Reply to Reviewer 3

Interactive comment on "Analysis of Groundwater Response to Oscillatory Pumping Test in Unconfined Aquifers: Consider the Effects of Initial Condition and Wellbore Storage" by Ching-Sheng Huang et al.

Reviewed by W. Barrash

This is a comment on the Reply to Reviewer 2 (hess-2018-199-AC2-supplement.pdf). I am familiar with the subject and the data which the authors have misrepresented and misused in the original manuscript, as noted below. The data (in Fig. 8 of the ms and in the text of the ms) were misrepresented as being actual field data from the experiment at the BHRS. The authors admit this in their AC-2 supplement where they say they digitized data from Fig. 4(a) of Rabinovich et al. 2015. *** But the data do not look at all similar (data are too smooth and they unrealistically match ideal oscillations, and they are not at the same relative amplitude and phase positions), so the authors' statement notwithstanding, the authors presented and analyzed a very suspect digitizing operation and/or very suspect transcription to the figure without quality control as expected for scientific research - and then analyzed and interpreted the "data" with the false attribution to our OHT work at the BHRS. ***

Response: Rabinovich et al. (2015) mentioned that "In this work we focus our attention on the first dominant frequency, using only a single harmonic to represent the signal and thus simplifying computations in the comparison with the semi-analytical solution." in the third paragraph of section 3.2. The field test results for the hydraulic head as a function of time shown in Fig. 4(a) of their paper is given at the end of this reply as panel (a) of Fig. R1. In addition, they also mentioned that "First, two initial periods of data were removed in order to avoid transient flow associated with the onset of pumping, thus assuring steady periodic flow." in the second paragraph of section 3.2. We therefore digitized the portion of their f1(FFT) data in panel (b) of Fig. R1 because the head fluctuation can be regarded as a simple harmonic motion (i.e., steady periodic flow). It is apparent to see that our digitized data in Fig. R1 are very close to their f1 data in either the amplitude or the phase. Our data may have some reading errors but their influence on the parameter estimation is negligible from the least-squares sense. We think there might be a misunderstanding in their comments as follows "the authors have misrepresented and misused in the original manuscript" and "they are not at the same relative amplitude and phase positions".

Furthermore, as also noted by Dr. Cardiff, the authors missed the essential details that the experiment was conducted in wells subdivided by straddle packers, i.e., not conducted in open fully penetrating wells. And the actual oscillatory pumping configuration does not involve any wellbore storage. *** That is, their premise for using the data is unfounded. ***

Response: As we stated in the Reply to Reviewer 2, the inner boundary condition in the previous manuscript describing flux across the screen of a fully penetrating well is changed to a new one that is applicable to a partially penetrating well as below

$$2\pi r_w K_r l \frac{\partial h}{\partial r} - \pi r_c^2 \frac{\partial h}{\partial t} = \begin{cases} Q\sin(\omega t) & \text{for } z_l \le z \le z_u \\ 0 & \text{outside screen interval} \end{cases} \quad \text{at} \quad r = r_w \qquad \text{(R1)}$$

where h is hydraulic head, r is radial distance from the centerline of the pumping well, z is elevation, t is time, K_r is radial hydraulic conductivity, r_c and r_w are respectively inner and outer radiuses of the well, z_l and z_u are respectively lower and upper elevations of screen interval, and $l = z_u - z_l$ is screen length. A new analytical solution based on Eq. (R1) is presented in the revised manuscript. It can reduce to a special case of no wellbore effect when letting $r_c = 0$. With this new solution, we will redo curve fitting in Fig. 8 of our paper. Therefore, we sincerely hope that the reviewers can kindly provide us the full time series and f1(FFT) data shown in their figure (i.e., in Fig. 4(a) of Rabinovich et al. (2015)).

The email I received in October 2016 was very perfunctory and did not indicate an understanding of the need to consider context and metadata in order to use field data properly. I do not feel obligated to respond to such inquiries that essentially say: "send me the data," and I do not have the time to engage in discussion to find out what the person wants or needs, and then (as may be necessary if people are unfamiliar with field experiments or field data) to guide and review to be sure the data are treated and/or used properly. I am speaking from experience on this.

