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COMPUTER NOTES

A COMPUTERIZED TECHNIQUE FOR ESTIMATING THE HYDRAULIC CONDUCTIVITY OF AQUIFERS FROM SPECIFIC CAPACITY DATA

by Kenneth R. Bradbury[a] and Edward R. Rothschild[b]

Abstract. Specific capacity data obtained from well construction reports can provide useful estimates of hydraulic conductivity (K). A simple computer program has been developed which can correct specific capacity data for partial penetration and well loss and, using an iterative technique, provide rapid estimates of K at hundreds of data points. The program allows easy data handling and is easily linked with existing statistical programs or contour mapping routines. The method was tested at two field sites in Wisconsin, one underlain by a sandy outwash aquifer, the other by fractured dolomite. In both areas, estimates of K from corrected specific capacity data agree reasonably well with data from pumping tests.

Introduction

Hydrogeologists continually seek and test simple, quick, and inexpensive methods for determining aquifer characteristics. The use of specific capacity tests to determine transmissivity (T), and ultimately hydraulic conductivity (K), is one such tool. Although the use of specific capacity data in estimating aquifer parameters is certainly not new (Theis *et al.*, 1963; Lohman, 1972), commonly used estimation techniques (described below) are somewhat slow and cumbersome. In this paper we describe a computer program which rapidly and accurately provides estimates of aquifer transmissivity at hundreds of points where specific capacity data are available, and we demonstrate that the technique gives excellent results at two field sites in Wisconsin. Because the solution is performed with the use of a computer, data can be manipulated easily and linked with available graphical and statistical packages.

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A specific capacity test involves pumping a well (of known construction) at a known rate and period of time, and measuring the drawdown within the well at the end of the test period. The length of the test is determined by how long it takes for the water level in the well to reach a state of apparent equilibrium, that is, when the change in drawdown is minimal with time. Specific capacity is defined as the discharge divided by the drawdown in the well, and the units generally used are gallons per minute per foot of drawdown (GPM/FT).

Theis *et al.* (1963) present a method of estimating transmissivity from specific capacity. They treat a specific capacity test as a short nonequilibrium pumping test, and utilize a graphical solution to estimate transmissivity. Several other workers, including Walton (1970), Lohman (1972), and Gabrysch (1968) have applied Theis' method to field problems. In this study, we replace the graphical approach with a short computer program utilizing an iterative procedure.

Estimating T from specific capacity involves a series of assumptions. These assumptions include a known storage coefficient (S), minimal well loss, full penetration, and a nonleaky, homogeneous and isotropic, artesian aquifer of infinite areal extent. (These assumptions are essential to use of the Theis equation, and are described in many basic texts.) Fortunately, because specific capacity varies with the logarithm of 1/S, the solution is not very sensitive to variations in S, which can be estimated with sufficient accuracy from previous studies in an area, or by using representative values for a given aquifer type. If appropriate data are available, well loss corrections can be made. Corrections for partial penetration may be very important because few wells fully penetrate an aquifer. A method adopted from Brons and Marting (1961) is used in this study to correct for partial penetration.

To demonstrate the method, specific capacity data were used to estimate hydraulic conductivities for aquifers in two large field areas in Wisconsin (see Figure 1). One aquifer is a confined, fractured dolomite (area A), and the other consists of unconfined, unconsolidated sands and gravels (area B). In Wisconsin, specific capacity tests are generally performed by drillers at the time of well installation. Reports of the tests, as well as geologic logs and well construction reports for most wells are available at the Wisconsin Geological and Natural History Survey. In this study, we use available information to determine aquifer transmissivity, corrected for partial penetration of the wells, and

