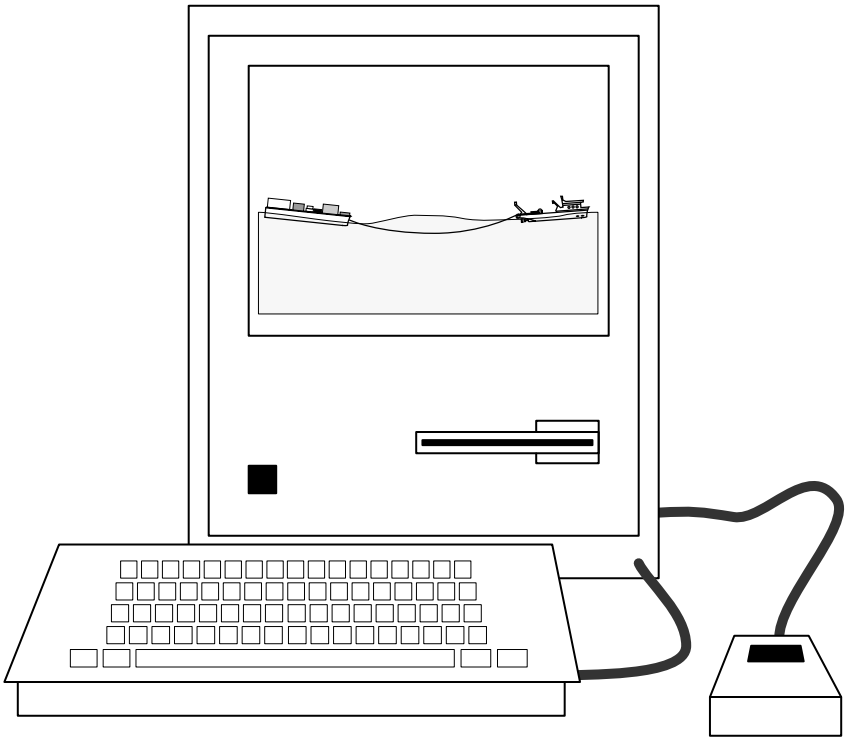
Introducing Towsim™

Tug, Barge, and Towline Analysis

from SeaSoft® Systems



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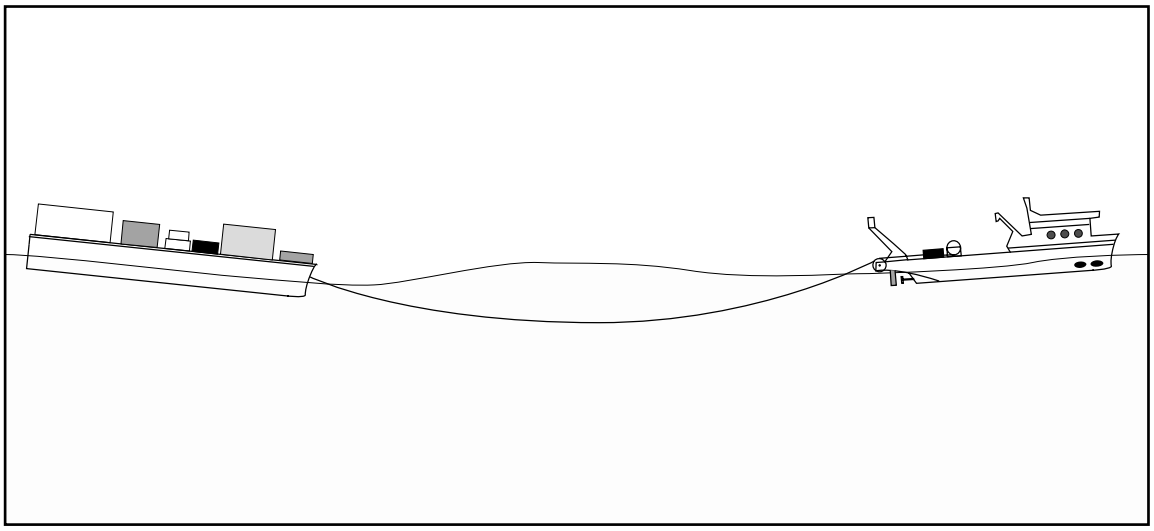
Description and Capabilities of Towsim



Executive Summary

Towsim is a comprehensive program used for design, evaluation, maintenance and failure analysis of simple or composite towlines used in open-ocean tug-barge-towline systems. It provides detailed towline and vessel performance data under arbitrary water depth and environmental conditions, including characteristic (r.m.s.) and peak towline loads in the forecast maximum storm for a particular route. The analysis can be used to optimize towline characteristics in trip planning for a specific route / environment and is suitable for on-board real-time use in an advisory capacity for setting optimal towline scope and / or optimal tug heading during storm penetration or survival preparations. Characteristics of the towline, including mass, hydrodynamic and elastic properties of each element of a multi-element towline, are fully specifiable. Tug-barge-towline systems are characterized by extreme nonlinearities at every phase of performance analysis; **Towsim** fully accommodates these nonlinearities at all levels, including system statics, quasi-statics (low-frequency oscillations, produced by variable wind and wave-drifting forces, with typical periods of oscillation of one to ten minutes) and dynamics (wave-induced oscillations with typical periods of 4 to 30 seconds). Direct comparison of **Towsim**'s nonlinear dynamic load calculation with the quasi-static catenary calculation often used as an approximation is provided as an output option. Execution is carried out in the frequency domain, resulting in short execution times and unambiguous predictions of statistical response.

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Introduction

Towsim models the highly nonlinear dynamics of a tug-barge-towline system with multi-element towline. Physical towline characteristics including mass, hydrodynamic and elastic properties of each element of a multi-element towline are fully specifiable. Long-period oscillations of the system are characterized and contributions to long-period motions from low-frequency components of variable wind and wave-drift force are computed. Towline load calculations, unlike quasi-static catenary calculations which are often erroneously applied in this situation, are fully dynamic and utilize a proprietary algorithm for the fast and efficient calculation of nonlinear low-frequency and wave-frequency dynamic load levels. It has been designed to provide a complete, wave-basin-type environment that functions in the following capacities:

• *Towline Design*

Towsim provides detailed towline performance data for particular tug-barge-towline combinations under specifiable water depth and environmental conditions. This permits, for example, reliable estimation of peak towline loads in the forecast "maximum storm" for a particular route. This analysis can then be used to optimize towline characteristics for a specific route and vessel configuration.

• *Route Planning*

Towsim is well-suited to route optimization analyses for routing around forecast significant weather systems. Such planning can reduce risk of towline failure in the event of worse-than-forecast conditions and can improve barge handling and tracking performance.

• *Towline Evaluation & Failure Analysis*

The flexibility of **Towsim** with regard to variations in vessel, towline and environmental characteristics makes it useful for the evaluation of existing towline configurations and detailed analysis of line failures.

• *Real-Time on-Board Advisory*

Microcomputer execution capability permits on-board installation of **Towsim** which can then be used to adjust towline payout and tugboat heading to achieve minimum line loads in given environmental conditions. This capability is particularly useful in extreme conditions when the probability of line failure is significant.

Overview

The program comprises three distinct phases of calculation: "static", "low-frequency" (typical periods of oscillation of one to four minutes) and "wave-frequency" (typical periods of oscillation of 4 to 30 seconds).

• *Statics*

Calculates static offset characteristics of the towline which may comprise up to ten uniform, nonlinear elastic sublines; each of these can be assigned arbitrary mass, elastic and hydrodynamic properties. The calculation incorporates a proprietary (analytically exact) treatment of the nonlinear catenary-elastic behavior of towline materials.

For determination of mean towline profile, any one of the following "boundary conditions" may be specified: mean line tension at tugboat, mean horizontal line tension component, mean tug-barge separation, mean line departure angle from horizontal at tugboat.

The user-interface program has extensive help capabilities to provide weight, elasticity and breaking strength estimates for a wide range of towline materials including wire rope, chain, Kevlar, polypropylene and nylon.

• *Low-Frequency Dynamics*

Low-frequency tug-barge relative oscillations can be excited by slowly-varying wind and current speeds and by the action of second-order wave-drift forces. The highly nonlinear force-separation characteristic of this dynamical system requires a fully nonlinear

model of the low-frequency dynamics; **Towsim** uses a carefully crafted energy-based model to account for these nonlinearities. Built-in analytical models for all low-frequency exciting forces are used to estimate the resulting oscillations in vessel separation and towline tension. Wave-drift forces are automatically computed; alternatively, wave-drift force coefficients can be supplied by the user for special applications.

Damping of low-frequency oscillations is determined using a fully nonlinear model for current, wind, wave and towline damping contributions. The characteristic period and amplitude of the low-frequency contribution to motions and line tension oscillations are output.

• *Wave-Frequency Dynamics*

Wave-excited dynamics are characterized by extensive regular and irregular wave calculations. These features provide complete flexibility for modelling of realistic under-way conditions as well as model-basin test conditions.

Regular wave analysis: Wave-frequency contributions to vessel motions are computed at the mean tug-barge separation as determined by the specified mean towline profile. This calculation is done by one or more of the SeaSoft vessel motion programs; for example **Shipsim** or **Jacksim**. Alternatively, vessel motion RAOs can be user-supplied. Vessel motion calculation is carried out in the frequency domain and wave-frequency vessel motions are assumed to be uninfluenced by towline tension oscillations. (Low-frequency vessel motions, by contrast, are determined ONLY by towline tension oscillations.) Calculation of maximum and minimum towline tension values at tug and barge due to regular wave excitation is fully nonlinear. Regular wave characteristics including amplitude, period and direction relative to tugboat heading are specifiable.

Irregular wave analysis: The results of regular wave response calculations for tug and barge are superposed to provide irregular wave towline endpoint motion statistics. These endpoint motions are then used in turn as input for a nonlinear irregular wave analytical model of towline tension oscillations. The outputs from these calculations are statistics of relative endpoint motions and towline tension oscillation at each end, including maximum / minimum expected tension values for a given storm duration. The irregular wave calculation can be done for a wide choice of irregular wave spectra and for either long-crested irregular waves such as those produced in a wave basin, or naturally occurring short-crested irregular waves. In addition an independent swell component of arbitrary height, period and direction can be specified simultaneously with the irregular sea.

