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October 12, 1985
ST-HL-AE-1399
File No.: G9.17

Mr. George W. Knighton, Chief
Licensing Branch No. 3
Division of Licensing
U. S. Nuclear Regulatory Commission
Washington, DC 20555

South Texas Project
Units 1 and 2
Docket Nos. STN 50-498, STN 50-499
Responses to DSER/FSAR Items; Section 2.5

Dear Mr. Knighton:

The attachments enclosed provide STP's response to Draft Safety Evaluation Report (DSER) or Final Safety Analysis Report (FSAR) items.

The item numbers listed below correspond to those assigned on STP's internal list of items for completion which includes open and confirmatory DSER items, STP FSAR open items and open NRC questions. This list was given to your Mr. N. Prasad Kadambi on October 8, 1985 by our Mr. M. E. Powell.

The attachments include mark-ups of FSAR pages which will be incorporated in a future FSAR amendment unless otherwise noted below.

The items which are attached to this letter are:

Attachment	Item No.*	Subject
1	F 2.5-1	Section 2.5.4 and 2.5.C; Incorporate the latest dates that figures were updated. Have also included updated Sections 2.2.2 and 2.5.1 which pertains to oil and gas production.
	F 2.5-21	Table 2.5.C-3; Semi-annual update
	F 2.5-31	Fig. 2.5.C-9; Geotechnical instrumentation heave/settlement movement. (Unit 1)

* Legend
D - DSER Open Item C - DSER Confirmatory Item
F - FSAR Open Item Q - FSAR Question Response Item

L1/DSER/s

B001 1/1

Houston Lighting & Power Company

Attachment	Item No.*	Subject
1 (Cont'd)	F 2.5-32	Fig. 2.5.C-10; Geotechnical instrumentation heave/settlement movement. (Unit 2)
	F 2.5-33	Fig 2.5.C-11; differential movements between buildings. (Unit 1)
	F 2.5-34	Fig 2.5.C-12; differential movements between buildings. (Unit 2)
	F 2.5-35	Fig's 2.5.C-13A & 13B; differential movement profile between buildings (Unit 1)
	F 2.5-36	Fig's 2.5.C-14 & 14A; differential movement profile between buildings (Unit 2)
	F 2.5-39	Figure 2.5.C-19A; regional near-surface subsidence monitoring
	F 2.5-40	Figure 2.5.C-20; regional upper shallow aquifer monitoring data
	F 2.5-41	Figure 2.5.C-21; regional lower shallow aquifer monitoring data
	F 2.5-43	Figure 2.5.C-23; cross-section L-M horizontal subsidence monitoring
	F 2.4-44	Figure 2.5.C-24; cross-section H-E horizontal subsidence monitoring
	F 2.5-45	Figure 2.5.C-25B; regional subsidence and deep aquifer
	F 2.5-46	Figure 2.5.4-65; piezometric level vs. time (Unit 1)
	F 2.5-47	Figure 2.5.4-66; piezometric level vs. time (Unit 2)
	F 2.5-48	Figure 2.5.4-70B Historic piezometric levels of deep aquifer zone

If you should have any questions concerning this matter, please contact Mr. Powell at (713) 993-1328.

Very truly yours,

M. R. Wisenburg
Manager, Nuclear Licensing

JSP/bl

Attachments: See above

* Legend

D - DSER Open Item C - DSER Confirmatory Item

F - FSAR Open Item Q - FSAR Question Response Item

L1/DSER/s

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Revised 9/25/85

Attachment 1

Two Big Three pipelines from the Freeport, Texas area carry oxygen and nitrogen to the Celanese Chemical Company. The closest approach of the pipelines to STP is their termination point at the Celanese plant.

There is little or no potential for future expansion of the oil and gas production fields within 5 miles of the site because each field is surrounded by dry holes and the limits of the structure of each field are known from reflection geophysical data. As of August 1985 there has been a decline in production in each field. ~~except for the Petrucha field, which increased in 1971 when two new wells were put into production.~~ Production zones in all the fields are in the Frio Formation at depths ranging from 10,200 to 12,650 ft. Development of producing zones in Eocene age sands is unlikely because of the great depth of such sands (estimated to be about 20,000 ft) in the vicinity of the site.

Data concerning the four fields within 5 miles of the site are shown in Table 2.2-3. An evaluation of the possibility of the development of oil and gas production fields closer to the site than those now indicated on Figure 2.2-3 is presented in Section 2.5.1.1.6.6.7.2.

The proposed La Salle LNG terminal site is located about 35 miles southwest of the STP site and five miles northwest of Port O'Connor. A 36-inch pipeline trends in a west-northwest direction, 463 miles to Pecos County, Texas. The La Salle terminal is the pipelines' closest point to the STP. (Ref. 2.2-20) 2 Q312.02N

2.2.2.4 Waterways. The primary waterway in the vicinity of the site is the Colorado River, which is used primarily for barge traffic. From the Gulf Intracoastal Waterway, which is 125 ft wide and 12 ft deep, the river winds along a 15-mile stretch until it approaches the turning basin. The river channel is approximately 15 ft deep and 100 ft wide. The minimum depth of the Colorado River between the Gulf and the Crysen Terminal is 7-1/2 ft. During the 12-month period from July 1981 through June 1982, 1186 barges and 934 tug boats used the river for the transportation of raw and finished materials to the Celanese, DuPont, Parker Brothers, and Crysen facilities. There are presently no plans by the U.S. Army Corps of Engineers (USACE) to enlarge the river for larger operations. However, the USACE has begun a diversion project at the mouth of the Colarado River. 50

The project is situated on the Texas Coastline approximately one mile south of Matagorda (see Figure 2.2-6). The river diversion features are to be located in Matagorda Bay and the Colorado River adjacent to the Gulf Intracoastal Waterway near the town of Matagorda. 50

The project, initiated in May, 1984 and projected to be completed in the summer of 1988, is expected to enhance the Bay's commercial productivity and take advantage of incidental opportunities to provide flood control and reduce navigation hazards and navigation maintenance dredging. Project details and impacts are discussed in an Environmental Impact Statement prepared by the USACE in March 1981.

2.2.2.5 Airports. The current aerial navigation charts (Houston sectional) show only two airports within 10 miles of the STP. C-Level Farm, 9.5 miles to the west-northwest of the proposed plant, has a 3,700-ft turf runway.

3. Five-percentile meteorological conditions based on the data given in Section 2.3 without building wake correction.

4. Distance downwind from break using the X/Q's where the centerline concentrations reach the lower flammability limit of 5 v/o (2.5×10^{-3} lb/ft^3) and reach the upper flammability limit of 15 v/o ($75. \times 10^{-3}$ lb/ft^3): 1,020 meters and 540 meters respectively for the 16-in. line and 1,550 meters and 800 meters respectively for the 30-in. line.

5. The amount of gas within the flammability limits based on the amount of gas released in the time for plume to travel between the above points: 5.5×10^4 lb for the 16-in. line and 1.7×10^5 lb for the 30-in. line.

6. The equivalent amount of TNT using the method of item 3 in Section 2.2.3.1.4.1: 5.3×10^5 lb TNT for the 16-in. line and 1.6×10^6 lb TNT for the 30-in. line.

7. The resultant overpressure for a detonation centered at the midpoint of the flammable mixture using the same methods as item 4 in Section 2.2.3.1.4 is given in Table 2.2-8. 35

Since the overpressure is less than that due to tornado winds, the occurrence of this improbable event will not affect the ability to safely shut down the plant.

The above analysis is conservative since the amount of gas considered in the detonation includes gas off the centerline of the plume which is below the lower flammability limit. This will be particularly significant for the portion of the plume nearest the plant and will not only reduce the equivalent yield but will also increase the effective distance from the plant. The analysis is also conservative because the effects of buoyancy were neglected. Methane has a density of approximately 50 percent of air, which causes the gas to rise and leads to additional dispersion.

2.2.3.1.5 Gas and Oil Production Fields: (Gas and oil production fields are discussed in more detail in Section 2.5.1.1.6.6.7.2.) The gas and oil production fields within 5 miles of the STP site are ~~described~~ identified in Section 2.2.2 and ~~their location is~~ shown on Figure 2.2-3. ~~and Figure 2.5.1-1.~~ The closest well to the STP site is a single well in the South Duncan Slough gas field, approximately 1.6 miles from the nearest STP safety-related structure. 2 Q361.2

As stated in Section 2.2.1.4.6, it is assessed that there is very little potential for future expansion of the oil and gas fields within 5 miles of the STP site. This conclusion was based on production data from the existing fields and the geological data for the site vicinity. Nevertheless, the likelihood and potential consequences of accidents which might occur during gas or oil well drilling operation or production operations adjacent to the STP site were evaluated. This analysis, summarized in Appendix 2.2.B, shows that even if a gas well is drilled at the worst location immediately adjacent to the STP site there would be no adverse effect on STP safety-related structures. The fields within Matagorda County do not produce hydrogen sulfide gas, and the potential for an accidental release of toxic gas within 15 miles of the STP site is therefore nil. This analysis also shows that the existing gas well located 1.6 miles from the plant poses no credible hazard to the STP plant. 2 Q312.3

TABLE 2.2-3

GAS AND OIL PRODUCTION FIELDS WITHIN 5 MILES OF THE STP SITE

	Duncan Slough	South Duncan Slough	Cane Island	Petrucha	
Type of Field	Oil & Gas	Gas	Gas	Gas	
Total Number	12	10	0	~~4~~ 3	
Number of Wells Production	9	~~4~~ 3	0	~~3~~ 2	35
Total Production*	(G)3~~7~~4,000*** (O)2,~~906,895~~ 18,447	(G)~~28,642~~ 31,297 (O) None	(G)945.5** (O) None	(G)16,~~376~~ 573 (O) None	
Storage Facilities	Storage Tanks	None	None	None	
Transportation Methods	Pipeline	Pipeline	----	Pipeline	

*Gas production (G) in million cubic feet and oil production (O) in barrels.

**Cane Island Field was shut down March 9, 1972. 35

***Approximation.

extraction from this dome and other salt domes in the vicinity are discussed in Section 2.5.1.1.6.6.7.2. Salt domes in the vicinity have not been a source of ground surface movements, except where exploitation activity by man such as extraction of minerals and fluids has taken place.

2.5.1.1.6.6.7.2 Man's Activities - Man's activities resulting in sources of potential ground surface movement in the vicinity of the site are: the withdrawal of groundwater in the near surface; the withdrawal of oil and gas, often accompanied by saltwater in the deep subsurface; the extraction of sulfur from the caps of salt domes from both near surface and subsurface; and the storage of liquid petroleum gas in the cavities following sulfur extraction or within salt domes.

1. Mineral Extraction and Fluid Injection

Mineral production in Matagorda County in the site vicinity has been confined to subsurface extraction of groundwater, sulfur, oil, and gas. Waste industrial fluids and liquefied petroleum gas are injected into the subsurface or stored in cavities in salt domes in the vicinity of the site. These activities of man have a minimal impact on the stability of the ground surface at the site and in the surrounding area.

Groundwater is used to supplement water diverted from the Colorado River for irrigation purposes in the region. These withdrawals have resulted in some artesian head decline. Future groundwater withdrawal in the area and potential impact on ground surface stability are evaluated in the section. Groundwater conditions at the project site and in the surrounding areas are discussed in detail in Section 2.4.13. Oil and gas, both in volume and in value, have been the primary mineral extracted in the region. Within a radius of 15 miles of the plant site, there are 64 petroleum fields which have produced ~~in excess of 100~~ approximately 103 million barrels of oil and ~~1,190,000~~ in excess of 1,208,000 MMCF of gas. Of the fields, 41 produce oil and gas and 23 produce gas only, with condensate. The locations of these fields are shown on Figure 2.5.1-1. 2 Q361. 01 33 Q231 .02N 44

Fluid injection (e.g., salt water, gas) is used for secondary and enhanced recovery of hydrocarbons. According to the latest report on such operations in Texas (Ref. 2.5.1-169) which provides the status of injection projects as of January 1, 1982, there are four fields in Matagorda County at which there are listed active injection projects: Blessing, Southwest Pheasant, North Markham, and Arch (however, one project, North Markham, has been carried as "temporarily discountinued" since February 1978). These fields are 13 to 18 miles from the Plant Site (see Figure 2.5.1-1). 46 Q230. 06N

Two geopressured geothermal fairways of the Frio Formation exist in Matagorda County. The STP site is located on the northern edge of one of the fairways (Ref. 2.5.1-68a). The most recent literature indicates that both fairways are unsuitable for geothermal development: "Because of limited lateral extent of reservoirs and lack of sufficient thickness of permeable sandstones . . ." (Ref. 2.5.1-6a). Geothermal exploration within the STP site vicinity is not anticipated throughout the lifetime of the plant. Based on discussion with the Texas Railroad Commission, the responsible regulatory agency, it is concluded that there are no geothermal wells existing or proposed within 15 miles of the site. 30 Q230. 01N 33 Q231. 02N

This mining process was carried out before the modern-day viscous mud injection techniques were developed. Sulfur mining has ceased at Big Hill, and further subsidence is not expected. In the event that sulfur mining is resumed, subsidence of the ground surface will be at a distance of at least 10 miles from the plant site and will not in any way influence the safe operation of the plant.

5. Subsidence from Oil and Gas Production

The most carefully documented field studies of subsidence resulting from the production of oil and gas are: the Goose Creek field in Harris County, Texas; the Wilmington and Inglewood oil fields in the Los Angeles Basin, California; the Bolivar coastal oil fields in Lake Maracaibo, Venezuela; the Po Delta oil fields in Italy; the Niigata gas field in Japan; and the Rio Vista and River Island gas fields in California. These studies were reviewed and evaluated at the PSAR stage. A review of oil and gas production and subsidence was made in August ~~1984~~ 1985 for the FSAR. 44

Post-Construction Permit (CP) oil and gas exploration within five miles of the Plant Site has been limited. Eighteen new wells have been drilled or permitted between 1975 and 1984; two pre-existing wells underwent workover operations, eight of these were dry holes, two were cancelled, and one was abandoned. Of the remaining wells, seven are gas wells, one is an oil producer and one produces both oil and gas. Locations of the new or reworked wells within five miles of the Plant Site are shown on Figure 2.5.1-1A; summaries of well information are provided in Table 2.5.1-1. Figure 2.5.1-1A also shows the locations of Post-CP seismic reflection profiling near the Plant Site. Discussion of the geophysical data and the interpretations of local geologic structure based on the most appropriate information is provided in Section 2.5.1.2. 46 Q231.07N

An evaluation of the factors leading to the causes of ground surface subsidence in oil and gas fields (Refs. 2.5.1-21, 2.5.1-38, 2.5.1-101, 2.5.1-115, 2.5.1-126, and 2.5.1-163) yields certain guidelines for evaluating subsidence potential in petroleum-producing areas. These guidelines are:

a. Subsidence in areas producing groundwater, oil and gas usually occurs where the producing formations are of a relatively young geologic age, Miocene and younger.

b. Depth to the producing horizons is moderate, no greater than 6,000 ft and usually less than 4,000 ft.

c. Oil- and gas-producing sands are unconsolidated and are interbedded with clays or even semiconsolidated clays, not hard shales. The formations overlying the producing zones contain high percentages of clay.

d. Where subsidence is related to the withdrawal of oil and gas, the petroleum yield is accompanied by the production of very large volumes of water. Wilmington field in California and Goose Creek in Texas are excellent examples.

A brief description of the Goose Creek oil field in Baytown, Harris County, Texas follows. The field was studied by Pratt and Johnson (Ref. 2.5.1-117), who first reported the occurrence of subsidence at the location. The field was discovered in 1912, and its greatest development took place between 1912 and 1918. Production was obtained from numerous horizons between 1,000 ft and 4,100 ft in very soft, unconsolidated, fine sands interbedded with soft clays. Although Goose Creek has been considered a salt dome because of its shape, wells drilled to 5,000 ft on the top of the structure did not penetrate cap rock or the underlying salt. One well in later years reportedly penetrated salt at approximately 10,000 ft, but no details were ever provided. By 1929, production from the field was 66,397,000 barrels per acre. In 1918, subsidence reportedly started rather suddenly. Because the field was located on marshy ground only a few inches above sea level, the subsidence allowed the marshy area to be completely submerged. Measurements several years later showed the subsided area to have sunk about 3.25 ft, with an areal extent of about 2.5 miles by 1.5 miles. There is peripheral "faulting" at the edge of the subsided area. After 1950, drilling was carried out on the flanks of the Goose Creek structure, and the cumulative production at the end of 1973 was 127,235,432 barrels of oil from a total of 1,388 wells. It should be noted that the early reports concerning the Goose Creek production specifically mention the large amount of water and the extremely large amount of sand produced with the oil. It was this fact that led Pratt and Johnson (Ref. 2.5.1-117) to regard the subsidence as the result of extraction of oil, water, gas, and sand, accompanied by increased compaction of the clays. They suggest also that other important factors are reduction of gas pressure and drying of clays with the escape of gas.

In Matagorda County, and specifically in the area within a 15-mile radius of the plant site, the 64 oil and gas fields have little relation to the criteria listed above as pertinent to ground surface subsidence. 2 Q361.44

According to Sheets and Cockrell (Ref. 2.5-168), the Frio Formation of the Mio-Oligocene age is the most important producing formation in southeast Texas. Oil and gas production in Matagorda County is primarily from thin sands (less than 15 ft thick) within the upper and middle Frio Formation at a median depth of 10,000 ft. Less important petroleum producing strata in Matagorda County are the lower Frio and Miocene sands. Of the 64 fields within a 15-mile radius of the site, only four gas fields and two oil and gas fields produce from the Miocene strata above the Frio Formation. (Changes in the number of oil and gas fields from year to year do not necessarily reflect changes in production since field boundaries are subject to redefinition.) 33 Q231.02N 44

Twenty-three of the fields have been gas producers only. Of these, 19 fields have produced from the Frio Formation of Oligocene age at depths greater than 7,000 ft, with the probable median depth about 10,000 ft; two gas fields have produced from the Miocene with a median depth of 7,800 ft; and two Miocene fields have produced from a depth of 4,100 ft. There are gas fields located offshore which are producing from the Miocene and lower Frio age depths in Matagorda Bay. They are insignificant in that they are far removed from the site. The gas produced by fields within a 15-mile radius of the site contain no significant hydrogen sulfide, and are classified as sweet gases. There is accordingly no potential for release of toxic gases from these fields (Ref. Appendix 2.2.B). 2 Q361.1 44 33 Q231.02N 2 Q361.01

Forty-one of the local fields produce or have produced both oil and gas, with 38 of the fields producing from the Frio Formation at a median depth of about 10,000 ft; two other oil and gas fields produce from the Miocene sands at depths of 2,000 ft to 5,600 ft. The Big Hill field, which was abandoned in 1907, produced from a depth of 875 ft. 33 Q231.02N

All of the oil and gas production in the fields shown on Figure 2.5.1-1 is from thin sands. Where production comes from multiple sands, the sands are usually widely spaced, as in the Hammon field, which produces from eight zones ranging in depth from 7,317 ft to 10,887 ft. The producing sand formations in Matagorda County are firm to well consolidated, and no sand production has been reported. Moderate water production is associated with some, if not all, of the Matagorda County oil and gas fields. Many of the Matagorda fields are controlled by faults associated with domal structures (See Section 2.5.1.1.6.3.2.1.2). Oil and gas production is controlled and limited by this faulting. The field operators, by showing that there is no fluid movement across a fault, were allowed new field status. Production quotas for new fields were higher than those allowed for newly completed wells in existing fields. Faulting, together with the scattered thin sands, has contributed to many fields with only one or two wells each.

Texas Railroad Commission spacing regulations, with certain exceptions, permit no more than one oil well to 40 acres, and no more than one gas well to 160 acres. Constraints such as these spacing regulations did not exist in the early days (1930s) of oil field development in Texas. These spacing regulations and a state-controlled production rate are designed to prevent excessive withdrawal of oil and gas from any one area on a given structure.

The ~~1983~~ 1984 Annual Records of the Texas Railroad Commission show that of the 64 fields within a 15-mile radius of the plant site, ~~19~~ 21 of the 41 oil and gas fields and ~~15~~ 14 of the 23 gas fields have been abandoned or shutin (See FSAR Figure 2.5.1-1). Abandoned field status denotes that commercial production has closed and all wells have been plugged, while shutin field status denotes that wells are no longer in production but may again be producers in the future. The total oil that has been produced within the 15-mile radius is approximately 10~~2~~3 million barrels, and the total gas that has been produced exceeds 1,~~190~~ 208,000 MMCF. The North Markham-North Bay City field has been the largest producer of oil and gas within the 15-mile radius, with a total production of approximately 49,~~2~~500,000 barrels of oil and approximately 59~~7~~4,000 MMCF of gas. Production in the fields has continued to remain low since August 1978. Data concerning the four fields closest to the STP site are tabulated below. 44

	Collegeport- North Collegport Southwest College- port Citrus Grove	South Duncan Slough	Cane Island	Petrucha
Location from STP site	7 miles SW	2.7 miles N	1.7 miles N	3.9 miles NE
Present status	producing	producing	abandoned March 9, 1972	producing
Total oil production (barrels)	~~424,640~~ 427,400	none	none	none
Total gas production (x 1 MMCF)	~~450,031~~ 453,830	~~30,521~~ 31,300	945	~~16,487~~ 16,573

44

2

33 Q 231.02N

33 Q 231.02N

The two closest producing fields to the plant are the South Duncan Slough-Cane Island and Petrucha fields. The South Duncan Slough-Cane Island field is located 2.7 miles north of the plant site. The Petrucha field is located 3.9 miles northeast of the plant site as shown on Figure 2.5.1-1. A discussion of the production history of both fields follows. As will be seen, no potential for ground surface subsidence from fluid extraction activities at either field exists at the STP site. 2 Q36L 33 Q231 02N

The South Duncan Slough field first produced in May 1970. As of December 198~~3,~~4 ten wells had been drilled, ~~four~~ three of which were producing gas only and ~~six~~ seven of which were nonproductive. The producing wells are the following. 2 Q361 1

ATTACHMENT 1
ST-HL-AE- 2399
PAGE 9 OF 60

- Partners Oil Company Gulf Coast Water Company No. 1st (1). Completed September 1979; TD 11,250 ft.

- TXO Production Corporation Steele No. 2. Completed March 1980; TD 11,300 ft.

Delete and reinsert below

- TXO Production Corporation Steele No. 3. Completed March 1981; TD 11,515 ft.

- Partners Oil Company Gulf Coast Water Company Unit 1. Completed September 1981; TD 11,400 ft.

The nonproducing wells in the South Duncan Slough field are:

- Kinsey Interests, Inc. Pierce Estate No. 2. Completed September 1972; TD 11,535 ft. (No longer listed in Railroad Commission of Texas Gas Production Ledger.) 46

- Royal Resources Corporation Pierce Estate Oil and Gas Int. No. 2-A. Completed June 1970; TD 11,371 ft. (No longer listed in Railroad Commission of Texas Gas Production Ledger.) 46

- Petro-Lewis Corporation (Royal Resources Corporation, former operator) Pierce Estate Oil and Gas Int. No. 1. Completed March 1970; TD 11,478 ft.

- TXO Production Corporation Louise M. Steele et.al. No. 1. Completed January 1970; TD 11,332 ft.

- TXO Production Corporation (Royal Resources Corporation, former operator) Pierce Estate Oil and Gas Int. No. 1-A. Completed June 1970; TD 10,517 ft.

- Morris Cannan Pierce Estate No. 1. Completed September 1981; TD 11,125 ft. 44

An additional nonproductive well was drilled prior to August 1978 but information about the well is not available since it was not registered with the Railroad Commission of Texas. 35

The structure of the South Duncan Slough field is reportedly a small anticline on the upthrown side of a regional fault. Production is obtained from three zones at depths of approximately 10,700, 11,000 ft and 11,100 ft. The 44
Petro-Lewis Corporation Pierce Estate No. 1 produced from a ten foot zone at a depth of 11,326 ft; however, the well is presently (December 1983) considered shutin. The average thickness of the zones is about 15 ft. The producing area is at least 550 acres. 33|44 Q231. 02N

Production through 1983 has been: 33 Q 231. 02N 44

1970	465 MMCF gas	1977	376 MMCF
1971	1,501 MMCF gas	1978	183 MMCF
1972	2,061 MMCF gas	1979	840 MMCF
1973	1,063 MMCF gas	1980	5,128 MMCF
1974	675 MMCF gas	1981	10,008 MMCF
1975	440 MMCF gas	1982	5,472 MMCF
1976	430 MMCF gas	1983	1,879 MMCF
		1984	776 MMCF

2 Q361. 01

33 Q 23L 02N

44

Cumulative production to the end of 198~~3~~4 was approximately ~~30,500~~ 31,300 MMCF of gas. Since production remains relatively low there is no effect on plant safety or operation.

