Analysis Report for AP-070

Analysis of Culebra Pumping Tests Performed Between December 2003 and August 2005

(AP-070: Analysis Plan for Non-Salado Hydraulic-Test Interpretations

Task Number 1.4.2.3

Author:  
Randall M. Roberts, 6822  
Repository Performance Department

Technical Review:  
Richard L. Beauheim, 6822  
Repository Performance Department

QA Review:  
Maria Chavez, 6820  
Carlsbad Programs Group

Management Review:  
Mark Rigali, 6822  
Manager, Repository Performance Department

WIPP:1.4.2.3:TD:QA-L:DPRP1:PKG# 539221
Contents

1. Introduction ............................................................................................................................. 7
2. nSIGHTS Overview ................................................................................................................ 7
3. Test and Analysis Procedures ................................................................................................. 9
4. Analysis Results.................................................................................................................... 10
   4.1 SNL-1............................................................................................................................ 10
   4.2 SNL-2............................................................................................................................ 14
   4.3 SNL-3............................................................................................................................ 18
   4.4 SNL-5............................................................................................................................ 21
   4.5 SNL-9............................................................................................................................ 24
   4.6 SNL-12.......................................................................................................................... 27
   4.7 SNL-14.......................................................................................................................... 30
   4.8 WIPP-11........................................................................................................................ 33
   4.9 WIPP-25........................................................................................................................ 37
   4.10 C-2737........................................................................................................................... 41
References...................................................................................................................................... 44
Appendix A -- Culebra Pumping Tests – December 2003 to August 2005................................... 45
Appendix B – nSIGHTS Listings .................................................................................................. 47

Table

Table 1. Transmissivity Estimates. .............................................................................................. 10

Figures

Figure 1. Directory structure for Culebra nSIGHTS analyses................................................... 8
Figure 2. Data folder containing the pressure and flow-rate files for nPre input......................... 8
Figure 3. Post folder containing simulation output and post-processed data. ......................... 8
Figure 4. Pressure data from SNL-1. ....................................................................................... 11
Figure 5. Log-log diagnostic plot of the final SNL-1 pressure-buildup test............................. 12
Figure 6. Estimates of transmissivity derived from the SNL-1 perturbation analysis................ 12
Figure 7. Simulations of the SNL-1 pressure response............................................................. 13
Figure 8. Detail of simulations of the SNL-1 pressure response................................................. 13
Figure 9. Simulations of pressure change and derivative during the final SNL-1 pressure-buildup test.................................................................................................................. 14
Figure 10. Pressure data from SNL-2. ...................................................................................... 15
Figure 11. Log-log diagnostic plot of the final SNL-2 pressure-buildup test............................ 16
Figure 12. Estimates of transmissivity derived from the SNL-2 perturbation analysis............ 16
Figure 13. Simulations of the SNL-2 pressure response............................................................ 17
Figure 14. Simulations of pressure change and derivative during the final SNL-2 pressure-buildup test.................................................................................................................. 17
Figure 15. Pressure data from SNL-3. ...................................................................................... 18
Figure 16. Log-log diagnostic plot of the SNL-3 pressure-buildup test.................................... 19
Figure 17. Estimates of transmissivity derived from the SNL-3 perturbation analysis........... 19
Figure 18. Simulations of the SNL-3 pressure response.......................................................... 20
Figure 19. Simulations of pressure change and derivative during the SNL-3 pressure-buildup test............................................................................................................................... 20
Figure 20. Pressure data from SNL-5. .................................................................................. 21
Figure 21. Log-log diagnostic plot of the final SNL-5 pressure-buildup test............................ 22
Figure 22. Estimates of transmissivity derived from the SNL-5 perturbation analysis........... 22
Figure 23. Simulations of the SNL-5 pressure response.......................................................... 23
Figure 24. Simulations of pressure change and derivative during the final SNL-5 pressure-buildup test.......................................................................................................................... 23
Figure 25. Pressure data from SNL-9. .................................................................................. 24
Figure 26. Log-log diagnostic plot of the SNL-9 pressure-buildup test................................. 25
Figure 27. Estimates of transmissivity derived from the SNL-9 perturbation analysis.......... 25
Figure 28. Simulations of the SNL-9 pressure response.......................................................... 26
Figure 29. Simulations of pressure change and derivative during the SNL-9 pressure-buildup test.......................................................................................................................... 26
Figure 30. Pressure data from SNL-12. ................................................................................. 27
Figure 31. Log-log diagnostic plot of the final SNL-12 pressure-buildup test......................... 28
Figure 32. Estimates of transmissivity derived from the SNL-12 perturbation analysis......... 28
Figure 33. Simulations of the SNL-12 pressure response......................................................... 29
Figure 34. Simulations of pressure change and derivative during the SNL-12 pressure-buildup test.......................................................................................................................... 29
Figure 35. Pressure data from SNL-14. ................................................................................. 30
Figure 36. Log-log diagnostic plot of the final SNL-14 pressure-buildup test......................... 31
Figure 37. Estimates of transmissivity derived from the SNL-14 perturbation analysis........ 31
Figure 38. Simulations of the SNL-14 pressure response......................................................... 32
Figure 39. Simulations of pressure change and derivative during the final SNL-14 pressure-buildup test.......................................................................................................................... 32
Figure 40. Pressure data from WIPP-11. ............................................................................. 33
Figure 41. Log-log diagnostic plot of the final WIPP-11 pressure-buildup test....................... 34
Figure 42. A single radially varying transmissivity estimate obtained from the WIPP-11 perturbation analysis. ............................................................................................................. 35
Figure 43. Estimates of radially varying transmissivity derived from the WIPP-11 perturbation analysis.................................................................................................................. 35
Figure 44. Simulations of the WIPP-11 pressure response..................................................... 36
Figure 45. Simulations of pressure change and derivative during the final WIPP-11 pressure-buildup test.......................................................................................................................... 36
Figure 46. Pressure data from WIPP-25. ............................................................................. 37
Figure 47. Log-log diagnostic plot of the final WIPP-25 pressure-buildup test....................... 38
Figure 48. Estimates of transmissivity derived from the WIPP-25 perturbation analysis....... 38
Figure 49. Simulations of the WIPP-25 pressure response..................................................... 39
Figure 50. Simulations of pressure change and derivative during the final WIPP-25 pressure-buildup test.......................................................................................................................... 39
Figure 51. Pressure data from C-2737. .............................................................................. 40
Figure 52. Log-log diagnostic plot of the final C-2737 pressure-buildup test......................... 41
Figure 53. Estimates of transmissivity derived from the C-2737 perturbation analysis.......... 42
Figure 54. Simulations of the C-2737 pressure response. ......................................................... 43
Figure 55. Simulations of pressure change and derivative during the C-2737 pressure-buildup test. ........................................................... 43

Figure B-1. Estimates of flow dimension derived from the SNL-1 perturbation analysis. ........ 53
Figure B-2. Estimates of static formation pressure derived from the SNL-1 perturbation analysis. ........................................................................................................................................... 53
Figure B-3. Estimates of tubing string radius derived from the SNL-1 perturbation analysis. ... 54
Figure B-4. Estimates of skin hydraulic conductivity derived from the SNL-1 perturbation analysis........................................................................................................................................... 54
Figure B-5. Estimates of skin radius derived from the SNL-1 perturbation analysis.................. 54
Figure B-6. Flow rates measured during the SNL-1 testing. ..................................................... 55
Figure B-7. Estimates of radially varying transmissivity derived from the SNL-2 perturbation analysis........................................................................................................................................... 60
Figure B-8. Estimates of static formation pressure derived from the SNL-2 perturbation analysis. ........................................................................................................................................... 60
Figure B-9. Estimates of tubing string radius derived from the SNL-2 perturbation analysis. ... 61
Figure B-10. Flow rates measured during the SNL-2 testing. ..................................................... 61
Figure B-11. Estimates of time-varying skin hydraulic conductivity derived from the SNL-3 perturbation analysis........................................................................................................................................... 66
Figure B-12. Estimates of static formation pressure derived from the SNL-3 perturbation analysis........................................................................................................................................... 67
Figure B-13. Estimates of skin radius derived from the SNL-3 perturbation analysis.............. 67
Figure B-14. Flow rates measured during the SNL-3 testing. ..................................................... 68
Figure B-15. Estimates of specific storage derived from the SNL-5 perturbation analysis. ...... 73
Figure B-16. Estimates of static formation pressure derived from the SNL-5 perturbation analysis........................................................................................................................................... 74
Figure B-17. Estimates of tubing string radius derived from the SNL-5 perturbation analysis. . 74
Figure B-18. Flow rates measured during the SNL-5 testing. ..................................................... 75
Figure B-19. Estimates of lambda and omega derived from the SNL-9 perturbation analysis. .. 80
Figure B-20. Estimates of fracture and matrix specific storage derived from the SNL-9 perturbation analysis. ........................................................................................................................................... 81
Figure B-21. Estimates of fracture transmissivity and matrix hydraulic conductivity derived from the SNL-9 perturbation analysis.................................................................................................................. 81
Figure B-22. Estimates of static formation pressure derived from the SNL-9 perturbation analysis........................................................................................................................................... 82
Figure B-23. Estimates of skin specific storage derived from the SNL-9 perturbation analysis. 82
Figure B-24. Estimates of skin hydraulic conductivity and radius derived from the SNL-9 perturbation analysis. ........................................................................................................................................... 83
Figure B-25. Flow rates measured during the SNL-9 testing. ..................................................... 83
Figure B-26. Estimates of radially varying flow dimension derived from the SNL-12 perturbation analysis. ........................................................................................................................................... 91
Figure B-27. Estimates of static formation pressure derived from the SNL-12 perturbation analysis........................................................................................................................................... 91
Figure B-28. Estimates of time-varying skin hydraulic conductivity derived from the SNL-12 perturbation analysis. ........................................................................................................................................... 92
Figure B-29. Estimates of skin specific storage derived from the SNL-12 perturbation analysis. ................................................................................................................. 92
Figure B-30. Estimates of skin radius derived from the SNL-12 perturbation........................................ 93
Figure B-31. Estimates of fracture and matrix specific storage derived from the SNL-12
perturbation analysis ........................................................................................................... 93
Figure B-32. Estimates of fracture and matrix specific storage derived from the SNL-12
perturbation analysis ........................................................................................................... 94
Figure B-33. Estimates of fracture transmissivity and matrix hydraulic conductivity derived
from the SNL-12 perturbation analysis ................................................................................. 94
Figure B-34. Flow rates measured during the SNL-12 testing ......................................................... 95
Figure B-35. Estimates of Lambda and Omega derived from the SNL-14 perturbation analysis.
..................................................................................................................................................... 101
Figure B-36. Estimates of fracture and matrix specific storage derived from the SNL-14
perturbation analysis ........................................................................................................... 102
Figure B-37. Estimates of fracture transmissivity and matrix hydraulic conductivity derived
from the SNL-14 perturbation analysis ................................................................................ 102
Figure B-38. Estimates of skin radius derived from the SNL-14 perturbation analysis ............... 103
Figure B-39. Estimates of distance to linear no-flow boundary derived from the SNL-14
perturbation analysis ........................................................................................................... 103
Figure B-40. Estimates of tubing string radius derived from the SNL-14 perturbation analysis.
..................................................................................................................................................... 104
Figure B-41. Estimates of static formation pressure derived from the SNL-14 perturbation
analysis ....................................................................................................................................... 104
Figure B-42. Flow rates measured during the SNL-14 testing ....................................................... 105
Figure B-43. Estimates of skin hydraulic conductivity derived from the WIPP-11 perturbation
analysis ....................................................................................................................................... 112
Figure B-44. Estimates of static formation pressure derived from the WIPP-11 perturbation
analysis ....................................................................................................................................... 112
Figure B-45. Estimates of skin radius derived from the WIPP-11 perturbation analysis ............... 113
Figure B-46. Estimates of tubing string radius derived from the WIPP-11 perturbation analysis.
..................................................................................................................................................... 113
Figure B-47. Flow rates measured during the WIPP-11 testing ....................................................... 114
Figure B-48. Estimates of static formation pressure derived from the WIPP-25 perturbation
analysis ....................................................................................................................................... 120
Figure B-49. Estimates of time-varying skin hydraulic conductivity derived from the WIPP-25
perturbation analysis .............................................................................................................. 121
Figure B-50. Estimates of skin radius derived from the WIPP-25 perturbation analysis .............. 121
Figure B-51. Estimates of skin specific storage derived from the WIPP-25 perturbation analysis.
..................................................................................................................................................... 122
Figure B-52. Estimates of test-zone compressibility derived from the WIPP-25 perturbation
analysis ....................................................................................................................................... 122
Figure B-53. Flow rates measured during the WIPP-25 testing ..................................................... 123
Figure B-54. Estimates of specific storage derived from the C-2737 perturbation analysis .... 129
Figure B-55. Estimates of test-zone compressibility derived from the C-2737 perturbation
analysis ....................................................................................................................................... 129
Figure B-56. Estimates of static formation pressure derived from the C-2737 perturbation analysis................................................................................................................ 130
Figure B-57. Estimates of skin hydraulic conductivity derived from the C-2737 perturbation analysis................................................................................................................ 130
Figure B-58. Estimates of skin specific storage derived from the C-2737 perturbation analysis. ..................................................................................................................................................... 131
Figure B-59. Estimates of skin radius derived from the C-2737 perturbation analysis............. 131
Figure B-60. Flow rates measured during the C-2737 testing. .................................................. 132
1. Introduction

This report discusses the analyses of pumping tests performed in the Culebra Dolomite Member of the Rustler Formation at the Waste Isolation Pilot Plant (WIPP) site between December 2003 and August 2005. These analyses were performed between August 2005 and May 2006 in accordance with the Sandia National Laboratories (SNL) Analysis Plan for Non-Salado Hydraulic-Test Interpretations, AP-070, Revision 1 (Beauheim, 2004). The computer code used for analysis was nSIGHTS (n-dimensional Statistical Inverse Graphical Hydraulic Test Simulator), version 2.30. A detailed description of the approach followed in these analyses can be found in Beauheim et al. (1993, Appendix B) and Roberts et al. (1999, Chapter 6). The data analyzed for this report were collected at the following wells: SNL-1, SNL-2, SNL-3, SNL-5, SNL-9, SNL-12, SNL-13, SNL-14, WIPP-11, WIPP-25, and C-2737. Both barometric and earth-tide effects were removed from the data sets prior to analysis.

2. nSIGHTS Overview

The nSIGHTS code consists of two independent applications: nPre.exe and nPost.exe. The pre-processor and simulator, nPre, is used to process the field data prior to analysis, set up the mathematical model, and then run the model in inverse mode to estimate the hydraulic parameters of interest, e.g., transmissivity ($T$), flow dimension ($n$), etc. It also generates the data used to quantify the uncertainty associated with those hydraulic-parameter estimates. The post-processor, nPost, post-processes the results stored in the nPre output files, allowing graphical and statistical analysis of the simulation results.

All field data used in each analysis are entered or read into nPre and stored in a configuration file with an nPre extension. The field data include well radius, tubing-string radius, formation thickness, fluid density, and the transient pressure and flow-rate data. All input field data, including the reference ERMS numbers and field notebooks for each well, are listed in Appendix A.

The conceptual model chosen based on the characteristics of the test response determines the fitting parameters that will be estimated for each analysis. The model fitting parameters for each analysis are specified in the nPre configuration files named for each of the wells. Five hundred (500) sets of optimized fitting parameters were generated for each analysis in this report as part of the fitting-parameter uncertainty calculation. These 500 optimized parameter sets are stored in the nPre output file with an nOpt extension. The corresponding transient pressure simulations are stored in an nPre output file with an nXYsim extension. Both the nOpt and nXYsim files are read by nPost and all of the post-processing results are stored in a configuration file with an nPost extension.

The nSIGHTS input and output files for each tested well are stored in a directory structure like that shown in Figure 1.
Figure 1. Directory structure for Culebra nSIGHTS analyses.

The nPre configuration file is stored in the folder named for the tested well (Figure 1). Transient pressure and flow-rate files are stored in the Data folder (Figure 2) and all nPre output files as well as the nPost configuration file are stored in the Post folder (Figure 3).

Figure 2. Data folder containing the pressure and flow-rate files for nPre input.

