

## **APPENDIX D**

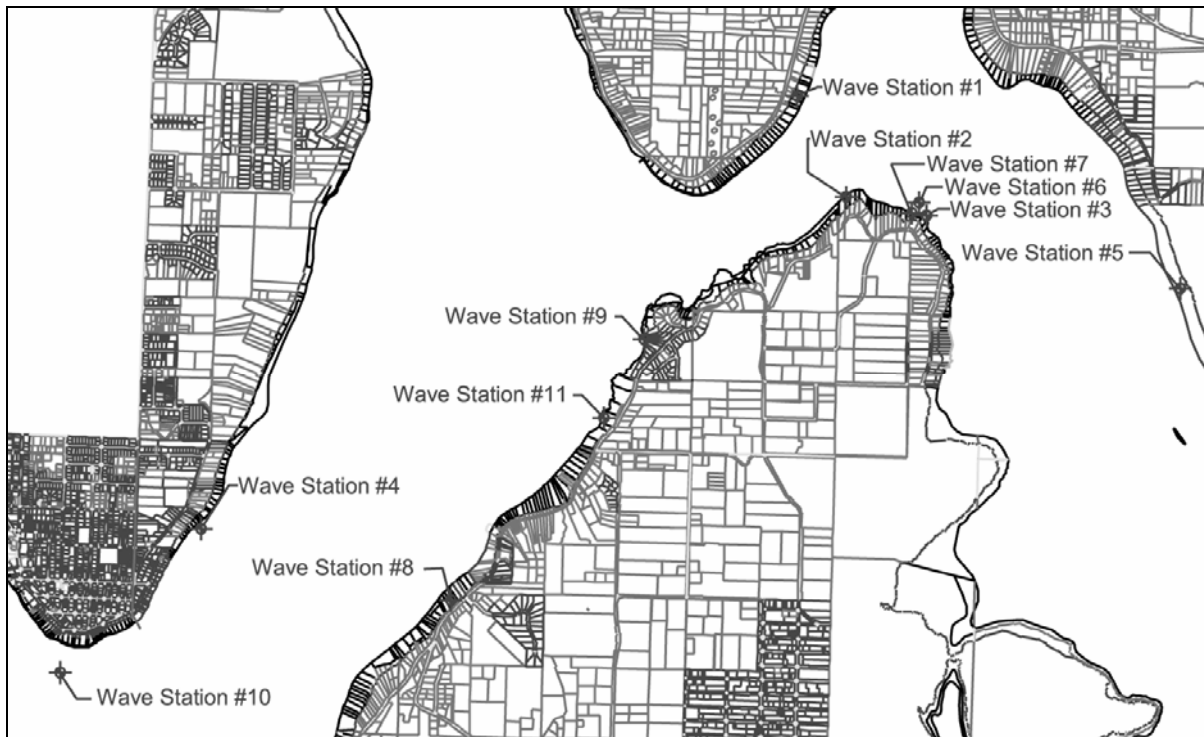
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### Wake Measurements

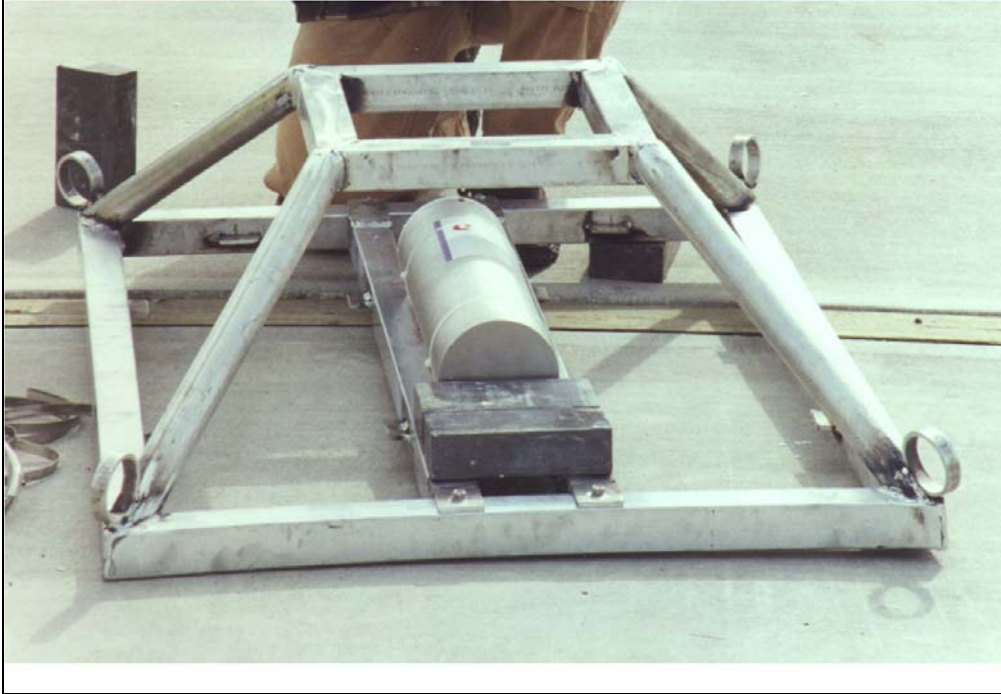


This Appendix presents analyzed wake time series, wake statistics, and supporting information for wake measurements in Rich Passage conducted as part of previous work for WSF and the Attorney General's office. PI Engineering conducted extensive monitoring of water surface elevations in the study area during 1999 and 2000 to characterize wake heights, periods and energy for a number of vessels on the Seattle-Bremerton ferry route. Wakes were characterized using parameters including the six highest waves in a wake and the corresponding wave periods and energy density associated with the six highest waves.

As part of this study PI Engineering re-analyzed the original wake and water level time series collected in Rich Passage to provide data for preliminary verification of wake propagation models as discussed in Section 5 of this report. The re-analysis involved computation of zero-upcrossing and zero-down-crossing wave heights, wave period, and wave energy density time series as well as spectral analysis to determine the distribution of energy as a function of wave frequency. The analysis of wake statistics was also extended from previous work. Time series statistics and results of the analysis are shown below.



**Figure D-1. Location of wave gauges deployed in Rich Passage 1999-2002**



**Figure D-2. Equipment used for data collection in Rich Passage between 1999 and 2002**

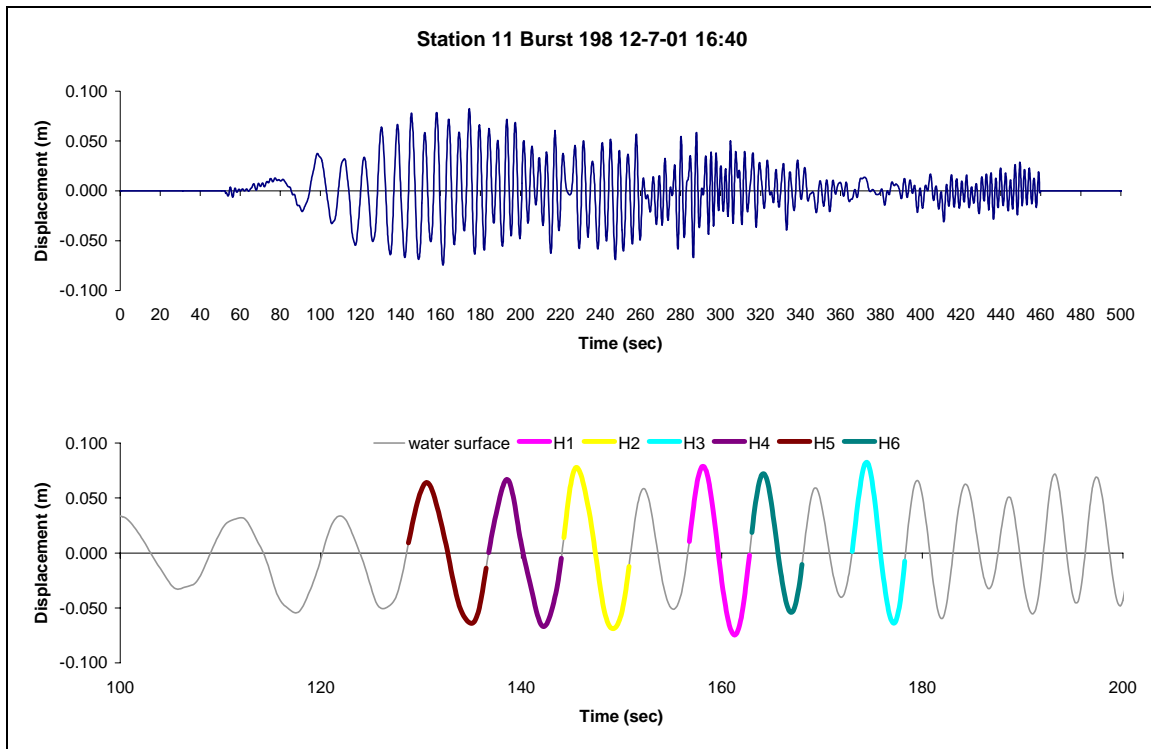
Data were collected from up to three stations simultaneously during each deployment recovery interval. Macrowave pressure-sensing wave gauges manufactured by Coastal Leasing, Inc., were fastened to underwater frames and deployed at depths of 3-8 ft by SCUBA divers (Figure D-2 Appendix D). The wave gauges recorded nearly continuously at a sampling rate of 4Hz (4 samples per second) for approximately a one-month period. To enable the measurement of as many wake events as possible, the gauges recorded continuously for 34 minutes and were off for only two minutes before starting the next 34-minute burst

PI Engineering used standard Seabird procedures and custom-developed software to convert the pressure measurements into water surface elevations.

In addition to wave measurement, PI Engineering collected and processed ferry positions determined with differential GPS. GPS measurements were used to determine the speed of fast ferries, sailing line, and positioning relative to wave gauges. All ferry traffic data were correlated with wave gauge data for all ferry runs for which wave data were obtained. The GPS correlations enabled positive identification of vessel wakes in the burst measurements associated with specific vessel transits on the Seattle-Bremerton route. Vessel speeds reported refer to the speed determined from the GPS position coordinates through time. Speeds have not been adjusted for local variations in tidal currents in Rich Passage, which may be as much as  $\pm 3$  to 4 knots.

