Pomoxis annularis*), bluegill (*Lepomis macrochirus*), and pumpkinseed (*Lepomis*

Table 3.20. Peach Bottom - Impingement of the four dominant species

Species		1973 ^a	1974 ^b	1975 ^c	Total
Common name	Scientific name	number (%)	number (%)	number (%)	number (%)
Channel catfish	<i>Ictalurus punctatus</i>	716 (23)	4,217 (62)	4,050 (72)	8,983 (58)
White crappie	<i>Pomoxis annularis</i>	932 (30)	1,501 (22)	168 (3)	2,601 (17)
Bluegill	<i>Lepomis macrochirus</i>	1,247 (40)	504 (7)	722 (14)	2,523 (16)
Pumpkinseed	<i>Lepomis gibbosus</i>	87 (3)	109 (2)	239 (4)	435 (3)
	Total	2,982 (96)	6,331 (93)	5,229 (93)	14,542 (94)

^aOnly collected in November and December^bIn December 1974 a third unit started operating^cOnly collected January through June

gibbosus). In an independent analysis of impingement data collected from November 1973 through December 1975, Mathur et al. also found these four species to be the predominant fish impinged at the site.²¹

The impingement data were evaluated in two ways: (1) temporal variations in the impingement of the four most dominant species are discussed, and (2) a statistical analysis of the data was made identifying and assessing the physical factors of the environment and the biological characteristics of species that contribute to impingement.

a. Species evaluation

(i) Channel catfish

Channel catfish (*Ictalurus punctatus*) were the most numerous species impinged (58%) from November 1973 to June 1975. Channel catfish were impinged throughout the 20-month period; however, the greatest impingement occurred from December through May (Fig. 3.40 and Table 3.21). During this period, two major peaks in impingement occurred. The first occurred from December 1973 through February 1974 and was composed of fish with a mean fork length of 62 mm. According to Mansueti and Hardy,²² fish of this size are approximately six months old. The second large peak of channel catfish impingement occurred from December 1974 to May 1975 and consisted of fish with a mean length of 90 mm. Fish of this size represent one-year-old individuals.²² During both peak periods of impingement, over 50% of the catfish were impinged during the night.

(ii) White crappie

White crappie (*Pomoxis annularis*) were the second most abundant fish impinged (17%) during the 20-month period. During each year, over 90% of the impingement of this species occurred from December to February (Fig. 3.41, Table 3.21). These fish had a mean fork length

Fig. 3.40. Peach Bottom - Impingement of channel catfish (*Ictalurus punctatus*) at Peach Bottom Unit 2 (dashed line) and Unit 3 (dotted line) for November 1973 through June 1975.

Table 3.21. Peach Bottom - Impingement of the four dominant fish species from November 1973 through June 1975

Species	November 1973 Number (%)	December Number (%)	January 1974 Number (%)	February Number (%)	March Number (%)	April Number (%)	May Number (%)	June Number (%)	July Number (%)	August Number (%)	September Number (%)
Channel catfish	27 ^a	689 (8)	1400 (16)	931 (10)	230 (3)	205 (2)	71 (1)	67 (1)	212 (2)	105 (1)	217 (2)
White crappie	2 ^a	930 (36)	265 (10)	131 (5)	3 ^a	3 ^a	1 ^a	16 (1)	5 ^a	3 ^a	3 ^a
Bluegill	11 ^a	1239 (49)	9 ^a	55 (2)	2 ^a	18 (1)	1 ^a	0	0	0	14 (1)
Pumpkinseed	2 (1)	82 (19)	16 (4)	32 (7)	4 (1)	13 (3)	1 ^a	0	1 ^a	1 ^a	4 (1)

Species	October Number (%)	November Number (%)	December Number (%)	January 1975 Number (%)	February Number (%)	March Number (%)	April Number (%)	May Number (%)	June Number (%)	Total fish impinged
Channel catfish	66 (1)	80 (1)	633 (7)	332 (4)	608 (7)	1277 (14)	1058 (12)	500 (6)	275 (3)	8983
White crappie	5 ^a	39 (1)	1028 (40)	118 (5)	12 (1)	23 (1)	4 ^a	2 ^a	9 ^a	2601
Bluegill	14 (1)	41 (2)	348 (14)	262 (10)	426 (17)	59 (2)	5 ^a	11 ^a	9 ^a	2523
Pumpkinseed	2 ^a	1 ^a	35 (8)	6 (1)	108 (20)	86 (20)	18 (4)	16 (4)	5 (1)	435

^aPercentage of fish impinged is less than 1%.

