WINGEOTECH_FAD Software for Estimating Cone Tip Resistance from Formation Resistivity in Sedimentary and Basement Terrains of Nigeria.

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ABSTRACT

A software package called WINGEOTECH_FAD, was designed to estimate cone tip resistances from formation resistivity values obtained from Vertical Electrical Sounding (VES) 1-D computer-assisted modeling as a means of assessing the competence of subsurface lithological units. The equations used were developed from empirical relationships between field observed resistivities and cone tip resistances in both sedimentary and basement terrains of Nigeria. The FORTRAN 95 programming language using the LAHEY Compiler was adopted. The software can be used in *in-situ* assessment of the competence of subsurface lithological units where VES derived formation resistivity values are available.

(Keywords: formation resistivity, cone tip resistance, WINGEOTECH_FAD software).

INTRODUCTION

The Vertical Electrical Sounding (VES) technique measures vertical variations in apparent resistivity values with respect to a fixed centre of array. (Telford et al., 1990). The VES data are interpreted in terms of subsurface layering and layer resistivity and thickness values. The Cone Penetrometer Test (CPT) is an in situ testing method used for the determination of geotechnical engineering properties of soils and in the delineation of soil stratigraphy (NCHRP Synthesis 368, 2007). Formation resistivity increases with increase in the degree of compaction with consequent increase in cone tip resistance.

An attempt has been made in this study to develop a computer software code-named WINGEOTECH_FAD for estimating cone tip resistance from formation resistivity as a means of assessing the competency of subsurface lithological units.

Figure 1 shows the cross plots of formation resistivity and cone tip resistance from five localities within sedimentary and basement terrains of Nigeria for linear and power regression analyses (Fadugba et al., 2011). The empirical equations relating the formation resistivity obtained from Vertical Electrical Sounding (VES) with the cone tip resistance of the Cone Penetrometer Test (CPT) are the following:

(i) Basement Environment:

$RES = 13.44 * CPT - 92.15$ --- (Linear Regression)
$RES = 5.740 * (CPT^{1.133})$----(Curvilinear Regression)

(ii) Sedimentary Environment:

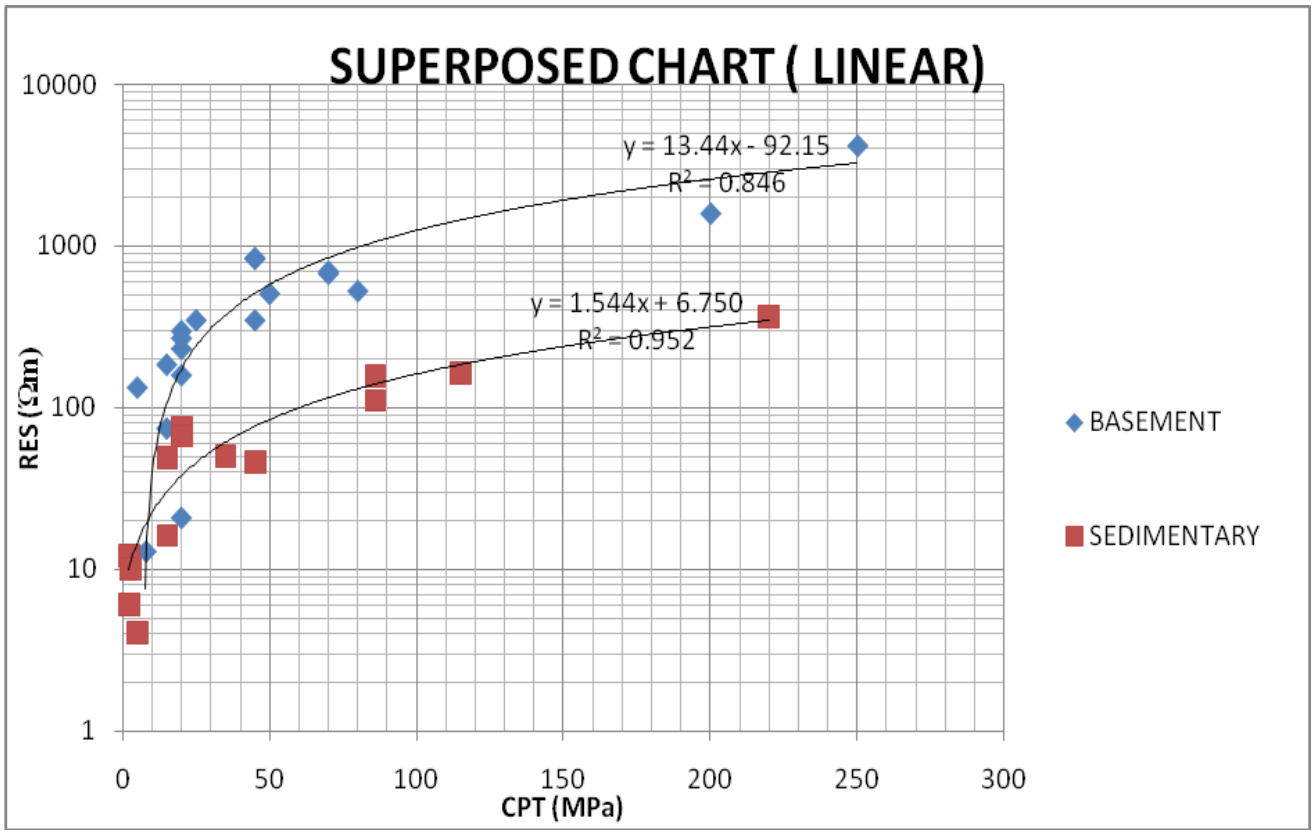
$RES = 1.544 * CPT + 6.750$----(Linear Regression)
$RES = 3.632 * (CPT^{0.803})$---- (Curvilinear Regression)

