UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING APPEAL BOARD

In the Matter of	)	
	)	
VIRGINIA ELECTRIC AND POWER COMPANY	)	Doc. Nos. 50-338 OL
	)	50-339 OL
(North Anna Power Station, Units 1 and 2)	)	(Pump House Settlement and Turbine Missiles)

RESPONSES

Interrogatory 1: What are the current settlement measurements beneath all Class I structures at North Anna?

Vepco Response: The settlement of Class I structures other than the Service Water Pump House and related piping is not relevant to this reopened proceeding. Charts and tables of settlement measurements through March 1979 for the pump house and the service water lines north of the expansion joints are provided in "Vepco's Testimony on Service Water Pump House Settlement," served on the parties April 27, 1979.

Interrogatory 2: During 1977, what principle determined what pump house measurements were taken, and by whom?

Vepco Response: During 1977 settlement monitoring of the Units 1 and 2 Service Water Pump House by the surveying firm of Moore, Hardee & Carrouth Associates was governed by Technical Specification 3/4.7.12, which specified that certain points be

measured at least once every six months. As described in Vepco's testimony on Service Water Pump House settlement, dated April 27, 1979, Moore, Hardee & Carrouth Associates use surveying equipment and methods that satisfy the standard of accuracy required by the Technical Specification.

However, as also indicated in Vepco's testimony, more frequent monitoring was performed by the Stone & Webster construction surveyors to provide information for engineering evaluations. The frequency of this supplemental monitoring was based on judgment by Stone & Webster engineers, with the concurrence of Vepco engineers.

Following the filling of the reservoir in August 1976, monitoring by the Stone & Webster construction surveyors was performed once every two weeks, but this was reduced to approximately once each month by 1977. Deviations from scheduled Stone & Webster monitoring during 1977 were caused by job conditions, but the actual frequency of monitoring was consistent with the purpose of this supplemental monitoring.

Interrogatory 3: How often does Vepco recommend that pump house settlement measurements be taken at North Anna?

Vepco Response: We concur with a monitoring frequency of once every six months, as required by Technical Specification 3/4.7.12, though we have increased this frequency to once each month since the average settlement of the pump house exceeded

percent of the allowable value given in the Technical Specification. We have asked the NRC to revise the Technical Specification to permit an allowable settlement of the pump house based on the movements that can be accommodated by the expansion joints in the service water lines rather than on an estimation of possible future settlement. Should the NRC revise the Technical Specification in this manner, we would eventually reduce the monitoring frequency to the original frequency of once every six months.

However, in view of the settlement over the past six months of the service water lines north of the expansion joints, as indicated in Figure 25B of Vepco's testimony on Service Water Pump House settlement of April 27, 1979, monthly monitoring would be continued even if the Technical Specification were revised. Until a reduction in this rate of settlement can be identified, we believe that frequent monitoring is advisable. Also, since the April 1979 survey indicated pump house settlement greater than would be expected on the record of the last few months, we have temporarily increased our monitoring to once a week in order to provide a better basis for evaluating the current settlement.

Interrogatory 4: In the summer of 1977, Vepco prepared affidavits on North Anna foundation conditions in response to an Atomic Safety and Licensing Board request of June 2, 1977.

Which, if any, statements in those answers and affidavits are no longer accurate?

Vepco Response: Several statements in Vepco's response to the limited appearances of Mrs. Allen and Mr. Pollard, submitted to the Atomic Safety and Licensing Board on July 5, 1977, have subsequently been found to have been based on incorrect information. To the best of our knowledge those statements are the following:

On pages 6, 7, and 8 the groundwater level beneath the pump house was said to be at about elevation 275 at that time. These statements were based on groundwater levels measured at piezometers P-13 and P-14, as shown in Figure 11B of Vepco's testimony on Service Water Pump House settlement of April 27, 1979. Figure 11B also shows that the groundwater level measured at piezometer P-14 fell following the installation of Drain 4 to an elevation much below the elevation of Drain 4. Obviously this is not possible. From this behavior we conclude that there must be an error in the calculated elevation of the tip of piezometer P-14, which is the basis for calculating the groundwater level at that piezometer. In other words, the actual groundwater level at piezometer P-14 may be 4 to 5 feet higher than the measured level. Thus, the groundwater level beneath the pump house in June 1977 may have been at elevation 278 to 279 rather than elevation 274 to 275.

2349 007

On page 10 it is stated that "the horizontal drain system will not cause additional settlement." This statement was based on a belief that the groundwater level beneath the pump house was at about elevation 275, so that installing drains at that same elevation would not lower the groundwater level and, therefore, would not cause settlement. As indicated above, the actual groundwater level beneath the pump house must have been higher than elevation 275, so installing the drains did lower the groundwater level and, therefore, did cause settlement.

On page 18 the 1/4-inch settlement of the pump house after the filling of the reservoir with water is attributed solely to the weight of water in the reservoir. As discussed in Vepco's testimony of April 27, 1979, some of this settlement may have been caused by the installation of the first horizontal drain in October 1977.

Interrogatory 5: Please supply the installation date for each horizontal drain at North Anna.

Vepco Response: The six horizontal drains were installed (that is, completed by the withdrawal of the drill casing from around the slotted plastic drain pipe) on the following dates:

Drain	Date
1	October 8, 1976
2	July 26, 1977
3	August 29, 1977
4	July 13, 1977
5	August 10, 1977
6	July 5, 1977

Interrogatory 6: Please supply the installation date for each expansion joint at North Anna.

Vepco Response: Expansion joints were installed in service water lines 1 (westernmost) and 3 during the period August 20 to 24, 1976, and in service water lines 2 and 4 (easternmost) during the period September 30 to October 4, 1976. (Some of the past documents on this subject say the expansion joints were installed in "early" 1976. This is incorrect.)

Interrogatory 7: What specific construction activities connected with the construction of which unit brought about the "destruction" of markers described in Vepco's November 22, 1978 letter to the NRC?

Vepco Response: The answer to this question would not be relevant to this proceeding. None of the destroyed markers was on the Service Water Pump House or the service water lines north of the expansion joints.

2349 009

Interrogatory 8: Why has it been necessary to fill the service water reservoir more than once? What are the dates of, and what have been the effects, of the successive fillings?

Vepco Response: As shown in Figure 7E and 11A of Vepco's testimony on Service Water Pump House, dated April 27, 1979, the Service Water Reservoir has been filled three times.

During the initial filling of the reservoir, which started on August 17, 1976, work was begun to install the horizontal drains under the pump house. The contractor doing the installation drilled through the clay liner of the reservoir by mistake on August 29, 1976. The reservoir was emptied, starting on August 30, in order to repair the damaged liner. The reservoir was refilled starting September 26.

Starting in December 1976 the reservoir was again emptied to repair leaks that had been detected in the underwater spray piping. The final filling of the reservoir started on February 20, 1977. Since that time, the water level in the reservoir has been maintained in its operating range, nominally elevation 313 to 315.

It is believed that settlement of the pump house resulted from both the first and the second filling of the reservoir, as shown by the interpretation of the settlement data in Figure 7E of Vepco's testimony of April 27, 1979. The third filling does not appear to have caused additional settlement.

As shown in Figure 11A of Vepco's testimony, most of the piezometers near the pump house did not respond to any filling of the reservoir; they appear to have indicated primarily the drawdown in groundwater level caused by excavating the pit (to elevation 269) required for the installation of the horizontal drains. Piezometer P-14, however, did respond to the several fillings. This piezometer was installed in an angled borehole so that it is located beneath the pump house, as shown in Figure 9 of Vepco's testimony. It appears that the increase in weight of the pump house when the pump intake bays filled with water as the reservoir was filled tended to compress the pocket of water-filled sand surrounding the piezometer tip and to cause an increase in water pressure in the sand pocket. Thus, filling and emptying the reservoir resulted in rising and falling readings at piezometer P-14 that are not believed to represent the general groundwater level beneath the pump house.

Interrogatory 9: Is the pump house "punching into the liner" of the reservoir?

Vepco Response: We do not agree with the NRC statement that the pump house "punches into the liner material." Prior to filling the reservoir with water, the settlement of the pump house resulted from the compression or consolidation of the thick layer of underlying saprolite due to the increase in

stress in this layer caused by adding the weight of the pump house. The imposed stress spreads out over a wider and wider area with depth below the pump house, so settlement of the top of the saprolite layer extends some distance out from the walls of the pump house. Even though there is no load applied to the top of the clay liner next to the pump house, it settles equally with the pump house. Thus, the pump house does not "punch" into the liner.

Interrogatory 10: If the situation demands it, would it be possible to construct another pump house for Units 1 and 2 at North Anna? On what site?

Vepco Response: If the Units 1 and 2 Service Water Pump House were abandoned or removed, a new pump house could be constructed in the immediate vicinity of the existing pump house. Such a location would permit the most efficient connections to the existing service water lines and spray piping in the reservoir. Such a second pump house would not be immune to settlement itself, and it would be a needless expense.

Interrogatory 11: What remedial action, if any, is VEPCO currently considering or planning to deal with the Unit 1 pump house settlement at North Anna?

Vepco Response: There is no further remedial action required to deal with the pump house settlement. The expansion joints

installed in the service water lines can safely accommodate movements caused by future settlement well in excess of the allowable settlement in the current Technical Specification, as described in Vepco's Testimony of April 27, 1979.

Interrogatory 12: What effect have the heavy rains of 1978 and 1979 had upon the foundation conditions at North Anna?

Vepco Response: Several periods of heavy rainfall occurred during 1978 and 1979, such as 2.2 inches of rain in a two-day period in late January 1978, 3.7 inches in late April and early May, 1.6 inches in a three-day period in late June, and over 3 inches in a five-day period in January 1979. No correlation can be identified, however, between these periods of heavy rainfall and the settlement of the pump house. Even the groundwater levels measured at piezometers in the vicinity of the pump house are not clearly related to periods of heavy rainfall; an occasional reflection of a heavy rain can be seen in one piezometer or another, but these are typically small fluctuations.

