The methods available for analyzing data of unsteady-state flow are the Walton curve-fitting method, the Hantush inflection-point method (both of which, however, neglect the aquitard storage), the Hantush curve-fitting method, and the Neuman and Witherspoon ratio method (both of which do take aquitard storage into account).

4.2.1 Walton's method

With the effects of aquitard storage considered negligible, the drawdown due to pumping in a leaky aquifer is described by the following formula (Hantush and Jacob 1955)

$$s = \frac{Q}{4\pi KD} \int_u^\infty \frac{1}{y} \exp\left(-y - \frac{r^2}{4L^2y}\right) dy$$

or

$$s = \frac{Q}{4\pi KD} W(u,r/L) \tag{4.6}$$

where

$$u = \frac{r^2S}{4KDt} \tag{4.7}$$

Equation 4.6 has the same form as the Theis well function (Equation 3.5), but there are two parameters in the integral: u and r/L. Equation 4.6 approaches the Theis well function for large values of L, when the exponential term $r^2/4L^2y$ approaches zero.

On the basis of Equation 4.6, Walton (1962) developed a modification of the Theis curve-fitting method, but instead of using one type curve, Walton uses a type curve for each value of r/L. This family of type curves (Figure 4.5) can be drawn from the tables of values for the function W(u,r/L) as published by Hantush (1956) and presented in Annex 4.2.

Walton's method can be applied if the following assumptions and conditions are satisfied:
- The assumptions listed at the beginning of this chapter;
- The aquitard is incompressible, i.e. the changes in aquitard storage are negligible;
- The flow to the well is in unsteady state.

Procedure 4.3
- Using Annex 4.2, plot on log-log paper W(u,r/L) versus 1/u for different values of r/L; this gives a family of type curves (Figure 4.5);
- Plot for one of the piezometers the drawdown s versus the corresponding time t on another sheet of log-log paper of the same scale; this gives the observed time-drawdown data curve;
- Match the observed data curve with one of the type curves (Figure 4.6);
- Select a match point A and note for A the values of W(u,r/L), 1/u, s, and t;
- Substitute the values of W(u,r/L) and s and the known value of Q into Equation 4.6 and calculate KD;
- Substitute the value of KD, the reciprocal value of 1/u, and the values of t and r into Equation 4.7 and solve for S;