The field discovery well in the Petrucha field was completed on March 12, 1962, but very little information has been made available as to the structural and stratigraphic conditions in this field. The discovery well was the result of reflection seismic surveys by Pan American Petroleum Corporation (now Amoco). Bulletin of the American Association of Petroleum Geologists, Vol. 47, No. 6, pp. 1,082-1,083, 1963, reports the structure of the Petrucha field as follows:

> "The Pan American's Petrucha No. 1, a rank wildcat, is the discovery well for this field. Completion was in the Discorbis section of the lower Frio. This well was perforated and completed for a standard choke orifice test of 11,200 MMCF. The accumulation is found on the north flank of a large, elongated structure with a strong dip of the Frio beds into the downthrown side of a large regional down-to-the-coast strike fault. The production is separated from updip dry holes on the south by minor faulting. The only other production from this interval, located within the same fault block, is approximately 25 miles southwest."

This well produced from a sand at 12,450 ft to 12,470 ft. Another sand at 12,650 ft in other wells also produces, but this report cannot be verified because no electric logs of producing intervals are available for wells other than the first. Since workover operations in late 1981 this well is now listed by the Railroad Commission as both an oil and gas well with the oil workover portion of the well perforated from 11,780 ft to 11,790 ft. Information on oil production from this well is not available as of March 1985. 33 Q231. 02N 46

From late 1973 to date ~~(December 1983)~~ August, 1985, four new wells have been drilled, not counting the workover of the above well. One is a gas producer and three are dry holes. The dry holes are in the western section of the field. 33 Q 231. 02N 2 Q361. 01 46

ATTACHMENT 1
ST-HL-AE- 1399
PAGE 11 OF 60

The ~~three~~ two producing wells in the Petrucha eld are listed below. Map number refers to PSAR Figure 2.5.1-5: 2 Q361.01

Map No. 33 Q231.02N

100. Amoco Production Company Petrucha Gas Unit no. 2, D. McFarlane Survey, A-61. Completed March 1971; TD 13,500 ft.

Delete from here & insert where indicated on page 79

102. Amoco Production Company (Pan American Petroleum Corporation), Petrucha No. 1, D., McFarlane Survey, A61. Completed Novenber 3, 1981 (oil) and April 22, 1982 (gas): T.D. 15,005 ft (workover of well originally completed February 1961). 46

104. Amoco Production Company Butter no. 1, D. McFarlane Survey, A-61. Completed February 1973; TD 13,000 ft. 33 Q231.02N

46

The nonproducing wells (plugged or shutin) are: 33 Q231.02N

Insert well #102

Map No.

102.

103. Amoco Production Company Seerden No. 1, D. McFarlane Survey, A-61. Completed May 1972; TD 13,051 ft.

Amoco Production Company John Butter No. 3, D. McFarlane Survey, A-61. Completed September 23, 1975; T. D. 13,400 ft. 2 Q361.01

105. Amoco Production Company Butter no. 2, D. McFarlane Survey, A-61. Completed July 1973; TD 13,400 ft. 33 Q231.02N 46

The only other producing well drilled in the Petrucha Field since 1973 was the Amoco Production Company, John Butter No. 3. This well is no longer listed in the Texas Railroad Commission Gas Production Ledger. The well was completed in September of 1975 and was drilled to a total depth of 13,400 ft. The well is located at approximately North 367300, East 2969100 based upon the Texas Grid System. The well location is approximately 4.6 miles northeast of the center of the Unit 1 Reactor. 33 Q231.02N 2 Q361.01

The three dry holes are:

Map No.

101. Amoco Production Company Penny No. 1, John Raney Survey, A-80. Completed August 22, 1973; TD 13,485 ft. The Penny No. 1 was directionally drilled in order to better intercept any productive zone. This well is approximately 4,300 ft west of the discovery well in the Petrucha Field.

Amoco Production Company Lawson No. 1, John Raney Survey, A-80. Completed March 6, 1974; TD 12,900 ft.

Amoco Production Company Culver No. 1, was drilled to a depth of 13,200 ft and was terminated as a dry hole. This dry well indicates the southeastern limits of the Petrucha field. 2 Q361.01

The production figures listed below show that the peak production of the Petrucha field occurred in 1974 and that there has been a steady decline since that year, including production from the Butter No. 3 unit. The Butter No. 3 unit was placed in production during July 1976. The present decline rate can be expected to continue. The available data show the following yearly rates of gas production: 33 Q231.02N

1962	3 MMCF
1963	55 MMCF
1964	951 MMCF
1965	735 MMCF

1966	603 MMCF
1967	553 MMCF
1968	452 MMCF
1969	349 MMCF
1970	393 MMCF
1971	1,429 MMCF
1972	1,717 MMCF
1973	2,226 MMCF
1974	2,255 MMCF
1975	1,869 MMCF
1976	1,139 MMCF
1977	476 MMCF
1978	315 MMCF
1979	265 MMCF
1980	259 MMCF
1981	196 MMCF
1982	136 MMCF
1983	111 MMCF
1984	86 MMCF

33 Q231.02N

33 Q231.02N

44

With the Penny no. 1 unit and the Lawson no. 1 unit dry, the western limits of the Petrucha field have been determined, placing the field boundaries east of the Colorado River. 2 Q361.01 33 Q231.02N

There has been no known subsidence in Matagorda County that can be attributed to the withdrawal of oil and gas. This was reconfirmed in 1983. In addition, none of the fields in the county fits the guidelines developed from oil and gas fields that were associated with subsidence elsewhere in the world. Finally, none of the fields lie closer to the site than the distance represented by the depth to its producing interval; therefore, subsidence from these fields could not encroach on the site area. 33Q231.02N 2Q361.01 33 Q231.02N

6. Oil and Gas Production at the Project Site

The site of the STP has been drilled for oil and gas. Available records indicate that nine wells ranging in depth from 4,056 ft to 16,154 ft have been drilled on the site. All of these wells were nonproductive: three stopped in the Miocene and six bottomed in the Frio Formation of Oligocene age. The nine wells (see PSAR Figure 2.5.1-32 for well locations) are tabulated below.

member that could be considered oil- and/or gas-productive. In the case of L. A. Wagner Broughton and Lloyd no. 1, which was bottomed in the Miocene, it was suggested that a section on the electric log between 3,850 ft and 3,875 ft was possibly productive. However, Mr. Wagner pointed out that the sections were cored and the cores showed lime and "shells," which accounted for the "kick" on the electric log. This condition is not uncommon and often leads to unwarranted statements of shows. It is surmised from the well logs that the nonproductivity of wells on the site is the result of both a lack of suitable stratigraphic or structural oil traps and a general thinning of the oil- and gas-producing Frio sands from north to south. This thinning is noticeable when one compares the Frio sand section in well no. 25, located just north of the site, with well no. 8, in the southern part of the site (see PSAR Figure 2.5.1-32). Well no. 25 (Tenneco Oil Co. Pierce Estate no. 1, N. Clopper Survey A-16) is in the abandoned Cane Island field. The thinning and pinching out of sands basinward, in this case toward the Gulf Coast Geosyncline, is a normal sedimentary depositional process and is not unique to this area.

The only field producing from Miocene horizons adjacent to the STP site is the Collegeport field (which includes Collegeport North and Citrus Grove fields). This field is approximately 7 miles southwest of the plant site. It produces from a low-relief, anticlinal structure with minor faulting. There are 32 producing zones ranging in depth from 1,980 ft to 5,675 ft. The average thickness of a producing zone is 15 ft. As of December 198~~3~~ 4, the field had produced ~~424,640~~ approximately 427,400 barrels of oil and ~~450,031~~ 453,830 MMCF of gas. Although electric logs indicate that in general the Miocene sand bodies at the Collegeport field are correlative with those beneath the site, the sands at the site are nonproductive. The most logical reason is that structural conditions that would trap any oil or gas are absent at the STP site. 33 44 Q 231. 02N

The abandoned Cane Island field, situated approximately 1.7 miles north of the plant site, produced from two sands in the upper Frio. The sands average 5 ft in thickness. In the site area, the sand development in the upper Frio appears to be very poor, and the absence of oil or gas may be attributed to stratigraphy. Currently (December 1983), the field is still considered abandoned. 33 Q 231. 02N

On the basis of the stratigraphic and structural data obtained from the exploratory wells drilled at the site, it is apparent that there is little possibility of obtaining commercial quantities of oil and gas in the Miocene formations, i.e., to a depth of approximately 7,200 ft. Also, because six of the wells at the site were drilled to depths of between 10,000 ft and 16,000 ft with no indications of oil and gas, finding commercial quantities of oil and gas in the Frio formation down to the greatest depth drilled is precluded.

Assuming that the Frio sands are nonproductive, oil and gas production could be possible only in some lower horizon in the Eocene (Wilcox) or Paleocene. The depth to the Wilcox - or even to some formation higher in the Eocene - is not known, but the Wilcox is believed to be very deep, at least 20,000 ft (Ref. 2.5.1-34).

The gradational and statistical density test evaluation of the Category I structural backfill will be updated for all sources upon completion of backfill operations. 36

The results of field testing and inspection activities are maintained as part of the permanent project records stored in the site QA vault.

2.5.4.6 <u>Groundwater Conditions</u>. Site and regional groundwater conditions are discussed in Section 2.4.13 and Section 2.5.1.2.10. Control of the groundwater during construction is discussed in this section together with summary descriptions of the observed and projected groundwater conditions.

Two aquifer zones separated by an aquiclude (deep confining zone) exist in the site area. The shallow aquifer zone is temporarily affected by plant construction dewatering while the deep aquifer zone is well below the influence of any construction activities. The deep aquifer zone is subject to regional groundwater withdrawal for irrigation and other purposes, as described in the above-referenced sections. PSAR Figures 2.4.13-1A through 2.4.13-1C show generalized geohydraulic cross-sections through the site area.

For foundation engineering purposes, the shallow aquifer zone and aquiclude have been divided into 13 generalized layers (see Figures 2.5.1-38 through 2.5.1-40 and Section 2.5.4.3) which have been assigned alphabetical designations (A through N, exclusive of I). Of these generalized layers, the B, C, E, G, H, M, and N layers are composed primarily of cohesionless material while 36
the remainder consist primarily of cohesive soils. The natural piezometric level in the upper portion of the shallow aquifer zone (from the ground surface to a depth of 40 ft) is about 1 ft below the ground surface as measured in layer C. Layer C is located about 37 ft below the ground surface. The natural piezometric level in the deeper portion of the shallow aquifer, which includes the E, G and H layers, is about 9 ft below the ground surface. The E, G, and H layers are typically located 60, 80, and 120 ft, respectively, below the ground surface.

The deep aquifer zone extends from a range of 250 ft to 300 ft to a range of 800 ft to 1,000 ft below the ground surface and is confined by a substantial continuous clay layer from the shallow aquifer. The piezometric level in the deep aquifer zone in the plant area was at a depth of about 60 ft below the ground surface in 1975, and at a depth of about 70 ft in 1985 (see PSAR Figure 44
2.5.1-16E, FSAR Figures 2.5.4-70A and 2.5.4-70B, and Appendix 2.5.C).

The groundwater in the shallow aquifer zone will be allowed to return to the natural elevations upon completion of the plant area substructure construction and backfill. There are no requirements for any artificial groundwater control by either dewatering or recharge during plant operation. The piezometric levels in the shallow and deep aquifer zones will be monitored throughout the life of the plant as discussed in Section 2.5.4.13 and Appendix 2.5.C.

2.5.4.6.1 <u>Foundation Stability Due to Groundwater Conditions</u>: The influence of the piezometric pressures on the stability of the foundations and the supporting soil has been considered for the periods of excavation, backfill, and building construction and during plant operations.

Excessive piezometric pressures in the subsoil could potentially result in instability of the excavation bottom during construction with associated heave and loss of strength as well as possible uplift of foundations and substructures. To control piezometric pressures in the subsoil, ground-water-level control criteria were established and used as a basis for design, installation, and operation of the Dewatering System. The ground-water control criteria are described in Section 2.5.4.6.2; the design of the Dewatering System is described in Section 2.5.4.6.3; and the results of the monitoring of the piezometric elevations are given in Section 2.5.4.6.4.

The groundwater level will return to between Els. 17 ft and 26 ft MSL after
decommissioning of the Dewatering System. Future piezometric-level declines
in the shallow aquifer zone due to groundwater withdrawal are not expected,
primarily because of poor quality water and relatively low yields (see Section
2.4.13.2.5). The applied foundation pressures used in the bearing-capacity 36
evaluation have been based on the lower level which is most conservative for
the mat foundations supporting the Category I structures, as these substructures have very substantial displacements reducing the net effective foundation pressures as the groundwater level increases. The derivations of coefficients of subgrade reaction have been based on the highest postulated piezometric pressure, as this will cause the lowest effective confining pressures, thereby reducing the stiffness of the soil. Another consideration supporting the selection of the highest groundwater table for the settlement analyses is that the higher water level in the shallow aquifer zone (El.26 ft MSL) will increase the total as well as effective stresses in the material of the aquiclude and deep aquifer zone where the major portion of the settlement is anticipated to occur (see Section 2.5.4.10), thereby conservatively increasing the estimated total settlement. Long-term groundwater withdrawal of the deep aquifer is conservatively estimated to further reduce the piezometric level 87 ft ~~during the lifetime of the plant.~~ between 1973 and 2020. The concomitant regional subsidence is estimated to be less than 3 ft, will be uniform across the plant site, and will not affect the stability and performance of the plant facilities (see Section 2.5.1.2.9.6).

2.5.4.6.2 Groundwater Control Criteria: The construction specification for dewatering requires that the piezometric elevation be maintained at least 5 ft below the excavation bottom within all permeable strata in the shallow aquifer zone that subsequently would be supporting Category I structures, i.e., the E, G and H layers. This requirement was met during all construction operations.

During substructure construction, the piezometric-level control criteria were
established to maintain a calculated factor of safety of at least 1.3 against 36
uplift of the partially completed structures at all times.

The lowest permissible piezometric elevation has been based on limiting the
net increase in foundation pressure to 5.5 kip/ft^2. This limiting pressure 44
does not significantly reduce the factors of safety against bearing-capacity
failure (see Section 2.5.4.10.2.3) and allows for some beneficial acceleration
of the settlement process during construction.

All seepage and rain into the excavation (see Section 2.5.4.5) were collected by ditches and sumps and were removed by pumping.

2.5.4.6.3 Construction Dewatering: The construction Dewatering System for the plant structures consisted of one perimeter installation around the entire excavation area supplemented with local systems around the deeper RCB-FHB excavations for each unit. The configuration of the excavation and the layout of the Dewatering System is shown on Figure 2.5.4-64. The perimeter wells were installed at 50-ft spacing and penetrated the E layer. The design installation capacity was 33 gal/min for each well at 100-ft total design head. The deep wells of the perimeter system were supplemented by sand drains (see Figure 2.5.4-64) at 10-ft spacing to relieve the excess piezometric pressure and provide drainage of the C layer.

The local Dewatering Systems consisted of deep wells penetrating the E layer with every fourth well typically penetrating the G and H layers of Unit 1 and every other well typically penetrating the H layer of Unit 2 (the G layer is not present in Unit 2). The wells of the local system were installed at approximately 40-ft spacing. The deep wells of the local Dewatering Systems had a design capacity of 32 gal/min at 140-ft total head.

Piezometers were installed in the C, E, G, and H layers as shown on Figure 2.5.4-64 to monitor the drawdown and performance of the Dewatering System. Pore pressure cells were installed in selected piezometers in the building areas and also in the backfill to allow monitoring after construction of the building foundations.

2.5.4.6.4 Groundwater Recordings During Construction: The actual responses of the piezometers located in the C, E, G, and H layers are shown on Figures 2.5.4-65 ~~and~~ 2.5.4-65A AND 2.5.4-65B for Unit 1, Figures 2.5.4-66 ~~and~~ 2.5.4-66A AND 2.5.4-66B for Unit 2. 26 Q241 .2N

The perimeter system pumping rate was initially 2,900 gal/min, and a steady-state condition was reached after about 6 weeks of pumping at a rate of about 1,300 gal/min. At both units, local systems discharged initially at a rate of about 500 gal/min each. The long-term combined pumping of the Unit 1 local system plus the perimeter system was 1,300 gal/min. The combined pumping of Unit 2's local system plus the perimeter system was 1,500 gal/min. This indicates a significant drop in perimeter pumping as the local systems reached a steady-state condition.

The C-layer artesian pressure was relieved after about 75 days of pumping, at which time the piezometric surface was just below the top of the layer. There was insignificant drawdown in the C layer after this point due to the very low permeability of the layer.

Layer E responded rapidly to the perimeter Dewatering System pumping, and the piezometric pressures were reduced to about El. -30 ft MSL, i.e., near the top of the E layer in less than 5 days. The piezometric level in the E layer subsequently dropped to about El. -46 ft MSL over a period of 50 days. This period represents the actual dewatering (lowering of the phreatic surface) in the E layer. The local Dewatering Systems, as they became operational, further reduced the piezometric level to about El. -50 ft MSL, which is near the bottom of the E layer.

The piezometric levels in the G and H layers also responded to the perimeter pumping system, which demonstrates that the G and H layers are hydraulically connected with the E layer some distance from the plant area. The piezometric levels in the G and H layers were drawn down to about El. -20 ft MSL over a 120-day period.

The G and H layers respectively responded very rapidly to the local pumping, and the peizometric pressures were drawn down to about El. -70 ft MSL, i.e., near the top of the G layer, in less than 10 days. It is evident from the similarity of response that the G and H layers are hydraulically connected. The recharge of the G and H layers was very rapid upon termination of the local dewatering, system for Unit 1 in November, 1976. The increase in piezometric level within the H layer (note that the G layer does not exist in Unit 2) was likewise very rapid when the pumping of the local dewatering system for Unit 2 was terminated in February of 1978, which demonstrates that there had not been any significant depletion of the lower portion of the shallow aquifer zone due to the construction dewatering. 36

The pumping of the perimeter dewatering system has been gradually reduced since early 1978, to allow for a controlled increase in groundwater elevation within the plant area as the building construction and backfill proceeds. The pumping rate of the perimeter system was 600 gal/min in February, 1979. The groundwater elevation increased during 1978 at a typical rate of 4 ft per month within the E layer due to this reduction in pumping rate. The piezometric level in the C layer increased by a nominal amount (i.e. less than 10 ft) during the same time period. As of August 1984 the pumping rate of the 36
perimeter system was approximately 700 gal/min, consequently plant area water 44
levels as of this date were slightly lower than 1979. ← Insert X 36

2.5.4.6.5 Permeability Determinations: The design of the Dewatering System for construction was primarily based on a series of three pumping tests performed at the plant site. Three additional pump tests, two in the shallow aquifer and one in the deep aquifer, were conducted in wells located 1 to 3 miles from the plant site.

The properties of the upper section of the shallow aquifer zone were determined by a pump test run in layers B and C. The lower section of the shallow aquifer zone consists of three separate layers (E, G, and H) at the plant site. Two pump tests, one short term (5 days) and one long term (12 days), were performed to determine the properties of this lower section. Both of these tests were run in layer E, and the hydraulic properties of layers G and H were considered to be essentially the same as those of layer E. The estimate of similarity between layers E, G, and H was based on a comparison of grain size, density, fabric, and piezometric response during the long-term pump test.

On the basis of the pump test results, the permeability, transmissibility, and storage coefficients of the two sections that constitute the shallow aquifer zone were computed. A summary of the aquifer characteristics is given in Table 2.5.4-33. The results of laboratory permeability tests on the structural backfill materials are also included in this table.

2.5.4.6.6 Groundwater History: The groundwater elevations in the general plant area within the shallow aquifer zone for the period September

Insert X (2.5.4-64)

In November 8 1984 rewatering of the power block began with deactivation of portions of the perimeter system. Groundwater is being allowed to return to ambient level in a gradual controlled manner. As of July 1985 the pumping rate of the perimeter system was approximately 250 gpm with the plant area water level at approximately el. +10 ft. MSL.

JUNE 1985

1973 to just before initiation of the plant area Dewatering System in November 1975 are shown on Figures 2.5.4-67 through 2.5.4-69. The piezometer locations are shown on Figure 2.5.4-50 and 2.5.4-51. The piezometric response within the shallow aquifer zone during dewatering operations through July 1984 is depicted on Figures 2.5.4-65, 2.5.4-65A, 2.5.4-65B, 2.5.4-66, 2.5.4-66A, and 2.5.4.66B. 26 Q 241 .02N 4

The groundwater in the lower portion of the shallow aquifer is expected to return to its normal preconstruction elevation at 17 ft as controlled by the ambient piezometric pressure in the E, G, and H layers. The piezometric pressure of the C layer, i.e., the upper zone of the shallow aquifer, will be similar to the pressure of the deeper part of the shallow aquifer zone in the immediate vicinity of the plant structures due to the interconnection of the upper and lower zones by the pervious backfill. However, the pressure is expected to increase in the upper zone to the general ambient elevation near 26 ft MSL at locations beyond 200 ft from the plant structure limits (to be supported by piezometric data obtained after plant backfill and natural recharge).

The probable maximum flood (PMF) is described in Section 2.4.3. The postulated maximum runup for which the plant structures are designed varies around the perimeter of structures and is discussed in detail in Section 3.4. The groundwater piezometric pressures will rise to the PMF elevation for a short period of time because of the direct hydraulic communication through the backfill. The increased piezometric pressures will dissipate within a short period of time as indicated by the rapid responses described in Section 2.5.4.6.5.

Historical piezometric levels in the site vicinity show the progressive lowering of the piezometric elevation of the deep aquifer zone (see PSAR Figure 2.4.13-5A). Prior to significant groundwater withdrawals, which began in the 1940's, deep aquifer-zone piezometric levels were slightly above ground surface. In recent history, the piezometric elevations have remained at about sea level from 1967 to 1973 near the eastern boundary but have declined from about El. -14 ft MSL to about El. -28 ft MSL at the western site boundary. For the STP plant site area, the 1975 piezometric level was estimated to be at El. -33 ft MSL (see PSAR Figure 2.5.1-16D)~~; in 1984 this level is at about El. -43 ft MSL (see Figure 2.5.4-70B).~~ AND FOR 1984 AND 1985 EL-43 FT MSL AND -42 FT MSL, RESPECTIVELY (see Figure 2.5.4-70B). 44

The groundwater elevations in the deep aquifer zone are conservatively estimated to be lowered an additional 87 ft below the observed elevations described above, in the period between 1973 and 2020 (see Section 2.5.1.2). Leave at 87 FT Leave at 2020

2.5.4.6.7 Monitoring of Groundwater Elevations: The piezometric elevations in the plant area were recorded on a weekly basis during construction (see Section 2.5.4.6.4 above). The regional groundwater conditions in the shallow and deep aquifer zones are being recorded on a monthly frequency.

2.5.4.6.8 Groundwater Flow: The plant area groundwater flow coincides with the regional flow as described in Section 2.4.13.2.4. The groundwater movements are westward in the deep aquifer and toward the southeast in the shallow aquifer. 5 Figures 2.5.4-70, 2.5.4-70A, and 2.5.4-70B show the gradient in the deep aquifer zone at various times between 1951 and 1985. PSAR Figures 2.4.13-11 and 2.4.13-14 show the preconstruction gradient of the lower and 26 Q 241. 02N 4

ATTACHMENT 1
ST-HL-AE-1399
PAGE 21 OF 60

The preliminary construction phase re-analysis also included using a deeper stratigraphic column and a more efficient and versatile computer program. The preliminary (1979) studies included two of the three regimes of heave/settlement process, that is, heave and recompression of heave. The third regime, net settlement, was being approached when the preliminary study was completed.