where; RES represents formation resistivity values in Ωm and CPT represents cone tip resistivity in KgF/cm^2 .

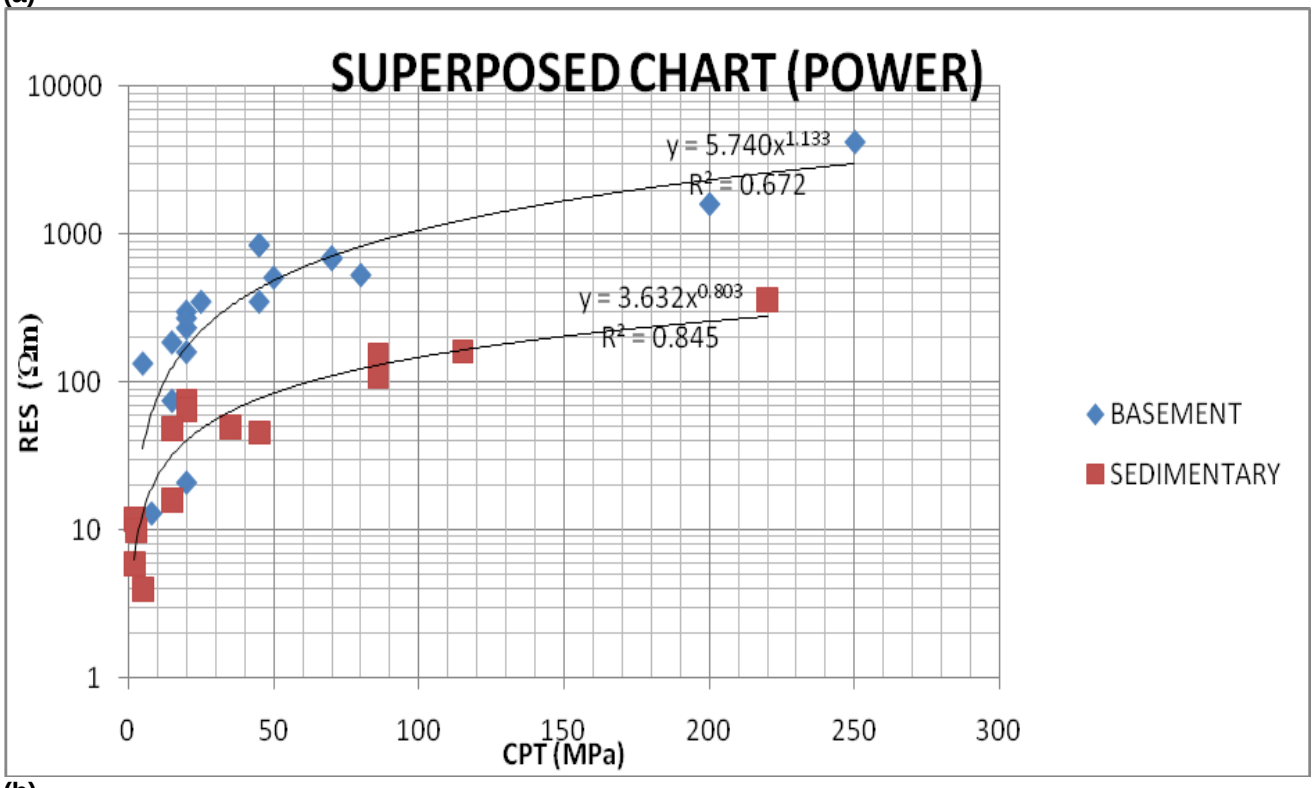
THE SOFTWARE (WINGEOTECH_FAD)

The software (Wingeotech_fad) utilizes the empirical equations developed above to calculate cone tip resistance from the 1-D computer assisted modeling of depth sounding curves. The procedure employed in the software consists of the following steps. The flow chart is contained in Figure 2.

i. A welcome message that will introduce the software to the user will first be shown.



(a)



(b)

Figure 1: Crossplots of Formation Resistivity and Cone Tip Resistance in Sedimentary and Basement Terrains for (a) Linear Regression and (b) Power Regression (Fadugba et al., 2011).