For towline design purposes the analysis of system response to wave excitation, described above, is supplemented by a wave-frequency analysis of towline performance which is unencumbered by the complex phasing of the six degrees of vessel motion in a wave field. This analysis comprises, at each specified period of oscillation, a simulated constant amplitude tangential motion of one end of the towline. This motion thereby serves to excite towline tension oscillations; there is no motion of the opposite end. This supplementary capability is useful for standardized quantitative characterization of towline performance at wave frequencies.

• *Characteristic & Peak Tension Estimates*

Towsim provides a variety of options for characterization of towline loads in irregular wave conditions, including estimates of the mean tension level, the one or two standard deviation tension level, the most probable peak tension level in a storm of given duration, and upper and lower bounds to the peak tension level in a storm of given duration. The bounding calculations are useful because they are independent of assumptions relating to the statistical independence or correlations between low- and wave-frequency load contributions.

The following appendices document a typical trial run of **Towsim**. Appendix A contains samples of operator console displays presented during a session with the user-interface program used to create and modify the data file required for program execution. Appendix B contains overall system-related tabular output from **Towsim**. Appendix C contains sample tug-specific output. Appendix D contains sample barge-specific output.

APPENDIX A: Sample Input Stream

```
+=====================================================+
|                                                     |
|                                                     |
|                                                     |
|             **   Welcome to Tow-Sim   **            |
|                                                     |
|                                                     |
|                 Tow-Sim  Version 2.92                |
|                 Copyright (C) 1988 by                |
|                    SeaSoft Systems                   |
|                                                     |
|                                                     |
+=====================================================+
```

```
****  Page 1: Site conditions  ****


    Two-line Identification for this run

1) [Towsim Sample Problem                                          ]
2) [                                                               ]

3) Units of measure: Metric

4) Site water depth:          100.00 meters
5) Water density:            1025.18 kgw/cubic meter
```

```
****  Page 2: Tug Hydrostatic Characteristics  ****

 1) Vessel displacement ....................    2950.00 metric tons
 2) Transverse metacentric height (KMT).....       4.50 meters
 3) Longitudinal metacentric height (KML)...      42.20 meters
 4) Vertical center of buoyancy (VKB).......       2.70 meters
 5) Vertical center of gravity (VKG)........       2.70 meters
 6) Vessel water plane area ................     552.00 square meters
 7) Length of vessel at waterline ..........      50.75 meters
 8) Beam of vessel at waterline ............      10.88 meters
 9) Vessel draft ...........................       5.44 meters

10) Pitch damping is .......................   Computed
12) Roll damping is ........................   Computed
14) Heave damping is .......................   Computed

16) Pitch period is ........................   Computed
18) Roll period is .........................   Computed
20) Heave period is ........................   Computed
```

```
****  Page 3: Tug Gyradii and Bilge Specifications  ****

 1) Pitch Gyradius ..........................      14.20 meters
 2) Roll Gyradius ...........................       3.60 meters
 3) Yaw Gyradius ............................      15.00 meters
 4) Bilge radius at maximum beam station ...       1.50 meters

 5) Is there a bilge keel ..................    No
 9) Forward speed (knots) ..................        .00

10) Specify passive roll-supression system?     No
```

```
****  Page 4: Tug Low-Frequency Dynamics Characteristics  ****

 1) Wind force model .......................  Barge
 2) Current force model ....................  Barge

10) Include constant force/moment on vessel   No
```

```
****  Page 5: Tug Environmental Area, Moment and Enhancement Data  ****

 Include <<Wind?>>   Yes

 2) Head-on wind effective drag area ..............     118.00 square meters
 3) Head-on wind drag area centroid (from CG) ......       .00 meter
 4) Beam-on wind effective drag area ..............     550.00 square meters
 5) Beam-on wind drag area centroid (from CG) ......       .00 meter
 6) Wind force enhancement factor .................      1.00

10) Include <<Current>>?   Yes

11) Head-on current effective drag area ............      59.00 square meters
12) Head-on current drag area centroid (from CG) ...       .00 meter
13) Beam-on current effective drag area ............     225.00 square meters
14) Beam-on current drag area centroid (from CG) ...       .00 meter
15) Current force enhancement factor ..............      1.00

20) Head-on <<wave drift force>> enhancement factor       1.00


****  Page 6: Barge Hydrostatic Characteristics  ****

 1) Vessel displacement ...................    6034.00 metric tons
 2) Transverse metacentric height (KMT).....      32.20 meters
 3) Longitudinal metacentric height (KML)...      45.10 meters
 4) Vertical center of buoyancy (VKB).......       2.04 meters
 5) Vertical center of gravity (VKG)........      13.20 meters
 6) Vessel water plane area ................    1480.00 square meters
 7) Length of vessel at waterline ..........      43.40 meters
 8) Beam of vessel at waterline ............      34.20 meters
 9) Vessel draft ...........................       4.08 meters

10) Pitch damping is .......................   Computed
12) Roll damping is ........................   Computed
14) Heave damping is .......................   Computed

16) Pitch period is ........................   Computed
18) Roll period is .........................   Computed
20) Heave period is ........................   Computed
```

```
****  Page 7: Barge Gyradii and Bilge Specifications  ****

 1) Pitch Gyradius ..........................      25.50 meters
 2) Roll Gyradius ...........................      27.30 meters
 3) Yaw Gyradius ............................      18.40 meters
 4) Bilge radius at maximum beam station ...        .00 meters

 5) Is there a bilge keel ..................    No
 9) Forward speed (knots) ..................        .00

10) Specify passive roll-supression system?     No


****  Page 8: Barge Low-Frequency Dynamics Characteristics  ****

 1) Wind force model .......................  Barge
 2) Current force model ....................  Barge

10) Include constant force/moment on vessel   No


****  Page 9: Barge Environmental Area, Moment and Enhancement Data  ****

 1) Include <<Wind?>>   Yes

 2) Head-on wind effective drag area ..............    2600.00 square meters
 3) Head-on wind drag area centroid (from CG) ......       .00 meter
 4) Beam-on wind effective drag area ..............    2700.00 square meters
 5) Beam-on wind drag area centroid (from CG) ......       .00 meter
 6) Wind force enhancement factor ..................       .84

10) Include <<Current>>?   Yes

11) Head-on current effective drag area ............     139.00 square meters
12) Head-on current drag area centroid (from CG) ...       .00 meter
13) Beam-on current effective drag area ............     177.00 square meters
14) Beam-on current drag area centroid (from CG) ...       .00 meter
15) Current force enhancement factor ..............      1.00

20) Head-on <<wave drift force>> enhancement factor        .80
```

```
****  Page 10: Towline information ****

 1) Vessel type for barge ....................... Ship/barge-type
 2) Number of sublines (Max 10) ..................  2
 3) Maximum horizontal load ......................     500.00 metric tons
 4) Offset increment for static offset table .....      10.00 meters
 5) Number of points in interpolation table ...... 30
 6) Reset default added mass coefficient .........       1.00
 7) Reset default square-law drag coefficient ....       1.00
 8) Towline attachment height at Tug .............       6.80 meters
 9) Towline attachment height at Barge ...........       6.70 meters

10) Mean line profile determined by .............. Towline tension
11) Towline tension  ............................      70.00 metric tons

12) Low-frequency surge damping is ..............   Computed
14) Low-frequency sway damping is ................   Computed
16) Low-frequency yaw damping is .................   Computed


**** Page 10A: Subline Specifics ****

—> Subline attached to tug

 1) Tow line type A (of  1 type(s))
 2) Subline number:  1 of  2

 3) Subline composition ..........................      Wire
 4) Subline length ...............................     700.00 meters
 5) Subline outside diameter .....................      60.00 millimeters
 6) Wt/unit length in water ......................      12.81 kgw/meter
 7) Breaking strength ............................     232.67 metric tons
 8) Added mass coefficient .......................       1.00
 9) Transverse drag coefficient ..................       1.00
10) Compliance coefficient #1  (alpha1) ..........  0.559E-04 (m.ton)**-1
11) Compliance coefficient #2  (alpha2) ..........  0.000E+00 (m.ton)**-2
12) Compliance coefficient #3  (alpha3) ..........  0.000E+00 (m.ton)**-3

("?" for default physical data; "C", "D", "I" to Copy, Delete, Insert)
```

```
**** Page 10A: Subline Specifics ****

—> Subline attached to barge

 1) Tow line type A (of  1 type(s))
 2) Subline number:  2 of  2

 3) Subline composition ..........................      Nylon
 4) Subline length ...............................      30.00 meters
 5) Subline outside diameter .....................     141.00 millimeters
 6) Wt/unit length in water ......................       1.34 kgw/meter
 7) Breaking strength ............................     375.05 metric tons
 8) Added mass coefficient .......................       1.00
 9) Transverse drag coefficient ..................       1.00
10) Compliance coefficient #1  (alpha1) ..........  0.126E-02 (m.ton)**-1
11) Compliance coefficient #2  (alpha2) ..........  0.000E+00 (m.ton)**-2
12) Compliance coefficient #3  (alpha3) ..........  0.000E+00 (m.ton)**-3

("?" for default physical data; "C", "D", "I" to Copy, Delete, Insert)


****  Page 11: Low-frequency dynamics selection  ****

1) Calculate low-frequency dynamics:   Yes


****  Page 13: Wind Conditions  ****


 1) Wind speed ...............................      30.00 knots
 2) Wind heading ............................     210.00 degrees

 3) Wind spectral type .....................  Davenport
```

```
****  Page 14: Current Conditions  ****


 1) Current speed ..........................       1.00 knots
 2) Current heading ........................     180.00 degrees
 3) Current variation with depth ........... No variation

 4) Current spectral type .................. Steady current


****  Page 15: Line Extension / Regular wave characteristics  ****


1) Regular wave characteristics follow



****  Page 16: Regular Wave Characteristics  ****


1) Number of different periods (Max 30): 30
2) Periods (seconds) —
         3.00         3.50         4.00         4.50         5.00         5.50
         6.00         6.50         7.00         7.50         8.00         8.50
         9.00         9.50        10.00        10.50        11.50        11.50
        12.00        12.50        13.00        13.50        14.00        14.50
        15.00        15.50        16.00        16.50        17.00        17.50

3) Use constant wave height or wave slope:  height
4) Wave height ............................       4.00 meters

5) Wave direction .........................     180.00 degrees


****  Page 17: Irregular wave specifications  ****


 1) Include irregular waves?   Yes

 2) Wave type:  Bretschneider
 4) Wave direction:   180.00 degrees

                         — Wave parameters —

 6) Significant height:       5.50 meters
 7) Spectrum peak period:     6.00 seconds

 8) Use long-crested irregular wave model


****  Page 18: Background swell characteristics  ***


 1) Specify background swell?   Yes


 2) Swell height:                3.00 meters
 3) Swell period:               12.00 seconds
 4) Swell heading:             200.00 degrees


****  Page 19: Output options 1 ****


 1) Output static offset data ................................ Yes
 2) Compute quiescent equilibrium ............................ Yes
 3) Output mean orientation & line loads data ................ Yes
 4) Output low-frequency motions/loads data .................. Yes
 5) Include wave-frequency dynamics .......................... Yes

 6) Output wave-frequency fairlead motions and line load RAOs   Yes
 7) Output static/dynamic line load RAO comparisons at tug .... Yes
 8) Output wave-frequency line load RAOs at barge  ............ Yes
 9) Output one-page line dynamics summaries ................... Yes

12) Use <<Upper Bound>> algorithm for wave-frequency loads .... Yes
13) Storm duration (hours) for peak motion/load statistics.....  6.00
14) Treat barge as an anchor ................................. No
15) Swap tug, barge data



****  Page 20: Output options 2 ****


 1) Use <<two>> standard deviation (sigma) statistical output values
 3) Output RAOs for principal wave directions ..................   Yes
 7) Output vessel motions summary ..............................   Yes
 9) User-supplied vessel wave-frequency RAO data ...............   No
10) User-supplied wave drift force coefficients  ...............   No
11) Create plotter file .......................................   No

12) Debug option is off
```

