Validation of GEDAP Programs "Wavetran" and "Boat-Wave"

Cumming, D.; Mak, L. M.

Publisher's version / Version de l'éditeur:
https://doi.org/10.4224/8895739
Laboratory Memorandum; no. LM-2004-14, 2004

National Research Council Canada
Institute for Ocean Technology

Conseil national de recherches Canada
Institut des technologies océaniques

Laboratory Memorandum

LM-2004-14

Validation of Gedap Programs 'Wavetran' and 'Boat-Wave'

D. Cumming and L. Mak

June 2004

Canada

DOCUMENTATION PAGE

REPORT NUMBER	NRC REPORT NUMBER	DATE
LM-2004-14		June 2004

REPORT SECURITY CLASSIFICATION	DISTRIBUTION
Unclassified	Unlimited

TITLE

VALIDATION OF GEDAP PROGRAMS ‘WAVETRAN’ AND ‘BOAT_WAVE’

AUTHOR(S)

D. Cumming and L. Mak

CORPORATE AUTHOR(S)/PERFORMING AGENCY(S)

Institute for Ocean Technology, National Research Council, St. John’s, NL

PUBLICATION

N/A

SPONSORING AGENCY(S)

Institute for Ocean Technology, National Research Council, St. John’s, NL

IMD PROJECT NUMBER	NRC FILE NUMBER		
42_960_26			
KEY WORDS	**PAGES**	**FIGS.**	**TABLES**
Software, WAVETRAN, BOAT_WAVE	iv, 12, App. A-D	16	9

SUMMARY

This report documents the validation, using realistic physical wave data acquired in the Institute for Ocean Technology (IOT) Offshore Engineering Basin (OEB), of GEDAP programs ‘WAVETRAN’ and ‘BOAT_WAVE’. ‘WAVETRAN’ is used to translate unidirectional regular or irregular wave data from a stationary wave probe to another stationary point using linear theory. ‘BOAT_WAVE’ is used to translate unidirectional regular or irregular wave data from a stationary wave probe to a defined point on a moving model using linear theory. An attempt will be made to define an envelope for valid use of the software.

ADDRESS

National Research Council
Institute for Ocean Technology
Arctic Avenue, P. O. Box 12093
St. John's, NL A1B 3T5
Tel.: (709) 772-5185, Fax: (709) 772-2462

National Research Council Canada
Conseil national de recherches Canada

Institute for Ocean Technology
Institut des technologies océaniques

VALIDATION OF GEDAP PROGRAMS 'WAVETRAN' AND 'BOAT_WAVE'

LM-2004-14

D. Cumming, L. Mak

June 2004

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS AND ABBREVIATIONS

cm	centimeter(s)
Cxy(τ)	Cross-Covariance Function
d	water depth
EW1	East Wave Probe
FFT	Fast Fourier Transform
g	acceleration due to gravity (9.808 m/s^2)
GDAC	General Data Acquisition and Control
GEDAP	General Data Analysis Package
Hav	Average Wave Height
Hmax	Maximum Wave Height
Hz	Hertz
IMD	Institute for Marine Dynamics (now IOT – Institute for Ocean Technology)
IOT	Institute for Ocean Technology
IR	infrared
k	wave number
L_w	wave length
m	meter(s)
mm	millimeter(s)
MW1	Middle Wave Probe
NC1	North Center Wave Probe
NRC	National Research Council

LIST OF SYMBOLS AND ABBREVIATIONS (cont'd)

NW1	North West Wave Probe
OEB	Offshore Engineering Basin
$Rxy(\tau)$	Cross Correlation Function
s	second(s)
SW1	South West Wave Probe
t	tonne(s), time
T1, T2	time segment start, end time
Tav	Average Wave Period
Tmax	Maximum Wave Period
Tw	Wave Period
WW1	West Wave Probe
π	3.14159
τ	time shift

VALIDATION OF GEDAP PROGRAMS 'WAVETRAN' AND 'BOAT_WAVE'

1.0 INTRODUCTION

This report documents the validation, using realistic physical wave data acquired in the Institute for Ocean Technology (IOT) Offshore Engineering Basin (OEB), of GEDAP programs 'WAVETRAN' and 'BOAT_WAVE'. 'WAVETRAN' is used to translate unidirectional regular or irregular wave data from a stationary wave probe to another stationary point using linear theory. 'BOAT_WAVE' is used to translate unidirectional regular or irregular wave data from a stationary wave probe to a defined point on a moving model using linear theory. An attempt will be made to define an envelope for valid use of the software.

2.0 BACKGROUND

IOT performs seakeeping experiments in the OEB on scaled self-propelled, radio controlled free-running physical models of ships using standard procedures described in Reference 1. A photograph of a typical ship model taken during a seakeeping test in the OEB is provided in Figure 1. Moored platforms are also commonly tested in wind, waves and current (see Figure 2). Waves are generated in the OEB using standard procedures described in Reference 2. To measure the wave field during testing, IOT would typically install a number of stationary capacitance wave probes at known positions in the OEB co-ordinate system as shown in Figure 3. IOT often tailors model test programs for clients/ collaborators involved in validating time domain numerical prediction software. For these projects, providing time domain wave information at some defined point on the model (typically the model's center of gravity) is a common requirement. GEDAP programs 'WAVETRAN' or 'BOAT_WAVE' can, using data from a stationary wave probe as an input, be used to estimate the variation in wave height at a stationary or moving model subjected to a unidirectional regular or irregular wave field. This document has been written to validate the software, establish boundaries for acceptable output and provide IOT clients/collaborators with some confidence in the integrity of the results generated.

These programs do not provide acceptable results in multi-directional or non-linear waves. Poor results are noted when the generated waves are steep enough to break or where there is a measurable variation in wave celerity as the waves propagate the length of the tank.

3.0 DESCRIPTION OF THE OFFSHORE ENGINEERING BASIN

The IOT Offshore Engineering Basin (OEB) has a working area of 26 m by 65.8 m with a depth that can be varied from 0.1 m to 3.0 m. The depth used for the validation exercise described in this report was 2.8 m. Waves are generated using 168 individual, computer controlled wet back wavemaker segments, hydraulically activated, fitted around the perimeter of the tank in an “L” configuration. Each segment can be operated in one of three modes of articulation: flapper mode (± 15º), piston mode (± 400 mm) or a combination of both modes. The wavemakers are capable of generating both regular and irregular waves up to 0.5 m significant wave height. Passive wave absorbers are fitted around the other two sides of the tank. The facility has a recirculating water system based current generation capability with current speed dependent on water depth, extensive video coverage and is serviced over its entire working area by a 5 t lift capacity crane. Additional information on the OEB can be found in Appendix A.

4.0 DESCRIPTION OF GEDAP PROGRAMS ‘WAVETRAN’ AND ‘BOAT_WAVE’

Both ‘WAVETRAN’ and ‘BOAT_WAVE’ were designed to be used by the GEDAP data analysis software package described in Reference 3. A brief description of the GEDAP software package and documentation on all GEDAP programs available to the IOT user can be found on the IOT internal web site.

‘BOAT_WAVE’ reads in a GEDAP V1 file containing Eta1(t) where Eta1(t) is the wave elevation record of a unidirectional regular or irregular wave train at the position (x1, y1) of a stationary wave probe. At each time step, ‘BOAT_WAVE’ calculates the wave elevation at a desired point on the physical model, specified by two planar position input files X_LOC(t) and Y_LOC(t) normally measured using the QUALISYS optical tracking system described in Reference 4 with additional information presented in Appendix B. Note the QUALISYS infrared (IR) markers on the ship model shown in Figure 1. The wave elevation time series at the desired point on the model is stored in an output file.

‘WAVETRAN’ reads in a GEDAP V1 file containing Eta1(t) where Eta1(t) is the wave elevation record of a unidirectional regular or irregular wave train at the position of a stationary wave probe (x1, y1). At each time step, ‘WAVETRAN’ then calculates the corresponding wave elevation record Eta2(t) at some other defined stationary point (x2, y2) and stores this time series in an output file. Note the array of wave probes around the platform in Figure 2.

For both programs, the user specifies the direction of propagation of the unidirectional wave train and the water depth. In addition, both programs use FFT techniques to compute the phase shift of each frequency component on the basis of linear wave theory. The wave direction and planar position in the OEB must be specified in a co-ordinate system defined as follows (see Figure 3):

- origin at the south west corner of the tank.
- X co-ordinate positive east

- Y co-ordinate positive north

<u>WARNING</u>: If the planar position data acquired from QUALISYS is not provided in this co-ordinate system, GEDAP program 'TRANSFORM1' must be run to perform a co-ordinate transformation before using 'WAVETRAN' or 'BOAT_WAVE'. Also the positions of the wave probes must also be input by the user in this co-ordinate system.

If there is a tilt to any of the wave probes, this can result in significant probe position errors. For example, for a water depth of 2.8 m, it will only require a 4 degree tilt in a wave probe to get a 0.2 m error in position.

5.0 OEB TEST CONFIGURATIONS

The software was validated using available data acquired during a number of projects carried out over the last few years in the OEB. The following experiments were carried out:

<u>Data Set 1 – Project 977:</u>

Data from three wave probes were acquired for most of the experiments in Data Set 1. A ship model was operating in the tank with planar (X, Y) position measured using QUALISYS during each run. The co-ordinates of each wave probe are provided as follows:

South West Probe (SW1): X = 15.347 m, Y = 5.775 m
North West Probe (NW1): X = 15.230 m, Y = 20.828 m
North Center Probe (NC1): X = 29.413 m, Y = 20.837 m

See Figure 3 for layout of OEB for Data Set 1.

Wave Configurations - Data Set 1:

Regular Waves:

Flume Mode, west wavemakers used only, blanking plates Installed covering north beaches – nominal wave period = 1.12 s to 3.628 s, wave height = 0.0735 m to 0.5 m.

Oblique Waves, west and south wavemakers used, waves generated 60 degrees relative to west wall, no blanking plates installed – nominal wave period = 1.12 s to 3.023 s, wave height = 0.0735 m to 0.5 m.

Irregular Waves:

Flume Mode, west wavemakers used only, blanking plates installed covering north beaches – nominal modal period = 2.6 s, nominal significant wave height = 0.283 m – multiple wave segments were used to cover spectrum. North west wave probe data unavailable.

Oblique Waves, west and south wavemakers used, waves generated 60 degrees relative to west wall, no blanking plates installed – nominal modal period = 2.6 s, nominal significant wave height = 0.283 m – multiple wave segments were used to cover the spectrum.

See Tables 1 - 3 for list of Data Set 1 waves.

<u>Data Set 2 – Project 903:</u>

Data from three wave probes were acquired for most of the experiments in Data Set 2. There was no physical model in the tank during these experiments. The co-ordinates of each wave probe are provided as follows:

East Probe (EW1): X = 43.541 m, Y = 13.285 m
West Probe (WW1): X = 15.005 m, Y = 13.340 m
Middle Probe (MW1): X = 29.373 m, Y = 13.330 m

See Figure 4 for layout of OEB for Data Set 2.

Wave Configurations - Data Set 2:

Regular Waves:

Flume Mode, west wavemakers used only, blanking plates Installed covering north beaches – nominal wave period = 1.43 s to 6.67 s, wave height = 0.05 m to 0.7 m.

Irregular Waves:

Flume Mode, west wavemakers used only, blanking plates installed covering north beaches – nominal mean period = 1.43 to 2.5 s, nominal significant wave height = 0.05 m to 0.6 m – one wave segment from each wave reviewed.

See Table 4, 5 for list of Data Set 2 waves.

6.0 ‘WAVETRAN’ VALIDATION

The data analysis procedure and the results of the validation of program ‘WAVETRAN’ is presented in this section. For Data Set 1, waves measured using the North West and South West probes were moved to the North Center probe position and compared to waves measured using the North Center probe. For Data Set 2, waves measured using the East and West probes were moved to the Middle probe position and compared to waves measured using the Middle probe. All data acquired in the OEB is initially formatted as GDAC test data acquisition files described in References 5, 6.

Data Analysis Procedure

The following basic data analysis sequence was followed:

- Run GEDAP Program ‘SPLIT_DAC’ to split GDAC test data acquisition files acquired during experiments in the OEB into separate GEDAP format wave data files in model scale units.
- Run GEDAP program ‘WAVETRAN’ to move wave data from one probe position to a second wave probe position. The user inputs the X, Y position of each wave probe in the specified OEB co-ordinate system with the origin defined at the south west corner of the tank, the water depth (m) and the wave direction with respect to the west tank wall (degrees).
- Use GEDAP Program ‘GPLOT’ to review the wave data from all wave probes in the time domain to determine an acceptable common time segment.
- Run GEDAP Program ‘SELECT1’ to select a common time segment that includes valid data for all wave probes of interest.
- Run GEDAP Program ‘XCORR’ to carry out a cross-correlation between all wave channel time series signals.
- Run GEDAP Program ‘ZCA’ to determine the average wave height, period (H_{AV}, T_{AV}) for regular waves and average as well as maximum wave height, period (H_{MAX}, T_{MAX}) for irregular waves by carrying out a time domain zero crossing analysis on the wave time series signals.
- Run GEDAP Program ‘WAVE’ to estimate the breaking wave height given a user specified wave period (s) and water depth (m). (Regular waves only).

Cross-Correlation of two wave signals:

Program ‘XCORR’ computes Rxy(τ) where Rxy(τ) is the cross-correlation function of two input time series signals, x(t) and y(t). It then locates the value of τ (tau), the time shift in seconds between the two input time series signals, at which the maximum value of Rxy(τ) occurs and applies this time shift to y(t) to obtain a new signal called ys(t). This time-shifted signal ys(t) has maximum correlation with the first input signal, x(t).

The cross-correlation function Rxy(τ) is defined as follows:

$$Rxy(\tau) = Cxy(\tau) / (sigma\_x * sigma\_y)$$

where Cxy(τ) = the cross-covariance function of x(t) and y(t),
sigma_x = the standard deviation of x(t)
and sigma_y = the standard deviation of y(t).

If the two input signals are identical, Rxy(τ) has a maximum value of 1.0 at τ = zero seconds. The cross-covariance function Cxy(τ) is defined by:

$$Cxy(\tau) = E[(x(t) - mux) * (y(t + \tau) - muy)]$$

where E[z] = the expected value of z,
mux = mean value of x(t),
and muy = mean value of y(t).

Cxy(τ) is computed by an FFT technique which is typically 50 to 100 times faster than calculating Cxy(τ) directly in the time domain. If time shift τ has a negative value, then y(t) leads x(t).

The results of the cross-correlation and zero crossing analysis are presented in Appendix C for the regular waves and Appendix D for the irregular waves.

The criterion for an unacceptable wave signal transfer has been defined as:

$$[\tau/T_{AV}] * 100\% > 10\%$$

Evaluating the Validation Envelope for 'WAVETRAN':

An effort was made to define a safe operating envelope for 'WAVETRAN' using the available data. Plots of Nominal Wave Height (m) vs. Nominal Wave Frequency (Hz) are provided in Figure 5 (regular waves, flume mode), and Figure 6 (regular oblique waves). Plots of Average Wave Height (m) vs. Average Wave Frequency (Hz) are presented in Figure 7 (irregular waves, flume mode) and Figure 8 (irregular oblique waves).

The maximum limit for using 'WAVETRAN' is defined by the relationship:

$$L_w(0.1*TANH(k * d))*A$$

Where: L_w = wave length (m) = $(2 * \pi)/(g * T_w^2)$
g = acceleration due to gravity = 9.808 m/s^2
π = 3.14159

T_w = wave period (s)
k = wave number (m^{-1}) = $(4 * \pi^2)/(g * T_w^2)$
d = water depth (m)
A = constant
= 0.8 for regular waves, flume mode
= 0.7 for regular oblique waves
= 1/3 for all irregular waves

The values that exceed the unacceptable criterion are defined by red dots in Figures 5 to 8.

Example Time Series Plots:

The following comparative time series plots are provided:

Figure 9: Linear, Regular Wave, Flume Mode
Figure 10: Non-Linear, Regular Wave, Flume Mode
Figure 11: Linear, Irregular Wave, Flume Mode
Figure 12: Non-Linear, Irregular Wave, Flume Mode
Figure 13: Linear, Regular Oblique Wave
Figure 14: Non-Linear, Regular Oblique Wave

Example Spectral Density Plots:

A variance spectral density analysis was carried out on both a linear as well as non-linear irregular wave to determine whether using 'WAVETRAN' had any significant impact on the spectral characteristics.

Figure 15: Linear Irregular Wave
Figure 16: Non-Linear Irregular Wave

A comparison of the spectral parameters for each wave probe is listed in Table 6.

Repeatability Check:

The analysis was carried out on six runs that were repeated during the testing. The results of this analysis are provided in Table 7.

7.0 'BOAT_WAVE' VALIDATION

The validation procedure for 'BOAT_WAVE' was very similar to the procedure adopted for 'WAVETRAN'. Only data from Data Set 1 was used to validate this software as there was no moving model in the tank during Data Set 2 project #903.

Data Analysis Procedure

The following basic data analysis sequence was followed:

- Run GEDAP Program ‘SPLIT_DAC’ to split GDAC test data acquisition files acquired during experiments in the OEB into separate GEDAP format wave data files in model scale units.
- Use GEDAP program GPLOT to view the QUALISYS two planar position channels and manually remove any spikes or other unwanted anomalies using GEDAP program DESPIKE or glitch fixing by linear interpolation (GFL) available within GPLOT.
- Run GEDAP program ‘BOAT_WAVE’ to move wave data from the three wave probe positions to the center of gravity of the moving model as measured using QUALISYS. The user inputs the X, Y position of each wave probe in the specified OEB co-ordinate system with the origin defined at the south west corner of the tank, the water depth (m) and the wave direction with respect to the west tank wall (degrees). It was also important to verify that the QUALISYS planar position data was also specified in the OEB co-ordinate system with the origin defined at the south west corner of the tank.
- Use GEDAP Program ‘GPLOT’ to review the wave data from all wave probes in the time domain to determine an acceptable common time segment.
- Run GEDAP Program ‘SELECT1’ to select a common time segment that includes valid data for all wave probes of interest.
- Run GEDAP Program ‘XCORR’ as described in Section 6.0 to carry out a cross-correlation between all three wave channel time series signals at the center of gravity of the model.

WARNING: If the position of the model as measured using QUALISYS is not carefully despiked, these unwanted anomalies will be reflected in the wave data moved to the model.

Since ‘BOAT_WAVE’ is essentially based on the same principals as ‘WAVETRAN’, it is assumed that the valid operating envelope for ‘BOAT_WAVE’ matches the valid operating envelope for ‘WAVETRAN’ and the same user restrictions apply. To verify this assumption, a small random subset of runs from Data Set 1 were evaluated using the same criterion ($[\tau/T_{AV}] * 100\% > 10\%$) as was used for ‘WAVETRAN’. The results of the regular wave analysis for flume mode and oblique waves are presented in Table 8 while the irregular wave analysis for flume mode and oblique waves is presented in Table 9.

8.0 DISCUSSION

The primary objective of the validation exercise was to determine if the software provided satisfactory results relative to a defined criterion and attempt to define the boundaries of acceptable performance. The two wave data sets used to achieve these goals were not dedicated to validating this software so there are some limitations.

8.1 'WAVETRAN' Validation Results

Referring to plots defining the envelope for valid use of 'WAVETRAN' (Figures 5 – 8):

Other than for the regular wave, flume mode (Figure 5), there is not enough data to fully define the envelope for valid use however the following observations can be made:

Regular Waves, Flume Mode (Figure 5): There is enough data available for this situation to make definitive conclusions with respect to the performance of the software. There is little scatter in the data and the invalid results can be expected for wave height and frequency combinations that exceed a line defined by L_w(0.1*TANH(k * d))*0.8. Also, due to scatter at very low wave amplitudes, the software is not deemed to be reliable at wave heights less than 10 cm.

Regular Oblique Waves (Figure 6): Even though there is a smaller data set available, it is apparent that there is more scatter and less reliability when using 'WAVETRAN' in oblique seas. Generally invalid results can be expected for wave height and frequency combinations that exceed a line defined by L_w(0.1*TANH(k * d))*0.7. Also, due to scatter at very low wave amplitudes, the software is not deemed to be reliable at wave heights less than 10 cm.

Irregular Waves, Flume Mode (Figure 7): The envelope for valid use of 'WAVETRAN' is more complex in irregular seas. Generally invalid results can be expected for average wave height and frequency combinations that exceed a line defined by L_w(0.1*TANH(k * d))/3 - for average wave heights less than 0.25 m. For average wave heights greater than 0.25 m, there appears to be more stability in the results. This is probably due to the fact that an average wave height and frequency is being used and although individual waves in the irregular wave time series may be breaking; it doesn't appear to have a major impact on the average wave height or frequency of the wave train.

Irregular Oblique Waves (Figure 8): There is insufficient irregular oblique wave data available to fully define an envelope for valid use of 'WAVETRAN' however the data implies that generally invalid results can be expected for average wave height and frequency combinations that exceed a line defined by L_w(0.1*TANH(k

* d))/3. It is safe to say however, that some scatter can be expected in the results and caution must be exercised in using ‘WAVETRAN’ in this situation.

Generally the results using ‘WAVETRAN’ for regular waves with the OEB in flume mode are the best. Figure 9 illustrates a typical time series plot and demonstrates that there is little phase shift or deviation in wave height.

Figure 10 illustrates what happens if a regular wave breaks between the time it is measured using the two west wave probes and when it reaches the north center wave probe. There is an unacceptable phase shift although there does not appear to be a major impact on wave height.

There is fairly a consistent correlation between the outputs of the three wave probes when measuring linear irregular waves with the tank in flume mode (Figure 11). The phase relationship comparison is very good however there is some variation in wave height noted.

There does not appear to be any correlation between the wave probe signals for the non-linear irregular wave illustrated in Figure12. It is clear that ‘WAVETRAN’ gives unacceptable results in this situation.

Figure 13 and 14 provide an example of the difference in phase relationship that can be expected after transferring a linear and non-linear regular oblique wave. Note the lower wave amplitude for the north west probe in Figure 13. This probe is located close to the corner in the tank where the west wave board bank and north beach meet. It is possible that the location of the north west probe may result in some local distortion here since the data from the south west probe looks fine. Figure 14 illustrates the impact on phase when waves break between wave probe locations.

An example comparison of the spectral characteristics between the wave probes was investigated for a linear (Data Set 2: File IR_010_001) and non-linear (Data Set 2: File IR_018_001) irregular wave case in Figures 15, 16, and Table 6. The fact that there are relatively small differences between the spectra for each wave probe - even for the non-linear waves (little difference in spectral shape, amplitude, spectral peak) implies that the overall characteristics do not change significantly. Thus there is likely a phase shift in the time series of the non-linear wave but little alteration in the spectral characteristics.

8.2 ‘BOAT_WAVE’ Validation Results

Referring to Tables 8, 9 and comparing the results with the results for the same runs from ‘WAVETRAN’ presented in Appendix C and D, it is apparent that the same trends exist and thus it can be assumed that the valid envelope defined for ‘WAVETRAN’ can be adopted for ‘BOAT_WAVE’.