In 1983, an additional settlement evaluation was made which included projections of the movement curves. This evaluation included the use of the revised construction load schedule, and the use of the field instrument data obtained through April 1983. The study also considered the effect of the main cooling reservoir (MCR) embankment load and water load (Ref. 2.5.C-1). The study utilized the information from the previous (1979) analysis, an interim (1981) study, and the trend line plots of instrumentation data from construction day 1500 (approximately 19 October 1979) to construction day 2800 (approximately 11 May 1983). 35

The projections of future settlement were made using the previous analyses and instrument data. This was confirmed with an analysis using a consolidated model based on a compressibility concept similar to a compression/tension spring analogy.

The results of the construction phase settlement analysis described herein are further addressed in Section 2.5.C.4.5 below. The settlement projection curves for the behavior of the structures are shown on Figure 2.5.C-9, 2.5.C-9A, 2.5.C-10, and 2.5.C-10A superimposed on the actual observations. 35

2.5.C.4.5 <u>Predicted and Actual Movement</u>.

2.5.C.4.5.1 <u>Unit 1 Area:</u> The actual movements for the Reactor Contain-
ment, Fuel Handling, Mechanical-Electrical Auxiliaries, and Diesel-Generator 26
Buildings are shown on Figures 2.5.C-9 and 2.5.C-9A. These curves have been Q
taken directly from Sondex, BHP, and Structural Bench Mark observations at 241
points near the foundation elevations for the buildings, as noted on the fig- 01N
ure. The projected movement curves, based on the settlement analysis as 26
described in Section 2.5.C.4.4.1 above, have been superimposed on the observed Q
movement curves for each building. These projected movement curves are based 241
on the settlement analysis for actual construction loads and instrument data 01N
to April 1983. ~~The projected movement curves show an agreement with the actu-~~ 44
~~al observed heave, recompression, and settlement.~~ Insert X 35

The projected maximum differential settlement between structural bench mark (SBM) locations, see Figure 2.5.C-3, is shown on Table 2.5.C-4. The projected tilt within the various structures is shown on Table 2.5.C-5. The observed differential movement between buildings is shown on Figure 2.5.C-11. The differential movement profile within buildings (tilt) is shown on Figures 2.5.C-13A and 2.5.C-13B.

The effect of the embankment load and water load of the essential cooling pond was considered in the Design Phase (1974-1975) analysis and the recent (1983) settlement projections. The essential cooling pond has little effect on the settlement of Unit 1 because there is very little load and subsequent subsurface stress field change. The pond is but a rearrangement of load due to the shallow excavation and low dikes.

Insert X (2.5.C-6)

Until about April 1985, the projected movement curves showed good agreement with the actual observed heave, recompression and settlements. From April to August 1985, the observed settlements are slightly higher than the projected settlements. The difference is attributed to a slower rate of rewatering than was assumed in the 1983 settlement evaluation.

(Ref. 2.5.C-1)

The effects of the MCR embankment and water load have been considered (Ref. 2.5.C-1). The effect of the embankment, which has been in place some time, is accounted for in the field instrument data and subsequently the current (1983) settlement projections which used the instrument data. The effect of the MCR water load ~~(Ref. 2.5.C-3)~~ on the structures will be small, ~~It is on the order of 0.005 feet (approximately 1/16 inch)~~ and was not taken into ~~direct~~ account ~~because it is such a small value.~~ in the projections. 35

after day 3400 (approximately end of 1984)

Very little differential settlement has been observed between the Unit 1 buildings. Also, very little anticipated differential settlement is projected for the Unit 1 structures (Table 2.5.C-4). The anticipated tilt after day 3400 (Approximately end of 1984) for Unit 1 (Table 2.5.C-5) is projected to be small, and observed tilts are small since day 3400. 39

2.5.C.4.5.2 Unit 2 Area: The actual movements for the Reactor Containment, Fuel Handling, Mechanical-Electrical Auxiliaries, and Diesel-Generator Buildings are shown on Figures 2.5.C-10 and 2.5.C-10A. These curves have been obtained directly from Sondex, BHP, and Structural Bench Mark observations at points near the foundation elevations for the buildings as noted on the figure. 26 Q 241.01N 3

The projected movement curves are based on the settlement analysis as described in Section 2.5.C.4.4.1, above, have been superimposed on the observed movement curves for each building. The projected movement curves are based on the settlement analysis for actual construction loads and instrument data to May 1983 and the anticipated Unit 2 construction loads and schedule. ~~The projected movement curves show an agreement with the actual observed heave, recompression and settlement.~~ Insert (I) 35 44

The projected maximum differential settlement between locations (see Figure 2.5.C-3) are shown on Table 2.5.C-6. The projected tilt within the various structures is shown on Table 2.5.C-7. The observed differential movements between buildings ~~is~~ are shown on Figures 2.5.C-12 and 2.5.C-12A. The differential movement profiles within buildings (tilts) ~~is~~ are shown on Figures 2.5.C-14 and 2.5.C-14A.

The effect of the essential cooling pond embankment load and water load was not considered for the Unit 2 settlement evaluation and projection, ~~It was not considered because~~ as it is quite distant ~~from Unit 2~~ and has no effect on the stress field beneath Unit 2. 35

The effect of MCR is the same as previously discussed for Unit 1.

A small amount of differential settlement has been observed between the Unit 2 buildings after day 3400. Generally only a small amount of future differential settlement is anticipated. The anticipated tilt for Unit 2, Table 2.5.C-7, is generally small, and the observed tilt is ~~not~~ also small since day 3400.

2.5.C.4.6 Conclusions.

2.5.C.4.6.1 Behavior of Foundation Soils and Structures: The current geotechnical instrumentation data show that the foundations soils in the plant area did heave and recompress in good agreement with the projections obtained from the preliminary construction phase analysis. The projections have been updated (1983) to reflect the actual load history, the projected loading, and 35

Insert (I)

IR The observed settlements for unit 2 show some departure from the projected movement curves. This departure is attributed to higher foundation loading rates and slower rewatering rate than were assumed in the 1983 settlement study.

schedule to completion, and are shown on Figures 2.5.C-9 and 2.5.C-9A for Unit 1 and Figures 2.5.C-10 and 2.5.C-10A for Unit 2. 35

The differential movements between Unit 1 structures measured as of ~~mid 1984~~ are shown on Figures 2.5.C-11 and 2.5.C-11A. The recorded differential movements vary from negligible between the ~~Isolation Valve Cubicle (IVC)~~ and the Reactor Containment Building (RCB) to ~~about~~ 1 in. between the IVC and the Turbine-Generator Building (TGB). 44

The differential movements between the Unit 2 structures measured as of ~~mid-1984~~ are shown on Figures 2.5.C-12 and 2.5.C-12A. These differential movements vary from ~~negligible~~ between the ~~Mechanical Electric Auxiliary Building (MEAB)~~ and the ~~RCB~~ to ~~0.4~~ in. between the MEAB and the FHB.

~~The measured differential movements between structures for Unit 1 and Unit 2 to date are within the design criteria defined in Section 2.5.4.11.~~ 35

The measured differential ~~movements within the~~ structures of Unit 1, as of ~~mid 1984~~ are shown on Figures 2.5.C-13A and 2.5.C-13B. These figures indicate that there was very little change in the differential movements since February 1982. The maximum differential ~~movements~~ were 0.2 in. in the RCB, 0.5 in. in the FHB (north-south section), 0.7 in. in the MEAB (east-west section) and 0.12 in. in the DGB. 44 35 44 35

The measured differential ~~movements within the~~ structures of Unit 2 as of ~~mid 1984~~ are shown on Figures 2.5.C-14 and 2.5.C-14A. The measured maximum differential movements were 0.13 in. in the RCB, 0.35 in. in the FHB (north-south section) 0.6 in the MEAB (east-west section) and 0.24 in. in the DGB. 44

~~The measured differential movements and tilt within structures for Unit 1 and 2 are within the design criteria defined in Section 2.5.4.11.~~ 35

2.5.C.4.6.2 Predictions of Differential Movements During Plant Operation: The design criteria for differential settlement affecting piping systems are defined in Section 2.5.4.11 and are applicable after the actual pipe connections between the buildings have been made. It is estimated that no pipe connections are to be made prior to the end of 1984. 43 39

The projected tilt and differential settlement for Unit 1, after construction day 3400 (end of 1984) are reported in Tables 2.5.C-4 and 2.5.C-5. The values are acceptably small. 35

The projected tilt and differential settlement for Unit 2, after construction day 3400, are reported in Tables 2.5.C-6 and 2.5.C-7. The projected tilt and differential settlement for Unit 2 after day 3400 will be acceptably small. 39

2.5.C.5 Regional Subsidence Monitoring Program

2.5.C.5.1 Regional Subsidence Monitoring System Description. The regional subsidence monitoring program is capable of monitoring both vertical and horizontal ground surface movements at the STP site. This is accomplished by the installation of a deep reference bench mark, 13 near-surface monuments for measurement of vertical ground surface movement, and 9 near-surface monuments for measurement of horizontal ground surface movement (see Figure

Insert (II)

It is noted however that the differential movements and tilts referred to above are measured from the time of installation of structural benchmarks at early stages of construction. Differential movements and tilts from construction day 3400 are well below the corresponding criteria values defined in Section 2.5.4.11.

2.5.C-1). To supplement the vertical and horizontal near-surface monuments, an array of open standpipe piezometers was used to monitor the two distinct groundwater aquifer zones. As shown on Figure 2.5.C-18, 30 permanent piezometers have been installed; 21 of these are located in the shallow aquifer zone, and 9 are located in the deep aquifer zone (See Table 2.5.C-2).

The deep reference bench mark functions as datum for the near-surface subsidence monuments, and this datum was established by a first-order-level loop from the primary reference bench mark (see Section 2.5.C.2) prior to the commencement of dewatering and plant area excavation operations. The relative movement of the primary reference bench mark versus the deep reference bench mark is established periodically to provide continuity between measurements of the settlement and subsidence monitoring systems.

2.5.C.5.2 Instrument and Installation Description.

2.5.C.5.2.1 Deep Reference Bench Mark: The deep reference bench mark was designed to enable the continuous measurement of total subsidence at the STP site throughout the life of the plant. The deep reference bench mark was positively anchored to the strata and was installed at a depth below the zone of potential regional subsidence caused by groundwater withdrawals, with the top of the anchorage approximately 1,134 ft below the ground surface. The anchorage and riser pipe were separated from possible consolidation effects of the overlying compressible zones by a 4-in.- diameter casing. To provide continuous ground surface subsidence measurements, a modified Stevens type F recorder will be installed and operated within an instrument shelter when the plant area backfill reaches final grade. The recorder will be supported on the ground surface, free to move relative to the bench mark. Continuous recordings will be obtained by attaching the top of the deep bench mark riser pipe by a weight-tensioned wire to a chart drum which will turn proportionally to the settlement as a clock-controlled pen moves over the chart at constant speed. 35

233 (DBM) The DBM is

The deep reference bench mark (DBM) was installed in [redacted] existing exploratory borehole which had been drilled to a total depth of 2,619.5 ft below the ground surface ~~(Boring Z[illegible])~~. ~~This boring was~~ located immediately south of the plant structures, as shown on Figure 2.5.C-1. A 4-in.-diameter casing was installed to a total depth of 1,115 ft (bottom of casing at elevation -1,087 ft MSL). The bottom 100 ft of a 2-in.-diameter galvanized pipe was anchored in grout below elevation -1,107 ft MSL, thus leaving a 20-ft open section to prevent influence between the anchor and casing.

2.5.C.5.2.2 Near-Surface Subsidence Monuments: A series of 13 near-surface subsidence monuments was installed in the plant vicinity, as shown on Figure 2.5.C-1. These bench marks were anchored at a depth of about 18 ft, thereby minimizing the effects of seasonal shrink/swell ground surface movements due to variations in water content in the surface clays. The elevations of the near-surface monuments are periodically determined relative to the deep reference bench mark by conventional survey techniques to a precision of ±0.01 ft.

The near-surface vertical monuments consist of an approximately 18-ft-long, 3/4-in.-diameter steel rod. A borehole was drilled to a depth of 10 ft for installation of the monument, and the rod was inserted in the borehole and

2.5.C.5.2.5 Regional Deep Aquifer Piezometers: The eight regional deep aquifer piezometers installed in 1974 were designed to register the composite artesian pressure for the deep aquifer zone. A ninth deep aquifer piezometer (no. 029) was installed in 1975 adjacent to the deep reference bench mark. A 5-ft-long, wire-wrapped pipe base screen was positioned opposite each major sand stratum below a 280-ft depth with solid pipe between the screen sections. Sand was placed around the standpipe and screen sections up to a depth of 220 ft, and a bentonite-cement grout was placed around the standpipes through the remainder of the aquiclude and shallow aquifer zone. The piezometers were installed with 1-1/2-in. and 2-in. diameter screens and riser pipes. These piezometers are of sufficient diameter to allow sampling of the groundwater at selected depths and can be used to monitor water quality (see Section 2.4.13.4). The piezometers were developed by inserting a 1-in.-diameter steel pipe to the bottom and pumping compressed air into the standpipe until the water was clear. Reaction time was checked as described above for the shallow aquifer piezometers. The piezometer installations have vented, removable caps and are protected with barricades. The depths of the piezometer installations 20
and the diameters are listed in Table 2.5.C-2A.

Measurements of the piezometric elevations are obtained by using apparatus and methods similar to those used for the shallow aquifer piezometers (see Section 2.5.C.5.2.4) and are likewise recorded to a precision of ±0.1 ft.

2.5.C.5.3 Frequency of Observation. During construction, the near-surface subsidence monuments and the shallow aquifer piezometers are monitored on a monthly basis (see Table 2.5.C-1). The regional horizontal strain monitoring is implemented on a semiannual basis. The regional deep aquifer piezometers are monitored on a weekly basis. The total subsidence monitoring at the deep reference bench mark will be monitored by a continuous recording device when final grade is achieved in the plant area as described in Section 2.5.C.5.2.1.

2.5.C.5.4 Interpretation of Field Data. Subsidence monitoring data have been checked and evaluated by geotechnical engineering personnel. Initially the monitoring data were plotted directly in the field as the measurements are obtained to allow direct field cognizance of the quality of the data and events which may have affected the data. Similar plots were maintained in the engineer's office and periodically checked against the field plots. 44

Currently, the subsidence data are periodically compiled and reviewed in the office. 44

2.5.C.5.5 Monitoring Results.

2.5.C.5.5.1 Deep Reference Bench Mark: Subsidence monitoring data of the deep reference bench mark location will be provided when the continuous subsidence monitoring instrumentation has been installed.

2.5.C.5.5.2 Regional Near-Surface Subsidence Monitoring: The locations of the regional subsidence monuments are shown on Figure 2.5.C-1.

The observed movements of the individual monuments are shown on Figures 2.5.C-19 AND 2.5.C-19A. The deep reference bench mark is used as a reference for regional near-surface monitoring. The combined relative movements of the regional 2 Q36 04

horizontal strain and near surface subsidence monuments through March 1984 are shown in Figures 2.5.C-23 and 2.5.C-24. 44 35

Figures 2.5.C-25, 2.5.C-25A, and 2.5.C-25B, show contours of the total subsidence as of January 1979, January 1981, and June 1984, respectively. The contours of total subsidence experienced since 1976 are superimposed on contours of the decline in piezometric levels of the deep aquifer since the start of construction activities (1975 data shown on Figure 2.5.4-70 (4) used as basis). 35 5 44 Q 361 .10 35

Monuments SV-I, (subsequently replaced by monument SV-N in May 1980) and SV-H are within the area subject to significant heave caused by plant area excavation, structural loads and backfill. Monument I (N) has subsequently followed the recompression of heave essentially controlled by Unit 1 Construction (See Figure 2.5.C-9), but the monument has also been influenced by settlement caused by construction of the embankment for the main cooling reservoir. Monuments F, G, and J have further been influenced by continued excavations north and east of Unit 1 for the Essential Cooling Water pipes and the Essential Cooling Pond. The 1981 review concluded that the net effect was that the stress reduction due to plant area excavation caused a local heave which to some extent has offset the otherwise uniform regional subsidence pattern. Construction of the main cooling reservoir embankment has caused a comparatively steepened gradient on the south side of the plant. The present review (1984) indicates that the monuments continue to be influenced by near-surface effects of plant construction, though the vertical control curves generally flattened and in some cases rebounded slightly during the 1981-1984 period (see Figure 2.5.C-19). 26 Q 241 02N 35 35 44 44

The average subsidence for the six monuments outside the area of major influence from the plant area stress reduction (i.e., A, B, C, D, E, and K) show an interpreted subsidence rate range of from less than 0.1 in. to about 0.2 in. per year. Short-term movements deviating from the long-term trends have been recorded during irrigation pumping within the deep aquifer. These movements relative to the long-term trend have been typically about 0.3 in., entirely within the elastic range of deformation for the clay strata underlying the site region. 44 35

2.5.C.5.5.3 Regional Horizontal Strain Monitoring: The base line distance between the horizontal strain monitoring monuments is shown in Tables 2.5.C-3, 2.5.C-3A, and 2.5.C-3B, together with the relative changes in the distances as measured twice a year. The surveys will be conducted at 6-month intervals, construction conditions permitting. Figures 2.5.C-23 and 2.5.C-24 show the combined movements for regional horizontal strain and near-surface subsidence monuments through March 1984. The recorded movements are within the criteria for accuracy of the measurements (1:10,000) except between monuments G and J where a difference of -0.134 ft was observed over a distance of 740 ft on June, 8 1978 (See Table 2.5.C-3A). This anomaly has subsequently fully recovered and is being attributed to a survey inaccuracy. The overall evaluation is that the recorded differences in distance between the occasions appears to be random and no trends can be discerned. 26 Q241.02N 2 Q361. 4 44 44 26 Q244 .02N 5 Q361.9 26 Q241 .2N

2.5.C.5.5.4 Regional Shallow Aquifer Monitoring: Locations of the piezometers are shown on Figure 2.5.C-18. The piezometers located in the shallow aquifer zone are identified in Table 2.5.C-2. Time history plots of

shallow aquifer groundwater fluctuations commencing in 1973 are provided on Figures 2.5.C-20 and 2.5.C-20A for the upper zone, and on Figures 2.5.C-21 and 2.5.C-21A for the lower zone. As can be seen, there is no evidence of sustained regional groundwater table lowering during the preconstruction and construction monitoring periods. The decline in the lower zone of the shallow aquifer starting in November 1975 was caused by plant construction dewatering, and a corresponding recovery has occurred since the dewatering pumping rate has been gradually reduced beginning in early 1978 (see Section 2.5.4.6.4). 26 Q241.02N

2.5.C.5.5.5 Regional Deep Aquifer Monitoring: Locations of the piezometers are shown on Figure 2.5.C-18. The piezometers located in the deep aquifer zone are identified in Table 2.5.C-2. Provided on Figures 2.5.C-22 and 2.5.C-22A are time-history plots of deep aquifer groundwater fluctuations commencing in January 1975, which show that during the rice irrigation season the piezometric level is lowered, particularly at the northern site boundary. The piezometric level increases again during the winter non-growing season. The decline of piezometer No. 604 during the beginning of 1976 was caused by start of pumping in the adjacent deep well used for plant construction purposes. Similarly, piezometer No. 613 and to some extent No. 614 are affected by deep well pumping for construction purposes. This localized drawdown is temporary and will partially recover when the construction withdrawal is reduced to the quantity for normal plant operation. The construction dewatering system is described in Section 2.5.C.6.1.2. The groundwater conditions are also further described in Section 2.4.13.2.3. 26 Q241.02N 5 Q361.08 26 Q24 021

2.5.C.5.6 Conclusions. The regional shallow aquifer monitoring demonstrates that piezometric levels within the shallow aquifer zone have remained near their 1973 ambient levels outside the area of influence from construction dewatering. This substantiates the PSAR conclusion that this aquifer zone is little used. The construction dewatering effects in the plant area on this aquifer zone are addressed in Section 2.5.4.6.

There have not been any significant regional changes in the groundwater conditions of the deep aquifer during the monitoring period of 1973 through ~~July~~ JUNE 198~~4~~5. The relative decline varies between the irrigation pumping and non-pumping seasons. Based on the piezometers most removed from on-site pumping (605, 606, 607, 608), the average annual decline between January 1975 and ~~July 1984~~ MAY 1985 (Figures 2.5.4-70, 2.5.4-70A, and 2.5.4-70B) has been approximately one foot or less. (Peak declines in these piezometers occurred in 1981; between 1981 and 198~~4~~5 piezometric levels have generally stabilized or recovered partially.) This is less than the predicted decline of 1.9 ft per year based on the projections described in Section 2.5.1.2.9.6.2.5. The drawdown and recovery associated with the irrigation pumping has followed the general preconstruction seasonal pattern. 35 5 Q 361.08

As of ~~June~~ MAY 198~~4~~5 the net vertical movements of the near-surface subsidence monuments range between approximately 0.5 and 2.25 in. The average subsidence rate of the monuments farthest removed from the plant area ranges from less than 0.1 in. to about 0.2 in. per year, which is less than the 0.6 to 0.8 in. predicted during the PSAR studies (i.e., 2.5 to 3.0 ft between 1973 and 2020, see Section 2.5.1.2.9.6.3.1). The vertical movements were initially rather uniform within the accuracy of the measurements; however, plant construction has affected the movements, particularly during 1978 and 1979. The apparent subsidence to the south of the plant structures has been due to subsurface 26 Q241.02N 5 Q361.10

ATTACHMENT 1
ST-HL-AE-1399
PAGE 31 OF 60

And 2.5.C-25C

consolidation caused by construction of the MCR embankment. The plant area 5
itself has shown less subsidence than the general regional pattern due to the Q361.
heave caused by the construction excavation unloading. The subsidence con- 10
tours of Figures 2.5.C-25, 2.5.C-25A, and 2.5.C-25B indicate that the near- 35
surface influence of plant construction affects most of the subsidence monu-
ment network. The influence of the MCR embankment construction is evident in 44
the gradient toward the south from the plant area; however, the steepness of 35
the gradient in this direction is less than in the previous plate. Comparison
of the subsidence contours to deep aquifer drawdown contours provide evidence
to suggest that only a small amount of the observed movement may be the result 44
of deep aquifer groundwater withdrawal. Near-surface phenomena from construc-
tion loading initiation of MCR drilling and fluctuation of water levels in the
shallow aquifer appear to impose a more pronounced effect on the ground sur-
face movement record.

The overall conclusion is that the regional subsidence and the decline in
regional piezometric pressure within the deep aquifer have been less than
anticipated for the monitored period. The regional behavior supports the
conclusion expressed in the PSAR that there are no discontinuities in the near
surface stratigraphy in the site area (see Section 2.5.1). 35

2.5.C.6 Construction Monitoring Program

2.5.C.6.1 <u>Construction Monitoring System Description</u>. The construction
monitoring program was capable of monitoring lateral soil movements of the
slopes for the local deep excavations for the RCB and FHB for Units 1 and 2
from which the slope stability could be assessed. The construction monitoring
system also includes monitoring the effectiveness of the dewatering system.
This has been accomplished by the installation of six inclinometers and an 44
array of open standpipe piezometers and pore pressure cells (PPCs) located in
the C, E, G, and H layers of the shallow aquifer zone in the plant area.

2.5.C.6.1.1 <u>Slope Stability Monitoring System</u>: Three torpedo inclinome-
ters were installed for each unit (see Figure 2.5.4-52) to allow observations
of the slopes that subsequently would be located under foundations for Catego-
ry I structures. These instruments were installed prior to commencement of
the deep local excavations. All these instruments have been decomissioned as 44
of August 1984.

