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GEOLOGICAL SURVEY

HANDTC, A FORTRAN PROGRAM TO CALCULATE
INNER-ZONE TERRAIN CORRECTIONS

By

J. B. Spielman and D. A. Ponce

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Menlo Park, California

1984

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J. B. Spielman¹ and D. A. Ponce¹

¹U.S. Geological Survey, Menlo Park, CA

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Abstract

FORTRAN program "Handtc" computes inner-zone terrain corrections for Hayford-Bowie zones C through F and Hammer zones D through H. The terrain corrections are based on the formula for the gravitational attraction of a vertical cylinder. The input file consists of four record types: a station record, a zone label record, a compartment elevation record, and a blank record. The program generates two files: an output file and a print file. The output file lists the station name, total terrain correction, and the various zone terrain corrections in integer format. The print file lists the station name, station elevation, units, method, zone labels, compartment elevations, terrain corrections for each compartment, terrain correction for each zone, and the total terrain correction. The format of the print file is such that it can be quickly scanned and compared to the input file to check for errors in format, zone labels, compartment elevations, or anomalous terrain corrections. The program was developed on a Digital VAX/VMS 11/750 computer and is compatible with ANSI Standard FORTRAN-77.

Introduction

A program 'handtc' to calculate inner-zone terrain corrections for gravity stations has been developed in support of the U.S. Geological Survey's effort to characterize potential radioactive waste storage sites at the Nevada Test Site, Nevada. Determining complete Bouguer anomalies from gravity data necessitates the calculation of terrain corrections to remove the effect of topography surrounding a gravity station.

Generally, there are two manual terrain correction systems in use. Hayford-Bowie (1912) devised a system of dividing the terrain surrounding a gravity station into zones and compartments. In practice, this is accomplished by placing a transparent template of concentric rings and radial lines (fig. 1a) centered at a gravity station on the largest scale topographic map available. The template's circular rings divide the topography into lettered zones and the radial lines divide each zone into equal compartments. As a convenience, compartments may be considered numbered in a clockwise direction beginning from due north to facilitate the recalculation of a compartment elevation. A system of subcompartments was devised (H. W. Oliver, written commun., 1970) based on Bowie's (1917, p. 9-18) subdivided zones to make the Hayford-Bowie system more accurate in areas of steep terrain (fig. 1b). Generally, subcompartments are used when the terrain correction of a zone is greater than 1 milligal.

The second system, devised by Hammer (1939), was modeled after the Hayford-Bowie system of 1912. Hammer designed the system to obtain equidimensional compartments by relating the ratio of the outer and inner radii of a zone to the width of the compartments in that zone (fig. 2). Hammer believed that the method maximized accuracy while minimizing the total number of compartments.

Modern terrain correction procedures are separated into a three part process: (1) the estimation of the innermost or field terrain correction, (2) the calculation of the inner-zone correction, and (3) the calculation of outer-zone terrain correction by computer analysis.

Since topographic contour maps do not show the detail required near a station, the innermost terrain correction is usually estimated in the field with the aid of templates and charts, or sketched and later calculated in the office. The innermost zones correspond to the Hayford-Bowie A and B zones with an outer radius of 68 m (223 ft), or the Hammer A, B, and C zones with an outer radius of 53 m (175 ft).

Part 2, the inner-zone corrections are calculated by estimating compartment elevations using a transparent template based on either Hayford-Bowie's or Hammer's system of zones (figs. 1 and 2). Compartment elevations are recorded on a terrain correction form, an example of which is shown in figure 3. The inner-zones generally correspond to Hayford-Bowie zones C through F with an outer radius of 2.29 km (7,513 ft), or Hammer zones D through H with an outer radius of 2.61 km (8,578 ft).

The outer-zone terrain correction which extends from the outer radius of the inner-zone correction (part 2) to a radial distance of 166.7 km (Hayford-Bowie zone O) is calculated using a computer program based on a grid of digital terrain data (Plouff, 1977). The starting radius of the computer terrain correction is a function of the accuracy and availability of digital terrain data. The computer terrain correction may start as close as 590 m (outer radius of Hayford-Bowie zone D) from a station provided digital terrain data is available with average elevations estimated at a 1/4-minute geographic grid.

Program "Handtc" calculates inner-zone terrain corrections for Hayford-Bowie zones C through F (including subzones) and Hammer zones D through H. The inner and outer radii and number of compartments for these zones are shown in table 1. The program is based on the formula for the gravitational attraction of a vertical cylinder (Hammer, 1939). The program is designed for any computer compatible with ANSI Standard FORTRAN-77.

Formula

The formula used for calculating inner-zone terrain corrections is exact and based on the gravity effect along the axis at one end of a vertical cylinder (fig. 4a).

$$g_{cylinder} = 2\pi Gd(h + r - (r^2 + h^2)^{\frac{1}{2}}),$$

where

$g_{cylinder}$ = vertical component of gravity,
G = universal gravity constant,
d = density,
r = radius of cylinder,

and

h = height of cylinder.

The formula for the effect of a zone, which is a cylindrical shell, or the difference of two concentric vertical cylinders of the same height (fig. 4b) is

$$g_{zone} = 2\pi Gd(r_2 - r_1 + (r_1^2 + h^2)^{\frac{1}{2}} - (r_2^2 + h^2)^{\frac{1}{2}}),$$

where

r_1 = inner radius of zone,
 r_2 = outer radius of zone,

and

h = height of cylinder
= (station elevation) - (compartment elevation).