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Fig. 3.41. Peach Bottom - Impingement of white crappie (*Pomoxis annularis*) at Peach Bottom Unit 2 (dashed line) and Unit 3 (dotted line) from November 1973 through June 1975.

of 110 mm (size range of 40 to 240 mm). Fish of this size range include one- and two-year-old individuals,²³ but most were about nine months old. Of the 2484 crappie impinged during these peak periods, 64% were impinged at night.

(iii) Bluegill

Bluegill (*Lepomis macrochirus*) were the third most common fish collected (16%) on the intake screens at the Peach Bottom station. This species was primarily impinged in winter (December to February) when 92% of the individuals were collected (Fig. 3.42, Table 3.21). The mean length of impinged fish was 70 mm (size range of 40 to 180 mm). Fish of this size class were approximately one year old. In addition, 72% of the bluegills collected during these winter peaks were impinged at night.

(iv) Pumpkinseed

Pumpkinseed (*Lepomis gibbosus*) were the fourth most numerous fish species impinged, comprising 3% of the impinged population (Fig. 3.43, Table 3.21). This species is very similar to the bluegill, both in aspects of its life history and in its temporal variation in numbers impinged. Impingement was greatest from December through March, when 85% of all individuals were impinged. The average size of impinged fish was 66 mm (size range was 40 to 120 mm). This size range represents approximately one-year-old fish.²³ Night impingement accounted for 53% of all individuals impinged.

(v) Statistical analysis

The impingement data were analyzed to determine and evaluate which factors, acting independently or in combination, contributed to impingement.

(vi) Total impingement analysis

The raw data analyzed in this study were originally reported as actual numbers of fish impinged during two 12-hr sampling periods, usually sampled once a week. Variables recorded with each sample included: (1) year, month, week, day, and time; (2) total number of fish impinged by sample and by species; (3) intake water temperature; (4) mean fork length; (5) total weight by sample and by species; (6) daily river flow; (7) total volume of fish (ft³); and (8) intake area of Unit 2 or 3.

Unit 3 began operation in December 1974 and continued until the end of the study period. During this time, two separate samples were taken (one for Unit 2 and one for Unit 3). Because the intakes of both units are adjacent to each other, these samples were combined for all statistical analyses. In April and May 1975, no data were recorded for impingement at Unit 2.

A total of 182 12-hr samples were collected during the 20-month study period, resulting in an average of 85 fish (± 174) collected per 12-hr sample. Thus, there was a very large variation in the number of fish impinged between samples, and the distribution of number of fish impinged does not approximate the normal distribution.

Fig. 3.42. Peach Bottom - Impingement of bluegill (*Lepomis macrochirus*) at Peach Bottom Unit 2 (dashed line) and Unit 3 (dotted line) for November 1973 through June 1975.

Fig. 3.43. Peach Bottom - Impingement of pumpkinseed (*Lepomis gibbosus*) at Peach Bottom Unit 2 (dashed line) and Unit 3 (dotted line) from November 1973 through June 1975.

The total number of fish impinged (including only the four dominant species) were analyzed as a function of temperature, river flow, and mean length. The correlation coefficients for the main variables and the interaction effects of several variables are shown in Table 3.22. The two main effects (river flow and water temperature) and the interaction effects [(temperature x river flow), (temperature x mean length), and (mean length x river flow)] were all significantly different from zero; only the main effect (body length) was insignificant. Even though the correlations are significantly different from zero, each of the variables may only explain a small percentage of the variation in impingement.

