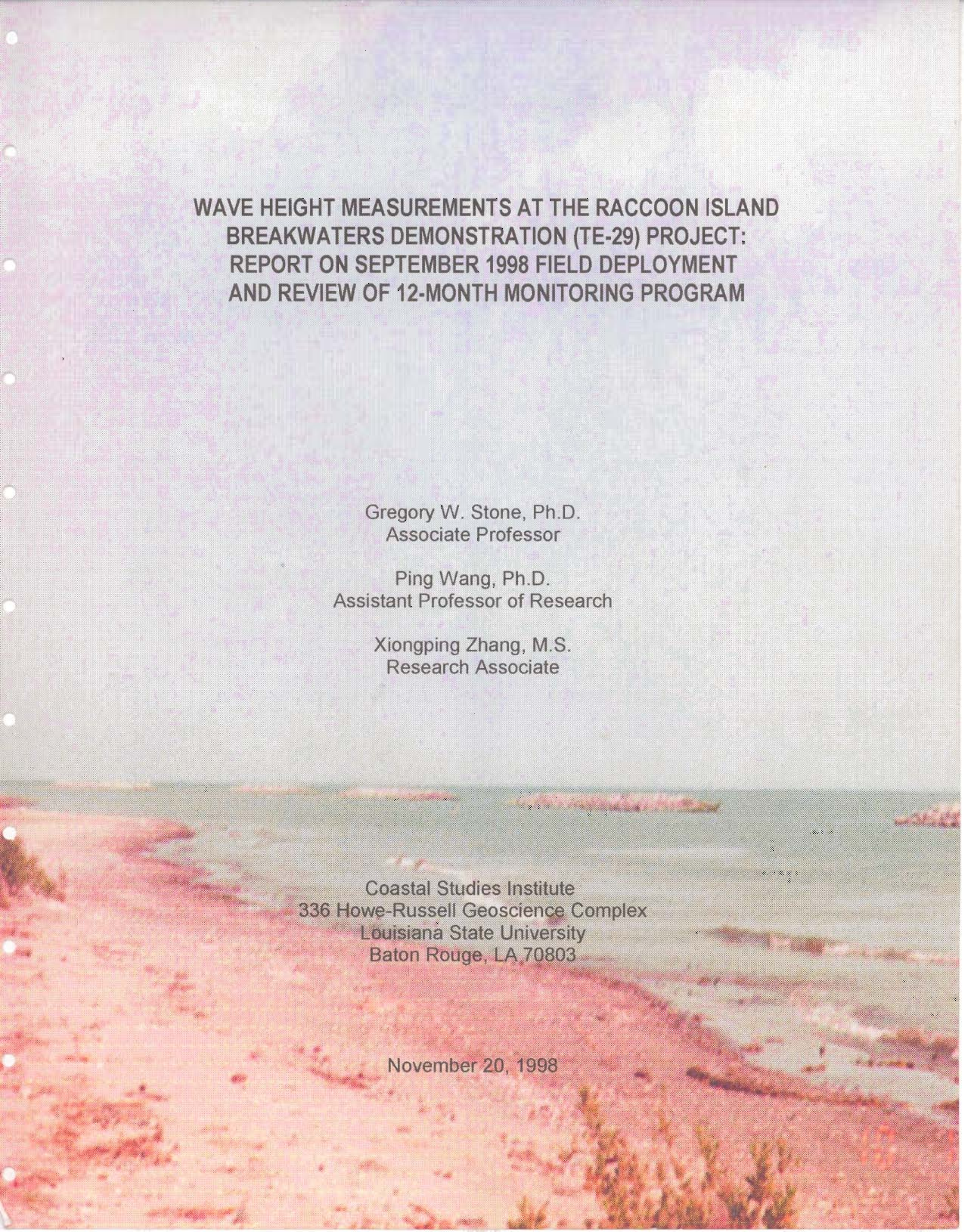

WAVE HEIGHT MEASUREMENTS AT THE RACCOON ISLAND BREAKWATERS DEMONSTRATION (TE-29) PROJECT: REPORT ON SEPTEMBER 1998 FIELD DEPLOYMENT AND REVIEW OF 12-MONTH MONITORING PROGRAM

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TABLE OF CONTENTS

LIST OF PLATES

LIST OF FIGURES

LIST OF APPENDICES

INTRODUCTION

In May 1997, scientists in the Coastal Studies Institute at Louisiana State University, were contracted by the Louisiana Department of Natural Resources/Coastal Restoration Division, to monitor wave conditions at the Raccoon Island Breakwaters Demonstration Project (TE-29) funded under the Coastal Wetlands Planning, Protection and Restoration Act (see Figure 1 for location). This is the fourth of a series of reports in which the experimental design, field deployment, and information in the form of wave statistics and spectra are presented and interpreted along with bathymetric and topographic surveys of the site. Previous deployments are discussed in Stone et al. (1997, 1998a, 1998b). Comparisons with results obtained from the first, second, and third deployments in October 1997, March 1998 and July 1998, respectively, are also discussed.

The fourth wave measurement experiment at Raccoon Island was conducted on September 24th, 1998. Beach profile surveys occupying the same transects established in October 1997, March 1998, and July 1998 were conducted along with the wave measurements. An additional beach survey was conducted in November 1997 due to rapid morphological adjustment to the breakwaters. Results from the November 1997 beach survey are also summarized in this report.

The objectives of the present study are as follows:

1. Quantification through field measurement, of the response of nearshore wave conditions to breakwater construction with emphasis on adjustments to wave heights, period and spectral characteristics.
2. Quantification of nearshore morphological response to breakwater construction.

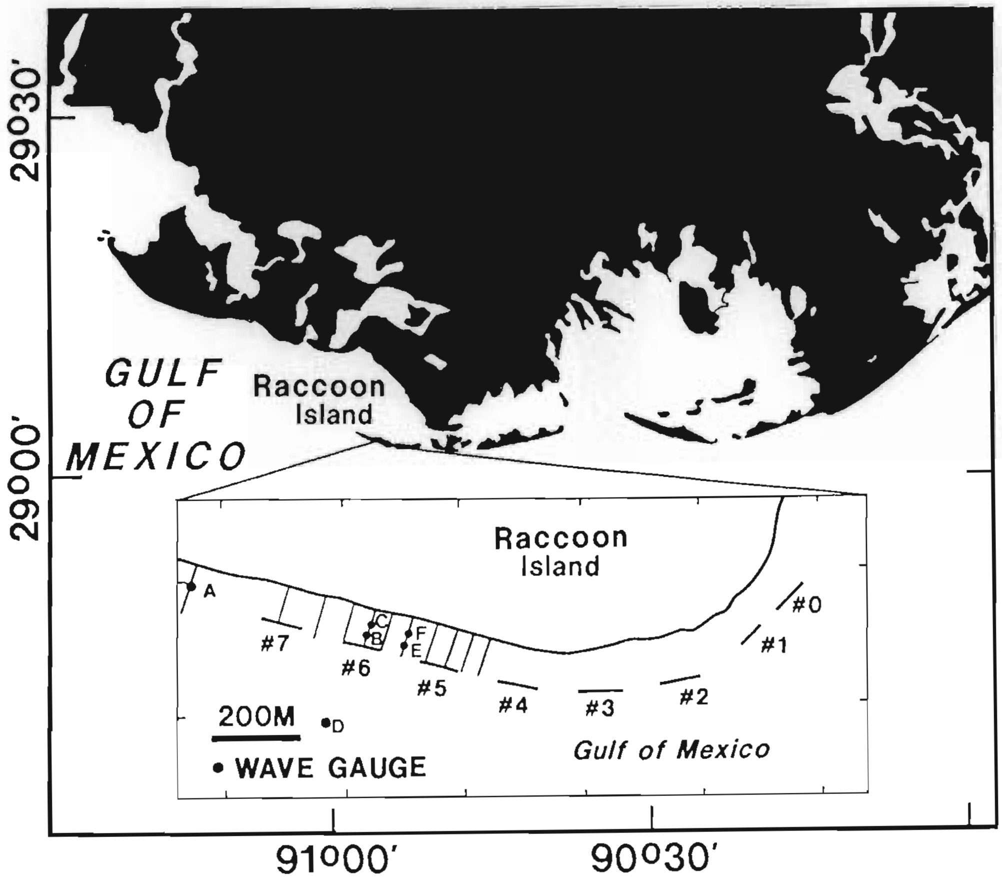


Figure 1. Study area, showing the locations of wave gages and survey lines.

Objective 1 complies with contractual obligations as dictated by the contractor. Although there has been some discussion among agencies and personnel within the contracting agency as to the need for wave monitoring at Raccoon Island, the necessity is seldom questioned among experts in the scientific and engineering disciplines. Examples of the importance of obtaining such information and using it to quantify the performance of these structures has been amply demonstrated in the scientific and engineering literature (Dally and Pope, 1986; Carver et al., 1993; Chasten et al., 1993; Gravens and Rosati, 1994). In short, these data will be essential in establishing and/or refining the most effective segment length, optimal distance to the shoreline, and optimal spacing-width ratio. The latter is a critical criterion which will prove essential should segmented breakwaters be adequately evaluated as a potential shore protection option for coastal Louisiana.

Objective 2 is not contracted within the scope of services for the Raccoon Island breakwaters study. however, it was included in this work at no charge to the contractor, because of the overall importance of quantifying topographic and bathymetric changes due to breakwater construction. As described in more detail later in this report, only the western flank of the breakwaters array was subject to detailed beach/bathymetric monitoring through conventional surveys. This was due to two factors:

1. The vast majority of sediment accumulation that was potentially attributable to breakwater construction was being observed along the west flank of the breakwaters array.
2. Given the limited funding available for this project, it was decided that the area where sedimentation was most apparent would be the one focussed upon.

The data obtained from these surveys have proven critical in enhancing our comprehension of sedimentation patterns in the vicinity of the breakwaters at Raccoon Island. These data and our interpretation are presented in detail in this report.

INSTRUMENTATION AND SAMPLING SCHEMES

Wave height and period were measured with four precise, Paroscientific digital quartz pressure transducers. The pressure transducers, which record the instantaneous fluctuation of water level, are capable of 0.01% accuracy and 0.0001% resolution. For conditions at the Raccoon Island breakwaters site, the accuracy of the instrument is expected to be well within 5 mm (0.2 in). The pressure transducers were assembled by CSI personnel in a self-contained, solid-state recording package, suitable for underwater deployment. An example of the laboratory test of the pressure sensor array is shown in Plate 1. The instrument packages are capable of sampling at a high frequency of 4 Hz.

Plate 1. The pressure transducer array used in the Raccoon Island breakwater study. The pressure sensors and solid-state recorders are housed in a water-tight casing and are being tested in the Coastal Studies Institute's Wave Simulation Facility.

After a series of on-site experiments, an optimal sampling scheme was determined, which allowed maximum temporal coverage and efficient data processing. Two thousand and forty-eight (2048) readings (one burst of approximately 8.5 minutes) were recorded every 10 min at 4 Hz. The 4-Hz sampling allows reliable measurement of high-frequency wave components with periods as low as 1 second. The 8.5-minute burst, which is sufficient in duration to include 70 to 150 waves of 3- to 7-second periods, yields reliable data for statistical analysis of wave spectra and was deemed appropriate for the objectives of this study. The locations of the deployments are shown in Figure 1, and include those sites landward and seaward of the breakwaters, and the control site to the west. The latter provides information on a similar but unprotected location.

The nearshore morphology was surveyed using the standard level and transit procedure utilizing a Topcon electronic total station. For the surveying range at the breakwater project, the accuracy of the instrument is expected to be within 10 mm (0.4 in.) in the horizontal and 5 mm (0.2 in.) in the vertical. Eleven survey lines spanning the four westernmost breakwaters were surveyed (Figure 1). A beach profile at the control site was surveyed to represent a no-structure scenario and allow some indication of potential changes to the profile due to the breakwater construction. Additional beach profiles covering the entire breakwater site were surveyed in November 1997. At the eastern portion of the project location, the exposure of vegetation at the shoreline and a muddy bottom between the shoreline and the breakwaters precluded quarterly surveying given the budgetary constraints associated with this project. Thus, morphological analyses concentrate on the western, sand-dominated portion. The profile locations of the project are shown in Figure 1. Temporary benchmarks were established using 1.5-m (5-

ft) long PVC pipes. Beach posts and pipes protruding from the crown of the breakwaters were used as elevation controls. A temporary elevation, measured relative to an estimated zero water level during the October 2, 1997 survey, was used but will be tied to the NGVD datum at a later date. The density of survey points along profile lines is a direct function of the topographic/bathymetric complexity. Breaks in slope associated with morphological/bathymetric features were recorded during each survey. The profile surveys start landward at the edge of the vegetation, and end seaward at the crown of the breakwater, or at the same relative locations for the survey lines in the gaps between breakwaters.

The bathymetric and topographic surveys were conducted to determine trends associated with sedimentation/erosion induced by the segmented breakwaters. The topographic survey and nearshore morphological analysis was not part of the contract with LADNR. However, this undertaking is viewed here as being critical to a more profound comprehension of the impacts of the breakwaters on coastal processes and sediment transport at the monitoring sites. The topographic surveys were conducted during each wave monitoring event on a quarterly basis. Nearshore morphological changes will be analyzed by LADNR by comparing pre- and post-construction surveys, and each of the quarterly surveys. As discussed in the following sections, this additional undertaking of morphological monitoring has proven to be important and the results from which have significant implications for the potential future use of this type of structure in shoreline protection along Louisiana's coast.

WAVE MEASUREMENTS

The fourth wave measurement was conducted on September 24th, 1998 during a mild southerly wind condition. The incident wave conditions were observed to be quite different during the September1998 measurements when compared to the July 1998 measurements, but similar to those encountered during October 1997 and March 1998 measurements. During the October 1997, March 1998, and September 1998 measurements, choppy seas, largely attributable to local winds, were encountered. During the July 1998 measurements, long period swell waves dominated. Wave heights were observed to be generally lower than 0.3 m (1 ft) approaching nearly perpendicular to the shoreline. During the October 1997 measurements, wave heights were observed to be approximately 0.3 m (1 ft), approaching nearly perpendicular to the shoreline. During the March 1998 measurements, wave heights were estimated to be approximately 0.4 m (1.3 ft), approaching the shoreline at a highly oblique angle from the west. During the September 1998 measurements, the normally incident wave heights were approximately 0.3 m (1 ft).

The control wave gage A (Figure 1) was deployed west of the breakwaters away from any influence of the structures. Wave gage B was deployed approximately 80 m (260 ft) landward of the center of breakwater #6 (Figure 1). Wave gages A and B were deployed at the same distance of approximately 15 m (50 ft) seaward of the shoreline. The average water depth at the inside location (B) was approximately 0.30 m (1.0 ft), considerably shallower than the 1.0 m (3.3 ft) at the control site. This difference in water depth between the landward breakwaters and the control site was caused by significant breakwater-induced morphological change, as discussed in the following sections. Wave gage C (Figure 1) which was used in the March 1998 measurement, was judged unnecessary during both the July and September 1998 measurement, mainly because of the shallow and narrow water body landward of the breakwaters. The shallow water landward of the breakwaters resulted from a significant amount of sand accumulation, which is quantified and discussed in the following sections. Wave gage D, measuring offshore wave conditions, was deployed approximately 200 m (600 ft) seaward of the center of breakwater #6. The average water depth at the offshore location was approximately 1.6 m (5.2 ft). The wave gage at site B was moved to the gap (site E) between breakwaters #6 and #5 (Figure 1) after the sampling at site B was completed. Deployment at site F, landward of the gap between the breakwaters, was not possible due to the shallow, narrow water body. The water depth at site E was similar to that at site B.

The control wave gage A and the offshore gage (D) remained at the same location throughout the entire experiment. Measurements at site B landward of the center of the breakwaters were conducted in the early afternoon. Measurements at site E landward of the breakwater gap were conducted in late afternoon. Comparisons between wave conditions in the protected (landward of the center of the breakwater), unprotected, and offshore sites are based on simultaneous measurements. While comparisons between wave conditions in the protected sites and the gaps are influenced by the slight time difference, this influence is assessed by the continuous measurement at the control and offshore sites. During the September 1998 measurement, this difference had no influence on wave comparisons as discussed in the following sections.

DATA ANALYSES

One of the major objectives of this monitoring project is to quantify the influence of the breakwaters on incident wave conditions. This was accomplished by comparing wave conditions measured behind the breakwaters with the conditions at the control site, the latter being devoid of the influence of the breakwaters. Comparisons between wave conditions landward of the breakwater and those in the gap also provide direct information on the breakwaters' influence on waves in the immediate vicinity of the tips of the structures. This information is critical in establishing and/or refining the optimal segment length and spacing width ratio.

The raw data record of water level fluctuations is a composite of waves of different frequency (Appendix 2). In order to examine the energy contributions of each frequency and to obtain a statistical representation of the wave characteristics, a spectral analysis is necessary. The spectral analysis of the raw data was based on the "Field Wave Gaging Program, Wave Data Analysis Standard," recommended by the Coastal Engineering Research Center (see Earle et al., 1995 for a detailed review).

Significant wave height was calculated based on CERC's recommended procedure

$$H_{mo} = 4.0\sqrt{m_o} \qquad \textbf{Eq. 1}$$

where the zero moment, m_o, is computed as

$$m_o = \sum_{n=1}^{N_b} C_{zz}(f_n)df_n \qquad \textbf{Eq. 2}$$

where $C_{zz}(f_n)$ is the power spectrum density of the nth frequency f_n, and df_n is the bandwidth. The peak period T_p is given by

$$T_p = \frac{1}{f_p} \qquad \textbf{Eq. 3}$$

where f_p, the peak frequency, is the frequency for which spectral wave energy density is a maximum. The power spectrum densities were calculated using the Welch method of the fast Fourier transformation (Welch, 1967).

Beach profile analyses, including shoreline-position comparisons and volume change calculations, were conducted using the software BMAP (Beach Morphology Analysis Package). BMAP was developed and verified in the Coastal Engineering Research Center for various beach profile analyses.

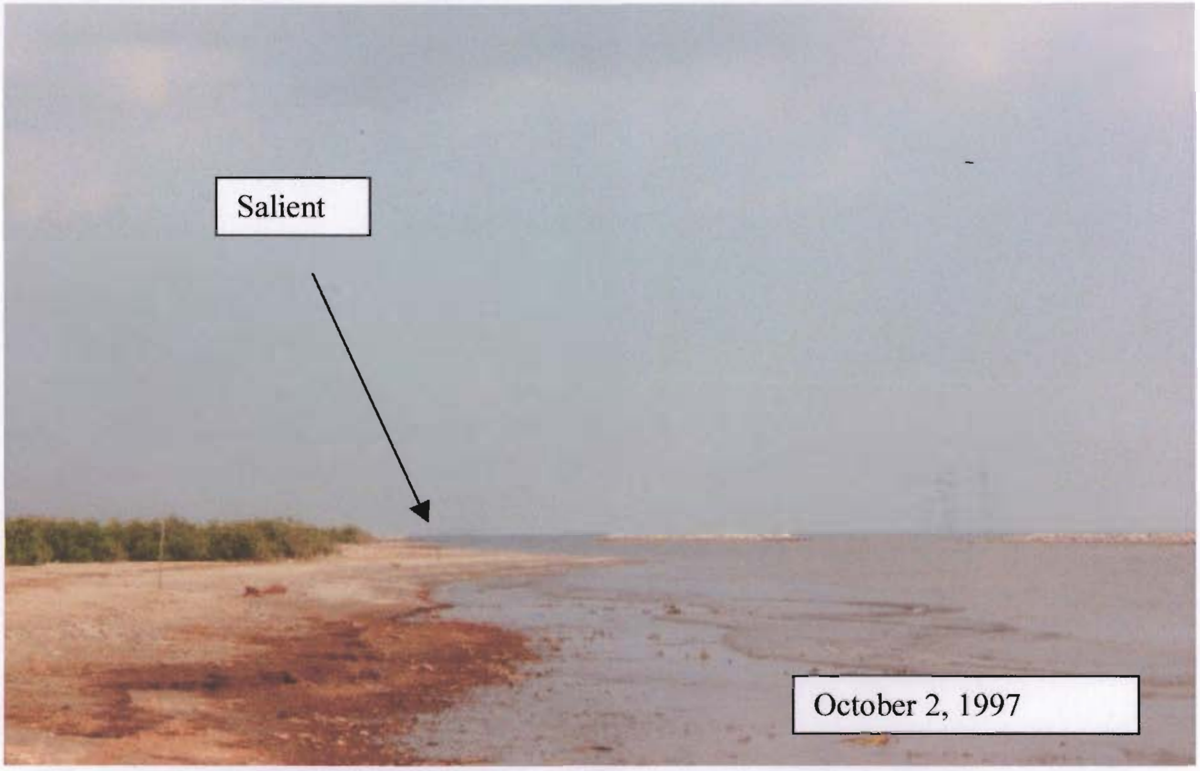
RESULTS

During the 12-month period of monitoring, substantial morphological changes were measured. These morphological changes have significantly changed the function of the breakwaters in terms of reducing the wave energy arriving at the Raccoon Island shoreline. It is, therefore, necessary to briefly summarize the time sequence of the morphological changes before the discussion of the breakwaters' influence on nearshore wave propagation.

General Overview of Morphological Changes

Significant morphological changes were measured during the 12 months post-construction monitoring. This morphological change has effectively changed the configuration of the detached, segmented breakwaters. Appendix 1 illustrates the sequence of morphological changes that occurred during the first 12 months of monitoring after construction. The following time-series of morphological changes was observed during the six field trips to the study site in the 12-month period (Plate 2):

1. Approximately 3 months after breakwater construction, a salient was observed along the Raccoon Island shoreline, resulting in moderate shoreline gain landward of the centers of the breakwaters and recession landward of the gaps between the segments (Plate 2A);
2. Approximately 6 months post-construction, substantial sand accumulation was measured directly landward of the center of the breakwaters, resulting in an emerged sand body. The development of the salient appeared to have reached quasi-equilibrium (Plate 2B);
3. Approximately 9 months post-construction, the sand accumulation in the vicinity of the breakwaters continued and extended to the gaps between the segments, resulting in a continuous sand body connecting the segments #6, #5, #4, and #3. Substantial amounts of sand emerged Gulfward of the structures (Plate 2C). A substantial salient was developed landward of the center of the westernmost segment, resulting in a local shoreline gain of over 20 meters.
4. Approximately 12 months post-construction, the sand accumulation between the breakwaters and the shoreline continued, while the sand accumulated Gulfward of the structures was eroded (Plate 2D). The salient developed landward of the center of the westernmost segment was almost completely eroded and the shoreline returned to its previous location, indicating that the westernmost salient was temporary and probably related to seasonal wave characteristics.



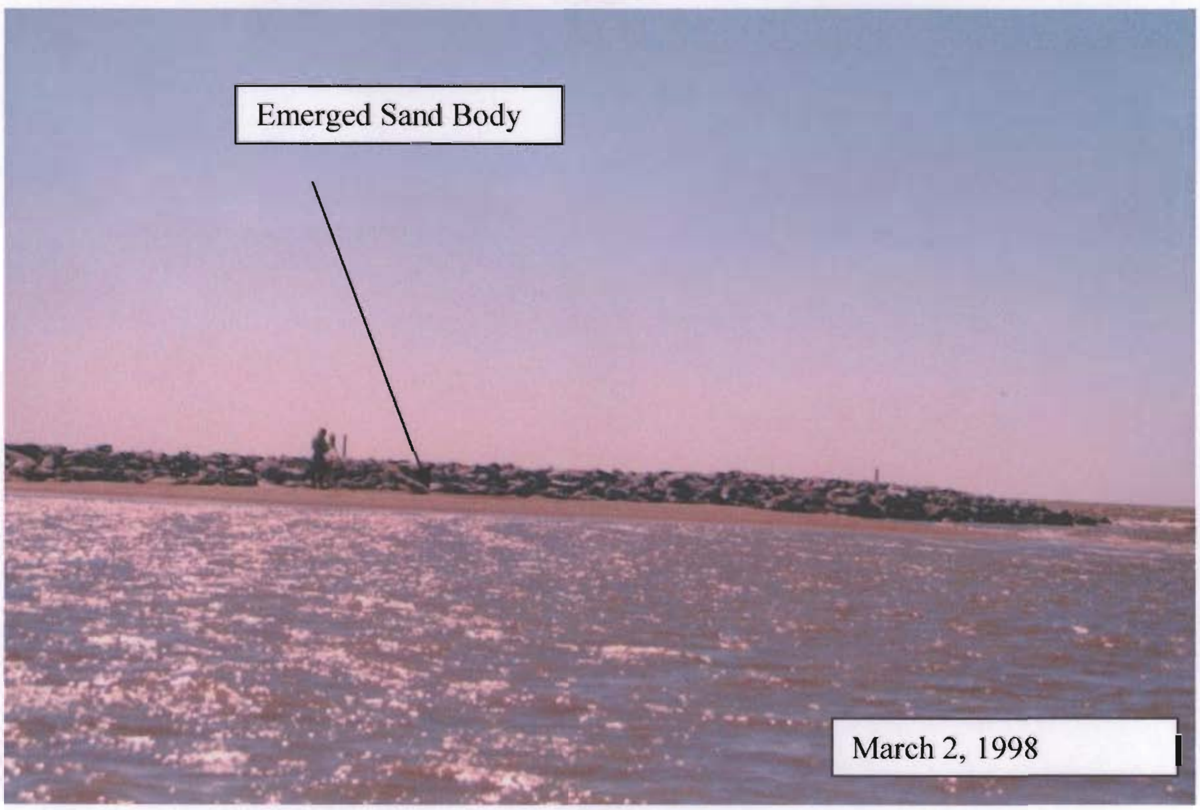
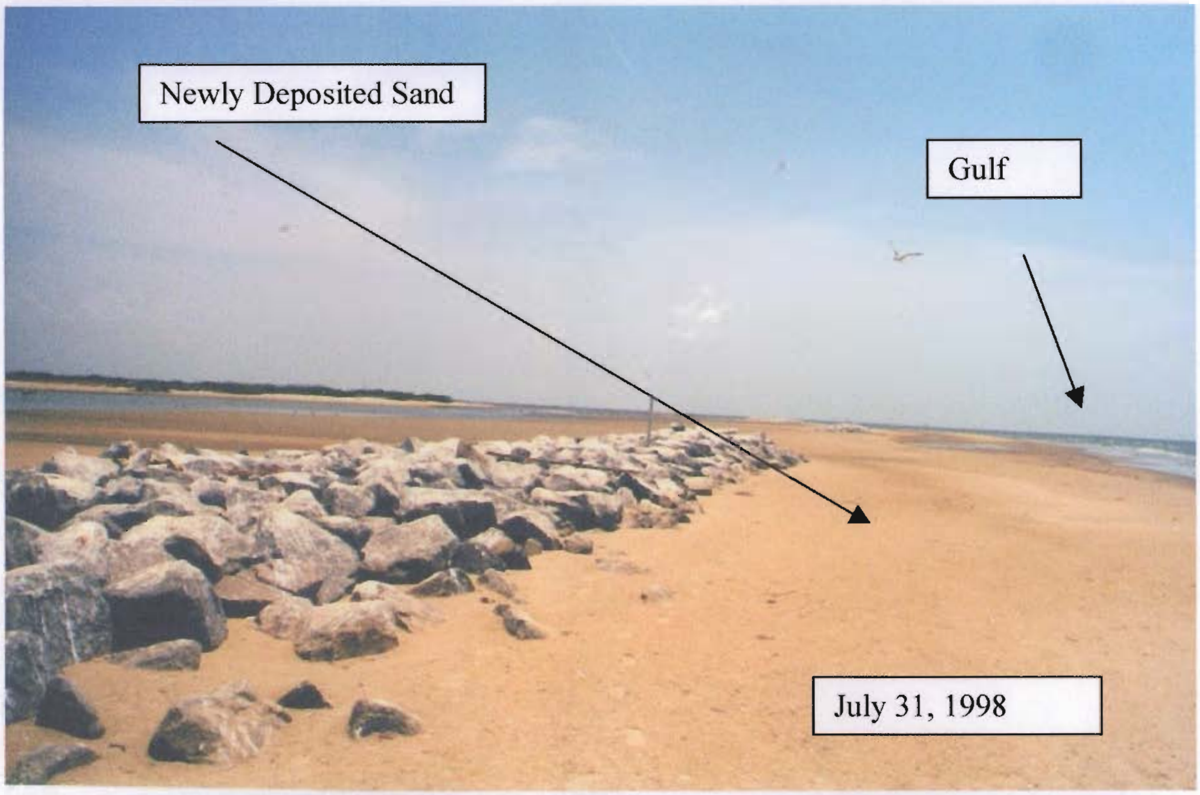


Plate 2. Time-series morphological changes during the 12-month monitoring.



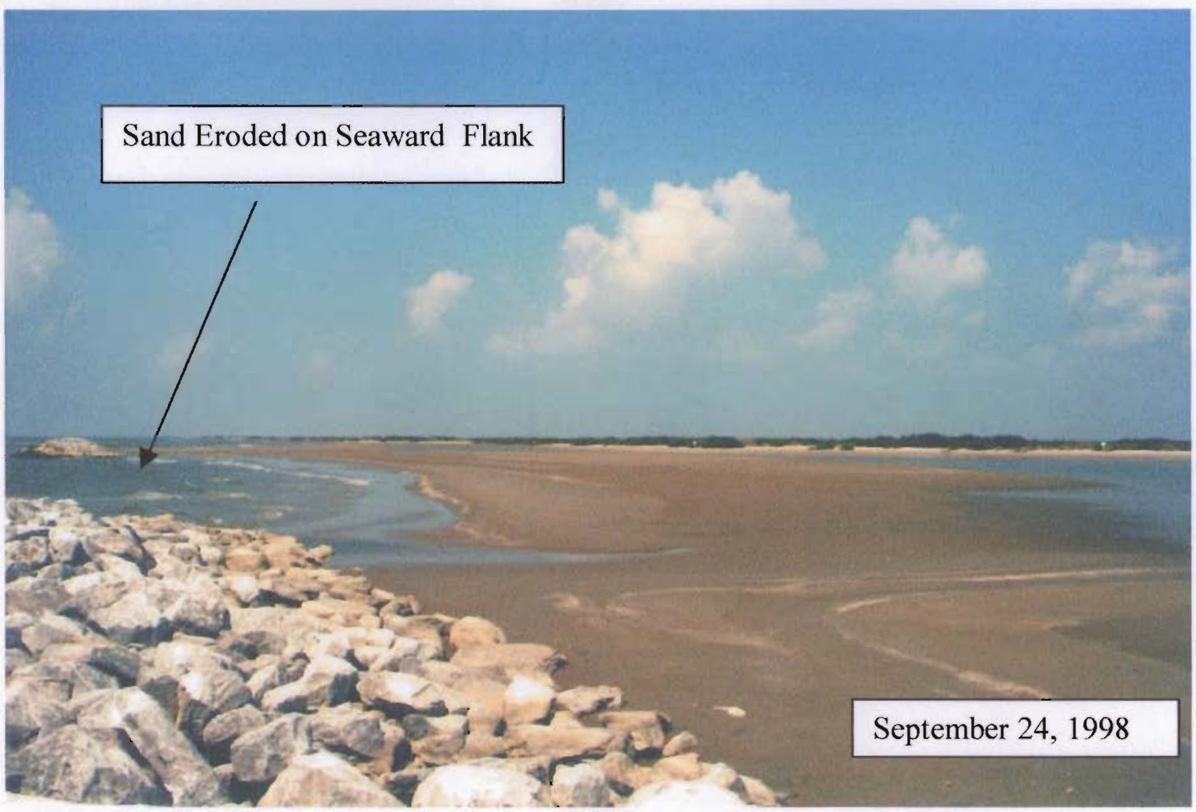


Plate 2 (Contd.).Time-series morphological changes during the 12-month monitoring.

Compared to conditions during the October 1997 and March 1998 field experiments, significant morphological changes have occurred during both the July 1998 and September 1998 measurements. The morphological changes are discussed quantitatively later in this report. As discussed in the third report (Stone et al., 1998b) and summarized above, a large sand body emerged both landward and seaward of the breakwaters as observed during the July 1998 measurements, spanning breakwaters #6, #5, #4, and partly #3 (Plate 3). The emerged sand body has filled the gaps between the above mentioned breakwater segments. The water body landward of the breakwaters became much shallower when compared to the beginning of the project. The morphological conditions have changed significantly during the four months between March 1998 and July 1998 surveys (Stone et al., 1998b). These morphological changes have significantly altered the function of the structures due to the accumulation between the gaps and seaward of the breakwaters.

Data obtained from the September 1998 field experiment suggest that a significant volume of sediment that had accumulated seaward of the breakwaters had been eroded between the July and September surveys (Plate 4). Field observation and beach surveys indicate that some of the sediment had been transported landward and accumulated between the breakwaters and the shoreline. It is also conceivable that some of this material was reworked offshore and deposited as bars (Plate 4). The breakwaters remained connected by the emerged sand body and blocked the Gulf waves from reaching the shoreline, similar to the conditions encountered during the July 1998 measurements. The water body between the breakwaters and the shoreline was substantially narrower (Plates 3 and 4). Thus, results from the July and September 1998 wave measurements are not directly comparable with the results from previous measurements due to the dramatic morphological changes that occurred. Despite the significant differences, a similar report format to that used in the October 1997 and March 1998 reports was used in the July 1998 and present report for the convenience of time-series comparisons.

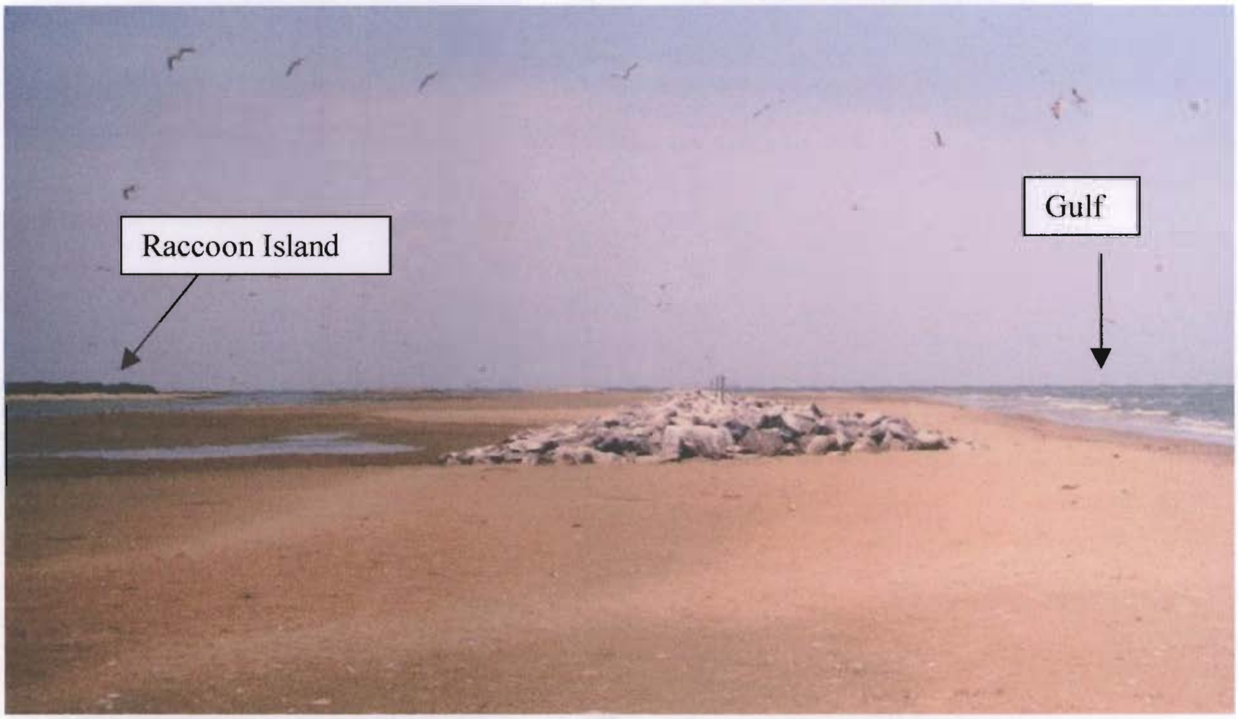


Plate 3. The breakwaters #6, #5, #4, and #3 were surrounded by an emerged sand body both landward and seaward and the structures were not directly exposed to wave action. Photograph looking east, July 31, 1998.

Wave Diffraction and Breaking

Wave diffraction around the tips of the breakwaters and wave breaking were almost completely absent and had no influence at the shoreline during both the July and September 1998 measurements due to the emerged sand body in the vicinity of the breakwaters. This contrasted significantly with the field conditions encountered during the October 1997 and March 1998 measurements. Incident wave propagation from the

Gulf was negligible along the Raccoon Island shoreline during both the July and September 1998 measurements. Little to no wave activity was observed landward of breakwaters #6, #5, #4, and #3.

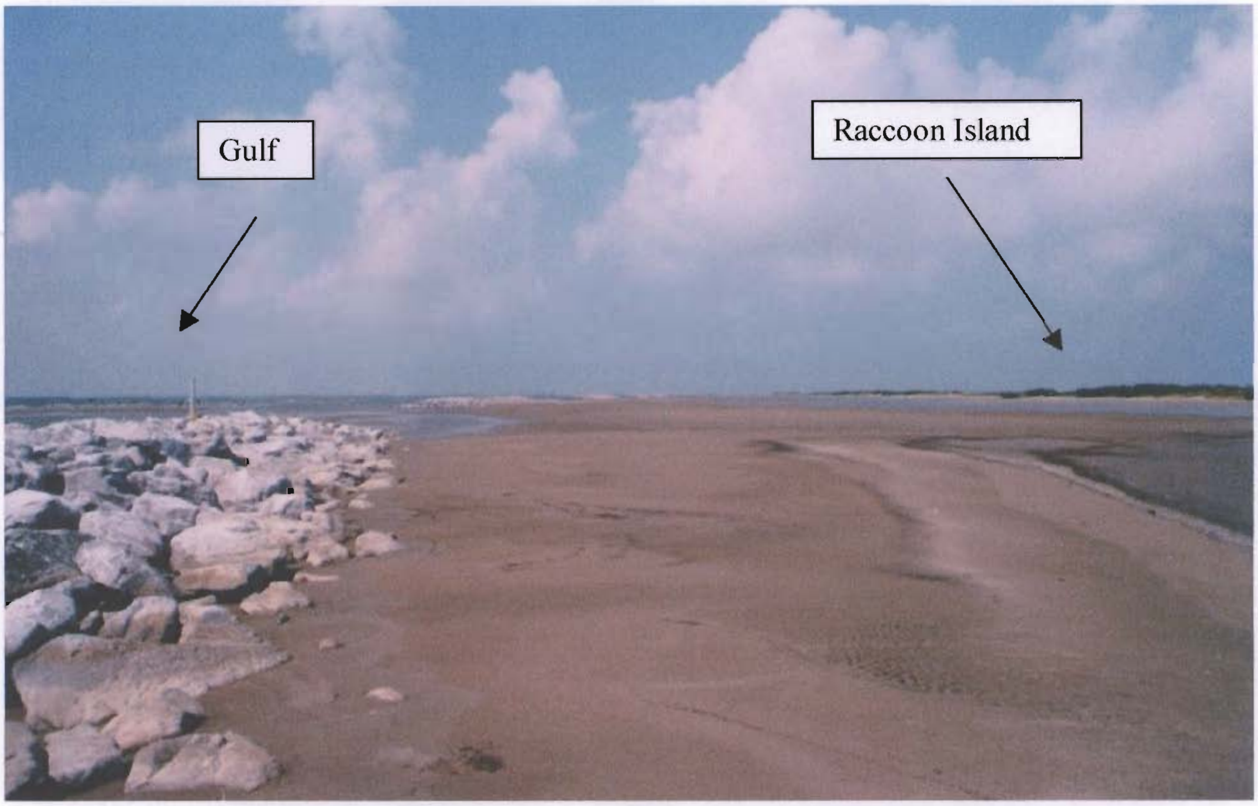


Plate 4. The breakwaters #6, #5, #4, and #3 were connected by an emerged sand body. The sediment that had accumulated immediately seaward of the breakwaters had been eroded between July and September 1998. Note the narrow water body landward of the breakwaters. Photograph looking west, September, 1998.

Hydrodynamic conditions landward of the breakwaters and at the Raccoon Island shoreline have changed substantially due to the emergence of the sand body in the gaps between breakwaters. Waves during fairweather conditions were entirely blocked by the emerged sand body adjacent to the breakwaters. Wave breaking was not observed at the shoreline landward of the breakwaters (Plate 5).

Plate 5. Photograph showing negligible wave action landward of breakwaters #6 and #5 and at the adjacent Raccoon Island shoreline. Note the shallow and narrow water body. Photograph looking southeast, September 24, 1998.

Significant Wave Heights: September 1998 Deployment

Significant wave heights measured at the offshore site during the September 1998 deployment ranged from 0.16 m (0.52 ft) to 0.30 m (0.98 ft) with an average of 0.22 m (0.72 ft) (Figure 2). Wave heights increased moderately toward late afternoon. Similar wave heights and trends were measured at the control site, with significant wave heights ranging from 0.15 m (0.49 ft) to 0.27 m (0.89 ft) (Figure 2). Landward of the breakwaters, the average water depth was less than 0.35 m (1.15 ft) throughout the period of measurement, and the water body was narrow, approximately 15 m (49 ft) wide, and almost entirely isolated from the Gulf (Plates 5 and 6).

The wave measurements landward of the breakwaters are considered to be less accurate than those from the offshore measurements and from the previous measurements due to 1) technical difficulties in gage installation caused by the shallow water, 2) extremely low magnitude of the signal and low signal-to-noise ratio, and 3) very high frequency wind-generated ripples. Visual observations indicated a ripple height of less than 3 cm landward of the breakwaters.

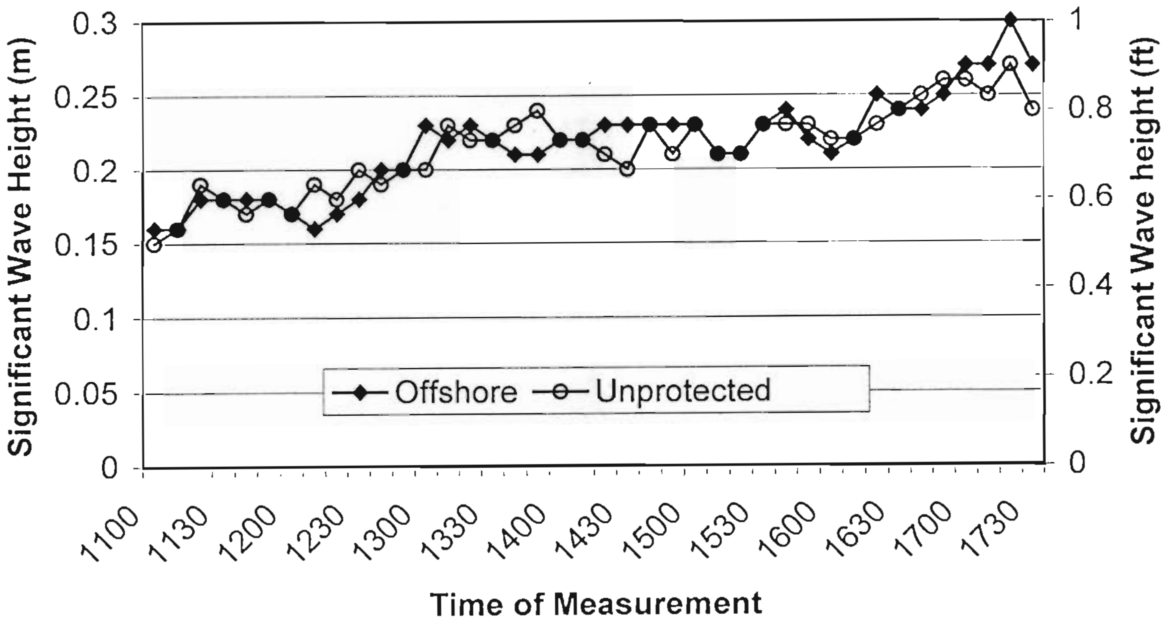


Figure 2. Time series of significant wave heights measured at the offshore and unprotected sites, September 1998.

Significant Wave Heights: Overview of the Four Deployments

Results from the October 1997, March 1998, July 1998, and September 1998 measurements are summarized in Figure 3 for comparison. It is worth emphasizing that the difference between landward of the center of the breakwater and landward of the gap did not exist during both the July and September 1998 measurements, and wave heights were reduced by nearly 100% landward of the breakwaters. No sediment transport was observed landward of the breakwaters and at the Raccoon Island shoreline.

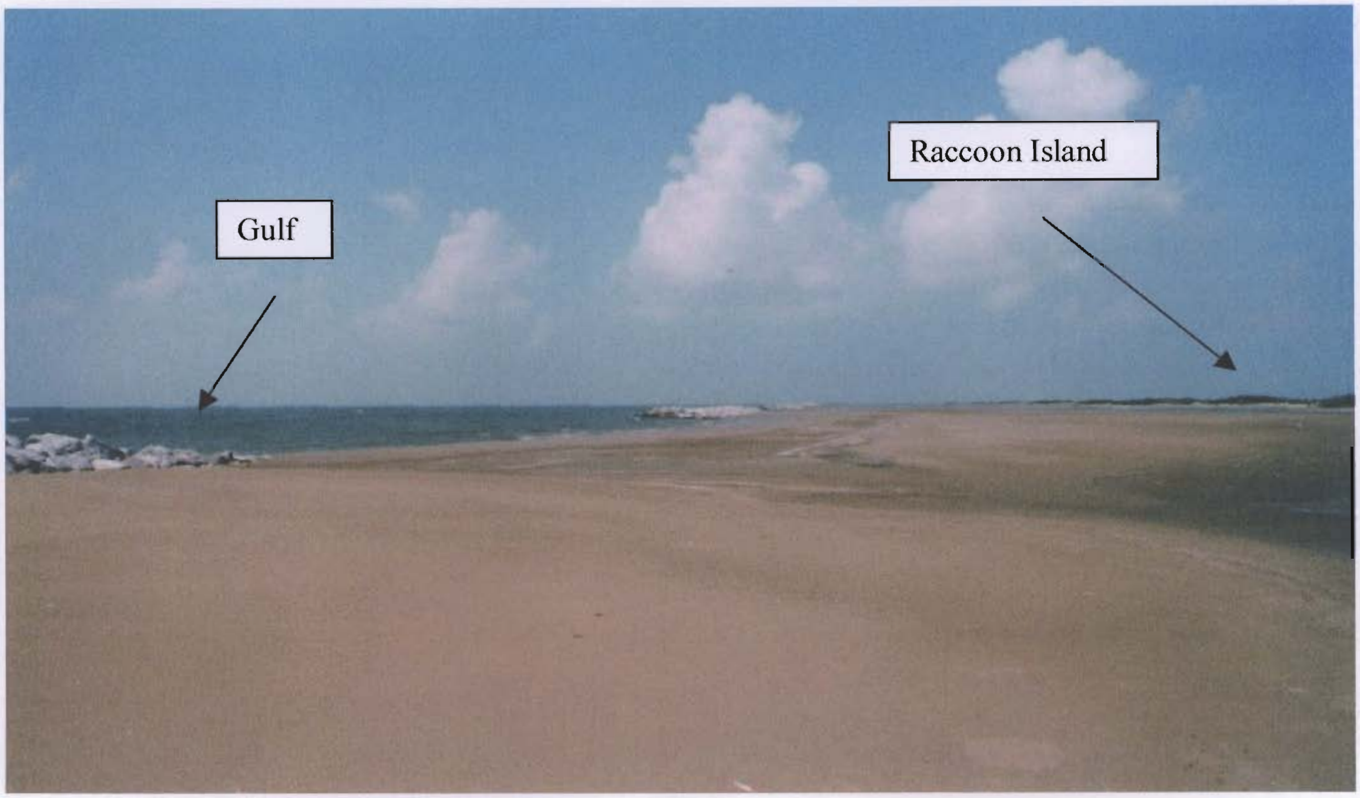


Plate 6. Photograph showing the emerged sand body extending from breakwater #6 through #3 resulting in an enclosed shallow and narrow water body landward of the breakwaters. Photograph looking west, September 24, 1998.

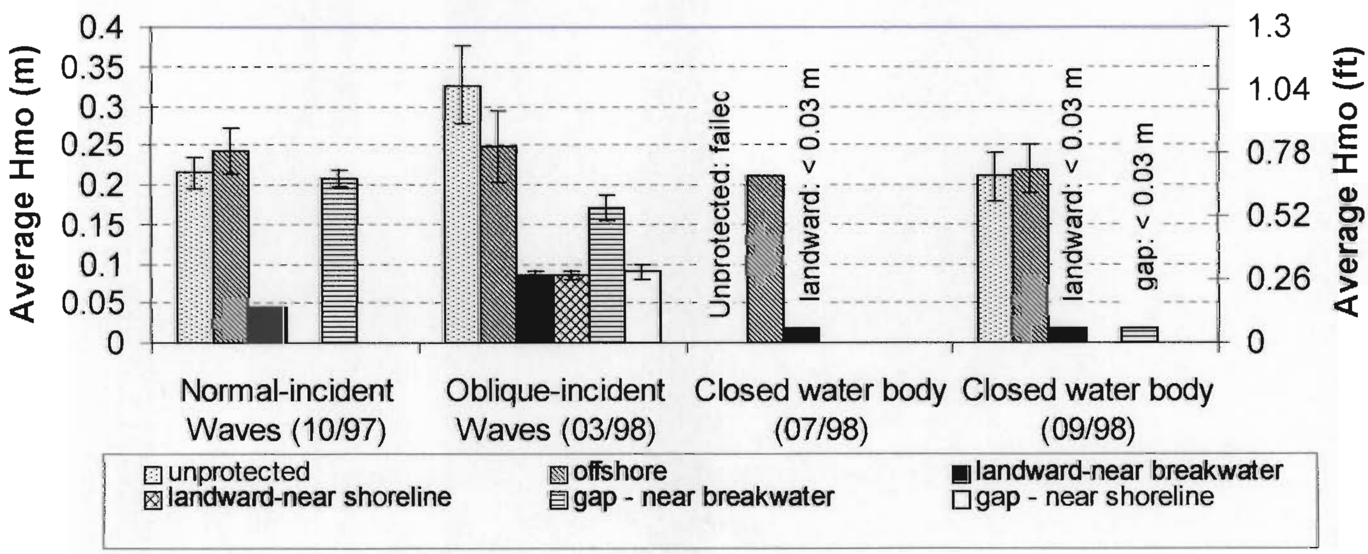


Figure 3. Comparison of significant wave heights at various locations for October 1997, March 1998, July 1998, and September 1998 deployments.

During the first two wave measurement experiments conducted on October 1997 and March 1998, a considerable wave-height reduction of more than 70%, was measured in the lee of the structures during both normally (October, 1997) and obliquely (March, 1998) incident wave conditions. A greater percentage of wave-height reduction landward of the center of the breakwaters, 90% as compared to 70%, was measured during normally incident waves. This is directly attributable to the influence of the breakwaters. In the gap between the breakwaters, wave heights were virtually unchanged when compared to the unprotected site during normally incident wave conditions. A wave-height reduction of 50% was measured, however, during obliquely incident waves.

Substantially modified morphological conditions were encountered during the July and September 1998 measurements, and waves propagating from the Gulf were totally dissipated by the emerged sand body in the vicinity the breakwaters. There were no differences between wave conditions landward of the center of the breakwaters and landward of the gap between the breakwaters (Plates 3 and 4). The extremely shallow water landward of the breakwaters, presented technical difficulties with instrumentation during the July 1998 measurements. During the September 1998 measurements, the shallow water body narrowed significantly due to further sediment accumulation. Water depths were significantly different at the inside and gap sites when compared with the depth at the control site. Comparison of wave conditions among the protected and unprotected sites are somewhat influenced by the depth difference.

It is noteworthy that in contrast to conditions encountered during the October 1997 and March 1998 measurements, waves landward of the breakwaters during the July and September 1998 measurements were locally wind generated as opposed to having propagated from the Gulf. Due to low wind speeds encountered during both the July and September 1998 measurements, as well as the narrow water body, practically no waves were observed landward of the breakwaters (Plate 4), both landward of the center and the gaps.

Peak Wave Period and Wave Spectra: September 1998 Deployment

Peak wave period, also referred to as dominant wave period or period of maximum wave energy, is defined as the wave period corresponding to the center frequency of the frequency band with the maximum non-directional spectral density. During the September 1998 measurement, relatively short-period locally wind-generated waves dominated. Peak wave period ranged from 3 to 6 seconds with average peak wave periods at offshore and unprotected sites of approximately 4 seconds (Figure 4). With a few exceptions, the peak wave period remained fairly constant throughout the measurements. Peak wave period cannot be determined reliably from the landward gage for both July and September 1998 measurements due to the shallow water and low signal strength as discussed earlier. Visual observations indicated that the ripples landward of the breakwaters were locally generated.

The results from the wave spectral analysis are summarized in Appendix 3. The wave spectra illustrate the distribution of wave energy with respect to each frequency component. The peaks in the wave spectra indicate that the waves of the specific frequencies carry more energy than other frequencies. Several distinct features were observed from the September 1998 measurements:

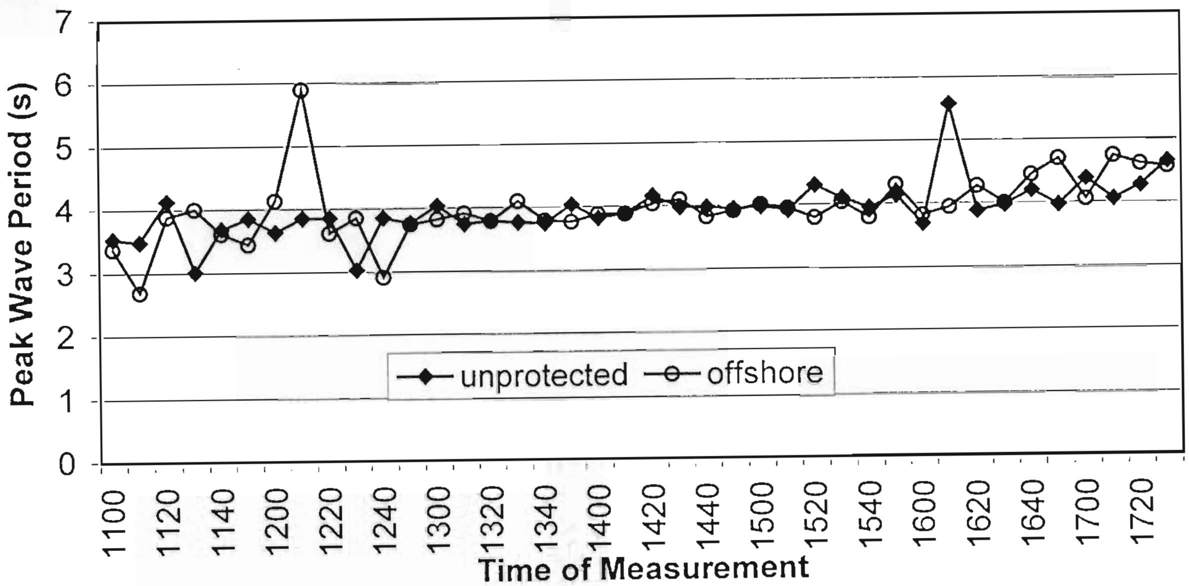


Figure 4. Measured peak wave period during September 1998. Note the relatively short period averaging 4 s indicating locally wind-generated wave conditions.

1. The magnitudes of the power spectral density obtained at the landward locations are very low and their distribution patterns do not reflect the characteristics of water waves. The irregular distribution patterns are believed to be caused by the low signal strength and low signal-to-noise ratio.
2. Almost all the wave energy was distributed between 0.1 to 1.0 Hz, or 1.0 to 10 seconds. Contributions from wave components with periods longer than 10 s or shorter than 1.0 s were not significant during the period of measurement.
3. Compared to the July 1998 measurements, more wave energy was distributed in higher frequency components, indicating a locally wind-generated wave condition during the September measurements 1998 as compared to the swell-dominated condition encountered during the July 1998 measurements.

Peak Wave Period and Wave Spectra: Overview of the Four Deployments

It is generally accepted that permeable, rubble-mound breakwaters, such as those at the study site, function somewhat similar to a low-pass filter in that they reduce higher frequency waves more effectively than their lower frequency counterparts (SPM, 1984). This low-pass effect was apparent during the normally incident wave conditions encountered in October 1997 (Figure 5). The average peak wave period measured landward of the center of the breakwaters was considerably longer than those at other sites, especially that at the unprotected site. Differences in peak wave period were minimal during the oblique incident wave conditions (Figure 5) encountered during the March 1998 measurements. During the July 1998 measurements, the offshore wave periods were much longer than those encountered during the October 1997, March 1998, and September, 1998 measurements, indicating swell-dominated conditions as opposed to locally generated seas. Wave periods landward of the structures during the July and September 1998 measurements were not reliable due to minimal signal strength.

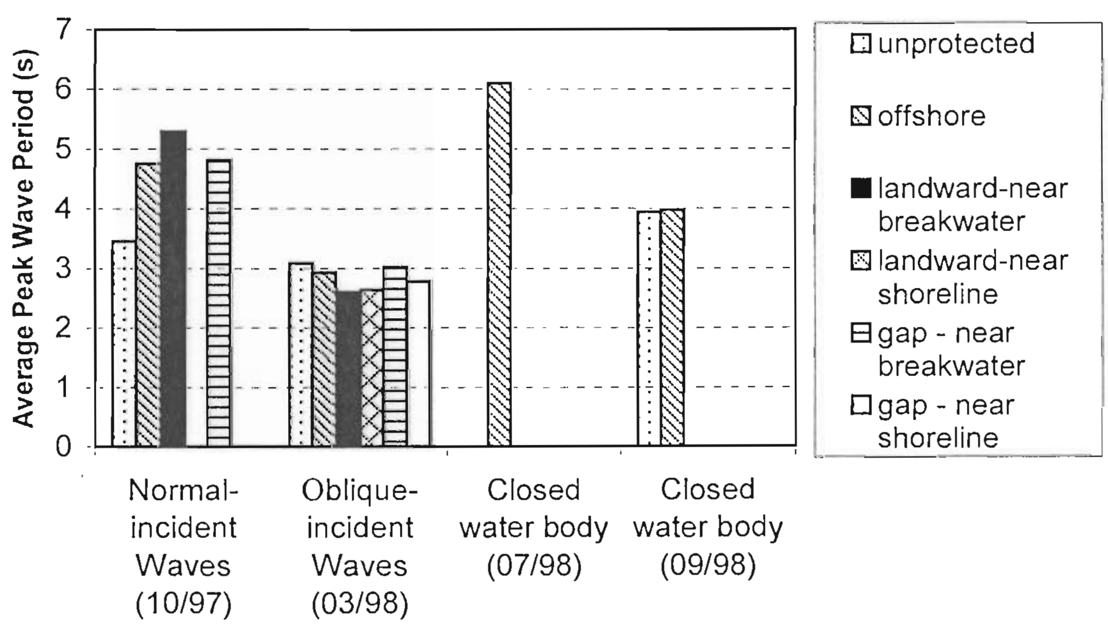


Figure 5. Comparison of peak wave periods at various locations.

Shoreline Morphology and Nearshore Bathymetry: September 1998 Survey

Similar change trends as those described in the previous reports (Stone et al., 1997, 1998a, and b) were measured during the September 1998 measurements. No dramatic shoreline change landward of breakwaters #6, #5, #4, and #3 was calculated due to minimal wave energy. A dramatic change was measured at the westernmost breakwater #7. The significant shoreline gain of 22 m (72 ft) measured between March 1998 and July 1998 (Stone et al., 1998b) was completely removed between July 1998 and September 1998 (Figure 6). It is apparent that shoreline change landward of breakwater #7 is strongly influenced by longshore sediment transport patterns. It is reasonable to conclude that the dramatic shoreline change landward of breakwater #7 was controlled by seasonal wave climate. Overall, shoreline change between July 1998 and September 1998 was small due to substantially reduced wave energy.

The trend of sand accumulation between the breakwaters and the shoreline detected since March 1998 (Stone et al., 1998a, and b) was also calculated from the period of measurement between July 1998 and September 1998 (Figure 7). Except for a loss of approximately 10 m^3/m at the westernmost breakwater #7 due to the erosion of the temporary salient which developed during March 1998 to July 1998, the remainder of the profiles gained between 8 to 31 m^3/m of sediment during the two months between July 1998 to September 1998.

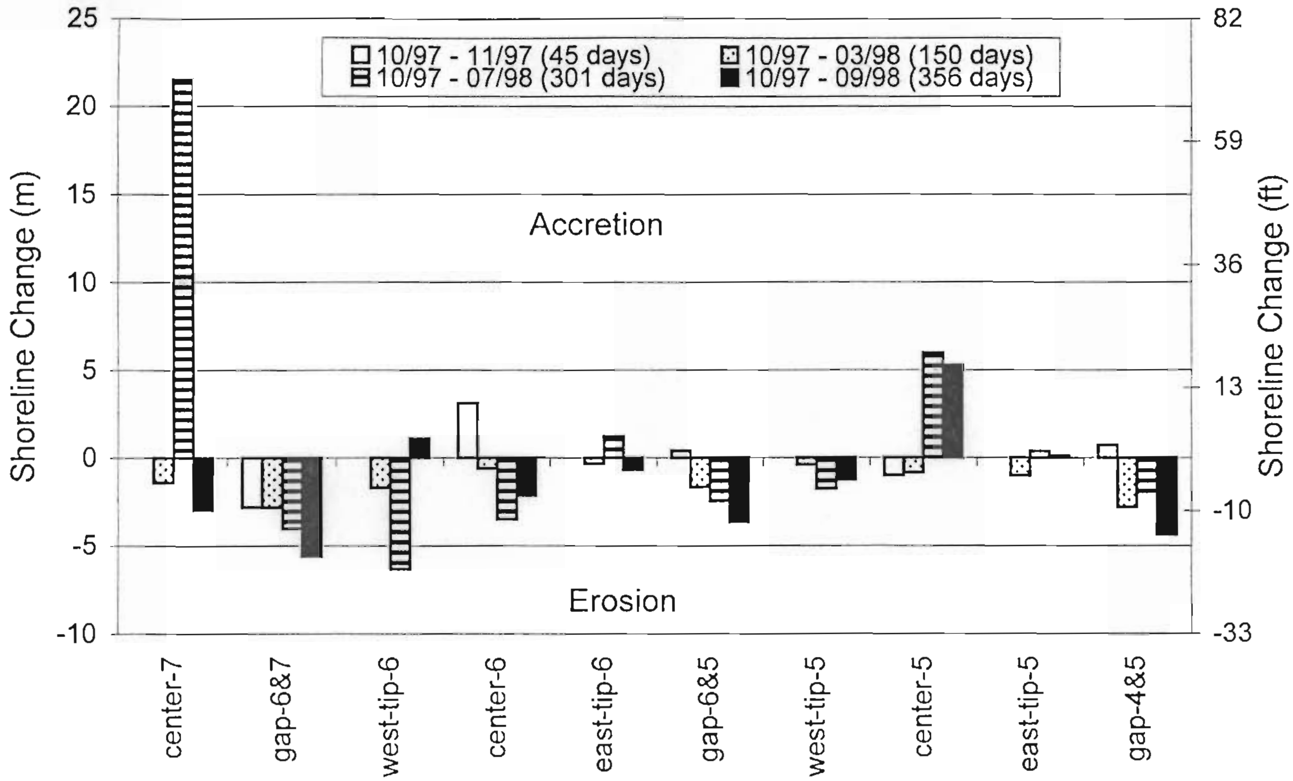


Figure 6. Shoreline change during October 1997 to November 1997, October 1997 to March 1998, October 1997 to July 1998, and October 1997 to September 1998, respectively. Note the overall small magnitude of change (except landward of the westward-most breakwater #7 during March 1998 to July 1998). Transects across the tips of the breakwaters were not surveyed in November 1997. NB: The shoreline is defined as the zero intercept with the profile.

Shoreline Morphology and Nearshore Bathymetry: Overview of the Four Measurements

As discussed in the previous reports (Stone et al., 1997, 1998a, 1998b), the presence of the segmented breakwaters has induced a significant change in nearshore morphology. As an immediate and mostly expected response, development of beach cusps or salients was observed along Raccoon Island shortly after the construction of the breakwaters. A zero water depth estimated during the first beach profile survey on October 2, 1997 was used here as a temporary indicator of shoreline position. All the elevations will be tied to NGVD at a later date.

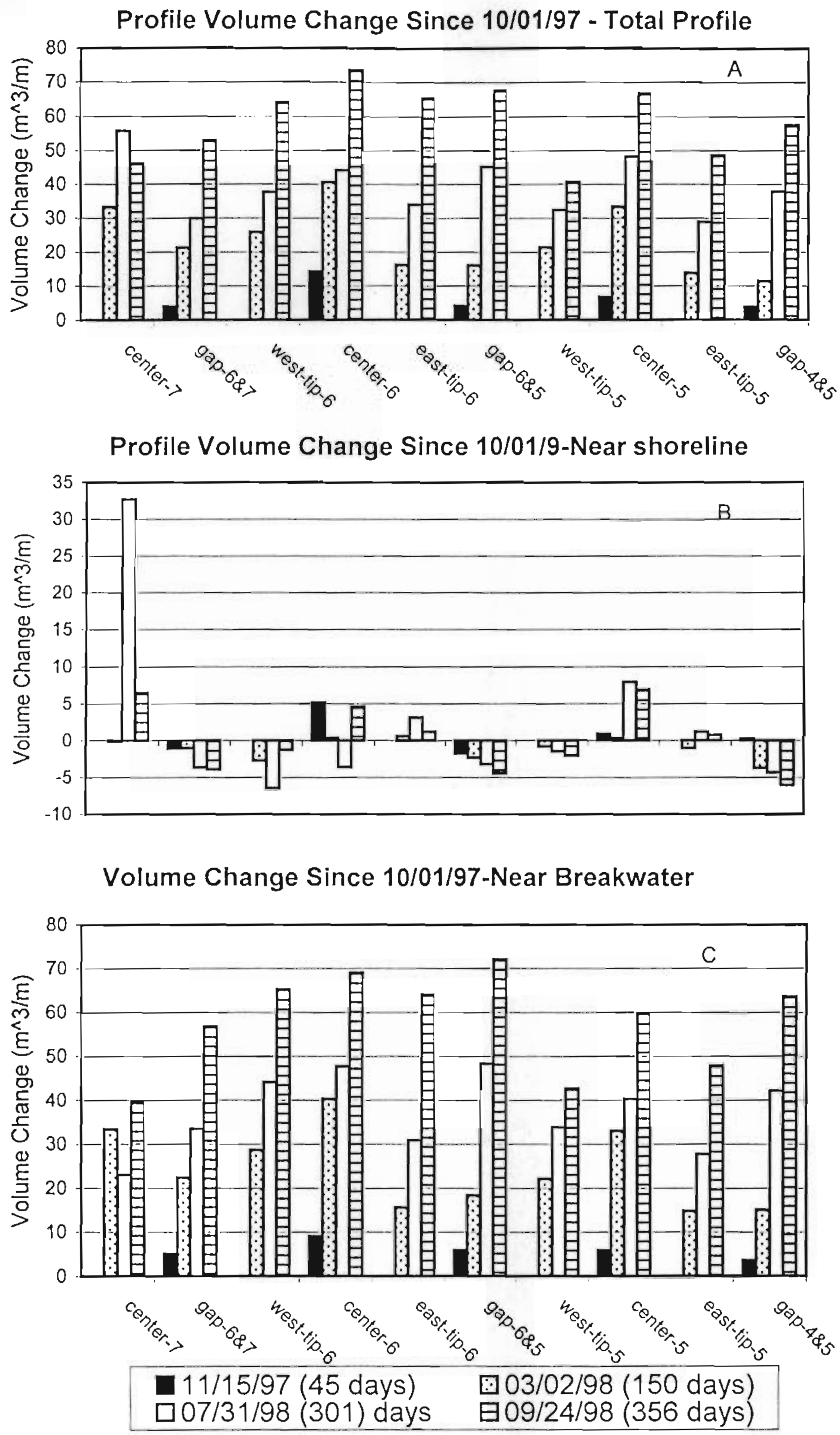


Figure 7. Beach-profile volume changes from the vegetation line to the breakwaters (A). Changes in the vicinity of the shoreline, from the vegetation line to the trough bottom (B). Changes landward adjacent to the breakwaters, from bottom of trough to the end of the profiles (C). Positive indicates volume gain and negative volume loss.

Both field observation and quantitative data obtained from beach-profile surveys indicate that the shoreline adjustment in the form of salient development seemed to have reached a quasi-equilibrium condition (Figure 6) landward of most of the segments after November 1997. No significant further adjustment in the vicinity of the shoreline was observed or measured between October 1997 and March 1998 (Stone et al., 1998a). Slight shoreline retreat, generally less than 3 m, was measured in March 1998, as compared to that of October 1997. Greater shoreline retreat was measured between the gap of the breakwaters (2 to 3 m) when compared to that landward of the center of the breakwaters (approximately 1m) from the March 1998 beach profile survey, although the overall change in the vicinity of the shoreline was small (Stone et al., 1998a).

A considerably different shoreline change pattern was measured from the July 1998 survey (Figure 6) when a 22 m (72 ft) gain landward of the center of breakwater #7 was measured. Sand accumulation at breakwater #7 is apparently related to the impoundment of longshore sediment transport. In addition, the closure of the gaps between adjacent breakwaters may have been increasing the trapping efficiency at the westernmost structure by further reducing the amount of wave energy arriving at the downdrift shoreline (during westerly wind and/or incident waves propagating from the west). The shoreline landward of the gap between breakwaters #7 and #6, and landward of breakwater #6 experienced 3 m (10 ft) to 6 m (20 ft) of shoreline retreat during the 301 days between October 1997 to July 1998. Except for a near 6 m (20 ft) shoreline gain measured landward of the center of breakwater #5, shoreline changes at all the other locations were small. Similar to the findings from the March 1998 survey, the overall changes in the vicinity of the shoreline were of much lower magnitude when compared to the volume changes across the entire profile and in the vicinity of the breakwaters, as discussed in the following section.

Similar change trends as those described above were determined from the September 1998 measurements. No dramatic shoreline change landward of breakwaters #6 through #3 was expected due to minimal wave energy. A dramatic change was measured at the westernmost breakwater #7. The sediment accumulation which resulted in significant shoreline gain of 22 m (72 ft) measured between March 1998 and July 1998, was completely removed between July 1998 and September 1998. It is apparent that shoreline change landward of breakwater #7 is strongly influenced by longshore sediment transport patterns. It is reasonable to conclude that the dramatic shoreline change landward of breakwater #7 is controlled by seasonal wave climate. Overall, shoreline change between July 1998 and September 1998 was small due to substantially reduced wave energy.

Between October 1997 and March 1998, substantial sand accumulation (Figure 7) was measured directly landward of the breakwaters with a large body of sand having aggraded to a height of approximately 0.3 m above an estimated zero water level on October 2, 1997 (Stone et al., 1998a and b). Considerable sand accumulation (Figure 7) was also measured in the gap between the breakwater segments when the October 1997 and the March 1998 surveys were compared.

Results from the July 1998 survey show that the trend of sand accumulation in the vicinity of the breakwaters continued between March 1998 and July 1998 (Figure 7). The continued sand accumulation in the vicinity of the breakwaters, which is apparently related to the presence of the breakwaters, has significantly changed the impact of the breakwaters on the nearshore wave field. Beach profiles at the control site, devoid of the influence of the breakwaters, did not show the pattern and magnitude of sand accumulation measured in the region influenced by the breakwaters (Figure 8). The gaps between breakwaters, #6 and #5, #5 and #4, and #4 and #3 have been experiencing substantial net deposition, forming a long, emerged sand bar approximately 50 m from the present Raccoon Island shoreline (Plate 2). The July 1998 survey indicated that a large amount of sand also accumulated seaward of the breakwaters, forming a beach up to 20 m (60 ft) wide seaward of the breakwaters during the low-tide condition (Plate 7). Breakwaters #6, #5, #4, and #3 were surrounded by the emerged sand body and were not directly exposed to the Gulf waves as observed during the July 1998 survey. Our present survey, as a compliment to the wave measurements, did not extend seaward of the breakwaters.