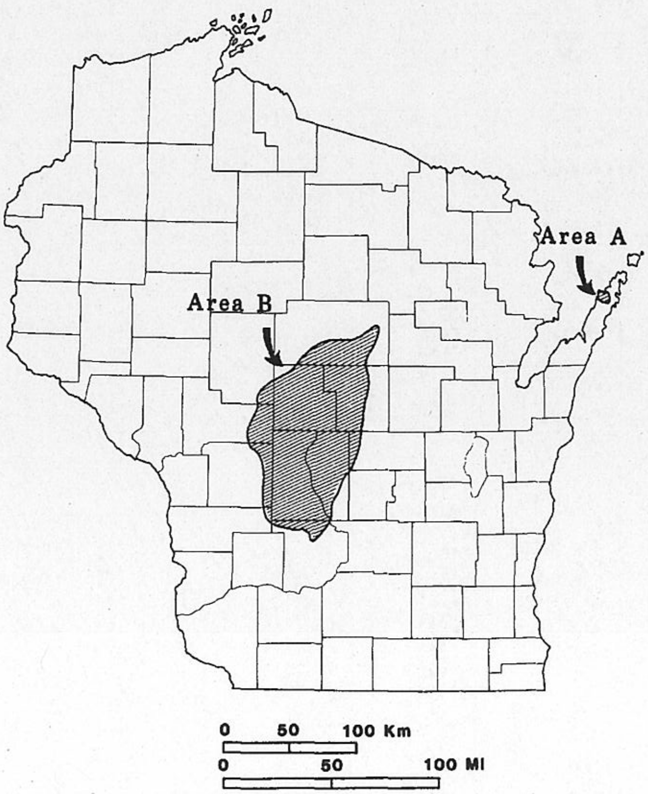

Fig. 1. Map of Wisconsin showing locations of field areas A (fractured dolomite) and B (sand and gravel).

then produce maps of hydraulic conductivity. The maps agree well with the more limited data available from pumping tests.

There are many advantages of using specific capacity information to compute hydraulic conductivity. The data are generally readily available and abundant: for area A, 224 specific capacity tests were available versus 5 pumping tests; for area B, 268 specific capacity tests were available versus 11 pumping tests. Estimates of hydraulic conductivity, based on specific capacity data, are quick, easy, and inexpensive, and when used in conjunction with limited pumping test data, may be the best method for mapping aquifer characteristics over large areas.

Computer Program Development

Theis *et al.* (1963) describe a method for estimating the transmissivity of an aquifer from the specific capacity of wells. Their analysis is based on the Jacob equation, given in consistent units as:

$$T = \frac{Q}{4\pi s} \ln\left(\frac{2.25\ Tt}{r_w^2 S}\right) \qquad (1)$$

where

T = transmissivity (L^2/t),

Q = discharge (L^3/t),

s = drawdown in the well (L),

t = pumping time (t),

S = storage coefficient (dimensionless), and

r_w = radius of the well (L).

Because T appears twice, this formula cannot be solved directly, and Theis *et al.* (1963) and Walton (1970) (among others) propose graphical solutions involving matching the specific capacity data to a family of curves. The graphical methods have the disadvantage of requiring a different set of curves for every possible combination of well radius, pumping period, and storage coefficient. In addition, any corrections for partial penetration or well loss require additional calculations.

Well loss is an increase in drawdown in the well bore over drawdown in the aquifer adjacent to the well. It is due to turbulent flow as water enters the well bore and pump, and depends on the pumping rate, construction of the well, and hydraulic properties of the tested aquifer. It is possible to correct specific capacity data for well loss using the equation (Csallany and Walton, 1963):

$$S_w = CQ^2 \qquad (2)$$

where

S_w = well loss (L),

C = well loss constant (t^2/L^5), and

Q = discharge (L^3/t).

Csallany and Walton present an equation with which to evaluate C from step-drawdown data.

Most private wells penetrate less than the full thickness of aquifers. During a specific capacity test, partially penetrating wells may yield anomalously low values of specific capacity, depending on the ratio of penetration (L) to aquifer thickness (b). In Wisconsin, the L/b ratio is sometimes as low as 0.1. Thus, a correction for partial penetration is necessary before estimating transmissivity from specific capacity. For unsteady drawdown in a partially penetrating well, Sternberg (1973) shows that

$$s = \frac{Q}{4\pi T} \left[\ln\left(\frac{2.25\ Tt}{r_w^2 S}\right) + 2\ s_p\right] \qquad (3)$$

where s_p is a "partial penetration factor" given by Brons and Marting (1961) as

$$s_p = \frac{1 - L/b}{L/b}\left(\ln \frac{b}{r_w} - G\{L/B\}\right) \qquad (4)$$

where

b = aquifer thickness (L),

L = length of open interval (L), and

G = a function of the L/b ratio.

Brons and Marting evaluate G(L/b) for various values of (b/r_w). In the present study the polynomial equation

$$G\{L/b\} = 2.948 - (7.363\ L/b) + 11.447\ \{L/b\}^2 - 4.675\ \{L/b\}^3 \qquad (5)$$

was fitted to the data of Brons and Marting by multiple regression, with a correlation coefficient of 0.992. Rewriting equation (3) to incorporate equation (2), we have

$$T = \frac{Q}{4\pi (s - s_w)} [\ln(\frac{2.25\ Tt}{r_w{}^2 S}) + 2\ s_p] \qquad (6)$$

The solution of equation (6) yields an estimate of T which is corrected for well loss and partial penetration, and incorporates t, S, and r_w.

