Oil Spill Model Development
Northwest Canadian Pacific Coast
Technical Background

Submitted to

Living Oceans Society
Offshore Oil and Gas Campaign

Sointula, British Columbia
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Submitted by

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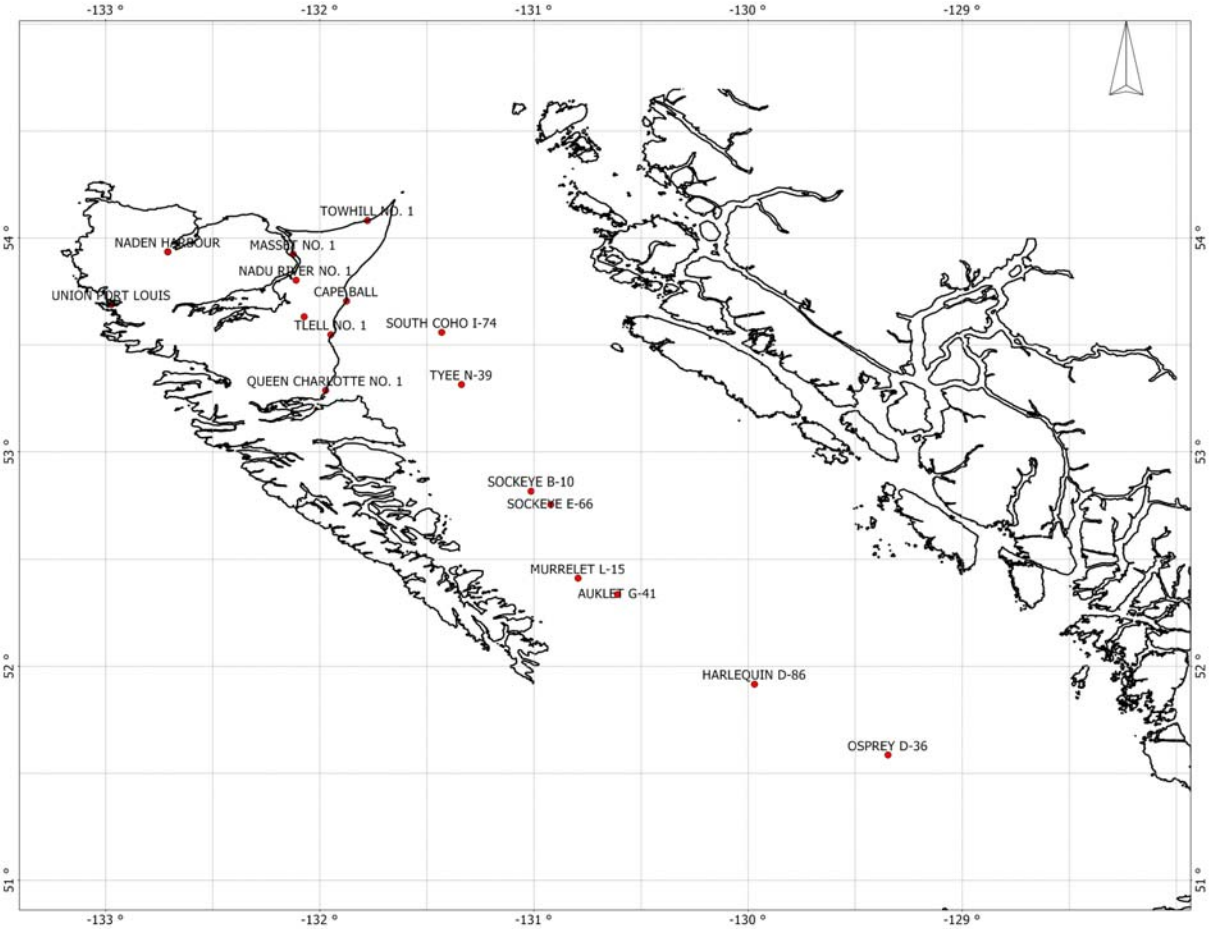
1.0 INTRODUCTION

In January 2007, the Living Oceans Society (Living Oceans), Sointula, B.C. requested Triton Consultants Ltd., an oceanographic and engineering consultancy based in Vancouver, to develop an oil spill model of the northwest Canadian Pacific coast. The aim of this model was to assess the potential impact of an oil spill on the BC coast. Living Ocean's Offshore Oil and Gas Campaign has a goal to clearly demonstrate the risks of offshore oil activity through application of internationally-accepted scientific methods. The fate of oil spilled during drilling operations or from damaged tankers was investigated by Living Oceans using this model with assistance from Triton and US NOAA's National Ocean Service of Response and Restoration. Modelling efforts were concentrated on potential oil drilling operations in the Queen Charlotte Basin (Figure 1) and shipping operations in Douglas Channel (Figure 2) as these pose the most immediate risks to the coast.

This technical report described the background engineering and scientific data and assumptions leading to the selection of the oil spill model and development of the model itself.

Figure 1: Exploratory Wells[1]



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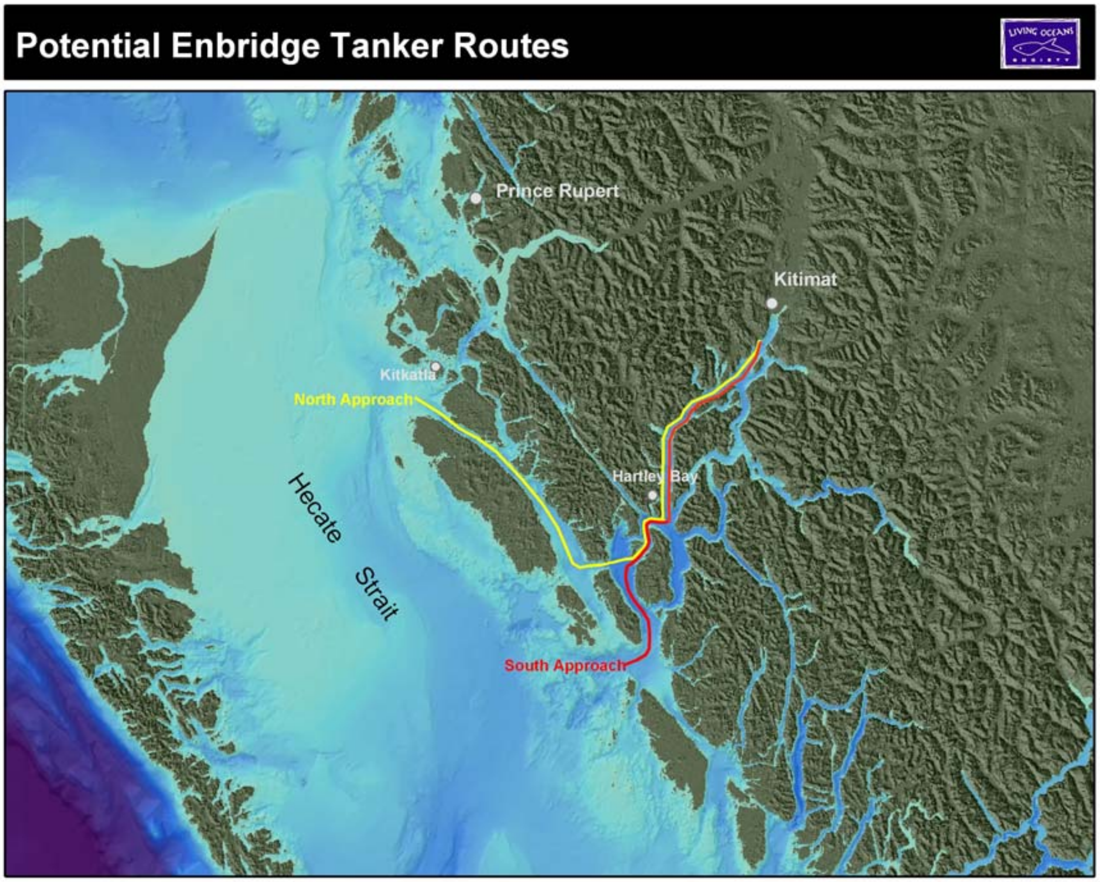
[1] Created from GIS data provided on Ministry of Energy, Mines and Petroleum Resources website http://www.offshoreoilandgas.gov.bc.ca/offshore-map-gallery/download.htm on 2007 March 27.

Figure 2: Potential Shipping Routes - Douglas Channel[2]



1.1 MODEL SELECTION

Several oil spill modelling software packages were evaluated during the preparation of Triton's proposal for undertaking this modelling work. The report *A Review of Models in Support of Oil and Gas Exploration off the North Coast of British Columbia* (M.G.G. Foreman, et al, 2006) was reviewed for guidance in selecting the appropriate modelling tool. That report was prepared with an aim to select the best available global technology for modelling such phenomena. The key conclusions of the study were considered and many of the software packages identified in the report investigated including ASA's OILMAP, Sintef's OSCAR and US NOAA's GNOME. Triton investigated these three packages in detail and determined that each has its own relative advantages and disadvantages, but all three were deemed suitable for the present application.

GNOME was selected for the use in the present study for the following reasons:

- The high cost of the commercial software (OILMAP and OSCAR) relative to the project budget

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[2] Prepared by Living Oceans Society from data provided by Enbridge during the permit application process.

- The fact that the expectations of the present study are high but less onerous than for a real-time oil spill response scenario
- The fact that NOAA's GNOME experts are based in Washington State meant that support was readily available in person within a few hours drive, in the same time zone, and the model had been tested extensively, by NOAA, in West Coast waters.
- Colleagues in other engineering and oceanographic consulting firms had come to the same conclusion independently on other oil industry projects.

1.2 DESCRIPTION OF GNOME

GNOME is a publicly available[3] oil spill trajectory model that simulates oil movement due to winds, currents, tides, spreading, evaporation and weathering. GNOME was developed by the Hazardous Materials Response Division (HAZMAT) of the National Oceanic and Atmospheric Administration Office of Response and Restoration (NOAA OR&R). HAZMAT uses this model during spill response to calculate a "best guess" of a spill's trajectory and the associated uncertainty in that trajectory.

To use GNOME, the user describes a spill scenario by entering information into the program; GNOME then creates and displays an oil spill "movie" showing the predicted trajectory of the oil spilled in the scenario. Typical GNOME users make use of NOAA-provided GNOME Location Files for their regions of interest; these files contain pre-packaged tide and current data, and make it easier to work with GNOME. However, for the present North Coast application, no Location Files presently exist in the GNOME database, requiring the use of GNOME in diagnostic mode[4] and the development of the hydrodynamic database and tools described in Section 2 of this report. NOAA describes GNOME as "an excellent tool for creating scenarios and building intuition regarding oil spill trajectories at a particular location" that can:

- Estimate the trajectory of spills by processing user-provided information on wind and weather conditions, circulation patterns, river flow, and the oil spill(s) to be simulated.
- Predict the trajectories that can result from the inexactness (uncertainty) in current and wind observations and forecasts.
- Use weathering algorithms to make simple predictions about the changes the oil will undergo while it is exposed to the environment.
- Quickly be updated, re-run, and saved with new information.
- Provide trajectory output (including uncertainty estimates) in a geo-referenced format that can be used as input to GIS (geographic information system) programs.

The GNOME user manual (NOAA, 2002) is available online and provides an excellent tutorial on use of the model.

2.0 METHODOLOGY

The general approach taken by Triton for this study was to develop the necessary tools and to provide the technical advice which would allow Living Oceans to undertake their own spill analyses. This approach was adopted for a number of reasons including:

- The requirement that the range of scenarios to be considered (i.e., spill location, type, size, date) could not be specified a priori, since they require constant revision following consideration of previous oil spill model results (i.e., the simulation parameters evolve as experience is gained from previous simulations)

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[3] Available from http://response.restoration.noaa.gov/

[4] Diagnostic Mode is designed primarily for expert modellers, such as contingency planners and the modellers who provide full tactical support for spill response teams.

- The cost efficiencies that this approach implies
- The simplification of communication between Living Oceans staff specifically responsible for the spill modelling, habitat experts and those responsible for dissemination of the information to the public.

This approach required completion of the following tasks prior to Living Ocean preparing simulations of the scenarios summarized in Appendix C

- Re-activation of archived files pertaining to an existing computational model grid of the northwest coast (Hecate Domain)
- Construction of a new computational model grid of Douglas Channel and adjacent channels (Douglas Domain) specifically for this project.
- Implementation of hydrodynamic models based on the Hecate and Douglas domains (both two-dimensional and three-dimensional)
- Development of the a Windows-based conversion utility GNOMEUtil for converting the results of the hydrodynamic model to a format compatible with GNOME
- Compilation of wind data summaries and wind time series for use in the GNOME scenario modelling
- Training of Living Oceans personnel on the use of the conversion utility and the GNOME modeling system
- Documentation of key assumptions in this report to Living Oceans.

Each of these tasks is described in detailing in the following report sections.

2.1 REACTIVATION OF EXISTING HECATE DOMAIN GRID

Figure 3 shows the triangular finite element model grid of the Hecate Domain. This grid was originally developed by the Institute of Ocean Sciences (IOS) and consists of 7575 nodes[5]. Water depths in the Hecate model domain are shown in Figure 4.

The spatial resolution of this model is suitable for oil spill modeling in Hecate Strait and the open coast, but is insufficiently detailed for modelling spills within the coastal fjord system (see Section 2.2 Construction of Douglas Channel Grid)

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[5] For comparison, note that a typical NOAA GNOME domain has many fewer than 1000 nodes.

