APPENDIX E

Step Test Analysis

Step Test Analysis

E.1 Introduction

An initial step test was carried out in both pumping wells (PW1 and PW2) to determine well performance and the required pumping rate for a subsequent constant discharge test. This appendix summarizes the interpretation of these step tests.

E.2 Step Test in PW1

On September 9, 2005, a step-drawdown test was performed in PW1 to evaluate well performance and to estimate the appropriate pumping rates for subsequent (constant rate) pump tests. The step test consisted of four steps ranging from Q_1 =600 m^3/day (110 USgpm) to Q_4 =3183 m^3/day (584 USgpm). The duration of each step was 100 minutes.

Figure E1 shows the (cumulative) drawdown in the pumping well. The incremental drawdown for each step (Δs_i), estimated from the drawdown plot, is also shown. The drawdown in a pumping well is commonly assumed to equal (Kruseman & de Ridder, 1994):

$$s_w = BQ + CQ^2 \quad \text{(Equation E1)}$$

where Q equals the pumping rate (in m^3/day) and B and C are constants expressing linear and non-linear well losses, respectively. The Hantush-Bierschenk method was used to estimate the parameters B and C for pumping well PW1 (see Kruseman and de Ridder (1994), p. 201). Figure E2 shows the specific drawdown plotted against the corresponding pumping rates. Using a straight line fit to the data, the well loss parameters are estimated to be B = 0.00082 day/m^2 (y-intercept) and C = $1.52\text{x}10^{-7}$ d^2/m^5) (for t = Δ100 min).

Note that the last step did not conform to this linear approximation (Figure E2). The significantly higher specific drawdown in the last step is likely a result of desaturation of the upper well screen during this last step. Therefore, the well loss parameters only apply to pumping rates < 2,500 m^3/day

Kruseman and de Ridder define the well efficiency (due to non-linear flow resistance) as:

$$E_w = BQ/(BQ + CQ^2) \quad \text{(Equation E2)}$$

Using equation E2, the well efficiency for PW1 is in the order of 79% for a pump rate of 300 gpm, suggesting that non-linear well losses are not significant. The low well losses are due to the aggressive development carried out on the well. The well was jetted, surged and air lifted for 8.5 hours using the air rotary rig. This procedure was observed to remove a significant volume of fine to medium sand from the formation, thus forming an efficient natural sand and gravel filter pack.

E.3 Step Test in PW2

On September 6, 2005, a step-drawdown test was performed in PW2 to evaluate well performance and to estimate the appropriate pumping rates for subsequent (constant rate) pump tests. The step test consisted of four steps ranging from Q_1 =616 m^3/day (113 USgpm) to Q_4 =2889 m^3/day (530 USgpm). The duration of each step was 60 minutes.

Figure E3 shows the (cumulative) drawdown in the pumping well. The incremental drawdown for each step (Δs_i), estimated from the drawdown plot, is also shown. Note that the pumping rate in the fourth step was not significantly higher than in the third step (due to limitations in the capacity of the pump). Hence the fourth step was not included in the step test interpretation (see below).

Again, the Hantush-Bierschenk method was used to estimate the well loss parameters B and C for pumping well PW2 (see equation E1). Figure E4 shows the specific drawdown plotted against the corresponding pumping rates. Using a straight line fit to the data, the well loss parameters are estimated to be B = 0.00049day/m^2 (y-intercept) and C ~ 0 d^2/m^5) (for t = Δ60 min). It should be noted that the duration of the step tests (60 minutes) did not allow for steady-state conditions to develop. Hence these well loss parameters are likely to change for longer duration pumping.

Using equation E2, the well efficiency for PW2 is estimated to be approaching 100%, i.e. there appear to be no non-linear well losses. This results is consistent with observations during the subsequent CD pump test which showed very little difference in drawdown in the pumping well PW2 and the nearby monitoring well MW2. This very high efficiency of this well is a result of the extensive development work carried out on this well using jetting, surging and air-lifting with compressed air. Pumping well PW2 was developed for almost 2 days (20.5 hours) to remove a substantial amount of fine to coarse sand sized sediments that were entering the well screen.