For a cylindircal sector or compartment (fig. 4b), the gravity effect is

$$g_{\text{compartment}} = \frac{2\pi Gd}{n} (r_2 - r_1 + (r_1^2 + h^2)^{\frac{1}{2}} - (r_2^2 + h^2)^{\frac{1}{2}}),$$

where

n = number of compartments in the zone or cylindrical shell.

The vertical attraction for each compartment is summed to give the terrain effect for each zone. The terrain corrections for each zone are summed and added to the innermost or field terrain correction to obtain the total "hand" terrain correction for each station.

Program Usage

A generalized flow chart of the program is shown in figure 5. The program operates interactively, requesting the input, output, and print file names.

A sample of the input file is shown in table 2 and consists of 4 types of records: (1) a station record, (2) zone label records, (3) compartment elevation records, and (4) a blank record to signify the end of a station.

The station record contains parameters in the following columns:

<u>Column</u>	<u>Format</u>	<u>Item</u>
1-5	a5	Station name
7-12	f6.1	Elevation
14-16	i3	Field terrain correction in 0.01 mGal units
18	a1	Elevation unit: blank or F for feet, M for meters
20-22	a3	Terrain correction system: blank or HAY for Hayford-Bowie, HAM for Hammer.

The second record contains only a zone label. Zone labels must begin in column 1:

1-2 a2 Zone label: C, C1, C2, D, D1, D2, E, E1, E2, F, F1, F2, G, or H.

The third record contains the compartment elevations, each separated by a blank space. Compartment elevations must be in the same units as the station elevation. Compartment elevations are read in 'list-directed' or 'free' format. The number of elevations must equal the number of compartments for a zone (see table 1), unless a slash is used to terminate the input record. A slash may be used when the remaining compartments (or all compartments) have a

terrain correction of zero. A slash will set the remaining compartment elevations equal to the station elevation and thus produce a terrain correction of zero. Zone records and associated compartment elevation records are repeated until all zones desired are completed for a station.

The fourth record type, a blank line, must be placed after the last compartment elevation record to terminate the terrain correction for that particular station.

Program Output

The program generates two files, an output file and a print file. The output file (table 3) lists the station name, total terrain correction, and the various zone terrain corrections, to the nearest 0.01 mGal in integer format. The format is:

<u>Column</u>	<u>Format</u>	<u>Item</u>
1-5	a5	Station name
6-11	i6	Total hand terrain correction
12-17	i6	Hayford-Bowie A and B zone field terrain correction
18-23	i6	Hammer A, B, and C zone field terrain correction
24-29	i6	C zone terrain correctin (Hayford-Bowie only)
30-35	i6	D zone terrain correction (either system)
36-41	i6	E zone terrain correction (either system)
42-47	i6	F zone terrain correction (either system)
48-53	i6	G zone terrain correction (Hammer only)
54-59	i6	H zone terrain correction (Hammer only).

The print file (table 4) is a summary for each station. Terrain corrections are expressed in 0.01 mGal units for each zone and compartment, and are printed below the zone label and compartment elevation, respectively. The format is such that the print file can be quickly scanned and compared to the input file to check for errors in format, zone labels, compartment elevations, or anomalous terrain corrections. Totals for the station and zones are also shown in units of mGal.

Program Messages

Error messages occur for the following conditions: (1) error in opening input file, the program prompts the user to 'try again?' (2) error in reading station record, the program lists the station name and terminates, (3) missing station record, program lists the station name and terminates (4) missing or error in compartment elevation record, the program displays station name, zone, number of elements found, and terminates, (5) missing blank record, program lists the station name and terminates.

A warning message results when a compartment elevation is zero. The program lists the station name, zone, and number of compartments that have zero elevation.

References

Bowie, William, 1917, Investigations of gravity and isostasy: U.S. Coast and Geodetic Survey Special Publication No. 40, 196 p.

Hayford, John F., and Bowie, William, 1912, The effect of topography and isostatic compensation upon the intensity of gravity: U.S. Coast and Geodetic Survey Special Publication No. 10, 132 p.

Hammer, Sigmund, 1939, Terrain corrections for gravimeter stations: Geophysics, vol. 4, p. 184-194.

Plouff, Donald, 1977, Preliminary documentation for a FORTRAN program to compute gravity terrain corrections based on topography digitized on a geographic grid: U.S. Geological Survey Open-File Report 77-535, 45 p.

Figure 1A.

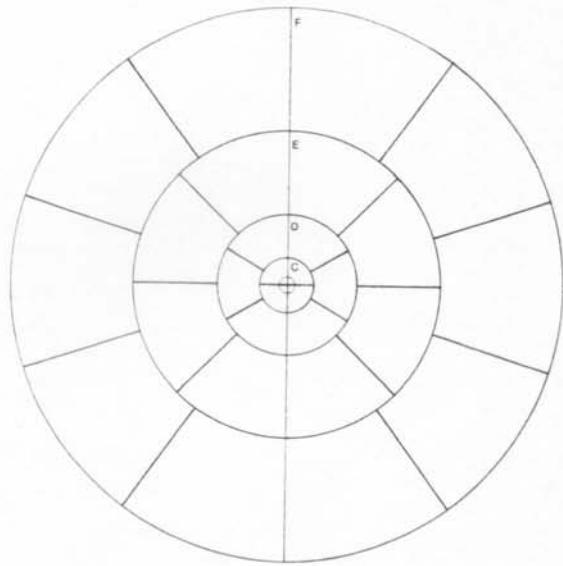


Figure 1B.

