Problem Statement

Using the iterative method in a computer program, calculate the internal node values of a rectangular figure in two different situations when the outer values are given.

Assumptions

1. –The rectangular circuit board is 8 inches long by 6 inches high.
   –The top edge has a steady temperature of 80°C.
   –The right edge has a steady temperature of 90°C.
   –The bottom edge has a steady temperature of 110°C.
   –The left edge has a steady temperature of 120°C.
   –The tolerance level is 0.01°C.
   –The initial internal node temperature is 0°C.
   –The distance between readings is 1.0 inches.

2. –The aquifer is 1.600 kilometers long by 2.000 kilometers high.
   –The top edge has a steady hydraulic head of 100.0 meters.
   –The right edge has a steady hydraulic head of 50.0 meters.
   –The bottom edge has a steady hydraulic head of 30.0 meters.
   –The left edge has a steady hydraulic head of 60.0 meters.
   –The tolerance level is 0.1°C.
   –The initial internal node temperature is 0°C.
   –The distance between readings is 200.0 meters.

Theory

The equation to approximate the values of the internal nodes:

newA(Row, Col) = (A(Row - 1, Col) + A(Row + 1, Col) + A(Row, Col - 1) + A(Row, Col + 1)) / 4

(This equation takes the average values of the surrounding nodes to estimate the value)

Solution

A flowchart was created to outline the program. (see page 3 & 4)

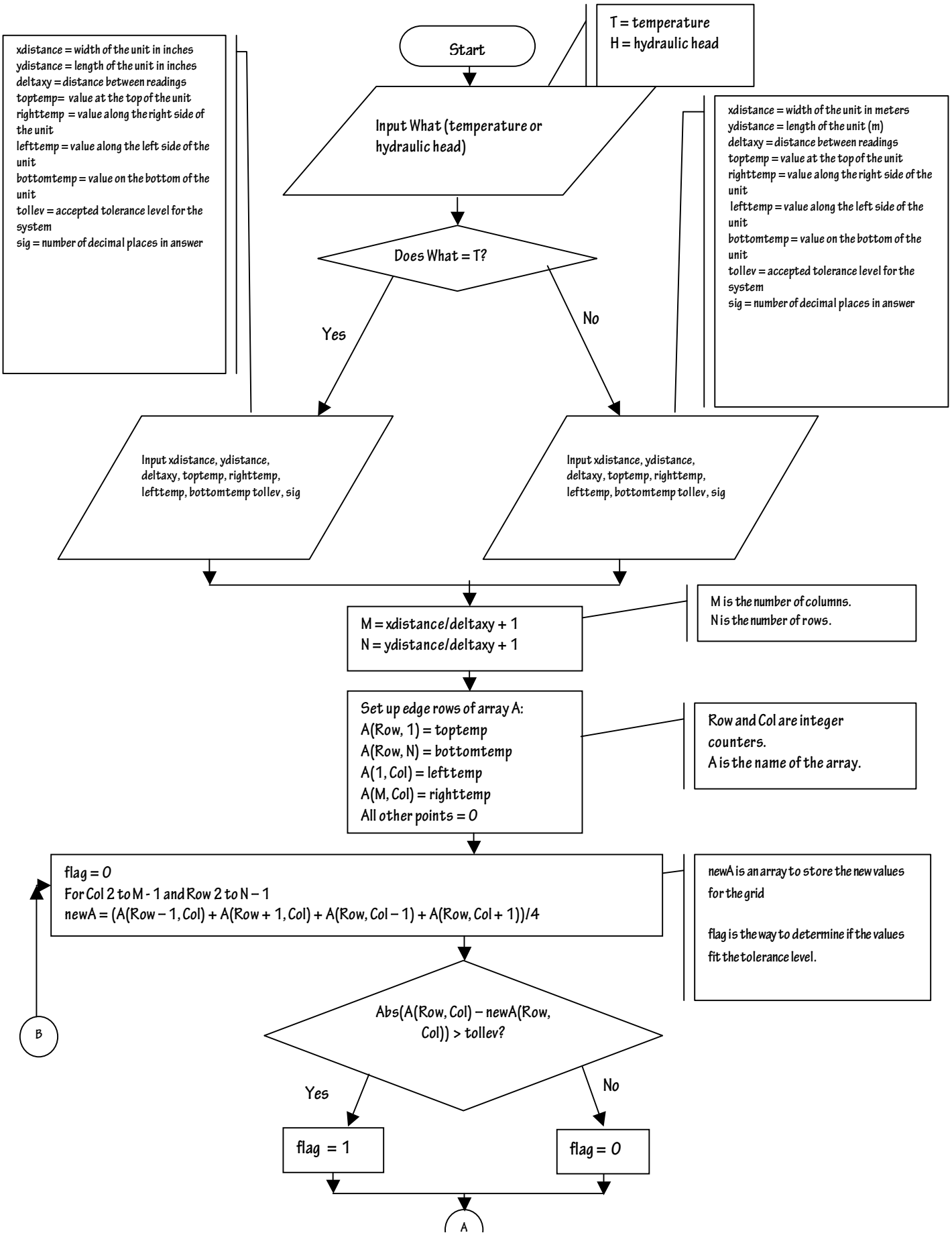
A program was created. (see page 5 & 6)

