ORIGINAL

Rockwell Hanford Operations

0009232

SUPPORTING DOCUMENT	Number	Rev. Ltr./ Chg. No.	Page 1 of
PROGRAM: Surveillance and Maintenance	SD- WM-PTR-001	0-0	117

Document Title: Development of an Interstitial Liquid Level Measurement Technique for Use in the In-Tank Liquid Observation Wells (LOW)	Baseline Document ☐ Yes ☒ No WBS No. or Work Package No. WA-614
Key Words: LOW, Interstitial Liquid Level, Criteria, Surveillance, Interpretation	Prepared by (Name and Dept. No.) C. M. Walker 65950 (signature) C M Walker 9-27-82 See Page 2 for Approvals Date 9/25/82

Abstract

The Fiscal Year 1982 in-tank liquid level measurement development program was performed under conditions simulating a routine surveillance operation and had two prime objectives; to assess acoustic, neutron and gamma probe performance and to develop bases for the definition of leak/intrusion action criteria. Both of these goals were achieved, and it was determined that the scans obtained in Liquid Observation Wells (LOWs) could be used for the purpose of leak and intrusion detection. The study involved monitoring of LOWs in both dynamic and static waste storage tanks.

* Distribution	Name	Mail Address
	Department of Energy Richland Operations Office	
*	R. D. Izatt	Federal/700
*	J. J. Schreiber	Federal/700
*	A. R. Schwankoff	Federal/700
	Rockwell Hanford Operations	
*	D. C. Bartholomew	2750E/200E
	D. A. Berg	2750E/200E
*	K. G. Carothers	2750E/200E
*	J. L. Deichman	2750E/200E
*	G. T. Dukelow	2750E/200E
	J. H. Garbrick	2750E/200E
	K. A. Gasper	2750E/200E
*	W. F. Heine	2750E/200E
*	B. A. Higley	2750E/200E
*	G. A. Huff	2750E/200E
*	L. A. Johnson	2750E/200E
	J. D. Keck	2750E/200E
*	R. D. Keck	271T/200W
*	E. J. Kosiancic	2750E/200E
	W. P. Kunkel	2750E/200E
	P. G. Lorenzini	2750E/200E
	R. G. Oliver	271T/200W
*	J. K. Prince	2750E/200E
	R. D. Prosser	2750E/200E
*	R. C. Roal	2750E/200E
	J. F. Renken	2750E/200E
	J. H. Roecker	2750E/200E
*	W. W. Schulz	2704S/200W
	H. P. Shaw	2750E/200E
*	H. C. Spanheimer	2750E/200E

(May be continued on page 2)

Initial Release Stamp

12

1982 OCT 11 PM 2:42

OFFICIALLY RELEASED

SUPPORTING DOCUMENT	Number SD– WM-PTR-001	Page 2

Approvals

- [ ] (signature) 10/1/82 — Program Office
- [ ] M. A. Huff 9-30-82 — Research and Engineering
- [ ] R. A. Berg 9-30-82 — Plant Operations
- [x] W P (signature) 9/30/82 — Health, Safety and Environment
- [ ] Quality Assurance
- [ ] Training
- [ ] (signature) Carothers 9/30/82 — End Function
- [x] L A Dietz for R. J. Gurth — End Function
- [x] (signature)
- [ ] R D Keck 9/29/82
- [x] RA VanMeter — Approval Authority

* Distribution	Name	Mail Address
*	F. S. Stong	271T/200W
	R. J. Gurth	2750E/200E
*	L. A. Dietz	2750E/200E
*	R. A. VanMeter	2750E/200E
*	C. M. Walker	2750E/200E
*	D. G. Wilkins	2750E/200E
	D. D. Wodrich	2750E/200E
	C. R. Hatch	2750E/200E

* COMPLETE DOCUMENT (no asterisk, title page/summary or revision page only)

DEVELOPMENT OF AN INTERSTITIAL LIQUID LEVEL MEASUREMENT TECHNIQUE FOR USE IN THE MONITORING OF IN-TANK LIQUID OBSERVATION WELLS

C. M. Walker

Process Engineering Department
Tank Farm and Evaporator Process Control Group

September 25, 1982

Prepared for the United States
Department of Energy under
Contract DE-AC06-77RL01030

Rockwell International
Rockwell Hanford Operations
Energy Systems Group
Richland, WA 99352

EXECUTIVE SUMMARY

The Fiscal Year (FY) 1982 in-tank liquid-level measurement development program was performed under conditions simulating routine surveillance operations and had two prime objectives:

- Provide a representative assessment of gamma, neutron, and acoustic probe performance in a wide range of tank and waste types

- Develop bases for the definition of leak/intrusion action criteria

These goals were achieved, and it was concluded that scans obtained in the in-tank liquid observation wells (LOW) could be used for intrusion and leak detection surveillance commencing FY 1983.

The tanks monitored in the program were classed as being either dynamic or static. Dynamic tanks were those committed to the ongoing 241-TX salt well jet pumping program where related activities and production information were available for comparison with the LOW scan results. As periods of pump operation and periods of pump shutdown occurred in the dynamic tanks, the study evaluated profile responses to events simulating either a leak (pumping) or an intrusion (shutdown and equilibration). No process activities or water additions were undertaken in the static tanks, and the scan profiles were therefore amenable to study of instrument system repeatability.

Data summaries for all tanks and probe types are detailed in the discussion of test results. In general, it was found that all probe types presented scan profiles showing moisture level changes that could be directly related to process events in each of the dynamic tanks. However, the ability to correlate between probes was diminished during periods of jet pumping. The problem varied in degree between tanks and lessened during periods of recovery after pump shutdown. In all static tanks where the level of drainable liquid was well formed and stable, the scans presented clearly defined zones of transition that were in agreement between probes. The combined instrument and interpretation precision of the data was ±0.2 ft for the neutron and gamma probe data, and it is believed that further modification could permit measurement variance to within ±0.1 ft. The measurement precision of the acoustic probe data was found to be .04 ft. Studies concerned with development of a LOW scan interpretive technique found that proper analysis of data could not be accomplished on the basis of one profile (or one probe) type alone. The application of data from the other probes as well as previous scans of the same type must be used for the interpretation; therefore the overall system data precision was ±0.2 ft.

The instrument systems used to obtain LOW scan information were found to be the principal sources of problems affecting data interpretation. Components identified as error sources were the cable, the probe stabilization assembly, the measurement wheel, the electronic module/ microprocessor interface and the Computer Automated Surveillance System drum plotter. Most discrepancies were recognized at the time of data interpretation and could be discounted from the analysis of measurement precision. However, modifications are needed to provide a more robust and dirt resistant system for routine process use.

CONTENTS

SECTION I

SECTION II

FIGURES:

APPENDIX:

I. INTRODUCTION

The principal objective of the Rockwell Hanford Operations (Rockwell) Surveillance Program is to provide timely notification of radioactive waste storage tank leaks or liquid intrusions. To this end, the program will use the most effective techniques available for detection and prompt response to liquid level changes that may occur. Reliability of the systems now in place to provide this capability for the 149 single-shell tanks is progressively diminishing in the course of ongoing stabilization activities.

Single-shell tanks are equipped with conductivity electrodes for detecting the waste surface and external peripheral drywells for use in the detection of tank leaks. Conductivity devices were at one time extremely effective when applied to the detection of changes in the level of a liquid surface. However, the waste surfaces in many tanks are no longer liquid and thus are not conductive; this allows the instruments to give only a rough indication of surface level. The number of these tanks will increase as stabilization programs proceed; current capability for the detection of an interstitial liquid loss below the level of solids contact is very uncertain unless significant solids depression occurs. Timely response to liquid intrusions is similarly affected, as no indication would be observed until the intrusion has increased the liquid level above the level of the solids. For certain tanks, the volume of the liquid change without detection could be greater than 100,000 gal. The external leak detection drywells are also undergoing a loss of effectiveness as leak detection devices due to continuing decay of radioisotopes which move with the water front (i.e., ^{106}Ru). Depending upon the location of the leak source, the well spacings about certain tanks are such that losses much greater than the nominal 30,000 gal remaining after jet pumping would not be observed.(1) It can therefore be concluded that these two systems could fail to detect the loss of entire drainable liquid inventories in some of the tanks.

As a result of the reduction of surveillance effectiveness, Rockwell has undertaken a development program designed to demonstrate a capability for detecting changes in liquid volume that could occur within solid waste. The technique determined to be most applicable involves use of sensors (gamma, neutron, and acoustic) to obtain profile scans from within liquid observation wells (LOW). These scans were nondestructive, noncontacting, rapid, capable of being repeated in situ, and covered the full vertical range of the contained waste. Technical feasibility of the concept has been demonstrated and documented, and a prototype system developed for further testing.(2) The continuing investigation has involved a systematic program designed to provide bases for interpretation of the test information, mechanical details for data acquisition, recording parameters relating to data scaling, and response criteria. This document is a summary of the testing undertaken to achieve these objectives.

II. CONCLUSIONS

The following conclusions have been developed after evaluation of the development study results.

- Gamma and neutron probe scans could be used for routine in-tank leak and intrusion detection surveillance commencing fiscal year (FY) 1983. The acoustic probe scans provided a superior identification of the interstitial liquid level under all test conditions. However, this system is a prototype and will not be available for routine use until late FY 1983.
- Each of the probe types show immediate and definitive response to events denoting a waste tank leak or intrusion. These responses are seen as both interstitial liquid level movements and changes within other zones of the profiles.
- The combined instrument system/interpretation measurement precision observed is ±0.2 ft for the period of study. Some of the factors affecting data repeatability have been identified and corrected by Computer Automated Surveillance System (CASS) software programming, and a reduction of this variance to ±0.1 ft during FY 1983 is possible.
- The LOWs were found to be exceptionally versatile windows for access to stored wastes over the full range of depths. In addition to demonstrating the ability to detect radiation and moisture level changes, the probe types presented information that showed the variable nature of these wastes. Many of the features exhibited in the data profiles are not understood, but the LOWs offer the potential for further in situ characterization studies using both current and other sensor types.
- The CASS could be upgraded to provide capacity for receiving data for all tanks to be equipped with LOWs.
- The capability for obtaining acoustic probe scans with the monitoring van could be provided.
- The neutron probe suffered from the lack of a suitable standard with which to calibrate the instruments.
- The use of multiple LOWs within a single tank is not required for purposes of leak/intrusion detection. The measurement points in tank 114-TX (three LOWs and the saltwell weight factor instrumentation) all indicated similar responses to jet pump process activities within 2 wk following a change of status.
- No deleterious effects of the high temperature (211°F) in TK-104-SX were observed in the LOW or probe performances. However, this is only a short term evaluation.

III. SYSTEM DESCRIPTION

A. TANKS EQUIPPED WITH LIQUID OBSERVATION WELLS

The program involved interpretation of gamma, neutron, and acoustic probe scans obtained in a series of LOWs. All of the systems are similar to the extent that they are drywells constructed of epoxy-polyester resin, reinforced with fiberglass matting, sealed at their lower ends and sized to extend to within 1 in. of the tank bottom liners. The use of fiberglass was predicated by need for an interface material having properties compatible with the acoustic probe requirements. However, there were dimensional differences between the wells used in conjunction with the earlier FY 1981 Development Program and those installed during May and June of 1982.[3] For the former, the nominal inside and outside diameters were 7.5 in. and 8.5 in. respectively, thus limiting their use to tanks having available 12-in. risers. The latter installations had dimensions of 3.1-in. inside diameter (ID) and 3.5-in. outside diameter (OD, nominal) and were designed for the more available 4-in. risers.

The LOWs were installed in a total of 12 waste storage tanks whose selections were based upon a best-fit with factors which would test concern about the LOW surveillance concept. The following is a description of these factors.

1. The tank contained a large volume of solids, and the drainable interstitial liquid level was not accessible by the surface conductivity probe.[4]

2. The tank was static, and its moisture distribution had stabilized. Such tanks permitted the interstitial liquid level to be unambiguously determined for the purpose of defining precision of the interpretive techniques.

3. The tank was being jet pumped and the ability to detect changes could be evaluated. Also, these systems were equipped with weight factor instrumentation to provide second source information during periods of pump shut down.

4. One of the tanks contained a high heat load in conjunction with a high-hydrostatic head; therefore, performance of a LOW and the probes in a high heat/stress environment could be studied.

5. The desire to evaluate the system in a variety of solid waste components (i.e., sludge, saltcake, diatomaceous earth) was a final consideration for tank selection.

6. One tank, which was being jet pumped, was to be equipped with three LOWs in a configuration to permit monitoring of changes in moisture distribution about the tank.

7. No new risers were to be installed. Only existing, and available, risers that best conformed to an optimum location were selected.

8. Preference was given to any tank whose status was either "questionable" integrity or "leaker."

Table 1 is a listing of the tanks selected to receive the LOWs during FY 1982. In addition to the waste types and projected volumes, the riser identifications and bases for selection are given. It is to be noted that five of the tanks are classed as being static and the remaining seven are committed to the 241-TX farm saltwell jet pumping program. Within these two groupings, the tanks represent a best accommodation with all of the other factors considered. Figure 1 shows plan views of each tank to denote the location of the LOWs in reference to other measurement systems. These systems include surface level gauges, and saltwell and screened observation well weight factor instruments.

B. DETECTOR PROBES

The following probe types were used to obtain the profile scans within in-tank LOWs. Only their basic features are discussed as pertinent to the program, and more detailed descriptions are given in Reference 2.

1. Neutron Probe (Appendix B1)

The basic components of the neutron probe are a fast neutron source and a slow neutron (thermal) detector that measures moisture content of the surrounding medium in terms of detector count rate. The principle of operation is that the slow neutron flux density in the vicinity of the probe is mainly effected by the hydrogen content. The source selected for application to the development program is 1.5 Ci ^{241}Am-Be contained in a detachable, sealed module at the base of the probe. The slow neutron detector is a BF-3 proportional counter contained within a housing above the source. This latter component is stored in a special cask when not in use.

2. Gamma Probe (Appendix B2)

This probe is a lead shielded Geiger-Muller (GM) detector whose applicability is based upon the assumption that the major gamma emitters are in the liquid waste phase. Changes incurred by liquid leakage or intrusion can thus be observed by the effect upon the characteristic gamma profile as liquid movement occurs.

TABLE 1. Underground Waste Tanks that Received 3.5-in. Liquid Observations Wells (FY 1982).

Tank	Current waste surface level (in.)	Waste types & volumes (thousand gal)		Salt cake	Drainable interstitial liquid (thousand gal)	Available riser	Distance from tank center	Selection Bases
		Liquid	Sludge					
111-BY[a]	244.0	---	26	569	245	R-12	20.5 ft	b, c, d
106-S[a]	165.9	---	32	580	146	R-8	5 ft	b, c, d
109-S[a]	185.0	---	13	555	124	R-8	5 ft	b, c, d
112-S[a]	197.8	---	6	666	160	R-8	5 ft	c, d
104-SX[e]	280.6	---	169	541	243	R-14	30 ft	b, c, d, f
105-TX[e]	228.75	---	6	609	197	R-9A	20.5 ft	c, f, h, i
109-TX[e]	169.2	---	9	450	188	R-3	8 in.	c, g, h
110-TX[e]	190.0	---		530	186	R-13	0 ft	c, f, h, i
112-TX[a]	225.0	9	---	664	240	R-7	5 ft	c, h
114-TX[e]	213.5	9	---	645	275	R-12A	20.5 ft	c, h, i, j
e						R-7	5 ft	
e						R-9A	20.5 ft	
115-TX[a]	228.5	---	---	640	283	R-9A	20.5 ft	c, h, i
118-TX[e]	123.0	---	---	347	137	R-5	5 ft	c, h

[a] 8.5 in. OD Fiberglass LOW (Dwg H-2-74501 and H-2-74578).
[b] Contains varietal solids waste (both sludge and salt cake).
[c] Contains a large volume of solids and drainable interstitial liquid.
[d] Tank is static-required for monitor of a stable tank.
[e] 3.5" OD Fiberglass LOW (Dwg H-2-91924, Sheets 1 & 2).
[f] High temperature in bulk waste.
[g] Tank 109-TX contained 135,000 gal of 1C-TBP sludge at time of first use as an evaporator bottoms tank.
[h] Tank is or will be salt well jet pumped-required for monitor of a dynamic tank.
[i] Tank is either a declared leaker or of questionable integrity.
[j] Three LOW installed to monitor variations in interstitial liquid level during jet pumping.

3. Acoustic Probe

The acoustic probe consists of broadband 1-MHz lead metaniobate transducers for the transmission and reception of an acoustic signal. The principle of operation is the reflection differences in signal amplitude as effected by the impedance characteristics of the encountered media. Use of the probe requires a coupling solution to provide a path for transmission of the ultrasonic pulse to and from the fiberglass inner surface.

C. DATA ACQUISITION

The computer controlled drywell monitoring systems have been used to obtain scans with the neutron and gamma probes. The van instrumentation comprises a system of complete automated control designed to generate reproducible scans of minimum variance. As with the probes, a detailed description of the system is given in Reference 5. The following is a brief summary of the features pertinent to the LOW scan development program.

1. All scans have been obtained in accordance with standard operating procedures[6,7] that describe requirements for systematic and reproducible data development.

2. The Micronova Computer[8] is programed to perform the following functions.

   - The computer provides an automatic indexing of the scan to the top of the LOW riser flange.

   - The computer memory contains data describing the well depth and the distance from the tank bottom to the probe center of activity when the probe is at the well bottom (offset). For the well identified by operator input and using the reference point index, the probe is automatically lowered to the bottom of the LOW, and the scan profile then commences upon computer command for start of ascent.

   - The computer provides stringent control of both data interval (0.1 ft) and rate of probe retrieval (0.1 ft/s). This rate is computed and corrected every 0.05 ft of travel.

   - Scan data are stored in a compacted format capable of retaining information generated from normal shift-scheduled scans before transmittal to the CASS central computer. Transfer is via substations located in the 200 East and 200 West Areas.

3. Since June 10, 1982, the LOW monitoring van has been equipped with a probe stabilization assembly designed to correct two transient errors: movement of the van and probe boom during the scan and occasional measurement wheel slippage.

4. The output from the neutron probe BF-3 detector requires prior instrument adjustment to set the amplifier gain. This adjustment is routinely made by Instrument Maintenance personnel prior to any scheduled use of the neutron probe.

The acoustic probe scans have been obtained using prototype instrumentation under the auspices of the Instrument Engineering Design and Development Group (IED&D). The data are recorded on a strip chart recorder as a signal amplitude, and inch/foot markers on the the chart denote location of the signal with respect to the tank bottom liner. Each charts minor division was equivalent to 0.2 in. of tank elevation.

D. COMPUTER AUTOMATED SURVEILLANCE SYSTEM

The data transmitted from the monitoring vans to CASS via the transfer substations were processed by the Eclipse Computer, corrected for tank bottom offset and plotted by the graphics plotter. The profiles presented for interpretation were plots of counts per each 0.1 ft interval versus distance from the tank bottom in feet.

IV. TEST PROCEDURE

A. DATA TRANSMITTAL

1. Neutron and Gamma Probes

Until early June 1982, all scans were obtained at frequencies designed to provide a data base population of a size sufficient for the period of January through late August 1982.[2] However, system modifications that greatly affected precision of the data were implemented prior to June 10, 1982. As a result, the period designated for statistical analysis was reduced to between June 11 and September 10. The monitoring frequencies for all LOW were increased accordingly to accommodate the change.

Data acquired in the course of a routine shift schedule (approximately 10 scans of up to 500 data points each) were then transferred to CASS central computer via one of the 200 East or 200 West Area transfer substations under header identifications that described probe type, tank number, and scan depth. Upon receipt of this information, Technical Systems personnel then processed the data in accordance with special programs for scaling and plotting. The graphs generated for interpretation were plots of total counts per each 0.1 ft of probe travel (ordinate) versus linear distance in feet (abscissa). The distance scale for all plots was 1 in. of chart per 4 ft of probe travel. Ranges applied to the ordinate axis (counts) were 1 in. per 500 counts (gamma) and 1 in. per 100 and 300 counts (neutron) for the 7.5 in. and 3.1 in. ID LOW respectively.

In addition to the 3 yr retention of all data on tape backup for historical record, the Technical System Group transmitted computer generated plots to the Tank Farm Surveillance Analysis (TFSA), Tank Farm and Evaporator Process Control (TF&EPC), and IED&D for evaluation.

2. Acoustic Probe

The acoustic probe scans were obtained by the IED&D group using prototype equipment. The instrument readout was on an X-Y recorder strip chart showing reflected signal amplitude versus distance of probe travel from the bottom of the well. Inch-foot markers along one side of the chart were used to measure distance, and the chart scale was to the nearest 0.2 in. The addition of a predetermined detector offset value was required to include the distance from the tank bottom to the detector window. The monitoring frequencies for the acoustic probe were as described for the dry well van system probes and copies of each scan were transmitted to TF&EPC for interpretation.

B. DATA RECORDING AND INTERPRETATION

The interpretation of dynamic tank vapor space/liquid or solids/drainable interstitial liquid interfaces was, in many instances, difficult on the basis of a single scan or single scan type. Therefore, a referee technique involving profiles of all three probe types was used to establish the zone in which the interstital liquid level was determined to exist. Once established, both this zone and the total scan profile were examined for changes occurring in subsequent profiles. The following techniques were employed.

- Visual Interpretation

  The gamma and neutron profile plots were initially evaluated by overlay comparison with both baseline and immediately preceding plots of the same probe type. A light box was used to provide precise alignment of the graph to within the width of the plotted line. All portions of the profile were then examined to identify zones of possible change.

  The exact location of the vapor space or solids/drainable liquid level was next determined. The technique employed was to first locate the level at the measured midpoint of the determined zone of change and then to measure its distance from the tank bottom liner. An engineering scale of 40 divisions/inch (1 division = 0.1 ft), drafting triangles and a transparent overlay mat were used to define this vertical distance. All scans were graded with respect to reproducibility, sharpness of the point of transition and anomalies within specific zones. Randomly selected scans were submitted for interpretation by five designated individuals. The results reported were then statistically analyzed to determine the measurement precision of the technique described above. The technique applied to acoustic scan interpretation was similar, except that the distance from the chart zero to the amplitude change midpoint was obtained by counting the inch-foot marks and then adding a fixed value (offset) to adjust the reading to the tank bottom liner.

- Computer Assisted Interpretation

  The technique developed to provide a computer assessment of the neutron and gamma probe scans was essentially similar to that employed for visual interpretation. First, the scans were superimposed on inputted baseline data to provide a plotted comparison with a reference profile. The location and value of the established interstitial liquid level was also included. Vertical (tank) measurements of the change between this point and the new superimposed profile were then measured and reported. All interpretations were performed using a Cathode ray tube (CRT) and hard copy printout for record purposes.

- Data Population Analysis

The data development program underwent three major equipment changes during the study. Only one prototype monitoring van was available for service in the earliest phase, and the first production upgraded van was not released for operational use until April 15, 1982. The new equipment eliminated a series of problems associated with worn out and otherwise defective components, but data repeatability was still affected by spurious errors introduced by monitoring van and probe boom movement while the scans were being taken. This problem was addressed when the probe stabilization system was demonstrated in van 6 on June 11, 1982. All subsequent neutron and gamma scans were made using this van.

V. TEST RESULTS: DYNAMIC TANKS

A. DISCUSSION OF RESULTS

One of the two major objectives of this study was to provide a definition of ability for each probe type to detect waste solids moisture changes resulting from liquid loss or intrusion. For this reason, certain of the LOWs were installed in tanks committed to the 241-TX jet pumping operation. The program thus provided a basis for relating on-going changes in drainable liquid volume and redistribution both when the pumps were in operation and when they were shut down. In addition, weight factor instrumentation within salt-well screens and screened observation wells provided a secondary system for correlative analysis of the probe data.

The ability of the three different probe types to detect liquid volume changes within waste solids was demonstrated. Data profiles obtained for each of the seven tanks that were being jet pumped all showed zones of transition that could be related to those of the other probe types and of associated process instrumentation. Three of the tanks had LOWs in place at the time of their pumping starts, and preliminary data representative of a stable state were available. For these tanks, the interstitial liquid levels were essentially fully developed, static and with well defined interstital liquid levels which were in close agreement between probes. The effect of pumping commencement was immediately evident in all cases. However, the characteristic clarity of the point of liquid/solids interface rapidly diminished as pumping proceeded. The transition zones became widely distributed, and identification of a distinctive location became progressively more difficult. Interpretation therefore required careful analysis and comparison of each profile against its peers taken within the same time interval. The problem was most severe during pumping through the mid range of the removal program when liquid drainage is occuring within a large solids volume. The condition was further complexed by the fact that the capability for interstitial liquid level interpretation was totally lost at times for the various probe types. The remaining four tanks (105, 109, 110, and 114-TX) were monitored only after jet pumping was well underway, and the problems of interpration were similar to the above. However, zones of transition and their changes could still be identified in the profiles of each probe type.

Tank 114-TX was equipped with three LOWs installed at locations 7, 21.1, and 25.5 ft from the point of liquid removal. At the time of first scans, the jet pump program was at a point of diminished production and improved discernability of the still changing zones was evident. The most significant feature provided by comparison of data from the three different locations was that the interpreted interstitial liquid levels at the peripheral LOWs were in general agreement and only slightly different from that measured at the location closest to the salt well screen. This latter well showed the lowest levels at the time of jet pump shutdown and the highest levels near the end of the stabilization period. The principal cause of the difference was considered to be the continuous water addition via the salt well weight factor instrument dip tubes, but a response to a pump pit decontamination flush (60-100 gal) was also noted. It was concluded that a liquid loss, or intrusion, would be detected within 2 wk regardless of LOW location, and that multiple LOWs within a tank are therefore not necessary.

Each of the data types exhibited responses to the movement of moisture through the solids media. The differences seen in these responses were considered to be due to features specific to the probe principles of operation, associated instrumentation and how the nonhomogeneous media are seen. The following observations were pertinent to probe performance.

- Gamma Scan Data

  The gamma probe profiles showed a high level of response to periods of both pumping and pump shutdown, and each tank revealed a characteristic waste profile above and below the interpreted interstitial liquid level as pumping proceeded. The profiles above the liquid levels remained relatively stable, but changes denoting continual liquid drainage were observed. The basic problem associated with the high count zones (peaks) was the fact that a moving interface was often lost when passing through them. Both the profiles for tanks 112-TX and 118-TX exhibited such zones that offered a multiplicity of locations for interface interpretation. Comparison with other data as a referee technique was therefore required in the analysis. The zones of difference were believed to be due to media structural and chemical variations that influence retention of liquid.(9) Slow drainage from some of these areas above the liquid/solids interface was observed in the profiles, and the possibility does exist for its continuation over a period of many months.

- Neutron Probe

  The neutron probe data suffered from lack of a suitable standard with which to calibrate the instrument, and the variability of the scan amplitudes was often so great that no assessment of moisture content changes was possible.(10) However, a more critical feature of the variability was its effect upon the interstitial liquid level interpretation process, where errors in the range of ±0.2 ft have resulted. The distortion condition was most severe for profiles in which the transition was already not clearly defined. Proper utilization of the neutron concept therefore requires that the probe, and associated instrumentation, be calibrated before use. In addition to daily checks against a fixed standard, periodic calibration in a test well having zones of precise moisture levels ranging to at least 50 vol% moisture, is required. Neutron probe calibration and test well construction are discussed in Reference 10.

  The tank 112-TX and tank 118-TX data contain examples of the failure of neutron scans to monitor the process of continuing change in moisture level. Here, the profiles followed related information in the early phases of pumping but then became stable. The effect was considered to be due to the heterogeneous nature of the waste solids, and associated differences in capillarity and chemically bonded water were the most plausible causes. However, other factors have been described in the literature (References 11 and 12) and should be investigated. Some evidence of slow drainage from these higher layers was indicated, but the lack of instrument calibration prevented quantitative assessment. Finally the effect of water within the LOW has been noted (see discussion of tank 241-TX-115). The well was checked with dry swabs and the presence of acoustic probe couplant (dilute silica gel solution) was verified. The extent and potential of this problem will be investigated.

- Acoustic Probe

Wastes which contained a relatively stable liquid volume presented acoustic probe scans that showed a well formed signal response profile at the zone of transition. However, the scans rapidly became more difficult to interpret when pumping was in progress. The problem varied in severity from minimal to totally unreadable and appeared to correlate to similar problems in other probe data. The most erratic scans were observed in tank 118-TX, and a fundamental difference in the character of the solids (from that of the other evaporator bottoms tanks) was considered to be the cause. As the pump tank to the 242-T evaporator, fresh feed and recycle bottoms were added in an 8:1 ratio, and salt cake deposited was therefore different from that of a normal bottoms receiver tank. The tank most recently served as a receiver for neutralized 234-5 Z Plant high and low salt acid waste, and some sludge accumulation from this use was possible.

A possibly significant feature of the Tank 118-TX acoustic data was the trace indication of the original liquid/vapor space surface that was seen on all later scans. The reason for the persistance of reflected signal at this location is not known.

B. CORRELATION OF LOW DATA WITH RELATED SALT WELL PROCESS INFORMATION

The weight factor systems installed in the jet pump salt well screens provided data of marginal value to the interpretation of the LOW scans. These instruments, whose essential purpose was to regulate pumping rates during operation, measured the tank interstititial liquid level only when the pumps were shut down. This feature was accepted, because it was recognized that information gathering outages would occur in the course of routine processing. However, problems associated with instrument malfunction and dip tube pluggage often resulted in no or very erratic information. The condition was most severe for the specific gravity data, which often ranged from 0 to greater than 2 within only several days. The problem was never resolved beyond assuming nominal specific gravity values for use to adjust the weight factor readings to liquid levels values. Other factors, which combined to give an instrument measurement precision of $\pm$2.0 ft, were purge rate variability and improperly positioned dip tubes. The data are listed in Appendix A and are also shown in all figures which illustrate plots of interstitial liquid level. The fact of an assumed specific gravity value is noted where applicable. Similar systems were installed in screened observation wells at two of the tanks (tanks 105-TX and 115-TX). However, the same problems persisted, and no data were obtained for analysis.

C. SPECIFIC TANK DESCRIPTION OF RESULTS

The following are by-tank descriptions of the test results. In addition to the listings of measurement data that are given in Appendix A, information plots and representative scan profiles are illustrated in the figures to be discussed. It is to be noted that two symbols are shown in profile illustrations. The first is an inverted arrow to denote the waste surface level (automatic or manual liquid level gauge). The second is a horizontal bar that intersects the profile at the determined drainable interstitial liquid surface.

1. Tank 112-TX

The measured waste surface level prior to pumping start up was 21.3 ft, and the most current in-tank photographs showed the gauge plummet to be contacting the edge of a liquid pool. Scan data for each probe type indicated drainable liquid levels that were within 0.2 ft of this value.

Equipment malfunctions prevented the obtaining of routine scheduled profile information during the first month of operation, but those scans that were obtained all showed that a liquid level decrease had occured. The measured interstitial liquid level data are plotted in Figure 2, and Figures 3 through 6 are illustrations of typical scan profiles. The following observations were made.

- As shown in Figure 2, the degree of correlation of interpretation results recorded for each probe type showed a progressive improvement during the shutdown stabilization period. By March 7 this difference was less than 0.3 ft. However, subsequent pumpout resulted in a reduction in the ability to relate the different probe types. Data recorded after April 1 showed stability of the neutron scans in the range of 11.5 ± 0.1 ft, erratic behavior of the acoustic reflected signal, and two different levels of transition in the gamma scans. That these differences were seen while pumping was in progress was not unexpected. The zone of change had become transient and poorly defined as a result of continuing drainage from higher levels in the heterogeneous solids. The flowrate of this drainage was variable and subject to a wide range of permeability differences.

- Figures 3A, B, and C are illustrations of typical tank 112-TX gamma probe profiles. The first (3A) shows the changes that had taken place between the time prior to jet pumping startup and March 17, 1982. The principal features of the scans are a pronounced response to the initial pumping, a progressive increase in the transition zone during shutdown, and then a second decrease following pump restart on March 11, 1982. Figure 3B then follows this second pumping, which continued through June 12, 1982. The second shutdown period and subsequent restart on July 16, 1982 are illustrated in Figure 3C. All of these figures show the development of a characteristic stable upper profile (peaks and troughs) as the zone of transition proceeds to a lower level. The fact of continued drainage from these high count zones is most evident in the latter two illustrations. Also noteworthy is the liquid/solids level interface peak seen in the late stage of the first shutdown period. The cause for this peak has not been explained, but it has been observed in the profiles of other tanks. Finally, the presence of three zones of change appear to be related to the non homogeneous nature of the solids media. As drainage proceeds, the rates of the change seen may be either increased or slowed depending upon a number of possible effects, all of which are associated with solids porosity differences. Zones of different composition or structure (particular size) could then serve as channels to restrict flow and even cause the development of perched (saturated waste) layers.

- Figure 4, a gamma/neutron composite, shows the agreement between zones of change observed in the two profiles. Here it is seen that the zone of most active gamma change (at 5.7 ft) is coincident with a regression within the high count region of the neutron profile. A second area of transition is the 11.8 ft elevation where repeated scans have shown relative stability of both gamma and neutron counts. The correlation indicates matrix stratification and restriction of liquid movement. However, both scan types have continued to show that some drainage is proceeding and that the final characteristic profile has not been fully developed. Finally, the gamma profile shows a stable peak in the range of 16 to 20 ft, whereas the neutron scans show the presence of very little moisture. Further reduction of the gamma counts at this surface and in the absence of drainable liquid is not expected to occur.

- Figures 5A and B show representative neutron profiles obtained during the same period. Correlation with the scans of the other probe types is seen during the initial periods, but the later data indicate stabilization of the interpreted liquid level in the range of 11.6 ± 0.2 ft. On the scan of May 27, the first indication of a regression in counts in the range of 5.6 ± 0.2 ft was seen. This suggestion of a transition zone was first considered to be spurious and associated with the inability to calibrate the probe. However, the indication was repeated in later data, disappeared following prolonged jet pump shut down between June 6 and July 16, 1982, and then reappeared in the August scans after pump restart. The development of a permanent trough in this region is therefore anticipated.

- Typical Acoustic Probe Scans are illustrated in Figure 6. As with the gamma and neutron scans, a clear definition of change in reflected signal amplitude scan is seen during periods of no pumping activity. However, drainage induced by jet pump operation resulted in a range of erratic signals that offered the interpreter a variety of choices. The problem appeared to be most severe when the rates of liquid removal were greatest. The phenomenon suggested that the true interstitial liquid level had no clearly defined transition for the acoustic signal to see. Rather, it was a zone, or series of zones, in which the liquid was being both removed by pumping and added to by upper region drainage. Other factors that appeared to be related to the the problem were the nonhomogeneous nature of the media and the fact that the detector window was very small and therefore rarely saw the same area twice.

2. TK-118-TX

Interpreted interstitial liquid data recorded for tank 118-TX are listed in Appendix A. The results, which are also illustrated in Figures 7 through 10 were found to be unique in comparison with those of all of the other dynamic tanks. As shown in Figure 7, the profiles provided an interstitial liquid level correlation between probe types to within 0.3 ft to the time of pump start, and the fact that liquid was being removed was immediately indicated by each profile type. Then, for the period extending through mid-April, the liquid regression was observed as a continuing process, but with the progressive decrease in ability to interpret individual scans. The following observations were noted.

- Figures 8A, B, and C are overlays of representative gamma scan profiles which illustrate the changes that followed the course of jet pumping and subsequent shutdown. It is seen that the initial scan had two characteristic radiation peaks, one at the surface and a second within the range of 3 to 5 ft above the tank bottom. The principal changes to be noted are the progressive reduction of the surface level peak, the development and subsequent disappearance of a small middle zone peak, and finally the emergence of a zone of reduced radiation activity at the surface. The middle zone was extremely active during the period of pumping, and the region of the small peak eventually became the low point in the profile. Interpretation of the changes observed within this zone was difficult due to stability of the neutron scans and the erratic nature of the acoustic probe data. Finally, the profile depression seen in the zone between the vapor space shine and the first peaks is not typical. The possibility of moderation by low level waste above the drainable liquid level is suggested.

- Typical neutron profiles obtained during the same period are illustrated in Figure 9A. The scans show changes that are in agreement with those of other probe types during the initial pumping stage. However, all subsequent data have remained relatively stable. Figure 9B is an illustration of the data expanded for analysis to show that the zone of transition is decreasing. Variance in the amplitude of the profiles has been noted, and integration to determine any trends is not possible.

- Interpretation of the acoustic probe scans during the jet pumping operation presented the problems illustrated in Figure 10. As in all other probe types and tanks, the scan taken immediately after start-up indicated a change. However, the complexity of the data soon became severe, and it was very difficult to identify the true zone of activity. In addition to the apparent inability to interpret the data, a second feature of concern was the fact that the signal amplitude change at the initial liquid level continued to appear in all scans. The problem and the special nature of the waste in this tank require further study.

3. Tank 241-TX-115

Pumping preceded the first LOW scans by almost two days, and approximately 2,500 gal of liquid had been removed. However, these first profiles were considered to be essentially representative of a prestart-up condition. The fact of profile change was immediately evident for all of the probe types on the subsequent scans. As shown in the tabulated data (Appendix A) and in Figures 11 through 15, the profiles showed a high degree of correlation. The following observations were pertinent to the interpretations.

- Figure 11 is a plot of the interpreted interstitial liquid level measurement results recorded for each scan type. With the exception of the neutron data after July 20, the results showed a correlation to within $\pm$0.3 ft. In addition, the fact of corresponding response to jet pumping activities is evident.

- Figure 12 is an overlay series of representative gamma scan data during periods of both pumping and pumping shutdown. The first profile is that which was obtained immediately following the start of pumping and is assumed to contain some element of initial change.

  Due to equipment problems, the second scan was not obtained until 2 wk later (dashed plot) and 2 days after pump shutdown. Here again some recovery is assumed to have taken place, but a major reduction of the total profile has occurred. The next three scans show the progression of stabilization recovery during shutdown, with the growth of the characteristic interface peak and a continuing loss of counts above the interface zone. The final scan, obtained 3 days after pump restart, shows the continuation of liquid level decrease. In addition to immediate response to pumping operations, it is to be noted that the total count levels have undergone significant reductions at all elevations above 5 ft from the tank bottom.

