Report of the Exploration / Demobilization of Wells 4 and 5 San Onofre Nuclear Generating Stations Units 2 & 3

PREPARED FOR

SOUTHERN CALIFORNIA EDISON
P.O. BOX 800
ROSEMEAD, CALIFORNIA 91770

JULY 1979

Woodward-Clyde Consultants

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REPORT OF THE EXPLORATION/DEMOBILIZATION OF WELLS 4 AND 5 SAN ONOFRE NUCLEAR GENERATING STATIONS UNITS 2 AND 3

0.0 EXECUTIVE SUMMARY

The investigation/demobilization of Wells 4 and 5 is described in detail in the accompanying report. The scope of that work included the investigation of the areas around Wells 4 and 5 to detect and delineate possible cavities caused by the dewatering operation at these wells, and to stabilize the affected area by pressure grouting if cavities are found. The investigation of these wells made use of drilling exploration in conjunction with a crosshole seismic technique to provide closure information between drill holes. The calibration of the crosshole seismic work involved the measurements made around a known small cavity at Well 3. For this reason, the accompanying report also includes a description of the work completed at Well 3.

The specific investigation work completed at Well 4 included shallow exploration to a depth of about 40 feet below grade utilizing a construction excavation for direct observation followed by deeper exploration (to a depth of 200 feet below grade) utilizing eight carefully sampled exploration drill holes. Crosshole seismic measurements were then caried out between the drill holes. The specific investigation work completed for Well 5 included the exploration and grouting of a small, shallow cavity using 19 drill holes and 29 grout injection holes followed by deeper exploration (to a depth of 200 feet below plant grade) utilizing four carefully sampled exploration drill holes. Crosshole seismic measurements were also made between these drill holes.

Conservative interpretations were made of all data resulting in

the detection of a small, shallow cavity at Well 5 (subsequently stabilized by pressure grouting) and no cavities in Well 4 or at greater depths in Well 5. Based on these findings, Wells 4 and 5 were capped and are considered demobilized.

1.0 INTRODUCTION

1.1 Background Conditions

Cavities have been detected and defined at Dewatering Wells 3, 5, 6, 7 and 8 (located on Figure 1) by drilling exploration. These cavities were formed by internal piping during the use of the dewatering wells. The mechanics of that process, as well as the evidence at every cavity which has been investigated by drilling, indicates that a cavity will be full of loose sand attrited from the roof and walls of the cavity and deposited by settling gently through the contained water. The cavities, where they exist, therefore have the characteristics of being adjacent to dewatering wells, and of being filled with loose sand.

The cavity at Well 5 was defined by shallow drilling during construction in the vicinity of Well 5. This cavity was found to be small in plan, and to extend from 25 to about 55 feet (Elev. +5 to -25 ft) below plant grade.* To stabilize this area so construction could proceed, the area down to a depth of 60 feet (Elev. -30 ft) below plant grade was grouted as discussed in Appendix B. Areas below 60 feet were not investigated at the time the shallow exploration was carried out.

The area around Well 4 was excavated to about 40 feet below the present ground surface** to gain access to the well casing. During this operation, areas near the base of the excavation experienced minor caving due to ground water inflow as discussed in Appendix B. Subsequently, the excavation was backfilled with lean concrete and compacted soil fill.

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* Plant grade is defined at Elev. +30 ft and is coincident with the present ground surface elevation at Well 5.

** Present ground surface is at Elev. +26.5 ft.

Due to the proximity of structures to Wells 4 and 5 (Figures 2 and 3, respectively), deep-drilling access in the vicinity of these wells to the depths of interest (below 60 feet at Well 5 and below 40 feet at Well 4) was limited.

1.2 Scope of Work

The scope of work for the exploration/demobilization of Wells 4 and 5 was to develop and implement a program to investigate the existence of cavities in the depths of interest at Wells 4 and 5, and to maximize the information obtained from these borings. The procedure developed to accommodate this scope of work involved three basic steps: (1) the careful drilling and sampling of at least four borings near the well, located according to the information available for the trajectory of the well; (2) the preparation of the boreholes for crosshole seismic measurements; and (3) the performance of crosshole measurements. If a possible cavity were indicated by step 1 or 3, additional drilling exploration would be required. The primary purpose of the crosshole seismic measurements is to provide closure information between borings and to guide the location of additional borings, if required to verify or delineate a cavity.

Although geophysical procedures have been used for cavity detection (Appendix A), it was felt necessary to calibrate the specific crosshole seismic techniques (Appendix C) for the types of cavities at this site. To accomplish this, the known cavity at Well 3 was used to refine the techniques for the crosshole measurements, and to define specific cavity detection criteria for the crosshole data obtained from Wells 4 and 5.

1.3 Organization of the Report

This report has been organized to provide a succinct description of the procedures, data and analyses used to investigate and demobilize Wells 4 and 5 and to calibrate the crosshole seismic procedure at Well 3. Specifically, Section 1 introduces the

study and is followed by a description of the geophysical methods in Section 2. The field measurements are discussed in Section 3 and Section 4 describes the analysis of data. The conclusions of the study are presented in Section 5. A discussion of some theoretical and practical principles of the method is presented in Appendix A. Appendix B describes the exploration borings and the preparation of the borings used for the crosshole work. Appendix C presents the details of the techniques and procedures. Appendices D, E, and F present the data and their interpretation for Wells 3, 4 and 5, respectively. The logs of deep exploration borings for wells 4 and 5 and corresponding results of gyroscopic survey, are included in Appendix G.

2.0 GEOPHYSICAL METHODS

For ease of reference in the presentation of the results in Sections 3 and 4, this section will summarize the methods used to acquire the seismic data, and will present a simplified view of the mechanisms of cavity detection for this site. Some theoretical and practical aspects of the cavity detection process for this site are given in Appendix A. Procedural and equipment details are contained in Appendix C.

The process consists of drilling several holes around the well which are arranged and inclined to investigate areas of interest and to investigate seismically across all sides of the well at all elevations of interest. A plastic casing is grouted into each hole and a hammer is inserted into one of the holes to generate a seismic signal. Geophones are placed in the other holes to detect the signal as shown in Figure 4. The data are then analyzed to determine if a cavity might be present between the holes.

The boreholes were carefully logged for the results of standard penetration tests, visual inspection of the cuttings and samples, and the drilling characteristics. The grouting of the casing was done from the annular space between the casing and the side of the drill hole with a nonshrink grout. Grout volumes were carefully measured, and compared to the calculated volume of the annulus as discussed in Appendix G.

The seismic signal was created by a weight (hammer) allowed to strike an anvil which tightly gripped the casing. The signal was detected in adjacent boreholes by geophones which tightly gripped their casings.

Each experiment was performed with the hammer and geophones at the same elevation. The entire array would be lowered to the bottom of the hole, and secured at that elevation. A number of

blows would then be applied, and recorded on a signal-enhancing oscillograph that adds the signals from each blow. This has the effect of minimizing the random seismic noise, and enhancing the repeatable elements of the phenomenon. When the work at that elevation was complete, the entire array was raised either 5 or 10 feet (depending on conditions), and the process was repeated. When the top of the hole was reached, the hammer was interchanged with one of the geophones, and the the entire sequence of measurements was repeated. By this means, coverage was provided along each traverse between a pair of holes with each hole serving as both transmitter and receiver.

The data were analyzed by comparing, qualitatively and quantitatively (Section 4, Appendices D through F), each recorded trace with its vertical neighbors in any one receiver hole. Thus the method relies on changes of and differences in the traces within each individual hole. The following is a discussion of the reasons for such changes and differences, and a summary of the trace characteristics expected if cavity is present.

Studies of the cavities found at this site, as well as certain theoretical considerations, indicate that the cavities should be filled with loose sand. The poroelastic properties of this loose sand are such that it should, for the specific source signal being used, attenuate a dilatational (P) wave rather efficiently; but it should attenuate a shear (S) wave rather poorly, unless the cavity is large compared to the distance between the source and receiver holes.* When the cavity is comparatively large, both waves should be attenuated. The poroelastic properties of the undisturbed native sand, on the other hand, are such that it

* See Appendix A. This conclusion refers only to the combination of the hammer source used, the specific properties of the native San Mateo sand, and the specific properties of the loose sand infilling those cavities. The conclusion should not be applied to other combinations of conditions without specific analysis of those conditions.

should not, for the specific source signal being used, greatly attenuate either the P- or S-waves. The foregoing statements apply for a wave which passes through these cavities, as shown in Figure 5.

Because of the relative properties of the undisturbed native sand and the loose cavity-infill sand, travel-time calculations indicate a propensity for these waves to travel faster around, rather than through, these cavities. Figure 6 shows this case, and develops the concept of wave attenuation due to diffraction around the cavity. This diffraction attenuation should be enhanced for the native sand near the cavity because this sand has a stress gradient from the edge of a cavity out to the point in the formation where the cavity's existence is not felt. The diffraction attenuation is expected to be relatively more severe for the P-wave than the S-wave, because the P-wavelengths are shorter.

Both of these considerations, a wave traveling through and a wave traveling around a cavity, indicate that the waves will be changed when passing through or around a cavity, as compared to passing through the native sand. More specifically, these considerations indicate that the P-wave will probably be the most affected, but that the S-wave should also be affected if the cavity is larger than about 1/2 to 2/3 the distance between bore holes. Further, because of the stress gradient near the cavity, it is expected that the waves will be altered somewhat if they pass close to a cavity, compared to their shapes when passing only through the native sand. Thus, in principle, seismic techniques should be effective for detecting cavities at the site. For this reason, the techniques were tested in calibration experiments at the cavity of Well 3, as discussed in Section 4.1 and Appendix D. Those experiments agreed with the theoretical expectations; but, perhaps more importantly, they allowed definition of qualitative and quantitative criteria for the

possible existence of cavities between bore holes specifically at this site.

3.0 FIELD MEASUREMENTS

Field measurements made for the investigation/demobilization of Wells 4 and 5 and for the calibration work on Well 3 include cleaning and inspection of the inside of the well casing, the drilling and logging of shallow exploration borings and crosshole seismic measurements. The subsections that follow describe the drilling exploration and crosshole measurements and coverage.

3.1 Drilling Exploration

Eight deep exploration drill holes were drilled and logged at Well 4 as located on Figure 2. Also indicated on Figure 2 are the deviations of the boreholes from the vertical in plan view. The general procedures followed in drilling, the measurements of borehole deviation from vertical, and the logs of borings are described in Appendices B and G. The drilling exploration showed no evidence of cavity; however, small zones of disturbed material and lean concrete were encountered in the boreholes within 40 feet of the plant grade. These materials resulted from the excavation used to access Well 4 as discussed above.

In addition to the shallow exploration and grout holes used to stabilize the area in the upper 60 feet around Well 5 as discussed in Section 1.1 and Appendix B, four deep exploration borings were drilled and logged at Well 5 as located on Figure 3. The details of this work are presented in Appendix B and G. The drilling exploration showed no evidence of cavity.

The known cavity at Well 3 was identified and measured using exploration drill holes and air lift cleaning with limited sonar and mechanical caliper measurements as discussed in Appendix B. A total of 31 borings were drilled at Well 3 as shown on Figure 7. Based on a detailed review of these data, the location and geometry of the cavity at Well 3, as revealed by the drilling exploration and sonar and caliper measurements, are summarized on Figure 8.

3.2 Crosshole Geophysical Measurements and Coverage

The details of the instrumentation, field procedures and processing of data for the geophysical measurements are described in Appendix C. The field procedures evolved during the calibration work at Well 3 and were carried out uniformly on Wells 4 and 5. As indicated above, the crosshole measurements at Well 3 were made to calibrate the technique and develop cavity-detection criteria to be applied at Wells 4 and 5. This was to provide closure between the exploration borings drilled at these locations. To accomplish this calibration, exploration borings C, E, Q, T, U and V were selected and prepared for crosshole measurements as described in Appendix D. These borings provide data both across and around the known cavity as shown on Figure 9 by the red and green transects, respectively.

In order to minimize the number of drill holes at Wells 4 and 5, all deep borings at these wells were prepared and used for crosshole geophysical measurements. At Well 4, this required the use of eight borings, six extending to the full well depth of 200 feet, and two shallow holes. Four borings extending to the full well depth of 200 feet were drilled at Well 5. The crosshole coverage for the depth intervals of interest (below 40 feet for Well 4 and below 60 feet for Well 5), as discussed in Appendices E and F for Wells 4 and 5, respectively, established closure information between the exploration drill holes for these wells.

4.0 ANALYSIS OF GEOPHYSICAL DATA

The analysis of data from the crosshole measurements was completed in two steps: (1) the data from Well 3 were analyzed and correlated to the known cavity to develop a conservative set of criteria for use in the interpretation of the possible existence of cavities between boreholes; and (2) the criteria developed from Well 3 were applied to the analysis of data for Wells 4 and 5. The subsections that follow describe the analysis of Well 3 data to develop cavity-detection criteria, and the analysis of Wells 4 and 5 data using those criteria.

4.1 Calibration Analysis of Well 3 Data

The crosshole transects shown on Figure 9 represent the coverage achieved in the depth range of the known cavity. Considering the general principles of wave transmission through and around a filled cavity, as discussed in Section 2 and Appendix A, crosshole data associated with the red transects on Figure 9 should display more attenuation and waveform disturbance than those data associated with the green transects. As discussed in Appendix A, it is expected that the portion of the wave-train associated with dilatational (P-wave) energy will be more attenuated than that associated with shear wave energy. Using this as an initial basis for inspection of the data, the waveforms for the green and red transect pairs (for example U-V and V-U for green and U-Q and Q-U for red) shown on Figure 9 were analyzed to develop cavity-detection criteria. Criteria compatible with the observations made regarding wave attenuation in Appendix A should yield higher attenuation in the region of the cavity for red transect pairs compared to green transect pairs.

The data to be analyzed were processed as indicated in Appendix C and analyzed as indicated in Appendix D. In brief, a first-cut qualitative inspection of the processed waveform records showed general agreement, with the red transects exhibiting greater

attenuation and waveform disturbance than the green transects. Specifically, the inspection of data from the transects indicated that amplitudes less than 10 to 20% of the largest amplitudes in a given transect are associated with a cavity or spurious. Such an amplitude reduction in reversed transects represents the best indicator since spurious reductions are less likely to occur in several reverse repeats on the same transect. Also, the reduction of amplitude in both P-waves and S-waves is strong evidence for a cavity. Also, by applying several different candidate sets of criteria involving the use of normalized amplitudes of the compression and shear waves, a set of semi-quantitative criteria that best fit the red and green transects shown on Figure 9 were achieved as follows:

CAVITY-DETECTION CRITERIA

Observation from Values of Normalized Amplitude	Interpretation
PxS* = 0 in both directions	Possible Cavity
PxS = 0 in one direction ≤ 0.2 in the other direction	Possible Cavity
PxS ≤ 0.1 in both directions	Possible Graze**
PxS ≤ 0.1 in one direction and ≤ 0.2 in the other	Possible Graze**
PxS = 0.2 in both directions	Native Soil
PxS > 0.2 in either direction	Native Soil

By applying the above criteria to the waveform data presented in Appendix D, the interpretations shown on Table 1 were found. These interpretations correlate well with the red and green transects on Figure C using red as cavity and green as native soil.

*The P- and S-wave amplitudes are normalized to the maximum amplitude of each wave for any depth in a given transect. This allows for the product PxS to be used as a single sensitive indicator of the effects of both waves together.

**The interpretation of possible graze indicates a smaller reduction in signal than expected for possible cavity and may reflect the effects of a small cavity nearby that does not intersect the transect or the effects of poor compiling of the casing to the bore hole.

4.2 Analysis of Well 4 and 5 Data

By applying the criteria developed from the Well 3 calibration case to the waveform data for Wells 4 and 5, interpretations of cavity, graze, and native were made on all transects for these wells as presented in Appendices E and F, respectively. Specifically, Well 4 data exhibited a native soil interpretation for all depths except at a depth near 40 feet on transects 5-7 (7-5) and 8-7 (7-8) and at a depth of 175 to 180 feet on transects 2-1 (1-2) and 2-5 (5-2). The transect 5-7 (7-5) and 8-7 (7-8) interpretation was likely influenced by loose soil and concrete just above the 40-ft depth (Figure B-4 and B-6, Appendix B), the grout just above these depths in the shot and receiver holes, and the fact that the wellbore intersects or is very close to these transects. Because of these effects and the fact that native soil is interpreted along transects just 5 feet deeper, the anomalous interpretation along these transects are due to construction disturbances at the time of initial demobilization activities. The 3-2 (2-3) transect bounding the well to the south shows native sand at all depths (40 to 200 feet) while the 2-1 (1-2) and 2-5 (5-2) transects bounding the well further south indicates possible graze at a depth of 175 to 180 feet. For this reason and because the cavity must be connected to the well the crosshole results of 2-1 (1-2) and 2-5 (5-2) transects at this depth are not considered applicable.

Interpretations made for the Well 5 waveform data presented in Appendix E show native soil interpretation throughout the depths of interest.

In addition to the above interpretation, the shear wave velocities and wave forms were essentially unaffected in the depths of interest around Wells 4 and 5 indicating no degredation of properties or presence of significant cavities associated with these wells.

5.0 CONCLUSIONS

Based on the foregoing discussions and the boring logs supplemented by crosshole seismic data presented in Appendices B, D, E and F, it is concluded that no cavities extend beyond boundary A shown on Figure 10 for depths of 40 to 200 feet at Well 4. Further, based on the interpretation made on transects crossing the area bounded by boundary A, it is concluded that no cavities of structural significance exist within boundary A on Figure 10. Similarly, for Well 5 it is concluded that no cavity extends beyond boundary B shown on Figure 11 for depths of 60 to 200 feet, and no cavities of structural significance exist within boundary B. It is therefore concluded that no further drilling is required at Wells 4 and 5.

TABLE 1

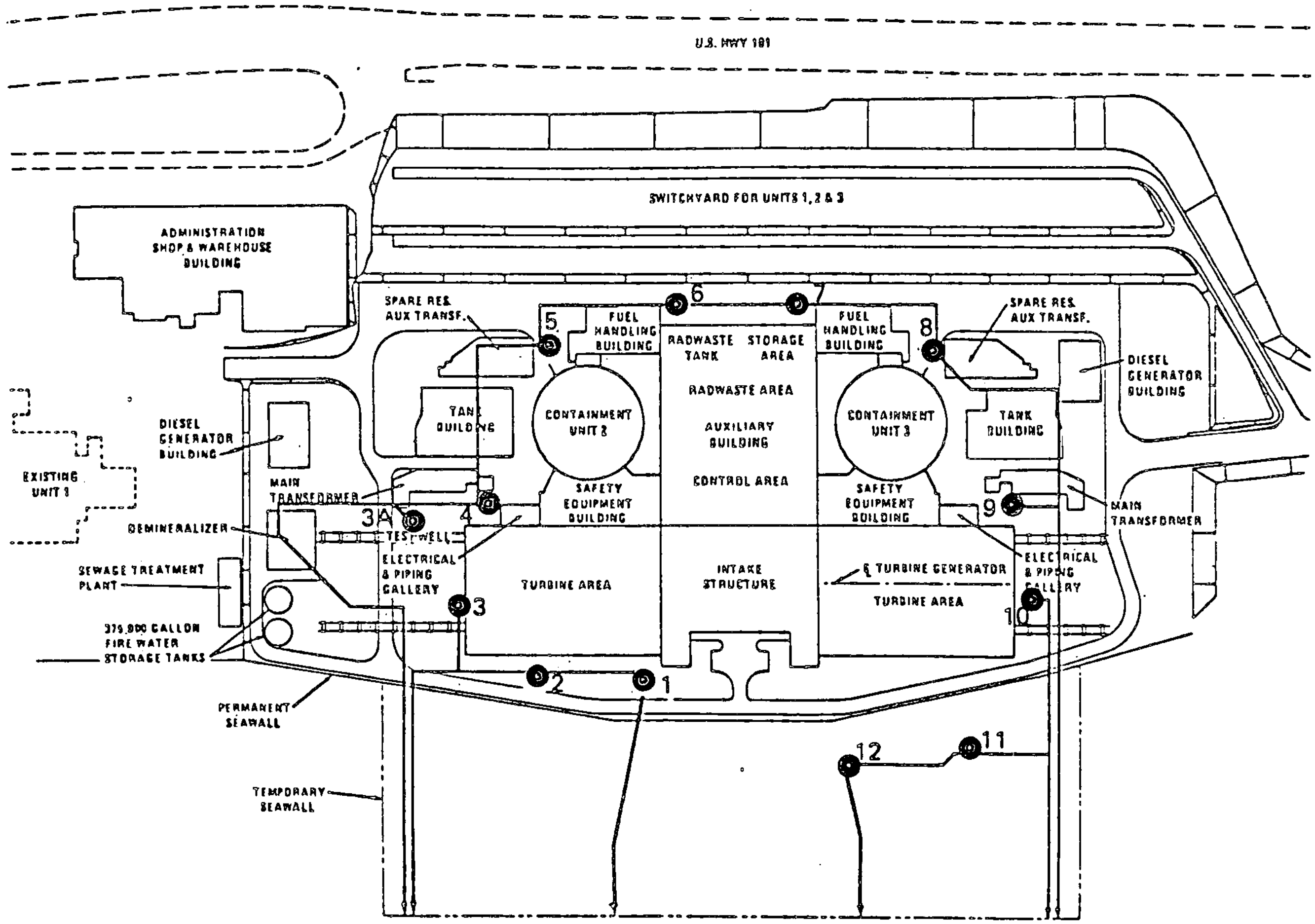
SUMMARY OF PxS TRACE AMPLITUDE INTERPRETATION FOR WELL 3

Transect	Depth Interval Fitting Criteria: PxS=0	0<PxS<0.1	0.1<PxS<0.2	Reverse Transect	Depth Interval Fitting Criteria: PxS=0	0<PxS<0.1	0.1<PxS<0.2	Interpretation
V-T	30-55'	--	60-65'	T-V	--	50	--	Possible cavity at 30-50'.
V-Q	--	--	95-130'	Q-V	--	90-95'	80-85' 100-105'	Possible graze near 95'.
V-U	--	--	--	U-V U-V	-- --	-- --	-- --	Native soil at all depths.
U-T	--	--	130-140' 170'	T-U	--	--	--	Native soil at all depths.
U-Q	30-45'	50-55' 90'	80' 95-100'	Q-U	--	45	40', 50'	Possible cavity at 30-55'.
	45-50' 30-50'	-- --	-- --	Q-U	32-59'	--	85'	Possible graze at 85-90'
Q-C	-- --	-- --	-- --	None				Native soil to depth of Hole C.*
Q-T	--	50-59'	40-45'	T-Q	--	--	--	Native soil at all depths.
U-E	--	--	--	None				Native soil to depth of Hole E.*
U-C	30-55'	--	--	None				Possible cavity at 30-55'.*
Q-E	32-59' 30-59'	-- --	-- --	None				Possible cavity at 30-60'.*

* No reverse leg for strict application of criteria.

SAN ONOFRE NUCLEAR GENERATING STATION UNITS 2 & 3

PLOT PLAN



Project: SONGS 2 & 3	SITE LOCATION PLAN	Fig.
Project No. 411301	DEWATERING WELLS SONGS UNITS 2 AND 3	1

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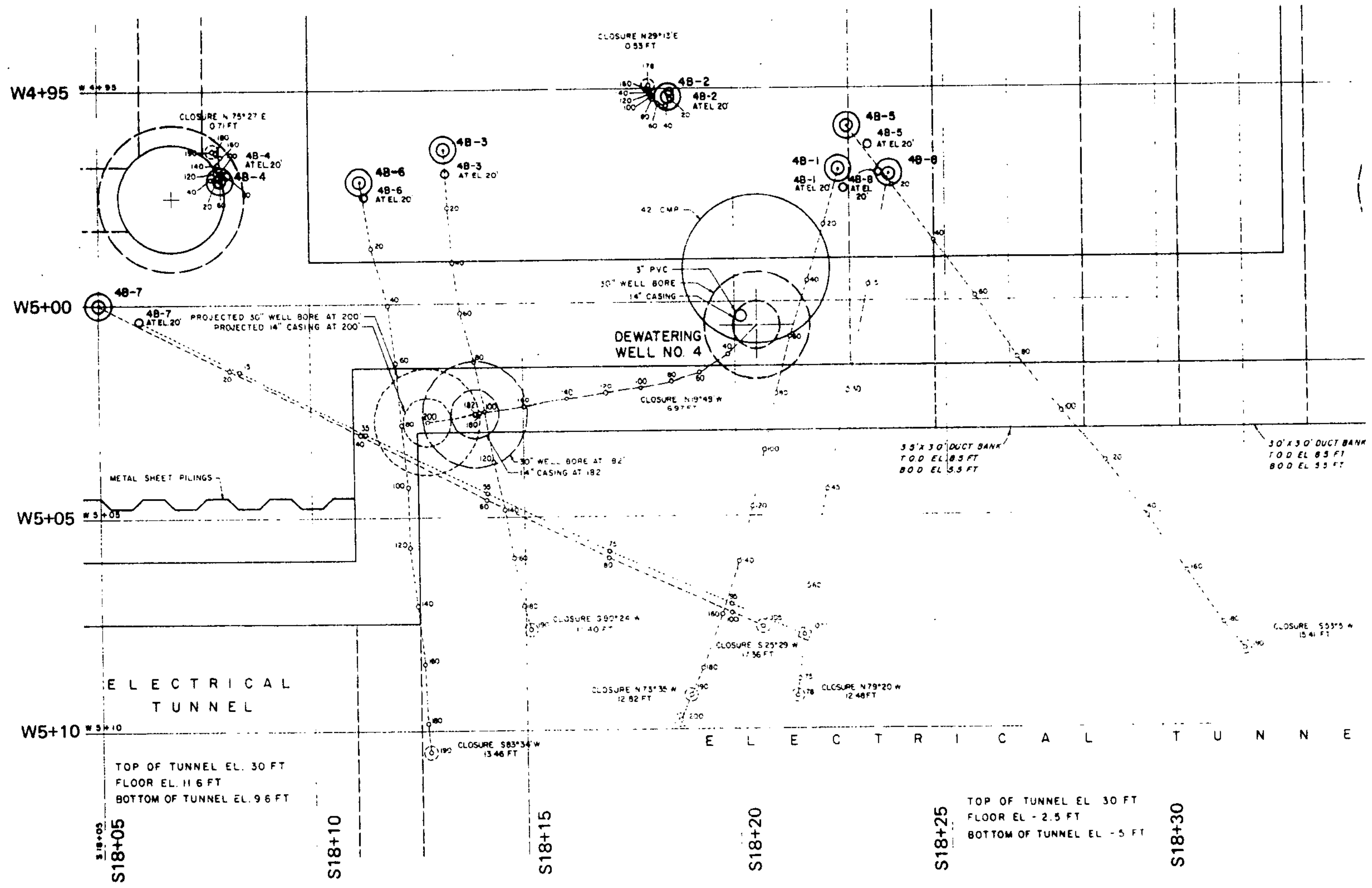

Project: **SONGS 2 & 3** Project No. **411301**	**DEWATERING WELL NO. 4 LOCATION PLAN**	Fig. **2**

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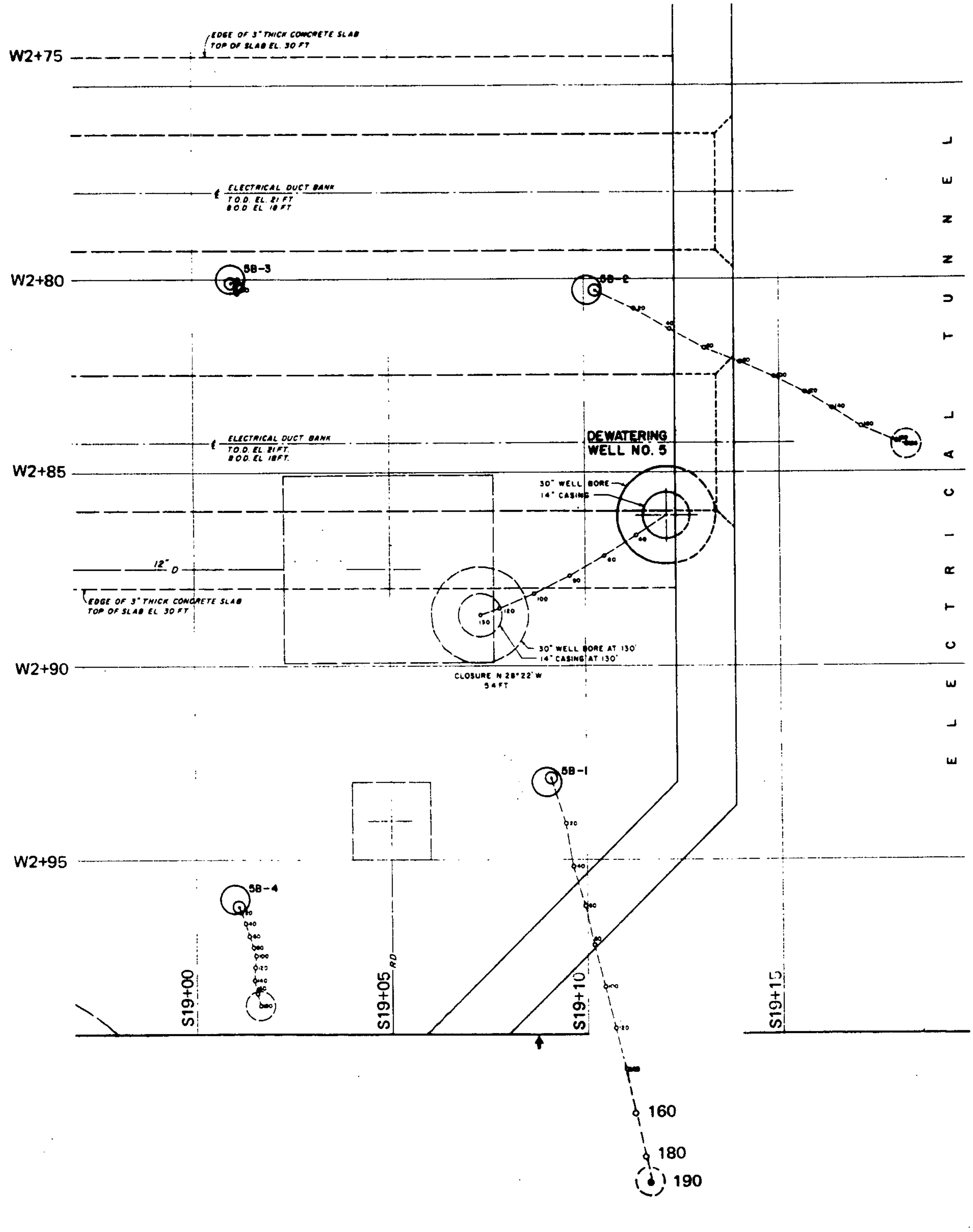

Project: **SONGS 2 & 3**
Project No. **411301**

DEWATERING WELL NO. 5 LOCATION PLAN

Fig. 3

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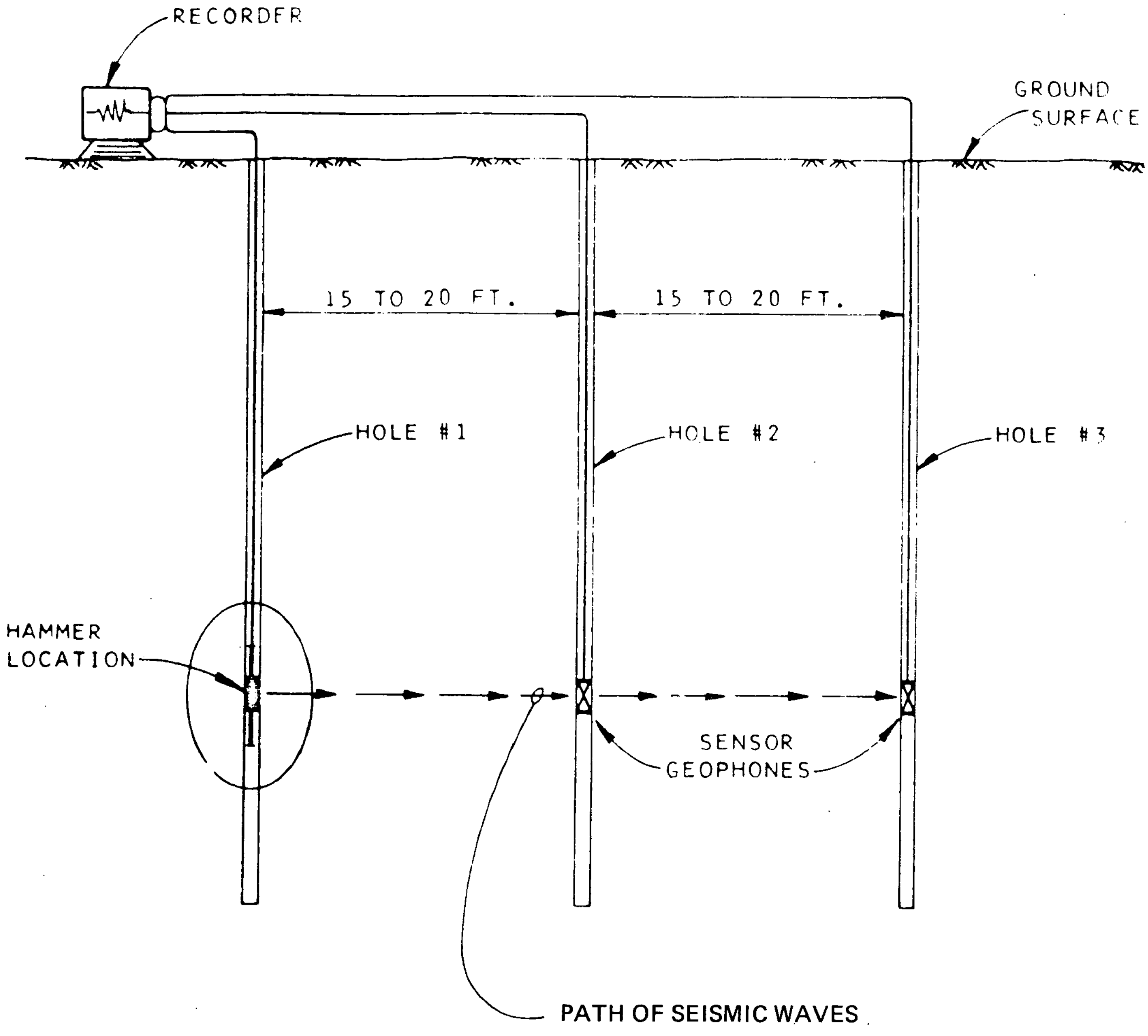
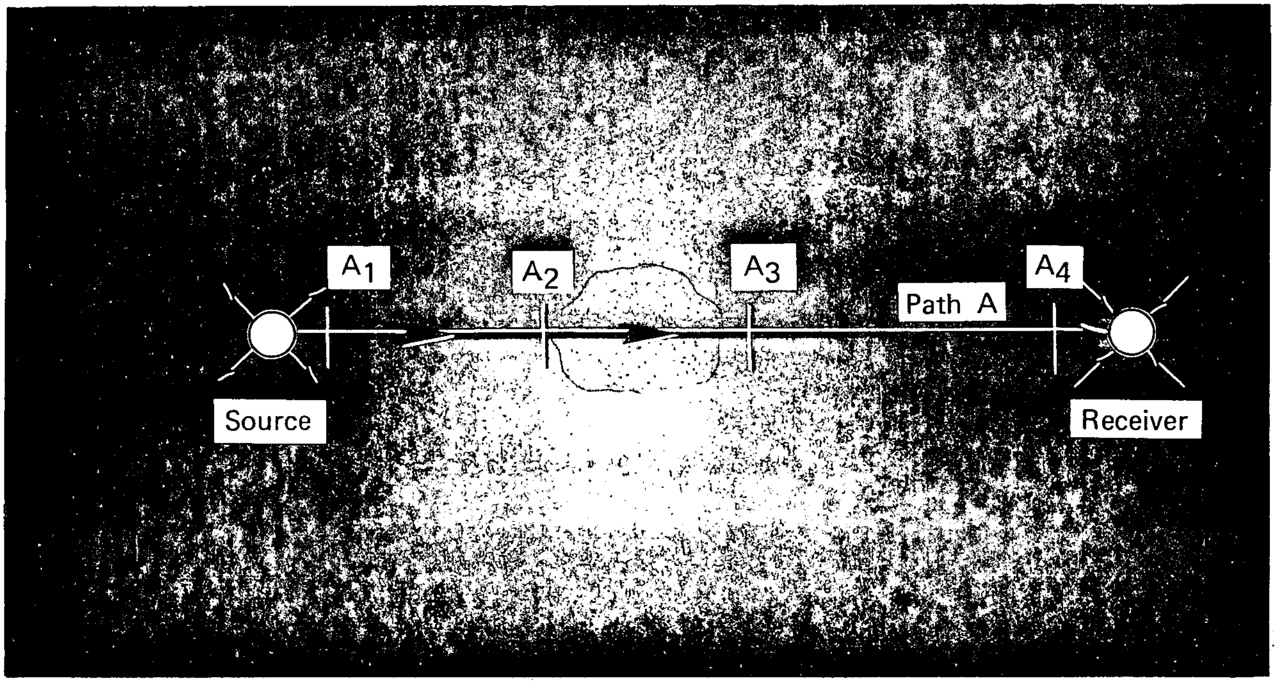
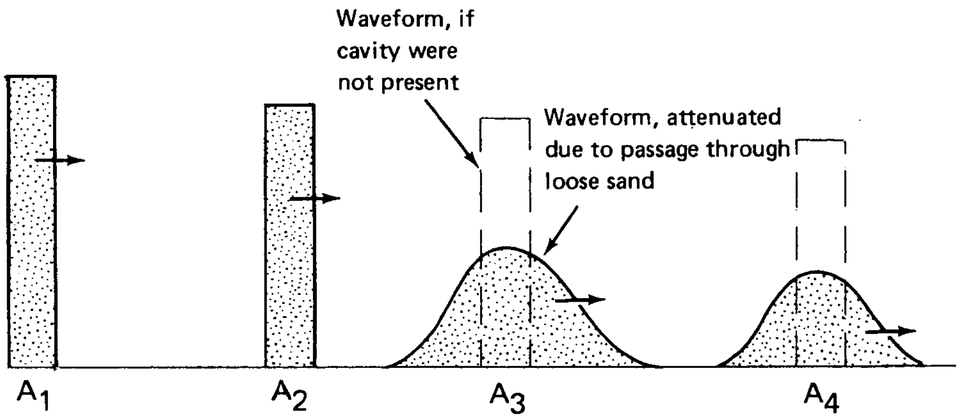


Project:	SONGS 2 & 3	ARRANGEMENT OF INSTRUMENTS FOR CROSSHOLE SURVEY	Fig. 4
Project No.	411301		

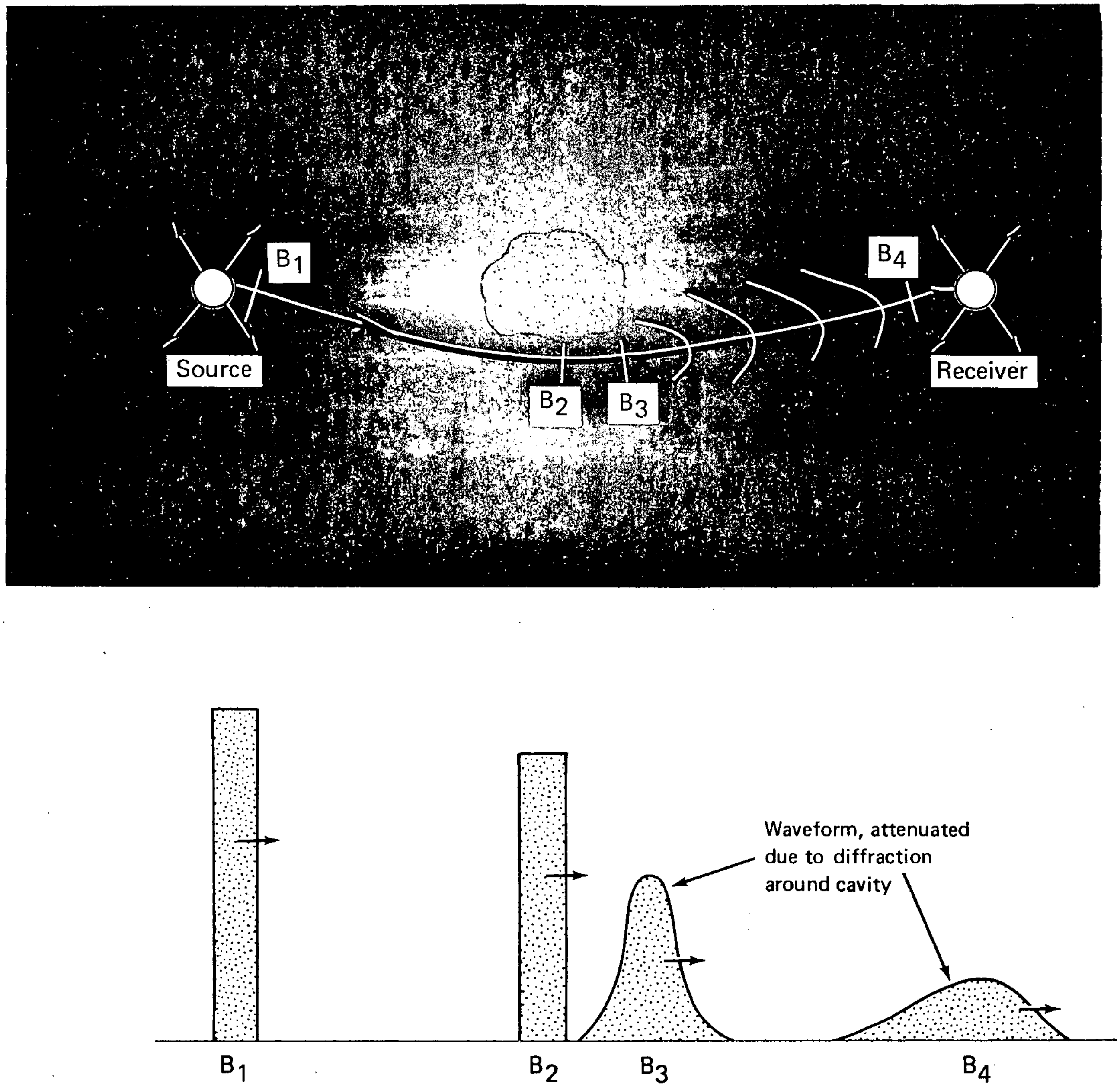
WOODWARD – CLYDE CONSULTANTS

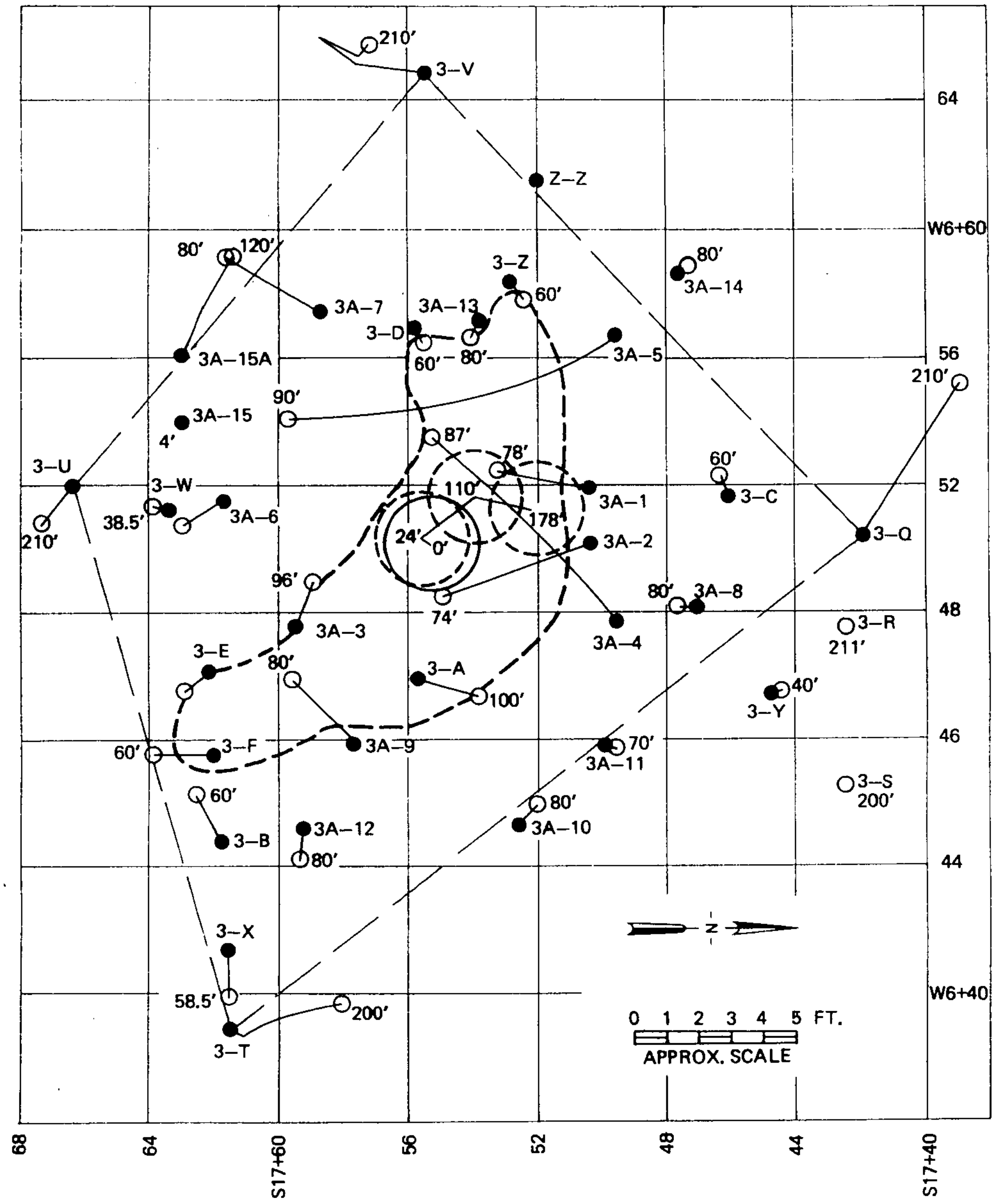




Project: **SONGS 2 & 3** Project No. **411301**	**WAVE PROPAGATION THROUGH CAVITY FILLED WITH LOOSE SAND**	Fig. **5**

WOODWARD – CLYDE CONSULTANTS


B1
B4
Source
Receiver
B2
B3
Waveform, attenuated due to diffraction around cavity
B1
B2
B3
B4



Project: SONGS 2&3 Project No. 411301	DEWATERING WELL NO. 3 LOCATION OF DRILL HOLES	Fig. 7

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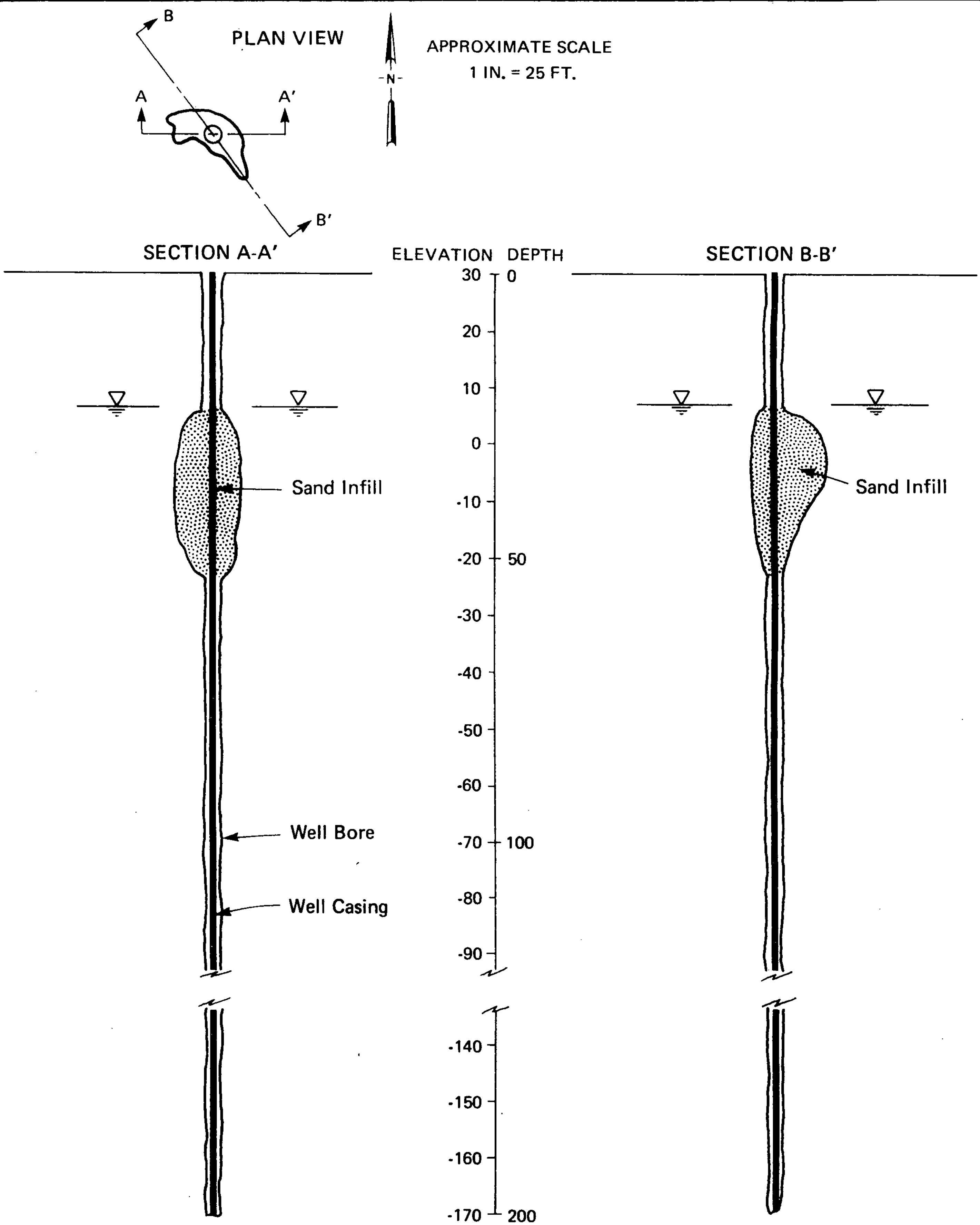

Project:	SONGS 2 & 3	PLAN AND SECTION VIEWS OF WELL NO. 3	Fig. 8
Project No.	411301		

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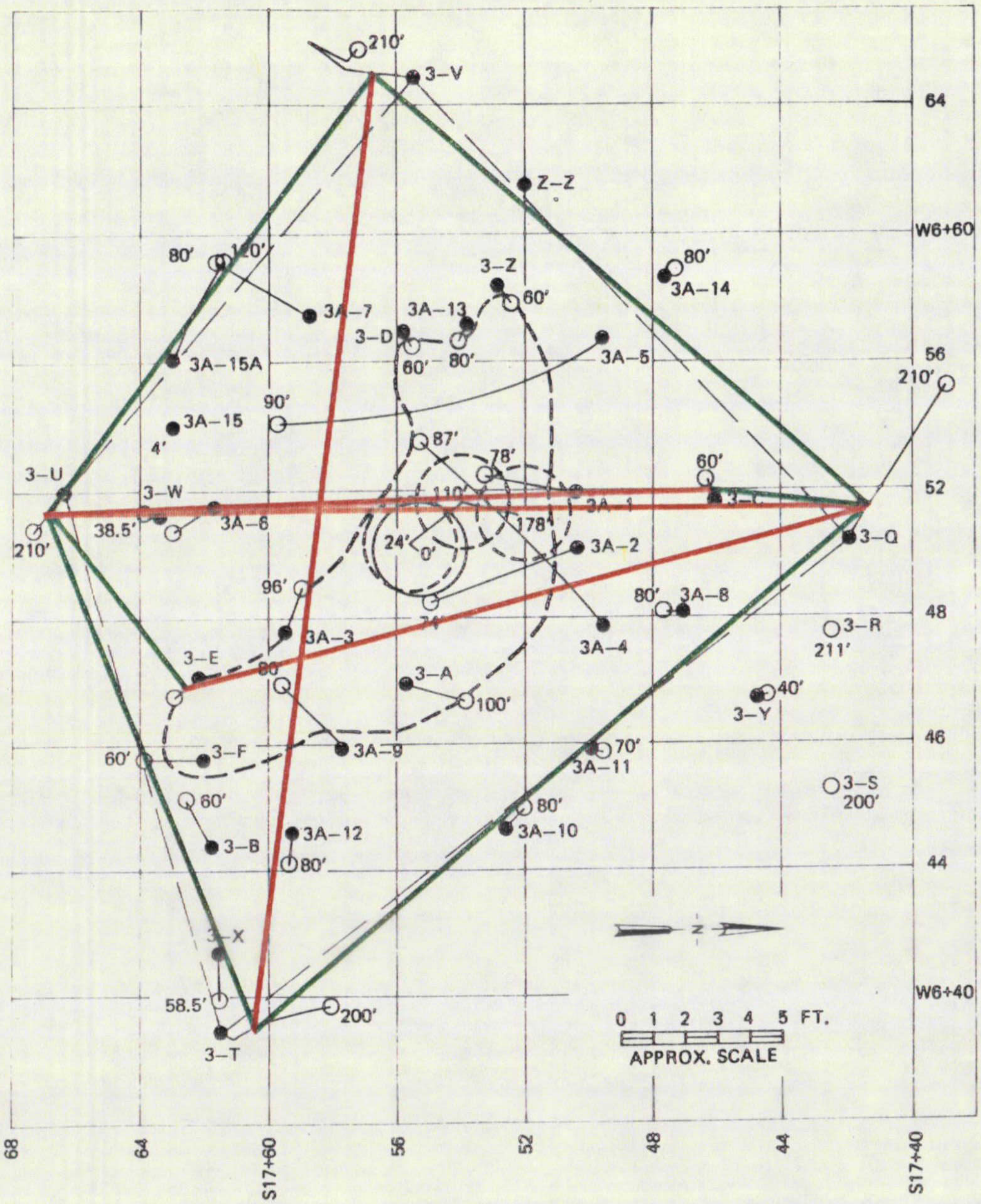

TYPICAL CROSSHOLE TRANSECTS 30-60 FT.

Across possible cavity

Across native soil

Project:	SONGS 2 & 3	DEWATERING WELL NO. 3 LOCATION OF DRILL HOLES AND CROSSHOLE TRANSECTS (30 TO 60 FT.)	Fig. 9
Project No.	41130I		

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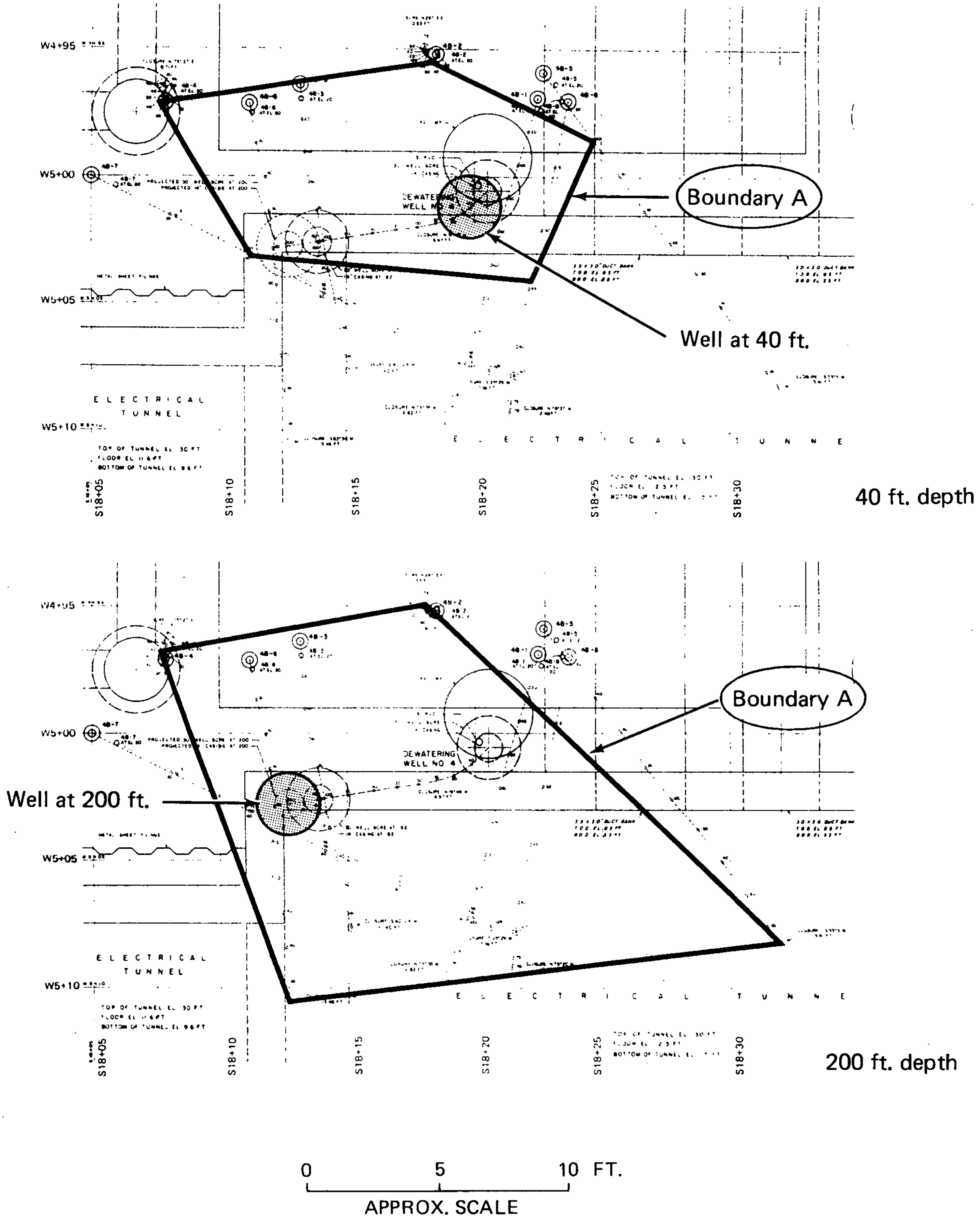

Project:	SONGS 2 & 3	DEWATERING WELL NO. 4	Fig.
Project No.	41130I	CAVITY BOUNDARY PLAN AT 40 AND 200 FT.	10

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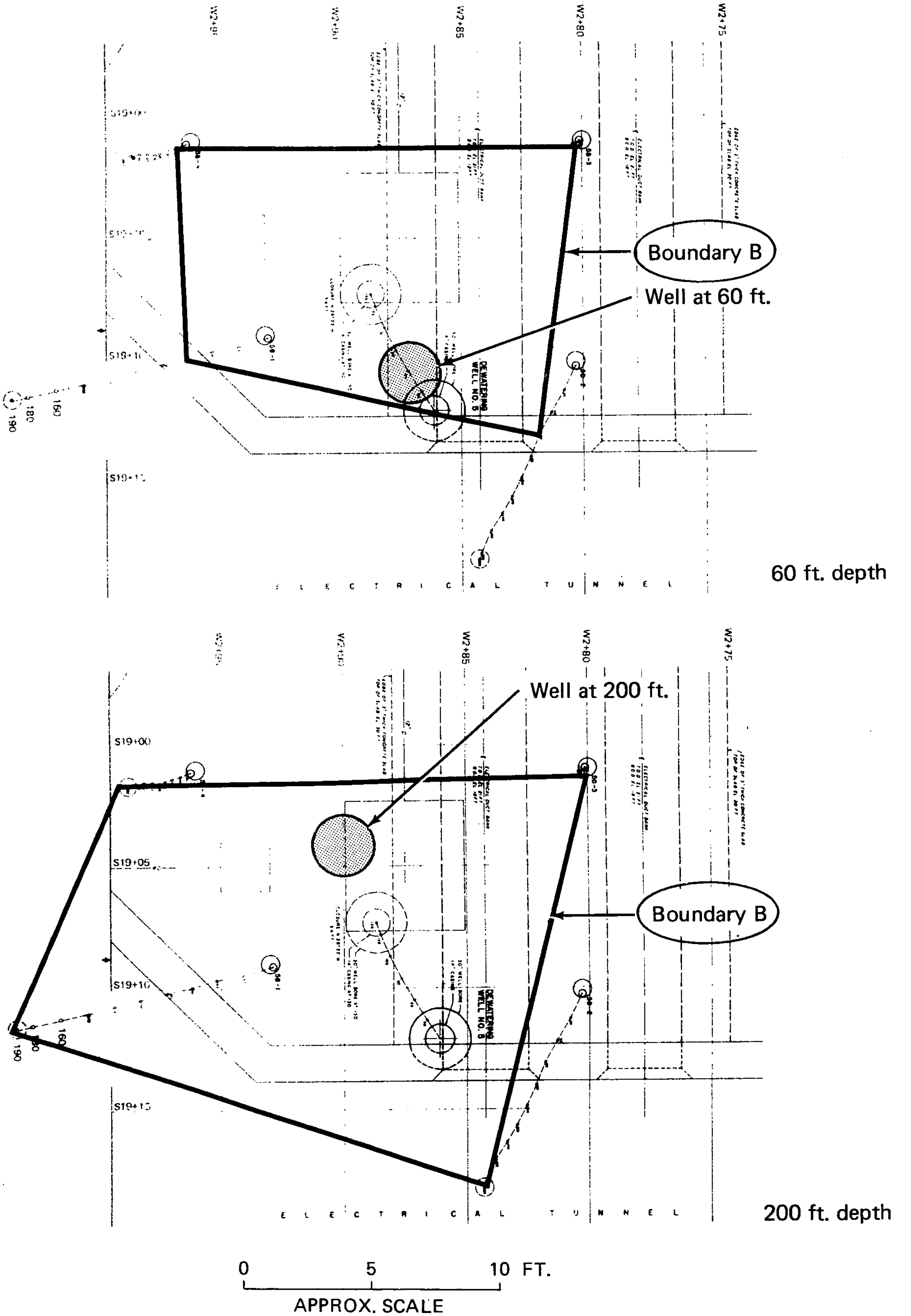

Project:	SONGS 2 & 3	DEWATERING WELL NO. 5	Fig.
Project No.	41130I	CAVITY BOUNDARY PLAN AT 60 AND 200 FT.	11

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APPENDIX A
SEISMIC PRINCIPLES FOR CAVITY DETECTION

A-1 INTRODUCTION

The use of seismic methods to detect possible cavities around the dewatering wells at SONGS has been studied by performing extensive experiments at the known cavity at Well 3. The seismic signatures have been empirically calibrated to define their characteristic shape in the presence of cavity and in the undisturbed native San Mateo sand. Those empirical calibrations are described in detail in Appendix D. Appendix A presents, in a qualitative way, certain seismic principles which could cause the seismic signals to be altered by the presence of a cavity. This is not intended to be a rigorous theoretical development. A reference list is attached to this appendix.

Seismic and other geophysical methods have been used by others to detect cavities in the past. For example, the Institut fur Geophysik der Ruhr-Universtat have done extensive model, theoretical, and field studies, and have successfully detected infilled cavities (see reference list, authors Dresen, Baule). Theoretical studies have also been done by Greenfield (1978); and combined theoretical and experimental work has been published by Cook (1965), and by Rechtien et al (1976), who detected and delineated open and infilled cavities. These published works used mostly surface refraction and/or reflection techniques, but the present work uses crosshole techniques. It is for this reason that this appendix has been prepared.

The details of the techniques and procedures used for this study are given in Appendix C. For purposes of this appendix, the procedure is as follows: carefully logged holes are drilled in an array around the well, and a casing is grouted into place in

each hole; seismic waves are generated in one of the holes (source), and the seismic signatures are sensed by geophones in the other holes (receivers); then the seismic signatures are analyzed, (by comparison to the theoretically expected wave forms and the calibration at Well 3), to determine if cavities possibly exist. The intent is only to identify the possible existence of cavities in a conservative way so that borings can be planned to thoroughly delineate the cavities if they in fact exist. Thus, this crosshole seismic method does not need to delineate or otherwise describe the cavities: it needs only to identify their possible existence in a conservative way. In this context, conservative means that the crosshole seismic method would identify all cavities and also identify features which are not cavities.

A-2 THE CAVITY/UNDISTURBED SAND SYSTEM

The cavities were formed by internal piping during the use of the dewatering wells. The mechanics of that process, as well as the evidence at cavities which has been investigated by drilling, indicate that a cavity will be full of loose sand attrited from the roof and walls, and deposited by falling gently through the contained water. This means that the infilling sand is loose, and is subjected to a confining pressure equal only to its own weight (not the formation overburden or other stresses). Thus, the infilling sand will be weak, will have low seismic velocities, and will be highly hysteretic compared to the native undisturbed sand. In other words, the infilling sand will be substantially different in properties from the native undisturbed sand. The crosshole seismic method in effect relies on those differences in properties to detect the presence of the cavity.

In addition to these property differences between cavity infill sand and native undisturbed sand, it is expected that there will also be property differences between the native sand in the vicinity of the cavity and the native undisturbed sand at some

distance away from the cavity, as Figure A-1 shows, and as will now be discussed.

The San Mateo sand is known to be highly preconsolidated, and to presently have very high residual stresses (Fugro, 1974, 1976). Thus the mean stress is very high in the undisturbed state. Near the cavity, however, because one of the principal stresses must be zero, the mean stress is expected to be smaller than in the undisturbed state, as shown in Figure A-1(a). As a consequence, the wave velocities, which are functions of the mean stress, are expected to be lower for the native sand near the cavity than for the native sand at some distance away; and for the same reason the damping is expected to be somewhat higher for the native sand near the cavity. These trends are shown in Figure A-1(b) and (c). This means that the property differences being detected (velocities, attenuation, change of signature) may extend further than the cavity boundary. Thus the crosshole seismic method may not only indicate the presence of a cavity intervening between source and receiver, but may also respond to the presence of a cavity which is near to the plane between the source and receiver.

A-3 SOURCE WAVES

Appendix C presents details of how the waves were generated; and Appendix D (especially lines Q-C and U-E) presents the details of the source signatures. For purposes of this appendix, the source is an impulse impact which creates both dilatational (P) and shear (S) waves, which have the following characterstics:

	Undisturbed Sand	Infill Sand
P-wave velocity, fps	2000-7000*	1000-6000**
S-wave velocity, fps	1000-2000*	400-600**
P-wave predominant frequency, cps	800-1000	800-1000
S-wave predominant frequency, cps	100-200	100-200
P-wave wavelength, feet	2-8	1-7
S-wave wavelength, feet	5-20	2-6

* measured (see Appendix D)

** estimated (material is too lossy to measure reliable velocities).

A-4 WAVE PROPAGATION NEAR CAVITIES

A-4.1 Propagation Through a Cavity

Figure A-2 has been prepared to illustrate a rather idealized propagation through a lower-velocity and lossy infilled cavity. The source signal is idealized as a step pulse which would propagate through the undisturbed sand, which has relatively high velocities and is relatively nonlossy. The pulse propogates with only slight attenuation from point A1 (source) to A2 at the edge of the cavity. As the wave enters the cavity, there will be complex reflections and refractions, and the waveshape will change. If the infill material is relatively lossy, however, a major change in the waveform will be due to energy losses in that material, due to energy partitioning associated with poroelasticity, as will now be discussed.

A poroelastic medium is a saturated particulate medium composed of a granular skeleton and pore water. Shear waves propagate through the skeleton of a poroelastic medium; but dilatational waves propagate through both the skeleton and the water in an interactive way, dispersing into waves of two kinds, as shown in Figure A-3. The waves of the First Kind predominate at the lower

frequencies of propagation, and the waves of the Second Kind become more important at the higher frequencies of propagation. The waves of the First Kind are dilatational waves whose velocity and damping depend on the propagation frequency and on the relative stiffness of the soil-skeleton/water system. These velocity and damping dependencies are summarized in Figure A-4. The frequency abscissa is normalized to the characteristic frequency, which is a soil property given approximately by:

$$f_c = \frac{ng}{2\pi k} \cdot R$$

where n = porosity, g = gravity, and k = permeability, and for these conditions, R is approximately unity. The velocities and damping are parametricized on θ, which is in effect a stiffness ratio between the skeleton and the pore water (the pore water is assumed to have no entrained air). The upper graph shows that the waves of the First Kind can travel very fast for high frequencies and low stiffness ratios; but the lower graph shows that, for frequencies near the characteristic frequency, the damping can be quite high, especially for low stiffness ratios.

The characteristic frequencies for the two soils involved here are: for undisturbed native sand, 2700 cps; and for loose infill, 800 cps. Comparison with the source characteristics given in Section A-3 indicates: in the undisturbed native sand, the P-wave frequencies are well below the characteristic frequency, so that damping, and therefore waveform attenuation, should be rather small; but in the loose infill sand, the P-wave frequencies are about the same as the characteristic frequency, so that damping, and therefore waveform attenuation, should be rather large.

The waves of the Second Kind at low frequencies involve actual movements and drainage of pore water. As a consequence, waves of the Second Kind evanesce rapidly, and do not, as a practical matter, propagate at all.

As a consequence of the above two poroelastic considerations (P-wave in cavity propagating at or near the infill's characteristic frequency; some of the energy partitioning to Second-Kind waves, which rapidly evanesce), it is to be expected for this case that P-wave signal damping, and therefore attenuation, will be significantly large for propagation through the cavity. An approximate quantification of the First-Kind damping effect is shown in Figure A-4: point N, for the native sand, indicates a damping of 2%, or less*; and point C, for the cavity-infill sand, indicates a damping of 5% or more*. Because of this increased damping upon propagation of waves with these frequency characteristics through sands of these material properties, severe attenuation of P-wave amplitude would be diagnostic of these waves propagating through these cavities.

The S-wave propogates as only one kind of wave, and is thus altered only by attenuation and boundary effects. Point D on Figure A-5 shows the damping effect, at a value lower than the P-wave. Thus, the S-wave of the type generated here will propagate through the loose infill sand at a lower damping; and, becuase it is at a lower frequency and longer wavelength than the P-wave, it will undergo fewer attenuative cycles than the P-wave.

Based on these considerations, one would expect the following behavior for these waves propagating through a cavity with these infill sands:

1. The P-wave should be significantly attenuated;

* For ease of calculation, values of θ were taken from Ishihara (1970) for tests on sands of nearly equal conditions to the native and infill sands. The Ishihara dense sand, however, was not as dense as the native sand; and the Ishihara loose sand was not as loose as the infill sand. The effect is that point N should be lower and point C should be higher.

2. The S-wave should be less attenuated than the P-wave.

Statements 1 and 2 above are of course relative, and apply heuristically to a cavity/source-receiver geometry as in Figure A-2. If the cavity were very large with respect to source-receiver distance, (for example 1/2 to 2/3 the travel path distance) the attenuation of the shear wave could become appreciable, and Statement 2 might be modified to: 2a, The S-wave could also be significantly attenuated.

The discussion above applies only to cavities which are filled with sand. If a cavity contained water only, then the P-wave could propagate very efficiently through that cavity; but the S-wave would not propagate through. Thus, Statements 1 and 2 must be modified for the case of a water-filled cavity as follows:

1b. The P-wave should be only slightly attenuated.

2b. The S-wave should disappear upon transmission through (but not necessarily upon transmission around, see Section A-4.2 below) the cavity.

A-4.2 Propagation Around a Cavity

For these sands, with the properties given in Section A-2, simple travel-time calculations indicate that the wave traveling through the cavity will, if it is not destroyed by the high damping, arrive somewhat later than the wave which travels around the cavity as shown idealized in Figure A-6. Thus, the early part of the recorded seismic signature could be from a wave which traveled around the cavity. Such a wave would also be attenuated due to diffracting around the cavity.

The diffraction-attenuation effect is expected to be pronounced. Figure A-7 has been prepared to illustrate this point.

Considering two possible propagation paths C and D, at distances c and d from the straight-through path, it can be seen that the wave velocities and the dampings are different. Thus, the waves would arrive at the receiver at different times and with different amounts of attenuation. The superposing effect of these waves at the receiver would be an attenuated and smoothened replica of the original wave.

The diffraction-attenuation effect will hold for both P- and S-waves; but the effect is expected to be less for the S-waves because of their longer wavelengths in the native sands.

For these reasons, Statements 1 and 2 would, for the case of a wave traveling around a cavity in heavily prestressed sand, be as follows:

1c. The P-wave should be significantly attenuated;

2c. The S-wave should be less attenuated than the P-wave.

A-5 OTHER EFFECTS

There are certain practical aspects of the crosshole seismic surveys which must be inspected for their effects on the seismic signatures being used to define the possible existence of cavities. Details of the procedures are given in Appendix C. This discussion will identify the important practical aspects, and will define their effects on the end result.

Because this seismic method is intended only to indicate where drilling should be done to verify and delineate a possible cavity, it is only necessary that these other possible effects be conservative. To be conservative, it must be demonstrated that the effect will not conceal the existence of a cavity if a cavity is present. One possible case, that of a water-filled cavity, has already been considered in Section A-4.1 above, with the

conclusion that, even though the P-wave might not show distinct effects from having passed through a water-filled cavity, the possible existence of the cavity would be detected from the disappearance of the S-wave. Other cases will now be considered.

A-5.1 Air Entrainment

During the operation of the wells, it is possible that air could have been entrained in the sands above the drawdown cone. This would have an effect on the P-wave: the velocity would be less in this zone than in the undisturbed sand, and sometimes would be less than the dilatation velocity in pure (deaired) water; and the signal shape may be attenuated, even if cavity is not present, because of an accentuation of the poroelastic-damping effects discussed in Section A-4.1. It is demonstrated in Appendix D that such effects have been observed, so it must be assumed that the native sands have air entrained in them in the drawdown zone. Inspection of the velocity-depth data (Appendix D) indicates that: (1) the depth to which the P-wave velocities appear to have been affected by air entrainment (and other processes of similar effect) is about 40 to 60 feet; and (2) the S-wave velocity appears to be less affected.

These effects (a slowing and attenuation of the P-wave, and probably no effect on the S-wave) are consistent with Statements 1 and 2 for a through-traveling wave, and with Statements 1b and 2b for an around-traveling wave. Thus the effect of air entrainment is conservative for purposes of detecting cavities, because it could indicate cavity where cavity does not exist, but has no features which would mask the detection of an existing cavity.

The effects of air entrainment could be unconservative, however, if they are not properly considered when the method is being calibrated at a known cavity. The calibration was done for this project at Well 3 (Appendix D), where the cavity was delineated

(by borings) to extend to about 60 or 70 feet below the present surface (experience with these wells shows that the floors of the cavities are funnel-shaped, centered on the well, so that an exact value for the depth to bottom is not possible). Thus a large part of the calibration cavity lies in the upper zone (to depths of 40 to 60 feet) thought to have been affected by air entrainment or other similar processes. For this reason, the records were carefully inspected, comparing the seismic signatures across known cavity to the seismic signatures across known native sand. Those comparisons showed that, although the signatures across known native sand showed a reproducible velocity decrease and attenuation in the upper zone, those signatures were easily recognizable as being different from the signatures across known cavity (Appendix D). Thus for this case and the conditions prevailing, the possible air entrainment did not affect the calibration.

A-5.2 Casing Coupling

The grouting of the casing in the holes is an important process, affecting the degree and the location of the coupling of the source signal into the ground, and the location of the recieved signal. If the grouting were poorly done, allowing some ungrouted sections, the result would be a poorly coupled source signal, delivered into the ground at some elevation other than the source's, or received in the receiver casing at some elevation other than the geophone's. The P-wave portion of the source signal would be expected to couple into the ground efficiently through the surrounding water, so the effects on the initial part of the received P-wave signal should be small, particularly in terms of arrival time. The S-wave portion of the source signal, however, would not be expected to couple through the water, but would have to follow a longer travel path along the ungrouted part of the casing at the source and/or receiver. Thus the anticipated effects of poor coupling are:

1d. The P-wave signal should be about the same as for the well coupled case.

2d. The S-wave should arrive later and might be attenuated compared to the well coupled case.

3. Reciprocal experiments, reversing the source and receiver, might not yield the same results due to small changes in instrument location.

All of these statements would yield results which are conservative for the cavity-detection case; but they could be unconservative for the calibration case. For this reason, the grouting of the holes for the calibration was done with great care: the volumes of grout were monitored and compared to the calculated annular volume to be as discussed in Appendix G after the grout had been placed to fill the annulus, grout pumping was continued in controlled overflow to allow opportunity for possible voids in the grout to fill; and nonshrink grout was used. The records of the calibration experiments were analyzed to see if the effects of Statements 1d, 2d and 3 could be recognized. The effects of Statement 3 were detected in some cases, in that a few reciprocal experiments did not reproduce; but the effects of Statements 1d and 2d were not apparent. The effect of possible nonreciprocity were considered in establishing cavity-detection criteria in the calibration (Appendix D).

A-5.3 Timing Errors

Timing errors could result from signal-trace initiation from the crystal triggers (Appendix C), and from the techniques used to pick off arrival times from the signal traces. The effects of these errors have been minimized by designing the triggers to have timing lags in the microsecond range. Futhermore, interpretative errors were minimized by having all timing picks made by the same geophysicist.

The cavity criteria which evolved from the calibration procedure (Appendix D) do not use arrival times or seismic velocities, so timing errors are not important to this work.

A-5.4 Equipment Calibration

The key items of equipment are the hammer source, the geophone receivers, and the signal-conditioning and recording gear. None of these were specifically calibrated for this work.

The hammer source was manually operated (Appendix C), and was used to produce several blows for each recording (the recorder stored and added the signals from a number of blows). The recorded results were monitored to make sure that the manual operation was not resulting in increased source input for the cavity-detection case, or in decreased source input for the calibration case.

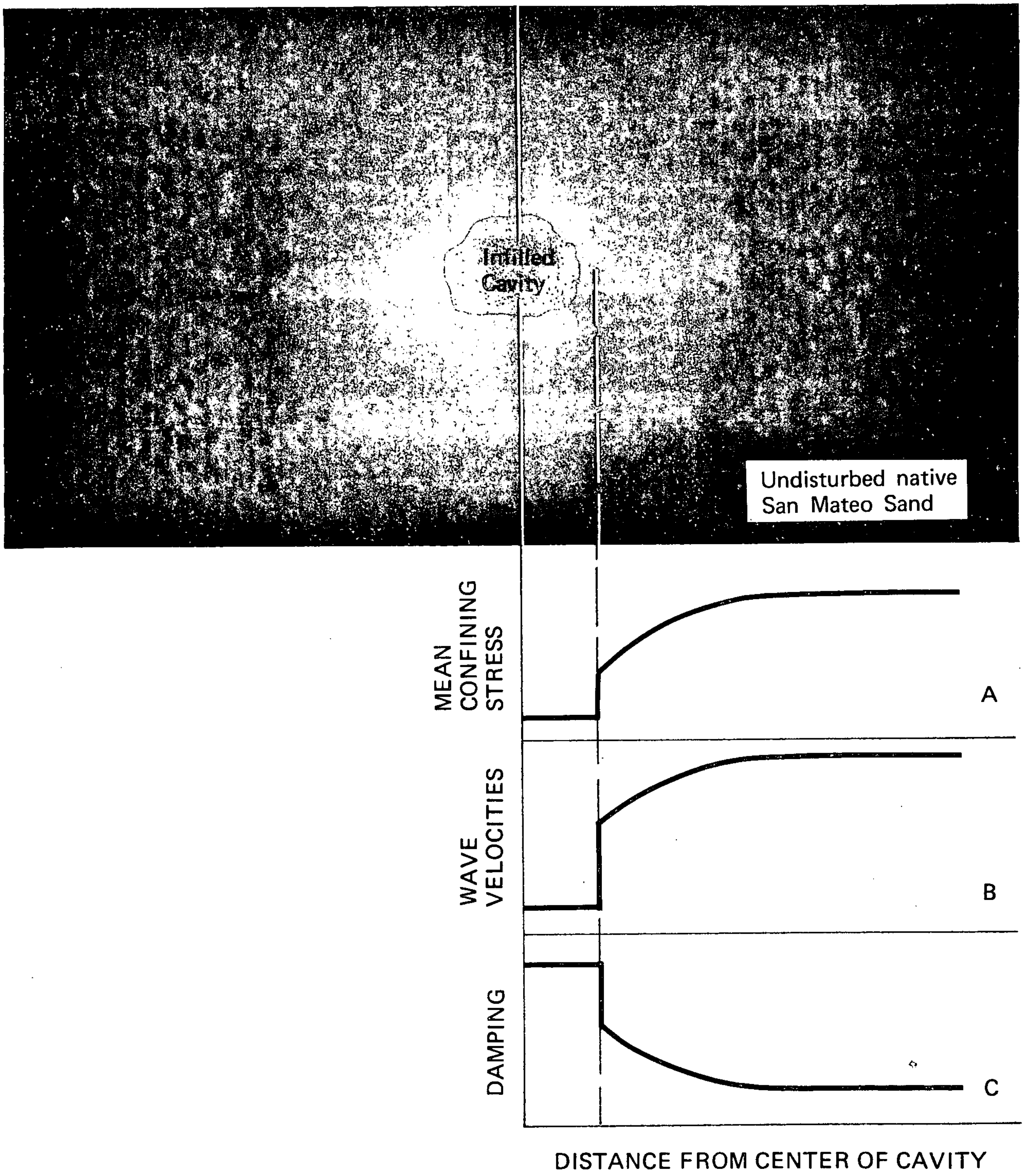
The geophone receivers were all of the same model and same manufacturer. Their sensitivities were periodically checked by placing them in the same receiver hole. Those sensitivities did not vary by more than a few percent, except for one geophone which was consistently down 10 to 20% below the other geophones.

The signal-conditioning and recording gear were one unit. Gains on all channels were the same in each set of measurements. The analyses of amplitude data were done by normalizing the amplitude of each recording for a given receiver hole to the maximum amplitude recorded in that hole for each data set, Appendices C and D.

A-5.5 Distance Effects

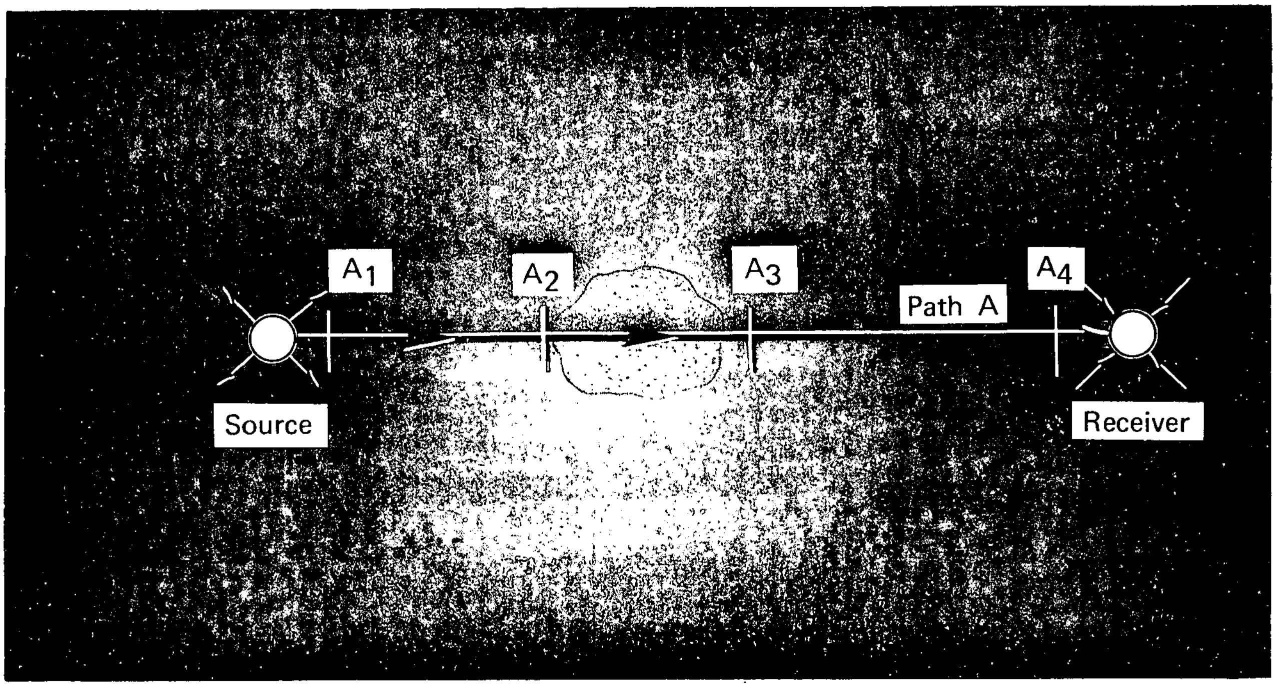
Because the distances between source and receivers are short in this work, it is important that they be known accurately. For this reason, the trajectory of each hole was measured with an inclinometer, and the source-receiver distances were calculated for each elevation where experiments were performed.

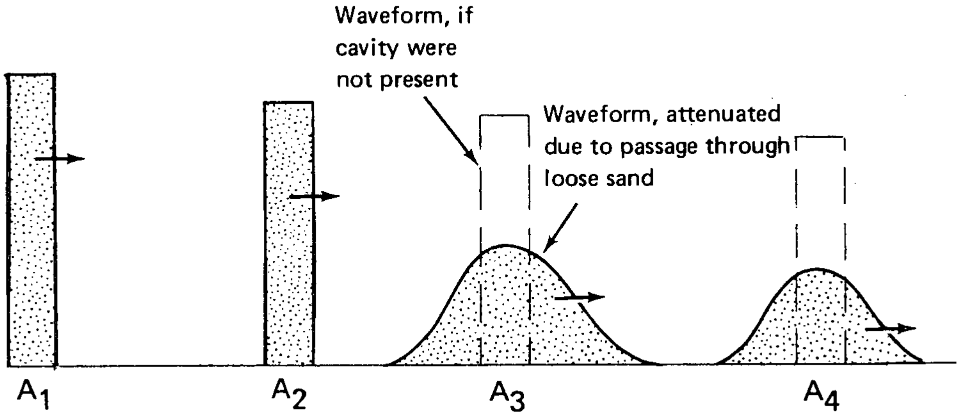
Even though the source-receiver distances were accurately known, their magnitude varied; thus it was necessary to inspect the calibration-experiment data (Well 3, Appendix D) to ascertain if the attenuating effects of distance could have been mistaken for the attenuating effects of cavity, thus invalidating the calibration criteria. It was found that the differences between the signal quality for cavity and noncavity were much more profound than the differences between signal of long and short propagation distances (Appendix D, especially legs Q-V cf. Q-E, U-T cf. U-C and U-Q). Thus for these conditions, the effects of varying distances did not affect the criteria for cavity calibration. The effects of varying distances in the cavity-detection process are all conservative for the crosshole distances actually used.



Project: **SONGS 2 & 3** Project No. **41130I**	**CAVITY–SANDSTONE SYSTEM SHOWING PROBABLE VARIATIONS IN PROPERTIES**	Fig. **A-1**

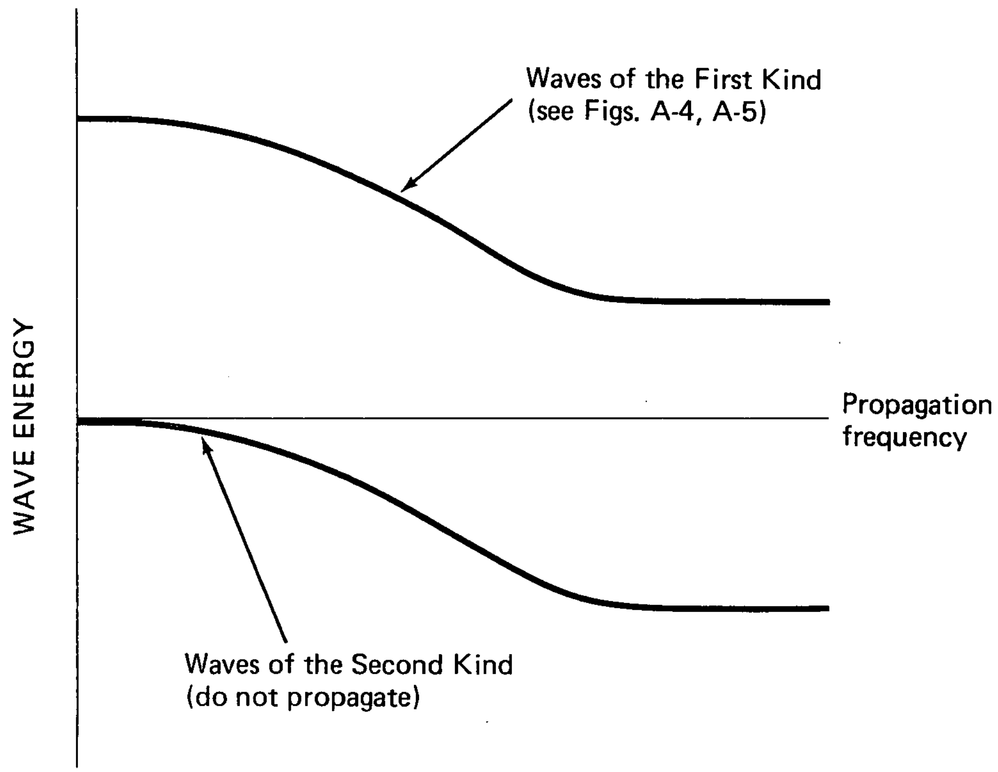
WOODWARD–CLYDE CONSULTANTS



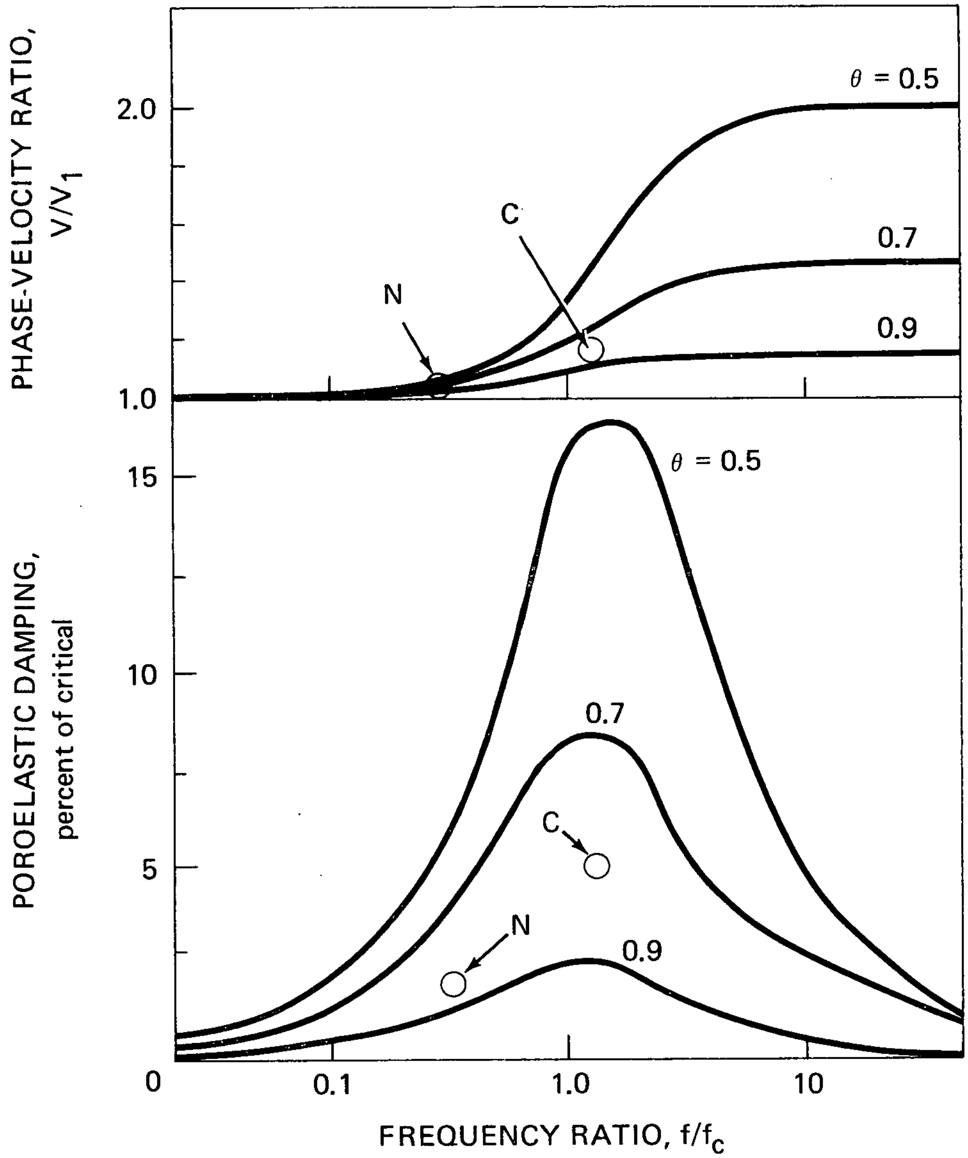


Project: **SONGS 2 & 3** Project No. **41130I**	**WAVE PROPAGATION THROUGH CAVITY FILLED WITH LOOSE SAND**	Fig. **A-2**

WOODWARD – CLYDE CONSULTANTS



Project: **SONGS 2 & 3** Project No. **41130I**	**PARTITIONING OF WAVES DUE TO POROELASTIC EFFECTS**	Fig. A-3



V = Velocity of propagating wave.

V_1 = Phase velocity for undrained conditions: low propagation frequency, or high characteristic frequency.

V_n = Phase velocity for drained conditions: high propagation frequency, or low characteristic frequency.

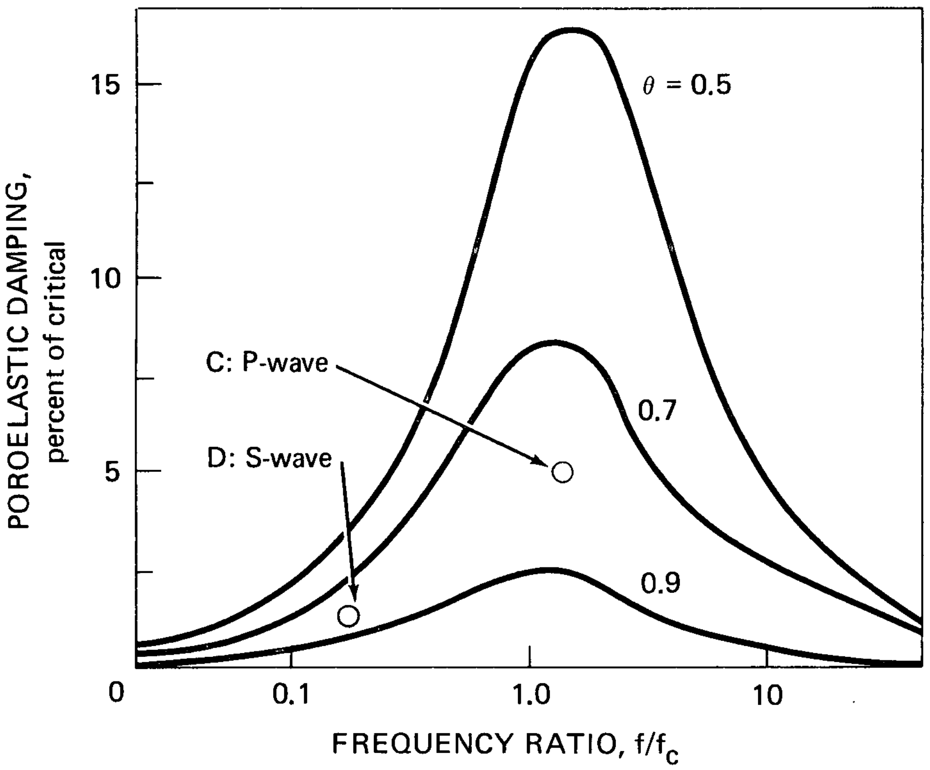
$\theta = \left(\frac{V_1}{V_n}\right)^2$, stiffness ratio.

f_c = Characteristic frequency for the material condition, see text.