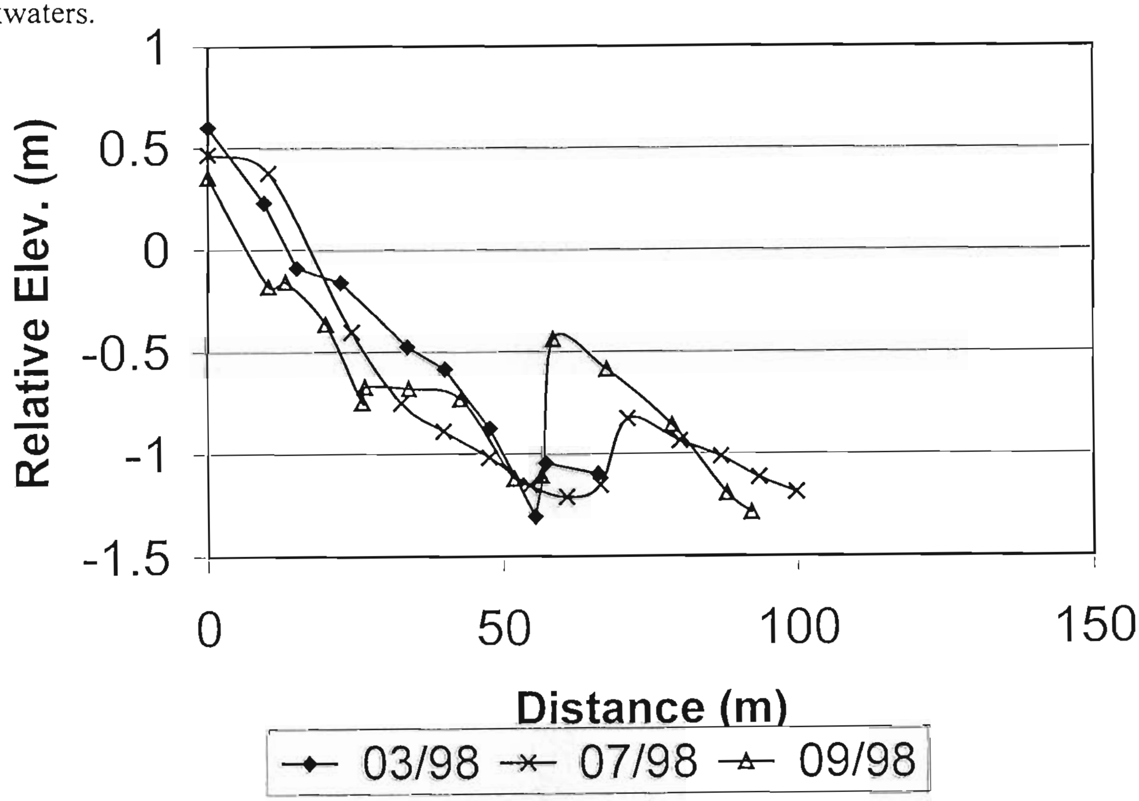


Figure 8. Beach profiles at the control site for March, July, and September 1998 surveys.

Plate 7. Sand accumulation seaward of the breakwaters, July 31, 1998. Photograph was taken looking east.

The trend of sand accumulation between the breakwaters and the shoreline detected since March 1998 was also calculated from the period of measurement between July 1998 and September 1998 (Figure 7). Except for a loss of approximately 10 m^3/m at the westernmost breakwater #7 due to the erosion of the temporary salient which developed during March 1998 to July 1998, the remainder of the profiles gained between 8 to 31 m^3/m during the period between July 1998 and September 1998.

Substantial sand accumulation on the beach profiles between the vegetation line and the breakwaters were measured during the 12-month period between the beginning of October, 1997 to the end of September, 1998. Deposition varied from 40 m^3/m to over 70 m^3/m landward of the center of breakwater #6 (Figure 7A). Patterns of sand accumulation appear to follow the trend evident for the period from March 1998 to July 1998 (Stone et al, 1998a, 1998b). Most of the sand accumulation occurred in the immediate leeward vicinity of the breakwaters (Figure 7C). The magnitude of deposition or erosion in the vicinity of the shoreline is much smaller than that in the vicinity of the breakwater, except at breakwater #7 during March 1998 through July 1998. The accumulation landward of breakwater #7 during March 1998 through July 1998 has proven to be temporary as most of the sediment was eroded during the period between July 1998 and September 1998.

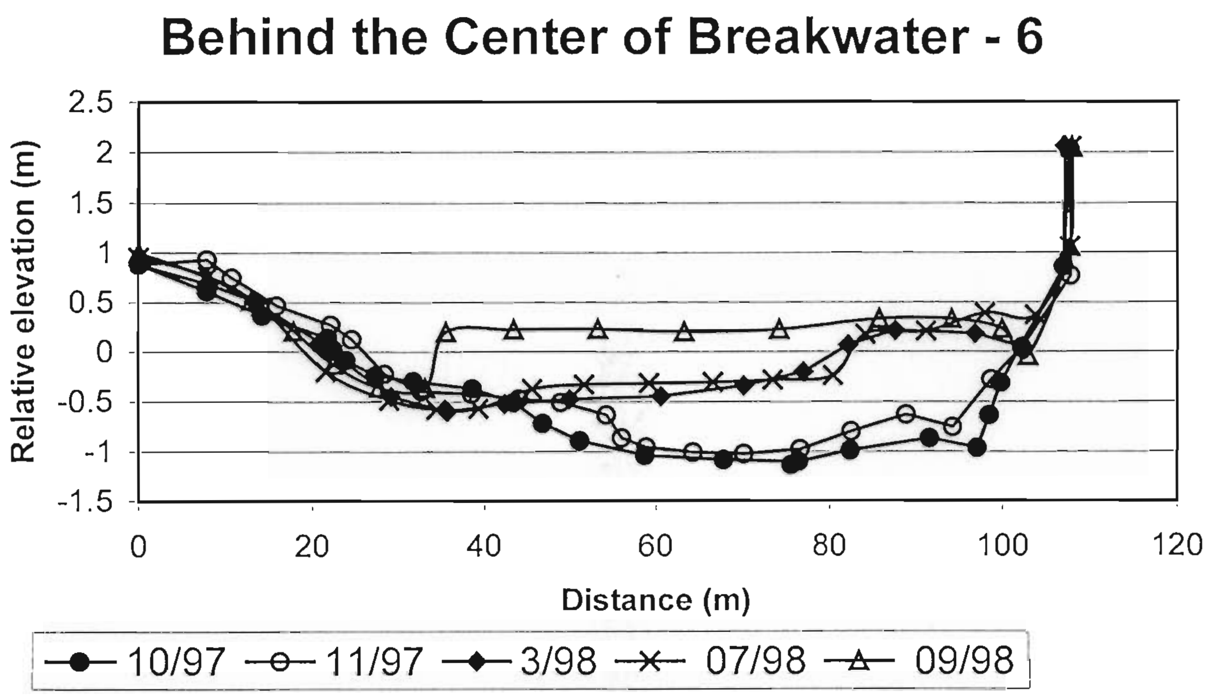
Between March 1998 and July 1998, most sand accumulation occurred in the gaps between the breakwater segments, resulting in an expansive emerged sand body. Approximately 29 and 26 m^3/m of sand accumulation were measured between the gaps of breakwaters #6 and #5 and breakwater #5 and #4, respectively. It is worthy of note that this amount of accumulation was measured between the breakwater to the vegetation line. Since a significant amount of sand has accumulated seaward of the breakwaters, the actual amount of sand accumulation in the nearshore system is significantly greater (Plates 2 and 7).

Between July 1998 and September 1998, a similar amount of sand accumulation was measured at nearly all the profiles except the westernmost one. This pattern is different from those measured during March 1998 and July 1998 surveys. Between October 1997 and March 1998, most of the sediment accumulation was measured landward of the center of the breakwaters. While between March 1998 and July 1998, most sand accumulation was measured in the gap between the breakwaters, resulting in the closure of the gaps. Large quantities of sand also emerged seaward of the breakwaters between March 1998 and July 1998. Between July 1998 and September 1998, sand accumulation continued to occur between the Raccoon Island shoreline and breakwaters. The beach seaward of the breakwaters was eroded (Plate 8). Beach erosion was prevalent during these periods at the control site to the west (Figure 8).

Plate 8. Seaward of the breakwaters, September 1998. Note that the July beach (Plate 6) was eroded. Photograph looking west, September 24, 1998.

Results from the March 1998 survey indicated that the maximum accumulation occurred landward of the center of the breakwaters and decreased toward the gaps. Results from the July 1998 survey, on the other hand, indicate that the sand accumulation had shifted to the gaps between the breakwater segments (Figure 9). An elevation change of up to 1 m (3 ft) was measured in the gap between the breakwaters, especially between #6 and #5 and between #5 and #4 (Appendix 4). A different accumulation pattern was interpreted from analyzing the data obtained from the September 1998 survey. An elevation increase of up to 0.5 m of the sand surface landward of the breakwaters was measured at all the eleven profiles. The water body between the shoreline and the breakwaters was significantly narrowed (Plate 4).

Sand accumulation during the 12 months after breakwater construction was concentrated directly in the immediate leeward vicinity of the breakwaters and the gaps (Appendix 3). This sand accumulation pattern has not been documented by previous studies on similar types of detached, segmented breakwaters (e.g., Toyohira, 1974; Walker et al., 1980). The implications at this juncture are that sand accumulating in the vicinity of the Raccoon Island breakwaters cannot be attributed to longshore transport only. At this stage of the study, it is reasonable to hypothesize that the presence of the breakwaters has significantly influenced the cross-shore sediment transport patterns in addition to being a longshore sediment trap as typically expected. The emergence of a sand body seaward of several of the breakwaters provides direct evidence of onshore sediment transport and shoaling (Plate 7). The development of the salient at the westernmost breakwater (#7) during March 1998 to July 1998 appears to be directly related to the impoundment of longshore sediment transport along the shoreline due to easterly transport of sediment during seasonal, southwest deep-water wave approaches.



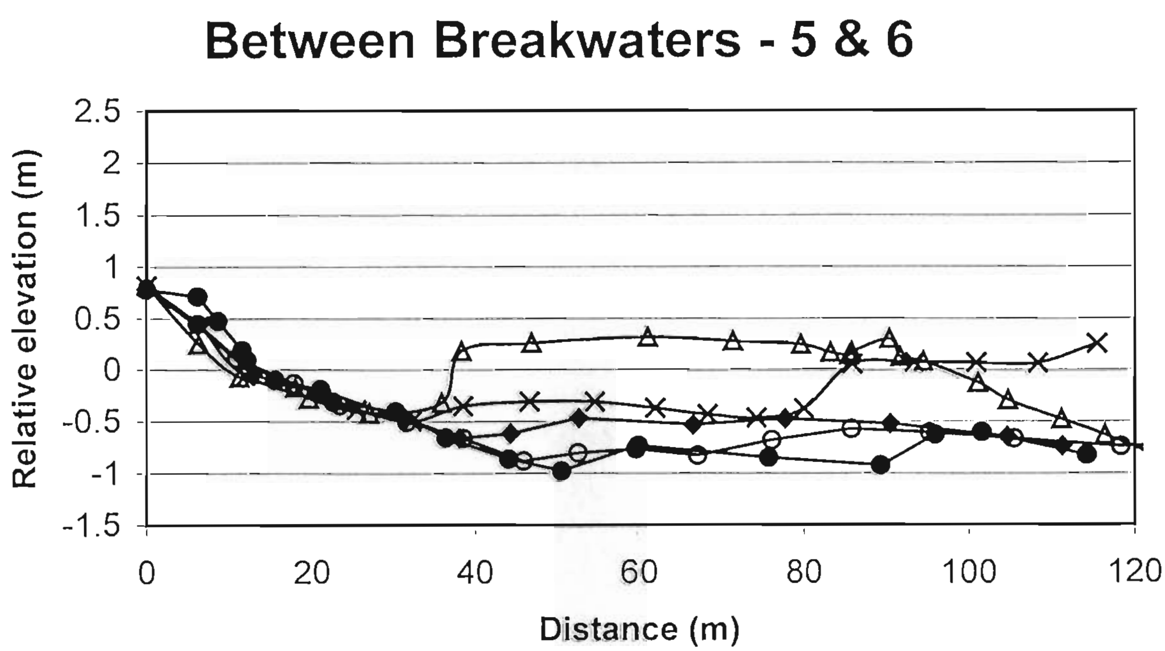


Figure 9. Examples of beach profiles across the center of the breakwaters and across the gap between segments.

SUMMARY AND CONCLUSIONS

The results from the October 1997, March 1998, July 1998, and September 1998 deployments allow for the following summary.

Influence of the Structures on Wave Height

The results from the first two wave measurement deployments before the gaps between breakwaters #6, #5, #4, and #3 were closed by rapid sand accumulation, indicate that the detached, segmented breakwaters functioned differently in terms of wave-height reduction during normally and obliquely incident wave approaches. During normally incident waves, wave height was 90% lower landward of the center of the breakwaters than that at the unprotected site, while wave propagation through the gaps between the segments was largely unaffected. Wave diffraction around the tips of the breakwaters during the shore-perpendicular wave approaches created zones where longshore transport converged near the shoreline behind the center of the breakwaters (caused by convergent wave trains) in addition to zones of divergence behind the gaps. This wave-breaking pattern was observed to induce the development of a salient.

During the oblique incident waves encountered in the March 1998 measurements, a reduction of wave height of approximately 70% was measured, when compared to the unprotected site, landward of the center of the breakwaters. This indicates a 20% reduction when compared to conditions during normally incident waves (90% wave-height reduction). Wave heights landward of the gaps between the segments were 50% lower than at the unprotected site under obliquely incident waves, while wave conditions in the gap were almost the same under normally incident waves.

The July and September 1998 measurements, more than ten months after breakwater construction, indicate that changes in the nearshore morphology had significantly altered the functioning of the breakwaters. The gaps between breakwaters #6, #5, #4, and #3 had been in filled by sand. During the July 1998 measurement, a temporary spit growing landward from the western tip of breakwater #6 resulted in a nearly closed, shallow water body landward of these breakwaters. Results from the wave measurements in July and September 1998 are not directly comparable to the results from the two previous measurements due to the significant morphological changes in the vicinity of the breakwaters. Further sand accumulation during the July and September 1998 period resulted in the development of an even narrower water body of only 15 to 20 m wide. This resulted in approximately 80% of the original 100 m gap between shoreline and breakwaters having been filled in by sand. The presence of the emerged sand body adjacent to the breakwaters has resulted in the cessation of wave attack along the Raccoon Island shoreline. Because of the presence of the emerged sand body, wave heights landward of the breakwaters were reduced by nearly 100%. Results from wave measurements in July and September 1998 do not reflect the influence of segmented breakwaters and should not be compared directly with the results from October 1997 and March 1998 measurements due to the significant change in nearshore morphology.

Influence of the Structures on Nearshore Morphology

A rapid shoreline response in the form of rhythmic salient development, was observed shortly after the construction of the breakwaters in October 1997. The initial shoreline adjustment reached quasi-equilibrium approximately three months after breakwater construction. No significant further planform shoreline adjustment was measured in November 1997 and March 1998 surveys. Between March 1998 and July 1998, the Raccoon Island shoreline position remained fairly stable except at the westernmost breakwater (#7). An apparent salient had developed resulting in a shoreline accretion of more than 20 m (60 ft) landward of the center of breakwater #7. The development of the salient at breakwater #7 may have been due to the impoundment of longshore sediment transport by the detached breakwaters, as generally expected for this type of structure and previously observed at other locations. Seasonal wind and wave patterns may have contributed to the eastward trend of longshore sediment transport and the development of the salient during the summer. The above salient was eroded back to a previous shoreline position between July and September, 1998.

A substantial amount of sand accumulation, ranging from 40 to over 70 m^3/m, was measured in the immediate vicinity of the breakwater segments, as well as in the gaps between the breakwaters during the first 12 months after construction. A sand body has emerged landward of the breakwaters. This large amount of sand accumulation, ranging from 45 to 75 m^3/m between the breakwaters and the vegetation line on Raccoon Island, cannot be readily explained with our present understanding of the coastal processes and sediment transport in this area. Field observations during the March 1998, July 1998, and September 1998 measurements indicate that the presence of the breakwater structures has apparently influenced the previous cross-shore equilibrium.

IMPLICATIONS OF FINDINGS

The data presented here provide several important preliminary implications for breakwater use in shoreline protection along Louisiana's coast. The data presented in this report are most promising and warrant further evaluation with respect to the potential role of detached breakwaters in shoreline protection along the Louisiana coast. However, prior to presenting these implications, it is essential to view the findings and implications presented here as preliminary because of the short time period (12 months) over which the data have been gathered. Numerous questions remain unanswered as to the morphological response of the nearshore environment fronting Raccoon Island to breakwater construction. **Therefore, it is highly recommended that the following questions be addressed in detail through carefully conceived and executed field monitoring prior to assessing the potential use of breakwater construction for coastal protection along Louisiana's sandy beaches.**

Questions That Remain Unanswered

1. Why did sand accumulation begin preferentially along the western flank of the breakwaters array (#7, 6, 5, 4 and 3 respectively)?
2. Where is the primary sand source for the sediment that accumulated in the vicinity of the breakwaters within the initial 12-month monitoring period and beyond should the trend continue?
3. What is the volume of sediment that comprises the source and what is the projected longevity and availability to nearshore processes of this source?

4. What are the precise roles that longshore and cross-shore sediment transport play at the study site?
5. Is the erosion measured along the Raccoon Island beach to the west of the structures attributable to the influence of the structures and/or attributable to background erosion along the island?
6. Can the design criteria used to construct the breakwaters be refined to maximize sediment accumulation?
7. Are the trends that have been established for the first 12 months of monitoring likely short or longer-term?

It is our recommendation that until these questions are addressed and answered through the acquisition of quality, field measurements and other supporting information deemed appropriate to meet this objective, the data presented here on the performance of the Raccoon Island breakwaters should not be used as grounds for widespread construction of similar structures along the Louisiana coast. Although the results presented in this report are indeed promising with respect to the potential advantages associated with using such structures to protect the adjacent beach and accumulate sand, notwithstanding, significant problems have been experienced elsewhere in the state of Louisiana that have involved hard structures. Examples include the breakwaters at Holly Beach and revetments along East Timbalier Island.

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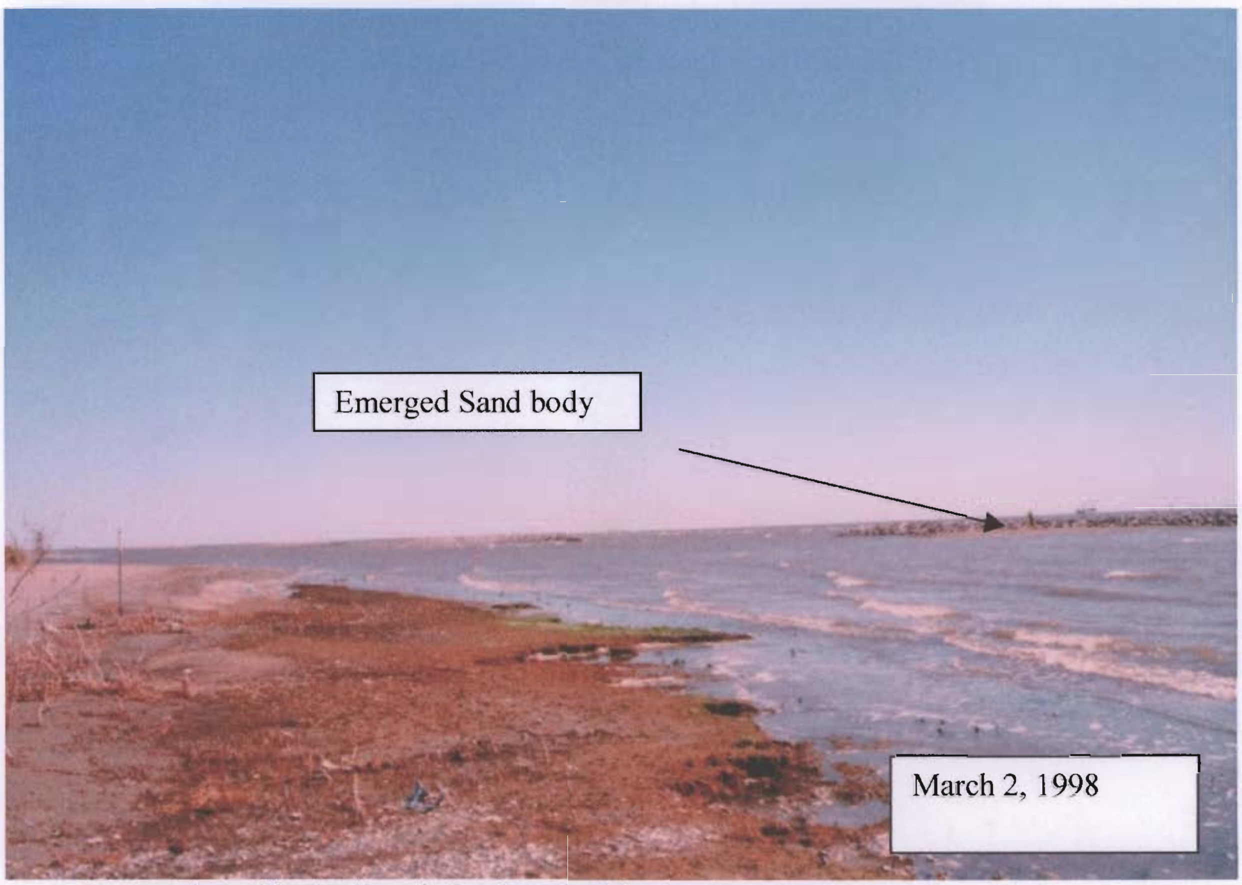
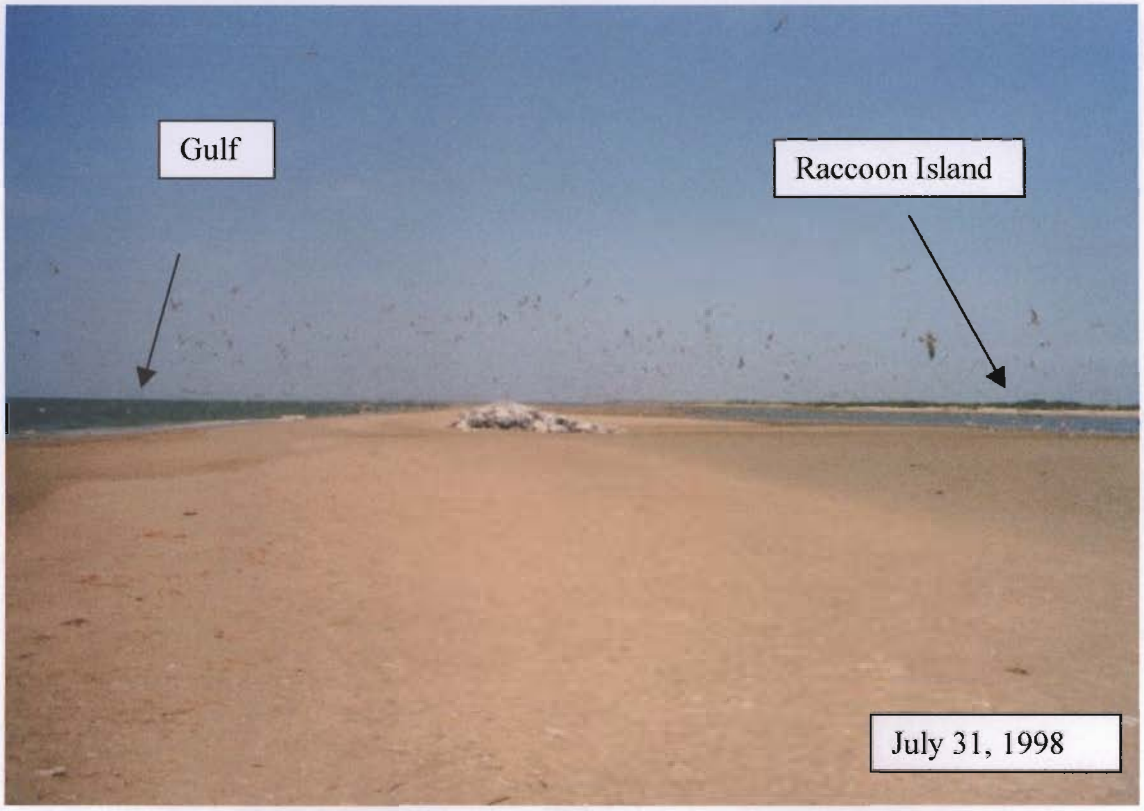
APPENDIX 1

Morphological Changes in the vicinity of Raccoon Island breakwaters.

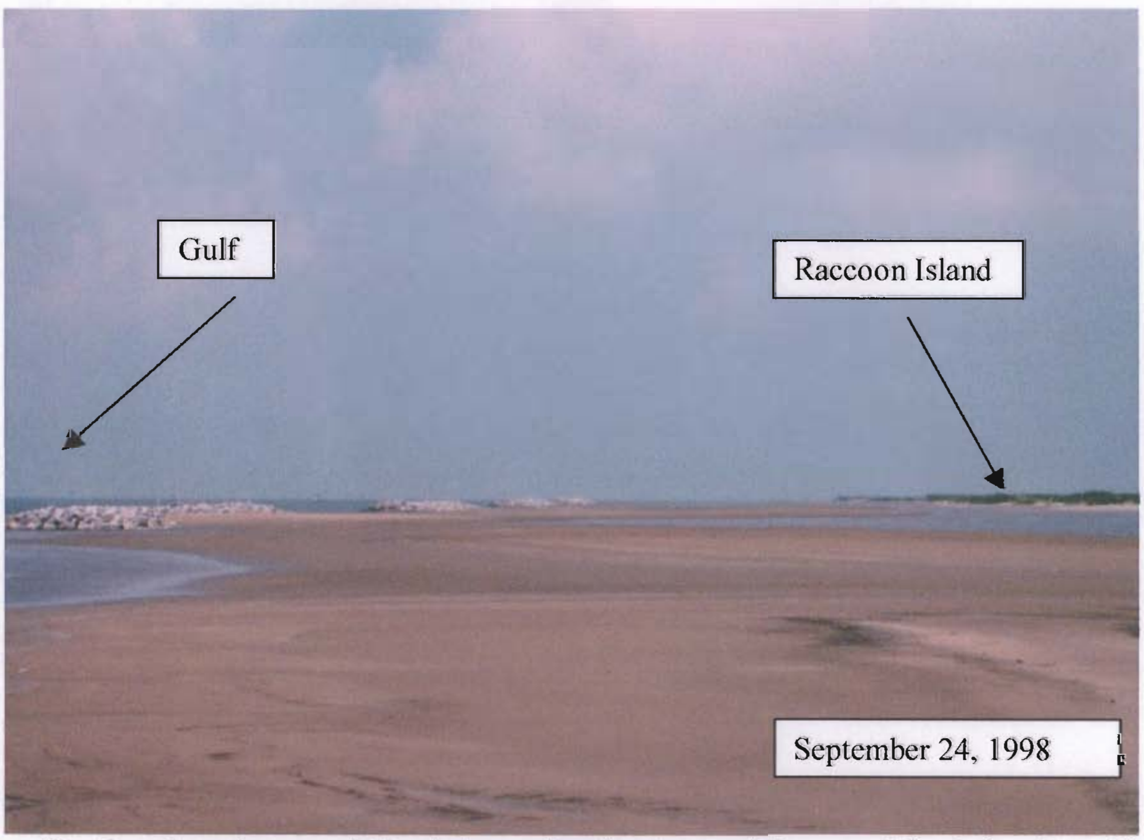
No emerged sand body between breakwaters and Raccoon Island shoreline.



Emerged sand body directly landward of the breakwaters.

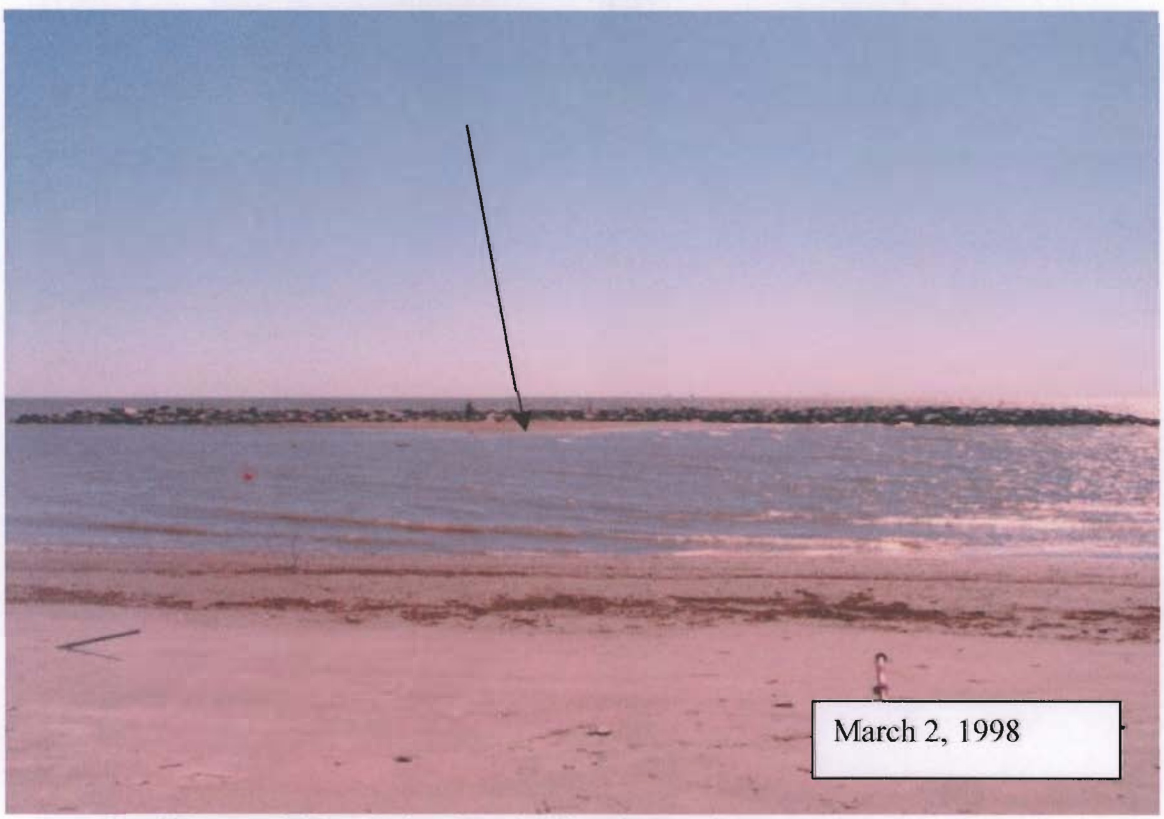


Large amount of sand accumulation both landward and seaward of breakwaters.

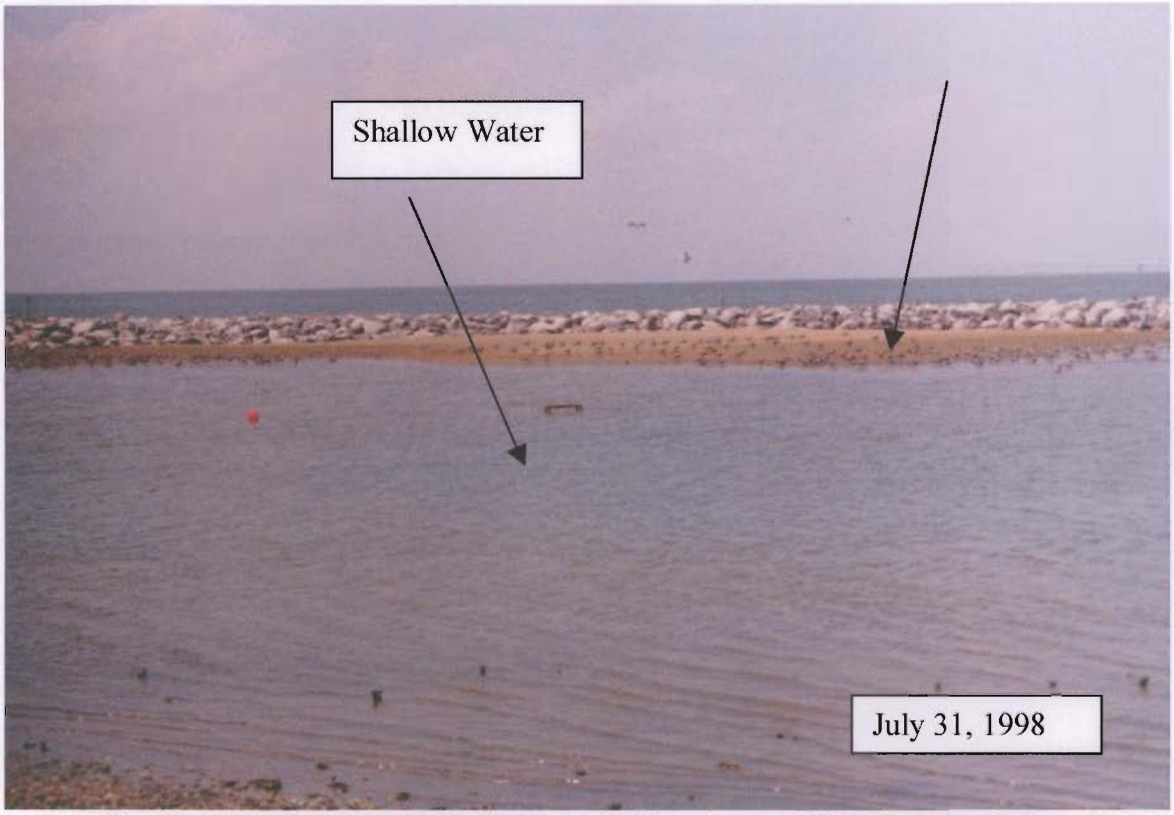


Continued sand accumulation between breakwaters and Raccoon Island shoreline. Note that the Gulfward accumulation (above) was eroded.

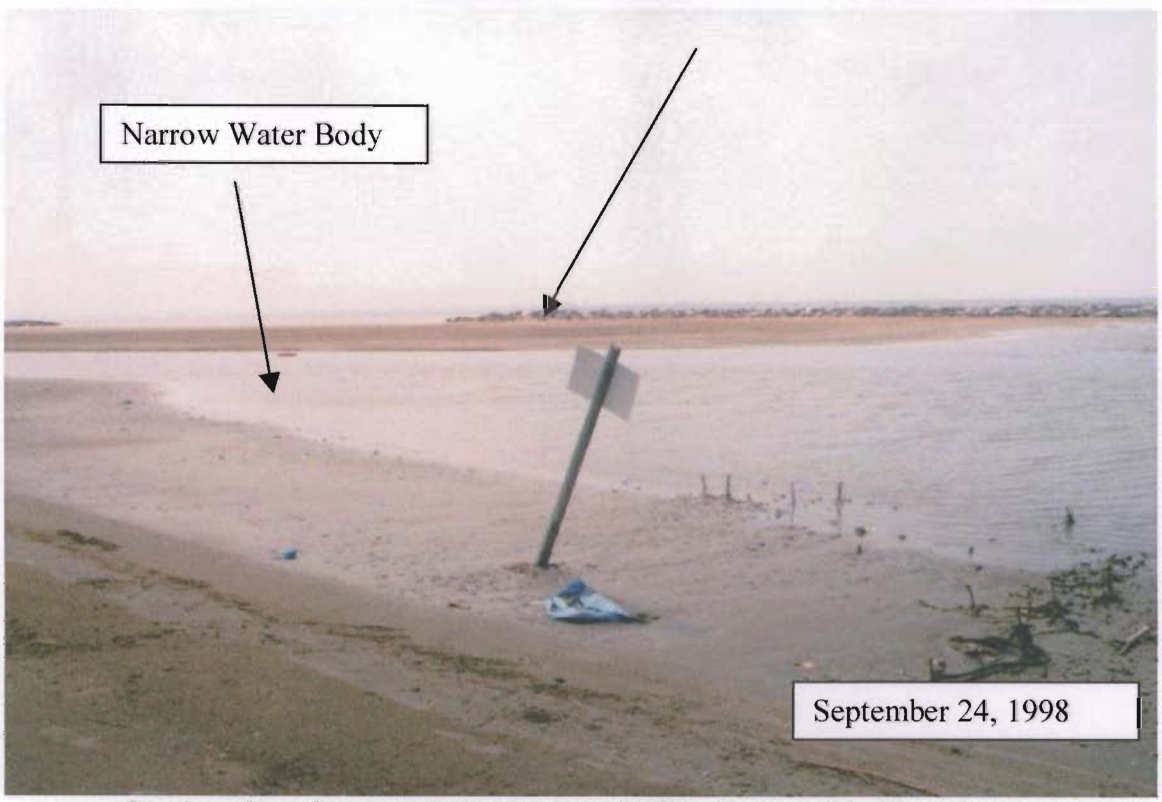
No sand emerged directly landward of breakwater#6



Sand Emerged directly landward of breakwater#6.



Continued sand accumulation landward of breakwater #6. Note the shallow water.



Continued sand accumulation landward of breakwater #6. Note the narrow water body between the emerged sand body and Raccoon Island shoreline.

No sand body emerged in the gaps between the breakwaters.

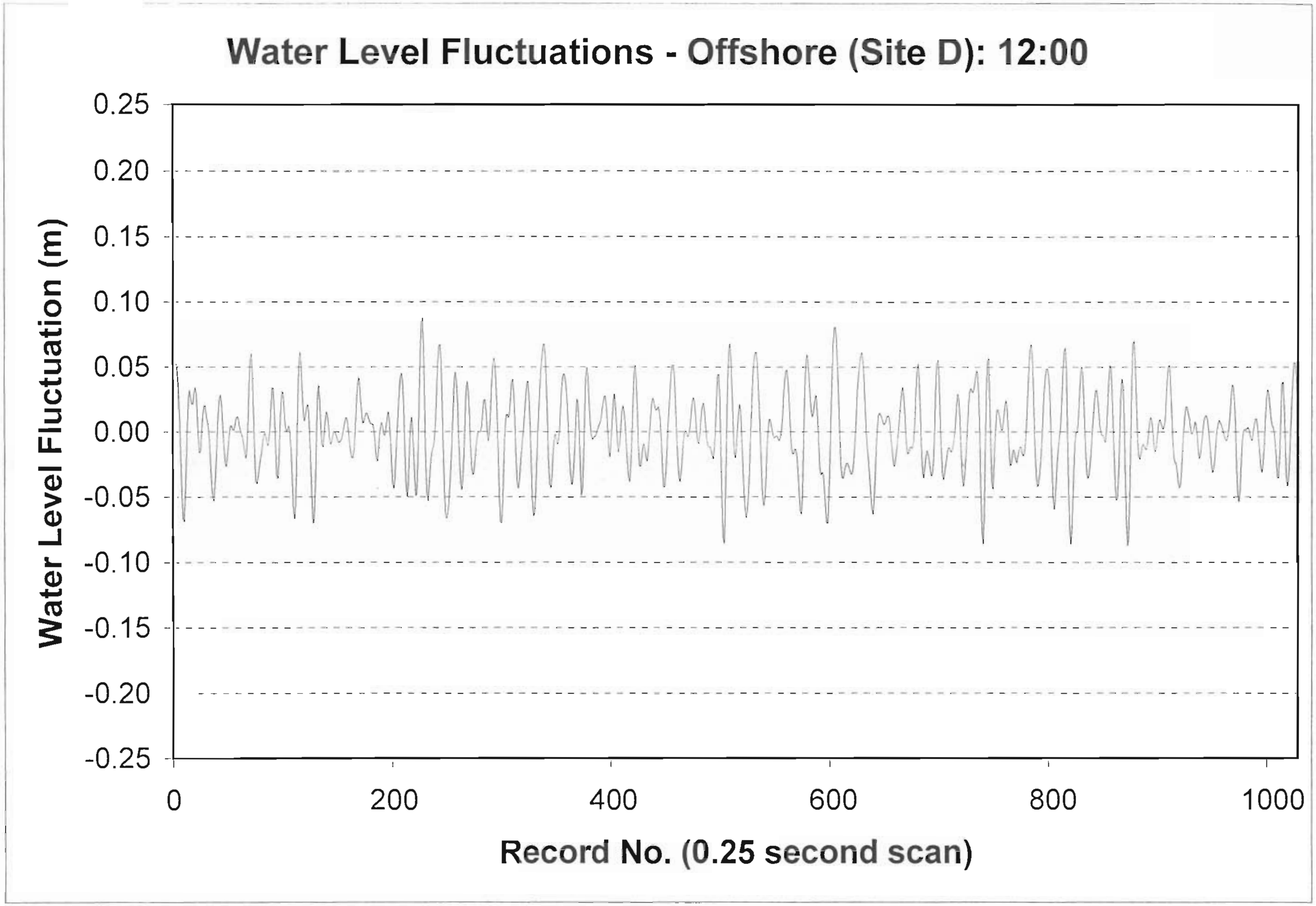
No emerged sand body in the gap although an emerged sand body directly landward of the breakwater is observed.

Emerged sand body in the gap between breakwaters.

Emerged sand body in the gap between breakwaters.

APPENDIX 2

Examples of raw water-level data at the study sites showing the complexity and presence of various waves at different frequencies.


Water Level Fluctuations - Offshore (Site D): 12:00
Water Level Fluctuation (m)
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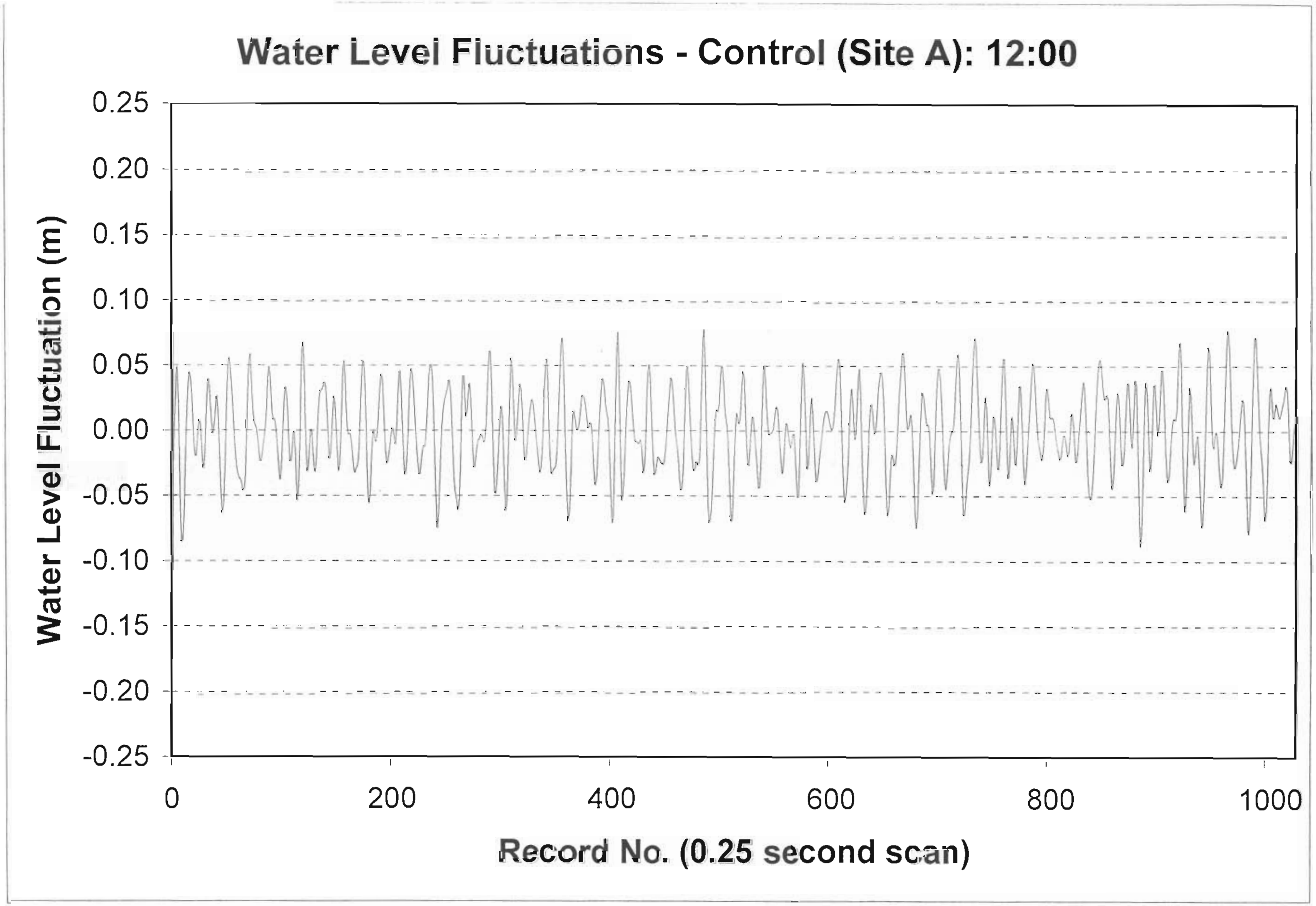
0.20
0.15
0.10
0.05
0.00
-0.05
-0.10
-0.15
-0.20
-0.25
0
200
400
600
800
1000
Record No. (0.25 second scan)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Water Level Fluctuation (m)
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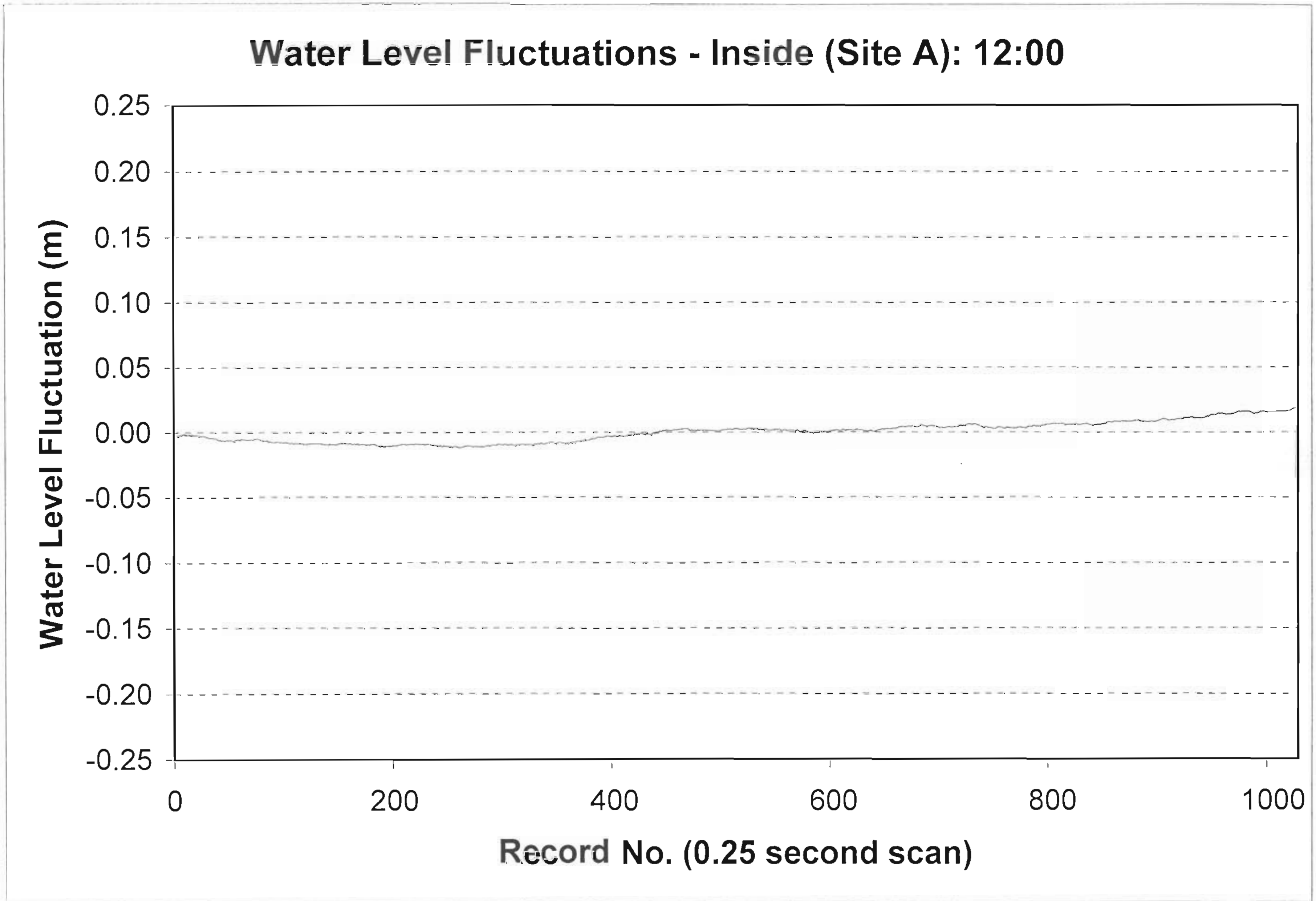
0.20
0.15
0.10
0.05
0.00
-0.05
-0.10
-0.15
-0.20
-0.25
0
200
400
600
800
1000
Record No. (0.25 second scan)


Water Level Fluctuations - Inside (Site A): 12:00
Water Level Fluctuation (m)
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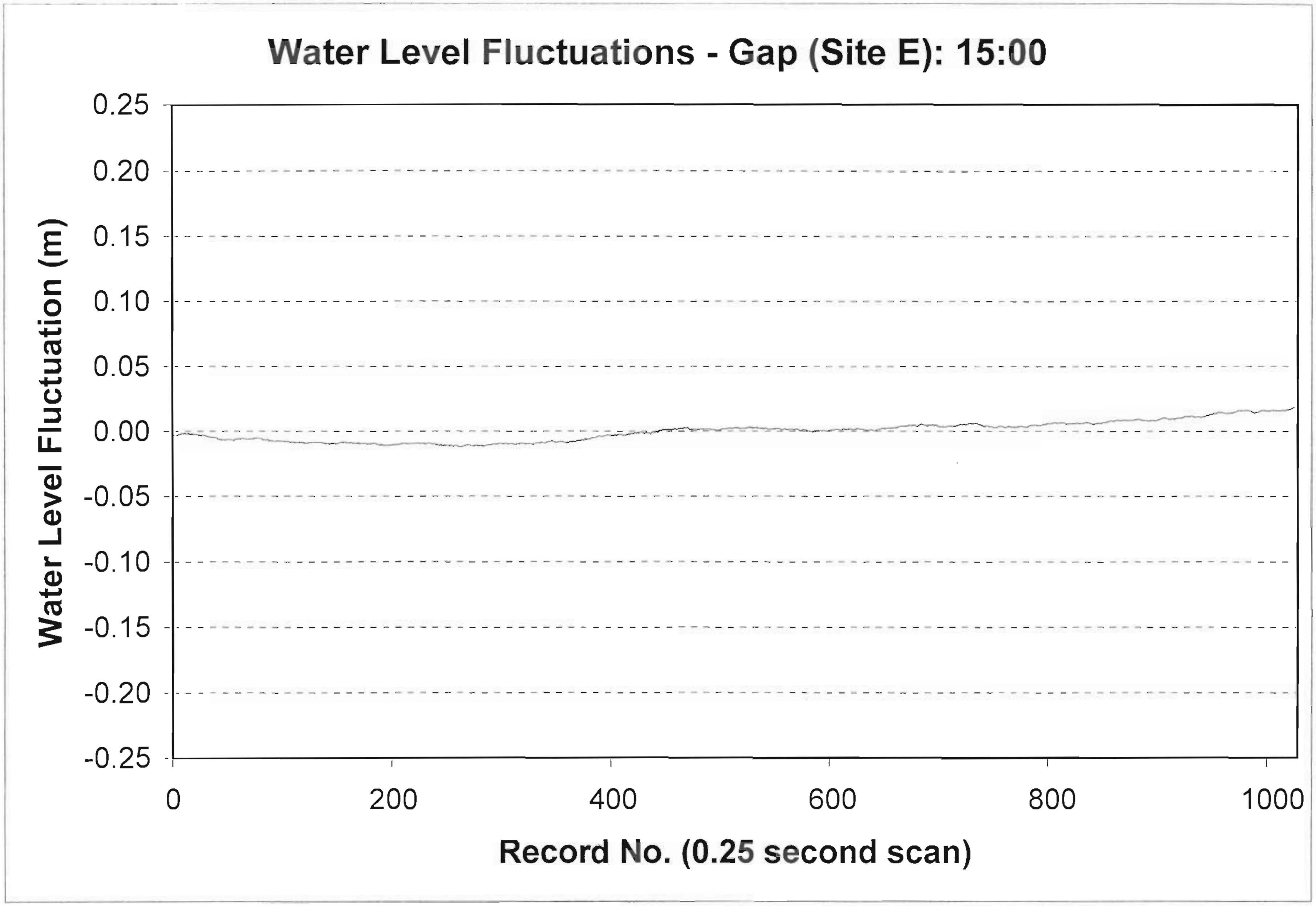
0.20
0.15
0.10
0.05
0.00
-0.05
-0.10
-0.15
-0.20
-0.25
0
200
400
600
800
1000
Record No. (0.25 second scan)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Water Level Fluctuation (m)
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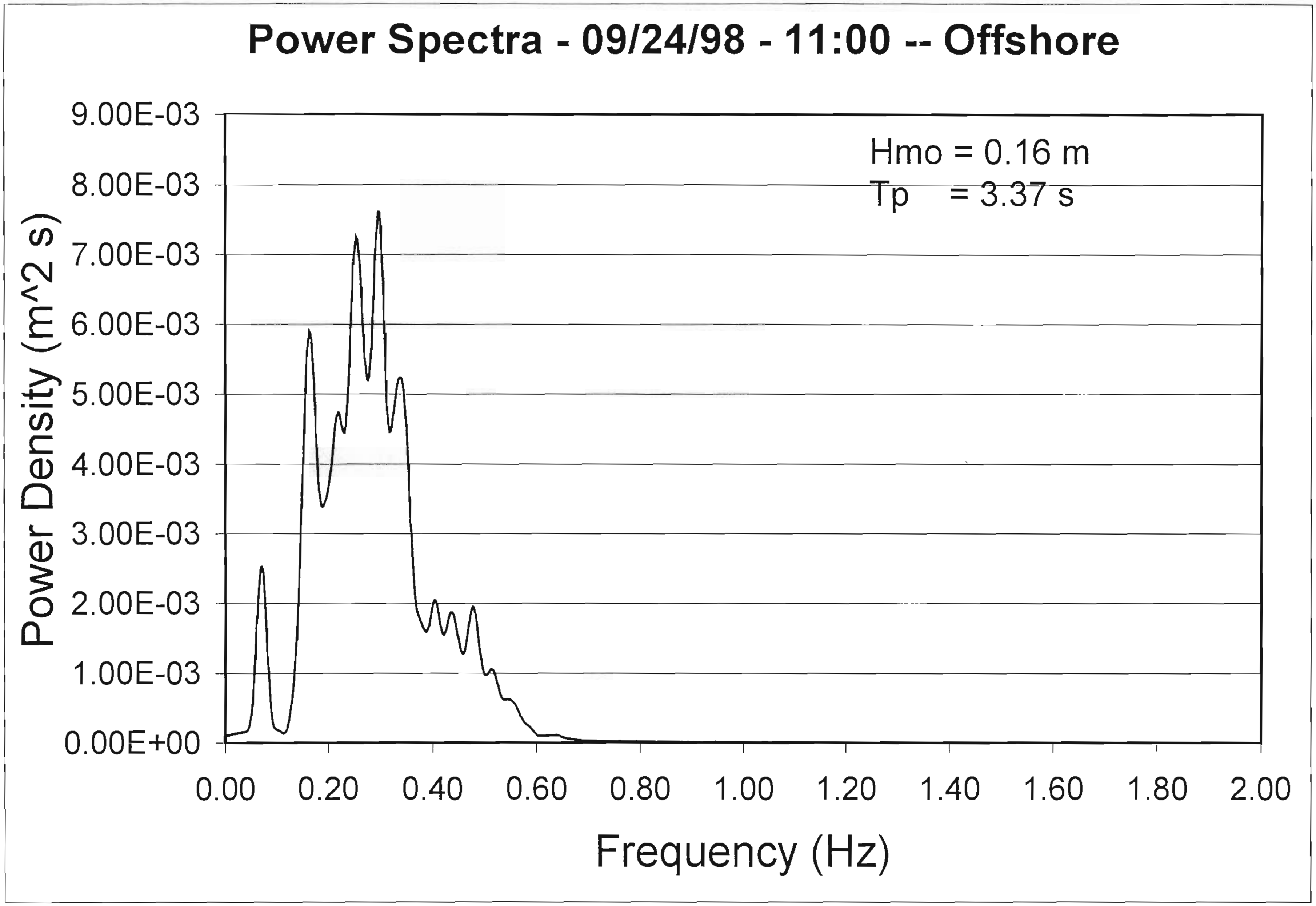
0.15
0.10
0.05
0.00
-0.05
-0.10
-0.15
-0.20
-0.25
0
200
400
600
800
1000
Record No. (0.25 second scan)

APPENDIX 3

Wave spectra measured during September 1998 deployment. Spectral distributions obtained from the inside measurements were not reliable due to the low signal strength and low signal-to-noise ratio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Hmo = 0.16 m
Tp = 3.37 s
Power Density (m^2 s)
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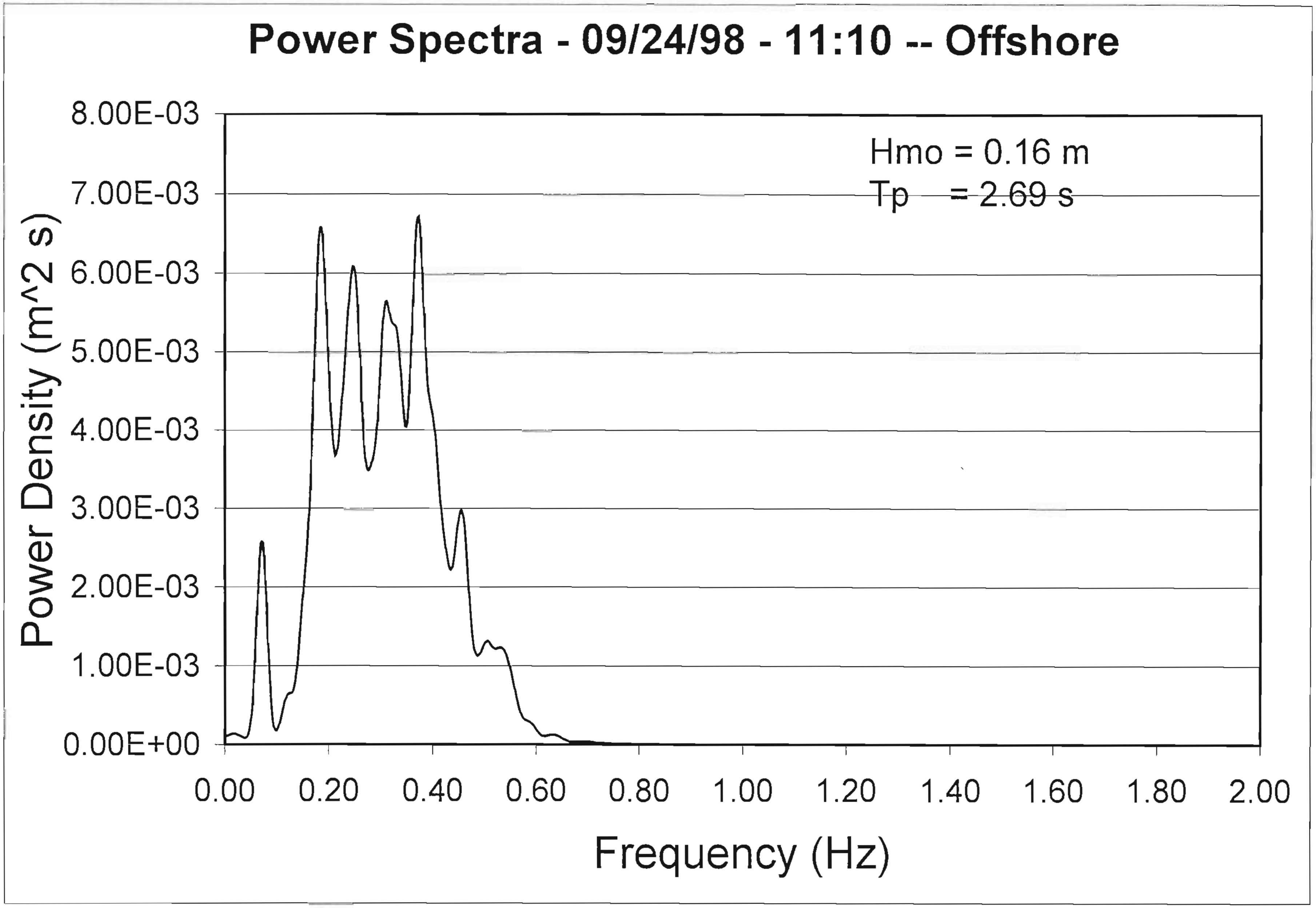
8.00E-03
7.00E-03
6.00E-03
5.00E-03
4.00E-03
3.00E-03
2.00E-03
1.00E-03
0.00E+00
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1.80
2.00
Frequency (Hz)



