INTERPRETATION OF A STEP TEST

Introduction

This lesson will teach you how to input and interpret data for a step-drawdown test. Step-drawdown tests (or step tests) are often conducted prior to standard constant-rate aquifer tests in order to determine well efficiency and choose the pumping rate for a constant-rate test.

Conceptual model

The Lesson is using a case study from St-Petersburg wellfield that is described on our website. The step test was conducted in the Vendian sandstone aquifer that has a thickness of 20 m. The aquifer is confined, infinite, horizontal, with its top located at the depth of 100 m below the ground level.

The excel spreadsheet "Lesson5_Excel" contains the original and the formatted data for this Lesson. It can be downloaded from our website.

To start this lesson, you have to create a new ANSDIMAT project. This is done through the menu "*Aquifer test analysis>New project*". Each project consists of several files and needs to be saved in a different file folder. For this lesson, create a new folder "…\ANSDIMAT_lesson5" and then save your ANSDIMAT model in this folder under the name "Lesson5".

Data input

For data input, we will use the wizard method that you learned in Lesson 2. After the project is created, the data input wizard opens automatically.
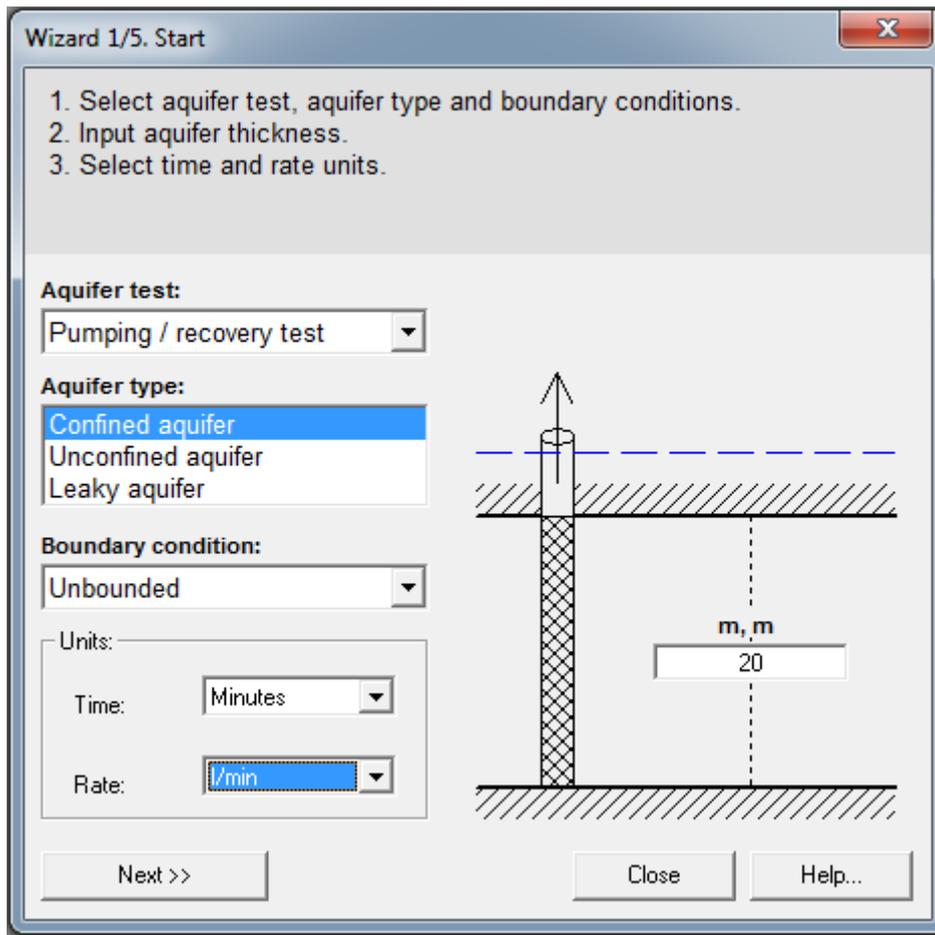
The wizard leads you through the five consecutive data input steps that are organised through four dialog windows.

>   Wizard window 1. Test info

Select the parameters corresponding to the test, the type of aquifer and the boundary conditions, then enter the thickness of the aquifer in the schematic representation on the right of the window. In this case:

- "pumping/recovery test"
- "confined aquifer"
- "unbounded"
- Thickness = 20 m.
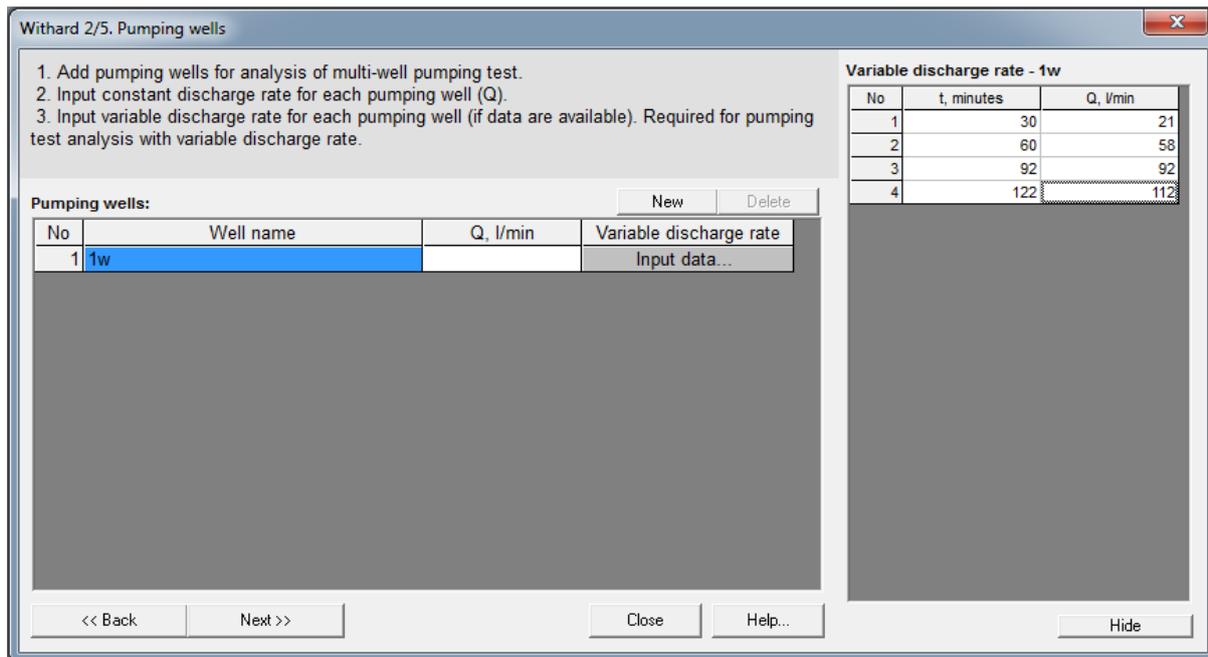- Time should be in minutes
- Rate should be in l/min