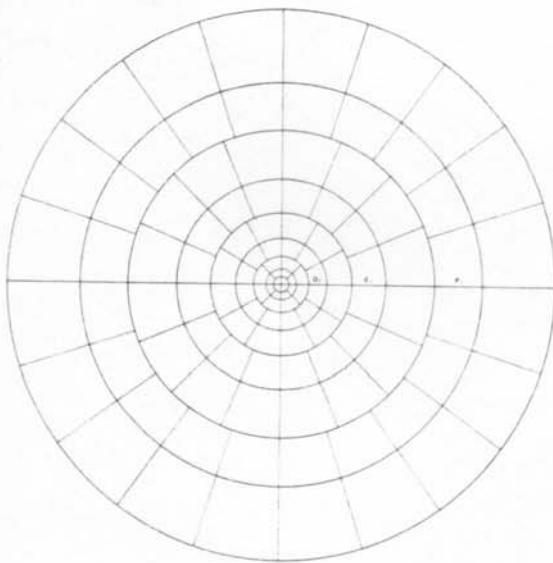


Figure 1. -- Hayford-Bowie template for (A) 'whole zones' and (B) subzones at a scale of 1:62,500

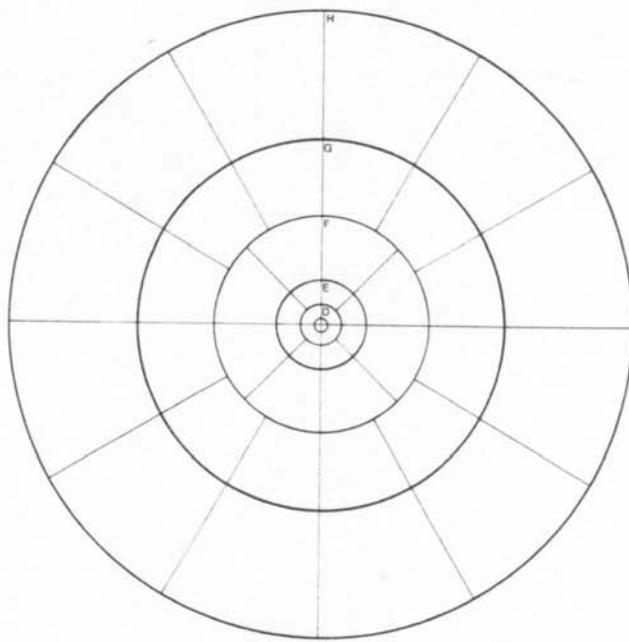


Figure 2. -- Hammer template at a map scale of 1:62,500.

HAYFORD-BOWIE TERRAIN CORRECTION FORM

PROJECT:

MAP:

NAME: DATE:

STATION:		ELEV:		AB:	
C	C1 (8)				
(4)	C2 (8)				
D	D1 (12)				
(6)	D2 (12)				
STATION:		ELEV:		AB:	
C	C1 (8)				
(4)	C2 (8)				
D	D1 (12)				
(6)	D2 (12)				
STATION:		ELEV:		AB:	
C	C1 (8)				
(4)	C2 (8)				
D	D1 (12)				
(6)	D2 (12)				
STATION:		ELEV:		AB:	
C	C1 (8)				
(4)	C2 (8)				
D	D1 (12)				
(6)	D2 (12)				

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Figure 3. -- Terrain correction form.

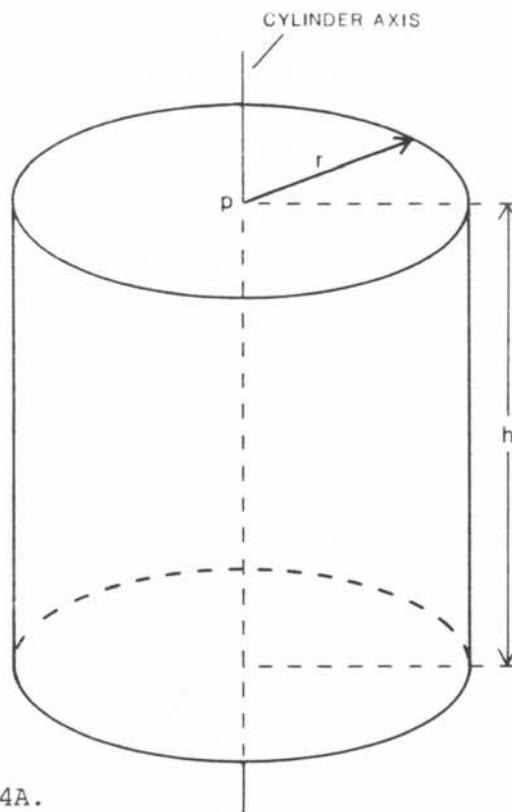


Figure 4A.