The outflow from the horizontal drains installed beneath the pump house, on the other hand, is strongly related to periods of heavy rainfall. A heavy rain can practically double the outflow rate. The drains rapidly remove the excess groundwater and protect against fluctuations in groundwater level that might induce further settlement.

Request for Documents 13: Provide copies of all Stone & Webster notes and memoranda related to settlement inspection visit of April 13, 1978.

Vepco Response: Copies of all Stone & Webster notes and memoranda related to the settlement inspection visit on April 13, 1978, are attached. Entries that do not relate to pump house settlement or horizontal drains have been deleted as irrelevant.

Attachment 1 is a record of a telephone conversation on March 30, 1978, between C. M. Robinson, Jr., of Vepco and B. N. MacIver of Stone & Webster indicating the date of the visit and identifying the geotechnical monitoring data that should be available to the NRC staff during the visit.

Attachment 2 is a copy of the rough notes by B. N. MacIver during a meeting with Vepco representatives on April 10, 1978, to discuss the site visit.

Attachment 3 is a copy of the rough notes by B. N. MacIver during the site visit on April 13, 1978.

Attachment 4 is a list of attendees at a meeting during the site visit on April 13, 1978.

2349 014

Request for Documents 14: Provide copies of all VEPCO notes and memoranda related to settlement inspection visit of April 13, 1978, including Mr. Kip Robinson's log entries.

Vepco Response: The notes of C. M. Robinson, Jr., and Carroll Chewning are attached. (The copy of Mr. Chewning's notes has been touched up by hand to make it more legible.) Entries that do not relate to pump house settlement or horizontal drains have been deleted as irrelevant.

2349 015

Request for Documents 15: Provide copies of all correspondence with and from Dr. R. Torrence Martin, Clay Minerologist of Lincoln, Massachusetts, regarding North Anna foundation materials and behavior.

Vepco Response: Copies of all correspondence with and from Dr. R. Torrence Martin, clay mineralogist of Lincoln, Massachusetts, regarding North Anna foundation materials and behavior are attached as follows:

Attachments 1, 7, and 8 are copies of Stone & Webster purchase orders for Dr. Martin's services, while attachments 3 and 6 are copies of cost statements submitted by Dr. Martin (no such statement can be found for services performed under Purchase Order No. E-18425). The dollar amounts have been deleted.

Attachments 2 and 4 are technical reports by Dr. Martin dated March 22 and May 22, 1976, respectively, on the mineralogy of residual soil and saprolite in the vicinity of the Service Water Reservoir.

Attachment 9 is a technical report by Dr. Martin dated December 22, 1976, on the mineralogy of saprolite beneath the Units 3 and 4 Circulating Water Intake Tunnels. His studies indicated that the mineralogy of this material is different from that of the material in the vicinity of the Service Water Reservoir.

Request for Documents 16: Provide copies of all correspondence with and from Dr. Ralph Peck, regarding North Anna foundation materials and behavior.

Vepco Response: The correspondence is attached.

2349 017

Request for Documents 17: Provide a copy of the letter from the VEPCO junior staff member alluded to in paragraph 2 of the NRC memorandum of March 28, 1978, entitled SUMMARY OF MARCH 16, MEETING TO DISCUSS MATTERS RELATED TO THE SERVICE WATER PUMPHOUSE AND PIPING.

Vepco Response: The letter of March 13, 1978, from W. L. Proffitt to R. B. Bradbury, is attached.

2349 018

Supplemental Interrogatory 1: Who on the Vepco staff prepared the LER regarding rock anchors found on page 5 of NRC's LER Output of 5/20/76? Does VEPCO regard that design deficiency report as essentially correct?

Vepco Response: The rock anchors will be used for North Anna 3 and 4, not North Anna 1 and 2, and so they are irrelevant to this proceeding.

The people who prepared or substantially contributed to the above responses are the following:

Interrogatories 2, 3, 4, 5, 6, 8, 9, 10, 11, 12. . .	.Bruce N. MacIver, Stone & Webster
Interrogatories 1, 7	.objection made
Request for Documents 13, 15	.Bruce N. MacIver, Stone & Webster
Request for Documents 14	.C. M. Robinson, Jr., and Carroll Chewning, Vepco
Requests for Documents 16, 17.	.Charles E. Sorrell, Vepco
Supplemental Interrogatory 1	.objection made

2349 019

QUESTION 13, ATTACHMENT 1, PAGE 1 OF 2 PAGES

NOTES OF TELEPHONE CONVERSATION
NORTH ANNA POWER STATION - Units 1&2

STONE & WEBSTER ENGINEERING CORPORATION
J.O. 11715/12050

2.1.F1
7/77

Call Date 3/30/76

Time 1600

FROM	TO		
✓		C.M. Robinson, Jr.	OF VEPCO
			OF WESTINGHOUSE
	✓	R.N. MacIver	OF STONE & WEBSTER
			OF

SUBJECT Site visit by NRC to review geotechnical monitoring records

SUMMARY Prompted by a letter to the NRC from Mrs. June Allen dated January 24, 1976, Lyman Heller of the NRC staff has requested that he be able to visit the site (tentatively scheduled for April 13 or 14) to review, among other things, the following geotechnical monitoring data:

1. Performance of the horizontal drains under the Units 1 and 2 Service Water Pump House, including the time-history of flow rates and the potential for clogging
2. Settlement of the Units 1 and 2 Service Water Pump House since monitoring began

(SUMMARY CONTINUED ON PAGE 2)

ACTION REQUIRED Several types of monitoring data must be up-dated and plots prepared that are suitable for becoming public documents.

DISTRIBUTION:
ALL Tel Cons with VEPCO

- [ ] W.V. Harrison VEPCO
- [ ] ~~T.R. Boyer VEPCO~~
- [ ] E. Lintner VEPCO
- [ ] W. Chamberlain
- [ ] M.A. Salvi
- [ ] R.B. Bradbury
- [ ] ~~G.L. Bisset~~ Originator
- [ ] File Job Bk.

ALL which affect FIELD efforts;

- [ ] A.A. Dasenbrock
- [ ] R.J. Daly-NA
- [ ] F. DiCesare
- [x] G.J. Burroughs
- [ ] FIC-North Anna

Misc. for information dissemination

ALL which cause "Expansion of scope" or "cost increase", signature below is required BEFORE distribution;

sig: R A Bradbury
Project Engineer

2349 020

C.M. Robinson, Jr., Vepco 3/30/78

B.N. MacIver, S & W 1600

SUMMARY (CONTINUED):

3. Piezometer readings
4. Settlement of the service water spray piping
5. Settlement of the Units 3 and 4 Service Water Pump House
6. Settlement of the Units 1 and 2 Circulating Water Intake Structure with respect to the service water lines
7. Horizontal movement of the Units 1 and 2 Circulating Water Intake Structure

This is to be a low-key viewing of data in the field and nothing has to be sent to Lyman Heller in advance. However, the possibility is not excluded that he may wish to have copies of some documents and these then would become public.

Robinson will come to Boston earlier in the week of the site visit to review the data to be presented to Lyman Heller.

QUESTION 13, ATTACHMENT 2

10 APR 78
ENM

MEETING WITH VEPCO
ABOUT SITE VISIT

Kip Robinson
Gene Brown
Carroll Chewning
Nusi Georges
Bruce MacIver
S.N. Purohit
Glenn Gardner.
W.B. Dodson

To site on Thursday:

MacIver
Bradbury
Dodson
Purohit

Stoneridge
Heller, start at 9:00 - 10:00 Thursday

At Staunton

Heller's purpose of visit is to answer Allen's letter of 24 Jan

- Service water lines analysis:

41,100 psi allowable.

0.2 # 32,500 NOT CHECKED
0.15 # 31,000

- Spray piping
per 15 # 2.6 in.

2349 022

QUESTION 13, ATTACHMENT 3

SITE VISIT BY LYMAN HELLER

First, tour of site ... then chicken ...
Back in conference room at 1230.

Flow from horizontal drains
Piezometers at Units 1 and 2 SWPH
Settlement of Units 1 and 2 SWPH
Settlement of Units 3 and 4 SWPH
Analysis of service water lines at SWPH
Settlement of spray piping

QUESTION 13, ATTACHMENT 4.

ATTENDANCE LIST

VEPCO MEETING 4/13/78 AT NORTH ANNA

NAME	AFFILIATION	DISCIPLINE	TELEPHONE NO.
Lyman Heller	U.S. NRC	Geotech. Engr.	301-492-7973
Daniel M. Gillen	U.S. NRC	Geotech. Engr.	301-492-7972
Carroll G. Chewning	VEPCO	Asst. Project Engr.	804-771-3374
Surendra N. Purohit	S&W	Lead Engineer (Engineering Mechanics)	
R. B. Bradbury	S&W	Project Engr.	
C. M. Robinson, Jr.	VEPCO	Civil Engineer	804-771-3894
Robert M. Neil	VEPCO	Licensing Engineer	804-771-4494
E. L. Brown	VEPCO	Civil Engineer	804-771-3736
A. S. Lucks	S&W	Chief Geotech. Engr.	
B. N. MacIver	S&W	Senior Soils Engineer	
W. B. Dodson	S&W	Project Engr.	

2347 024

3.30.78
Lynn Heller
Wants ½ visit NA

Question 14 -
Robinson notes (2 pages)

settlement of purchase, see plots, w/ time, + pressure readings w/ time

List for NRC Mtg @ NA, 4.13.78:

1. Plots of settlement
   a. Spray Piping
   b. SWPH 1&2

2349 U25

4.13.78

NORTH ANNA

MTG. w/ NRC on Geotechnical Mts.

