Slug Testing Using Level TROLL® 500 and Level TROLL® 700 Instruments and AQTESOLV™ Software

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Introduction

Aquifer pumping tests can be expensive and require significant investments in labor and time. In addition, contaminated water must be treated or transported out of the test area. As an alternative to pumping tests, many hydrologists perform slug tests: to determine many point estimates of hydraulic conductivity (K); to obtain results more quickly than with a pumping test; to develop small scale studies; to collect very good data in low K layers; and to reduce expenses.

An aquifer slug test is typically conducted at a single well location. Slug tests require the depression or elevation of static water in a well and the measurement of time it takes to equilibrate. This is accomplished by inserting a slug into a well, causing the water level to rise, or by removing the slug, causing the water level to fall. Time and level are measured until the water level returns to its original static position. Measurements are logged at an extremely rapid sampling rate, typically as fast as the instrument will allow. Alternatively, a logarithmically decaying sampling rate can be used. A valuable reference for slug testing is *The Design, Performance, and Analysis of Slug Tests* by J.J. Butler, Jr. (1997).

The In-Situ Inc. Level TROLL® 500 and 700 Instruments offer fast linear sampling (2 and 4 samples/sec., respectively) for slug testing. The Level TROLL 700 probes also offer true logarithmic sampling. Win-Situ® Software allows real-time viewing and graphing of data.

Data can be managed within Win-Situ Software and can also be exported to AQTESOLV™ Software for further analysis and to apply the desired method of analysis (e.g., Bouwer-Rice) to the data.
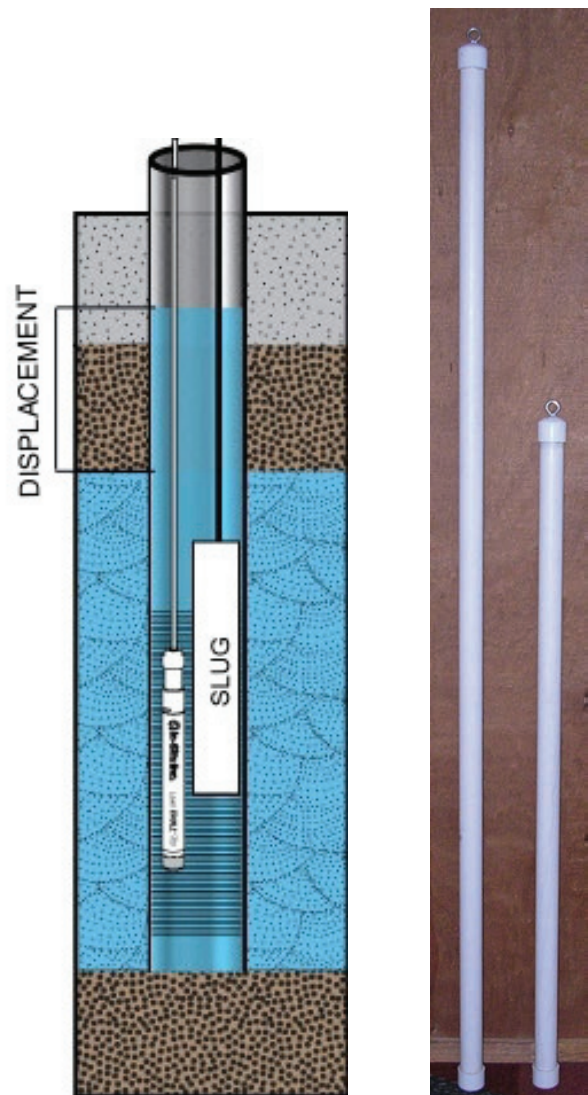

Figure 1. Water level displacement in a slug test. A 6-ft slug and a 4-ft slug.

Required equipment

- Level TROLL 500 or 700 Instrument with communication cable, submersible cable, and TROLL® Com Device
- A laptop computer running Win-Situ® 5 Software or a RuggedReader® Handheld PC running Win-Situ® Mobile Software
- Rugged Water Level Tape 200
- Well dock
- Slug[1] or bucket and hose/funnel (a slug can consist of a solid object that can slide into a well past the Level TROLL cable or a known volume of water)
- Cable for slug
- AQTESOLV™ Software (See www.aqtesolv.com for purchase information.)