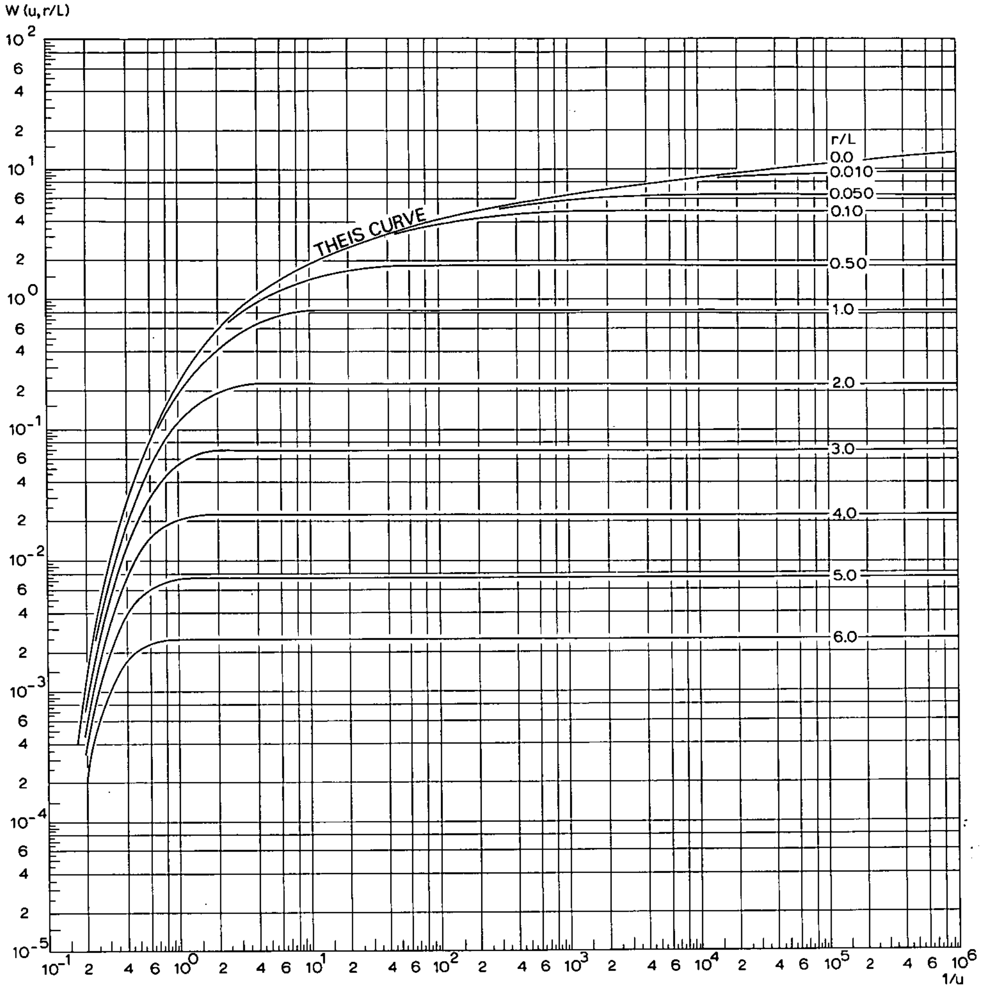

Figure 4.5 Family of Walton's type curves W(u,r/L) versus 1/u for different values of r/L

- From the type curve that best fits the observed data curve, take the numerical value of r/L and calculate L. Then, because $L = \sqrt{KDc}$, calculate c;
- Repeat the procedure for all piezometers. The calculated values of KD, S, and c should show reasonable agreement.

Remark

- To obtain the unique fitting position of the data plot with one of the type curves, enough of the observed data should fall within the period when leakage effects are negligible, or r/L should be rather large.

Example 4.3

Compiled from the pumping test 'Dalem', Table 4.2 presents the corrected drawdown data of the piezometers at 30, 60, 90, and 120 m from the well. Using the data from the piezometer at 90 m, we plot the drawdown data against the corresponding values of t on log-log paper. A comparison with the Walton family of type curves shows that the plotted points fall along the curve for $r/L = 0.1$ (Figure 4.6). The point where $W(u,r/L) = 1$ and $1/u = 10^2$ is chosen as match point A_{90}. On the observed data sheet, this point has the coordinates $s = 0.035$ m and $t = 0.22$ d. Introducing the appropriate numerical values into Equations 4.6 and 4.7 yields

$$KD = \frac{Q}{4\pi s} W(u,r/L) = \frac{761}{4 \times 3.14 \times 0.035} \times 1 = 1731 \text{ m}^2/\text{d}$$