Vepco	NRC	S&W
Bob Neil	L. Heller	S. Lucks
C. Channing	D.M. Gillen (Don)	B. MacIver
EL Brown		Bradbury
CMR Jr.		Dodson
		Purdit
		Fiorentes
		Lucks

Horizontal Drain Performance: ∈ last drain complete Aug. 28, '77; elev. of piezometers: P-10 (270.8), P-12 (269.4), TW-1 (275.9, 9-8-77), P-11 (dry) 275.4); no maintenance on drains since installation; bacteria sampled - August -; chlorine treatment will be performed this year; showed him plot of drain discharges; readings have 0 ppm SS & ½ ppm turbidity; latest pieg. readings for 11, 12, 13, 14; piezometers have responded to drains - took plots of piezometric elevations & flow

Settlement: 0 ft in '77 @ installation of horiz drains; told him not 75% threshold level; does reservoir filling tend to "outlift" reservoir - unable to tell; took spray piping locations;

Question 14 -
Chewning notes (1 page)

4-13-78 meeting At Site
with Dr. Lyman Heller
+ David Gillen of NRC

Vapco
Kip Robinson, Gene Brown, Carroll Chewning, Neil

S+W
Bob Bradbury
Brad Dodson
S. Purohit
Bruce McIver

Morning - took tour of S. W. P. H., horizontal drains

Lunch

Afternoon - Conference Rm

Horizontal Drains - ≈ 1½" perforated pipes to carry off ground water
Bruce McIver graphed piezometers readings to
Dr. Heller + discussed these relative to installation of drains

Service Water Pumphouse Settlement - Bruce McIver
Dr. Heller not concerned with our present handling

THIS COPY TO ☐ PURCH DEPT ☐ PROJECT ACCOUNT DIV ☐ CLIENT ☐ FIELD ACCT'ANT ☐ LOCAL PURCH AGENT ☐ MATERIAL DEPT. ☐ COST DIV. ☐ ENGINEER DEPT. ☐ INSPECTOR ☐

☐ PARTIALLY ☒ COMPLETELY

FILLS REQ. NO. 17429

OF J. H. Bryant

TO BE USED FOR

ACCOUNT NO. 8100 13100 118760

PURCHASE ORDER

STONE & WEBSTER ENGINEERING CORPORATION

P. O. BOX 2325, BOSTON, MASSACHUSETTS 02107

P. O. NO. E-17561

PAGE 1 OF 2

J. O. NO. 11715

TO

Dr. R. T. Martin

South Great Road

Lincoln, MA 01773

DATE February 10, 1976

THE ABOVE PURCHASE ORDER AND JOB OFFICE NUMBERS MUST APPEAR ON ALL INVOICES AND CORRESPONDENCE

TERMS Net 30 days

PRICE FOR See below

PREPAY CHARGES IF PURCHASED F.O.B. DESTINATION

SHIPMENT DUE See below

SUBMIT REPORT TO:

Stone & Webster Engineering Corporation
Attention Mr. J. H. Bryant
P.O. Box 2325
Boston, MA 02107

ADDRESS ALL CORRESPONDENCE TO THE ABOVE ADDRESS.

SEND INVOICE IN TRIPLICATE TO:

Stone & Webster Engineering Corporation
Attention Mr. W. E. Chamberlain
P.O. Box 2325
Boston, MA 02107

SHIP VIA See below

ITEM NO.	QUANTITY	DESCRIPTION OF MATERIAL	UNIT PRICE	AMOUNT

THE SELLER, BY ACCEPTING THIS ORDER, AGREES TO THE SEVERAL CONDITIONS PRINTED ON THE REVERSE SIDE HEREOF and to the Amendments to "Conditions," attached hereto.

Furnish consulting services for North Anna Units 1 and 2 of Virginia Electric and Power Company as follows:

A. For meeting held in Purchaser's Boston office relative to soil properties and settlement completed on February 4, 1976, for an estimated 5 hr period.

B. For analysis of long-term settlements of structures founded on saprolites.

START - Week of February 9, 1976.

COMPLETION - Six days as required by Purchaser for initial review of consolidation test data and mineralogy.

RATE $ /8 hr day, exclusive of any travel and living expenses. Less than an 8 hr day shall be invoiced on a pro rata basis of above rate.

The above rate is FIRM.

The above Dr. R. T. Martin is an independent contractor and not an employee of Stone & Webster Engineering Corporation.

Purchase order may be terminated by Purchaser at any time by written notice without any additional charge to Purchaser.

2349 028

FPZ:SDA

STONE & WEBSTER ENGINEERING CORPORATION
T. A. Maguire
MANAGER OF PURCHASING

P. O. NO. E-17561

CONTINUATION OF ORDER
A4535 16

STONE & WEBSTER ENGINEERING CORPORATION
P. O. BOX 2325, BOSTON, MASS. 02107

P.O. NO E-17561
PAGE 2 OF 2
J.O. NO 11715
DATE February 10, 1976
THE ABOVE PURCHASE ORDER AND JOB ORDER NUMBERS MUST APPEAR ON ALL INVOICES AND CORRESPONDENCE

TO Dr. R. T. Martin

IMPORTANT: NOTE INSTRUCTIONS ON FIRST SHEET

TAXES - The above rate is exclusive of sales, use, excise, and similar taxes. Such taxes, if applicable, shall be for the Purchaser's account.

This purchase order will not be deemed completed until all the requirements of the order have been complied with, all as stated in the order.

Invoices on this order on an hourly, daily, or other unit basis shall include the individual's name, classification, units worked, price per unit and extension of costs.

Invoices shall also include, where applicable, a breakdown of expense by expense category such as reproductions, travel, telephone calls, wires, meals, hotels, etc.

Seller agrees to furnish such supporting detail, as may be required by Purchaser, to support charges as invoiced and to make available for audit purposes all records covering charges pertinent to this order.

The above rate and other data taken from Seller's verbal quotation to Purchaser's Mr. G. H. Barry on February 6, 1976.

COPIES ONLY:

Client Authorization - Verbal authorization from Client's Mr. F. Prince to Purchaser's Mr. W. H. Chamberlain.

ESTIMATED TOTAL PRICE OF ORDER $

2349 029

FPZ:GDA

STONE & WEBSTER ENGINEERING CORPORATION
T. A. Maguire
MANAGER OF PURCHASING

P.O. NO E-17561

R. TORRENCE MARTIN
Clay Mineralogist
CHIPMUNK CROSSING
LINCOLN MA 01773
617 · 259-8913

MINERALOGY of SOILS at NORTH ANNA
of VIRGINIA ELECTRIC & POWER

The mineralogy of two samples was examined: the major objective to determine the possibility that the somewhat unusual field observed settlements were related to a change in fabric of the clay material. The first requirement for clay fabric study is to know the mineralogy; preliminary mineralogical data are reported here.

Samples were supplied by Mr. Bruce McIver of Stone & Webster Engineering. Identification of the samples for J.O. #11715 was:

Sample 3D, Boring 720, from Turbine Bldg.

Sample 4E, Boring P-11, from Surface Water Resevoir

The mineralogy was determined using X-ray diffraction on random powder and oriented aggregate specimens from different size fractions and for different hydration conditions. The d value range examined was from 35A to 1.7A. The results summarized below are based upon the whole soil.

	Relative Amount in Sample	
	4E	3D
Illite	0.05-0.1	0.05-0.1
Kaolin	0.45	0.3
Quartz	0.15	0.05
Feldspar	0.1	0.5

The relative amounts are a good indication of differences in a particular mineral between the two samples. However, the amount of the various minerals are only rough approximations based upon a linear interpol-

ation of peak amplitudes relative to reference minerals. The major clay kaolin is dominately hydrated halloysite because with no drying, d values of both hydrated and dehydrated halloysite were obtained with the hydrated spacing being the stronger of the two. Halloysite also is indicated by the fact that the clay does not orient at all in sample 4E. The orientation in sample 3D suggests the presence of kaolinite; some kaolinite may be present in sample 4E. In sample 4E the halloysite content is large enough to prevent orientation of the illite as well. Illite as used here includes mica. No smectite was detected in the -2μ fraction; however, the -2μ fraction was obtained without any chemical pretreatment of the sample. The illite in Sample 3D is more mica like than in sample 4E because of the sharpness of the 10A peak. The shape of the 10A peak in both samples was not noticeably changed with hydration state indicating no smectite interstratification.

The presence of halloysite and especially hydrated halloysite should be considered when interpreting bulk density and water content data. For example, standard laboratory compaction of hydrated halloysite gives a maximum dry density of about 70 pcf at an optimum water content of about 45% (HRB, v. 34, pp. 566-82, 1955). Hydrated halloysite converts irreversibly to dehydrated halloysite in about one week at room temperature and 50% relative humidity. Clearly, extreme care in handling of samples is required. A normal water content determination (110°C.) on hydrated halloysite includes water, w= 13.9, that is properly mineral. For sample 4E, this means that as much as 6% of the water content actually belongs to hydrated halloysite.

Fabric means the spatial arrangement of solid particles and associated voids. The halloysite morphology and the high halloysite content precludes measurements on the clay itself as an indicator of fabric change resulting from consolidation.

Other possibilities are to measure the orientation of the sand size particles and/or the size and distribution of voids. Methods are available for measuring fabric or an indicator of fabric on sand size material. (Clays & Clay Minerals, v.22, pp. 397-408, 1974, and Soils & Foundations, v. 12, pp. 17-36, 1972.) Unfortunately, the soils at North Anna contain both sand and clay so that sample preparation for fabric investigation of the sand particles may require considerable effort. Changes in pore size distribution that result from consolidation probably would be the easiest procedure to obtain an indication of fabric change. Sample preparation is again hindered by the requirement of a dry sample for pore size distribution measurement.

R.T.M.

RTM:
22 March 1976

2349 032

QUESTION 15, ATTACHMENT 3

→ J Bryant.