Table 3.22. Peach Bottom - Correlation of the main and interaction effects with the total number of fish impinged

Effect	Correlation coefficient (Pearson)	Significance level
Total X temperature	-0.21	0.001
Total X mean length	-0.04	0.216
Total X river flow	-0.28	0.001
Temperature X river flow	-0.20	0.001
Temperature X mean length	-0.45	0.001
Mean length X river flow	-0.12	0.006

The linear regression equation estimating the total number of fish impinged as a function of the two important variables, temperature (°C) and river flow (ft³/sec), is:

$$\text{Total impinged} = 85 + 0.11 (\text{Temperature}) + 0.05 (\text{River flow}) .$$

The R² value of this relationship (0.24) indicates that only 24% of the variation in impingement for both Units 2 and 3 combined can be explained by temperature and flow. These results vary from those of Mathur et al.,²¹ who reported that 39% of the variation in impingement for Unit 2 and 73% of the variation in impingement for Unit 3 could be explained by temperature and river flow; however, data from November 1973 through December 1975 were used for the latter study. Differences between the results of the two studies may be due to the inclusion of data from the last half of 1975 and the analysis of Units 2 and 3 (as was performed by Mathur et al.²¹) separately.

(vii) Species analysis

The following analysis was performed on the four major species impinged to identify the biological characteristics of the species (mean body length) and various environmental factors (i.e., time of year and water temperature) that contribute to impingement.

A chi-square contingency table was constructed to determine whether temperature had a differential effect on impingement of the four major species. The frequency of a species impinged as a function of temperature showed a significant correlation, that is, temperature affects the propensity of a species to be impinged differently for different species.

Multiple linear regressions were performed on the number (and $\log_{10}$ number) of fish impinged as a function of temperature and body length. For all species, the $\log_{10}$ transformations resulted in higher correlation coefficients (Table 3.23). Temperature and length explained a larger percentage of the variation in impingement for channel catfish (58%) and white crappie (54%) than for bluegill (24%) and pumpkinseed (28%). In addition, these two variables explained a larger percentage of the variations in impingement of the two species (catfish and crappie) than was reported in the analysis by Mathur et al.²¹ This may have been due to the fact that the latter authors did not use a $\log_{10}$ transformation on the data.

Table 3.23. Peach Bottom - Multiple regression summary of factors influencing impingement

Species	Dependent variable ^a	Constant	Coefficient		R ²
			Temperature	Length:	
Channel catfish	Total number	106	-0.023	+0.770	0.19
	$\log_{10}$ total	1.98	-0.003	0.009	0.34
White crappie	Total number	98	-0.100	-0.180	0.04
	$\log_{10}$ total	1.89	-0.002	0.001	0.29
Bluegill	Total number	148	-0.140	-0.730	0.02
	$\log_{10}$ total	2.08	0.002	-0.010	0.06
Pumpkinseed	Total number	15	-0.020	^b	0.02
	$\log_{10}$ total	0.95	0.001	-0.001	0.08

^aDependent variable refers to the total number of the specific species impinged or $\log_{10}$ total number of the specific species impinged.

^bContribution of length variable to regression was insignificant

Although there are some statistically significant correlations between the above-mentioned variables, there still remains a significant amount of variation in the number of fish being impinged which cannot be explained by a linear relationship between changes in either temperature or average length of the fish. Mathur et al.²¹ reported that the rate of impingement at Peach Bottom seemed to vary with the operating conditions at the station. Fish may concentrate in the vicinity of the screens when the plant is down and thus are vulnerable to impingement during start-up, particularly during the winter. As the operation of the plant becomes routine, fishes seem to adapt to the new conditions and impingement declines. Mathur et al. also found that Conowingo Pond elevation partially explained variations in impingement: the lower the pond elevation, the higher the impingement.²¹

b. Summary and conclusions

Of the four dominant species impinged at Peach Bottom, the channel catfish represented 58% of the total. This species was impinged throughout the year, with 52% collected in three winter months (December through February) and approximately 50% impinged during nighttime samples. The other three species (white crappie, bluegill, and pumpkinseed) are all small carnivores having similar habits and life histories. These species were impinged predominantly in the winter months [at temperatures less than 46 to 54°F (8 to 12°C)] and at night (Table 3.24). Therefore, it would seem that the probability of being impinged is not only due to the function of the relative numbers of fish present in the system, but also to the time of year and the time of day the sample is collected. Even though the ORNL analysis suggests that there is greater impingement at night, Mathur et al.²¹ found little difference in impingement between day and night samples in their analysis of Peach Bottom data. This difference in the results of the two studies could be due to the inclusion of impingement data from July through December 1975 by Mathur et al.²¹ In addition, these authors also eliminated selected samples that were collected when flows at the site exceeded 300,000 gpm. Removal of the samples collected under conditions of exceedingly high flow substantially lowers the observed differences in the day and night impingement.²¹ The majority of the fish that were impinged were also determined to be immature (one year old or less), as indicated by the size range of 60 to 110 mm in length. In this respect, impingement seems to be a function of size.