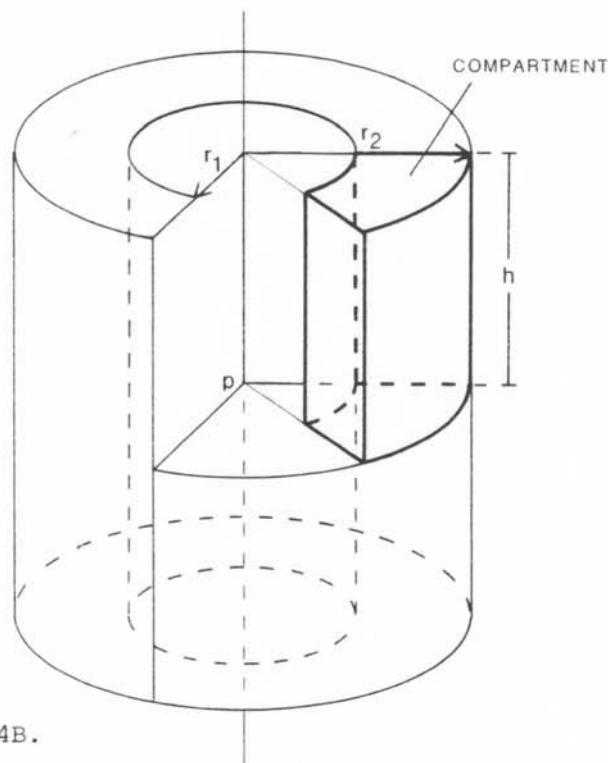


Figure 4B.

Figure 4. -- Notation for gravity effect of (A) a cylinder, and (B) a cylindrical compartment.

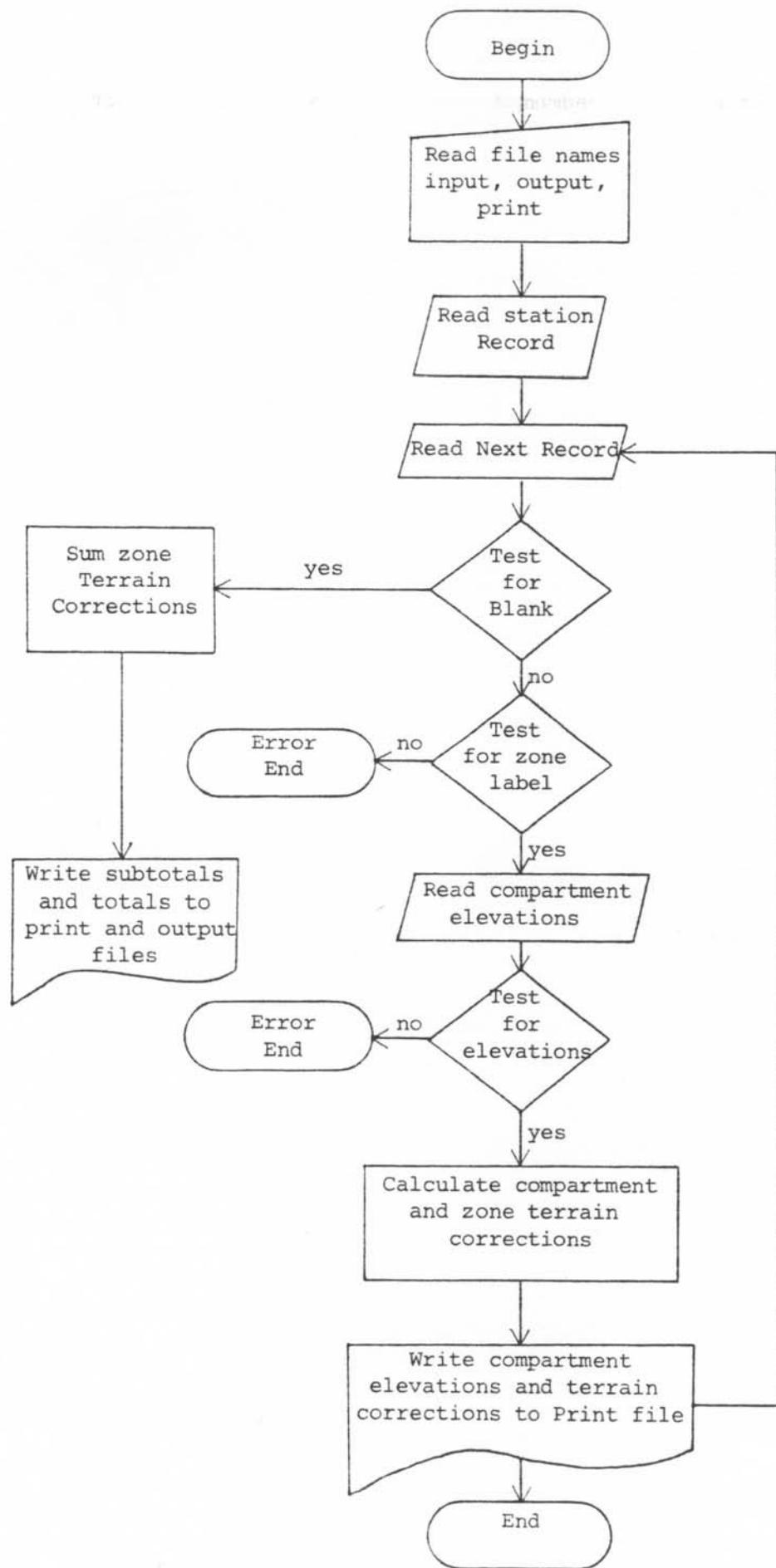


Figure 5. -- Flow chart of program Handtc.