- Figure 13 is an overlay series of the neutron probe data covering the same period as that discussed above. Here, a neutron scan is shown for 1 wk following start-up to illustrate the shorter term detection of change. Some degree of response can be seen in all following scans for both pumping and nonpumping periods. Due to the inability to properly calibrate the probe, no integration analysis to evaluate changes in moisture content was attempted. This calibration problem is most evident in profile 2. The last two scans (July 16, 1982 and July 19, 1982) show evidence of higher thermal neutron counts at the bottom of the LOW, and the possibility of uncontaminated water within the well was confirmed by swab testing. As the wells are sealed when not in use, the cause has been determined to be the acoustic probe couplant solution.

  The LOW installed in tank 115-TX was one of the first 3.5 in. nominal OD units to be scanned with the neutron probe. The results, which were typical for all of the smaller units, showed a significantly increased thermal neutron count along all portions of the waste traverse. The effect is recognized to be due to the smaller wall thickness and diameter of the access tube (Reference 9, Chapter 10).

- Figure 14 is a composite illustration of gamma and neutron probe scans that were obtained on the same date and during pump shutdown. The interpreted interstitial liquid levels, which are denoted on each profile, can be seen to be displaced by a distance of less than 0.1 ft. However, it is to be noted that this degree of correlation was not observed when the jet pump is in operation. Equipment problems prevented use of the acoustic probe prior to June 29, 1982, but scans obtained subsequent to that date showed a sharply defined change in signal amplitude which indicated an interstitial liquid level in good agreement with those of the neutron and gamma profiles (±0.2 ft see appendix data for July 12, 1982). Typical acoustic probe scans are illustrated in Figure 15. In addition to a clear definition of liquid level transition, these scans also show a significant noise reduction. This is a characteristic feature of the 3.5 in. OD LOW data and is considered to be due to the wall thickness difference between the two wells (0.5 in. for the larger wells versus 0.2 in.).

4. Tank 114-TX

The tank was a special case study designed to evaluate the need for multiple LOWs in the same tank. Information sought in the scans obtained from these systems was twofold. First, installation within a dynamic tank provided measurement data similating a leak/intrusion state. The jet pump operation represented either event and scans from three different locations would assist in the assessment of liquid movement through a typically nonhomogeneous media. The second objective was to determine the nature of differences between different locations that might exist for the interpreted drainable liquid/solids interface and in the profiles above and below this level. The three installation locations for the LOWs are shown in Figures 1A and 16. Orientation of the systems in respect to the jet pump salt well are listed in Table 2.

TABLE 2. Orientation of Systems.

LOW Identification	Riser	Salt well distance (ft)	Azimuth
511460	R12	25.5	0
511463	R9	21.21	76°
511469	R7	7.1	315°

The scan information obtained from the tank 114-TX LOWs was not concurrent with the early stages of jet pumping. Operations had been in progress for greater than 4 mo at the time of the first scans in June 1982, and approximately 100,000 gal of interstitial liquid had already been removed. The tank was, in fact, approaching an end point in its jet pumping program, and rates of removal had been reduced to within the range of 100 gal/d. Tabulated data are listed in Appendix A, and the following observations of the scan information from Figures 16 through 20 have been made.

- Figure 16 is a plot of the measured interstitial liquid level results which illustrates features typical of those seen in all other dynamic tank data. As expected, the response to jet pumping events (start-up and shutdown) is seen to be both more rapid and more prominant in the LOW closest to the salt well screen; however, the degree of variance between probe types is greatest for the farthest well. These data indicate that a leak or intrusion would be evidenced within a 2 wk period for a well situated within 25 ft of the event source.

- Figures 17A, B and C and 19A are composited gamma scan profiles of the respective LOWs to illustrate changes occuring between June 13 and July 28, 1982. The critical dates are jet pump shutdown on June 10, introduction of pump pit flush on July 6, jet pump restart on July 16, and shutdown on July 23, 1982. In all profiles, the areas of change were seen to take place in the range of 2.1 to 3.2 ft and the period prior to July 16 was one of increase within the zone. The effect of pump restart was immediately evident in the subsequent scan obtained in each LOW. Distance from the salt well screen did not appear to be significant for the two farthest LOWs, but both the rate of response and magnitude of the change is greater in LOW number 511469. This well is only 7 ft from the salt well screen, and the level increase to above that of the peripheral wells is considered to be the result of the dip tube water additions at the salt well screens. Discrete portions of the radiation profiles above the drainable liquid/solids interface that show an indication of drainage during this short time period are noted on the figures (see Figures 17C.2 and 18C.2). Figure 19A shows the relative appearances of the gamma profiles obtained in the three different LOWs. While intrinsic similarities denote the locations of zones of stratification, the fact of vertical differences between locations is indicated.

- The neutron probe scans (see Figures 18A, B, C and 19B) indicated zones of response and magnitudes of change similar to those of the gamma probe. However, the problem of scan amplitude variability was again evident, and extreme care in the visual interpretation of the data was required to overcome the difficulty.

  Profile features above the interstitial liquid level were reproduced with some evidence of change in the same zone as seen in the gamma scans. Also, the profiles of the different LOW locations did show moisture level similarities at the same elevations.

- Figures 19A and B are overlay illustrations of the gamma and neutron probe profiles obtained at the three different LOW locations. The period covered is from June 13 (solid lines) to July 12 (dashed lines), when the jet pumping was shut down and the zones of activity are showing an increase. In addition to the response correlation, these figures also show the irregularity of the waste. The configurations suggest that both the surface and the zones of stratification have slumped toward the tank center.

- Figure 20A, B, and C are illustrations of the acoustic probe scans. In all cases the change in signal amplitude, denoting the liquid/solids interface, is seen to be clearly defined. Correlation of the measured liquid level with those obtained by the nearest in time neutron or gamma profile analysis is within $\pm$0.3 ft.

5. Tanks 241-TX-105, 241-TX-109 and 241-TX-110

Tanks TX-105, -109 and -110 were the three remaining dynamic systems. For each, the respective jet pump operations were started well in advance of the first scan data, and initial response information was not available. However, changes in the profiles obtained subsequent to start-up were observed to be consistant with all other dynamic tanks. Measurement data shown in Figure 21 and AppendiX A. In addition, representative pertinent observations are summarized in Table 3 and the following discussions.

TABLE 3. Tank 105-TX, 109-TX, and 110-TX Observations.

Activity	Tank 105-TX (date/gal pump)	Tank 109-TX (date/gal pump)	Tank 110-TX (date/gal pump)
Jet pump start	3-25-82	3-18-82	12-19-81
First scan			
Gamma	5-28-82/71,430	6-13-82/28,587	5-28-82/94,811
Neutron	5-27-82/70,957	6-11-82/28,587	5-22-82/94,254
Acoustic	7-15-82/82,566	7-15-82/28,587	7-12-82/99,710
Pump shutdown	6-10-82/82,566	6-10-82/28,587	6-10-82/99,710
Pump restart	--	7-16-82	--
7-27-82 gal	82,566	32,839	100,500

6. Tank 105-TX

Figure 22 is an illustration of typical gamma and neutron scan profiles. As shown, both the gamma and neutron profiles indicated a response to pumping prior to and following the June 10 stoppage. The zone of activity in each scan type was in the the range of 4.3 to 5.6 ft above the tank bottom liner, and the rate of change was slow and indicated only limited drainage from the solids above the intersitital liquid level. The correlation of interpreted liquid levels between probe types was within 0.2 ft after accounting for time displacment.

7. Tank 109-TX

As shown in Figure 23, the characteristic increase of the recovery period prior to July 16, 1982 is slight but measureable, and the response to pump restart was detected by all probe types. Each of the profiles exhibited zones of transition that were clearly refined, and their general configurations were those typical of a static tank.

8. Tank 110-TX

Figure 24 shows representative gamma and neutron scan profiles obtained within the period of June 10 to July 27, 1982, and all show the zone of activity to be in the range of 2.0 to 3.5 ft above the tank bottom liner. The fact of the zone's proximity to the start-of-scan location limits applicability of the LOW to the detection of further decreases. Some indication of drainage is seen in the solids above the drainable liquid interface, but no estimate of relative moisture level is possible. Below this level, the scans show a decrease rate approaching stability. As previously stated, the problem of amplitude variability restricted interpretation of the neutron probe data.

The acoustic probe scans taken in each tank as shown in Figure 25 were insufficient for trend evaluation, but they did provide correlation with the other profiles. The apparent instability of the reflected signal seen in the scan taken on July 21, 1982 is not explained.

VI. TEST RESULTS: STATIC TANKS

A. MEASUREMENT PRECISION

The study described in the preceding section demonstrates the capability of LOW scan information to detect waste storage tank leaks or intrusions. A second essential requirement of a surveillance dedicated system is its ability to present data that is both readable and repeatable to within an acceptable range of variance. The near-term goal stated in Reference 13 is a measurement precision of ±0.2 ft, and a potential for further reduction, for an interpreted liquid/solids or vapor space interface. Consideration of this requirement necessarily involves study of the two factors that affect the reliability of the interpreted results. These are the precision of the data presented for analysis (i.e., instrument system) and the ability of the technician reviewer to perform an analysis to within the defined action limits.

The data used to evaluate measurement precision consisted of LOW scans obtained in five tanks. Bases for their inclusion were that each had been inactive for more than 1 yr prior to January 1982 and that there was no record of activities involving water additions of greater than 10 gal. The one exception was a 4000 gal addition to tank 109-S during September 1981. This was a special test of prototype probe response and is described in Reference 5. The following LOW equipped tanks were involved:

Tank	Nominal OD LOW (ft)
106-S	8.5 in.
109-S	8.5 in.
112-S	8.5 in.
111-BY	8.5 in.
104-SX (Installed 6-10-82)	3.5 in.

Appendix A has listings of the interpreted liquid/ solids or vapor space levels recorded for the gamma, neutron and acoustic probe scans. Where applicable, waste surface level measurements (manual or automatic liquid level gauges) are included for purposes of comparison. Figures 27 through 31 are illustrations of representative gamma, neutron and acoustic probe profiles for the respective tanks.

The study results indicated that the problems having the greatest effect upon precision of presented data are associated with process instrumentation. The most frequently occuring evidence of errant data was found to be the result of malfunctions relating to the monitoring van instrumentation and the probe stabilization system. These problems will be discussed in a later section. Although many of the discrepancies were recognized and were corrected by the methods applied to data interpretation, a deviation of ±0.2 ft has remained for application to the system as it currently exists.

The interpretive techniques applied to the visual analysis of the scan profiles have a measurement precision of ±0.1 ft. However, the process demands a high level of dedication to careful alignment to within the width of one printed line (0.015 in.) and distance measurements to within 0.025 in. The charts are large, can be easily disturbed by a slight movement after alignment, and it was found that repeated analyses were frequent. Human fatigue is therefore a considered factor when a series of scans are received for analysis. As all data are reviewed by a second TFSA individual, it is anticipated that the technique must be repeated in its entirety to verify a result. Another problem that requires resolution is data storage and ease of recovery. The present technique is cumbersome and does not provide easy reference to the critical decision making steps.

B. DATA REPEATABILITY

Figure 32 is a full scale illustration of a typical scan profile as generated by the CASS drum plotter. A review of all scan profiles presented in this format has been made and the following observations were developed.

- Approximately 6% of the scans exhibited variant features that introduced a potential for interpretation error. However, many of the discrepancies were identified at the time of analysis as being equipment related and were thus not anomalous. In most instances of errant data, careful alignment of the scan with reference information provided a correction without need for rerun. Figure 33 is an example of type of misalignment most frequently encountered. The problem was most prominant as monitoring van instrumentation and probe stabilizer malfunctions, but distortion introduced by the CASS drum plotter was also observed. These problems will be discussed in the following equipment performance section.

- Extraction of data recognized as being defective left a remaining measurement precision of ±0.2 ft, as determined by profile alignment analysis. However, the possibility of improvement is presented by application of the CASS computer to the overall process of data presentation.

C. VISUAL INTERPRETATION

Visual interpretation of the CASS-generated profiles to the required degree of precision was possible. However, the process was tedious and demanding of close attention to detail. Techniques applied to the analysis were essentially similar to those recommended by the IED&D (Ref. 5), but minor revisions were applied; these techniques follow.

- Development of baseline profiles for use in the application of change criteria cannot be done on the basis of one scan alone. Reference information provided by concurrent analysis of other probe type data is essential to the process. Secondary resources (waste surface level data, in-tank photographs, and a knowledge of the waste type and process history) are also valuable aids. Selection of the scan to be used as a baseline then requires careful overlay comparison of at least five consecutive profiles to eliminate the inadvertant use of distorted or incomplete data.

- Once the liquid/solids or vapor space transition zone is identified by referee analysis, measure the midpoint along the zone. This is the designated location of the interstitial liquid surface (see Fig. 32).

- An overlay technique is always used to compare one or more scans with a baseline. The method determined to be most effective is to affix the baseline profile chart to a light box and then to carefully overlay the profiles undergoing study.

- The initial step performed with a new profile is to check for distortion introduced by the drum plotter. This is done by overlay alignment of the chart coordinates, tick marks, and reference information. If precise superimposition is not possible, then a new plot must be made.

- Carefully align the chart abscissa (x axis) and the scan profiles using known fixed features on the data. That portion of the profile which denotes the zone of probe upward travel into the dome riser is a characteristic feature and should always match that of the baseline. If it does not, then position the scans to provide a match and reexamine the total profile. Depending upon the nature of the misalignment, a problem of missing data or improper probe bottom indexing can be identified and corrected. The realignment will most frequently permit use of the data without need for reruns. However, the fixed dominant waste structure features may occasionally be mismatched as a result of either missing data points within the scan or a valid change. Data rerun is required in either case.

- Review of all portions of the profile and note any changes from the previous scans. Analysis must be total, because such changes could occur at locations other than that of the interstitial liquid levels. Examples of such changes are seen in Figures 8B, 17C, and 18C.

- Carefully measure the change in level. This is done by first determining the transition zone midpoint and then measuring along a line drawn perpendicular to the ordinate axis of the base line chart. An engineering ruler graduated 40 divisions an inch (0.025) and drafting triangles are used to make an accurate determination. However, An alternate overlay technique employing a precision transparent grid of 20 divisions an inch was successfully used to facilitate performance of this step.

This study has shown that independent analysis of a single scan is not possible, and that support information provided by other sources and previous scans are essential elements of the interpretation process. The visual interpretation technique was studied in two series of independent analyses performed by five different individuals. For the first, 16 randomly selected profiles were listed for study, but no specific instructions for comparison or reference analysis were stated. The results indicated a measurement variance of ± 0.4 ft between reviewers. The second series of scans were submitted with comparative baseline charts attached to denote the transition zones and points of interstitial liquid level. Here, the process involved overlay of the profile and alignment with the reference information as described in the steps above. The results showed that the standard deviation between reviewers was ±0.1 ft for all tanks that had stable, well-formed drainable liquid surfaces. These are the tanks for which action criteria are to be assigned. For the dynamic tanks, a slightly larger range of ±0.2 ft demonstrated the need for referee information when the profile is undergoing change. The test data are listed in Appendix C.

The acoustic probe scans received from IED&D were evaluated in the manner described in Reference 5. The technique consisted of first drawing a line from the point of reflected signal amplitude change to the inch-foot marks along the top side of the chart. The elevation was then determined by simply counting the marks between the origin and the point of intercept and then adding a predetermined offset valve. This value corrected the scan to include the distance from the tank bottom to the probe's center of activity. The point of reflection change was clearly defined for the static tanks, and a measurement precision to within ±0.05 ft was determined.

The above procedures were used in the analysis of the neutron, gamma and acoustic probe scans taken in the static tanks. The following observations were made.

- Correlation of the interpreted interstitial liquid level data between the different probe types was within the range of ±0.3 ft. This difference was also recorded in the FY 1981 development study (Ref. 5).

- Profiles for each of the three scan types showed sharp definitions of the zone of transition. This is typical for static tanks whose interstitial liquid surfaces are well formed and stable.

- The interstitial liquid level increase in tank 112-S, which had been previously noted in Reference 5, has continued through May 1982. Subsequent data have remained stable. Figure 28 illustrates the changes that had taken place both at the interpreted liquid level and in the underlying media (gamma only). The previously reported indication of a slowly decreasing salt cake surface as seen by the neutron probe[5] was not observed in the data obtained since January 1982.

- Indication of an interstitial liquid level increase in tank 106-S was observed for each scan type. The increase of approximately 0.2 ft is consistant with a similar increase recorded in the automatic gauge liquid level gauge data. In-tank photographs taken October 1, 1981 show the gauge plummet to be at the edge of a liquid pool.

VII. COMPUTER ASSISTED DATA ANALYSIS

This section describes the results of studies designed to employ a computer in the process of profile data interpretation. The decision to proceed with this purpose in mind was made at an early stage due to problems soon recognized in the visual interpretation technique as applied to the scans presented in the Figure 32 format. The inherent features of the process were that it demanded very close attention to detail, required a high degree of visual-manual dexterity in the performance of alignment and measurement steps, and involved the manipulation of two or more large charts at one time. While possible, the process required frequent recheck to verify analysis results. The ability of the computer to support, or to totally take over, these tedious steps was therefore the objective of the study. The base assumption of utility was the fact that the CASS Eclipse Computer contained all of the information necessary to establish a precisely measured elevation value for any data point on the scan profile. Both current and reference base line information were thus available for treatment by software program analysis. The facilities used for ECLIPSE access included a terminal, a CRT with hard copy unit and a table plotter.

A. MEASUREMENT TECHNIQUE

The initial study involved attempts to develop a capability for independent computer interpretation and identification of the point, or points, of active zone transition. However, the conventional polynomial curve fit analysis techniques employed showed no degree of promise and were subsequently abandoned. The investigation then proceeded to a direct simulation of the techniques used for visual interpretation. These steps were CRT overlay of multiple data, alignment, definition of a reference data base, identification of the zone(s) of transition, and then measurement of the observed changes. The decision process thus remained within the purview of the analyst, and the function of the computer was primarily to perform all steps more rapidly and accurately. However, other functions concerning integration of the profiles to determining changes in activity level within specific regions and slope analysis were also tested. The following results were obtained.

- Data Overlay

  The initial step dealt with direct overlay of multiple scans. This process was easily and precisely accomplished through use of the CRT. The only time delay was due to the inability of the computer to store on-line data, and creation of the data base required input from information stored on tape.

- Alignment of the Profiles

  The problem of profile alignment was partially solved by an algorithm for least squares curve fit analysis of the data against a fixed feature in the reference profile. The portion selected for analysis was that which denoted the point of upward entry of the probe into the tank dome riser. This is a constant point of reference having a characteristic profile, and riser survey data indicate that it is always within ±0.15 in. of the fixed distance from the tank bottom (Ref. 14). This is approximately 10% of a scan data point interval and is therefore insignificant. Through application of the technique in conjunction with careful study of the total profile, it has been found that most of the misalignment problems can be eliminated, the cause identified, and the data rendered usable without need for scan rerun. However, the process does not identify the problem of a missing data point within the profile, and the potential for this to occur does exist as an infrequent possibility. However, the fact of no data for à specific 0.1 ft interval can be recognized by the monitoring van Micronova Computer, which is currently instructed to abort the scan if it does not receive data for each probe travel interval.

Other points of reference considered for use in data alignment were the characteristic features that are typical of all scans obtained in the same LOW. Such features (peaks or rills) are associated with stratification of the solids media and are essentially fixed in location from scan to scan. However, the possibility for solids settling, crystal growth or leaching processes could not be eliminated on the basis of current knowledge of effective mechanisms.

- Range Scaling

Programs for expanding the scale of either axis were developed to permit an easier viewing of the data. Only the footage range was varied for these tests, and a scale of 2 tank feet an inch was found to be well suited to visual inspection.

An integration procedure for analysis of the gamma count data has been demonstrated. The program is similar to that which is currently used for study of radiation peaks in external drywell scans, and its applicability to the analysis process is well documented. Figure 33 is an illustration of the application. The procedure follows:

Assume y_i (gamma count at x_i) is equal to of function (f [x,i]), where x_i is a distance from the bottom of the tank. If a value (N) is chosen such that N dX is equal to the top of the tank, or any other designated location, then the integral of the gamma counts (IG) is equal to:

$$\int_0^n f(yi)dx \text{ or } \int_0^n yidx$$

which is approximately equal to:

$$\sum_{i=1}^{n} (yidx) \text{ or } {}^{n}(\sum_{y=1} yi \quad dx)$$

Figure 33 is an illustration of the technique supplied to the integration analysis of a gamma profile. The analysis was not performed with the neutron probe scans, due to the wide variability of the thermal neutron counts.

B. DATA DISPLAY AND HARD COPY PRESENTATION

The data were displayed first on the Tectronix CRT and a permanent record was generated by the hard copy unit. Then, if need for a more extensive analysis of more then two scans was determined, the table plotter was used to develop a multicolor record for up to six profiles. Other features of the display and related computer programs permitted the analyst to locate the midpoint of a profile transition zone, identify it by an appropriate symbol and then have the computer measure its distance from the tank bottom and a baseline location. The process was found to be both rapid and accurate to one data interval (±0.1 ft).

VIII. EQUIPMENT PERFORMANCE AND NEEDS

A. COMPUTER AUTOMATED SURVEILLANCE SYSTEM

LOW scan information transmitted to the CASS central computer was processed in an analyst mode by Technical Systems personnel. Many problems were encountered during the early development phases of the computer controlled van transfers, but they were subsequently resolved. The problems were both hardware and software related.

The CASS drywell protocol was initially improperly structured to provide the fastest transfer of data. This software was redesigned and installed into the central computer. Also, the computer could not trap data if there were problems associated with it. Typical problems were invalid headers, data terminators or trailer information. Modifications have since been to permit CASS to accept any data that is transferred. These data can then be edited by an analyst for processing.

The following is a summary of technical requirements for the use of the CASS central computer in the processing and presenting of LOW information. The items listed are those which are considered to be needed to permit full and efficient utilization of a computerized surveillance system. The estimates of capacity are based upon maximum anticipated numbers of LOWs and their frequency of monitoring.

1. Receiving Data

The CASS has mass storage (disk) and memory capacity for the receiving of data relating to the LOWs.

- Data sets for each LOW and associated probe type are involved.
- Depending upon LOW length, the information received for each LOW and scan type will consist of between 450 to 530 data points, plus a 4% overhead to include header information.

2. Data Processing

Data received into the ECLIPSE Computer shall be stored in the data base. Here it is available for processing by comparison with inputted baseline information that covers the full range for that specific LOW and scan type. Processing shall consist of the following:

- Provide a capability for alignment of the data if it is determined necessary
- Permit data clipping (noise, spikes, etc.)
- Compare the new scan against an inputted base line record of the total profile

- Compare the data against an inputted (base line) interstitial liquid level value and calculate any change in elevation from that point to a corresponding location on the new data profile

- Integrate under the profile to determine total counts between the tank bottom and any point to be inputted by the analyst. The capability for analysis between scans of different probe types should be included

- Perform a statistical analysis to identify specific areas of regression that exceed established limits for change.

3. Data Presentation

- CASS will generate a plot of the new data profile (solid line) superimposed on a base line profile (dashed line). The plot will have the following information:

  - Measured discrepancy (± ft) between the baseline interstitial liquid level and the projected point of intercept with the new data

  - Baseline and new data counts above and below the interstitial liquid level (ILL)

  - Issue a following report to include areas requiring further TFS&A analysis.

- A second CRT (the present unit will serve as a standby) with capability for hard copy profile printout will be required for routine review, interpretation on alignment of the data profile (if a need for alignment is determined). Color graphics capability is desired.

- Plotter copy (pen or drum type) output will be required for special studies. High resolution, speed and multicolor are desired. Also, the data presentation must not be subject to distortion by paper misalignment. Note: The drum plotter presently in use is not satisfactory, as each plot must be carefully checked against a precision template to assure proper scaler alignment.

4. On-Line Data Capability

- Capacity for base line data of each LOW and probe type.

- Capability for 4 mo on-line retention for each LOW and probe type plus a 10% overage for reruns and special scans.

5. Archives

- After 3 yr of storage, one tape representing the first 4 mo of each calendar year will be dumped to a new tape. All remaining tapes will be discarded after review and approval of TFS&A.

- Specific archival requirements may be stated for specific cases where data have indicated increase/decrease trends.

B. DRY WELL MONITORING VAN SYSTEM

The task of obtaining neutron and gamma probe repeatable scans with the computer controlled monitoring vans was affected to some degree by a variety of equipment constraints and problems. First, the test was conducted concurrent to the program for van system upgrade and the first modified system was not released until April 1982.[12] Therefore, all prior data were obtained using the prototype van 7, which itself required upgrade (released July 16, 1982). A second condition having an effect upon data repeatability was the occurrence of spurious errors introduced by van and probe movement during the scan. The problem was addressed by introduction of the new probe stabilization assembly during June 1982. Other components identified as error sources follow.

1. Measurement wheel

The effect of dirt on the wheel and of wear was found to have a critical effect upon the measurement precision. Operating procedures were revised to state more stringent requirment for cleanliness.

2. Cable

Frayed cable introduced distorted or spurious data.

3. Neutron Probe

As discussed in earlier sections, the lack of a calibration facility prevented application of the neutron probe to its fullest potential. In addition to being unable to integrate under the profile and assess differences in moisture level, the variability also caused problems in the process of scan interpretation. The test provided only for a start-of-day preset adjustment of the voltage discriminator and amplifier gain controls, but a new system for calibration against a standard is being developed.

4. Cable Anchor

The scanning probe is suspended from the stabilization fixture by means of a cable anchor. This is a collar swedged onto the cable 2 ft above the probe attachment point. Original testing established a requirement for four crimps on the cable anchor to prevent slippage. Unfortunately, the cable anchor on van 5 (on which the prototype stabilization unit was installed) was improperly swedged. Over a period of several weeks the cable anchor slipped several inches until computer programming prevented wells to be scanned. Obviously, the data accumulated during this several week period was positionally shifted by the amount of the slippage and the analysis was correspondingly adjusted.

5. Mechanical Probe Stabilizer Difficulties

Several mechanical problems developed that affected the indexing of the probe to the well top. This is the method used by the computer to establish the starter point. These problems translated to a shift in the index point which, as noted, affects the data position erratically. This shift can be several inches in magnitude. A design of sturdier components has been introduced.

6. Stabilizer Well Head Mounting

The stabilizer unit must be mounted on the well head in a clocked manner according to the flange bolt pattern. Operators sometimes set the unit on top of the bolts causing a one to two inch displacement. The problem has been addressed by design changes with procedure revision.

7. Program Related Error (Software)

Because data is passed to the dry well van computer from an electronic module called a paper tape punch interface, a trap was placed in the program to examine the received data. This trap was used initially to simply throw away data not meeting the format specifications. When this occurred, a data point would not be plotted and a plot shift would result. It was felt that because the modules had been revised and checked extensively, the probability of badly formatted data was low. However, should it happed the eclipse plotting routines would be disrupted. Thus, the trap was left in the program but did not cause the system to error the scan out. Doing so would require the operators to rescan the well and was, therefore, a trade-off for operational convenience. The trap has now been changed to error the scan and cause it to be redone. This prevents data shift for this reason.

8. System Depth Errors

The electronics which transfer depth information to the computer from the shaft encoder are severely comprised in the prototype system by many long external cables. Induced noise has cause spurious depth indications to the computer. This changes the apparent probe position and results in a plot shift. The magnitude can amount to several inches.

9. Eclipse Plotting Routine Error (Software)

It was discovered that the revised commerical plotting routines used by the Eclipse caused plot inconsistencies. Corrections were made which now initialize the plot axis correctly eliminating this error. The error magnitude could amount to several inches.

C. ACOUSTIC PROBE

Although essential to the study of LOW scan reliability, the acoustic probe instrumentation could not be evaluated on the basis of equipment performance. The components, with the exception of the probe, were laboratory use instruments transported and assembled in the field by a specially trained technician. The scans were then obtained with readout provided by a chart recorder. The specialist was thus able to recognize various information and apply the necessary corrections at the time. Near-term plans involve use of the probe in the present form.

IX. ACKNOWLEDGMENTS

Those within Tank Farm Surveillance and Operations and Instrument Engineering Design and Development are gratefully acknowledged for their efforts in gathering of the data and technical support of the monitoring equipment. Special thanks are owed to R. C. Adams and F. S. Strong, who could not have been more dedicated to this program.

All monitoring van data were transmitted to the Central Surveillance Computer for processing and plotting by Technical Systems personnel. The work of L. A. Dietz and R. L. Coats in development of software was of special value to the recognition of problems as they occurred and to the process of data interpretation.

Others who greatly assisted in this study were R. F. Meisinger (TF&EPC), who compiled and plotted data, and B. A. Higley (Waste management process technology), who provided valuable consultation in the evaluation of test results.

REFERENCES

1. R. E. Isaacson, "High Level Waste Tank Monitoring Frequency and Action Criteria", RHO-ST-34, Rockwell Hanford Operations, Richland, Washington (January 1981).

2. G. N. Langlois/F. S. Stong, " In Tank Dry Well Monitoring Systems Development Report," RHO-RE-SR-1, Rockwell Hanford Operations, Richland, Washington (October 9, 1981).

3. Letter dated November 9, 1981, D. R. Carpenter to W. F. Heine, "Tanks to Receive 3 1/2 inch, O. D. Fiberglass Liquid Observation Wells."

4. B. A. Higley, "Criteria for Selection of Single-Shell High Level Waste Tanks to be Monitored with Liquid Observation Wells," SD-WM-TI-024, Rockwell Hanford Operations, Richland, Washington (June 1982).

5. C. M. Walker, "Process Test Plan for Development of an Interstitial Liquid Level measurement Technique," SD-RE-PTP-002, Rockwell Hanford Operations, Richland, Washington (February 1982).

6. Standard Operating Procedure TO-040-330, "Vertical Dry Well Monitoring with the Computer Controlled Dry Well Van System".

7. Standard Operating Procedure TO-040-340, "Taking Dry Well Readings with the Neutron Probe."

8. C. M. Walker, "Operability Test Procedure for Leak Detection Monitor Van Upgrade," SD-RE-OTP-006, Rockwell Hanford Operations, Richland, Washington (February 1982).

9. J. J. Kirk, "Permeability and Capillarity of Hanford Waste Material and its Limits of Pumpability," RHO-CD-925 (Rev. 2), Rockwell Hanford Operations, Richland, Washington (August 1980).

10. Letter July 6, 1982, B. B. Brenden/G. A. Sandness (BNL) to W. F. Heine, "Evaluation of Liquid Observation Well (LOW) Technology, Final Letter Report, Work Order #CD2144."

11. Technical Report Series 112, "Neutron Moisture Gauges," International Atomic Energy Agency, Vienna, Austria, 1970.

12. V. I. Ferronskiy et al, "Radioisotope Investigative Methods in Engineering Geology and Hydrogeology," Moscow, 1968 (translation).

13. B. A. Higley, "Criteria for Liquid Observation Well (LOW) Monitoring of the Hanford Single-Shell High Level Waste Tanks," SD-WM-TI-007, Rockwell Hanford Operations, Richland, Washington (May 1982).

14. R. G. Geier, "Criteria - Waste Tank Dome Elevator Surveys", ARH-CD-407, Atlantic Richfield Hanford Company, Richland, Washington (August 11, 1975).

SECTION II

FIGURES

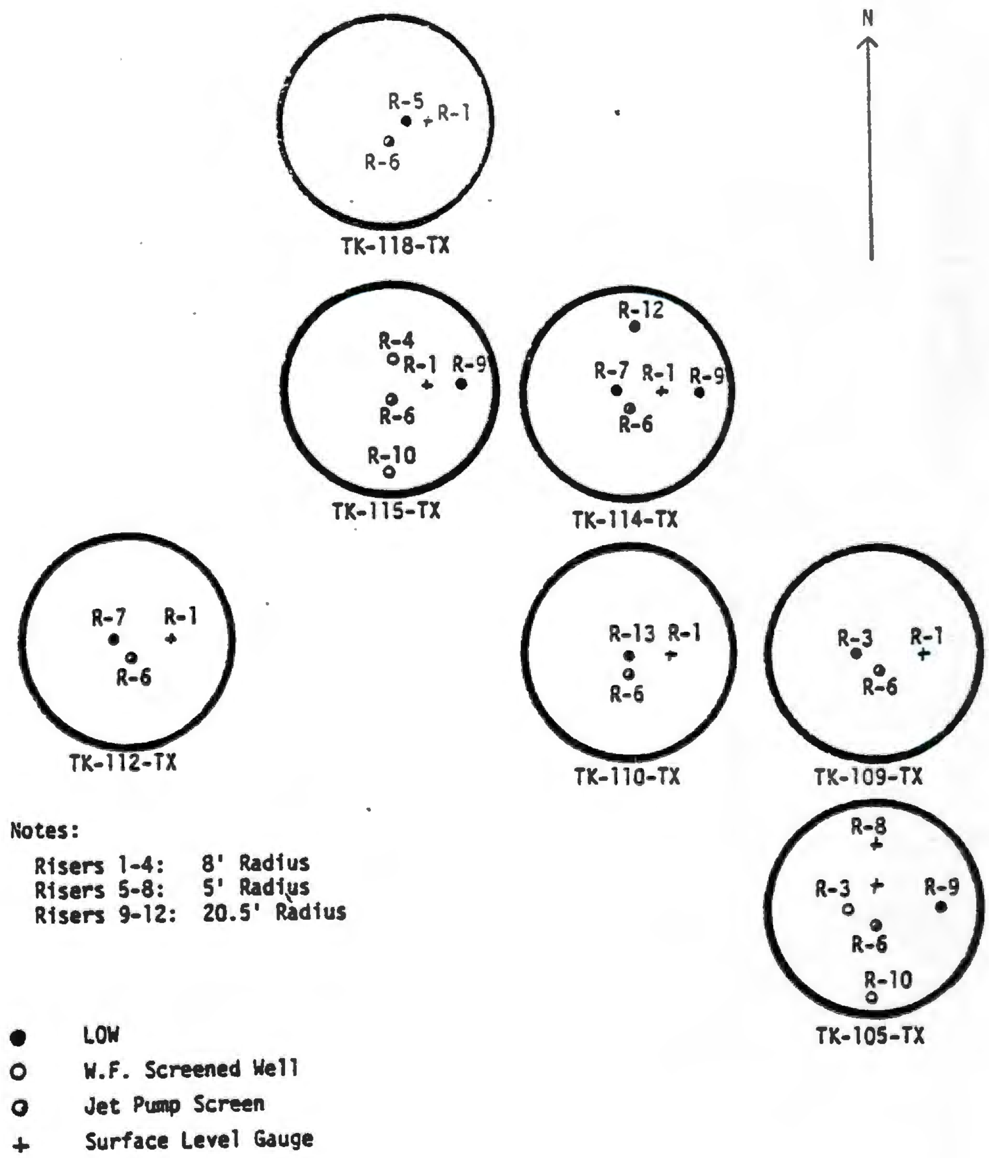


FIGURE 1A: Tank Dome Plans - Locations of Liquid Observation Wells(LOWs) and related Measurement Facilities.