Figure 3. Post folder containing simulation output and post-processed data.
3. Test and Analysis Procedures

At some of the tested wells discussed in this report (e.g., SNL-1, SNL-2, SNL-12, C-2737), long-term pressure records were available leading up to the tests. When helpful, these pressure records were used to specify pre-test history sequences for the nSIGHTS test simulations.

The testing sequence at most of the wells discussed in this report consisted of a series of pumping events at more or less constant rates. Typically, a pump would be installed in the well and then turned on only long enough to bring water to ground surface. The day before the actual test was to begin, the pump would be operated just long enough to establish the rate the pump could sustain over the intended duration of the test and to set all control valves and the pump motor speed appropriate to that rate. The well would then be allowed to recover overnight before beginning the constant-rate test. In some instances (e.g., SNL-2), installing the pump and setting the rate were accomplished in the same day. In other instances (e.g., WIPP-11), the final constant-rate test was begun after only a few hours of recovery from the rate-setting event.

For analysis, these pre-test pumping events were treated in one of two ways. For SNL-1, SNL-12, and WIPP-11, the pre-test pumping events were simulated in the same way as the constant-rate test, but less weight was given to the pre-test pumping events in the parameter optimization process. For SNL-2, SNL-3, SNL-5, SNL-9, SNL-14, C-2737, and WIPP-25, the pre-test pumping events were treated as “history” periods and the associated pressures were simply specified in the simulations. All pressure recoveries were simulated.

Test analysis involved finding the values of the fitting parameters that produced the best simulated matches to the pressure data collected during the constant-rate test and subsequent recovery period. In addition to the formation properties of interest (principally transmissivity and flow dimension), tubing string radius was also included as a fitting parameter so that nSIGHTS could exactly match the amount of wellbore storage observed during the test. The main objective of these analyses was to estimate $T$ in the vicinity of each well for subsequent use in $T$-field generation and WIPP performance assessment calculations. Correlation between estimated $T$ values and the other fitting parameters reported in Appendix B would be of interest if these correlations resulted in large uncertainty in the estimated $T$ values. The uncertainty in the estimated $T$ values shown in Table 1, however, is seen to be relatively small, so any correlation between $T$ and other fitting parameters is not of interest.

The uncertainty quantification method applied to the analyses in this report is a process referred to as perturbation analysis. In this process, preliminary analyses are performed in which a reasonable fit is obtained to the specified constraints defined in the nPre configuration file. The resulting values of the fitting parameters are the baseline solution set – a single value for each fitting parameter that provides a satisfactory fit to the data (satisfactory being a judgment call on the part of the analyst). Perturbation analysis begins by assigning a plus/minus range corresponding to the parameter space one wishes to investigate to each of the baseline fitting-parameter values. These plus/minus fitting-parameter ranges for each analysis are listed in Appendix B. Starting at the baseline value, the fitting parameters are randomly perturbed to fall somewhere within their assigned ranges and are then optimized from these random starting points. The objective of perturbation analysis is to adequately sample the parameter space and locate all of the minima within the parameter space. By definition, the parameter-space
minimum that provides the best quantitative fit to the data, measured in terms of the smallest sum of squared errors (SSE), is the global minimum (assumed true solution), and the other minima are referred to as local minima. Local minima are effectively localized depressions in the parameter-space topography that trap the inverse regression algorithm during its attempt to find the global minimum – the smallest SSE.

Five hundred (500) perturbation/optimization runs were performed for each of the analyses discussed in this report. From these perturbation results, only those solutions that provided a satisfactory fit (as determined by the analyst) to the data are presented in this report – effectively those solutions that fall within the global minimum. In some cases, the original baseline solution may not fall within the global minimum defined through perturbation analysis.

4. Analysis Results

Discussions of the individual test analyses are given below. A summary of the transmissivity estimates obtained from perturbation analysis of each test is shown in Table 1.

<table>
<thead>
<tr>
<th>Well</th>
<th>Geometric Mean (m²/s)</th>
<th>Minimum (m²/s)</th>
<th>Maximum (m²/s)</th>
<th>Variance</th>
</tr>
</thead>
<tbody>
<tr>
<td>SNL-1</td>
<td>6.24E-04</td>
<td>5.97E-04</td>
<td>6.51E-04</td>
<td>2.95E-05</td>
</tr>
<tr>
<td>SNL-2</td>
<td>1.07E-04</td>
<td>1.03E-04</td>
<td>1.12E-04</td>
<td>2.32E-05</td>
</tr>
<tr>
<td>SNL-3</td>
<td>9.88E-04</td>
<td>4.32E-04</td>
<td>4.53E-03</td>
<td>7.84E-02</td>
</tr>
<tr>
<td>SNL-5</td>
<td>4.86E-06</td>
<td>2.20E-06</td>
<td>8.56E-06</td>
<td>4.31E-02</td>
</tr>
<tr>
<td>SNL-9</td>
<td>3.86E-05</td>
<td>3.56E-05</td>
<td>3.96E-05</td>
<td>5.90E-06</td>
</tr>
<tr>
<td>SNL-12</td>
<td>4.97E-04</td>
<td>4.89E-04</td>
<td>5.09E-04</td>
<td>1.01E-05</td>
</tr>
<tr>
<td>SNL-14</td>
<td>4.92E-05</td>
<td>4.81E-05</td>
<td>4.91E-05</td>
<td>2.00E-06</td>
</tr>
<tr>
<td>WIPP-11</td>
<td>4.27E-04</td>
<td>8.34E-05</td>
<td>2.42E-03</td>
<td>4.59E-01</td>
</tr>
<tr>
<td>WIPP-25</td>
<td>2.51E-04</td>
<td>2.21E-04</td>
<td>3.13E-04</td>
<td>2.50E-04</td>
</tr>
<tr>
<td>C-2737</td>
<td>6.62E-07</td>
<td>6.57E-07</td>
<td>6.63E-07</td>
<td>2.66E-08</td>
</tr>
</tbody>
</table>

4.1 SNL-1

On March 3, 2005, the Culebra interval in SNL-1 was acidized by injecting 48 barrels (7.63 m³) of a 15% hydrochloric acid (HCl) solution followed by 48 barrels (7.63 m³) of fresh water into the well. A pump was installed in the well after the acidization on March 3, 2005, and an evaluation of potential pumping rates was performed on March 4, 2005. Testing activities in SNL-1 were initiated on March 7, 2005. Three preliminary pumping episodes lasting between 19.5 minutes and 17.7 hours occurred before the final 40.46-hr test at 35 gpm. Figure 4 shows the pressure record from SNL-1 used in this analysis. The pressures measured prior to the start of the testing activities on March 7, 2005, were included in the nSIGHTS simulation as a pressure history. The pressures shown in Figure 4 were separated into 11 nSIGHTS sequences.
for this analysis. The details of each sequence, i.e., start/end time, flow rate, etc., are specified in the SNL-1.nPre file and are listed in Appendix B.1.

![Pressure data from SNL-1.](image)

**Figure 4. Pressure data from SNL-1.**

The specified SNL-1 conceptual model, based on the characteristics of the final buildup period diagnostic plot shown in Figure 5, was a composite-geometry \( n \) system with wellbore storage and skin. The pressure derivative indicated radial flow \( (n = 2) \) until about 500 minutes elapsed time (Figure 5). After that time, the upward sloping late-time derivative indicates far-field sub-radial flow \( (n < 2) \), which could be indicative of a decrease in transmissivity with distance. The range of transmissivity \( (T) \) values estimated from the SNL-1 analysis for the radial-flow period \( (?) \) is shown in Figure 6. The SNL-1 geometric mean \( T \) value was 6.24E-4 m\(^2\)/s. The Cartesian, detailed Cartesian, and log-log pressure-buildup diagnostic simulations corresponding to the \( T \) values in Figure 6 are shown in Figures 7, 8, and 9, respectively.
Figure 5. Log-log diagnostic plot of the final SNL-1 pressure-buildup test.

Figure 6. Estimates of transmissivity derived from the SNL-1 perturbation analysis.
Figure 7. Simulations of the SNL-1 pressure response.

Figure 8. Detail of simulations of the SNL-1 pressure response.
4.2 SNL-2

The Culebra interval in SNL-2 was acidized on January 19, 2005, by injecting 48 barrels (7.63 m$^3$) of a 15% HCl solution followed by 48 barrels (7.63 m$^3$) of fresh water into the well. A pump was installed in the well after the acidization on January 19, 2005, and an evaluation of potential pumping rates was performed that evening. A constant-rate (12 gpm) pumping test was initiated in SNL-2 on January 20, 2005, and continued for approximately 96.4 hours. The first 79 hours of pressure buildup following the end of pumping were also included in the analysis. About 79 hours after the pressure buildup began, the SNL-2 pressure response began to exhibit pressure changes not associated with SNL testing activities, precluding its usefulness for analysis. Figure 10 shows the pressure record from SNL-2 used in this analysis. The pressures measured prior to the start of the pumping test on January 19, 2005 were included in the nSIGHTS simulation as a pressure history. The pressures shown in Figure 10 were separated into four nSIGHTS sequences for this analysis. The details of each sequence, i.e., start/end time, flow rate, etc., are specified in the SNL-2.nPre file and are listed in Appendix B.2.

![Figure 9. Simulations of pressure change and derivative during the final SNL-1 pressure-buildup test.](image-url)
The specified SNL-2 conceptual model, based on the characteristics of the buildup-period diagnostic plot shown in Figure 11, was a composite-$T$ system with wellbore storage. The pressure derivative exhibits a radial stabilization between 1 and 10 minutes elapsed time (Figure 11) and then rises until approximately 100 minutes elapsed time, indicating a decrease in $T$. After that time, the downturn in the derivative probably results from the complex pre-test pressure history whose pressure changes are not associated with SNL testing activities. The range of $T$ values estimated from the SNL-2 analysis corresponding to the first derivative stabilization is shown in Figure 12. The geometric mean $T$ value was $1.07E-4$ m$^2$/s. The Cartesian and log-log pressure-buildup diagnostic simulations corresponding to these $T$ values are shown in Figures 13 and 14, respectively.
Figure 11. Log-log diagnostic plot of the final SNL-2 pressure-buildup test.

Figure 12. Estimates of transmissivity derived from the SNL-2 perturbation analysis.
Figure 13. Simulations of the SNL-2 pressure response.

Figure 14. Simulations of pressure change and derivative during the final SNL-2 pressure-buildup test.
4.3 SNL-3

A constant-rate (10 gpm) pumping test was initiated in SNL-3 on April 14, 2004, and continued for approximately 2.2 days. The subsequent 10.4 days of pressure buildup were also included in this analysis. Figure 15 shows the pressure record from SNL-3 used in this analysis. The pressures shown in Figure 15 were separated into three nSIGHTS sequences; details of each sequence, i.e., start/end time, flow rate, etc., are specified in the SNL-3.nPre file and are listed in Appendix B.3.

![Figure 15. Pressure data from SNL-3.](image)

The specified SNL-3 conceptual model, based on the characteristics of the pressure-buildup diagnostic plot shown in Figure 16, was a composite-$T$ system with wellbore storage and a time-dependent skin. The observed linear upward trend in the derivative beginning at approximately 0.04 days (Figure 16) is indicative of constantly decreasing $T$ in a radial flow system. The range of $T$ values estimated from the SNL-3 analysis that affect the early-time fit to the linear part of the derivative is shown in Figure 17. The geometric mean of these $T$ values is 9.88E-4 m²/s. The simulated SNL-3 Cartesian and log-log pressure-buildup diagnostic responses corresponding to the $T$ values shown in Figure 17 are shown in Figures 18 and 19, respectively.
Figure 16. Log-log diagnostic plot of the SNL-3 pressure-buildup test.

Figure 17. Estimates of transmissivity derived from the SNL-3 perturbation analysis.
Figure 18. Simulations of the SNL-3 pressure response.

Figure 19. Simulations of pressure change and derivative during the SNL-3 pressure-buildup test.
4.4 SNL-5

Various pumping rates were evaluated in well SNL-5 over a 3.5-hr period on July 19, 2004. The actual pumping test began on July 20, 2004, had an average rate of 3.5 gpm, and lasted approximately 94.1 hr. The pressure response from July 19 – August 18, 2004 (Figure 20) was included in this analysis. The pressures shown in Figure 20 were separated into five nSIGHTS sequences for this analysis. The details of each sequence, i.e., start/end time, flow rate, etc., are specified in the SNL-5.nPre file and are listed in Appendix B.4.

![Figure 20. Pressure data from SNL-5.](image)

The specified SNL-5 conceptual model, based on the characteristics of the final pressure-buildup diagnostic plot shown in Figure 21, was a composite-$T$ system with wellbore storage. The pressure derivative appears to stabilize between approximately 90 and 300 minutes (Figure 21) and then begins to trend downward, indicating an increase in $T$. The range of $T$ values estimated from the SNL-5 analysis is shown in Figure 22. Variations in $T$ were estimated by optimizing both the value of $T$ and the distance ($r$) at which that value occurred at three discrete points (indicated by three colors in Figure 22) in the model. Values of $T$ between those three points were linearly interpolated by the code. For each simulation, the value of $T$ in the model varied continuously. The match to the stabilized portion of the derivative was affected by $T$ values that were changing linearly with distance between the first two populations (red and black) shown in Figure 22. The geometric mean $T$ value of 4.86E-6 m$^2$/s was therefore calculated from these combined populations. The simulated SNL-5 Cartesian and log-log pressure-buildup diagnostic responses corresponding to the $T$ values shown in Figure 22 are shown in Figures 23 and 24, respectively.
Figure 21. Log-log diagnostic plot of the final SNL-5 pressure-buildup test.

Figure 22. Estimates of transmissivity derived from the SNL-5 perturbation analysis.
Figure 23. Simulations of the SNL-5 pressure response.

Figure 24. Simulations of pressure change and derivative during the final SNL-5 pressure-buildup test.
4.5 SNL-9

A constant-rate pumping test at 12.5 gpm was initiated in SNL-9 on December 2, 2003, and lasted approximately 90.6 hr. The pressure response from December 2, 2003 – March 17, 2004 (Figure 25) was included in this analysis. The pressures shown in Figure 25 were separated into three nSIGHTS sequences for this analysis. The details of each sequence, i.e., start/end time, flow rate, etc., are specified in the SNL-9.nPre file and are listed in Appendix B.5.

Figure 25. Pressure data from SNL-9.

The specified SNL-9 conceptual model, based on the characteristics of the final pressure-buildup diagnostic plot shown in Figure 26, was a dual-porosity system with wellbore storage and skin. The range of fracture $T$ values (Figure 27) estimated from this analysis corresponds to a stabilized derivative beginning at approximately 2.0E4 minutes in Figure 26. The geometric mean $T$ estimate was 3.86E-5 m$^2$/s. The simulated SNL-9 Cartesian and log-log pressure-buildup diagnostic responses corresponding to the $T$ values shown in Figure 27 are shown in Figures 28 and 29, respectively.
Figure 26. Log-log diagnostic plot of the SNL-9 pressure-buildup test.

Figure 27. Estimates of transmissivity derived from the SNL-9 perturbation analysis.
Figure 28. Simulations of the SNL-9 pressure response.

Figure 29. Simulations of pressure change and derivative during the SNL-9 pressure-buildup test.
4.6 SNL-12

Various pumping rates were evaluated in well SNL-12 over a 2.7-hr period on August 9, 2004. The actual pumping test began on August 10, 2004, had an average rate of 20 gpm, and lasted approximately 95.7 hr. The pressure response from April 12 – September 14, 2004 (Figure 30) was included in this analysis. Pressures from April 12 – August 9, 2004 were included as a pressure history in the nSIGHTS simulations. The pressures shown in Figure 30 were separated into six nSIGHTS sequences for this analysis. The details of each sequence, i.e., start/end time, flow rate, etc., are specified in the SNL-12.nPre file and are listed in Appendix B.6.

![Figure 30. Pressure data from SNL-12.](image)

The specified SNL-12 conceptual model, based on the characteristics of the final pressure-buildup diagnostic plot shown in Figure 31, was a dual-porosity and composite-$n$ system with wellbore storage and a time-dependent skin. The near-field $n$ was specified to be radial. The range of $T$ values (Figure 32) estimated from this analysis corresponds to the derivative stabilization between approximately 1000 and 2000 minutes in Figure 31. The geometric mean $T$ value was 4.97E-4 m$^2$/s. The simulated SNL-12 Cartesian and log-log pressure-buildup diagnostic responses corresponding to the $T$ values shown in Figure 32 are shown in Figures 33 and 34, respectively.
Figure 31. Log-log diagnostic plot of the final SNL-12 pressure-buildup test.