R. TORRENCE MARTIN
Clay Mineralogist
CHIPMUNK CROSSING
LINCOLN MA 01773

617 · 259-8913

22 March 1976

Stone & Webster Engineering Corporation
Attention: Mr. W. H. Chamberlain
P.O.Box 2325
Boston, MA 02107

S T A T E M E N T

Technical services for period
4 Feb thru 22 March 1976 on:
J.O. #11715 (P.O. #E-17561) $

2349 033

MAR 24 197[illegible] Chamberlain
Old Payment

R. TORRENCE MARTIN
Clay Mineralogist
CHIPMUNK CROSSING
LINCOLN MA 01773

617 - 259-8913

MINERALOGY OF SOILS AT NORTH ANNA SITE OF VIRGINIA ELECTRIC AND POWER

The major clay mineral was halloysite. The hydration state of the halloysite varied considerably. The mineralogical data suggested clay mineral contents betweeen 20 and 75 percent with a lot of clay mineral larger than 2μ equivalent spherical diameter.

Preliminary mineralogical work on two samples from North Anna indicated fairly high clay mineral content for the whole soil and also indicated that the clay was high in halloysite (Martin report to Stone & Webster, March 1976). The object of the present study was to examine the mineralogy of a larger suite of samples in order to establish the kind of clay minerals over the site and the clay mineral content over the site. Mr. Bruce McIver of Stone & Webster Engineering supplied the additional samples for this study. The boring, sample number, and depth below original ground surface are shown in Table 1. as supplied by Mr. McIver.

Approximately 200 cm^3 of each soil sample was lightly crushed to have all particles or aggregates smaller than about 3mm. diameter and then thoroughly mixed to ensure a homogeneous sample. A 5 g. whole soil subsample was air dried and crushed so that 100% passed a 74μ sieve.

The -2μ fraction was obtained as follows. A 50 g subsample in distilled water was mixed for 20 min in a Waring blender, poured into a beaker, and diluted with distilled water to give about a 6% slurry. One or two decantations of the clear supernatant liquid gave a stable suspension that was stirred, and allowed to settle 7 hr. so that the top 10 cm contained only particles less than 2μ equivalent spherical

diameter. Oriented aggregate and random powder mounts of the -2μ fraction were prepared for X-ray diffraction, XRD. The XRD was Cu K_α radiation at 40 KV and 20 ma with a goniometer speed of 1° 2θ per min. The XRD data are summarized in Table 1. Halloysite was the major clay mineral in all samples.

Samples 4E and 4F were high in hydrated halloysite because both gave the strong 10.8A peak characteristic of hydrated halloysite. Sample 6B also showed some hydrated halloysite. Except for sample 4C the other samples contained interstratified illite-smectite which may have masked the presence of hydrated halloysite. All samples showed a marked increase in amplitude of the 7.3A peak on drying suggesting that the halloysite was at least partially hydrated. This amplitude increas must have come from collapse of the halloysite because drying produced no change in the amplitude of the 020 clay peak. The basal spacing of 7.3A and the resistance to orientation were two further suggestions that the kaolin mineral was halloysite.

The amplitude ratio of the 001 halloysite peak to the 020 clay peak in sample 4F was 1.1 compared to 1.2 for the reference halloysite, when both specimens were random powder mounts. The oriented aggregate mount for sample 4F gave 001/020 of only 3.7 The amplitude ratio 001/020 for oriented aggregate mounts of the clay minerals illite, smectite, or kaolinite would be several hundred. The highest 001/020 kaolin amplitude ratio was 11 for oriented aggregate mounts on samples 1F and 7C. The kaolin mineral must be halloysite. This very modest orientation may have been due to orientation of the smectite and illite minerals or to the presence of platy halloysite particles. The scanning electron microscopic examination of sample 4F showed abundant platy particles with maximum dimension of 0.5μ or less which must be halloysite particles rather than kaolinite because the basal spacing is too high for kaolinite and the very modest orientation effect observed would be inconsistent with any significant kaolinite concentration.

Smectite was detected in 4 of the seven samples. The smectite in sample 1F was clearly a separate phase because 5 orders of the basal sequence were observed in the hy-

drated state. Drying at 300°C. gave an illite peak at 10A and the dehydrated smectite peak at 9.7A. Since no 10A peak was observed in the hydrated state, it was inferred that the illite was part of an interstratified illite-smectite, I/S, phase as distinct from the separate smectite phase. Samples 4C, 4E, and 4F showed no change in the 10A peak with hydration state; therefore, interstratified illite-smectite was presumed absent.

Two ~~of~~ the -2μ fraction samples contained crystalline phases other than the three clay minerals listed in Table 1. Sample 1F contained a small amount of feldspar, but no quartz. Presumably the feldspar was from small unweathered fragments attached to halloysite aggregates. X-ray diffraction peaks at 6.3 and 4.2A in sample 7C were attributed to lepiocrocite and goethite respectively because heating to 300° C destroyed both peaks and gave the hematite peak at 2.69A.

Relative amount of clay species in Table 1 were based on Bedford, Indiana halloysite; Wyo. montmorillonite; and Illinois illite. The relative amount is directly proportional to the weight fraction present only when two conditions are satisified. These conditions are: 1) the soil mineral being determined has XRD characteristics identical to the reference mineral used; and 2) the mass absorption coefficient of the soil sample is identical to that of the reference mineral used. For the suite of samples under investigation, the reference minerals for illite and smectite are probably reasonable and the halloysite reference mineral probably gives an under estimation of the halloysite content. Mass adsorption coefficients to Cu K_α radiation for halloysite, smectite, and illite are 31, 40, and 50 respectively. Not making allowance for iron present in the mass absorption coefficient for the sample, exclusive of that in the clay mineral structure, the most serious error in relative amount would be under estimation of the halloysite content. The magnitude of the under estimation of halloysite are likely to vary from a low of about 15% under estimation for sample 1F to as much as 100% under estimation for sample 7C because of the hydrous iron oxide content. The ralative amount of smectite and illite are not changed much because of their higher mass absorption coefficients and because they are present in lesser amount.

Three estimates of clay in the whole soil are given in Table 1. The minimum percent clay mineral was obtained in the absence of any mass absorption correction to the -2μ fraction. The probable clay mineral percentage in Table 1 was calculated making absorption coefficient correction after first using a guess of the iron content not in the clay mineral structures. By the use of what are believed to be extremes in the range of iron content the error in probable clay mineral percent is ± 5 irrespective of the actual value which means that the percentage error decreases as the clay mineral content increases.

The calculation in the last column of Table 1 used XRD data from the -2μ fraction and from the whole soil. Since the - 2μ fraction was <100%<2μ, then the amplitude ratio 020 peak from the whole soil to 020 peak from the -2μ fraction represents the percent -2μ in the whole soil. This procedure has several implicit assumptions: 1) the clay minerals in the -2μ fraction and the whole soil are the same; 2) the mass absorption coefficient of the -2μ fraction and the whole soil are the same; and 3) clay minerals occur only in the -2μ fraction. That the clay minerals are the same is considered reasonable. Any decrease in mass absorption coefficient in the whole soil relative to the -2μ fraction from probable dilution of free iron oxide content between the -2μ fraction and the whole soil tends to be offset by the increase in mass absorption coefficient for the whole soil relative to the -2μ fraction due to the potash feldspar content of the whole soil. It is probable that free iron oxides are present in larger particle sizes as coatings on these particles. Therefore, one would expect assumption 2 to be a reasonable first approximation. The disparity between the last two columns in Table 1. is considered at least partly due to clay mineral in the greater than 2μ size.

To recapitulate, all samples contain halloysite as the major clay mineral and there is a sizeable fraction of the soil that is clay mineral.

R. Torrence Martin
22 May 1976

Table 1. Summary of Clay Mineral Data on Samples from North Anna Power Station*

Depth Below Original Ground (ft.)	3	14	26	26	27	60	77
Boring	P-10	P-11	SWR-5	SWR-7	SWR-4	SWR-3	SWR-4
Sample	1F	4E	4C	7C	2A2	4F	6B
Clay Size Fraction (Relative Amount)							
Halloysite	0.35	0.50+	0.30	0.20	0.45	0.45+	0.40
Illite	0.02	0.08	0.20	0.10	0.15	0.10	0.15
Smectite	0.20	0	0.04	0.03	0.01	0	0
Whole Soil							
Clay Mineral (%)							
Minimum	15	20	15	15	20	10	5
Probable	25	30	25	25	30	15	10
-2μ Size (%) (from XRD)	40	45	55	75	45	20	20

- - - - - - - - - - -

* see text for details
\+ high in hydrated halloysite

2349 038

QUESTION 15, ATTACHMENT 6.

John C.

R. TORRENCE MARTIN
Clay Mineralogist
CHIPMUNK CROSSING
LINCOLN MA 01773
617 · 259-8913

8 July, 1976

Mr. W. H. Chamberlain
Stone & Webster Engineering Corp.
P. O. Box 2325
Boston, MA 02107

S T A T E M E N T

Reference Job #11715; P. O. #E-17561

14 June presentation to ~~EBBA~~ NRC $

off to pay
Charge 11715
JUL 12 1976 Chamberlain
W Chamberlain

2349 039

QUESTION 15, ATTACHMENT 7

THIS COPY TO: [ ] PURCH. DEPT. [ ] PROJECT ACCOUNT. DIV. [ ] CLIENT [ ] FIELD ACC'TANT [ ] LOCAL PURCH. AGENT [ ] MATERIAL DEPT. [ ] COST DIV. [ ] ENGINEER DEPT. [ ] INSPECTOR [ ]

[ ] PARTIALLY [X] COMPLETELY

FIELD REQ. NO. 14923

OF J. H. Bryant

TO BE USED FOR

ACCOUNT NO. 8100.13100 118760

MEMO OF CHANGES

VIRGINIA ELECTRIC AND POWER COMPANY
STONE & WEBSTER ENGINEERING CORPORATION, AGENT
P O BOX 2325 BOSTON, MASSACHUSETTS 02107

P O NO E-17561-A

PAGE 1 OF 1

J O NO 11715

TO

Dr. R. T. Martin

South Great Road

Lincoln, MA 01773

DATE July 15, 1976

▲ THE ABOVE PURCHASE ORDER AND JOB ORDER NUMBERS MUST APPEAR ON ALL INVOICES AND CORRESPONDENCE

INSTRUCTIONS

These instructions supersede all prior agreements insofar as they affect changes herein specified

Manufacturers and contractors will acknowledge these instructions without reservation or modification

THE SELLER MUST SIGN AND RETURN AT ONCE TO THE ABOVE ADDRESS THE ACCEPTANCE COPY OF THIS MEMORANDUM OF CHANGES

ISSUED FOR ACCOUNTING PURPOSES ONLY. ORIGINAL AND ACCEPTANCE COPY DESTROYED.