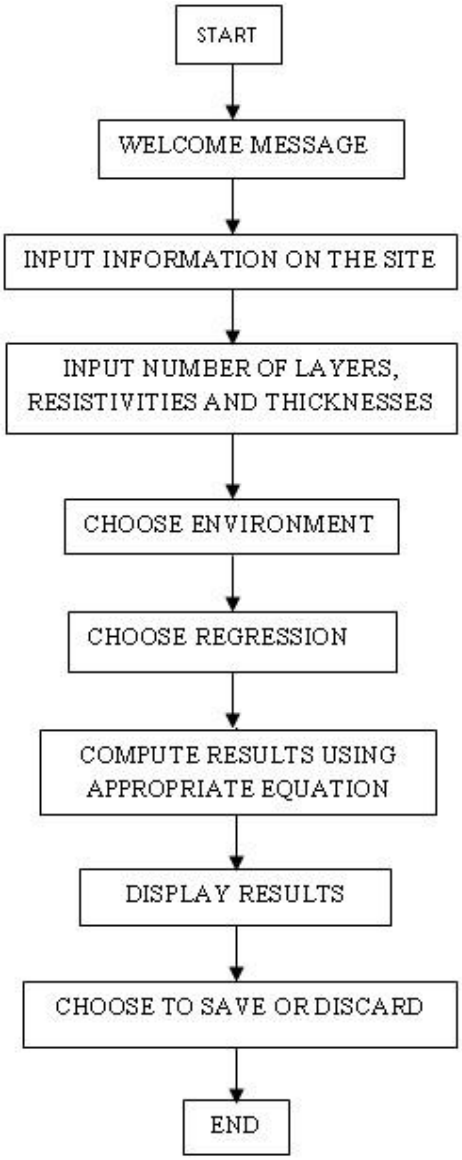


Figure 2: Flowchart of WINGEOTECH_FAD Software.

ii. Information on the VES station will be required of the user. The information includes date, name of observer, geographic coordinate, VES station number etc. for proper site identification. The segment of the FORTRAN code used is given below:

```
WRITE(*,*)' ENTER THE FOLLOWING INFORMATION'
WRITE(*,*)' '
WRITE(*,*)' LOCATION:   '
READ(*,*)LOCATION
WRITE(*,*)' 'WRITE(*,*)' NAME OF OBSERVER:  '
READ(*,*)NAM
WRITE(*,*)' DATE (DD-MM-YYYY) :  '
READ(*,*)DATE
WRITE(*,*)' '
WRITE(*,*)' ENVIRONMENT (SED OR BASEMENT) '
READ(*,*)ENVI
WRITE(*,*)' '
WRITE(*,*)' VES STATION NO  '
READ(*,*)VES
WRITE(*,*)' '
WRITE(*,*)' COORDINATES '
WRITE(*,*)' '
WRITE(*,*)' NORTHINGS:  '
READ(*,*)NORTHING
WRITE(*,*)' '
WRITE(*,*)' EASTINGS:   '
READ(*,*)EASTINGS
WRITE(*,*)' '
```

iii. Inputting of the number of layers which will serve as a control to the number of times the formation resistivities and thickness will be required. The segment of the FORTRAN code used is given below:

```
do i=1,s
WRITE(*,*)'  INPUT THE RESISTIVITY VALUE =  '
READ(*,*) res(i)
end do
```

```
do i=1,(s-1)

WRITE(*,*)'        INPUT THE THICKNESS =  '


READ(*,*) H(i)

end do
```

iv. The environment of the study whether basement or sedimentary terrain and the type of regression to be employed in the conversion will also be prompted in order to properly select the empirical equation to use for the conversion The segment of the FORTRAN code used is given below:

```
WRITE(*,*)'  ------IDENTIFY SITE ENVIRONMENT----- '

WRITE(*,*)'   '

WRITE(*,*)'   1----  BASEMENT TERRAIN '

WRITE(*,*)' '

WRITE(*,*)'   2----  SEDIMENTARY TERRAIN'

READ(*,*)a

IF (a==1) THEN

! THIS IS FOR THE BASEMENT TERRAIN  WRITE(*,*)' '

WRITE(*,*)'        ------MAKE A CHOICE OF THE REGRESSION YOU WANT TO APPLY----- '

WRITE(*,*)'   '

WRITE(*,*)'    1----  LINEAR REGRESSION'

WRITE(*,*)' '

WRITE(*,*)'    2----  CURVILINEAR REGRESSION'

write(*,*)

READ(*,*)d

! FOR THE LINEAR

if (d == 1) then

do m=1,s

CPT(m)=(res(m)+92.15)/13.44

end do

else

! FOR THE CURVILINEAR

do n=1,s

CPT(n)=(RES(n)/5.74)**0.882613
end do

end if

ELSE

! THIS IS FOR THE SEDIMENTARY TERRAIN

WRITE(*,*)'        ------MAKE A CHOICE OF THE REGRESSION YOU WANT TO APPLY----- '

WRITE(*,*)'   '

WRITE(*,*)'   1----  LINEAR REGRESSION' WRITE(*,*)' '

WRITE(*,*)'   2----  CURVILINEAR REGRESSION'

write(*,*)"

READ(*,*)d

! FOR THE LINEAR

if (d == 1) then

do m=1,s

CPT(m)=(res(m)-6.75)/1.544

end do

else

! FOR THE CURVILINEAR

do n=1,s

CPT(n)=(RES(n)/3.632)**1.24533

end do

end if

END IF
```

v. Displaying of the result will follow and the user will be prompted either to save or discard the results. If the user chooses to save, the results (MODEL RESULT) will be saved in a folder containing the application. The model result can be open with notepad or any text editor for proper documentation.