(After Ishihara, 1970)

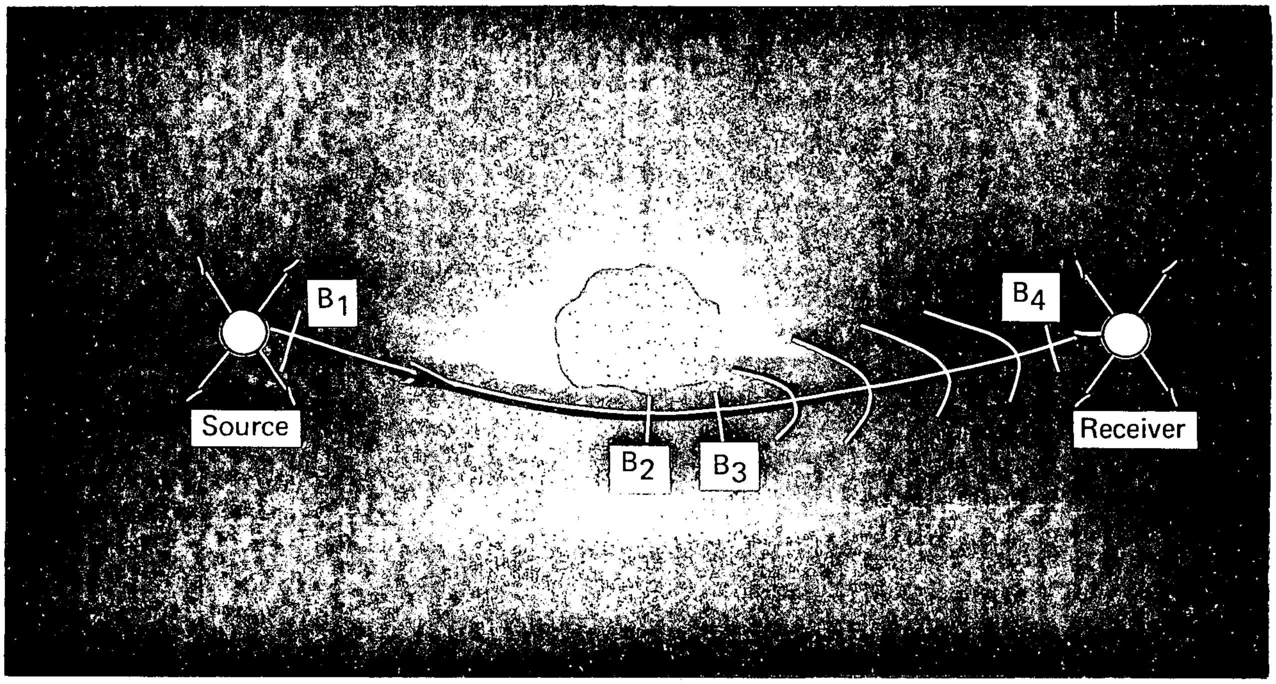
Project: **SONGS 2 & 3** Project No. **41130I**	**POROELASTIC VELOCITY AND DAMPINGS FOR WAVES OF THE FIRST KIND**	Fig. A-4

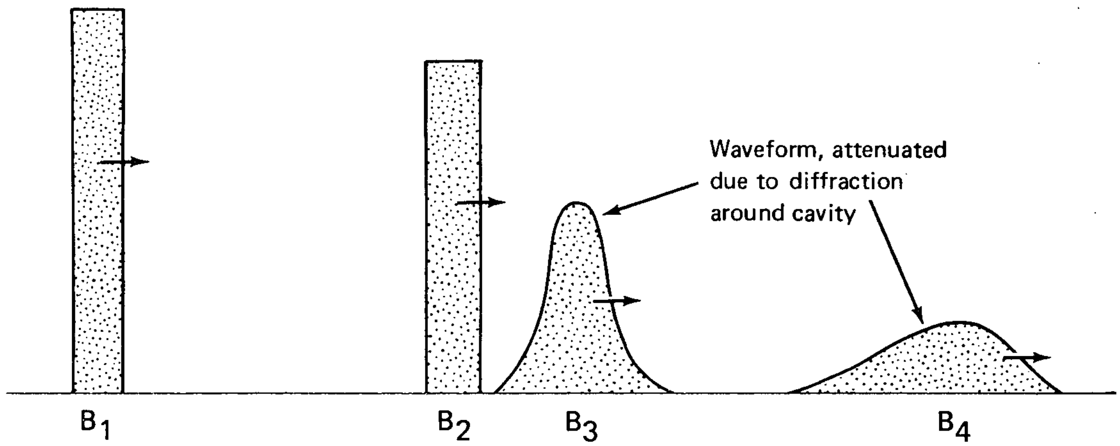
WOODWARD—CLYDE CONSULTANTS



Project: **SONGS 2 & 3** Project No. **411301**	**COMPARISON OF POROELASTIC DAMPING FOR P- AND S-WAVES FOR LOOSE INFILL SAND**	Fig. A-5

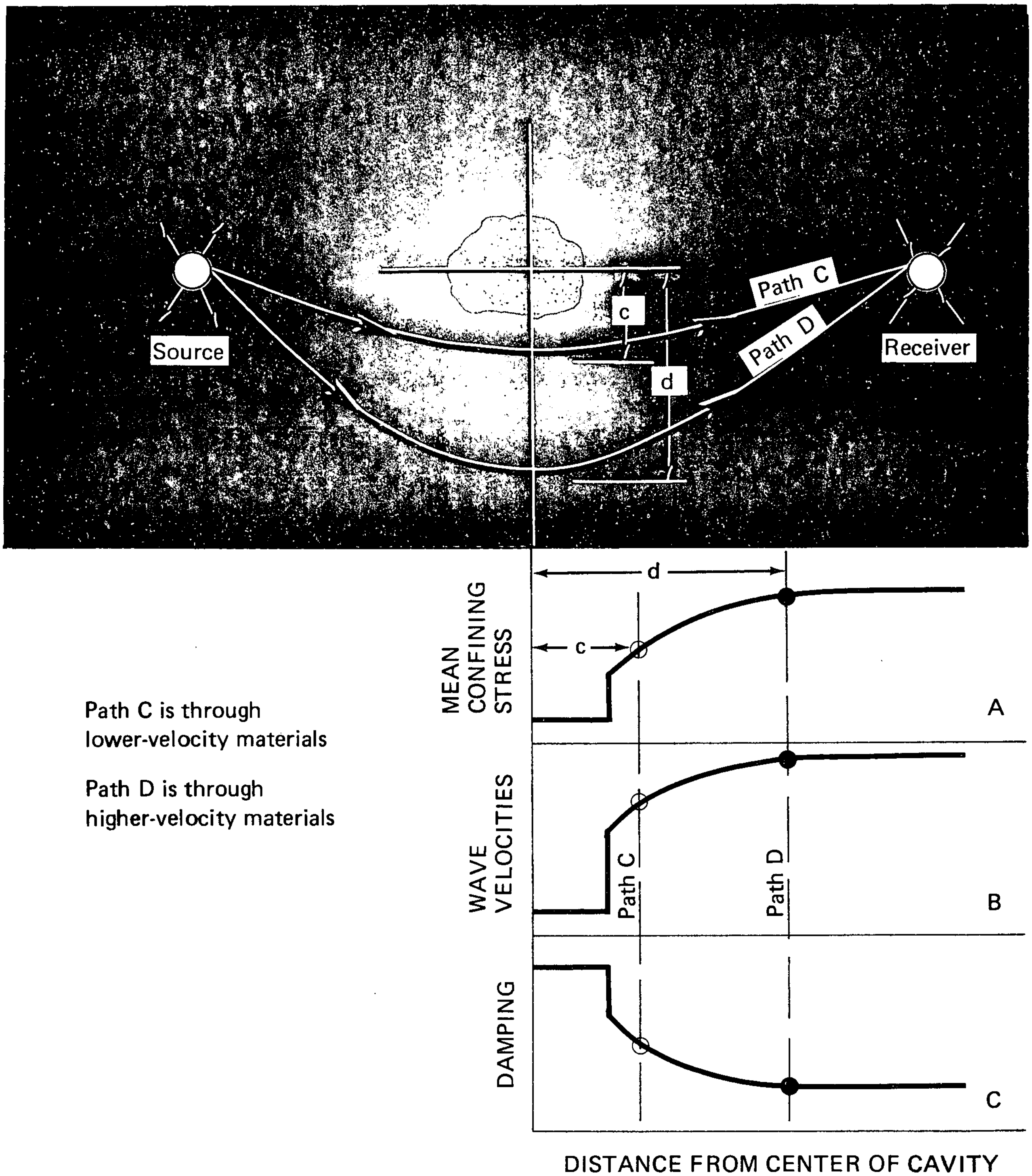
WOODWARD – CLYDE CONSULTANTS





Project: **SONGS 2 & 3** Project No. **41130I**	**WAVE PROPAGATION AROUND CAVITY**	Fig. **A-6**

WOODWARD—CLYDE CONSULTANTS



Path C is through lower-velocity materials

Path D is through higher-velocity materials

Project: **SONGS 2 & 3** Project No. **41130I**	**EFFECTS OF MEAN–STRESS VALUE**	Fig. **A-7**

WOODWARD – CLYDE CONSULTANTS

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APPENDIX B
BACKGROUND INFORMATION AND DEEP DRILLING AND GROUTING EXPLORATION FOR WELLS 3, 4 AND 5

B-1 WELL 3

Well 3 was drilled in July 1974 and operated from August 1974 until January 1977. An airlift operation was commenced on 28 March 1978 to remove the gravel pack from the annulus around the well casing at Well 3 to allow removal of the well casing and the filling of the wellbore with concrete. This operation revealed evidence of a shallow cavity. Mechanical caliper and sonar investigations indicated that the cavity was both shallow and of limited lateral extent.

A total of 31 borings were drilled at Well 3 as located on Figure B-1. These borings were investigation holes drilled to identify the boundaries of the filled cavity and locate any areas of open cavity. Of these, six were prepared for crosshole seismic investigation; four of these six extended to the full depth of the wellbore (approximately 200 feet). Graphic logs of each borehole are presented on Figure B-2.

An SPT-sampler or a 2-inch diameter disc attached to the end of the drill rod was driven by a 140-lb hammer falling 30 inches. Such penetration tests were performed at 5-foot intervals. If loose soil was encountered, the disk was driven continuously until refusal (defined as 50 blows/3 inches). The relative ease of penetration was used to distinguish between loose cavity fill materials and the native San Mateo formation.

The cavity delineated by the drilling program extends in a northwesterly-southeasterly direction. It is approximately 15

feet by 6 feet in plan dimension between depths of 30 to 60 feet as indicated on Figure B-3. The cavity was full of loose sand during airlift cleaning. The cavity was partially cleaned using an airlift to a maximum depth of 54 feet, and was later backfilled with loose sand to be used as a calibration case for the crosshole technique.

To date, no grouting has been done at Well 3, except to backfill around the PVC casing in those borings used in the crosshole seismic survey.

B-2 WELL 4

Well 4 was drilled in June 1974 and operated in October 1974 and then from April 1975 to June 1976. After pumping had been terminated at Well 4, it was demobilized for construction schedule purposes by cutting off the top of the 14-inch diameter casing, backfilling it with sand, and welding on a steel cap. The well was subsequently reopened and the sand backfill removed by airlifting. The excavation made to reopen the well extended to Elev. -8 feet as located on Figure B-4. A small area under the electrical and piping gallery and an area at the north end of the excavation caved locally due to groundwater inflow. A 42-inch diameter piece of CMP casing was placed around the well casing and extended to the ground surface to allow access to the well. The excavation was then backfilled to Elev. +5 feet by 70 cubic yards of lean concrete and between Elev. +5 feet and ground surface with compacted soil fill. Air lift and wire brush cleaning and TV logging of the inside of the casing did not reveal any observable deterioration of the well casing. As a follow up to this information, exploration drilling was undertaken specifically to locate and delineate possible cavities.

Eight exploration borings as located on Figure B-5 were drilled and sampled, and PVC casing was grouted in place to facilitate

crosshole seismic measurements; six of these holes were drilled to the full depth of the well. SPT samples were taken at 10-foot intervals. Graphic logs of each boring are presented on Figure B-6 (detailed logs of these borings are presented in Appendix G). As these logs indicate, there was no evidence of cavities; however, small zones of disturbed material and lean concrete were encountered in the boreholes within 40 feet of the ground surface. These materials resulted from the reopening operation as described above.

No grouting has been done at Well 4 except in backfill around the PVC casing in the eight borings prepared for the crosshole seismic survey.

B-3 WELL 5

Well 5 was drilled on 24 June 1974 and was operated from April 1975 to May 1976. After pumping had been terminated the well was idle until about December 1976 when it was demobilized by cutting off the top of the 14-inch diameter casing, backfilling with sand, and welding on a steel cap.

A shallow drilling program (holes 20 to 57 feet deep) was begun to check for the presence of near-surface cavities. Shallow cavities were of particular concern because the area around the well had been excavated to Elev. +6 feet for construction access. During the drilling of the shallow investigation holes, the ground surface immediately surrounding the well began to cave. Subsequently, a total of 19 shallow holes were drilled as located on Figure B-7. Of these borings all encountered native soil throughout the depths investigated except Boring 5-F which was interpreted to have drifted toward the well into the cavity. Because no SPT samples were taken during this program, the distinction between cavity fill and native material was made by checking the static penetration of the drill stem while it supported the full weight of the drilling rig. Subsequently a

2-inch diameter disc connected to A-rod was driven into the annular space between the well casing and the well bore using a 140-lb hammer falling 30 inches. The continuous driving record from this operation showed 1 to 2 blows per foot to a depth of about 24 feet at which point a driving resistance of 50 blows for 6-inches of penetration was encountered and the operation was terminated. It was interpreted that the annular space contained sand infill to a depth of 24 feet (about Elev. -18 feet) with gravel pack below this depth.

To facilitate the delineation of the local cavity suggested by the cavity adjacent to the well bore during drilling and the later exploration of the deeper portions of the well, a 30-inch diameter steel casing was vibrated into place around the well to Elev. -30 feet. During this operation a depression of the ground surface up to about 1 foot deep developed around the well. This depression was eliptical in plan shape with its long axis in an east-west direction with a maximum plan dimension of 8 to 10 feet. Locally toward Boring 5-F it extended as far as 8 feet from the center of the well bore.

A shallow pressure grouting program was set up to stabilize the cavity area around Well 5 with the following specific objectives: (1) define the extent of the cavity from grout pipe driving records; (2) seal the upper zone around the casing to minimize or eliminate fall-in from this area during cleaning of the well below Elev. -30 feet; (3) fill all open cavity areas in the vicinity of the well above Elev. -30 feet; and (4) grout loose materials in the vicinity of the well above Elev. -30 feet. Grout pipes were driven or jetted into place at 32 locations around Well 5 as shown on Figure B-8. A summary of grout pipe depths and driving conditions is presented in Table B-1. Based on the observed depression caused by driving the 30-inch diameter casing, the initial boring data and the grout pipe installation

data, the configuration of the cavity at Well 5 was interpreted as shown on Figure B-9.

All grout pipes located on Figure B-8 were pressure grouted with cement grout. Grout volumes injected into each hole are summarized in Table B-2. These small volumes of grout take confirm the small size of the cavity. Subsequent to these operations, a 4-foot diameter section of CMP was placed around the well casing and extended to the level of the present ground surface. The excavation was then backfilled to the present ground surface with compacted soil fill.

The well was subsequently reopened 27 May 1978 and airlifting was attempted to remove the sand within the casing. The casing was cleaned to about 150 feet (sand was removed to about 119 feet and sand and gravel from 119 to 150 feet) when further progress was made difficult by gravel flowing into the casing from the well annulus. Based on monitoring of the material in the annulus between the 30-inch casing and the 14-inch well casing, it was found that as gravel flowed into the casing below the 115-foot depth, the surface of the material dropped from a depth of 25 feet to a depth of about 29 feet. The volume of gravel removed from the casing in the 119 to 150-foot interval (assuming a 50% sand and gravel mixture in the 14-inch casing) is about equal to the volume of material displaced in the annulus between the 14- and 30-inch casings at the 25- to 29-foot interval. Also the volume of material removed during airlift cleaning is within 5% (less than 1/10 of a cubic yard difference) of that calculated for the depth intervals of material removed from the casing and the annulus. Subsequent TV monitoring of the casing indicated small holes at depths of 115, 125 and 126 feet, with gravel inflow presumeably through holes below a depth of 115 feet. These observations indicate that the gravel pack was likely entering the casing at a depth below 115 feet with no apparent

arching of the gravel in the annulus between the wellbore and the well casing between depths of 25 and 115 feet. A summary of this operation is presented graphically on Figure B-10.

In addition to the shallow exploration drilling, four closely spaced holes were drilled to the full depth of the well to investigate the area around the well below the depth of pressure grouting, and to facilitate crosshole seismic measurements. These borings were sampled at 10-foot intervals using the SPT. No evidence of cavity was found. PVC casing was grouted into place in each hole.

A plot plan showing the locations of the four deep drill holes is presented in Figure B-11. Figure B-12 contains the graphic logs for each borehole (detailed logs of these boreholes are presented in Appendix G).

TABLE B-1

SUMMARY OF CONDITIONS AT GROUT PIPE LOCATIONS
WELL NO. 5

Grout Pipe Location No.	Length of Grout Pipe (ft)	Conditions
A	32	The pipes were driven adjacent to the well bore with little resistance between 0 and 15 to 20 feet and increasing resistance to driving beyond that point.
B	32	
C	32	
D	32	
E	25	
F	25	
G	25	
H	25	
1	25	*B
2	25	*B
3	22	Pipe set in exploration hole 5-G
4	16	*B
5	25	*A
6	15	*B
7	15	Pipe set in exploration hole 5-F
8	25	Pipe set in exploration hole 5-I
9	15	Pipe set in exploration hole 5-K
10	22	Pipe set in exploration hole 5-J
11	25	Pipe set in exploration hole 5-D
12	15	Pipe set in exploration hole 5-B
13	15	Pipe set in exploration hole 5-C
14	24	Pipe set in exploration hole 5-E
15	15	*B
16	15	Pipe set in exploration hole 5-H
17	15	Pipe set in exploration hole 5-A
18	15	Pipe set in exploration hole 5-L
19	35	*B
20	25	*B
21	23	*B
22	25	*B
23	25	*B
26	35	*B

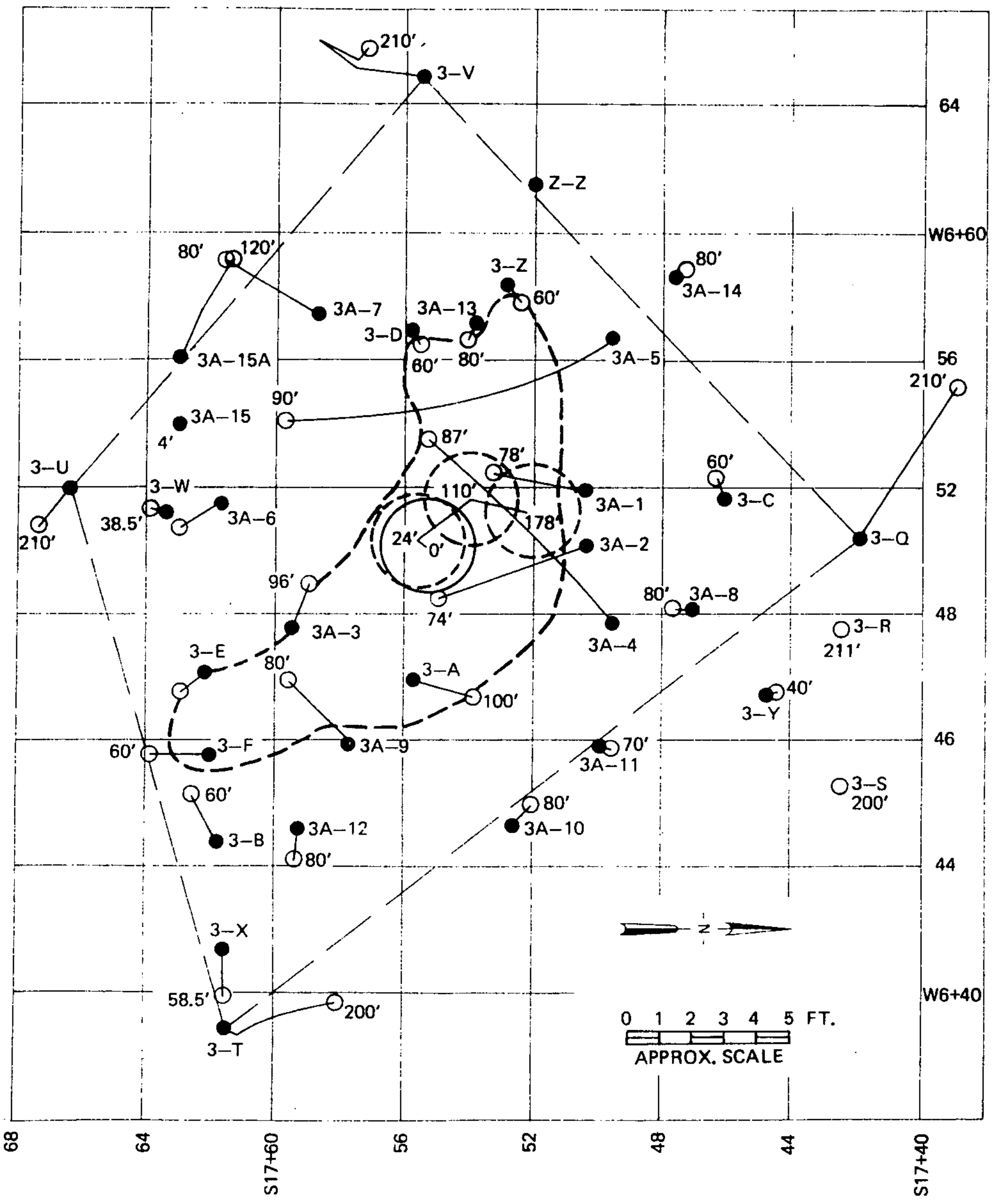
* The procedure for installation of the grout pipe was completed by: (A) pre-drilling and jetting or; (B) pre-drilling and driving with a jack hammer. Pre-drilling was completed with an air drill.

TABLE B-2

SUMMARY OF GROUT INJECTED AT WELL 5

Grout Pipe Location No.	Volume of Grout Injected (cubic feet)
A	2.0
B	1.0
C	1.7
D	1.5
E	1.1
F	0.4
G	0.5
H	0.4
1	0.9
2	0.6
3	0.6
4	0.3
5	2.0
6	0.6
7	0.7
8	0.8
9	0.6
10	0.6
11	1.3
12	0.4
13	0.4
14	0.3
15	0.3
16	0.5
17	0.4
18	0.4
19	--
20	0.2
21	1.1
22	--
23	0.4
26	--
Total of 32 holes — TOTAL	22.00

Note: Grout pipe Nos. 19, 22 and 26 were placed but not grouted to expedite later grouting during air lift cleaning operations. This was not necessary and the grout pipes were abandoned.



Project:	SONGS 2 & 3	DEWATERING WELL NO. 3	Fig.
Project No.	411301	LOCATION OF DRILL HOLES	B-1

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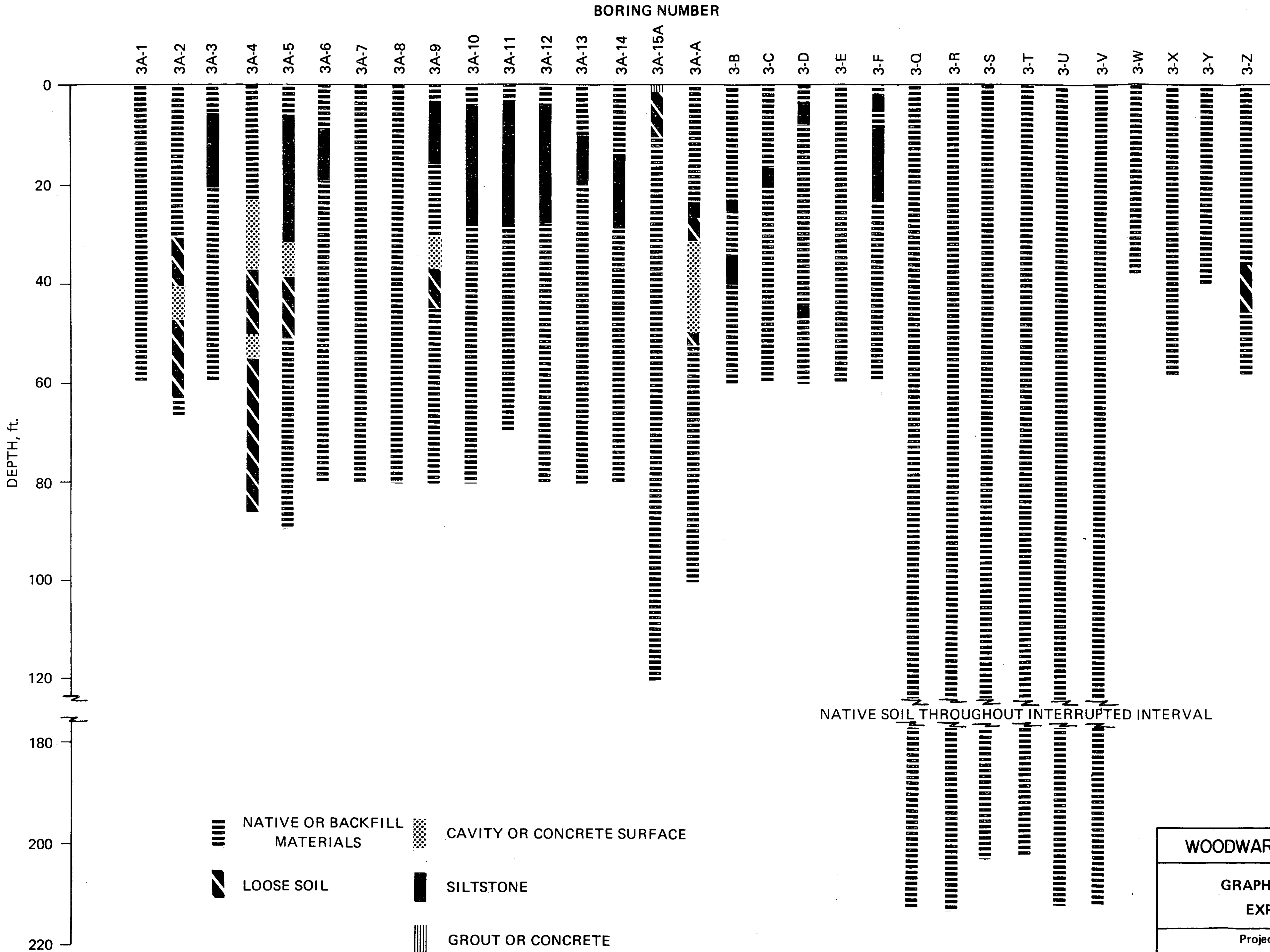

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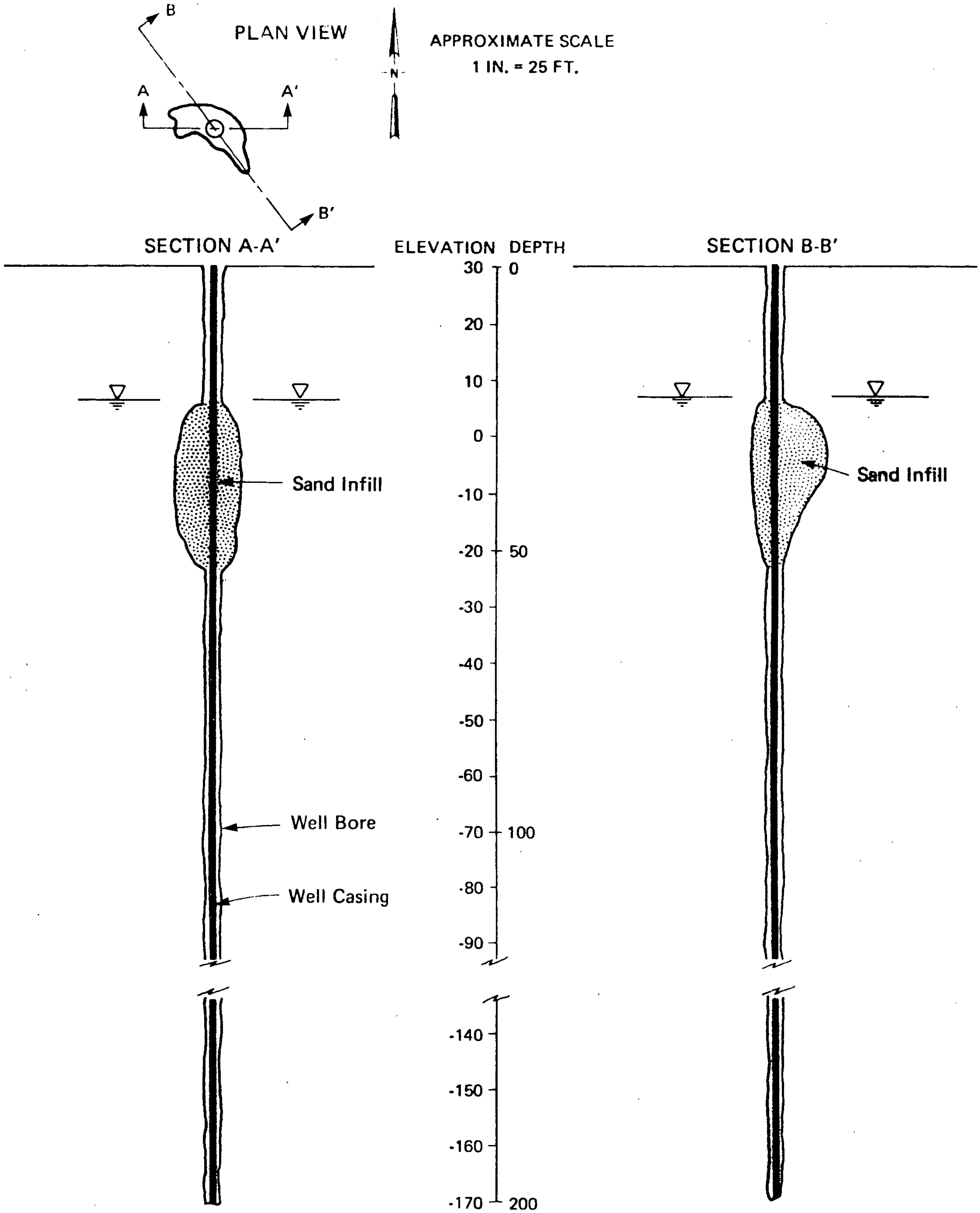
GRAPHIC LOGS OF WELL NO. 3
EXPLORATION BORINGS

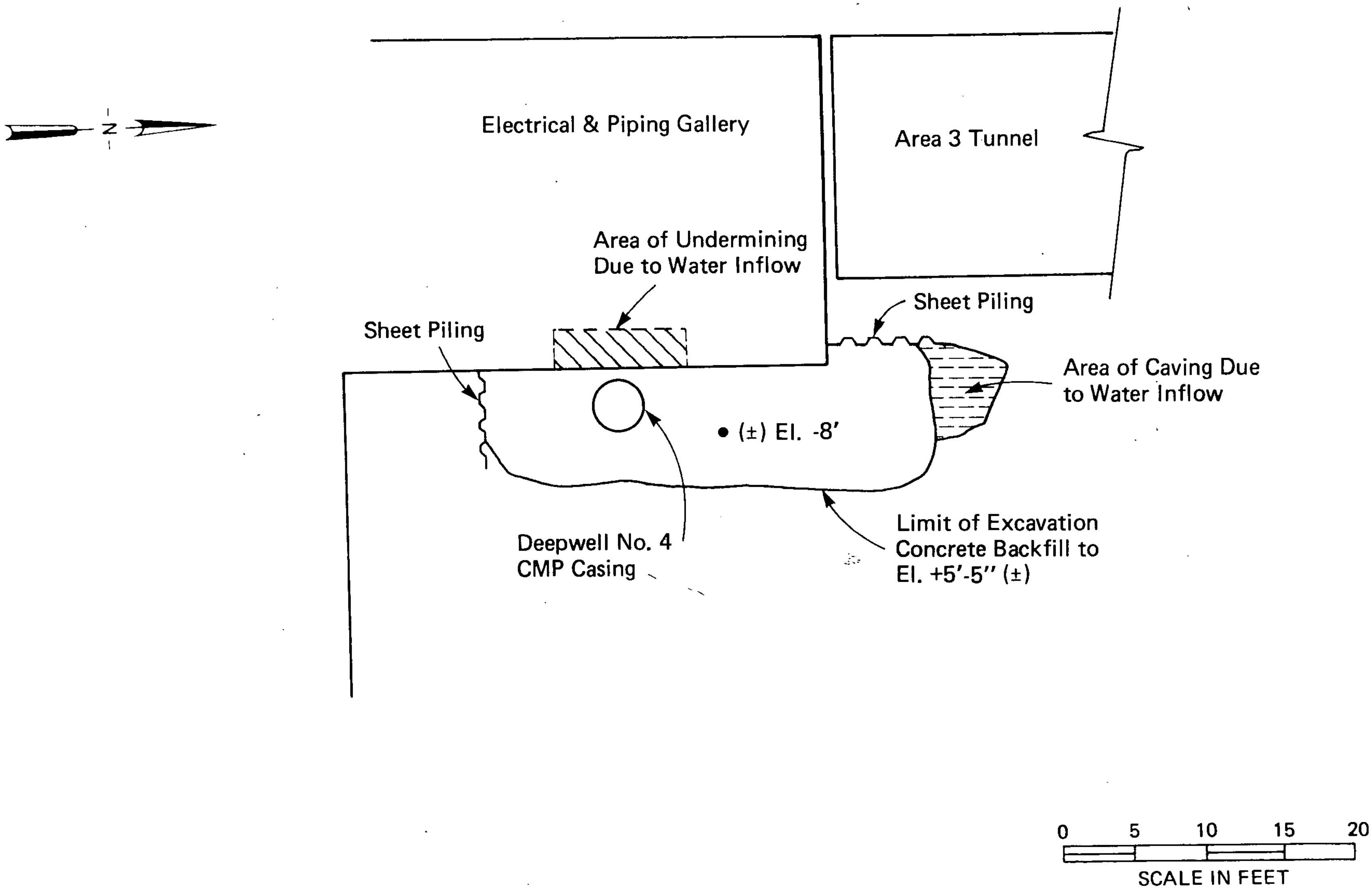
Project No. 411301
SONGS 2 & 3

Fig. B-2



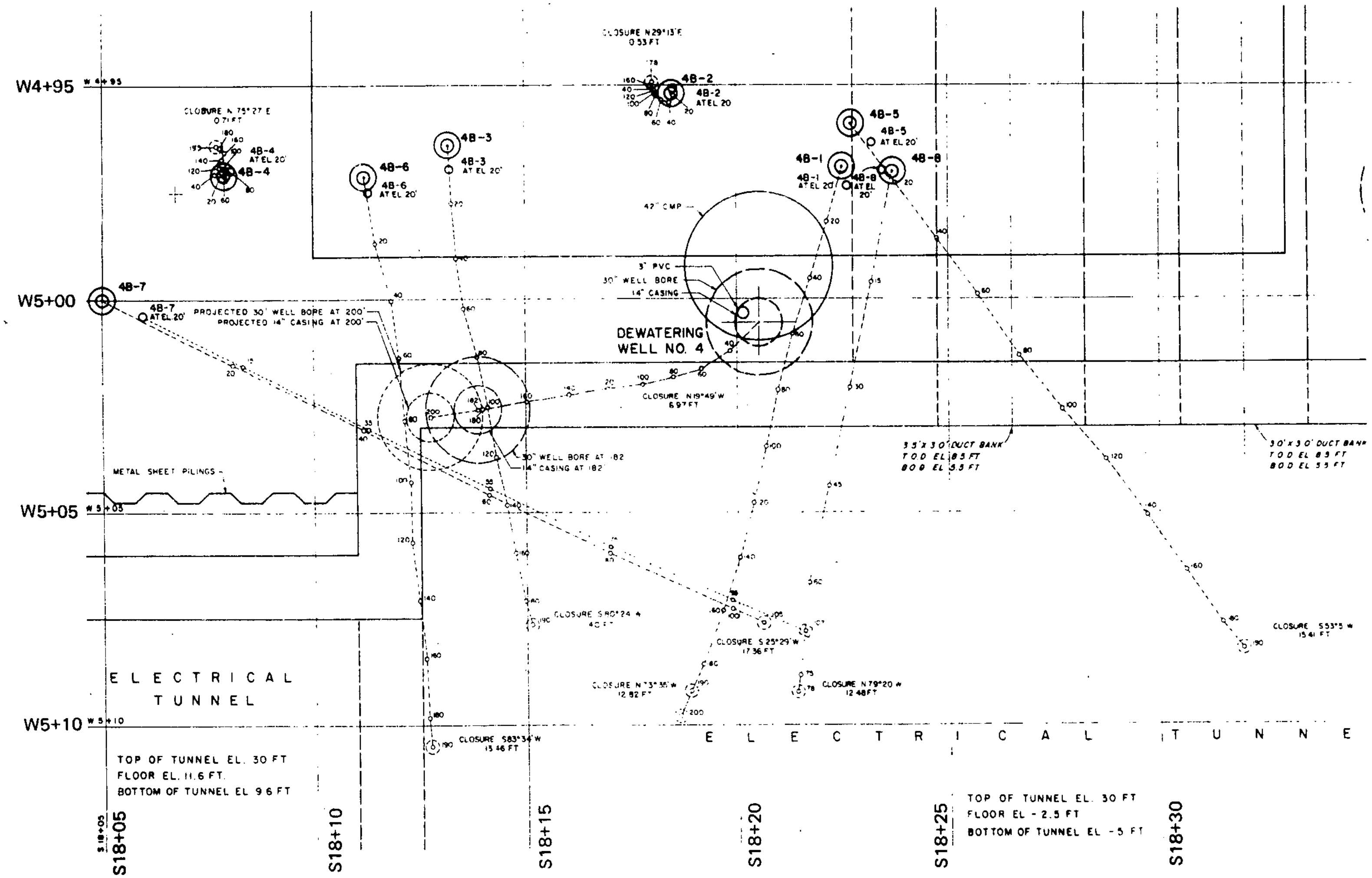
Project:	SONGS 2 & 3	PLAN AND SECTION VIEWS OF WELL NO. 3	Fig. B-3
Project No.	411301		

WOODWARD – CLYDE CONSULTANTS



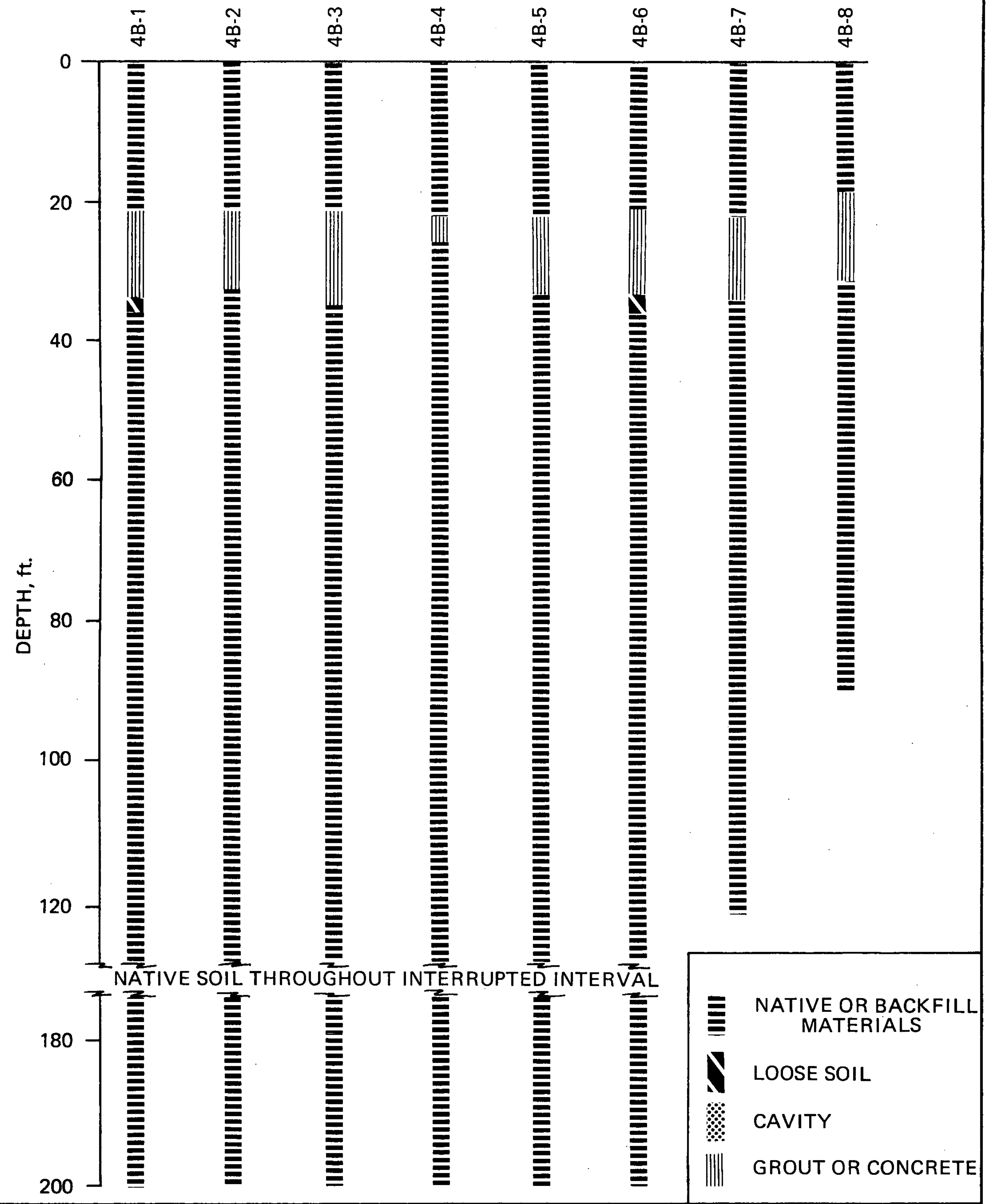
Project:	SONGS 2 & 3	PLAN OF EXCAVATION MADE TO REOPEN WELL NO. 4	Fig.
Project No.	411301		B-4

WOODWARD-CLYDE CONSULTANTS



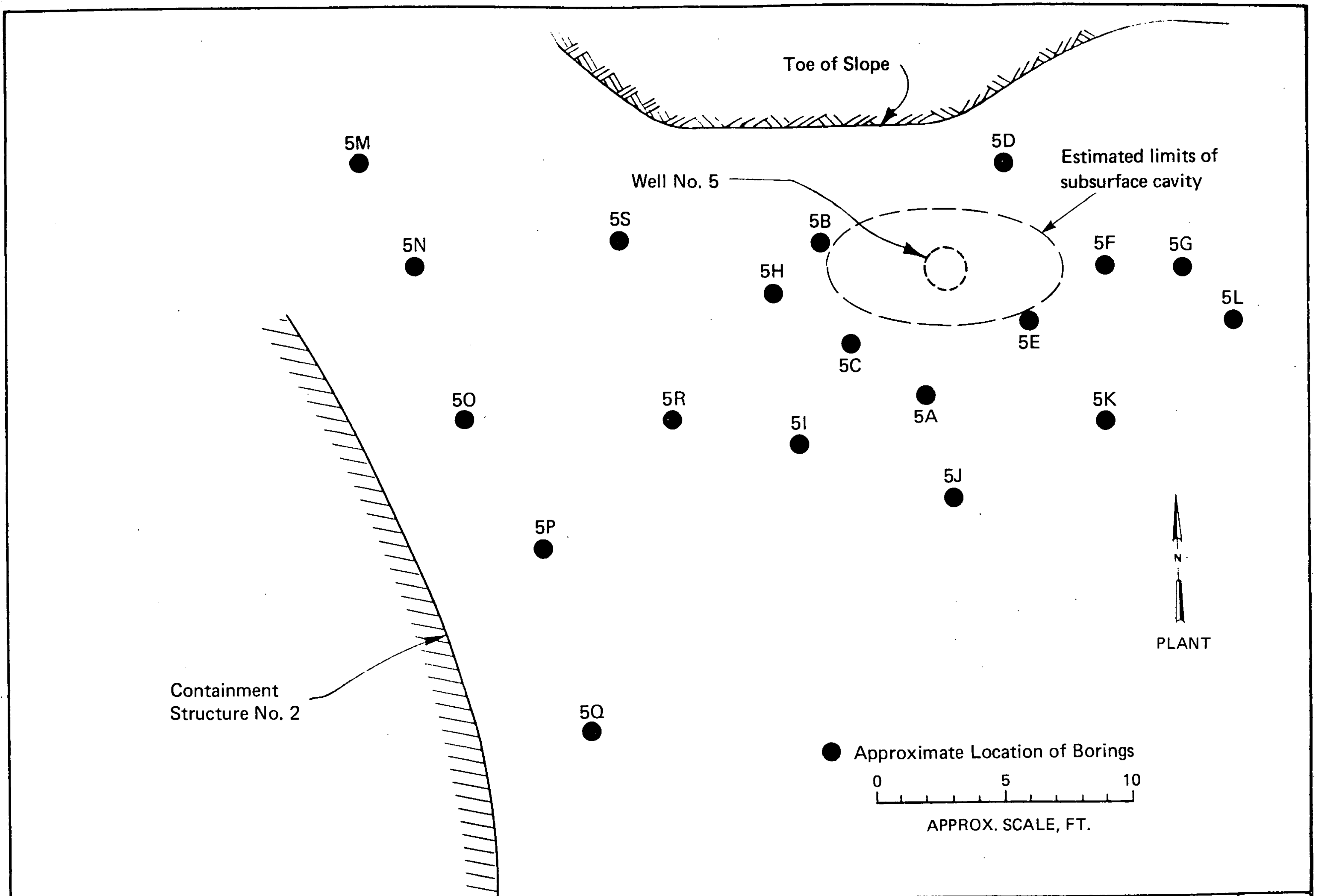
Project:	SONGS 2 & 3	DEWATERING WELL NO. 4 LOCATION OF DRILL HOLES	Fig.
Project No.	411301		B-5

WOODWARD-CLYDE CONSULTANTS



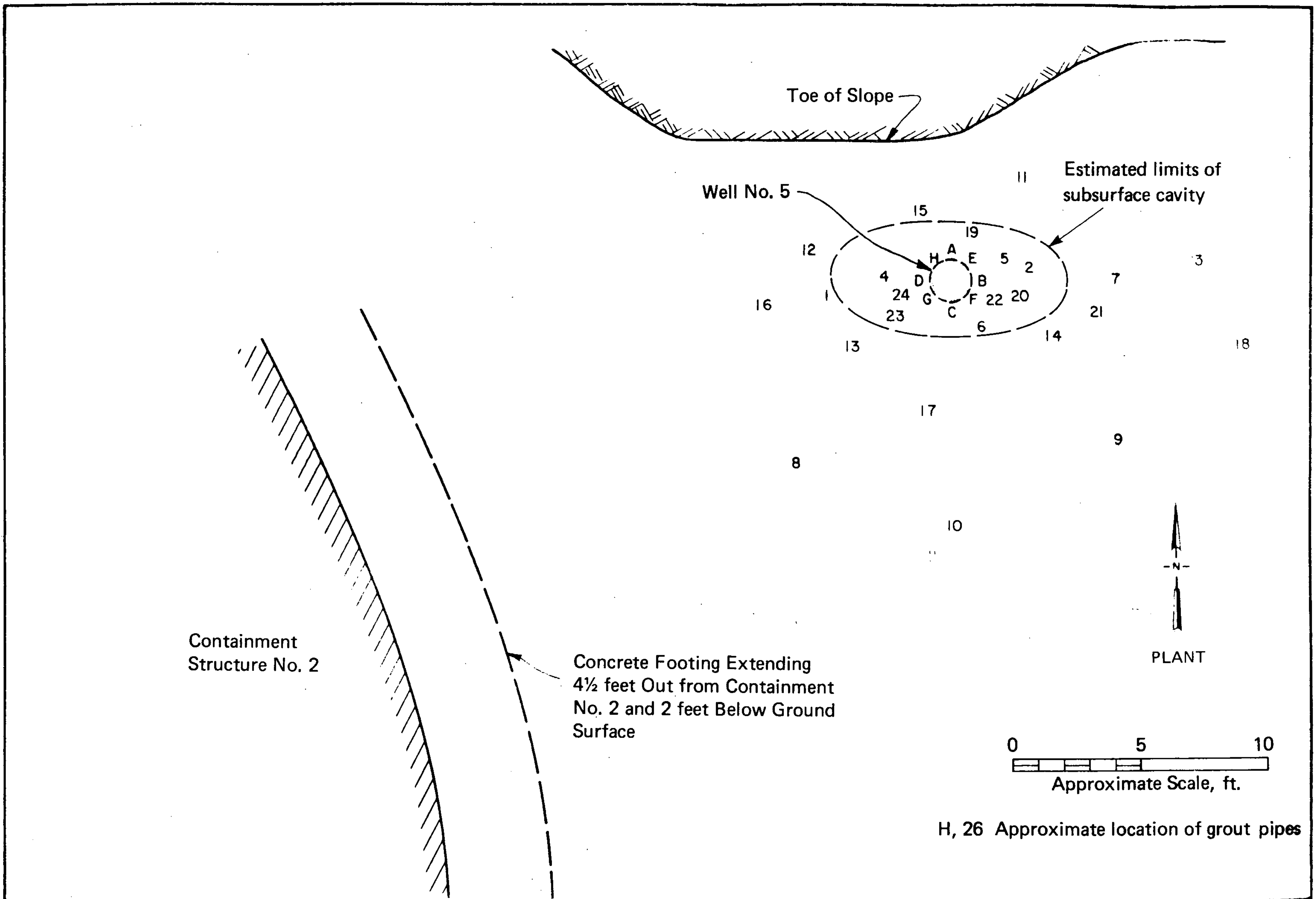
Project:	SONGS 2 & 3	GRAPHIC LOGS OF WELL NO. 4 EXPLORATION BORINGS	Fig. B-6
Project No.	41130I		

WOODWARD—CLYDE CONSULTANTS



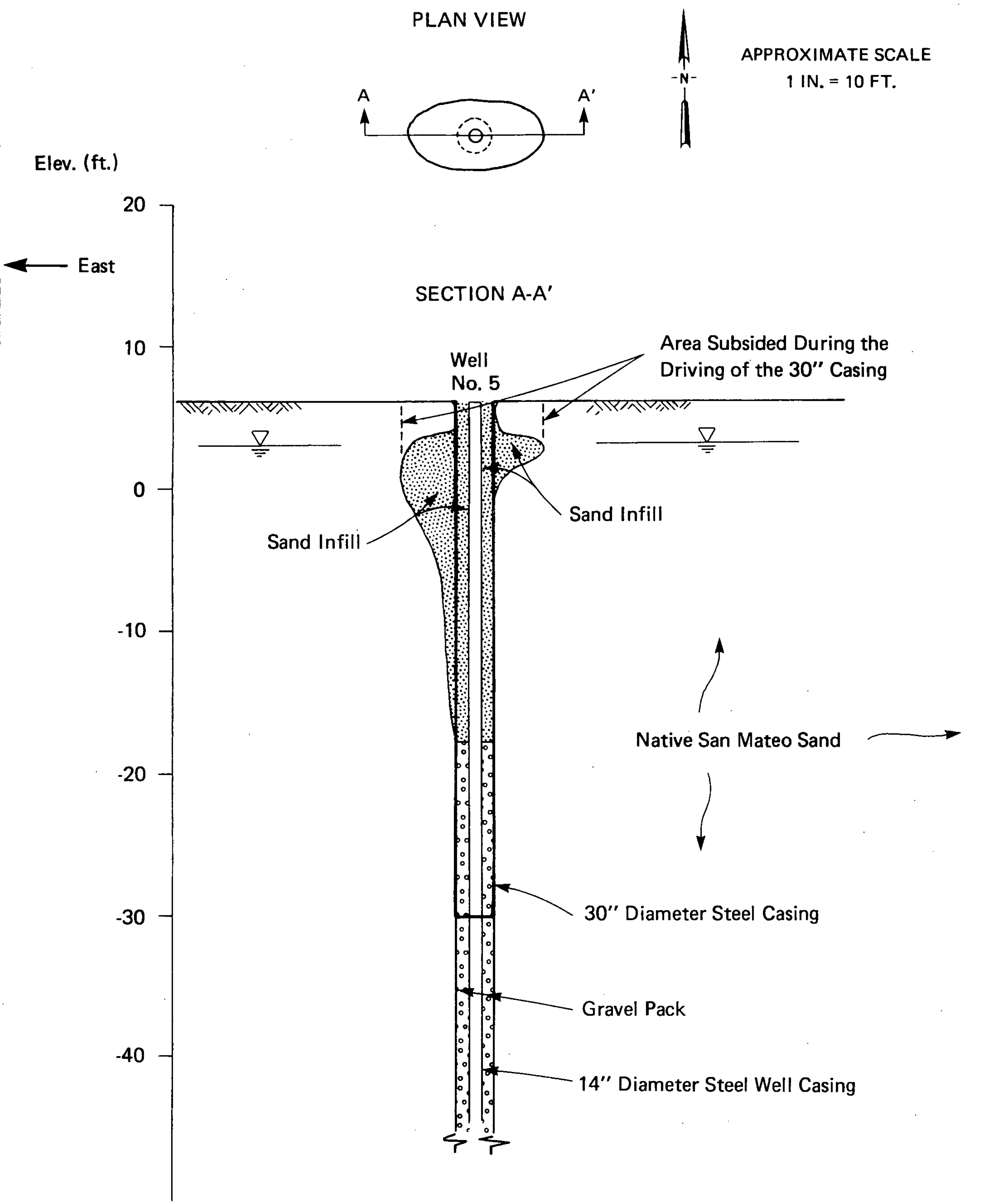
Project: SONGS 2 & 3 Project No. 411301		PLAN VIEW OF CAVITY AND EXPLORATION BORINGS AT WELL NO. 5	Fig. B-7

WOODWARD-CLYDE CONSULTANTS



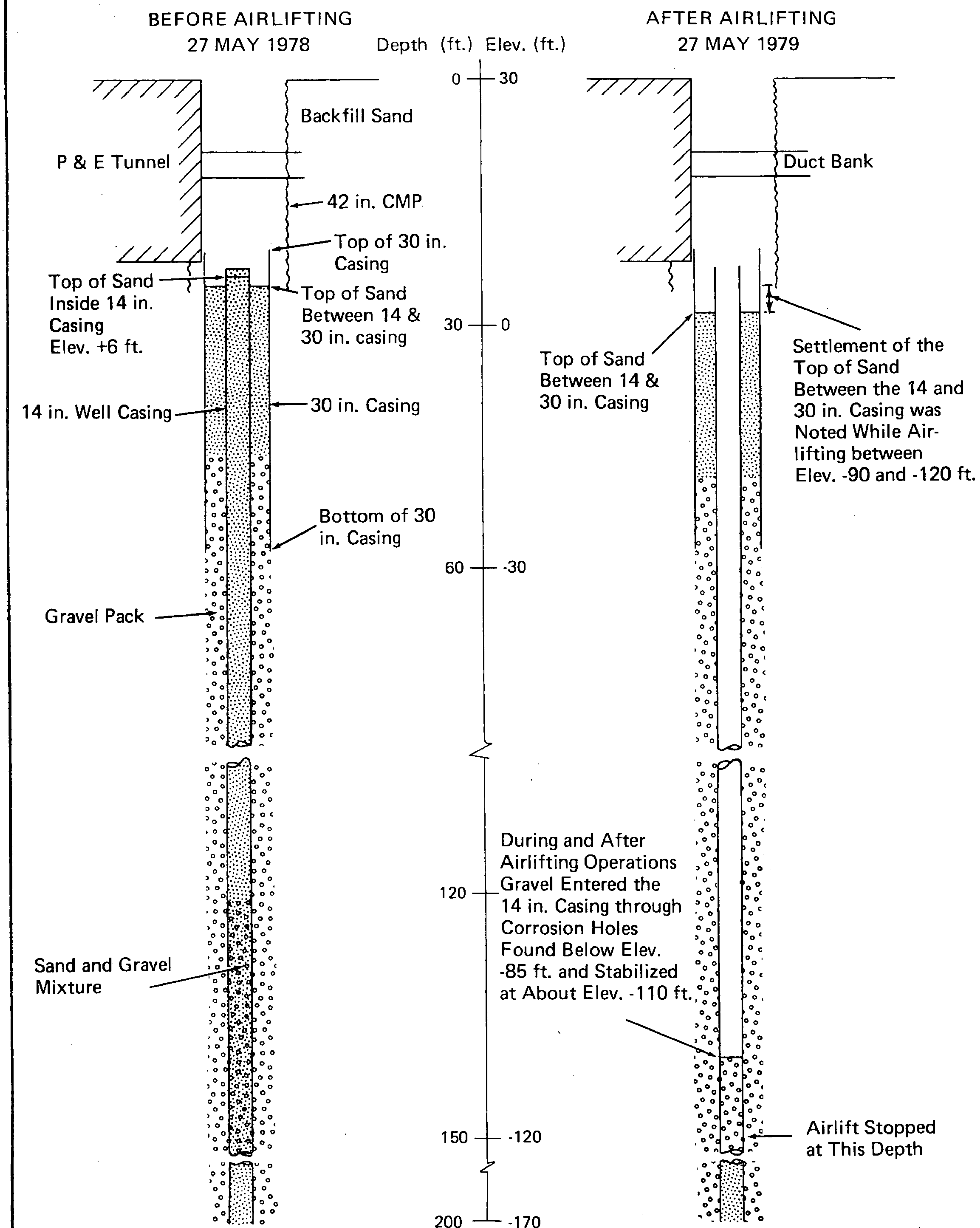
Project:	SONGS 2 & 3	SKETCH OF APPROXIMATE LOCATION OF GROUT INJECTION POINTS FOR THE WELL NO. 5 GROUTING OPERATION	Fig.
Project No.	411301		B-8

WOODWARD-CLYDE CONSULTANTS



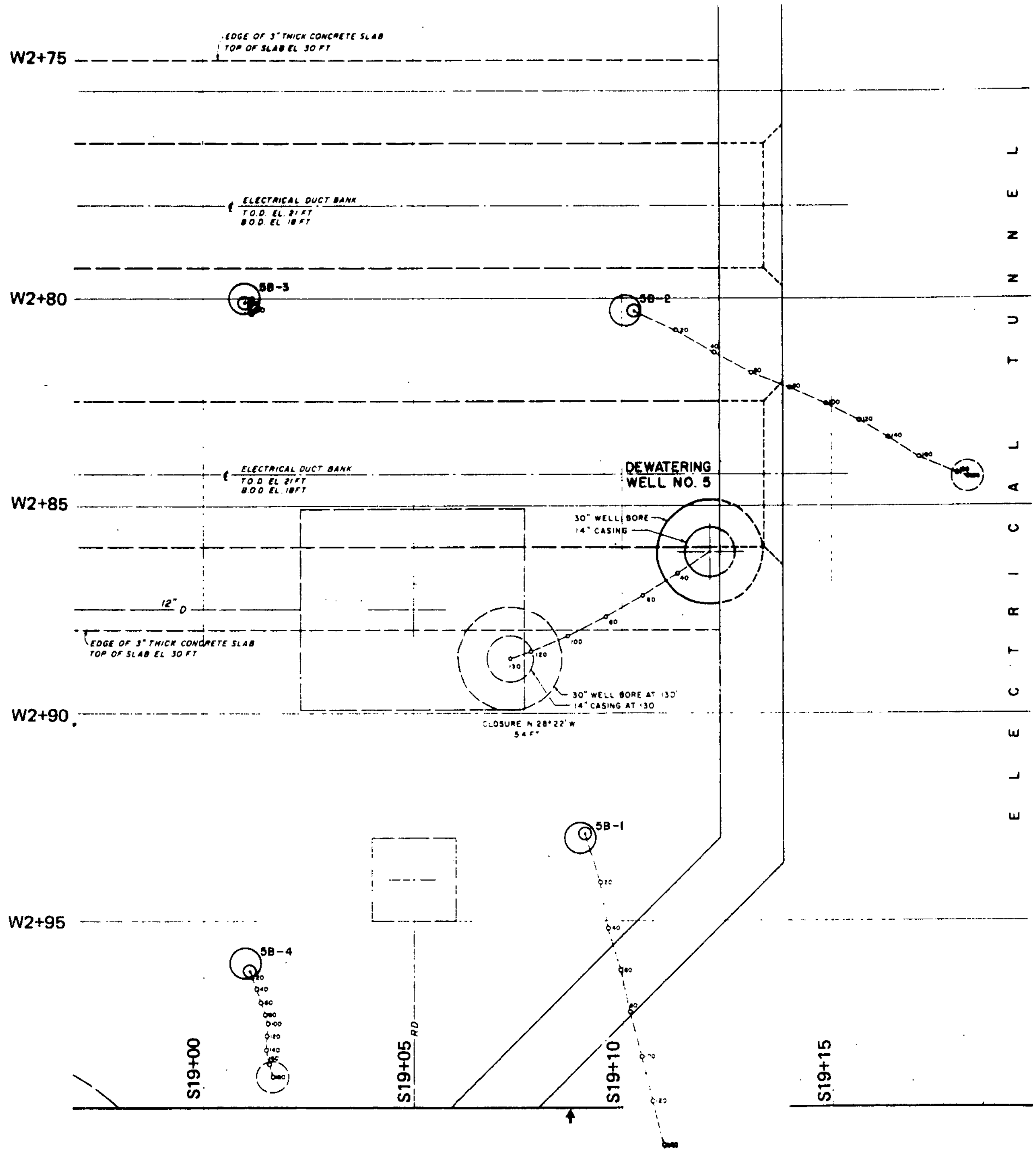
Project:	SONGS 2 & 3	PLAN AND EAST-WEST CROSS SECTION THROUGH CAVITY AT WELL NO. 5	Fig.
Project No.	411301		B-9

WOODWARD–CLYDE CONSULTANTS



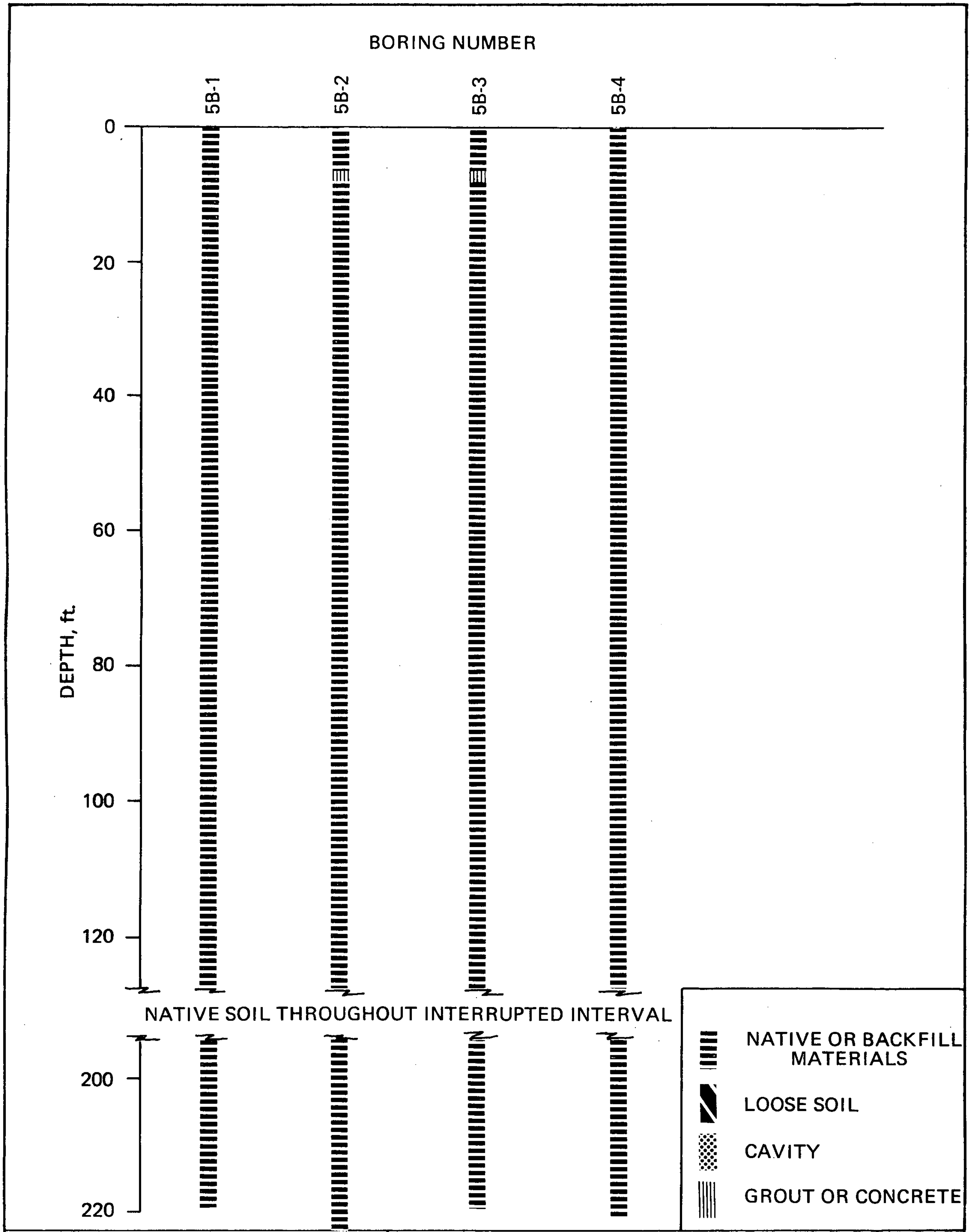
Project: SONGS 2 & 3	SUMMARY OF AIRLIFT OPERATIONS	Fig.
Project No. 411301	DEWATERING WELL NO. 5	B-10

WOODWARD–CLYDE CONSULTANTS



Project:	SONGS 2 & 3	DEWATERING WELL NO. 5	Fig.
Project No.	411301	LOCATION OF DRILL HOLES	B-11

WOODWARD – CLYDE CONSULTANTS



Project:	SONGS 2 & 3	GRAPHIC LOGS OF WELL NO. 5 EXPLORATION BORINGS	Fig. B-12
Project No.	41130I		

WOODWARD—CLYDE CONSULTANTS

APPENDIX C
CROSSHOLE GEOPHYSICAL MEASUREMENTS

C-1 INTRODUCTION

The crosshole seismic method is a standard geophysical technique which has, in this case, been modified for application to providing closure between exploration borings to detect sand-filled cavities. The modification consists of additional data processing and interpretive techniques.

In normal use, the method consists of measuring the time taken by dilatational (P) and shear (S) waves to travel from a borehole source to one or more receivers in other boreholes (Figure C-1). The source and receivers are normally located at the same elevation at known distances from each other. Thus, the velocity of each wave (Cp and Cs) can be calculated, and material properties deduced.

The instrumentation consists of an energy source, receivers, signal conditioners and recorder, and a spectral analyzer. The sections that follow describe the instrumentation, the field procedures and the method of processing the data.

C-2 INSTRUMENTATION

C-2.1 Source

Seismic energy is generated by a mechanical borehole impulse instrument composed of a stationary part and a hammer (Figure C-2). The stationary part consists of a hydraulic cylinder block with pistons on each side fixed to curved plates. When hydraulic pressure is applied to the pistons, the plates move outward and grip the borehole walls. The movable part of the energy source, the hammer, slides on guides mounted on the cylinder block. The hammer can be lifted above or lowered below the cylinder block to a maximum travel distance of 12 inches in either direction.

To produce a downward impulse, the hammer is raised manually and allowed to drop freely onto the top of the cylinder block. This blow produces a downward motion which is transmitted through the metal plates to the surrounding medium. Upward motion is produced by smartly raising the hammer such that it strikes the bottom of the cylinder block. The moment of hammer impact is detected by means of piezoelectric crystals embedded in both ends of the instrument.

C-2.2 Receivers

The seismic energy generated by the hammer is detected by vertically oriented 4.5-cps geophones. The geophones are placed in adjacent boreholes at the same elevation as the hammer, and are held against the borehole walls by pressurized bladders (Figure C-3). The geophones, being vertically oriented, are more sensitive to the vertically polarized S-waves than to the P-waves. The outputs of the geophones are velocity-time histories (Figure C-4).

C-2.3 Recorder

The velocity-time histories are recorded by a 12-channel signal enhancement seismograph (Geometrics/Nimbus ES-1200). The information is stored digitally, and later played back in analog form onto photographic paper. The chosen sampling interval of 0.05 msec results in a 50-msec record length. Up-blows and down-blows received at all the geophones are displayed simultaneously.

Signal enhancement is obtained by adding hammer blows together. Random noise tends to cancel when added, while coherent events tend to become larger. This results in an increased signal-to-noise ratio.

C-2.4 Spectral Analyzer

An additional instrument used in this instance is a spectrum analyzer (Rockland Systems FFT 512/S). The analyzer is capable of real-time processing of captured transients using a 1024-point Fast Fourier Transform. The velocity-time histories are transmitted to the analyzer, and the resulting spectra are recorded on a X-Y recorder (Figure C-5). The spectra are plotted on a log-frequency scale showing the power referenced to one volt (rms).

C-3 FIELD PROCEDURES

Field procedures consist of obtaining measurements across the boreholes such that the well is surrounded by transects for most of its depth. Redundancy is provided by reversed and multiple paths. This is accomplished by several set-ups of the hammer and three geophones in alternate boreholes as shown schematically on Figure C-6.

For testing, the hammer and the geophone array are placed at the first depth of interest. The instruments are moved along the boreholes at 5- to 10-foot intervals. The 10-foot intervals are generally only used below 100 feet.

Three sets of wave form data were obtained as follows: (1) five hammer blows in each direction (up and down) made at the same gain and recorded for wave form analysis; (2) five hammer blows in each direction added to the previous five hammer blows (10 blow total) and recorded at variable output gain for visual wave velocity interpretation; and (3) five hammer blows in each direction added to the previous 10 hammer blows (15 blow total) and recorded at variable output gain for visual wave velocity interpretation. During these measurements the input gain (instrument sensitivity) was always kept constant. The output gain was kept constant for the wave form analysis records (item 1 above), while for the wave velocity analysis it was varied (items

2 and 3). The total 15 hammer blow records were then retained in instrument memory (at constant input gain) and transmitted to a frequency analyzer for processing and recording.

C-4 DATA PROCESSING

Because of the large quantity of data obtained from the crosshole measurements, the data were numerically processed to facilitate analysis. Specifically, the raw records were photographically reduced and drafted for each traverse on a single page format as shown on Figure C-7 for Well 4, traverse 1 to 4. Additional processing to develop wave velocity, crosshole distance, closest distance, spectral amplitude and trace amplitude data are described below.

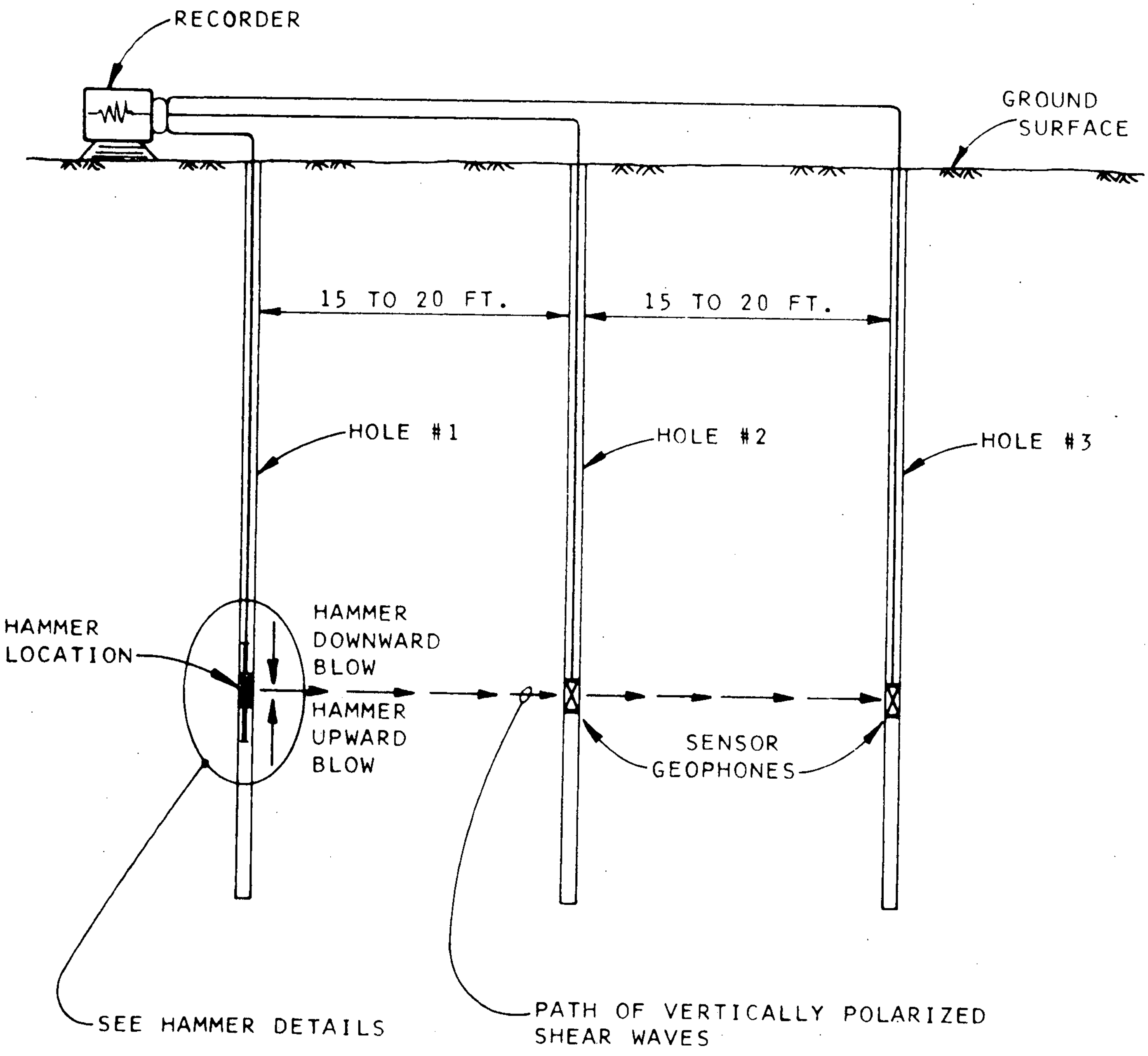
Velocity information is obtained by dividing the crosshole distance by the travel time. The latter values can typically be picked from the waveform records with an accuracy of $\pm$0.1 msec. As discussed in Appendix D, travel times and velocities were not used in the diagnostic criteria.

Crosshole distance is calculated from gyro data except for the Well 3 data. The latter data were mostly obtained from plots of borehole inclinometer measurements with back-calculations as a check. The gyro and inclinometer instruments used were the Eastman Whipstock Gyroscopic Multishot Survey Instrument and the Terra-Probe TP-2, respectively, with accuracies on the order of 0.0005 inch/foot. Cumulative errors for a 200-foot borehole would be less than one inch. The closest distances of the well to the crosshole array travel paths were calculated and plotted for each traverse as shown in Figure C-8 to aid in data interpretation.

The spectral amplitude data are derived from the power spectra plotted by the frequency analyzer (Figure C-5). Based on the predominant frequencies noted on the waveform records, 1 KHz and

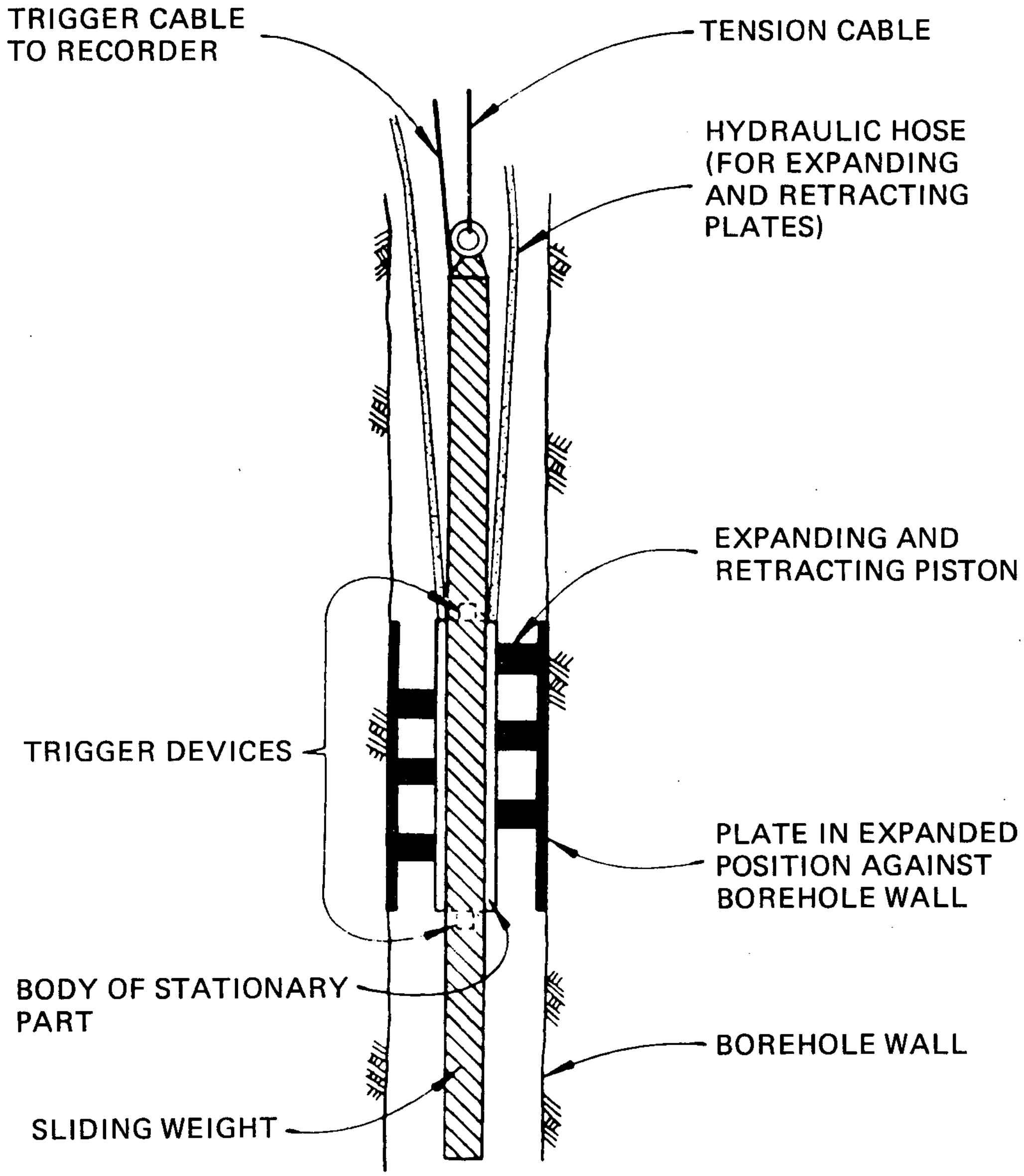
125 Hz were selected as typical frequencies for P-waves and S-waves, respectively. The average spectral amplitudes at these frequencies are calculated using a 5-point average around the center frequency. For the 125 Hz value, the 5 Hz resolution means that the values at 115, 120, 125, 130 and 135 Hz are added and divided by 5. For the 1 KHz value, the compression of the frequency axis (log scale) means that the most diagnostic measurable value is that obtained by taking the 5-point average of the five highest peaks in the 0.9 to 1.1 KHz band. An arbitrary amplitude scale is used wherein a unit value corresponds to about 5 dB. As discussed in Appendix D, spectral values were not used in the diagnostic criteria.

The trace-amplitude data are derived from the waveform records (Figure C-9). These values represent the peak-to-peak trace amplitudes at each depth normalized to the largest trace amplitude in the set. As discussed in Appendix D, these normalized amplitudes are quite useful as one of the diagnostic criteria (the other two are the log of the boring, and the quality of the traces).



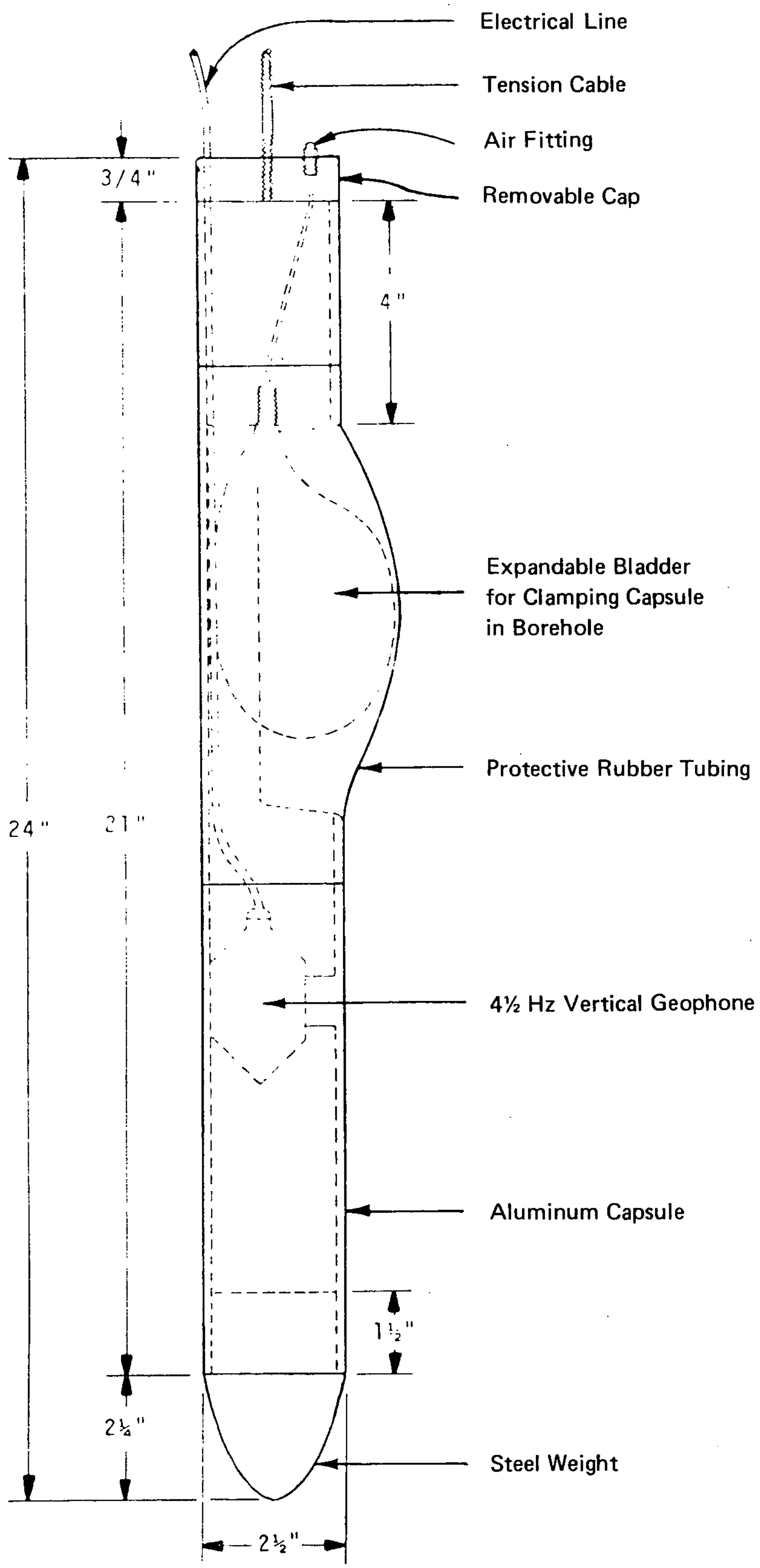
Project:	SONGS 2 & 3	ARRANGEMENT OF INSTRUMENTS FOR CROSSHOLE SURVEY	Fig. C-1
Project No.	41130I		

WOODWARD—CLYDE CONSULTANTS



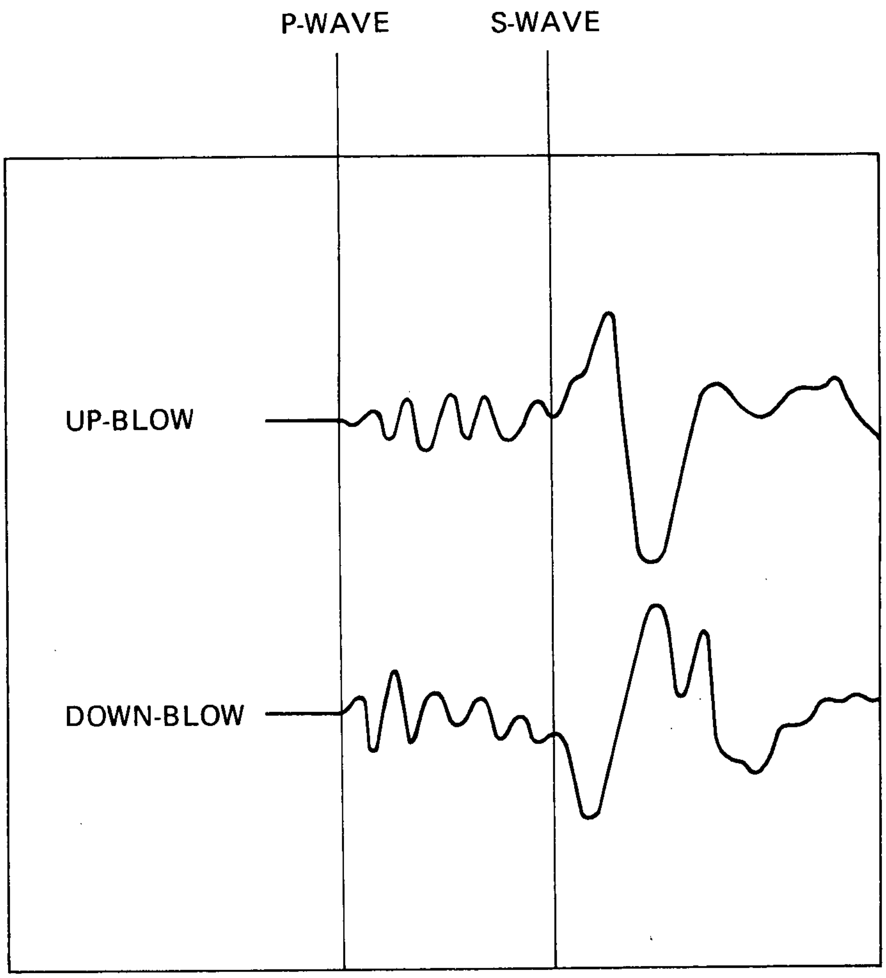
Project: SONGS 2 & 3 Project No. 41130I	DETAILS OF SHEAR WAVE HAMMER	Fig. C-2

WOODWARD – CLYDE CONSULTANTS

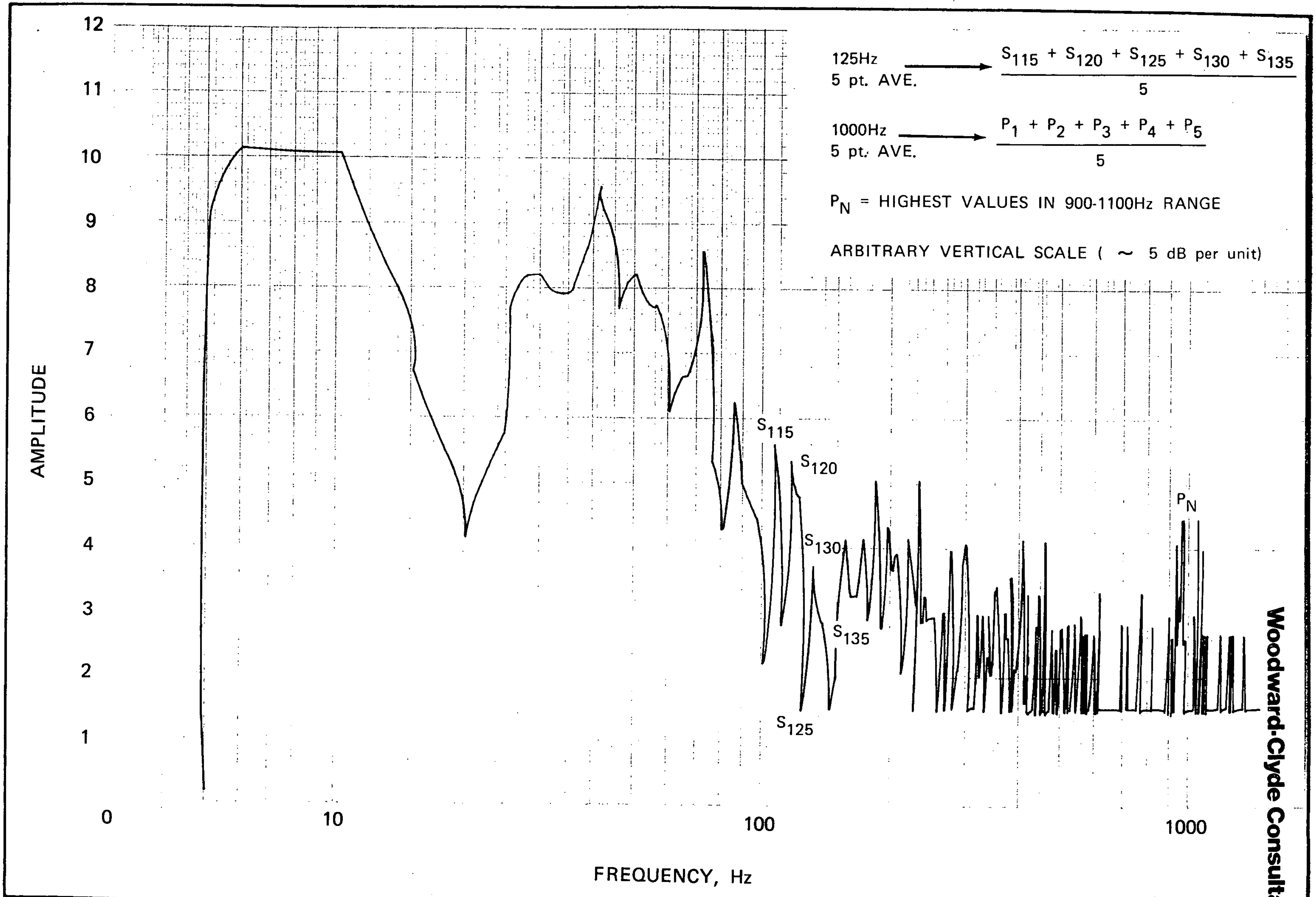


Project:	SONGS 2 & 3	BOREHOLE GEOPHONE CAPSULE	Fig. C-3
Project No.	41130I		

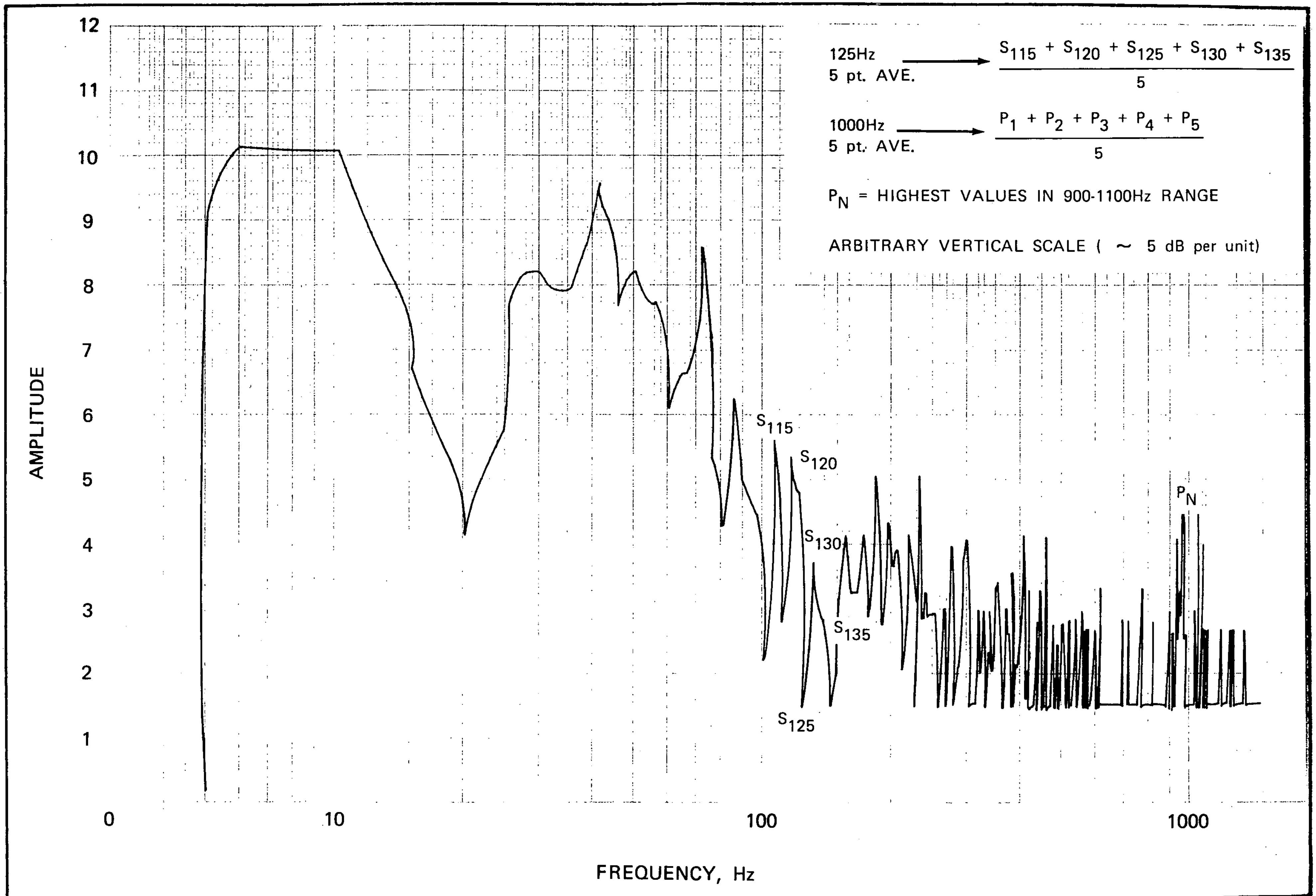
WOODWARD–CLYDE CONSULTANTS



Project:	SONGS 2 & 3	WAVEFORM RECORDS	Fig.
Project No.	411301	OF SAMPLE PAIR OF TRACES	C-4



Project:	SONGS 2 & 3	TYPICAL EVALUATION OF 5–POINT AVERAGED SPECTRAL AMPLITUDE	Fig. C-5
Project No.	41130I		



Project: SONGS 2 & 3 Project No. 411301	TYPICAL EVALUATION OF 5–POINT AVERAGED SPECTRAL AMPLITUDE	Fig. C-5

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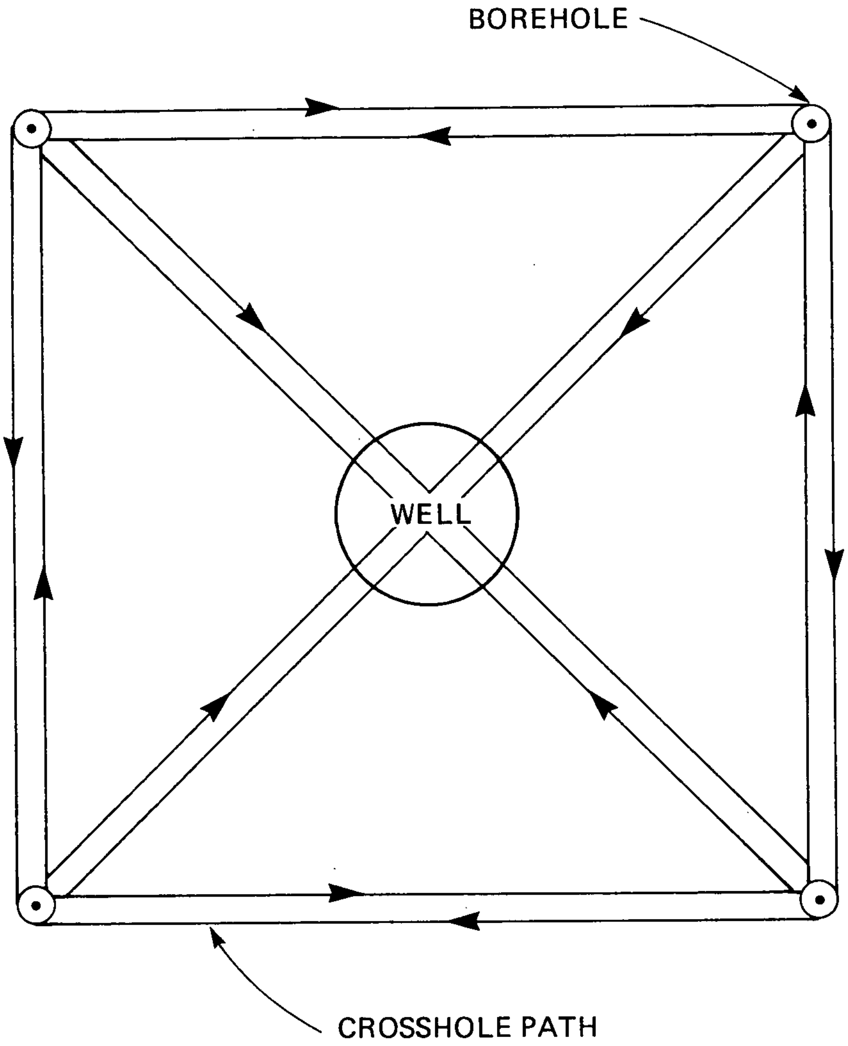
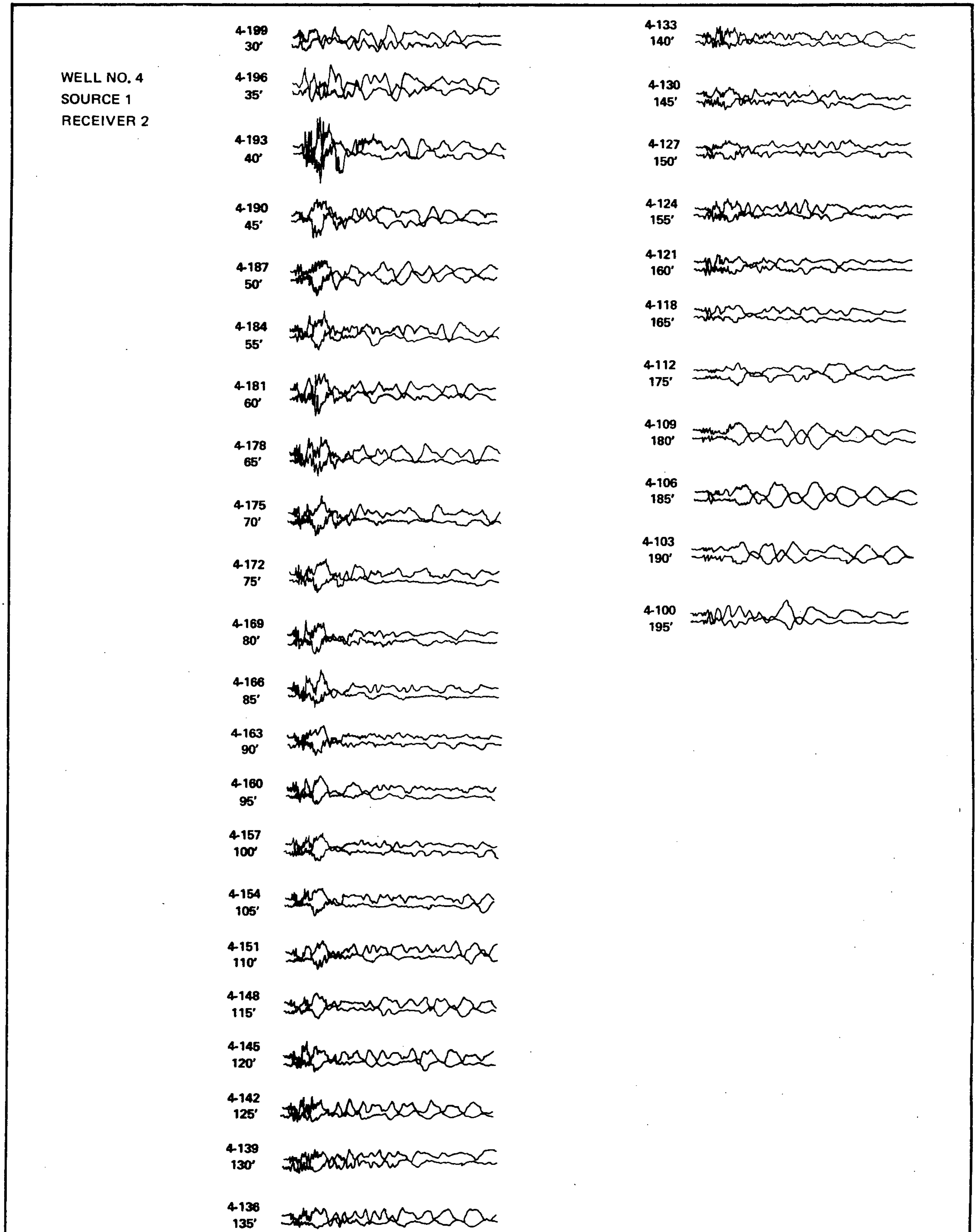


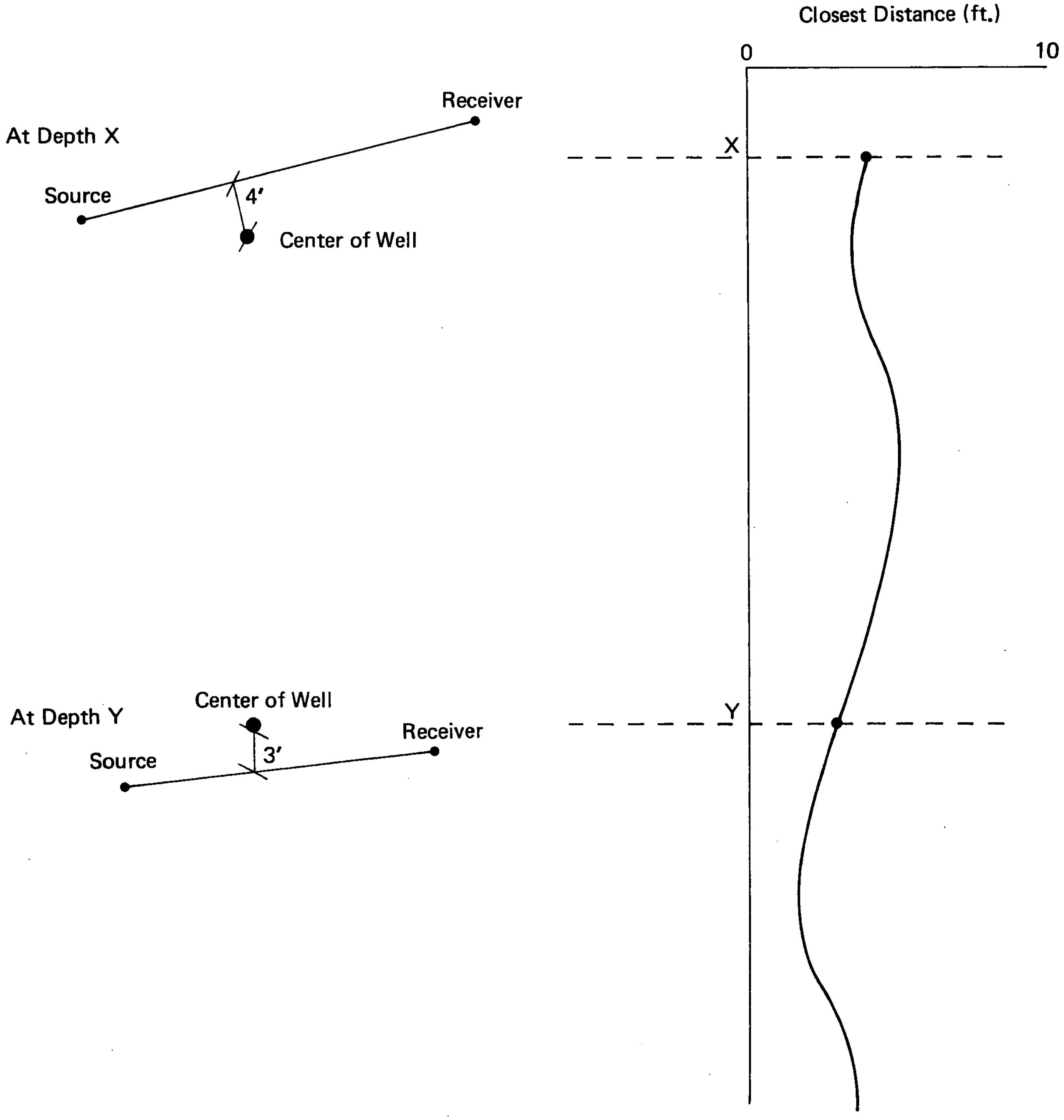
Project:	SONGS 2 & 3	SCHEMATIC SHOWING REDUNDANCY OF TYPICAL CROSSHOLE MEASUREMENTS	Fig. C-6
Project No.	411301		

WOODWARD—CLYDE CONSULTANTS



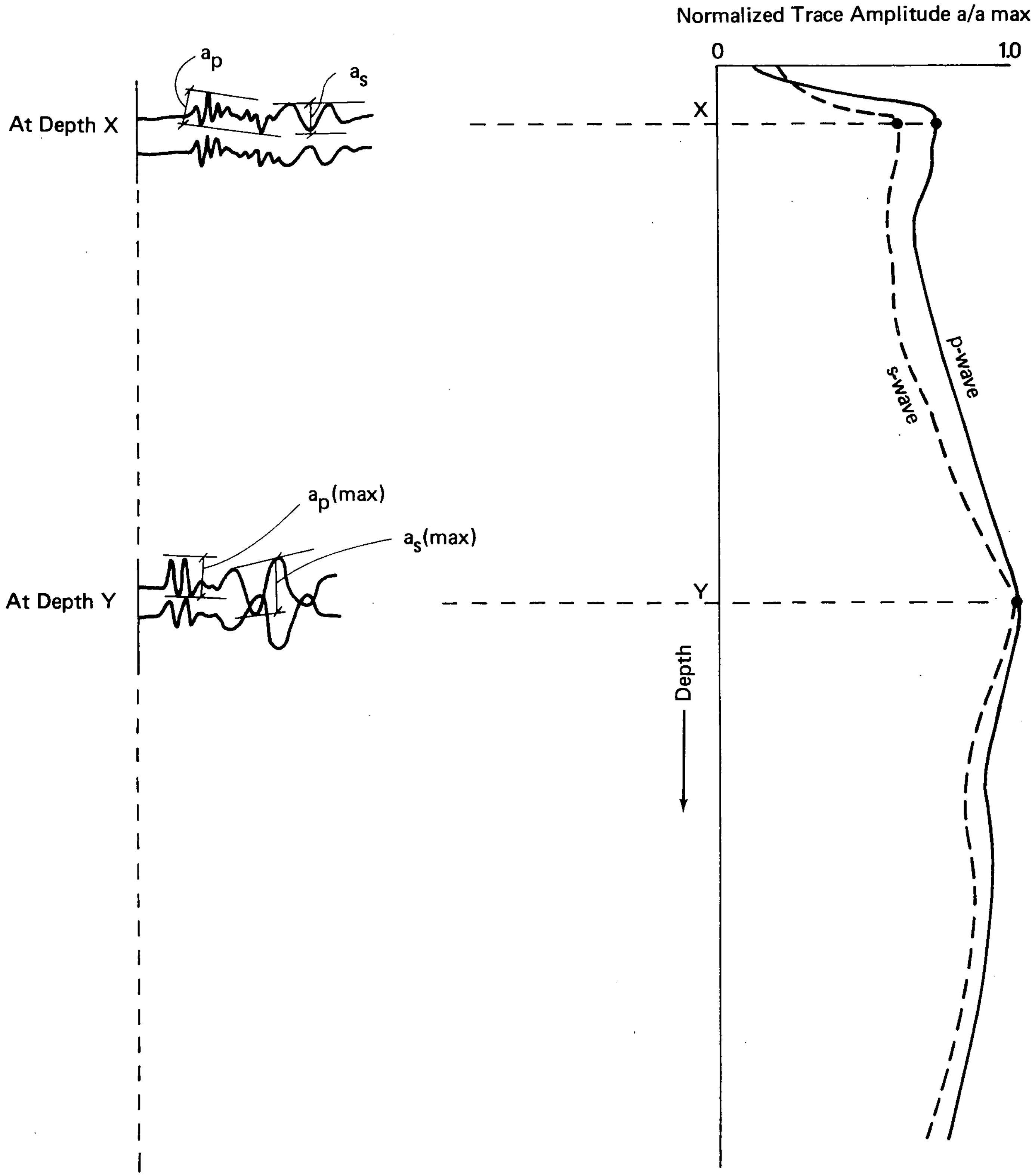
Project: SONGS 2 & 3 Project No. 41130I	TYPICAL CROSSHOLE DATA SUMMARY OF PARTICLE VELOCITY TIME-HISTORIES	Fig. C-7

WOODWARD – CLYDE CONSULTANTS



Project:	SONGS 2 & 3	SCHEMATIC DIAGRAM OF THE DEVELOPMENT OF CLOSEST DISTANCE VS. DEPTH PLOT	Fig.
Project No.	41100I		C-8

WOODWARD–CLYDE CONSULTANTS



Project:	SONGS 2 & 3	SCHEMATIC DIAGRAM OF THE DEVELOPMENT OF NORMALIZED TRACE AMPLITUDE VS. DEPTH PLOT	Fig. C-9
Project No.	41100I		

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APPENDIX D
CALIBRATION OF DETECTION CRITERIA AT A KNOWN CAVITY AT WELL 3

D-1 INTRODUCTION

A quantitative calibration of the cavity detection technique was achieved by making crosshole measurements of the known cavity at Well 3. This cavity was defined by drilling exploration and well measurements at Well 3 as discussed in Appendix B and shown on Figure D-1. Exploration borings C, E, Q, T, U and V (Figure D-2) were prepared and used for the crosshole seismic measurements as described in Appendix C. The purpose of these measurements was to develop empirical criteria for the detection of a cavity between exploration borings using the principles described in Appendix A.