Figure 3: Hecate Domain - Grid Network

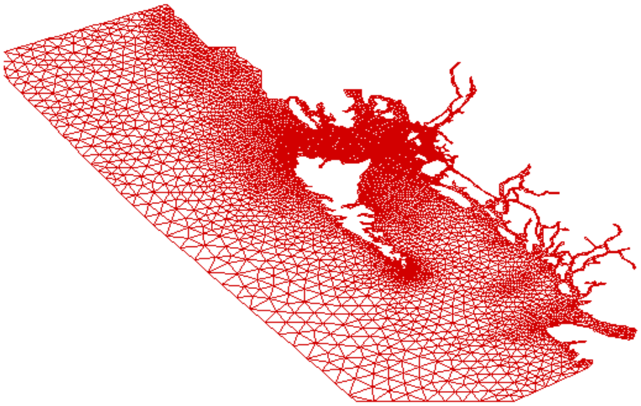

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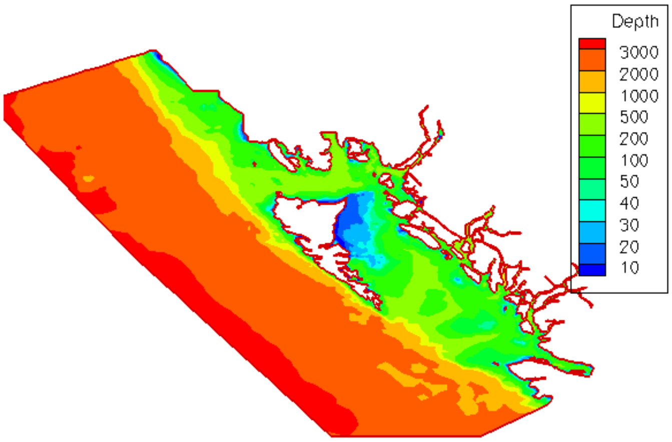
Figure 4: Hecate Domain - Water Depths (m)



2.2 CONSTRUCTION OF DOUGLAS CHANNEL GRID

As described in Section 2.1, the Hecate domain grid is too coarse to be used for modelling inter-coastal spills. It was therefore necessary to increase the number of computational triangles in regions of particular importance. However, Triton's experience had shown that a very significant effort was required to input the detailed information from each high resolution nautical chart and it was decided to concentrate on those areas of greatest interest to the Living Ocean Society; specifically areas centred on Douglas Channel encompassing marine developments at Kitimat and the proposed shipping route (see Figure 2).

Rather than dramatically increasing the number of computational nodes in the Hecate model by appending the high resolution Douglas region to it, it was decided to construct a second grid that could be used independently. The disadvantage of this approach was that the spills that propagate out of the Douglas domain into the Hecate domain would be more difficult to simulate; however, this was not seen as a major limitation relative to the major efficiency advantages of maintaining the modest size of the Hecate domain.

Significant challenges were encountered during compilation of the Douglas Channel grid, such as:

- Corrupt CHS fieldsheet files with regions of missing data that could not be identified until many days of manipulation were invested.
- Erroneous elevations of digital contours (e.g., some 20 fathom contours digitizes as 20 m)
- Apparent mixture of horizontal datums within a single dataset (NDI Environmental Dataset).

Eventually many of the relevant CHS nautical charts (CHS 3724, 3742, and 3743) had to be digitized by hand to provide a model grid that could be used with confidence. The above issues resulted in this portion of the work requiring two or three times the anticipated level of effort.

Figure 6 shows the computational grid network for the Douglas domain consisting of 158,328 nodes which is more than two orders of magnitude more detailed than a typical NOAA domain. Figure 5 shows the modelled variation of water depth across the domain.

Figure 5: Douglas Domain - Water Depth (m)

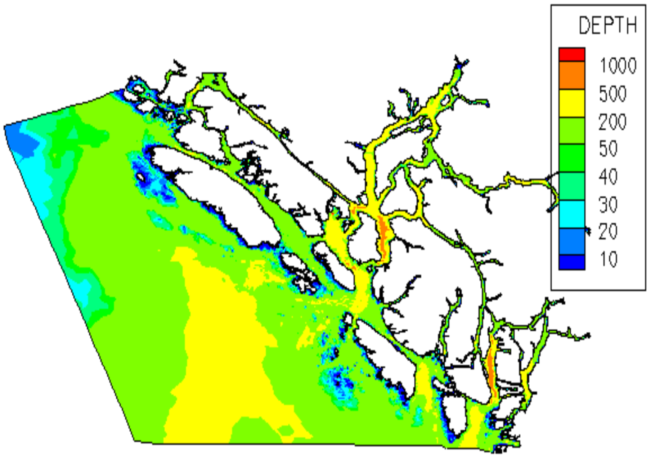
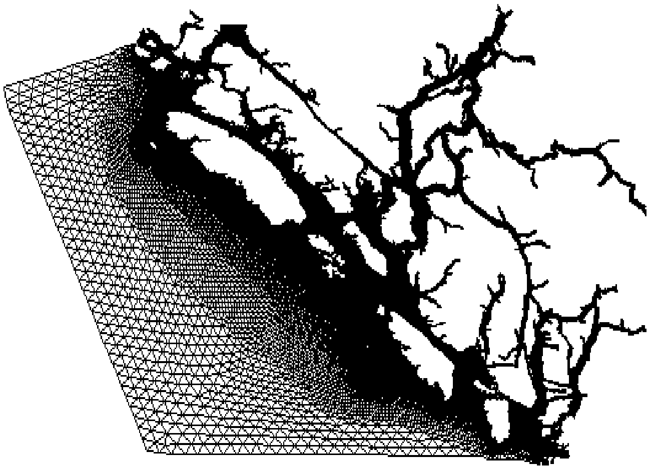


Figure 6: Douglas Domain - Grid Network



2.3 HYDRODYNAMIC MODEL SELECTION

The model grids described above were used in a series on numerical finite element hydrodynamic models to compute currents throughout the model domains. Triton made use of the finite element models developed by Dr. Roy Walters (formerly US Geological Survey and the New Zealand National Institute of Water and Atmospheric Research) including two harmonic models (Tide2D, Tide3D) and two time-stepping models (RiCOM2D and RiCOM3D). These models have been used by the Institute of Ocean Sciences (DFO Sidney, B.C.), are well-respected within the scientific community and have proven to produce accurate estimates of hydrodynamic conditions as long as they are applied correctly and in the appropriate circumstances.

The relative benefits of the various models considered are summarized in Table 1.

Table 1: Model Comparison

Criterion	Harmonic Model (Tide2D, Tide3D)	Time-stepping Model (RiCOM2D, RiCOM3D)
Physics - Advection	Simplified treatment of advection	included
Physics – Density Effects	Included	Not included (in available version)
Modelling Consultant Involvement	Required for generation of initial harmonic database; not required to generate scenarios	Required for every scenario considered.
Ease of File Transfer	Files generated locally from database – no need to transfer	File size can reach 1GB; cannot be transferred by email and very difficult to transfer between team members - even by FTP

Triton's recommendation, which was accepted by Living Oceans, was that the modelling be done with Tide3D. Tide3D is a three-dimensional frequency domain solution to the non-linear, shallow water equations for sea level and velocity using a finite element discretisation in space and a harmonic expansion in time (Walters, 1987). Because the governing equations are elliptic, there are no stability criteria such as associated with hyperbolic time-stepping methods.

The shallow water equations can be written as:

Continuity

$$\frac{\partial \eta}{\partial t} + \nabla \cdot (H + \eta)\overline{U} = 0$$

Momentum

$$\frac{\partial u}{\partial t} + (u \cdot \nabla)u + f \times u + g\nabla\eta - \frac{\partial}{\partial z}(N\frac{\partial u}{\partial z}) = -\frac{g}{\rho_0}\int_z^0 \nabla\rho dz$$

where

$$\boldsymbol{N}\frac{\partial \boldsymbol{u}}{\partial z} = \Psi \ (\boldsymbol{z} = 0)$$

$$\mathrm{N}\frac{\partial \mathrm{u}}{\partial z} = \tau |u| u \quad (z = -H)$$

The equations are approximated using standard Galerkin techniques. The spatial domain is discretised by defining a set of 2-dimensional triangular elements in the horizontal plane and sigma coordinates in the vertical. A standard Lagrangian basis of polynomial degree p is defined on the master element and this basis is used to interpolate variable quantities within each element.

The numerical solution applies harmonic decomposition of the governing shallow water equations and solves the equations in the frequency domain rather than using time-stepping procedures. This technique is exceptionally computationally efficient and is particularly suited to modeling tidal motions where the number of frequencies is small in number or for modeling steady state forcing mechanisms such as quasi-stationary wind/pressure systems or river flow.

Tide3D has two major limitations:

- Drying flats can not be modeled (no drying elements)
- Non-steady or non-harmonic forcing conditions cannot be modeled

Neither limitation is significant in the present application given the scale of the area modeled.

2.4 HYDRAULIC MODELLING

The harmonic tidal model was calibrated on the basis of available CHS tidal height data in the study region. Figure 7 and Figure 8 are plots of the variation of M2 (typical semi-diurnal) and K1 (typical diurnal) in the vicinity of Douglas Channel. The annotations indicate the CHS station name, the amplitude of the constituent in metres (black text), and the tidal phase relative to Greenwich (red text).

Figure 7: Measured CHS Variation of M2

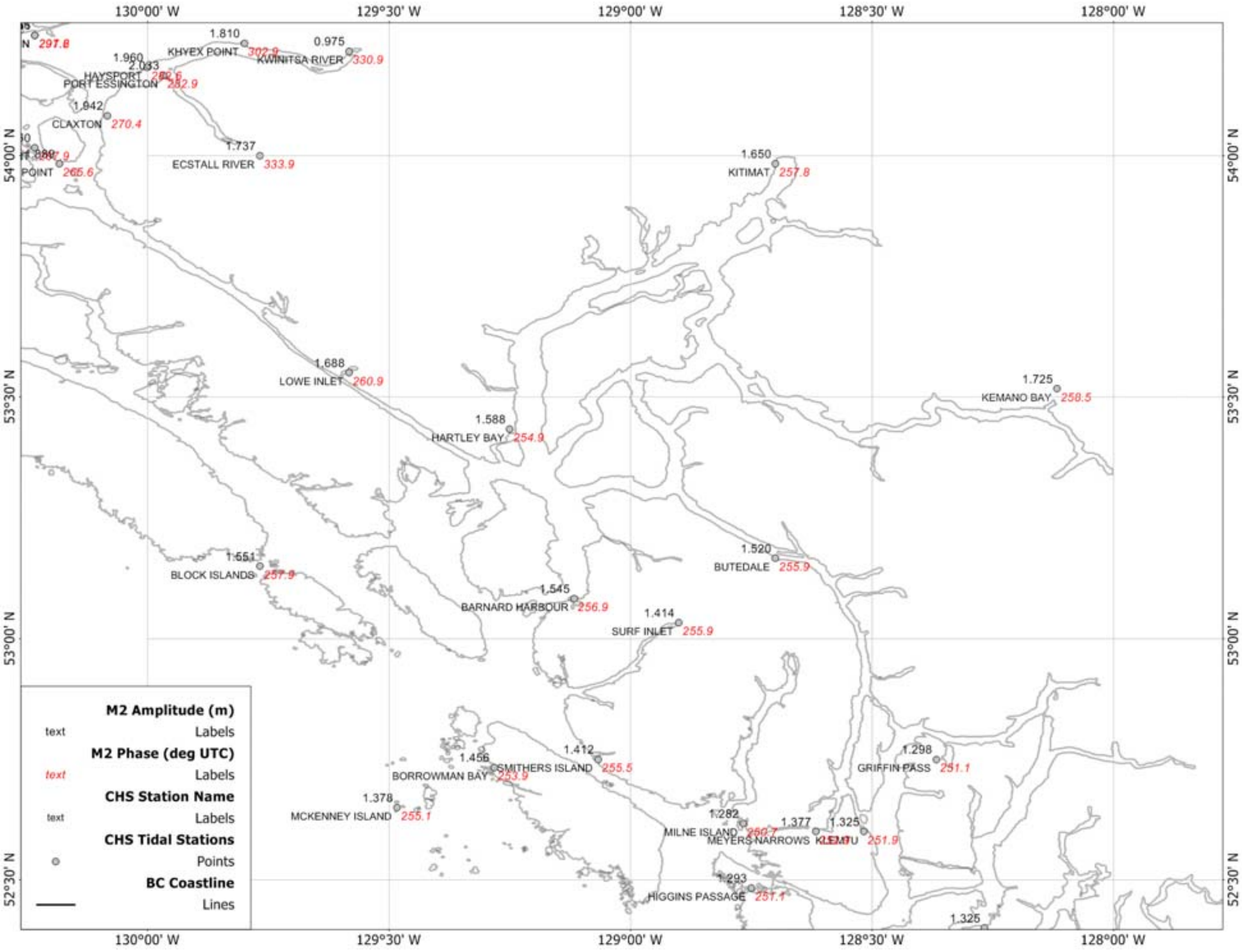
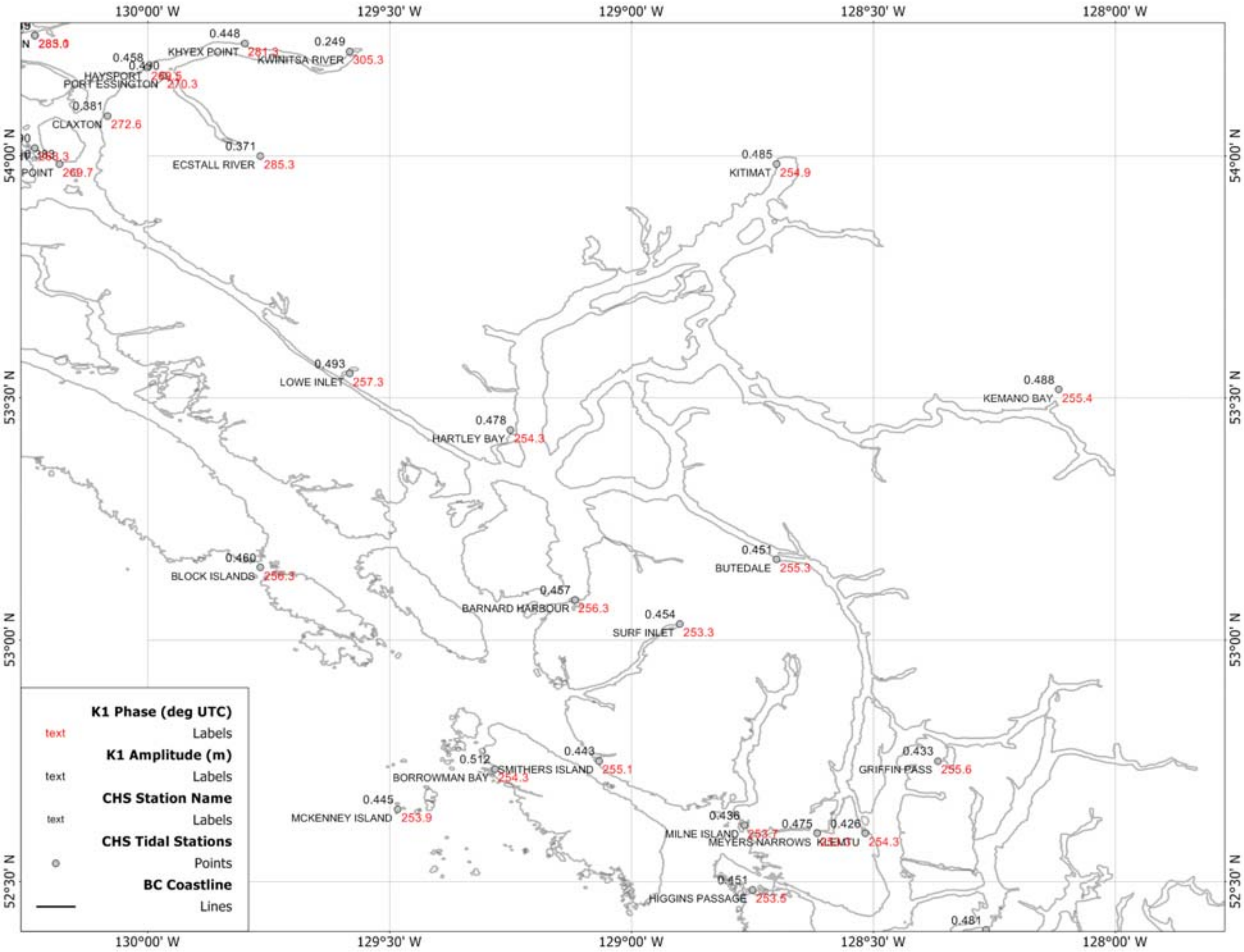