E.4 References

Kruseman and de Ridder, 1994. Analysis and Evaluation of Pumping Test Data, ILRI publication 47, (2nd Edition), International Institute for Land Reclamation and Improvement, Wageningen, The Netherlands, 1994.

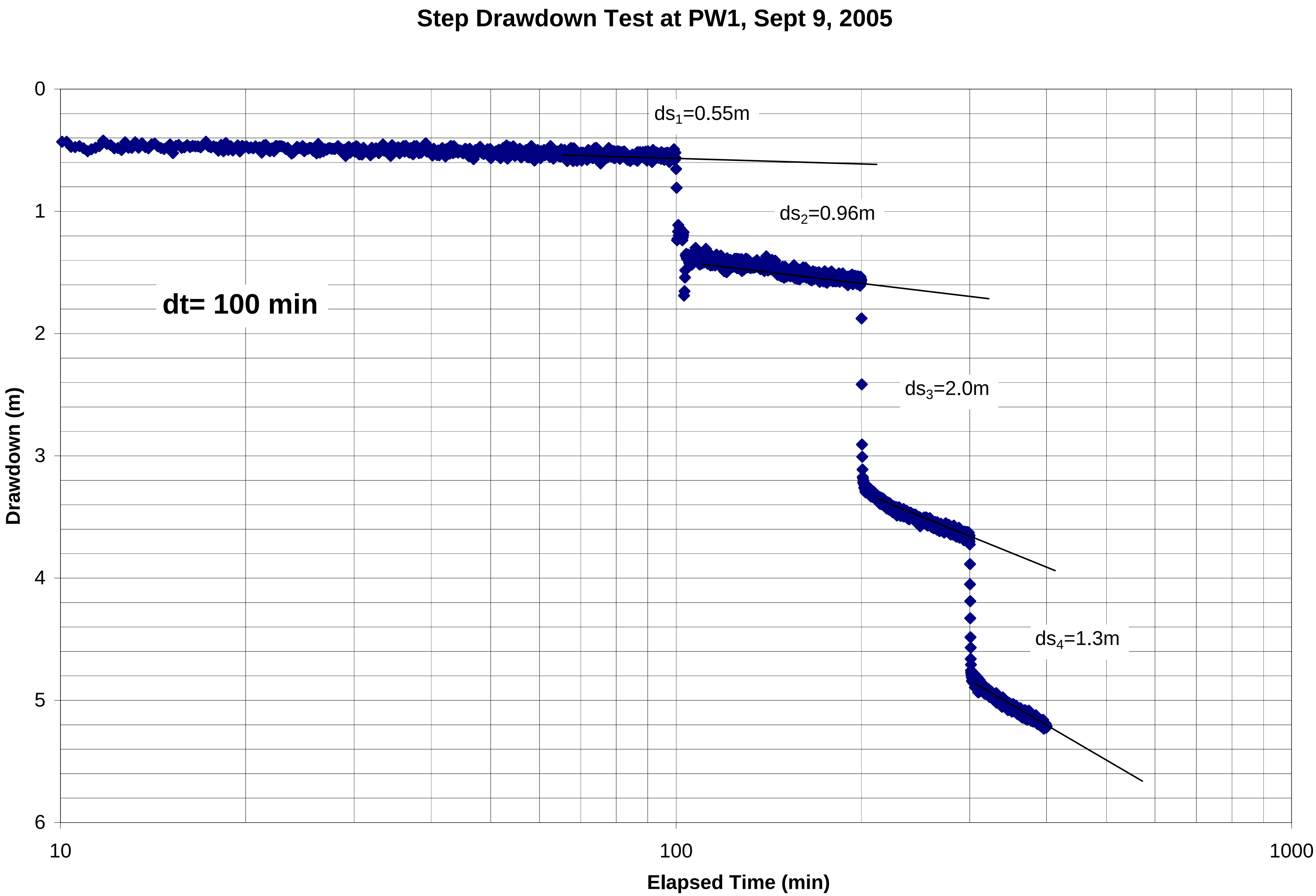

Figure E1. Step Drawdown Test at PW1.