2.5.C.6.1.2 <u>Dewatering Monitoring System</u>: Open standpipe piezometers 26
were installed in the C, E, G, and H layers of the shallow aquifer zone and in Q241.
the structural backfill to allow observations of the dewatering performed for 02N
construction of the plant area buildings. The locations of these piezometers
are shown on Figure 2.5.4-64. Twenty piezometers were located in the C layer, 35
36 in the E layer, 4 in the G layer, 10 in the H layer, and 4 in the structur- 26
al backfill. Certain piezometers within the excavation were located adjacent Q241.
to settlement/heave instrumentation to provide piezometric-level data directly 02N
correlative to the settlement/heave observations. In order to permit contin-
ued monitoring of piezometric levels during plant construction, PPCs were 35
installed in selected piezometers and subsequently monitored remotely at a
terminal for each unit (Figure 2.5.4-64). In addition, a number of PPCs were
installed directly in the structural backfill to monitor the groundwater in
this material. Five PPCs were located within the C layer, 22 in the E layer, 35
4 in the G layer, 7 in the H layer, and 10 within the structural backfill.

TABLE 2.5.C-3B (Continued)

REGIONAL HORIZONTAL STRAIN MONITORING DATA 35

Between Monuments	Initial Distance (ft) Monitored on 3-30-76	Monitored on 3-16-84 Distance (ft)	Distance Change (ft)[a]	Monitored on 9-14-84 Distance (ft)	Distance Change (ft)
B-G	1,457.749	1,457.822	0.073	1,457.837	0.088
G-J	741.098	741.048	-0.050	741.104	0.006
J-L	1,120.640	1,120.606	-0.034	1,120.617	- 0.023
E-C	1,921.247	1,921.133	-0.114	1921.139	- 0.108
C-F	977.849	977.740	-0.109	977.861	0.012
F-H	1,431.962	1,432.013	0.051	1431.902	- 0.060
M-B	832.907[b]	832.908	0.001	832.923	0.016
M-G	2,290.519[b]	2,290.730	0.211	2,290.760	0.241

44

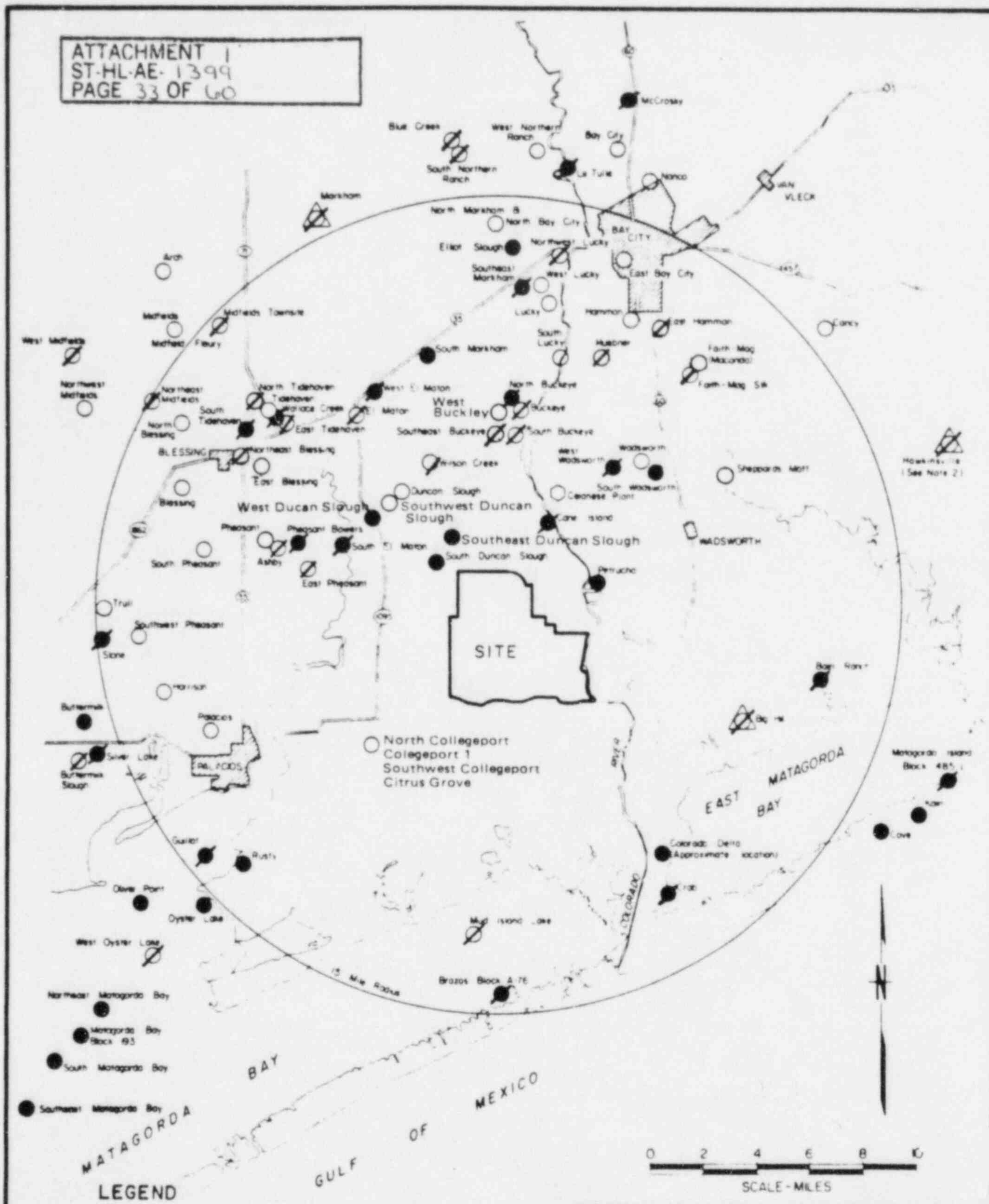
[a]Distance changes are relative to the initial distance determined either on March 30, 1976 or June 8, 1978.

[b]Monument "M" was installed in April, 1978 as a backup for "B"; Initial distances between "M" and "B", and "M" and "G" were monitored on June 8, 1978. 35

Note: For locations of the horizontal near surface monuments, see Figure 2.5.C-1.

ATTACHMENT 1
ST-HL-AE-1399
PAGE 32 OF 60

ATTACHMENT 1
ST-HL-AE-1399
PAGE 33 OF 60



LEGEND

- Location of industrial disposal wells
- Location of oil and gas fields
- Location of salt domes
- Location of gas fields
- Nonproducing fields

NOTES

1. Oil and gas fields within a 15 mile radius of the South Texas Project plant site. Fields outside 15 mile radius show recent area of interest or continuation of a producing trend.
2. Hawkinsville Salt Dome is located 23.7 miles in the direction N 73° E of the plant site.

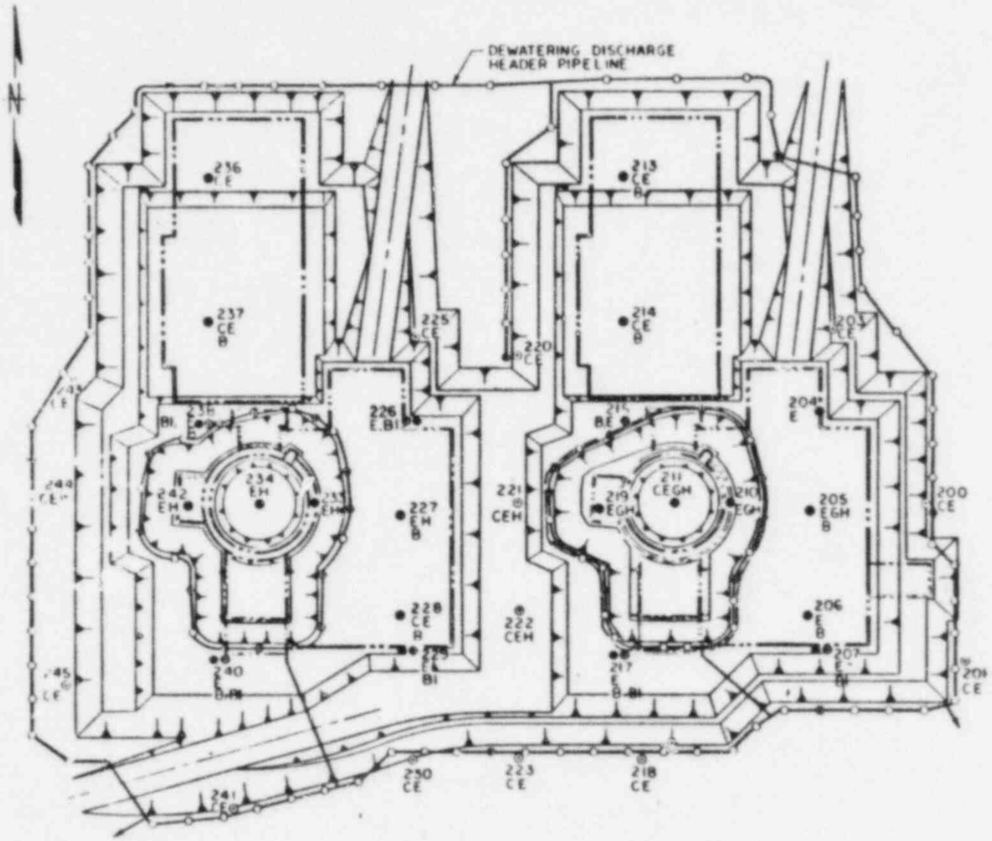
SOUTH TEXAS PROJECT UNITS 1 & 2

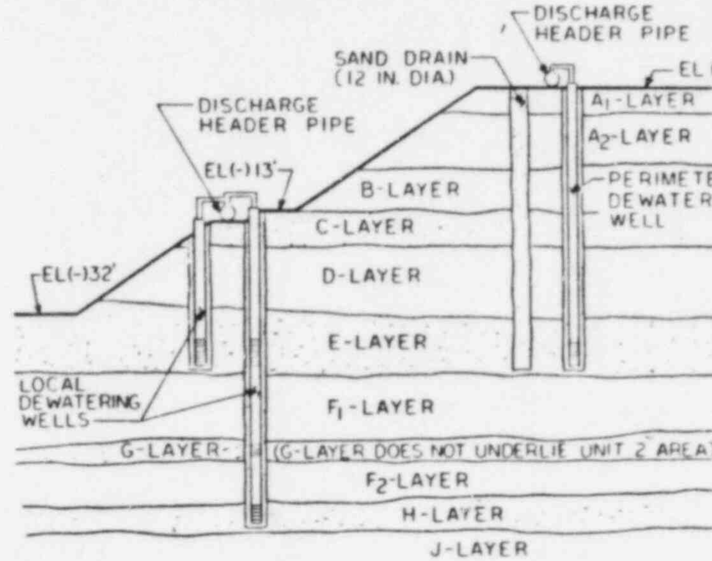
OIL AND GAS FIELDS AND SALT DOMES

Figure 2.5.1-1

Amendment 44

ATTACHMENT 1
ST-HL-AE-1399
PAGE 34 OF 60





SCHEMATIC DEWATERING SYSTEM DETAILS

(N. T. S.)

LEGEND

- ○ TRC WELLS WITH SCREEN IN LAYER "E"
- ◎ TRC WELLS WITH PIEZOMETERS OUTSIDE THE SCREENS
- ⊕ TRC WELLS WITH ADDITIONAL SCREENS IN LAYERS "G-H"
- ● PIEZOMETER FOR INSTALLATION OF PORE PRESSURE CELL
- ⊙ PIEZOMETER, OPEN STAND PIPE
- —o—o— DISCHARGE HEADER PIPELINE
- B - PORE PRESSURE CELL WAS INSTALLED IN BACKFILL
- C,E,G,H - LAYER IN WHICH STANDPIPE PIEZOMETER WAS INSTALLED
- BI - STANDPIPE PIEZOMETER WAS INSTALLED IN BACKFILL

NOTES

1. SAND DRAINS (12 IN. DIA.) WERE INSTALLED ON APPROXIMATE 10 FT CENTERS BETWEEN THE PERIMETER DEWATERING SYSTEM WELLS.

2. PORE PRESSURE CELLS OUT OF SERVICE

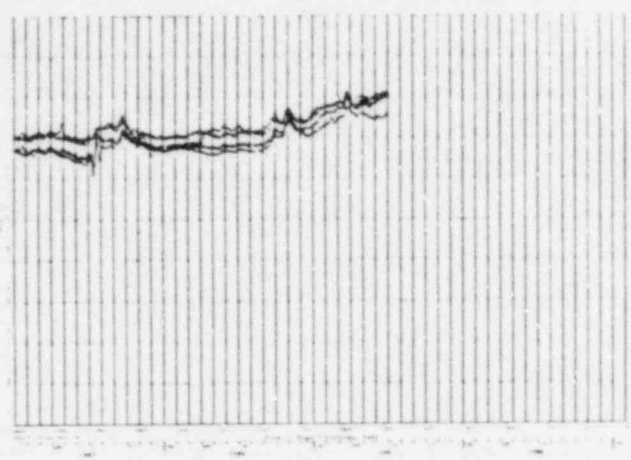
205B	214C
205E	217B
210E	227E
210G	228C
211C	234H
211E	237B
213B	240E

SOUTH TEXAS PROJECT UNITS 1 & 2

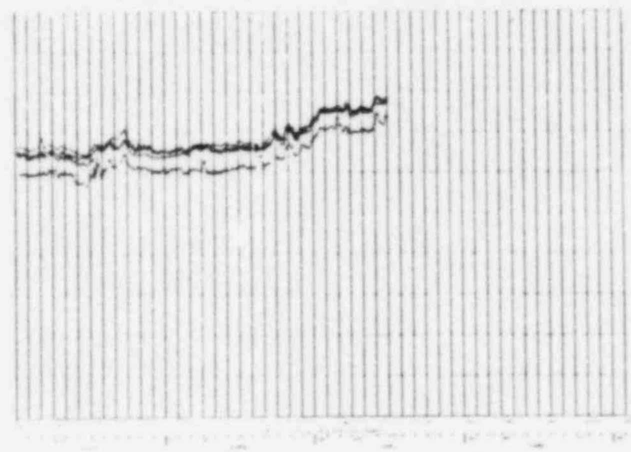
DEWATERING SYSTEM LAYOUT

Figure 2.5.4-64 Amendment 44

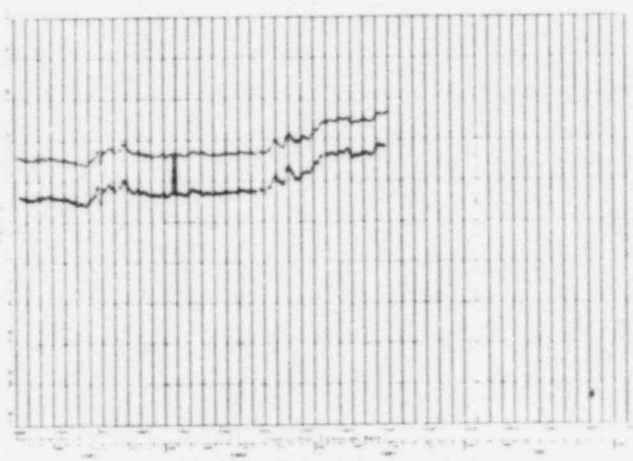
ATTACHMENT 1
ST-HL-AE-1399
PAGE 35 OF 60



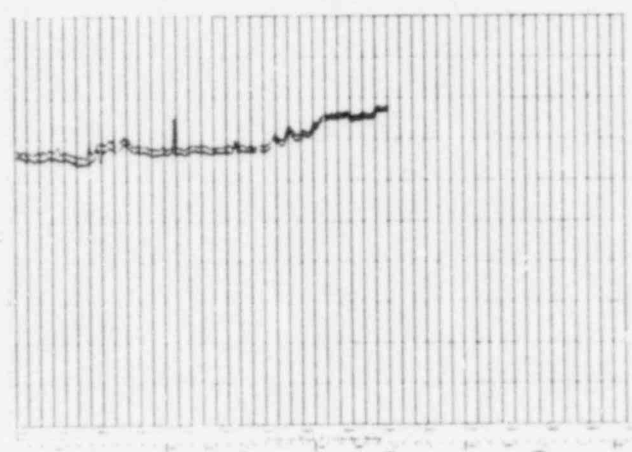
PIEZOMETRIC READINGS IN C-LAYER



PIEZOMETRIC READINGS IN E-LAYER



PIEZOMETRIC READINGS IN G-LAYER



PIEZOMETRIC READINGS IN H-LAYER

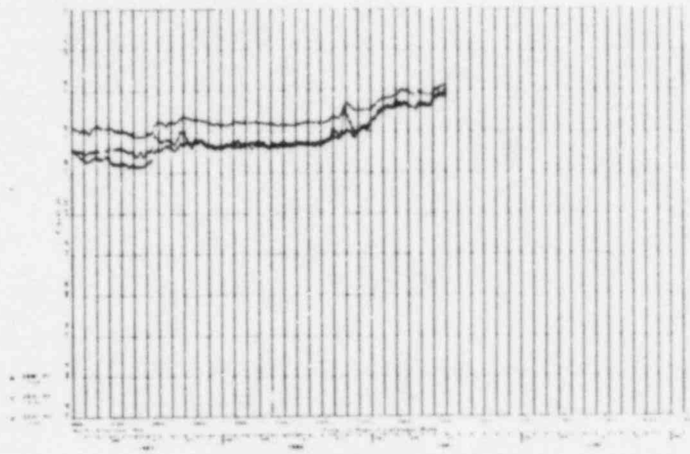
NOTES:

1. See Figure 2.5.4-65A for other notes regarding this figure.
2. Piezometer 210H was converted to a Pore Pressure Cell (PPC) in 1976 and first read as such on 10/1/76. Piezometers 211G, 213C, 213E, 219G and 219H were converted to PPC in 1977 and first read as such on 9/23/77.

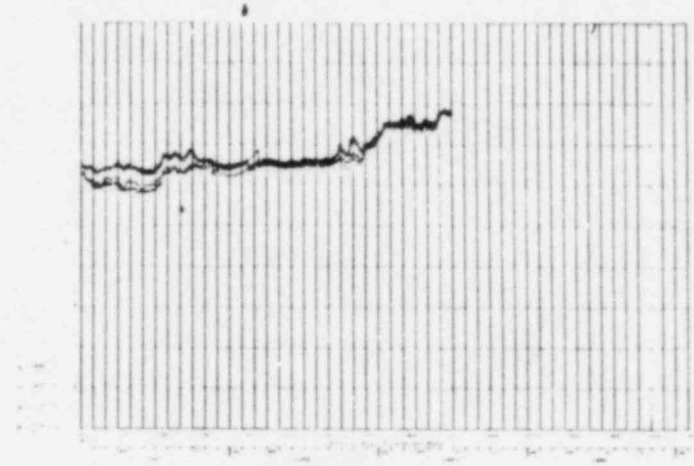
SOUTH TEXAS PROJECT
UNITS 1 & 2

PIEZOMETRIC LEVEL VS. TIME
UNIT 1

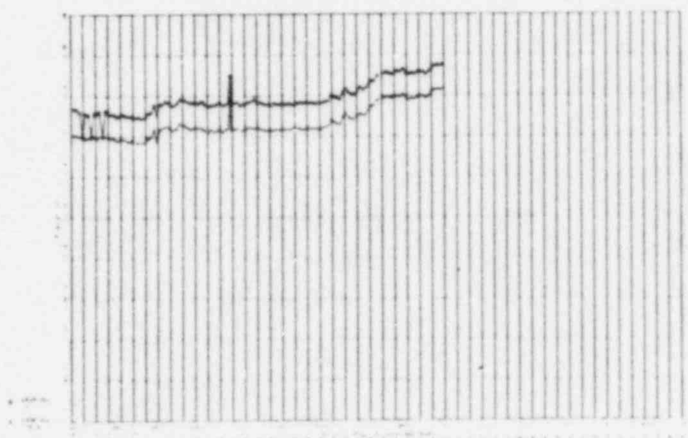
Figure 2.5.4-65B



PIEZOMETRIC READINGS IN C–LAYER



PIEZOMETRIC READINGS IN E–LAYER



PIEZOMETRIC READINGS IN H–LAYERS

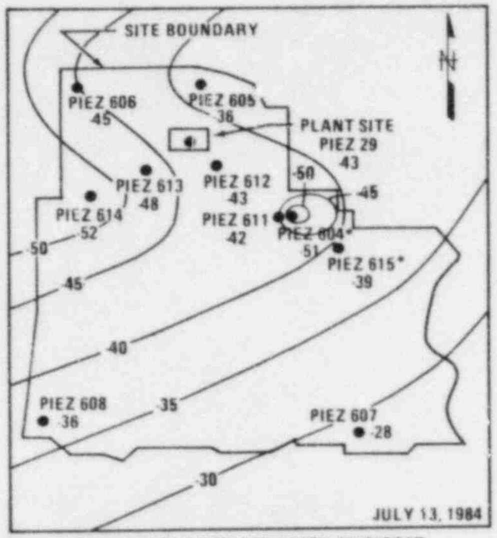
NOTES:

1. See Figure 2.5.4–66A for notes regarding this figure.
2. Piezometers 233H and 242H were converted to Pore Pressure Cells (PPC) in 1977 and first read as such on 9/23/77.

