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DOCUMENTATION OF FOUR OCEAN-RELATED COMPUTER MODULES

by

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Cambridge, Massachusetts 02139

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Author

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Related Reports

Chen, H.S., K.P. Yue, Chiang C. Mei. A HYBRID ELEMENT METHOD FOR CALCULATING THREE-DIMENSIONAL WATER WAVE SCATTERING. MITSG 76-10. Sea Grant Program. Cambridge: Massachusetts Institute of Technology, September 1976.

Christodoulou, G., J. Connor, B. Pearce. MATHEMATICAL MODELING OF DISPERSION IN STRATIFIED WATERS. MITSG 76-14. Sea Grant Program. Cambridge: Massachusetts Institute of Technology. November 1976. Two volumes; 155 pp. each.

Note

The preceding publications may be ordered from Communications, M.I.T. Sea Grant Program, Room 5-331, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139.

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INTRODUCTION

This report contains the documentation of a series of ocean-related computer programs developed recently at MIT. The documentation work was carried out under the sponsorship of the NOAA Sea-Grant program, project A/D-4, entitled "Program Documentation and Preparation of User Oriented Modules". Over the years, it has been observed that there is a considerable number of inquiries and requests from various government agencies as well as from the marine industry to exercise a number of the computer programs that were developed as by-products of government-sponsored research projects. In the absence of any user-oriented documentations, the routine running of such existing programs would often have to be turned down on the grounds that this would neither be an appropriate research activity for the MIT faculty, nor of great educational value to individual research assistants. With the proper documentation, the matter is entirely different. The documented programs can be made available to the public domain almost immediately, representing, perhaps, a maximum utilization of products of the corresponding research efforts.

The present series of documentation has a secondary purpose. It also serves as the starter elements for a system of software capabilities which is to supplement the Marine Industry Advisory Service (MIDAS) of the MIT Sea-Grant program. In time, the list of available programs will increase in size and through a periodic dissemination of summary flyers, the industry and researchers can be informed of the availability of the latest engineering computation tools.

In the documentation to follow, each individual program or module is described in a separate chapter. Each follows a common format of presentation as below:

1. Identification
2. Purpose
3. Overall Program Description
4. Execution Control
5. Data Preparation
6. Sample Data and Output
7. References

All programs described herein were not modified in regard to flexibility and generalities, since this would require substantial effort in the area of debugging and testing. Users are advised to stay close to the original purposes for which the programs are intended.

MODULE 1: Program MCTRAJ

1. Identification:

Title:	MCTRAJ (Monte Carlo Simulation of Oil Spill Trajectories)
Authors:	J. W. Devanney, III R. J. Stewart
Documented by:	R. W. Yeung Y. H. Kim
Specification:	Machine: IBM370 Source Language: PL/I Supporting Peripheral Equipment: Disk Sequential
Component Subprogram:	RANDUM (FORTRAN IV)

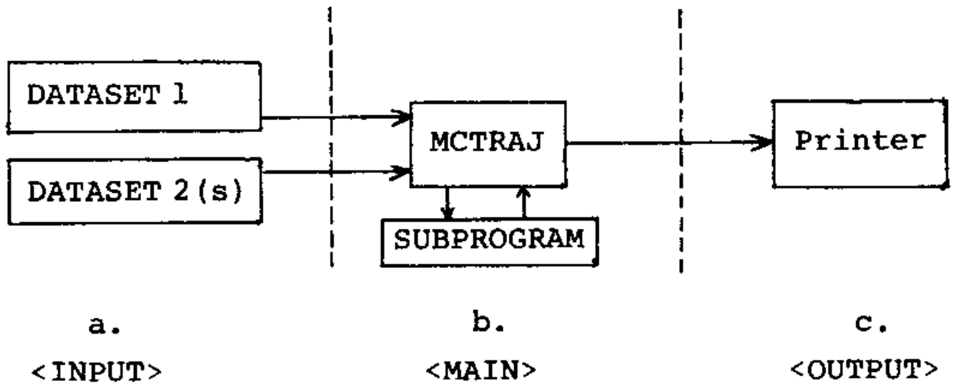
2. Purpose:

MCTRAJ is the offshore oil-spill trajectory-simulation program which is based on the trajectory equation:

$$\vec{U}_{oil} = \vec{U}_{current} + (0.03)\vec{U}_{surface\ wind} \cdot$$

This formula has been proven to be consistent with laboratory and field observation (Hoult, 1972). The wind is modeled as a nine-state Markov process [see Ref. 1], in which the probability of the change in wind direction is represented by a 9×9 matrix. The current is treated as a non-random quantity which could be assigned direction and speed as a function of the geographical location. This program does not include effects of tidal variations.

3. Overall Program Description:



a. The INPUT stage consists of two types of data file sets:
   1) DATASET 1 is a data file for describing the physical boundaries and the chart of current speeds and direction.
   2) DATASET 2(s) includes one (or more) wind-transition matrix which is to be applied to the specific area under study. The wind matrices represent a nine-state Markov process of wind description. These data files will be referred to as a group by the name "TRANSMAT".

b. RANDUM is the only subprogram required for running the main program "MCTRAJ". It generates uniformly distributed random real numbers in the range [0., 1.0] and random integers between zero and 2^{31}.

c. OUTPUT is divided basically into three parts. The first part represents the physical boundaries and current chart, merely a printout of data input; the second is a three-hour transition matrix (including wind statistics) on a seasonal basis for each one of the weather stations used in DATASET 2; and the last part is the summary of when and where the sample oil spill is released and how many days are required to impact the specific region and what percentages of the oil spill arrived there.

4. Execution Control:

Control cards arrangement in a typical run:

```
// 'username', keywords and comments
/*MITID(userparm)
/*SRI level
/*MAIN CPU times and output limits
//STEPNAME EXEC  PLIXG,PROG='U.projno.progno.MCTRAJ.
                             LOAD(TEMPNAME)',DISP=SHR
//G.WNDATA1   DD  DSN='U.projno.progno.TRANSMAT.
                        weather-station name 1',DISP=SHR
//G.WNDATA2   DD  DSN='U.projno.progno.TRANSMAT.
                        weather-station name 2',DISP=SHR
         .
         :  (as many as desired, maximum = 6)
         .
//G.SYSIN  DD  DSN='U.projno.progno.MCTRAJ.DATA',DISP=SHR
 /*
```

Explanations:

a. PLIXG is one of the cataloged procedures available from IBM which is used for execution of modules that have already been linked. In the present instance the module is stored on a disk file with the name in quotes after the "=" symbol.

b. To generate a load module for MCTRAJ, the following control cards will compile the source program and store the object modules in a disk file:

1) Allocate storage for data set name
'U.projno.progno.MCTRAJ.LOAD(TEMPNAME);SPACE=(1600,(25,3,1))

2) Control cards for creating load module

```
//'username'
/*MITID
/*MAIN
//STEP1 EXEC FORCE
//C.SYSIN  DD*,DCB=BLKSIZE=2000
     cards of subroutine'RANDUM'
//STEP2 EXEC PLIXCL,PARM.L='MAP,LIST,DCBS'
//C.SYSIN  DD*,DCB=BLKSIZE=2000
     cards of mainprogram 'MCTRAJ'
//L.SYSLMOD  DD  DSN=U.projno.progno.MCTRAJ.LOAD(TEMPNAME),
//     DISP=OLD,DCB=BLKSIZE=6144,SIZE=
/*
```

c. The file sets WNDATA1 and WNDATA2 are each a three-hour transition matrices corresponding to one weather station. Each can be generated by running the program package"T14TRAN" with an appropriate weather tape.

SYSIN is the input dataset file name which contains a description of the physical boundaries, a chart of current, speed, and direction for the specific area under study, as well as other control data for program execution.

5. Input Data Preparation

a. File SYSIN (This file should be the first one to be prepared. The parameters in this file control the characters of the whole program.)

Parameters for Execution:

Card 1: NUM_LNCH = m, NUM_TMAT = n;

m,n are integers, m = number of launch points of oil spill, n = number of transition-matrix files, or weather stations, that will be used as wind data.

Card 2: DRFT=m;

DRFT, which is BINARY FIXED, is the oil-drift factor, and is set normally = 3. This implies the induced velocity on the oil layer will be 3% of the velocity of the wind.

Card 3: MAX_SEA_DAYS=m,NSPILLS=n;

m and n are integers. m is the maximum number of days to be simulated after each release of a sample oil spill. n is the number of sample realizations to be made, recommended to be no less than 200.

Card 4: $m_1\ m_2\ m_3\ \ldots m_M\ n_1, n_2, n_3\ \ldots n_M$

(m_i, n_i), M pairs of integer numbers, are the initial "latitude" and "longitude" in nautical miles where the sample spill is released. These are given relative to the upper left-hand corner of the grid system. (See Figure 1.) Figure 2 should also be referred to for definition of latitude and longitude. M must be equal to NUM_LNCH defined in Card 1.

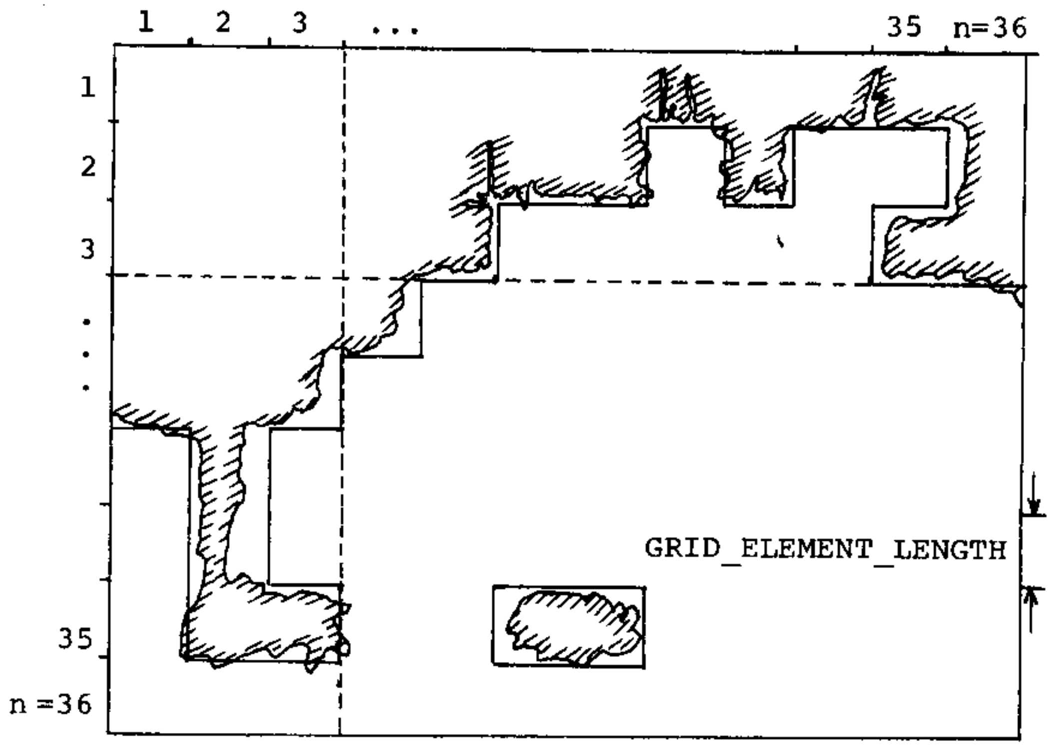


Figure 1. Physical Boundaries of Specific Area

Note: 1) The entire area to be studied should be subdivided into a number of grid elements. Simplify all the complicated coastline geometry as above.

2) The grid pattern should be 36 x 36.

Card 5: 'DB REL 42' 'DB REL 23' ....'DB REL 58'

Labels used to identify the launch points, M of these are to be supplied.

Card 6: GRID_ELEMENT_LENGTH=n;

n, integer, size of square element in nautical miles - i.e. edge length.

Card 7: 'WINTER' 'SPRING' 'SUMMER' 'AUTUMN'

Labels for seasons, supply in order as indicated.

Card 8: 'CALM' 'N' 'NE' 'E' 'SE' 'S' 'SW' 'W' 'NW'

Label system for nine-state wind and current directions, supply these as indicated.

Caution: The conventions used in the program are that winds are named by the direction they are blowing from and the current by the direction of flow (opposite definition to wind).

Cards 9:

$$\begin{pmatrix} k_{11} & \cdots & k_{1n} \\ k_{21} & \cdots & k_{2n} \\ \vdots & & \vdots \\ k_{m1} & \cdots & k_{mn} \end{pmatrix}$$

A(mxn)=(36x36) matrix of integer mode, with each number separated by at least a blank, assigns an integer label to each of the grid elements in Figure 1. This integer label will be associated with a verbal label defined by Cards 16 described below. Sea areas should be assigned the integer label 0.

Cards 10: 'weather-station-name1'
'weather-station-name2'
⋮
(as many cards as the number of stations)

Labels for weather stations. The total number of weather stations must be equal to NUM_TMAT specified in Card 1.

Chart of Current Direction and Speed:

Card 11: "Name of Gulf or Bay'

Label: Specific area where the sample oil spills are released and tracked.

Card 12: 'Current data from EDS'

Label for current information

Cards 13:

$$\begin{pmatrix} 3 & 0 & 1 & \cdots & 7 & 9 \\ 4 & 2 & 3 & \cdots & & \\ \vdots & & & & & \\ 2 & 8 & 4 & \cdots & 0 & 3 \\ 1 & 1 & 3 & \cdots & 4 & 6 \end{pmatrix}$$

(36×36) matrix of current direction: The current direction in each grid element is expressed in terms of the following code: calm=1, N=2, NE=3, E=4, SE=5, S=6, SW=7, W=8, NW=9. (See also Card 8.)

Cards 14:

$$\begin{pmatrix} 0.1 & 0.5 & 0.9 & \cdots & & 0.025 \\ 0.8 & & & & & \vdots \\ \vdots & & & & & \\ 0.0 & 2.5 & 0.4 & \cdot\cdot & 0.8 & 1.2 \end{pmatrix}$$

(36×36) matrix of current speeds, real numbers. The current speed for each grid element is given in knots.

