SCE&G
A SCANA COMPANY

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Document Control Desk
U. S. Nuclear Regulatory Commission
Washington, DC 20555

Attention: K. R. Cotton

Gentlemen:

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Subject: VIRGIL C. SUMMER NUCLEAR STATION
DOCKET NO. 50/395
OPERATING LICENSE NO. NPF-12
TECHNICAL SPECIFICATION CHANGE REQUEST
ULTIMATE HEAT SINK - TSP 99-0280

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South Carolina Electric and Gas Company (SCE&G), acting for itself and as agent for South Carolina Public Service Authority, hereby requests an amendment to the Virgil C. Summer Nuclear Station (VCSNS) Technical Specifications (TS) in accordance with 10CFR50.90. This proposed amendment will revise the VCSNS TS 3/4.7.5 to incorporate new temperature and level limits for the ultimate heat sink during Modes 1-4. The minimum required service water pond level is increased from elevation 415' to elevation 416.5' and the maximum allowed temperature at the discharge of the service water pumps is decreased from 95°F to 90.5°F. No change to the Bases section is required.

The amendment request is contained in the following documents:

Attachment I	Explanation of Changes Summary Marked-up Technical Specification Pages Revised Technical Specification Pages
Attachment II	Safety Evaluation
Attachment III	No Significant Hazards Determination
Attachment IV	Environmental Impact Determination
Attachment V	V.C. Summer Nuclear Station Service Water Pond Thermal Study, Rev. 1, Tetra Tech NUS, Inc., Sept. 1999

This proposed TS amendment request has been reviewed by both the Plant Safety Review Committee and the Nuclear Safety Review Committee.

SCE&G requests NRC review and approval of this change to the VCSNS TS as expeditious as practical.

I certify under penalty of perjury that the foregoing is true and correct.

Should you have questions, please call Mr. Jim Turkett at (803) 345-4047 or Mr. Lou Cartin at (803) 345-4728.

Very truly yours,

Stephen A. Byrne

JT/SAB
Attachments: 5

c:	J. L. Skolds	(w/o Attachment V)
	N. S. Carns	(w/o Attachment V)
	T. G. Eppink	(w/o Attachments)
	R. J. White	
	L. A. Reyes	
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	T. P. O'Kelley	(w/o Attachment V)
	RTS (TSP 99-0280)	(w/o Attachment V)
	File (813.20)	
	DMS (RC-00-0249)	

STATE OF SOUTH CAROLINA :
: TO WIT :
COUNTY OF FAIRFIELD :

I hereby certify that on the 12th day of June 2000, before me, the subscriber, a Notary Public of the State of South Carolina personally appeared Stephen A. Byrne, being duly sworn, and states that he is Vice President, Nuclear Operations of the South Carolina Electric & Gas Company, a corporation of the State of South Carolina, that he provides the foregoing response for the purposes therein set forth, that the statements made are true and correct to the best of his knowledge, information, and belief, and that he was authorized to provide the response on behalf of said Corporation.

WITNESS my Hand and Notarial Seal

Notary Public

My Commission Expires

July 13, 2005
Date

Replace the following pages of the Appendix A Technical Specifications with the enclosed pages. The revised pages are indicated by marginal lines.

Remove Page	Insert Page
3/4 7-13	3/4 7-13

SCE&G -- EXPLANATION OF CHANGES

Page	Affected Section	Bar #	Description of Change	Reason for Change
3/4 7-13	3/4.7.5	1	a. Changed minimum water level from elevation 415' to 416.5'. b. Changed maximum water temperature from 95°F to 90.5°F.	Due to a functional review of the Service Water System, SCE&G determined that the service water pond (SWP) temperature limit within the Technical Specifications needed to be decreased to account for the expected temperature rise in the SWP during the design basis LOCA. This submittal reflects the results and conclusions of a new thermal study performed by Tetra Tech NUS, Inc.

PLANT SYSTEMS

3/4.7.5 ULTIMATE HEAT SINK

LIMITING CONDITION FOR OPERATION

3.7.5 The service water pond (ultimate heat sink) shall be OPERABLE with:

a. A minimum water level at or above elevation ~~415~~ 416.5 Mean Sea Level, USGS datum, and

b. A water temperature of less than or equal to ~~95°F~~ 90.5°F at the discharge of the service water pumps.

APPLICABILITY: MODES 1, 2, 3 and 4.

ACTION:

With the requirements of the above specification not satisfied, be in at least HOT STANDBY within 6 hours and in COLD SHUTDOWN within the following 30 hours.

SURVEILLANCE REQUIRMENTS

4.7.5 The service water pond shall be determined OPERABLE at least once per 24 hours by verifying the water temperature and water level to be within their limits.

3/4.7.5 ULTIMATE HEAT SINK

LIMITING CONDITION FOR OPERATION

3.7.5 The service water pond (ultimate heat sink) shall be OPERABLE with:

a. A minimum water level at or above elevation 416.5 Mean Sea Level, USGS datum, and

b. A water temperature of less than or equal to 90.5°F at the discharge of the service water pumps.

APPLICABILITY: MODES 1, 2, 3 and 4.

ACTION:

With the requirements of the above specification not satisfied, be in at least HOT STANDBY within 6 hours and in COLD SHUTDOWN within the following 30 hours.

SURVEILLANCE REQUIREMENTS

4.7.5 The service water pond shall be determined OPERABLE at least once per 24 hours by verifying the water temperature and water level to be within their limits.

SAFETY EVALUATION FOR REVISING THE ULTIMATE HEAT SINK TEMPERATURE/LEVEL LIMITS FOR THE VIRGIL C. SUMMER NUCLEAR STATION TECHNICAL SPECIFICATIONS

Description of Amendment Request

The Virgil C. Summer Nuclear Station (VCSNS) Technical Specifications (TS) are being revised to incorporate new temperature and level limits for the ultimate heat sink (UHS) during plant operation in Modes 1-4. These limits are contained in Section 3/4.7.5. The minimum required service water pond (SWP) level is increased from the 415' elevation to 416.5' and the maximum allowed temperature at the discharge of the service water pumps is decreased from 95°F to 90.5°F. No change to the Bases section is required.

Background

For Modes 1-4, Technical Specification 3.7.5 currently requires that the Service Water Pond (SWP) be operable with:

a) A minimum water level at or above elevation 415 Mean Sea Level, USGS datum, and

b) A water temperature of less than or equal to 95°F at the discharge of the service water pumps.

Conformance to these limits is verified and documented at least once per 24 hours by verifying the water temperature and water level to be within their limits in accordance with surveillance requirement 4.7.5.

Consistent with the recommendations of Regulatory Guide 1.27, Revision 2, "Ultimate Heat Sink for Nuclear Plants", the above limitations on minimum water level and maximum temperature were based on providing a 30 day cooling water supply to safety related equipment without exceeding their design basis temperature during either a normal cooldown of the facility or during postulated post accident conditions. Thermal analyses of the SWP during a normal shutdown and a design basis loss-of-coolant accident (LOCA) were performed to support the SWP design and are described in Sections 9.2.5.3 of the FSAR and SCE&G's response to FSAR Question 371.2. For these analyses, a catastrophic loss of the Monticello Reservoir was assumed at which time the SW pond level was assumed to instantaneously drop from it's normal operating level to 415'. A 36 inch pipe connects the SWP to the Monticello Reservoir and is designed with an invert elevation of 415' to prevent SWP drawdown below this minimum level.

During a service water system (SWS) functional review, it was determined that the SWP temperature limit within the Technical Specification needed to be decreased to account for the expected temperature rise in the SWP during the design basis LOCA. As a result, interim administrative limits were defined based on existing analyses to assure adequate initial condition protection. In addition, SCE&G contracted for a new SWP thermal analysis to serve as the basis for a formal revision the VCSNS Technical Specification. This submittal reflects the results and conclusions of the new study, which was performed by Tetra Tech NUS, Inc.

Safety Evaluation

The new SWP thermal study is performed consistent with the recommendations of Regulatory Guide 1.27, Revision 2 and is described in detail in the report entitled "V. C. Summer Nuclear Station Service Water Pond Thermal Study", Revision 1, dated September 1999 prepared by Tetra Tech NUS, Inc. (see Attachment V). A brief summary is provided below.

A SWP thermal model was developed and validated using field data taken during the station's 10th Refueling Outage (RF-10). To validate the SWP model, the following work elements were undertaken:

SWP Topographic and Bathymetric Surveys

Topographic and bathymetric surveys of the SWP were conducted to accurately establish the physical characteristics of the pond. The survey had a horizontal accuracy of $\pm$ 2 inches and a vertical accuracy of $\pm$ 2.0 inches and provided an accurate representation of the pond's surface area and volume distribution.

SWP Temperature Profiles

Temperature profiles were taken before and during the station's RF-10 to evaluate the extent of thermal stratification when the pond is exposed to a significant heat load. The field data indicates that mixing of the warmer surface waters occurs at greater depth through time and that mixing is reasonably complete horizontally.

SWP Circulation Patterns

A dye injection/fate study and an analysis of the vertical temperature profiles in the pond were conducted to assess the degree of "short-circuiting", if any, that occurs in the SWP. The data shows that the entire pond is used in cooling, that the SWP is performing as designed, and that no "short-circuiting" is occurring.

National Weather Service Data

In order to calculate the atmospheric heat flux from the SWP, the wind speed, air temperature, relative humidity, solar radiation, and cloud cover must be specified. The requisite data was obtained from the National Weather Service (NWS) for the years 1965 through 1996 and for January to October in 1997.

Model Calibration

During RF-10, the SWS flow rate and inlet/outlet temperatures were measured to determine the SWS heat load during the plant shutdown and to provide data to calibrate the SWP thermal model. Appropriate hydrological parameters for the thermal model were chosen based on a combination of literature information, field testing, and record of measured SW pump discharge temperature during the field test period. Results from the calibrated model were then compared to the measured temperatures at the discharge of the service water pumps for more than one year, concluding at the completion of the field tests. The modeled and measured data for the period prior to calibration showed excellent agreement thus validating the model with its chosen parameters.

Consistent with the SWP's existing design basis, the expected temperature rise at the SWS inlet was then evaluated for a hypothetical LOCA and a normal shutdown using the calibrated SW pond thermal model. In accordance with Regulatory Guide 1.27, Revision 2 requirements, a severe combination of conditions were chosen to demonstrate the pond's capability to dissipate heat. This included the selection of operational parameters, physical pond parameters and extant meteorological conditions:

Operational Parameters

The temporal distribution of flow rate and heat load to the SWP in the event of either a LOCA or a normal shutdown was defined. In order to impose the most severe thermal conditions on the SWP, the heat load on the pond was maximized by assuming that VCSNS was operating at 102% of rated thermal power prior to the postulated incident (i.e., LOCA or normal shutdown).

For the design basis LOCA, the following conservative assumptions were made:

1. Prior to and during the LOCA, equipment heat loads on the SWS were assumed at maximum design values.

2. The heat load to the reactor building (RB) was based on the LOCA mass and energy releases which released the largest amount of energy to the containment, where it is available for transport to the SWP by way of the Reactor Building Cooling Units (RBCUs) during injection and recirculation and the Residual Heat Removal (RHR) heat exchangers during recirculation. The double-ended pump suction break (as described in Section 6.2.1.3.10 of the VCSNS FSAR) was chosen as the break type and location for the study.

3. Energy transport from the RB to the SWP was maximized by assuming both trains of RB cooling available. Heat removal by the RBCUs was maximized by assuming zero fouling, maximum airflow, and maximum service water flow.

4. Energy transport from the RHR system during recirculation (i.e., RHR to component cooling water to service water to the SWP) was maximized by assuming both trains available, clean-unfouled heat exchangers, and maximum flow.

For the normal shutdown, the following conservative assumptions were made:

1. Prior to and during the plant shutdown, equipment heat loads on the SWS were assumed at maximum design values for normal operation.

2. RHR cooldown was initiated at the earliest possible time: 4 hours after shutdown at 350°F.

3. RHR cooldown to 100°F was assumed to be complete within 48 hours; transient heat loads considered included decay heat, reactor coolant system sensible heat, and reactor coolant pump heat. The maximum allowed number of reactor coolant pumps were assumed operating in accordance

with plant procedures to maximize the heat addition to the reactor coolant system and ultimately the SWP.

4. After 48 hours, the plant was assumed to be maintained in a safe, long term shutdown condition at 100 °F using both trains of RHR to remove decay heat.

5. For the normal shutdown, both trains of CCW and SW were assumed to be operating; and, to maximize the rate at which energy is added to the SWP, the heat generated during the plant shutdown was added to the SWP at the time it was generated (i.e., no transport delay).

The temperature rise associated with the SW pump heat was not explicitly considered within the LOCA or normal shutdown thermal analyses. Its effect (i.e., a temperature rise of $\leq$ 0.035 °F) was, however, accounted for in the selection of the proposed initial condition limits for the UHS.

Physical Parameters

The most restrictive pond physical state during an incident would be the prior loss of Monticello Reservoir resulting in a minimum initial pond elevation of 415 feet (i.e., the minimum value allowed by Technical Specification 3.7.5a which corresponds to the invert of the connection between the SWP and Monticello Reservoir). An additional loss of 0.25 feet was also considered to account for the change in surface elevation over the accident period due to seepage from the pond.

Meteorological Conditions

A 32 year period of record, 1965 through 1996, was investigated in order to define the most restrictive (i.e., resulting in the maximum SWP intake temperature) meteorological conditions. It was determined that time periods of July to August 1968, 1986, and 1993 will assure that the most restrictive intake temperature for any averaging period ranging from 1 hour to 50 days. Normal shutdown and LOCA simulations for various incident initiation times within each of these periods were then run until the time resulting in the maximum intake temperature for the SWP was found.

Using the calibrated thermal model, the SWP thermal distribution during a LOCA and normal shutdown were then simulated using the worst case combination of meteorology, physical parameters, and operational parameters. Although the transient performance of the SWP was similar during both incidents, the SWS initial and maximum intake temperatures during the LOCA were limiting. The initial intake temperature at LOCA initiation was 90.92°F. The maximum intake temperature was

95.12°F at approximately 10 days after the LOCA; this is slightly greater than the SWS design limit of 95 °F. Sensitivity studies indicate, however, that the 95°F design limit can be met under worst case conditions by either restricting the pre-incident SWS intake temperature to $\leq$ 90.65°F or the pre-incident SWP level to $\geq$ 416.4 feet. Both pre-incident restrictions are conservatively reflected in the proposed changes to the VCSNS Technical Specifications to provide a margin of safety and to bound the effect of the SW pump heat, which was not explicitly considered within the thermal analyses. The proposed changes are based on analysis values and thus do not account for instrumentation uncertainties. Uncertainties associated with the measurement of SWP level and the SW pump discharge temperature will, however, be included within plant procedures to ensure the plant is operated within the bounds of the analysis.

The proposed changes impose more restrictive operating limitations, and their use provides increased assurance that the SWS design temperature will not be exceeded. Since the SWP will continue to provide a 30 day cooling water supply to safety related equipment without exceeding their design basis temperature, the changes are consistent with the plant's design basis as stated in the bases of the Technical Specifications.

NO SIGNIFICANT HAZARDS EVALUATION FOR REVISING THE ULTIMATE HEAT SINK TEMPERATURE/LEVEL LIMITS FOR THE VIRGIL C. SUMMER NUCLEAR STATION TECHNICAL SPECIFICATIONS

Description of Amendment Request

The Virgil C. Summer Nuclear Station (VCSNS) Technical Specifications (TS) are being revised to incorporate new temperature and level limits for the ultimate heat sink (UHS) during plant operation in Modes 1-4. These limits are contained in Section 3/4.7.5. The minimum required service water pond (SWP) level is increased from the 415' elevation to 416.5' and the maximum allowed temperature at the discharge of the service water pumps is decreased from 95°F to 90.5°F. No change to the Bases section is required.

Basis for No Significant Hazards Consideration Determination

South Carolina Electric & Gas Company (SCE&G) has evaluated the proposed changes to the VCSNS TS described above against the significant Hazards Criteria of 10CFR50.92 and has determined that the changes do no involve any significant hazard. The following is provided in support of this conclusion.

1. Does the change involve a significant increase in the probability or consequences of an accident previously evaluated?

   Implementation of the new temperature and level limits for the service water pond do not contribute to the initiation of any accident evaluated in the FSAR. Supporting factors are as follows:

   - The new limits maintain the Service Water System (SWS) design temperature of 95°F during a normal shutdown and post accident and have been developed in accordance with the general requirements of Regulatory Guide 1.27, Revision 2.

   - Overall plant performance and operation is not altered by the proposed changes.

   - Fluid and auxiliary systems, which are important to safety, are not adversely impacted and will continue to perform their design function.

Therefore, since the reactor coolant pressure boundary integrity and system functions are not impacted, the probability of occurrence of an accident evaluated in the VCSNS FSAR will be no greater than the original design basis of the plant.

The SWP level and temperature limits relate to the plant's ability to reject heat to the ultimate heat sink during normal operation, a normal plant shutdown and hypothetical accident conditions. The new limits preserve the SWS design temperature of 95°F, even during worst case post accident conditions, thus assuring that equipment within the SWS and its interfacing systems remain qualified and that the heat transport capability of the SWS and its interfacing systems remains within design values. Since the SWS and its interfacing systems will continue to perform their design functions, it is concluded that the consequences of an accident previously evaluated in the FSAR are not increased.

2. Does the change create the possibility of a new or different kind of accident from any accident previously evaluated?

The proposed changes revise the UHS temperature and level limits within TS 3/4.7.5 to incorporate the results of a new thermal analysis performed in accordance with the requirements of Regulatory Guide 1.27, Revision 2. The new limits ensure that SW temperature, as measured at the discharge of the SW pump, remain less than the design value of 95°F. No new accident initiator mechanisms are introduced as:

- Structural integrity of the RCS is not challenged.
- No new failure modes or limiting single failures are created.
- Design requirements on all affected systems are met.

Since the safety and design requirements continue to be met and the integrity of the reactor coolant system pressure boundary is not challenged, no new accident scenarios have been created. Therefore, the types of accidents defined in the FSAR continue to represent the credible spectrum of events to be analyzed which determine safe plant operation.

3. Does this change involve a significant reduction in margin of safety?

The proposed changes revise the UHS temperature and level limits with TS 3/4.7.5 to incorporate the results of a new thermal analysis performed in accordance with the requirements of Regulatory Guide 1.27, Revision 2. The new limits ensure that SW temperature, as measured at the discharge of the SW pump, remain less than the design value of 95°F under both normal and post-accident conditions using the worst case combination of meteorology and operational parameters. Design margins associated with systems, structures and components that are cooled by the SWS are not affected. Since the SWS design temperature is maintained during both normal and worst case accident conditions, the results and conclusions for all design basis accidents remain applicable.

The proposed changes impose more restrictive operating limitations, and their use provides increased assurance that the SWS design temperature will not be exceeded. Since the UHS will continue to provide a 30 day cooling water supply to safety related equipment without exceeding their design basis temperature, it is concluded that the changes do not involve a significant reduction in the margin of safety.

Pursuant to 10 CFR 50.91, the preceding analyses provides a determination that the proposed Technical Specifications change poses no significant hazard as delineated by 10 CFR 50.92.

ENVIRONMENTAL IMPACT DETERMINATION FOR REVISING THE ULTIMATE HEAT SINK LEVEL AND TEMPERATURE LIMITS IN THE VIRGIL C. SUMMER NUCLEAR STATION TECHNICAL SPECIFICATIONS

Environmental Assessment

This proposed Technical Specification change has been evaluated against criteria for and identification of licensing and regulatory actions requiring environmental assessment in accordance with 10 CFR 51.21. It has been determined that the proposed change meets the criteria for categorical exclusion as provided for under 10 CFR 51.22(c)(9). The following is a discussion of how the proposed Technical Specification change meets the criteria for categorical exclusion.

10 CRF 51.22(c)(9): Although the proposed change involves change to requirements with respect to inspection or Surveillance Requirements,

(I) the proposed change involves No Significance Hazards Consideration (refer to No Significance Hazards Evaluation);

(ii) there are no significant changes in the types or significant increase in the amounts of any effluents that may be released offsite since the proposed change does not affect the generation of any radioactive effluents nor does it affect any of the permitted release paths; and

(iii) there is no significant increase in individual or cumulative occupational radiation exposure.

Accordingly, the proposed change meets the eligibility criteria for categorical exclusion set forth in 10 CFR 51.22(c)(9). Based on the aforementioned information and pursuant to 10 CFR 51.22(b), no environmental assessment or environmental impact statement need be prepared in connection with issuance of an amendment to the Technical Specifications incorporating the proposed change.

V. C. Summer Nuclear Station

Service Water Pond Thermal Study

V. C. Summer Nuclear Station
Service Water Pond Thermal Study

Prepared for

South Carolina Electric & Gas Company
Columbia, South Carolina

by

Tetra Tech NUS, Inc.
Aiken, South Carolina

Rev. 1 - September 1999

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1.0 WORK ELEMENT ONE – SERVICE WATER POND TOPOGRAPHIC AND BATHYMETRIC SURVEYS

Topographic and bathymetric surveys of the V. C. Summer Nuclear Station Service Water Pond (SWP) were conducted between October 2, 1997 and October 15, 1997 by Michael E. Weatherly, P.E., under contract to Tetra Tech NUS. A total of 1,686 survey data points were collected utilizing the following equipment:

- Berm Topographic Survey – TopCon Total Station and Hewlett Packard Data Collector
- Pond Bathymetric Survey – International Measurements Corporation Range-Azimuth Positioning System and Ratheon Survey Grade Fathometer

The survey has a horizontal accuracy of ±2 inches and a vertical accuracy of ±2 inches. Drawings of the SWP and environs were created with industry-standard drafting and design software, including AutoCad Release 13 and Softdesk Civil/Survey modules. A series of plan view (1-foot and 5-foot contour intervals) and cross-sectional view drawings of the SWP are presented in Appendix A. The survey report, which contains complete data files, drawings, maps, and photographs, is included in a separate volume entitled *Topographic Survey of V. C. Summer Nuclear Power Plant Cooling Pond – Jenkinsville, South Carolina.*

2.0 WORK ELEMENT TWO – SERVICE WATER POND TEMPERATURE PROFILES

2.1 Introduction

Temperature profiles were taken to evaluate the extent of thermal stratification before and during the station's Refueling Outage #10 (RF-10). It was assumed that the profiling completed before the outage would be representative of late summer conditions in the pond. Temperature patterns in the pond during the outage were expected to indicate circulation patterns within the pond, including "short-circuiting" that may have occurred between the pond inlet and the pumphouse.

2.2 Methods

Temperature profiles were taken once before the outage and twice during the early part of the outage (Table 2-1). Temperatures were measured at 1-meter intervals at each of the 13 stations marked by buoys (Figure 2-1). A YSI Model 57 meter was used for temperature measurement; readings were recorded on separate field sheets for each station.

2.3 Results

In general, there was little horizontal variability in temperatures at a given depth. For example, 0.7°C was the maximum difference between temperature readings at the same depth and on the same date among the four stations on Transect C (Table 2-2; complete temperature observations are presented in Appendix B). The depths listed in Table 2-2 are the same depths that were sampled for dye concentrations (see Section 3); they are also used to show changes in temperature with depth at each station and date (Figures B-1 through B-13). Transect C bisects the pond along a northeast-to-southwest axis (Figure 2-1), and includes the

Table 2-1. Time Line for Thermal Monitoring and Dye Studies, Service Water Pond, V. C. Summer Nuclear Station.

Date	Event
October 3, 1997	Pond temperature profile series
October 4, 1997	Begin shutdown (RF-10)
October 6, 1997	Inject dye
	Start automatic sampling at pumphouse
October 8, 1997	Pond temperature profile series
	Pond dye profile series
	Pumphouse samples recovered
October 10, 1997	Pumphouse samples recovered
October 12, 1997	Pumphouse samples recovered
October 13, 1997	Pond temperature profile series
	Pond dye profile series
October 14, 1997	Pumphouse samples recovered
October 16, 1997	Pumphouse samples recovered

deepest station sampled, C2 (see Figure B-8). The shapes of the temperature-depth curves are similar for each sampling date, indicating that mixing is reasonably complete horizontally.

There was also fairly good mixing with depth, at least during the pre-shutdown period. Top-to-bottom variation in temperature on October 3 was about 1.0°C (Table 2-2). According to limnological convention, a change of 1.0°C or more over a 1-meter depth interval is required for a water body to be considered stratified. This condition was not observed during the study (Appendix B), nor do historical profiles indicate stratification in the Service Water Pond during summer (Mr. Steve Summer, SCE&G, Columbia, SC). However, there were some discontinuities in temperature with depth that occurred after shutdown. On October 8, there was a 1.3 to 1.6°C difference between 5 and 8 meters and between 17 and 20 meters (Table 2-2, Figures B-1 through B-5, Figures B-7 through B-9, and Figures B-11 through B-13). On October 13, similar discontinuities were seen at Station C2 from 11 to 14 meters and again at 17 to 20 meters (Figure B-8), and at Station B2 from 14 to 17 meters (Figure B-4). The other shallower stations had minor temperature changes with depth on October 13. The range of temperatures seen in the pond was greatest on October 8, about 22 to 27°C; it was reduced to about 22.5 to 25.5°C on October 13.

2.4 Discussion and Conclusions

Comparison of temperature profiles for the two post-shutdown sampling dates appear to show that mixing of the warmer surface waters occurs at greater depth through time. Although not as strong as typical summer stratification, the discontinuities observed represent a resistance to mixing that takes a combination of time and energy to overcome. Also, their occurrence during shutdown, when a heat load is being applied to the pond, indicates that warm water entering the pond stays near the surface until the heat is dissipated to the atmosphere and the deeper water. In sum, the temperature profiles indicate the cooling pond is performing as designed and no "short-circuiting" is occurring.