APPENDIX B: Sample Output

SeaSoft Systems Software Library

Volume 10

Tugboat, Barge and Towline Analysis

TOW-SIM Version 2.92

Towsim Sample Problem

**
******************* I. Line Characteristics Summary ******************
**

>>> Line Type A of 1 Type(s)

Segment	Type	Length (m.)	Nominal Diameter (mm)	Submerged Weight (kgw/m.)	Elastic Coefficients Alpha 1 (m.ton**-1)	Alpha 2 (m.ton**-2)	Alpha 3 (m.ton**-3)
1	Wire	700.00	60.00	12.81	0.559E-04	0.000E+00	0.000E+00
2	Nylon	30.00	141.00	1.34	0.126E-02	0.000E+00	0.000E+00

Table Index	Tug Tension (m.ton)	Barge Tension (m.ton)	Horizontal Tension (m.ton)	Line angle — Tug (deg)	Barge —	Endpoint Separation (m.)	Bottom Length (m.)
1	4.68	4.33	.00	90.0	-90.0	.00	.00
2	6.84	6.63	5.00	43.0	-41.0	652.40	.00
3	22.72	22.67	22.24	11.8	-11.1	726.48	.00
4	39.75	39.73	39.48	6.7	-6.4	731.35	.00
5	56.91	56.90	56.72	4.6	-4.5	733.54	.00
6	74.11	74.10	73.97	3.5	-3.4	735.21	.00
7	91.32	91.32	91.21	2.8	-2.8	736.70	.00
8	108.54	108.54	108.45	2.4	-2.4	738.12	.00
9	125.77	125.77	125.69	2.0	-2.1	739.50	.00
10	143.00	143.00	142.93	1.8	-1.8	740.86	.00
11	160.23	160.24	160.17	1.6	-1.6	742.22	.00
12	177.47	177.47	177.41	1.4	-1.5	743.56	.00
13	194.70	194.71	194.66	1.3	-1.4	744.90	.00
14	211.94	211.95	211.90	1.2	-1.3	746.24	.00
15	229.18	229.19	229.14	1.1	-1.2	747.57	.00
16	246.42	246.42	246.38	1.0	-1.1	748.91	.00
17	263.66	263.66	263.62	.9	-1.0	750.24	.00
18	280.89	280.90	280.86	.9	-1.0	751.57	.00
19	298.13	298.14	298.10	.8	-.9	752.90	.00
20	315.37	315.38	315.34	.8	-.9	754.23	.00
21	332.61	332.62	332.59	.7	-.8	755.55	.00
22	349.85	349.86	349.83	.7	-.8	756.88	.00
23	367.09	367.10	367.07	.6	-.8	758.21	.00
24	384.33	384.34	384.31	.6	-.7	759.54	.00
25	401.57	401.58	401.55	.6	-.7	760.87	.00
26	418.81	418.82	418.79	.6	-.7	762.19	.00
27	436.05	436.06	436.03	.5	-.7	763.52	.00
28	453.29	453.30	453.28	.5	-.6	764.85	.00
29	470.53	470.54	470.52	.5	-.6	766.18	.00
30	487.77	487.78	487.76	.5	-.6	767.50	.00

```
 **                                                                  **
 ******************  II.  Equilibrium Condition Summary  ******************
 **                                                                  **


>>> Specified environmental conditions produced the following
    net moment and force components:

                                  Global system          Vessel system

         X Force                    -73.43 m.ton           -74.92 m.ton
         Y Force                    -15.09 m.ton             2.72 m.ton
         Vertical Moment              0.00 ton-meter         0.00 ton-meter


>>> Specified environmental conditions produced the
    following net global quasi-static displacements:

                                   Global system          Vessel system

         X Displacement              -719.89 m.             -734.46 m.
         Y Displacement              -148.00 m.               26.64 m.
         Yaw Displacement              13.69 deg              13.69  deg

         Vessel Orientation            13.69 deg


>>> Estimated mean line conditions in specified environment


                                                                 Fairlead
  Line    - Total Tension -  Horizontal  Endpoint   Bottom     Line Angle
 #/Type       (m.ton)         Tension   Separation  Length    Plan   Profile
           Tug     Barge     (m.ton)      (m.)      (m.)       (deg)


 1/a       75.10     75.09      74.96    735.29       .00    11.61    3.49
```

```
**********       III.  VESSEL AND ENVIRONMENT SUMMARY        **********


Water depth .......................     100.00 meters
Water density .....................    1025.18 kgw/cubic meter
Air density .......................    1.25440 kgw/cubic meter
Vessel displacement ...............    6034.00 metric tons
Transverse metacentric height .....      32.20 meters
Longitudinal metacentric height ....     45.10 meters
Vertical center of buoyancy ........      2.04 meters
Vertical center of gravity .........     13.20 meters
Vessel water plane area ............    1480.00 square meters
Length of vessel at waterline ......     43.40 meters
Beam of vessel at waterline ........     34.20 meters
Vessel draft .......................      4.08 meters
Wind force model ...................  Barge
Current force model ................  Barge
Surge damping is ...................  Computed
Sway  damping is ...................  Computed
Yaw   damping is ...................  Computed

——— WIND CONDITIONS ———

Wind spectral type .................  Davenport
Wind speed .........................     30.00 knots
Wind heading .......................    210.00 degrees
Head-on effective drag area ........   2600.00 square meters
Head-on drag area centroid .........       .00 meters
Beam-on effective drag area ........   2700.00 square meters
Beam-on drag area centroid .........       .00 meters
Wind force enhancement factor ......       .84

——— CURRENT CONDITIONS ———

Current spectral type ..............          Steady current
Current speed ......................      1.00 knots
Current heading ....................    180.00 degrees
Head-on effective drag area ........    139.00 square meters
Head-on drag area centroid .........       .00 meters
Beam-on effective drag area ........    177.00 square meters
Beam-on drag area centroid .........       .00 meters
Current force enhancement factor ...      1.00

——— WAVE CONDITIONS ———

Wave spectral type .................  Bretschneider
Computed significant wave height ...      5.29 meters
Direction of maximum seas ..........    180.00 degrees
Spectrum peak period ...............      6.00 seconds
Computed significant swell height ..      3.00 meters
Swell direction.....................    200.00 degrees
Swell period .......................     12.00 seconds
Head-on wave drift force factor ....       .80
```

********** IV. STATIC EQUILIBRIUM SUMMARY **********

>>> Most stable equilibrium <<<

— (GLOBAL COORDINATE SYSTEM) —

Vessel heading	13.69	degrees
Vessel Northwards displacement	-719.89	meters
Vessel Westwards displacement	-148.00	meters

Environmental forces: Most stable equilibrium

— (VESSEL COORDINATE SYSTEM) —

Static (x,y) forces due to wind:	(-39.9,	-11.7)	metric tons
Static (x,y) forces due to wave reflection:	(-24.2,	16.7)	metric tons
Static (x,y) forces due to swell reflection:	(-8.4,	-2.8)	metric tons
Static (x,y) forces due to current:	(-2.4,	.6)	metric tons

********** V. LOW-FREQUENCY DYNAMICS SUMMARY **********

Long-period single-amplitude surge motions:

Period	28.68	sec
Still water damping	.55	percent
Damping due to wind	.99	percent
Damping due to current	2.90	percent
Damping due to wave reflection	10.12	percent
Damping due to swell reflection	.58	percent
Total damping from linear sources	15.13	percent
Linearized square-law line damping	.84	percent
Total linearized square-law damping	.84	percent
Net equivalent linear damping	15.97	percent
Two sigma motion due to wind	1.11	meters
Two sigma motion due to wave reflection	3.28	meters
Two sigma motion due to swell reflection	2.07	meters
Total Two sigma motion	4.32	meters
Extreme motion in 6.0 hr. storm	6.65	meters

Long-period single-amplitude “sway” motions (low sway-yaw mode):

Period	130.76	sec
Still water damping	1.38	percent
Damping due to wind	1.23	percent
Damping due to current	1.38	percent
Damping due to wave reflection	19.50	percent
Damping due to swell reflection	.99	percent
Total damping from linear sources	24.48	percent
Linearized square-law line damping	.01	percent
Total linearized square-law damping	3800.01	percent
Net equivalent linear damping	3824.48	percent
Two sigma motion due to wind	3.44	meters
Two sigma motion due to wave reflection	15.25	meters
Two sigma motion due to swell reflection	7.11	meters
Total Two sigma motion	17.17	meters
Extreme motion in 6.0 hr. storm	27.44	meters