The following sections describe the processed crosshole data used in the calibration analysis and the empirical criteria subsequently developed.

D-2 DESCRIPTION OF PROCESSED DATA

A review of all the crosshole data including waveform trace data, Fourier spectra data and wave velocities, indicated that the waveform trace data were the most useful for cavity detection. This was determined by the distinctness and the signal to noise ratio of the anomaly which occurs when a crosshole transect crosses the known cavity. The Fourier spectra data were usable, but were not as definitive due to the low signal to noise ratio. Those data were therefore not used for final analysis. The wave velocity data were not found useful for cavity detection under these conditions. The average of all velocity data for Wells 3, 4 and 5 are presented on Figure D-3, which shows agreement at depth with crosshole and downhole geophysical measurements made

at the site in 1972 (Appendix 2E, Attachment 3, SONGS 2 and 3 PSAR). Differences near the surface between earlier measurements and the present measurements likely reflect effects of air entrainment caused by dewatering. These air entrainment effects are prevalent at Wells 3, 4, and 5. The crosshole-distance and closest-distance to the well data were useful in evaluating the waveform data. For these reasons, the data presented are restricted to distance, waveform and waveform derived data. Specifically, Figures D-4 through D-26 represent waveform traces plotted at each depth where measurements were made for all transects made between borings C, E, Q, T, U and V; and Figures D-27 through D-34 present plots of normalized P- and S-wave trace amplitudes, closest-distance and crosshole-distance with depth. Also shown on these figures are plots of normalized PxS-wave trace amplitudes versus depth, thereby combining the effects of reductions in P- and S-wave amplitudes. Table D-1 presents a summary of the Appendix D figures.

D-3 DEVELOPMENT OF THE EMPIRICAL CRITERIA

As discussed in Appendix A, the P-wave and S-wave amplitudes should be attenuated more along a transect intersected by a sand-filled cavity than by one that has a clear travel path through the native sand. This greater attenuation is due to a combination of diffraction of wave energy around the cavity, greater damping of wave energy across the cavity, and reflection losses at the boundaries of the filled cavity. The above effects will also cause distortion of the waveforms and phase changes. Direct examination of the waveform traces indicates that waveforms for transects intersected by cavity (shown in red in Figure D-2) show greater attenuation in the depth interval 30 to 60 feet than do the waveforms for transects not intersecting cavity (shown in green on Figure D-2).

Samples of non-cavity transects for Well 3 include U-T and U-E. Figure D-4 shows the waveform set in the U-T transect. The traces exhibit minor P-wave and S-wave variation. Particular

attention is paid to the P-waves which at shallow depths (30-60 feet) show amplitude values similar to those at depth. Figure D-24 shows the waveform set in the U-E transect. Here again, the amplitudes are fairly consistent with moderate reduction at 35 to 40 feet, yet still quite evident P-wave. It should be noted that at these depths, the cavity is nearby and may be causing the amplitude reduction in what might be termed a graze situation. The V-Q transect waveforms in Figure D-9 also show such a P-wave amplitude reduction in an otherwise unaffected group of waveforms at depths near 95 feet. This feature is noted on some of the other transects and may in fact be due to a small disturbed zone or cavity adjacent to the well at these depths. Again, the shallow waveforms show minor amplitude reduction. These and the remaining transects show that amplitude variations may normally drop to as much as 20 to 30% of the largest values in each set, yet still be considered native sand indications.

Samples of transects which cross the cavity include Q-E and Q-U. The Q-U transect shown in Figure D-11 again shows a P-wave amplitude reduction at the 95-foot region, but also shows a strong reduction of both P-wave and S-wave amplitudes at depths of 40 to 50 feet, where the cavity must be crossed. In Figure D-22 the Q-E transect shows virtual absence of any seismic energy above 55 feet. A similar situation occurs in the V-T transect shown in Figure D-8, where the P-wave is virtually absent above 60 feet, although noise having a similar appearance does occur. These and the remaining transects show that amplitudes less than 10 to 20% of the largest values in each set are associated with cavity or are spurious. A very small amplitude value approaching or equal to zero is strongly indicative of such a situation. A severe amplitude reduction on reversed transects is the best indicator since spurious reductions are less likely to occur on several repeats of the same transect. Also, the reduction of amplitude in both P-waves and S-waves is strong evidence for a cavity.

Consideration of the above factors suggests that a cavity indication should be based on the reduction of amplitudes to below 20% of the largest normal amplitudes and should be seen in both directions of travel for a given transect. This may apply to both the S-wave and P-wave, although the latter condition is more evident. This effect can be accentuated by multiplication of the normalized amplitude values so that a PxS value is derived. A fraction such as 0.1 or 0.2 can be used to indicate the amount of amplitude reduction. Using this method, empirically comparing the Well 3 crosshole data with the data developed on cavity configuration at Well 3 (Appendix C), the following criteria are developed:

1. LOG OF BORING

Observation	Interpretation
Loose sand encountered, or void encountered (based on SPT, samples, changes in drilling rate and/or feed pressure)	Cavity

2. PRODUCT OF NORMALIZED P AND S AMPLITUDES

Observation	Interpretation
PxS = 0 in both directions	Possible Cavity
PxS = 0 in one direction and ≤ 0.2 in the other direction	Possible Cavity
PxS ≤ 0.1 in both directions	Possible Graze
PxS ≤ 0.1 in one direction and ≤ 0.2 in the other direction	Possible Graze
PxS = 0.2 in both directions	Native Soil
PxS > 0.2 in either direction	Native Soil

A graze is a disturbance which results in a strong amplitude reduction, but not necessarily strong enough to imply that a sizable cavity may exist between the borings. This is also considered to minimize the chance that an odd-shaped cavity or less amplitude picking accuracy might otherwise lead to missing a cavity indication. An accuracy of 0.1 in the amplitude picks is typical. A significant cavity would, however, be associated with the total or almost total absence of P-wave energy in both directions of travel.

Using the above criteria, the data at Well 3 are summarized in Table D 2 and show excellent correlation with the known cavity as shown in Figure D-2. These criteria apply only to the specific conditions at the San Onofre site.

TABLE D-1

SUMMARY OF APPENDIX D FIGURES

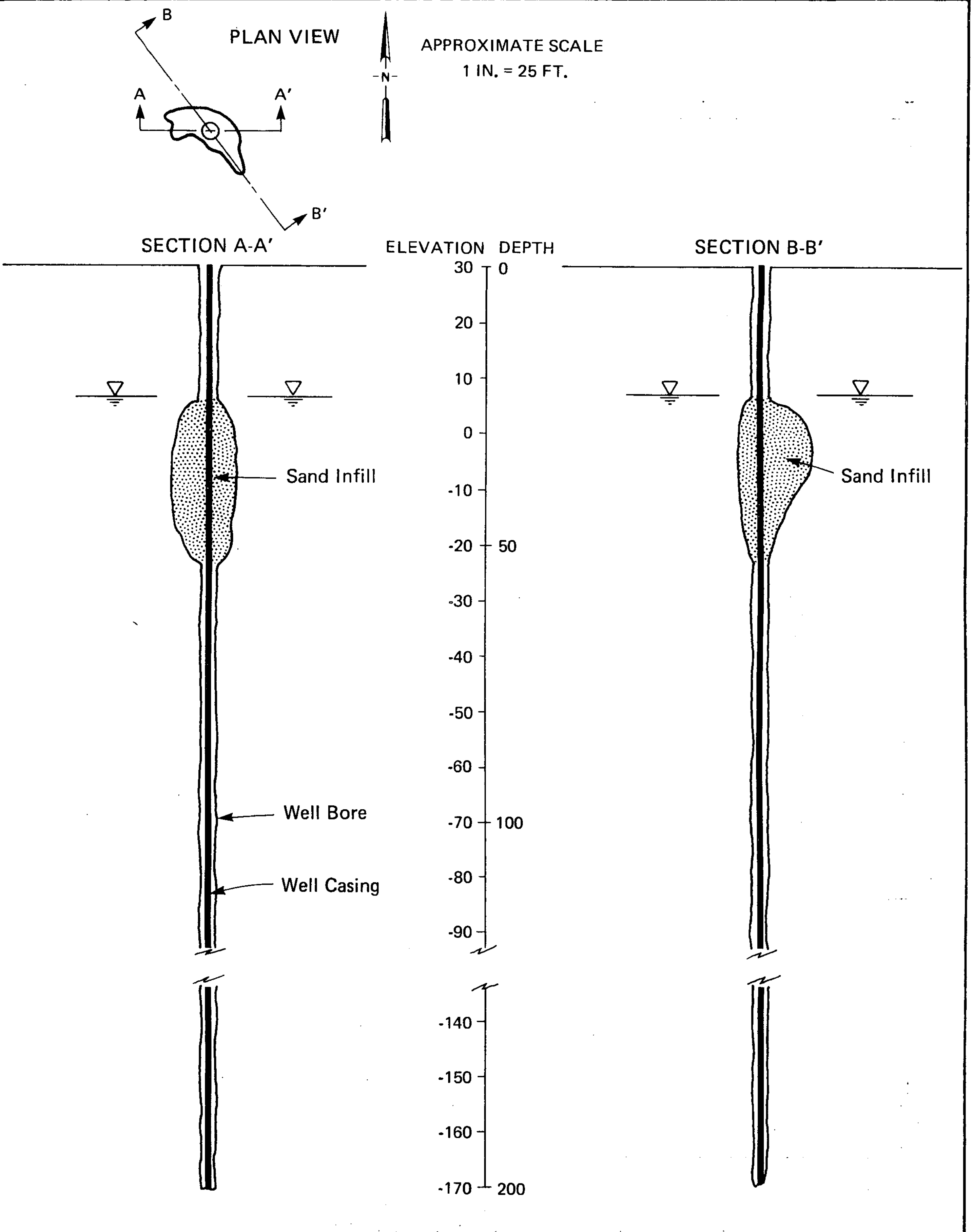
Figure No.	Title	
D-1	Plan and Cross-section of Cavity and Wellbore at Well 3	
D-2	Dewatering Well 3 - Location of Drillhole and Crosshole Transects	
D-3	P- and S-wave Velocity versus Depth (Averaged for borings 3, 4 and 5)	
D-4 to D-26	Well 3 Waveform Trace Figures	
	Source	Receiver
D-4 to D-6	U	T,Q,V
D-7 to D-9	V	U,T,Q
D-10 to D-12	Q	T,U,V
D-13 to D-15	T	U,Q,V
D-16 to D-17	U	Q,V
D-18 to D-20	Q	C,E,T
D-21 to D-23	Q	C,E,U
D-24 to D-26	U	E,C,Q
D-27 to D-34	Well 3 Waveform Data Summary Figures	
	Source	Receiver
D-27	U	T,Q,V
D-28	V	U,T,Q
D-29	Q	T,U,V
D-30	T	U,Q,V
D-31	U	Q,V
D-32	Q	C,E,T
D-33	Q	C,E,U
D-34	U	E,C,Q

TABLE D-2

SUMMARY OF PxS TRACE AMPLITUDE INTERPRETATION FOR WELL 3

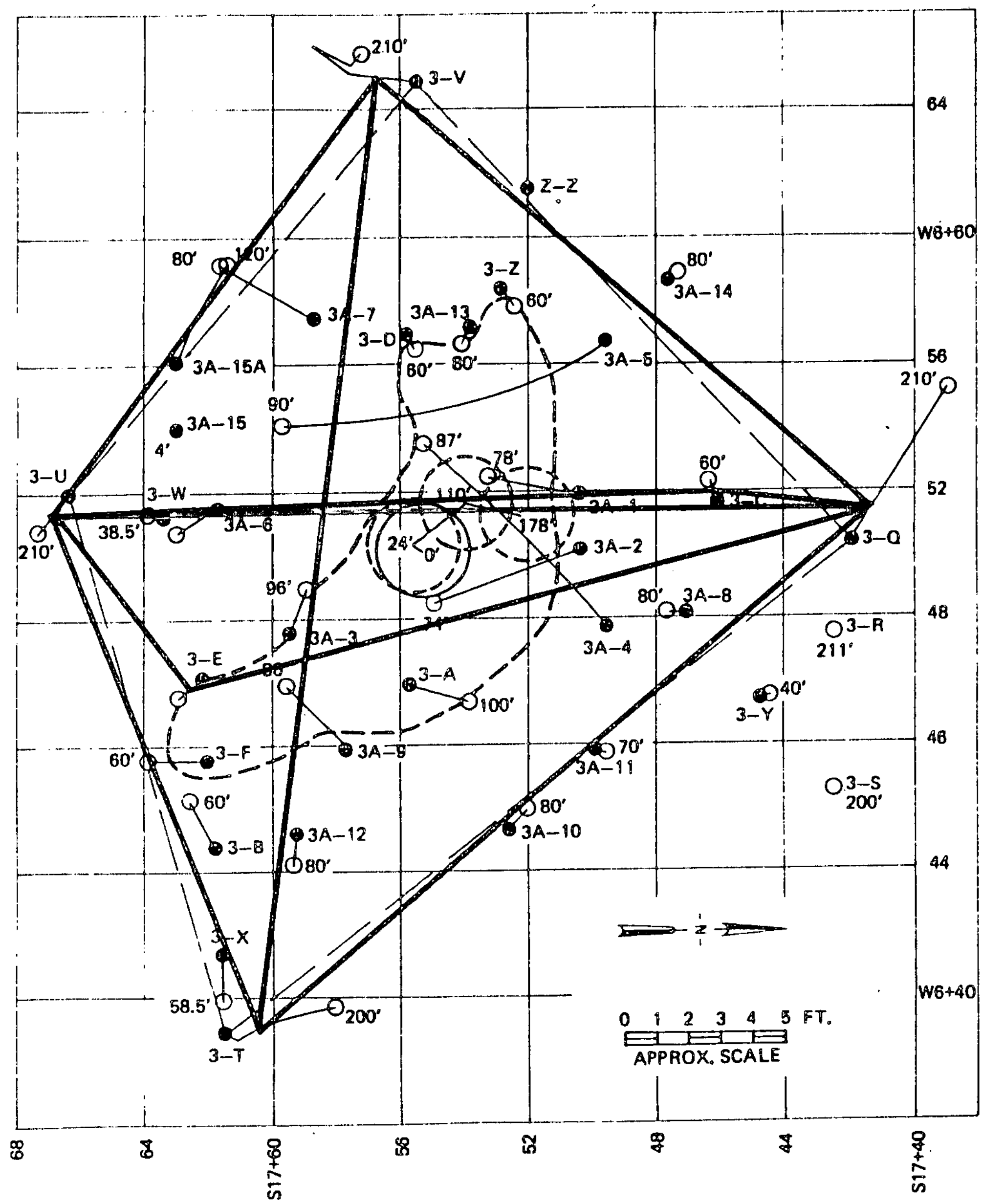
	Depth Interval Fitting Criteria				Depth Interval Fitting Criteria			
Transect	PxS=0	0<PxS<0.1	0.1<PxS<0.2	Reverse Transect	PxS=0	0<PxS<0.1	0.1<PxS<0.2	Interpretation
V-T	30-55'	--	60-65'	T-V	--	50	--	Possible cavity at 30-50'.
V-Q	--	--	95-130'	Q-V	--	90-95'	80-85' 100-105'	Possible graze near 95'.
V-U	--	--	--	U-V U-V	-- --	-- --	-- --	Native soil at all depths.
U-T	--	--	130-140' 170'	T-U	--	--	--	Native soil at all depths.
U-Q	30-45'	50-55' 90'	80' 95-100'	Q-U	--	45	40', 50'	Possible cavity at 30-55'.
	45-50' 30-50'	-- --	-- --	Q-U	32-59'	--	85'	Possible graze at 85-90'
Q-C	-- --	-- --	-- --	None				Native soil to depth of Hole C.*
Q-T	--	50-59'	40-45'	T-Q	--	--	--	Native soil at all depths.
U-E	--	--	--	None				Native soil to depth of Hole E.*
U-C	30-55'	--	--	None				Possible cavity at 30-55'.*
Q-E	32-59' 30-59'	-- --	-- --	None				Possible cavity at 30-60'.*

* no reverse leg for strict application of criteria



Project:	SONGS 2 & 3	PLAN AND SECTION VIEWS OF WELL NO. 3	Fig.
Project No.	41130I		D-1

WOODWARD—CLYDE CONSULTANTS



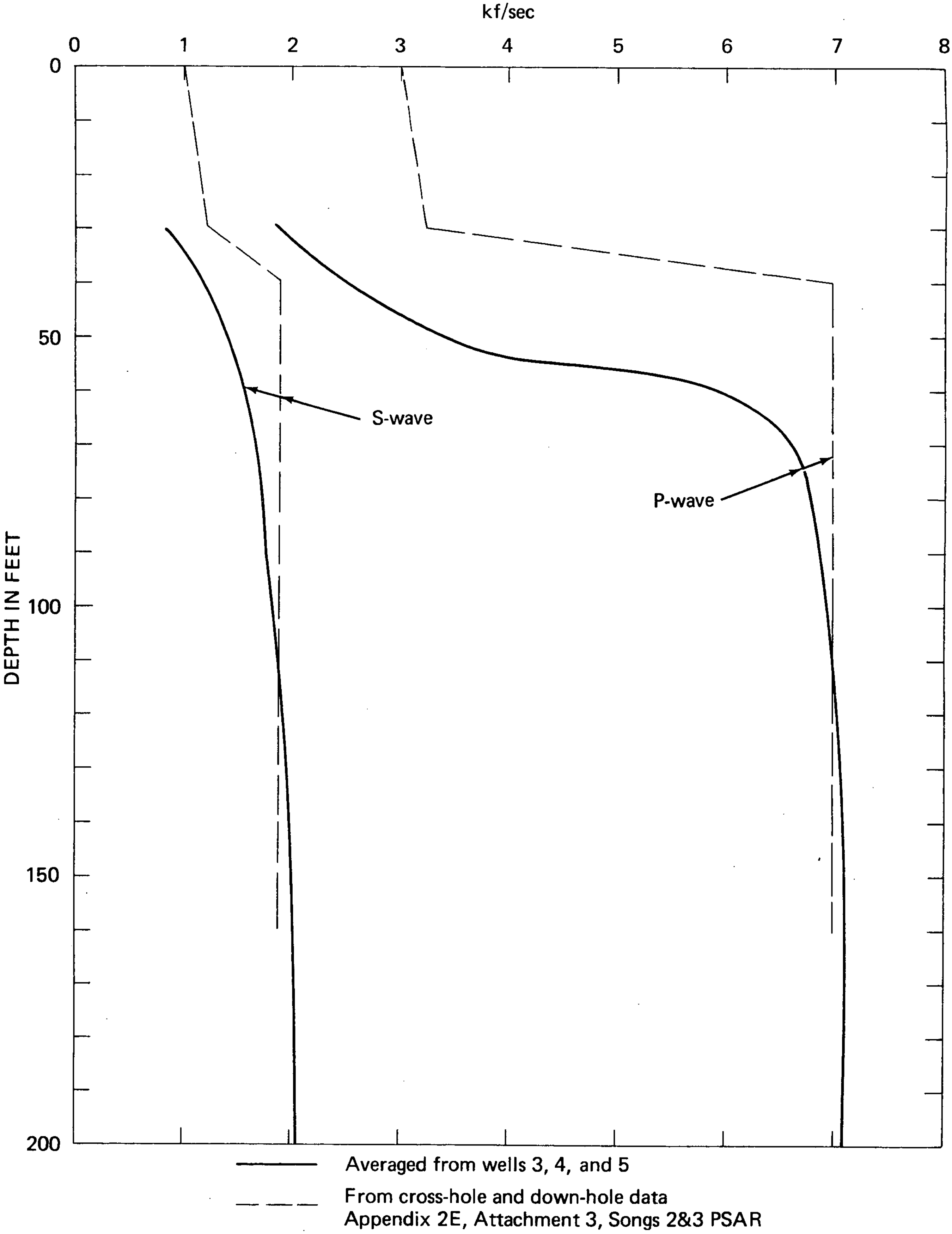
TYPICAL CROSSHOLE TRANSECTS 30-60 FT.

Across possible cavity

Across native soil

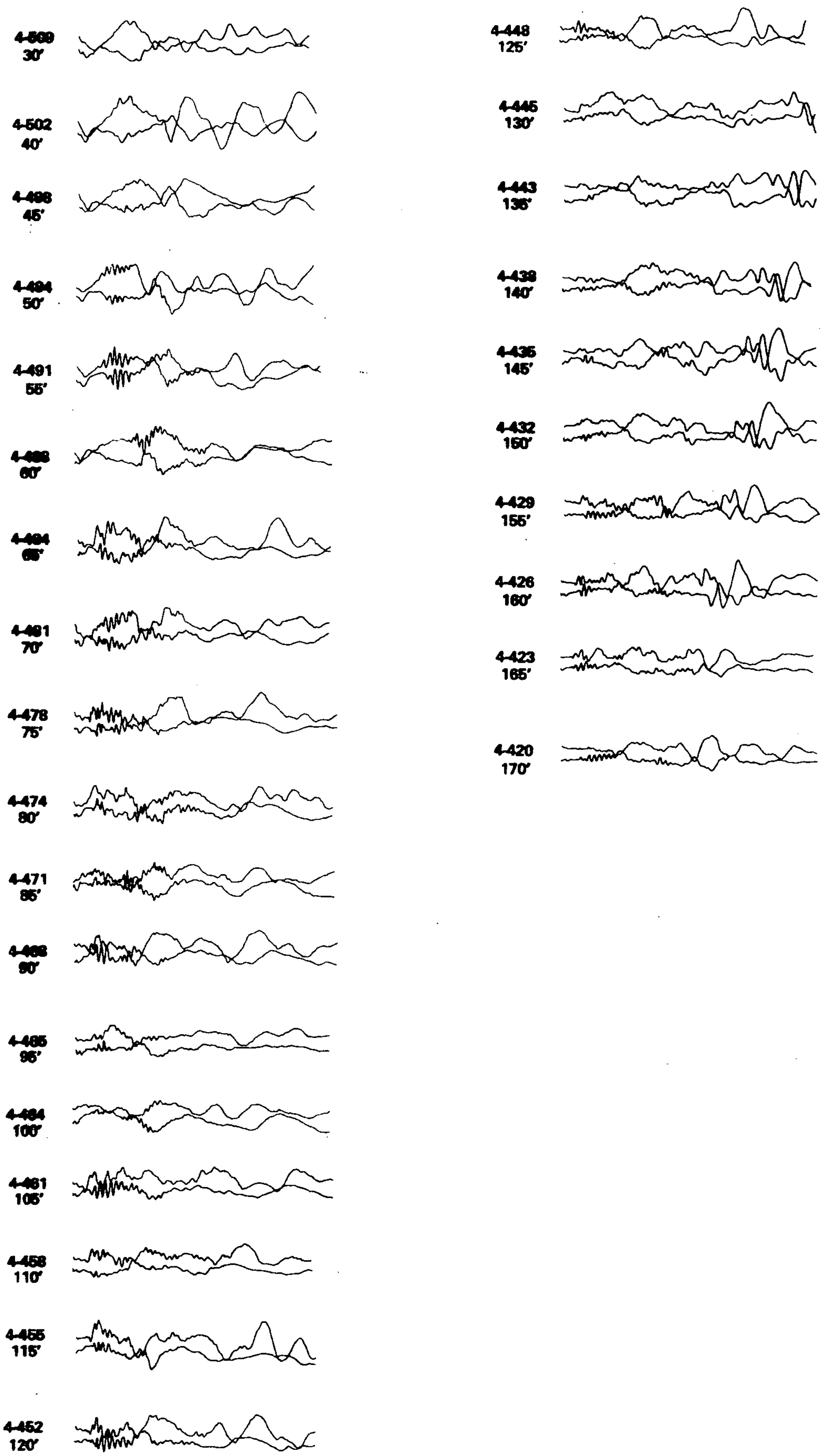
Project:	SONGS 2 & 3	DEWATERING WELL NO. 3 LOCATION OF DRILL HOLES AND CROSSHOLE TRANSECTS (30 TO 60 FT.)	Fig. D-2
Project No.	41130I		

WOODWARD—CLYDE CONSULTANTS

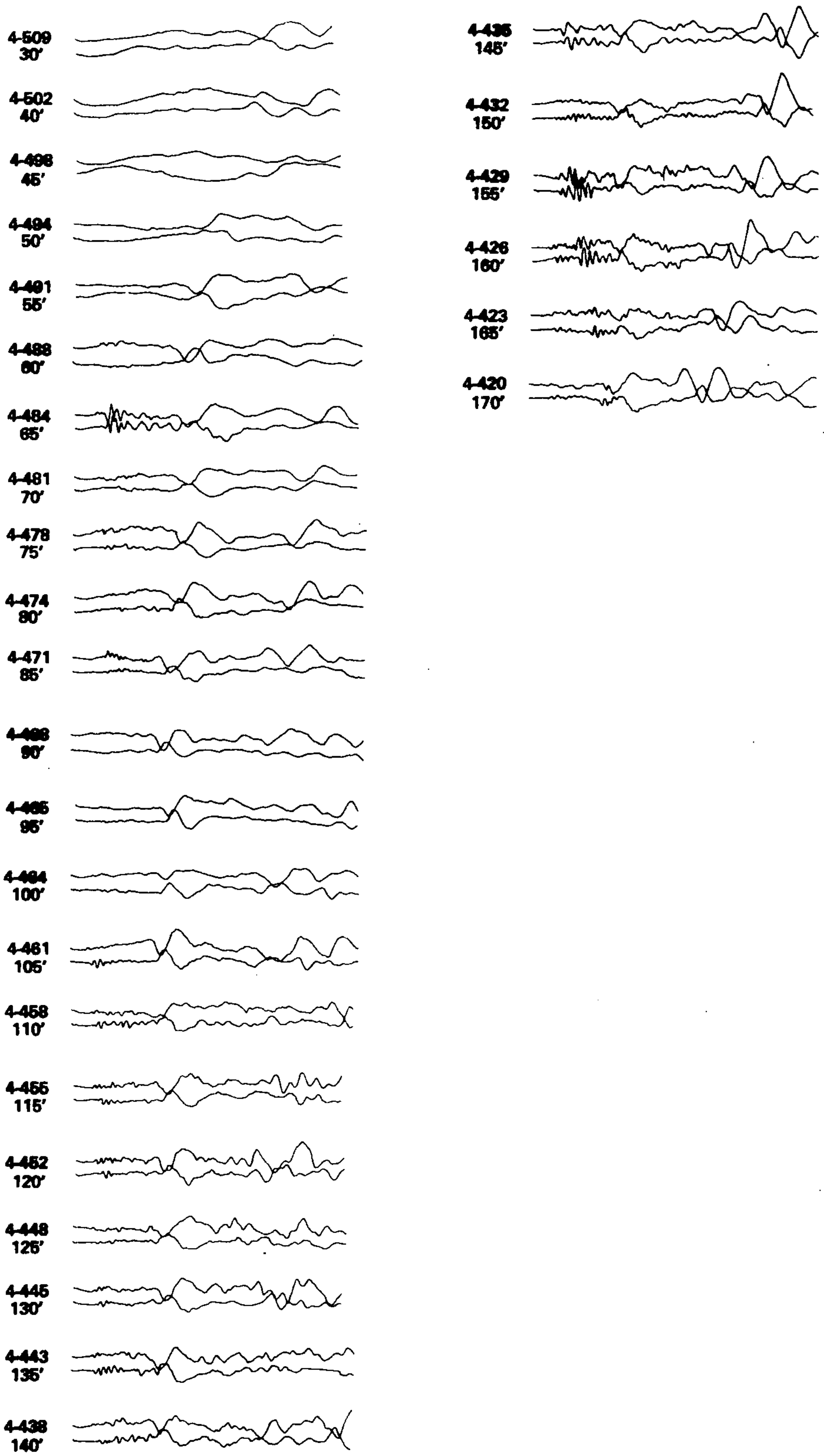


Project:	SONGS 2 & 3	P-WAVE AND S-WAVE VELOCITY vs DEPTH	Fig. D-3
Project No.	41130I		

WOODWARD–CLYDE CONSULTANTS

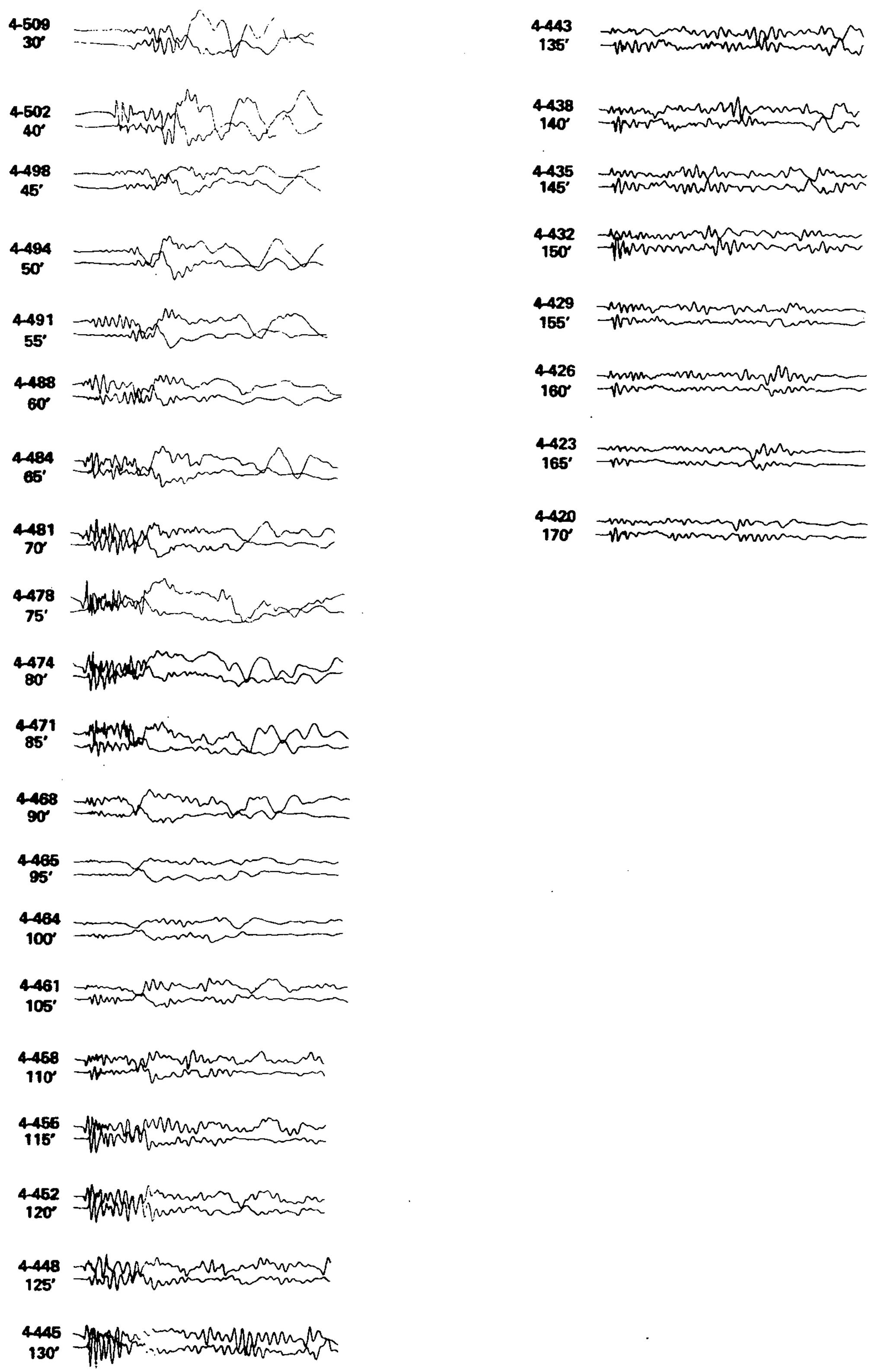


Project:	SONGS 2 & 3	WELL NO. 3 U → T WAVEFORM TRACE	Fig.
Project No.	411301		D-4



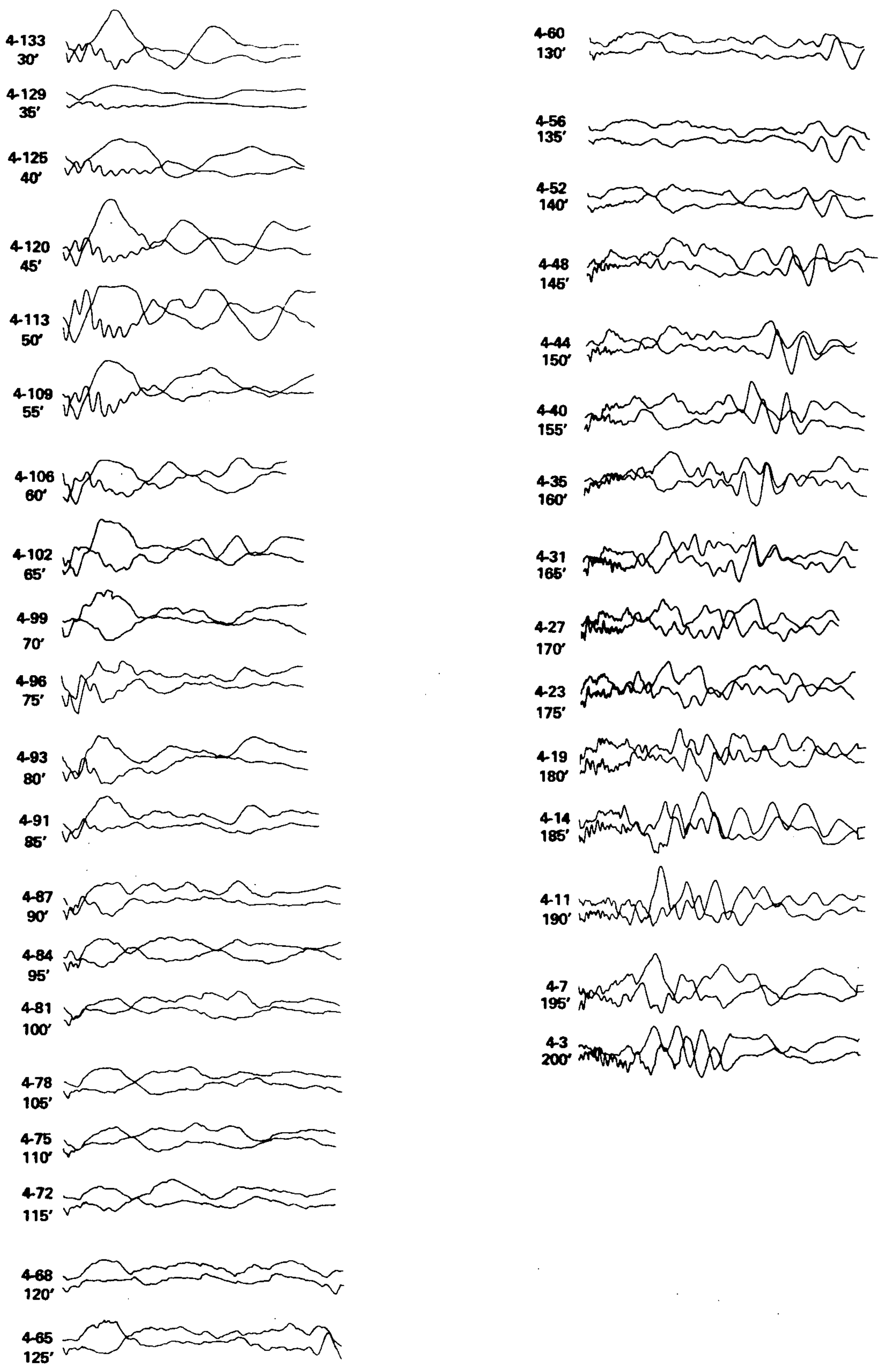
Project:	SONGS 2 & 3	WELL NO. 3 U → Q WAVEFORM TRACE	Fig.
Project No.	41130I		D-5

WOODWARD – CLYDE CONSULTANTS



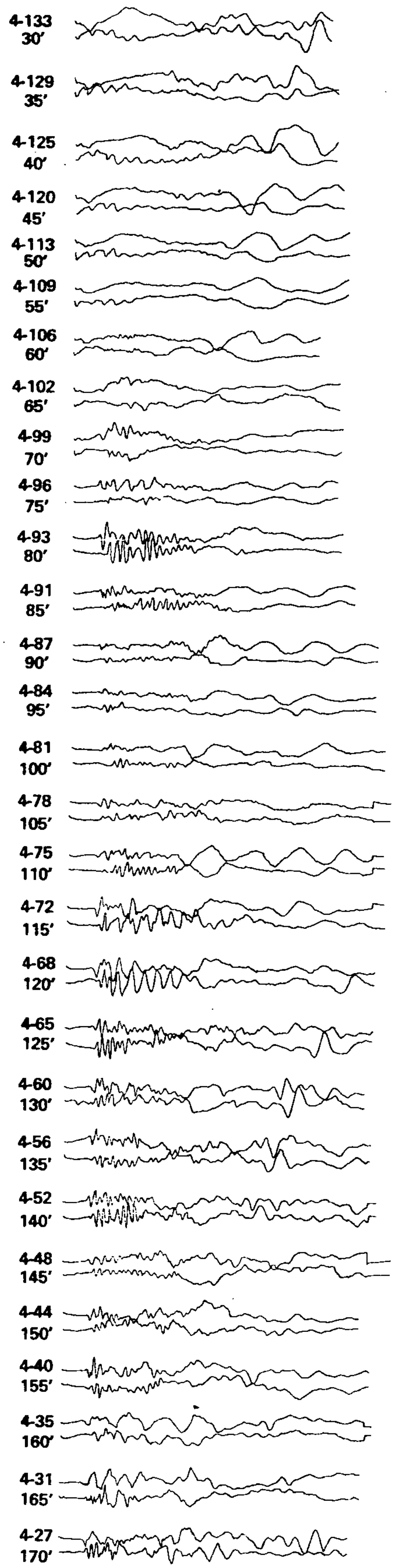
Project: SONGS 2 & 3 Project No. 411301	WELL NO. 3 U → V WAVEFORM TRACE	Fig. D-6

WOODWARD—CLYDE CONSULTANTS



Project:	SONGS 2 & 3	WELL NO. 3 V → U WAVEFORM TRACE	Fig.
Project No.	411301		D-7

WOODWARD – CLYDE CONSULTANTS



Project:	SONGS 2 & 3	WELL NO. 3 V → T WAVEFORM TRACE	Fig.
Project No.	41130I		D-8

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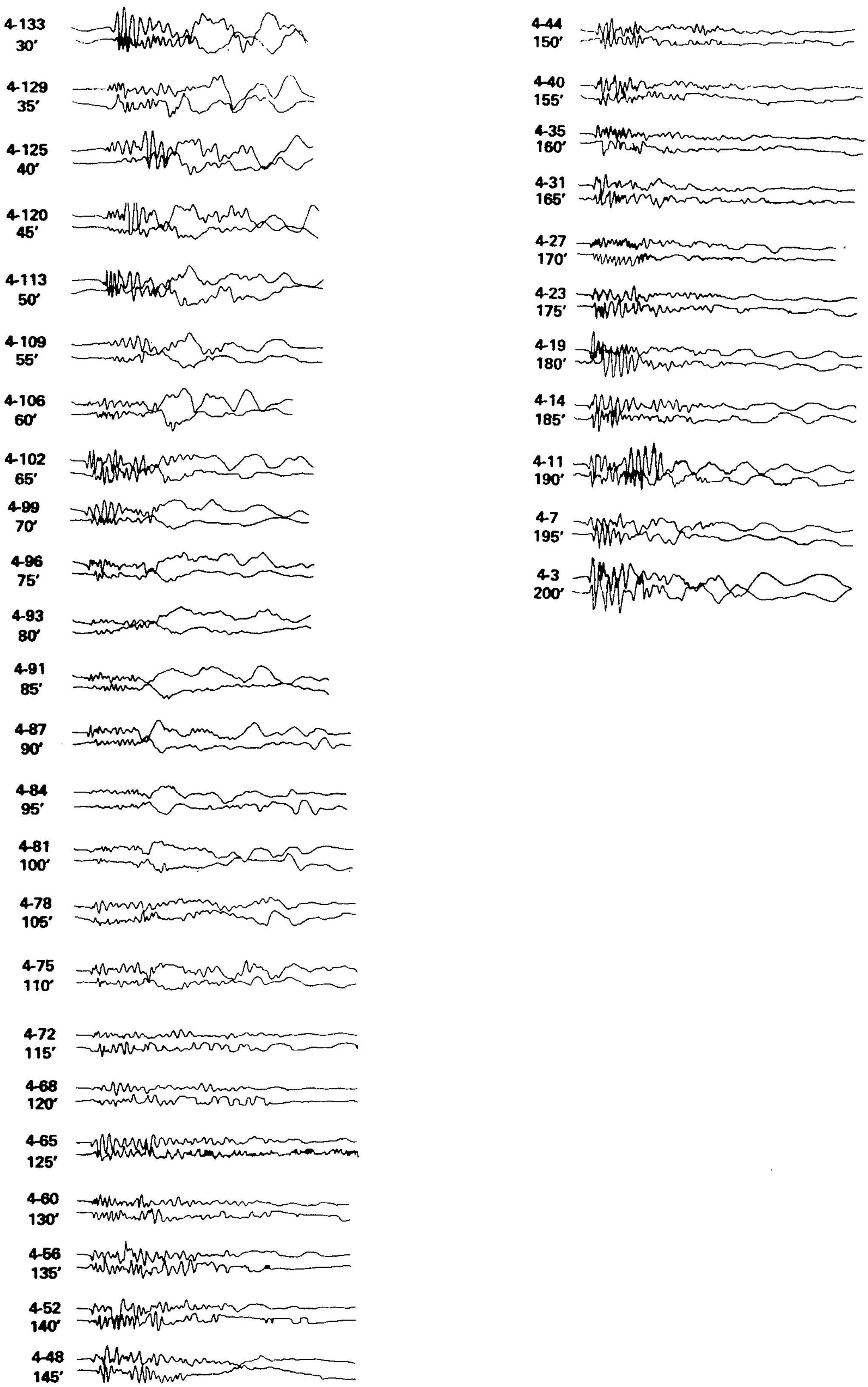

Project:	SONGS 2 & 3	WELL NO. 3 V → Q WAVEFORM TRACE	Fig.
Project No.	41130I		D-9

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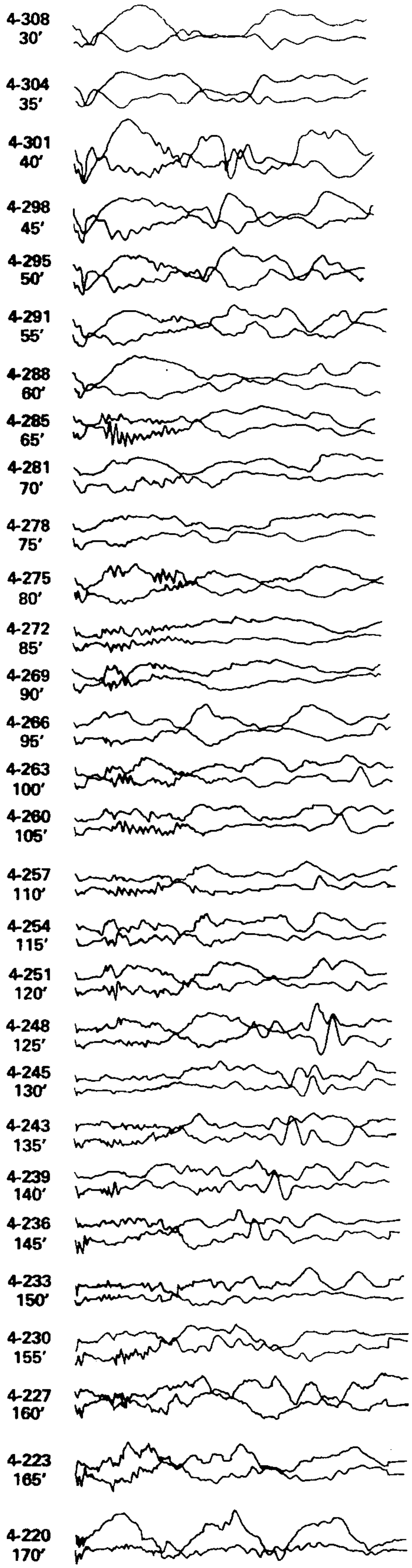
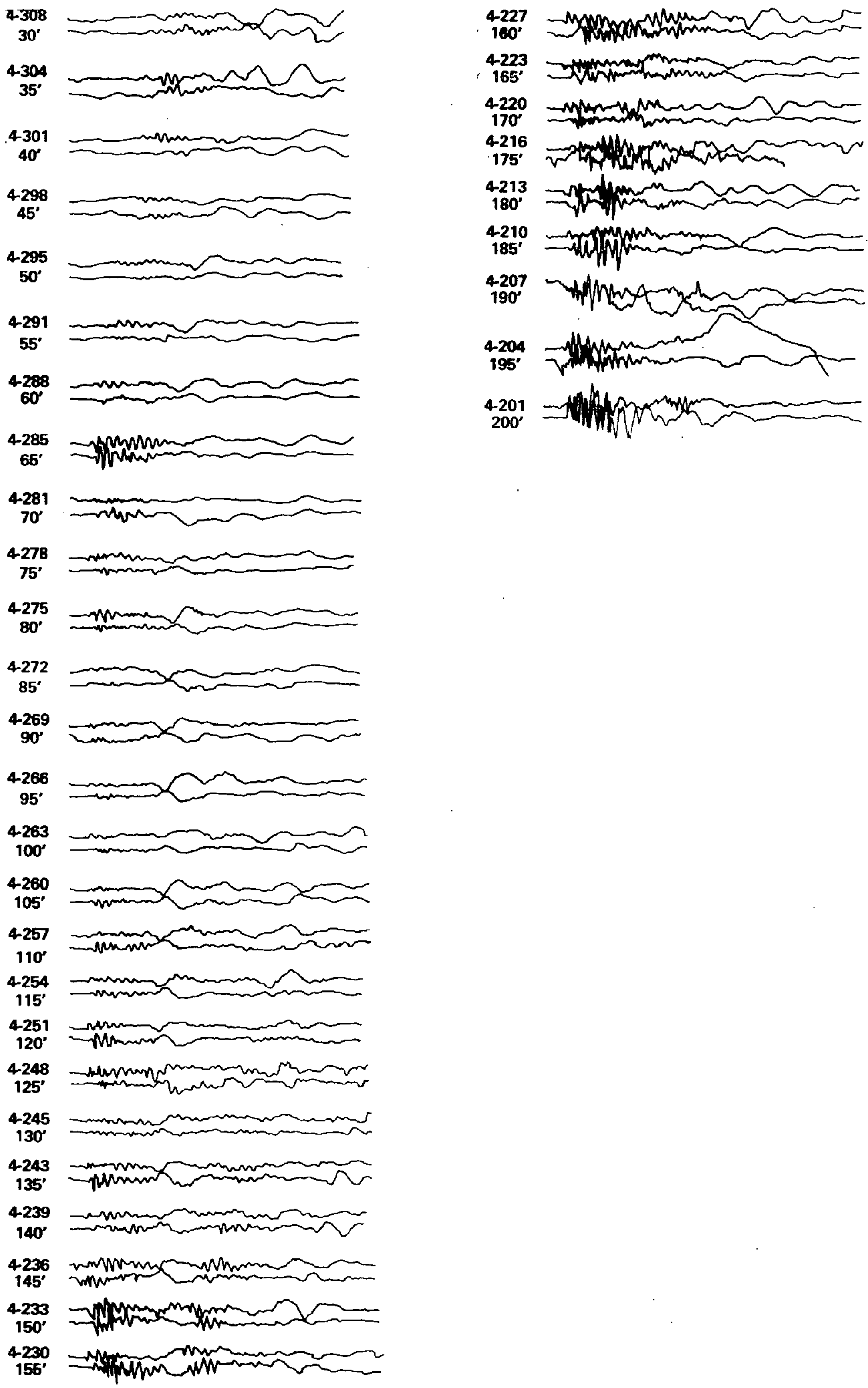


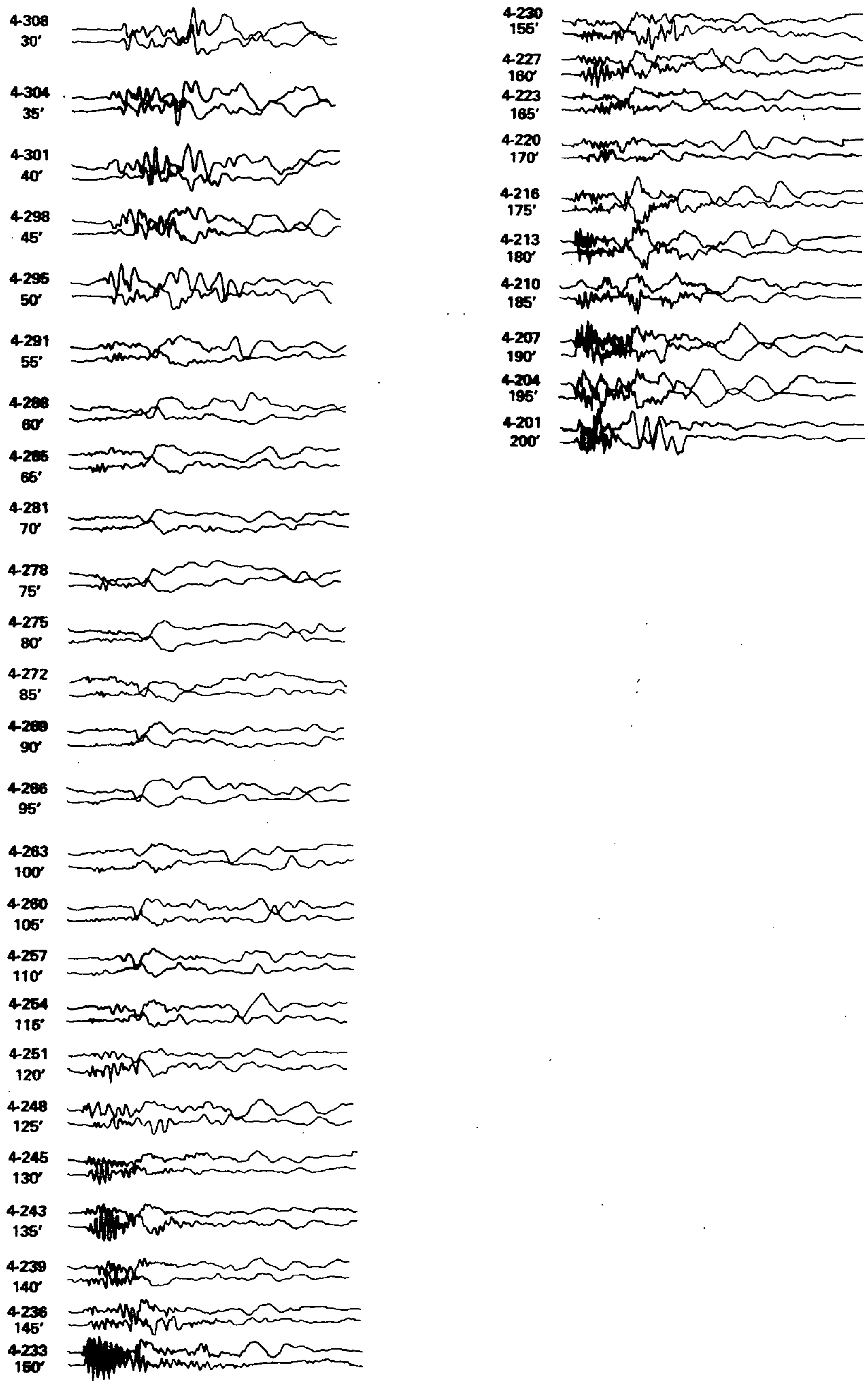
Project:	SONGS 2 & 3	WELL NO. 3 Q → T WAVEFORM TRACE	Fig.
Project No.	411301		D-10

WOODWARD–CLYDE CONSULTANTS



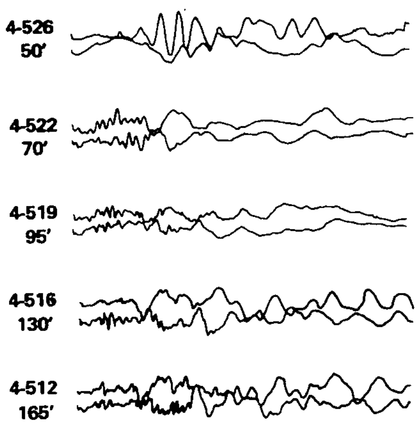
Project:	SONGS 2 & 3	WELL NO. 3 Q → U WAVEFORM TRACE	Fig.
Project No.	411301		D-11

WOODWARD—CLYDE CONSULTANTS



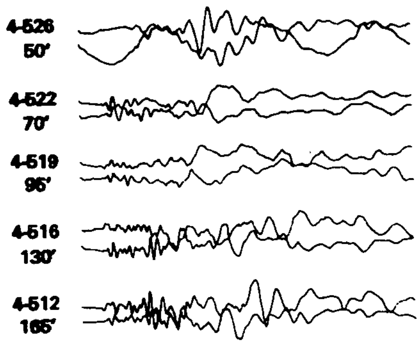
Project: SONGS 2 & 3 Project No. 41130I	WELL NO. 3 Q → V WAVEFORM TRACE	Fig. D-12

WOODWARD–CLYDE CONSULTANTS



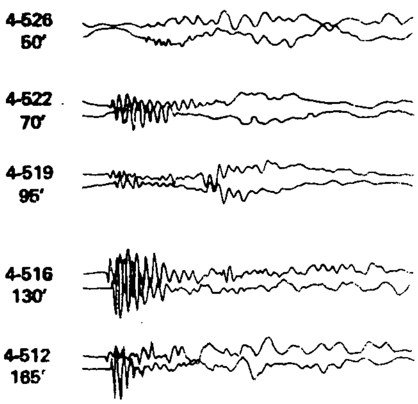
Project: SONGS 2 & 3	Project No. 411301	WELL NO. 3 T → U WAVEFORM TRACE	Fig. D-13

WOODWARD–CLYDE CONSULTANTS



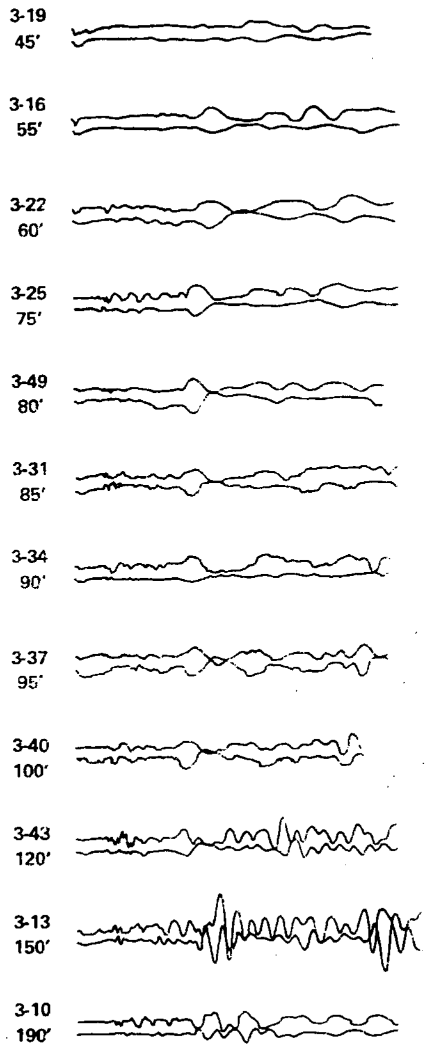
Project:	SONGS 2 & 3	WELL NO. 3 T → Q WAVEFORM TRACE	Fig. D-14
Project No.	411301		

WOODWARD—CLYDE CONSULTANTS



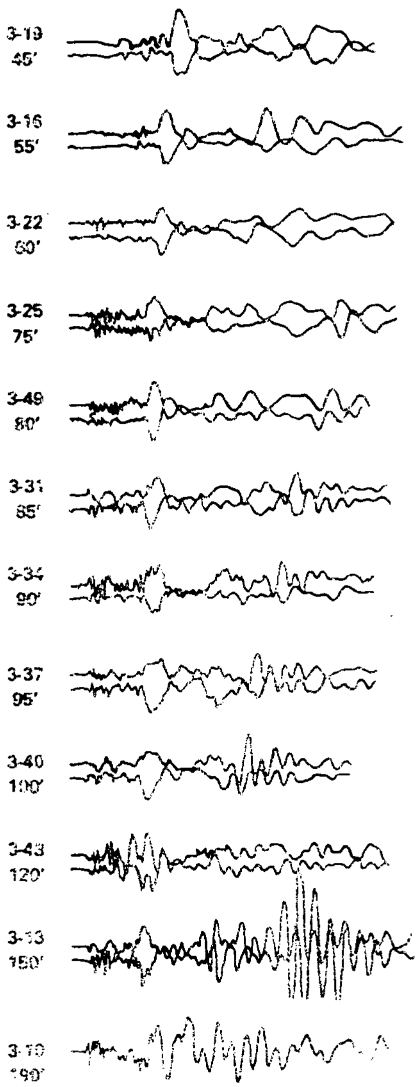
Project:	SONGS 2 & 3	WELL NO. 3 T → V WAVEFORM TRACE	Fig.
Project No.	411301		D-15

WOODWARD—CLYDE CONSULTANTS



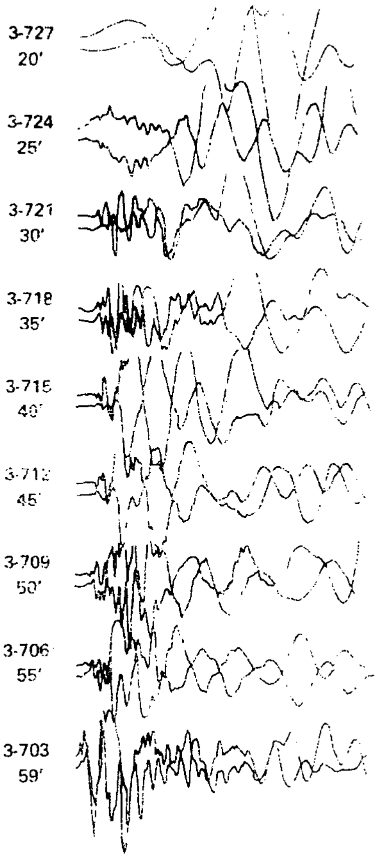
Project:	SONGS 2 & 3	WELL NO. 3 U → Q WAVEFORM TRACE	Fig.
Project No.	411301		D-16

WOODWARD – CLYDE CONSULTANTS

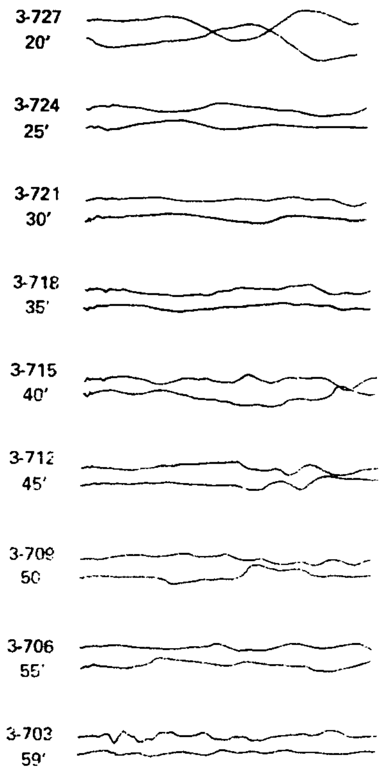


Project:	SONGS 2 & 3	WELL NO. 3 U → V WAVEFORM TRACE	Fig.
Project No.	411301		D-17

WOODWARD – CLYDE CONSULTANTS

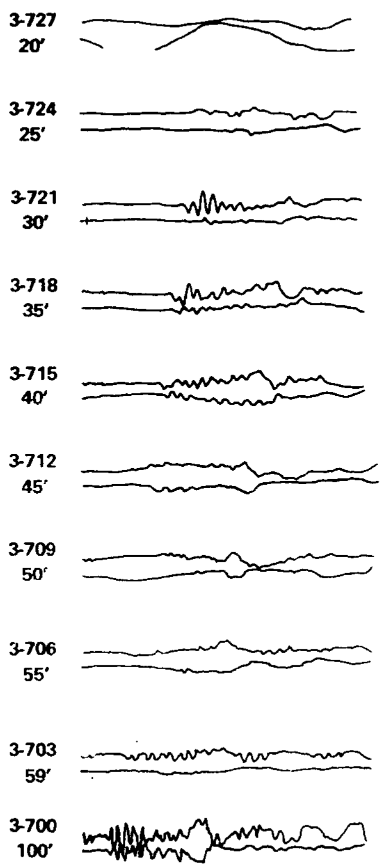


Project:	SONGS 2 & 3	WELL NO. 3 Q→C WAVEFORM TRACE	Fig.
Project No.	411301		D-18



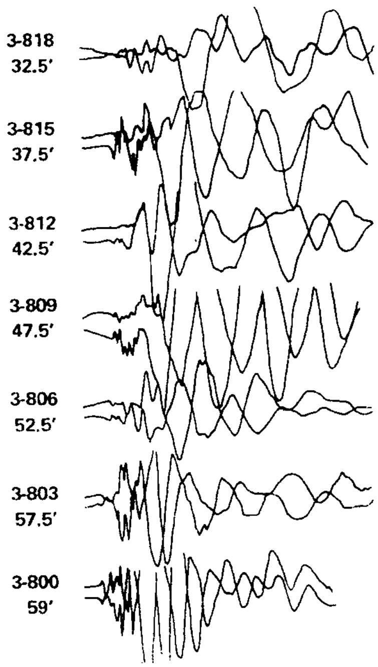
Project:	SONGS 2 & 3	WELL NO. 3 Q → E WAVEFORM TRACE	Fig.
Project No.	41130I		D-19

WOODWARD—CLYDE CONSULTANTS



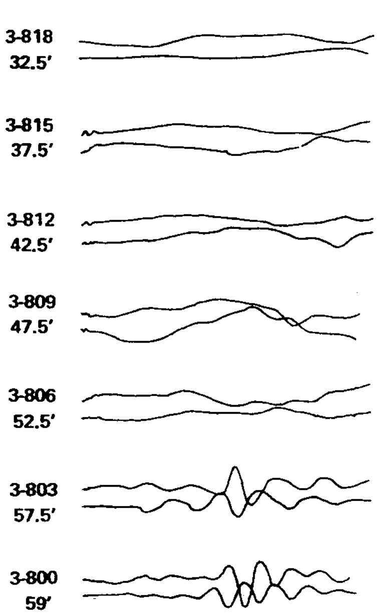
Project:	SONGS 2 & 3	WELL NO. 3 Q → T WAVEFORM TRACE	Fig.
Project No.	411301		D-20

WOODWARD—CLYDE CONSULTANTS



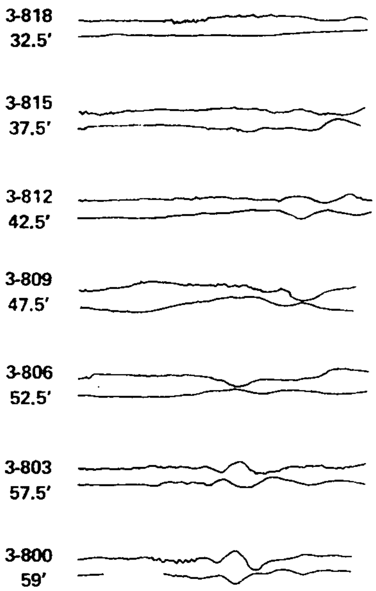
Project:	SONGS 2 & 3	WELL NO. 3 Q → C WAVEFORM TRACE	Fig.
Project No.	411301		D-21

WOODWARD – CLYDE CONSULTANTS



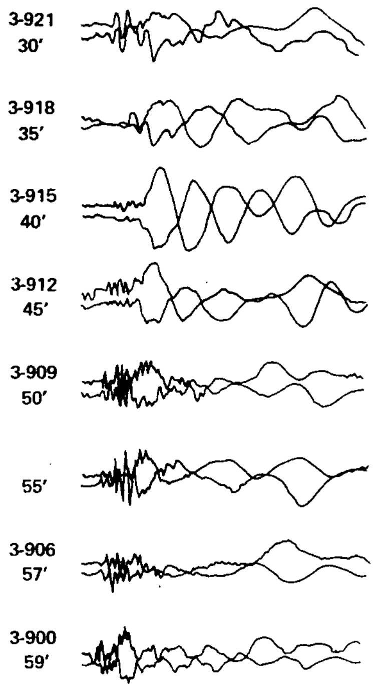
Project:	SONGS 2 & 3	WELL NO. 3 Q → E WAVEFORM TRACE	Fig.
Project No.	411301		D-22

WOODWARD – CLYDE CONSULTANTS



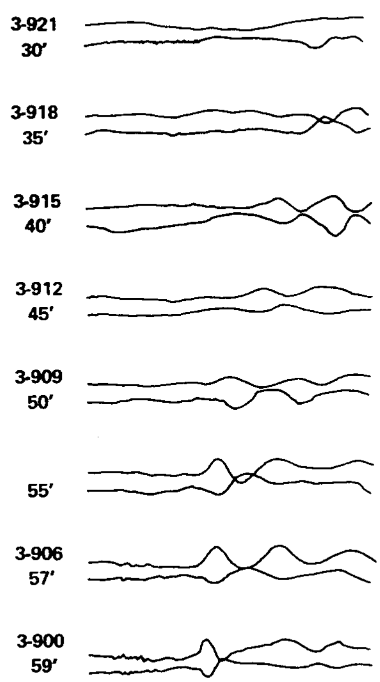
Project:	SONGS 2 & 3	WELL NO. 3 Q → U WAVEFORM TRACE	Fig.
Project No.	411301		D-23

WOODWARD–CLYDE CONSULTANTS

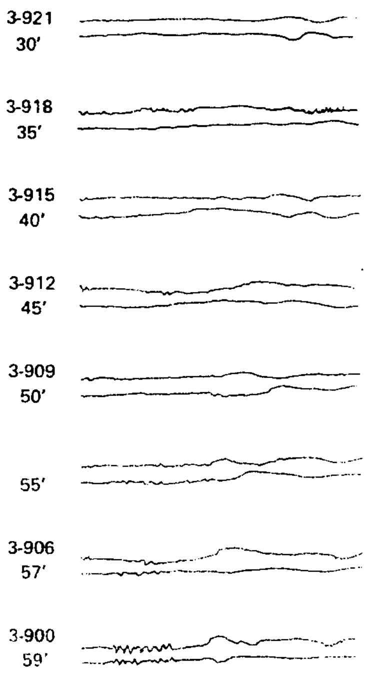


Project:	SONGS 2 & 3	WELL NO. 3 U → E WAVEFORM TRACE	Fig.
Project No.	411301		D-24

WOODWARD—CLYDE CONSULTANTS

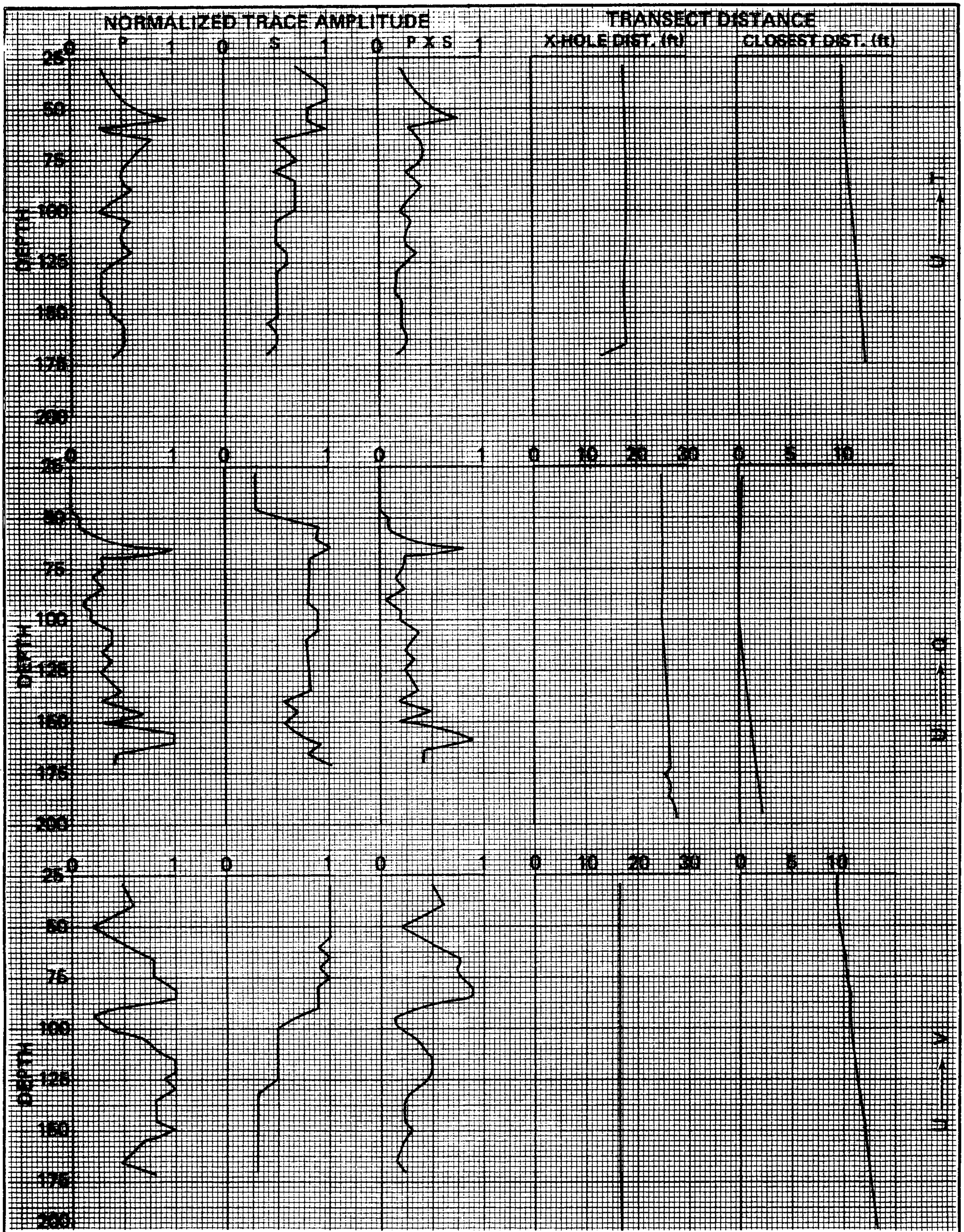


Project:	SONGS 2 & 3	WELL NO. 3 U → C WAVEFORM TRACE	Fig. D-25
Project No.	411301		



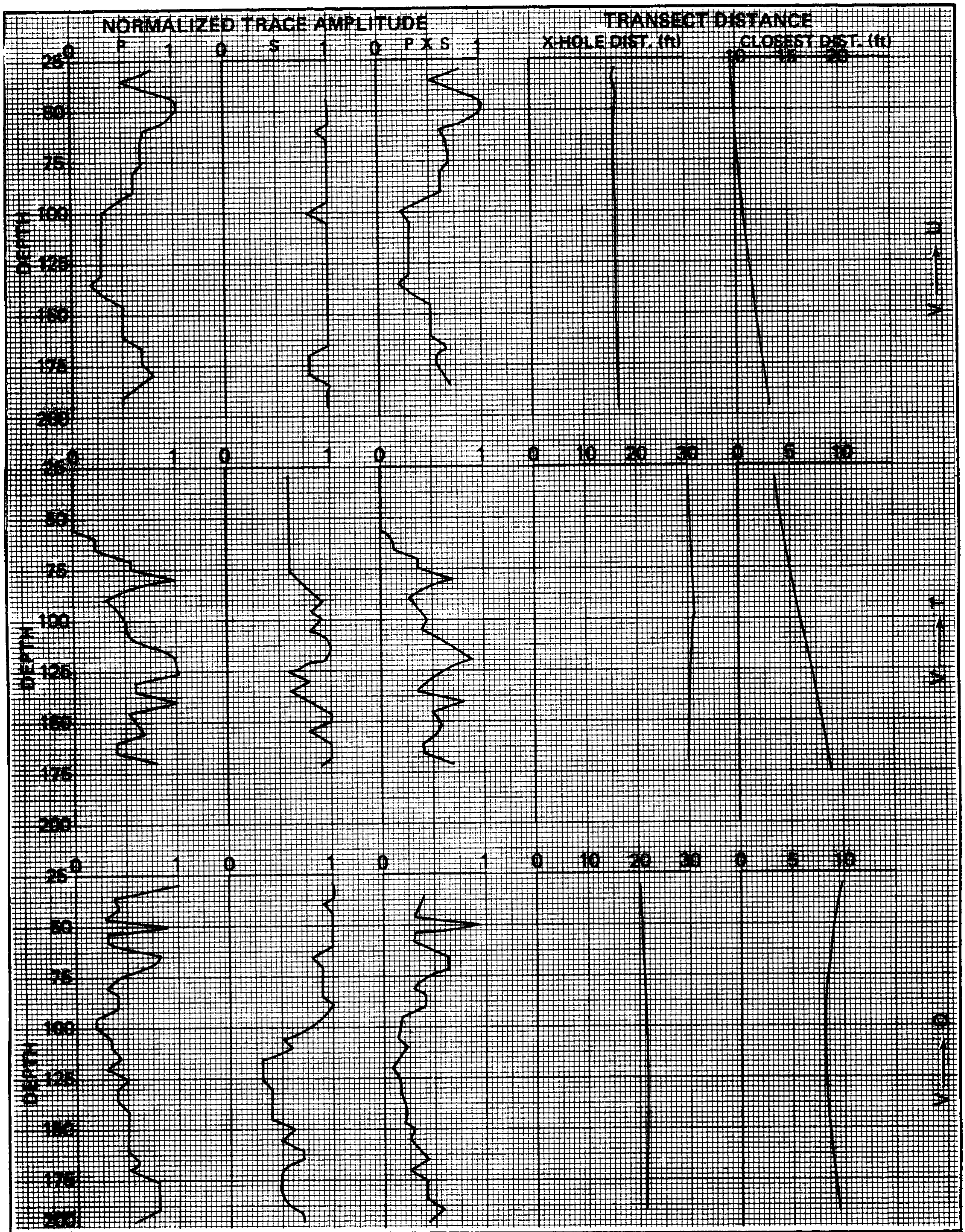
Project:	SONGS 2 & 3	WELL NO. 3 U → Q WAVEFORM TRACE	Fig.
Project No.	41130I		D-26

WOODWARD—CLYDE CONSULTANTS



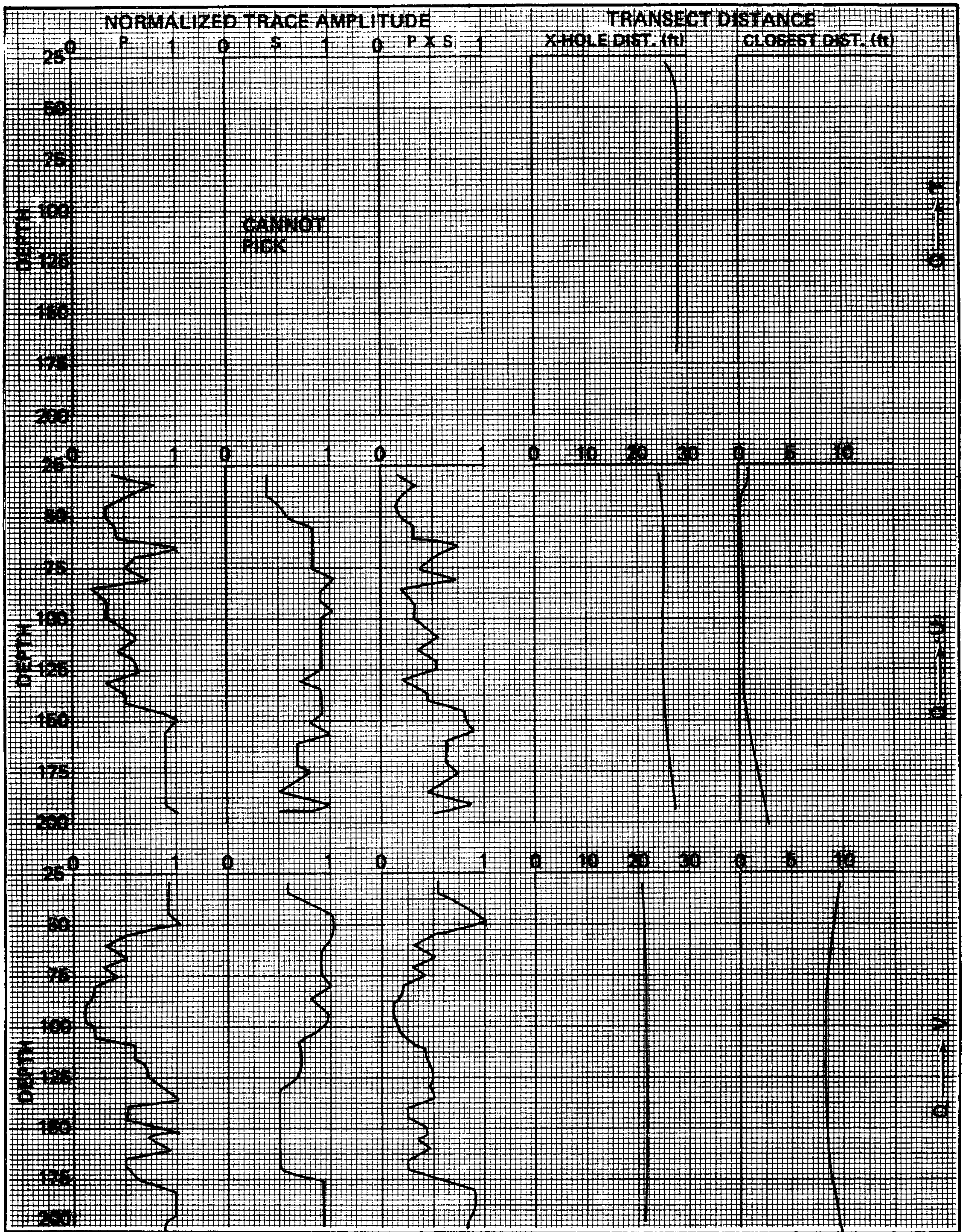
Project:	SONGS 2&3	WAVEFORM TRACE DATA SUMMARY FOR WELL NO. 3 SOURCE U AND RECEIVER T, Q, V	Fig.
Project No.	411301		D-27

WOODWARD—CLYDE CONSULTANTS



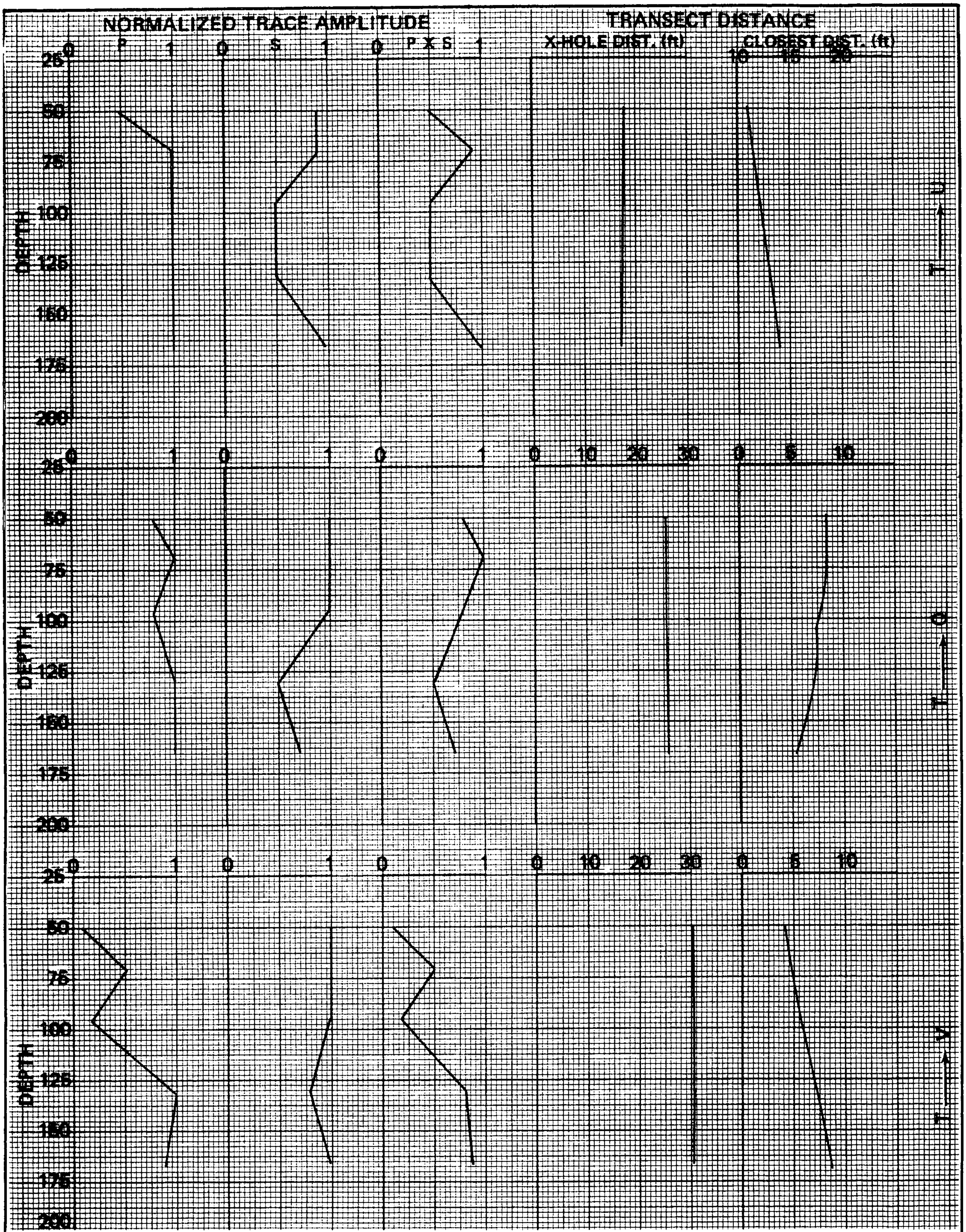
Project:	SONGS 2&3	WAVEFORM TRACE DATA SUMMARY FOR	Fig.
Project No.	41130I	WELL NO. 3 SOURCE V AND RECEIVER U, T, Q	D-28

WOODWARD – CLYDE CONSULTANTS



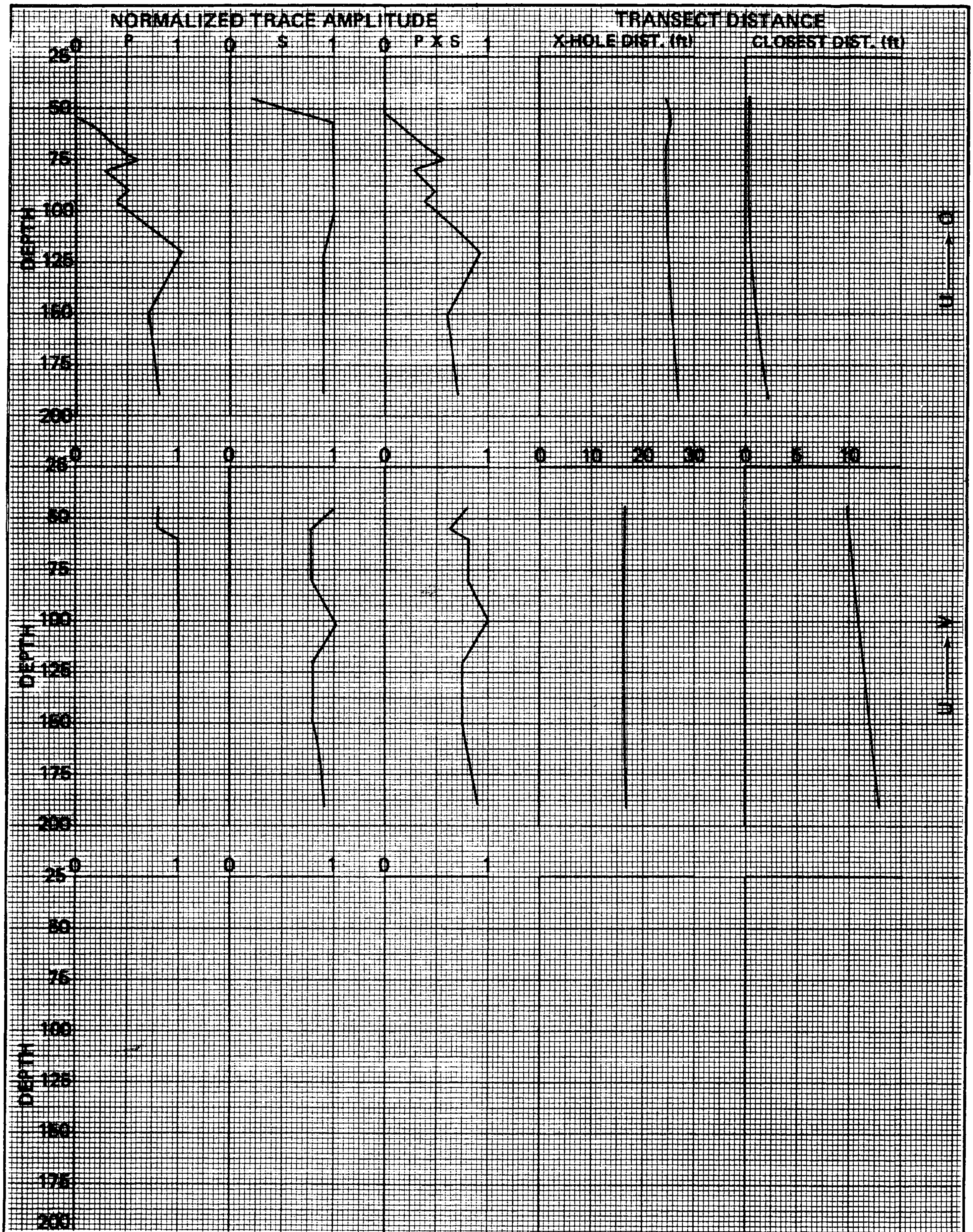
Project:	SONGS 2&3	WAVEFORM TRACE DATA SUMMARY FOR WELL NO. 3 SOURCE Q AND RECEIVER T, U, V	Fig. D-29
Project No.	411301		

WOODWARD – CLYDE CONSULTANTS



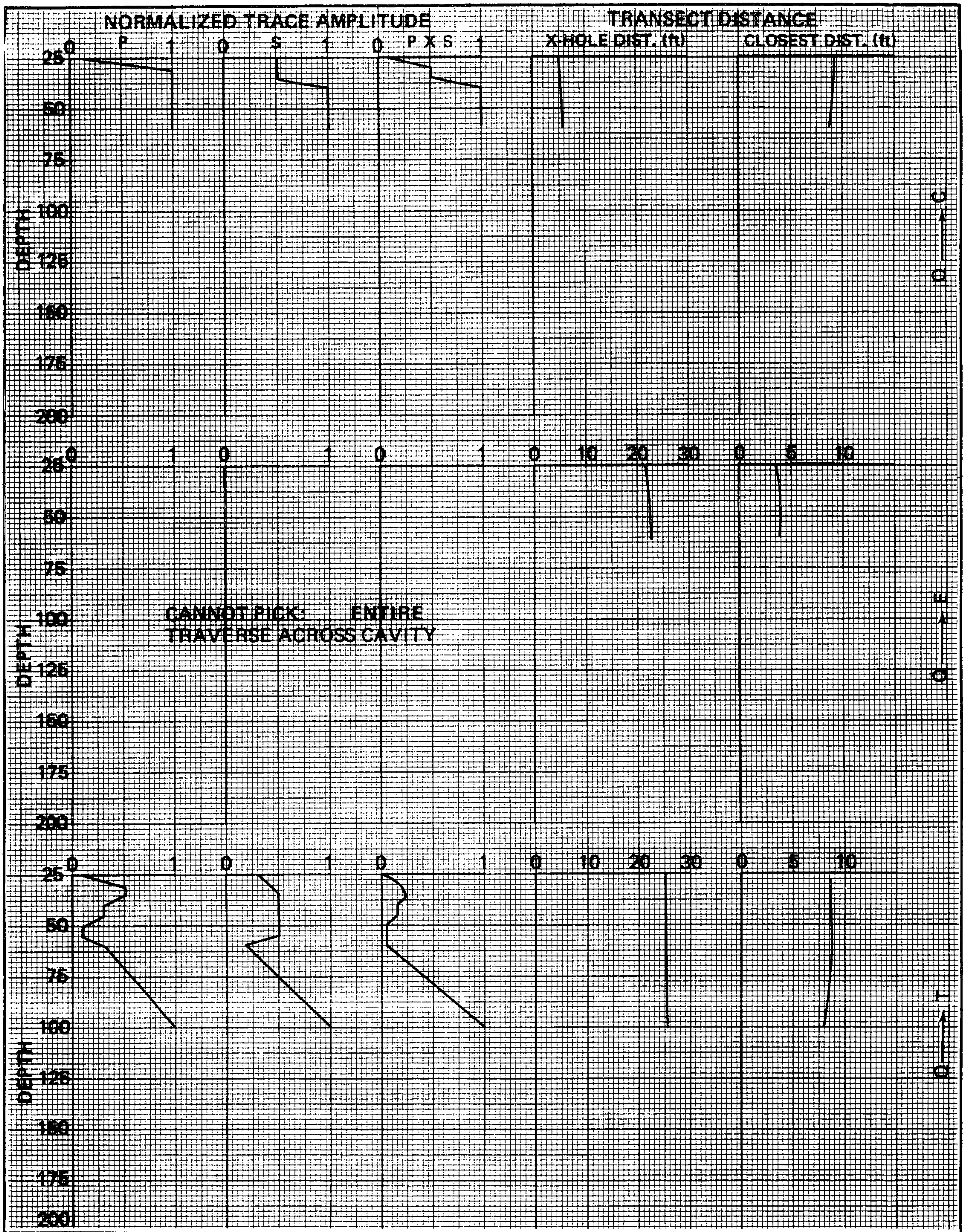
Project:	SONGS 2&3	WAVEFORM TRACE DATA SUMMARY FOR WELL NO. 3 SOURCE T AND RECEIVER U, Q, V	Fig.
Project No.	41130I		D-30

WOODWARD—CLYDE CONSULTANTS



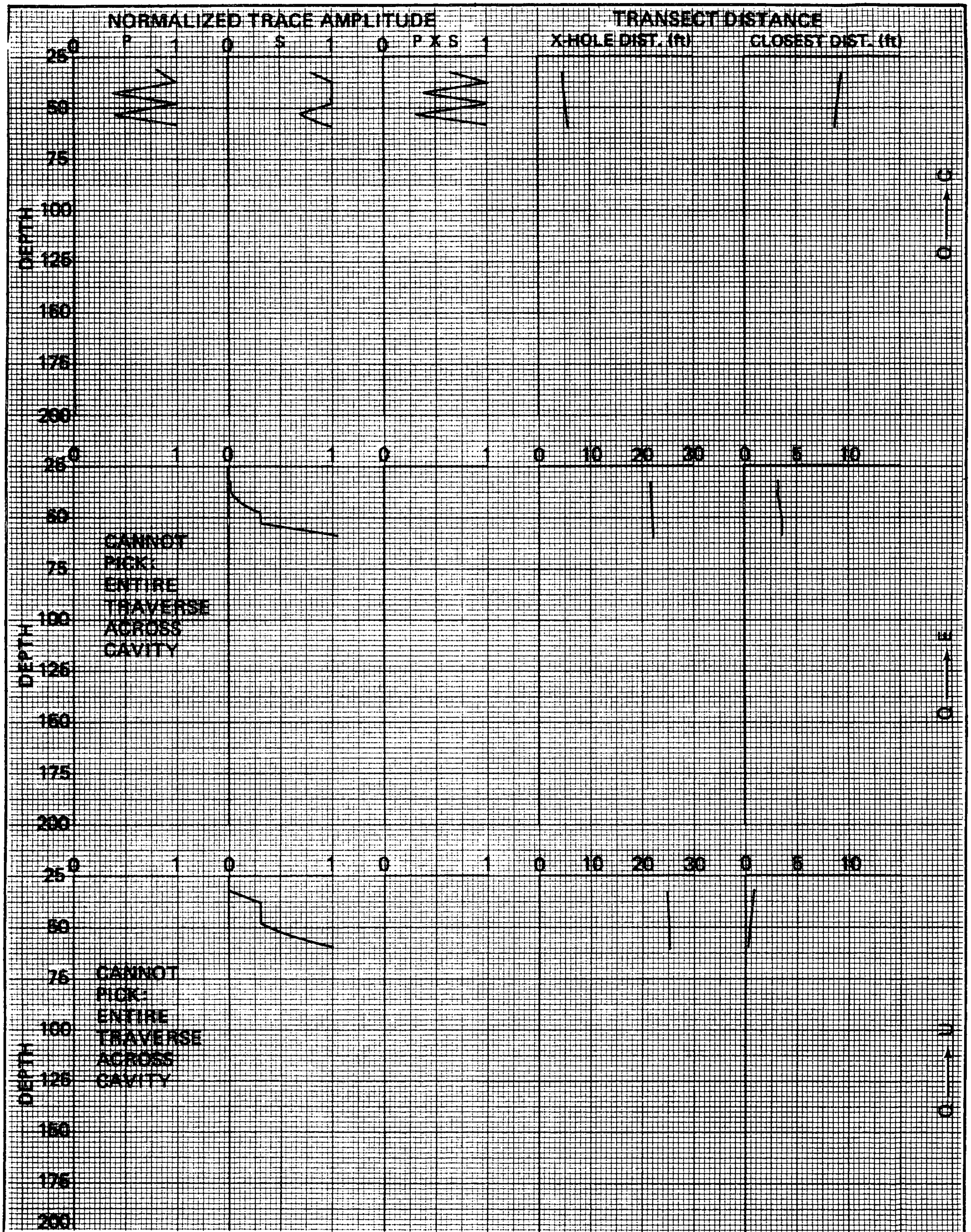
Project:	SONGS 2&3	WAVEFORM TRACE DATA SUMMARY FOR WELL NO. 3 SOURCE U AND RECEIVER Q, V	Fig.
Project No.	411301		D-31

WOODWARD—CLYDE CONSULTANTS



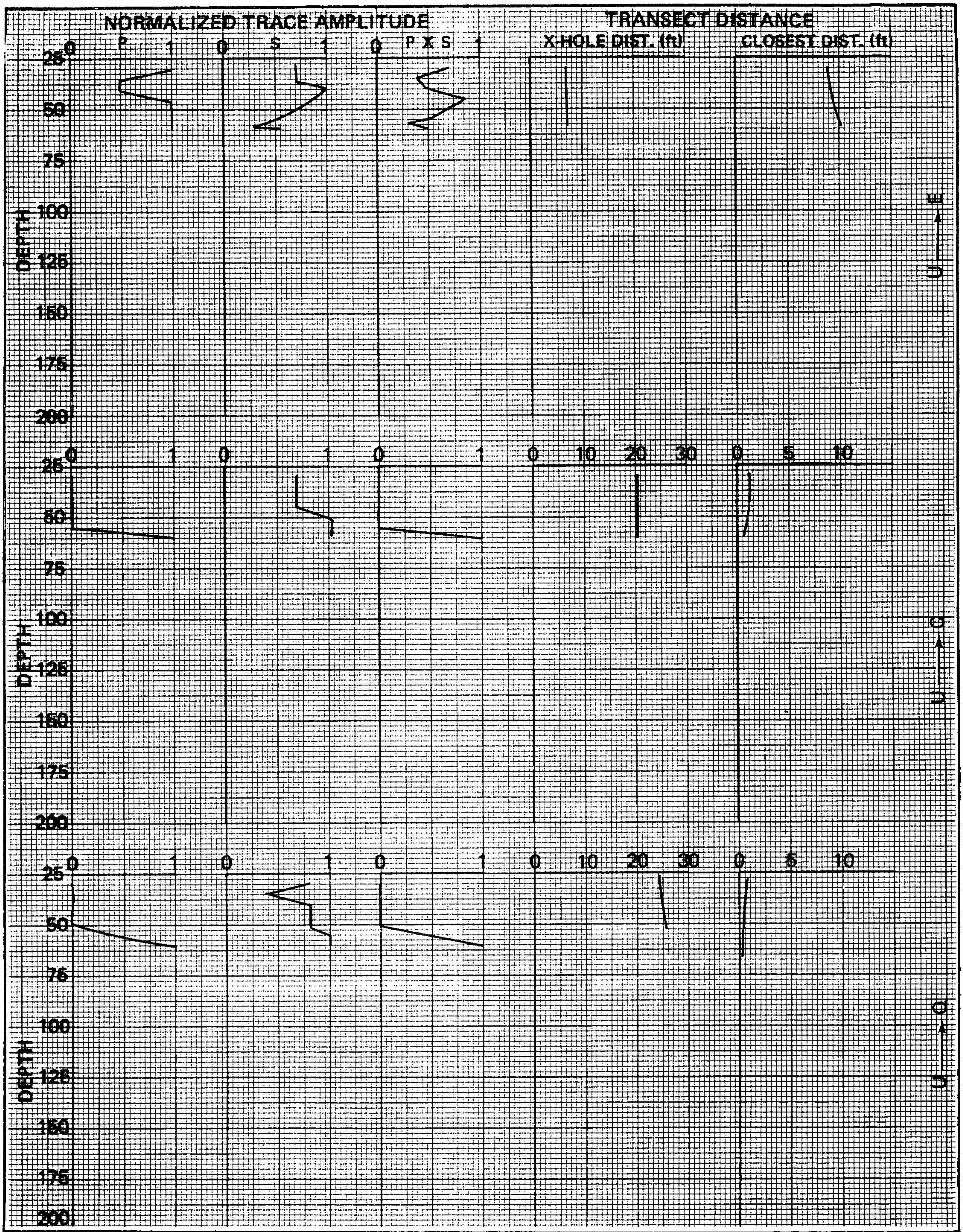
Project:	SONGS 2&3	WAVEFORM TRACE DATA SUMMARY FOR	Fig.
Project No.	41130I	WELL NO. 3 SOURCE Q AND RECEIVER C, E, T	D-32

WOODWARD – CLYDE CONSULTANTS



Project:	SONGS 2&3	WAVEFORM TRACE DATA SUMMARY FOR WELL NO. 3 SOURCE Q AND RECEIVER C, E, U	Fig.
Project No.	411301		D-33

WOODWARD—CLYDE CONSULTANTS



Project:	SONGS 2&3	WAVEFORM TRACE DATA SUMMARY FOR WELL NO. 3 SOURCE U AND RECEIVER E, C, Q	Fig.
Project No.	411301		D-34

WOODWARD—CLYDE CONSULTANTS

APPENDIX E

CROSSHOLE GEOPHYSICAL DATA AND INTERPRETATION FOR WELL 4

E-1 INTRODUCTION

The crosshole method was used to provide closure on a total of eight boreholes at Well 4 (Figure E-1). All boreholes are referenced to a surface elevation of 26.5 feet. The last set of measurements was made after the drilling of borings 4B-7 and 4B-8 at a lower ground surface elevation, and had to be corrected back to 26.5 feet. The sections which follow describe the coverage obtained, present selected waveform data as defined in Appendix D, and present the results of applying the detection criteria described in Appendix D.