To ensure statistically robust representation of measured wake characteristics, PI Engineering developed and used software to identify each of the six largest wave heights for all analyzed bursts and calculate their associated wave periods. Bursts retained for statistical analysis were first screened through a rigorous quality control process to positively identify the

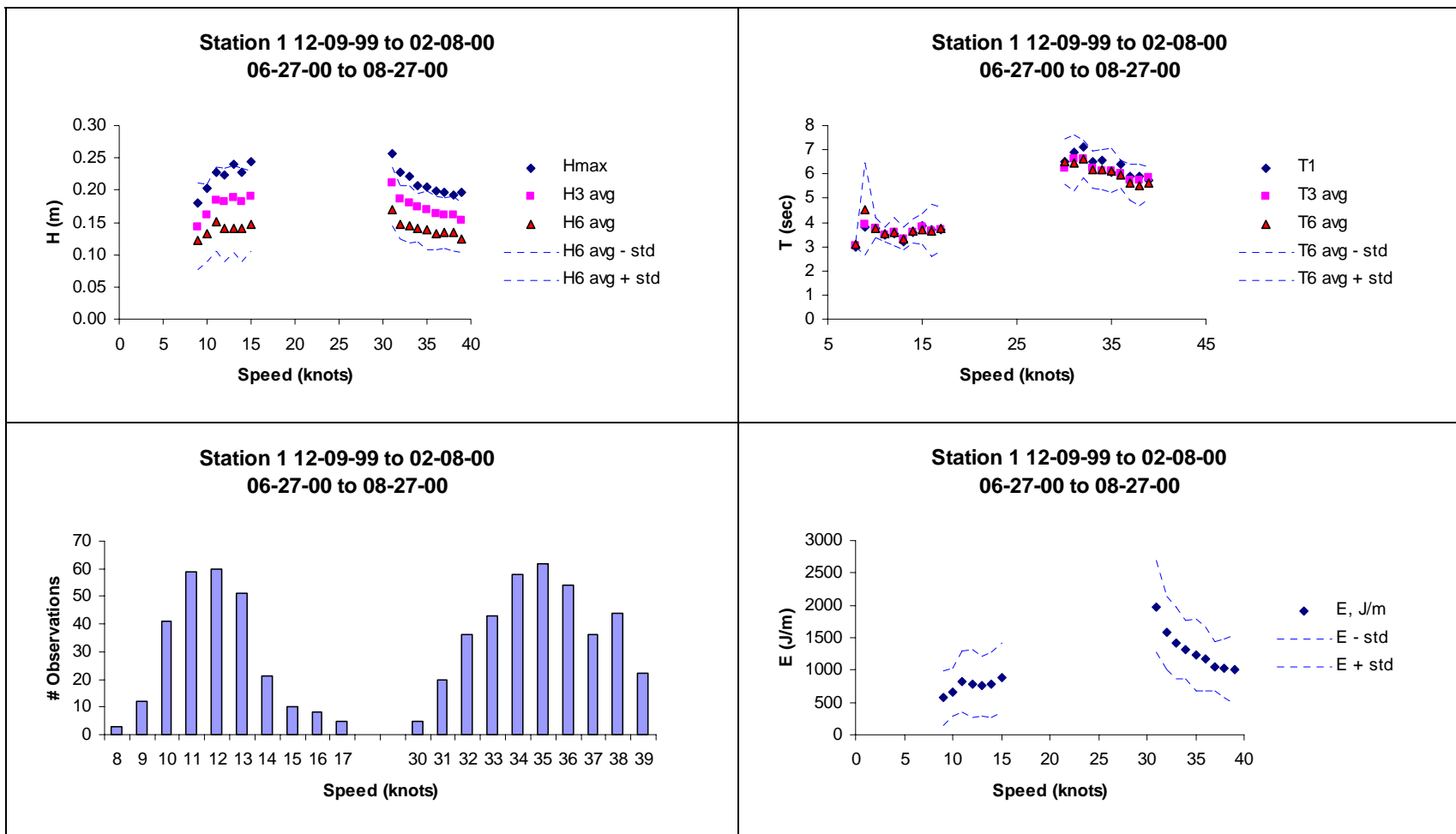
presence of a vessel wake within the measured burst. **Figure D-3** is an example of the six highest waves selected from a wave burst in descending order. As a result of the processing and analysis, the following parameters were obtained for each ferry run selected for analysis:



**Figure D-3. Example time series of water surface displacement associated with a nearshore wake (top) and the six largest waves in the wake (bottom)**

Examples of nearshore wake parameter plots for *Chinook* class ferries transiting Rich Passage between September 1999 and August 2000 are shown below in **Figures D-4 through D-9**. Figures D4 through D-9 are supplementary to Figure 3-30 in the main report.





**Figure D-4. Wake statistical parameters for Chinook class ferries measured nearshore at Station 1 in Rich Passage at a range of speeds**

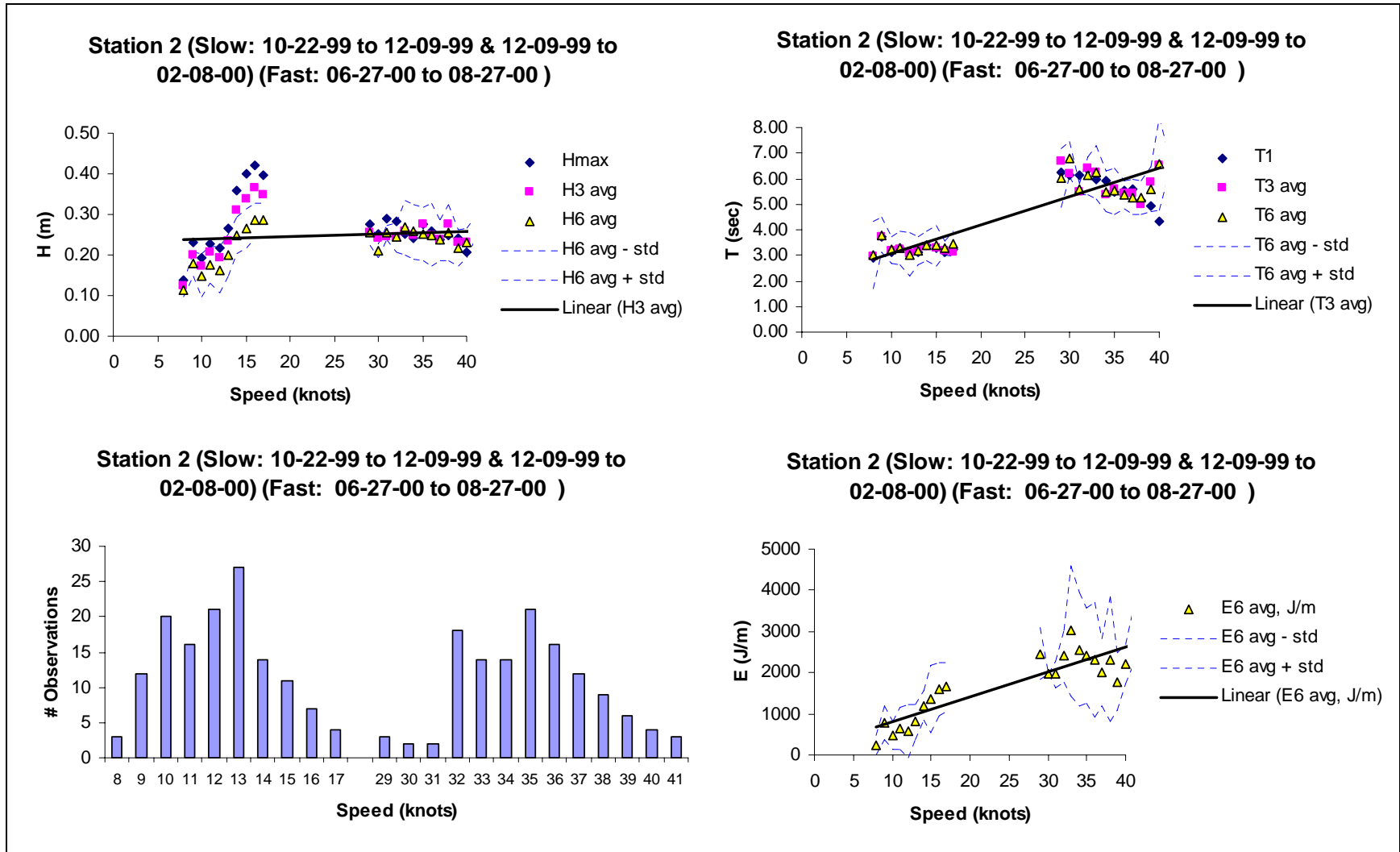
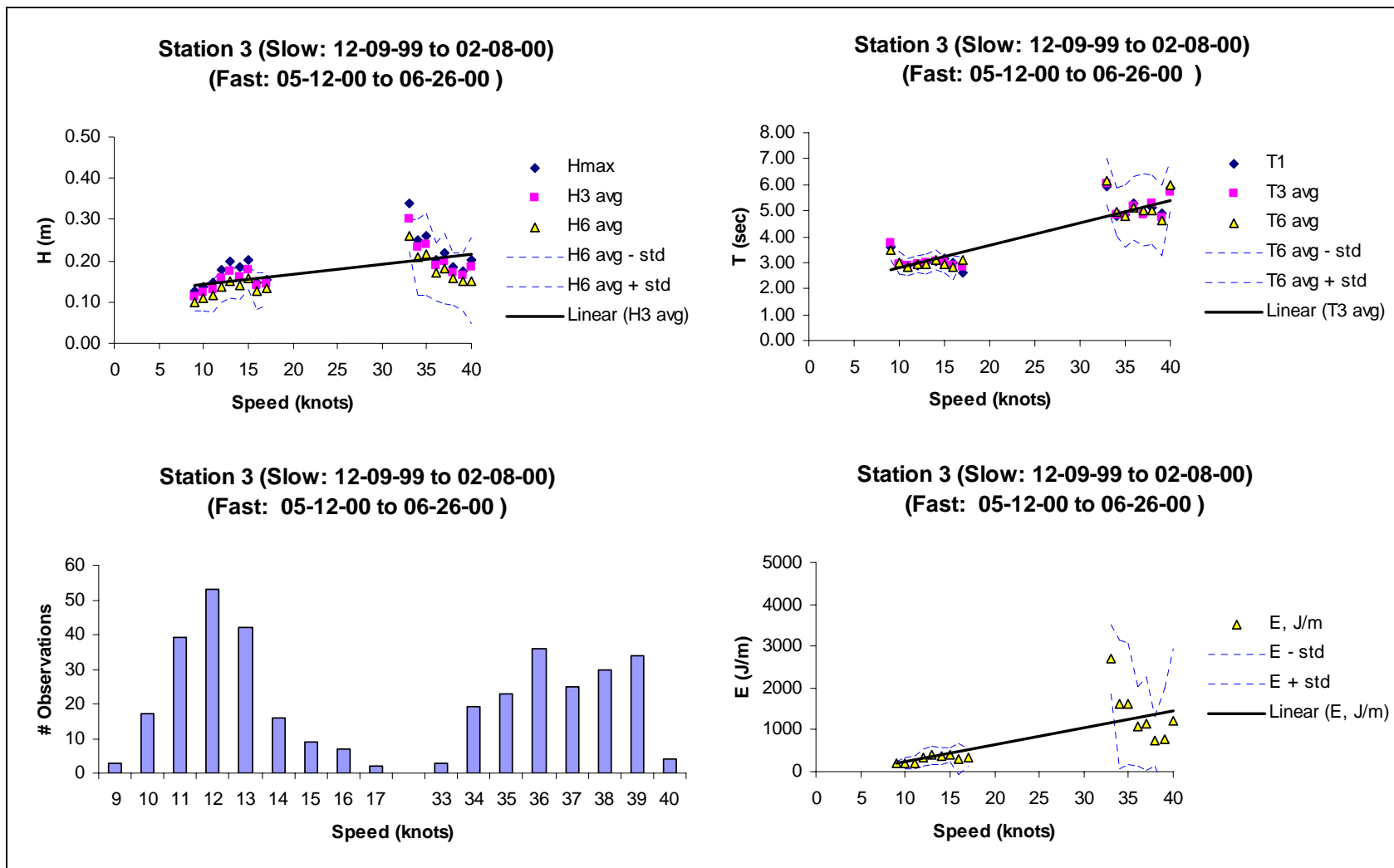


Figure D-5. Wake statistical parameters for Chinook class ferries measured nearshore at Station 2 in Rich Passage at a range of speeds.