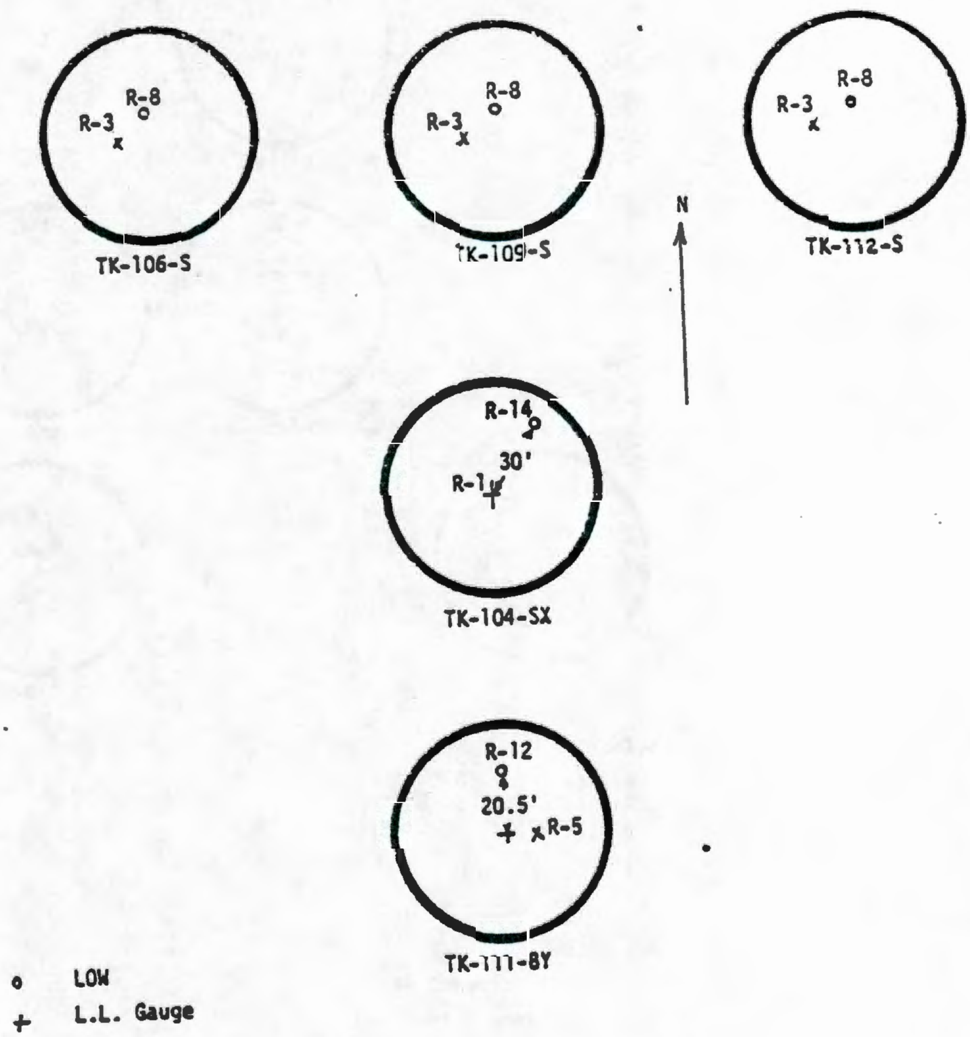


FIGURE 1B: Tank Dome Plans - Locations of Liquid Observation Wells(LOWs) and Related Measurement Facilities

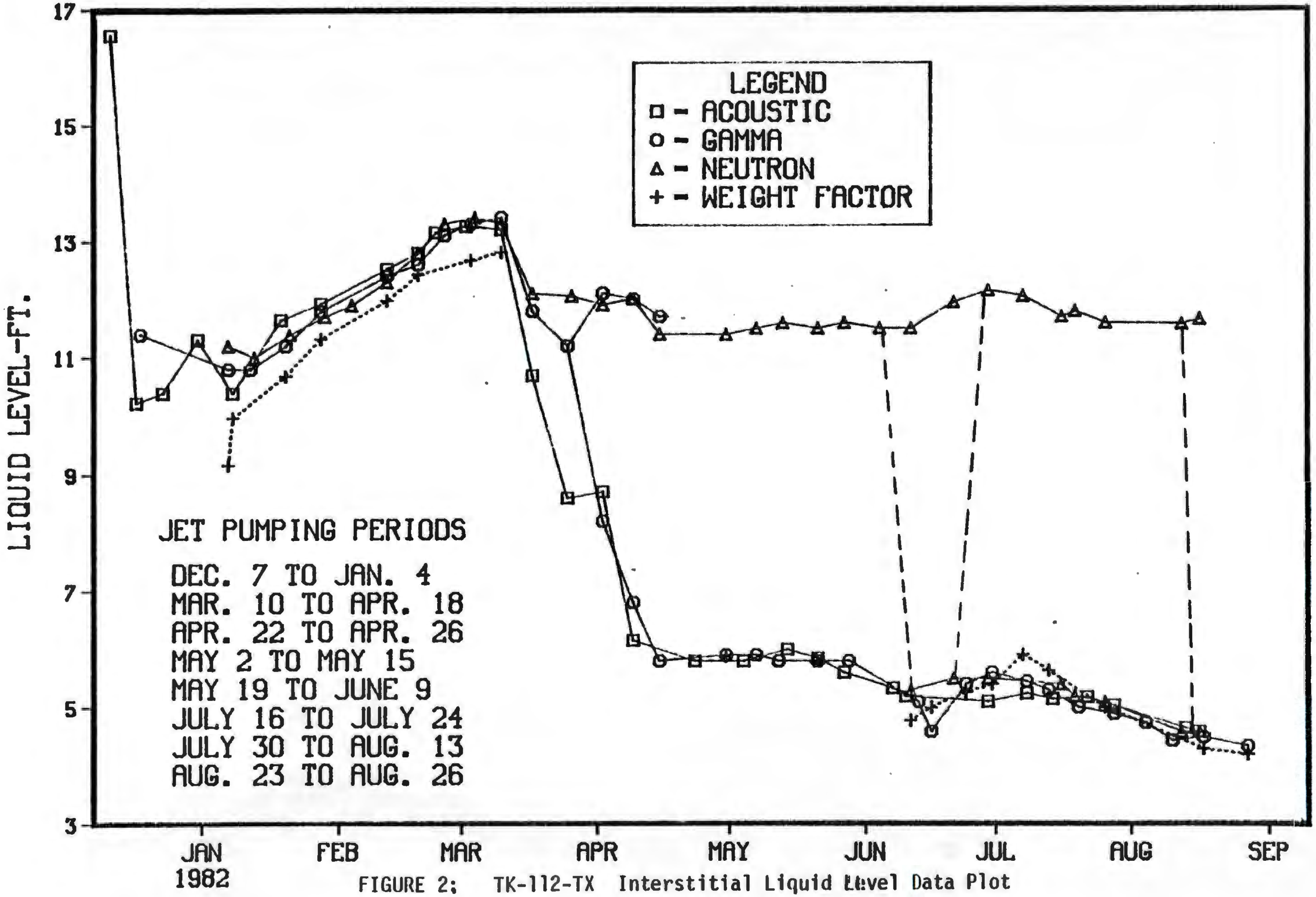


FIGURE 2; TK-112-TX Interstitial Liquid Level Data Plot

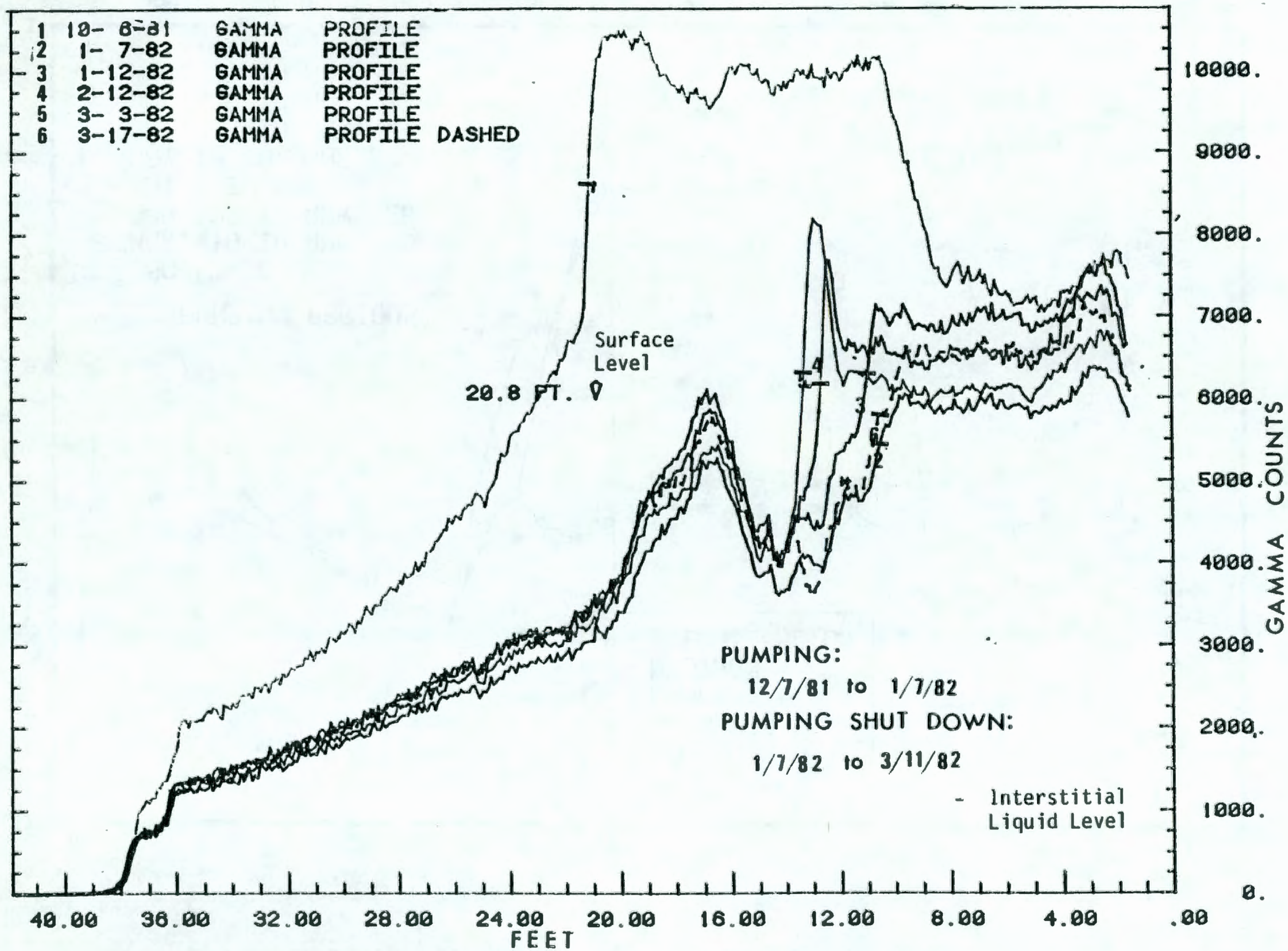


FIGURE 3A: TK-112-TX - Composite of Gamma Scan Profiles

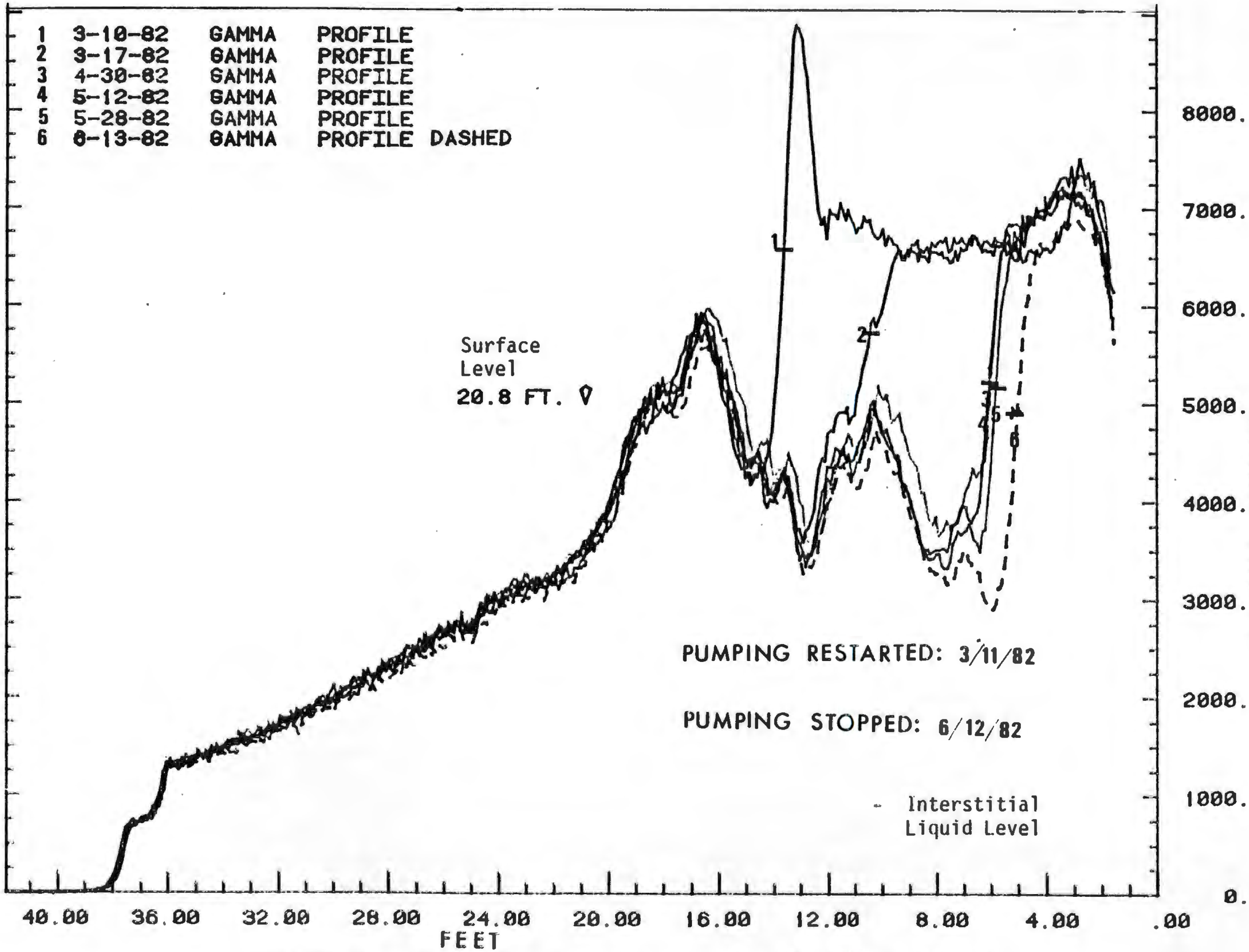


FIGURE 3B: TK-112-TX - Composite Gamma Scan Profiles(continued)

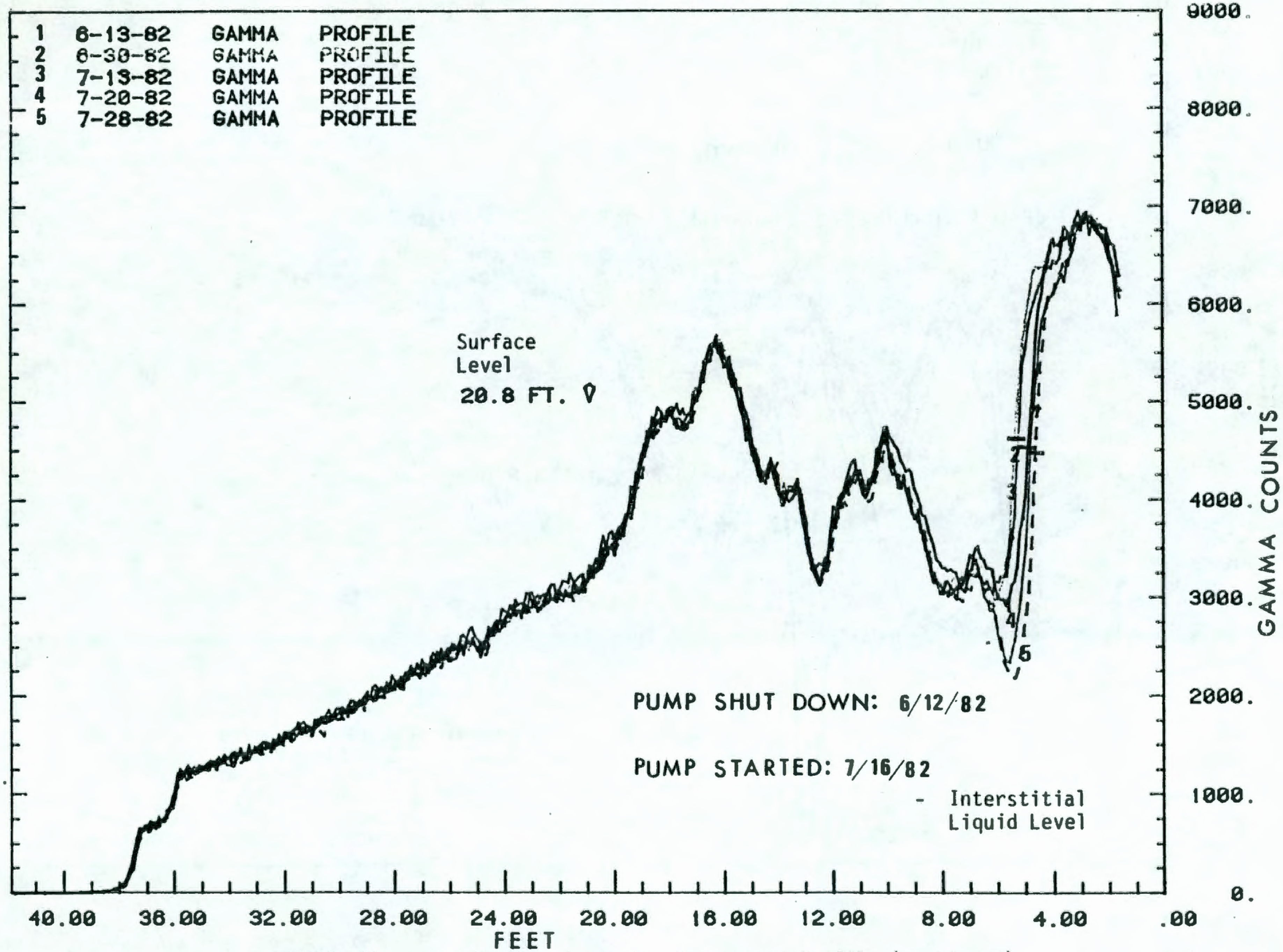


FIGURE 3C: TK-112-TX - Composite Gamma Scan Profiles(continued)

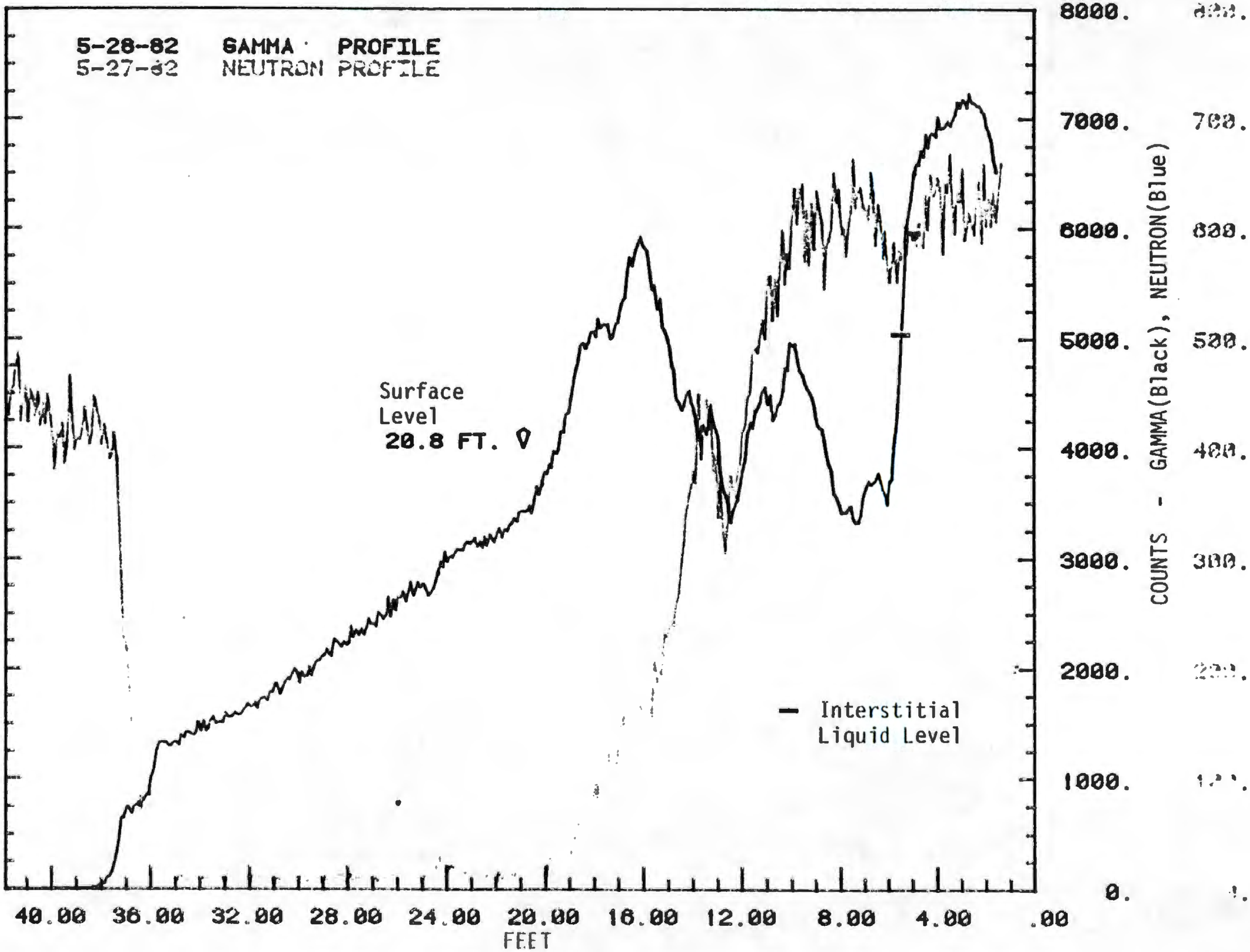


FIGURE 4: Gamma/Neutron Scan Profiles Taken Within 24 Hours
TK 112 TX

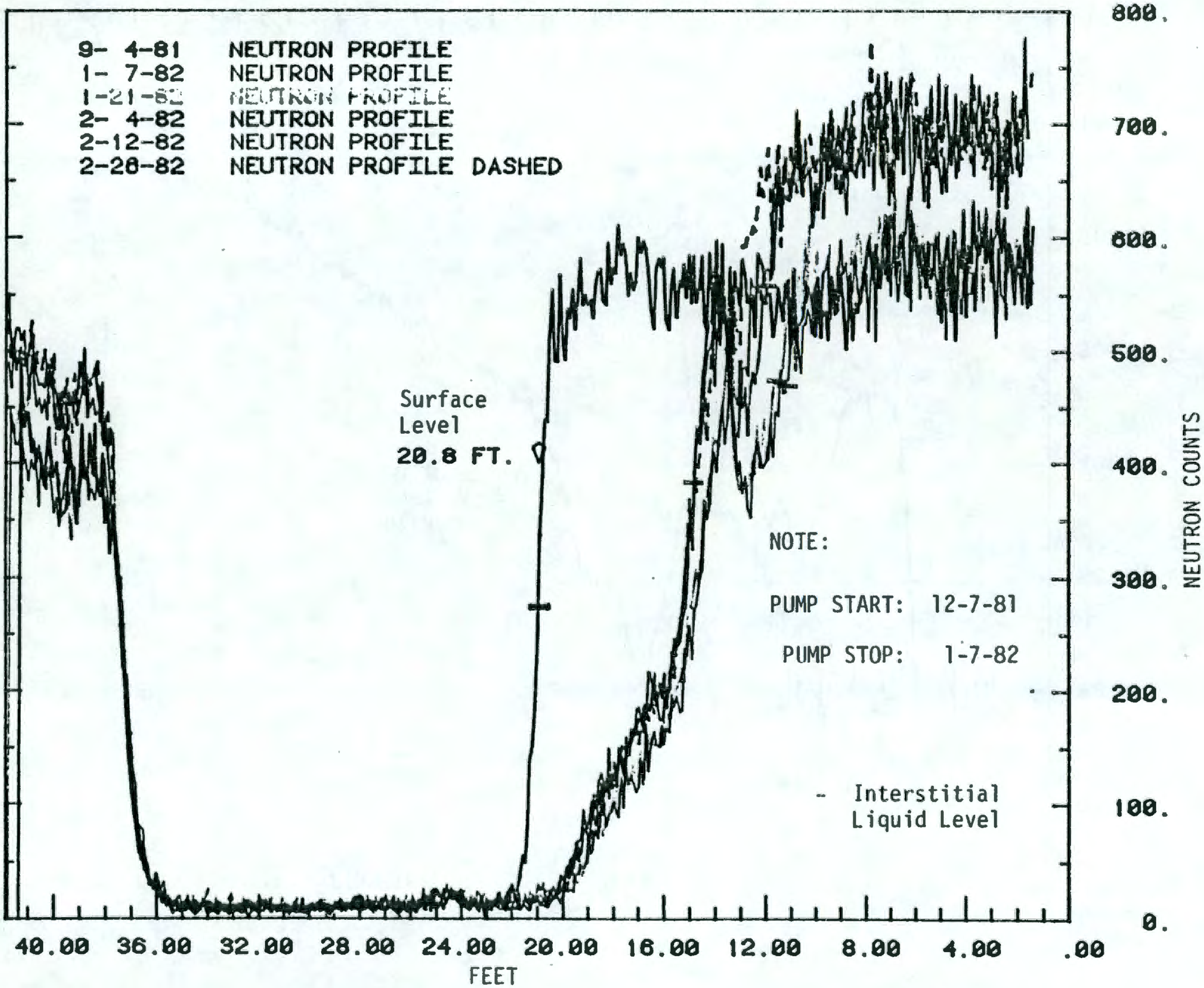


FIGURE 5A: TK-112-TX - Composite Neutron Scan Profiles

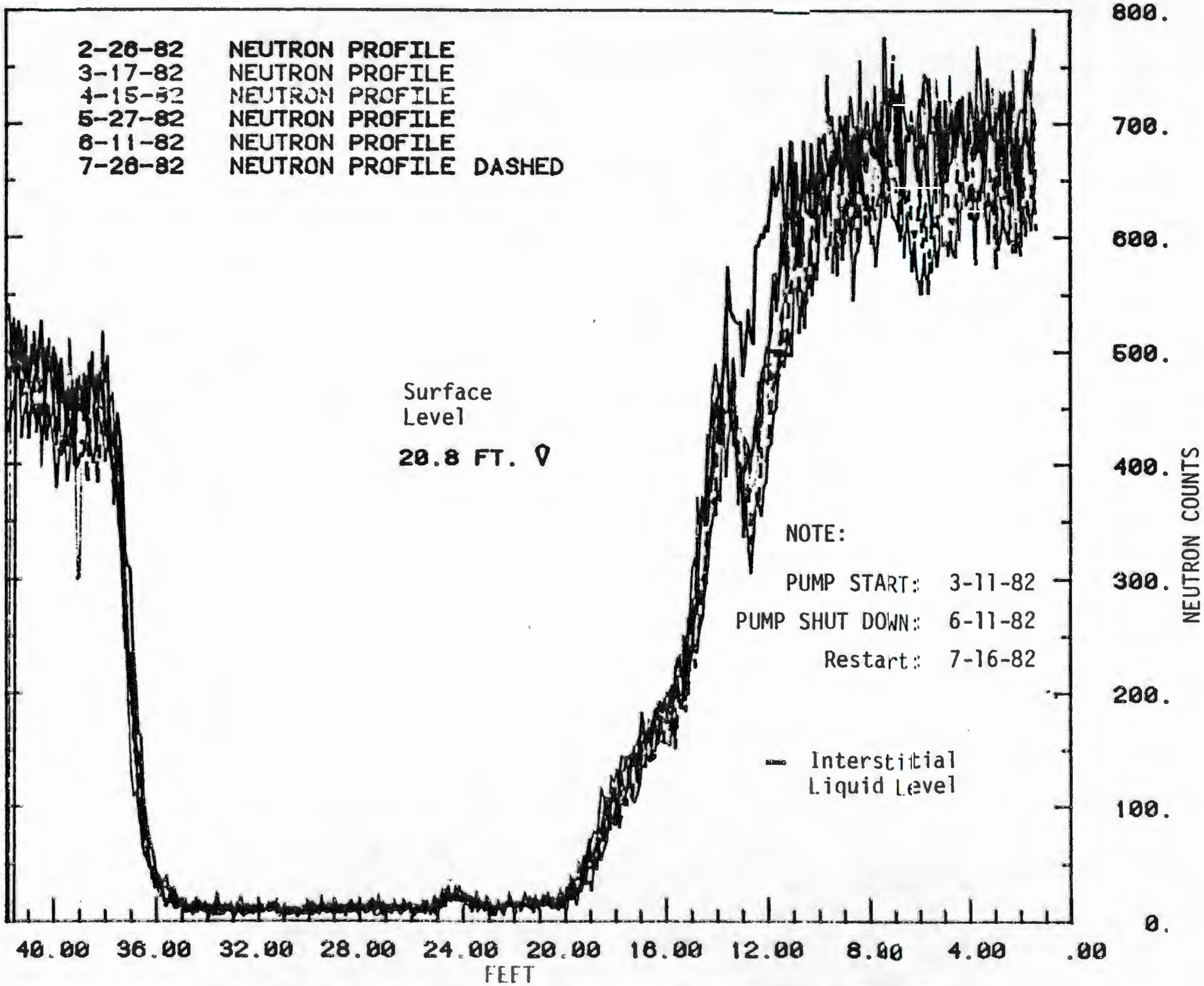


FIGURE 5B: TK-112-TX - Composite Neutron Scan Profiles

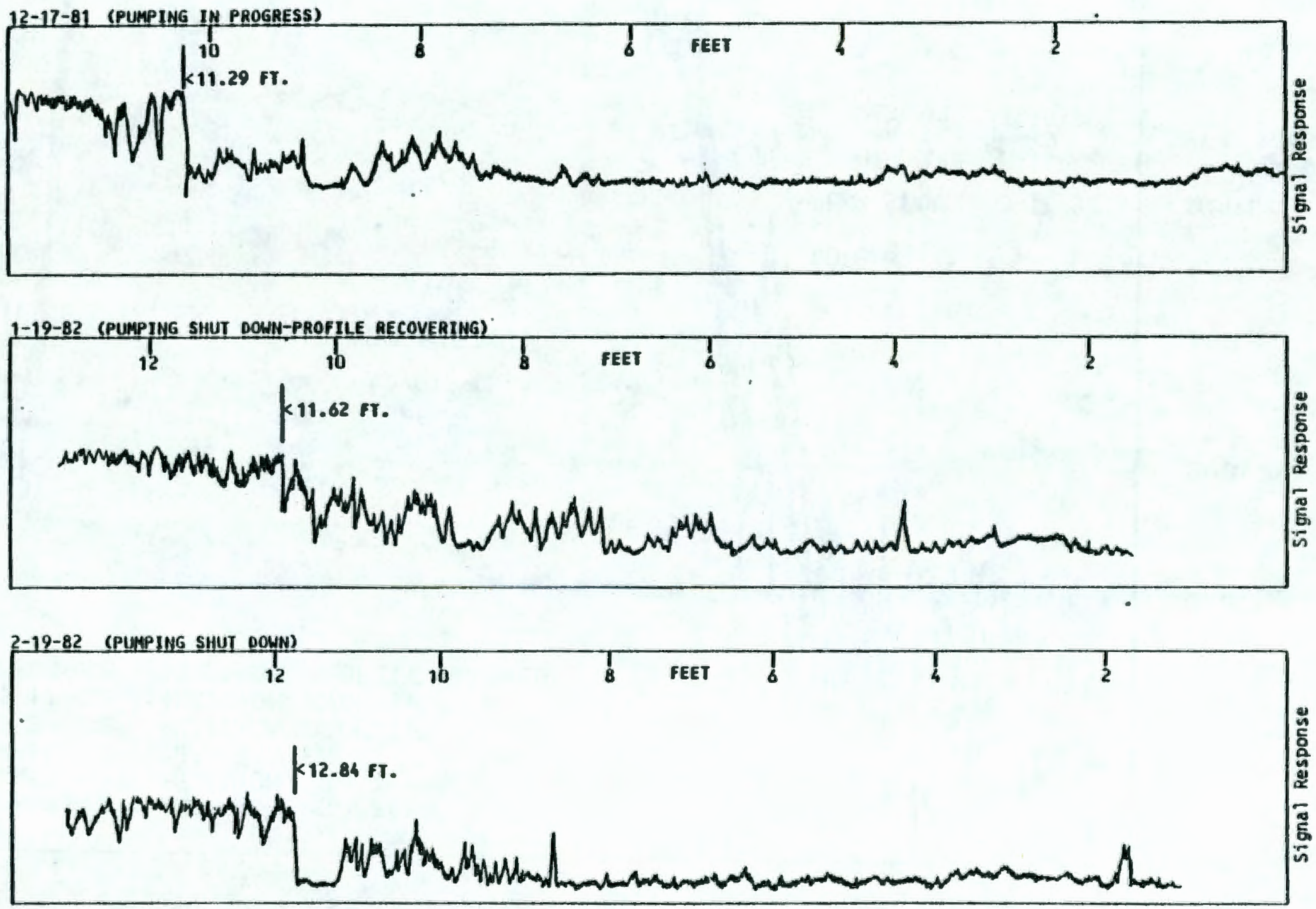


FIGURE 6: TK-112-TX ACOUSTIC PROBE SCANS OFFSET = 1.04 FT.

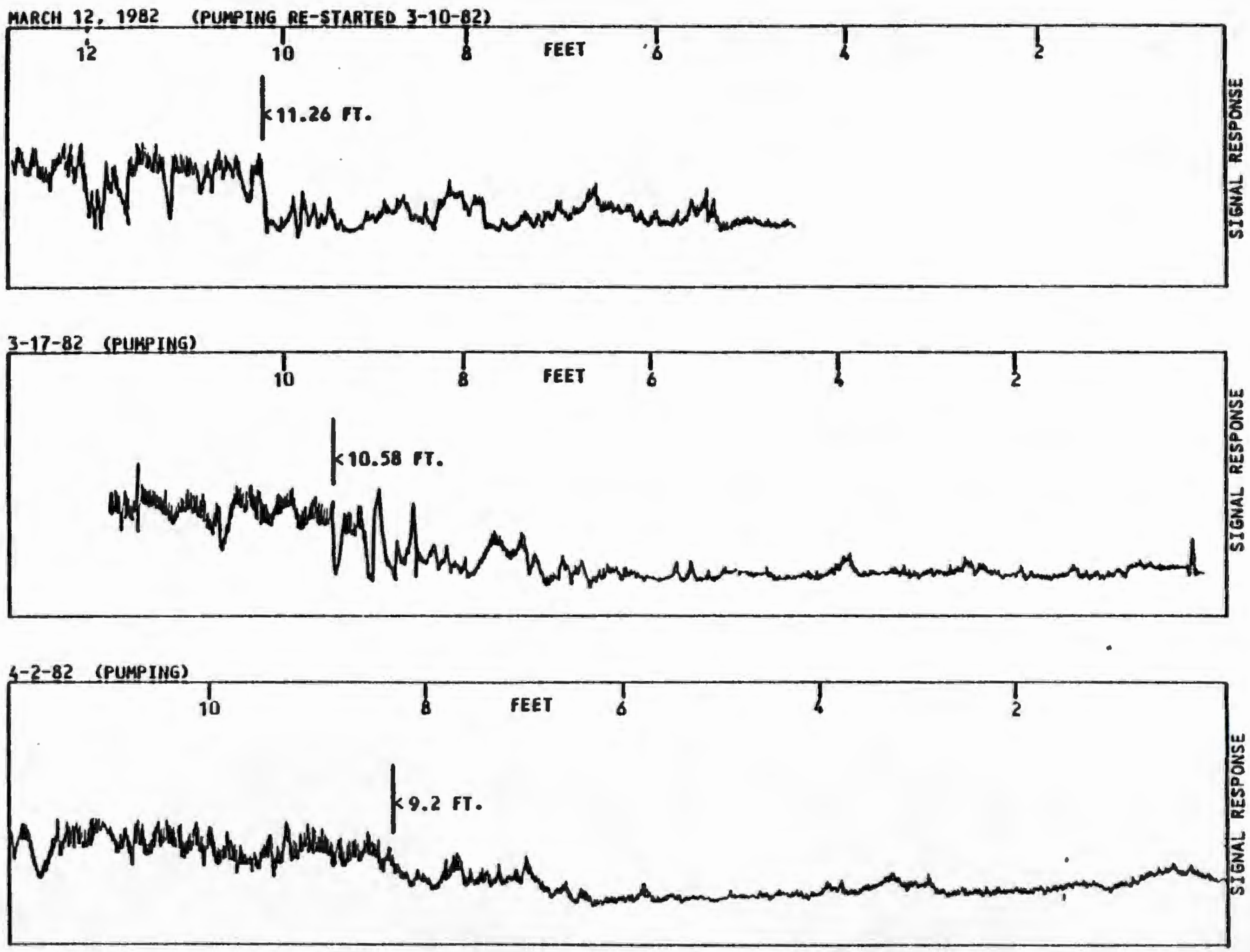


FIGURE 6 (Continued): TK-112-TX ACOUSTIC PROBE SCANS OFFSET = 1.04 FT.