Figure 2 shows a flow chart for a computer program which solves equation (6). The program first reads the data in the inconsistent units (gallons per minute, inches, feet, etc.) which are customarily used on driller's logs. After converting to consistent units (feet, seconds), the program solves equations (2), (4), and (5) directly. It then solves equation (6) iteratively, using an initial estimate of T (TGUESS) to calculate an updated estimate (TCALC). The program then substitutes the updated estimate for the original guess, and repeats the process until TGUESS and TCALC agree within a small error criterion (ERR). Finally the program prints the results.

Appendix A is a simple BASIC computer code written for an Apple IIe computer illustrating the estimation technique for a single well. A sample output is included in Appendix B. In practice, we expand this program to do several hundred estimations. The program is easily modified to change the types and methods of input and output. Currently it is designed to accept input either interactively or via a data file that has been merged with the program file. By including well coordinates in the input data, the output can be used directly in graphics plotting packages, as well as in statistical routines. The variables ERR and TGUESS have been assigned values of 0.1E-5 and 0.1, respectively. These can be altered by changing lines 300 and 320 of the program. The program also has been written in FORTRAN and is available from the authors.

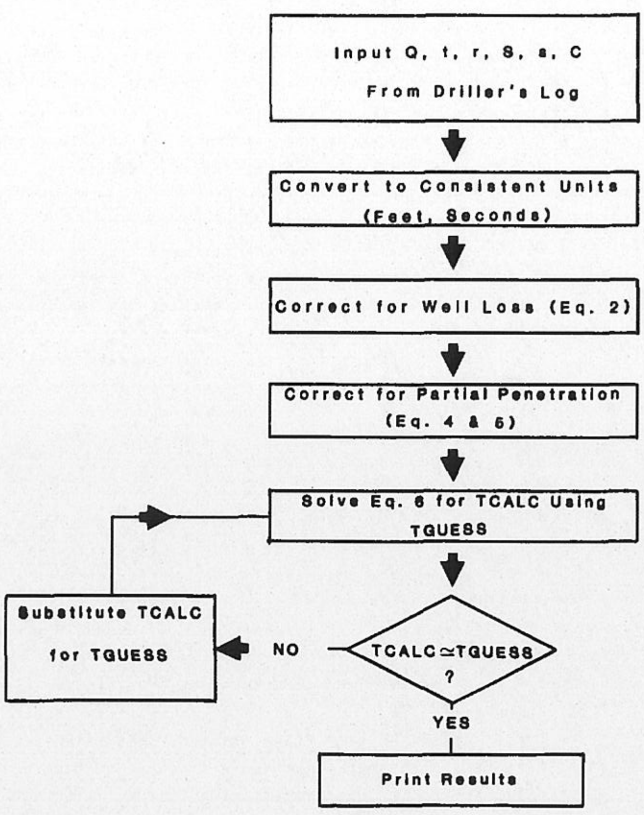

Fig. 2. Computer program flow chart.

Description of Field Sites

The aquifer analysis method described above was utilized for the two study areas in Wisconsin shown in Figure 1. The first (area A), called the Peninsula site, is in Door County, northeastern Wisconsin, and encompasses 17.8 mi² (46.1 km²). The aquifer at the Peninsula site is a highly fractured Silurian dolomite. Studies of the interactions of ground water at the site with surface water in adjacent Green Bay used computer modeling (Bradbury, 1982). The computer models required extensive data on transmissivity and hydraulic conductivity of the dolomite aquifer. Because the results of five available pumping tests in the area (Sherrill, 1978) might not adequately describe spatial variability of the fractured dolomite aquifer, the transmissivity estimation technique was applied to specific capacity data from 224 local wells. The use of specific capacity tests increased the average density of hydraulic conductivity data from 0.3 to 12.6 points/mi² (0.78 to 32.6 points/km²).

The second site (area B) encompasses a large portion of the Central Sand Plain of Wisconsin, which is underlain by an aquifer of sandy glacial outwash, and has an area of approximately 612 mi² (1585 km²). The sand and gravel aquifer in the

Table 1. Statistical Results of Estimates of Hydraulic Conductivity (K) from Specific Capacity for Two Areas in Wisconsin. Geometric Means, Standard Deviations (σ), and 95 Percent Confidence Limits Are Given

	K (ft/sec)
AREA A: Fractured dolomite (N = 223)	
Geometric mean	7.8×10^{-5}
σ	0.61
95% C.I.	$6.5 \times 10^{-5} - 9.3 \times 10^{-5}$
AREA B: Sandy outwash (N = 266)	
Geometric mean	2.1×10^{-3}
σ	0.25
95% C.I.	$1.6 \times 10^{-3} - 2.2 \times 10^{-3}$

area is widely utilized for spray irrigation of crops, especially potatoes. Recent indications of ground-water contamination by pesticides in the area (Rothschild *et al.*, 1982) prompted further study of the aquifer, including computer modeling (Rothschild, 1982). Specific capacity data for the area are abundant (268 points) in comparison to the number of pumping tests (11), and the transmissivity estimation technique was used to help describe the hydraulic characteristics of the aquifer. By utilizing specific capacity data the density of data points for transmissivity was increased from 0.018 points/mi² (pumping tests) to 0.44 points per mi² (0.045 to 1.14 points/km²).