9.0 CONCLUSIONS AND RECOMMENDATIONS

Based on the data sets analyzed, the following recommendations and restrictions for using 'WAVETRAN' and 'BOAT_WAVE' are provided in this section:

9.1 Programs 'WAVETRAN' and 'BOAT_WAVE'

- Satisfactory results can be derived using 'WAVETRAN' and 'BOAT_WAVE' to analyze regular waves with the OEB in flume mode for wave height and frequency combinations not exceeding a line defined by L_w(0.1*TANH(k * d))*0.8 and the wave heights greater than 10 cm.
- Satisfactory results can be derived using 'WAVETRAN' and 'BOAT_WAVE' to analyze regular oblique waves with the OEB for wave height and frequency combinations not exceeding a line defined by L_w(0.1*TANH(k * d))*0.7 and the wave heights greater than 10 cm.
- Satisfactory results can be derived using 'WAVETRAN' and 'BOAT_WAVE' to analyze irregular waves with the OEB in flume mode for average wave height and frequency combinations not exceeding a line defined by L_w(0.1*TANH(k * d))/3 - for average wave heights less than 0.25 m although caution should be exercised by the user since more data is required to further validate the software.
- Satisfactory results can be derived using 'WAVETRAN' and 'BOAT_WAVE' to analyze irregular oblique waves with the OEB for wave height and frequency combinations not exceeding a line defined by L_w(0.1*TANH(k * d))/3 although caution must be exercised as the data set analyzed was too small to fully define a valid operating envelope.
- 'WAVETRAN' and 'BOAT_WAVE' work best in regular waves with the OEB in flume mode however scatter can be expected in the integrity of the results for oblique and/or irregular waves.
- The location of the wave probes appears to have an influence of the integrity of the results using 'WAVETRAN'. It is recommended that 'WAVETRAN' not be used to transfer data from a wave probe positioned close to wave boards or beaches in oblique waves.
- There is little variation in the irregular wave spectral characteristics between wave probes after 'WAVETRAN' has been used to transfer the wave data from one point to another – even for non-linear waves.
- Good repeatability has been demonstrated.

9.2 Other Recommendations

- Additional data is required to fully validate these programs – especially in oblique irregular seas.
- Only wave data acquired in the OEB has been used in this document. A separate exercise should be carried out to derive/validate software to move wave data from a wave probe fitted at one end of the IOT tow tank carriage to a specified point on a free-running model free to surge.

10.0 ACKNOWLEDGEMENTS

The authors would like to thank Dr. E. Baddour for permission to use wave data from Project #903 in assist with the validation of this software.

11.0 REFERENCES

1) Institute for Ocean Technology Standard Test Method: Seakeeping, V1.0, 42-8595-S/GM-5, November 15, 2001.

2) Institute for Ocean Technology Standard Test Method: Environmental Modeling – Waves, Wind, Current, V4.0, 42-8595-S/GM-3, January 3, 2002.

3) Miles, M.D.,"The GEDAP Data Analysis Software Package", NRC Institute for Mechanical Engineering, Hydraulics Laboratory Report No. TR-HY-030, August 11, 1990.

4) Sullivan, M., "Optical Tracking at the Institute for Marine Dynamics", Proc. of the 4th Canadian Marine Hydrodynamics and Structures Conference, Ottawa, June 23 – 25, 1997, IMD Report #IR-1997-15, July 1997.

5) Miles, M.D.,"Test Data File for New GDAC Software", NRC Institute for Marine Dynamics Software Design Specification, Version 3.0, January 2, 1996.

6) Miles, M.D.,"DACON Configuration File for New GDAC Software", NRC Institute for Marine Dynamics Software Design Specification, Version 3.2, August 14, 1996.

Tables

Validation of GEDAP Program 'WAVETRAN' & 'BOAT_WAVE' - DATA SET 1						
Regular Waves - Flume Mode:						
						Est. Wave Breaking
	T1	**T2**	**Wave Period**	**Wave Frequency**	**Wave Height**	**Wave Height**
Filename	**(s)**	**(s)**	**(s)**	**(Hz)**	**(m)**	**(m)**
NOTE: OEB in Flume Mode (waves generated 0 deg. from west wall), blanking walls installed covering all north beaches.						
FS8_180HG_0HG_0p75WL_0p04WS_002	60	80	1.12	0.8929	0.0735	0.19578
FS8_180HG_0HG_0p75WL_0p1WS_001	60	80	1.12	0.8929	0.1838	0.19578
FS8_180HG_0HG_1p0WL_0p04WS_001	50	70	1.29	0.7752	0.0980	0.25973
FS8_0HG_1p0WL_0p1WS_001	45	65	1.29	0.7752	0.2450	0.25973
FS8_180HG_0HG_1p5WL_0p04WS_001	40	60	1.58	0.6329	0.1470	0.38945
FS8_0HG_1p5WL_0p1WS_001	35	55	1.58	0.6329	0.3675	0.38945
test_011	40	60	1.649	0.6064	0.3330	0.42398
test_008	40	60	1.814	0.5513	0.3330	0.51145
test_132	35	55	1.814	0.5513	0.5000	0.51145
FS13_180HG_0HG_2p0WL_0p04WS_001	60	80	1.82	0.5495	0.1960	0.51474
FS13_0HG_2p0WL_0p1WS_001	52	70	1.82	0.5495	0.4900	0.51474
test_141	35	55	1.909	0.5238	0.3330	0.56424
test_153	32	52	1.909	0.5238	0.5000	0.56424
test_140	35	55	2.015	0.4963	0.3330	0.62435
test_154	30	50	2.015	0.4963	0.5000	0.62435
FS8_180HG_0HG_2p5WL_0p04WS_001	40	70	2.04	0.4902	0.2450	0.63861
FS0_180HG_2p5WL_0p06WS_001	60	90	2.04	0.4902	0.3675	0.63861
FS8_0HG_2p5WL_0p08WS_001	28	45	2.04	0.4902	0.4900	0.63861
test_139	35	60	2.134	0.4686	0.3330	0.69217
test_150	30	49	2.134	0.4686	0.5000	0.69217
test_138	40	60	2.267	0.4411	0.3330	0.7668
test_149	32	52	2.267	0.4411	0.5000	0.7668
test_137	35	55	2.418	0.4136	0.3330	0.84805
test_148	30	50	2.418	0.4136	0.5000	0.84805
test_136	35	55	2.591	0.3860	0.3330	0.93463
test_147	35	60	2.591	0.3860	0.5000	0.93463
test_135	32	56	3.023	0.3308	0.3330	1.1152
test_146	35	60	3.023	0.3308	0.5000	1.1152
test_134	30	55	3.628	0.2756	0.3330	1.2922
test_145	35	60	3.628	0.2756	0.5000	1.2922
NOTE:						
Wave height, wave period and wave direction are nominal values.						
Estimated breaking wave height computed for user input water depth and wave period (computed using GEDAP Program 'WAVE')						
T1, T2 - Start, End Segment Select Time						

TABLE 1: DATA SET 1 – REGULAR WAVES, FLUME MODE

Validation of GEDAP Program 'WAVETRAN' & 'BOAT_WAVE' - DATA SET 1						
Regular Oblique Waves:						
						Est. Wave Breaking
	T1	**T2**	**Wave Period**	**Wave Frequency**	**Wave Height**	**Wave Height**
Filename	**(s)**	**(s)**	**(s)**	**(Hz)**	**(m)**	**(m)**
NOTE: Oblique waves generated 60 degrees from the west wall, blanking walls removed.						
FS8_120HG60HG_0p75WL_0p04WS_001	70	88	1.12	0.8929	0.0735	0.19578
FS8_120HG60HG_0p75WL_0p1WS_001	65	75	1.12	0.8929	0.1838	0.19578
FS8_120HG_1p0WL_0p04WS_001	60	74	1.29	0.7752	0.0980	0.25973
FS8_120HG_1p0WL_0p1WS_001	60	76	1.29	0.7752	0.2450	0.25973
test_289	35	60	1.395	0.7168	0.3330	0.30372
test_288	36	56	1.511	0.6618	0.3330	0.35627
FS8_120HG_1p5WL_0p04WS_001	58	76	1.58	0.6329	0.1470	0.38945
FS8_120HG_1p5WL_0p1WS_001	55	80	1.58	0.6329	0.3675	0.38945
test_285	35	70	1.649	0.6064	0.3330	0.42398
test_314	34	56	1.814	0.5513	0.3330	0.51145
FS8_120HG_2p0WL_0p04WS_001	55	78	1.82	0.5495	0.1960	0.51474
FS8_120HG_2p0WL_0p08WS_001	52	78	1.82	0.5495	0.3920	0.51474
test_195	32	58	2.015	0.4963	0.3330	0.62435
FS8_120HG_2p5WL_0p04WS_001	52	70	2.04	0.4902	0.2450	0.63861
FS8_120HG_2p5WL_0p06WS_001	52	74	2.04	0.4902	0.3675	0.63861
test_191	32	55	2.267	0.4411	0.3330	0.7668
test_292	32	68	2.267	0.4411	0.5000	0.7668
test_189	30	54	2.418	0.4136	0.3330	0.84805
test_187	32	55	2.591	0.3860	0.3330	0.93463
test_348	30	53	2.591	0.3860	0.5000	0.93463
test_304	32	55	2.79	0.3584	0.3330	1.0242
test_346	30	53	2.79	0.3584	0.5000	1.0242
test_185	30	52	3.023	0.3308	0.3330	1.1152
test_290	30	65	3.023	0.3308	0.5000	1.1152
NOTE:						
Wave height, wave period and wave direction are nominal values.						
Estimated breaking wave height computed for user input water depth and wave period (computed using GEDAP Program 'WAVE')						
T1, T2 - Start, End Segment Select Time						

TABLE 2: DATA SET 1 – REGULAR OBLIQUE WAVES

Validation of GEDAP Program 'WAVETRAN' & 'BOAT_WAVE'		
Irregular Waves in the OEB:		
Irregular Waves - Flume Mode - Data Set 1:		
Nominal Significant Wave Ht. = 0.283 m, Modal Period = 2.6 s.		
	T1	**T2**
Run	**(s)**	**(s)**
NOTE: OEB in Flume Mode (waves generated 0 deg. from west wall), blanking walls installed covering all north beaches.		
TEST_022	60	100
TEST_025	60	100
TEST_028	60	100
TEST_031	60	100
TEST_034	60	100
TEST_037	60	100
TEST_040	60	100
TEST_043	60	100
TEST_046	60	100
TEST_086	50	90
TEST_089	50	90
TEST_092	55	95
TEST_095	55	95
TEST_098	55	95
TEST_101	55	95
TEST_104	60	100
TEST_107	55	95
TEST_110	55	95
TEST_113	55	95
Irregular Oblique Waves - Data Set 1:		
Nominal Significant Wave Ht. = 0.283 m, Modal Period = 2.6 s.		
	T1	**T2**
Run	**(s)**	**(s)**
NOTE: OEB oblique waves generated 60 deg. from west wall, blanking walls removed.		
Nominal Significant Wave Ht. = 0.283 m, Modal Period = 2.6 s.		
TEST_321	40	80
TEST_323	45	75
TEST_325	45	75
TEST_327	45	75
TEST_329	45	75
TEST_331	45	75
TEST_333	45	75
TEST_335	45	75
TEST_337	45	75
TEST_339	45	75
TEST_341	45	75
NOTE: T1, T2 - Start, End Segment Select Time		
The wave spectrum was divided into a number of components - each test is a different segment.		

TABLE 3: DATA SET 1 – IRREGULAR OBLIQUE & FLUME MODE WAVES

Validation of GEDAP Program 'WAVETRAN' - Regular Waves in the OEB:						
REGULAR WAVES - FLUME MODE - Data Set 2:						
						Est. Wave Breaking
	T1	**T2**	**Wave Period**	**Wave Frequency**	**Wave Height**	**Wave Height**
File Name	**(s)**	**(s)**	**(s)**	**(Hz)**	**(m)**	**(m)**
NOTE: OEB in Flume Mode (waves generated 0 deg. from west wall), blanking walls installed covering all north beaches.						
RD_001_001	40	60	2.00	0.50	0.10	0.61583
RD_002_001	40	60	2.00	0.50	0.20	0.61583
RD_003_001	40	60	2.00	0.50	0.30	0.61583
RD_004_001	40	60	2.00	0.50	0.40	0.61583
RD_005_001	40	60	2.00	0.50	0.50	0.61583
RD_006_001	40	60	2.00	0.50	0.60	0.61583
RD_007_002	40	60	2.00	0.50	0.70	0.61583
RD_008_001	45	65	1.67	0.60	0.05	0.43475
RD_009_001	45	65	1.67	0.60	0.10	0.43475
RD_010_001	45	65	1.67	0.60	0.15	0.43475
RD_011_001	45	65	1.67	0.60	0.20	0.43475
RD_012_001	45	65	1.67	0.60	0.25	0.43475
RD_013_001	45	65	1.67	0.60	0.30	0.43475
RD_014_001	45	65	1.67	0.60	0.35	0.43475
RD_015_001	45	65	1.67	0.60	0.40	0.43475
RD_016_001	45	65	1.67	0.60	0.45	0.43475
RD_017_001	45	65	1.67	0.60	0.50	0.43475
RD_018_001	47	67	1.43	0.70	0.05	0.31914
RD_019_001	47	67	1.43	0.70	0.10	0.31914
RD_020_001	47	67	1.43	0.70	0.15	0.31914
RD_021_001	47	67	1.43	0.70	0.20	0.31914
RD_022_001	47	67	1.43	0.70	0.25	0.31914
RD_023_001	47	67	1.43	0.70	0.30	0.31914
RS_001_001	40	60	2.50	0.40	0.05	0.89024
RS_002_001	40	60	2.50	0.40	0.10	0.89024
RS_003_001	40	60	2.50	0.40	0.15	0.89024
RS_004_001	40	60	2.50	0.40	0.20	0.89024
RS_005_001	40	60	2.50	0.40	0.25	0.89024
RS_006_001	40	60	2.50	0.40	0.30	0.89024
RS_007_001	40	60	2.50	0.40	0.35	0.89024
RS_008_001	40	60	2.50	0.40	0.40	0.89024
RS_009_001	40	60	3.33	0.30	0.10	1.2151
RS_010_001	40	60	3.33	0.30	0.20	1.2151
RS_011_001	40	60	3.33	0.30	0.30	1.2151
RS_012_001	40	60	3.33	0.30	0.40	1.2151
RS_013_001	40	60	3.33	0.30	0.50	1.2151
RS_014_001	40	60	3.33	0.30	0.60	1.2151
RS_015_001	40	60	4.00	0.25	0.05	1.3698
RS_016_001	40	60	4.00	0.25	0.10	1.3698
RS_017_001	40	60	4.00	0.25	0.15	1.3698
RS_018_001	40	60	4.00	0.25	0.20	1.3698
RS_019_001	40	60	4.00	0.25	0.25	1.3698
RS_020_001	40	60	4.00	0.25	0.30	1.3698
RS_021_001	40	60	4.00	0.25	0.35	1.3698
RS_022_001	40	60	4.00	0.25	0.40	1.3698
RS_023_001	40	70	5.00	0.20	0.05	1.5046
RS_024_001	40	70	5.00	0.20	0.10	1.5046
RS_025_001	40	70	5.00	0.20	0.15	1.5046
RS_026_001	40	70	5.00	0.20	0.20	1.5046
RS_027_001	40	70	5.00	0.20	0.25	1.5046
RS_028_001	60	100	6.67	0.15	0.05	1.6144
RS_029_001	45	85	6.67	0.15	0.10	1.6144
RS_030_002	60	100	6.67	0.15	0.15	1.6144
NOTE:						
Wave height, wave period and wave direction are nominal values.						
Estimated breaking wave height computed for user input water depth and wave period (computed using GEDAP Program 'WAVE')						
T1, T2 - Start, End Segment Select Time						

TABLE 4: DATA SET 2 – REGULAR WAVES, FLUME MODE

Validation of GEDAP Program 'WAVETRAN' - Irregular Waves in the OEB:					
IRREGULAR WAVES - FLUME MODE - Data Set 2:					
Run	**T1 (s)**	**T2 (s)**	**Mean Freq. (Hz)**	**Mean Period (s)**	**Significant Wave Height (m)**
NOTE: OEB in Flume Mode (waves generated 0 deg. from west wall), blanking walls installed covering all north beaches.					
IR_001_001	60	100	0.40	2.50	0.10
IR_002_001	60	100	0.40	2.50	0.20
IR_003_001	60	100	0.40	2.50	0.30
IR_004_001	60	100	0.40	2.50	0.40
IR_005_001	60	100	0.40	2.50	0.50
IR_006_001	60	100	0.40	2.50	0.60
IR_007_001	60	100	0.50	2.00	0.05
IR_008_001	60	100	0.50	2.00	0.10
IR_009_001	60	100	0.50	2.00	0.15
IR_010_001	60	100	0.50	2.00	0.20
IR_011_001	60	100	0.50	2.00	0.25
IR_012_001	60	100	0.50	2.00	0.30
IR_013_001	60	100	0.50	2.00	0.35
IR_014_001	60	100	0.50	2.00	0.40
IR_015_001	60	100	0.60	1.67	0.05
IR_016_001	60	100	0.60	1.67	0.10
IR_017_001	60	100	0.60	1.67	0.15
IR_018_001	60	100	0.60	1.67	0.20
IR_019_001	60	100	0.60	1.67	0.25
IR_020_001	60	100	0.60	1.67	0.30
IR_021_001	60	100	0.70	1.43	0.05
IR_022_001	60	100	0.70	1.43	0.10
IR_023_001	60	100	0.70	1.43	0.15
IR_024_001	60	100	0.70	1.43	0.20
NOTE:					
Significant wave height, wave period and wave direction are nominal values.					
T1, T2 - Start, End Segment Select Time					

TABLE 5: DATA SET 2 – IRREGULAR FLUME MODE WAVES

File: IR_010_001	**LINEAR IRREGULAR WAVE**	
Wave Probe WW1	**Frequency of Spectral Peak (Hz)**	**0.52500**
Wave Probe WW1	**Period of Spectral Peak (s)**	**1.9048**
Wave Probe WW1	**Significant Wave Height Est. (m)***	**0.17886**
Wave Probe MW1	**Frequency of Spectral Peak (Hz)**	**0.52497**
Wave Probe MW1	**Period of Spectral Peak (s)**	**1.9049**
Wave Probe MW1	**Significant Wave Height Est. (m)***	**0.18184**
Wave Probe EW1	**Frequency of Spectral Peak (Hz)**	**0.52500**
Wave Probe EW1	**Period of Spectral Peak (s)**	**1.9048**
Wave Probe EW1	**Significant Wave Height Est. (m)***	**0.17839**
File: IR-018_001	**NON-LINEAR IRREGULAR WAVE**	
Wave Probe WW1	**Frequency of Spectral Peak (Hz)**	**0.54250**
Wave Probe WW1	**Period of Spectral Peak (s)**	**1.8433**
Wave Probe WW1	**Significant Wave Height Est. (m)***	**0.18038**
Wave Probe MW1	**Frequency of Spectral Peak (Hz)**	**0.54247**
Wave Probe MW1	**Period of Spectral Peak (s)**	**1.8434**
Wave Probe MW1	**Significant Wave Height Est. (m)***	**0.18667**
Wave Probe EW1	**Frequency of Spectral Peak (Hz)**	**0.52500**
Wave Probe EW1	**Period of Spectral Peak (s)**	**1.9048**
Wave Probe EW1	**Significant Wave Height Est. (m)***	**0.17217**

*** NOTE:** Significant wave height estimate = 4 * standard deviation from the zeroth spectral moment (M_0) after filtering at lower and upper frequency limit of spectrum.