Response: Our email explicitly stated the need of time-varying hydraulic head data in Figure 4 of Rabinovich et al. (2015) for parameter estimation. The original letter by the second author to the reviewer Dr. W. Barrash is given below: “I’m a graduate student working on a study related to the topic of parameter estimation for oscillatory pumping test data. … In the paper, the hydraulic head data measured at the Boise Site was analyzed and illustrated in Figure 4. Would you please provide the original measured hydraulic head versus time data and the after applying the Fourier analysis data? …”

So now, given the above experience with the authors, the Reply to Reviewer 2 states they want to do a reanalysis and modify their analytical model to include partially penetrating wells and thereby match the OHT field pumping configuration. But they go on to say "Curve fitting to the data will be conducted using the present solution with and without considering the wellbore storage effect."

*** But this is still an inappropriate use of the data they are requesting. It doesn’t make sense to analyze data with an inappropriate model (which the authors explicitly acknowledge is their intention in their reply) in order to compare the results with modeling using data appropriate for the model. ***

If the analysis is conducted correctly, it will be a foregone conclusion that the results will differ and the real data from the BHRS will look bad by comparison. This is not an appropriate use of the OHT data we collected, and there is no sound reason to put the data in the literature in a confusing context. Anyone who is competent in collecting and modeling/analyzing OHT field data would know not to use a wellbore storage model with data such as the BHRS data.

I strongly recommend that the ms by the authors not be published with BHRS OHT data. I recommend that the authors find other data that are appropriate for their analysis, or better yet, collect their own data.

Response: Rabinovich et al. (2015) applied the analytical solution of Dagan and Rabinovich (2014) to analyze data obtained from the oscillatory piston pumping test conducted at the Boise Hydrogeophysical Research Site (BHRS). In spite of no wellbore storage effect (i.e., $r_c = 0$), our new solution in the revised manuscript has two superiorities over their solution. One is to consider the finite radius of an oscillatory pumping well expressed as Eq. (R1), and the other is to include the delayed yield effect denoted as

$$K_z \frac{\partial h}{\partial z} = -\varepsilon\, S_y \int_0^t \frac{\partial h}{\partial t'} \exp(-\varepsilon(t-t'))\, \mathrm{d}t' \quad \text{at} \quad z = b \qquad \text{(R2)}$$

where K_z is vertical aquifer hydraulic conductivity, b is aquifer thickness, ε is an empirical constant, and the term on the right-hand side accounts for the effect of delayed gravity drainage (Moench, 1995). Since their solution is applicable to the BHRS data, our new solution should be applicable as well. The comment "It doesn't make sense to analyze data with an inappropriate model" is his prejudice.

Furthermore, on another issue, the authors have missed the point about small specific yield values for short duration tests that have been reported repeatedly in the literature (see citations at the end of these comments to Neuman 1975; Moench 1994; Chen and Ayers 1998; Barrash et al. 2006 - all from or cited in Barrash et al. 2006 on the BHRS aquifer - which is cited in Rabinovich et al. 2015). The authors cite general text books that give specific yield values from drainage over considerably longer periods of time than those of a short-duration pumping test - i.e., inappropriate for the subject of the paper and missing the relevant and well-documented parameter range.