Results

Reliability of Estimates

Results of the computer estimation of hydraulic conductivities from specific capacity data agree well with values calculated using full-scale pumping tests. Table 1 gives a statistical summary of hydraulic conductivity estimates for 223 wells in fractured dolomite (area A) and 266 wells in sandy outwash (area B). Because hydraulic conductivity data are generally log-normally distributed (Freeze, 1975), the geometric mean gives a good measure of the central tendency of the data, and sigma (σ) represents the standard deviation of the log-transformed data. Table 1 shows that, using many data points, the specific capacity estimates give a lower mean hydraulic conductivity for fractured dolomite (7.8×10^{-5} ft/sec) than for sandy outwash (2.1×10^{-3} ft/sec). Standard deviation values show that the fractured dolomite has statistically more variation in hydraulic conductivity than does the sandy outwash, and that the range of variation in both materials is small enough to make the results useful. Freeze (1975) reports that computer models can give meaningful estimates of hydraulic head when hydraulic conductivity "σ of K" values are less than 0.5, but that meaningful head predictions are impossible when σ is greater than 2.0. Thus the σ values of 0.61 and 0.25 reported here give confidence of reasonable results when using the data in computer simulations to predict hydraulic heads.

In spite of the well-known difficulties in estimating hydraulic conductivities from specific capacity data, the range of values predicted by our method is relatively small. Figure 3 presents average hydraulic conductivities for various materials, and shows the range of values obtained from our computer estimates. As noted by Winter (1981) the standard error in estimating values of hydraulic conductivity is often close to 100 percent or even higher. Thus the ranges of values shown on Figure 3 are quite narrow when compared to the possible ranges of hydraulic conductivity values, and the variation in K is less than one order of magnitude for the sandy outwash and just over an order of magnitude for the fractured dolomite.

Comparing estimates from individual wells, the results of the computer program are surprisingly close to data determined by pumping tests (Table 2). In the fractured dolomite of area A (wells 1-5), specific capacity data give hydraulic conductivity estimates which are slightly smaller than but of the

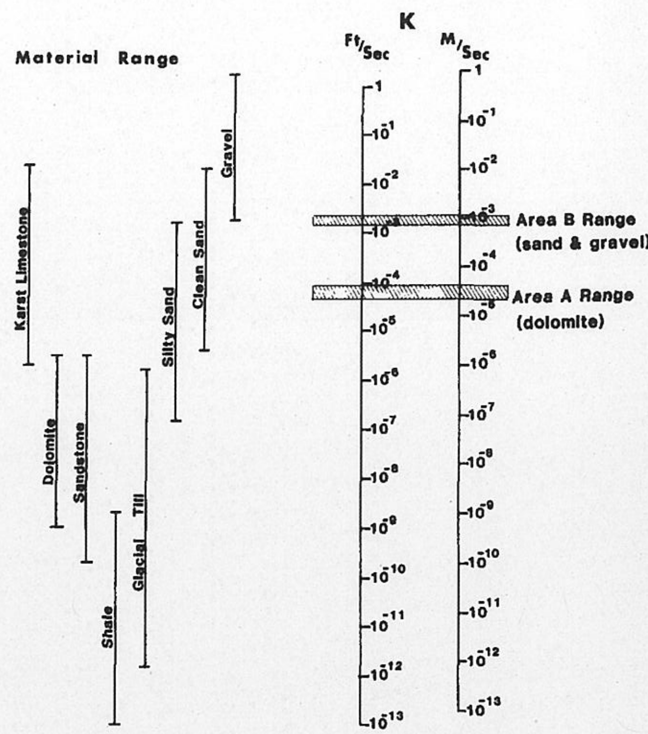

Fig. 3. Ranges of hydraulic conductivity (K) for various geologic materials, showing ranges determined from specific capacity estimates in this study (after Freeze and Cherry, 1979).