Once you complete this step, the window should look like Figure 1. Click "*Next*" to move to the next wizard window.

ANSDIMAT – software for analytical modelling of groundwater wells
E-mail: support@ansdimat.com
Tel: +61 478 633 429

ANSDIMAT
www.ansdimat.com

Figure 1. Wizard dialog window 1 for Lesson 5

Wizard window 2. Pumping wells

Enter the name of the pumping well (PW1) and its discharge rate. In this case, the test has a variable discharge rate: click in the "*input data*" tag under "*Variable discharge rate*" in the table. An additional field appears to the right of the window, allowing to enter the duration of each stage and the correspondent discharge rate. **Check that the units in the column headers correspond to the data entered**. Once all data is entered, the window should look like Figure 2. Note, that for more straightforward interpretation of variable pumping rate tests, pumping rates should be listed for the end of pumping periods, as shown on Figure 2.

ANSDIMAT – software for analytical modelling of groundwater wells
E-mail: support@ansdimat.com
Tel: +61 478 633 429

ANSDIMAT
www.ansdimat.com

Figure 2. Wizard dialog window 2 for Lesson 5

Click "Next" to enter the information about drawdown in observation wells.

Wizard window 3. Observation wells

For each observation well, enter its name then click on "*input data*" to enter drawdown and recovery time series. A new panel appears to the right of the window. Copy and paste time and drawdown data in this panel from the worksheet "Formatted data" of the file "Lesson5_Excel". *Check that the units in the field headers correspond to the data being entered*.

In this case, observations are made in the pumping well so the name of the observation well should be the same as the name of the pumping well (PW1). As recovery was not measured during the test, this field should remain empty.

Once the data are entered, the window should look like Figure 3. The drawdown table should contain 40 rows.
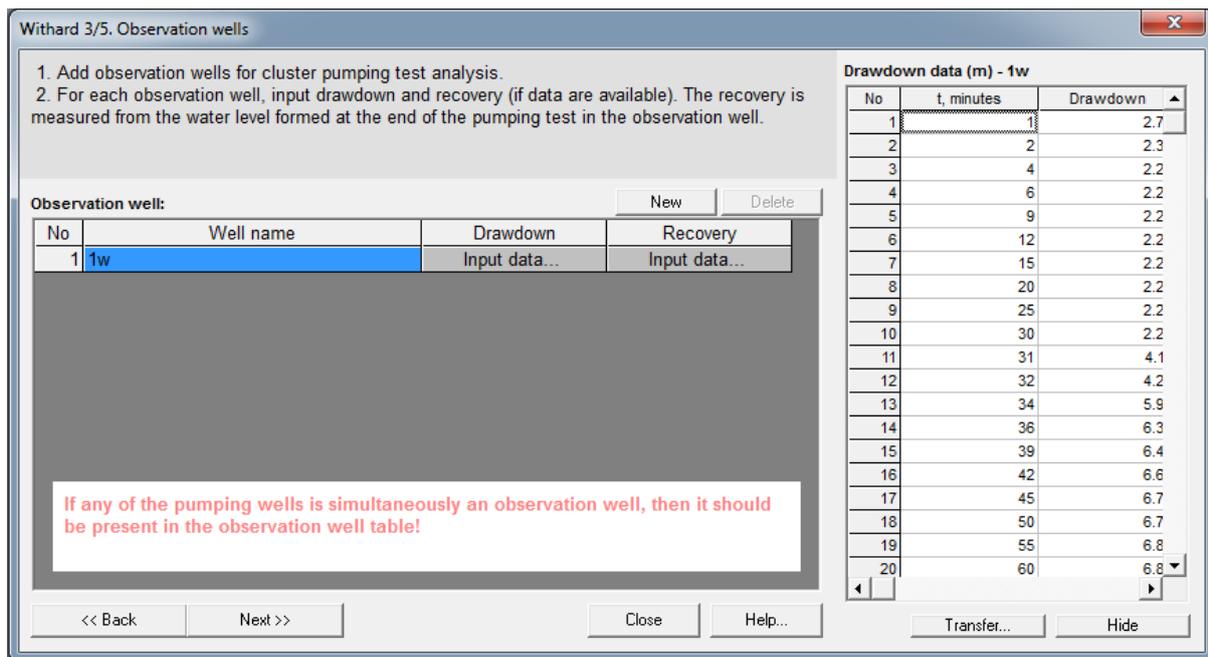
ANSDIMAT – software for analytical modelling of groundwater wells
E-mail: support@ansdimat.com
Tel: +61 478 633 429

ANSDIMAT
www.ansdimat.com

Figure 3. Wizard dialog window 3 for Lesson 5

When you are ready, click "Next" to enter the distance between pumping and observation wells.