A satisfactory linear relationship between number of fish impinged and temperature existed before and after transformation to $\log_{10}$. The $\log_{10}$ transformation of the number impinged as a function of temperature and length results in a higher correlation coefficient for each species. Temperature and length affect the propensity of a given species to be impinged. This propensity varies for different species.

In the opinion of the ORNL staff, the present impingement monitoring program at Peach Bottom is adequate to fulfill the objectives of the Technical Specifications. The monitoring data on impingement were also collected in such a manner as to identify and explain some relationships between physical factors and impingement. It is desirable that the present impingement program be continued until such time as both Units 2

Table 3.24. Peach Bottom - Percent of each dominant fish species impinged in winter and night samples

Species	Percent impinged in winter (December-February)	Percent impinged at night
Channel catfish	52	~50
White crappie	97	64
Bluegill	92	72
Pumpkinseed	85 ^a	53

^aDecember through March only.

and 3 are consistently operational for at least a one-year period at optimum levels of power generation. After this period, all impingement data could be re-analyzed to determine the effects of impingement on the population of fishes in Conowingo Pond. If, on the basis of that analysis, impingement is found not to have an observable effect on fish populations, the impingement monitoring program could be modified to a reduced level.

3. Entrainment

Entrainment studies have focused on the mortality of zooplankton passing through the condensers of the plant. Samples were taken with a Van Dorn bottle at the condenser intakes and at the discharge structure. Samples from different depths were integrated and filtered through a #20-mesh plankton net to represent zooplankton density in the entire water column. Carmine and neutral red dyes were used to differentiate live and dead organisms. Mortalities were calculated from density data of live and dead animals at the intake and discharge. Densities were adjusted for settling and disintegration of dead animals in the discharge. The percent mortality at the discharge was calculated as the ratio of the density of dead organisms to the adjusted density of total organisms in the discharge. Percent mortality in the intake was subtracted from the percent mortality in the discharge to obtain the percent mortality due to entrainment:

$$M_e = D_d - D_i$$

where

D_d = percent dead at discharge

D_i = percent dead at intake.

The method used to estimate entrainment mortality reported in the Peach Bottom semiannual reports represents the mortality of all animals collected in the discharge that were killed due to plant passage, as well as other factors. This method tends to underestimate entrainment mortality because it estimates the increase in the number of dead organisms between the intake and discharge rather than the reduction

in number of live organisms. A method to estimate the fraction of living organisms killed would provide a more realistic approach because it calculates the true cropping factor of the plant on the plankton. Entrainment mortality can be calculated for the latter method by subtracting the percent live at the discharge from the percent live at the intake and dividing by the percent live at the intake:

$$M_e = \frac{L_i - L_d}{L_i} \times 100 ,$$

where

L_i = percent live at intake

L_d = percent live at discharge.²⁴

C. CHEMICAL EFFLUENTS

The Technical Specifications requirements for chlorine at Peach Bottom state that the concentration of total residual chlorine at the point of discharge into Conowingo Ford shall not be greater than 0.1 mg/liter. Chlorination data were presented monthly in the form of chlorination rate at each condenser, time of chlorination (day and hour), and the concentration of total chlorine residual (milligrams per liter) at the end of the discharge canal. Examination of the chlorine data in the monthly reports indicated that chlorine concentrations at the discharge were consistently less than 0.1 mg/liter. If these limits were exceeded, abnormal occurrence reports were filed.

D. AVIAN MORTALITY

1. Cooling towers

The Peach Bottom Atomic Power Station employs a hybrid system for reactor cooling as the method of heat dissipation. During operations, approximately half the water comes from once-through cooling, while the remainder is diverted through force-draft cooling towers. The force-draft towers are 53 ft in height.

No monitoring data on bird population are provided in the Technical Specifications for assessment of impacts related to cooling towers.

2. Transmission lines

Only one 500-kV transmission line was required to integrate Peach Bottom to the applicant's bulk power system. No prediction of environmental impact was made, although the Susquehanna River basin is a major flyway used by many species of waterfowl, including Canada geese, black ducks, mallards, and scaups.