Figure 32. Estimates of transmissivity derived from the SNL-12 perturbation analysis.
Figure 33. Simulations of the SNL-12 pressure response.

Figure 34. Simulations of pressure change and derivative during the SNL-12 pressure-buildup test.
4.7 SNL-14

Various pumping rates were evaluated in well SNL-14 over a 4.6-hr period on July 20, 2005. A constant-rate (30 gpm) pumping test was initiated in SNL-14 on August 4, 2005. Pumping ended on August 26, 2005, and the subsequent pressure buildup through January 3, 2006 was included in this analysis (Figure 35). The pressures shown in Figure 35 were separated into eight nSIGHTS sequences for this analysis. SNL-14 pressures from June 14 – August 4, 2005 were included in the nSIGHTS simulations as a pressure history. The details of each sequence, i.e., start/end time, flow rate, etc., are specified in the SNL-14.nPre file and are listed in Appendix B.7.

![Figure 35. Pressure data from SNL-14.](image)

The specified SNL-14 conceptual model, based on the characteristics of the final pressure-buildup diagnostic plot shown in Figure 36, was a dual-porosity system with wellbore storage, a time-dependent skin, and a linear no-flow boundary. The range of fracture $T$ values (Figure 37) estimated from this analysis corresponds to the derivative stabilization that begins at approximately 3 days in Figure 36. The assumed effect of the no-flow boundary then begins to dominate the response after about 8 days (Figure 36). The fracture $T$ estimates are shown in Figure 37. The geometric mean fracture $T$ estimate derived from this analysis was 4.9E-5 m$^2$/s.
The simulated SNL-14 Cartesian and log-log pressure-buildup diagnostic responses corresponding to the $T$ values shown in Figure 37 are shown in Figures 38 and 39, respectively.

![Log-log diagnostic plot of the final SNL-14 pressure-buildup test.](image)
Figure 37. Estimates of transmissivity derived from the SNL-14 perturbation analysis.

Figure 38. Simulations of the SNL-14 pressure response.
The Culebra interval in WIPP-11 was acidized on January 5, 2005, by injecting 43 barrels (6.84 m³) of a 15% HCl solution charged with liquid nitrogen followed by 58 barrels (9.22 m³) of fresh water into the well. An evaluation of potential pumping rates was performed over a 3.5-hr period on January 31, 2005. The pumping test began on February 1, 2005 and continued until February 20, 2005 at a rate of 35 gpm. The pumping-test data and the subsequent pressure buildup through April 4, 2005 were included in this analysis (Figure 40). The pressures shown in Figure 40 were separated into eight nSIGHTS sequences for this analysis. The details of each sequence, i.e., start/end time, flow rate, etc., are specified in the WIPP-11.nPre file and are listed in Appendix B.8.
The specified WIPP-11 conceptual model, based on the characteristics of the final pressure-buildup diagnostic plot shown in Figure 41, was a composite-$T$ system with wellbore storage. 

Relatively high $T$ variability was indicated by the constantly changing slope of the derivative in Figure 41. This $T$ variability was simulated by optimizing a $T(r)$ function in the WIPP-11 model. Both the value of $T$ and the distance from the borehole to that value were optimized using six discrete points. The value of $T$ in the model was linearly interpolated between the six discrete points. An example of a single $T(r)$ solution is shown in Figure 42. Note that the relationship between $T$ and distance in the model depends on the value of specific storage ($S_s$) in the model, which was fixed at 1.0E-6 m$^{-1}$ in this analysis. The range of estimated $T$ and radius ($r$) values for the complete $T(r)$ function is shown in Figure 43. Those $T$ values that correspond to the derivative stabilization that begins at approximately 7.0E-4 days in Figure 41, i.e., the near-field $T$ values, are those values that are interpolated between the first two sets of points shown in Figure 43. The geometric mean estimate of $T$ derived from these first two sets of points was 4.27E-4 m$^2$/s. The simulated WIPP-11 Cartesian and log-log pressure-buildup diagnostic responses corresponding to the $T$ values shown in Figure 43 are shown in Figures 44 and 45, respectively.
Figure 41. Log-log diagnostic plot of the final WIPP-11 pressure-buildup test.

Figure 42. A single radially varying transmissivity estimate obtained from the WIPP-11 perturbation analysis.
Figure 43. Estimates of radially varying transmissivity derived from the WIPP-11 perturbation analysis.

Figure 44. Simulations of the WIPP-11 pressure response.
4.9 WIPP-25

A constant-rate pumping test was initiated in well WIPP-25 on September 22, 2004, at a rate of 30 gpm. Pumping was interrupted for about three minutes approximately five hours after the test was started. Pumping ended on September 23, 2004, and the subsequent pressure buildup through September 29, 2004 (Figure 46), was included in this analysis. The pressures shown in Figure 46 were separated into six nSIGHTS sequences for this analysis. WIPP-25 pressures from September 20 – 22, 2004, were included in the nSIGHTS simulations as a pressure history. The details of each sequence, i.e., start/end time, flow rate, etc., are specified in the WIPP-25.nPre file and are listed in Appendix B.9.
The specified WIPP-25 conceptual model, based on the characteristics of the final pressure-buildup diagnostic plot shown in Figure 47, was an infinite-acting radial system with wellbore storage and a time-dependent skin. The range of $T$ values estimated from this analysis is shown in Figure 48. The geometric mean estimate of $T$ derived from this analysis was 2.51E-4 m$^2$/s. The simulated WIPP-25 Cartesian and log-log pressure-buildup diagnostic responses corresponding to the $T$ values shown in Figure 48 are shown in Figures 49 and 50, respectively.
Figure 47. Log-log diagnostic plot of the final WIPP-25 pressure-buildup test.

Figure 48. Estimates of transmissivity derived from the WIPP-25 perturbation analysis.
Figure 49. Simulations of the WIPP-25 pressure response.

Figure 50. Simulations of pressure change and derivative during the final WIPP-25 pressure-buildup test.
4.10 C-2737

A constant-rate pumping test was initiated in well C-2737 on March 4, 2004. Pumping ended on March 5, 2004, after 10.4 hours of pumping at 0.3 gpm, and the subsequent pressure buildup through March 18, 2004, was included in this analysis (Figure 51). C-2737 pressures from January 1 – March 4, 2004, which included a series of pumping exercises in late January 2004, were included in the nSIGHTS simulations as a pressure history. The pressures shown in Figure 51 were separated into six nSIGHTS sequences for this analysis. The details of each sequence, i.e., start/end time, flow rate, etc., are specified in the C-2737.nPre file and are listed in Appendix B.10.

![Figure 51. Pressure data from C-2737.](image)

The specified C-2737 conceptual model, based on the characteristics of the final pressure-buildup diagnostic plot shown in Figure 52, was an infinite-acting radial system with wellbore storage and skin. The range of \( T \) values estimated from this analysis is shown in Figure 53. The mean estimate of \( T \) derived from this analysis was 6.62E-7 m\(^2\)/s. The simulated C-2737 Cartesian and log-log pressure-buildup diagnostic responses corresponding to the \( T \) values shown in Figure 53 are shown in Figures 54 and 55, respectively.
Figure 52. Log-log diagnostic plot of the final C-2737 pressure-buildup test.

Figure 53. Estimates of transmissivity derived from the C-2737 perturbation analysis.
Figure 54. Simulations of the C-2737 pressure response.

Figure 55. Simulations of pressure change and derivative during the C-2737 pressure-buildup test.
References


## Appendix A -- Culebra Pumping Tests – December 2003 to August 2005

<table>
<thead>
<tr>
<th>Well</th>
<th>Date and Time Start DAS</th>
<th>Date and Time Stop DAS</th>
<th>Date and Time Start Pump</th>
<th>Date and Time Stop Pump</th>
<th>Borehole Diameter (in)</th>
<th>Inside Casing Diameter (in)</th>
<th>Culebra Interval (ft)</th>
<th>Specific Gravity (g/cm³)</th>
<th>Troll Filenames</th>
<th>DAS Filenames</th>
<th>Field Notebook</th>
</tr>
</thead>
<tbody>
<tr>
<td>Well</td>
<td>Date and Time Start DAS</td>
<td>Date and Time Stop DAS</td>
<td>Date and Time Start Pump</td>
<td>Date and Time Stop Pump</td>
<td>Borehole Diameter (in)</td>
<td>Inside Casing Diameter (in)</td>
<td>Culebra Interval (ft)</td>
<td>Specific Gravity (g/cm³)</td>
<td>Troll Filenames (ERMS# 539221)</td>
<td>DAS Filenames (ERMS# 543540)</td>
<td>Field Notebook (ERMS# 540244)</td>
</tr>
<tr>
<td>--------</td>
<td>-------------------------</td>
<td>------------------------</td>
<td>--------------------------</td>
<td>-------------------------</td>
<td>------------------------</td>
<td>--------------------------</td>
<td>-------------------------</td>
<td>---------------------------</td>
<td>----------------------------------------</td>
<td>----------------------------------------</td>
<td>-------------------------------</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>WIPP-11 (C) 5-sec Flow &amp; Well Level Data_02-07 to 02-10-05rev.xls</td>
<td>WIPP-11 (C) 5-sec Flow &amp; Well Level Data_02-10 to 02-14-05rev.xls</td>
<td>WIPP-11 (C) 5-sec Flow &amp; Well Level Data_02-14 to 02-17-05rev.xls</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>WIPP-11 (C) 5-sec Flow &amp; Well Level Data_02-17 to 02-20-05rev.xls</td>
<td>WIPP-25 (C) 5-sec Flow &amp; Well Level Data_09-16 to 11-23-2004 Comments.xls</td>
<td>WIPP Notebook #4</td>
</tr>
</tbody>
</table>

SN16771 2004-09-20 135045

WIPP Notebook #4
Appendix B – nSIGHTS Listings

B.1 SNL-1 nSIGHTS Listings

**********
nPre 2.30Q
**********

Version date   22 July 2005
Listing date   23 May 2006
QA status      QA:Q
Config file    C:\nSIGHTS\Culebra\SNL-1\SNL-1.nPre

Control Settings

Main Settings
Simulation type Forward
Simulation subtype Normal
Phase to simulate Liquid
Skin zone? yes
External boundary Fixed Pressure
Curve data source Objects

Liquid Phase Settings
Aquifer type Confined
Aquifer horizontal permeability Isotropic
System porosity Single
Compensate flow dimension geometry yes
Leakage None

Test Zone Settings
Test zone volume can vary no
Test zone compressibility can vary no
Test zone temperature can vary no
Default test-zone temperature 20.00 [C]
Solution variable Pressure
Allow negative head/pressure yes

Parameters

Formation
Formation thickness 28.000 [ft]
Flow dimension f(r) point
Static formation pressure 73.767 [psi]
External boundary radius 1000000 [m]
Formation conductivity 7.24422E-05 [m/sec]
Formation spec. storage 1.00000E-06 [l/m]
Skin
Radial thickness of skin                            9.439796 [m]
Skin zone conductivity                           7.78386E-03 [m/sec]
Skin zone spec. storage                          1.00000E-07 [l/m]

Fluid
Fluid density                                   1027.80 [kg/m^3]
Fluid thermal exp. coeff.                     0.00000E+00 [1/C]

Test-Zone
Well radius                                      2.165 [in]
Tubing string radius                            1.5001279 [in]

Numeric
# of radial nodes                                  250 []
# of skin nodes                                     50 []
Pressure solution tolerance                     1.45038E-11 [psi]
STP flow solution tolerance                    1.58503E-11 [USgpm]

f(x) Points Parameters

Flow dimension
Points type                                    f(r)
Radius #1                                        0.0 [m]
Y value#1                                         2.0 []
Radius #2                                2445.3687063 [m]
Y value#2                                       1.017654 []
Parameter curve type                          Step Full

Calculated Parameters

Formation
Transmissivity                                  6.18250E-04 [m^2/sec]
Storativity                                      8.53440E-06 []
Diffusivity                                     7.24422E+01 [m^2/sec]

Skin Zone
Transmissivity                                  6.64305E-02 [m^2/sec]
Storativity                                      8.53440E-07 []
Diffusivity                                     7.78386E+04 [m^2/sec]
Skin factor                                     -5.10339E+00 []

Test Zone
Open hole well-bore storage                  4.52547E-07 [m^3/Pa]
Grid Properties

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grid increment delta</td>
<td>0.05811</td>
</tr>
<tr>
<td>First grid increment</td>
<td>5.68132E-01 [m]</td>
</tr>
<tr>
<td>Skin grid increment delta</td>
<td>0.10513</td>
</tr>
<tr>
<td>Skin first grid increment</td>
<td>6.09598E-03 [m]</td>
</tr>
<tr>
<td>Skin last grid increment</td>
<td>9.47501E-01 [m]</td>
</tr>
<tr>
<td>Increment ratio</td>
<td>5.99611E-01 [m]</td>
</tr>
</tbody>
</table>

Sequences

**Sequence: H_01**
- Sequence type: History
- Start time: -250970.960 [min]
- Duration: 250979.962 [min]
- Time step type: Static
- Static time step: 1.000000 [day]
- Type: Curve
- Wellbore storage: None

**Sequence: H_02**
- Sequence type: History
- Start time: 9.002 [min]
- Duration: 4203.000 [min]
- Time step type: Static
- Static time step: 2.000 [min]
- Type: Curve
- Wellbore storage: Open

**Sequence: H_03**
- Sequence type: History
- Start time: 4212.002 [min]
- Duration: 155.728 [min]
- Time step type: Static
- Static time step: 0.500 [min]
- Type: Curve
- Wellbore storage: Open

**Sequence: F_01**
- Sequence type: Flow
- Start time: 4367.730 [min]
- Duration: 127.400 [min]
- Time step type: Log
- First log step: 1.66667E-04 [min]
- # of time steps: 250
- Type: Fixed
- Fixed value: -40.0 [USgpm]
- Wellbore storage: Open

**Sequence: F_02**
- Sequence type: Flow
<table>
<thead>
<tr>
<th>Sequence: F_03</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sequence type</td>
</tr>
<tr>
<td>Start time</td>
</tr>
<tr>
<td>Duration</td>
</tr>
<tr>
<td>Time step type</td>
</tr>
<tr>
<td>First log step</td>
</tr>
<tr>
<td># of time steps</td>
</tr>
<tr>
<td>Type</td>
</tr>
<tr>
<td>Fixed value</td>
</tr>
<tr>
<td>Wellbore storage</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sequence: F_04</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sequence type</td>
</tr>
<tr>
<td>Start time</td>
</tr>
<tr>
<td>Duration</td>
</tr>
<tr>
<td>Time step type</td>
</tr>
<tr>
<td>First log step</td>
</tr>
<tr>
<td># of time steps</td>
</tr>
<tr>
<td>Type</td>
</tr>
<tr>
<td>Fixed value</td>
</tr>
<tr>
<td>Wellbore storage</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sequence: H_04</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sequence type</td>
</tr>
<tr>
<td>Start time</td>
</tr>
<tr>
<td>Duration</td>
</tr>
<tr>
<td>Time step type</td>
</tr>
<tr>
<td>Static time step</td>
</tr>
<tr>
<td>Type</td>
</tr>
<tr>
<td>Wellbore storage</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sequence: F_05</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sequence type</td>
</tr>
<tr>
<td>Start time</td>
</tr>
<tr>
<td>Duration</td>
</tr>
<tr>
<td>Time step type</td>
</tr>
<tr>
<td>First log step</td>
</tr>
<tr>
<td># of time steps</td>
</tr>
<tr>
<td>Type</td>
</tr>
<tr>
<td>Fixed value</td>
</tr>
<tr>
<td>Wellbore storage</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sequence: F_06</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sequence type</td>
</tr>
</tbody>
</table>

---
Start time                                   6109.750     [min]
Duration                                     2427.790     [min]
Time step type                                    Log
First log step                            1.66667E-04     [min]
# of time steps                                   250
Type                                            Fixed
Fixed value                                       -35.0     [USgpm]
Wellbore storage                                 Open