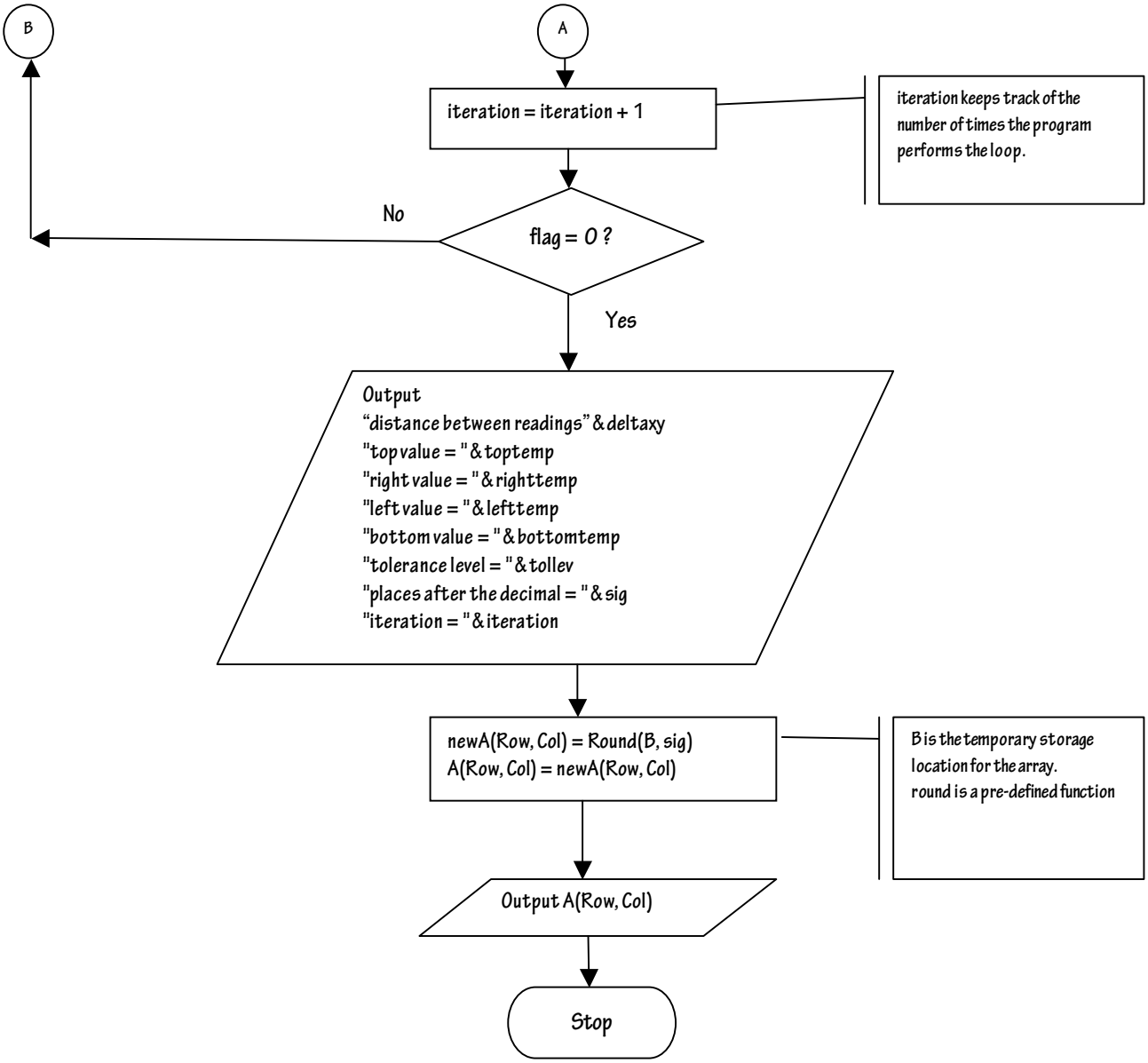
Both situations were run through the program. The output values can be seen on page 7 & 8

A illustrated view of the solutions (showing the variations of the values better) can be seen on page 9.