**Figure D-6. Wake statistical parameters for Chinook class ferries measured nearshore at Station 3 in Rich Passage at a range of speeds.**

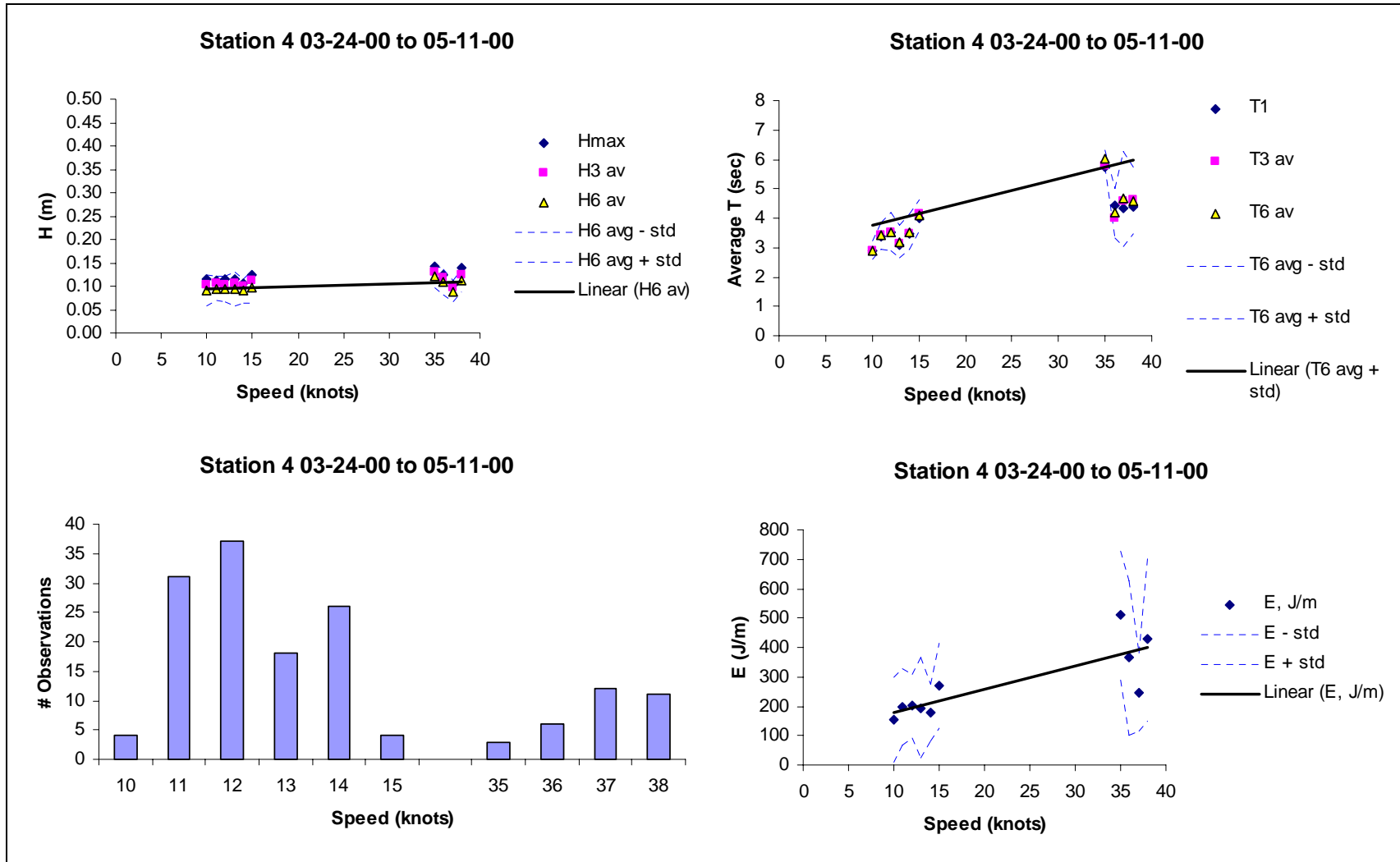
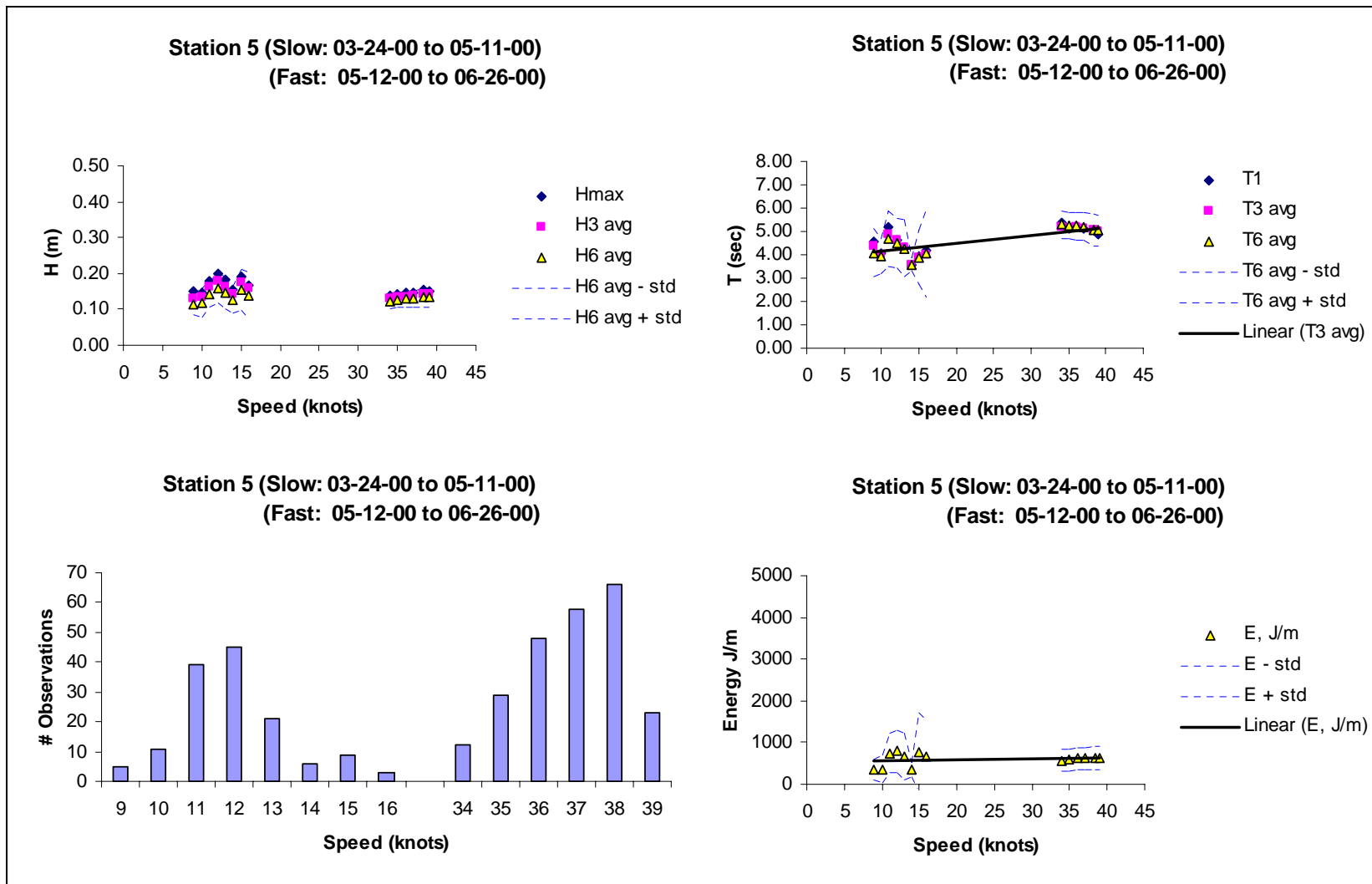


Figure D-7. Wake statistical parameters for Chinook class ferries measured nearshore at Station 4 in Rich Passage at a range of speeds.



**Figure D-8. Wake statistical parameters for Chinook class ferries measured nearshore at Station 5 in Rich Passage at a range of speeds**