Sequence: F_07

Sequence type                                     Flow
Start time                                   8537.540     [min]
Duration                                   241462.460     [min]
Time step type                                    Log
First log step                            1.66667E-04     [min]
# of time steps                                   250
Type                                            Fixed
Fixed value                                       0.0     [USgpm]
Wellbore storage                                 Open

Test Zone Curves

Curve object to use                      Pressure Curve
Curve type                                     Pressure
Start sequence                                     H_01
End sequence                                       H_04
Curve time base                                    Test
Curve Y data units                                [psi]
Curve Y data is log 10                           no

Simulation Results Setup

Output ID                                           DAT
Output type                                  Pressure
Pressure capture type                        Test Zone
Output units                                  [psi]

Output ID                                           DAT
Output type                                  Flow Rate
Flow rate output type                         Well
Output units                                  [USgpm]

SNL-1 nSIGHTS Optimization Settings

**********
nPre 2.30Q
**********

Version date   22 July 2005
Listing date   23 May 2006
QA status       QA:Q
Config file     C:\nSIGHTS\Culebra\SNL-1\SNL-1.nPre
Parameters

Formation

Formation thickness 28.000 [ft]
Flow dimension \( f(r) \) point
Static formation pressure Optimization
  Minimum value 65.000 [psi]
  Maximum value 80.000 [psi]
  Estimate value 73.767 [psi]
  Range type Linear
  Sigma 1.00000E+00
External boundary radius 1000000 [m]
Formation conductivity Optimization
  Minimum value 1.00000E-08 [m/sec]
  Maximum value 1.00000E-01 [m/sec]
  Estimate value 7.24422E-05 [m/sec]
  Range type Log
  Sigma 1.00000E+00
Formation spec. storage 1.00000E-06 [1/m]

Skin

Radial thickness of skin Optimization
  Minimum value 0.0001 [m]
  Maximum value 10.0 [m]
  Estimate value 9.439796 [m]
  Range type Log
  Sigma 1.00000E+00
Skin zone conductivity Optimization
  Minimum value 1.00000E-05 [m/sec]
  Maximum value 1.00000E-01 [m/sec]
  Estimate value 7.78386E-03 [m/sec]
  Range type Log
  Sigma 1.00000E+00
Skin zone spec. storage 1.00000E-07 [1/m]

Fluid

Fluid density 1027.80 [kg/m^3]
Fluid thermal exp. coeff. 0.00000E+00 [1/C]

Test-Zone

Well radius 2.165 [in]
Tubing string radius Optimization
  Minimum value 1.0 [in]
  Maximum value 2.165 [in]
  Estimate value 1.5001279 [in]
  Range type Linear
  Sigma 1.00000E+00

Numeric

# of radial nodes 250 []
# of skin nodes 50 []
Pressure solution tolerance 1.45038E-11 [psi]
SNL-1 Fitting-Parameter Estimates

**Figure B-1.** Estimates of flow dimension derived from the SNL-1 perturbation analysis.

**Figure B-2.** Estimates of static formation pressure derived from the SNL-1 perturbation analysis.
Figure B-3. Estimates of tubing string radius derived from the SNL-1 perturbation analysis.

Figure B-4. Estimates of skin hydraulic conductivity derived from the SNL-1 perturbation analysis.
Figure B-5. Estimates of skin radius derived from the SNL-1 perturbation analysis.

Figure B-6. Flow rates measured during the SNL-1 testing.
B.2  SNL-2 nSIGHTS Listings

**********
nPre 2.30Q
**********

Version date   22 July 2005
Listing date    23 May 2006
QA status       QA:Q
Config file     C:\nSIGHTS\Culebra\SNL 2\SNL-2.nPre

Control Settings

Main Settings
Simulation type          Forward
Simulation subtype       Normal
Phase to simulate        Liquid
Skin zone ?              no
External boundary         Fixed Pressure
Curve data source        Objects

Liquid Phase Settings
Aquifer type            Confined
Aquifer horizontal permeability Isotropic
System porosity          Single
Compensate flow dimension geometry yes
Leakage                  None

Test Zone Settings
Test zone volume can vary   no
Test zone compressibility can vary   no
Test zone temperature can vary   no
Default test-zone temperature 20.00 [C]
Solution variable         Pressure
Allow negative head/pressure yes

Parameters

Formation
Formation thickness 25.000 [ft]
Flow dimension 2.0 [ ]
Static formation pressure 98.376 [psi]
External boundary radius 1000000 [m]
Formation conductivity $f(r)$ point
Formation spec. storage 1.00000E-06 [1/m]

Fluid
Fluid density 1009.00 [kg/m^3]
Fluid thermal exp. coeff. 0.000000E+00 [1/C]
**Test-Zone**

Well radius 2.165 [in]
Tubing string radius 1.5000144 [in]

**Numeric**

# of radial nodes 250
Pressure solution tolerance 1.45038E-11 [psi]
STP flow solution tolerance 1.58503E-11 [USgpm]

---

**f(x) Points Parameters**

**Formation conductivity**

<table>
<thead>
<tr>
<th>Points type</th>
<th>Radius #1</th>
<th>Y value #1</th>
<th>Radius #2</th>
<th>Y value #2</th>
<th>Radius #3</th>
<th>Y value #3</th>
</tr>
</thead>
<tbody>
<tr>
<td>f(r)</td>
<td>0.001</td>
<td>1.47460E-02</td>
<td>742.6866088</td>
<td>1.31862E-05</td>
<td>5782.035865</td>
<td>3.23096E-04</td>
</tr>
</tbody>
</table>

Parameter curve type Linear

---

**Calculated Parameters**

**Formation**

Transmissivity $f(r)$
Storativity $7.62000E-06$ []
Diffusivity $f(r)$

**Test Zone**

Open hole well-bore storage $4.60910E-07$ [m^3/Pa]

**Grid Properties**

Grid increment delta $0.06713$ []
First grid increment $3.81844E-03$ [m]

---

**Sequences**

**Sequence: H_01**

Sequence type History
Start time -527196.135 [min]
Duration 526196.135 [min]
Time step type Static
Static time step 500.000 [min]
Type Curve
Wellbore storage None
Sequence: H_02

Sequence type: History
Start time: -1000.000 [min]
Duration: 1002.082 [min]
Time step type: Static
Static time step: 1.000 [min]
Type: Curve
Wellbore storage: None

Sequence: F_01

Sequence type: Flow
Start time: 2.082 [min]
Duration: 5786.254 [min]
Time step type: Log
First log step: 1.66667E-04 [min]
# of time steps: 250
Type: Fixed
Fixed value: -12.0 [USgpm]
Wellbore storage: Open

Sequence: F_02

Sequence type: Flow
Start time: 5788.336 [min]
Duration: 4711.664 [min]
Time step type: Log
First log step: 1.66667E-04 [min]
# of time steps: 250
Type: Fixed
Fixed value: 0.0 [USgpm]
Wellbore storage: Open

Test Zone Curves

Curve object to use: P Curve
Curve type: Pressure
Start sequence: H_01
End sequence: H_02
Curve time base: Test
Curve Y data units: [psi]
Curve Y data is log 10: no

Simulation Results Setup

Output ID: DAT
Output type: Pressure
Pressure capture type: Superposition
DAT[1] operation: + Pressure
Type: Constant
Fixed radius: 0.0001 [m]
Output units: [psi]

Output ID: DAT
Output type: Flow Rate
Flow rate output type: Well
Output units [USgpm]

SNL-2 Optimization Settings

**********
nPre 2.30Q
**********

Version date 22 July 2005
Listing date 23 May 2006
QA status QA:Q
Config file C:\nSIGHTS\Culebra\SNL 2\SNL-2.nPre

Parameters

Formation
Formation thickness 25.000 [ft]
Flow dimension 2.0 []
Static formation pressure Optimization
  Minimum value 86.000 [psi]
  Maximum value 110.000 [psi]
  Estimate value 98.376 [psi]
  Range type Linear
  Sigma 1.00000E+00
External boundary radius 1000000 [m]
Formation conductivity f(r) point
Formation spec. storage 1.00000E-06 [1/m]

Fluid
Fluid density 1009.00 [kg/m^3]
Fluid thermal exp. coeff. 0.00000E+00 [1/C]

Test-Zone
Well radius 2.165 [in]
Tubing string radius Optimization
  Minimum value 1.5 [in]
  Maximum value 4.0 [in]
  Estimate value 1.5000144 [in]
  Range type Linear
  Sigma 1.00000E+00

Numeric
# of radial nodes 250 []
Pressure solution tolerance 1.45038E-11 [psi]
STP flow solution tolerance 1.58503E-11 [USgpm]
SNL-2 Fitting Parameter Estimates

Figure B-7. Estimates of radially varying transmissivity derived from the SNL-2 perturbation analysis.

Figure B-8. Estimates of static formation pressure derived from the SNL-2 perturbation analysis.
Figure B-9. Estimates of tubing string radius derived from the SNL-2 perturbation analysis.

Figure B-10. Flow rates measured during the SNL-2 testing.
B.3 SNL-3 nSIGHTS Listings

***********
nPre 2.30Q
***********

Version date   22 July 2005
Listing date   27 Apr 2006
QA status      QA:Q
Config file    C:\nSIGHTS\Culebra\SNL 3\SNL-3.nPre

Control Settings

Test Description

Main Settings
Simulation type                                 Forward
Simulation subtype                               Normal
Phase to simulate                                Liquid
Skin zone ?                                         yes
External boundary                        Fixed Pressure
Curve data source                               Objects

Liquid Phase Settings
Aquifer type                                   Confined
Aquifer horizontal permeability               Isotropic
System porosity                                  Single
Compensate flow dimension geometry                  yes
Leakage                                            None

Test Zone Settings
Test zone volume can vary                            no
Test zone compressibility can vary                   no
Test zone temperature can vary                       no
Default test-zone temperature                     20.00     [C]
Solution variable                              Pressure
Allow negative head/pressure                       yes

Parameters

Formation
Formation thickness  20.000     [ft]
Flow dimenion                                      2.0     []
Static formation pressure                       165.540     [psi]
External boundary radius                        1000000     [m]
Formation conductivity                        f(r) point
Formation spec. storage                     1.00000E-06     [1/m]
Skin
Radial thickness of skin  
0.0000173 [m]  
Skin zone conductivity  
f(t) point  
Skin zone spec. storage  
1.00000E-06 [1/m]

Fluid
Fluid density  
1035.00 [kg/m^3]  
Fluid thermal exp. coeff.  
0.00000E+00 [1/C]

Test-Zone
Well radius  
2.165 [in]  
Tubing string radius  
1.8 [in]

Numeric
# of radial nodes  
250 []  
# of skin nodes  
50 []  
Pressure solution tolerance  
1.45038E-11 [psi]  
STP flow solution tolerance  
1.58503E-11 [USgpm]

f(x) Points Parameters
Formation conductivity
Points type  
f(r)  
Radius #1  
6.0299749 [m]  
Y value#1  
1.53552E-04 [m/sec]  
Radius #2  
763.3368394 [m]  
Y value#2  
1.74206E-05 [m/sec]  
Radius #3  
2588.6872667 [m]  
Y value#3  
9.99827E-06 [m/sec]  
Parameter curve type  
Linear

Skin zone conductivity
Points type  
f(t)  
Time #1  
206444.160000 [day]  
Y value#1  
6.83458E-10 [m/sec]  
Time #2  
207131.761160 [day]  
Y value#2  
3.20516E-10 [m/sec]  
Time #3  
211592.768300 [day]  
Y value#3  
2.50530E-10 [m/sec]  
Time #4  
289669.414910 [day]  
Y value#4  
2.08608E-10 [m/sec]  
Time #5  
403870.639170 [day]  
Y value#5  
1.91428E-10 [m/sec]  
Parameter curve type  
Linear
Calculated Parameters

Formation
Transmissivity f(r)
Storativity 6.09600E-06 []
Diffusivity f(r)

Skin Zone
Transmissivity f(t)
Storativity 6.09600E-06 []
Diffusivity f(t)
Skin factor f(r)

Test Zone
Open hole well-bore storage 6.47025E-07 [m^3/Pa]

Grid Properties
Grid increment delta 0.08400 []
First grid increment 4.82025E-03 [m]
Skin grid increment delta 0.00001 []
Skin first grid increment 3.53484E-07 [m]
Skin last grid increment 3.53593E-07 [m]
Increment ratio 1.36322E+04 []

Sequences

Sequence: H_01
Sequence type History
Start time 1.454250 [day]
Duration 0.935190 [day]
Time step type Static
Static time step 0.050000 [day]
Type Fixed
Fixed value 165.444 [psi]
Wellbore storage Open

Sequence: F_01
Sequence type Flow
Start time 2.389440 [day]
Duration 2.216029 [day]
Time step type Log
First log step 1.15741E-07 [day]
# of time steps 250
Type Fixed
Fixed value -10.0 [USgpm]
Wellbore storage Open

Sequence: F_02
Sequence type Flow
Start time: 4.605469 [day]
Duration: 10.394531 [day]
Time step type: Log
First log step: 1.15741E-07 [day]
# of time steps: 250
Type: Fixed
Fixed value: 0.0 [USgpm]
Wellbore storage: Open

Simulation Results Setup

Output ID: DAT
Output type: Pressure
Pressure capture type: Test Zone
Output units: [psi]

Output ID: DAT
Output type: Flow Rate
Flow rate output type: Well
Output units: [USgpm]

SNL-3 Optimization Settings

******
nPre 2.30Q
******

Version date: 22 July 2005
Listing date: 27 Apr 2006
QA status: QA:Q
Config file: C:\nSIGHTS\Culebra\SNL 3\SNL-3.nPre

Parameters

Formation
Formation thickness: 20.000 [ft]
Flow dimension: 2.0 []
Static formation pressure: Optimization
  Minimum value: 140.000 [psi]
  Maximum value: 180.000 [psi]
  Estimate value: 165.540 [psi]
  Range type: Linear
  Sigma: 1.00000E+00
External boundary radius: 1000000 [m]
Formation conductivity: f(r) point
Formation spec. storage: 1.00000E-06 [l/m]

Skin
Radial thickness of skin: Optimization
  Minimum value: 1.0E-05 [m]
  Maximum value: 1.0 [m]
  Estimate value: 0.0000173 [m]
Range type  
Sigma  
Skin zone conductivity  
Skin zone spec. storage

**Fluid**

Fluid density  
Fluid thermal exp. coeff.

**Test-Zone**

Well radius  
Tubing string radius

**Numeric**

# of radial nodes  
# of skin nodes  
Pressure solution tolerance  
STP flow solution tolerance

**SNL-3 Fitting Parameter Estimates**

![Graph](image)

**Figure B-11.** Estimates of time-varying skin hydraulic conductivity derived from the SNL-3 perturbation analysis.
Figure B-12. Estimates of static formation pressure derived from the SNL-3 perturbation analysis.