Cards 15: ((COMPOMAT(I,J),J=1,2),I=1,9)

COMPOMAT represents the resolution of a direction vector along the axes of the grid system. Using the notation as shown in Figure 2, input data is as follows:

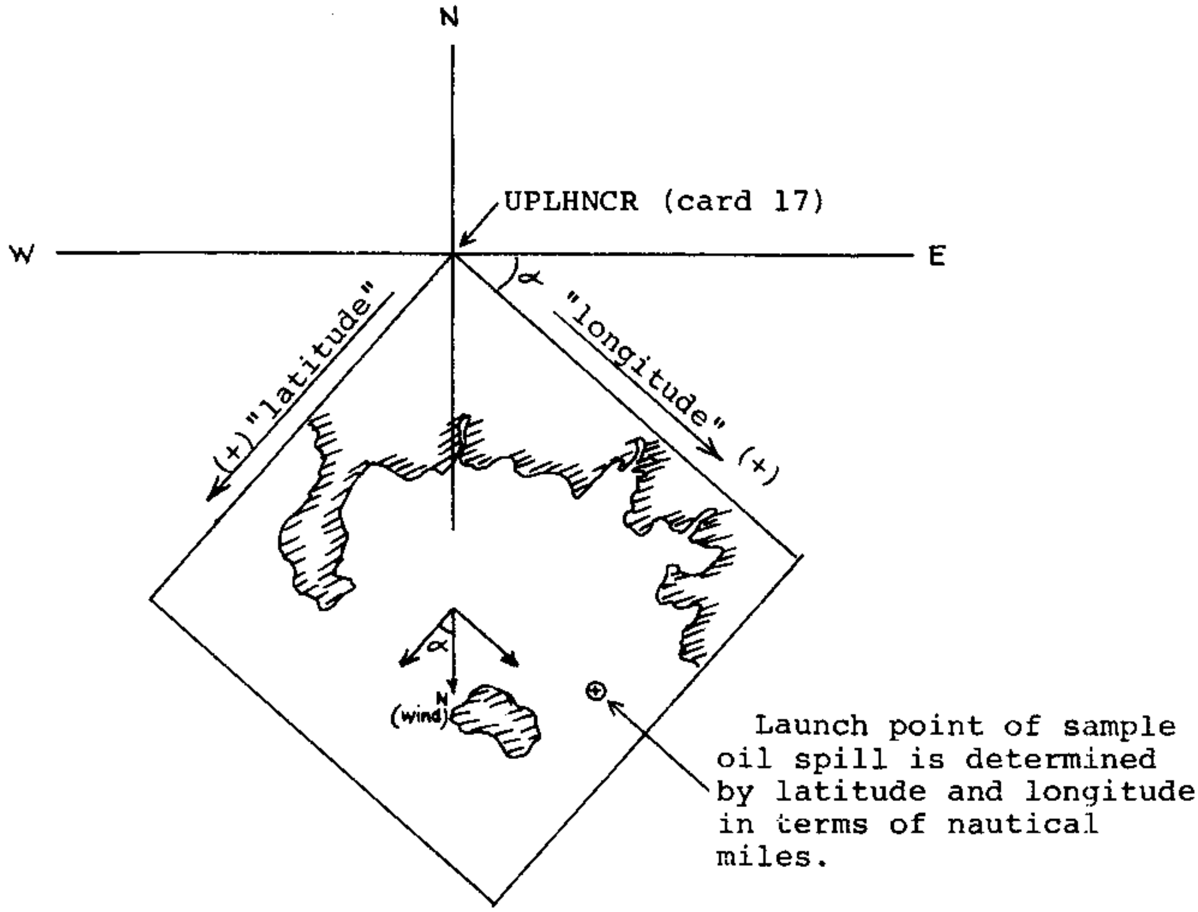


Figure 2. Relation between Grid Coordinates and Global Coordinates

Cards 15 (cont.)

	COMPOMAT(I,1)	COMPOMAT(I,2)
I=1 Direction = Calm	0.	0.
I=2 Direction = North	$\cos\alpha$	$\sin\alpha$
I=3 Direction = North-East	$\cos(\alpha-45°)$	$\sin(\alpha-45°)$
I=4 Direction = East	$\cos(\alpha-90°)$	$\sin(\alpha-90°)$
⋮	⋮	⋮

As an example, for $\alpha=45°$, the following 18 numbers are to be input: 0.0 0.0 ·707 ·707 1. 0. ·707 -·707 0. -1 -·707 -·707 -1. 0. -·707 ·707 0. 1.

Cards 16: 'Geographical name1'
' " name2'
' " '
⋮

Labels for all possible impact regions or places within the area of survey. Each geographical name has its own characteristic number which was assigned earlier by Cards 9. Note that the only difference between land and water is just the labeling.

Card 17: 'label name for Ref. Point'

Label assigned to the reference point (upper left-hand corner) of the grid System. As an example the origin may be denoted by '63.5N - 147.2W'.

Cards 18:

$$\begin{pmatrix} 1 & 1 & 1 & \cdots & 2 & 2 \\ 1 & 1 & 1 & & 2 & 2 \\ 1 & 1 & 1 & & & \\ \vdots & & & & & \\ 3 & 3 & 3 & & 3 & 3 \\ 3 & 3 & 3 & & 3 & 3 \end{pmatrix}$$

(36×36) matrix. This integer matrix indicates which wind-transition matrix will be used for which grid element. Characteristic value 1,2,3... corresponds to the number assigned to each weather station 1,2,3... respectively, which are in turn described by data files WNDATA1, WNDATA2, WNDATA3,... respectively.

b. File (s)WNDATAj contain card images of the wind-data file-sets wind-transition matrices generated by the program T14TRAN. Details concerning input and output relation of T14TRAN are described in a separate documentation (Chapter II of this report). Here it suffices to know that each run of T14TRAN will generate wind transition matrices associated with one particular weather station. Each data file thus generated can be saved for repeated application whenever the wind data of that station is desired. In order to relate the source of such data with the proper weather station, the file when created is tagged with the name of the weather station. For example see the DSN name of the //G.WNDATA1 card in Section II.4. In program MCTRAJ it will be referred to internally as file WNDATA1. The wind data described by WNDATA1 will then be applicable in a region consisting of the set of grid elements whose wind-transition-matrix numbers have the value of 1 [cards 18 of "SYSIN"].

When the wind-transition matrices (abbreviated here as "TRANSMAT") are availabe on disk, no additional data preparation in connection with file(s) WNDATAj will be necessary. However, we show below, for the sake of completeness, the structure of a typical WNDATA fileset which is necessary for successful execution of MCTRAJ. One should bear in mind that the number of such filesets should be the same as the number of weather stations that the user would like to use in the simulation.

File Structure of WNDATAj:

(1) Three-hour Wind Transition Matrices

Cards 1:

$$\begin{bmatrix} x_{11} & x_{12} & \cdots & x_{18} & x_{19} \\ \cdot & & & & x_{29} \\ \cdot & & & & \cdot \\ \cdot & & & & \cdot \\ \cdot & & & & \cdot \\ x_{81} & & & & x_{89} \\ x_{91} & \cdots & & x_{98} & x_{99} \end{bmatrix}$$

(9×9) matrix (real mode) for winter. x_{ij} represents the probability that the wind, now blowing from direction i, wiil be coming from direction j in three hours.

Cards 2: Same as Cards 1, except for spring

Cards 3: " " " " " " summer

Cards 4: " " " " " " autumn

(2) Wind Statistics for Mean Velocity and Standard Deviation

Card 5: x_1 y_1

Card 6: x_2 y_2

⋮

Card 13: x_9 y_9

Real numbers. These are summaries of wind statistics; x_i is the wind mean velocity and y_i the standard deviation for each assigned direction. The direction starts from calm (card 5) and ends with NW (card 13).

(3) Steady-State Probabilities for Each Season

Card 14: a_1 a_2 a_3 .... a_9

Card 15: b_1 b_2 b_3 .... b_9

Card 16: c_1 c_2 c_3 .... c_9

Card 17: d_1 d_2 d_3 .... d_9

Real number. These numbers define the probability of the occurrence of a certain wind direction for each season. Each corresponds to one card.

6. Sample Data and Output

The following data corresponds to a typical run made in generating results of the "Gulf-of-Alaska Oil-Spill Study" described in Ref. [3]. It is used here as a sample for the purpose of illustration. Wind data from three weather stations were used in this run. They are given labels of YAKUTAT. ALASKA, MIDDLETON ISLAND. ALASKA, and KOKIAK, KOKIAK ISLAND. ALASKA.

a. Input

(1) Data Listing of File SYSIN (pages 15-19)

(2) Data Listing of File WNDATAj (pages 20-24)

The following is typical of all wind-data files. The case of station Yakutat is used for illustration. Note that all labels and headings are to be omitted if data is supplied as separate input.