Power Spectra - 09/24/98 - 11:10 -- Offshore
Hmo = 0.16 m
Tp = 2.69 s
Power Density (m^2 s)
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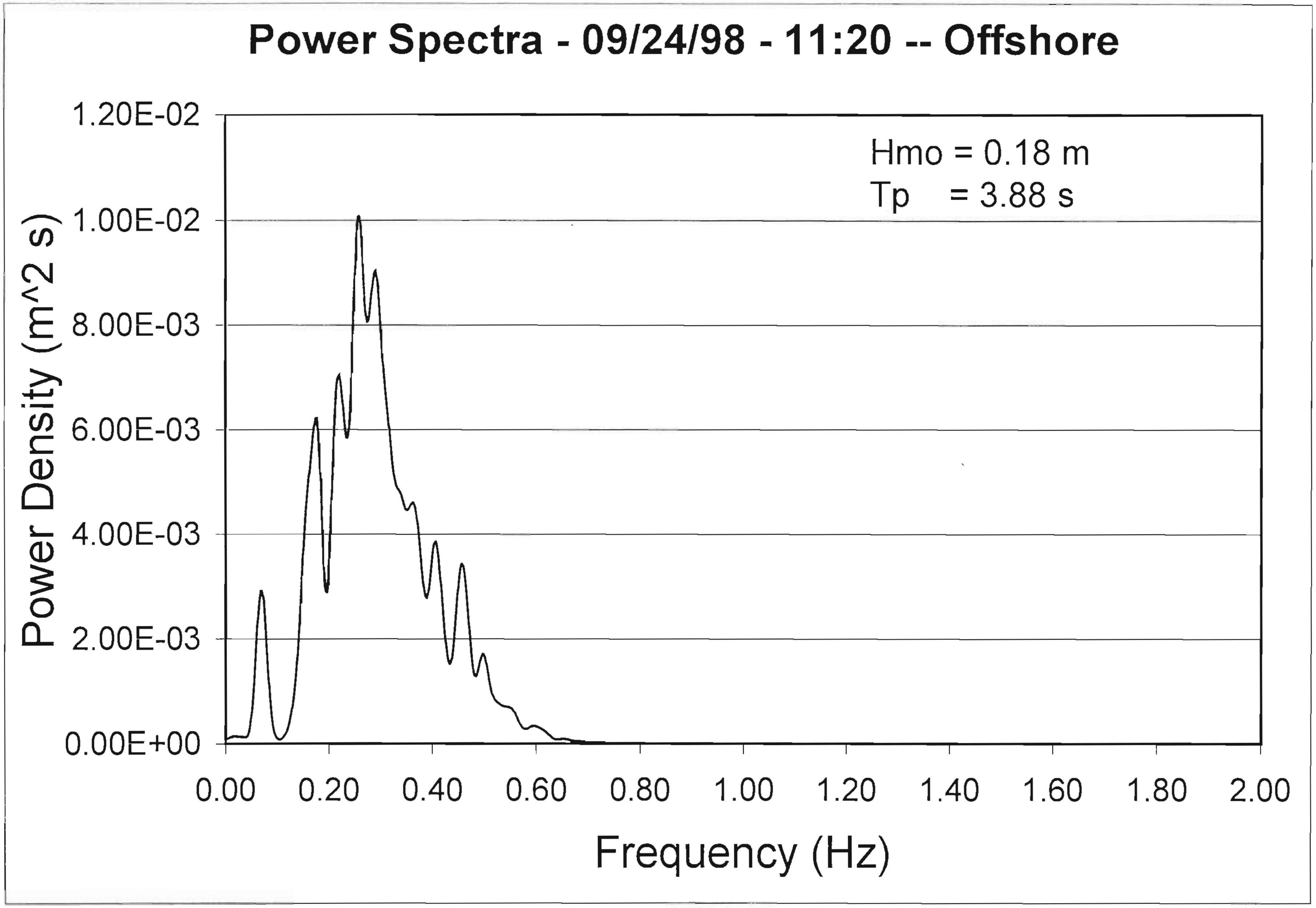
7.00E-03
6.00E-03
5.00E-03
4.00E-03
3.00E-03
2.00E-03
1.00E-03
0.00E+00
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1.80
2.00
Frequency (Hz)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Tp = 3.88 s
Power Density (m^2 s)
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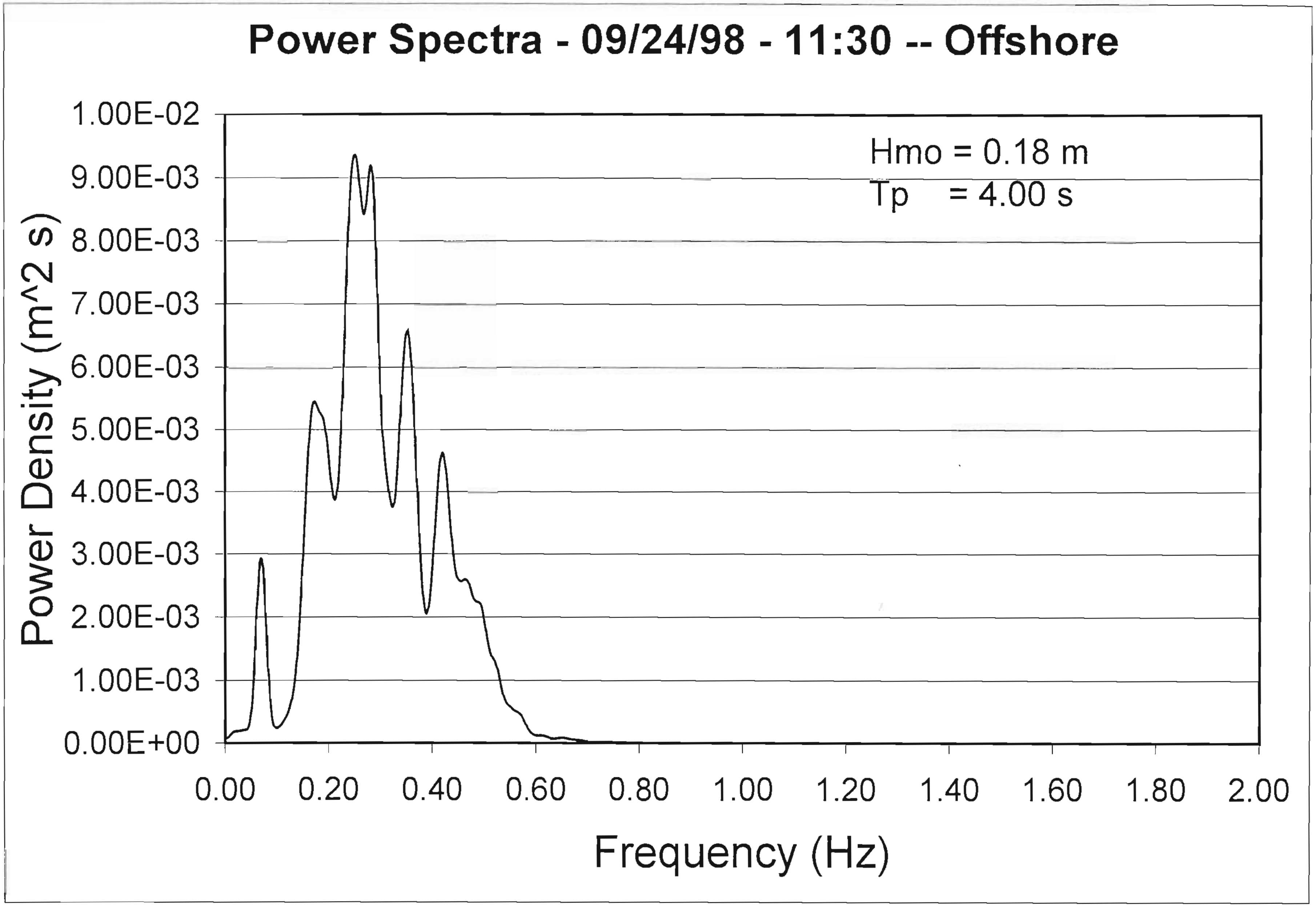
1.00E-02
8.00E-03
6.00E-03
4.00E-03
2.00E-03
0.00E+00
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1.80
2.00
Frequency (Hz)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Tp = 4.00 s
Power Density (m^2 s)
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6.00E-03
5.00E-03
4.00E-03
3.00E-03
2.00E-03
1.00E-03
0.00E+00
0.00
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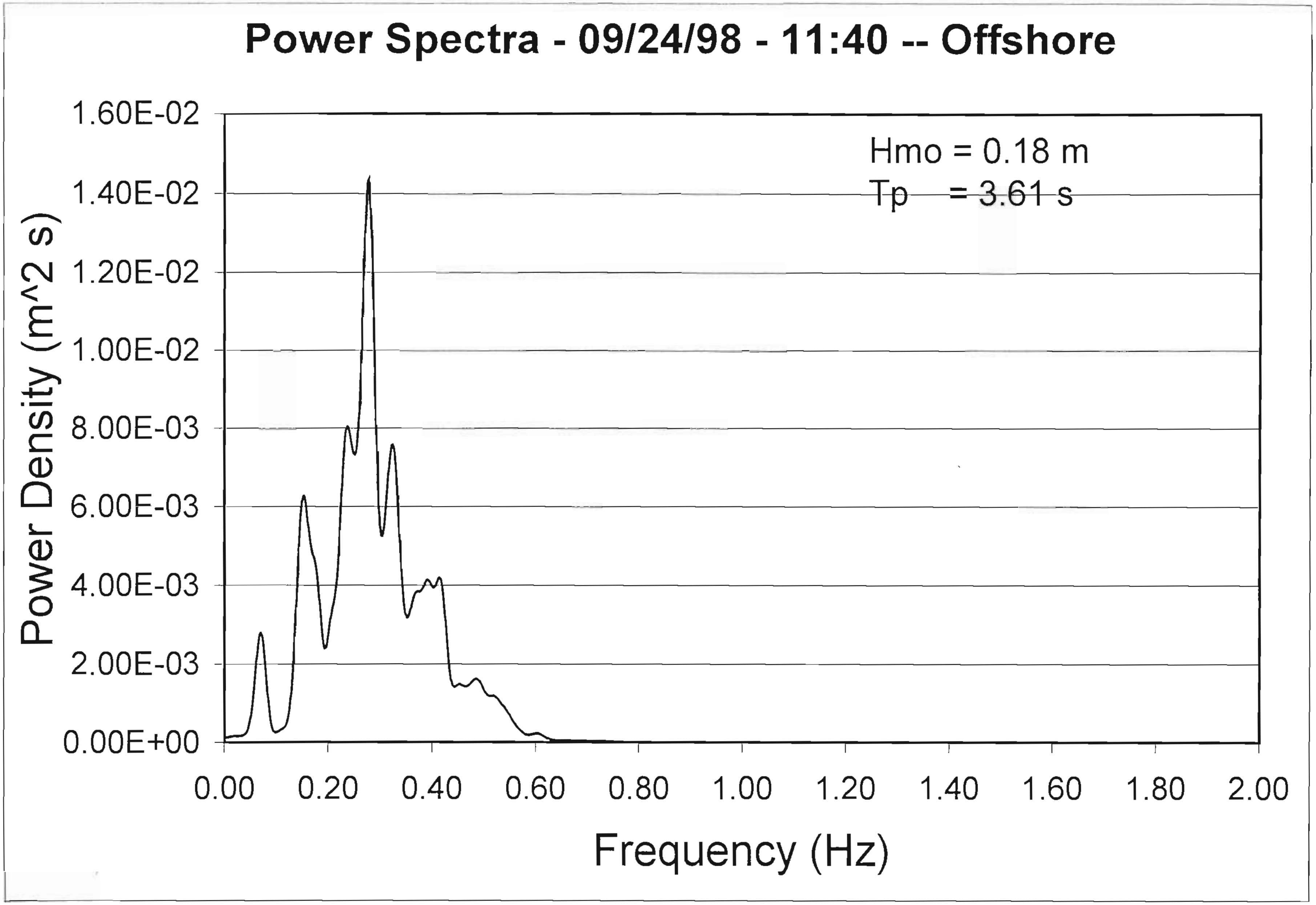
1.00
1.20
1.40
1.60
1.80
2.00
Frequency (Hz)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Power Density (m^2 s)
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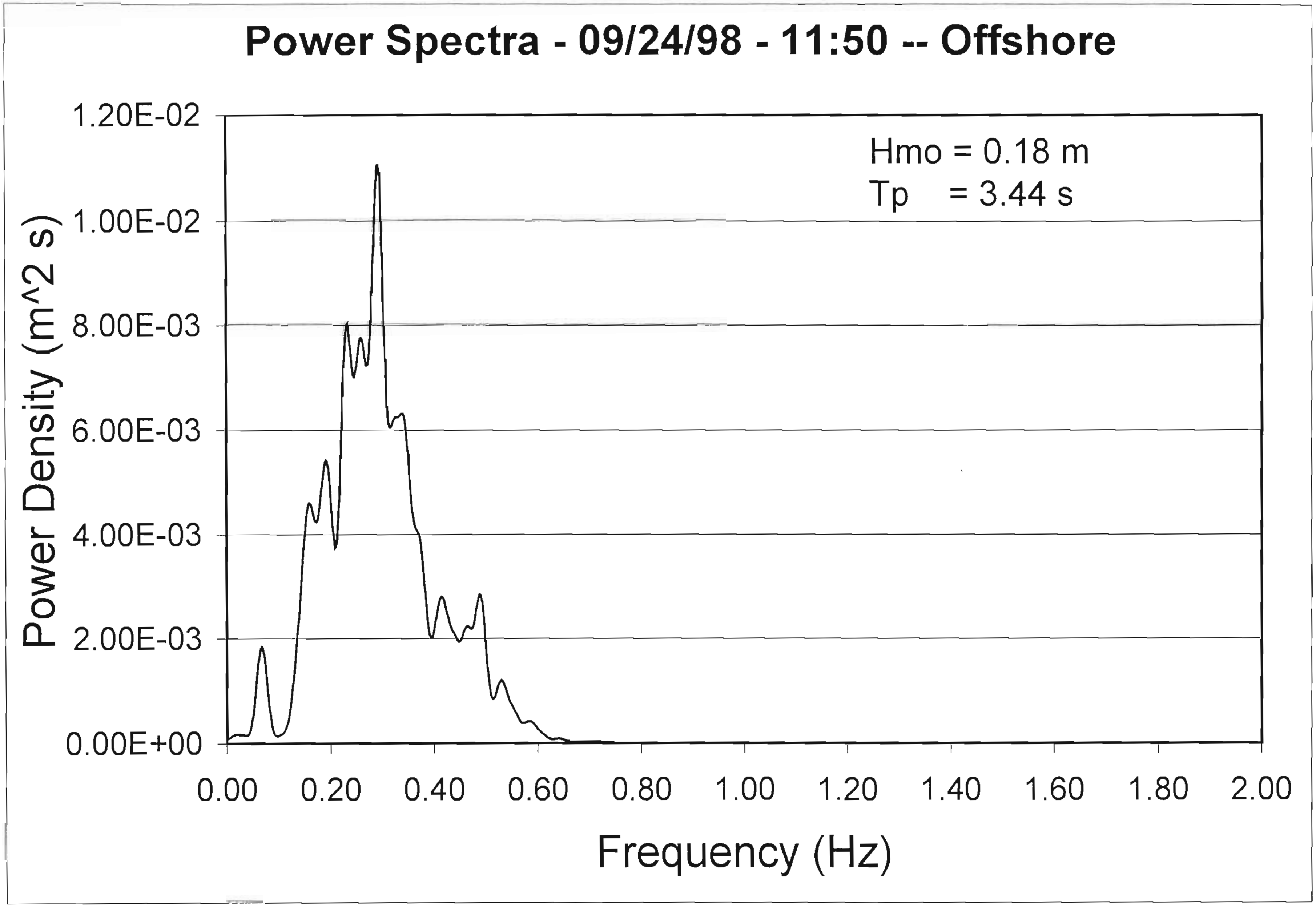
1.20E-02
1.00E-02
8.00E-03
6.00E-03
4.00E-03
2.00E-03
0.00E+00
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1.80
2.00
Frequency (Hz)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Tp = 3.44 s
Power Density (m^2 s)
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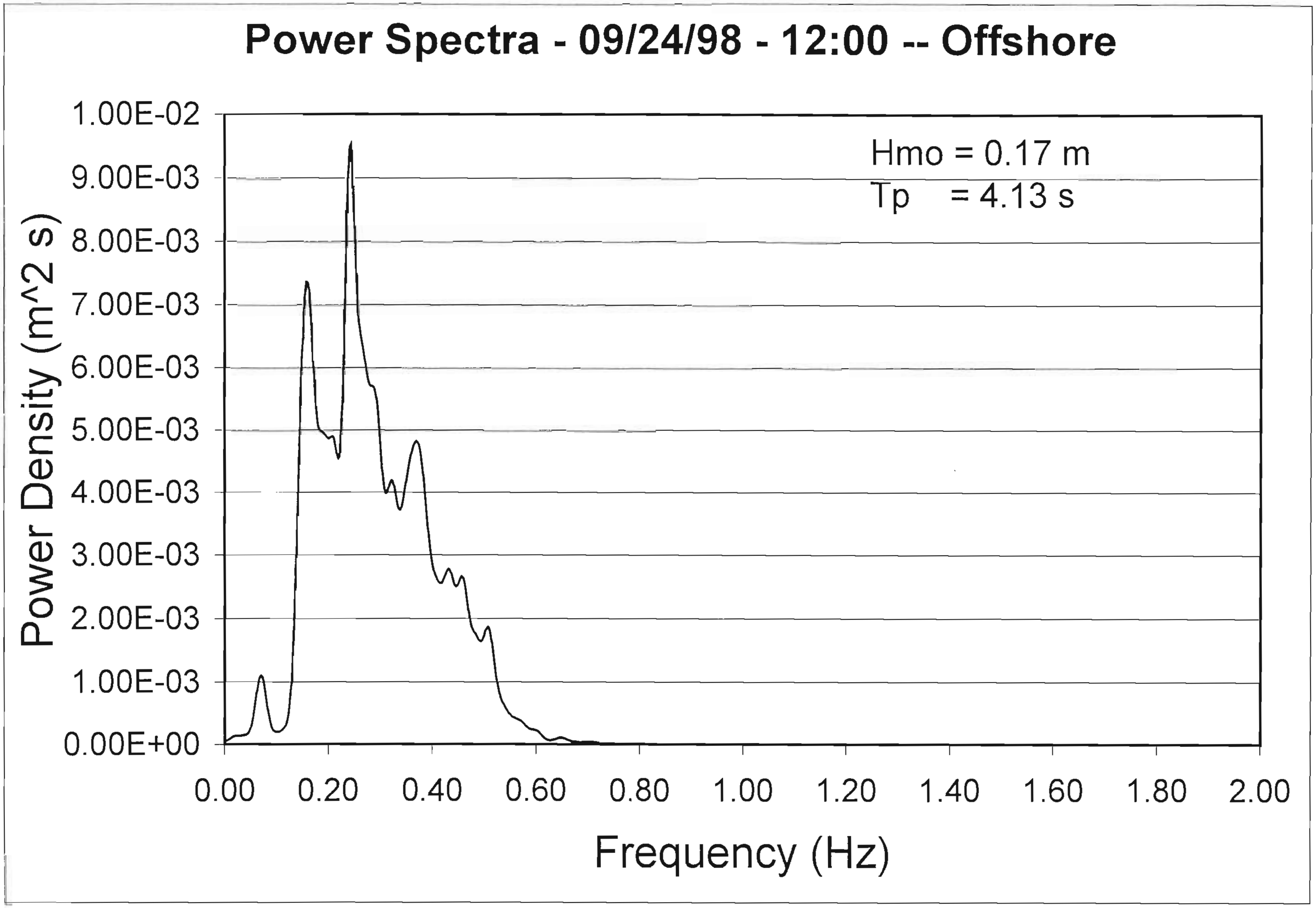
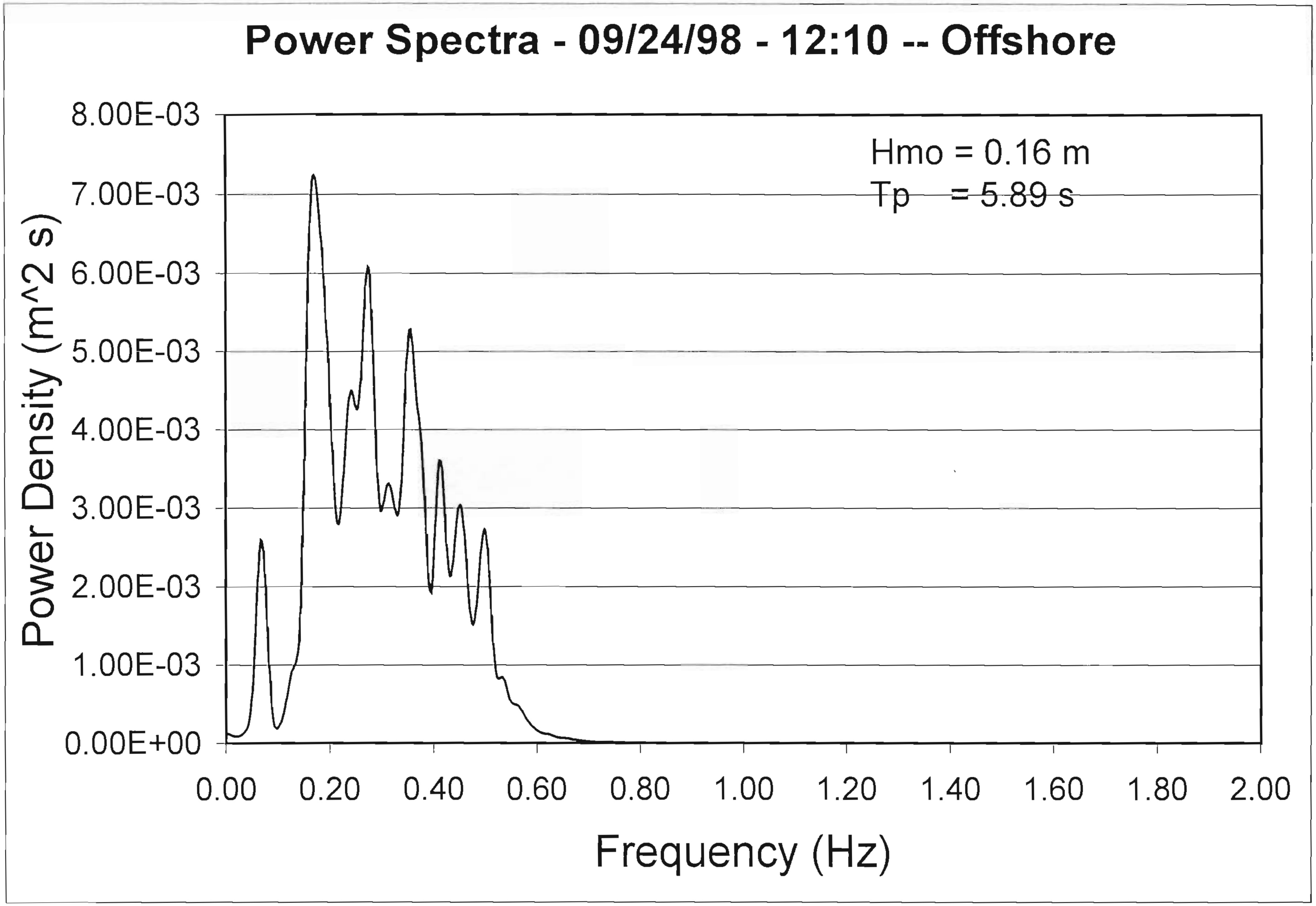
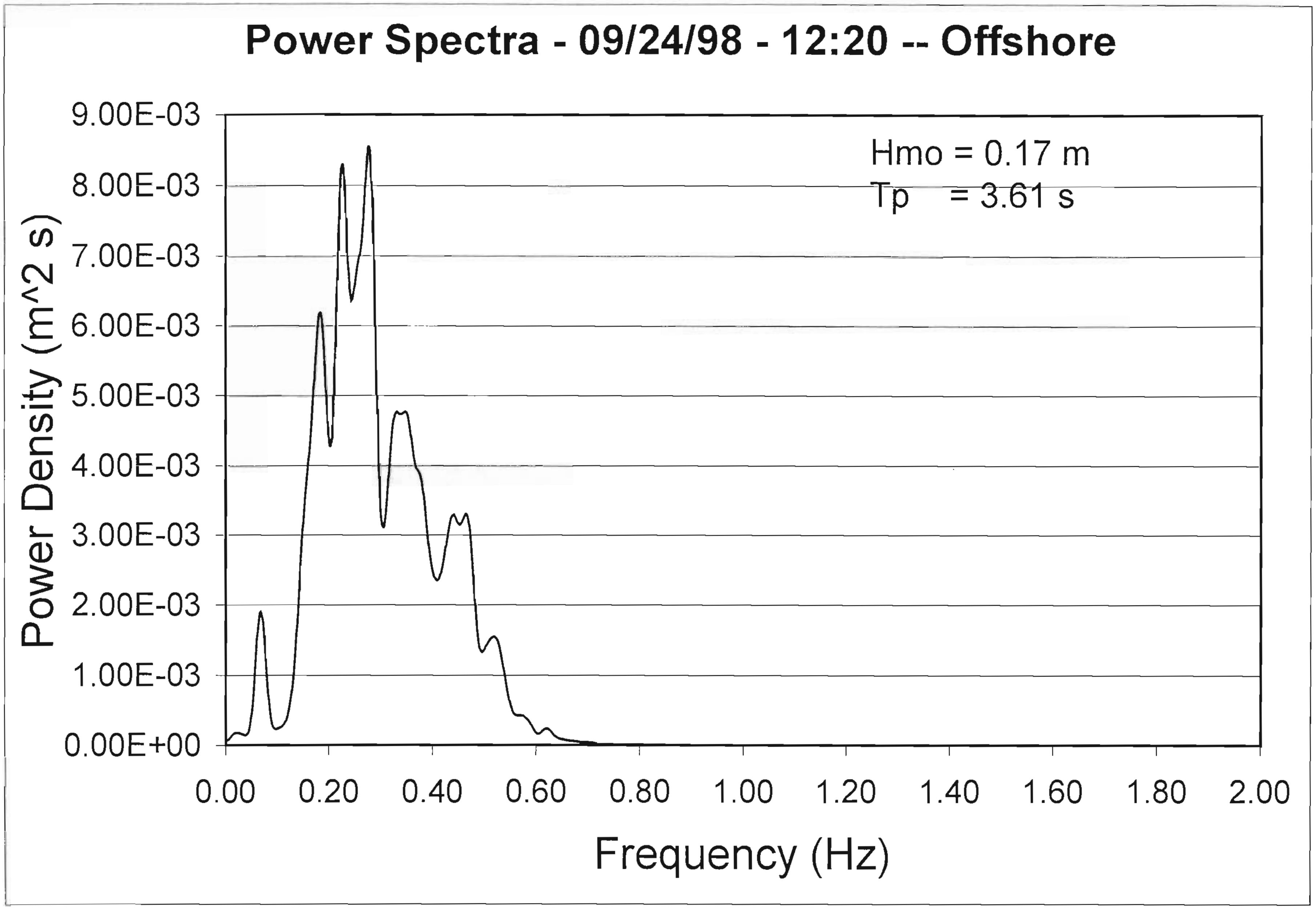
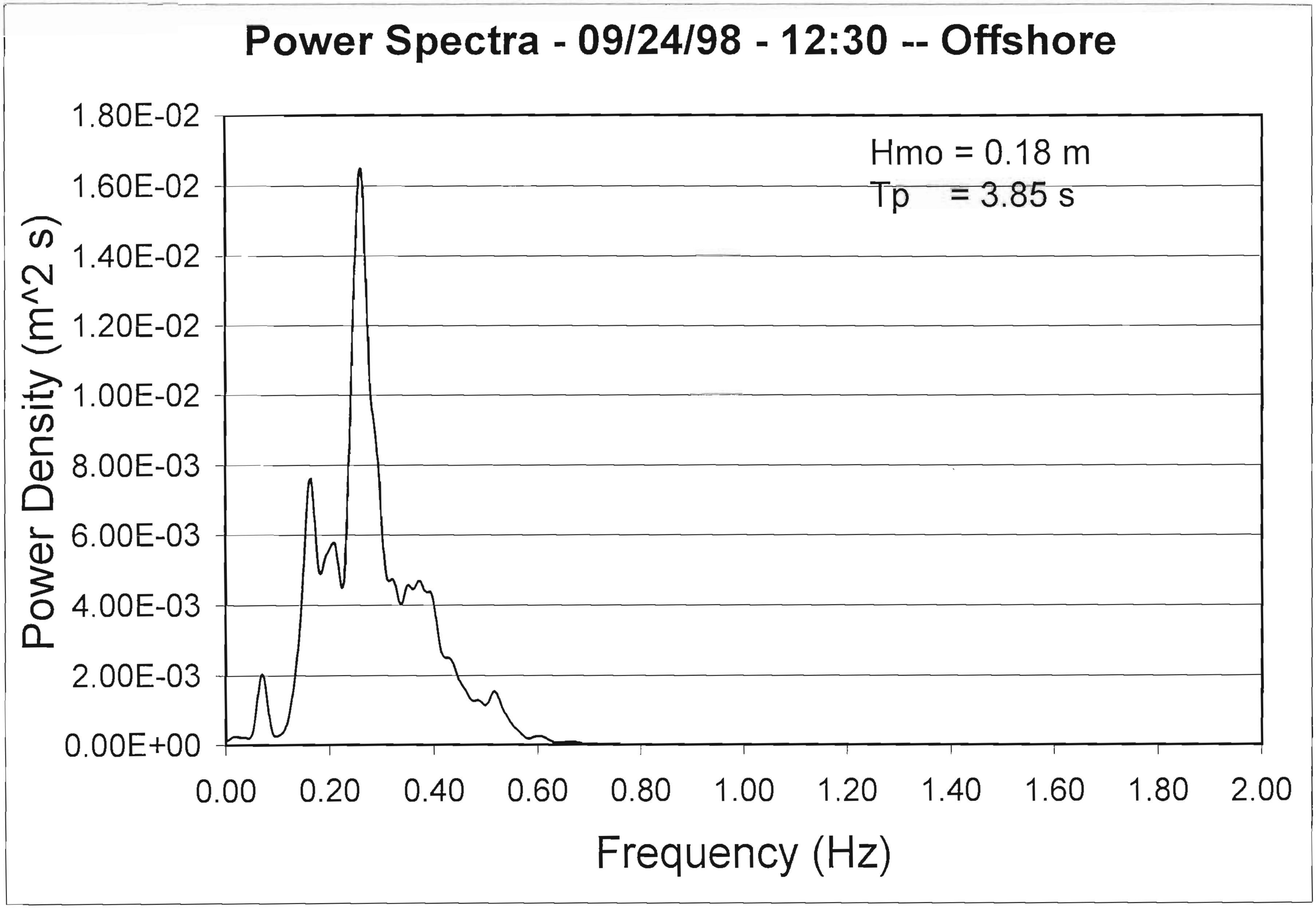
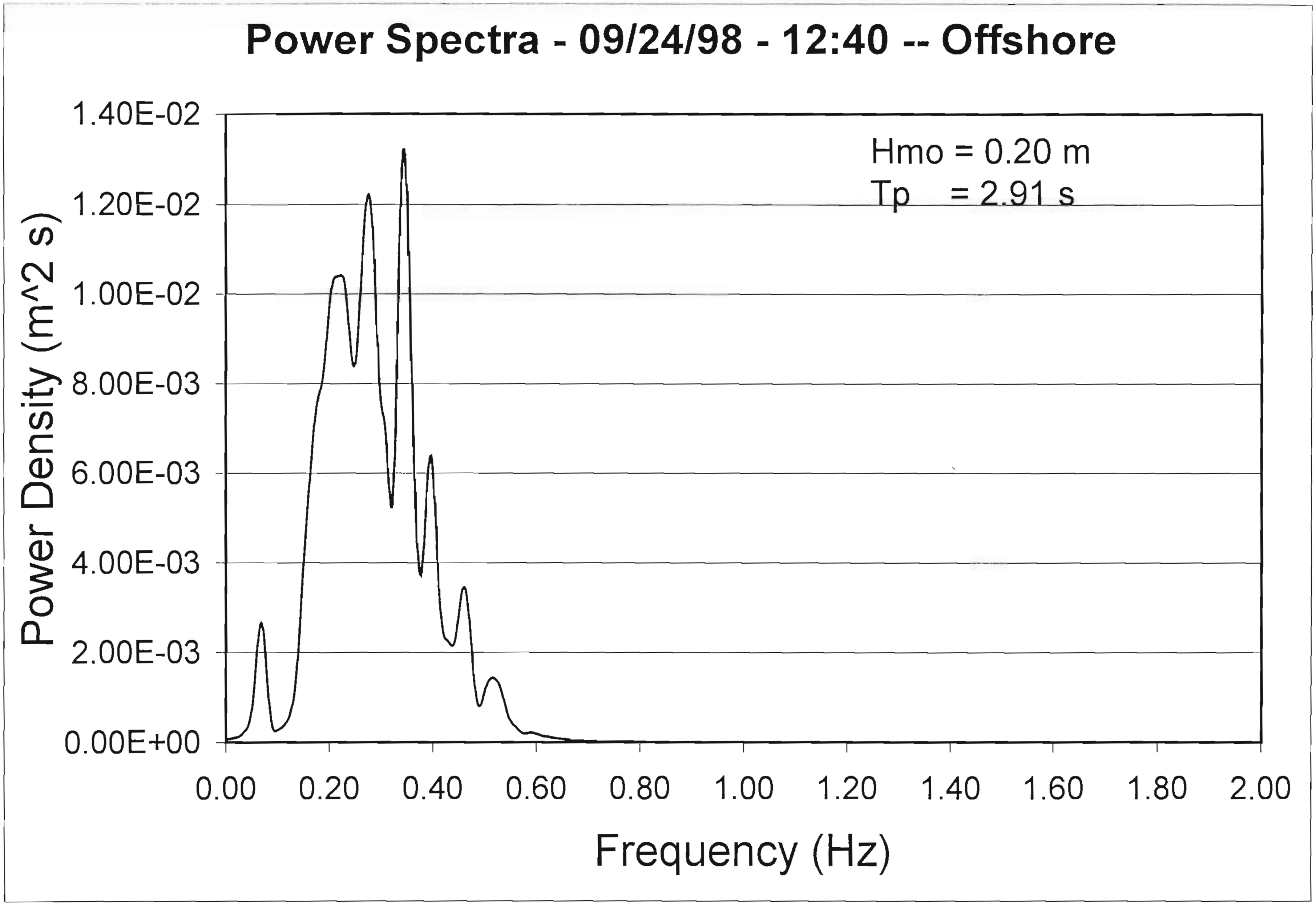
8.00E-03
6.00E-03
4.00E-03
2.00E-03
0.00E+00
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1.80
2.00
Frequency (Hz)

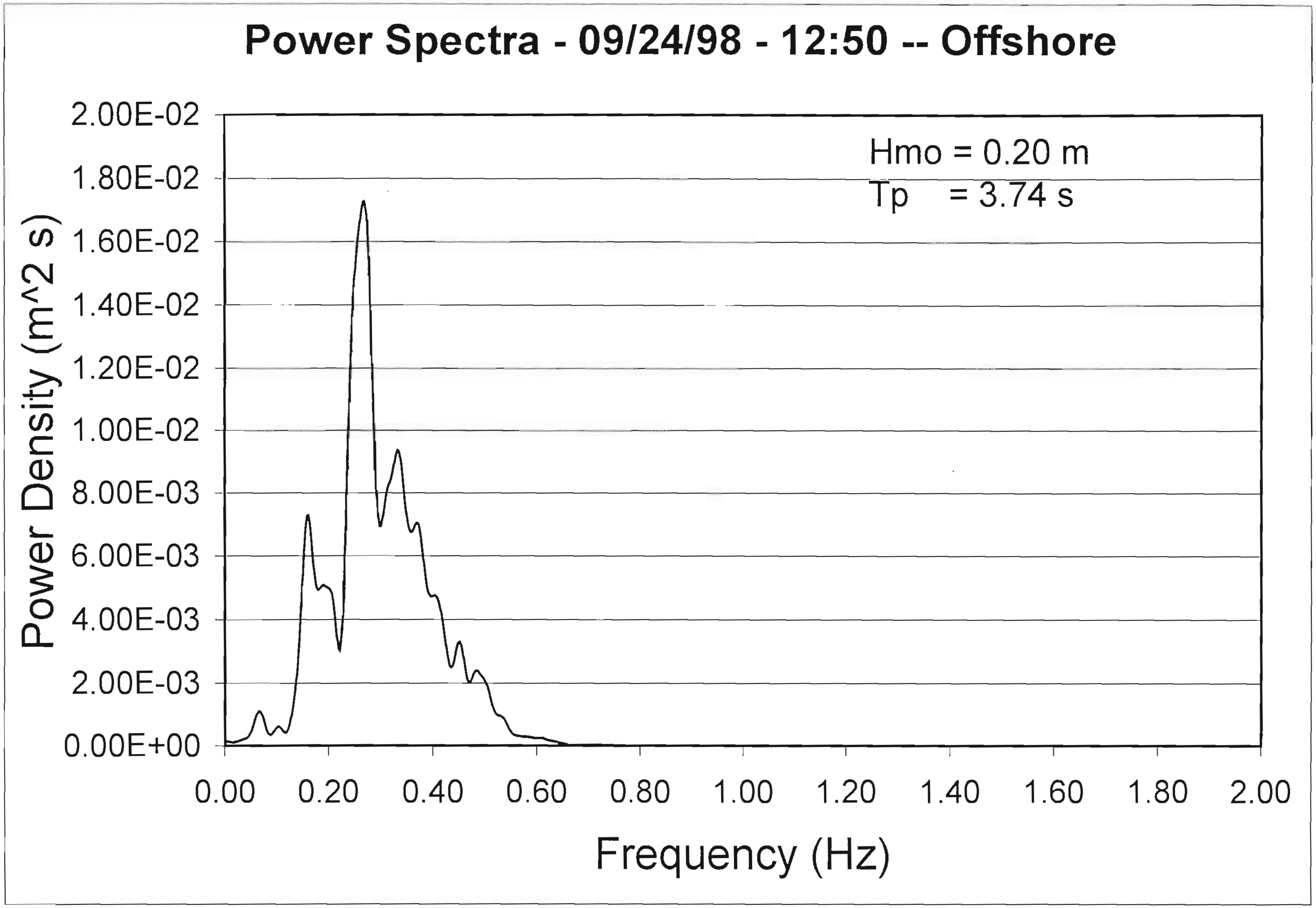

Power Spectra - 09/24/98 - 12:00 -- Offshore
Hmo = 0.17 m
Tp = 4.13 s
1.00E-02
9.00E-03
8.00E-03
7.00E-03
6.00E-03
5.00E-03
4.00E-03
3.00E-03
2.00E-03
1.00E-03
0.00E+00
Power Density (m^2 s)
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1.80
2.00
Frequency (Hz)

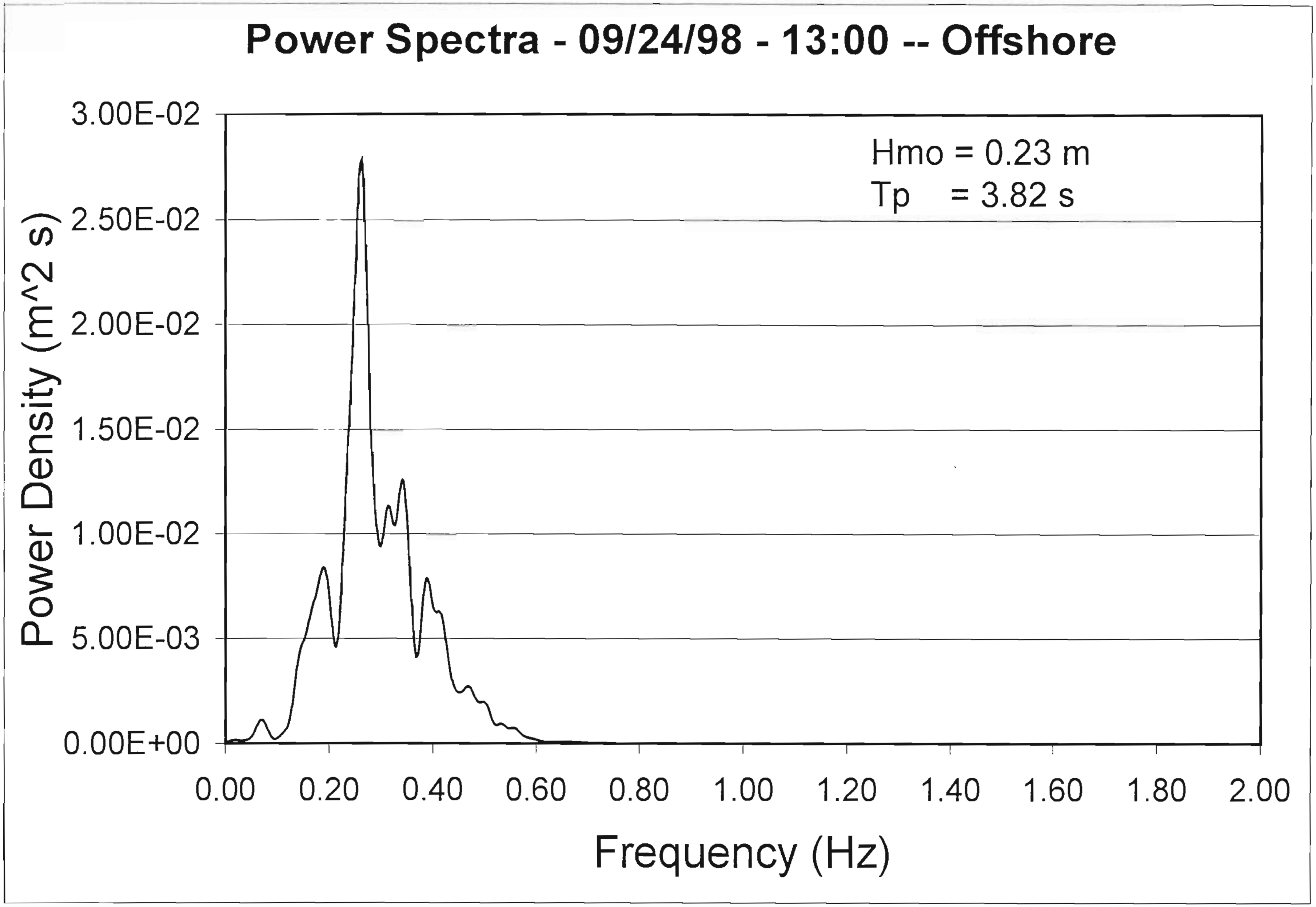

Power Spectra - 09/24/98 - 12:10 -- Offshore
Hmo = 0.16 m
Tp = 5.89 s
8.00E-03
7.00E-03
6.00E-03
5.00E-03
4.00E-03
3.00E-03
2.00E-03
1.00E-03
0.00E+00
Power Density (m^2 s)
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1.80
2.00
Frequency (Hz)

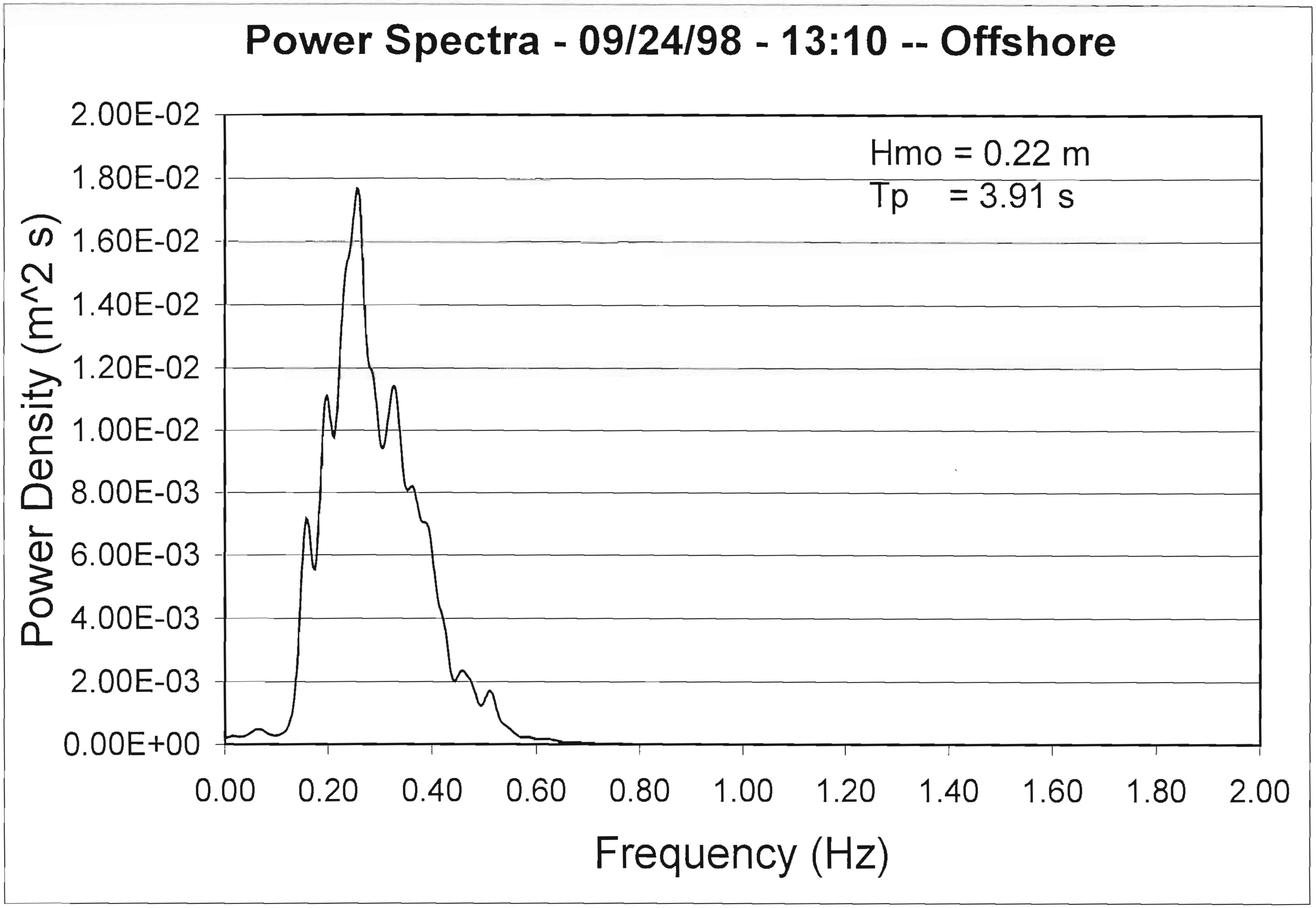

Power Spectra - 09/24/98 - 12:20 -- Offshore
Hmo = 0.17 m
Tp = 3.61 s
Power Density (m^2 s)
9.00E-03
8.00E-03
7.00E-03
6.00E-03
5.00E-03
4.00E-03
3.00E-03
2.00E-03
1.00E-03
0.00E+00
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1.80
2.00
Frequency (Hz)

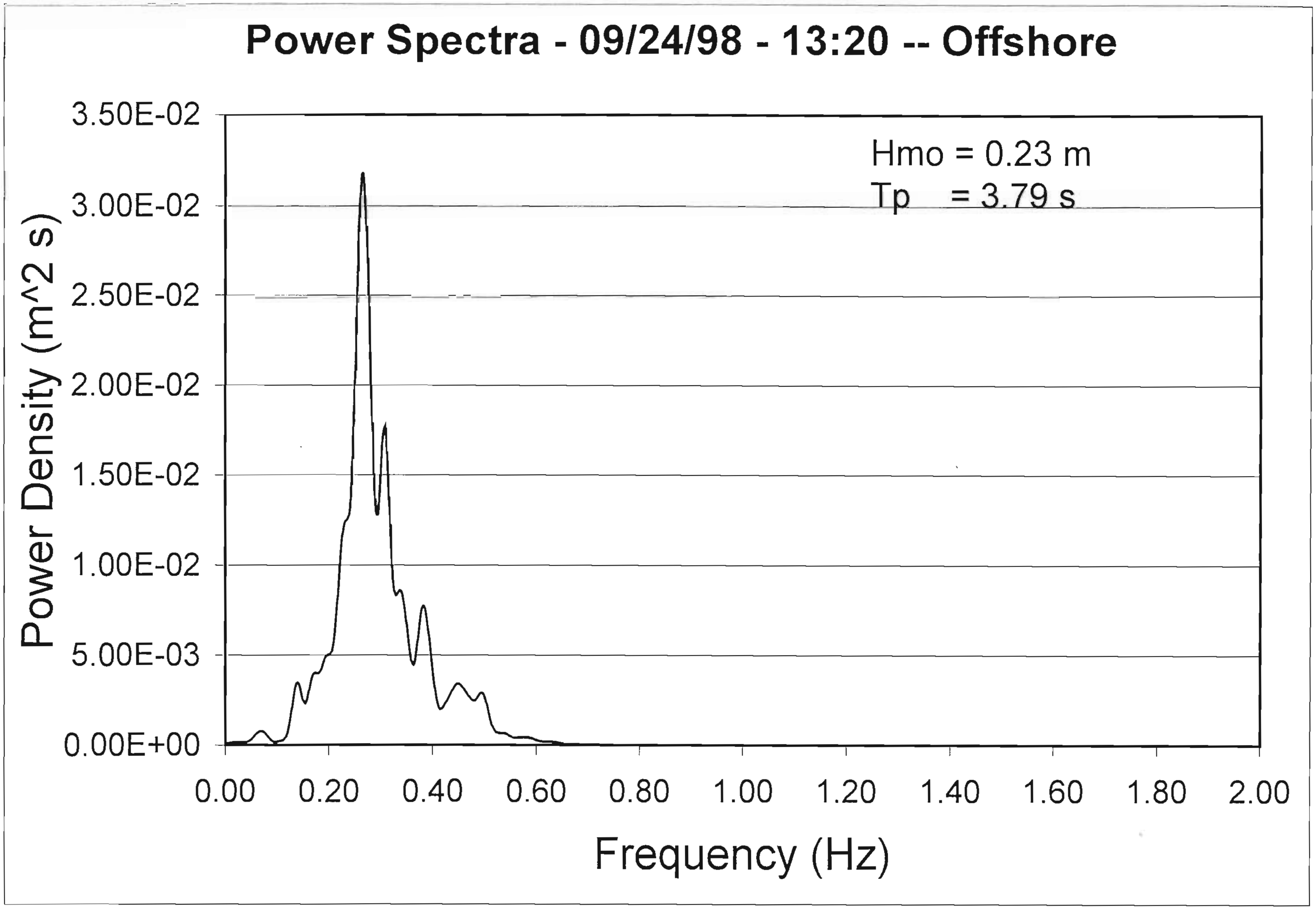

Power Spectra - 09/24/98 - 12:30 -- Offshore
Hmo = 0.18 m
Tp = 3.85 s
Power Density (m^2 s)
1.80E-02
1.60E-02
1.40E-02
1.20E-02
1.00E-02
8.00E-03
6.00E-03
4.00E-03
2.00E-03
0.00E+00
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1.80
2.00
Frequency (Hz)

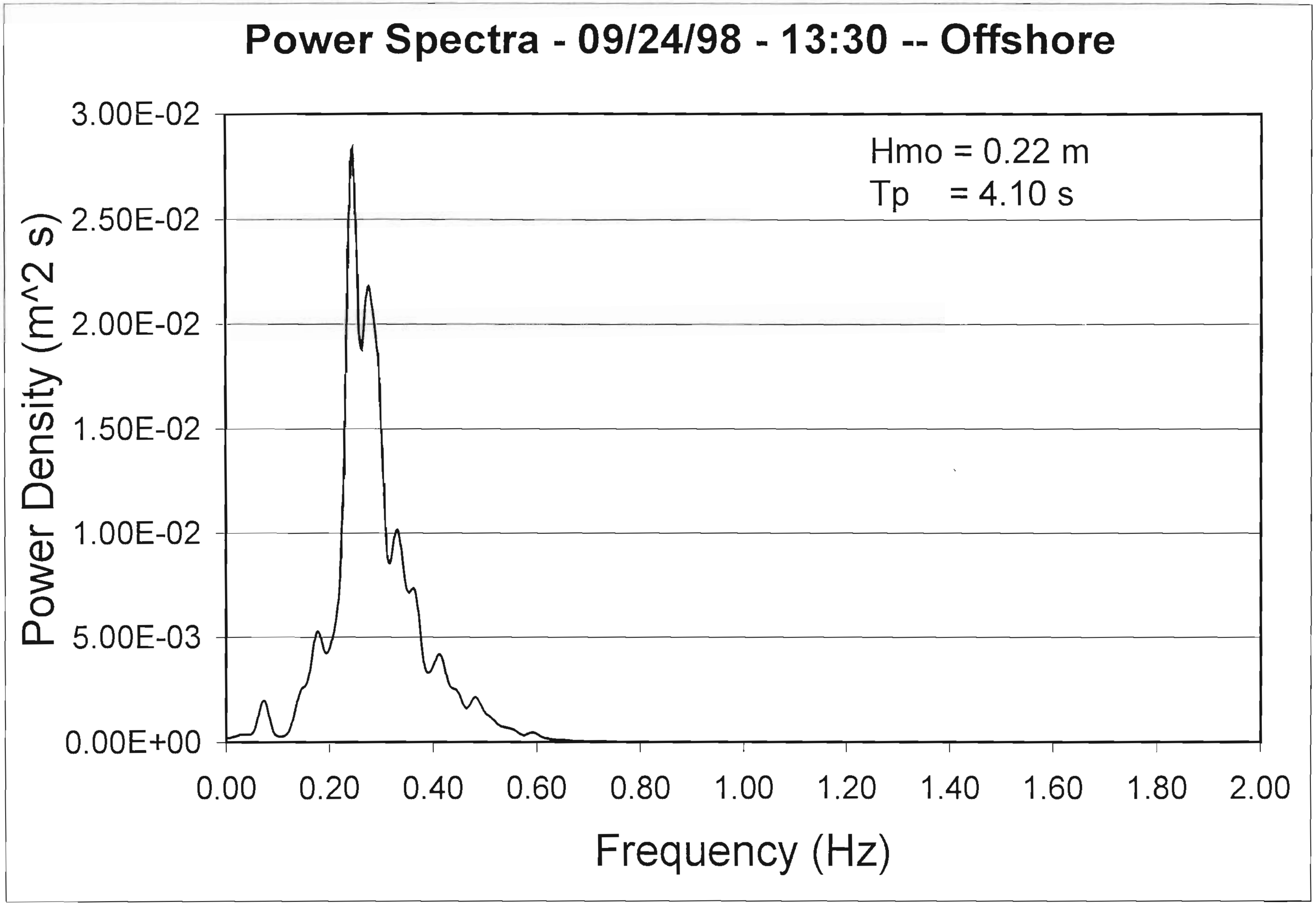

Power Spectra - 09/24/98 - 12:40 -- Offshore
Hmo = 0.20 m
Tp = 2.91 s
Power Density (m^2 s)
1.40E-02
1.20E-02
1.00E-02
8.00E-03
6.00E-03
4.00E-03
2.00E-03
0.00E+00
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1.80
2.00
Frequency (Hz)

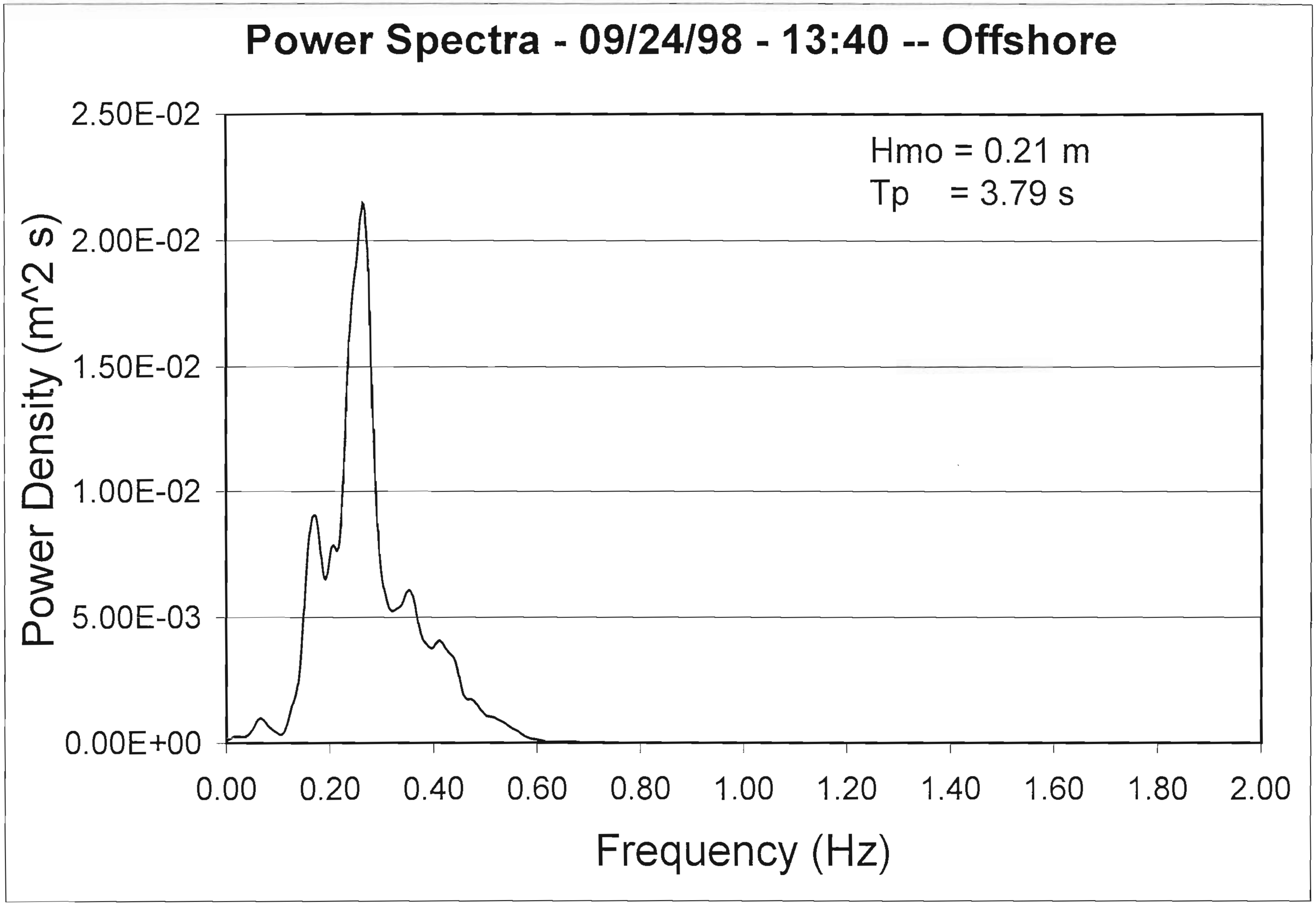

Power Spectra - 09/24/98 - 12:50 -- Offshore
Hmo = 0.20 m
Tp = 3.74 s
Power Density (m^2 s)
2.00E-02
1.80E-02
1.60E-02
1.40E-02
1.20E-02
1.00E-02
8.00E-03
6.00E-03
4.00E-03
2.00E-03
0.00E+00
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1.80
2.00
Frequency (Hz)

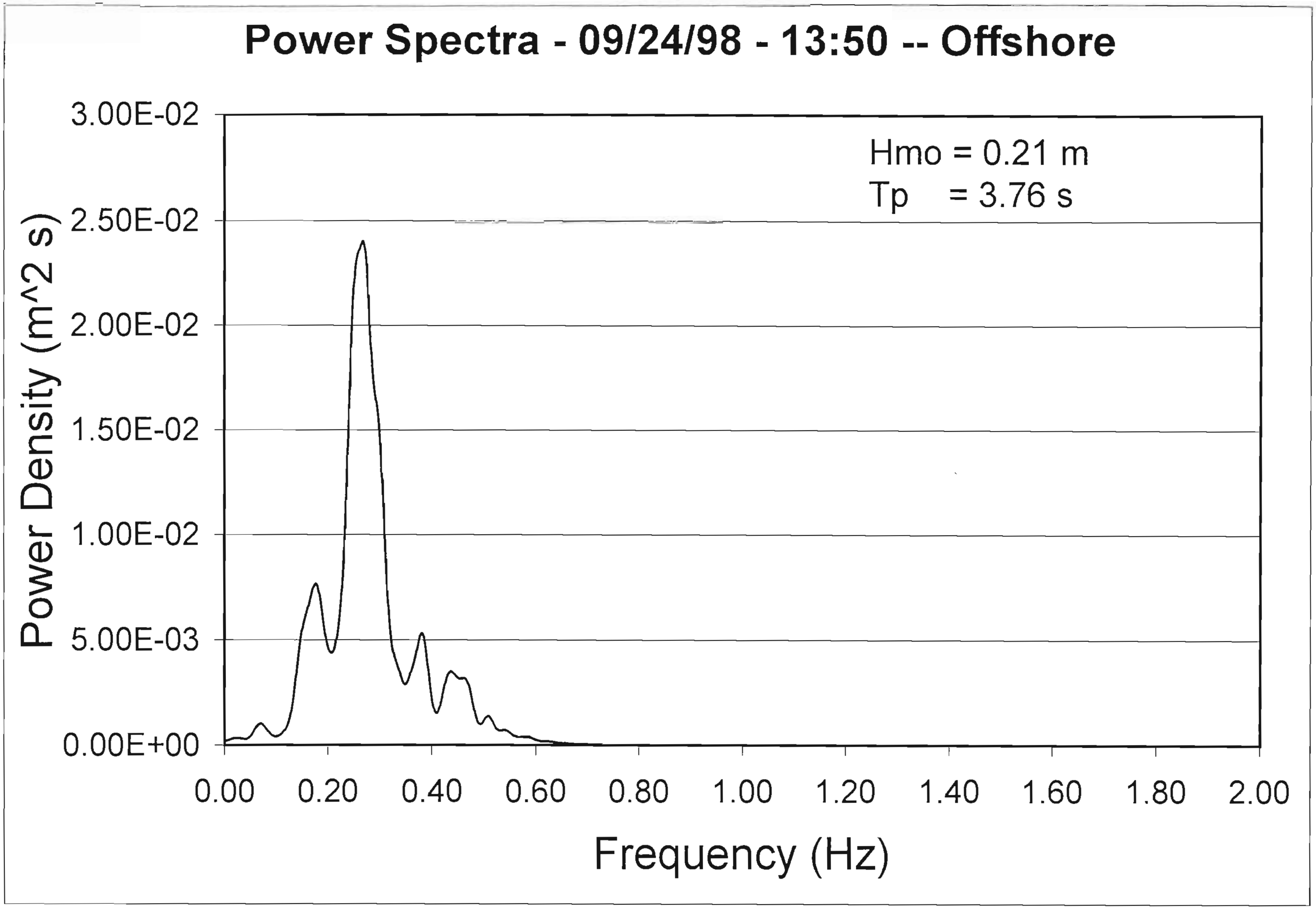

Power Spectra - 09/24/98 - 13:00 -- Offshore
Hmo = 0.23 m
Tp = 3.82 s
Power Density (m^2 s)
3.00E-02
2.50E-02
2.00E-02
1.50E-02
1.00E-02
5.00E-03
0.00E+00
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1.80
2.00
Frequency (Hz)

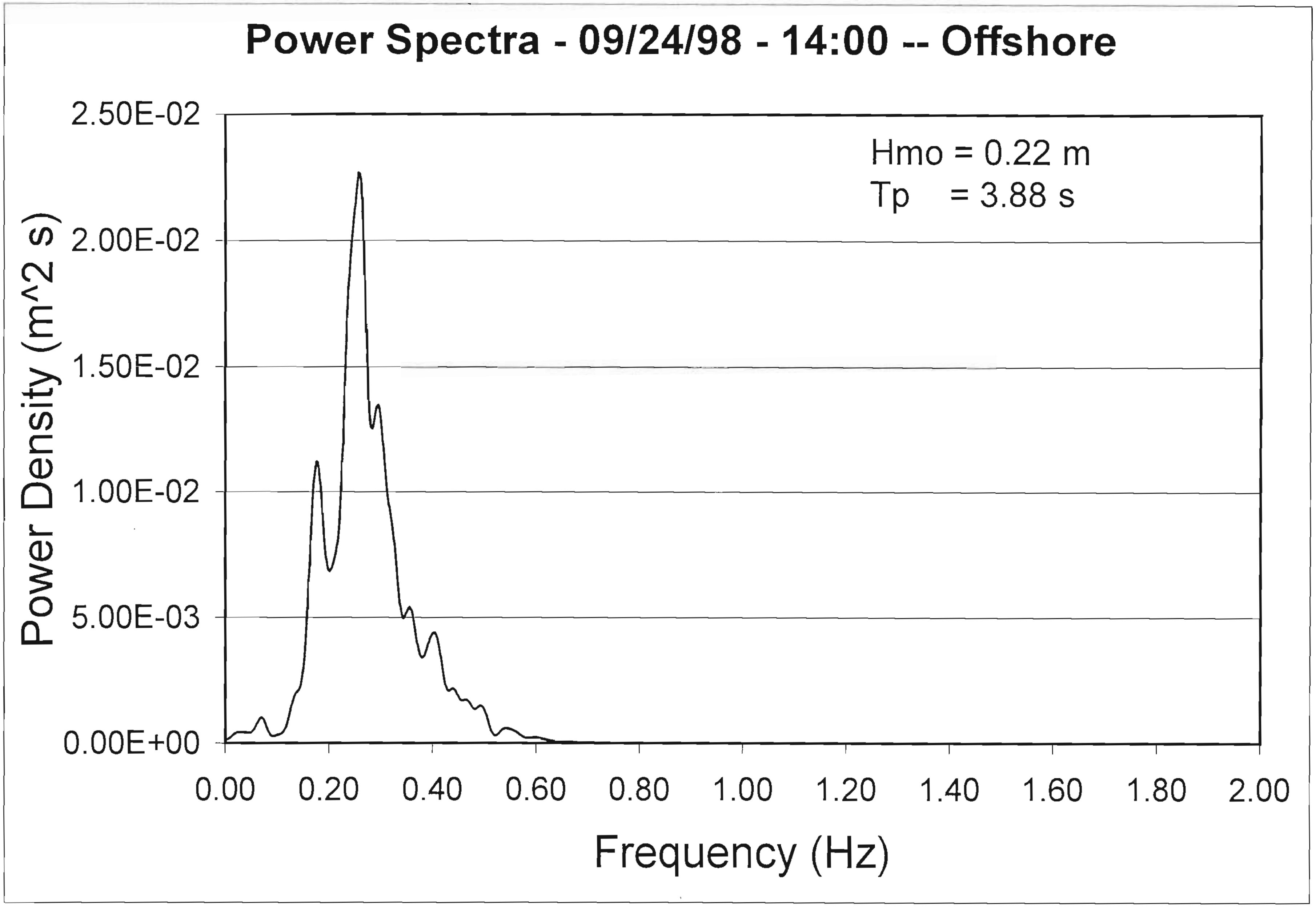

Power Spectra - 09/24/98 - 13:10 -- Offshore
Hmo = 0.22 m
Tp = 3.91 s
Power Density (m^2 s)
2.00E-02
1.80E-02
1.60E-02
1.40E-02
1.20E-02
1.00E-02
8.00E-03
6.00E-03
4.00E-03
2.00E-03
0.00E+00
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1.80
2.00
Frequency (Hz)


Power Spectra - 09/24/98 - 13:20 -- Offshore
Hmo = 0.23 m
Tp = 3.79 s
Power Density (m^2 s)
3.50E-02
3.00E-02
2.50E-02
2.00E-02
1.50E-02
1.00E-02
5.00E-03
0.00E+00
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1.80
2.00
Frequency (Hz)

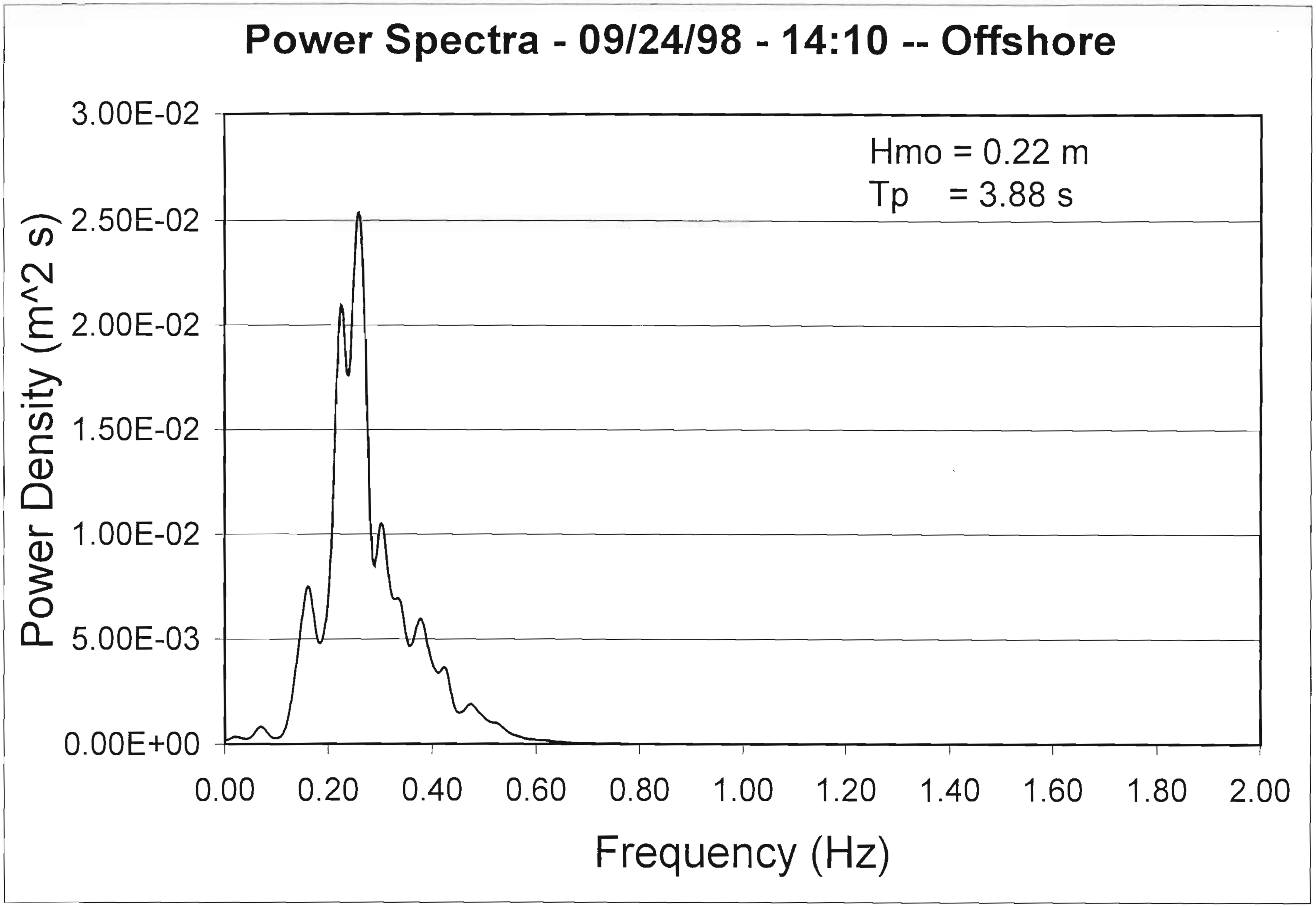

Power Spectra - 09/24/98 - 13:30 -- Offshore
Hmo = 0.22 m
Tp = 4.10 s
Power Density (m^2 s)
3.00E-02
2.50E-02
2.00E-02
1.50E-02
1.00E-02
5.00E-03
0.00E+00
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1.80
2.00
Frequency (Hz)

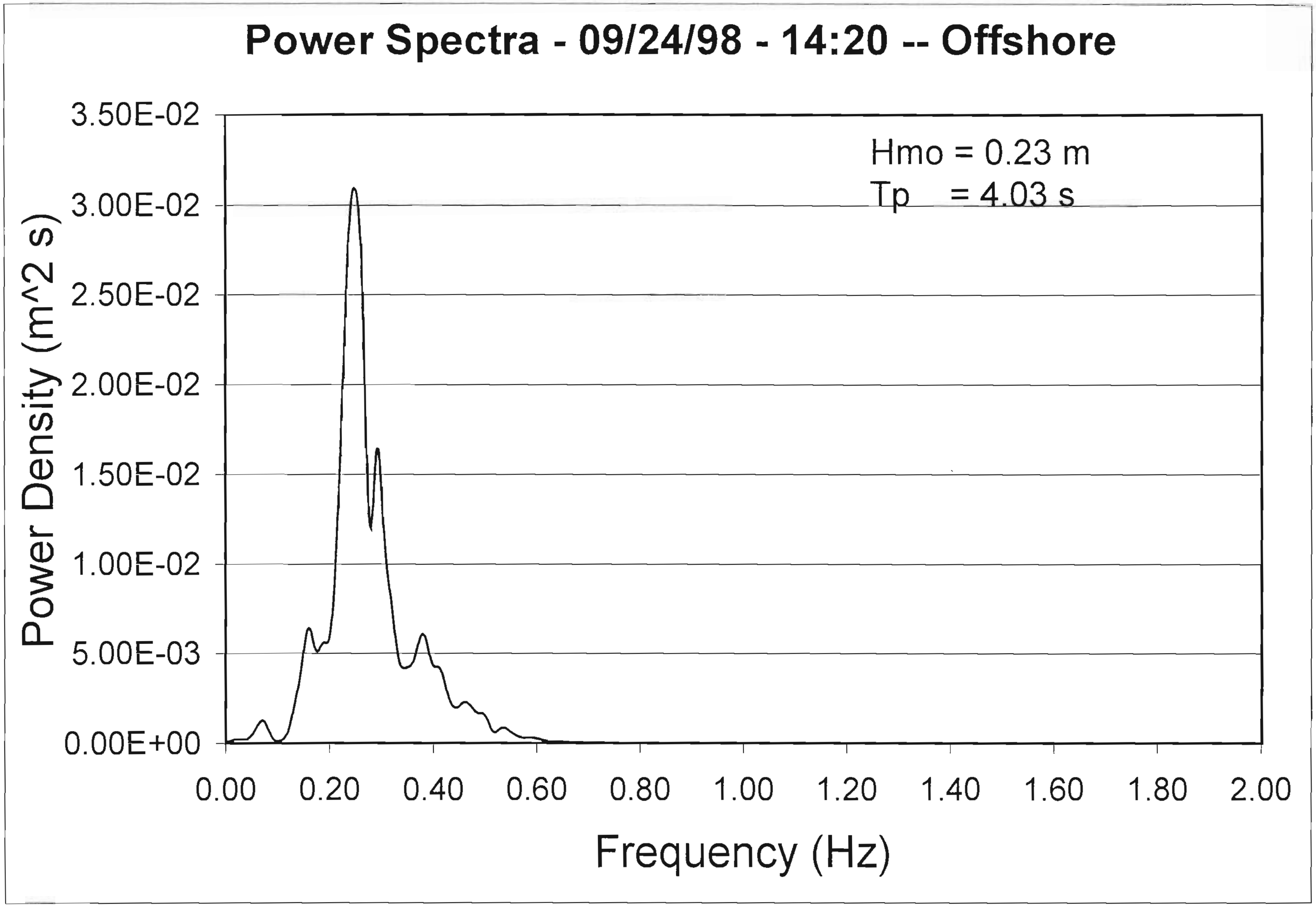

Power Spectra - 09/24/98 - 13:40 -- Offshore
Hmo = 0.21 m
Tp = 3.79 s
Power Density (m^2 s)
2.50E-02
2.00E-02
1.50E-02
1.00E-02
5.00E-03
0.00E+00
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1.80
2.00
Frequency (Hz)


Power Spectra - 09/24/98 - 13:50 -- Offshore
Hmo = 0.21 m
Tp = 3.76 s
Power Density (m^2 s)
3.00E-02
2.50E-02
2.00E-02
1.50E-02
1.00E-02
5.00E-03
0.00E+00
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1.80
2.00
Frequency (Hz)

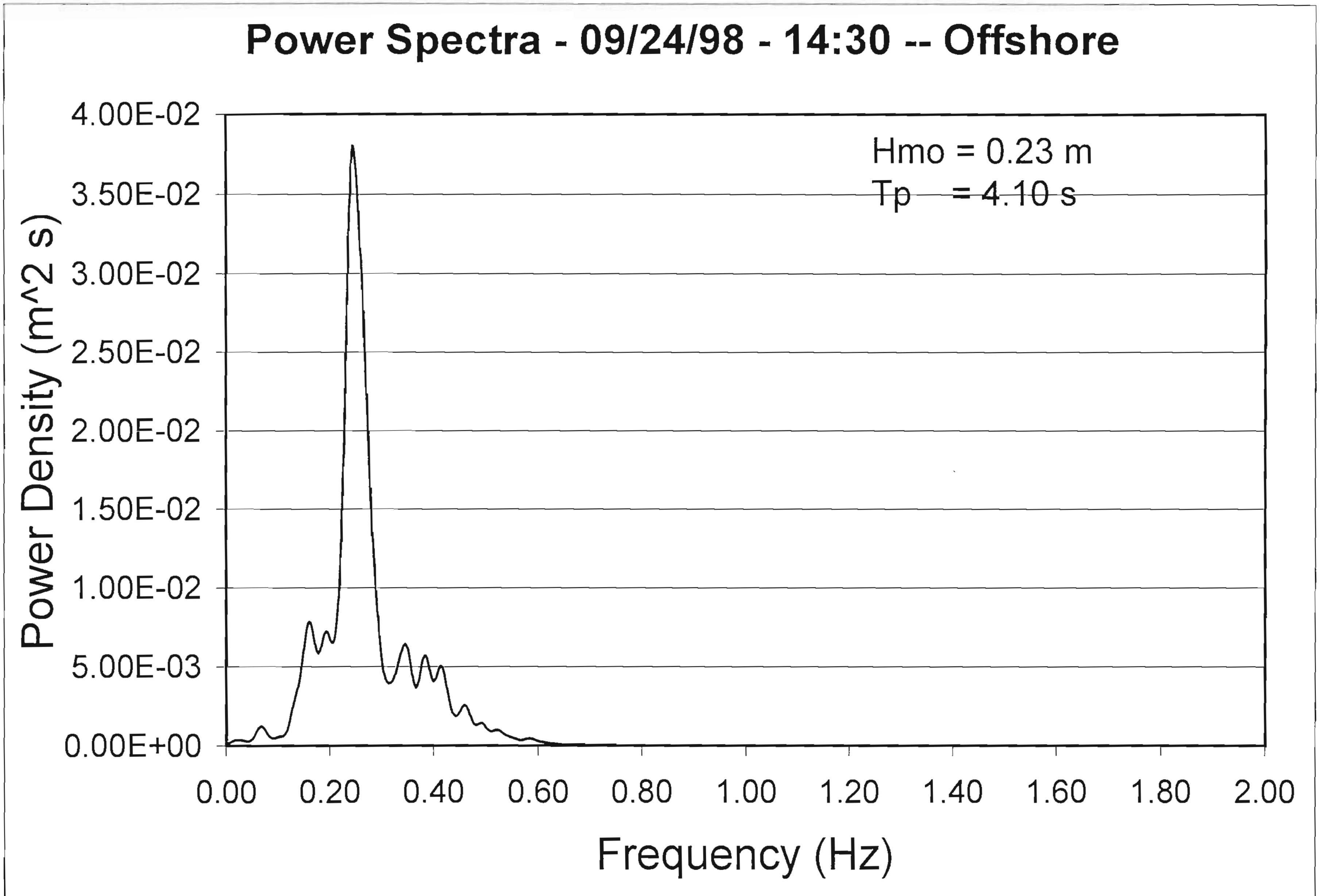


Power Spectra - 09/24/98 - 14:00 -- Offshore
Hmo = 0.22 m
Tp = 3.88 s
Power Density (m^2 s)
2.50E-02
2.00E-02
1.50E-02
1.00E-02
5.00E-03
0.00E+00
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1.80
2.00
Frequency (Hz)

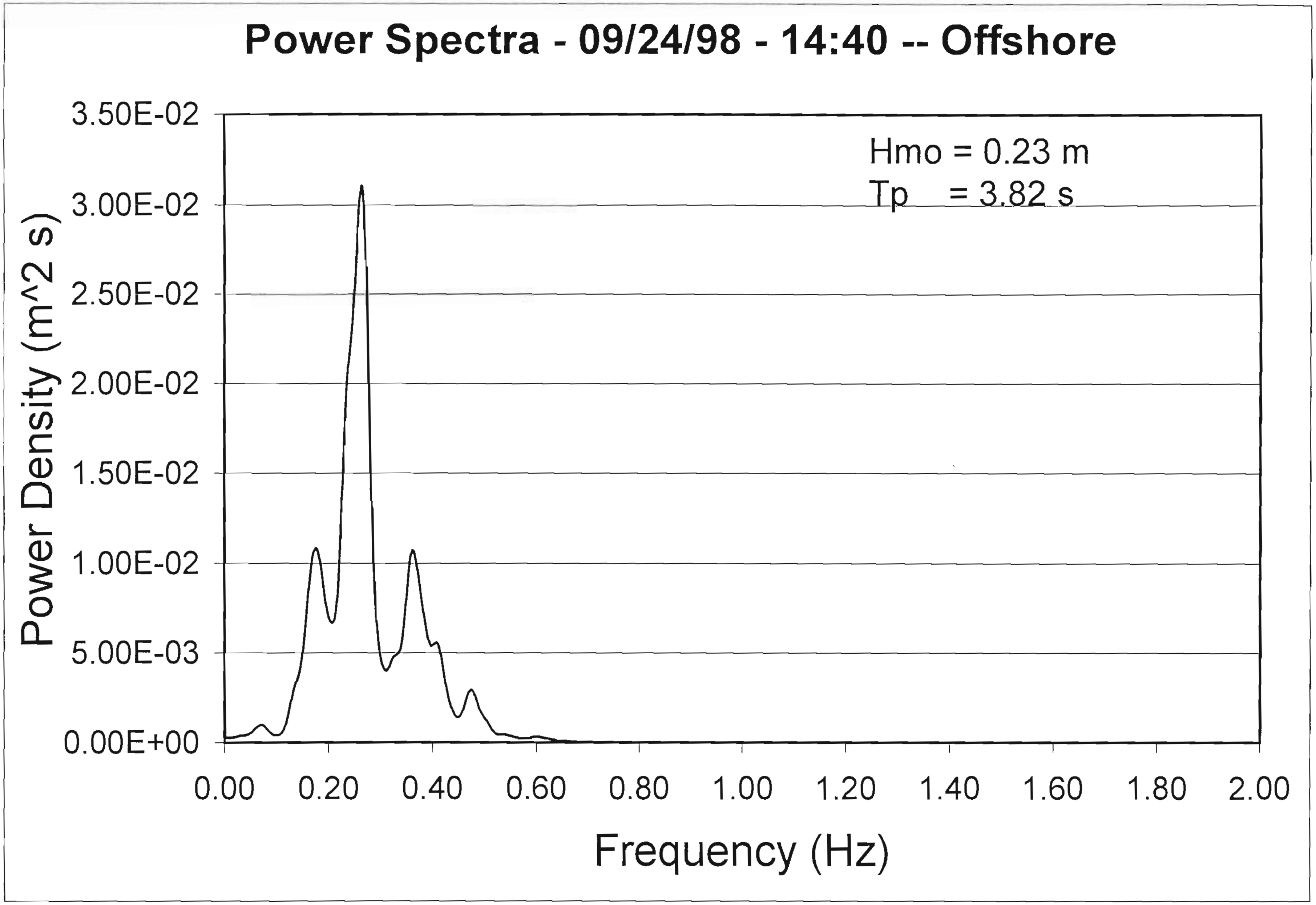

Power Spectra - 09/24/98 - 14:10 -- Offshore
Hmo = 0.22 m
Tp = 3.88 s
Power Density (m^2 s)
3.00E-02
2.50E-02
2.00E-02
1.50E-02
1.00E-02
5.00E-03
0.00E+00
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1.80
2.00
Frequency (Hz)