Table 1. -- Zones, radii, and number of compartments for Hayford-Bowie and Hammer systems

Zone	Radii		Radii		Number of Compartments
	Inner (m)	Outer	Inner (ft)	Outer	
<u>Hayford-Bowie Zones</u>					
C	68	230	223	755	4
D	230	590	755	1,936	6
E	590	1,280	1,936	4,199	8
F	1,280	2,290	4,199	7,513	10
<u>Hayford-Bowie Subzones with Subcompartments</u>					
C1	68	130	223	427	8
C2	130	230	427	755	8
D1	230	380	755	1,247	12
D2	380	590	1,247	1,936	12
E1	590	870	1,936	2,854	16
E2	870	1,280	2,854	4,199	16
F1	1,280	1,680	4,199	5,512	20
F2	1,680	2,290	5,512	7,513	20
<u>Hammer Zones</u>					
D	53	170	175	558	6
E	170	390	558	1,280	8
F	390	895	1,280	2,936	8
G	895	1530	2,936	5,018	12
H	1530	2615	5,018	8,578	12

Table 2. -- Example of input file

STAT1 4300 020 F HAM
 d
 4417 4423.5 4430 4436.5 4443 4449
 e
 4530 4545 4559 4573 4586 4599 4612 4624.5
 f
 4642 4663.5 4684 4703.5 4722 4740 4757.5 4747.5
 g
 4819 4881 4938 4991 5040 5086.5 5130.5 5173 5213 5252 5290 5327
 h
 4976 5057 5131 5198 5261 5321 5377 5431 5483 5533 5581 5627.5

 STAT2 1757.0 02 M HAY
 c
 1757 1752 /
 d
 1754 1743 1749 1765 1766 1767

 STAT3 2971 04 M
 c1
 2950 2950 2955 2955 2955 2940 2935 2945
 c2
 2930 2935 2930 2940 2950 2910 2900 2930
 d1
 2885 2880 2915 2880 2905 2935 2950 2895 2850 2830 2880 2925
 d2
 2825 2810 2865 2830 2915 2970 2910 2835 2770 2750 2850 2915
 e1
 2800 2790 2850 2825 2900 2960 2900 2840 2790 2745 2830 2900 2920 2900 2880 2830
 e2
 2760 2750 2840 2815 2895 2970 2875 2835 2770 2730 2820 2880 2900 2880 2820 2790
 f1
 2760 2750 2800 2800 2850 2900 2850 2800 2750 2700 2750 2760 2730 2700 2690 2660 2650 2680 2700
 f2
 2720 2730 2760 2760 2800 2850 2820 2780 2750 2740 2700 2720 2720 2700 2690 2650 2640 2670 2695

 STAT4 6729.5 01 F
 c1
 6693 6676 6676 6693 6709 6693 6676 6709
 c2
 6676 6628 6611 6628 6660 6644 6628 6693
 d1
 6660 6594 6578 6562 6545 6578 6578 6611 6594 6578 6594 6693
 d2
 6660 6628 6611 6594 6512 6496 6496 6545 6496 6496 6545 6628

 STAT5 2120 01
 c
 2135 2140 2140 2145
 d
 2260 2270 2275 2285 2300 2275
 e
 2415 2440 2460 2480 2500 2480 2455 2440
 f
 2625 2675 2715 2760 2795 2835 2840 2830 2800 2775

Table 3. -- Example of output file

STAT	TOTAL	AB	ABC	C	D	E	F	G	H
STAT1	668		20		100	123	121	152	152
STAT2	4	2			1				
STAT3	407	4		57	145	95	107		
STAT4	52	1			32				
STAT5	166	1		2	34	54	74		