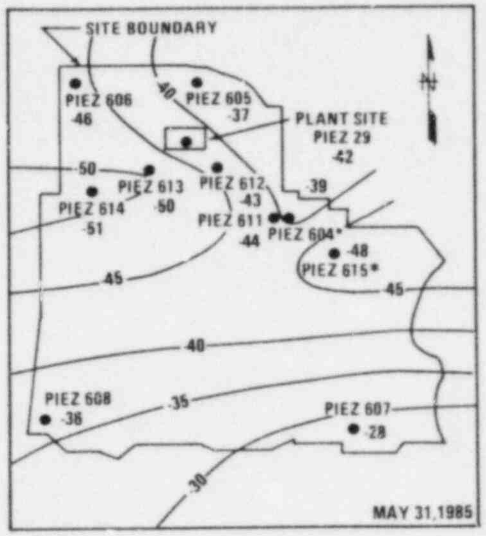
SOUTH TEXAS PROJECT UNITS 1 & 2

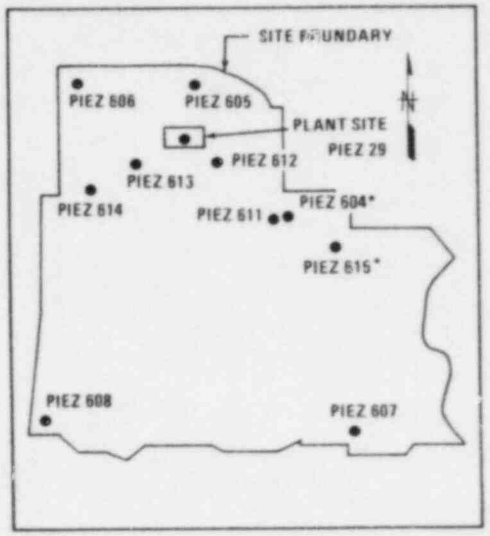
PIEZOMETRIC LEVEL VS. TIME
UNIT 2

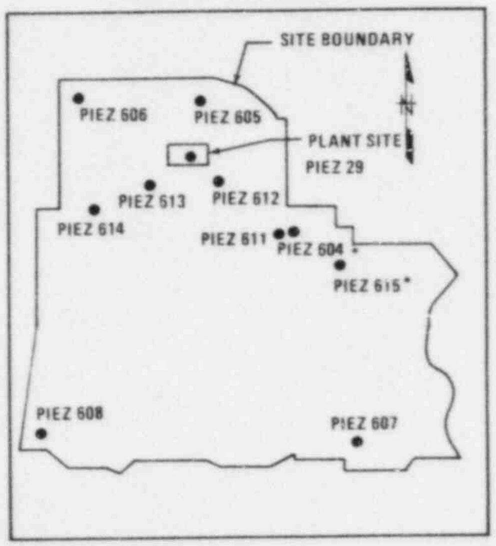
Figure 2.5.4-66B

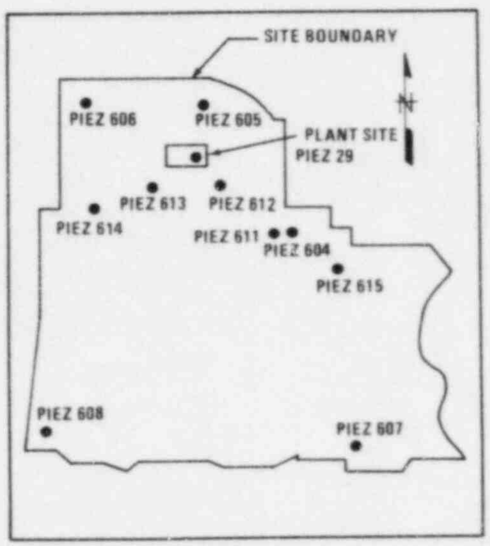


NOTE: ALL READINGS ARE BASED ON DIRECT MEASUREMENT OF PIEZOMETRIC LEVEL OF THE DEEP AQUIFER ZONE AT STP SITE









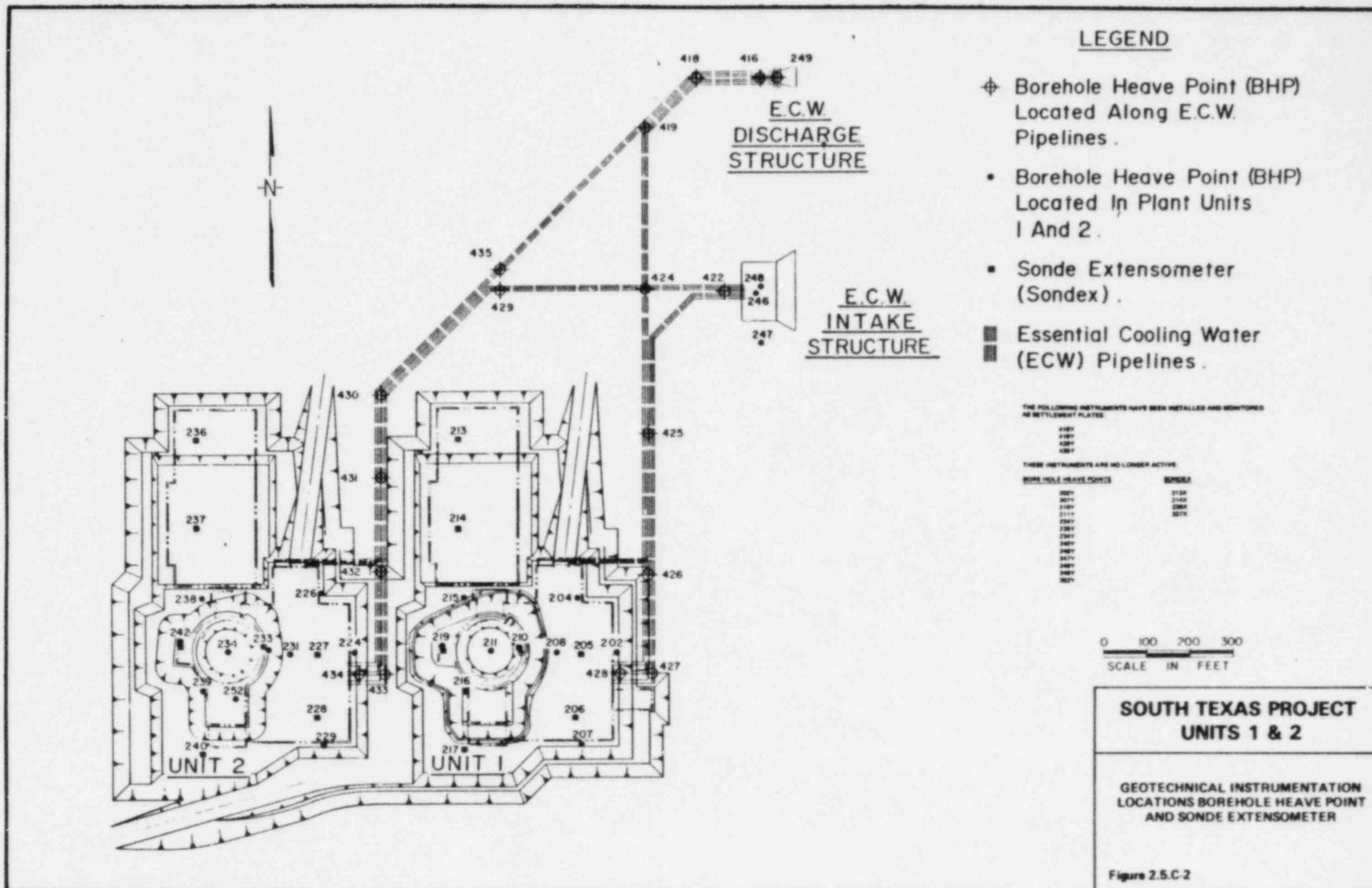
NOTES:

1.) PIEZOMETRIC LEVEL MAP ELEVATIONS BASED ON 5 FEET MSL CONTOUR INTERVAL.
2.) *PIEZOMETER NO. 604 IS LOCATED ADJACENT TO WELL NO. 5.
3.) *PIEZOMETER NO. 615 IS LOCATED ADJACENT TO WELL NO. 7.
4.) WELL NO. 5 WAS INOPERATIVE BETWEEN DECEMBER, 1979 AND JULY, 1980.
5.) PIEZOMETERS NO. 612, NO. 613, NO. 614, AND NO. 615 WERE INSTALLED IN NOVEMBER, 1979.
6.) PIEZOMETER NO. 614 IS LOCATED 95 FEET NORTHEAST OF WELL NO. 6.

SOUTH TEXAS PROJECT UNITS 1 AND 2

HISTORIC PIEZOMETRIC LEVELS OF DEEP AQUIFER ZONE

Figure 2.5.4 – 70B

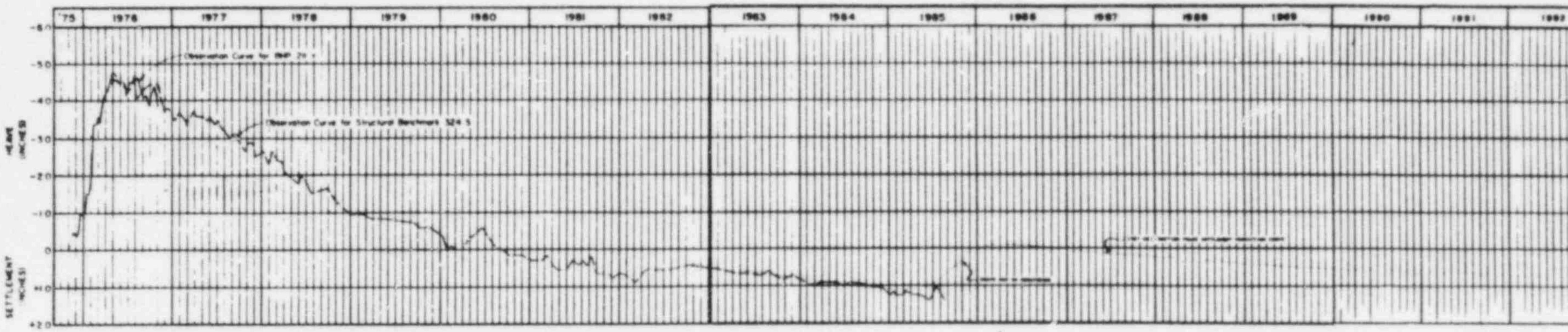


SOUTH TEXAS PROJECT UNITS 1 & 2

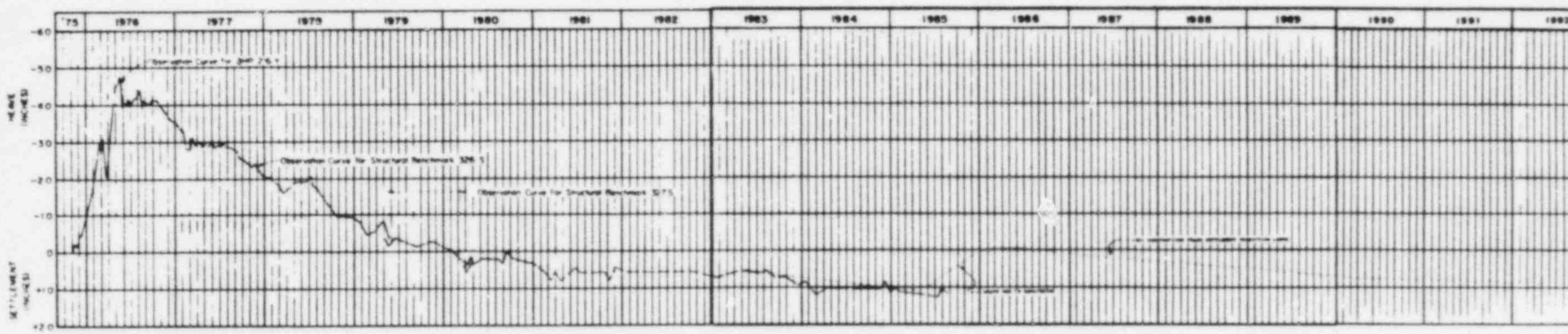
GEOTECHNICAL INSTRUMENTATION LOCATIONS BOREHOLE HEAVE POINT AND SONDE EXTENSOMETER

Figure 2.5.C-2

ATTACHMENT 1
ST-HL-AE-1399
PAGE 38 OF 60



REACTOR CONTAINMENT BUILDING

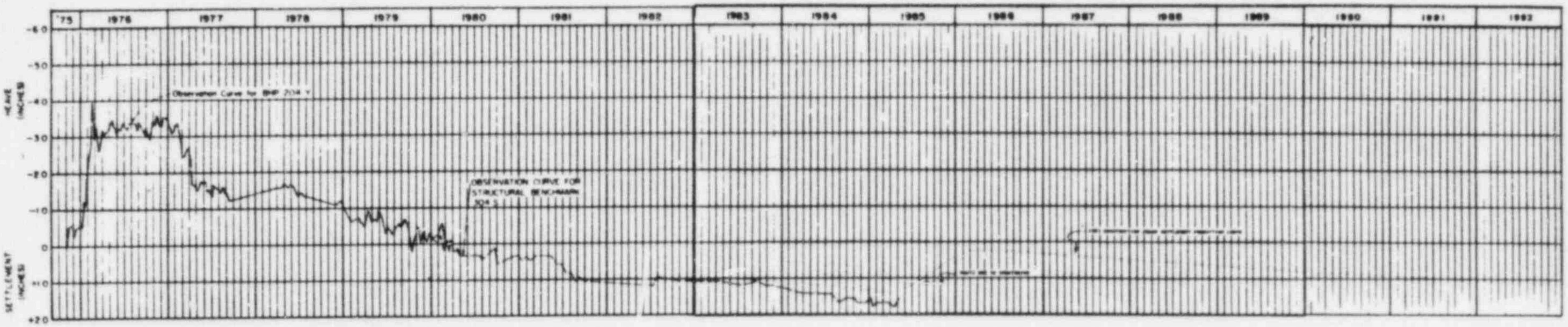


FUEL HANDLING BUILDING

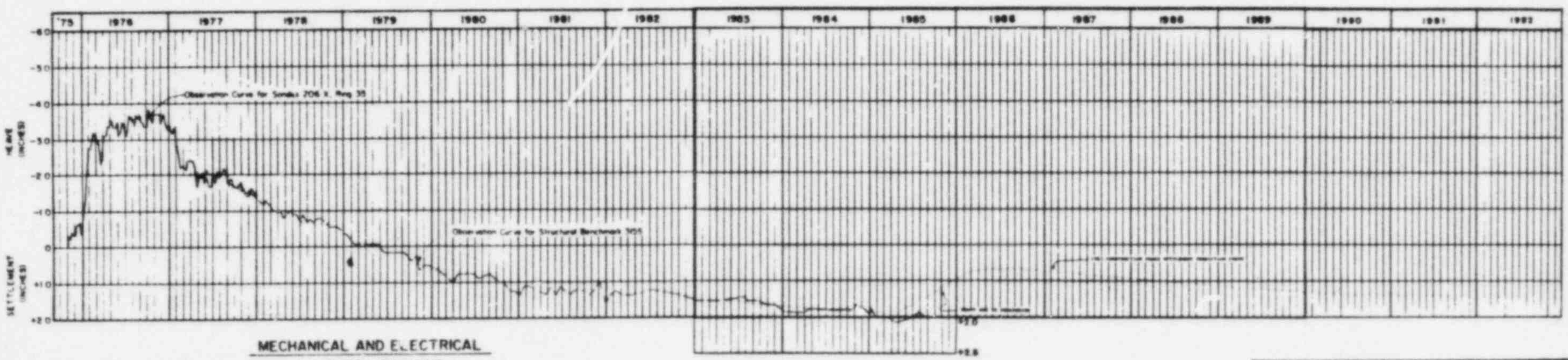
SOUTH TEXAS PROJECT UNITS 1 & 2

GEOTECHNICAL INSTRUMENTATION
HEAVE/SETTLEMENT MOVEMENT
FOR UNIT 1 (RCB, FHB)

Figure 2.5.C-9



DIESEL GENERATOR BUILDING



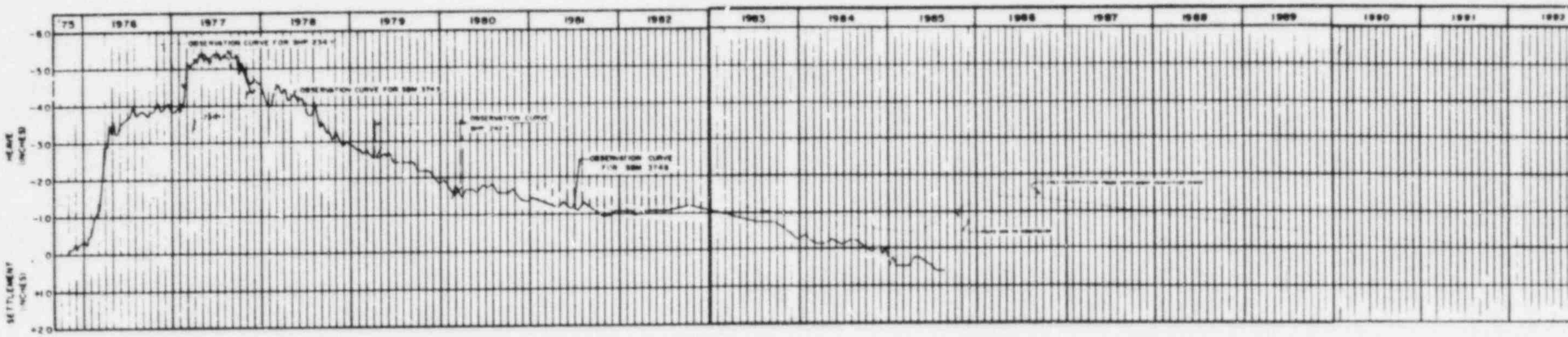
MECHANICAL AND ELECTRICAL AUXILIARY BUILDING

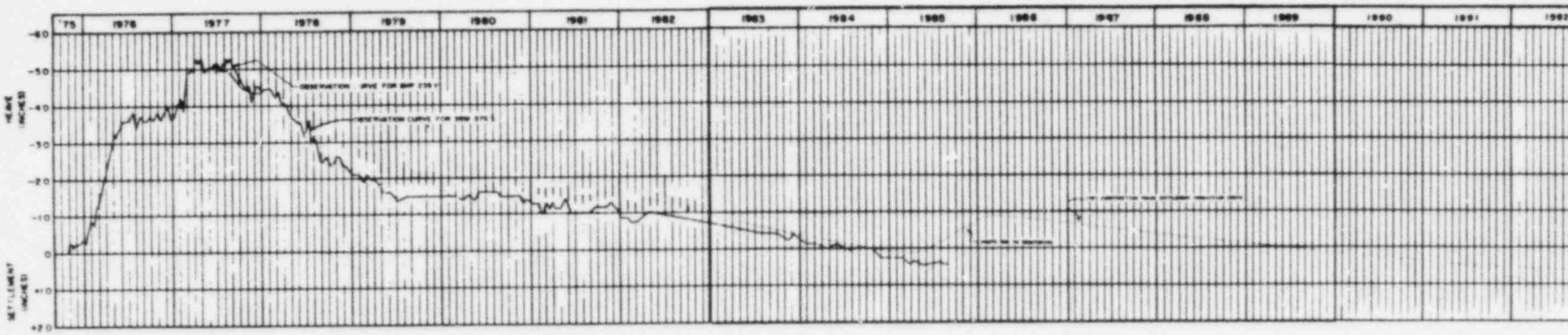
SOUTH TEXAS PROJECT UNITS 1 & 2

GEOTECHNICAL INSTRUMENTATION
HEAVE/SETTLEMENT MOVEMENT
FOR UNIT 1 (DGB, MEAB)

Figure 2.5.C-9A

ATTACHMENT 1
ST-HL-AE-1399
PAGE 41 OF 60



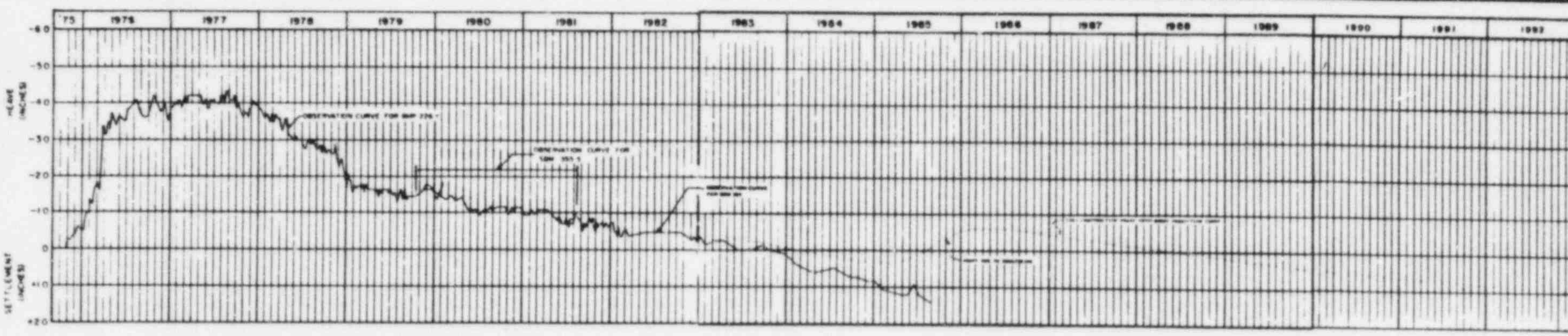


SOUTH TEXAS PROJECT UNITS 1 & 2

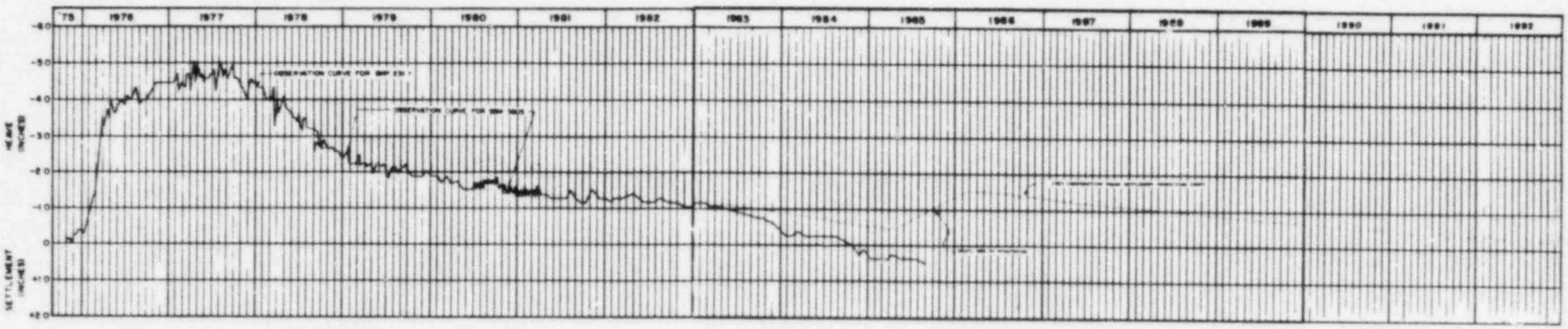
GEOTECHNICAL INSTRUMENTATION
HEAVE/SETTLEMENT MOVEMENT
FOR UNIT 2 (RCB, FHB)

Figure 2.5.C-10

ATTACHMENT 1
ST-HL-AE-1399
PAGE 42 OF 60



DIESEL GENERATOR BUILDING

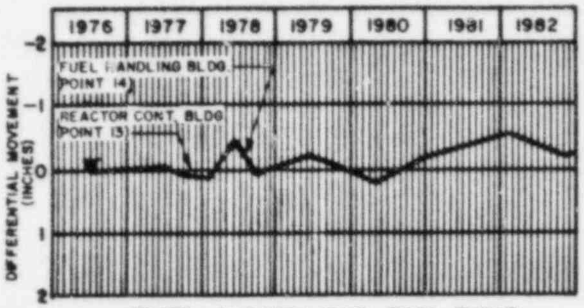


MECHANICAL AND ELECTRICAL
AUXILIARY BUILDING

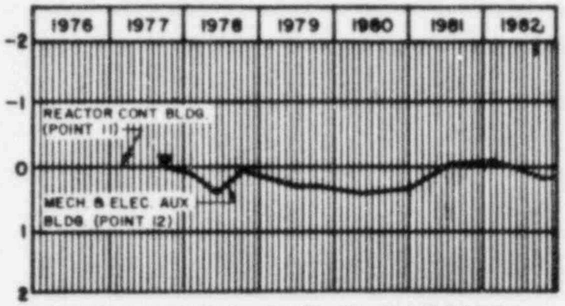
**SOUTH TEXAS PROJECT
UNITS 1 & 2**

GEOTECHNICAL INSTRUMENTATION
HEAVE/SETTLEMENT MOVEMENT
FOR UNIT 2 (DGB, MEAB)

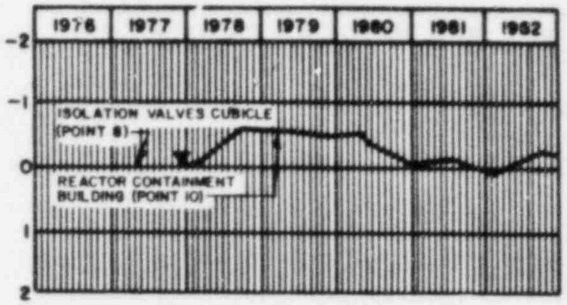
Figure 2.5.C-10A



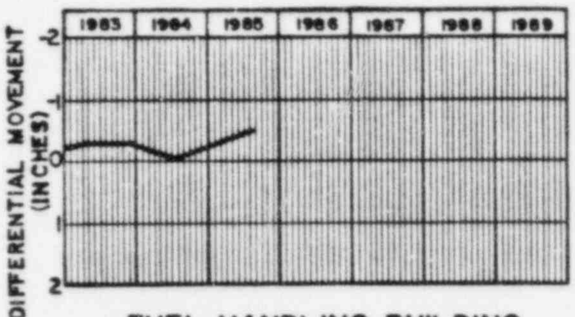
FUEL HANDLING BUILDING
VERSUS
REACTOR CONTAINMENT BUILDING



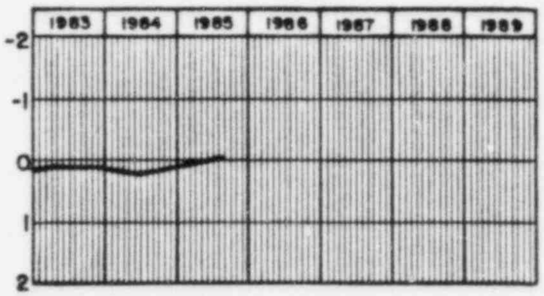
MECHANICAL AND ELECTRICAL
AUXILIARY BUILDING
VERSUS
REACTOR CONTAINMENT BUILDING



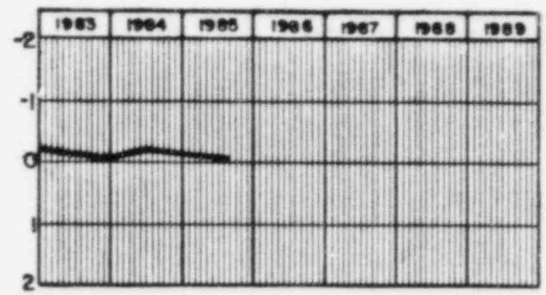
ISOLATION VALVES CUBICLE
VERSUS
REACTOR CONTAINMENT BUILDING



FUEL HANDLING BUILDING
VERSUS
REACTOR CONTAINMENT BUILDING



MECHANICAL AND ELECTRICAL
AUXILIARY BUILDING
VERSUS
REACTOR CONTAINMENT BUILDING



ISOLATION VALVES CUBICLE
VERSUS
REACTOR CONTAINMENT BUILDING

CONTROL POINTS	3	4	7	8	9	10	11	12	13	14	17	18
HEAVE (INCHES) SEE NOTE 2	-0.1	0.3	-0.4	-2.8		-2.5	-2.5	-2.6	-4.3	-4.1	-2.8	-2.4