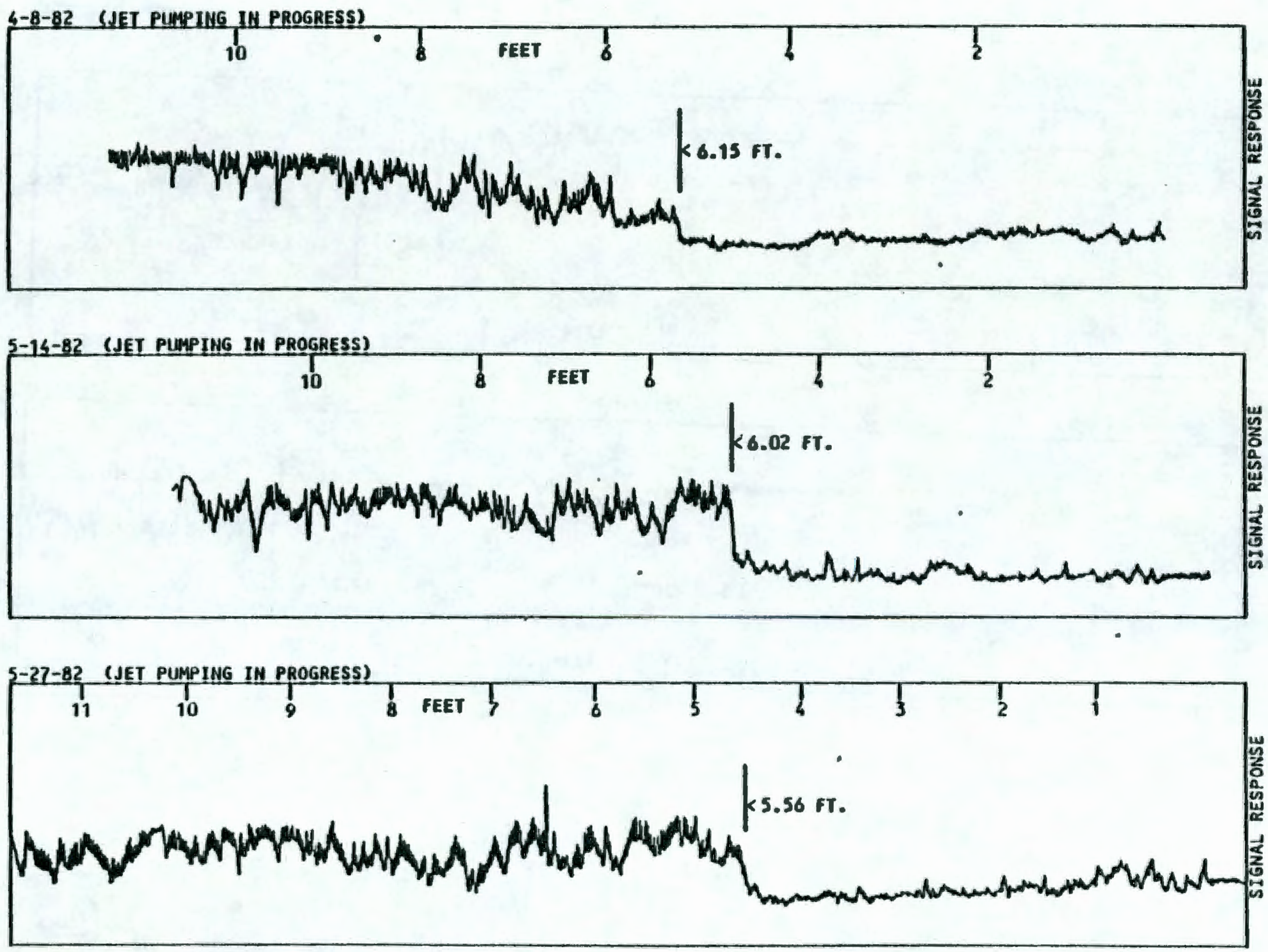


FIGURE 6 (Continued): TK-112-TX ACOUSTIC PROBE SCANS; OFFSET = 1.04 FEET

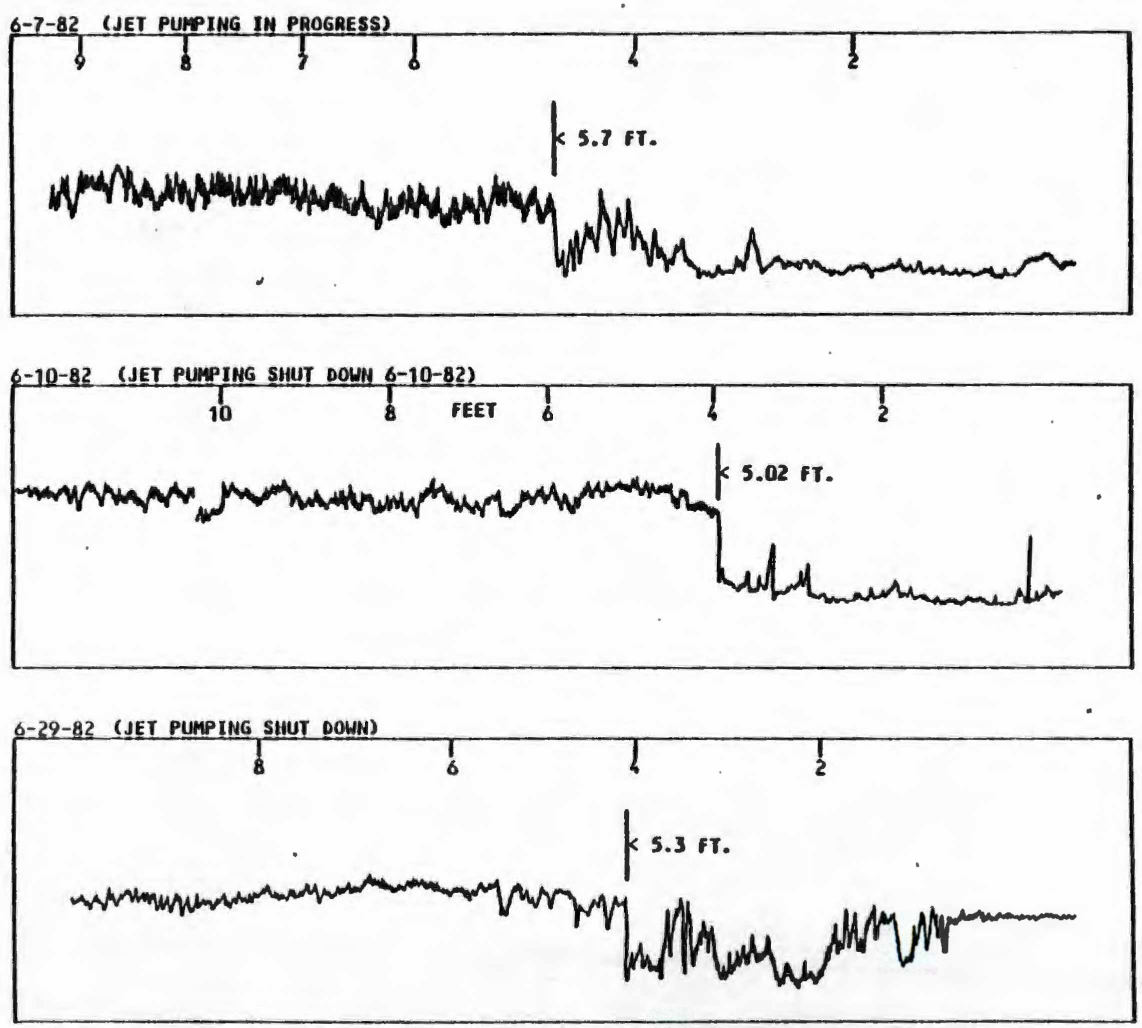


FIGURE 6 (Continued): TK-112-TX ACOUSTIC PROBE SCANS OFFSET = 1.04 FEEET

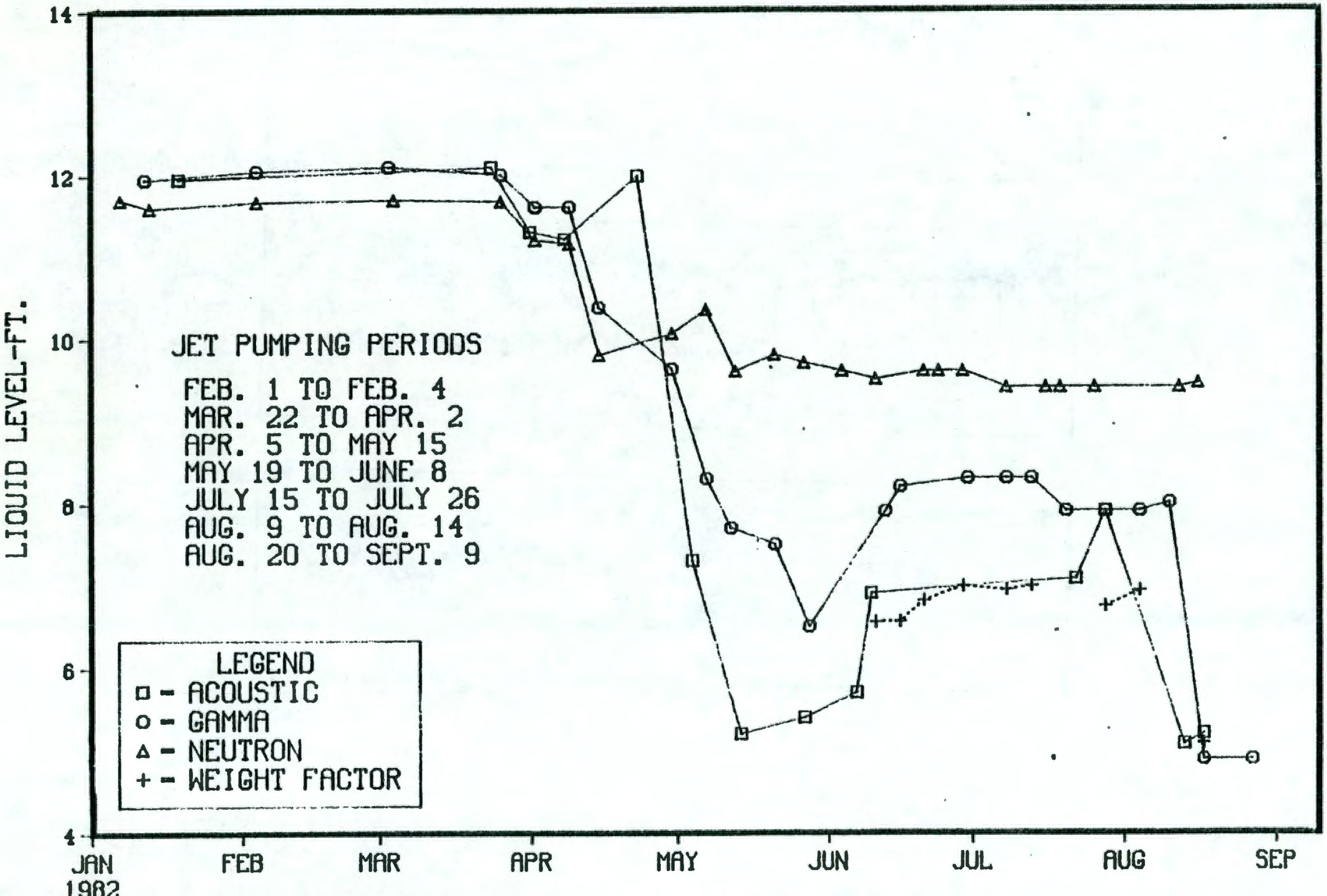


FIGURE 7: TK-118-TX Interstitial Liquid Level Data Plot

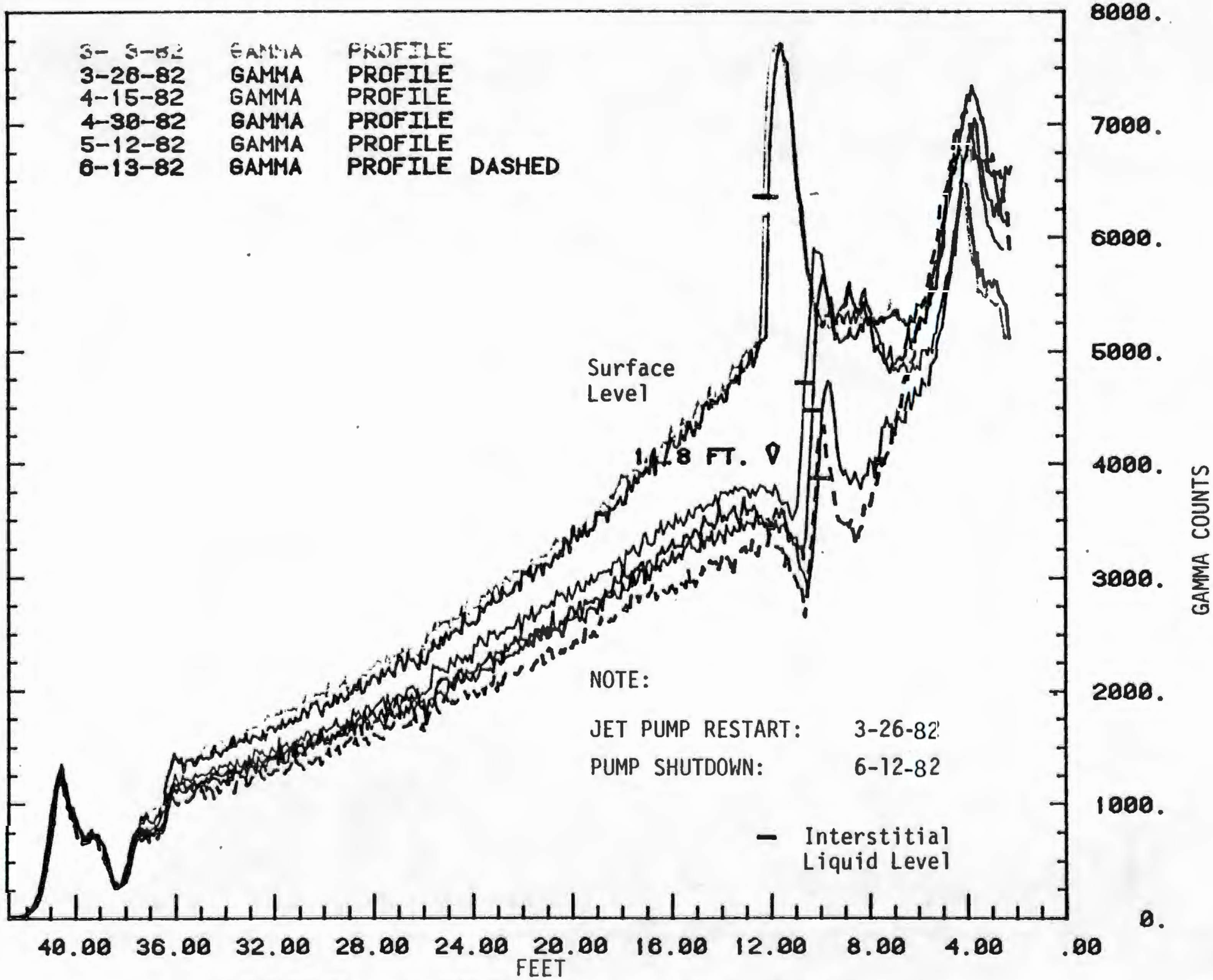


FIGURE 8A: TK-118-TX Gamma Composite Profiles.

