SHADZO: A COMPUTER PROGRAM FOR ESTIMATING THE POSITION AND SHAPE OF THE SURFACE SHADOW ZONE IN SONAR OPERATIONS

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15 November 1972
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by

BERNARD DE RAIGNIAC and JOHN PADLEY

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Published

15 November 1972

APPROVED FOR DISTRIBUTION
(June 1972)

Ir M.W. van Batenburg
Director
## TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABSTRACT</td>
<td>1</td>
</tr>
<tr>
<td>INTRODUCTION</td>
<td>2</td>
</tr>
<tr>
<td>1. THEORY: POSITION AND SHAPE OF THE SURFACE SHADOW ZONE</td>
<td>3</td>
</tr>
<tr>
<td>1.1 Background</td>
<td>3</td>
</tr>
<tr>
<td>1.2 Distance</td>
<td>4</td>
</tr>
<tr>
<td>1.3 Extent</td>
<td>5</td>
</tr>
<tr>
<td>1.4 Maximum Thickness</td>
<td>6</td>
</tr>
<tr>
<td>1.5 Shape</td>
<td>6</td>
</tr>
<tr>
<td>2. DESCRIPTION OF THE SHADZ0 PROGRAM</td>
<td>9</td>
</tr>
<tr>
<td>2.1 Hardware Configuration</td>
<td>9</td>
</tr>
<tr>
<td>2.2 Software Configuration</td>
<td>9</td>
</tr>
<tr>
<td>2.3 Program Inputs</td>
<td>10</td>
</tr>
<tr>
<td>2.4 Program Details</td>
<td>11</td>
</tr>
<tr>
<td>2.5 Program Outputs</td>
<td>12</td>
</tr>
<tr>
<td>2.6 Operation</td>
<td>14</td>
</tr>
<tr>
<td>REFERENCES</td>
<td>19</td>
</tr>
<tr>
<td>APPENDIX A</td>
<td></td>
</tr>
<tr>
<td>DETAILED PROGRAM INFORMATION</td>
<td>20</td>
</tr>
<tr>
<td>A.1 Flow Chart</td>
<td>21</td>
</tr>
<tr>
<td>A.2 Explanatory Diagrams and Program Listing</td>
<td>26</td>
</tr>
</tbody>
</table>

### List of Figures

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Formation of the shadow zone.</td>
<td>7</td>
</tr>
<tr>
<td>2.</td>
<td>Distance, extent and maximum thickness of the shadow zone.</td>
<td>7</td>
</tr>
<tr>
<td>3.</td>
<td>Ray path in a multi-layer, constant-gradient medium.</td>
<td>8</td>
</tr>
<tr>
<td>4.</td>
<td>Estimation of shadow zone shape.</td>
<td>8</td>
</tr>
<tr>
<td>5.</td>
<td>Examples of distance (range), extent (extension) and maximum thickness plots.</td>
<td>17</td>
</tr>
<tr>
<td>6.</td>
<td>Example of shadow zone shape plot.</td>
<td>18</td>
</tr>
</tbody>
</table>
SHALZO: A COMPUTER PROGRAM FOR ESTIMATING THE POSITION AND SHAPE OF THE SURFACE SHADOW ZONE IN SONAR OPERATIONS

by

Bernard de Raigniac and John Padley

ABSTRACT

SHADZO is a composite program which calculates the position and shape of the first surface shadow zone as a function of the source depth for a given sound speed profile. The program is small enough to be run on a shipboard mini-computer in a few minutes.
INTRODUCTION

It has been found from SACLANTCEN's reverberation studies that information on the position and extent of the surface shadow zone* is needed during at-sea experiments. Thus, a program has been developed which, given the sound speed profile, calculates the pertinent characteristics of the shadow zone and can be run on a shipboard mini-computer in a few minutes. In order to make the maximum possible information available to the scientists aboard ship, the program also includes the estimation of shadow zone shape.

SHADZO (surface SHADow ZOne program) is a composite program which calculates the position and shape of the surface shadow zone, as a function of the source depth, for a given sound speed profile. These characteristics are obtained by direct investigation of the limiting rays, rather than by representation of the sound field by ray-tracing with a high density of rays.

This memorandum describes the theoretical basis for, and the implementation of, the two basic parts of SHADZO: (1) a part that calculates the distance (i.e., the inner range limit), the extent and the maximum thickness as functions of source depth, and (2) a part that estimates the shape of the shadow zone for selected source depths. A flow chart, a listing, and explanatory diagrams of SHADZO are given in Appendix A.

* The surface shadow zone treated here is the first (i.e., shortest-range shadow zone; the recurring surface shadow zones at longer ranges are not covered.
1. **THEORY: POSITION AND SHAPE OF THE SURFACE SHADOW ZONE**

1.1 **Background**

When the sound source is located above the critical depth*, $z_{\text{crit}}$, there is a shadow zone along the surface at certain ranges. This surface shadow zone has been discussed by Mellberg, who calls it "shadow layer", in Ref. 1. Mellberg provides formulae for the maximum thickness and horizontal extent of the shadow zone, based on a 2-layer, constant gradient model of the medium. The present memorandum provides a further description of the characteristics of the shadow zone, based on a multi-layer, constant-gradient model.

Figures 1 and 2 illustrate the formation of the surface shadow zone in a medium approximated by a two-layer, constant-gradient model. Figure 1a shows the rays which limit the shadow zone, both in range and depth, when the source is between the surface and the minimum-speed-depth, $z_m$. At the surface, the shadow zone is bounded by rays which have zero grazing angle. The maximum depth, or maximum thickness of the shadow zone, is the depth at which the ray that was horizontal at the source becomes horizontal again. When the source is located between the minimum-speed depth $z_m$ and the critical depth, $z_{\text{crit}}$, as in Fig. 1b, a shadow zone of smaller range extent and smaller maximum thickness will occur.

Figure 2 illustrates the distance, extent and maximum thickness of the shadow zone, again for a 2-layer model. The multi-layer model will be introduced next, and then these three characteristics will be discussed in turn.

---

*The critical depth is the depth at which the sound speed is the same as at the sea surface.
In SHADZO, a multi-layer, constant-gradient model of the medium is used. The rays propagate along circle segments in each layer, as illustrated in Fig. 3. The radius of the path in the $i$th layer is given by:

$$R_i = \frac{k}{g_i} \quad [\text{Eq. 1}]$$

where

$$k = \text{Snell's constant of the ray} = \frac{c}{\cos \alpha} \text{ (at any depth)}$$

$$g_i = \text{gradient in the } i\text{th layer} = \frac{c_i - c_{i-1}}{\Delta z_i}.$$ 

The horizontal distance travelled by the ray in the $i$th layer is then:

$$\Delta d_i = R_i (\sin \alpha_{i-1} - \sin \alpha_i)$$

$$= \Delta z_i \frac{\sqrt{k^2 - c_{i-1}^2} - \sqrt{k^2 - c_i^2}}{c_i - c_{i-1}}. \quad [\text{Eq. 2}]$$

### 1.2 Distance

The distance to the shadow zone, as illustrated in Fig. 2, is defined as the inner range limit of the shadow zone at the surface. Appendix A of Ref. 2 provides formulae for the distance, for both 2-layer and multi-layer constant-gradient models.