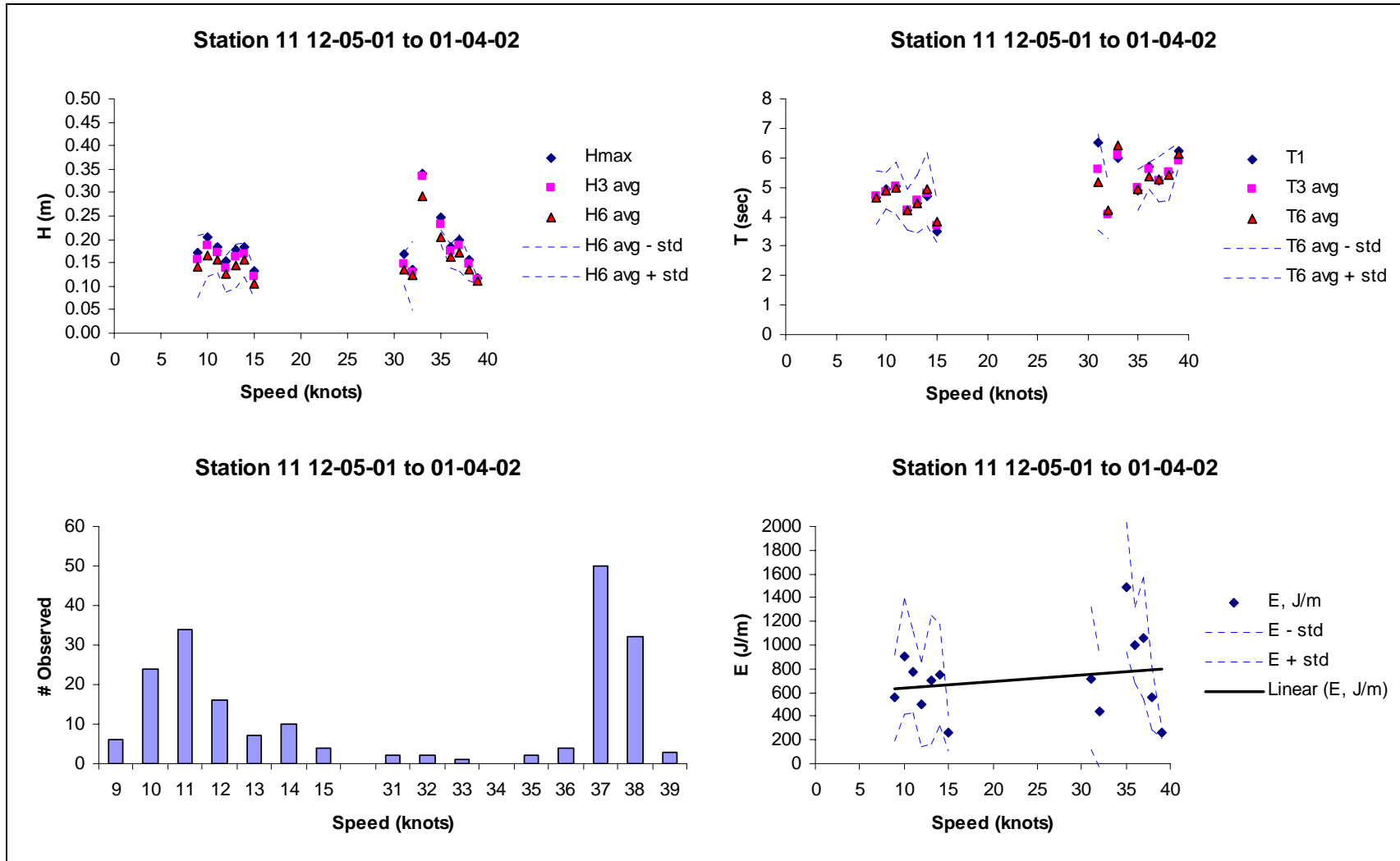
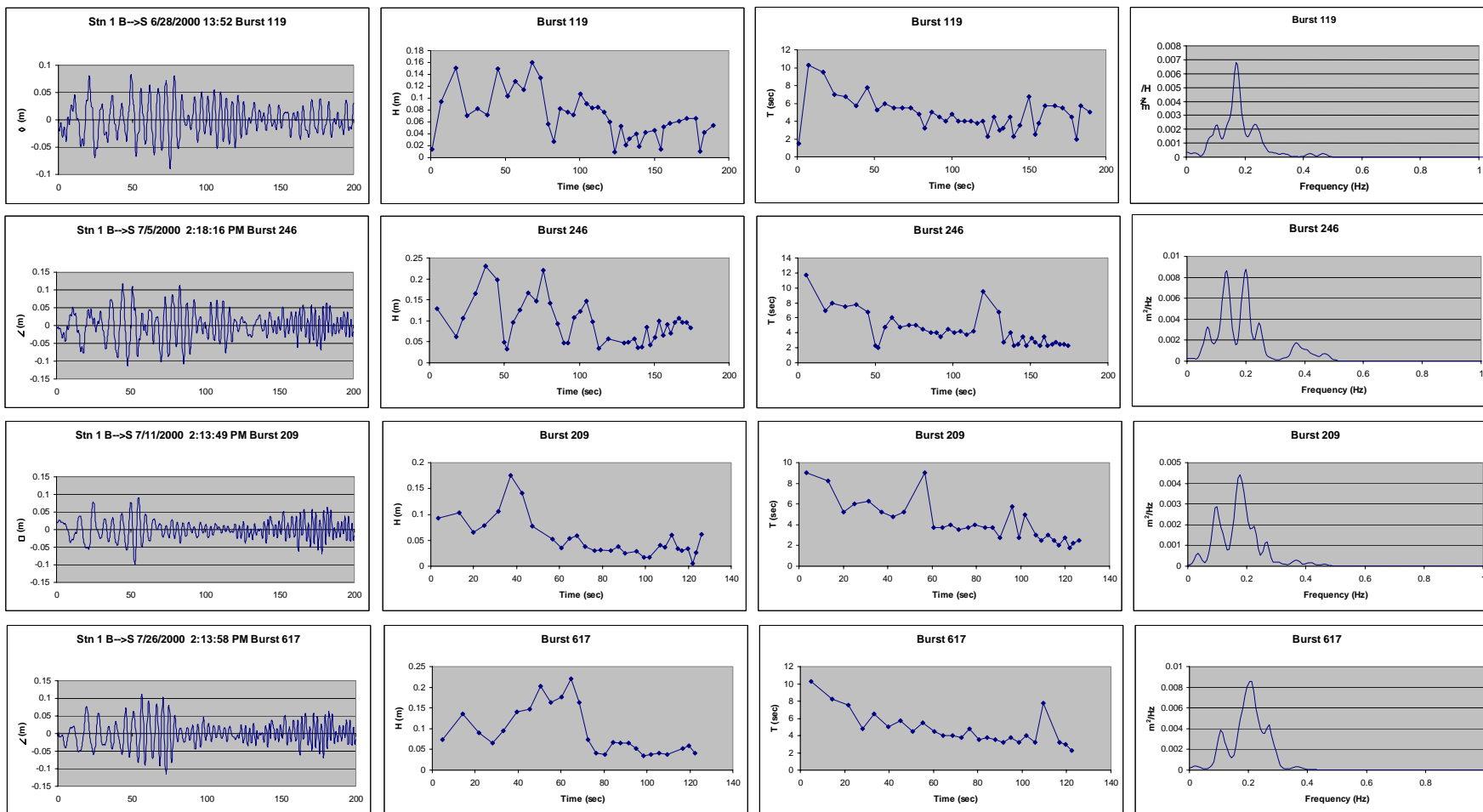
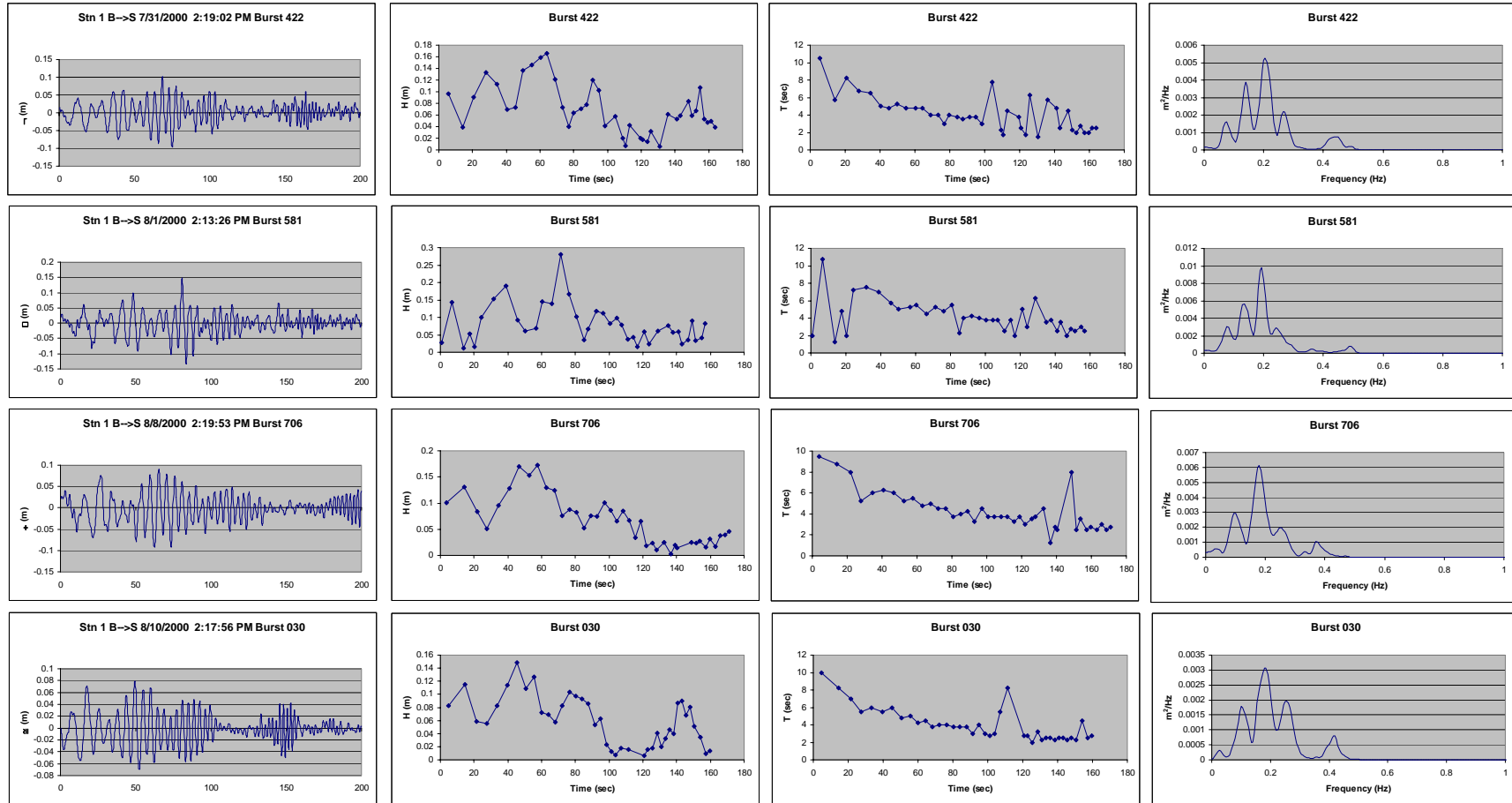


Figure D-9. Wake statistical parameters for Chinook class ferries measured nearshore at Station 11 in Rich Passage at a range of speed

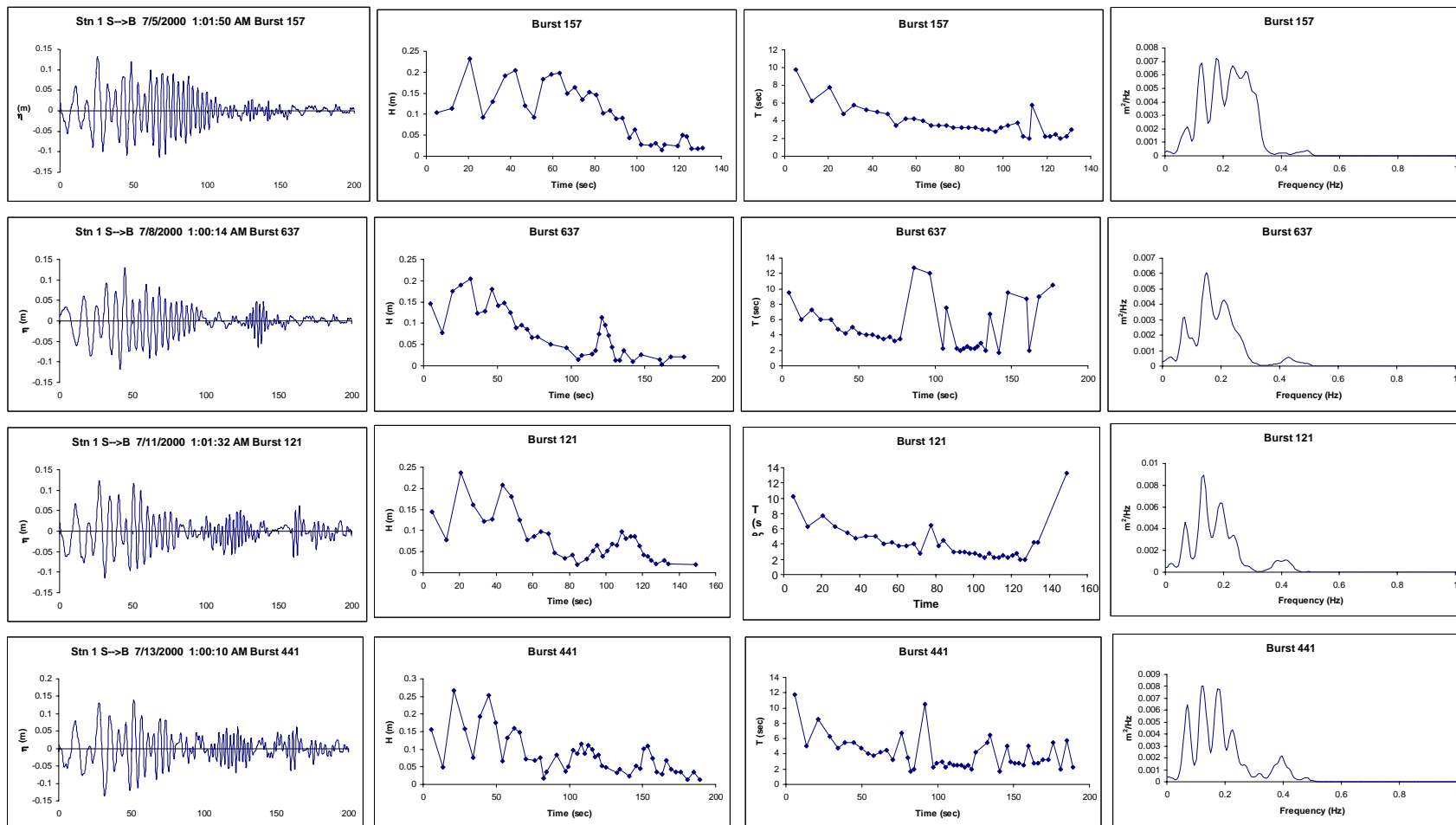
Example time series of Chinook class vessel wakes measured at Stations 1 and 2 in Rich Passage are shown below.