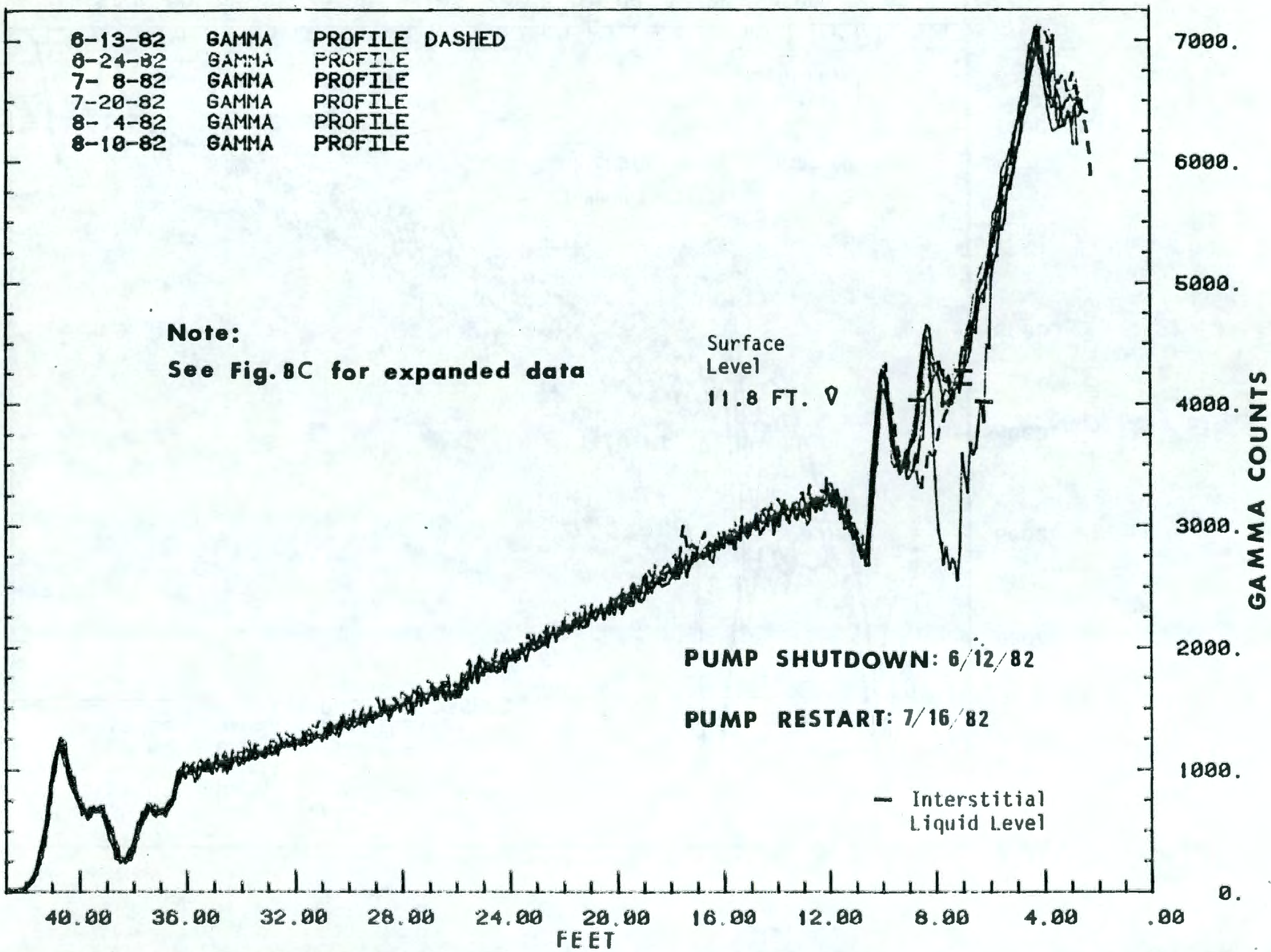


FIGURE 8B: TK -118 - TX Gamma Composite Profiles

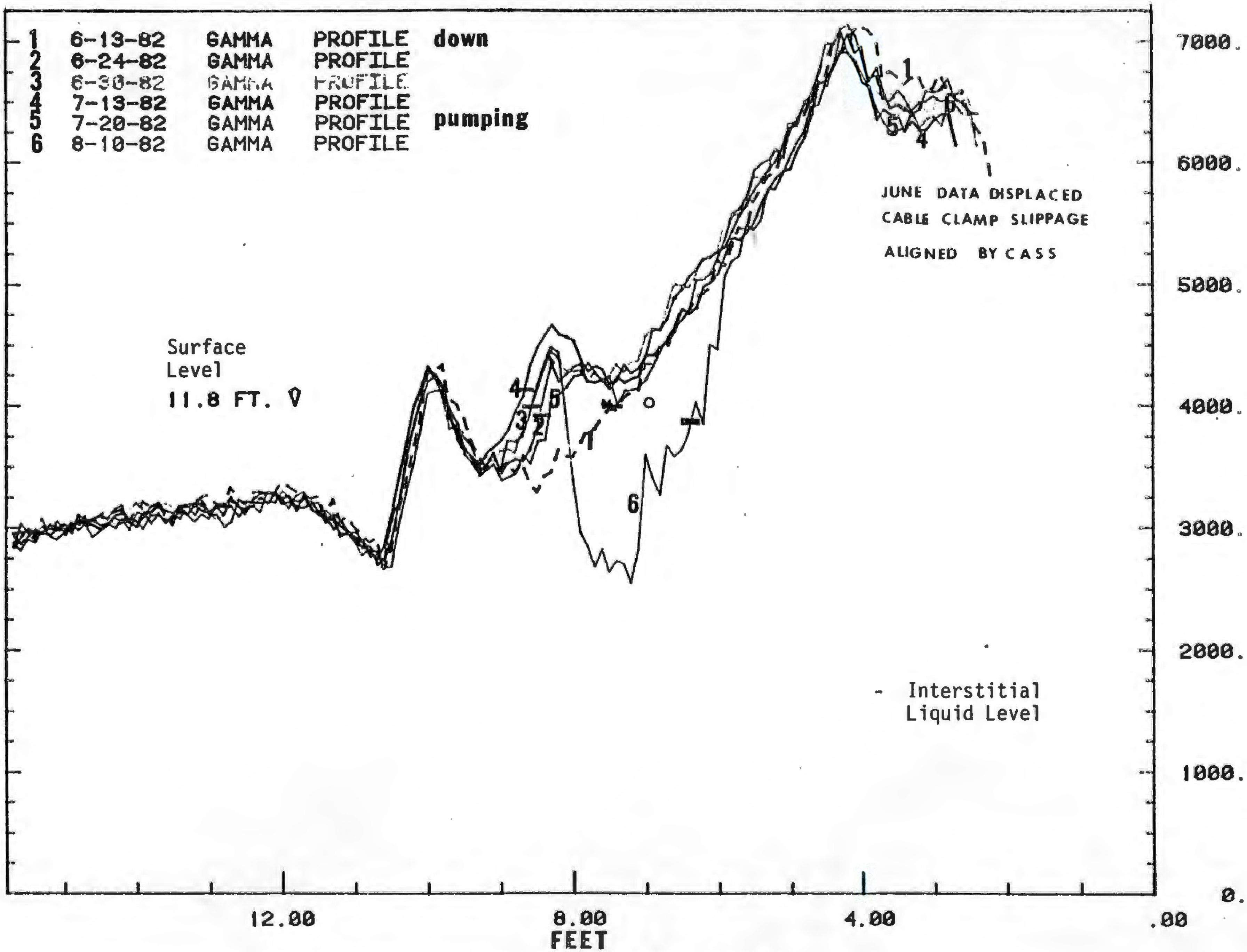


FIGURE 8C: TK-118-TX GAMMA SCANS

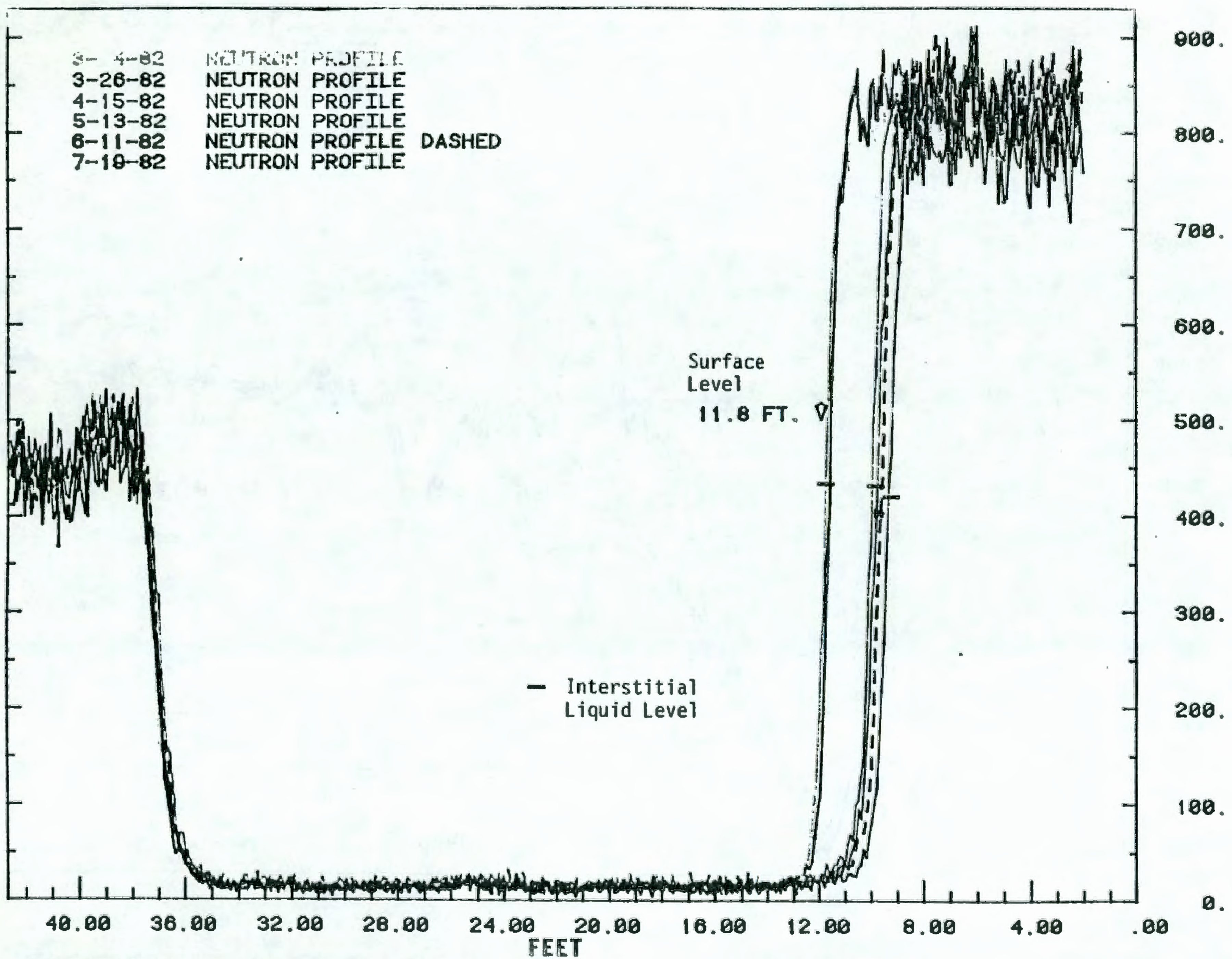


FIGURE 9A: TK-119-TY NEUTRON SCANS

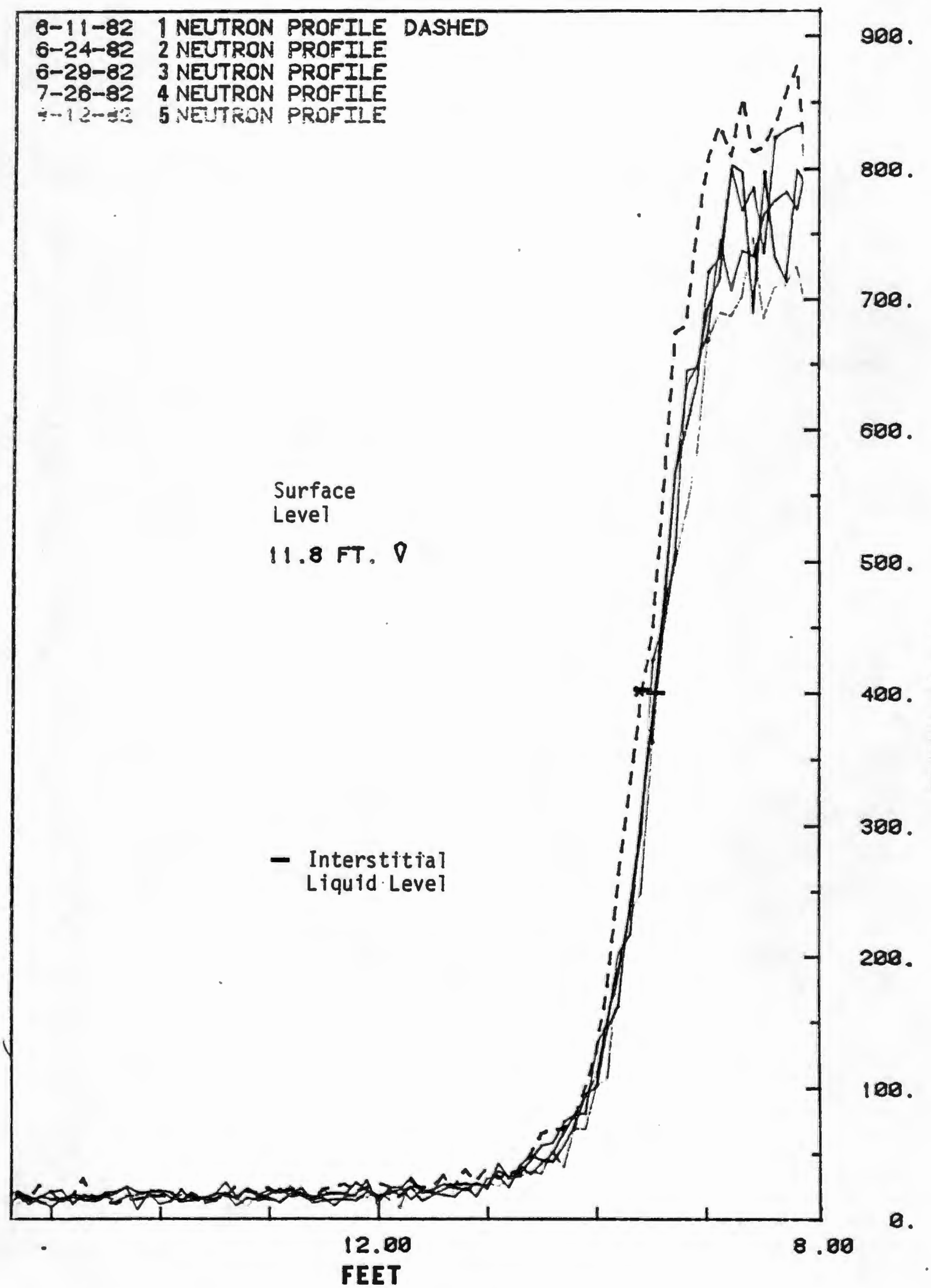


FIGURE 9B: TK-118-TX NEUTRON SCANS

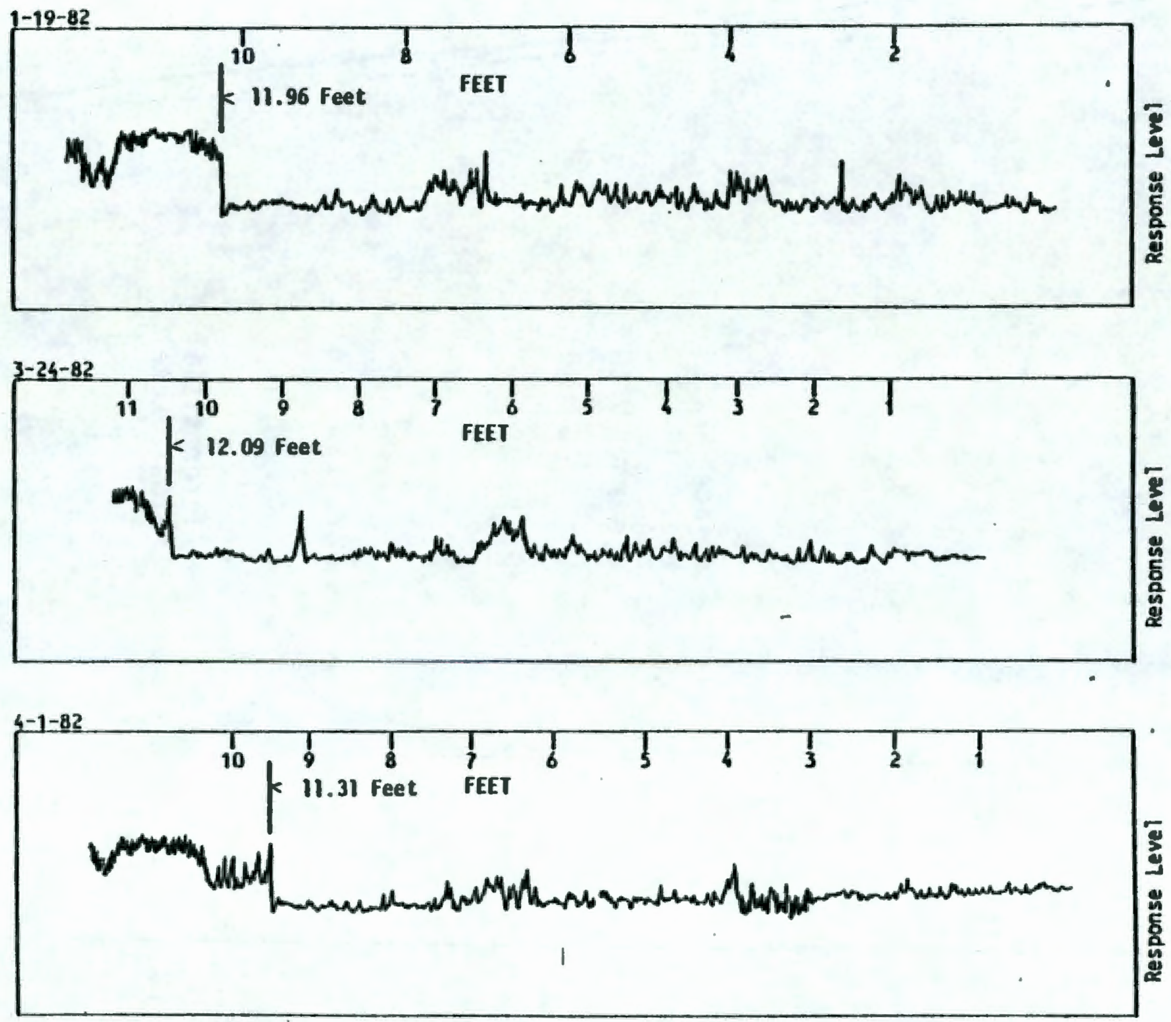


FIGURE 10: ACOUSTIC PROBE SCANS - TK-118-TX; Offset = 1.71 feet

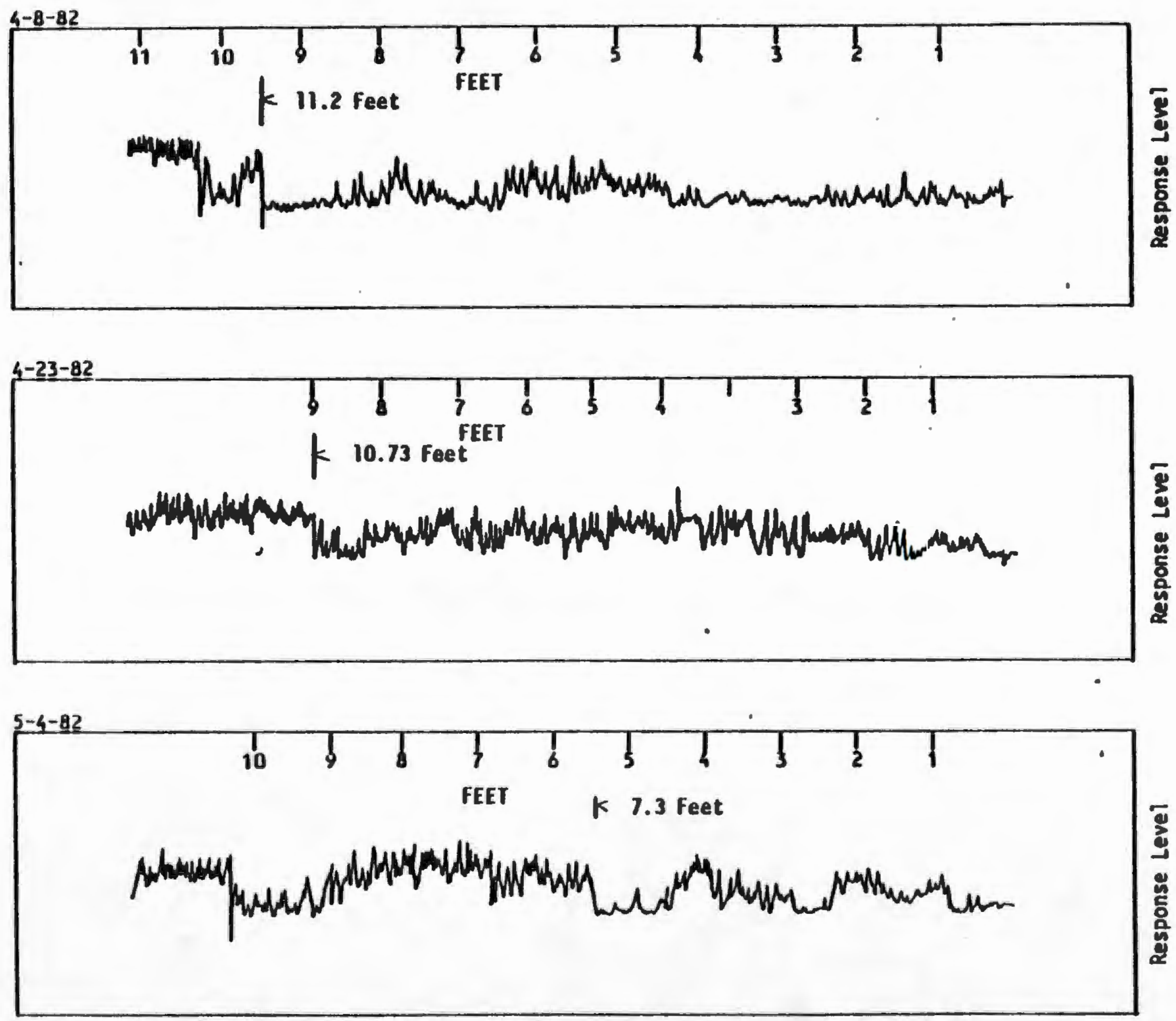


FIGURE 10(continued): Acoustic Probe Scans - TK-118-TX; Offset = 1.71 feet

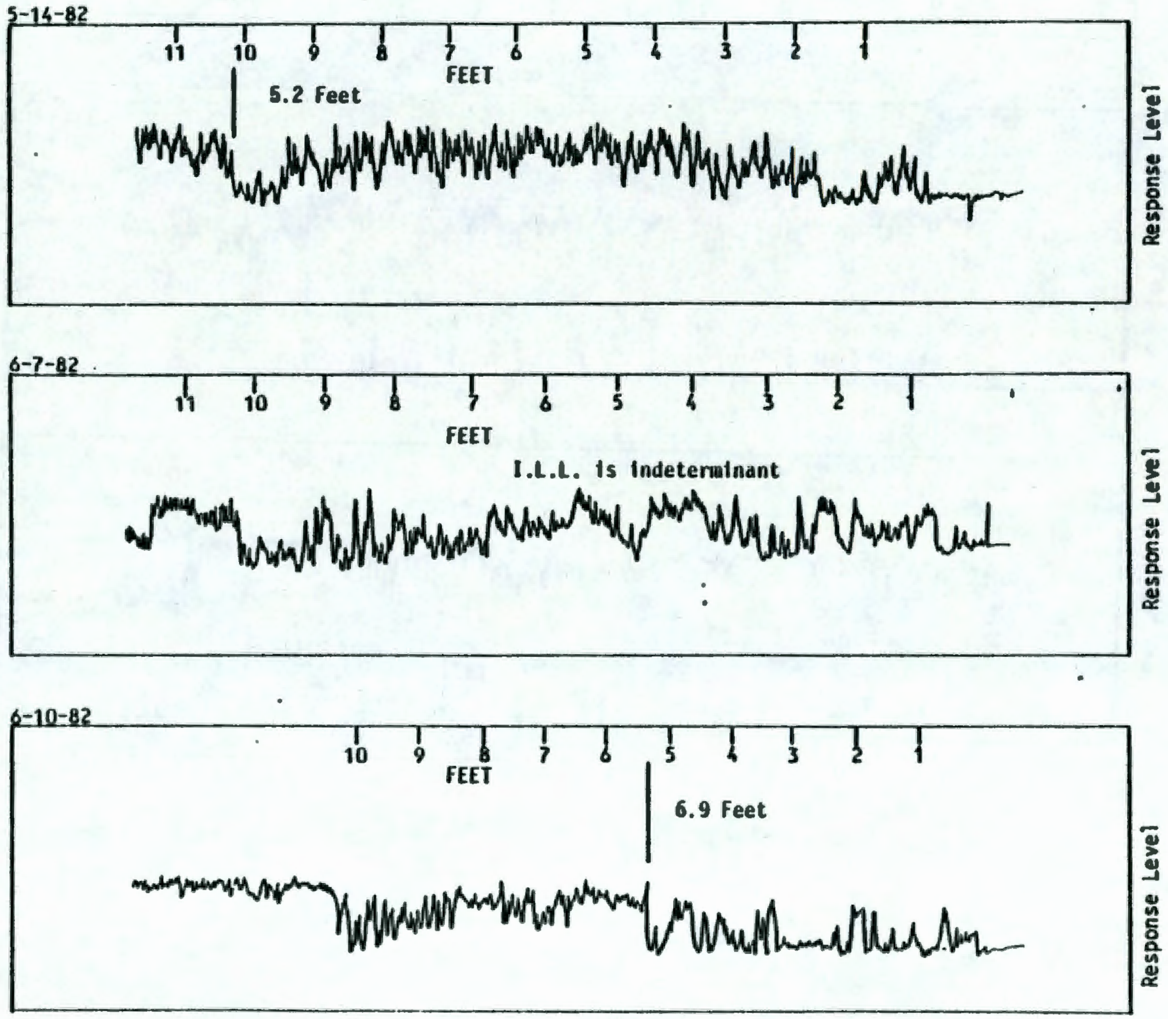


FIGURE 10(continued): Acoustic Probe Scans - TK-118-TX; Offset = 1.71 feet

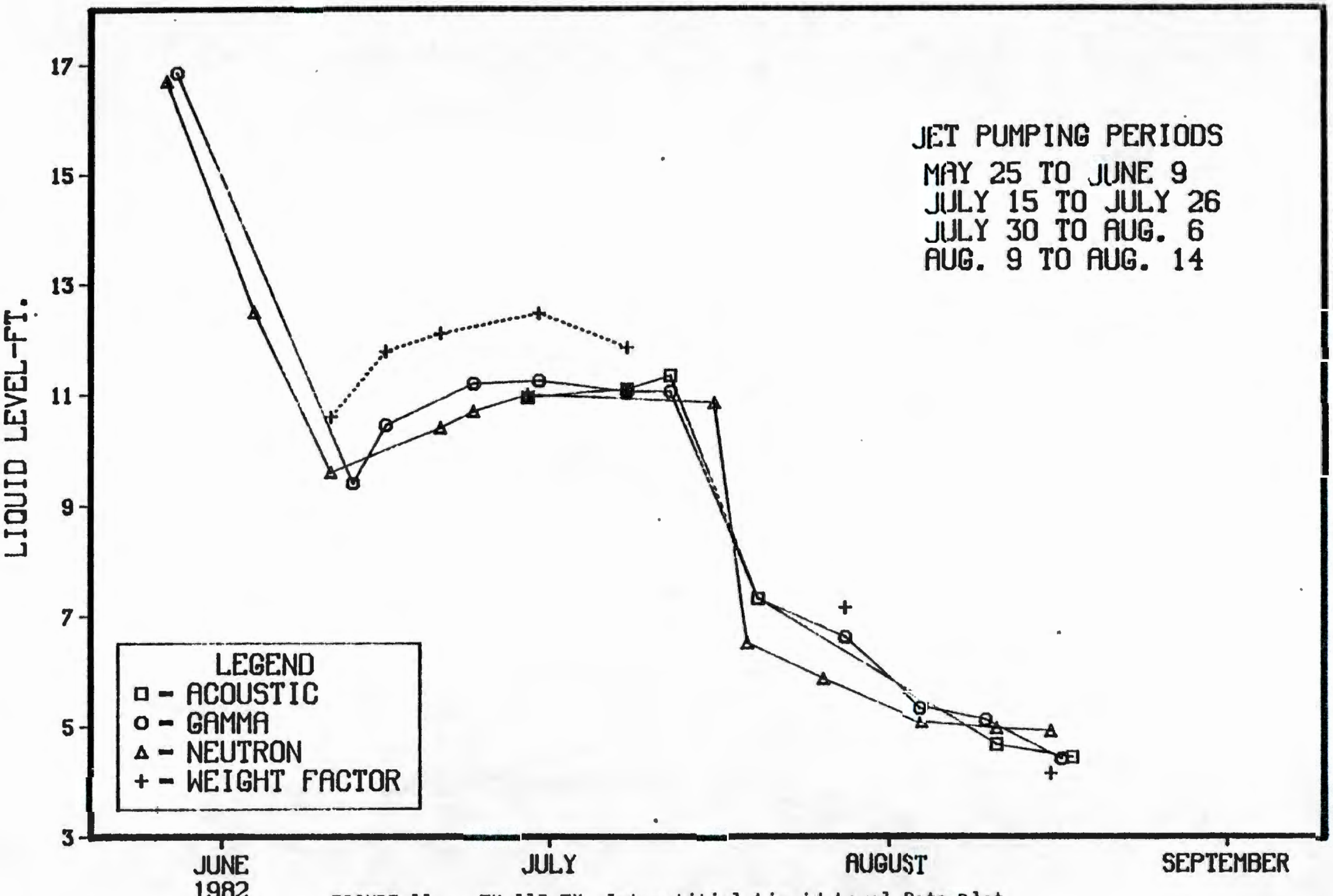


FIGURE 11: TK-116-TX Interstitial Liquid Level Data Plot

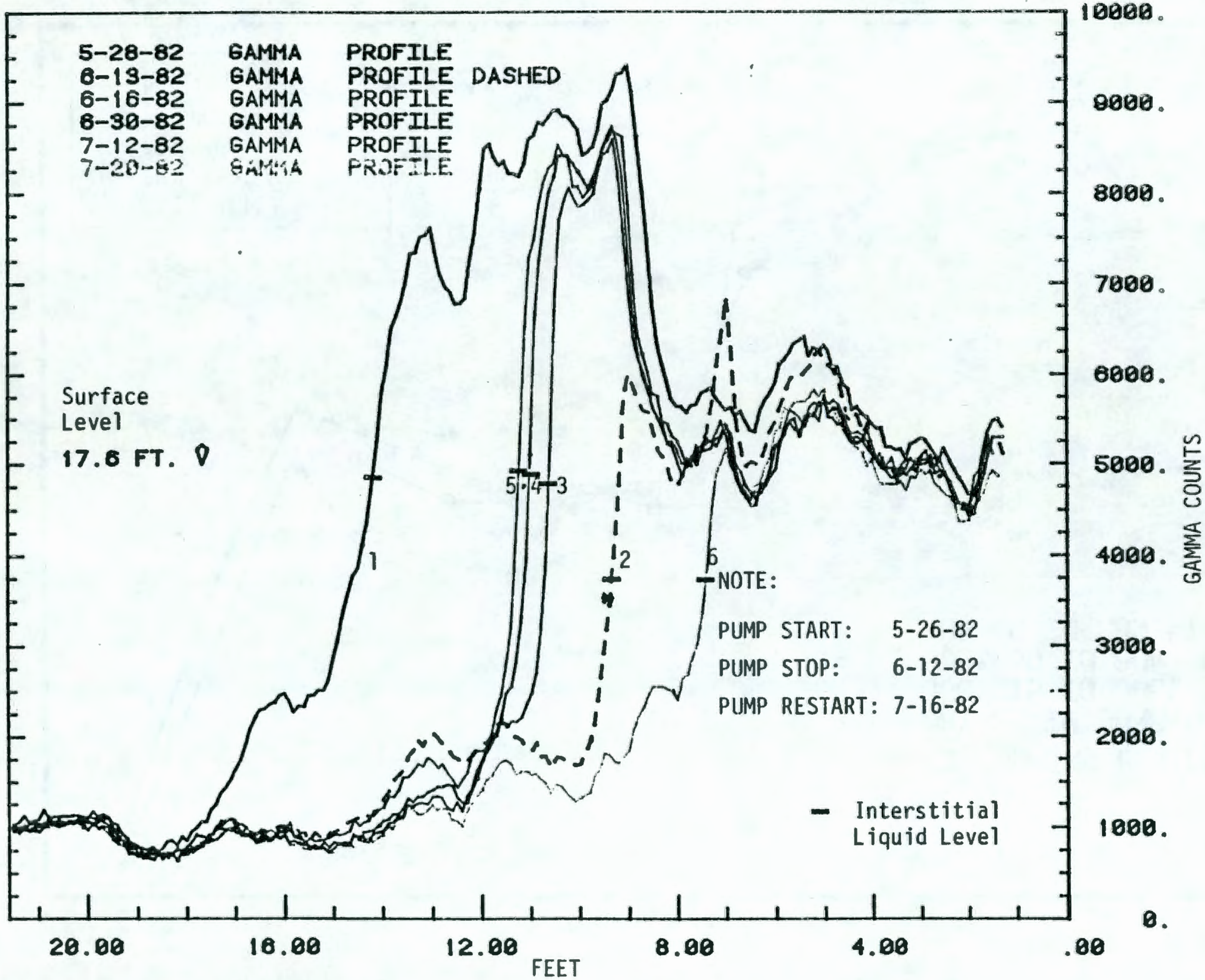


FIGURE 12: Composite of Gamma Scan Profiles - TK-115-TX

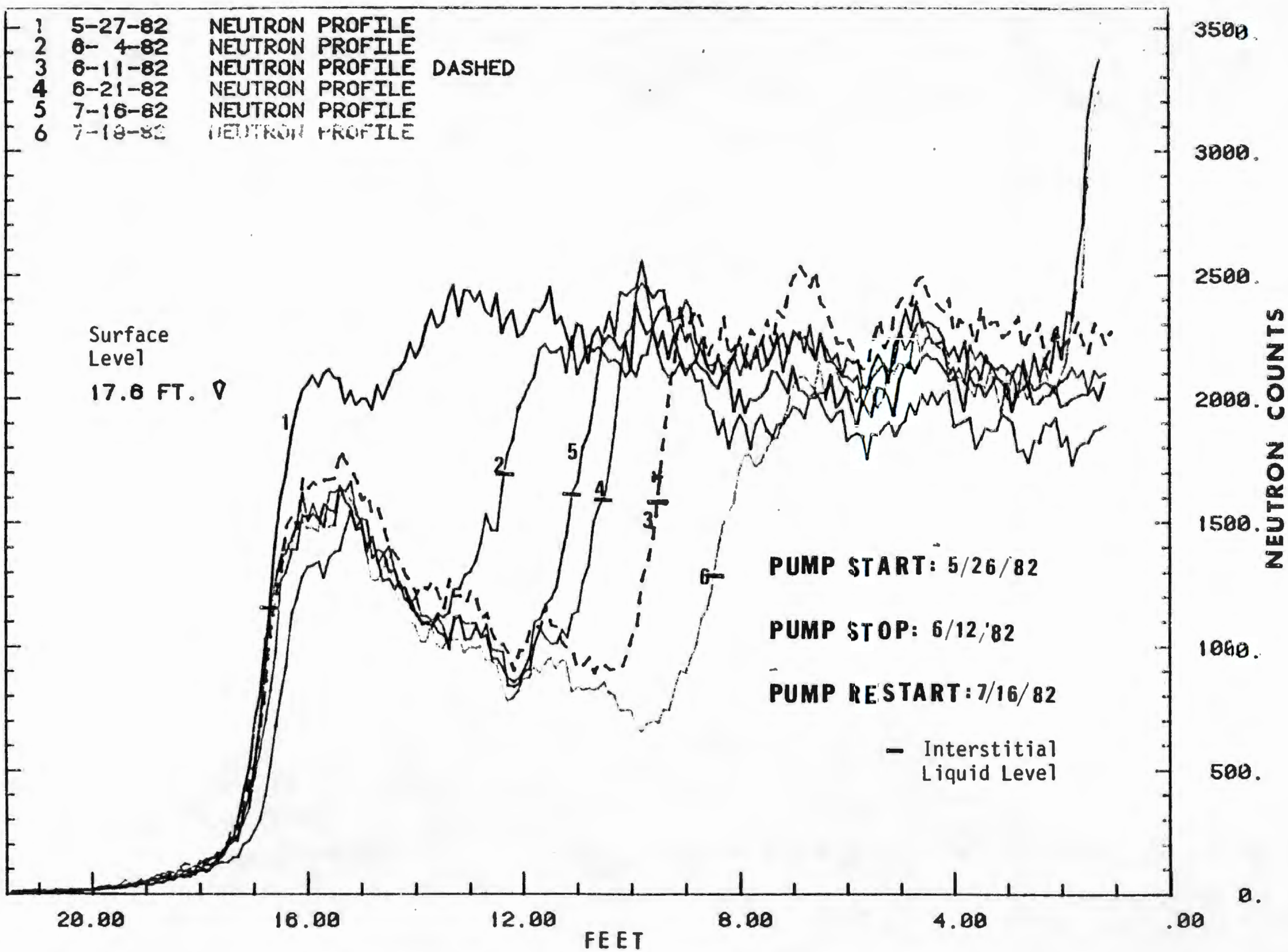


FIGURE 13: Composite of Neutron Scan Profiles TK-115-TX

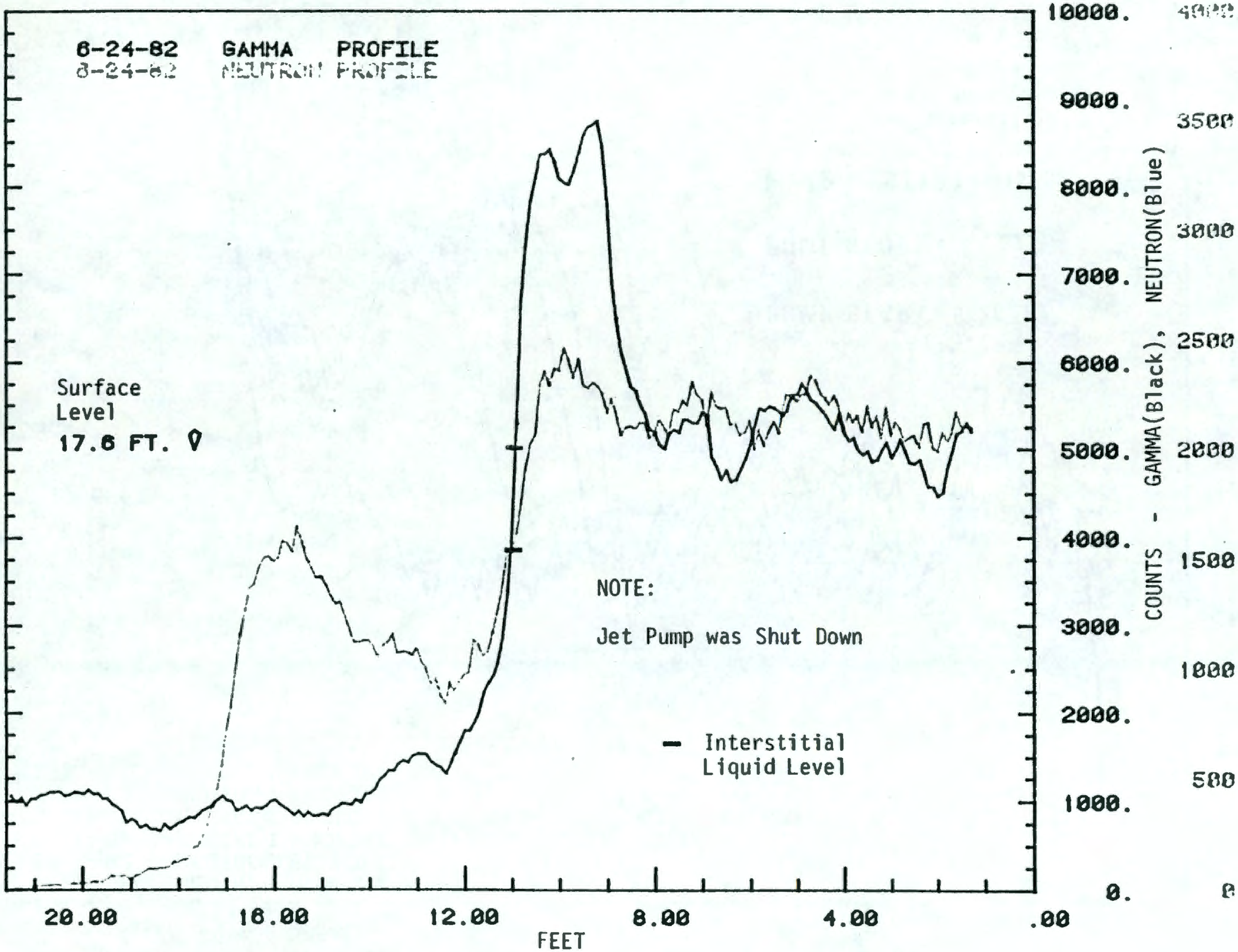


FIGURE 14: Gamma/Neutron Scan Composite - TK-115-TX

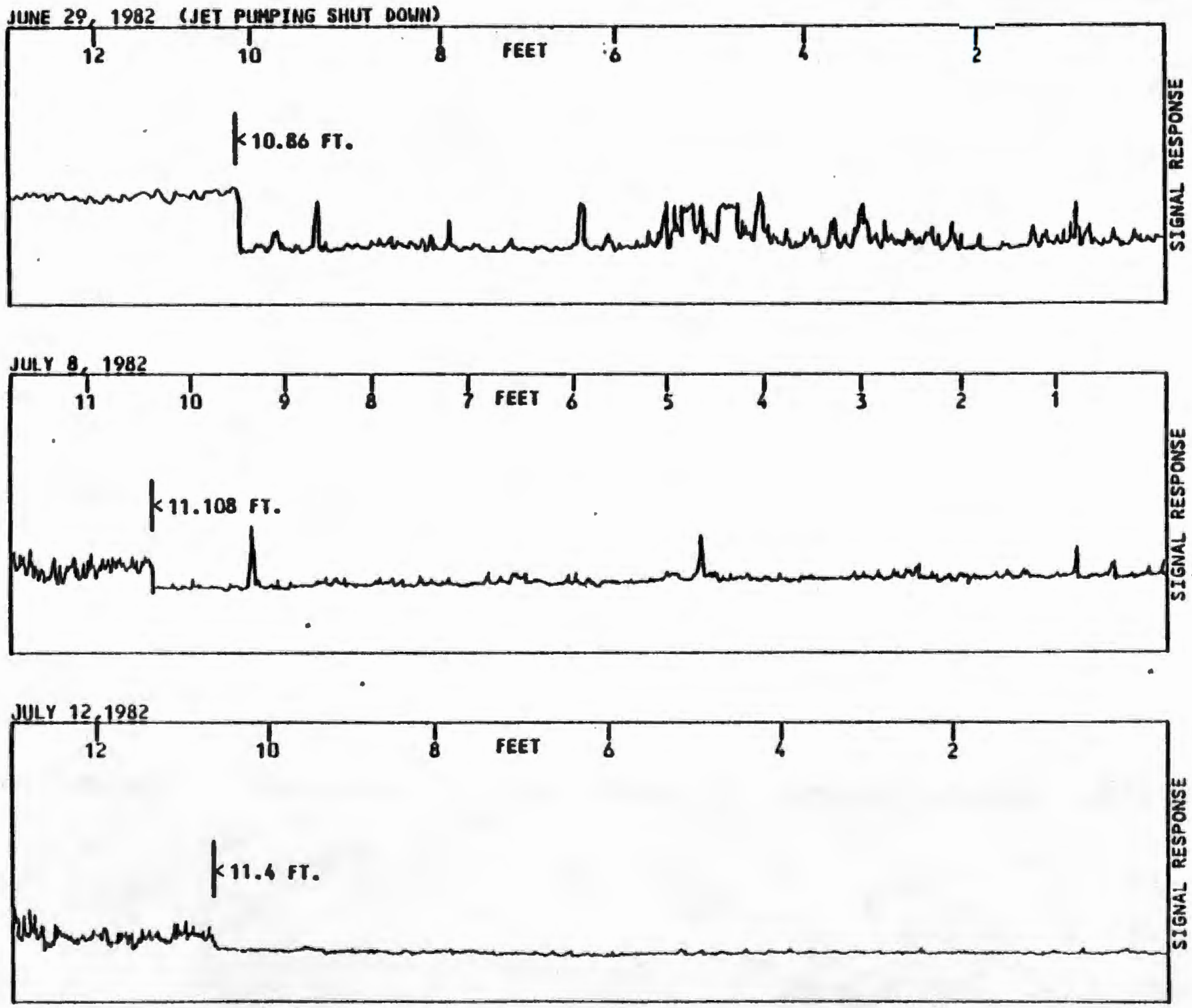


FIGURE 15: TK-115-TX ACOUSTIC PROBE SCANS OFFSET = 0.758 FEET

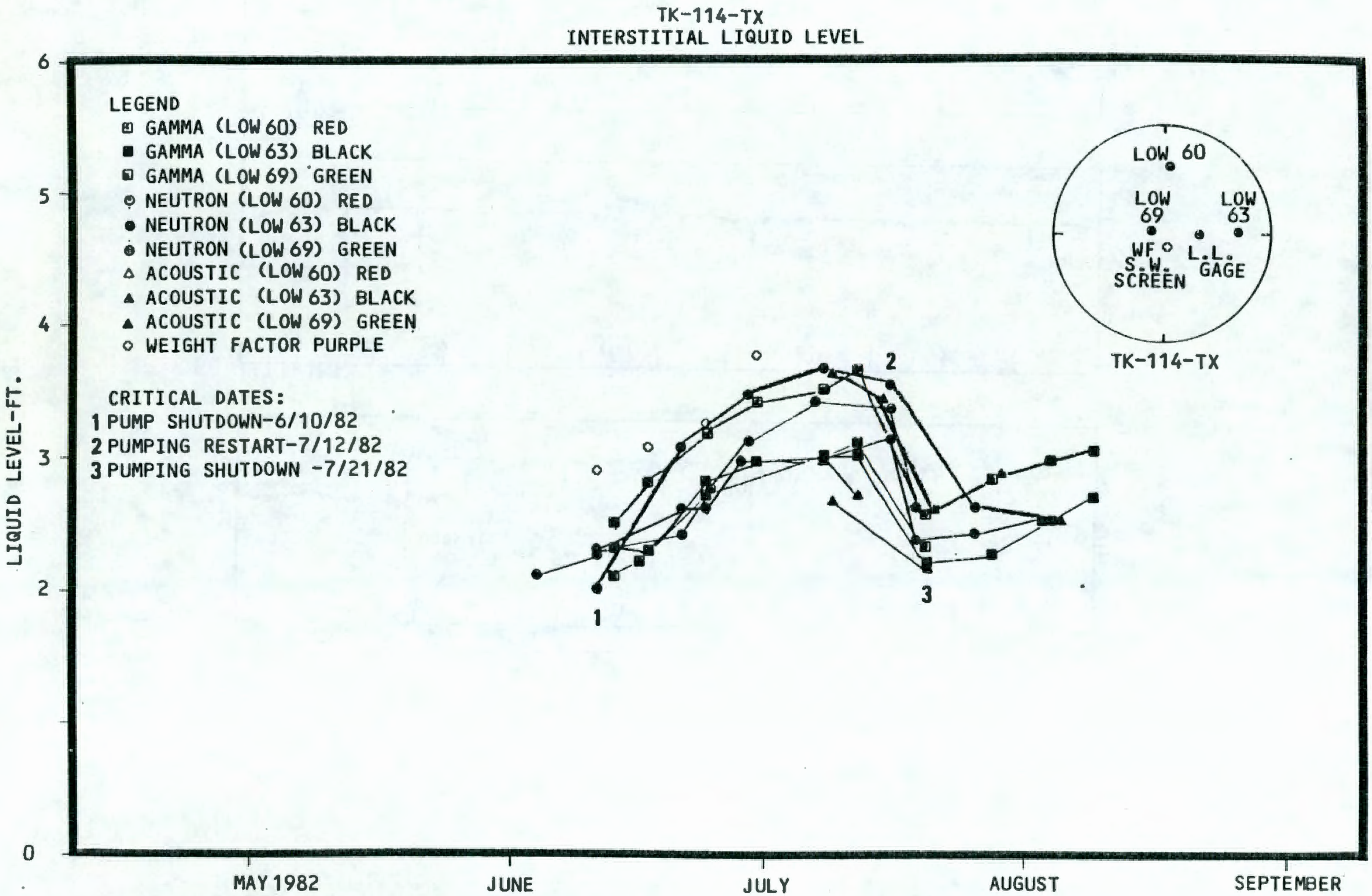


FIGURE 16: TK-114-TX INTERSTITIAL LIQUID LEVEL DATA PLOT

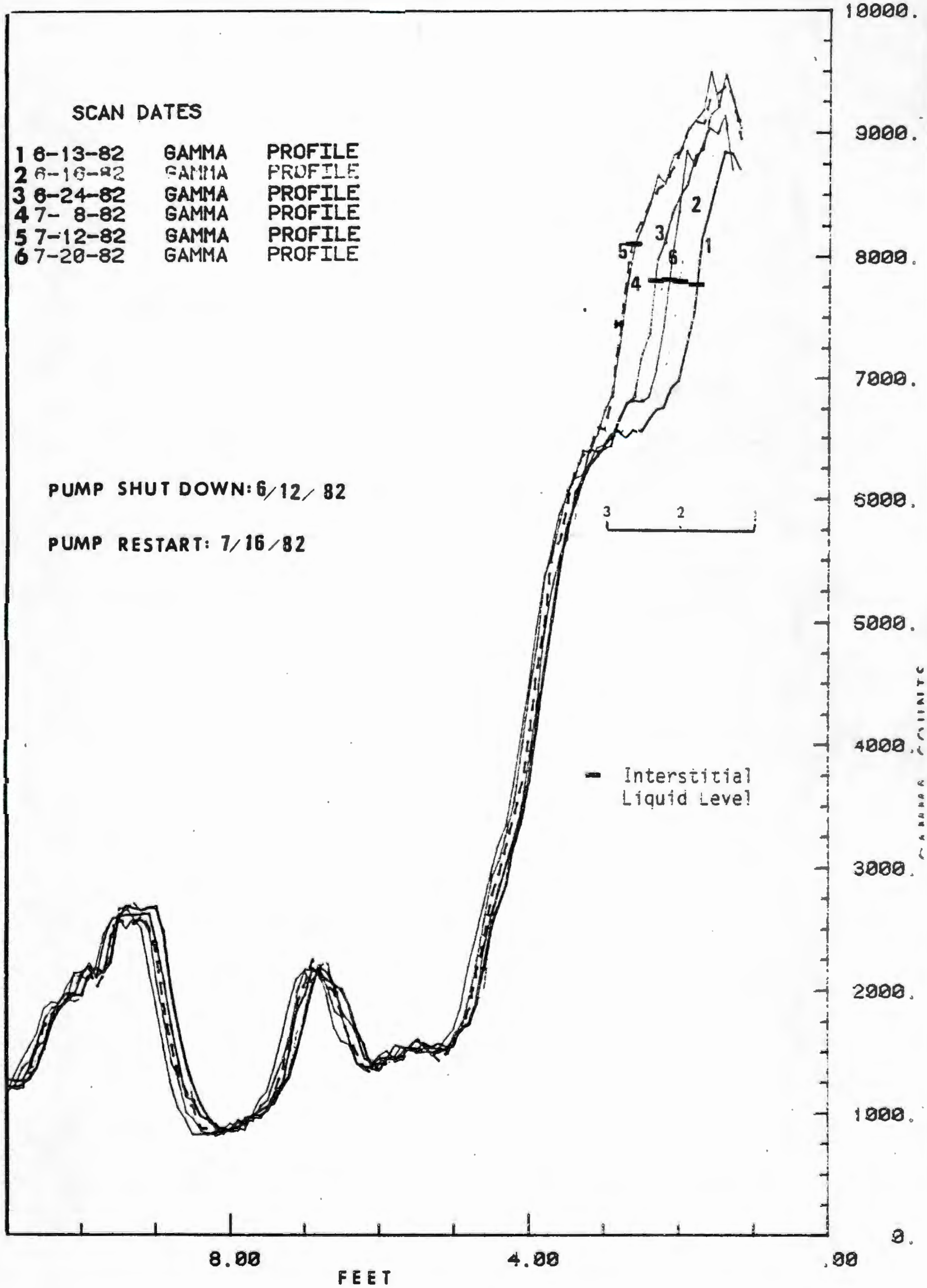