Table 4. -- Example of print file

LISTING OF COMPARTMENT ELEVATIONS AND TERRAIN CORRECTIONS FROM HANDTC PROGRAM

Appendix -- Listing of Program Handtc

c PROGRAM TO CALCULATE INNER ZONE TERRAIN CORRECTIONS FOR
c HAYFORD-BOWIE ZONES C THORUGH F, AND HAMMER ZONES D THROUGH H
c
c EXPLANATION OF VARIABLES
c blank: flags end of old station and start of new one (blank
c card)
c const: universal gravity constant (elev in meters,tc in hundredths
c of mGal)
c delev: difference between station and compartment elevations
c dens: density 2.67 g/cm³
c elev: station elevation
c f2msq: conversion factor of feet to meter squared
c ham: hay or ham for Hayford-Bowie or Hammer methods
c iab: integer form of field tc, Hayford-Bowie ab or Hammer abc
c itotal: integer value of total
c izone: integer location of zone in array ring
c mtype: equals Hayford-Bowie or Hammer for a station in the
c print file
c ncomp: number of compartments for the current zone
c nring: total no. of zones
c nring2: number of whole zones
c nstat: number of stations processed
c ostr: string to contain output record
c pstr: string to contain print record
c stat: station name
c total: total terrain correction for a station
c ttab: real value for iab
c twopi: pi multiplied by 2
c twopicd: $2 * \pi * \text{gravity constant} * \text{the density}$
c type: feet or meters
c unit1: f or m
c zone: the zone calculated, (i.e. c, c1, c2, d, d1 . . .)
c
c EXPLANATION OF ARRAY VARIABLES
c dr(6): difference of radii
c elcomp(12): elev for each compartment
c frac(2,12): constant portion of terrain correction formula
c icomp(2,12): number of compartments for each zone
c ielcomp(20): elcomp in integer form
c itc(20): tc in integer form
c iflag(12): flags if a zone has been calculated, (-9999. = not
c calculated)
c itzone(6): integer form of tzone
c method(2): Hayford-Bowie or Hammer
c osp(9): spacing for output string
c psp(9): spacing for print string
c r1(2,12): inner radius of zones
c r1sq(2,12): squares of r1 (inner radius)
c r2(2,12): outer radius of zones
c r2sq(2,12): squares of r2 (outer radius)
c ring(2,12): the array of zones, lower case
c ring2(2,12): the array of zones, upper case
c tc(12): tc for each separate compartment
c tzone(6): total tc for each zone
c unit2(2): feet or meters
c zlab(9): zone labels for print string

```

c
c
dimension elcomp(20),icomp(2,12),r1(2,12),r2(2,12),r1sq(2,12),
&r2sq(2,12),tzone(12),itzone(12),tc(20),itc(20),ielcomp(20),
&dr(2,12),frac(2,12),iflag(12),osp(9),psp(9)
character*1 unit1,b1,slash,elstr(132),ans
character*2 zone,blank,ring(2,12),ring2(2,12)
character*3 ham
character*5 stat
character*6 unit2(2),type,zlab(9)
character*13 method(2),mtype
character*32 infile,printfile,outfile
character*64 ostr
character*100 pstr
c
c INITIALIZE HAYFORD ZONE LABELS, RADII, AND NUMBER OF COMPARTMENTS
  data (ring(1,j),j=1,12)/*c ','d ','e ','f ','c1','c2',
  &'d1','d2','e1','e2','f1','f2'/
  data (ring2(1,j),j=1,12)/*C ','D ','E ','F ','C1','C2',
  &'D1','D2','E1','E2','F1','F2'/
  data (r1(1,j),j=1,12)/68.,230.,590.,1280.,68.,130.,
  &230.,380.,590.,870.,1280.,1680./
  data (r2(1,j),j=1,12)/230.,590.,1280.,2290.,130.,230.,
  &380.,590.,870.,1280.,1680.,2290./
  data (icomp(1,j),j=1,12)/4,6,8,10,8,8,12,12,16,16,20,20/
c
c INITIALIZE HAMMER ZONE LABELS, RADII, AND NUMBER OF COMPARTMENTS
c VARIABLE RANGE FROM 2-6 SO THAT HAYFORD BOWIE
c D ZONE AND HAMMER D ZONE HAVE THE SAME IZONE
  data (ring(2,j),j=2,6)/*d ','e ','f ','g ','h'/
  data (ring2(2,j),j=2,6)/*D ','E ','F ','G ','H'/
  data (r1(2,j),j=2,6)/175.,558.,1280.,2936.,5018./
  data (r2(2,j),j=2,6)/558.,1280.,2936.,5018.,8578./
  data (icomp(2,j),j=2,6)/6,8,8,12,12/
c
c INITIALIZE OUTPUT AND PRINT STRINGS (USED TO LEAVE BLANKS
c IN THE OUPUT AND PRINT FILES WHERE NO TC WAS CALCULATED)
  data osp/24,30,36,42,48,54,6,12,18/
  data psp/27,39,51,63,75,87,1,15,15/
  data zlab/'    TC:','    TD:','    TE:','    TF:','    TG:','
  &           '    TH:','TOTAL:','    TAB:','TABC:'/
c
c INITIALIZE VARIABLES
  data b1,blank,slash/' ',' ',' ',' '/
  data unit2/'feet ','meters'/
  data method/'Hayford-Bowie','Hammer'      '/
c
nstat=0
f2msq=.3048*.3048
const=0.667
dens=2.67
twopi=2*3.14159
twopicd=twopi*const*dens

```

```

c
c FILE ATTACHMENT
    print 20
20 format(' TERRAIN CORRECTION PROGRAM! ')
50 print 21
21 format(' TYPE NAME OF INPUT FILE (__.ITC)')
    read(5,100) infile
100 format(a32)
    open(unit=7,file=infile,form='formatted',status='old',
&blank='zero',err=201)
    print 22
22 format(1x,'TYPE NAME OF PRINT FILE (__.HPR)')
    read(5,101) printfile
101 format(a32)
    open(unit=8,file=printfile,form='formatted',status='new')
    print 23
23 format(1x,'TYPE NAME OF OUTPUT FILE (__.HTC)')
    read(5,102) outfile
102 format(a32)
    open(unit=9,file=outfile,form='formatted',status='new')

c
c CONVERT HAMMER RADII FROM FEET TO METERS
    do 1 i1=2,6
        r1(2,i1)=.3048*r1(2,i1)
        r2(2,i1)=.3048*r2(2,i1)
1 continue

c
c CALCULATE RADII SQUARED, DIFFERENCE OF RADII, AND ARRAY FRAC
    kring=12
    nn=1
    do 2 i2=1,2
        do 3 i3=nn,kring
            r1sq(i2,i3)=r1(i2,i3)*r1(i2,i3)
            r2sq(i2,i3)=r2(i2,i3)*r2(i2,i3)
            dr(i2,i3)=r2(i2,i3)-r1(i2,i3)
            frac(i2,i3)=twopicd/icomp(i2,i3)
3 continue
    kring=6
    nn=2
2 continue

c
c WRITE COLUMN HEADINGS FOR PRINT AND OUTPUT FILES
    write(8,103)
103 format(6x,'LISTING OF COMPARTMENT ELEVATIONS AND
&TERRAIN CORRECTIONS FROM HANDTC PROGRAM')
    write(9,104)
104 format(2x,'STAT',2x,'TOTAL',3x,'AB',4x,'ABC',3x,'C',
&5x,'D',5x,'E',5x,'F',5x,'G',5x,'H')

c
c DO LOOP TO BEGIN A TERRAIN CORRECTION
    do 4 i4=1,1000