Long-period single-amplitude “yaw” motions (high sway-yaw mode):

Period	20.81	sec
Still water damping	.73	percent
Damping due to wind	.30	percent
Damping due to current	.39	percent
Damping due to wave reflection	5.52	percent
Damping due to swell reflection	.58	percent
Total damping from linear sources	7.51	percent
Linearized square-law line damping	0.00	percent
Total linearized square-law damping	.04	percent
Net equivalent linear damping	7.55	percent
Two sigma motion due to wind	.00	deg
Two sigma motion due to wave reflection	.78	deg
Two sigma motion due to swell reflection	.32	deg
Total Two sigma motion	.85	deg
Extreme motion in 6.0 hr. storm	1.58	deg

```
**                                                                    **
*********  VI.  Low-Frequency Maximum/Minumum Line Loads Summary   *********
**                                                                    **

+++ This data reflects <<maximum>>  “two sigma”  LOW-FREQUENCY loads +++

 Line    - Total Tension -  Horizontal  Endpoint    Bottom      Line
#/Type       (m.ton)         Tension    Separation   Length     Profile
          Tug      Barge     (m.ton)      (m.)       (m.)      Angle
                                                               (deg)

1/a      125.69    125.69     125.61     739.49        .00      2.04

+++ This data reflects <<minimum>>  “two sigma”  LOW-FREQUENCY loads +++

 Line    - Total Tension -  Horizontal  Endpoint    Bottom      Line
#/Type       (m.ton)         Tension    Separation   Length     Profile
          Tug      Barge     (m.ton)      (m.)       (m.)      Angle
                                                               (deg)

1/a       38.84     38.82      38.56     731.09        .00      6.93
```

```
**                                                                    **
*********  VI.  Low-Frequency Maximum/Minumum Line Loads Summary   *********
**                                                                    **

+++ This data reflects <<maximum>> storm extreme LOW-FREQUENCY loads +++

 Line    - Total Tension -  Horizontal  Endpoint    Bottom      Line
#/Type       (m.ton)         Tension    Separation   Length     Profile
          Tug      Barge     (m.ton)      (m.)       (m.)      Angle
                                                               (deg)

1/a      154.32    154.32     154.25     741.75        .00      1.65

+++ This data reflects <<minimum>> storm extreme LOW-FREQUENCY loads +++

 Line    - Total Tension -  Horizontal  Endpoint    Bottom      Line
#/Type       (m.ton)         Tension    Separation   Length     Profile
          Tug      Barge     (m.ton)      (m.)       (m.)      Angle
                                                               (deg)

1/a       30.95     30.93      30.57     728.83        .00      9.30
```

```
**                                                              **
**************      VII.  Line Endpoint Motion/Load Data      *************
**                                                              **
```

Wave heading .... 166.3 deg
Wave height ....   4.0 m.
Water depth .... 100.0 m.
Endpoint separation   735.3 m.
Forward Speed ......   .0 meters/sec

>>> NOTES:

1) Line data measured at Tugboat
2) Motions/loads arise from regular wave excitation
3) RAOs are 'single amplitude/single amplitude'
4) Positive phase angles are phase leads
5) Phase angles relative to wave crest at centroid of Tugboat

Encounter Wave Period (sec)	Wave Length (m.)	Wave slope (deg)	++++ Quasi-Linear ++++ Motion RAOs (m./m.) Endpoint Normal Comp. amp/phase	Endpoint Tangent Comp. amp/phase	++++ Nonlinear ++++ Load Data (m.ton) Peak amp/phase	Min amp/phase
3.00	14.0	51.3	0.00/ -60	.03/ -89	75.72/ -85	74.48/ 95
3.50	19.1	37.7	.01/ 130	.05/ 90	76.59/ 46	73.61/ 226
4.00	25.0	28.9	.07/ -63	.01/ -57	77.47/ -68	72.73/ 112
4.50	31.6	22.8	.09/ -22	.13/ -88	76.43/ 15	73.77/ 195
5.00	39.0	18.5	.23/ 120	.11/-119	79.32/-103	70.88/ 77
5.50	47.2	15.3	1.09/ 160	.24/ 172	81.93/-177	68.27/ 3
6.00	56.1	12.8	2.45/-157	.49/-169	85.66/ 164	64.54/ 344
6.50	65.9	10.9	2.94/-117	.41/-134	80.01/ 166	70.19/ 346
7.00	76.4	9.4	2.65/ -93	.19/ -99	90.68/ -80	59.52/ 100
7.50	87.7	8.2	2.30/ -79	.10/ -5	91.02/ 24	59.18/ 204
8.00	99.8	7.2	2.03/ -70	.22/ 40	96.14/ 46	54.06/ 226
8.50	112.7	6.4	1.82/ -64	.33/ 53	98.09/ 18	52.11/ 198
9.00	126.3	5.7	1.67/ -58	.42/ 59	84.22/ -62	65.97/ 118
9.50	140.7	5.1	1.55/ -54	.49/ 64	99.40/ 101	50.80/ 281
10.00	155.9	4.6	1.46/ -50	.55/ 67	90.53/ 9	59.67/ 189
10.50	171.7	4.2	1.38/ -47	.60/ 70	98.35/ 75	51.85/ 255
11.00	188.3	3.8	1.32/ -44	.64/ 72	124.13/-153	26.07/ 27
11.50	205.4	3.5	1.28/ -41	.67/ 74	121.69/ 35	28.51/ 215
12.00	223.0	3.2	1.24/ -38	.71/ 75	118.47/ 107	31.73/ 287
12.50	241.1	3.0	1.21/ -36	.73/ 76	92.84/ 178	57.36/ 358
13.00	259.5	2.8	1.18/ -34	.76/ 77	93.05/ -16	57.15/ 164
13.50	278.1	2.6	1.16/ -32	.78/ 78	113.68/ 38	36.52/ 218
14.00	297.0	2.4	1.14/ -31	.81/ 79	122.00/ 75	28.20/ 255
14.50	315.9	2.3	1.13/ -29	.83/ 80	118.82/ 106	31.38/ 286
15.00	334.9	2.2	1.12/ -28	.85/ 80	107.85/ 135	42.35/ 315
15.50	353.8	2.0	1.11/ -27	.87/ 81	93.02/ 166	57.18/ 346
16.00	372.8	1.9	1.10/ -26	.89/ 81	79.92/-112	70.28/ 68
16.50	391.6	1.8	1.09/ -25	.91/ 82	89.84/ -8	60.36/ 172

```
**                                                              **
**************    VIII. Dynamic/Static Line Load Comparison   *************
**                                                              **
```

Wave heading .... 166.3 deg
Wave height ....   4.0 m.
Water depth .... 100.0 m.
Endpoint separation   735.3 m.
Forward Speed ......   .0 meters/sec

>>> NOTES:

1) Line data measured at Tugboat
2) Motions/loads arise from regular wave excitation
3) RAOs are 'single amplitude/single amplitude'
4) Positive phase angles are phase leads
5) Phase angles relative to wave crest at centroid of Tugboat

Encounter Wave Period (sec)	Wave Length (m.)	Wave slope (deg)	++++ Quasi-Static ++++ Load Data (m.ton) Peak amp/phase	Min amp/phase	++++ Dynamic ++++ Load Data (m.ton) Peak amp/phase	Min amp/phase
3.00	14.0	51.3	75.92/ -86	74.28/ 94	75.72/ -85	74.48/ 95
3.50	19.1	37.7	76.74/ 53	73.46/ 233	76.59/ 46	73.61/ 226
4.00	25.0	28.9	77.43/ -68	72.77/ 112	77.47/ -68	72.73/ 112
4.50	31.6	22.8	76.36/ -3	73.84/ 177	76.43/ 15	73.77/ 195
5.00	39.0	18.5	79.49/-104	70.70/ 76	79.32/-103	70.88/ 77
5.50	47.2	15.3	82.31/-178	67.89/ 2	81.93/-177	68.27/ 3
6.00	56.1	12.8	86.29/ 166	63.91/ 346	85.66/ 164	64.54/ 344
6.50	65.9	10.9	80.29/ 172	69.91/ 352	80.01/ 166	70.19/ 346
7.00	76.4	9.4	90.73/ -80	59.47/ 100	90.68/ -80	59.52/ 100
7.50	87.7	8.2	90.96/ 23	59.24/ 203	91.02/ 24	59.18/ 204
8.00	99.8	7.2	96.16/ 46	54.04/ 226	96.14/ 46	54.06/ 226
8.50	112.7	6.4	98.14/ 19	52.06/ 199	98.09/ 18	52.11/ 198
9.00	126.3	5.7	83.98/ -60	66.22/ 120	84.22/ -62	65.97/ 118
9.50	140.7	5.1	99.53/ 101	50.67/ 281	99.40/ 101	50.80/ 281
10.00	155.9	4.6	90.63/ 11	59.57/ 191	90.53/ 9	59.67/ 189
10.50	171.7	4.2	98.58/ 75	51.62/ 255	98.35/ 75	51.85/ 255
11.00	188.3	3.8	123.65/-154	26.55/ 26	124.13/-153	26.07/ 27
11.50	205.4	3.5	121.74/ 35	28.46/ 215	121.69/ 35	28.51/ 215
12.00	223.0	3.2	118.56/ 107	31.64/ 287	118.47/ 107	31.73/ 287
12.50	241.1	3.0	92.72/ 177	57.48/ 357	92.84/ 178	57.36/ 358
13.00	259.5	2.8	92.97/ -15	57.23/ 165	93.05/ -16	57.15/ 164
13.50	278.1	2.6	113.77/ 38	36.43/ 218	113.68/ 38	36.52/ 218
14.00	297.0	2.4	122.12/ 75	28.08/ 255	122.00/ 75	28.20/ 255
14.50	315.9	2.3	118.93/ 106	31.27/ 286	118.82/ 106	31.38/ 286
15.00	334.9	2.2	107.91/ 135	42.29/ 315	107.85/ 135	42.35/ 315
15.50	353.8	2.0	93.00/ 165	57.20/ 345	93.02/ 166	57.18/ 346
16.00	372.8	1.9	79.68/-113	70.52/ 67	79.92/-112	70.28/ 68
16.50	391.6	1.8	89.81/ -7	60.39/ 173	89.84/ -8	60.36/ 172

```
**                                                              **
**************       VII.  Line Endpoint Motion/Load Data      *************
**                                                              **
```

```
                      Wave heading .......   166.3 deg
                      Wave height ........     4.0 m.
                      Water depth ........   100.0 m.
                      Endpoint separation    735.3 m.
                      Forward Speed ......      .0 meters/sec
```