E-2 COVERAGE

Table E-1 presents a summary of figures of the processed crosshole data used for the final analysis of Well 4. A total of 15 configurations provide good coverage around the well.

Figures E-2 through E-6 illustrate the crosshole coverage at various depths. The following conclusions can be drawn:

1. The coverage at a depth of 40 feet (Figure E-2) is excellent on the east side of the well with numerous redundant paths. The coverage to the south, west and most of the north side of the well is good, although limited in redundancy. A small gap of a few feet occurs on the north side between two subparallel reversed paths. The small size of the gap and convergence of these paths towards the well means that any cavity of significant size would be detected as such on at least one path, with a graze indication on the others; and such were not noted.

2. The coverage at 70 feet (Figure E-3) is good everywhere except for a sector to the north of the well which has adequate coverage. At this depth, the gap is at its maximum size of about 5 feet. Again, any significant cavity should still be detectable as such.

3. The coverage at 100, 150 and 200 feet (Figure E-4 through E-6) is good to excellent. Numerous and redundant paths surround the well at these depths.

E-3 NEAR-SURFACE DISTURBANCES

The structure on the west side of the well goes to a depth of 32 feet and may, therefore, be of concern for nearby paths above 40 feet. The paths which may show evidence of these effects are those between any borehole and boring 4B-7 or 4B-8, and to a lesser extent, between either boring 4B-5 or 4B-1 and either 4B-6 or 4B-3. Loose sand, backfill concrete and grout, which may influence the data, are present in all of the boreholes to depths of about 35 feet. Because excavations approaching this depth were inspected by direct observation during the well reopening operations, crosshole data interpretation is only necessary below a depth of 40 feet.

E-4 PROCESSED WAVEFORM RECORDS AND PERTINENT DATA

The waveform records processed as indicated in Appendix C are presented in Figures E-7 through E-33 and are listed in Table E-1. The records are presented as a function of depth and arranged by source configuration. The waveform data quality is good to excellent except for some of the records in Figures E-16 through E-21. The latter records are adequate, although somewhat obscured by noise at the beginning of each record.

Figures E-34 through E-43 present waveform data summaries pertinent to the interpretation of the waveform records as discussed in Appendix D. As listed in Table E-1, the figure

showing the normalized P-wave and S-wave amplitudes as well as their product are grouped by source configuration. The crosshole distance and closest distance to the well are also presented.

It was noted during the data processing that the shear wave velocities and wave forms in all Well 4 transects were essentially unaffected indicating no degredation of properties or presence of significant cavities associated with this well.

E-5 DATA INTERPRETATION

The data presented in Figures E-3 through E-43 were interpreted in accordance with the criteria developed in Appendix D. A summary of the results of this interpretation is presented on Table E-2 and Figures E-44 through E-48. All transects except three indicate native soil. Figure E-44 for a depth of 40 to 45 feet indicates possible cavity on the 5-7, (7-5) and 8-7 (7-8) transects. This interpretation is likely influenced by loose soil along the transect due to caving caused during the well reopening operation (Figure B-4, Appendix B), the grout present just above these depths in Borings 5 , 7, and 8, and the fact that the transect is intersected by or is very close to the wellbore. For these reasons, and because measurements made just below this depth (i.e., 50 feet) indicate native soil, the interpretation is that cavity does not exist at the 40 to 45 foot depth. The other transects giving an indication other than native are 2-5 (5-2) at 180 feet and 2-1 (1-2) at 175 feet. These indicate a possible graze. The 3-2 (2-3) transect bounding the well to the south shows native sand at all depths (40 to 200 feet) while the 2-1 (1-2) and 2-5 (5-2) transects bounding the well further south indicate possible graze at a depth of 175 to 180 feet. For this reason and because the cavity must be connected to the well, the crosshole results of 2-1 (1-2) and 2-5 (5-2) transects at 175 to 180 feet are likely due to poor casing coupling at this depth in Boring 4-2 yielding conservative results and are not considered applicable.

TABLE E-1

SUMMARY OF APPENDIX E FIGURES

Figure No.	Description
E-1	Well 4 Location of Drill Holes
E-2	Well 4 Location of Drill Holes and Crosshole Transects at 40-foot Depth
E-3	Well 4 Location of Drill Holes and Crosshole Transects at 70-foot Depth
E-4	Well 4 Location of Drill Holes and Crosshole Transects at 100-foot Depth
E-5	Well 4 Location of Drill Holes and Crosshole Transects at 150-foot Depth
E-6	Well 4 Location of Drill Holes and Crosshole Transects at 200-foot Depth
E-7 to E-33	Well 4 Waveform Trace Figures

	Source	Receiver
E-7 to E-9	1	2,3,4
E-10 to E-12	3	1,2,4
E-13 to E-15	2	1,3,4
E-16 to E-17	8	5,7
E-18 to E-19	7	5,8
E-20 to E-21	5	7,8
E-22 to E-24	6	5,3,4
E-25 to E-27	5	1,2,6
E-28 to E-30	2	1,5,6
E-31 to E-33	2	1,5,4

E-34 to E-43 Well 4 Waveform Data Summary Figures

	Source	Receiver
E-34	1	2,3,4
E-35	3	1,2,4
E-36	2	1,3,4
E-37	8	5,7
E-38	7	5,8
E-39	5	7,8
E-40	6	5,3,4
E-41	5	1,2,6
E-42	2	1,5,6
E-43	2	1,5,4

Figure No.	Description
E-44 to E-48	Well 4 Interpreted Transect Summary Figures
	Depth
E-44	40 feet
E-45	70 feet
E-46	100 feet
E-47	150 feet
E-48	180 feet

TABLE E-2

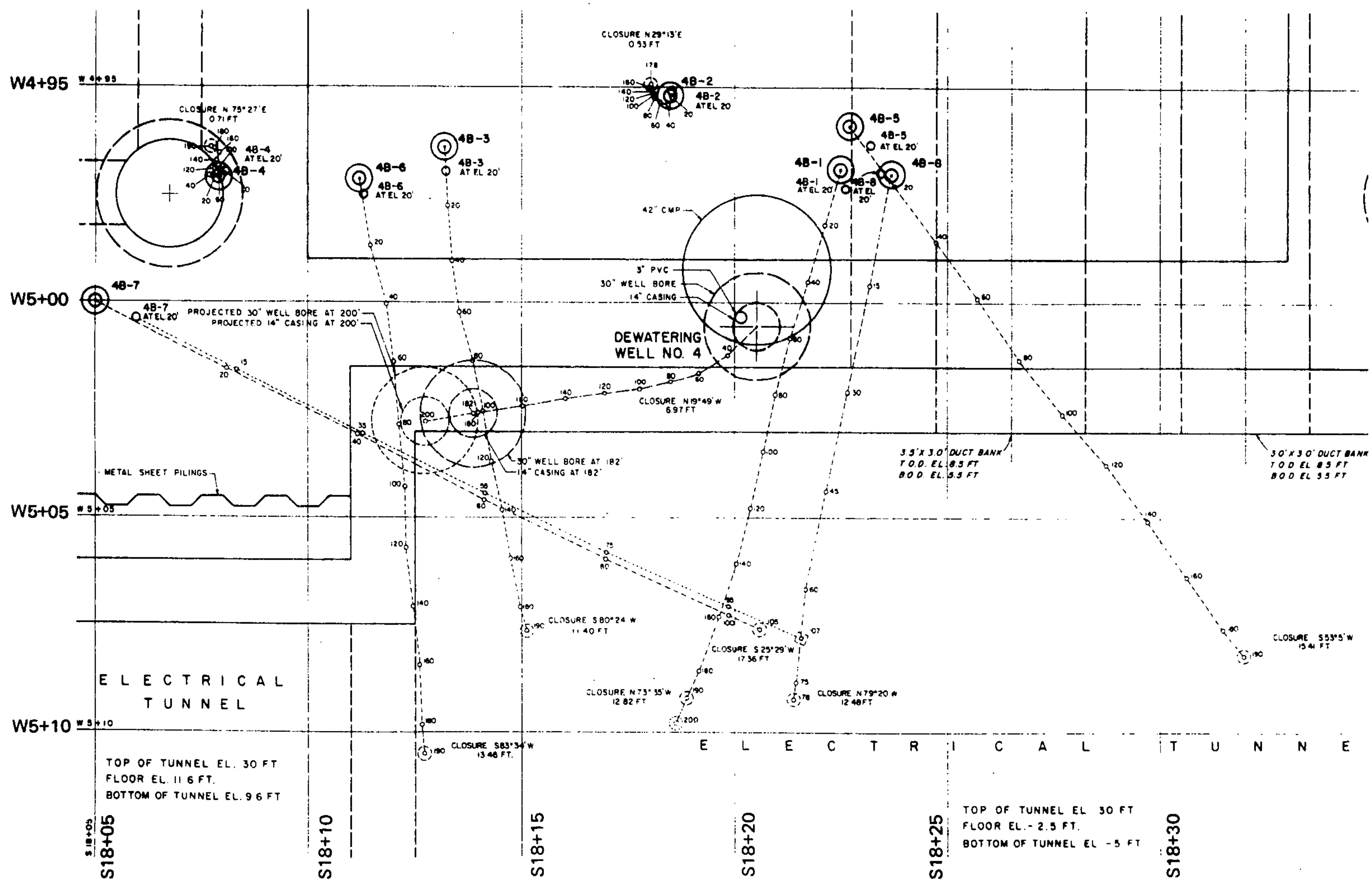
SUMMARY OF PxS TRACE AMPLITUDE INTERPRETATION FOR WELL 4

Transect	Depth Interval Fitting Criteria PxS=0	0<PxS<0.1	0.1<PxS<0.2	Reverse Transect	Depth Interval Fitting Criteria PxS=0	0<PxS<0.1	0.1<PxS<0.2	Interpretation
5-2	--	105-115' 175'	95-100' 125', 185'	2-5	--	180'	45', 130' 150'	Possible graze at 175 to 180'.
				2-5	--	--	--	
5-1	--	--	--	None				Native at all depths.*
6-4	--	--	--	None				Native at all depths.*
6-3	--	--	--	None				Native at all depths.*
6-5	--	--	55', 90-100' 115', 175'	5-6	--	--	45' 105-115'	Native at all depths.
5-8	--	--	--	8-5	--	--	--	Native to depth of Hole 8.
5-7	40'	--	--	7-5	40'	--	--	Possible cavity at 40'; see Section E-5.
8-7	--	--	40-45'	7-8	40-45'	--	--	Possible cavity at 40-45'; see Section E-5
2-4	--	--	135-190'	None				Native at all depths.*
	--	--	--					
2-3	--	--	--	3-2	--	--	--	Native at all depths.
2-1	--	175-190'	80-100' 155'	1-2	--	--	95-115', 125' 135-160', 170' 175'	Possible graze at 175'.
	--	--	180-195'					
	--	--	--					

Table E-2
Page 2

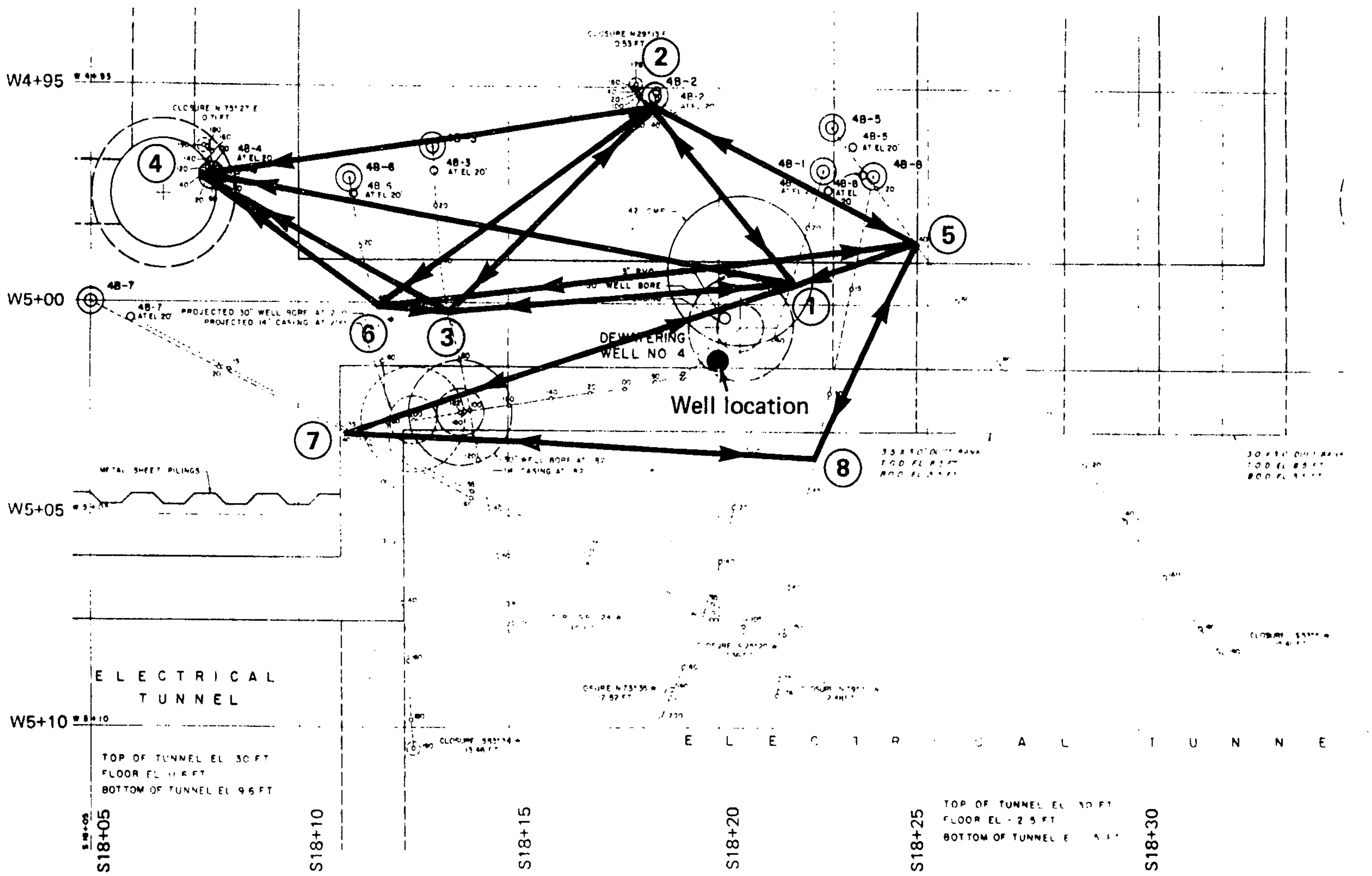
	Depth Interval Fitting Criteria				Depth Interval Fitting Criteria			
Transect	PxS=0	0<PxS<0.1	0.1<PxS<0.2	Reverse Transect	PxS=0	0<PxS<0.1	0.1<PxS<0.2	Interpretation
3-4	--	--	--	None				Native at all depths.*
3-1	--	95', 105'	80', 90' 100'	1-3	--	--	--	Native at all depths.
1-4	--	--	--	None				Native at all depths.*
2-6	--	--	40'	None				Native at all depths.*

* No reverse leg for strict application of criteria



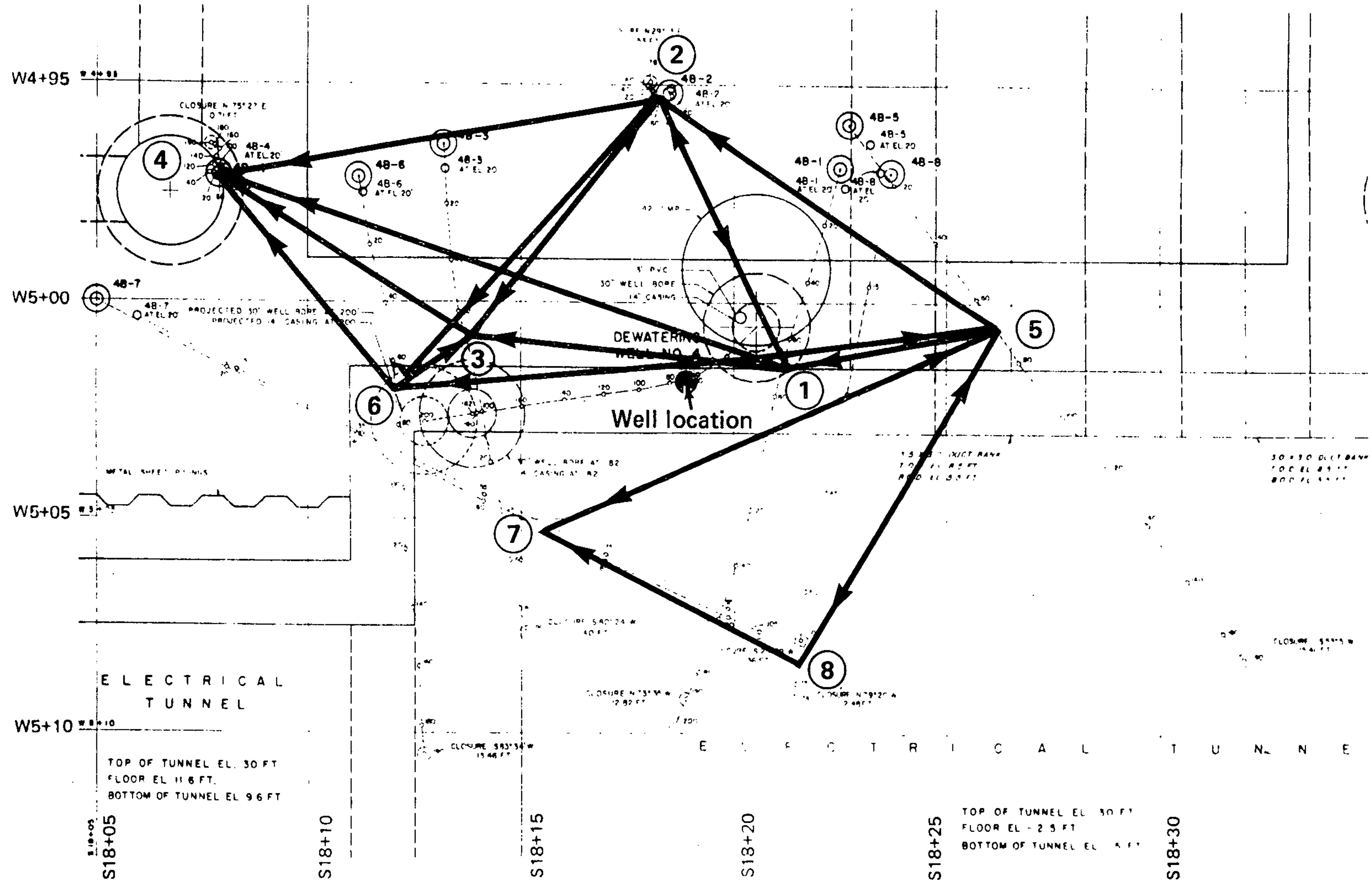
Project:	SONGS 2 & 3	DEWATERING WELL NO. 4 LOCATION OF DRILL HOLES	Fig. E-1
Project No.	411301		

WOODWARD-CLYDE CONSULTANTS



(1) Indicates the end point boring for the transect at a depth of 40 ft.

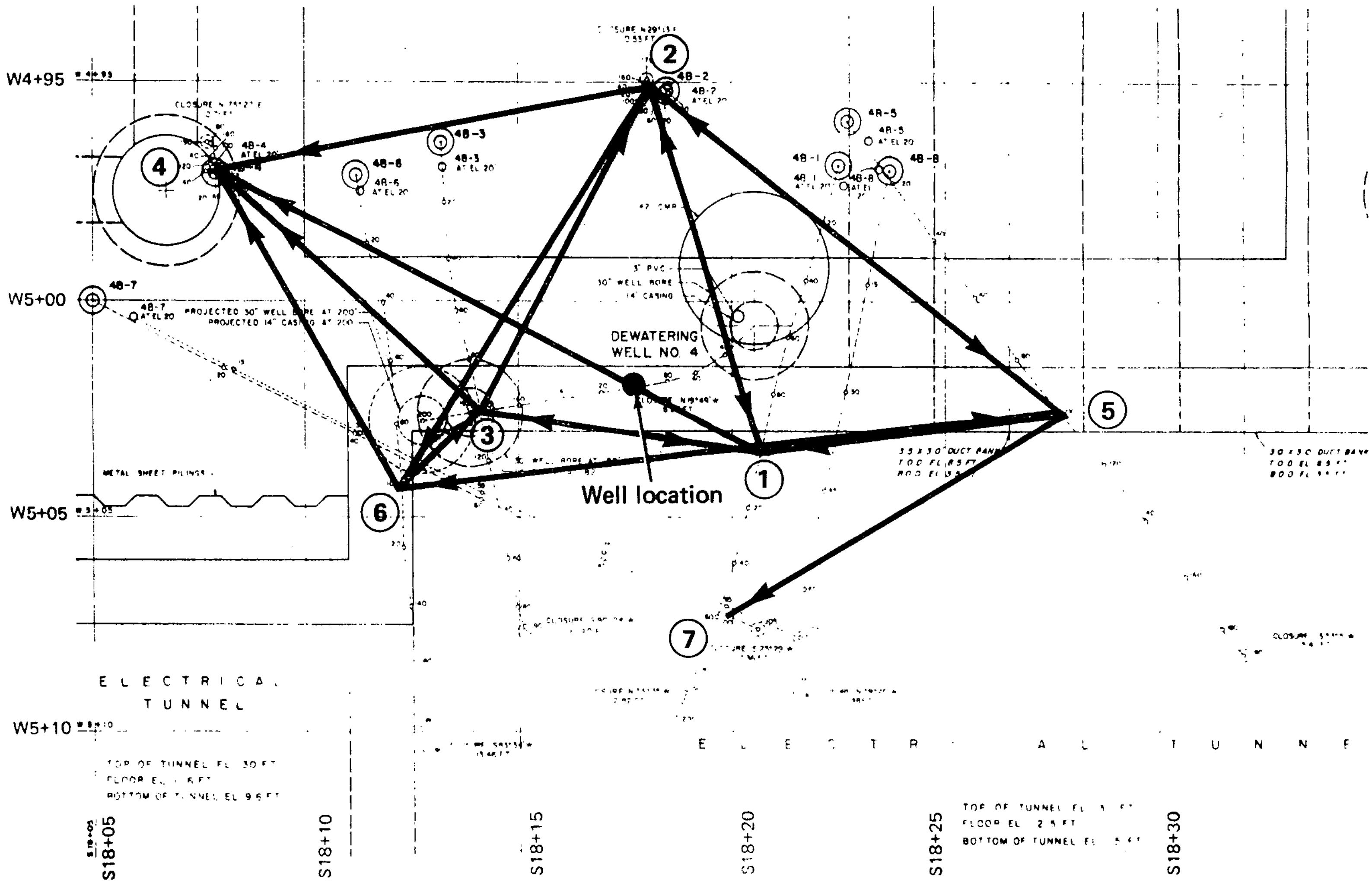
Project:	SONGS 2 & 3	DEWATERING WELL NO. 4 LOCATION OF DRILL HOLES AND CROSSHOLE TRANSECTS AT 40' DEPTH	Fig.
Project No	41130I		E-2



(1) Indicates the end point boring for the transect at a depth of 70 ft.

Project:	SONGS 2 & 3	DEWATERING WELL NO. 4 LOCATION OF DRILL HOLES AND CROSSHOLE TRANSECTS AT 70 FT. DEPTH	Fig E-3
Project No	41130I		

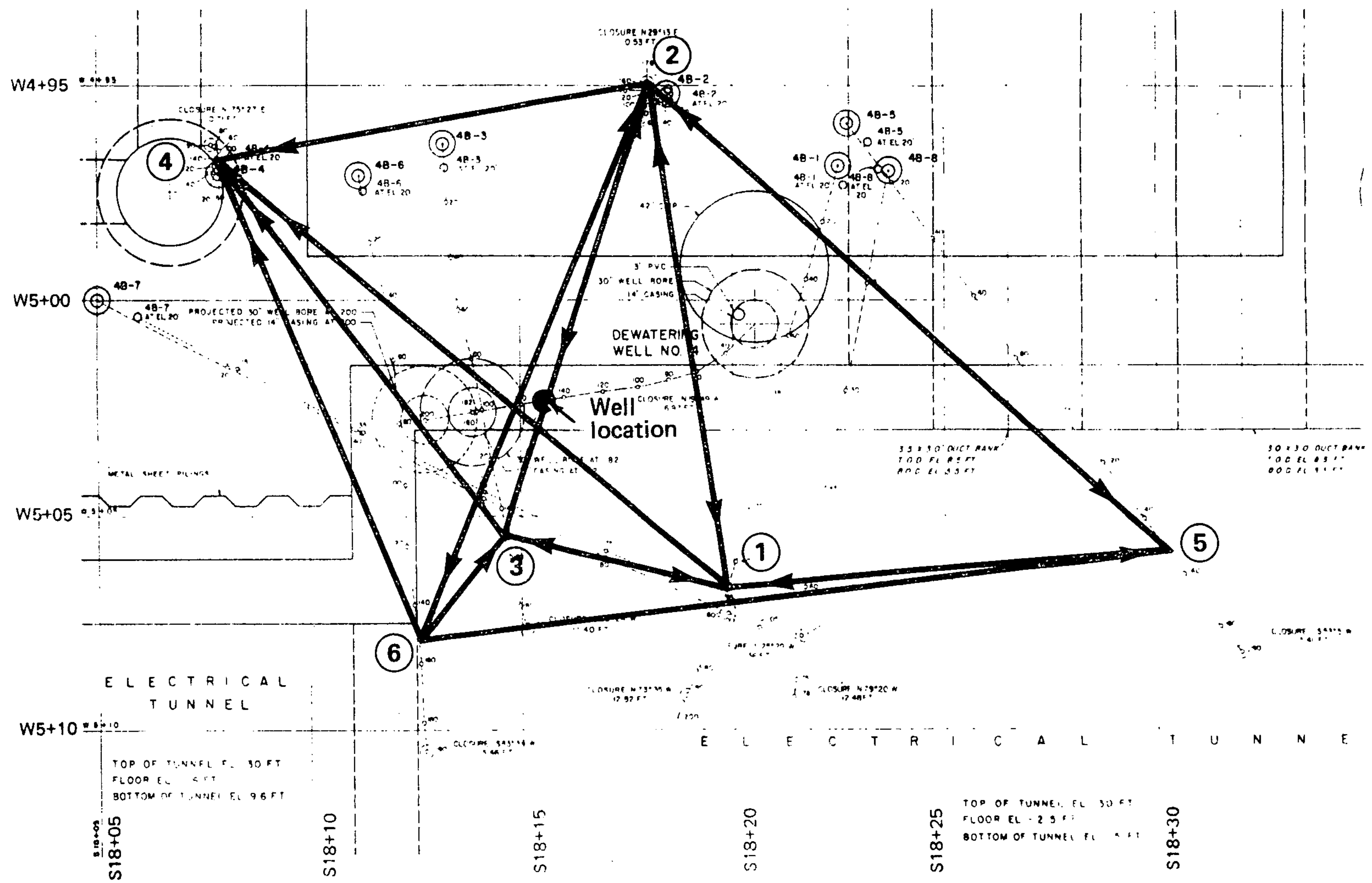
WOODWARD-CLYDE CONSULTANTS



(1) Indicates the end point boring for the transect at a depth of 100 ft.

Project:	SONGS 2 & 3	DEWATERING WELL NO. 4 LOCATION OF DRILL HOLES AND CROSSHOLE TRANSECTS AT 100 FT. DEPTH	Fig
Project No	41130I		E-4

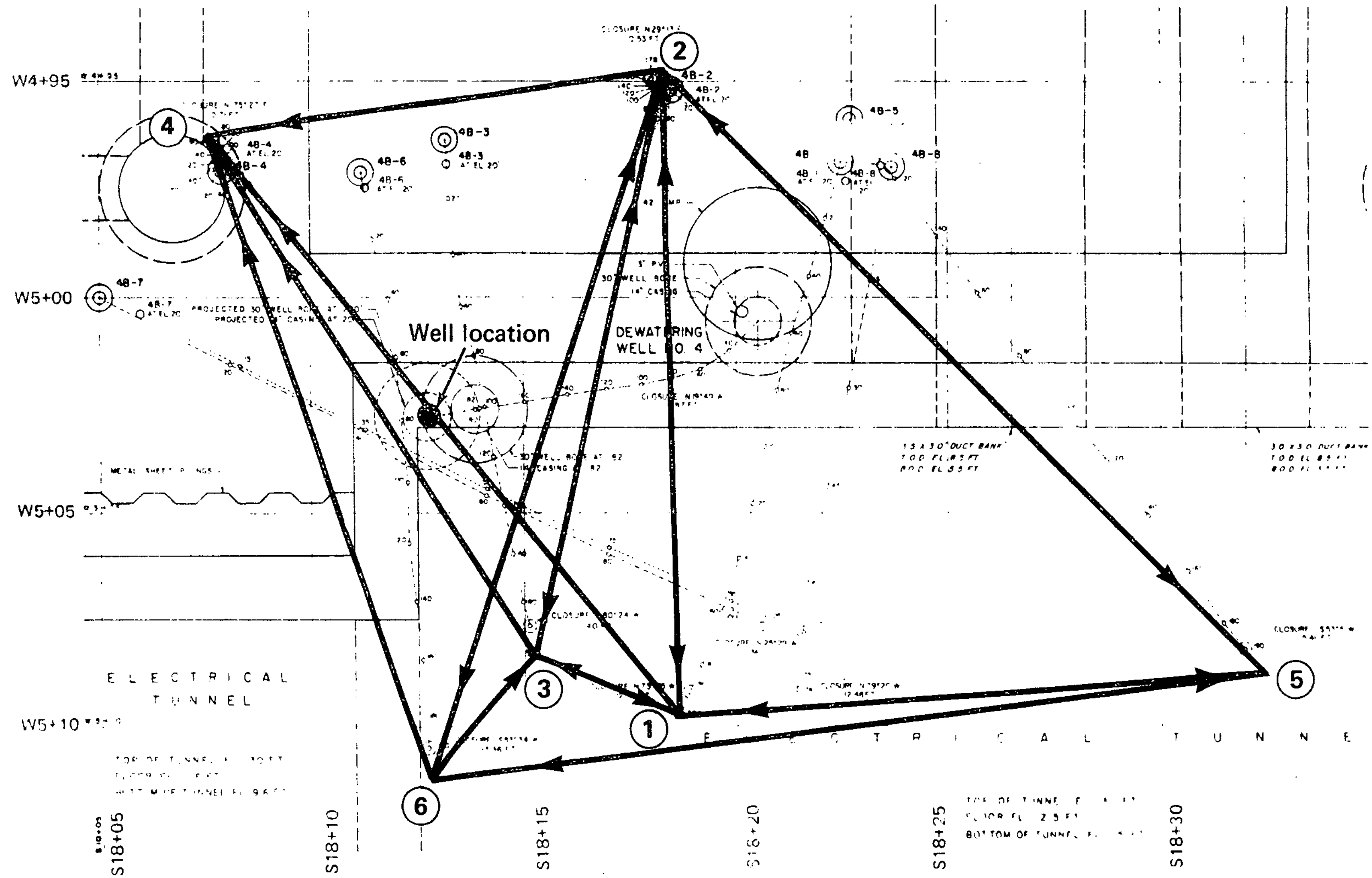
WOODWARD-CLYDE CONSULTANTS



① Indicates the end point boring for the transect at a depth of 150 ft.

Project:	SONGS 2 & 3	DEWATERING WELL NO. 4 LOCATION OF DRILL HOLES AND CROSSHOLE TRANSECTS AT 150 FT. DEPTH	Fig E-5
Project No	41130I		

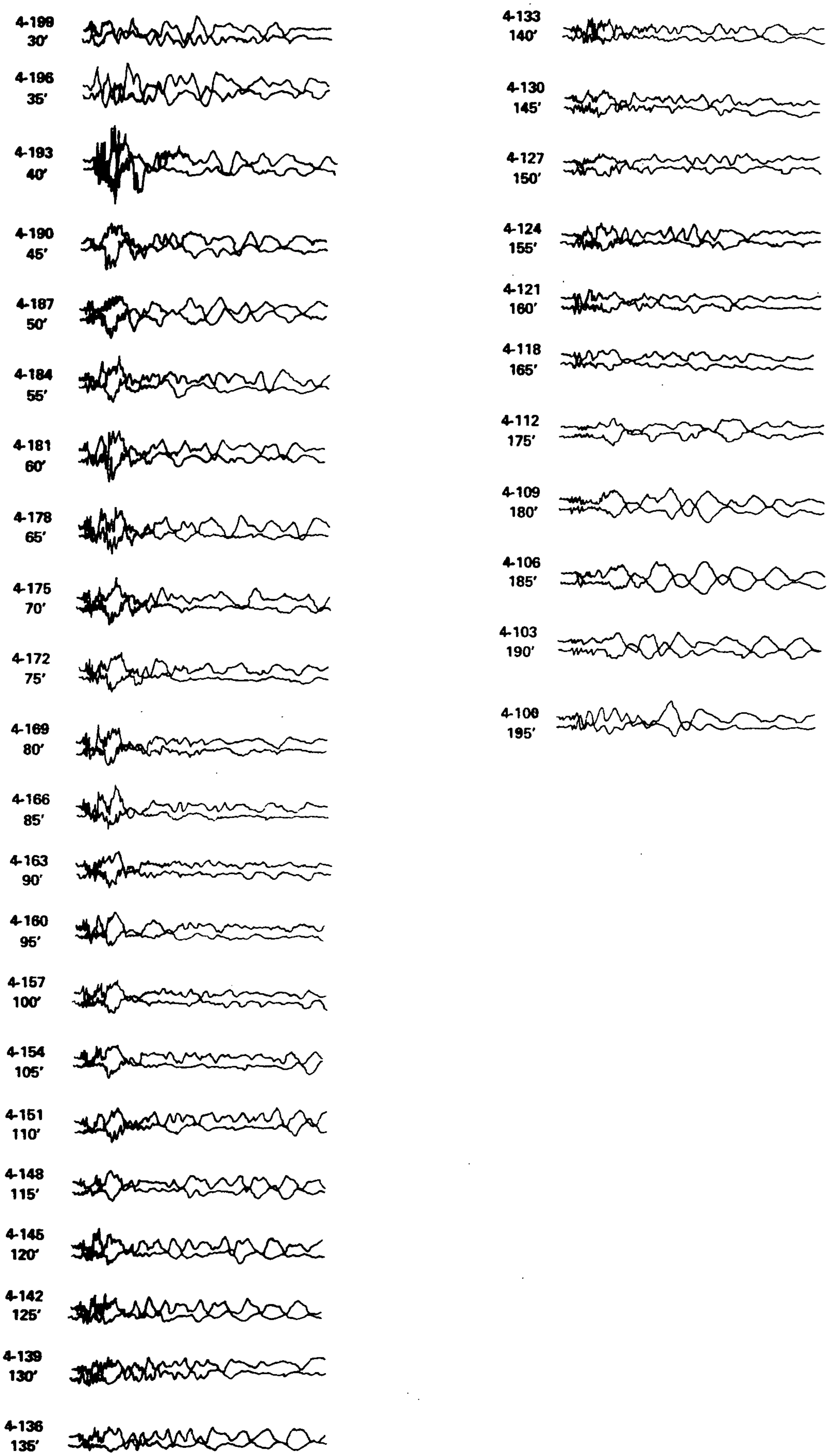
WOODWARD-CLYDE CONSULTANTS



① Indicates the end point boring for the transect at a depth of 200 ft.

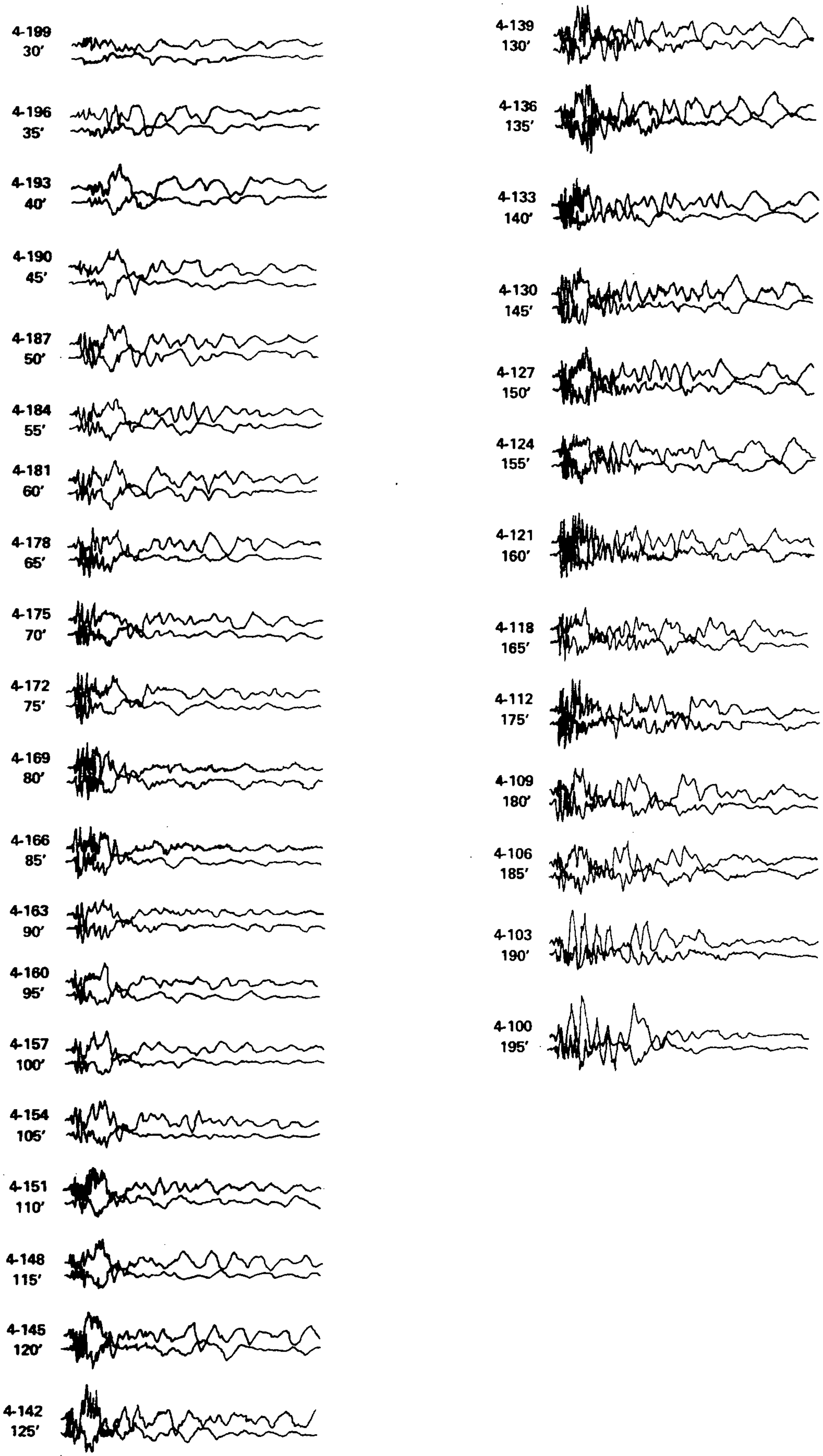
Project:	SONGS 2 & 3	DEWATERING WELL NO. 4 LOCATION OF DRILL HOLES AND CROSSHOLE TRANSECTS AT 200 FT. DEPTH	Fig.
Project No	41130I		E-6

WOODWARD-CLYDE CONSULTANTS



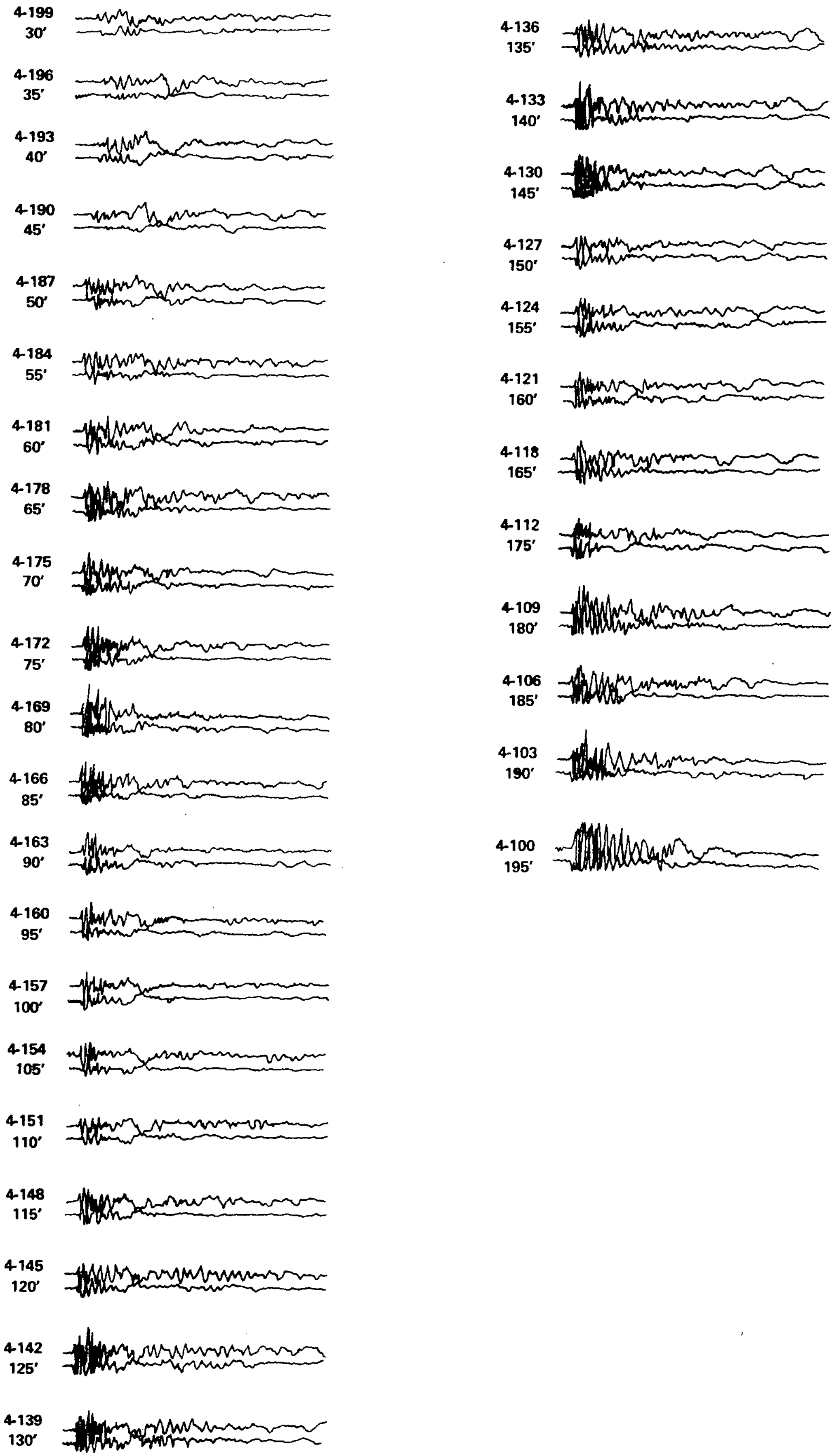
Project: **SONGS 2 & 3** Project No. **411301**	**WELL NO. 4 1 → 2 WAVEFORM TRACE**	Fig. **E-7**

WOODWARD – CLYDE CONSULTANTS



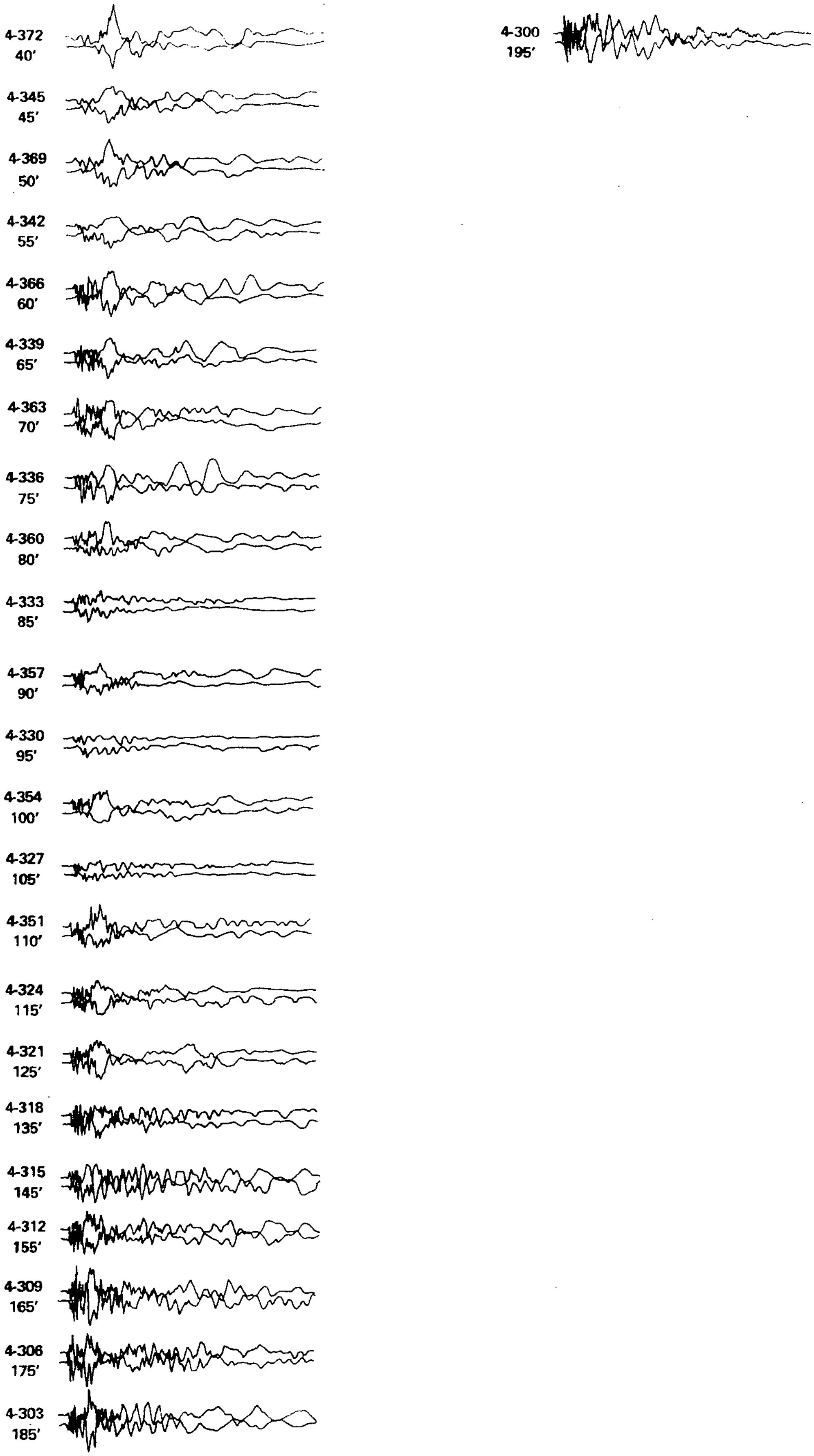
Project: **SONGS 2 & 3** Project No. **41130I**	**WELL NO. 4 1 → 3 WAVEFORM TRACE**	Fig. E-8

WOODWARD – CLYDE CONSULTANTS



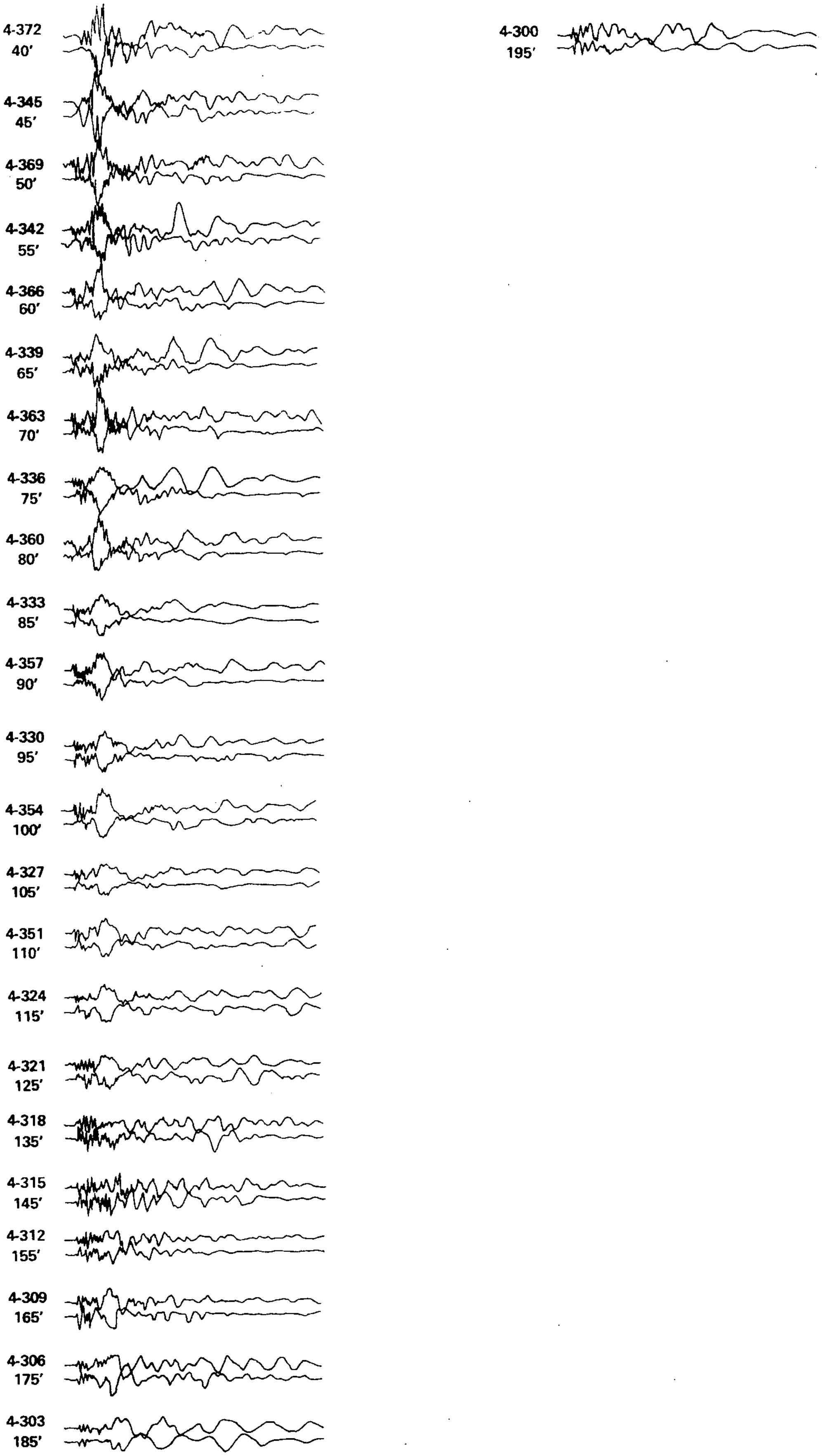
Project: SONGS 2 & 3 Project No. 411301	WELL NO. 4 1 → 4 WAVEFORM TRACE	Fig. E-9

WOODWARD – CLYDE CONSULTANTS

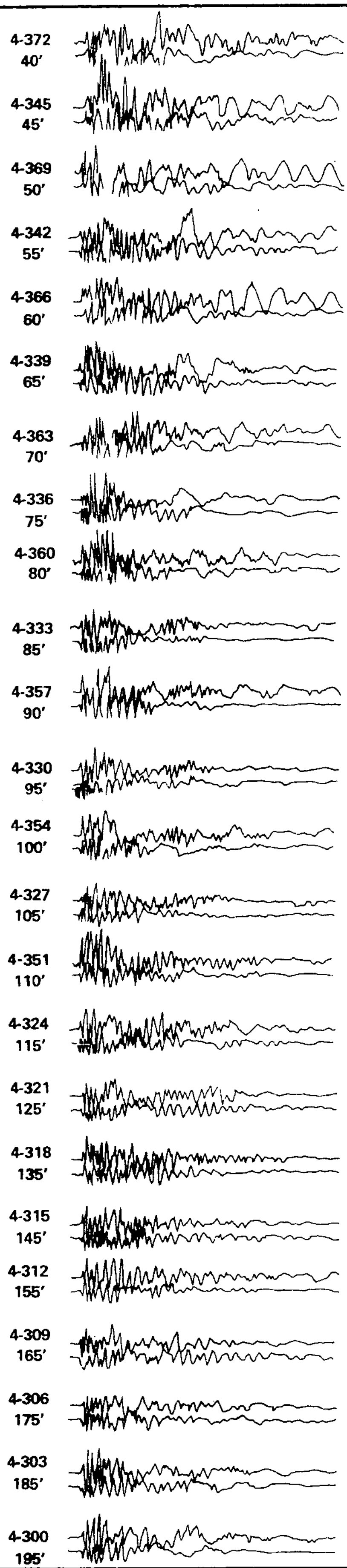


Project: **SONGS 2 & 3** Project No. **411301**	**WELL NO. 4 3 → 1 WAVEFORM TRACE**	Fig. **E-10**

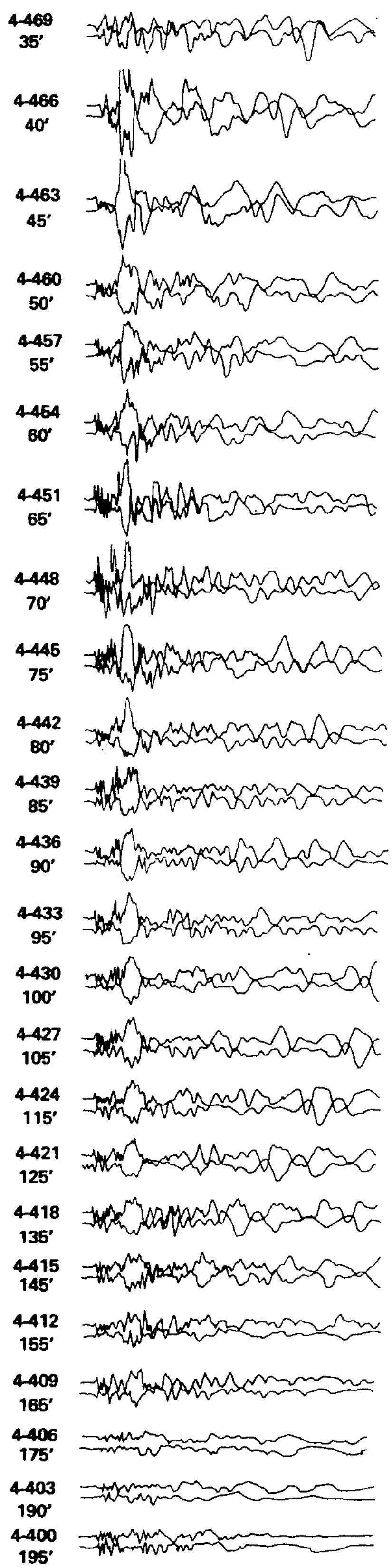
WOODWARD–CLYDE CONSULTANTS



Project: **SONGS 2 & 3** Project No. **41130I**	**WELL NO. 4 3 → 2 WAVEFORM TRACE**	Fig. **E-11**

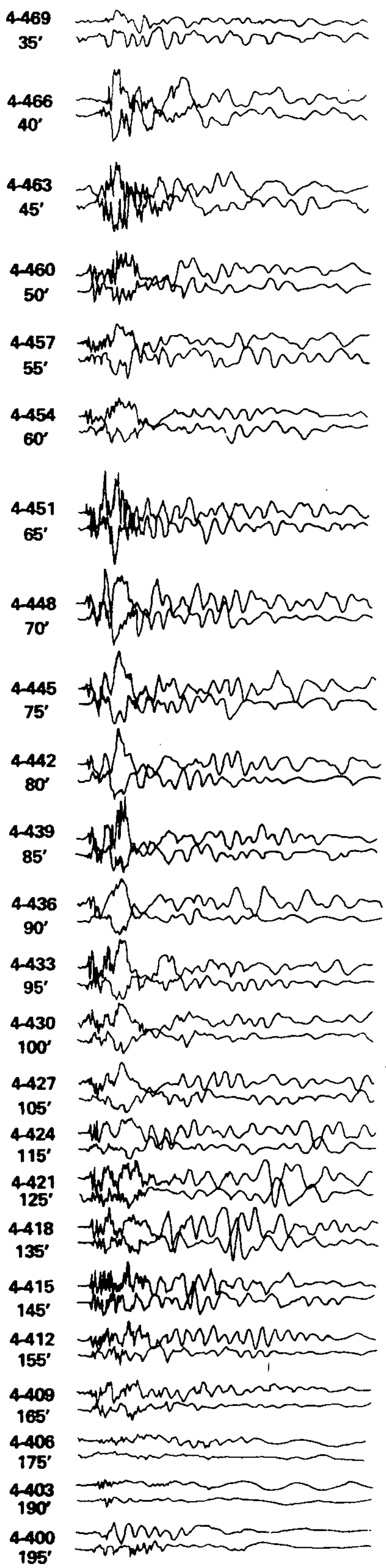


Project: **SONGS 2 & 3** Project No. **411301**	**WELL NO. 4 3 → 4 WAVEFORM TRACE**	Fig. **E-12**

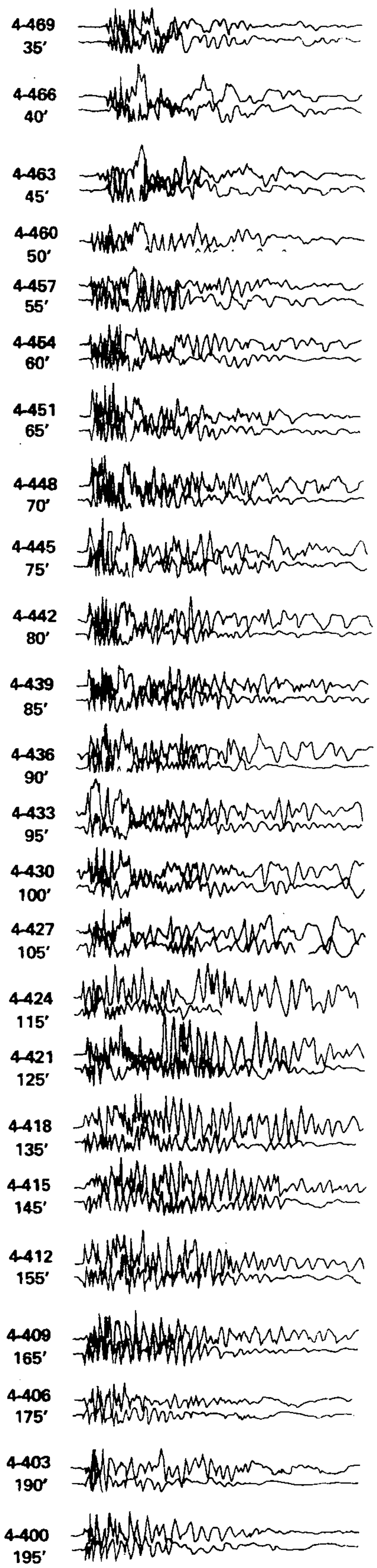


Project: SONGS 2 & 3 Project No. 41130I	WELL NO. 4 2 → 1 WAVEFORM TRACE	Fig. E-13

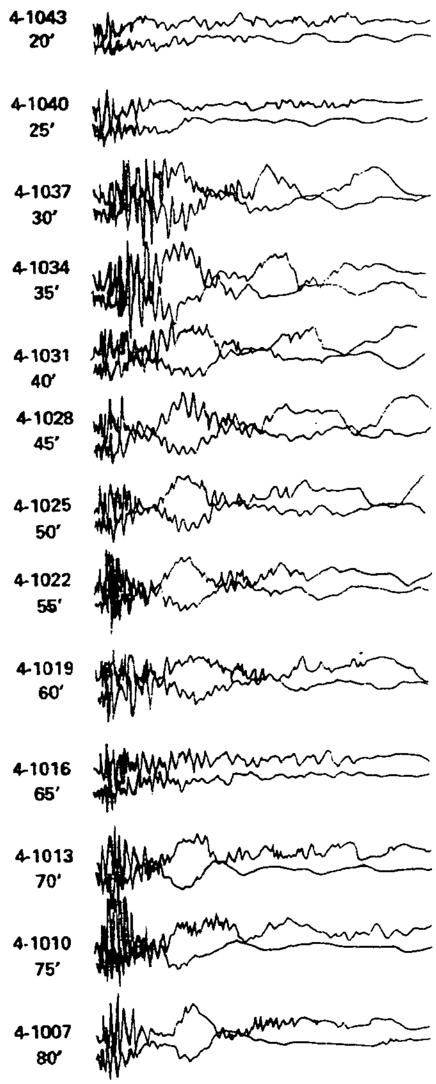
WOODWARD – CLYDE CONSULTANTS



Project: **SONGS 2 & 3** Project No. **41130I**	**WELL NO. 4 2→3 WAVEFORM TRACE**	Fig. **E-14**

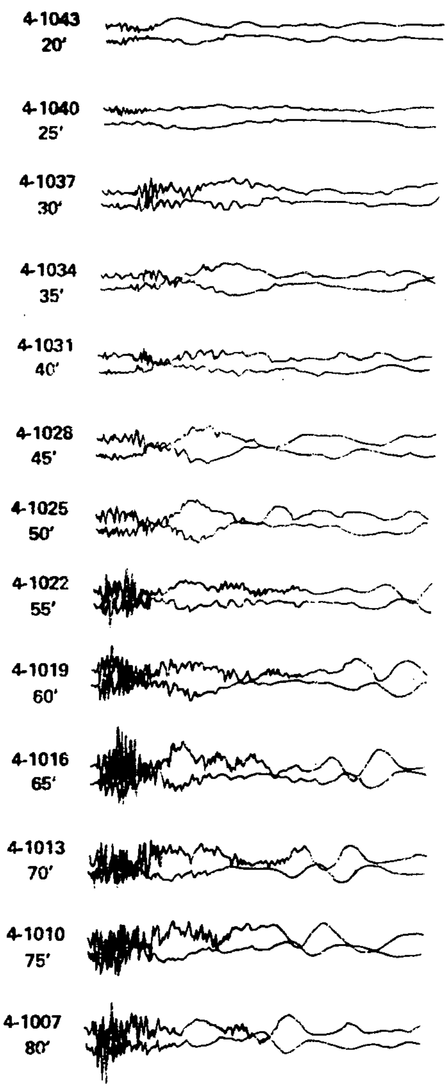


Project: **SONGS 2 & 3** Project No. **411301**	**WELL NO. 4 2→4 WAVEFORM TRACE**	Fig. E-15



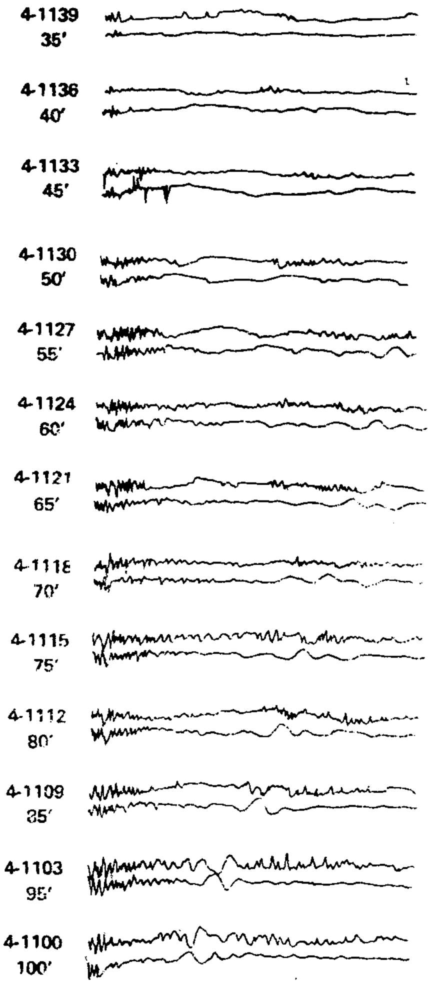
Project:	SONGS 2 & 3	WELL NO. 4 8→5 WAVEFORM TRACE	Fig.
Project No.	411301		E-16

WOODWARD – CLYDE CONSULTANTS



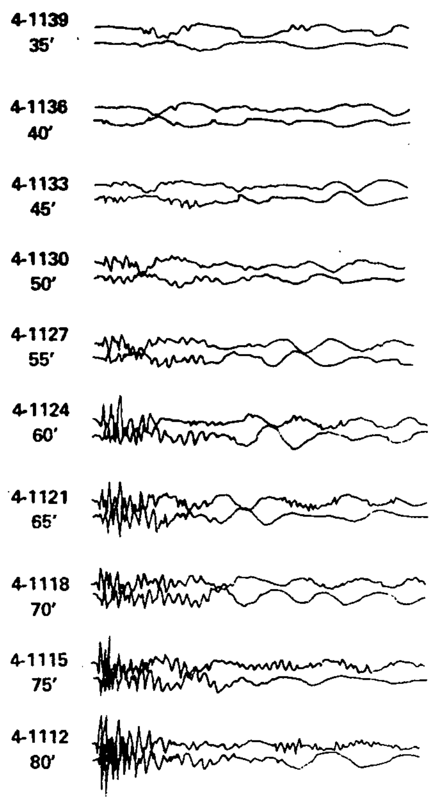
Project:	SONGS 2 & 3	WELL NO. 4 8 → 7 WAVEFORM TRACE	Fig.
Project No.	411301		E-17

WOODWARD – CLYDE CONSULTANTS



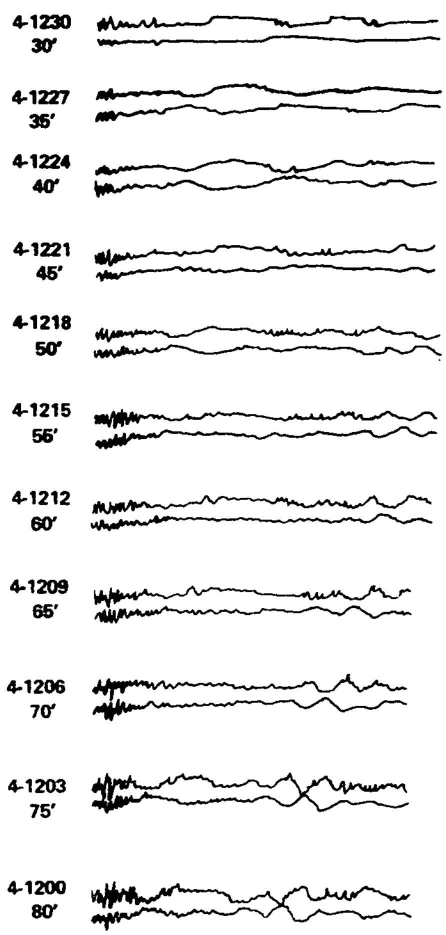
Project: Project No.	SONGS 2 & 3 411301	WELL NO. 4 7 → 5 WAVEFORM TRACE	Fig. E-18

WOODWARD—CLYDE CONSULTANTS



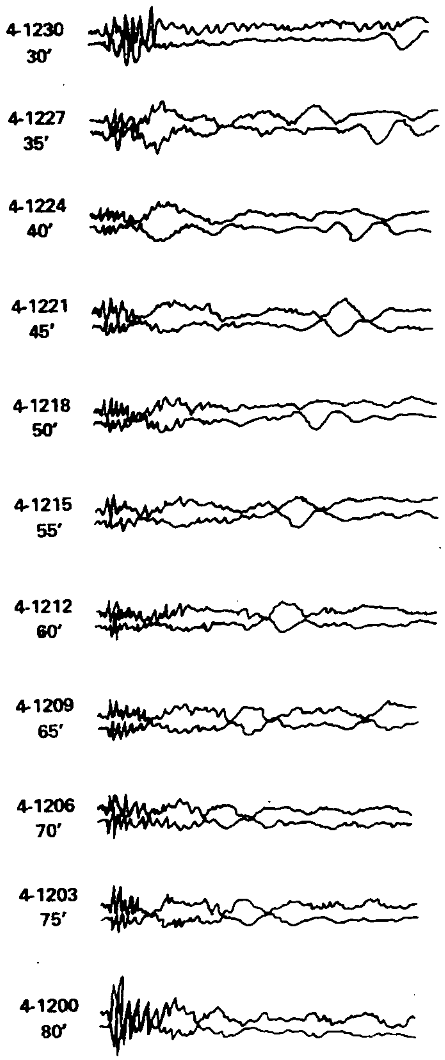
Project: SONGS 2 & 3 Project No. 411301	WELL NO. 4 7 → 8 WAVEFORM TRACE	Fig. E-19

WOODWARD – CLYDE CONSULTANTS



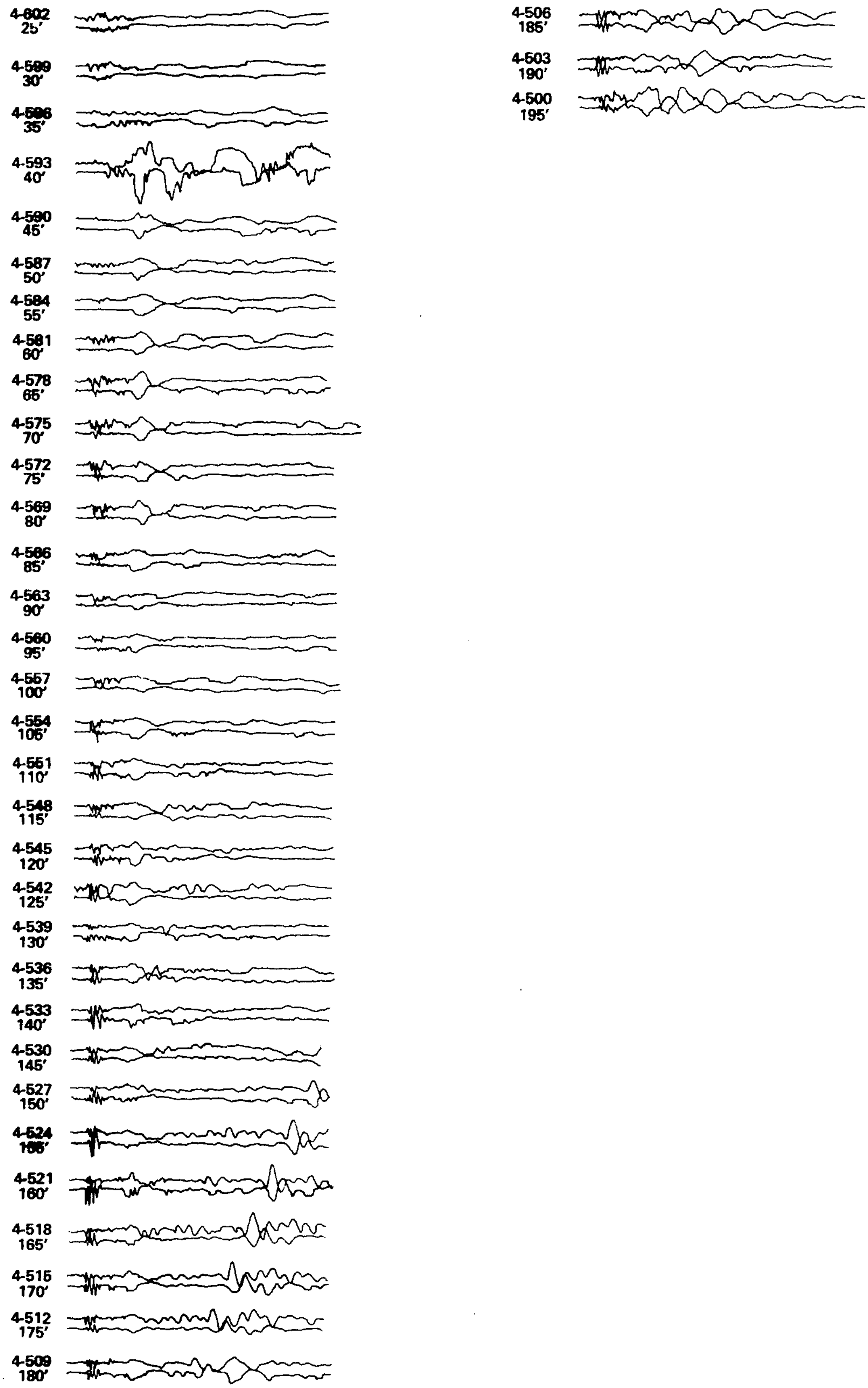
Project:	SONGS 2 & 3	WELL NO. 4 5 → 7 WAVEFORM TRACE	Fig.
Project No.	411301		E-20

WOODWARD – CLYDE CONSULTANTS



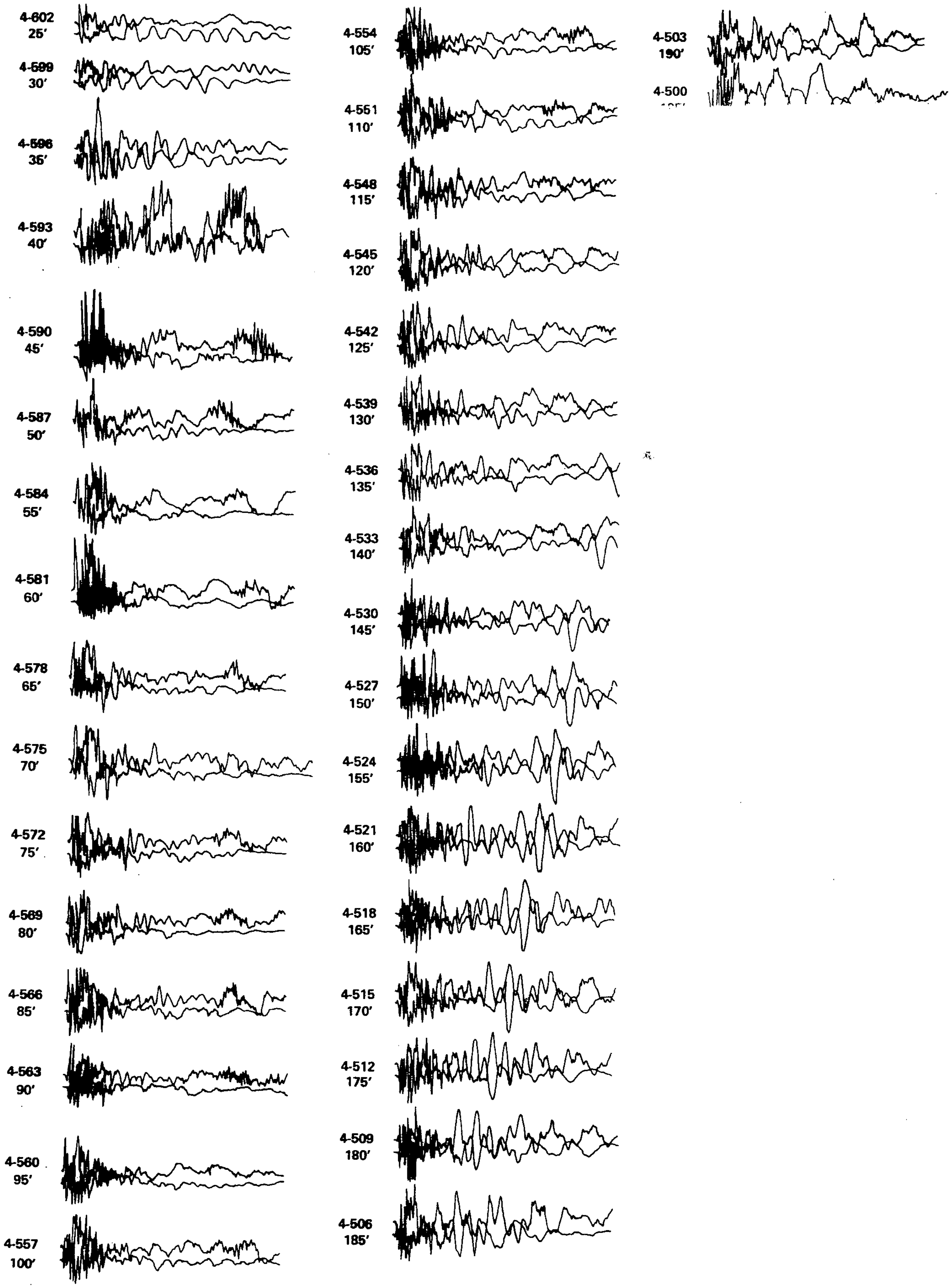
Project:	SONGS 2 & 3	WELL NO. 4 5 → 8 WAVEFORM TRACE	Fig.
Project No.	41130I		E-21

WOODWARD — CLYDE CONSULTANTS



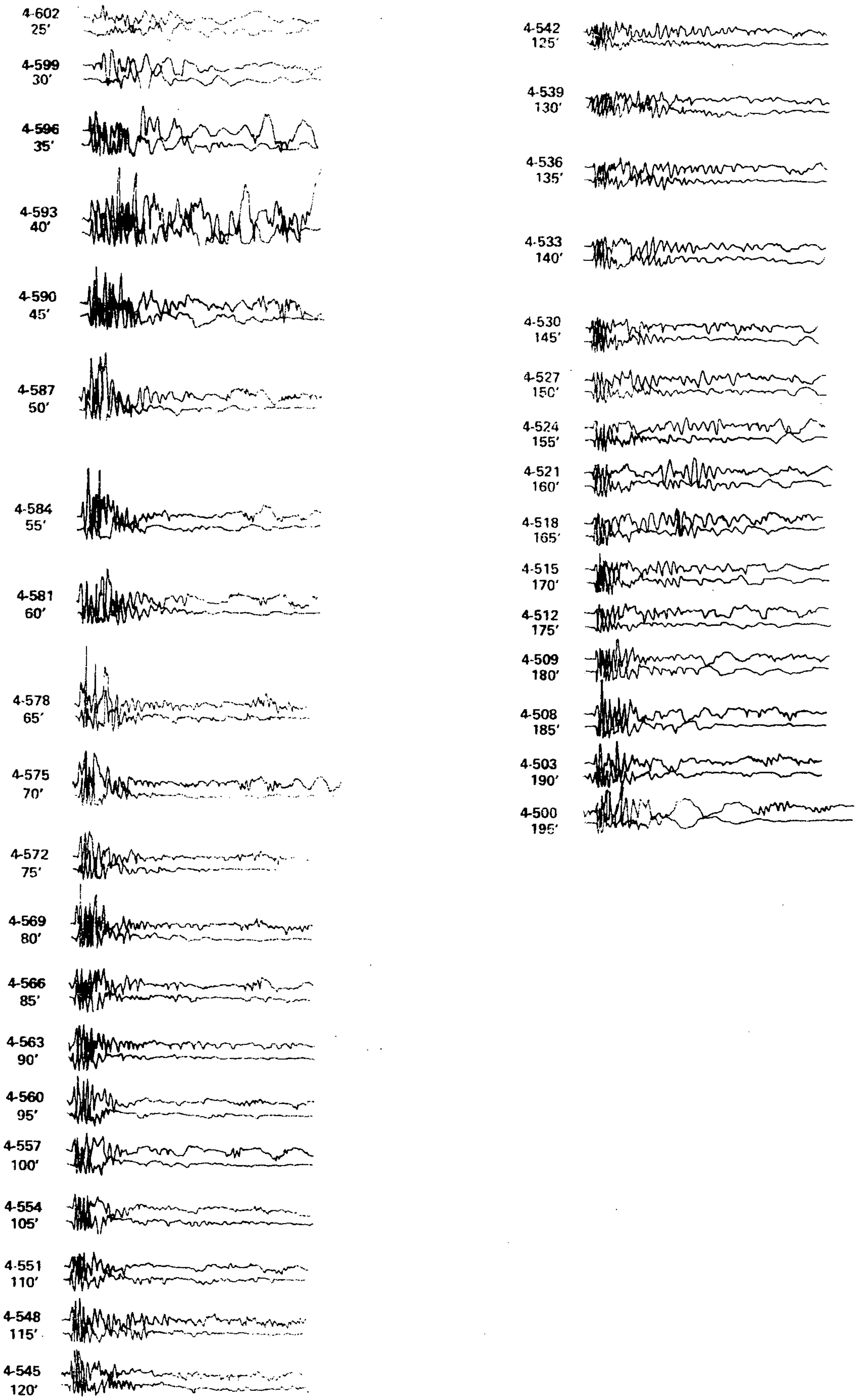
Project:	SONGS 2 & 3	WELL NO. 4 6 → 5 WAVEFORM TRACE	Fig.
Project No.	41130I		E-22

WOODWARD – CLYDE CONSULTANTS



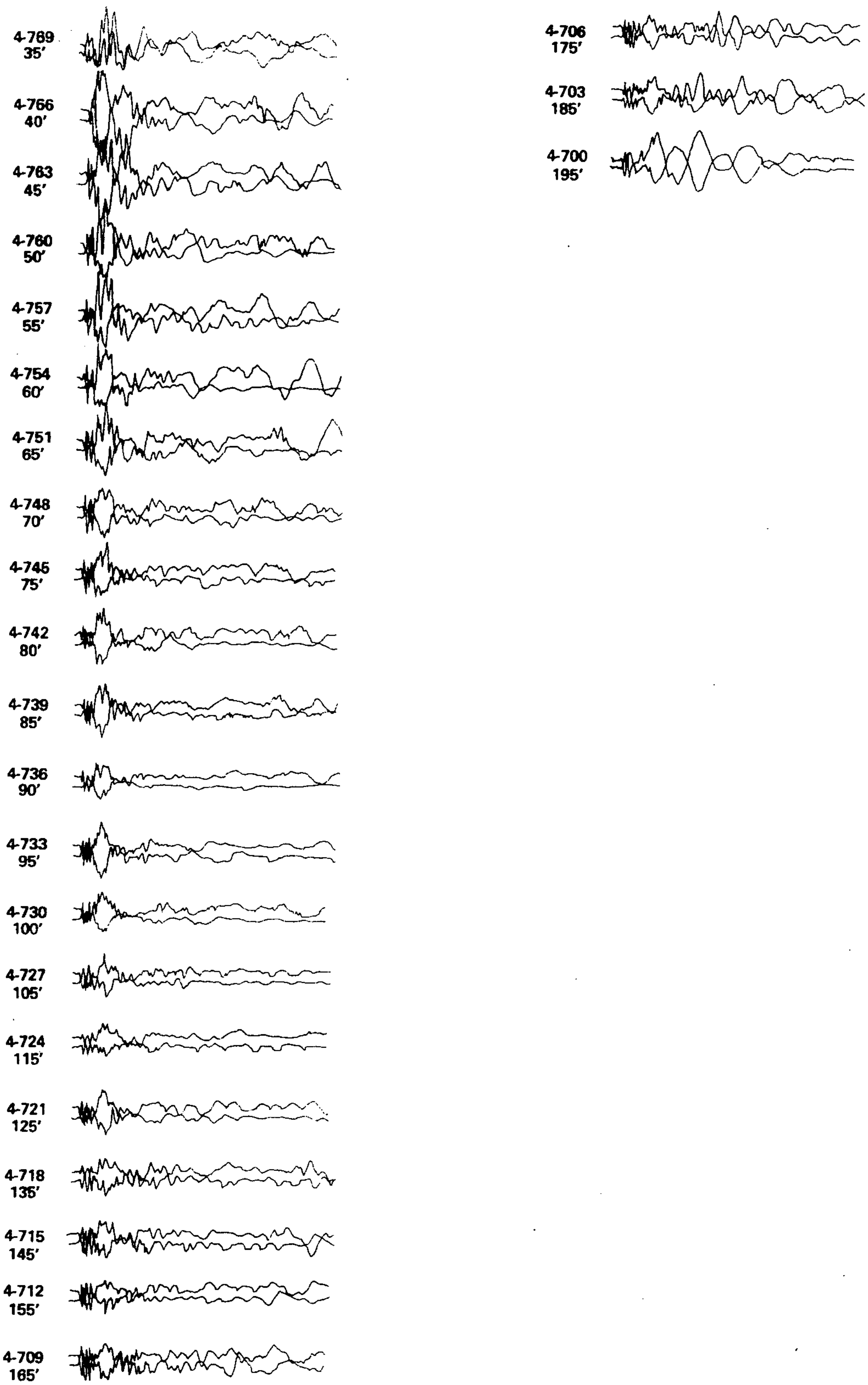
Project:	SONGS 2 & 3	WELL NO. 4 6 → 3 WAVEFORM TRACE	Fig.
Project No.	411301		E-23

WOODWARD – CLYDE CONSULTANTS



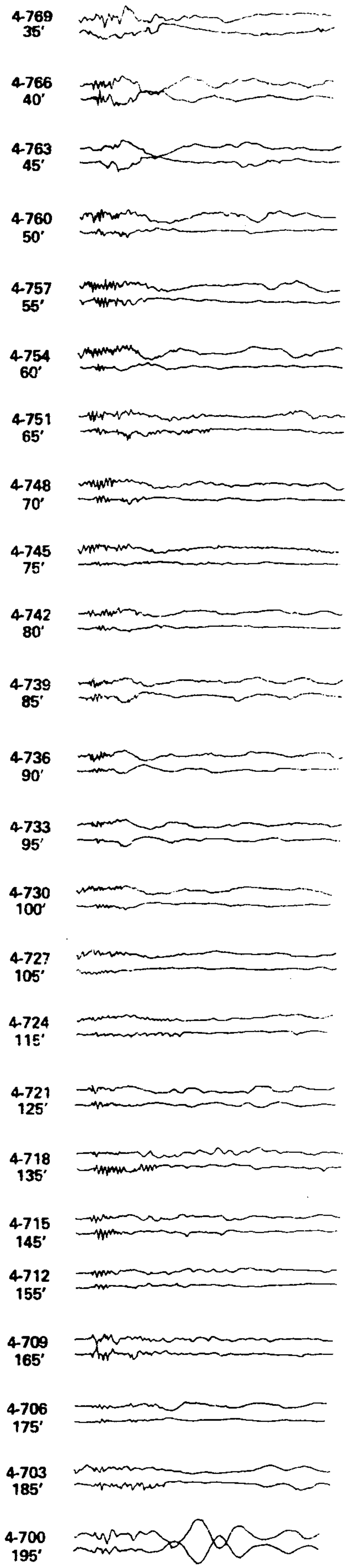
Project:	SONGS 2 & 3	WELL NO. 4 6 → 4 WAVEFORM TRACE	Fig.
Project No.	41130I		E-24

WOODWARD—CLYDE CONSULTANTS



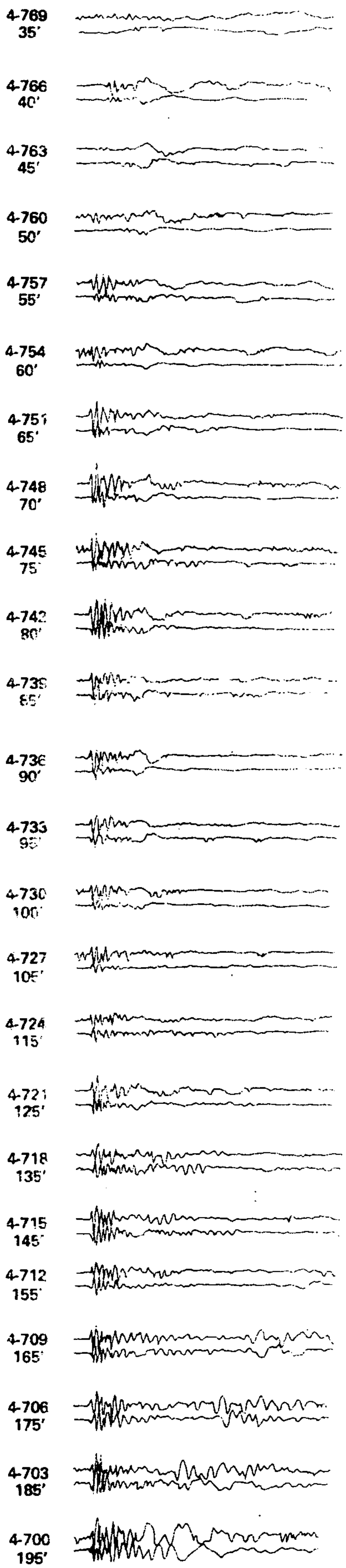
Project:	SONGS 2 & 3	WELL NO. 4 5 → 1 WAVEFORM TRACE	Fig.
Project No.	411301		E-25

WOODWARD – CLYDE CONSULTANTS



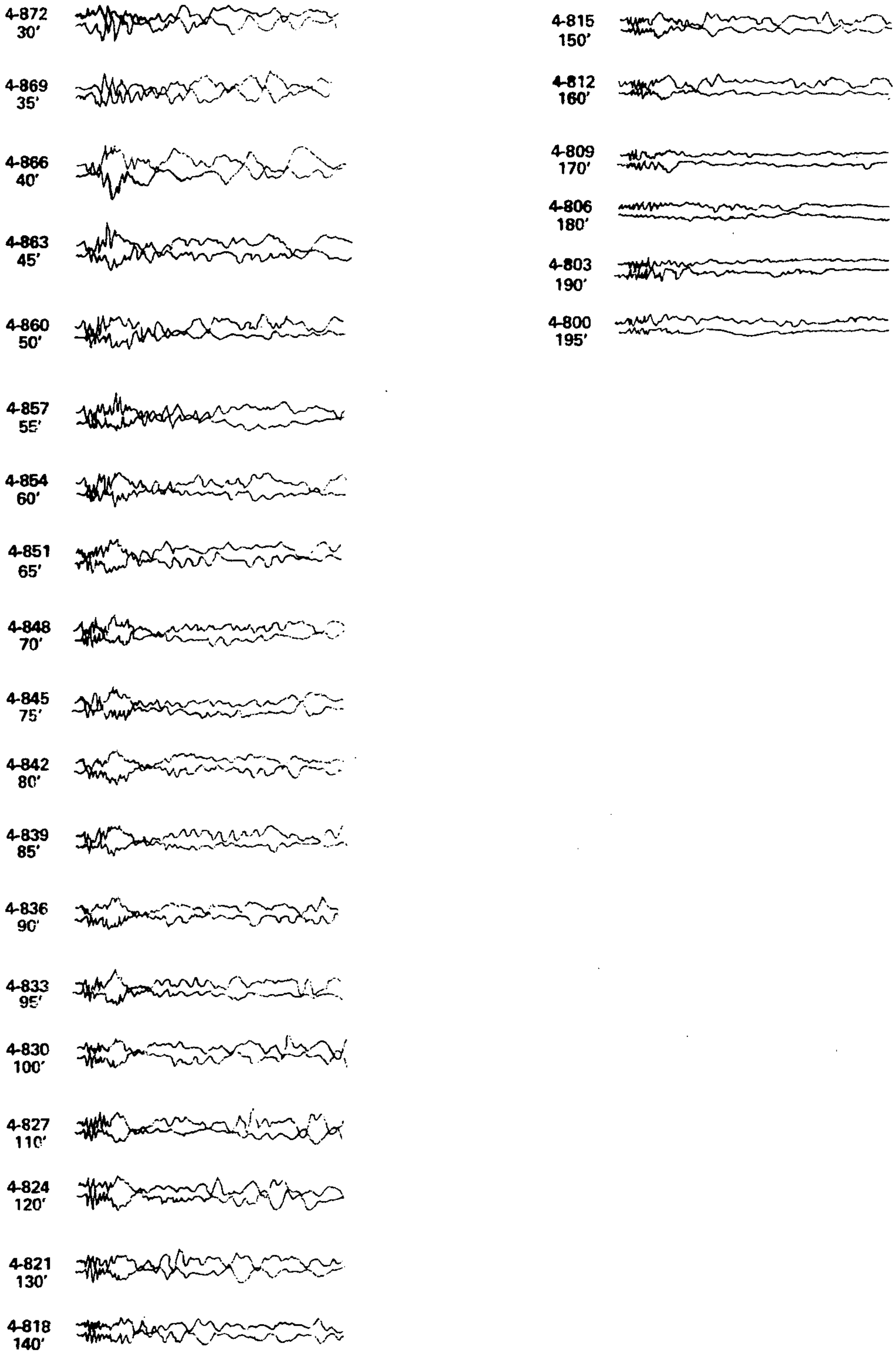
Project:	SONGS 2 & 3	WELL NO. 4 5 → 2 WAVEFORM TRACE	Fig.
Project No.	41130I		E-26

WOODWARD – CLYDE CONSULTANTS



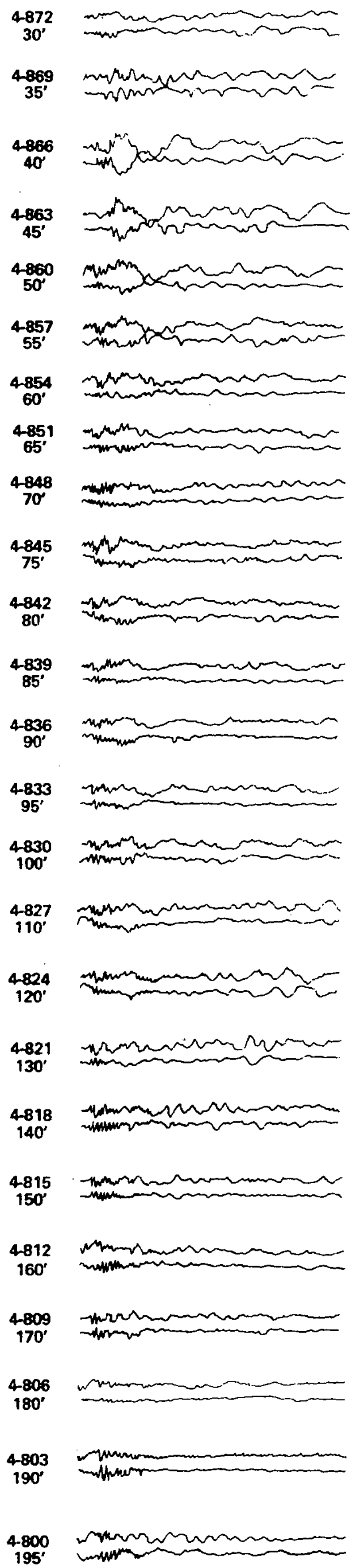
Project:	SONGS 2 & 3	WELL NO. 4 5 → 6 WAVEFORM TRACE	Fig. E-27
Project No.	411301		