TABLE 6: COMPARISON OF SPECTRAL PARAMETERS ('WAVETRAN')

REPEATABILITY CHECK:

File Name	T1 (s)	T2 (s)	Wave Period (s)	Wave Height (m)	Transfer EW1 to MW1 Rxy (tau)	Transfer EW1 to MW1 tau (s)	Transfer EW1 to MW1 % Wave Period	Transfer WW1 to MW1 Rxy (tau)	Transfer WW1 to MW1 tau (s)	Transfer WW1 to MW1 % Wave Period	EW1 Hav (m)	EW1 Tav (s)	WW1 Hav (m)	WW1 Tav (s)	MW1 Hav (m)	MW1 Tav (s)
RD_015_001	45	65	1.67	0.40	0.9408	0.26375	15.79	0.9841	-0.2283	13.67	0.3626	1.671	0.3495	1.668	0.3679	1.668
RD_015_002	45	65	1.67	0.40	0.9684	0.26619	15.94	0.9768	-0.26742	16.01	0.3707	1.669	0.3728	1.669	0.3683	1.667
RD_022_001	47	67	1.43	0.25	0.9724	0.23249	16.26	0.9869	-0.2340	16.36	0.2335	1.429	0.2359	1.428	0.2462	1.429
RD_022_002	47	67	1.43	0.25	0.9792	0.22395	15.66	0.9879	-0.2364	16.53	0.2381	1.429	0.2370	1.428	0.2504	1.428
RS_005_001	40	60	2.50	0.25	0.9849	0.04884	1.95	0.9915	-0.0586	2.34	0.5009	2.496	0.4640	2.504	0.5082	2.504
RS_005_002	40	60	2.50	0.25	0.9846	0.05251	2.10	0.9919	-0.059832	2.39	0.4927	2.496	0.4691	2.504	0.5088	2.504
RS_010_001	40	60	3.33	0.20	0.9981	0.00244	0.07	0.9971	-0.0501	1.50	0.1721	3.327	0.1558	3.315	0.1863	3.332
RS_010_002	40	60	3.33	0.20	0.9974	-0.00244	0.07	0.9967	-0.039074	1.17	0.1785	3.321	0.1571	3.314	0.1851	3.333
RS_024_001	40	70	5.00	0.10	0.9937	0.053738	1.07	0.9845	0.2956	5.91	0.1332	4.990	0.1144	5.002	0.0974	4.991
RS_024_002	40	70	5.00	0.10	0.9928	0.04458	0.89	0.9835	0.2901	5.80	0.1338	4.993	0.1150	5.006	0.0974	4.998
RS_028_001	60	100	6.67	0.05	0.9745	0.71704	10.75	0.9865	-0.3261	4.89	0.0312	5.782	0.0423	6.672	0.0289	6.632
RS_028_002	60	100	6.67	0.05	0.9741	0.68039	10.20	0.9822	-0.3506	5.26	0.0360	6.650	0.0419	6.660	0.0297	6.639

TABLE 7: REPEATABILITY CHECK - 'WAVETRAN'

Validation of GEDAP Program 'BOAT_WAVE' - Regular Waves in the OEB:

Regular Waves Data Set 1:														
						Transfer NW1 to NC1			**Transfer SW1 to NC1**			**Transfer SW1 to NW1**		
Filename	**T1 (s)**	**T2 (s)**	**Wave Period (s)**	**Wave Frequency (Hz)**	**Wave Height (m)**	**Rxy (tau)**	**tau (s)**	**% Wave Period**	**Rxy (tau)**	**tau (s)**	**% Wave Period**	**Rxy (tau)**	**tau (s)**	**% Wave Period**
NOTE: OEB in Flume Mode (waves generated 0 deg. from west wall), blanking walls installed covering all north beaches.														
FS8_180HG_0HG_0p75WL_0p04WS_002	70	95	1.12	0.8929	0.0735	0.9980	-0.0916	8.18	0.9983	-0.0702	6.27	0.9978	0.0214	1.91
FS8_0HG_1p0WL_0p1WS_001	40	70	1.29	0.7752	0.2450	0.8675	-0.5973	46.30	0.8936	-0.4911	38.07	0.9912	0.0989	7.67
FS13_180HG_0HG_2p0WL_0p04WS_001	60	80	1.82	0.5495	0.1960	0.9973	-0.0489	2.69	0.9973	-0.0269	1.48	0.9978	0.0196	1.07
FS8_180HG_0HG_2p5WL_0p04WS_001	40	70	2.04	0.4902	0.2450	0.9904	-0.0366	1.80	0.9914	-0.0037	0.18	0.9978	0.0330	1.62
test_150	30	49	2.134	0.4686	0.5000	0.9950	-0.1625	7.62	0.9953	-0.1695	7.94	0.9979	-0.0070	0.33
test_148	30	50	2.418	0.4136	0.5000	0.9964	-0.0587	2.43	0.9978	-0.0538	2.22	0.9980	0.0049	0.20
test_134	30	55	3.628	0.2756	0.3330	0.9913	-0.1436	3.96	0.9973	0.1374	3.79	0.9890	0.2810	7.75
Regular Waves - Data Set 1:														
						Transfer NW1 to NC1			**Transfer SW1 to NC1**			**Transfer SW1 to NW1**		
Filename	**T1 (s)**	**T2 (s)**	**Wave Period (s)**	**Wave Frequency (Hz)**	**Wave Height (m)**	**Rxy (tau)**	**tau (s)**	**% Wave Period**	**Rxy (tau)**	**tau (s)**	**% Wave Period**	**Rxy (tau)**	**tau (s)**	**% Wave Period**
NOTE: Oblique waves generated 60 degrees from the west wall, blanking walls removed.														
FS8_120HG60HG_0p75WL_0p04WS_001	70	88	1.12	0.8929	0.0735	0.9680	-0.06599	5.89	0.9912	-0.16498	14.73	0.9804	-0.0990	8.84
FS8_120HG_1p0WL_0p1WS_001	60	76	1.29	0.7752	0.2450	0.9825	-0.21902	16.98	0.9591	-0.52018	40.32	0.9777	-0.2973	23.04
FS8_120HG_1p5WL_0p1WS_001	55	80	1.58	0.6329	0.3675	0.9799	-0.17714	11.21	0.9610	-0.47035	29.77	0.9828	-0.2902	18.36
FS8_120HG_2p0WL_0p08WS_001	52	78	1.82	0.5495	0.3920	0.9928	-0.14174	7.79	0.9947	-0.23461	12.89	0.9965	-0.0904	4.97
test_292	32	68	2.267	0.4411	0.5000	0.9853	-0.16076	7.09	0.9892	-0.18128	8.00	0.9952	-0.0274	1.21
test_348	30	53	2.591	0.3860	0.5000	N/A	N/A	N/A	0.9680	-0.06965	2.69	N/A	N/A	N/A
test_185	30	52	3.023	0.3308	0.3330	0.998	0	0.00	0.9958	-0.06354	2.10	0.9958	-0.0611	2.02

NOTE:

Wave height, wave period and wave direction are nominal values.

Estimated breaking wave height computed for user input water depth and wave period.

Rxy (tau) - cross correlation function between two wave probe signals. If two signals are identical, Rxy (tau) = 1.0.

tau - time lag (s) between two wave probe signals.

Non-linear Wave is defined as 0.7*H/L < 0.1TANH(kd) (ie: wave is too close to breaking to provide satisfactory solution using WAVETRAN)

Where: H = wave height (m)

L = wave length (m) = $2*PI/g*T_W^2$

g = acceleration due to gravity (m/s^2) = 9.808 m/s^2

PI = 3.14159

T_W = wave period (s)

k = wave number (m^{-1}) = $(4*PI^2)/(g*T_W^2)$

d = water depth (m)

% Wave Period = (tau/nominal wave period) * 100

N/A = Not Available

T1, T2 - Start, End Segment Select Time

Linear Data in **BLACK**, Non-linear Data in **RED**

TABLE 8: 'BOAT_WAVE' VALIDATION - REGULAR WAVES

Validation of GEDAP Program 'BOAT_WAVE' - Irregular Waves in the OEB:

Data Set 1:

Run	T1 (s)	T2 (s)	Transfer NW1 to NC1 Rxy (tau)	tau (s)	% Wave Period	Transfer SW1 to NC1 Rxy (tau)	tau (s)	% Wave Period	Transfer SW1 to NW1 Rxy (tau)	tau (s)	% Wave Period
NOTE: OEB in Flume Mode (waves generated 0 deg. from west wall), blanking walls installed covering all north beaches.											
Nominal Significant Wave Ht. = 0.283 m, Modal Period = 2.6 s.											
TEST_025	70	100	0.9665	-0.08062	4.89	0.9390	-0.069626	4.22	0.9884	0.011	0.67
TEST_037	70	100	0.9393	-0.095278	5.09	0.9173	-0.073291	3.91	0.9909	0.018	0.98
TEST_086	50	90	0.9348	-0.004885	0.29	0.9200	0.004885	0.29	0.9856	0.034	2.04
TEST_101	60	95	0.9509	0	0.00	0.9312	0.003665	0.18	0.9861	0.004	0.18
TEST_113	63	80	0.9743	0.039475	2.01	0.9651	0.062329	3.17	0.9890	0.017	0.85

NOTE: % Wave Period has been defined as tau/Average Wave Period @ north center wave probe
Rxy (tau) - cross correlation function between two wave probe signals. If two signals are identical, Rxy (tau) = 1.0.
tau - time lag (s) between two wave probe signals. (-ve is lead)
T1, T2 - Start, End Segment Select Time

Data Set 1:

Run	T1 (s)	T2 (s)	Transfer NW1 to NC1 Rxy (tau)	tau (s)	% Wave Period	Transfer SW1 to NC1 Rxy (tau)	tau (s)	% Wave Period	Transfer SW1 to NW1 Rxy (tau)	tau (s)	% Wave Period
NOTE: OEB oblique waves generated 60 deg. from west wall, blanking walls removed.											
Nominal Significant Wave Ht. = 0.283 m, Modal Period = 2.6 s.											
TEST_323	40	70	N/A	N/A	N/A	0.8523	-0.1759	6.61	N/A	N/A	N/A
TEST_329	40	70	N/A	N/A	N/A	0.9329	-0.14292	6.62	N/A	N/A	N/A
TEST_335	40	70	N/A	N/A	N/A	0.8148	-0.1759	8.98	N/A	N/A	N/A
TEST_341	40	70	N/A	N/A	N/A	0.8669	-0.18323	10.43	N/A	N/A	N/A