Response: We didn't miss the point about the reasonable values of S_y. Reviewer 2 gave the following comments: "The authors seem to have chosen parameters that are unrealistic for most aquifers. For example, they use a specific yield value of $S_y = 0.1$." We think the value of $S_y = 0.1$ is reasonable for most aquifers as clearly explained in our response to his comment. Huang and Yeh (2007) proposed an approach for on-line aquifer parameter estimation based on the sensitivity analysis. In their paper, three sets of pumping drawdown data were analyzed. Two sets of them, data sets 1 and 2, are synthetic with assuming S_y = 0.1 while the third set is field pumping data from Cape Cod site (Moench et al., 2000). The well F507-080 was pumped with an average rate 1.21 m^3/min for 72 hours and the data were observed at well F505-032. The time-drawdown data set 1 was generated by Neuman's model (1974) for a pumping period of 1 to 176,360 seconds (49 hours) while the data set 2 was generated by Moench's model (1997) for a pumping period of 0.6 to 600,000 seconds (166.7 hours). The time-drawdown data and the related normalized sensitivities are plotted in Fig. R2a (Fig. 2 in Huang and Yeh (2007)) for data set 1 and in Fig. R2b (Fig. 3 in Huang and Yeh (2007)) for data set 2. (Note that the figures mentioned herein are shown at the end of this reply.) This figure clearly indicates the drawdown is very insensitive to the change in S_y in the early period of 1 to 100 seconds. Fig. R3 shows the curve of estimated S_y versus time dramatically fluctuates in the early period and converges to the value of 0.1 after about 80 seconds for data set 1 in panel (a) (Fig. 5 in Huang and Yeh (2007)) and 125 seconds for data set 2 in panel (b) (Fig. 6 in Huang and Yeh (2007)). Fig. R4 (Fig. 7 in Huang and Yeh (2007)) demonstrates the estimated S_y versus time when analyzing the field pumping data from Cape Cod site. The estimated S_y keeps at a value of 0.3 for the first 20 minutes, then goes down rapidly and reaches a minimal at 100 minutes. On the basis of those data analyses, it is obvious that the estimation of S_y using early time (or short duration) data is not reliable.

We realize that the estimated S_y for unconfined aquifers from a constant rate pumping test ranges from 0.01 to 0.3, but from an oscillatory pumping test may be very low. The present solution will be rerun with default value of $S_y = 10^{-4}$ for the analyses given in the Results and Discussion section.

References

Barrash, W., Clemo, T., Fox, J.J., and Johnson, T.C.: Field, laboratory, and modeling investigation of the skin effect at wells with slotted casing, Journal of Hydrology, 326(1-4), 181-198, 2006.

Chen, X. and Ayers, J.F.: Aquifer properties determined from two analytical solutions, Ground Water, 36(5), 783-791, 1998.

Huang, Y.C., Yeh, H.D.: The use of sensitivity analysis in on-line aquifer parameter estimation, Journal of Hydrology, 335(3-4), 406-418, 2007.

Moench, A.F.: Specific yield as determined by type-curve analysis of aquifer-test data, Ground Water, 32(6), 949-957, 1994.

Moench, A.F.: Combining the Neuman and Boulton models for flow to a well in an unconfined aquifer, Ground Water, 33(3), 378–384, 1995.

Moench, A.F.: Flow to a well of finite diameter in a homogenous anisotropic water table aquifer, Water Resources Research, 33, 1397- 1407, 1997.

Moench, A.F., Garabedian S.P., and LeBlanc D.L.: Estimation of Hydraulic Parameters from an Unconfined Aquifer Test Conducted in a Glacial Outwash Deposit, Cape Cod, Massachusetts. USGS Open-File Report: 00-485, 2000.

Neuman, S.P.: Effects of partial penetration on flow in unconfined aquifers considering delayed aquifer response. Water Resources Research, 10, 303-312, 1974.

Neuman, S.P.: Analysis of pumping test data from anisotropic unconfined aquifers considering delayed gravity response, Water Resources Research, 11(2), 329-342, 1975.

Rabinovich, A., Barrash, W., Cardiff, M., Hochstetler, D., Bakhos, T., Dagan, G., and Kitanidis, P. K.: Frequency dependent hydraulic properties estimated from oscillatory pumping tests in an unconfined aquifer, Journal of Hydrology, 531, 2–16, 2015.