LEGEND:

▼ INDICATES START OF DIFFERENTIAL MOVEMENT COMPARISON

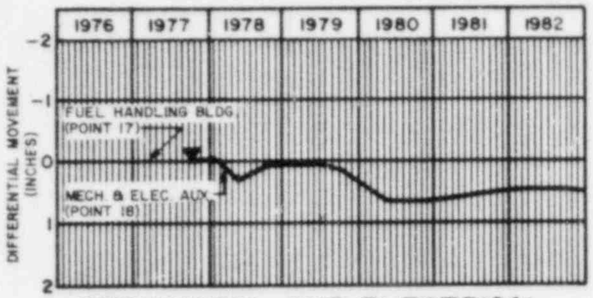
NOTES:

1. SEE FIGURE 2.5.C-15 FOR LOCATION OF ANALYSIS CONTROL POINTS.
2. POSITIVE NUMBER INDICATES SETTLEMENT.

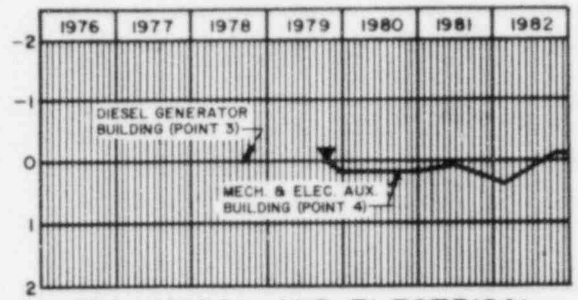
SOUTH TEXAS PROJECT
UNITS 1&2

DIFFERENTIAL MOVEMENTS
BETWEEN BUILDINGS
UNIT 1

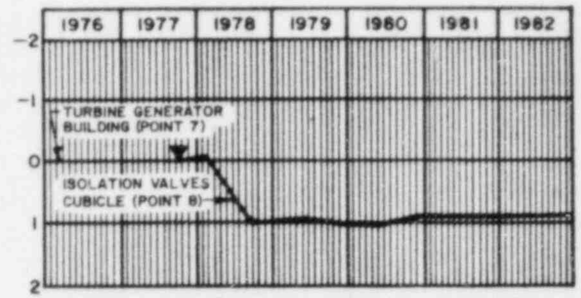
Figure 2.5.C-11



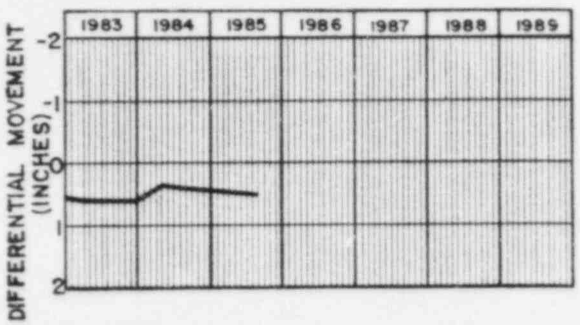
MECHANICAL AND ELECTRICAL AUXILIARY BUILDING VERSUS FUEL HANDLING BUILDING



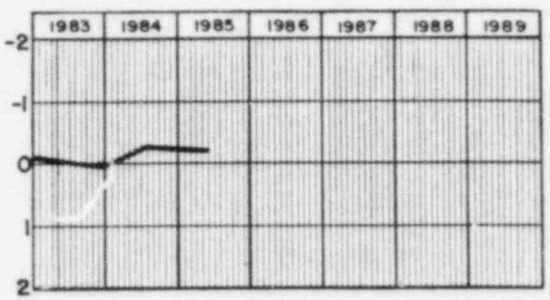
MECHANICAL AND ELECTRICAL AUXILIARY BUILDING VERSUS DIESEL GENERATOR BUILDING



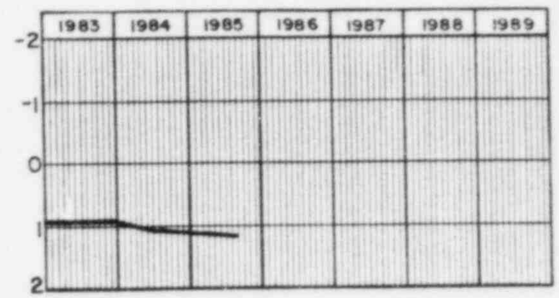
ISOLATION VALVES CUBICLE VERSUS TURBINE GENERATOR BUILDING



MECHANICAL AND ELECTRICAL AUXILIARY BUILDING VERSUS FUEL HANDLING BUILDING



MECHANICAL AND ELECTRICAL AUXILIARY BUILDING VERSUS DIESEL GENERATOR BUILDING



ISOLATION VALVES CUBICLE VERSUS TURBINE GENERATOR BUILDING

CONTROL POINTS	3	4	7	8	9	10	11	12	13	14	17	18
HEAVE (INCHES) SEE NOTE 2	-0.1	0.3	-0.4	-2.5		-2.5	-2.5	-2.8	-4.3	-4.1	-2.6	-2.4

LEGEND:

▼ INDICATES START OF DIFFERENTIAL MOVEMENT COMPARISON

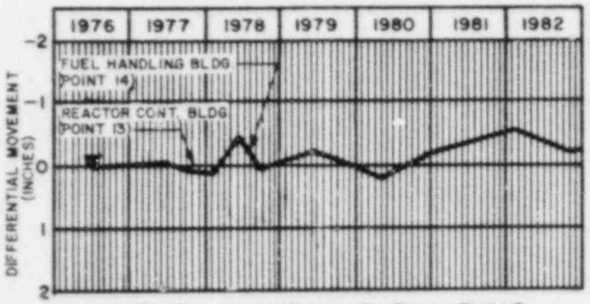
NOTES:

1. SEE FIGURE 2.5.C-15 FOR LOCATION OF ANALYSIS CONTROL POINTS.
2. POSITIVE NUMBER INDICATES SETTLEMENT.

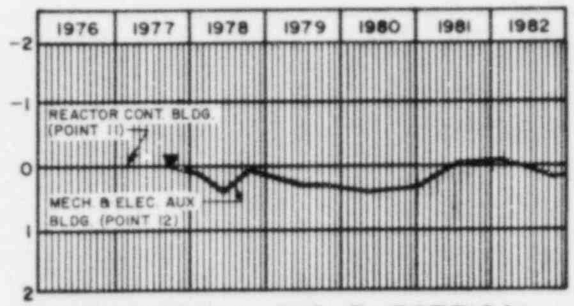
SOUTH TEXAS PROJECT UNITS 1&2

DIFFERENTIAL MOVEMENTS BETWEEN BUILDINGS UNIT 1

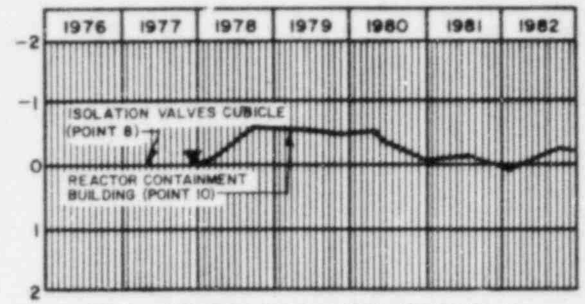
Figure 2.5.C-11A



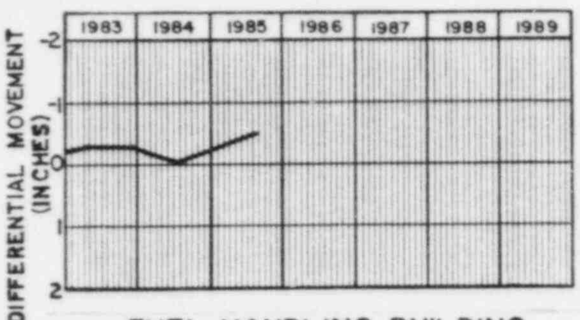
FUEL HANDLING BUILDING
VERSUS
REACTOR CONTAINMENT BUILDING



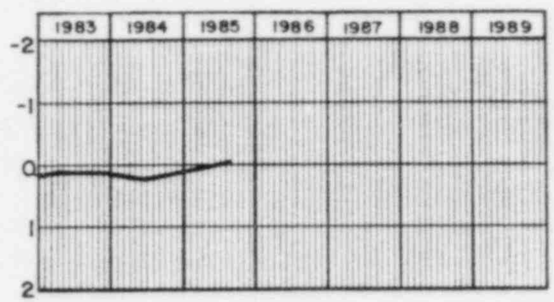
MECHANICAL AND ELECTRICAL
AUXILIARY BUILDING
VERSUS
REACTOR CONTAINMENT BUILDING



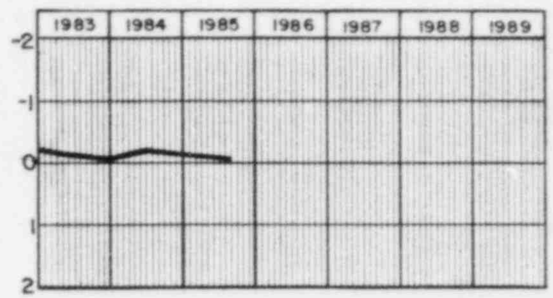
ISOLATION VALVES CUBICLE
VERSUS
REACTOR CONTAINMENT BUILDING



FUEL HANDLING BUILDING
VERSUS
REACTOR CONTAINMENT BUILDING



MECHANICAL AND ELECTRICAL
AUXILIARY BUILDING
VERSUS
REACTOR CONTAINMENT BUILDING



ISOLATION VALVES CUBICLE
VERSUS
REACTOR CONTAINMENT BUILDING

CONTROL POINTS	3	4	7	8	9	10	11	12	13	14	17	18
HEAVE (INCHES) SEE NOTE 2	-0.1	0.3	-0.4	-2.5		-2.5	-2.5	-2.6	-4.3	-4.1	-2.6	-2.4

LEGEND:

▼ INDICATES START OF DIFFERENTIAL MOVEMENT COMPARISON

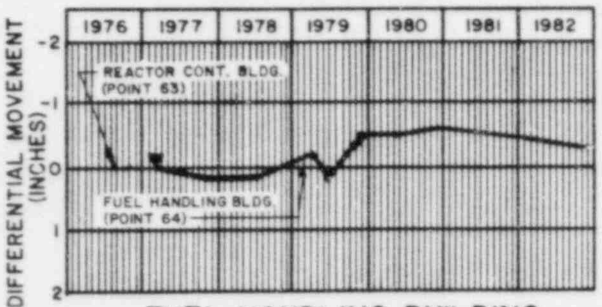
NOTES:

1. SEE FIGURE 2.5.C-15 FOR LOCATION OF ANALYSIS CONTROL POINTS.
2. POSITIVE NUMBER INDICATES SETTLEMENT.

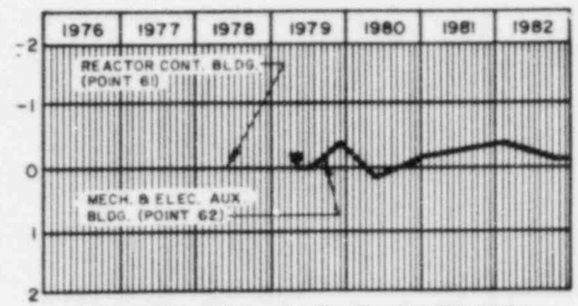
SOUTH TEXAS PROJECT
UNITS 1&2

DIFFERENTIAL MOVEMENTS
BETWEEN BUILDINGS
UNIT 1

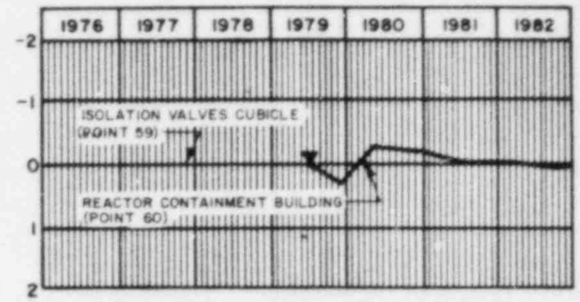
Figure 2.5.C-11



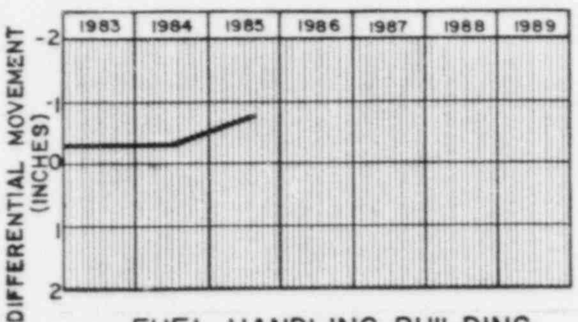
FUEL HANDLING BUILDING
VERSUS
REACTOR CONTAINMENT BUILDING



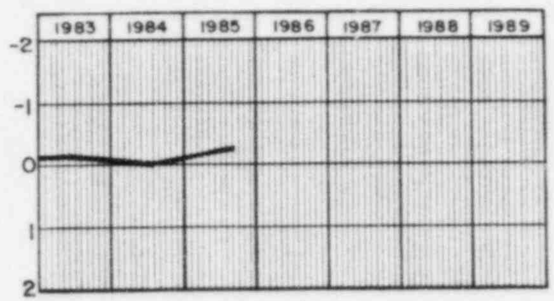
MECHANICAL AND ELECTRICAL
AUXILIARY BUILDING
VERSUS
REACTOR CONTAINMENT BUILDING



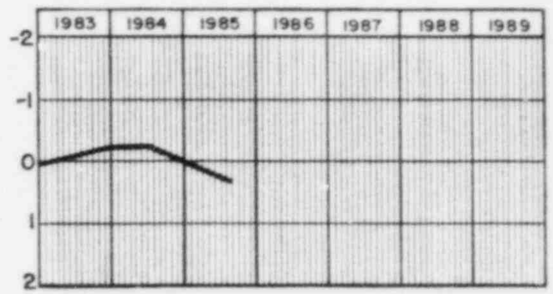
ISOLATION VALVES CUBICLE
VERSUS
REACTOR CONTAINMENT BUILDING



FUEL HANDLING BUILDING
VERSUS
REACTOR CONTAINMENT BUILDING



MECHANICAL AND ELECTRICAL
AUXILIARY BUILDING
VERSUS
REACTOR CONTAINMENT BUILDING



ISOLATION VALVES CUBICLE
VERSUS
REACTOR CONTAINMENT BUILDING

CONTROL POINTS	53	54	57	58	59	60	61	62	63	64	67	68
HEAVE (INCHES) SEE NOTE 2			0.5		-2.3	-2.3	-2.1	-2.1	-5.1	-5.0	-2.3	-2.3

LEGEND:

▼ INDICATES START OF DIFFERENTIAL MOVEMENT COMPARISON

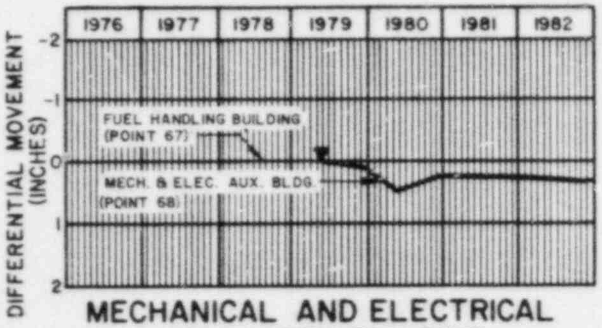
NOTES:

1. SEE FIGURE 2.5.C-15 FOR LOCATION OF ANALYSIS CONTROL POINTS.
2. POSITIVE NUMBER INDICATES SETTLEMENT

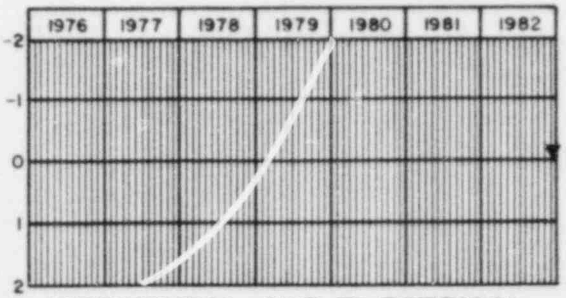
SOUTH TEXAS PROJECT
UNITS 1 & 2

DIFFERENTIAL MOVEMENTS
BETWEEN BUILDINGS
UNIT 2

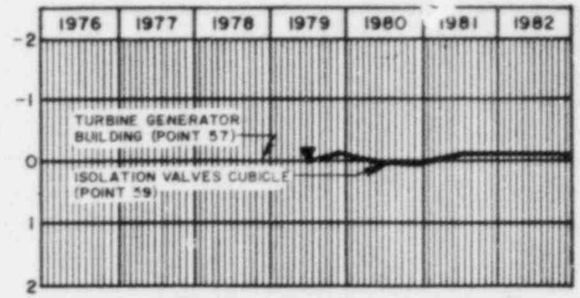
Figure 2.5.C-12



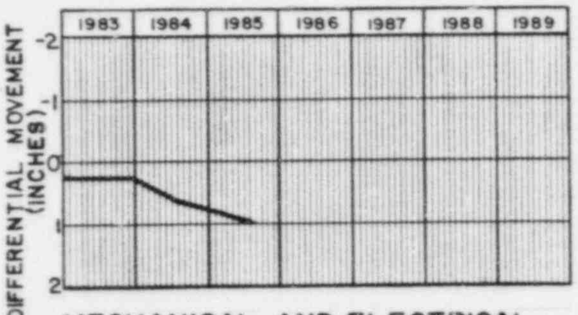
MECHANICAL AND ELECTRICAL AUXILIARY BUILDING VERSUS FUEL HANDLING BUILDING



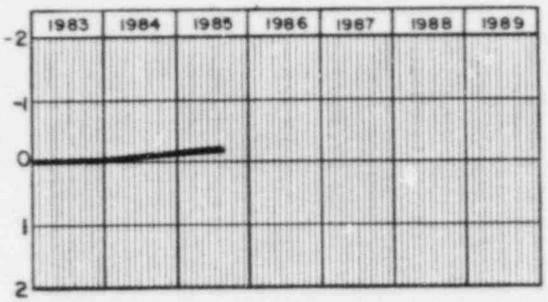
MECHANICAL AND ELECTRICAL AUXILIARY BUILDING VERSUS DIESEL GENERATOR BUILDING



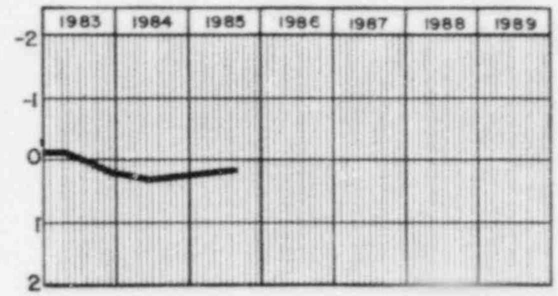
ISOLATION VALVES CUBICLE VERSUS TURBINE GENERATOR BUILDING



MECHANICAL AND ELECTRICAL AUXILIARY BUILDING VERSUS FUEL HANDLING BUILDING



MECHANICAL AND ELECTRICAL AUXILIARY BUILDING VERSUS DIESEL GENERATOR BUILDING



ISOLATION VALVES CUBICLE VERSUS TURBINE GENERATOR BUILDING

CONTROL POINTS	53	54	57	58	59	60	61	62	63	64	67	68
HEAVE (INCHES) SEE NOTE 2			0.5		-2.3	-2.3	-2.1	-2.1	-5.1	-5.0	-2.3	-2.3

LEGEND:

▼ INDICATES START OF DIFFERENTIAL MOVEMENT COMPARISON

NOTES:

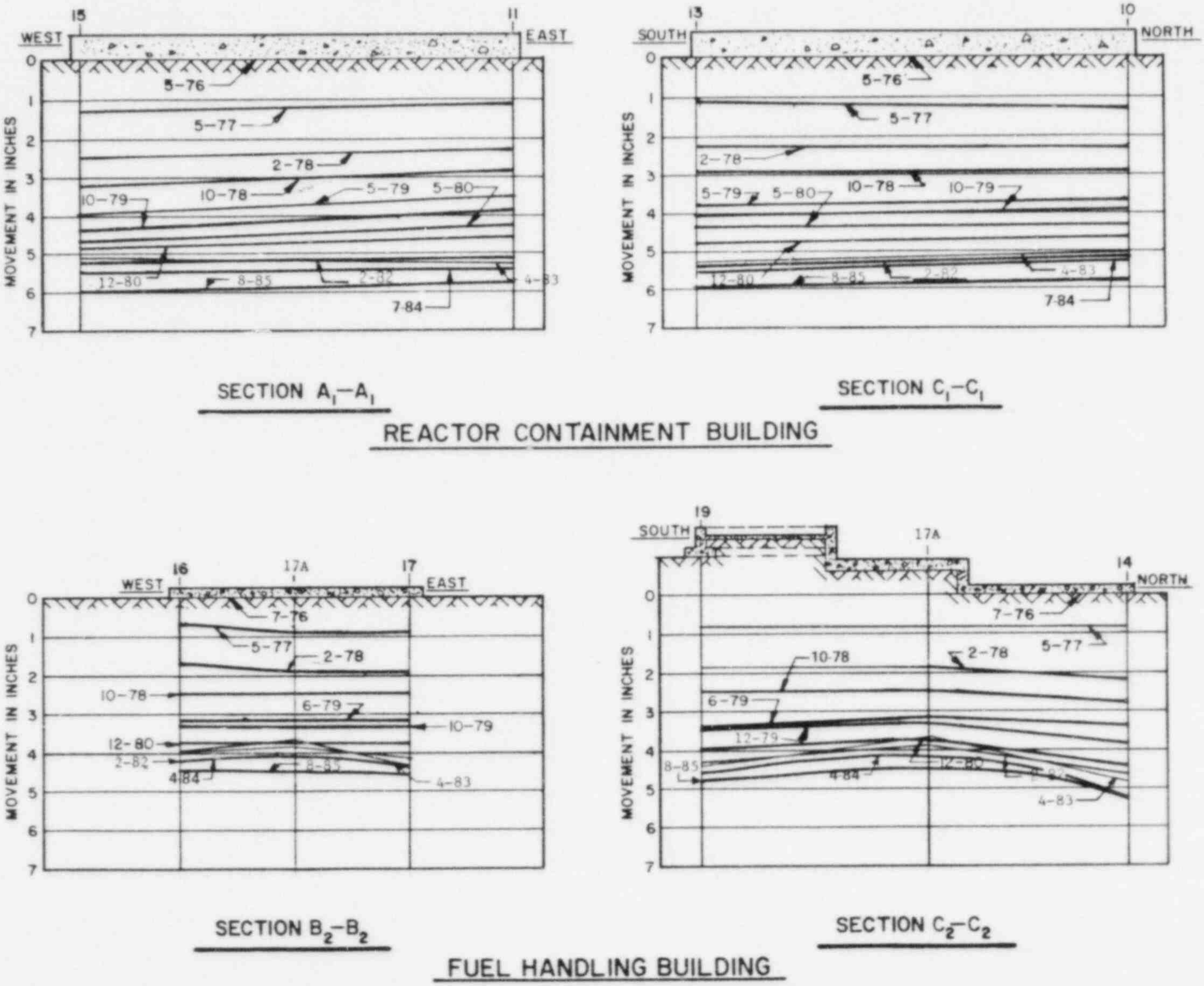
1. SEE FIGURE 2.5.C-15 FOR LOCATION OF ANALYSIS CONTROL POINTS.
2. POSITIVE NUMBER INDICATES SETTLEMENT

SOUTH TEXAS PROJECT
UNITS 1 & 2

DIFFERENTIAL MOVEMENTS BETWEEN BUILDINGS
UNIT 2

Figure 2.5.C-12A

ATTACHMENT 1
ST-HL-AE- 1399
PAGE 48 OF 60



NOTES

1. SEE FIGURE 2.5.C–15 FOR LOCATIONS OF ANALYSIS CONTROL POINTS.
2. SUBSCRIPT NUMBER INDICATES BUILDING CODE AS SHOWN IN FIGURE 2.5.C–15 SEE NOTE 1
3. MOVEMENT SHOWN HEREIN INDICATES SETTLEMENT OF INDIVIDUAL ANALYSIS CONTROL POINT SINCE MAT CONSTRUCTION. THE TOTAL MOVEMENT WILL INCLUDE RECOMPRESSION OF HEAVE (AVERAGE 4 INCHES) PLUS A NET SETTLEMENT (AVERAGE INCHES).
4. STRUCTURAL BENCHMARK AT ANALYSIS CONTROL POINT 19 WAS INSTALLED IN OCTOBER, 1978.