FIGURE 17A: TK-114-TX Gamma Scan Composite: LOW 511460

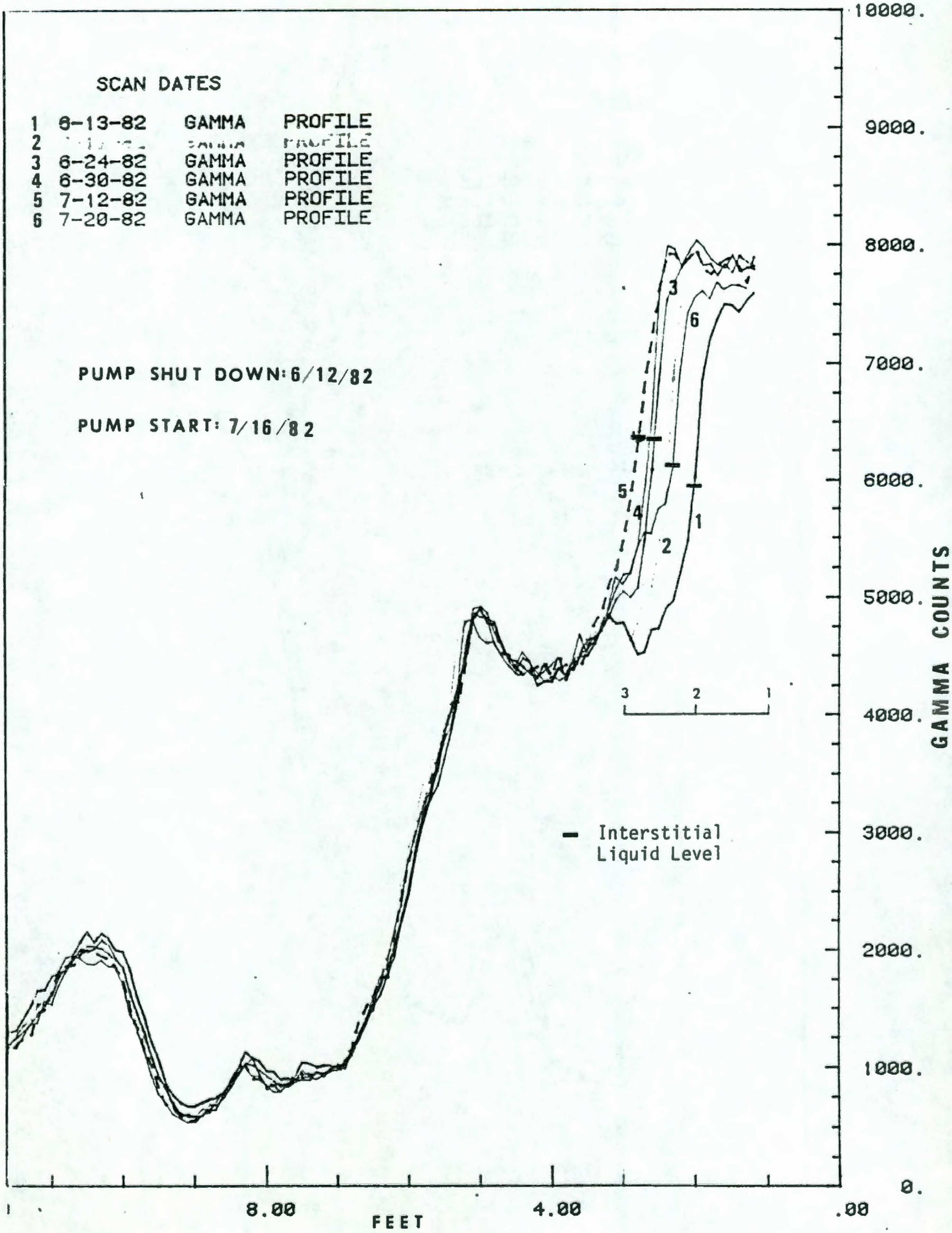


FIGURE 17B: TK-114-TX Gamma Scan Composite: LOW 511463

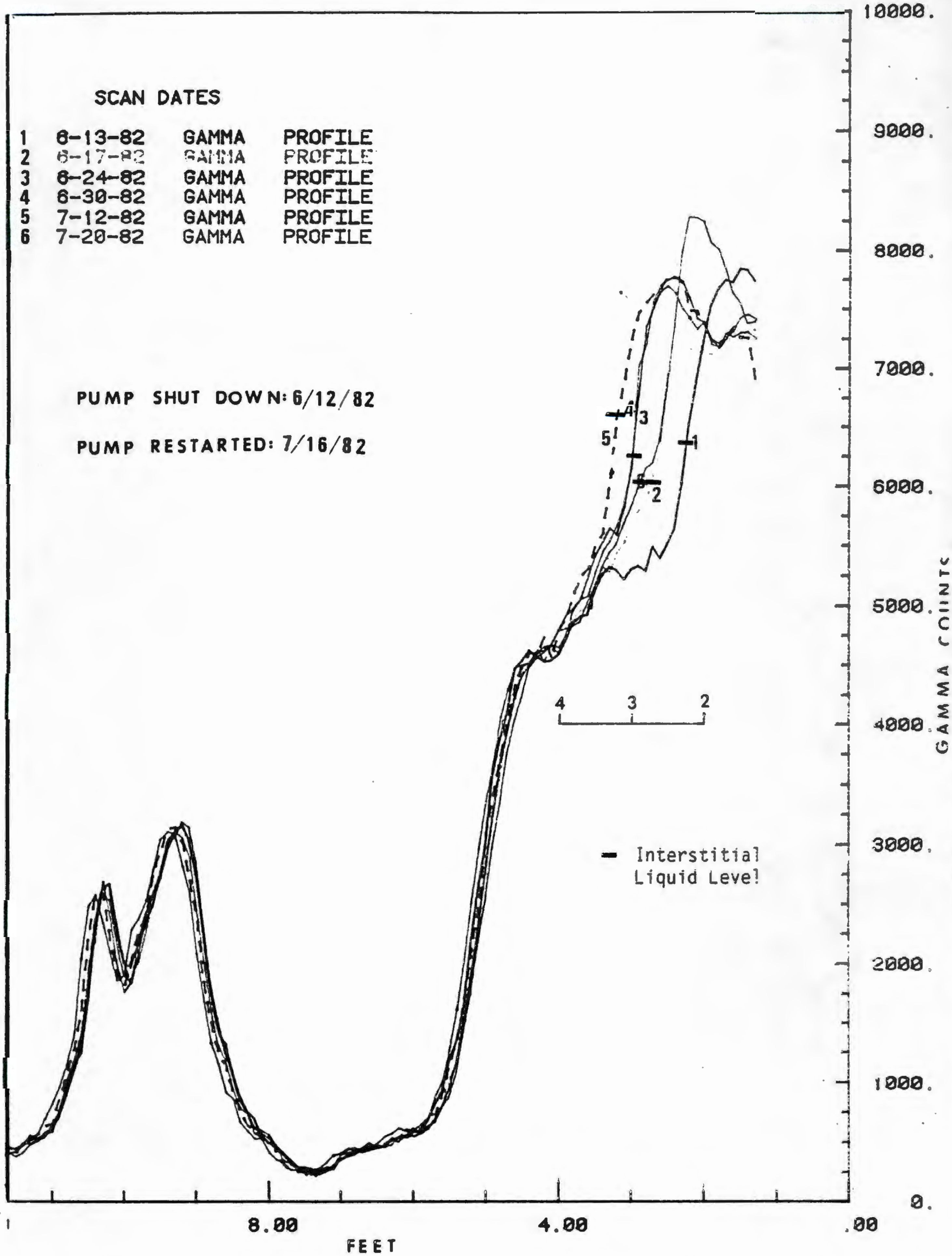


FIGURE 17C.1: TK -114-TX Gamma Scan Composite: LOW 511469

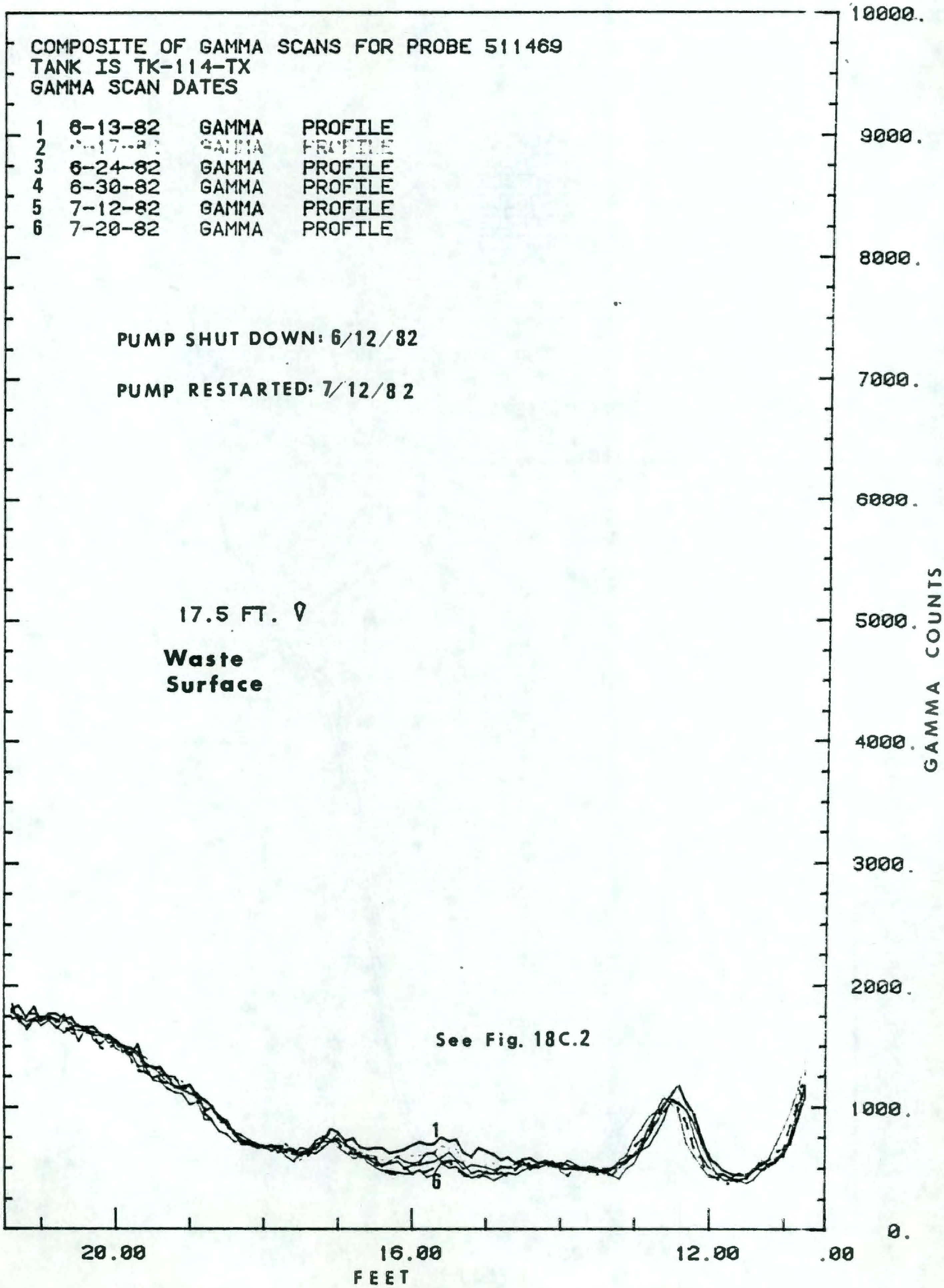


FIGURE 17C.2: TK-114-TX Gamma Scan Composite: LOW 511469

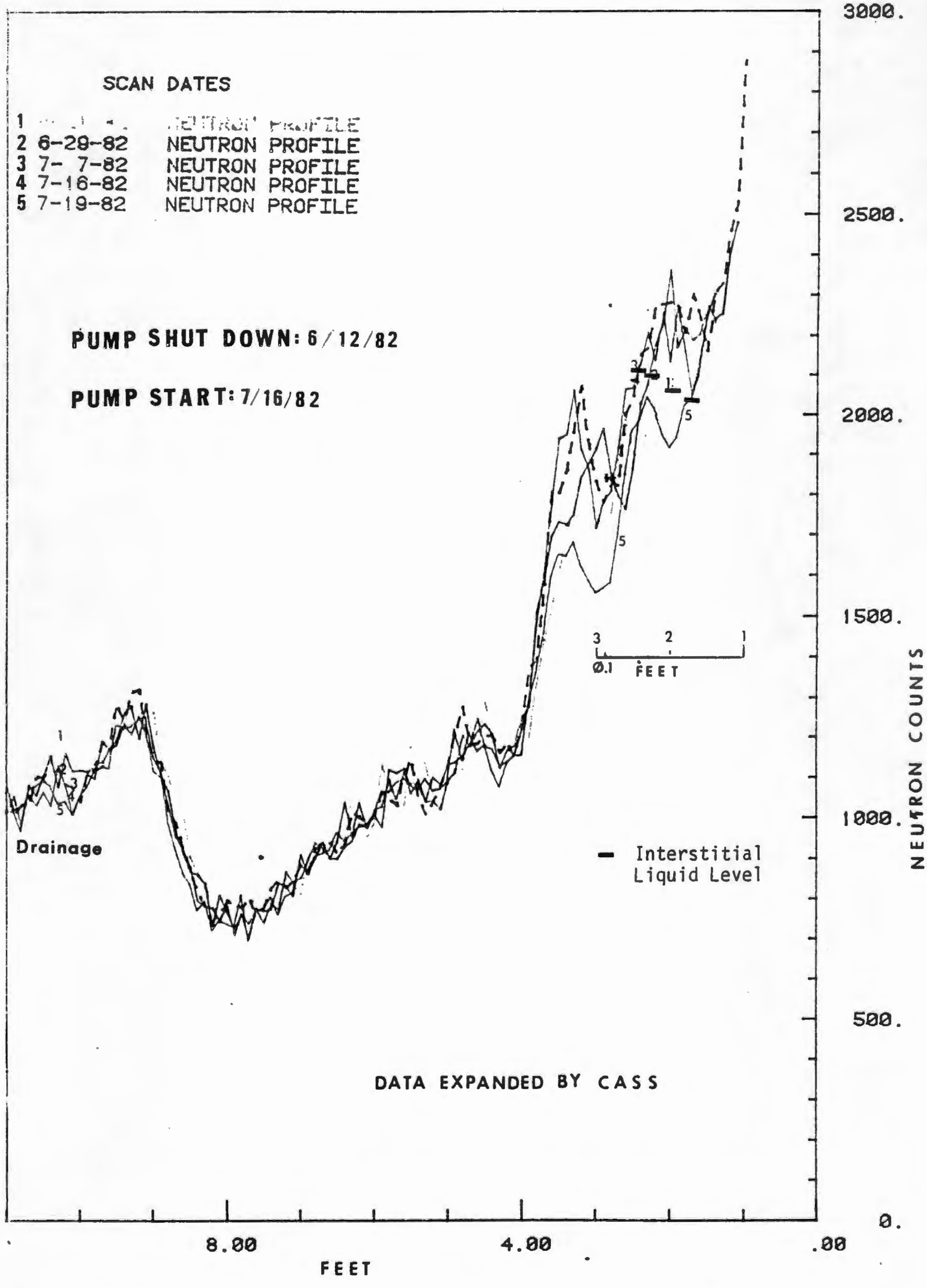


FIGURE 18A: TK-114-TX Neutron Scan Composite: LOW 511460

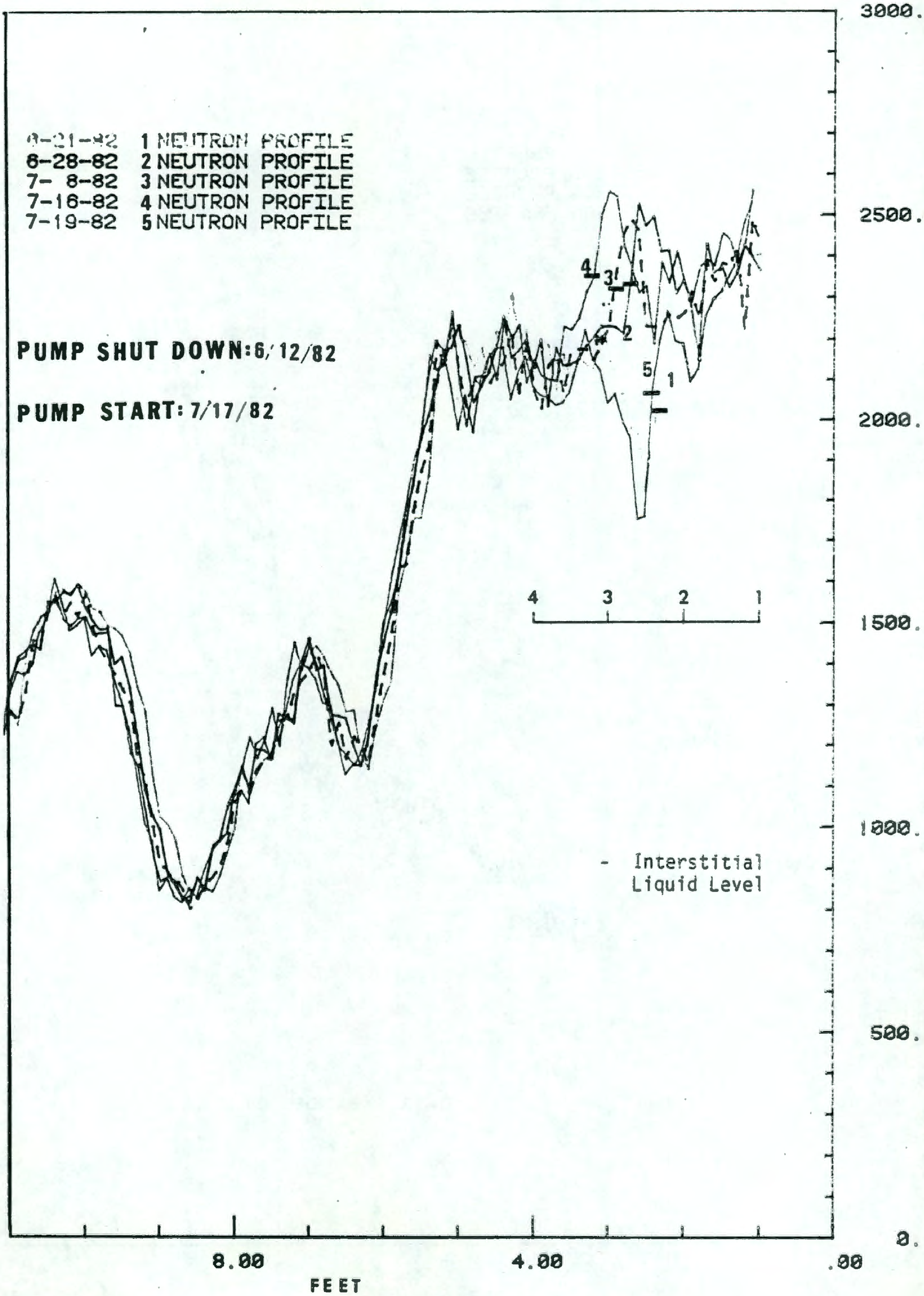


FIGURE 18B: TK-114-TX Neutron Scan Composite: LOW 511463

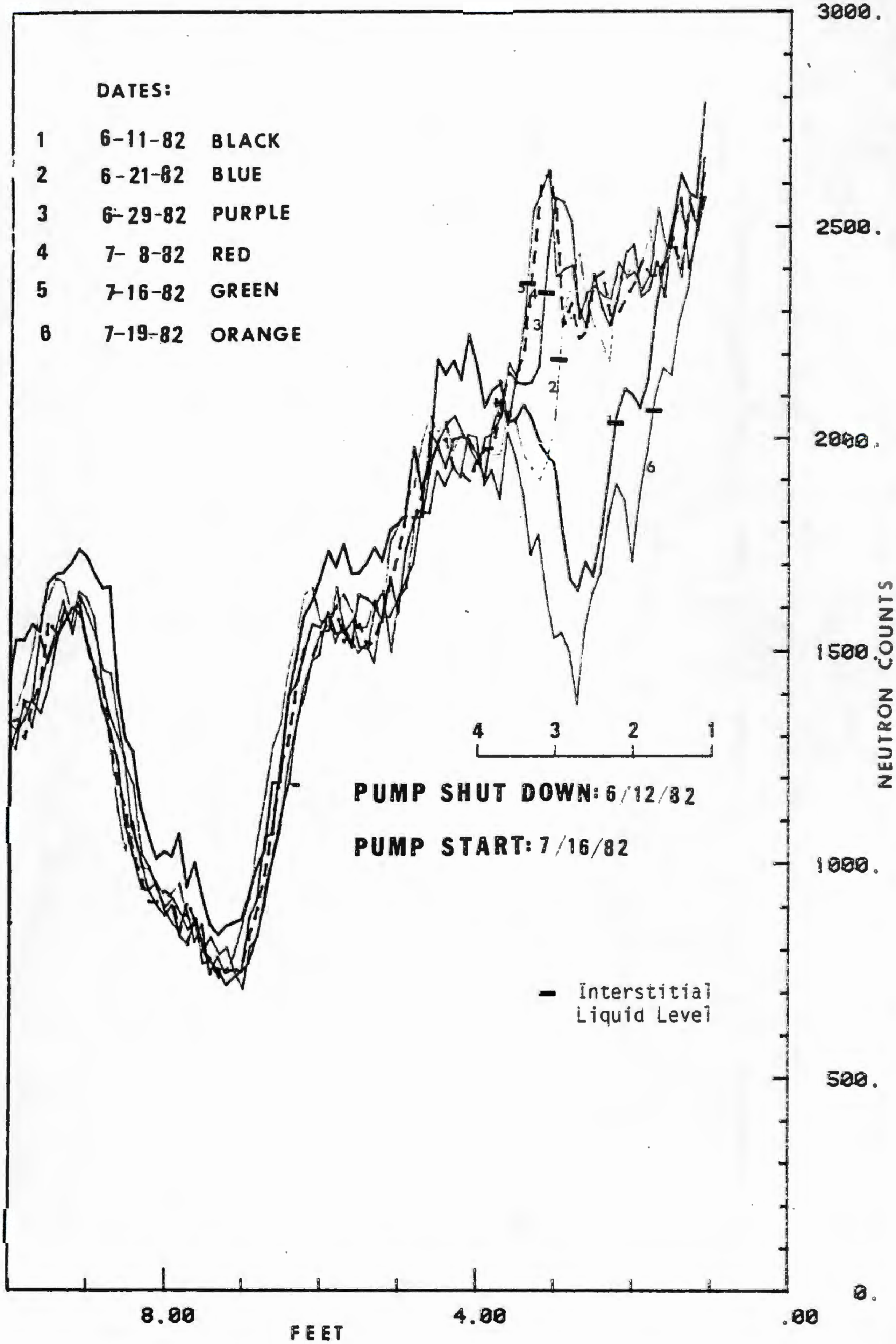


FIGURE 18C.1: TK-114-TX Neutron Scan Composite: LOW 511469

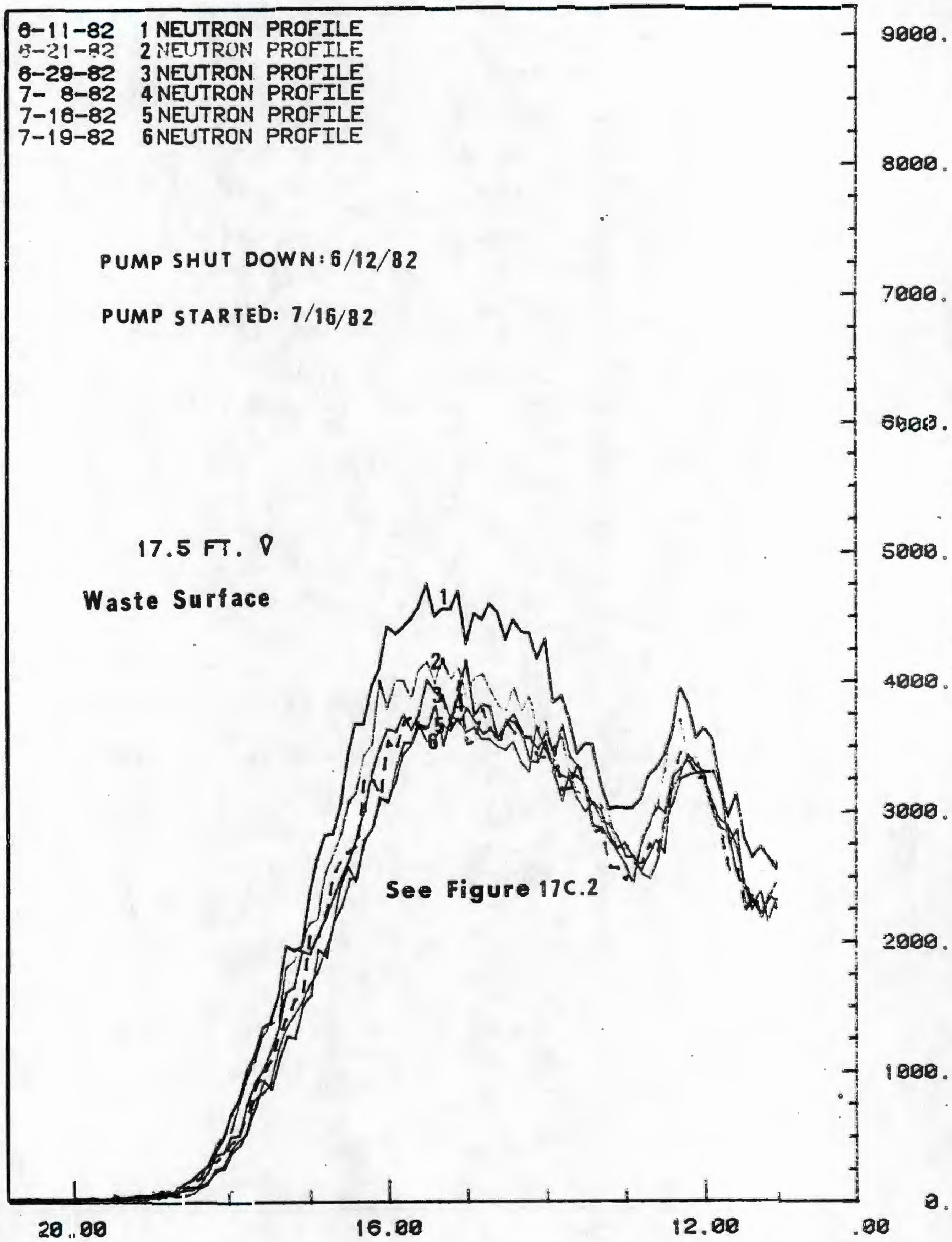


FIGURE 18C.2: TK-114-TX Neutron Scan Composite: LOW 511469

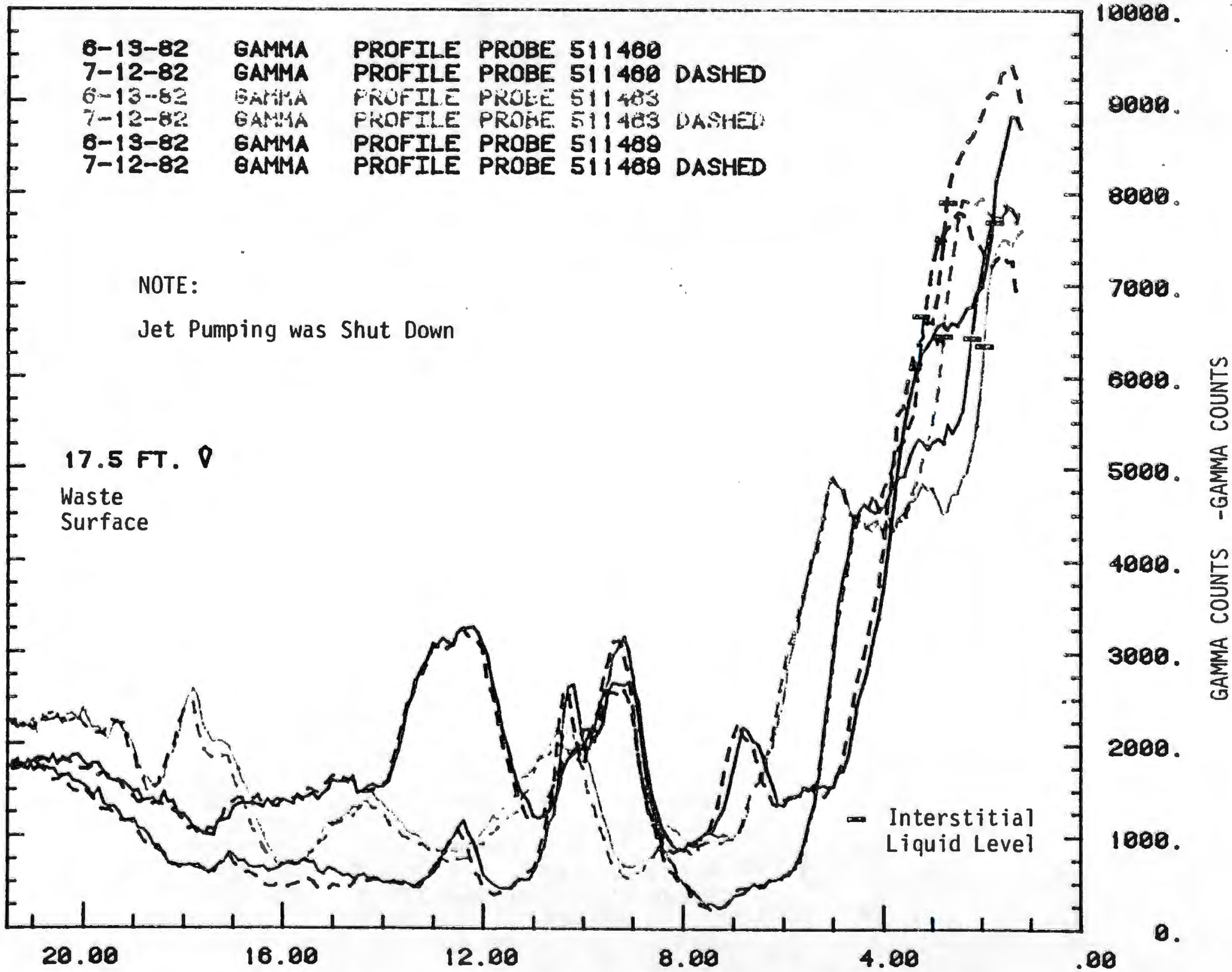


FIGURE 19A: Comparison of Gamma Scans - Three LOWs in TK-114-TX

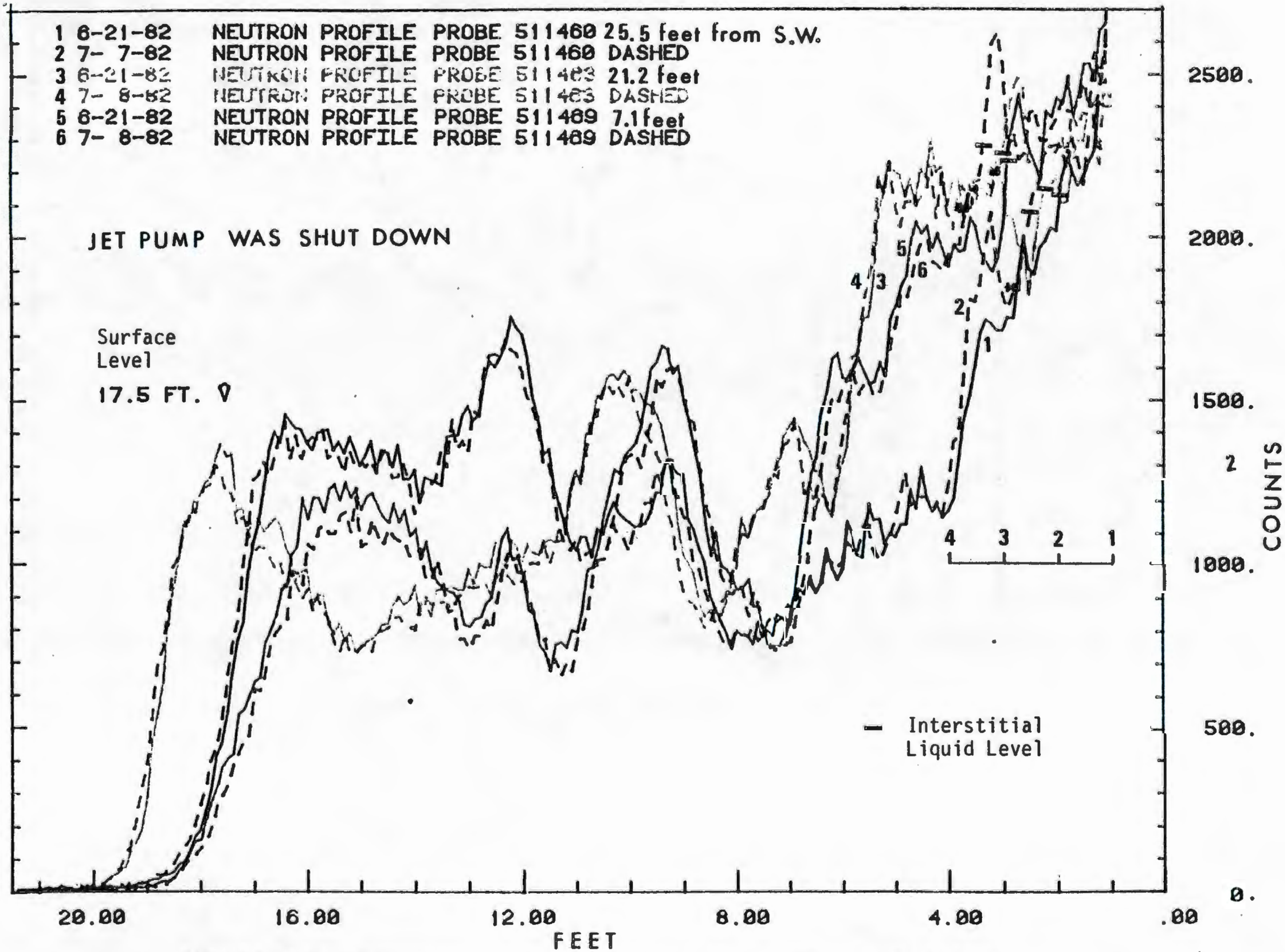


FIGURE 19B: Comparison of Neutron Scans - Three LOWs in TK-114-TX

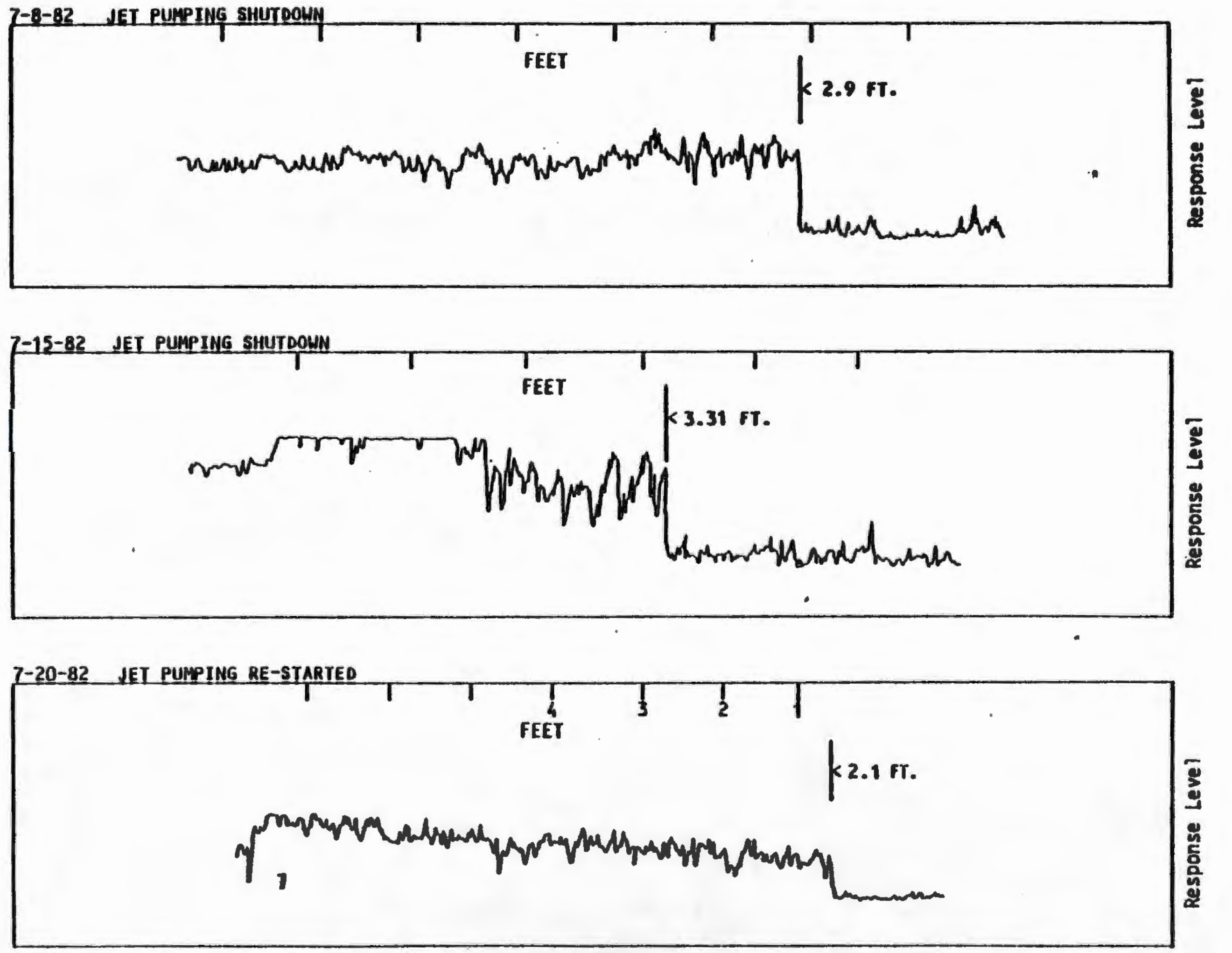


FIGURE 20 A: TK-114-TX ACOUSTIC SCANS LOW NUMBER 51-14-60: OFFSET = 0.77 FT.

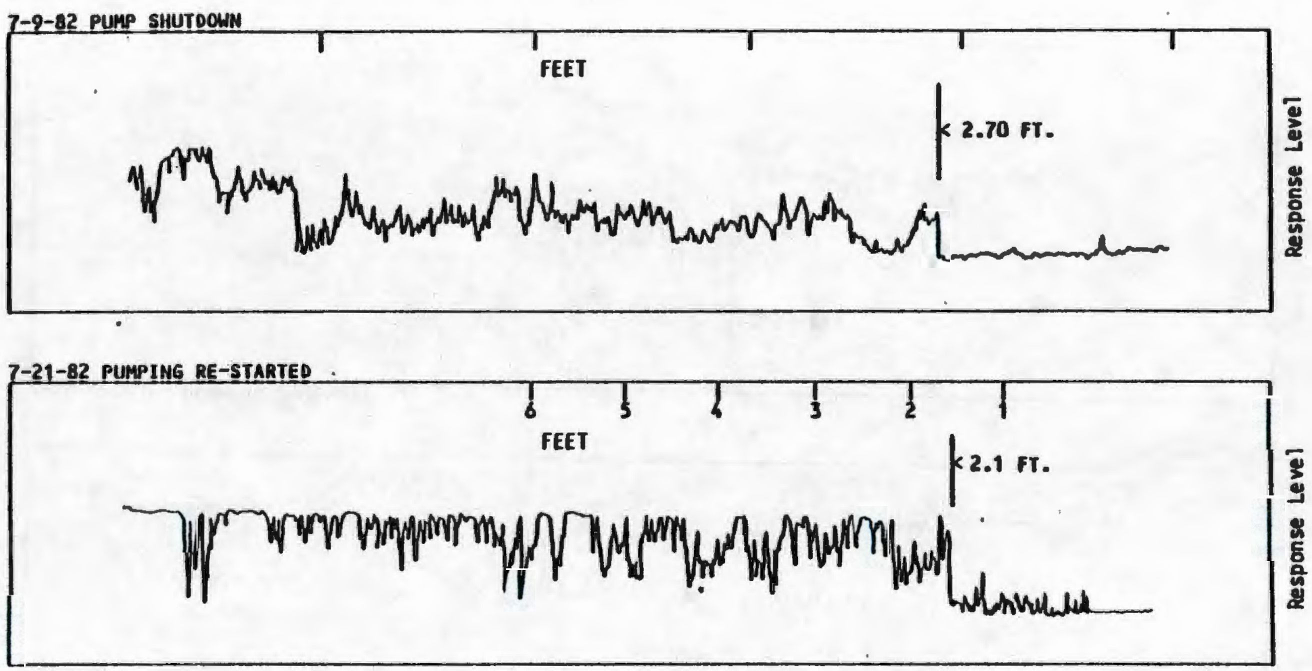


FIGURE 20B: TK-114-TX Acoustic Probe Scans; LOW Number 51-14-60 - Offset = 0.63 FT.

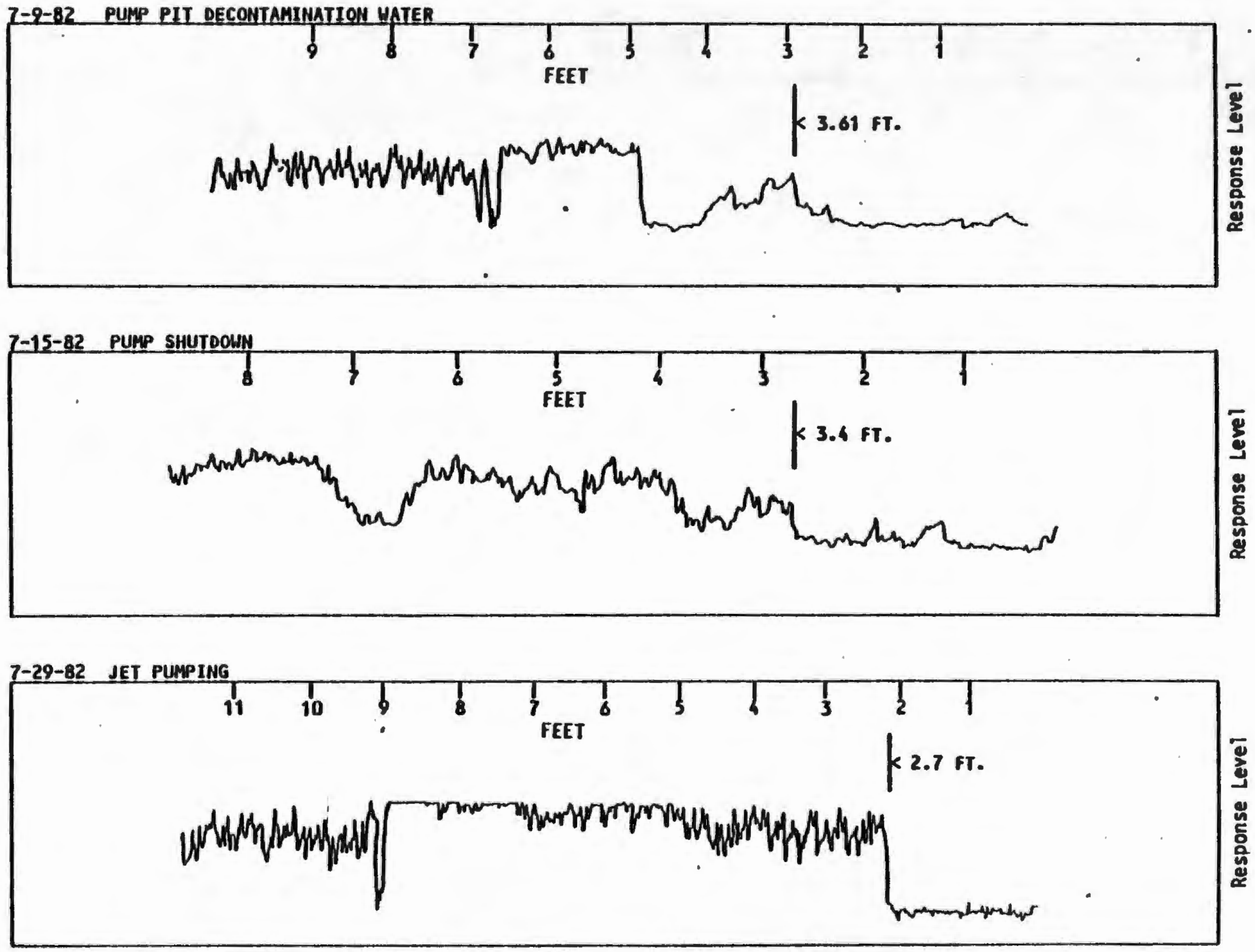


FIGURE 20 C: TK-114-TX ACOUSTIC PROBE SCANS LOW NUMBER 51-14-69: OFFSET = 0.78 FT.