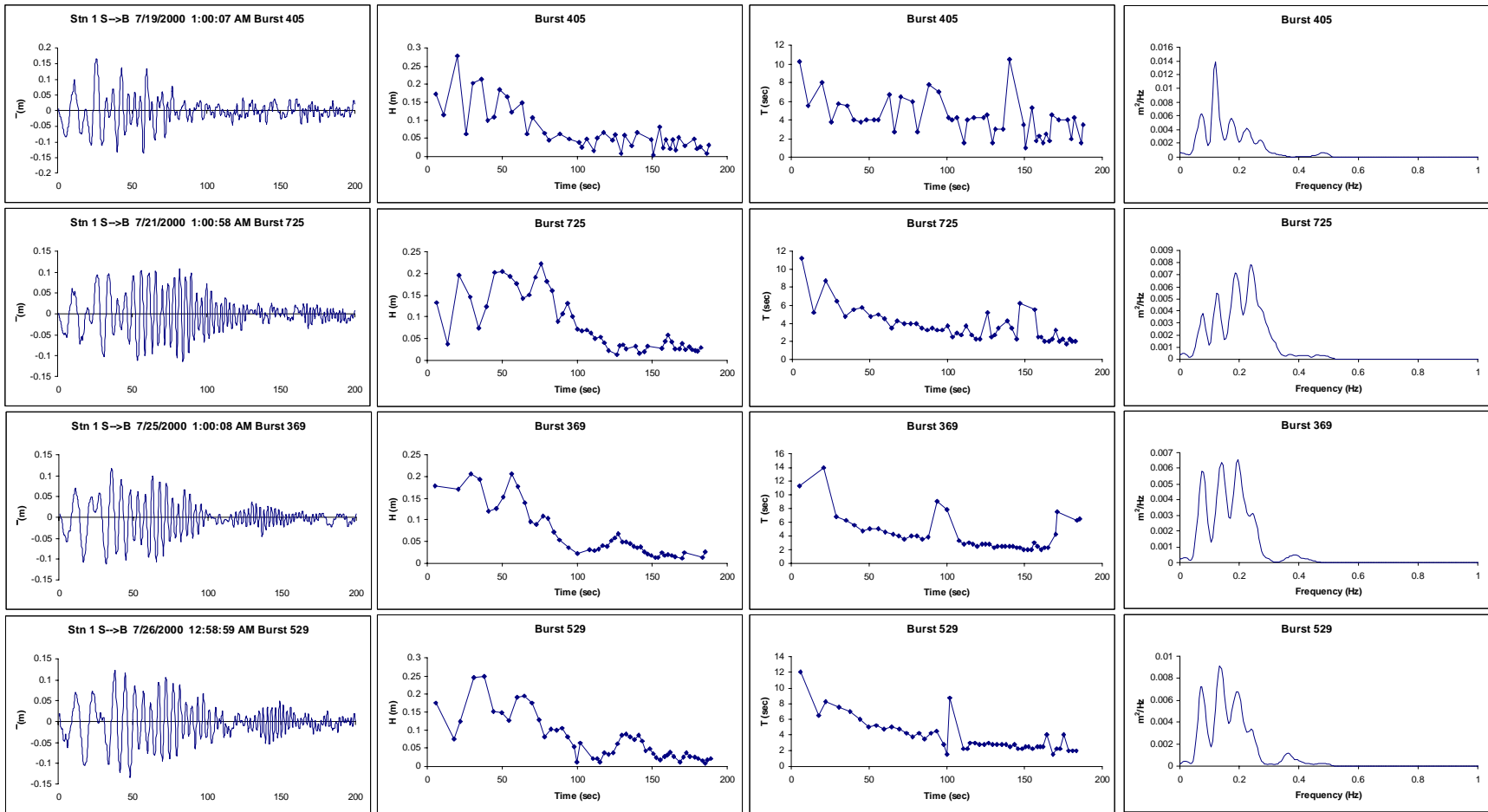
**Chinook Class Vessel Wakes Measured at Station 1 from Bremerton to Seattle**