PROGRAM DESIGN AND DISCRIPTION

The software (WINGEOTECH_FAD) was developed with FORTRAN 95 language and LAHEY compiler. The software requires an initial input of the number of layers interpreted from the depth sounding curve. The inputted number of layers will serve as constraint to the number of times the user will be requested to enter the formation resistivities and the thicknesses of the respective layers.

Apart from the formation resistivity values and thicknesses, the software also requires information on the location, environment of the study area whether basement or sedimentary terrain, name of observer, Vertical Electrical Sounding (VES) station number, date and the geographic coordinate in Northings and Eastings (UTM) of the site of investigation. These parameters are required for proper recording of the results of the model. Figures 3 and 4 are the prompt showing the introductory message of the software and the interface requesting for the input parameters, respectively.
During the process, the user will also be required to input the environment of the study area and indicate the type of regression desired (Figure 5). The linear regression gives best approximation. This is evident from the correlation coefficient of the various regression discussed earlier (see Figure 1).

The output of the program displays the inputted parameters including the name, date, location, geographic coordinate, environment and VES station number. The output tabulates the layer resistivity values, thicknesses and the derived cone tip resistance. Figure 6 is the prompt showing the results of the conversion of formation resistivity values obtained from VES 1, at Asaka-Aboh Road Bridge site, to cone tip resistance. The derived cone tip resistances are useful in the assessment of competence of subsurface layers. The main program code is contained in the appendix.

After the display of results, the user will be required to choose either to print the results or quit the process. The printing is done by exporting the displayed results to the file containing the application. This file is automatically saved as 'MODEL RESULT' and can be opened with Notepad, Microsoft Word or any text editor for subsequence processing of results.

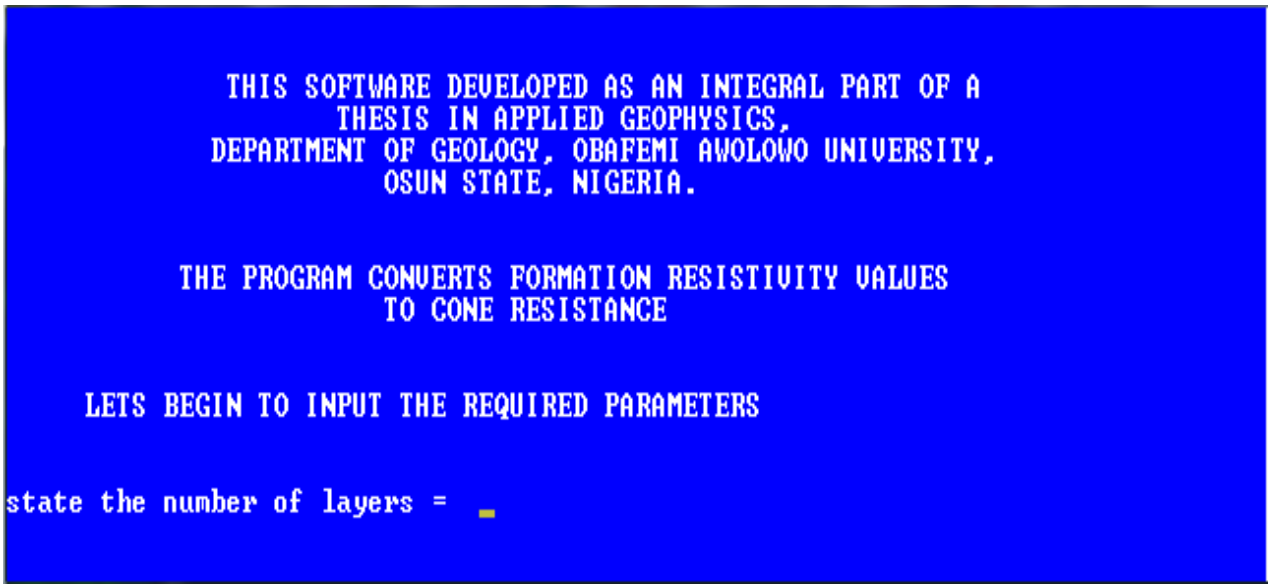


Figure 3: Introductory Message by the Software.