Table 2. Comparison of Values of Hydraulic Conductivity (K) Obtained from Pumping Tests with Values Estimated from Specific Capacities for Wells in Two Different Areas in Wisconsin

Well	*Pumping test* *K (ft/sec)*	*Specific capacity estimate* *K (ft/sec)*
AREA A: Fractured dolomite		
1	2.8×10^{-4}	7.3×10^{-4}
2	1.7×10^{-4}	1.0×10^{-5}
3	3.0×10^{-4}	5.0×10^{-4}
4	8.8×10^{-4}	2.8×10^{-4}
5	3.9×10^{-4}	1.0×10^{-4}
Geometric mean	3.5×10^{-4}	1.6×10^{-4}
σ	0.26	0.75
AREA B: Sandy outwash		
6	2.9×10^{-3}	1.5×10^{-3}
7	3.4×10^{-3}	1.5×10^{-3}
8	2.7×10^{-3}	2.8×10^{-3}
9	2.2×10^{-3}	1.8×10^{-3}
10	2.8×10^{-3}	1.8×10^{-3}
11	2.4×10^{-3}	2.0×10^{-3}
12	2.1×10^{-3}	1.8×10^{-3}
13	3.3×10^{-3}	2.7×10^{-3}
14	1.5×10^{-3}	1.9×10^{-3}
15	2.4×10^{-3}	2.2×10^{-3}
16	1.5×10^{-3}	2.8×10^{-3}
Geometric mean	2.4×10^{-3}	2.0×10^{-3}
σ	0.12	0.10

same order of magnitude as values derived from full-scale pumping tests using identical wells. In the sandy outwash of area B (wells 6-16), slight variations in K were also detected by specific capacity tests. Wells 9-12 in area B are radial collector wells. These wells are larger in diameter and are more efficient than the high capacity wells used for other specific capacity tests (Karnauskas, 1977). This efficiency difference is evident in consistently lower K values as determined by specific capacity tests, and highlights the importance of knowledge of well construction when interpreting such data. One of the poorer comparisons is for well 16. Due to the nature of outwash in this area the observation wells for the pumping test may not have been in full hydraulic connection with the pumping well. Much of the variation in values for the Central Sand Plain (area B) is explained by poor depth-to-bedrock control. Due to the high transmissivity of the overlying sands and gravels, few area wells are drilled to bedrock. In general, comparisons are poorer for the fractured dolomite of area A than for the sandy outwash of area B. The fractured dolomite is less homogeneous than the outwash, and the fracture system there may not truly approximate a porous media.

Contour Mapping

Contour maps of hydraulic conductivity for the two study areas are a valuable product of the computer program (Figures 4 and 5). The maps are produced by estimating T from specific capacity, then calculating K from aquifer thickness. Because all data are computerized, it is relatively simple to plot and contour the data using standard software packages. Interpolation, graphing, and smoothing packages were used to produce the maps in Figures 4 and 5 for the two study areas.

Distinct trends and differences are discernible in both areas. Figure 4 shows the hydraulic conductivity distribution in the fractured dolomite of the Peninsula area (area A). Because of the logarithmic distribution of K in the fractured dolomite the data are contoured by base 10 logs. As would be expected for a fractured dolomite aquifer, the areal distribution of K appears almost random with the exception of an area of higher K near the center of the area. The likelihood of this area having a higher K was confirmed by additional modeling efforts using a parameter estimation model (Bradbury, 1982).

In the sandy outwash of area B (Figure 5) the areal variation in K is less, and arithmetic contours are plotted. Variations in K shown on the map may be related to known depositional outwash facies in the area (Rothschild, 1982). The statistical inter-

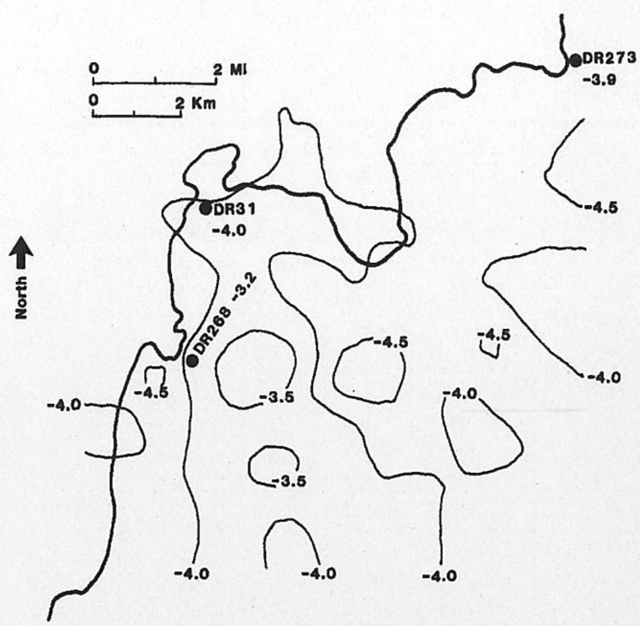

Fig. 4. Contour plot of hydraulic conductivity in study area A based on specific capacity and aquifer thickness data. Base 10 logs are plotted; contour interval is 0.5 log unit. Locations and log hydraulic conductivity values are shown for three wells where pumping tests were conducted.