From Eq. 2, we see that the total horizontal distance, $d$, travelled by a ray in traversing $n$ layers between the source depth and the surface is given by

$$d = \sum_{i=1}^{n} \Delta d_i = \sum_{i=1}^{n} \Delta z_i \frac{\sqrt{k^2 - c_{i-1}^2} - \sqrt{k^2 - c_i^2}}{c_i - c_{i-1}}.$$
To avoid computing errors when \( c_i \approx c_{i-1} \), this expression may be transformed into

\[
d = \sum_{i=1}^{n} \Delta z_i \frac{c_{i-1} + c_i}{\sqrt{k^2 - c_{i-1}^2} + \sqrt{k^2 - c_i^2}}.
\]  
[Eq. 3]

\( d \) may be expressed as a function of grazing angle at the surface, \( \gamma \), by writing \( k = c_0 / \cos \gamma \). Thus, we see that the distance to the shadow zone, \( D \), is obtained from Eq. 3 simply by setting \( \gamma = 0 \); then, we have \( k = c_0 \) and

\[
D = \sum_{i=1}^{n} \Delta z_i \frac{c_{i-1} + c_i}{\sqrt{c_0^2 - c_{i-1}^2} + \sqrt{c_0^2 - c_i^2}}.
\]  
[Eq. 4]

1.3 Extent

The horizontal extent of the shadow zone at the surface is determined by two rays having zero grazing angle, as illustrated in Fig. 2. It can be seen from Fig. 2 that the horizontal distance travelled by the long-range limiting ray in going between source depth and critical depth is a measure of the extent of the shadow zone. Thus, the extent is given by

\[
E = 2 \sum_{i=n+1}^{k} \Delta z_i \frac{c_{i-1} + c_i}{\sqrt{c_0^2 - c_{i-1}^2} + \sqrt{c_0^2 - c_i^2}}
\]  
[Eq. 5]

where it is assumed that there are \( n \) layers between the source depth and the surface and \( k \) layers between the critical depth and the surface.
1.4 Maximum Thickness

As discussed in Ref. 1 and illustrated in Figs. 1 and 2, the maximum depth of the shadow zone is the depth where a ray that was horizontal at the source becomes horizontal again. At this depth, \( z_t \), the sound speed is equal to \( c_s \), the sound speed at source depth.

1.5 Shape

The shape of the shadow zone can be defined as the envelope of the downward-refracted rays, as illustrated by the dashed curves in Fig. 1. This envelope is relatively difficult to calculate exactly, so an estimate of the shape is obtained as follows. First, at closely-spaced depths, we determine the locus of points at which rays vertex (i.e. become horizontal). For the case shown in Fig. 1b, we see that this locus would provide a reasonable estimate of the envelope. Figure 4 illustrates the case of a limiting ray, such as might be encountered in the presence of a strong negative gradient; in this case, the locus of vertices is not a good estimate. To improve the estimate, at each depth, the intersections of rays vertexing at shallower depths are determined. Finally, at each depth, that point (vertex or intersection) is used which results in the smallest extent of the shadow zone. The estimation of shadow zone shape from these vertices and intersections is illustrated in Fig. 4.

---

\[ z < z_m \]

It would be clearly not provide a reasonable estimate for the case in Fig. 1a; however, this case is not addressed here, as the shape estimation part of SHADZO has been implemented only for cases in which \( z_s > z_m \).
FIG. 1 FORMATION OF THE SHADOW ZONE

FIG. 2 DISTANCE, EXTENT AND MAXIMUM THICKNESS OF THE SHADOW ZONE
FIG. 3 RAY PATH IN A MULTI-LAYER, CONSTANT-GRADIENT MEDIUM

FIG. 4 ESTIMATION OF SHADOW ZONE SHAPE
2. **DESCRIPTION OF THE SHADZO PROGRAM**

2.1 **Hardware Configuration**

The program was written to run under the Hewlett-Packard Real-Time System [Ref. 3], and thus requires a minimum hardware configuration of:

- H-P 2116B Computer with 16K Memory
- H-P 12578A Direct Memory Access
- H-P 12579A Extended Arithmetic Unit
- H-P 12591A Memory Protect
- Fixed Head Disc or Drum Storage Unit
- Time Base Generator
- Operator Console (ASR-33 or ASR-35 Teleprinter)

In addition, the SHADZO program requires a Tektronix T4002/4802 Graphic Computer Terminal with Tektronix Joystick 015-0175000 and Hard Copy Unit 4601. The Tektronix Terminal can be used in place of the operator console, if an additional paper-tape input device is available. In the absence of a Tektronix Terminal, the program can still produce a printed output on any output writer.

2.2 **Software Configuration**

The program requires a Real-Time System generated to provide a minimum background disc-resident area of 20K (octal) locations. The Tektronix Terminal should be allocated logical unit number 16 and should be used with the Real-Time teleprinter drive DRV00.
2.3 Program Inputs

The data are input to the program via a punched tape containing the temperature or sound speed profile. Table 1 gives an example of such a profile, as well as the required format.

**TABLE 1**

**TYPICAL DATA TAPE**

<table>
<thead>
<tr>
<th>FL 11</th>
<th>Profile name—up to 6 alphanumeric characters.</th>
</tr>
</thead>
<tbody>
<tr>
<td>29</td>
<td>7</td>
</tr>
<tr>
<td>-16</td>
<td>No. of points on the profile—integer, negative for temperatures, positive for velocities.</td>
</tr>
<tr>
<td>ø , 24</td>
<td>Temperature or velocity profile.</td>
</tr>
<tr>
<td>2, 22.8</td>
<td>Pairs of points giving depth in metres and temperature in °C or velocity in m/s.</td>
</tr>
<tr>
<td>12, 22.2</td>
<td></td>
</tr>
<tr>
<td>16, 19.5</td>
<td></td>
</tr>
<tr>
<td>18, 18</td>
<td></td>
</tr>
<tr>
<td>20, 16.5</td>
<td></td>
</tr>
<tr>
<td>24, 15.5</td>
<td></td>
</tr>
<tr>
<td>28, 14.8</td>
<td></td>
</tr>
<tr>
<td>40, 14.3</td>
<td></td>
</tr>
<tr>
<td>64, 13.5</td>
<td></td>
</tr>
<tr>
<td>180, 13.5</td>
<td></td>
</tr>
<tr>
<td>250, 13.45</td>
<td></td>
</tr>
<tr>
<td>400, 13.4</td>
<td></td>
</tr>
<tr>
<td>450, 13.35</td>
<td></td>
</tr>
<tr>
<td>2500, 13.35</td>
<td></td>
</tr>
</tbody>
</table>

In the conversion from temperature profile to sound speed profile [according to the Leroy formula (Ref. 4)], the salinity and longitude are considered constants, being pre-set to 38.6 parts/thousand and 40°, respectively. Source depth values are input via the Operator Console.
2.4 Program Details

The SAKO program is written in Fortran II, with the exception of the routines for the Tektronix Terminal, which are standard SACLANTCEN library routines written in Assembler Code.