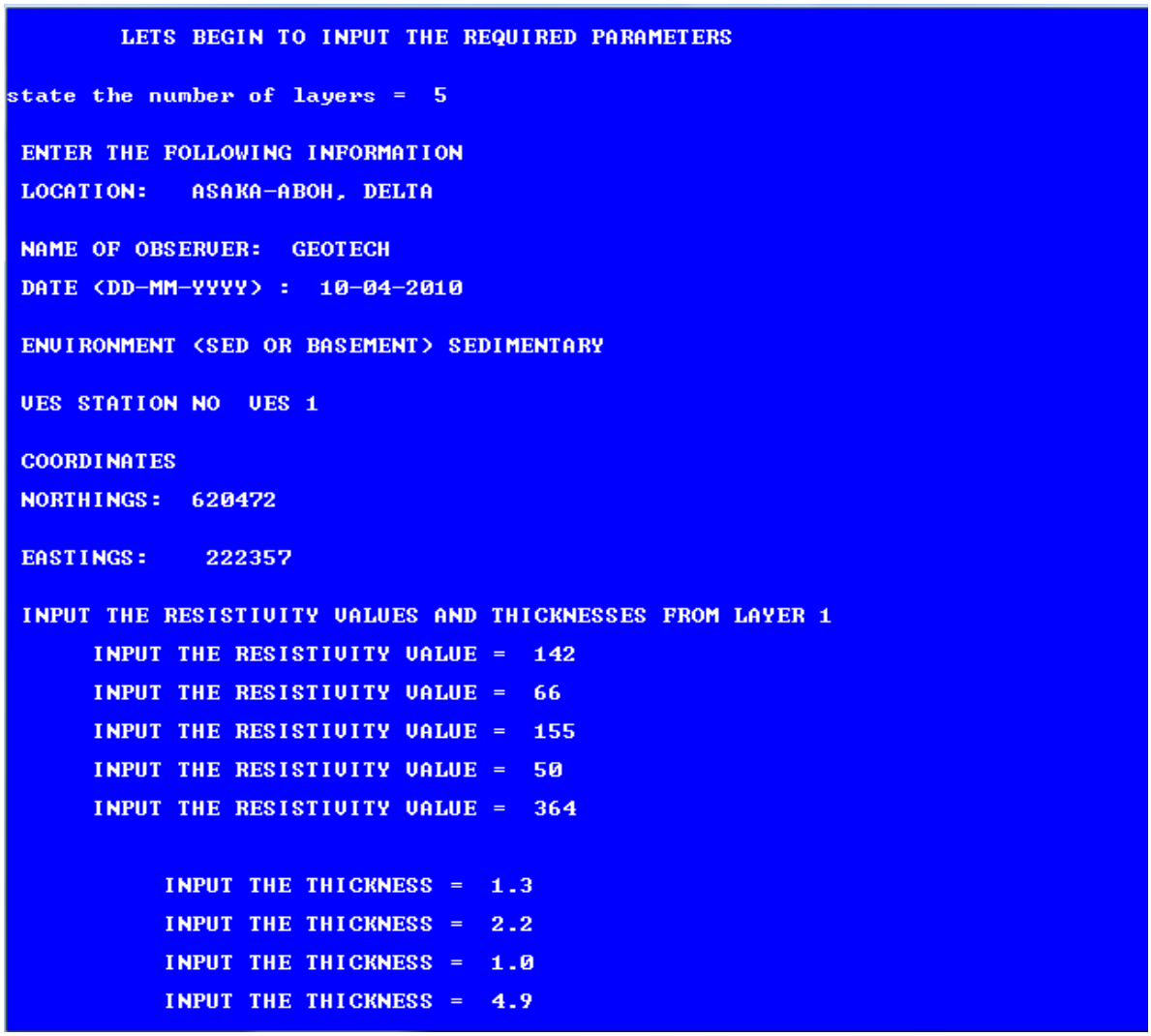


Figure 4: Prompt for input of Geoelectric Parameters.

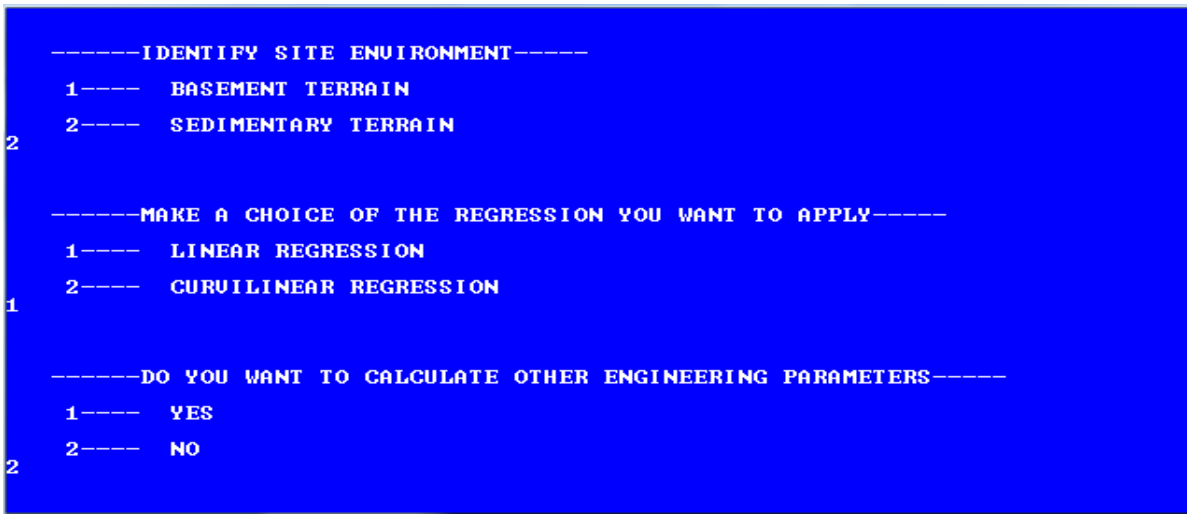


Figure 5: Prompt for Input of Parameters.