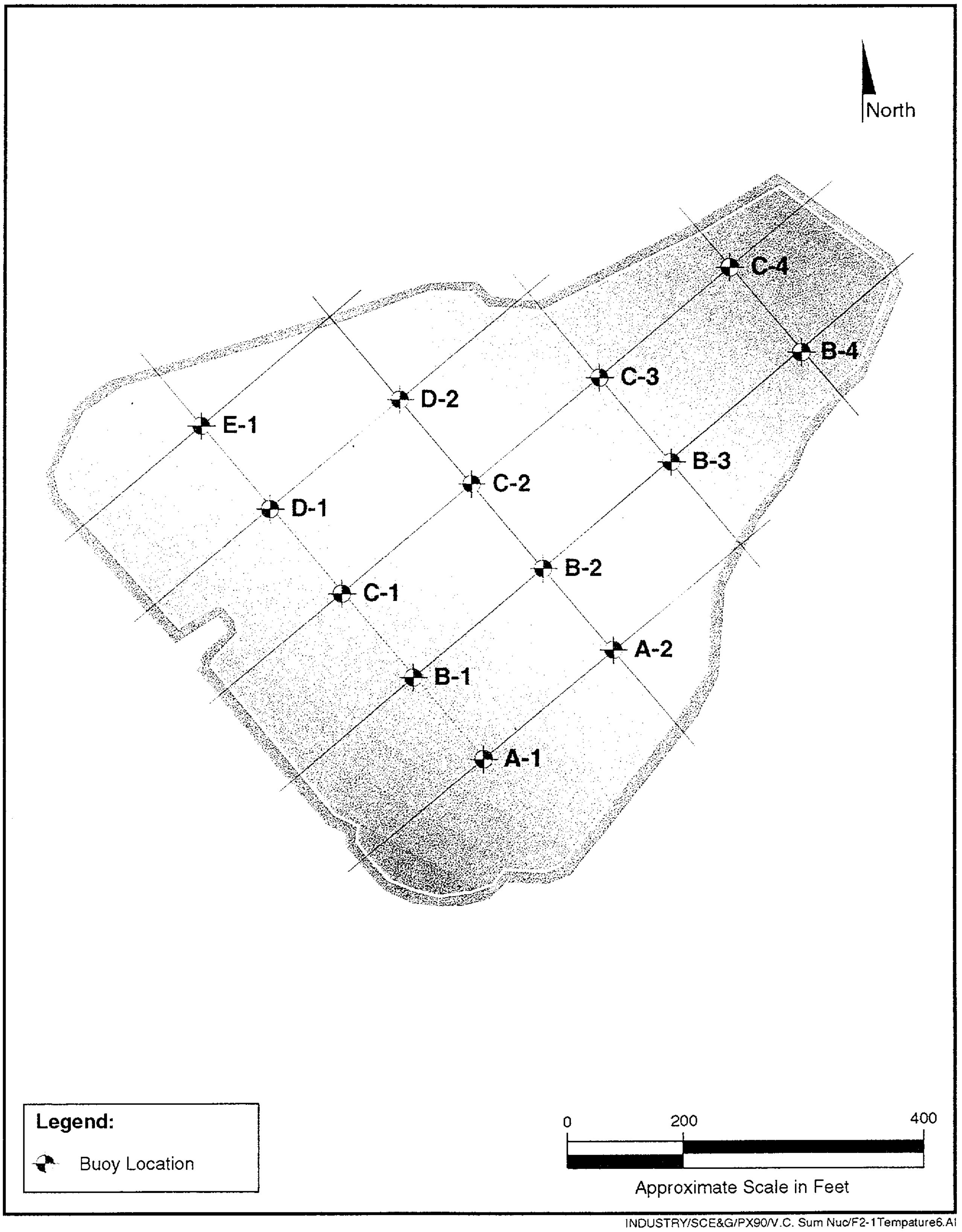

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Figure 2-1. Temperature monitoring stations in VCSNS service water pond.

Table 2-2. Temperatures (°C) at Selected Depths, Transect C, V. C. Summer Nuclear Station Service Water Pond.

	Stations			
Depth (m)	C1	C2	C3	C4
		October 3, 1997		
0	24.0	24.0	24.0	24.6
2	23.8	23.8	24.0	24.5
5	23.3	23.2	23.3	23.9
8	23.2	23.0	23.2	23.7
11		23.0		
14		23.0		
17		23.0		
20		23.0		
		October 8, 1997		
0	26.9	26.7	26.4	26.4
2	26.0	26.0	25.9	26.0
5	25.7	25.5	25.8	25.8
8	24.3	24.2	24.2	
11		23.8		
14		23.7		
17		23.6		
20		22.1		
		October 13, 1997		
0	25.4	25.6	25.5	25.0
2	25.1	25.4	25.4	25.0
5	25.0	25.2	25.2	25.0
8	25.0	25.1	25.2	25.0
11		25.1		
14		23.8		
17		23.8		
20		22.5		

3.0 WORK ELEMENT THREE – SERVICE WATER POND CIRCULATION PATTERNS

3.1 Introduction

The primary goal of this phase of the investigation was to assess the degree of "short-circuiting," if any, that occurs in the pond. In other words, the purpose of this study was to assess how much of the pond is actually used in the cooling process. The fraction of the pond that is used in cooling is an input parameter for the water temperature modeling being done for Work Element Four – Computer Modeling of Service Water Pond Temperatures During Worst-Case Condition. The approaches taken for estimating this fraction were a dye injection/fate study and an analysis of vertical temperature profiles in the pond. Pond temperature profiles were described previously in Section 2.0.

3.2 Methods

The following text describes the methods used in the dye study; the Service Water Pond itself and the temperature profiling have been previously characterized. Because timing is an important part of the study, the methods are listed in a chronology of activities performed for the circulation investigation.

On October 6 (see Table 2-1), about three gallons of a 20 percent solution of Rhodamine WT dye were injected into the Service Water Pond system at a point well upstream of the pond inlet. The injection took less than an hour, and relative to the approximate 20-day residence time of water in the pond, it was essentially a "slug" of dye in the system. Samples of the original dye solution were retained and later combined to make a nominal standard for dye concentration. Also, samples were taken at the pond inlet for analysis and to be mixed with pond water for dye controls, which were set up in large plastic containers near the pond. Dye was mixed in the controls to a final concentration similar to that expected in the pond after mixing in the surface layer. The purpose of the controls was to monitor breakdown of the dye over time.

An automatic water sampler (ISCO Model 3700) was set up on October 6 to sample water coming from the pond into the pumphouse. The sampler was programmed to fill 24 bottles in 48 hours by taking a small sample (1/4 of a bottle) every one-half hour. Samples were removed from the sampler and the sampling program restarted every two days until October 16 (see Table 2-1).

Water samples were usually analyzed for dye concentration the day they were collected, and always within 2 days of collection. A Turner fluorometer (Model 112) outfitted with filters designed for use with Rhodamine was used to analyze the dye samples and standards. A series of diluted nominal standards were prepared and a straight line was fitted by regression to the fluorometer readings of the standards. Concentrations of all samples were calculated by substituting the sample fluorescence into the standard regression equation. This resulted in some negative dye concentration estimates, due to variability in day-to-day fluorometer response. The readings for nominal standards did not have an obvious trend in time, so the variability appeared to be random and use of a single standard curve seemed justifiable. Fluorometer readings and the standard curve are included in Appendix C.

Dye samples were collected from all pond sampling stations on two dates after the dye was introduced. These were the same two sampling dates when the post-shutdown temperature profiling was done (see Table 2-1). Samples were collected at a depth of 2 meters and then at 3-meter intervals to the bottom.

3.3 Results

Although variable, dye concentrations in the control containers did not undergo a monotonic decline (Figure 3-1), and no correction factors for breakdown of dye were used. Dye concentrations at the pumphouse began to increase in the samples collected October 12; a sharp increase is evident October 13, after which concentrations mostly remained above 0.5 ppb (Figure 3-2). In the pond on October 8, dye concentrations along Transect C varied from about 1.9 to 2.9 ppb at 2 and 5 meters depth, and deeper samples were all less than about 0.5 ppb (Figures C-2 through C-5). On October 13, there was much less variation of dye concentration with depth; most values for Transect C were between 0.5 and 1.2 ppb.

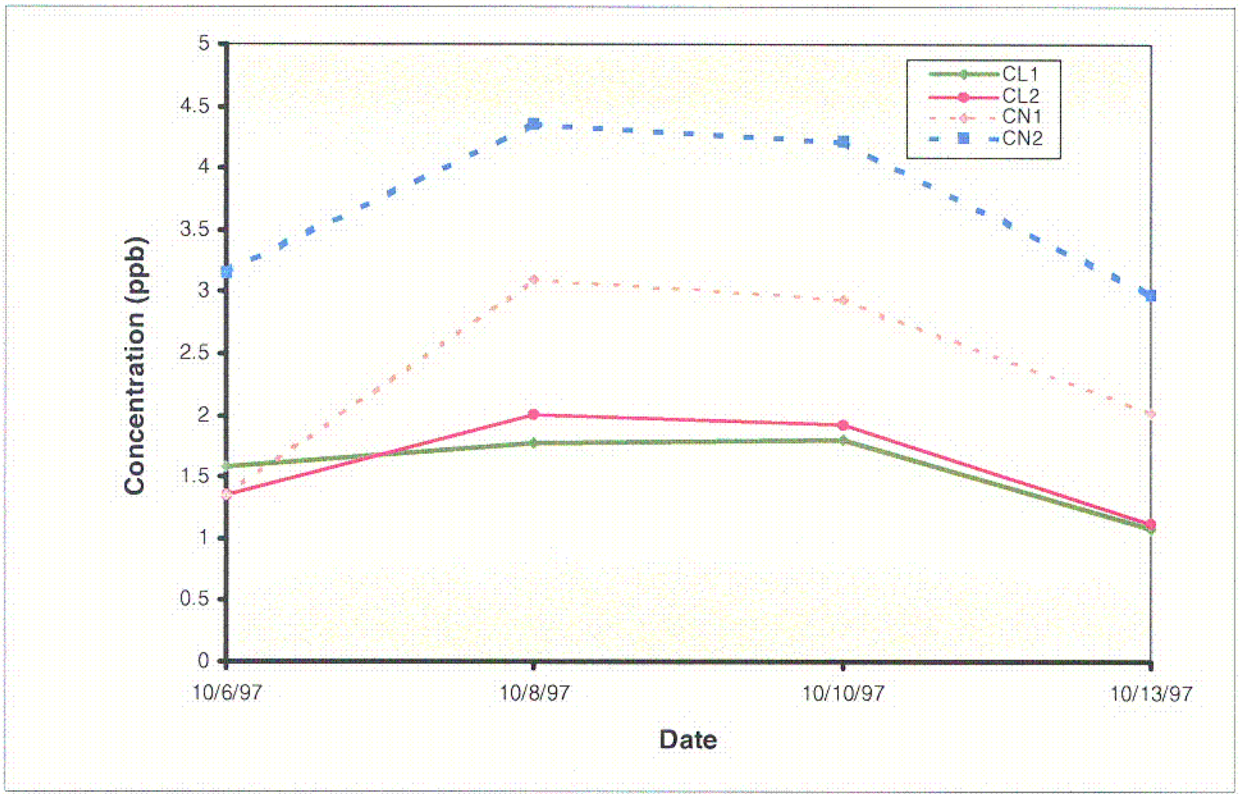

Figure 3-1. Controls for Dye Breakdown -- Light vs. Not Light.

3.4 Discussion

Using Transect C as a representative example, the pond data indicate that dye injected on October 6 had mixed into the upper 5 to 7 meters of water throughout the pond by October 8. The temperature profiles on October 8 show a temperature discontinuity between 5 and 8 meters (see Table 2-2) that can explain the lack of mixing at 8 meters and below. By October 13, the dye had mixed throughout the pond, except, perhaps, to depths below 14 meters (Figure C-3). This mixing is also mirrored in the lack of variability in temperature data from 0 to 11 meters depth on October 13 (Table 2-2), and the sharp increase in dye concentration at the pumphouse on the same date (Figure 3-2).

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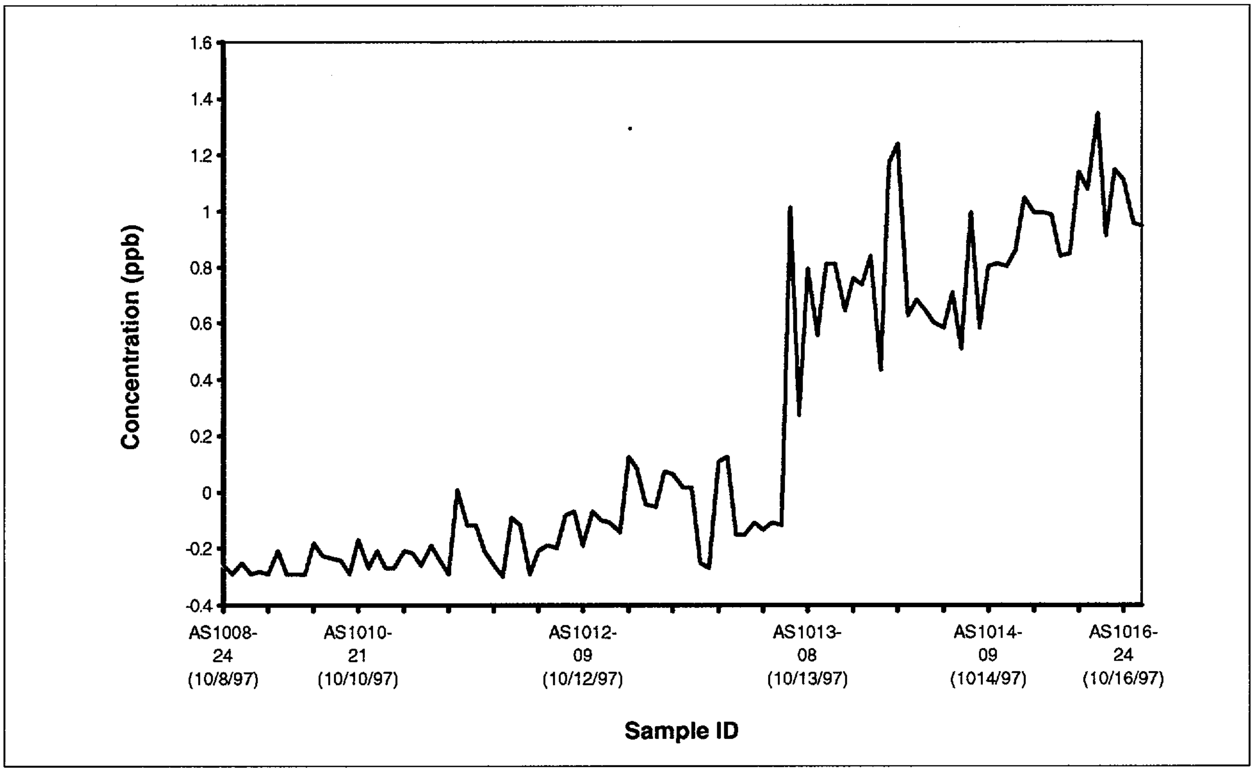

Figure 3-2. Dye Concentrations at Pump House.

3.5 Conclusions

It is clear from the data that nearly the entire pond is used in cooling. Based on temperature (Figures B-4 and B-8) and dye distributions (Figure C-3) in the pond on the same day that dye levels increased sharply at the pumphouse (October 13), it is possible that water below a point between 14 and 17 meters deep may not be as involved in cooling as the upper waters. This probably relates to the depth of the pumphouse inlet, which extends from elevation 370 feet to 385 feet, approximately 12-17 meters below the normal level of the pond (423.7 feet). It seems reasonable that water below the depth of the pumphouse inlet would not be involved in cooling.

In sum, no short circuiting was observed in the system, although the volume of water below the pumphouse inlet may not be involved in cooling. Given the study results, it is difficult to imagine conditions under which short circuiting would occur. If incoming water is warmer than the water in the pond, it is likely to stay near the surface until the excess heat is dissipated.

4.0 WORK ELEMENT FOUR – COMPUTER MODELING OF SERVICE WATER POND TEMPERATURES DURING WORST-CASE CONDITIONS

4.1 Background

The Service Water Pond (SWP) at the V. C. Summer Nuclear Station (VCSNS) was designed to comply with the directives of Regulatory Guide 1.27 (NRC 1976a). It was also designed to ensure that the intake water temperature does not exceed the 95°F maximum acceptable limit of the Service Water System components. Thermal analyses of the pond during a normal shutdown and a design-basis loss of coolant accident (LOCA) were originally performed to support the SWP design (SCE&G 1998a). Since that time, revised heat rejection rates have been developed for normal full power operation, normal shutdown, and LOCA (SCE&G 1998b).

A previous computer mathematical model study defined the long-term characteristics of the thermal regime in Monticello Reservoir (Toblin 1985). The reservoir is used as both the sink for heat rejected by VCSNS and as the storage reservoir for the Fairfield Pumped Storage Facility. The study demonstrated that even under worst-case conditions the reservoir will meet the quantitative thermal limitations placed on it (SCDHEC 1984). This report documents the application of the model used in that study to the revised heat rejection rates to the SWP. In particular, the SWP's thermal response to the revised heat rejection rates will be compared with the 95°F limit described above.

Field studies of the thermal and flow characteristics of the SWP were conducted in October 1997 before and after the station's Refueling Outage #10 (RF-10). These studies included top-to-bottom temperature measurements at 13 stations and dye studies designed to characterize circulation patterns within the pond. Sections 2.0 and 3.0 of this report document the results of those studies. Earlier analyses of the SWP (SCE&G 1998a) postulated that as little as one-half of the surface of the pond could be effective in dissipating heat to the atmosphere. The RF-10 field studies showed that the entire surface area of the pond was involved in this heat transfer.

4.2 Mathematical Model

The model used to describe the temporal and spatial thermal distribution within the SWP contains three major components:

- Heat transfer between the pond and the atmosphere
- Transport of the heated water discharged near the pond's surface
- Internal movement of heat within the pond (vertical transport)

These components are coupled within the model to simulate the pond's thermal characteristics.

4.2.1 Atmospheric Heat Transfer

The flux of heat across the surface of a water body has various components that can be either positive (heat entering the water) or negative (heat exiting the water). The major processes considered are solar radiation, atmospheric radiation, back radiation from the water body, evaporation, and conduction.

The net solar heat flux, ϕ_{sn}, consists of incident solar radiation minus reflected solar radiation. The incident clear sky solar radiation is a function of latitude, time of day, and time of year. In addition, reflection, scattering, and absorption by gases, water vapor, and particulates in the atmosphere will affect this term. Accordingly, empirical representations are usually used to calculate the temporal distribution of incident solar radiation at a particular site. Reflected solar radiation from the water surface is a function of solar altitude and sky conditions and can range from 5 to 10 percent of incident solar radiation (Thackston and Parker 1971). The net temporal distribution of solar radiation absorbed by the water was calculated according to the methods described in Thackston and Parker (1971). Their description of the factor by which net solar radiation is reduced by cloud cover, $(1 - 0.71c^2)$, where c is the cloud cover in the range of 0 to 1, was also used.

Atmospheric radiation is emitted by the constituents of the atmosphere and is, essentially, "black body" radiation. The latter is described by the Stefan-Boltzmann law (Bird et al. 1966):

$$\phi_a = \varepsilon \, \sigma \, (T_a + 273)^4 \qquad (1)$$

where ε = atmospheric emissivity (1 for a theoretical black body), σ = Stefan-Boltzmann constant (1.17×10^{-3} Cal/m^2-day-K^4), and $T_a + 273$ = absolute temperature of the atmosphere in K. The emissivity of the atmosphere can be empirically described as:

$$\varepsilon = 9.4 \times 10^{-6} \, (T_a + 273)^2 \, (1 + 0.17c^2) \qquad (2)$$

where the cloud cover term describes the darkening of the sky and attendant increase in emissivity. The net atmospheric radiation, ϕ_{an}, is taken as 97 percent (the water reflecting 3 percent) of the incident radiation (Ryan and Stolzenbach 1972).

The back radiation from the water surface, ϕ_b, is also described by equation 1, except that the temperature used is the water surface temperature, T_s. The emissivity of the water is well known as 0.97 (Ryan and Stolzenbach 1972).

The evaporative heat flux, ϕ_e, from the water surface is mechanistically equivalent to the latent heat of vaporization of the water being evaporated into an atmospheric boundary layer (which is in equilibrium with the water surface) and subsequently transported to the atmosphere. This transport (convection) of heat has two components: forced convection (due to the wind) and free convection (due to buoyancy effects).

The forced convection term, ϕ_{e1}, is empirically described as:

$$\phi_{e1} = k \, W_2 \, (e_s - e_a) \qquad (3)$$

where k is a constant, W_2 is the wind speed 2 meters above the water surface in meters per second, e_s is the saturated vapor pressure at the temperature of the water surface in mm Hg, and e_a is the vapor pressure of the air. The form of the free convection term is taken from experimental work of free convection over a flat plate modified by the fact that water vapor is lighter than air (and therefore evaporation increases buoyancy forces). The result is:

$$\phi_{e2} = 18.4 \, (T_{sv} - T_{av})^{1/3} \, (e_s - e_a) \qquad (4)$$

where $T_{sv} = (T_s + 273) / (1 - 0.378e_s/p)$, $T_{av} = (T_a + 273) / (1 - 0.378e_a/p)$, and p = atmospheric pressure in mm Hg. The total evaporative heat flux, ϕ_e, is then the sum of $\phi_{e1} + \phi_{e2}$. A value of k = 31.3 (for the units given above) has been found to be appropriate (Ryan and Stolzenbach 1972).

Heat conducted from the water to the atmosphere via the atmospheric boundary layer must be transported analogously to the convection of evaporative heat. The heat conduction flux, ϕ_c, is related to ϕ_e through the Bowen ratio, R. That is:

$$R = \phi_c / \phi_e = C_b P(T_s - T_a)/(e_s - e_a) \quad (5)$$

where C_b = Bowen's constant = 6.1×10^{-4} $(^{\circ}C)^{-1}$ for average wind conditions and P = 760 mm Hg.

The total heat flux, ϕ, into the water surface is then:

$$\phi = \phi_{sn} + \phi_{an} - \phi_b - \phi_e - \phi_c \quad (6)$$

4.2.2 Near-Surface Heat Transport

As heated water enters a cooling pond it tends to mix with the receiving water. This mixing is a function of turbulence (which is related to velocity) of the discharged water. However, even for heated water discharged quiescently, a minimum amount of mixing is engendered by the convective nature of the flow. That is, the heated water (being less dense than the cooler receiving water) will tend to spread over the receiving water with vertical mixing occurring across the boundary between these two masses. The ratio of the heated surface layer flow after and before this mixing is called the dilution factor. Values of the dilution factor, D, can range from 1.5 (Jirka et al. 1978) to 10 or more (NRC 1976a).

After the velocity differences between the discharged and receiving water are damped, the heated water will tend to form a layer on top of the pond in response to buoyant forces. This layer will convect along the top of the pond as a density current. (For a shallow pond, entrance and wind mixing will tend to counter this stratified behavior.) The major impact of the wind on the reservoir (other than its effect on cooling, as given by equation 3) is to change the shapes of isotherms. The density currents ensure that the entire pond surface is used for cooling except under the very strongest winds, which are transient in nature (Jirka et al. 1978). Field studies (see Sections 2.0 and 3.0) confirm this.

The heated surface layer will tend to be vertically uniform in temperature in response to instabilities caused by cooling at the water surface. The equation which describes the heat distribution along the surface layer under these circumstances is:

$$\partial T/\partial t + (1/h)\, \partial\, (DQ_oT)/\partial A = \partial\, (E_L w^2 \partial T/\partial A)/\partial A + \phi/\rho c_p h \quad (7)$$

where T = temperature, t = time, h = depth of surface layer, A = area, D = dilution factor, Q_o = discharge flow rate, E_L = longitudinal diffusion coefficient, w = width, ρ = water density, c_p = specific heat of water, and ϕ is given by equation (6) (except for the effect of the vertical distribution of absorbed solar radiation, as described in the next subsection). The boundary conditions to equation (7) describe the temperature at the end of the mixing zone (the mixed temperature being described by the discharge temperature, subsurface pond temperature, and dilution factor) and no heat flux across the downstream boundary.

4.2.3 Internal Heat Transport

The temperature distribution beneath the surface layer will tend to be constant in the horizontal direction with the dominant temperature gradients occurring in the vertical direction (Ryan 1972). The vertical gradients will be affected by advective flows (down-welling induced by upper level cooling, entrainment into the mixing region, selective withdrawals such as plant intake water, and river inflows and outflows), vertical diffusion, and atmospheric heat transfer.

The equation used to describe the heat transport beneath the surface layer is:

$$\partial T/\partial t + (1/A)\, \partial (vAT)/\partial z = (1/A)\, \partial (E_V A \partial T/\partial z)/\partial z + H/\rho c_p \qquad (8)$$

where T, t, A, ρ, and c_p are defined as before, z = depth, v = vertical velocity, E_V = vertical diffusion coefficient, and H = heat sources. The heat sources are made up of inflows, outflows, and solar radiation. The latter has been found to be absorbed in both the surface layer (longer wave length components) and exponentially with depth (shorter wave length components). The vertical distribution of absorbed solar radiation, ϕ_z, is:

$$\phi_z = (1 - \beta)\, \phi_{sn} e^{-\eta z} \qquad (9)$$

where β is the longer wave fraction absorbed in the surface layer and η is the extinction coefficient of solar radiation in the water (a function of the clarity of the water) (Ryan 1972). β is typically in the range of 0.4 to 0.5; η is taken equal to $1.7/s_d$, where s_d = Secchi disk depth (in the same units as z).

4.3 Model Parameters

Application of the previously described model to the SWP requires specification of the parameters in equations 1 through 9. These parameters, which describe the thermal dynamics of the SWP or the forces acting on it, can be categorized as physical (SWP dimensions), meteorological, hydrological, or operational.

4.3.1 Physical Parameters

The field testing program included a bathymetric survey of the SWP, which is described in Section 1.0. The average surface elevation of the SWP during the months of September and October 1997, within which the field test was performed, was 423.71 feet. From January 1, 1997 to August 31, 1997, the average surface elevation was 423.71 feet with a standard deviation of only 0.46 foot. This average elevation was used for subsequent analyses of 1997 pond behavior. The surface area of the SWP at this elevation is 1.88×10^6 feet^2. The pond is approximately 80 feet deep under these conditions. The intake from the SWP to the service water system is 15 feet high, from elevation 370 feet to 385 feet.

4.3.2 Meteorological Parameters

In order to calculate the atmospheric heat flux (equation 6), the wind speed (and height of measurement), air temperature, relative humidity (or dew point), solar radiation, and cloud cover must be specified. The National Weather Service (NWS) maintains a long-term continuous record of meteorological parameters measured at the Columbia, South Carolina metropolitan airport (approximately 26 miles southeast of the site) (NCDC 1993).

The requisite data were obtained for the complete years 1965 through 1996; data through October 1997 were also obtained. This data has been taken at a height of 20 feet above grade since January 12, 1967. It was taken at a height of 36 feet prior to that date. The latter data was transformed to 20-foot height using the well-established logarithmic wind profile (Ryan and Stolzenbach 1972).