(1) Data Listing of File SYSIN

```
NUM_LNCH=4,NUM_TMAT=3;
DRFT=3;
MAX_SEA_DAYS=150,NSPILLS=200;
 18 62 65 252  465 330 277 163
 'DB REL 42' 'DB REL 23' 'ADS 2' 'DB REL 58'
GRID_ELEMENT_LENGTH=15;
'WINTER' 'SPRING' 'SUMMER' 'AUTUMN'
'CALM' ' N' ' NE' ' E' ' SE' ' S' ' SW' ' W' ' NW'
16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16
16 16 16 16 16 17 17 17 17 17 18 18 18 18 18 18 18 18
16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16
16 16 16 16  0  0  0  0  0  0  0  0  0  0  0  0  0 18
15 15 15 15 15 15 15 15 15 15 15 15 15 15 15 15 15 15
15 16  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0 19
15 15 15 15 15 15 15 15 15 15 15 15 15 15 15 15 15  0
 0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0 19
15 15 15 15 15 15 15 15 15 15 15 15 15 15 15 15  0  0
 0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0 19
15 15 15 15 15 15 15 15 15 15 15 15 15 15 15 15  0  0
 0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0 19
14 14 14 14 14 14 14 14 14 14 14 14 14 14 15  0  0  0
 0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0 19
12 12 12 12 12 12 12 13 13 13 13 14  0  0 15  0  0  0
 0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0 19
12 12 12 12 12 12 12  0  0  0 14  0  0  0  0  0  0  0
 0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0 20
12 12 12 12 12 12 12 12  0  0  0  0  0  0  0  0  0  0
 0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0 20
12 12 12 12 12 12 12 12  0 11  0  0  0  0  0  0  0  0
 0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0 20
 7  7  8  8  8 12 12 12 12 11  0  0  0  0  0  0  0  0
 0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0 20
 7  0  0  8  8  8 10 10 10 11  0  0  0  0  0  0  0  0
 0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0 20
 7  0  8  8  8 10 10 10  0  0  0  0  0  0  0  0  0  0
 0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0 20
 7  0  8  8  8 10 10  0  0  0  0  0  0  0  0  0  0  0
 0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0 20
 7  0  8  8  8 10 10  0  0  0  0  0  0  0  0  0  0  0
 0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0 20
 7  0  0  8  8  9  9  0  0  0  0  0  0  0  0  0  0  0
 0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0 20
 7  0  0  8  8  9  9  0  0  0  0  0  0  0  0  0  0  0
 0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0 20
 7  0  0  8  8  8  9  0  0  0  0  0  0  0  0  0  0  0
 0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0 20
 7  7  0  0  0  8  9  0  0  0  0  0  0  0  0  0  0  0
 0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0 20
 7  7  0  0  0  9  0  0  0  0  0  0  0  0  0  0  0  0
 0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0 20
 7  7  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
 0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0 20
 7  7  7  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
 0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0 21
 7  7  0  0  0  0  1  1  0  0  0  0  0  0  0  0  0  0
 0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0 21
 7  7  7  6  0  0  1  1  0  0  0  0  0  0  0  0  0  0
 0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0 21
```

```
 6  6  6  6  0  0  1  1  2  0  0  0  0  0  0  0  0  0
 0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0 21
 6  6  6  6  6  0  1  2  2  2  0  0  0  0  0  0  0  0
 0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0 21
 6  6  6  6  6  0  2  2  2  2  0  0  0  0  0  0  0  0
 0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0 21
 6  6  6  6  6  0  3  3  3  3  0  0  0  0  0  0  0  0
 0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0 21
 6  6  6  6  0  0  3  3  3  0  0  0  0  0  0  0  0  0
 0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0 21
 6  6  6  6  0  0  3  3  3  0  0  0  0  0  0  0  0  0
 0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0 21
 6  6  6  6  0  0  0  0  0  0  0  0  0  0  0  0  0  0
 0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0 21
 6  6  6  6  0  0  0  0  4  4  0  0  0  0  0  0  0  0
 0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0 21
 5  5  5  5  0  0  0  0  0  0  0  0  0  0  0  0  0  0
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 5  5  5  5  5  0  0  0  0  0  0  0  0  0  0  0  0  0
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 5  5  5  5 24 24 24 24 24 24 24 24 24 24 24 24 23 23
23 23 23 23 23 23 23 23 22 22 22 22 22 22 22 22 22 22
'YAKUTAT, ALASKA'
'MIDDLETON ISLAND, ALASKA'
'KOKIAK, KODIAK ISLAND, ALASKA'
'GULF OF ALASKA'
  'NULL HYPOTHESIS, NO CURRENT AT ALL'
 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
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 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
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 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
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'CAPE DOUGLAS-CAPE IGVAK................'
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'SEWARD..................................'
'MONTAGUE ISLAND.........................'
'WESTERN PRINCE WILLIAM SOUND............'
'EASTERN PRINCE WILLIAM SOUND............'
'HINCINBROOK ISLAND-KATALLA..............'
'CAPE ST. ELIAS-ICY CAPE.................'
'PT. RIOU-YAKUTAT........................'
'YAKUTAT-CAPE FAIRWEATHER................'
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(2) Data Listing of File WNDATAj

3 HOUR TRANSITION MATRIX: WINTER YAKUTAT, ALASKA

	CALM	N	NE	E	SE	S	SW	W	NW
CALM	0.691	0.030	0.112	0.111	0.023	0.006	0.003	0.011	0.014
N	0.343	0.043	0.100	0.229	0.043	0.057	0.014	0.057	0.114
NE	0.185	0.029	0.327	0.398	0.031	0.010	0.003	0.009	0.007
E	0.073	0.007	0.154	0.659	0.077	0.011	0.009	0.006	0.003
SE	0.057	0.007	0.084	0.324	0.395	0.091	0.020	0.014	0.007
S	0.041	0.017	0.091	0.198	0.140	0.380	0.091	0.025	0.017
SW	0.094	0.047	0.156	0.109	0.047	0.172	0.281	0.078	0.016
W	0.250	0.038	0.077	0.058	0.077	0.038	0.192	0.212	0.058
NW	0.439	0.073	0.073	0.171	0.049	0.073	0.000	0.024	0.098

WIND STATISTICS FOR WINTER

DIRECTION	MEAN	STD DEV
CALM	0.0000E+00	0.0000E+00
N	4.0428E+00	1.5347E+00
NE	6.3711E+00	3.6488E+00
E	8.8851E+00	4.4299E+00
SE	1.1811E+01	7.1261E+00
S	9.2610E+00	4.0782E+00
SW	9.5938E+00	3.7405E+00
W	6.9231E+00	4.5777E+00
NW	4.6829E+00	2.2679E+00

3 HOUR TRANSITION MATRIX: SPRING YAKUTAT, ALASKA

	CALM	N	NE	E	SE	S	SW	W	NW
CALM	0.479	0.043	0.114	0.174	0.035	0.036	0.041	0.048	0.030
N	0.218	0.084	0.143	0.210	0.101	0.042	0.025	0.059	0.118
NE	0.175	0.047	0.244	0.394	0.055	0.017	0.017	0.025	0.025
E	0.064	0.026	0.114	0.600	0.123	0.036	0.022	0.010	0.005
SE	0.048	0.013	0.066	0.324	0.420	0.092	0.020	0.007	0.011
S	0.059	0.032	0.059	0.158	0.167	0.275	0.135	0.077	0.041
SW	0.112	0.027	0.045	0.054	0.031	0.157	0.332	0.148	0.094
W	0.210	0.016	0.033	0.045	0.021	0.021	0.152	0.362	0.140
NW	0.167	0.058	0.083	0.038	0.038	0.006	0.071	0.288	0.250

WIND STATISTICS FOR SPRING

DIRECTION	MEAN	STD DEV
CALM	0.0000E+00	0.0000E+00
N	4.7479E+00	1.9628E+00
NE	5.2618E+00	2.6099E+00
E	7.8064E+00	3.4992E+00
SE	1.0384E+01	5.9109E+00
S	7.3184E+00	3.2104E+00
SW	6.5157E+00	2.7867E+00
W	6.5656E+00	2.5591E+00
NW	6.4615E+00	2.5605E+00

3 HOUR TRANSITION MATRIX: SUMMER YAKUTAT, ALASKA

	CALM	N	NE	E	SE	S	SW	W	NW
CALM	0.405	0.048	0.064	0.127	0.060	0.056	0.066	0.093	0.081
N	0.194	0.140	0.093	0.116	0.062	0.031	0.078	0.124	0.163
NE	0.190	0.065	0.155	0.400	0.085	0.020	0.030	0.010	0.045
E	0.041	0.019	0.092	0.605	0.170	0.035	0.017	0.012	0.009
SE	0.043	0.020	0.033	0.296	0.439	0.110	0.043	0.012	0.004
S	0.078	0.033	0.015	0.100	0.190	0.290	0.175	0.078	0.041
SW	0.122	0.032	0.019	0.026	0.032	0.124	0.315	0.249	0.082
W	0.155	0.023	0.010	0.008	0.010	0.021	0.195	0.421	0.157
NW	0.169	0.053	0.023	0.045	0.015	0.034	0.113	0.297	0.252

WIND STATISTICS FOR SUMMER

DIRECTION	MEAN	STD DEV
CALM	0.0000E+00	0.0000E+00
N	4.4077E+00	1.6158E+00
NE	4.4800E+00	1.7719E+00
E	6.7646E+00	3.1329E+00
SE	7.9451E+00	3.5531E+00
S	6.1896E+00	2.5149E+00
SW	6.1379E+00	2.3198E+00
W	6.6088E+00	2.4909E+00
NW	5.5225E+00	2.3108E+00

3 HOUR TRANSITION MATRIX: AUTUMN YAKUTAT, ALASKA

	CALM	N	NE	E	SE	S	SW	W	NW
CALM	0.553	0.040	0.116	0.143	0.030	0.030	0.022	0.042	0.025
N	0.266	0.147	0.266	0.147	0.037	0.000	0.000	0.064	0.073
NE	0.117	0.024	0.383	0.388	0.042	0.007	0.007	0.012	0.019
E	0.062	0.016	0.188	0.592	0.096	0.015	0.013	0.010	0.008
SE	0.042	0.023	0.076	0.335	0.363	0.115	0.023	0.020	0.003
S	0.068	0.034	0.081	0.223	0.196	0.236	0.108	0.034	0.020
SW	0.116	0.036	0.080	0.098	0.063	0.170	0.268	0.134	0.036
W	0.275	0.049	0.042	0.049	0.014	0.035	0.127	0.310	0.099
NW	0.395	0.070	0.012	0.058	0.070	0.035	0.023	0.163	0.174

WIND STATISTICS FOR AUTUMN

DIRECTION	MEAN	STD DEV
CALM	0.0000E+00	0.0000E+00
N	4.6727E+00	1.8689E+00
NE	5.9463E+00	2.8041E+00
E	8.0216E+00	3.9729E+00
SE	1.1364E+01	7.1359E+00
S	8.7230E+00	5.1607E+00
SW	7.7678E+00	4.3670E+00
W	5.5574E+00	2.6787E+00
NW	5.4884E+00	2.2295E+00

STEADY STATE PROBABILITIES YAKUTAT, ALASKA

	WINTER	SPRING	SUMMER
CALM	0.264	0.165	0.141
N	0.019	0.032	0.035
NE	0.161	0.109	0.054
E	0.396	0.340	0.252
SE	0.082	0.124	0.139
S	0.034	0.060	0.073
SW	0.018	0.061	0.103
W	0.014	0.066	0.130
NW	0.011	0.042	0.072

b. <u>Output</u>

The typical output consists of first a printout of all relevant input data, and then the results. The supplied data will be printed out in the following sequence:

1) 36×36 map of geographical region.

2) 36×36 matrix of presumed current pattern - directional assignment.

3) 36×36 matrix of presumed current pattern - speed assignment.

4) For each weather station:
   a) 3-hour transition matrices and wind statistics for each of the four seasons;
   b) steady-state probabilities for each direction and season.

The results will be presented in the following sequence. The contents are self-explanatory.

1) Characteristics of launch points.

2) For each launch point, a summary of trajectory behavior for each season. (See printout to follow.)

SUMMARY OF TRAJECTORY BEHAVIOR

WIND DRIFT SET AT 3.0 PERCENT WIND SPEED

CURRENT HYPOTESIS: NULL HYPOTHESIS, NO CURRENT AT ALL

TRANSITION MATRICES USED WERE:

YAKUTAT, ALASKA
MIDDLETON ISLAND, ALASKA
KOKIAK, KODIAK ISLAND, ALASKA

LAUNCH POINT: DR REL 23

SEASON: WINTER

IMPACT REGION	PERCENTAGE	AVERAGE TIME AT SEA	MINIMUM TIME AT SEA
REMAINED IN AREA........................	50.00	150 DAYS	150 DAYS
AFOGNAK ISLAND..........................	2.00	129 DAYS	121 DAYS
NORTH KODIAK ISLAND.....................	0.00	0 DAYS	150 DAYS
SOUTH KODIAK ISLAND.....................	0.00	0 DAYS	150 DAYS
TRINITY ISLANDS.........................	0.00	0 DAYS	150 DAYS
CAPE IGVAK-AMBER BAY....................	0.00	0 DAYS	150 DAYS
CAPE DOUGLAS-CAPE IGVAK.................	0.00	0 DAYS	150 DAYS
WEST SHORE OF COOK INLET................	0.00	0 DAYS	150 DAYS
EAST SHORE OF COOK INLET................	0.00	0 DAYS	150 DAYS
SOUTHERN KENAI PENINSULA................	25.50	101 DAYS	72 DAYS
SEWARD..................................	6.00	108 DAYS	74 DAYS
MONTAGUE ISLAND.........................	7.50	75 DAYS	47 DAYS
WESTERN PRINCE WILLIAM SOUND............	0.00	0 DAYS	150 DAYS
EASTERN PRINCE WILLIAM SOUND............	0.00	0 DAYS	150 DAYS
HINCINBROOK ISLAND-KATALLA..............	1.00	60 DAYS	52 DAYS
CAPE ST. ELIAS-ICY CAPE.................	7.50	38 DAYS	28 DAYS
PT. RIOU-YAKUTAT........................	0.00	0 DAYS	150 DAYS
YAKUTAT-CAPE FAIRWEATHER................	0.00	0 DAYS	150 DAYS
CAPE FAIRWEATHER-CHICHAGOF ISLAND.......	0.00	0 DAYS	150 DAYS
NEARSHORE, SOUTHEAST OCEAN BOUNDARY.....	0.00	0 DAYS	150 DAYS
SOUTHEAST OCEAN BOUNDARY................	0.50	136 DAYS	137 DAYS
SOUTHERN PORTION, SOUTHEAST OCEAN BNDRY.	0.00	0 DAYS	150 DAYS
SOUTHERN PORTION, SOUTHWEST OCEAN BNDRY.	0.00	0 DAYS	150 DAYS
SOUTHWEST OCEAN BOUNDARY................	0.00	0 DAYS	150 DAYS
NEARSHORE, SOUTHWEST OCEAN BOUNDARY.....	0.00	0 DAYS	150 DAYS

7. References

[1.] Devanney, J. W. and Stewart, R., "Potential Spill Trajectories", Massachusetts Institute of Technology Report No. MITSG 73-5, February 1973, pp. 51-119.

[2.] Hoult, D. P., "Oil Spreading on the Sea", *Annual Review of Fluid Mechanics*, 1972, pp. 59-64.

[3.] Devanney, J. W., Stewart, R. J. and Briggs, W., "Oil Spill Trajectory Studies for Atlantic Coast and Gulf of Alaska", Report to Council on Environmental Quality, MITSG Report No. 74-20, April 1974, pp. 1-186.

MODULE II: Program T14TRAN

1. Identification:

Title:	T14TRAN (TDF14 Tape Generated Transition Matrices)
Author:	J. W. Devanney, III R. J. Stewart
Documented by:	R. W. Yeung Y. H. Kim
Specification:	Machine: IBM370 Source Language: PL/I Supporting Peripheral Equipment: Tape Drive
Subprogram:	RANDUM PLIPLT

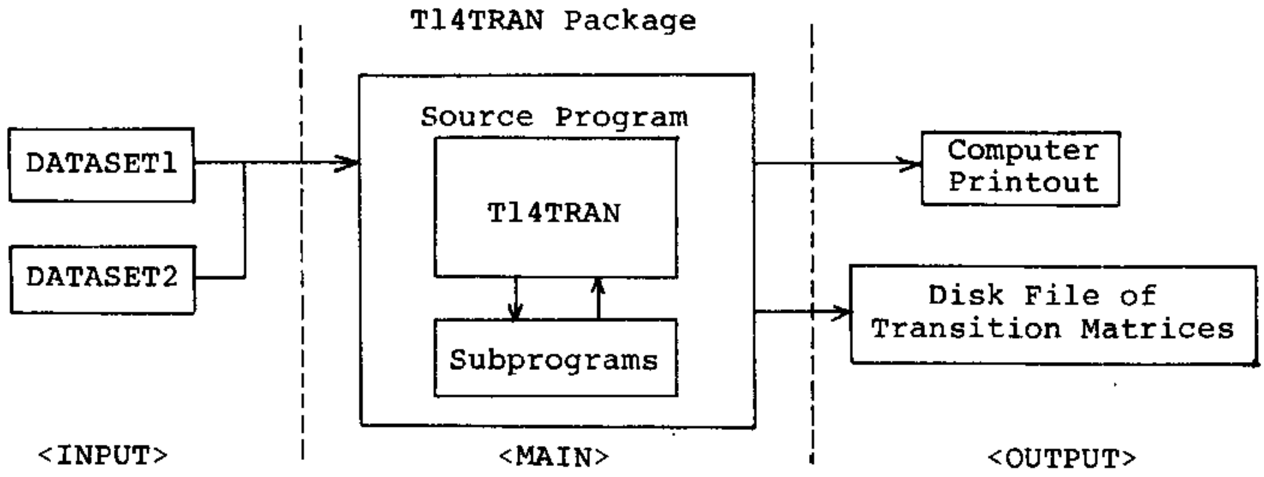
2. Purpose:

T14TRAN is a program which takes as input a TDF-14* formatted data tape prepared by the National Climatic Center and generates as output the resultant probabilistic wind transition matrices to be used by the offshore (MCTRAJ) and onshore (NEARSHORE) spill-tracking programs.

---

*Tape-data Format Code.

3. Overall Program Description



a. INPUT consists of one set of data cards (dataset 1) specifying execution parameters and a TDF-14 formatted tape (dataset 2) which is the core data. A typical TDF-14* tape contains detail information of wind direction and speed recorded over a period of many years at a specific weather station.

b. The subprogram RANDUM generates uniformly distributed random real numbers between zero and one, and random integers between zero and 2^{31}. The subprogram PLIPLT plots several dependent variables against a base variable. This is a MIT-based plotting routine in PLI.

c. OUTPUT consists of three parts:

Part (1) is merely a reproduction of the execution control data input.

Part (2) contains the three-hour transition matrices and the analysed statistical results of wind data for each season.

---

*TDF-14 tapes and a manual describing data format can be obtained from the National Climatic Center of National Oceanic and Atmospheric Administration, Environmental Data Service, Ashville, North Carolina.

Part (3) shows wind speed distribution in the form of tables and plots.

4. Execution Control

Control card arrangement in a typical run for IMB 370 at MIT is as follows:

```
//'username', keywords and comments
/*MITID
/*SRI level
/*MAIN  CPU time limit and line limits
/*SETUP  DDNAME=WDTAPE,UNIT=TAPE9,ID=(SLOTNO,NORING,SAVE,NL),
/*A=authentication characters, comment
    [NOAA tapes usually come as no-label tapes; this control
     card requests tape mounting.]
//STEPNAME  EXEC  PLIXG,PROG='U.projno.progno.TRANSMAT.
                              LOAD(TEMPNAME)'
    [Call PLI-execution program to execute load module on
     disk file.]
//G.TMAT  DD  DSN=U.projno.progno.TRANSMAT. weather station name,
//     DCB=BLKSIZE=12000,DISP=(OLD,KEEP)
    [This disk space must be available for storing results
     before "GO" stage is possible.]
//G.WDTAPE DD UNIT=TAPE9,VOL=SER=SLOTNO,DISP=CSHR,KEEP),
//     LABEL=(1,NL)
    [WDTAPE is the file name for the supplied data tape,
     referred to internally by T14TRAN.]
//G.SYSIN  DD *
{data cards for SYSIN}
/*
/*EOJ
```

In preparing these job control cards, we assume that the TDF-14 tape has been assigned a specific slot number and certain authentication characters by the tape librarian. Due to the large volume of output data, the results are concurrently written on a disk file called "TMAT". Hence, allocation of disk space should be made beforehand, e.g. a dataset name as below will be sufficiently informative of the nature of the stored data for future reference:

DSN=U.projno.progno.TRANSMAT. weather station name

The procedure PLIXG performs execution of a load module only. This is assumed to be stored on the fileset "TRANSMAT" with DSN name given between quotes after the "=" symbol.

5. Input Data Preparation

a. File SYSIN (This file requires only one card.)

Card 1: '(1)' '(2)' (3) '(4)' (See the sample data and output.)

(1): variable name: DSRD_STN_NUM (Desired Weather Station Number). The National Climatic Center assigns a specific number for each weather station. If this station number does not match with the station number on the TDF-14 tape after a number of trials, the job will be aborted.

(2): variable name: LTR_STN_NUM (Later Weather Station Number). Set as any arbitrary number. It serves to stop execution of the program. If more than one file occurs on the tape, corresponding to different station numbers, LTR_STN_NUM should be the same as the number for the second file.

(3): variable name: LIMITREAD. LIMITREAD indicates the maximum number of physical records the user allows the program to search to find the desired weather station number.

(4): variable name: WIND_LABEL. This is the label to be used for the weather station under study.

b. File WDTAPE

Detailed information can be obtained from the TDF-14 manual. We provided below in Table II.1 and Table II.2 a brief description of how TDF-14 tapes are formated.

Table II.1.

Brief Explanation of TDF-14 Tape Format - Tape Deck Type 1440

	Bytes	Element	Example	Remarks
header (15 bytes)	4	tape deck no.*	1440	
	5	station no.	14704	Otis Air Force Base MA.
	2	year *	49	1949
	2	month	01	01=Jan.; 12=Dec.
	2	day	09	01→31: day of month
00 hr weather information (80 bytes)	2	hour	00	00~23: local standard time.
	8	*		other information
	2	wind direction	77	see the next page
	3	wind speed	13	000~199(knots)
	64	*		other information
	1	record mark*	ǂ or blank	

one physical tape record (six observations and 495 bytes long)

80 bytes for 01 hr — 01 hr information

Note: data may be recorded at 3-hour interval, particularly for most of the East Coast stations since 1965.

4×80 =320 bytes:

02 hr "

03 hr "

04 hr "

05 hr "

15 bytes for header as above

another physical record — 480 bytes next 06 through 11 hr

...

*This information is <u>not</u> used by program.

Table II.2.

Wind Direction Code

Direction	Code	Degree (°)
N	11	349~011
NNE	12	012~033
NE	22	034~056
ENE	32	057~078
E	33	079~101
ESE	34	102~123
SE	44	124~146
SSE	54	147~168
S	55	169~191
SSW	56	192~213
SW	66	214~236
WSW	76	237~258
W	77	259~281
WNW	78	282~303
NW	88	304~326
NNW	18	327~348
Calm	00	

6. Sample Data and Output

a. Input

(1) SYSIN

Card 1:

'14704' '12345' 500 'OTIS AFB AT FALMOUTH, MA'

(2) WDTAPE (TDF-14 formatted data)

One magnetic tape from NOAA of Otis AFB weather station wind data.

b. Output

After the tape has been properly positioned so that data acquisition can start from 00 hr, the program proceeds to input data day by day. The data for the first 20 days are printed out for visual inspection. The interpretation for the following variables are:

CDDIR = wind direction, see Table II.2.

F2DGTS,BITRECDGT combine to define the wind speed as follows:
wind speed (knots) = 10*F2DGTS+FIXZD(BITREPCDGT)

CDGT = alphanumerical representation of the last 4 digits of BITREPCDGT

The results of the statistical analysis of the wind data is next printed out page by page in the form of transition matrices, and concurrently stored on the disk file 'TRANSMAT' supplied by the DD statement as described in Section II.4. The typical printout is shown in Section I.6.

Finally, a tabulation and computer plot for the speed distribution in each of the octant directions are given. These are repeated for each season. The definition of the variable DEPj in these printouts is

$$\text{DEPj} = (\text{direction}_{j+1}) \text{ for } j = 1,8$$

where direction_1, direction_2,... correspond to N, NE,... etc. and

$$\text{DEP}_9 = \left(\sum_{j=1}^{8} \text{DEPj}\right)/8$$

7. References

[1] Devanney, J. W. and Stewart, R., "Potential Spill Trajectories", Massachusetts Institute of Technology Report No. MITSG 73-5, February 1973, pp. 51-119.

[2] Survey of TD 1440 Data Format, National Climatic Center, U. S. Dept. of Commerce, National Oceanic and Atmospheric Administration Environmental Data Service.

[3] TDF-14 Surface Observations, National Climatic Center, U.S. Dept. of Commerce, National Oceanic and Atmospheric Administration Environmental Data Service.

MODULE III. Program NEARSHORE

1. Identification:

Title:	NEARSHORE (Nearshore Oil-Spill Tracking Simulation)
Author:	J. W. Devanney, III R. J. Stewart
Documented by:	R. W. Yeung Y. H. Kim
Specification:	Machine: IBM370 Source Language: PL/I Supporting Peripheral Equipment: Disk Sequential
Component Subprograms:	RANDUM (FORTRAN IV) LGAM (PL/1)

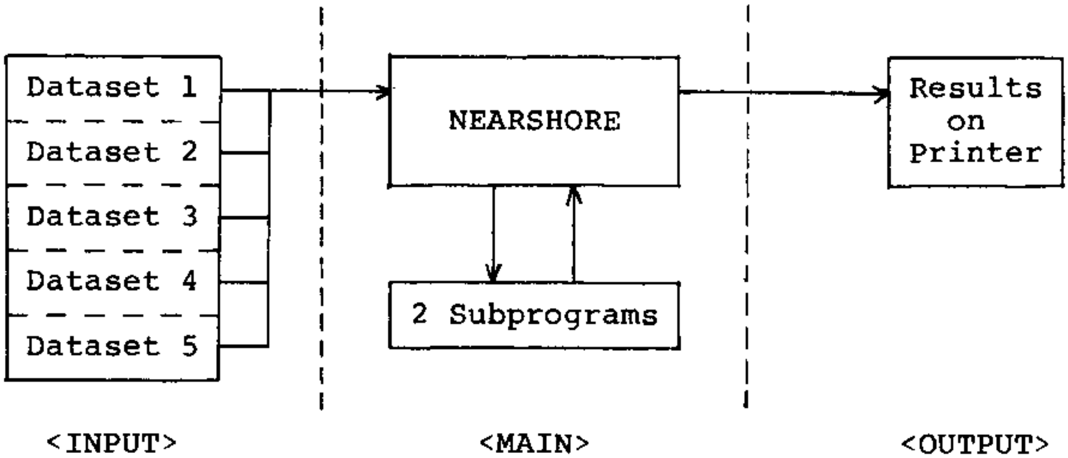
2. Purpose:

NEARSHORE is the nearshore oil-spill tracking-simulation program based on the following trajectory equation

$$\vec{U}_{oil} = \vec{U}_{current} + f\,\vec{U}_{surface\,wind}$$

where f is the drift speed factor. This is the same equation used by Program MCTRAJ, except, in the case of NEARSHORE, $\vec{U}_{current}$ allows the specification of an additional component corresponding to the presence of tidal current whereas MCTRAJ does not. Further, more detailed statistical analysis of the spill is given by NEARSHORE than by MCTRAJ. The tidal current is treated as a non-random quantity which could be assigned a direction and speed as functions of time and of the physical location. The wind is modeled as a nine-state Markov process as in the case of MCTRAJ.

3. Overall Program Description



a. The INPUT block consists of five dataset files.

Dataset 1 (file name = SYSIN) contains data describing the characteristics of the problem: (1) labels for impact areas, seasons, current directions, wind directions, launch points, etc.; (2) definition of physical boundary and map size, drift factor; (3) number of sample spills to be released, location of launch points, etc.

Dataset 2 (file name = NBMAP) assigns integer "labels" to each grid element within the map of the region. Corresponding to each value of this integer, an alphanumeric (verbal) label, usually the geographical name, will be assigned. The aggregate serves to define the extent of the physical boundaries.

Dataset 3 (file name = BCURR) is the current chart that shows the tidal current speed in global latitude and longitude direction for each hour.

Dataset 4 (file name = CFAC) is the current factor, as a function of the time of the day, which will be used to multiply the speed data defined by Dataset 3 to obtain the tidal variations.

Dataset 5 (file name = WNDATA) is a "TRANSMAT" (Wind Transition Matrices) which has been generated earlier from the wind data for the specific area under study. The procedure for the generation of a "TRANSMAT" can be found under the documentation for the program package "T14TRAN".

b. RANDUM and LGAM are subprograms required for the successful running of NEARSHORE. RANDUM is a program which generates uniformly distributed random real numbers between zero and one, and random integers between zero and 2^{31}. The subprogram LGAM computes the double precision natural logarithm of the Gamma function for a given argument.

c. OUTPUT - A summary of the type of information presented is given below. The output contains first a griditized description of the physical area under study. Next, the results of the simulation study are summarized for each season. Results for each season are arranged in an identical fashion. Under the heading of each season, the statistical results for the movement of the primary, secondary and tertiary components of an oil sample (see Figure 1) are presented in succession. The statistical results consist of the following set of tabulations:

(1) Summary of spill probabilities for each impact region, defined by the labels of Dataset 2;

(2) The statistics of wind conditions which drive the spill distribution of (1);

(3) Time history of oil accumulation in three selected "critical areas";

(4) Short-term and long-term wind conditions at the time of grounding for each impact region.

4. Execution Control

Control cards arrangement for a typical run using the IBM 370 machine at MIT is as follows:

```
//'username', keywords comments
/*MITID
/*SRI level
/*MAIN CPU time and output limits
//STEPNAME  EXEC  PLIXG,PROG='U.projno.progno.OIL.LOAD
                                                  (TEMPNAME)',
//       DISP=SHR
//G.BCURR  DD  DSN=U.projno.progno.CURRENT.DATA,DISP=SHR
//G.CFAC  DD  DSN=U.projno.progno.CURRENT.FACTOR,DISP=SHR
//G.NBMAP  DD  DSN=U.projno.progno.region.MAP,DISP=SHR
//G.WNDATA  DD  DSN=U.projno.progno.TRANSMAT.weather station,
                                                  DISP=SHR
//G.SYSIN  DD  DSN=U.projno.progno.NEARSHORE.DATA,DISP=SHR
/*
```

PLIXG is used here to execute a load module which is stored on disk under the name of U.projno.progno.OIL.LOAD(TEMPNAME) . The files BCURR, CFAC, NBMAP and WNDATA are already placed on disk, ready to be used. For the sake of convenient reference, we summarize below the physical meaning of each of the data files:

<u>SYSIN</u> supplies general information such as alphanumeric labels and values of run parameters;

<u>NBMAP</u> contains a map of physical boundaries of the region;

<u>BCURR</u> contains current information of the basin or bay under study;

<u>CFAC</u> contains the speed factor for tidal currents;

<u>WNDATA</u> stores the wind-transition matrices applicable to this study.

5. Input Data Preparation

a. File SYSIN

Card 1: m_1 m_2 n x

Variable names = XMAT, YMAT, INC, TINC. (XMAT,YMAT), integers, represent the number of horizontal and vertical grid elements to be used (see Figure 2). There is no restriction on size.
INC = the number of time increments to be taken per hour in the simulation. Four is a reasonable number.
TINC = a real number, being the inverse of INC.

Card 2: OUTPUTFORM='a';m x

Variable name=(OUTPUTFORM,DRFT,GRID-LENGTH). 'a' is either 'SHORT' or 'LONG'. If 'LONG' is specified a more detailed print-out of input data covering
(i) current speed and direction,
(ii) current factor,
(iii) wind transition matrices,
will be reproduced. Such print-out will be skipped if 'SHORT' is specified.
m = drift factor, an integer specifying the percentage of surface wind speed which is to be used in the trajectory equation.
x = a real number indicating the length of each square grid-element, in terms of nautical miles.

Card 3: 'PRIMARY' 'SECONDARY' 'TERTIARY'

Variable name=(GROUP(3)). These alphanumeric labels are used to designate the volumetric components of oil spills as shown in Figure 1. The categorization is defined by the numbers R and R2 on Card 14.

Card 4: m_1 m_2

Variable name=(MAX_SEA_DAYS,NSPILLS), integers
m_1 is the maximum number of days that the user would like to trace the trajectory for each oil spill. A reasonable number is ten.
m_2 is the total number of sample oil spills released, A minimum of 200 is recommended.

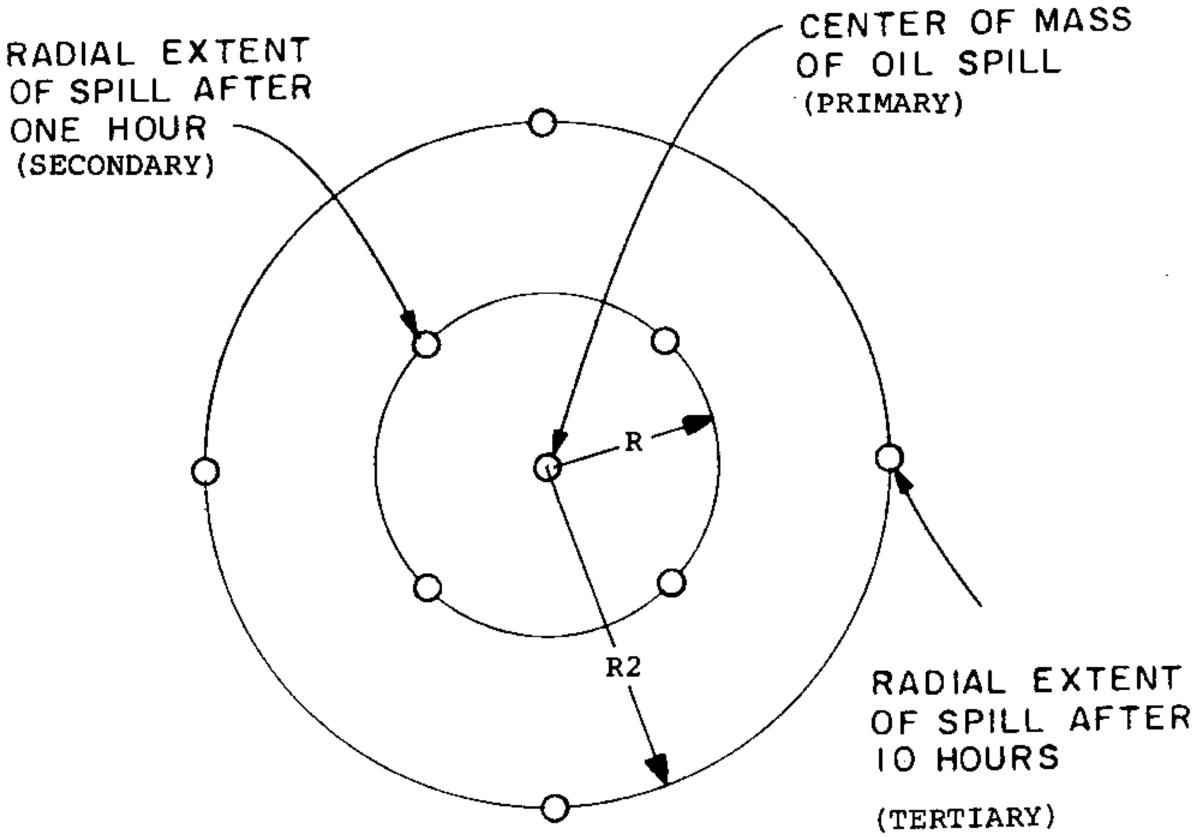


FIGURE 1. 9 POINT ARRAY REPRESENTATION OF 1 MILLION GALLON OIL SPILL

Card 5: 'WINTER' 'SPRING' 'SUMMER' 'AUTUMN'

Variable name=(SEASONS(4)). Labels to be supplied as indicated.

Card 6: n m_1 m_2 m_3

Variable name=(TCUMINR,IMPACTINDX(3)). integers

m_1, m_2, m_3 are integers associated with three specific regions which especially concern the user regarding the severity of impact; e.g. $(m_2, m_3, m_4) = (43,34,35)$ indicates West Island, Great Neck, and Sippican Neck of Figure 2, respectively. A more detailed statistical analysis is provided for these so-called "critical impact regions".

n is the time increment (in hours) used in recording the time history of the amount of spill that reaches each of the critical impact regions. The accumulation starts from the time of the release.

Card 7: 'CALM' 'N' 'NE' 'E' 'SE' 'S' 'SW' 'W' 'NW'

Variable name=DIR_BLURB(9). Labels to be input as indicated.

Card 8: 'abc'

Variable name=LOCALE. Alphanumeric label of region of study, e.g. 'BUZZARDS BAY'.

Card 9: 'abc'

Variable name=WIND_LABEL. Label for name of weather station associated with the wind transition matrix.

Cards 10: c_1 s_1

c_2 s_2

c_3 s_3

$\vdots$

c_{17} s_{17}

Variable name=((COMPONMAT(I,J),J=1,2),I=1,2)

c_j, s_j defines the resolution of the j-th wind direction into the "latitude" and "longitude" coordinate system the user has chosen in Figure 2. These may be calculated by the following formulae:

Cards 10: (cont.)

$(c_1,s_1) = (0,0)$ corresponding to "calm"

$$\left.\begin{array}{l} c_j = -\cos(\beta_j-\alpha) \\ s_j = -\sin(\beta_j-\alpha) \end{array}\right\} \text{for } j = 2,3,\ldots 17 \text{ corresponding to directions N, N×NE, NE,...etc.}$$

where $\beta_j = (j-2)\pi/8$ and α is the angle between the true North and the user's y-axis, measuring positive for clockwise rotation.

Card 11: NUM_L_PTS=m

m indicates how many launch points the user wishes to consider

Cards 12: 'launch pt 1' 'launch pt 2' ....'launch pt m'

Variable name=LAUNCH_PT, alphanumeric label for the place where the sample spills are released. m such labels are to be supplied.

Cards 13: $x_1\ x_2\ x_3,\ldots.x_m$
$y_1\ y_2\ y_3,\ldots.y_m$

Variable name=(XI,YI).
(XI,YI) are the coordinates of the launch point in nautical miles, with respect to the origin as indicated in Figure 2.

Card 14: x_1,y_2

Variable name=(R,R2).
x_1,y_2 are real numbers.
R is the radial extent of spill after one hour. (see Figure 1)
R2 is the radial extent of spill after ten hours. (see Figure 1)
See Ref. 1. for some discussion.

Card 15: m

Variable name=(N_SEA). This integer is used to indicate that any impact region number (specified in the file NBMAP) which is less than or equal to N_SEA is to designate an open-sea boundary.

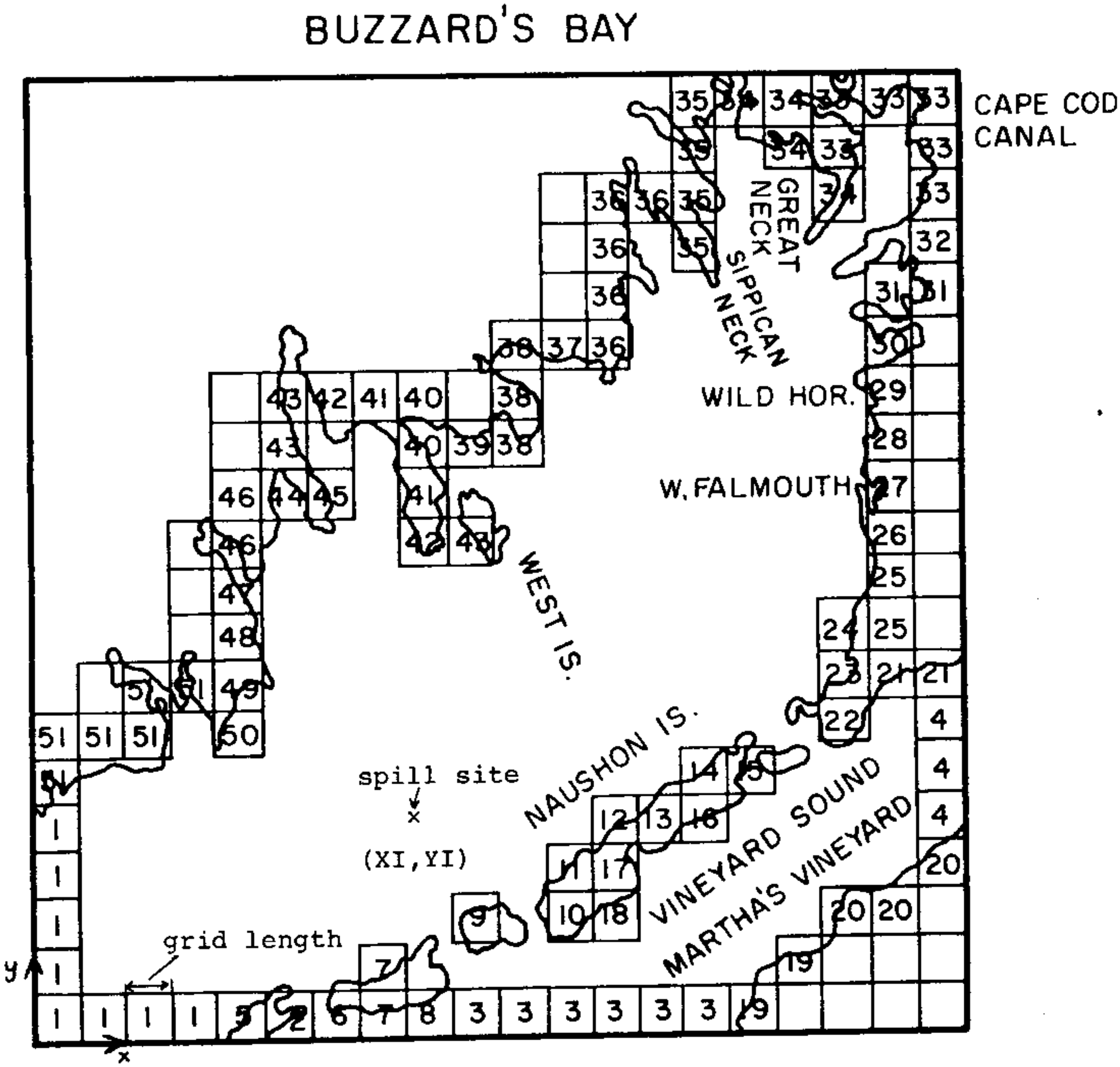


Figure 2. Gridwork of physical area (BUZZARDS BAY).

b. File NBMAP

This provides a griditized description of the physical region under study. The input data consists of integers to be assigned to each grid element. Any element not representing the bay is to be assigned an integer value other than zero. Open seas should have an integer value less than or equal to N SEA of Card 15 in File SYSIN. Elements of the same integer value are collectively referred to as an impact region. See, for example, Figure 2. Data is to be given in accordance with the following PLI format:

GET EDIT ((BMAP(I,J), J=1,YMAT),I=1,XMAT)
Format = (F(2))

c. File BCURR

BCURR is the tidal current information file. Hourly direction and speed values of tidal currents can be obtained graphically from tidal current charts published by the U.S. Coast and Geodetic Survey. Such charts give tropic velocities for hours around maximum flood and maximum ebb. Effects of day-to-day variations are specified in File CFAC. Hourly current values should be assigned to each of the grid elements of the physical map defined by File NBMAP. For each grid element, the current velocity vector $\vec{V}(= V_x\hat{i} + V_y\hat{j})$ is given in knots with respect to the user's grid work. A consecutive twelve hours record is desired. Therefore the total number of data required is

$$N_{total} = 12 \times (XMAT*YMAT) \times 2$$

where (XMAT*YMAT) is the total number of grid elements (see SYSIN Card 1).

The current data should be prepared according to the following card format:

$(\{[((V_x)_{i,j,k},(V_y)_{i,j,k}),j=1,YMAT],i=1,XMAT\},k=0,11)$

GET EDIT format is (E(5,2),E(5,2))

j = index for 'latitude' grid of basin map.
i = " " 'longitude' grid of basin map.
k = the hour of the day.

d. File CFAC

The current data defined by File BCURR are tropic velocities, which correspond to the greater flood and greater ebb velocities at the time of the moon's maximum declinations. The effect of the day-to-day variation in a lunar cycle can be specified in this file. These current factors which will be used to multiply the velocities given in BCURR are to be input as follows:

```
GET EDIT(((CF(I,ID,C),C=1,4),ID=0,29),I=1,4)
```

where CF = the current factor
I = the season index (I=1 is winter, 2 is spring, 3 is summer and 4 is autumn)
ID = lunar day index
C = hour-group index for each day:

```
C=1 corresponds to hr=0 to 5 data in BCURR
C=2      "       " hr=6 to 11  "   "   "
C=3      "       " hr=12 to 17 "   "   "
C=4      "       " hr=18 to 23 "   "   "
```

E. File WNDATA

WNDATA is the wind transition matrix based on a first-order Markov process. This represents the probability that the wind will shift from one direction to another after three hours and is assumed to depend only on the direction from which the wind is presently blowing. Documentation for the program package "TRANSMAT" shows how to generate such 3-hour transition matrices. Both 9×9 and 33×33 transition matrices are necessary in the running of NEARSHORE. These wind-transition matrices for an appropriate weather station must be first generated according to Chapter II. We strongly recommend using disk instead of card storage for the file WNDATA because a typical file of wind transition matrices consists of 843 cards. Typical data structure of file WNDATA can be found described in the documentation of MCTRAJ or T14TRAN.

6. <u>Sample Input and Output</u>

a. Input Files

The sample data given below corresponds to a run for the oil-spill study at Buzzard's Bay, Massachusetts.

Data used for files SYSIN, NBMAP and CFAC is reproduced on pages 48 and 49. Those for files BCURR and WNDATA are sufficiently straightforward, and hence have been omitted.

b. Output File.

The generally lengthy ouput can be easier understood if the following hierarchy of the loopings of solution algorithm is observed.

1. Launch Points Loop
   2. Season Loop
      3. Spill Model Point-Group Loop; i.e. Primary, Secondary, Tertiary
         4. Table of Results:
            a. Summary of Probabilities of Spill for Each Impact Region
            b. Wind Speed Grounding Statistics
            c. Grounding % as a function of time for three critical areas.
            d. Short Term vs. Long Term Grounding statistics as a function of wind conditions at grounding.

A copy of the typical printout of 4a,b,c, and d are shown on pages 50 to 54 for illustration purposes.

Sample Data of File SYSIN

```
 20  20  4  0.25
  OUTPUTFORM='SHORT';     3   1.0
'PRIMARY'  'SECONDARY'  'TERTIARY'
 10  500
'WINTER' 'SPRING' 'SUMMER' 'AUTUMN'
5   9  42  50
'CALM' 'N' 'NE' 'E' 'SE' 'S' 'SW' 'W' 'NW'
'BUZZARDS BAY'
'OTIS AFB. MASS.'
  0.0        0.0
 -1.0        0.0
 -0.924     -0.383
 -0.707     -0.707
 -0.383     -0.924
  0.0       -1.0
  0.383     -0.924
  0.707     -0.707
  0.924     -0.383
  1.0        0.0
  0.924      0.383
  0.707      0.707
  0.383      0.924
  0.0        1.0
 -0.383      0.924
 -0.707      0.707
 -0.924      0.383
NUM_L_PTS=1;
'LOWER BUZZARDS BAY'
8.5
5.2
0.25. 0.5.
4
```

Sample Data of File NBMAP

```
1 1 1 1 1 515151515151515151515151515151511 0 0 0 0 0 515151515151515151515151515151
1 0 0 0 0 0 515151515151515151515151515151511 0 0 0 0 0 0 515151515151515151515151515151
5 0 0 0 0 0 5049484746464646464646464646462 0 0 0 0 0 0 0 0 0 4443434343434343434343
6 0 0 0 0 0 0 0 0 0 0 450 4242424242424242427 7 0 0 0 0 0 0 0 0 0 0 414141414141414141
8 0 0 0 0 0 0 0 0 0 4241404040404040403 0 9 0 0 0 0 0 0 0 430 393939393939393939
3 0 0 0 0 0 0 0 0 0 0 0 383838383838383838383 0 10110 0 0 0 0 0 0 0 0 373737373737
3 0 1817120 0 0 0 0 0 0 0 0 363636363636363 0 0 0 130 0 0 0 0 0 0 0 0 0 0 363636
3 0 0 0 16140 0 0 0 0 0 0 0 0 0 35353535190 0 0 0 150 0 0 0 0 0 0 0 0 0 0 0 34
19190 0 0 0 0 0 0 0 0 0 0 0 0 0 0 3434202020200 0 0 2223240 0 0 0 0 0 0 0 343333
2020200 0 0 0 21252526272829303l0 0 0 3320202020204 4 4 2121212121212121213132333333
```

Sample Data of File CFAC