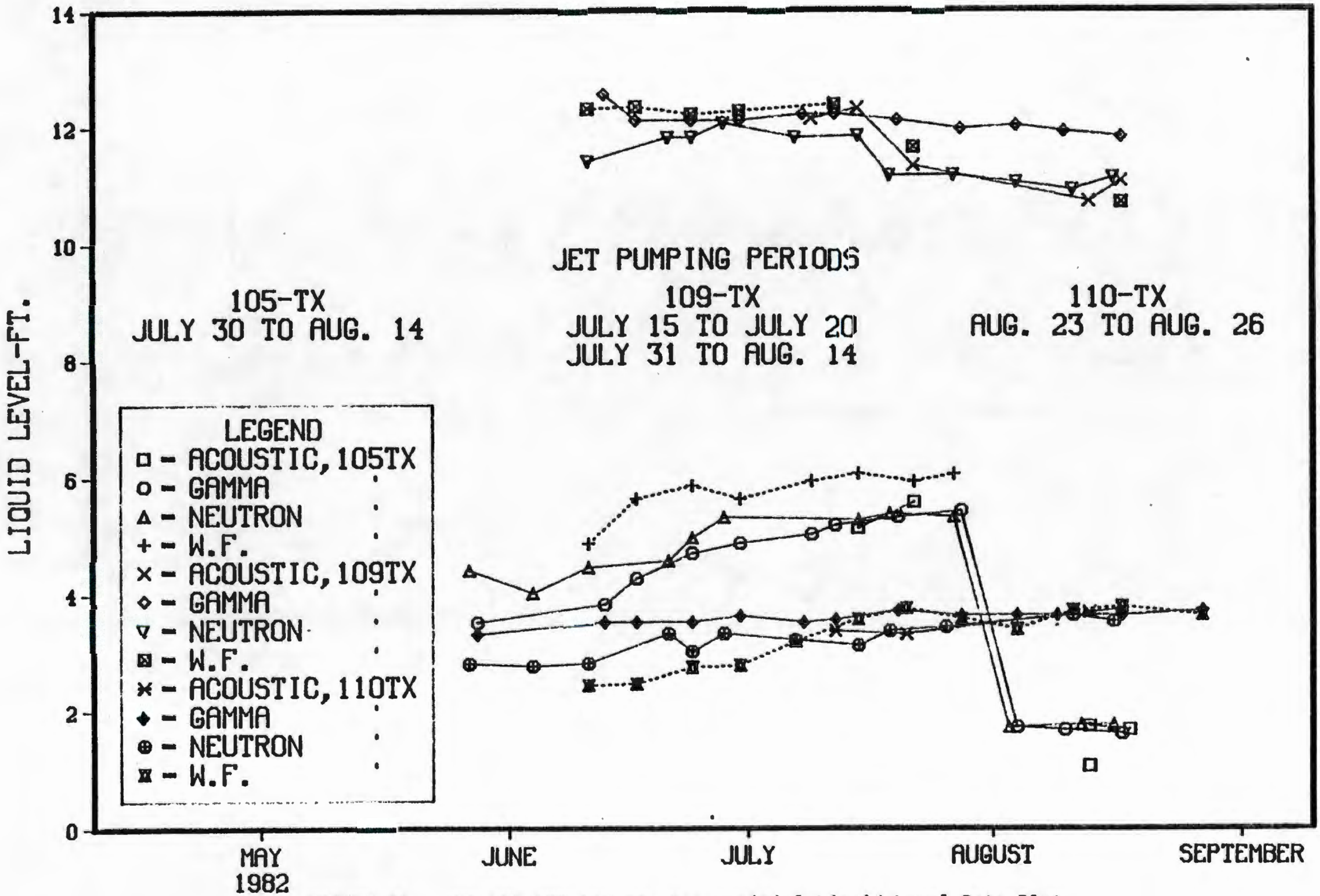


FIGURE 21: TK-105,109,110-TX Interstitial Liquid Level Data Plot

II-42

SD-WM-PTR-001

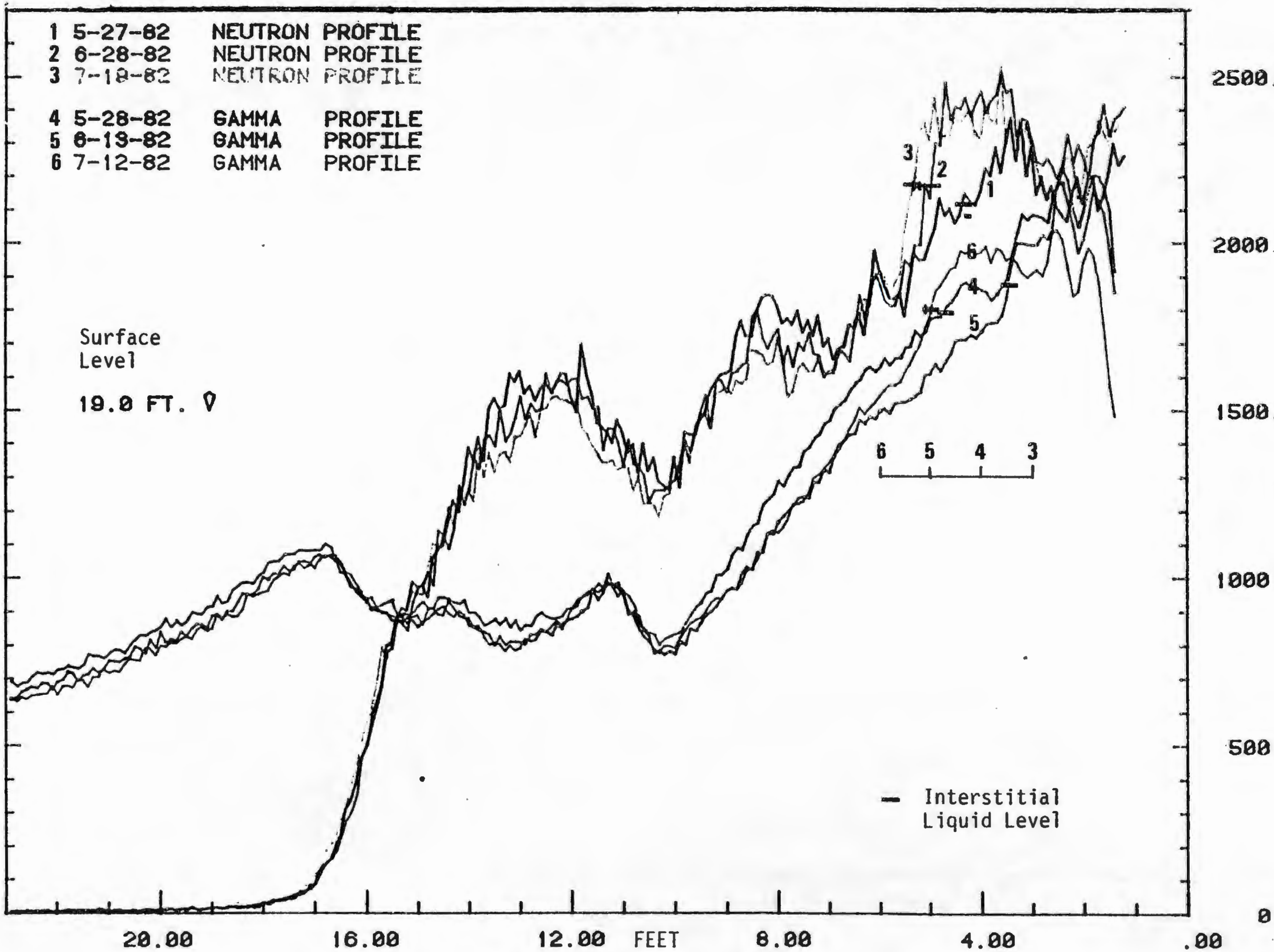


FIGURE 22: TK-105-TX Gamma/Neutron Profile Scan Composites

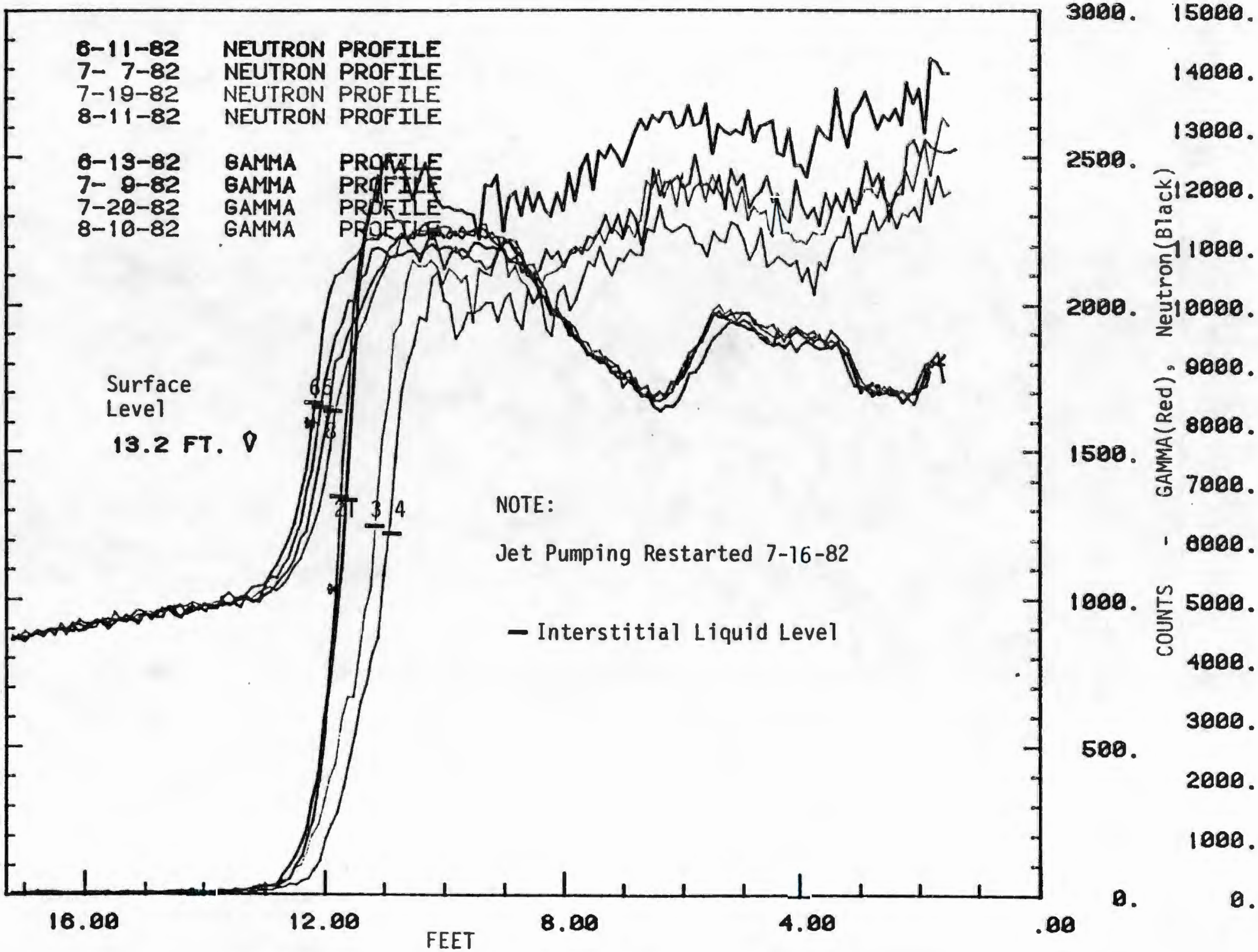


FIGURE 23: TK-109-TX Gamma/Neutron Profile Scan Composites

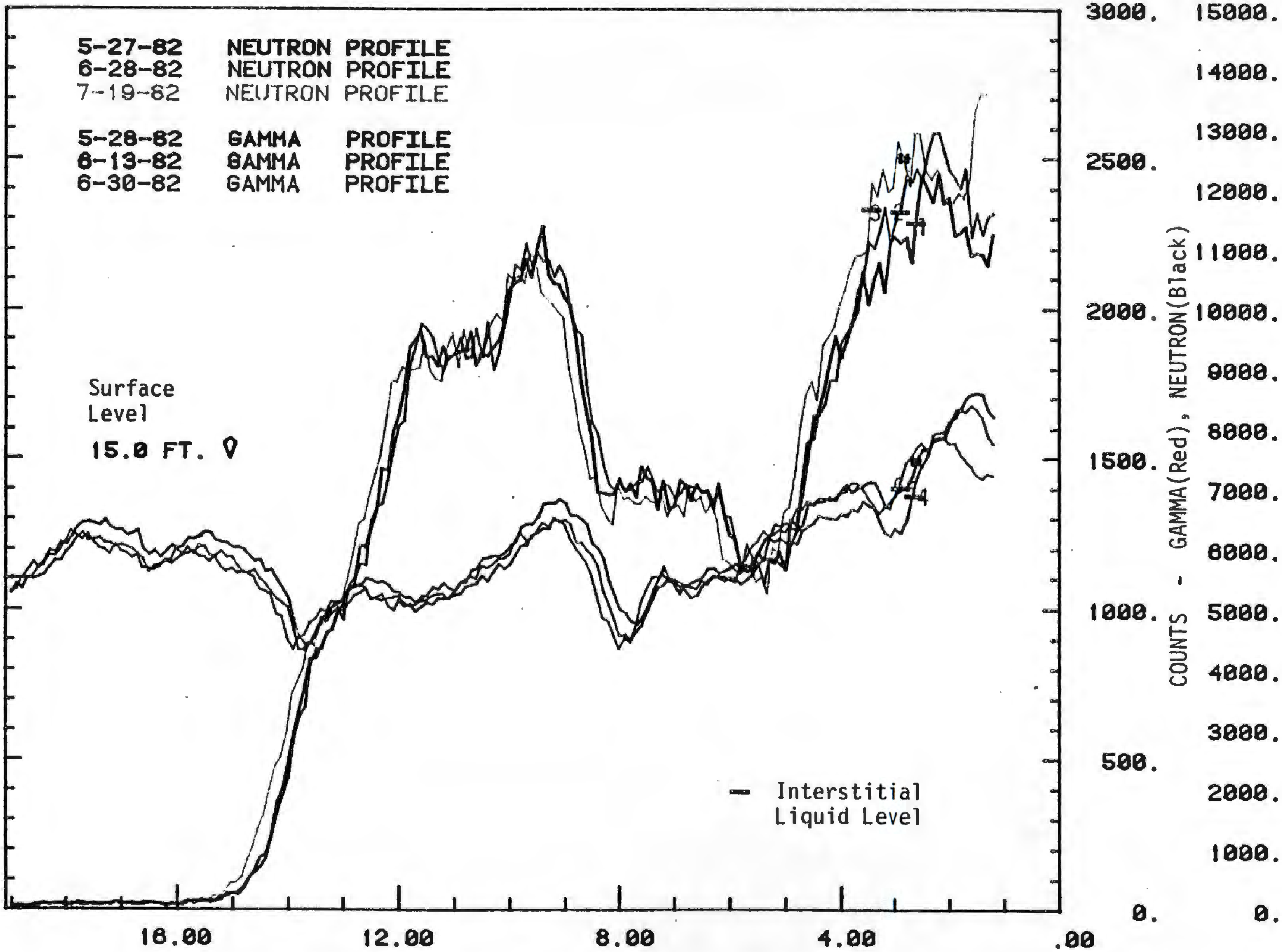


FIGURE 24: TK-110-TX Gamma/Neutron Profile Scan Composites

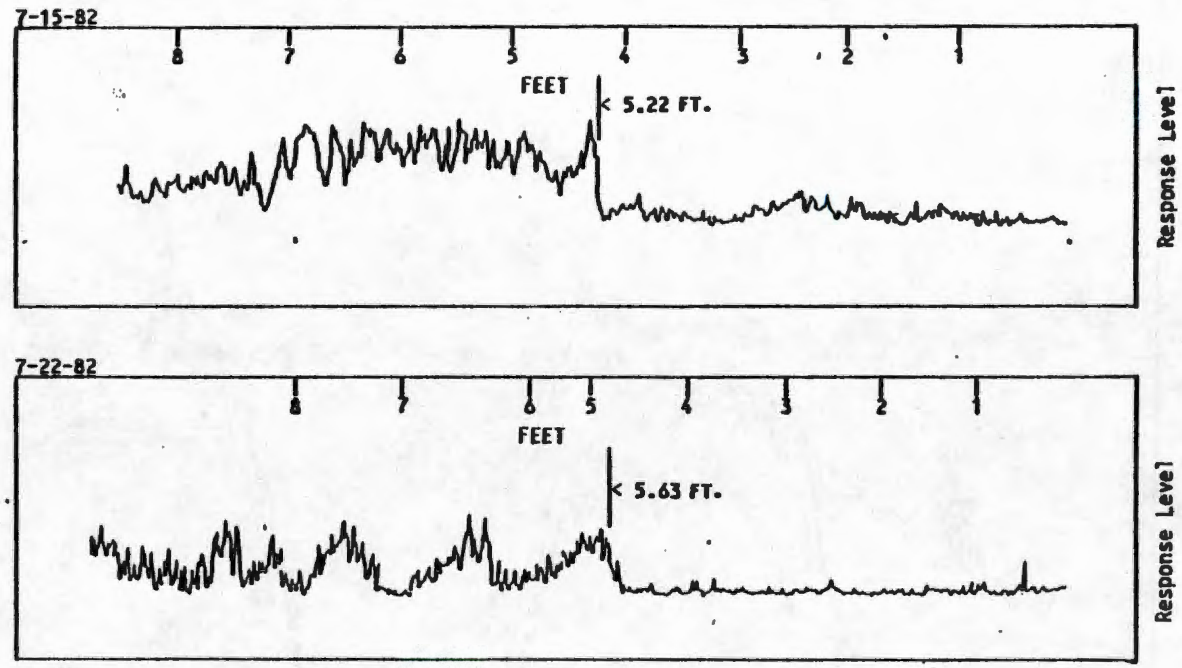


FIGURE 25: TK-105-TX Acoustic Scan Profiles - Offset = 1.04 feet

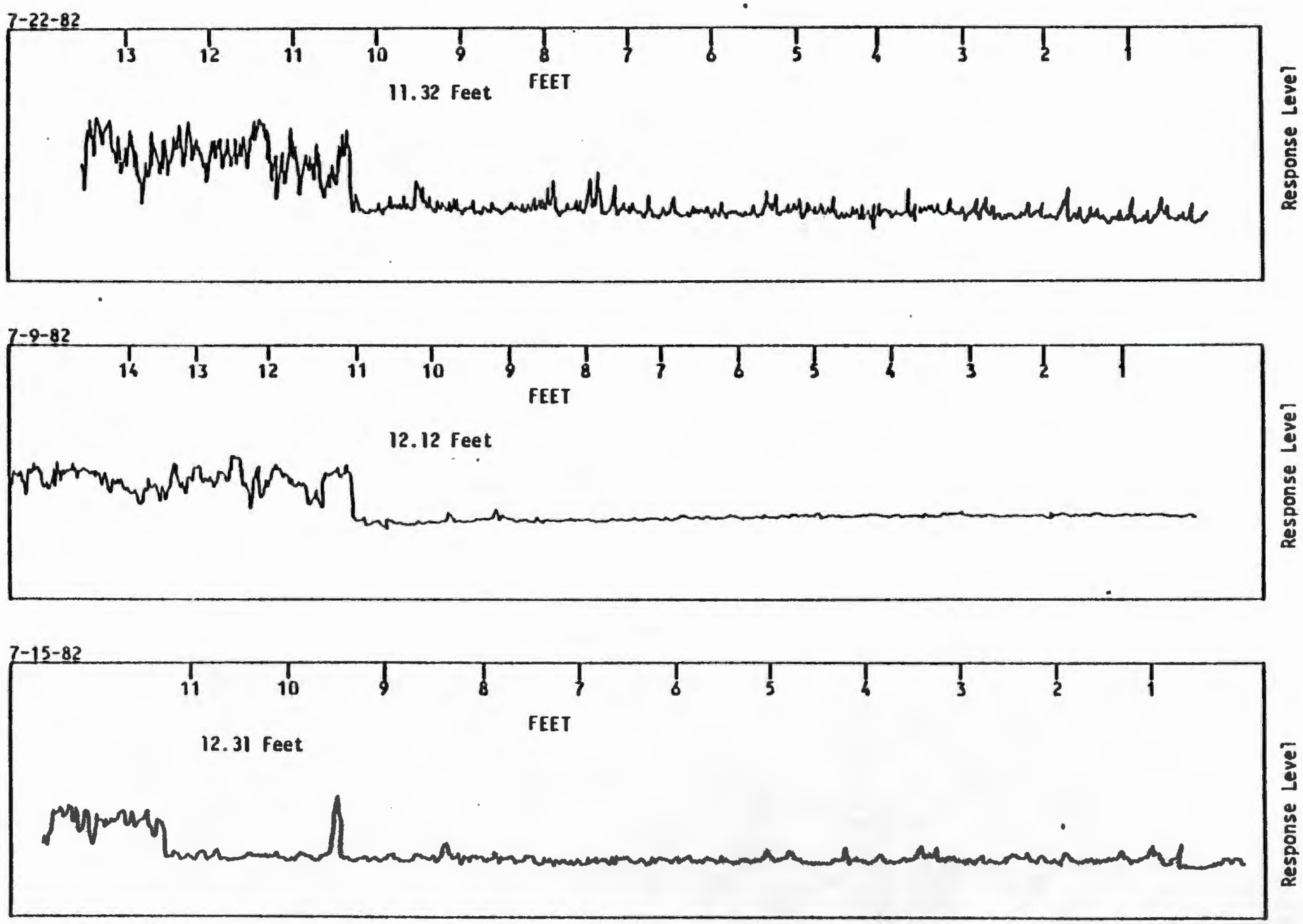


FIGURE 25(continued): TK-109-TX Acoustic Scan Profiles - Offset = 1.04 Feet

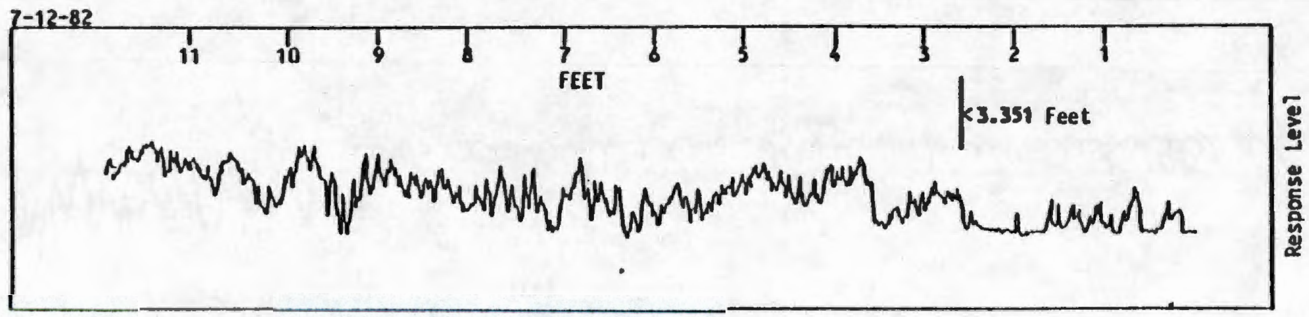


FIGURE 25(continued); TK-110-TX acoustic Scan Profile - Offset = 0.893 Feet

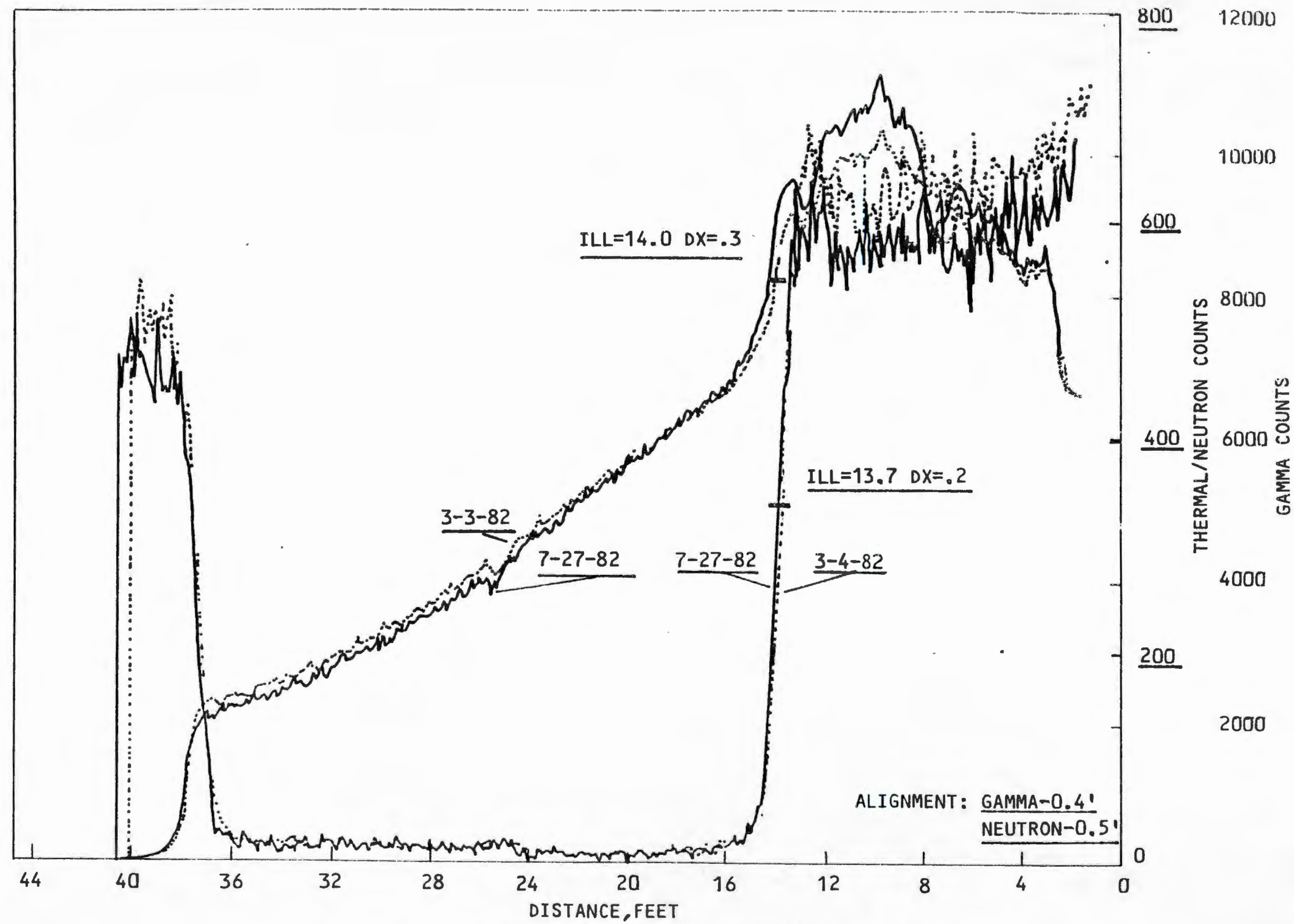


FIGURE 26 : TK-106-S GAMMA/NEUTRON COMPOSITE PROFILES

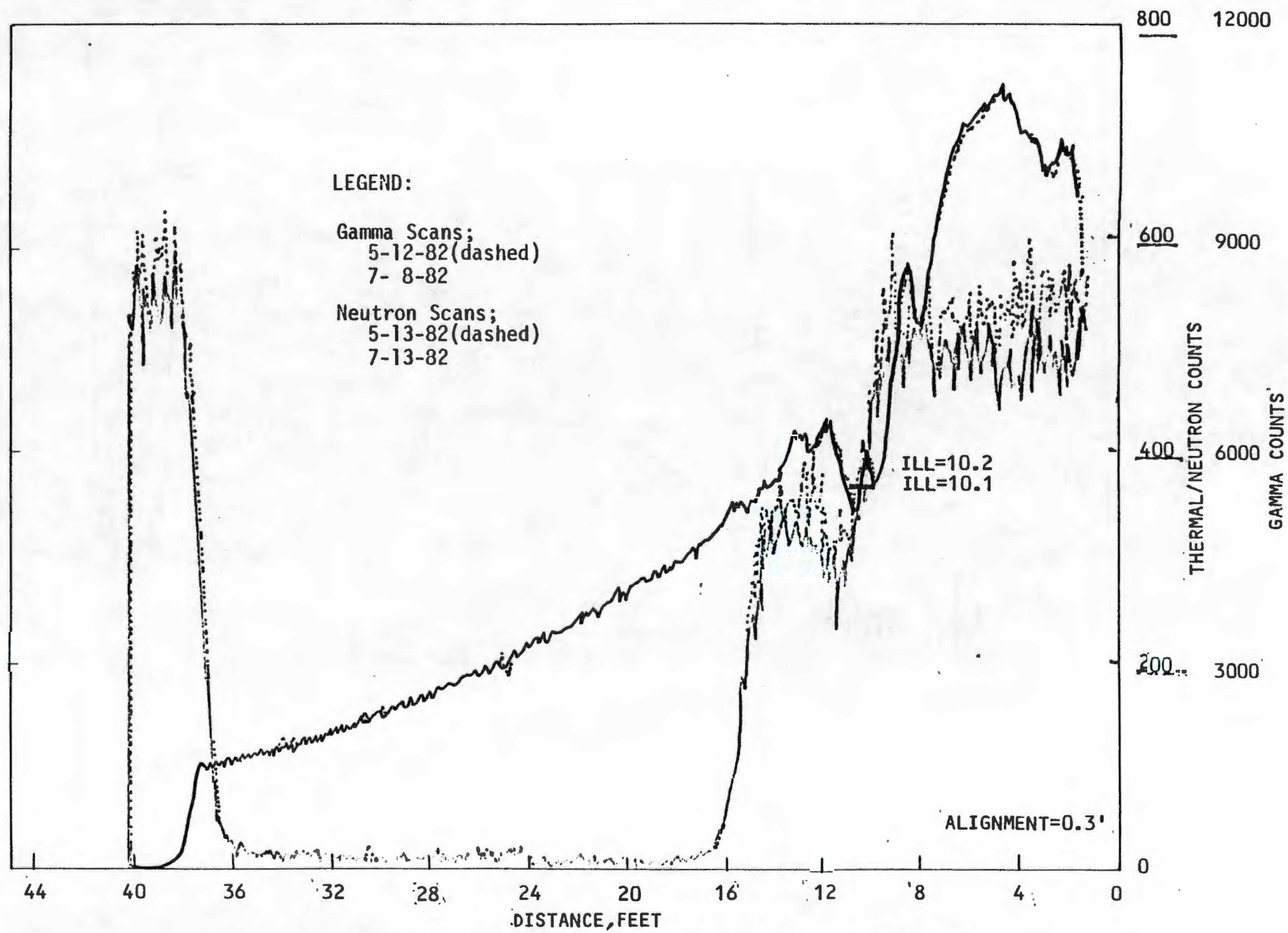


FIGURE 27 : TK-109-S GAMMA NEUTRON COMPOSITE PROFILES

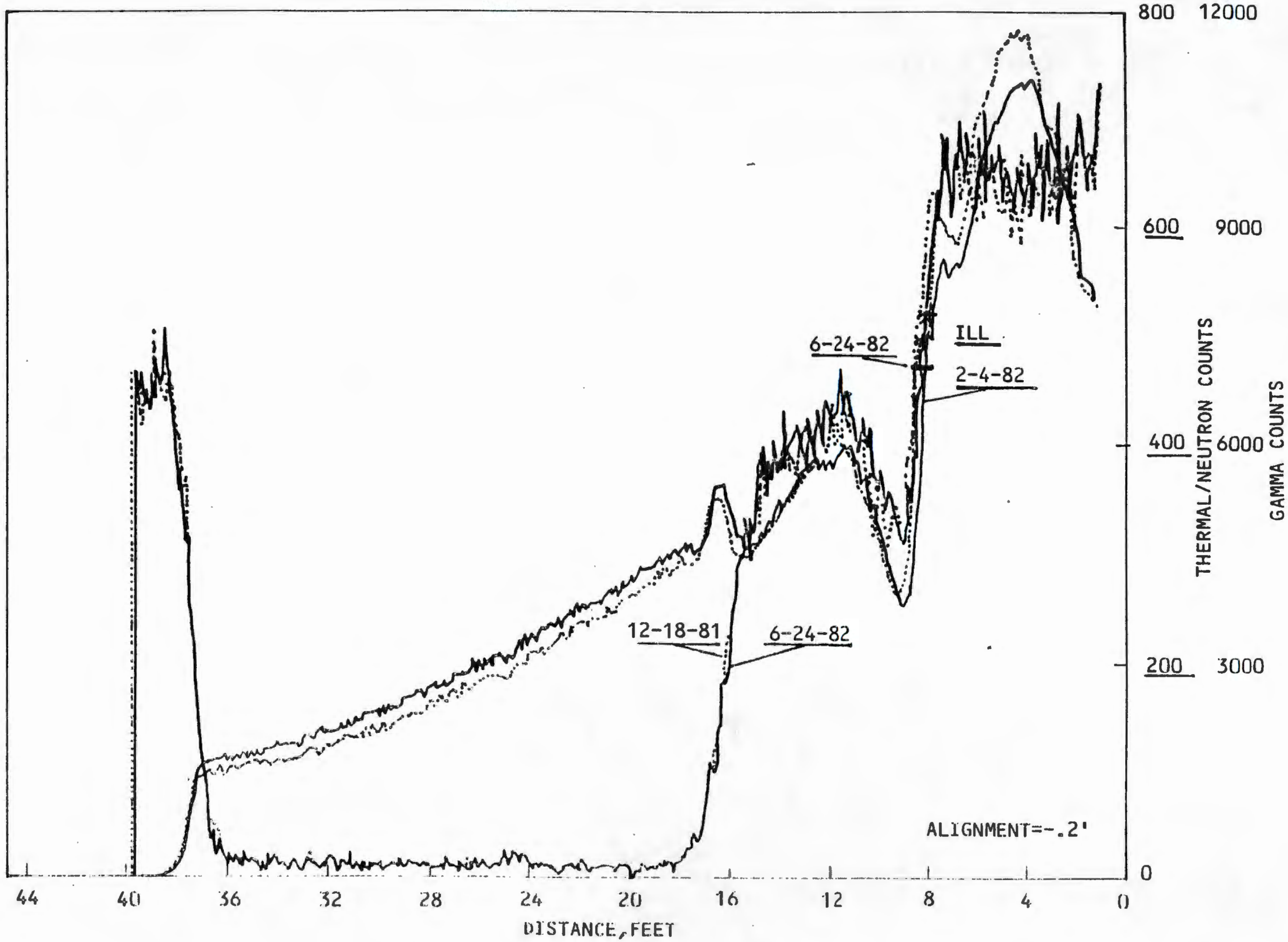


FIGURE 28: TK-112-S COMPOSITE GAMMA/NEUTRON SCANS

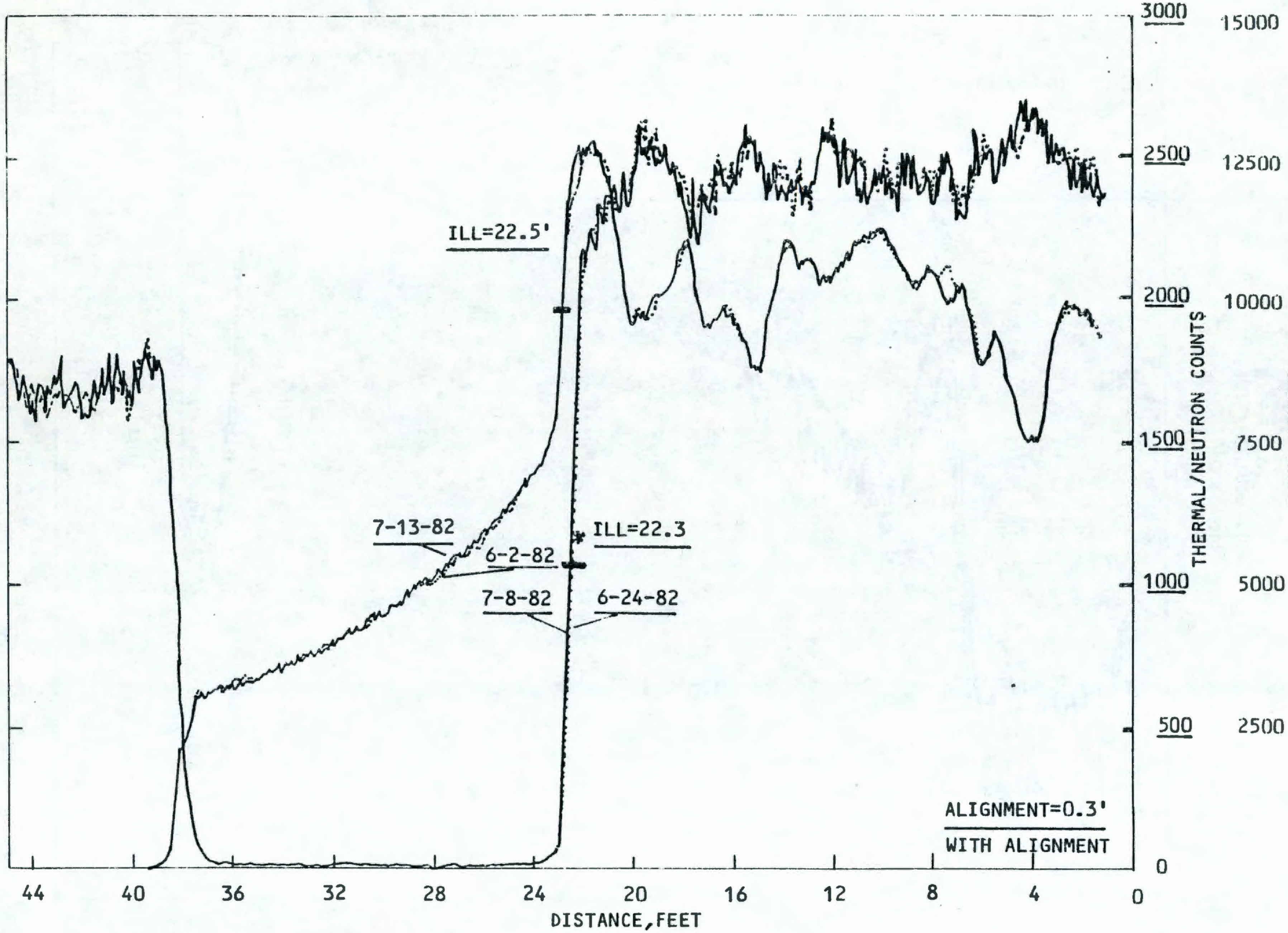


FIGURE 29: TK-104-SX GAMMA/NEUTRON COMPOSITE SCANS

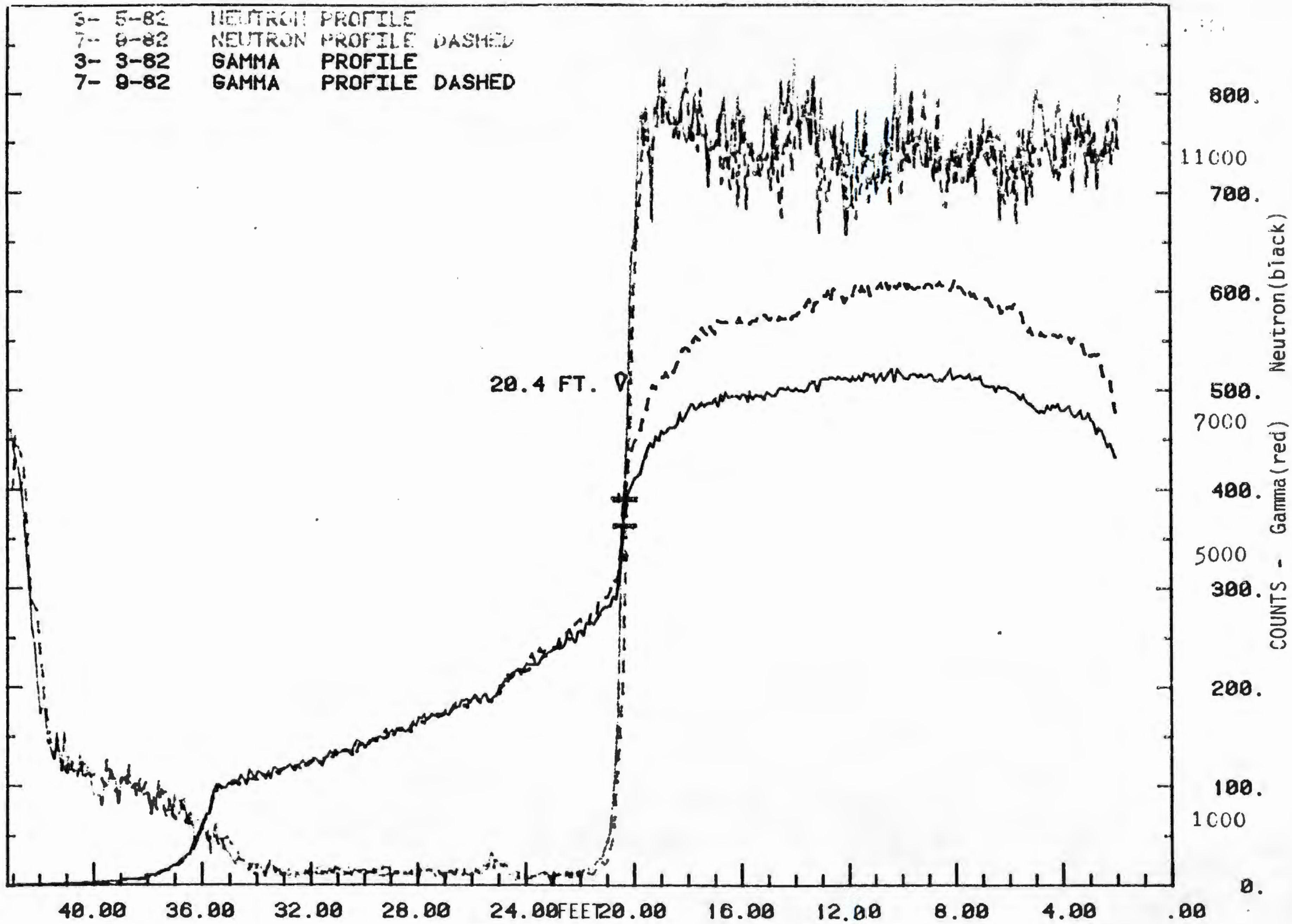


FIGURE 30: TK-111-BY Gamma/Neutron Composite Scans

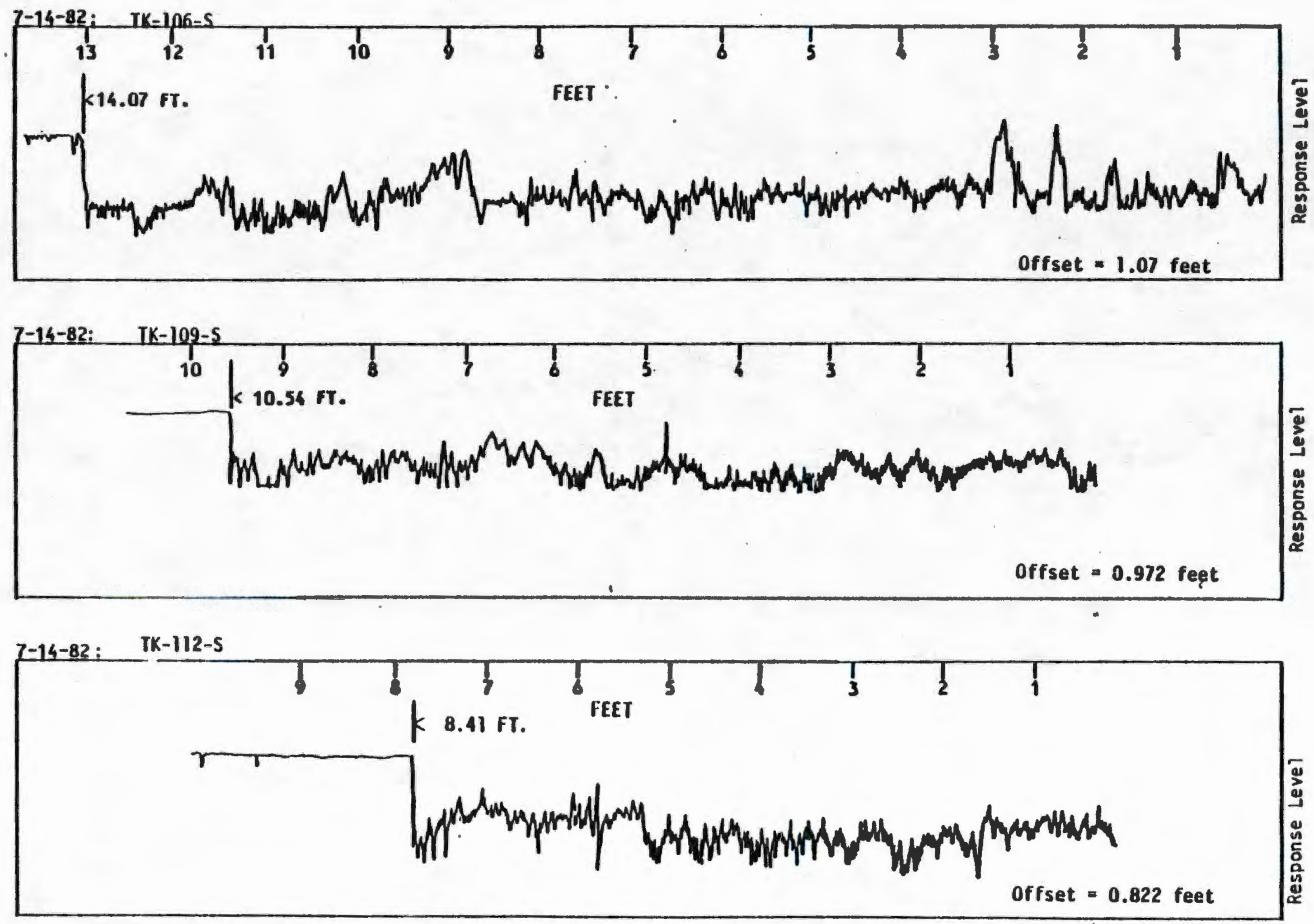
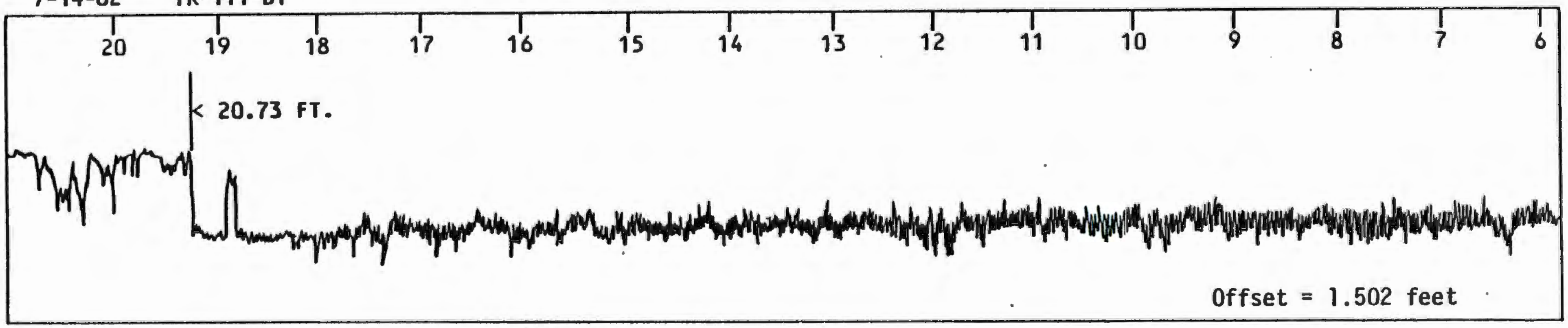