The program consists of four basic sections, as follows:

**Section One**: Reading of the data tape, and conversion of temperatures to sound speeds if necessary.

**Section Two**: Calculation and printing of distance, extent and maximum thickness.

**Section Three**: Calculation and graphical display of distance, extent and maximum thickness.

**Section Four**: Calculation and graphical display of shadow zone shape.

The first section is performed once for each set of data; the other sections are performed as many times as required.

Sections two and three can be run with two alternative models of the sound speed profile: (1) a multi-layer, constant-gradient model, using all of the sound speeds calculated from the Leroy formula; and (2) an approximation using two constant-gradient layers.

---

8 Because of the restriction in H-P Fortran II which allows only five characters per identifier, the program name actually used is "SHAZO". There are some discrepancies between the terminology used in the text of this memorandum and the terminology used in the program and its outputs shown below. The correspondence is as follows:

<table>
<thead>
<tr>
<th>Term in Text</th>
<th>Term in Program</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sound speed</td>
<td>Velocity</td>
</tr>
<tr>
<td>Maximum thickness</td>
<td>Thickness</td>
</tr>
<tr>
<td>Distance</td>
<td>Range</td>
</tr>
<tr>
<td>Extent</td>
<td>Extension</td>
</tr>
</tbody>
</table>
A flow chart and listing of the program, together with diagrams indicating the significance of variable names for points on the sound speed profile, are given in the appendix.

2.5 Program Outputs

The outputs from the program are prints and plots, as described below.

2.5.1 Prints

a. Sound speed profile: A sample output is given in Table 2.

TABLE 2
EXAMPLE OF SOUND SPEED PROFILE OUTPUT

<table>
<thead>
<tr>
<th>DEPTHS</th>
<th>VELOCITIES</th>
</tr>
</thead>
<tbody>
<tr>
<td>METRES</td>
<td>METRES/SEC</td>
</tr>
<tr>
<td>.00</td>
<td>1537.3</td>
</tr>
<tr>
<td>6.00</td>
<td>1535.2</td>
</tr>
<tr>
<td>8.00</td>
<td>1533.5</td>
</tr>
<tr>
<td>12.00</td>
<td>1532.1</td>
</tr>
<tr>
<td>16.00</td>
<td>1525.0</td>
</tr>
<tr>
<td>18.00</td>
<td>1520.8</td>
</tr>
<tr>
<td>20.00</td>
<td>1516.4</td>
</tr>
<tr>
<td>24.00</td>
<td>1513.5</td>
</tr>
<tr>
<td>28.00</td>
<td>1511.4</td>
</tr>
<tr>
<td>40.00</td>
<td>1510.5</td>
</tr>
<tr>
<td>64.00</td>
<td>1507.8</td>
</tr>
<tr>
<td>180.00</td>
<td>1509.7</td>
</tr>
<tr>
<td>250.00</td>
<td>1510.7</td>
</tr>
<tr>
<td>400.00</td>
<td>1513.8</td>
</tr>
<tr>
<td>450.00</td>
<td>1513.7</td>
</tr>
<tr>
<td>2500.00</td>
<td>1548.0</td>
</tr>
</tbody>
</table>
b. Distance, extent and maximum thickness: An example is given in Table 3 for the multi-layer model. The output from the two-layer model has a similar format.

### TABLE 3

**EXAMPLE OF SHADOW ZONE CHARACTERISTICS OUTPUT**

**MULTILAYER MODEL**

<table>
<thead>
<tr>
<th>SOURCE DEPTH M</th>
<th>EXTENSION RANGE METRES</th>
<th>THICKNESS METRES</th>
<th>S. VELOCITY M/SEC</th>
</tr>
</thead>
<tbody>
<tr>
<td>100.0</td>
<td>35826.4</td>
<td>794.3</td>
<td>57.5</td>
</tr>
<tr>
<td>200.0</td>
<td>34794.9</td>
<td>1310.0</td>
<td>39.8</td>
</tr>
<tr>
<td>300.0</td>
<td>33733.8</td>
<td>1840.6</td>
<td>27.8</td>
</tr>
<tr>
<td>400.0</td>
<td>32640.1</td>
<td>2387.4</td>
<td>24.9</td>
</tr>
<tr>
<td>500.0</td>
<td>31511.9</td>
<td>2951.6</td>
<td>22.6</td>
</tr>
<tr>
<td>600.0</td>
<td>30341.5</td>
<td>3536.8</td>
<td>20.3</td>
</tr>
<tr>
<td>700.0</td>
<td>29122.7</td>
<td>4146.2</td>
<td>19.3</td>
</tr>
<tr>
<td>800.0</td>
<td>27849.2</td>
<td>4752.9</td>
<td>18.6</td>
</tr>
<tr>
<td>900.0</td>
<td>26513.1</td>
<td>5451.0</td>
<td>17.8</td>
</tr>
<tr>
<td>1000.0</td>
<td>25104.4</td>
<td>6155.3</td>
<td>17.0</td>
</tr>
<tr>
<td>1100.0</td>
<td>23610.1</td>
<td>6902.5</td>
<td>16.2</td>
</tr>
<tr>
<td>1200.0</td>
<td>22012.7</td>
<td>7701.2</td>
<td>15.3</td>
</tr>
<tr>
<td>1300.0</td>
<td>20288.1</td>
<td>8563.5</td>
<td>14.4</td>
</tr>
<tr>
<td>1400.0</td>
<td>18400.3</td>
<td>9587.4</td>
<td>13.4</td>
</tr>
<tr>
<td>1500.0</td>
<td>16292.9</td>
<td>10561.1</td>
<td>12.5</td>
</tr>
<tr>
<td>1600.0</td>
<td>13865.9</td>
<td>11774.6</td>
<td>9.6</td>
</tr>
<tr>
<td>1700.0</td>
<td>10908.2</td>
<td>13253.4</td>
<td>6.7</td>
</tr>
<tr>
<td>1800.0</td>
<td>6755.3</td>
<td>15329.9</td>
<td>3.0</td>
</tr>
</tbody>
</table>

2.5.2 Plots

All graphical outputs are plotted on the Tektronix Terminal and have a similar format. The results are plotted on a 5 x 5 grid and a scale factor for each parameter is printed on the display; this scale factor is the number of metres equivalent to one division of the display (i.e., full scale is five times the scale factor). At the end of each display, a copy is produced on the Hard Copy Unit. The origin of the plot is the upper left hand corner; the vertical
parameter is depth and the other relevant parameter is plotted horizontally.

a. Distance, extent and maximum thickness: one plot is produced for each parameter. Examples are given in Fig. 5.

b. Shape: One plot is produced. If more than one source depth is requested, all outputs are plotted on the same graph to the same scale. An example is given in Fig. 6.