Conclusion

In this experiment, we created a program to find values at internal points within an area if outer points are known. One situation analyzed temperatures on a circuit board, and the other evaluated hydraulic head values in an aquifer. 38 iterations were completed for both. This program used an "iterative method." Almost a guess-and-check method, the program ran through many times until the previous values were close to the new values. There program knew when to stop because of termination criteria given by the user in the beginning of the program. If even one of the internal node values differed by more than the termination criteria, the program would be repeated. If the nodes were closer together, there would be more iterations because the values would change more slowly. While the iterative method by hand is a time consuming process, a computer program makes it an efficient way to calculate internal node values.


Start
T = temperature
H = hydraulic head
xdistance = width of the unit in inches
ydistance = length of the unit in inches
deltaxy = distance between readings
toptemp= value at the top of the unit
righttemp = value along the right side of the unit
lefttemp = value along the left side of the unit
bottomtemp = value on the bottom of the unit
tollev = accepted tolerance level for the system
sig = number of decimal places in answer
Input What (temperature or hydraulic head)
Does What = T?
Yes
No
xdistance = width of the unit in meters
ydistance = length of the unit (m)
deltaxy = distance between readings
toptemp = value at the top of the unit
righttemp = value along the right side of the unit
lefttemp = value along the left side of the unit
bottomtemp = value on the bottom of the unit
tollev = accepted tolerance level for the system
sig = number of decimal places in answer
Input xdistance, ydistance, deltaxy, toptemp, righttemp, lefttemp, bottomtemp tollev, sig
Input xdistance, ydistance, deltaxy, toptemp, righttemp, lefttemp, bottomtemp tollev, sig
M = xdistance/deltaxy + 1
N = ydistance/deltaxy + 1
M is the number of columns.
N is the number of rows.
Set up edge rows of array A:
A(Row, 1) = toptemp
A(Row, N) = bottomtemp
A(1, Col) = lefttemp
A(M, Col) = righttemp
All other points = 0
Row and Col are integer counters.
A is the name of the array.
flag = 0
For Col 2 to M - 1 and Row 2 to N – 1
newA = (A(Row – 1, Col) + A(Row + 1, Col) + A(Row, Col – 1) + A(Row, Col + 1))/4
newA is an array to store the new values for the grid
flag is the way to determine if the values fit the tolerance level.
B
Abs(A(Row, Col) – newA(Row, Col)) > tollev?
Yes
No
flag = 1
flag = 0
A


B
A
iteration = iteration + 1
iteration keeps track of the number of times the program performs the loop.
No
flag = 0 ?
Yes
Output
"distance between readings" & deltaxy
"top value = " & toptemp
"right value = " & righttemp
"left value = " & lefttemp
"bottom value = " & bottomtemp
"tolerance level = " & tollev
"places after the decimal = " & sig
"iteration = " & iteration
newA(Row, Col) = Round(B, sig)
A(Row, Col) = newA(Row, Col)
B is the temporary storage location for the array.
round is a pre-defined function
Output A(Row, Col)
Stop