Wizard window 4. Distance

Because observations are made in the pumping well, enter the radius of the well as the distance in metres - 0.11 (Figure 4).
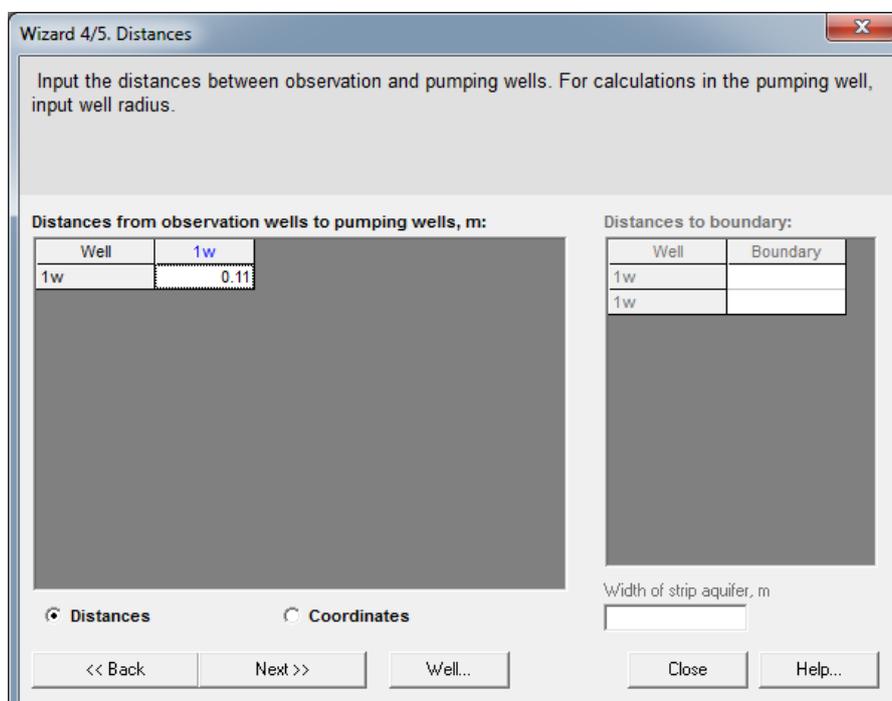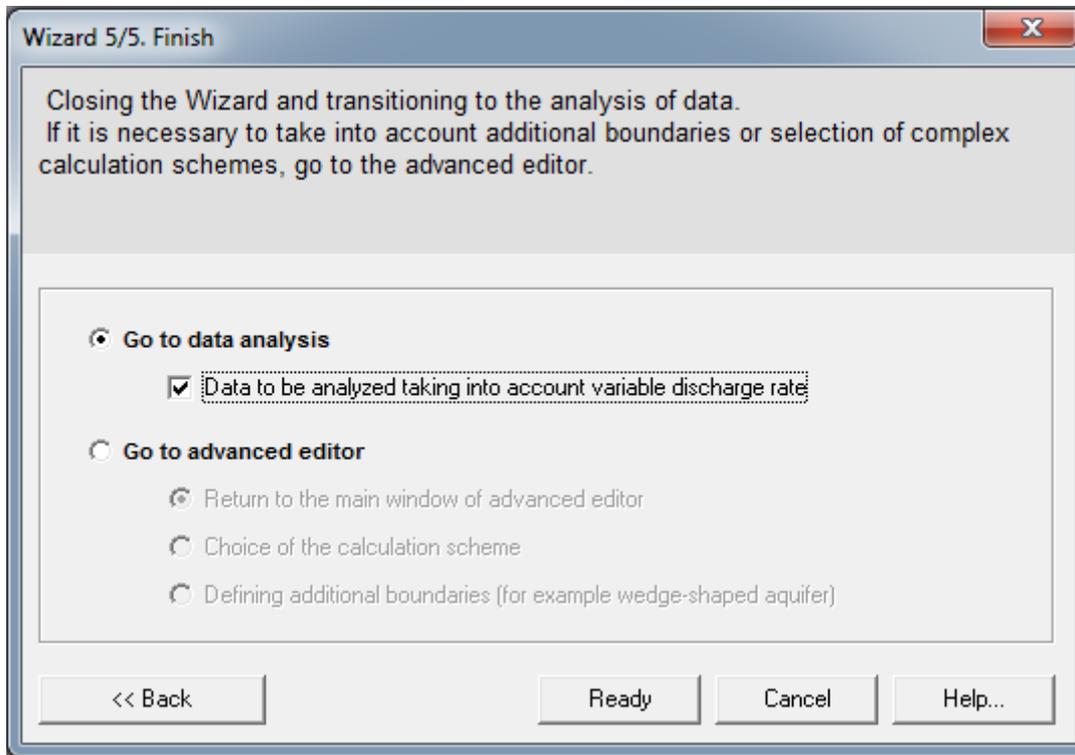

Figure 4. Wizard dialog window 4 for Lesson 5

ANSDIMAT – software for analytical modelling of groundwater wells
E-mail: support@ansdimat.com
Tel: +61 478 633 429

ANSDIMAT
www.ansdimat.com

Wizard window 5. Final steps

This dialog window offers the possibility to enter the advanced data editing mode. This might be necessary when dealing with complex boundary situations. In this case, there is no need to use the advanced editing function: select "*Go to data analysis*" and tick the box "*Data to be analysed taking into account variable discharge rate*". The window should look like Figure 5.

Figure 5. Wizard dialog window 5 for Lesson 5

To check that all your inputs are correct, you can use the "Back" button and navigate in the previous windows. Verify that all your data is correctly entered with the correct units for time and volumes. Especially check the units for the time series as the units entered for the pumping rate do not automatically transfer to the time series for pumping rate variation and drawdown.