TABLE 9: 'BOAT_WAVE' VALIDATION – IRREGULAR WAVES

Figures

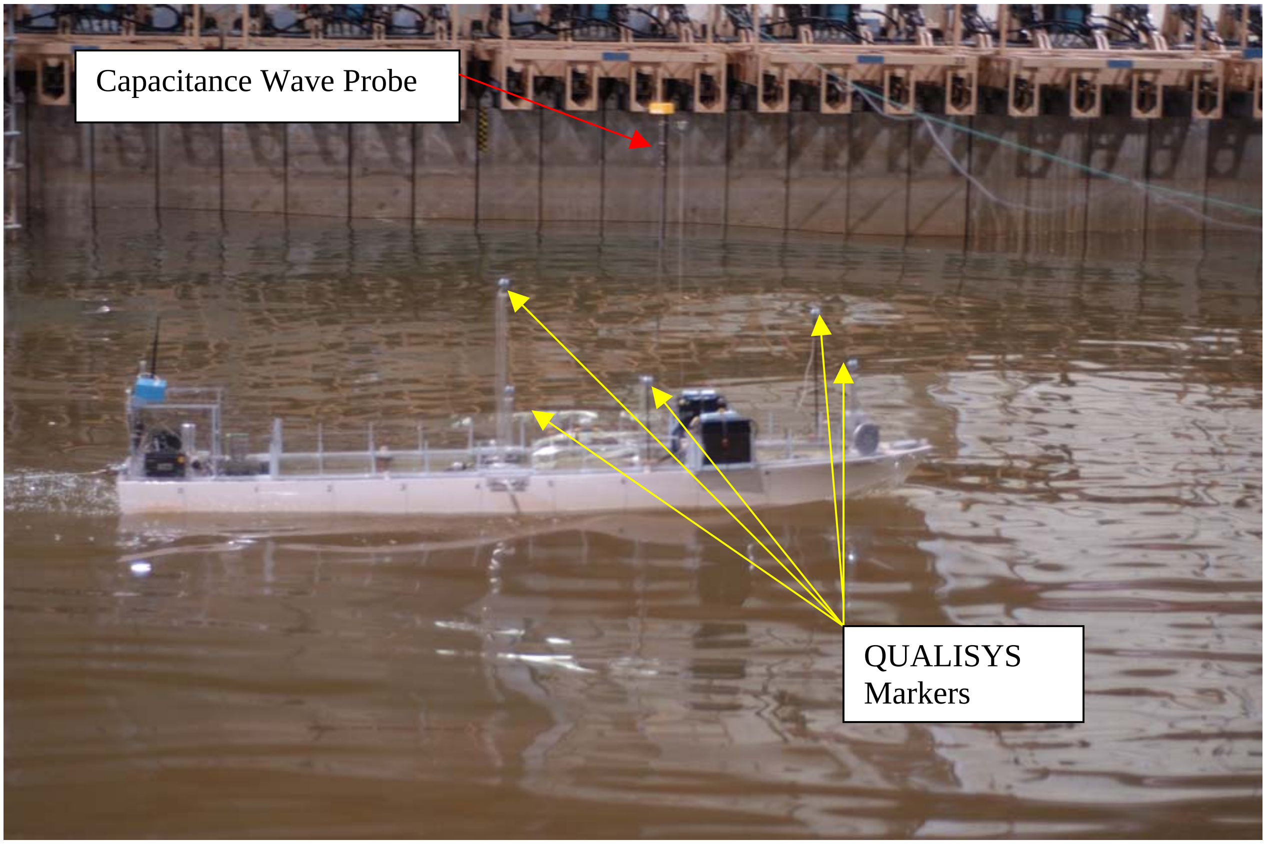


Figure 1: Typical Seakeeping Test on a Ship Model in OEB

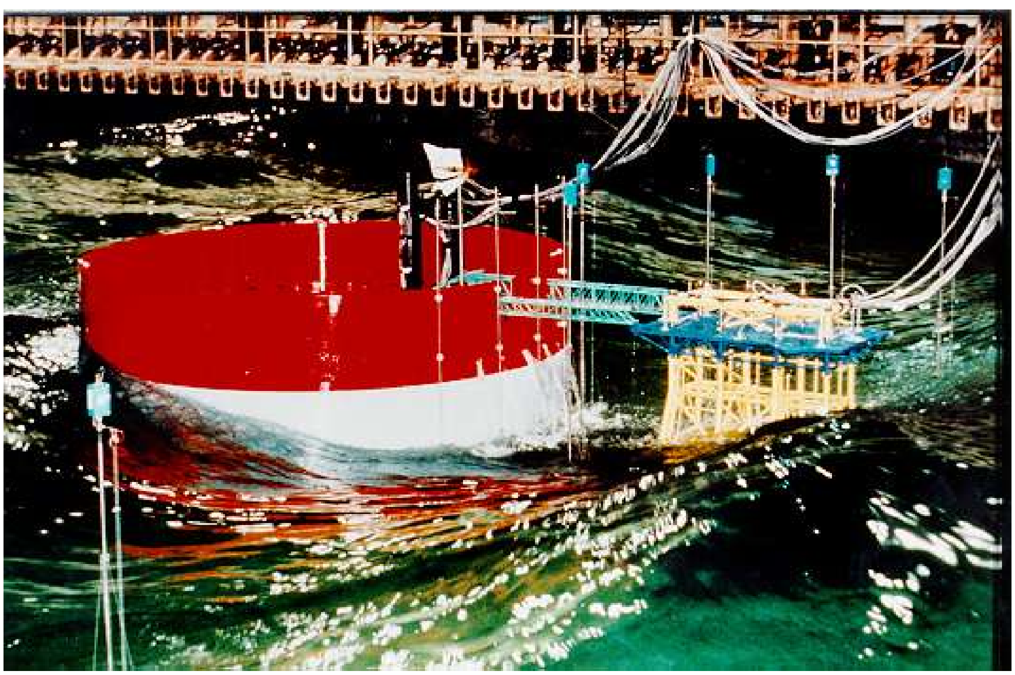


Figure 2: Typical Moored Platform in OEB

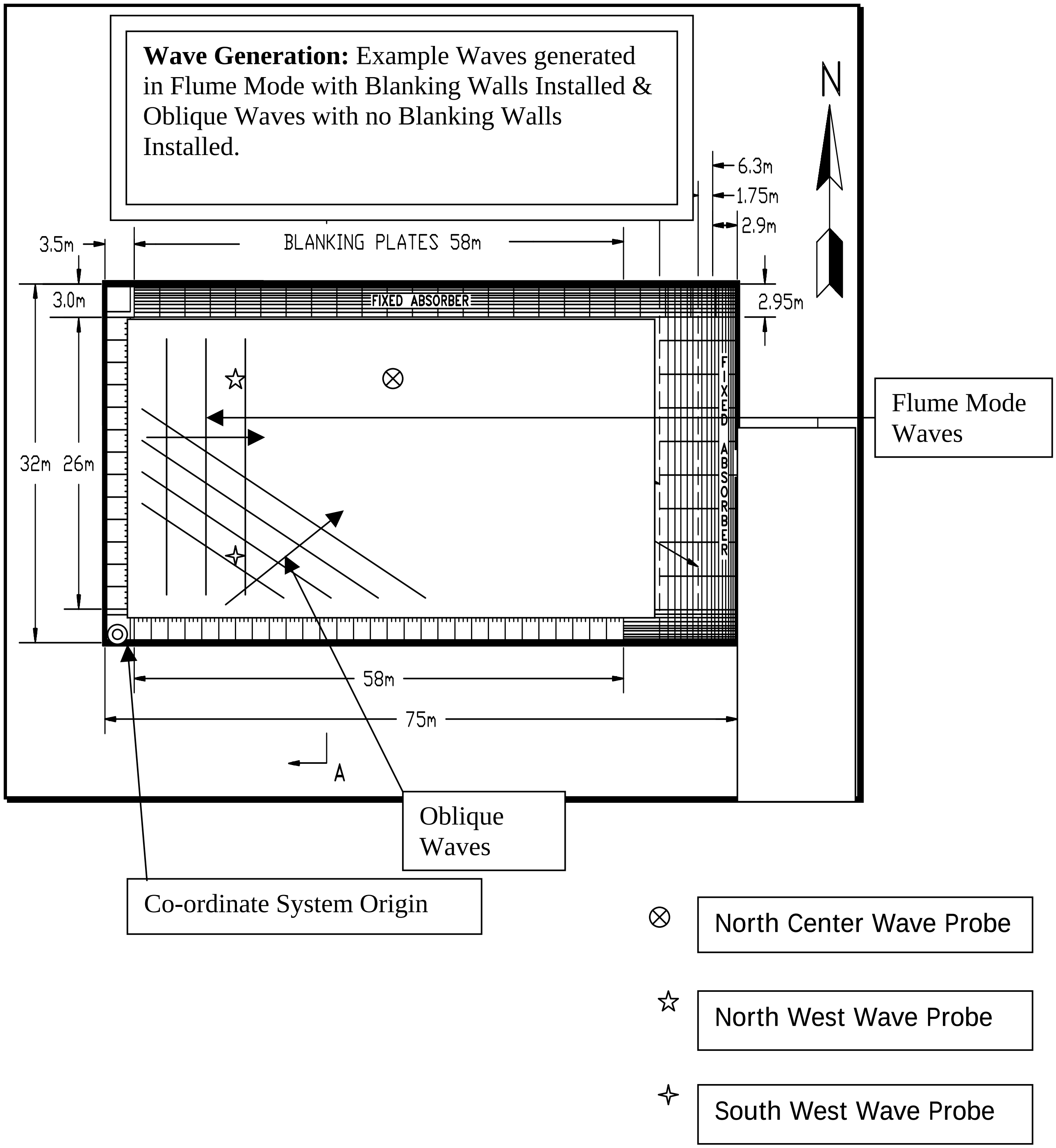


Figure 3: Offshore Engineering Basin – Data Set 1

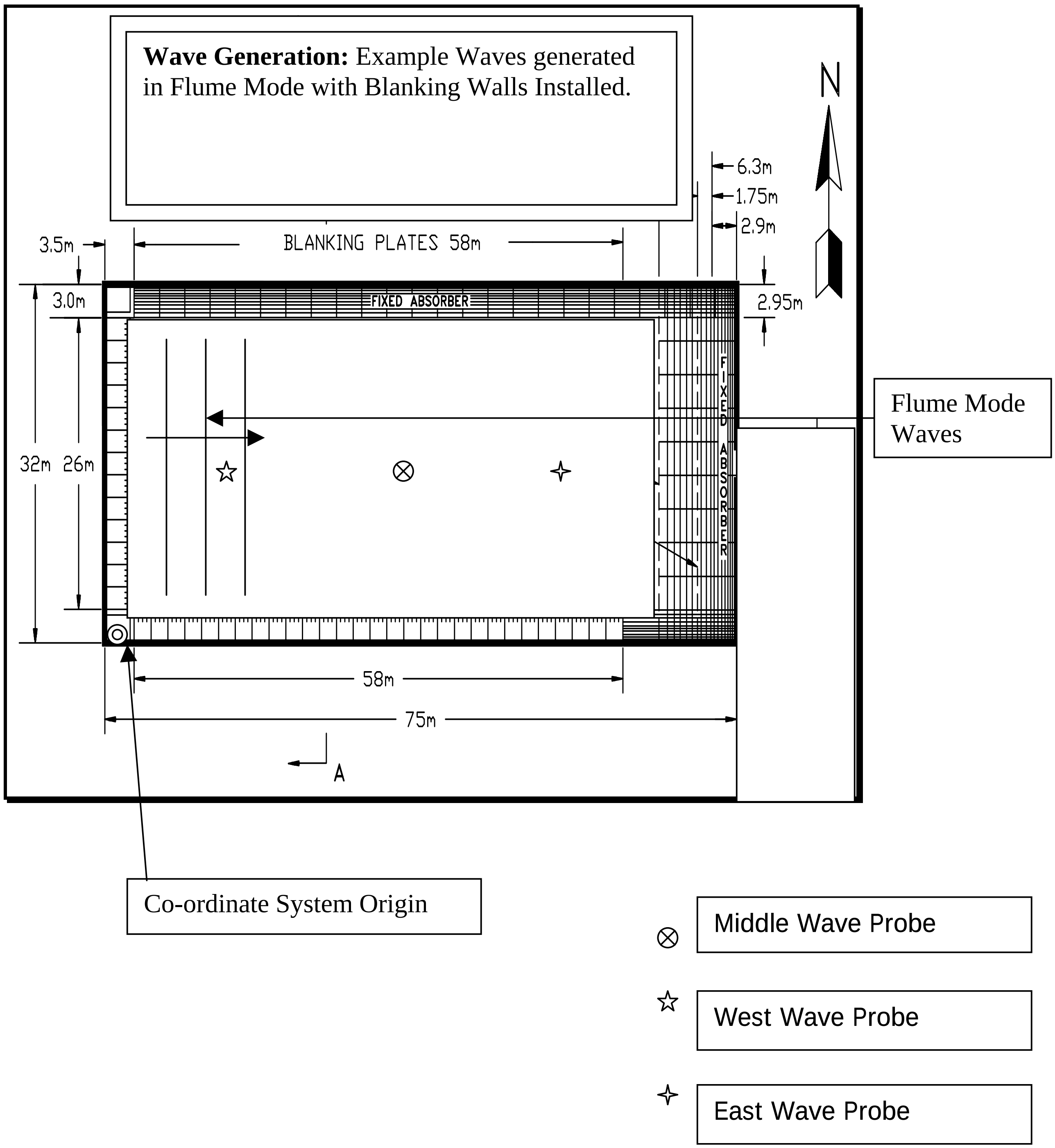


Figure 4: Offshore Engineering Basin – Data Set 2

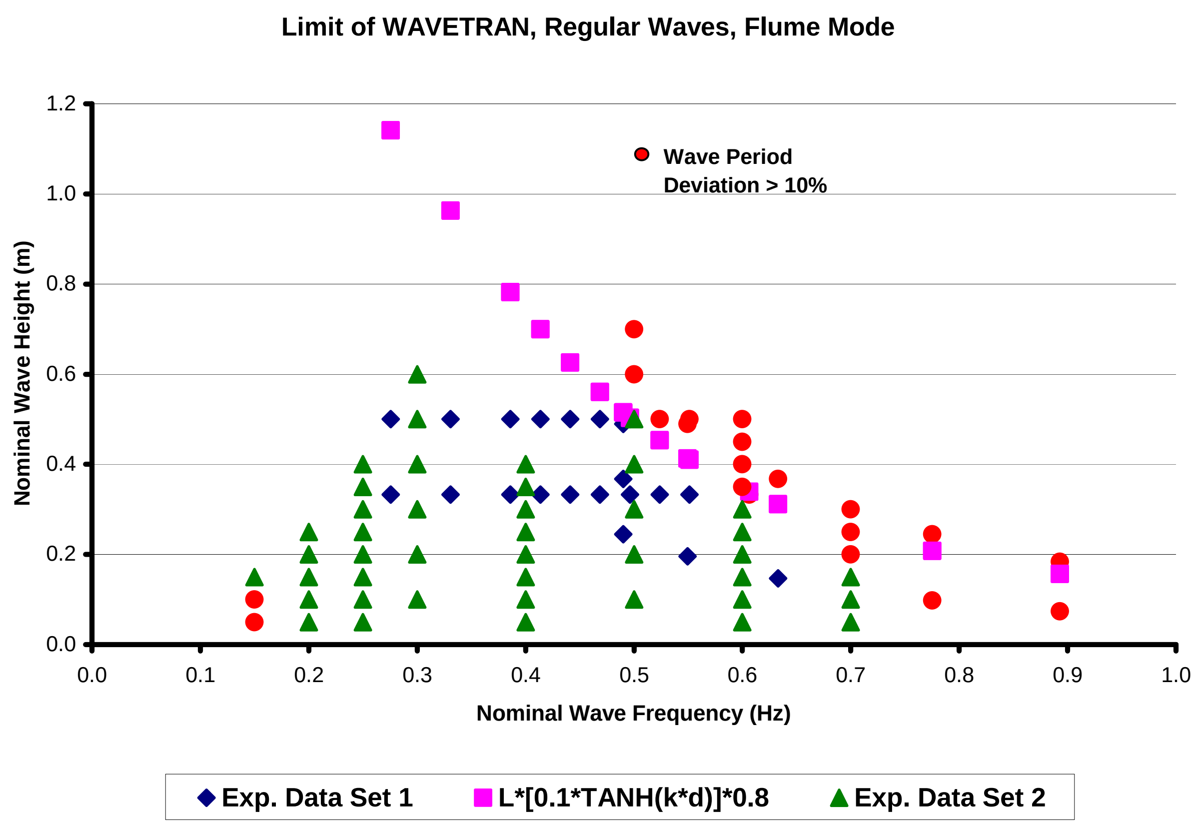


Figure 5: Limit of 'WAVETRAN', Regular Waves, Flume Mode

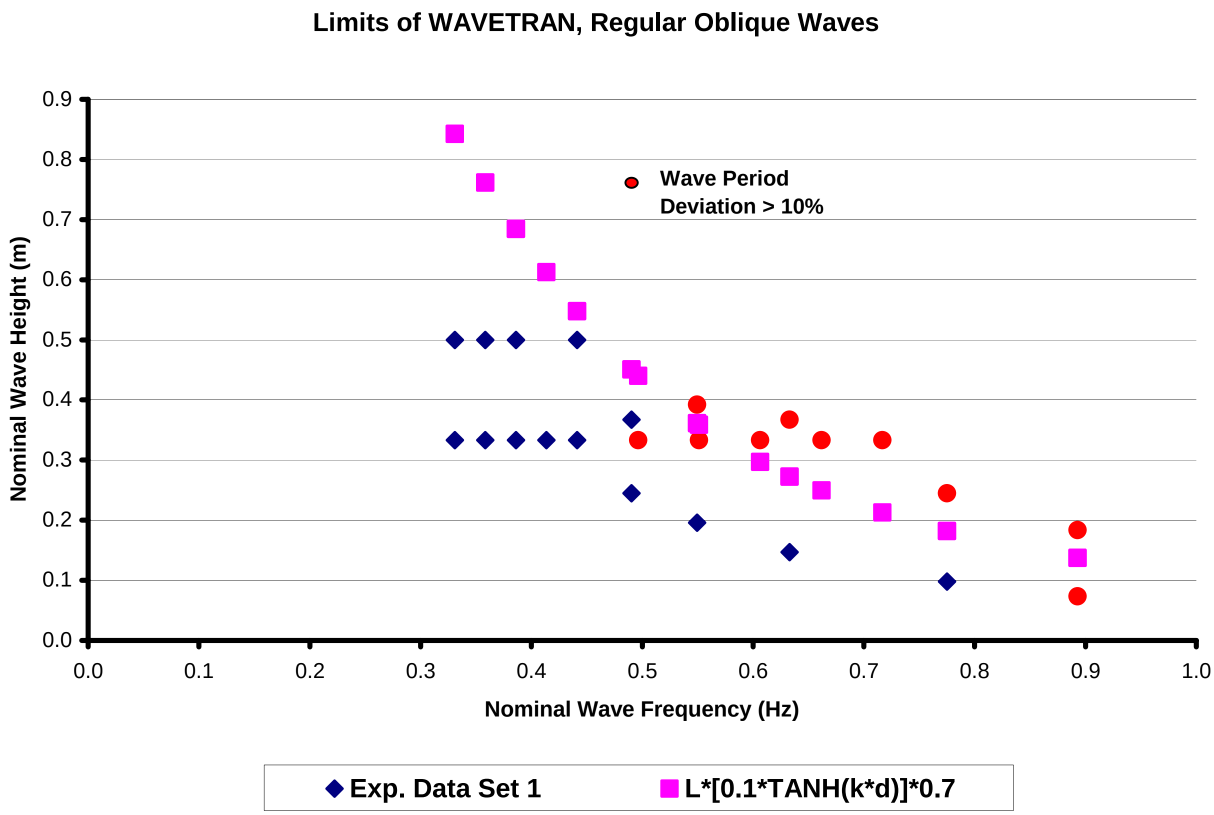


Figure 6: Limit of 'WAVETRAN', Regular Oblique Waves

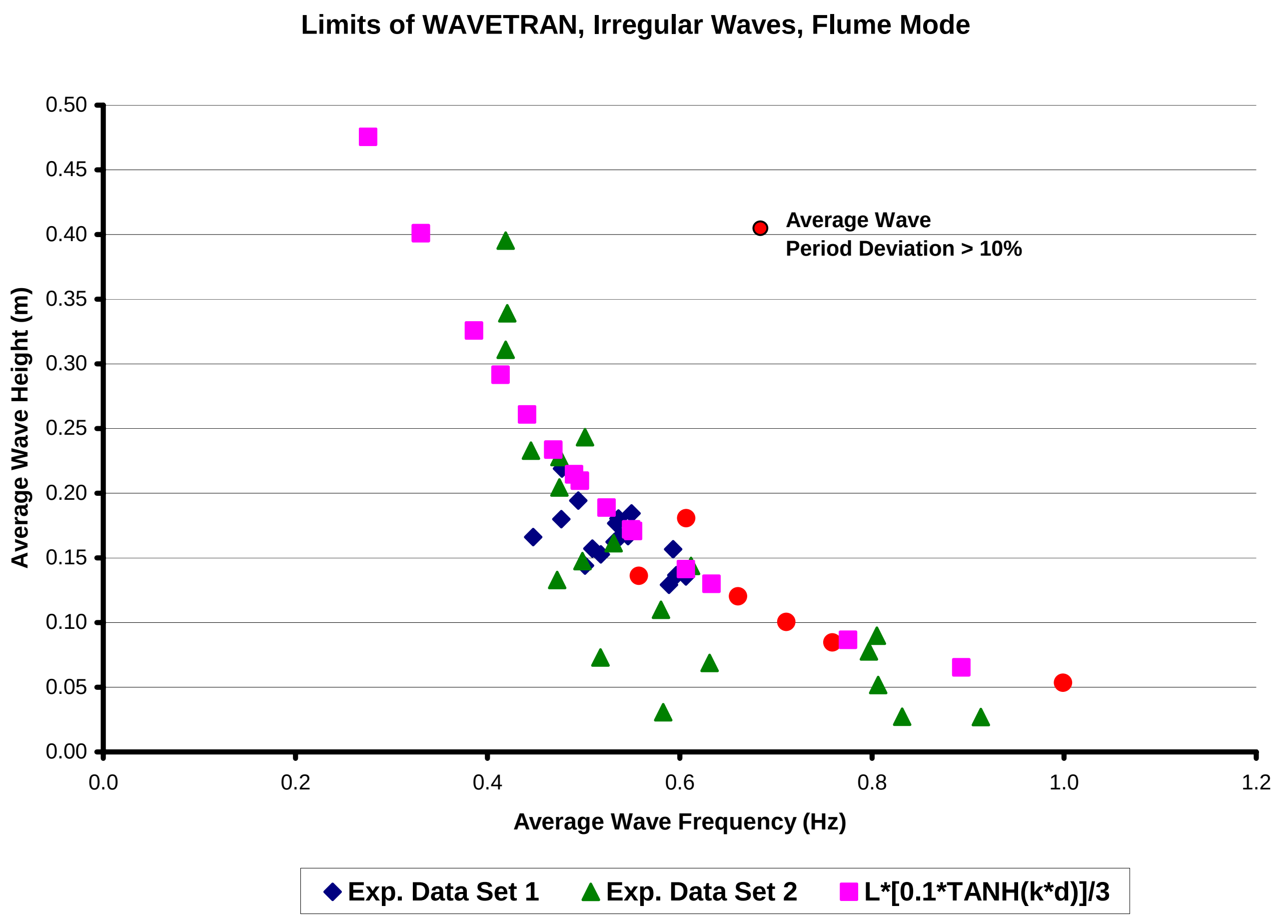


Figure 7: Limit of 'WAVETRAN', Irregular Waves, Flume Mode

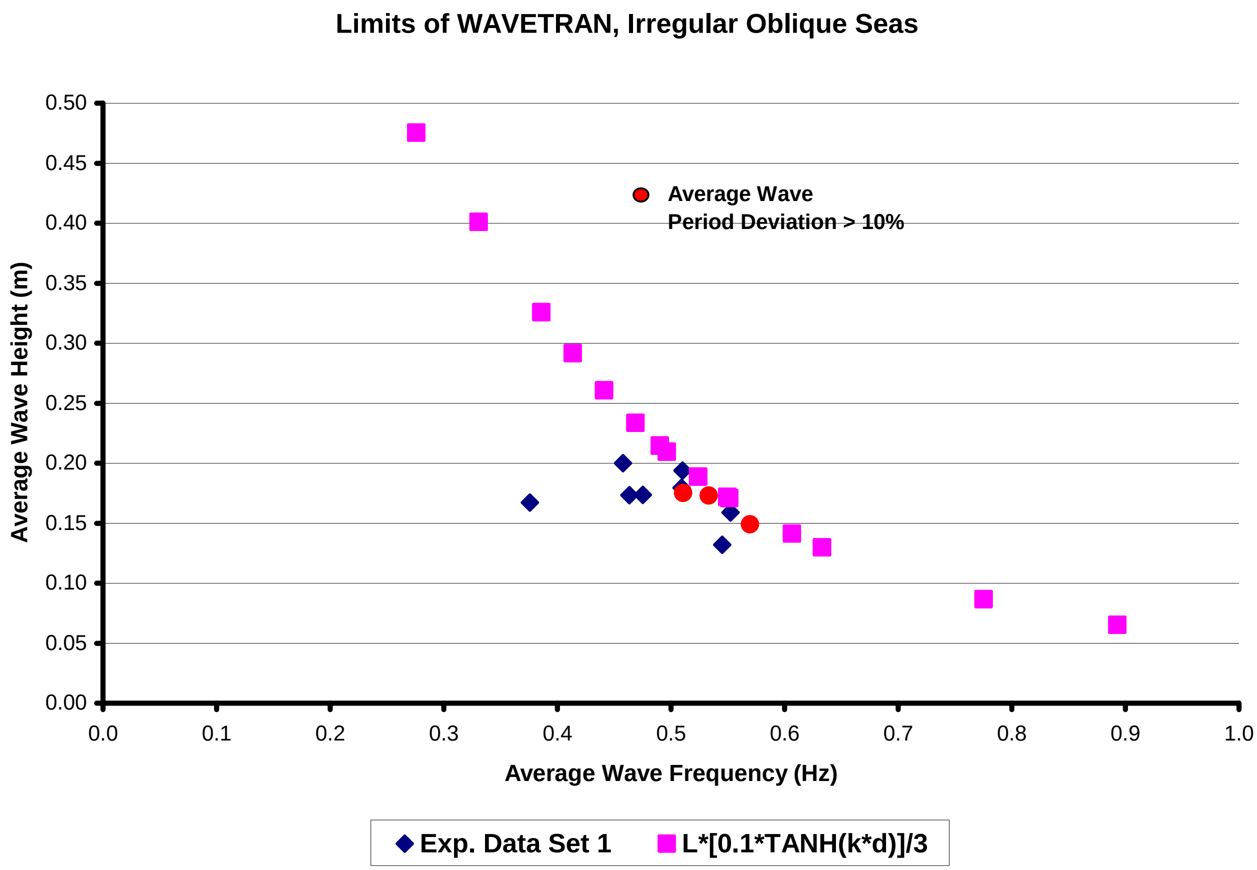


Figure 8: Limit of ‘WAVETRAN’, Irregular Oblique Waves

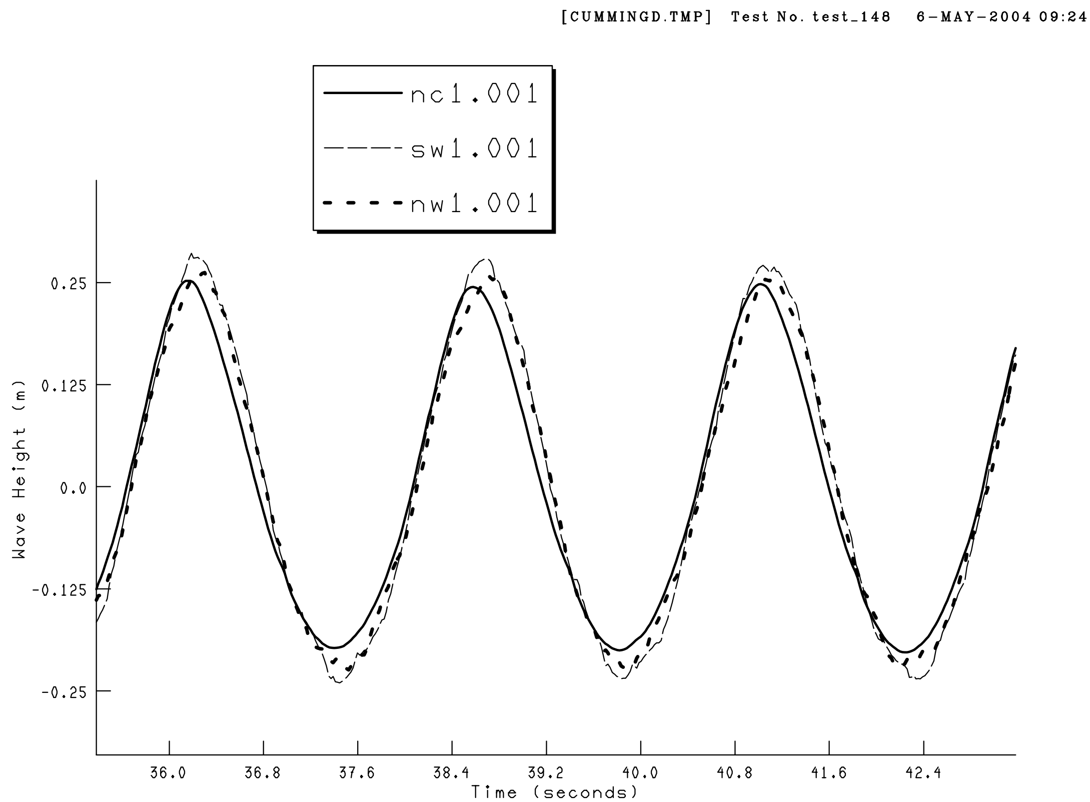


Figure 9: Example - Linear, Regular Wave, Flume Mode

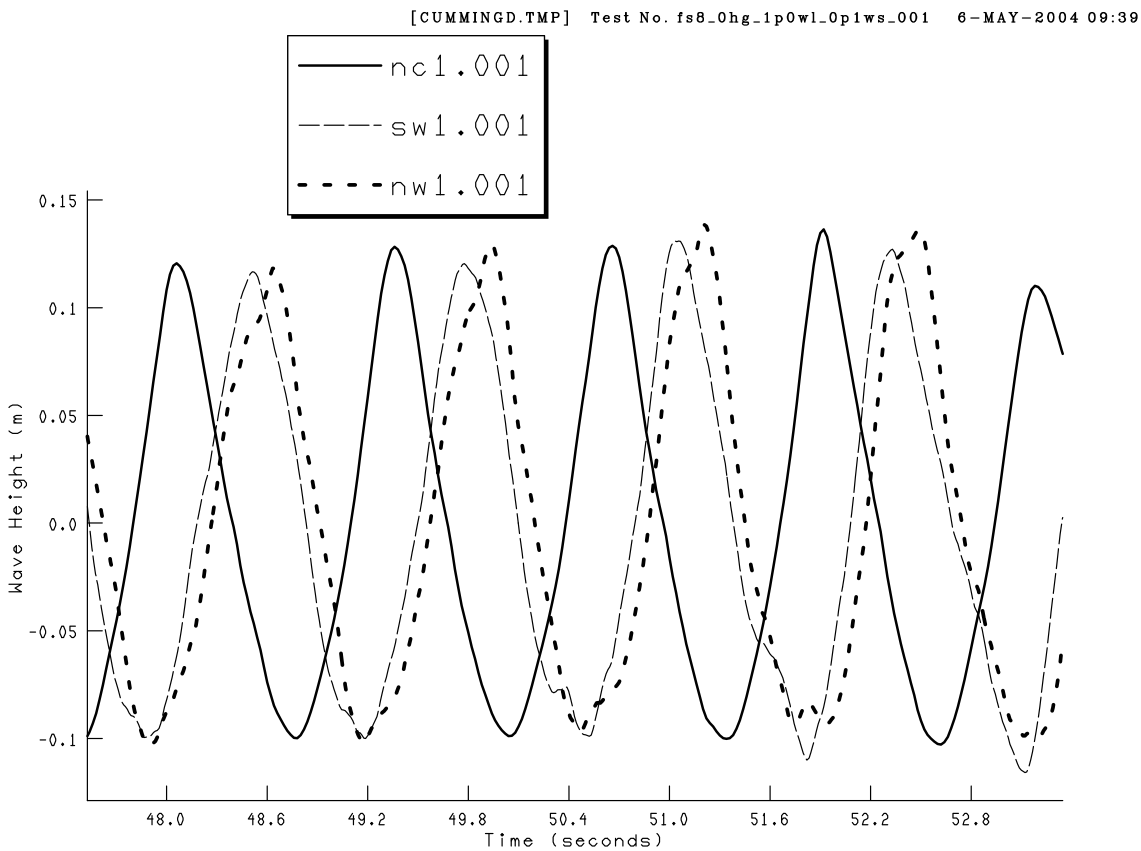


Figure 10: Example – Non-Linear, Regular Wave, Flume Mode

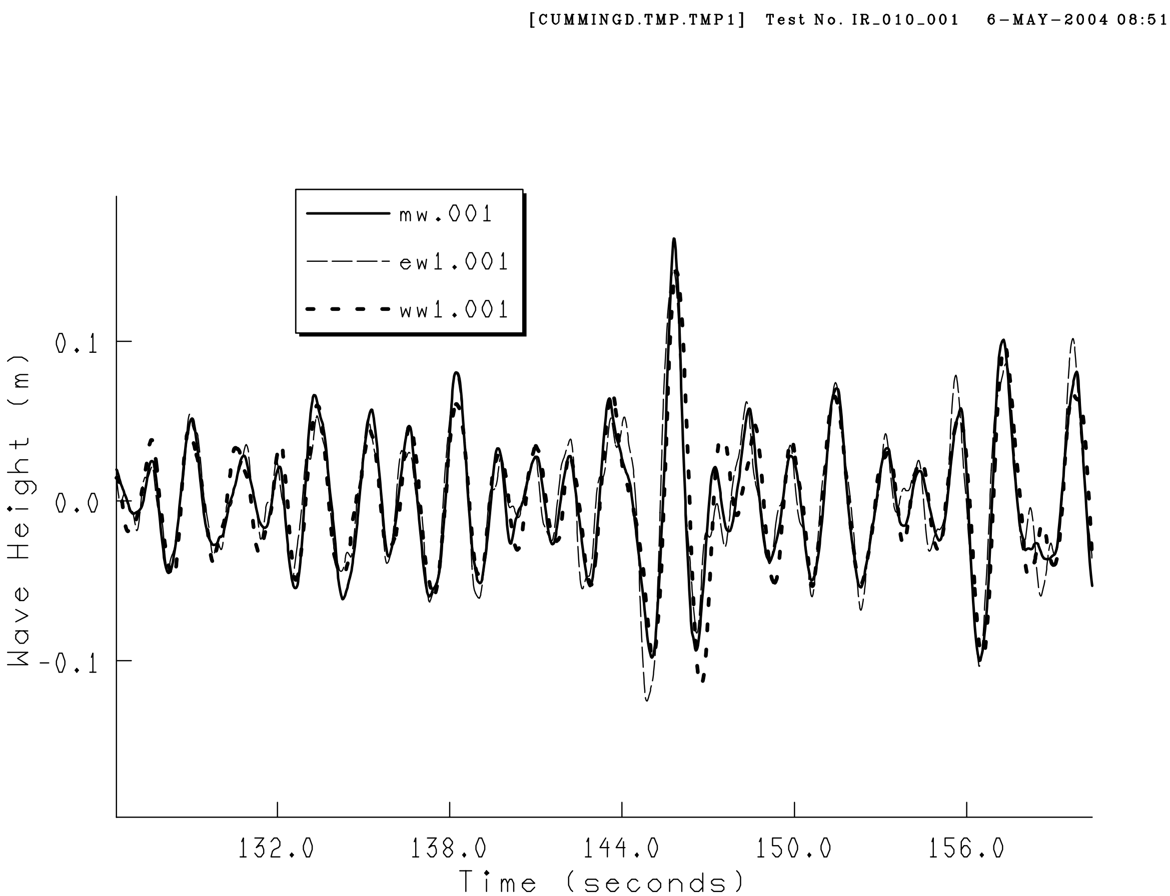


Figure 11: Example - Linear, Irregular Wave, Flume Mode

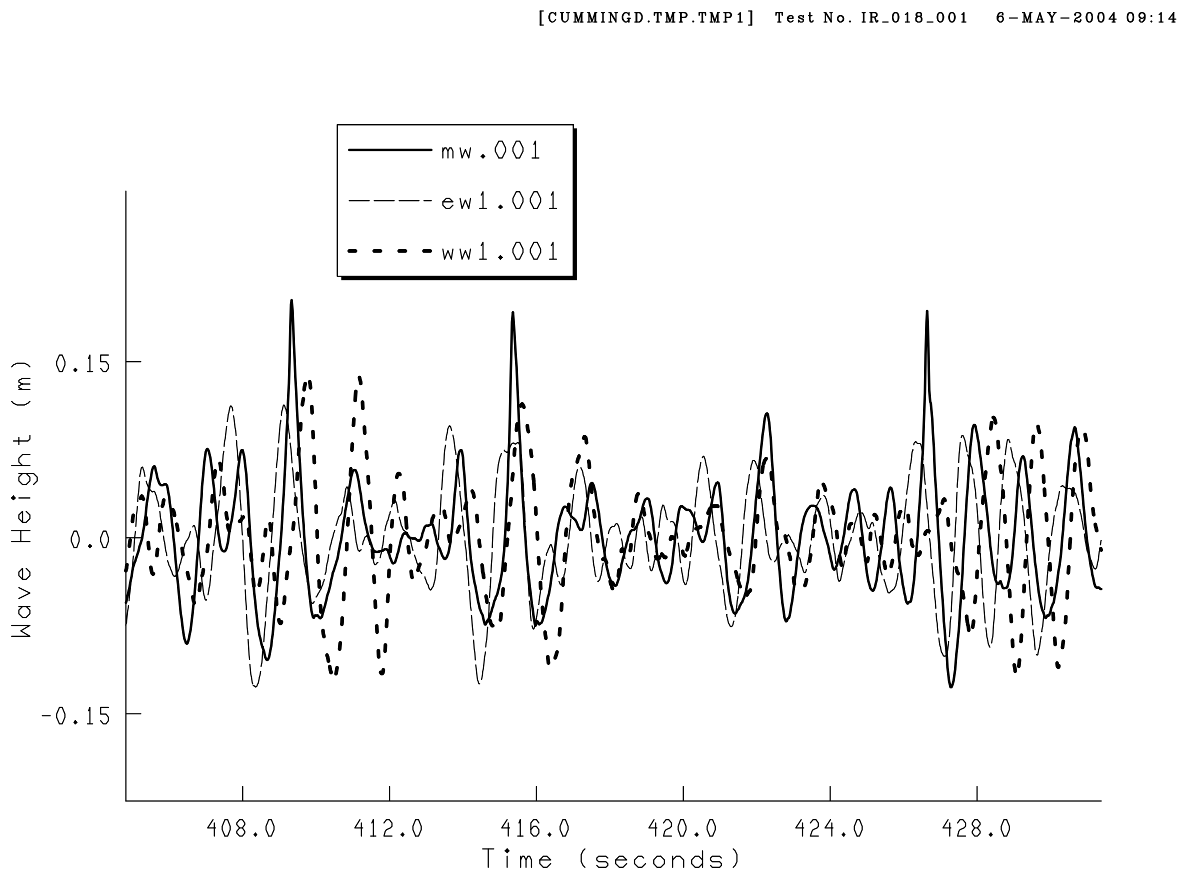


Figure 12: Example – Non-Linear, Irregular Wave, Flume Mode

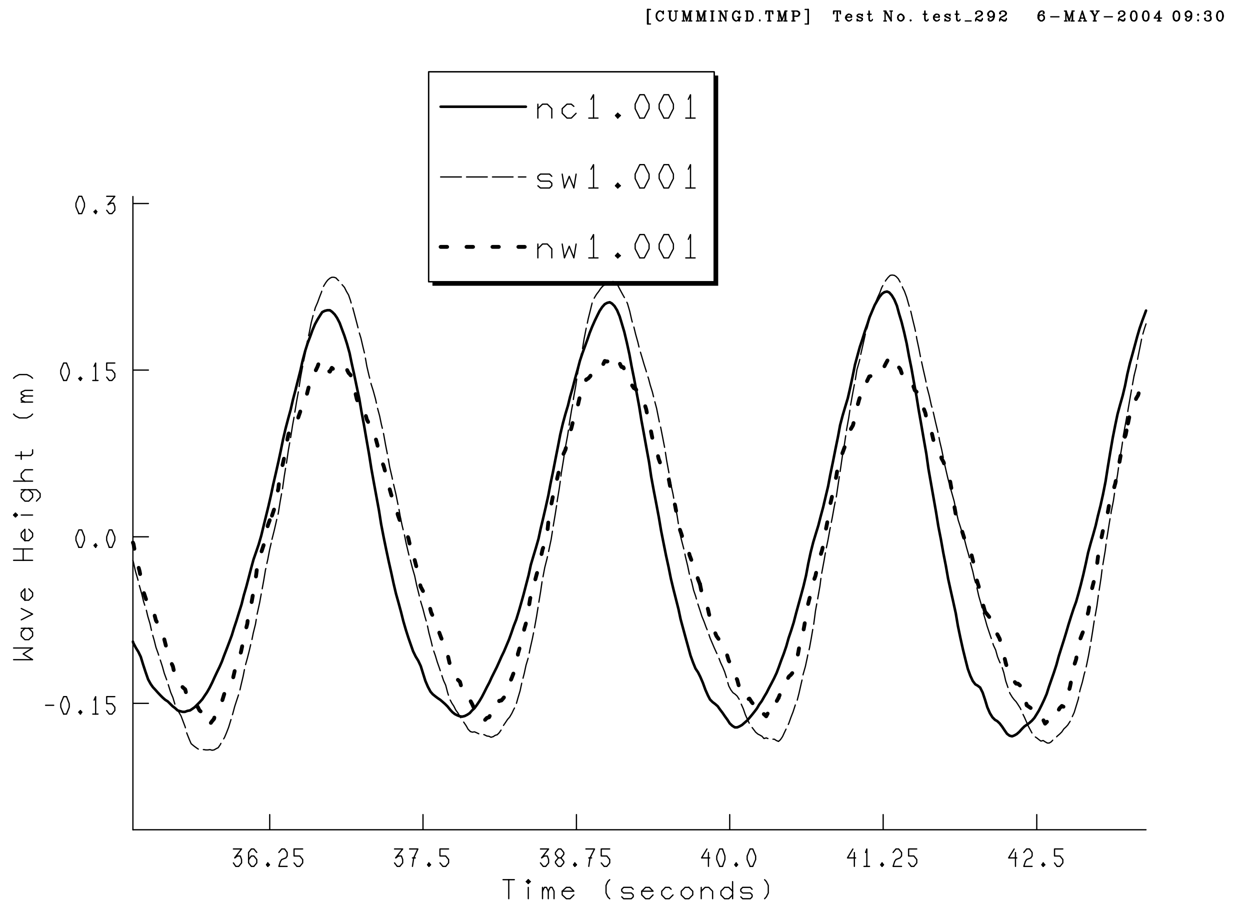


Figure 13: Example - Linear, Regular Oblique Wave

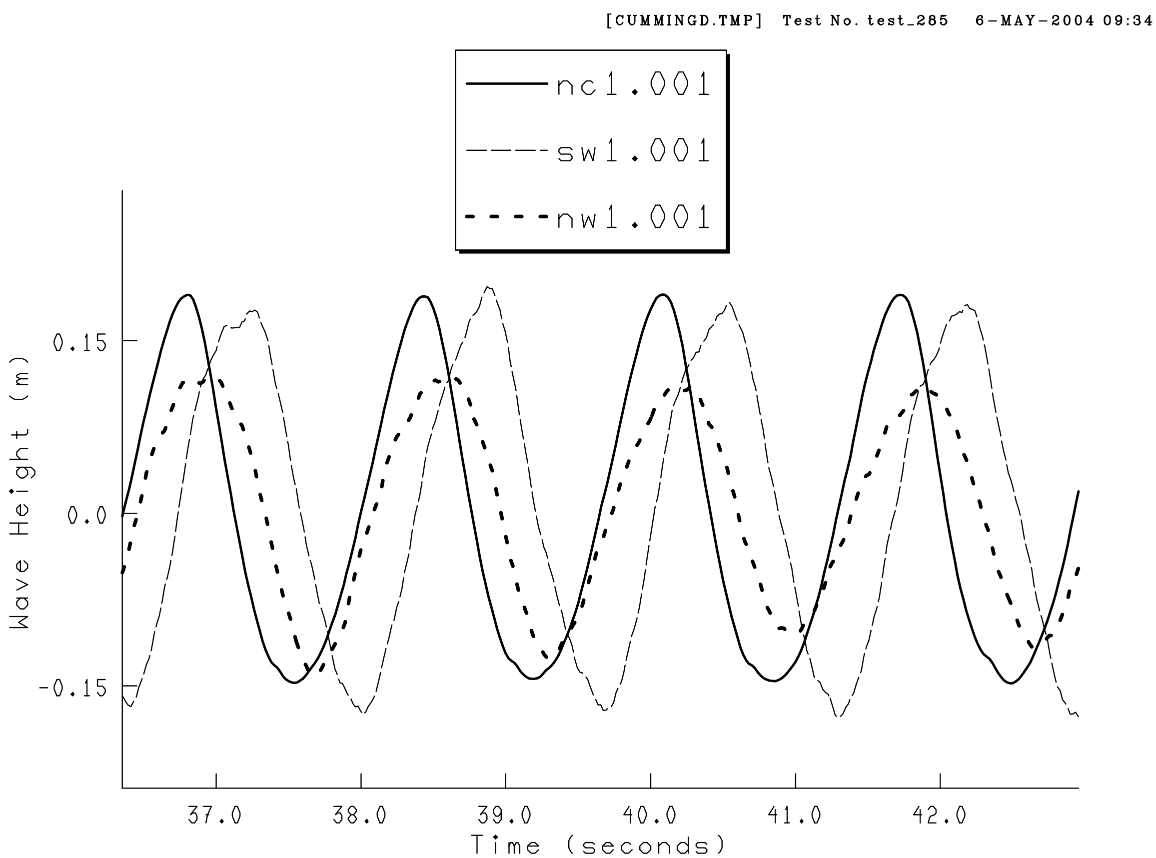


Figure 14: Example – Non-Linear, Regular Oblique Wave

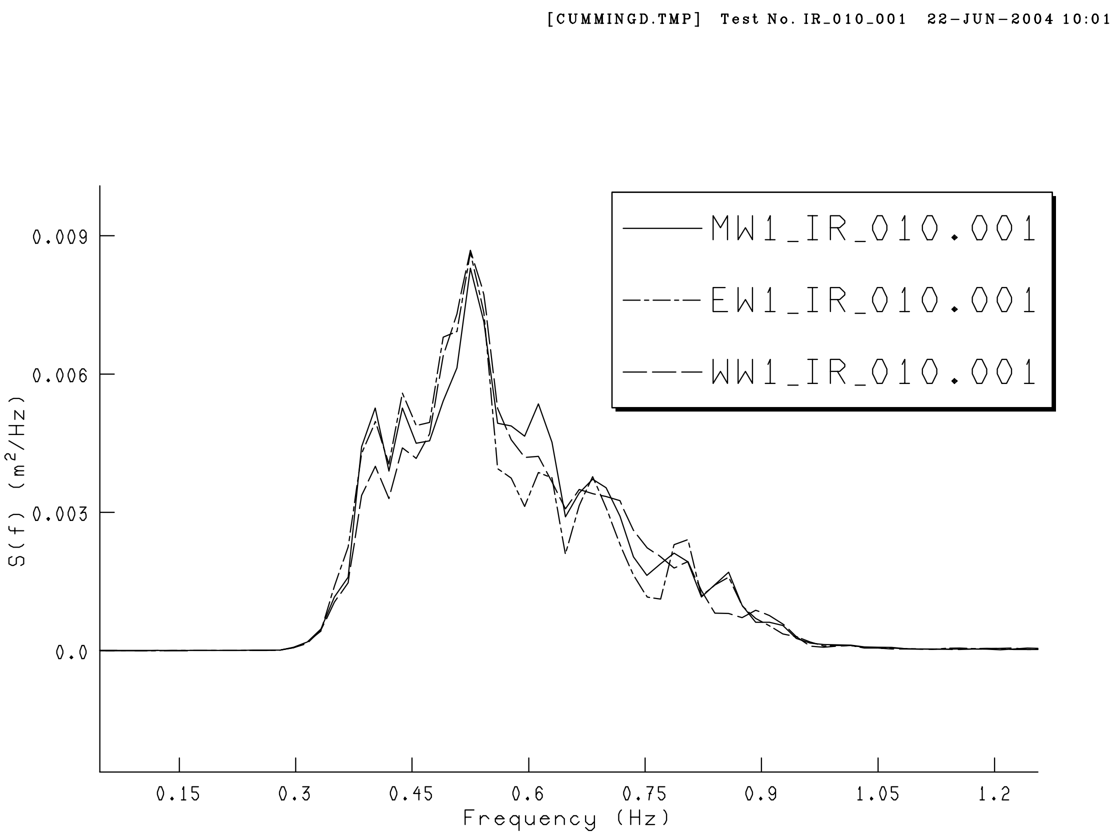


Figure 15: Example Spectral Density Comparison – Linear Irregular Wave

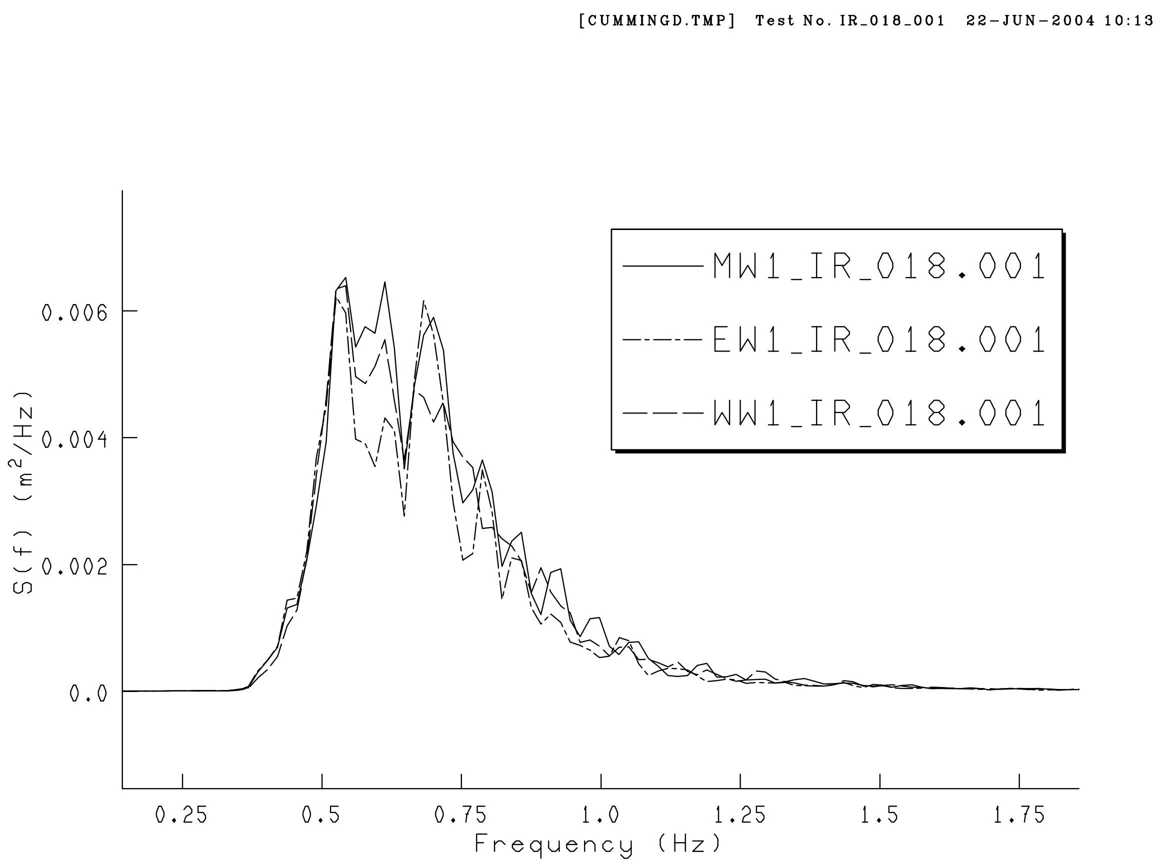
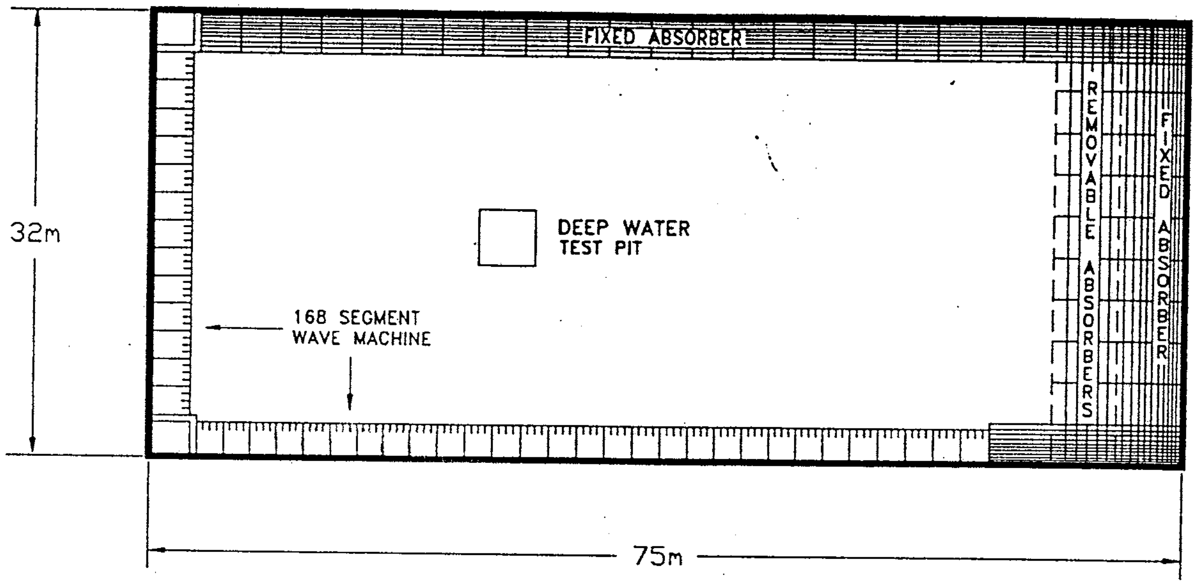


Figure 16: Example Spectral Density Comparison – Non-Linear Irregular Wave

Appendix A
Description of the Offshore Engineering Basin

INSTITUTE FOR MARINE DYNAMICS (NRC)
ST. JOHN'S, NEWFOUNDLAND (709) 772-4939 CANADA