WOODWARD – CLYDE CONSULTANTS



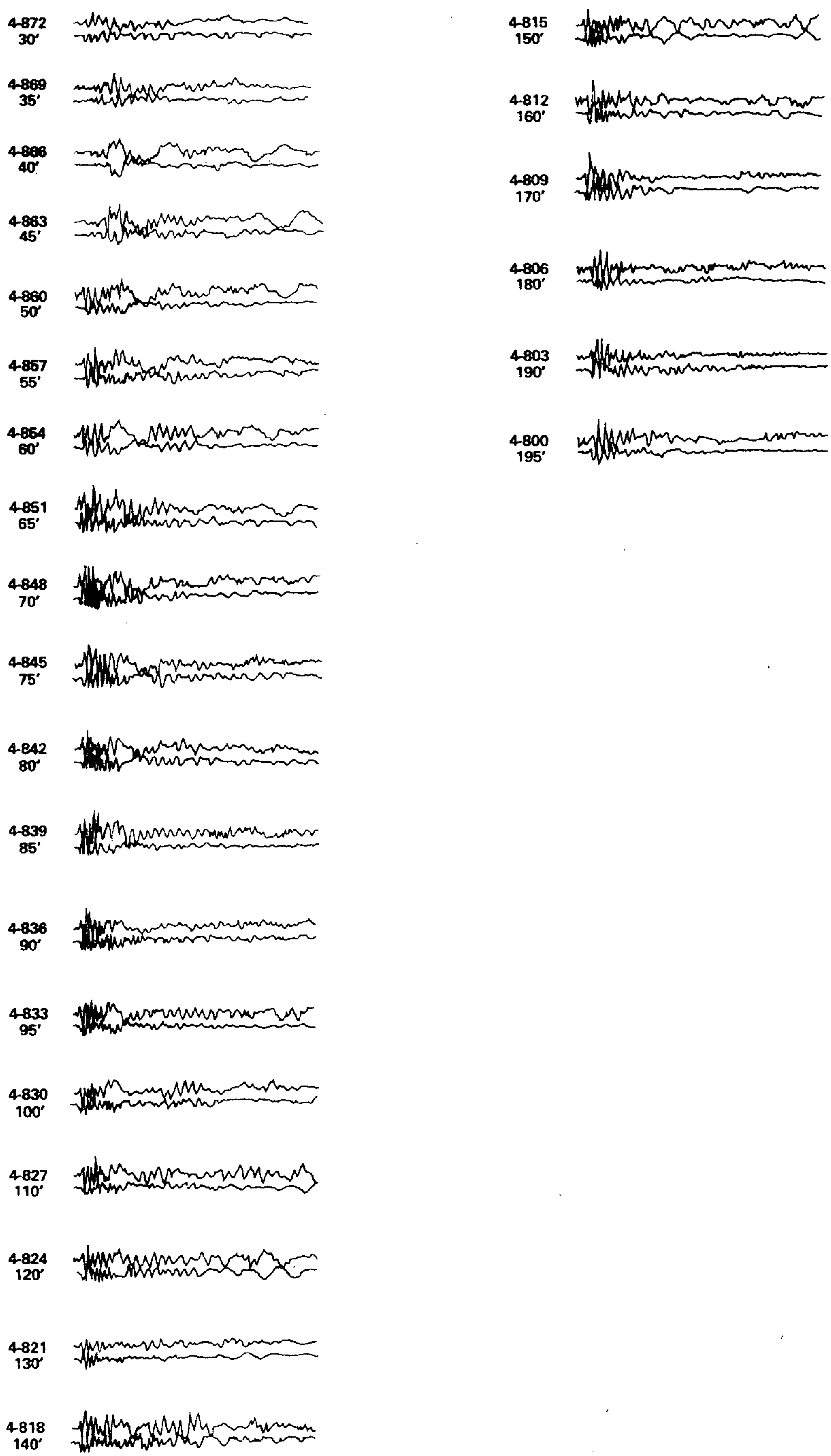
Project:	SONGS 2 & 3	WELL NO. 4 2 → 1 WAVEFORM TRACE	Fig.
Project No.	411301		E-28

WOODWARD – CLYDE CONSULTANTS



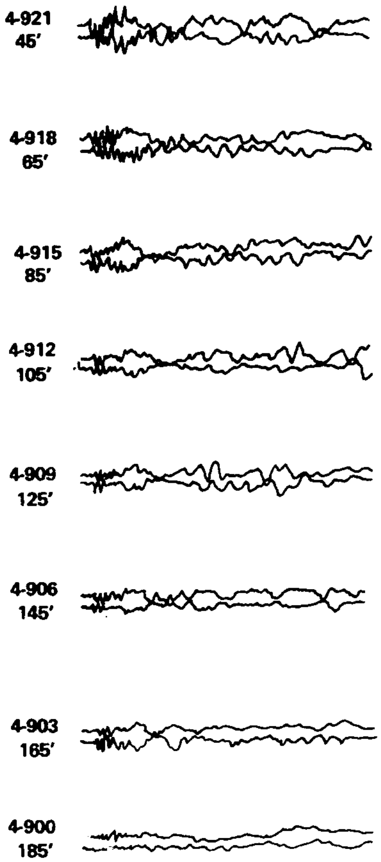
Project:	SONGS 2 & 3	WELL NO. 4 2 → 5 WAVEFORM TRACE	Fig.
Project No.	41130I		E-29

WOODWARD – CLYDE CONSULTANTS



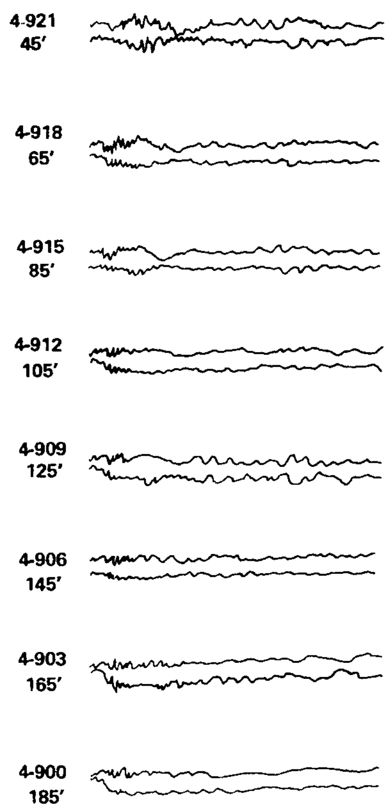
Project:	SONGS 2 & 3	WELL NO. 4 2 → 6 WAVEFORM TRACE	Fig.
Project No.	41130I		E-30

WOODWARD—CLYDE CONSULTANTS



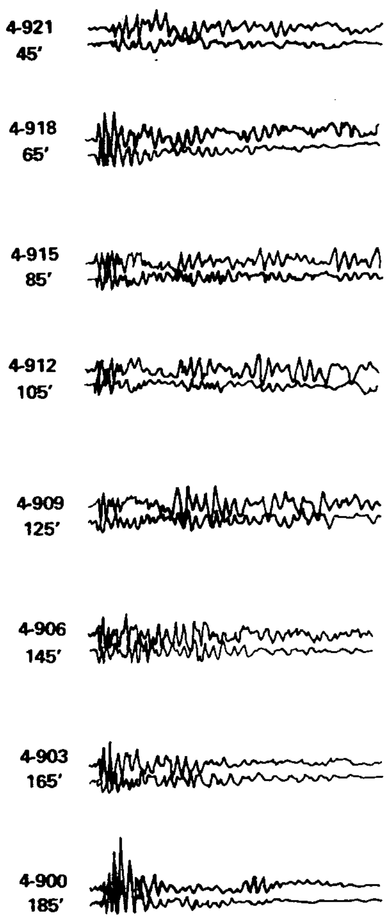
Project:	SONGS 2 & 3	WELL NO. 4 2 → 1 WAVEFORM TRACE	Fig. E-31
Project No.	411301		

WOODWARD–CLYDE CONSULTANTS



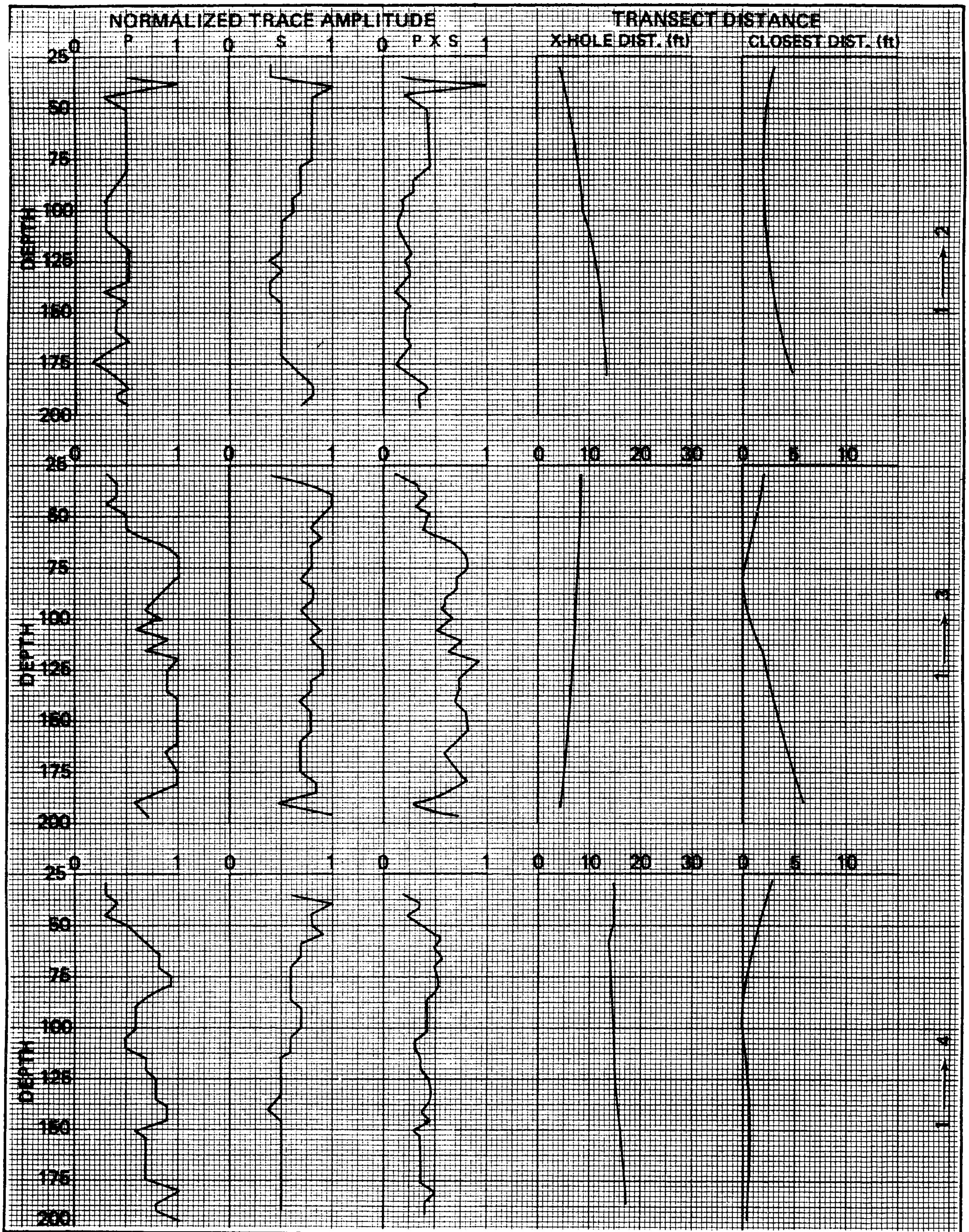
Project:	SONGS 2 & 3	WELL NO. 4 2→5 WAVEFORM TRACE	Fig. E-32
Project No.	411301		

WOODWARD—CLYDE CONSULTANTS



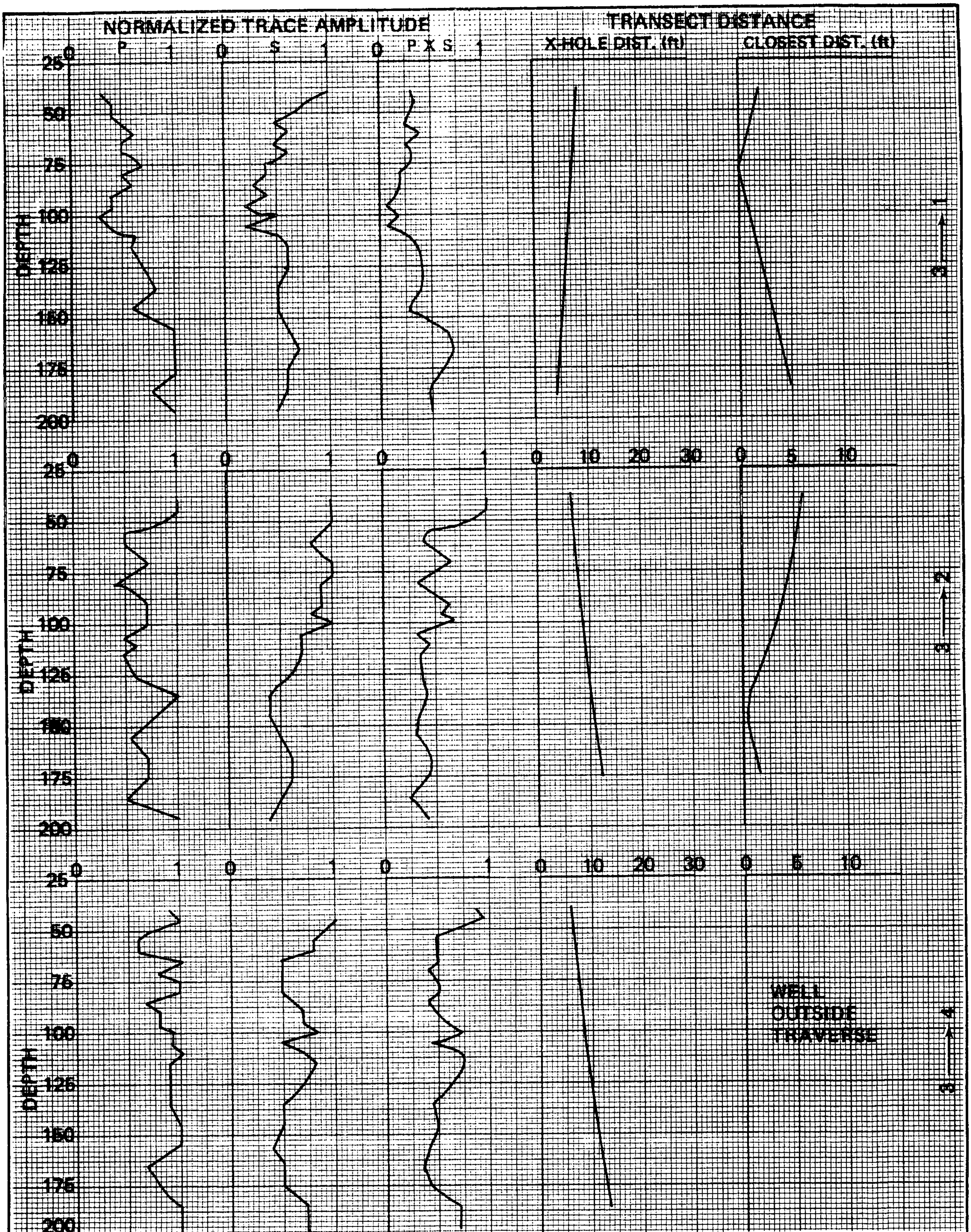
Project:	SONGS 2 & 3	WELL NO. 4 2 → 4 WAVEFORM TRACE	Fig.
Project No.	411301		E-33

WOODWARD—CLYDE CONSULTANTS



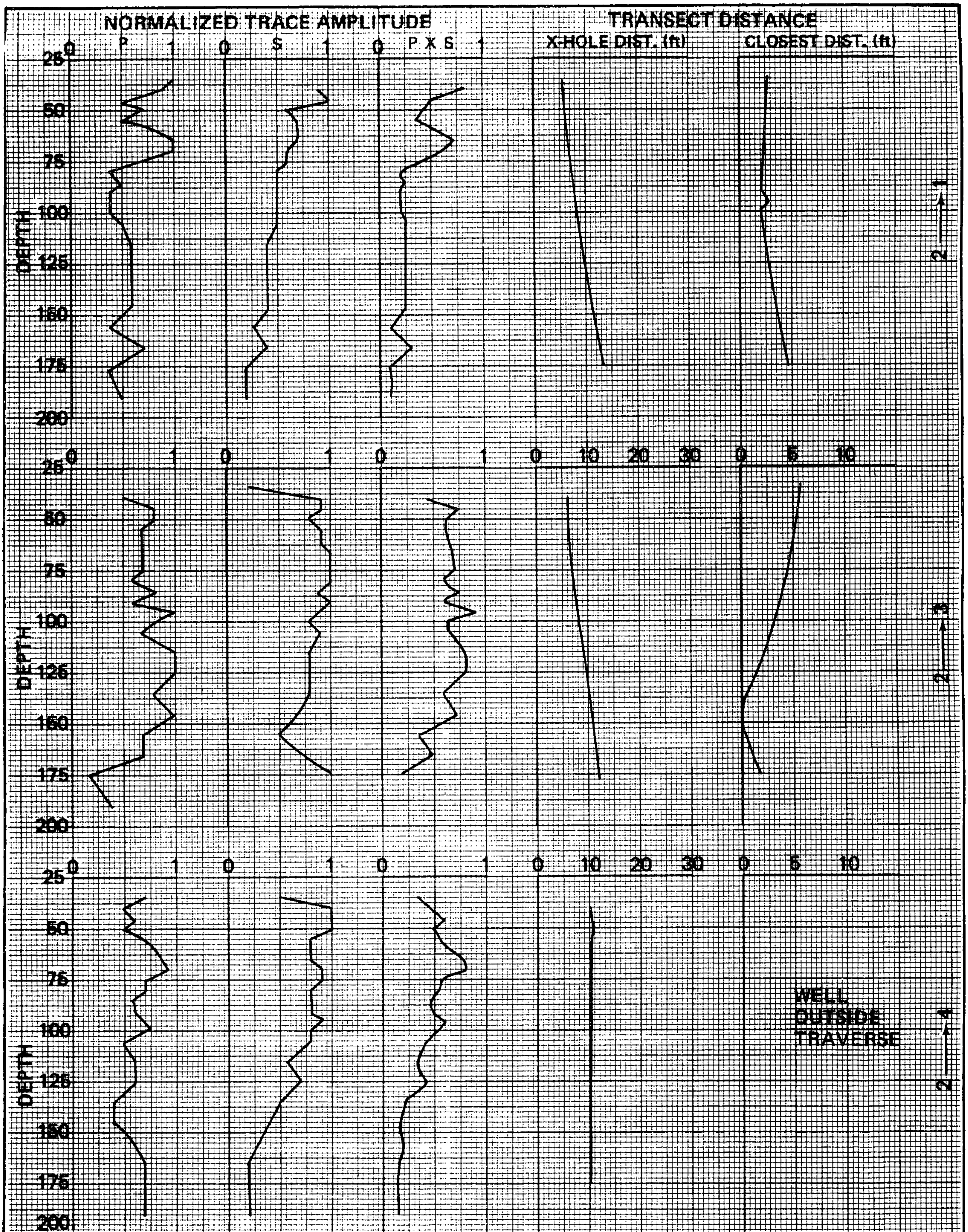
Project:	SONGS 2&3	WAVEFORM TRACE DATA SUMMARY FOR WELL NO. 4 SOURCE 1 AND RECEIVER 2, 3, 4	Fig. E-34
Project No.	41130I		

WOODWARD—CLYDE CONSULTANTS



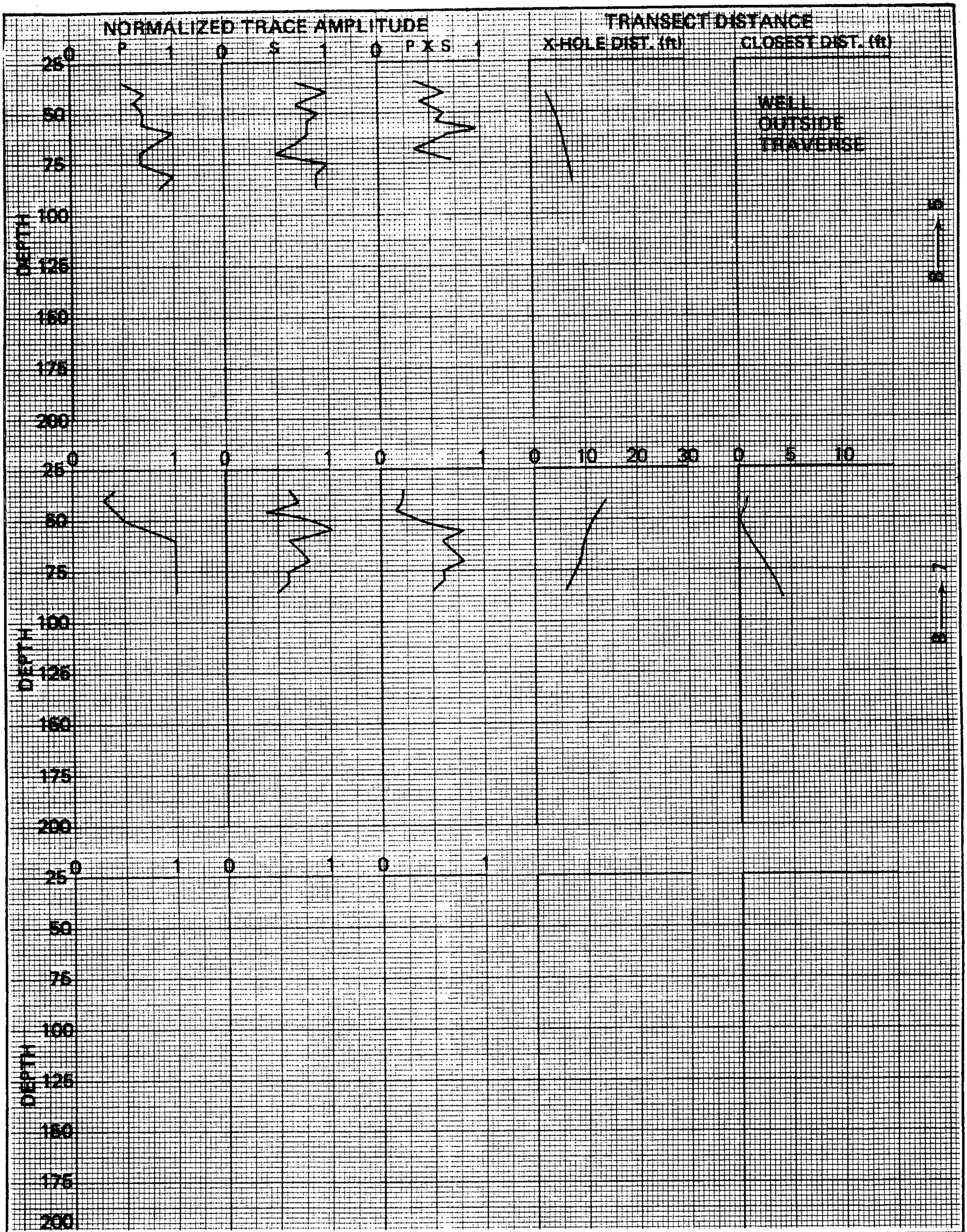
Project:	SONGS 2&3	WAVEFORM TRACE DATA SUMMARY FOR	Fig.
Project No.	411301	WELL NO. 4 SOURCE 3 AND RECEIVER 1, 2, 4	E-35

WOODWARD – CLYDE CONSULTANTS



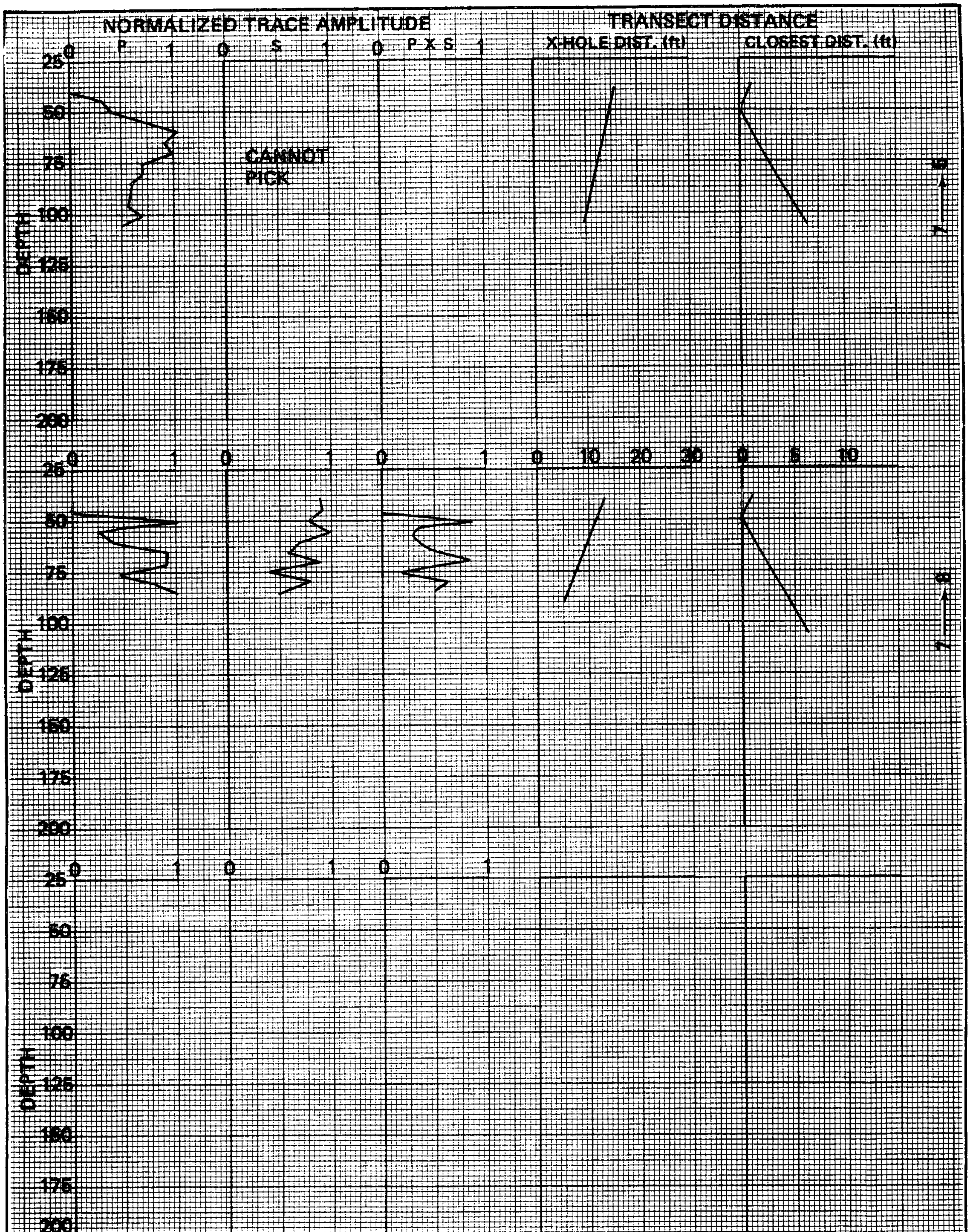
Project:	SONGS 2&3	WAVEFORM TRACE DATA SUMMARY FOR WELL NO. 4 SOURCE 2 AND RECEIVER 1, 3, 4	Fig. E-36
Project No.	41130I		

WOODWARD – CLYDE CONSULTANTS



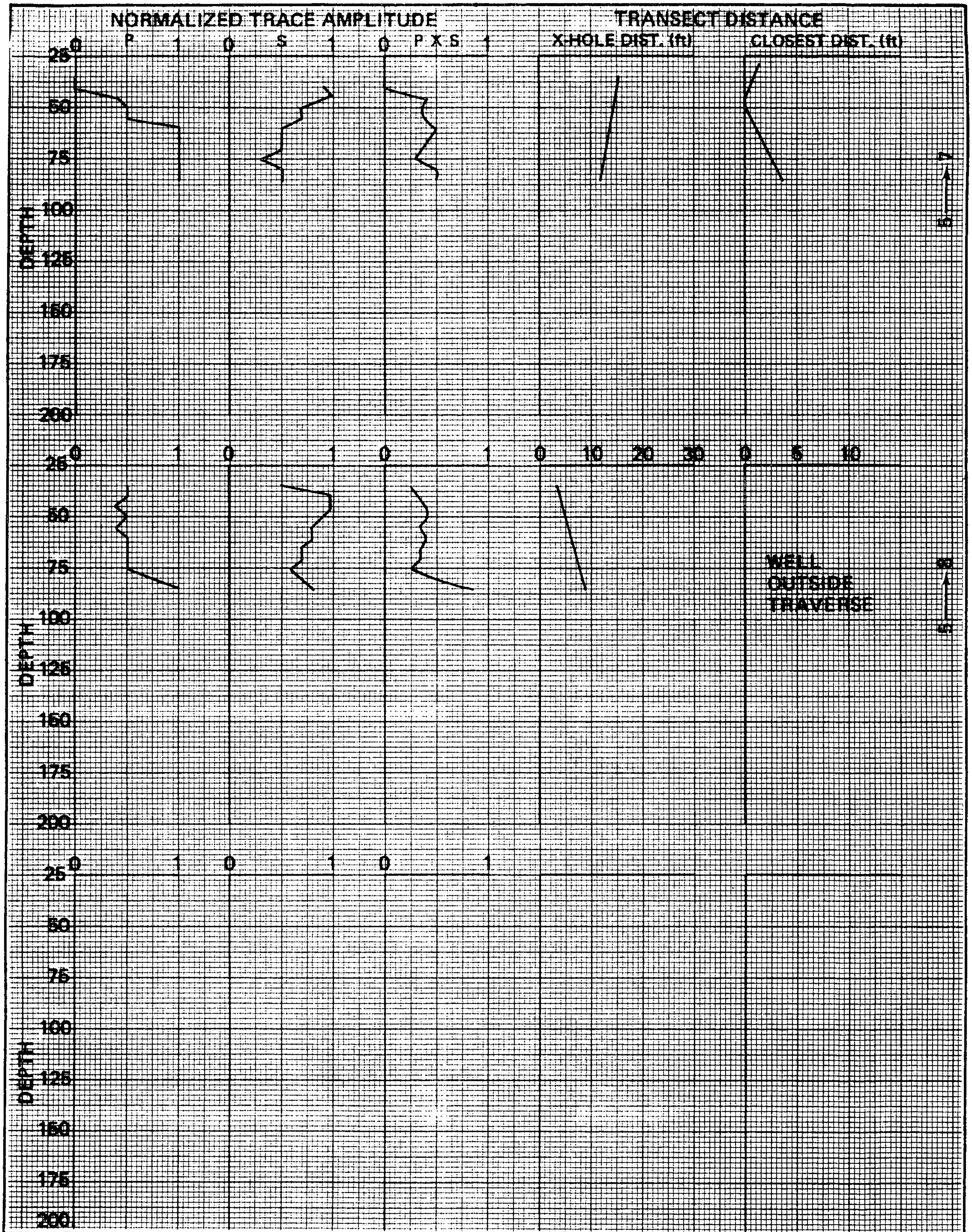
Project:	SONGS 2&3	WAVEFORM TRACE DATA SUMMARY FOR WELL NO. 4 SOURCE 8 AND RECEIVER 5, 7	Fig. E-37
Project No.	41130I		

WOODWARD—CLYDE CONSULTANTS



Project:	SONGS 2&3	WAVEFORM TRACE DATA SUMMARY FOR	Fig.
Project No.	411301	WELL NO. 4 SOURCE 7 AND RECEIVER 5, 8	E-38

WOODWARD–CLYDE CONSULTANTS



Project:	SONGS 2&3	WAVEFORM TRACE DATA SUMMARY FOR WELL NO. 4 SOURCE 5 AND RECEIVER 7, 8	Fig. E-39
Project No.	411301		

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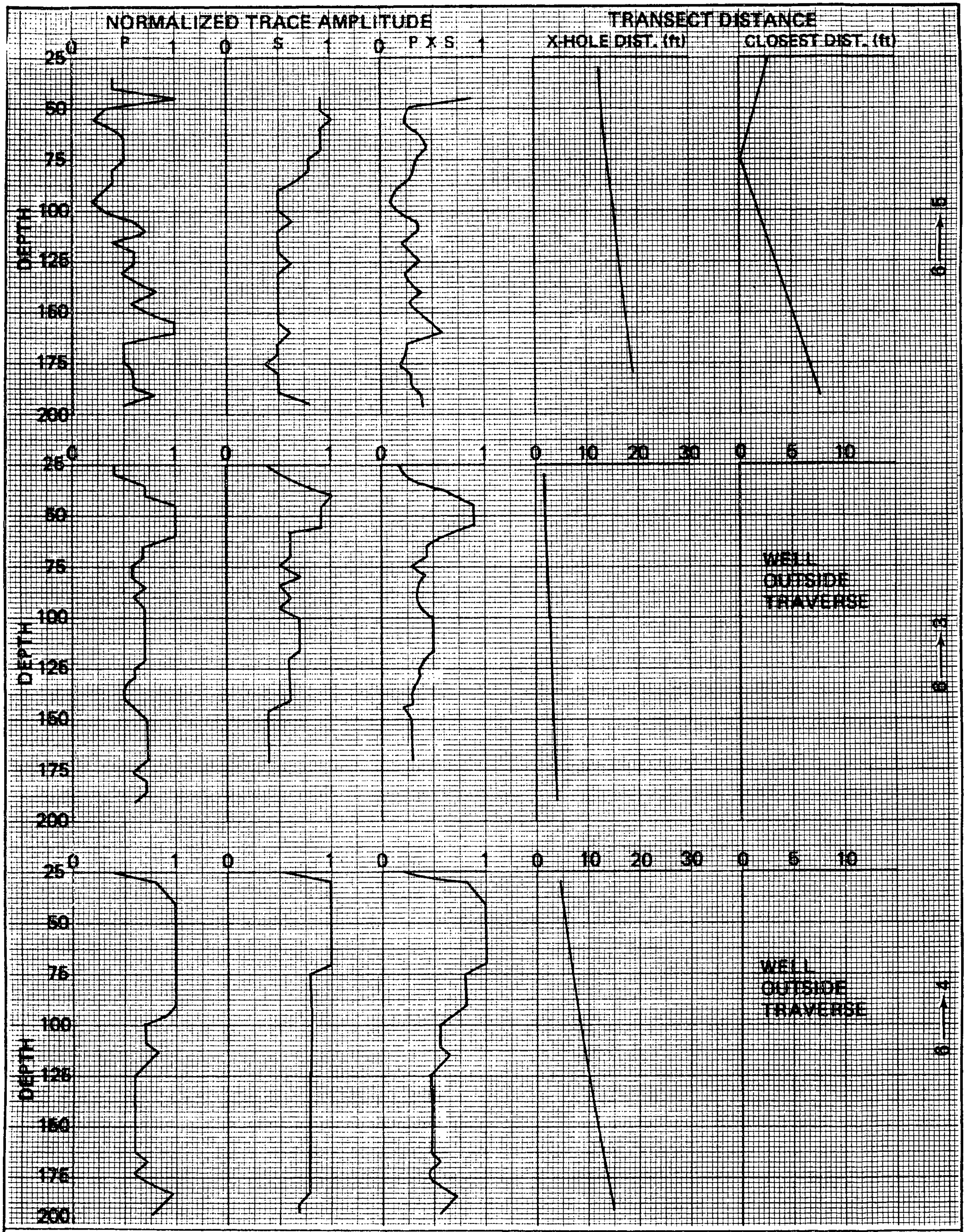

Project:	SONGS 2&3	WAVEFORM TRACE DATA SUMMARY FOR WELL NO. 4 SOURCE 6 AND RECEIVER 5, 3, 4	Fig.
Project No.	41130I		E-40

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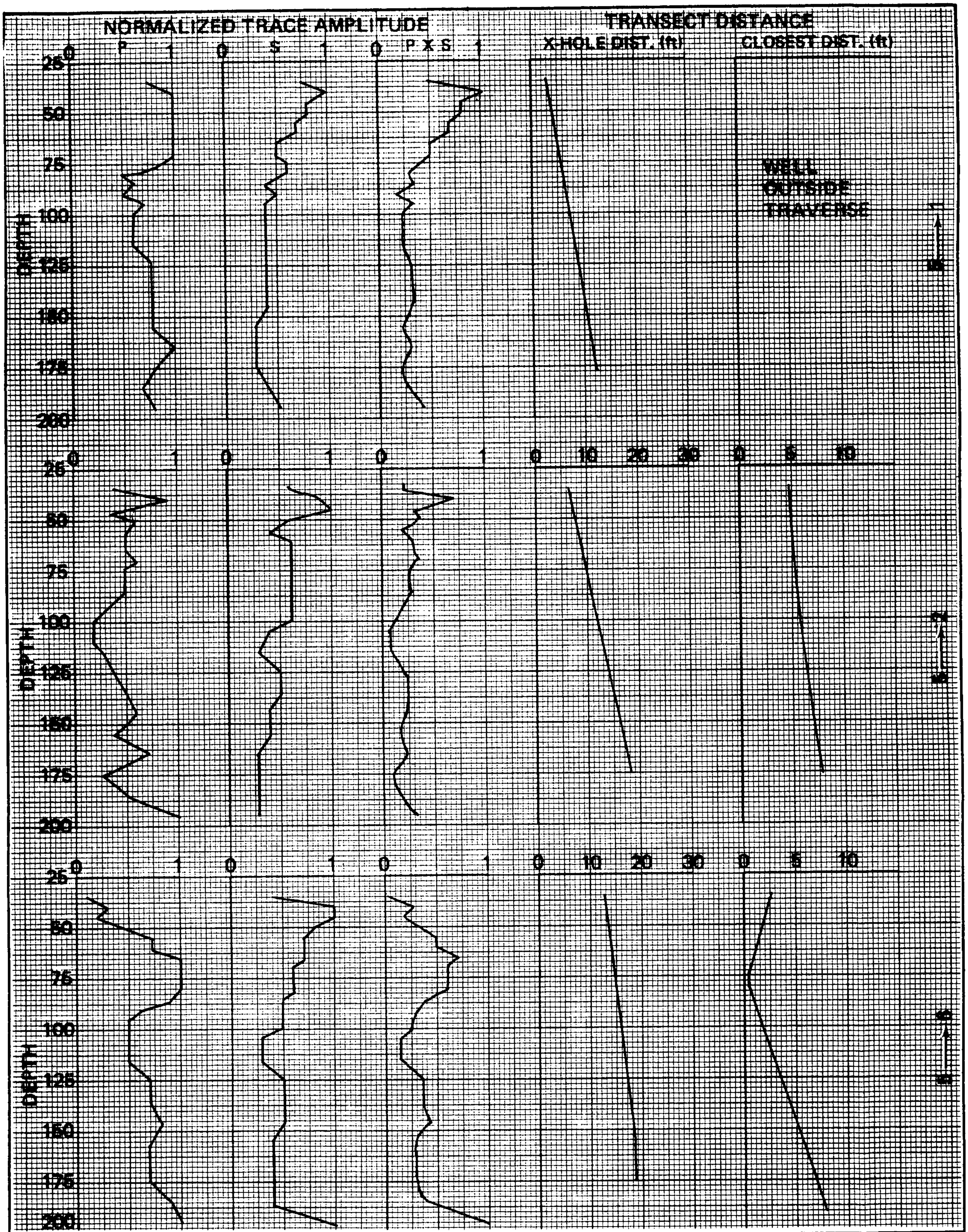

Project:	SONGS 2&3	WAVEFORM TRACE DATA SUMMARY FOR	Fig.
Project No.	41130I	WELL NO. 4 SOURCE 5 AND RECEIVER 1, 2, 6	E-41

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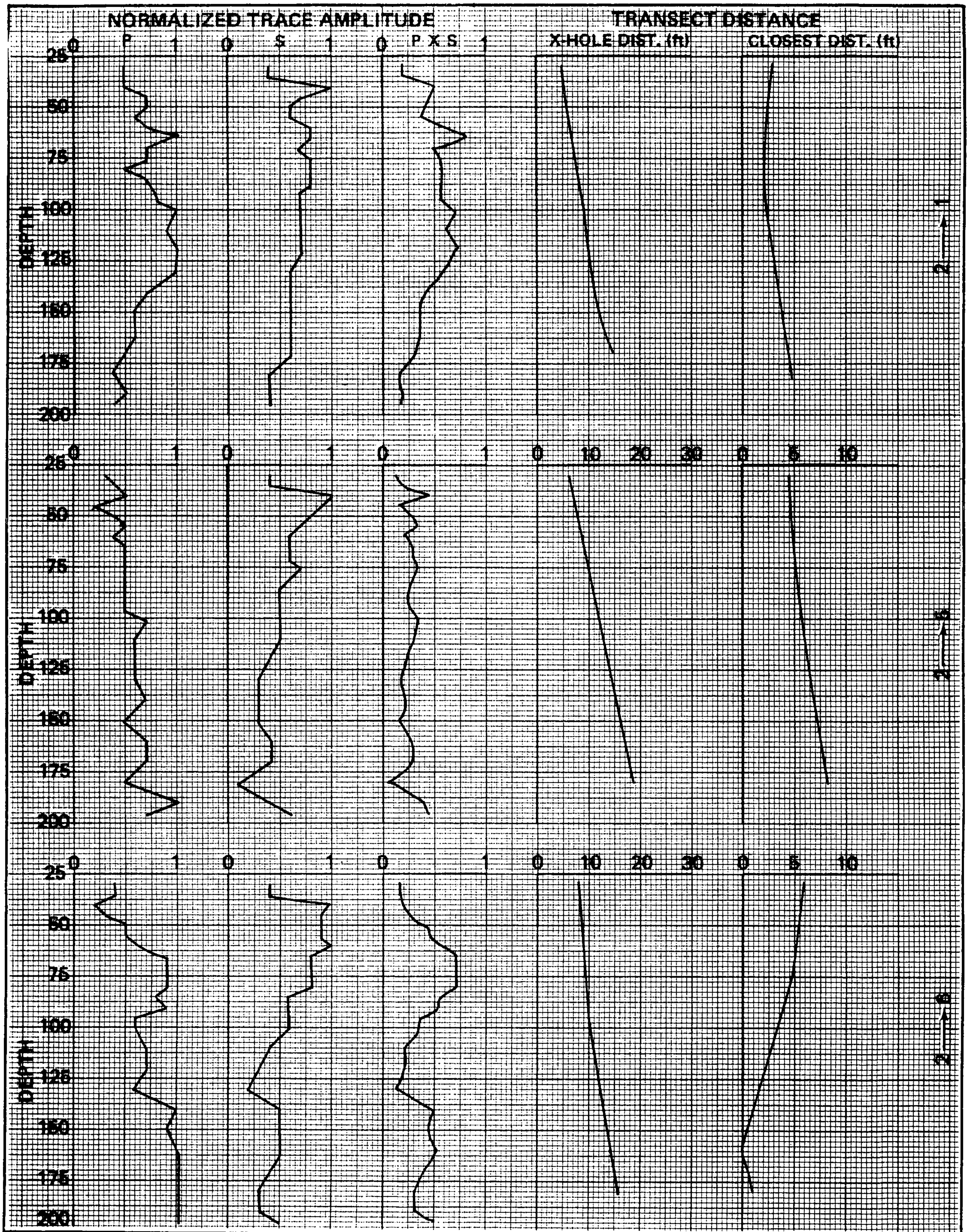
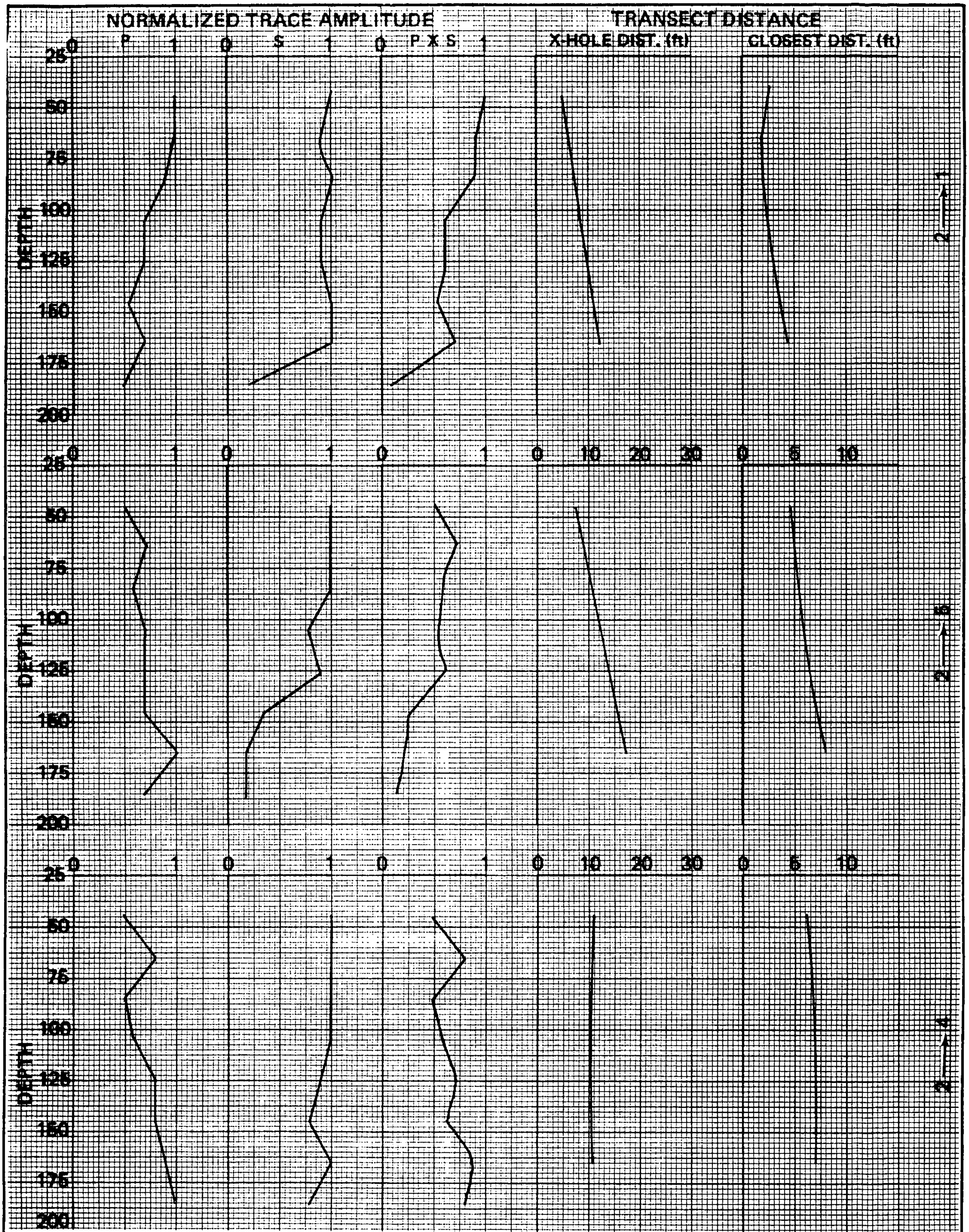


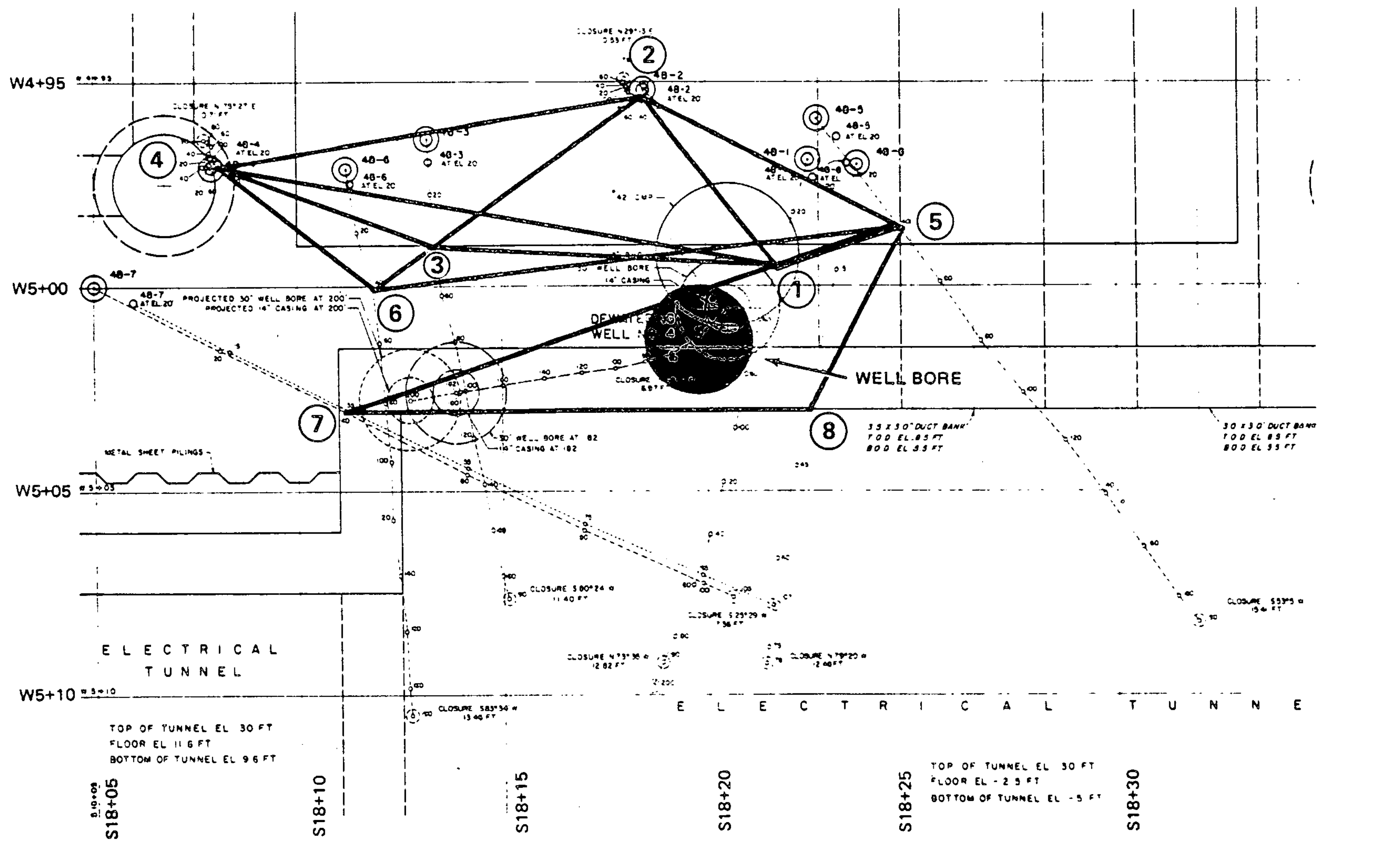
Project:	SONGS 2&3	WAVEFORM TRACE DATA SUMMARY FOR WELL NO. 4 SOURCE 2 AND RECEIVER 1, 5, 6	Fig. E-42
Project No.	41130I		

WOODWARD – CLYDE CONSULTANTS



Project:	SONGS 2&3	WAVEFORM TRACE DATA SUMMARY FOR	Fig.
Project No.	411301	WELL NO. 4 SOURCE 2 AND RECEIVER 1, 5, 4	E-43

WOODWARD—CLYDE CONSULTANTS

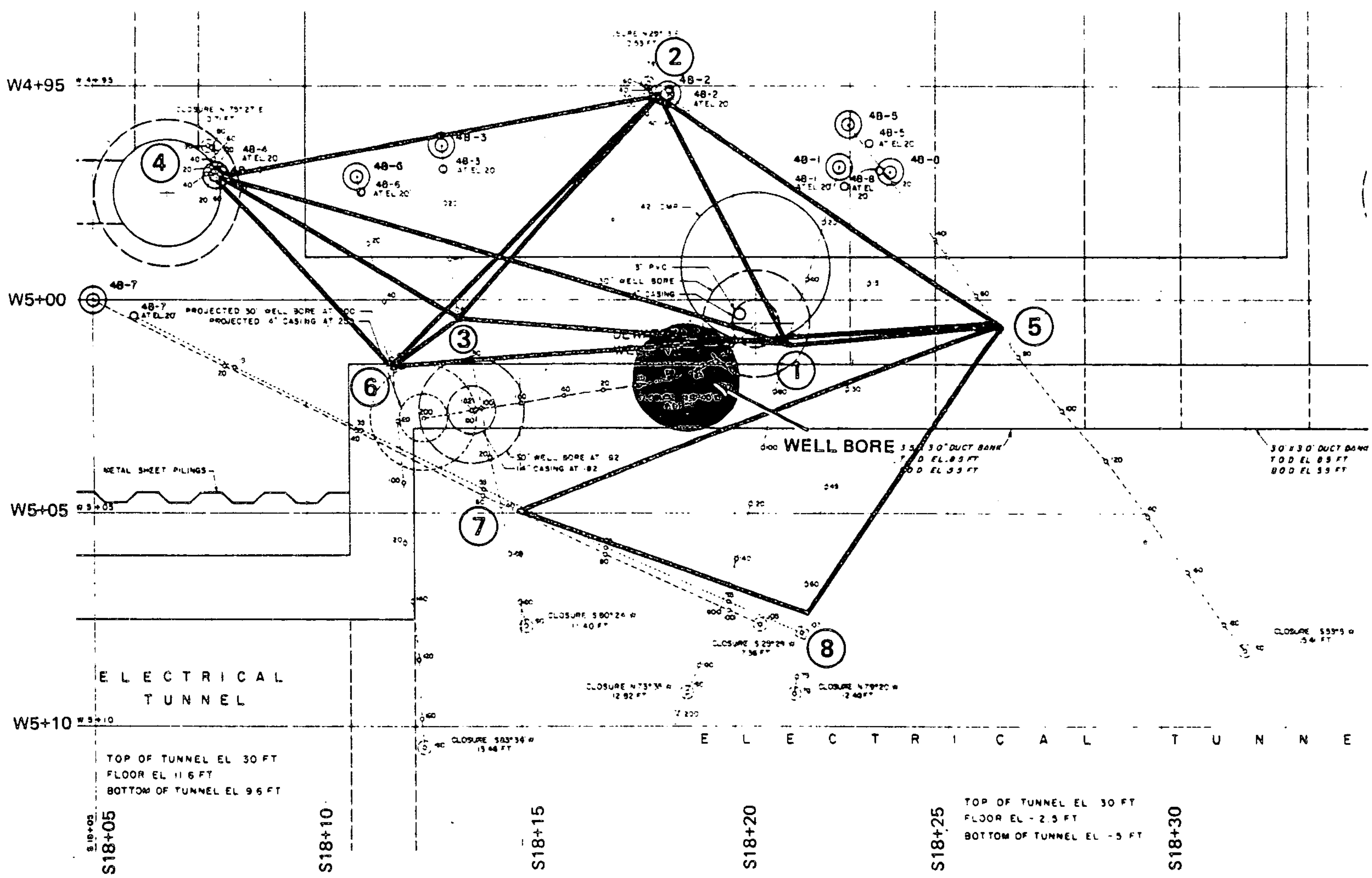


CROSSHOLE TRANSECTS AT 40 FT.

(thick line)	Across possible cavity
(double line)	Across native soil
(1)	Indicates the end point boring for the transect at a depth of 40 ft.

Project:	SONGS 2 & 3	DEWATERING WELL NO. 4 LOCATION OF DRILL HOLES AND CROSSHOLE TRANSECTS AT 40 FT. DEPTH	Fig. E-44
Project No.	411301		

WOODWARD-CLYDE CONSULTANTS



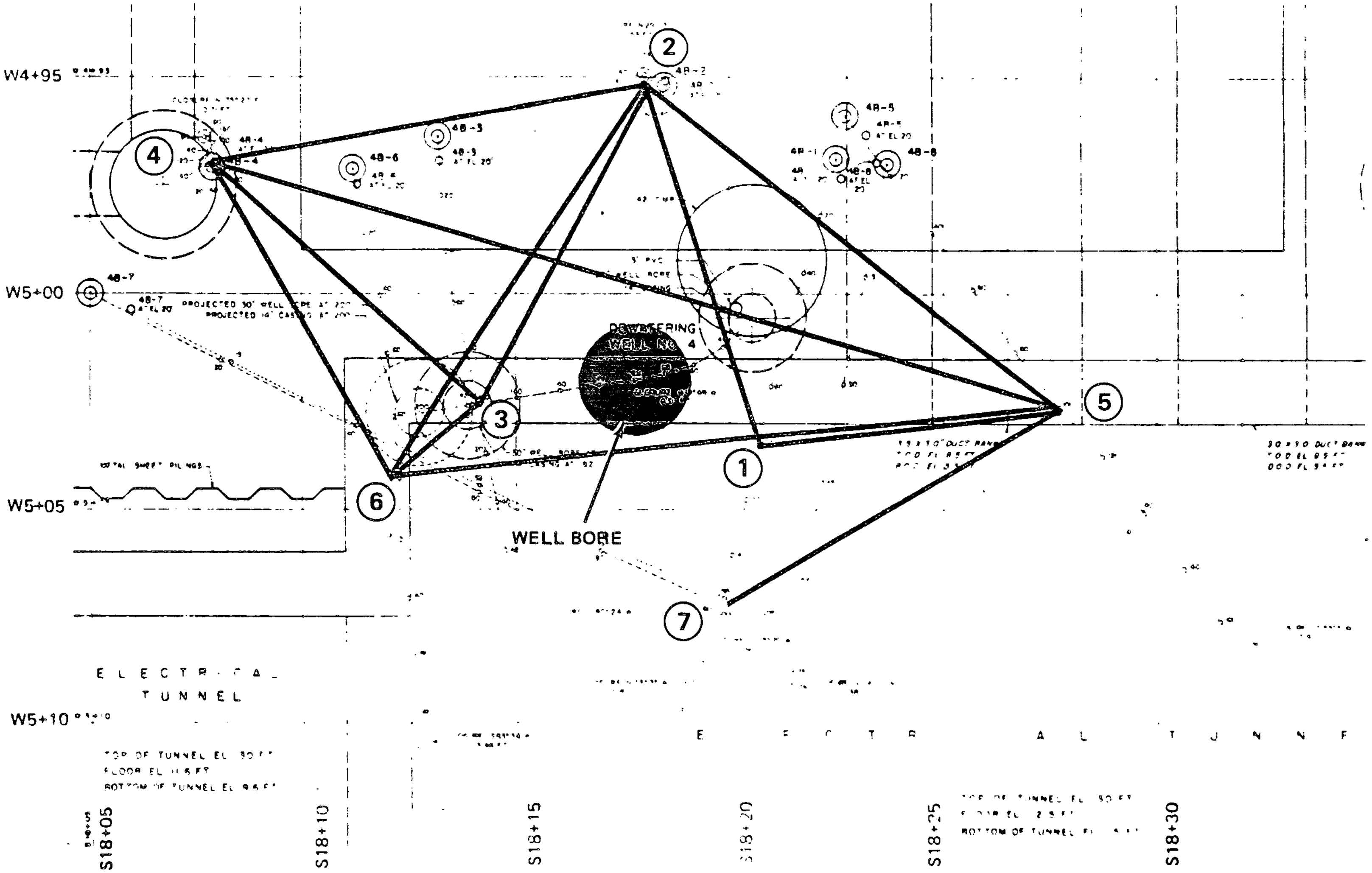
CROSSHOLE TRANSECTS AT 70 FT.

Across native soil

(1) Indicates the end point boring for the transect at a depth of 70 ft.

Project: SONGS 2 & 3 Project No. 411301	DEWATERING WELL NO. 4 LOCATION OF DRILL HOLES AND CROSSHOLE TRANSECTS AT 70 FT. DEPTH	Fig. E-45

WOODWARD-CLYDE CONSULTANTS



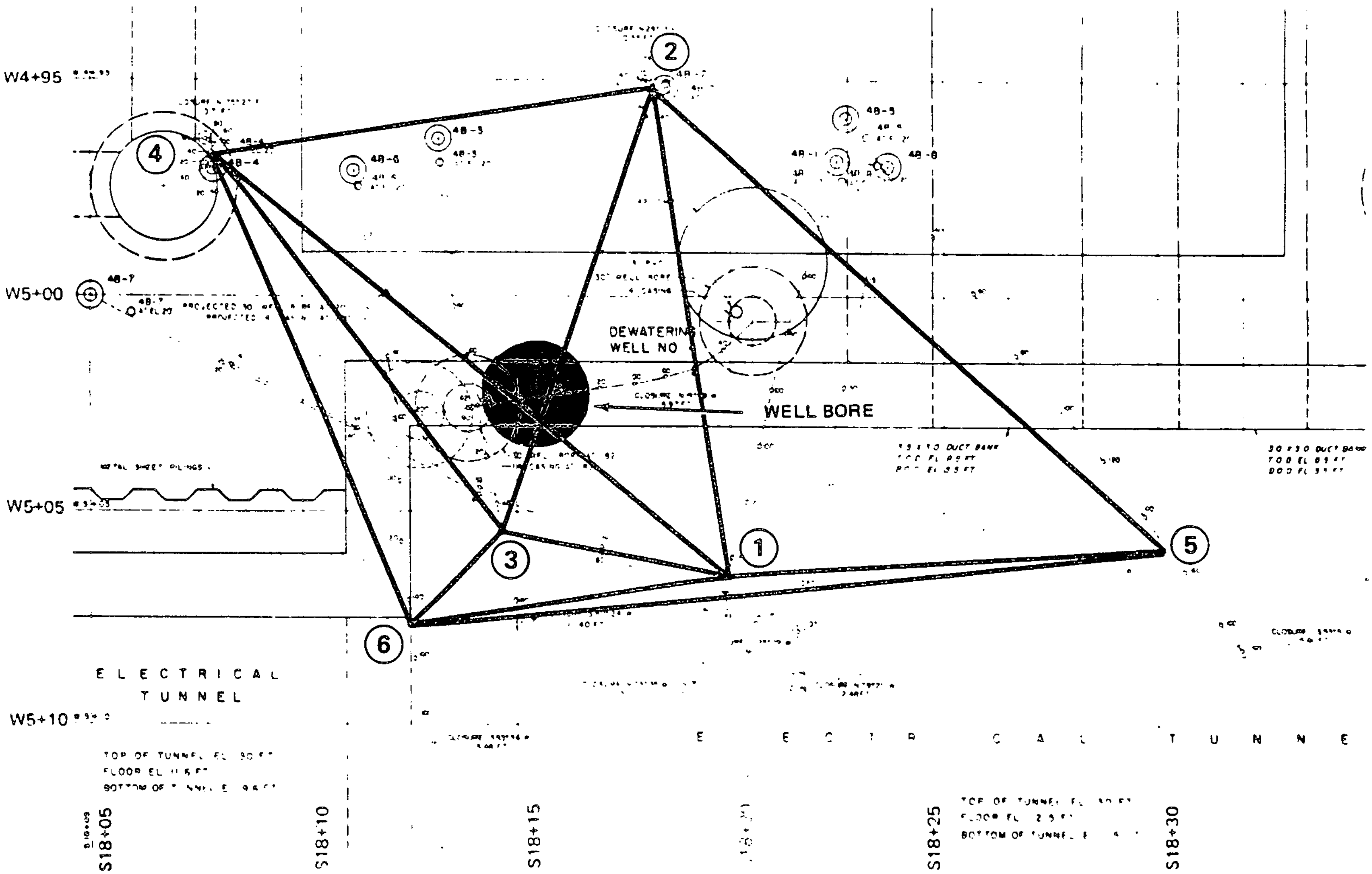
CROSSHOLE TRANSECTS AT 100 FT.

——— Across native soil

(1) Indicates the end point boring for the transect at a depth of 100 ft.

Project	SONGS 2 & 3	DEWATERING WELL NO. 4 LOCATION OF DRILL HOLES AND CROSSHOLE TRANSECTS AT 100 FT. DEPTH	Fig.
Project No	41130I		E-46

WOODWARD-CLYDE CONS...



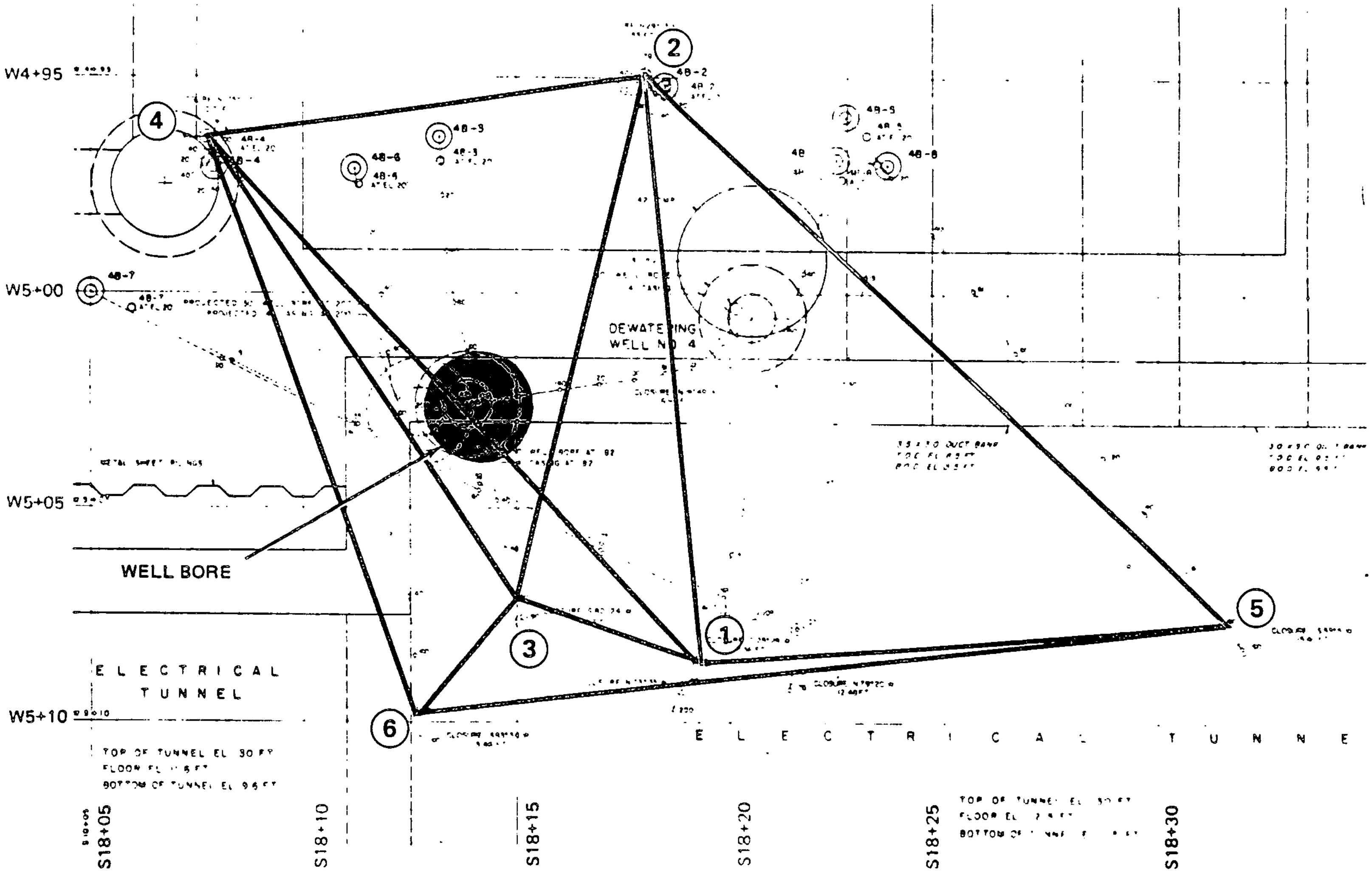
CROSSHOLE TRANSECTS AT 150 FT.

——— Across native soil

(1) Indicates the end point boring for the transect at a depth of 150 ft.

Project:	SONGS 2 & 3	DEWATERING WELL NO. 4 LOCATION OF DRILL HOLES AND CROSSHOLE TRANSECTS AT 150 FT. DEPTH	Fig
Project No	41130I		E-47

WOODWARD-CLYDE CONSULTANTS



CROSSHOLE TRANSECTS AT 180 FT.

Across native soil

Across possible graze

(1) Indicates the end point boring for the transect at a depth of 180 ft.

Project: Project No	SONGS 2 & 3 411301	DEWATERING WELL NO. 4 LOCATION OF DRILL HOLES AND CROSSHOLE TRANSECTS AT 180 FT. DEPTH	Fig E-48

APPENDIX F
CROSSHOLE GEOPHYSICAL DATA FOR WELL 5

F-1 INTRODUCTION

The crosshole method was used to provide closure on a total of four boreholes at Well 5 (Figure F-1). All boreholes are referenced to a surface elevation of +30 feet. The sections which follow describe the coverage obtained, present waveform data as defined in Appendix D, and present the results of applying the detection criteria described in Appendix D.

F-2 COVERAGE

Table F-1 presents a summary of the processed crosshole data used in the final analysis of Well 5. Six configurations provide good coverage on all sides of the well. In Figure F-2 the coverage at 60 feet is shown to be good, although limited on the south side. Below 60 feet, at 100, 150 and 175 feet, the coverage is good everywhere as shown in Figures F-3 through F-5. This coverage is somewhat limited on the northeast side below 175 feet because the PVC casing in Boring 5B-3 does not penetrate below this depth.

F-3 PROCESSED WAVEFORM RECORDS AND PERTINENT DATA

The waveform records are presented in Figures F-6 through F-17 and summarized in Table F-1. The records are presented as a function of depth and arranged by source configuration. The waveform data quality is good to excellent throughout.

Figures F-18 through F-21 present waveform data summaries pertinent to the interpretation of the waveform records as discussed in Appendix D. As listed in Table F-1, the figure showing normalized P-wave and S-wave amplitudes, as well as their product, are grouped by source configuration. The crosshole distance and closest distance to the well are also presented.

It was noted during the data processing that the shear wave velocities and wave forms in all Well 5 transects were essentially unaffected indicating no degredation of properties or presence of significnt cavities associated with this well.

F-4 DATA INTERPRETATION

Because the area down to a depth of 60 feet was extensively drilled and pressure grouted as described in Appendix B, crosshole data interpretation is only necessary below this depth. The data presented in Figures F-6 through F-21 were interpreted in accordance with the criteria developed in Appendix D. A summary of the results of this interpretation is presented on Table F-2 and Figures F-22 through F-25. These interpretations show native soil for all transects.

TABLE F-1

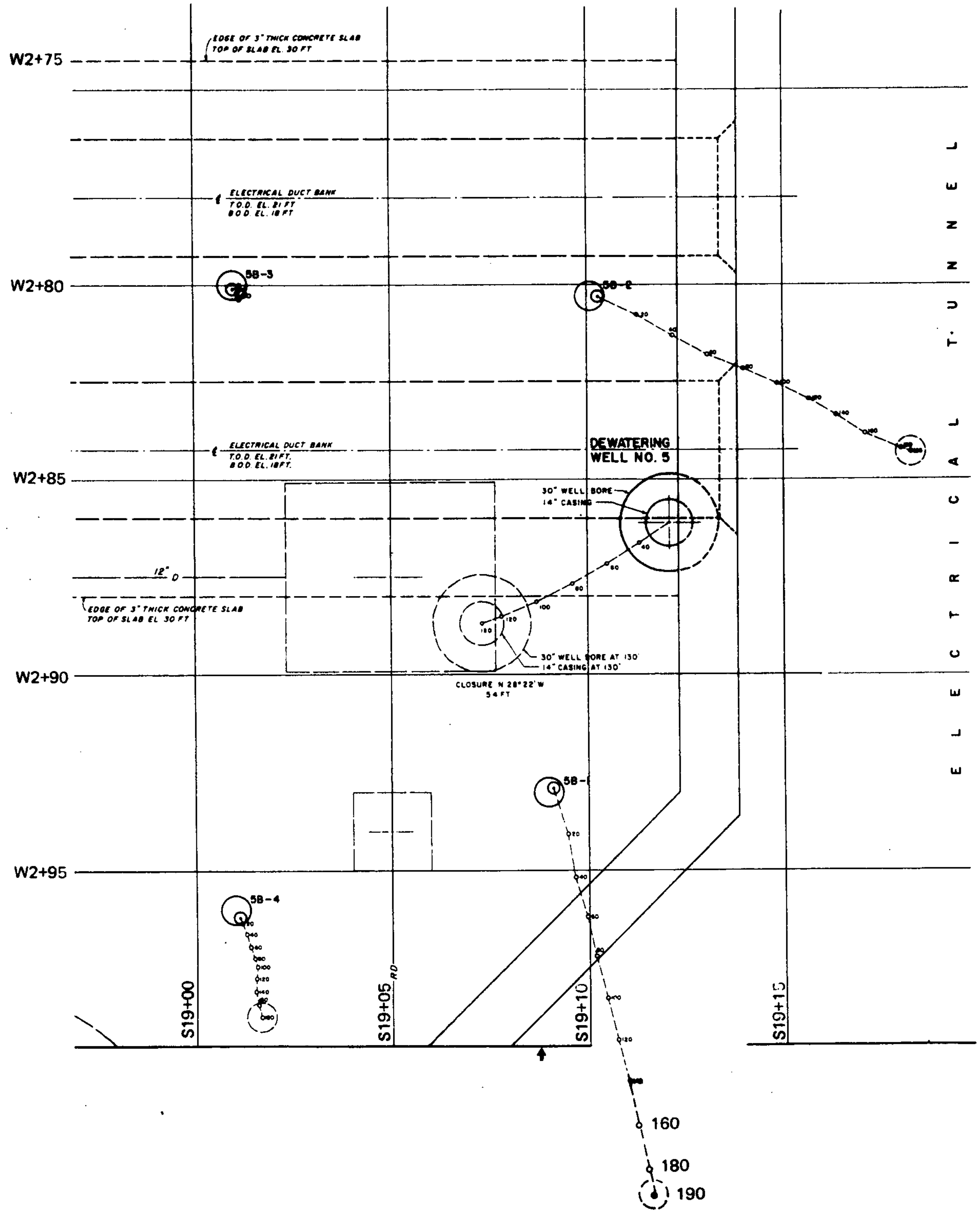
SUMMARY OF APPENDIX F FIGURES

Figure No.	Description	
F-1	Well 5 Location of Drill Holes	
F-2	Well 5 Location of Drill Holes and Crosshole Transects at 60-foot Depth	
F-3	Well 5 Location of Drill Holes and Crosshole Transects at 100-foot Depth	
F-4	Well 5 Location of Drill Holes and Crosshole Transects at 150-foot Depth	
F-5	Well 5 Location of Drill Holes and Crosshole Transects at 175-foot Depth	
F-6 to F-17	Well 5 Waveform Trace Figures	
	Source	Receiver
F-6 to F-8	2	1,3,4
F-9 to F-11	3	1,2,4
F-12 to F-14	2	2,3,4
F-15 to F-17	4	1,2,3
F-18 to E-21	Well 5 Waveform Data Summary Figures	
	Source	Receiver
F-18	2	1,3,4
F-19	3	1,2,4
F-20	2	2,3,4
F-21	4	1,2,3
F-22 to F-25	Well 5 Interpreted Transect Summary Figures	
	Depth	
F-22	60 feet	
F-23	100 feet	
F-24	150 feet	
F-25	200 feet	

TABLE F-2

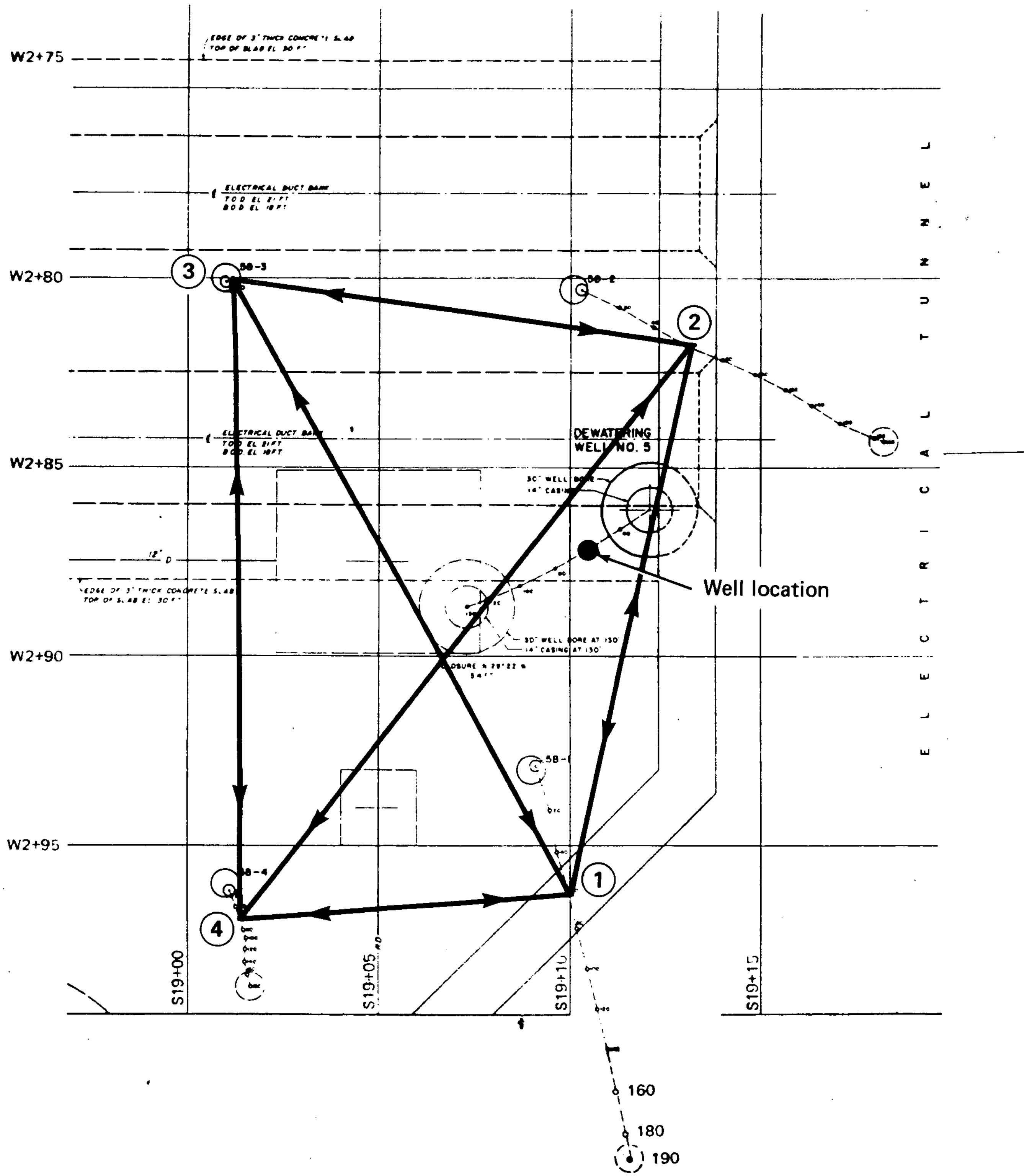
SUMMARY OF PxS TRACE AMPLITUDE INTERPRETATION FOR WELL 5

	Depth Interval Fitting Criteria				Depth Interval Fitting Criteria			
Transect	PxS=0	0<PxS<0.1	0.1<PxS<0.2	Reverse Transect	PxS=0	0<PxS<0.1	0.1<PxS<0.2	Interpretation
2-1	--	--	60', 85' 175'	1-2	--	--	--	Native at all depths.
2-3	--	--	60', 70-80' 135', 140'	3-2	--	--	--	Native to depth of Hole 3.
2-4	--	--	120'	4-2	--	--	160', 170'	Native at all depths.
3-1	--	--	130-140'	1-3	--	--	--	Native to depth of Hole 3.
3-4	--	--	60', 130-140'	4-3	--	--	150'	Native to depth of Hole 3.
1-4	--	--	--	4-1	--	--	--	Native at all depths.



Project:	SONGS 2 & 3	DEWATERING WELL NO. 5	Fig.
Project No.	411301	LOCATION OF DRILL HOLES	F-1

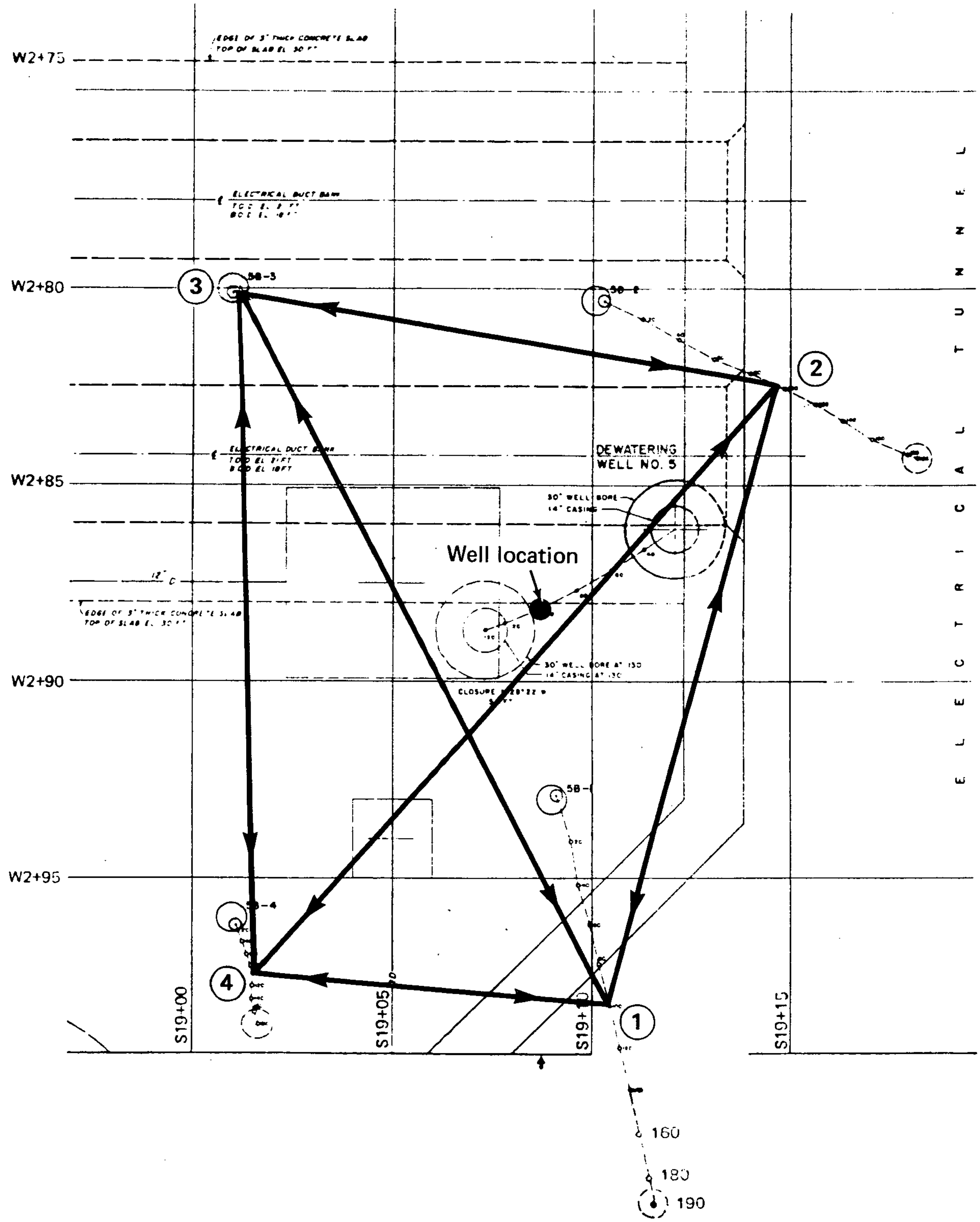
WOODWARD—CLYDE CONSULTANTS



(1) Indicates the end point boring for the transect at a depth of 60 ft.

Project: SONGS 2 & 3	Project No. 411301	DEWATERING WELL NO. 5 LOCATION OF DRILL HOLES AND CROSSHOLE TRANSECTS AT 60 FT. DEPTH	Fig. F-2

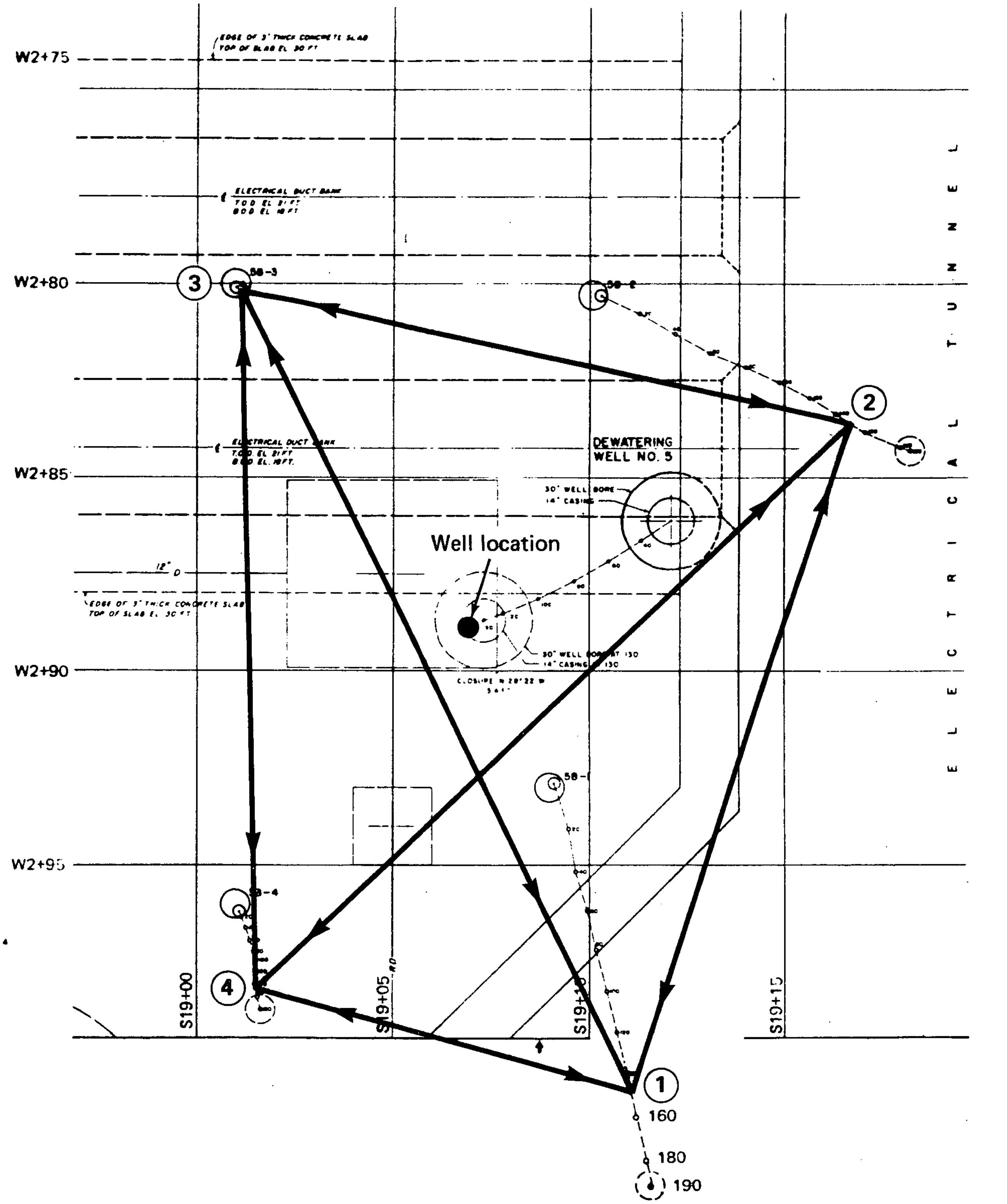
WOODWARD–CLYDE CONSULTANTS



① Indicates the end point boring for the transect at a depth of 100 ft.

Project:	SONGS 2 & 3	DEWATERING WELL NO. 5 LOCATION OF DRILL HOLES AND CROSSHOLE TRANSECTS AT 100 FT. DEPTH	Fig.
Project No.	411301		F-3

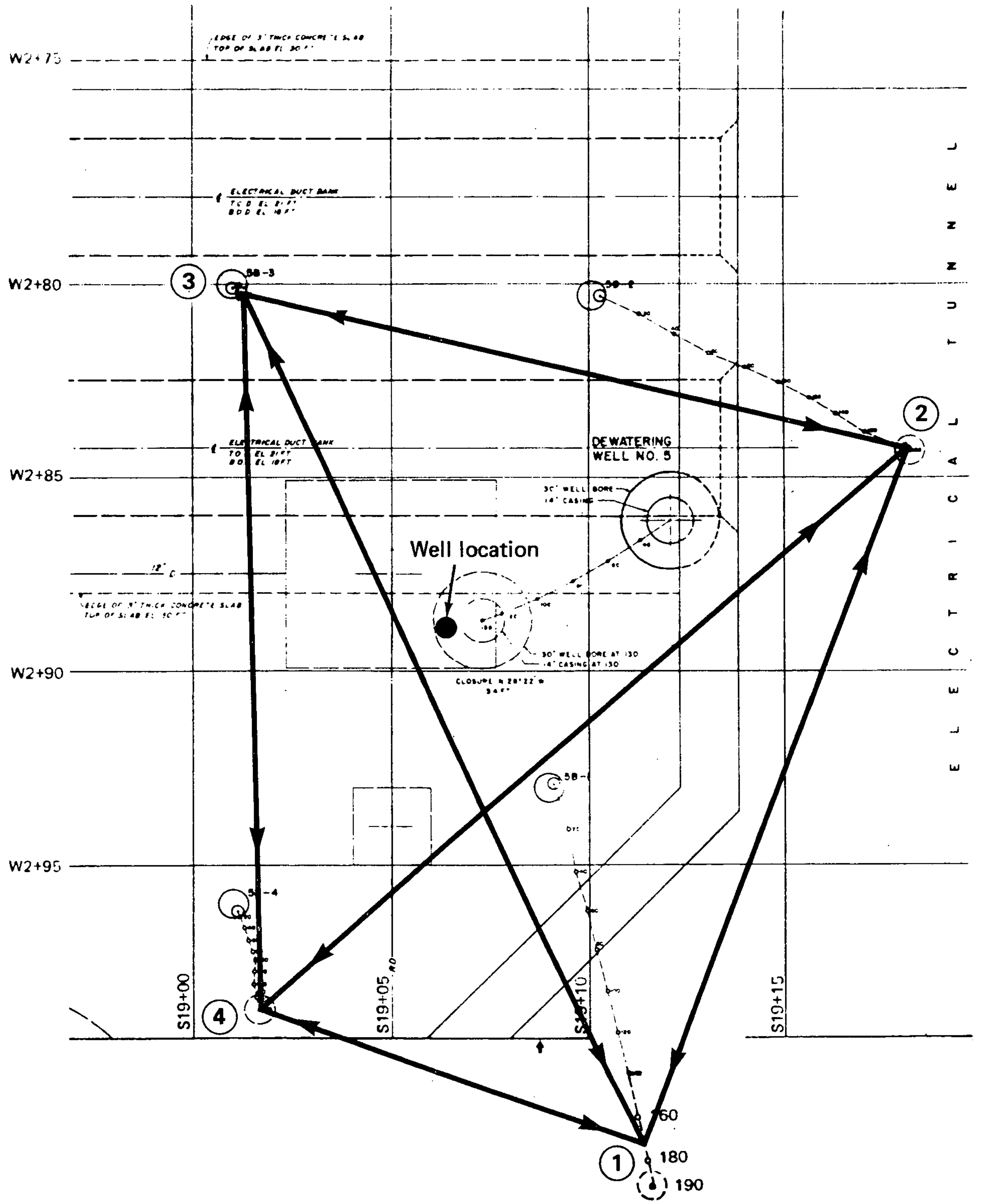
WOODWARD—CLYDE CONSULTANTS



1 Indicates the end point boring for the transect at a depth of 150 ft.

Project:	SONGS 2 & 3	DEWATERING WELL NO. 5 LOCATION OF DRILL HOLES AND CROSSHOLE TRANSECTS AT 150 FT. DEPTH	Fig. F-4
Project No.	411301		

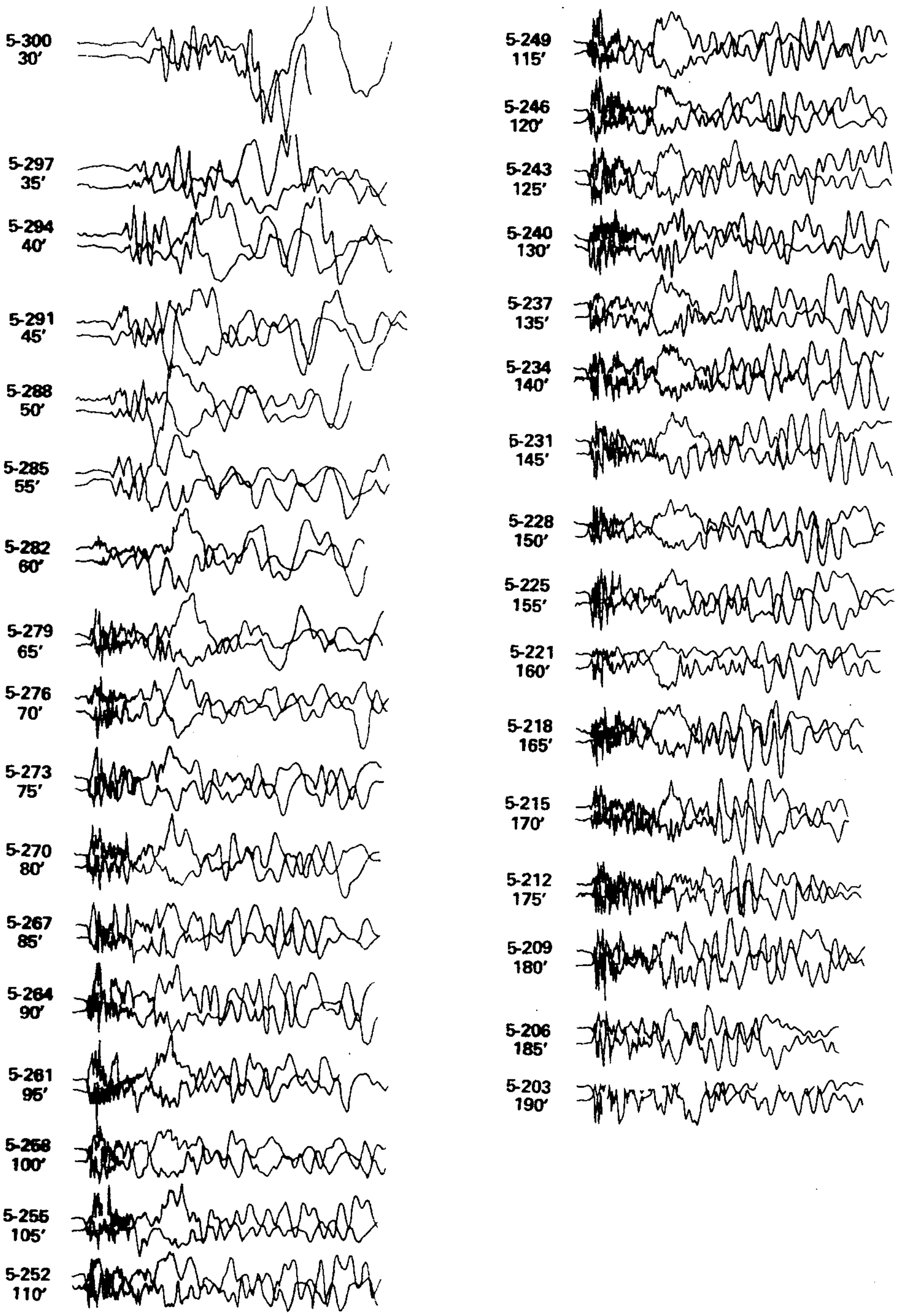
WOODWARD–CLYDE CONSULTANTS



① Indicates the end point boring for the transect at a depth of 175 ft.