```

```

c
c  INITIALIZE TERRAIN CORRECTIONS TO -9999.
c  WHEN FINISHED WITH A STATION, THIS VALUE INDICATES
c  THAT A TC WAS NOT CALCULATED FOR A ZONE
      total=0.0
      do 5 i5=1,12
          tzone(i5)=-9999.
          iflag(i5)=2
      5 continue

c
c  INITIALIZE OUTPUT AND PRINT STRINGS TO ALL BLANK, FOR
c  EACH NEW STATION
      ostr=' '
      pstr=' '

c
c  READ STATION RECORD .
      read(7,105,err=202,end=999) stat,elev,iab,unit1,ham
105 format(a5,1x,f6.1,1x,i3,1x,a1,1x,a3)
      nstat=nstat + 1

c
c  TEST FOR FEET OR METERS
      if (unit1.eq.'m' .or. unit1.eq.'M') then
          type=unit2(2)
      else
          type=unit2(1)
      end if

c
c  TEST FOR HAYFORD-BOWIE OR HAMMER
      if (ham.eq.'ham' .or. ham.eq.'HAM') then
          mtype=method(2)
          k=2
          nring=6
          nring2=6
      else
          mtype=method(1)
          k=1
          nring=12
          nring2=4
      end if

c
      write(8,106) stat,elev,type,mtype
106 format(/1x,'STATION: ',a5,2x,'ELEVATION: ',f7.1,1x,a6,
     &2x,'METHOD: ',a13)

c
c  READ NEXT RECORD AND CHECK FOR ZONE LABEL OR BLANK RECORD
      51 read(7,107,end=600) zone
107 format(a2)
      if (zone.eq.blank) go to 600

c
c  DETERMINE NUMBER OF COMPARTMENTS
      do 6 i6=1,nring
          if (zone.eq.ring(k,i6) .or. zone.eq.ring2(k,i6)) then
              izone=i6
              go to 52
          end if
      6 continue
      go to 203
52 ncomp=icomp(k,izone)

```

```

c
c INITIALIZE COMPARTMENT ELEVATIONS TO STATION ELEVATION (IF A
c SLASH TERMINATES THE INPUT RECORD, REMAINING ELEMENTS WILL EQUAL
c THE STATION ELEVATION AND HAVE A TC OF ZERO
    do 7 i7=1,20
    7 elcomp(i7)=elev
c
c READ COMPARTMENT ELEVATION RECORD AS A STRING
    read(7,109) elstr
109 format(132a1)
c
c FIND COLUMN OF FIRST ELEVATION AND END OF LAST ELEVATION
    do 8 i8=1,132
    8 if (elstr(i8).ne.b1) goto 53
    goto 205
53  do 9 i9=132,1,-1
    9 if (elstr(i9).ne.b1) goto 54
    goto 205
c
c DETERMINE NUMBER OF COMPARTMENT ELEVATIONS
54 nel=1
    do 10 i10=i8,i9
    if(elstr(i10).eq.b1 .and. elstr(i10-1).ne.b1) nel=nel+1
    if(elstr(i10).eq.slash) goto 55
10 continue
    if(nel.ne.ncomp) goto 204
55 backspace 7
    read(7,*,err=205,end=205) (elcomp(j),j=1,ncomp)
c
c CALCULATE DELTA ELEVATION AND COMPARTMENT TC
    do 11 i11=1,ncomp
        delev=(elev-elcomp(i11))**2
        if(type.eq.unit2(1)) delev=delev*f2msq
        tc(i11)=frac(k,izone)*(dr(k,izone)+sqrt(r1sq(k,izone)+delev) -
        & sqrt(r2sq(k,izone)+delev))
        tsum=tc(i11)+tsum
11 continue
    tzone(izone)=tsum
    tsum=0
c
c WRITE COMPARTMENT ELEVATIONS AND TC'S TO PRINT FILE
    do 12 i12=1,ncomp
        itc(i12)=tc(i12) + 0.5
        if(tc(i12).le.-0.5) itc(i12)=itc(i12)-1
        ielcomp(i12)=elcomp(i12) + 0.5
        if (elcomp(i12).le.-0.5)ielcomp(i12)=ielcomp(i12)-1
12 continue
    itzone(izone)=tzone(izone) + 0.5
    write(8,108) ring(k,izone),(ielcomp(j),j=1,ncomp)
108 format(1x,a2,5x,20(1x,i5))
    write(8,110) itzone(izone),(itc(j),j=1,ncomp)
110 format(4x,i3,20(1x,i5))