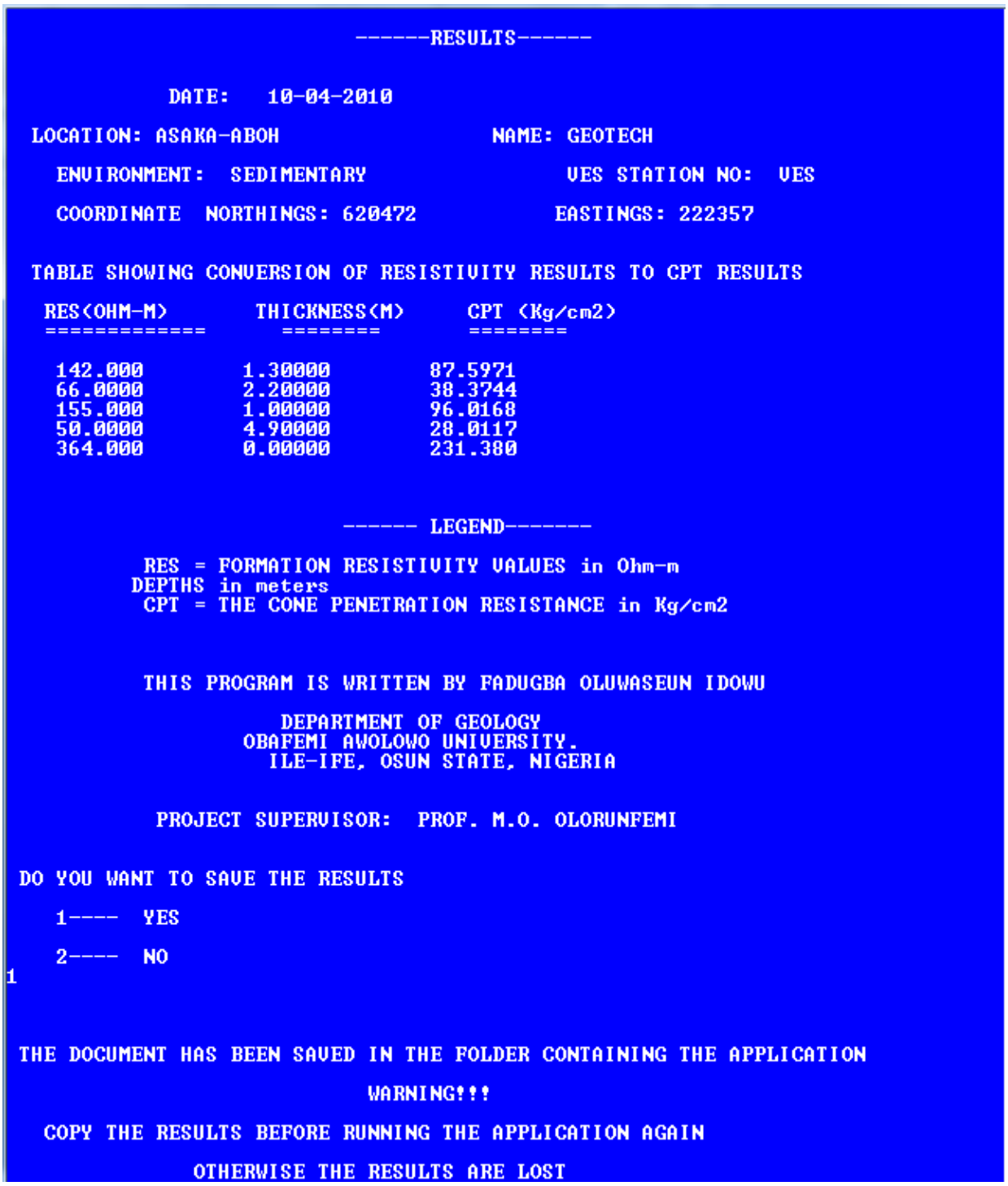


Figure 6: Prompt for Result Display (Asaka-Aboh VES1 Locality).

SOFTWARE LIMITATIONS

The software cannot be applied to data from a saline water environment where the formation resistivity is abnormally decreased by the water salinity and where differentiation between sand and clay on the basis of resistivity is difficult. It is not also advised to be used in hydrocarbon impacted environment with abnormally high formation resistivity.

CONCLUSION

The software (WINGEOTECH_FAD) presented has been designed to calculate the cone tip resistance from formation resistivity obtained from a 1-D computer assisted modeling of vertical electrical sounding data. The FORTRAN 95 programming language was developed with a LAHEY Compiler. The software can be used in in-situ assessment of the competence of subsurface lithological units where VES derived formation resistivity are available.