>>> NOTES:

1) Line data measured at Barge
2) Motions/loads arise from regular wave excitation
3) RAOs are 'single amplitude/single amplitude'
4) Positive phase angles are phase leads
5) Phase angles relative to wave crest at centroid of Tugboat

Encounter Wave Period (sec)	Wave Length (m.)	Wave slope (deg)	++++ Quasi-Linear ++++ Motion RAOs (m./m.) Endpoint Normal Comp. amp/phase	Endpoint Tangent Comp. amp/phase	++++ Nonlinear ++++ Load Data (m.ton) Peak amp/phase	Min amp/phase
3.00	14.0	51.3	0.00/ 51	0.00/-140	75.97/ -86	74.21/ 94
3.50	19.1	37.7	.02/ 7	.04/ 174	76.77/ 55	73.41/ 235
4.00	25.0	28.9	0.00/ -30	.08/ 110	77.39/ -68	72.80/ 112
4.50	31.6	22.8	.06/ 93	.14/-109	76.35/ -10	73.84/ 170
5.00	39.0	18.5	.13/ -58	.07/ 98	79.53/-104	70.66/ 76
5.50	47.2	15.3	.22/ 76	.06/ 42	82.41/-178	67.77/ 2
6.00	56.1	12.8	.34/ -83	.20/-106	86.48/ 167	63.71/ 347
6.50	65.9	10.9	.49/ -88	.33/-104	80.39/ 174	69.80/ 354
7.00	76.4	9.4	.72/ 119	.44/ 107	90.69/ -80	59.50/ 100
7.50	87.7	8.2	1.05/-138	.53/-150	90.88/ 23	59.31/ 203
8.00	99.8	7.2	1.50/-115	.61/-131	96.11/ 46	54.07/ 226
8.50	112.7	6.4	1.96/-152	.66/-177	98.11/ 19	52.08/ 199
9.00	126.3	5.7	2.29/ 118	.67/ 86	83.87/ -59	66.32/ 121
9.50	140.7	5.1	2.57/ -15	.64/ -51	99.52/ 100	50.66/ 280
10.00	155.9	4.6	3.20/ 171	.55/ 134	90.64/ 11	59.54/ 191
10.50	171.7	4.2	5.66/ -28	.33/ -94	98.62/ 75	51.56/ 255
11.00	188.3	3.8	15.75/-164	2.39/ 37	123.39/-154	26.80/ 26
11.50	205.4	3.5	4.23/ -7	1.37/-162	121.69/ 35	28.49/ 215
12.00	223.0	3.2	2.50/ 92	1.16/ -54	118.54/ 107	31.64/ 287
12.50	241.1	3.0	1.92/ 177	1.09/ 38	92.64/ 176	57.54/ 356
13.00	259.5	2.8	1.63/-107	1.06/ 119	92.92/ -15	57.27/ 165
13.50	278.1	2.6	1.47/ -41	1.05/-170	113.76/ 38	36.42/ 218
14.00	297.0	2.4	1.37/ 16	1.04/-107	122.13/ 75	28.06/ 255
14.50	315.9	2.3	1.30/ 69	1.04/ -52	118.93/ 106	31.26/ 286
15.00	334.9	2.2	1.25/ 115	1.05/ -3	107.90/ 135	42.28/ 315
15.50	353.8	2.0	1.21/ 157	1.06/ 40	92.97/ 165	57.22/ 345
16.00	372.8	1.9	1.18/-165	1.07/ 79	79.59/-113	70.60/ 67
16.50	391.6	1.8	1.16/-131	1.08/ 114	89.78/ -6	60.40/ 174

```
**                                                              **
****  IX. Upper bound <<<Wave-Frequency>>> Motion/Load Statistical Data  ***
**                                                              **
```

—— Wave Characteristics ——

Wave Spectral Type — Bretschneider; Long-crested seas

```
      Requested Significant wave height ....      5.50 m.
      Calculated Significant wave height ...      5.29 m.
      Spectrum peak period .................      6.00 seconds
      Spectrum characteristic wind speed ...      8.30 meters/sec
      Direction of maximum seas ............    180.00 degrees

      +++ Background Swell Data +++

      Requested Significant swell height ...      3.00 m.
      Calculated Significant swell height ..      3.00 m.
      Swell direction ......................    200.00 degrees
      Swell period .........................     12.00 seconds
```

>>> NOTE: Wave-frequency motion/loads computed at EXTREME low-frequency offset point

+++ Upper Bound <<Wave-Frequency>> Motions/Loads Summary +++

<Endpoint MOTIONS:>	Two-Sigma variation (m.)	Two-Sigma rate (m./sec)	Two-Sigma Characteristic Period (sec)
Tug-end tangential	1.28	.90	8.95
Tug-end normal	4.70	4.31	6.86
Barge-end tangential	2.31	1.34	10.82
Barge-end normal	8.58	4.94	10.90
Relative tangential	2.57	1.53	10.57
Relative normal	9.91	6.74	9.23

<Endpoint LOADS:>	Mean value PLUS Two-sigma variation (m.ton)	Mean value MINUS Two-sigma variation (m.ton)
Tug-end loads	187.15	121.49
Barge-end loads	187.11	121.54

+++ Most Probable Extreme Upper Bound <<Wave-Frequency>> Motions/Loads +++

>>> Storm duration: 6.00 hrs. <<<

```
   <Endpoint motion variations:>              Most Probable
                                              Extreme value

      Tug-end tangential ...................      2.50 m.
      Tug-end normal .......................      9.18 m.
      Barge-end tangential .................      4.51 m.
      Barge-end normal .....................     16.75 m.
      Relative tangential ..................      5.02 m.
      Relative normal ......................     19.34 m.

   <Endpoint loads (mean plus extreme variation):>

      Tug-end extreme load .................    218.40 m.ton
      Barge-end extreme load ...............    218.32 m.ton
```

X. Upper Bounds on Net Characteristic Line Loads

Upper Bound Two-Sigma <<Maximum/Minimum>> Line Loads

(m.ton)

Line #/Type	Mean Tension		++++ MAXIMUM ++++ Tension		++++ MINIMUM ++++ Tension	
	Tug	Barge	Tug	Barge	Tug	Barge
1/a	75.10	75.09	135.40	135.38	14.80	14.81

Upper Bound Two-Sigma Line Load <<Variations>>

(m.ton)

Line #/Type	Mean Tension		Low-frequency Variation		Wave-frequency Variation	
	Tug	Barge	Tug	Barge	Tug	Barge
1/a	75.10	75.09	50.59	50.59	32.83	32.78

XI. Upper Bounds on Storm Extreme Line Loads

Upper Bound Storm-Extreme <<Maximum/Minimum>> Line Loads

(m.ton)

Line #/Type	Mean Tension		++++ MAXIMUM ++++ Tension		++++ MINIMUM ++++ Tension	
	Tug	Barge	Tug	Barge	Tug	Barge
1/a	75.10	75.09	218.40	218.32	.00	1.26

Upper Bound Storm-Extreme Line Load <<Variations>>

(m.ton)

Line #/Type	Mean Tension		Low-frequency Variation		Wave-frequency Variation	
	Tug	Barge	Tug	Barge	Tug	Barge
1/a	75.10	75.09	79.22	79.23	64.08	64.00

APPENDIX C: Sample Tug Output

SeaSoft Systems Software Library

Volume 1

Displacement-Hull Offshore Vessels

SHIPSIM Version 2.9

Towsim Sample Problem

```
**                                                              **
*****************  I.  PHYSICAL CHARACTERISTICS SUMMARY  *****************
**                                                              **


 ——  SITE CHARACTERISTICS  ——


          WATER DEPTH ..........................    100.00 METERS
          WATER DENSITY ........................   1025.18 KGW/CUBIC METER


 ——  VESSEL CHARACTERISTICS  ——


          DISPLACEMENT .........................   2950.00 M.TONS
          VERTICAL (Z) KB ......................      2.70 METERS
          VERTICAL (Z) KG ......................      2.70 METERS
          LONGITUDINAL GM ......................     39.50 METERS
          TRANSVERSE GM ........................      1.80 METERS
          PITCH GYRADIUS .......................     14.20 METERS
          ROLL GYRADIUS ........................      3.60 METERS
          YAW GYRADIUS .........................     15.00 METERS


 ——  DYNAMICALLY SIMILAR BOX CHARACTERISTICS  ——


          BOX LENGTH ...........................     50.12 METERS
          BOX WIDTH ............................     10.85 METERS
          BOX DRAFT ............................      5.29 METERS
```

```
**                                                              **
**************  II.  UNMOORED VESSEL MOTION CHARACTERISTICS  **************
**                                                              **
```