Figure 8: Measured CHS Variation of K1

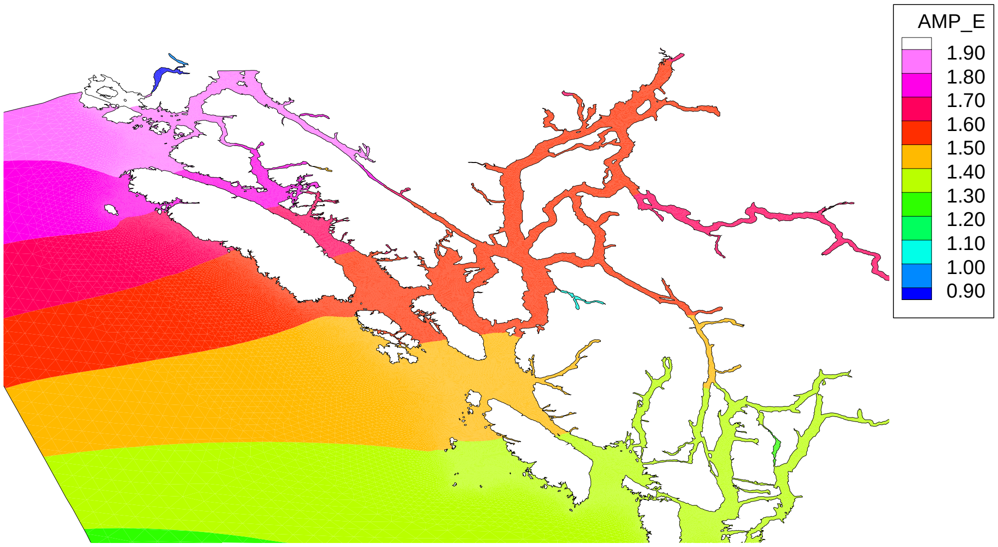


Note that successful calibration of the model in this area implies good calibration in the majority of the exposed regions of the Douglas model and the vast majority of the Hecate domain, since the two domains are driven in series only from the western (open North Pacific) boundary of the Hecate domain.

Seasonal effects (January and July) were included by applying a monthly-averaged wind field, computing tidal residuals based on the eight tidal constituents, and including the effects of measured water density variations where available. Water density fields across the Hecate domain were computed from temperature and salinity data provided by Dr. Michael Foreman of the Institute of Ocean Sciences. Unfortunately, there was insufficient density data available in Douglas Channel to include these effects in the Douglas domain.

Figure 9: Modelled Variation of Tidal Constituent - M2

Tidal Constituent Amplitude (m)



Tidal Constituent Phase (deg UTC)

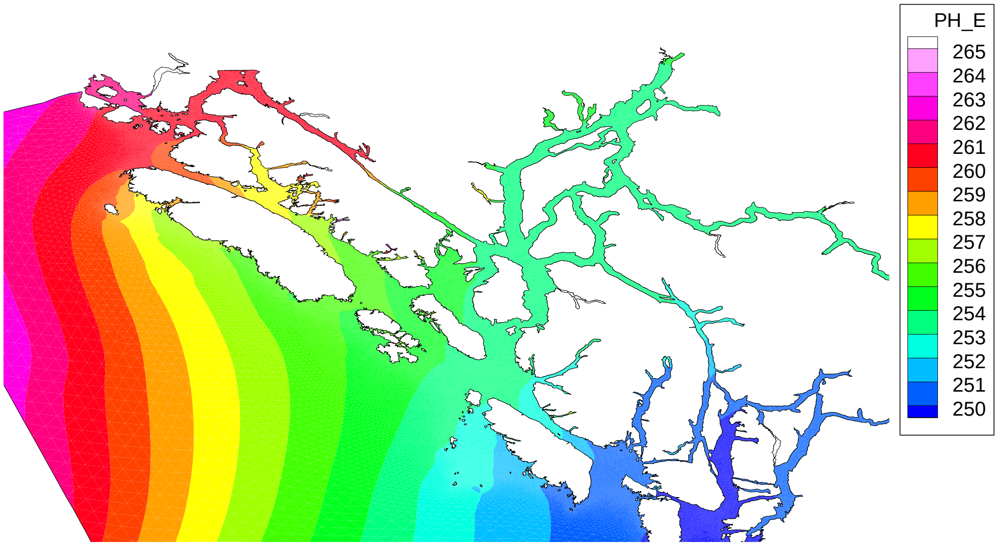
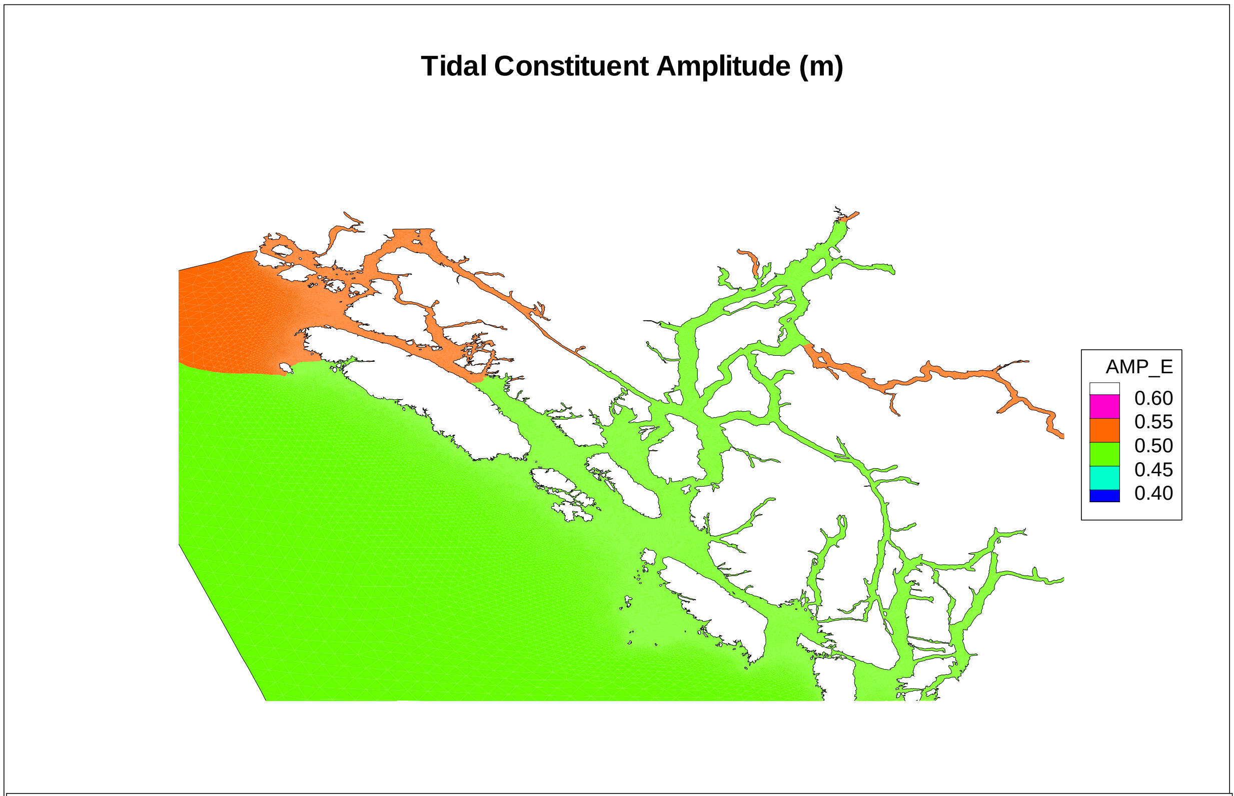
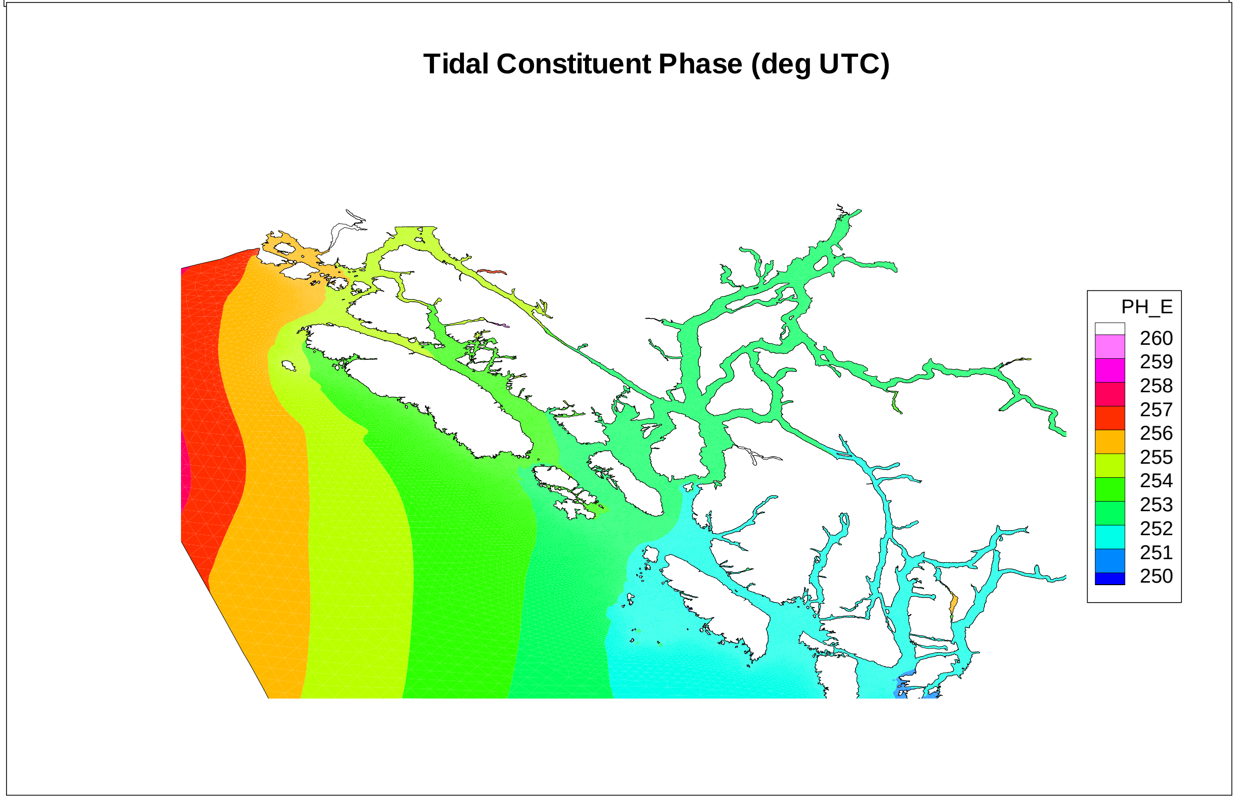