Program:

```
Option Explicit
Sub temperature()
'
'temperature Macro
'Macro created by L.Imming, R.Shaw, and S.Timmons for 6 December 2007.
'xdistance is the width of the unit in inches or meters.
'ydistance is the length of the unit in inches or meters.
'deltaxy is the distance between readings. This is a distance determined by the user.
'toptemp is the value at the top of the unit.
'righttemp is the value along the right side of the unit.
'lefttemp is teh value along the left side of the unit.
'bottomtemp is the value on the bottom of the unit.
'tollev is the accepted tolerance level for the system. This is a value determined by the user.
'What is the variable used to determine the input type.
'T is the code for using temperature values.
'HH is the code for using distance values (for Hydraulic Head).
'M is the number of columns.
'N is the number of rows.
'Flag is the way to determine if the values fit the tolerance level.
'iteration keeps track of the number of times the program performs the loop.
'B is the temporary storage location for the array.
'round is a pre-defined function
'sig is the number of decimal places in the answer. This is determined by the user.

Dim toptemp As Single, bottomtemp As Single, lefttemp As Single, ydistance As Single, deltaxy As Single, righttemp As Single, T As String, HH As String, What As String, flag As Integer, xdistance As Single, iteration As Single, Row As Single, Col As Single, N As Single, M As Single, tollev As Single, oldA(11, 11) As Single, newA(11, 11) As Single, A(11, 11) As Single, sig As Integer, B As Single
Open ("F:\engrprjt3\temperature.txt") For Output As 1

What = InputBox("Temperature or Hydraulic Head? (T or HH)")  'input values here
If (What = "T") Then
  xdistance = InputBox("Enter the width of the unit. (in inches)")
  ydistance = InputBox("Enter the length of the unit. (in inches)")
  deltaxy = InputBox("Enter accepted distance between readings. For example, 1.0 inches.")
  toptemp = InputBox("Enter the temperature (Celsius) at the top of the unit.")
  righttemp = InputBox("Enter the temperature (Celsius) of the unit on the right side.")
  lefttemp = InputBox("Enter the temperature (Celsius) of the unit on the left side.")
  bottomtemp = InputBox("Enter the temperature (Celsius) of the unit on the bottom.")
  tollev = InputBox("Enter the tolerance level.")
  sig = InputBox("How many decimal places?")
Elself (What = "HH") Then
  xdistance = InputBox("Enter the width of the unit. (in meters)")
  ydistance = InputBox("Enter the length of the unit. (in meters)")
  deltaxy = InputBox("Enter accepted distance between readings. For example, 1.0 meters.")
  toptemp = InputBox("Enter the hydraulic head (meters) at the top of the unit.")
  righttemp = InputBox("Enter the hydraulic head (meters) of the unit on the right side.")
  lefttemp = InputBox("Enter the hydraulic head (meters) of the unit on the left side.")
  bottomtemp = InputBox("Enter the hydraulic head (meters) of the unit on the bottom.")
  tollev = InputBox("Enter the tolerance level.")
  sig = InputBox("How many decimal places?")
Else
  MsgBox ("Please select T or HH")
End If
```

```
M = xdistance / deltaxy + 1    'number of columns
N = ydistance / deltaxy + 1    'number of rows
iteration = 0

For Row = 1 To N
  A(Row, 1) = lefttemp    'inputs the value for the program on the left side of the unit
  A(Row, M) = righttemp 'inputs the value for the program on the right side of the unit
Next Row
For Col = 1 To M
  A(1, Col) = toptemp     'inputs the value for the program for the top of the unit
  A(N, Col) = bottomtemp                'inputs the value for the program for the bottom of the unit
Next Col

For Row = 2 To (N - 1)     'inputs the initial values for the internal nodes
  For Col = 2 To (M - 1)
    A(Row, Col) = 0
  Next Col
Next Row

Do
flag = 0
For Row = 2 To (N - 1)     'calculates the average value for each internal node
  For Col = 2 To (M - 1)
    newA(Row, Col) = (A(Row - 1, Col) + A(Row + 1, Col) + A(Row, Col - 1) + A(Row, Col + 1)) / 4
    If (Abs(A(Row, Col) - newA(Row, Col)) > tollev) Then flag = 1    'compares the new node to the old node to see if accepted
    A(Row, Col) = newA(Row, Col)        'replaces old node with new node
  Next Col
Next Row
iteration = iteration + 1 'keeps track of number of iterations
If (flag = 0) Then Exit Do
Loop

Print #1, "Width = " & xdistance                        'provides the echo check of inputted values
Print #1, "Length = " & ydistance
Print #1, "distance between readings = " & deltaxy
Print #1, "top value = " & toptemp
Print #1, "right value = " & righttemp
Print #1, "left value = " & lefttemp
Print #1, "bottom value = " & bottomtemp
Print #1, "tolerance level = " & tollev
Print #1, "places after the decimal = " & sig
Print #1, " "
Print #1, "iteration = " & iteration
Print #1, " "
For Row = 1 To N
  For Col = 1 To M
    B = A(Row, Col)
    newA(Row, Col) = Round(B, sig)     'rounds the new node to number places after the decimal point
    A(Row, Col) = newA(Row, Col)
    Print #1, A(Row, Col),                              'prints the nodes in the form of a matrix
  Next Col
  Print #1, " "
Next Row
Close
End Sub
```