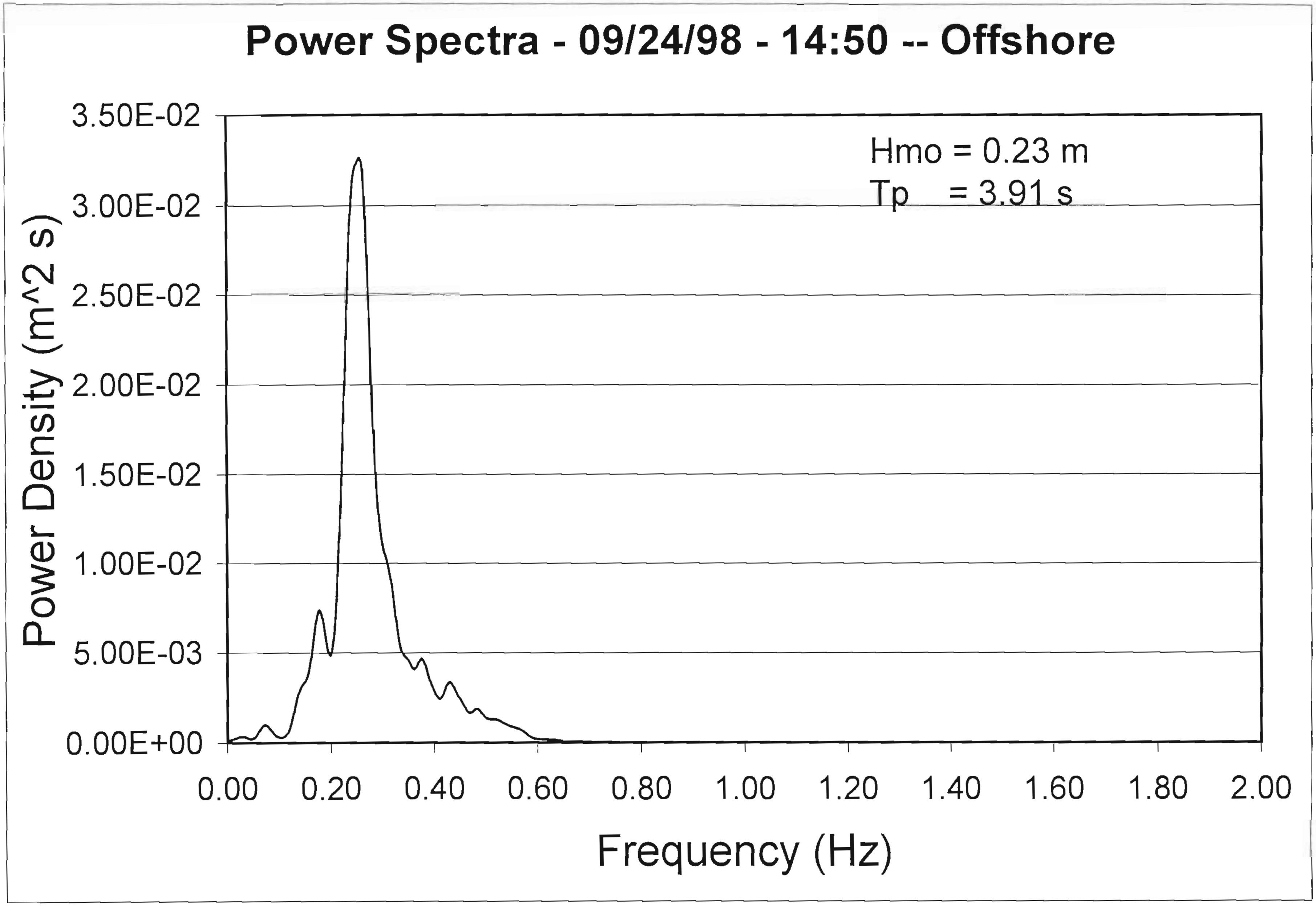


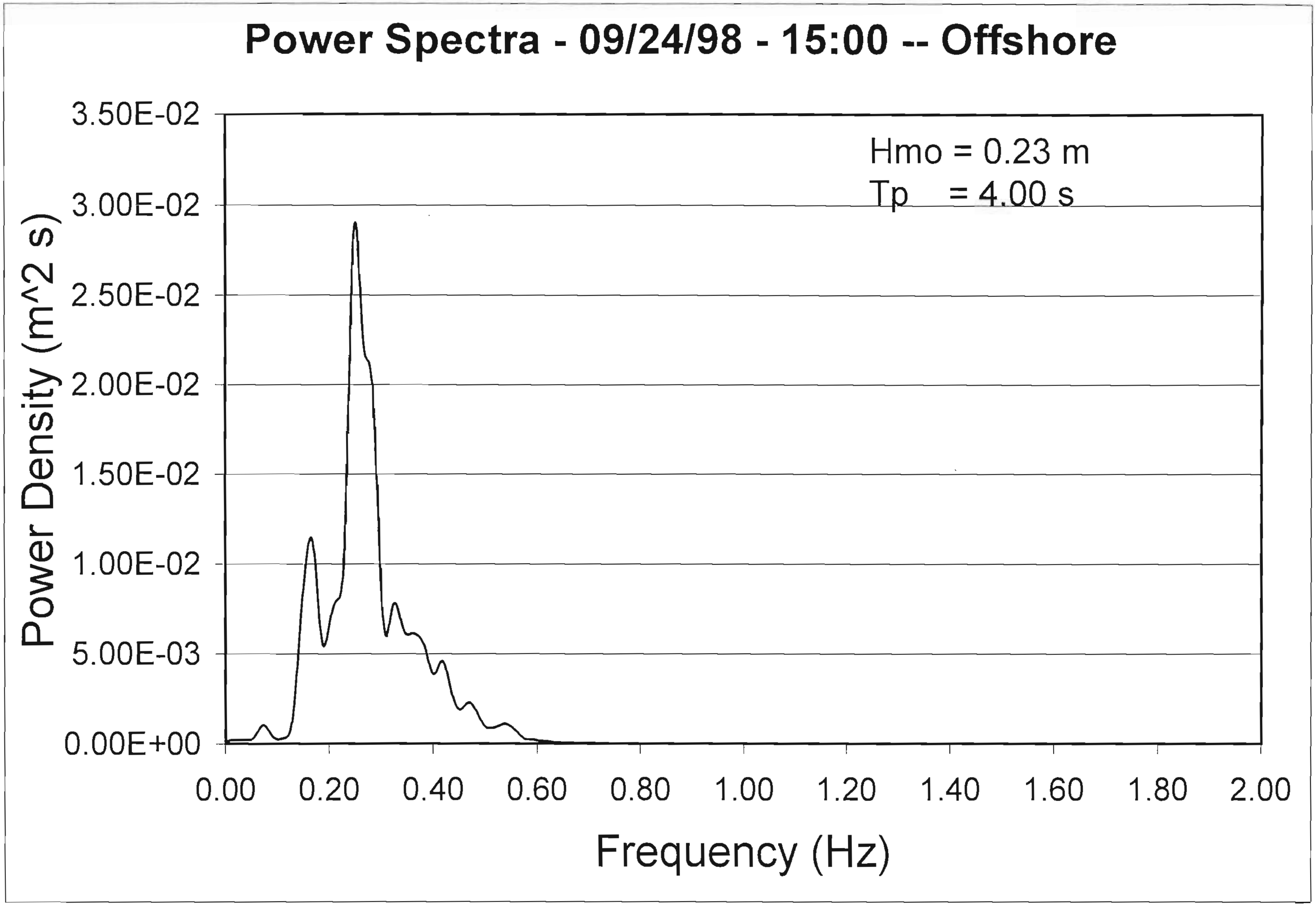
Power Spectra - 09/24/98 - 14:20 -- Offshore
Hmo = 0.23 m
Tp = 4.03 s
Power Density (m^2 s)
3.50E-02
3.00E-02
2.50E-02
2.00E-02
1.50E-02
1.00E-02
5.00E-03
0.00E+00
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1.80
2.00
Frequency (Hz)

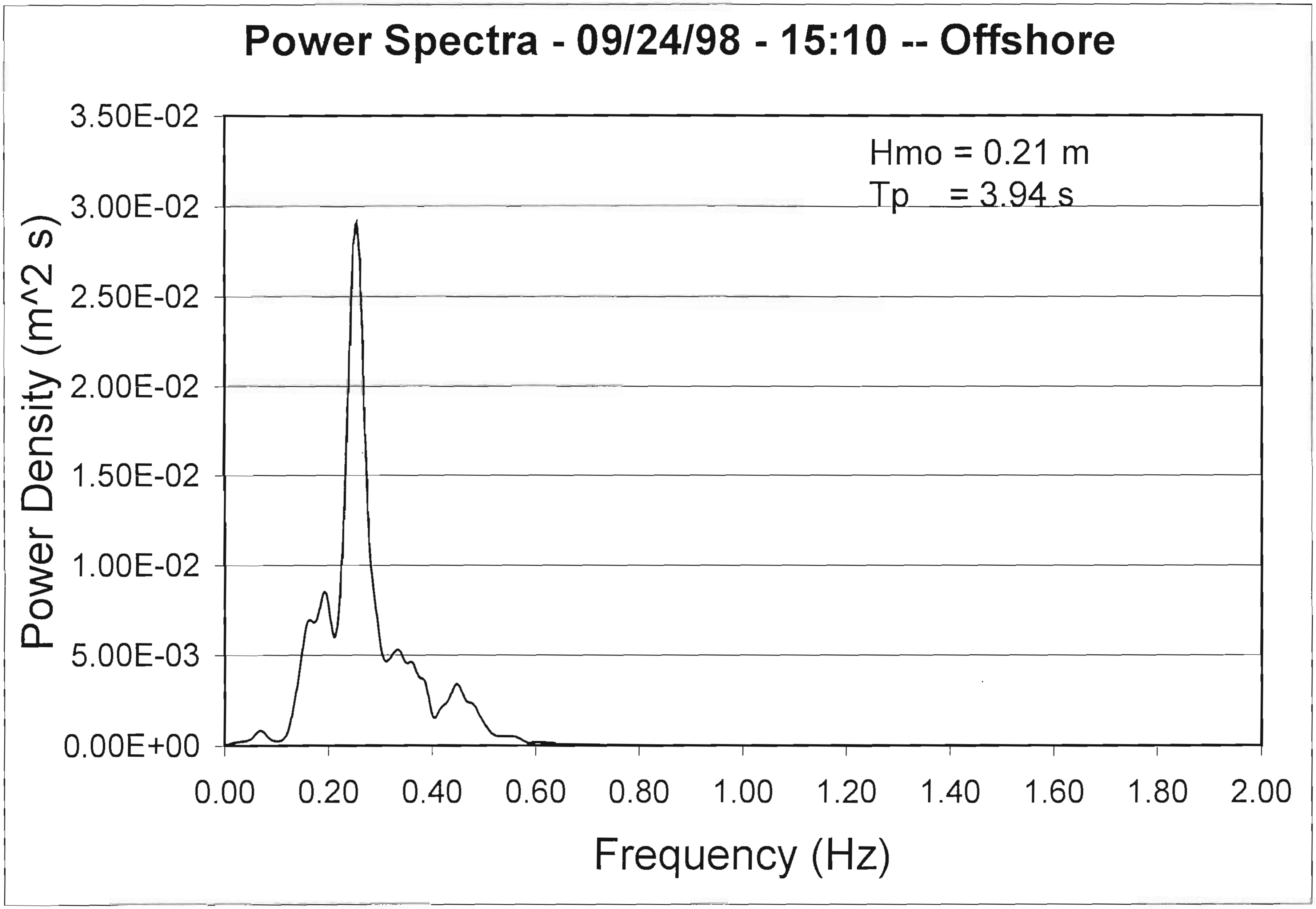


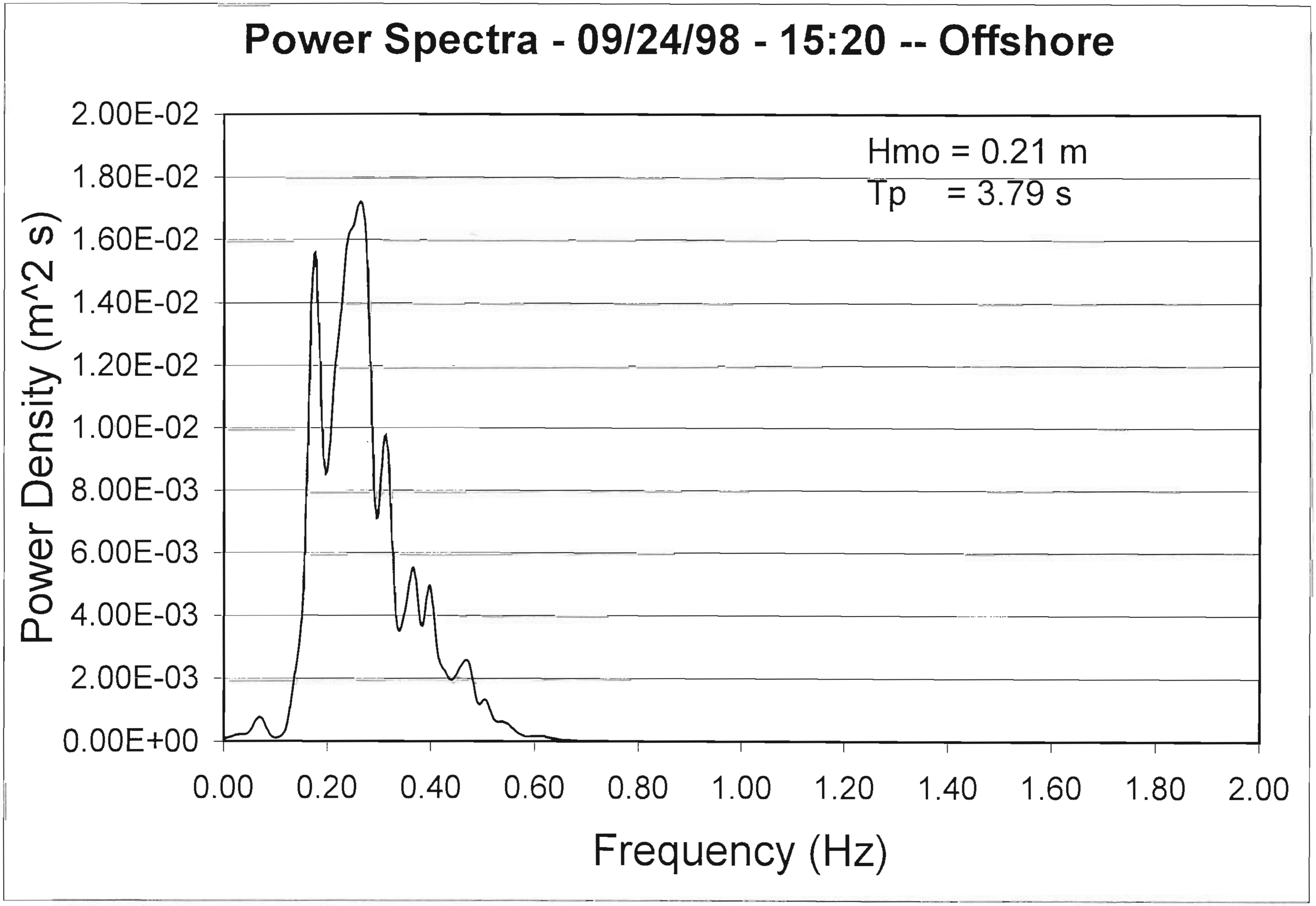
Power Spectra - 09/24/98 - 14:30 -- Offshore
Hmo = 0.23 m
Tp = 4.10 s
Power Density (m^2 s)
4.00E-02
3.50E-02
3.00E-02
2.50E-02
2.00E-02
1.50E-02
1.00E-02
5.00E-03
0.00E+00
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1.80
2.00
Frequency (Hz)

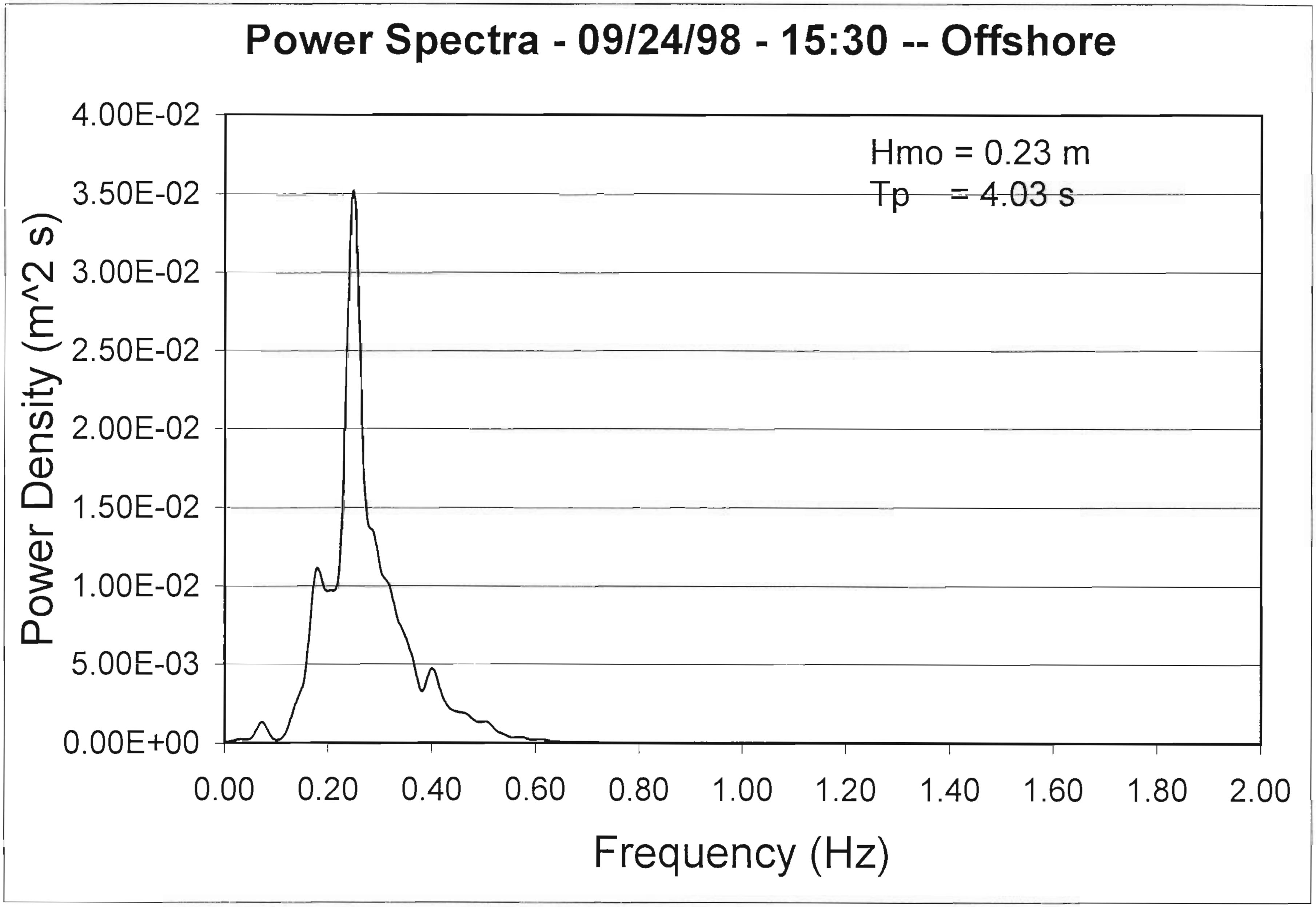

Power Spectra - 09/24/98 - 14:40 -- Offshore
Hmo = 0.23 m
Tp = 3.82 s
Power Density (m^2 s)
3.50E-02
3.00E-02
2.50E-02
2.00E-02
1.50E-02
1.00E-02
5.00E-03
0.00E+00
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1.80
2.00
Frequency (Hz)


Power Spectra - 09/24/98 - 14:50 -- Offshore
Hmo = 0.23 m
Tp = 3.91 s
Power Density (m^2 s)
3.50E-02
3.00E-02
2.50E-02
2.00E-02
1.50E-02
1.00E-02
5.00E-03
0.00E+00
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1.80
2.00
Frequency (Hz)

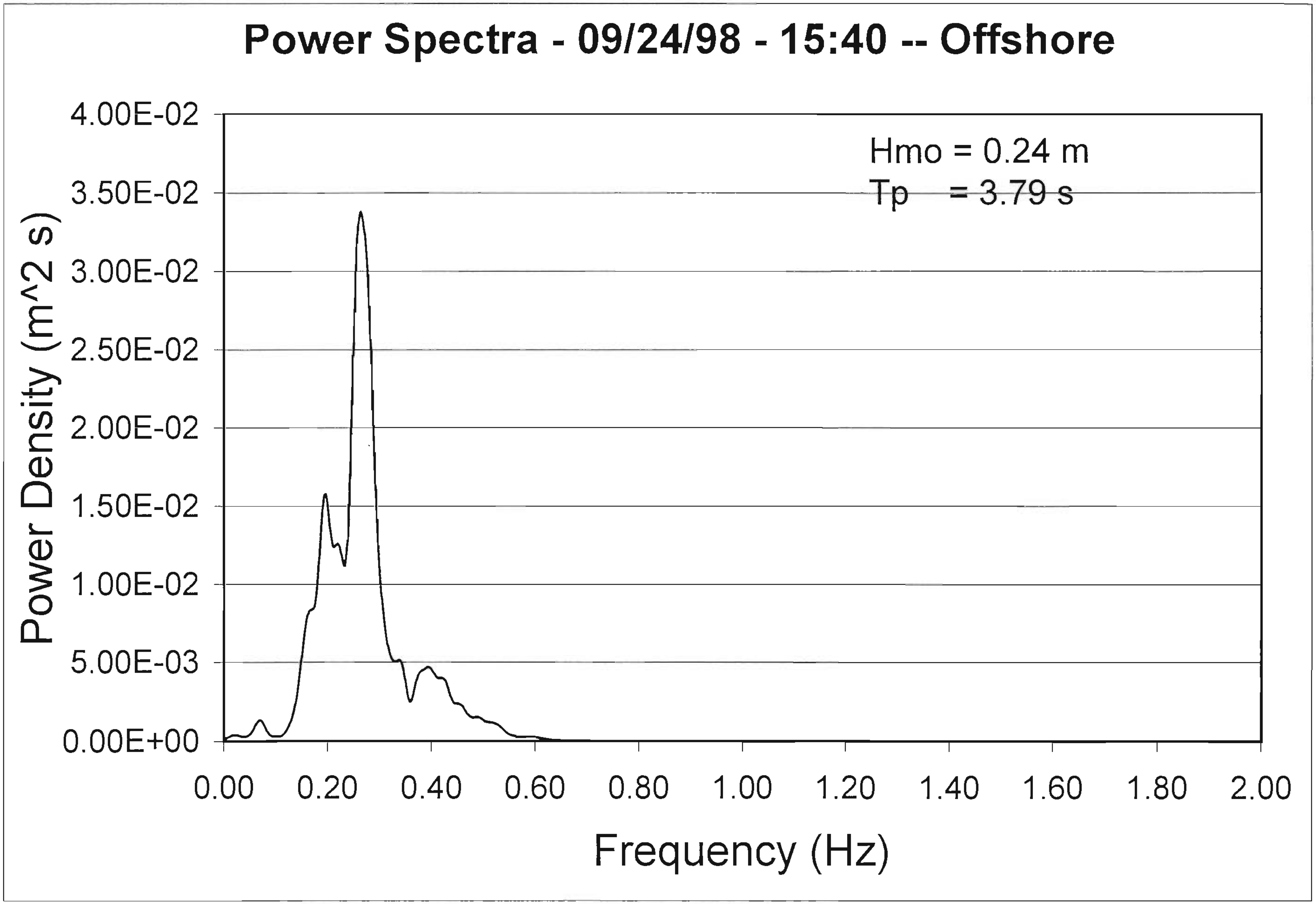

Power Spectra - 09/24/98 - 15:00 -- Offshore
Hmo = 0.23 m
Tp = 4.00 s
Power Density (m^2 s)
3.50E-02
3.00E-02
2.50E-02
2.00E-02
1.50E-02
1.00E-02
5.00E-03
0.00E+00
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1.80
2.00
Frequency (Hz)

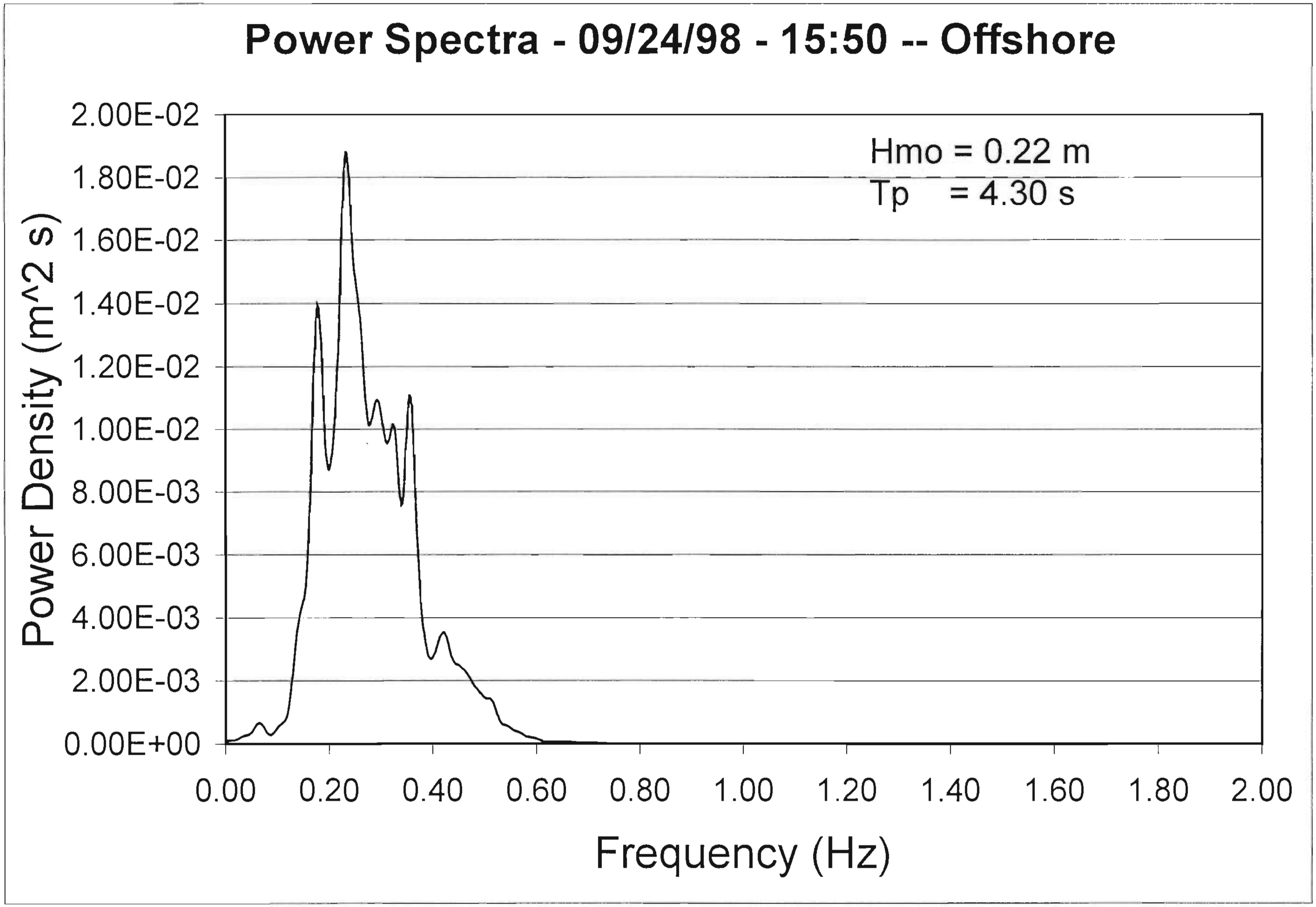

Power Spectra - 09/24/98 - 15:10 -- Offshore
Hmo = 0.21 m
Tp = 3.94 s
3.50E-02
3.00E-02
2.50E-02
2.00E-02
1.50E-02
1.00E-02
5.00E-03
0.00E+00
Power Density (m^2 s)
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1.80
2.00
Frequency (Hz)

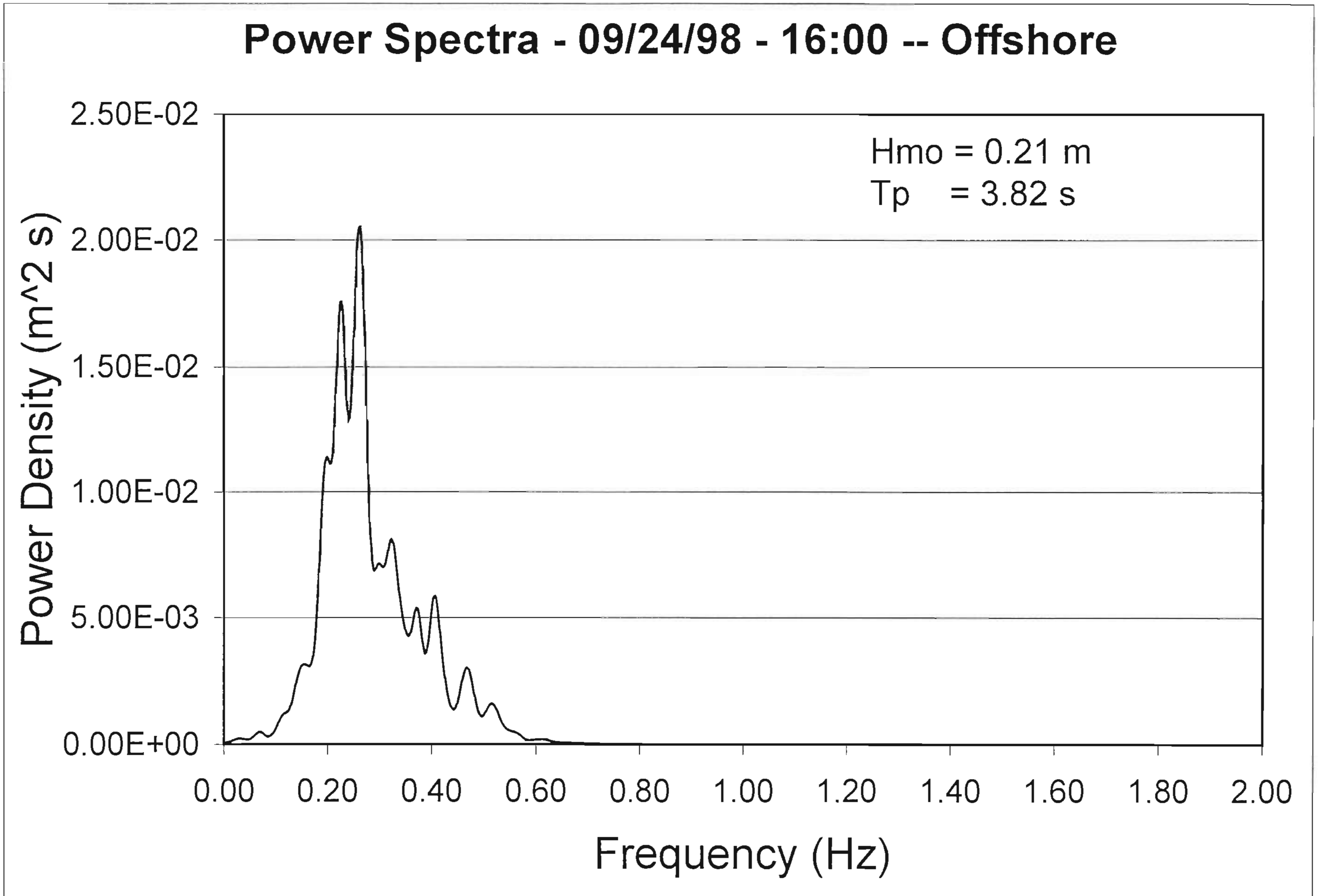

Power Spectra - 09/24/98 - 15:20 -- Offshore
Hmo = 0.21 m
Tp = 3.79 s
Power Density (m^2 s)
2.00E-02
1.80E-02
1.60E-02
1.40E-02
1.20E-02
1.00E-02
8.00E-03
6.00E-03
4.00E-03
2.00E-03
0.00E+00
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1.80
2.00
Frequency (Hz)

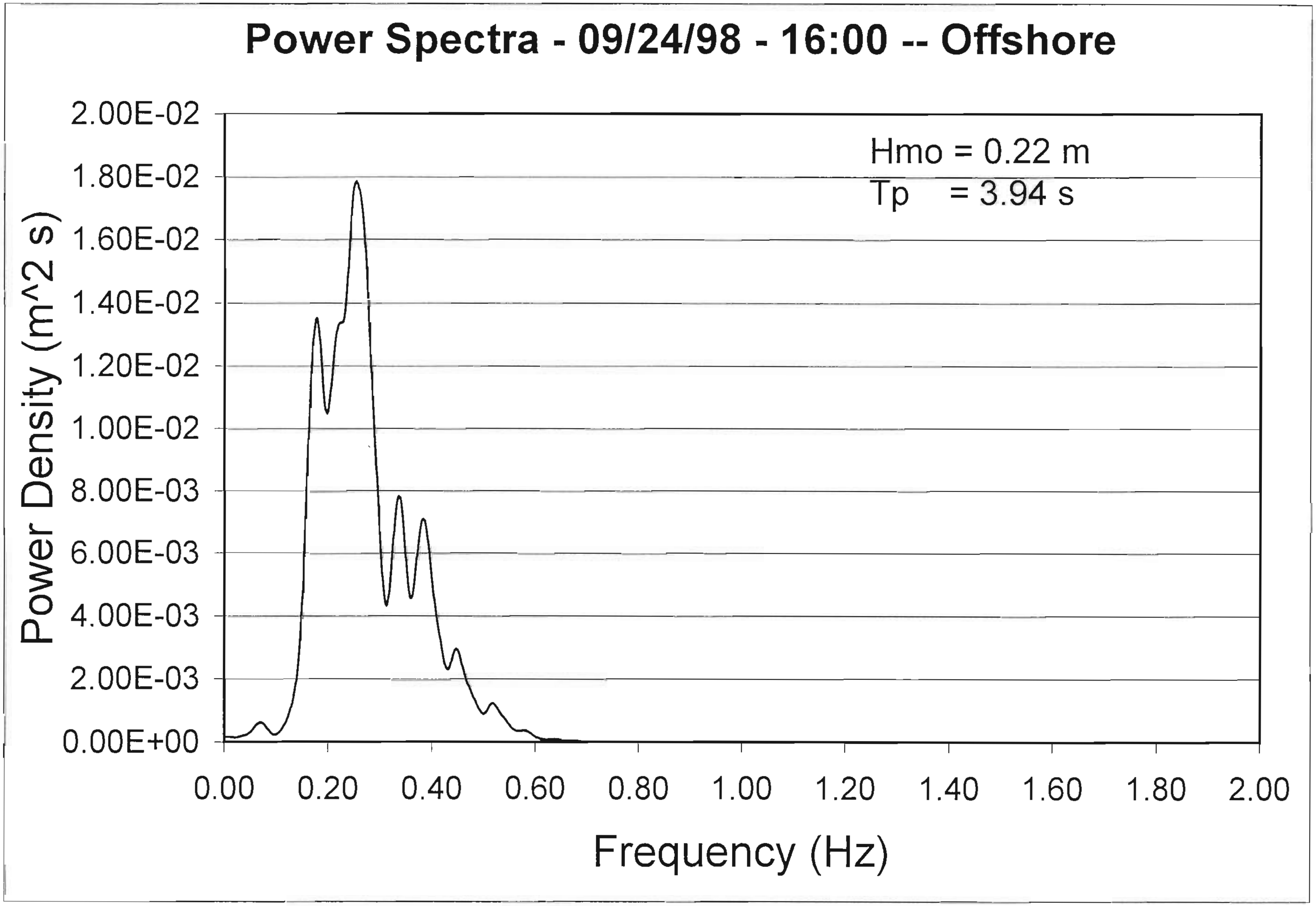


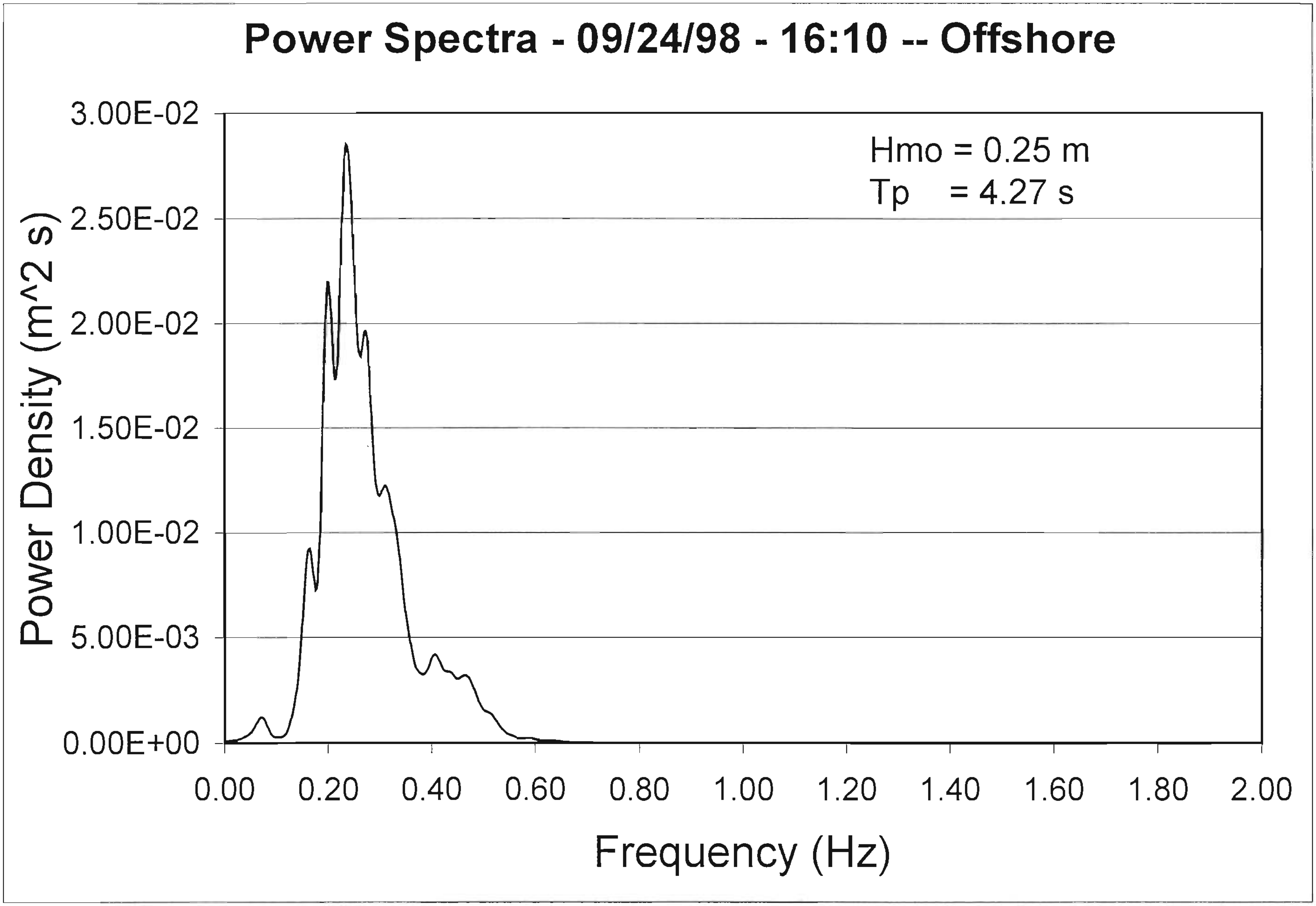
Power Spectra - 09/24/98 - 15:30 -- Offshore
Hmo = 0.23 m
Tp = 4.03 s
Power Density (m^2 s)
4.00E-02
3.50E-02
3.00E-02
2.50E-02
2.00E-02
1.50E-02
1.00E-02
5.00E-03
0.00E+00
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1.80
2.00
Frequency (Hz)

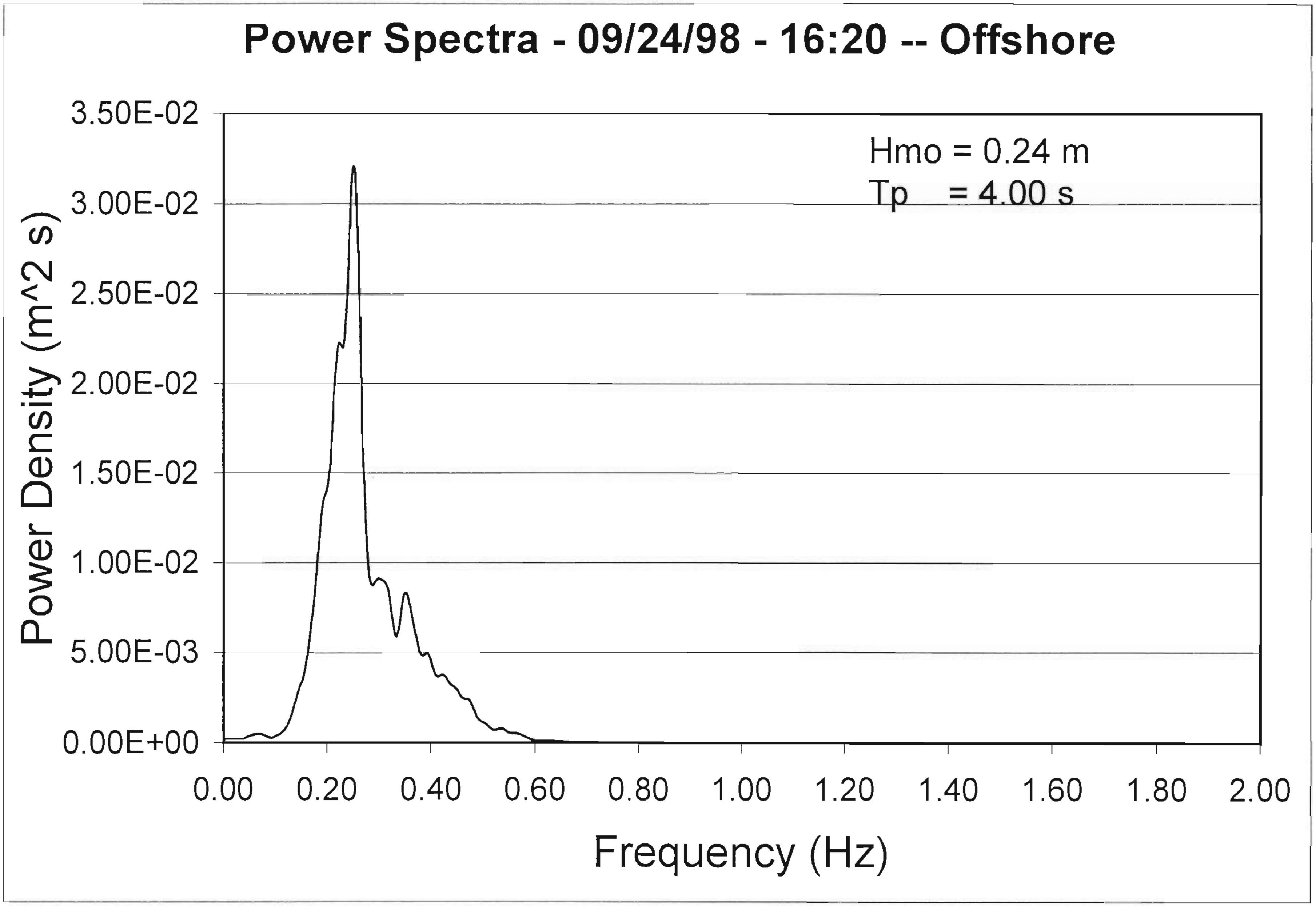

Power Spectra - 09/24/98 - 15:40 -- Offshore
Hmo = 0.24 m
Tp = 3.79 s
Power Density (m^2 s)
4.00E-02
3.50E-02
3.00E-02
2.50E-02
2.00E-02
1.50E-02
1.00E-02
5.00E-03
0.00E+00
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1.80
2.00
Frequency (Hz)

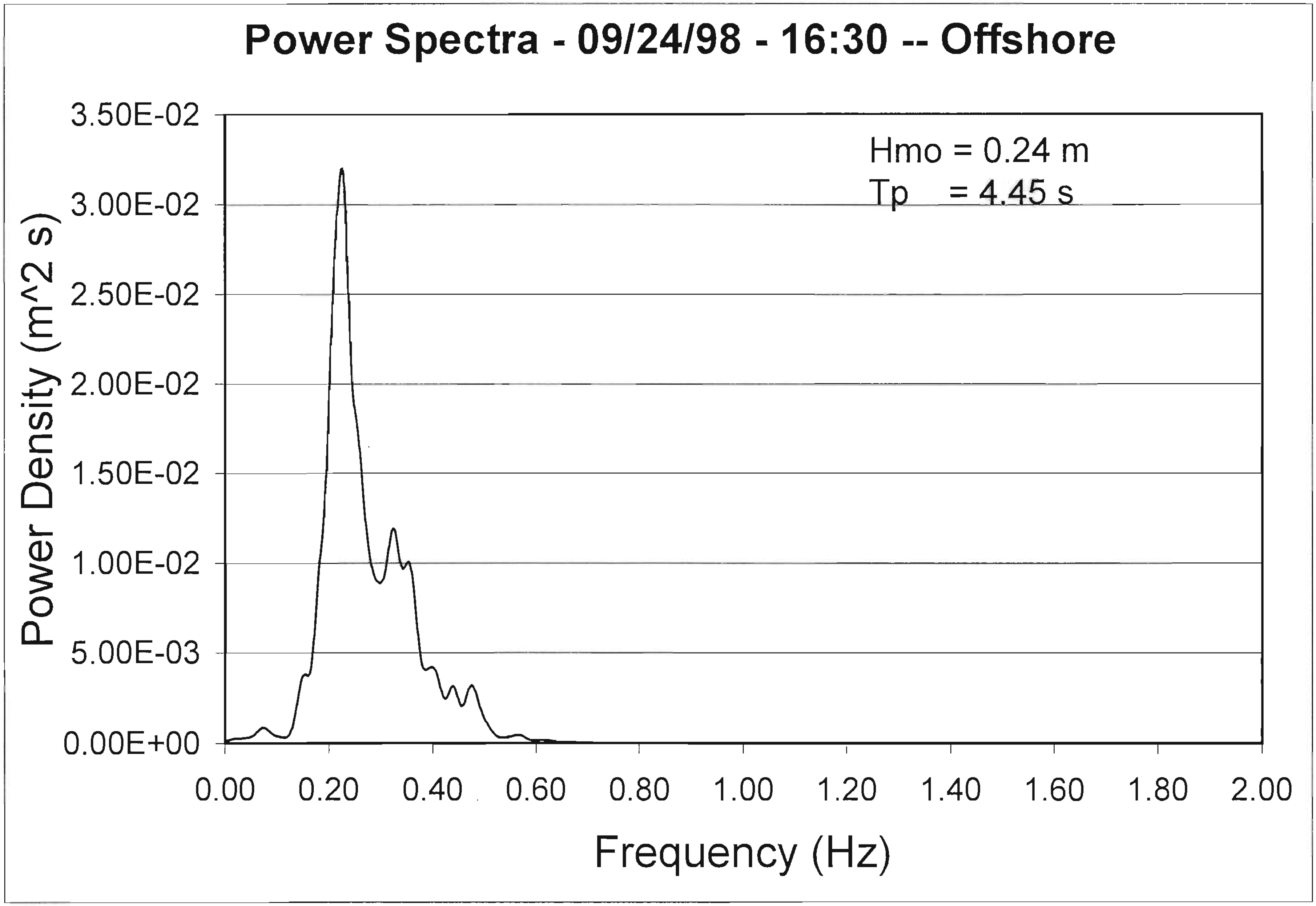

Power Spectra - 09/24/98 - 15:50 -- Offshore
Hmo = 0.22 m
Tp = 4.30 s
Power Density (m^2 s)
2.00E-02
1.80E-02
1.60E-02
1.40E-02
1.20E-02
1.00E-02
8.00E-03
6.00E-03
4.00E-03
2.00E-03
0.00E+00
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1.80
2.00
Frequency (Hz)

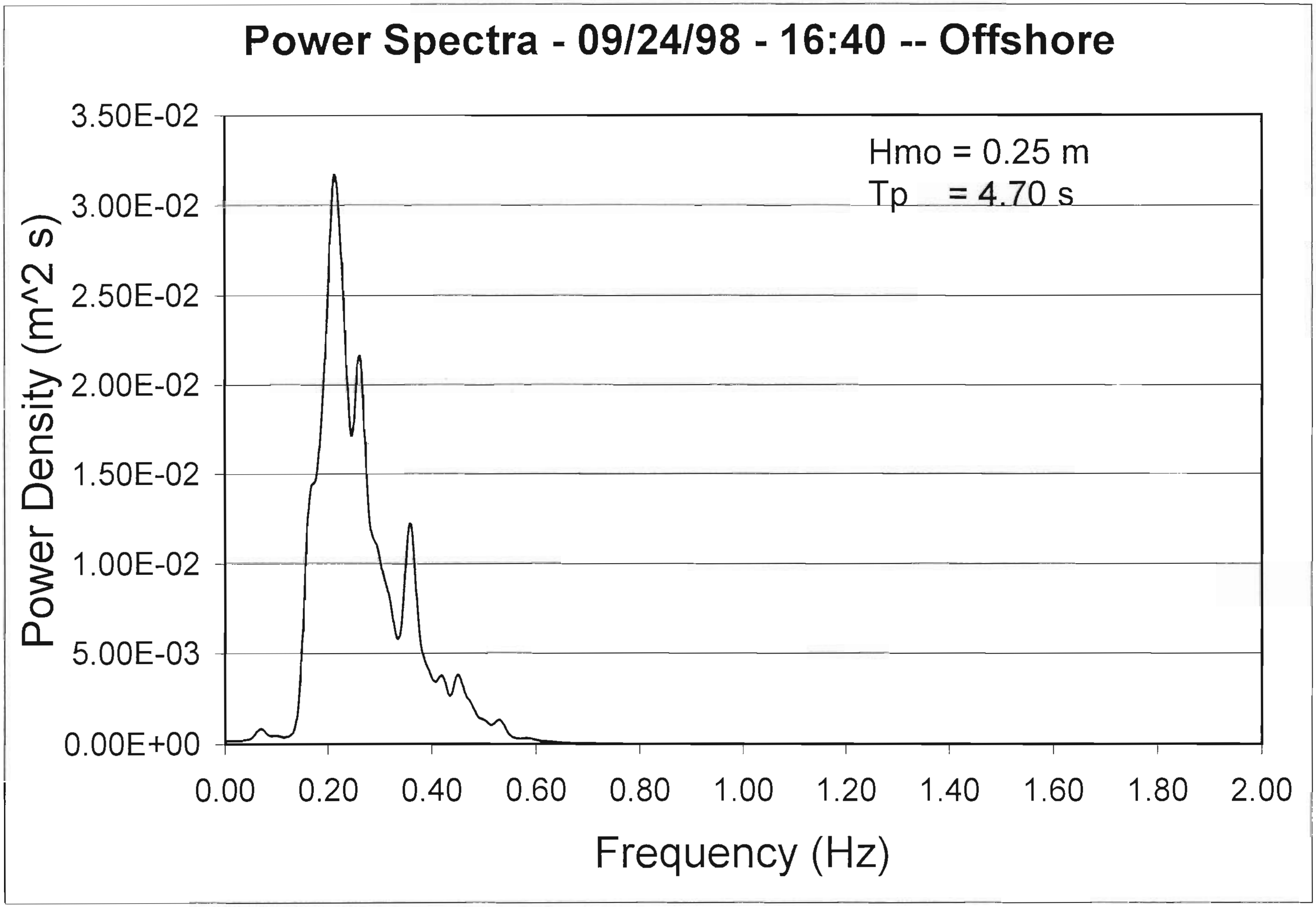

Power Spectra - 09/24/98 - 16:00 -- Offshore
Hmo = 0.21 m
Tp = 3.82 s
Power Density (m^2 s)
2.50E-02
2.00E-02
1.50E-02
1.00E-02
5.00E-03
0.00E+00
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1.80
2.00
Frequency (Hz)


Power Spectra - 09/24/98 - 16:00 -- Offshore
Hmo = 0.22 m
Tp = 3.94 s
Power Density (m^2 s)
2.00E-02
1.80E-02
1.60E-02
1.40E-02
1.20E-02
1.00E-02
8.00E-03
6.00E-03
4.00E-03
2.00E-03
0.00E+00
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1.80
2.00
Frequency (Hz)

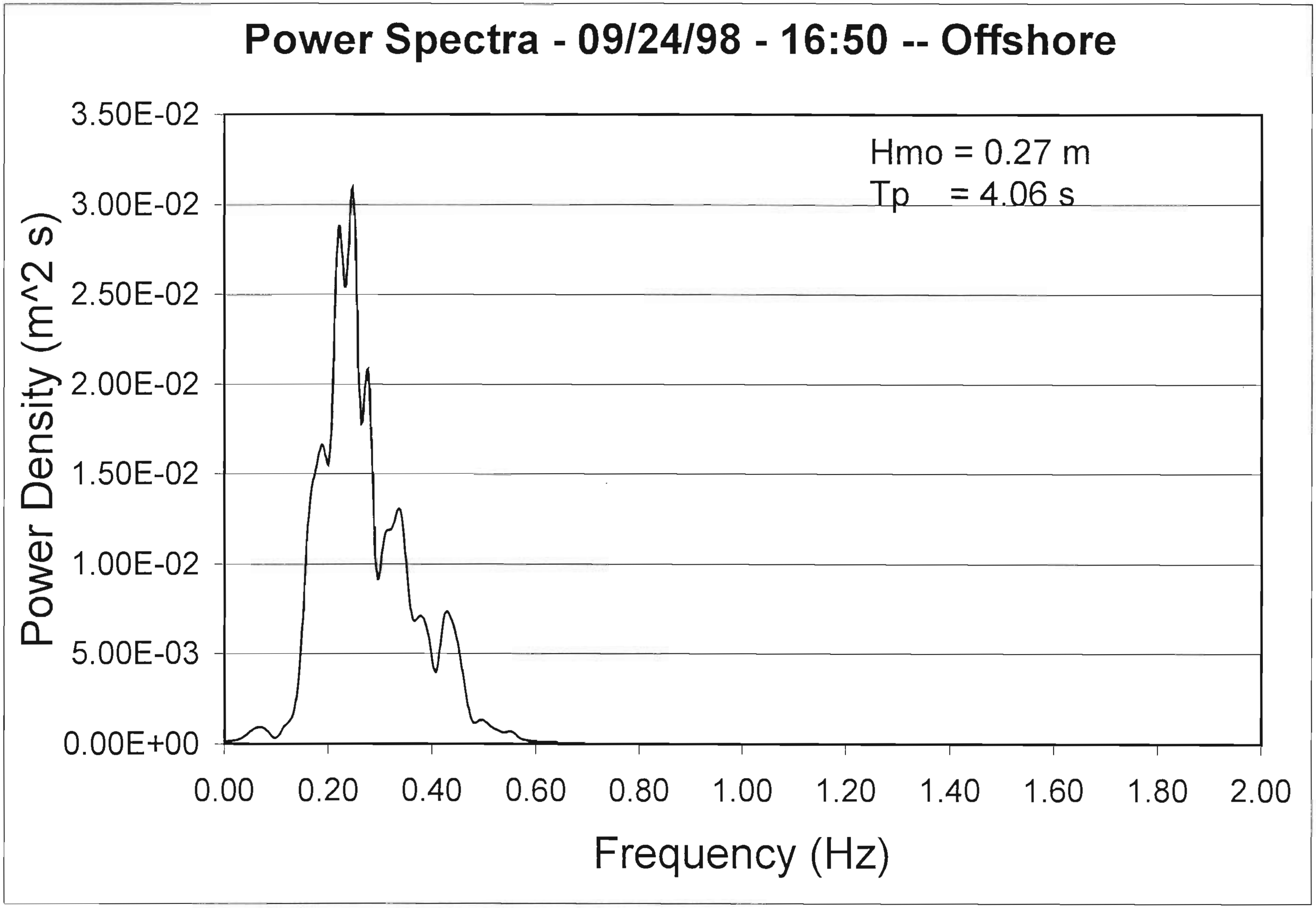

Power Spectra - 09/24/98 - 16:10 -- Offshore
Hmo = 0.25 m
Tp = 4.27 s
3.00E-02
2.50E-02
2.00E-02
1.50E-02
1.00E-02
5.00E-03
0.00E+00
Power Density (m^2 s)
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1.80
2.00
Frequency (Hz)

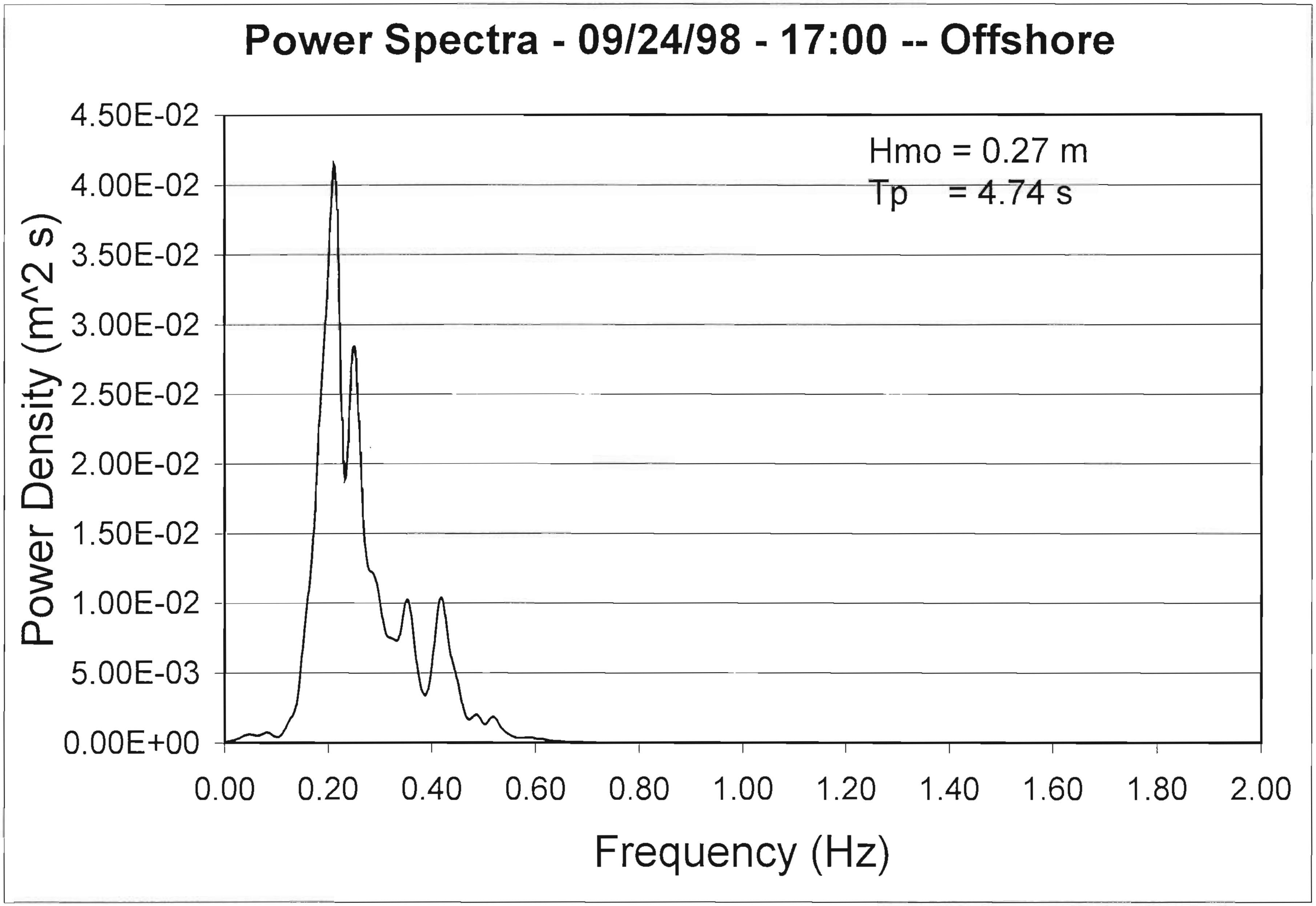

Power Spectra - 09/24/98 - 16:20 -- Offshore
Hmo = 0.24 m
Tp = 4.00 s
Power Density (m^2 s)
3.50E-02
3.00E-02
2.50E-02
2.00E-02
1.50E-02
1.00E-02
5.00E-03
0.00E+00
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1.80
2.00
Frequency (Hz)

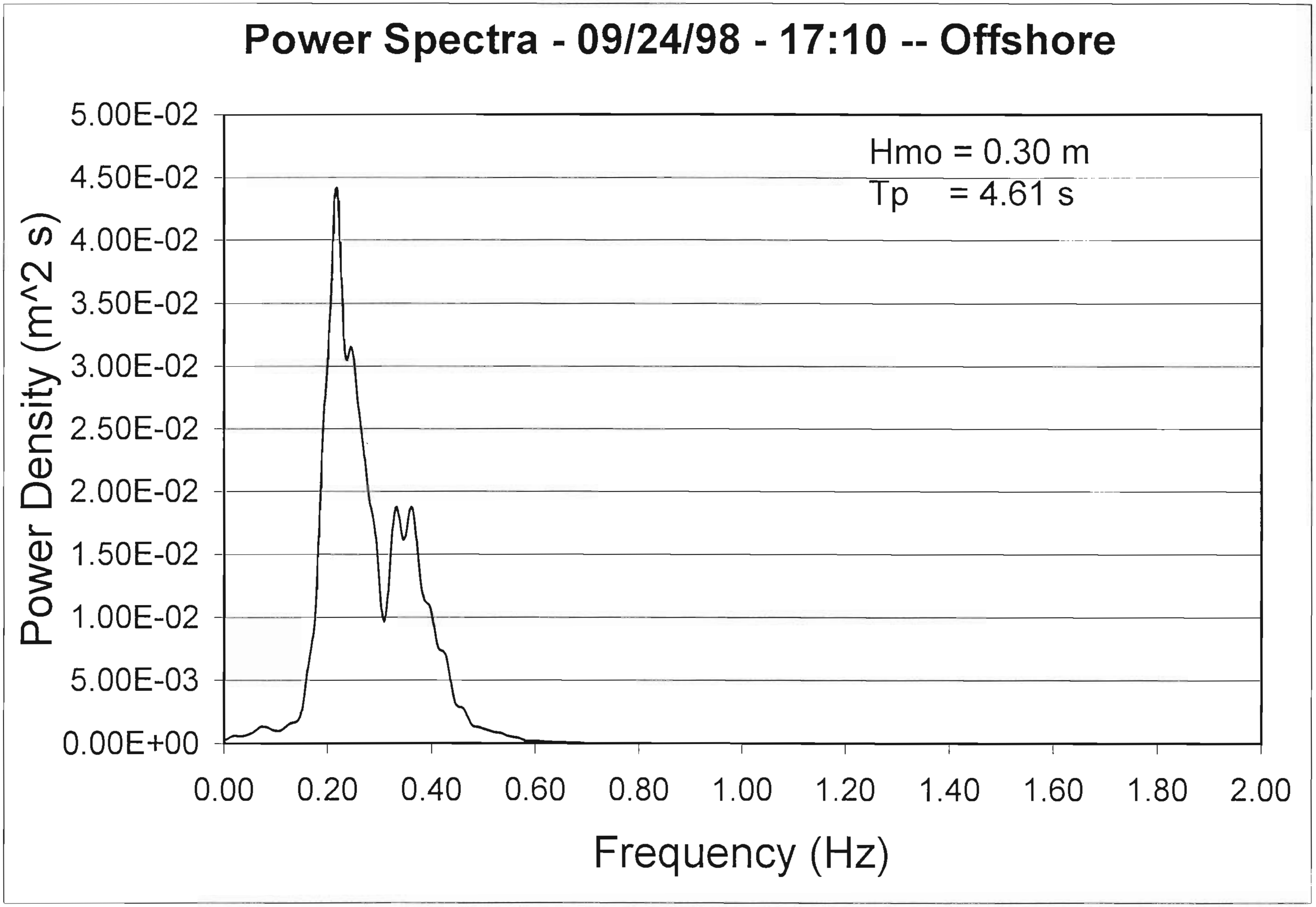

Power Spectra - 09/24/98 - 16:30 -- Offshore
Hmo = 0.24 m
Tp = 4.45 s
3.50E-02
3.00E-02
2.50E-02
2.00E-02
1.50E-02
1.00E-02
5.00E-03
0.00E+00
Power Density (m^2 s)
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1.80
2.00
Frequency (Hz)

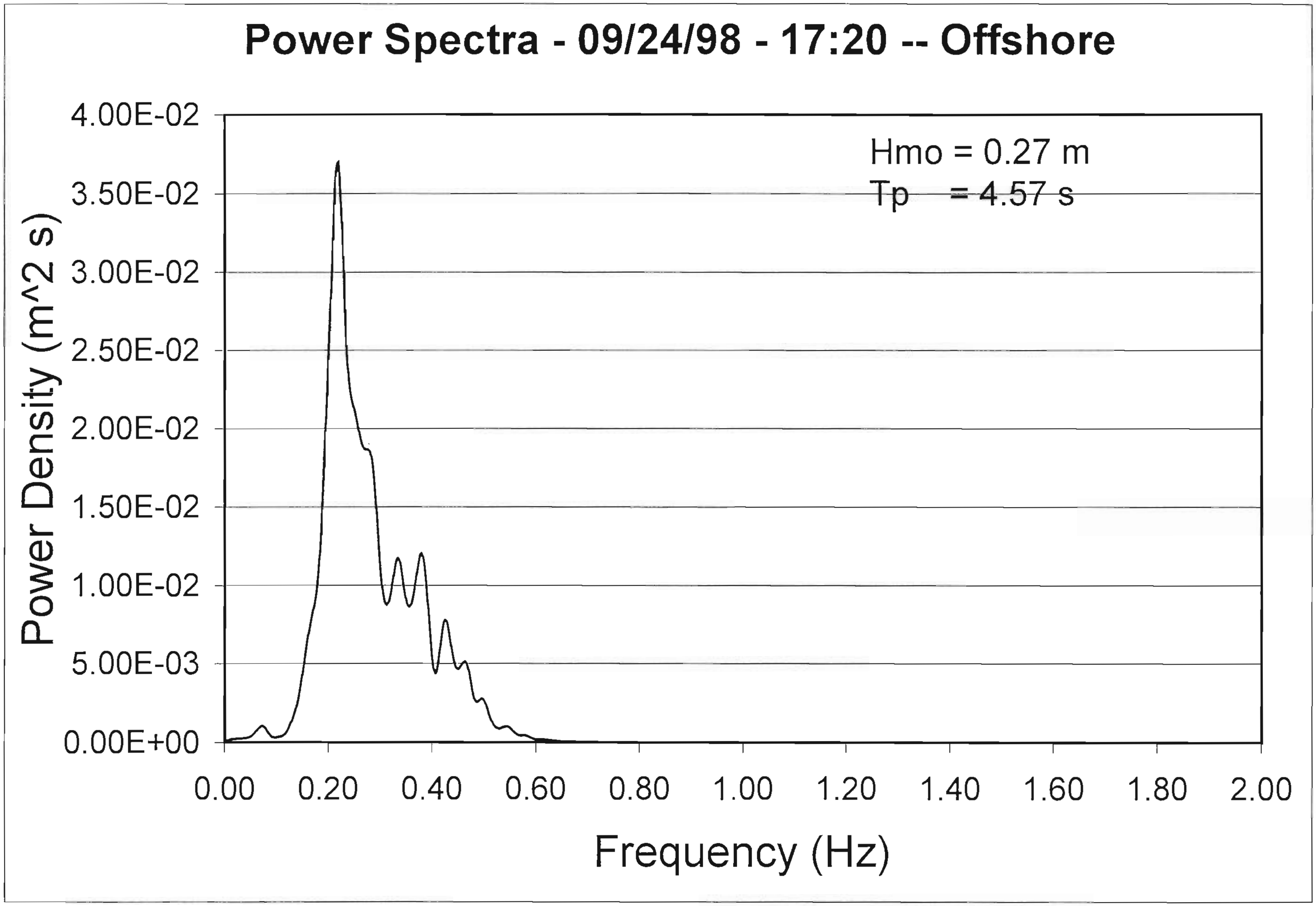


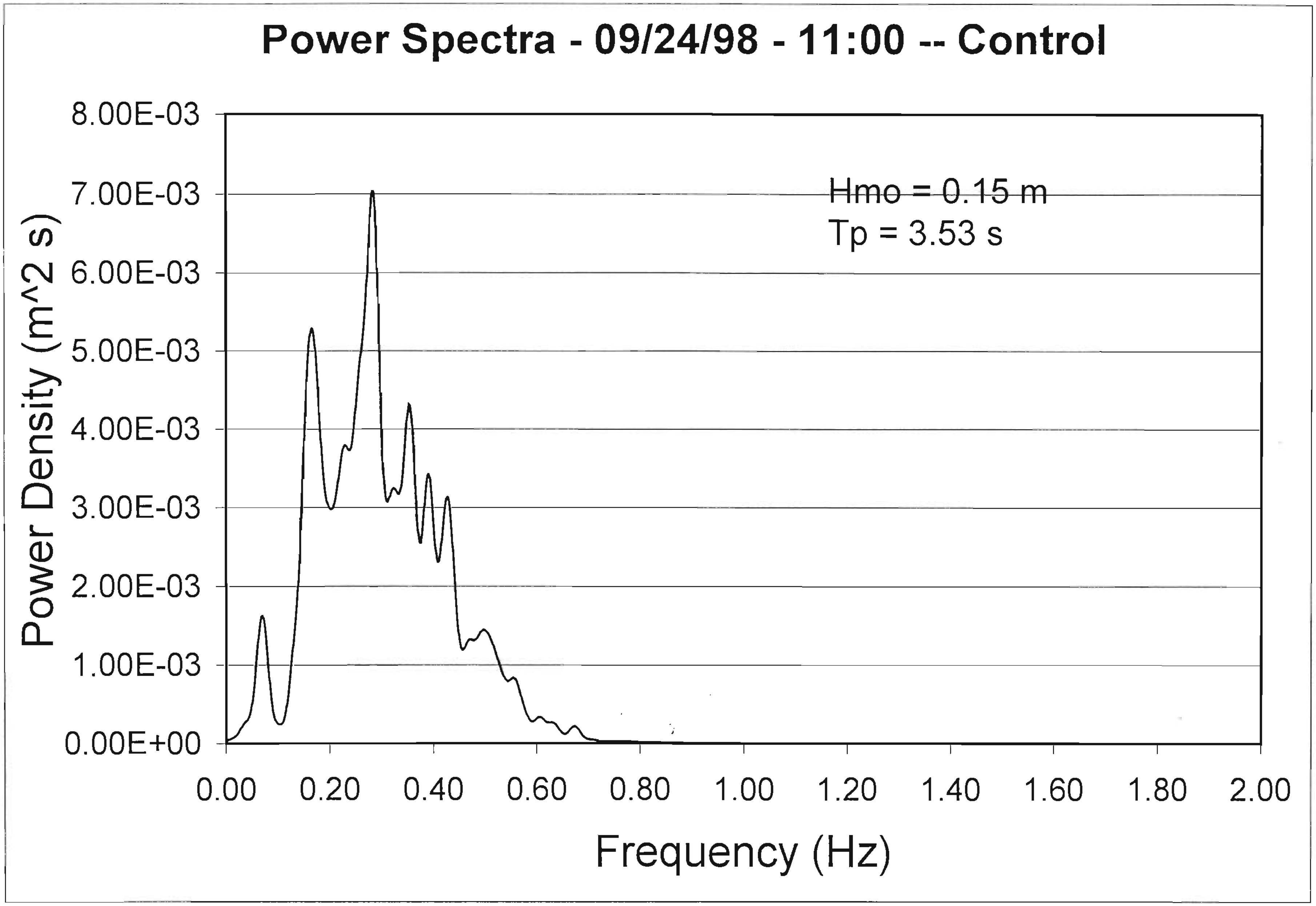
Power Spectra - 09/24/98 - 16:40 -- Offshore
Hmo = 0.25 m
Tp = 4.70 s
Power Density (m^2 s)
3.50E-02
3.00E-02
2.50E-02
2.00E-02
1.50E-02
1.00E-02
5.00E-03
0.00E+00
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1.80
2.00
Frequency (Hz)