**Chinook Class Vessel Wakes Measured at Station 1 from Bremerton to Seattle**

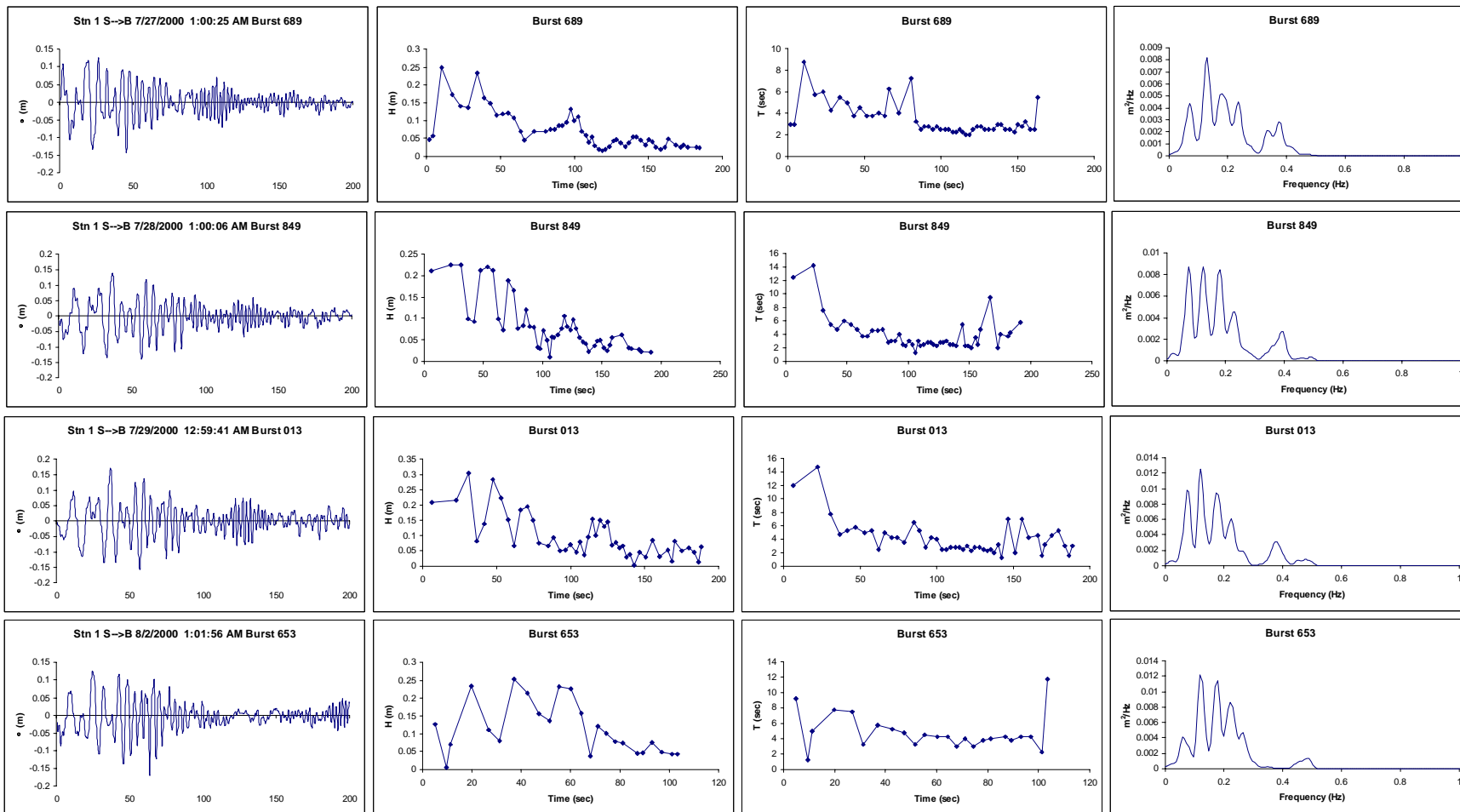


Chinook Class Vessel Wakes Measured at Station 1 from Seattle to Bremerton

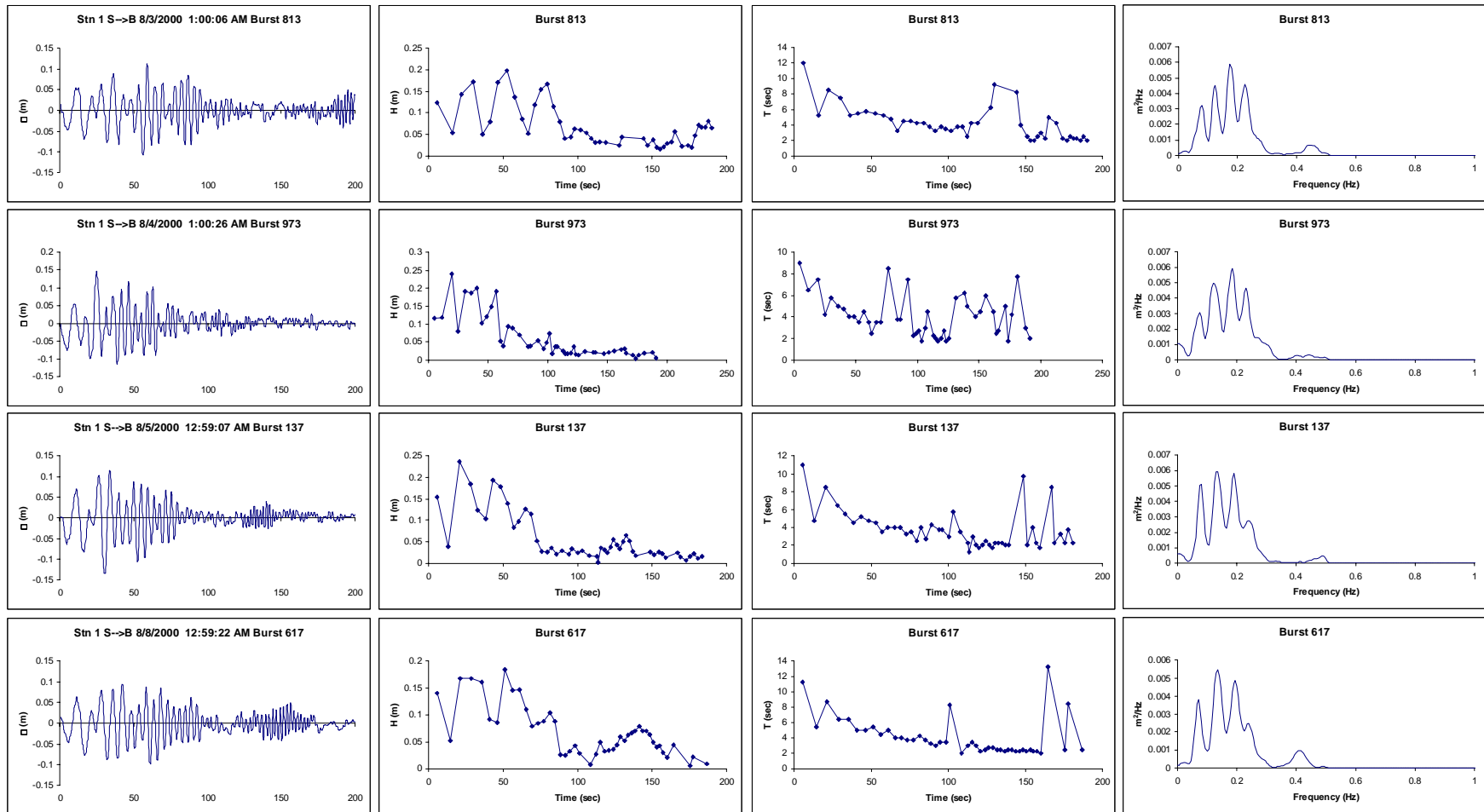


**Chinook Class Vessel Wakes Measured at Station 1 from Seattle to Bremerton**

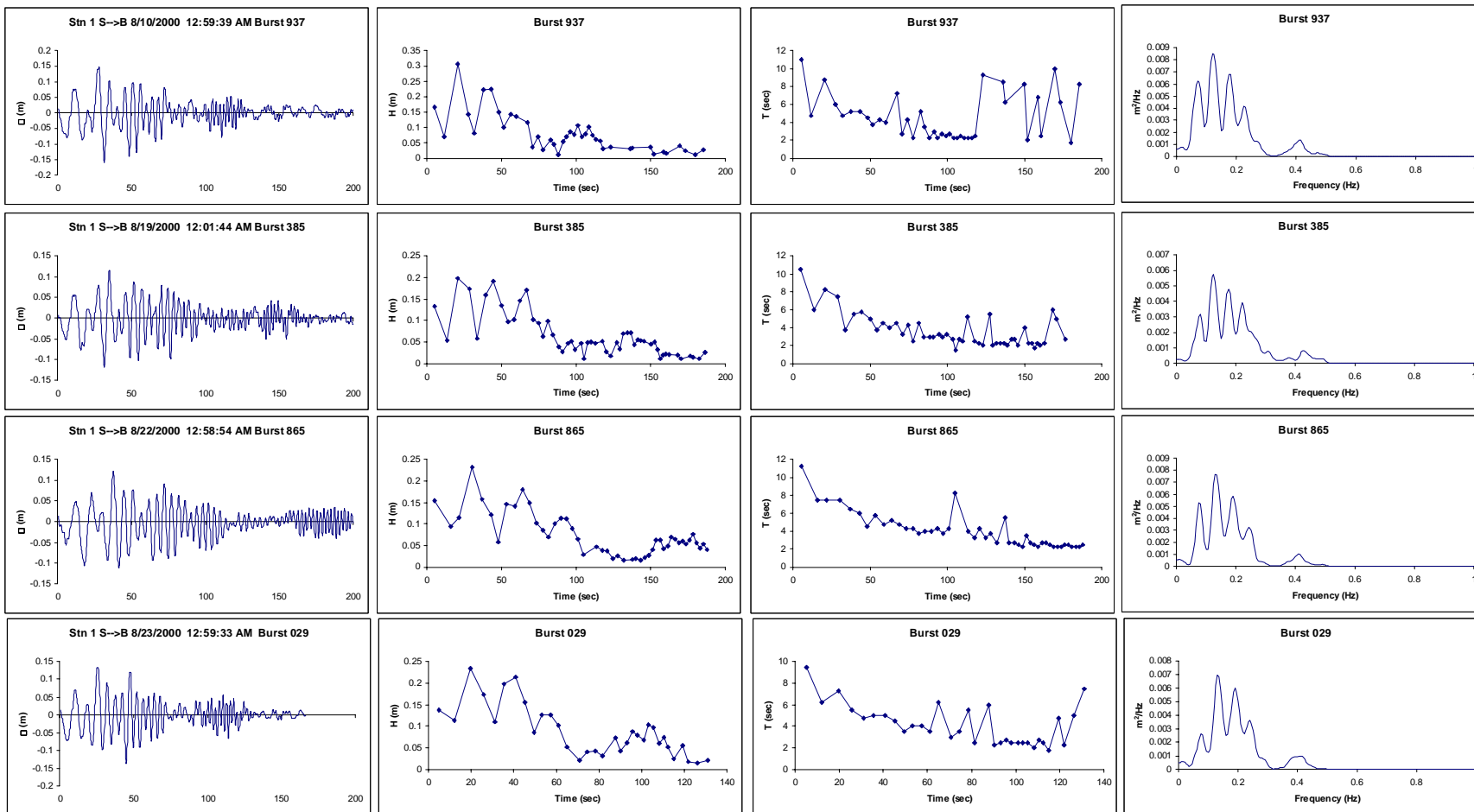




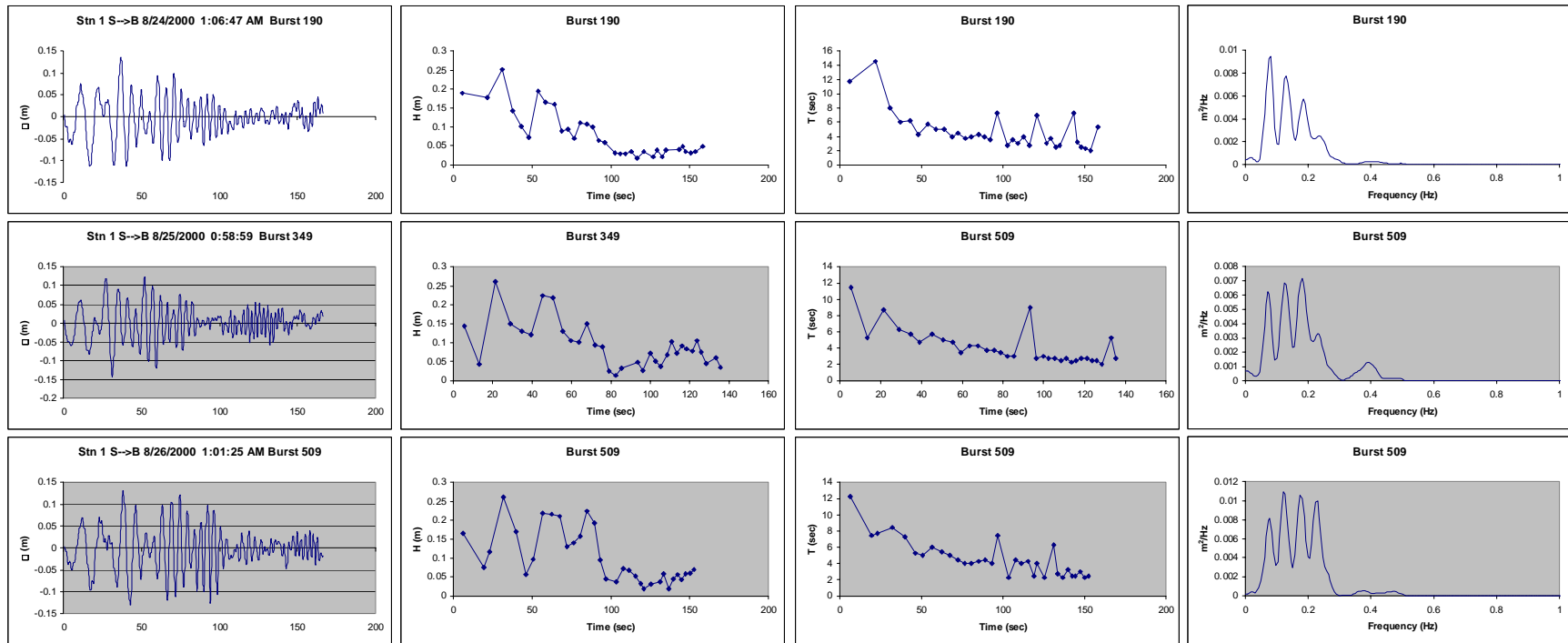
**Chinook Class Vessel Wakes Measured at Station 1 from Seattle to Bremerton**



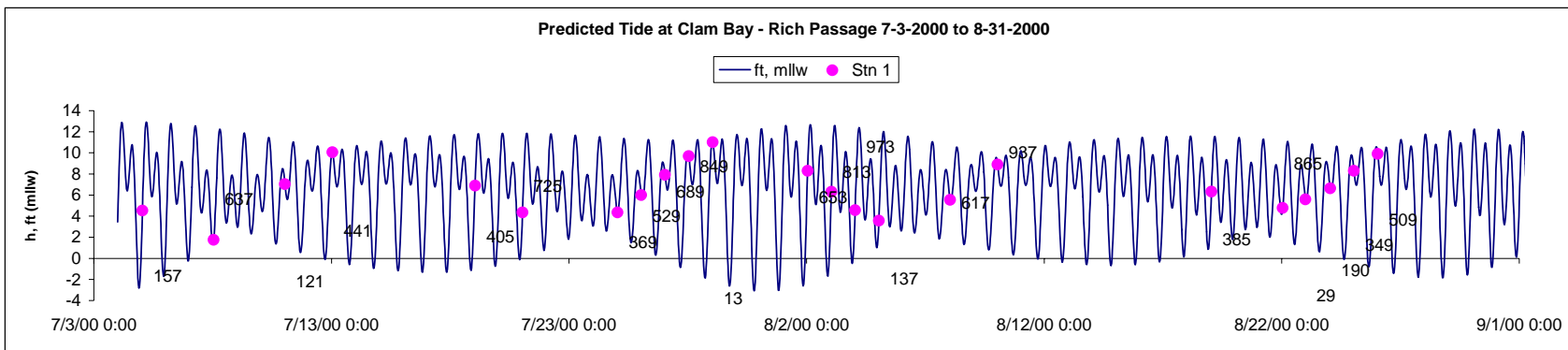
**Chinook Class Vessel Wakes Measured at Station 1 from Seattle to Bremerton**



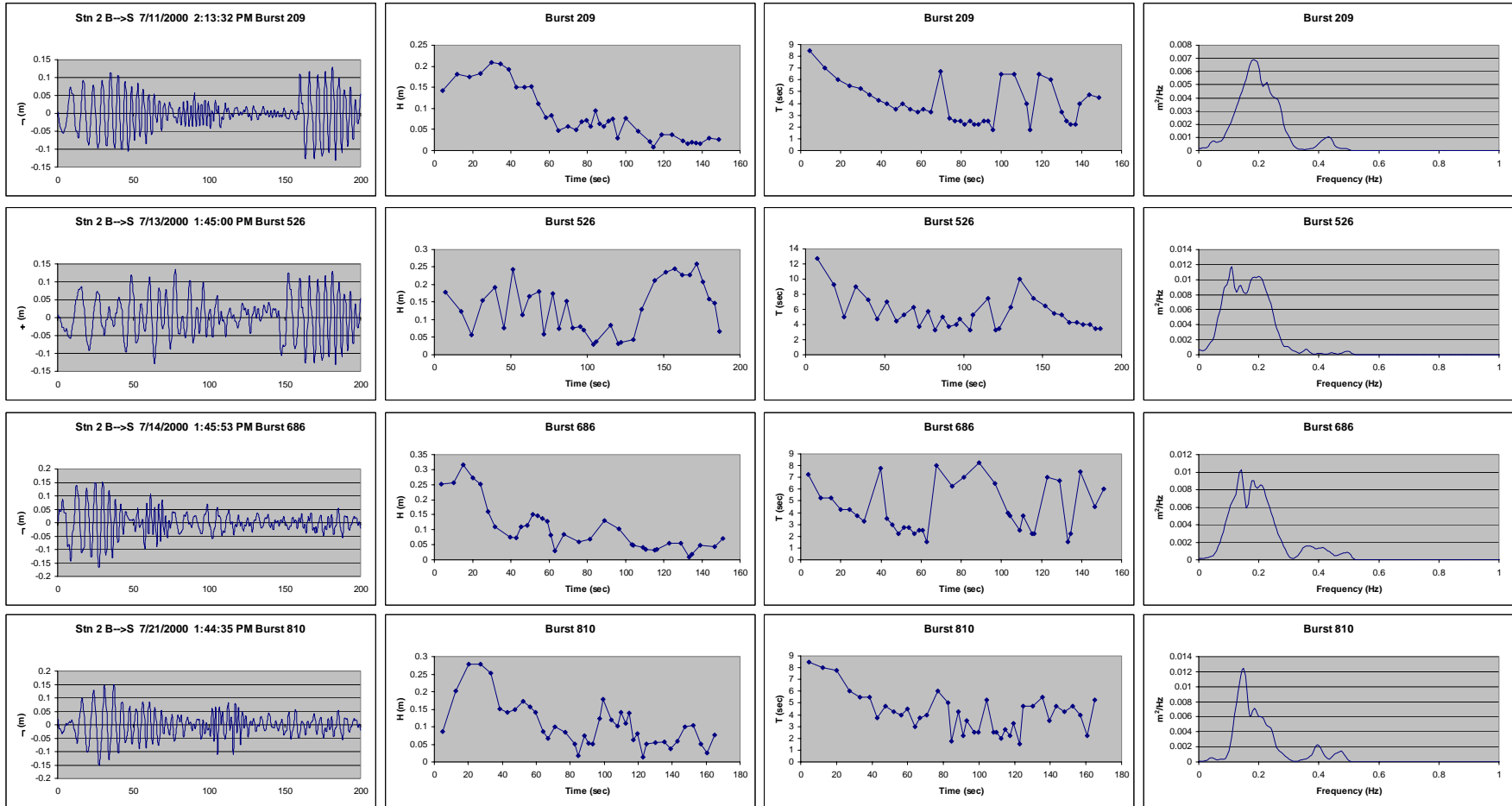
**Chinook Class Vessel Wakes Measured at Station 1 from Seattle to Bremerton**