Figure B-13. Estimates of skin radius derived from the SNL-3 perturbation analysis.
Figure B-14. Flow rates measured during the SNL-3 testing.
B.4 SNL-5 nSIGHTS Listings

nPre 2.30Q
**********

Version date 22 July 2005
Listing date 27 Apr 2006
QA status QA:Q
Config file C:\nSIGHTS\Culebra\SNL 5\SNL-5.nPre

Control Settings

Main Settings
- Simulation type: Forward
- Simulation subtype: Normal
- Phase to simulate: Liquid
- Skin zone: no
- External boundary: Fixed Pressure
- Curve data source: Objects

Liquid Phase Settings
- Aquifer type: Confined
- Aquifer horizontal permeability: Isotropic
- System porosity: Single
- Compensate flow dimension geometry: yes
- Leakage: None

Test Zone Settings
- Test zone volume can vary: no
- Test zone compressibility can vary: no
- Test zone temperature can vary: no
- Default test-zone temperature: 20.00 [C]
- Solution variable: Pressure
- Allow negative head/pressure: yes

Parameters

Formation
- Formation thickness: 7.0104 [m]
- Flow dimension: 2.0 [ ]
- Static formation pressure: 155.335 [psi]
- External boundary radius: 1000000 [m]
- Formation conductivity: f(r) point
- Formation spec. storage: 9.48085E-07 [1/m]

Fluid
- Fluid density: 1011.00 [kg/m^3]
- Fluid thermal exp. coeff.: 0.000000E+00 [1/C]
Test-Zone
Well radius 2.165 [in]
Tubing string radius 1.8175729 [in]

Numeric
# of radial nodes 250 
Pressure solution tolerance 1.45038E-11 [psi]
STP flow solution tolerance 1.58503E-11 [USgpm]

f(x) Points Parameters

Formation conductivity
Points type \( f(r) \)
Radius #1 50.369803 [m]
Y value#1 1.09028E-06 [m/sec]
Radius #2 82.8396426 [m]
Y value#2 4.21197E-07 [m/sec]
Radius #3 1248.930036 [m]
Y value#3 3.24706E-06 [m/sec]
Parameter curve type Linear

Calculated Parameters

Formation
Transmissivity \( f(r) \)
Storativity 6.64645E-06 []
Diffusivity \( f(r) \)

Test Zone
Open hole well-bore storage 6.75381E-07 [m^3/Pa]

Grid Properties
Grid increment delta 0.06713 []
First grid increment 3.81844E-03 [m]

Sequences

Sequence: H_01
Sequence type History
Start time 0.000 [min]
Duration 145.114 [min]
Time step type Static
Static time step 1.000 [min]
Type Curve
Wellbore storage Open
Sequence: H_02

Sequence type: History
Start time: 145.114 [min]
Duration: 206.947 [min]
Time step type: Static
Static time step: 0.167 [min]
Type: Curve
Wellbore storage: Open

Sequence: F_01

Sequence type: Flow
Start time: 352.061 [min]
Duration: 983.687 [min]
Time step type: Log
First log step: 1.66667E-04 [min]
# of time steps: 250
Type: Fixed
Fixed value: 0.0 [USgpm]
Wellbore storage: Open

Sequence: F_02

Sequence type: Flow
Start time: 1335.748 [min]
Duration: 5647.770 [min]
Time step type: Log
First log step: 1.66667E-04 [min]
# of time steps: 250
Type: Fixed
Fixed value: -3.5 [USgpm]
Wellbore storage: Open

Sequence: F_03

Sequence type: Flow
Start time: 6983.518 [min]
Duration: 36116.482 [min]
Time step type: Log
First log step: 1.66667E-04 [min]
# of time steps: 250
Type: Fixed
Fixed value: 0.0 [USgpm]
Wellbore storage: Open

Test Zone Curves

Curve object to use: P Curve
Curve type: Pressure
Start sequence: H_01
End sequence: H_02
Curve time base: Test
Curve Y data units: [psi]
Curve Y data is log 10: no
Simulation Results Setup

Output ID DAT  
Output type Pressure  
Pressure capture type Test Zone  
Output units [psi]

Output ID DAT  
Output type Flow Rate  
Flow rate output type Well  
Output units [USgpm]

Output ID P_S_01  
Output type Pressure  
Pressure capture type Superposition  
P_S_01[1] operation + Pressure  
Type Constant  
Fixed radius 0.001 [m]  
Output units [psi]

SNL-5 Optimization Settings

**********
nPre 2.30Q  
**********

Version date 22 July 2005  
Listing date 27 Apr 2006  
QA status QA:Q  
Config file C:\nSIGHTS\Culebra\SNL 5\SNL-5.nPre

Parameters

Formation

Formation thickness 7.0104 [m]  
Flow dimension 2.0 [ ]  
Static formation pressure Optimization  
Minimum value 140.000 [psi]  
Maximum value 175.000 [psi]  
Estimate value 155.335 [psi]  
Range type Linear  
Sigma 1.00000E+00  
External boundary radius 100000 [m]  
Formation conductivity f(r) point  
Formation spec. storage Optimization  
Minimum value 1.00000E-08 [1/m]  
Maximum value 1.00000E-04 [1/m]  
Estimate value 9.48085E-07 [1/m]  
Range type Log  
Sigma 1.00000E+00
Fluid
Fluid density                                   1011.00     [kg/m^3]
Fluid thermal exp. coeff.                   0.00000E+00     [1/C]

Test-Zone
Well radius                                        2.165     [in]
Tubing string radius                       Optimization
    Minimum value                                    1.2     [in]
    Maximum value                                  2.166     [in]
    Estimate value                             1.8175729     [in]
    Range type                                    Linear
    Sigma                                    1.00000E+00

Numeric
# of radial nodes                                   250     []
Pressure solution tolerance                  1.45038E-11     [psi]
STP flow solution tolerance                  1.58503E-11     [USgpm]

SNL-5 Fitting Parameter Estimates

Figure B-15. Estimates of specific storage derived from the SNL-5 perturbation analysis.
Figure B-16. Estimates of static formation pressure derived from the SNL-5 perturbation analysis.

Figure B-17. Estimates of tubing string radius derived from the SNL-5 perturbation analysis.
Figure B-18. Flow rates measured during the SNL-5 testing.
### B.5 SNL-9 nSIGHTS Listings

**nPre 2.30Q**

#### Control Settings

**Main Settings**
- Simulation type: Forward
- Simulation subtype: Normal
- Phase to simulate: Liquid
- Skin zone?: yes
- External boundary: Fixed Pressure
- Curve data source: Objects

**Liquid Phase Settings**
- Aquifer type: Confined
- Aquifer horizontal permeability: Isotropic
- System porosity: Dual
- Matrix block type: Prismatic
- Compensate flow dimension geometry: yes
- Leakage: None

**Test Zone Settings**
- Test zone volume can vary: no
- Test zone compressibility can vary: no
- Test zone temperature can vary: no
- Default test-zone temperature: 20.00 °C
- Solution variable: Pressure
- Allow negative head/pressure: yes

**Parameters**

**Formation**
- Formation thickness: 23.00 ft
- Flow dimension: 2.0
- Static formation pressure: 120.303 psi
- External boundary radius: 1000000 m

**Fracture**
- Fracture conductivity: 5.39328E-04 m/sec
- Fracture spec. storage: 2.61158E-08 l/m
<table>
<thead>
<tr>
<th><strong>Matrix</strong></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Matrix volume factor</td>
<td>0.990000</td>
<td>[decimal]</td>
<td></td>
</tr>
<tr>
<td>Geometry factor (Alpha)</td>
<td>1200</td>
<td>[1/m^2]</td>
<td></td>
</tr>
<tr>
<td>Matrix conductivity</td>
<td>1.01579E-12</td>
<td>[m/sec]</td>
<td></td>
</tr>
<tr>
<td>Matrix spec. storage</td>
<td>3.59532E-04</td>
<td>[1/m]</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Skin</strong></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Radial thickness of skin</td>
<td>0.0904817</td>
<td>[m]</td>
<td></td>
</tr>
<tr>
<td>Skin zone conductivity</td>
<td>4.44686E-05</td>
<td>[m/sec]</td>
<td></td>
</tr>
<tr>
<td>Skin zone spec. storage</td>
<td>6.94574E-07</td>
<td>[1/m]</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Fluid</strong></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Fluid density</td>
<td>1022.00</td>
<td>[kg/m^3]</td>
<td></td>
</tr>
<tr>
<td>Fluid thermal exp. coeff.</td>
<td>0.00000E+00</td>
<td>[1/C]</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Test-Zone</strong></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Well radius</td>
<td>4.21</td>
<td>[in]</td>
<td></td>
</tr>
<tr>
<td>Tubing string radius</td>
<td>4.0</td>
<td>[in]</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Numeric</strong></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td># of radial nodes</td>
<td>250</td>
<td>[]</td>
<td></td>
</tr>
<tr>
<td># of skin nodes</td>
<td>50</td>
<td>[]</td>
<td></td>
</tr>
<tr>
<td># of matrix nodes</td>
<td>1</td>
<td>[]</td>
<td></td>
</tr>
</tbody>
</table>

### Calculated Parameters

<table>
<thead>
<tr>
<th><strong>Dual Porosity</strong></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Fracture thickness</td>
<td>0.070104</td>
<td>[m]</td>
<td></td>
</tr>
<tr>
<td>Matrix thickness</td>
<td>6.940296</td>
<td>[m]</td>
<td></td>
</tr>
<tr>
<td>Lambda - interporosity flow</td>
<td>2.58442E-06</td>
<td>[]</td>
<td></td>
</tr>
<tr>
<td>Omega - storativity ratio</td>
<td>7.33720E-07</td>
<td>[]</td>
<td></td>
</tr>
<tr>
<td>Beta - transient parameter</td>
<td>3.52236E+00</td>
<td>[]</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Skin Zone</strong></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Transmissivity</td>
<td>3.11743E-04</td>
<td>[m^2/sec]</td>
<td></td>
</tr>
<tr>
<td>Storativity</td>
<td>4.86924E-06</td>
<td>[]</td>
<td></td>
</tr>
<tr>
<td>Diffusivity</td>
<td>6.40228E+01</td>
<td>[m^2/sec]</td>
<td></td>
</tr>
<tr>
<td>Skin factor</td>
<td>6.82275E+00</td>
<td>[]</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Test Zone</strong></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Open hole well-bore storage</td>
<td>3.23900E-06</td>
<td>[m^3/Pa]</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Grid Properties</strong></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Grid increment delta</td>
<td>0.07758</td>
<td>[]</td>
<td></td>
</tr>
<tr>
<td>First grid increment</td>
<td>1.59248E-02</td>
<td>[m]</td>
<td></td>
</tr>
<tr>
<td>Skin grid increment delta</td>
<td>0.01251</td>
<td>[]</td>
<td></td>
</tr>
<tr>
<td>Skin first grid increment</td>
<td>1.34639E-03</td>
<td>[m]</td>
<td></td>
</tr>
<tr>
<td>Skin last grid increment</td>
<td>2.45472E-03</td>
<td>[m]</td>
<td></td>
</tr>
</tbody>
</table>
Sequences

Sequence: H_01
- Sequence type: History
- Start time: 17000.000 [min]
- Duration: 1876.000 [min]
- Time step type: Static
- Static time step: 100.000 [min]
- Type: Curve
- Wellbore storage: None

Sequence: F_01
- Sequence type: Flow
- Start time: 18876.000 [min]
- Duration: 5438.598 [min]
- Time step type: Static
- Static time step: 1.000 [min]
- Type: Fixed
- Fixed value: -12.5 [USgpm]
- Wellbore storage: Open

Sequence: F_02
- Sequence type: Flow
- Start time: 24314.598 [min]
- Duration: 147090.402 [min]
- Time step type: Log
- First log step: 1.66667E-04 [min]
- # of time steps: 250
- Type: Fixed
- Fixed value: 0.0 [USgpm]
- Wellbore storage: Open

Test Zone Curves
- Curve object to use: Pressure Curve
- Curve type: Pressure
- Start sequence: H_01
- End sequence: H_01
- Curve time base: Test
- Curve Y data units: [psi]
- Curve Y data is log 10: no

Simulation Results Setup
- Output ID: DAT
- Output type: Pressure
- Pressure capture type: Test Zone
- Output units: [psi]
SNL-9 Optimization Settings

**********
nPre 2.30Q
**********

Version date   22 July 2005
Listing date   28 Apr 2006
QA status      QA:Q
Config file    C:\nSIGHTS\Culebra\SNL 9\SNL-9.nPre

Parameters

Formation
Formation thickness    23.000     [ft]
Flow dimension         2.0     []
Static formation pressure 120.303     [psi]
External boundary radius 1000000     [m]

Fracture
Fracture conductivity  5.39328E-04     [m/sec]
Fracture spec. storage  2.61158E-08     [1/m]

Matrix
Matrix volume factor   0.990000     [decimal]
Geometry factor (Alpha) 1200     [1/m^2]
Matrix conductivity    1.01579E-12     [m/sec]
Matrix spec. storage   3.59532E-04     [1/m]

Skin
Radial thickness of skin 0.0904817     [m]
Skin zone conductivity  4.44686E-05     [m/sec]
Skin zone spec. storage  6.94574E-07     [1/m]

Fluid
Fluid density          1021.00     [kg/m^3]
Fluid thermal exp. coeff. 0.000000E+00     [1/C]

Test-Zone
Well radius           4.21     [in]
Tubing string radius  4.0     [in]
Numeric

# of radial nodes  
250 

# of skin nodes  
50 

# of matrix nodes  
1 

SNL-9 Fitting Parameter Estimates

Figure B-19. Estimates of lambda and omega derived from the SNL-9 perturbation analysis.
Figure B-20. Estimates of fracture and matrix specific storage derived from the SNL-9 perturbation analysis.

Figure B-21. Estimates of fracture transmissivity and matrix hydraulic conductivity derived from the SNL-9 perturbation analysis.
Figure B-22. Estimates of static formation pressure derived from the SNL-9 perturbation analysis.

Figure B-23. Estimates of skin specific storage derived from the SNL-9 perturbation analysis.
Figure B-24. Estimates of skin hydraulic conductivity and radius derived from the SNL-9 perturbation analysis.

Figure B-25. Flow rates measured during the SNL-9 testing.
B.6 SNL-12 nSIGHTS Listings

**********
nPre 2.30Q
**********

Version date   22 July 2005
Listing date   22 May 2006
QA status      QA:Q
Config file    C:\nSIGHTS\Culebra\SNL 12\SNL-12.nPre

Control Settings

Main Settings
Simulation type                                 Forward
Simulation subtype                               Normal
Phase to simulate                                Liquid
Skin zone ?                                         yes
External boundary                        Fixed Pressure
Curve data source                               Objects

Liquid Phase Settings
Aquifer type                                   Confined
Aquifer horizontal permeability               Isotropic
System porosity                                    Dual
Matrix block type                             Prismatic
Compensate flow dimension geometry                  yes
Leakage                                            None

Test Zone Settings
Test zone volume can vary                            no
Test zone compressibility can vary                   no
Test zone temperature can vary                       no
Default test-zone temperature                      20.00     [C]
Solution variable                              Pressure
Allow negative head/pressure                      yes

Parameters

Formation
Formation thickness                              40.000     [ft]
Flow dimension                               f(r) point
Static formation pressure                       112.680     [psi]
External boundary radius                        1000000     [m]

Fracture
Fracture conductivity                       4.15134E-03     [m/sec]
Fracture spec. storage                      2.28474E-10     [1/m]
### Matrix

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Matrix volume factor</td>
<td>0.990000</td>
</tr>
<tr>
<td>Geometry factor (Alpha)</td>
<td>1200</td>
</tr>
<tr>
<td>Matrix conductivity</td>
<td>5.66514E-12</td>
</tr>
<tr>
<td>Matrix spec. storage</td>
<td>1.24864E-04</td>
</tr>
</tbody>
</table>

### Skin

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radial thickness of skin</td>
<td>0.0005369</td>
</tr>
<tr>
<td>Skin zone conductivity</td>
<td>f(t) point</td>
</tr>
<tr>
<td>Skin zone spec. storage</td>
<td>1.91614E-07</td>
</tr>
</tbody>
</table>

### Fluid

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fluid density</td>
<td>1004.40</td>
</tr>
<tr>
<td>Fluid thermal exp. coeff.</td>
<td>0.00000E+00</td>
</tr>
</tbody>
</table>

### Test-Zone

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Well radius</td>
<td>2.165</td>
</tr>
<tr>
<td>Tubing string radius</td>
<td>2.0</td>
</tr>
</tbody>
</table>

### Numeric

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td># of radial nodes</td>
<td>250</td>
</tr>
<tr>
<td># of skin nodes</td>
<td>50</td>
</tr>
<tr>
<td># of matrix nodes</td>
<td>6</td>
</tr>
</tbody>
</table>

### f(x) Points Parameters

#### Flow dimension

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Points type</td>
<td>f(r)</td>
</tr>
<tr>
<td>Radius #1</td>
<td>0.3592</td>
</tr>
<tr>
<td>Y value#1</td>
<td>2.0</td>
</tr>
<tr>
<td>Radius #2</td>
<td>135.1541817</td>
</tr>
<tr>
<td>Y value#2</td>
<td>-0.0525097</td>
</tr>
</tbody>
</table>