Figure 10: Modelled Variation of Tidal Constituent - K1



Tidal Constituent Amplitude (m)



Tidal Constituent Phase (deg UTC)

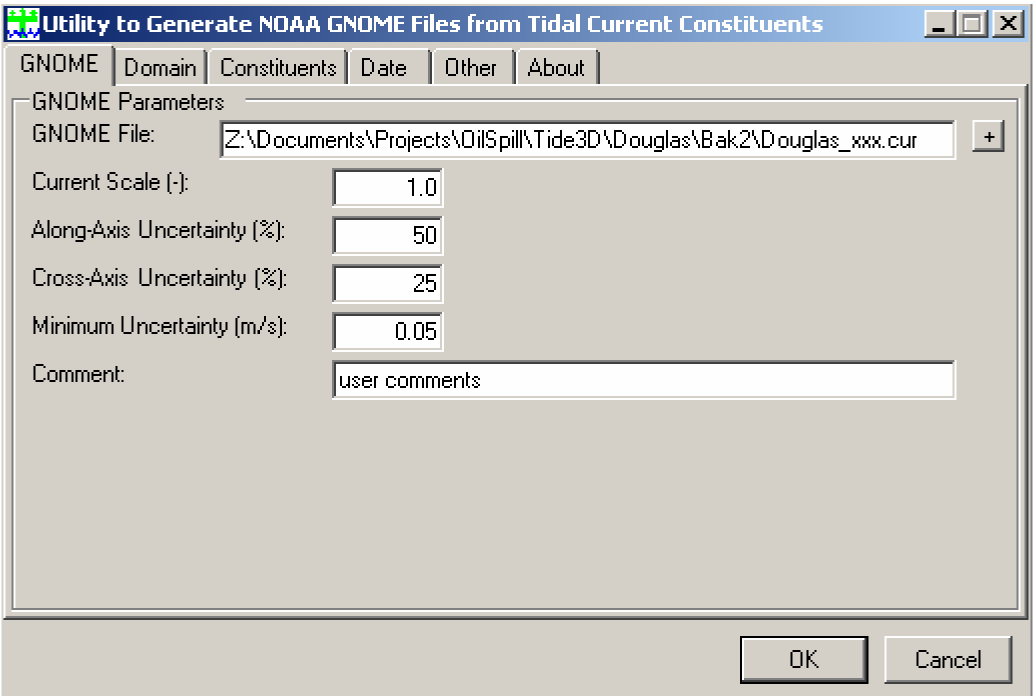
A comparison of Figure 7 with Figure 9 (M2) and Figure 8 with Figure 10 (K1) indicates that a good calibration, in terms of tidal height, had been achieved. Ideally, the model would then be verified against long-term current measurements at important locations. A search was undertaken for existing current data in the area of interest. This search yielded a series of oceanographic reports by Debrocky Seatech done 30 years ago (Webster, 1978) which included a number of oceanographic datasets and discussions that were useful but not sufficient for verification. As an alternative, a less rigorous but indicative verification was made against maximum tidal currents indicated on the CHS charts.

2.5 DEVELOPMENT OF GNOMEUTIL

A key aspect of the project was the development of a utility to generate a database of GNOME-compatible (time-stepping) hydrodynamic files covering the area of interest from the Tide3D harmonic database. The utility was developed using Microsoft .NET languages and was named GNOMEUtil. The utility runs on Windows-based computers with the Microsoft .NET framework 1.1 installed, or on Linux, Solaris, Mac OS X, Windows, and Unix machines with Mono framework 1.2 installed.

Below are a number of screenshots demonstrating the use of the utility. When the utility is launched, the user is prompted to browse to the folder containing the Tide3D database. Figure 11 is the first tab of the input dialog which solicits the name of the GNOME time-varying current file (*.cur), an overall scale factor (usually 1.0), along- and cross-axis uncertainty (NOAA recommends 50% and 25% respectively, minimum uncertainty (not presently used in GNOME), and any user specified comments.

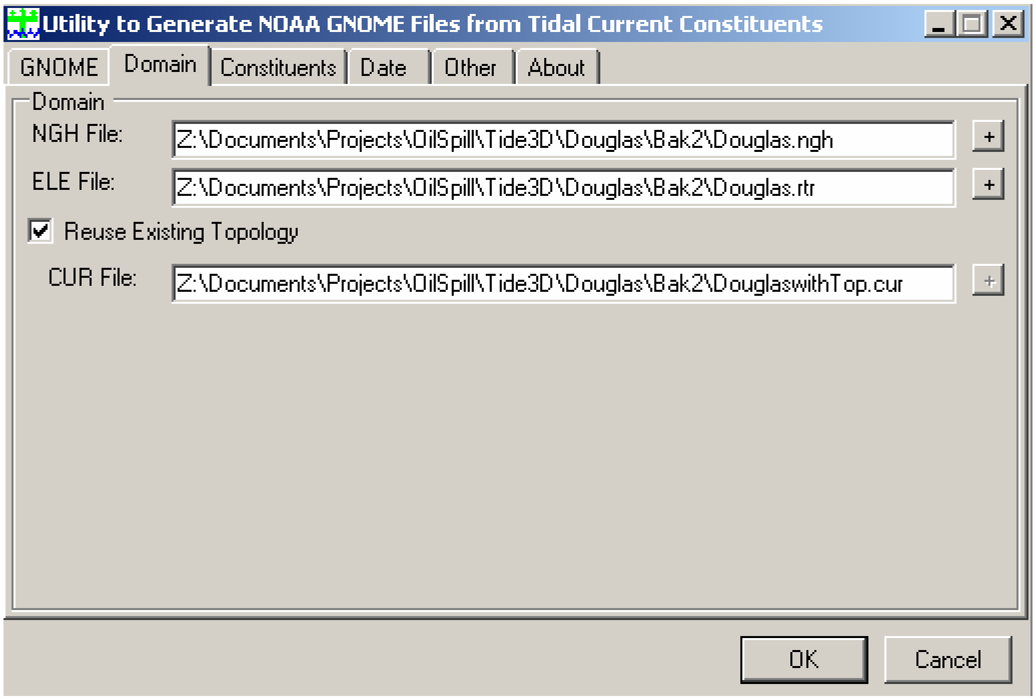
Figure 11: GNOMEUtil - GNOME Tab



GNOME File: Z:\Documents\Projects\OilSpill\Tide3D\Douglas\Bak2\Douglas_xxx.cur
Current Scale (-): 1.0
Along-Axis Uncertainty (%): 50
Cross-Axis Uncertainty (%): 25
Minimum Uncertainty (m/s): 0.05
Comment: user comments

Figure 12 shows the second tab of the input dialog which solicits the name of the nodal neighbours file (*.ngh), the triangular element topology file (*.ele), and the option to read an existing GNOME currents file (*.cur) which greatly improves the speed with which the output currents file is read by GNOME.

Figure 12: GNOMEUtil - Domain Tab



Domain

NGH File: Z:\Documents\Projects\OilSpill\Tide3D\Douglas\Bak2\Douglas.ngh

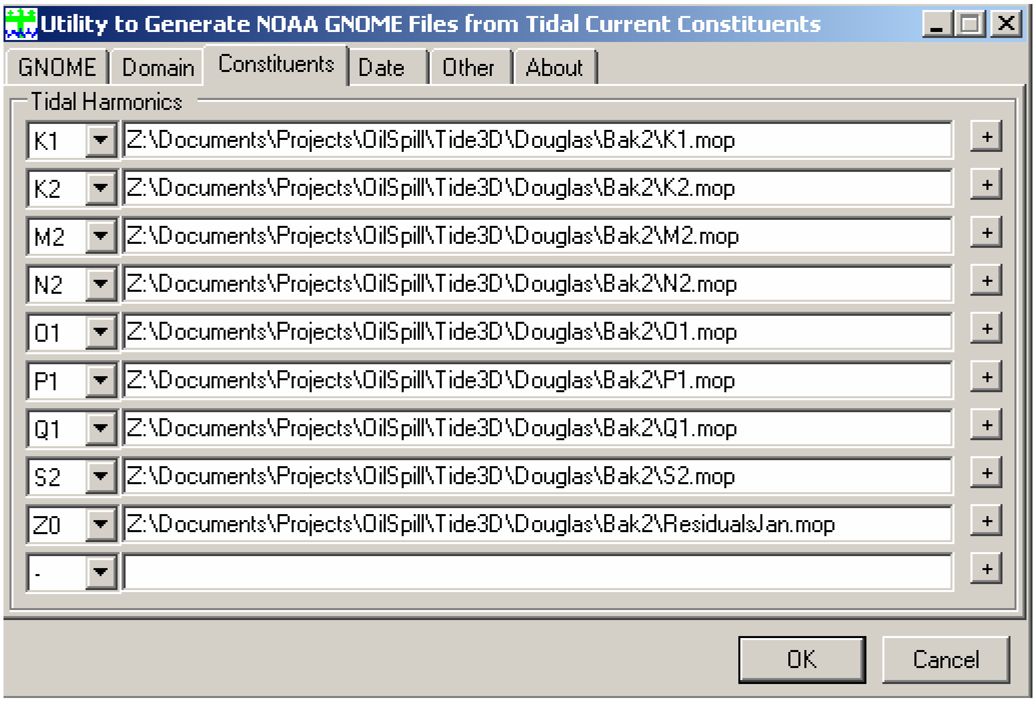
ELE File: Z:\Documents\Projects\OilSpill\Tide3D\Douglas\Bak2\Douglas.rtr

☑ Reuse Existing Topology

CUR File: Z:\Documents\Projects\OilSpill\Tide3D\Douglas\Bak2\DouglaswithTop.cur

Figure 13 shows the third tab of the input dialog which solicits up to ten Tide3D harmonic constituent model output files (*.mop) such as M2 (twice-a-day effect of the moon), S2 (twice-a-day effect of the sun) and Z0 (tidal residual, seasonally constant component).

Figure 13: GNOMEUtil - Constituents Tab

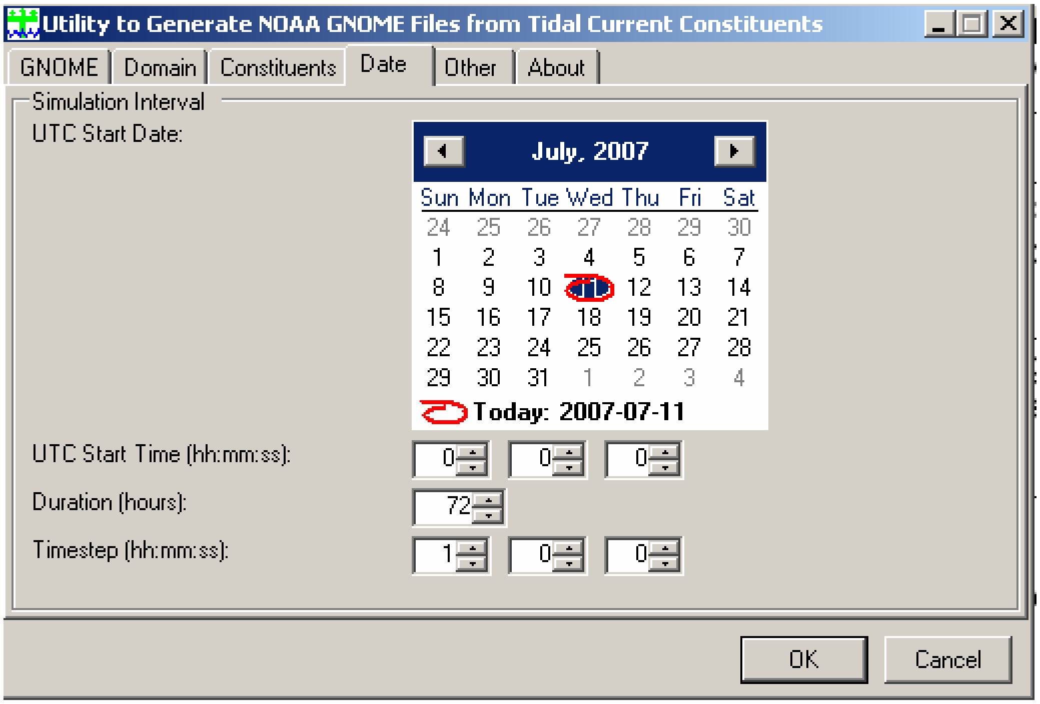


Tidal Harmonics

K1	Z:\Documents\Projects\OilSpill\Tide3D\Douglas\Bak2\K1.mop
K2	Z:\Documents\Projects\OilSpill\Tide3D\Douglas\Bak2\K2.mop
M2	Z:\Documents\Projects\OilSpill\Tide3D\Douglas\Bak2\M2.mop
N2	Z:\Documents\Projects\OilSpill\Tide3D\Douglas\Bak2\N2.mop
O1	Z:\Documents\Projects\OilSpill\Tide3D\Douglas\Bak2\O1.mop
P1	Z:\Documents\Projects\OilSpill\Tide3D\Douglas\Bak2\P1.mop
Q1	Z:\Documents\Projects\OilSpill\Tide3D\Douglas\Bak2\Q1.mop
S2	Z:\Documents\Projects\OilSpill\Tide3D\Douglas\Bak2\S2.mop
Z0	Z:\Documents\Projects\OilSpill\Tide3D\Douglas\Bak2\ResidualsJan.mop
-	

Figure 14 allows the user to specify the starting Coordinated Universal Time (UTC), desired duration of the simulation in hours, and the time interval between surface current velocity fields[6].