APPENDIX

MAIN PROGRAM (**WINGEOTECH_FAD)**

```
PROGRAM Fadproject

IMPLICIT NONE

integer:: s,W

REAL,DIMENSION(10):: CPT

REAL,DIMENSION(10):: RES

REAL,DIMENSION(10):: H

CHARACTER(15)::LOCATION,NAM,ENVI,VES,NORTHING,
EASTINGS,DATE

INTEGER::i,a,d,m,n,l

WRITE(*,*)''

open (UNIT=9,
FILE='RESULTS.txt',STATUS='REPLACE',ACTION='WRITE
')

WRITE(*,*)'  THIS SOFTWARE DEVELOPED AS AN
INTEGRAL PART OF A B.Sc'

WRITE(*,*)'  THESIS IN APPLIED
GEOPHYSICS '

WRITE(*,*)'  DEPARTMENT OF GEOLOGY,
OBAFEMI AWOLOWO UNIVERSITY'

WRITE(*,*)'  OSUN STATE, NIGERIA.'

WRITE(*,*)''

WRITE(*,*)'  THE PROGRAM CONVERTS FORMATION
RESISTIVITY VALUES'

WRITE(*,*)'  TO CONE RESISTANCE '

WRITE(*,*)''

WRITE(*,*)'  LETS BEGIN TO INPUT THE REQUIRED
PARAMETERS'

WRITE(*,*)' '

WRITE(*,*)'state the number of layers =  '

READ(*,*) s

!READING FIELD DATA

WRITE(*,*)' '

WRITE(*,*)' ENTER THE FOLLOWING INFORMATION'

WRITE(*,*)' '

WRITE(*,*)' LOCATION:   '

READ(*,*)LOCATION

WRITE(*,*)' '

WRITE(*,*)' NAME OF OBSERVER:  '

READ(*,*)NAM

WRITE(*,*)' DATE (DD-MM-YYYY) :  '

READ(*,*)DATE

WRITE(*,*)' '

WRITE(*,*)' ENVIRONMENT (SED OR BASEMENT) '

READ(*,*)ENVI

WRITE(*,*)' '

WRITE(*,*)' VES STATION NO  '

READ(*,*)VES

WRITE(*,*)' '

WRITE(*,*)' COORDINATES '

WRITE(*,*)' '

WRITE(*,*)' NORTHINGS:  '

READ(*,*)NORTHING
```

```
WRITE(*,*)' '

WRITE(*,*)' EASTINGS:    '

READ(*,*)EASTINGS

WRITE(*,*)' '

WRITE(*,*)' INPUT THE RESISTIVITY VALUES AND THICKNESSES FROM LAYER 1 '

WRITE(*,*)' '

do i=1,s

WRITE(*,*)'  INPUT THE RESISTIVITY VALUE =  '

READ(*,*) res(i)

end do

do i=1,(s-1)

WRITE(*,*)'          INPUT THE THICKNESS =  '

READ(*,*) H(i)

end do

! READING DATA COMPLETED

! EXECUTION

WRITE(*,*)'   ------IDENTIFY SITE ENVIRONMENT----- '

WRITE(*,*)'    '

WRITE(*,*)'    1----  BASEMENT TERRAIN '

WRITE(*,*)' '

WRITE(*,*)'    2----  SEDIMENTARY TERRAIN'

READ(*,*)a

   IF (a==1) THEN

   ! THIS IS FOR THE BASEMENT TERRAIN

       WRITE(*,*)' '

       WRITE(*,*)'        ------MAKE A CHOICE OF THE REGRESSION YOU WANT TO APPLY----- '

       WRITE(*,*)'    '

       WRITE(*,*)' 1----  LINEAR REGRESSION'

       WRITE(*,*)' '

       WRITE(*,*)'2----CURVILINEAR REGRESSION'
write(*,*)

        READ(*,*)d

       ! FOR THE LINEAR

         if (d == 1) then

         do m=1,s

CPT(m)=(res(m)+92.15)/13.44

         end do

       else

       ! FOR THE CURVILINEAR

         do n=1,s

CPT(n)=(RES(n)/5.74)**0.882613

         end do

         end if

   ELSE

   ! THIS IS FOR THE SEDIMENTARY TERRAIN

    WRITE(*,*)'        ------MAKE A CHOICE OF THE REGRESSION YOU WANT TO APPLY----- '

       WRITE(*,*)'    '

       WRITE(*,*)'  1----  LINEAR REGRESSION'

       WRITE(*,*)' '

       WRITE(*,*)'    2----  CURVILINEAR REGRESSION'

write(*,*)"

    READ(*,*)d

         ! FOR THE LINEAR

       if (d == 1) then

       do m=1,s
```

```
CPT(m)=(res(m)-6.75)/1.544

          end do

        else

         ! FOR THE CURVILINEAR

          do n=1,s

CPT(n)=(RES(n)/3.632)**1.24533

          end do

          end if

   END IF

! END OF EXECUTION

!DISPLAY ANSWER WITHOUT THE ENGINEERING PARAMETERS

WRITE(*,*)' '

 WRITE(*,*)' '

WRITE(*,*)'                    ------RESULTS------ '

WRITE(*,*) '      '

 WRITE(*,*) '          DATE:  ',DATE