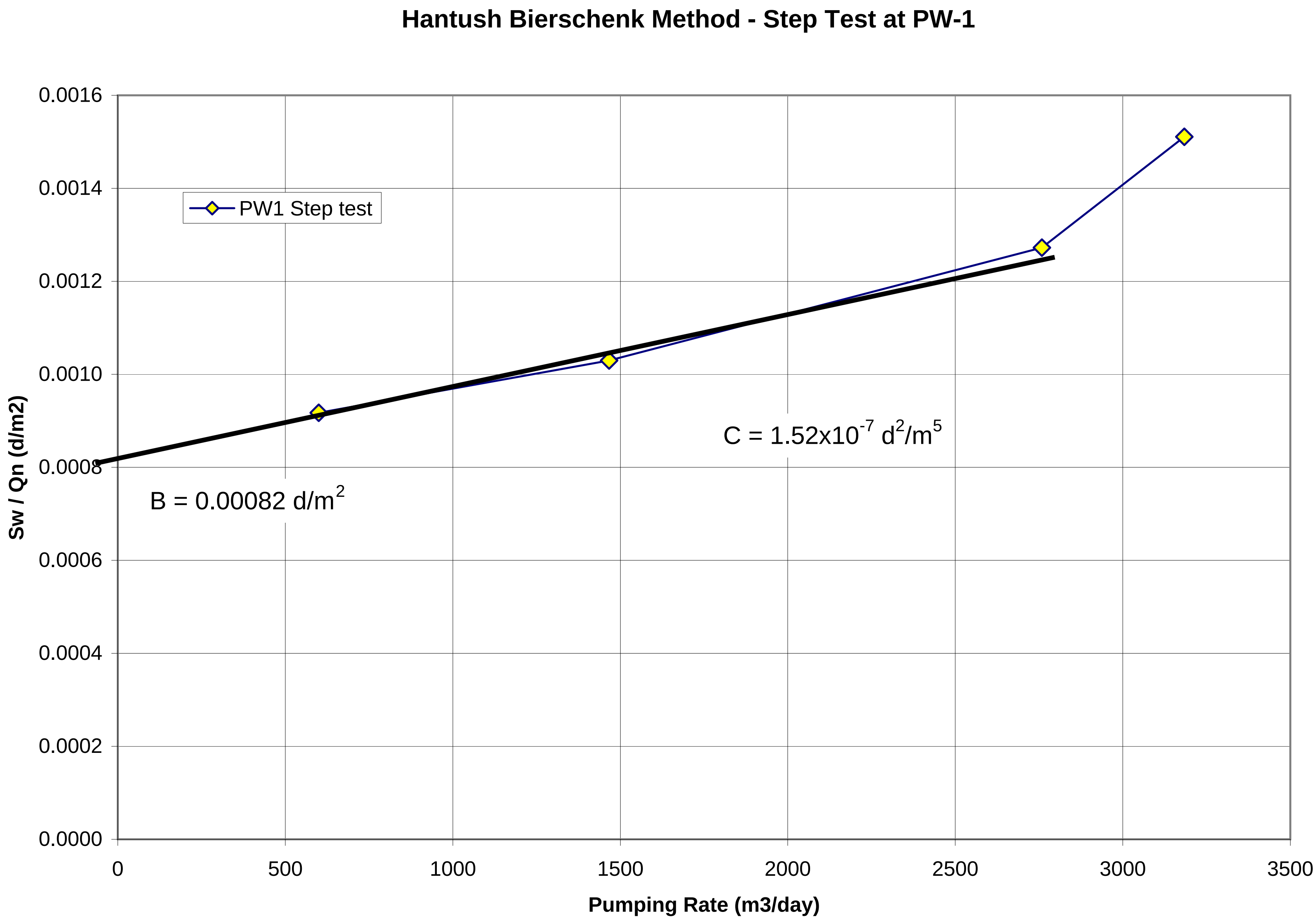

Figure E2. Analysis of Step Test in PW1 using Hantush Bierschenk Method.