A previous study found that the NWS data was representative of site conditions (Toblin 1985). Since the long-term record is from the NWS station and these data are representative of site conditions, the NWS data set was used for all SWP simulations, including model calibration and shutdown and accident simulations. The NWS wind speed and air temperature data were compared with site measurements for the period of September and October 1997. The average site wind speed during this period, 5.83 miles per hour (mph), was 1.15 mph greater than the average NWS wind speed. This is consistent with the relationship found previously for this parameter (Toblin 1985). Inspection of the NWS wind speed data for this period indicated a large number of calms (zero wind speed); 30.3 percent of the hourly data were calms. This compared with 13.4 percent for the years 1965 through 1995 and 19.7 percent for the period of 1996 through October 1997 (which includes the period in question). Both the local and national NWS offices confirmed that there was no reason or condition which would invalidate the data as supplied (Cartin 1998). The average NWS air temperature during this period, 68.29°F, was 0.74°F greater than that of the site. The NWS wind speed and air temperature data were used as the basis for all simulation periods.

4.3.3 Hydrological and Operational Parameters

The specification of hydrological parameters necessary to solve equations (7) and (8) include the dilution factor (D), depth of the surface layer (h), longitudinal and vertical diffusion coefficients (E_L and E_V), the fraction of the net solar radiation flux absorbed at the surface (β), and the extinction coefficient (η). In addition, previous studies have shown that the evaporative heat flux, as calculated by equations (3) and (4), is too large. A multiplicative constant, C, can be defined which results in a better approximation of the actual flux (Firstenberg and Fisher 1976; Toblin 1985).

The values of the hydrological parameters indicated above were chosen based on a combination of literature information, field testing, and a continuous record of SWP intake temperatures and corresponding heat loads during the field testing period.

The extinction coefficient, η, can be estimated as $1.7/s_d$ (Jirka et al. 1978), where s_d = Secchi disk depth. The disk depth was measured at 2 locations as 12.24 feet, resulting in an extinction coefficient of 0.14 feet^{-1}.

As an aid in studying the other hydrological parameters, a non-linear iterative least squares analysis was performed comparing model results at the location of interest (the intake from the SWP) with those measured during the field testing period. The model calibration period began on September 30, 1997, after the SWP was isolated from Monticello Reservoir. Under normal operating conditions and prior to that time the two water bodies were hydrologically connected, with the invert of their connection at 415 feet elevation. The discharge to the SWP prior to the shutdown on October 5, 1997 was taken as 21,467 gallons per minute (gpm) with a temperature rise of 1.77°F, corresponding to 1.90×10^7 BTU per hour (SCE&G 1998b).

Subsequent to the shutdown, the heat load and flow rate were distributed over time as provided by SCE&G (1998b). Figure 4-1 shows the temperature rise as a function of time during the calibration period. The flow rate during this period ranged from approximately 21,300 gpm to 23,600 gpm until hour 298; at that hour the flow decreased to 12,700 gpm with a corresponding increase in temperature rise (the heat load remaining constant just prior to and after the flow rate change). At hour 344, the flow rate increased to near its previous range.

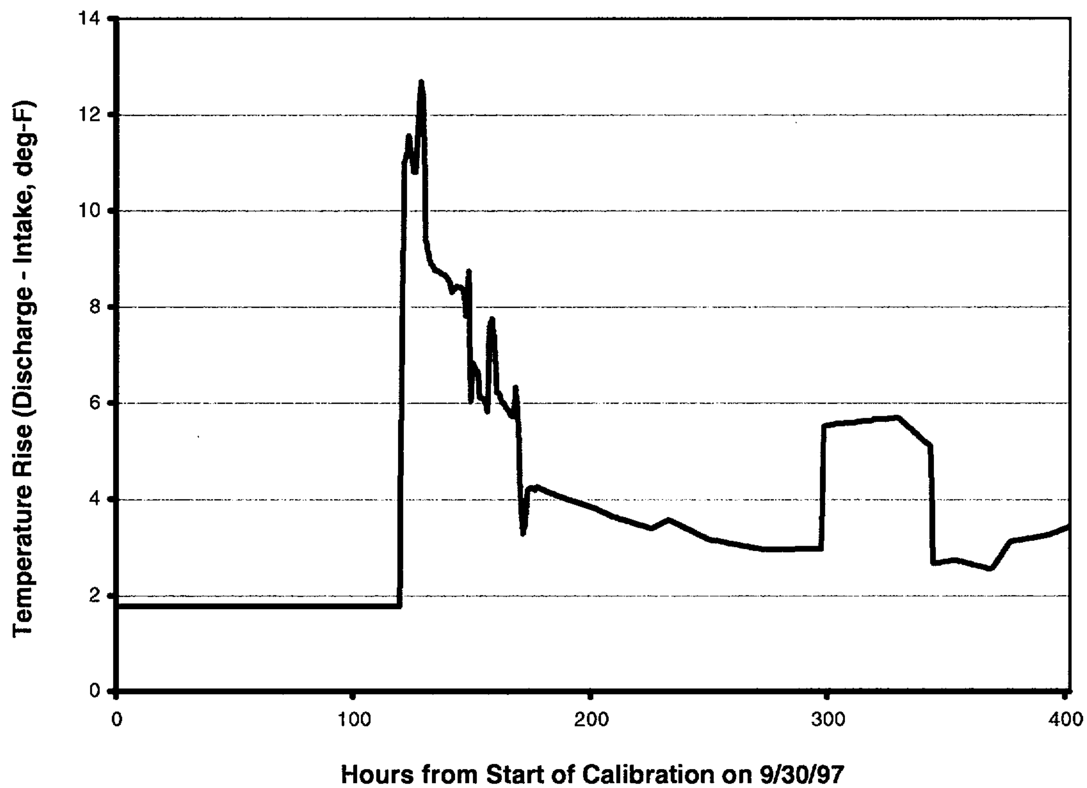

Figure 4-1. Temperature Rise of Water Discharged to SWP During Calibration Period.

The SWP simulation period for the calibration began on January 1, 1996 in order to assure damping of initial conditions (although only the results beginning on September 30, 1997 were used for the calibration); the simulation period ended on October 16, 1997. The calibration consisted of 402 hourly intake temperatures.

β is typically in the range of 0.4 to 0.5 (Jirka et al. 1978). The least squares analysis indicated that a value of 0.4 was appropriate. This was the same value found for Monticello Reservoir (Toblin 1985). Cooling ponds are generally designed for low Froude Number (tranquil) discharges because this aids the transfer of heat to the atmosphere. The dilution factor, D, is generally in the range of 1.5 to 2.0 for such discharges. For example, a value of 1.9 was found for Monticello Reservoir (Toblin 1985). A value of 1.5 for the SWP was indicated by the least squares analysis.

A theoretical analysis of the depth of the surface layer indicates that (Jirka et al. 1978):

$$h^4 = .01\ Q_0^2 D^3 L / (4\ \{\Delta\rho/\rho\} G w^2) \qquad (10)$$

where Q_0 = discharge flow rate, L = pond length (2,070 feet for 423.71 surface elevation), $\Delta\rho$ = density difference between intake and discharge water, G = acceleration due to gravity, and w = pond width (908 feet for 423.71 surface elevation). The value of h calculated for the previously indicated SWP parameters and a temperature rise (discharge minus intake) of 12.69°F, the maximum hourly temperature rise seen during refueling outage #10 (RF-10), is 0.92 foot. The value indicated by the regression analysis is 1.0 foot. The latter was used in the analysis.

The vertical diffusion coefficient, E_V, can range from 0.12 m^2/day (molecular diffusion) to 100 times that value, 12 m^2 per day (Ryan 1972). The least squares analysis for this study indicated a value of E_V = 0.26 m^2 per day. E_L, the longitudinal diffusion coefficient, is characterized by Fisher's equation (Fisher 1967):

$$E_L = 0.17\ f^{0.5}\ Uw^2/R_h \qquad (11)$$

where f = friction factor, U = velocity, and R_h = hydraulic radius. A value of f = 0 corresponds to a plug flow surface layer (no longitudinal mixing). A value of $f = 1.0 \times 10^{-5}$ was indicated by the least squares analysis. Values of E_V and f for Monticello Reservoir were 0.46 m^2 per day and 10^{-6}, respectively.

The value of C, the multiplicative factor used to modify the calculated evaporative heat flux, has been found to be less than one. The least squares analysis leads to a value of 0.84, which is close to the value of 0.78 found elsewhere (Firstenberg and Fisher 1976). The value found previously for Monticello Reservoir was 0.65 (Toblin 1985). The value of C may be related to the size of the water body; the smaller the pond, the more efficient the convective heat transport will be and, therefore, the higher the value of C. This trend is found in the three examples above.

4.3.4 Model Calibration Results

Figure 4-2 illustrates the comparison between the measured and modelled plant intake temperatures from the SWP for more than 1 year, concluding at the completion of the field tests. The long-term variations in measured data are slightly damped when compared with the modelled data. This is probably due to the hydrologic connection between the SWP and the much larger Monticello Reservoir; the latter would respond more slowly to meteorological changes than would the former, and this damping effect could be passed on to the SWP via the connection. Even so, the two sets of data show excellent qualitative agreement, tracking each other throughout the period. For the model calibration period (September 30, 1997 to October 16, 1997), the two sets of data are almost indistinguishable on the figure, with the standard deviation between them being 0.42°F, with a bias (average value of measured minus modelled temperature) of zero. The excellent comparison of the measured and modelled data for the period prior to calibration is a validation of the model with its chosen parameters.

There is a 1.00°F model bias (i.e., the average temperature by which the measured value exceeds the modelled value) for the 1+ years of data examined. Inspection of Figure 4-2 shows that this bias is a result of the measured data being greater than the model predictions during the colder months of the year. When the pond intake temperatures are at their highest, the conditions of interest in demonstrating compliance with thermal limits, the model tends to slightly overpredict the intake temperatures.

4.4 Pond Intake Temperature Response to LOCA and Normal Shutdown

In order to apply the previously described model to a hypothetical LOCA or normal shutdown, the conditions defining extant meteorological, physical (pond configuration), and operational (plant discharge to SWP) parameters must be defined. NRC (1976a) requires that a severe combination of conditions be chosen to demonstrate the pond's capability to dissipate heat during an accident.

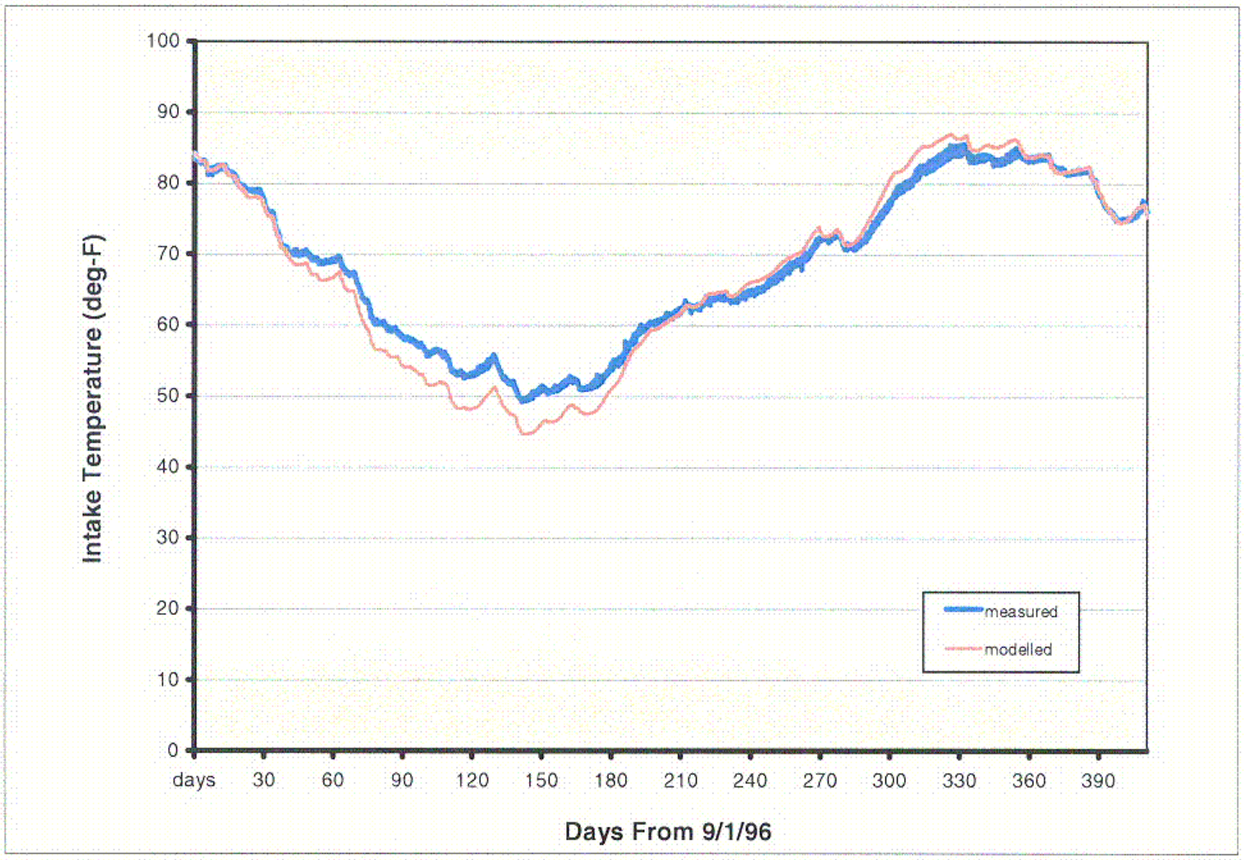

Figure 4-2. Measured and Modelled Intake Temperatures for the Period September 1, 1996 through October 16, 1997.

4.4.1 Meteorological Conditions

NRC requires a long-term record (at least 30 years) of meteorological conditions to define the worst case climatological measurements (NRC 1976a). The previously described (Section 4.3.2) NWS data were used for model calibration and verification; they were also used for simulation of the SWP response to the revised LOCA and normal shutdown as well.

A complete 32-year period of record, 1965 through 1996, was investigated in order to define the most restrictive (i.e., resulting in the maximum SWP intake temperature) meteorological conditions. The operational conditions existing prior to RF-10 were used in combination with the calibrated model to simulate the SWP temperatures for the entire 32-year period. The operational conditions were a pond elevation of 423.71 feet with a constant discharge flow rate of 21,467 gpm and a temperature rise of 1.77°F.

Rolling averages, over periods of 1 hour and 1 to 50 days, of intake temperatures from the SWP were calculated for the 32-year simulation period. Table 4-1 shows the year with the highest mean temperature (over the given averaging period) for each averaging period. The table also gives the second highest year (the year, excluding the highest year, with the highest mean temperature). NRC (1976a) states that three critical time periods should be considered: 1 day, 5 days (approximating intake temperature response time), and 30 days.

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Table 4-1. SWP Intake Temperatures Over Various Averaging Periods (page 1 of 2).

	Maximum Temperature Year			Second Highest Temperature Year		
Averaging Period (days)	Intake Temperature (average, deg-F)	End of Period (date)	End of Period (hour)	Intake Temperature (average, deg-F)	End of Period (date)	End of Period (hour)
1hour	87.92	8/26/68	5:00	87.59	7/31/93	2:00
1	87.92	8/27/68	3:00	87.57	7/31/93	18:00
2	87.88	8/27/68	4:00	87.53	8/1/93	3:00
3	87.79	8/27/68	6:00	87.47	7/22/69	23:00
4	87.68	8/27/68	11:00	87.42	7/23/69	2:00
5	87.56	8/27/68	16:00	87.38	7/23/69	3:00
6	87.44	8/27/68	18:00	87.33	7/23/69	4:00
7	87.31	8/27/68	21:00	87.29	7/23/69	8:00
8	87.25	8/1/93	22:00	87.25	7/23/69	18:00
9	87.24	8/1/93	23:00	87.22	7/23/69	21:00
10	87.22	8/2/93	0:00	87.17	7/24/69	0:00
11	87.20	8/2/93	0:00	87.15	8/3/95	3:00
12	87.19	8/2/93	1:00	87.15	8/4/86	13:00
13	87.17	8/2/93	2:00	87.15	8/4/86	21:00
14	87.14	8/2/93	4:00	87.14	8/5/86	3:00
15	87.11	8/5/86	16:00	87.11	8/2/93	9:00
16	87.09	8/6/86	14:00	87.08	8/2/93	19:00
17	87.06	8/7/86	9:00	87.05	8/2/93	23:00
18	87.04	8/8/86	5:00	87.02	8/3/93	0:00
19	87.01	8/9/86	3:00	86.99	8/3/93	3:00
20	86.99	8/10/86	4:00	86.96	8/3/93	8:00
21	86.97	8/11/86	0:00	86.92	8/4/93	0:00
22	86.95	8/12/86	1:00	86.88	8/4/93	5:00
23	86.93	8/12/86	21:00	86.84	8/4/93	19:00
24	86.90	8/13/86	2:00	86.79	8/5/93	1:00
25	86.87	8/13/86	12:00	86.74	8/5/93	10:00
26	86.84	8/13/86	21:00	86.68	8/6/93	8:00
27	86.81	8/13/86	23:00	86.63	8/6/93	22:00
28	86.77	8/14/86	1:00	86.57	8/7/93	3:00
29	86.73	8/14/86	4:00	86.51	8/7/93	17:00
30	86.70	8/14/86	14:00	86.45	8/4/69	4:00
31	86.66	8/14/86	20:00	86.40	8/4/69	13:00
32	86.62	8/15/86	1:00	86.35	8/4/69	19:00
33	86.57	8/15/86	7:00	86.30	8/5/69	0:00
34	86.52	8/16/86	4:00	86.24	8/5/69	5:00
35	86.48	8/17/86	6:00	86.18	8/6/69	2:00
36	86.44	8/18/86	18:00	86.17	8/25/95	2:00
37	86.41	8/19/86	22:00	86.17	8/25/95	8:00
38	86.37	8/20/86	3:00	86.17	8/25/95	21:00

Table 4-1. SWP Intake Temperatures Over Various Averaging Periods (page 2 of 2).

	Maximum Temperature Year			Second Highest Temperature Year		
Averaging Period (days)	Intake Temperature (average, deg-F)	End of Period (date)	End of Period (hour)	Intake Temperature (average, deg-F)	End of Period (date)	End of Period (hour)
39	86.33	8/20/86	13:00	86.17	8/26/95	2:00
40	86.29	8/21/86	0:00	86.16	8/26/95	7:00
41	86.24	8/21/86	10:00	86.15	8/26/95	17:00
42	86.20	8/22/86	4:00	86.13	8/26/95	21:00
43	86.15	8/23/86	1:00	86.11	8/27/95	4:00
44	86.12	8/24/86	4:00	86.09	8/27/95	23:00
45	86.08	8/25/86	17:00	86.07	8/28/95	6:00
46	86.04	8/27/86	1:00	86.04	8/28/95	19:00
47	86.01	8/28/86	8:00	86.01	8/29/95	1:00
48	85.99	8/28/86	19:00	85.97	8/29/95	5:00
49	85.95	8/28/86	21:00	85.94	8/30/95	2:00
50	85.92	8/29/86	0:00	85.90	8/31/95	6:00

Consideration of the meteorological conditions from the time periods July to August 1968, 1986, and 1993 will assure that the most restrictive intake temperature for any of the averaging periods from 1 hour to 50 days will be simulated.

4.4.2 Physical Parameters

The most restrictive pond physical state during an accident would be the loss of Monticello Reservoir resulting in an elevation in the SWP of 415 feet (the invert of the connection between the SWP and Monticello Reservoir). In addition, a loss of 0.25 foot of surface elevation over the accident period is expected from seepage through the pond (SCE&G 1998b). The SWP surface area and length at elevation 415 feet is 1.60×10^6 feet^2 and 788 feet, respectively. After the seepage loss, the surface area and length would be 1.59×10^6 feet^2 and 785 feet, respectively.

The worst case meteorological conditions, described in the previous subsection, were reanalyzed with this restrictive pond geometry. The same periods during 1968, 1986, and 1993 (July through August) were still responsible for the worst case meteorological conditions.

4.4.3 Operational Parameters

SCE&G (1998b) describes the temporal distribution of flow rate and heat load to the SWP in the event of either a LOCA or a normal shutdown. In order to impose the most severe thermal conditions on the SWP, the heat load on the pond was maximized by assuming that the VCSNS was operating at a constant power level of 102 percent (of its current rated thermal power level of 2,900 MWt) prior to the postulated incident (LOCA or normal shutdown). The model simulations were begun in January of the year preceding the worst case meteorology to assure damping of initial conditions. The flow rate and temperature rise from the beginning of model simulation until incident initiation were taken as 24,000 gpm and 4.78°F (corresponding to 57.35×10^6 BTU per hour), respectively.

The temperature rise preceding and following both the LOCA and the normal shutdown is shown in Figure 4-3. The flow rate during the LOCA is 32,000 gpm; the flow rate during the normal shutdown is 26,000 gpm. The heat rejected to the SWP during these two events is shown in Figure 4-4. Although the peak heat rate rejected during the LOCA is greater than that during the shutdown, the total heat rejected from the two is nearly equal.

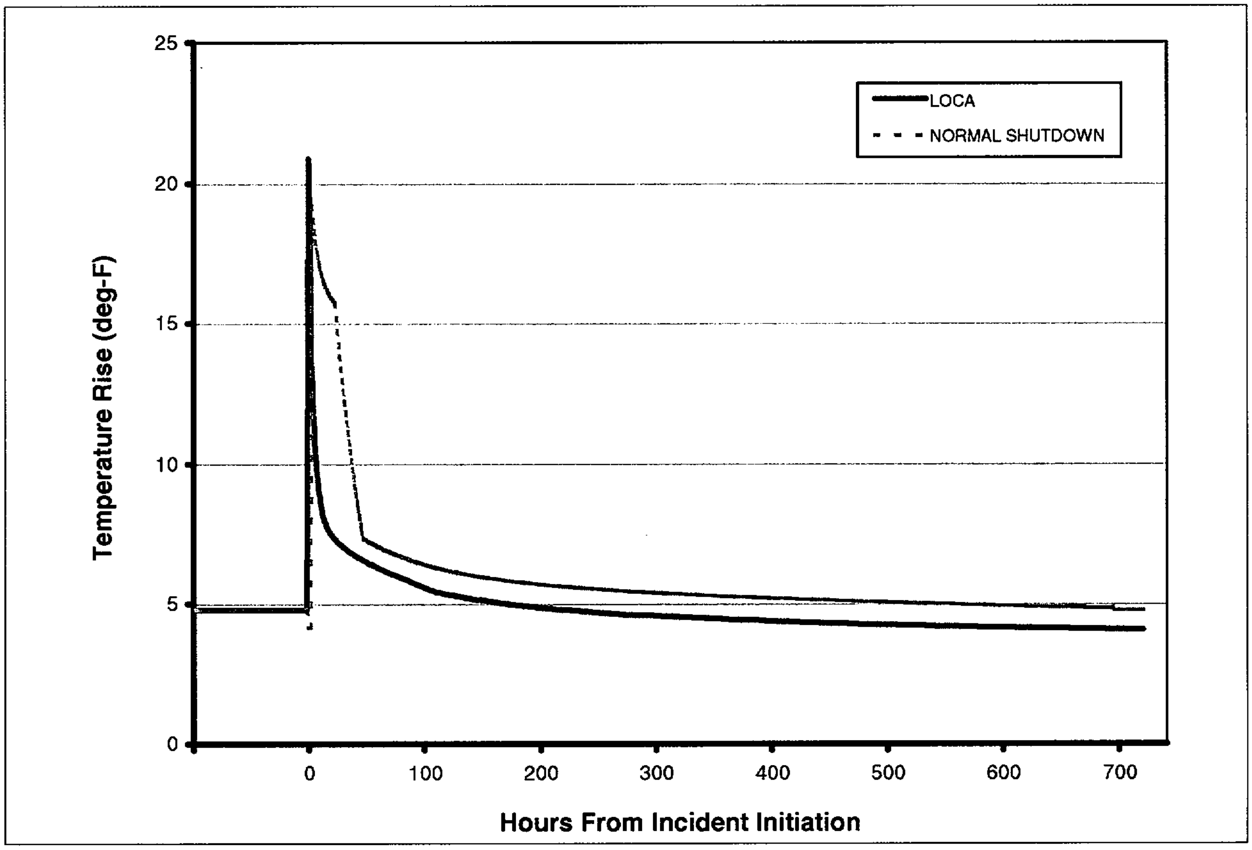

Figure 4-3. Temperature Rise (Discharge – Intake) During Simulated Incident.

VCSNS has the capacity for changing the flow rate, using either or both of two pumping systems. An example of the use of only one system is illustrated in Figure 4-1, where only one system was operating between hours 298 and 344 (from start of calibration); the decrease of nearly 50 percent of flow resulted in an almost doubling of the temperature rise. It is expected that two-system operation would be more restrictive on the SWP (for a given heat load). The rate of cooling decreases as the water temperature approaches the equilibrium temperature so that lower temperatures result in less surface cooling (for the same heat load). This was verified by simulating the SWP response to the pre-incident conditions described above (surface elevation = 415 feet, heat load = 57.35×10^6 BTU/hr) for one and two pumping system operation (flow rate = 12,000 or 24,000 gpm). The maximum intake temperature was found to be 93.24°F and 93.48°F, respectively. Therefore, the more restrictive two-system flow was used in all subsequent simulations.