2.6 Operation

To run the program, load the data tape in the tape reader and enter the program (under the Real-Time System, this is effected by typing "ON, SHADZO" on the Operator Console). If the last point on the temperature or sound speed profile is not deep enough to allow the critical depth to be calculated, the computer prints:

THE LAST POINT OF THE B.T. IS ABOVE THE CRITICAL DEPTH

and the program ends. In this case, the data tape must be retyped. Once a correct data tape has been read and the sound speed profile has been calculated and listed as shown in Table 2, the computer will print:

FOR SHADOW ZONE SHAPE TYPE 1 OTHERWISE TYPE -1 *

2.6.1 Distance, Extent and Maximum Thickness:

If -1 is replied to the question about shadow zone shape, the computer outputs:

FOR GRAPHIC OUTPUT TYPE 1 OTHERWISE TYPE -1

* All questions of this type should be answered by either -1 or 1, followed by carriage return, line feed.
and after the response to this request, the computer outputs:

FOR MULTILAYER TYPE 1, FOR 2 LAYER TYPE -1

When the type of model has been selected, if no graphic output was requested, then the computer prints:

TYPE IN S.DEPTH: START, STEP, END

The source depths for which output is required should then be typed in, giving the minimum depth first, and with values separated with commas. No output is produced for source depths greater than the critical depth. When the source depth has been input, the results are calculated and printed.

If graphic output is selected, then the three graphs are displayed and after the last output, the joystick is enabled and the computer prints:

TO EXPAND PLOT POSITION CURSOR AT MAXIMUM SOURCE DEPTH REQUIRED AND TYPE 1 OTHERWISE TYPE Ø

If an expansion is required, then the horizontal line of the cursor should be placed at the maximum source depth for the new plots and 1 should be typed. A new set of displays is then produced, and the expansion option is repeated. (It is not possible at this stage to increase the maximum source depth of the display. If this is required, the program must be continued and reprocessing of the same data requested. See below). If expansion of the plots is not required, type 0.

2.6.2 Shadow Zone Shape

If the shape is requested, then the source depths are requested as for the printer output above. The source depths must be below the depth of minimum sound speed; if the starting depth is less than this value, then it is automatically adjusted to this value.
If the source depth exceeds the critical depth, the calculation stops. If only one source depth is required, the second and third parameters should be zero. The computer then calculates and displays the shape.

2.6.3 Termination

After the relevant output has finished, the computer prints:

TYPE 0 TO REPROCESS, 1 TO PROCEED NEW DATA OK 2 TO STOP

If the response is 0, the program returns to the point at which it asks if the shadow zone shape is required. If the response is 1, a new data tape is read and processing restarts. If the response is 2, the program ends.
FIG. 5 EXAMPLES OF DISTANCE (RANGE), EXTENT (EXTENSION) AND MAXIMUM THICKNESS PLOTS
XBT FL 11

CRITICAL DEPTH = 1562.15 METRES

DEPTH SCALE = 20 M/UNIT
RANGE SCALE = 10000 M/UNIT

SOURCE DEPTH = 106.6 M TO 1766.5 M IN STEPS OF 206.6 M

FIG. 6 EXAMPLE OF SHADOW ZONE SHAPE PLOT
REFERENCES


APPENDIX A

DETAILED PROGRAM INFORMATION

A.1 Flow Chart

A.2 Explanatory Diagrams and Program Listing

Note: The word "velocity" used in this Appendix corresponds to the words "sound speed" used in the Main Text.
A.1 Flow Chart

SHADZO FLOW CHART

START

1

PAPER TAPE READER
READ DATA TAPE

TEMPERATURE?
YES

CONVERT TEMPERATURES TO VELOCITIES

FIND TURNING POINT

OUTPUT VELOCITY PROFILE

PRINTER

2
2

FIND CRITICAL DEPTH AND MAXIMUM VELOCITY

3

IS SHAPE REQUIRED?

NO

YES

GRAPHIC OUTPUT?

NO

CALCULATE AND DISPLAY SHAPE

CALCULATE AND DISPLAY RANGE EXTENSION AND THICKNESS

CALCULATE AND PRINT RANGE EXTENSION AND THICKNESS

SAME B.T?

YES

3

NO

NEW B.T?

YES

1

STOP

NO
PRINT FOR OUTPUT

READ IN SOURCE DEPTHS AND IF TWO LAYER OR MULTI LAYER

OUTPUT HEADING

CALCULATE CURRENT SOURCE DEPTH

2 LAYER TYPE OR MODEL MULTI LAYER

TWO LAYER CALCULATIONS MULTILAYER CALCULATIONS

PRINT RESULTS

ANOTHER SOURCE DEPTH?

EXIT
SHAPE OUTPUT

ENTER

TTY.

READ IN SOURCE DEPTHS

CALCULATE MAXIMUM THICKNESS AND SCALE FACTORS

OUTPUT GRATICULE

TEXTRONIX

CALCULATE SHAPE

DISPLAY RESULTS

TEXTRONIX

LAST SOURCE DEPTH?

NO

YES

EXIT

25
A.2 Explanatory Diagrams and Program Listing

- SOURCE DEPTH
- CRITICAL DEPTH

* Point on velocity profile with index, depth and velocity
O Interpolated point with depth and velocity

PARAMETERS USED IN CALCULATION OF RANGE, EXTENSION AND THICKNESS
PARAMETERS USED IN CALCULATION OF SHAPE

(1, D, V) Point on velocity profile with index, depth and velocity
O (D, V) Interpolated point with depth and velocity
FINarl
Tbis progr4ss was developed at -
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ITALY.

P R O S H A S M A Z E O (3.73)
J.o. 27-14-71

DIMENSION 6(44),V(44),C(44),IASCI(10),INAME(6)
DIMENSION PA(1,120),CA(1,2)

THIS PROGRAM PREDICTS THE RANGE AND EXTENSION
OF THE SHADOW ZONE FOR VARIOUS SOURCE DEPTHS.
READ DATA TAPE AND CONVERT TEMPERATURES TO
VELOCITIES IF NECESSARY.