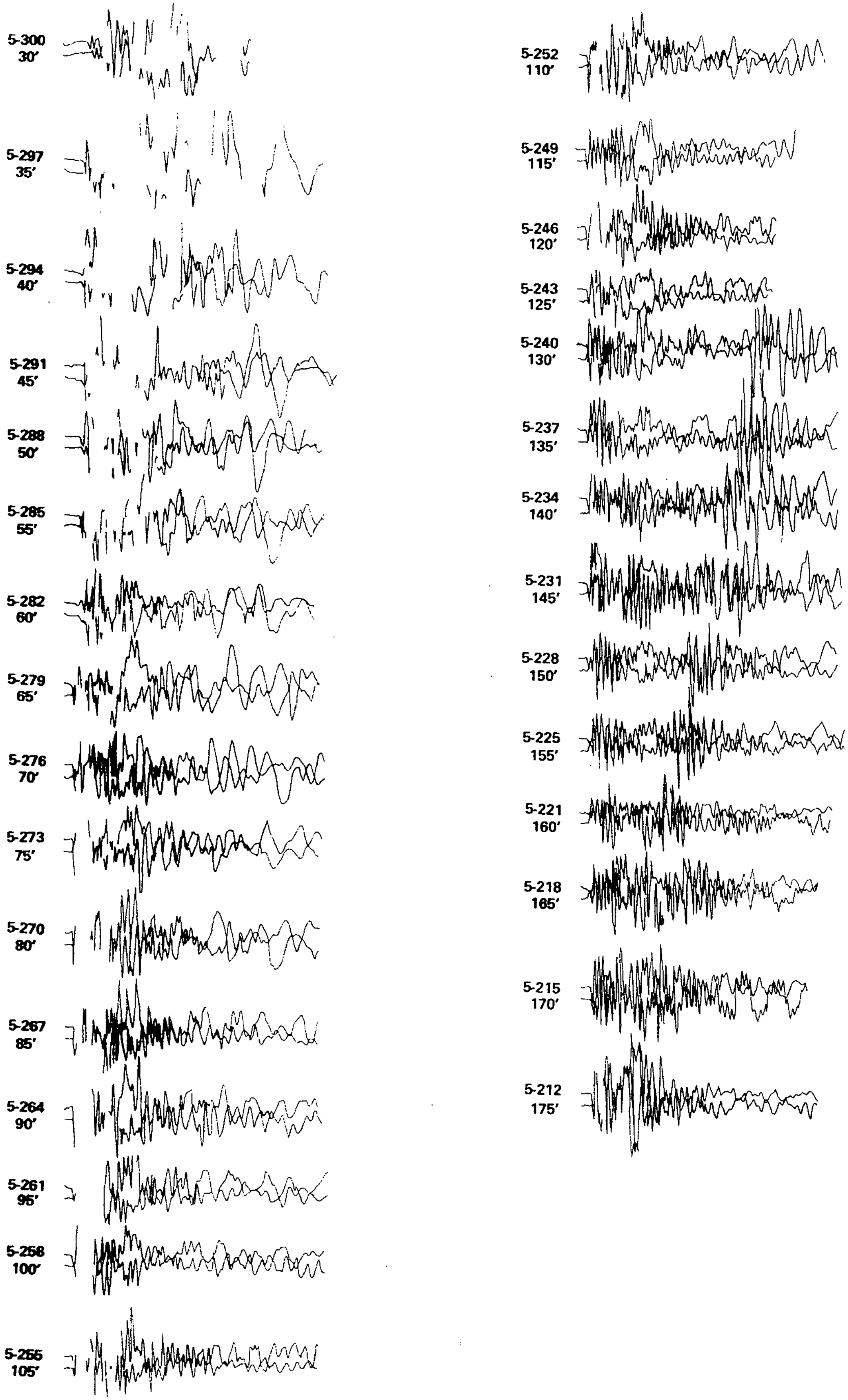
Project:	SONGS 2 & 3	DEWATERING WELL NO. 5 LOCATION OF DRILL HOLES AND CROSSHOLE TRANSECTS AT 175 FT. DEPTH	Fig.
Project No.	411301		F-5

WOODWARD – CLYDE CONSULTANTS



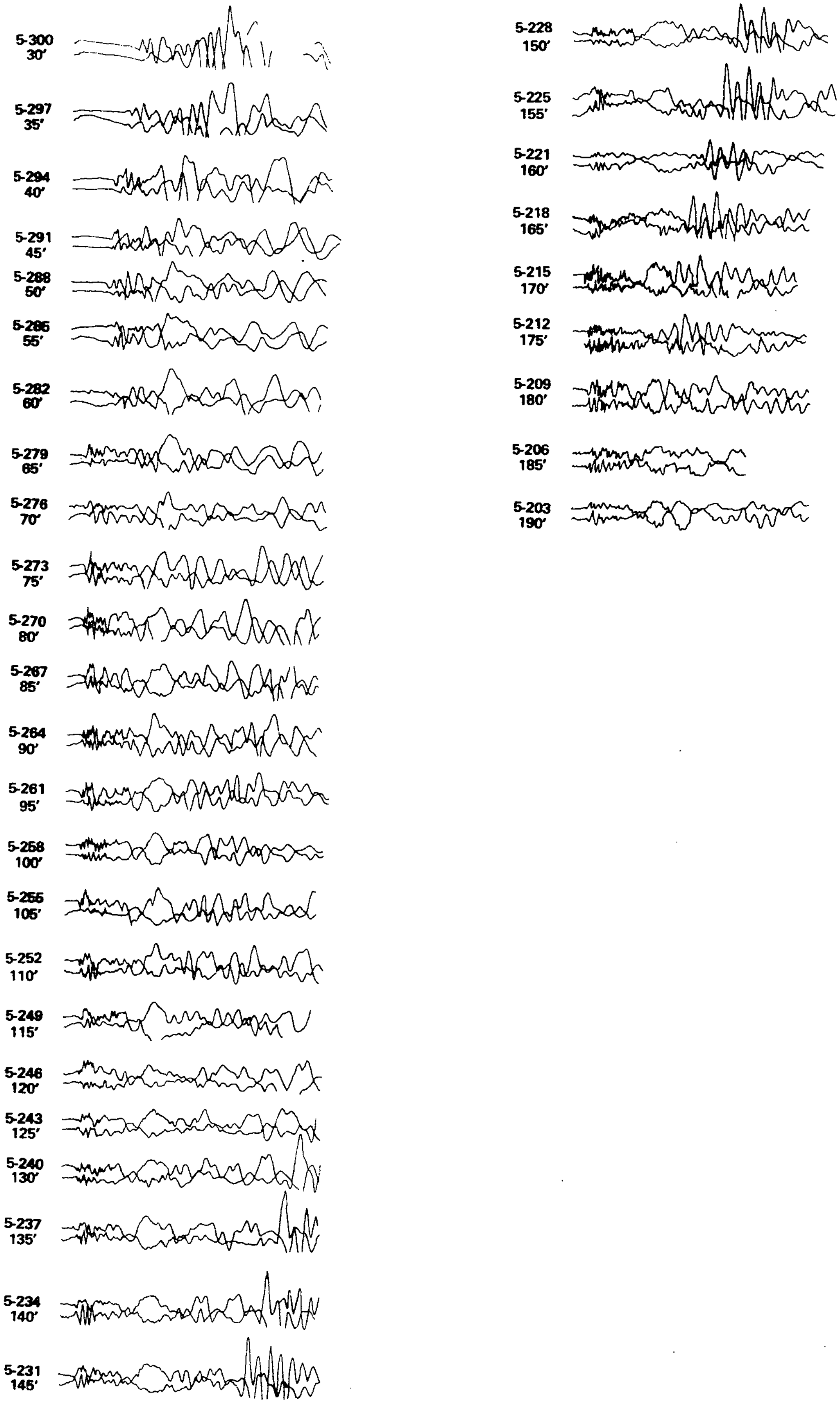
Project:	SONGS 2 & 3	WELL NO. 5 2 → 3 WAVEFORM TRACE	Fig.
Project No.	41130I		F-6

WOODWARD—CLYDE CONSULTANTS



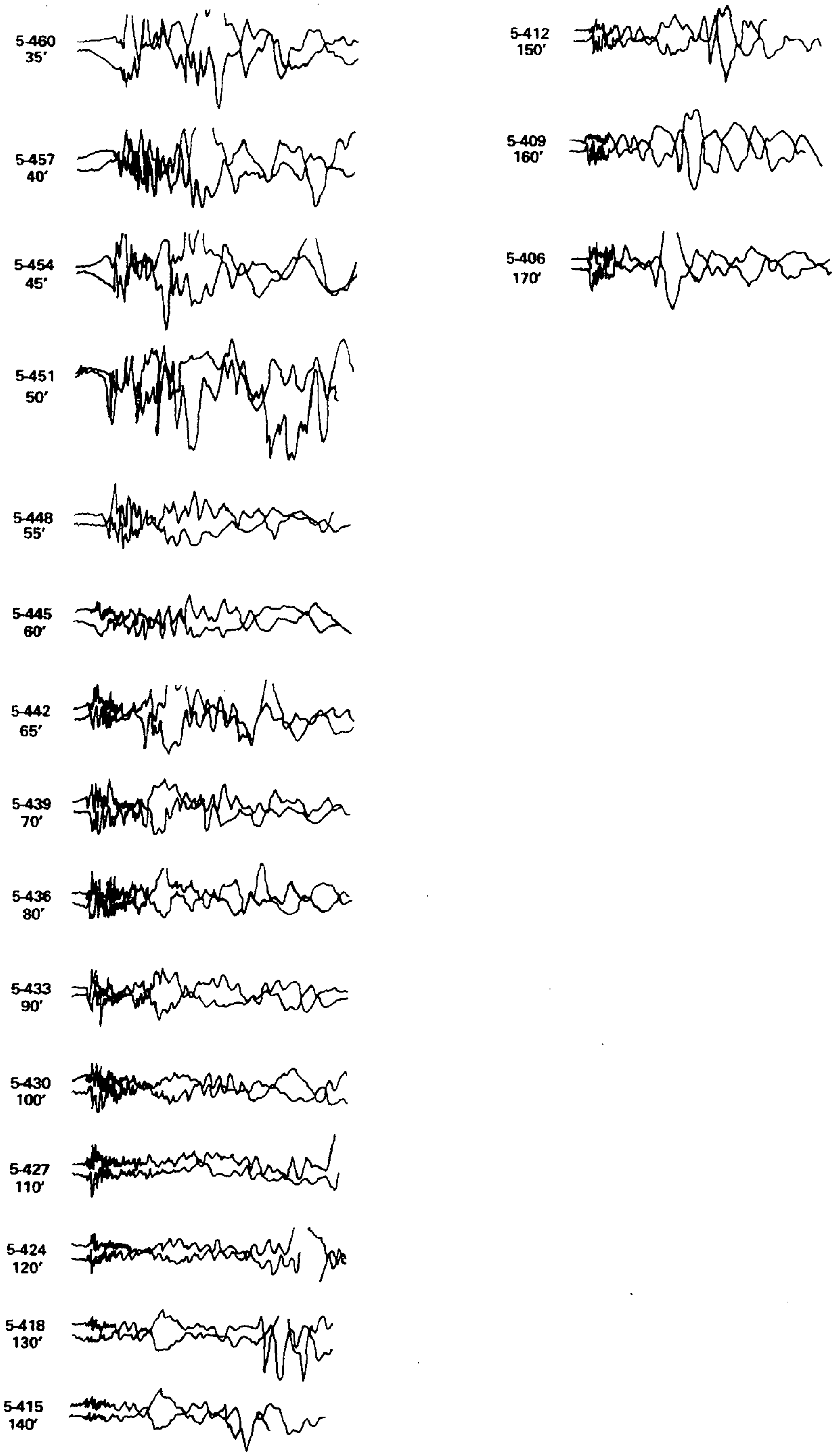
Project: SONGS 2 & 3 Project No. 41130I	WELL NO. 5 2 → 3 WAVEFORM TRACE	Fig. F-7

WOODWARD–CLYDE CONSULTANTS

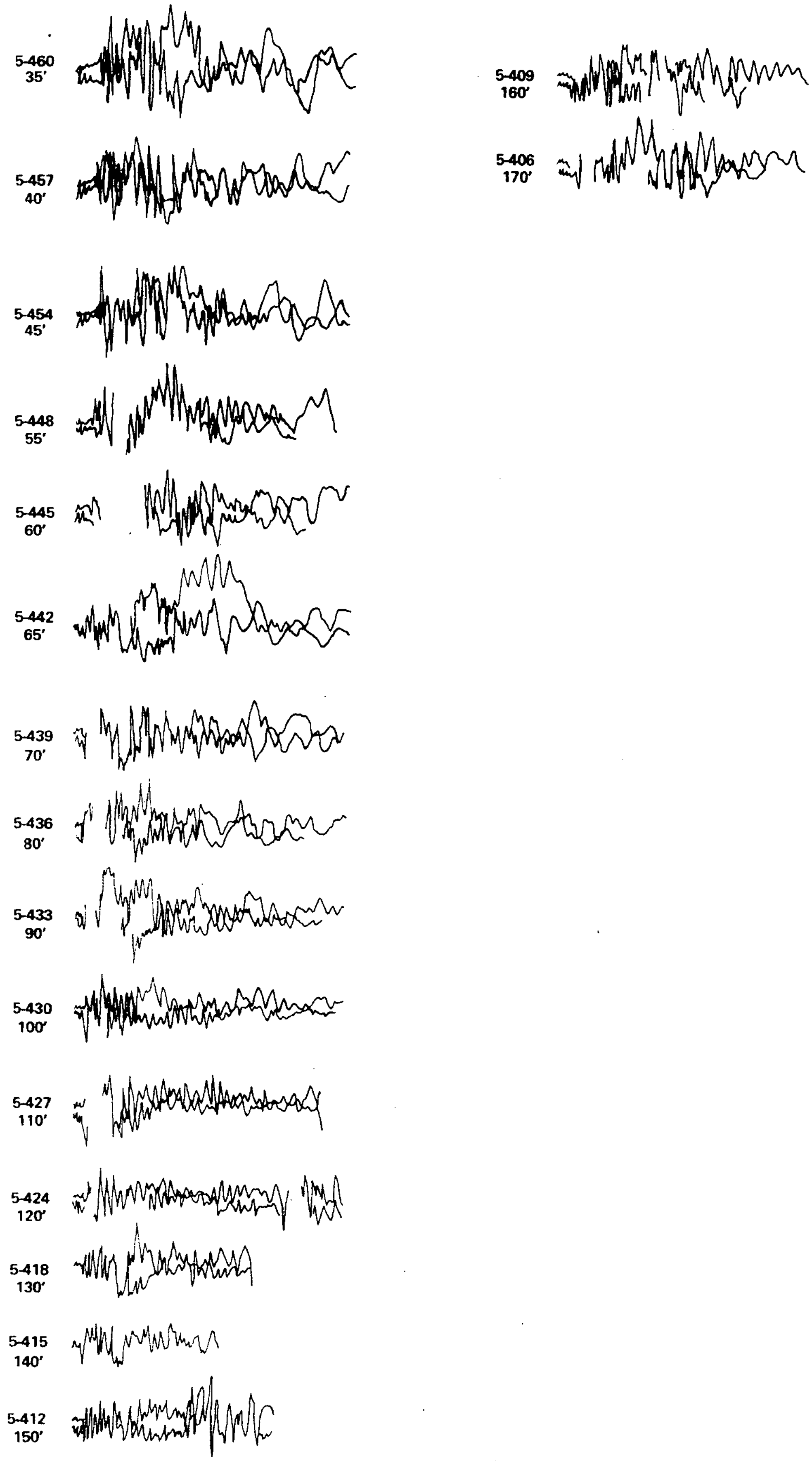


Project: SONGS 2 & 3 Project No. 41130I	WELL NO. 5 2→4 WAVEFORM TRACE	Fig. F-8

WOODWARD–CLYDE CONSULTANTS

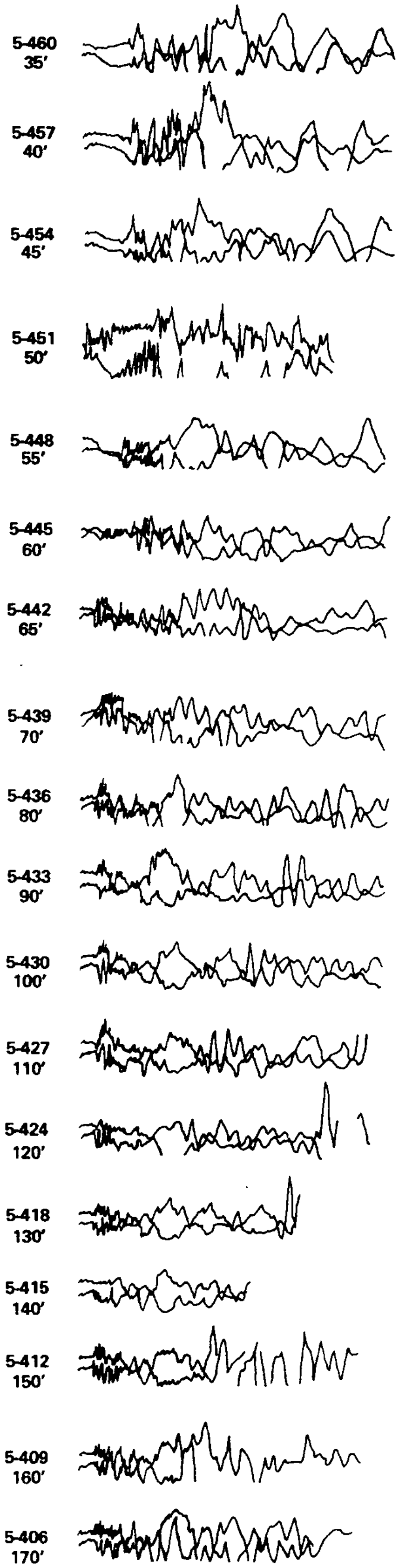


Project: **SONGS 2 & 3** Project No. **41130I**	**WELL NO. 5 3 → 1 WAVEFORM TRACE**	Fig. **F-9**



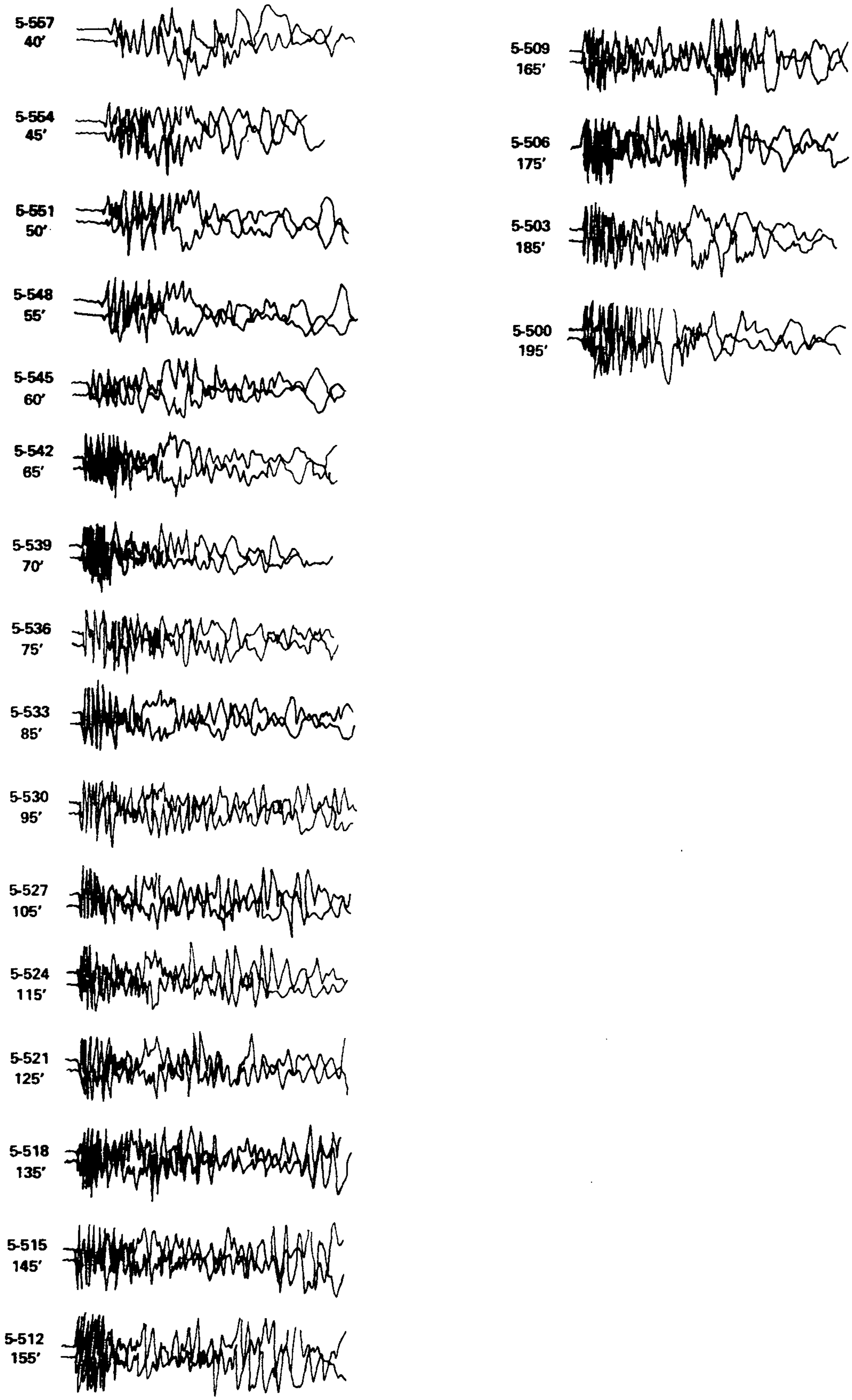
Project: SONGS 2 & 3 Project No. 41130I	WELL NO. 5 3 → 2 WAVEFORM TRACE	Fig. F-10

WOODWARD–CLYDE CONSULTANTS



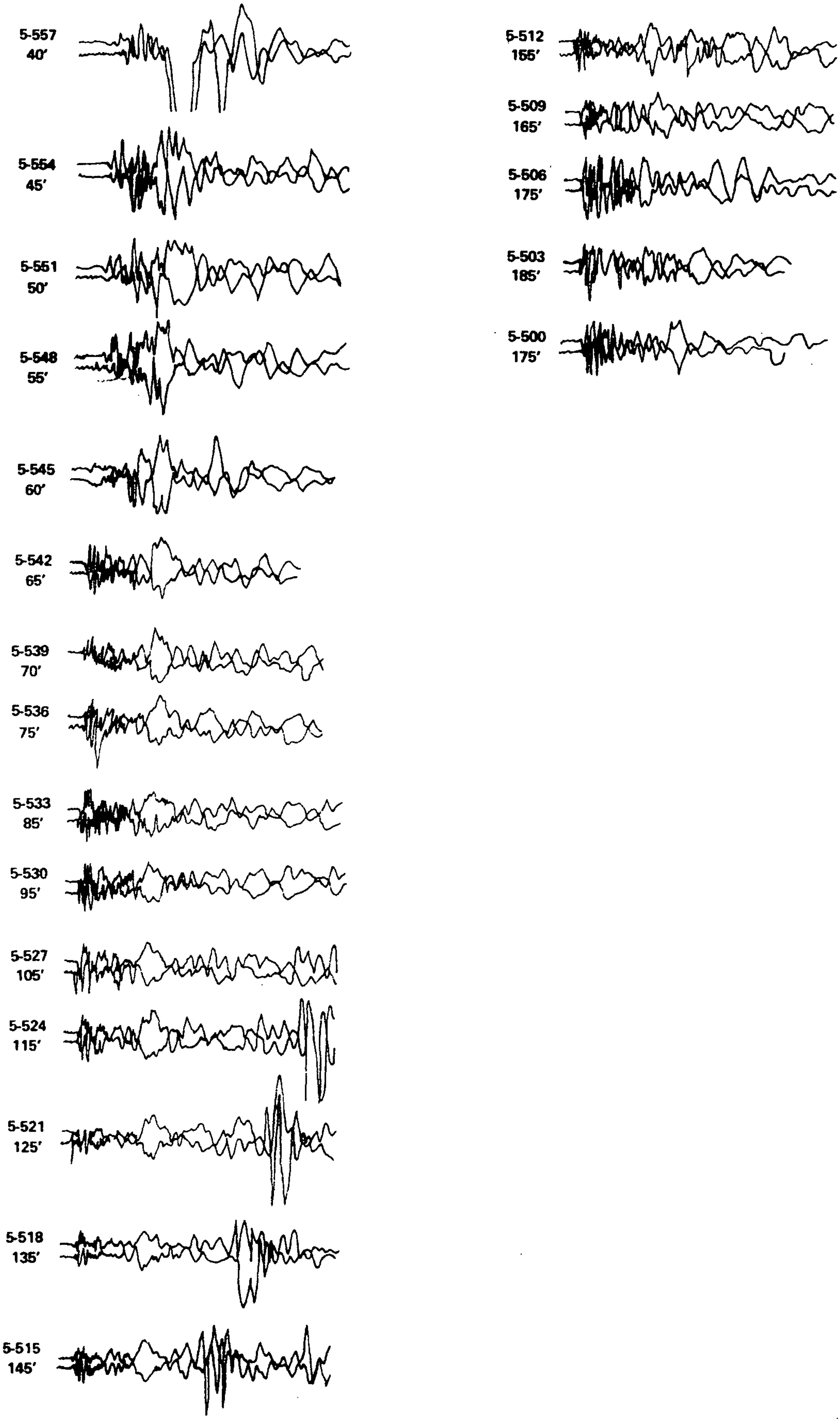
Project: **SONGS 2 & 3** Project No. **411301**	**WELL NO. 5 3→4 WAVEFORM TRACE**	Fig. **F-11**

WOODWARD–CLYDE CONSULTANTS



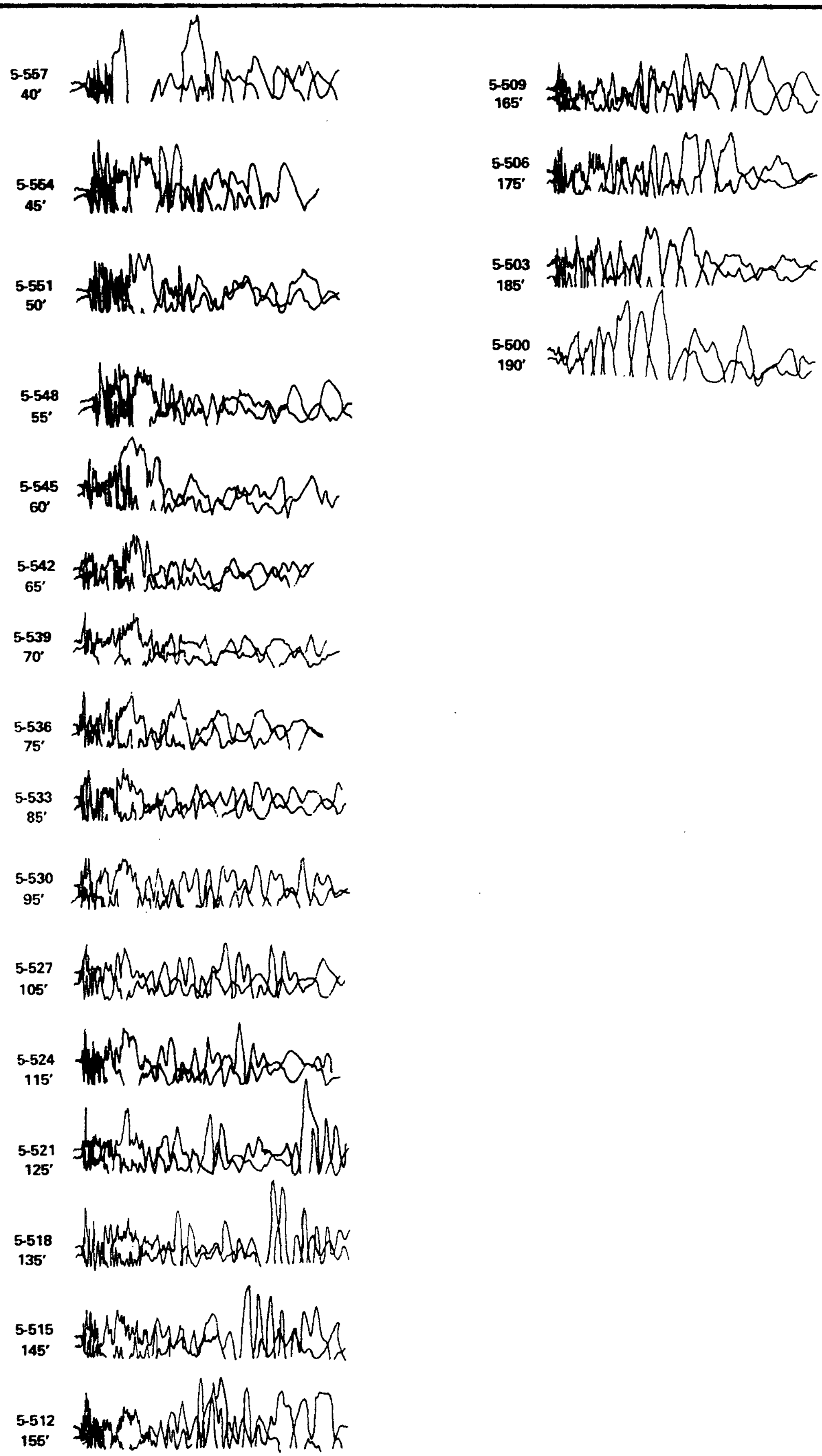
Project: **SONGS 2 & 3** Project No. **411301**	WELL NO. 5 2 → 2 WAVEFORM TRACE	Fig. F-12

WOODWARD – CLYDE CONSULTANTS



Project: **SONGS 2 & 3** Project No. **411301**	**WELL NO. 5 2 → 3 WAVEFORM TRACE**	Fig. **F-13**

WOODWARD–CLYDE CONSULTANTS

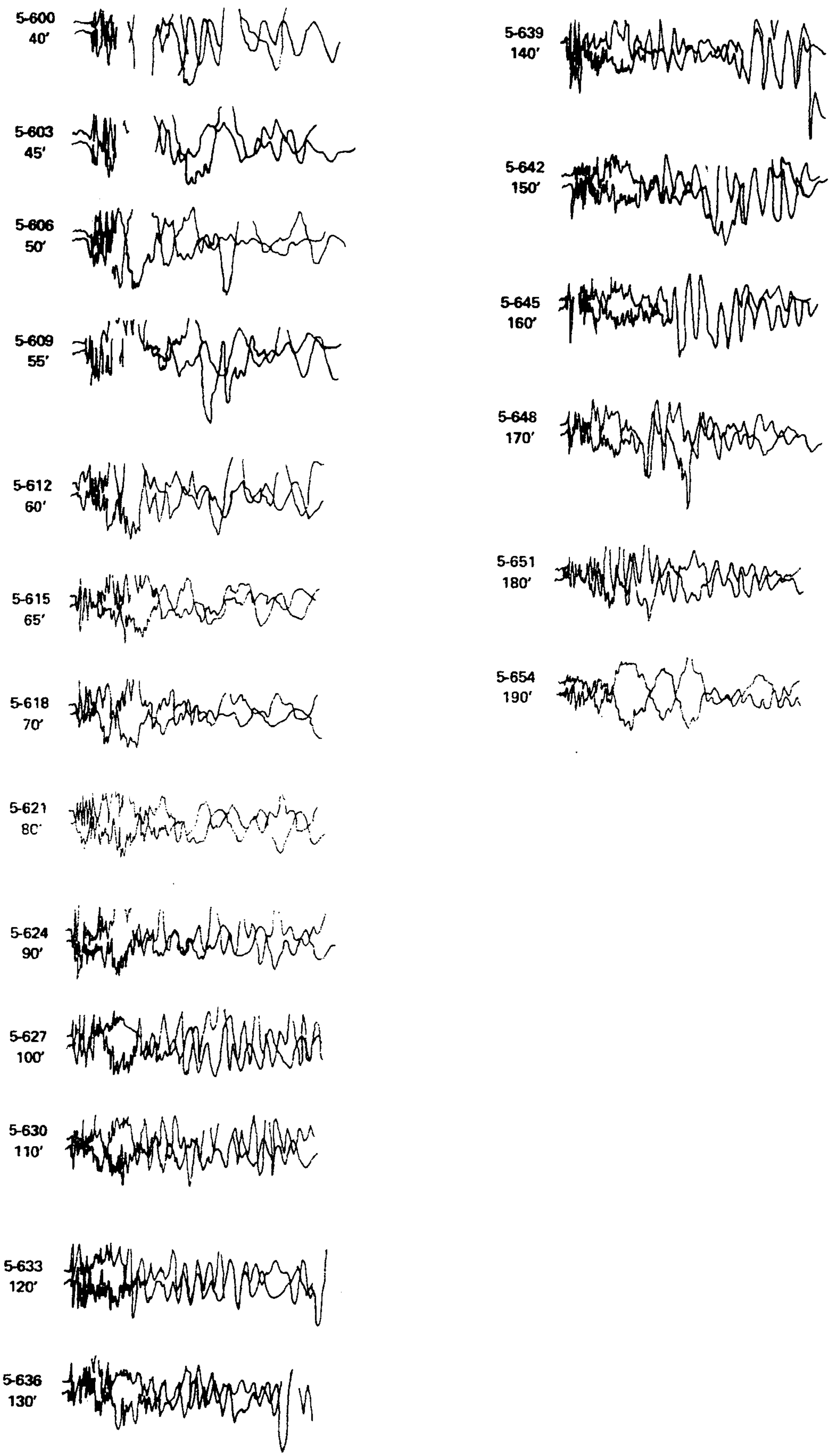


Project: SONGS 2 & 3
Project No. 41130I

WELL NO. 5 2 → 4 WAVEFORM TRACE

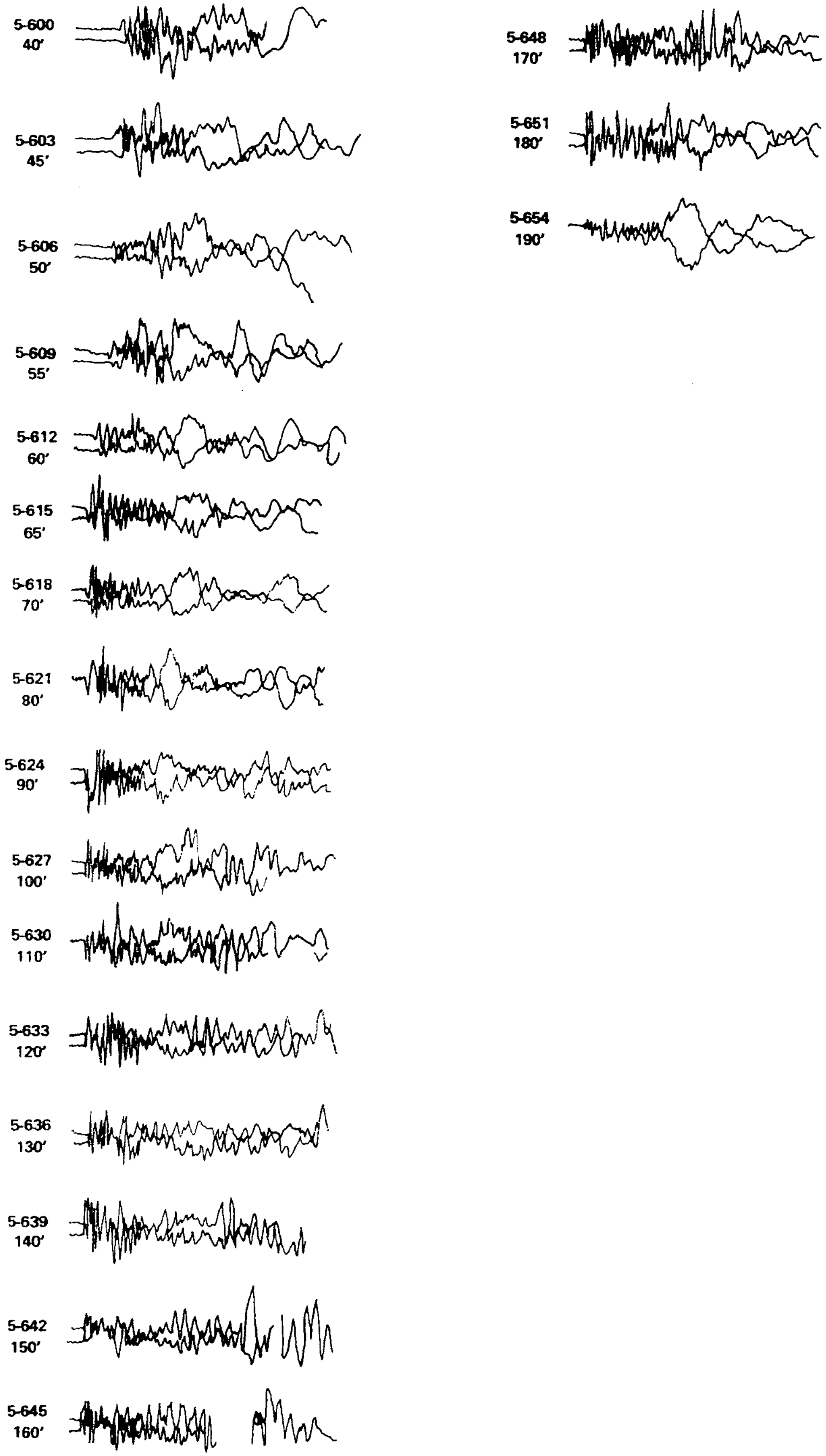
Fig. F-14

WOODWARD–CLYDE CONSULTANTS



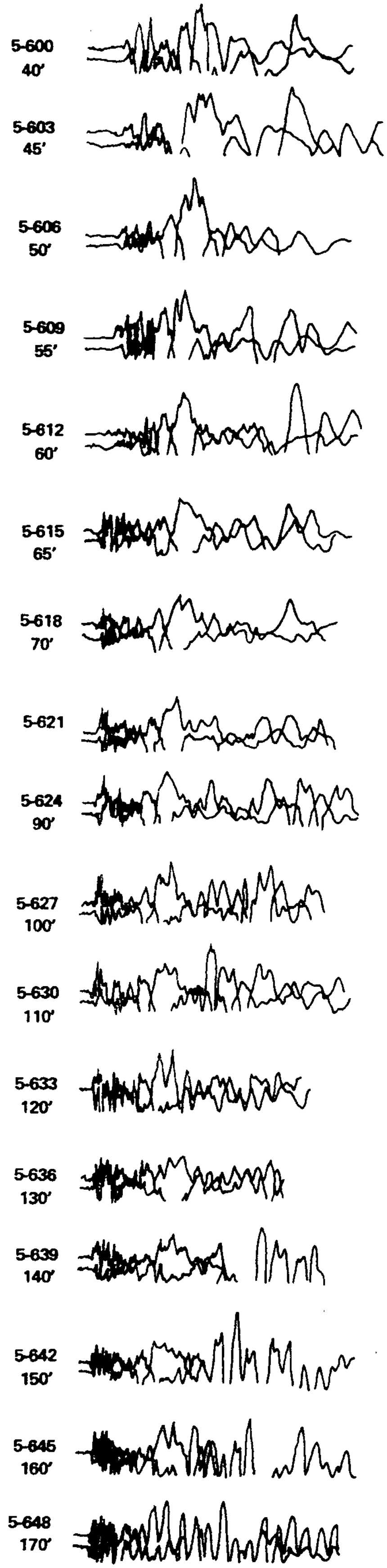
Project: SONGS 2 & 3 Project No. 411301	WELL NO. 5 4 → 1 WAVEFORM TRACE	Fig. F-15

WOODWARD – CLYDE CONSULTANTS

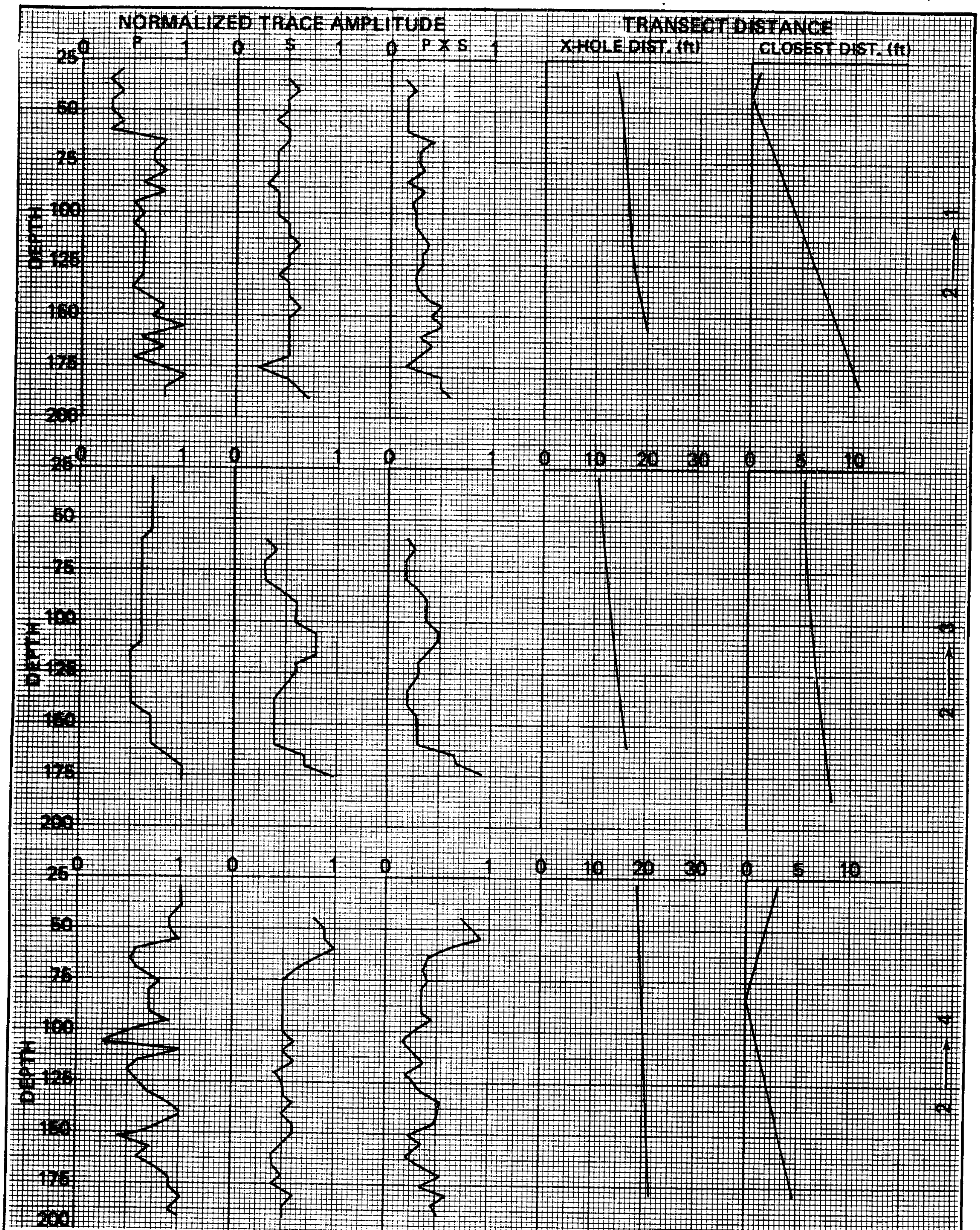


Project: SONGS 2 & 3 Project No. 41130I	WELL NO. 5 4 → 2 WAVEFORM TRACE	Fig. F-16

WOODWARD – CLYDE CONSULTANTS

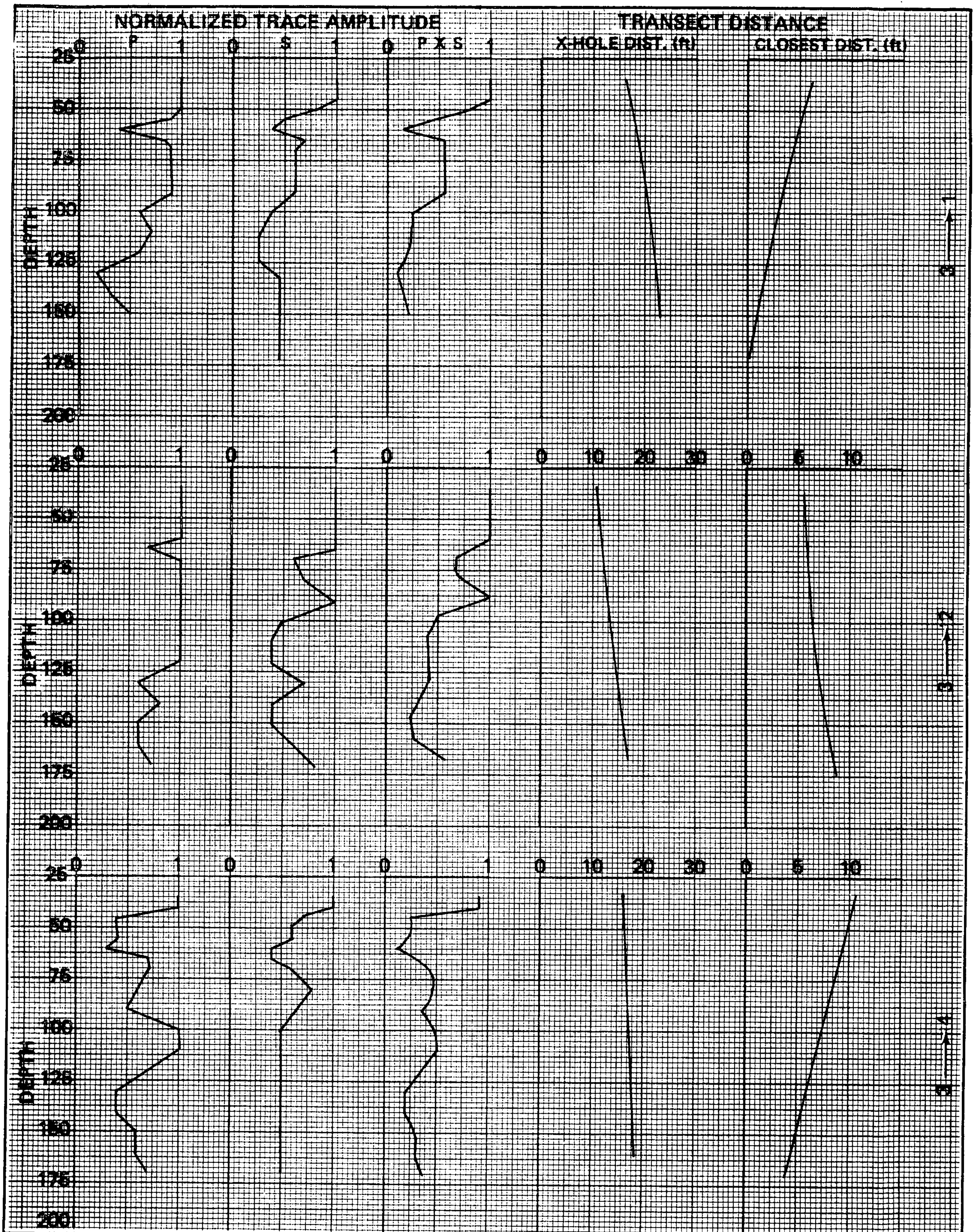


Project: SONGS 2 & 3 Project No. 41130I	WELL NO. 5 4 → 3 WAVEFORM TRACE	Fig. F-17



Project: SONGS 2&3 Project No. 411301	WAVEFORM TRACE DATA SUMMARY FOR WELL NO. 5 SOURCE 2 AND RECEIVER 1, 3, 4		Fig. F-18

WOODWARD—CLYDE CONSULTANTS

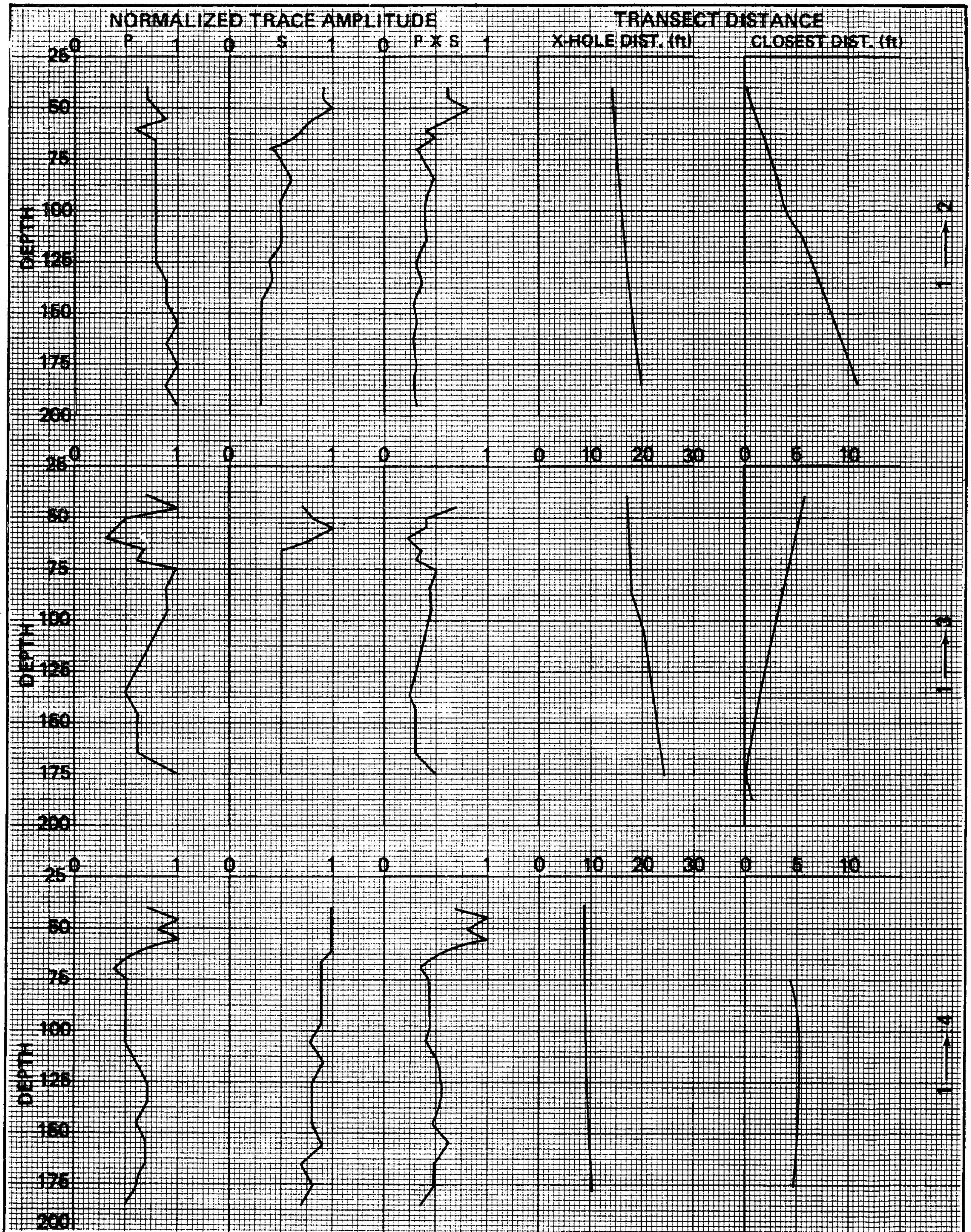


Project:	SONGS 2&3
Project No.	411301

WAVEFORM TRACE DATA SUMMARY FOR WELL NO. 5 SOURCE 3 AND RECEIVER 1, 2, 4

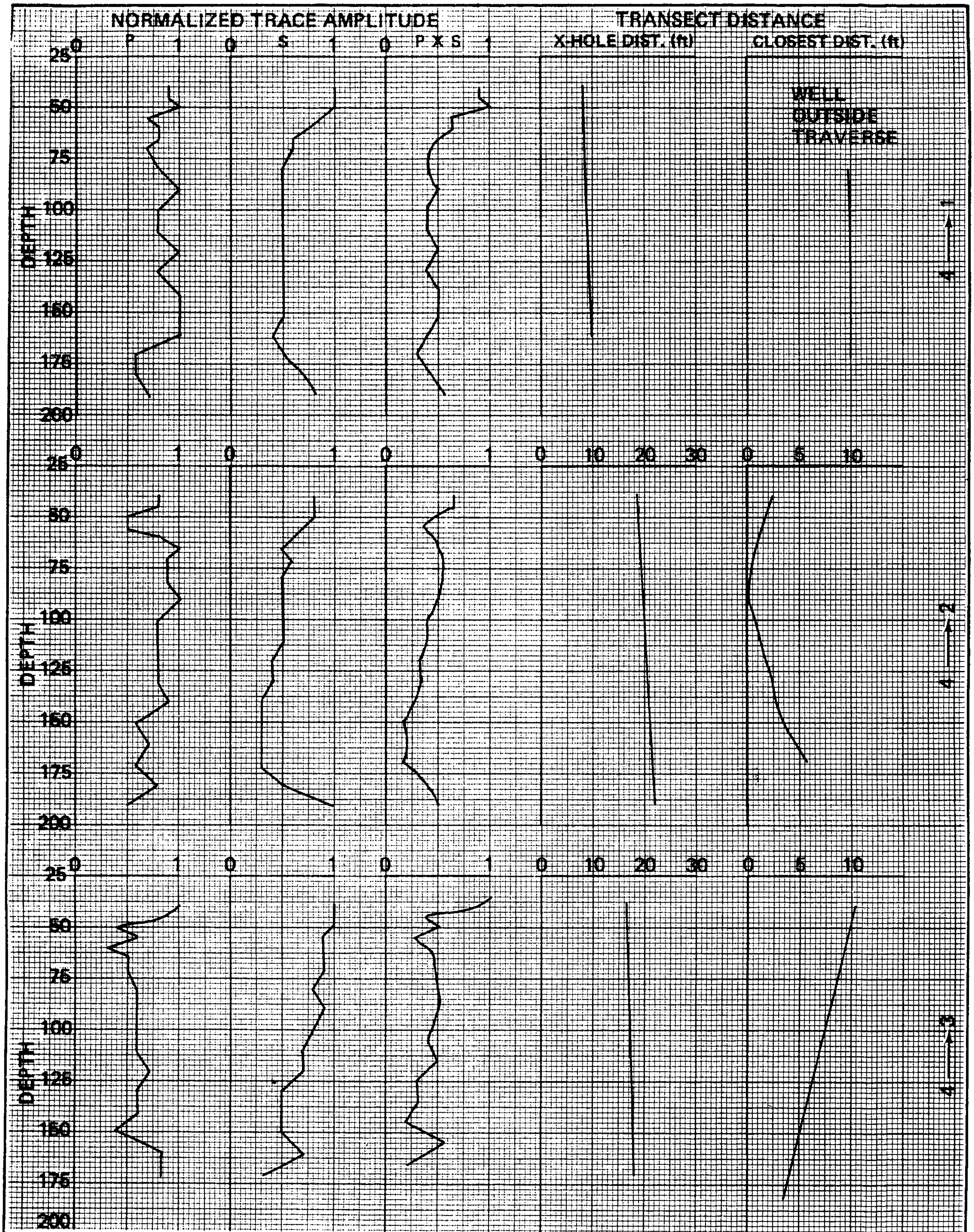
Fig. F-19

WOODWARD—CLYDE CONSULTANTS



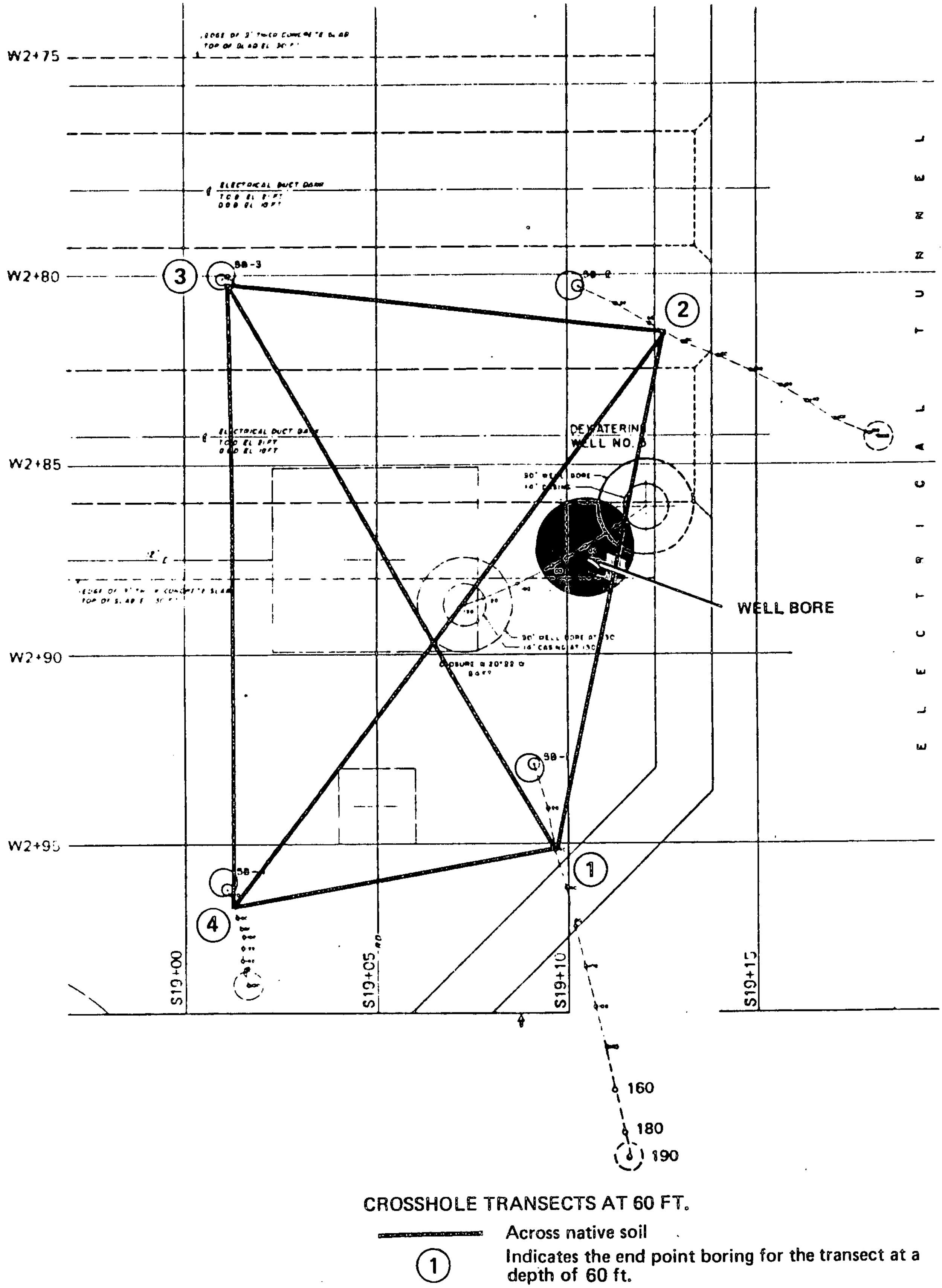
Project:	SONGS 2&3	WAVEFORM TRACE DATA SUMMARY FOR WELL NO. 5 SOURCE 2 AND RECEIVER 2,3,4	Fig. F-20
Project No.	41130I		

WOODWARD–CLYDE CONSULTANTS



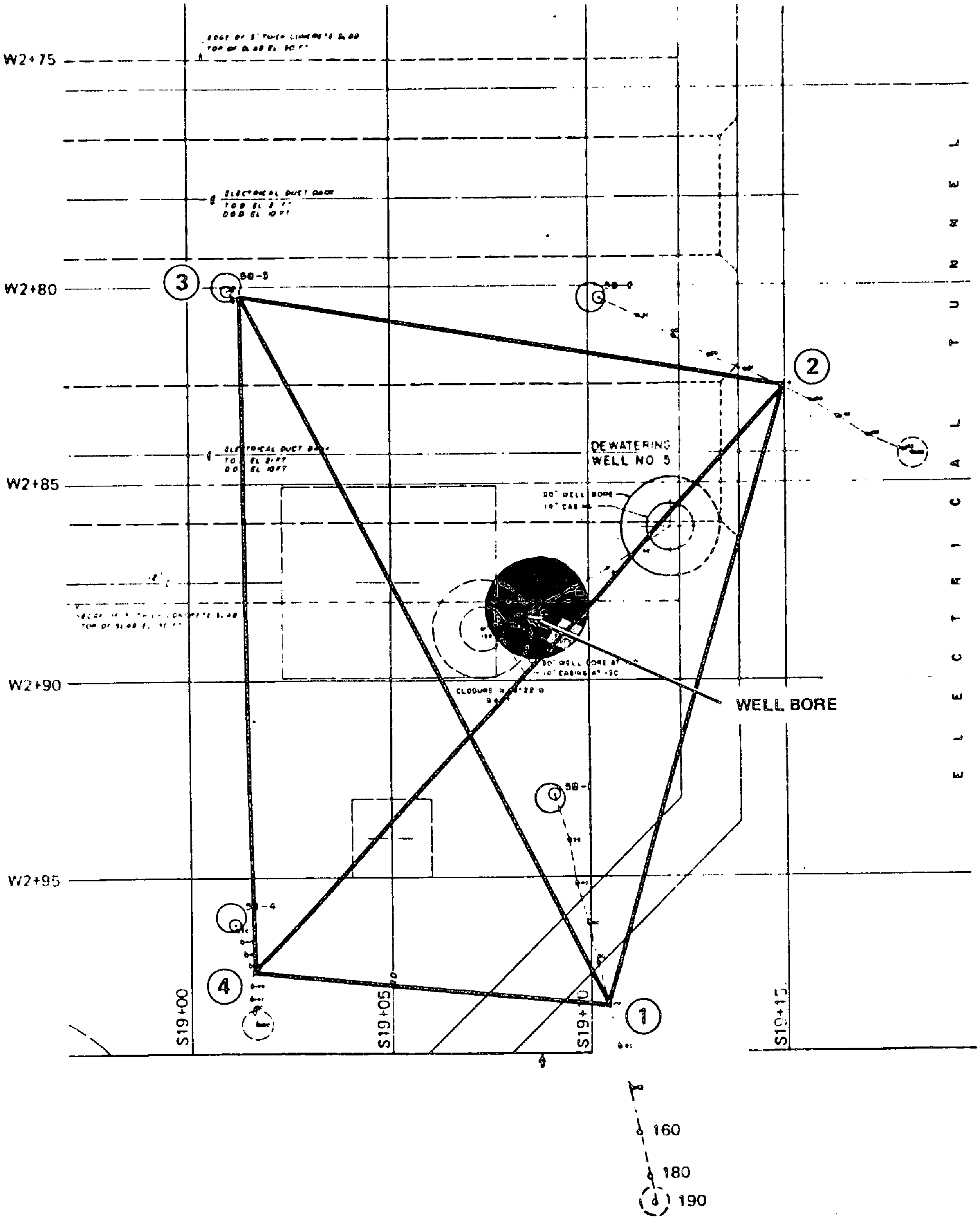
Project:	SONGS 2&3	WAVEFORM TRACE DATA SUMMARY FOR	Fig.
Project No.	41130I	WELL NO. 5 SOURCE 4 AND RECEIVER 1, 2, 3	F-21

WOODWARD – CLYDE CONSULTANTS



Project:	SONGS 2 & 3	DEWATERING WELL NO. 5 LOCATION OF DRILL HOLES AND INTERPRETED CROSSHOLE TRANSECTS AT 60 FT. DEPTH	Fig. F-22
Project No	411301		

WOODWARD-CLYDE CONSULTANTS



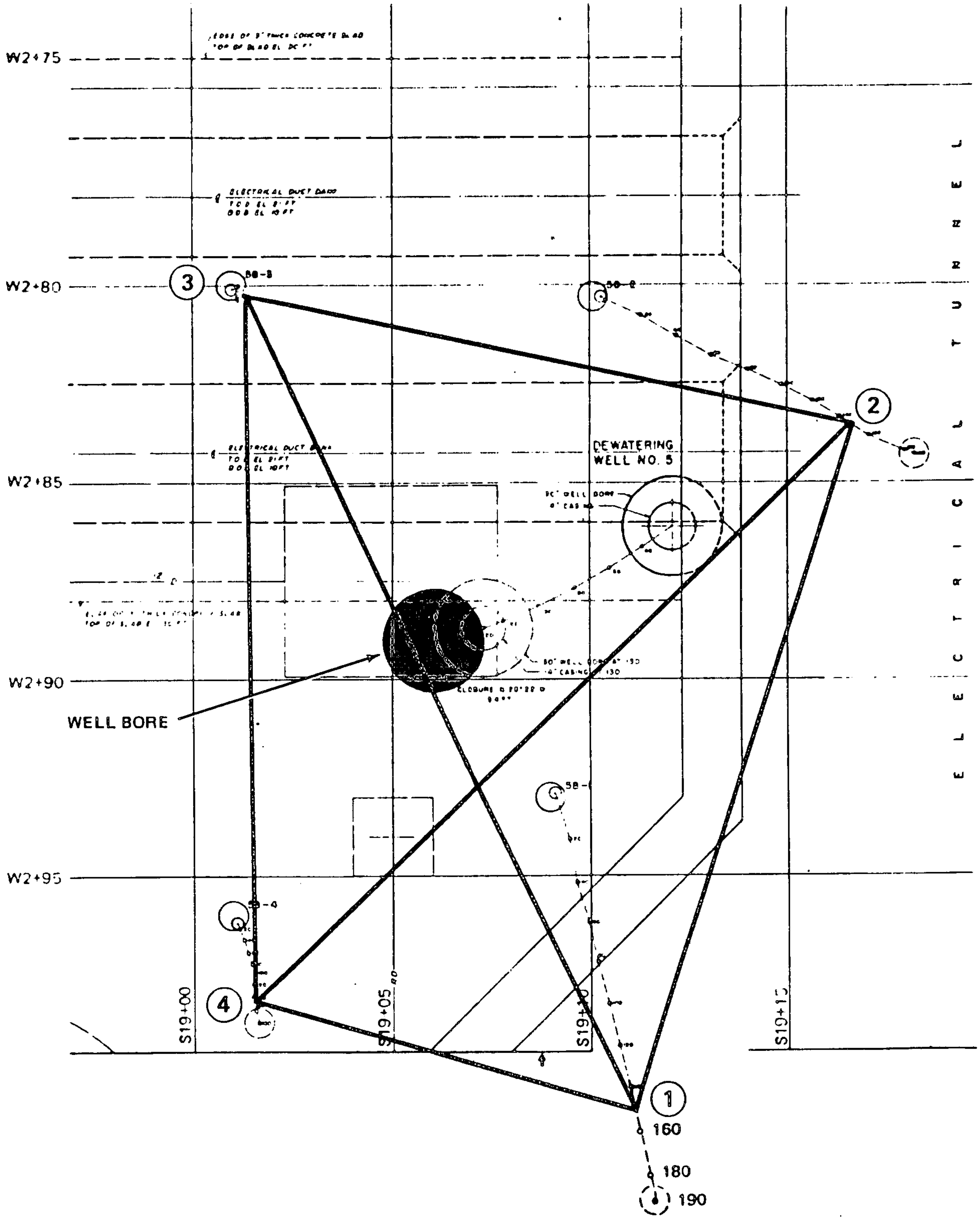
CROSSHOLE TRANSECTS AT 100 FT.

Across native soil

(1) Indicates the end point boring for the transect at a depth of 100 ft.

Project:	SONGS 2 & 3	DEWATERING WELL NO. 5 LOCATION OF DRILL HOLES AND INTERPRETED CROSSHOLE TRANSECTS AT 100 FT. DEPTH	Fig. F-23
Project No	411301		

WOODWARD–CLYDE CONSULTANTS



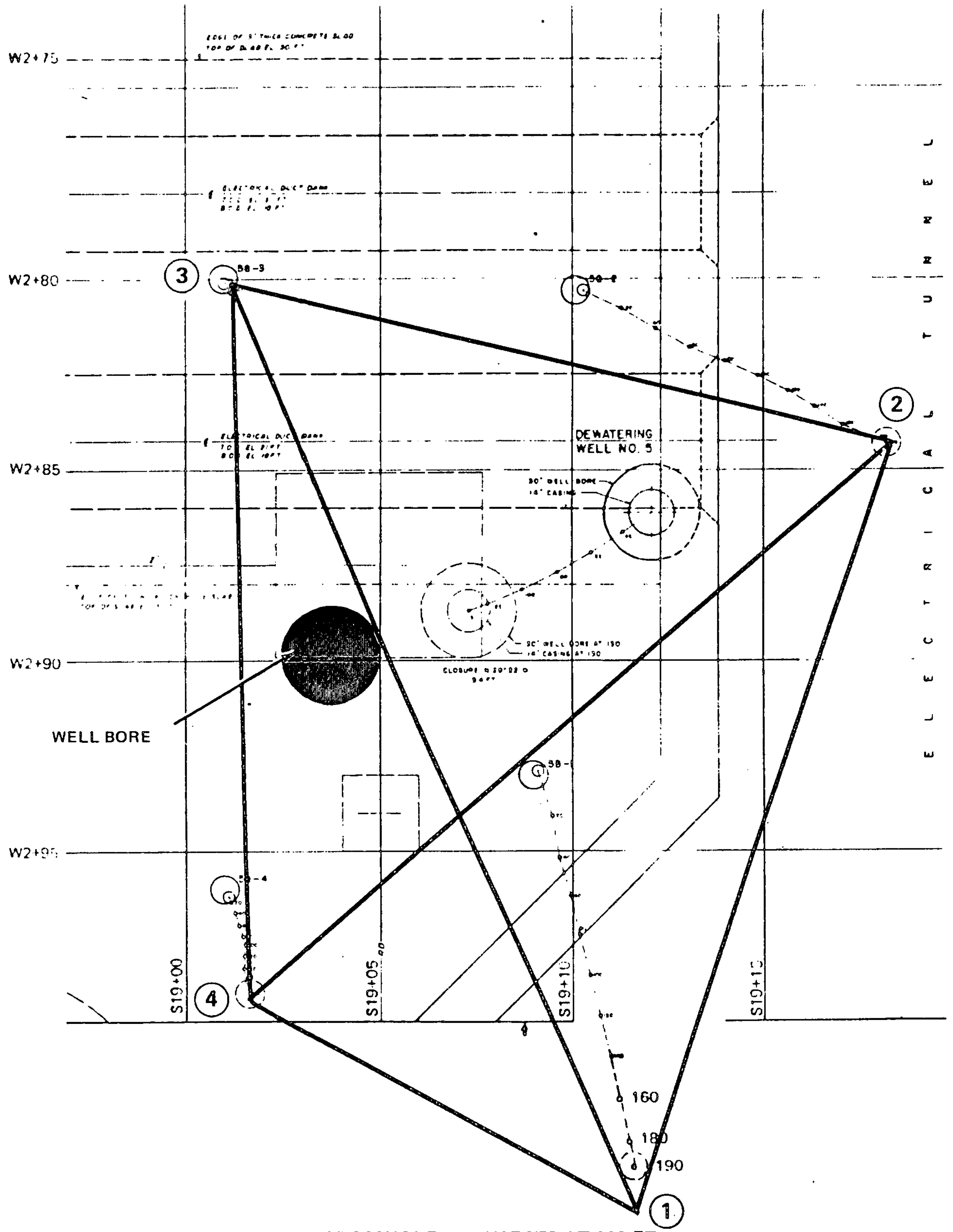
CROSSHOLE TRANSECTS AT 150 FT.

Across native soil

① Indicates the end point boring for the transect at a depth of 150 ft.

Project:	SONGS 2 & 3	DEWATERING WELL NO. 5 LOCATION OF DRILL HOLES AND INTERPRETED CROSSHOLE TRANSECTS AT 150 FT. DEPTH	Fig. F-24
Project No	41130I		

WOODWARD–CLYDE CONSULTANTS



CROSSHOLE TRANSECTS AT 200 FT.

— Across native soil

(1) Indicates the end point boring for the transect at a depth of 200 ft.

Project: SONGS 2 & 3	DEWATERING WELL NO. 5 LOCATION OF DRILL HOLES AND INTERPRETED CROSSHOLE TRANSECTS AT 200 FT. DEPTH	Fig. F-25
Project No. 411301		

WOODWARD-CLYDE CONSULTANTS

APPENDIX G
DETAILS OF THE DEEP EXPLORATION DRILLING PROGRAM FOR WELLS 4 AND 5

G.1 INTRODUCTION

This appendix contains data on the deep exploration drilling performed at Wells 4 and 5. Deep drilling exploration at dewatering Well 4 has included deep drilling (8 borings) to depths ranging from 90 to 200 feet, consisting of the careful drilling, sampling, and logging of all bore holes. At Well 5 deep exploration drilling (0-200 feet) included sampling, logging, and physical surveying four deep borings. The deep exploration of Wells 4 and 5 is discussed in the sections that follow.

G-2 DEWATERING WELL 4

The exploration drilling program consisted of the drilling and sampling of eight deep (90 to 200 feet) borings located around Well 4 as shown on Figure G-1. The holes varied in inclination from vertical to 79° and were oriented to provide a closure fence so as to detect cavities around the well and beneath adjacent structures. The holes also served as source/receiver points for crosshole seismic measurements to provide closure information between the borings.

A Joy-Sprague and Henwood hydraulic truck-mounted rotary drill rig was used to drill Borings 4B-1 through 4B-6. A CME-750 modified hydraulic rotary drill rig was used to drill Borings 4B-7 and 4B-8.

Holes were drilled using rotary drilling techniques with biodegradable Revert and water as the drilling fluid. Holes were advanced by tri-cone bit, drag bit, diamond core bit, or by

carbide-tipped bit attached to BX or NX casing. Each hole was reamed to a minimum diameter of 7-7/8 inches. Four-inch I.D., blank PVC casing was grouted into each hole. Following casing placement, each hole was gyroscopically surveyed to determine drift.

G-3 DEWATERING WELL 5

The deep exploration phase at Well 5 consisted of the drilling and sampling of four 200-foot deep borings located around Well 5 as shown on Figure G-2. The borings varied in inclination from vertical to 86 and were oriented to provide closure around Well 5 and to provide relatively equally spaced source/receiver points for the crosshole seismic measurements.

A Joy-Sprague and Henwood hydraulic truck-mounted rotary drill rig was used for all borings. Holes were drilled using rotary drill techniques with biodegradable Revert and water as the drilling fluid. Holes were advanced with tri-cone bit, drag bit or carbide tipped bit attached to BX or NX casing. Each hole was reamed to a minimum 7-7/8-inch diameter. Four-inch I.D., blank PVC casing was grouted into each hole. Following casing placement, each boring was surveyed gyroscopically to determine drift.

G-4 SAMPLING

Sampling was conducted to differentiate the disturbed materials from native San Mateo Formation sand. Sampling was conducted at 5-foot intervals with Standard Penetration Tests (SPT) using a 2-inch O.D. split-spoon drive sampler in accordance with ASTM D 1586. A detailed log of each hole was kept by the geologist on site. The logs of Borings 4B-1 through 4B-8, and Borings 5B-1 through 5B-4 are presented in Attachment G-1. Data recorded included depth and blowcounts of SPT's, descriptions of subsurface materials, drilling rates, drilling difficulties, etc. Samples were examined as soon as recovered and immediately placed in labelled plastic bags.

G-5 CASING GROUTING

After each boring was reamed, 4-inch I.D., blank PVC casing was placed in the hole and grouted. Casing was gravity grouted through 3/4-inch flush joint pipe in the annulus using a 1.1 mix of cement and water by volume with 1.41 pounds of Intraplast-N additive per sack of cement. The amounts of grout used in each hole are recorded on each log and tabulated in Table G-1.

G-6 DOWNHOLE SURVEY OF BORINGS

After casing installation each boring was gyroscopically surveyed at 15- and/or 20-foot intervals to determine drift and to confirm the orientation of the boring. The gyroscopic survey data are assembled in Attachment G-2. The data have been reduced to plant coordinates and plotted on the location plans of the wells (Figures G-1 and G-2 for Wells 4 and 5 respectively).

During the drillng most borings were surveyed at 20-foot intervals with a magnetic single-shot sonde to check drift and permit drill orientation corrections as required. The single-shot data are recorded on the drill logs. All borings were within practical field tolerances and no corrections were required.

G-7 DISCUSSION OF THE DRILLING PROGRAM

The materials encountered during exploration drilling at Wells 4 and 5 include backfill sand, disturbed sand, San Mateo Formation sand and concrete. These materials are tabulated as encountered during drilling in Table G-2, Drill Log Summary.

The location and orientation of the exploration borings at Well 4 are shown on the location plan, Figure G-1. All eight borings encountered backfill sand for the Gallery Building 21 to 22 feet thick, which extended from the surface (Elev. +25.6) to the top of a concrete mat at Elev. 4.4 to 5.5 (refer to Section 2.1). The concrete, identified where cored as site batch plant mix A-3,

varied from 3 to 14 feet in thickness and was underlain in six borings by sound San Mateo Formation sand. One foot of disturbed sand was encountered at the base of the concrete mat at a depth of 34 feet (Elev. -6.5) in 4B-6. San Mateo Formation sand was recovered from the remaining drilled length of Borings 4B-1 and 4B-6. Significant losses of drilling fluid occured during drilling of 4B-1 and 4B-8. No losses were reported in the remaining borings. Significant quantities of grout were used for installation of PVC casing in Boring 4B-1 and 4B-8. Section 1.1 in the main body of the report and Appendix B discuss minor sloughing which occurred in the 35-foot deep excavation (to Elev. -8 feet) around Well 4. This caving extended locally beneath the electrical tunnel (base at depth of 32 feet, Elev. -5 feet) as shown on Figure B-4. The fluid losses and excess grout used in Borings 4B-1 and 4B-8, both of which pass under the electrical tunnel, probably are related to the area of disturbed foundation materials beneath the tunnel.

At Well 5, two borings, 5B-1 and 5B-4 encountered native San Mateo Formation sand throughout. The remaining two borings, 5B-2 and 5B-3 encountered backfill sand for the electrical tunnel to a depth of 12 and 13 feet (Elev. 18 and 17) respectively. In addition, Boring 5B-3 encountered 3 inches of concrete at elevation +22.5 feet which is related to a protective covering over an electrical duct. The remainder of the materials encountered were sound San Mateo Formation sand. No significant drilling fluid losses occurred. No excessive grout takes occurred during casing installation.

TABLE G-1

CASING INSTALLATION DATA, EXPLORATION BORINGS
AT DEWATERING WELL - SITES 4 AND 5

BORING NO.	BORING DEPTH (FT)	BORING DIAMETER (IN.)	CASING[1] LENGTH (FT)	CALCULATED[2] (ANNULUS) VOLUME	GROUT[2] VOLUME ACCEPTED	EXCESS[2] GROUT	EXCESS GROUT (%)
4B-1	205	8-7/8	200	45	53	8	18
4B-2	205	7-7/8	200	31	34	3	10
4B-3	205	7-7/8	200	31	33	2	6
4B-4	205	7-7/8	200	31	32	1	3
4B-5	205	7-7/8	200	31	33	2	6
4B-6	200	7-7/8	200	31	33	2	6
4B-7	125	9	122	28	30	2	7
4B-8	90	7-7/8	90	13	25	12	92
5B-1	206	9	200	46	45	-1	-2
5B-2	205	8-7/8	197	44	43	-1	-2
5B-3	200	9	180	44	44	0	0
5B-4	200	9	193	45	48	3	6

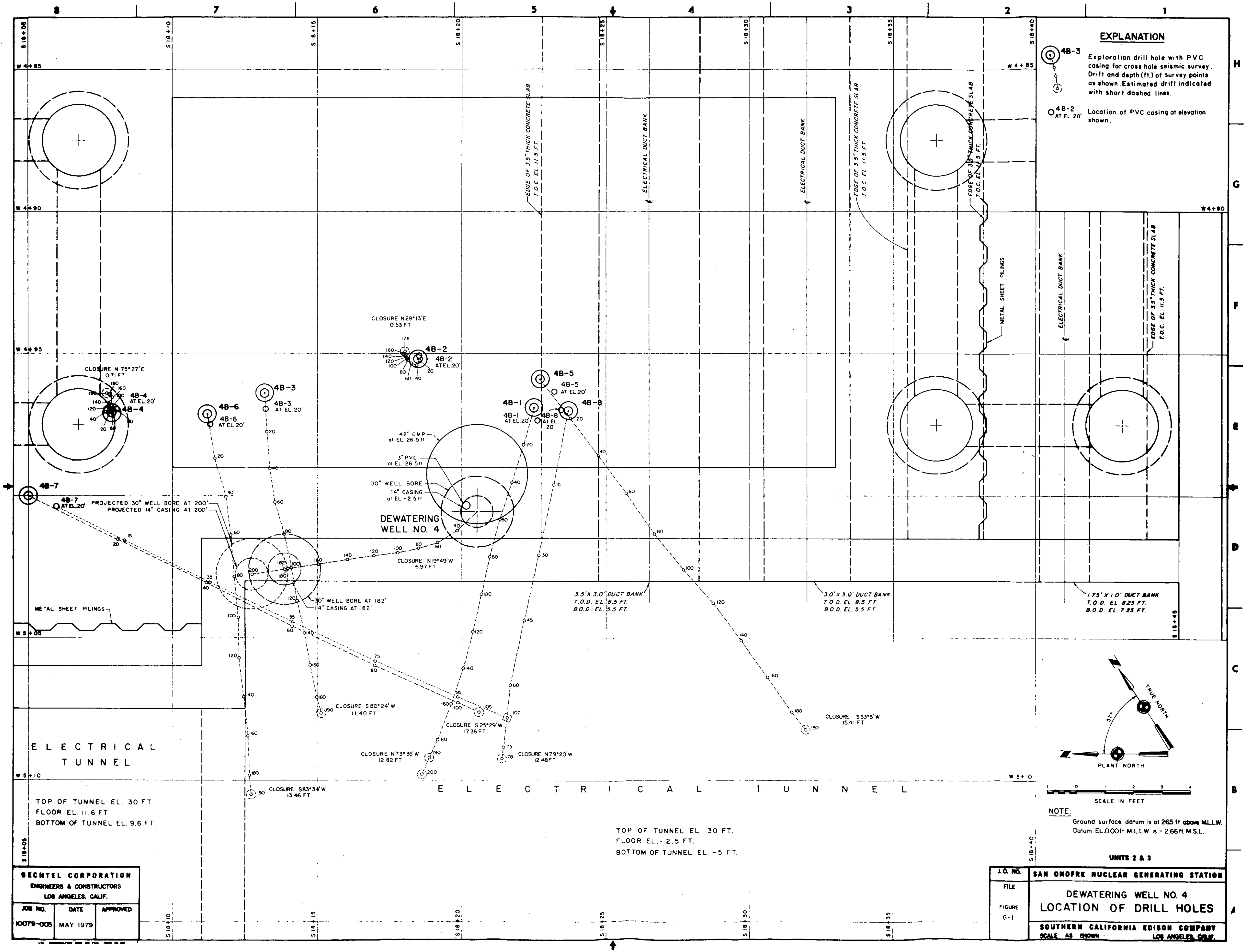
(1)All casing is blank PVC, nominal 4-inch I.D., 4.5-inch O.D.

(2)Grout volume in sacks of cement adjusted for mix factor.

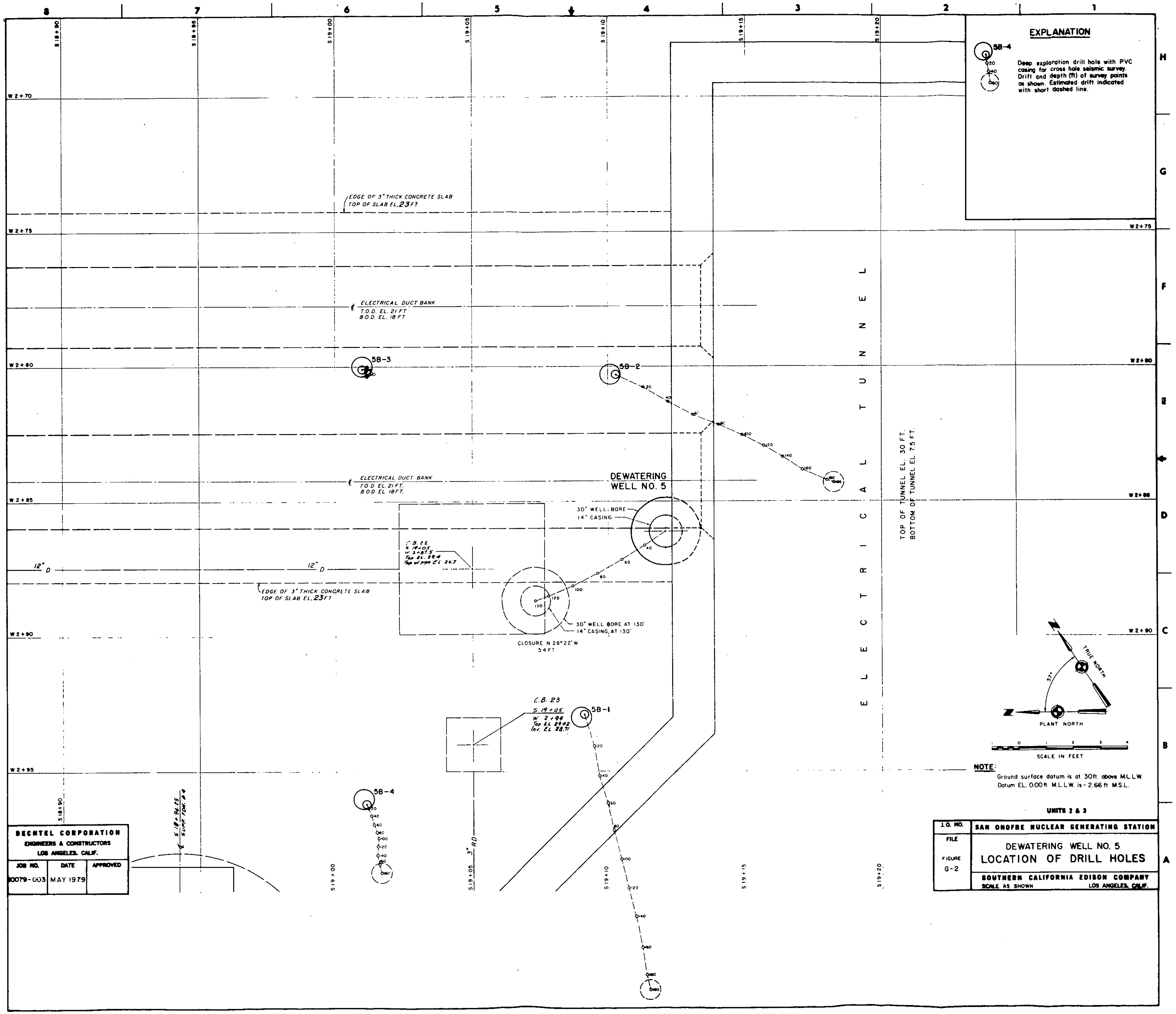
TABLE G-2

DRILL LOG SUMMARY
DEWATERING WELLS NO. 4 AND 5

HOLE NO.	COLLAR ELEV.	BACKFILL SAND FROM ELEV.	BACKFILL SAND TO ELEV.	A-3 CONCRETE FROM ELEV.	A-3 CONCRETE TO ELEV.	DISTURBED SAND FROM ELEV.	DISTURBED SAND TO ELEV.	NATIVE (SAN MATEO FM) FROM ELEV.	NATIVE (SAN MATEO FM) TO ELEV.
4B-1	26.5	26.5	5.5	5.5	-7.5	-7.5	-8.5	-9.5	-173.5 BOH
4B-2	26.5	26.5	5.5	5.5	-5.5	none		-5.5	-173.5 BOH
4B-3	26.5	26.5	5.5	5.5	-8.0	none		-8.0	-173.5 BOH
4B-4	26.5	26.5	4.5	4.5	1.5	none		1.5	-173.5 BOH
4B-5	26.5	26.5	4.5	4.5	-6.5	none		-6.5	-173.5 BOH
4B-6	26.5	26.5	5.5	5.5	-6.5				
		-6.5	-8.5			none		-8.5	-173.5 BOH
4B-7	26.5	26.5	4.5	4.5	-7.5	none		-7.5	-95.5 BOH
4B-8	23.4	23.4	4.4	4.4	-7.6	none		-7.6	-66.6 BOH
5B-1	30.0	none		none		none		30.0	-170 BOH
5B-2	30.0	30.0	18.0	none		none		18.0	-170 BOH
5B-3	30.0	30.0	17.0	3" concrete @ 22.5		none		17.0	-170 BOH
5B-4	30.00	none		none		none		30.0	-170 BOH



EXPLANATION
4B-3 Exploration drill hole with PVC casing for cross hole seismic survey. Drift and depth (ft.) of survey points as shown. Estimated drift indicated with short dashed lines.
4B-2 AT EL.20' Location of PVC casing at elevation shown.
CLOSURE N29°13'E 0.53 FT
CLOSURE N 75°27'E 0.71 FT.
4B-1
4B-2
4B-3
4B-4
4B-5
4B-6
4B-7
4B-8
42" CMP at EL 26.5 ft
3" PVC at EL 26.5 ft
30" WELL BORE
14" CASING at EL -2.5 ft
DEWATERING WELL NO. 4
PROJECTED 30" WELL BORE AT 200'
PROJECTED 14" CASING AT 200'
CLOSURE N19°49'W 6.97 FT
30" WELL BORE AT 182'
14" CASING AT 182'
CLOSURE S80°24'W 11.40 FT
CLOSURE S25°29'W 17.36 FT
CLOSURE N73°35'W 12.82 FT
CLOSURE N79°20'W 12.48 FT
CLOSURE S83°34'W 13.46 FT.
CLOSURE S53°5'W 15.41 FT
EDGE OF 3.5' THICK CONCRETE SLAB T.O.C. EL. 11.5 FT.
ELECTRICAL DUCT BANK
METAL SHEET PILINGS
3.5' X 3.0' DUCT BANK T.O.D. EL. 8.5 FT. B.O.D. EL. 5.5 FT.
3.0' X 3.0' DUCT BANK T.O.D. EL. 8.5 FT. B.O.D. EL. 5.5 FT.
1.75' X 1.0' DUCT BANK T.O.D. EL. 8.25 FT. B.O.D. EL. 7.25 FT.
ELECTRICAL TUNNEL
TOP OF TUNNEL EL. 30 FT.
FLOOR EL. 11.6 FT.
BOTTOM OF TUNNEL EL. 9.6 FT.
TOP OF TUNNEL EL. 30 FT.
FLOOR EL. -2.5 FT.
BOTTOM OF TUNNEL EL. -5 FT.
TRUE NORTH
PLANT NORTH
SCALE IN FEET
NOTE:
Ground surface datum is at 26.5 ft. above M.L.L.W.
Datum EL. 0.00 ft. M.L.L.W. is -2.66 ft. M.S.L.
UNITS 2 & 3
BECHTEL CORPORATION
ENGINEERS & CONSTRUCTORS
LOS ANGELES, CALIF.
JOB NO. 10079-003
DATE MAY 1979
APPROVED
SAN ONOFRE NUCLEAR GENERATING STATION
DEWATERING WELL NO. 4
LOCATION OF DRILL HOLES
FIGURE G-1
SOUTHERN CALIFORNIA EDISON COMPANY
SCALE AS SHOWN
LOS ANGELES, CALIF.



EXPLANATION
5B-4
Deep exploration drill hole with PVC casing for cross hole seismic survey. Drift and depth (ft) of survey points as shown. Estimated drift indicated with short dashed line.
EDGE OF 3" THICK CONCRETE SLAB
TOP OF SLAB EL.23FT
ELECTRICAL DUCT BANK
T.O.D. EL. 21 FT
B.O.D. EL. 18 FT
5B-3
5B-2
DEWATERING
WELL NO. 5
30" WELL BORE
14" CASING
C.B. 22
12" D
EDGE OF 3" THICK CONCRETE SLAB
TOP OF SLAB EL.23FT
30" WELL BORE AT 130'
14" CASING AT 130'
CLOSURE N 28°22' W
5.4 FT
C.B. 23
S 19+05
W 2+94
Top EL 29.42
Inv. EL 28.71
5B-1
5B-4
S 18+94.25
SUPP. FDN. #4
3" RD
E L E C T R I C A L   T U N N E L
TOP OF TUNNEL EL. 30 FT.
BOTTOM OF TUNNEL EL. 7.5 FT.
TRUE NORTH
PLANT NORTH
37°
SCALE IN FEET
NOTE:
Ground surface datum is at 30ft. above M.L.L.W.
Datum EL. 0.00ft M.L.L.W. is -2.66 ft M.S.L.
S 18+90
S 18+95
S 19+00
S 19+05
S 19+10
S 19+15
S 19+20
W 2+70
W 2+75
W 2+80
W 2+85
W 2+90
W 2+95
BECHTEL CORPORATION
ENGINEERS & CONSTRUCTORS
LOS ANGELES, CALIF.
JOB NO. 10079-003
DATE MAY 1979
APPROVED
UNITS 2 & 3
I.O. NO.
SAN ONOFRE NUCLEAR GENERATING STATION
FILE
FIGURE G-2
DEWATERING WELL NO. 5
LOCATION OF DRILL HOLES
SOUTHERN CALIFORNIA EDISON COMPANY
SCALE AS SHOWN
LOS ANGELES, CALIF.

ATTACHMENT G-1

LOGS OF BORINGS 4B-1 THROUGH 4B-8 AND 5B-1 THROUGH 5B-4

BECHTEL

GEOLOGIC DRILL LOG

PROJECT	JOB NO.	SHEET NO.	HOLE NO.
SONGS Units 2 & 3	10079	1 OF 3	4B-1

SITE	COORDINATES	ANGLE FROM HORIZ.	BEARING
Unit 2 Well 4	S 18 + 22.6 / W 4 + 96.8 at El. 26.5' For PVC, S 18 + 22.62 / W 4 + 97.34 at El. 20'	86°	N73°35'W

BEGUN	COMPLETED	DRILLER	DRILL MAKE AND MODEL	HOLE SIZE	OVERBURDEN (FT.)	ROCK (FT.)	TOTAL DEPTH
10/12/78	10/18/78	P C Exploration	Joy-S&H	5-1/4" to 20' 4.3" to 200'	35	165	200'

CORE RECOVERY (FT./%)	CORE BOXES	SAMPLES	EL. TOP OF CASING	GROUND EL.	DEPTH/EL. GROUND WATER	DEPTH/EL. TOP OF ROCK
---	---	14	---	26.5'	21.5'/5'	35'/-8.5'

SAMPLE HAMMER WEIGHT/FALL	CASING LEFT IN HOLE: DIA./LENGTH	LOGGED BY:
140#/30"	4" PVC/200' Solid	B. Hebbron / R. Nelson / Mendell M. Bell

Water Pressure Tests: Single Shot Record

Sampler Type and Diameter	Sampler Advance / Length Core Run	Sample Recovery / Core Recovery	Sample Blows "N" / Percent Core Recovery	Water Pressure Tests	Depth (FT)
SS	5.5"	5"	50/5.5"	Drift 4°SW	20
NX	1'	1'	100%		34
SS	5"	5"	50/5"		35
SS	2"	2"	50/2"	Drift 3°45'NE	40
SS	2.5"	2.5"	50/2.5"		50
SS	2"	2"	50/2"	Drift 3°45'SW	60

Elevation (FT): 26.5, 20, 10, 0, -10, -20, -30, -40
Depth (FT): 0, 10, 20, 30, 40, 50, 60, 70

Depth	Description and Classification
0.0-21.0'	BACKFILL SAND: Tan, fine-to coarse-grained quartzose sand, very dense well compacted sand.
21.0-34.0'	A-3 Concrete: Small aggregate.
34.0-35.0'	DISTURBED SAND: Fine to coarse quartzose sand.
35.0-200.0'	SAN MATEO FORMATION: Light tan, fine-to coarse-grained well graded sand; very slightly weathered; very slightly micaceous, very dense.
40'	At 40', sand, principally medium-to coarse-grained.
50'	As above but with some (10-20%) silt fraction.
60'	Typical San Mateo Formation, very well compacted.

Notes on: Water Levels, Water Return, Character of Drilling, etc.

- Began drilling on day shift.
- Started hole with 5-1/4" tricone rock bit and Revert drilling mud.
- Set 4.3" casing at 20'.
- Changed to 4" tricone rock bit at 20'.
- Good circulation.
- At 33' removed rock bit and put on core barrel Cored 1 foot.
- End day shift 10/12/78
- Begin day shift 10/13/78.
- Began drilling with open carbide tipped drag bit.
- 100% loss of circulation at 34'.
- Reamed hole to advance 4.3" diameter casing to 40'.
- Mixed 1 sack Revert. Driller reports firm ground past 35'.
- 100% circulation regained when reaming and after casing set to 40'.

SS = SPLIT SPOON; ST = SHELBY TUBE; D = DENNISON; P = PITCHER; O = OTHER

SITE	HOLE NO.
Unit 2 Well 4	4B-1

GEOLOGIC DRILL LOG

PROJECT: SONGS Units 2 & 3 | JOB NO.: 10079 | | HOLE NO.: 4B-1

Sampler Type and Diameter	Sampler Advance / Length Core Run	Sample Recovery / Core Recovery	Sample Blows "N" / Percent Core Recovery	Water Pressure Tests: Loss in G.P.M.	Pressure P.S.I.	Time Minutes	Elevation FT	Depth FT	Description and Classification	Notes on: Water Levels, Water Return, Character of Drilling, etc.
SS	2"	1"	50/2"	Single Shot Record				70	35.0-200.0' <u>San Mateo Formation</u> (continued) Well graded quartzose sand.	
							-50			
SS	3"	2"	50/3"	Drift	4°0'	East		80	Chiefly medium-to coarse-grained, subrounded, quartzose, well compacted sand with a scattering of fines.	100% circulation.
							-60			
SS	2"	0"	50/2"					90		Normal drilling rate: 1 ft/1 minute.
							-70			
SS	2"	0"	50/2"	Drift	4°0'	South		100		End day shift 10/13/78. Begin day shift 10/16/78.
							-80			
SS	3"	1"	50/3"					110	Medium-to coarse-grained quartzose, clean, well compacted, uncemented sand.	Normal drilling rate and good circulation.
							-90			
SS	2"	2"	50/2"	Camera	Malfunction			120		
							-100			
SS	3"	0"	50/3"					130		
							-110			
SS	2"	0"	50/2"	Drift	4°0'	SW		140		End day shift 10/16/78. Begin swing shift 10/16/78.
							-120			
								150		

SS = SPLIT SPOON; ST = SHELBY TUBE; D = DENISON; P = PITCHER; O = OTHER

SITE: Unit 2 Well 4 | HOLE NO.: 4B-1

10070-2 (4-78)

GEOLOGIC DRILL LOG

PROJECT: SONGS Units 2 & 3 | JOB NO.: 10079 | | HOLE NO.: 4B-1

Sampler Type and Diameter	Sampler Advance / Length Core Run	Sample Recovery / Core Recovery	Sample Blows "N" / Percent Core Recovery	Water Pressure Tests: Loss in G.P.M.	Pressure P.S.I.	Time Minutes	Elevation FT	Depth FT	Description and Classification	Notes on: Water Levels, Water Return, Character of Drilling, etc.
SS	6"	6"	50/6"	Single Shot Record				150	35.0-200.0' San Mateo Formation (continued)	Firm drilling.
									Sand and dark micaceous clay-like silt; sand is iron oxide stained in part; minor gray sand; sand-silt ratio 50:50; a sand/silt phase of San Mateo Formation.	
							-130			
SS	2"	2"	50/2"	Drift	4°SW			160	Sand (SP) angular to subrounded, minor mica; tannish gray, very dense.	No water loss.
							-140			
SS	2"	2"	50/2"					170		No water loss.
							-150			
SS	3"	3"	50/3"	Drift	4°SW			180		Firm drilling.
							-160			
SS	2"	0"	50/2"					190		
							-170			Reamed to 205' total depth with 8-7/8" bit on swing shift 10/16/78.
SS	2"	2"	50/2"	Drift	4°SW			200		
									Bottom of Hole: 200' Installed 200' of 4" solid PVC with 53 sacks of cement on 10/18/78. Water: cement ratio 1:1 with 1.41 lbs. of Intraplast additive per sack of cement. Conducted Eastman Gyroscopic survey inside PVC casing on 10/25/78.	