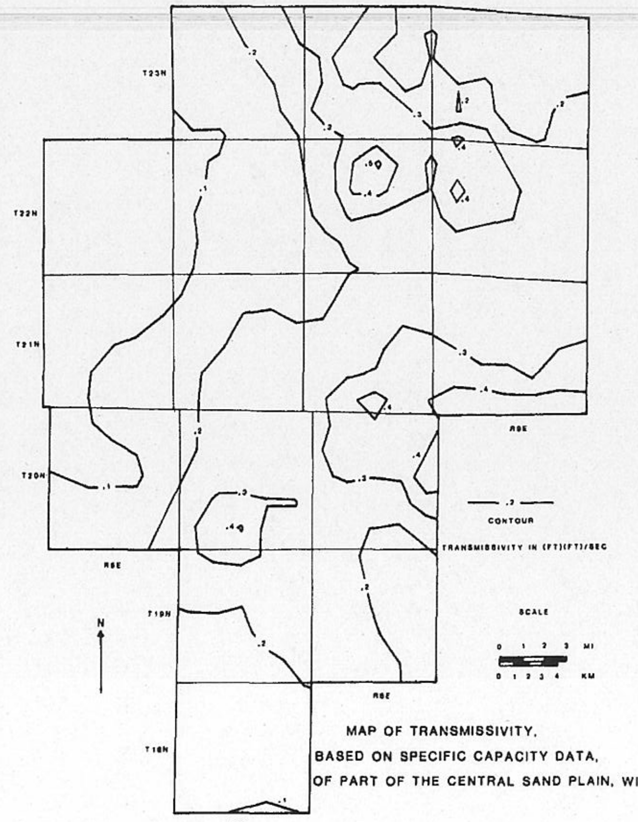

Fig. 5. Map of hydraulic conductivity based on specific capacity data for area B.

pretations of Figures 4 and 5 might be aided by advanced statistical techniques such as kriging which are beyond the scope of the present study.

Conclusions

Although the use of specific capacity data for estimating aquifer characteristics is not new, computer techniques can produce reliable estimates at more points and with less effort than in the past. Computers allow the rapid evaluation and manipulation of specific capacity data from large numbers of data points. The ability to use such data to describe the transmissivity and hydraulic conductivity of aquifers statistically or graphically is an important tool. The method described here has been successfully tested for sandy outwash and fractured dolomite aquifers at two field areas in Wisconsin.