PHI=48.
SAL=38.6
10 DO 20 I=1,6
20 INAME(I)=28448
READ(5,38)(INAME(I),I=1,6)
30 FORMAT(8A1)
READ(5,9)IDAY,MONTH,INEAR,H0,MINUT
READ(5,9)MODE
N=ABS(500E)
DO 35 1=1,N
35 READ(5,9)U(1),V(I)
IF(MODE)=48.50
40 CALL 3TRAN(V+O,N,Sal,phi)
50 CALL FINTE(V,N,TURN)
DTURN=3(T,TURN)
VTURN=V(1,TURN)

CALL EXEC(3,11658,-1)
WRITE(6,60)(INAME(I),I=1,6),IDAY,MONTH,INEAR,H0,MINUT
60 FORMAT(24X,"SHADOW ZONE PREDICTIONS",//,7X,"XBT ",6A1,
1 12X,"DATE",13.2(12.12X="TIME",13.2=12//,
2 5X,"DEPHTS",13X,"VELOCITIES",5X,"METRES",10X,
3 ","HECTIM/SEC")
WRITE(6,70)(U(I),V(I),1=1,N)
70 FORMAT(16X,N,2T11)

FIND CRITICAL DEPTH ETC.

IF(V(1)-V0)DP,100
80 WRITE(1,90)
90 FORMAT(104"THE LAST POINT OF THE B.T. IS ABOVE THE ",
1 1 "CRITICAL DEPTH")
Step 1-4 

n=1(1) 

D=b 

i=1 

Go 12 

i=2 

n=3(1) 

D=3(1) 

i=1 

12 

CONTINUE 

CALL FIXVL(1,3,7)UCRT+1CRITN,ITURN) 

VCRIT=1 

WRITE(139)DCRIT 

134 FORMAT(12A5,"CRITICAL DEPTH =",F3.2," METRES") 

C C REQUEST TYPE OF CALCULATION AND OUTPUT C C 

144 WRITE(1,145) 

145 "= ?

ZONE SHAPE TYPE 1 OTHERWISE TYPE -1 

READ(1,*1)ISHAPE 

IF(ISHAPE. EQ.150)150 

150 n=1 

i=1 

155 FORMAT("FIXED GRAPHIC OUTPUT TYPE 1 OTHERWISE TYPE 

READ(1,*)IGRAPH 

WRITE (1,150) 

163 FORMAT("FIXED MULTILAYER TYPE 1, FOR 2 LAYER TYPE 

READ(1,*)ILAY 

IF(IGRAPH. EQ.1)170,350 

C C *************** C C 

C C PRINTER OUTPUT C C 

170 WRITE(1,180) 

180 FORMAT("TYPE IN S.DEPTH = START=STEP=END") 

READ(1,*)SD1,SD2,SD3 

C C OUTPUT READING ETC. C C 

CALL EXEC(3,1,108,-1) 

IF(LAYER. EQ.150)150 

190 n=1 

i=1 

204 FORMAT(2X,"T4O LAYER MODEL") 

GO TO 230 

213 WRITE(-9)22 

224 FORMAT(2X,"MULTILAYER MODEL") 

230 WRITE(1,240) 

240 FORMAT(2X,"SOURCE DEPTH"A"EXTENSION"A"RANGE"A"THICKNESS" 

1 5X,5X,VELCITY,4X,"METRES",5X,"METRES",5X,"METRES", 

2 6X,"METRES",1X,"A/SEC") 

C C CALCULATE SOURCE DEPTH ETC. C C 

Mx=(3D3-5D1)/5D2*1. 

D=x 

i=1+4X 

SCEP=31+FLOAT(I-1)*D02
IF (DEP > 250) 340
250 IF (DEP = 0) GOTO 250
260 IF (DEP = 0) GOTO 270
270 CALL FIVAL (V, 0, DEP, VEL, IDEP, ITURN)
   CALL FIVAL (V, 0, DEP, 19, ITURN)
   GO TO 290
290 CALL FIVAL (V, +, DEP, VEL, IDEP, ITURN)
   CALL FIVAL (V, +, DEP, 19, ITURN)
   CALL FIVAL (V, +, DEP, 17, ITURN)
   CALL FIVAL (V, +, DEP, 18, ITURN)
290 IF (LAYER) 380, 312

**Two Layer Model**

330 CALL T = C(v, w, vcr, tcr, de, t, d, turn, vel, range, ext, thick)
   GO TO 320

**Multilayer Model**

310 CALL MULTI (V +, vel, vcr, tcr, de, t, d, turn, vel, range, ext)
   THICK = DEP

**Print Results**

320 WRITE (6, 330) DEP, R, A, DEP, VEL, RANGE, THICK, VEL
330 FORMAT (F10.1, 3F14.1, F15.2)
340 CONTINUE
   GO TO 156

**Graphic Output**

350 SMA = DEP x 2.95
360 SMA = (SMA - DEP) / 10 + 0.0

**Find Maximum Values**

360 IF (LAYER) 370, 380
370 CALL T = C(v, w, vcr, tcr, smax, d, d, turn, vel, range, e, th)
   CALL T = C(v, w, vcr, tcr, smin, d, d, turn, vel, range, e, th)
   GO TO 420
380 IF (SMA > 0.5) 390, 400
390 CALL FIVAL (V +, smax, vel, idep, turn)
   CALL FIVAL (V +, smax, 19, turn)
   GO TO 410
400 CALL FIVAL (V +, smax, vel, idep, 18, turn)
   CALL FIVAL (V +, smax, 19, 17, turn)
   CALL FIVAL (V +, smax, 19, 16, turn)
410 CALL MULTI (V +, vel, vcr, tcr, smax, idep, 1
   v, 0, smax, max)
   CALL FIVAL (V +, smax, vel, idep, turn)
   CALL FIVAL (V +, smax, 19, turn)
   CALL MULTI (V +, vel, vcr, tcr, smin, idep, 1
   v, 0, smax, max)
CALCULATE SCALE FACTORS

CALL ISCAL(ISCAL(SODAX))
CALL ISCA(ISCAL(TODAX))
CALL ISCA(ISCAL(RADAX))
CALL ISCA(ISCAL(EAXMAX))
DO 555 J=1,3

OUTPUT GRATICULE

CALL GRAT(INA-E,ISCA,DCRIT,LAYER,ISMAP)
CALL DARK(628+644)
CALL ALPHA
IF(J-2)*3=46#499
432 WRITE(16,444)ISCTM
444 FORMAT("THICKNESS SCALE =",15," M/UNIT")
CALL DANC(912,15)
CALL ALPHA
WRITE(16,454)
454 FORMAT("THICKNESS")
GO TO 520
460 WRITE(16,470)ISCR
470 FORMAT("RANGE SCALE =",15," M/UNIT")
CALL DANC(912,15)
CALL ALPHA
WRITE(16,480)
480 FORMAT("RANGE")
GO TO 520
490 WRITE(16,520)ISCEA
520 FORMAT("EXTENSION SCALE =",15," M/UNIT")
CALL DANC(912,15)
CALL ALPHA
WRITE(16,510)
510 FORMAT("EXTENSION")
520 STEP=(SODAX-DAX)/100.