Although the three most restrictive periods of meteorological data (July through August, 1968, 1986, and 1993) were determined prior to incident simulations, the worst case incident initiation time within these periods was not. The most restrictive initiation time was determined iteratively for each postulated incident (LOCA and normal shutdown). Simulations were performed for various incident initiation times within

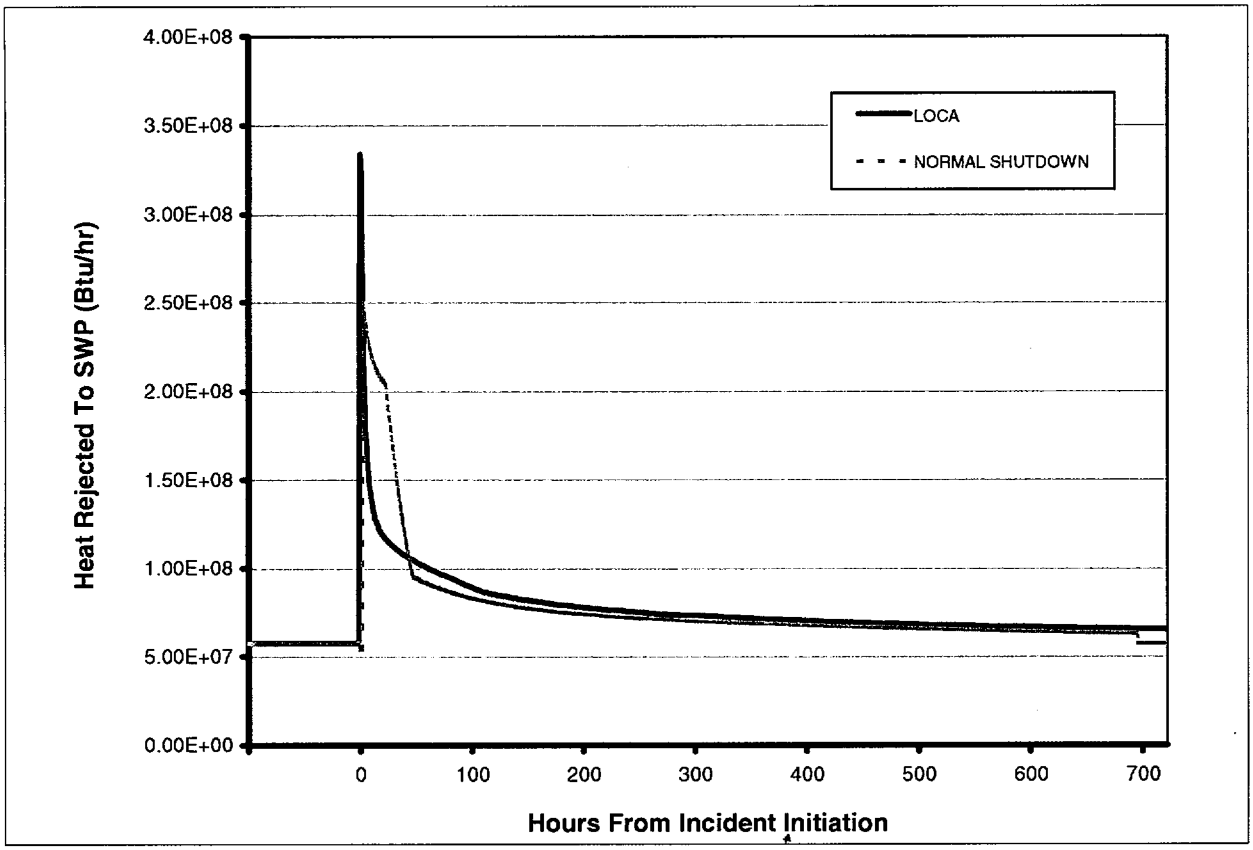

Figure 4-4. Heat Rejected to SWP During Simulated Incident.

each of the periods for the restrictive conditions described previously (102 percent power preceding the incident, surface elevation = 415 feet, two pumping system operation) until the time resulting in the maximum intake temperature from the SWP was found. That time was then used for subsequent simulations.

4.4.4 LOCA Intake Temperatures

The SWP thermal distribution during a LOCA was simulated using the worst case combination of meteorology, physical parameters, and operational parameters; the hypothetical LOCA was initiated on August 15, 1968 at 18:00. SWP surface elevations were kept constant (unless otherwise noted) throughout each simulation. Table 4-2 shows the maximum intake temperature during the LOCA for surface elevations of 414.75 (worst-case elevation minus 0.25 feet of seepage), 415 (worst-case elevation), and 417.5 (equilibrium SWP level with Monticello Reservoir at its emergency drawdown limit) feet. The table also indicates the intake temperature at the start of the LOCA. One simulation was performed with the SWP at 417.5-foot elevation prior to the LOCA with an instantaneous drop to 414.75 feet at the beginning of the LOCA (denoted elevation = 417.5 > 414.75).

Figure 4-5 illustrates the temporal distribution of intake temperatures during the LOCA at elevation 415 feet. The temperature is seen to peak approximately 10 days after initiation of the LOCA. This duration is a function of both the SWP intake temperature response time (4.3 days; as discussed in Section 4.5.1) and the variations in meteorology during this period.

Table 4-2. Maximum SWP Intake Temperatures During LOCA.

SWP Surface Elevation (feet)	Maximum Intake Temperature (°F)	Intake Temperature at LOCA Initiation (°F)
414.75	95.12	90.92
415	95.06	90.88
417.5	94.44	90.49
417.5 > 414.75	94.94	90.49

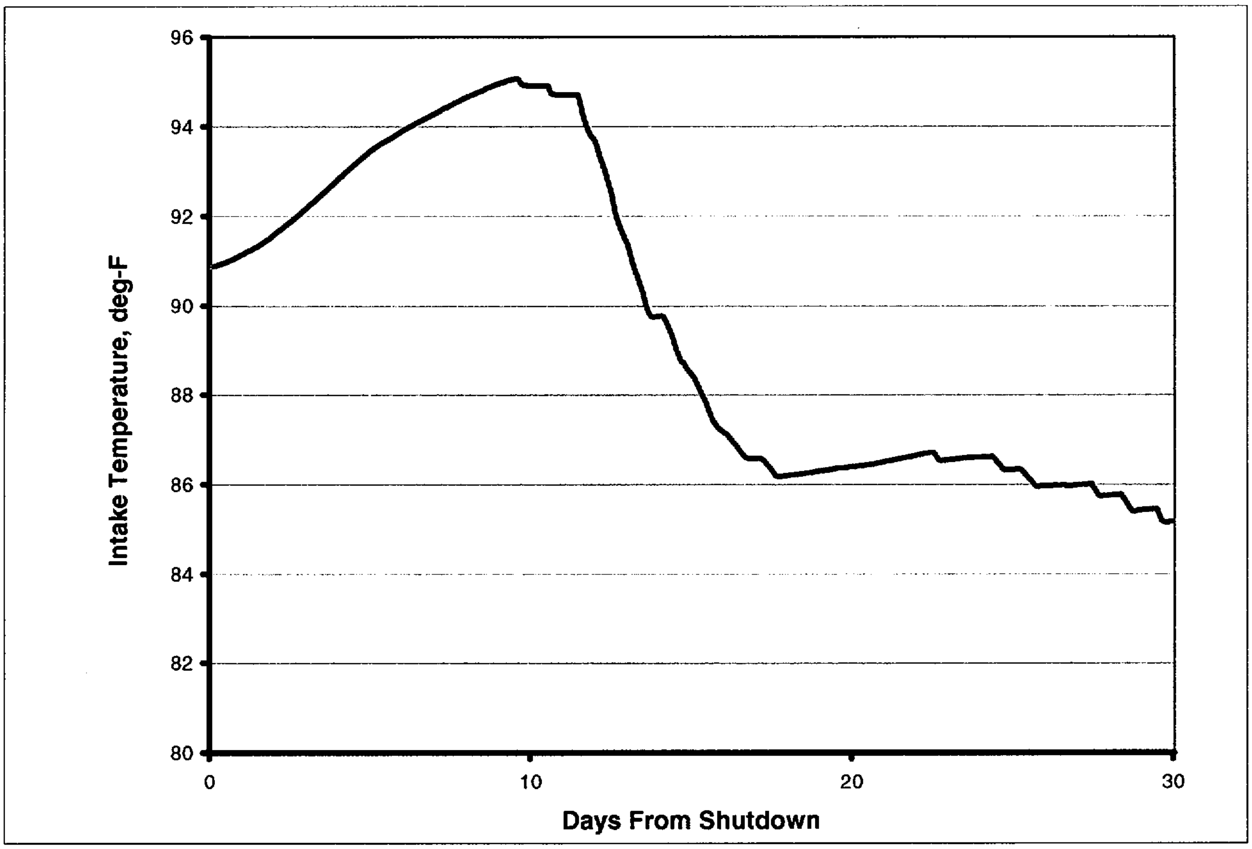

Figure 4-5. SWP Intake Temperature During LOCA.

4.4.5 Normal Shutdown Intake Temperatures

The SWP thermal distribution during a normal shutdown was simulated using the worst-case combination of meteorology, physical parameters, and operational parameters; the hypothetical shutdown was initiated on August 15, 1968 at 15:00. SWP surface elevations were kept constant (unless otherwise noted) throughout each simulation. Table 4-3 shows the maximum intake temperature during the shutdown for surface elevations of 414.75 (worst-case elevation minus 0.25 feet of seepage), 415 (worst-case elevation), and 417.5 (equilibrium SWP level with Monticello Reservoir at its emergency drawdown limit) feet. The table also indicates the intake temperature at the start of the shutdown. One simulation was performed with the SWP at 417.5 foot elevation prior to the shutdown with an instantaneous drop to 414.75 feet at the beginning of the shutdown (denoted elevation = 417.5 > 414.75).

Table 4-3. Maximum SWP Intake Temperatures During Normal Shutdown.

SWP Surface Elevation (feet)	Maximum Intake Temperature (°F)	Intake Temperature at Shutdown Initiation (°F)
414.75	95.04	90.90
415	94.97	90.86
417.5	94.33	90.48
417.5 > 414.75	94.84	90.48

The intake temperatures are nearly the same as those for the LOCA, reflecting the similarity in heat rejection rates of the two events as well as the importance of the meteorology (both events assumed to occur during the same meteorological conditions). Figure 4-5 would also be representative of the time distribution of the intake temperatures during a normal shutdown.

4.4.6 <u>Effect of Physical and Operational Parameter Changes on Maximum Intake Temperature</u>

Although the maximum intake temperature for each year of the 32-year meteorological data base was not calculated, Table 4-1, presented previously, gives the intake temperature for the years with the highest and second highest mean temperatures. It is seen that going from the second highest year to the highest, with pre-RF-10 conditions (423.71 feet elevation, 21,467 gpm discharge flow, and 19.0×10^6 BTU per hour heat rejection rate) results in an increase in maximum intake temperature of 0.33°F, from 87.59°F to 87.92°F.

Table 4-4 shows the stepwise maximum intake temperatures in going from pre-RF-10 conditions to those during the postulated LOCA. It is interesting to note that of all of the steps (from normal surface elevation to 415 feet, from 1997 operations to maximum design service water system conditions for normal operation, and from maximum design service water system conditions to a LOCA from 102 percent power), the addition of the heat rejected from the LOCA to the SWP is the least important.

Table 4-4. Maximum SWP Intake Temperature (Pre-RF-10 to LOCA Conditions).

Surface Elevation (feet)	Discharge Conditions	Maximum Intake Temperature (°F)	Notes
423.71	1997 Operations	87.92	21,467 gpm, $19.0\text{x}10^6$ BTU per hour
415	1997 Operations	90.15	21,467 gpm, $19.0\text{x}10^6$ BTU per hour
415	Normal Operation – Max Design	93.48	24,000 gpm, $57.35\text{x}10^6$ BTU per hour
415	LOCA	95.06	102 percent power preceding LOCA

4.4.7 <u>VCSNS Operation Strategies to Meet Intake Temperature Design Limit</u>

As noted previously in Section 4.1, the Service Water System is designed based on a maximum intake water temperature of 95°F. As indicated in Sections 4.4.4 and 4.4.5, this design limit may be slightly exceeded during a hypothetical LOCA or shutdown occurring during severe meteorological conditions. Therefore, plant operation strategies were investigated which would assure maintaining the design limit, even during worst case meteorology.

Given a hypothetical LOCA under worst-case meteorological conditions, two factors -- the heat load discharged to the pond and the pond surface elevation (level) prior to the LOCA -- would determine the intake temperature. Figure 4-6 depicts the maximum intake temperature at various pond elevations for a heat load on the SWP of 57.35×10^6 BTU/hr. The pond surface elevation is assumed to instantaneously drop to 414.75 feet, 0.25 feet below the invert of the pipe which connects the SWP and Monticello Reservoir, at the LOCA initiation. It is seen that the pond would always meet the 95°F design limit for pre-LOCA surface elevations of at least 416.4 feet. At elevations less than this, the design limit would still be met if the pre-LOCA heat load were reduced. At 414.75 feet pre-LOCA surface elevation, the heat load would be limited to 54.2×10^6 BTU/hr. with a corresponding intake temperature at LOCA initiation of 90.67°F. At 415.65 feet pre-LOCA surface elevation, the heat load would be limited to 55.58×10^6 BTU/hr. with corresponding intake temperature at LOCA initiation of 90.65°F Accordingly, if the plant were operated such that either the intake temperature was less than 90.65°F or the surface elevation was at least 416.4 feet, then the maximum intake temperatures would not exceed 95°F even for a LOCA during worst-case meteorological conditions.

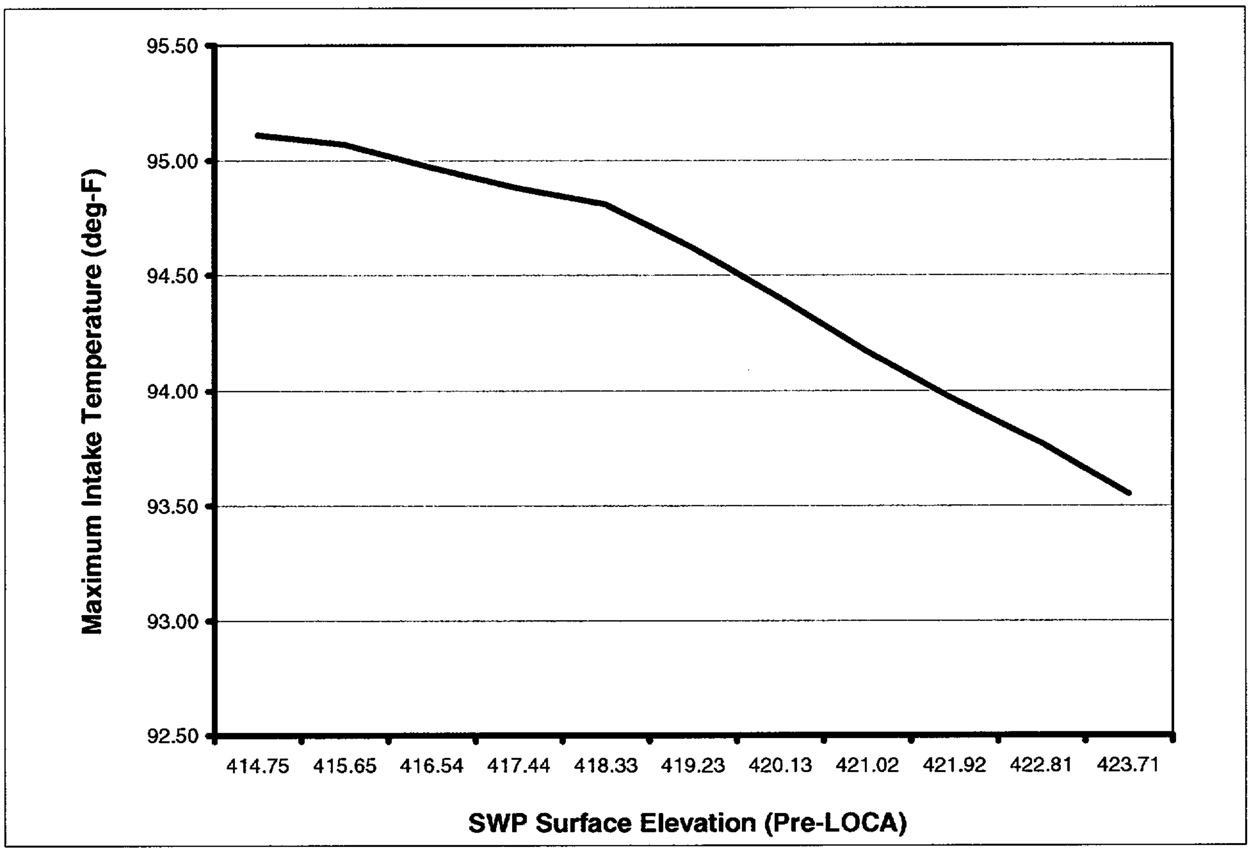

Figure 4-6. Maximum Intake Temperature during a LOCA as a Function of Pre-LOCA SWP Elevation.

4.5 Other Pond Responses

Although the maximum intake temperature is the important design parameter that assures safe plant operation, the SWP's intake temperature response time, vertical temperature distribution, and evaporation during the hypothetical LOCA were also investigated.

4.5.1 Intake Temperature Response Time

The SWP's thermal response to a pulse release of heat was investigated. Constant meteorological conditions and pre-RF-10 discharge conditions were simulated. The time to peak intake temperature (response time) was found to be 4.3 days for a worst-case surface elevation of 415 feet and 7.6 days for a normal surface elevation of 423.71 feet.

4.5.2 Vertical Temperature Distribution

The previous study of Monticello Reservoir (Toblin 1985) showed that the reservoir stratifies during the summer. Figure 4-7, which shows the vertical temperature distribution at the beginning of the postulated LOCA and at the time of maximum intake temperature, illustrates that the SWP stratifies as well. The warming of the pond during the LOCA (due to both the heat rejected and the assumed meteorology) is clearly indicated; it is also seen that the advection engendered by the surface discharge and subsurface withdrawal results in a relatively constant temperature from the surface to the intake level. A more rapid temperature decrease in the pond is seen below the intake, where heat transport relies more on diffusion than advection.

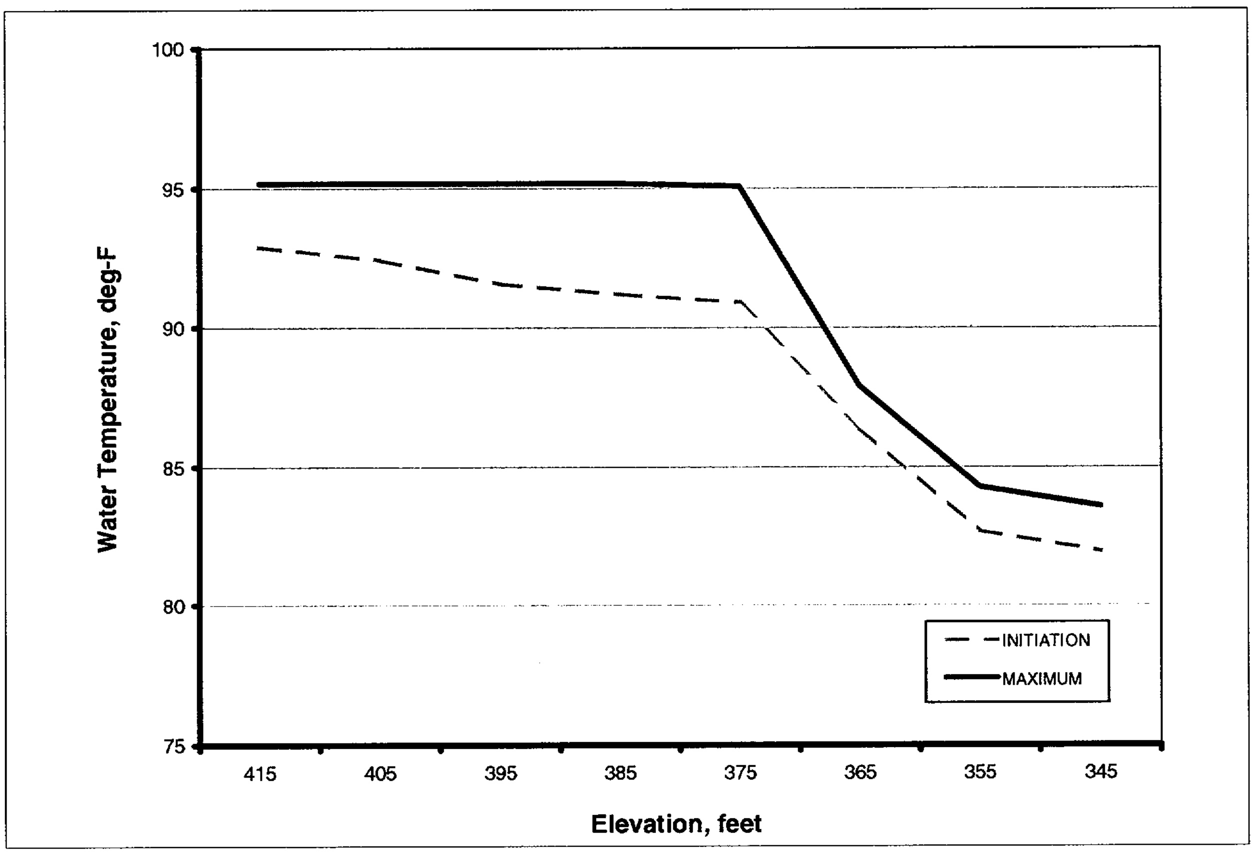

Figure 4-7. Vertical Temperature Distribution in the SWP During the LOCA.

4.5.3 Volume Evaporated

The volume evaporated from the surface of the pond during the 30-day period following the postulated LOCA initiation was determined to be 1.56×10^6 feet^3. For the 10-day period following the accident initiation, the volume evaporated was 4.96×10^5 feet^3.

4.6 Summary and Conclusions

A model of the Service Water Pond at V. C Summer Nuclear Station was constructed for the purpose of simulating intake temperatures from the pond under conditions of varying meteorology and heat input. The model was calibrated based on data obtained during Refueling Outage #10 (RF-10). The model was verified using measured intake temperatures from the more than one year prior to RF-10; the model showed excellent agreement with measured intake temperatures.

A worst-case combination of meteorology (based on 32 years of sequential data), pond physical parameters and operating conditions was defined. The temporal distribution of the intake temperature from the SWP was simulated for these conditions during a hypothetical LOCA. A maximum intake temperature of 95.12°F was determined; this is slightly greater than the design limit of 95°F. Pond intake temperature of less than 90.65°F or surface elevation greater than 416.4 feet would ensure meeting the design limit during a LOCA, even under worst-case conditions.

References

Bird, R. B., W. E. Stewart, and E. N. Lightfoot, 1966, *Transport Phenomena*, Section 14, John Wiley and Sons, Inc.

Cartin, L. R., 1998, *SW Pond Analysis – NWS Data*, Engineers Technical Work Record, Tab-412, South Carolina Electric and Gas Company, November.

Firstenberg, H. and G. Fisher, 1976, *An Investigation of Cooling Lakes for the Closed-Cycle Operation of Electric Generating Stations*, Volume I, NUS Corporation.

Fisher, H. B., 1967, *The Mechanics of Dispersion in Natural Streams* in Journal of the Hydraulics Division, ASCE, Volume 93.

Jirka, G. H., M. Watanabe, K. H. Octavio, C. F. Cerco, and D. R. F. Harleman, 1978, *Mathematical Predictive Models for Cooling Ponds and Lakes*, Report No. 238, R. M. Parsons Laboratory for Water Resources and Hydrodynamics, M.I.T., December.

NCDC (National Climatic Data Center), 1993, *Local Climatological Data*, NOAA National Climatic Data Center, Asheville, North Carolina.

NRC (U.S. Nuclear Regulatory Commission), 1976a, *Ultimate Heat Sink for Nuclear Power Plants*, Regulatory Guide 1.27, Revision 2, January.

NRC (U.S. Nuclear Regulatory Commission), 1976b, *Calculation of Annual Doses to Man from Routine Releases of Reactor Effluents for the Purpose of Evaluating Compliance with 10 CFR Part 50, Appendix I*, Regulatory Guide 1.09, Revision 0.

Ryan, P. J. and K. D. Stolzenbach, 1972, *Environmental Heat Transfer*, in Engineering Aspects of Heat Disposal from Power Generation, Section 1, R. M. Parsons Laboratory for Water Resources and Hydrodynamics, M.I.T., June.

Ryan, P. J., 1972, *Temperature Distributions in Lakes and Reservoirs*, in Engineering Aspects of Heat Disposal from Power Generation, Section 2, R. M. Parsons Laboratory for Water Resources and Hydrodynamics, M.I.T., June.

SCDHEC (South Carolina Department of Health and Environmental Control), 1984, *Permit Number SC0030856, Authorization to Discharge Under The National Pollutant Discharge Elimination System*, for V. C. Summer Nuclear Station Unit No. 1.

SCE&G (South Carolina Electric & Gas Company), 1998a, *Virgil C. Summer Final Safety Analysis Report (FSAR)*, Amendment 98-01.

SCE&G (South Carolina Electric & Gas Company), 1998b, *Analysis Inputs for SW Pond Reanalysis*, Design Calculation DC02230-007, Revision 0, February.

Thackston, E. L. and F. L. Parker, 1971, *Effect of Geographical Location on Cooling Pond Requirements and Performance*, 16130FDQ, Water Pollution Control Research Series, Water Quality Office, Environmental Protection Agency, March.

Toblin, A., 1985, *V. C. Summer Station Environmental Program, Computer Mathematical Model Study*, NUS-4687, NUS Corporation, March.