SS = SPLIT SPOON; ST = SHELBY TUBE; D = DENISON; P = PITCHER; O = OTHER

SITE: Unit 2 Well 4 | HOLE NO.: 4B-1

GEOLOGIC DRILL LOG

PROJECT	JOB NO.	SHEET NO.	HOLE NO.
SONGS Units 2 & 3	10079	1 OF 3	4B-2

SITE	COORDINATES	ANGLE FROM HORIZ.	BEARING
Unit 2 Well 4	S 18 + 18.5 / W 4 + 95.2 at El. 26.5' For PVC, S 18 + 18.51 / W 4 + 95.09 at El. 20'	90°	—

BEGUN	COMPLETED	DRILLER	DRILL MAKE AND MODEL	HOLE SIZE	OVERBURDEN (FT.)	ROCK (FT.)	TOTAL DEPTH
10/18/78	10/19/78	P C Exploration	Joy-S&H	5-1/4" to 21' 3-1/2" to 200'	32	168	200'

CORE RECOVERY (FT./%)	CORE BOXES	SAMPLES	EL. TOP OF CASING	GROUND EL.	DEPTH/EL. GROUND WATER	DEPTH/EL. TOP OF ROCK
8.2'/ 75%	—	14	—	26.5'	21.5'/5'	32'/-5.5'

SAMPLE HAMMER WEIGHT/FALL	CASING LEFT IN HOLE: DIA./LENGTH	LOGGED BY:
140#/30"	4" PVC/200' Solid	Mendell M. Bell / B. Hebbron

SAMPLER TYPE AND DIAMETER	SAMPLER ADVANCE LENGTH CORE RUN	SAMPLE RECOVERY CORE RECOVERY	SAMPLE BLOWS "N" PERCENT CORE RECOVERY	WATER PRESSURE TESTS: LOSS IN G.P.M.	PRESSURE P.S.I.	TIME IN MINUTES	ELEVATION FT	DEPTH FT	DESCRIPTION AND CLASSIFICATION	NOTES ON: WATER LEVELS, WATER RETURN, CHARACTER OF DRILLING, ETC.
				Single Shot Record			26.5	0	0.0-21.0' <u>BACKFILL SAND</u>: Tan, fine-to coarse-grained quartzose sand; well compacted.	Began drilling on day shift. Hole advanced with 5-1/4" bit using Revert drilling mud.
							20			
								10		
							10			
								20		
NC	4.0'	2.7'	67.5%						21.0-32.0' <u>A-3 CONCRETE</u>: Angular to partially rounded, multi-colored aggregate in a sand-cement matrix. Aggregate sizes range from 5-45mm in largest dimension.	NC core barrel used to core cement.
							0			
NC	5.0'	4.0'	80%							End day shift 10/18/78
								30		Begin day shift 10/19/78.
NC	2.0'	1.5'	75%							
									32.0-200.0' <u>SAN MATEO FORMATION</u>: Tan, fine-to coarse-grained subrounded to subangular quartzose sand; very dense.	Changed to open carbide bit (NC). Good circulation. Drilling rate 1 ft/ 50 seconds.
							-10			
SS	3"	0"	50/3"	Drift	0°30'NW			40		
							-20			
SS	3"	3"	50/3"					50	Well compacted, fine-to coarse-grained, quartzose uncemented, silty in part, subrounded sand.	
							-30			
SS	3"	3"	50/3"	Drift	10°N			60		
							-40			
								70		

SS = SPLIT SPOON; ST = SHELBY TUBE; D = DENNISON; P = PITCHER; O = OTHER	SITE	HOLE NO.
	Unit 2 Well 4	4B-2

HBCF 19-1

GEOLOGIC DRILL LOG

PROJECT	JOB NO.		HOLE NO.
SONGS Units 2 & 3	10079	2 of 3	4B-2

SAMPLER TYPE AND DIAMETER	SAMPLER ADVANCE / LENGTH CORE RUN	SAMPLE RECOVERY / CORE RECOVERY	SAMPLE BLOWS "N" / PERCENT CORE RECOVERY	WATER PRESSURE TESTS: LOSS IN G.P.M.	WATER PRESSURE TESTS: PRESSURE P.S.I.	WATER PRESSURE TESTS: TIME MINUTES	ELEVATION FT	DEPTH FT	GRAPHIC LOG	SAMPLE	DESCRIPTION AND CLASSIFICATION	NOTES ON: WATER LEVELS, WATER RETURN, CHARACTER OF DRILLING, ETC.
SS	3"	3"	50/3"	Single Shot Record				70			32.0-200.0' San Mateo Formation (continued) Chiefly medium-to coarse-grained, very well compacted sand.	
							-50					
SS	4"	3"	50/4"	Drift	0°15'	N		80			Fine-to medium-grained, slightly silty, well compacted quartzose sand.	Normal drilling rate of 1 ft/1 minute.
							-60					
SS	4"	2"	50/4"					90				Good clean hole.
							-70					
SS	2"	1"	50/2"	Drift	0°15'	NW		100			Same as above with a scattering of coarse-grained sand.	
							-80					
SS	3"	2"	50/3"					110			Well graded, fine-to coarse-grained, quartzose sand.	100% circulation. Normal drilling.
							-90					
SS	4"	2"	50/4"	Drift	0°10'	NE		120			Chiefly medium-to coarse-grained quartzose sand.	
							-100					
SS	3"	0"	50/3"					130				
							-110					
SS	2"	2"	50/2"	Drift	0°20'	NW		140			Well graded fine-to coarse-grained sand.	
							-120					
								150				

SS = SPLIT SPOON; ST = SHELBY TUBE; D = DENISON; P = PITCHER; O = OTHER

SITE	HOLE NO.
Unit 2 Well 4	4B-2

GEOLOGIC DRILL LOG

PROJECT	JOB NO.		HOLE NO.
SONGS Units 2 & 3	10079	3 of 3	4B-2

Sampler Type and Diameter	Sampler Advance / Length Core Run	Sample Recovery / Core Recovery	Sample Blows "N" / Percent Core Recovery	Water Pressure Tests: Loss in G.P.M.	Pressure P.S.I.	Time Minutes	Elevation FT	Depth FT	Description and Classification	Notes on: Water Levels, Water Return, Character of Drilling, etc.
SS	3"	3"	50/3"	Single Shot Record				150	32.0-200.0' San Mateo Formation (continued) Iron stained, fine-to medium-grained silty sand.	
							-130			
SS	2"	0"	50/2"	Drift	0°10	NW		160		
							-140			
SS	3"	2"	50/3"					170	Yellow, fine-to coarse-grained, slightly silty.	Continued good circulation and clean hole. Normal drilling.
							-150			
SS	2"	2"	50/2"	Drift	0°20	NW		180	Beige, few very coarse particles over 1/4" in diameter.	
							-160			
SS	3"	3"	50/3"					190		End day shift 10/19/78. Begin swing shift.
							-170			
SS	3"	3"	50/3"	Drift	0°20	N		200	Bottom of Hole: 200' On 10/24/78 - grouted in 200' of 4" solid PVC with 34 sacks of cement. Water: cement ratio 1:1 with 1.41 lbs. Intraplast additive per sack of cement. Conducted Eastman Gyroscopic survey inside PVC casing on 10/25/78.	On 10/20/78 hole was reamed with 7-7/8" tri-cone bit to 205'. Hole left open with 4" PVC installed from 10/20/78 P.M. to 10/24/78 P.M. due to walkout by operating engineers.

SS = SPLIT SPOON; ST = SHELBY TUBE; D = DENISON; P = PITCHER; O = OTHER

SITE: Unit 2 Well 4 — HOLE NO. 4B-2

10070-2 (4-78)

GEOLOGIC DRILL LOG

PROJECT	JOB NO.	SHEET NO.	HOLE NO.
SONGS Units 2 & 3	10079	1 of 3	4B-3

SITE	COORDINATES	ANGLE FROM HORIZ.	BEARING
Unit 2 Well 4	S 18 + 13.2 / W 4 + 96.4 at El. 26.5' For PVC, S 18 + 13.27 / W 4 + 96.92 at El. 20'	86°	S80°24'N

BEGUN	COMPLETED	DRILLER	DRILL MAKE AND MODEL	HOLE SIZE	OVERBURDEN (FT.)	ROCK (FT.)	TOTAL DEPTH
10/27/78	10/31/78	P C Exploration	Joy-S&H	7-7/8" to 34.5' 3-1/2" to 200'	34.5	165.5	200'

CORE RECOVERY (FT./%)	CORE BOXES	SAMPLES	EL. TOP OF CASING	GROUND EL.	DEPTH/EL. GROUND WATER	DEPTH/EL. TOP OF ROCK
---	—	15	—	26.5'	21.5'/5'	34.5'/-8'

SAMPLE HAMMER WEIGHT/FALL	CASING LEFT IN HOLE: DIA./LENGTH	LOGGED BY:
140#/30"	4" PVC/200' Solid	B. Hebbron / Mendell M. Bell

SAMPLER TYPE AND DIAMETER	SAMPLER ADVANCE / LENGTH CORE RUN	SAMPLE RECOVERY / CORE RECOVERY	SAMPLE BLOWS "N" / PERCENT CORE RECOVERY	WATER PRESSURE TESTS: LOSS IN G.P.M.	PRESSURE P.S.I.	TIME IN MINUTES	ELEVATION FT	DEPTH FT	DESCRIPTION AND CLASSIFICATION	NOTES ON: WATER LEVELS, WATER RETURN, CHARACTER OF DRILLING, ETC.
				Single Shot Record			26.5	0	0.0-21.0' BACKFILL SAND: Tan, fine-to coarse-grained quartzose sand; well compacted.	Began drilling hole on day shift with 7-7/8" tri-cone rock bit and Revert drilling mud.
							20			
								10		
							10			
								20		
									21.0-34.5' A-3 CONCRETE: Sand cement matrix with small aggregate.	
							0			
								30		End day shift.
									34.5-200.0' SAN MATEO FORMATION: Sand, (SP) poorly sorted, angular to subangular, fine-to coarse-grained, light tan, very dense.	Begin swing shift. From 34.5' advancing hole with 3-1/2" rock bit and Revert mud.
							-10			
SS	3"	3"	50/3"	Drift	3°S30°E			40		Firm drilling.
							-20			
SS	3"	3"	50/3"					50		No water loss.
							-30			
SS	3"	3"	50/3"	Drift	3°30'S10°W			60		
							-40			
								70		

SS = SPLIT SPOON; ST = SHELBY TUBE; D = DENNISON; P = PITCHER; O = OTHER

H&CF 19-1

GEOLOGIC DRILL LOG

PROJECT	JOB NO.		HOLE NO.
SONGS Units 2 & 3	10079	2 of 3	4B-3

SAMPLER TYPE AND DIAMETER	SAMPLER ADVANCE / LENGTH CORE RUN	SAMPLE RECOVERY / CORE RECOVERY	SAMPLE BLOWS "N" / PERCENT CORE RECOVERY	WATER PRESSURE TESTS: LOSS IN G.P.M.	PRESSURE P.S.I.	TIME MINUTES	ELEVATION FT	DEPTH FT	DESCRIPTION AND CLASSIFICATION	NOTES ON: WATER LEVELS, WATER RETURN, CHARACTER OF DRILLING, ETC.
SS	3"	3"	50/3"	Single Shot Record				70	34.5-200.0' San Mateo Formation (continued)	Firm drilling with 3.5" bit.
							-50			
SS	3"	3"	50/3"	Drift	3°30	S20°W		80		No water loss.
							-60			
SS	3"	3"	50/3"					90		
							-70			Firm drilling.
SS	3"	3"	50/3"	Drift	3°30	S20°W		100		
							-80			
SS	2"	2"	50/2"					110		
							-90			Firm drilling. No water loss.
SS	3"	3"	50/3"	Drift	3°10'	S20°W		120		
							-100			
SS	2"	2"	50/2"					130		
							-110			
SS	2"	2"	50/2"	Drift	3°30'	S15°W		140		Hard drilling from 140-150'. No water loss.
							-120	150		

SS = SPLIT SPOON; ST = SHELBY TUBE; D = DENISON; P = PITCHER; O = OTHER

SITE	HOLE NO.
Unit 2 Well 4	4B-3

GEOLOGIC DRILL LOG

PROJECT	JOB NO.		HOLE NO.
SONGS Units 2 & 3	10079	3 of 3	4B-3

Sampler type and diameter	Sampler advance / Length core run	Sample recovery / Core recovery	Sample blows "N" / Percent core recovery	Water pressure tests: Loss in G.P.M.	Pressure P.S.I.	Time minutes	Elevation FT	Depth FT	Description and classification	Notes on: water levels, water return, character of drilling, etc.
SS	2"	2"	50/2"	Single Shot Record				150	34.5-200.0' San Mateo Formation (continued) Sample contains minor amount of silt.	Hard to firm drilling.
							-130			
				Drift	3°10	S20°W		160		End swing shift 10/27/78. Begin day shift 10/30/78. No sample taken at 160'; communication breakdown at shift change.
							-140			
SS	3"	0"	50/3"					170		
							-150			
SS	5"	3"	50/5"	Camera Malfunction				180	Fine-to coarse-grained quartzose, sub-rounded sand; very dense.	Good circulation, clean hole.
							-160			
SS	5"	2"	50/5"					190	Fine-to medium-grained sand.	Normal drilling rate: 1 ft/1 minute.
							-170			From 10/30 to 10/31/78 on the swing shift - reamed hole with 7-7/8" bit to 200'; drilled additional hole to 205'.
SS	5.5"	4"	50/5.5"	Drift overexposed				200	Same as above with minor coarse fractions.	

Bottom of Hole: 200'

On 10/31/78 - grouted in 200' of 4" solid PVC with 33 sacks of cement. Water: cement ratio 1:1 with 1.41 lbs. Intraplast additive per sack of cement.

Conducted Eastman Gyroscopic survey inside PVC casing on 10/31/78.

SS = SPLIT SPOON; ST = SHELBY TUBE; D = DENISON; P = PITCHER; O = OTHER

SITE: Unit 2 Well 4

HOLE NO. 4B-3

GEOLOGIC DRILL LOG

BECHTEL

PROJECT	JOB NO.	SHEET NO.	HOLE NO.
SONGS Units 2 & 3	10079	1 of 3	4B-4

SITE	COORDINATES	ANGLE FROM HORIZ.	BEARING
Unit 2 Well 4	S 18 + 07.9 / W 4 + 97.1 at El. 26.5' For PVC, S 18 + 08.09 / W 4 + 96.97 at El. 20'	90°	---

BEGUN	COMPLETED	DRILLER	DRILL MAKE AND MODEL	HOLE SIZE	OVERBURDEN (FT.)	ROCK (FT.)	TOTAL DEPTH
10/25/78	10/26/78	P C Exploration	Joy-S&H	5-1/4" to 25' 3-1/2" to 200'	25	175	200'

CORE RECOVERY (FT./%)	CORE BOXES	SAMPLES	EL. TOP OF CASING	GROUND EL.	DEPTH/EL. GROUND WATER	DEPTH/EL. TOP OF ROCK
---	---	16	---	26.5'	21.5'/5'	25'/ 1.5'

SAMPLE HAMMER WEIGHT/FALL	CASING LEFT IN HOLE: DIA./LENGTH	LOGGED BY:
140#/30"	4" PVC 200' Solid	B. Hebbron / Mendell M. Bell

SAMPLER TYPE AND DIAMETER	SAMPLER ADVANCE / LENGTH CORE RUN	SAMPLE RECOVERY / CORE RECOVERY	SAMPLE BLOWS "N" / PERCENT CORE RECOVERY	WATER PRESSURE TESTS: LOSS IN G.P.M.	PRESSURE P.S.I.	TIME IN MINUTES	ELEVATION FT	DEPTH FT	DESCRIPTION AND CLASSIFICATION	NOTES ON: WATER LEVELS, WATER RETURN, CHARACTER OF DRILLING, ETC.
				Single Shot Record			26.5	0	0.0-22.0' <u>BACKFILL SAND</u>: Tan, fine-to coarse-grained well compacted quartzose sand.	Began drilling hole on day shift with 5-1/4" tri-cone rock bit and Revert mud as drilling fluid.
							20			
								10		
							10			
								20		
									22.0-25.0' <u>A-3 CONCRETE</u>	Changed to diamond core bit.
SS	5"	2"	50/5"	Drift	>0°10	SW				
							0		25.0-200.0' <u>SAN MATEO FORMATION</u>: Well graded, fine-to coarse-grained, well compacted, uncemented subrounded quartzose sand.	Changed diamond bit to open end carbide bit.
								30		
SS	4.5"	2"	50/4.5"							
							-10			
								40		
SS	4"	0"	50/4"	Drift	0°15'N					
							-20			
								50		Good circulation. Normal drilling rate approximately 1 ft/1 minute.
SS	5"	1"	50/5"							
							-30		Chiefly medium-to coarse-grained sand.	
								60		
SS	3"	0"	50/3"	Drift	0°20'NE					
							-40			
								70		

SS = SPLIT SPOON; ST = SHELBY TUBE; D = DENNISON; P = PITCHER; O = OTHER

SITE	HOLE NO.
Unit 2 Well 4	4B-4

GEOLOGIC DRILL LOG

PROJECT	JOB NO.		HOLE NO.
SONGS Units 2 & 3	10079	2 of 3	4B-4

Sampler Type and Diameter	Sampler Advance Length Core Run	Sample Recovery Core Recovery	Sample Blows "N" Percent Core Recovery	Water Pressure Tests (Single Shot Record)			Depth (FT)	Description and Classification	Notes on: Water Levels, Water Return, Character of Drilling, etc.
							70	25.0-200.0' <u>San Mateo Formation</u> (continued)	
SS	3"	1"	50/3"					Medium-to coarse-grained, well compacted sand.	
SS	6"	2"	50/6"	Drift	0°30'	NE		Fine-to medium-grained quartzose, slightly silty sand.	
SS	2"	2"	50/2"						
SS	1"	1"	50/1"	Drift	0°30'	NE			End day shift 10/25/78. Begin swing shift.
SS	2"	2"	50/2"						
SS	2"	2"	50/2"	Drift	0°30'	N			No water loss; firm drilling.
SS	2"	2"	50/2"						
SS	2"	2"	50/2"	Drift	0°30'	N	150		

SS = SPLIT SPOON; ST = SHELBY TUBE; D = DENISON; P = PITCHER; O = OTHER

SITE: Unit 2 Well 4 — HOLE NO. 4B-4

10070-2 (4-78)

GEOLOGIC DRILL LOG

PROJECT	JOB NO.		HOLE NO.
SONGS Units 2 & 3	10079	3 of 3	4B-4

SAMPLER TYPE AND DIAMETER	SAMPLER ADVANCE / LENGTH CORE RUN	SAMPLE RECOVERY / CORE RECOVERY	SAMPLE BLOWS "N" / PERCENT CORE RECOVERY	WATER PRESSURE TESTS: LOSS IN G.P.M.	PRESSURE P.S.I.	TIME MINUTES	ELEVATION FT	DEPTH FT	DESCRIPTION AND CLASSIFICATION	NOTES ON: WATER LEVELS, WATER RETURN, CHARACTER OF DRILLING, ETC.
				Single Shot Record				150	25.0-200.0' San Mateo Formation (continued)	Drill rate 2.5 ft/1 minute. No water loss.
SS	2"	2"	50/2"							
							-130			
								160		
SS	2"	2"	50/2"	Drift 0°30'N						
							-140			
								170		
SS	2"	2"	50/2"							
							-150			
								180		
SS	2"	2"	50/2"	Drift 0°30'N						
							-160			
								190		
							-170			On 10/25-26/78, hole reamed to 205' using 7-7/8" bit.
SS	2"	2"	50/2"					200		

Bottom of Hole: 200'

On 10/26/78 - grouted in 205' of 4" solid PVC with 32 sacks of cement. Water: cement ratio 1:1 with 1.41 lbs. Intraplast additive per sack of cement.

Conducted Eastman Gyroscopic survey inside PVC casing on 10/31/78.

SS = SPLIT SPOON; ST = SHELBY TUBE; D = DENISON; P = PITCHER; O = OTHER

SITE: Unit 2 Well 4

HOLE NO. 4B-4

GEOLOGIC DRILL LOG

PROJECT	JOB NO.	SHEET NO.	HOLE NO.
SONGS Units 2 & 3	10079	1 of 3	4B-5

SITE	COORDINATES	ANGLE FROM HORIZ.	BEARING
Unit 2 Well 4	S 18 + 22.7 / W 4 + 95.9 at El. 26.5' For PVC, S 18 + 23.22 / W 4 + 96.37 at El. 20'	85°	S53°S'W

BEGUN	COMPLETED	DRILLER	DRILL MAKE AND MODEL	HOLE SIZE	OVERBURDEN (FT.)	ROCK (FT.)	TOTAL DEPTH
11/14/78	11/16/78	P C Exploration	Joy S&H	7-7/8" to 35' 3-1/2" to 200'	33	167	200'

CORE RECOVERY (FT./%)	CORE BOXES	SAMPLES	EL. TOP OF CASING	GROUND EL.	DEPTH/EL. GROUND WATER	DEPTH/EL. TOP OF ROCK
---	---	8	---	26.5'	21.5'/5'	33'/-6.5'

SAMPLE HAMMER WEIGHT/FALL	CASING LEFT IN HOLE: DIA./LENGTH	LOGGED BY:
140#/30"	4" PVC 200' Solid	B. Hebbron

SAMPLER TYPE AND DIAMETER	SAMPLER ADVANCE / LENGTH CORE RUN	SAMPLE RECOVERY / CORE RECOVERY	SAMPLE BLOWS "N" / PERCENT CORE RECOVERY	WATER PRESSURE TESTS: LOSS IN G.P.M.	PRESSURE P.S.I.	TIME IN MINUTES	ELEVATION FT	DEPTH FT	GRAPHIC LOG	SAMPLE	DESCRIPTION AND CLASSIFICATION	NOTES ON: WATER LEVELS, WATER RETURN, CHARACTER OF DRILLING, ETC.
							26.5	0			0.0-22.0' BACKFILL SAND: Tan, fine-to coarse-grained, quartzose compacted sand.	Began drilling on day shift with 7-7/8" tri-cone rock bit and Revert drilling fluid.
							20					
								10				
							10					Good circulation
								20				
											22.0-33.0' A-3 CONCRETE: Cement-sand mixture with small aggregate.	About 2' per hour drilling rate.
							0					
								30				
											33.0-200.0' SAN MATEO FORMATION: Well graded, fine-to coarse-grained, subrounded, well compacted, uncemented quartzose sand; silty in part, very dense.	End day shift 11/14/78. Begin day shift 11/15/78.
SS	3"	0"	50/3"									
							-10					Changed to open end carbide bit at 35'.
SS	2"	0"	50/2"					40				
							-20					Normal drilling rate: 1 ft/1 minute. 100% circulation.
								50				No sample at 50', driller miscounted rods.
							-30					
SS	3"	2"	50/3"					60			Fine-grained silty sand, brown, iron stained; very dense.	Heavy cuttings.
							-40					
								70				

GEOLOGIC DRILL LOG

PROJECT	JOB NO.		HOLE NO.
SONGS Units 2 & 3	10079	2 of 3	4B-5

SAMPLER TYPE AND DIAMETER	SAMPLER ADVANCE / LENGTH CORE RUN	SAMPLE RECOVERY / CORE RECOVERY	SAMPLE BLOWS "N" / PERCENT CORE RECOVERY	WATER PRESSURE TESTS: LOSS IN G.P.M.	PRESSURE P.S.I.	TIME MINUTES	ELEVATION FT	DEPTH FT	GRAPHIC LOG	SAMPLE	DESCRIPTION AND CLASSIFICATION	NOTES ON: WATER LEVELS, WATER RETURN, CHARACTER OF DRILLING, ETC.
SS	2"	0"	50/2"					70			33.0-200.0' San Mateo Formation (continued)	
							-50					
SS	1.5"	1.5"	50/1.5"					80			Chiefly medium-grained with lens of very fine-grained, silty, brown sand.	
							-60					
SS	2"	2"	50/2"					90			Chiefly fine-grained with minor amount of medium-and coarse-grained sand.	Normal drilling rate: 1 ft/1 minute. Good circulation, clean hole.
							-70					
SS	2"	2"	50/2"					100			Well graded fine-to coarse-grained quartzose sand, dense.	Variable sample interval from 100-200'.
							-80					
								110				
							-90					
SS	1.5"	1.5"	50/1.5"					120				
							-100					
								130				
							-110					
								140				
SS	2"	2"	50/2"								Chiefly fine-to medium-grained quartzose sand with scattering of coarse sizes.	
							-120					
								150				

SS = SPLIT SPOON; ST = SHELBY TUBE; D = DENISON; P = PITCHER; O = OTHER

SITE	HOLE NO.
Unit 2 Well 4	4B-5

GEOLOGIC DRILL LOG

PROJECT	JOB NO.		HOLE NO.
SONGS Units 2 & 3	10079	3 of 3	4B-5

SAMPLER TYPE AND DIAMETER	SAMPLER ADVANCE / LENGTH CORE RUN	SAMPLE RECOVERY / CORE RECOVERY	SAMPLE BLOWS "N" / PERCENT CORE RECOVERY	WATER PRESSURE TESTS: LOSS IN G.P.M.	PRESSURE P.S.I.	TIME MINUTES	ELEVATION FT	DEPTH FT	DESCRIPTION AND CLASSIFICATION	NOTES ON: WATER LEVELS, WATER RETURN, CHARACTER OF DRILLING, ETC.
								150	33.0-200.0' San Mateo Formation (continued)	Driller reports occasional firm silty clay zones.
								160		
SS	3"	2"	50/3"				-130		Brown, silty, very fine-grained sand. Very firm and dense.	
								170		
							-140			Normal drilling rate: 1 ft/1 minute.
								180		
							-150			100% circulation; good clean hole.
								190		
							-160			
SS	1"	1"	50/1"					200	Fine-to medium-grained quartzose sand.	End day shift 11/15/78.
									Bottom of Hole: 200' On 11/16/78 - grouted in 200' of 4" solid PVC with 33 sacks of cement. Water: cement ratio 1:1 with 1.41 lbs. Intraplast additive per sack of cement. Conducted Eastman Gyroscopic survey inside PVC casing on 11/17/78.	Hole reamed to 7-7/8" diameter from 0-205' on 11/16/78 (day shift).

SS = SPLIT SPOON; ST = SHELBY TUBE; D = DENISON; P = PITCHER; O = OTHER

SITE	HOLE NO.
Unit 2 Well 4	4B-5

GEOLOGIC DRILL LOG

PROJECT	JOB NO.	SHEET NO.	HOLE NO.
SONGS Units 2 & 3	10079	1 of 3	4B-6

SITE	COORDINATES	ANGLE FROM HORIZ.	BEARING
Unit 2 Well 4	S 18 + 11.2 / W 4 + 97.1 at El. 26.5' For PVC, S 18 + 11.29 / W 4 + 97.51 at El. 20'	86°	S83°34'N

BEGUN	COMPLETED	DRILLER	DRILL MAKE AND MODEL	HOLE SIZE	OVERBURDEN (FT.)	ROCK (FT.)	TOTAL DEPTH
11/8/78	11/13/78	P C Exploration	Joy-S&H	7-1/4" to 35' 3-1/2" to 200'	35	165	200'

CORE RECOVERY (FT./%)	CORE BOXES	SAMPLES	EL. TOP OF CASING	GROUND EL.	DEPTH/EL. GROUND WATER	DEPTH/EL. TOP OF ROCK
—	—	8	—	26.5'	21.5'/5'	35/-8.5

SAMPLE HAMMER WEIGHT/FALL	CASING LEFT IN HOLE: DIA./LENGTH	LOGGED BY:
140#/30"	4" PVC 200' Solid	B. Hebbron

SAMPLER TYPE AND DIAMETER	SAMPLER ADVANCE / LENGTH CORE RUN	SAMPLE RECOVERY / CORE RECOVERY	SAMPLE BLOWS "N" / PERCENT CORE RECOVERY	WATER PRESSURE TESTS: LOSS IN G.P.M.	PRESSURE P.S.I.	TIME IN MINUTES	ELEVATION FT	DEPTH FT	DESCRIPTION AND CLASSIFICATION	NOTES ON: WATER LEVELS, WATER RETURN, CHARACTER OF DRILLING, ETC.
							26.5	0	0.0-21.0' <u>BACKFILL SAND</u>: Tan, fine-to coarse-grained, quartzose, well compacted sand.	Began drilling on day shift with 7-1/4" tri-cone rock bit and Revert drilling mud.
							20			
								10		
							10			
								20	21.0-33.0' <u>A-3 CONCRETE</u>: Cement-sand mixture with small aggregate.	End day shift 11/8/78. Begin day shift 11/9/78
							0			
								30		
SS	18"	0"	19-8-8 / 16						33.0-35.0' <u>BACKFILL SAND</u>: As above except medium dense.	
							-10		35.0-200.0' <u>SAN MATEO FORMATION</u>: Fine-to coarse-grained, subrounded, quartzose well compacted, uncemented, silty in part, sand; well graded.	Changed to open carbide bit.
SS	4"	0"	50/4"					40		Good circulation but some coarse particles remaining in hole. Thickened mud.
							-20			
SS	3"	2"	50/3"					50		Normal drill rate: 1 ft/1 minute.
							-30			
SS	2"	2"	50/2"					60	Same as above but with a thin lens of rusty very fine-grained silty sand.	
							-40			
								70		

GEOLOGIC DRILL LOG

PROJECT	JOB NO.		HOLE NO.
SONGS Units 2 & 3	10079	2 of 3	4B-6

SAMPLER TYPE AND DIAMETER	SAMPLER ADVANCE LENGTH CORE RUN	SAMPLE RECOVERY CORE RECOVERY	SAMPLE BLOWS "N" PERCENT CORE RECOVERY	WATER PRESSURE TESTS: LOSS IN G.P.M.	PRESSURE P.S.I.	TIME MINUTES	ELEVATION FT	DEPTH FT	DESCRIPTION AND CLASSIFICATION	NOTES ON: WATER LEVELS, WATER RETURN, CHARACTER OF DRILLING, ETC.
SS	2.5"	2"	50/2.5'					70	35.0-200.0' San Mateo Formation (continued)	
							-50			
SS	2"	0"	50/2"					80		End day shift 11/9/78. Begin day shift 11/10/78.
							-60			
SS	2"	2"	50/2"					90	Fine-to medium-grained, silty, quartzose sand.	100% drilling fluid circulation.
							-70			
SS	2"	2"	50/2"					100		Drills easy; about 1 ft/40 seconds. 100-200' - variable sample interval.
							-80			
								110		
							-90			
SS	1.5"	1.5"	50/1.5'					120	Well graded, fine-to coarse-grained, well compacted, very quartzose sand.	
							-100			Normal drilling: 1 ft/1 minute.
								130		
							-110			
								140		
							-120			Good circulation, clean hole.
								150		

SS = SPLIT SPOON; ST = SHELBY TUBE; D = DENISON; P = PITCHER; O = OTHER

SITE: Unit 2 Well 4

HOLE NO. 4B-6

GEOLOGIC DRILL LOG

PROJECT	JOB NO.		HOLE NO.
SONGS Units 2 & 3	10079	3 of 3	4B-6

SAMPLER TYPE AND DIAMETER	SAMPLER ADVANCE / LENGTH CORE RUN	SAMPLE RECOVERY / CORE RECOVERY	SAMPLE BLOWS "N" / PERCENT CORE RECOVERY	WATER PRESSURE TESTS: LOSS IN G.P.M.	PRESSURE P.S.I.	TIME MINUTES	ELEVATION FT	DEPTH FT	GRAPHIC LOG	SAMPLE	DESCRIPTION AND CLASSIFICATION	NOTES ON: WATER LEVELS, WATER RETURN, CHARACTER OF DRILLING, ETC.
SS	2"	2"	50/2"					150			35.0–200.0' San Mateo Formation (continued)	Good circulation; normal drilling.
								160				Driller reports occasional clay zones.
SS	1"	1"	50/1"					170			Well graded, fine-to coarse-grained, well compacted, silty sand.	
								180				No mud loss.
								190				Normal drilling.
SS	1"	0"	50/1"					200			Bottom of Hole: 200' On 11/13/78 - grouted in 200' of 4" solid PVC with 33 sacks of cement. Water: cement ratio 1:1 with 1.41 lbs. Intraplast additive per sack of cement. Conducted Eastman Gyroscopic survey inside PVC casing on 11/15/78.	11/13/78 Reamed hole to 7-7/8" diameter prior to placement of PVC pipe.

SS = SPLIT SPOON; ST = SHELBY TUBE; D = DENISON; P = PITCHER; O = OTHER

SITE: Unit 2 Well 4

HOLE NO. 4B-6

GEOLOGIC DRILL LOG

PROJECT	JOB NO.	SHEET NO.	HOLE NO.
SONGS Units 2 & 3	10079	1 OF 2	4B-7

SITE	COORDINATES	ANGLE FROM HORIZ.	BEARING
Unit 2 Well 4	S 18 + 05.0 / W 5 + 00.0 at El. 26.5' For PVC, S 18 + 06.00 / W 5 + 00.37 at El. 20'	80°	S25°44'W

BEGUN	COMPLETED	DRILLER	DRILL MAKE AND MODEL	HOLE SIZE	OVERBURDEN (FT.)	ROCK (FT.)	TOTAL DEPTH
11/27/78	12/1/78	All Terrain Drilling	CME 750	6" to 35' 3-1/2" to 122'	34	91	125'

CORE RECOVERY (FT./%)	CORE BOXES	SAMPLES	EL. TOP OF CASING	GROUND EL.	DEPTH/EL. GROUND WATER	DEPTH/EL. TOP OF ROCK
---	---	1	---	26.5	21.5'/5'	34.0'/-7.5'

SAMPLE HAMMER WEIGHT/FALL	CASING LEFT IN HOLE: DIA./LENGTH	LOGGED BY:
140#/30"	4" PVC 122' Solid	R. Nelson / S. Sanders

SAMPLER TYPE AND DIAMETER	SAMPLER ADVANCE / LENGTH CORE RUN	SAMPLE RECOVERY / CORE RECOVERY	SAMPLE BLOWS "N" / PERCENT CORE RECOVERY	WATER PRESSURE TESTS: LOSS IN G.P.M.	PRESSURE P.S.I.	TIME IN MINUTES	ELEVATION FT	DEPTH FT	DESCRIPTION AND CLASSIFICATION	NOTES ON: WATER LEVELS, WATER RETURN, CHARACTER OF DRILLING, ETC.
							26.5	0	0.0-22.0' BACKFILL SAND: Fine-to coarse-grained quartzose sand; structural fill.	Began drilling hole on day shift. Advancing hole with 6" rock bit and Revert drilling mud. Mixed 1 sack Revert.
							20	10		
							10	20		
							0		22.0-34.0' A-3 CONCRETE: Sand-cement matrix with small aggregate.	Concrete drills at 2-1/2 ft/1 hour. End day shift 11/27/78 Begin day shift 11/28/78. Concrete drilling at rate of about 1 ft/1 hour. Started drilling at 28' and drilled through cement at 34' 5 hours later.
								30		
SS	6"	5"	50/6"				-10		34.0-125.0' SAN MATEO FORMATION: Tan, medium-to very coarse-grained, subangular to subrounded, slightly weathered quartzose sand.	Changed to 3-1/2" OD casing (WL) to drill at 35'. Hole logged from cuttings only.
							-20	40		
							-30	50		
							-40	60		
								70		

SS = SPLIT SPOON; ST = SHELBY TUBE; D = DENNISON; P = PITCHER; O = OTHER

SITE	HOLE NO.
Unit 2 Well 4	4B-7

H&CF 19-1

GEOLOGIC DRILL LOG

PROJECT	JOB NO.		HOLE NO.
SONGS Units 2 & 3	10079	2 of 2	4B-7

SAMPLER TYPE AND DIAMETER	SAMPLER ADVANCE LENGTH CORE RUN	SAMPLE RECOVERY CORE RECOVERY	SAMPLE BLOWS "N" PERCENT CORE RECOVERY	WATER PRESSURE TESTS: LOSS IN G.P.M.	PRESSURE P.S.I.	TIME MINUTES	ELEVATION FT	DEPTH FT	GRAPHIC LOG	SAMPLE	DESCRIPTION AND CLASSIFICATION	NOTES ON: WATER LEVELS, WATER RETURN, CHARACTER OF DRILLING, ETC.
								70			34.0-122.0' San Mateo Formation (continued)	
							-50					
								80				Drilling slow but even.
							-60					
								90				No water loss.
							-70					
								100				
							-80					
								110				
							-90					Reamed hole on 11/29-30/78 with 9" rock bit. Had problems with sanding in and slight delays while waiting for instructions about reaming, gyroing.
								120				
											Bottom of Hole: 125' On 12/1/78 - grouted in 122' of 4" solid PVC with 30 sacks of cement. Water: cement ratio 1:1 with 1.41 lbs. Intraplast additive per sack of cement. Conducted Eastman Gyroscopic survey of hole on 11/28/78, prior to placement of PVC, and again on 12/12/78 after placement of PVC.	

SS = SPLIT SPOON; ST = SHELBY TUBE; D = DENISON; P = PITCHER; O = OTHER

SITE: Unit 2 Well 4

HOLE NO. 4B-7

GEOLOGIC DRILL LOG

PROJECT	JOB NO.	SHEET NO.	HOLE NO.
SONGS Units 2 & 3	10079	1 of 2	4B-8

SITE	COORDINATES	ANGLE FROM HORIZ.	BEARING
Unit 2 Well 3	S 18 + 23.7 / W 4 + 97.0 at El. 26.5' For PVC, S 18 + 23.45 / W 4 + 97.00 at El. 20'	81°	N79°20'W

BEGUN	COMPLETED	DRILLER	DRILL MAKE AND MODEL	HOLE SIZE	OVERBURDEN (FT.)	ROCK (FT.)	TOTAL DEPTH
12/7/78	12/8/78	All Terrain Drilling	CME 750	3-3/4"	31	59	90'

CORE RECOVERY (FT./%)	CORE BOXES	SAMPLES	EL. TOP OF CASING	GROUND EL.	DEPTH/EL. GROUND WATER	DEPTH/EL. TOP OF ROCK
---	---	1	---	23.4'	18.4'/5'	31.0'/-7.6

SAMPLE HAMMER WEIGHT/FALL	CASING LEFT IN HOLE: DIA./LENGTH	LOGGED BY:
140#/30"	4" PVC 90' Solid	S. Sanders

SAMPLER TYPE AND DIAMETER	SAMPLER ADVANCE / LENGTH CORE RUN	SAMPLE RECOVERY / CORE RECOVERY	SAMPLE BLOWS "N" / PERCENT CORE RECOVERY	WATER PRESSURE TESTS: LOSS IN G.P.M.	PRESSURE P.S.I.	TIME IN MINUTES	ELEVATION FT	DEPTH FT	DESCRIPTION AND CLASSIFICATION	NOTES ON: WATER LEVELS, WATER RETURN, CHARACTER OF DRILLING, ETC.
							23.4	0	0.0-19.0' BACKFILL SAND: Fine-to coarse-grained sand; structural fill.	Began drilling on day shift. Advanced hole with 3-3/4" rock bit and Revert drilling fluid. Mixed 1 sack Revert.
							20			
								10		
							10			
								20	19.0-31.0' A-3 CONCRETE: Sand-cement mixture with small aggregate.	Log is based on information from cuttings.
							0			
								30		
SS	5"	3"	50/5"						31.0-90.0' SAN MATEO FORMATION: Tan, fine-to very coarse-grained, subangular to subrounded slightly weathered, quartzose sand.	
							-10			
								40		
							-20			
								50		Water loss of about 100 gallons at 55'.
							-30			End day shift 12/7/78. Begin swing shift 12/7/78.
								60		
							-40			
								70		

SS = SPLIT SPOON; ST = SHELBY TUBE; D = DENNISON; P = PITCHER; O = OTHER

SITE	HOLE NO.
Unit 2 Well 4	4B-8

H&CF 19-1

GEOLOGIC DRILL LOG

PROJECT	JOB NO.		HOLE NO.
SONGS Units 2 & 3	10079	2 of 2	4B-8

SAMPLER TYPE AND DIAMETER	SAMPLER ADVANCE LENGTH CORE RUN	SAMPLE RECOVERY CORE RECOVERY	SAMPLE BLOWS "N" PERCENT CORE RECOVERY	WATER PRESSURE TESTS: LOSS IN G.P.M.	PRESSURE P.S.I.	TIME MINUTES	ELEVATION FT	DEPTH FT	GRAPHIC LOG	SAMPLE	DESCRIPTION AND CLASSIFICATION	NOTES ON: WATER LEVELS, WATER RETURN, CHARACTER OF DRILLING, ETC.
								70			31.0-90.0' San Mateo Formation (continued)	
							-50				Very dense.	
								80				
							-60					
							-66.5	90				Reamed hole to 7-7/8" diameter on swing shift.
											Bottom of Hole: 90' On 12/8/78 - grouted in 90' of 4" solid PVC with 25 sacks of cement. Water: cement ratio 1:1 with 1.41 lbs. Intraplast additive per sack of cement. Conducted Eastman Gyroscopic survey inside PVC casing on 12/8/78.	NOTE: The water loss in this hole and recorded at 55' is interpreted to have occurred at 31' along a small disturbed zone at the Concrete - San Mateo Formation contact. Boring was at 55' when water loss occurred, and loss was noted at that depth. -R.L.B. 4/12/79.

SS = SPLIT SPOON; ST = SHELBY TUBE; D = DENISON; P = PITCHER; O = OTHER

SITE: Unit 2 Well 4

HOLE NO. 4B-8

10070-2 (4-78)

GEOLOGIC DRILL LOG

PROJECT	JOB NO.	SHEET NO.	HOLE NO.
SONGS Units 2 & 3	10079	1 of 3	5B-1

SITE	COORDINATES	ANGLE FROM HORIZ.	BEARING
Unit 2 Well 5	S 19 + 09.1 + W 2 + 92.9	86°	S80°W

BEGUN	COMPLETED	DRILLER	DRILL MAKE AND MODEL	HOLE SIZE	OVERBURDEN (FT.)	ROCK (FT.)	TOTAL DEPTH
10/4/78	10/5/78	P C Exploration	Joy-S&H	5-1/4" to 20' 3-1/2" to 200'	0	200	200'

CORE RECOVERY (FT./%)	CORE BOXES	SAMPLES	EL. TOP OF CASING	GROUND EL.	DEPTH/EL. GROUND WATER	DEPTH/EL. TOP OF ROCK
---	---	20	---	30	25'/5'	0'/30'

SAMPLE HAMMER WEIGHT/FALL	CASING LEFT IN HOLE: DIA./LENGTH	LOGGED BY:
140#/30"	4" PVC/200' Solid	Mendell M. Bell / B. Hebbron

SAMPLER TYPE AND DIAMETER	SAMPLER ADVANCE / LENGTH CORE RUN	SAMPLE RECOVERY / CORE RECOVERY	SAMPLE BLOWS "N" / PERCENT CORE RECOVERY	WATER PRESSURE TESTS: LOSS IN G.P.M.	PRESSURE P.S.I.	TIME IN MINUTES	ELEVATION FT	DEPTH FT	DESCRIPTION AND CLASSIFICATION	NOTES ON: WATER LEVELS, WATER RETURN, CHARACTER OF DRILLING, ETC.
				Single Shot Record			30	0	0.0-200.0' SAN MATEO FORMATION: Tan to brown, fine-to coarse-grained subrounded to subangular quartzose sand; very dense.	Began drilling on swing shift. Advanced hole with 5-1/4" bit using Revert mud and water to 20'.
SS	4"	4"	50/4"				20	10	Sand (SP), poorly sorted, medium-to fine-grained, angular to subrounded, scant mica, dense, tannish-gray San Mateo Formation.	Drilled moderately firm. Placed 4" casing to 20'.
SS	4"	4"	50/4"	Drift 3°S5°W			10	20		Advanced hole from 20' with 3-1/2" bit using Revert mud and water.
SS	2"	2"	50/2"				0	30	Coarse-grained dense sand.	
SS	2"	2"	50/2"	Drift 3°S20°W			-10	40		
SS	3"	3"	50/3"				-20	50		
SS	2"	2"	50/2"	Drift 3°S15°W			-30	60		End swing shift. Begin day shift 10/5/78.
							-40	70		

SS = SPLIT SPOON; ST = SHELBY TUBE; D = DENNISON; P = PITCHER; O = OTHER

GEOLOGIC DRILL LOG

PROJECT	JOB NO.		HOLE NO.
SONGS Units 2 & 3	10079	2 of 3	5B-1

Sampler Type and Diameter	Sampler Advance / Length Core Run	Sample Recovery / Core Recovery	Sample Blows "N" / Percent Core Recovery	Water Pressure Tests (Loss in G.P.M. / Pressure P.S.I. / Time Minutes)	Elevation FT	Depth FT	Description and Classification	Notes on: Water Levels, Water Return, Character of Drilling, Etc.
SS	2"	2"	50/2"	Single Shot Record	-40	70	0.0-200.0' San Mateo Formation (continued) Fine-to medium-grained, well compacted sand.	Normal drilling rate: 1 ft/1 minute. 100% circulation.
SS	4"	2"	50/4"	Drift 3°0'S	-50	80	Medium-to coarse-grained quartzose, sub-rounded, well compacted sand.	
SS	1"	1"	50/1"		-60	90	Well graded fine-to coarse-grained sand.	
SS	2"	1"	50/2"	Drift 3°0'NW	-70	100		Pulled out of hole to change drill bit.
SS	2"	2"	50/2"		-80	110	Brown, very well compacted, very fine-grained sand.	
SS	2"	1"	50/2"	Drift 3°0'S	-90	120	Well graded fine-to coarse-grained sand.	
SS	2"	1"	50/2"		-100	130	Chiefly medium-to coarse-grained sand, clean.	
SS	2"	2"	50/2"	Drift 3°0'S	-110	140	Well graded fine-to coarse-grained, sub-rounded, well compacted sand.	Good circulation.
					-120	150		

SS = SPLIT SPOON; ST = SHELBY TUBE; D = DENISON; P = PITCHER; O = OTHER

SITE	HOLE NO.
Unit 2 Well 5	5B-1

10070-2 (4-78)

GEOLOGIC DRILL LOG

PROJECT	JOB NO.		HOLE NO.
SONGS Units 2 & 3	10079	3 of 3	5B-1

SAMPLER TYPE AND DIAMETER	SAMPLER ADVANCE LENGTH CORE RUN	SAMPLE RECOVERY CORE RECOVERY	SAMPLE BLOWS "N" PERCENT CORE RECOVERY	WATER PRESSURE TESTS: LOSS IN G.P.M.	PRESSURE P.S.I.	TIME MINUTES	ELEVATION FT	DEPTH FT	DESCRIPTION AND CLASSIFICATION	NOTES ON: WATER LEVELS, WATER RETURN, CHARACTER OF DRILLING, ETC.
SS	1"	1"	50/1"	Single Shot Record			-120	150	0.0-200.0' San Mateo Formation (continued)	
SS	1"	1"	50/1"	Drift	3°N60°W		-130	160		End day shift 10/5/78. Begin swing shift 10/5/78.
SS	3"	3"	50/3"				-140	170		Firm drilling. No water loss.
SS	2"	2"	50/2"	Drift	3°S10°W		-150	180		Firm drilling.
SS	2"	2"	50/2"				-160	190		
SS	2"	2"	50/2"	Drift	3°S10°W		-170	200		No water loss.
									Bottom of Hole: 200' Installed 200' of 4" solid PVC - grouted with 45 bags 1:1 grout with 1.41 lbs. Intraplast additive per sack of cement. Conducted Eastman Gyroscopic survey of hole on 10/9/78.	10/5-6/78 reamed hole 0-206' with 9" bit.

SS = SPLIT SPOON; ST = SHELBY TUBE; D = DENISON; P = PITCHER; O = OTHER

SITE	HOLE NO.
Unit 2 Well 5	5B-1

GEOLOGIC DRILL LOG

PROJECT	JOB NO.	SHEET NO.	HOLE NO.
SONGS Units 2 & 3	10079	1 OF 3	5B-2

SITE	COORDINATES	ANGLE FROM HORIZ.	BEARING
Unit 2 Well 5	S 19 + 10.3 / W 2 + 80.3	86°	S30°W

BEGUN	COMPLETED	DRILLER	DRILL MAKE AND MODEL	HOLE SIZE	OVERBURDEN (FT.)	ROCK (FT.)	TOTAL DEPTH
10/2/78	10/3/78	P C Exploration	Joy-S&H	5-1/4" to 20' 3-1/2" to 200'	8	192	200'

CORE RECOVERY (FT./%)	CORE BOXES	SAMPLES	EL. TOP OF CASING	GROUND EL.	DEPTH/EL. GROUND WATER	DEPTH/EL. TOP OF ROCK
----	----	19	----	30'	25'/5'	12'/18'

SAMPLE HAMMER WEIGHT/FALL	CASING LEFT IN HOLE: DIA./LENGTH	LOGGED BY:
140#/30"	4" PVC/197' Solid	Mendell M. Bell / B. Hebbron

SAMPLER TYPE AND DIAMETER	SAMPLER ADVANCE / LENGTH CORE RUN	SAMPLE RECOVERY / CORE RECOVERY	SAMPLE BLOWS "N" / PERCENT CORE RECOVERY	WATER PRESSURE TESTS: LOSS IN G.P.M.	PRESSURE P.S.I.	TIME IN MINUTES	ELEVATION FT	DEPTH FT	DESCRIPTION AND CLASSIFICATION	NOTES ON: WATER LEVELS, WATER RETURN, CHARACTER OF DRILLING, ETC.
				Single Shot Record			30	0	0.0-12.0' <u>BACKFILL SAND</u>: Tan, fine-to coarse-grained quartzose sand.	Began drilling on swing shift. Advancing hole with 5-1/4" bit using Revert mud and water.
SS	4"	4"	50/4"				20	10		
									12.0-200.0' <u>SAN MATEO FORMATION</u>: Sand (SP) poorly sorted, angular to subrounded, minor mica, tannish-gray, dense.	4" casing placed to 20'.
SS	4"	4"	50/4"	Drift	3°S5°E		10	20		Hole advanced from 20-200' with 3-1/2" bit using Revert mud and water.
SS	4"	4"	50/4"				0	30		
SS	4"	4"	50/4"	Camera	malfunction		-10	40		No fluid loss.
SS	4"	4"	50/4"				-20	50		
SS	4"	4"	50/4"	Camera	malfunction		-30	60		
							-40	70		End swing shift.

SS = SPLIT SPOON; ST = SHELBY TUBE; D = DENNISON; P = PITCHER; O = OTHER

SITE	HOLE NO.
Unit 2 Well 5	5B-2

GEOLOGIC DRILL LOG

PROJECT	JOB NO.		HOLE NO.
SONGS Units 2 & 3	10079	2 of 3	5B-2

Sampler type and diameter	Sampler advance / Length core run	Sample recovery / Core recovery	Sample blows "N" / Percent core recovery	Water pressure tests: Loss in G.P.M. / Pressure P.S.I. / Time minutes	Elevation FT	Depth FT	Description and Classification	Notes on: water levels, water return, character of drilling, etc.
SS	4"	4"	50/4"	Single Shot Record	-40	70	12.0-200.0' San Mateo Formation (continued)	Start day shift 10/3/78.
SS	10"	3"	22-50/4"	Underexposed film	-50	80	Very fine-grained, silty and clayey sand. Tan to greenish brown, well compacted, uncemented.	Normal drilling rate: 1 ft/1 minute. Losing approximately 10% circulation.
SS	2"	2"	50/2"		-60	90		
SS	3"	2"	50/3"	Drift 3°0'SE	-70	100	Medium-to coarse-grained silty, well compacted sand.	
SS	3"	1"	50/3"		-80	110	Clean, medium-to coarse-grained quartzose sand.	
SS	3"	3"	50/3"	Drift 2°45 SE	-90	120		Good circulation, clean hole.
SS	2"	1"	50/2"		-100	130	Chiefly coarse-grained quartzose sand, clean.	
SS	2"	0"	50/2"	Drift 2°45 SE	-110	140		
					-120	150		

SS = SPLIT SPOON; ST = SHELBY TUBE; D = DENISON; P = PITCHER; O = OTHER

SITE	HOLE NO.
Unit 2 Well 5	5B-2

GEOLOGIC DRILL LOG

PROJECT	JOB NO.		HOLE NO.
SONGS Units 2 & 3	10079	3 of 3	5B-2

Sampler Type and Diameter	Sampler Advance / Length Core Run	Sample Recovery / Core Recovery	Sample Blows "N" / Percent Core Recovery	Water Pressure Tests: Loss in G.P.M.	Pressure P.S.I.	Time Minutes	Elevation FT	Depth FT	Description and Classification	Notes on: Water Levels, Water Return, Character of Drilling, etc.
SS	2"	2"	50/2"	Single Shot Record			-120	150	12.0-200.0' San Mateo Formation (continued) Well graded, fine-to coarse-grained, well compacted sand.	
SS	3"	2"	50/3"	Drift	2°30	SE	-130	160		Nearly 100% circulation.
SS	2"	2"	50/2"				-140	170	Fine-to medium-grained sand with occasional coarse particles.	Drilling rate: 1 ft/1 minute.
SS	2"	2"	50/2"	Drift	2°30	SE	-150	180	Same as above with coarse, tabular particles up to 1/4" length.	No water loss.
SS	3"	2"	50/3"				-160	190	Same as above but fewer coarse particles; very dense.	End day shift 10/3/78. Begin swing shift. Hole reamed with 8-7/8" bit to 205' on swing shift.
SS	2"	1"	50/2"				-170	200	Bottom of Hole: 200' On 10/4/78, installed 197' of 4" solid PVC pipe in hole and grouted with 43 sacks of cement. Water: cement ratio 1:1 with 1.41 lbs. of Intraplast additive per sack of cement. Conducted Eastman Gyroscopic survey of hole on 10/6/78.	

SS = SPLIT SPOON; ST = SHELBY TUBE; D = DENISON; P = PITCHER; O = OTHER

SITE	HOLE NO.
Unit 2 Well 5	5B-2

GEOLOGIC DRILL LOG

PROJECT	JOB NO.	SHEET NO.	HOLE NO.
SONGS Units 2 & 3	10079	1 of 3	5B-3

SITE	COORDINATES	ANGLE FROM HORIZ.	BEARING
Unit 2 Well 5	S 19 + 01.0 / W 2 + 80.1	90°	---

BEGUN	COMPLETED	DRILLER	DRILL MAKE AND MODEL	HOLE SIZE	OVERBURDEN (FT.)	ROCK (FT.)	TOTAL DEPTH
9/28/78	9/29/78	P C Exploration	Joy-S&H	3-1/2"	13	187	200'

CORE RECOVERY (FT./%)	CORE BOXES	SAMPLES	EL. TOP OF CASING	GROUND EL.	DEPTH/EL. GROUND WATER	DEPTH/EL. TOP OF ROCK
---	---	16	---	30'	25'/5'	13'/17'

SAMPLE HAMMER WEIGHT/FALL	CASING LEFT IN HOLE: DIA./LENGTH	LOGGED BY:
140#/30"	4" PVC/180' Solid	B. Hebbron / R. Nelson / V. Richards

SAMPLER TYPE AND DIAMETER	SAMPLER ADVANCE / LENGTH CORE RUN	SAMPLE RECOVERY / CORE RECOVERY	SAMPLE BLOWS "N" / PERCENT CORE RECOVERY	WATER PRESSURE TESTS: LOSS IN G.P.M.	PRESSURE P.S.I.	TIME IN MINUTES	ELEVATION FT	DEPTH FT	DESCRIPTION AND CLASSIFICATION	NOTES ON: WATER LEVELS, WATER RETURN, CHARACTER OF DRILLING, ETC.
				Single Shot Record			30	0	0.0-13.0' BACKFILL SAND: Fine to coarse, subangular to subrounded quartzose sand. At 7.5' 3" thick concrete slab.	Began drilling on day shift. Started hole with tri-cone rock bit and dilute Revert drilling mud.
							20	10		
SS	17"	9"	29-25-50/5"						13.0-20.0' SAN MATEO FORMATION: Fine-to coarse-grained sand; well graded, light tan, very slightly weathered; occasional micaceous siltstone pod; very dense.	100% circulation. Placed 21' of 4.3" diameter casing.
							10	20		
SS	4"	2.5"	50/4"	Camera	malf	unction				
							0	30		
SS	2.75"	1.5"	50/2.75"							Drilling rate steady: 1 ft/50-60 seconds.
							-10	40		No circulation loss.
SS	4.5"	3"	50/4.5"	Drift	vertical					
							-20	50		
SS	3"	2.5"	50/3"						Siltstone, gray-green, arenaceous (very fine) slightly weathered with very small amount of orange oxide staining; micaceous; slightly plastic.	
							-30	60		
SS	3"	2"	50/3"	Drift	0°10'	N70°W				
									Predominantly fine-to medium-grained, poorly graded sand.	
							-40	70		

SS = SPLIT SPOON; ST = SHELBY TUBE; D = DENNISON; P = PITCHER; O = OTHER

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GEOLOGIC DRILL LOG

PROJECT	JOB NO.		HOLE NO.
SONGS Units 2 & 3	10079	2 of 3	5B-3

Sampler type and diameter	Sampler advance / Length core run	Sample recovery / Core recovery	Sample blows "N" / Percent core recovery	Water pressure tests (Single Shot Record)			Elevation FT	Depth FT	Description and Classification	Notes on: water levels, water return, character of drilling, etc.
				Loss in G.P.M.	Pressure P.S.I.	Time minutes				
							-40	70	13.0-200.0' San Mateo Formation (continued)	
SS	2.5"	1"	50/2.5"						Siltstone, gray-green, laminated with thin sand layers; well cemented.	
							-50	80		
SS	2"	1.5"	50/2"	Drift	0°5'	S80°W			Siltstone, gray-green, same as above but very weakly cemented; moderately plastic.	
							-60	90		
SS	2.5"	1"	50/2.5"						Sand, tan, fine-to coarse-grained, well graded; 1/4" dark siltstone layer, very dense.	
							-70	100		
SS	2.5"	1"	50/2.5"	Drift	0°10'	N70°W			Sand, tan, fine-to coarse-grained, very dense.	End day shift 9/28/78. Begin swing shift.
							-80	110		
SS	1"	0"	50/1"							Good circulation, clean hole.
							-90	120		
SS	2"	1"	50/2"	Drift	10'W					No drilling problems.
							-100	130		
SS	1"	1"	50/1"							
							-110	140		
SS	2"	2"	50/2"	Drift	5'S85°W					
							-120	150		

SS = SPLIT SPOON; ST = SHELBY TUBE; D = DENISON; P = PITCHER; O = OTHER

SITE	HOLE NO.
Unit 2 Well 5	5B-3

GEOLOGIC DRILL LOG

PROJECT	JOB NO.		HOLE NO.
SONGS Units 2 & 3	10079	3 of 3	5B-3

SAMPLER TYPE AND DIAMETER	SAMPLER ADVANCE / LENGTH CORE RUN	SAMPLE RECOVERY / CORE RECOVERY	SAMPLE BLOWS "N" / PERCENT CORE RECOVERY	WATER PRESSURE TESTS: LOSS IN G.P.M.	PRESSURE P.S.I.	TIME MINUTES	ELEVATION FT	DEPTH FT	DESCRIPTION AND CLASSIFICATION	NOTES ON: WATER LEVELS, WATER RETURN, CHARACTER OF DRILLING, ETC.
				Single Shot Record			-120	150	13.0-200.0' San Mateo Formation (continued)	
SS	1"	0"	50/1"							
							-130	160		
SS	4"	1"	50/4"	Drift	1'W					
									Light tan sandstone (SW), fine-to medium-grained, very dense.	
							-140	170		
SS	1"	0"	50/1"							
							-150	180		No problems.
SS	4"	2"	50/4"	Drift	0°				Light tan sandstone.	1/2 sack Revert added.
							-160	190		
SS	2"	1"	50/2"				-170	200		
									Bottom of Hole: 200' On 9/29/78 grouted in 180' of 4" solid PVC with 44 sacks of cement. Water: cement ratio 1:1 with 1.41 lbs. of Intraplast additive per sack of cement. Conducted Eastman Gyroscopic survey of hole on 10/5/78.	From 9/28-29/78 reamed hole from 0-200' with 9" rock bit.

SS = SPLIT SPOON; ST = SHELBY TUBE; D = DENISON; P = PITCHER; O = OTHER

SITE: Unit 2 Well 5

HOLE NO. 5B-3

10070-2 (4-78)

GEOLOGIC DRILL LOG

PROJECT	JOB NO.	SHEET NO.	HOLE NO.
SONGS Units 2 & 3	10079	1 of 3	5B-4

SITE	COORDINATES	ANGLE FROM HORIZ.	BEARING
Unit 2 Well 5	S 19 + 01.1 / W 2 + 96.2	90°	---

BEGUN	COMPLETED	DRILLER	DRILL MAKE AND MODEL	HOLE SIZE	OVERBURDEN (FT.)	ROCK (FT.)	TOTAL DEPTH
9/22/78	9/25/78	P C Exploration	Joy-S&H	5-1/4" to 20' 3-1/2" to 200'	0	200	200'

CORE RECOVERY (FT./%)	CORE BOXES	SAMPLES	EL. TOP OF CASING	GROUND EL.	DEPTH/EL. GROUND WATER	DEPTH/EL. TOP OF ROCK
---	---	13	---	30'	25'/5'	0'/30'

SAMPLE HAMMER WEIGHT/FALL	CASING LEFT IN HOLE: DIA./LENGTH	LOGGED BY:
140#/30"	4" PVC/193' Solid	V. Richards / B. Hebbron

SAMPLER TYPE AND DIAMETER	SAMPLER ADVANCE / LENGTH CORE RUN	SAMPLE RECOVERY / CORE RECOVERY	SAMPLE BLOWS "N" / PERCENT CORE RECOVERY	WATER PRESSURE TESTS: LOSS IN G.P.M.	PRESSURE P.S.I.	TIME IN MINUTES	ELEVATION FT	DEPTH FT	DESCRIPTION AND CLASSIFICATION	NOTES ON: WATER LEVELS, WATER RETURN, CHARACTER OF DRILLING, ETC.
				Single Shot Record			30	0	0.0-200.0' <u>SAN MATEO FORMATION</u>: Light tan, fine-to medium-grained, subangular to angular quartzose sand, very dense.	Began drilling on swing shift. Advanced hole with 5-1/4" rock bit from 0-20'. Replaced hole with 4.3" casing.
SS	18"	18"	30-32-35 / 67				20	10		
SS	12"	12"	32-50/6"	Drift	55'W		10	20		Used open end carbide bit on NC casing to advance hole from 20-200'. 75% water return.
SS	6"	3"	50/6"				0	30		1/2 sack Revert added.
SS	4"	2"	50/4"	Drift	50'S20°W		-10	40		
SS	4"	0"	50/4"				-20	50		
SS	3"	3"	50/3"	Drift	55'N15°W		-30	60		
							-40	70		

SS = SPLIT SPOON; ST = SHELBY TUBE; D = DENNISON; P = PITCHER; O = OTHER

SITE	HOLE NO.
Unit 2 Well 5	5B-4

MACE 18:1

GEOLOGIC DRILL LOG

PROJECT	JOB NO.		HOLE NO.
SONGS Units 2 & 3	10079	2 of 3	5B-4

SAMPLER TYPE AND DIAMETER	SAMPLER ADVANCE / LENGTH CORE RUN	SAMPLE RECOVERY / CORE RECOVERY	SAMPLE BLOWS "N" / PERCENT CORE RECOVERY	WATER PRESSURE TESTS: LOSS IN G.P.M.	PRESSURE P.S.I.	TIME MINUTES	ELEVATION FT	DEPTH FT	DESCRIPTION AND CLASSIFICATION	NOTES ON: WATER LEVELS, WATER RETURN, CHARACTER OF DRILLING, ETC.
SS	3"	3"	50/3"	Single Shot Record			-40	70	0.0-200.0' San Mateo Formation (continued) Light gray, very fine to medium micaceous siltstone with some oxidation of micas; portions are very fine claystone, very dense.	Drilling very slow in clay and silt zone, material very dense.
SS	2"	2"	50/2"	Drift	60'S	15°W	-50	80		
SS	2"	0"	50/2"				-60	90		Good circulation. No problems drilling.
SS	2"	2"	50/2"	Drift	60'S	10°W	-70	100		
SS	1"	1"	50/1"				-80	110		
SS	1"	0"	50/1"	Drift	50'S	10°W	-90	120		End swing shift 9/22/78. Begin day shift 9/25/78.
SS	5"	2"	50/5"				-100	130	Medium-to coarse-grained subrounded, well compacted sand.	
SS	4"	2"	50/4"	Drift	0°50	S	-110	140		Losing about 20% circulation. Normal drilling rate: 1 ft/1 minute.
							-120	150		

SS = SPLIT SPOON; ST = SHELBY TUBE; D = DENISON; P = PITCHER; O = OTHER

SITE: Unit 2 Well 5

HOLE NO. 5B-4

GEOLOGIC DRILL LOG

PROJECT	JOB NO.		HOLE NO.
SONGS Units 2 & 3	10079	3 of 3	5B-4

SAMPLER TYPE AND DIAMETER	SAMPLER ADVANCE / LENGTH CORE RUN	SAMPLE RECOVERY / CORE RECOVERY	SAMPLE BLOWS "N" / PERCENT CORE RECOVERY	WATER PRESSURE TESTS: LOSS IN G.P.M.	PRESSURE P.S.I.	TIME MINUTES	ELEVATION FT	DEPTH FT	DESCRIPTION AND CLASSIFICATION	NOTES ON: WATER LEVELS, WATER RETURN, CHARACTER OF DRILLING, ETC.
SS	3"	1"	50/3"	Single Shot Record			-120	150	0.0-200.0' San Mateo Formation (continued) Chiefly fine-to medium-grained sand.	
SS	3"	0"	50/3"	Drift	0°40'	SW	-130	160		Good clean hole.
SS	2"	2"	50/2"				-140	170	Fine-to coarse-grained subrounded, tan, quartzose sand.	
SS	2"	0"	50/2"	Camera malfunction			-150	180		End day shift 9/25/78. Begin swing shift.
SS	2"	0"	50/2"				-160	190		
SS	1"	0"	50/1"	Drift	0°50'	S20°W	-170	200		
									Bottom of Hole: 200' On 9/27/78 grouted in 193' of 4" solid PVC with 48 sacks of cement. Water: cement ratio 1:1 with 1.41 lbs. of Intraplast additive per sack of cement. Conducted Eastman Gyroscopic survey of hole on 10/3/78.	From 9/25-26/78 reamed hole 0-200' with 9" rock bit.

SS = SPLIT SPOON; ST = SHELBY TUBE; D = DENISON; P = PITCHER; O = OTHER

SITE: Unit 2 Well 5

HOLE NO. 5B-4

ATTACHMENT G-2

SUMMARY OF DOWNHOLE GYROSCOPIC SURVEY DATA

Gyroscopic Survey results are attached for Wells 4 and 5 and for Borings 4B-1 thru 4B-8 and Borings 5B-1 thru 5B-4. Two surveys were run on Borings 4B-7: one prior to setting the PVC and the other afterwards.

BECHTEL POWER CORP.- DEEP WELL #4 -EASTMAN GYRO MULTI-SHOT SURVEY
SAN ONOFRE POWER PLANT

NORTH FOR THIS SURVEY IS 'PLANT NORTH', N 57 00 W

DATE: 5 OCTOBER 1978
JOB NO: P-1078-G0086
GYRO SURVEY BY: EASTMAN WHIPSTOCK, INC.
FILE: F135-11
PITT

VERTICAL SECTION IS IN
PLANE OF BOTTOM HOLE CLOSURE.

RECORD OF SURVEY

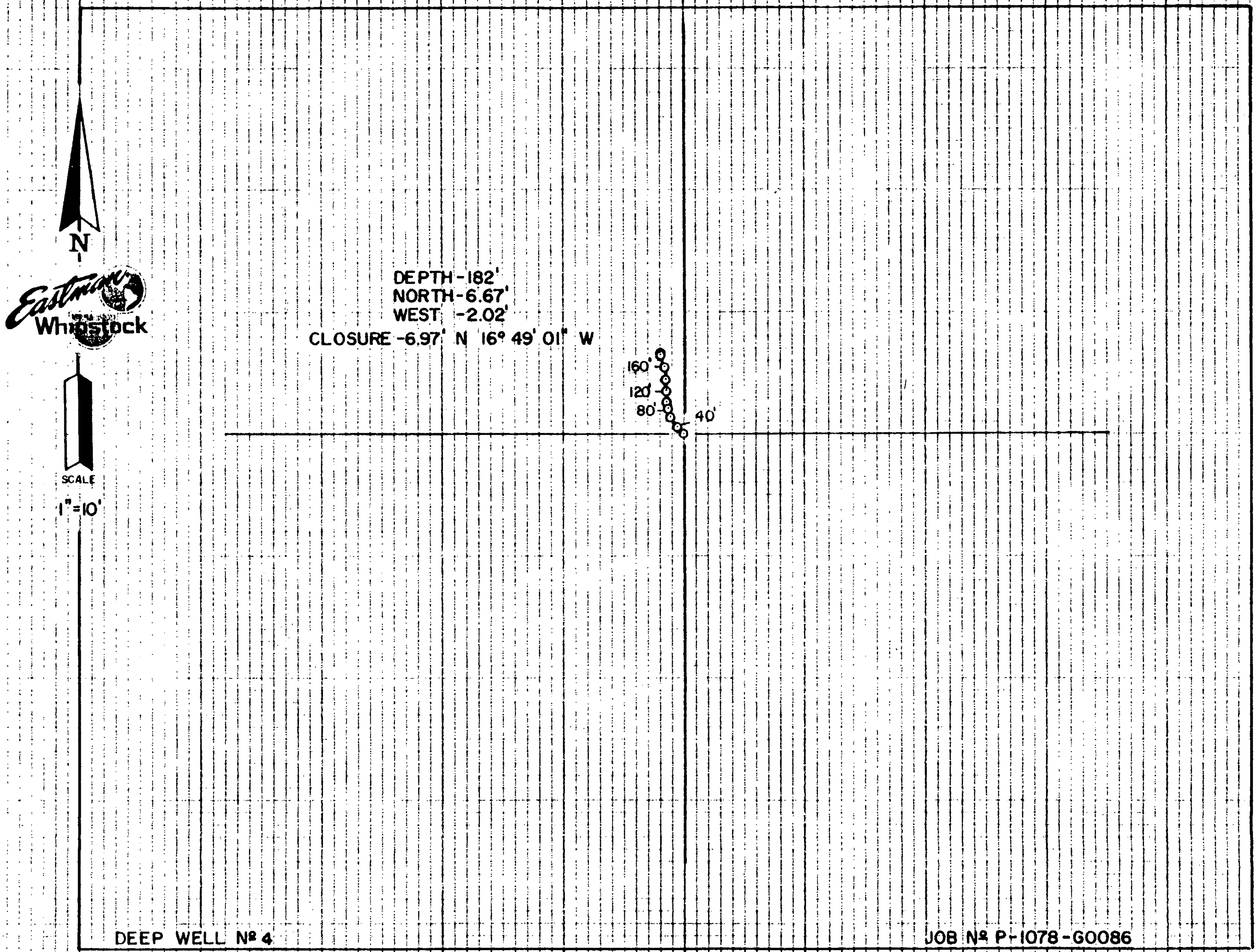
ANGLE AVERAGING METHOD

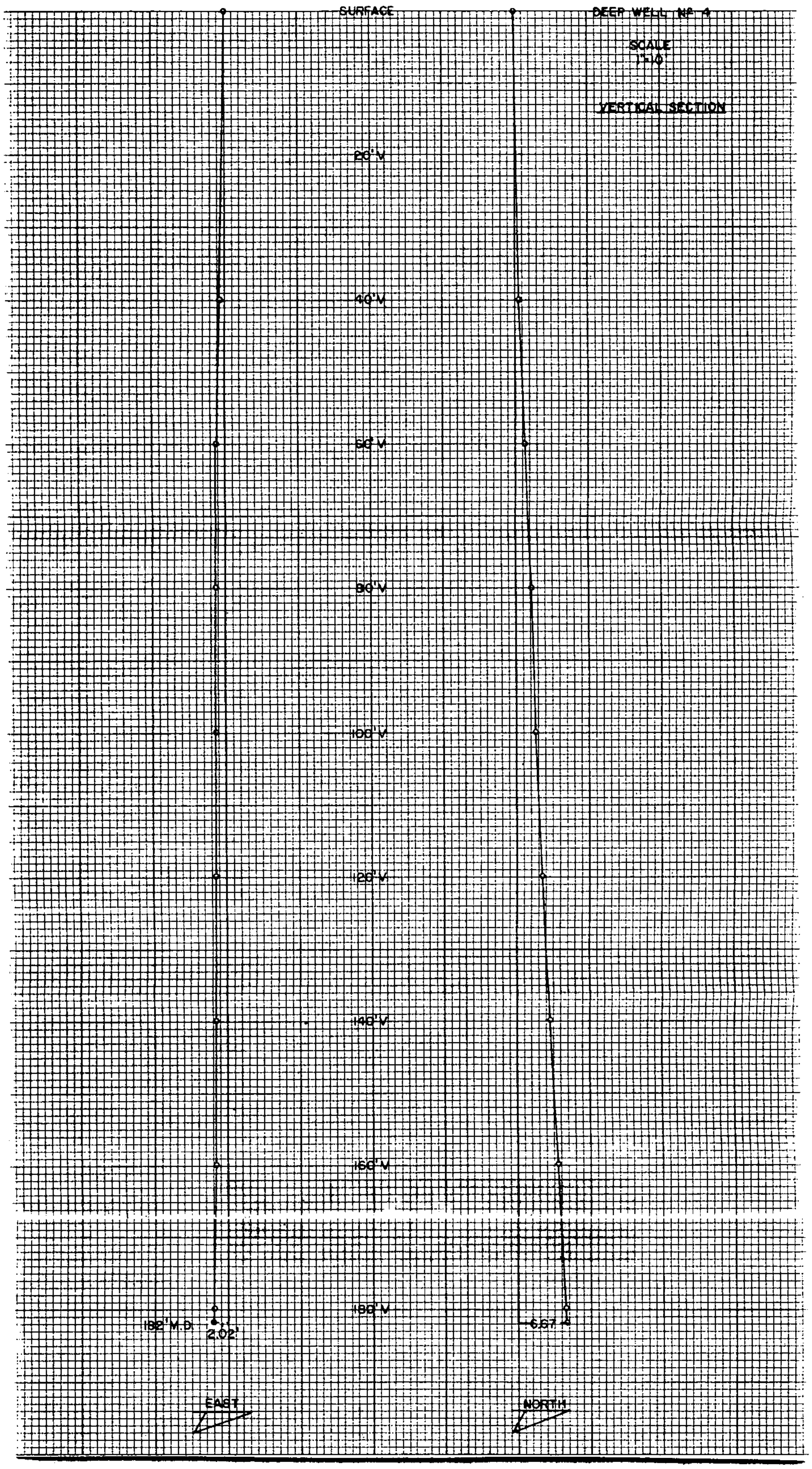
MEASURED DEPTH FEET	DRIFT ANGLE D M	DRIFT DIRECTION D	TRUE VERTICAL DEPTH FEET	VERTICAL SECTION FEET	R E C T A N G U L A R C O O R D I N A T E S FEET	
0.	0 0	0	0.00	0.00	0.00	0.00

NORTH FOR THIS SURVEY IS 'PLANT NORTH', N 57 00 W

40.	2 45	N 44 W	39.99	0.85	0.69 N	0.67 W
60.	1 55	N 19 W	59.97	1.64	1.38 N	1.09 W
80.	2 0	N 14 W	79.96	2.32	2.04 N	1.29 W
100.	2 15	N 8 W	99.95	3.06	2.77 N	1.43 W
120.	2 30	N 8 W	119.93	3.88	3.59 N	1.54 W
140.	2 50	N 9 W	139.91	4.80	4.51 N	1.68 W
160.	3 0	N 8 W	159.88	5.81	5.52 N	1.83 W
180.	3 5	N 10 W	179.85	6.86	6.56 N	2.00 W
182.	3 5	N 10 W	181.85	6.97	6.67 N	2.02 W

FINAL CLOSURE - DIRECTION: N 16 DEGS 49 MINS 1 SECS W
DISTANCE: 6.97 FEET


N
Eastman Whipstock
SCALE
1"=10'
DEPTH-182'
NORTH-6.67'
WEST -2.02'
CLOSURE-6.97' N 16° 49' 01" W
160'
120'
80'
40'
DEEP WELL Nº 4
JOB Nº P-1078-G0086


SURFACE
DEEP WELL Nº 4
SCALE
1"=10'
VERTICAL SECTION
20' V
40' V
60' V
80' V
100' V
120' V
140' V
160' V
180' V
182' M.D.
2.02'
6.67'
EAST
NORTH

BECHTEL POWER CORP.--- HOLE: 4-B-1 ---EASTMAN GYRO MULTI-SHOT SURVEY
SAN ONOFRE POWER PLANT

NORTH FOR THIS SURVEY IS "PLANT NORTH", N 57 00 W

DATE: 25 OCTOBER 1978
JOB NO: P-1078-G0139
GYRO SURVEY BY: EASTMAN WHIPSTOCK, INC.
FILE: F136-6
PITT

VERTICAL SECTION IS IN
PLANE OF BOTTOM HOLE CLOSURE.

RECORD OF SURVEY

ANGLE AVERAGING METHOD

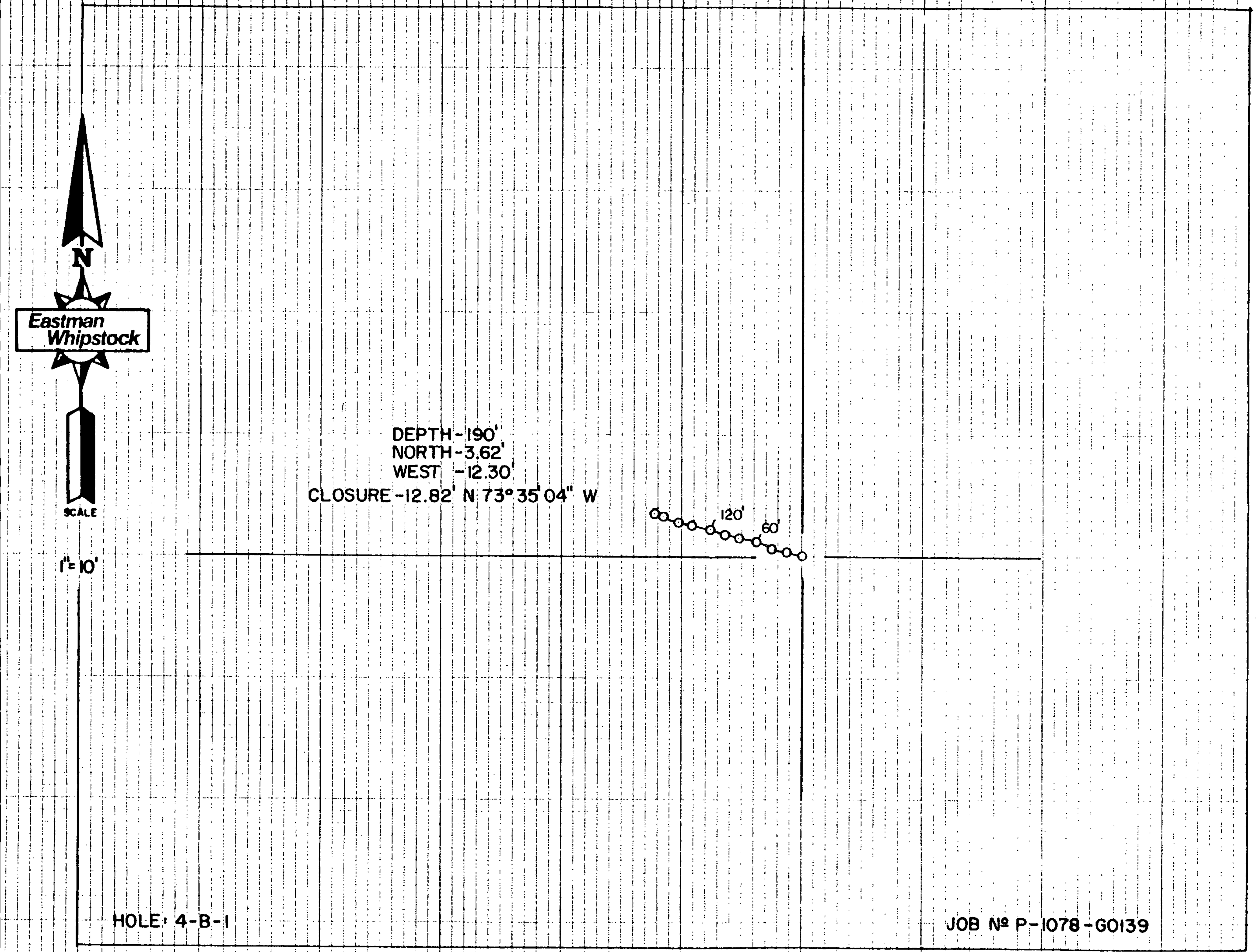
BECHTEL POWER CORP.--- HOLE: 4-B-1 ---EASTMAN GYRO MULTI-SHOT SURVEY 17:57:10 25-OCT-78 PAGE NO.

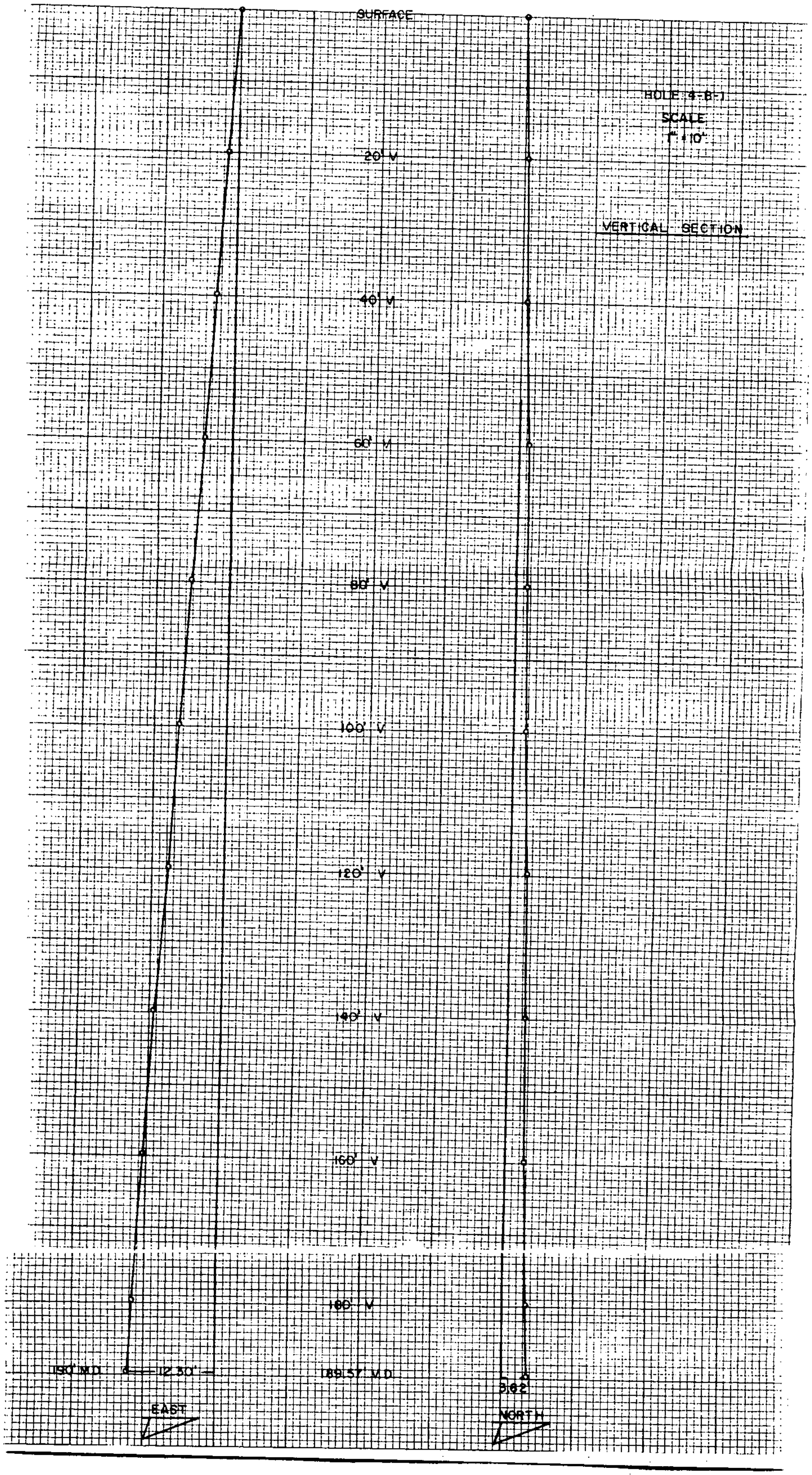
MEASURED DEPTH FEET	DRIFT ANGLE D M	DRIFT DIRECTION D	TRUE VERTICAL DEPTH FEET	VERTICAL SECTION FEET	RECTANGULAR COORDINATES FEET	
0.	3 55	N 74 W	0.00	0.00	0.00	0.00

NORTH FOR THIS SURVEY IS 'PLANT NORTH', N 57 00 W

MEASURED DEPTH FEET	DRIFT ANGLE D M	DRIFT DIRECTION D	TRUE VERTICAL DEPTH FEET	VERTICAL SECTION FEET	RECTANGULAR COORDINATES FEET	
20.	3 55	N 74 W	19.95	1.37	0.38 N	1.31 W
40.	4 0	N 72 W	39.91	2.75	0.78 N	2.63 W
60.	3 50	N 72 W	59.86	4.11	1.20 N	3.93 W
80.	3 55	N 78 W	79.81	5.46	1.55 N	5.24 W
100.	3 50	N 78 W	99.77	6.81	1.83 N	6.56 W
120.	3 55	N 77 W	119.72	8.16	2.13 N	7.88 W
140.	3 45	N 73 W	139.68	9.50	2.47 N	9.17 W
160.	3 50	N 70 W	159.63	10.82	2.89 N	10.43 W
180.	3 50	N 69 W	179.59	12.15	3.36 N	11.68 W
190.	3 55	N 65 W	189.57	12.82	3.62 N	12.30 W

FINAL CLOSURE - DIRECTION: N 73 DEGS 35 MINS 4 SECS W
DISTANCE: 12.82 FEET


N
Eastman Whipstock
SCALE
1" = 10'
DEPTH - 190'
NORTH - 3.62'
WEST - 12.30'
CLOSURE - 12.82' N 73° 35' 04" W
120'
60'
HOLE: 4-B-1
JOB № P-1078-G0139


HOLE 4-B-1
SCALE
1" = 10'
VERTICAL SECTION
SURFACE
20' V
40' V
60' V
80' V
100' V
120' V
140' V
160' V
180' V
190' M.D.
12.30'
189.57' V.D.
3.62'
EAST
NORTH

BECHTEL POWER CORP.--- HOLE: 4-B-2 ---EASTMAN GYRO MULTI-SHOT SURVEY
SAN ONOFRE POWER PLANT

NORTH FOR THIS SURVEY IS 'PLANT NORTH', N 57 00 W

DATE: 25 OCTOBER 1978
JOB NO: P-1078-30138
GYRO SURVEY BY: EASTMAN WHIPSTOCK, INC.
FILE: F136-5
PITT

VERTICAL SECTION IS IN
PLANE OF BOTTOM HOLE CLOSURE.

RECORD OF SURVEY

ANGLE AVERAGING METHOD

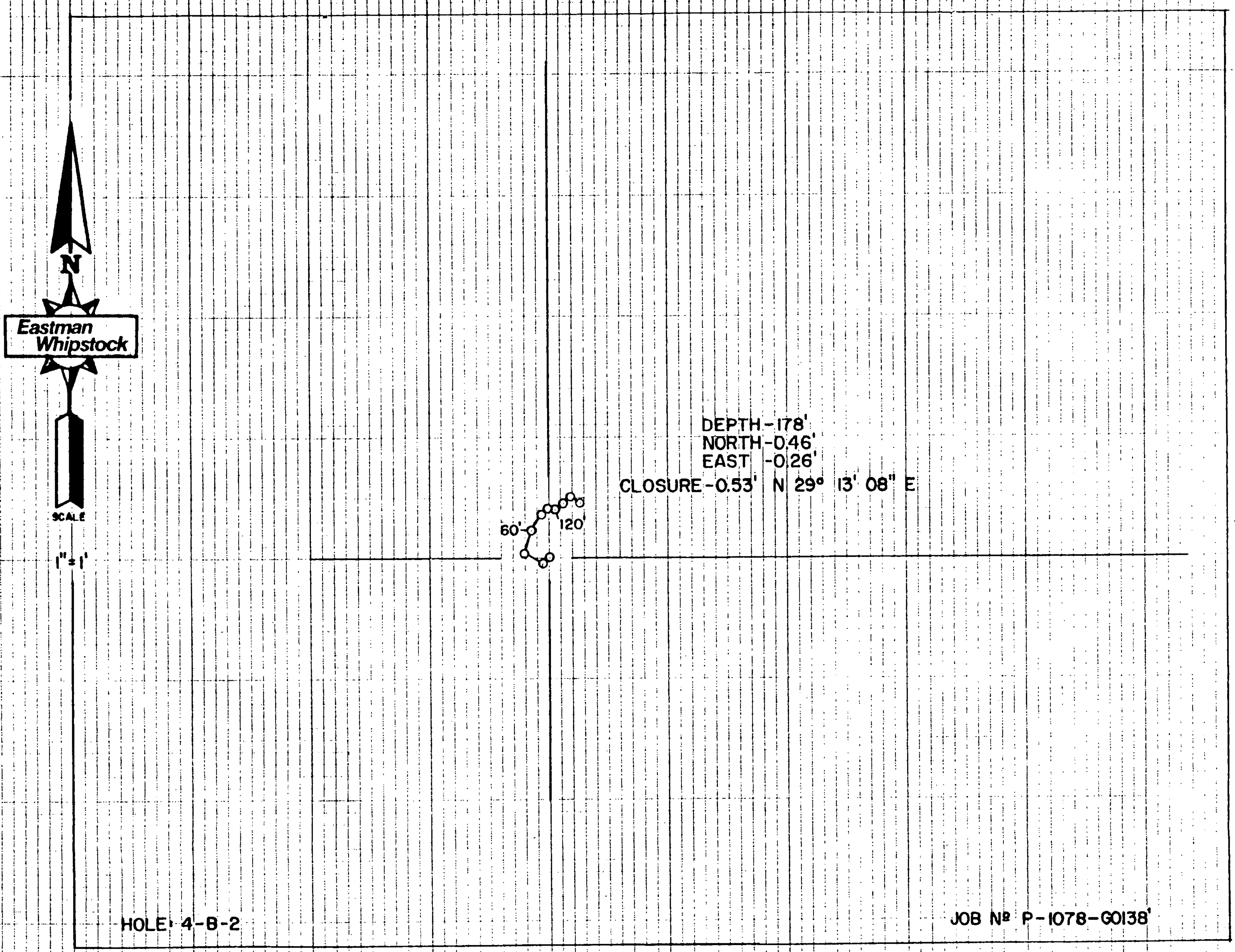
BECHTEL POWER CORP.--- HOLE: 4-B-2 ---EASTMAN GYRO MULTI-SHOT SURVEY 17:35:22 25-OCT-78 PAGE NO.

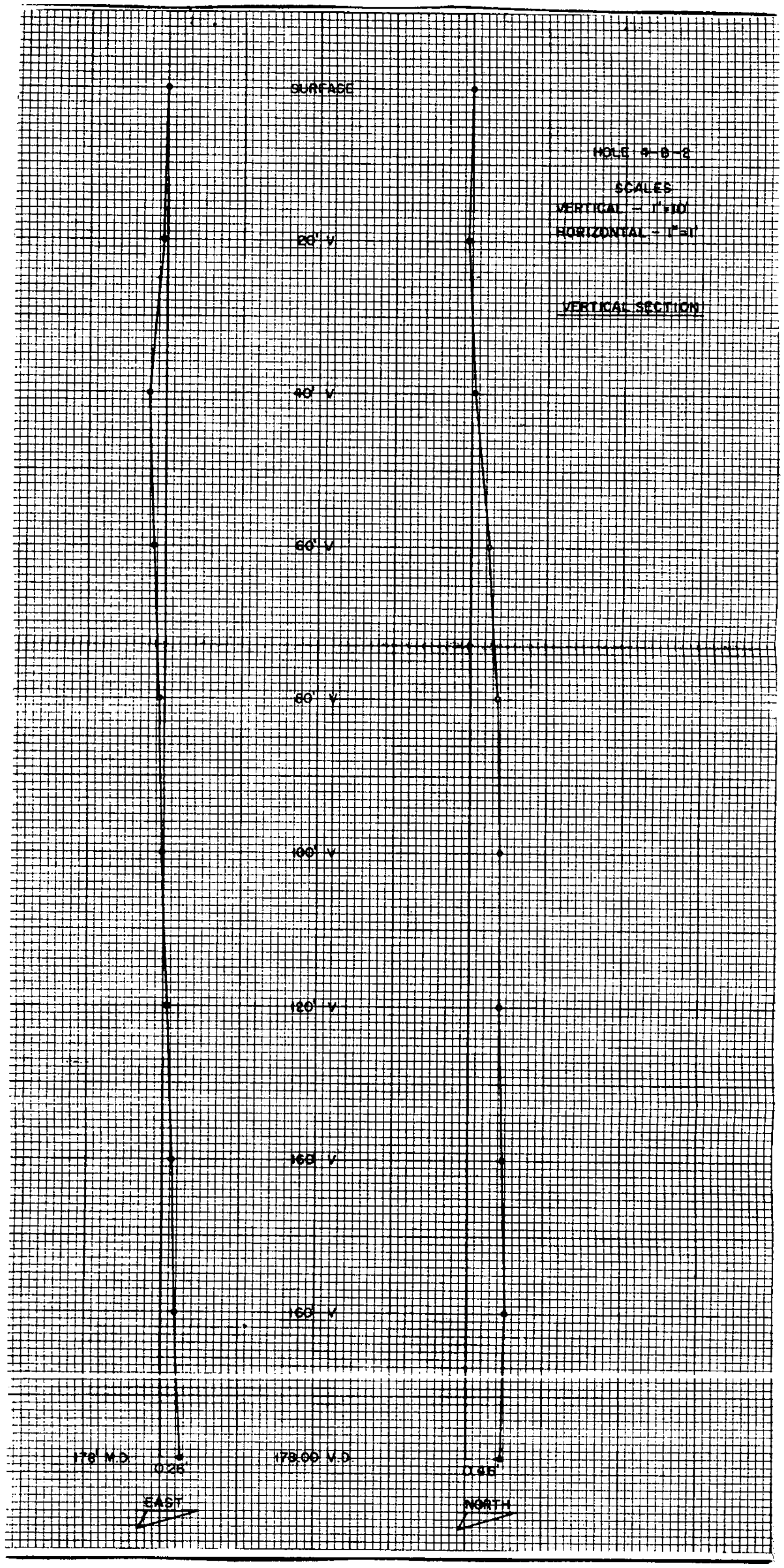
MEASURED DEPTH FEET	DRIFT ANGLE D M	DRIFT DIRECTION D	TRUE VERTICAL DEPTH FEET	VERTICAL SECTION FEET	RECTANGULAR COORDINATES FEET	
0.	0 0	0	0.00	0.00	0.00	0.00

NORTH FOR THIS SURVEY IS "PLANT NORTH", N 57 00 W

20.	0 25	S 41 W	20.00	-0.07	0.05 S	0.05 W
40.	0 40	N 20 E	40.00	-0.07	0.04 N	0.21 W
60.	0 30	N 22 E	60.00	0.13	0.23 N	0.14 W
80.	0 20	N 32 E	80.00	0.28	0.36 N	0.07 W
100.	0 5	N 82 E	100.00	0.34	0.40 N	0.01 W
120.	0 15	S 80 E	120.00	0.37	0.40 N	0.05 E
140.	0 15	N 8 W	140.00	0.46	0.46 N	0.11 E
160.	0 15	S 44 E	160.00	0.53	0.50 N	0.19 E
178.	0 15	S 82 E	178.00	0.53	0.46 N	0.26 E

FINAL CLOSURE - DIRECTION: N 29 DEGS 13 MINS 8 SECS E
DISTANCE: 0.53 FEET


Eastman Whipstock
N
SCALE
1" = 1'
DEPTH - 178'
NORTH - 0.46'
EAST - 0.26'
CLOSURE - 0.53' N 29° 13' 08" E
60'
120'
HOLE: 4-B-2
JOB № P-1078-G0138'



SURFACE
HOLE 4-B-2
SCALES
VERTICAL SECTION
20' V
40' V
60' V
80' V
100' V
120' V
140' V
160' V
178' M.D.
0.26'
EAST
NORTH

BECHTEL POWER CORP.---- HOLE: 4-B-3 ---EASTMAN GYRO MULTI-SHOT SURVEY
SAN ONOFRE POWER PLANT

NORTH FOR THIS SURVEY IS "PLANT NORTH", N 57 00 W

DATE: 31 OCTOBER 1978
JOB NO: P-1078-G0154
GYRO SURVEY BY: EASTMAN WHIPSTOCK, INC.
FILE: F136-10
PITT

VERTICAL SECTION IS IN
PLANE OF BOTTOM HOLE CLOSURE.

RECORD OF SURVEY

ANGLE AVERAGING METHOD

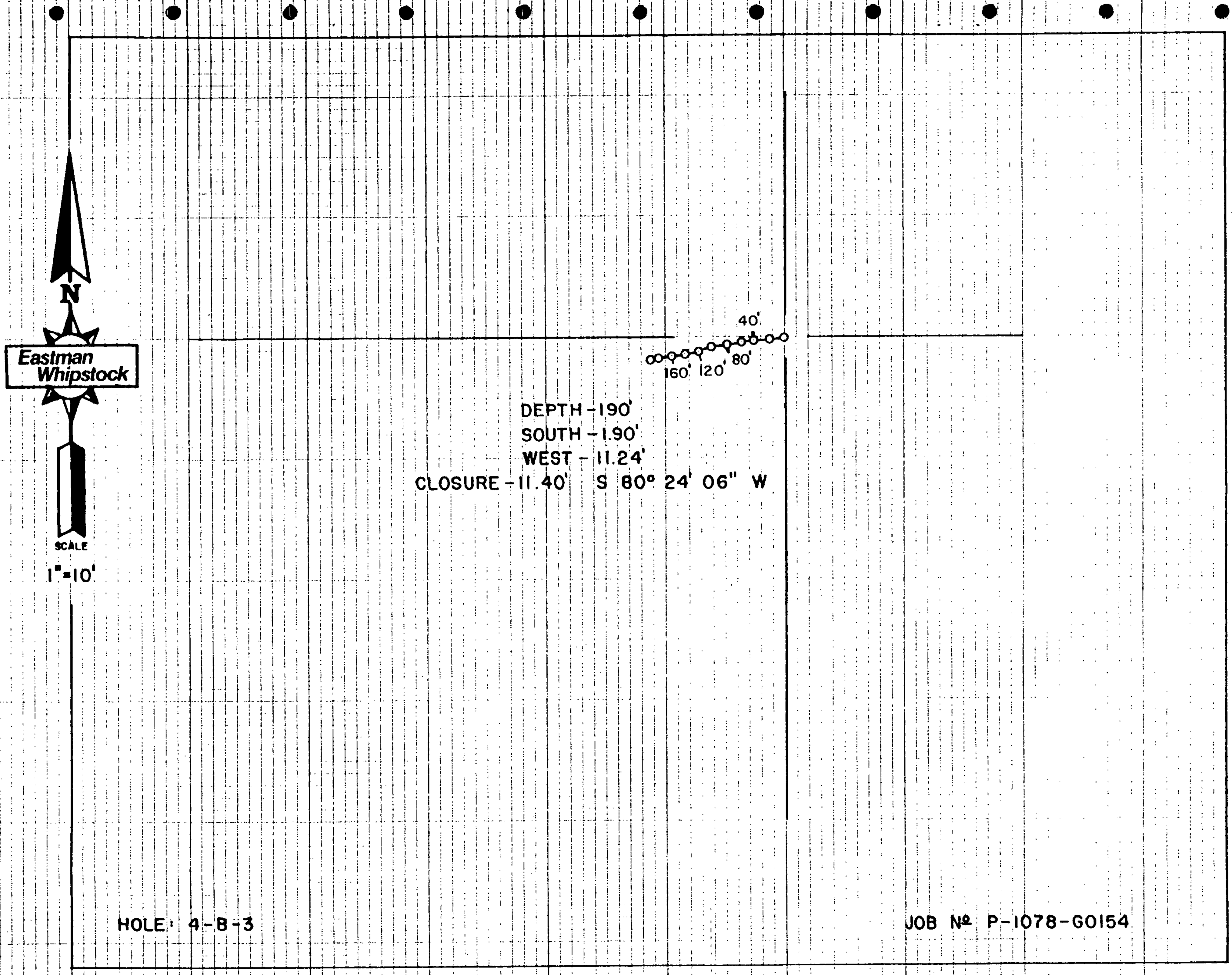
BECHTEL POWER CORP.--- HOLE: 4-B-3 ---EASTMAN GYRO MULTI-SHOT SURVEY 10:24:28 01-NOV-78 PAGE NO.