OUTPUT RESULTS

DO 555 I=1,40
SDEP=DE+FLOAT(I)*STEP
IF(J-2)*52=53
525 IF(LAYEK)530,540
530 CALL T-O(V*,VCHIT,UCRIT,SDEP,DAT,TURN,TURN,1)
RA(I)-EX(I)+TH
GO TO 540
540 IF(SDEP-DAT)550,560
550 CALL NIVAL(V*,V*+SDEP,VEL,DTEP,ITURN+1)
CALL NIVAL(V*,D+VEL,DEP,19+H,ITURN)
GO TO 570
560 CALL NIVAL(D*,V*+SDEP,VEL,DTEP,ITURN)
CALL NIVAL(V*,D+VEL,DEP,19+H,ITURN)
CALL NIVAL(D*,D+VEL+VEL,17+ITURN+1)
CALL NIVAL(V*,D+VEL+VEL,18+ITURN)
570 CALL MULTI(V*,VEL,VCRIT,UCRIT,SDEP,ICRIT,DUP*V,DEP,V,

31
CALCULATE CO-ORDINATES FOR DISPLAY

536 IF(J-2)590,345,619
594 IX=(IA/FLOAT(ISCM))/2.5+20.
GO TO 620
620 IX=(IA(I)/FLOAT(ISCM))*2.5+20.
GO TO 620
619 IX=(EI(I)/FLOAT(ISCEA))*2.5+20.
620 IX=331.-(SD9/FLOAT(ISCM))*12.
IF(1-2)636,546
636 CALL EXPM(IX,IX)
GO TO 650
646 CALL EXIGM(IX,IX)
656 CALL CTIME
CALL HANDC
C
666 CALL NAMK(30,331)
CALL ALPHA

REQUEST IF EXPANSION IS REQUIRED

676浊舨("TO EX-A441 ILOT POSITION CURSOR AT MAXIMUM SOURCE "
1 "DEPTH REQUIRED AND TYPE 1"*/3"X,"OTHERWISE TYPE 2")
CALL CURSL(II4+141+1+1)
IF(12=40)710,636

CALCULATE NEW MAXIMUM SOURCE DEPTH

696 SD9AX=(631.-FLOAT(IY))/12.*FLOAT(ISCM)
IF(60=AX-3.2*1-6,00)450,696
706 GO TO 360
716 CALL EXASE
CALL HOME
GO TO 1500

Calculation and DISPLAY OF SHADOW ZONE SHAPE

726 9ITE(12,2,0)
READ(1,4)SO1,SO2,SU3
IF(SO1-91UTU=-1.)730,746
730 SD1=0UTUXM+1.
746 IF(SD2)750,970+766
756 nK=1
GO TO 765
766 IF(SO3-SU1)770,776,760
776 nK=1
GO TO 765
786 M=SD2-3.01)/5.01+1.

32
C

FIND MAXIMUM VALUES

785 SDEP=SD1
CALL FIVAL(V+V*SDEP*VSDEP*ISDEP*ISDEP*ITURN)
CALL FIVAL(V+V*SDEP*VMAX*I1*I0*ITURN)
CALL FIVAL(V+V*VMAX*I1*I0*ITURN+1)
CALL FIVAL(V+V*VMAX*I1*I0*ITURN+1)
DG 790 I=I+1
799 C(I)=(C(I)-C(I-1))/129.
CALL JEPS(2*J+1+SDEP*VSDEP*VMAX*I0*ITURN*10,
1 C*I0*I1*I01*I12*I2*RAD)

C
CALCULATE SCALE FACTORS

ISCTR=ISCAL(JLAX)
ISCRA=ISCAL(JLST2)

C
OUTPUT GRATICULE

CALL SHAT([NAME,ISCTR,DCRIT,LAYER,ISHAP])
CALL DARK(D1+D58)
CALL ALPHA
WRITE(16,170)ISCRA
CALL DARK(D58)
CALL ALPHA
IF (I4-2.092*918
89% WRITE(16,170)SDEP
900 FORMAT("SOURCE DEPTH = ",F6.1," METERS")
GO TO 930
910 WRITE(16,172)S1,D58,SD2
920 FORMAT("SOURCE DEPTH = ",F6.1," M TO",F6.1,"
1 " % IN STEPS OF",F6.1," M")
930 CALL DARK(912,15)
CALL ALPHA
WRITE(16,170)
DO 113 X=1,IX

C
CALCULATE RESULTS

SDEP=S01+FLOAT(J-1)*S02
CALL FIVAL(V+V*SDEP*VSDEP*ISDEP*ISDEP*ITURN)
CALL FIVAL(V+V*SDEP*VMAX*I1*I0*ITURN)
CALL FIVAL(V+V*VMAX*I1*I0*ITURN+1)
CALL FIVAL(V+V*VMAX*I1*I0*ITURN+1)
STEP=(VMAX-00)/104.
Z0L1=91.
Z0L2=9.
RNE1=9.
RNE2=1.*E19
RADI=7.
RAD2=7.
DO 135 I=1,1
Z=FLOAT(I)*STEP
CALL O+TPS(2*J+1+SDEP*VSDEP*VMAX*I0*ITURN*10,
1 C*I0*I1*I01*I12*I2*RAD)

33
C

FINISH POINTS TO RETAIN

C IF(RAD)942.943,950
948 RANGE=INT(A1)
GO TO 962
955 E=(Z-Z(0))/RAD
RANGE=INT(E+RAD*SQRT(E1*(Z-E))
964 IF(DIST2-RANGE)764,980
973 RA(I)=RANGE
GO TO 990
990 RA=N*1=DIST1
RA(I)=DIST1
ZOLD1=E
RAD1=RA
995 IF(RAD2)1661,1668,1613
1048 RANGE=N*E2
GO TO 1029
1028 E=(Z-Z(0))/RAD2
RANGE=N*E2-RAD2*SQRT(E1*(Z-E))
1042 IF(RANGE-DIST2)1030,1040
1030 EX(I)=RANGE
GO TO 1059
1059 EX=2=DIST2
EX(I)=DIST2
ZOLD2=E
RAD2=RA
1058 CONTINUE