and

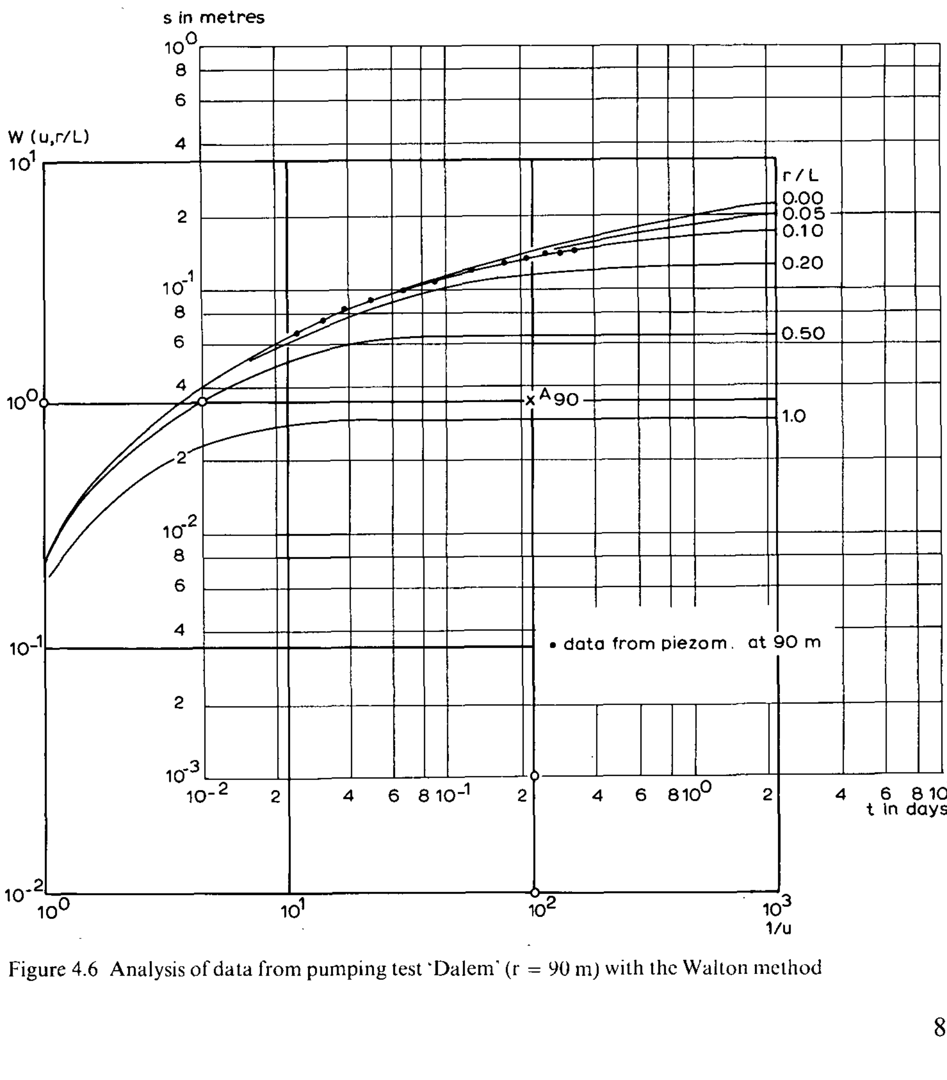

Figure 4.6 Analysis of data from pumping test 'Dalem' (r = 90 m) with the Walton method

$$S = \frac{4KDt}{r^2}u = \frac{4 \times 1731 \times 0.22}{90^2} \times \frac{1}{10^2} = 1.9 \times 10^{-3}$$

Further, because r = 90 m and r/L = 0.1, it follows that L = 900 m and hence $c = L^2/KD = (900)^2/1731 = 468$ d.

Table 4.2 Drawdown data from pumping test 'Dalem', The Netherlands (after De Ridder 1961)

Time (d)	Drawdown (m)	Time (d)	Drawdown (m)
Piezometer at 30 m distance and 14 m depth			
0	0		
1.53×10^{-2}	0.138	8.68×10^{-2}	0.190
1.81	0.141	1.25×10^{-1}	0.201
2.29	0.150	1.67	0.210
2.92	0.156	2.08	0.217
3.61	0.163	2.50	0.220
4.58	0.171	2.92	0.224
6.60×10^{-2}	0.180	3.33×10^{-1}	0.228
extrapolated steady-state drawdown			0.235 m
Piezometer at 60 m distance and 14 m depth			
0	0	8.82×10^{-2}	0.127
1.88×10^{-2}	0.081	1.25×10^{-1}	0.137
2.36	0.089	1.67	0.148
2.99	0.094	2.08	0.155
3.68	0.101	2.50	0.158
4.72	0.109	2.92	0.160
6.67×10^{-2}	0.120	3.33×10^{-1}	0.164
extrapolated steady-state drawdown			0.170 m
Piezometer at 90 m distance and 14 m depth			
0	0		
2.43×10^{-2}	0.069	1.25×10^{-1}	0.120
3.06	0.077	1.67	0.129
3.75	0.083	2.08	0.136
4.68	0.091	2.50	0.141
6.74	0.100	2.92	0.142
8.96×10^{-2}	0.109	3.33×10^{-1}	0.143
extrapolated steady-state drawdown			0.147 m
Piezometer at 120 m distance and 14 m depth			
0	0		
2.50×10^{-2}	0.057	1.25×10^{-1}	0.105
3.13	0.063	1.67	0.113
3.82	0.068	2.08	0.122
5.00	0.075	2.50	0.125
6.81	0.086	2.92	0.127
9.03×10^{-2}	0.092	3.33×10^{-1}	0.129
Extrapolated steady-state drawdown			0.132 m