—— NATURAL PERIODS AT ZERO SPEED ——

NATURAL ROLL PERIOD	6.3 SECONDS
NATURAL PITCH PERIOD	5.9 SECONDS
NATURAL HEAVE PERIOD	6.2 SECONDS

—— QUASI-LINEAR ZERO SPEED DAMPING COEFFICIENTS ——

NATURAL ROLL DAMPING	5.8 PERCENT
NATURAL PITCH DAMPING	9.3 PERCENT
NATURAL HEAVE DAMPING	12.4 PERCENT

REGULAR WAVE HEIGHT	4.0 METERS
WATER DEPTH	100.0 METERS

**   **
************** II. UNMOORED VESSEL MOTION CHARACTERISTICS **************
**   **

—— REGULAR WAVE DATA: WAVE HEADING = 180.0 DEG
WAVE HEIGHT = 4.0 M.
FORWARD SPEED = .0 M./SEC

+++ QUASI-LINEAR RESPONSE RAOS (S.A./S.A.) +++

WAVE PERIOD (SEC)	WAVE LENGTH (M.)	WAVE SLOPE (DEG)	SURGE (M./ M.) AM/PHASE	SWAY (M./ M.) AM/PHASE	HEAVE (M./ M.) AM/PHASE
3.00	14.0	51.29	.03/ -90.1	0.00/ 90.0	0.00/ 44.8
3.50	19.1	37.68	.05/ 89.4	0.00/ -90.4	0.00/-131.0
4.00	25.0	28.85	0.00/ 87.7	0.00/ -91.4	0.00/-129.4
4.50	31.6	22.80	.12/ -95.5	0.00/ 86.6	.04/ 53.2
5.00	39.0	18.46	.13/ -99.2	0.00/ 84.3	.09/ 59.4
5.50	47.2	15.26	.04/-102.6	0.00/ 82.2	.05/ 72.4
6.00	56.1	12.82	.09/ 75.0	0.00/ -99.3	.16/ -83.6
6.50	65.9	10.93	.23/ 73.6	0.00/-100.2	.49/ -53.6
7.00	76.4	9.42	.36/ 73.1	0.00/-100.6	.70/ -31.9
7.50	87.7	8.21	.47/ 73.2	0.00/-100.5	.81/ -19.7
8.00	99.8	7.21	.56/ 73.9	0.00/-100.1	.86/ -12.9
8.50	112.7	6.39	.63/ 74.8	0.00/ -99.5	.90/ -8.8
9.00	126.3	5.70	.69/ 75.9	0.00/ -98.8	.92/ -6.2
9.50	140.7	5.12	.74/ 77.0	0.00/ -98.0	.94/ -4.5
10.00	155.9	4.62	.77/ 78.2	0.00/ -97.3	.95/ -3.4
10.50	171.7	4.19	.80/ 79.3	0.00/ -96.6	.96/ -2.6
11.00	188.3	3.82	.83/ 80.3	0.00/ -96.0	.97/ -2.0
11.50	205.4	3.51	.85/ 81.3	0.00/ -95.4	.97/ -1.5
12.00	223.0	3.23	.87/ 82.1	0.00/ -94.9	.98/ -1.2
12.50	241.1	2.99	.89/ 82.9	0.00/ -94.4	.98/ -1.0
13.00	259.5	2.77	.90/ 83.6	0.00/ -94.0	.98/ -.8
13.50	278.1	2.59	.92/ 84.2	0.00/ -93.6	.98/ -.6
14.00	297.0	2.42	.93/ 84.7	0.00/ -93.3	.99/ -.5
14.50	315.9	2.28	.95/ 85.1	0.00/ -93.0	.99/ -.4
15.00	334.9	2.15	.97/ 85.6	0.00/ -92.7	.99/ -.3
15.50	353.8	2.03	.98/ 85.9	0.00/ -92.5	.99/ -.3
16.00	372.8	1.93	1.00/ 86.2	0.00/ -92.3	.99/ -.2
16.50	391.6	1.84	1.02/ 86.5	0.00/ -92.1	.99/ -.2
17.00	410.4	1.75	1.03/ 86.8	0.00/ -92.0	.99/ -.2
17.50	429.2	1.68	1.05/ 87.0	0.00/ -91.8	.99/ -.1

```
**                                                                    **
**************  II.  UNMOORED VESSEL MOTION CHARACTERISTICS  **************
**                                                                    **
```

```
  ——  REGULAR WAVE DATA:  WAVE HEADING  = 180.0 DEG
                          WAVE HEIGHT   =   4.0 M.
                          FORWARD SPEED =    .0 M./SEC

                       +++  QUASI-LINEAR RESPONSE RAOS (S.A./S.A.)  +++
```

WAVE PERIOD (SEC)	WAVE LENGTH (M.)	WAVE SLOPE (DEG)	ROLL (DEG/DEG) AM/PHASE	PITCH (DEG/DEG) AM/PHASE	YAW (DEG/DEG) AM/PHASE
3.00	14.0	51.29	0.00/ -85.6	0.00/ -87.6	0.00/ 180.0
3.50	19.1	37.68	0.00/ 96.7	0.00/ 101.9	0.00/ -.4
4.00	25.0	28.85	0.00/ 100.0	.01/ -62.7	0.00/ 178.6
4.50	31.6	22.80	0.00/ -76.2	.02/ -52.2	0.00/ 176.6
5.00	39.0	18.46	0.00/ -71.6	.05/ 143.4	0.00/ -5.7
5.50	47.2	15.26	0.00/ -63.4	.33/ 163.3	0.00/ -7.8
6.00	56.1	12.82	0.00/ 139.8	.86/-161.8	0.00/ -9.3
6.50	65.9	10.93	0.00/-154.1	1.15/-127.1	0.00/ -10.2
7.00	76.4	9.42	0.00/-117.6	1.15/-108.7	0.00/ -10.6
7.50	87.7	8.21	0.00/-106.7	1.11/-100.0	0.00/ -10.5
8.00	99.8	7.21	0.00/-102.0	1.08/ -95.7	0.00/ -10.1
8.50	112.7	6.39	0.00/ -99.6	1.05/ -93.4	0.00/ -9.5
9.00	126.3	5.70	0.00/ -98.0	1.03/ -92.1	0.00/ -8.8
9.50	140.7	5.12	0.00/ -97.0	1.02/ -91.3	0.00/ -8.0
10.00	155.9	4.62	0.00/ -96.2	1.01/ -90.8	0.00/ -7.3
10.50	171.7	4.19	0.00/ -95.7	1.01/ -90.6	0.00/ -6.6
11.00	188.3	3.82	0.00/ -95.2	1.00/ -90.4	0.00/ -6.0
11.50	205.4	3.51	0.00/ -94.8	1.00/ -90.3	0.00/ -5.4
12.00	223.0	3.23	0.00/ -94.5	1.00/ -90.2	0.00/ -4.9
12.50	241.1	2.99	0.00/ -94.2	1.00/ -90.1	0.00/ -4.4
13.00	259.5	2.77	0.00/ -94.0	1.00/ -90.1	0.00/ -4.0
13.50	278.1	2.59	0.00/ -93.8	1.00/ -90.1	0.00/ -3.6
14.00	297.0	2.42	0.00/ -93.6	.99/ -90.1	0.00/ -3.3
14.50	315.9	2.28	0.00/ -93.4	.99/ -90.0	0.00/ -3.0
15.00	334.9	2.15	0.00/ -93.2	.99/ -90.0	0.00/ -2.7
15.50	353.8	2.03	0.00/ -93.1	.99/ -90.0	0.00/ -2.5
16.00	372.8	1.93	0.00/ -93.0	.99/ -90.0	0.00/ -2.3
16.50	391.6	1.84	0.00/ -92.9	.99/ -90.0	0.00/ -2.1
17.00	410.4	1.75	0.00/ -92.8	.99/ -90.0	0.00/ -2.0
17.50	429.2	1.68	0.00/ -92.7	.99/ -90.0	0.00/ -1.8


```
**                                                                    **
**************  II.  UNMOORED VESSEL MOTION CHARACTERISTICS  **************
**                                                                    **
```

```
  ——  REGULAR WAVE DATA:  WAVE HEADING  = 180.0 DEG
                          WAVE HEIGHT   =   4.0 M.
                          FORWARD SPEED =    .0 M./SEC
```


```
>>> NOTE: Point coordinates are given in vessel system;
    Vectorial motion components are in a rotated r.h. system
    with (x,z) in plane of line, z upwards along line tangent

       +++ DISPLACEMENT RAOS IN M. PER UNIT WAVE AMP. (S.A./S.A.)  +++

          ——     COORDINATES     ——
            (  -25.4,     .0,    6.8)
```