```
0.7 0.7 0.8 0.7 0.7 0.8 0.9 0.7 0.7 0.8 1.0 0.8 0.8 0.9 1.0 0.9 0.9 0.9 1.0 0.9
0.9 1.0 1.0 0.9 0.9 0.9 1.0 0.9 0.9 0.9 1.0 0.9 0.9 0.9 0.9 0.9 0.9 0.8 0.8 0.8
0.8 0.7 0.7 0.8 0.8 0.7 0.7 0.7 0.7 0.6 0.7 0.7 0.8 0.6 0.7 0.7 0.8 0.7 0.7 0.7
0.8 0.7 0.7 0.8 0.9 0.8 0.8 0.8 0.9 0.8 0.8 0.9 1.0 0.9 0.9 1.0 1.0 0.9 0.9 1.0
1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.9 0.9 0.9 0.9
0.8 0.9 0.8 0.8 0.7 0.8 0.8 0.7 0.7 0.7 0.8 0.6 0.7 0.7 0.8 0.7 0.7 0.7 0.8 0.7
0.7 0.7 0.8 0.7 0.7 0.7 0.8 0.8 0.7 0.8 0.8 0.8 0.8 0.8 0.9 0.9 0.9 0.9 0.9 0.9
0.9 0.9 0.9 1.0 1.0 1.0 0.9 1.0 1.0 1.0 0.9 1.0 1.0 1.0 0.9 1.0 1.0 0.9 0.8 1.0
1.0 0.9 0.8 0.9 1.0 0.8 0.7 0.8 0.9 0.8 0.7 0.8 0.9 0.7 0.7 0.7 0.9 0.7 0.8 0.7
0.9 0.8 0.8 0.8 0.9 0.8 0.9 0.8 0.9 0.8 0.9 0.8 0.9 0.9 1.0 0.9 1.0 0.8 0.9 0.9
1.0 0.8 0.8 0.8 1.0 0.8 0.8 0.8 0.9 0.8 0.8 0.8 0.9 0.8 0.7 0.8 0.9 0.8 0.7 0.8
0.9 0.8 0.7 0.8 0.9 0.8 0.7 0.8 0.9 0.8 0.7 0.8 0.9 0.8 0.7 0.8 0.9 0.8 0.7 0.8
0.8 0.7 0.8 0.8 0.8 0.7 0.8 0.8 0.9 0.7 0.6 0.8 0.9 0.7 0.8 0.8 0.9 0.7 0.8 0.8
0.9 0.7 0.8 0.8 1.0 0.8 0.8 0.8 1.0 0.8 0.9 0.9 1.0 0.8 0.8 0.9 1.0 0.8 0.8 0.9
1.0 0.8 0.8 0.9 1.0 0.9 0.9 0.9 1.0 0.9 0.8 0.9 0.9 0.9 0.8 0.9 0.9 0.9 0.8 0.8
0.8 0.8 0.8 0.8 0.7 0.8 0.8 0.7 0.7 0.8 0.8 0.7 0.7 0.8 0.8 0.7 0.7 0.8 0.9 0.7
0.8 0.9 1.0 0.8 0.8 0.9 1.0 0.9 0.9 1.0 1.0 0.9 0.9 1.0 1.0 0.9 0.9 1.0 1.0 0.9
0.9 0.9 0.9 0.9 0.9 0.8 0.9 0.8 0.8 0.8 0.8 0.8 0.8 0.7 0.7 0.7 0.8 0.7 0.7 0.7
0.7 0.7 0.8 0.7 0.7 0.7 0.8 0.7 0.7 0.7 0.6 0.7 0.7 0.7 0.8 0.8 0.7 0.8 0.8 0.8
0.8 0.8 0.9 0.9 0.9 0.8 0.9 0.9 0.9 0.9 0.9 1.0 1.0 0.9 0.9 1.0 1.0 1.0 0.9 1.0
1.0 1.0 0.9 1.0 1.0 0.9 0.9 1.0 1.0 0.9 0.8 1.0 1.0 0.9 0.8 0.9 0.9 0.8 0.7 0.8
0.9 0.8 0.7 0.8 0.9 0.7 0.7 0.7 0.9 0.8 0.8 0.7 0.9 0.8 0.9 0.8 0.9 0.8 0.9 0.8
0.9 0.9 1.0 0.8 0.9 0.9 1.0 0.8 0.9 0.9 1.0 0.8 0.8 0.9 1.0 0.8 0.8 0.8 0.9 0.8
0.7 0.8 0.9 0.8 0.7 0.8 0.9 0.8 0.7 0.8 0.7 0.8 0.7 0.8 0.9 0.8 0.7 0.8 0.9 0.8
```

Typical Printout of NEARSHORE

SUMMARY OF PROBABILITIES FOR BUZZARDS BAY

WIND DRIFT SET AT 3.0 PERCENT WIND SPEED   LAUNCH POINT: LOWER BUZZARDS BAY
SEASON: SPRING   POINT GROUP: PRIMARY

IMPACT REGION	PERCENTAGE	AVERAGE TIME AT SEA	MINIMUM TIME AT SEA
0	0.00	0.0 HOURS	0 HOURS
1	2.60	38.9 HOURS	12 HOURS
2	0.80	23.8 HOURS	14 HOURS
3	2.60	32.0 HOURS	17 HOURS
4	3.20	38.7 HOURS	18 HOURS
5	1.20	25.2 HOURS	10 HOURS
6	0.40	19.3 HOURS	17 HOURS
7	2.60	16.9 HOURS	7 HOURS
8	1.00	24.9 HOURS	17 HOURS
9	5.40	19.1 HOURS	6 HOURS
10	0.60	19.3 HOURS	8 HOURS
11	4.40	21.0 HOURS	6 HOURS
12	13.00	25.4 HOURS	4 HOURS
13	0.80	14.4 HOURS	11 HOURS
14	8.60	26.1 HOURS	7 HOURS
15	2.00	39.6 HOURS	20 HOURS
16	0.00	0.0 HOURS	0 HOURS
17	0.00	0.0 HOURS	0 HOURS
18	0.40	24.5 HOURS	19 HOURS
19	0.00	0.0 HOURS	0 HOURS
20	0.00	0.0 HOURS	0 HOURS
21	0.00	0.0 HOURS	0 HOURS
22	0.80	40.7 HOURS	23 HOURS
23	5.60	39.0 HOURS	15 HOURS
24	5.80	36.5 HOURS	16 HOURS
25	2.60	44.8 HOURS	19 HOURS
26	5.00	42.6 HOURS	18 HOURS
27	5.40	53.1 HOURS	20 HOURS
28	3.60	63.2 HOURS	26 HOURS
29	1.00	52.9 HOURS	36 HOURS
30	2.00	61.8 HOURS	29 HOURS
31	1.20	65.8 HOURS	43 HOURS
32	0.60	57.1 HOURS	53 HOURS
33	0.60	54.5 HOURS	45 HOURS
34	1.00	71.0 HOURS	51 HOURS
35	0.40	84.6 HOURS	50 HOURS
36	1.40	69.0 HOURS	22 HOURS
37	0.20	157.0 HOURS	157 HOURS
38	1.20	77.2 HOURS	24 HOURS
39	0.20	51.0 HOURS	51 HOURS
40	0.00	0.0 HOURS	0 HOURS
41	0.20	29.3 HOURS	29 HOURS
42	2.40	35.2 HOURS	11 HOURS
43	1.60	28.3 HOURS	10 HOURS
44	0.40	67.8 HOURS	40 HOURS
45	1.20	41.7 HOURS	16 HOURS
46	0.20	61.0 HOURS	61 HOURS
47	0.60	33.6 HOURS	22 HOURS
48	0.60	57.5 HOURS	23 HOURS
49	1.40	32.0 HOURS	14 HOURS
50	1.00	41.4 HOURS	11 HOURS
51	1.20	38.0 HOURS	26 HOURS

WIND SPEED GROUNDING STATISTICS FOR BUZZARDS BAY

LAUNCH POINT: LOWER BUZZARDS BAY

SEASON: SPRING

POINT GROUP: PRIMARY

IMPACT REGION	% AGROUND WITH WIND <12 KNOTS	AVG TIME AT SEA WITH WIND <12 KNOTS	MIN TIME AT SEA WITH WIND <12 KNOTS	% AGROUND WITH WIND >12 KNOTS	AVG TIME AT SEA WITH WIND >12 KNOTS	MIN TIME AT SEA WITH WIND >12 KNOTS
0	0.00	0HR	0HR	0.00	0HR	0HR
1	15.38	27HR	20HR	84.62	41HR	12HR
2	25.00	17HR	17HR	75.00	26HR	14HR
3	53.85	26HR	17HR	46.15	39HR	17HR
4	62.50	45HR	18HR	37.50	28HR	18HR
5	0.00	0HR	0HR	100.00	25HR	10HR
6	50.00	17HR	17HR	50.00	21HR	21HR
7	30.77	23HR	9HR	69.23	14HR	7HR
8	40.00	37HR	30HR	60.00	17HR	17HR
9	29.63	26HR	10HR	70.37	16HR	6HR
10	66.67	14HR	8HR	33.33	31HR	31HR
11	50.00	27HR	6HR	50.00	15HR	6HR
12	50.77	30HR	7HR	49.23	20HR	4HR
13	25.00	18HR	18HR	75.00	13HR	11HR
14	41.86	32HR	13HR	58.14	22HR	7HR
15	50.00	34HR	20HR	50.00	45HR	23HR
16	0.00	0HR	0HR	0.00	0HR	0HR
17	0.00	0HR	0HR	0.00	0HR	0HR
18	50.00	31HR	31HR	50.00	19HR	19HR
19	0.00	0HR	0HR	0.00	0HR	0HR
20	0.00	0HR	0HR	0.00	0HR	0HR
21	0.00	0HR	0HR	0.00	0HR	0HR
22	25.00	52HR	52HR	75.00	37HR	23HR
23	57.14	46HR	16HR	42.86	29HR	15HR
24	73.53	36HR	19HR	26.47	37HR	16HR
25	46.15	35HR	19HR	53.85	53HR	22HR
26	56.00	45HR	18HR	44.00	40HR	20HR
27	62.96	52HR	25HR	37.04	55HR	20HR
28	33.33	57HR	37HR	66.67	66HR	26HR
29	80.00	51HR	36HR	20.00	61HR	61HR
30	20.00	58HR	41HR	80.00	63HR	29HR
31	33.33	81HR	54HR	66.67	58HR	43HR
32	33.33	55HR	55HR	66.67	58HR	53HR
33	0.00	0HR	0HR	100.00	55HR	45HR
34	40.00	68HR	51HR	60.00	73HR	52HR
35	100.00	85HR	50HR	0.00	0HR	0HR
36	42.86	91HR	76HR	57.14	53HR	22HR
37	0.00	0HR	0HR	100.00	157HR	157HR
38	33.33	67HR	66HR	66.67	82HR	24HR
39	0.00	0HR	0HR	100.00	51HR	51HR
40	0.00	0HR	0HR	0.00	0HR	0HR
41	100.00	29HR	29HR	0.00	0HR	0HR
42	41.67	28HR	17HR	58.33	41HR	11HR
43	50.00	38HR	16HR	50.00	19HR	10HR
44	100.00	68HR	40HR	0.00	0HR	0HR
45	83.33	38HR	16HR	16.67	63HR	63HR
46	100.00	61HR	61HR	0.00	0HR	0HR
47	33.33	39HR	39HR	66.67	31HR	22HR
48	33.33	74HR	74HR	66.67	49HR	23HR
49	14.29	27HR	27HR	85.71	33HR	14HR
50	60.00	43HR	14HR	40.00	40HR	11HR

51	50.00	40HR	27HR	50.00	37HR	26HR

PERCENT AGROUND AS A FUNCTION OF TIME FROM RELEASE (AGGREGATE OF ALL IMPACT AREAS, PLUS 3 CRITICAL

	ALL AREAS	CRIT AREA 1	CRIT AREA 2	CRIT AREA 3
	IMPACT ZONE NUM=	9	42	50
5.0	0.01	0.00	0.00	0.00
10.0	0.08	0.02	0.00	0.00
15.0	0.18	0.03	0.00	0.00
20.0	0.31	0.03	0.01	0.00
25.0	0.43	0.04	0.01	0.00
30.0	0.51	0.04	0.01	0.00
35.0	0.61	0.05	0.02	0.00
40.0	0.66	0.05	0.02	0.01
45.0	0.71	0.05	0.02	0.01
50.0	0.75	0.05	0.02	0.01
55.0	0.80	0.05	0.02	0.01
60.0	0.84	0.05	0.02	0.01
65.0	0.87	0.05	0.02	0.01
70.0	0.90	0.05	0.02	0.01
75.0	0.92	0.05	0.02	0.01
80.0	0.93	0.05	0.02	0.01
85.0	0.94	0.05	0.02	0.01
90.0	0.94	0.05	0.02	0.01
95.0	0.95	0.05	0.02	0.01
100.0	0.96	0.05	0.02	0.01
105.0	0.96	0.05	0.02	0.01
110.0	0.97	0.05	0.02	0.01
115.0	0.98	0.05	0.02	0.01
120.0	0.99	0.05	0.02	0.01
125.0	0.99	0.05	0.02	0.01
130.0	0.99	0.05	0.02	0.01
135.0	0.99	0.05	0.02	0.01
140.0	0.99	0.05	0.02	0.01
145.0	0.99	0.05	0.02	0.01
150.0	0.99	0.05	0.02	0.01
155.0	0.99	0.05	0.02	0.01
160.0	1.00	0.05	0.02	0.01
165.0	1.00	0.05	0.02	0.01
170.0	1.00	0.05	0.02	0.01
175.0	1.00	0.05	0.02	0.01
180.0	1.00	0.05	0.02	0.01
185.0	1.00	0.05	0.02	0.01
190.0	1.00	0.05	0.02	0.01
195.0	1.00	0.05	0.02	0.01
200.0	1.00	0.05	0.02	0.01
205.0	1.00	0.05	0.02	0.01
210.0	1.00	0.05	0.02	0.01
215.0	1.00	0.05	0.02	0.01
220.0	1.00	0.05	0.02	0.01
225.0	1.00	0.05	0.02	0.01
230.0	1.00	0.05	0.02	0.01
235.0	1.00	0.05	0.02	0.01
240.0	1.00	0.05	0.02	0.01

SHORT TERM VS LONG TERM GROUNDINGS FOR BUZZARDS BAY

LAUNCH POINT: LOWER BUZZARDS BAY
SEASON: SPRING

POINT GROUP: PRIMARY

IMPACT REGION	WIND UNDER 12 KNOTS AT GROUNDING				WIND OVER 12 KNOTS AT GROUNDING			
	0<T<3	3<T<10	10<T<30	T>30	0<T<3	3<T<10	10<T<30	T>30
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	0.00	0.00	7.69	7.69	0.00	0.00	30.77	53.85
2	0.00	0.00	25.00	0.00	0.00	0.00	50.00	25.00
3	0.00	0.00	46.15	7.69	0.00	0.00	23.08	23.08
4	0.00	0.00	12.50	50.00	0.00	0.00	31.25	6.25
5	0.00	0.00	0.00	0.00	0.00	16.67	33.33	50.00
6	0.00	0.00	50.00	0.00	0.00	0.00	50.00	0.00
7	0.00	7.69	7.69	15.38	0.00	15.38	46.15	7.69
8	0.00	0.00	20.00	20.00	0.00	0.00	60.00	0.00
9	0.00	7.41	11.11	11.11	0.00	25.93	33.33	11.11
10	0.00	33.33	33.33	0.00	0.00	0.00	0.00	33.33
11	0.00	9.09	31.82	9.09	0.00	18.18	27.27	4.55
12	0.00	3.08	32.31	15.38	0.00	16.92	21.54	10.77
13	0.00	0.00	25.00	0.00	0.00	0.00	75.00	0.00
14	0.00	0.00	27.91	13.95	0.00	9.30	37.21	11.63
15	0.00	0.00	20.00	30.00	0.00	0.00	20.00	30.00
16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
18	0.00	0.00	0.00	50.00	0.00	0.00	50.00	0.00
19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	0.00	0.00	0.00	25.00	0.00	0.00	25.00	50.00
23	0.00	0.00	25.00	32.14	0.00	0.00	32.14	10.71
24	0.00	0.00	23.53	50.00	0.00	0.00	14.71	11.76
25	0.00	0.00	23.08	23.08	0.00	0.00	15.38	38.46
26	0.00	0.00	20.00	36.00	0.00	0.00	24.00	20.00
27	0.00	0.00	3.70	59.26	0.00	0.00	11.11	25.93
28	0.00	0.00	0.00	33.33	0.00	0.00	16.67	50.00
29	0.00	0.00	0.00	80.00	0.00	0.00	0.00	20.00
30	0.00	0.00	0.00	20.00	0.00	0.00	20.00	60.00
31	0.00	0.00	0.00	33.33	0.00	0.00	0.00	66.67
32	0.00	0.00	0.00	33.33	0.00	0.00	0.00	66.67
33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00
34	0.00	0.00	0.00	40.00	0.00	0.00	0.00	60.00
35	0.00	0.00	0.00	100.00	0.00	0.00	0.00	0.00
36	0.00	0.00	0.00	42.86	0.00	0.00	14.29	42.86
37	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00
38	0.00	0.00	0.00	33.33	0.00	0.00	16.67	50.00
39	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00
40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
41	0.00	0.00	100.00	0.00	0.00	0.00	0.00	0.00
42	0.00	0.00	16.67	25.00	0.00	0.00	41.67	16.67
43	0.00	0.00	12.50	37.50	0.00	12.50	25.00	12.50
44	0.00	0.00	0.00	100.00	0.00	0.00	0.00	0.00
45	0.00	0.00	33.33	50.00	0.00	0.00	0.00	16.67
46	0.00	0.00	0.00	100.00	0.00	0.00	0.00	0.00
47	0.00	0.00	0.00	33.33	0.00	0.00	33.33	33.33
48	0.00	0.00	0.00	33.33	0.00	0.00	33.33	33.33
49	0.00	0.00	14.29	0.00	0.00	0.00	42.86	42.86
50	0.00	0.00	20.00	40.00	0.00	0.00	20.00	20.00
51	0.00	0.00	16.67	33.33	0.00	0.00	33.33	16.67

7. References

[1] Devanney, J.W., Stewart, R. J. and Briggs, W., "Oil Spill Trajectory Studies for Atlantic Coast and Gulf of Alaska", Report to Council on Environmental Quality, MITSG Report No. 74-20, April 1974, pp. 1-186.

[2] Devanney, J.W. and Stewart, R. J., "Potential Spill Trajectories", Massachusetts Institute of Technology Report No. MITSG 73-5, February 1973, pp. 51-119.

MODULE 4: Program TWOFOIL

1. Identification:

Title:	TWOFOIL (Two-Hydrofoil Interaction Problem)
Authors:	R. W.Yeung
Documented by:	R. W. Yeung
Specifications:	Machine: IBM370 Source Language: FORTRAN IV
Component Subprograms:	TWFOIL, DUCK1, DUCK4 (FORTRAN IV) SIMQ(IBM-SSP).

2. Purpose:

TWOFOIL is a program which seeks the solution of the two-dimensional lifting flow about two symmetric bodies. This may be viewed as either one of the following physical problems: the determination of the lift characteristics of twin foils that are not necessarily identical or the estimation of the interaction force and moment of two ships in water very shallow with respect to their drafts. An extension of the Ryan-Glover technique [Ref. 1] of vortex-distribution is used to solve the coupled integral equations.

3. Overall Program Description:

a. Background

The coordinate system used in the program is shown in

Figure 1. The foils are assumed symmetric and defined by a sequence of input data pounts. Functionally, each foil surface is described parametrically by the non-dimensional function $\bar{x}(\phi)$, $\bar{y}_j(\phi)$

$$\left.\begin{aligned} x &= x_{oj} + L_j\bar{x}(\phi) \ , \qquad (1) \\ y &= y_{oj} + L_j\bar{y}_j(\phi) \qquad (2) \end{aligned}\right\} j = 1,2$$

where

$$\bar{x} = (1 + \cos\phi)/2, \ \phi = [0, 2\pi] \qquad (3)$$

and the function $\bar{y}_j$ is obtained by a spline fit of the given data, treating $\bar{y}$ as a function of ϕ . The transformation given by (3) allows the foils to have round noses at the leading edges.

The mathematical representation of the solution of this inviscid-flow problem can be written in terms of two unknown vortex distributions, each located around the actual contour of the foils. Let these be denoted by $\gamma_1(s)$ and $\gamma_2(s)$, s being an arc-length parameter. Then by considering the "fluid" regions inside the body contours as motionless, one can recast the problem as an internal-flow problem with the condition that the tangential velocity vanishes along the inside of the contour. This boundary condition yields the following coupled integral equation for $\gamma_1(\phi(s))$ and $\gamma_2(\phi(s))$:

$$\begin{aligned} \frac{-\gamma_i(\phi_m)}{2} &+ \sum_{j=1}^{2} \int_{S_j} \gamma_j(\tilde{\phi})\, K\,(\phi_m, \tilde{\phi})\, d\tilde{\phi} \\ &= -L_i \left[\bar{x}'(\phi_m) \cos\alpha + \bar{y}'_j(\phi_m) \sin\alpha\right] \qquad i = 1,2 \end{aligned} \qquad (4)$$

where K is the velocity-induction kernel function for a vortex, and ϕ_m m = 1,2,3,... correspond to a finite number of "pivotal-points" where the tengential velocity condition is satisfied.

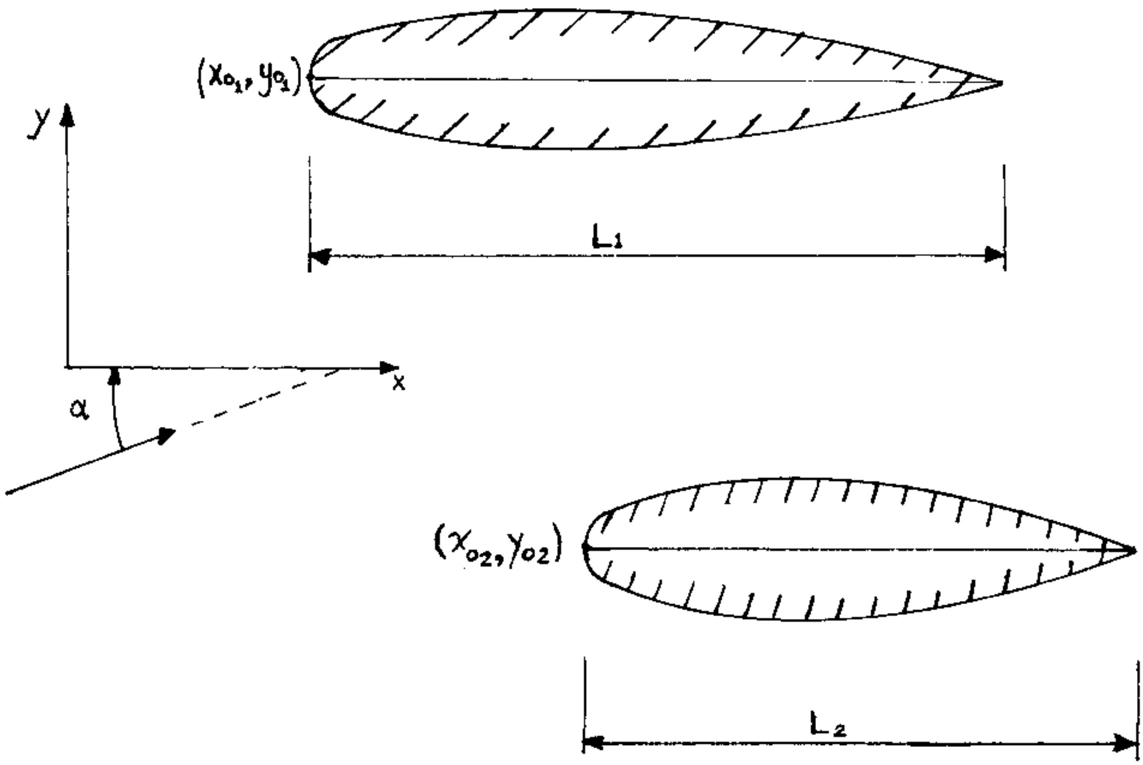


Figure 1. Definition of Coordinate System

After Equation (4) is solved, the surface velocity outside of the foil at the m-th pivotal point is given by:

$$q_i^+(S_m) = \gamma_i(\phi_m)\frac{d\phi_m}{ds} , \quad i = 1,2$$

For the uniqueness of (4), a Kutta condition, stating that loading at the trailing edge must vanish, is applied to both foils.

b. Program Algorithm

A summary of the overall program algorithm of TWOFOIL is shown in Figure 2. The main program initially inputs the geometry data of the two foils. Data concerning the angles of attack and the number of relative configurations that is to be considered are next read. Within the nested loopings corresponding to relative configurations and angle of attack, the major routine "TWFOIL" is called.

This routine first calls DUCK1* to fit the foil data and DUCK4* to interpolate additional geometric characteristics that are necessary for setting up a discretized version of Equation (4). Next, the influence coefficients representing the kernel function of (4) and the right-hand-side of the corresponding matrix equations are calculated and stored. The linear-equations subroutine SIMQ† is called to solve the system of equations. The process yields the values of the vorticity at the pivotal points ϕ_m , which are then used to calculate the surface velocity on the foils, and subsequently the force and moment.

---

* These spline routines are modifications from those developed for Course 13.50, credited originally to Professor Kerwin of the Department of Ocean Engineering, MIT.

† This is a standard IBM-370 routine available from the SSP (Scientific Subroutine Package).

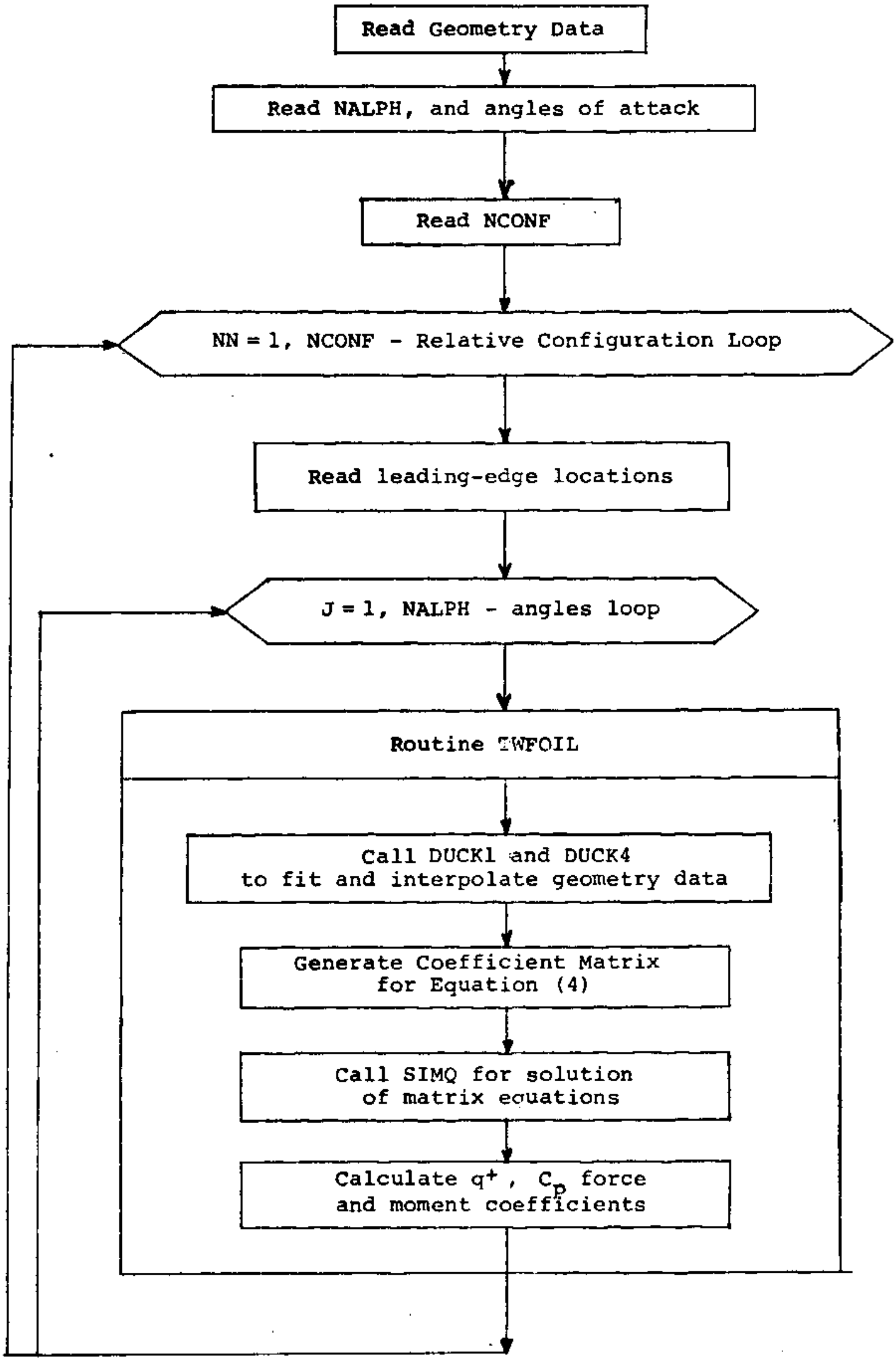


Figure 2. Block diagram of Program TWOFOIL

4. <u>Data Preparation</u>:

The only input-output devices necessary for the execution of this program are the card reader (FORTRAN File No.5) and the printer (File No. 6). The following is a description of the required input data and their associated formats:

Card 1: (NAME(I), I=1,20) (20A4)

Eighty columns for title of problem.

Card 2: N, NSHIP (2I2)

N = no. of points to be used to discretize the chord length of each foil. This should not exceed 25.
NSHIP = no. of foils or bodies. Either one or two is permissble.

Card 3: DEPTH (F10.4)

DEPTH = Water-depth if one considers a ship interaction problem. For two-dimensional air-foils assign a value of 0.25.

Card 4: (SL(K), RAD(K), NDATA(K), K=1, NSHIP) (2F10.4,I2)

SL(K) = chord length of the k-th foil or body.
RAD(K) = leading edge radius of the k-th foil. If set equal zero, the curve fitting at the leading edge will be assigned a zero-moment condition.
NDATA(K) = no. of offsets points to be input to represent the foil.

Card 5: (DATX(J,1), DATY(J,1), J=1 , NDATA(K)) (2F10.4)

($DATX_j$, $DATY_j$) = x and y offsets ,(given relative to the leading edge of the foil) that define the <u>upper</u> part of the first foil. The data should start from the trailing edge of the foil and go forward towards the leading edge. The data should be nondimensionalized by the chord length. Hence, DATX will have the range of [0,1]. For ships in very shallow water, DATY should be input as the double-sectional area/ship length.

Repeat Cards 4 and 5 for the second foil if a two-body problem is being considered.

Card 6: NALPH, (ATTK(I), I = 1, NALPH) (I2,8F10.4)

NALPH = number of angles of attack
ATTK(I) = i-th angle of attack, in radians

Card 7: NCONF (I2)

NCONF = the number of relative configurations for which the problem is to be solved.

Card 8: (XO(K), YO(K), K = 1,2) (2F10.4)

(XO_K , YO_K) = leading-edge coordinates of the k-th body. Repeat this card as many times as NCONF specified in Card 7.

5. Sample Data and Output

A sample run is shown here by considering the flow about two NACA 0024-thickness form airfoils. Two relative configurations are considered. The data listing is shown on the next page. The output-printout is shown in pages 62-66. An explanation of the labeling is given below.

(XM,YM)	=	coordinates of the control or pivotal points
DX/DP, DX2/DP2	=	$x'(\phi)$ and $x''(\phi)$
DY/DP, DY2/DP2	=	$y'(\phi)$ and $y''(\phi)$
DS	=	differential arc-length element ds between grind points on foil.
RHS	=	right-hand side of the discretized form of the integral equation (4). This number should be of order equal to SL(K)$_*$2N.
G	=	$\gamma(\phi)$
Q^+	=	surface velocity, defined to be positive if it circulates on the body in a counter-clockwise direction.
CP	=	local pressure coefficient = $2(p - p_\infty)/\rho U^2$

It is worthwhile to note that the type of Kutta-condition imposed precludes the existence of a stagnation point at the trailing edge; hence the theory is more appropriate for cusped-end bodies.

a) Listing of input data for *SYSIN* file