C DISPLAY RESULTS

C DO 1059 I=1,120
Z=FLOAT(I)*STEP
IX=Z/FLOAT(ISCTA)290.23.
IY=31.12/FLOAT(ISCTI)120.
1063 CALL DAHT(IX*IY)
GO TO 1059
1074 CALL EIGHT(IX*IY)
1030 CONTINUE
DO 1099 I=1,120
I=I-1
Z=FLOAT(I)*STEP
IX=EX(I)*FLOAT(ISCTA)290.23.
IY=31.12/FLOAT(ISCTI)120.
1094 CALL EIGHT(I1*I Y)
1099 CONTINUE
CALL HADC
CALL ERASE
CALL ALPHA
CALL HOME
GO TO 1500

C

C Requests NEXT OPERATION

C

C
C
1500 WRITE(1,1510)
1510 FORMAT("TYPE 1 TO REPROCESS, 1 TO PROCESS NEW DATA ",
          1, "2 TO STOP")
          READ(1,*),I
          IF(I-1)14,11,1520
1520 STOP
          END
THIS IS THE FIRST SET OF SUBROUTINES FOR THE
P=604A, S=60

SUBROUTINE MULTI(V0,VEL,VCRLT,UCRP,SUEP,ICRIT,IDEP,
1
V0+RANGE,EXT)

DIMENSION V(I),J(I),T(40)

THIS SUBROUTINE CALCULATES THE RANGE AND EXTENSION OF
THE SHOT ZONE FOR THE MULTILAYER MODEL.

DCRIT=0(ICRIT)
VCRIT=V(1CRIT)
DO 10 I=1,ICRP
10 T(I)=S-QT((V0+V(I))2*(V0-V(I-1)))+SQR((V0+V(I))*(V0-V(I)))
DEP1=(IDEP)
VEL1=V(IDEP)

CALCULATE EXTENSION

IF(DEP1-UCRP)=0,30
20 I=IDEP+1
DEP2=DI(I)
VEL2=V(I)
S=S-QT((V0+VEL2)*(V0-VEL2))+SQR((V0+VEL2)*(V0-VEL2))
EXT=(IDEP2-SUEP)*(VEL+VEL2)/S
S=S-QT((V0+VCRIT)*(V0-VCRIT))
EXT=EXT+(VCRIT-DCRIT)*(VCRIT+VCRIT)/S
GO TO 40
30 EXT=(DCRIT-SUEP)*(VCRIT+VEL)/SQR((V0+VEL)*(V0-VEL))
40 IF(DEP2-UCR1)=5,70
50 I=IDEP+2
DO 60 I=I+1,ICRP
60 EXT=EXT+(J(I)-J(I-1))*(V(I)+V(I-1))/T(I)
70 EXT=EXT+2.

CALCULATE RANGE

S=S-QT((V0+VEL1)*(V0-VEL1))+SQR((V0+VEL1)*(V0-VEL1))
RANGE=(SUEP-DEP1)*(VEL+VEL1)/S
DO 80 I=1,IDEP
80 RANGE=RANGE+(J(I)-J(I-1))*(V(I)+V(I-1))/T(I)
RETURN
END
SUBROUTINE T0(VA,VCRIT,DCRIT,SDEP,DT0,DTURN,
1 VTURN,RANGE,EXT,THICK)

C
C THIS SUBROUTINE CALCULATES THE RANGE, EXTENSION AND
THICKNESS OF THE SHADOW ZONE FOR THE 2 LAYER MODEL.
C
C IF(DT0-DCRIT)IT=2
10 VEL=VTURN+(VCRIT-VTURN)*(SDEP-DTURN)/(DCRIT-DTURN)
S=SQR((V0+VEL)*(V0-VEL))
EXT=2.*((DCRIT-SDEP)*(VCRIT+VEL))/S
S=S+2.*T((V0+VTURN)*(V0-VTURN))
RANGE=(SDEP-DTURN)*(VTURN+VEL)/S
THICK=O+*(DT0-D0)*(V0-VEL)/(V0-VTURN)
G0 TO 30
20 VEL=VTURN+(V0-VTURN)*(SDEP-DTURN)/(D0-DTURN)
S=SQR((V0+VTURN)*(V0-VTURN))
RANGE=SDEP*(V0+VEL)/S
EXT=2.*((CRIT-DTURN)*(VCRIT+VTURN))/S
S=S+2.*T((V0+VEL)*(V0-VEL))
THICK=DTURN*(DCRIT-DTURN)*(VEL+VTURN)/(V0-VTURN)
30 RETURN
END

C
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PAGE 353

SUBROUTINE BTRAN(V,D,N,S,PHI)
DIMENSION V(I),D(I)
C
C THIS SUBROUTINE CALCULATES THE SOUND VELOCITIES V(I)
AT DEPTHS D(I) FROM THE TEMPERATURE VALUES INITIALLY
STORED IN ARRAY V. S IS THE SALINITY AND PHI THE
C LATITUDE.
C
C DO 10 I =1,N
V(I)=1.43+3.9*(V(I)-18.3)-3.006*(V(I)-10.5)*(V(I)-10.5)
1 -2.24*(V(I)-18.3)*D(I)/61+1.29*(S-35.0)*0.01
2 *(V(I)-18.3)*(S-35.0)+D(I)/61+1.E-7*D(I)*D(I)
3 +2.2E-1*PHI(I)*0*(V(I)-18.3)*D(I)/61+1.E-4
4 *(V(I)-18.3)*D(I)/61+2.6E-4*V(I)*(V(I)-5.0)*(V(I)-25.0)
10 CONTINUE
RETURN
END
C
C
SUBROUTINE FINTP(V, N, ITURN)
DIMENSION V(1)

C
C THIS SUBROUTINE FINDS THE MINIMUM ELEMENT OF
C ARRAY V AND PLACES ITS SUFFIX IN LOCATION ITURN
C
C VMIN=V(1)
DO 20 I=2, N
IF(V(I)-V(I-1)) 10, 20, 20
10 V+IN=V(I)
IMIN=I
20 CONTINUE
ITURN=IMIN
RETURN
END

C
C

SUBROUTINE FIVAL(A,3, VALUE, RESLT, ISSCR, N1, N2)
DIMENSION A(1), B(1)

C
C THIS SUBROUTINE FINDS THE VALUE IN ARRAY B WHICH
C CORRESPONDS TO "VALUE" IN ARRAY A AND PLACES IT IN
C RESLT. N1 AND N2 ARE THE LIMITS OF THE ARRAY SUBSCRIPTS
C SO ARRANGED THAT N2 IS THE SUBSCRIPT OF THE LARGEST
C VALUE OF A.
C
C N=IABS(N1-N2)
IF(N1-N2) 10, 20, 20
10 INCR=1
GO TO 30
20 INCR=-1
30 DO 50 I=1, N
I=N1+INCR*I
J=I-INCR
IF(VALUE-A(I)) 50, 40, 40
40 DEL=(VALUE-A(I)) *(A(J)-A(I))
RESLT=RESLT+DEL*(B(J)-B(I))
ISSCR=I
GO TO 50
50 CONTINUE
60 RETURN
END
T-IS IS THE SECOND SET OF SUBROUTINES FOR THE PROGRAM S-420

SUBROUTINE GRAT(1,.AME,.ISCSU,.OCRT,.LAYER,.ISHAP)

DO 9 = 0, 4 (1)

THIS SUBROUTINE PRODUCES THE BASIC GRATICULE FOR GRAPHIC DISPLAYS.