Step test interpretation

After inputs are completed, click "*Ready*" to display the data analysis window. A new window opens with a graph displaying drawdown (s, m) as a function of time (lg(t), days). The time series is displayed on the left panel of the screen with the time expressed in days and the drawdown in meters. Your dialog window will look like Figure 6.
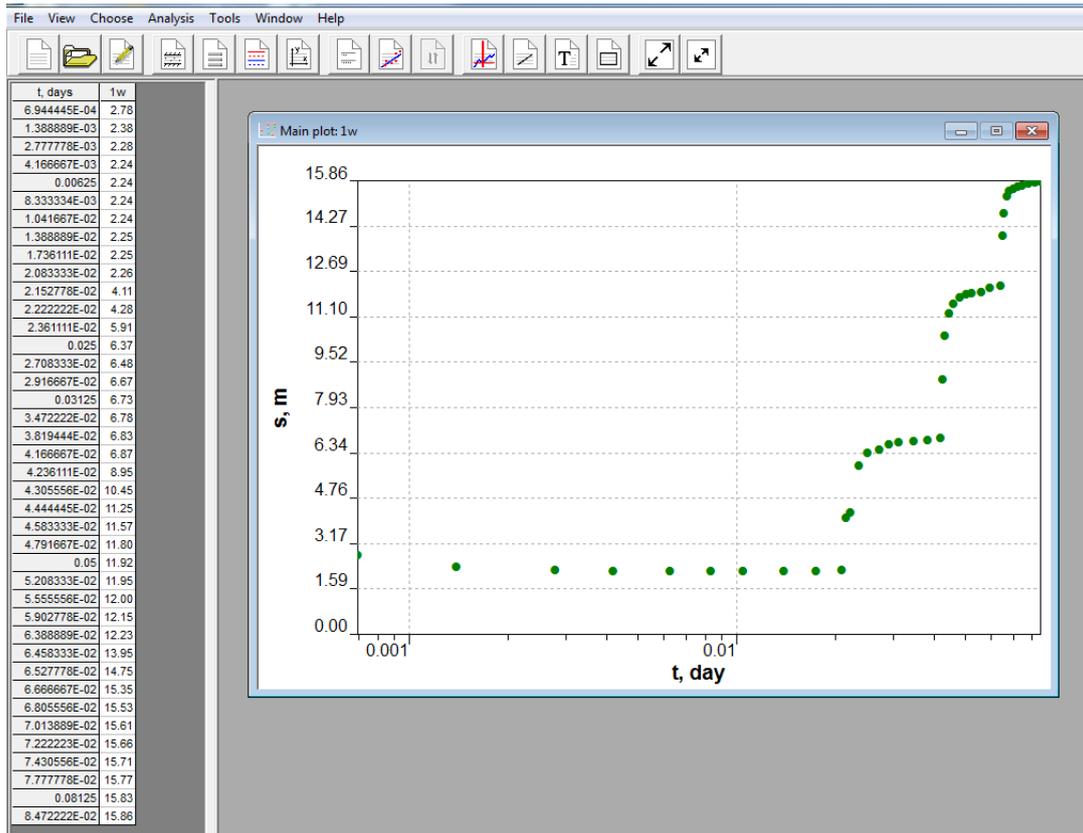
ANSDIMAT – software for analytical modelling of groundwater wells
E-mail: support@ansdimat.com
Tel: +61 478 633 429

ANSDIMAT
www.ansdimat.com

Figure 6. Plot dialog window

Defining a step function for variable pumping rate

Next step is to define a step function for variable pumping rate. This is a user-defined function that needs to be created for tests with variable pumping rates. This function indicates the duration of each step in the pumping test and the related pumping rate.
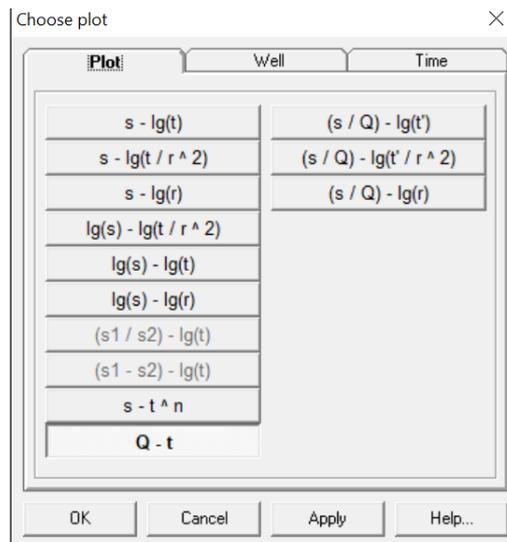

Figure 7. Menu "Choose/Plot" with selected "Q-t" type of plot

ANSDIMAT – software for analytical modelling of groundwater wells
E-mail: support@ansdimat.com
Tel: +61 478 633 429