```
         ***   SAMPLE PROBLEM WITH 2 NACA-024 AIRFOILS   ***
2002                    2 NACA 024 AIRFOILS
.25
1.                       18
1.          .00252
.95         .01613
.90         .02896
.80         .05247
.70         .07328
.60         .09127
.50         .10588
.40         .11607
.30         .12004
.25         .11883
.20         .11475
.15         .10691
.10         .09365
.075        .08400
.050        .07109
.025        .05299
.0125       .03788
0.          0.
1.                       18
1.          .00252
.95         .01613
.90         .02896
.80         .05247
.70         .07328
.60         .09127
.50         .10588
.40         .11607
.30         .12004
.25         .11883
.20         .11475
.15         .10691
.10         .09365
.075        .08400
.050        .07109
.025        .05299
.0125       .03788
0.          0.
01                 ANGLES
0.
03
0.          0.          0.          -.5
0.            0.          .75         -.5
.75             .5        0.          0.
```

(b) Printer Output of Sample Problem

*** SAMPLE PROBLEM WITH 2 NACA-C24 AIRFOILS ***

INTEROPLATED DATA OF FOIL GEOMETRY

M	PHI	XM	YM	DX/DP	DX2/DP2	DY/DP	DY2/DP2	DS	
1	0.157080	0.993844	0.005550	-0.078217	-0.493844	0.022480	0.056046	0.025602	1
2	0.471239	0.945503	0.017261	-0.226995	-0.445503	0.057516	0.150456	0.073210	2
3	0.785398	0.853553	0.040268	-0.353553	-0.353553	0.083239	0.044391	0.113630	3
4	1.099557	0.726995	0.067923	-0.445503	-0.226995	0.090053	-0.007750	0.142173	4
5	1.413716	0.578217	0.094767	-0.493844	-0.078217	0.077432	-0.073360	0.156368	5
6	1.727876	0.421783	0.114305	-0.493844	0.078217	0.043165	-0.145617	0.155078	6
7	2.042035	0.273005	0.119702	-0.445503	0.226995	-0.011462	-0.196755	0.139434	7
8	2.356194	0.146447	0.106172	-0.353553	0.353553	-0.074816	-0.200679	0.113049	8
9	2.670353	0.054497	0.073674	-0.226996	0.445503	-0.127551	-0.041258	0.081325	9
10	2.984512	0.006156	0.026615	-0.078218	0.493844	-0.168693	-0.014154	0.057901	10
11	3.298674	0.006156	-0.026615	0.078218	0.493844	-0.168693	0.014154	0.057901	11
12	3.612833	0.054497	-0.073674	0.226996	0.445503	-0.127551	0.041258	0.081325	12
13	3.926991	0.146447	-0.106172	0.353554	0.353553	-0.074816	0.200679	0.113049	13
14	4.241151	0.273005	-0.119702	0.445503	0.226995	-0.011462	0.196755	0.139434	14
15	4.555310	0.421783	-0.114305	0.493844	0.078217	0.043165	0.145617	0.155078	15
16	4.869470	0.578217	-0.094767	0.493844	-0.078218	0.077432	0.073360	0.156368	16
17	5.183629	0.726995	-0.067923	0.445503	-0.226996	0.090053	0.007750	0.142173	17
18	5.497787	0.853553	-0.040268	0.353553	-0.353553	0.083239	-0.044391	0.113630	18
19	5.811947	0.945503	-0.017261	0.226995	-0.445503	0.057516	-0.150456	0.073210	19
20	6.126106	0.993844	-0.005590	0.078217	-0.493844	0.022480	-0.056046	0.025602	20

M	PHI	XM	YM	DX/DP	DX2/DP2	DY/DP	DY2/DP2	DS	
21	0.157080	0.993844	-0.494410	-0.078217	-0.493844	0.022480	0.056046	0.025602	21
22	0.471239	0.945503	-0.482739	-0.226995	-0.445503	0.057516	0.150456	0.073210	22
23	0.785398	0.853553	-0.459732	-0.353553	-0.353553	0.083239	0.044391	0.113630	23
24	1.099557	0.726995	-0.432077	-0.445503	-0.226995	0.090053	-0.007750	0.142173	24
25	1.413716	0.578217	-0.405233	-0.493844	-0.078217	0.077432	-0.073360	0.156368	25
26	1.727876	0.421783	-0.385695	-0.493844	0.078217	0.043165	-0.145617	0.155076	26
27	2.042035	0.273005	-0.380298	-0.445503	0.226995	-0.011462	-0.196755	0.139434	27
28	2.356194	0.146447	-0.393828	-0.353553	0.353553	-0.074816	-0.200679	0.113049	28
29	2.670353	0.054497	-0.426326	-0.226996	0.445503	-0.127551	-0.041258	0.081325	29
30	2.984512	0.006156	-0.473385	-0.078218	0.493844	-0.168693	-0.014154	0.057901	30
31	3.298674	0.006156	-0.526615	0.078218	0.493844	-0.168693	0.014154	0.057901	31
32	3.612833	0.054497	-0.573674	0.226996	0.445503	-0.127551	0.041258	0.081325	32
33	3.926991	0.146447	-0.606172	0.353554	0.353553	-0.074816	0.200679	0.113049	33
34	4.241151	0.273005	-0.619702	0.445503	0.226995	-0.011462	0.196755	0.139434	34
35	4.555310	0.421783	-0.614305	0.493844	0.078217	0.043165	0.145617	0.155078	35
36	4.869470	0.578217	-0.594767	0.493844	-0.078218	0.077432	0.073360	0.156368	36
37	5.183629	0.726995	-0.567923	0.445503	-0.226996	0.090053	0.007750	0.142173	37
38	5.497787	0.853553	-0.540268	0.353553	-0.353553	0.083239	-0.044391	0.113630	38
39	5.811947	0.945503	-0.517261	0.226995	-0.445503	0.057516	-0.150456	0.073210	39
40	6.126106	0.993844	-0.505590	0.078217	-0.493844	0.022480	-0.056046	0.025602	40