Acknowledgments

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Appendix A

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10  PRINT : PRINT : PRINT :
20  PRINT "A PROGRAM TO ESTIMATE AQUIFER TRANSMISSIVITY"
30  PRINT "AND HYDRAULIC CONDUCTIVITY"
40  PRINT "FROM SPECIFIC CAPACITY TESTS"
50  PRINT ""
60  PRINT "WRITTEN BY K. BRADBURY AND E. ROTHSCHILD. SEPTEMBER 1981"
70  PRINT ""
80  PRINT "************************************************************"
90  PRINT "****************** LIST OF VARIABLES ******************"
100  PRINT
110  PRINT "NUM = IDENTIFICATION NUMBER OF WELL"
120  PRINT "DIAM = DIAMETER OF WELL (INCHES)"
130  PRINT "LGTH = LENGTH OF OPEN INTERVAL OR WELL SCREEN (FEET)"
140  PRINT "LVL = STATIC WATER LEVEL...NEGATIVE FOR FLOWING WELL (DEPTH I
     N FEET)"
150  PRINT "PUMP = DEPTH TO WATER WHILE PUMPING DURING SPECIFIC CAPACITY
     TEST (FEET)"
160  PRINT "LN = LENGTH OF TEST (HOURS)"
170  PRINT "GPM = PUMPING RATE DURING TEST (GALLONS/MINUTE)"
180  PRINT "AQTHIC = THICKNESS OF AQUIFER (FEET)"
190  PRINT "S = ESTIMATED OR MEASURED STORAGE COEFFICIENT (UNITLESS)"
200  PRINT "C = WELL LOSS COEFFICIENT (WALTON, BULL 49)... USE 1 IF UNKNO
     WN"
210  PRINT "SC = SPECIFIC CAPACITY CORRECTED FOR WELL LOSS (GALLONS/MINUT
     E/FOOT)"
220  PRINT "T = TRANSMISSIVITY (FEET * FEET/SECOND)"
230  PRINT "K = HYDRAULIC CONDUCTIVITY (FEET/SECOND)"
240  PRINT "ERR = CONVERGENCE CRITERIA FOR T ESTIMATE (FEET * FEET/SECOND
     )"
250  PRINT "**************************************************************
     "
260  PRINT "HOW MANY WELLS WILL BE ANALYZED?"
270  INPUT XX
280  DIM NUM(XX),DIAM(XX),LGTH(XX),LVL(XX),PUMP(XX),LN(XX),GPM(XX),AQTHIC
     (XX)
290  DIM SC(XX),S(XX),C(XX),T(XX),K(XX),KOUNT(XX),FLUB(XX),ITER(XX)
300 ERR = 0.1E - 5
310 KOUNT = 0
320 TGUESS = 0.1
330  REM  ************************************************************
340  REM  READ IN RAW DATA IN UNITS GIVEN ON DRILLERS LOGS
350  REM  ************************************************************
360  PRINT "DO YOU WANT TO ENTER DATA INTERACTIVELY OR FROM A FILE?"
370  PRINT "ENTER 0 IF INTERACTIVELY OR 1 IF FROM FILE"
380  INPUT A
390  IF A = 1 THEN  GOTO 530
400  FOR Z = 1 TO XX
410  PRINT "WELL NUMBER=": INPUT NUM(Z)
420  PRINT "WELL DIAMETER (IN)= ": INPUT DIAM(Z)
430  PRINT "STATIC WATER LEVEL (FT)= ": INPUT LVL(Z)
440  PRINT "DEPTH TO WATER DURING TEST (FT)= ": INPUT PUMP(Z)
450  PRINT "THE LENGTH OF THE TEST (HR)= ": INPUT LN(Z)
460  PRINT "PUMPING RATE (GPM)= ": INPUT GPM(Z)
470  PRINT "THICKNESS OF AQUIFER (FT)= ": INPUT AQTHIC(Z)
480  PRINT "OPEN INTERVAL (FT)= ": INPUT LGTH(Z)
490  PRINT "STORAGE COEFFICIENT= ": INPUT S(Z)
500  PRINT "WELL LOSS COEFFICIENT= ": INPUT C(Z)
510  NEXT Z
520  GOTO 560
530  FOR Z = 1 TO XX
540  READ NUM(Z),DIAM(Z),LVL(Z),PUMP(Z),LN(Z),GPM(Z),AQTHIC(Z),LGTH(Z),S(
     Z),C(Z)
550  NEXT Z
560  REM  ************************************************************
570  REM  DO ANALYSIS FOR EACH WELL
580  REM  ************************************************************
590  FOR Y = 1 TO XX
600 FLUB(Y) = 0:ITER(Y) = 0
610  REM  ************************************************************
620  REM  CHANGE TO CONSISTENT UNITS AND CALCULATE DRAWDOWN
630  REM  ************************************************************
640 R = DIAM(Y) / 24.0
650 TIME = LN(Y) * 3600.0
660 Q = GPM(Y) / 449.0
670 DD =  - (LVL(Y) - PUMP(Y))
680  IF (DD <  = 0.0) GOTO 1090
690 KOUNT = KOUNT + 1
700  REM  ************************************************************
710  REM  CORRECT DRAWDOWN FOR WELL LOSS USING THE EQUATION SW=CQQ
720  REM  SEE WALTON, BULL. 49, PAGE 27
730  REM  C IS ESTIMATED FROM STEP DRAWDOWN TESTS.
740  REM  ************************************************************
750 SW = C(Y) * Q * Q
760 DD = DD - SW
770 SC(Y) = GPM(Y) / DD
780  REM  ************************************************************
790  REM  CALCULATE AQUIFER TRANSMISSIVITY USING THE JACOB EQUATION
800  REM  USING A CORRECTION FOR PARTIAL PENETRATION AS GIVEN BY
810  REM  STERNBURG (1973)
820  REM  ************************************************************
830  REM  FIRST CALCULATE SP PARAMETERS FOR USE IN THE EQUATION
840  REM  ************************************************************
850 B = LGTH(Y) / AQTHIC(Y)
860  IF (B > 1.0) GOTO 1090
870 HRW = AQTHIC(Y) / R
880 GB = 2.9480 - (7.363 * B) + (11.447 * B * B) - (4.675 * B * B * B)
890 SP = ((1.0 - B) / B) * ( LOG (HRW) - GB)
900  REM  ************************************************************
910  REM  NOW SOLVE FOR T USING ITERATIONS
920  REM  ************************************************************
930 TQUESS = 0.1
940  FOR W = 1 TO 25
950 F1 = Q / (4.0 * 3.1416 * DD)
960 F2 = (2.25 * TGUESS * TIME) / (R * R * S(Y))
970 TCALC = F1 * ( LOG (F2) + (2.0 * SP))
980 TEST =  ABS (TCALC - TGUESS)
990 TGUESS =  ABS (TCALC)
1000  IF (TEST <  = ERR) THEN  GOTO 1060
1010 KOUNT(Y) = W
1020  NEXT W
1030  IF (KOUNT(Y) = 25) AND (TEST > ERR) THEN  GOTO 1050
1040  GOTO 1060
1050 ITER(Y) = 1: GOTO 1100
1060 T(Y) = TCALC
1070 K(Y) = T(Y) / AQTHIC(Y)
1080  GOTO 1100
1090 FLUB(Y) = 1
1100  NEXT Y
1110  REM  ************************************************************
1120  REM  PRINT OUTPUT
1130  REM  ************************************************************
1140  PR# 1
1150  PRINT "************************************************************"
1160  PRINT "AQUIFER PROPERTIES AS DETERMINED BY ANALYSIS OF "
1170  PRINT "             SPECIFIC CAPACITY TESTS"
1180  PRINT "************************************************************"
1190  PRINT ""
1200  FOR V = 1 TO XX
1210  IF FLUB(V) = 1 GOTO 1330
1220  IF ITER(V) = 1 GOTO 1390
1230  PRINT ""
1240  PRINT "WELL NUMBER ";NUM(V)
1250  PRINT "SPECIFIC CAPACITY (GPM/FT) = ";SC(V)
1260  PRINT "TRANSMISSIVITY (FT*FT/SEC) = ";T(V)
1270  PRINT "             USING A STORAGE COEFFICIENT = ";S(V)
1280  PRINT "             NUMBER OF ITERATIONS = ";KOUNT(V)
1290  PRINT "HYDRAULIC CONDUCTIVITY (FT/SEC) = ";K(V)
1300  NEXT V
1310  PRINT "THE NUMBER OF WELLS IN THIS RECORD IS ";XX
1320  GOTO 1430
1330  PRINT ""
1340  PRINT "WELL NUMBER ";NUM(V)
1350  PRINT "INPUT ERROR, EITHER:"
1360  PRINT "     1. WATER LEVEL WAS HIGHER DURING TEST THAN BEFORE, OR:"