Figure 14: GNOMEUtil - Date Tab



Simulation Interval

UTC Start Date:

July, 2007

Sun	Mon	Tue	Wed	Thu	Fri	Sat
24	25	26	27	28	29	30
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31	1	2	3	4

Today: 2007-07-11

UTC Start Time (hh:mm:ss): 0 0 0

Duration (hours): 72

Timestep (hh:mm:ss): 1 0 0

Figure 15 is the final tab of the dialog box requesting the user to specify whether the harmonic database files (*.mop) are from a Tide2D or Tide3D simulation, and the typical latitude of the domain for tidal prediction.

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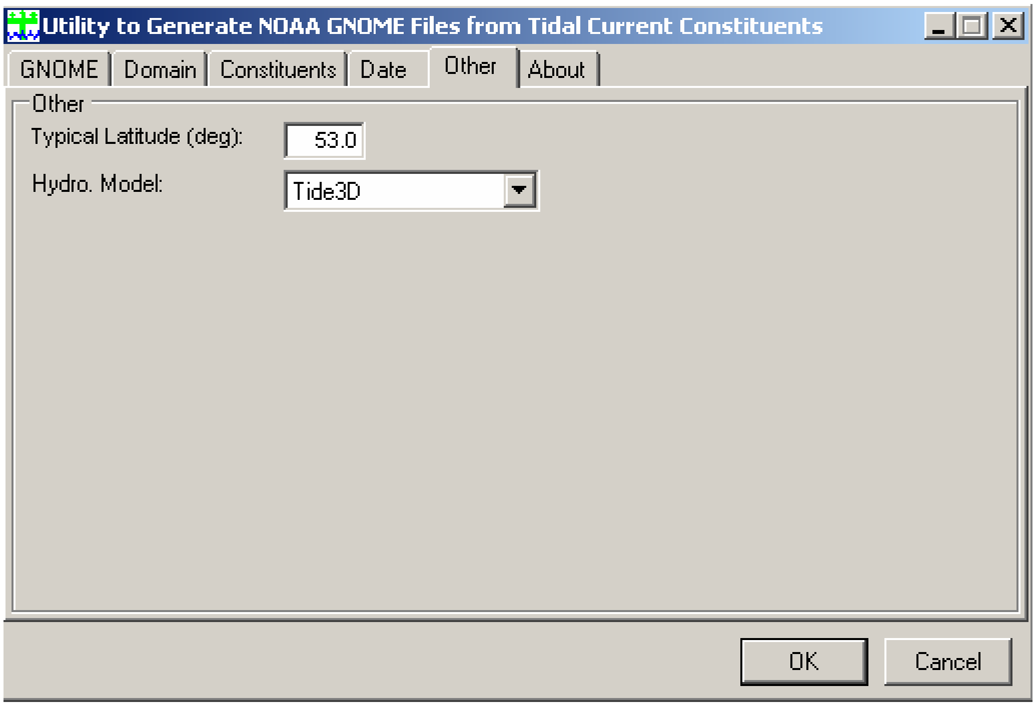
[6] Typically one hour; GNOME interpolates linearly to the specified timestep of the spill simulation (typically 15 minutes).

Figure 15: GNOMEUtil - Other Tab



Typical Latitude (deg): 53.0

Hydro. Model: Tide3D

This development of GNOMEUtil meant that it was now possible to generate a large number of hydrodynamic files from the hydrodynamic models results which could represent typical tidal and non-tidal currents at each vertex of the Hecate and Douglas domain grids.

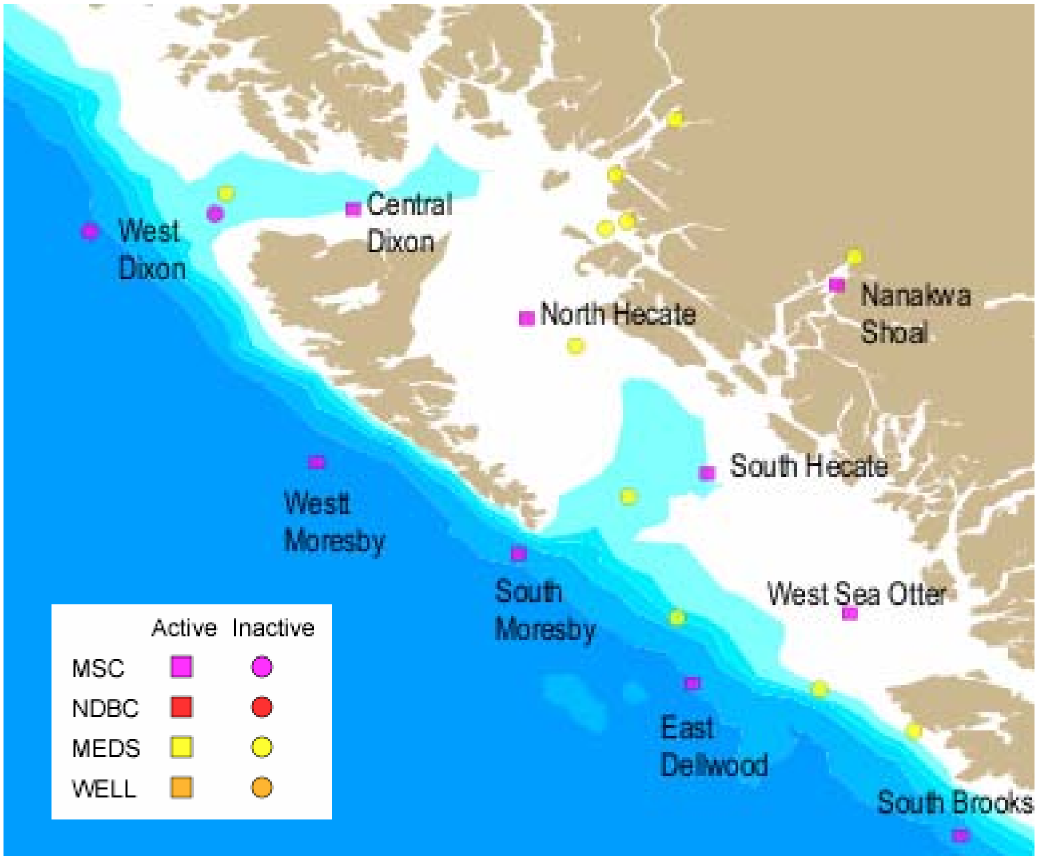
2.6 WIND FIELDS

GNOME provides the ability to model a time-varying spatially-uniform wind as a universal spill mover. Available wind data from the Marine Environmental Data Service stations identified in Table 2 and plotted in Figure 16 were compiled and formatted for use in GNOME. These stations are marine buoys which measure true overwater winds. Therefore, no modifications of the raw wind measurements were required prior to reformatting into a GNOME-compatible format.

Table 2: MEDS Wind Stations

Station	Location	Latitude (deg N)	Longitude (deg W)
1	West Dixon Entrance (C46205)	54.30	133.40
2	Central Dixon Entrance (C46145)	54.38	132.43
3	North Hecate Strait (C46183)	53.57	131.14
4	West Moresby (C46208)	52.50	132.70
5	South Moresby (C46147)	51.82	131.20
6	East Dellwood (C46207)	50.86	129.91
7	South Brooks (C46132)	49.73	127.92
8	Nanakwa Shoal (C46181)	53.82	128.84
9	South Hecate Strait (C46185)	52.42	129.80

Figure 16: Wind Stations



Bivariate histograms of wind speed versus direction are included in Appendix A and B.

Several questions arose over the course of the project concerning the most appropriate wind station to use in a specific spill simulation. Fortunately, the spatial variation of wind in Hecate Strait is modest (see Figure 17 and Figure 18).

Figure 17: Sample Spatial Variation of Wind - January

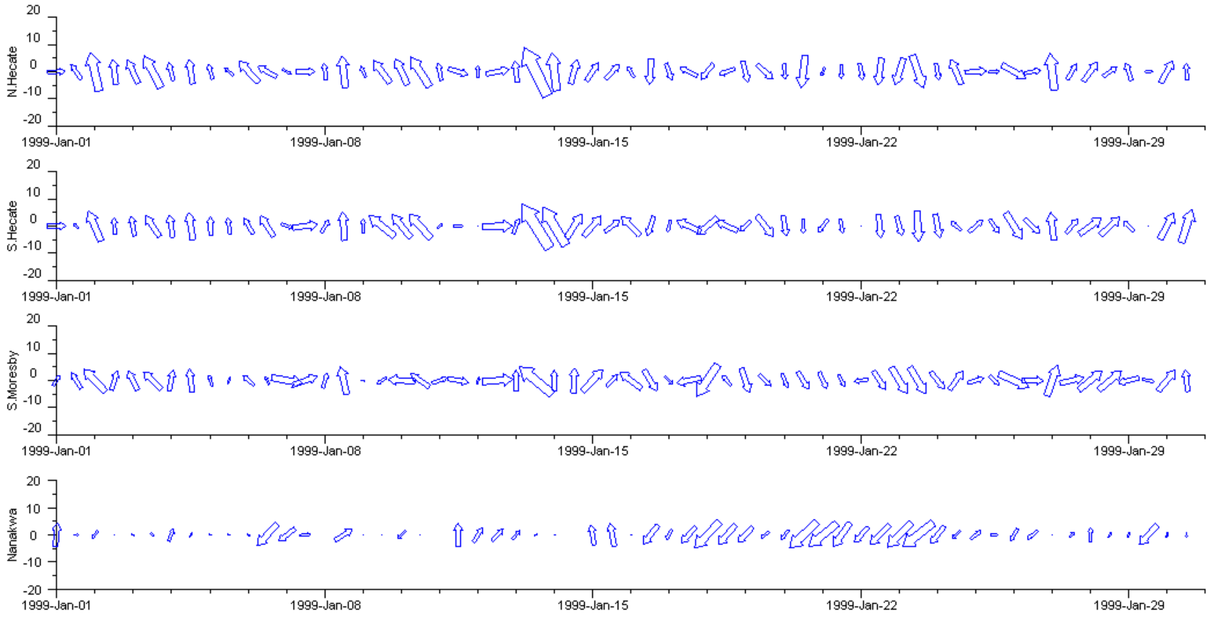
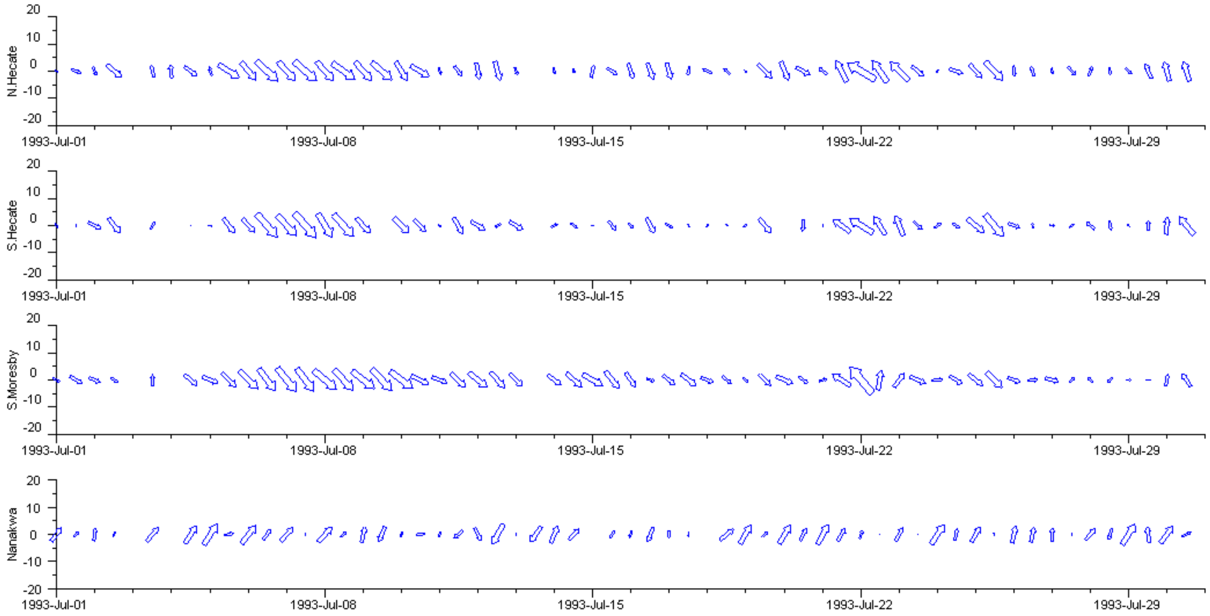


Figure 18: Sample Spatial Variation of Wind - July



Monthly average (January and July) wind fields were computed from the available buoy data which were used in the hydraulic modelling.

2.7 GNOME MODELLING

As noted previously, the actual GNOME spill modelling was undertaken by Living Oceans personnel. Appendix C contains a summary of the final scenarios as modelled. The results of these simulations are presented on Living Oceans' website (www.livingoceans.org). It is beyond the scope of this report to describe the details of these simulations.