LEGEND

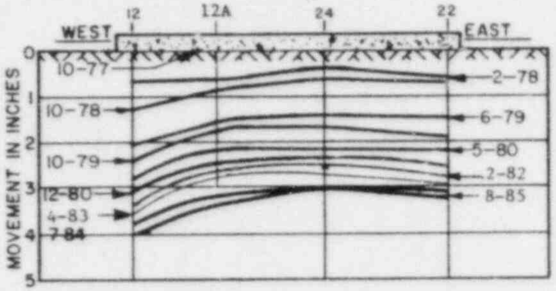
13 ANALYSIS CONTROL POINT
2-78 DATE READINGS WERE TAKEN

20 0 20 40 60 80
HORIZONTAL SCALE IN FEET

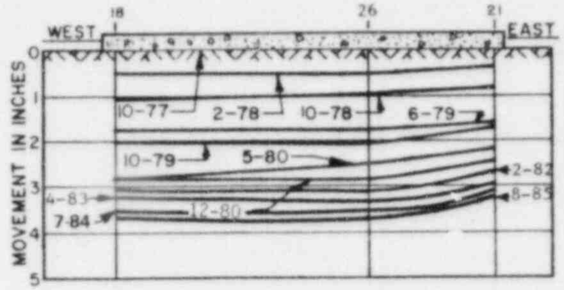
SOUTH TEXAS PROJECT
UNITS 1 & 2

DIFFERENTIAL MOVEMENT PROFILE
WITHIN BUILDINGS
UNIT 1

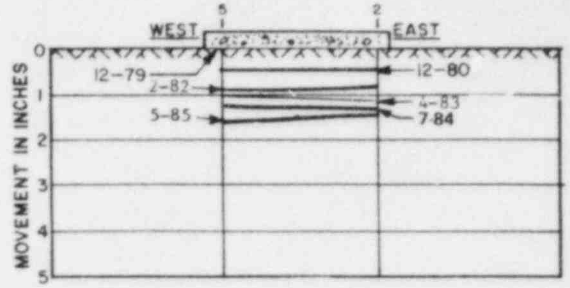
Figure 2.5.C–13A



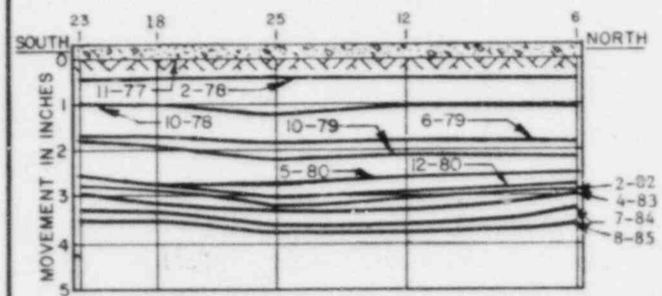
SECTION A_3—A_3



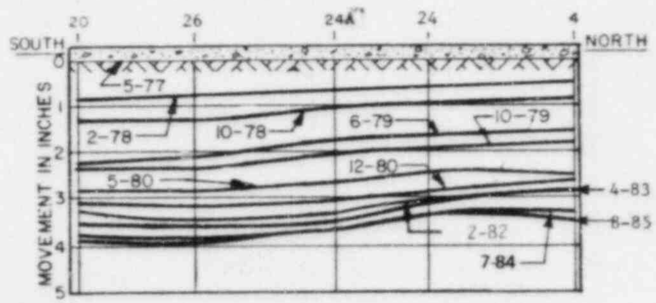
SECTION B_3—B_3



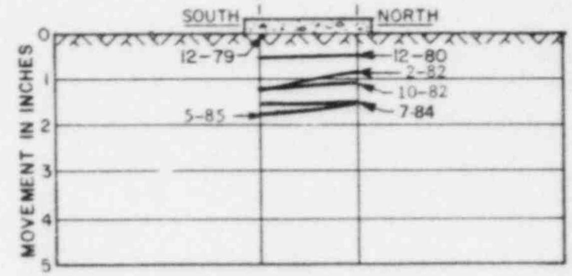
SECTION F_4—F_4



SECTION D_3—D_3



SECTION E_3—E_3



SECTION G_4—G_4

MECHANICAL & ELECTRICAL AUXILIARY BUILDING

DIESEL GENERATOR BUILDING

NOTES

1. FOR NOTES AND LEGEND SEE FIGURE 2.5.C-13A
2. MOVEMENT SHOWN HEREIN INDICATES SETTLEMENT OF EACH INDIVIDUAL ANALYSIS CONTROL POINT SINCE MAT CONSTRUCTION. THE TOTAL MOVEMENT WILL INCLUDE RECOMPRESSION OF HEAVE (AVERAGE 3 INCHES) PLUS A NET SETTLEMENT (AVERAGE INCHES).

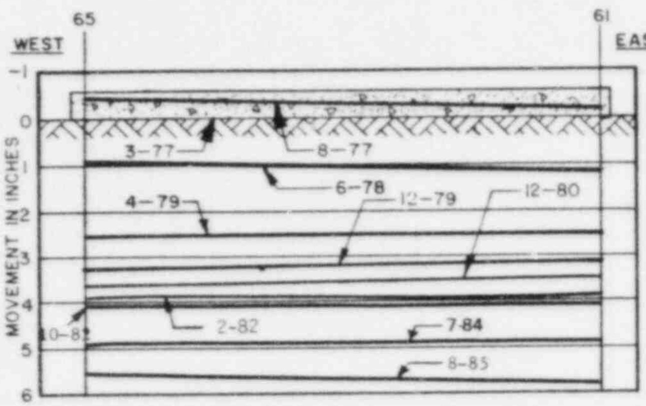
20 0 20 40 60 80
HORIZONTAL SCALE IN FEET

3. THE SAME POINT IN DIFFERENT SECTIONS MAY SHOW DIFFERENT MOVEMENTS ON THE SAME DATE, BECAUSE THEY ARE MEASURED FROM DIFFERENT STARTING DATES.

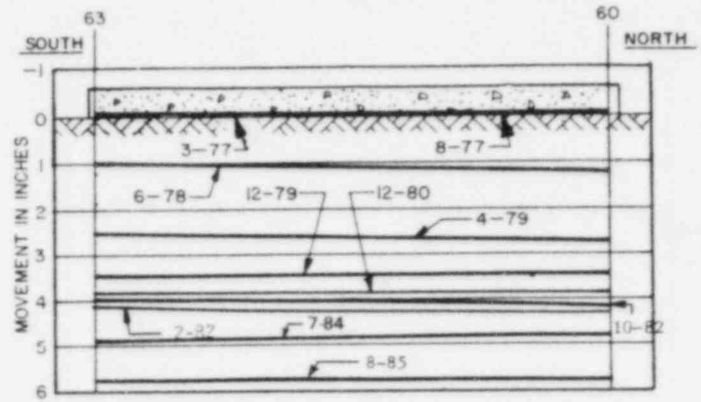
SOUTH TEXAS PROJECT
UNITS 1 & 2

DIFFERENTIAL MOVEMENT PROFILE
WITHIN BUILDINGS
UNIT 1

Figure 2.5.C-13B



SECTION M_1—M_1



SECTION O_1—O_1

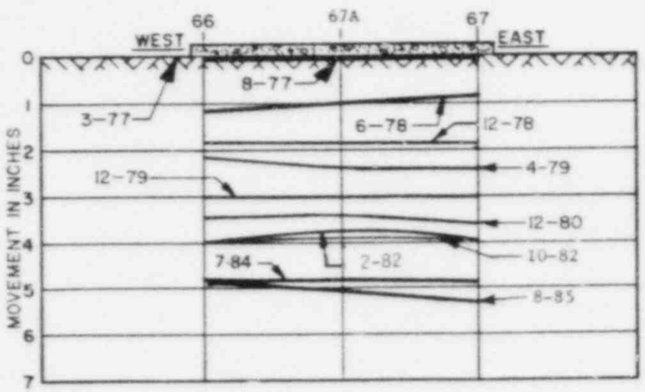
REACTOR CONTAINMENT BUILDING

NOTES

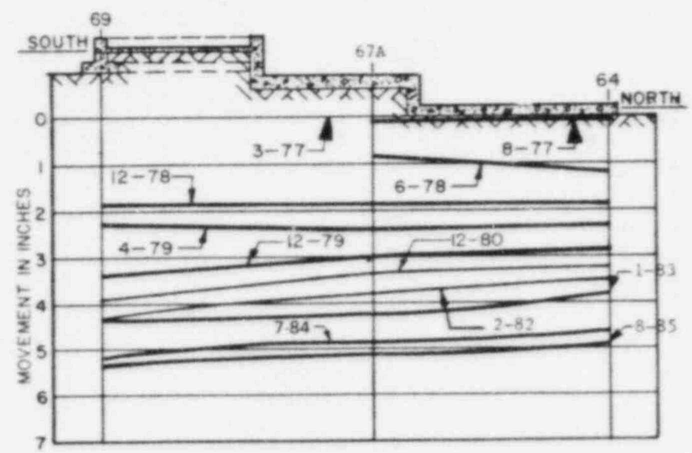
1. SEE FIGURE 2.5.C-15 FOR LOCATIONS OF ANALYSIS CONTROL POINTS.
2. SUBSCRIPT NUMBER INDICATES BUILDING CODE AS SHOWN IN FIGURE 2.5.C-15 SEE NOTE 1
3. POSITIVE MOVEMENT SHOWN HEREIN INDICATES SETTLEMENT OF INDIVIDUAL ANALYSIS CONTROL POINT SINCE MAT CONSTRUCTION. THE TOTAL MOVEMENT WILL INCLUDE RECOMPRESSION OF HEAVE (AVERAGE 5 INCHES) PLUS A NET SETTLEMENT (AVERAGE INCHES).

LEGEND

63 ANALYSIS CONTROL POINT
12-79 DATE READINGS WERE TAKEN



SECTION N_2—N_2



SECTION O_2—O_2

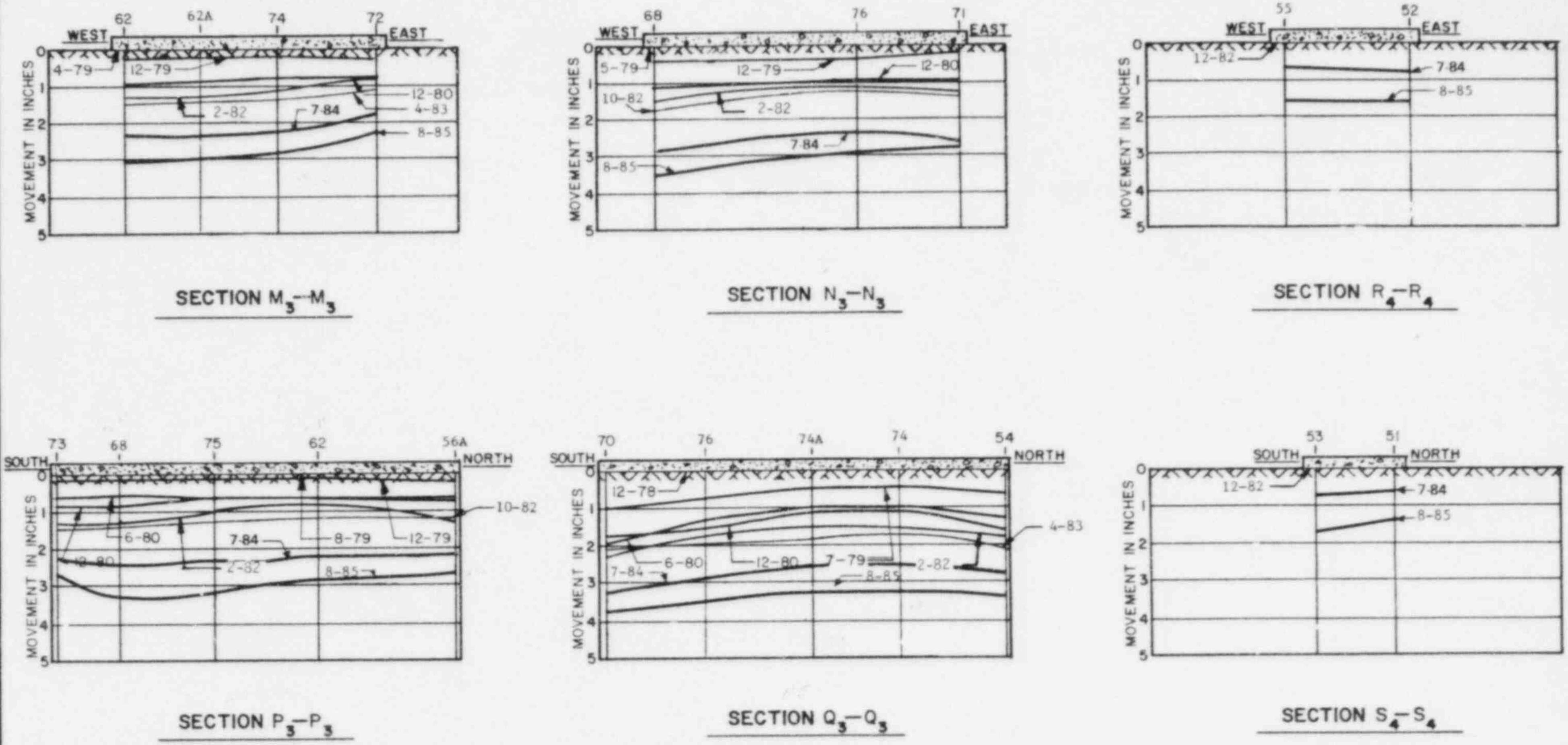
FUEL HANDLING BUILDING

SOUTH TEXAS PROJECT
UNITS 1 & 2

DIFFERENTIAL MOVEMENT PROFILE
WITHIN BUILDINGS
UNIT 2

Figure 2.5.C-14

ATTACHMENT 1
ST-HL-AE-1399
PAGE 51 OF 60



MECHANICAL & ELECTRICAL AUXILIARY BUILDING

DIESEL GENERATOR BUILDING

NOTES

1. FOR NOTES AND LEGEND SEE FIGURE 2.5.C-14
2. MOVEMENT SHOWN HEREIN INDICATES SETTLEMENT OF INDIVIDUAL ANALYSIS CONTROL POINT SINCE MAT CONSTRUCTION. THE TOTAL MOVEMENT WILL INCLUDE RECOMPRESSION OF HEAVE (AVERAGE 2 INCHES) PLUS A NET SETTLEMENT (AVERAGE INCHES)

20 0 20 40 60 80
HORIZONTAL SCALE IN FEET

3. THE SAME POINT IN DIFFERENT SECTIONS MAY SHOW DIFFERENT MOVEMENTS AT THE SAME DATE, BECAUSE THEY ARE MEASURED FROM DIFFERENT STARTING DATES.

SOUTH TEXAS PROJECT
UNITS 1 & 2

DIFFERENTIAL MOVEMENT PROFILE
WITHIN BUILDINGS
UNIT 2

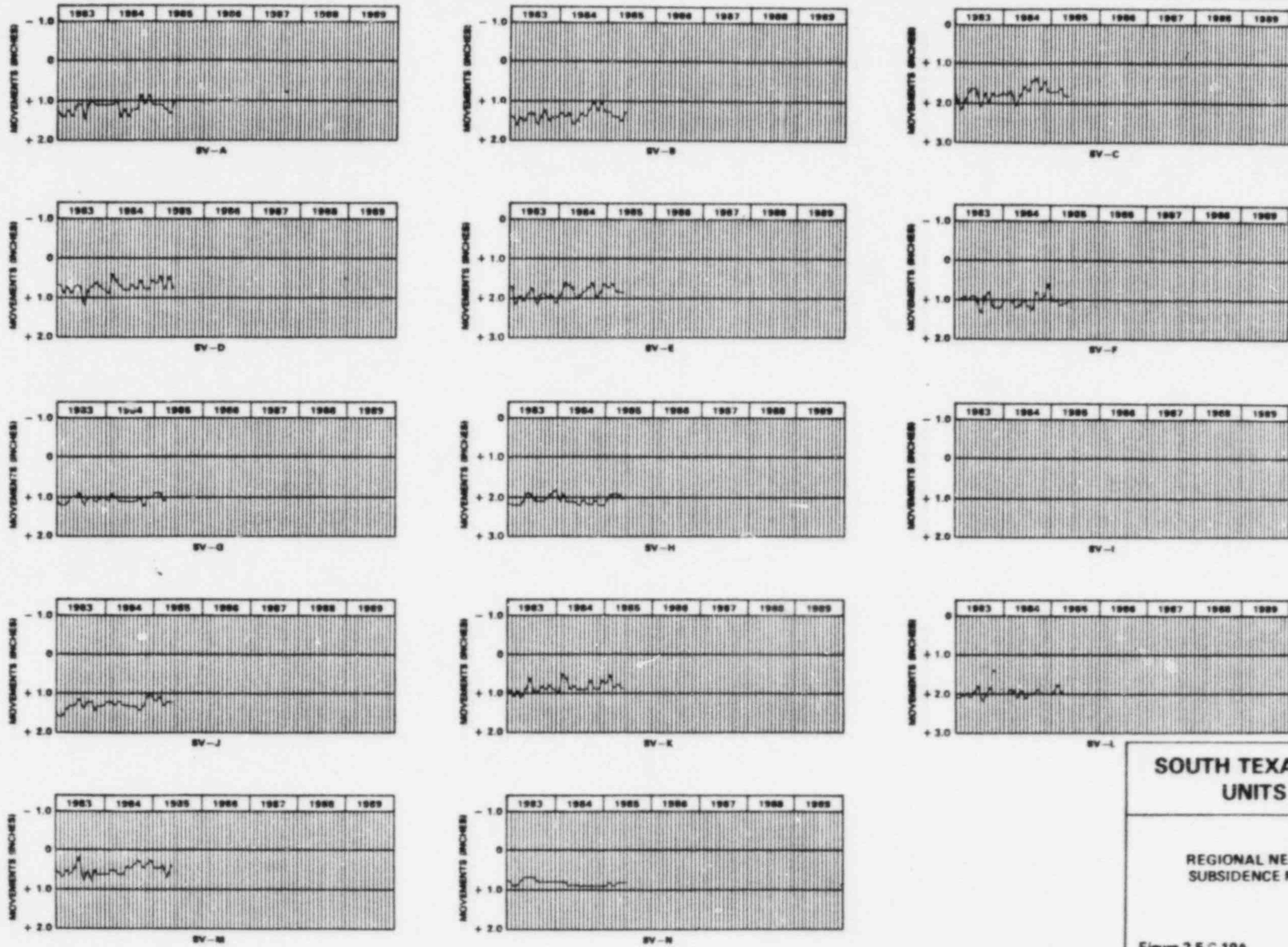
Figure 2.5.C-14A

TO BE AMENDED LATE ~~1984~~ 1986

SOUTH TEXAS PROJECT
UNITS 1 & 2

DIFFERENTIAL MOVEMENT OF YARD PIPING

Figure 2.5.C-16 ~~Amendment 35~~

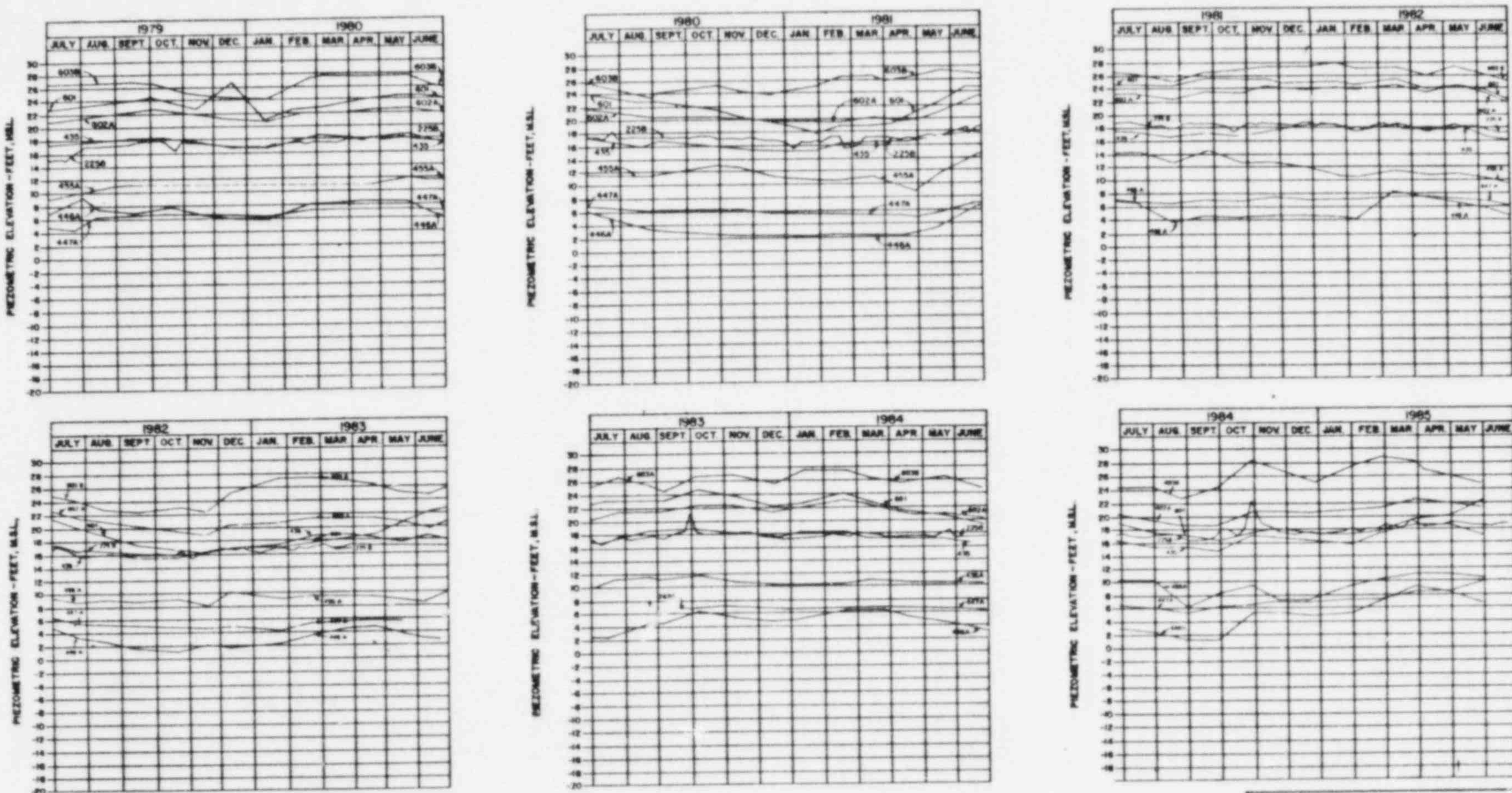


SOUTH TEXAS PROJECT
UNITS 1 & 2

REGIONAL NEAR-SURFACE SUBSIDENCE MONITORING

Figure 2.5.C-19A

ATTACHMENT 1
ST-HL-AE- 1399
PAGE 54 OF 60



NOTES:

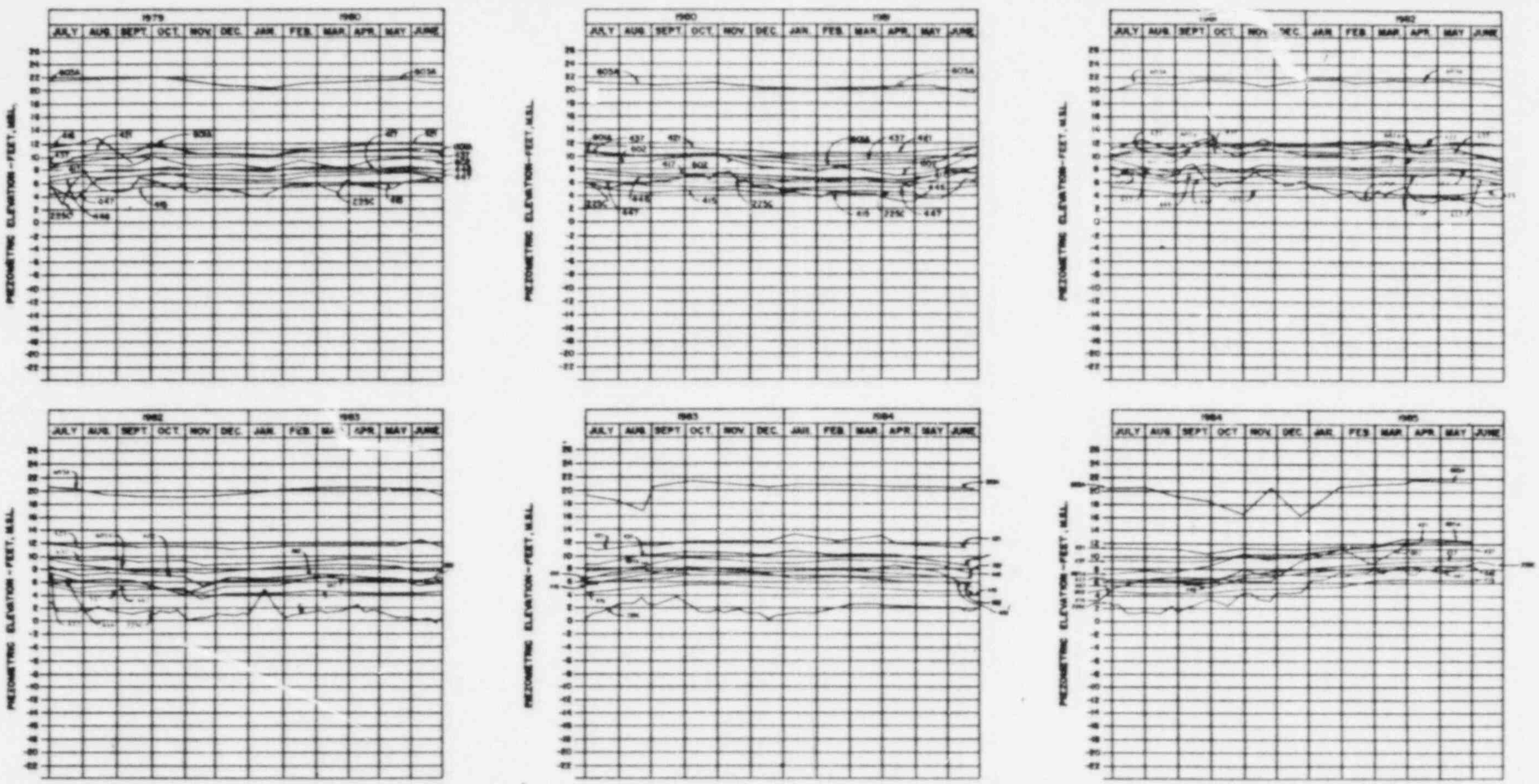
1. Refer To Figure 2.5.C-18 For Locations Of The Permanent Piezometers.
2. Site Preparation-Surface Drainage Was Started On September 22, 1975.
3. Plant Dewater Was Started On Nov 15, 1975.
4. Dewatering For Make-up Pump Station Was Started On December 27, 1976.

SOUTH TEXAS PROJECT
UNITS 1 & 2

REGIONAL UPPER SHALLOW AQUIFER MONITORING DATA

Figure 2.5.C-20A

ATTACHMENT 1
ST-HL-AE-1399
PAGE 55 OF 60



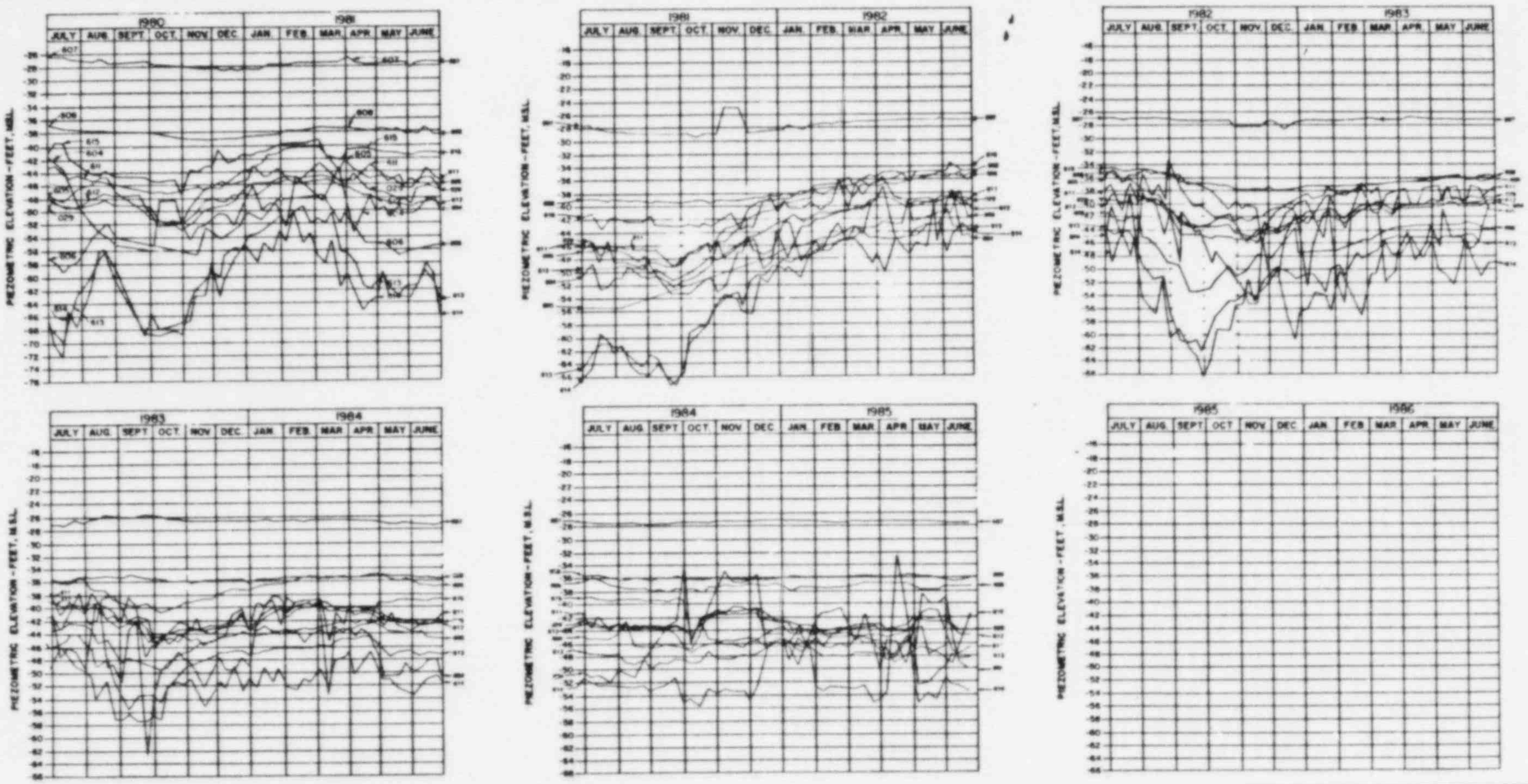
NOTES:

1. Refer To Figure 2.5.C-18 For Locations Of The Permanent Piezometers.
2. Site Preparation-Surface Drainage Was Started On September 22, 1975.
3. Plant Dewater Was Started On Nov 15, 1975.
4. Dewatering For Make-up Pump Station Was Started On December 27, 1976.

SOUTH TEXAS PROJECT
UNITS 1 & 2

REGIONAL LOWER SHALLOW
AQUIFER MONITORING DATA

Figure 2.5.C-21A



NOTES:

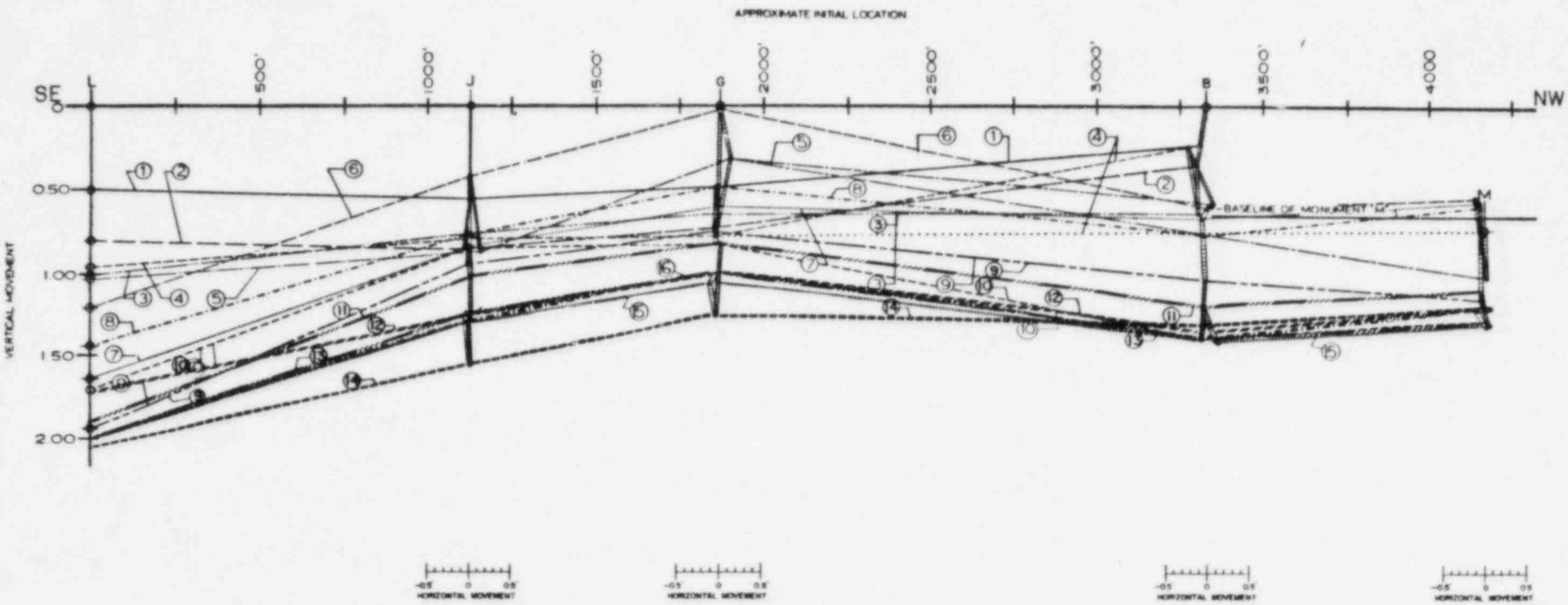
1. Refer To Figure 2.5.C-18 For Locations Of The Permanent Piezometers.
2. Site Preparation-Surface Drainage Was Started On September 22, 1975.
3. Plant Dewater Was Started On Nov 15, 1975.
4. Dewatering For Make-up Pump Station Was Started On December 27, 1976.

SOUTH TEXAS PROJECT UNITS 1 & 2

REGIONAL DEEP AQUIFER MONITORING DATA

Figure 2.5.C-22A

ATTACHMENT 1
ST-HL-AE-1399
PAGE 57 OF 60



NOTES:

1. HORIZONTAL DISPLACEMENTS ARE CUMULATIVE FROM SOUTHEAST TO NORTHWEST ARE RELATIVE TO POINT "L", WHICH IS ASSUMED TO BE FIXED.
2. MONUMENT "B" WAS DISTURBED BY CONSTRUCTION ACTIVITIES AND MONUMENT "M" WAS INSTALLED IN APRIL, 1978, AS A REPLACEMENT AND BACKUP FOR MONUMENT "B".

LEGEND:

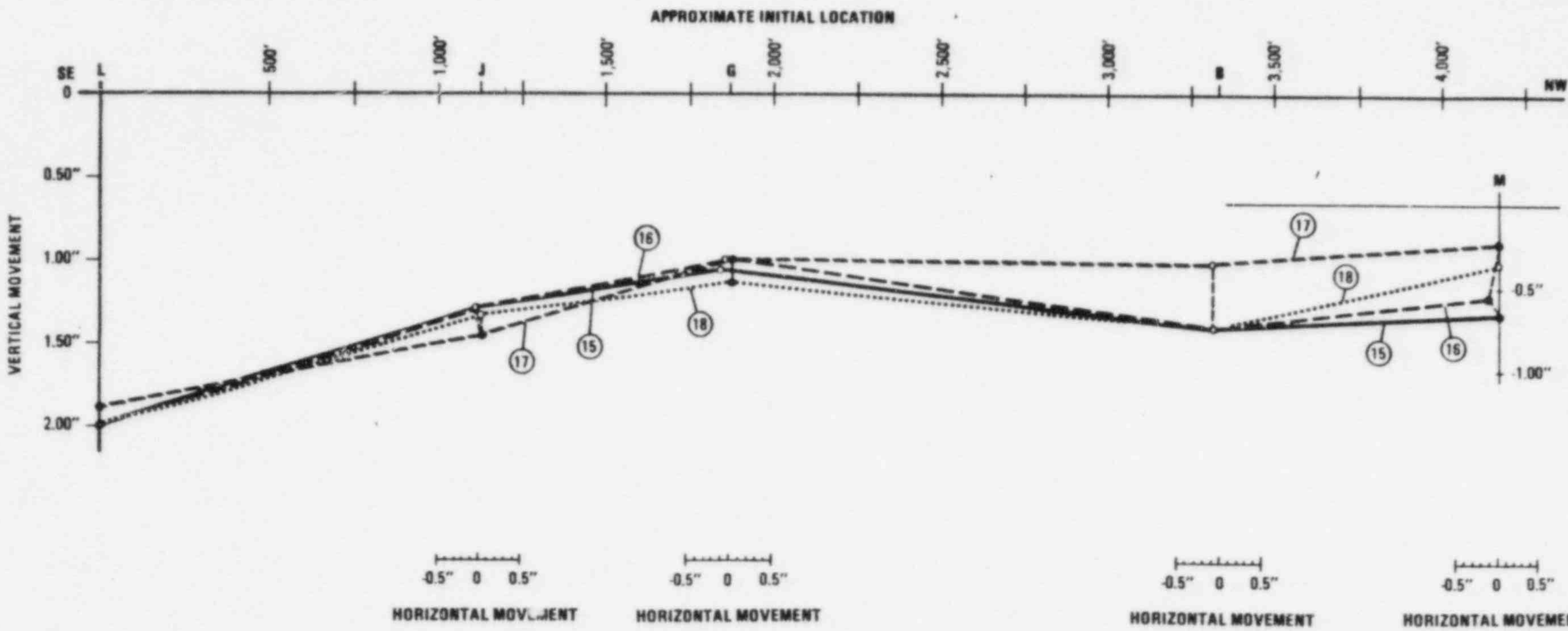
BASELINE MARCH, 1976

1. OCTOBER, 1976
2. AUGUST, 1977
3. OCTOBER, 1977
4. JUNE, 1978
5. SEPTEMBER, 1978
6. APRIL, 1979
7. OCTOBER, 1979
8. APRIL, 1980
9. OCTOBER, 1980
10. APRIL, 1981
11. SEPTEMBER, 1981
12. FEBRUARY, 1982
13. SEPTEMBER, 1982
14. FEBRUARY, 1983
15. SEPTEMBER, 1983
16. MARCH, 1984

SOUTH TEXAS PROJECT UNITS 1 & 2

CROSS-SECTION L-M
HORIZONTAL STRAIN-REGIONAL SUBSIDENCE MONITORING DATA COMBINED

Figure 2.5.C-23



NOTES:

1. HORIZONTAL DISPLACEMENTS ARE CUMULATIVE FROM SOUTHEAST TO NORTHWEST ARE RELATIVE TO POINT "L" WHICH IS ASSUMED TO BE FIXED
2. MONUMENT "B" WAS DISTURBED BY CONSTRUCTION ACTIVITIES AND MONUMENT "M" WAS INSTALLED IN APRIL 1978, AS A REPLACEMENT AND BACKUP FOR MONUMENT "B"

LEGEND

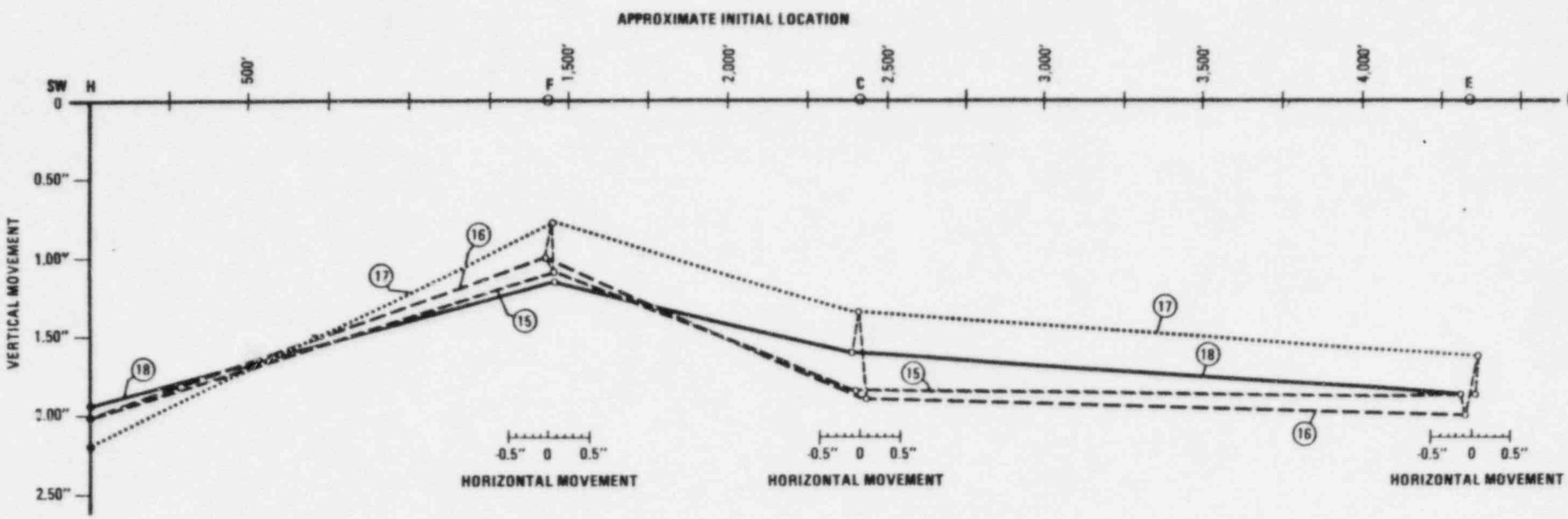
BASELINE MARCH 1976
(15) SEPTEMBER 1983
(16) MARCH 1984
(17) SEPTEMBER 1984
(18) MARCH 1985

SOUTH TEXAS PROJECT
UNITS 1 & 2

CROSS-SECTION L-M
HORIZONTAL STRAIN-REGIONAL
SUBSIDENCE MONITORING
DATA COMBINED

Figure 2.5.C-23A

ATTACHMENT 1
ST-HL-AE-1399
PAGE 58 OF 60



NOTES

LEGEND

BASELINE MARCH 1978

(15) SEPTEMBER 1983

(16) MARCH 1984

(17) SEPTEMBER 1984

(18) MARCH 1985

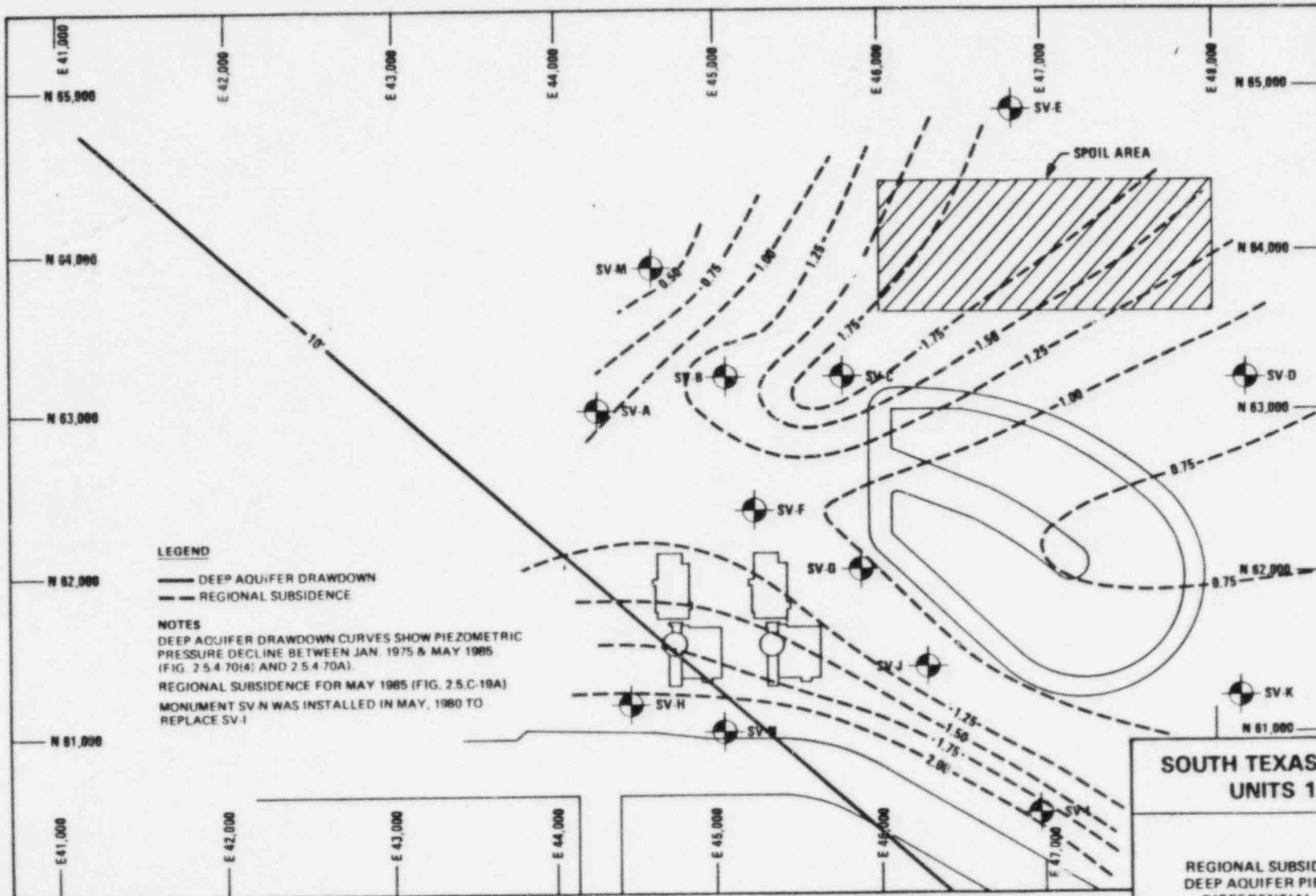
SOUTH TEXAS PROJECT
UNITS 1 & 2

CROSS-SECTION H-E
HORIZONTAL STRAIN-REGIONAL
SUBSIDENCE MONITORING
DATA COMBINED

Figure 2.5.C-24A

ATTACHMENT 1
ST-HL-AE-1399
PAGE 59 OF 60

ATTACHMENT 1
ST-HL-AE- 1399
PAGE 60 OF 60



SOUTH TEXAS PROJECT
UNITS 1 & 2

REGIONAL SUBSIDENCE AND DEEP AQUIFER PIEZOMETRIC DIFFERENTIAL DECLINE

Figure 2.5.C-25C