Hardware setup

1. Open the well head and measure the water level reading with a Rugged Water Level Tape 200. Record this value. (If the well was not vented to atmospheric pressure, take a few readings and make sure the level has equilibrated.)
2. Connect the PC or RuggedReader Handheld PC, TROLL Com Device, Level TROLL instrument, and communication cable. Re-check all connections prior to deployment.
3. Lower the Level TROLL instrument into the well below the level where you will insert the slug, but not at the very bottom of the well where it could encounter silt.
4. Using a well dock, secure the submersible (downhole) cable to the top of the well so that it cannot move.

Hint: Any movement by the Level TROLL instrument is undesirable and will be recorded in the data as a change in pressure/level.

5. Wait at least 20 minutes, then use the Rugged Water Level Tape 200 to confirm that the groundwater level returned to its original height after the Level TROLL was placed in the water.

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1 To make a solid slug, obtain a section of PVC pipe that will fit down the monitoring well. Fill it with sand, cap both ends, and put a screw eye on one end. Alternatively, fill a bailer with sand and seal the bailer. Butler (1998) provides additional guidance.
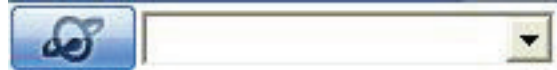
Win-Situ software setup

After the water level is static, program an internal data log on the Level TROLL instrument.

1. Install Win-Situ 5 to the PC or install Win-Situ Mobile to the RuggedReader Handheld PC.
2. Open Win-Situ 5 or Win-Situ Mobile Software.
3. The screen will show the My Data tab. Click the Connect button to establish communication with the instrument.

Hint: On first connection, be sure to select the correct COM port for a USB or serial connection, then connect to the device. If you are unsure which COM port to select, use Windows® Device Manager.

4. Synchronize the PC and instrument clocks, if necessary.
5. Confirm that power and memory are sufficient.
6. Set up a site, if necessary.
7. To set up a data log, follow the steps in the Logging Setup Wizard, accessed under the Logging tab.
8. Select the Site where this set of data will be logged and supply a name for the log.
9. Select the parameters to measure (it is recommended to select all) and make sure that the units are acceptable.
10. Choose either Fast Linear or True Logarithmic (700 only) logging method.
11. Choose the appropriate sampling rate to take and store a measurement (0.5 sec for Fast Linear or 15 min for True Logarithmic).
12. Select a Manual Start.