Please refer to Purchase Order No. E-17561 dated February 10, 1976, covering consulting services and note the following:

Increase the estimated total price of order in the amount of $

Previous Estimated Total Price of Order	$
Increase by this Memo. of Changes	
Revised Estimated Total Price of Order	$

Client Authorization - Verbal from Client's Mr. F.Prince to Purchaser's Mr. W. H. Chamberlain on June 15, 1976.

All other terms and conditions remain unchanged.

2349 040

Virginia Electric and Power Company

CRB:MLQ

STONE & WEBSTER ENGINEERING CORPORATION, Agent

T. A. Maguire

MANAGER OF PURCHASING

P O NO E-17561-A

QUESTION 15, ATTACHMENT 8, PAGE 1 OF 2 PAGES

THIS COPY TO: ☐ PURCH DEPT. ☐ PROJECT ACCOUNT DIV. ☐ CLIENT ☐ FIELD ACCTANT ☐ LOCAL PURCH AGENT ☐ MATERIAL DEPT. ☐ COST DIV. ☐ ENGINEER DEPT. ☐ INSPECTOR ☐

☐ PARTIALLY ☒ COMPLETELY

FILES REQ. NO. 31898

OF R. T. DeConto

TO BE USED FOR: Consulting Services

ACCOUNT NO.: 8100.1310911 8760

COMPLETED

PURCHASE ORDER

A 4530.45A(5) (8/76)

STONE & WEBSTER ENGINEERING CORPORATION
P. O. BOX 2325, BOSTON, MASS. 02107

P.O. NO. E-18425

PAGE 1 OF 2

J.O. NO. 12180

TO

Dr. R. T. Martin
Chipmunk Crossing
Lincoln, MA 01773

DATE: November 22, 1976

THE ABOVE PURCHASE ORDER AND JOB ORDER NUMBERS MUST APPEAR ON ALL INVOICES AND CORRESPONDENCE

TERMS: Net cash

PRICE FOR: See below

PREPAY CHARGES IF PURCHASED F.O.B. DESTINATION

SHIPMENT DUE: See below

~~SHIP TO~~ Submit Reports To:

Stone & Webster Engineering Corporation
Attention Mr. R. T. DeConto
P.O. Box 2325
Boston, MA 02107

ADDRESS ALL CORRESPONDENCE TO THE ABOVE ADDRESS

SEND INVOICE IN TRIPLICATE TO:

Stone & Webster Engineering Corporation
Attention Mr. J. Prior
P.O. Box 2325
Boston, MA 02107

SHIP VIA: -

ITEM NO.	QUANTITY	DESCRIPTION OF MATERIAL	UNIT PRICE	AMOUNT

THE SELLER, BY ACCEPTING THIS ORDER, AGREES TO THE SEVERAL CONDITIONS ATTACHED HERETO AND MADE A PART HEREOF, and to the Amendments to "Conditions," revised July 9, 1976, attached hereto.

THIS CONFIRMS VERBAL ADVICE TO DR. R. T. MARTIN BY PURCHASER'S MISS P. J. HENDRICKSON ON NOVEMBER 10, 1976.

Furnish consulting services for North Anna Units 3 and 4 of Virginia Electric and Power Company as follows:

Perform X-ray diffraction tests on clay fraction of six samples.

The results of these tests are to be used in analyses of settlements of Units 3 and 4 intake tunnels.

START - Immediately.

RATE - $ /8 hr day, exclusive of any travel and living expenses. Less than an 8 hr day shall be invoiced on a prorata basis of above rate.

The above rate is FIRM.

2349 041

The above Dr. R. T. Martin is an independent Contractor and not an employee of Stone & Webster Engineering Corporation.

P.O. NO. E-18425

STONE & WEBSTER ENGINEERING CORPORATION

T. A. Martino
MANAGER OF PURCHASING

PJH:EM

NOTED

CONTINUATION OF ORDER

STONE & WEBSTER ENGINEERING CORPORATION
P. O. BOX 2325, BOSTON, MASS. 02107

P. O. NO. E-18425

PAGE 2 OF 2

J. O. NO. 12180

TO

Dr. R. T. Martin

DATE November 22, 1976

THE ABOVE PURCHASE ORDER AND JOB ORDER NUMBERS MUST APPEAR ON ALL INVOICES AND CORRESPONDENCE

IMPORTANT: NOTE INSTRUCTIONS ON FIRST SHEET

REPRODUCTION OF REPORTS - The Purchaser reserves the right to reproduce any and all reports necessary for Purchaser's purposes received from the Seller on this Purchase Order despite any notice prohibiting the same on the document.

Purchase order may be terminated by Purchaser at any time by written notice without any additional charge to Purchaser.

TAXES - The above rate is exclusive of sales, use, excise, and similar taxes. Such taxes, if applicable, shall be for the Purchaser's account.

This purchase order will not be deemed completed until all the requirements of the order have been complied with, all as stated in the order.

Invoices on this order on an hourly, daily, or other unit basis shall include the individual's name, classification, travel, telephone calls, wire, meals, hotels, etc.

Seller agrees to furnish such supporting detail, as may be required by Purchaser, to support charges as invoiced and to make available for audit purposes all records covering charges pertinent to this order.

The above rate taken from Seller's verbal quotation to Purchaser's Miss P. J. Hendrickson on November 10, 1976.

COPIES ONLY:

Client Authorization - Client's Mr. Carl W. Pennington to Mr. E. H. McCallig - VEPCO correspondence NCS-3227 dated October 19, 1976.

ESTIMATED TOTAL PRICE OF ORDER $

2349 042

PJH:EM

STONE & WEBSTER ENGINEERING CORPORATION

T. A. Maguire
MANAGER OF PURCHASING

P. O. NO. E-18425

R. TORRENCE MARTIN
Clay Mineralogist
CHIPMUNK CROSSING
LINCOLN MA 01773

617 - 259-8913

Mr. R. T. DeConto
Stone & Webster Engineering Corporation
P. O. Box 2325
Boston, MA 02107

Dear Mr DeConto;

Preliminary mineralogical data on samples from North Anna Units 3 & 4 (Job #12180) are reported. The mineralogy was based upon X-ray diffraction, XRD, data.

Comparison of data for whole soil to data from previous North Anna samples indicates several marked differences in the present sample suite:

1) Kaolin is not the dominant clay phase in any sample.
2) Hornblende is abundant in samples 5, 2B1, & 8.
3) Feldspars and quartz are very low in samples 5, 2B1, & 8.

Sample 1 contains illite with no expandable layers as the only clay phase; therefore, fractionation of this sample was omitted.

X-ray diffraction data from the fine fraction are summarized in the lower part of Table 1. The mineralogy is very different from previous North Anna samples. Kaolin is present in all but sample 1 but in no sample is kaolin the dominant clay phase. The kaolin basal spacing is large for kaolinite and the intensity o f the basal peak is greatly enhanced by oven drying, both of these features suggest halloysite that is partly hydrated. The 020 clay peak disappeared completely upon orientation for sample 2B1 and 4. The very strong assymetrical shape characteristic of the halloysite 020 peak was lacking in all samples. Therefore, the XRD data from the 020 peak strongly suggest that the kaolin mineral is kaolinite, not halloysite. Because of the contrasting data between basal and 020, the identity of the kaolin mineral species remains uncertain. The relative quantity given for kaolin in Table 1 was based on halloysite in order to provide a direct comparison with previous data.

The 2:1 layer silicate phases in sample 4 were dominately illite with a small percentage of smectite layers. For samples 5, 2B1, and 8, the expandable phase or phases were decidedly different from that present in previous samples. A peak of 12A upon glycerol treatment was attributed to vermiculite because, while drying at 300°C collapsed the peak to 10A, room humidity caused rapid reexpansion. For sample 8, 30 hrs of drying at 300°C were required to essentailly eliminate the rapid rehydration. Sample 8 also gave a long spacing at 26.8A indicative of complex interlayering of 2:1 layer components. The 17.7A expanded phase and illite relative amounts given in Table 1 are with relation to smecite and illite from earlier North Anna samples.

Clearly the present suite of samples from North Anna have different mineralogy from previous samples. You may want to consider these preliminary data before proceeding in any more detail. I look forward to hearing from you.

Sincerely yours,

R. Torrence Martin
22 December 1976

Table 1. Mineralogy from XRD Data on Soil Samples from North Anna Power Station

Identification:		Relative Amount				
boring		703	706	705	704	701
sample		4	5	2B1	8	1
Whole Soil						
clay		0.10	0.10	0.24	0.25	0.15
quartz		0.15	0.10	0	0	0.35
feldspar		0.5	0.1	0	0.1	0.60
hornblende		0	0.10	0.4	0.5	0
Fine Fraction:						
Clay						
kaolin		0.16	0.04	0.11	0.06	(see
illite		0.55	0.10	0.01	0	
expandable	26.8A	0	0	0	0.05	text)
"	17.7A	0.02	0	0.08	0.02	
"	12.A	0	0.10	0.08	0.50	
Nonclay						
quartz		0	0	0	0	
feldspar		0.2	0.15	0	0	
hornblende		0	0.08	0.25	0.50	

Question 16 -
Peck Correspondence

RBP

RALPH B. PECK CIVIL ENGINEER: GEOTECHNICS

17 January 1976
J938

Mr. Stanley Ragone
Senior Vice President
Virginia Electric and Power Company
Richmond, Virginia 23261

Subject: North Anna Power Station
Service Water Pump House Settlement

Dear Mr. Ragone:

In accordance with your request, I have reviewed the documents forwarded with your letter of 2 January 1976 concerning the geotechnical data and settlements of the SWPH for Units 1 and 2.