3.0 REFERENCES

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Appendix A – Wind Speed/Wind Direction Histograms - January

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COASTAL ENGINEERING ANALYSIS PACKAGE
CEAData - Bivariate Histogram

                         Project Number: 07-101
                                 Client: Living Oceans Society
                            Description: North Coast Oil Spill Modelling
                                Analyst: M.R. Larson
                          Analysis Date: 2007-05-22 09:00:16

INPUT PARAMETERS
Row Variable
                     File (-): Z:\Documents\Projects\OilSpill\Wind\QCWind.h5
                    Group (-): /Variables/Node_1988
                  Dataset (-): /Variables/Node_1988/U
                      (i,j,k): (1,1,1)
                      Station: West Dixon Entrance
Column Variable
                     File (-): Z:\Documents\Projects\OilSpill\Wind\QCWind.h5
                    Group (-): /Variables/Node_1988
                  Dataset (-): /Variables/Node_1988/UDir
                      (i,j,k): (1,1,1)
                      Station: West Dixon Entrance
Time Screening
       Start Time (YYYY MM DD HH:MN:SS): 1988-01-01 00:00:00
        Stop Time (YYYY MM DD HH:MN:SS): 2007-12-31 23:00:00
       Season of Interest (MM DD MM DD): 1 1 1 31
                      Hours of Interest: All

Parameter Screening
          Parameter Screening: None (All Valid Records)

OUTPUT PARAMETERS
    Potential Number of Observations in Specified Time Interval (-):    14880
 Actual Number of Valid Observations in Specified Time Interval (-):    12456

                                        /Variables/Node_1988/UDir (from deg T)
        Total  337.5   22.5   67.5  112.5  157.5  202.5  247.5  292.5  337.5
                      N      NE     E     SE     S      SW     W      NW
/Variables/Node_1988/U (m/s)                       Total Observations (Count)

    Calm  1128

    0.00
           549       127     66     72     53     56     51     64     60
    2.50
          1760       253    164    216    224    295    249    187    172
    5.00
          2882       398    306    396    360    432    428    311    251
    7.50
          2765       378     86    409    441    526    368    283    274
   10.00
          1848       115     26    257    465    493    172    191    129
   12.50
          1018        38     14    158    399    251     61     71     26
   15.00
           380        37      7     52    191     60     16     13      4
   17.50
           108         4      2     10     78     11      0      3      0
   20.00
            18         0      0      2     16      0      0      0      0
   22.50

Total    12456      1350    671   1572   2227   2124   1345   1123    916
```

```
COASTAL ENGINEERING ANALYSIS PACKAGE
CEAData - Bivariate Histogram

                         Project Number: 07-101
                                 Client: Living Oceans Society
                            Description: North Coast Oil Spill Modelling
                                Analyst: M.R. Larson
                          Analysis Date: 2007-05-22 09:00:58

INPUT PARAMETERS
Row Variable
                     File (-): Z:\Documents\Projects\OilSpill\Wind\QCWind.h5
                    Group (-): /Variables/Node_1988
                  Dataset (-): /Variables/Node_1988/U
                      (i,j,k): (2,1,1)
                      Station: Central Dixon Entrance
Column Variable
                     File (-): Z:\Documents\Projects\OilSpill\Wind\QCWind.h5
                    Group (-): /Variables/Node_1988
                  Dataset (-): /Variables/Node_1988/UDir
                      (i,j,k): (2,1,1)
                      Station: Central Dixon Entrance
Time Screening
       Start Time (YYYY MM DD HH:MN:SS): 1988-01-01 00:00:00
        Stop Time (YYYY MM DD HH:MN:SS): 2007-12-31 23:00:00
       Season of Interest (MM DD MM DD): 1 1 1 31
                      Hours of Interest: All

Parameter Screening
          Parameter Screening: None (All Valid Records)

OUTPUT PARAMETERS
    Potential Number of Observations in Specified Time Interval (-):    14880
 Actual Number of Valid Observations in Specified Time Interval (-):    10458

                                        /Variables/Node_1988/UDir (from deg T)
        Total  337.5   22.5   67.5  112.5  157.5  202.5  247.5  292.5  337.5
                     N      NE     E     SE     S      SW     W      NW
/Variables/Node_1988/U (m/s)                       Total Observations (Count)

    Calm  1301

    0.00
           684        138    114    122     98     60     32     55     65
    2.50
          1707        286    191    258    307    283    129    117    136
    5.00
          2294        233    190    378    580    381    182    212    138
    7.50
          2175         94    206    472    684    280    136    190    113
   10.00
          1317         47    131    318    477    114     66    115     49
   12.50
           714          9     66    233    324     24     18     30     10
   15.00
           218          2     33     53    112      2      0     12      4
   17.50
            46          0      2      5     37      2      0      0      0
   20.00
             2          0      0      0      2      0      0      0      0
   22.50

Total    10458        809    933   1839   2621   1146    563    731    515
```

```
COASTAL ENGINEERING ANALYSIS PACKAGE
CEAData - Bivariate Histogram

                         Project Number: 07-101
                                 Client: Living Oceans Society
                            Description: North Coast Oil Spill Modelling
                                Analyst: M.R. Larson
                          Analysis Date: 2007-05-22 08:59:07

INPUT PARAMETERS
Row Variable
                     File (-): Z:\Documents\Projects\OilSpill\Wind\QCWind.h5
                    Group (-): /Variables/Node_1988
                  Dataset (-): /Variables/Node_1988/U
                      (i,j,k): (3,1,1)
                      Station: North Hecate Strait
Column Variable
                     File (-): Z:\Documents\Projects\OilSpill\Wind\QCWind.h5
                    Group (-): /Variables/Node_1988
                  Dataset (-): /Variables/Node_1988/UDir
                      (i,j,k): (3,1,1)
                      Station: North Hecate Strait
Time Screening
       Start Time (YYYY MM DD HH:MN:SS): 1988-01-01 00:00:00
        Stop Time (YYYY MM DD HH:MN:SS): 2007-12-31 23:00:00
       Season of Interest (MM DD MM DD): 1 1 1 31
                      Hours of Interest: All

Parameter Screening
          Parameter Screening: None (All Valid Records)

OUTPUT PARAMETERS
    Potential Number of Observations in Specified Time Interval (-):   14880
 Actual Number of Valid Observations in Specified Time Interval (-):   10542

                                        /Variables/Node_1988/UDir (from deg T)
        Total  337.5   22.5   67.5  112.5  157.5  202.5  247.5  292.5   337.5
                      N      NE     E     SE     S      SW     W      NW
/Variables/Node_1988/U (m/s)                       Total Observations (Count)

    Calm  1274

    0.00
           817       162     93    130    191    108     47     29     57
    2.50
          1429       323    201    237    187    146    118    101    116
    5.00
          2042       504    122    237    325    258    269    162    165
    7.50
          2044       379     60    215    499    414    199    116    162
   10.00
          1415       139     17    157    589    346     46     48     73
   12.50
           819        34     15     60    500    174      8     16     12
   15.00
           392        14      9     11    306     39      1      7      5
   17.50
           182         0      1      6    150     18      1      4      2
   20.00
            29         3      3      1     18      1      1      0      2
   22.50
            11         4      2      2      3      0      0      0      0
   25.00
```

```
            11         2      1      4      2      0      0      1      1
   27.50
             7         2      1      1      0      1      2      0      0
   30.00
             7         2      1      0      0      0      1      0      3
   32.50
            12         3      0      0      1      1      1      4      2
   35.00
             7         1      0      1      1      1      0      0      3
   37.50
            11         3      0      0      3      0      2      1      2
   40.00
            11         0      0      4      1      0      1      2      3
   42.50
             7         2      1      1      0      0      0      0      3
   45.00
             6         1      1      3      0      0      0      0      1
   47.50
             3         1      0      1      1      0      0      0      0
   50.00
             6         0      0      0      2      0      0      2      2
  999.00

Total    10542      1579    528   1071   2779   1507    697    493    614
```

```
COASTAL ENGINEERING ANALYSIS PACKAGE
CEAData - Bivariate Histogram

                         Project Number: 07-101
                                 Client: Living Oceans Society
                            Description: North Coast Oil Spill Modelling
                                Analyst: M.R. Larson
                          Analysis Date: 2007-05-22 09:01:41

INPUT PARAMETERS
Row Variable
                     File (-): Z:\Documents\Projects\OilSpill\Wind\QCWind.h5
                    Group (-): /Variables/Node_1988
                  Dataset (-): /Variables/Node_1988/U
                      (i,j,k): (4,1,1)
                      Station: West Moresby
Column Variable
                     File (-): Z:\Documents\Projects\OilSpill\Wind\QCWind.h5
                    Group (-): /Variables/Node_1988
                  Dataset (-): /Variables/Node_1988/UDir
                      (i,j,k): (4,1,1)
                      Station: West Moresby
Time Screening
       Start Time (YYYY MM DD HH:MN:SS): 1988-01-01 00:00:00
        Stop Time (YYYY MM DD HH:MN:SS): 2007-12-31 23:00:00
       Season of Interest (MM DD MM DD): 1 1 1 31
                      Hours of Interest: All

Parameter Screening
          Parameter Screening: None (All Valid Records)

OUTPUT PARAMETERS
    Potential Number of Observations in Specified Time Interval (-):    14880
 Actual Number of Valid Observations in Specified Time Interval (-):    10000

                                        /Variables/Node_1988/UDir (from deg T)
        Total  337.5   22.5   67.5  112.5  157.5  202.5  247.5  292.5  337.5
                      N      NE     E     SE     S      SW     W      NW
/Variables/Node_1988/U (m/s)                       Total Observations (Count)

    Calm   756

    0.00
           739       105     73    109    104     99    103     82     64
    2.50
          1496       204    117    152    236    264    210    163    150
    5.00
          1995       216     80    161    388    370    267    305    208
    7.50
          2228       171     57    228    544    431    244    291    262
   10.00
          1500        73     13    168    485    287    157    174    143
   12.50
           839        27     12    116    346    137     69     57     75
   15.00
           361        15      4     44    187     50     16     28     17
   17.50
            73         2      1      9     45      1      5      9      1
   20.00
            12         0      0      3      6      0      3      0      0
   22.50
             1         0      0      0      1      0      0      0      0
   25.00
```

```
Total    10000       813    357    990   2342   1639   1074   1109    920
```

```
COASTAL ENGINEERING ANALYSIS PACKAGE
CEAData - Bivariate Histogram

                         Project Number: 07-101
                                 Client: Living Oceans Society
                            Description: North Coast Oil Spill Modelling
                                Analyst: M.R. Larson
                          Analysis Date: 2007-05-22 09:02:27

INPUT PARAMETERS
Row Variable
                     File (-): Z:\Documents\Projects\OilSpill\Wind\QCWind.h5
                    Group (-): /Variables/Node_1988
                  Dataset (-): /Variables/Node_1988/U
                      (i,j,k): (5,1,1)
                      Station: South Moresby
Column Variable
                     File (-): Z:\Documents\Projects\OilSpill\Wind\QCWind.h5
                    Group (-): /Variables/Node_1988
                  Dataset (-): /Variables/Node_1988/UDir
                      (i,j,k): (5,1,1)
                      Station: South Moresby
Time Screening
       Start Time (YYYY MM DD HH:MN:SS): 1988-01-01 00:00:00
        Stop Time (YYYY MM DD HH:MN:SS): 2007-12-31 23:00:00
       Season of Interest (MM DD MM DD): 1 1 1 31
                      Hours of Interest: All

Parameter Screening
          Parameter Screening: None (All Valid Records)

OUTPUT PARAMETERS
    Potential Number of Observations in Specified Time Interval (-):    14880
 Actual Number of Valid Observations in Specified Time Interval (-):     6354

                                        /Variables/Node_1988/UDir (from deg T)
        Total  337.5   22.5   67.5  112.5  157.5  202.5  247.5  292.5  337.5
                      N     NE     E     SE     S      SW     W      NW
/Variables/Node_1988/U (m/s)                       Total Observations (Count)

    Calm  1882

    0.00
           205        26     26     22     38     23     27     24     19
    2.50
           638        98     74     48     79     96    102     67     74
    5.00
          1065       128    114    103    187    171    128    133    101
    7.50
          1064        77    109    111    160    246    134    110    117
   10.00
           814        23     66     85    240    157    101     68     74
   12.50
           372         3     23     49    145     58     36     31     27
   15.00
           203         6      2     19    113     38     13     11      1
   17.50
            54         5      4      3     33      5      2      1      1
   20.00
            17         1      0      2      9      1      2      1      1
   22.50
            10         0      0      2      3      3      0      2      0
   25.00
```

```
             7         0      0      3      2      2      0      0      0
   27.50
             5         0      0      3      2      0      0      0      0
   30.00
             6         0      1      3      1      1      0      0      0
   32.50
             4         0      0      1      1      1      0      0      1
   35.00
             3         1      0      1      1      0      0      0      0
   37.50
             1         0      0      0      1      0      0      0      0
   40.00
             2         0      1      0      1      0      0      0      0
   42.50
             1         0      0      0      1      0      0      0      0
   45.00
             1         0      0      1      0      0      0      0      0
   47.50

Total     6354       368    420    456   1017    802    545    448    416
```

```
COASTAL ENGINEERING ANALYSIS PACKAGE
CEAData - Bivariate Histogram

                         Project Number: 07-101
                                 Client: Living Oceans Society
                            Description: North Coast Oil Spill Modelling
                                Analyst: M.R. Larson
                          Analysis Date: 2007-05-22 09:03:20