APPENDIX A

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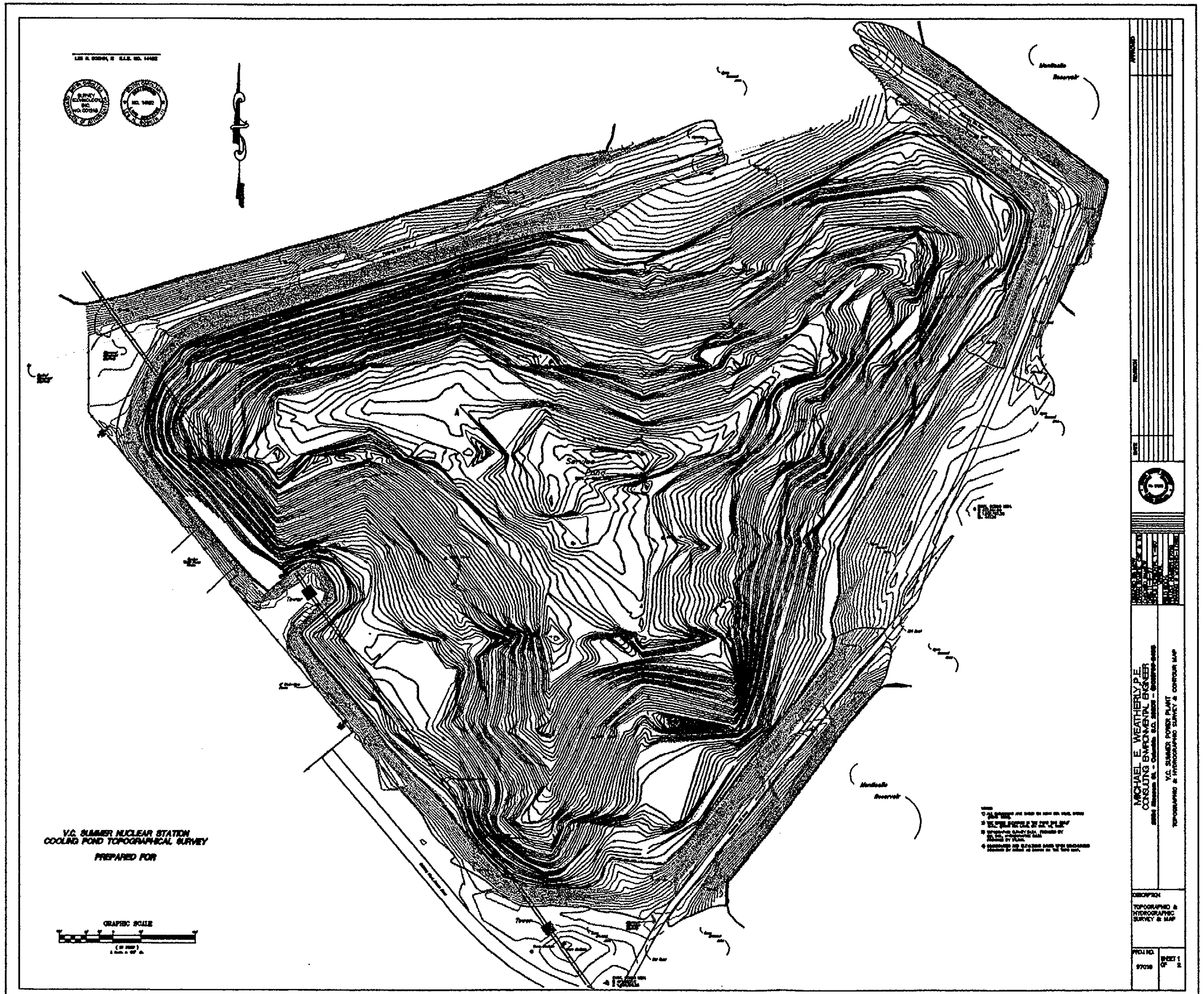

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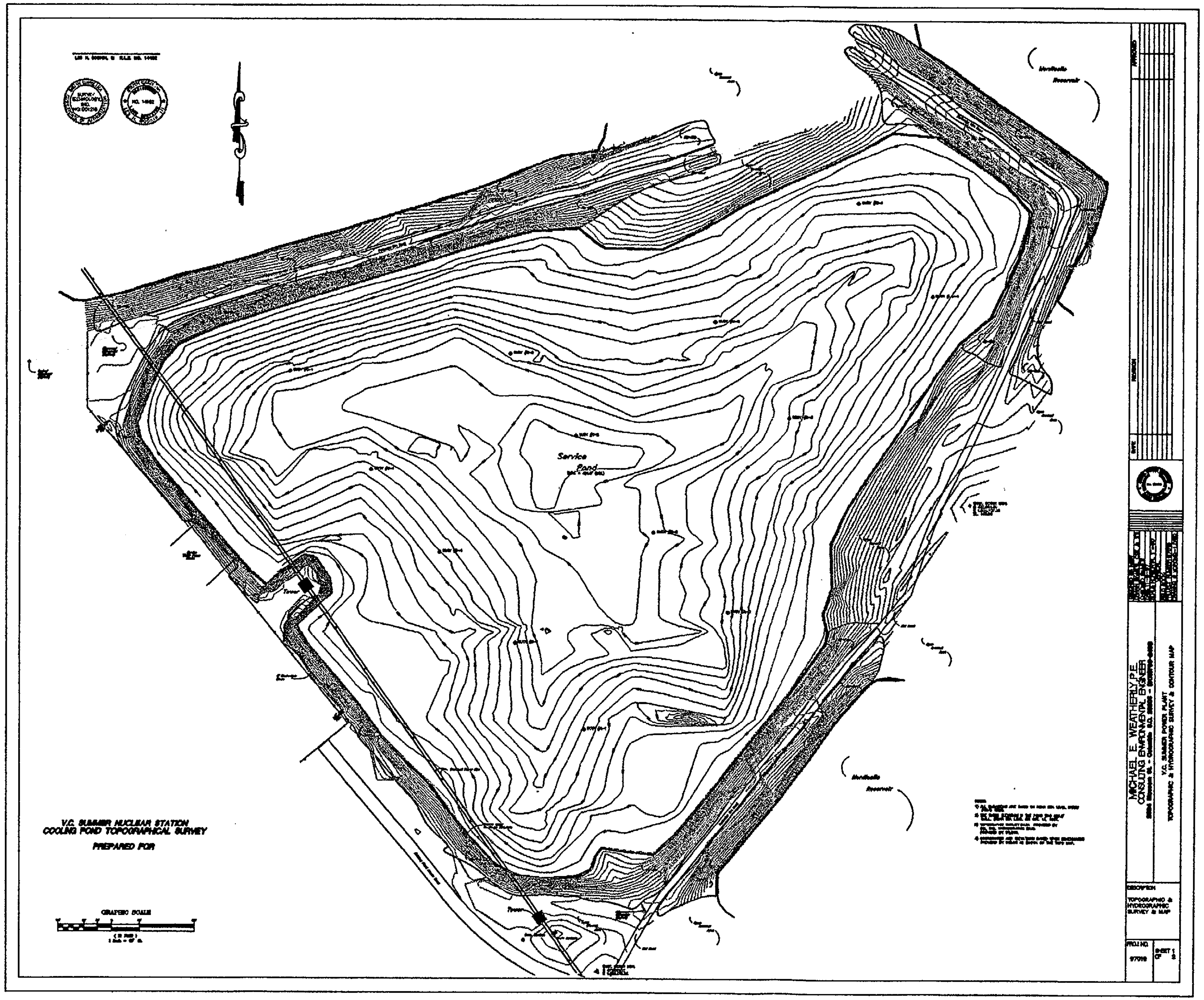

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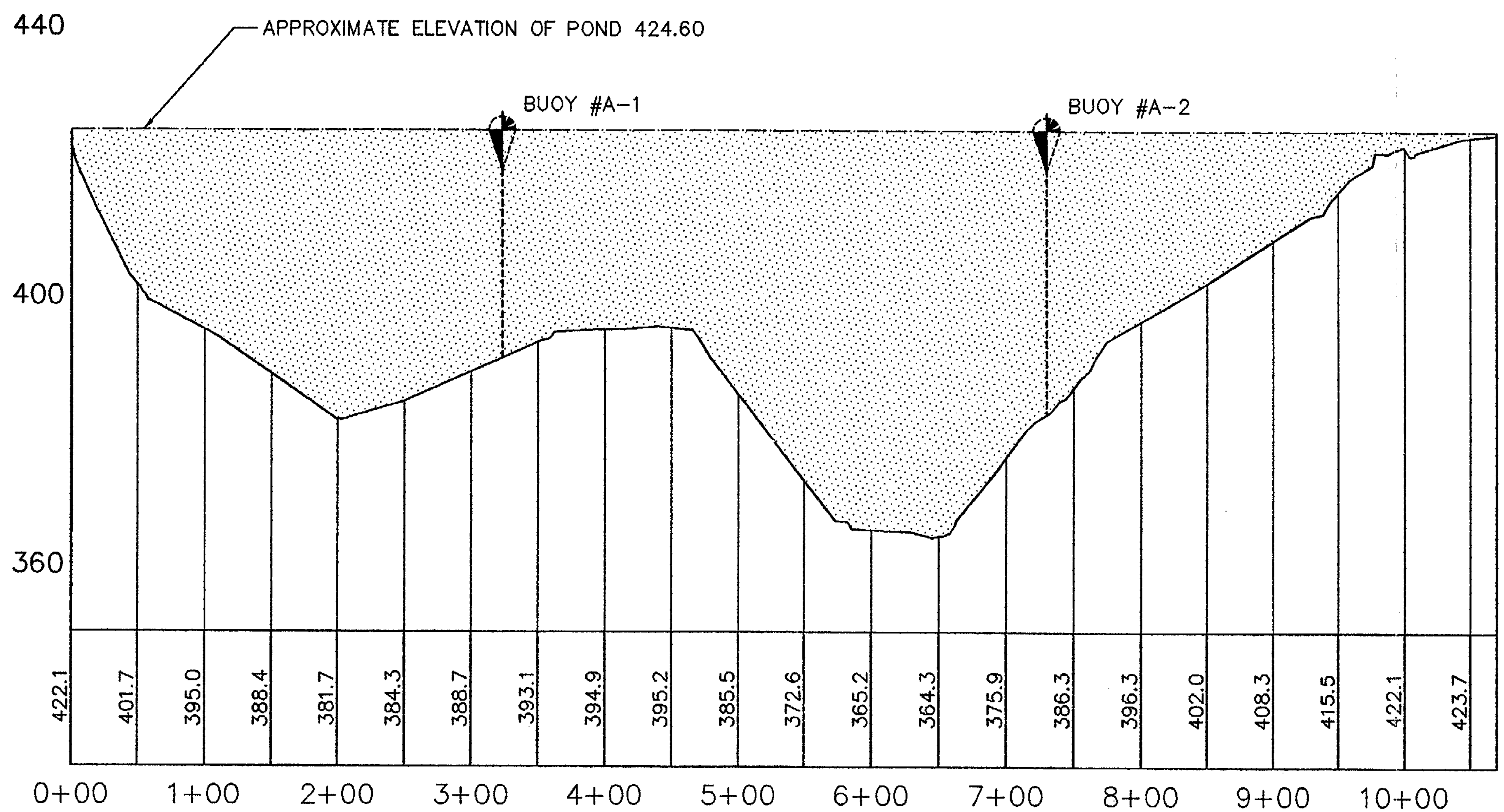

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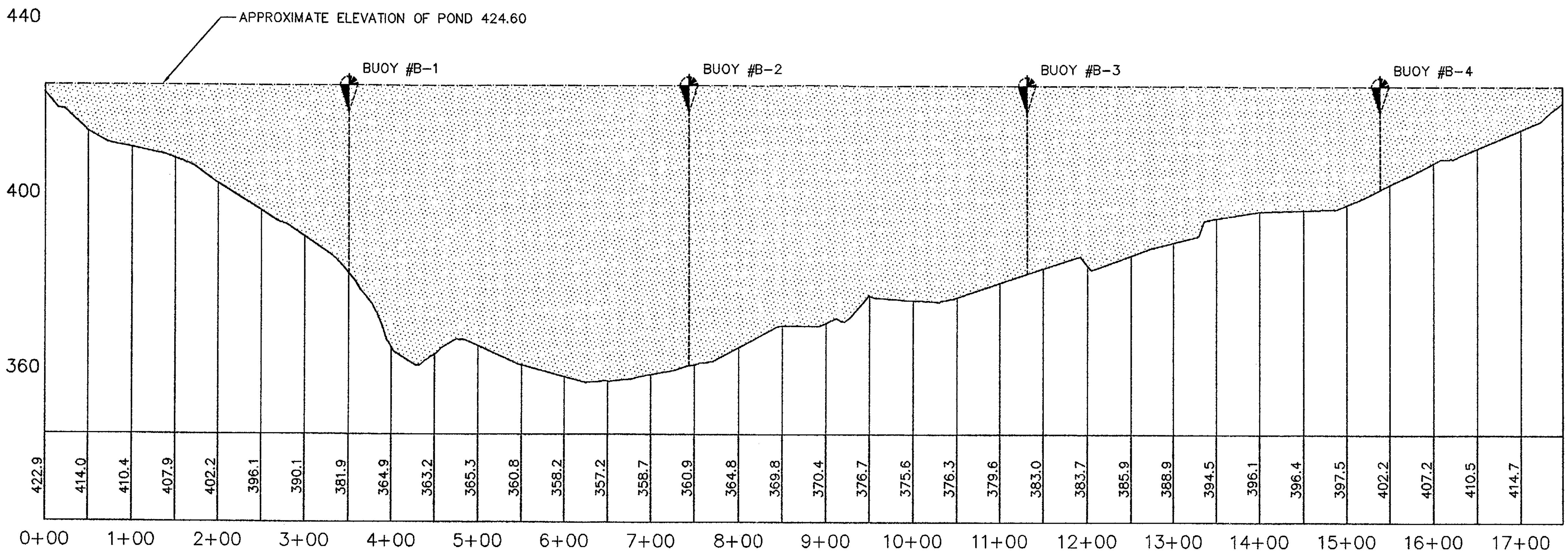

BUOY CENTERLINE 'B'

TETRA TECH NUS, INC.
AIKEN, SOUTH CAROLINA

V.C. SUMMER NUCLEAR STATION
SERVICE WATER POND
CROSS-SECTIONAL VIEW
OCTOBER 1998

CONTRACT NO. PX90
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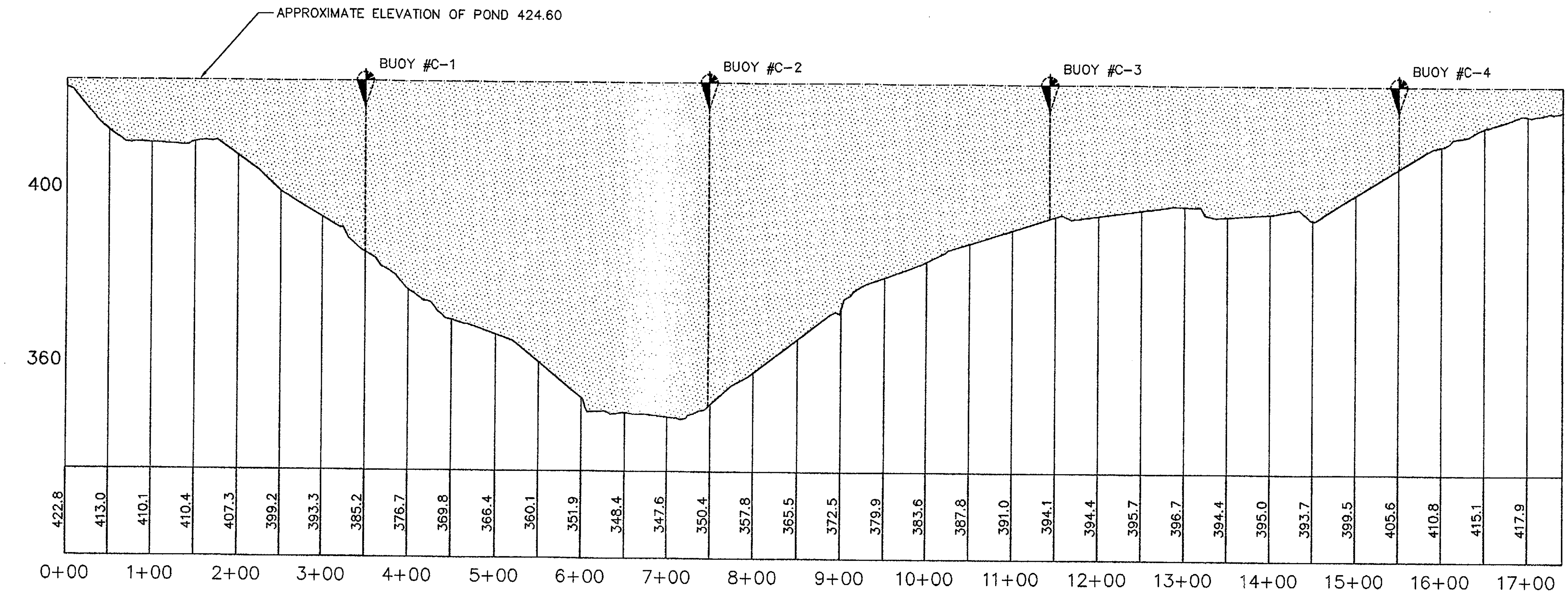

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TETRA TECH NUS, INC.
AIKEN, SOUTH CAROLINA

V.C. SUMMER NUCLEAR STATION
SERVICE WATER POND
CROSS-SECTIONAL VIEW

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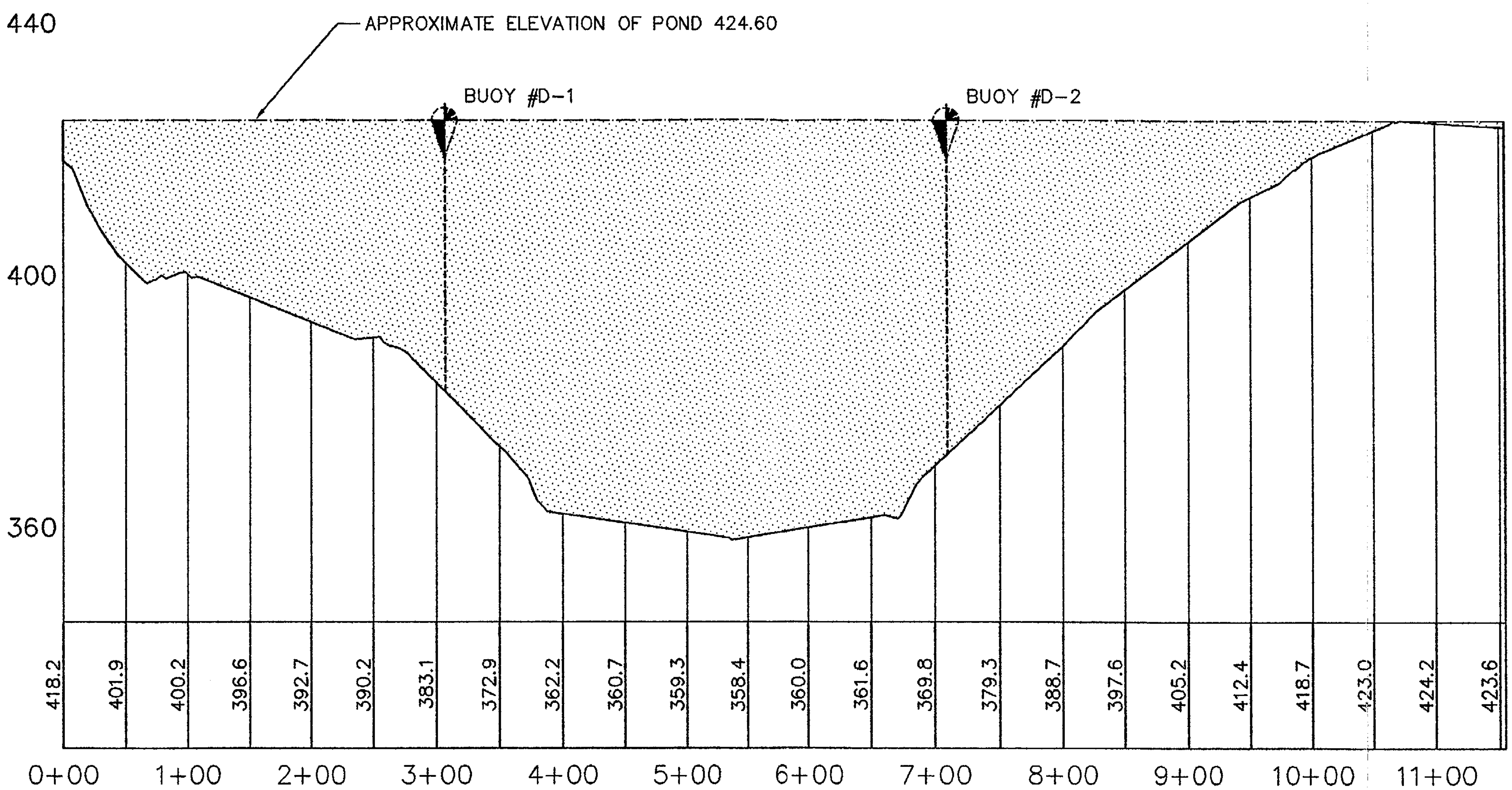

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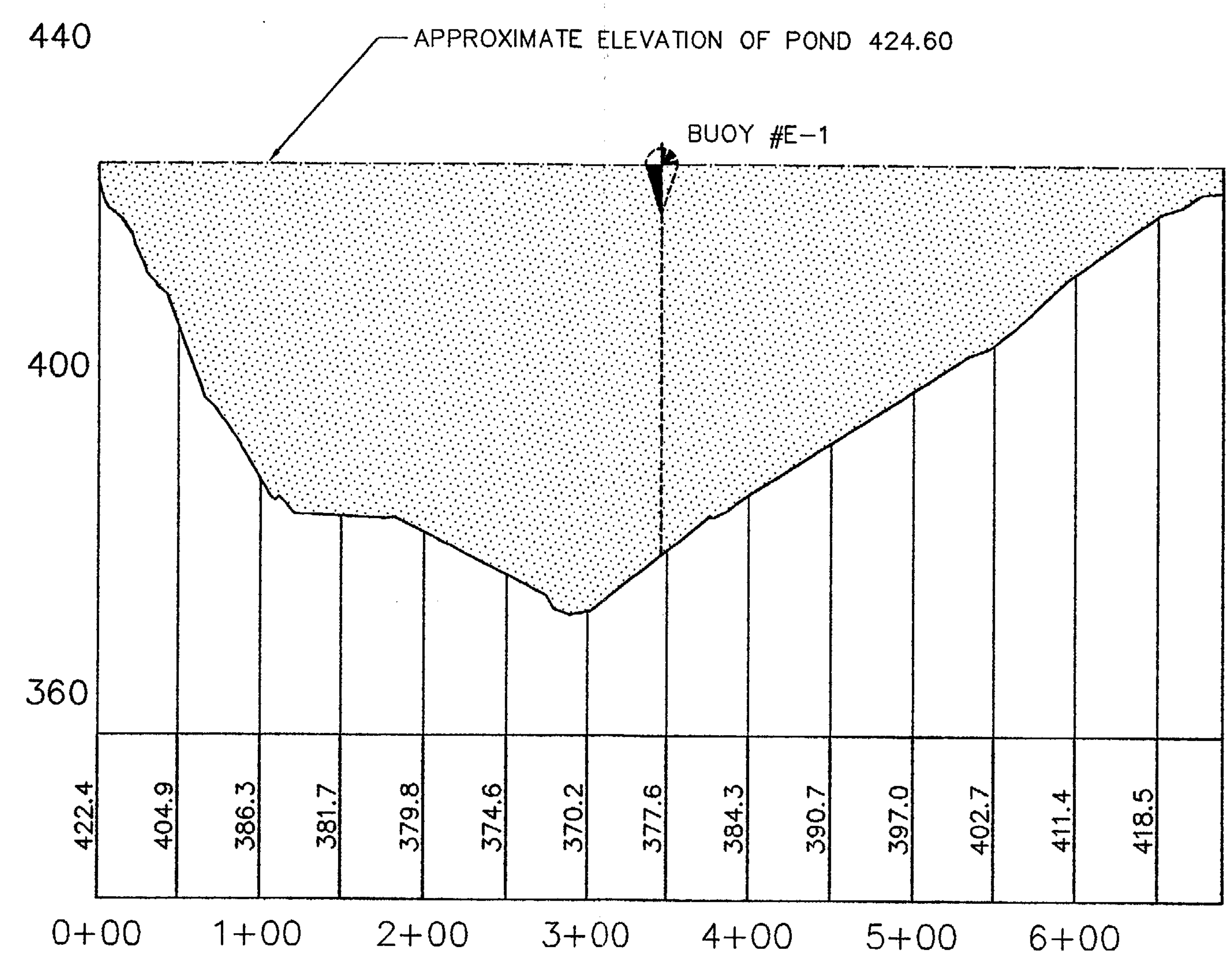

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SERVICE WATER POND
CROSS-SECTIONAL VIEW