The compressible portion of the subsurface materials beneath the Pump House and the adjacent dike consists of residual soil and highly weathered bedrock, most of which is designated a saprolite because it retains a structure inherited from the parent rock. The settlement characteristics of such materials, particularly with respect to the rate at which the settlement may continue with time, are not as predictable from the results of soil tests and calculations as are corresponding characteristics and behavior of sedimentary soils. Under these circumstances, the most reliable procedure for settlement prediction is to combine the results of conventional settlement forecasts with measurements of settlement of the prototype at early stages of construction, and to revise the estimate in accordance with the findings. This procedure has been used by Stone and Webster in their revisions of estimated settlement. Hence, I am in agreement with their general approach.

As might be expected in view of the nature of the subsu - face materials, several interpretations of the laboratory data and of the observed settlement are possible. Rather than comment step by step on the Stone and Webster forecast, I shall indicate my own reasoning in this letter. Since the results

1101 WARM SANDS DRIVE, S.E. ALBUQUERQUE, NEW MEXICO 87123 505-292-2484

of the two forecasts are not greatly different, the difference in procedure may be regarded as largely academic.

The consolidation tests on samples of the saprolite resulted in time-compression curves that displayed very rapid compression in the first quarter minute, followed by a much slower compression. The volumetric data indicate that the samples were only about 75 per cent saturated at the time the consolidation tests were started (see Table 1). Hence, the sudden compression of the samples is indicative not of the hydrodynamic time lag known as primary consolidation, but of instantaneous compression of air voids. After the initial rapid compression, unsaturated specimens continue to deform under load at a rate that decreases with time. The rate is sometimes linear with respect to the logarithm of time and thus corresponds to typical secondary consolidation, but the mechanism responsible for the movement is more complex than that associated with secondary consolidation for saturated soils and does not necessarily follow the same laws.

Samples of saprolites sometimes expand either while they are being taken or while they are being prepared for testing. This expansion reduces the degree of saturation. It is unlikely, however, that sampling or testing disturbance could account fully for the relatively low degree of saturation of the test specimens. The vertical strain required to eliminate the air voids in one-dimensional compression can readily be calculated and is shown in Table 1. By means of the curves of strain vs. consolidation stress for the samples, Fig. 1, the vertical pressures can be determined that would be necessary to eliminate the air voids and cause the samples to be completely saturated. These pressures vary considerably for the various samples, as seen in Table 1, but are generally on the order of 17 kips per square foot or more. None of the time-compression curves plotted in the furnished documents corresponds to pressures large enough to saturate the samples, with the possible exception of one of the curves for test No. 10. For this sample, the pressure to produce saturation was about 8 kips per square foot. The time-compression curve for a load of 8.13 kips per square foot shows a far greater rate and amount of delayed settlement than any other. Hence, it is likely that this curve is influenced by primary consolidation. Under the

dike and SWPH, however, the applied loads are generally not great enough to produce saturation.

No rational and proven procedure yet exists for relating the rates of delayed compression determined from laboratory tests on unsaturated saprolites to those observed in the field. In the field, the structure of an unsaturated saprolite crushes to some extent under load. The crushing is a function of the applied stress. It occurs rapidly as the load is applied and continues at a decreasing rate for some months thereafter. Unlike secondary consolidation, which usually continues to decrease logarithmically with time, the settlement of an unsaturated saprolite may practically cease, as illustrated by the behavior of the SWPH from May to November, 1975, when no settlement was experienced at all (Fig. 2).

In my judgment, a reasonable estimate of the settlement of the SWPH due to increased stress in the saprolite can be made in the following manner: Reference to Fig. 3 indicates that the more compressible part of the residual material, with a standard penetration resistance of less than 100 blows per foot, has a thickness of about 40 feet beneath the SWPH and the adjacent dike. On the simplifying assumption that the compressibility of the residual material is approximately the same throughout the 40-foot depth, the strain can be determined by dividing the vertical settlement by 40 feet. At the time the fill for the dike was at elevation 318, the added load was about 2.3 kips per square foot and the settlement of the point at the NW corner of the SWPH (the point of maximum settlement) was leveling off at about 0.26 feet. The corresponding vertical strain was, therefore, 0.65 per cent. The dike was then completed by raising its crest to elevation 327.5, whereupon the average stress was increased to about 3.5 kips per square foot. By extrapolating in Fig. 1 from point A, representing a strain of 0.65 per cent and a stress of 2.3 kips per square foot, along a path roughly parallel to the family of strain - log pressure curves from the consolidation tests, to point B corresponding to a stress of 3.5 kips per square foot, a strain of 1.2 per cent is obtained. The corresponding settlement would be 0.012 times 40 feet, or 0.48 feet. The actual settlement (Fig. 2) several months after this stage of construction appeared to be approaching 0.44 feet until the rate increased sometime in September, 1974. Unusually great rainfall occurred

in September, as shown also in Fig. 2, and appears to have produced further settlement. A second acceleration of settlement occurred in January 1975, following relatively heavy December and January rains.

In the preceding calculations, the stresses used are those at the base of the embankment. At greater depths, the initial overburden stresses are appreciable and should theoretically be taken into account. Furthermore, consideration should also theoretically be given to the decrease in compressibility of the saprolite with depth, which has a compensating effect. However, the essential feature of the simple procedure used for the settlement prediction is extrapolation along a curve parallel to the general family of laboratory strain - log pressure curves; complicating the procedure would not significantly alter the results.

Values of compressibility used initially by Stone and Webster were based on the slopes of recompression curves, on the assumption that such slopes more nearly represent the compressibility of the undisturbed soil in place. The procedure I have suggested, which appears to check reasonably well with measurements, takes the initial curved portion of the strain - log pressure curve at face value. In my view, the flat shape of the unloading and reloading curves corresponds to the behavior of the crushed structure of the saprolite, which may differ considerably from the original open structure. Hence, I believe the laboratory curves without correction are a better first approximation. The difference possibly accounts in large measure for the initial underestimate of settlement.

The effect of adding 10 feet of water in the reservoir should be small at the north end of the SWPH and a maximum at the south end. Hence, the effect of reservoir filling should be to reduce the differential settlement of the pump house. The settlement at the south end can be estimated with sufficient accuracy by interpolation on the curve showing the settlement as a function of the stress due to the weight of the dike (Insert, Fig. 2). The value is found to be about 0.06 feet.

According to the foregoing considerations, the settlement of the north end of the SWPH should not appreciably exceed the

present maximum value, even on addition of the weight of the reservoir. However, other possible reasons for settlement must also be considered.

A substantial part of the total settlement of the NW corner (about 0.12 feet) that has actually been experienced appears not to be associated with increase in load. Probably, as suggested by Stone and Webster, it can be attributed to rainfall. Two mechanisms are conceivable: increase from moist to saturated weight of the fill and possibly of the upper part of the unsaturated subsoil; and weakening of the bonds between the particles of the saprolite due to an increase in moisture content. Both effects should produce greater settlements of the north than the south side of the pump house. Yet, in reality the settlements attributed to rainfall have been almost equal. No explanation other than possible variation in compressibility of the subsoil is evident for the anamolous behavior. Furthermore, calculations of settlement of the north side, due to the increase in weight of the select fill in the embankment by saturation, can account for only about 0.06 ft (point C in Fig. 1). Hence, it appears that this potential mechanism for the settlement plays a minor role.

Before construction, the moisture content of the saprolite in the vicinity was probably in equilibrium with rainfall and existing overburden pressures. Beneath the reservoir blanket evaporation will cease but, unless the blanket is seriously defective, infiltration will also decrease. It is unlikely that the net change in moisture content will be appreciable or will involve settlement beneath the reservoir. Beneath the dike, where stresses have been appreciably increased, added moisture might activate further settlement, but to a considerable extent equilibrium with the new stress conditions may already have been achieved by the settlement during the rainfalls of September and December 1974. Subsequently, according to Fig. 2, there were substantial rains from March to November 1975 when no settlement occurred. Hence, it is probable that this source of future settlement can be discounted.

One additional possibility for future increase in settlement deserves consideration. Reactivation of settlement under unchanged ambient conditions has been noted in subsoils that achieved a state of secondary consolidation under a surcharge

loading, after the surcharge was reduced to the final loading. The settlement at first stopped (or there was even a slight rebound) when the surcharge was reduced, but subsequently it resumed approximately in accordance with the time-settlement relation that would have prevailed if the final loading had been applied from the beginning without surcharge. The rainfall between September 1974 and January 1975 (Fig. 2) might be considered to have caused a temporary surcharge by increasing the unit weight of the dike and upper subsoil. The subsequent reduction of rate of settlement to zero would indicate that the increase of stress due to saturation in subsequent rains has not exceeded that which caused the settlement. Eventually, however, settlements of a secondary type might resume. Extrapolation of the June-August 1974 portion of the settlement curve (after application of the dike load but before significant rainfall) suggests that, if the settlement should start again at the beginning of 1976, the increase should not exceed 0.03 ft by the end of 1976, 0.06 ft by 1986, and 0.09 ft by 2086.

My review has, in summary, led to the conclusion that filling the reservoir should not cause appreciable settlement of the north side of the SWPH, where the maximum settlement has occurred so far, but may cause as much as 3/4 inch of settlement on the south side. Thus the tilt of the SWPH will be reduced. Progressive settlement in the future may be negligible, but could increase by about 0.03 ft in 1976, to about 0.06 ft by 1986, and to about 0.09 ft by 2086.