 WRITE(*,*)' '

WRITE(*,*) '  LOCATION: ',LOCATION, '              NAME: ',NAM

WRITE(*,*)' '

WRITE(*,*)'    ENVIRONMENT:  ',ENVI,'              VES STATION NO:  ',VES

WRITE(*,*)' '

WRITE(*,*)'    COORDINATE NORTHINGS: ',NORTHING,' EASTINGS: ',EASTINGS

WRITE(*,*)' '

WRITE(*,*)' '

 WRITE(*,*)  '    TABLE SHOWING CONVERSION OF RESISTIVITY RESULTS TO CPT RESULTS '

WRITE(*,*)' '

WRITE(*,*) '   RES(OHM-M)        THICKNESS(M)      CPT (Kg/cm2)'

WRITE(*,*) '  =============    ========    ========'

 do l=1,s

 WRITE (*,*) RES(L), H(L), CPT(L)

 end do

 WRITE(*,*)' '

WRITE(*,*)'                    ------ LEGEND------- '

 WRITE(*,*)' '

 WRITE(*,*)'              RES = FORMATION RESISTIVITY VALUES in Ohm-m '

 WRITE(*,*)'         DEPTHS in meters '

 WRITE(*,*)'              CPT = THE CONE PENETRATION RESISTANCE in Kg/cm2 '

 WRITE(*,*)' '

 WRITE(*,*)'          THIS PROGRAM IS WRITTEN BY FADUGBA OLUWASEUN IDOWU'

 WRITE(*,*)' '

 WRITE(*,*)'    DEPARTMENT OF GEOLOGY'

 WRITE(*,*)' OBAFEMI AWOLOWO UNIVERSITY.'

 WRITE(*,*)'    OSUN STATE, NIGERIA'

 WRITE(*,*)' '

 WRITE(*,*)'          PROJECT SUPERVISOR:  PROF. M.O. OLORUNFEMI '

 WRITE(*,*)' '

 WRITE(*,*)'                    '

! END OF ENG PARAMETERS

! TO PRINT

WRITE(*,*)' DO YOU WANT TO SAVE THE RESULTS  '

WRITE(*,*)'    '

       WRITE(*,*)'   1----  YES'
```

```
      WRITE(*,*)' '

      WRITE(*,*)'   2----  NO'

write(*,*)''

READ(*,*)W

IF (W==1) THEN

 WRITE(9,*)' '

WRITE(9,*)'            ------RESULTS------ '

WRITE(9,*)' '

 WRITE(9,*) '          DATE:   ',DATE

 WRITE(9,*)' '

WRITE(9,*) '  LOCATION: ',LOCATION, '              NAME:
',NAM

WRITE(9,*)' '

WRITE(9,*)'     ENVIRONMENT:   ',ENVI,'              VES
STATION NO:  ',VES

WRITE(9,*)' '

WRITE(9,*)'   COORDINATE NORTHINGS: ',NORTHING,'
EASTINGS: ',EASTINGS

WRITE(9,*)' '

WRITE(9,*)' '

 WRITE(9,*)  '   TABLE SHOWING CONVERSION OF
RESISTIVITY RESULTS TO CPT RESULTS '

WRITE(9,*)' '

WRITE(9,*) '  RES(OHM-M)       THICKNESS(M)    CPT
(Kg/cm2)'

WRITE(9,*)  '       ==============              ========
========'

 WRITE(9,*)' '

  do l=1,s

  WRITE (9,*) RES(L), H(L), CPT(L)

  end do

 WRITE(9,*)' '

WRITE(9,*)         ------ LEGEND------- '

WRITE(9,*)'              RES = FORMATION RESISTIVITY
VALUES in Ohm-m '

 WRITE(9,*)'         THICKNESS in meters '

 WRITE(9,*)'               CPT = CONE PENETRATION
RESISTANCE in Kg/cm2 '

 WRITE(9,*)' '

 WRITE(9,*)' '

 WRITE(9,*)'             THIS PROGRAM IS WRITTEN BY
FADUGBA OLUWASEUN IDOWU'

 WRITE(9,*)' '

 WRITE(9,*)'  DEPARTMENT OF GEOLOGY'

 WRITE(9,*)'                          OBAFEMI AWOLOWO
UNIVERSITY.'

 WRITE(9,*)'     OSUN STATE, NIGERIA'

 WRITE(9,*)' '

 WRITE(9,*)' '

 WRITE(9,*)'             PROJECT SUPERVISOR:  PROF.
M.O. OLORUNFEMI '

  WRITE(*,*)''

 WRITE(*,*)' THE DOCUMENT HAS BEEN SAVED IN THE
FOLDER CONTAINING THE APPLICATION'

  WRITE(*,*)''

 WRITE(*,*)'                    WARNING!!!    '

   WRITE(*,*)' '

   WRITE(*,*)'  COPY THE RESULTS BEFORE RUNNING
THE  APPLICATION AGAIN  '

   WRITE(*,*)' '

   WRITE(*,*)'             OTHERWISE THE RESULTS ARE
LOST'

   END if
```

```
stop

END PROGRAM Fadproject
```

REFERENCES

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