ANSDIMAT
www.ansdimat.com

Select plot "Q-t" from the menu "*Choose/Plot*" (Figure 7). The corresponding time series appears in the left panel of the screen (Figure 8) where each point marks the end of each pumping stage.
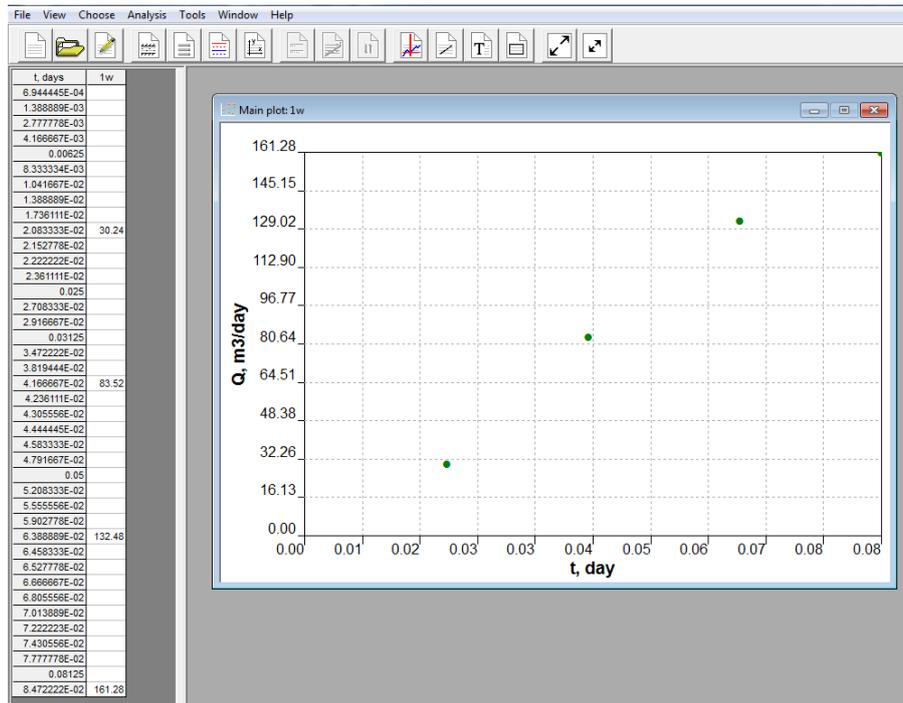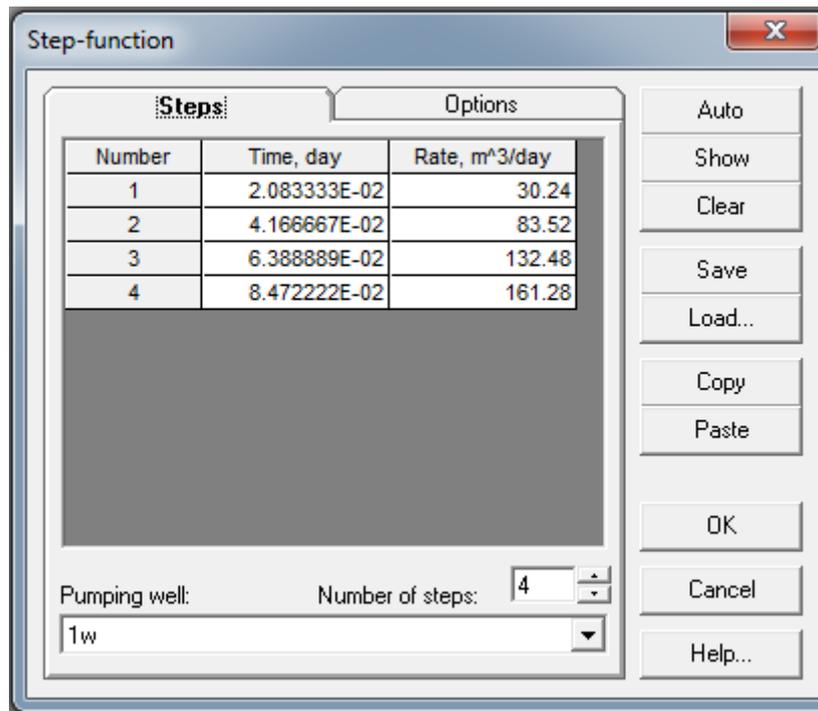

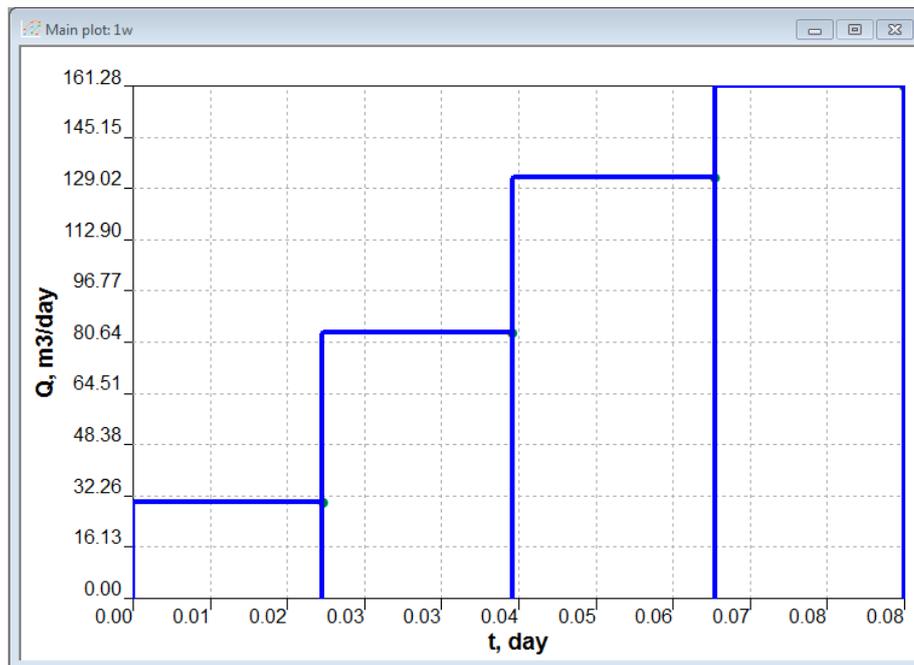**Figure 8**. "Q-t" plot for Lesson 5

Open the menu *Tools/step function*. This menu option is enabled only when the "Q-t" plot is selected in the menu "*Choose plot*", tab "*Plot*". A window appears, where time steps should be set. ANSDIMAT automatically defines time steps and pumping rates (see the default table for Lesson 5 on Figure 9). Check that the accurate number of steps is selected in the box "*Number of steps*". These values should be checked and can be manually changed: they should look like the Figure 9. Press button "*Show*" to display the step-function (Figure 10): if it does not look like figure 10, it has to be updated manually.