WAVE PERIOD (SEC)	X COMP AM/PHASE	Y COMP AM/PHASE	Z COMP AM/PHASE
3.00	0.00/ -60	.01/ -89	.03/ -89
3.50	.01/ 130	.01/ 89	.05/ 90
4.00	.07/ -63	0.00/ -55	.01/ -57
4.50	.09/ -22	.03/ -90	.13/ -88
5.00	.23/ 120	.02/-113	.11/-119
5.50	1.09/ 160	.04/ 176	.24/ 172
6.00	2.45/-157	.07/-174	.49/-169
6.50	2.94/-117	.05/-146	.41/-134
7.00	2.65/ -93	.01/-130	.19/ -99
7.50	2.30/ -79	.03/ 58	.10/ -5
8.00	2.03/ -70	.06/ 63	.22/ 40
8.50	1.82/ -64	.08/ 67	.33/ 53
9.00	1.67/ -58	.10/ 70	.42/ 59
9.50	1.55/ -54	.11/ 73	.49/ 64
10.00	1.46/ -50	.12/ 75	.55/ 67
10.50	1.38/ -47	.13/ 76	.60/ 70
11.00	1.32/ -44	.14/ 78	.64/ 72
11.50	1.28/ -41	.15/ 79	.67/ 74
12.00	1.24/ -38	.15/ 80	.71/ 75
12.50	1.21/ -36	.16/ 81	.73/ 76
13.00	1.18/ -34	.16/ 82	.76/ 77
13.50	1.16/ -32	.17/ 83	.78/ 78
14.00	1.14/ -31	.17/ 84	.81/ 79
14.50	1.13/ -29	.17/ 84	.83/ 80
15.00	1.12/ -28	.18/ 85	.85/ 80
15.50	1.11/ -27	.18/ 85	.87/ 81
16.00	1.10/ -26	.19/ 85	.89/ 81
16.50	1.09/ -25	.19/ 86	.91/ 82
17.00	1.08/ -24	.20/ 86	.93/ 82
17.50	1.08/ -23	.20/ 86	.95/ 83

```
**                                                              **
***************   III.  IRREGULAR WAVE STATISTICS SUMMARY   ***************
**                                                              **


  --  ENVIRONMENTAL CHARACTERISTICS  --


  WAVE SPECTRAL TYPE -- BRETSCHNEIDER
                      : LONG-CRESTED SEAS


           CALCULATED SIGNIFICANT WAVE HEIGHT .....   5.29 M.
           SPECTRUM PEAK PERIOD ...................   6.00 SECONDS
           CHARACTERISTIC WIND SPEED ..............   8.21 M./SECOND
           DIRECTION OF MAXIMUM SEAS ..............  180.00 DEGREES

       +++ BACKGROUND SWELL DATA +++

           CALCULATED SIGNIFICANT SWELL HEIGHT ....   3.00 M.
           SWELL DIRECTION ........................  200.00 DEGREES
           SWELL PERIOD ...........................   12.00 SECONDS


  --  VESSEL DYNAMICS SUMMARY  --


                  +++ SIGNIFICANT SINGLE AMPLITUDE FORCES/TORQUES +++

                       SIGNIFICANT     SIGNIFICANT   CHARACTERISTIC
                          VALUE           RATE        PERIOD (SEC)

SURGE (M.TONS)             251.48          258.78           6.11
SWAY  (M.TONS)              81.81           44.25          11.62
HEAVE (M.TONS)             586.95          325.50          11.33
ROLL  (M.TON-MTR)           60.32           32.49          11.67
PITCH (M.TON-MTR)         5552.18         4621.45           7.55
YAW   (M.TON-MTR)          489.19          274.28          11.21

                     +++ SIGNIFICANT SINGLE AMPLITUDE MOTIONS +++

                       SIGNIFICANT     SIGNIFICANT   CHARACTERISTIC
                          VALUE           RATE        PERIOD (SEC)

SURGE (M. )                1.35             .82          10.38
SWAY  (M. )                 .45             .23          12.07
HEAVE (M. )                1.73            1.12           9.76
ROLL  (DEG)                 .91             .50          11.49
PITCH (DEG)                9.50            9.11           6.55
YAW   (DEG)                 .63             .34          11.60
```


```
**                                                              **
***************   III.  IRREGULAR WAVE STATISTICS SUMMARY   ***************
**                                                              **


  --  ENVIRONMENTAL CHARACTERISTICS  --


  WAVE SPECTRAL TYPE -- BRETSCHNEIDER
                      : LONG-CRESTED SEAS


           CALCULATED SIGNIFICANT WAVE HEIGHT .....   5.29 M.
           SPECTRUM PEAK PERIOD ...................   6.00 SECONDS
           CHARACTERISTIC WIND SPEED ..............   8.21 M./SECOND
           DIRECTION OF MAXIMUM SEAS ..............  180.00 DEGREES

       +++ BACKGROUND SWELL DATA +++

           CALCULATED SIGNIFICANT SWELL HEIGHT ....   3.00 M.
           SWELL DIRECTION ........................  200.00 DEGREES
           SWELL PERIOD ...........................   12.00 SECONDS
```


```
  --  LOCAL MOTION SUMMARIES: SELECTED POINTS  --


>>> NOTE: Point coordinates are given in vessel system;
    Vectorial motion components are in a rotated r.h. system
    with (x,z) in plane of line, z upwards along line tangent

                              +++  SIGNIFICANT SINGLE AMP. DISPLACEMENTS +++

   POINT COORDINATES                X COMP          Y COMP          Z COMP
      ( X, Y, Z)

(  -25.4,     .0,    6.8)      4.69             .32             1.28
```

APPENDIX D: Sample Barge Output

SeaSoft Systems Software Library

Volume 1

Displacement-Hull Offshore Vessels

SHIPSIM Version 2.9

Towsim Sample Problem

```
**                                                              **
*****************  I.  PHYSICAL CHARACTERISTICS SUMMARY  *****************
**                                                              **


 ——  SITE CHARACTERISTICS  ——


          WATER DEPTH ..........................    100.00 METERS
          WATER DENSITY ........................   1025.18 KGW/CUBIC METER


 ——  VESSEL CHARACTERISTICS  ——


          DISPLACEMENT .........................   6034.00 M.TONS
          VERTICAL (Z) KB ......................      2.04 METERS
          VERTICAL (Z) KG ......................     13.20 METERS
          LONGITUDINAL GM ......................     31.90 METERS
          TRANSVERSE GM ........................     19.00 METERS
          PITCH GYRADIUS .......................     25.50 METERS
          ROLL GYRADIUS ........................     27.30 METERS
          YAW GYRADIUS .........................     18.40 METERS


 ——  DYNAMICALLY SIMILAR BOX CHARACTERISTICS  ——


          BOX LENGTH ...........................     43.70 METERS
          BOX WIDTH ............................     36.61 METERS
          BOX DRAFT ............................      3.68 METERS
```

```
**                                                              **
**************  II.  UNMOORED VESSEL MOTION CHARACTERISTICS  **************
**                                                              **
```

—— NATURAL PERIODS AT ZERO SPEED ——

```
          NATURAL ROLL PERIOD ....................  14.6 SECONDS
          NATURAL PITCH PERIOD ...................  10.9 SECONDS
          NATURAL HEAVE PERIOD ...................   8.4 SECONDS
```

—— QUASI-LINEAR ZERO SPEED DAMPING COEFFICIENTS ——

```
          NATURAL ROLL DAMPING ...................   5.0 PERCENT
          NATURAL PITCH DAMPING ..................   1.2 PERCENT
          NATURAL HEAVE DAMPING ..................  12.9 PERCENT


          REGULAR WAVE HEIGHT.....................   4.0 METERS
          WATER DEPTH ............................ 100.0 METERS
```


```
**                                                              **
**************  II.  UNMOORED VESSEL MOTION CHARACTERISTICS  **************
**                                                              **
```


—— REGULAR WAVE DATA: WAVE HEADING = 166.3 DEG
WAVE HEIGHT = 4.0 M.
FORWARD SPEED = .0 M./SEC

+++ QUASI-LINEAR RESPONSE RAOS (S.A./S.A.) +++

WAVE PERIOD (SEC)	WAVE LENGTH (M.)	WAVE SLOPE (DEG)	SURGE (M./ M.) AM/PHASE	SWAY (M./ M.) AM/PHASE	HEAVE (M./ M.) AM/PHASE
3.00	14.0	51.29	0.00/ -90.0	0.00/ 90.0	0.00/ 21.1
3.50	19.1	37.68	.04/ 89.9	.01/ -90.1	0.00/-147.0
4.00	25.0	28.85	.08/ -90.3	.02/ 89.7	.01/ 46.0
4.50	31.6	22.80	.13/ -90.6	.03/ 89.5	.02/ 56.7
5.00	39.0	18.46	.05/ -90.8	.01/ 89.2	.01/ 63.7
5.50	47.2	15.26	.08/ 89.0	.02/ -91.0	.02/-111.8
6.00	56.1	12.82	.22/ 88.8	.05/ -91.1	.09/-108.5
6.50	65.9	10.93	.35/ 88.8	.09/ -91.2	.20/-105.0
7.00	76.4	9.42	.46/ 88.8	.11/ -91.2	.37/ -99.9
7.50	87.7	8.21	.55/ 88.8	.13/ -91.1	.62/ -91.8
8.00	99.8	7.21	.62/ 88.9	.15/ -91.0	.93/ -79.0
8.50	112.7	6.39	.68/ 89.0	.17/ -91.0	1.24/ -61.8
9.00	126.3	5.70	.73/ 89.1	.18/ -90.9	1.42/ -43.9
9.50	140.7	5.12	.76/ 89.2	.19/ -90.8	1.43/ -29.7
10.00	155.9	4.62	.79/ 89.3	.19/ -90.7	1.38/ -20.0
10.50	171.7	4.19	.82/ 89.4	.20/ -90.6	1.31/ -13.8
11.00	188.3	3.82	.84/ 89.4	.20/ -90.6	1.25/ -9.7
11.50	205.4	3.51	.86/ 89.5	.21/ -90.5	1.21/ -7.0
12.00	223.0	3.23	.87/ 89.5	.21/ -90.4	1.17/ -5.2
12.50	241.1	2.99	.89/ 89.6	.22/ -90.4	1.14/ -3.9
13.00	259.5	2.77	.90/ 89.6	.22/ -90.4	1.11/ -3.0
13.50	278.1	2.59	.92/ 89.7	.22/ -90.3	1.10/ -2.3
14.00	297.0	2.42	.93/ 89.7	.23/ -90.3	1.08/ -1.8
14.50	315.9	2.28	.94/ 89.7	.23/ -90.3	1.07/ -1.4
15.00	334.9	2.15	.96/ 89.7	.23/ -90.2	1.06/ -1.1
15.50	353.8	2.03	.97/ 89.8	.24/ -90.2	1.05/ -.9
16.00	372.8	1.93	.99/ 89.8	.24/ -90.2	1.04/ -.8
16.50	391.6	1.84	1.00/ 89.8	.24/ -90.2	1.04/ -.6
17.00	410.4	1.75	1.02/ 89.8	.25/ -90.2	1.03/ -.5
17.50	429.2	1.68	1.04/ 89.8	.25/ -90.2	1.03/ -.4

```
**                                                                    **
**************  II.  UNMOORED VESSEL MOTION CHARACTERISTICS  **************
**                                                                    **
```