No monitoring data are presented in the Technical Specifications for assessment of avian mortality related to transmission lines.

E. SALT DRIFT

Salt drift is of concern during operation of the cooling towers; however, normal wind patterns at the plant site will carry the majority of salt drift over Conowingo Pond. The applicant expects actual drift loss to be 450 to 850 gpm.

No monitoring data are given in the Technical Specifications for assessment of impacts related to salt drift.

F. HERBICIDES

No herbicides were to be used at the site, except in the following cases.

1. in clearing areas containing flush cut stumps of trees and scrubs, a 4% solution (mixture containing equal parts of 2,4,D and 2,4,5-T) would be employed.
2. When necessary, an Amchem growth retardant (NAI-10637 + 1% NAA + 1% ethyl alpha-naphthalene acetate) would be applied to fresh cuts of trimmed trees.
3. When right-of-way access for maintenance is difficult, growth would be controlled by a mixture of Tordon #155 (Dow Chemical Company) and fuel oil.

No monitoring data on results of actual herbicide use at the site are given in the Technical Specifications; therefore, no assessment of impacts related to herbicide use can be made.

V. FINAL ASSESSMENT OF PEACH BOTTOM TECHNICAL SPECIFICATIONS

A. HYDROTHERMAL

1. Conclusions

PECO has conducted a hydrothermal monitoring program that apparently exceeds the requirements of the Technical Specifications. The boat survey data provide a fine resolution for defining the extent of the thermal plume, while the thermograph data provide adequate information to establish significant temporal effects. The only complaints pertaining to these studies is that no boat surveys were made during the early morning or evening and that there was extensive missing thermograph data during the preoperational period, as a result of frequent instrument relocation. The staff's analysis was limited by the absence of good in-plant data, in particular, data related to cooling tower operation.

2. Recommendations

The following recommendations are intended as suggestions for improving the hydrothermal monitoring program under Technical Specifications.

1. Additional boat surveys do not appear to be necessary.
2. Better thermal data could be obtained if the number of thermograph stations were increased to the 1974 level of 35. Additional instruments could be placed near the bottom at important stations such as those near the center line of the plume and those near the centerline of Conowingo Pond, downstream of PBAPS.
3. Probability and cross-correlation analyses of the thermograph data could be carried out. A cross-correlation study could provide a valuable predictive tool for the thermal impact in Conowingo Pond. However, for this to be effective, data would have to be collected for all the pertinent parameters at the same frequency as the thermograph data (hourly). The extent of missing data should be minimized. This could be accomplished by providing replicate instrumentation at stations to be considered in such a study.
4. A more complete analysis of thermal impact requires additional in-plant temperature monitoring. Data on the operating capacity of the cooling towers would also be useful.
5. The requirement of using three helper cooling towers whenever one unit exceeds 20% rated thermal power appears too restrictive.

B. ECOLOGICAL

1. Summary

1. There were no significant differences in total surface chlorophyll a concentrations among stations or between the preoperational and operational periods.
2. No significant differences were observed between zooplankton densities among stations or during all sampling years (preoperational and operational periods). Variations in densities appear to result from natural variations.
3. No significant differences were observed in biomass of benthos in Conowingo Pond during preoperational and operational years. Variations in standing crop appear to be a result of natural variation.
4. Catch per unit effort (CPE) was higher in the plume area during the summer than during the winter. No differences in CPE were observed during the winter between control and plume-affected areas.
5. There is no evidence of a reduction in fish standing crops due to impingement because only low numbers of fish were impinged. Impingement appears to be influenced by water temperature, body length (age class), and season of the year.
6. Entrainment mortalities as calculated at Peach Bottom tend to underestimate death induced by passage through the condensers. The ORNL staff has recommended utilization of another method that assesses changes in percent of living organisms before and after passage and gives a more accurate estimate of the cropping factor.

2. Validation and comparison of Technical Specifications

In Table 3.25, a summary is presented comparing the predictions of impact at Peach Bottom made in the FES with the results of the ORNL staff's analysis of the monitoring data. In addition, a comparison of the required Technical Specification monitoring is made with the utility's actual monitoring program (Table 3.26).