Figures

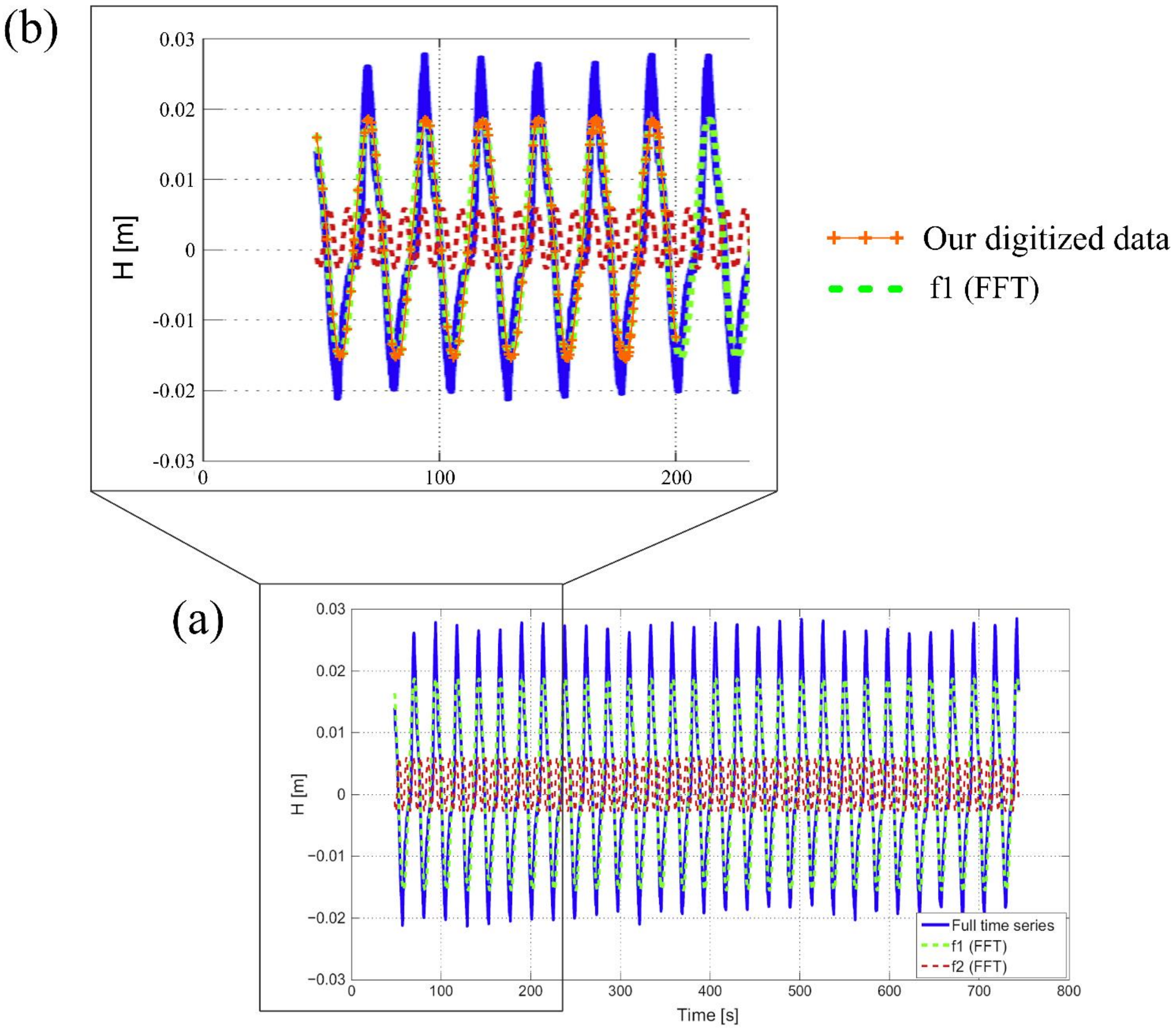

Figure R1. Field test results for hydraulic head as a function of time and our digitized data from f1(FFT). Panel (a) is adopted from Fig. 4(a) of Rabinovich et al. (2015). Panel (b) shows the agreement on our digitized data and their f1(FFT) data

(a)

(b)