```

```

c
c TEST FOR COMPARTMENTS WITH ZERO ELEVATION
    nzero=0
    do 13 i13=1,ncomp
13 if (elcomp(i13).eq.0.) nzero=nzero+1
    if(nzero.gt.0) then
        print 111, nzero,stat,zone
        write(8,111) nzero,stat,zone
111   format(/1x,'**WARNING,',i2,' COMPARTMENT(S) OF ZERO'
      & ' ELEVATION FOR STATION: ',a5,', ZONE: ',a2)
        endif
c
    go to 51
c
c SUMMATIONS OF TC'S
600 ttab=iab
    m=4
    do 14 i14=k,nring2
        m1=m+1
c        EXAMPLE: HAMMER ZONE NOT DONE
        if (mtype.eq.method(2) .and. tzone(i14).eq.-9999.) then
            tzone(i14)=0.0
c        EXAMPLE: C DONE (WHETHER OR NOT SUBZONES ARE DONE), WHOLE ZONE
        else if (tzone(i14).gt.-9999.) then
            tzone(i14)=tzone(i14)
            iflag(i14)=1
c        EXAMPLE: (C NOT DONE) C1 AND C2 DONE, COMPLETE SUBZONE
        else if (tzone(i14+m).gt.-9999. .and. tzone(i14+m1).gt.-9999.)
        & then
            tzone(i14)=tzone(i14+m) + tzone(i14+m1)
            iflag(i14)=1
c        EXAMPLE: C1 DONE, C2 NOT DONE, ONE SUBZONE DONE
        else if (tzone(i14+m).gt.-9999. .and. tzone(i14+m1).eq.-9999.)
        & then
            tzone(i14)=tzone(i14+m)
            iflag(i14)=1
c        EXAAMPLE: C1 NOT DONE, C2 DONE, ONE SUBZONE DONE
        else if (tzone(i14+m).eq.-9999. .and. tzone(i14+m1).gt.-9999.)
        & then
            tzone(i14)=tzone(i14+m1)
            iflag(i14)=1
c
        else
            tzone(i14)=0.0
        endif
        m=m+1
14 continue
c
c CONVERT TO INTEGER
    do 15 i15=k,nring2
        itzone(i15)=tzone(i15) + 0.5
15 continue

```

```

c
c  CALCULATE GRAND TOTAL
    total=0.0
    do 16 i16=k,nring2
        total=tzone(i16) + total
16 continue
    total=total + ttab
    itotal=total + 0.5

c
c  CALCULATE MGALS
    do 17 i17=k,nring2
        tzone(i17)=tzone(i17)*.01
17 continue
    total=total*.01
    ttab=ttab*.01

c
c  WRITE SUBTOTALS AND TOTALS TO PRINT AND OUTPUT FILES
c
c  RESET FLAGS FOR TOTAL, AB, AND ABC
    iflag(7)=1
    if (k.eq.1) then
        iflag(8)=1
        iflag(9)=2
    else
        iflag(8)=2
        iflag(9)=1
    endif

c
c  SET TZONE(7), (8), AND (9) TO TOTAL, AB, AND ABC
    tzone(7)=total
    itzone(7)=itotal
    tzone(8)=ttab
    itzone(8)=iab
    tzone(9)=tzone(8)
    itzone(9)=itzone(8)

c
c  WRITE ZONES C-H, TOTAL, AB OR ABC TO OUTPUT AND PRINT
c  STRINGS FOR CALCULATED ZONES ONLY
    do 18 i18=1,9
        if (iflag(i18).eq.1) then
            write(ostr(osp(i18):osp(i18)+5),112) itzone(i18)
            write(pstr(psp(i18):psp(i18)+5),113) zlab(i18)
            write(pstr(psp(i18)+6:psp(i18)+11),114) tzone(i18)
112    format(i6)
113    format(a6)
114    format(f6.2)
        endif
18 continue

c
c  WRITE STATION NAME TO OUTPUT STRING
    write(ostr(1:5),115) stat
115 format(a5)

```

```

c
c WRITE STRINGS TO OUTPUT AND PRINT FILES
    write(9,116) ostr
    write(8,117) pstr
116 format(1x,a64)
117 format(1x,a100)

c
c
    4 continue

c
c DIMENSION OF DO LOOP (1000) EXCEEDED
    goto 999

c
c ERROR STATEMENTS
201 print 24
24 format(/1x,'ERROR IN OPENING INPUT FILE. TRY AGAIN? (Y OR N)')
    read(5,118) ans
118 format(a1)
    if(ans.eq.'y' .or. ans.eq.'Y') then
        goto 50
    else
        goto 1000
    endif
202 print 119, stat
    write(8,119) stat
119 format(/1x,'**STOP, ERROR IN READING STATION RECORD: ', a5)
    goto 999
203 print 120, stat
    write(8,120) stat
120 format(/1x,'**STOP, ERROR FOR STATION: ',a5)
    goto 999
204 print 121, ncomp,nel,stat,zone
    write(8,121) ncomp,nel,stat,zone
121 format(/1x,'**STOP, ERROR IN COMPARTMENT ELEVATION RECORD',
    &' EXPECTING ',i2,' ELEMENTS, FOUND ',i2,',',
    &/9x,'FOR STATION: ',a5,', ZONE: ',a2)
    goto 999
205 print 122, stat,zone
    write(8,122) stat,zone
122 format(/1x,'**STOP, ERROR IN COMPARTMENT ELEVATION RECORD',
    &' FOR STATION: ',a5,', ZONE: ',a2)

c
c PRINT STATIONS PROCESSED, CLOSE FILES
999 print 123, nstat
    write(8,123) nstat
123 format(/1x,'NUMBER OF STATIONS READ: ',i4)
    close(7)
    close(8)
    close(9)
1000 stop
    end

```