FIGURE 31 : Acoustic Probe Scans - Static Waste Tanks

7-14-82 TK-111-BY



8-6-82 TK-104-SX

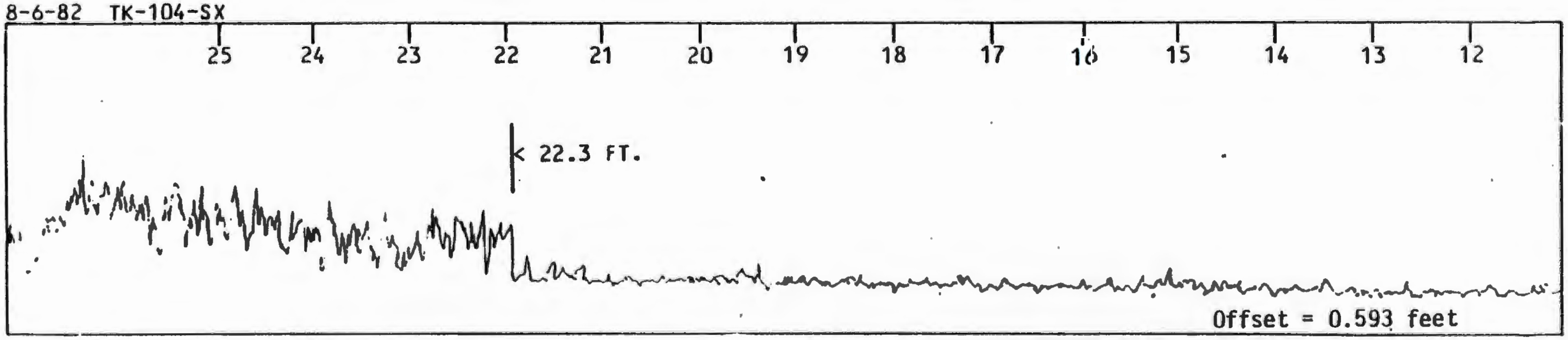


FIGURE 31(continued): Acoustic Probe Scans - Static Tanks

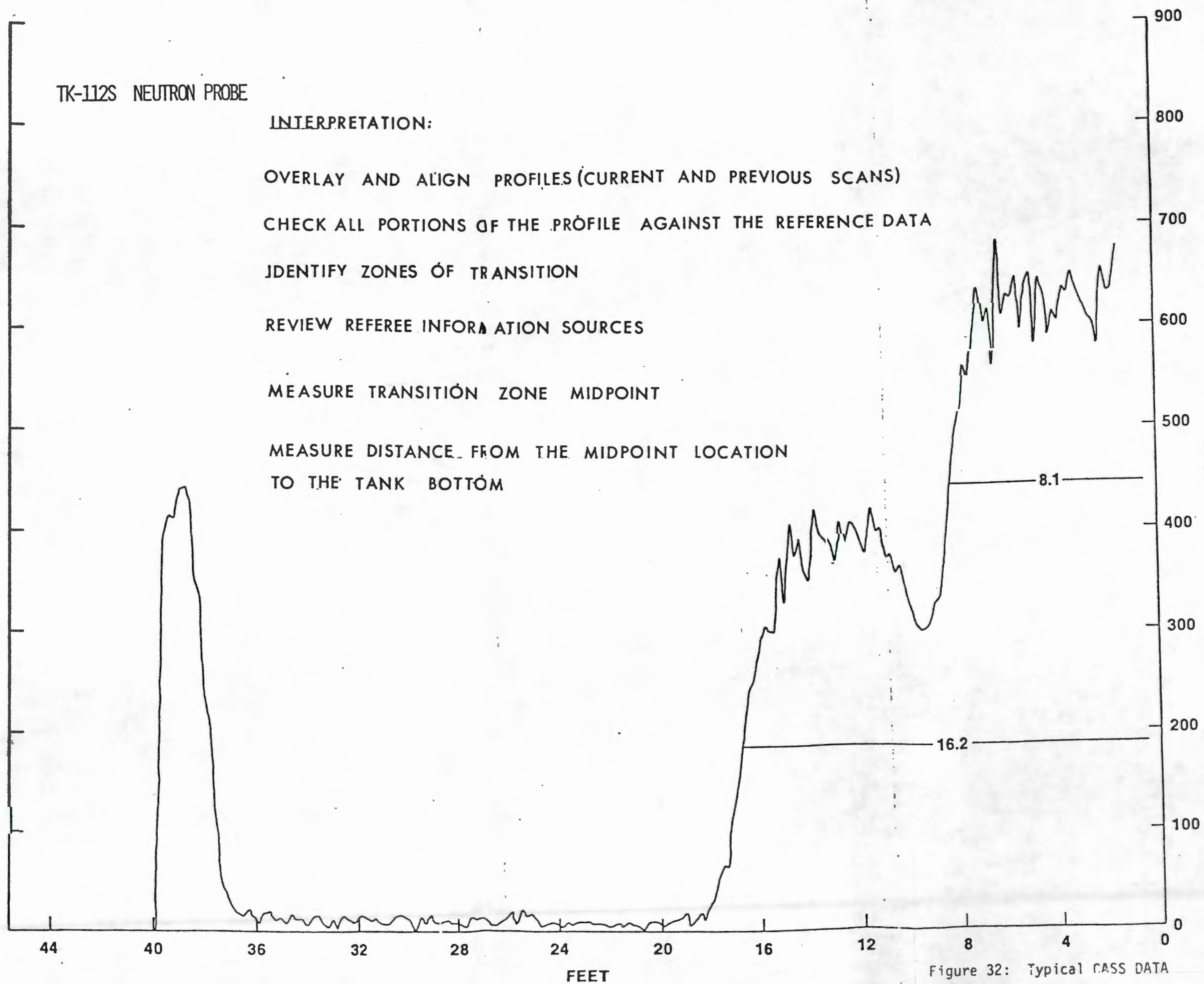


Figure 32: Typical CASS DATA

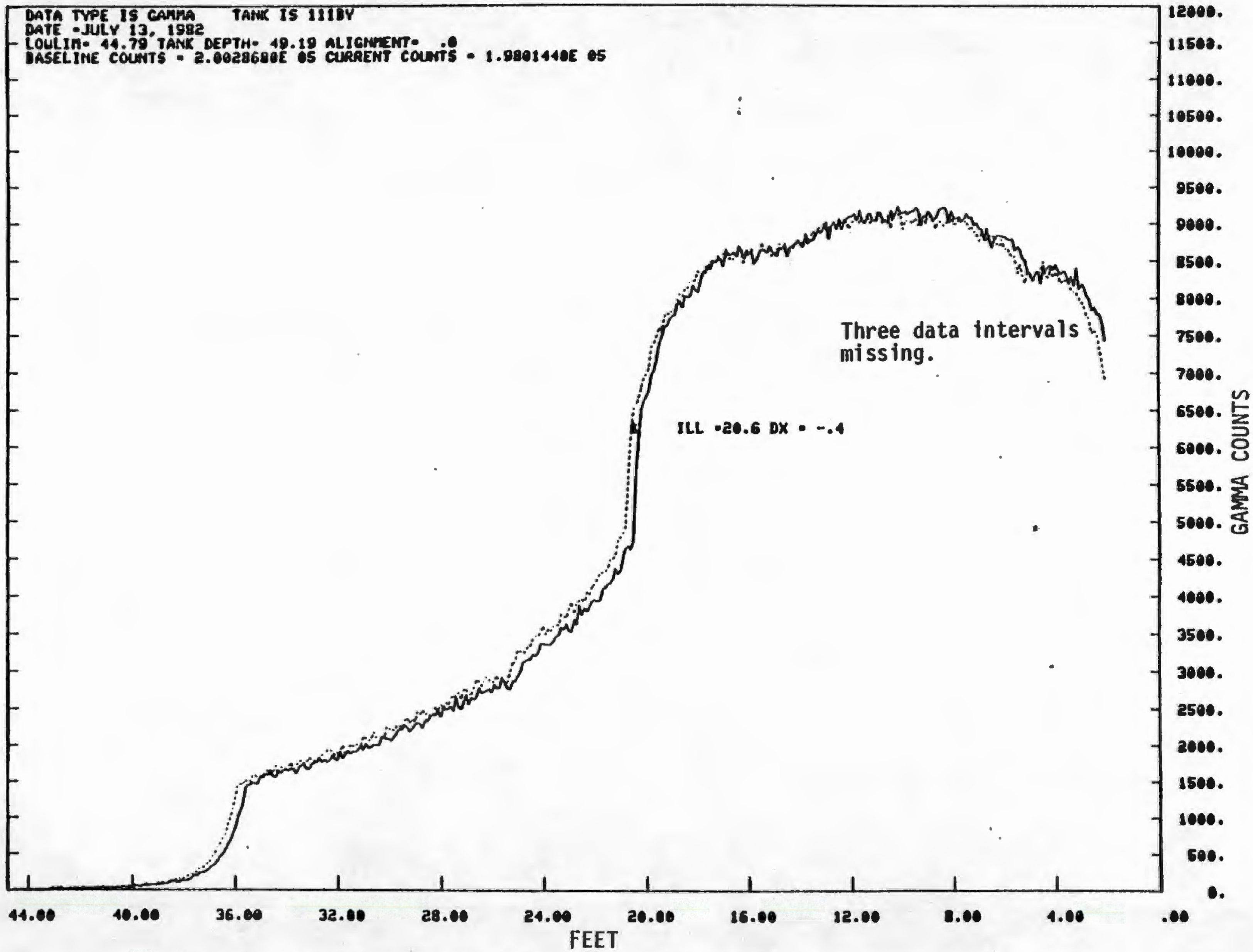


FIGURE 33: CASS Integration Analysis of Gamma Counts Data Prior to Realignment

APPENDIX A

TANK DATA SUMMARY

Tank-112-TX: Data Summary

Intestitial Liquid Level Interpretation
(All readings are in feet)

Date	Gamma	Neutron	Acoustic	Salt Well W.F.
12-11-81			16.55	
12-17-81			10.23	
12-18-81	11.4			
12-23-81			10.39	
12-31-81			11.3	
1-7-82	10.8	11.2		9.16
1-8-82			10.4	9.96
1-12-82	10.8			9.98
1-13-82		11.0		10.00
1-19-82			11.64	
1-20-82	11.2			10.69
1-21-82		11.4		10.83
1-28-82	11.8		11.92	11.33
1-29-82		11.7		11.20
2-4-82		11.9		11.48
2-12-82	12-4	12.3	12.52	11.98
2-19-82	12.6	12.8	12.8	12.42
2-23-82			13.5	
2-25-82	13.1	13.3		12.39
3-2-82			13.25	
3-3-82	13.3			12.67
3-4-82		13.4		12.57
3-10-82	13.4	13.3	13.2	12.87
3-17-82	11.8	12.1	10.7	
3-25-82	11.2		8.6	
3-26-82		12.05		
4-2-82	8.2 & 12.1	11.9	8.7	
4-9-82	6.8 & 12.0	12.0	6.15	
4-15-82	5.8 & 11.7	11.4		
4-23-82			5.8	
4-30-82	5.9 & 11.7	11.4		5.88
5-4-82			5.8	
5-7-82	5.9 & 11.8	11.5		
5-12-82	5.8 & 12.0			
5-13-82		11.6		
5-14-82			6.0	
5-21-82	5.8 & 12.1	11.5	5.85	
5-27-82		11.6	5.6	
5-28-82	5.8 & 12.15			
6-4-82		11.5		
6-7-82			5.33	
6-10-82			5.19	
6-11-82		11.5 & 5.3		4.78

(All readings are in feet)

Date	Gamma	Neutron	Acoustic	Salt Well W.F.
6-13-82	5.1 & 12.0			4.81
6-16-82	4.6			5.01
6-21-82		11.8		5.21
6-24-82	5.4			5.26
6-29-82		11.8	5.1	5.37
6-30-82	5.6			5.4
7-7-82		11.7		5.54
7-8-82	5.45		4.9	5.54
7-13-82	5.3			5.64
7-14-82			5.14	5.64
7-16-82		11.7 & 5.4		
7-19-82		11.8 & 5.2		
7-20-82	5.0			
7-22-82			5.18	
7-26-82		11.6 & 5.1		5.01
7-28-82	4.9		5.04	5.06
8-4-82	4.75			
8-10-82	4.45			
8-12-82		11.58 & 4.6		
8-13-82			4.65	
8-16-82		11.67 & 4.6	4.6	4.22
8-17-82	4.5			4.30
8-27-82	4.35			4.21

- Tank-118-TX: Data Summary

Interstitial Liquid Level Interstitial
(All readings are in feet)

Date	Gamma	Neutron	Acoustic	Salt Well W.F.
1-7-82		11.7		
1-12-82	11.95			
1-13-82		11.6		
1-19-82			11.96	
2-4-82	12.05	11.67		
3-3-82	12.1			
3-4-82		11.7		
3-24-82			12.09	
3-26-82	12.0	11.67		
4-1-82			11.3	
4-2-82	11.6	11.15		
4-15-82	10.37	9.8		
4-23-82			11.98	
4-30-82	9.62	10.06		
5-4-82			7.3	
5-7-82	9.9	10.35		
5-12-82	7.6			
5-13-82		9.6		
5-14-82			5.2	
5-21-82	7.5	9.8		
5-27-82		9.7	5.4	
5-28-82	6.5			
6-4-82		9.6		
6-7-82			5.7	
6-10-82			6.9	
6-11-82		9.5		6.55
6-13-82	6.8			6.57
6-16-82	7.6			6.56
6-21-82		9.6		6.81
6-24-82		9.6		6.97
6-29-82		9.6		6.98
6-30-82	8.1			6.83
7-8-82	8.3	9.4		6.93
7-13-82	8.3			6.98
7-16-82		9.4		
7-19-82		9.4		
7-20-82	7.7			
7-22-82			7.05	
7-26-82		9.4		
7-28-82	7.9		7.9	6.74
8-4-82	7.9			6.93
8-10-82	8.0			6.9
8-12-82		9.4		
8-13-82			5.08	
8-16-82		9.45		4.87
8-17-82	4.9		5.21	5.09
8-27-82	4.9			

TK-115-TX: Data Summary

Interstitial Liquid Level Interpretation

(All readings are in feet)

Date	Gamma	Neutron	Acoustic	Salt Well W.F.
5-27-82		16.7		
5-28-82	16.85			
6-4-82		12.5		
6-11-82		9.6		11.49
6-13-82	9.4			11.97
6-16-82	10.45			13.13
6-21-82		10.4		13.21
6-24-82	11.2	10.7		13.5
6-29-82		11.0	10.95	13.65
6-30-82	11.25			13.82
7-8-82	11.05		11.1	
7-12-82	11.05		11.33	
7-16-82		10.85		
7-19-82		8.25		
7-20-82	7.4		7.3	
7-26-82		8.4		
7-28-82	6.75			
8-4-82	5.35	5.07		
8-10-82	5.1			
8-11-82		4.95	4.65	
8-16-82		4.9		4.13
8-17-82	4.4			4.35
8-18-82			4.42	4.49

TK-114-TX(60): Data Summary

Interstitial Liquid Level Interpretation

(All readings are in feet)

Date	Gamma	Neutron	Acoustic	Salt Well W.F.
6-4-82		2.1		
6-11-82		2.3		2.89
6-13-82	2.1			3.00
6-16-82	2.2			2.86
6-21-82		2.4		3.13
6-24-82	2.7	2.7		3.23
6-29-82		3.1		3.78
7-7-82		3.4		
7-8-82	3.0		2.98	
7-12-82	3.1		2.7	
7-16-82		3.34		
7-19-82		2.6		
7-20-82	2.3			
7-26-82				
7-28-82				
7-29-82			2.41	3.09
8-4-82	2.45	2.5		3.52
8-9-82	2.75			3.40
8-11-82		2.85	2.69	3.77
8-16-82		3.23		3.84
8-17-82	2.9			3.72
8-18-82			2.78	3.64
8-27-82	3.0			3.76

TK-114-TX(63): Data Summary

Interstitial Liquid Level Interpretation

(All readings are in feet)

Date	Gamma	Neutron	Acoustic	Salt Well W.F.
6-11-82		2.25		2.89
6-13-82	2.3			3.00
6-17-82	2.28			3.06
6-21-82		2.6		3.13
6-24-82	2.8	2.6		3.23
6-28-82		2.95		3.90
6-30-82	2.95			3.96
7-8-82		2.97		
7-9-82			2.65	
7-12-82	3.0			
7-16-82		3.12		
7-19-82		2.35		
7-20-82	2.2		2.15	
7-21-82				
7-26-82		2.4		
7-28-82	2.25			
8-4-82	2.85	2.5		3.52
8-9-82	2.95			3.40
8-11-82		2.65	2.71	3.77
8-16-82		3.1		3.84
8-17-82	3.0			3.72
8-27-82	3.2			3.76

TK-114-TX(69): Data Summary

Interstitial Liquid Level Interpretation
(All readings are in feet)

Date	Gamma	Neutron	Acoustic	Salt Well W.F.
6-11-82		2.0		2.89
6-13-82	2.5			3.00
6-17-82	2.8			3.06
6-21-82		3.05		3.13
6-24-82	3.17	3.23		3.23
6-29-82		3.45		3.78
6-30-82	3.4			3.76
7-8-82	3.5	3.65		
7-9-82			3.61	
7-12-82	3.65			
7-15-82			3.41	
7-16-82		3.53		
7-19-82		1.95		
7-20-82	2.55			
7-21-82			2.57	
7-26-82		2.6		
7-28-82	2.82			
7-29-82			2.85	
8-4-82	3.0	3.0		4.52
8-9-82	3.2			3.40
8-11-82		3.15	3.15	3.77
8-16-82		3.27		3.84
8-17-82	3.25			3.72
8-18-82			3.24	3.64
8-27-72	3.45			3.76

TK-105-TX: Data Summary

Date	Interstitial Liquid Level Interpretation (All readings are in feet) Gamma	Neutron	Acoustic	Salt Well W.F.
5-27-82		4.4		
5-28-82	4.3			
6-4-82		4.0		
6-11-82		4.10		4.85
6-13-82	3.9			5.06
6.17-82	4.4			5.62
6-21-82		4.3		5.79
6-24-82	4.6	4.9		5.84
6-28-82		5.4		5.52
6-30-82	5.3			5.61
7-9-82	5.5			
7-12-82	5.5			
7-15-82		5.4	5.2	
7-19-82		5.32		
7-20-82	5.5			
7-22-82			5.63	
7-27-82		5.33		
7-28-82				
8-3-82		1.7		
8-4-82	1.7			
8-10-82		1.75		
8-13-82			1.73 & 1.05	
8-16-82		1.75		
8-17-82	1.6			
8-18-82			1.67	

TK-109-TX: Data Summary

Interstitial Liquid Level Interpretation
(All readings are in feet)

Date	Gamma	Neutron	Acoustic	Salt Well W.F.
6-11-82		11.4		12.29
6-13-82	12.55			11.86
6-17-82	12.1			12.33
6-21-82		11.8		11.96
6-24-82	12.1	11.8		12.2
6-28-82		12.05		11.97
6-30-82	12.1			12.26
7-7-82		11.8		12.05
7-8-82	12.2			12.26
7-9-82			12.12	12.43
7-12-82	12.2			
7-15-82		11.83	12.3	
7-19-82		11.15		
7-20-82	12.1			
7-22-82			11.32	
7-27-82		11.15		
7-28-82	11.95			
8-4-82	12.0	11.02		
8-10-82	11.9			
8-11-82		10.9		
8-13-82			10.7	
8-16-82		11.1		10.44
8-17-82	11.8		11.05	10.68

TK-110-TX: Data Summary

Interstitial Liquid Level Interpretation
(All readings are in feet)

Date	Gamma	Neutron	Acoustic	Salt Well W.F.
5-27-82		2.8		
5-28-82				
6-4-82		2.4		
6-11-82		2.8		2.42
6-13-82	2.4			2.31
6-17-82	2.5			2.45
6-21-82		2.8		2.67
6-24-82	2.8	3.0		2.73
6-28-82		3.2		2.80
6-30-82	2.7			2.76
7-7-82		3.2		
7-8-82	2.8			
7-12-82	2.9		3.35	
7-15-82		3.2		
7-19-82		3.35		
7-20-82	2.9			
7-21-82			3.29	
7-26-82				
7-28-82				
8-4-82	3.6			3.55
8-9-82	3.6			3.57
8-11-82		3.6		3.68
8-13-82			3.65	3.7
8-16-82		3.5		3.71
8-17-82	3.6		3.71	3.75
8-27-82	3.7			3.61

TK-106-S: Data Summary

Date	Waste Surface Level ft (in.)	Interstitial Liquid Level Interpretation (All readings are in feet) Gamma	Neutron	Acoustic
1-13-82	13.7	13.8	13.6	
1-19-82	13.7			13.8
2-4-82	13.7		13.6/B.6	
3-3-82	13.8	13.9	13.7	
4-2-82	13.8	13.9/13.9	13.7/13.8	
5-12-82	13.8	14.0/14.8		
5-13-82	13.8		13.7/13.7	
6-11-82			13.8/13.8	
6-13-82	13.9	Inst. Malfunction		
6-17-82	13.9	14.0		
6-21-82	13.9		13.7	
6-24-82	13.9	14.0	13.7	
6-30-82	13.9	14.0	13.8	
7-1-82	13.9			Inst. failure
7-8-82	13.9		13.7	
7-13-82	13.9	14.0		
7-14-82	13.9			14.1
7-16-82	13.9		13.8	
7-19-82	13.9		13.8	
7-20-82	13.9	14.1		
7-22-82	13.9			Inst. failure
7-27-82	13.9	14.1	13.8	14.0
8-10-82	13.9	14.0		14.1
8-16-82				14.0
9- 2-82		13.9		

TK-109-S: Data Summary

Date	Waste Surface Level ft (in.)	Interstitial Liquid Level Interpretation (All readings are in feet) Gamma	Neutron	Acoustic
1-13-82	15.4'	10.3	10.3	
1-19-82				10.4
2-4-82	15.4'		10.3	
3-4-82	15.4'	10.4	10.3/10.3	
4-2-82	15.4'	10.4/10.4	10.3/10.3	
5-12-82	15.4'	10.4		
5-13-82			10.2/10.2	
6-11-82	15.4'		10.3	
6-21-82			10.3	
6-24-82		10.3	10.3	
6-29-82			10.3	
6-30-82		10.3		
7-1-82	15.4'			Inst. failure
7-8-82			10.2	Inst. failure
7-13-82		10.3/10.3		
7-14-82				10.5
7-19-82			10.3	
7-20-82		10.3		
7-21-82				10.7
7-27-82	15.4'	10.3	10.2	10.5
8- 4-82		10.3		
8- 5-82			10.3	
8-10-82		10.4		10.7
8-16-82			10.4	10.5
9- 2-82	15.4'	10.4		

Note: Data were aligned to a different baseline profile than that used in Figure 27.

TK-112-S: Data Summary

Date	Waste Surface Level ft (in.)	Interstitial Liquid Level Interpretation, Feet (All readings are in feet) Gamma	Neutron	Acoustic
1-13-82	16.5'	8.2	8.2	
1-22-82	16.5'			8.1
2-4-82	16.5'		8.2/8.2	
3-4-82	16.5'	8.3	8.3	
4-2-82	16.5'	8.4/8.4	8.4/8.4	
5-12-82	16.5'	8.4/8.3		
5-13-82			8.4/8.4	
6-11-82	16.5'		Incomplete scan	
6-13-82		8.4		
6-17-82		8.4		
6-21-82			8.3	
6-24-82		8.4		
6-29-82			8.3	
6-30-82		8.4		
7-1-82	16.5'			8.4
7-8-82			8.3	Instr. Failure
7-13-82		8.4/8.4		
7-14-82				8.4
7-16-82			8.3	
7-19-82			8.3	
7-20-82		8.4		
7-21-82				8.4
7-27-82	16.5'	8.4	8.3	
8-10-82				8.5
8-12-82			8.4	
8-16-82		8.4		
9- 2-82	16.5'	8.4		

TK-111-BY: Data Summary

Date	Waste Surface Level ft (in.)	Interstitial Liquid Level Interpretation (All readings are in feet)		
		Gamma	Neutron	Acoustic
1-12-82	20.3'	20.4		
1-13-82			20.3	
1-22-82				20.8
2-4-82	20.3'	20.4/20.4/ 20.4	20.3/20.3	
3-3-82	20.3'	20.4/20.5		
3-5-82			20.4	
4-2-82	20.3'	20.5/20.5	20.4/20.4	
5-28-82	20.3'	20.5/20.5		
6-25-82	20.3'	20.5	20.4	
7-1-82	20.3'	20.5	20.4	
7-9-82		20.5	20.4	
7-13-82		20.5		
7-14-82				20.7
7-16-82			20.3	
7-20-82		20.4	20.4	
7-23-82				Inst. Failure
7-30-82		20.4	20.4	20.7
8-12-82	20.3'	20.4		20.7
8-20-82				20.7

TK-104-SX: Data Summary

Date	Waste Surface Level ft (in.)	Interstitial Liquid Level Interpretation (All readings are in feet) Gamma	Neutron	Acoustic
6-8-82	23.3'	22.3		
6-11-82			22.3	
6-13-82		22.3		
6-17-82		22.3		
6-21-82			22.3	
6-24-82		22.3	22.3	
6-29-82			22.3	
7-8-82	23.5'		22.3	
7-13-82		22.4		
7-15-82				22.3
7-16-82			22.3	
7-19-82			22.3	
7-20-82		22.5		
7-21-82				Instr. Malfunction
7-27-82			22.3	
8- 6-82	23.5'			22.3
8-10-82				22.5
8-12-82			22.3	
8-17-82		22.4		22.5
9- 2-82	23.5'	22.4		

Note: Data revised by comparison with different reference baseline

APPENDIX B

PROBES

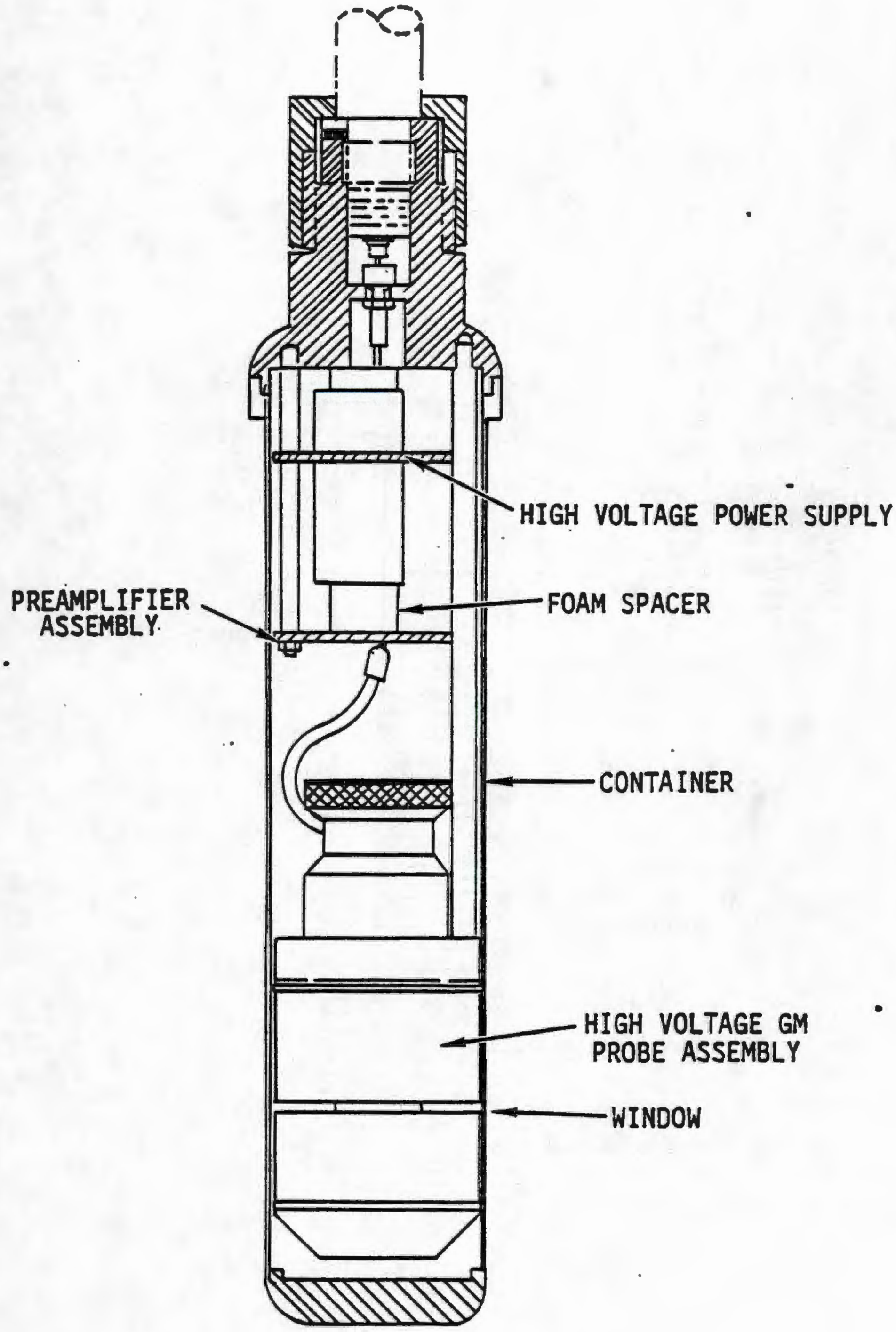


FIGURE : IN-TANK HIGH LEVEL GAMMA PROBE

APPENDIX B.2.

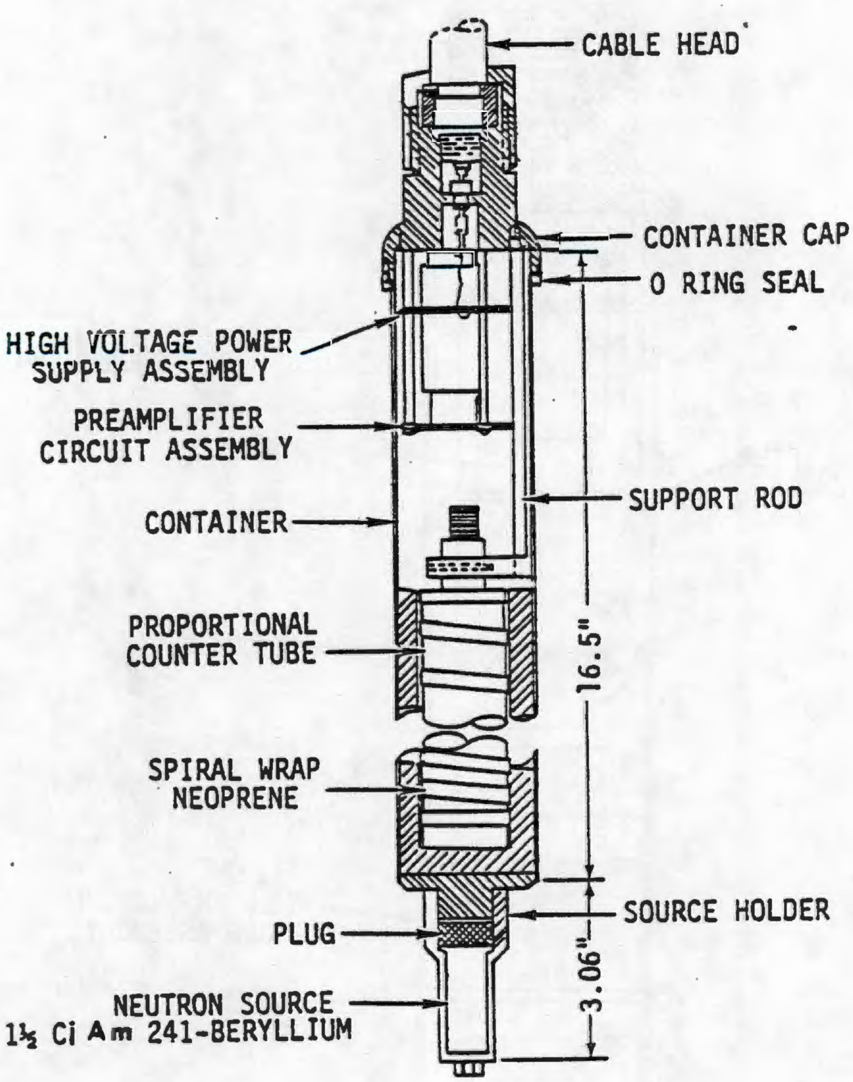


FIGURE : IN-TANK NEUTRON PROBE

APPENDIX C
INDEPENDENT INTERPRETATION OF LOW SCAN PROFILES

Date	LOW	Probe	Interpreted Interstitial Liquid Level				
			A	B	C	D	E
6-30-82	510996	Gamma	12.7	12.6	12.8	12.6	12.6
6-28-82		Neutron	11.7	11.7	11.7	11.7	11.7
6-03-82	400660	Gamma	13.9	13.8	13.9	13.8	13.8
7-08-82		Neutron	13.6	13.65	13.6	13.7	13.6
7-13-82	401260	Gamma	8.35	8.3	8.35	8.3	8.3
7-16-82		Neutron	8.1	8.1	8.2	8.0	8.1
7-13-82	400960	Gamma	10.6	10.55	10.5	10.7	10.6
7-16-82		Neutron	10.2	10.15	10.05	10.0	10.2
7-18-82	520369	Gamma	3.5	3.5	3.6	3.6	3.6
7-27-82		Neutron	5.5	5.4	5.5	5.6	5.6
7-27-82	410462	Gamma	22.4	22.4	22.4	22.4	22.4
7-27-82		Neutron	22.2	-	-	-	22.2

Note: Reference charts used for baseline information were randomly selected and were not the same as those used to develop the Appendix A measurements. Differences will therefore be noted.

Appendix C: Independent Interpretation of LOW Scan Profiles