Output Values:

1. Temperatures on a circuit board
Width = 6
Length = 8
distance between readings = 1
top value = 80
right value = 90
left value = 120
bottom value = 110
tolerance level = 0.01
places after the decimal = 2

iteration = 38

Initial Values for Rectangular Circuit Board

Iteration = 0 times

	80 ⊠C						
	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00	0.00
120 ⊠C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	90 ⊠C
	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00	
	110 ⊠C						

All values are in Celsius.

Final Values for Rectangular Circuit Board

Iteration = 38 times

	80 ⊠C						
	100.07	92.29	88.74	86.92	85.94	85.60	86.32
	108.02	100.35	95.77	93.01	91.26	90.16	89.66
120 ⊠C	111.67	105.34	101.01	98.09	95.95	94.11	92.18	90 ⊠C
	113.32	108.34	104.87	102.39	100.36	98.14	94.96
	113.29	109.84	107.75	106.27	104.94	103.15	99.53
	110 ⊠C						

All values are in Celsius.

2. Hydraulic head values in an aquifer
Width = 2000
Length = 1600
distance between readings = 200
top value = 100
right value = 50
left value = 60
bottom value = 30
tolerance level = 0.1
places after the decimal = 1

iteration = 38

nitial Values for Hydraulic Head

Iteration = 0 times

	100. m						
	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	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0
60.0 m	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	0.0	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	0.0	0.0
	30.0 m						

All values are in meters.

Final Values for Hydraulic Head

Iteration = 38 times

	100. m						
	78.8	85.4	87.7	88.0	86.7	83.1	74.1
	69.7	75.2	77.5	77.7	75.9	71.6	63.4
	64.9	68.2	69.7	69.5	67.7	64.0	58.1
	61.9	63.2	63.6	63.0	61.5	58.7	54.8
60.0 m	59.7	59.3	58.7	57.8	56.5	54.7	52.5
	57.7	55.8	54.3	53.2	52.2	51.3	50.6
	55.4	52.0	49.8	48.5	47.8	47.8	48.5
	52.0	47.2	44.5	43.2	42.8	43.5	45.7
	45.5	40.1	37.9	37.0	36.2	37.8	40.9
	30.0 m						

All values are in meters.Illustrated:

Final Values for Rectangular Circuit Board (With 3 Regions of Temperature Outlined)

Iteration = 38 times

	80 ⁰C						
	100.07	92.29	88.74	86.92	85.94	85.60	86.32
	108.02	100.35	95.77	93.01	91.26	90.16	89.66
120 ⁰C	111.67	105.34	101.01	98.09	95.95	94.11	92.18
	113.32	108.34	104.87	102.39	100.36	98.14	94.96
	113.29	109.84	107.75	106.27	104.94	103.15	99.53
	110 ⁰C						

90 ⁰C

All values are in Celsius.

___ = the highest temperature with a range from approximately 104 to 114 ⁰C.

___ = the medium temperatures with a range from approximately 94 to 104 ⁰C.

___ = the lowest temperatures with a range from approximately 86 to 93 ⁰C.

Final Values for Hydraulic Head (With 3 Regions of Depth Outlined)

Iteration = 38 times

	100. m						
	78.8	85.4	87.7	88.0	86.7	83.1	74.1
	69.7	75.2	77.5	77.7	75.9	71.6	63.4
	64.9	68.2	69.7	69.5	67.7	64.0	58.1
	61.9	63.2	63.6	63.0	61.5	58.7	54.8
60.0 m	59.7	59.3	58.7	57.8	56.5	54.7	52.5
	57.7	55.8	54.3	53.2	52.2	51.3	50.6
	55.4	52.0	49.8	48.5	47.8	47.8	48.5
	52.0	47.2	44.5	43.2	42.8	43.5	45.7
	45.5	40.1	37.9	37.0	36.2	37.8	40.9
	30.0 m						

50.0 m

All values are in meters.

___ = the deepest depth with a range from approximately 71 to 88 meters.

___ = the medium depth with a range from approximately 54 to 71 meters.

___ = the shallowest depth with a range from approximately 36 to 54 meters.