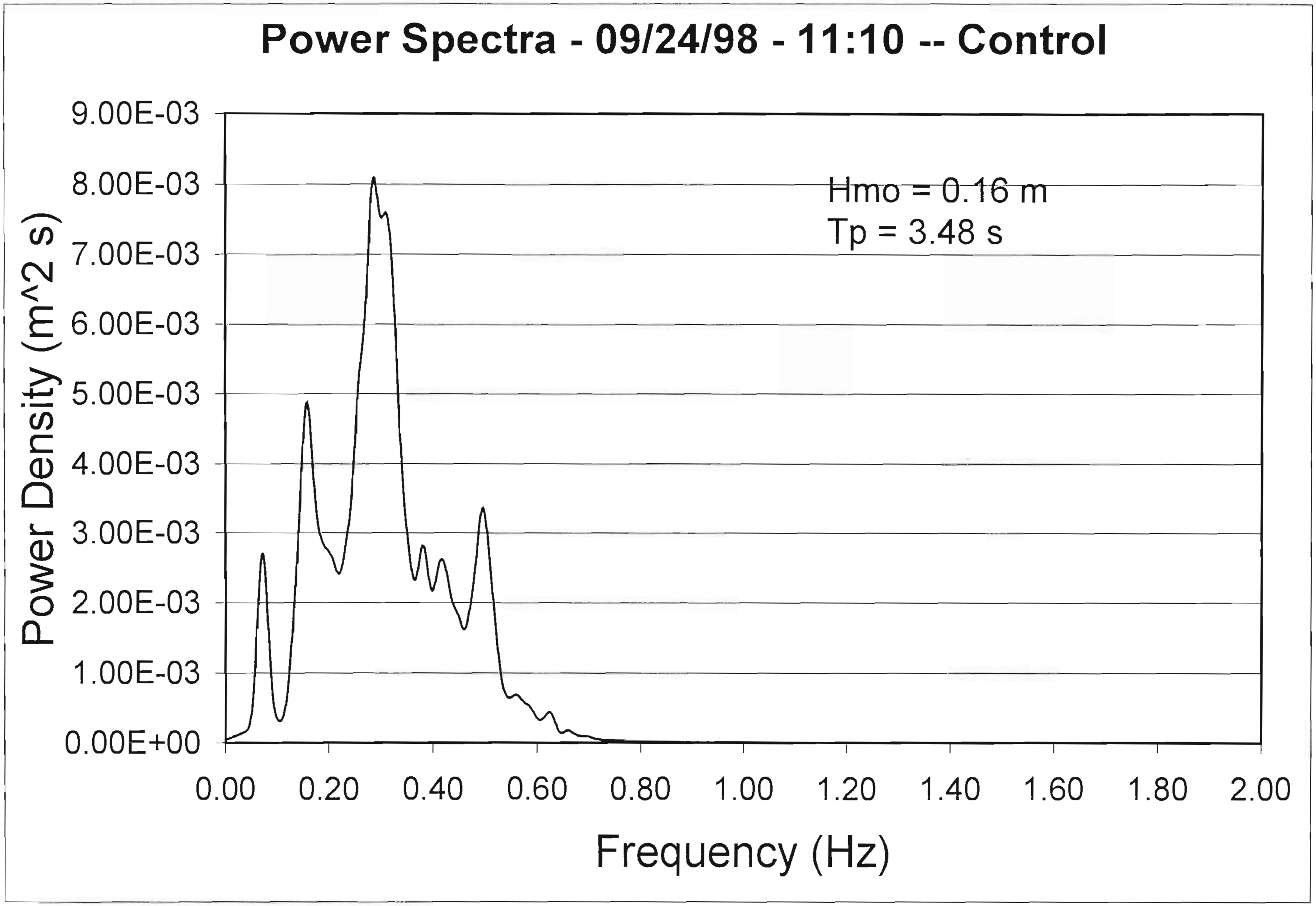

Power Spectra - 09/24/98 - 16:50 -- Offshore
Hmo = 0.27 m
Tp = 4.06 s
3.50E-02
3.00E-02
2.50E-02
2.00E-02
1.50E-02
1.00E-02
5.00E-03
0.00E+00
Power Density (m^2 s)
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1.80
2.00
Frequency (Hz)


Power Spectra - 09/24/98 - 17:00 -- Offshore
Hmo = 0.27 m
Tp = 4.74 s
Power Density (m^2 s)
4.50E-02
4.00E-02
3.50E-02
3.00E-02
2.50E-02
2.00E-02
1.50E-02
1.00E-02
5.00E-03
0.00E+00
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1.80
2.00
Frequency (Hz)

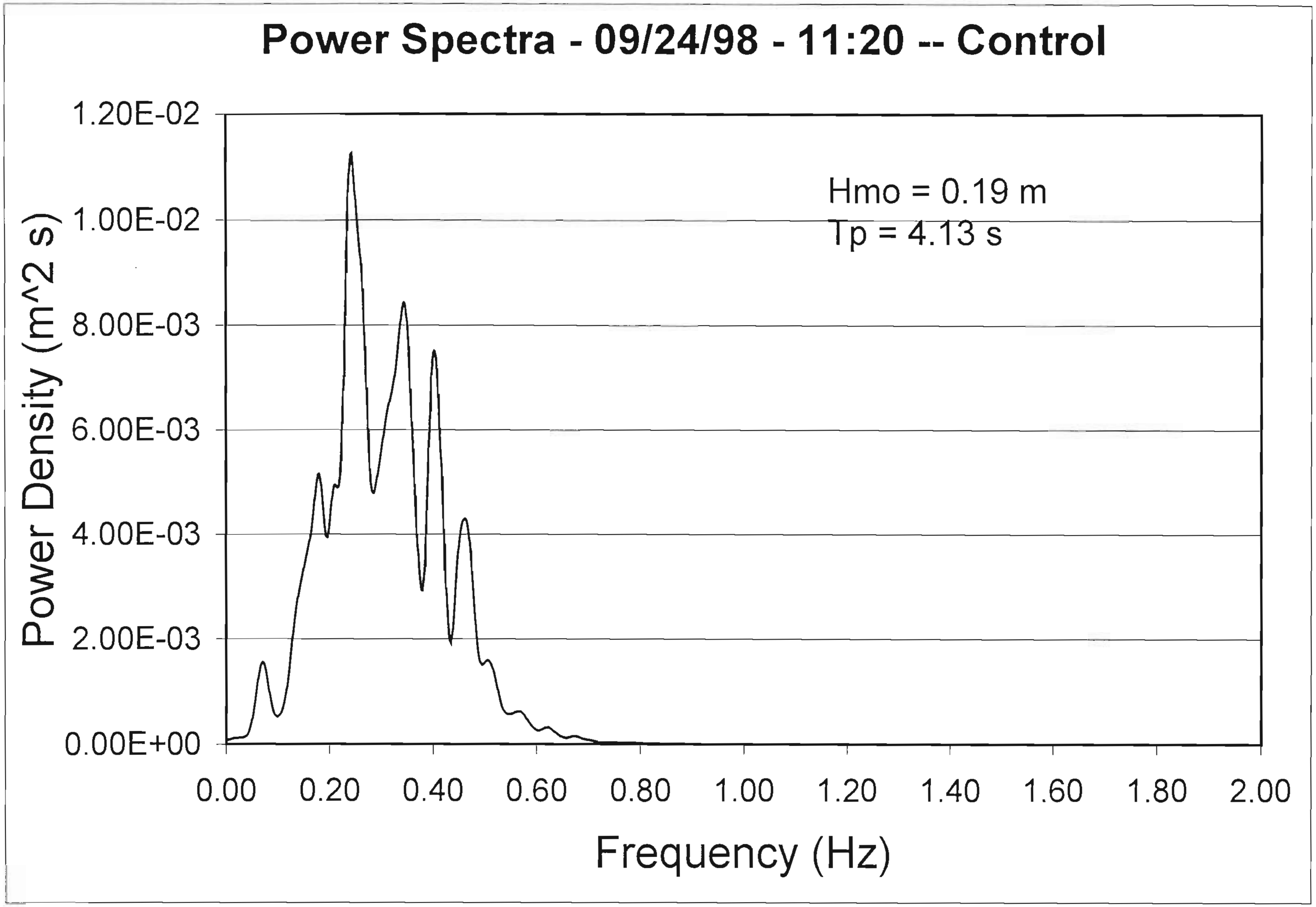

Power Spectra - 09/24/98 - 17:10 -- Offshore
Hmo = 0.30 m
Tp = 4.61 s
Power Density (m^2 s)
5.00E-02
4.50E-02
4.00E-02
3.50E-02
3.00E-02
2.50E-02
2.00E-02
1.50E-02
1.00E-02
5.00E-03
0.00E+00
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1.80
2.00
Frequency (Hz)

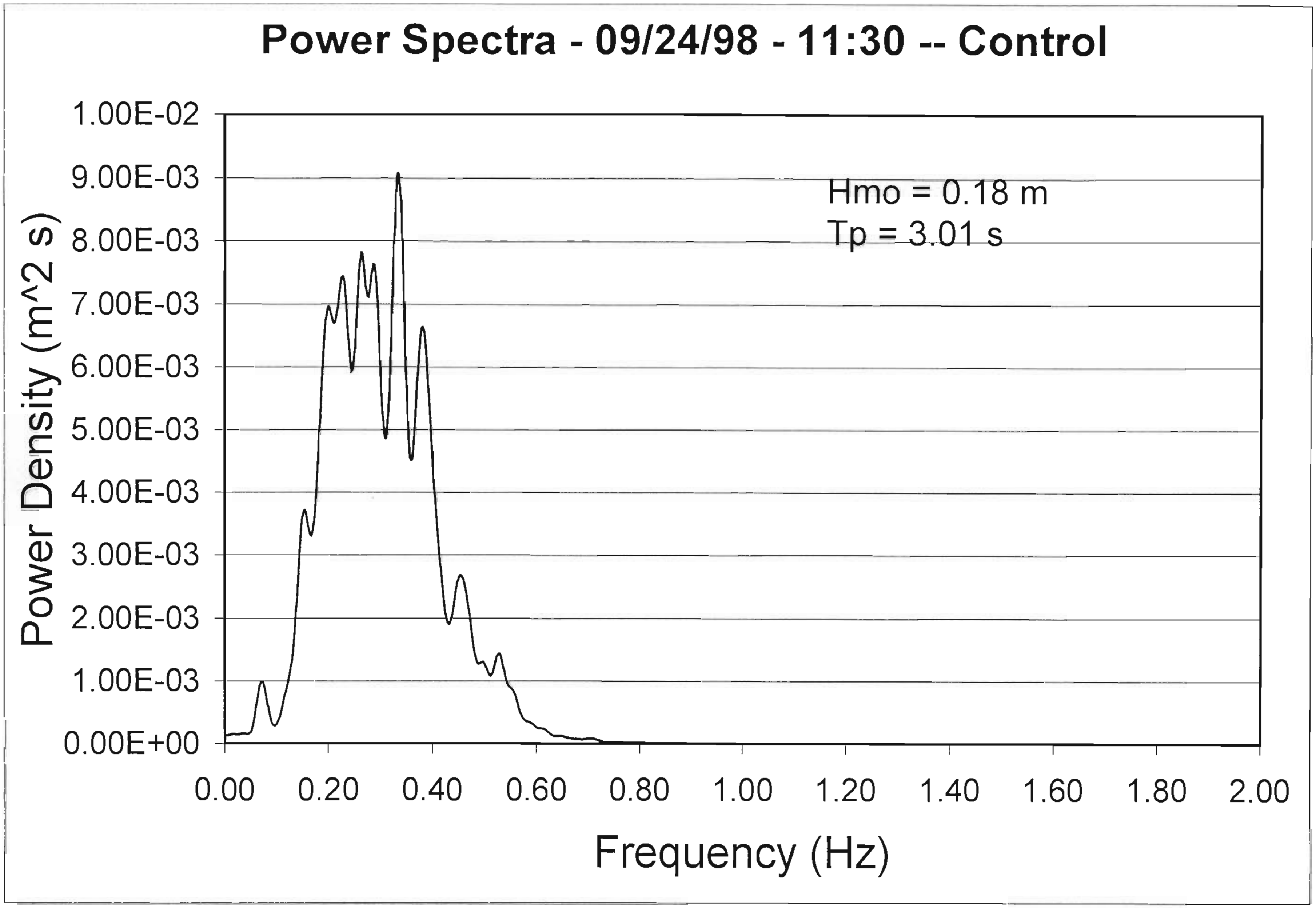

Power Spectra - 09/24/98 - 17:20 -- Offshore
Hmo = 0.27 m
Tp = 4.57 s
Power Density (m^2 s)
4.00E-02
3.50E-02
3.00E-02
2.50E-02
2.00E-02
1.50E-02
1.00E-02
5.00E-03
0.00E+00
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1.80
2.00
Frequency (Hz)


Power Spectra - 09/24/98 - 11:00 -- Control
Hmo = 0.15 m
Tp = 3.53 s
Power Density (m^2 s)
8.00E-03
7.00E-03
6.00E-03
5.00E-03
4.00E-03
3.00E-03
2.00E-03
1.00E-03
0.00E+00
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1.80
2.00
Frequency (Hz)

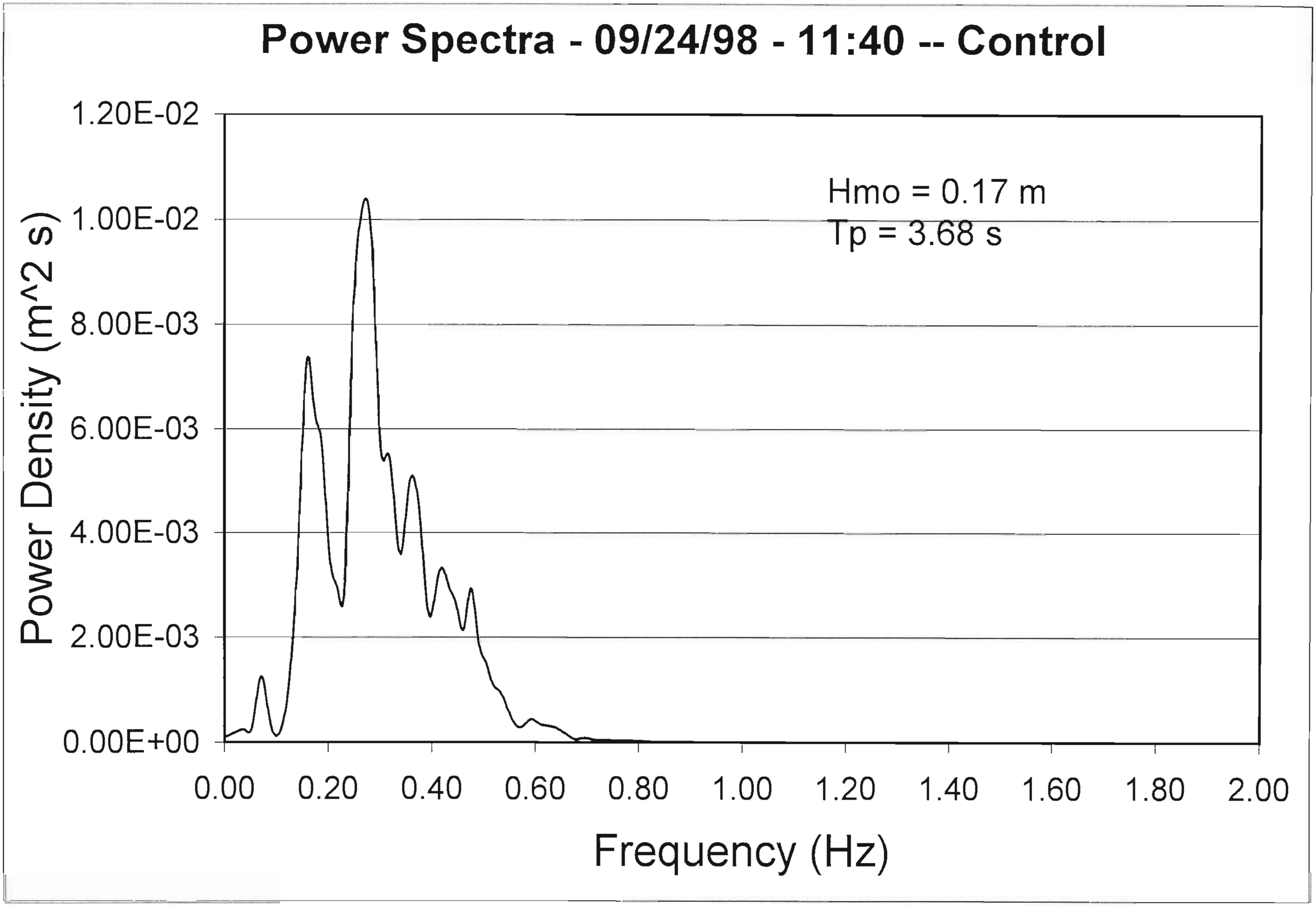


Power Spectra - 09/24/98 - 11:10 -- Control
Hmo = 0.16 m
Tp = 3.48 s
Power Density (m^2 s)
9.00E-03
8.00E-03
7.00E-03
6.00E-03
5.00E-03
4.00E-03
3.00E-03
2.00E-03
1.00E-03
0.00E+00
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1.80
2.00
Frequency (Hz)

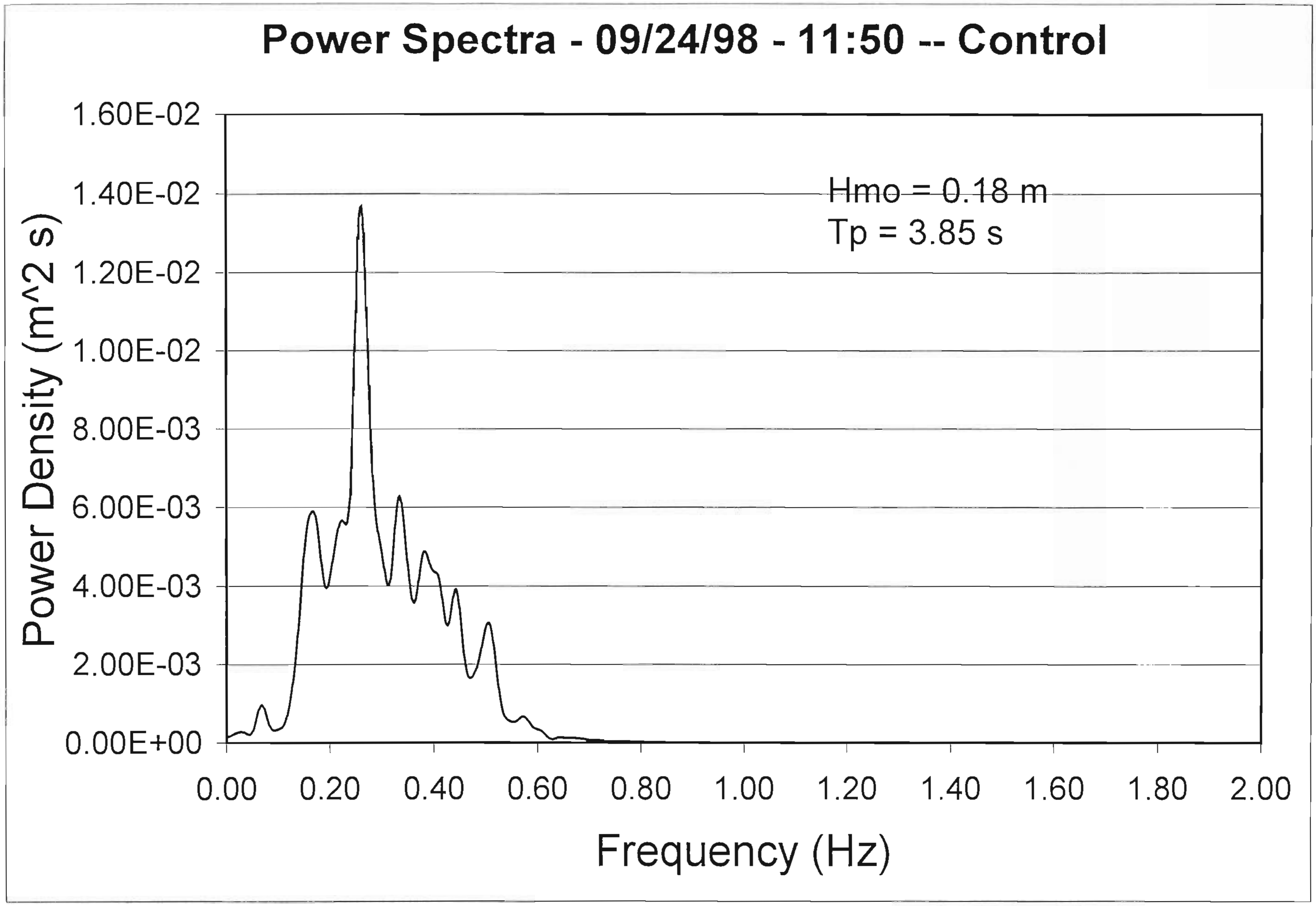

Power Spectra - 09/24/98 - 11:20 -- Control
Hmo = 0.19 m
Tp = 4.13 s
Power Density (m^2 s)
1.20E-02
1.00E-02
8.00E-03
6.00E-03
4.00E-03
2.00E-03
0.00E+00
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1.80
2.00
Frequency (Hz)

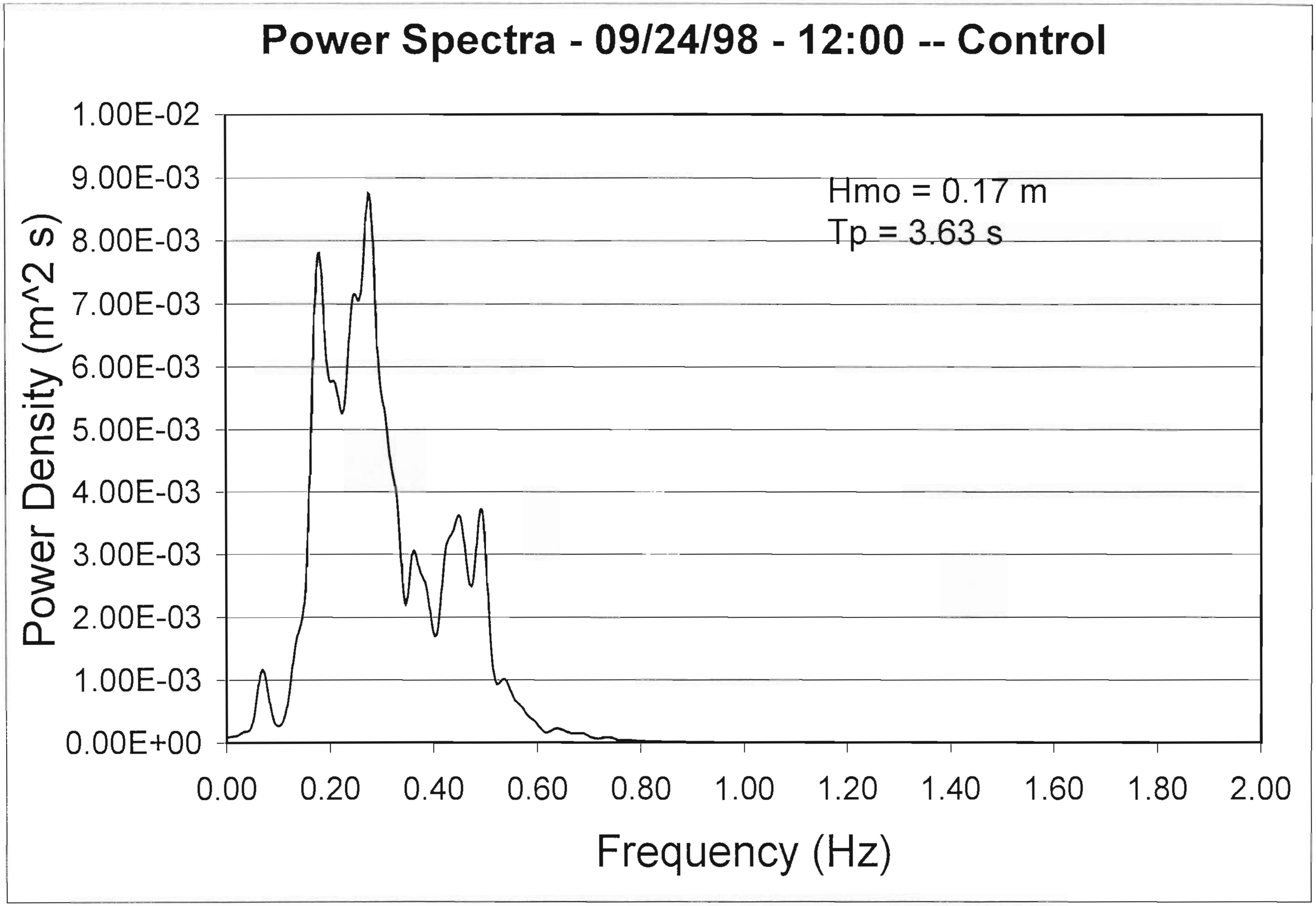


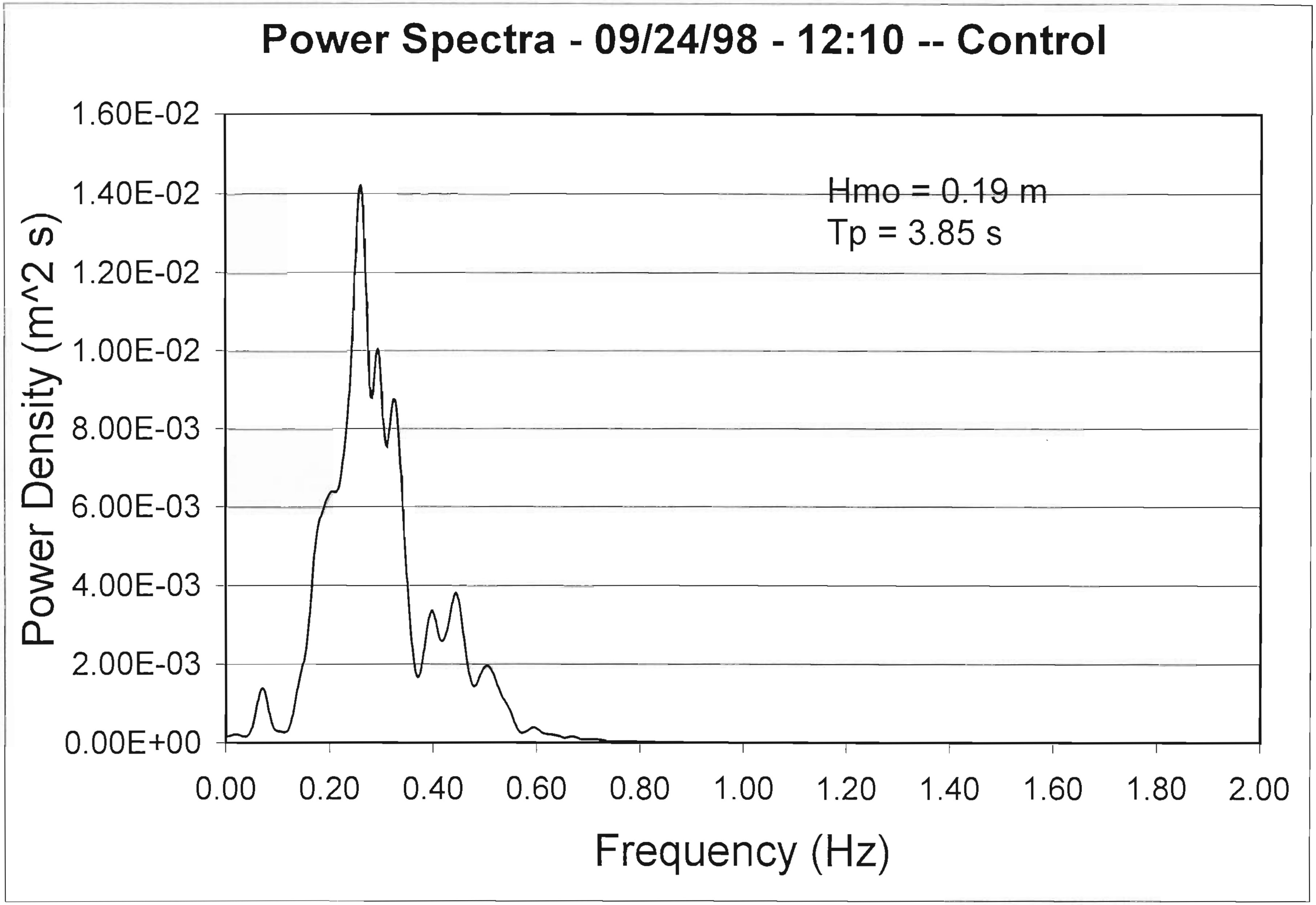
Power Spectra - 09/24/98 - 11:30 -- Control
Power Density (m^2 s)
1.00E-02
9.00E-03
8.00E-03
7.00E-03
6.00E-03
5.00E-03
4.00E-03
3.00E-03
2.00E-03
1.00E-03
0.00E+00
Hmo = 0.18 m
Tp = 3.01 s
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1.80
2.00
Frequency (Hz)

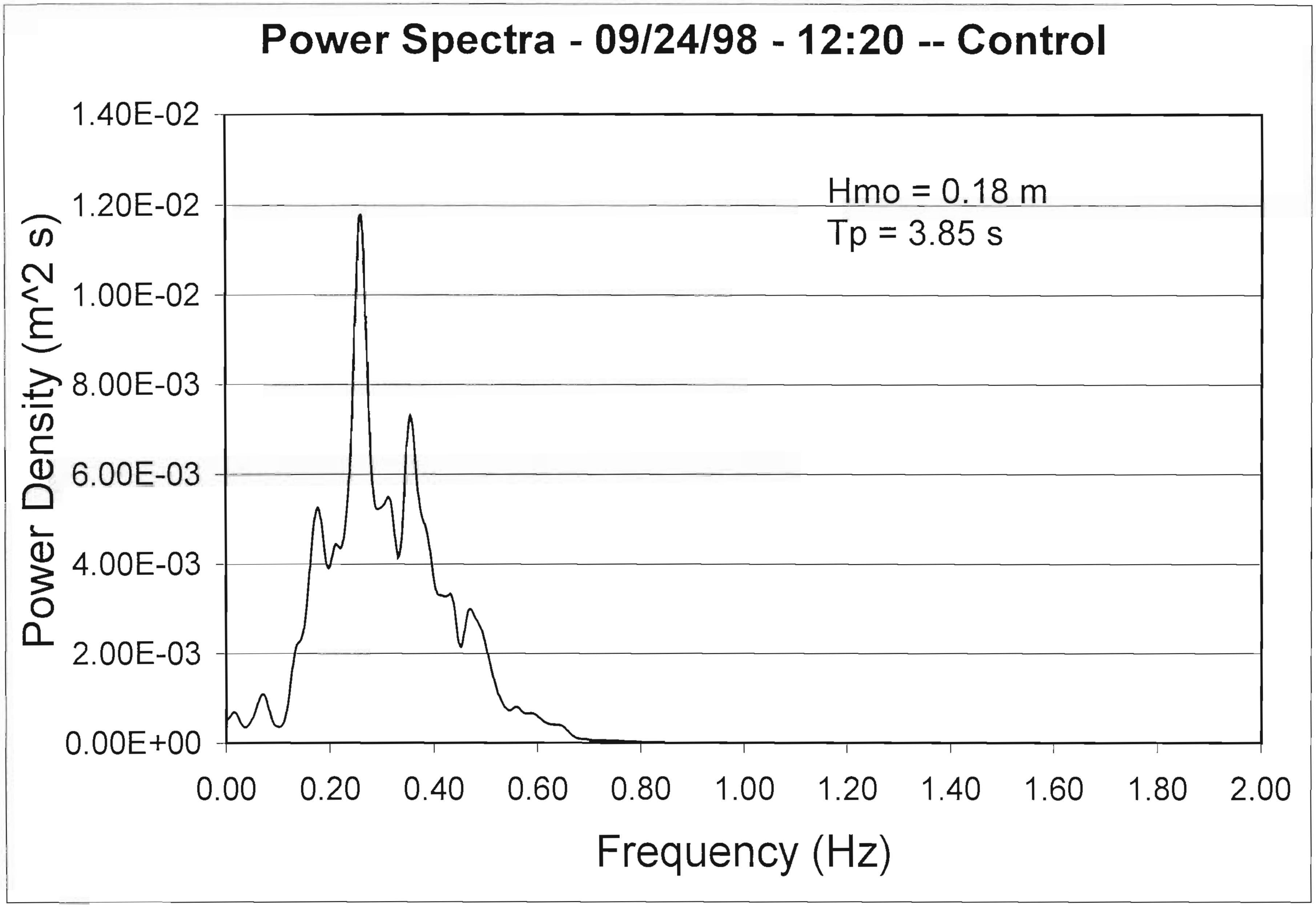


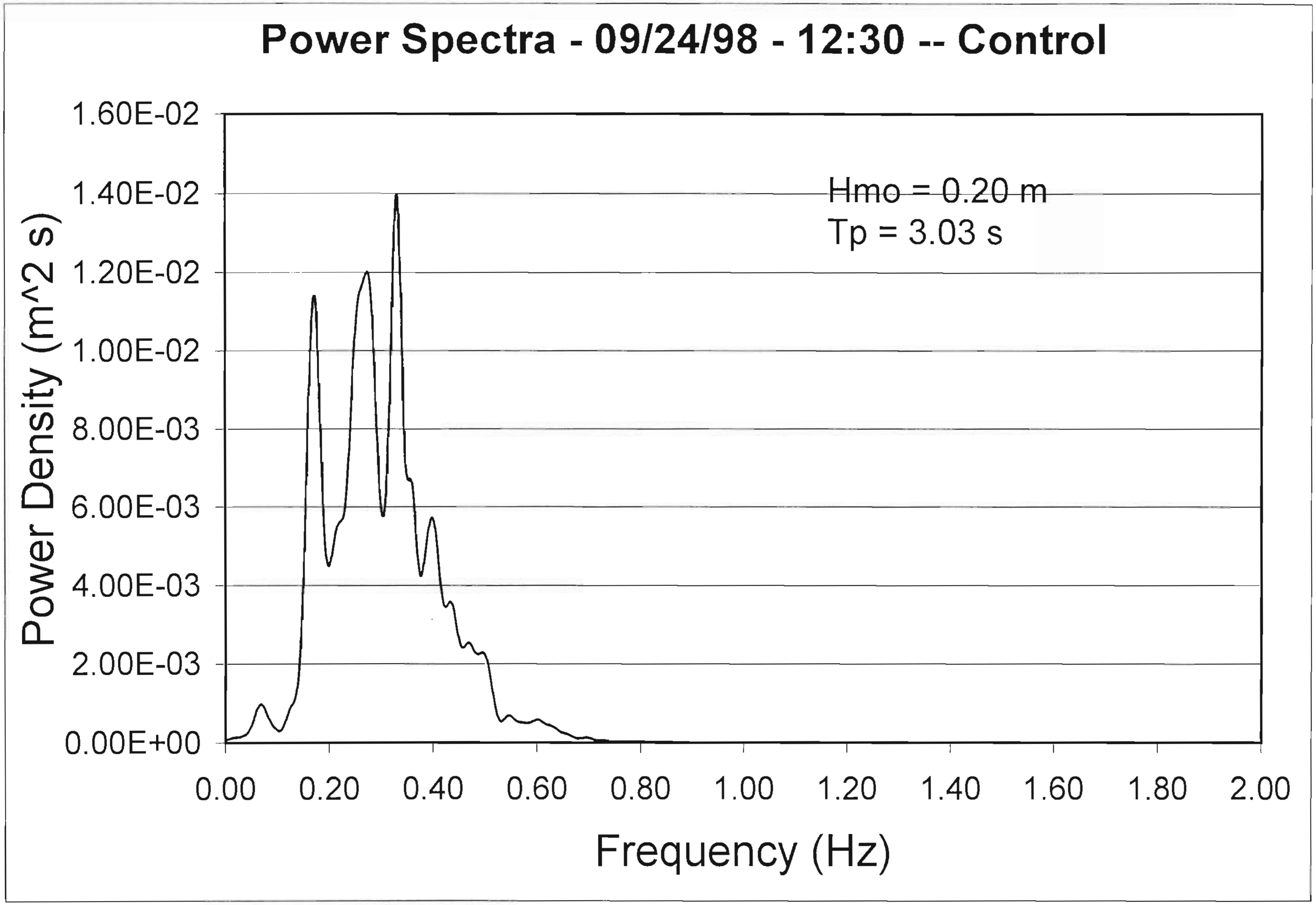
Power Spectra - 09/24/98 - 11:40 -- Control
Hmo = 0.17 m
Tp = 3.68 s
Power Density (m^2 s)
1.20E-02
1.00E-02
8.00E-03
6.00E-03
4.00E-03
2.00E-03
0.00E+00
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1.80
2.00
Frequency (Hz)

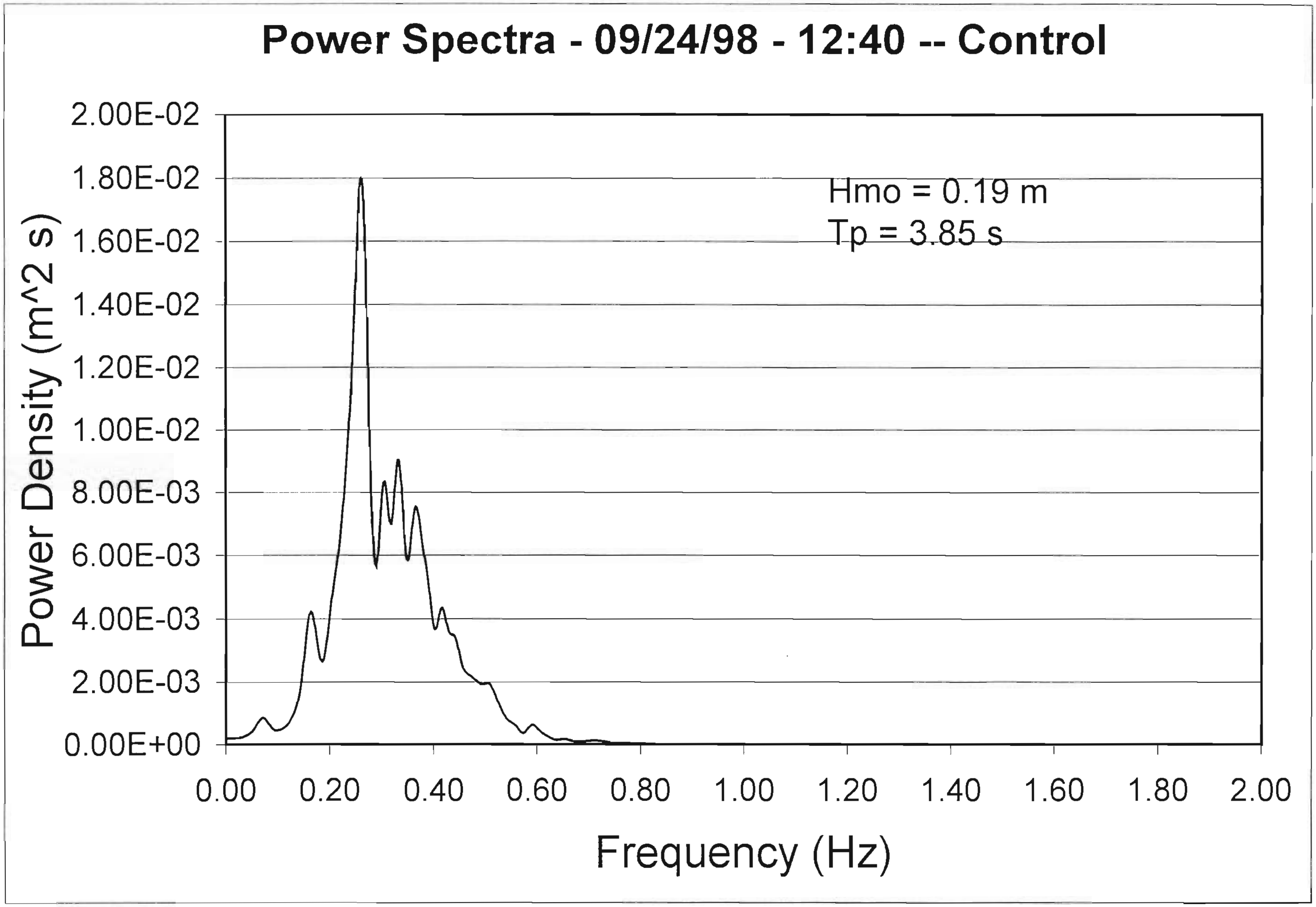

Power Spectra - 09/24/98 - 11:50 -- Control
Hmo = 0.18 m
Tp = 3.85 s
Power Density (m^2 s)
1.60E-02
1.40E-02
1.20E-02
1.00E-02
8.00E-03
6.00E-03
4.00E-03
2.00E-03
0.00E+00
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1.80
2.00
Frequency (Hz)

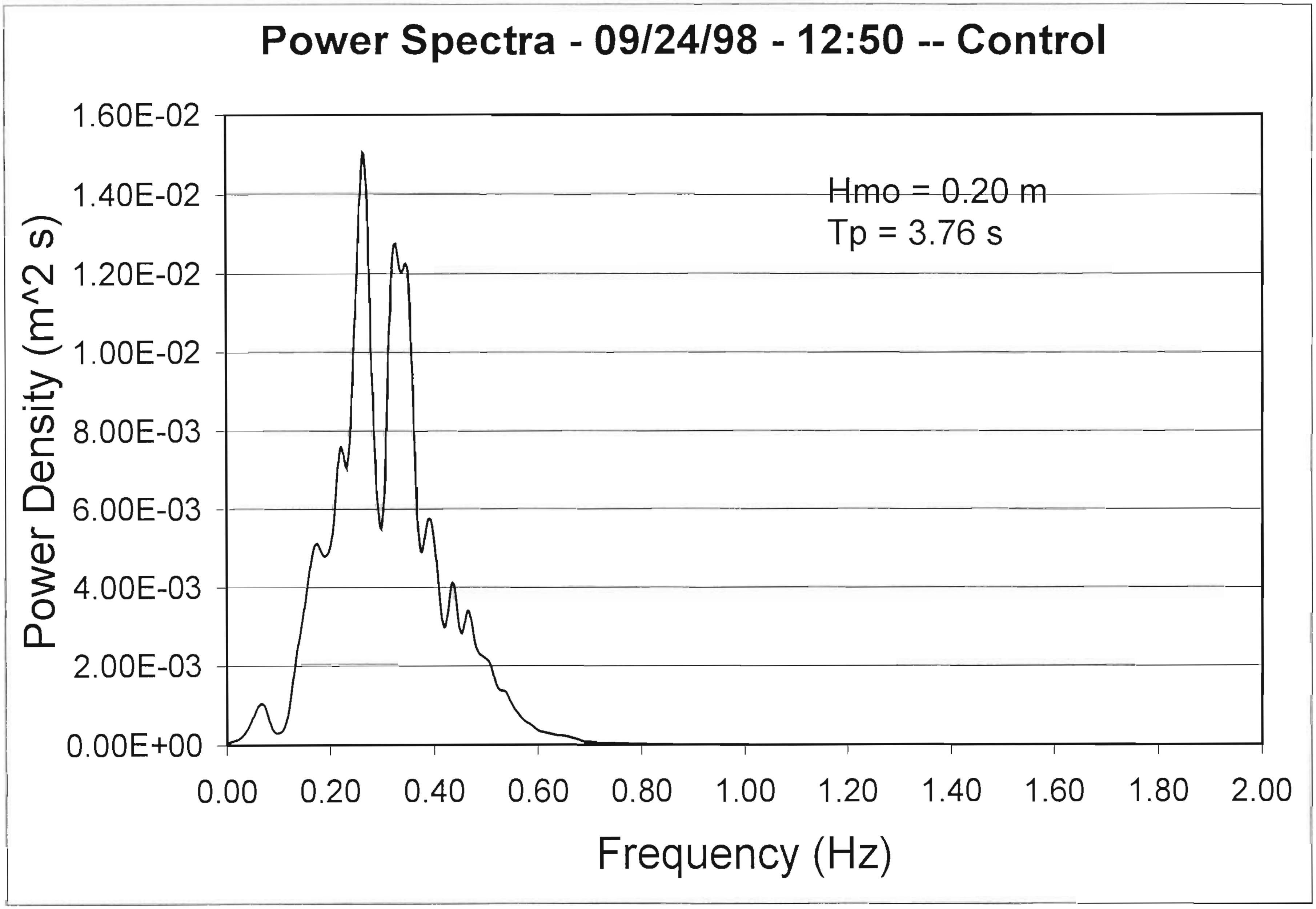

Power Spectra - 09/24/98 - 12:00 -- Control
Power Density (m^2 s)
1.00E-02
9.00E-03
8.00E-03
7.00E-03
6.00E-03
5.00E-03
4.00E-03
3.00E-03
2.00E-03
1.00E-03
0.00E+00
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1.80
2.00
Frequency (Hz)
Hmo = 0.17 m
Tp = 3.63 s

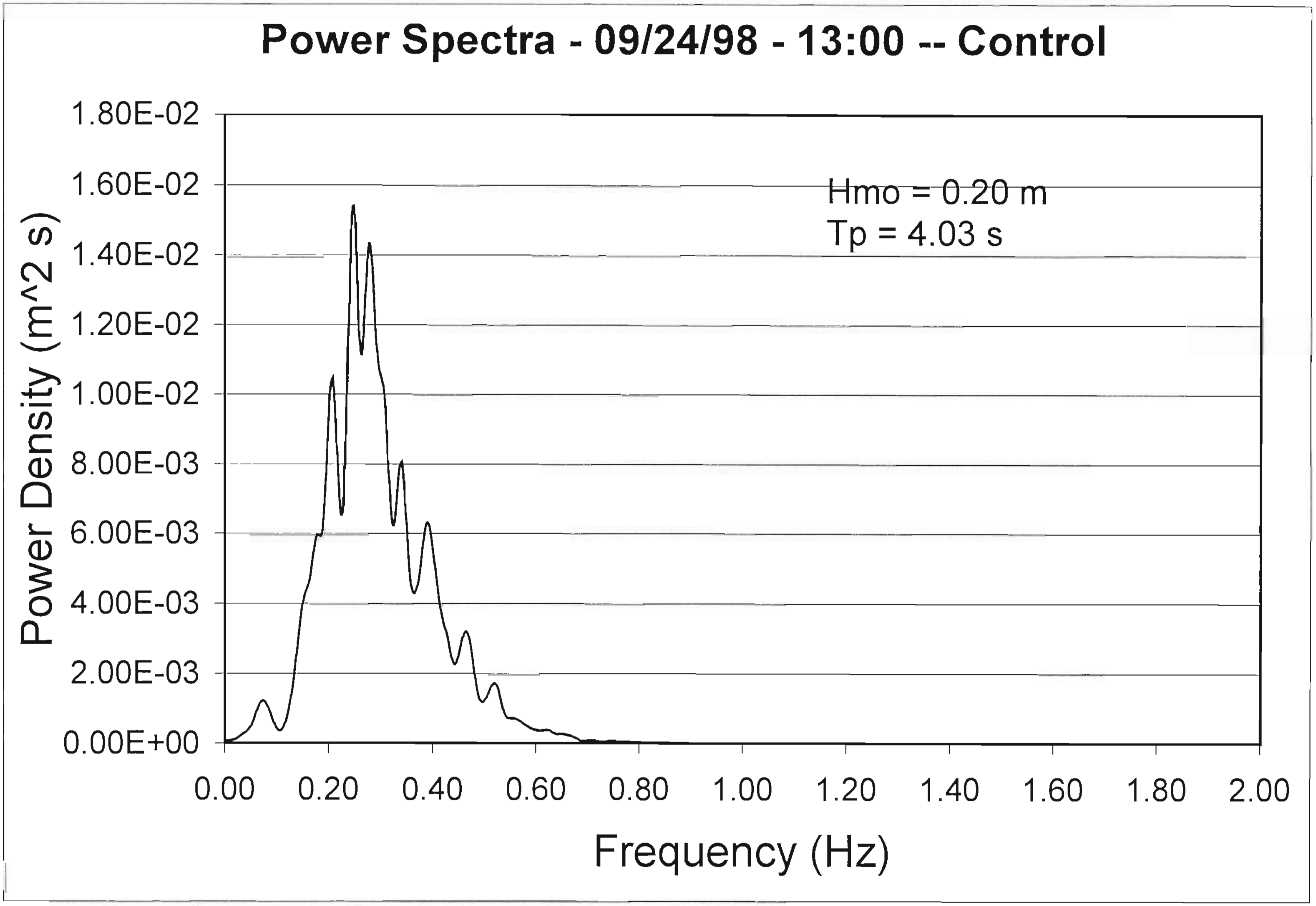

Power Spectra - 09/24/98 - 12:10 -- Control
Hmo = 0.19 m
Tp = 3.85 s
Power Density (m^2 s)
1.60E-02
1.40E-02
1.20E-02
1.00E-02
8.00E-03
6.00E-03
4.00E-03
2.00E-03
0.00E+00
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1.80
2.00
Frequency (Hz)

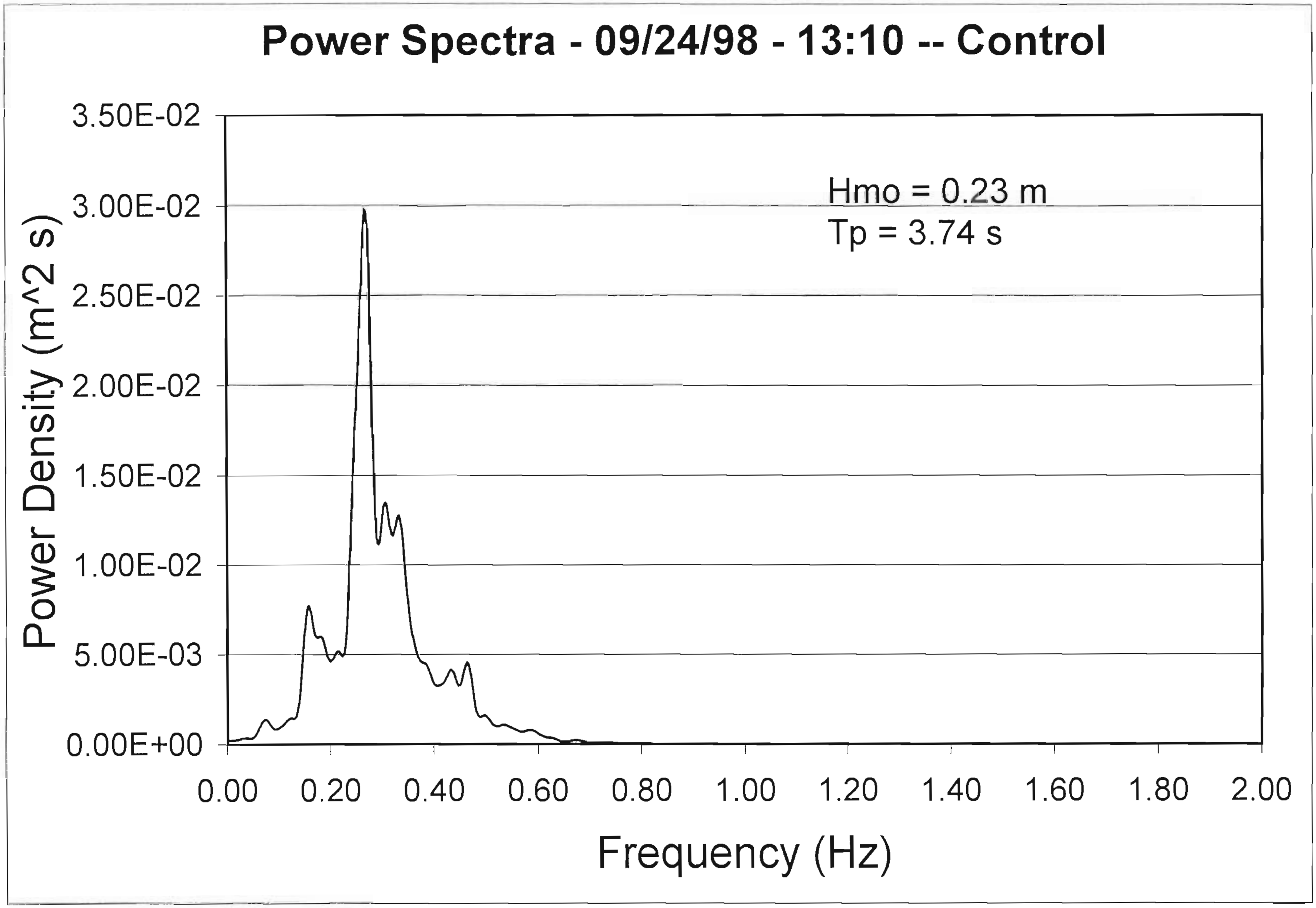

Power Spectra - 09/24/98 - 12:20 -- Control
Hmo = 0.18 m
Tp = 3.85 s
Power Density (m^2 s)
1.40E-02
1.20E-02
1.00E-02
8.00E-03
6.00E-03
4.00E-03
2.00E-03
0.00E+00
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1.80
2.00
Frequency (Hz)


Power Spectra - 09/24/98 - 12:30 -- Control
Hmo = 0.20 m
Tp = 3.03 s
Power Density (m^2 s)
1.60E-02
1.40E-02
1.20E-02
1.00E-02
8.00E-03
6.00E-03
4.00E-03
2.00E-03
0.00E+00
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1.80
2.00
Frequency (Hz)

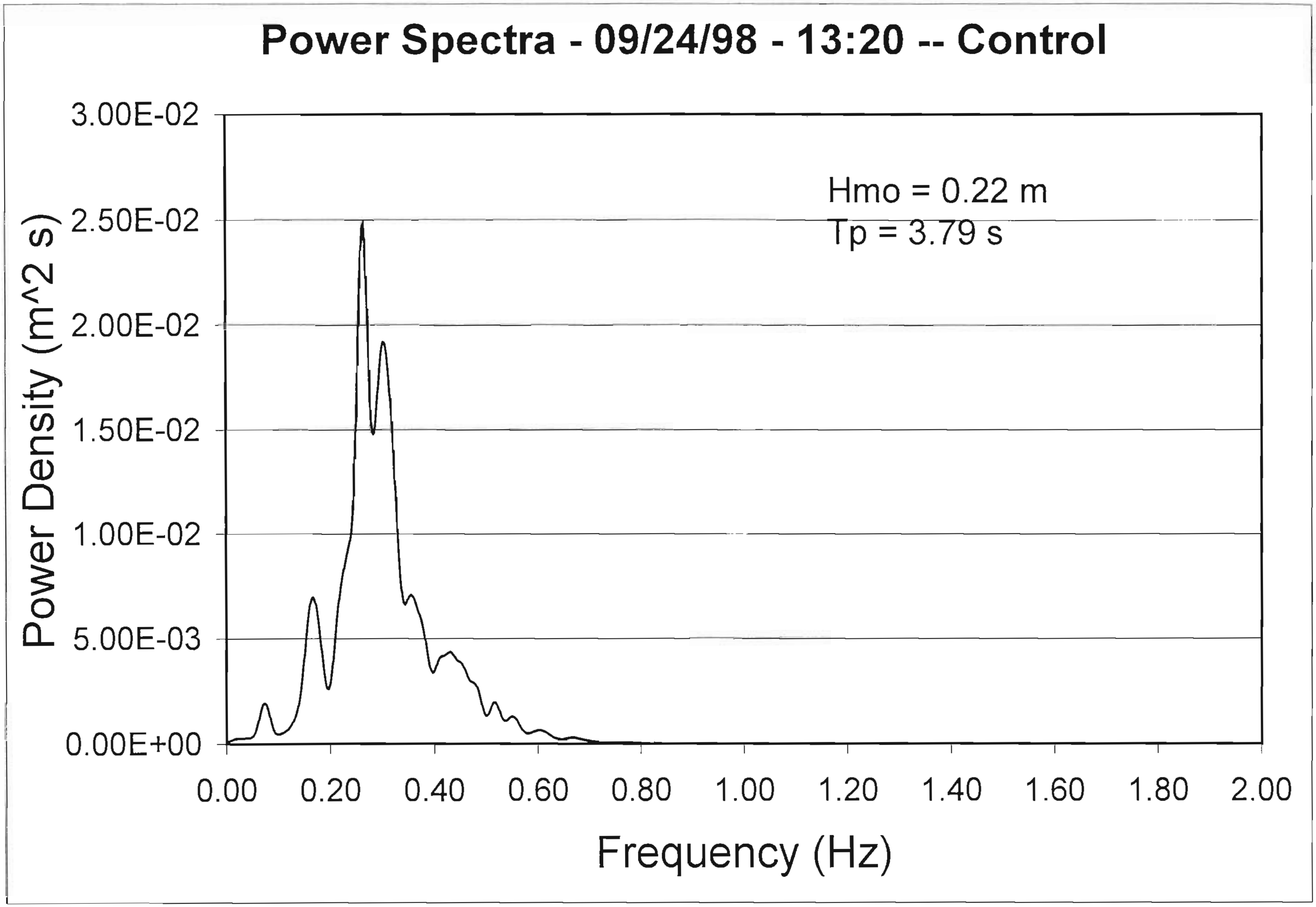

Power Spectra - 09/24/98 - 12:40 -- Control
Hmo = 0.19 m
Tp = 3.85 s
Power Density (m^2 s)
2.00E-02
1.80E-02
1.60E-02
1.40E-02
1.20E-02
1.00E-02
8.00E-03
6.00E-03
4.00E-03
2.00E-03
0.00E+00
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1.80
2.00
Frequency (Hz)


Power Spectra - 09/24/98 - 12:50 -- Control
Hmo = 0.20 m
Tp = 3.76 s
Power Density (m^2 s)
1.60E-02
1.40E-02
1.20E-02
1.00E-02
8.00E-03
6.00E-03
4.00E-03
2.00E-03
0.00E+00
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1.80
2.00
Frequency (Hz)

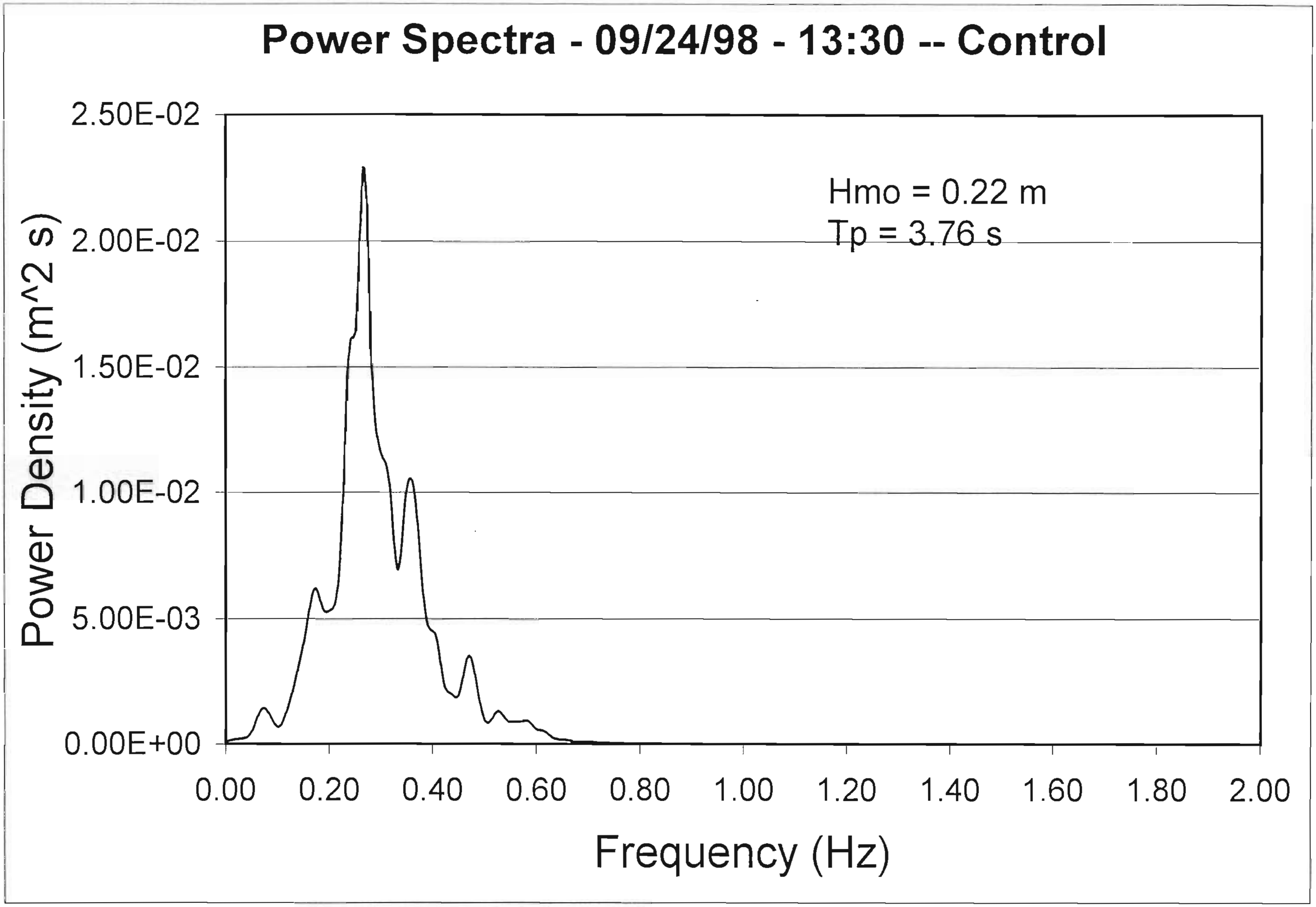

Power Spectra - 09/24/98 - 13:00 -- Control
Hmo = 0.20 m
Tp = 4.03 s
Power Density (m^2 s)
1.80E-02
1.60E-02
1.40E-02
1.20E-02
1.00E-02
8.00E-03
6.00E-03
4.00E-03
2.00E-03
0.00E+00
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1.80
2.00
Frequency (Hz)



Power Spectra - 09/24/98 - 13:10 -- Control
Hmo = 0.23 m
Tp = 3.74 s
Power Density (m^2 s)
3.50E-02
3.00E-02
2.50E-02
2.00E-02
1.50E-02
1.00E-02
5.00E-03
0.00E+00
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1.80
2.00
Frequency (Hz)

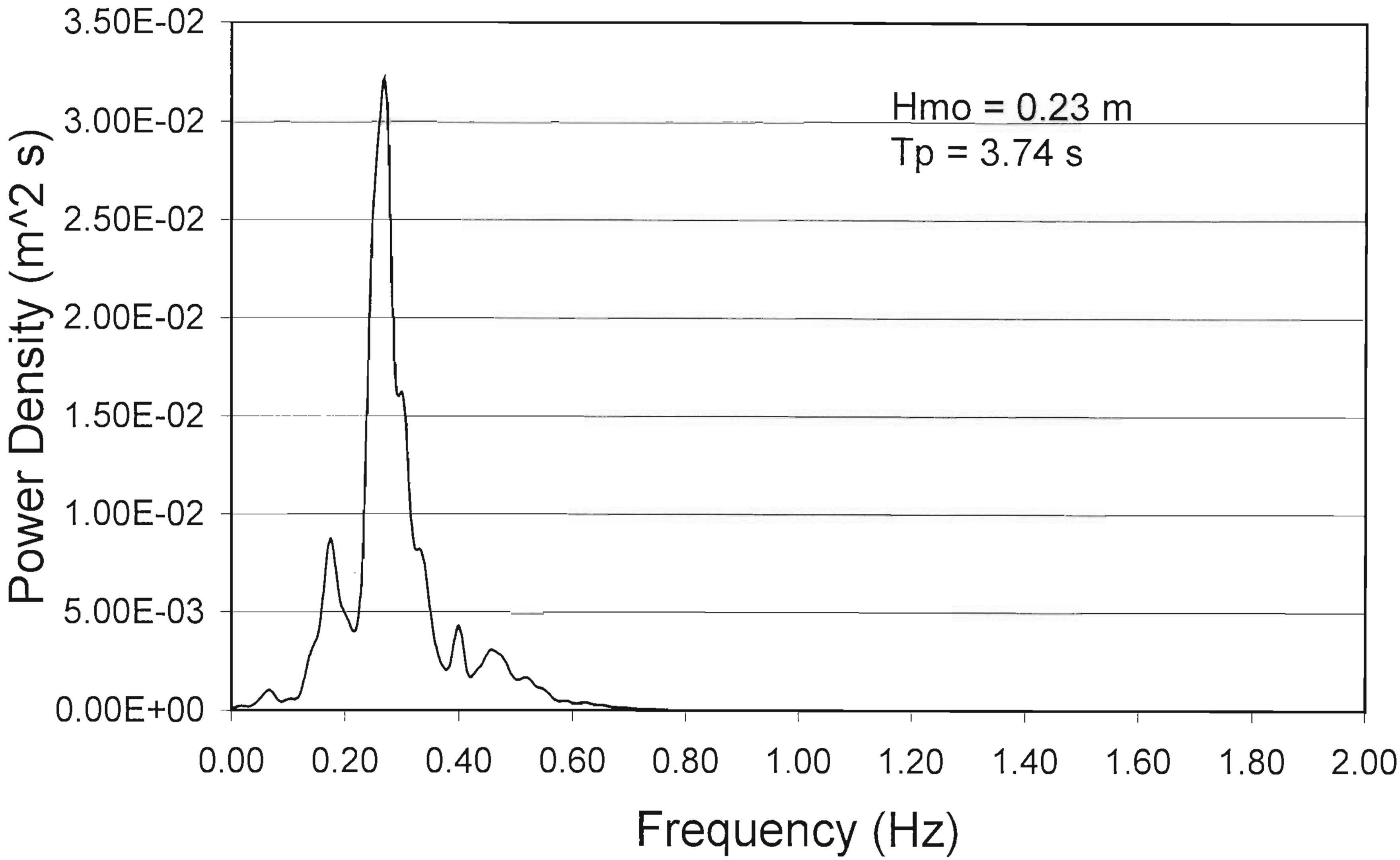


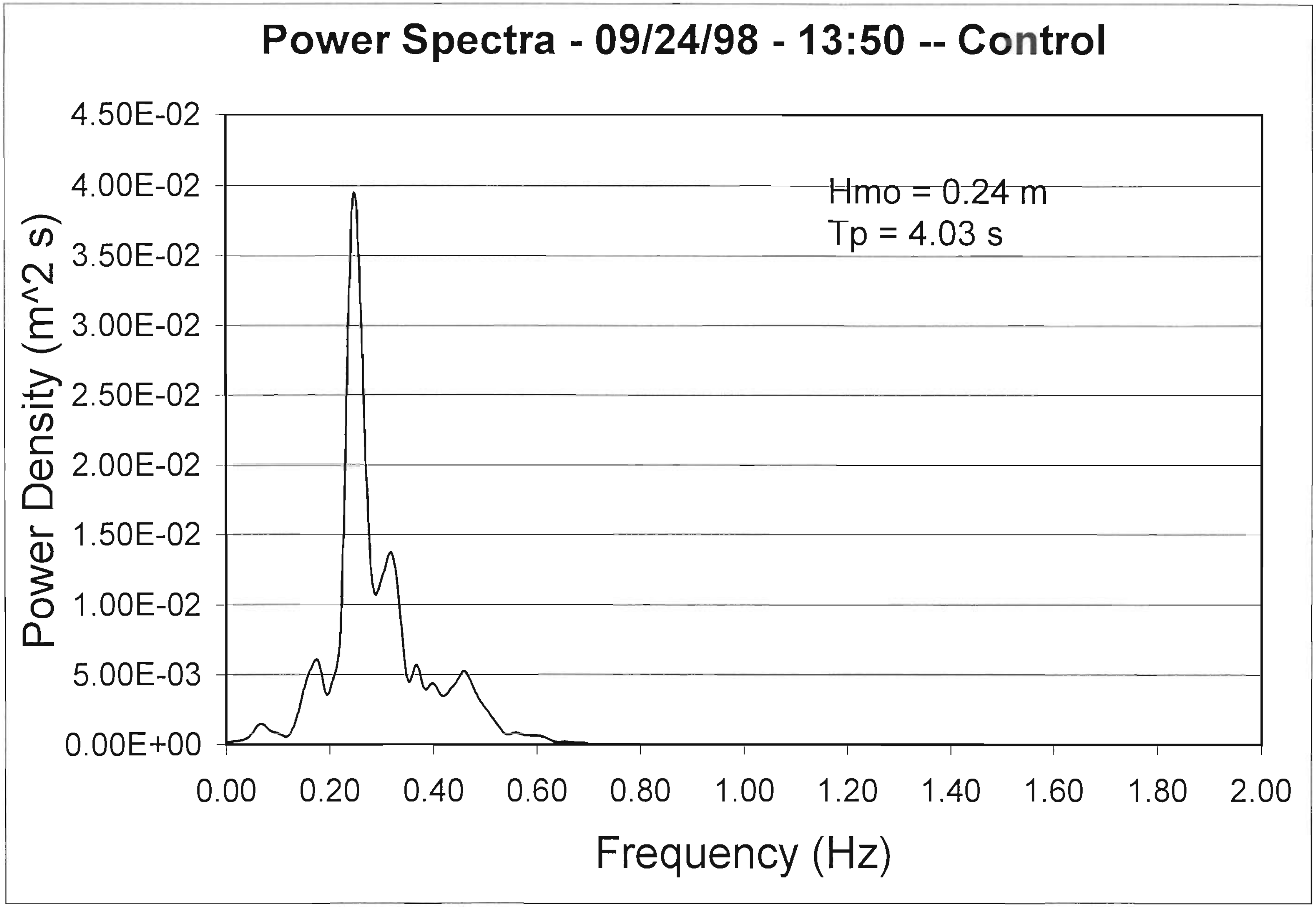
Power Spectra - 09/24/98 - 13:20 -- Control
Hmo = 0.22 m
Tp = 3.79 s
Power Density (m^2 s)
3.00E-02
2.50E-02
2.00E-02
1.50E-02
1.00E-02
5.00E-03
0.00E+00
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1.80
2.00
Frequency (Hz)



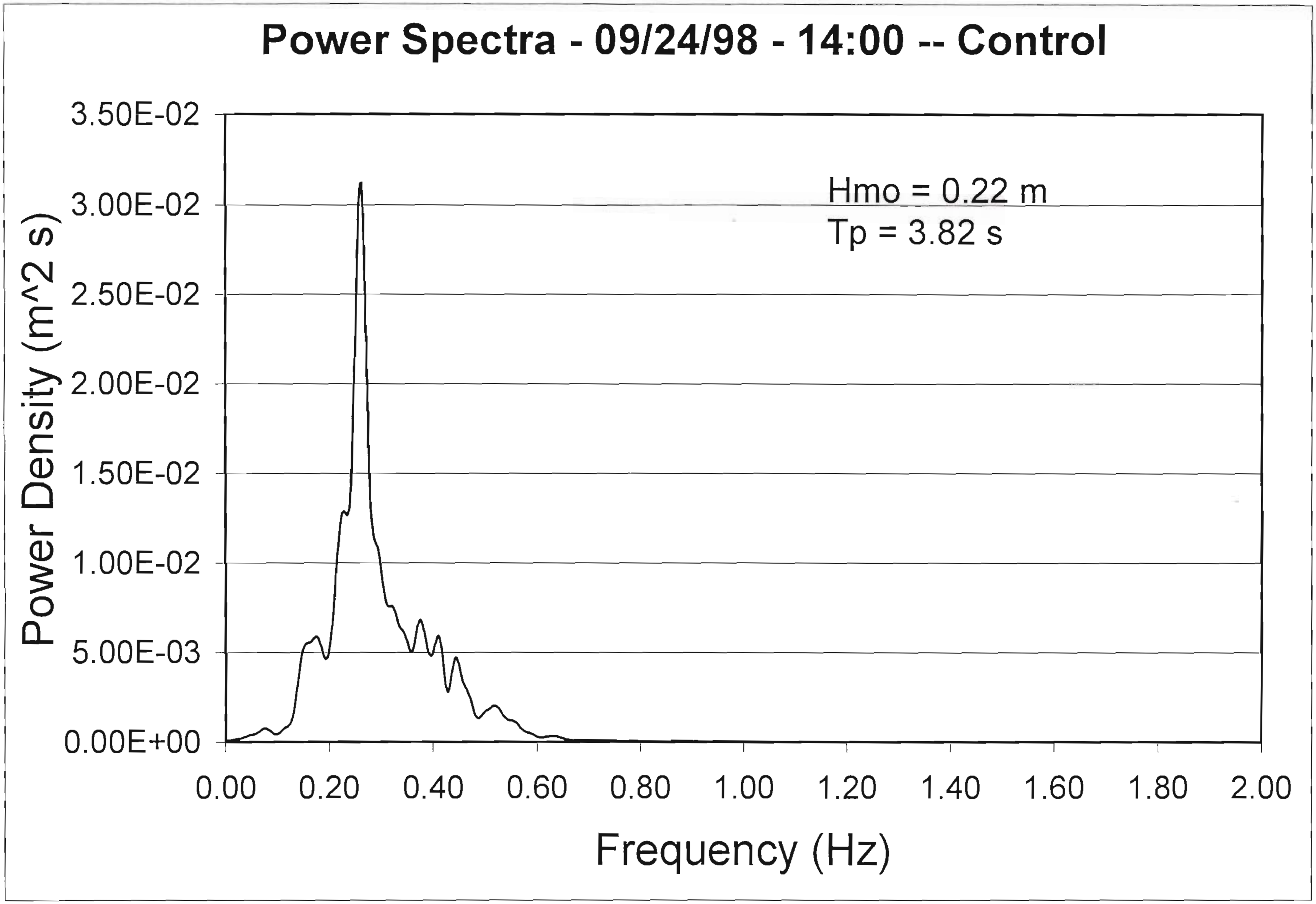
Power Spectra - 09/24/98 - 13:30 -- Control
Hmo = 0.22 m
Tp = 3.76 s
2.50E-02
2.00E-02
1.50E-02
1.00E-02
5.00E-03
0.00E+00
Power Density (m^2 s)
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1.80
2.00
Frequency (Hz)