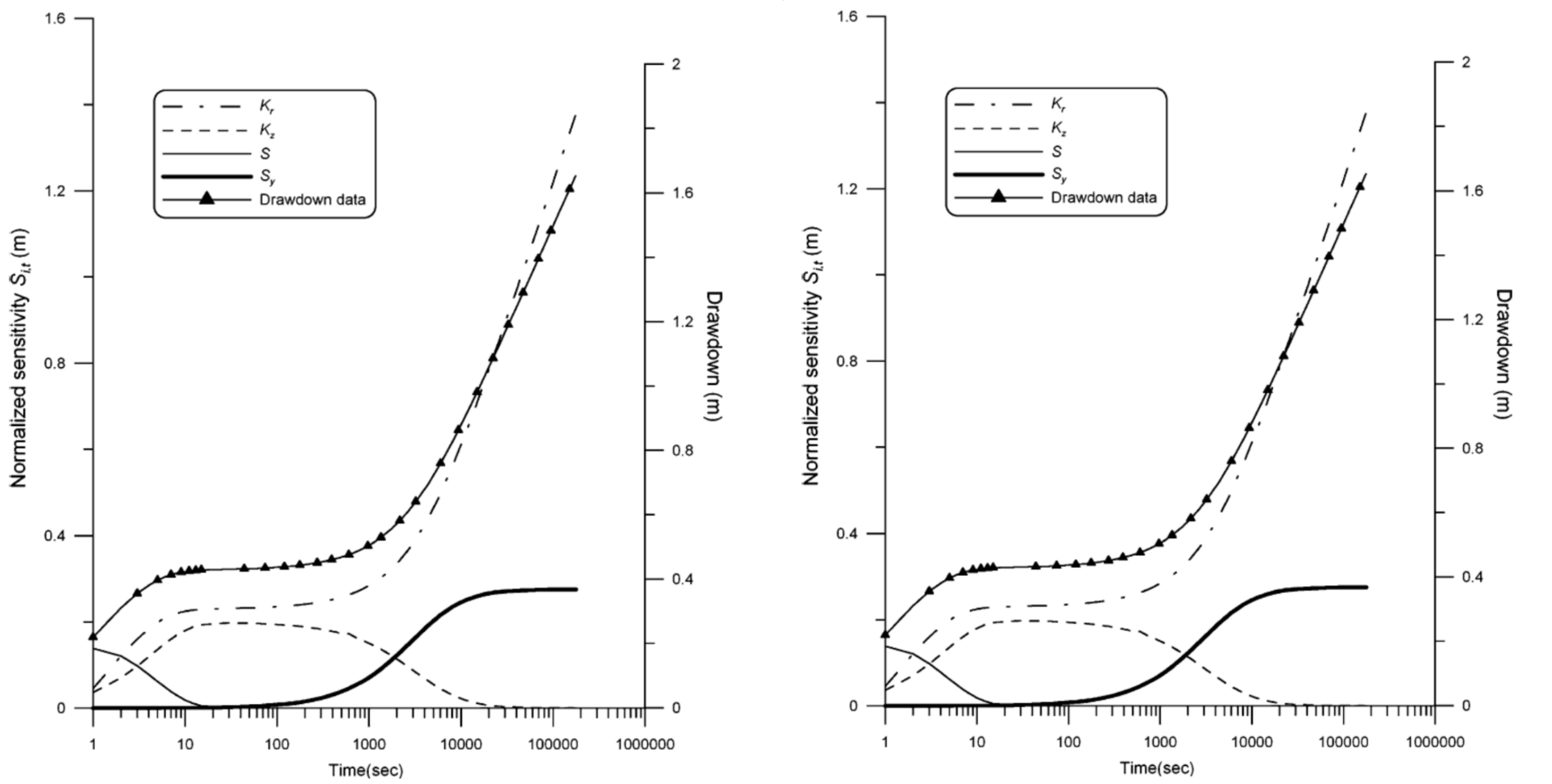

Figure R2. The time-drawdown data and the normalized sensitivities of the unconfined aquifer parameters (a) Neuman's model and (b) Moench's model (from Huang and Yeh (2007))