1370  PRINT "     2. THE SCREEN LENGTH IS LONGER THAN THE AQUIFER THICKNE
     SS."
1380  GOTO 1300
1390  PRINT ""
1400  PRINT "WELL NUMBER ";NUM(V)
1410  PRINT "SOLUTION DID NOT CONVERGE WITHIN 25 ITERATIONS"
1420  GOTO 1300
1430  END
```

Appendix B

As an example of computer program input and output, the following data from area A were input into the interactive computer program (Appendix A).

Number of wells to be analyzed = 2
Interactive data entry
Well number 1
Well diameter = 6 in.
Static water level = 42 ft
Depth to water during test = 57 ft
Length of test = 8 hr
Pumping rate = 10 gpm
Aquifer thickness = 205 ft
Open interval = 47 ft
Storage coefficient = 0.0002
Well loss coefficient = 32.7
Well number 2
Well diameter = 6 in.
Static water level = 132 ft
Depth to water during test = 141 ft
Length of test = 8 hr
Pumping rate = 10 gpm
Aquifer thickness = 115 ft
Open interval = 68 ft
Storage coefficient = 0.0002
Well loss coefficient = 32.7

Figure A1 is the computer output generated by these data.

```
************************************************************
AQUIFER PROPERTIES AS DETERMINED BY ANALYSIS OF
             SPECIFIC CAPACITY TESTS
************************************************************
WELL NUMBER 1
SPECIFIC CAPACITY (GPM/FT) = .666688713
TRANSMISSIVITY (FT*FT/SEC) = 5.93317103E-03
             USING A STORAGE COEFFICIENT = 2E-04
             NUMBER OF ITERATIONS = 3
HYDRAULIC CONDUCTIVITY (FT/SEC) = 2.89422977E-05

WELL NUMBER 2
SPECIFIC CAPACITY (GPM/FT) = 1.11117235
TRANSMISSIVITY (FT*FT/SEC) = 4.56944391E-03
             USING A STORAGE COEFFICIENT = 2E-04
             NUMBER OF ITERATIONS = 3
HYDRAULIC CONDUCTIVITY (FT/SEC) = 3.97342949E-05
THE NUMBER OF WELLS IN THIS RECORD IS 2
```

Fig. A-1. Example of computer printout.