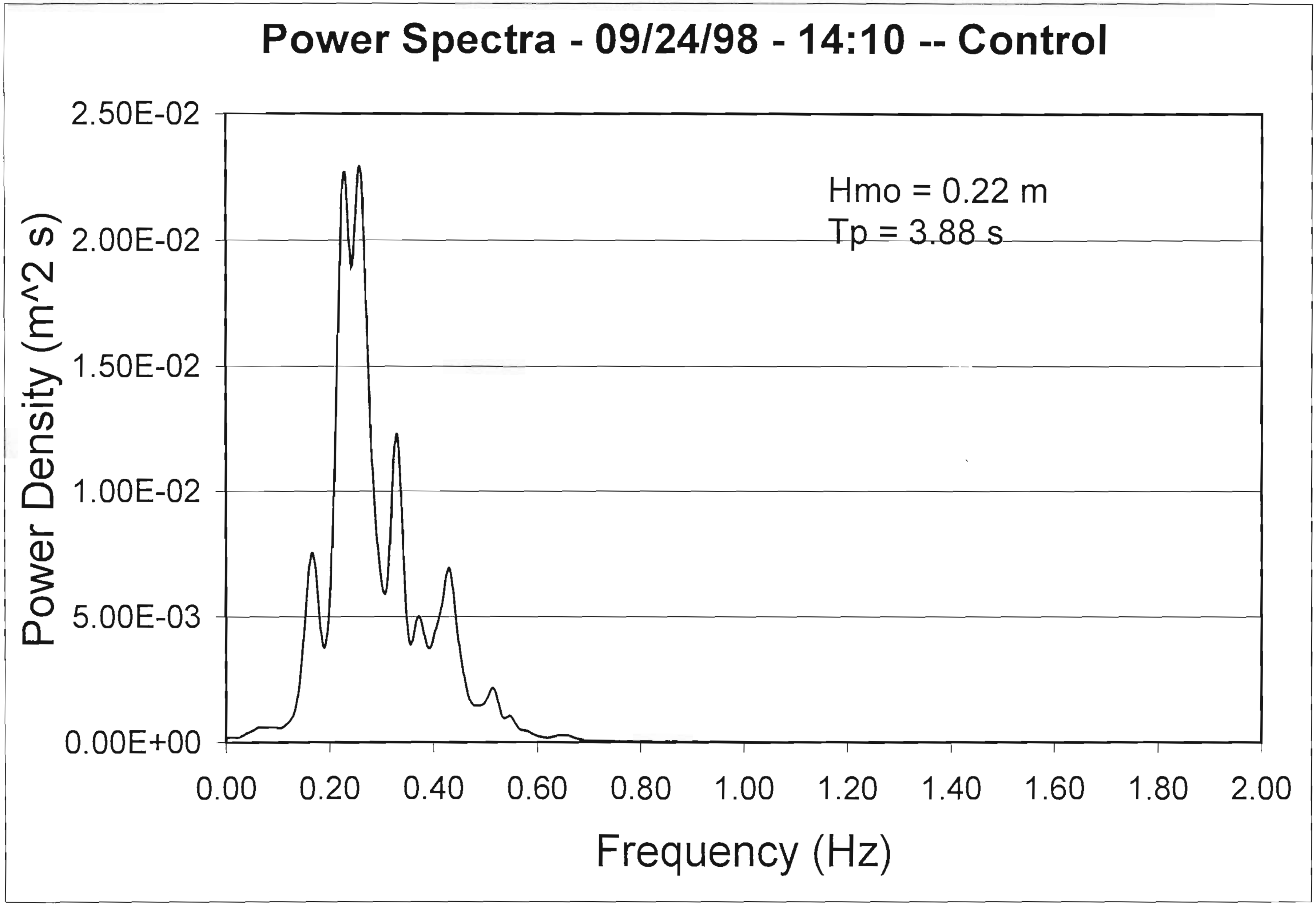
Power Spectra - 09/24/98 - 13:40 -- Control

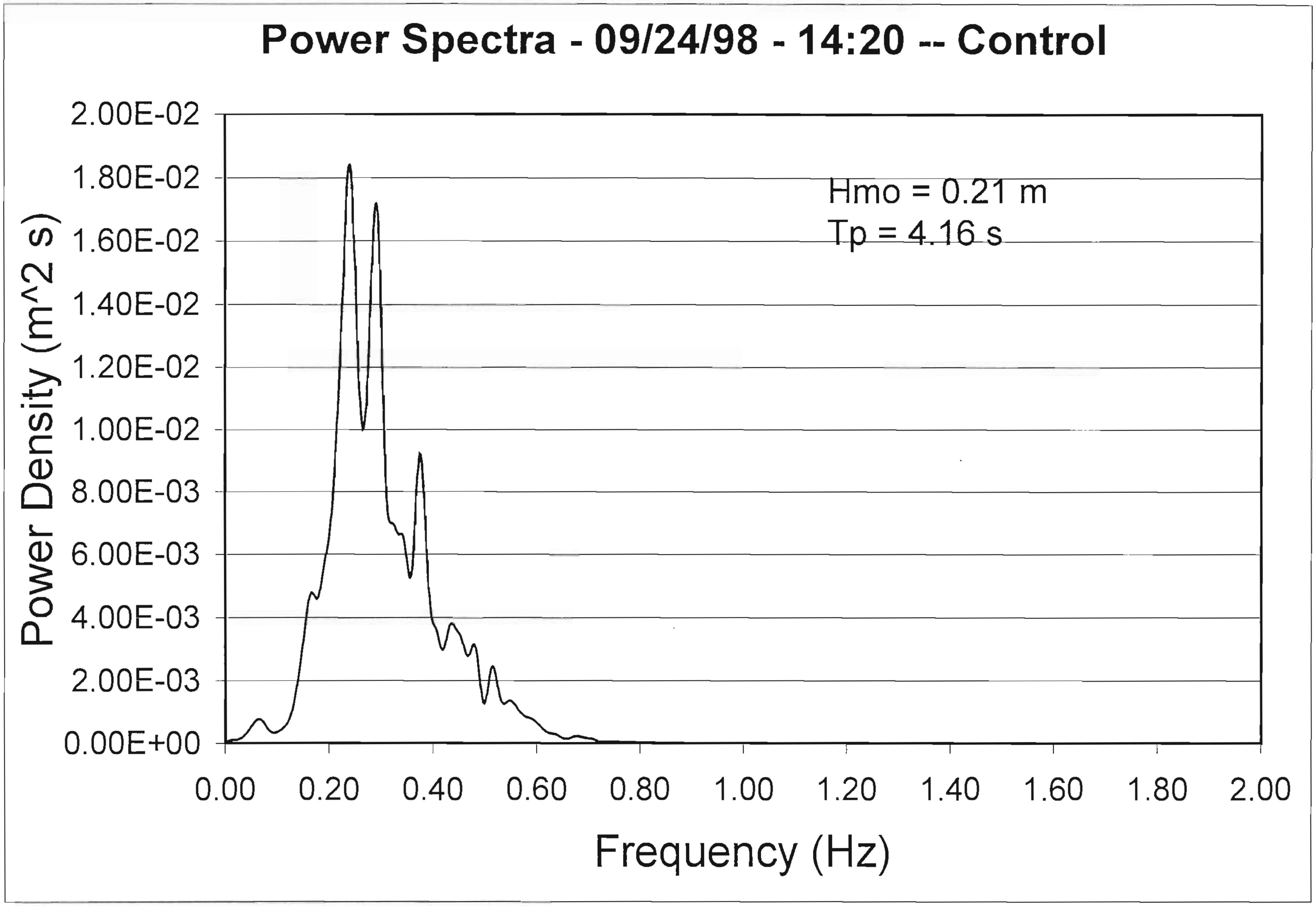


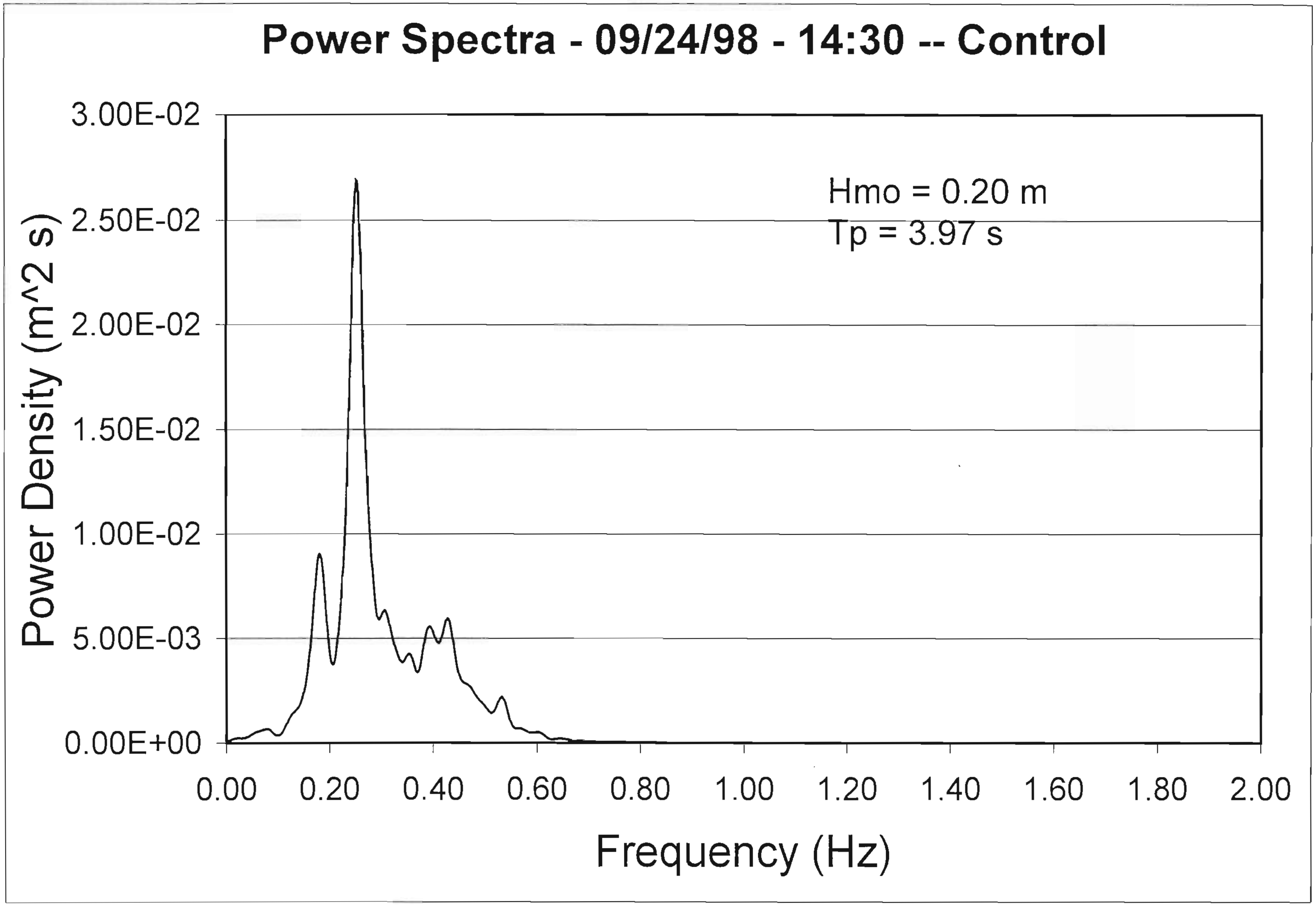


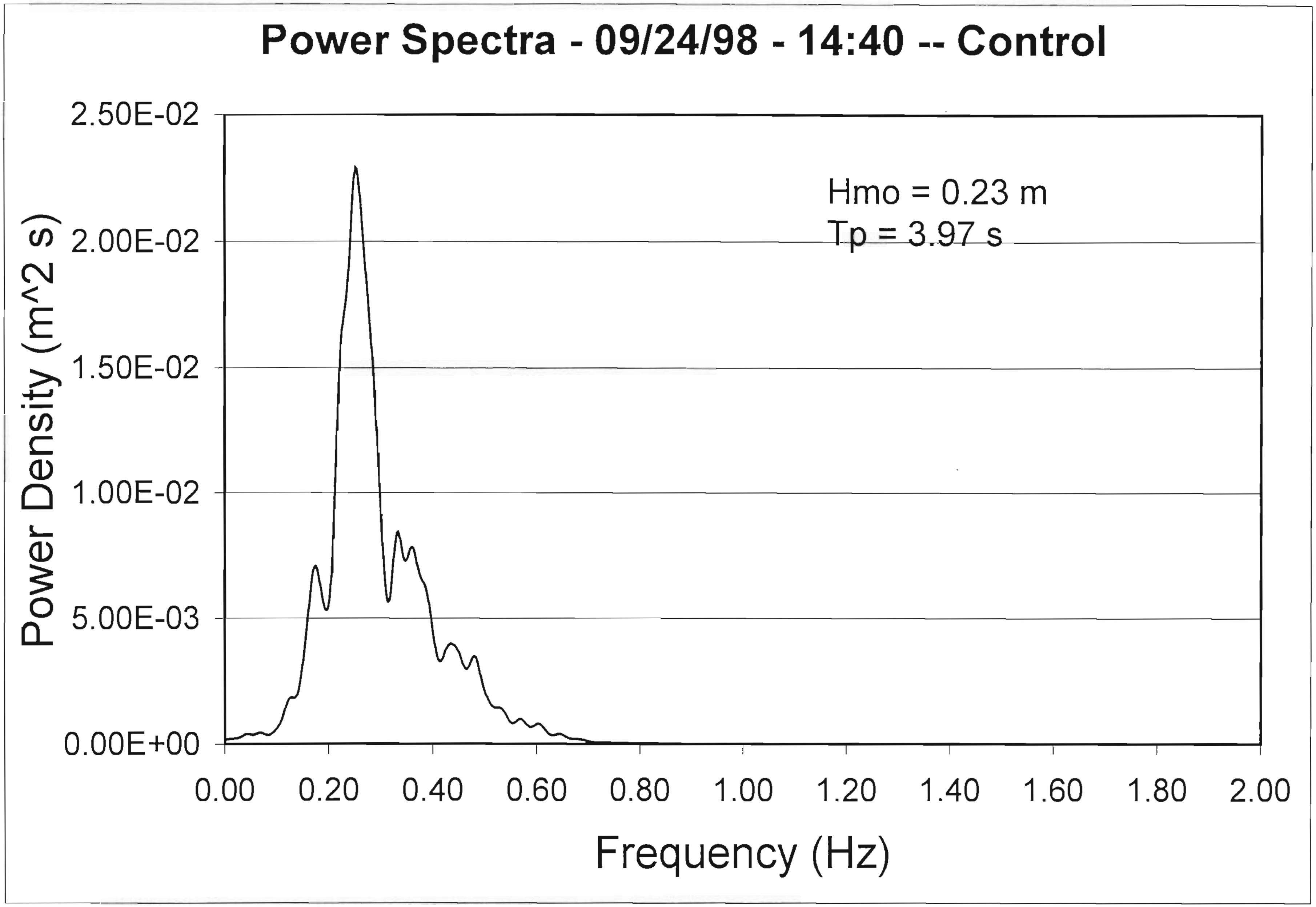
Power Spectra - 09/24/98 - 13:50 -- Control
Power Density (m^2 s)
4.50E-02
4.00E-02
3.50E-02
3.00E-02
2.50E-02
2.00E-02
1.50E-02
1.00E-02
5.00E-03
0.00E+00
Hmo = 0.24 m
Tp = 4.03 s
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1.80
2.00
Frequency (Hz)

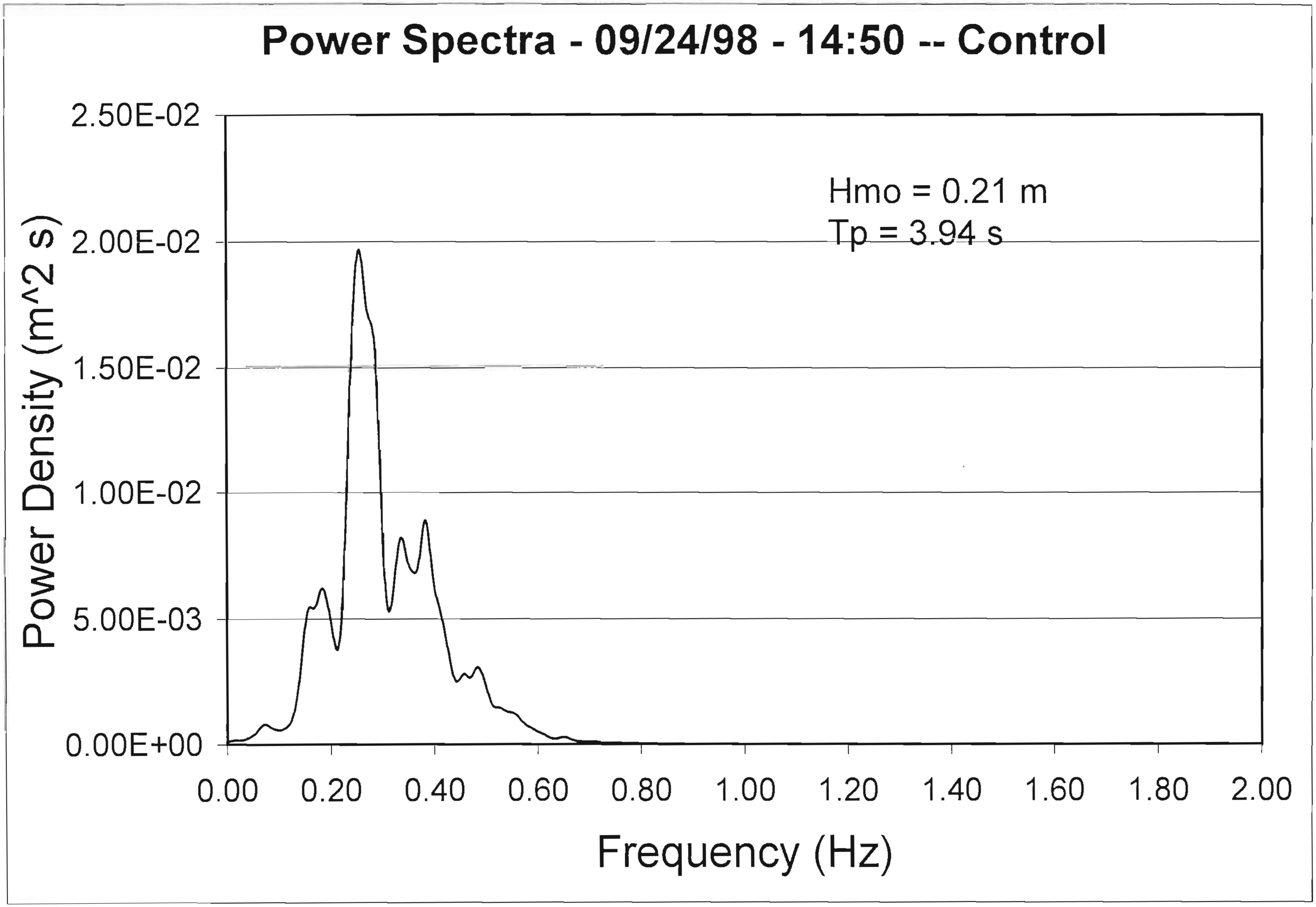

Power Spectra - 09/24/98 - 14:00 -- Control
Power Density (m^2 s)
3.50E-02
3.00E-02
2.50E-02
2.00E-02
1.50E-02
1.00E-02
5.00E-03
0.00E+00
Hmo = 0.22 m
Tp = 3.82 s
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1.80
2.00
Frequency (Hz)

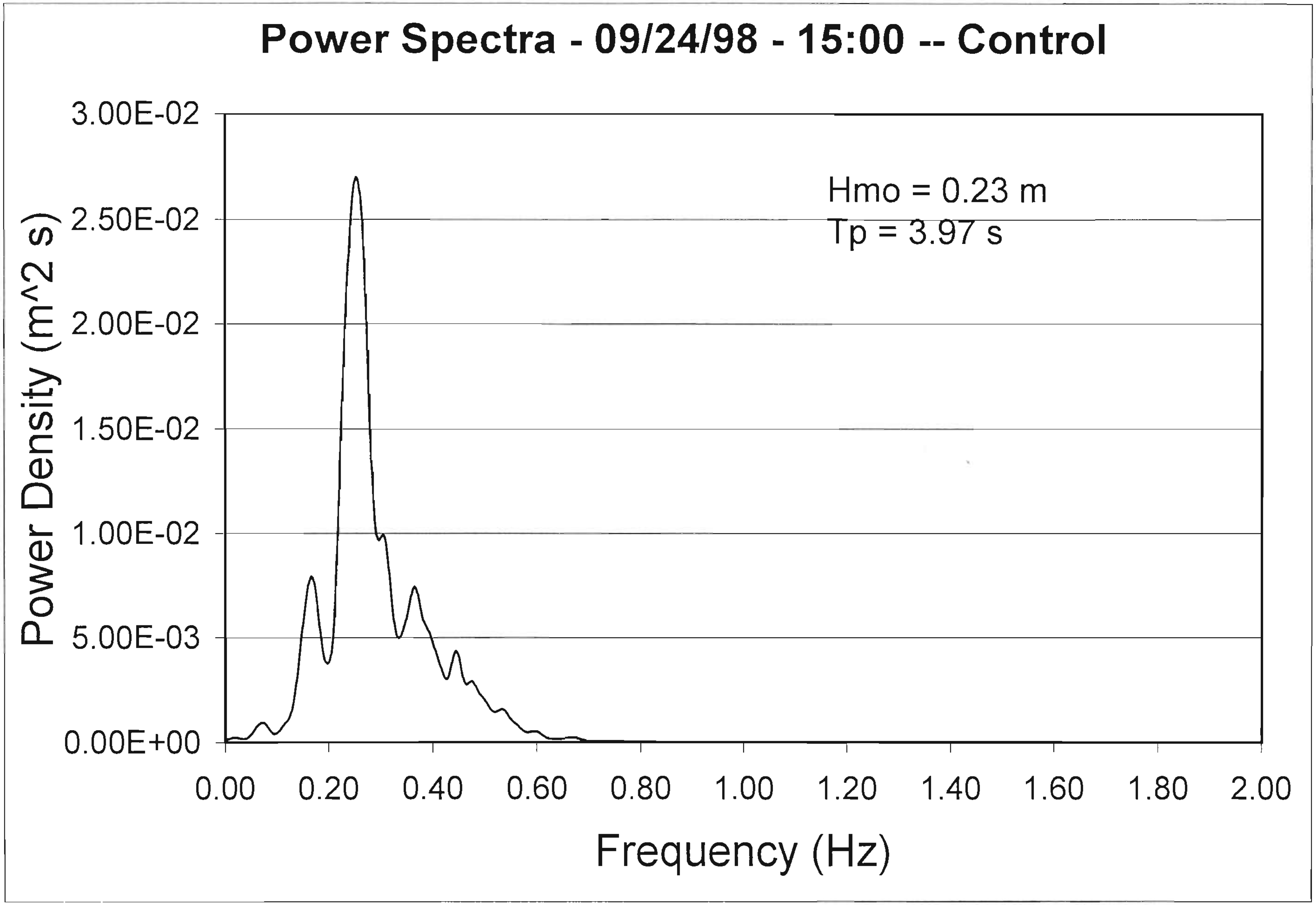

Power Spectra - 09/24/98 - 14:10 -- Control
Hmo = 0.22 m
Tp = 3.88 s
Power Density (m^2 s)
2.50E-02
2.00E-02
1.50E-02
1.00E-02
5.00E-03
0.00E+00
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1.80
2.00
Frequency (Hz)

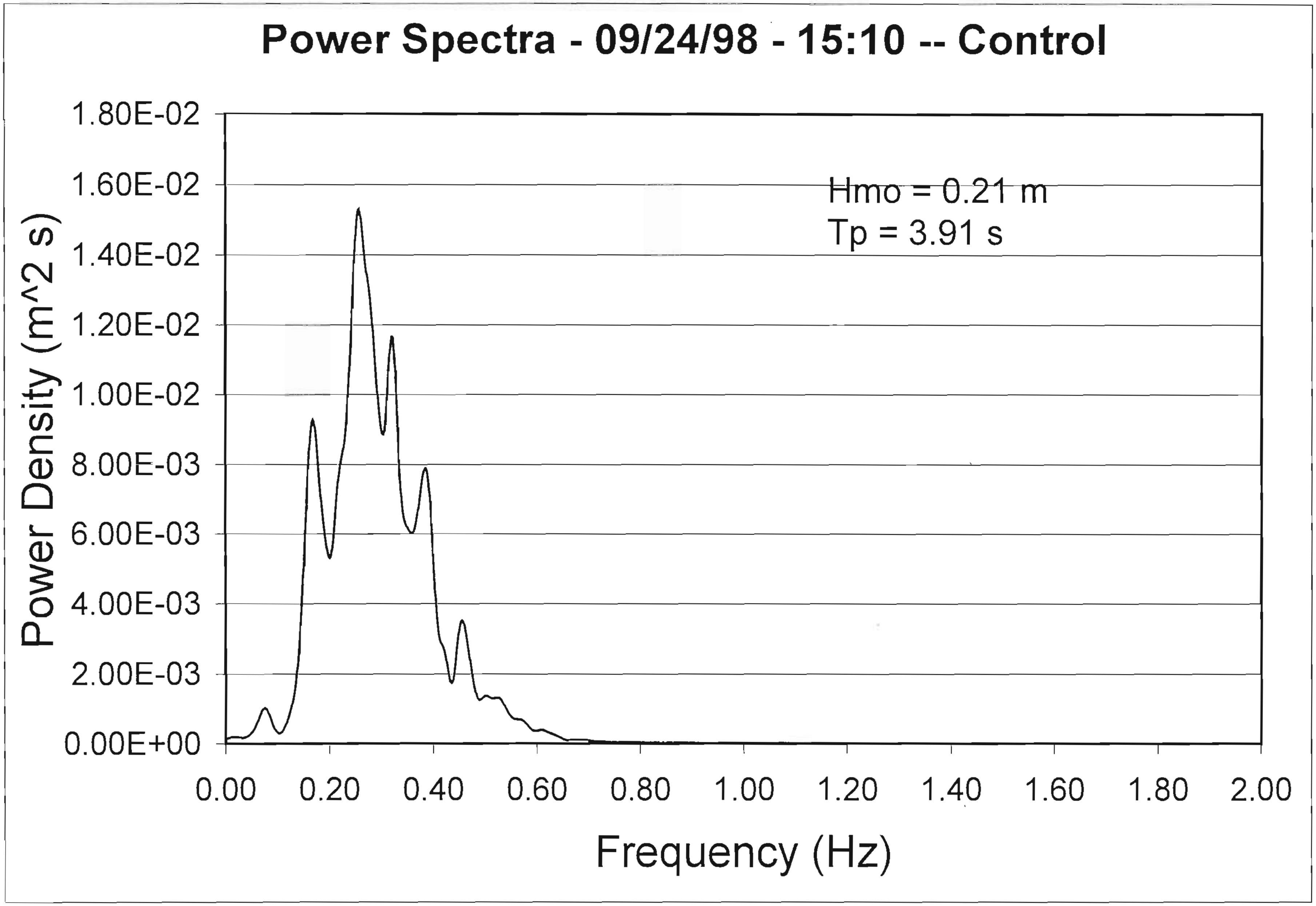

Power Spectra - 09/24/98 - 14:20 -- Control
Hmo = 0.21 m
Tp = 4.16 s
Power Density (m^2 s)
2.00E-02
1.80E-02
1.60E-02
1.40E-02
1.20E-02
1.00E-02
8.00E-03
6.00E-03
4.00E-03
2.00E-03
0.00E+00
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1.80
2.00
Frequency (Hz)

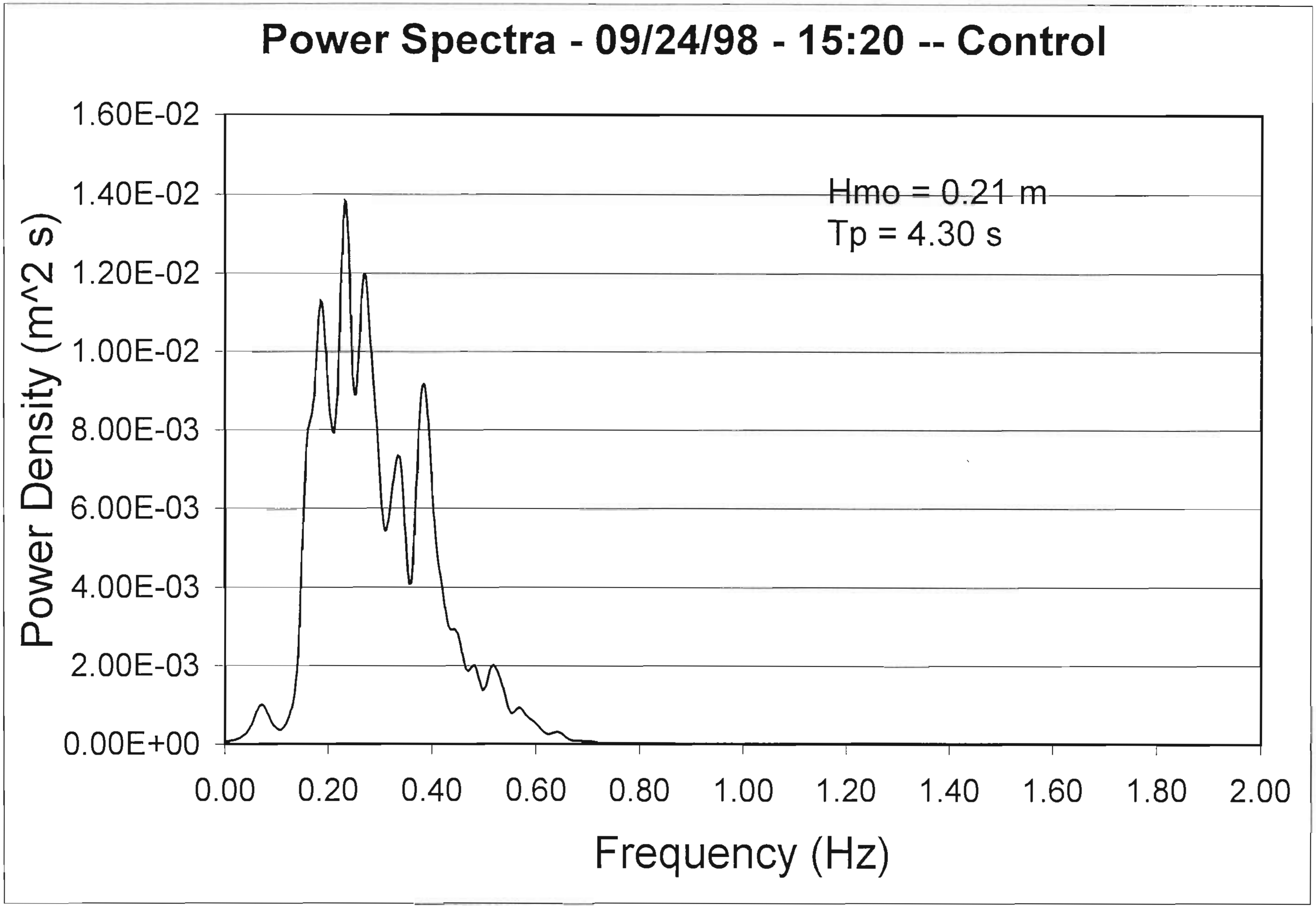

Power Spectra - 09/24/98 - 14:30 -- Control
Hmo = 0.20 m
Tp = 3.97 s
Power Density (m^2 s)
3.00E-02
2.50E-02
2.00E-02
1.50E-02
1.00E-02
5.00E-03
0.00E+00
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1.80
2.00
Frequency (Hz)

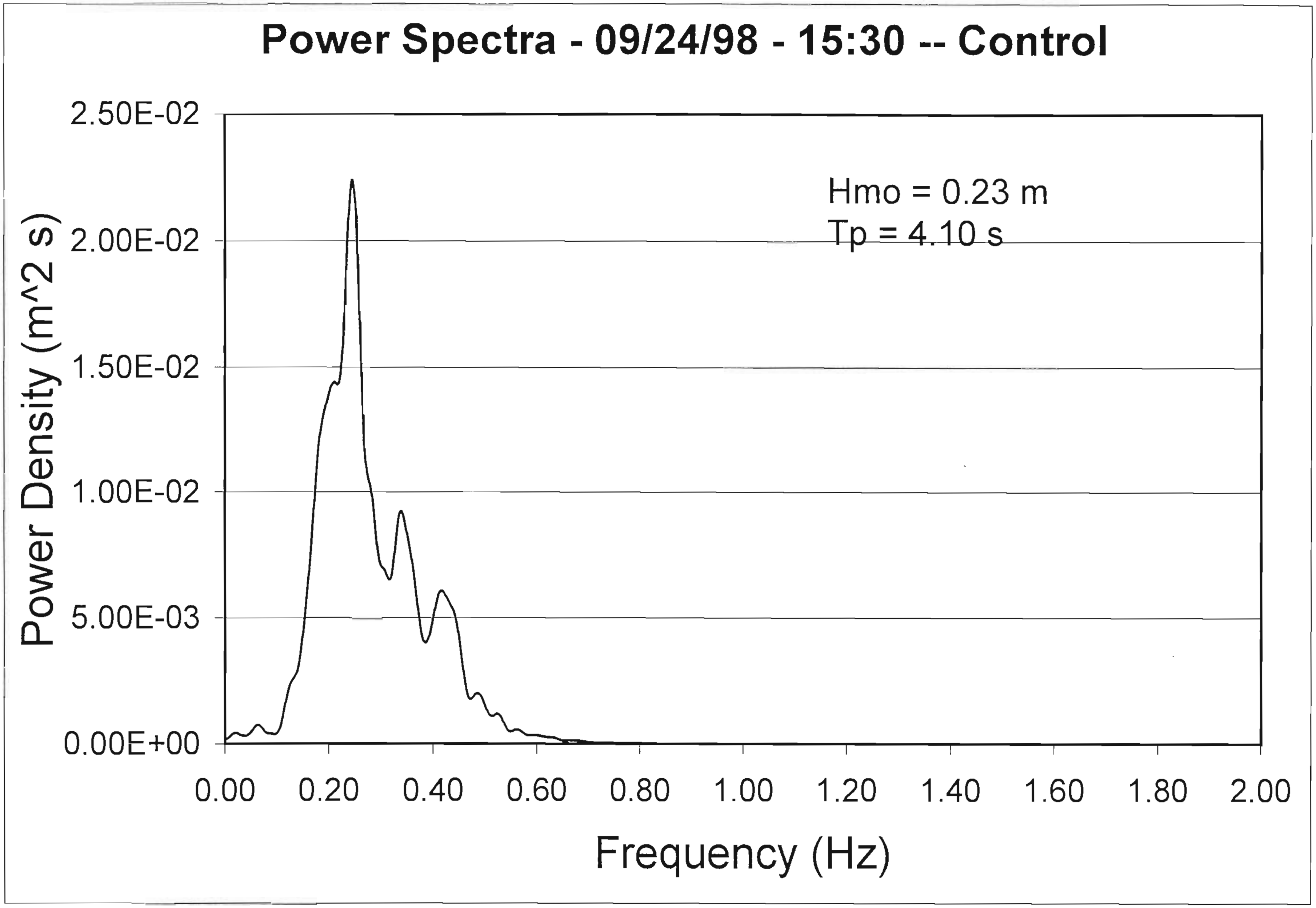

Power Spectra - 09/24/98 - 14:40 -- Control
Hmo = 0.23 m
Tp = 3.97 s
Power Density (m^2 s)
2.50E-02
2.00E-02
1.50E-02
1.00E-02
5.00E-03
0.00E+00
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1.80
2.00
Frequency (Hz)

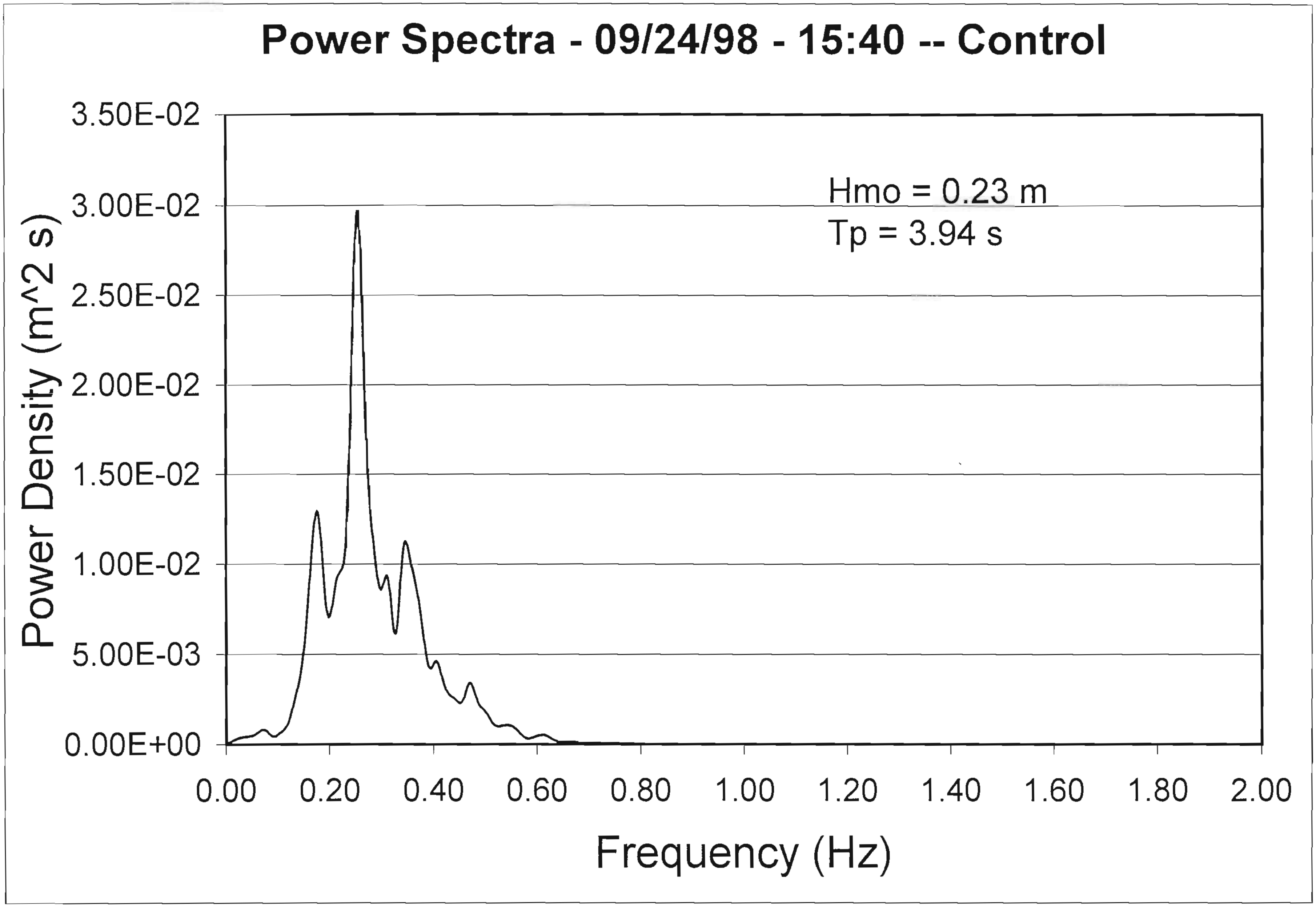

Power Spectra - 09/24/98 - 14:50 -- Control
Hmo = 0.21 m
Tp = 3.94 s
Power Density (m^2 s)
2.50E-02
2.00E-02
1.50E-02
1.00E-02
5.00E-03
0.00E+00
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1.80
2.00
Frequency (Hz)

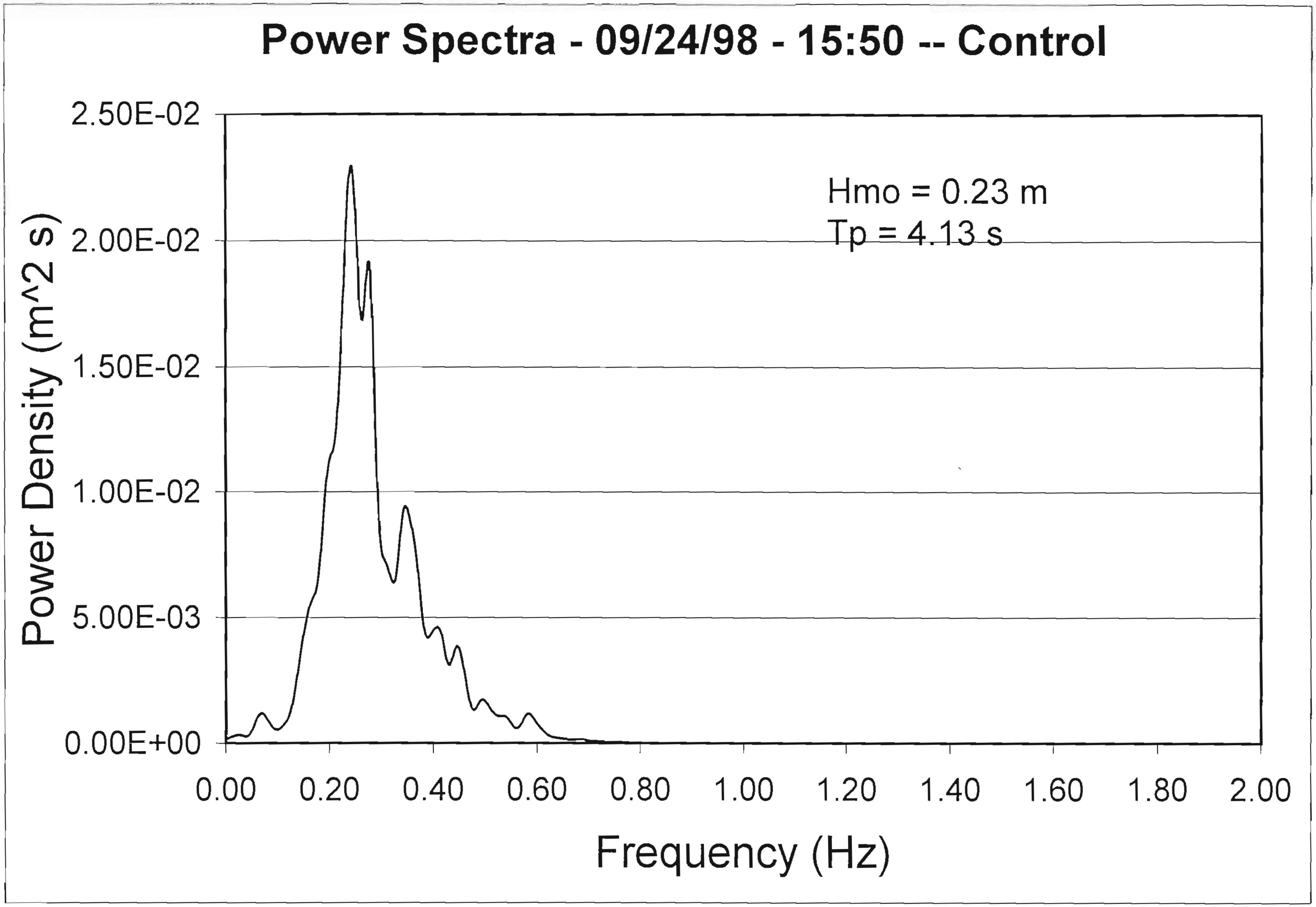

Power Spectra - 09/24/98 - 15:00 -- Control
Hmo = 0.23 m
Tp = 3.97 s
Power Density (m^2 s)
3.00E-02
2.50E-02
2.00E-02
1.50E-02
1.00E-02
5.00E-03
0.00E+00
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1.80
2.00
Frequency (Hz)

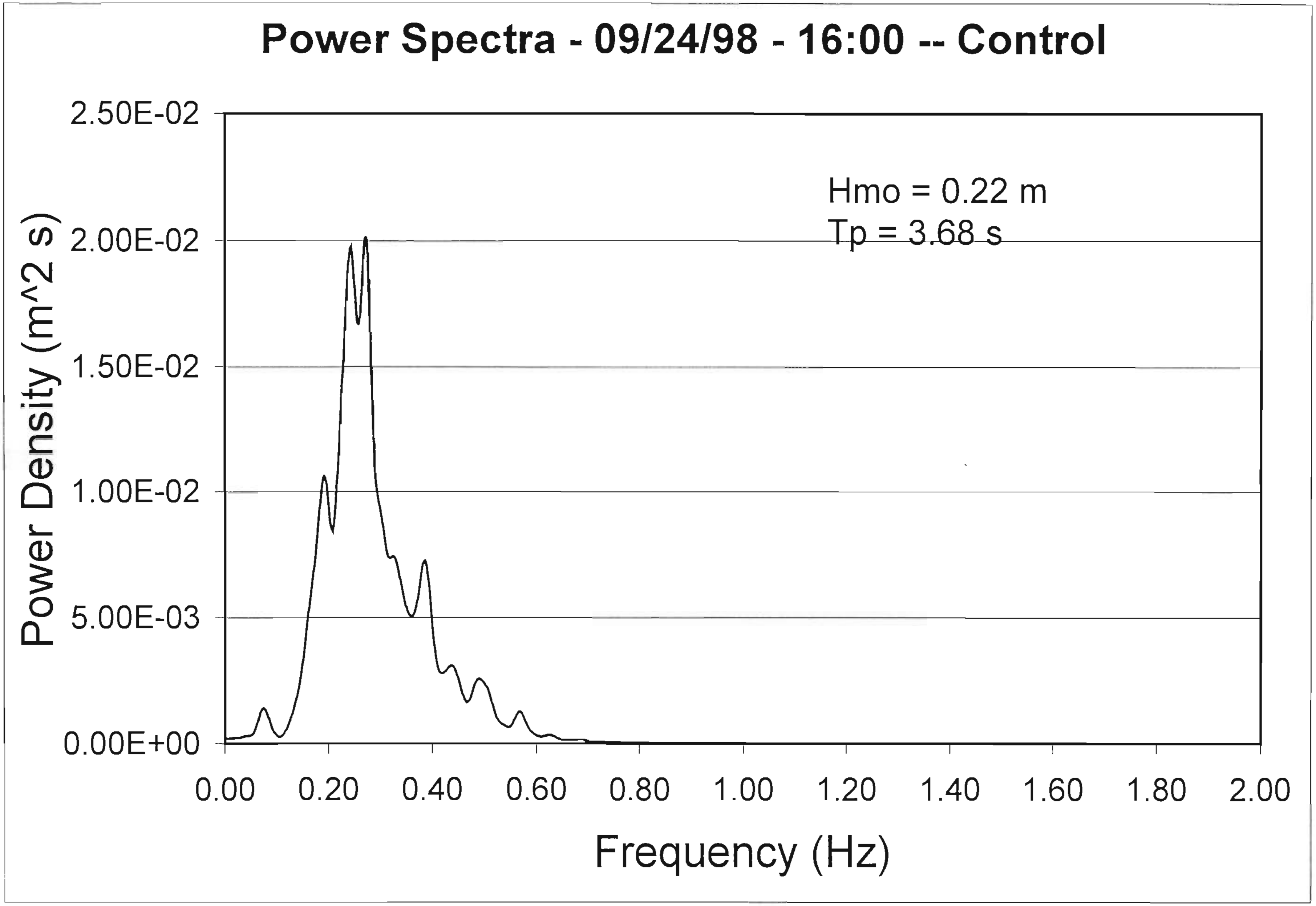

Power Spectra - 09/24/98 - 15:10 -- Control
Hmo = 0.21 m
Tp = 3.91 s
Power Density (m^2 s)
1.80E-02
1.60E-02
1.40E-02
1.20E-02
1.00E-02
8.00E-03
6.00E-03
4.00E-03
2.00E-03
0.00E+00
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1.80
2.00
Frequency (Hz)


Power Spectra - 09/24/98 - 15:20 -- Control
Hmo = 0.21 m
Tp = 4.30 s
Power Density (m^2 s)
1.60E-02
1.40E-02
1.20E-02
1.00E-02
8.00E-03
6.00E-03
4.00E-03
2.00E-03
0.00E+00
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1.80
2.00
Frequency (Hz)

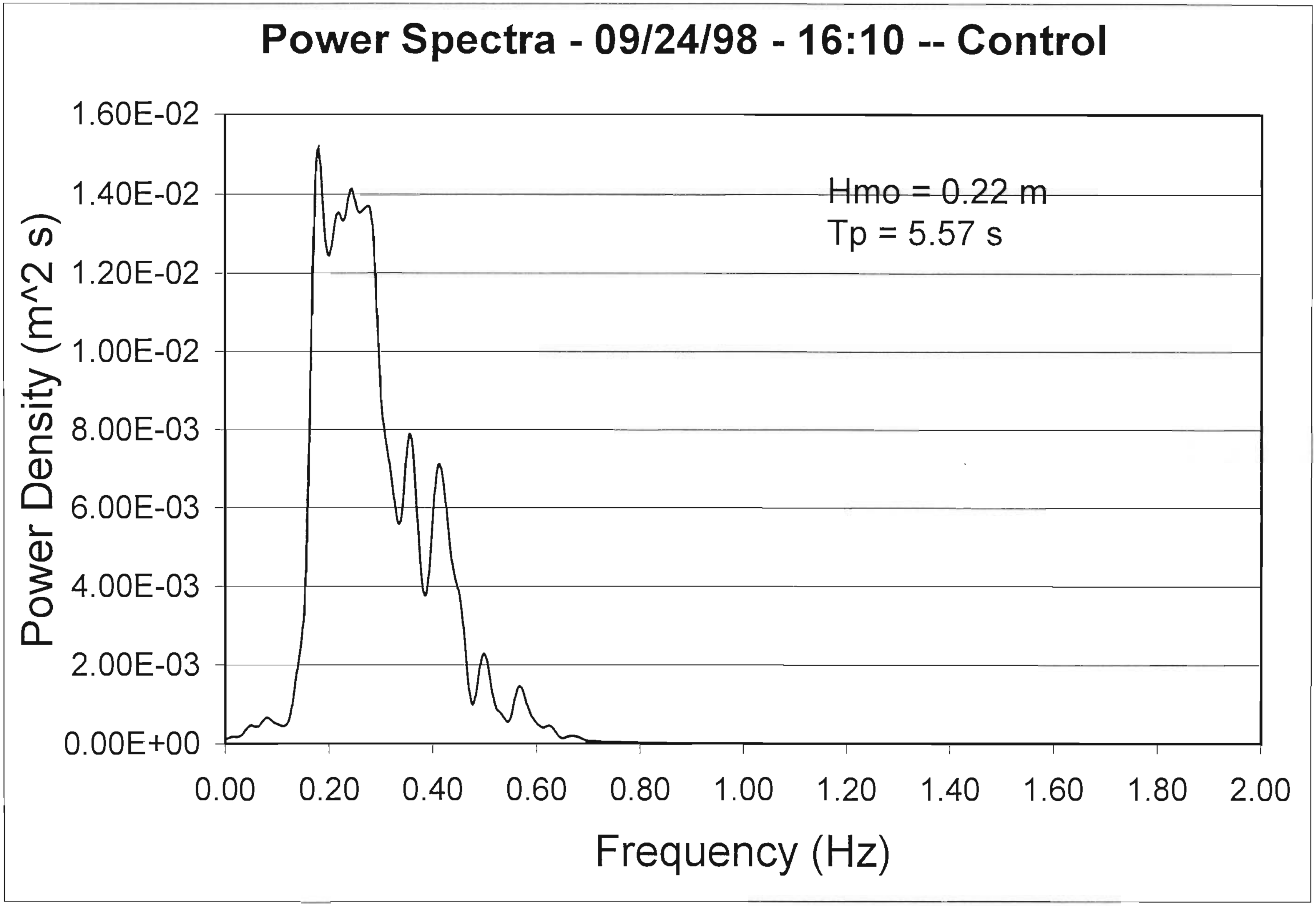

Power Spectra - 09/24/98 - 15:30 -- Control
Hmo = 0.23 m
Tp = 4.10 s
Power Density (m^2 s)
2.50E-02
2.00E-02
1.50E-02
1.00E-02
5.00E-03
0.00E+00
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1.80
2.00
Frequency (Hz)

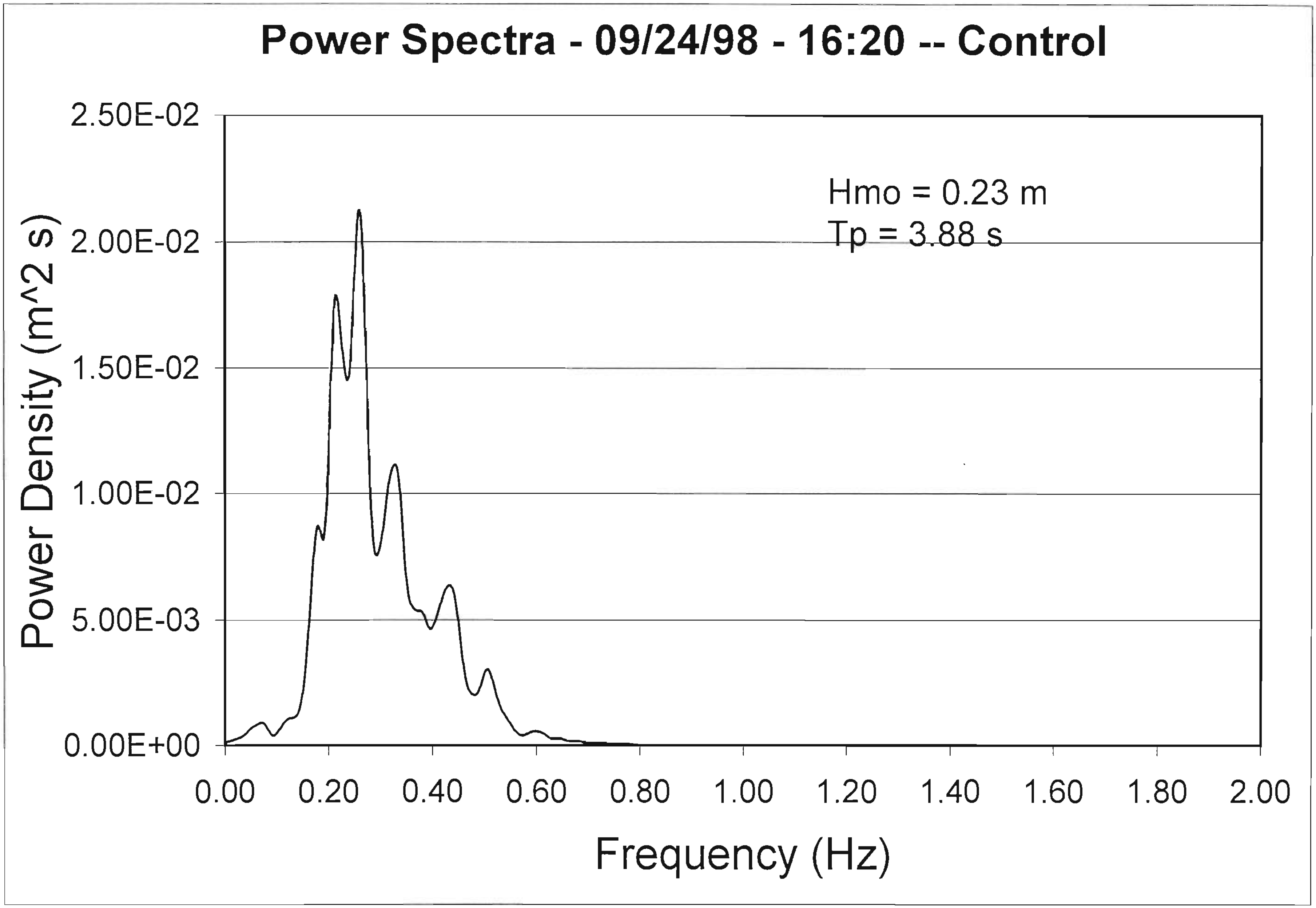

Power Spectra - 09/24/98 - 15:40 -- Control
Hmo = 0.23 m
Tp = 3.94 s
Power Density (m^2 s)
3.50E-02
3.00E-02
2.50E-02
2.00E-02
1.50E-02
1.00E-02
5.00E-03
0.00E+00
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1.80
2.00
Frequency (Hz)


Power Spectra - 09/24/98 - 15:50 -- Control
Hmo = 0.23 m
Tp = 4.13 s
Power Density (m^2 s)
2.50E-02
2.00E-02
1.50E-02
1.00E-02
5.00E-03
0.00E+00
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1.80
2.00
Frequency (Hz)

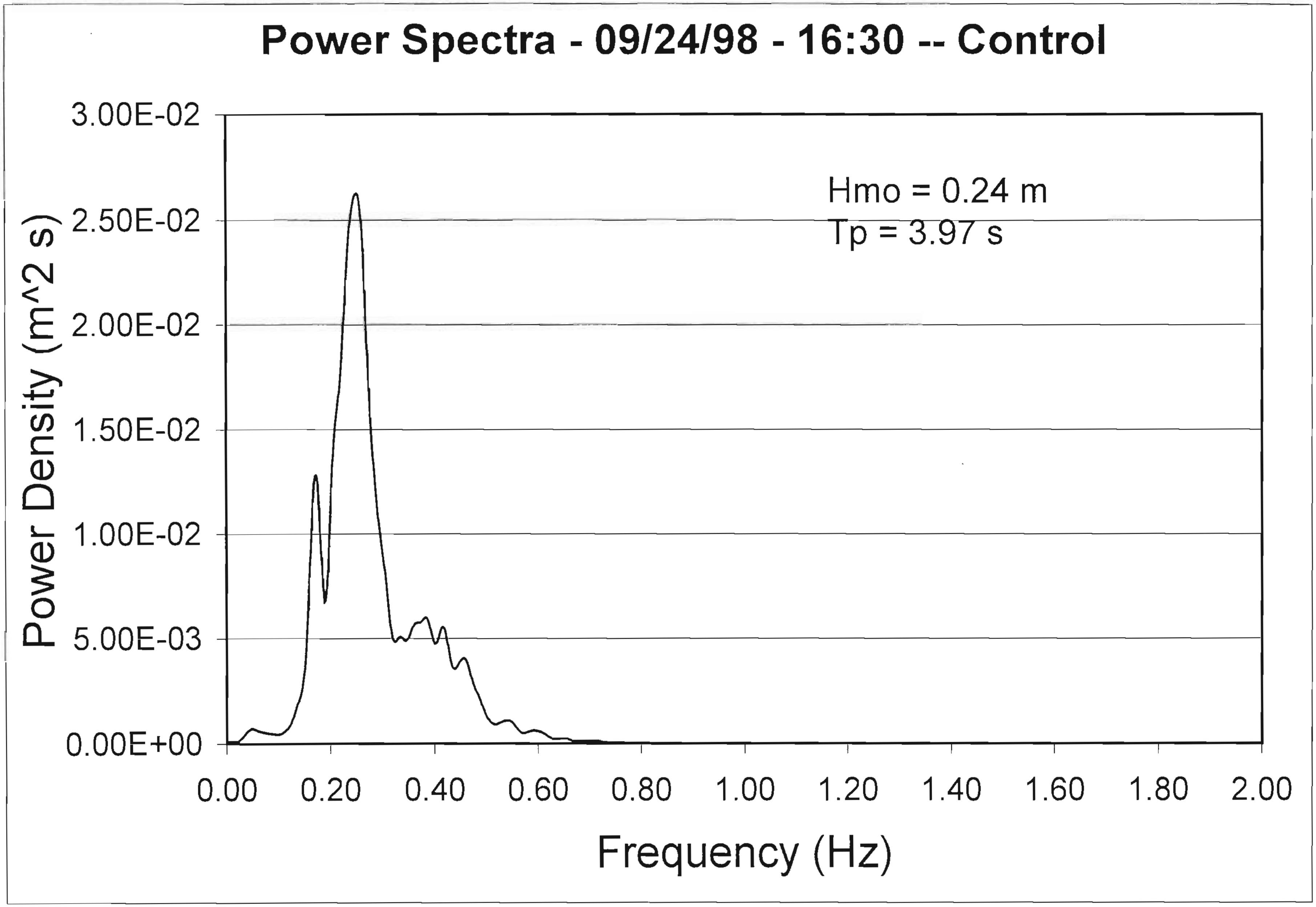


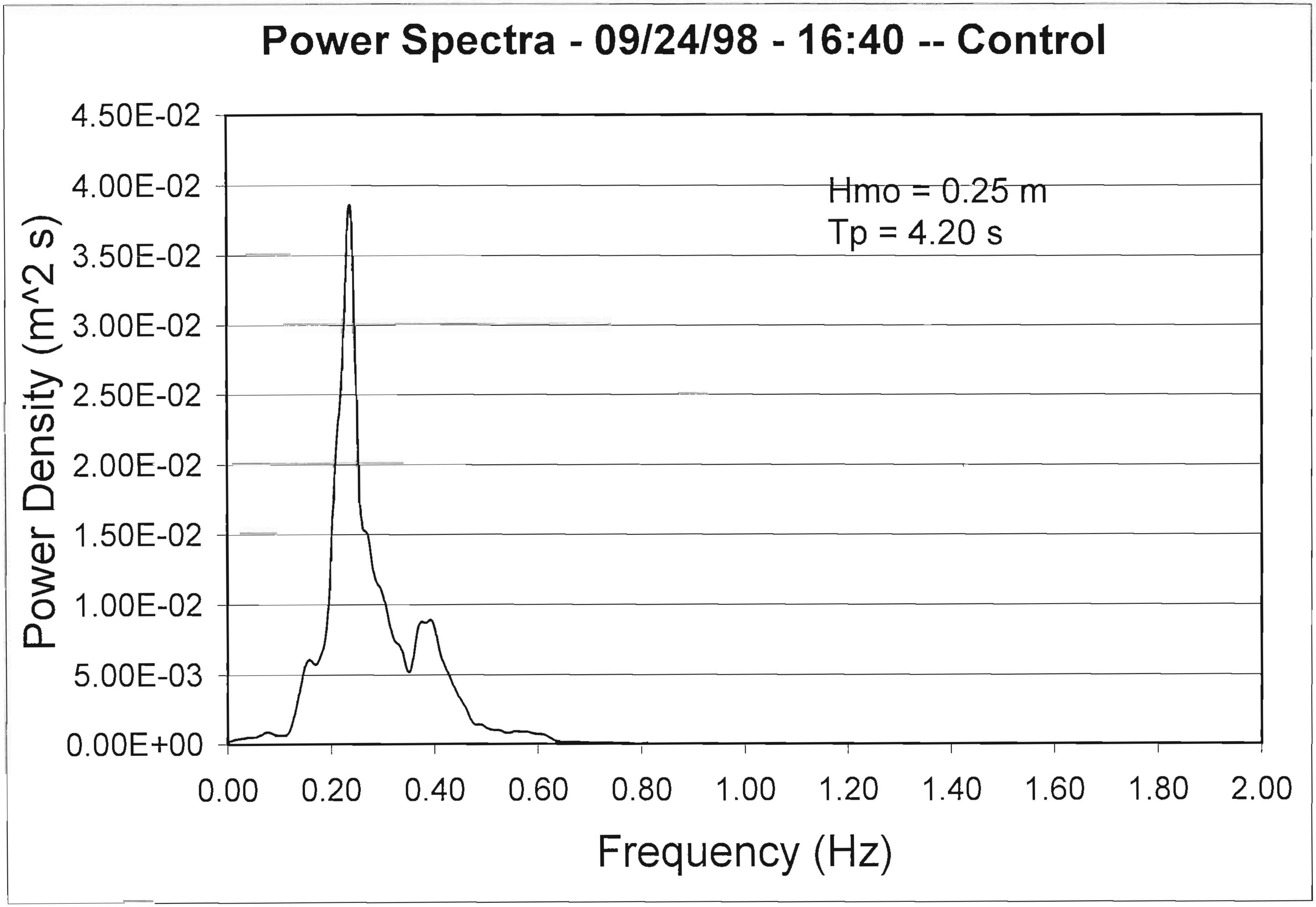
Power Spectra - 09/24/98 - 16:00 -- Control
Hmo = 0.22 m
Tp = 3.68 s
Power Density (m^2 s)
2.50E-02
2.00E-02
1.50E-02
1.00E-02
5.00E-03
0.00E+00
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1.80
2.00
Frequency (Hz)


Power Spectra - 09/24/98 - 16:10 -- Control
Hmo = 0.22 m
Tp = 5.57 s
Power Density (m^2 s)
1.60E-02
1.40E-02
1.20E-02
1.00E-02
8.00E-03
6.00E-03
4.00E-03
2.00E-03
0.00E+00
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1.80
2.00
Frequency (Hz)

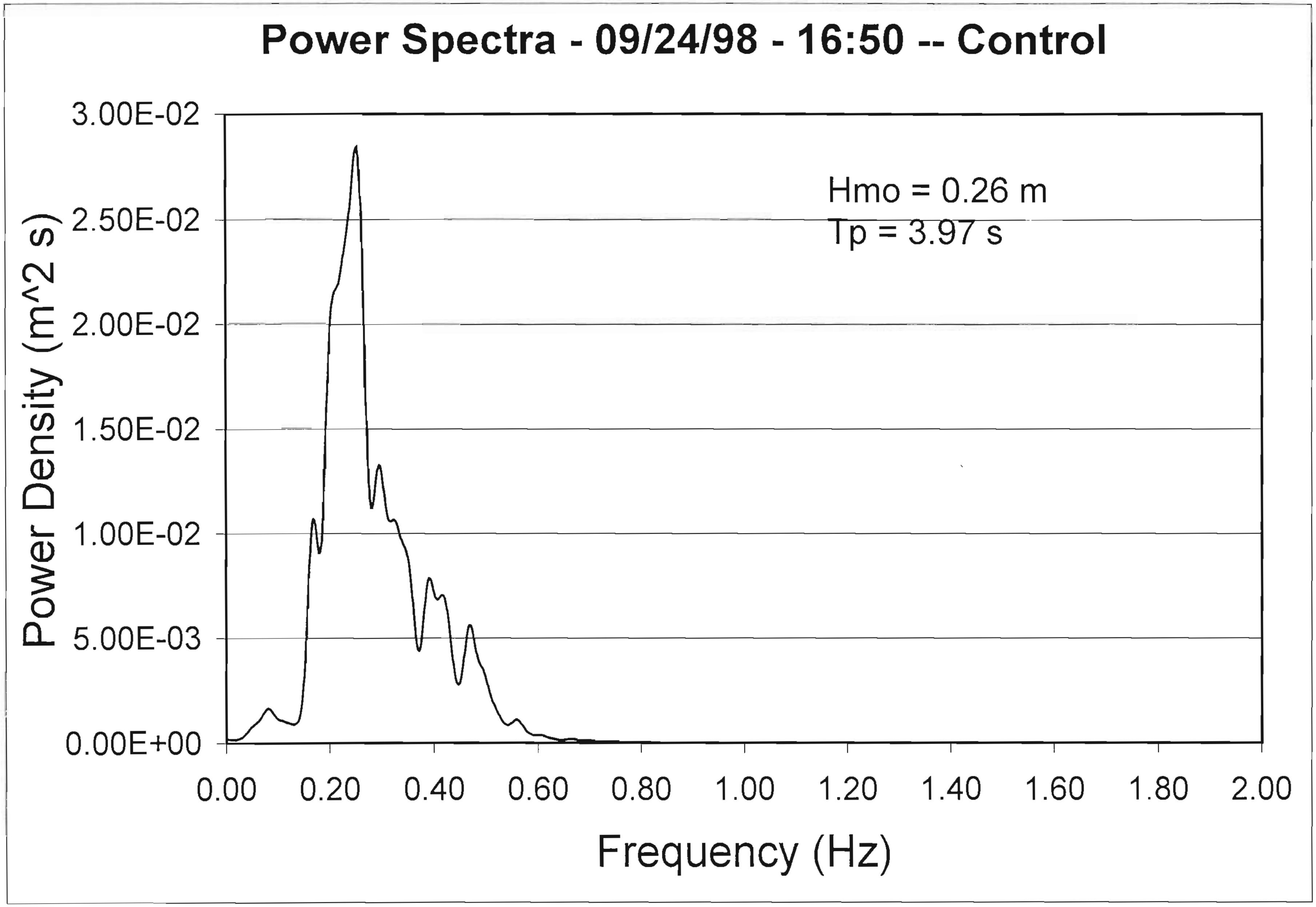


Power Spectra - 09/24/98 - 16:20 -- Control
Hmo = 0.23 m
Tp = 3.88 s
Power Density (m^2 s)
2.50E-02
2.00E-02
1.50E-02
1.00E-02
5.00E-03
0.00E+00
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1.80
2.00
Frequency (Hz)

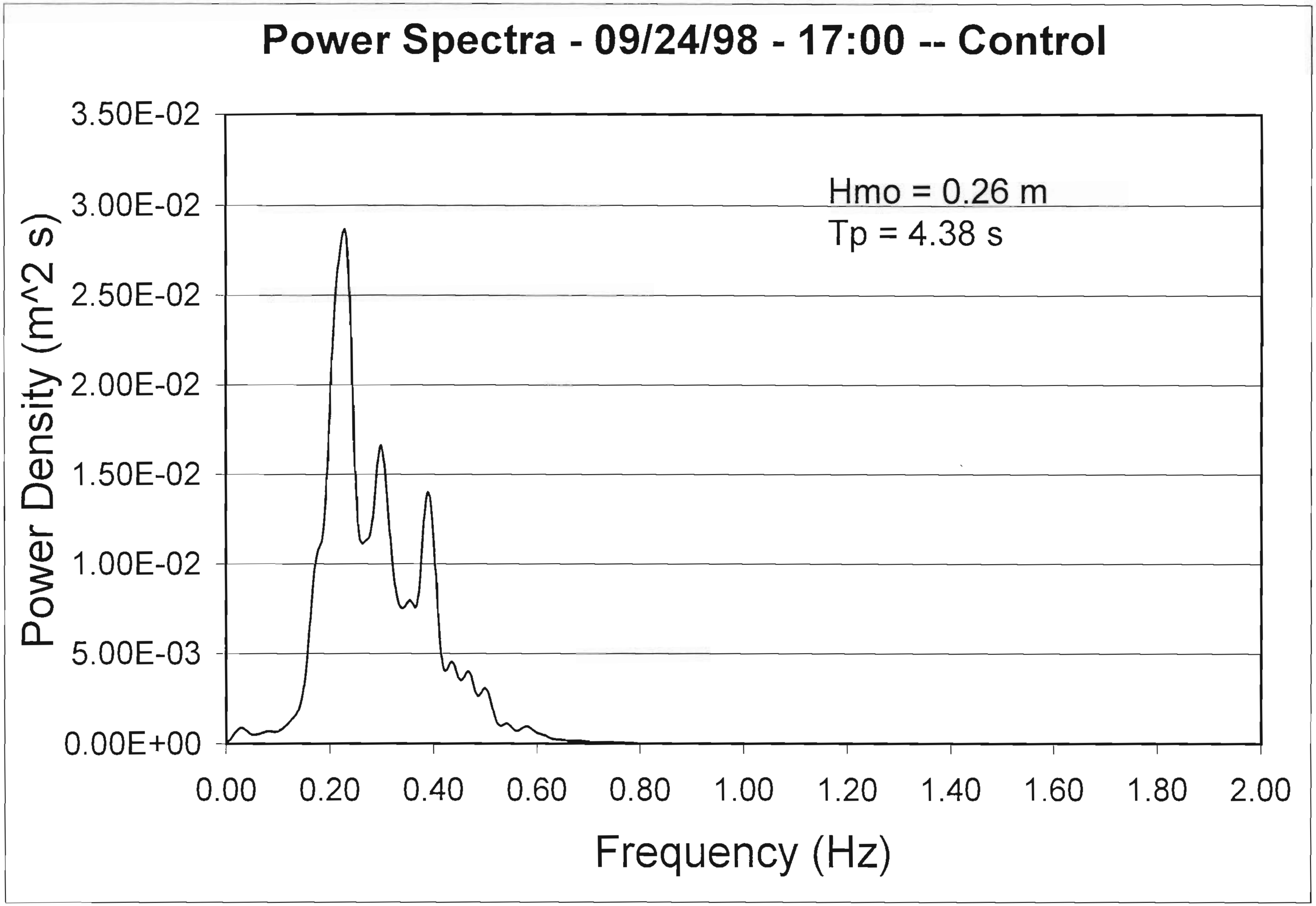

Power Spectra - 09/24/98 - 16:30 -- Control
Hmo = 0.24 m
Tp = 3.97 s
Power Density (m^2 s)
3.00E-02
2.50E-02
2.00E-02
1.50E-02
1.00E-02
5.00E-03
0.00E+00
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1.80
2.00
Frequency (Hz)