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APPENDIX B

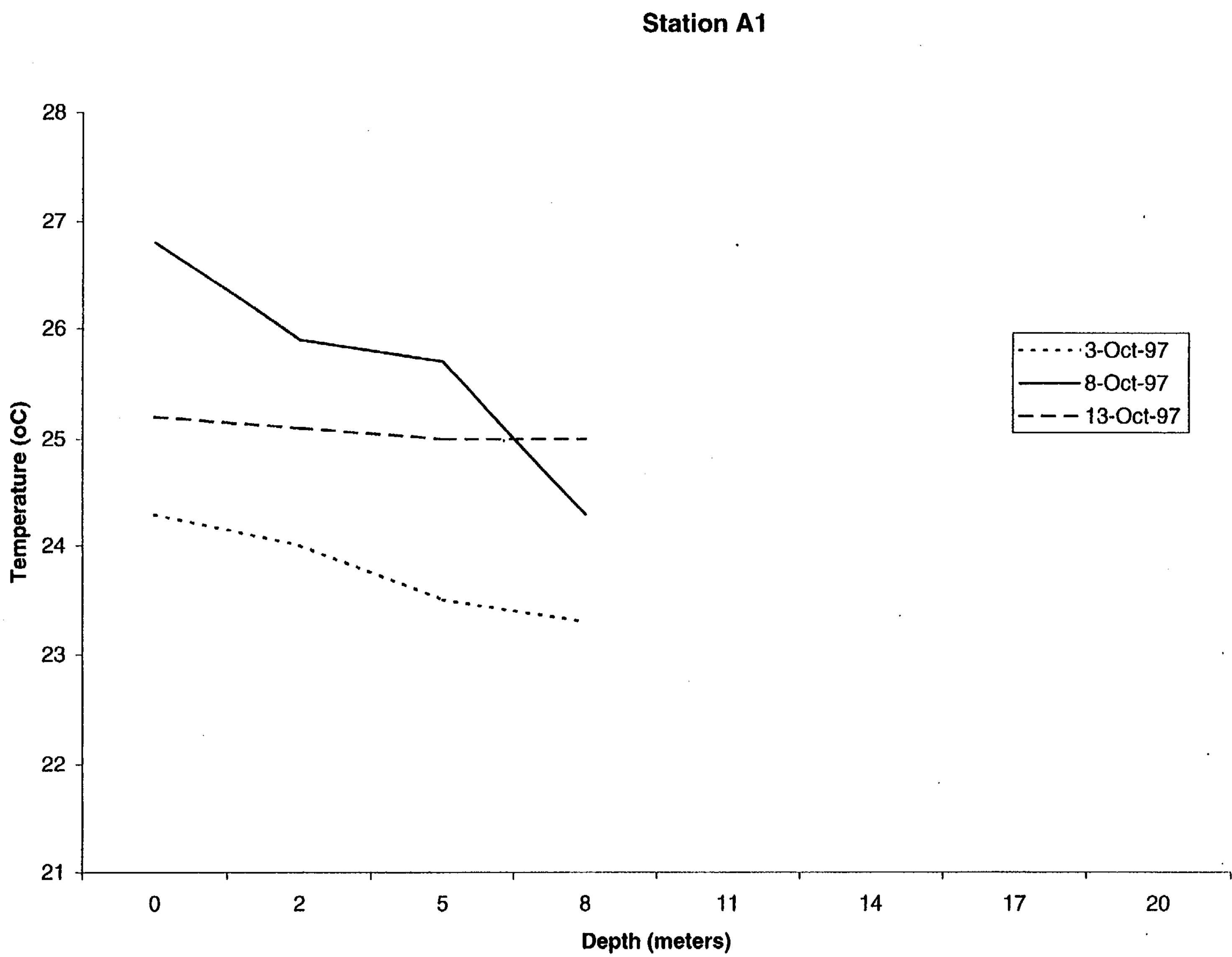
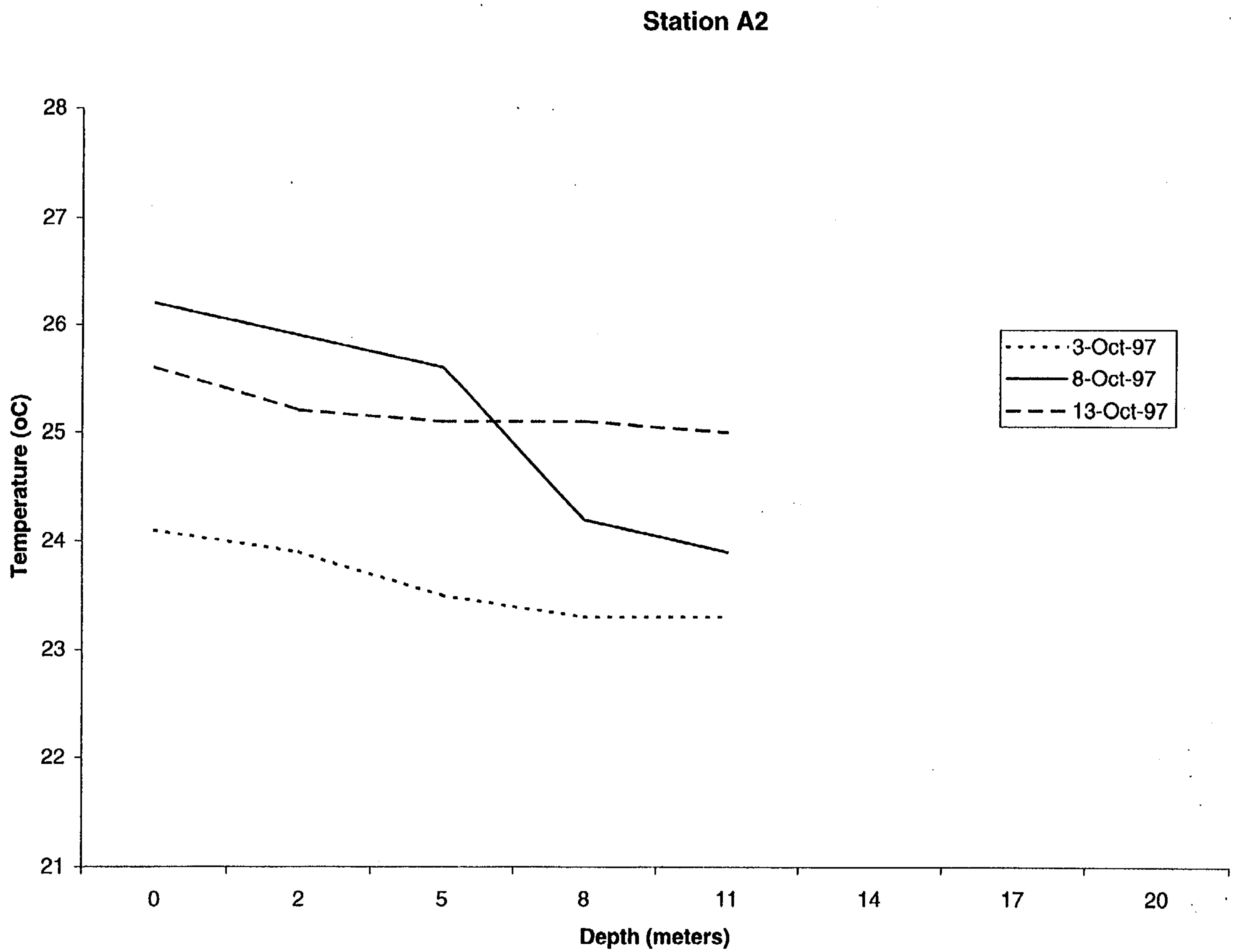


Figure B-1. Service Water Pond temperature profiles for three dates in October 1997



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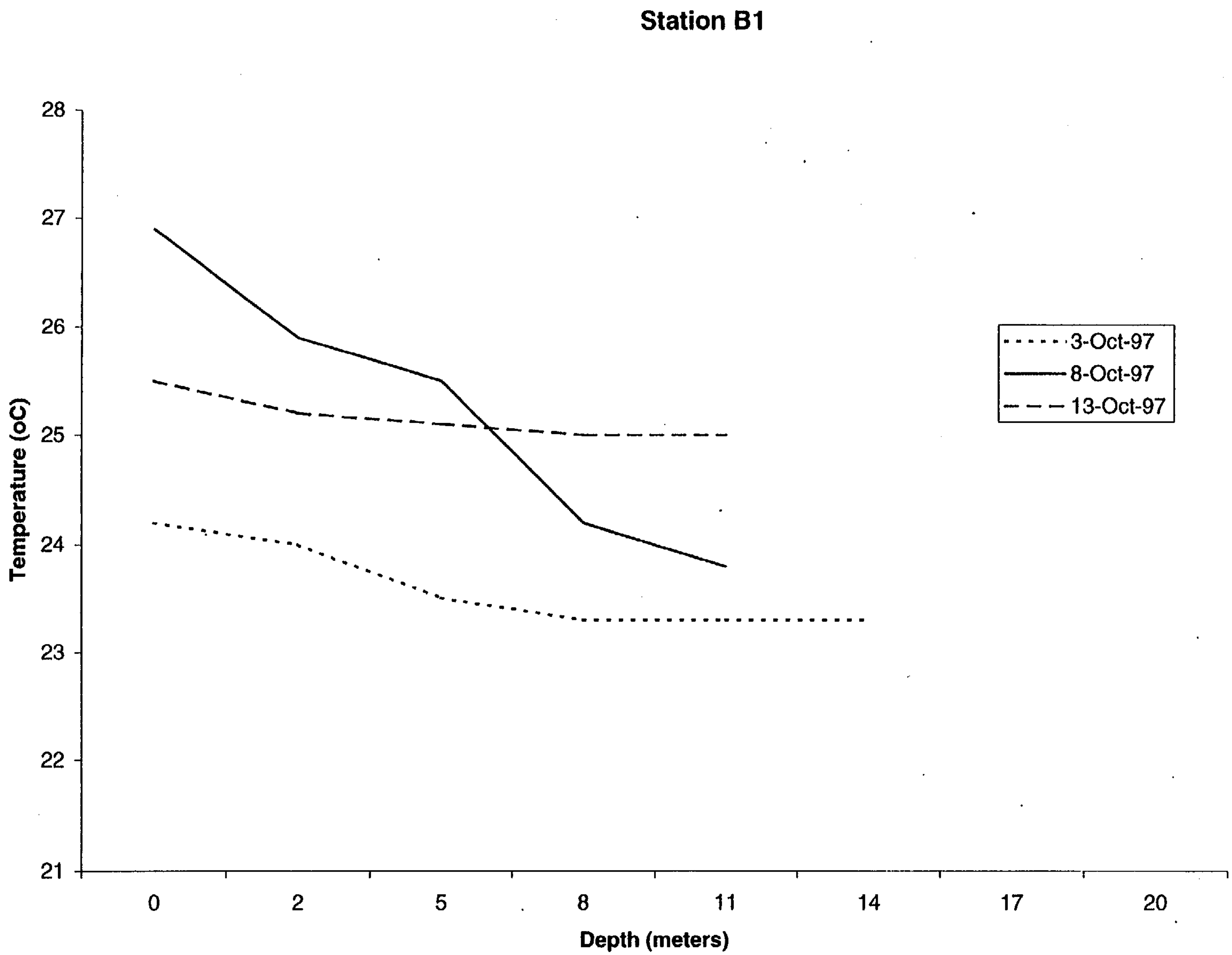


Figure B-3. Service Water Pond temperature profiles for three dates in October 1997

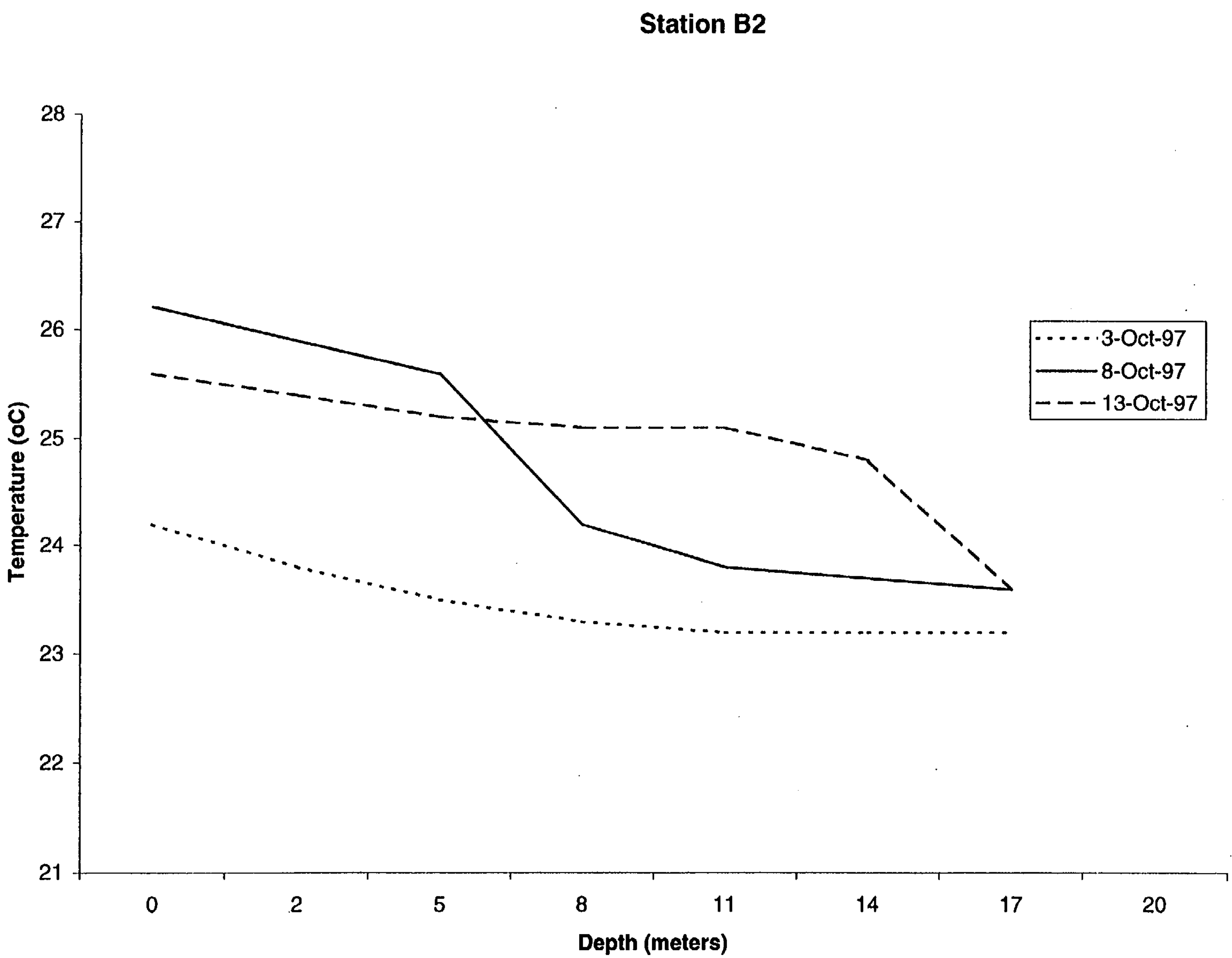


Figure B-4. Service Water Pond temperature profiles for three dates in October 1997

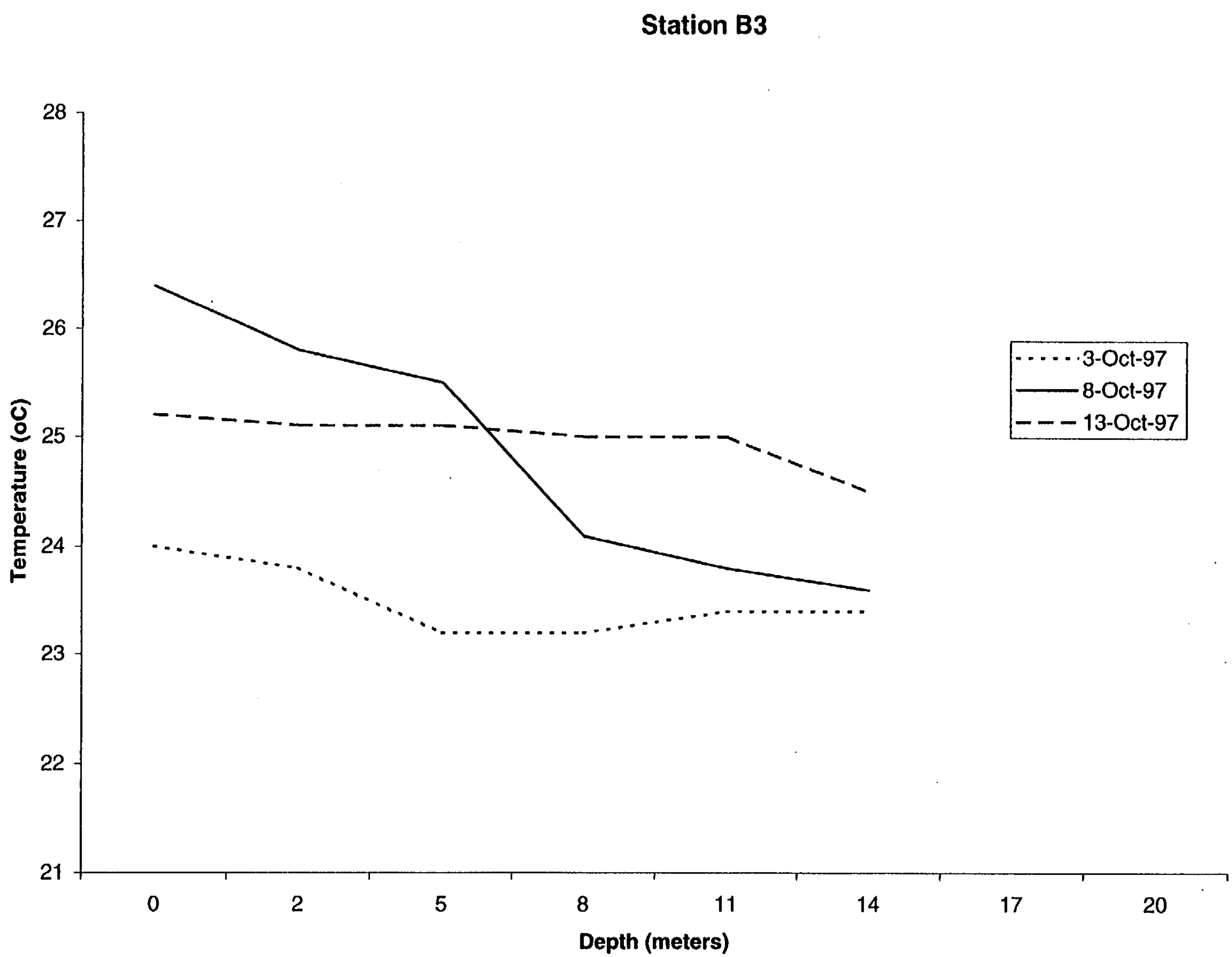
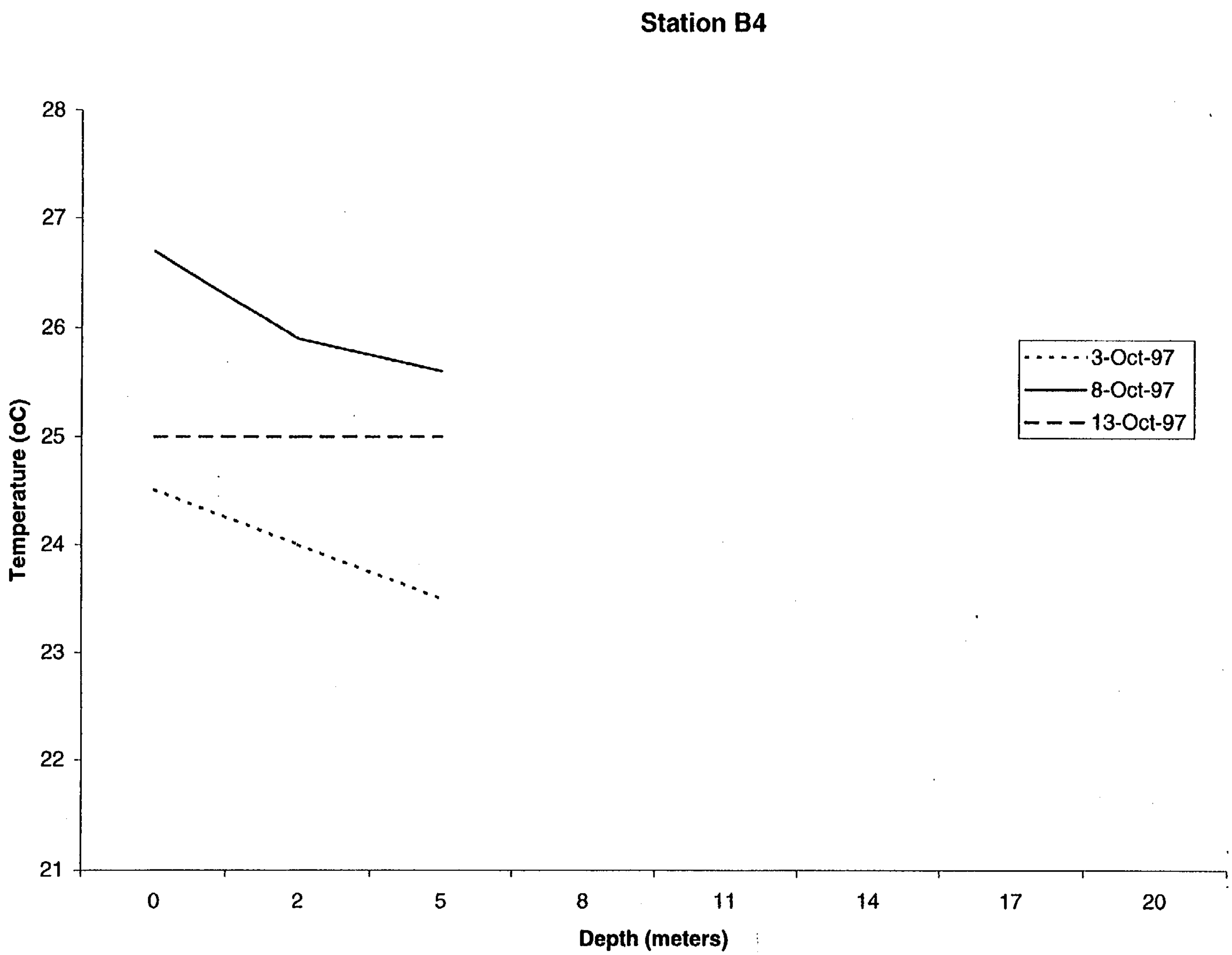


Figure B-5. Service Water Pond temperature profiles for three dates in October 1997



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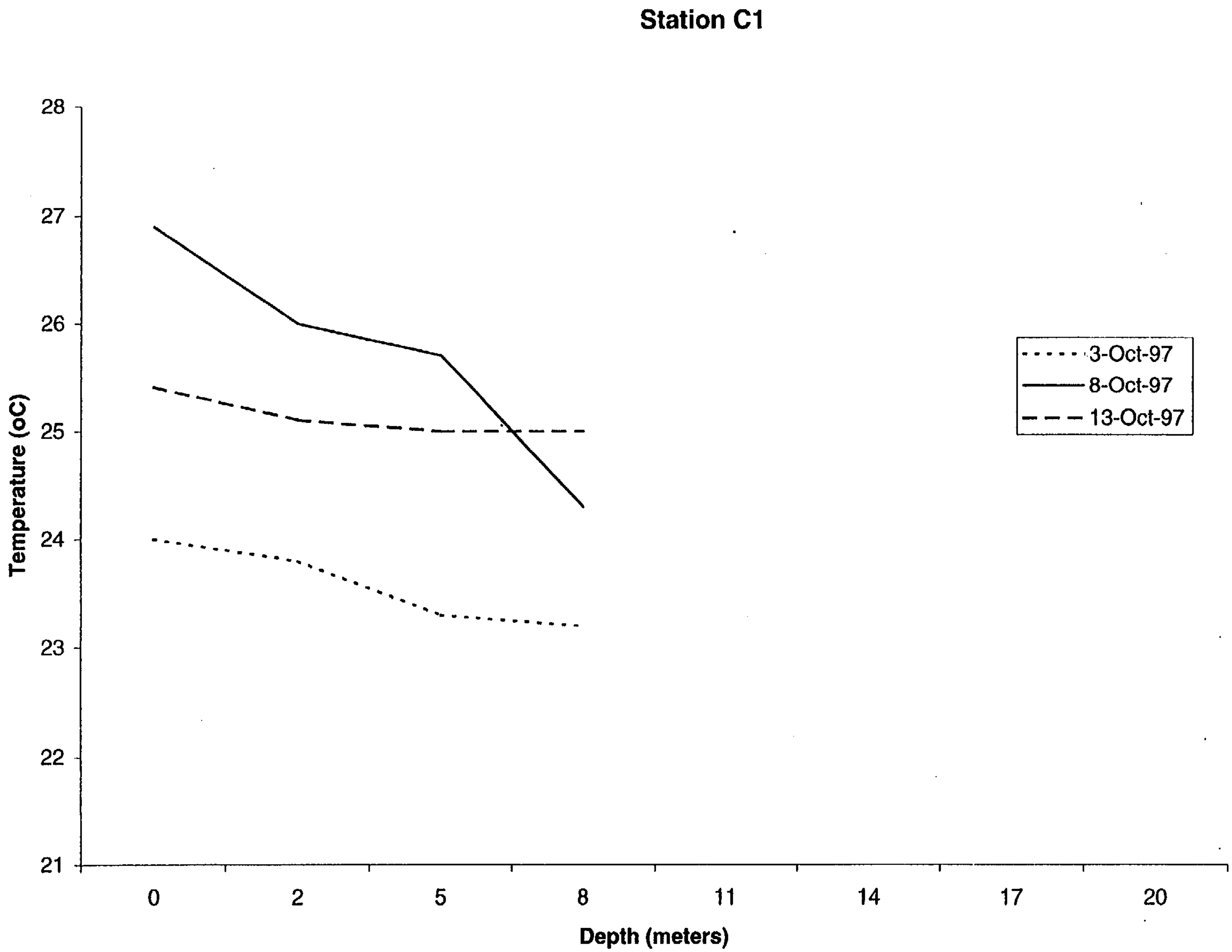

Figure B-7. Service Water Pond temperature profiles for three dates in October 1997

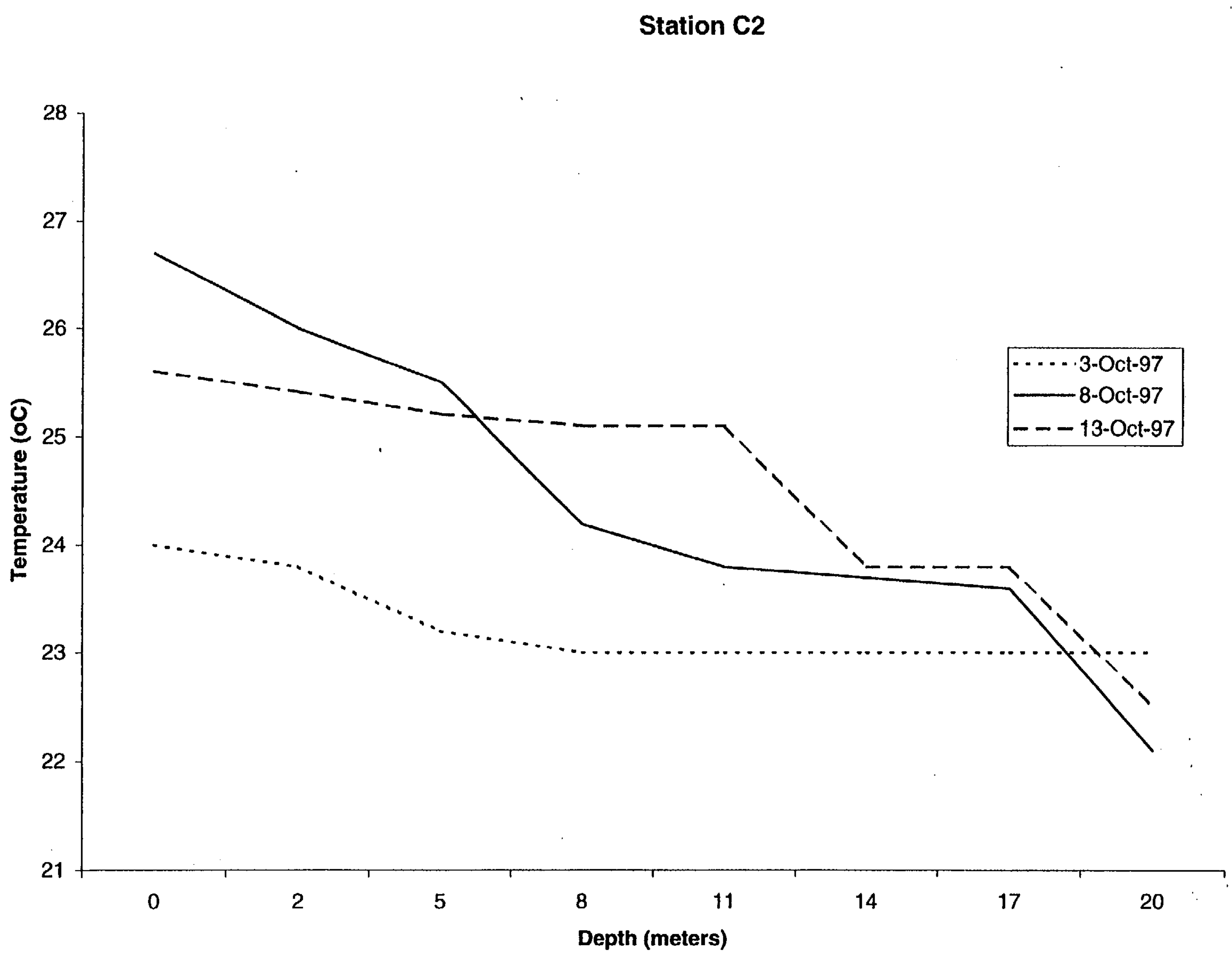

Figure B-8. Service Water Pond temperature profiles for three dates in October 1997