3. Conclusions and recommendations

a. Monitoring stations

In general, sampling stations were well chosen at Peach Bottom during the preoperational period, and consistent monitoring was maintained during and between all years. All but three of the sampling stations have comparable physical and chemical characteristics. Station 604 is located close to an island, where water velocities and current patterns may be unrepresentative of Conowingo Pond; Station 607 is located at

Table 3.25. Peach Bottom — Comparison of FES predicted impacts with observed impacts

Predicted impacts	Observations from monitoring data
Phytoplankton	
A possible reduction in phytoplankton production may occur.	There are no significant differences in chlorophyll <i>a</i> concentrations among stations and between pre-operational and operational years.
An alteration in species composition from diatoms and greens to an increase in the more heat tolerant blue-greens would be expected.	Shifts in species composition cannot be validated since no quantitative cell counts were made.
Zooplankton	
Significant reduction in microcrustaceans during late summer is expected.	No significant differences in zooplankton densities among stations and among years were observed.
Benthos	
Detrimental effects on resident benthos over a small portion of Conowingo Pond exposed to thermal discharges, outfall scouring, and chlorine releases are expected. This will not be of sufficient magnitude to be important to the pond as a whole.	No significant differences were observed in the biomass of benthos collected at all stations during preoperational and operational periods. Variations in standing crops were probably due to natural variations.
Fish	
In winter, fish will be attracted to discharge plume.	CPE was observed to be higher in the plume in summer than in winter. No differences were observed in CPE during winter in control and in discharge.
<i>Entrainment</i> — High entrainment mortality of zooplankton expected, with selection for heat tolerant forms.	Methods used to estimate entrainment do not give the fraction of living organisms entering the plant that are killed by passage through the condensers.
Standing crops may be lowered partially from entrainment losses.	No significant differences in standing crops of zooplankton were observed between preoperational and operational years.
<i>Impingement</i> — Standing crops of adult fishes may be reduced due to impingement.	No evidence of reduction of standing crops was observed (low numbers impinged). Impingement is a function of temperature, length (age class), and river flow.

Table 3.26. Peach Bottom - Comparison of utility monitoring programs with Technical Specifications requirements

Technical Specifications requirements	Utility program	Comments
Plant pigments		
Samples at 13 stations twice monthly	Adequate	
Concentrations of chlorophyll a, b, c and carotenoids at surface, 5, 10, and bottom	Adequate	Taken at surface and bottom only (as presented in monthly reports)
Zooplankton		
Triplicate zooplankton samples twice monthly at 13 stations	Adequate	Only report single samples but analyzed weekly
Benthos		
Sampled biweekly at 13 stations	Adequate	Only report monthly average of two samples, no overlap of sampling with both screens when screen mesh changed
Fish		
Sampling with seines, trawls, traps, and meter nets	Adequate	
Sampling biweekly, except meter nets weekly in spring	Adequate	
Data analyzed to estimate abundance, size, relative biomass of species on seasonal and annual basis, estimating growth and mortality, and age structure	Adequate	
Impingement		
Monitoring twice per week (2- to 12-hr periods) for three months after commencement of commercial operation	Attempted	Monitoring of impinged fish has consisted of several 12-hr surveys (six to ten) per month from commencement of operation until the present time
Entrainment		
Estimation of mortalities due to mechanical damage (during initial startup)	Attempted	Larval fish too low to estimate mortality
Estimate of mortalities relative to various operating modes (thermal conditions)	Adequate	
Sampling at intake, discharge, canal, and cooling tower ponds	Adequate	Except in cooling tower intake areas
Sampling bi-monthly when plant operation regular	Adequate	Samples not taken when zooplankton are extremely low (winter)
Chlorine		
Free available chlorine measured at discharge	Adequate	Free residual and total residual measured at condensers two and three when chlorination applied
Thermal tolerances		
Temperature preference, and avoidance and shock studies conducted	Adequate	

the mouth of a creek and may receive additional nutrients from this source; and Station 611, located at Conowingo Dam, has water depths of 90 to 100 ft, far exceeding depths at other stations in the Pond. However, monitoring data from these stations may assist in analyzing far-field effects within this system.

b. Primary production

Several plant pigments were monitored at various depths at each station in Conowingo Pond. No quantitative identification and enumeration of phytoplankton genera were made, making assessment of possible shifts in the phytoplankton community impossible. Due to the formation of ice cover on Conowingo Pond during winter months, chlorophyll *a* values are extremely low during December, January, February, and March. For this reason, sampling is best limited to the periods of highest primary production from April through November. Fluctuations of chlorophyll concentrations can be accurately predicted from the extensive years of monitoring this system.