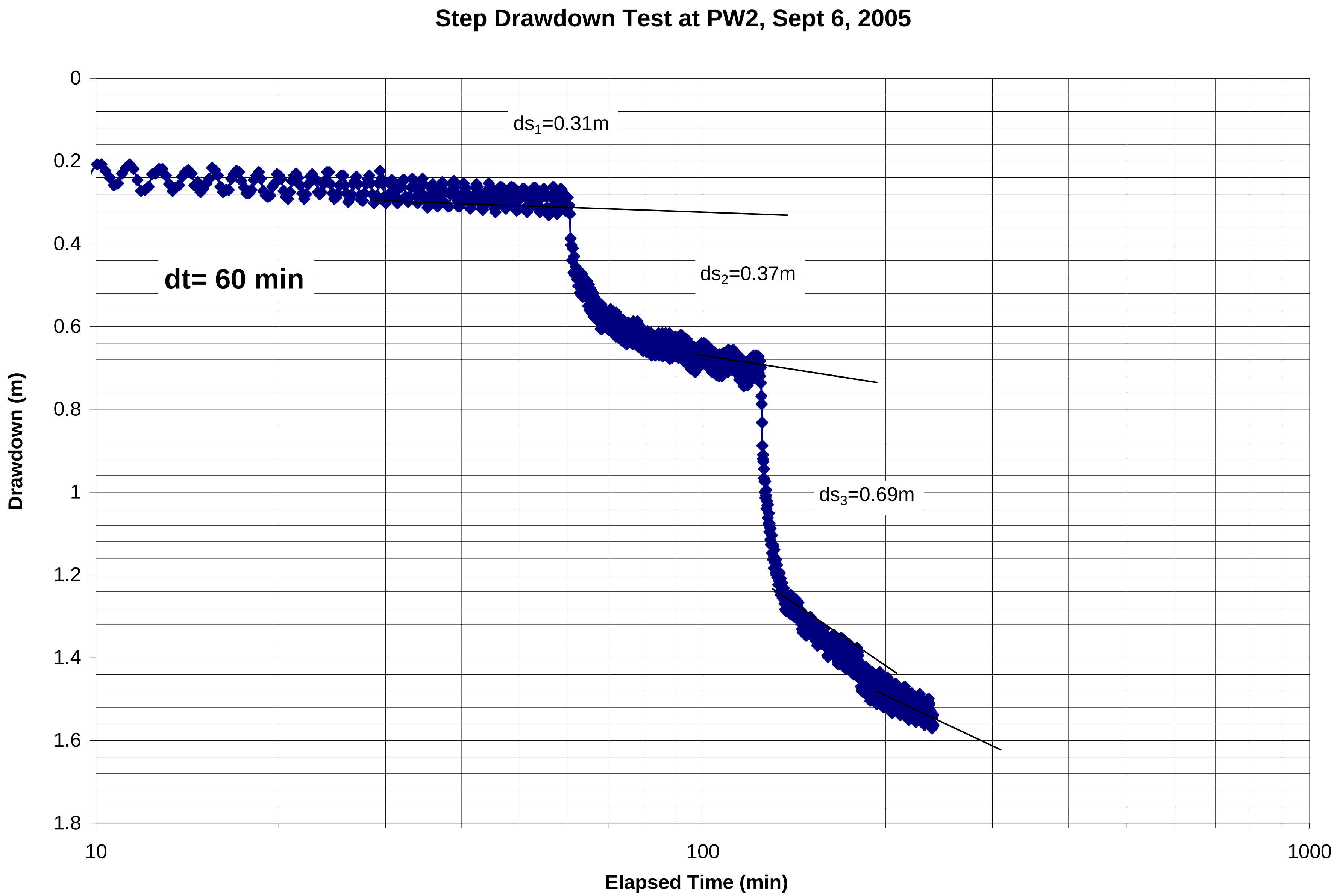

Figure E3. Step-Drawdown Test in PW2.