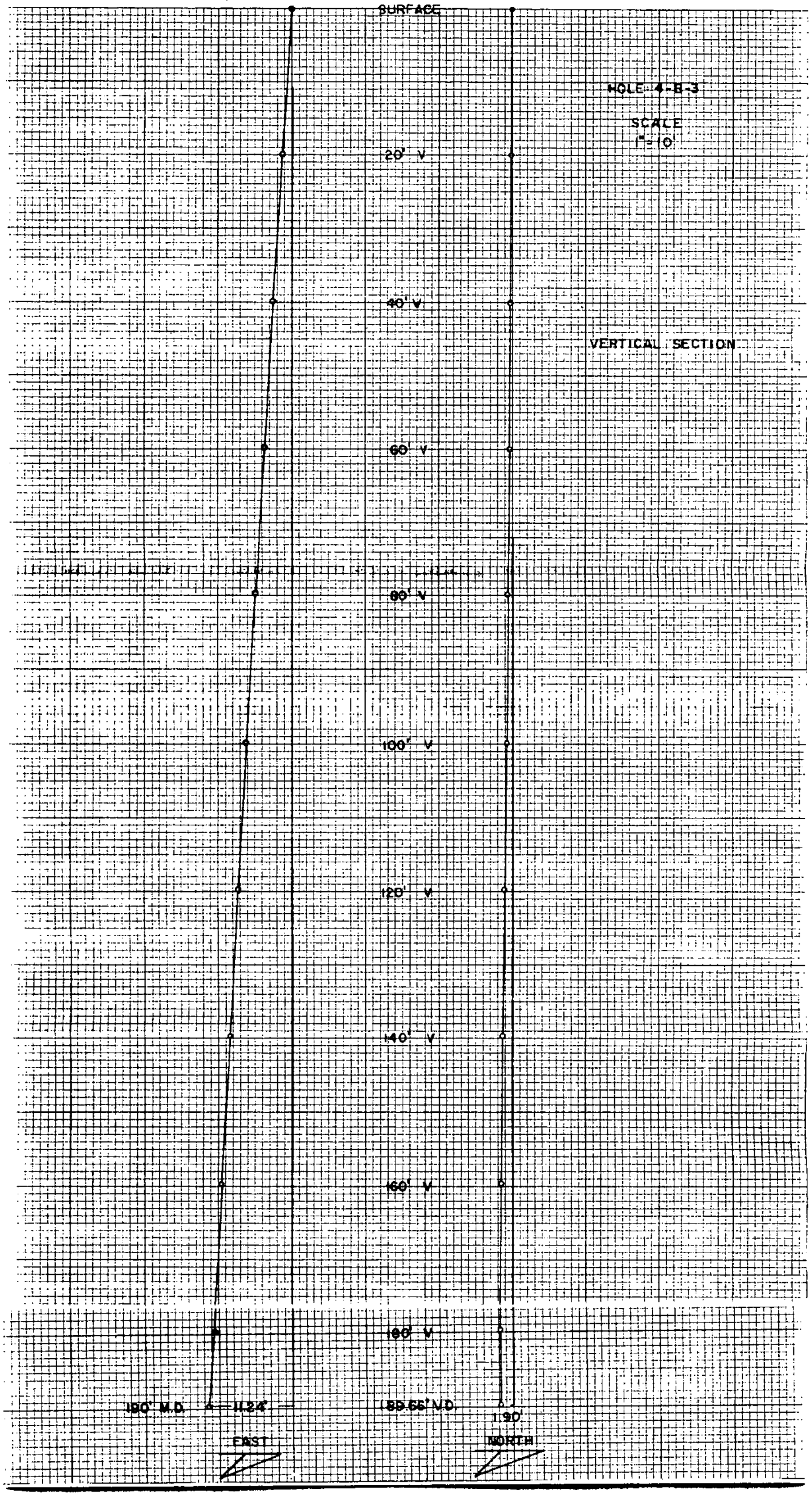
MEASURED DEPTH FEET	DRIFT ANGLE D M	DRIFT DIRECTION D	TRUE VERTICAL DEPTH FEET	VERTICAL SECTION FEET	RECTANGULAR COORDINATES FEET	
0.	3 55	S 87 W	0.00	0.00	0.00	0.00

NORTH FOR THIS SURVEY IS "PLANT NORTH", N 57 00 W

MEASURED DEPTH FEET	DRIFT ANGLE D M	DRIFT DIRECTION D	TRUE VERTICAL DEPTH FEET	VERTICAL SECTION FEET	RECTANGULAR COORDINATES FEET	
20.	3 55	S 87 W	19.95	1.36	0.07 S	1.36 W
40.	3 30	S 85 W	39.91	2.64	0.16 S	2.65 W
60.	3 20	S 79 W	59.88	3.84	0.33 S	3.83 W
80.	3 25	S 71 W	79.84	5.01	0.63 S	4.97 W
100.	3 25	S 84 W	99.81	6.20	0.89 S	6.14 W
120.	3 25	S 78 W	119.77	7.39	1.08 S	7.31 W
140.	3 10	S 78 W	139.74	8.54	1.32 S	8.44 W
160.	3 25	S 81 W	159.70	9.69	1.52 S	9.57 W
180.	3 10	S 76 W	179.67	10.83	1.75 S	10.69 W
190.	3 20	S 74 W	189.66	11.40	1.90 S	11.24 W

FINAL CLOSURE - DIRECTION: S 80 DEGS 24 MINS 6 SECS W
DISTANCE: 11.40 FEET


N
Eastman Whipstock
SCALE
1" = 10'
40'
80'
120'
160'
DEPTH - 190'
SOUTH - 1.90'
WEST - 11.24'
CLOSURE - 11.40' S 80° 24' 06" W
HOLE: 4-B-3
JOB Nº P-1078-G0154


SURFACE
HOLE 4-B-3
SCALE
1"=10'
20' V
40' V
VERTICAL SECTION
60' V
80' V
100' V
120' V
140' V
160' V
180' V
190' M.D.
11.24'
189.66' V.D.
1.90'
EAST
NORTH

BECHTEL POWER CORP.--- HOLE: 4-B-4 ---EASTMAN GYRO MULTI-SHOT SURVEY
SAN ONOFRE POWER PLANT

NORTH FOR THIS SURVEY IS "PLANT NORTH", N 57 00 W

DATE: 31 OCTOBER 1978
JOG NO: P-1078-G0153
GYRO SURVEY BY; EASTMAN WHIPSTOCK, INC.
FILE: F136-11
PITT

PLANE OF PROPOSED DIRECTION IS N 90 DEG. 0 MIN. E

RECORD OF SURVEY

ANGLE AVERAGING METHOD

MEASURED DEPTH FEET	DRIFT ANGLE D M	DRIFT DIRECTION D	TRUE VERTICAL DEPTH FEET	VERTICAL SECTION FEET	R E C T A N G U L A R C O O R D I N A T E S FEET	
0.	0 0	0	0.00	0.00	0.00	0.00

NORTH FOR THIS SURVEY IS "PLANT NORTH", N 57 00 W

MEASURED DEPTH FEET	DRIFT ANGLE D M	DRIFT DIRECTION D	TRUE VERTICAL DEPTH FEET	VERTICAL SECTION FEET	R E C T A N G U L A R C O O R D I N A T E S FEET	
20.	0 35	N 62 E	20.00	0.09	0.05 N	0.09 E
40.	0 25	S 75 W	40.00	0.03	0.21 N	0.03 E
60.	0 55	S 57 E	60.00	-0.01	0.02 S	0.01 W
80.	0 10	N 82 E	80.00	0.17	0.06 S	0.17 E
100.	0 10	N 66 W	100.00	0.18	0.00 S	0.18 E
120.	0 30	N 78 E	120.00	0.19	0.11 N	0.19 E
140.	0 35	S 42 E	140.00	0.37	0.05 N	0.37 E
160.	0 30	N 88 E	159.99	0.55	0.02 S	0.55 E
180.	0 30	N 6 E	179.99	0.68	0.10 N	0.68 E
190.	0 25	N 11 E	189.99	0.69	0.18 N	0.69 E

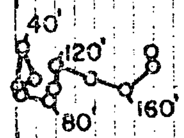
FINAL CLOSURE - DIRECTION: N 75 DEGS 26 MINS 33 SECS E
DISTANCE: 0.71 FEET

Eastman Whipstock

SCALE

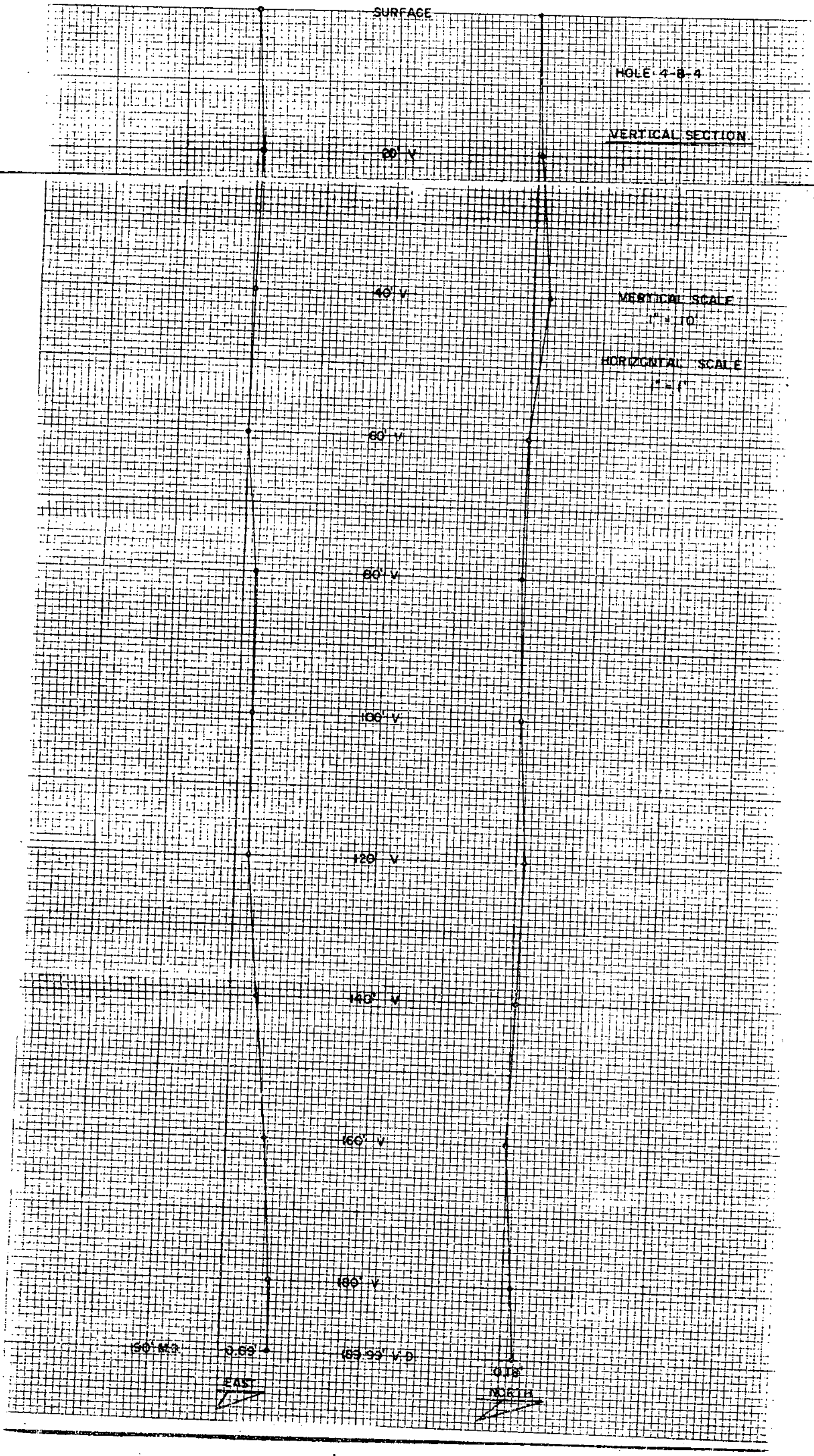
1" = 1'

DEPTH - 190'
NORTH - 0.18'
EAST - 0.69'
CLOSURE - 0.71' N 75° 26' 33" E



HOLE: 4-B-4

JOB Nº P-1078-G0153


SURFACE
HOLE 4-8-4
VERTICAL SECTION
20' V
40' V
VERTICAL SCALE
HORIZONTAL SCALE
60' V
80' V
100' V
120' V
140' V
160' V
180' V
190' M.D.
0.69'
189.93' V.D.
EAST
0.18'
NORTH

BECHTEL POWER CORP.-- HOLE: 4-B-5 --EASTMAN GYRO MULTI-SHOT SURVEY
SAN ONOFRE POWER PLANT

NORTH FOR THIS SURVEY IS "PLANT NORTH", N 57 00 W

DATE: 17 NOVEMBER 1978
JOB NO: P-1178-G0223
GYRO SURVEY BY: EASTMAN WHIPSTOCK, INC.
FILE: F136-20
PITT

VERTICAL SECTION IS IN
PLANE OF BOTTOM HOLE CLOSURE.

RECORD OF SURVEY

ANGLE AVERAGING METHOD

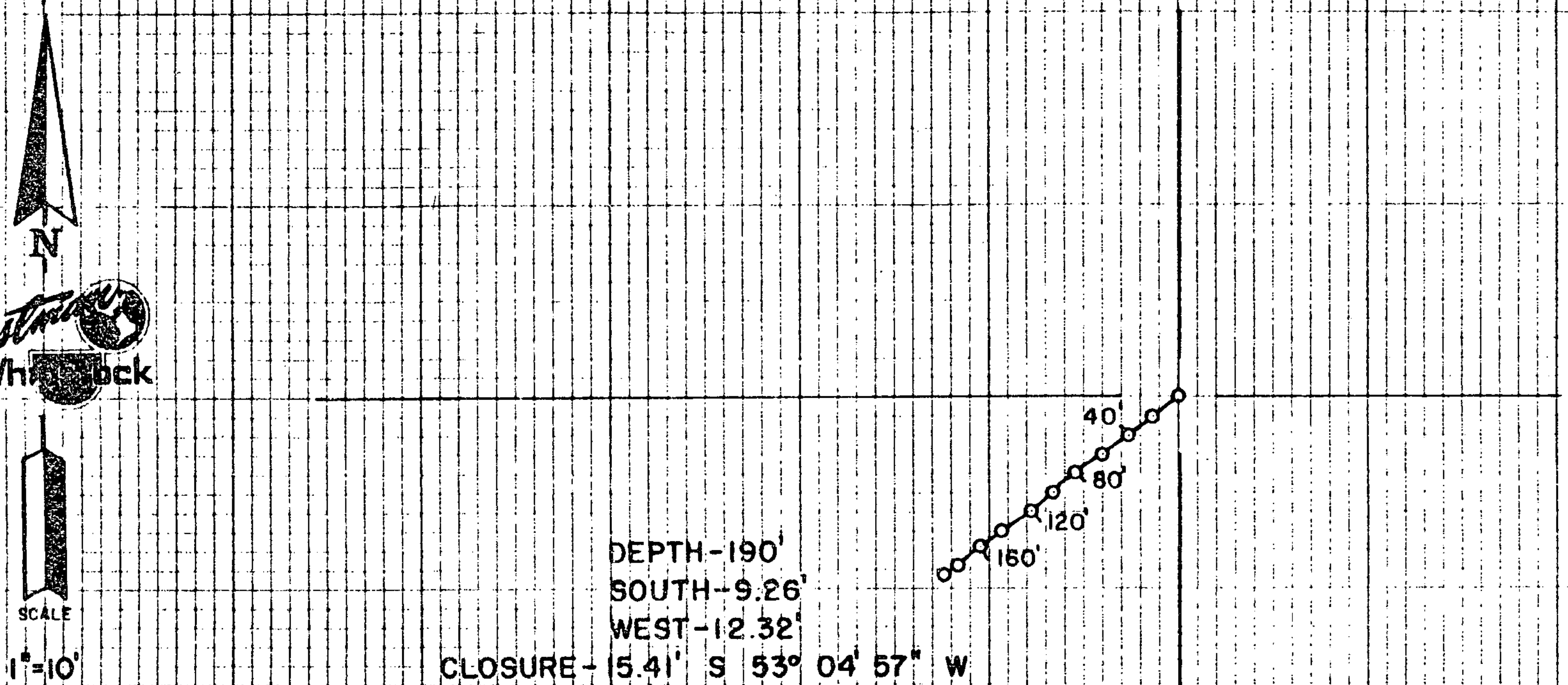
BECHTEL POWER CORP.-- HOLE: 4-B-5 --EASTMAN GYRO MULTI-SHOT SURVEY 03:05:16 00--72 PAGE NO. 1

MEASURED DEPTH FEET	DRIFT ANGLE D M	DRIFT DIRECTION D M	TRUE VERTICAL DEPTH FEET	VERTICAL SECTION FEET	RECTANGULAR COORDINATES FEET	
0.	5 0	S 52 0 W	0.00	0.00	0.00	0.00

NORTH FOR THIS SURVEY IS "PLANT NORTH", N 57 00 W

MEASURED DEPTH FEET	DRIFT ANGLE D M	DRIFT DIRECTION D M	TRUE VERTICAL DEPTH FEET	VERTICAL SECTION FEET	RECTANGULAR COORDINATES FEET	
20.	5 0	S 52 0 W	19.92	1.74	1.07 S	1.37 W
40.	4 20	S 56 0 W	39.86	3.37	2.03 S	2.69 W
60.	5 0	S 53 0 W	59.79	5.00	2.97 S	4.01 W
80.	4 55	S 56 0 W	79.72	6.72	3.98 S	5.42 W
100.	4 30	S 46 30 W	99.65	8.37	5.01 S	6.70 W
120.	4 25	S 50 30 W	119.59	9.92	6.04 S	7.87 W
140.	5 0	S 55 30 W	139.52	11.56	7.02 S	9.18 W
160.	4 5	S 55 30 W	159.46	13.14	7.92 S	10.48 W
180.	4 30	S 53 0 W	179.40	14.64	8.80 S	11.70 W
190.	4 25	S 54 0 W	189.37	15.41	9.26 S	12.32 W

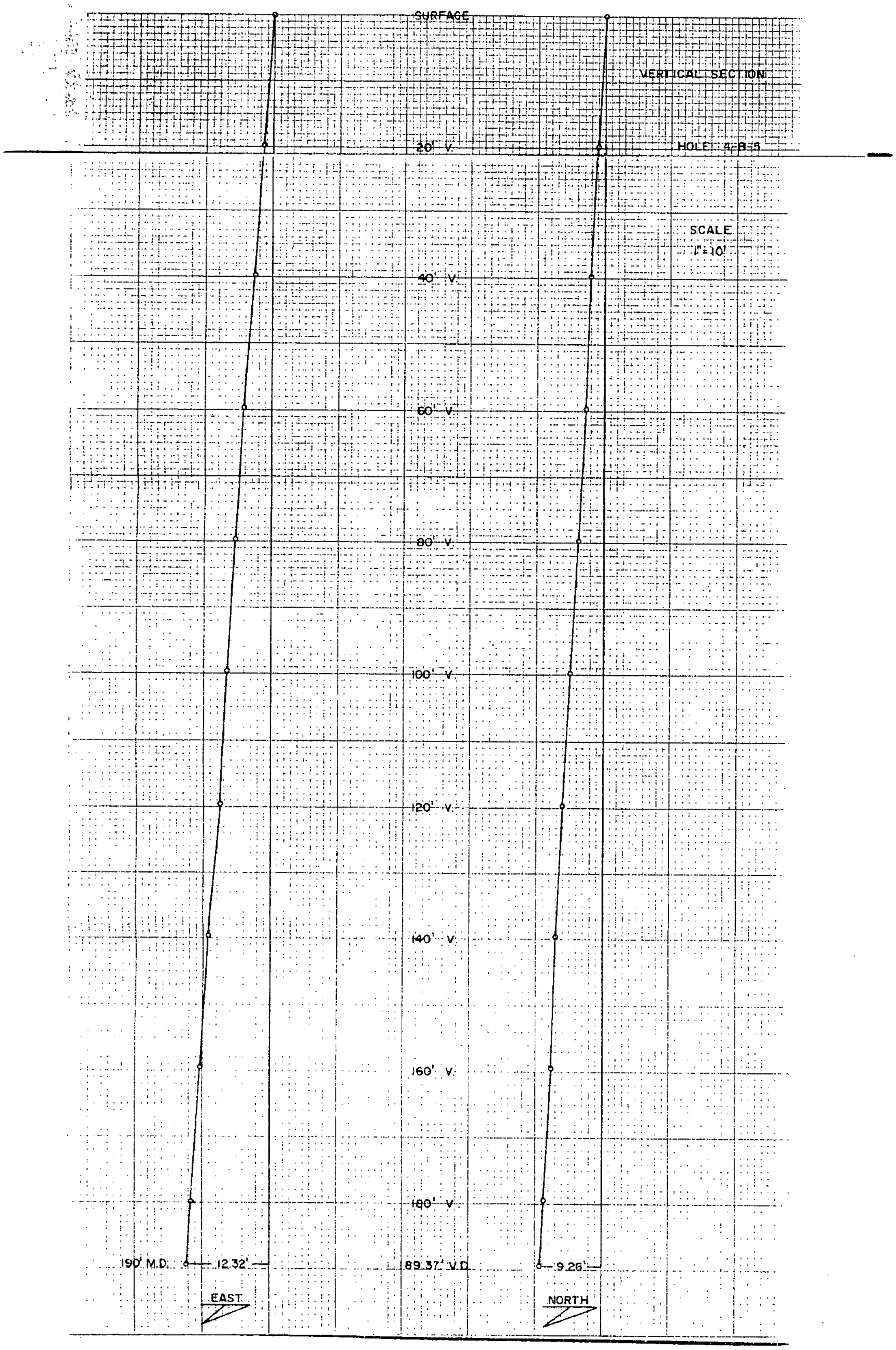
FINAL CLOSURE - DIRECTION: S 53 DEGS 4 MINS 57 SECS W
DISTANCE: 15.41 FEET



DEPTH - 190'
SOUTH - 9.26'
WEST - 12.32'
CLOSURE - 15.41' S 53° 04' 57" W

HOLE - 4-B-5

JOB Nº P-1178-G0223


SURFACE
VERTICAL SECTION
HOLE: 4-B-5
20' V.
SCALE
1"=10'
40' V.
60' V.
80' V.
100' V.
120' V.
140' V.
160' V.
180' V.
190' M.D.
12.32'
89.37' V.D.
9.26'
EAST
NORTH

BECHTEL POWER CORP.--- HOLE: 4-B-6 ---EASTMAN GYRO MULTI-SHOT SURVEY
SAN ONOFRE POWER PLANT

NORTH FOR THIS SURVEY IS "PLANT NORTH", N 57 00 W

DATE: 15 NOVEMBER 1978
JOB NO: P-1178-G0205
GYRO SURVEY BY: EASTMAN WHIPSTOCK, INC.
FILE: F136-17
PITT

VERTICAL SECTION IS IN
PLANE OF BOTTOM HOLE CLOSURE.

RECORD OF SURVEY

ANGLE AVERAGING METHOD

ECHTEL POWER CORP.--- HOLE: 4-B-6 ---EASTMAN GYRO MULTI-SHOT SURVEY 00:17:37 00--72 PAGE NO. 1

MEASURED DEPTH FEET	DRIFT ANGLE D M	DRIFT DIRECTION D M	TRUE VERTICAL DEPTH FEET	VERTICAL SECTION FEET	RECTANGULAR COORDINATES FEET	
0.	4 35	S 80 30 W	0.00	0.00	0.00	0.00

NORTH FOR THIS SURVEY IS "PLANT NORTH", N 57 00 W

20.	4 35	S 80 30 W	19.94	1.60	0.26 S	1.58 W
40.	3 30	S 68 0 W	39.89	2.99	0.65 S	2.93 W
60.	4 15	N 84 0 W	59.84	4.34	0.83 S	4.27 W
80.	4 0	S 76 0 W	79.79	5.78	0.93 S	5.71 W
100.	4 20	N 88 0 W	99.74	7.23	1.09 S	7.15 W
120.	3 50	S 87 0 W	119.69	8.65	1.10 S	8.58 W
140.	4 0	S 80 0 W	139.64	10.01	1.25 S	9.93 W
160.	4 0	S 89 30 W	159.59	11.41	1.38 S	11.32 W
180.	3 55	S 85 30 W	179.54	12.78	1.44 S	12.70 W
190.	3 50	S 83 30 W	189.52	13.46	1.51 S	13.37 W

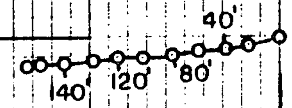
FINAL CLOSURE - DIRECTION: S 83 DEGS 34 MINS 24 SECS W
DISTANCE: 13.46 FEET

Eastman Whipstock

N

SCALE

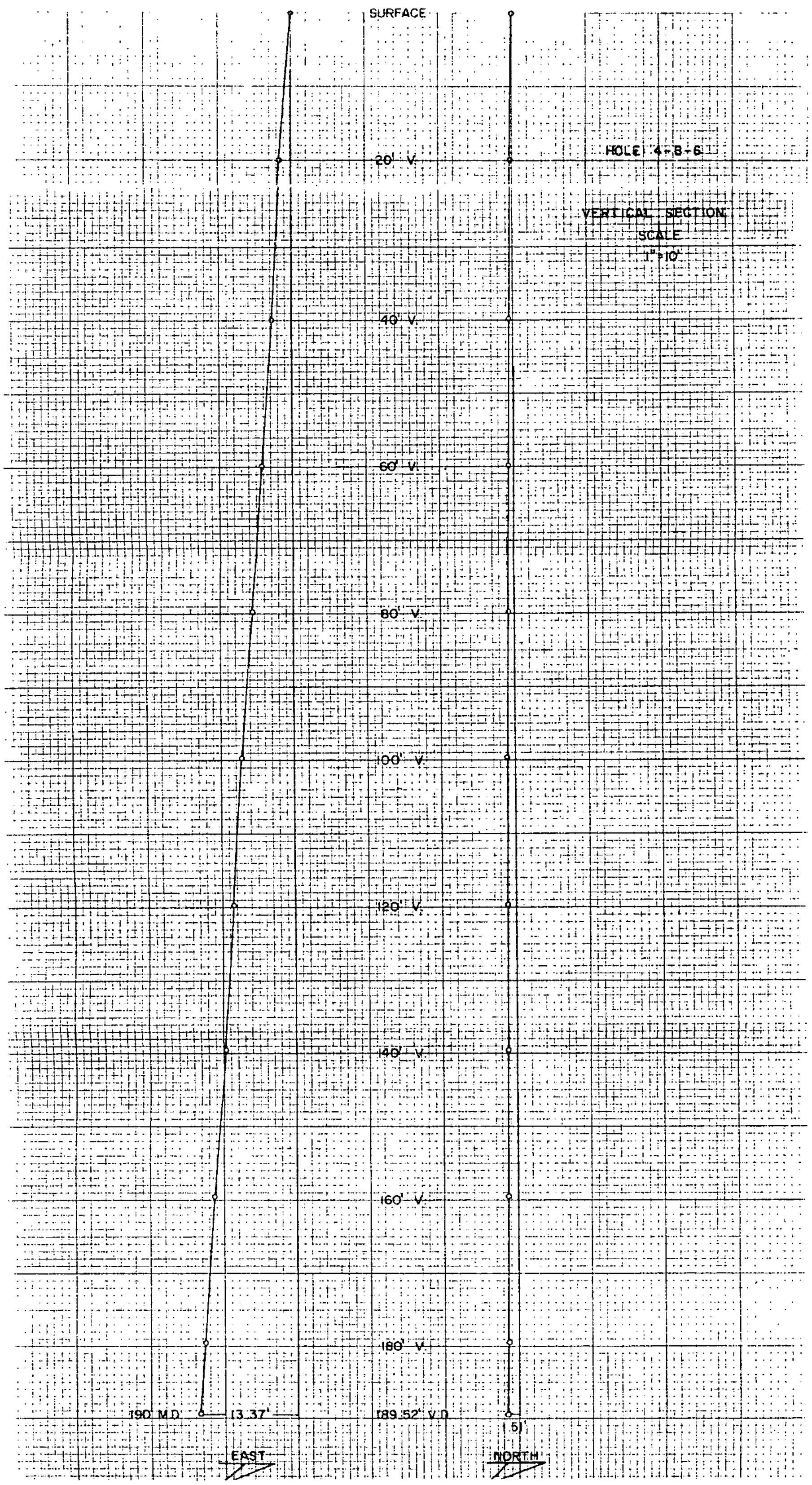
1" = 10'



DEPTH - 190'
SOUTH - 1.51'
WEST - 13.37'
CLOSURE - 13.46' S 83° 34' 24" W

HOLE - 4 - B - 6

JOB № P-1178-G0205



HOLE 4-B-6
VERTICAL SECTION
SCALE
1"=10'
SURFACE
20' V.
40' V.
60' V.
80' V.
100' V.
120' V.
140' V.
160' V.
180' V.
190' M.D.
13.37'
189.52' V.D.
(.5)'
EAST
NORTH

BECHTEL POWER CORP--- HOLE: 4-B-7 ---EASTMAN GYRO MULTI-SHOT SURVEY
SAN ONOFRE POWER PLANT

NORTH FOR THIS SURVEY IS 'PLANT NORTH', N 57 00 W

DATE: 28 NOVEMBER 1978
JOB NO: P-1178-G0260
SURVEY BY: EASTMAN WHIPSTOCK, INC.
FILE: F141-1
PITT

VERTICAL SECTION IS IN
PLANE OF BOTTOM HOLE CLOSURE.

RECORD OF SURVEY

ANGLE AVERAGING METHOD

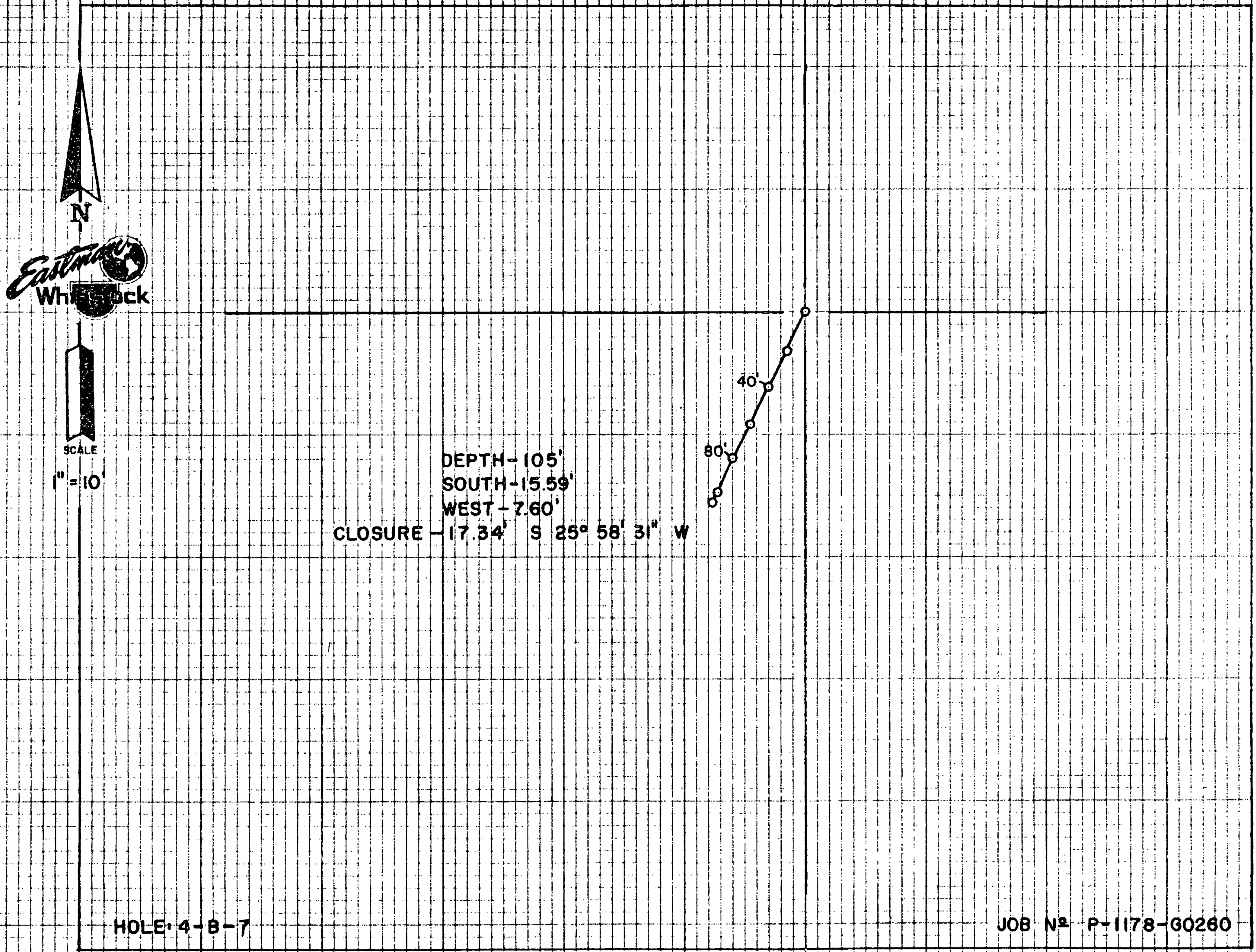
BECHTEL POWER CORP--- HOLE: 4-B-7 ---EASTMAN GYRO MULTI-SHOT SURVEY 00:11:50 00--72 PAGE NO. 1

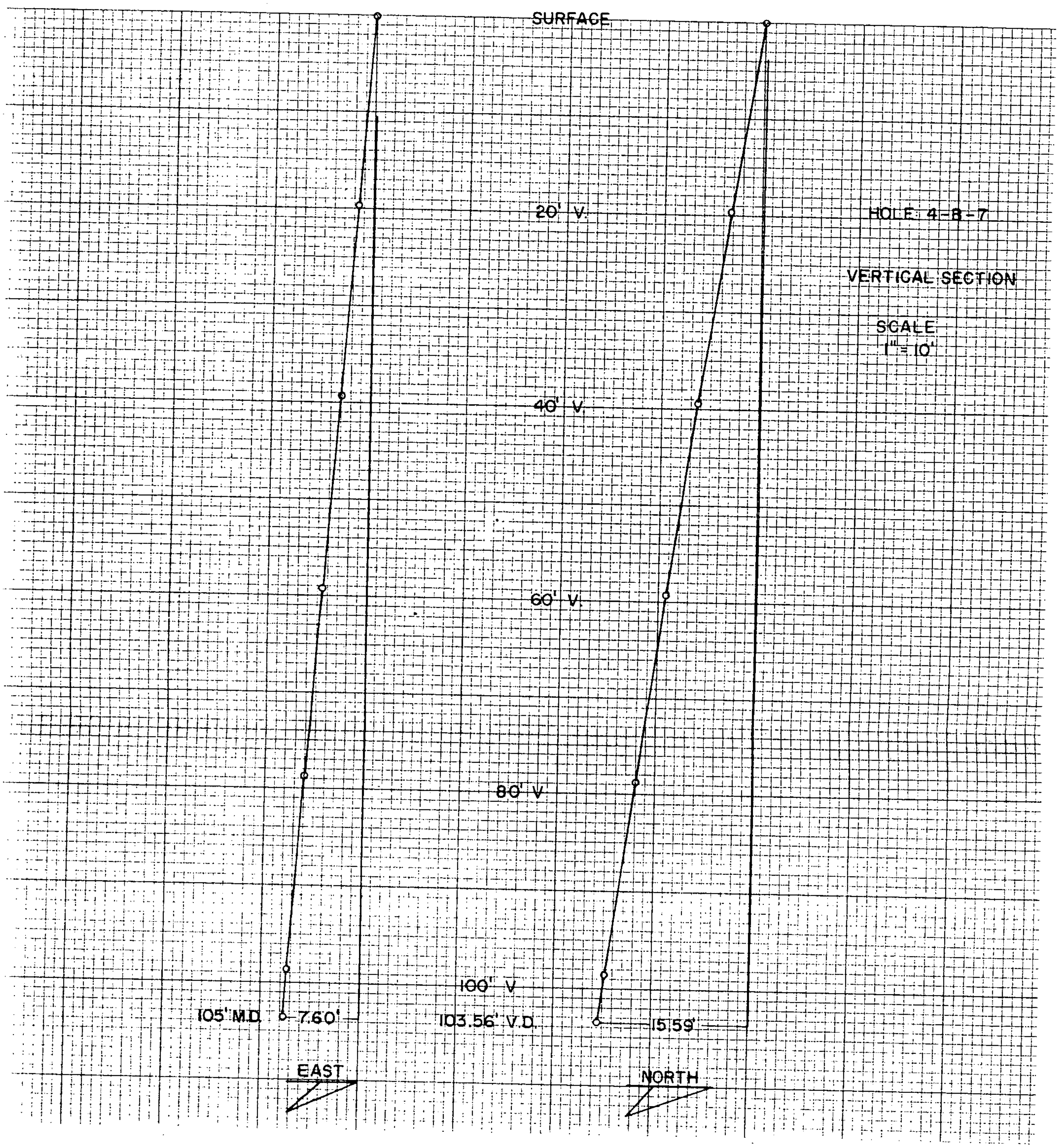
MEASURED DEPTH FEET	DRIFT ANGLE D M	DRIFT DIRECTION D	TRUE VERTICAL DEPTH FEET	VERTICAL SECTION FEET	RECTANGULAR COORDINATES FEET	
0.	10 0	S 26 W	0.00	0.00	0.00	0.00

NORTH FOR THIS SURVEY IS 'PLANT NORTH', N 57 00 W

MEASURED DEPTH FEET	DRIFT ANGLE D M	DRIFT DIRECTION D	TRUE VERTICAL DEPTH FEET	VERTICAL SECTION FEET	RECTANGULAR COORDINATES FEET	
20.	10 0	S 26 W	19.70	3.47	3.12 S	1.52 W
40.	9 45	S 27 W	39.40	6.90	6.19 S	3.05 W
60.	9 20	S 27 W	59.12	10.22	9.15 S	4.56 W
80.	9 5	S 26 W	78.87	13.42	12.01 S	5.99 W
100.	9 0	S 23 W	98.62	16.56	14.87 S	7.29 W
105.	9 0	S 23 W	103.56	17.34	15.59 S	7.60 W

FINAL CLOSURE - DIRECTION: S 25 DEGS 58 MINS 31 SECS W
DISTANCE: 17.34 FEET


N
Eastman Whipstock
SCALE
1" = 10'
40'
80'
DEPTH - 105'
SOUTH - 15.59'
WEST - 7.60'
CLOSURE - 17.34' S 25° 58' 31" W
HOLE 4-B-7
JOB Nº P-1178-G0260


SURFACE
20' V.
40' V.
60' V.
80' V.
100' V
105' M.D.
7.60'
103.56' V.D.
15.59'
EAST
NORTH
HOLE 4-B-7
VERTICAL SECTION
SCALE
1" = 10'

BECHTEL POWER CORP.---   HOLE: 4-B-7 (PVC)   ---EASTMAN GYRO MULTI-SHOT
SAN ONOFRE POWER PLANT, CA.

NORTH FOR THIS SURVEY IS "PLANT NORTH", N 57 00 W

DATE: 12 DECEMBER 1978
JOB NO: P-1278-G0322
GYRO SURVEY BY: EASTMAN WHIPSTOCK, INC.
FILE: F141-18
PITT

VERTICAL SECTION IS IN
PLANE OF BOTTOM HOLE CLOSURE.

RECORD OF SURVEY

ANGLE AVERAGING METHOD

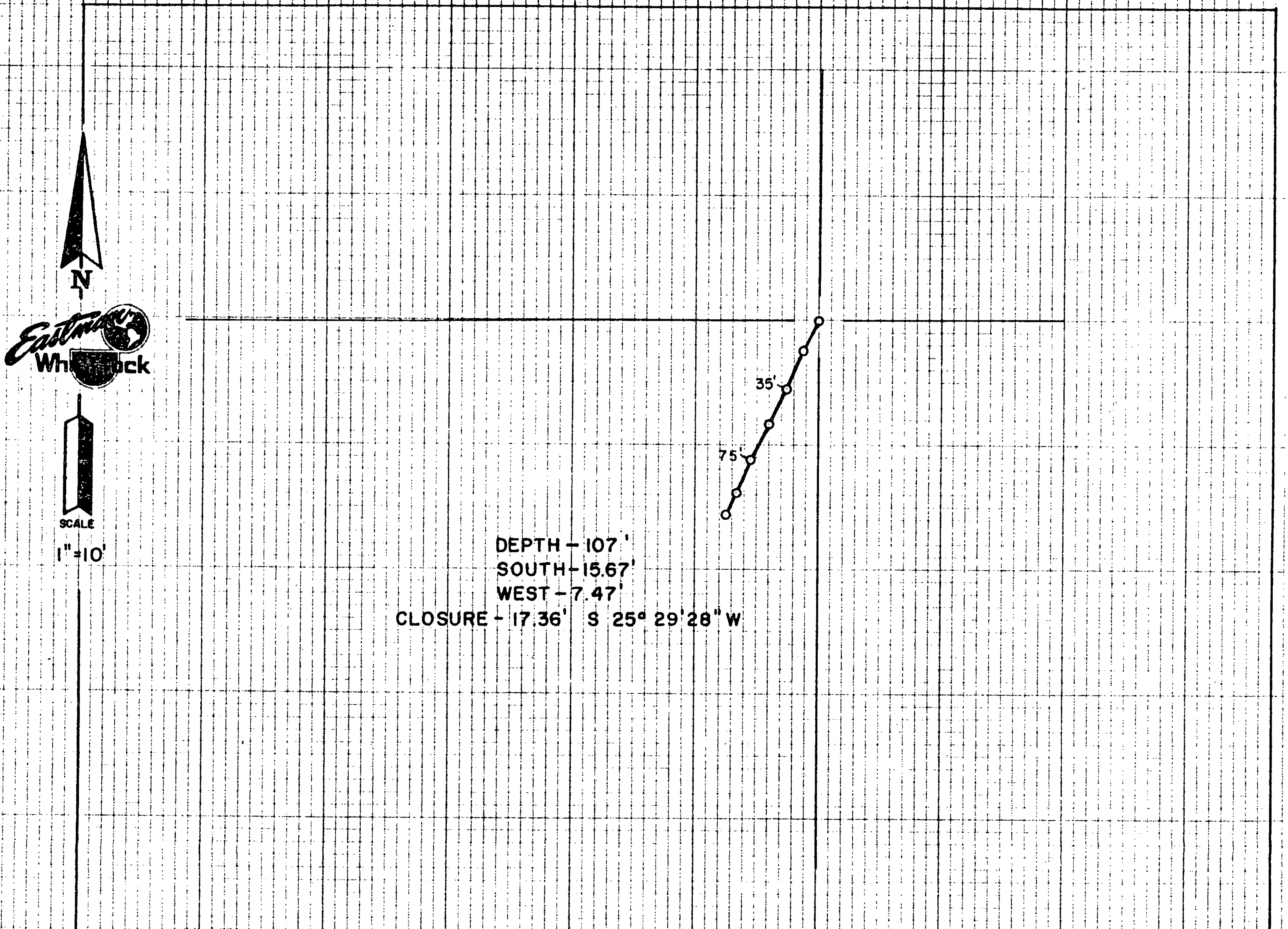
BECHTEL POWER CORP.--- HOLE: 4-B-7 (PVC) ---EASTMAN GYRO MULTI-SHOT 00:29:14 00--72 PAGE NO. 1

MEASURED DEPTH FEET	DRIFT ANGLE D M	DRIFT DIRECTION D M	TRUE VERTICAL DEPTH FEET	VERTICAL SECTION FEET	R E C T A N G U L A R C O O R D I N A T E S FEET	
0.	10 0	S 26 30 W	0.00	0.00	0.00	0.00

NORTH FOR THIS SURVEY IS 'PLANT NORTH', N 57 00 W

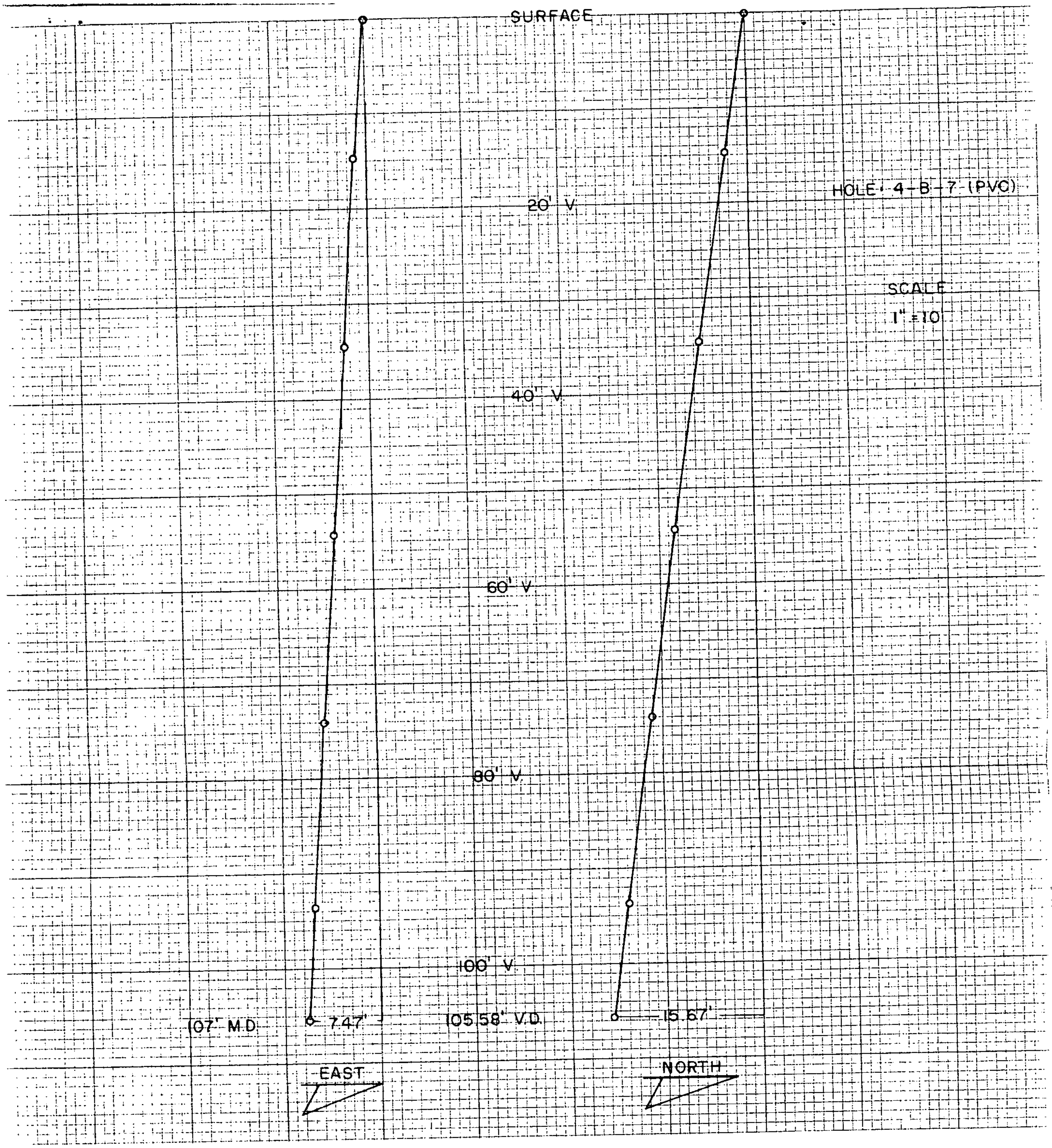
15.	10 0	S 26 30 W	14.77	2.60	2.33 S	1.16 W
35.	9 10	S 26 30 W	34.49	5.93	5.31 S	2.65 W
55.	9 20	S 26 0 W	54.23	9.15	8.19 S	4.07 W
75.	9 0	S 26 0 W	73.98	12.33	11.06 S	5.47 W
95.	9 0	S 22 30 W	93.73	15.46	13.91 S	6.75 W
107.	9 15	S 22 0 W	105.58	17.36	15.67 S	7.47 W

FINAL CLOSURE - DIRECTION: S 25 DEGS 29 MINS 28 SECS W
DISTANCE: 17.36 FEET



HOLE 4-B-7 (PVC)

P-1278-G322


SURFACE
HOLE 4-B-7 (PVC)
20' V
SCALE
1" = 10
40' V
60' V
80' V
100' V
107' M.D.
7.47'
105.58' V.D.
15.67'
EAST
NORTH

BECHTEL POWER CORP.--- HOLE: 4-B-8 ---EASTMAN GYRO MULTI-SHOT SURVEY
SAN ONOFRE POWER PLANT, CA.

NORTH FOR THIS SURVEY IS "PLANT NORTH", N 57 00 W

DATE: 8 DECEMBER 1978
JOB NO: P-1278-G0308
GYRO SURVEY BY: EASTMAN WHIPSTOCK, INC.
FILE: F141-10
PITT

RECORD OF SURVEY

ANGLE AVERAGING METHOD

BECHTEL POWER CORP.--- HOLE: 4-B-8 ---EASTMAN GYRO MULTI-SHOT SURVEY 00:00:41 00--72 PAGE NO. 1

MEASURED DEPTH FEET	DRIFT ANGLE D M	DRIFT DIRECTION D	TRUE VERTICAL DEPTH FEET	VERTICAL SECTION FEET	RECTANGULAR COORDINATES FEET	
0.	10 20	N 79 W	0.00	0.00	0.00	0.00

NORTH FOR THIS SURVEY IS "POANT NORTH", N 57 00 W

MEASURED DEPTH FEET	DRIFT ANGLE D M	DRIFT DIRECTION D	TRUE VERTICAL DEPTH FEET	VERTICAL SECTION FEET	RECTANGULAR COORDINATES FEET	
15.	10 20	N 79 W	14.76	2.69	0.51 N	2.64 W
30.	9 0	N 77 W	29.54	5.21	1.04 N	5.10 W
45.	9 0	N 79 W	44.36	7.55	1.52 N	7.40 W
60.	8 50	N 81 W	59.18	9.88	1.93 N	9.69 W
75.	7 55	N 82 W	74.02	12.06	2.25 N	11.85 W
78.	7 55	N 82 W	76.99	12.48	2.31 N	12.26 W

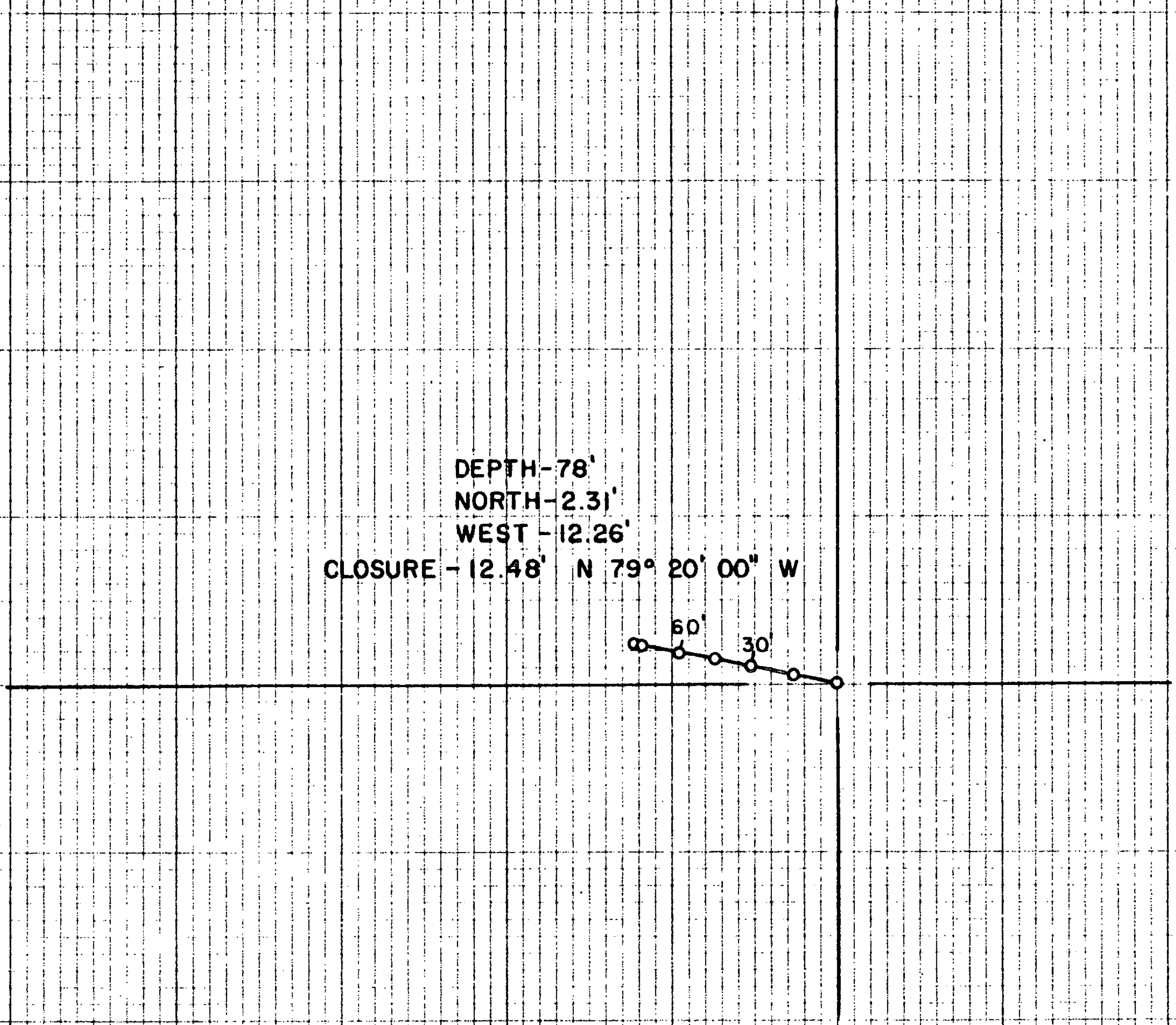
FINAL CLOSURE - DIRECTION: N 79 DEGS 20 MINS 0 SECS W
DISTANCE: 12.48 FEET

Eastman Whipstock

N

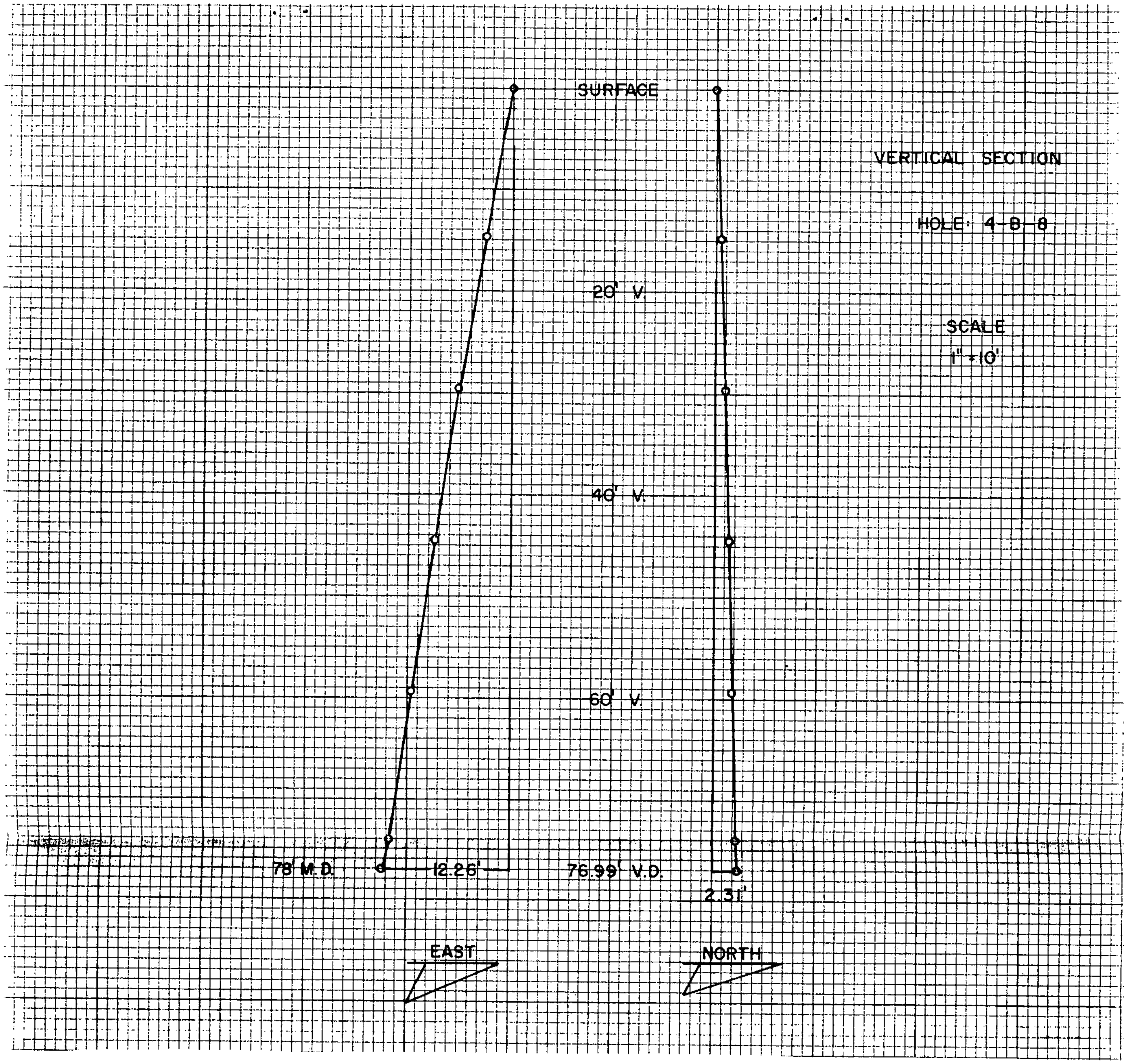
SCALE

1" = 10'



HOLE - 4-B-8

P-1278-G0308


SURFACE
VERTICAL SECTION
HOLE: 4-B-8
20' V.
SCALE
1" = 10'
40' V.
60' V.
78' M.D.
12.26'
76.99' V.D.
2.31'
EAST
NORTH

BECHTEL POWER CORP.--- DEEP WELL # 5 ---EASTMAN GYRO MULTI-SHOT SURVEY
SAN ONOFRE POWER PLANT

NORTH FOR THIS SURVEY IS 'PLANT NORTH', N 57 00 W

DATE: 19 SEPTEMBER 1978
JOB NO: P-0978-G0046
GYRO SURVEY BY: EASTMAN WHIPSTOCK, INC.
FILE: F134-20
PITT

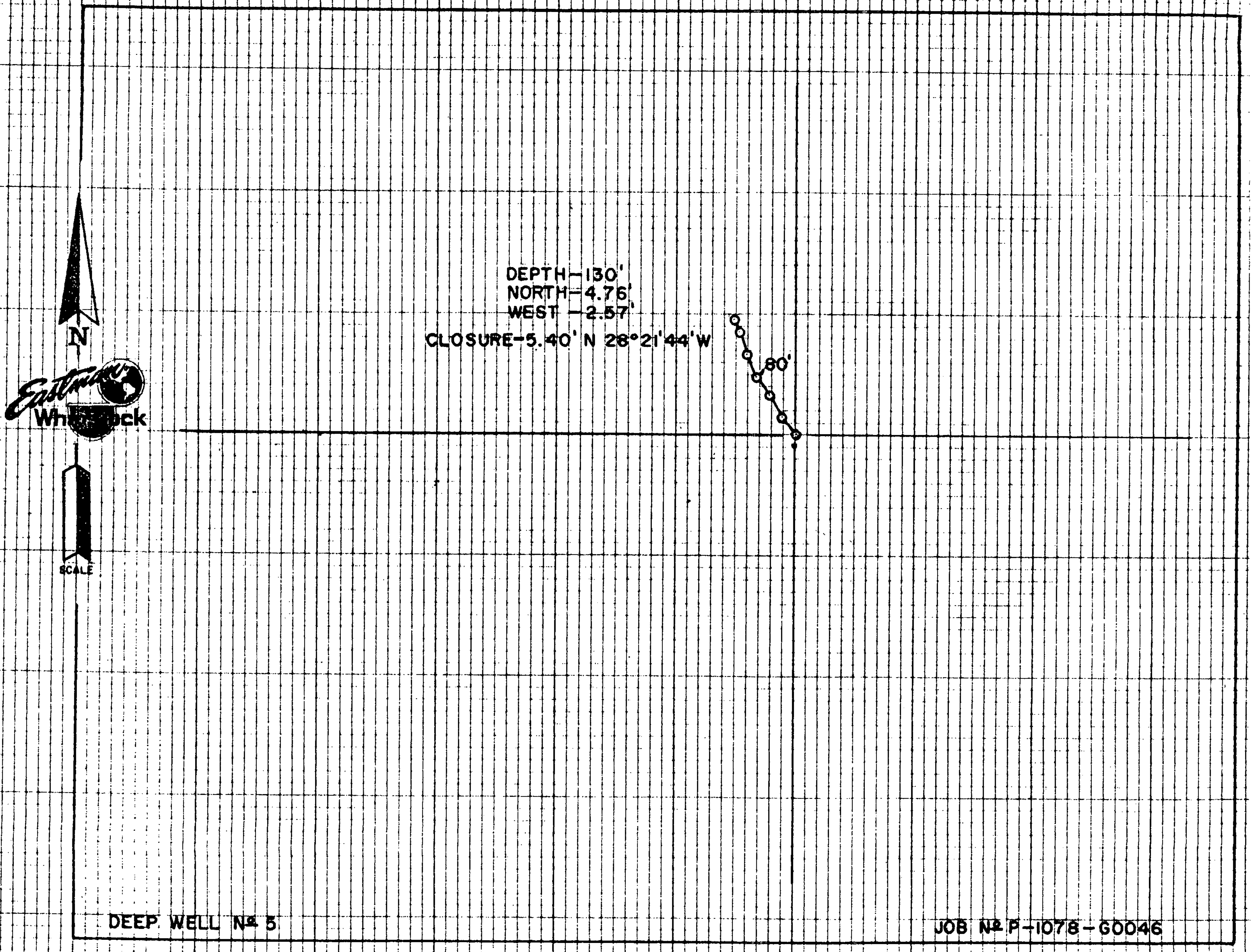
PLANE OF PROPOSED DIRECTION IS N 90 DEG. 0 MIN. E

RECORD OF SURVEY

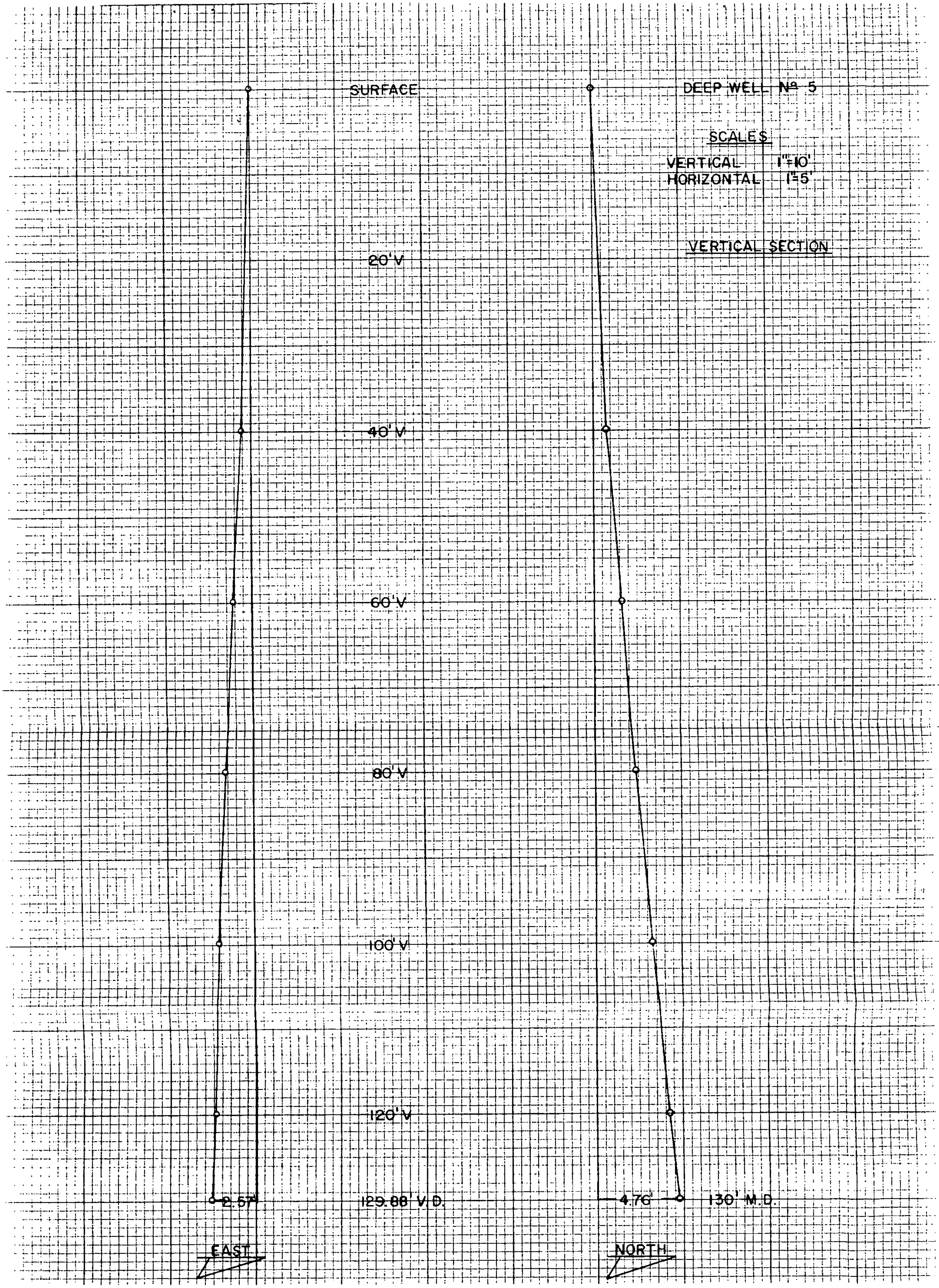
ANGLE AVERAGING METHOD

MEASURED DEPTH FEET	DRIFT ANGLE D M	DRIFT DIRECTION D	TRUE VERTICAL DEPTH FEET	VERTICAL SECTION FEET	RECTANGULAR COORDINATES FEET	
0.	0 0	0	0.00	0.00	0.00	0.00
NORTH FOR THIS SURVEY IS 'PLANT NORTH'. N 57 00 W						
40.	2 40	N 34 W	39.99	-0.52	0.77 N	0.52 W
60.	2 55	N 32 W	59.97	-1.05	1.59 N	1.05 W
80.	2 55	N 27 W	79.94	-1.55	2.47 N	1.55 W
100.	2 50	N 27 W	99.91	-2.01	3.37 N	2.01 W
120.	2 50	N 20 W	119.89	-2.40	4.27 N	2.40 W
130.	3 0	N 18 W	129.88	-2.57	4.76 N	2.57 W

FINAL CLOSURE - DIRECTION: N 28 DEGS 21 MINS 44 SECS W
DISTANCE: 5.40 FEET



DEPTH-130'
NORTH-4.76'
WEST -2.57'
CLOSURE-5.40' N 28°21'44'W
80'
N
SCALE
DEEP WELL Nº 5
JOB Nº P-1078-G0046


DEEP WELL № 5
SCALES
VERTICAL 1"=10'
HORIZONTAL 1"=5'
VERTICAL SECTION
SURFACE
20'V
40'V
60'V
80'V
100'V
120'V
2.57'
129.88' V.D.
4.76'
130' M.D.
EAST
NORTH

BECHTEL POWER CORP.--- HOLE: 5-B-1 ---EASTMAN GYRO MULTI-SHOT SURVEY
SAN ONOFRE POWER PLANT

NORTH FOR THIS SURVEY IS 'PLANT NORTH', N 57 00 W

DATE: OCTOBER 9 1978
JOB NO: P-1078-G0100
GYRO SURVEY BY: EASTMAN WHIPSTOCK, INNC.
FILE: F135-16
PITT

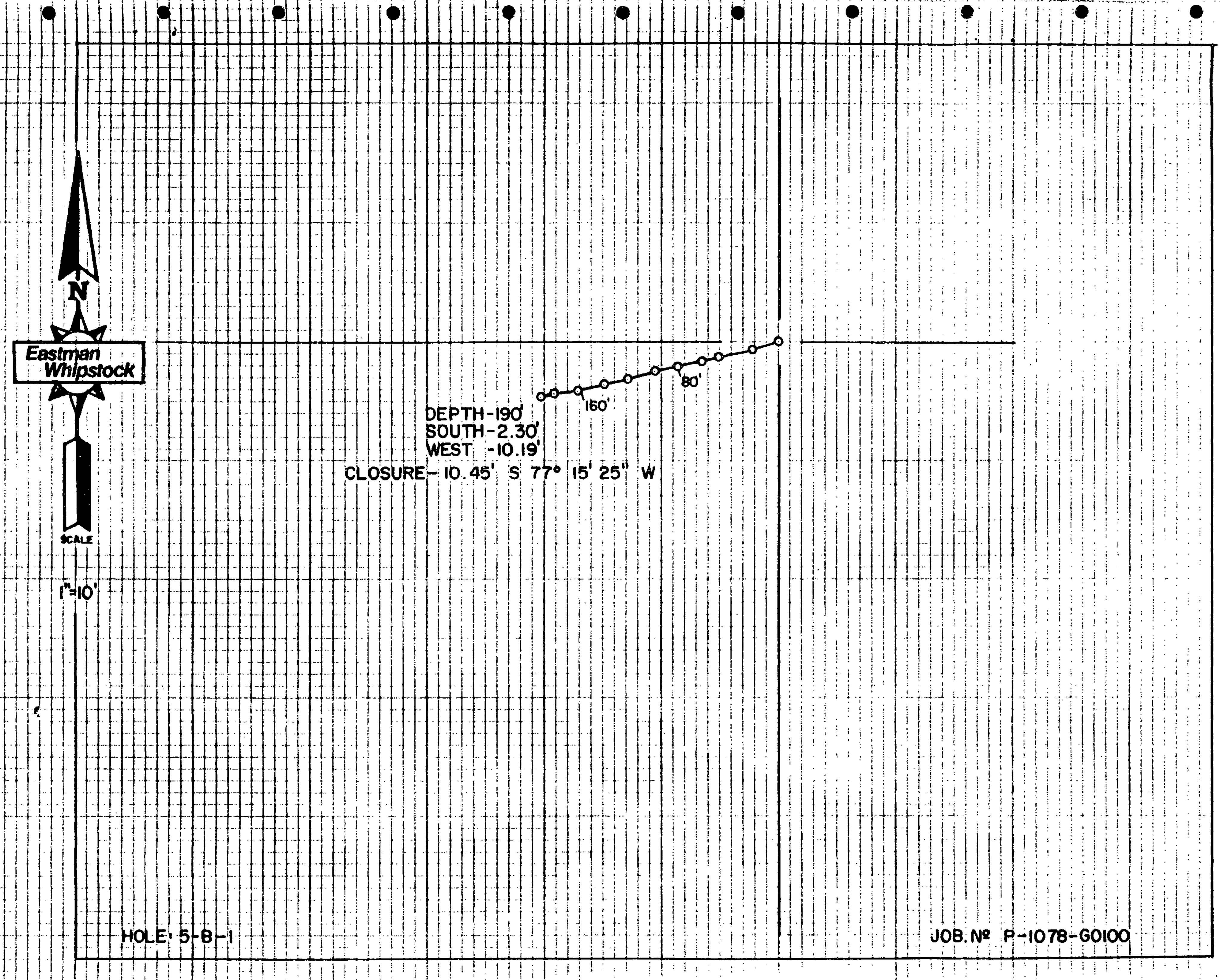
VERTICAL SECTION IS IN
PLANE OF BOTTOM HOLE CLOSURE.

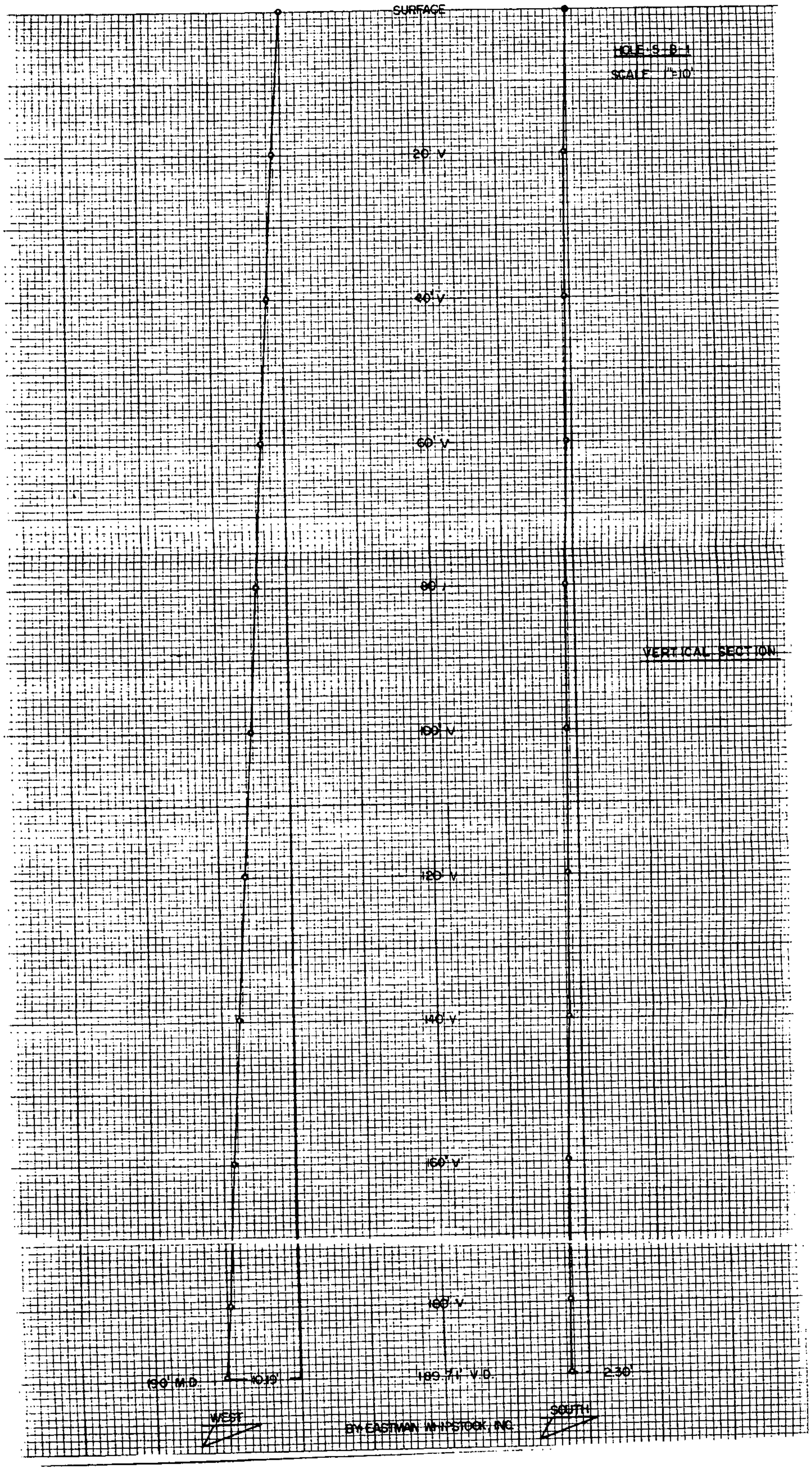
RECORD OF SURVEY

ANGLE AVERAGING METHOD

MEASURED DEPTH FEET	DRIFT ANGLE D M	DRIFT DIRECTION D	TRUE VERTICAL DEPTH FEET	VERTICAL SECTION FEET	R E C T A N G U L A R C O O R D I N A T E S FEET	
0.	3 30	S 73 W	0.00	0.00	0.00	0.00
NORTH FOR THIS SURVEY IS 'PLANT NORTH', N 57 00 W						
20.	3 30	S 73 W	19.96	1.22	0.36 S	1.17 W
40.	3 5	S 77 W	39.93	2.37	0.65 S	2.28 W
60.	2 50	S 82 W	59.90	3.40	0.84 S	3.29 W
80.	3 5	S 74 W	79.88	4.43	1.06 S	4.30 W
100.	3 15	S 77 W	99.85	5.53	1.33 S	5.37 W
120.	3 5	S 76 W	119.82	6.64	1.59 S	6.45 W
140.	3 10	S 76 W	139.79	7.73	1.86 S	7.50 W
160.	2 55	S 83 W	159.76	8.79	2.05 S	8.55 W
180.	3 15	S 80 W	179.73	9.86	2.21 S	9.61 W
190.	3 30	S 81 W	189.71	10.45	2.30 S	10.19 W

FINAL CLOSURE - DIRECTION: S 77 DEGS 15 MINS 25 SECS W
DISTANCE: 10.45 FEET


N
Eastman Whipstock
SCALE
1"=10'
80'
160'
DEPTH-190'
SOUTH-2.30'
WEST -10.19'
CLOSURE-10.45' S 77° 15' 25" W
HOLE: 5-B-1
JOB. Nº P-1078-G0100



SURFACE
HOLE S-B-1
SCALE 1"=10'
20' V
40' V
60' V
80' V
VERTICAL SECTION
100' V
120' V
140' V
160' V
180' V
190' M.D.
10.19'
189.71' V.D.
2.30'
WEST
BY EASTMAN WHIPSTOCK, INC.
SOUTH

BECHTEL POWER CORP.--- HOLE: 5-B-2 ---EASTMAN GYRO MULTI-SHOT SURVEY
SAN ONOFRE POWER PLANT

NORTH FOR THIS SURVEY IS "PLANT NORTH", N 57 00 W

DATE: 6 OCTOBER 1978
JOB NO: P-1078-G0090
GYRO SURVEY BY: EASTMAN WHIPSTOCK, INC.
FILE: F135-14
PITT

VERTICAL SECTION IS IN
PLANE OF BOTTOM HOLE CLOSURE.

RECORD OF SURVEY

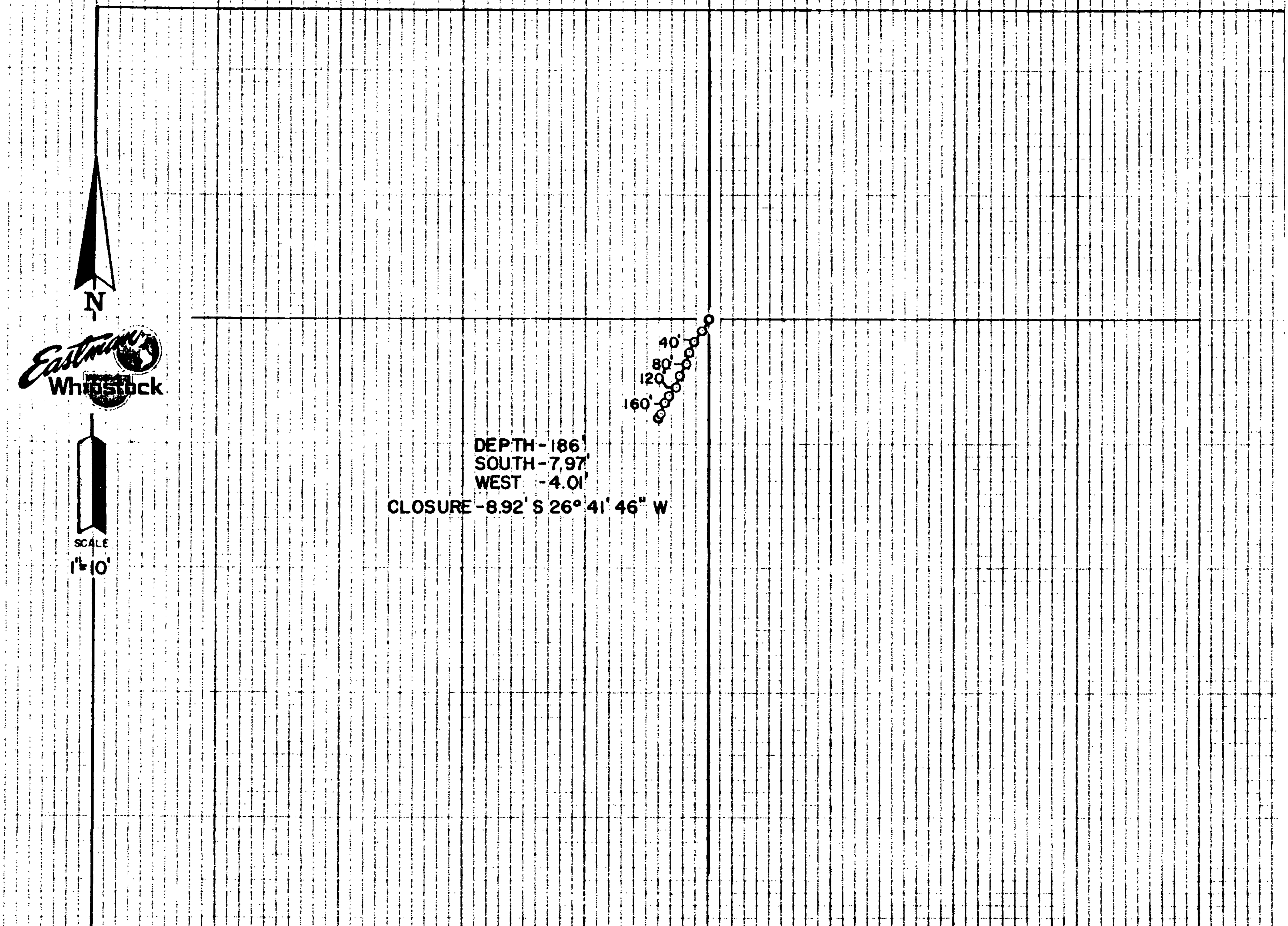
ANGLE AVERAGING METHOD

MEASURED DEPTH FEET	DRIFT ANGLE D M	DRIFT DIRECTION D	TRUE VERTICAL DEPTH FEET	VERTICAL SECTION FEET	RECTANGULAR COORDINATES FEET	
0.	3 10	S 26 W	0.00	0.00	0.00	0.00

NORTH FOR THIS SURVEY IS "PLANT NORTH", N 57 00 W

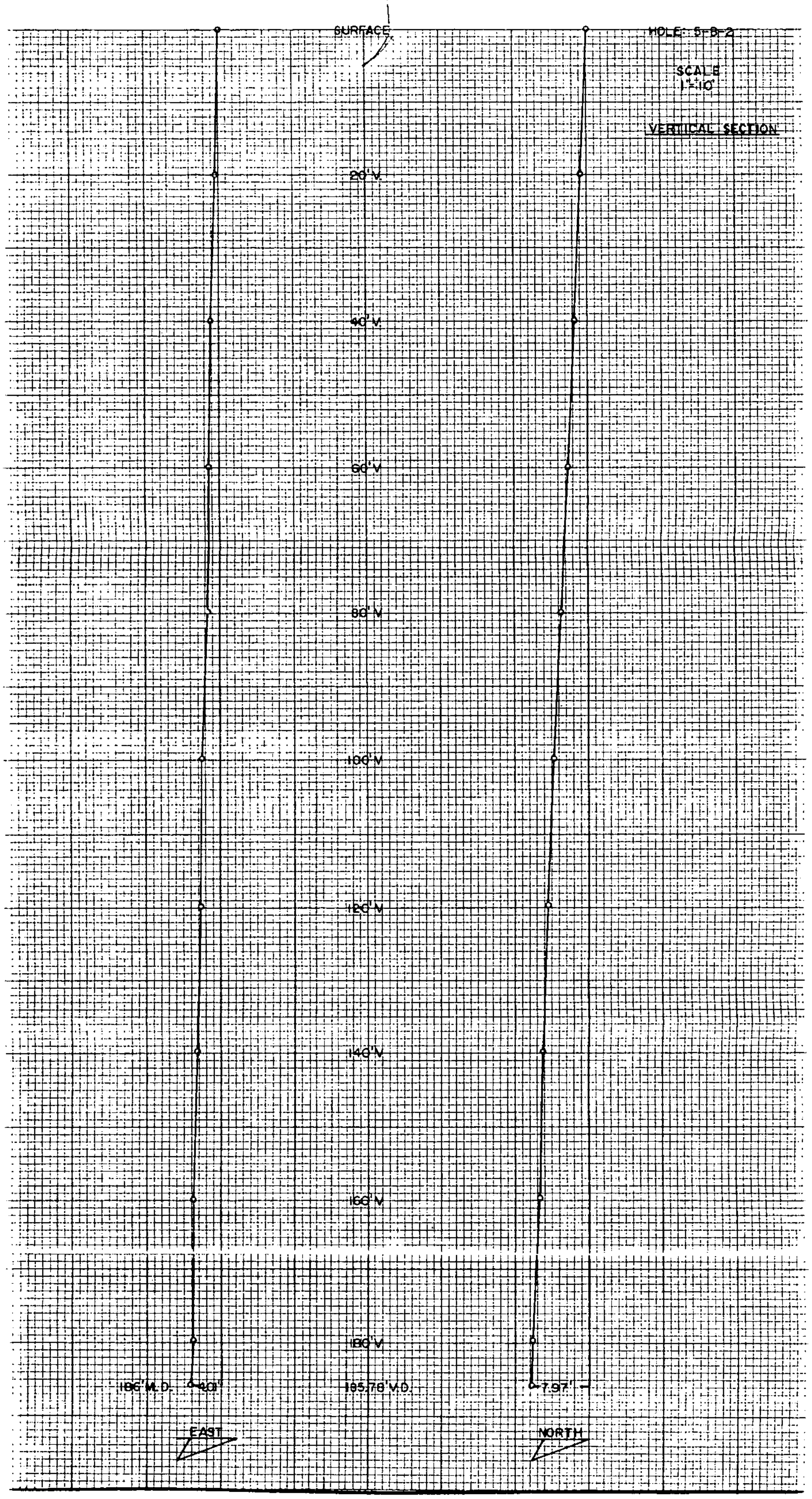
MEASURED DEPTH FEET	DRIFT ANGLE D M	DRIFT DIRECTION D	TRUE VERTICAL DEPTH FEET	VERTICAL SECTION FEET	RECTANGULAR COORDINATES FEET	
20.	3 10	S 26 W	19.97	1.10	0.99 S	0.48 W
40.	2 50	S 34 W	39.94	2.15	1.90 S	1.01 W
60.	3 0	S 24 W	59.92	3.17	2.79 S	1.50 W
80.	2 40	S 20 W	79.89	4.15	3.71 S	1.87 W
100.	2 45	S 27 W	99.87	5.10	4.57 S	2.25 W
120.	2 25	S 25 W	119.85	6.00	5.38 S	2.64 W
140.	2 10	S 36 W	139.83	6.79	6.07 S	3.05 W
160.	2 50	S 30 W	159.81	7.66	6.80 S	3.52 W
180.	2 50	S 19 W	179.79	8.65	7.70 S	3.93 W
186.	2 30	S 12 W	185.78	8.92	7.97 S	4.01 W

FINAL CLOSURE - DIRECTION: S 26 DEGS 41 MINS 46 SECS W
DISTANCE: 8.92 FEET



WELL Nº 5-B-2

JOB Nº P-1078-G0090


HOLE: S-B-2
SCALE
1"=10'
VERTICAL SECTION
SURFACE
20' V
40' V
60' V
80' V
100' V
120' V
140' V
160' V
180' V
186' M.D.
4.01'
185.78' V.D.
7.97'
EAST
NORTH

BECHTEL POWER CORP.--- HOLE: 5-B-3 ---EASTMAN GYRO MULTI-SHOT SURVEY
SAN ONOFRE POWER PLANT

NORTH FOR THIS SURVEY IS 'PLANT NORTH', N 57 00 W

DATE: 5 OCTOBER 1978
JOB NO: P-1078-G0084
GYRO SURVEY BY: EASTMAN WHIPSTOCK, INC.
FILE: F135-13
PITT

VERTICAL SECTION IS IN
PLANE OF BOTTOM HOLE CLOSURE.

RECORD OF SURVEY

ANGLE AVERAGING METHOD

BECHTEL POWER CORP.--- HOLE: 5-B-3 ---EASTMAN GYRO MULTI-SHOT SURVEY 00:06:47 00--72 PAGE NO. 1

MEASURED DEPTH FEET	DRIFT ANGLE D M	DRIFT DIRECTION D	TRUE VERTICAL DEPTH FEET	VERTICAL SECTION FEET	RECTANGULAR COORDINATES FEET		DOG LEG SEVERITY DEG/100FT
0.	0 0	0	0.00	0.00	0.00	0.00	0.0
NORTH FOR THIS SURVEY IS "PLANT NORTH", N 57 00 W							
20.	1 10	S 31 E	20.00	0.01	0.17 S	0.10 E	5.8
40.	0 55	N 56 W	40.00	0.36	0.42 S	0.16 W	10.2
60.	0 40	N 17 E	59.99	0.30	0.16 S	0.25 W	4.8
80.	0 15	S 52 E	79.99	0.15	0.12 S	0.10 W	4.0
100.	0 20	S 79 E	99.99	0.09	0.16 S	0.01 W	0.8
120.	0 30	N 85 W	119.99	0.19	0.30 S	0.03 W	4.2
140.	0 20	N 69 W	139.99	0.29	0.27 S	0.17 W	1.0
160.	0 20	N 13 W	159.99	0.30	0.18 S	0.24 W	1.6
165.	0 10	N 2 W	164.99	0.29	0.16 S	0.25 W	3.5

FINAL CLOSURE - DIRECTION: S 57 DEGS 1 MINS 7 SECS W
DISTANCE: 0.29 FEET

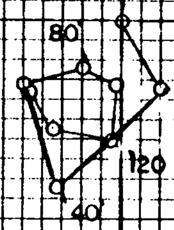
N

Eastman Whipstock

SCALE

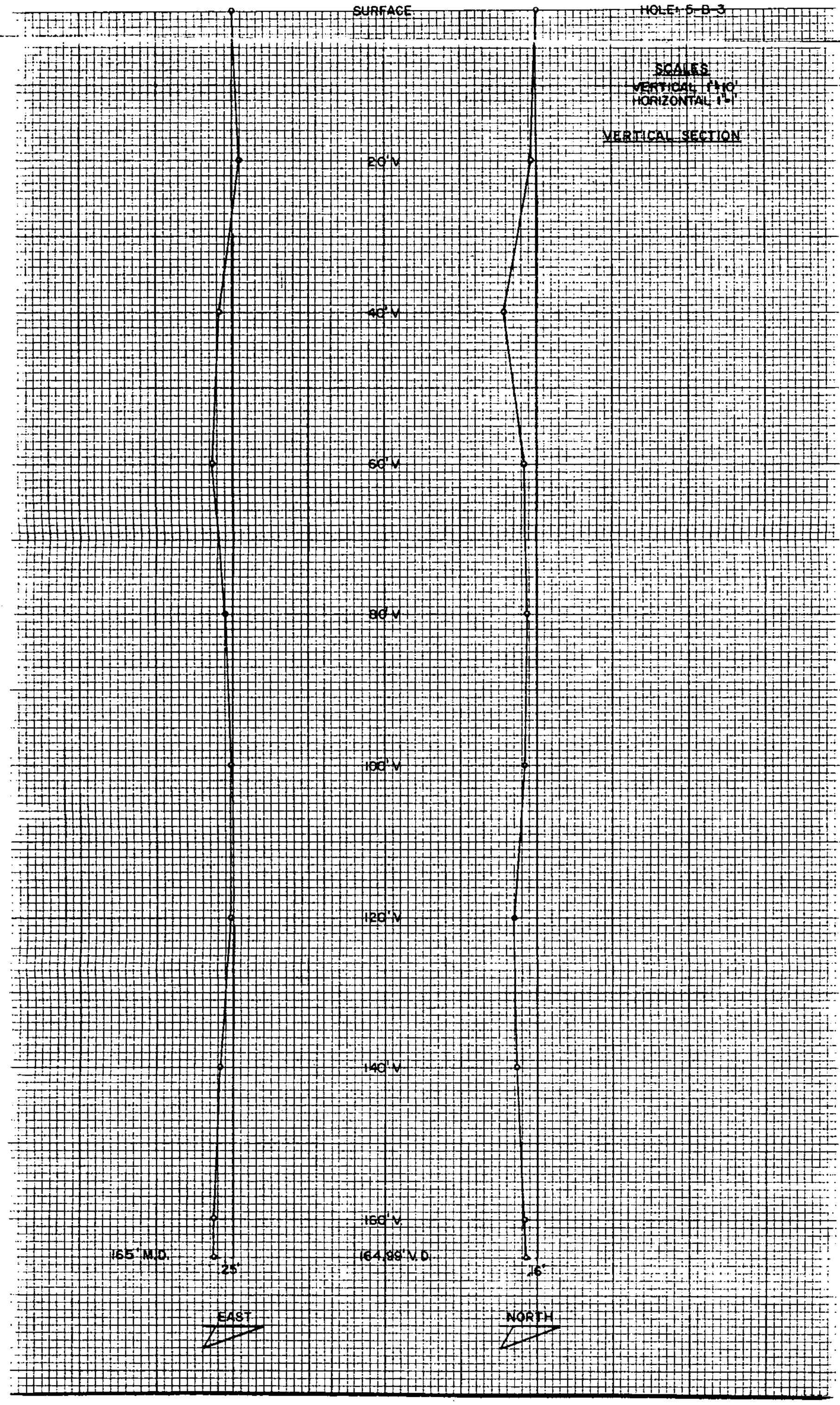
1" = .5'

DEPTH - 165'
SOUTH - 0.16'
WEST - 0.25'
CLOSURE - 0.29' S 57° 01' 07" W



WELL Nº 5-B-3

JOB Nº P-1078-G0084


SURFACE
HOLE: 5-B-3
SCALES
VERTICAL 1"=10'
HORIZONTAL 1"=1'
VERTICAL SECTION
20' V
40' V
60' V
80' V
100' V
120' V
140' V
160' V
165' M.D.
164.99' V.D.
.25'
.16'
EAST
NORTH

BECHTEL POWER CORP--- HOLE: 5-B-4 ---EASTMAN GYRO MULTI-SHOT SURVEY
SAN ONOFRE POWER PLANT

NORTH FOR THIS SURVEY IS 'PLANT NORTH', N 57 00 W

DATE: 3 OCTOBER 1978
JOB NO: P-1078-G0076
GYRO SURVEY BY: EASTMAN WHIPSTOCK, INC.
FILE: F135-9
PITT

VERTICAL SECTION IS IN
PLANE OF BOTTOM HOLE CLOSURE.

RECORD OF SURVEY

ANGLE AVERAGING METHOD

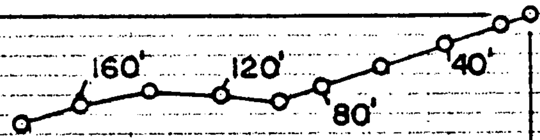
BECHTEL POWER CORP--- HOLE: 5-B-4 ---EASTMAN GYRO MULTI-SHOT SURVEY 00:18:31 00--72 PAGE NO. 1

MEASURED DEPTH FEET	DRIFT ANGLE D M	DRIFT DIRECTION D	TRUE VERTICAL DEPTH FEET	VERTICAL SECTION FEET	RECTANGULAR COORDINATES FEET	
0.	0 0	0	0.00	0.00	0.00	0.00

NORTH FOR THIS SURVEY IS 'PLANT NORTH', N 57 00 W

MEASURED DEPTH FEET	DRIFT ANGLE D M	DRIFT DIRECTION D	TRUE VERTICAL DEPTH FEET	VERTICAL SECTION FEET	RECTANGULAR COORDINATES FEET	
20.	0 50	S 70 W	20.00	0.14	0.05 S	0.14 W
40.	0 55	S 66 W	40.00	0.44	0.16 S	0.42 W
60.	1 5	S 78 W	59.99	0.79	0.27 S	0.75 W
80.	0 40	S 63 W	79.99	1.09	0.37 S	1.04 W
100.	0 40	S 88 W	99.99	1.33	0.43 S	1.27 W
120.	1 0	N 77 W	119.99	1.60	0.40 S	1.55 W
140.	1 0	S 83 W	139.99	1.94	0.39 S	1.90 W
160.	0 55	S 73 W	159.98	2.28	0.46 S	2.23 W
180.	0 55	S 77 W	179.98	2.60	0.54 S	2.54 W

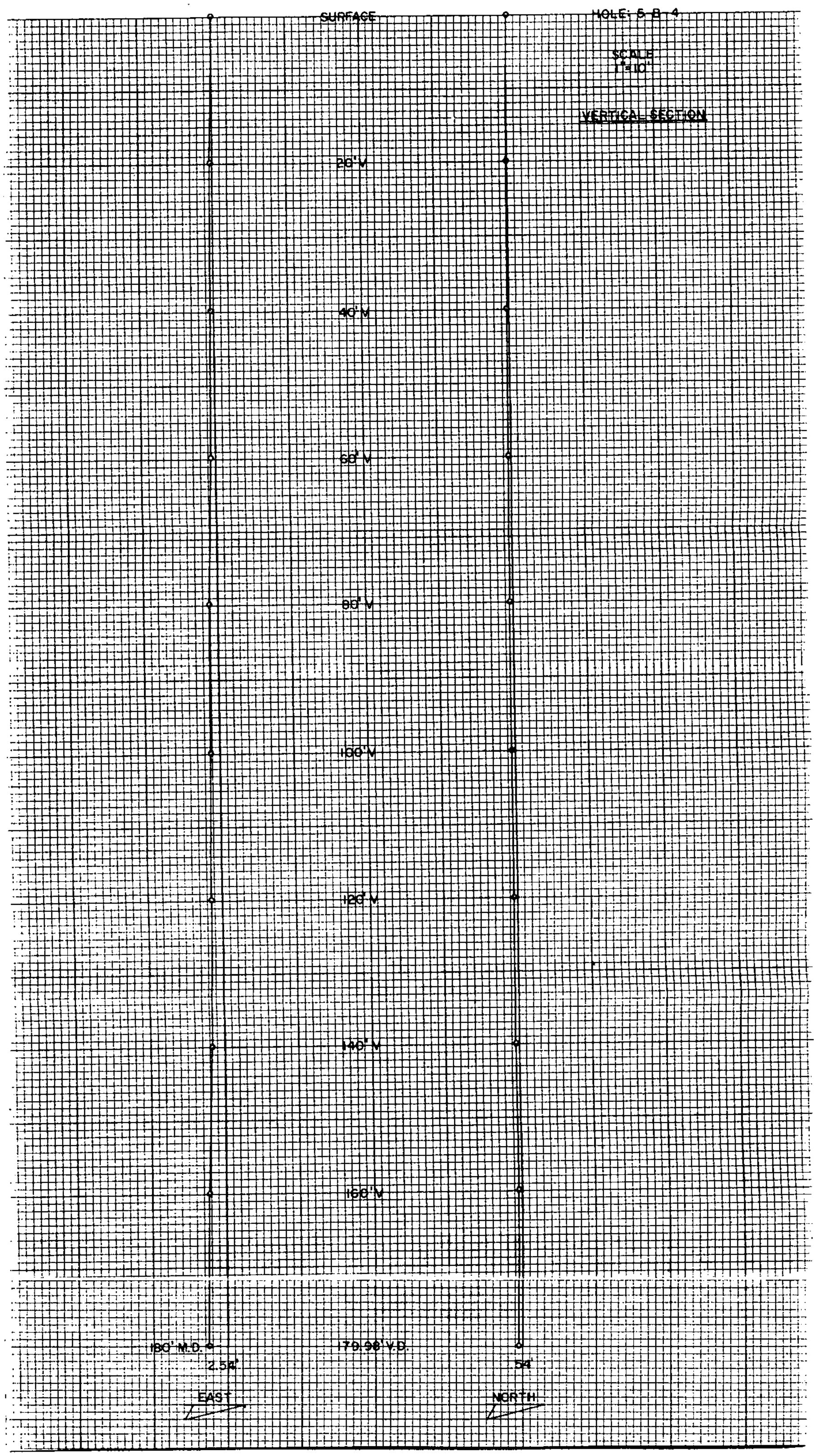
FINAL CLOSURE - DIRECTION: S 78 DEGS 1 MINS 42 SECS W
DISTANCE: 2.60 FEET



DEPTH-180'
SOUTH-0.54'
WEST -2.54'
CLOSURE-2.60' S 78° 01' 42" W

WELL № 5-B-4

JOB № P-1078-G0076



SURFACE
HOLE: 5-B-4
SCALE
1"=10'
VERTICAL SECTION
20' V
40' V
60' V
80' V
100' V
120' V
140' V
160' V
180' M.D.
179.98' V.D.
2.54'
.54'
EAST
NORTH