13. Set the level reference under Ground Water. Select Elevation (Win-Situ 5) or Level - Surface Elevation (Win-Situ Mobile).
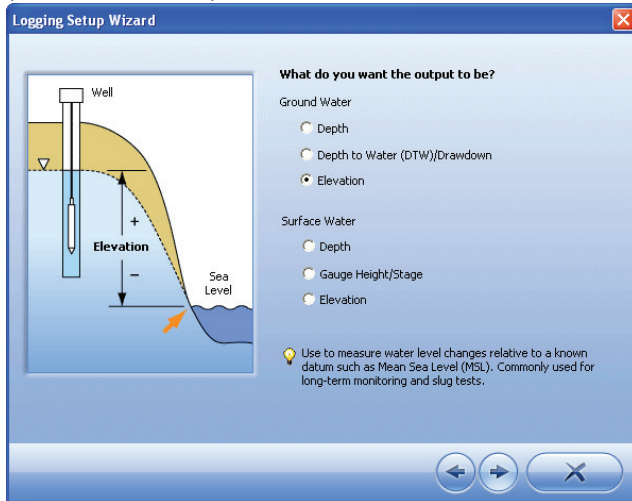
14. Select Set First Logged Reading to 0 (or any other point that you want) to view the relative water level changes in the Home tab.
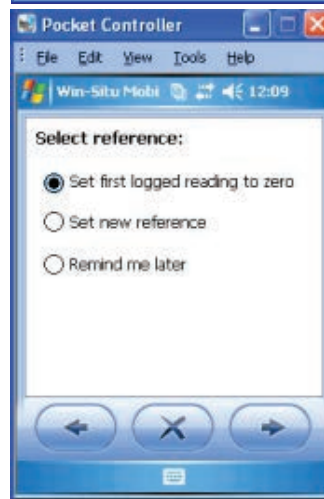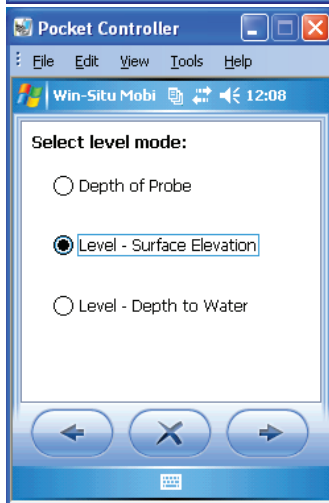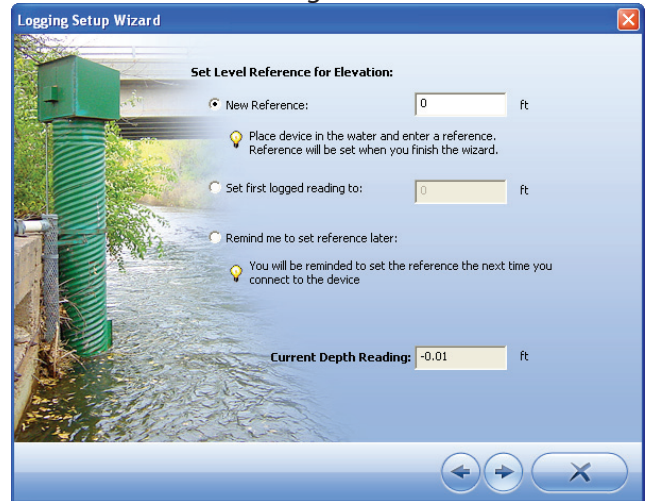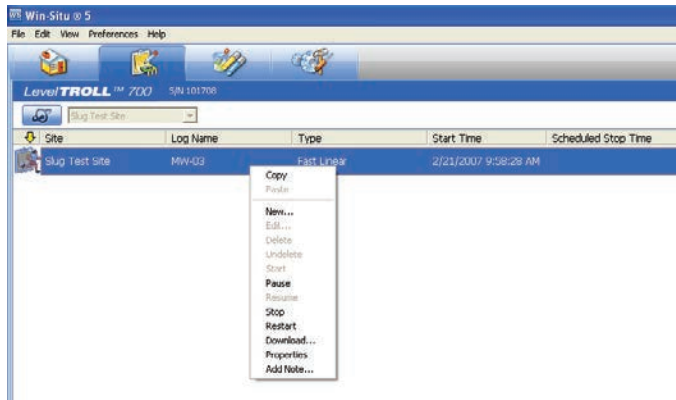

15. Set the specific gravity.
16. Review the settings on the summary page and click the check mark if everything is correct.

Running the test

Hint: You can start, stop, and control a test by simply right clicking on the test (Win-Situ 5). A running person icon to the left of the log indicates that the test is running.


1. Make sure that the Level TROLL instrument is deep enough in the well to avoid contact with the slug.
2. Place the slug just above the water level.
3. Start the internal data log by pressing the Start button.
4. Count to 3, then swiftly and smoothly lower the slug below the water's surface. Do not let the slug free-fall into the water.
5. Stop the test when the groundwater level returns to 0 or a level that is acceptable for your site. This can be viewed on the Home tab.
6. Click the download button.

   Select Download All. The data will be downloaded to the PC, automatically saved in the working directory, and organized by site.

7. Click the Data tab.
8. Select Preferences > General Settings. Customize the time format, and select Tab in the Export Delimeter Character field.
9. Select Preferences > Data View Settings, and check the box for Show Elapsed Time. See the Win-Situ 5 help menu for information about time formats.
10. To view data, right click on the data folder and export the data to text. The text file will be imported into AQTESOLV™ Software.

## Analysis with AQTESOLV Software

1. Open the software and select File > New.
2. Select Slug Test Wizard from the list to create a new data set for a slug test. Click OK.
3. Click Next to start the Slug Test Wizard.
4. Choose units of measurement for the Slug Test Analysis.
5. Enter your project information.
6. Enter the initial displacement (change in water level from static) and static water column height (depth to bottom of well from static water level). Enter the well name and coordinates (typically X=0, Y=0).
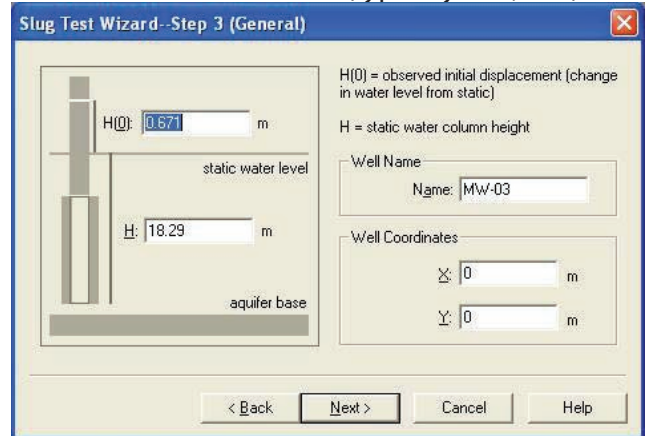