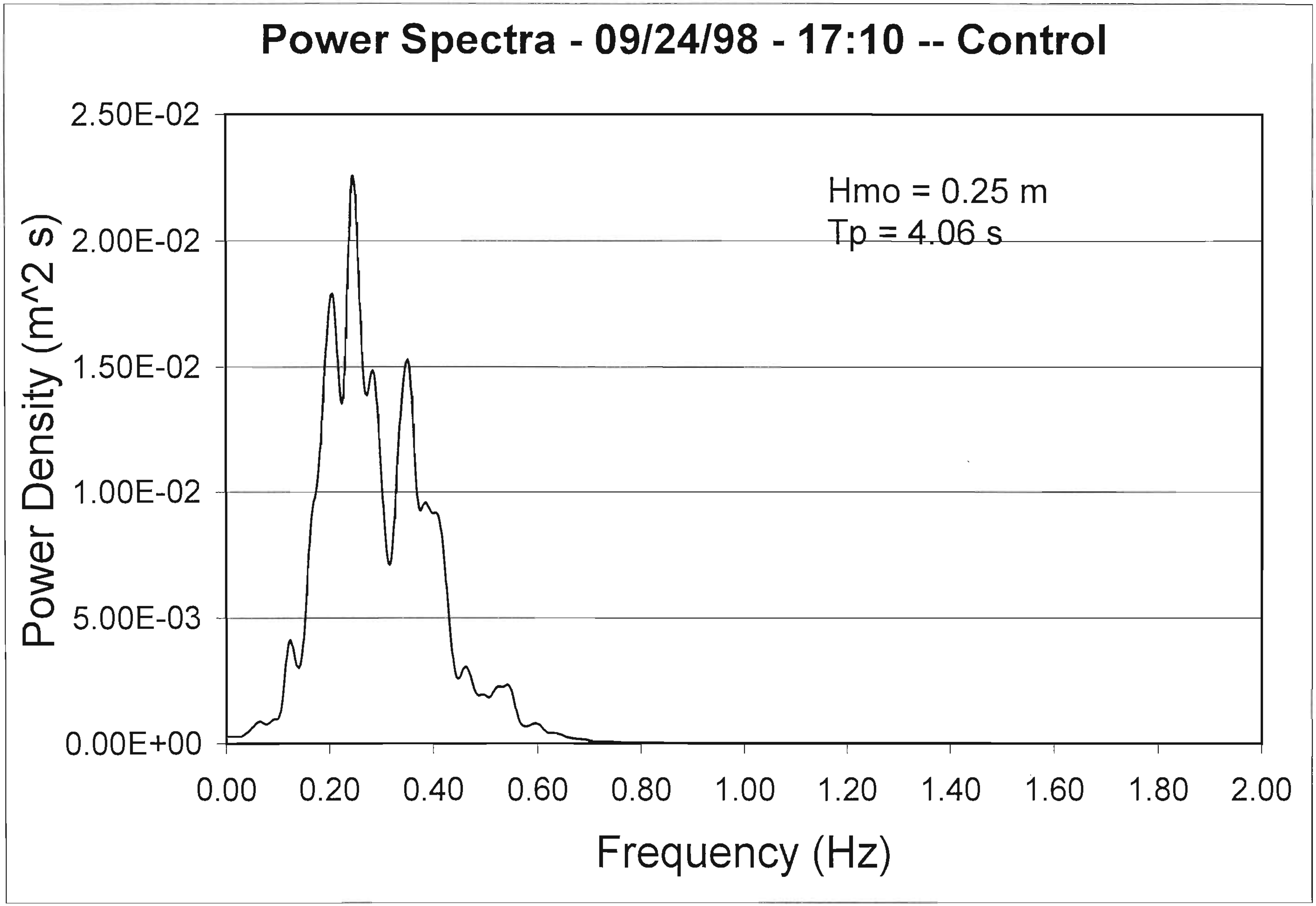


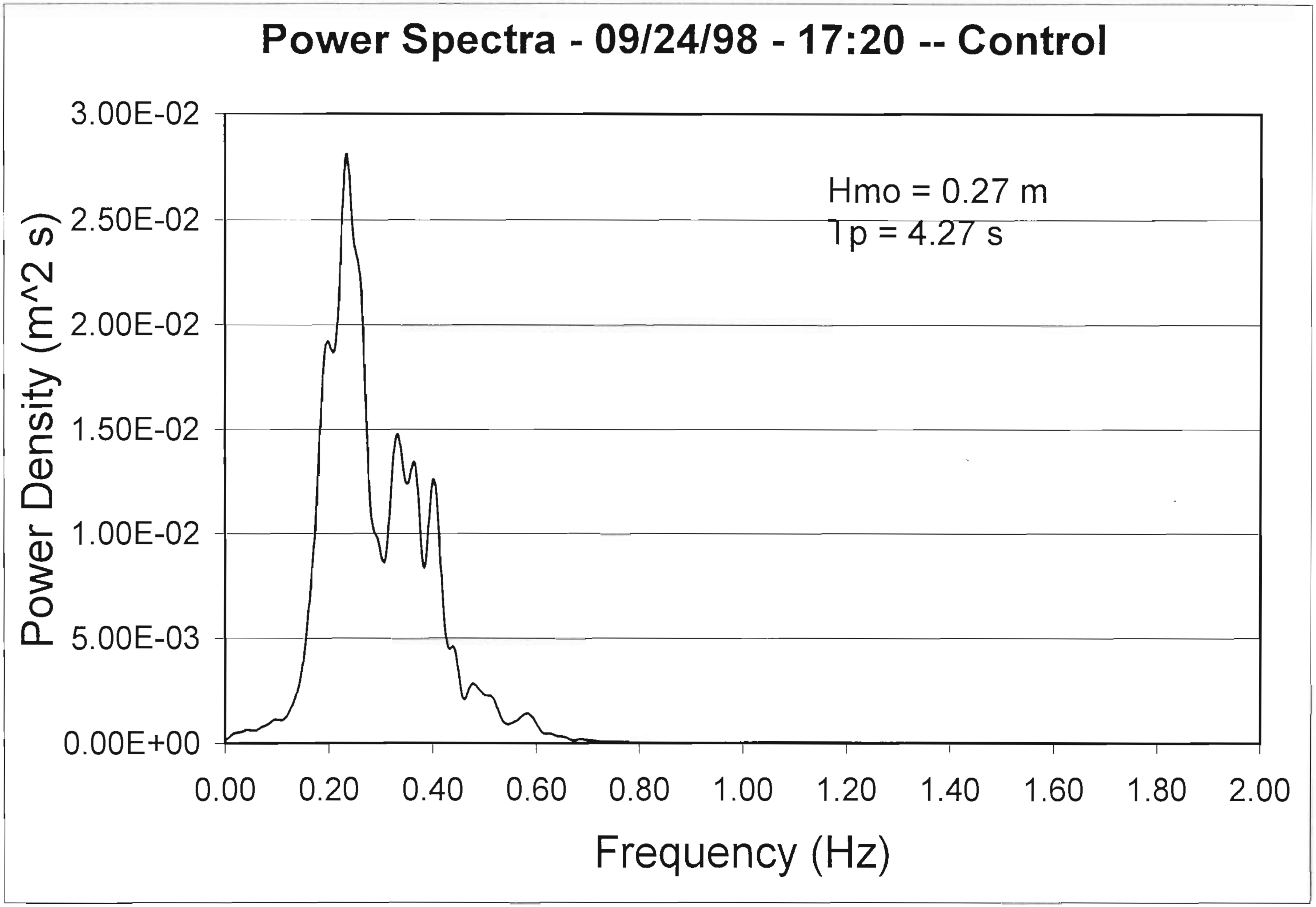
Power Spectra - 09/24/98 - 16:40 -- Control
Hmo = 0.25 m
Tp = 4.20 s
4.50E-02
4.00E-02
3.50E-02
3.00E-02
2.50E-02
2.00E-02
1.50E-02
1.00E-02
5.00E-03
0.00E+00
Power Density (m^2 s)
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1.80
2.00
Frequency (Hz)

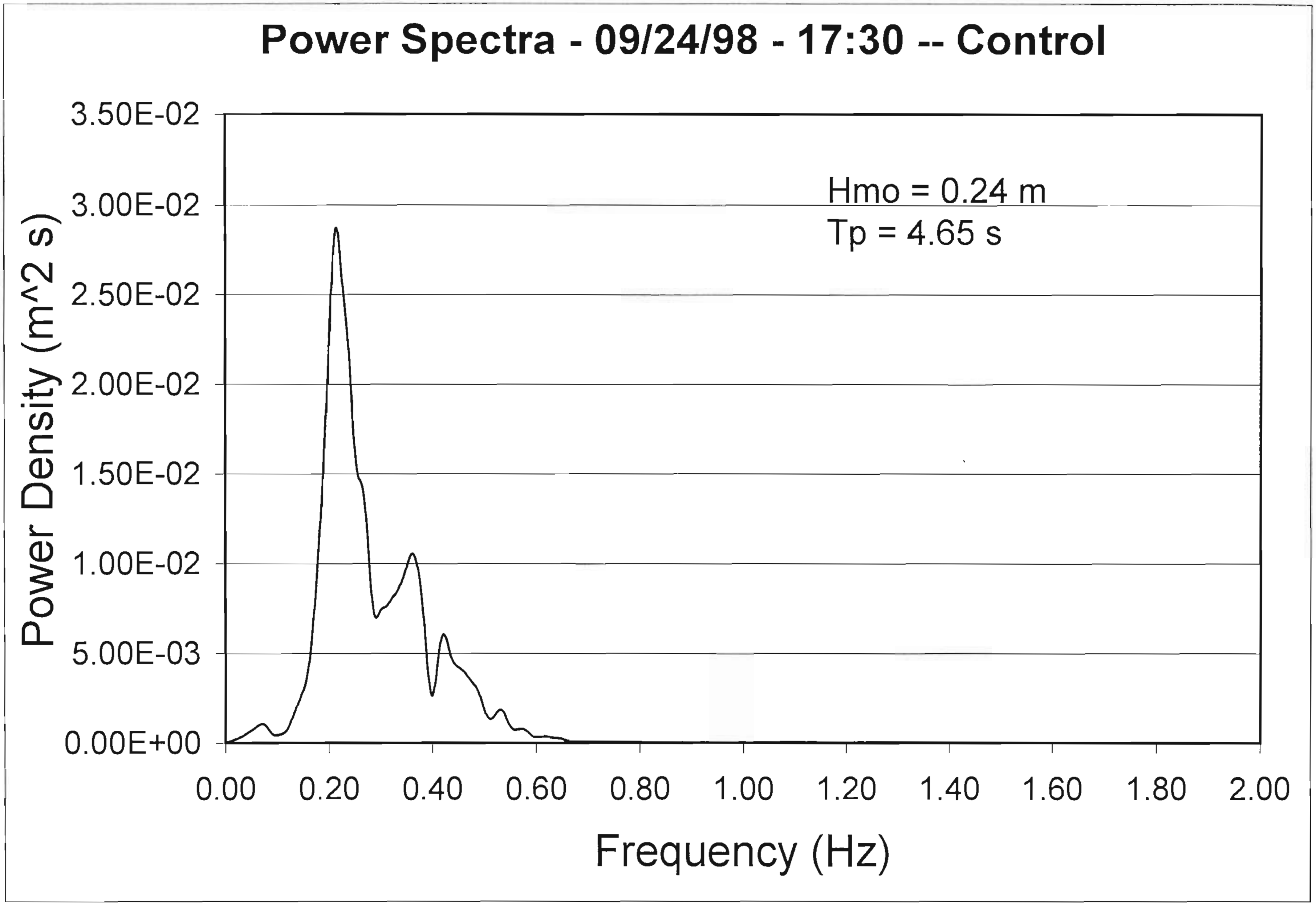


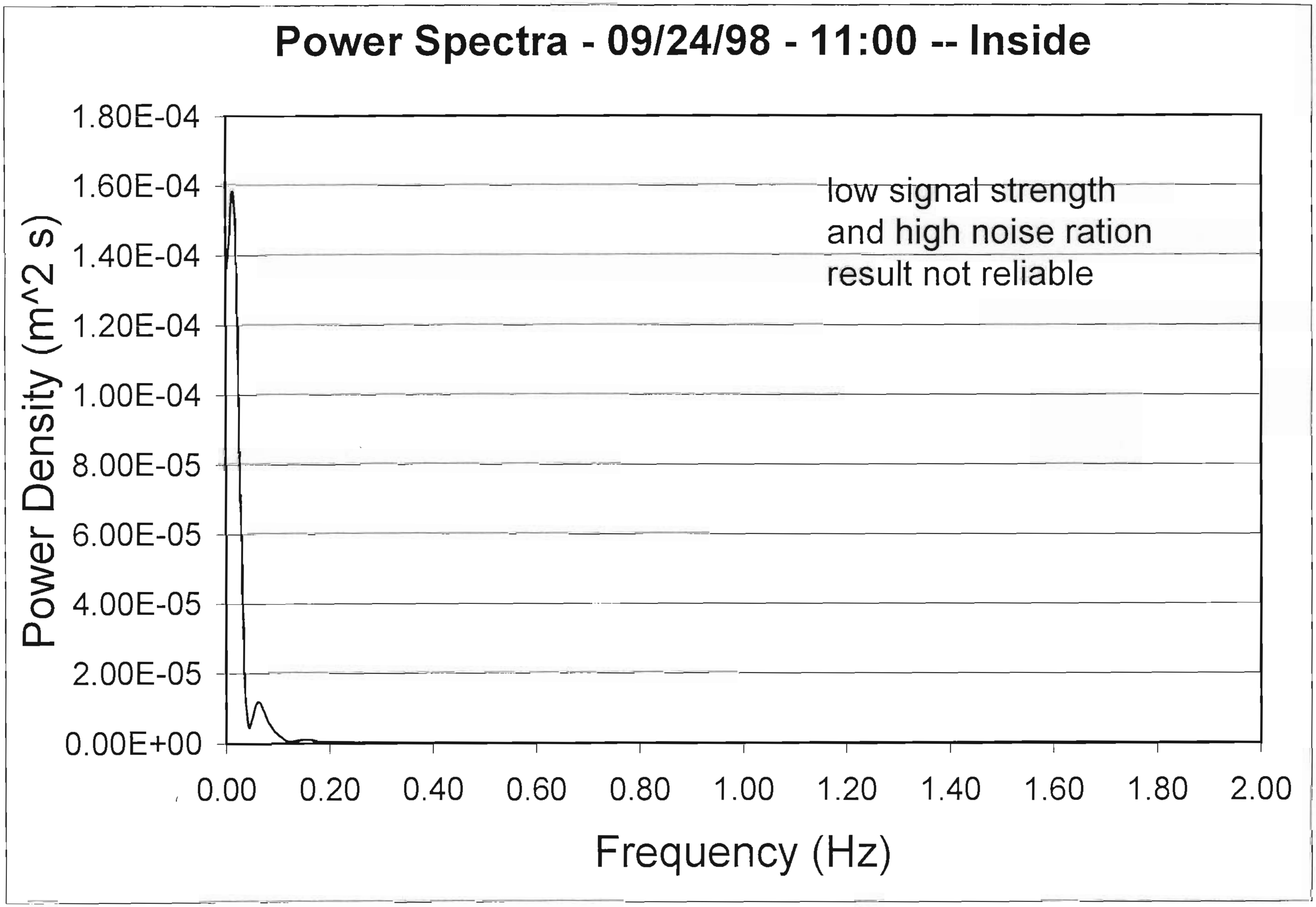
Power Spectra - 09/24/98 - 16:50 -- Control
Hmo = 0.26 m
Tp = 3.97 s
Power Density (m^2 s)
3.00E-02
2.50E-02
2.00E-02
1.50E-02
1.00E-02
5.00E-03
0.00E+00
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1.80
2.00
Frequency (Hz)

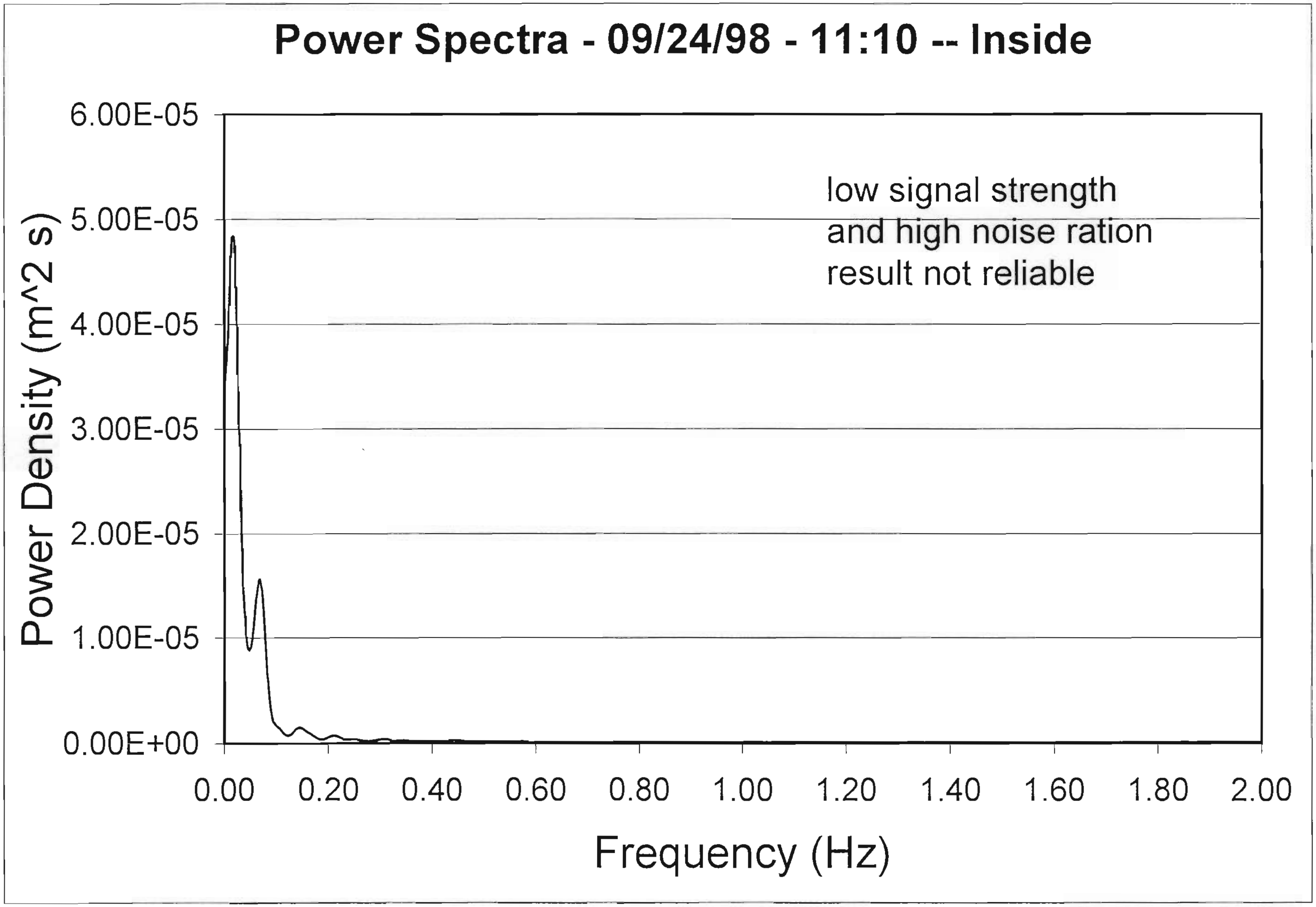

Power Spectra - 09/24/98 - 17:00 -- Control
Hmo = 0.26 m
Tp = 4.38 s
Power Density (m^2 s)
3.50E-02
3.00E-02
2.50E-02
2.00E-02
1.50E-02
1.00E-02
5.00E-03
0.00E+00
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1.80
2.00
Frequency (Hz)


Power Spectra - 09/24/98 - 17:10 -- Control
Hmo = 0.25 m
Tp = 4.06 s
Power Density (m^2 s)
2.50E-02
2.00E-02
1.50E-02
1.00E-02
5.00E-03
0.00E+00
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1.80
2.00
Frequency (Hz)

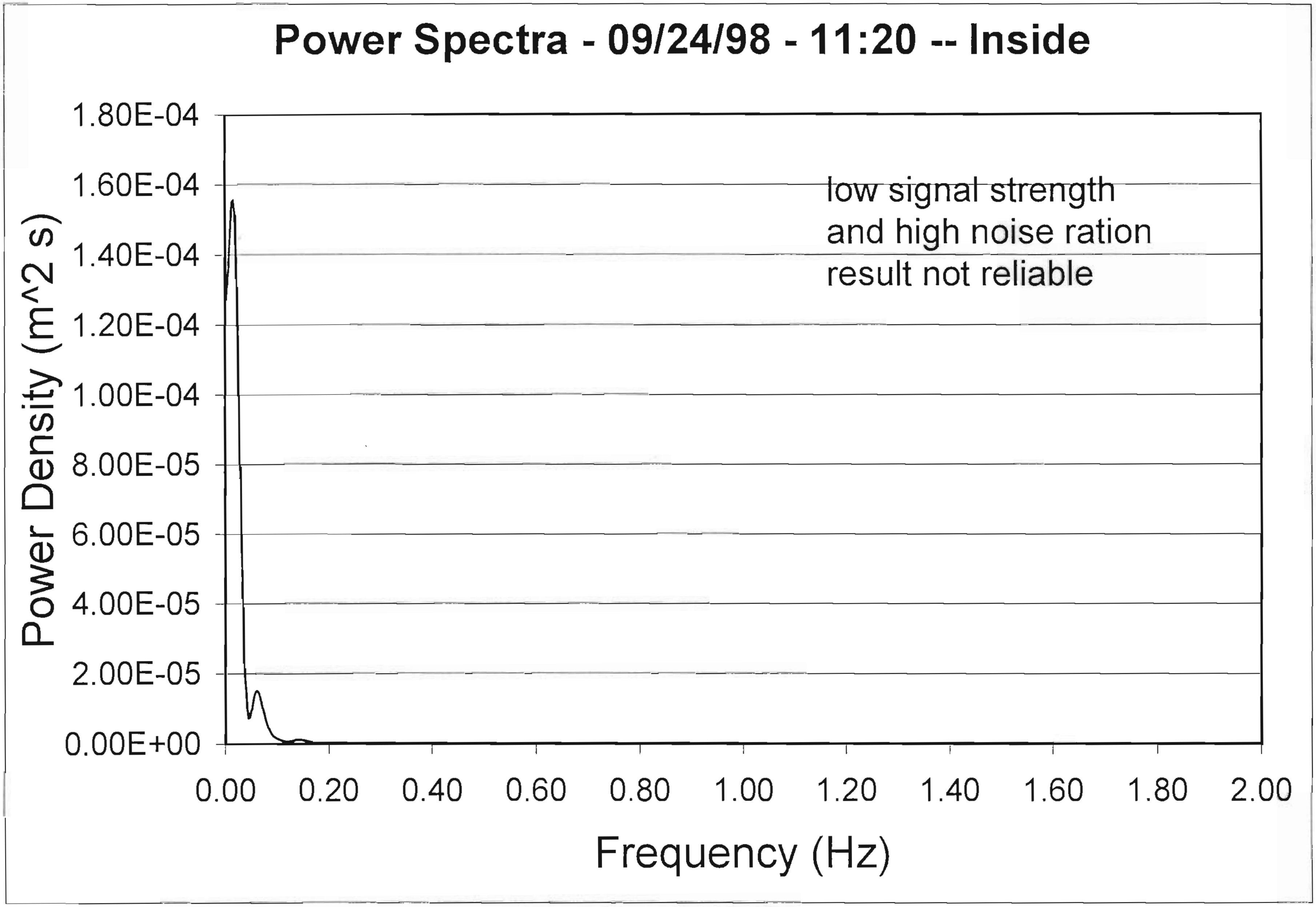

Power Spectra - 09/24/98 - 17:20 -- Control
Hmo = 0.27 m
Tp = 4.27 s
Power Density (m^2 s)
3.00E-02
2.50E-02
2.00E-02
1.50E-02
1.00E-02
5.00E-03
0.00E+00
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1.80
2.00
Frequency (Hz)

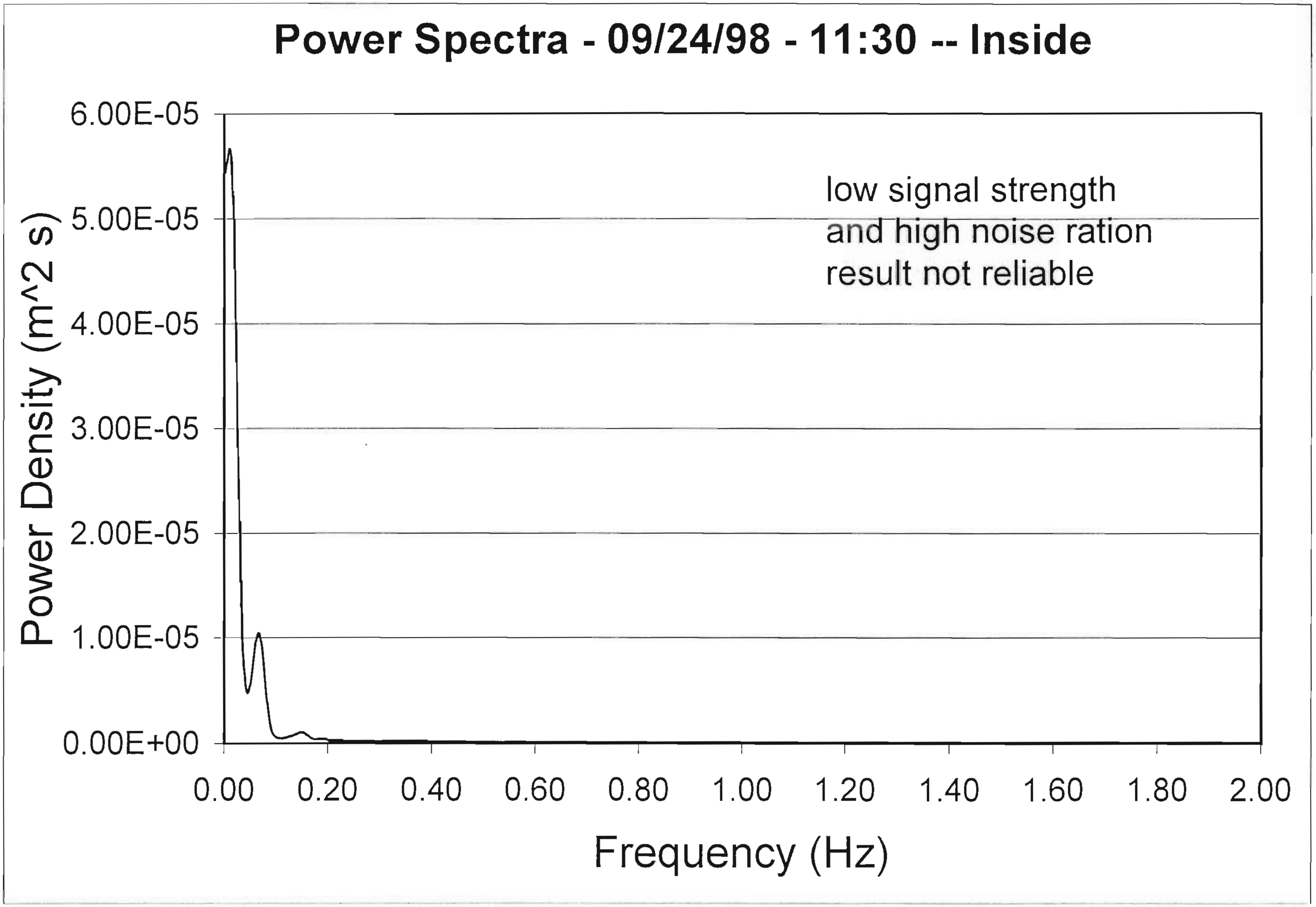

Power Spectra - 09/24/98 - 17:30 -- Control
Hmo = 0.24 m
Tp = 4.65 s
Power Density (m^2 s)
3.50E-02
3.00E-02
2.50E-02
2.00E-02
1.50E-02
1.00E-02
5.00E-03
0.00E+00
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1.80
2.00
Frequency (Hz)

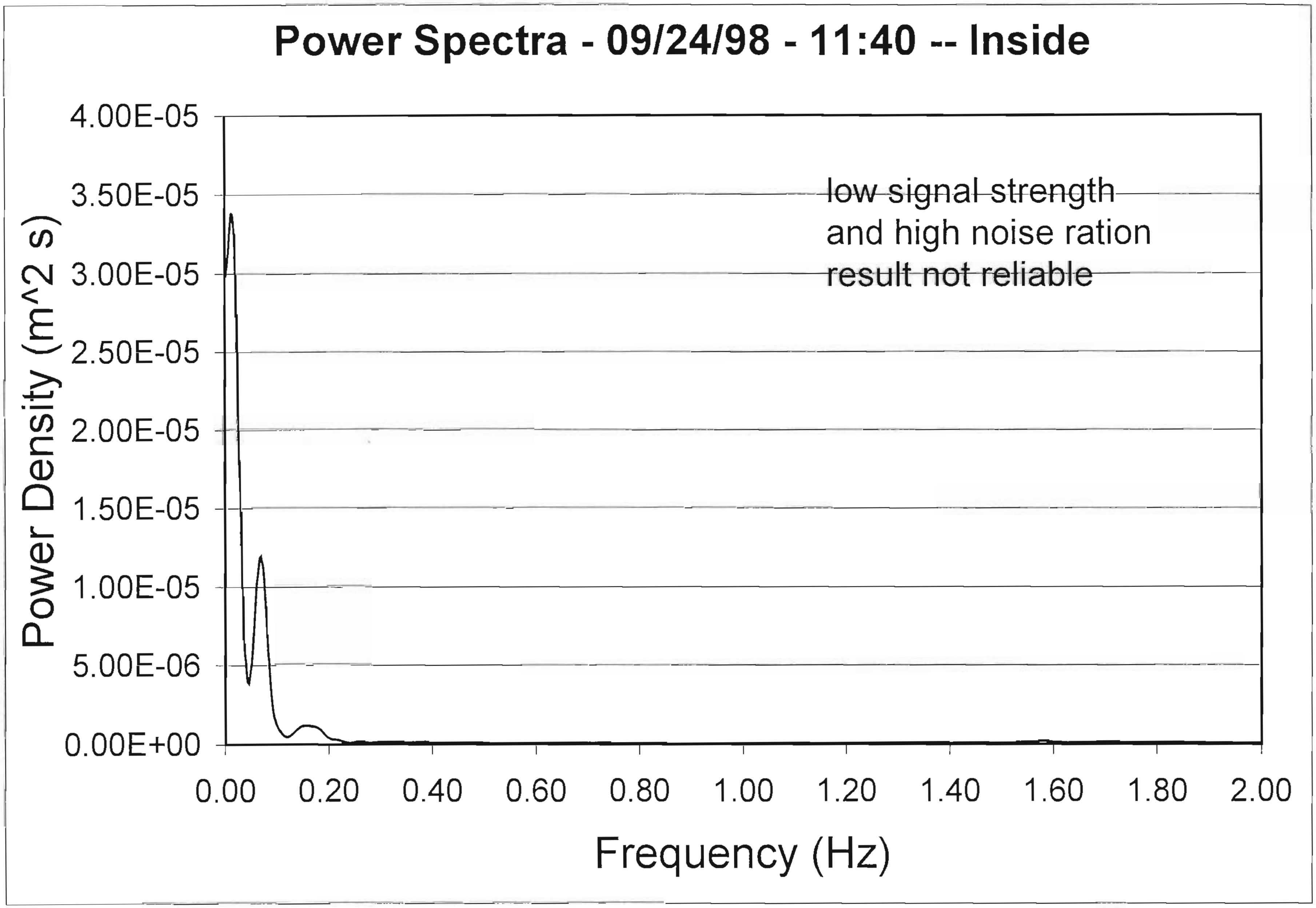

Power Spectra - 09/24/98 - 11:00 -- Inside
low signal strength
and high noise ration
result not reliable
Power Density (m^2 s)
1.80E-04
1.60E-04
1.40E-04
1.20E-04
1.00E-04
8.00E-05
6.00E-05
4.00E-05
2.00E-05
0.00E+00
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1.80
2.00
Frequency (Hz)

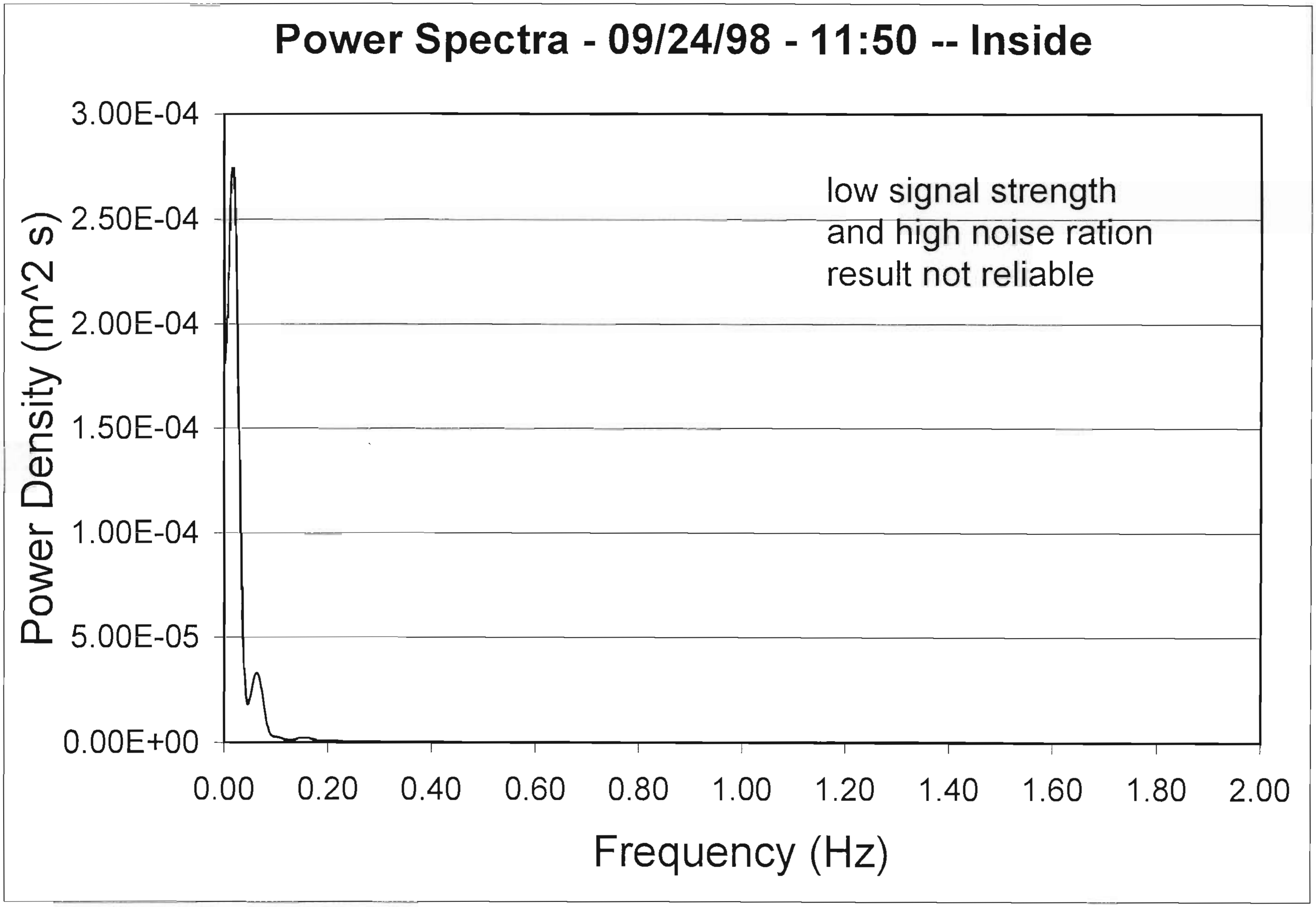


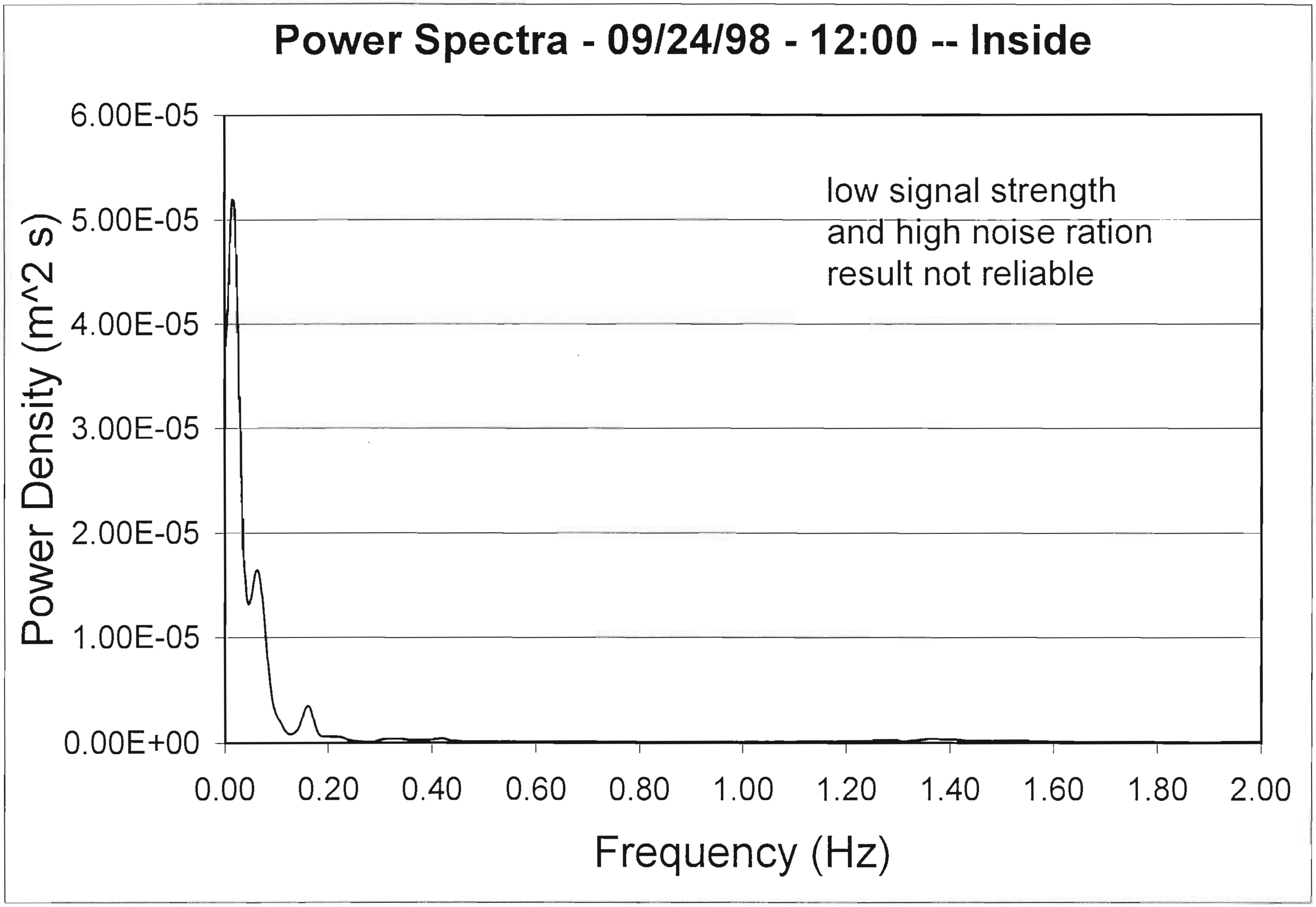
Power Spectra - 09/24/98 - 11:10 -- Inside
6.00E-05
5.00E-05
4.00E-05
3.00E-05
2.00E-05
1.00E-05
0.00E+00
Power Density (m^2 s)
low signal strength
and high noise ration
result not reliable
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1.80
2.00
Frequency (Hz)

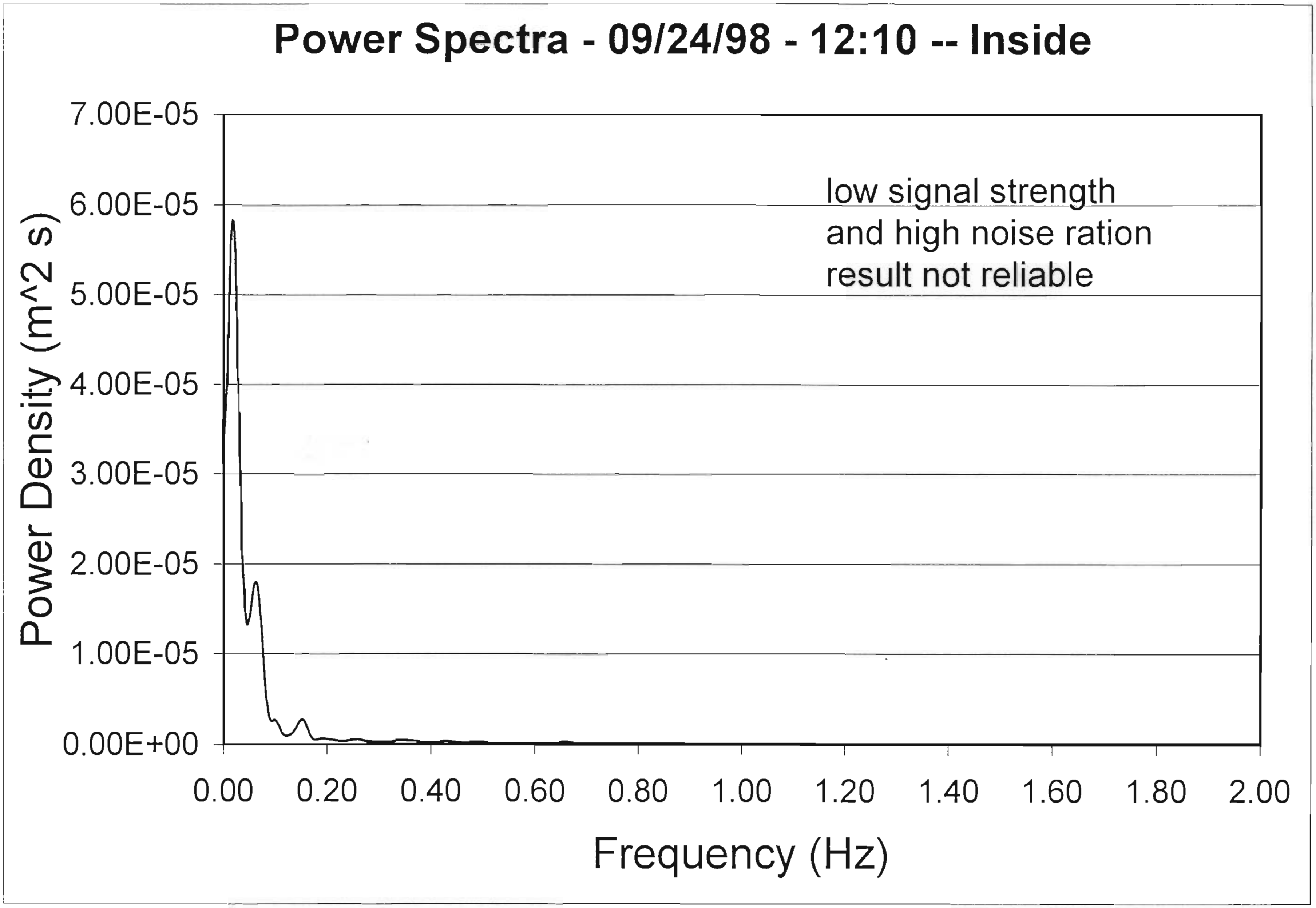

Power Spectra - 09/24/98 - 11:20 -- Inside
low signal strength
and high noise ration
result not reliable
Power Density (m^2 s)
1.80E-04
1.60E-04
1.40E-04
1.20E-04
1.00E-04
8.00E-05
6.00E-05
4.00E-05
2.00E-05
0.00E+00
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1.80
2.00
Frequency (Hz)

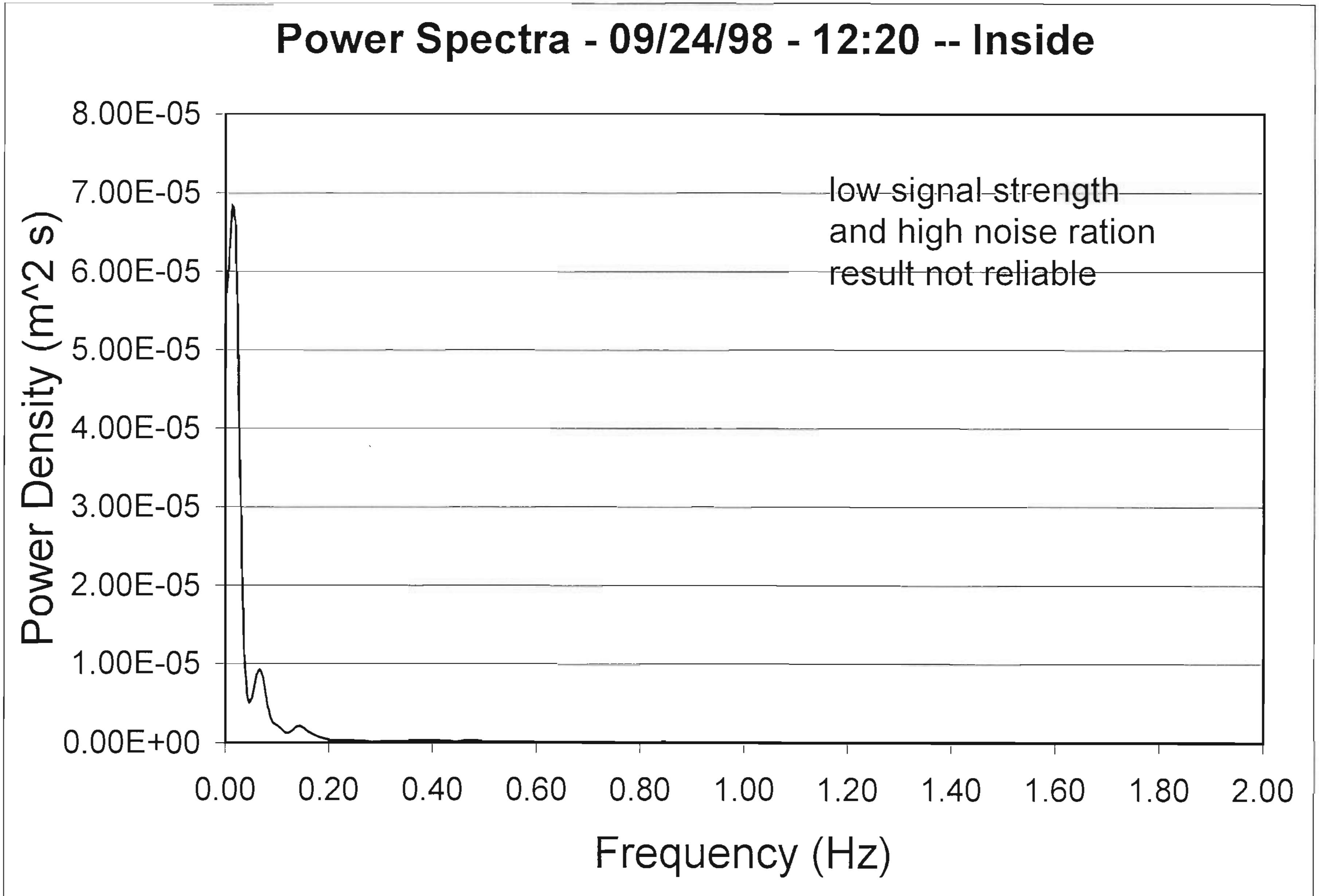

Power Spectra - 09/24/98 - 11:30 -- Inside
low signal strength
and high noise ration
result not reliable
Power Density (m^2 s)
6.00E-05
5.00E-05
4.00E-05
3.00E-05
2.00E-05
1.00E-05
0.00E+00
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1.80
2.00
Frequency (Hz)

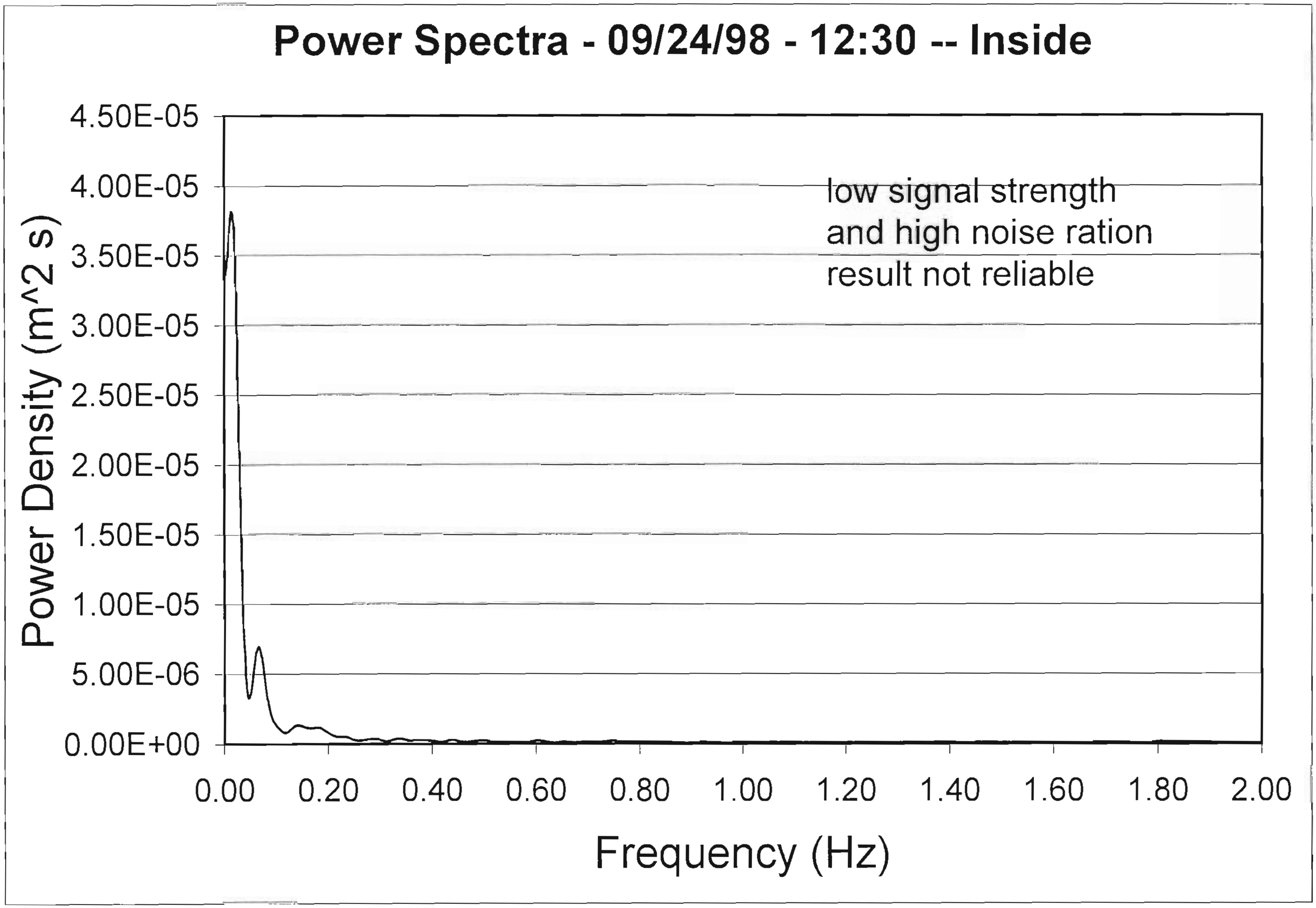

Power Spectra - 09/24/98 - 11:40 -- Inside
low signal strength
and high noise ration
result not reliable
4.00E-05
3.50E-05
3.00E-05
2.50E-05
2.00E-05
1.50E-05
1.00E-05
5.00E-06
0.00E+00
Power Density (m^2 s)
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1.80
2.00
Frequency (Hz)

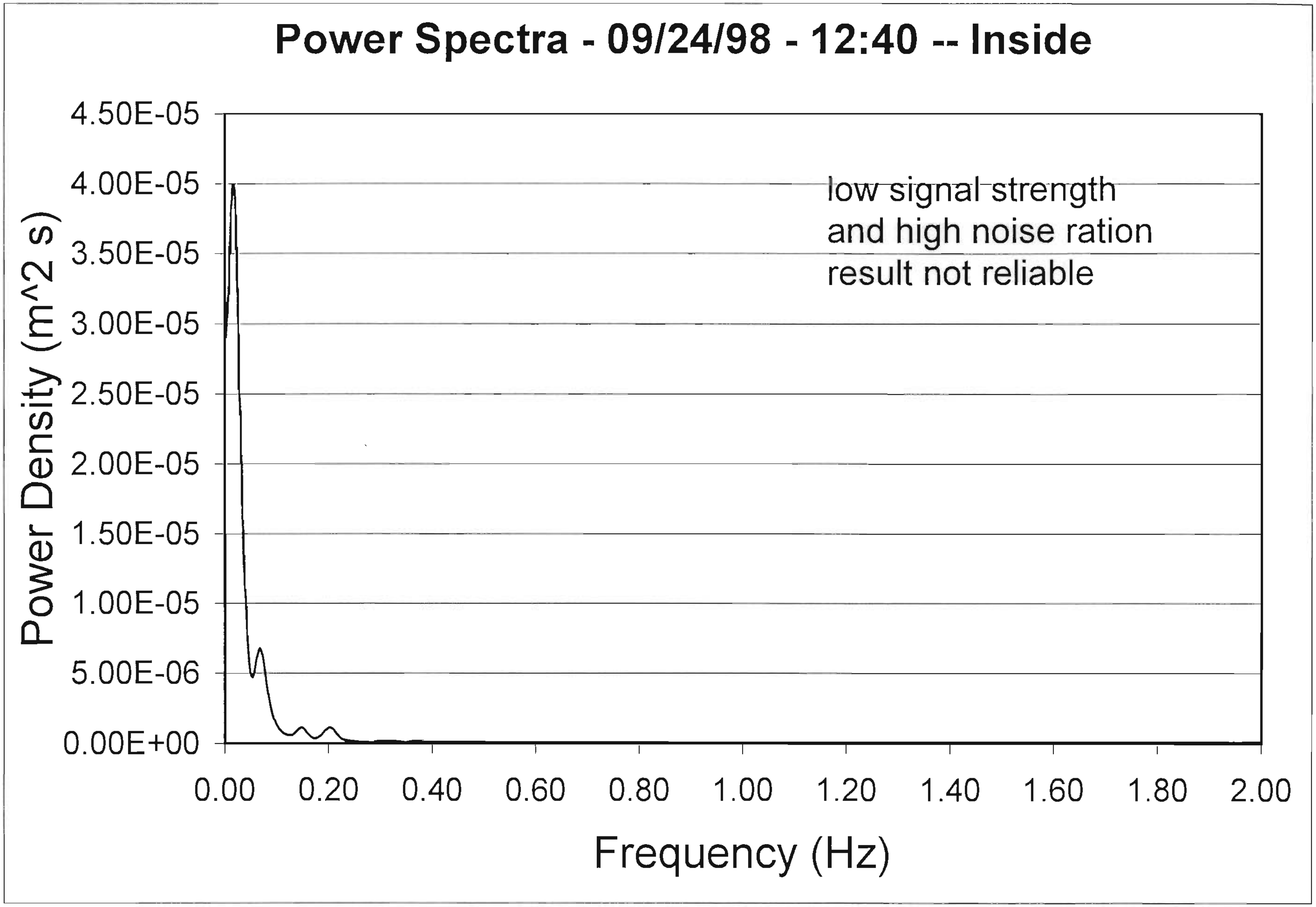

Power Spectra - 09/24/98 - 11:50 -- Inside
low signal strength
and high noise ration
result not reliable
Power Density (m^2 s)
3.00E-04
2.50E-04
2.00E-04
1.50E-04
1.00E-04
5.00E-05
0.00E+00
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1.80
2.00
Frequency (Hz)


Power Spectra - 09/24/98 - 12:00 -- Inside
6.00E-05
5.00E-05
4.00E-05
3.00E-05
2.00E-05
1.00E-05
0.00E+00
Power Density (m^2 s)
low signal strength
and high noise ration
result not reliable
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1.80
2.00
Frequency (Hz)

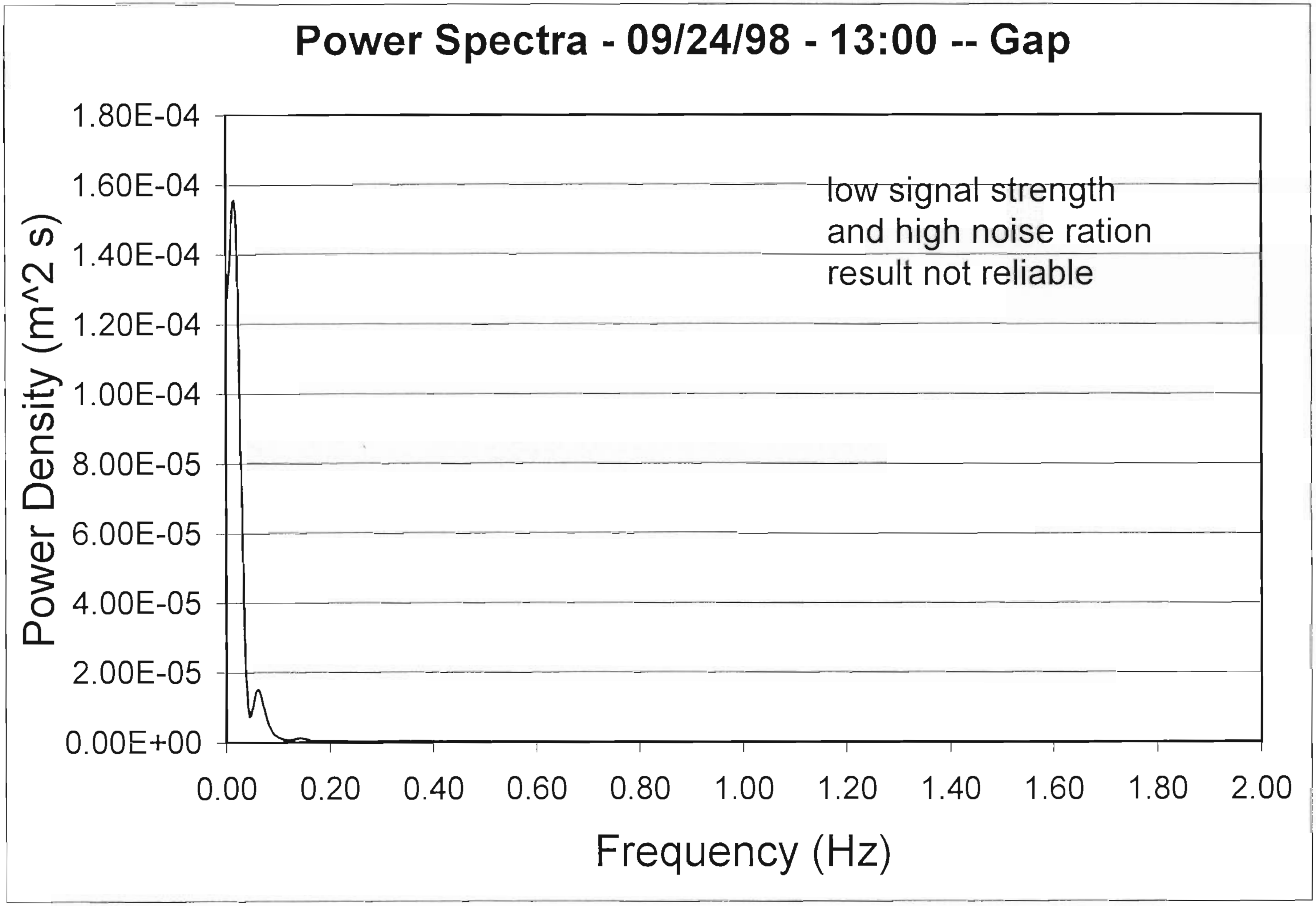

Power Spectra - 09/24/98 - 12:10 -- Inside
low signal strength
and high noise ration
result not reliable
Power Density (m^2 s)
7.00E-05
6.00E-05
5.00E-05
4.00E-05
3.00E-05
2.00E-05
1.00E-05
0.00E+00
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1.80
2.00
Frequency (Hz)


Power Spectra - 09/24/98 - 12:20 -- Inside
Power Density (m^2 s)
8.00E-05
7.00E-05
6.00E-05
5.00E-05
4.00E-05
3.00E-05
2.00E-05
1.00E-05
0.00E+00
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1.80
2.00
Frequency (Hz)
low signal strength
and high noise ration
result not reliable

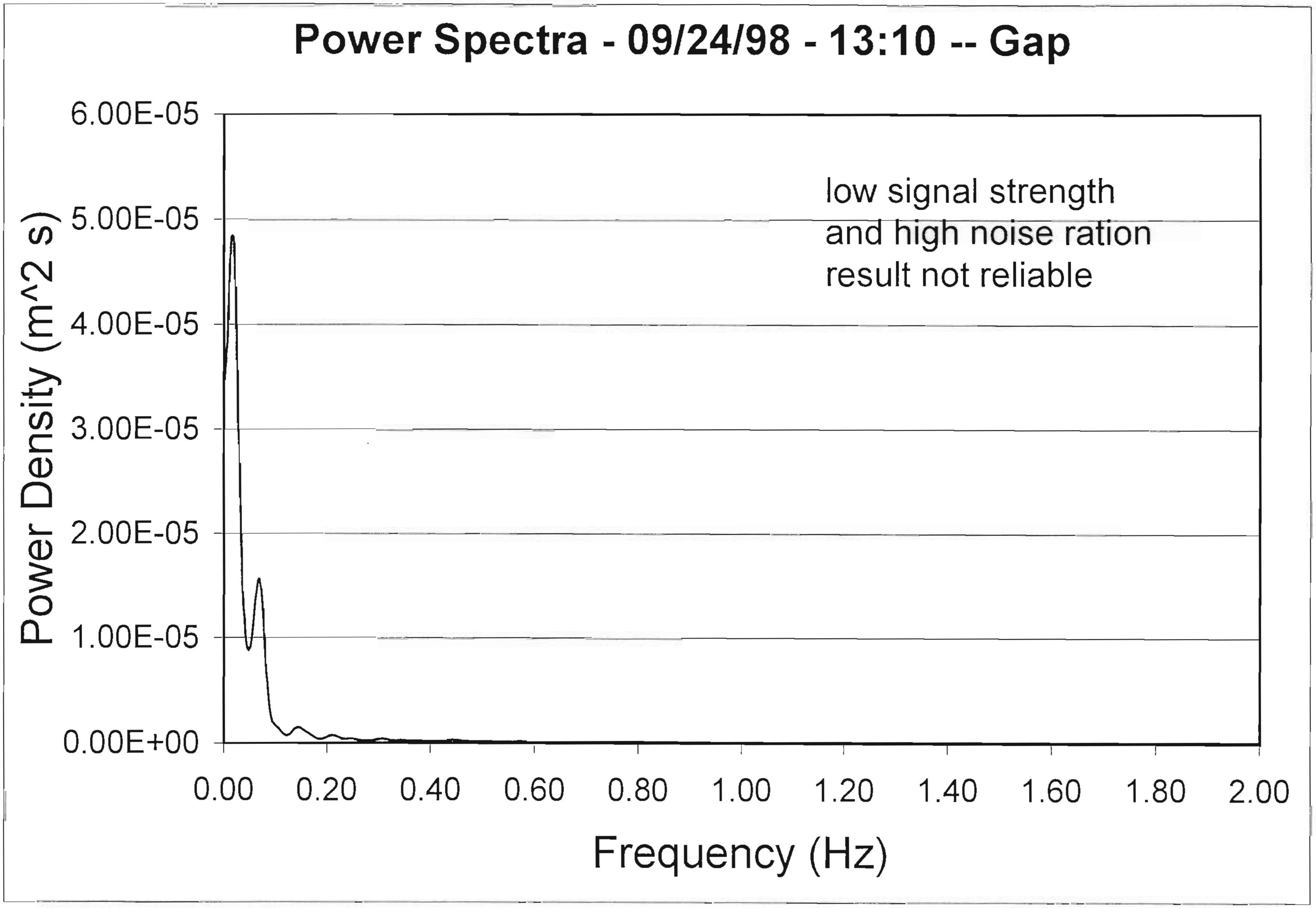

Power Spectra - 09/24/98 - 12:30 -- Inside
4.50E-05
4.00E-05
3.50E-05
3.00E-05
2.50E-05
2.00E-05
1.50E-05
1.00E-05
5.00E-06
0.00E+00
Power Density (m^2 s)
low signal strength
and high noise ration
result not reliable
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1.80
2.00
Frequency (Hz)

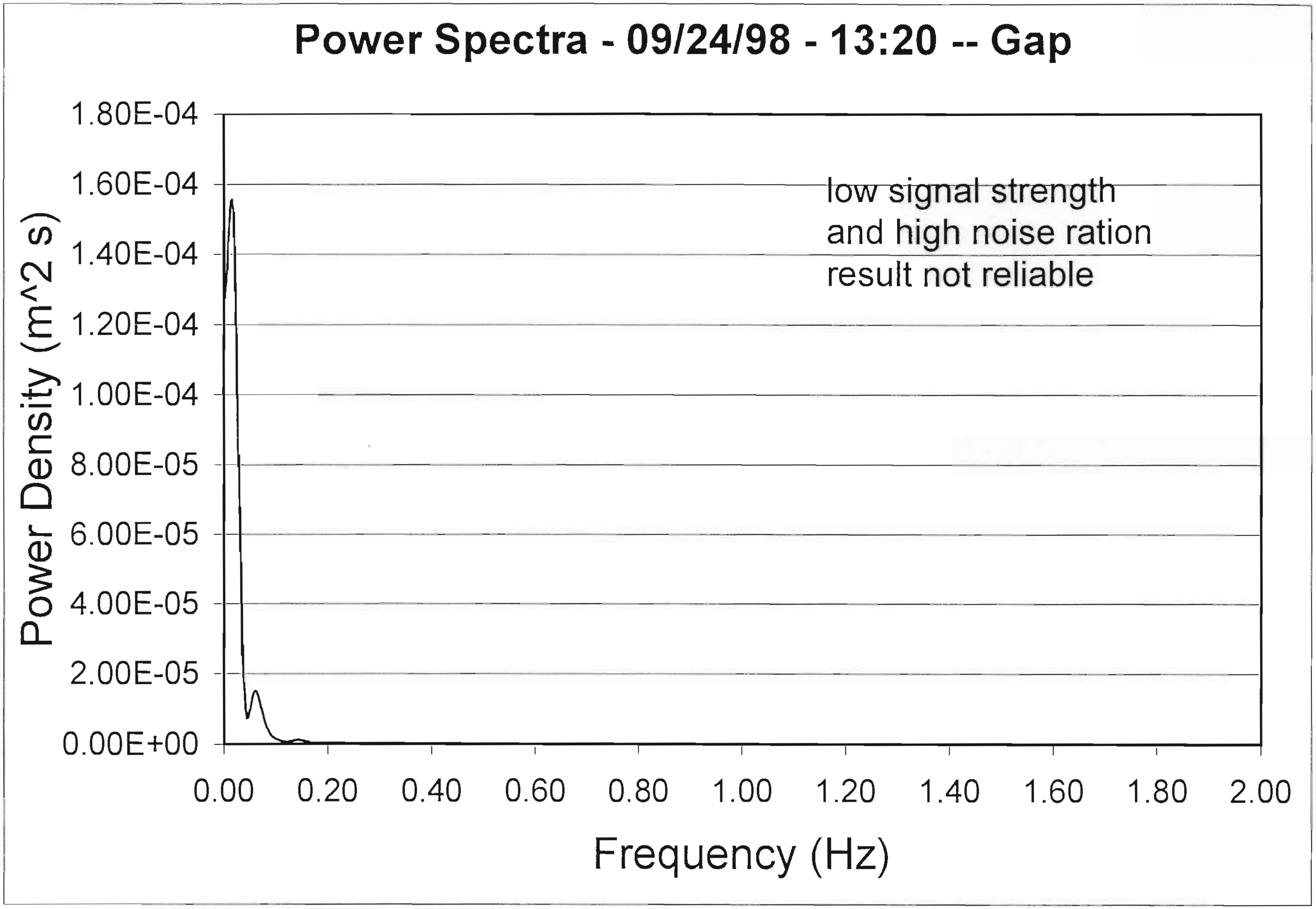


Power Spectra - 09/24/98 - 12:40 -- Inside
low signal strength
and high noise ration
result not reliable
Power Density (m^2 s)
4.50E-05
4.00E-05
3.50E-05
3.00E-05
2.50E-05
2.00E-05
1.50E-05
1.00E-05
5.00E-06
0.00E+00
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1.80
2.00
Frequency (Hz)