#### Skin zone conductivity

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Points type</td>
<td>f(t)</td>
</tr>
<tr>
<td>Time #1</td>
<td>9060.179</td>
</tr>
<tr>
<td>Y value#1</td>
<td>2.03363E-06</td>
</tr>
<tr>
<td>Time #2</td>
<td>16558.731</td>
</tr>
<tr>
<td>Y value#2</td>
<td>6.32041E-07</td>
</tr>
<tr>
<td>Time #3</td>
<td>25671.391</td>
</tr>
<tr>
<td>Y value#3</td>
<td>9.71358E-07</td>
</tr>
<tr>
<td>Time #4</td>
<td>74202.915</td>
</tr>
<tr>
<td>Y value#4</td>
<td>9.22399E-07</td>
</tr>
<tr>
<td>Time #5</td>
<td>90410.819</td>
</tr>
<tr>
<td>Y value#5</td>
<td>7.20814E-07</td>
</tr>
<tr>
<td>Time #6</td>
<td>219981.144</td>
</tr>
<tr>
<td>Y value#6</td>
<td>7.27608E-07</td>
</tr>
</tbody>
</table>
Parameter curve type  Linear

Calculated Parameters

Dual Porosity
Fracture thickness  0.12192 [m]
Matrix thickness  12.07008 [m]
Lambda - interporosity flow  4.95207E-07 []
Omega - storativity ratio  1.84827E-08 []
Beta - transient parameter  2.67930E+01 []

Skin Zone
Transmissivity  f(t)
Storativity  2.33616E-06 []
Diffusivity  f(t)
Skin factor  f(t)

Test Zone
Open hole well-bore storage  3.56965E-02 [STB/psi]

Grid Properties
Grid increment delta  0.08395 []
First grid increment  4.86293E-03 [m]
Skin grid increment delta  0.00020 []
Skin first grid increment  1.09048E-05 [m]
Skin last grid increment  1.10091E-05 [m]
Increment ratio  4.41718E+02 []
Number of nodes  1244 []

Sequences

Sequence: H_01
Sequence type  History
Start time  -171261.852 [min]
Duration  171436.852 [min]
Time step type  Static
Static time step  200.000 [min]
Type  Curve
Wellbore storage  None

Sequence: H_02
Sequence type  History
### Start time
- **175.000 [min]**  
### Duration
- **11.050 [min]**  
### Time step type
- Static  
### Static time step
- 0.100 [min]  
### Type
- Curve  
### Wellbore storage
- None  

#### Sequence: F_01
- **Sequence type**: Flow  
- **Start time**: 186.050 [min]  
- **Duration**: 162.350 [min]  
- **Time step type**: Static  
- **Static time step**: 0.167 [min]  
- **Type**: Curve  
- **Wellbore storage**: Open  

#### Sequence: F_02
- **Sequence type**: Flow  
- **Start time**: 348.400 [min]  
- **Duration**: 1004.400 [min]  
- **Time step type**: Log  
- **First log step**: 1.66667E-04 [min]  
- **# of time steps**: 250  
- **Type**: Fixed  
- **Fixed value**: 0.0 [USgpm]  
- **Wellbore storage**: Open  

#### Sequence: F_03
- **Sequence type**: Flow  
- **Start time**: 1352.800 [min]  
- **Duration**: 5742.050 [min]  
- **Time step type**: Log  
- **First log step**: 1.66667E-04 [min]  
- **# of time steps**: 250  
- **Type**: Curve  
- **Wellbore storage**: Open  

#### Sequence: F_04
- **Sequence type**: Flow  
- **Start time**: 7094.850 [min]  
- **Duration**: 44709.150 [min]  
- **Time step type**: Log  
- **First log step**: 1.66667E-04 [min]  
- **# of time steps**: 250  
- **Type**: Fixed  
- **Fixed value**: 0.0 [USgpm]  
- **Wellbore storage**: Open  

#### Test Zone Curves
- **Curve object to use**: Create Curve  
- **Curve type**: Flow Rate  
- **Start sequence**: F_01  
- **End sequence**: F_04
Curve time base                                    Test  
Curve Y data units                              [USgpm]  
Curve Y data is log 10                               no  
Curve object to use                             P Curve  
Curve type                                     Pressure  
Start sequence                                     H_01  
End sequence                                       H_02  
Curve time base                                    Test  
Curve Y data units                                [psi]  
Curve Y data is log 10                               no  

Simulation Results Setup

Output ID                                           DAT  
Output type                                  Pressure  
Pressure capture type                       Test Zone  
Output units                                    [psi]  

Output ID                                           DAT  
Output type                                 Flow Rate  
Flow rate output type                            Well  
Output units                                  [USgpm]  

Output ID                                         BOUND  
Output type                                 Pressure  
Pressure capture type                   Superposition  
BOUND[1] operation                        + Pressure  
    Type                                       Constant  
Fixed radius                                 0.0001     [m]  
Output units                                    [psi]  

SNL-12 nSIGHTS Optimization Settings

**********
nPre 2.30Q  
**********

Version date   22 July 2005  
Listing date   22 May 2006  
QA status      QA:Q  
Config file    C:\nSIGHTS\Culebra\SNL 12\SNL-12 - dbl poro - sans Bourdet.nPre

Parameters

Formation

Formation thickness                                40.000     [ft]  
Flow dimension                                  f(r) point  
Static formation pressure                         Optimization  
    Minimum value                                      103.000     [psi]
Maximum value                                115.000     [psi]
Estimate value                               112.680     [psi]
Range type                                    Linear
Sigma                                    1.00000E+00
External boundary radius                        1000000     [m]

Fracture
Fracture conductivity                      Optimization
   Minimum value                            1.00000E-06     [m/sec]
   Maximum value                            1.00000E-01     [m/sec]
   Estimate value                           4.15134E-03     [m/sec]
   Range type                                       Log
   Sigma                                    1.00000E+00
Fracture spec. storage                     Optimization
   Minimum value                            1.00000E-11     [1/m]
   Maximum value                            1.00000E-05     [1/m]
   Estimate value                           2.28474E-10     [1/m]
   Range type                                       Log
   Sigma                                    1.00000E+00

Matrix
Matrix volume factor                           0.990000     [decimal]
Geometry factor (Alpha)                            1200     [1/m^2]
Matrix conductivity                        Optimization
   Minimum value                            1.00000E-14     [m/sec]
   Maximum value                            1.00000E-07     [m/sec]
   Estimate value                           5.66514E-12     [m/sec]
   Range type                                       Log
   Sigma                                    1.00000E+00
Matrix spec. storage                       Optimization
   Minimum value                            1.00000E-07     [1/m]
   Maximum value                            1.00000E-02     [1/m]
   Estimate value                           1.24864E-04     [1/m]
   Range type                                       Log
   Sigma                                    1.00000E+00

Skin
Radial thickness of skin                   Optimization
   Minimum value                                1.0E-05     [m]
   Maximum value                                   10.0     [m]
   Estimate value                               0.0005369     [m]
   Range type                                       Log
   Sigma                                    1.00000E+00
Skin zone conductivity                       f(t) point
Skin zone spec. storage                    Optimization
   Minimum value                            1.00000E-07     [1/m]
   Maximum value                            1.00000E-02     [1/m]
   Estimate value                           1.91614E-07     [1/m]
   Range type                                       Log
   Sigma                                    1.00000E+00

Fluid
Fluid density                                   1004.40     [kg/m^3]
Fluid thermal exp. coeff.                   0.00000E+00     [1/C]

**Test-Zone**

Well radius                             2.165     [in]
Tubing string radius                     2.0      [in]

**Numeric**

# of radial nodes                        250     []
# of skin nodes                          50     []
# of matrix nodes                        6      []
SNL-12 Fitting Parameter Estimates

Figure B-26. Estimates of radially varying flow dimension derived from the SNL-12 perturbation analysis.

Figure B-27. Estimates of static formation pressure derived from the SNL-12 perturbation analysis.
Figure B-28. Estimates of time-varying skin hydraulic conductivity derived from the SNL-12 perturbation analysis.

Figure B-29. Estimates of skin specific storage derived from the SNL-12 perturbation analysis.
Figure B-30. Estimates of skin radius derived from the SNL-12 perturbation analysis.

Figure B-31. Estimates of fracture and matrix specific storage derived from the SNL-12 perturbation analysis.
Figure B-32. Estimates of fracture and matrix specific storage derived from the SNL-12 perturbation analysis.

Figure B-33. Estimates of fracture transmissivity and matrix hydraulic conductivity derived from the SNL-12 perturbation analysis.
Figure B-34. Flow rates measured during the SNL-12 testing.
B.7 SNL-14 nSIGHTS Listings

**********
nPre 2.30Q
**********

Version date   22 July 2005
Listing date    23 May 2006
QA status      QA:Q
Config file    C:\nSIGHTS\Culebra\SNL 14\SNL-14.nPre

Control Settings

Main Settings
Simulation type                                 Forward
Simulation subtype                               Normal
Phase to simulate                                Liquid
Skin zone ?                                         yes
External boundary                        Fixed Pressure
Curve data source                               Objects

Liquid Phase Settings
Aquifer type                                   Confined
Aquifer horizontal permeability               Isotropic
System porosity                                    Dual
Matrix block type                             Prismatic
Compensate flow dimension geometry                  yes
Leakage                                            None

Test Zone Settings
Test zone volume can vary                            no
Test zone compressibility can vary                   no
Test zone temperature can vary                       no
Default test-zone temperature                     20.00     [C]
Solution variable                              Pressure
Allow negative head/pressure                        yes

Parameters

Formation
Formation thickness                              27.000     [ft]
Flow dimension                                      2.0     []
Static formation pressure                       121.316     [psi]
External boundary radius                        1000000     [m]

Fracture
Fracture conductivity                       6.08099E-04     [m/sec]
Fracture spec. storage                      3.79982E-07     [l/m]
Matrix
Matrix volume factor                           0.990000     [decimal]
Geometry factor (Alpha)                            1200     [1/m^2]
Matrix conductivity                         2.96239E-12     [m/sec]
Matrix spec. storage                        4.22988E-05     [l/m]

Skin
Radial thickness of skin                      5.5191819     [m]
Skin zone conductivity                       f(t) point
Skin zone spec. storage                     1.00000E-06     [l/m]

Fluid
Fluid density                                   1060.00     [kg/m^3]
Fluid thermal exp. coeff.                   0.00000E+00     [1/C]

Test-Zone
Well radius                                       2.425     [in]
Tubing string radius                          1.7229424     [in]

Numeric
# of radial nodes                                   250     []
# of skin nodes                                      50     []
# of matrix nodes                                     4     []

f(x) Points Parameters
Skin zone conductivity
Points type                                        f(t)
Time #1                                       0.000000     [day]
Y value#1                                  1.37594E-03     [m/sec]
Time #2                                   175807.917390     [day]
Y value#2                                  1.17065E-03     [m/sec]
Time #3                                   1874850.258500     [day]
Y value#3                                  1.12243E-03     [m/sec]
Time #4                                  2399873.998100     [day]
Y value#4                                  3.11687E-02     [m/sec]
Parameter curve type                             Linear

Calculated Parameters

Dual Porosity
Fracture thickness                             0.082296     [m]
Matrix thickness                                8.147304     [m]
Lambda - interporosity flow                    2.21789E-06     []
Omega - storativity ratio                      9.07320E-05     []
Beta - transient parameter                    2.44445E-02     []
Skin Zone
Transmissivity \(f(t)\)
Storativity \(8.22960E-06\) [\(\cdot\)]
Diffusivity \(f(t)\)
Skin factor \(f(t)\)

Test Zone
Open hole well-bore storage \(5.78831E-07\) [\(\text{m}^3/\text{Pa}\)]

Grid Properties
Grid increment delta \(0.06078\) [\(\cdot\)]
First grid increment \(3.49749E-01\) [\(\text{m}\)]
Skin grid increment delta \(0.09197\) [\(\cdot\)]
Skin first grid increment \(5.93353E-03\) [\(\text{m}\)]
Skin last grid increment \(4.90366E-01\) [\(\text{m}\)]
Increment ratio \(7.13240E-01\) [\(\cdot\)]
Number of nodes 846 [\(\cdot\)]

Sequences
Sequence: H_01
Sequence type History
Start time \(-50.010420\) [\(\text{day}\)]
Duration \(34.960420\) [\(\text{day}\)]
Time step type Static
Static time step \(0.100000\) [\(\text{day}\)]
Type Curve
Wellbore storage None

Sequence: H_02
Sequence type History
Start time \(-15.050000\) [\(\text{day}\)]
Duration \(0.020000\) [\(\text{day}\)]
Time step type Static
Static time step \(0.000100\) [\(\text{day}\)]
Type Curve
Wellbore storage None

Sequence: H_03
Sequence type History
Start time \(-15.030000\) [\(\text{day}\)]
Duration \(0.033890\) [\(\text{day}\)]
Time step type Static
Static time step \(0.000500\) [\(\text{day}\)]
Type Curve
Wellbore storage None

Sequence: H_04
Sequence type History
Start time                                 -14.996110     [day]
Duration                                     0.013550     [day]
Time step type                                 Static
Static time step                             0.000116     [day]
Type                                            Curve
Wellbore storage                                 None

**Sequence: H_05**

Sequence type                                 History
Start time                                 -14.982560     [day]
Duration                                    14.982560     [day]
Time step type                                 Static
Static time step                             0.005000     [day]
Type                                            Curve
Wellbore storage                                 None

**Sequence: H_06**

Sequence type                                 History
Start time                                   0.000000     [day]
Duration                                    0.166450     [day]
Time step type                                 Static
Static time step                             0.001157     [day]
Type                                            Curve
Wellbore storage                                 None

**Sequence: F_01**

Sequence type                                    Flow
Start time                                   0.166450     [day]
Duration                                    21.650400     [day]
Time step type                                   Log
First log step                           1.15741E-07     [day]
# of time steps                                   250
Type                                            Curve
Wellbore storage                                 Open

**Sequence: F_02**

Sequence type                                    Flow
Start time                                   21.816850     [day]
Duration                                    130.183150     [day]
Time step type                                   Log
First log step                           1.15741E-07     [day]
# of time steps                                   250
Type                                            Fixed
Fixed value                                       0.0     [USgpm]
Wellbore storage                                 Open

**Test Zone Curves**

Curve object to use                             P Curve
Curve type                                           Pressure
Start sequence                                 H_01
End sequence                                  H_06
Curve time base                                  Test
Curve Y data units                                [psi]
Curve Y data is log 10

no

Curve object to use

Q Curve

Curve type

Flow Rate

Start sequence

F_01

End sequence

F_01

Curve time base

Test

Curve Y data units

[USgpm]

Curve Y data is log 10

no

Simulation Results Setup

Output ID

DAT

Output type

Pressure

Pressure capture type

Superposition

DAT[1] operation

+ Pressure

Type

Constant

Fixed radius

1.0 [m]

DAT[2] operation

- Delta P

Type

Constant

Fixed radius

1220.866283 [m]

Output units

[psi]

Output ID

DAT

Output type

Flow Rate

Flow rate output type

Well

Output units

[USgpm]

SNL-14 Optimization Settings

**********
nPre 2.30Q
**********

Version date 22 July 2005
Listing date 23 May 2006
QA status QA:Q
Config file C:\nSIGHTS\Culebra\SNL 14\SNL-14.nPre

f(x) Points Parameters

Skin zone conductivity

Points type

f(t)

Time #1

0.000000 [day]

Y value#1

Optimized

Time #2

Optimized

Minimum

86400.000000 [day]

Estimat

175807.917390 [day]

Maximum

734400.000000 [day]

Y value#2

Optimized

Time #3

Optimized

Minimum

735264.000000 [day]
SNL-14 Fitting Parameter Estimates

Figure B-35. Estimates of Lambda and Omega derived from the SNL-14 perturbation analysis.
Figure B-36. Estimates of fracture and matrix specific storage derived from the SNL-14 perturbation analysis.

Figure B-37. Estimates of fracture transmissivity and matrix hydraulic conductivity derived from the SNL-14 perturbation analysis.
Figure B-38. Estimates of skin radius derived from the SNL-14 perturbation analysis.

Figure B-39. Estimates of distance to linear no-flow boundary derived from the SNL-14 perturbation analysis.
Figure B-40. Estimates of tubing string radius derived from the SNL-14 perturbation analysis.