To update the step function, click on the "*Options*" tab and check the box "*Measurements*" (figure 11). This ties the end of the step to the measurement that were entered in the wizard. Click the button "*Auto*": the correct step function should appear on screen. Then click "*Ok*" to confirm your choice and use the defined function to determine well efficiency.
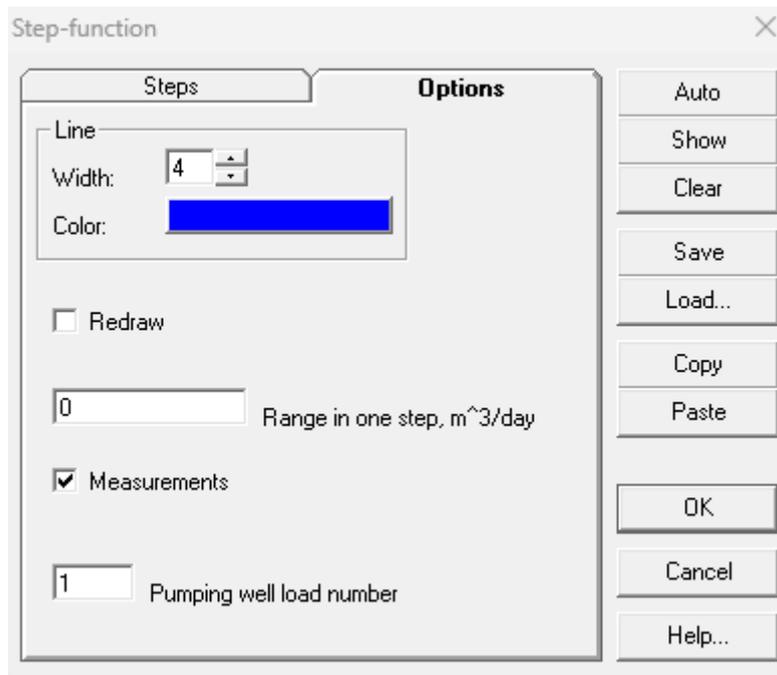
If the step function is correct, then click "Ok" to confirm your choice and use the defined function to determine well efficiency.

Figure 9. Step function dialog window with time and pumping rate steps that were automatically set up for Lesson 5

Figure 10. Q-t and Step-function plot for lesson 5

ANSDIMAT – software for analytical modelling of groundwater wells
E-mail: support@ansdimat.com
Tel: +61 478 633 429

ANSDIMAT
www.ansdimat.com

Figure 11: Step function dialog window with additional options; the measurement box should be ticked

Test interpretation

Select plot "*s-lg(t)*" from the menu "*Choose/Plot*". These are the standard plot coordinates for interpretation of step-drawdown tests.

Then open the menu *Analysis/step drawdown test*. A step-drawdown test table (Figure 12) and a plot dialog window (Figure 13) will appear. The plot dialog window will be showing actual time-drawdown measurements in "s-lg(t)" format and lines that approximate drawdown steps.

There should be as many lines as there are time steps. For each time step, ANSDIMAT automatically approximates the slope of the plateau in the semi-log plot starting from the end time of each step and extrapolates the line to the end of the test. ANSDIMAT then estimates the variation of the drawdown and the time length of the quasi-steady state period.

ANSDIMAT – software for analytical modelling of groundwater wells
E-mail: support@ansdimat.com
Tel: +61 478 633 429

ANSDIMAT
www.ansdimat.com

Figure 12. Step-drawdown interpretation table for Lesson 5
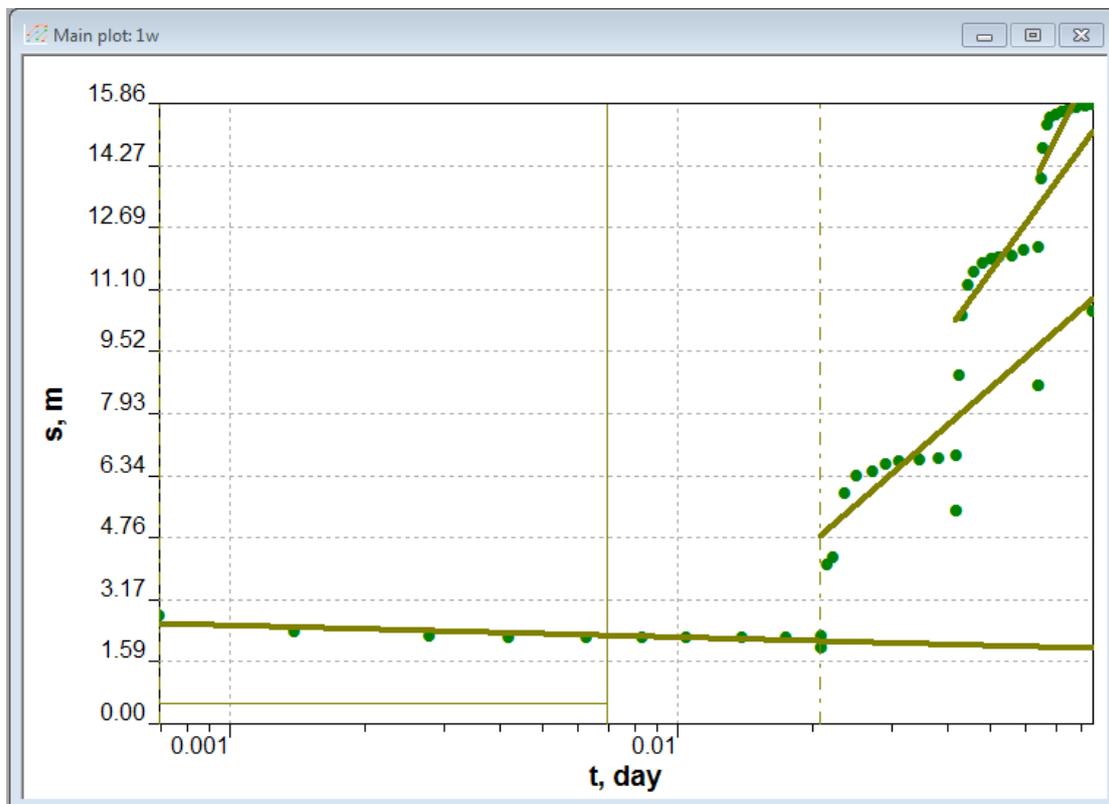
Figure 13. Step-drawdown plot dialog window for Lesson 5 with automatically drawn approximating lines