OFFSHORE ENGINEERING BASIN (1990)



OFFSHORE ENGINEERING BASIN

DESCRIPTION OF BASIN: Tank 75m (346.06 ft) in length, 32m (104.99) in width, water depth 0.4m (1.58 ft) to 3.5m (11.48 ft), 4m square pit at centre allows max. depth of 8.5m, no carriages fitted, models are floated, moored or self-propelled in various sea states, model rigging is facilitated by a moveable overhead crane (5000 kg).

WAVE GENERATION: 168 individual wavemaker segments in an "L" configuration, hydraulically actuated, which can also act as active wave absorbers, can be adjusted vertically to accommodate water depths of 0.4m – 3.5m, three modes of articulation: flapper ±15, piston ±400mm, and a combination of both, 1800kW power, also fixed and moveable passive wave absorbers.

CURRENT GENERATION: Nozzles at various depths charged by pumps delivering 90 l/s and producing surface current of 0.5 m/s.

WIND GENERATION: Horizontal array of 12 analog controlled fans, horizontal and vertical tilt, independently controlled 3.7kW DC motor for each fan.

MODEL SIZE: Ship models up to 4.5m in length, floating or fixed structures 0.5m – 6m diameter.

INSTRUMENTATION: Wave measurement using capacitance and digital probes, accelerometers, pressure transducers and electromagnetic flow meters, force measurement with strain gauge load cells.

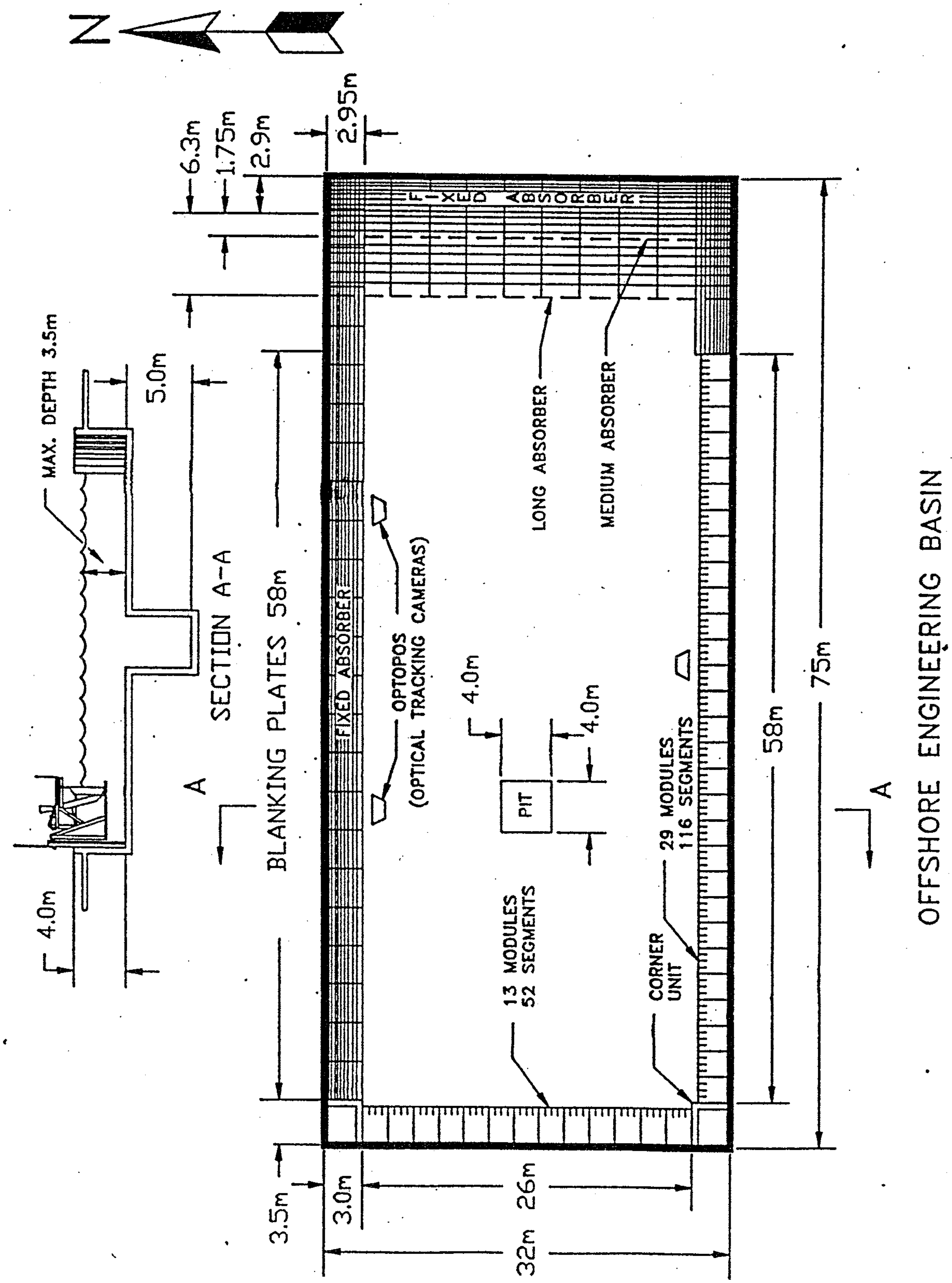
DATA ACQUISITION: VAX 3200 with 64 channels A/D (at 1000 Hz sample rate) which can simultaneously output 16 channels D/A, 32 channel bidirectional frequency modulated digital radio telemetry link, two 6 degrees of freedom optical tracking systems.

TESTS PERFORMED:
(1) Ship or structure behaviour in multi-directional extreme seas.
(2) Manoeuvring and station keeping.
(3) Tow out, set down and operation of offshore structures.
(4) Seakeeping in oblique waves.