The numerical values of settlement discussed in this letter refer to the point of maximum settlement of the SWPH, whereas those of Stone and Webster are the average values. This difference should be borne in mind in any comparisons.

The prediction of relative movements between dike, pump house, and piping would involve considerable uncertainty. Attention to details of design to permit safe allowance for settlements would be preferable to attempts at more refined prediction.

Yours very sincerely,

Ralph B. Peck

Ralph B. Peck

RBP/ajj

TABLE 1

CONSOLIDATION TEST DATA

Test No.	Boring No.	Sample No.	Depth ft	W_o %	γ_{do} pcf	S_r %	ϵ_{sat}	σ_v for saturation ksf	
1	P-11	2F	24.0	24.8	90.9	78	10	22	
2	P-11	3F	37.9	21.8	95.6	77	10	19	
3	P-11	5F	48.8	21.9	95.8	79	9	17	
4	SI-1	3B	40.1	27.2	86.4	78	11	17	
5	SI-1	5F	52.7	15.7	104.2	68	12	?	
6	SI-1	6E	63.0	31.0	90.3	98	1	?	
7	P-12	1F	8.5	21.2	103.0	90	4	10	
8	P-12	2F	18.1	14.6	98.8	56	18	?	
9	SI-2	1F	13.3	11.1	99.2	44	23	44+	
10	SWR-6	4G	58.5	46.3	66.4	80	12	8	
11	P-10	2B	22.1	22.1	112.5	100+		--	error
12	SWR-4	2D	28.3	23.5	92.5	78	10	18	
13	SWR-4	3E	39.9	24.4	93.2	80	9	?	
14	SWR-4	5D	63.2	22.3	91.9	73	12	27	
15	SWR-4	6	77.5	19.9	96.8	72	12	?	

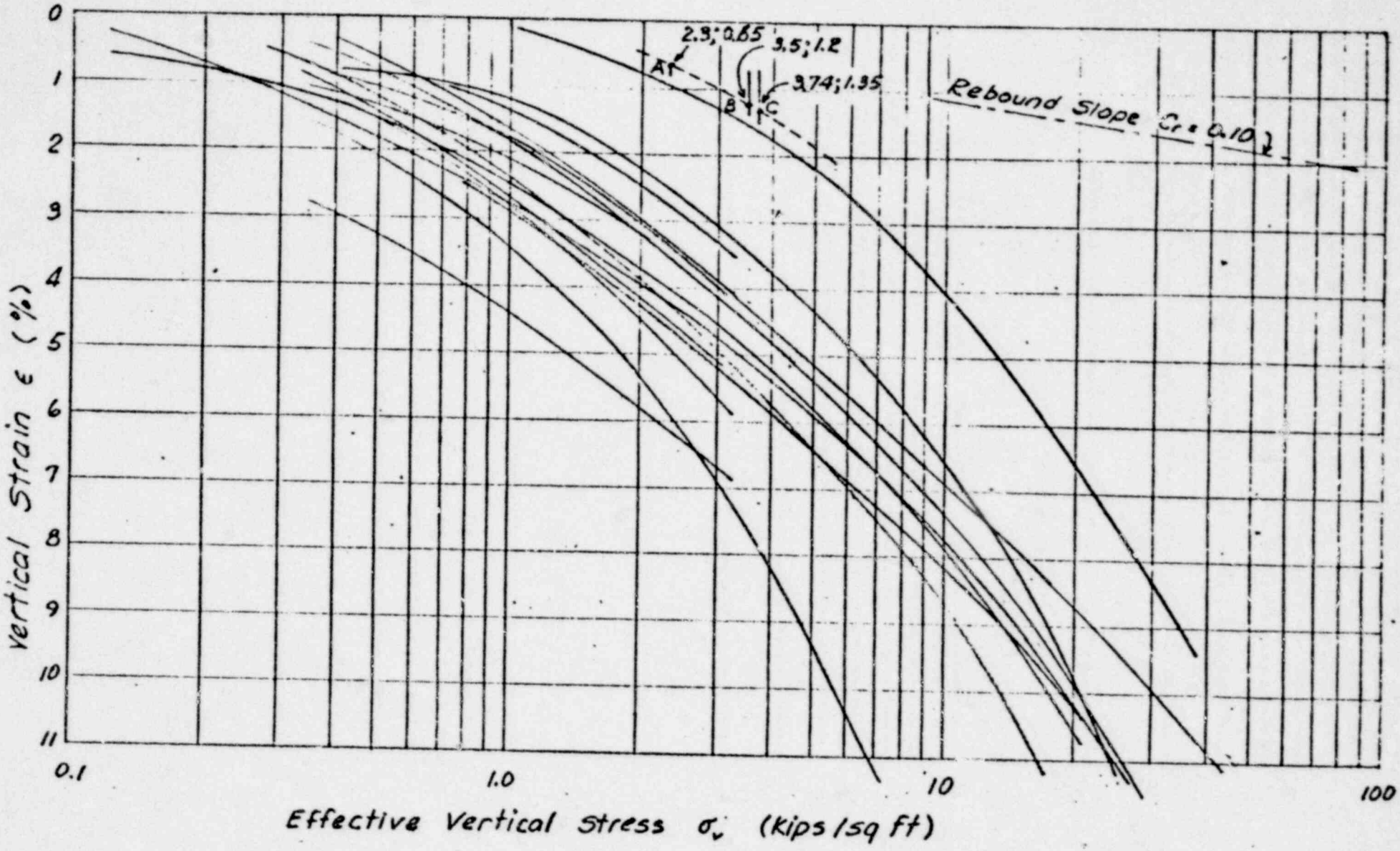
W, water content

S_r, degree of saturation

ϵ_{sat}, strain to eliminate air voids

σ_v for saturation, σ_v from e-log p curve corresponding to ϵ_{sat}

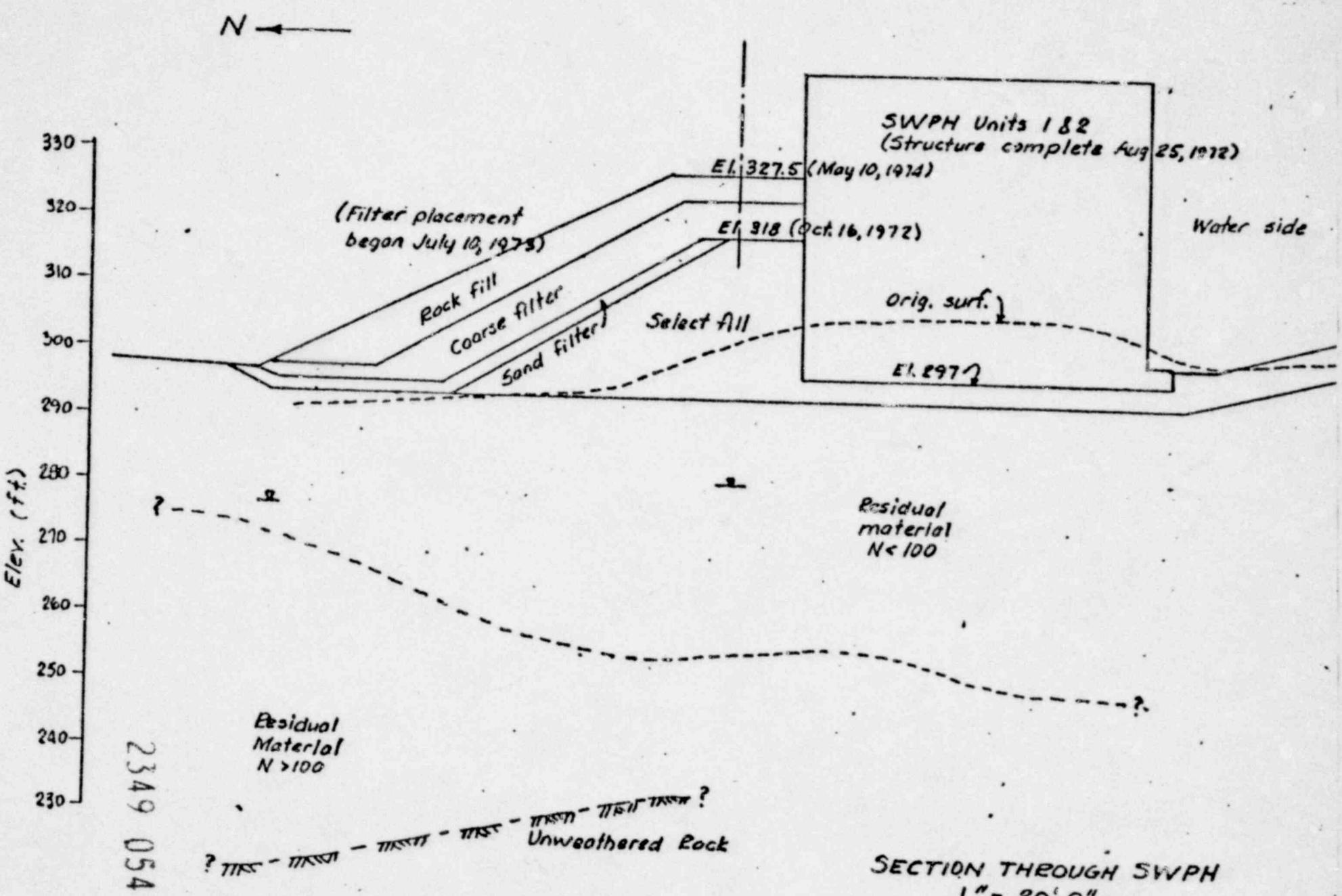
J938 ? test terminated below σ_v for saturation



STRAIN vs. STRESS CURVES FOR TESTS 1-15
(From S&W Fig. E 2.7-1)