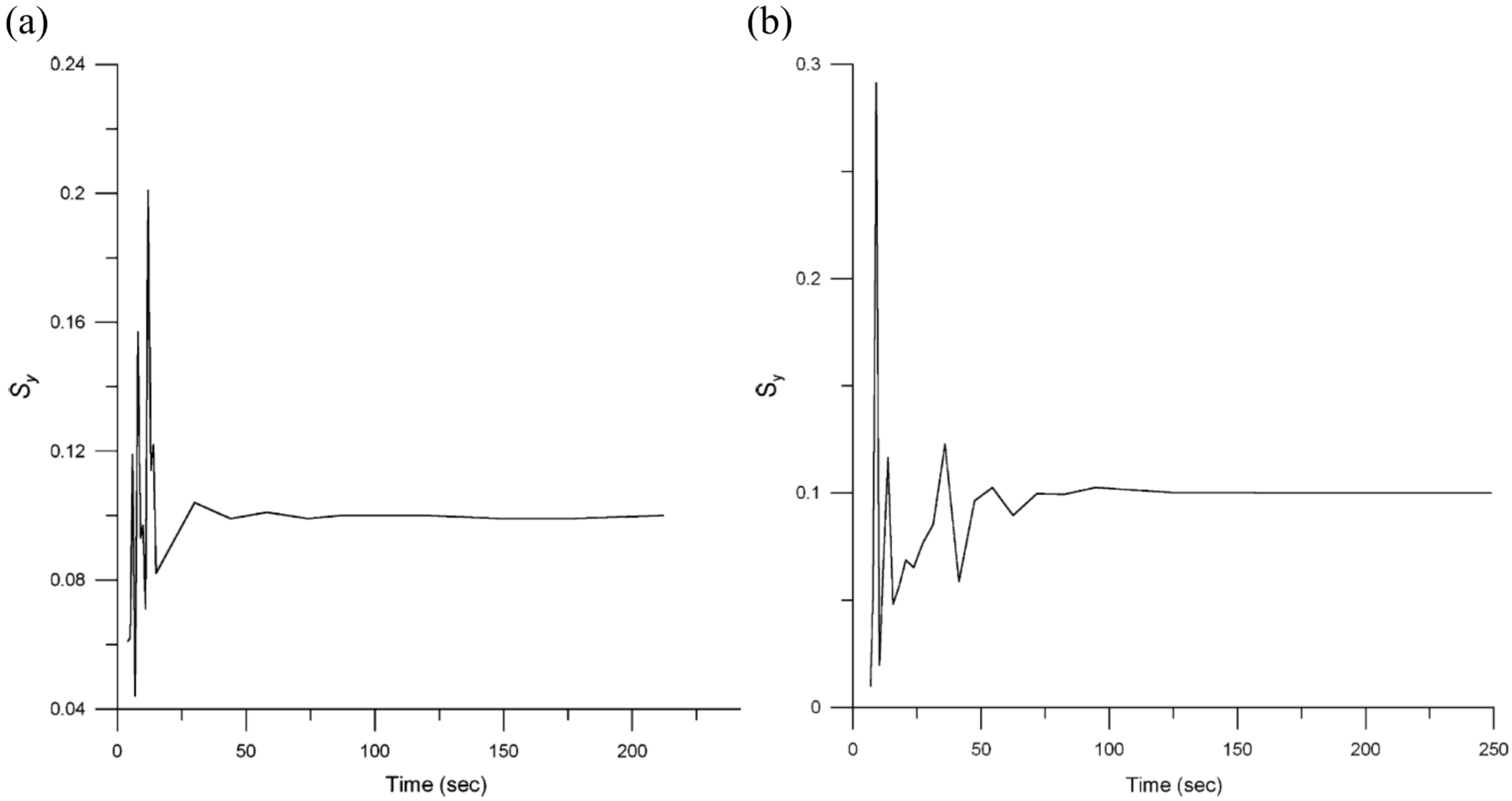

Figure R3. The estimated S_y versus time using (a) data set 1 and (b) data set 2 (from Huang and Yeh (2007))