```
*** FLOW SOLUTION FOR
  XO(1),YO(1) = (   0.0    ,    0.0     )
  XO(2),YO(2) = (   0.0    ,  -0.50000)
   ALPHA=0.0        NEQN= 38    ERROR=0
```

M	XM	YM	RHS	G	Q+	CP	
1	0.99384	0.00559	0.156E+01	-0.0684	-0.8395	0.2952	1
2	0.94550	0.01726	0.454E+01	-0.2043	-0.8765	0.2317	2
3	0.85355	0.04027	0.707E+01	-0.3594	-0.9936	0.0127	3
4	0.72699	0.06792	0.891E+01	-0.4897	-1.0820	-0.1708	4
5	0.57822	0.09477	0.988E+01	-0.5806	-1.1664	-0.3606	5
6	0.42178	0.11430	0.988E+01	-0.6187	-1.2533	-0.5708	6
7	0.27300	0.11970	0.891E+01	-0.5909	-1.3313	-0.7723	7
8	0.14645	0.10617	0.707E+01	-0.4901	-1.3621	-0.8553	8
9	0.05450	0.07367	0.454E+01	-0.3097	-1.1963	-0.4312	9
10	0.00616	0.02661	0.156E+01	-0.1028	-0.5580	0.6886	10
11	0.00616	-0.02661	-0.156E+01	0.1473	0.7990	0.3616	11
12	0.05450	-0.07367	-0.454E+01	0.3914	1.5122	-1.2866	12
13	0.14645	-0.10617	-0.707E+01	0.6624	1.8407	-2.3880	13
14	0.27300	-0.11970	-0.891E+01	0.8650	1.9489	-2.7983	14
15	0.42178	-0.11430	-0.988E+01	0.9050	1.8333	-2.3612	15
16	0.57822	-0.09477	-0.988E+01	0.7883	1.5838	-1.5083	16
17	0.72699	-0.06792	-0.891E+01	0.6063	1.3396	-0.7946	17
18	0.85355	-0.04027	-0.707E+01	0.4151	1.1478	-0.3174	18
19	0.94550	-0.01726	-0.454E+01	0.2279	0.9778	0.0438	19
20	0.99384	-0.00559	-0.156E+01	0.0684	0.8395	0.2952	20
21	0.99384	-0.49441	0.156E+01	-0.0684	-0.8395	0.2952	21
22	0.94550	-0.48274	0.454E+01	-0.2279	-0.9779	0.0438	22
23	0.85355	-0.45973	0.707E+01	-0.4151	-1.1478	-0.3174	23
24	0.72699	-0.43208	0.891E+01	-0.6063	-1.3396	-0.7946	24
25	0.57822	-0.40523	0.988E+01	-0.7883	-1.5838	-1.5083	25
26	0.42178	-0.38570	0.988E+01	-0.9050	-1.8333	-2.3612	26
27	0.27300	-0.38030	0.891E+01	-0.8650	-1.9489	-2.7983	27
28	0.14645	-0.39383	0.707E+01	-0.6624	-1.8407	-2.3880	28
29	0.05450	-0.42633	0.454E+01	-0.3914	-1.5122	-1.2866	29
30	0.00616	-0.47339	0.156E+01	-0.1473	-0.7990	0.3616	30
31	0.00616	-0.52661	-0.156E+01	0.1028	0.5580	0.6886	31
32	0.05450	-0.57367	-0.454E+01	0.3097	1.1963	-0.4312	32
33	0.14645	-0.60617	-0.707E+01	0.4901	1.3621	-0.8553	33
34	0.27300	-0.61970	-0.891E+01	0.5909	1.3313	-0.7723	34
35	0.42178	-0.61430	-0.988E+01	0.6187	1.2533	-0.5708	35
36	0.57822	-0.59477	-0.988E+01	0.5806	1.1664	-0.3606	36
37	0.72699	-0.56792	-0.891E+01	0.4897	1.0820	-0.1708	37
38	0.85355	-0.54027	-0.707E+01	0.3594	0.9936	0.0127	38
39	0.94550	-0.51726	-0.454E+01	0.2043	0.8765	0.2317	39
40	0.99384	-0.50559	-0.156E+01	0.0684	0.8395	0.2952	40

```
GMA = NON-DIMENSIONAL CIRCULATION = CIRCULATION/(U*L)
(CY,CX) = (FY,FX)/(.5*RHO*U**2*L(K))
CM = MOMENT ABT. MID-CHORD/(.5*RHO*(U*L)**2)
```

FOIL	GMA	CY	CM	CX/2
1	0.396625	-1.111457	0.124239	0.001262
2	-0.396624	1.111459	-0.124238	0.001263

```
*** FLOW SOLUTION FOR
  XO(1),YO(1) = (    0.0      ,     0.0      )
  XO(2),YO(2) = (    0.75000,    -0.50000)
   ALPHA=0.0          NEQN= 38      ERROR=0
```

M	XM	YM	RHS	G	Q+	CP	
1	0.99384	0.00559	0.156E+01	-0.0730	-0.8963	0.1966	1
2	0.94550	0.01726	0.454E+01	-0.2230	-0.9568	0.0846	2
3	0.85355	0.04027	0.707E+01	-0.3863	-1.0682	-0.1410	3
4	0.72699	0.06792	0.891E+01	-0.5220	-1.1534	-0.3302	4
5	0.57822	0.09477	0.988E+01	-0.6166	-1.2387	-0.5345	5
6	0.42178	0.11430	0.988E+01	-0.6575	-1.3319	-0.7740	6
7	0.27300	0.11970	0.891E+01	-0.6324	-1.4248	-1.0301	7
8	0.14645	0.10617	0.707E+01	-0.5350	-1.4868	-1.2105	8
9	0.05450	0.07367	0.454E+01	-0.3607	-1.3934	-0.9416	9
10	0.00616	0.02661	0.156E+01	-0.1646	-0.8931	0.2024	10
11	0.00616	-0.02661	-0.156E+01	0.0636	0.3449	0.8811	11
12	0.05450	-0.07367	-0.454E+01	0.2616	1.0107	-0.0216	12
13	0.14645	-0.10617	-0.707E+01	0.4342	1.2067	-0.4560	13
14	0.27300	-0.11970	-0.891E+01	0.5328	1.2006	-0.4413	14
15	0.42178	-0.11430	-0.988E+01	0.5666	1.1518	-0.3266	15
16	0.57822	-0.09477	-0.988E+01	0.5584	1.1219	-0.2587	16
17	0.72699	-0.06792	-0.891E+01	0.5062	1.1186	-0.2513	17
18	0.85355	-0.04027	-0.707E+01	0.3912	1.0816	-0.1698	18
19	0.94550	-0.01726	-0.454E+01	0.2251	0.9660	0.0668	19
20	0.99384	-0.00559	-0.156E+01	0.0730	0.8963	0.1966	20
21	1.74384	-0.49441	0.156E+01	-0.0655	-0.8035	0.3544	21
22	1.69550	-0.48274	0.454E+01	-0.2009	-0.8623	0.2565	22
23	1.60355	-0.45973	0.707E+01	-0.3508	-0.9698	0.0596	23
24	1.47699	-0.43208	0.891E+01	-0.4741	-1.0475	-0.0973	24
25	1.32822	-0.40523	0.988E+01	-0.5579	-1.1208	-0.2562	25
26	1.17178	-0.38570	0.988E+01	-0.5938	-1.2029	-0.4470	26
27	1.02300	-0.38030	0.891E+01	-0.5784	-1.3033	-0.6986	27
28	0.89645	-0.39383	0.707E+01	-0.5011	-1.3926	-0.9394	28
29	0.80450	-0.42633	0.454E+01	-0.3371	-1.3024	-0.6962	29
30	0.75616	-0.47339	0.156E+01	-0.1370	-0.7433	0.4475	30
31	0.75616	-0.52661	-0.156E+01	0.1002	0.5434	0.7047	31
32	0.80450	-0.57367	-0.454E+01	0.3049	1.1778	-0.3871	32
33	0.89645	-0.60617	-0.707E+01	0.4836	1.3438	-0.8057	33
34	1.02300	-0.61970	-0.891E+01	0.5841	1.3160	-0.7317	34
35	1.17178	-0.61430	-0.988E+01	0.6121	1.2400	-0.5375	35
36	1.32822	-0.59477	-0.988E+01	0.5745	1.1543	-0.3325	36
37	1.47699	-0.56792	-0.891E+01	0.4846	1.0709	-0.1468	37
38	1.60355	-0.54027	-0.707E+01	0.3559	0.9840	0.0317	38
39	1.69550	-0.51726	-0.454E+01	0.2026	0.8692	0.2444	39
40	1.74384	-0.50559	-0.156E+01	0.0655	0.8035	0.3544	40

```
GMA = NON-DIMENSIONAL CIRCULATION = CIRCULATION/(U*L)
(CY,CX) = (FY,FX)/(.5*RHO*U**2*L(K))
CM = MOMENT ABT. MID-CHORD/(.5*RHO*(U*L)**2)
```

FOIL	GMA	CY	CM	CX/2
1	-0.174746	0.365775	-0.086708	0.010849
2	-0.009021	0.001798	-0.019933	-0.008045

```
*** FLOW SOLUTION FOR
 XO(1),YO(1) = (   0.75000,    0.50000)
 XO(2),YO(2) = (   0.0    ,    0.0    )
  ALPHA=0.0        NEQN= 38    ERROR=0
```

M	XM	YM	RHS	G	Q+	CP	
1	1.74384	0.50559	0.156E+01	-0.0655	-0.8035	0.3544	1
2	1.69550	0.51726	0.454E+01	-0.2026	-0.8692	0.2444	2
3	1.60355	0.54027	0.707E+01	-0.3559	-0.9841	0.0316	3
4	1.47699	0.56792	0.891E+01	-0.4846	-1.0709	-0.1468	4
5	1.32822	0.59477	0.988E+01	-0.5746	-1.1543	-0.3325	5
6	1.17178	0.61430	0.988E+01	-0.6121	-1.2400	-0.5375	6
7	1.02300	0.61970	0.891E+01	-0.5841	-1.3160	-0.7318	7
8	0.89645	0.60617	0.707E+01	-0.4836	-1.3438	-0.8057	8
9	0.80450	0.57367	0.454E+01	-0.3049	-1.1778	-0.3871	9
10	0.75616	0.52661	0.156E+01	-0.1002	-0.5434	0.7047	10
11	0.75616	0.47339	-0.156E+01	0.1370	0.7433	0.4475	11
12	0.80450	0.42633	-0.454E+01	0.3371	1.3024	-0.6962	12
13	0.89645	0.39383	-0.707E+01	0.5011	1.3926	-0.9394	13
14	1.02300	0.38030	-0.891E+01	0.5784	1.3033	-0.6986	14
15	1.17178	0.38570	-0.988E+01	0.5938	1.2029	-0.4470	15
16	1.32822	0.40523	-0.988E+01	0.5579	1.1208	-0.2561	16
17	1.47699	0.43208	-0.891E+01	0.4741	1.0475	-0.0973	17
18	1.60355	0.45973	-0.707E+01	0.3508	0.9697	0.0596	18
19	1.69550	0.48274	-0.454E+01	0.2009	0.8623	0.2565	19
20	1.74384	0.49441	-0.156E+01	0.0655	0.8035	0.3544	20
21	0.99384	0.00559	0.156E+01	-0.0730	-0.8964	0.1965	21
22	0.94550	0.01726	0.454E+01	-0.2251	-0.9660	0.0668	22
23	0.85355	0.04027	0.707E+01	-0.3912	-1.0816	-0.1698	23
24	0.72699	0.06792	0.891E+01	-0.5062	-1.1186	-0.2513	24
25	0.57822	0.09477	0.988E+01	-0.5584	-1.1219	-0.2587	25
26	0.42178	0.11430	0.988E+01	-0.5686	-1.1518	-0.3266	26
27	0.27300	0.11970	0.891E+01	-0.5328	-1.2006	-0.4413	27
28	0.14645	0.10617	0.707E+01	-0.4342	-1.2067	-0.4560	28
29	0.05450	0.07367	0.454E+01	-0.2616	-1.0107	-0.0216	29
30	0.00616	0.02661	0.156E+01	-0.0636	-0.3449	0.8811	30
31	0.00616	-0.02661	-0.156E+01	0.1646	0.8930	0.2025	31
32	0.05450	-0.07367	-0.454E+01	0.3607	1.3934	-0.9415	32
33	0.14645	-0.10617	-0.707E+01	0.5350	1.4868	-1.2105	33
34	0.27300	-0.11970	-0.891E+01	0.6324	1.4248	-1.0301	34
35	0.42178	-0.11430	-0.988E+01	0.6575	1.3319	-0.7740	35
36	0.57822	-0.09477	-0.988E+01	0.6166	1.2387	-0.5345	36
37	0.72699	-0.06792	-0.891E+01	0.5220	1.1534	-0.3302	37
38	0.85355	-0.04027	-0.707E+01	0.3863	1.0682	-0.1410	38
39	0.94550	-0.01726	-0.454E+01	0.2230	0.9568	0.0846	39
40	0.99384	-0.00559	-0.156E+01	0.0730	0.8964	0.1965	40

```
GMA = NON-DIMENSIONAL CIRCULATION = CIRCULATION/(U*L)
(CY,CX) = (FY,FX)/(.5*RHO*U**2*L(K))
CM = MOMENT ABT. MID-CHORD/(.5*RHO*(U*L)**2)
```

FOIL	GMA	CY	CM	CX/2
1	0.009014	-0.001778	0.019936	-0.008046
2	0.174744	-0.365761	0.086705	0.010850

6. References

[1] Ryan, P.G., and Glover, E.J., "A Ducted Propeller Design Method: A New Approach Using Surface Vorticity Distribution Technique and Lifting Line Theory," Proceedings, RINA. 1972.

[2] Dand, J., "Ship-Ship Interactions in Shallow Water," Proceedings, 11th Symposium on Naval Hydrodynamics, London, 1976.

[3] Yeung, R.W., "On the Interactions of Ships in Shallow Water," Proceedings, 2nd STAR Symposium, San Francsico, 1976.