PUBLISHED DESCRIPTION: CONSTRUCTION AND COMMISSIONING OF THE OFFSHORE ENGINEERING AND SEAKEEPING BASIN AT THE INSTITUTE FOR MARINE DYNAMICS, J.J. Murray and G.J. Fudge, Proceedings of ther 22nd American Towing Tank Conference, 1989

INSTITUTE FOR MARINE DYNAMICS (NRC) — CANADA
ST. JOHN'S, NEWFOUNDLAND (709) 772-4939

OFFSHORE ENGINEERING BASIN (1990)



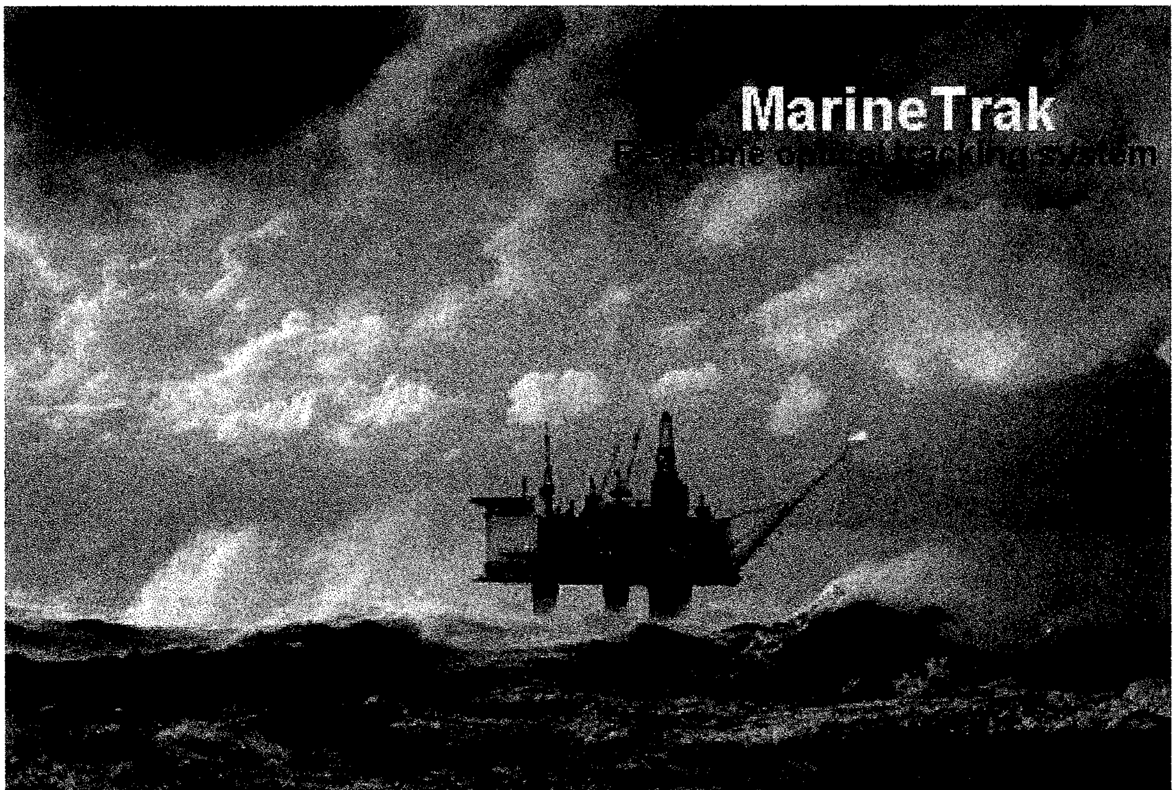
Appendix B
Description of the QUALISYS System

Optomatrix Technology AB

APPLICATION NOTE
APPLICATION NOTE
APPLICATION NOTE
APPLICATION NOTE
APPLICATION NOTE

MarineTrak EVM

3-D and 6-DOF data in real time



MarineTrak uses optical tracking technology to quickly and accurately measure objects remotely in either 3-D or 6-DOF (i.e Degree Of Freedom; X, Y, Z, roll, pitch, yaw) in naval test basins without disturbing the motion of the vessel.

The measurement of 6-DOF is monitored continuosly with an accuracy better than 1mm even for very large measurement areas such as ocean basins. The high measuring frequency and low latency of the system makes it possible for the output data to be used for on-line measurements.

The system was first developed for Marintek in Norway and is now established on the market. Today no fewer than 12 users have installed MarineTrak in their test facilities.

BENEFITS

- Real-time 6-DOF
- No physical contact, no interference
- Frequency 1-100Hz
- Multi-object capability
- High accuracy
- Large measurement area

Optomatrix Technology AB

MarineTrak EVM

3-D and 6-DOF data in real time

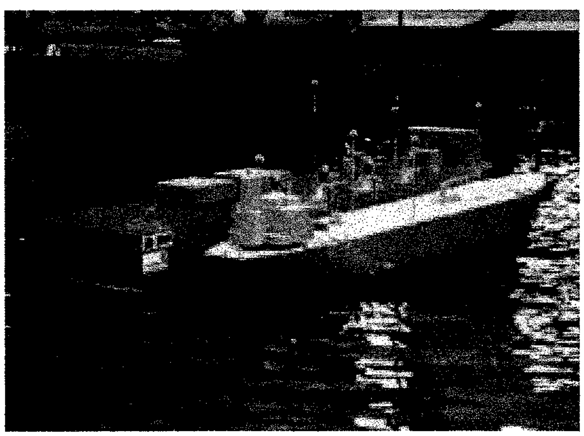
APPLICATION NOTE
APPLICATION NOTE
APPLICATION NOTE
APPLICATION NOTE
APPLICATION NOTE

System overview

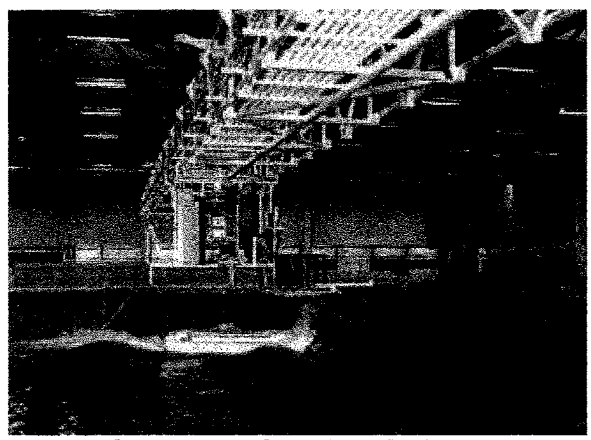
The main parts of the system consist of a real-time processing unit, a host PC, markers and a number of infrared-emitting cameras which represent the latest in motion capture technology. The cameras are divided into two groups to view the area occupied by the ship models. The number of cameras in use varies from 2 up to 16 depending on size of the test area and required accuracy.

Measurement Method

The method uses reflective or emitting markers placed on the object to be tracked. Cameras detect the infrared light reflected or emitted by the markers and calculate 2-D co-ordinates for the centre of each one. Each marker must be in the field of view of at least one camera from each group so that the 2-D data from each camera can be used to calculate the 3-D position of the marker. By using a rigid body which is a group of 3 or more markers with fixed positions relative to each other, 6-DOF can be calculated. The unique rigid body also enables the cameras to identify and keep track of multiple objects.



MarineTrak in use for model testing in the offshore basin at DHI Water & Environment, Denmark.



MarineTrak in towing tank at Marintek A/S, Norway

Typical applications

The MarineTrak system may be used in a wide variety of situations and in a wide range of measurements volumes. The system is completely modular. For instance, a typical set-up for a towing tank uses two cameras, but by adding cameras, a larger volume can be covered. The system is also ideal for field use since the cameras are portable and the system is easy to set up and calibrate.

User interface

MarineTrak comes with a Windows NT manager that allows the user to quickly and interactively set up and operate the system. If you want to integrate an external system, a variety of alternatives is available including drivers for DOS, Labview/Visual basic, Windows NT and TCP/IP. A version of Marine Trak is available for analog output 6-DOF.

For more information, contact us!

Optomatrix Technology AB, Esperantoplatsen 7-9 411 19 Göteborg, SWEDEN.
tel. +46 31 774 38 30, fax. +46 31 7743835, e-mail: sales@optomatrix.se
http://www.qualisys.com

QUALISYS

Summary

The MarineTrak system from Qualisys system uses optical tracking technology to study the movements of a ship or any other kind of floating vessel in a test environment. Three-dimensional position and roll, pitch, yaw angles of the object are measured and output in an on-line, real time fashion. The use of actively emitting IR markers enables the system to measure accurately even at large distances.

Background

When testing ship models in test basins there is a need to quickly and accurately measure position and attitude of the model. The measurement should be done remotely, and without disturbing the motion of the model. The solution to the problem is optical motion tracking. A few lightweight optical markers are attached to the model to enable special cameras mounted around the tank to cover the desired part of the water surface.

With the Marinetrak EVM system developed by Qualisys AB, Sweden, continuous monitoring of 6 D. O. F. (Degrees of Freedom) can be carried out, rendering an accuracy of better than 1 mm even for very large measurement areas. The high measuring frequency and low latency of the system enables the output data to be used for on-line measurements.

Measurement Principle

The measurement system consists of a number of infrared-sensitive cameras arranged to view the area occupied by the ship models. The camera detects the position of small infrared emitting markers attached to the model. Two-dimensional co-ordinates from each camera are sent to a central processing unit, where the different cameras' 2-D data, together with information about camera locations, are used to calculate three-dimensional co-ordinates for the markers. (Fig. 1).

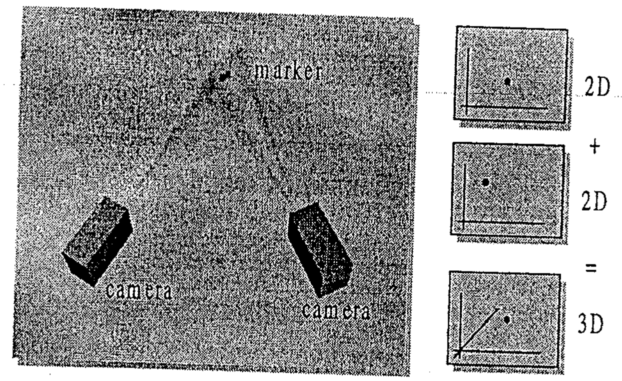


Fig. 1 Measurement principle

The camera locations are automatically calculated in a calibration procedure.

In order to cover large areas without sacrificing accuracy and resolution, Qualisys has devised a unique system utilising partly overlapping camera views in a sunfeather configuration (Fig. 2). Virtually unlimited measurement areas can be cov-

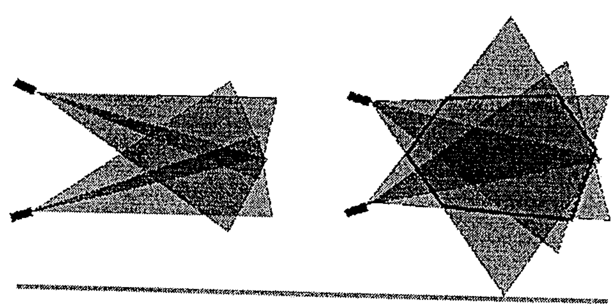


Fig. 2. Camera configurations

ered in this fashion

System features

The EVM system consists of between 2 and 16 cameras, divided in two camera groups. In order for a marker to be correctly measured, it must be in the field of view of at least one camera from each group. The software will calculate 3D co-ordinates for each marker, alternatively 6 D.O.F. for groups of markers whose inter-marker distances remain constant (Fig. 3).

Calibration of the system is made with a number of fixed reference markers, placed so that each camera views at least two reference markers. Alternatively, a portable calibration structure or a dynamic, wand based calibration may be used.

Since test basin measurements are often made at large distances, the use of active, infrared emitting markers is recommended. These markers are designed to be small, lightweight and totally autonomous.

The system delivers 3D co-ordinates or, alternatively, 6 D.O.F. through a serial link to the user's host computer. The 3D calculation software is running on a special processing unit, that communicates directly with the cameras.

Typical applications

The Marinetrak system may be used in a wide variety of situations, and in a wide range of measurement volumes. The system is completely modular, and by adding cameras, larger volumes can be covered. A typical set-up for a towing tank using two cameras is depicted in Fig. 4, whereas a set-up for a large basin may require up to 16 cameras (Fig. 5).

Since the cameras are completely portable, and the system is very easy to set up and calibrate, the system is also ideal for field use.

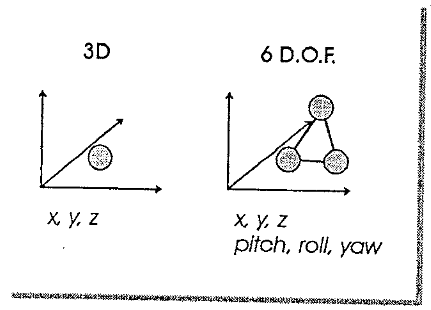


Fig.3. Output data

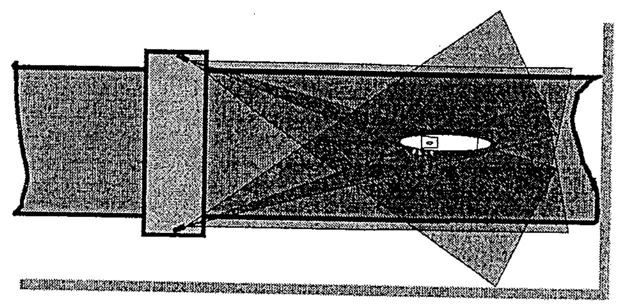


Fig 4. Configuration for towing tank

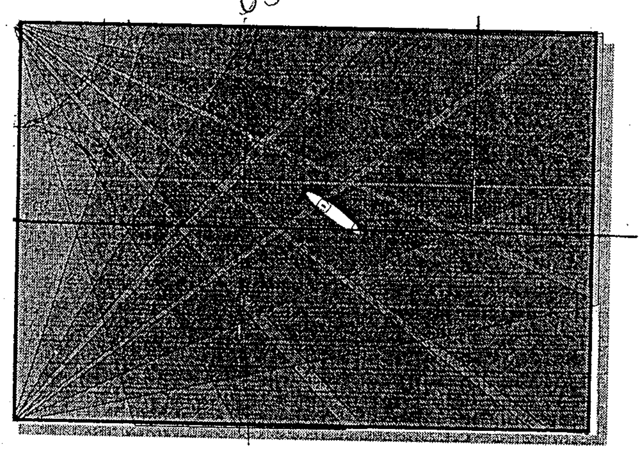


Fig. 5. Configuration for ocean tank

QUALISYS

System Lay-out

A Marinetrak EVM system consists of the following parts

Infrared emitting cameras (2-16)

Processing Unit (1)

Reference Markers (4 - 40)

Measurement Markers

Cables

3D Measurement Software

active leds ~ 100 - 500

MCU- 240 - $19,000 US @

EVM-PPU - $20,000

Specifications (typical)[1]

	50 m x 70 m area	6 m x 6 m area
Spatial resolution:	0,5 mm	0,1 mm
Relative accuracy:	+/- 1,5 mm	+/- 0,25 mm
Absolute accuracy:	+/- 10 mm	+/- 2 mm
Angular accuracy:	+/- 3 mrad	+/- 0,5 mrad
Frame rate:	30 fps	60 fps
No. of cameras:	14	4
Max. No. of markers	32	32
Max no. of rigid bodies:	10	10

[1] Actual specification may vary depending on measurement situation, hardware configuration, ambient conditions etc.

Qualisys AB Göteborgsvägen 74 SE- 433 63 SÄVEDALEN Sweden
Tel: +46 31 336 94 00 Fax: +46 31 336 94 00 E-mail: sales@qualisys.se

Appendix C
Analysis Results: 'WAVETRAN' Regular Waves

Validation of GEDAP Program 'WAVETRAN' - Regular Waves in the OEB:

Regular Flume Mode Waves Data Set 1:

Filename	T1 (s)	T2 (s)	Nominal Wave Period (s)	Nominal Wave Frequency (Hz)	Nominal Wave Height (m)	Est. Wave Breaking Wave Height (m)	Transfer NW1 to NC1 Rxy (tau)	tau (s)	% Wave Period	Transfer SW1 to NC1 Rxy (tau)	tau (s)	% Wave Period
NOTE: OEB in Flume Mode (waves generated 0 deg. from west wall), blanking walls installed covering all north beaches.												
FS8_180HG_0HG_0p75WL_0p04WS_002	60	80	1.12	0.8929	0.0735	0.19578	0.9951	-0.1307	11.67	0.9947	-0.1063	9.49
FS8_180HG_0HG_0p75WL_0p1WS_001	60	80	1.12	0.8929	0.1838	0.19578	0.9356	0.4946	44.16	0.9587	0.5729	51.15
FS8_180HG_0HG_1p0WL_0p04WS_001	50	70	1.29	0.7752	0.0980	0.25973	0.9952	-0.1334	10.34	0.9925	-0.0601	4.66
FS8_0HG_1p0WL_0p1WS_001	45	65	1.29	0.7752	0.2450	0.25973	0.9693	-0.4873	37.78	0.9714	-0.4031	31.25
FS8_180HG_0HG_1p5WL_0p04WS_001	40	60	1.58	0.6329	0.1470	0.38945	0.9906	-0.1001	6.34	0.9934	-0.0537	3.40
FS8_0HG_1p5WL_0p1WS_001	35	55	1.58	0.6329	0.3675	0.38945	0.9739	-0.3517	22.26	0.9781	-0.3029	19.17
test_011	40	60	1.649	0.6064	0.3330	0.42398	0.9682	-0.2335	14.16	0.9596	-0.2018	12.24
test_008	40	60	1.814	0.5513	0.3330	0.51145	0.9750	-0.1539	8.48	0.9728	-0.1417	7.81
test_132	35	55	1.814	0.5513	0.5000	0.51145	0.9469	-0.2400	13.23	0.9411	-0.2400	13.23
FS13_180HG_0HG_2p0WL_0p04WS_001	60	80	1.82	0.5495	0.1960	0.51474	0.9905	-0.0792	4.35	0.9916	-0.0450	2.47
FS13_0HG_2p0WL_0p1WS_001	52	70	1.82	0.5495	0.4900	0.51474	0.9630	-0.2666	14.65	0.9612	-0.2226	12.23
test_141	35	55	1.909	0.5238	0.3330	0.56424	0.9960	-0.0958	5.02	0.9957	-0.0689	3.61
test_153	32	52	1.909	0.5238	0.5000	0.56424	0.9893	-0.2134	11.18	0.9924	-0.1889	9.90
test_140	35	55	2.015	0.4963	0.3330	0.62435	0.9868	-0.0951	4.72	0.9849	-0.0706	3.51
test_154	30	50	2.015	0.4963	0.5000	0.62435	0.9710	-0.1793	8.90	0.9728	-0.1451	7.20
FS8_180HG_0HG_2p5WL_0p04WS_001	40	70	2.04	0.4902	0.2450	0.63861	0.9907	-0.0393	1.93	0.9901	0.0028	0.14
FS0_180HG_2p5WL_0p06WS_001	60	90	2.04	0.4902	0.3675	0.63861	0.9969	-0.0890	4.37	0.9974	-0.0323	1.58
FS8_0HG_2p5WL_0p08WS_001	28	45	2.04	0.4902	0.4900	0.63861	0.9741	-0.1505	7.38	0.9797	-0.1007	4.93
test_139	35	60	2.134	0.4686	0.3330	0.69217	0.9943	-0.0668	3.13	0.9937	-0.0546	2.56
test_150	30	49	2.134	0.4686	0.5000	0.69217	0.9926	-0.1446	6.78	0.9920	-0.1515	7.10
test_138	40	60	2.267	0.4411	0.3330	0.7668	0.9789	-0.0616	2.72	0.9854	-0.0567	2.50
test_149	32	52	2.267	0.4411	0.5000	0.7668	0.9868	-0.1585	6.99	0.9842	-0.1364	6.02
test_137	35	55	2.418	0.4136	0.3330	0.84805	0.9980	-0.0222	0.92	0.9974	0.0122	0.51
test_148	30	50	2.418	0.4136	0.5000	0.84805	0.9956	-0.0616	2.55	0.9968	-0.0567	2.34
test_136	35	55	2.591	0.3860	0.3330	0.93463	0.9926	0.0137	0.53	0.9921	0.0308	1.19
test_147	35	60	2.591	0.3860	0.5000	0.93463	0.9903	-0.0012	0.05	0.9873	-0.0287	1.11
test_135	32	56	3.023	0.3308	0.3330	1.1152	0.9944	-0.0012	0.04	0.9950	0.0721	2.38
test_146	35	60	3.023	0.3308	0.5000	1.1152	0.9823	-0.0228	0.76	0.9824	0.0291	0.96
test_134	30	55	3.628	0.2756	0.3330	1.2922	0.9930	-0.1182	3.26	0.9965	0.1261	3.47
test_145	35	60	3.628	0.2756	0.5000	1.2922	0.9895	-0.1154	3.18	0.9953	0.1227	3.38

Validation of GEDAP Program 'WAVETRAN' - Regular Waves in the OEB:

Regular Flume Mode Waves Data Set 1:

Filename	Nominal Wave Height (m)	Nominal Wave Period (s)	L*[0.1*TANH(k*d)]*0.8	Variation of basic wave parameters: SW1 Hav (m)	SW1 Tav (s)	NW1 Hav (m)	NW1 Tav (s)	NC1 Hav (m)	NC1 Tav (s)
NOTE: OEB in Flume Mode (waves generated 0 deg. from west wall), blanking walls installed covering all north beaches.									
FS8_180HG_0HG_0p75WL_0p04WS_002	0.0735	1.12	0.1566	0.0800	1.120	0.0769	1.119	0.0774	1.120
FS8_180HG_0HG_0p75WL_0p1WS_001	0.1838	1.12	0.1566	0.1701	1.119	0.1634	1.119	0.1741	1.120
FS8_180HG_0HG_1p0WL_0p04WS_001	0.0980	1.29	0.2078	0.0886	1.290	0.0988	1.292	0.1076	1.290
FS8_0HG_1p0WL_0p1WS_001	0.2450	1.29	0.2078	0.2232	1.288	0.2208	1.289	0.2220	1.288
FS8_180HG_0HG_1p5WL_0p04WS_001	0.1470	1.58	0.3117	0.1453	1.581	0.1523	1.581	0.1595	1.582
FS8_0HG_1p5WL_0p1WS_001	0.3675	1.58	0.3117	0.3375	1.582	0.3447	1.580	0.3598	1.576
test_011	0.3330	1.649	0.3394	0.3229	1.650	0.3245	1.649	0.3067	1.650
test_008	0.3330	1.814	0.4101	0.3238	1.814	0.3229	1.814	0.3069	1.814
test_132	0.5000	1.814	0.4101	0.4162	1.812	0.4161	1.813	0.4412	1.813
FS13_180HG_0HG_2p0WL_0p04WS_001	0.1960	1.82	0.4127	0.1993	1.821	0.1923	1.820	0.2006	1.819
FS13_0HG_2p0WL_0p1WS_001	0.4900	1.82	0.4127	0.4592	1.820	0.4494	1.821	0.4814	1.820
test_141	0.3330	1.909	0.4532	0.3323	1.910	0.3009	1.909	0.3188	1.911
test_153	0.5000	1.909	0.4532	0.4740	1.911	0.4587	1.910	0.4503	1.911
test_140	0.3330	2.015	0.5031	0.3408	2.014	0.3168	2.013	0.3214	2.017
test_154	0.5000	2.015	0.5031	0.4593	2.103	0.4549	2.013	0.4632	2.013
FS8_180HG_0HG_2p5WL_0p04WS_001	0.2450	2.04	0.5151	0.2268	2.038	0.2360	2.038	0.2260	2.037
FS0_180HG_2p5WL_0p06WS_001	0.3675	2.04	0.5151	0.3368	2.039	0.3450	2.040	0.3321	2.038
FS8_0HG_2p5WL_0p08WS_001	0.4900	2.04	0.5151	0.4842	2.038	0.4844	2.039	0.4774	2.041
test_139	0.3330	2.134	0.5607	0.3153	2.134	0.3015	2.134	0.2999	2.133
test_150	0.5000	2.134	0.5607	0.4888	2.137	0.4522	2.139	0.4556	2.136
test_138	0.3330	2.267	0.6260	0.3360	2.268	0.3052	2.268	0.3012	2.267
test_149	0.5000	2.267	0.6260	0.5108	2.267	0.4749	2.270	0.4415	2.267
test_137	0.3330	2.418	0.6999	0.3560	2.422	0.3460	2.420	0.3071	2.419
test_148	0.5000	2.418	0.6999	0.5141	2.418	0.4829	2.423	0.4486	2.425
test_136	0.3330	2.591	0.7819	0.2943	2.595	0.2949	2.589	0.2702	2.592
test_147	0.5000	2.591	0.7819	0.4745	2.592	0.4443	2.590	0.4107	2.593
test_135	0.3330	3.023	0.9626	0.2814	3.025	0.2610	3.023	0.2572	3.025
test_146	0.5000	3.023	0.9626	0.4171	3.026	0.3667	3.035	0.3523	3.026
test_134	0.3330	3.628	1.1413	0.2759	3.616	0.2721	3.644	0.2782	3.621
test_145	0.5000	3.628	1.1413	0.4362	3.616	0.3984	3.647	0.4132	3.629