Figure B-41. Estimates of static formation pressure derived from the SNL-14 perturbation analysis.
Figure B-42. Flow rates measured during the SNL-14 testing.
B.8  WIPP-11 nSIGHTS Listings

**********
nPre 2.30Q
**********

Version date   22 July 2005
Listing date   02 May 2006
QA status      QA:Q
Config file    C:\nSIGHTS\Culebra\WIPP 11\WIPP 11 - new Ss.nPre

Control Settings

Main Settings
Simulation type                                 Forward
Simulation subtype                               Normal
Phase to simulate                                Liquid
Skin zone ?                                         yes
External boundary                        Fixed Pressure
Curve data source                               Objects

Liquid Phase Settings
Aquifer type                                   Confined
Aquifer horizontal permeability               Isotropic
System porosity                                  Single
Compensate flow dimension geometry                  yes
Leakage                                            None

Test Zone Settings
Test zone volume can vary                            no
Test zone compressibility can vary                   no
Test zone temperature can vary                       no
Default test-zone temperature                     20.00     [C]
Solution variable                              Pressure
Allow negative head/pressure                          yes

Parameters

Formation
Formation thickness                              23.000     [ft]
Flow dimension                                         2.0     []
Static formation pressure                       106.497     [psi]
External boundary radius                        1000000     [m]
Formation conductivity                       f(r) point
Formation spec. storage                     1.00000E-06     [1/m]

Skin
Radial thickness of skin                               0.0047474     [m]
Skin zone conductivity                           6.61728E-04     [m/sec]
Skin zone spec. storage 1.00000E-04 [l/m]

Fluid
Fluid density 1038.00 [kg/m^3]
Fluid thermal exp. coeff. 0.00000E+00 [1/C]

Test-Zone
Well radius 4.4605 [in]
Tubing string radius 0.405 [ft]

Numeric
# of radial nodes 250 []
# of skin nodes 50 []
Pressure solution tolerance 1.45038E-11 [psi]
STP flow solution tolerance 1.58503E-11 [USgpm]

f(x) Points Parameters

Formation conductivity

<table>
<thead>
<tr>
<th>Points type</th>
<th>f(r)</th>
<th>Radius</th>
<th>Y value</th>
</tr>
</thead>
<tbody>
<tr>
<td>#1</td>
<td></td>
<td>28.16815</td>
<td>2.43671E-04</td>
</tr>
<tr>
<td>#2</td>
<td></td>
<td>277.5993399</td>
<td>1.02754E-05</td>
</tr>
<tr>
<td>#3</td>
<td></td>
<td>1300.4607014</td>
<td>6.22036E-05</td>
</tr>
<tr>
<td>#4</td>
<td></td>
<td>2540.1901332</td>
<td>3.63627E-05</td>
</tr>
<tr>
<td>#5</td>
<td></td>
<td>5805.4107287</td>
<td>1.03456E-05</td>
</tr>
<tr>
<td>#6</td>
<td></td>
<td>9934.8825796</td>
<td>4.00114E-05</td>
</tr>
</tbody>
</table>

Parameter curve type Linear

Calculated Parameters

Formation
Transmissivity f(r) 7.01040E-06 []
Storativity 7.01040E-06 []
Diffusivity f(r)

Skin Zone
Transmissivity 4.63898E-03 [m^2/sec]
Storativity 7.01040E-04 []
Diffusivity 6.61728E+00 [m^2/sec]
Skin factor f(r)
### Test Zone

Open hole well-bore storage 4.69662E-06 [m^3/Pa]

### Grid Properties

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grid increment delta</td>
<td>0.08016</td>
</tr>
<tr>
<td>First grid increment</td>
<td>9.85224E-03         [m]</td>
</tr>
<tr>
<td>Skin grid increment delta</td>
<td>0.00084</td>
</tr>
<tr>
<td>Skin first grid increment</td>
<td>9.49505E-05         [m]</td>
</tr>
<tr>
<td>Skin last grid increment</td>
<td>9.88463E-05         [m]</td>
</tr>
<tr>
<td>Increment ratio</td>
<td>9.96724E+01</td>
</tr>
</tbody>
</table>

### Sequences

**Sequence: H_01**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sequence type</td>
<td>History</td>
</tr>
<tr>
<td>Start time</td>
<td>0.000000            [day]</td>
</tr>
<tr>
<td>Duration</td>
<td>0.074990            [day]</td>
</tr>
<tr>
<td>Time step type</td>
<td>Static</td>
</tr>
<tr>
<td>Static time step</td>
<td>0.000100            [day]</td>
</tr>
<tr>
<td>Type</td>
<td>Curve</td>
</tr>
<tr>
<td>Wellbore storage</td>
<td>None</td>
</tr>
</tbody>
</table>

**Sequence: F_01**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sequence type</td>
<td>Flow</td>
</tr>
<tr>
<td>Start time</td>
<td>0.074990            [day]</td>
</tr>
<tr>
<td>Duration</td>
<td>0.147470            [day]</td>
</tr>
<tr>
<td>Time step type</td>
<td>Log</td>
</tr>
<tr>
<td>First log step</td>
<td>1.15741E-07         [day]</td>
</tr>
<tr>
<td># of time steps</td>
<td>250</td>
</tr>
<tr>
<td>Type</td>
<td>Curve</td>
</tr>
<tr>
<td>Wellbore storage</td>
<td>Open</td>
</tr>
</tbody>
</table>

**Sequence: F_02**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sequence type</td>
<td>Flow</td>
</tr>
<tr>
<td>Start time</td>
<td>0.222460            [day]</td>
</tr>
<tr>
<td>Duration</td>
<td>0.742120            [day]</td>
</tr>
<tr>
<td>Time step type</td>
<td>Log</td>
</tr>
<tr>
<td>First log step</td>
<td>1.15741E-07         [day]</td>
</tr>
<tr>
<td># of time steps</td>
<td>250</td>
</tr>
<tr>
<td>Type</td>
<td>Fixed</td>
</tr>
<tr>
<td>Fixed value</td>
<td>0.0                 [USgpm]</td>
</tr>
<tr>
<td>Wellbore storage</td>
<td>Open</td>
</tr>
</tbody>
</table>

**Sequence: H_02**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sequence type</td>
<td>History</td>
</tr>
<tr>
<td>Start time</td>
<td>0.964580            [day]</td>
</tr>
<tr>
<td>Duration</td>
<td>0.010410            [day]</td>
</tr>
<tr>
<td>Time step type</td>
<td>Static</td>
</tr>
<tr>
<td>Static time step</td>
<td>0.001000            [day]</td>
</tr>
<tr>
<td>Type</td>
<td>Curve</td>
</tr>
</tbody>
</table>
Wellbore storage: None

**Sequence: F_03**
- **Sequence type:** Flow
- **Start time:** 0.974990 [day]
- **Duration:** 3.525010 [day]
- **Time step type:** Log
- **First log step:** 1.15741E-07 [day]
- **# of time steps:** 250
- **Type:** Curve

**Sequence: H_03**
- **Sequence type:** History
- **Start time:** 4.500000 [day]
- **Duration:** 2.658910 [day]
- **Time step type:** Static
- **Static time step:** 0.001000 [day]
- **Type:** Curve

**Sequence: F_04**
- **Sequence type:** Flow
- **Start time:** 7.158910 [day]
- **Duration:** 13.067870 [day]
- **Time step type:** Log
- **First log step:** 1.15741E-07 [day]
- **# of time steps:** 250
- **Type:** Fixed
- **Fixed value:** -35.0 [USgpm]

**Sequence: F_05**
- **Sequence type:** Flow
- **Start time:** 20.226780 [day]
- **Duration:** 42.573220 [day]
- **Time step type:** Log
- **First log step:** 1.15741E-07 [day]
- **# of time steps:** 250
- **Type:** Fixed
- **Fixed value:** 0.0 [USgpm]

**Test Zone Curves**
- **Curve object to use:** Pressure
- **Curve type:** Pressure
- **Start sequence:** H_01
- **End sequence:** H_03
- **Curve time base:** Test
- **Curve Y data units:** [psi]
- **Curve Y data is log 10:** no

**Curve object to use:** Q Curve
Curve type                                    Flow Rate
Start sequence                                     F_01
End sequence                                       F_03
Curve time base                                    Test
Curve Y data units                              [USgpm]
Curve Y data is log 10       no

Simulation Results Setup
Output ID                                           DAT
Output type                                  Pressure
Pressure capture type                       Test Zone
Output units                                    [psi]
Output ID                                           DAT
Output type                                 Flow Rate
Flow rate output type                            Well
Output units                                  [USgpm]

OutputFiles
XY Forward Output
Write file ?                                        yes
File nameC:\nSIGHTS\Culebra\WIPP 11\Post\WIPP-11.nXYSim
Run ID                                          Perturb
If file exists                                Overwrite
Output data                                 AutoSimData

WIPP-11 Optimization Settings
**********
nPre 2.30Q
**********
Version date   22 July 2005
Listing date   02 May 2006
QA status      QA:Q
Config file    C:\nSIGHTS\Culebra\WIPP 11\WIPP 11 - new Ss.nPre

Parameters
Formation
Formation thickness                              23.000     [ft]
Flow dimension                                      2.0     []
Static formation pressure                  Optimization
   Minimum value                                100.000     [psi]
   Maximum value                                120.000     [psi]
   Estimate value                               106.497     [psi]
   Range type                                    Linear
   Sigma                                        1.00000E+00
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>External boundary radius</td>
<td>1000000</td>
<td>[m]</td>
</tr>
<tr>
<td>Formation conductivity</td>
<td>$f(r)$ point</td>
<td></td>
</tr>
<tr>
<td>Formation spec. storage</td>
<td>1.00000E-06</td>
<td>[1/m]</td>
</tr>
<tr>
<td>Skin</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Radial thickness of skin</td>
<td>Optimization</td>
<td></td>
</tr>
<tr>
<td>Minimum value</td>
<td>1.0E-05</td>
<td>[m]</td>
</tr>
<tr>
<td>Maximum value</td>
<td>10.0</td>
<td>[m]</td>
</tr>
<tr>
<td>Estimate value</td>
<td>0.0047474</td>
<td>[m]</td>
</tr>
<tr>
<td>Range type</td>
<td>Log</td>
<td></td>
</tr>
<tr>
<td>Sigma</td>
<td>1.00000E+00</td>
<td></td>
</tr>
<tr>
<td>Skin zone conductivity</td>
<td>Optimization</td>
<td></td>
</tr>
<tr>
<td>Minimum value</td>
<td>1.00000E-08</td>
<td>[m/sec]</td>
</tr>
<tr>
<td>Maximum value</td>
<td>1.00000E-03</td>
<td>[m/sec]</td>
</tr>
<tr>
<td>Estimate value</td>
<td>6.61728E-04</td>
<td>[m/sec]</td>
</tr>
<tr>
<td>Range type</td>
<td>Log</td>
<td></td>
</tr>
<tr>
<td>Sigma</td>
<td>1.00000E+00</td>
<td></td>
</tr>
<tr>
<td>Skin zone spec. storage</td>
<td>1.00000E-04</td>
<td>[1/m]</td>
</tr>
<tr>
<td>Fluid</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fluid density</td>
<td>1038.00</td>
<td>[kg/m^3]</td>
</tr>
<tr>
<td>Fluid thermal exp. coeff.</td>
<td>0.000000E+00</td>
<td>[1/C]</td>
</tr>
<tr>
<td>Test-Zone</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Well radius</td>
<td>4.4605</td>
<td>[in]</td>
</tr>
<tr>
<td>Tubing string radius</td>
<td>Optimization</td>
<td></td>
</tr>
<tr>
<td>Minimum value</td>
<td>0.200</td>
<td>[ft]</td>
</tr>
<tr>
<td>Maximum value</td>
<td>1.000</td>
<td>[ft]</td>
</tr>
<tr>
<td>Estimate value</td>
<td>0.405</td>
<td>[ft]</td>
</tr>
<tr>
<td>Range type</td>
<td>Linear</td>
<td></td>
</tr>
<tr>
<td>Sigma</td>
<td>1.00000E+00</td>
<td></td>
</tr>
<tr>
<td>Numeric</td>
<td></td>
<td></td>
</tr>
<tr>
<td># of radial nodes</td>
<td>250</td>
<td>[]</td>
</tr>
<tr>
<td># of skin nodes</td>
<td>50</td>
<td>[]</td>
</tr>
<tr>
<td>Pressure solution tolerance</td>
<td>1.45038E-11</td>
<td>[psi]</td>
</tr>
<tr>
<td>STP flow solution tolerance</td>
<td>1.58503E-11</td>
<td>[USgpm]</td>
</tr>
</tbody>
</table>

**Analysis Report**

**AP-070**

Page 111 of 132
WIPP-11 Fitting Parameter Estimates

Figure B-43. Estimates of skin hydraulic conductivity derived from the WIPP-11 perturbation analysis.

Figure B-44. Estimates of static formation pressure derived from the WIPP-11 perturbation analysis.
Figure B-45. Estimates of skin radius derived from the WIPP-11 perturbation analysis.

Figure B-46. Estimates of tubing string radius derived from the WIPP-11 perturbation analysis.
Figure B-47. Flow rates measured during the WIPP-11 testing.
B.9 WIPP-25 nSIGHTS Listings

**********
nPre 2.30Q
**********

Version date   22 July 2005
Listing date   02 May 2006
QA status      QA:Q
Config file    C:\nSIGHTS\Culebra\WIPP 25\WIPP-25.nPre

Control Settings

Main Settings
Simulation type                                 Forward
Simulation subtype                               Normal
Phase to simulate                                Liquid
Skin zone ?                                         yes
External boundary                        Fixed Pressure
Curve data source                               Objects

Liquid Phase Settings
Aquifer type                                   Confined
Aquifer horizontal permeability               Isotropic
System porosity                                  Single
Compensate flow dimension geometry                  yes
Leakage                                            None

Test Zone Settings
Test zone volume can vary                            no
Test zone compressibility can vary                   no
Test zone temperature can vary                       no
Default test-zone temperature                     20.00     [C]
Solution variable                              Pressure
Allow negative head/pressure                        yes

Parameters

Formation
Formation thickness                              25.000     [ft]
Flow dimension                                      2.0     []
Static formation pressure                      125.722     [psi]
External boundary radius                        1000000     [m]
Formation conductivity                      3.39004E-05     [m/sec]
Formation spec. storage                     1.00000E-06     [l/m]

Skin
Radial thickness of skin                         0.0086243     [m]
Skin zone conductivity                           f(t) point
Skin zone spec. storage: $1.88034 \times 10^{-8} \text{ [l/m]}$

**Fluid**
- Fluid density: $1022.00 \text{ [kg/m}^3\text{]}$
- Fluid thermal exp. coeff.: $0.00000 \times 10^0 \text{ [1/C]}$

**Test-Zone**
- Well radius: $2.475 \text{ [in]}$
- Volume change from normal: $0.45 \text{ [m}^3\text{]}$
- Test-zone compressibility: $1.55482 \times 10^{-8} \text{ [1/Pa]}$

**Numeric**
- # of radial nodes: $250$
- # of skin nodes: $50$
- Pressure solution tolerance: $1.45038 \times 10^{-11} \text{ [psi]}$
- STP flow solution tolerance: $1.58503 \times 10^{-11} \text{ [USgpm]}$

**f(x) Points Parameters**

<table>
<thead>
<tr>
<th>Time #</th>
<th>Y value#</th>
<th>Points type</th>
<th>f(t)</th>
</tr>
</thead>
<tbody>
<tr>
<td>150650.393</td>
<td>1.80134E-07</td>
<td>1</td>
<td>m/sec</td>
</tr>
<tr>
<td>156107.611</td>
<td>1.67710E-07</td>
<td>2</td>
<td>m/sec</td>
</tr>
<tr>
<td>167920.057</td>
<td>1.63584E-07</td>
<td>3</td>
<td>m/sec</td>
</tr>
<tr>
<td>169548.382</td>
<td>1.72878E-07</td>
<td>4</td>
<td>m/sec</td>
</tr>
<tr>
<td>190423.149</td>
<td>1.67647E-07</td>
<td>5</td>
<td>m/sec</td>
</tr>
<tr>
<td>239999.335</td>
<td>1.56946E-07</td>
<td>6</td>
<td>m/sec</td>
</tr>
</tbody>
</table>

**Calculated Parameters**

**Formation**
- Transmissivity: $2.40239 \times 10^2 \text{ [ft}^2\text{/day]}$
- Storativity: $7.62000 \times 10^{-6} \text{ []}$
- Diffusivity: $3.15275 \times 10^7 \text{ [ft}^2\text{/day]}$