7. Enter the saturated thickness of the aquifer. For unconfined aquifers, this is the measured depth from water table to bottom of aquifer. For confined aquifers, this is measured from the upper confining layer to the lower confining layer. Enter the anisotropy ratio, and the vertical to horizontal hydraulic conductivity ratio (typically equal to 1).
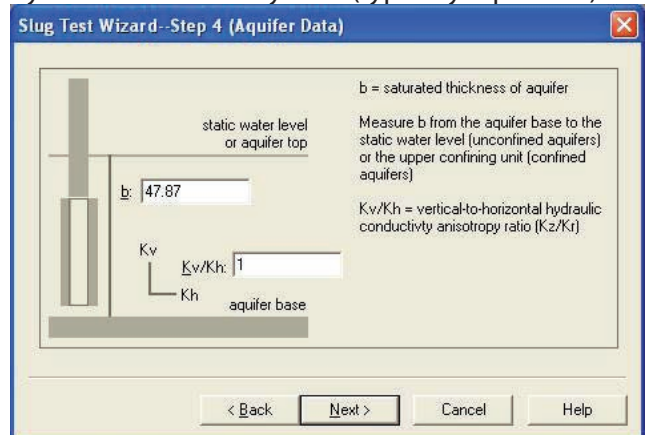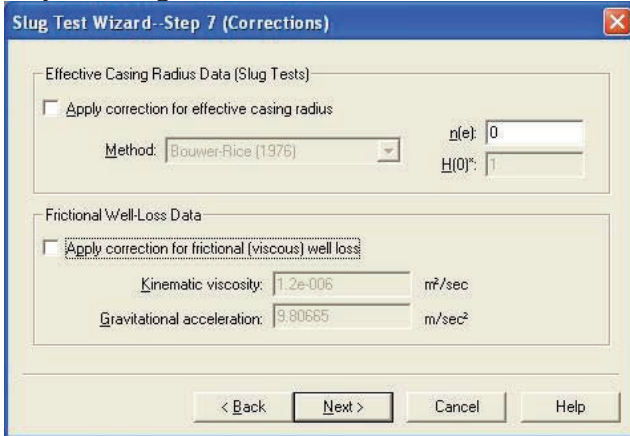
8. Enter well construction information.
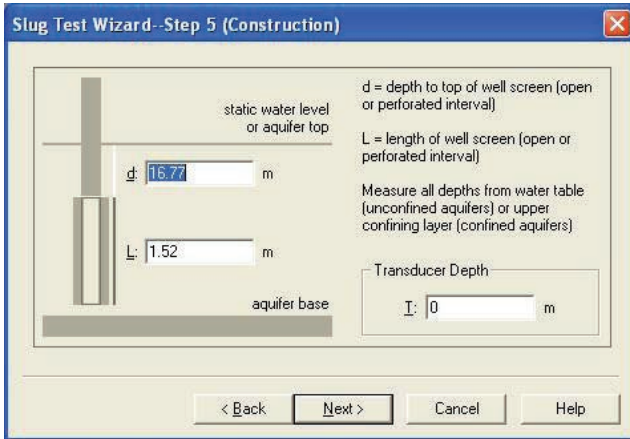

9. Enter well radius data.
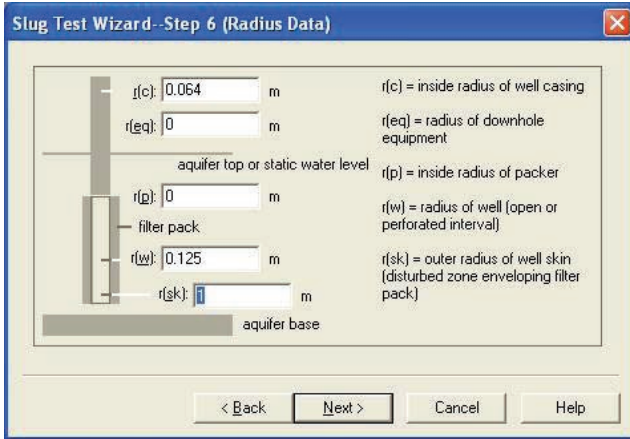
10. Enter optional correction data. For this example, no corrections are necessary because the well screen is fully submerged.