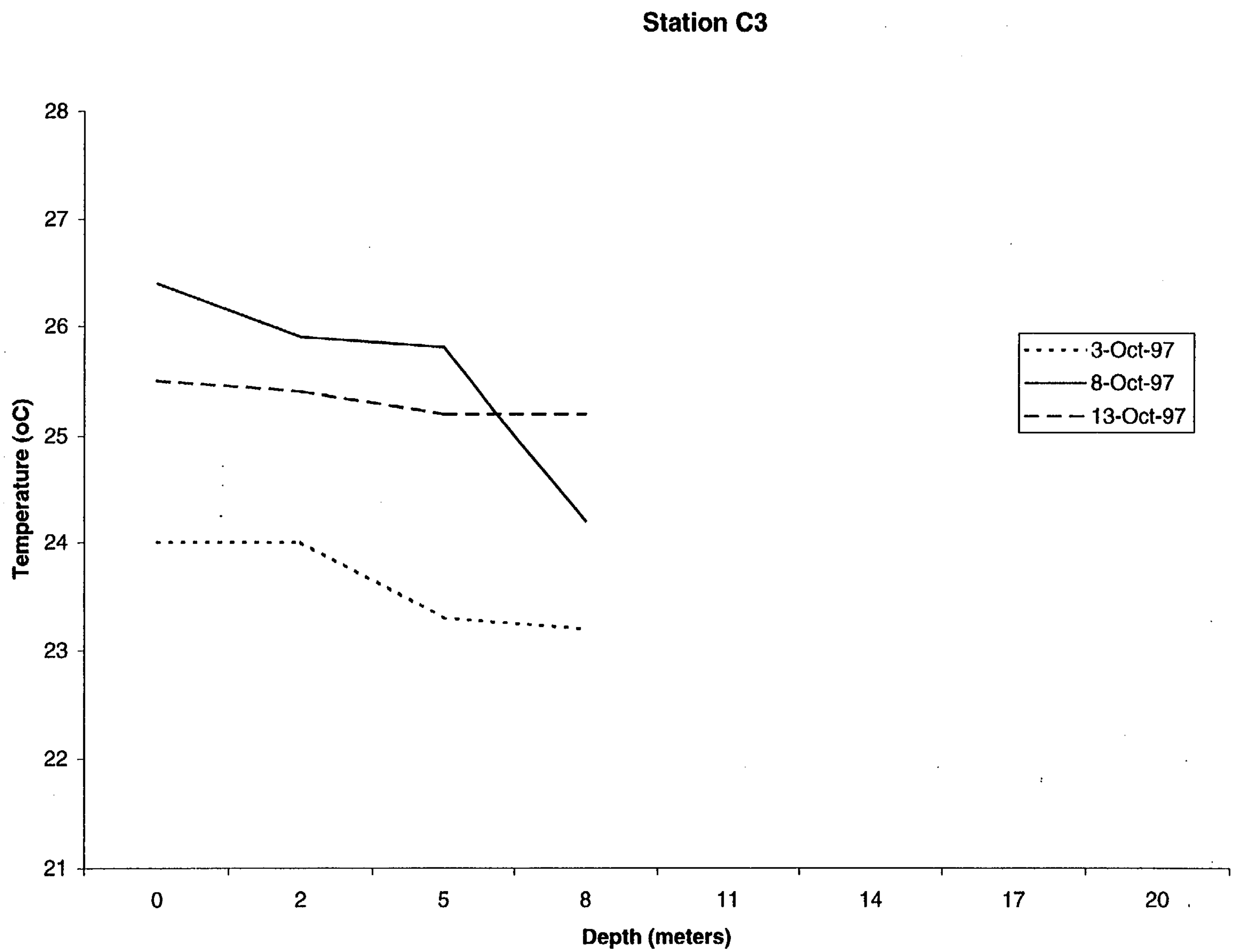

Figure B-9. Service Water Pond temperature profiles for three dates in October 1997

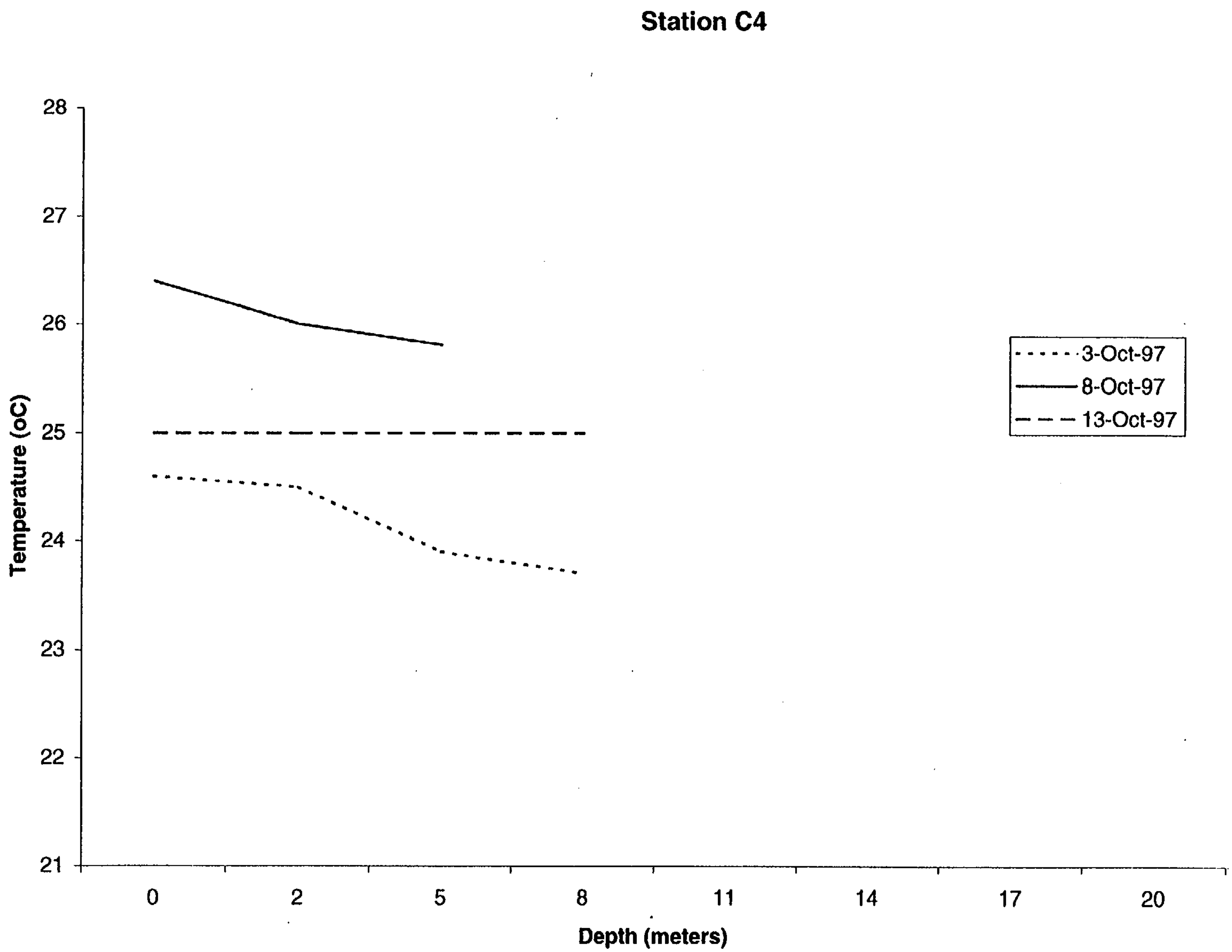

Figure B-10. Service Water Pond temperature profiles for three dates in October 1997

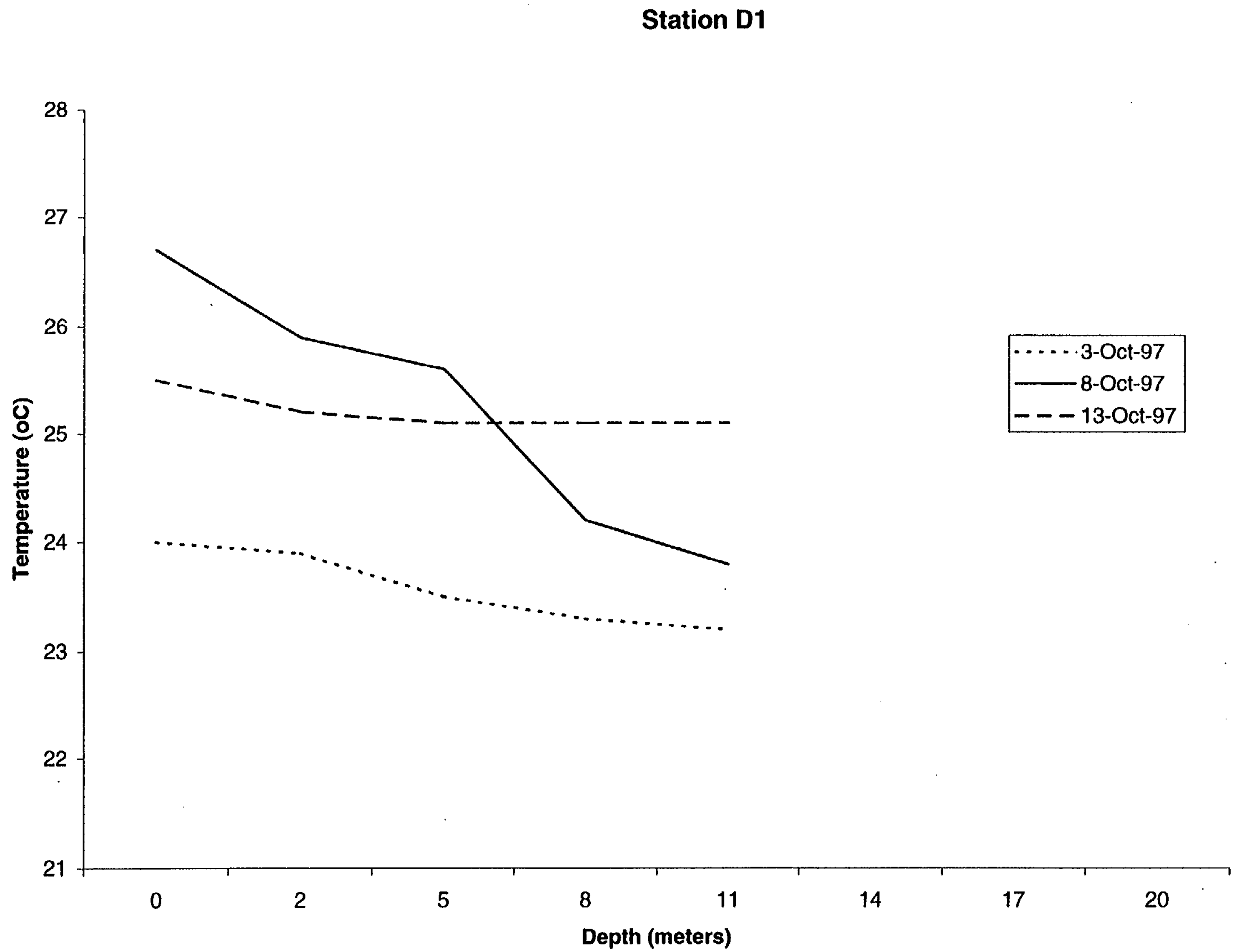

Figure B-11. Service Water Pond temperature profiles for three dates in October 1997

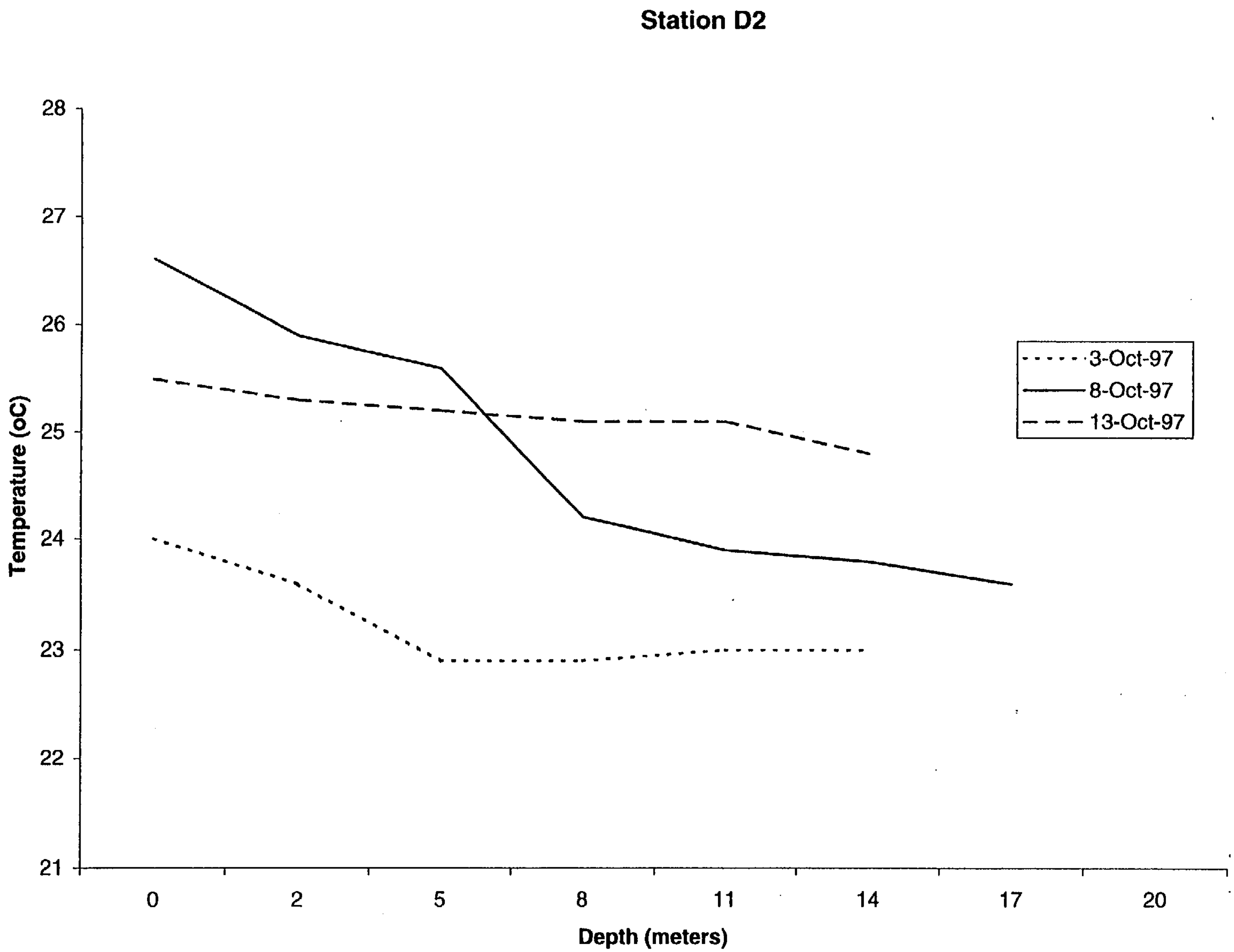

Figure B-12. Service Water Pond temperature profiles for three dates in October 1997

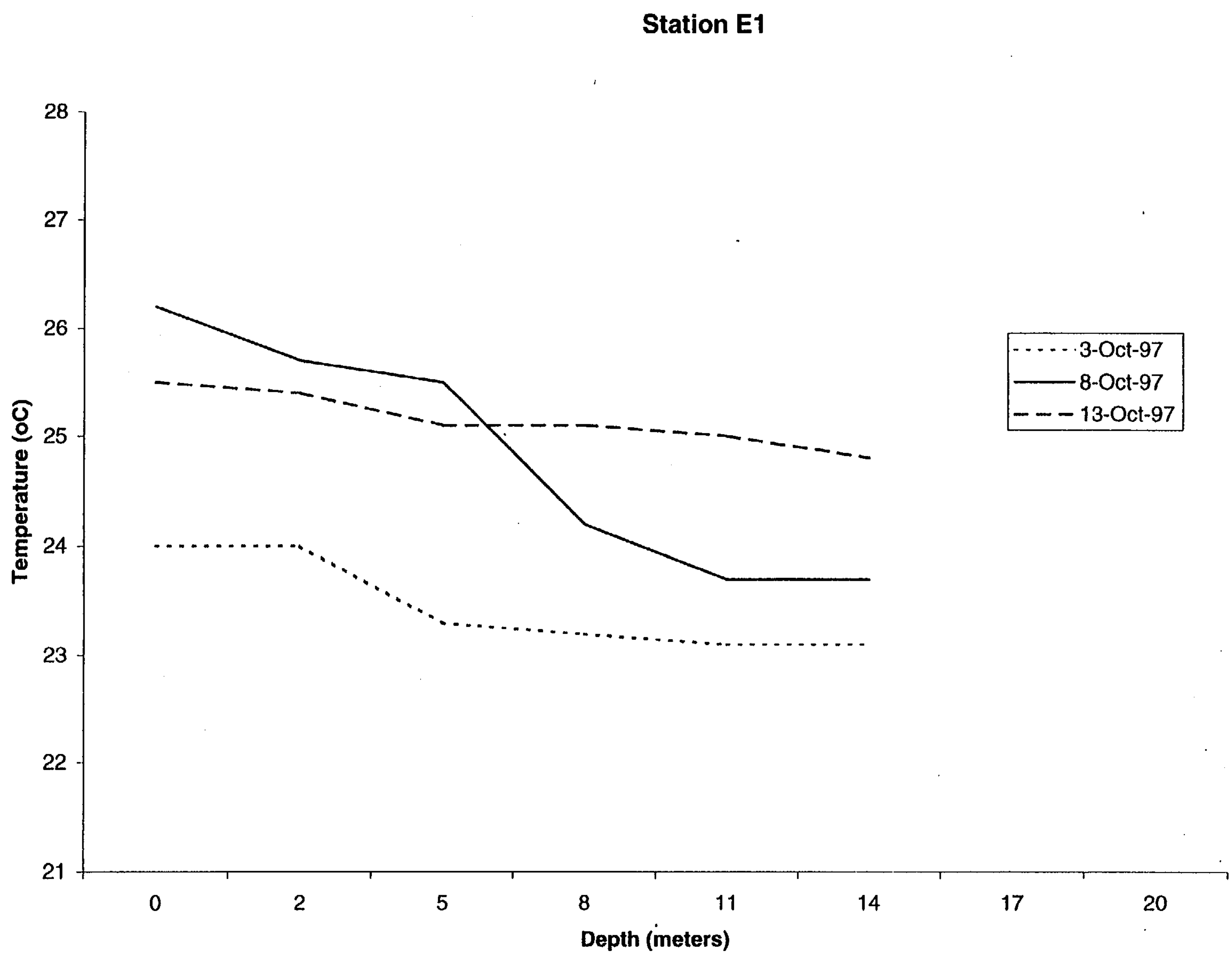

Figure B-13. Service Water Pond temperature profiles for three dates in October 1997