—— REGULAR WAVE DATA: WAVE HEADING = 166.3 DEG
WAVE HEIGHT = 4.0 M.
FORWARD SPEED = .0 M./SEC

+++ QUASI-LINEAR RESPONSE RAOS (S.A./S.A.) +++

WAVE PERIOD (SEC)	WAVE LENGTH (M.)	WAVE SLOPE (DEG)	ROLL (DEG/DEG) AM/PHASE	PITCH (DEG/DEG) AM/PHASE	YAW (DEG/DEG) AM/PHASE
3.00	14.0	51.29	0.00/ -80.8	0.00/ 92.2	0.00/ 0.0
3.50	19.1	37.68	0.00/ 140.5	0.00/ -84.5	.01/ 179.9
4.00	25.0	28.85	0.00/ -4.4	0.00/ 37.8	0.00/ -.3
4.50	31.6	22.80	0.00/ 9.2	.01/ 101.7	.01/ -.5
5.00	39.0	18.46	0.00/ 16.2	.04/ 111.9	.02/ -.8
5.50	47.2	15.26	0.00/-160.0	.07/ 116.6	.03/ -1.0
6.00	56.1	12.82	0.00/-159.0	.11/ 117.5	.03/ -1.1
6.50	65.9	10.93	0.00/-161.9	.16/ 116.2	.03/ -1.2
7.00	76.4	9.42	.01/-170.9	.23/ 113.6	.03/ -1.2
7.50	87.7	8.21	.01/ 171.8	.31/ 110.7	.03/ -1.1
8.00	99.8	7.21	.01/ 148.4	.44/ 107.9	.03/ -1.0
8.50	112.7	6.39	.01/ 128.7	.62/ 105.7	.03/ -1.0
9.00	126.3	5.70	.02/ 116.6	.92/ 104.2	.03/ -.9
9.50	140.7	5.12	.03/ 110.0	1.44/ 103.8	.03/ -.8
10.00	155.9	4.62	.05/ 106.5	2.54/ 105.2	.03/ -.7
10.50	171.7	4.19	.07/ 104.8	6.01/ 113.3	.03/ -.6
11.00	188.3	3.82	.10/ 104.4	20.18/-149.0	.03/ -.6
11.50	205.4	3.51	.14/ 105.0	5.90/ -99.5	.03/ -.5
12.00	223.0	3.23	.20/ 106.6	3.55/ -93.8	.03/ -.4
12.50	241.1	2.99	.28/ 109.6	2.68/ -91.9	.03/ -.4
13.00	259.5	2.77	.41/ 114.6	2.23/ -91.1	.03/ -.4
13.50	278.1	2.59	.61/ 123.4	1.95/ -90.7	.03/ -.3
14.00	297.0	2.42	.96/ 140.6	1.77/ -90.4	.03/ -.3
14.50	315.9	2.28	1.35/ 172.9	1.64/ -90.3	.03/ -.3
15.00	334.9	2.15	1.29/-150.6	1.54/ -90.2	.03/ -.2
15.50	353.8	2.03	1.00/-128.9	1.46/ -90.1	.03/ -.2
16.00	372.8	1.93	.80/-117.8	1.40/ -90.1	.03/ -.2
16.50	391.6	1.84	.67/-111.5	1.35/ -90.1	.03/ -.2
17.00	410.4	1.75	.58/-107.5	1.31/ -90.0	.03/ -.2
17.50	429.2	1.68	.52/-104.9	1.28/ -90.0	.04/ -.2

**   **
************** II. UNMOORED VESSEL MOTION CHARACTERISTICS **************
**   **

—— REGULAR WAVE DATA: WAVE HEADING = 166.3 DEG
WAVE HEIGHT = 4.0 M.
FORWARD SPEED = .0 M./SEC

>>> NOTE: Point coordinates are given in vessel system;
Vectorial motion components are in a rotated r.h. system
with (x,z) in plane of line, z upwards along line tangent

+++ DISPLACEMENT RAOS IN M. PER UNIT WAVE AMP. (S.A./S.A.) +++

WAVE PERIOD (SEC)	—— COORDINATES (21.7, .0, 6.7) X COMP AM/PHASE	Y COMP AM/PHASE	Z COMP AM/PHASE	—— COORDINATES (21.7, .0, 6.7) X COMP AM/PHASE	Y COMP AM/PHASE	Z COMP AM/PHASE
3.00	0.00/-128	.01/ -39	0.00/ 39	0.00/ 19	.02/ -59	.03/ -86
3.50	.02/-172	.04/ -81	.04/ -5	.02/ 32	.03/ -78	.06/ 53
4.00	0.00/ 149	.02/-105	.08/ -69	.07/ -61	.02/-101	.09/ -68
4.50	.06/ -86	.06/ 4	.14/ 70	.08/ 17	.07/ -18	.05/ -3
5.00	.13/ 121	.08/-166	.07/ -81	.10/ 118	.09/-154	.17/-104
5.50	.22/-103	.08/ -50	.06/-137	1.13/ 149	.06/ -77	.28/-178
6.00	.34/ 96	.08/ 132	.20/ 73	2.56/-150	.14/ 156	.44/ 166
6.50	.49/ 91	.10/ 117	.33/ 75	3.38/-113	.10/ 145	.20/ 172
7.00	.72/ -60	.11/ -41	.44/ -72	2.09/-104	.11/ -44	.61/ -80
7.50	1.05/ 41	.13/ 53	.53/ 29	2.99/ -97	.16/ 54	.62/ 23
8.00	1.50/ 64	.14/ 66	.61/ 48	3.26/ -89	.20/ 65	.83/ 46
8.50	1.96/ 27	.15/ 16	.66/ 2	2.70/-110	.21/ 33	.90/ 19
9.00	2.29/ -61	.16/ -83	.67/ -93	.63/ 112	.08/ -52	.35/ -60
9.50	2.57/ 164	.16/ 136	.64/ 128	3.90/ -29	.24/ 111	.96/ 101
10.00	3.20/ -8	.17/ -35	.55/ -45	2.33/-163	.17/ 5	.61/ 11
10.50	5.66/ 151	.19/ 127	.33/ 85	6.98/ -31	.29/ 107	.92/ 75
11.00	15.75/ 15	.15/ -59	2.39/-142	15.12/-160	.10/ 3	1.90/-154
11.50	4.23/ 172	.14/ 26	1.37/ 17	5.34/ -15	.25/ 54	1.83/ 35
12.00	2.50/ -87	.15/ 128	1.16/ 125	1.93/ 63	.27/ 104	1.70/ 107
12.50	1.92/ -2	.15/-141	1.09/-141	1.13/-146	.11/ 145	.69/ 177
13.00	1.63/ 72	.15/ -63	1.06/ -60	2.28/ -78	.09/ 19	.70/ -15
13.50	1.47/ 138	.14/ 0	1.05/ 9	2.63/ -37	.23/ 46	1.52/ 38
14.00	1.37/-163	.15/ 50	1.04/ 72	2.30/ -4	.30/ 68	1.84/ 75
14.50	1.30/-110	.20/ 97	1.04/ 127	1.59/ 24	.37/ 91	1.72/ 106
15.00	1.25/ -64	.25/ 157	1.05/ 176	.74/ 53	.35/ 128	1.29/ 135
15.50	1.21/ -22	.25/-149	1.06/-139	.14/-164	.21/ 164	.70/ 165
16.00	1.18/ 14	.25/-106	1.07/-100	.80/-101	.08/-138	.18/-113
16.50	1.16/ 48	.24/ -69	1.08/ -65	1.35/ -80	.11/ -19	.58/ -7
17.00	1.14/ 79	.24/ -36	1.09/ -33	1.75/ -63	.21/ 14	1.08/ 17
17.50	1.13/ 107	.24/ -6	1.10/ -4	2.00/ -48	.30/ 34	1.49/ 35

```
**                                                              **
***************   III.  IRREGULAR WAVE STATISTICS SUMMARY   ***************
**                                                              **


  --  ENVIRONMENTAL CHARACTERISTICS  --


  WAVE SPECTRAL TYPE -- BRETSCHNEIDER
                      : LONG-CRESTED SEAS


           CALCULATED SIGNIFICANT WAVE HEIGHT .....   5.29 M.
           SPECTRUM PEAK PERIOD ...................   6.00 SECONDS
           CHARACTERISTIC WIND SPEED ..............   8.21 M./SECOND
           DIRECTION OF MAXIMUM SEAS ..............  166.31 DEGREES

       +++ BACKGROUND SWELL DATA +++

           CALCULATED SIGNIFICANT SWELL HEIGHT ....   3.00 M.
           SWELL DIRECTION ........................  186.31 DEGREES
           SWELL PERIOD ...........................   12.00 SECONDS


  --  VESSEL DYNAMICS SUMMARY  --


                  +++ SIGNIFICANT SINGLE AMPLITUDE FORCES/TORQUES +++

                       SIGNIFICANT     SIGNIFICANT   CHARACTERISTIC
                          VALUE           RATE        PERIOD (SEC)

SURGE (M.TONS)             526.60          519.37           6.37
SWAY  (M.TONS)             118.11          126.67           5.86
HEAVE (M.TONS)            1293.83          731.75          11.11
ROLL  (M.TON-MTR)          377.93          369.62           6.42
PITCH (M.TON-MTR)        10587.43        10646.30           6.25
YAW   (M.TON-MTR)         2742.16         3728.11           4.62

                     +++ SIGNIFICANT SINGLE AMPLITUDE MOTIONS +++

                       SIGNIFICANT     SIGNIFICANT   CHARACTERISTIC
                          VALUE           RATE        PERIOD (SEC)

SURGE (M. )                  1.50             .94          10.04
SWAY  (M. )                   .22             .17           8.12
HEAVE (M. )                  1.90            1.10          10.85
ROLL  (DEG)                   .38             .18          13.28
PITCH (DEG)                 20.65           11.81          10.99
YAW   (DEG)                   .42             .49           5.32
```


```
**                                                              **
***************   III.  IRREGULAR WAVE STATISTICS SUMMARY   ***************
**                                                              **


  --  ENVIRONMENTAL CHARACTERISTICS  --


  WAVE SPECTRAL TYPE -- BRETSCHNEIDER
                      : LONG-CRESTED SEAS


           CALCULATED SIGNIFICANT WAVE HEIGHT .....   5.29 M.
           SPECTRUM PEAK PERIOD ...................   6.00 SECONDS
           CHARACTERISTIC WIND SPEED ..............   8.21 M./SECOND
           DIRECTION OF MAXIMUM SEAS ..............  166.31 DEGREES

       +++ BACKGROUND SWELL DATA +++

           CALCULATED SIGNIFICANT SWELL HEIGHT ....   3.00 M.
           SWELL DIRECTION ........................  186.31 DEGREES
           SWELL PERIOD ...........................   12.00 SECONDS
```


```
  --  LOCAL MOTION SUMMARIES: SELECTED POINTS  --


>>> NOTE: Point coordinates are given in vessel system;
    Vectorial motion components are in a rotated r.h. system
    with (x,z) in plane of line, z upwards along line tangent

                                  +++  SIGNIFICANT SINGLE AMP. DISPLACEMENTS +++

  POINT COORDINATES                    X COMP          Y COMP          Z COMP
     ( X, Y, Z)

(   21.7,     .0,    6.7)      8.55             .69            2.31
(   21.7,     .0,    6.7)      9.88             .75            2.57
```