c. Zooplankton

Monitoring procedures employed for zooplankton at Peach Bottom were conducted in an adequate manner for the purposes of the Technical Specification objectives. Sampling was conducted frequently, and the data are reported as both biomass and density. Zooplankton density fluctuations parallel changes observed in the primary producers. Because zooplankton concentrations are minimal during winter months, sampling of this trophic level might best be conducted only during periods of high densities from April through November. Again, the extensive period of monitoring at the site provides ample data for prediction of periods of change in this trophic level.

d. Benthos

Sampling of the benthos was the one portion of the monitoring program that was subject to criticism because sampling gear and sieve size changes were made several times, eliminating the potential for meaningful analysis across all sampling years. When gear changes occur, an attempt should be made during a transitional period to overlap sampling in order to allow assessment of efficiency between the different methods and in order for a correction factor to be applied. However, the present sampling program is adequate for the purposes of the Technical Specifications objectives.

e. Fish

The present fish monitoring program includes sampling by trawls, seines, and trap nets, although only the trawl data were analyzed for this study. The present program is entirely adequate in light of the objectives of the Technical Specifications program. The utility's consultants have performed additional studies in the laboratory that have added to the knowledge of the thermal effects on fish populations which were not

realized during the preoperational period. These studies include thermal-temperature preference studies and thermal tolerance studies for the major species in Conowingo Pond. The utility's consultants have performed extensive statistical analyses of the thermal effects data on fish populations at the site, and these are presented in several Semiannual Operating Reports and in a recent paper by Mathur et al.²¹ Fish data collected from the various sampling methods at this station could be integrated to develop a comprehensive picture of fish population changes in Conowingo Pond.

In the opinion of the ORNL staff, the fish monitoring program is entirely adequate for meeting the objectives of Technical Specifications.

f. Entrainment

Calculation of entrainment mortalities (M_e) at Peach Bottom were made using the following method:

$$M_e = M_d - M_i \quad ,$$

where

M_d = percent mortality at discharge

M_i = percent mortality at intake.

This method tends to underestimate entrainment mortality (see Sect. IV. B.3).

The following method should be employed to estimate entrainment mortality:

$$M_e = \frac{L_i - L_d}{L_i} \times 100 \quad ,$$

where

L_i = percent of organisms alive at the intake

L_d = percent of organisms alive at the discharge.

This method²⁴ estimates the death of live organisms passing through a power plant and is a more realistic estimate of true plant cropping effects on the plankton.

g. Impingement

The utility's consultants should be acknowledged for their use of superior sampling methods, consistency and frequency of ecological sampling over the preoperational and operational periods, and the presentation of the monitoring data in a consistent format. In addition, statistical analysis

of high quality was performed on the chlorophyll, zooplankton, benthic, and fish data to evaluate the effects of station operation on these trophic groups. Where deemed necessary, additional data were collected above the mandatory Technical Specifications requirements such as those performed for the impingement program. If, on the basis of this analysis, impingement is found not to have an observable effect on fish populations, the impingement monitoring program could be modified to a reduced level.

h. Sampling method

The present impingement monitoring program has included monitoring at both Units 2 and 3 from November 1973 through the present time. Impingement monitoring in the Technical Specifications Program specified that monitoring be conducted only at Unit 2 and only for a period of three months after the plant began commercial operation. The utility in general established a monitoring program adequate to address the impacts of plant operation. This program exceeds the general requirements of the Technical Specifications (Appendix B). The present program should be continued until such time as both Units 2 and 3 have been consistently operational (optimal circulating pump usage) for at least one year. After this period, all impingement data should be analyzed to determine the effects of impingement on the fish population in Conowingo Pond. The field monitoring program was also supported by invaluable laboratory studies on temperature effects on fish.

ACKNOWLEDGMENTS

The authors wish to acknowledge the assistance given the ORNL staff by the following individuals: Mr. George L. Zaimis and Mr. Walter E. Rosengarten of Philadelphia Electric Company; Dr. Timothy Robbins and Dr. Dilip Mathur of Ichthyological Associates; and Mr. Barry Nichols, Mr. Eddy Forman, and Mr. Donald Gantzer of Science Applications, Inc.

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