APPENDIX C

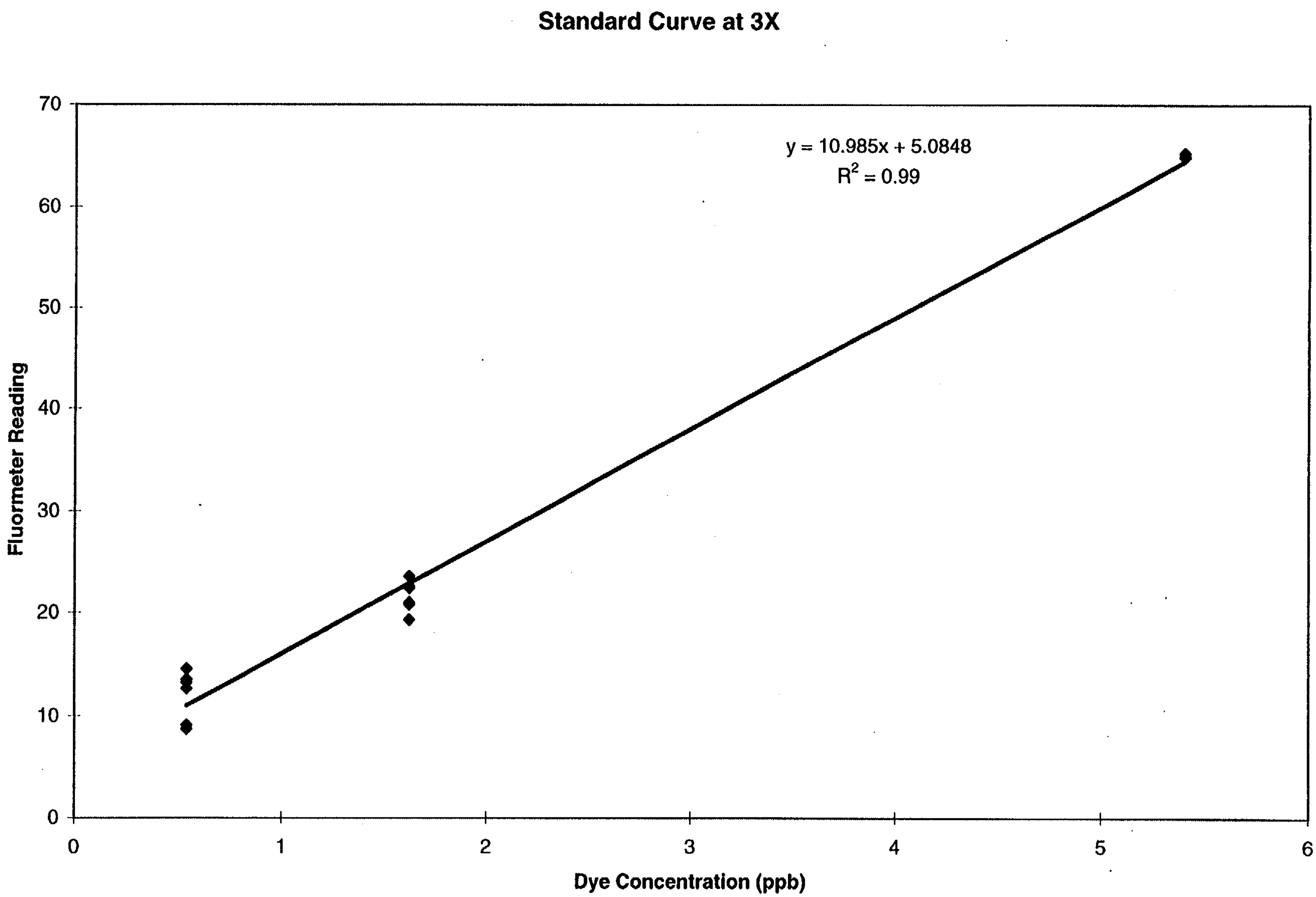

Figure C-1. Standard Curve for Dye at 3X Light Aperture

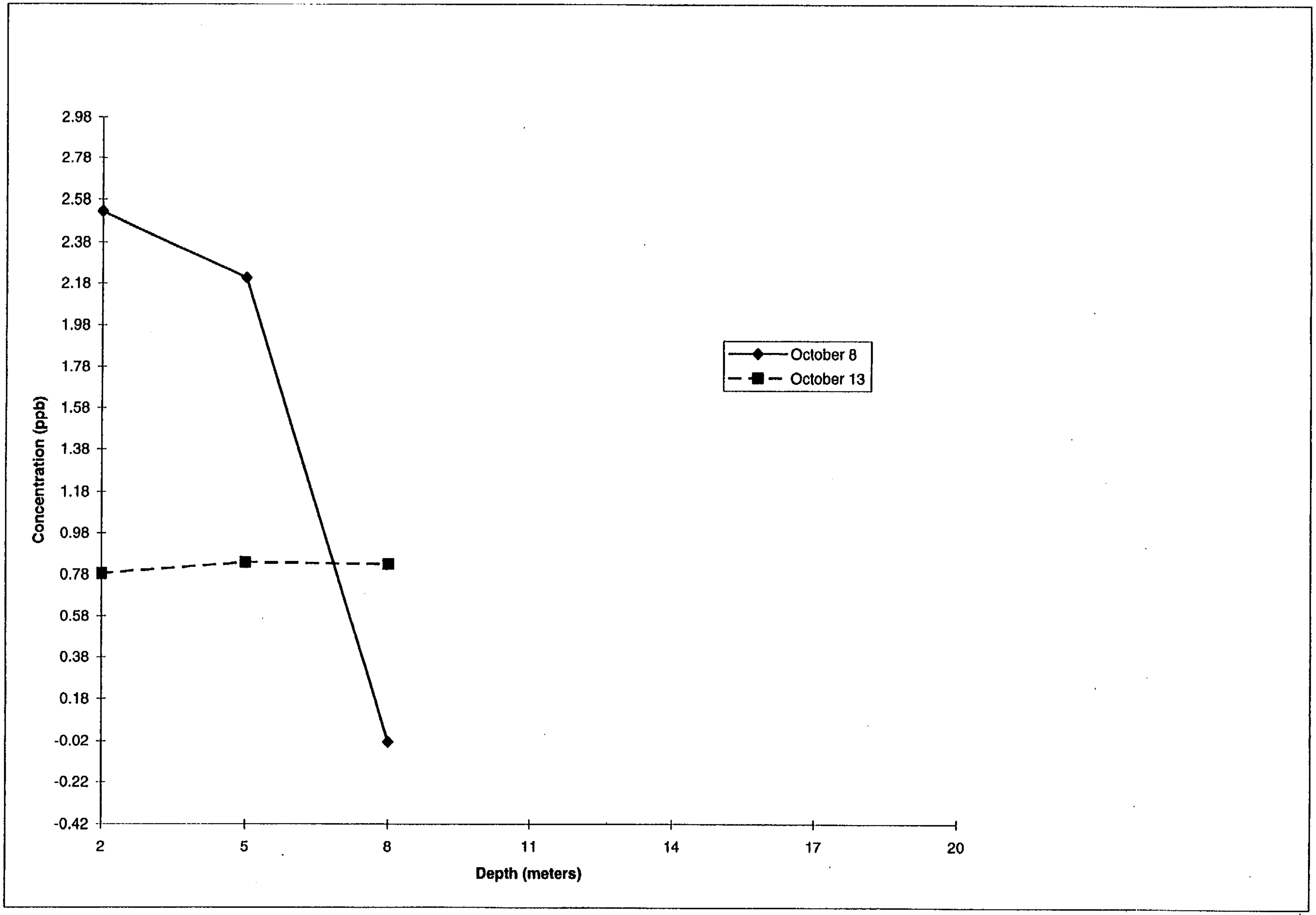

Figure C-2. Dye Concentration in Service Water Pond for Sample C1

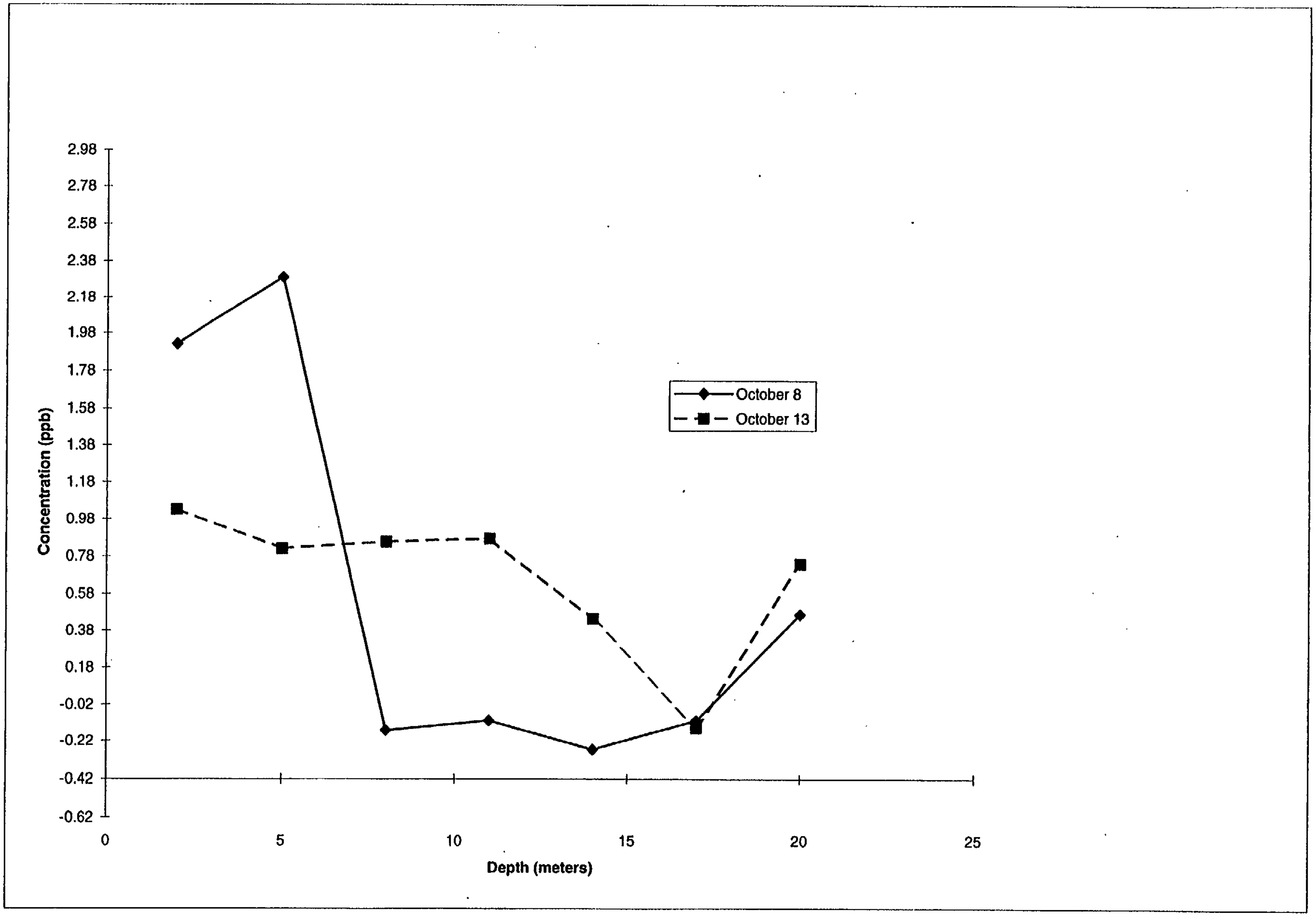

Figure C-3. Dye Concentration in Service Water Pond for Sample C2

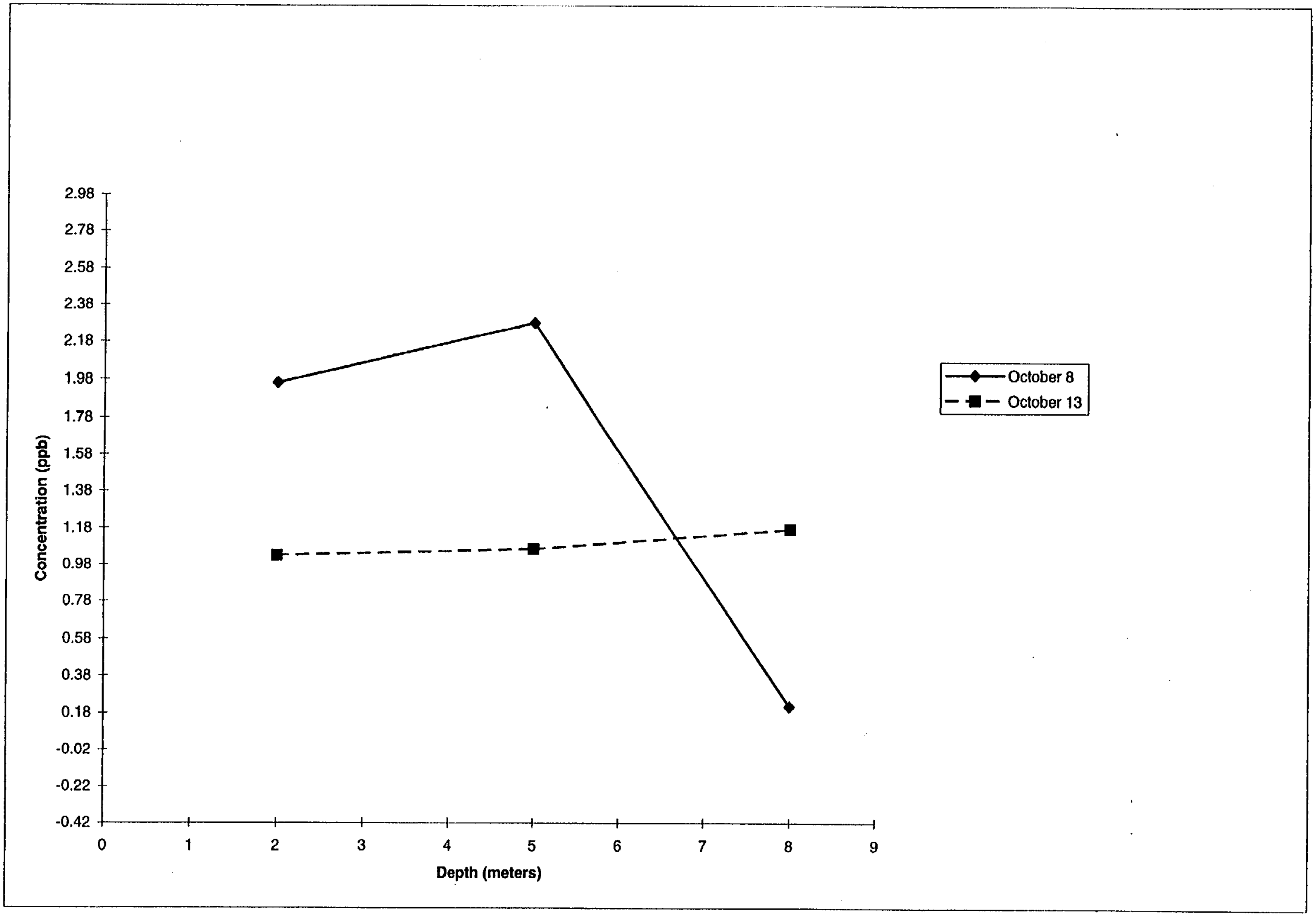

Figure C-4. Dye Concentration in Service Water Pond for Sample C3

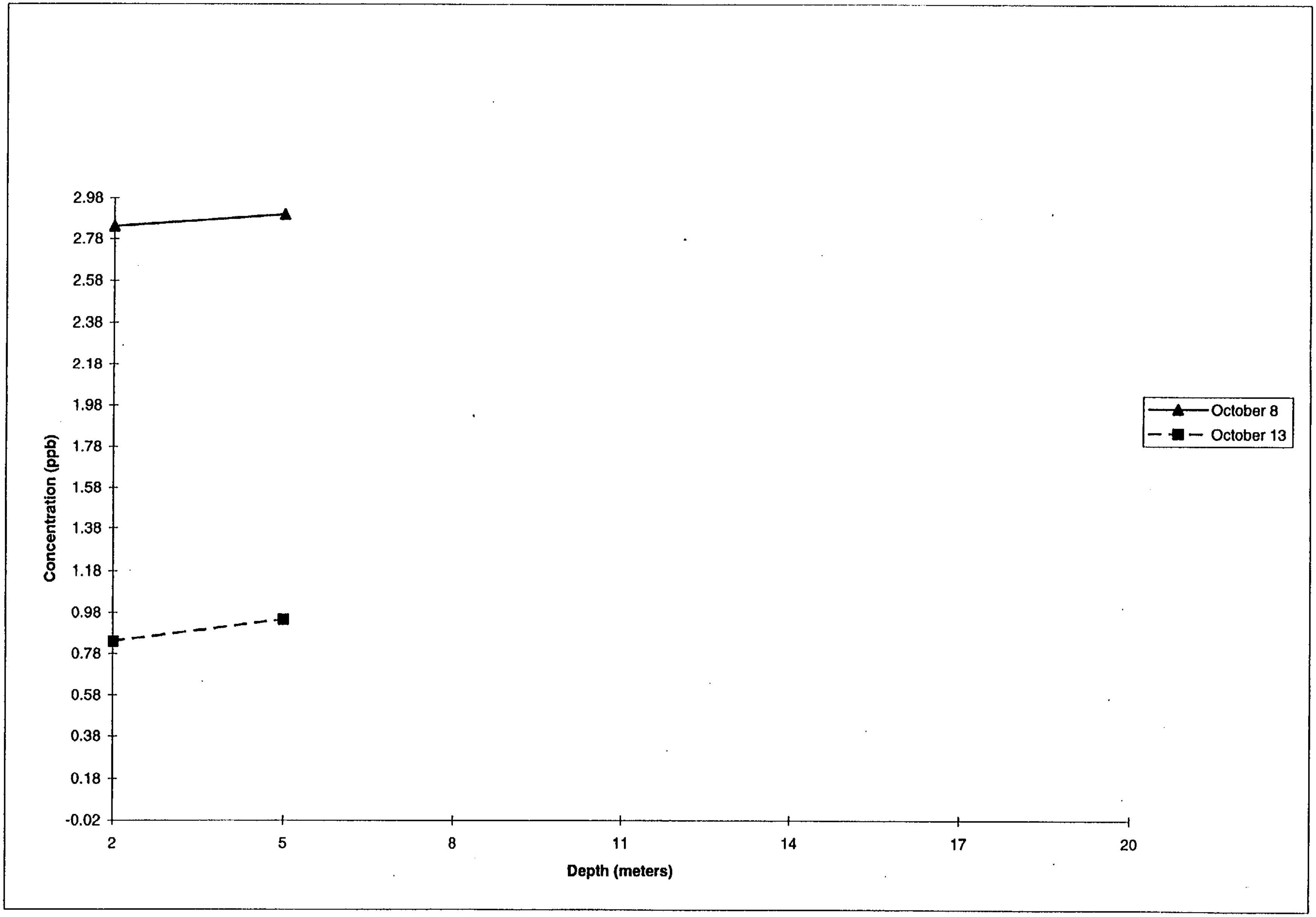

Figure C-5. Dye Concentration in Service Water Pond for Sample C4

Table C-1. Standard Curve for Dye at 3X Light Aperture

Standard Curve for dye				Notes:				
at 3X light aperature				dye concentrations nominal				
curve run 10-9-97				standards from mixture of all three containers used				
conc (ppb)	reading							
0.54	8.7							
0.54	9.1							
0.54	12.7							
0.54	13.3							
0.54	13.6							
0.54	14.6							
1.62	19.3							
1.62	20.8							
1.62	21							
1.62	22.4							
1.62	22.6							
1.62	23.6							
5.4	64.8							
5.4	64.9							
5.4	65.2							

Table C-2. Summary Statistics fo, ..ndard Curve at 3X Light Aperture

SUMMARY OUTPUT								
Regression Statistics								
Multiple R	0.994962986							
R Square	0.989951343							
Adjusted R Square	0.989178369							
Standard Error	2.133079652							
Observations	15							
ANOVA								
	df	*SS*	*MS*	*F*	*Significance F*			
Regression	1	5827.245626	5827.246	1280.705	2.25023E-14			
Residual	13	59.1503744	4.550029					
Total	14	5886.396						
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	5.084782609	0.812049545	6.261665	2.92E-05	3.330456562	6.839108655	3.330456562	6.839108655
X Variable 1	10.98519413	0.306960962	35.78694	2.25E-14	10.32204542	11.64834284	10.32204542	11.64834284

Table C-3. Dye Concentrations for Samples Read at 3X

Page 1 of 6

sample ID	reading	conc		Notes on sample ID
AS1008-01	2.2	-0.26206		AS = Automatic Sampler at pumphouse
AS1008-02	1.9	-0.28935		1008 = October 8 (date samples retrieved)
AS1008-03	2.3	-0.25296		-01, -02... = chronological sequence number
AS1008-04	1.9	-0.28935		
AS1008-05	2	-0.28025		
AS1008-06	1.9	-0.28935		
AS1008-07	2.8	-0.20746		
AS1008-08	1.9	-0.28935		
AS1008-09	1.9	-0.28935		
AS1008-10	1.9	-0.28935		
AS1008-11	3.1	-0.18016		
AS1008-12	2.6	-0.22566		
AS1008-13	2.5	-0.23476		
AS1008-14	2.4	-0.24386		
AS1008-15	1.9	-0.28935		
AS1008-16	3.2	-0.17106		
AS1008-17	2.1	-0.27116		
AS1008-18	2.8	-0.20746		
AS1008-19	2.1	-0.27116		
AS1008-20	2.1	-0.27116		
AS1008-21	2.8	-0.20746		
AS1008-22	2.7	-0.21656		
AS1008-23	2.2	-0.26206		
AS1008-24	3	-0.18926		
AS1010-01	2.4	-0.24386		
AS1010-02	1.9	-0.28935		
AS1010-03	5.2	0.010919		
AS1010-04	3.8	-0.11647		
AS1010-05	3.8	-0.11647		
AS1010-06	2.8	-0.20746		
AS1010-07	2.2	-0.26206		
AS1010-08	1.8	-0.29845		
AS1010-09	4.1	-0.08917		
AS1010-10	3.8	-0.11647		
AS1010-11	1.9	-0.28935		
AS1010-12	2.8	-0.20746		
AS1010-13	3	-0.18926		
AS1010-14	2.9	-0.19836		
AS1010-15	4.2	-0.08007		
AS1010-16	4.3	-0.07097		
AS1010-17	3	-0.18926		
AS1010-18	4.3	-0.07097		
AS1010-19	4	-0.09827		
AS1010-20	3.9	-0.10737		
AS1010-21	3.5	-0.14377		
AS1012-01	6.5	0.129208		
AS1012-01	6	0.083712		
AS1012-02	4.6	-0.04368		
AS1012-02	4.5	-0.05278		
AS1012-03	5.9	0.074613		

Table C-3. Dye Concentrations for Samples Read at 3X

AS1012-03	5.8	0.065514					
AS1012-04	5.3	0.020018					
AS1012-04	5.3	0.020018					
AS1012-05	2.3	-0.25296					
AS1012-05	2.1	-0.27116					
AS1012-06	6.3	0.11101					
AS1012-06	6.5	0.129208					
AS1012-07	3.4	-0.15287					
AS1012-07	3.4	-0.15287					
AS1012-08	3.9	-0.10737					
AS1012-08	3.6	-0.13467					
AS1012-09	3.9	-0.10737					
AS1012-09	3.8	-0.11647					
AS1013-01	16.2	1.011829					
AS1013-08	8.1	0.274795					
AS1014-01	13.8	0.793449					
AS1014-02	11.2	0.55687					
AS1014-03	14	0.811647					
AS1014-03	14	0.811647					
AS1014-04	12.2	0.647862					
AS1014-05	13.4	0.757052					
AS1014-05	13.2	0.738854					
AS1014-06	14.3	0.838944					
AS1014-07	9.9	0.438581					
AS1014-08	17.9	1.166515					
AS1014-09	18.7	1.239308					
AS1016-01	12	0.629663					
AS1016-02	12.6	0.684258					
AS1016-03	12.2	0.647862					
AS1016-04	11.7	0.602366					
AS1016-04	11.5	0.584167					
AS1016-05	12.9	0.711556					
AS1016-06	10.7	0.511374					
AS1016-07	16	0.993631					
AS1016-08	11.5	0.584167					
AS1016-09	13.9	0.802548					
AS1016-10	14	0.811647					
AS1016-10	13.9	0.802548					
AS1016-11	14.5	0.857143					
AS1016-12	16.6	1.048226					
AS1016-13	16	0.993631					
AS1016-14	16	0.993631					
AS1016-14	15.9	0.984531					
AS1016-15	14.3	0.838944					
AS1016-16	14.4	0.848044					
AS1016-17	17.6	1.139217					
AS1016-18	16.9	1.075523					
AS1016-19	19.9	1.348499					
AS1016-20	15.1	0.911738					
AS1016-21	17.7	1.148317					
AS1016-22	17.3	1.11192					

Table C-3. Dye Concentrations for Samples Read at 3X

AS1016-23	15.6	0.957234					
AS1016-24	15.5	0.948135					
CL11006	22.5	1.585077		CL1 = Dye control, light, no. 1			
CL11008	24.6	1.77616		1008 = October 8			
CL11010	24.9	1.803458					
CL11013	17.1	1.093722					
CL11013	16.8	1.066424					
CL21006	20	1.357598		CL2 = Dye control, light, no. 2			
CL21008	27.1	2.00364					
CL21010	26.3	1.930846					
CL21013	17.3	1.11192					
CL21013	17.4	1.121019					
CN11006	20.3	1.384895		CN1 = Dye control, dark, no. 1			
CN11006	19.5	1.312102					
CN11008	39.2	3.104641					
CN11010	37.3	2.931756					
CN11010	37.3	2.931756					
CN11013	27.2	2.012739					
CN11013	27.4	2.030937					
CN21006	39.7	3.150136		CN2 = Dye control, dark, no. 2			
CN21008	53	4.360328					
CN21010	51.5	4.22384					
CN21010	51.5	4.22384					
CN21013	37.8	2.977252					
CN21013	37.8	2.977252					
P1008A1-02	27.3	2.021838		P = Pond sample			
P1008A1-02	27.4	2.030937		1008 = October 8			
P1008A1-05	30.6	2.322111		A1 = Station A1			
P1008A1-05	30.4	2.303913		-02, -05... = depth in meters			
P1008A1-08	5.4	0.029117					
P1008A1-08	4.6	-0.04368					
P1008A2-02	23.2	1.648772					
P1008A2-02	22.9	1.621474					
P1008A2-08	4.4	-0.06187					
P1008A2-08	5.2	0.010919					
P1008A2-11	2.9	-0.19836					
P1008A2-11	3	-0.18926					
P1008B1-02	32.4	2.485896					
P1008B1-02	31.9	2.4404					
P1008B1-05	28.8	2.158326					
P1008B1-05	28.4	2.121929					
P1008B1-08	5.2	0.010919					
P1008B1-08	5.7	0.056415					
P1008B1-11	3.9	-0.10737					
P1008B1-11	4.5	-0.05278					
P1008B2-02	29.5	2.22202					
P1008B2-02	29.4	2.212921					
P1008B2-05	31.1	2.367607					
P1008B2-05	31	2.358508					
P1008B2-08	2.6	-0.22566					
P1008B2-08	2.8	-0.20746					

Table C-3. Dye Concentrations for Samples Read at 3X

P1008B2-11	3.5	-0.14377						
P1008B2-11	3.7	-0.12557						
P1008B2-14	2.9	-0.19836						
P1008B2-14	3.1	-0.18016						
P1008B2-17	3	-0.18926						
P1008B2-17	3.1	-0.18016						
P1008B3-02	26.2	1.921747						
P1008B3-02	26.5	1.949045						
P1008B3-05	26.8	1.976342						
P1008B3-05	26.8	1.976342						
P1008B3-08	5.2	0.010919						
P1008B3-08	4.9	-0.01638						
P1008B3-11	5.9	0.074613						
P1008B3-11	6.1	0.092812						
P1008B4-02	31.9	2.4404						
P1008B4-02	31.6	2.413103						
P1008B4-05	30.7	2.33121						
P1008B4-05	30.2	2.285714						
P1008C1-02	33	2.540491						
P1008C1-02	32.7	2.513194						
P1008C1-05	29.5	2.22202						
P1008C1-05	29.2	2.194722						
P1008C1-08	4.7	-0.03458						
P1008C1-08	4.9	-0.01638						
P1008C2-02	26.3	1.930846						
P1008C2-02	26.1	1.912648						
P1008C2-05	30.3	2.294813						
P1008C2-05	30.2	2.285714						
P1008C2-08	3.4	-0.15287						
P1008C2-08	3.2	-0.17106						
P1008C2-11	3.9	-0.10737						
P1008C2-11	3.9	-0.10737						
P1008C2-14	2.1	-0.27116						
P1008C2-14	2.2	-0.26206						
P1008C2-17	3.8	-0.11647						
P1008C2-17	4	-0.09827						
P1008C2-20	10.1	0.456779						
P1008C2-20	10.4	0.484076						
P1008C3-02	26.9	1.985441						
P1008C3-02	26.4	1.939945						
P1008C3-05	30.1	2.276615						
P1008C3-05	30.2	2.285714						
P1008C3-08	7.5	0.2202						
P1008C3-08	7.4	0.211101						
P1008C4-02	36.3	2.840764						
P1008C4-02	36.3	2.840764						
P1008C4-05	37.2	2.922657						
P1008C4-05	36.7	2.877161						
P1008D1-02	34.1	2.640582						
P1008D1-02	33.5	2.585987						
P1008D1-05	30.2	2.285714						

Table C-3. Dye Concentrations for Samples Read at 3X

P1008D1-05	30.2	2.285714					
P1008D1-08	2	-0.28025					
P1008D1-08	1.8	-0.29845					
P1008D1-11	6.9	0.165605					
P1008D1-11	7.1	0.183803					
P1008D2-02	31	2.358508					
P1008D2-02	30.5	2.313012					
P1008D2-05	29.2	2.194722					
P1008D2-05	29.1	2.185623					
P1008D2-08	3.9	-0.10737					
P1008D2-08	4.4	-0.06187					
P1008D2-11	3.8	-0.11647					
P1008D2-11	3.6	-0.13467					
P1008D2-14	3.3	-0.16197					
P1008D2-14	3.3	-0.16197					
P1008E1-02	34	2.631483					
P1008E1-02	33.6	2.595086					
P1008E1-05	30.5	2.313012					
P1008E1-05	30.5	2.313012					
P1008E1-08	4	-0.09827					
P1008E1-08	3.8	-0.11647					
P1008E1-11	4.3	-0.07097					
P1008E1-11	4.4	-0.06187					
P1008E1-14	5.3	0.020018					
P1008E1-14	5.5	0.038217					
P1013A1-02	13.9	0.802548					
P1013A1-05	13.2	0.738854					
P1013A1-08	13.2	0.738854					
P1013A2-02	16.9	1.075523					
P1013A2-05	14.1	0.820746					
P1013A2-08	14	0.811647					
P1013A2-08	14.4	0.848044					
P1013A2-11	16.5	1.039126					
P1013B1-02	14.6	0.866242					
P1013B1-05	14	0.811647					
P1013B1-08	12.5	0.675159					
P1013B1-08	12.5	0.675159					
P1013B1-11	13.6	0.77525					
P1013B2-02	13.5	0.766151					
P1013B2-05	14.4	0.848044					
P1013B2-08	15.4	0.939035					
P1013B2-11	13.6	0.77525					
P1013B2-14	12.1	0.638763					
P1013B2-17	4.3	-0.07097					
P1013B2-17	3.8	-0.11647					
P1013B3-02	13.6	0.77525					
P1013B3-05	14.3	0.838944					
P1013B3-05	14.5	0.857143					
P1013B3-08	14.4	0.848044					
P1013B3-11	15.8	0.975432					
P1013B4-02	13.5	0.766151					

Table C-3. Dye Concentrations for Samples Read at 3X

P1013B4-05	13.4	0.757052					
P1013C1-02	13.7	0.784349					
P1013C1-05	14.3	0.838944					
P1013C1-08	14.2	0.829845					
P1013C2-02	16.4	1.030027					
P1013C2-05	14.1	0.820746					
P1013C2-08	14.5	0.857143					
P1013C2-11	14.7	0.875341					
P1013C2-11	14.7	0.875341					
P1013C2-14	10	0.44768					
P1013C2-17	3.3	-0.16197					
P1013C2-17	3.6	-0.13467					
P1013C2-20	13.2	0.738854					
P1013C2-20	13.3	0.747953					
P1013C3-02	16.4	1.030027					
P1013C3-05	16.8	1.066424					
P1013C3-08	18	1.175614					
P1013C4-02	14.3	0.838944					
P1013C4-05	15.5	0.948135					
P1013D1-02	14.2	0.829845					
P1013D1-02	14.2	0.829845					
P1013D1-05	14.8	0.88444					
P1013D1-08	14.9	0.89354					
P1013D1-11	13.9	0.802548					
P1013D2-02	14.5	0.857143					
P1013D2-05	15.4	0.939035					
P1013D2-08	14.1	0.820746					
P1013D2-11	14.3	0.838944					
P1013D2-14	14.6	0.866242					
P1013E1-02	15.2	0.920837					
P1013E1-02	15.2	0.920837					
P1013E1-05	17.8	1.157416					
P1013E1-08	14.6	0.866242					
P1013E1-11	17	1.084622					
P1013E1-14	13.6	0.77525					
P1013E1-14	13.3	0.747953					