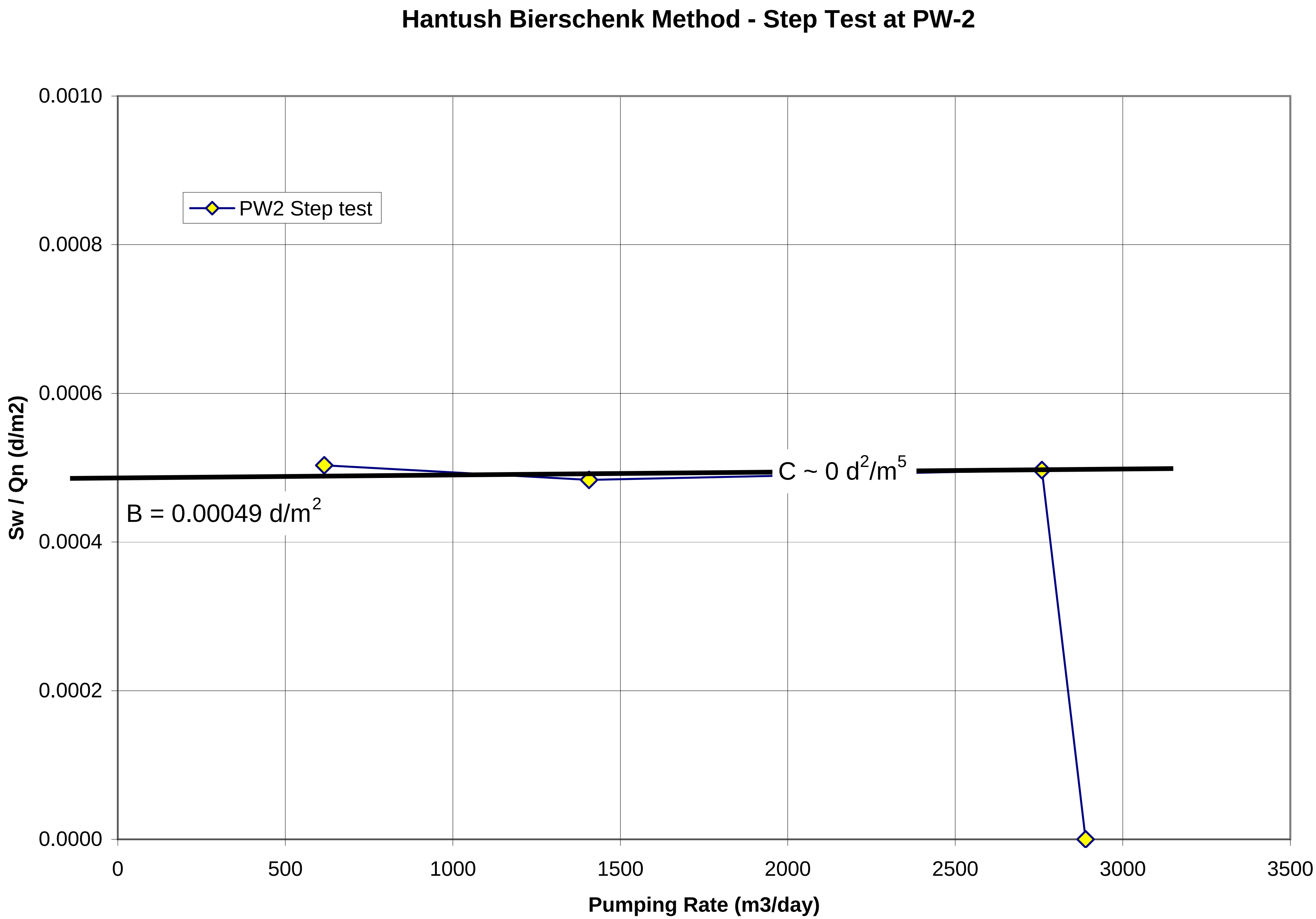

Figure E4. Analysis of Step test in PW2 using Hantush Bierschenk Method.