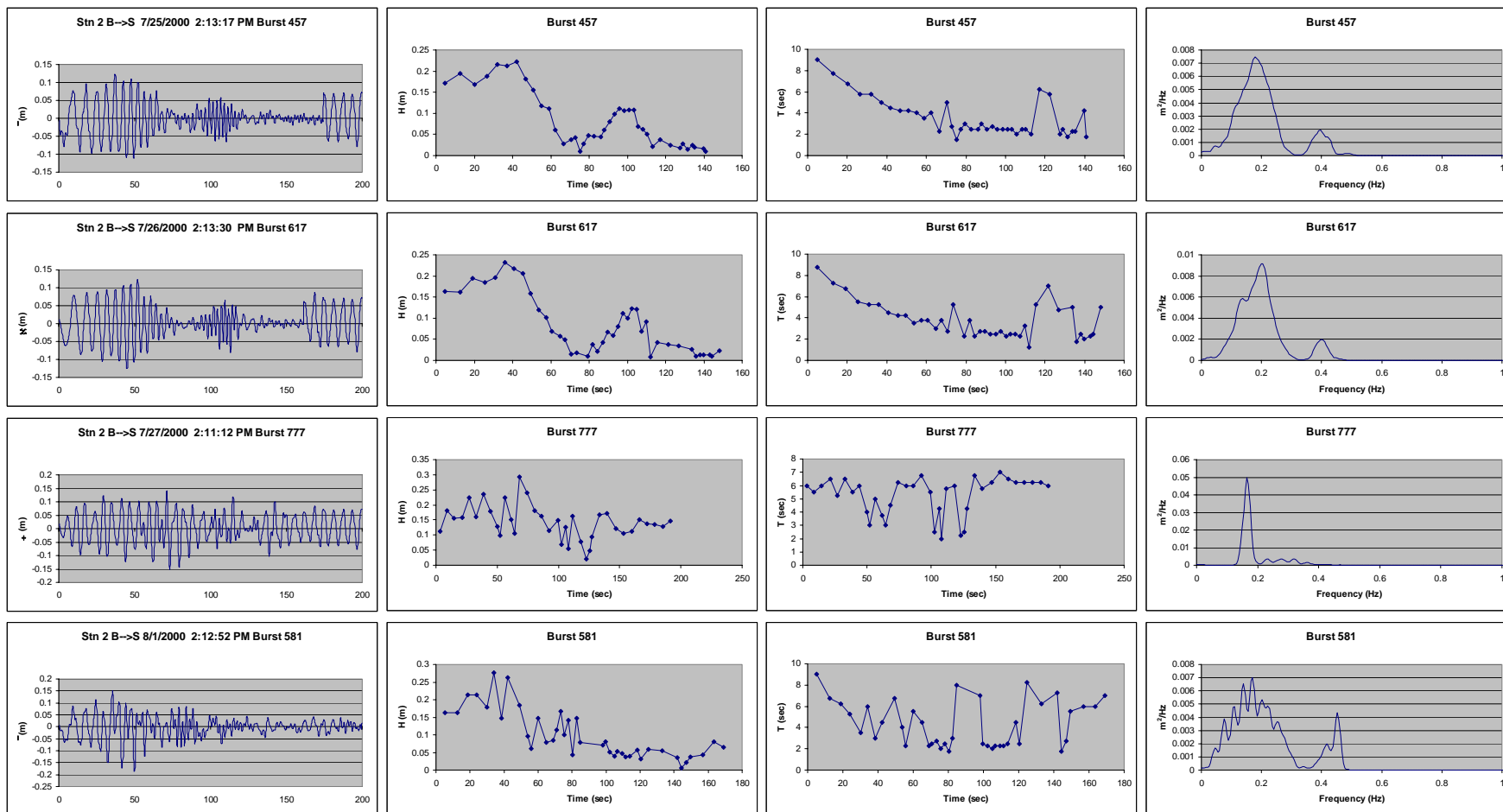
Chinook Class Vessel Wakes Measured at Station 1 from Seattle to Bremerton



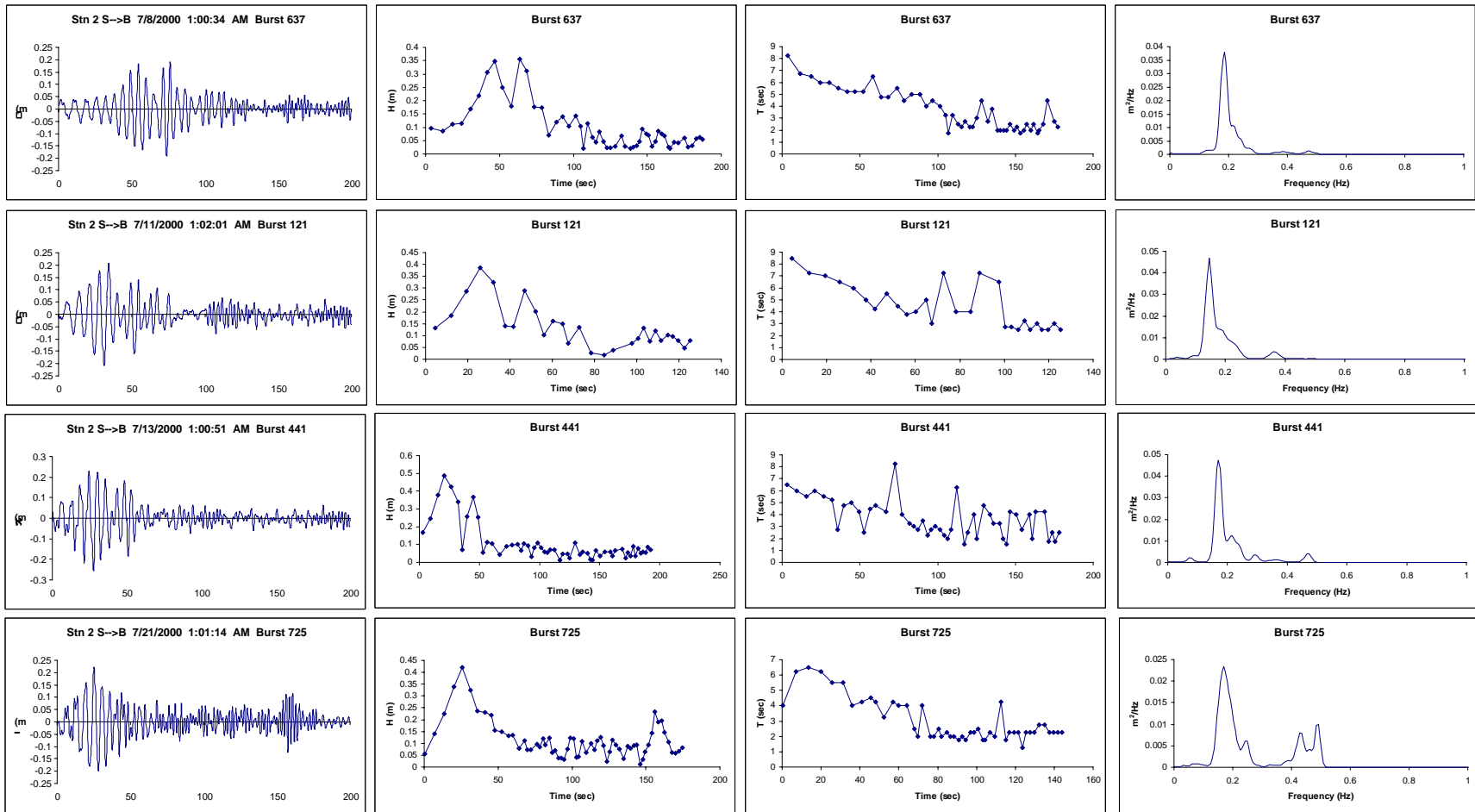
**Predicted Tide at Clam Bay – Rich Passage July 3, 2000 to August 31, 2000**