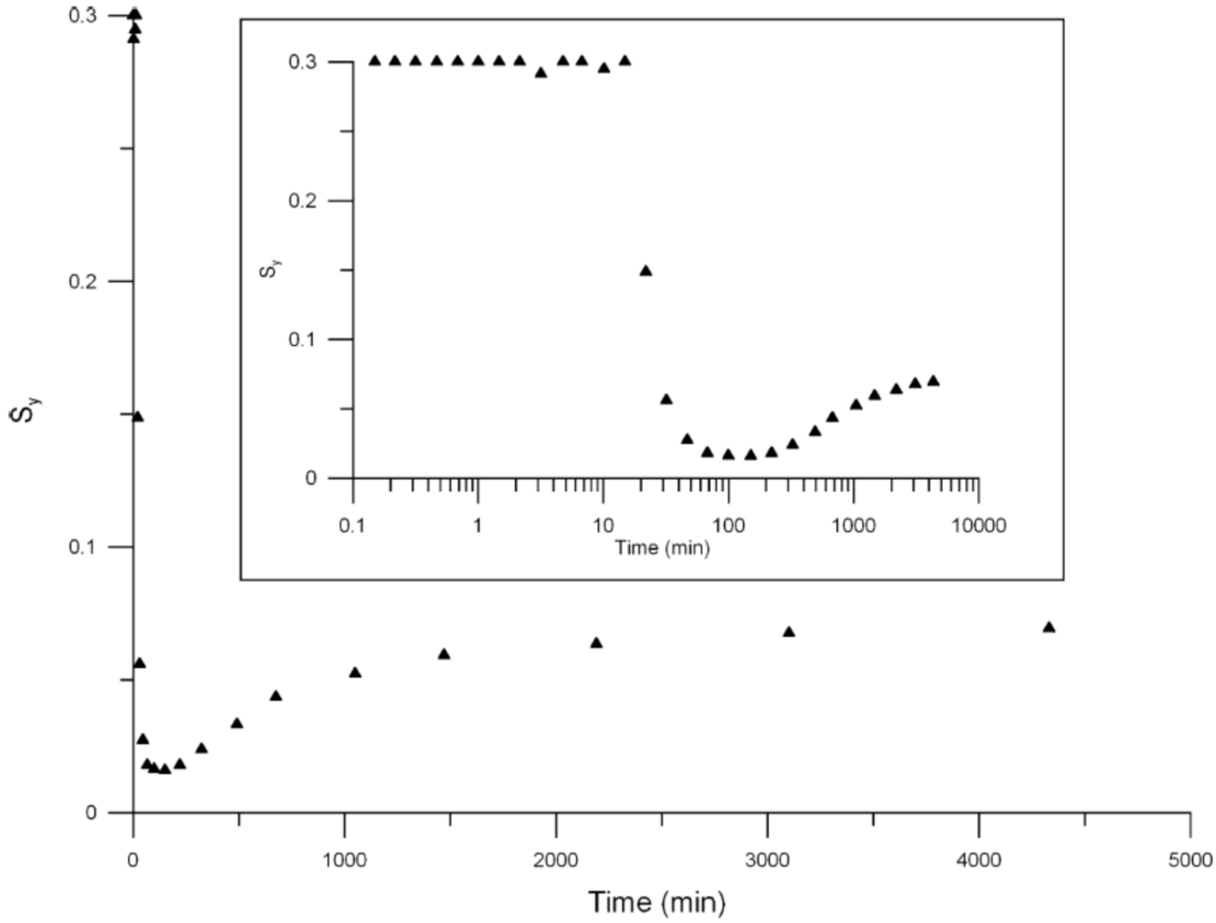

Figure R4. The estimated S_y versus time using field pumping data from Cape Cod site (from Huang and Yeh (2007))