ANSDIMAT – software for analytical modelling of groundwater wells
E-mail: support@ansdimat.com
Tel: +61 478 633 429

ANSDIMAT
www.ansdimat.com

The slope of the approximating line depends on the quantity of points that are used for analysis. Because the line should be approximating the quasi steady state period (i.e. the late period of each step), only the points for the late, quasy steady state period should be included into the analysis. Number of points for each step can be defined in the tab "Options" (Figure 14), the points are counted from the end of each step. Select 6 in the field "Number of points for approximation".

Changing the duration of each step field "time interval, dt, min" will also affect the shape of the approximating line as it determines the last point of each time step which is where the approximating line will be originating from. After you click on "*apply approximation*", the straight lines will be updated as shown on Figure 15. They are now better approximating the quasi steady state periods of each drawdown step and can be used for parameters interpretation.
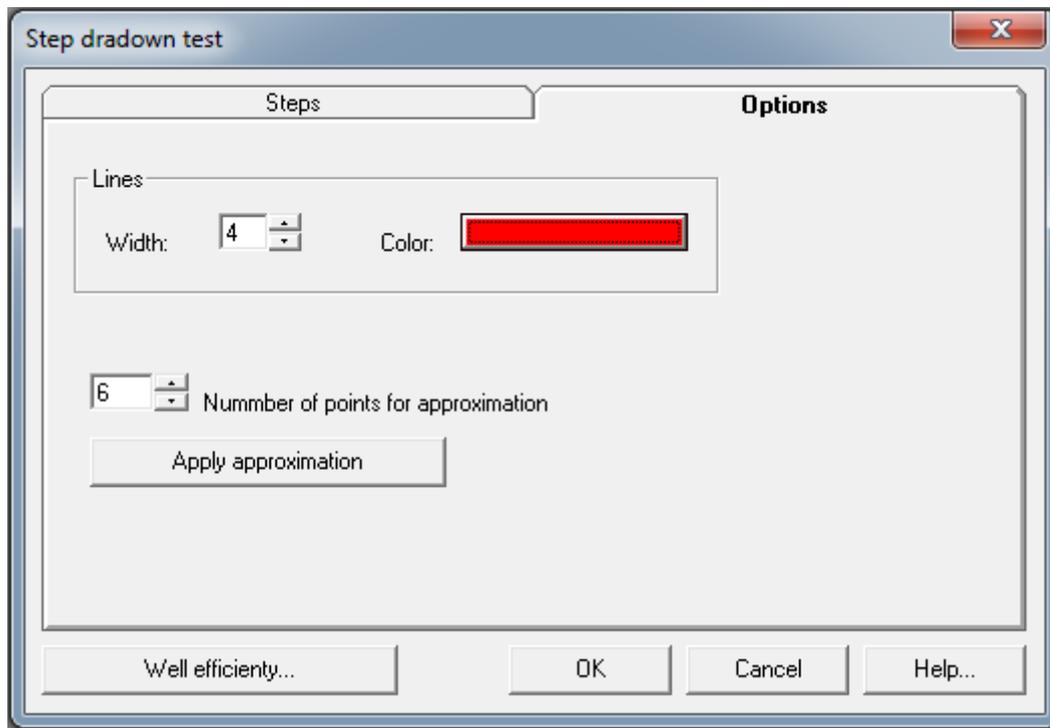
Figure 14. Tab "Option" of Step-drawdown test dialog window