**Chinook Class Vessel Wakes Measured at Station 2 from Bremerton to Seattle**

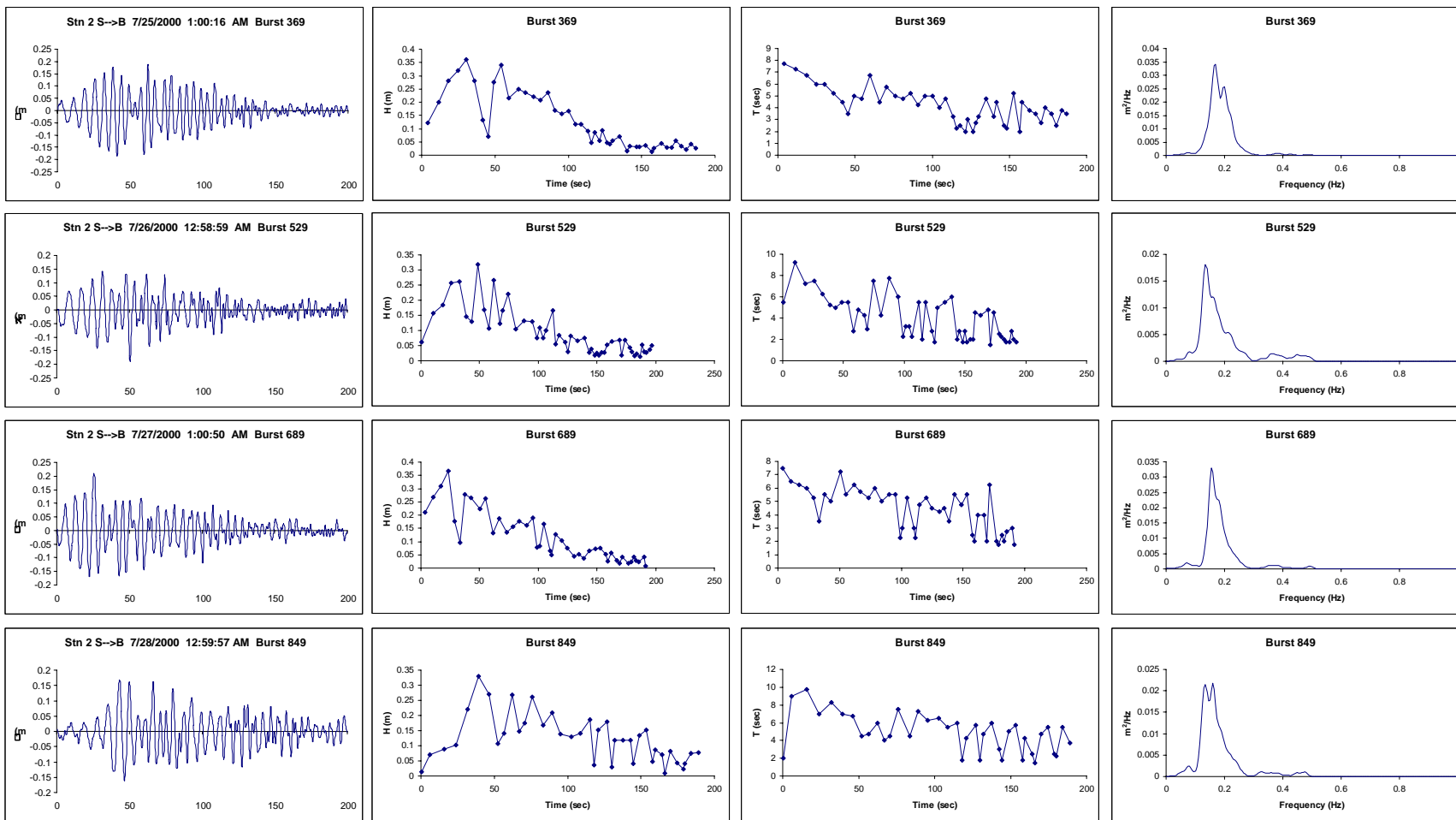


**Chinook Class Vessel Wakes Measured at Station 2 from Bremerton to Seattle**

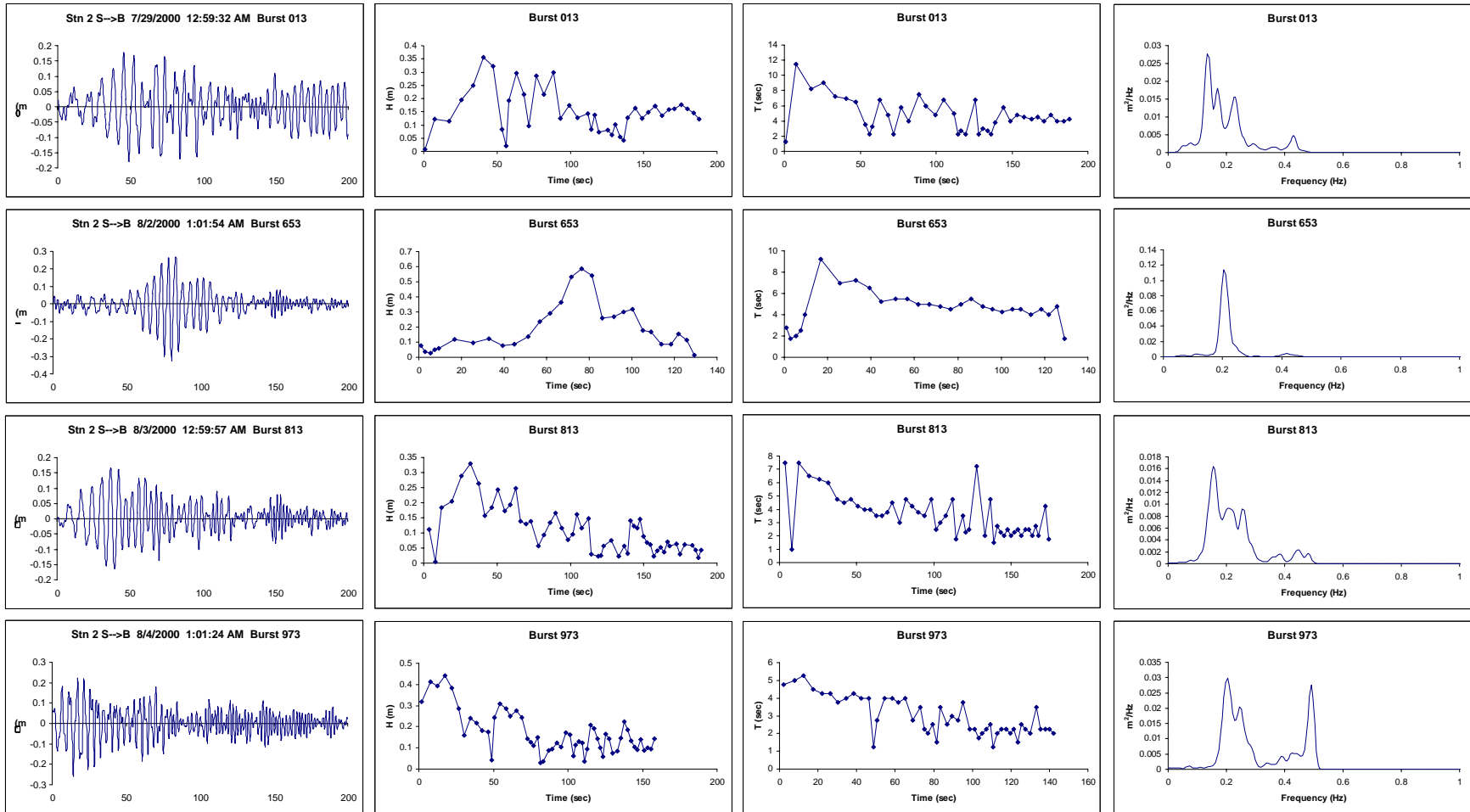


**Chinook Class Vessel Wakes Measured at Station 2 from Seattle to Bremerton**

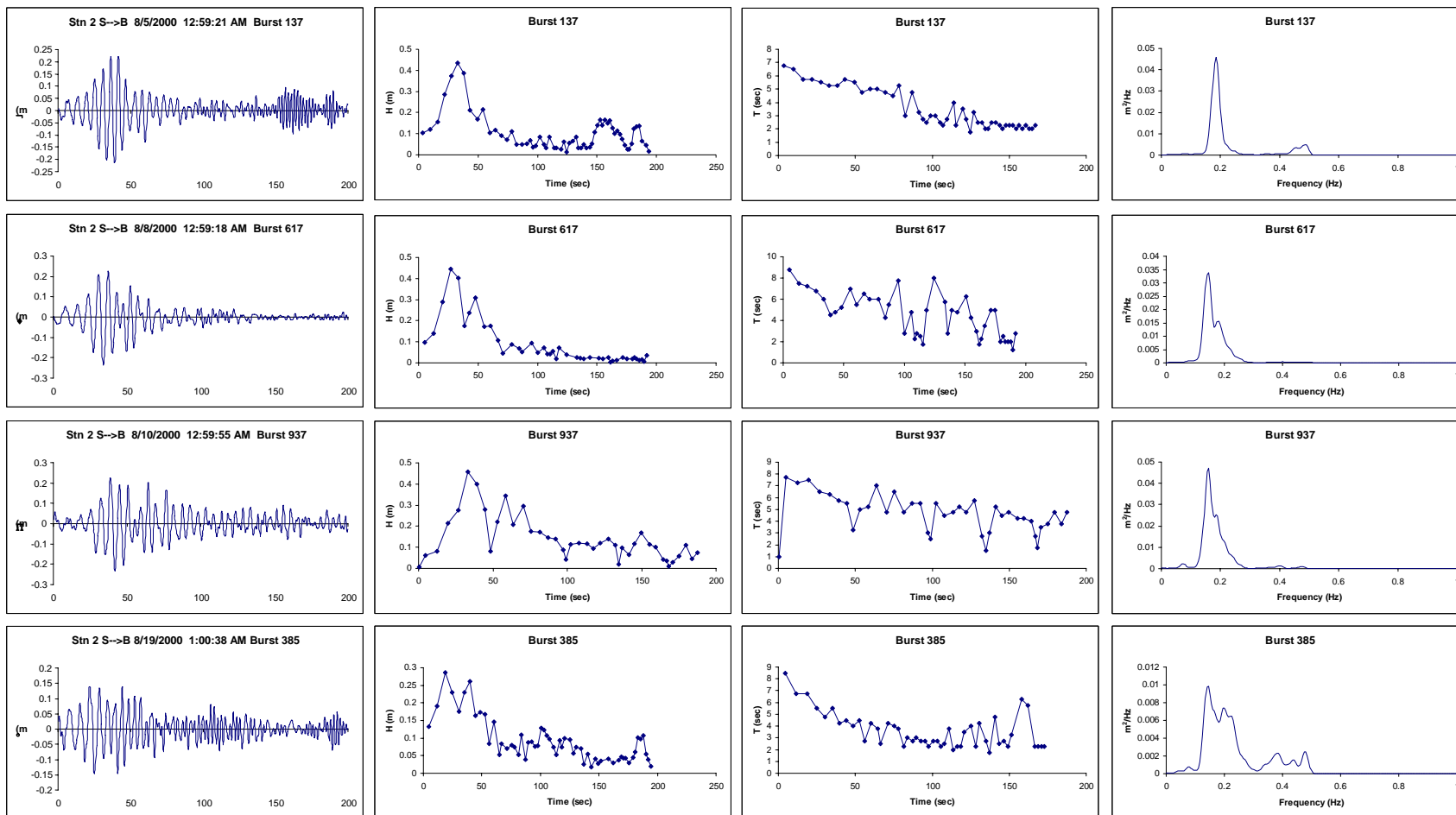




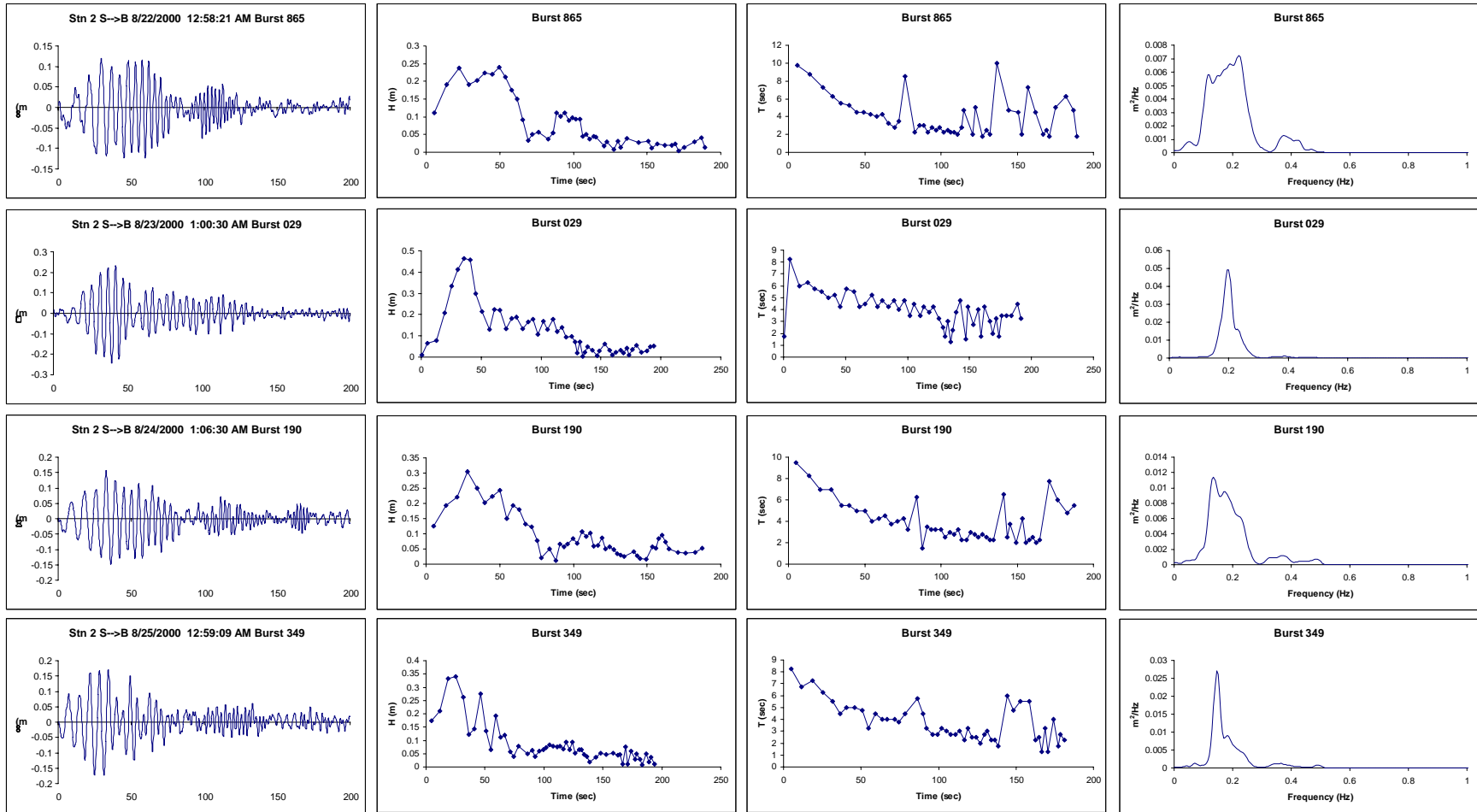
**Chinook Class Vessel Wakes Measured at Station 2 from Seattle to Bremerton**



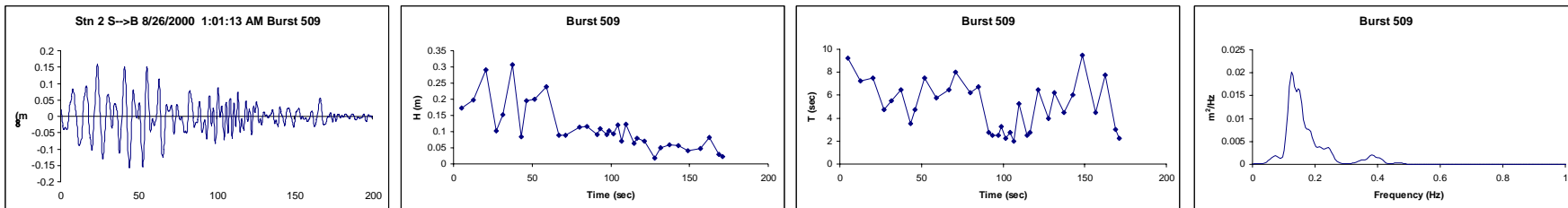
**Chinook Class Vessel Wakes Measured at Station 2 from Seattle to Bremerton**



Chinook Class Vessel Wakes Measured at Station 2 from Seattle to Bremerton



**Chinook Class Vessel Wakes Measured at Station 2 from Seattle to Bremerton**



**Chinook Class Vessel Wakes Measured at Station 2 from Seattle to Bremerton**

Example time series of car ferry wakes measured in Rich Passage are shown below.