11. Click Import.

12. Click Browse to select the text file created by Win-Situ Software.

13. Enter the structure of the file (number of columns, etc.). AQTESOLV™ will recognize the first row in the imported file containing water-level data. Click Select Starting Row to change the starting row to coincide with the initiation of the test (usually this is indicated by the maximum displacement value).
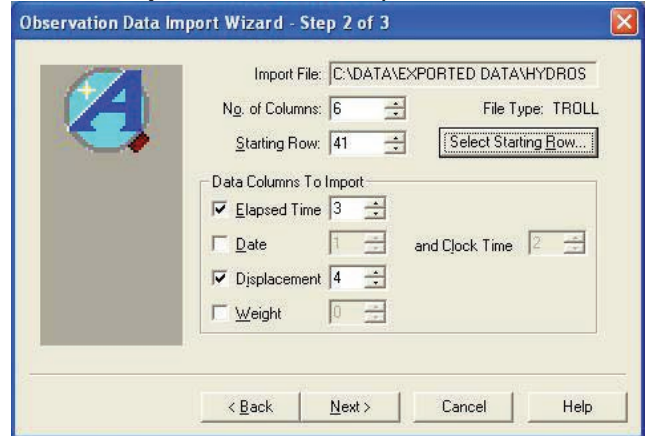
14. Select any data transformations that need to be performed. Click Finish and a summary screen will appear showing the number of measurements imported. Click OK.
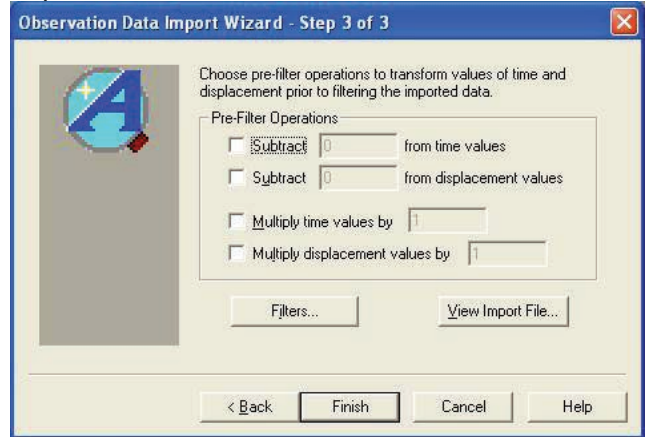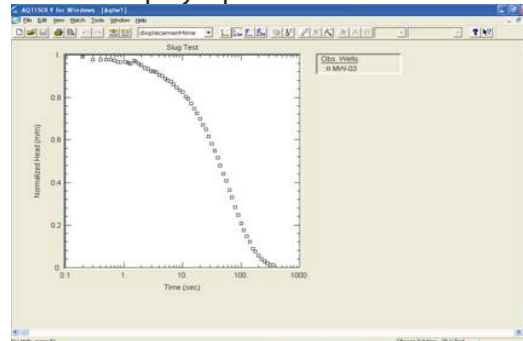

15. After completing the Import Wizard, the data are shown in the spreadsheet. Click Next.
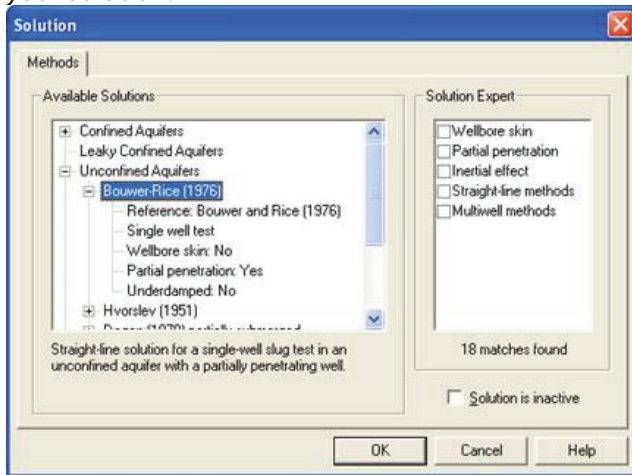
16. Click Finish to complete the Slug Test Wizard.