**Skin Zone**
- Transmissivity: $f(t)$
- Storativity: $1.43282 \times 10^{-7} \text{ []}$
- Diffusivity: $f(t)$
- Skin factor: $f(t)$
Test Zone
Test-zone volume  0.5446069 [m^3]
Isolated well-bore storage  8.46767E-09 [m^3/Pa]

Grid Properties
Grid increment delta  0.08268 []
First grid increment  6.16212E-03 [m]
Skin grid increment delta  0.00262 []
Skin first grid increment  1.65152E-04 [m]
Skin last grid increment  1.87317E-04 [m]
Increment ratio  3.28967E+01 []

Sequences

Sequence: H_01
Sequence type  History
Start time  0.000 [min]
Duration  2510.000 [min]
Time step type  Static
Static time step  30.000 [min]
Type  Curve
Wellbore storage  None

Sequence: H_02
Sequence type  History
Start time  2510.000 [min]
Duration  3.200 [min]
Time step type  Static
Static time step  0.167 [min]
Type  Curve
Wellbore storage  None

Sequence: F_01
Sequence type  Flow
Start time  2513.200 [min]
Duration  302.016 [min]
Time step type  Log
First log step  1.66667E-04 [min]
# of time steps  250
Type  Fixed
Fixed value  -30.0 [USgpm]
Wellbore storage  Isolated

Sequence: F_02
Sequence type  Flow
Start time  2815.216 [min]
Duration  3.336 [min]
Time step type  Log
First log step  1.66667E-04 [min]
# of time steps  250
Type: Fixed
Fixed value: 0.0 [USgpm]
Wellbore storage: Isolated

Sequence: F_03
Sequence type: Flow
Start time: 2818.552 [min]
Duration: 695.202 [min]
Time step type: Log
First log step: 1.6667E-04 [min]
# of time steps: 250
Type: Fixed
Fixed value: -30.0 [USgpm]
Wellbore storage: Isolated

Sequence: F_04
Sequence type: Flow
Start time: 3513.754 [min]
Duration: 9486.246 [min]
Time step type: Log
First log step: 1.6667E-04 [min]
# of time steps: 250
Type: Fixed
Fixed value: 0.0 [USgpm]
Wellbore storage: None

Test Zone Curves
Curve object to use: P Curve
Curve type: Pressure
Start sequence: H_01
End sequence: H_02
Curve time base: Test
Curve Y data units: [psi]
Curve Y data is log 10: no

Simulation Results Setup
Output ID: DAT
Output type: Pressure
Pressure capture type: Test Zone
Output units: [psi]

Output ID: DAT
Output type: Flow Rate
Flow rate output type: Well
Output units: [USgpm]

WIPP-25 Optimization Settings
***********
nPre 2.30Q
**Parameters**

### Formation

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Minimum Value</th>
<th>Maximum Value</th>
<th>Estimate Value</th>
<th>Range Type</th>
<th>Sigma</th>
</tr>
</thead>
<tbody>
<tr>
<td>Formation thickness</td>
<td>25.000</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flow dimension</td>
<td>2.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Static formation pressure Optimization</td>
<td>120.000</td>
<td>130.000</td>
<td>125.722</td>
<td>Linear</td>
<td></td>
</tr>
<tr>
<td>External boundary radius</td>
<td>1000000</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Formation conductivity Optimization</td>
<td>1.0000E-08</td>
<td>1.0000E-04</td>
<td>3.39004E-05</td>
<td>Log</td>
<td></td>
</tr>
<tr>
<td>Formation spec. storage</td>
<td>1.0000E-06</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Skin

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Minimum Value</th>
<th>Maximum Value</th>
<th>Estimate Value</th>
<th>Range Type</th>
<th>Sigma</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radial thickness of skin Optimization</td>
<td>0.0001</td>
<td>10.0</td>
<td>0.0086243</td>
<td>Log</td>
<td></td>
</tr>
<tr>
<td>Skin zone conductivity f(t) point</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Skin zone spec. storage Optimization</td>
<td>1.0000E-08</td>
<td>1.0000E-04</td>
<td>1.88034E-08</td>
<td>Log</td>
<td></td>
</tr>
<tr>
<td>Skin zone conductivity f(t) point</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Fluid

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Minimum Value</th>
<th>Maximum Value</th>
<th>Estimate Value</th>
<th>Range Type</th>
<th>Sigma</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fluid density</td>
<td>1022.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fluid thermal exp. coeff.</td>
<td>0.0000E+00</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Test-Zone

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Minimum Value</th>
<th>Maximum Value</th>
<th>Estimate Value</th>
<th>Range Type</th>
<th>Sigma</th>
</tr>
</thead>
<tbody>
<tr>
<td>Well radius</td>
<td>2.475</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Volume change from normal</td>
<td>0.45</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Test-zone compressibility Optimization</td>
<td>4.0000E-10</td>
<td>1.0000E-05</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Estimate value: $1.55482 \times 10^{-8}$ [1/Pa]  
Range type: Log  
Sigma: $1.00000 \times 10^0$  

**Numeric**  
# of radial nodes: 250  
# of skin nodes: 50  
Pressure solution tolerance: $1.45038 \times 10^{-11}$ [psi]  
STP flow solution tolerance: $1.58503 \times 10^{-11}$ [USgpm]  

**WIPP-25 Fitting Parameter Estimates**  

![Figure B-48](image)  

**Figure B-48.** Estimates of static formation pressure derived from the WIPP-25 perturbation analysis.
Figure B-49. Estimates of time-varying skin hydraulic conductivity derived from the WIPP-25 perturbation analysis.

Figure B-50. Estimates of skin radius derived from the WIPP-25 perturbation analysis.
Figure B-51. Estimates of skin specific storage derived from the WIPP-25 perturbation analysis.

Figure B-52. Estimates of test-zone compressibility derived from the WIPP-25 perturbation analysis.
Figure B-53. Flow rates measured during the WIPP-25 testing.
B.10  C-2737 nSIGHTS Listings

**********
nPre 2.30Q
**********

Version date   22 July 2005
Listing date   02 May 2006
QA status      QA:Q
Config file    C:\nSIGHTS\Culebra\C2737\C-2737.nPre

Control Settings

Main Settings
Simulation type                                 Forward
Simulation subtype                               Normal
Phase to simulate                                Liquid
Skin zone ?                                         yes
External boundary                        Fixed Pressure
Curve data source                               Objects

Liquid Phase Settings
Aquifer type                                   Confined
Aquifer horizontal permeability               Isotropic
System porosity                                  Single
Compensate flow dimension geometry                yes
Leakage                                            None

Test Zone Settings
Test zone volume can vary                            no
Test zone compressibility can vary                   no
Test zone temperature can vary                       no
Default test-zone temperature                     20.00     [C]
Solution variable                              Pressure
Allow negative head/pressure                        yes

Parameters

Formation
Formation thickness                              23.000     [ft]
Flow dimension                                      2.0     []
Static formation pressure                        90.241     [psi]
External boundary radius                        1000000     [m]
Formation conductivity                      9.91966E-08     [m/sec]
Formation spec. storage                     5.47899E-07     [1/m]

Skin
Radial thickness of skin                       0.093313     [m]
Skin zone conductivity                           2.75487E-07     [m/sec]
## Skin Zone spec. storage

Skin zone spec. storage: 1.86613E-06 [1/m]

### Fluid

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fluid density</td>
<td>1064.20</td>
<td>kg/m^3</td>
</tr>
<tr>
<td>Fluid thermal exp. coeff.</td>
<td>0.000000E+00</td>
<td>[1/C]</td>
</tr>
</tbody>
</table>

### Test-Zone

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Well radius</td>
<td>3.1205</td>
<td>[in]</td>
</tr>
<tr>
<td>Volume change from normal</td>
<td>0.0</td>
<td>[m^3]</td>
</tr>
<tr>
<td>Test-zone compressibility</td>
<td>1.09951E-07</td>
<td>[1/Pa]</td>
</tr>
</tbody>
</table>

### Numeric

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td># of radial nodes</td>
<td>250</td>
<td>[ ]</td>
</tr>
<tr>
<td># of skin nodes</td>
<td>50</td>
<td>[ ]</td>
</tr>
<tr>
<td>Pressure solution tolerance</td>
<td>1.45038E-11</td>
<td>[psi]</td>
</tr>
<tr>
<td>STP flow solution tolerance</td>
<td>1.58503E-11</td>
<td>[USgpm]</td>
</tr>
</tbody>
</table>

### Calculated Parameters

#### Formation

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transmissivity</td>
<td>6.95408E-07</td>
<td>[m^2/sec]</td>
</tr>
<tr>
<td>Storativity</td>
<td>3.84099E-06</td>
<td>[ ]</td>
</tr>
<tr>
<td>Diffusivity</td>
<td>1.81049E-01</td>
<td>[m^2/sec]</td>
</tr>
</tbody>
</table>

#### Skin Zone

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transmissivity</td>
<td>1.93128E-06</td>
<td>[m^2/sec]</td>
</tr>
<tr>
<td>Storativity</td>
<td>1.30823E-05</td>
<td>[ ]</td>
</tr>
<tr>
<td>Diffusivity</td>
<td>1.47625E-01</td>
<td>[m^2/sec]</td>
</tr>
<tr>
<td>Skin factor</td>
<td>-4.97913E-01</td>
<td>[ ]</td>
</tr>
</tbody>
</table>

#### Test Zone

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test-zone volume</td>
<td>0.1383593</td>
<td>[m^3]</td>
</tr>
<tr>
<td>Isolated well-bore storage</td>
<td>1.52128E-08</td>
<td>[m^3/Pa]</td>
</tr>
</tbody>
</table>

### Grid Properties

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grid increment delta</td>
<td>0.07825</td>
<td>[ ]</td>
</tr>
<tr>
<td>First grid increment</td>
<td>1.40469E-02</td>
<td>[m]</td>
</tr>
<tr>
<td>Skin grid increment delta</td>
<td>0.01588</td>
<td>[ ]</td>
</tr>
<tr>
<td>Skin first grid increment</td>
<td>1.26864E-03</td>
<td>[m]</td>
</tr>
<tr>
<td>Skin last grid increment</td>
<td>2.71870E-03</td>
<td>[m]</td>
</tr>
<tr>
<td>Increment ratio</td>
<td>5.16679E+00</td>
<td>[ ]</td>
</tr>
</tbody>
</table>

### Sequences

#### Sequence: H_01

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sequence type</td>
<td>History</td>
<td></td>
</tr>
<tr>
<td>Start time</td>
<td>-63.533180</td>
<td>[day]</td>
</tr>
</tbody>
</table>
Duration                                    25.573060     [day]
Time step type                                 Static
Static time step                             0.500000     [day]
Type                                            Curve
Wellbore storage                             Isolated

Sequence: H_02
Sequence type                                    History
Start time                                 -37.960120     [day]
Duration                                    0.827080     [day]
Time step type                                 Static
Static time step                             0.003000     [day]
Type                                            Curve
Wellbore storage                             Isolated

Sequence: H_03
Sequence type                                    History
Start time                                 -37.133040     [day]
Duration                                    1.133040     [day]
Time step type                                 Static
Static time step                             0.003000     [day]
Type                                            Curve
Wellbore storage                             Isolated

Sequence: H_04
Sequence type                                    History
Start time                                 -36.000000     [day]
Duration                                    36.004460     [day]
Time step type                                 Static
Static time step                             0.100000     [day]
Type                                            Curve
Wellbore storage                             Isolated

Sequence: F_01
Sequence type                                    Flow
Start time                                         0.004460     [day]
Duration                                    0.434640     [day]
Time step type                                    Log
First log step                                1.15741E-07     [day]
# of time steps                                   250
Type                                            Fixed
Fixed value                                        -0.3     [USgpm]
Wellbore storage                             Isolated

Sequence: F_02
Sequence type                                    Flow
Start time                                         0.439100     [day]
Duration                                    13.560900     [day]
Time step type                                    Log
First log step                                1.15741E-07     [day]
# of time steps                                   250
Type                                            Fixed
Fixed value                                        0.0     [USgpm]
Wellbore storage  Isolated

Test Zone Curves
Curve object to use  Create Curve
Curve type  Pressure
Start sequence  H_01
End sequence  H_04
Curve time base  Test
Curve Y data units  [psi]
Curve Y data is log 10  no

Simulation Results Setup
Output ID  DAT
Output type  Pressure
Pressure capture type  Test Zone
Output units  [psi]

Output ID  DAT
Output type  Flow Rate
Flow rate output type  Well
Output units  [USgpm]

C-2737 Optimization Settings
**********
nPre 2.30Q
**********
Version date  22 July 2005
Listing date  02 May 2006
QA status  QA:Q
Config file  C:\nSIGHTS\Culebra\C2737\C-2737.nPre

Parameters

Formation
Formation thickness  23.000  [ft]
Flow dimension  2.0  []
Static formation pressure  Optimization
Minimum value  85.000  [psi]
Maximum value  95.000  [psi]
Estimate value  90.241  [psi]
Range type  Linear
Sigma  1.00000E+00
External boundary radius  1000000  [m]
Formation conductivity  Optimization
Minimum value  1.00000E-09  [m/sec]
Maximum value  1.00000E-05  [m/sec]
Estimate value  9.91966E-08  [m/sec]
Range type  Log
Sigma  1.00000E+00
### Formation spec. storage

<table>
<thead>
<tr>
<th>Optimization</th>
<th>Minimum value</th>
<th>Maximum value</th>
<th>Estimate value</th>
<th>Range type</th>
<th>Sigma</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1.00000E-07</td>
<td>1.00000E-05</td>
<td>5.47899E-07</td>
<td>Log</td>
<td>1.00000E+00</td>
</tr>
</tbody>
</table>

### Skin

#### Radial thickness of skin

<table>
<thead>
<tr>
<th>Optimization</th>
<th>Minimum value</th>
<th>Maximum value</th>
<th>Estimate value</th>
<th>Range type</th>
<th>Sigma</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.0001</td>
<td>10.0</td>
<td>0.093313</td>
<td>Log</td>
<td>1.00000E+00</td>
</tr>
</tbody>
</table>

#### Skin zone conductivity

<table>
<thead>
<tr>
<th>Optimization</th>
<th>Minimum value</th>
<th>Maximum value</th>
<th>Estimate value</th>
<th>Range type</th>
<th>Sigma</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1.00000E-10</td>
<td>1.00000E-04</td>
<td>2.75487E-07</td>
<td>Log</td>
<td>1.00000E+00</td>
</tr>
</tbody>
</table>

#### Skin zone spec. storage

<table>
<thead>
<tr>
<th>Optimization</th>
<th>Minimum value</th>
<th>Maximum value</th>
<th>Estimate value</th>
<th>Range type</th>
<th>Sigma</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1.00000E-07</td>
<td>1.00000E-05</td>
<td>1.86613E-06</td>
<td>Log</td>
<td>1.00000E+00</td>
</tr>
</tbody>
</table>

### Fluid

| Fluid density | 1064.20 | [kg/m^3] |
| Fluid thermal exp. coeff. | 0.00000E+00 | [1/C] |

### Test-Zone

| Well radius | 3.1205 | [in] |
| Volume change from normal | 0.0 | [m^3] |

#### Test-zone compressibility

<table>
<thead>
<tr>
<th>Optimization</th>
<th>Minimum value</th>
<th>Maximum value</th>
<th>Estimate value</th>
<th>Range type</th>
<th>Sigma</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1.00000E-08</td>
<td>1.00000E-05</td>
<td>1.09951E-07</td>
<td>Log</td>
<td>1.00000E+00</td>
</tr>
</tbody>
</table>

### Numeric

| # of radial nodes | 250 | [] |
| # of skin nodes | 50 | [] |
| Pressure solution tolerance | 1.45038E-11 | [psi] |
| STP flow solution tolerance | 1.58503E-11 | [USgpm] |
C-2737 Fitting Parameter Estimates

Figure B-54. Estimates of specific storage derived from the C-2737 perturbation analysis.

Figure B-55. Estimates of test-zone compressibility derived from the C-2737 perturbation analysis.
Figure B-56. Estimates of static formation pressure derived from the C-2737 perturbation analysis.

Figure B-57. Estimates of skin hydraulic conductivity derived from the C-2737 perturbation analysis.
Figure B-58. Estimates of skin specific storage derived from the C-2737 perturbation analysis.

Figure B-59. Estimates of skin radius derived from the C-2737 perturbation analysis.
Figure B-60. Flow rates measured during the C-2737 testing.