INPUT PARAMETERS
Row Variable
                     File (-): Z:\Documents\Projects\OilSpill\Wind\QCWind.h5
                    Group (-): /Variables/Node_1988
                  Dataset (-): /Variables/Node_1988/U
                      (i,j,k): (6,1,1)
                      Station: East Dellwood
Column Variable
                     File (-): Z:\Documents\Projects\OilSpill\Wind\QCWind.h5
                    Group (-): /Variables/Node_1988
                  Dataset (-): /Variables/Node_1988/UDir
                      (i,j,k): (6,1,1)
                      Station: East Dellwood
Time Screening
       Start Time (YYYY MM DD HH:MN:SS): 1988-01-01 00:00:00
        Stop Time (YYYY MM DD HH:MN:SS): 2007-12-31 23:00:00
       Season of Interest (MM DD MM DD): 1 1 1 31
                      Hours of Interest: All

Parameter Screening
          Parameter Screening: None (All Valid Records)

OUTPUT PARAMETERS
    Potential Number of Observations in Specified Time Interval (-):    14880
 Actual Number of Valid Observations in Specified Time Interval (-):    11086

                                        /Variables/Node_1988/UDir (from deg T)
        Total  337.5   22.5   67.5  112.5  157.5  202.5  247.5  292.5   337.5
                      N      NE     E     SE     S      SW     W      NW
/Variables/Node_1988/U (m/s)                       Total Observations (Count)

    Calm  2426

    0.00
           368        32     28     42     73     42     45     49     57
    2.50
          1147       129    119     95    152    189    188    141    134
    5.00
          2148       310    225    158    279    413    309    253    201
    7.50
          2069       262    144    105    344    534    312    196    172
   10.00
          1475       121     70     47    360    401    236    149     91
   12.50
           798        45     32     21    327    226     60     52     35
   15.00
           465         9     29     13    264    104     18     24      4
   17.50
           161         0      0      1    128     18     10      4      0
   20.00
            22         0      0      0     22      0      0      0      0
   22.50
             7         0      0      0      7      0      0      0      0
   25.00
```

```
Total    11086       908    647    482   1956   1927   1178    868    694
```

```
COASTAL ENGINEERING ANALYSIS PACKAGE
CEAData - Bivariate Histogram

                         Project Number: 07-101
                                 Client: Living Oceans Society
                            Description: North Coast Oil Spill Modelling
                                Analyst: M.R. Larson
                          Analysis Date: 2007-05-22 09:04:07

INPUT PARAMETERS
Row Variable
                     File (-): Z:\Documents\Projects\OilSpill\Wind\QCWind.h5
                    Group (-): /Variables/Node_1988
                  Dataset (-): /Variables/Node_1988/U
                      (i,j,k): (7,1,1)
                      Station: South Brooks
Column Variable
                     File (-): Z:\Documents\Projects\OilSpill\Wind\QCWind.h5
                    Group (-): /Variables/Node_1988
                  Dataset (-): /Variables/Node_1988/UDir
                      (i,j,k): (7,1,1)
                      Station: South Brooks
Time Screening
       Start Time (YYYY MM DD HH:MN:SS): 1988-01-01 00:00:00
        Stop Time (YYYY MM DD HH:MN:SS): 2007-12-31 23:00:00
       Season of Interest (MM DD MM DD): 1 1 1 31
                      Hours of Interest: All

Parameter Screening
          Parameter Screening: None (All Valid Records)

OUTPUT PARAMETERS
    Potential Number of Observations in Specified Time Interval (-):    14880
 Actual Number of Valid Observations in Specified Time Interval (-):     7372

                                        /Variables/Node_1988/UDir (from deg T)
        Total  337.5   22.5   67.5  112.5  157.5  202.5  247.5  292.5  337.5
                      N      NE     E     SE     S      SW     W      NW
/Variables/Node_1988/U (m/s)                       Total Observations (Count)

    Calm   413

    0.00
           500        51     47    101     74     55     54     54     64
    2.50
          1237       140     83    196    206    161    155    127    169
    5.00
          1375       156     35    128    270    282    176    152    176
    7.50
          1453       149     35     82    429    296    133    141    188
   10.00
          1158        53      7     32    490    181     77    104    214
   12.50
           681        33      0      8    434     86     34     19     67
   15.00
           374         0      0      6    320     15      6     14     13
   17.50
           137         0      0      5    124      3      4      1      0
   20.00
            39         0      0      4     35      0      0      0      0
   22.50
             4         0      0      0      4      0      0      0      0
   25.00
```

```
             1         0      0      0      1      0      0      0      0
   27.50

Total     7372       582    207    562   2387   1079    639    612    891
```

```
COASTAL ENGINEERING ANALYSIS PACKAGE
CEAData - Bivariate Histogram

                         Project Number: 07-101
                                 Client: Living Oceans Society
                            Description: North Coast Oil Spill Modelling
                                Analyst: M.R. Larson
                          Analysis Date: 2007-07-12 14:13:26

INPUT PARAMETERS
Row Variable
                     File (-): Z:\Documents\Projects\OilSpill\Wind\QCWind.h5
                    Group (-): /Variables/Node_1988
                  Dataset (-): /Variables/Node_1988/U
                      (i,j,k): (8,1,1)
                      Station: Nanakwa Shoal
Column Variable
                     File (-): Z:\Documents\Projects\OilSpill\Wind\QCWind.h5
                    Group (-): /Variables/Node_1988
                  Dataset (-): /Variables/Node_1988/UDir
                      (i,j,k): (8,1,1)
                      Station: Nanakwa Shoal
Time Screening
       Start Time (YYYY MM DD HH:MN:SS): 1988-01-01 00:00:00
        Stop Time (YYYY MM DD HH:MN:SS): 2007-12-31 23:00:00
       Season of Interest (MM DD MM DD): 1 1 1 31
                      Hours of Interest: All

Parameter Screening
          Parameter Screening: None (All Valid Records)

OUTPUT PARAMETERS
    Potential Number of Observations in Specified Time Interval (-):    14880
 Actual Number of Valid Observations in Specified Time Interval (-):    10824

                                        /Variables/Node_1988/UDir (from deg T)
        Total  337.5   22.5   67.5  112.5  157.5  202.5  247.5  292.5   337.5
/Variables/Node_1988/U (m/s)                       Total Observations (Count)

    Calm   680

    0.00
          2404       503    446     71     48    100    261    574    401
    2.50
          1869       245    759     27     25    204    327    166    116
    5.00
          1811       205    888     16      6    304    360     20     12
    7.50
          1762       246   1159     13      4    169    165      4      2
   10.00
          1408       225   1081      5      3     33     59      2      0
   12.50
           765        58    689      0      0      2     15      0      1
   15.00
           124         4    119      0      0      0      1      0      0
   17.50
             1         0      1      0      0      0      0      0      0
   20.00

Total    10824      1486   5142    132     86    812   1188    766    532
```

Appendix B – Wind Speed/Wind Direction Histograms – July

```
COASTAL ENGINEERING ANALYSIS PACKAGE
CEAData - Bivariate Histogram

                         Project Number: 07-101
                                 Client: Living Oceans Society
                            Description: North Coast Oil Spill Modelling
                                Analyst: M.R. Larson
                          Analysis Date: 2007-05-22 09:31:14

INPUT PARAMETERS
Row Variable
                     File (-): Z:\Documents\Projects\OilSpill\Wind\QCWind.h5
                    Group (-): /Variables/Node_1988
                  Dataset (-): /Variables/Node_1988/U
                      (i,j,k): (1,1,1)
                      Station: West Dixon Entrance
Column Variable
                     File (-): Z:\Documents\Projects\OilSpill\Wind\QCWind.h5
                    Group (-): /Variables/Node_1988
                  Dataset (-): /Variables/Node_1988/UDir
                      (i,j,k): (1,1,1)
                      Station: West Dixon Entrance
Time Screening
       Start Time (YYYY MM DD HH:MN:SS): 1988-01-01 00:00:00
        Stop Time (YYYY MM DD HH:MN:SS): 2007-12-31 23:00:00
       Season of Interest (MM DD MM DD): 7 1 7 31
                      Hours of Interest: All

Parameter Screening
          Parameter Screening: None (All Valid Records)

OUTPUT PARAMETERS
    Potential Number of Observations in Specified Time Interval (-):    14880
 Actual Number of Valid Observations in Specified Time Interval (-):    11874

                                        /Variables/Node_1988/UDir (from deg T)
        Total  337.5   22.5   67.5  112.5  157.5  202.5  247.5  292.5  337.5
                      N      NE     E     SE     S      SW     W      NW
/Variables/Node_1988/U (m/s)                       Total Observations (Count)

    Calm   809

    0.00
          1086        95     68    123    115    142    215    180    148
    2.50
          3791       245    125    182    327    606    710    920    676
    5.00
          4015       125     54    104    389    698    509    941   1195
    7.50
          1716        34     23     51    265    287     68    121    867
   10.00
           413         7     11     24    101     61     19     13    177
   12.50
            41         0      0      8     12      4      0      0     17
   15.00
             3         0      0      1      0      1      1      0      0
   17.50

Total    11874       506    281    493   1209   1799   1522   2175   3080
```

```
COASTAL ENGINEERING ANALYSIS PACKAGE
CEAData - Bivariate Histogram

                         Project Number: 07-101
                                 Client: Living Oceans Society
                            Description: North Coast Oil Spill Modelling
                                Analyst: M.R. Larson
                          Analysis Date: 2007-05-22 09:32:50

INPUT PARAMETERS
Row Variable
                     File (-): Z:\Documents\Projects\OilSpill\Wind\QCWind.h5
                    Group (-): /Variables/Node_1988
                  Dataset (-): /Variables/Node_1988/U
                      (i,j,k): (2,1,1)
                      Station: Central Dixon Entrance
Column Variable
                     File (-): Z:\Documents\Projects\OilSpill\Wind\QCWind.h5
                    Group (-): /Variables/Node_1988
                  Dataset (-): /Variables/Node_1988/UDir
                      (i,j,k): (2,1,1)
                      Station: Central Dixon Entrance
Time Screening
       Start Time (YYYY MM DD HH:MN:SS): 1988-01-01 00:00:00
        Stop Time (YYYY MM DD HH:MN:SS): 2007-12-31 23:00:00
       Season of Interest (MM DD MM DD): 7 1 7 31
                      Hours of Interest: All

Parameter Screening
          Parameter Screening: None (All Valid Records)

OUTPUT PARAMETERS
    Potential Number of Observations in Specified Time Interval (-):    14880
 Actual Number of Valid Observations in Specified Time Interval (-):    11185

                                        /Variables/Node_1988/UDir (from deg T)
        Total  337.5   22.5   67.5  112.5  157.5  202.5  247.5  292.5  337.5
                      N      NE     E     SE     S      SW     W      NW
/Variables/Node_1988/U (m/s)                       Total Observations (Count)

    Calm   146

    0.00
          1431       149    135    189    207    170    185    233    163
    2.50
          3349        83    134    451    577    282    412   1090    320
    5.00
          3408         9     31    360    515     77    194   1795    427
    7.50
          1980        11     26    121    317     16     23    990    476
   10.00
           670        14     13     37     60     18     17    276    235
   12.50
           156        17      6     12     11     14     11     45     40
   15.00
            34         2      5      3      7      4      1      7      5
   17.50
             8         0      0      0      0      0      1      4      3
   20.00
             3         1      0      0      0      0      1      0      1
   22.50

Total    11185       286    350   1173   1694    581    845   4440   1670
```

```
COASTAL ENGINEERING ANALYSIS PACKAGE
CEAData - Bivariate Histogram

                         Project Number: 07-101
                                 Client: Living Oceans Society
                            Description: North Coast Oil Spill Modelling
                                Analyst: M.R. Larson
                          Analysis Date: 2007-05-22 09:33:41

INPUT PARAMETERS
Row Variable
                     File (-): Z:\Documents\Projects\OilSpill\Wind\QCWind.h5
                    Group (-): /Variables/Node_1988
                  Dataset (-): /Variables/Node_1988/U
                      (i,j,k): (3,1,1)
                      Station: North Hecate Strait
Column Variable
                     File (-): Z:\Documents\Projects\OilSpill\Wind\QCWind.h5
                    Group (-): /Variables/Node_1988
                  Dataset (-): /Variables/Node_1988/UDir
                      (i,j,k): (3,1,1)
                      Station: North Hecate Strait
Time Screening
       Start Time (YYYY MM DD HH:MN:SS): 1988-01-01 00:00:00
        Stop Time (YYYY MM DD HH:MN:SS): 2007-12-31 23:00:00
       Season of Interest (MM DD MM DD): 7 1 7 31
                      Hours of Interest: All

Parameter Screening
          Parameter Screening: None (All Valid Records)

OUTPUT PARAMETERS
    Potential Number of Observations in Specified Time Interval (-):    14880
 Actual Number of Valid Observations in Specified Time Interval (-):    10285

                                        /Variables/Node_1988/UDir (from deg T)
        Total  337.5   22.5   67.5  112.5  157.5  202.5  247.5  292.5  337.5
                      N      NE     E     SE     S      SW     W      NW
/Variables/Node_1988/U (m/s)                       Total Observations (Count)

    Calm   708

    0.00
          1579       229    175    178    239    244    174    155    185
    2.50
          2783       533    134    121    574    498    184    192    547
    5.00
          2549       427     15     42    904    283     27     78    773
    7.50
          1787        63      2     36    568    130      2     22    964
   10.00
           744         2      1     18    369     29      0     12    313
   12.50
           117         0      0      5    101      3      0      1      7
   15.00
            16         0      0      0     16      0      0      0      0
   17.50
             2         0      0      0      2      0      0      0      0
   20.00