17. An Error Log will display any errors detected in the data set.

18. If no errors are found, choose View > Displacement–Time to display a plot of the data.

19. Choose Match > Solution. Uncheck Solution is inactive box. Expand the list of solutions for Unconfined Aquifers. Select Bouwer-Rice (1976) as your solution.


20. Choose View > Options and check boxes for normalized head and recommended head range (Butler 1998).
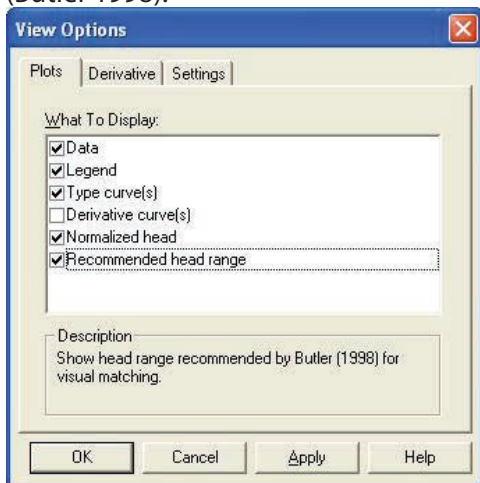
21. A preliminary match of the Bouwer-Rice solution to the slug test data is shown on the plot.
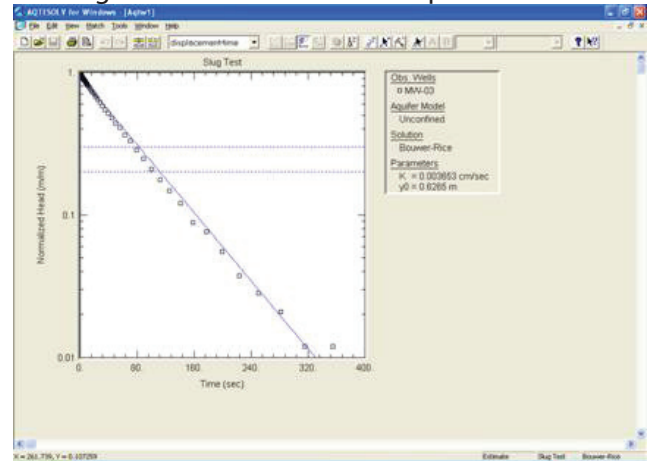
22. Choose Match > Visual, and follow instructions for matching the solution to the data. This is accomplished by drawing a line over the data points within the recommended head range.
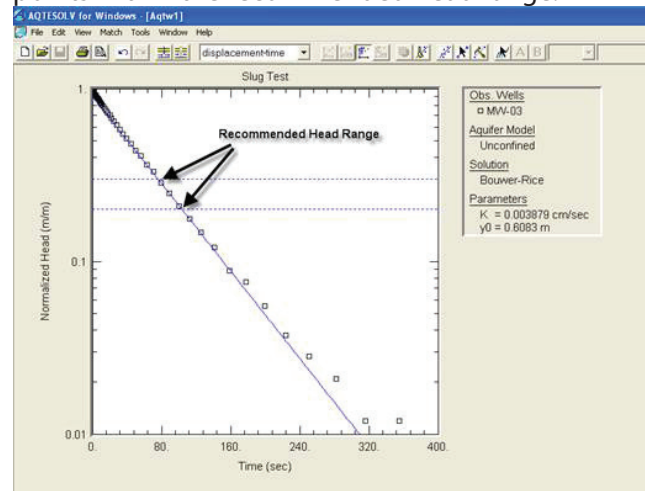
23. Choose File > Save As, and save your work.

References

1. AQTESOLV™ for Windows. http://www.aqtesolv.com/slug_test_analysis.htm
2. Bouwer, H. 1989. The Bouwer and Rice slug test—an update. *Ground Water* 3:304–309.
3. Bouwer, H. and R.C. Rice. 1976. A slug test method for determining hydraulic conductivity of unconfined aquifers with completely or partially penetrating wells. *Water Resources Research*, 3:423–428.
4. Butler, J.J., Jr. 1998. *The Design, Performance, and Analysis of Slug Tests*. Boca Raton: Lewis Publishers.

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