CALL E-458
CALL HOME
WRITE(16+12)
10 FORMAT (/)
CALL 2-DUAL
IF(ISM=1.5+2.)
20 WRITE(16+35)
30 FORMAT (2,4X:""
40 WRITE(16+35) (NAME(I) :I=1,6)
50 FORMAT (20X,"X = T","6(X,AL),"=")
IF(LAYER) $350,1:10$
60 WRITE(16+75)
70 FORMAT (22X,"T = 0 L A Y E R")
GO TO 120
80 WRITE(16+95)
90 FORMAT (A)
GO TO 120
100 WRITE(16+115)
110 FORMAT (22X,"U L T I L A Y E R")
120 CALL 2-DUAL
WRITE(16+120) JCRT
130 FORMAT (22X,"CRITICAL DEPTH = "F3.2," MEAS")
IF(ISM=1.5+16)
140 WRITE(16+130)
150 FORMAT (3X,"SOURCE ")
GO TO 190
160 WRITE(16+170)
170 FORMAT (13A1+"
180 WRITE(16+150) ISCSU
190 FORMAT ("DEPTH SCALE = "I5," m/UNIT")
CALL DARK(23+31)
CALL 2-DUAL(23+31)
CALL 3-DUAL(1023+31)
CALL 3-DUAL(1023+631)
CALL 9-DUAL(23+631)
DO 210 I=2234+23+248
CALL DARK(I+31)
CALL 3-DUAL(1+53)
DO 220 J=3+533+16
240 CALL POINT(I+1)
CALL DARK(I+599)
210 CALL 5-DUAL(I+31)
DO 230 I=1515+111+120
CALL DAXK(23*1)
CALL ZLUM(33*1)
DO 22 J=87,991,15
22 CALL ZLUM(J*1)
CALL DAXK(991*1)
CALL ZLUM(1d23*1)
CALL DAXK(7031)
CALL ALMEX
WRITE(16+2*4)
24 FORMAT("W"\$)
IF(ISHAP)252+27d
25 WRITE(15+2*5)
26 FORMAT("S"/"U"/"U"/"K"/"C"/"E"/)
27 WRITE(16+2*8d)
28 FORMAT("U"/"Z"/"P"/"F"/"G"/"
RETURN
END

FUNCTION ISCAL(RAMAX)
DIMENSION ISC(3),XMAX(3)

THIS FUNCTION TAKES THE NEXT VALUE ABOVE RAMAX FROM
THE SERIES 1*10**N, 2*10**N, 5*10**N WHERE N=1,2,3.......

ISC(1)=1
ISC(2)=2
ISC(3)=5
XMAX(1)=5.
XMAX(2)=1d.
XMAX(3)=.2.
10 DO 32 I=1,3
    IF(XMAX(I)-RAMAX)30+20
20 ISCAL=ISC(I)
    GO TO 50
30 CONTINUE
    DO 40 I=1,3
        ISC(I)=1.5*ISC(I)
40 XMAX(I)=1.5*XMAX(I)
    GO TO 10
50 RETURN
END

C
C
SUBROUTINE DIST
   REAL X(5), Y(5), Z(5), RSQ, VSQ, RD, ND, V, ZP
1   C*+V=IST1+DIST2+RAD)
   DI=SQRT(C(1)+C(3)*V(1))
   C   THIS SUBROUTINE CALCULATES THE DISTANCES TO THE
   C   VECTORS AT KAYS ORBIT ORCHESTRA AT A DEPTH Z AND ALSO
   C   THE RADIUS OF THE RAYS AT THESE POINTS
   C
   PS:=(1.0)=SQRT((2.5)+((a-b))
   C   FIND VELOCITY AT DEPTH Z ETC.
   C
   DSZPT=U(ISOZPT)
   VSZPT=V(ISOZPT)
   CALL FIVAL(U*V*Z*SK+IZPT+IYV+IY)
   IZPZ=IZP+1
   DZPT=D(ZPPT)
   VZPZ=V(ZPPT)
   C
   SK=SMOOTH CONSTANT FOR THE RAY
   C
   CALL FIVAL(U*V*Z*SK+IZPT+IYV+IY)
   ULZPT=U(ZPPT)
   VLZPT=V(ZPPT)
   C
   FIND THE DISTANCE TO THE FIRST TURNING POINT
   C
   DIST=.
3   DIST=(S(ZP-DEP)*SDEP+VSDEP*VZDEP)/(RSQ(SK+ZPDEP)+RSQ(SK+VZDEP))
7   IF(ISOZPT-IZP)10,30,10
1   J=J+1
   DO 20 I=K+1SOZPT
10   IF(ISOZPT-I)12,30,12
12   10 =.
13   DIST=.
   DIST=1.E+4
   GO TO 140
20   DIST=DISS1+C(I)/(RSQ(SK+V(I-1)))+RSQ(SK+V(I)))
30   IF(I.E-4.5K+ZPDEP)40,45,40
45   DIST=DISS1+(DZP-Z)*((VZP+SK)/RSQ(SK+VZDEP))
C
   FIND THE DISTANCE TO THE SECOND TURNING POINT
   C
   45 IF(ZP=Z+16*SK)
   50 DISS2=DISS1
   GO TO 140
60   IF((LZP=U(ISOZPT+1))70+40
70   IF(1.E-4-SK+VSDEP)80,80,40
80   DISS2=DISS1+2.0D0((LZP-SDEP)2.0D0(SK+VSDEP)/(RSQ(SK+VSDEP))
   GO TO 140
90   DISS2=DISS1+2.0D0((ISOZPT+1)-SDEP)2.0D0((ISOZPT+1)+VZDEP)/
     1
       (RSQ(SK+((ISOZPT+1)))+RSQ(SK+VZDEP))
100   J=ISOZPT+2
   DO 110 I=J+ILZPT

41
11: DIST2 = DIST2 + Z * C(1) / (RSQ(SK*V(I-1)) + RSQ(SK*V(I)));
12: IF (1.0 - Z * S*VLZPT) I36 + 140
13: DIST2 = DIST2 + Z * (S*VLZPT) / (RSQ(SK*VLZPT))
C
C CALCULATE RADIUS AT TURNING POINTS
C
14: RAD = Z * (S*ZPT - D) / (V(ZPT-1) - VZPT)
RETURN
END