The slopes are automatically recalculated on the main plot after the approximating lines have been changed.
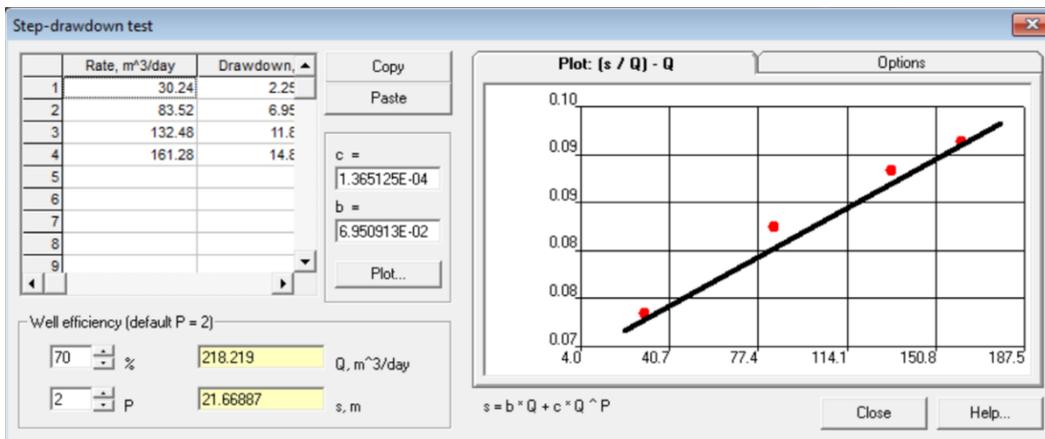
If necessary, an approximating line can be further refined manually to more accurately capture the quasi-steady state period. Click on the table's line that corresponds to the needed step. Position the mouse cursor on one end of the line then left click to move that point then do the same for the other end. In addition, you can move the line to any position by pressing the ALT + right mouse click or Alt + left mouse click buttons. This can be done for each step separately.
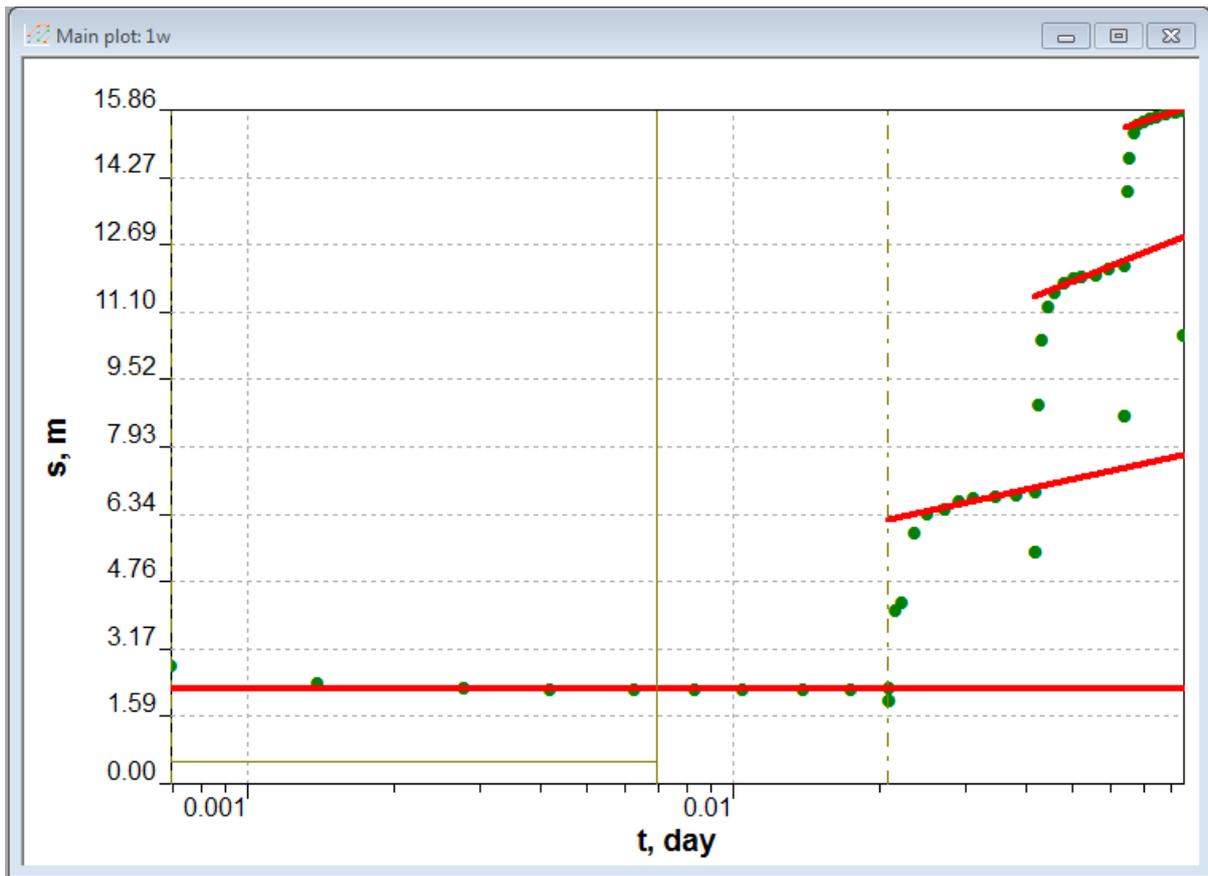
Figure 15. Step-drawdown plot dialog window for Lesson 5 with adjusted approximating lines

ANSDIMAT uses approximation lines to calculate (Ds) by extrapolating each line to the beginning and end of the corresponding step. It then sums up the Ds to calculate the cumulative drawdown at the end of each stage (s').

Clicking on "*Well efficiency*" will open a new dialog window (Figure 16) where pumping rate and drawdown are predicted as a function of well efficiency.

Figure 16. Well efficiency dialog window for lesson 5.

ANSDIMAT – software for analytical modelling of groundwater wells
E-mail: support@ansdimat.com
Tel: +61 478 633 429

ANSDIMAT
www.ansdimat.com

The window on Figure 16 displays a table with the cumulative drawdown at the end of each stage (s')
and a plot, where these drawdowns are presented as a function of pumping rate: (s/Q) – Q. The two
coefficients c and b are used to calculate well efficiency. The coefficient c is the slope of the line on the
(s/Q) – Q plot, b corresponds to the value for c = 0. Formulas are available in the ANSDIMAT help
(Hydrogeologist Workbench/Drawdown during aquifer tests/Determination of well efficiency).

The straight line can be manually adjusted by clicking on the left or right end with the corresponding
mouse button till it is visually approximating plotted circles. The field «Q» will show the predicted
pumping rate for the specified well efficiency (field «%») and the resulting drawdown.

The well efficiency calculator allows estimating the pumping rate and its corresponding drawdown for
a specified level of well efficiency. As turbulence increases with increasing pumping rate, so does the
well efficiency decrease. The calculator is used to determine the pumping rate for a constant rate aquifer
test, at which pumping can result in a sufficient drawdown, while keeping borehole losses at a
reasonably low level. A well efficiency of 70% or more is usually considered acceptable, with 65%
being accepted as the minimum efficiency (Kresic, 1997). For Lesson 5, a well efficiency of 70%
corresponds to the pumping rate of 218.219 m³/day (Figure 16).

Reference:

Kresic, N., 1997. *Quantitative Solutions in Hydrogeology and Groundwater Modeling*. CRC
Press. Boca Raton.

ANSDIMAT – software for analytical modelling of groundwater wells
E-mail: support@ansdimat.com
Tel: +61 478 633 429

ANSDIMAT
www.ansdimat.com