Regular Oblique Waves - Data Set 1:

Filename	T1 (s)	T2 (s)	Nominal Wave Period (s)	Nominal Wave Frequency (Hz)	Nominal Wave Height (m)	Est. Wave Breaking Wave Height (m)	Transfer NW1 to NC1 Rxy (tau)	Transfer NW1 to NC1 tau (s)	Transfer NW1 to NC1 % Wave Period	Transfer SW1 to NC1 Rxy (tau)	Transfer SW1 to NC1 tau (s)	Transfer SW1 to NC1 % Wave Period
NOTE: Oblique waves generated 60 degrees from the west wall, blanking walls removed.												
FS8_120HG60HG_0p75WL_0p04WS_001	70	88	1.12	0.8929	0.0735	0.19578	0.9902	-0.10958	9.78	0.9894	-0.1964	17.54
FS8_120HG60HG_0p75WL_0p1WS_001	65	75	1.12	0.8929	0.1838	0.19578	0.9375	-0.21729	19.40	0.9415	0.49521	44.22
FS8_120HG_1p0WL_0p04WS_001	60	74	1.29	0.7752	0.0980	0.25973	0.9824	-0.08927	6.92	0.9837	-0.0687	5.33
FS8_120HG_1p0WL_0p1WS_001	60	76	1.29	0.7752	0.2450	0.25973	0.9368	-0.22287	17.28	0.9475	-0.5181	40.16
test_289	35	60	1.395	0.7168	0.3330	0.30372	0.9177	-0.32282	23.14	0.9337	0.53997	38.71
test_288	36	56	1.511	0.6618	0.3330	0.35627	0.9392	-0.21509	14.23	0.9387	-0.6013	39.79
FS8_120HG_1p5WL_0p04WS_001	58	76	1.58	0.6329	0.1470	0.38945	0.9917	-0.05600	3.54	0.9955	-0.0604	3.82
FS8_120HG_1p5WL_0p1WS_001	55	80	1.58	0.6329	0.3675	0.38945	0.9664	-0.16834	10.65	0.9615	-0.4813	30.46
test_285	35	70	1.649	0.6064	0.3330	0.42398	0.9550	-0.22950	13.92	0.9585	-0.4817	29.21
test_314	34	56	1.814	0.5513	0.3330	0.51145	N/A	N/A	N/A	0.9729	-0.3061	16.87
FS8_120HG_2p0WL_0p04WS_001	55	78	1.82	0.5495	0.1960	0.51474	0.9867	-0.08528	4.69	0.9914	-0.0853	4.69
FS8_120HG_2p0WL_0p08WS_001	52	78	1.82	0.5495	0.3920	0.51474	0.9680	-0.14358	7.89	0.9859	-0.2499	13.73
test_195	32	58	2.015	0.4963	0.3330	0.62435	0.9957	-0.08574	4.25	0.9856	-0.2144	10.64
FS8_120HG_2p5WL_0p04WS_001	52	70	2.04	0.4902	0.2450	0.63861	0.9960	-0.05376	2.64	0.9941	-0.0934	4.58
FS8_120HG_2p5WL_0p06WS_001	52	74	2.04	0.4902	0.3675	0.63861	0.9894	-0.08355	4.10	0.9957	-0.1561	7.65
test_191	32	55	2.267	0.4411	0.3330	0.7668	0.9897	-0.10698	4.72	0.9946	-0.1252	5.52
test_292	32	68	2.267	0.4411	0.5000	0.7668	0.9734	-0.12334	5.44	0.9822	-0.1365	6.02
test_189	30	54	2.418	0.4136	0.3330	0.84805	0.9795	-0.0811	3.36	0.9873	0.00537	0.22
test_187	32	55	2.591	0.3860	0.3330	0.93463	0.9971	-0.1022	3.94	0.9908	-0.025	0.96
test_348	30	53	2.591	0.3860	0.5000	0.93463	N/A	N/A	N/A	0.9630	-0.0859	3.32
test_304	32	55	2.79	0.3584	0.3330	1.0242	N/A	N/A	N/A	0.9966	-0.025	0.89
test_346	30	53	2.79	0.3584	0.5000	1.0242	N/A	N/A	N/A	0.9971	-0.0653	2.34
test_185	30	52	3.023	0.3308	0.3330	1.1152	0.9982	-0.0017	0.06	0.9955	-0.0648	2.14
test_290	30	65	3.023	0.3308	0.5000	1.1152	0.9976	-0.0119	0.39	0.9939	-0.1038	3.43

NOTE:

Wave height, wave period and wave direction are nominal values.

Estimated breaking wave height computed for user input water depth and wave period.

Rxy (tau) - cross correlation function between two wave probe signals. If two signals are identical, Rxy (tau) = 1.0.

tau - time lag (s) between two wave probe signals. (-ve is lead)

Non-linear Wave is defined as 0.7*H/L < 0.1TANH(kd) (ie: wave is too close to breaking to provide satisfactory solution using WAVETRAN)

Where: H = wave height (m)

L = wave length (m) = $2*PI/g*T_W^2$

g = acceleration due to gravity (m/s^2) = 9.808 m/s^2

PI = 3.14159

T_W = wave period (s)

k = wave number (m^{-1}) = $(4*PI^2)/(g*T_W^2)$

d = water depth (m)

% Wave Period = (tau/nominal wave period) * 100

N/A = Not Available

T1, T2 - Start, End Segment Select Time

Linear Data in **BLACK**, Non-linear Data in **RED**

Regular Oblique Waves - Data Set 1:

Filename	Nominal Wave Height (m)	Nominal Wave Period (s)	L*[0.1*TANH(k*d)]*0.7	Variation of basic wave parameters: SW1 Hav (m)	SW1 Tav (s)	NW1 Hav (m)	NW1 Tav (s)	NC1 Hav (m)	NC1 Tav (s)
NOTE: Oblique waves generated 60 degrees from the west wall, blanking walls removed.									
FS8_120HG60HG_0p75WL_0p04WS_001	0.0735	1.12	0.1371	0.0902	1.122	0.0731	1.120	0.0881	1.122
FS8_120HG60HG_0p75WL_0p1WS_001	0.1838	1.12	0.1371	0.2023	1.120	0.1570	1.117	0.1766	1.121
FS8_120HG_1p0WL_0p04WS_001	0.0980	1.29	0.1818	0.0999	1.288	0.0868	1.286	0.0870	1.290
FS8_120HG_1p0WL_0p1WS_001	0.2450	1.29	0.1818	0.2316	1.289	0.1876	1.289	0.2319	1.290
test_289	0.3330	1.395	0.2126	0.3248	1.398	0.2545	1.398	0.3162	1.399
test_288	0.3330	1.511	0.2494	0.3218	1.508	0.2631	1.515	0.3250	1.503
FS8_120HG_1p5WL_0p04WS_001	0.1470	1.58	0.2727	0.1428	1.580	0.1265	1.577	0.1635	1.580
FS8_120HG_1p5WL_0p1WS_001	0.3675	1.58	0.2727	0.3779	1.580	0.2842	1.581	0.3805	1.573
test_285	0.3330	1.649	0.2970	0.3682	1.650	0.2970	1.649	0.3440	1.644
test_314	0.3330	1.814	0.3588	0.4212	1.812	N/A	N/A	0.3949	1.812
FS8_120HG_2p0WL_0p04WS_001	0.1960	1.82	0.3611	0.2430	1.817	0.1848	1.818	0.2378	1.819
FS8_120HG_2p0WL_0p08WS_001	0.3920	1.82	0.3611	0.4604	1.817	0.3284	1.818	0.4703	1.818
test_195	0.3330	2.015	0.4402	0.3533	2.015	0.3291	2.015	0.3651	2.015
FS8_120HG_2p5WL_0p04WS_001	0.2450	2.04	0.4507	0.2579	2.040	0.2244	2.039	0.2665	2.040
FS8_120HG_2p5WL_0p06WS_001	0.3675	2.04	0.4507	0.3737	2.041	0.3198	2.039	0.3700	2.038
test_191	0.3330	2.267	0.5478	0.3099	2.268	0.2270	2.269	0.2495	2.267
test_292	0.5000	2.267	0.5478	0.4198	2.268	0.3285	2.269	0.3860	2.267
test_189	0.3330	2.418	0.6124	0.3151	2.425	0.2667	2.416	0.2864	2.415
test_187	0.3330	2.591	0.6842	0.3485	2.593	0.3711	2.590	0.3715	2.588
test_348	0.5000	2.591	0.6842	0.4988	2.588	N/A	N/A	0.5678	2.588
test_304	0.3330	2.79	0.7615	0.3253	2.788	N/A	N/A	0.3300	2.791
test_346	0.5000	2.79	0.7615	0.4360	2.790	N/A	N/A	0.4474	2.793
test_185	0.3330	3.023	0.8423	0.2429	3.026	0.2649	3.026	0.2951	3.021
test_290	0.5000	3.023	0.8423	0.3828	3.028	0.412	3.027	0.4497	3.023

NOTE: Hav = Average Wave Height (m)
Tav = Average Wave Period (s)
NC1 = North Center Wave Probe
SW1 = South West Wave Probe moved to North Center Wave Probe Location
NW1 = North West Wave Probe moved to North Center Wave Probe Location

Validation of GEDAP Program 'WAVETRAN' - Regular Waves in the OEB:

REGULAR WAVES - Data Set 2:

						Est. Wave Breaking	Transfer EW1 to MW1			Transfer WW1 to MW1		
File Name	T1 (s)	T2 (s)	Wave Period (s)	Wave Frequency (Hz)	Wave Height (m)	Wave Height (m)	Rxy (tau)	tau (s)	% Wave Period	Rxy (tau)	tau (s)	% Wave Period
NOTE: OEB in Flume Mode (waves generated 0 deg. from west wall), blanking walls installed covering all north beaches.												
RD_001_001	40	60	2.00	0.50	0.10	0.61583	0.9982	-0.01221	0.61	0.9979	0.0232	1.16
RD_002_001	40	60	2.00	0.50	0.20	0.61583	0.9951	0.009769	0.49	0.9917	-0.0098	0.49
RD_003_001	40	60	2.00	0.50	0.30	0.61583	0.9831	0.050064	2.50	0.9836	-0.0525	2.63
RD_004_001	40	60	2.00	0.50	0.40	0.61583	0.9774	0.075707	3.79	0.9804	-0.1099	5.50
RD_005_001	40	60	2.00	0.50	0.50	0.61583	0.9882	0.12699	6.35	0.9593	-0.1624	8.12
RD_006_001	40	60	2.00	0.50	0.60	0.61583	0.9707	0.21857	10.93	0.9718	-0.2186	10.93
RD_007_002	40	60	2.00	0.50	0.70	0.61583	0.9587	0.28451	14.23	0.9471	-0.2210	11.05
RD_008_001	45	65	1.67	0.60	0.05	0.43475	0.9936	-0.06105	3.66	0.9956	0.0061	0.37
RD_009_001	45	65	1.67	0.60	0.10	0.43475	0.9939	-0.00366	0.22	0.9967	0.0073	0.44
RD_010_001	45	65	1.67	0.60	0.15	0.43475	0.9926	0.021979	1.32	0.9914	-0.0232	1.39
RD_011_001	45	65	1.67	0.60	0.20	0.43475	0.9932	0.062275	3.73	0.9904	-0.0598	3.58
RD_012_001	45	65	1.67	0.60	0.25	0.43475	0.9788	0.10868	6.51	0.9811	-0.0965	5.78
RD_013_001	45	65	1.67	0.60	0.30	0.43475	0.9629	0.14775	8.85	0.9549	-0.1551	9.29
RD_014_001	45	65	1.67	0.60	0.35	0.43475	0.9651	0.19415	11.63	0.9806	-0.2027	12.14
RD_015_001	45	65	1.67	0.60	0.40	0.43475	0.9408	0.26375	15.79	0.9841	-0.2283	13.67
RD_016_001	45	65	1.67	0.60	0.45	0.43475	0.9619	0.32114	19.23	0.9445	-0.3089	18.50
RD_017_001	45	65	1.67	0.60	0.50	0.43475	0.8886	0.39441	23.62	0.9576	-0.3431	20.55
RD_018_001	47	67	1.43	0.70	0.05	0.31914	0.9981	0.004152	0.29	0.9962	0.0200	1.40
RD_019_001	47	67	1.43	0.70	0.10	0.31914	0.9970	0.027352	1.91	0.9976	-0.0215	1.50
RD_020_001	47	67	1.43	0.70	0.15	0.31914	0.9971	0.084743	5.93	0.9981	-0.0691	4.83
RD_021_001	47	67	1.43	0.70	0.20	0.31914	0.9960	0.14702	10.28	0.9949	-0.1448	10.13
RD_022_001	47	67	1.43	0.70	0.25	0.31914	0.9724	0.23249	16.26	0.9869	-0.2340	16.36
RD_023_001	47	67	1.43	0.70	0.30	0.31914	0.9840	0.32774	22.92	0.9843	-0.3426	23.96
RS_001_001	40	60	2.50	0.40	0.05	0.89024	0.9974	0.006106	0.24	0.9983	-0.0049	0.20
RS_002_001	40	60	2.50	0.40	0.10	0.89024	0.9972	0.01099	0.44	0.9978	-0.0085	0.34
RS_003_001	40	60	2.50	0.40	0.15	0.89024	0.9934	0.017095	0.68	0.9964	-0.0269	1.07
RS_004_001	40	60	2.50	0.40	0.20	0.89024	0.9855	0.042738	1.71	0.9958	-0.0379	1.51
RS_005_001	40	60	2.50	0.40	0.25	0.89024	0.9849	0.048843	1.95	0.9915	-0.0586	2.34
RS_006_001	40	60	2.50	0.40	0.30	0.89024	0.9879	0.041517	1.66	0.9824	-0.0745	2.98
RS_007_001	40	60	2.50	0.40	0.35	0.89024	0.9760	0.065938	2.64	0.9751	-0.0830	3.32
RS_008_001	40	60	2.50	0.40	0.40	0.89024	0.9788	0.10257	4.10	0.9810	-0.1233	4.93
RS_009_001	40	60	3.33	0.30	0.10	1.2151	0.9986	-0.01221	0.37	0.9956	-0.0452	1.36
RS_010_001	40	60	3.33	0.30	0.20	1.2151	0.9981	0.002443	0.07	0.9971	-0.0501	1.50
RS_011_001	40	60	3.33	0.30	0.30	1.2151	0.9914	0.057391	1.72	0.9943	-0.0330	0.99
RS_012_001	40	60	3.33	0.30	0.40	1.2151	0.9915	0.031748	0.95	0.9929	-0.0501	1.50
RS_013_001	40	60	3.33	0.30	0.50	1.2151	0.9836	0.042738	1.28	0.9916	-0.0501	1.50
RS_014_001	40	60	3.33	0.30	0.60	1.2151	0.9827	0.035412	1.06	0.9886	-0.0537	1.61

REGULAR WAVES - Data Set 2:

File Name	T1 (s)	T2 (s)	Wave Period (s)	Wave Frequency (Hz)	Wave Height (m)	Est. Wave Breaking Wave Height (m)	Transfer EW1 to MW1 Rxy (tau)	Transfer EW1 to MW1 tau (s)	Transfer EW1 to MW1 % Wave Period	Transfer WW1 to MW1 Rxy (tau)	Transfer WW1 to MW1 tau (s)	Transfer WW1 to MW1 % Wave Period
RS_015_001	40	60	4.00	0.25	0.05	1.3698	0.9907	-0.29428	7.36	0.9921	-0.3932	9.83
RS_016_001	40	60	4.00	0.25	0.10	1.3698	0.9962	-0.16729	4.18	0.9937	-0.2723	6.81
RS_017_001	40	60	4.00	0.25	0.15	1.3698	0.9969	-0.09891	2.47	0.9929	-0.2198	5.49
RS_018_001	40	60	4.00	0.25	0.20	1.3698	0.9965	-0.0696	1.74	0.9935	-0.1771	4.43
RS_019_001	40	60	4.00	0.25	0.25	1.3698	0.9954	-0.03541	0.89	0.9929	-0.1539	3.85
RS_020_001	40	60	4.00	0.25	0.30	1.3698	0.9944	-0.0232	0.58	0.9927	-0.1392	3.48
RS_021_001	40	60	4.00	0.25	0.35	1.3698	0.9936	-0.00733	0.18	0.9917	-0.1294	3.24
RS_022_001	40	60	4.00	0.25	0.40	1.3698	0.9917	0.002443	0.06	0.9897	-0.1209	3.02
RS_023_001	40	70	5.00	0.20	0.05	1.5046	0.9951	-0.06534	1.31	0.9878	0.4275	8.55
RS_024_001	40	70	5.00	0.20	0.10	1.5046	0.9937	0.053738	1.07	0.9845	0.2956	5.91
RS_025_001	40	70	5.00	0.20	0.15	1.5046	0.9935	0.05557	1.11	0.9833	0.2846	5.69
RS_026_001	40	70	5.00	0.20	0.20	1.5046	0.9891	0.11969	2.39	0.9780	0.1637	3.27
RS_027_001	40	70	5.00	0.20	0.25	1.5046	0.9878	0.13434	2.69	0.9744	0.1435	2.87
RS_028_001	60	100	6.67	0.15	0.05	1.6144	0.9745	0.71704	10.75	0.9865	-0.3261	4.89
RS_029_001	45	85	6.67	0.15	0.10	1.6144	0.9734	0.68014	10.20	0.9940	-0.1441	2.16
RS_030_002	60	100	6.67	0.15	0.15	1.6144	0.9790	0.49716	7.45	0.9933	-0.0696	1.04

NOTE:

Wave height, wave period and wave direction are nominal values.

Estimated breaking wave height computed for user input water depth and wave period.

Rxy (tau) - cross correlation function between two wave probe signa If two signals are identical, Rxy (tau) = 1.0.

tau - time lag (s) between t\ (-ve is lead)

Non-linear Wave is defined as 0.7*H/L < 0.1TANH(kd) (ie: wave is too close to breaking to provide satisfactory solution using WAVETRAN)

Where: H = wave height (m)

L = wave length (m) = $2*PI/g*T_W^2$

g = acceleration due to gravity (m/s^2) = 9.808 m/s^2

PI = 3.14159

T_W = wave period (s)

k = wave number (m^{-1}) = $(4*PI^2)/(g*T_W^2)$

d = water depth (m)

% Wave Period = (tau/nominal wave period) * 100

N/A = Not Avai T1, T2 - Start, End Segment Select Time

Linear Data in **BLACK**, Non-linear Data in **RED**

Validation of GEDAP Program 'WAVETRAN' - Regular Waves in the OEB:

REGULAR WAVES - Data Set 2:

File Name	T1 (s)	T2 (s)	Wave Period (s)	Wave Frequency (Hz)	Wave Height (m)	Est. Wave Breaking Wave Height (m)	EW1 Hav (m)	EW1 Tav (s)	WW1 Hav (m)	WW1 Tav (s)	MW1 Hav (m)	MW1 Tav (s)
							Variation of basic wave parameters:					
NOTE: OEB in Flume Mode (waves generated 0 deg. from west wall), blanking walls installed covering all north beaches.												
RD_001_001	40	60	2.00	0.50	0.10	0.61583	0.1095	1.998	0.0997	2.000	0.0968	2.001
RD_002_001	40	60	2.00	0.50	0.20	0.61583	0.2186	2.000	0.2018	1.999	0.1962	2.001
RD_003_001	40	60	2.00	0.50	0.30	0.61583	0.3173	2.000	0.2896	2.000	0.2943	2.001
RD_004_001	40	60	2.00	0.50	0.40	0.61583	0.4066	2.001	0.3926	1.999	0.3964	1.999
RD_005_001	40	60	2.00	0.50	0.50	0.61583	0.4907	2.002	0.4776	2.001	0.4738	1.999
RD_006_001	40	60	2.00	0.50	0.60	0.61583	0.5402	2.000	0.5388	1.998	0.5532	1.999
RD_007_002	40	60	2.00	0.50	0.70	0.61583	0.5766	2.002	0.6479	1.999	0.6328	1.997
RD_008_001	45	65	1.67	0.60	0.05	0.43475	0.0456	1.670	0.0506	1.671	0.0491	1.671
RD_009_001	45	65	1.67	0.60	0.10	0.43475	0.0982	1.669	0.0973	1.670	0.1031	1.671
RD_010_001	45	65	1.67	0.60	0.15	0.43475	0.1426	1.670	0.1401	1.671	0.1505	1.670
RD_011_001	45	65	1.67	0.60	0.20	0.43475	0.1908	1.669	0.1846	1.671	0.1982	1.670
RD_012_001	45	65	1.67	0.60	0.25	0.43475	0.2438	1.671	0.2333	1.670	0.2543	1.670
RD_013_001	45	65	1.67	0.60	0.30	0.43475	0.2812	1.668	0.2706	1.671	0.2947	1.669
RD_014_001	45	65	1.67	0.60	0.35	0.43475	0.3266	1.669	0.3000	1.670	0.3251	1.668
RD_015_001	45	65	1.67	0.60	0.40	0.43475	0.3626	1.671	0.3495	1.668	0.3679	1.668
RD_016_001	45	65	1.67	0.60	0.45	0.43475	0.4136	1.670	0.3907	1.670	0.4036	1.669
RD_017_001	45	65	1.67	0.60	0.50	0.43475	0.4311	1.672	0.4447	1.668	0.4709	1.669
RD_018_001	47	67	1.43	0.70	0.05	0.31914	0.0518	1.430	0.0519	1.429	0.0528	1.430
RD_019_001	47	67	1.43	0.70	0.10	0.31914	0.0977	1.430	0.0996	1.430	0.1016	1.430
RD_020_001	47	67	1.43	0.70	0.15	0.31914	0.1471	1.431	0.1433	1.431	0.1533	1.431
RD_021_001	47	67	1.43	0.70	0.20	0.31914	0.1858	1.429	0.1920	1.429	0.1938	1.429
RD_022_001	47	67	1.43	0.70	0.25	0.31914	0.2335	1.429	0.2359	1.428	0.2462	1.429
RD_023_001	47	67	1.43	0.70	0.30	0.31914	0.2791	1.429	0.2813	1.427	0.2749	1.426
RS_001_001	40	60	2.50	0.40	0.05	0.89024	0.1038	2.501	0.1010	2.498	0.1160	2.502
RS_002_001	40	60	2.50	0.40	0.10	0.89024	0.2103	2.497	0.1994	2.501	0.2260	2.503
RS_003_001	40	60	2.50	0.40	0.15	0.89024	0.3181	2.495	0.3027	2.502	0.3369	2.503
RS_004_001	40	60	2.50	0.40	0.20	0.89024	0.4367	2.497	0.4018	2.501	0.4465	2.503
RS_005_001	40	60	2.50	0.40	0.25	0.89024	0.5009	2.496	0.4640	2.504	0.5082	2.504
RS_006_001	40	60	2.50	0.40	0.30	0.89024	0.5587	2.500	0.5317	2.503	0.5904	2.505
RS_007_001	40	60	2.50	0.40	0.35	0.89024	0.6304	2.500	0.6064	2.501	0.6889	2.505
RS_008_001	40	60	2.50	0.40	0.40	0.89024	0.7355	2.501	0.6801	2.504	0.7577	2.508
RS_009_001	40	60	3.33	0.30	0.10	1.2151	0.1028	3.329	0.0901	3.304	0.1097	2.328
RS_010_001	40	60	3.33	0.30	0.20	1.2151	0.1721	3.327	0.1558	3.315	0.1863	3.332
RS_011_001	40	60	3.33	0.30	0.30	1.2151	0.3457	3.306	0.3292	3.293	0.3856	3.303
RS_012_001	40	60	3.33	0.30	0.40	1.2151	0.3597	3.336	0.3251	3.329	0.3697	3.333
RS_013_001	40	60	3.33	0.30	0.50	1.2151	0.5141	3.338	0.4503	3.332	0.5107	3.334
RS_014_001	40	60	3.33	0.30	0.60	1.2151	0.5664	3.336	0.5123	3.331	0.6224	3.331

REGULAR WAVES - Data Set 2:

File Name	T1 (s)	T2 (s)	Wave Period (s)	Wave Frequency (Hz)	Wave Height (m)	Est. Wave Breaking Wave Height (m)	Variation of basic wave parameters: EW1 Hav (m)	EW1 Tav (s)	WW1 Hav (m)	WW1 Tav (s)	MW1 Hav (m)	MW1 Tav (s)
RS_015_001	40	60	4.00	0.25	0.05	1.3698	0.0348	3.979	0.0733	3.983	0.0472	3.986
RS_016_001	40	60	4.00	0.25	0.10	1.3698	0.0636	3.994	0.1286	3.990	0.0977	3.992
RS_017_001	40	60	4.00	0.25	0.15	1.3698	0.0909	4.009	0.1733	3.987	0.1405	3.997
RS_018_001	40	60	4.00	0.25	0.20	1.3698	0.1222	4.008	0.2343	3.986	0.1948	4.001
RS_019_001	40	60	4.00	0.25	0.25	1.3698	0.1494	4.014	0.2844	3.988	0.2456	4.003
RS_020_001	40	60	4.00	0.25	0.30	1.3698	0.1812	4.008	0.3341	3.987	0.2978	4.006
RS_021_001	40	60	4.00	0.25	0.35	1.3698	0.2134	4.018	0.3722	3.996	0.3519	4.006
RS_022_001	40	60	4.00	0.25	0.40	1.3698	0.2510	4.016	0.4305	4.012	0.4060	4.007
RS_023_001	40	70	5.00	0.20	0.05	1.5046	0.0565	4.982	0.0543	5.021	0.0393	4.994
RS_024_001	40	70	5.00	0.20	0.10	1.5046	0.1332	4.990	0.1144	5.002	0.0974	4.991
RS_025_001	40	70	5.00	0.20	0.15	1.5046	0.1388	4.999	0.1152	5.012	0.1019	4.998
RS_026_001	40	70	5.00	0.20	0.20	1.5046	0.2791	4.997	0.2145	5.001	0.2154	4.997
RS_027_001	40	70	5.00	0.20	0.25	1.5046	0.3324	4.995	0.2496	5.003	0.2587	5.000
RS_028_001	60	100	6.67	0.15	0.05	1.6144	0.0312	5.782	0.0423	6.672	0.0289	6.632
RS_029_001	45	85	6.67	0.15	0.10	1.6144	0.0630	6.645	0.0850	6.694	0.0590	6.652
RS_030_002	60	100	6.67	0.15	0.15	1.6144	0.1327	6.661	0.1879	6.675	0.1356	6.672

NOTE:

Wave height, wave period and wave direction are nominal values.

Estimated breaking wave height computed for user input water depth and wave period.

N/A = Not Available — T1, T2 - Start, End Segment Select Time

Linear Data in **BLACK**, Non-linear Data in **RED**

Appendix D
Analysis Results: 'WAVETRAN' Irregular Waves

Validation of GEDAP Program 'WAVETRAN' - Irregular Waves in the OEB:

Data Set 1:

NOTE: OEB in Flume Mode (waves generated 0 deg. from west wall), blanking walls installed covering all north beaches.

Nominal Significant Wave Ht. = 0.283 m, Modal Period = 2.6 s.

			Transfer NW1 to NC1			Transfer SW1 to NC1			Variation of basic wave parameters:			
	T1	T2	Rxy (tau)	tau	% Wave	Rxy (tau)	tau	% Wave	SW1	SW1	SW1	SW1
Filename	(s)	(s)		(s)	Period		(s)	Period	Hav (m)	Tav (s)	Hmax (m)	Tmax (s)
TEST_022	60	100	0.9186	-0.12946	5.79	0.8926	-0.090376	4.04	0.1657	1.992	0.3972	3.654
TEST_025	60	100	0.9107	-0.11603	7.04	0.8843	-0.094045	5.70	0.1708	2.013	0.2989	3.226
TEST_028	60	100	0.8810	-0.12287	7.29	0.8735	-0.09844	5.84	0.1705	1.807	0.3519	3.001
TEST_031	60	100	0.9400	-0.11114	6.07	0.9232	-0.079389	4.34	0.1745	1.981	0.3787	3.463
TEST_034	60	100	0.8768	-0.17539	10.64	0.8604	-0.1705	10.35	0.1782	1.632	0.3952	2.356
TEST_037	60	100	0.9015	-0.11455	6.12	0.8831	-0.080354	4.29	0.1711	1.863	0.4070	3.193
TEST_040	60	100	0.8040	-0.1844	10.28	0.7543	-0.17951	10.01	0.1459	1.605	0.2938	3.358
TEST_043	60	100	0.8502	-0.14778	8.70	0.8696	-0.09893	5.82	0.1437	1.662	0.3598	2.813
TEST_046	60	100	0.9291	-0.11211	6.03	0.9309	-0.070585	3.80	0.1780	1.857	0.3189	2.951
TEST_086	50	90	0.8837	-0.054951	3.28	0.8765	-0.019537	1.16	0.1675	1.931	0.3539	3.497
TEST_089	50	90	0.9342	0.020762	1.04	0.9169	0.042743	2.14	0.1532	1.922	0.3003	3.238
TEST_092	55	95	0.9011	-0.035192	1.68	0.8876	-0.01319	0.63	0.2118	1.873	0.3625	2.909
TEST_095	55	95	0.9352	0.022714	1.18	0.9245	0.052024	2.69	0.1700	2.045	0.3787	3.328
TEST_098	55	95	0.9133	-0.044941	2.41	0.8949	-0.008306	0.45	0.1821	1.685	0.4048	2.773
TEST_101	55	95	0.9116	-0.005132	0.25	0.9020	0.016852	0.83	0.2030	2.037	0.3516	3.232
TEST_104	60	100	0.9293	-0.025399	1.40	0.9269	0.030778	1.69	0.1709	1.566	0.4481	2.923
TEST_107	55	95	0.9030	-0.039329	1.88	0.8957	0.004639	0.22	0.1820	1.766	0.3705	3.420
TEST_110	55	95	0.9115	0.011233	0.60	0.9153	0.060081	3.20	0.1585	1.694	0.3740	2.771
TEST_113	55	95	0.9563	0.039079	1.99	0.9477	0.087925	4.48	0.1525	1.753	0.4129	2.798

Data Set 1:

Variation of basic wave parameters:

Filename	NW1 Hav (m)	NW1 Tav (s)	NW1 Hmax (m)	NW1 Tmax (s)	NC1 Hav (m)	NC1 Tav (s)	NC1 Hmax (m)	NC1 Tmax (s)
NOTE: OEB in Flume Mode (waves generated 0 deg. from west wall), blanking walls installed covering all north beaches.								
Nominal Significant Wave Ht. = 0.283 m, Modal Period = 2.6 s.								
TEST_022	0.1671	2.102	0.3730	3.604	0.1661	2.235	0.3657	3.598
TEST_025	0.1639	2.028	0.3033	3.177	0.1357	1.649	0.2529	2.730
TEST_028	0.1696	1.807	0.3522	3.045	0.1566	1.686	0.3724	3.243
TEST_031	0.1518	1.733	0.3795	2.841	0.1668	1.831	0.4400	2.991
TEST_034	0.1732	1.636	0.3967	2.370	0.1808	1.648	0.4480	2.610
TEST_037	0.1737	1.963	0.4139	3.320	0.1768	1.873	0.4747	2.512
TEST_040	0.1374	1.606	0.2941	3.125	0.1362	1.794	0.2713	3.086
TEST_043	0.1324	1.591	0.3536	2.751	0.1291	1.699	0.3380	2.707
TEST_046	0.1658	1.847	0.2915	3.014	0.1666	1.858	0.3092	2.891
TEST_086	0.1568	1.928	0.3368	3.487	0.1367	1.677	0.2936	3.052
TEST_089	0.1470	1.923	0.2982	3.192	0.1441	1.994	0.2663	3.971
TEST_092	0.2203	2.083	0.3365	3.226	0.2190	2.095	0.3794	2.993
TEST_095	0.1559	1.943	0.3673	3.245	0.1528	1.931	0.4010	3.262
TEST_098	0.1751	1.687	0.3921	3.170	0.1804	1.866	0.4049	3.143
TEST_101	0.1937	2.042	0.3562	3.289	0.1944	2.022	0.3404	3.468
TEST_104	0.1763	1.708	0.4321	2.996	0.1844	1.819	0.4540	2.981
TEST_107	0.1862	1.859	0.3695	3.403	0.1800	2.097	0.3980	3.172
TEST_110	0.1606	1.779	0.3674	2.809	0.1624	1.880	0.3684	2.835
TEST_113	0.1442	1.675	0.4108	2.578	0.1572	1.964	0.3768	3.248

NOTE: % Wave Period has been defined as tau/Average Wave Period @ north center wave probe

Rxy (tau) - cross correlation function between two wave probe signals. If two signals are identical, Rxy (tau) = 1.0.

tau - time lag (s) between two wave probe signals.

Validation of GEDAP Program 'WAVETRAN' - Irregular Waves in the OEB:

Data Set 1:

			Transfer NW1 to NC1			Transfer SW1 to NC1			Variation of basic wave parameters:			
	T1	T2	Rxy (tau)	tau	% Wave	Rxy (tau)	tau	% Wave	SW1	SW1	SW1	SW1
Filename	(s)	(s)		(s)	Period		(s)	Period	Hav (m)	Tav (s)	Hmax (m)	Tmax (s)
NOTE: OEB oblique waves generated 60 deg. from west wall, blanking walls removed.												
Nominal Significant Wave Ht. = 0.283 m, Modal Period = 2.6 s.												
TEST_321	40	80	N/A	N/A	N/A	0.8760	-0.19219	10.25	0.1766	1.789	0.3695	2.596
TEST_323	45	75	N/A	N/A	N/A	0.8313	-0.14804	5.56	0.1509	2.081	0.3441	3.291
TEST_325	45	75	N/A	N/A	N/A	0.8783	-0.164	8.35	0.1812	1.891	0.3490	2.851
TEST_327	45	75	N/A	N/A	N/A	0.8178	-0.16193	8.26	0.2123	2.085	0.4658	3.273
TEST_329	45	75	N/A	N/A	N/A	0.8908	-0.16583	7.68	0.1738	2.167	0.2941	3.392
TEST_331	45	75	N/A	N/A	N/A	0.8680	-0.16377	9.05	0.1593	1.882	0.3068	3.330
TEST_333	45	75	N/A	N/A	N/A	0.8547	-0.21033	9.63	0.2040	2.040	0.4116	2.639
TEST_335	45	75	N/A	N/A	N/A	0.7619	-0.21271	10.86	0.1683	1.694	0.2616	2.928
TEST_337	45	75	N/A	N/A	N/A	0.9012	-0.17956	9.79	0.1251	1.757	0.2705	2.440
TEST_339	45	75	N/A	N/A	N/A	0.8886	-0.21033	10.00	0.1679	1.818	0.3506	2.754
TEST_341	45	75	N/A	N/A	N/A	0.7975	-0.20538	11.70	0.1490	1.627	0.3373	3.075

NW1	NW1	NW1	NW1	NC1	NC1	NC1	NC1
Hav (m)	Tav (s)	Hmax (m)	Tmax (s)	Hav (m)	Tav (s)	Hmax (m)	Tmax (s)
N/A	N/A	N/A	N/A	0.1732	1.875	0.3582	2.684
N/A	N/A	N/A	N/A	0.1671	2.661	0.2502	4.121
N/A	N/A	N/A	N/A	0.1795	1.963	0.4104	3.511
N/A	N/A	N/A	N/A	0.1938	1.960	0.4419	3.241
N/A	N/A	N/A	N/A	0.1734	2.158	0.3298	4.075
N/A	N/A	N/A	N/A	0.1590	1.810	0.3447	3.145
N/A	N/A	N/A	N/A	0.1999	2.185	0.4040	3.859
N/A	N/A	N/A	N/A	0.1751	1.958	0.3604	3.192
N/A	N/A	N/A	N/A	0.1321	1.835	0.2810	2.559
N/A	N/A	N/A	N/A	0.1737	2.104	0.3542	3.211
N/A	N/A	N/A	N/A	0.1491	1.756	0.3188	3.508

NOTE: % Wave Period has been defined as tau/Average Wave Period @ north center wave probe

Rxy (tau) - cross correlation function between two wave probe signals. If two signals are identical, Rxy (tau) = 1.0.

tau - time lag (s) between two wave probe signals.

Validation of GEDAP Program 'WAVETRAN' - Irregular Waves in the OEB:

IRREGULAR WAVES - Data Set 2:

Filename	T1 (s)	T2 (s)	Mean Freq. (Hz)	Mean Period (s)	Sig. Wave Height (m)	Transfer EW1 to MW1 Rxy (tau)	Transfer EW1 to MW1 tau (s)	Transfer EW1 to MW1 % Wave Period	Transfer WW1 to MW1 Rxy (tau)	Transfer WW1 to MW1 tau (s)	Transfer WW1 to MW1 % Wave Period
NOTE: OEB in Flume Mode (waves generated 0 deg. from west wall), blanking walls installed covering all north beaches.											
IR_001_001	60	100	0.40	2.50	0.10	0.9752	0.033579	1.74	0.9616	-0.025031	1.29
IR_002_001	60	100	0.40	2.50	0.20	0.9569	0.064106	3.20	0.9376	-0.044568	2.22
IR_003_001	60	100	0.40	2.50	0.30	0.9259	0.089748	4.00	0.9216	-0.057999	2.58
IR_004_001	60	100	0.40	2.50	0.40	0.9302	0.11661	4.88	0.9105	-0.071431	2.99
IR_005_001	60	100	0.40	2.50	0.50	0.9397	0.1044	4.39	0.9121	-0.08242	3.47
IR_006_001	60	100	0.40	2.50	0.60	0.9115	0.11661	4.89	0.9107	-0.1105	4.63
IR_007_001	60	100	0.50	2.00	0.05	0.9626	-0.018926	1.10	0.9785	0.042127	2.45
IR_008_001	60	100	0.50	2.00	0.10	0.9508	0.033579	2.12	0.9262	-0.034799	2.20
IR_009_001	60	100	0.50	2.00	0.15	0.9055	0.098295	5.70	0.8849	-0.073873	4.29
IR_010_001	60	100	0.50	2.00	0.20	0.9668	0.043348	2.05	0.9576	-0.038462	1.82
IR_011_001	60	100	0.50	2.00	0.25	0.9149	0.088526	4.70	0.8549	-0.079978	4.25
IR_012_001	60	100	0.50	2.00	0.30	0.9160	0.09219	4.38	0.8515	-0.087304	4.15
IR_013_001	60	100	0.50	2.00	0.35	0.9272	0.10806	5.13	0.8091	-0.10196	4.84
IR_014_001	60	100	0.50	2.00	0.40	0.9172	0.12394	6.22	0.813	-0.12149	6.09
IR_015_001	60	100	0.60	1.67	0.05	0.9434	-0.029915	2.49	0.9074	-0.017705	1.47
IR_016_001	60	100	0.60	1.67	0.10	0.9130	0.027474	2.22	0.8501	-0.057999	4.68
IR_017_001	60	100	0.60	1.67	0.15	0.7684	0.14469	10.98	0.7516	-0.13615	10.33
IR_018_001	60	100	0.60	1.67	0.20	0.7966	0.15446	10.98	0.6904	-0.16667	11.85
IR_019_001	60	100	0.60	1.67	0.25	0.8688	0.10562	6.98	0.7066	-0.18377	12.14
IR_020_001	60	100	0.60	1.67	0.30	0.8654	0.1276	7.80	0.7366	-0.15935	9.75
IR_021_001	60	100	0.70	1.43	0.05	0.9326	-0.050673	4.63	0.9503	0.078758	7.19
IR_022_001	60	100	0.70	1.43	0.10	0.7710	0.14958	14.94	0.7172	-0.1569	15.67
IR_023_001	60	100	0.70	1.43	0.15	0.7936	0.087305	6.96	0.7616	-0.10074	8.03
IR_024_001	60	100	0.70	1.43	0.20	0.8373	0.095853	7.72	0.7348	-0.097073	7.82

IRREGULAR WAVES - Data Set 2:

	Mean	Mean	Sig. Wave	Variation of basic wave parameters:								
	Freq.	Period	Height	EW1	WW1	WW1	WW1	WW1	MW1	MW1	MW1	MW1
Filename	(Hz)	(s)	(m)	Tmax (s)	Hav (m)	Tav (s)	Hmax (m)	Tmax (s)	Hav (m)	Tav (s)	Hmax (m)	Tmax (s)
NOTE: OEB in Flume Mode (waves generated 0 deg. from west wall), blanking walls installed covering all north beaches.												
IR_001_001	0.40	2.50	0.10	2.701	0.0675	1.715	0.1119	2.786	0.0730	1.933	0.1372	2.768
IR_002_001	0.40	2.50	0.20	2.829	0.1408	1.991	0.2405	2.883	0.1476	2.005	0.2444	2.777
IR_003_001	0.40	2.50	0.30	2.891	0.2002	1.995	0.3364	2.870	0.2329	2.246	0.3914	3.384
IR_004_001	0.40	2.50	0.40	3.288	0.2685	2.103	0.4294	2.663	0.3108	2.388	0.4947	3.279
IR_005_001	0.40	2.50	0.50	2.655	0.3211	2.101	0.5471	2.733	0.3390	2.377	0.6124	3.378
IR_006_001	0.40	2.50	0.60	3.080	0.3290	1.997	0.6056	2.693	0.3954	2.387	0.6800	3.228
IR_007_001	0.50	2.00	0.05	2.613	0.0302	1.713	0.0573	3.217	0.0307	1.716	0.0592	3.090
IR_008_001	0.50	2.00	0.10	2.860	0.0639	1.521	0.1183	2.633	0.0688	1.585	0.1292	2.994
IR_009_001	0.50	2.00	0.15	2.791	0.1024	1.712	0.1710	2.983	0.1098	1.723	0.1905	3.157
IR_010_001	0.50	2.00	0.20	2.898	0.1148	1.801	0.2035	3.133	0.1328	2.117	0.2171	3.059
IR_011_001	0.50	2.00	0.25	2.972	0.1599	1.805	0.2646	3.297	0.1614	1.883	0.2915	2.870
IR_012_001	0.50	2.00	0.30	2.851	0.1870	1.805	0.3393	3.191	0.2044	2.106	0.3600	2.988
IR_013_001	0.50	2.00	0.35	2.725	0.2118	1.800	0.3924	2.537	0.2280	2.106	0.3715	2.799
IR_014_001	0.50	2.00	0.40	2.773	0.2429	1.889	0.3860	2.960	0.2432	1.994	0.4364	2.888
IR_015_001	0.60	1.67	0.05	2.163	0.0292	1.132	0.0594	1.948	0.0272	1.203	0.0554	2.396
IR_016_001	0.60	1.67	0.10	2.224	0.0524	1.167	0.1146	2.043	0.0517	1.240	0.1052	2.058
IR_017_001	0.60	1.67	0.15	2.532	0.0790	1.211	0.1515	2.224	0.0847	1.318	0.1852	2.273
IR_018_001	0.60	1.67	0.20	2.140	0.1021	1.342	0.2097	2.256	0.1005	1.407	0.2422	2.419
IR_019_001	0.60	1.67	0.25	2.411	0.1225	1.447	0.2858	2.285	0.1202	1.514	0.2632	2.318
IR_020_001	0.60	1.67	0.30	2.346	0.1446	1.508	0.3169	2.340	0.1438	1.635	0.3094	2.606
IR_021_001	0.70	1.43	0.05	1.972	0.0308	1.034	0.0569	1.656	0.0271	1.095	0.0485	2.038
IR_022_001	0.70	1.43	0.10	1.794	0.0516	0.984	0.1129	1.773	0.0534	1.001	0.1181	1.783
IR_023_001	0.70	1.43	0.15	1.652	0.0700	1.071	0.1559	2.245	0.0777	1.255	0.1711	2.056
IR_024_001	0.70	1.43	0.20	1.973	0.0919	1.192	0.2067	1.984	0.0898	1.242	0.1994	1.883

NOTE: % Wave Period has been defined as tau/Average Wave Period @ north center wave probe

Rxy (tau) - cross correlation function between two wave probe signals. If two signals are identical, Rxy (tau) = 1.0.

tau - time lag (s) between two wave probe signals.