2349 053

J938
13 Jan 75
EBP



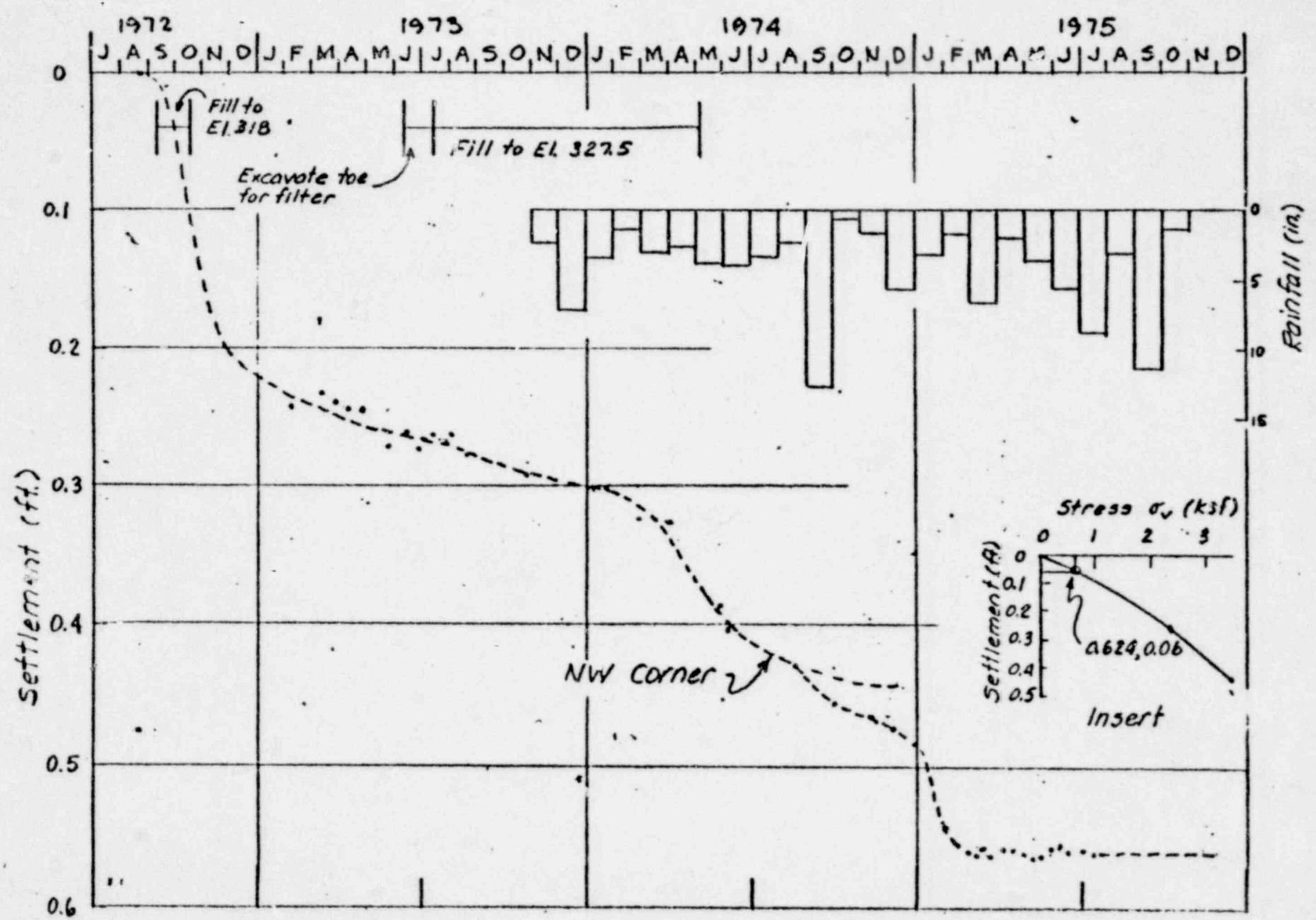
SECTION THROUGH SWPH
1" = 20'-0"

(From S&W Appendix E, NIF, Fig E 2.6-6, 12-23-75)

2349 054

J930
12 Jan 76
REP

Fig 9



SETTLEMENT OF SWPH
(From various S&W Drwgs.)

FIG. 2

2349 055

J938
12 Jan 76

RBP

RALPH B. PECK CIVIL ENGINEER: GEOTECHNICS

5 January 1976
J938

Mr. Stanley Ragone
Senior Vice President
Virginia Electric and Power Company
Richmond, Virginia 23261

Subject: North Anna Power Station

Dear Mr. Ragone:

This will reply to your letter of January 2 concerning my availability to review the settlement estimate of the Service Water Pump House for Units 1 and 2. As I discussed with Mr. Robinson today, after reviewing the documents he forwarded, I anticipate being able to complete the work by your deadline of 2 February.

Mr. Robinson agreed to advise Stone and Webster that I had been asked to do this work.

My rates and arrangements would be the same as those in my present Purchase Order, Number 75990, namely $400 per day, plus out-of-pocket expenses. On the assumption that the work will be conducted entirely at my office, I would consider the maximum time involved to be four days.

Yours very sincerely,

Ralph B. Peck

Ralph B. Peck

2349 056

RBP/ajj

January 0 2, 1976

Dr. Ralph B. Peck
1101 Warm Sands Drive, S.E.
Albuquerque, New Mexico 87123

Dear Dr. Peck:

This letter will confirm your conversation with our Mr. C. M. Robinson, Jr. on December 30, 1975 in which a discussion was held on your availability for consulting work in connection with a settlement problem at our North Anna Power Station near Mineral, Virginia. The problem is associated with settlement of the Service Water Pump House (SWPH) for Units 1 and 2. This is a safety related structure and is necessary for safe shutdown of the plant.

I have enclosed two documents which define the problem and offer explanations for the actual settlement being greater than that originally anticipated. The first document is entitled "Attachments 1-9 to Vepco Letter No. 622 Dated July 31, 1975." This document is a response to certain Nuclear Regulatory Commission (NRC) informal questions and gives the history of the settlement as well as calculations predicting future settlement.

The second document is entitled "Report on Geotechnical Investigations of Service Water Reservoir, North Anna Power Station Units 1 & 2, for Virginia Electric and Power Company." This report was prepared in response to an NRC letter dated July 24, 1975 (copy attached). The report is rather voluminous but it covers substantially more areas than just the settlement of the SWPH per se. The section of interest is Section E.3.

What we would like for you to do is the following:

1) Review Stone & Webster's calculations on future settlement.

2) Determine if Stone & Webster's approach and assumptions are justified.

3) Determine if Stone & Webster's conclusions on anticipated future settlement are as accurate as can reasonably be expected.

The only condition to this work is that it be completed by February 2, 1976.

After your review of the enclosed documents we would appreciate your contacting Mr. Robinson to discuss your availability for doing this work. If a satisfactory arrangement can be made, then we would authorize you to begin work and would confirm the arrangement with a purchase order. We would also appreciate details on your fee, billing procedure, etc. at that time.

If during the course of your review you find something that is not within the limits of interest specified above but nevertheless causes you concern, we would very much like to know about it.

We are hopeful that you can find the time to consult with us on this work and we look forward to hearing from you. If you have any questions, please feel free to call Mr. Robinson (804-771-3867) collect.

Very truly yours,

wcf

Stanley Ragone
Senior Vice President

2349 058

Question 17 -
Proffitt Letter

MAR 13 1978

J. O. Nos. 11715
12050

NAV-7023

Mr. R. . Bradbury
Stone & Webster Engineering Corporation
P. O. Box 2325
Boston, Massachusetts 02107

Dear Mr. Bradbury:

SETTLEMENT OF SERVICE WATER PUMP HOUSE
NORTH ANNA UNITS 1 AND 2

The North Anna Technical Specifications contain allowable settlement criteria for the Service Water Pump House (SWPH). During the installation of the horizontal drains, an abrupt settlement took place that now appears to be at least partially due to the lowering of the groundwater. With this change coupled with the normal expected settlement, it now appears that we are near the 75% of allowable settlement criteria which requires a special report to the Commission.

Accordingly, Stone & Webster is instructed to begin preparation of a special report as required by Tech Spec section 3/4.7.12 in anticipation of the time when settlement will exceed the 75% criteria. The report shall contain an evaluation of the settlement, future expected settlement, any remedial measures necessary, and any other information which would be appropriate for such a report.

We are particularly concerned about possible adverse affects on the service water piping. We believe this should be analyzed in great detail in order to determine if piping can be adversely affected by the present or future predicted settlement. Results of your piping investigation may be included in whole or in part with the special report mentioned above.

A draft report containing the information noted above, together with any other information you feel should be included, should be forwarded to us no later than April 14, 1978.

2349 059

If you have any questions, please contact our C. M. Robinson, Jr. (804-771-3894).

Very truly yours,

W. L. Proffitt
Senior Vice President

cc: Mr. G. J. Burroughs
Mr. A. A. Dasenbrock
Mr. H. W. Sorensen
Mr. F. W. Ries
Mr. W. B. Dodson

2349 060

CMRjr/bcb

CERTIFICATE OF SERVICE

I hereby certify that I have this day served Vepco's Answer to Intervenor Arnold's Interrogatories on Pump House Settlement, including the attached Responses, upon each of the persons named below:

Secretary
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

ATTENTION: Chief, Docketing & Service Section

Richard M. Foster, Esquire
1908-A Lewis Mountain Road
Charlottesville, Virginia 22903

Alan S. Rosenthal, Esquire
Atomic Safety and Licensing Appeal Board
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Washington, D.C. 20555

Atomic Safety and Licensing Board Panel
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

2349 061

Atomic Safety and Licensing Appeal Board
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

BY: /s/ James N. Christman
James N. Christman, Counsel
for Virginia Electric
and Power Company

DATED: May 4, 1979

2349 062