Total    10285      1254    327    400   2773   1187    387    460   2789
```

```
COASTAL ENGINEERING ANALYSIS PACKAGE
CEAData - Bivariate Histogram

                         Project Number: 07-101
                                 Client: Living Oceans Society
                            Description: North Coast Oil Spill Modelling
                                Analyst: M.R. Larson
                          Analysis Date: 2007-05-22 09:34:29

INPUT PARAMETERS
Row Variable
                     File (-): Z:\Documents\Projects\OilSpill\Wind\QCWind.h5
                    Group (-): /Variables/Node_1988
                  Dataset (-): /Variables/Node_1988/U
                      (i,j,k): (4,1,1)
                      Station: West Moresby
Column Variable
                     File (-): Z:\Documents\Projects\OilSpill\Wind\QCWind.h5
                    Group (-): /Variables/Node_1988
                  Dataset (-): /Variables/Node_1988/UDir
                      (i,j,k): (4,1,1)
                      Station: West Moresby
Time Screening
       Start Time (YYYY MM DD HH:MN:SS): 1988-01-01 00:00:00
        Stop Time (YYYY MM DD HH:MN:SS): 2007-12-31 23:00:00
       Season of Interest (MM DD MM DD): 7 1 7 31
                      Hours of Interest: All

Parameter Screening
          Parameter Screening: None (All Valid Records)

OUTPUT PARAMETERS
    Potential Number of Observations in Specified Time Interval (-):    14880
 Actual Number of Valid Observations in Specified Time Interval (-):    11317

                                        /Variables/Node_1988/UDir (from deg T)
        Total  337.5   22.5   67.5  112.5  157.5  202.5  247.5  292.5  337.5
                      N      NE     E     SE     S      SW     W      NW
/Variables/Node_1988/U (m/s)                       Total Observations (Count)

    Calm   325

    0.00
          1000        65     48     70    127    166    172    209    143
    2.50
          3474       102     34     60    305    566    651    930    826
    5.00
          3631        75     13     40    371    445    372    632   1683
    7.50
          1940        42      5     40    278    162    114    103   1196
   10.00
           762        31      2     32     92     38     11      5    551
   12.50
           177         6      0     11     11      3      0      0    146
   15.00
             8         0      0      7      0      1      0      0      0
   17.50

Total    11317       321    102    260   1184   1381   1320   1879   4545
```

```
COASTAL ENGINEERING ANALYSIS PACKAGE
CEAData - Bivariate Histogram

                         Project Number: 07-101
                                 Client: Living Oceans Society
                            Description: North Coast Oil Spill Modelling
                                Analyst: M.R. Larson
                          Analysis Date: 2007-05-22 09:35:14

INPUT PARAMETERS
Row Variable
                     File (-): Z:\Documents\Projects\OilSpill\Wind\QCWind.h5
                    Group (-): /Variables/Node_1988
                  Dataset (-): /Variables/Node_1988/U
                      (i,j,k): (5,1,1)
                      Station: South Moresby
Column Variable
                     File (-): Z:\Documents\Projects\OilSpill\Wind\QCWind.h5
                    Group (-): /Variables/Node_1988
                  Dataset (-): /Variables/Node_1988/UDir
                      (i,j,k): (5,1,1)
                      Station: South Moresby
Time Screening
       Start Time (YYYY MM DD HH:MN:SS): 1988-01-01 00:00:00
        Stop Time (YYYY MM DD HH:MN:SS): 2007-12-31 23:00:00
       Season of Interest (MM DD MM DD): 7 1 7 31
                      Hours of Interest: All

Parameter Screening
          Parameter Screening: None (All Valid Records)

OUTPUT PARAMETERS
    Potential Number of Observations in Specified Time Interval (-):    14880
 Actual Number of Valid Observations in Specified Time Interval (-):     7008

                                        /Variables/Node_1988/UDir (from deg T)
        Total  337.5   22.5   67.5  112.5  157.5  202.5  247.5  292.5  337.5
                      N      NE     E     SE     S      SW     W       NW
/Variables/Node_1988/U (m/s)                       Total Observations (Count)

    Calm   318

    0.00
           843        31     38     62    104    200    173    150     85
    2.50
          2171        25     25     85    203    334    408    647    444
    5.00
          2223        16      9     27    124    154    178    540   1175
    7.50
          1119         7      9     12     65     75     44     73    834
   10.00
           314         0      2      4     23     16     12      9    248
   12.50
            17         0      2      1      7      2      0      0      5
   15.00
             3         0      0      0      3      0      0      0      0
   17.50

Total     7008        79     85    191    529    781    815   1419   2791
```

```
COASTAL ENGINEERING ANALYSIS PACKAGE
CEAData - Bivariate Histogram

                         Project Number: 07-101
                                 Client: Living Oceans Society
                            Description: North Coast Oil Spill Modelling
                                Analyst: M.R. Larson
                          Analysis Date: 2007-05-22 09:36:17

INPUT PARAMETERS
Row Variable
                     File (-): Z:\Documents\Projects\OilSpill\Wind\QCWind.h5
                    Group (-): /Variables/Node_1988
                  Dataset (-): /Variables/Node_1988/U
                      (i,j,k): (6,1,1)
                      Station: East Dellwood
Column Variable
                     File (-): Z:\Documents\Projects\OilSpill\Wind\QCWind.h5
                    Group (-): /Variables/Node_1988
                  Dataset (-): /Variables/Node_1988/UDir
                      (i,j,k): (6,1,1)
                      Station: East Dellwood
Time Screening
       Start Time (YYYY MM DD HH:MN:SS): 1988-01-01 00:00:00
        Stop Time (YYYY MM DD HH:MN:SS): 2007-12-31 23:00:00
       Season of Interest (MM DD MM DD): 7 1 7 31
                      Hours of Interest: All

Parameter Screening
          Parameter Screening: None (All Valid Records)

OUTPUT PARAMETERS
    Potential Number of Observations in Specified Time Interval (-):    14880
 Actual Number of Valid Observations in Specified Time Interval (-):     9826

                                        /Variables/Node_1988/UDir (from deg T)
        Total  337.5   22.5   67.5  112.5  157.5  202.5  247.5  292.5  337.5
                      N      NE     E     SE     S      SW     W      NW
/Variables/Node_1988/U (m/s)                       Total Observations (Count)

    Calm   784

    0.00
          747         68     31     38     59    120    156    152    123
    2.50
         2543        117     37     33    114    300    528    719    695
    5.00
         3135        150     27     21    132    348    338    490   1629
    7.50
         2170        151     10      5     90    200     75     68   1571
   10.00
          409         35      2      1     57     56      5      4    249
   12.50
           30          1      0      3     18      4      1      0      3
   15.00
            7          0      0      0      7      0      0      0      0
   17.50
            1          0      0      0      1      0      0      0      0
   20.00

Total     9826        522    107    101    478   1028   1103   1433   4270
```

```
COASTAL ENGINEERING ANALYSIS PACKAGE
CEAData - Bivariate Histogram

                         Project Number: 07-101
                                 Client: Living Oceans Society
                            Description: North Coast Oil Spill Modelling
                                Analyst: M.R. Larson
                          Analysis Date: 2007-05-22 09:36:58

INPUT PARAMETERS
Row Variable
                     File (-): Z:\Documents\Projects\OilSpill\Wind\QCWind.h5
                    Group (-): /Variables/Node_1988
                  Dataset (-): /Variables/Node_1988/U
                      (i,j,k): (7,1,1)
                      Station: South Brooks
Column Variable
                     File (-): Z:\Documents\Projects\OilSpill\Wind\QCWind.h5
                    Group (-): /Variables/Node_1988
                  Dataset (-): /Variables/Node_1988/UDir
                      (i,j,k): (7,1,1)
                      Station: South Brooks
Time Screening
       Start Time (YYYY MM DD HH:MN:SS): 1988-01-01 00:00:00
        Stop Time (YYYY MM DD HH:MN:SS): 2007-12-31 23:00:00
       Season of Interest (MM DD MM DD): 7 1 7 31
                      Hours of Interest: All

Parameter Screening
          Parameter Screening: None (All Valid Records)

OUTPUT PARAMETERS
    Potential Number of Observations in Specified Time Interval (-):    14880
 Actual Number of Valid Observations in Specified Time Interval (-):     6927

                                        /Variables/Node_1988/UDir (from deg T)
        Total  337.5   22.5  67.5   112.5  157.5  202.5  247.5  292.5  337.5
                      N      NE     E      SE     S      SW     W      NW
/Variables/Node_1988/U (m/s)                       Total Observations (Count)

    Calm  1456

    0.00
           728        59     48     45     81    113    126    144    112
    2.50
          1261        37     11     41    170    214    169    286    333
    5.00
          1112        16      0     19    145    108     52    111    661
    7.50
          1052         7      0      3    171     49      4      8    810
   10.00
          1044         4      0      0     71     16      0      0    953
   12.50
           273         0      0      0     22      0      0      0    251
   15.00
             1         0      0      0      0      0      0      0      1
   17.50

Total     6927       123     59    108    660    500    351    549   3121
```

```
COASTAL ENGINEERING ANALYSIS PACKAGE
CEAData - Bivariate Histogram

                         Project Number: 07-101
                                 Client: Living Oceans Society
                            Description: North Coast Oil Spill Modelling
                                Analyst: M.R. Larson
                          Analysis Date: 2007-07-12 14:14:46

INPUT PARAMETERS
Row Variable
                     File (-): Z:\Documents\Projects\OilSpill\Wind\QCWind.h5
                    Group (-): /Variables/Node_1988
                  Dataset (-): /Variables/Node_1988/U
                      (i,j,k): (8,1,1)
                      Station: Nanakwa Shoal
Column Variable
                     File (-): Z:\Documents\Projects\OilSpill\Wind\QCWind.h5
                    Group (-): /Variables/Node_1988
                  Dataset (-): /Variables/Node_1988/UDir
                      (i,j,k): (8,1,1)
                      Station: Nanakwa Shoal
Time Screening
       Start Time (YYYY MM DD HH:MN:SS): 1988-01-01 00:00:00
        Stop Time (YYYY MM DD HH:MN:SS): 2007-12-31 23:00:00
       Season of Interest (MM DD MM DD): 7 1 7 31
                      Hours of Interest: All

Parameter Screening
          Parameter Screening: None (All Valid Records)

OUTPUT PARAMETERS
    Potential Number of Observations in Specified Time Interval (-):    14880
 Actual Number of Valid Observations in Specified Time Interval (-):     8878

                                        /Variables/Node_1988/UDir (from deg T)
        Total  337.5   22.5   67.5  112.5  157.5  202.5  247.5  292.5  337.5
/Variables/Node_1988/U (m/s)                       Total Observations (Count)

    Calm   442

    0.00
          1966       246    200     56     65    435    532    274    158
    2.50
          2500        83    305      4      6    932   1111     49     10
    5.00
          2849        24    172      1      3    860   1785      3      1
    7.50
          1036         6     68      0      1    159    801      1      0
   10.00
            85         0      8      0      0      4     73      0      0
   12.50

Total     8878       359    753     61     75   2390   4302    327    169
```

Appendix C – GNOME Scenario Summary

Scenario No.	Scenario Name	Spill Latitude deg N	Spill Latitude min	Spill Longitude deg W	Spill Longitude min	Spill Type	Spill Amount	Simulation/Spill Start UTC	Spill Stop UTC	Simulation Stop UTC	Model	Wind File
1	NessWinter	52	50.543	129	44.295	med. crude	11 million gallons	2007-Jan-01 00:00	2007-Jan-10 16:30	2007-Feb-01 00:00	Hecate	NS SM Jan 07 combo.WND
2	Ness Summer	52	50.543	129	44.295	med crude	257000 barrels	2007-Jul-01 00:00	2007-Jul-10 16:30	2007-Aug-01 00:00	Hecate	South Moresby July 31 93 06.WND
3	Grenville Winter	54	2.440	130	53.850	med crude	257000 barrels	2007-Jan-01 00:00	2007-Jan-10 16:30	2007-Jan-15 00:00	Hecate	NHS Jan 98 - 07.WND
4	Grenville Summer	54	2.440	130	53.850	med crude	700 tonnes	2007-Jul-01 00:00	2007-Jul-03 00:00	2007-Jul-12 00:00	Hecate	NHS July 98 -06. WND
5	Fin Island Winter	53	17.130	129	18.040	med crude	10000 barrels	2007-Jan-01 00:00	2007-Jan-01 04:00	2007-Jan-15 00:00	Douglas	Nanakwa Shoal Jan 07.WND
6	Fin Island Summer	53	17.130	129	18.040	med crude	10000 barrels	2007-Jul-01 00:00	2007-Jul-01 04:00	2007-Jul-15 00:00	Douglas	NS July 05 06 14 dys.WND
7	Sockeye B10 Winter	52	49.140	131	0.730	med crude	1000 barrels	2007-Jan-01 00:00	2007-Jan-01 04:00	2007-Feb-01 00:00	Hecate	SM Jan 05 - 07.WND
8	Sockeye B10 Summer	52	49.140	131	0.730	med crude	1000 barrels	2007-Jul-01 00:00	2007-Jul-01 04:00	2007-Aug-01 00:00	Hecate	South Moresby July 31 93 06.WND
GENERAL NOTES:												
1	All simulations done with unsteady wind as universal mover											
2	All simulations done with diffusion mover (diffusion coefficient of 100,000 cm^2/s, uncertainty factor 2.0)											
3	General model settings: include minimum regret, prevent land jumping											
4	Computational timestep of 15 minutes used throughout											
5	Refloat half life set to 72 hours											
6	All simulations based on harmonic prediction using eight major tidal constituents											
7	All other GNOME parameters set to their default values											