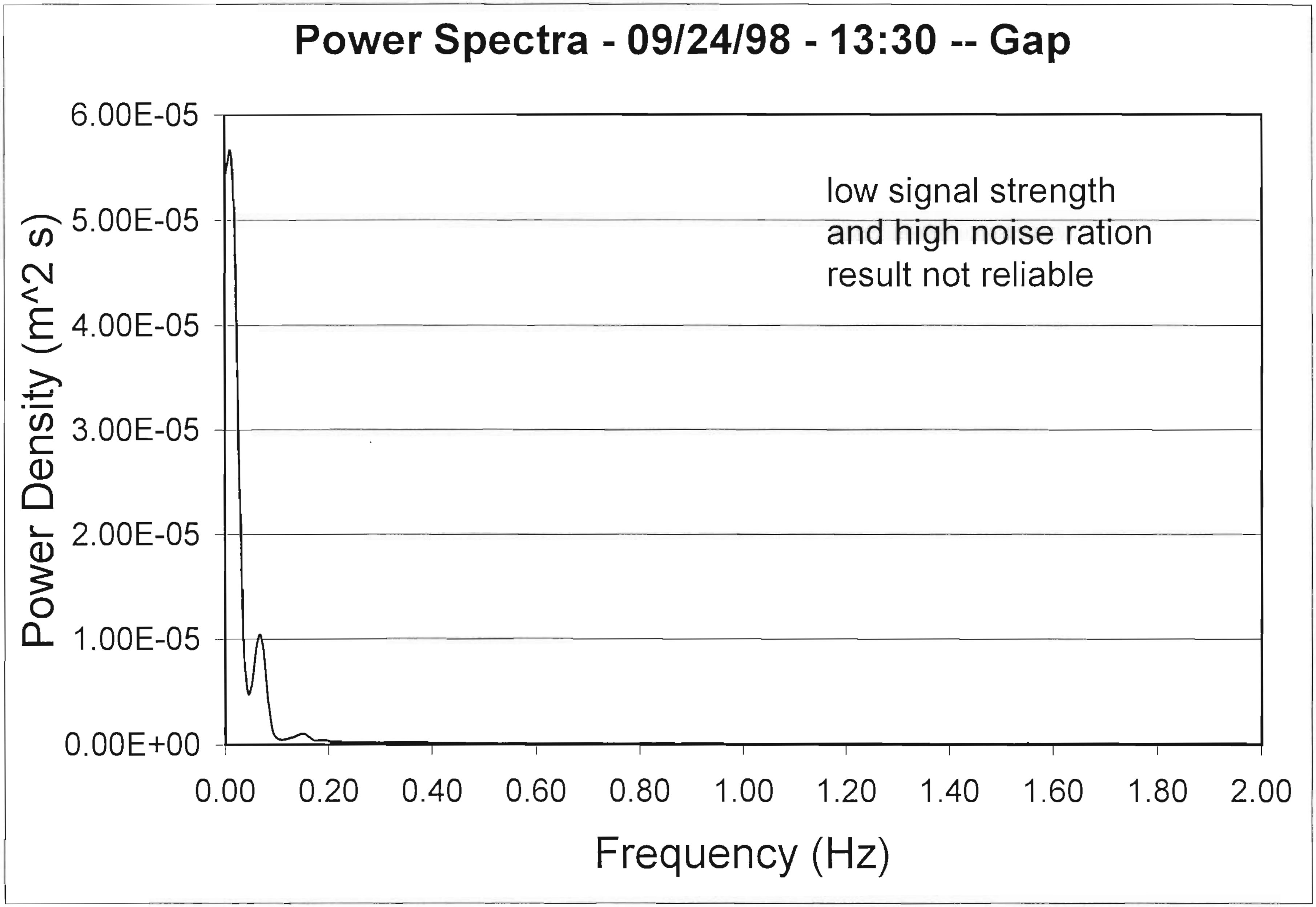


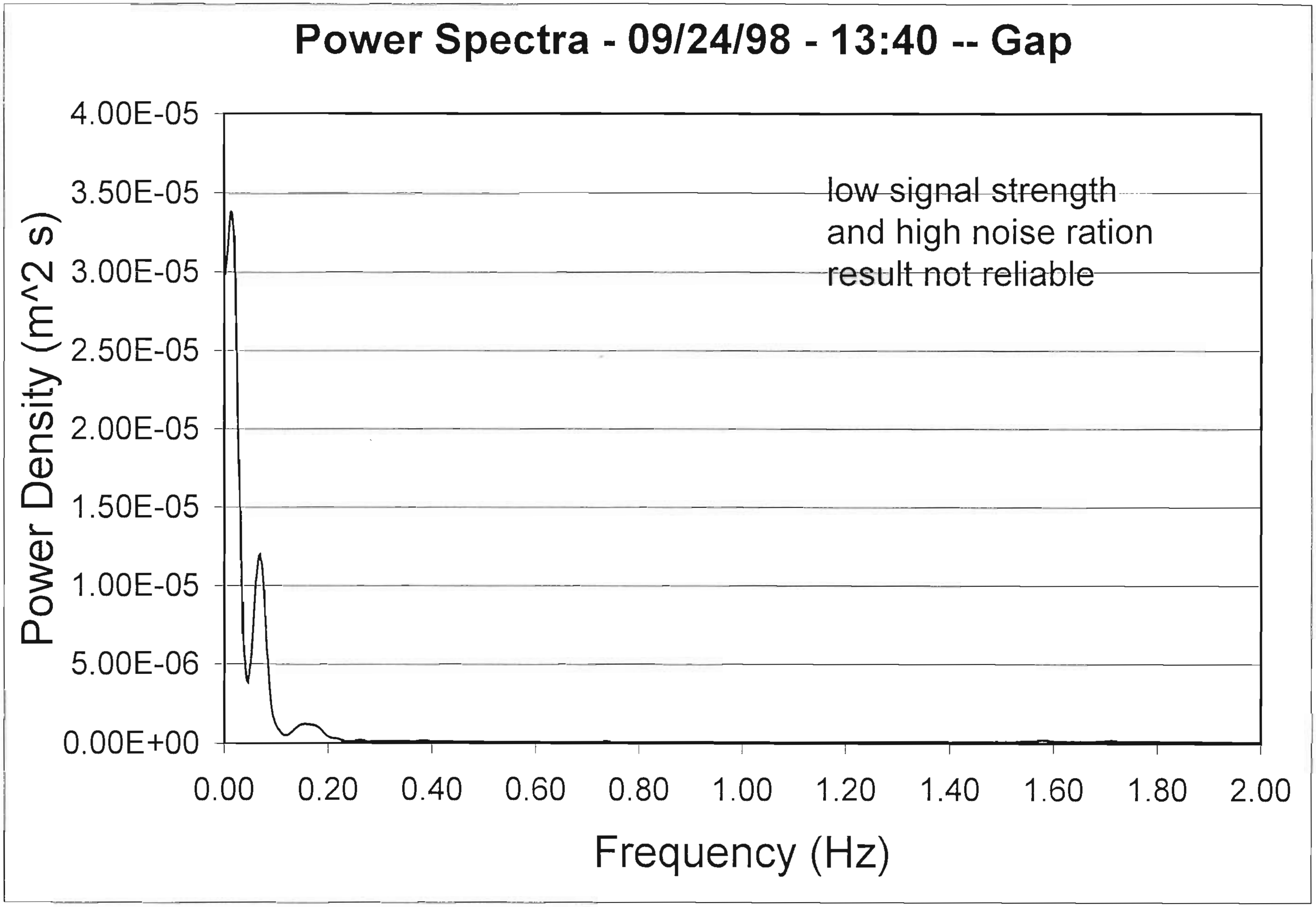
Power Spectra - 09/24/98 - 13:00 -- Gap
Power Density (m^2 s)
1.80E-04
1.60E-04
1.40E-04
1.20E-04
1.00E-04
8.00E-05
6.00E-05
4.00E-05
2.00E-05
0.00E+00
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1.80
2.00
Frequency (Hz)
low signal strength
and high noise ration
result not reliable


Power Spectra - 09/24/98 - 13:10 -- Gap
low signal strength
and high noise ration
result not reliable
Power Density (m^2 s)
6.00E-05
5.00E-05
4.00E-05
3.00E-05
2.00E-05
1.00E-05
0.00E+00
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1.80
2.00
Frequency (Hz)

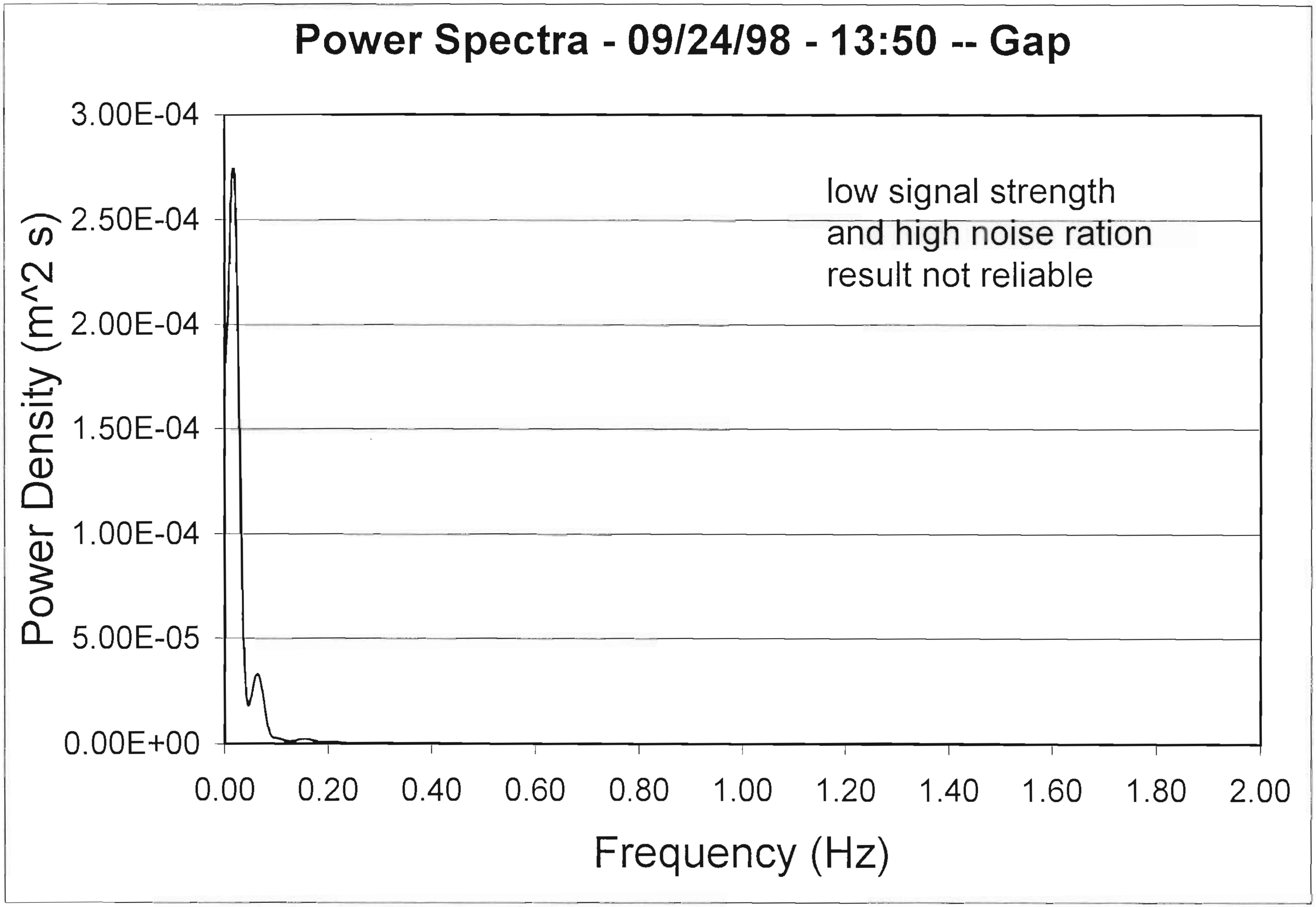


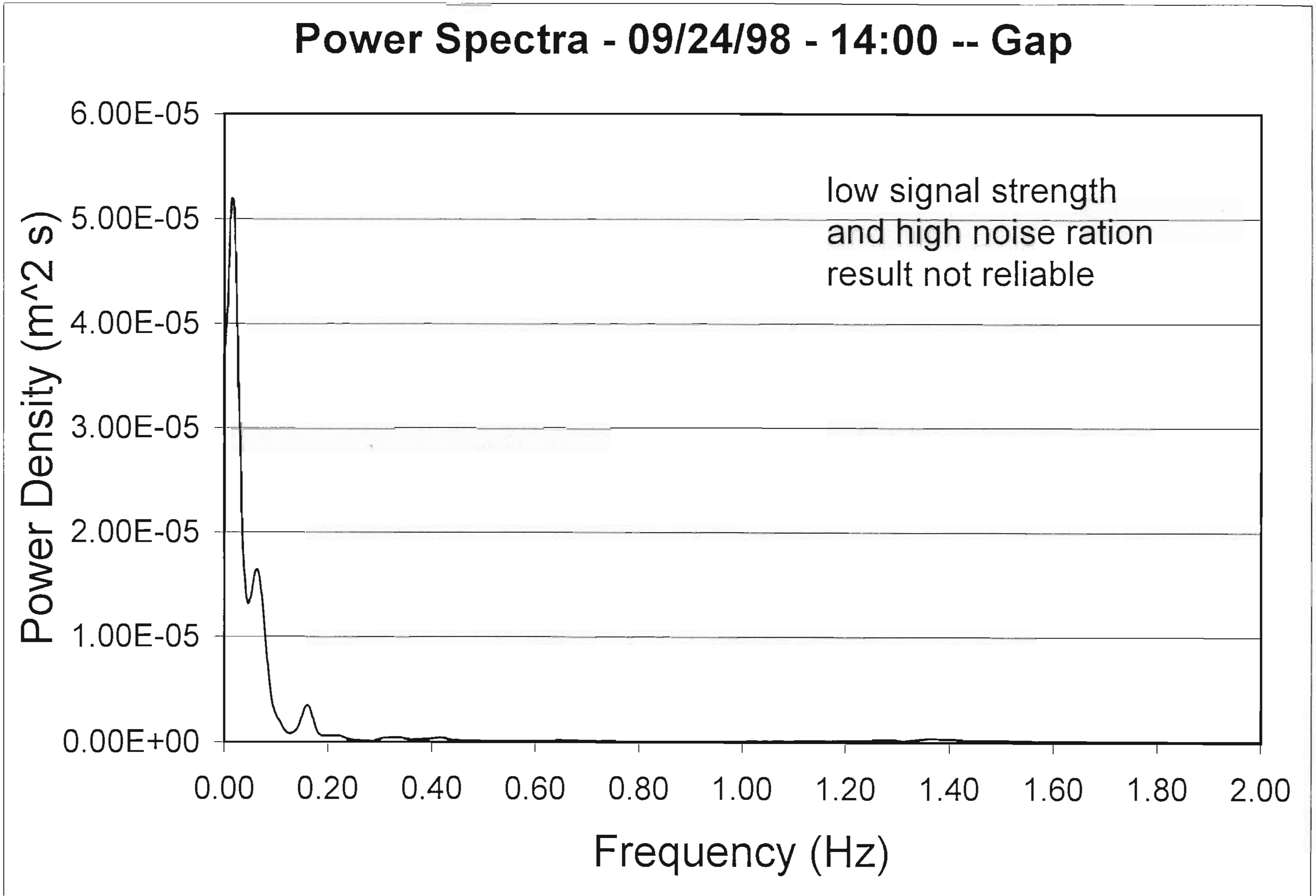
Power Spectra - 09/24/98 - 13:20 -- Gap
1.80E-04
1.60E-04
1.40E-04
1.20E-04
1.00E-04
8.00E-05
6.00E-05
4.00E-05
2.00E-05
0.00E+00
Power Density (m^2 s)
low signal strength
and high noise ration
result not reliable
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1.80
2.00
Frequency (Hz)

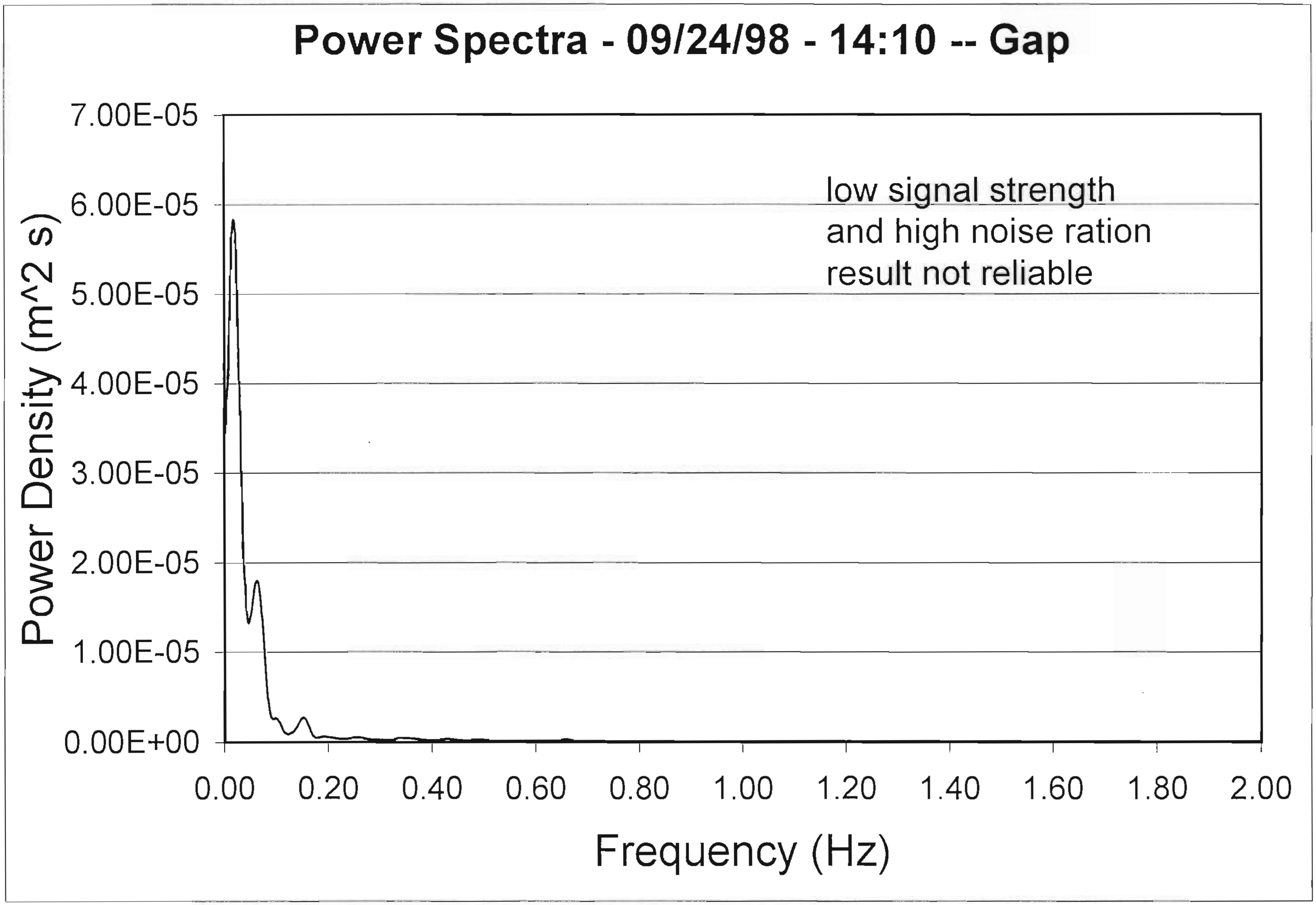

Power Spectra - 09/24/98 - 13:30 -- Gap
low signal strength
and high noise ration
result not reliable
Power Density (m^2 s)
6.00E-05
5.00E-05
4.00E-05
3.00E-05
2.00E-05
1.00E-05
0.00E+00
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1.80
2.00
Frequency (Hz)

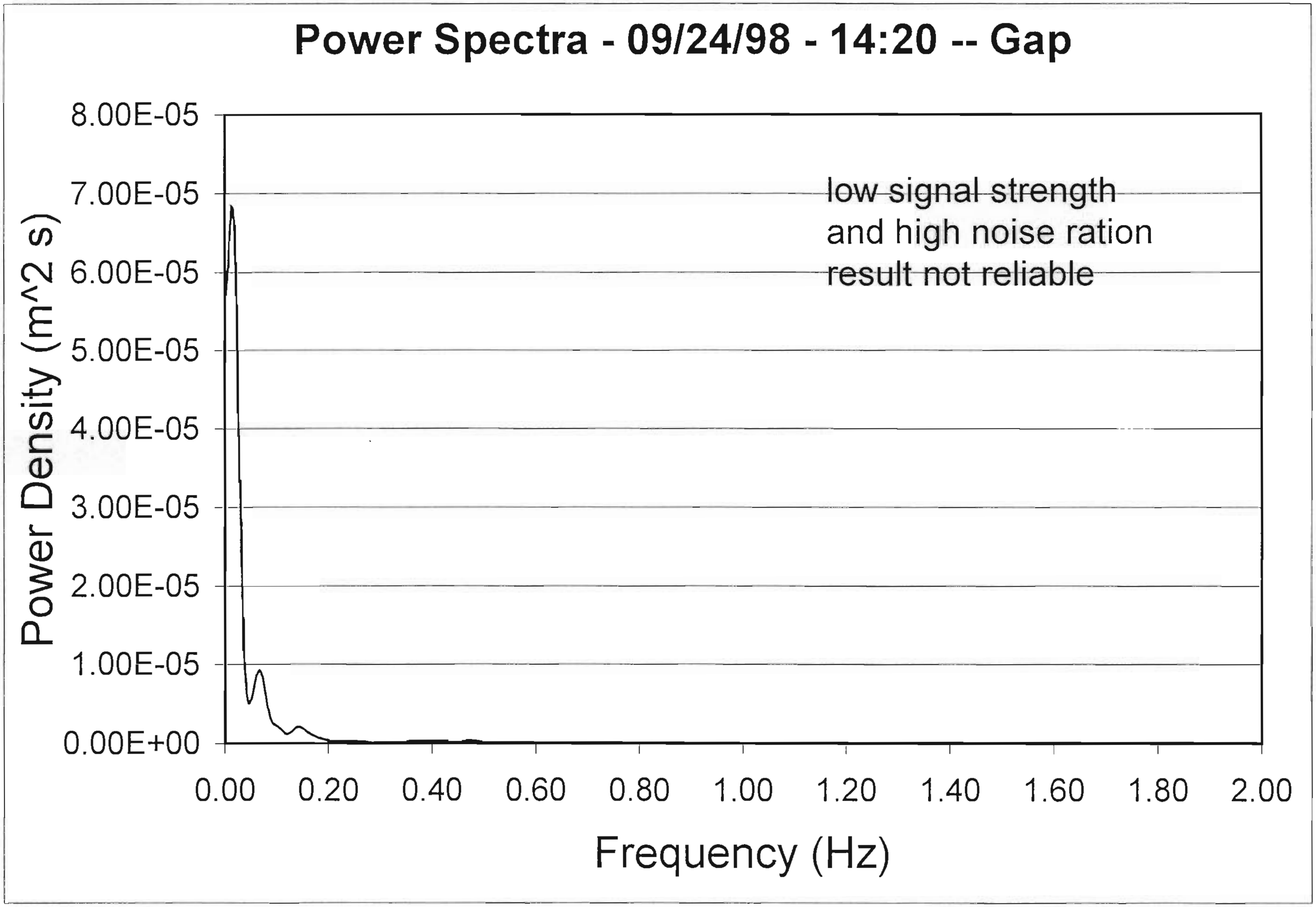


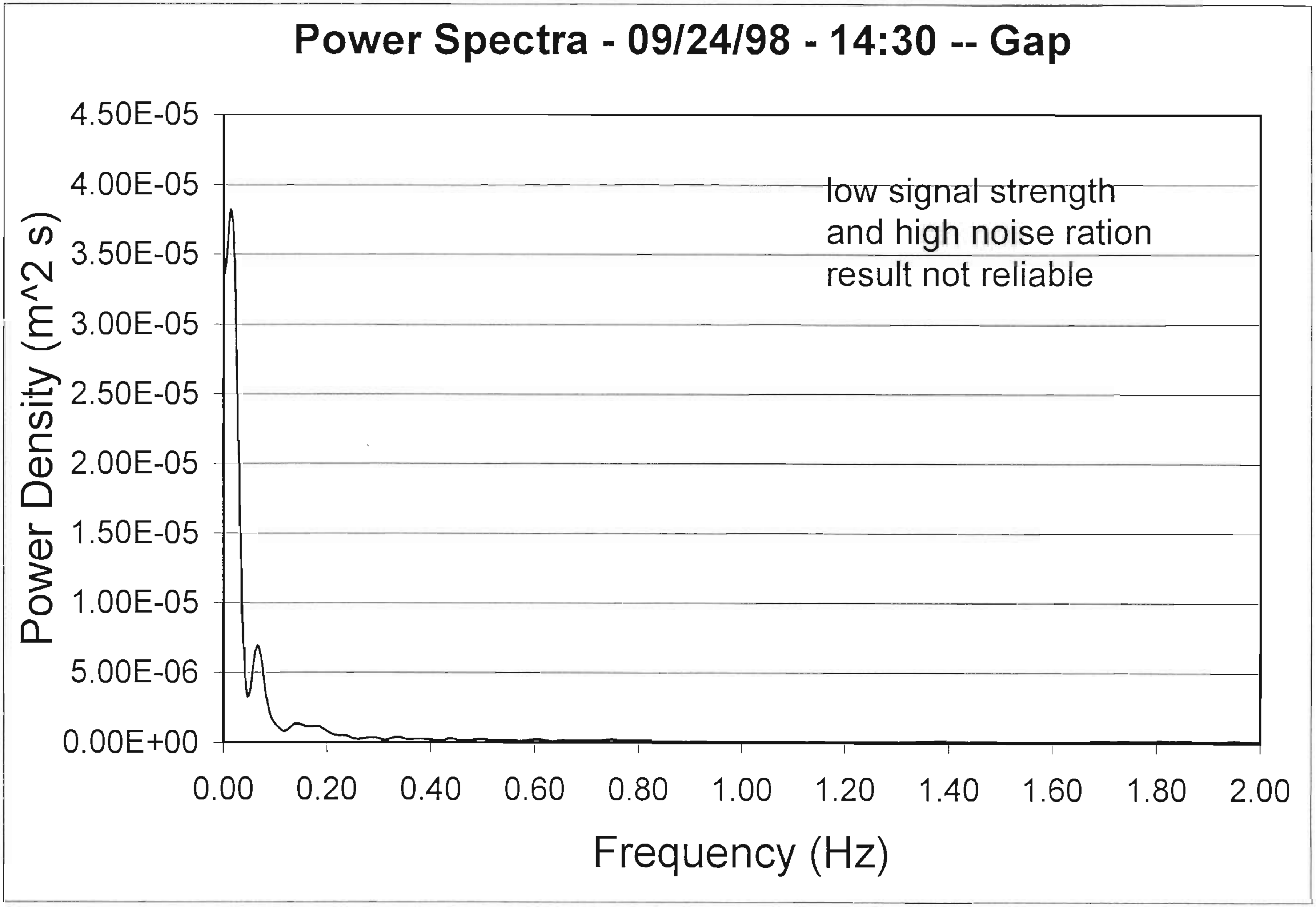
Power Spectra - 09/24/98 - 13:40 -- Gap
Power Density (m^2 s)
4.00E-05
3.50E-05
3.00E-05
2.50E-05
2.00E-05
1.50E-05
1.00E-05
5.00E-06
0.00E+00
low signal strength
and high noise ration
result not reliable
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1.80
2.00
Frequency (Hz)

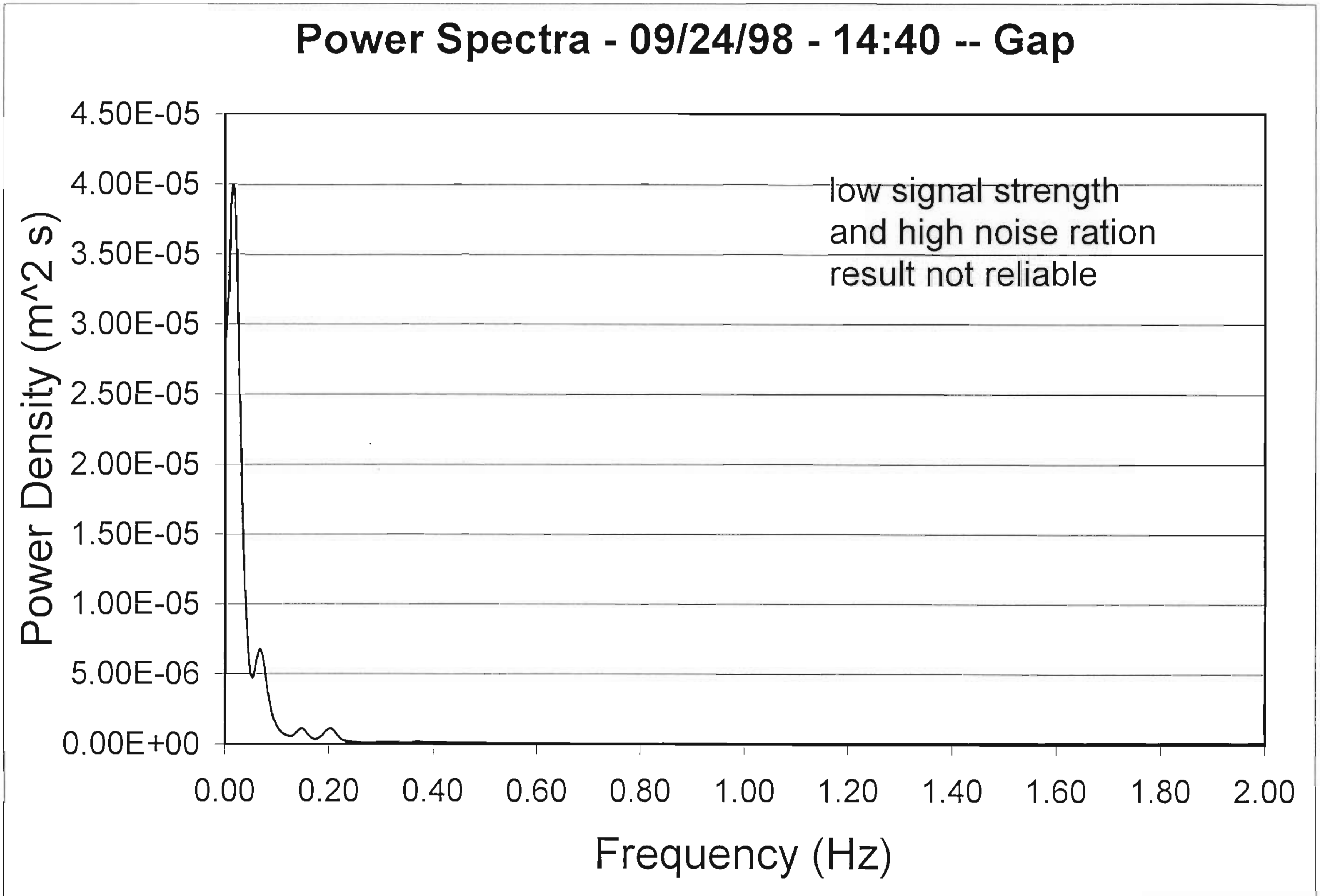

Power Spectra - 09/24/98 - 13:50 -- Gap
3.00E-04
2.50E-04
2.00E-04
1.50E-04
1.00E-04
5.00E-05
0.00E+00
Power Density (m^2 s)
low signal strength
and high noise ration
result not reliable
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1.80
2.00
Frequency (Hz)


Power Spectra - 09/24/98 - 14:00 -- Gap
low signal strength
and high noise ration
result not reliable
Power Density (m^2 s)
6.00E-05
5.00E-05
4.00E-05
3.00E-05
2.00E-05
1.00E-05
0.00E+00
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1.80
2.00
Frequency (Hz)


Power Spectra - 09/24/98 - 14:10 -- Gap
low signal strength
and high noise ration
result not reliable
Power Density (m^2 s)
7.00E-05
6.00E-05
5.00E-05
4.00E-05
3.00E-05
2.00E-05
1.00E-05
0.00E+00
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1.80
2.00
Frequency (Hz)

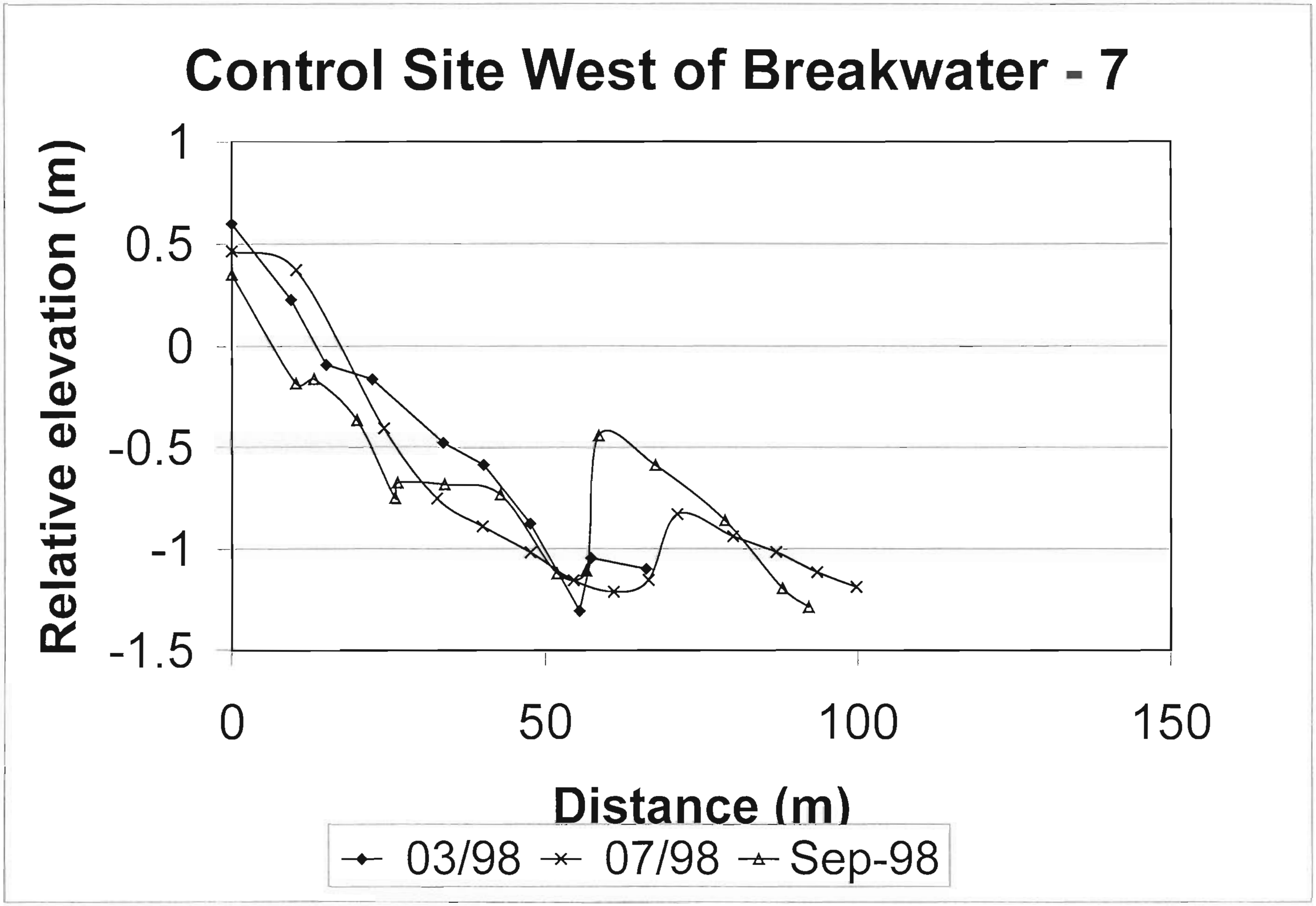

Power Spectra - 09/24/98 - 14:20 -- Gap
Power Density (m^2 s)
8.00E-05
7.00E-05
6.00E-05
5.00E-05
4.00E-05
3.00E-05
2.00E-05
1.00E-05
0.00E+00
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1.80
2.00
Frequency (Hz)
low signal strength
and high noise ration
result not reliable

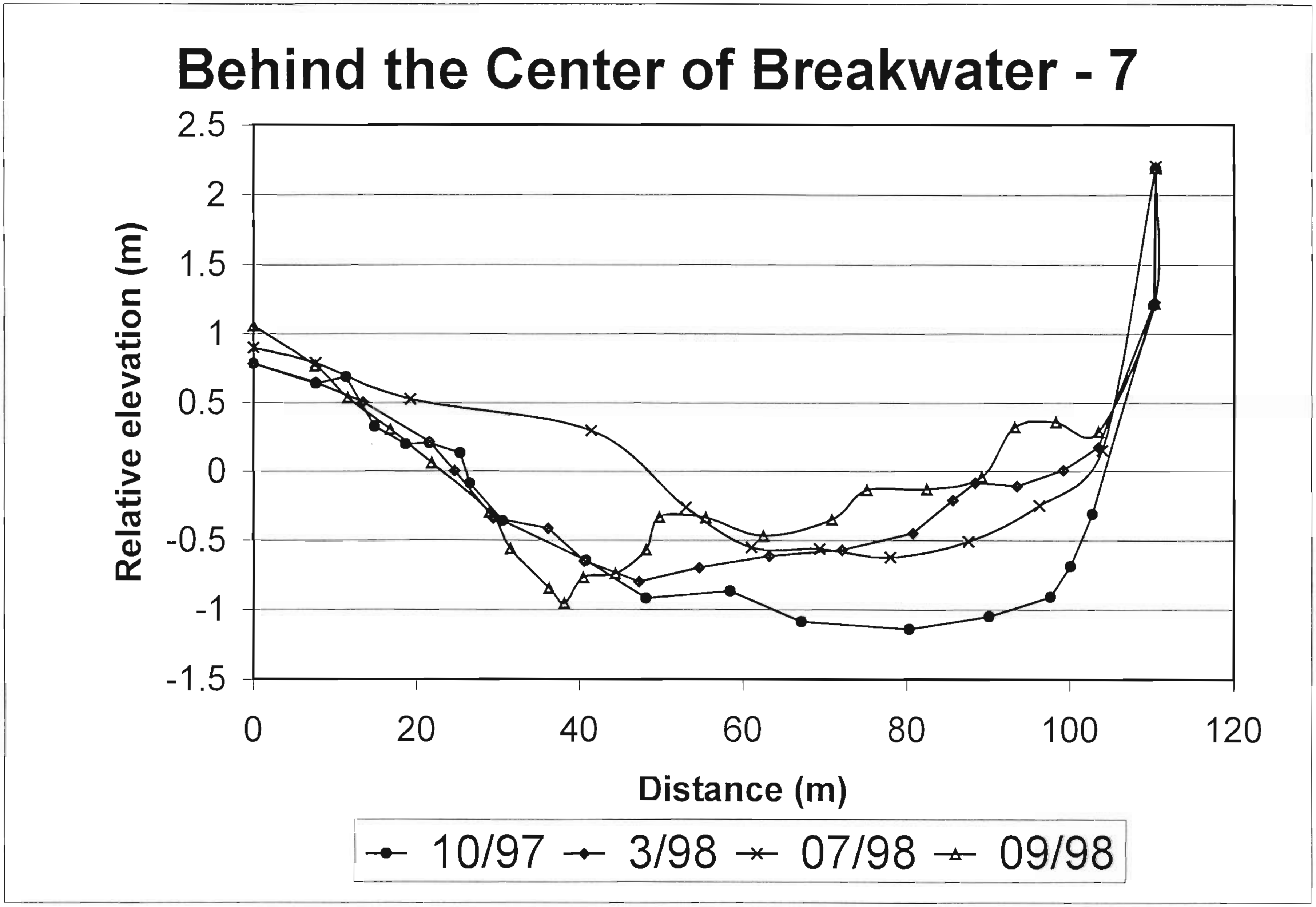

Power Spectra - 09/24/98 - 14:30 -- Gap
Power Density (m^2 s)
4.50E-05
4.00E-05
3.50E-05
3.00E-05
2.50E-05
2.00E-05
1.50E-05
1.00E-05
5.00E-06
0.00E+00
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1.80
2.00
Frequency (Hz)
low signal strength
and high noise ration
result not reliable

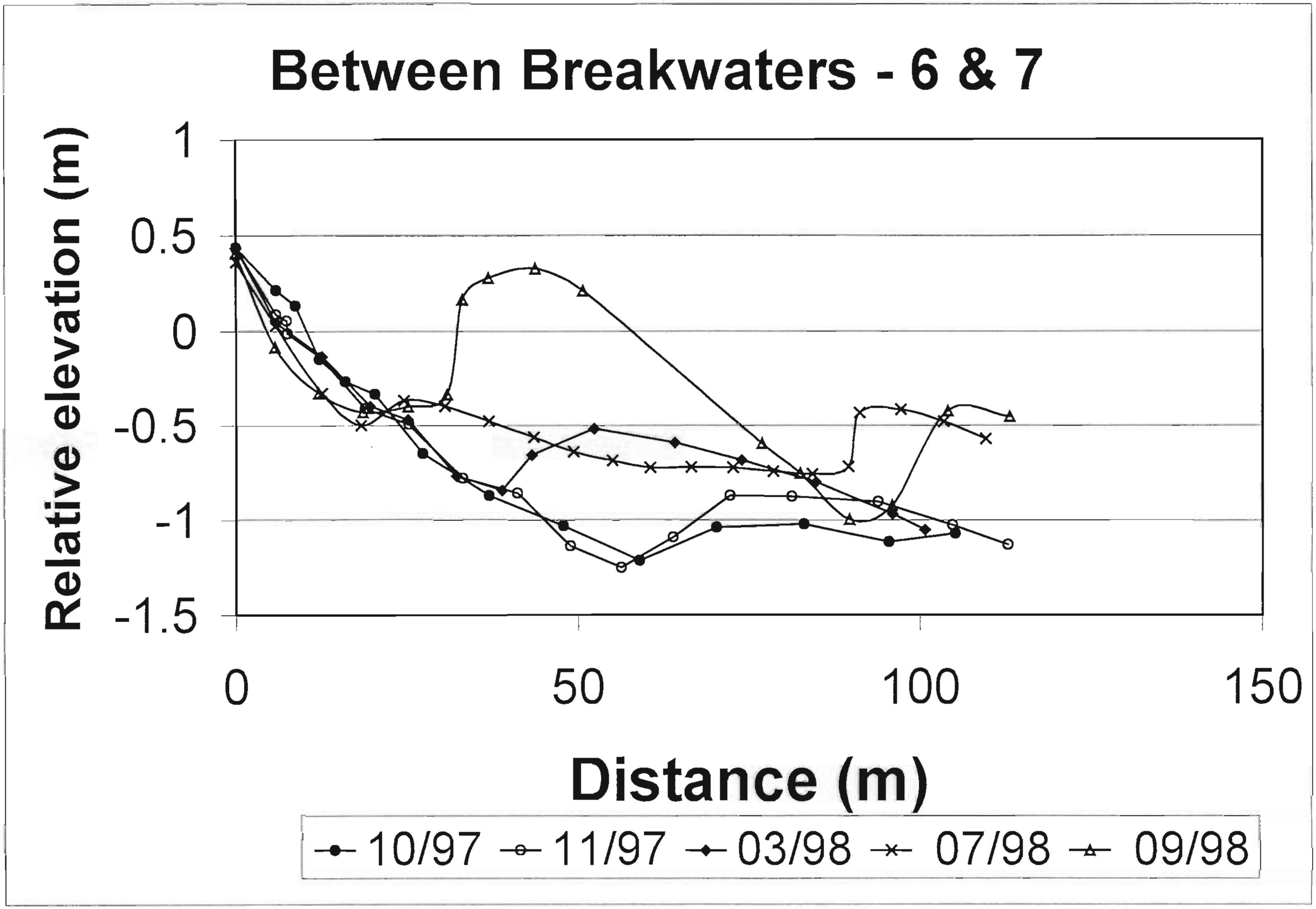

Power Spectra - 09/24/98 - 14:40 -- Gap
low signal strength
and high noise ration
result not reliable
Power Density (m^2 s)
4.50E-05
4.00E-05
3.50E-05
3.00E-05
2.50E-05
2.00E-05
1.50E-05
1.00E-05
5.00E-06
0.00E+00
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1.80
2.00
Frequency (Hz)

APPENDIX 4

Time-series of beach profiles (profile locations are shown in Figure 1)

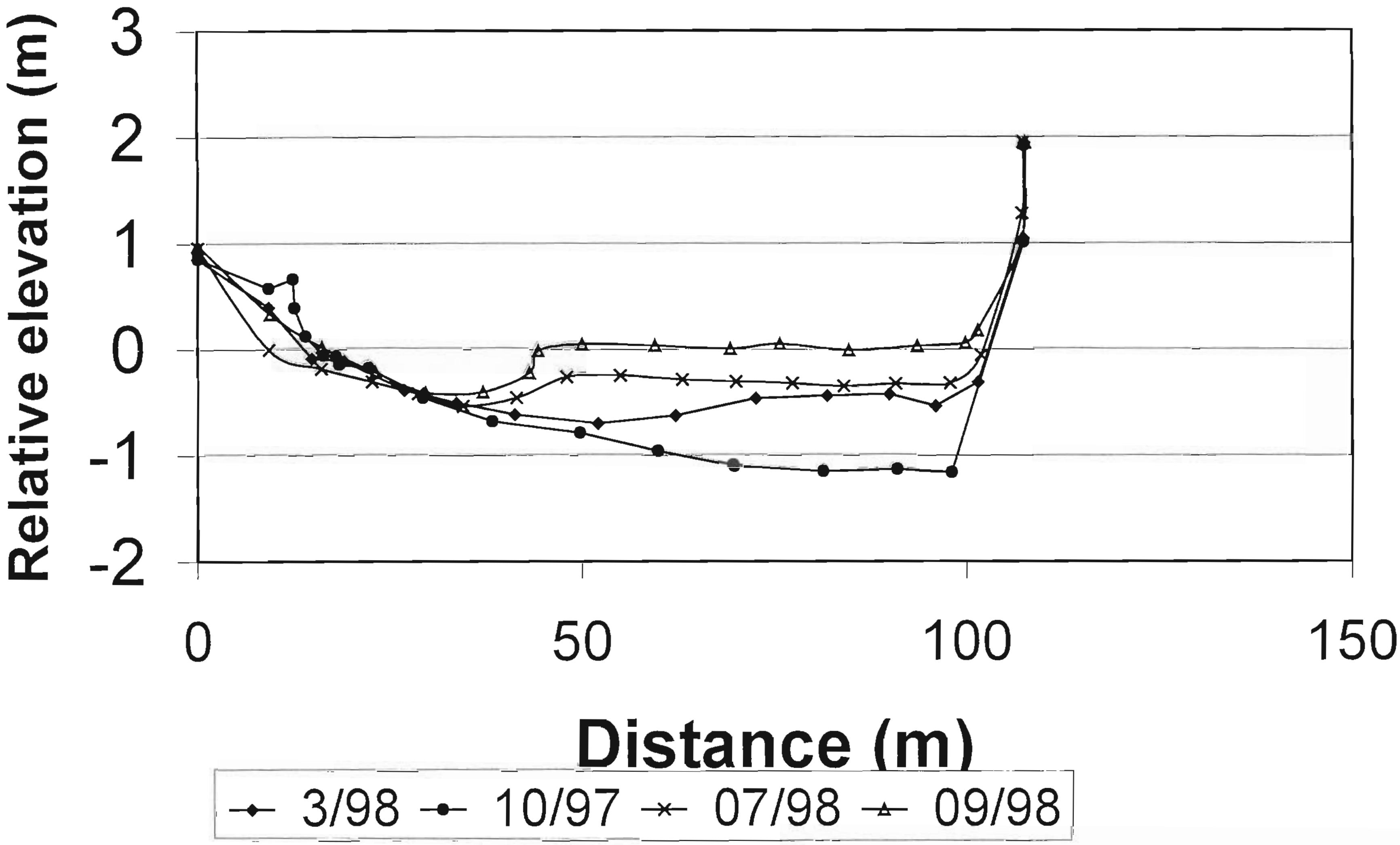

Control Site West of Breakwater - 7
Relative elevation (m)
1
0.5
0
-0.5
-1
-1.5
0
50
100
150
Distance (m)
03/98
07/98
Sep-98

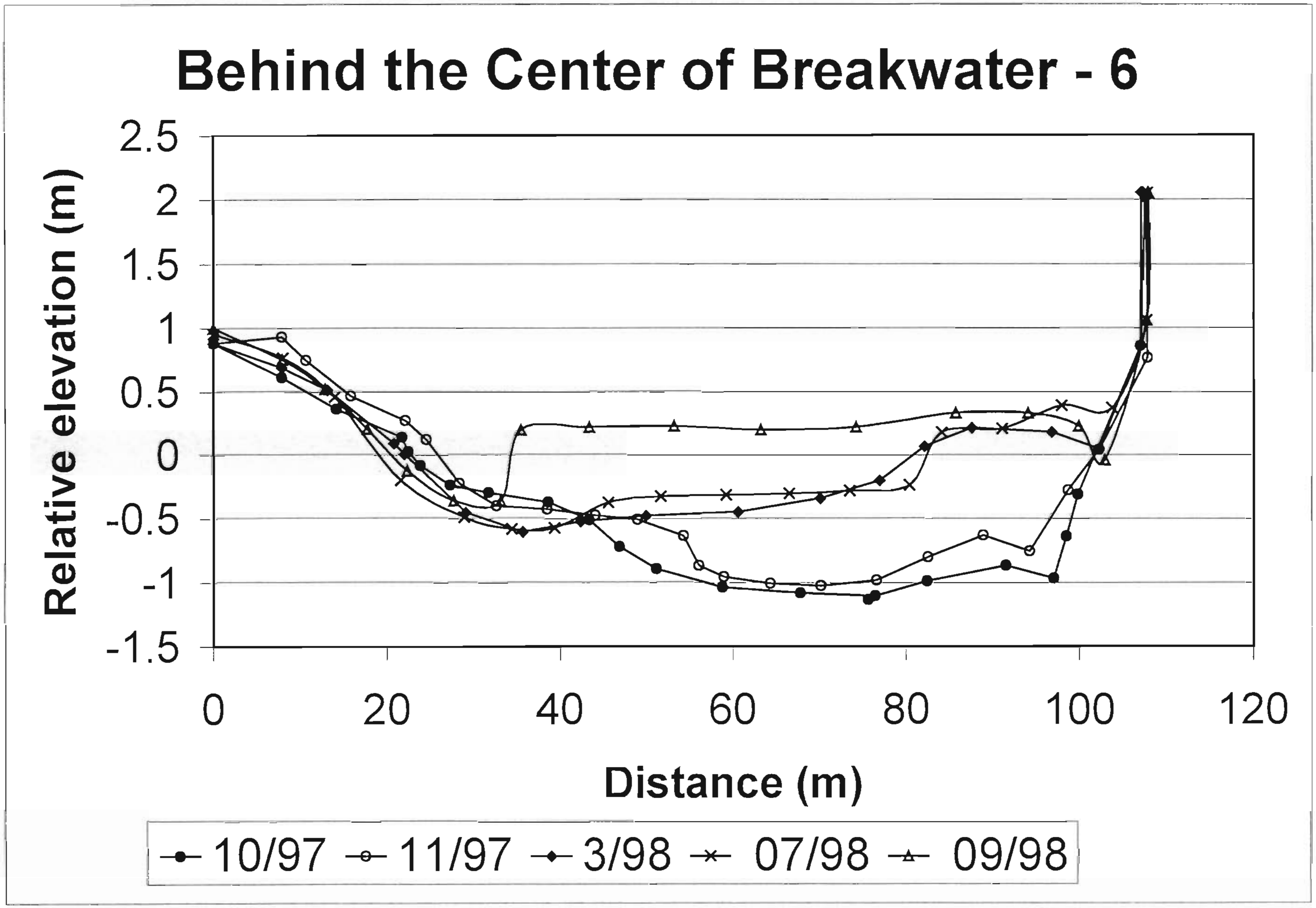

Behind the Center of Breakwater - 7
Relative elevation (m)
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
0
20
40
60
80
100
120
Distance (m)
10/97
3/98
07/98
09/98



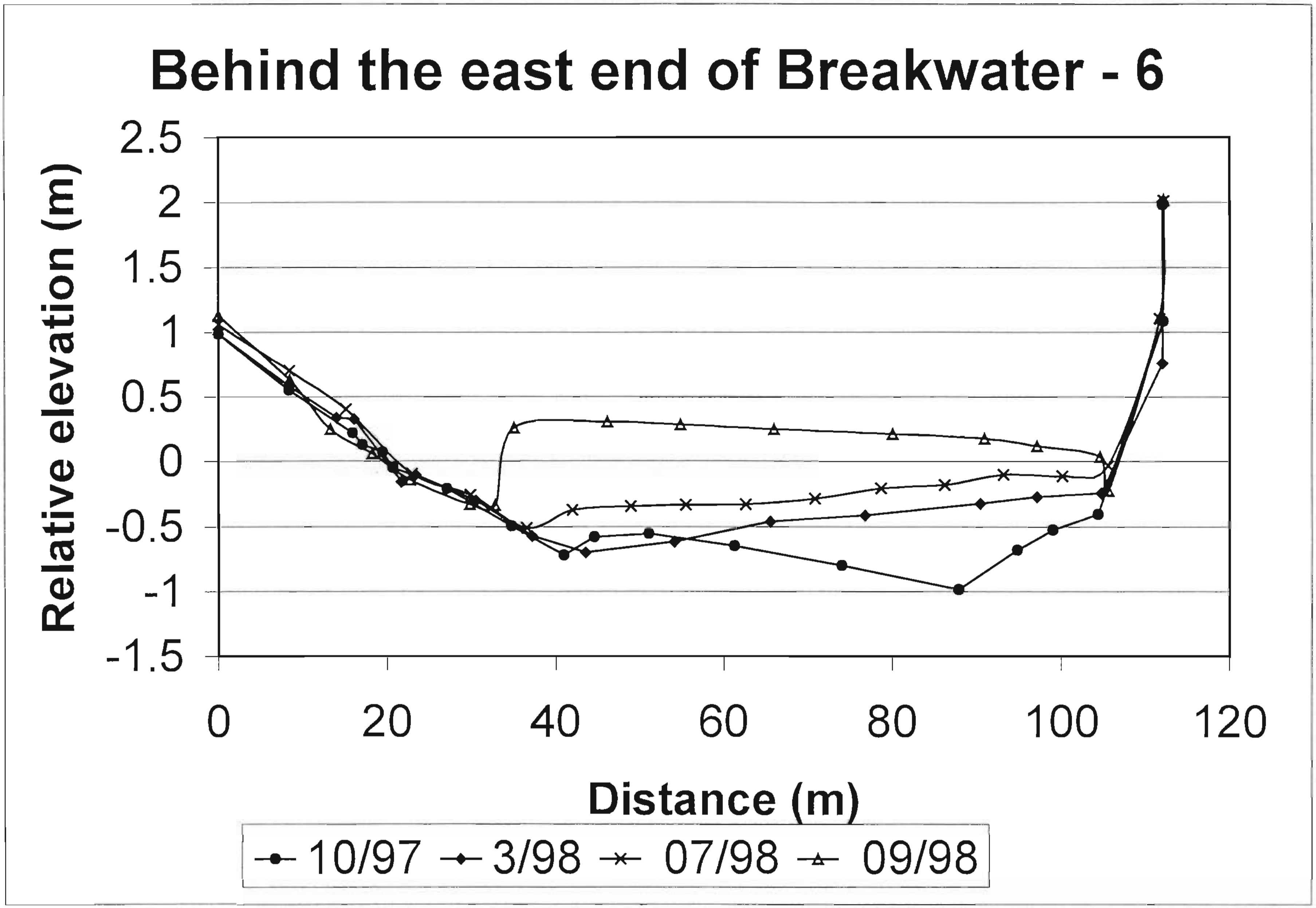
Between Breakwaters - 6 & 7
Relative elevation (m)
1
0.5
0
-0.5
-1
-1.5
0
50
100
150
Distance (m)
10/97
11/97
03/98
07/98
09/98

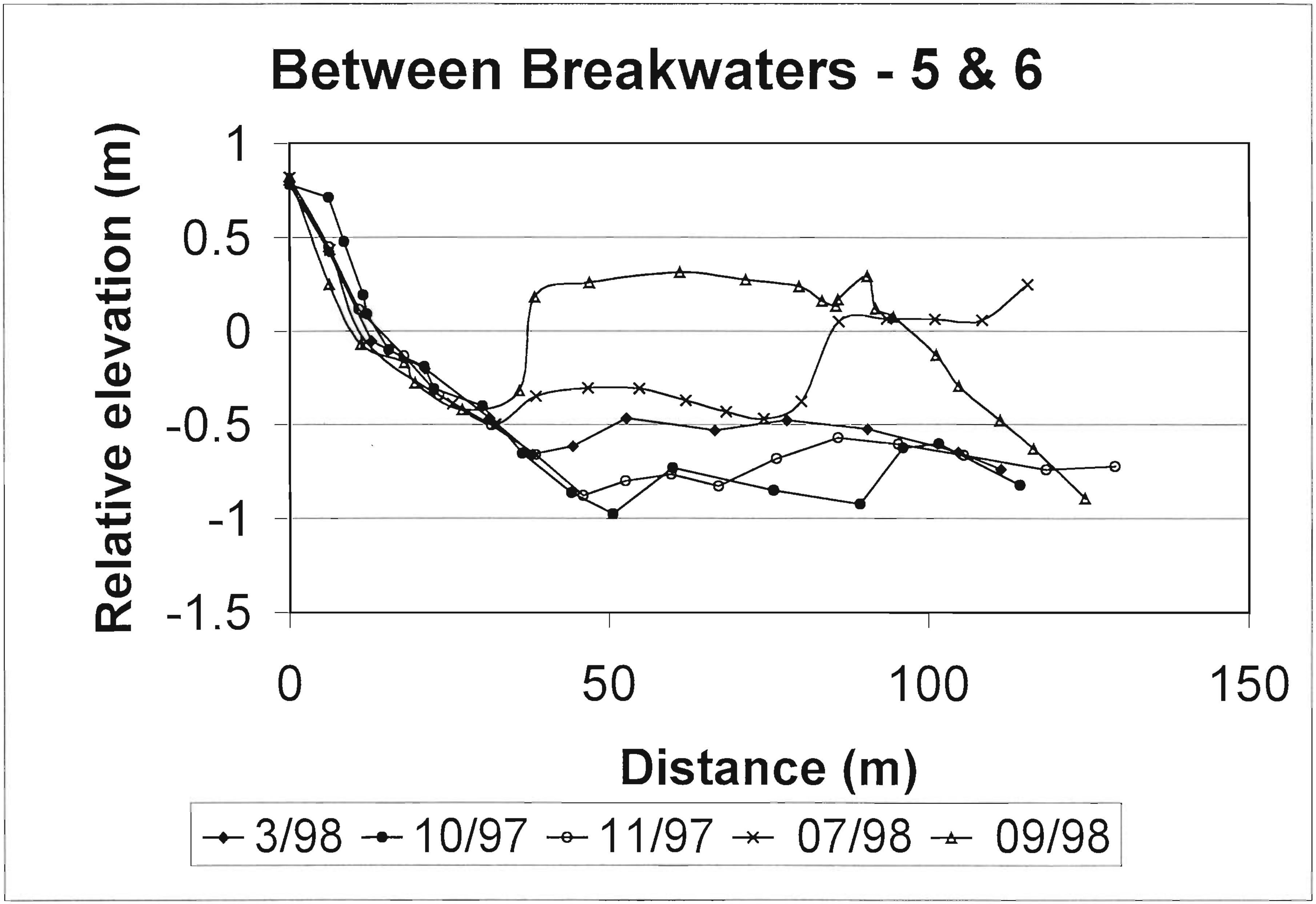
Behind West End of Breakwater - 6

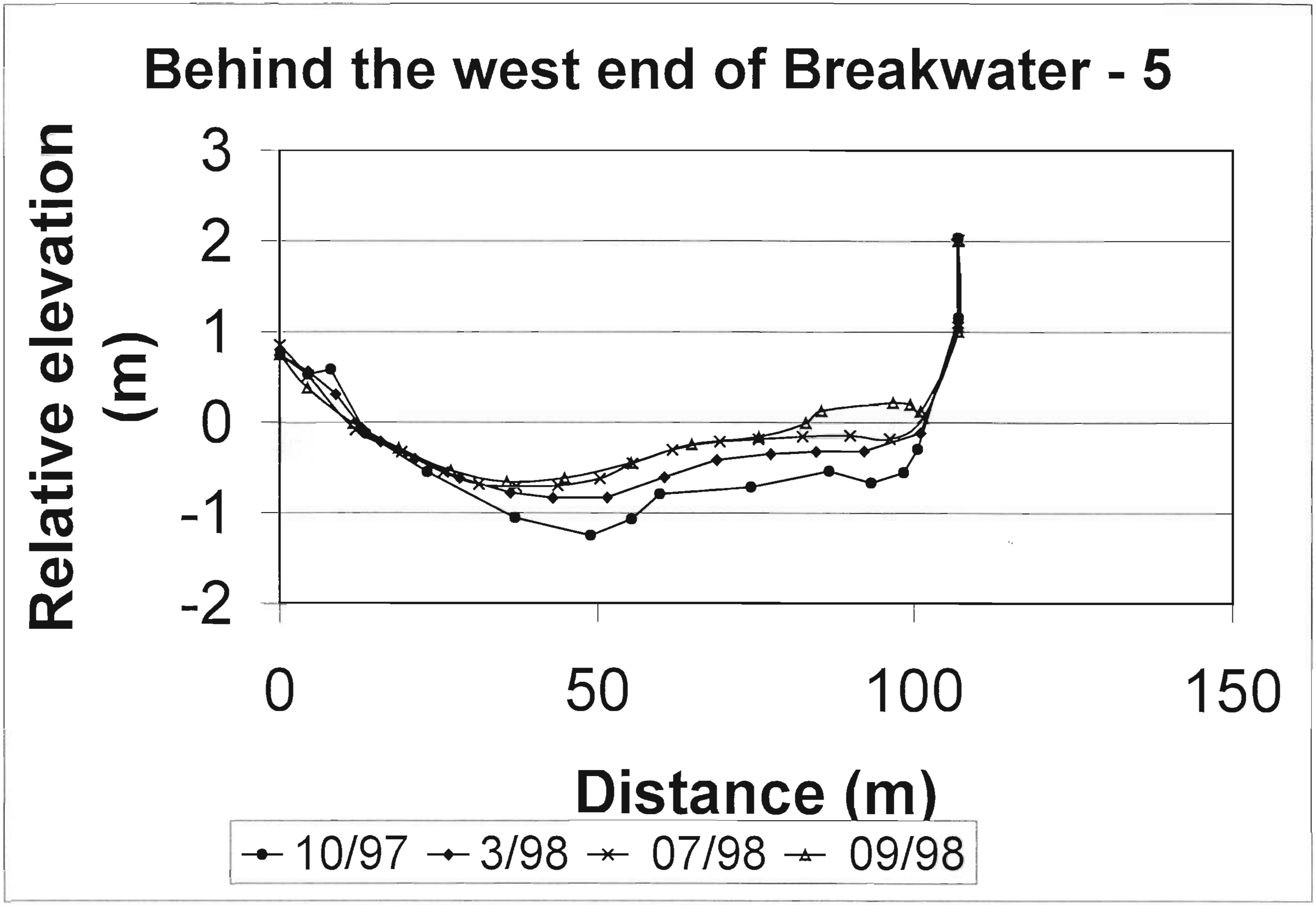


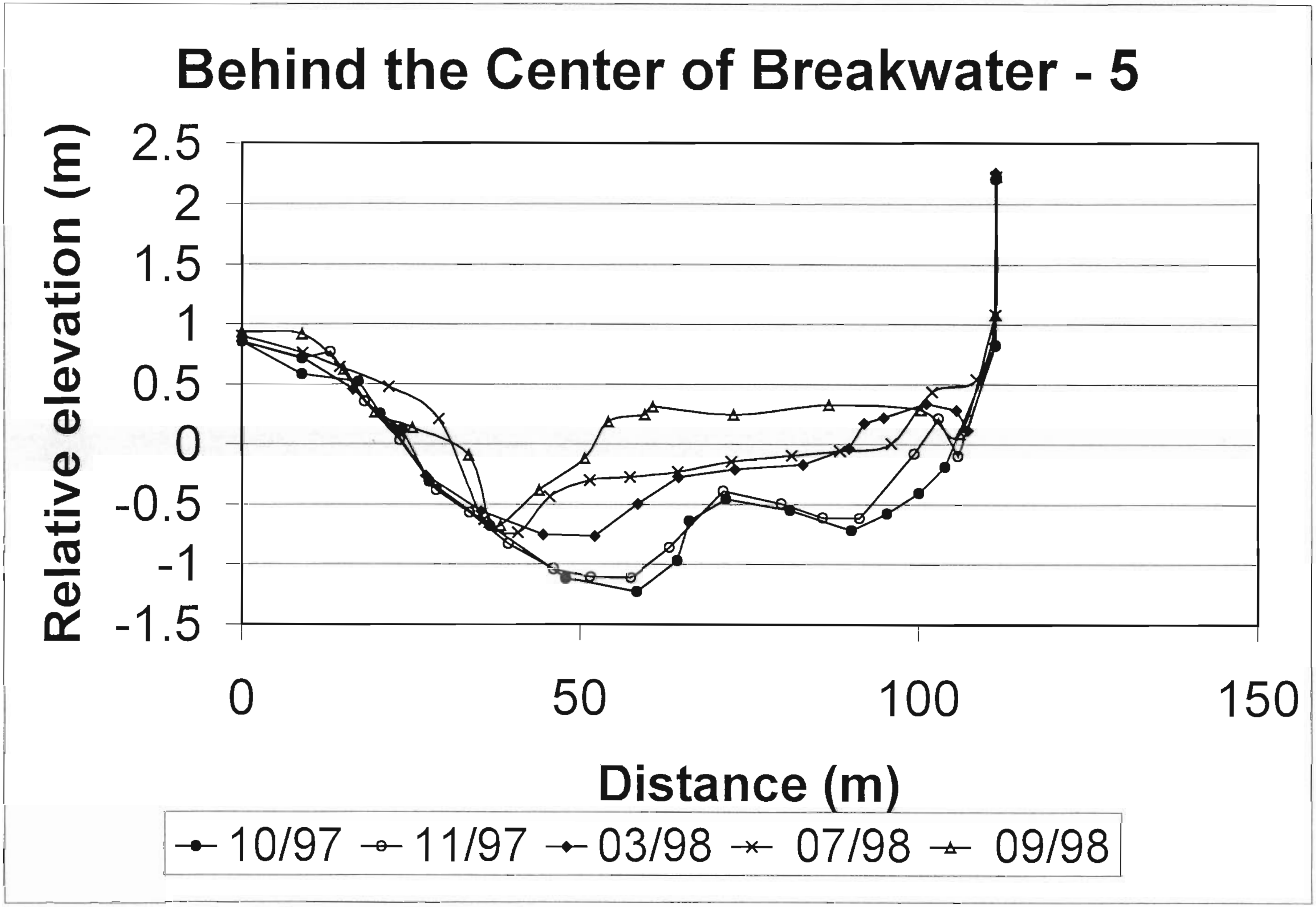


Behind the Center of Breakwater - 6
Relative elevation (m)
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
0
20
40
60
80
100
120
Distance (m)
10/97
11/97
3/98
07/98
09/98

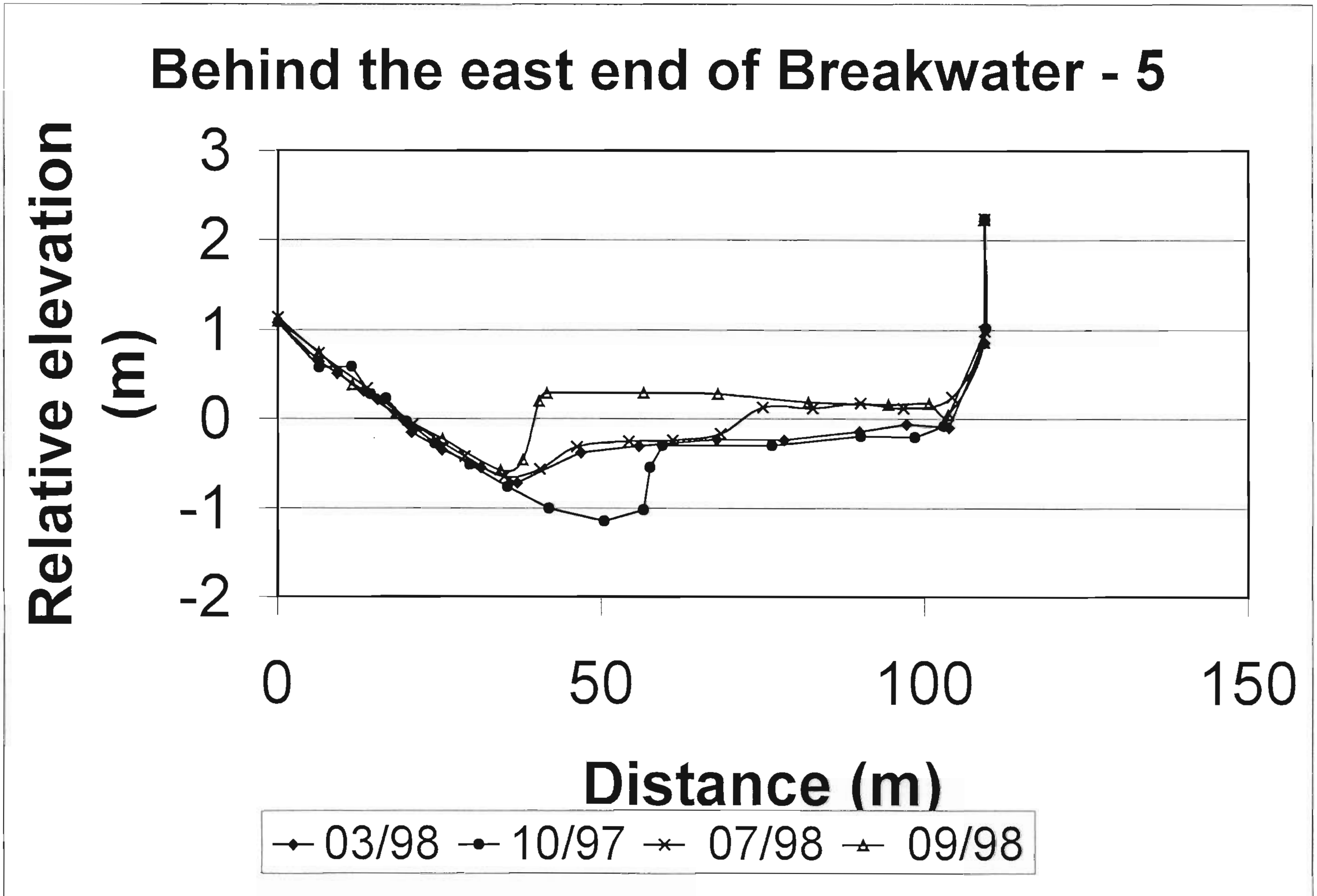

Behind the east end of Breakwater - 6
Relative elevation (m)
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
0
20
40
60
80
100
120
Distance (m)
10/97
3/98
07/98
09/98

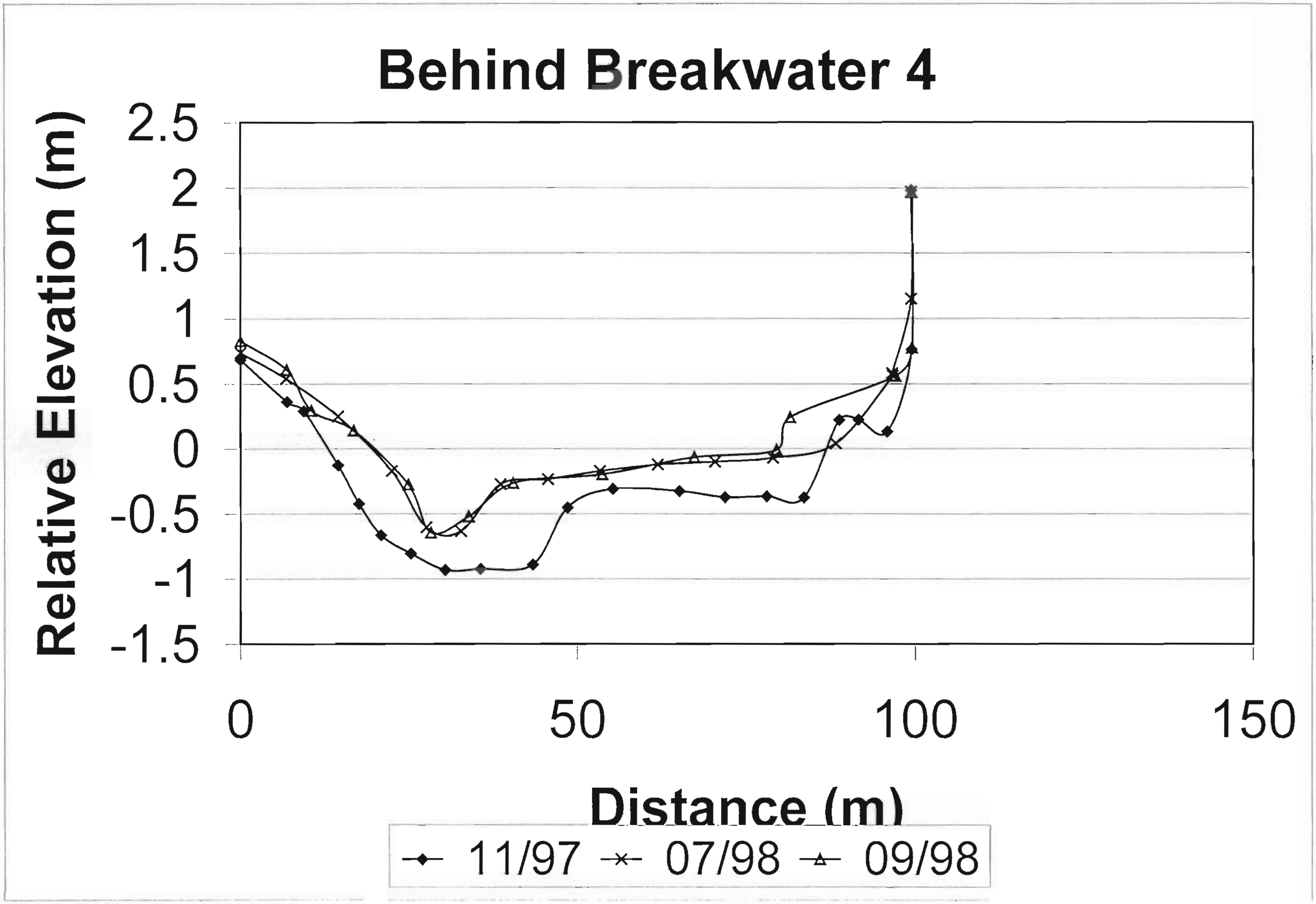

Between Breakwaters - 5 & 6
Relative elevation (m)
1
0.5
0
-0.5
-1
-1.5
0
50
100
150
Distance (m)
3/98
10/97
11/97
07/98
09/98


Behind the west end of Breakwater - 5
Relative elevation (m)
3
2
1
0
-1
-2
0
50
100
150
Distance (m)
10/97
3/98
07/98
09/98



Behind the Center of Breakwater - 5
Relative elevation (m)
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
0
50
100
150
Distance (m)
10/97
11/97
03/98
07/98
09/98


Behind the east end of Breakwater - 5
Relative elevation (m)
3
2
1
0
-1
-2
0
50
100
150
Distance (m)
03/98
10/97
07/98
09/98



Behind Breakwater 4
Relative Elevation (m)
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
0
50
100
150
Distance (m)
11/97
07/98
09/98