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Analysis Report for AP-070

Analysis of the IMC-461 Sinusoidal Test Conducted From 6/6/16 to 6/9/16

AP-070: Analysis Plan for Hydraulic-Test Interpretations

Task Number 4.4.2.3.1

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WIPP:4.4.2.3.1:TD:QA-L:RECERT:PKG# 539221

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1. Introduction

This report discusses the analyses of hydraulic tests performed in the Culebra Dolomite Member (Culebra) of the Rustler Formation (Figure 1) at the Waste Isolation Pilot Plant (WIPP) site at the IMC-461 well pad (Figure 2). These analyses were performed in accordance with the Sandia National Laboratories (SNL) Analysis Plan for Hydraulic-Test Interpretations, AP-070, Revision 2 (Beauheim, 2009). The computer code used for analysis was nSIGHTS (n-dimensional Statistical Inverse Graphical Hydraulic Test Simulator), version 2.50. 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).



Figure 1. WIPP stratigraphy.



2. Test and Analysis Procedures

Five sinusoidal tests, two constant rate tests, and three slug tests were performed as a suite of pneumatic testing on well IMC-461 between 6/6/16 and 6/9/16. The location of the IMC-461 well pad in the WIPP well network is shown in Figure 2. The well had been tested previously, but it has been acidized and brushed/maintained since those tests were conducted. Pneumatic tests were chosen as the well has a very small (~2") casing diameter making pump installation difficult to impossible. As the tests utilized an air compressor to change pressure in the well, no water was produced during testing.

The main objective of this analysis is to estimate T for subsequent use in T-field generation and WIPP performance assessment calculations, and to reevaluate aquifer parameters against analyses conducted on data from the previous IMC-461 slug tests. Test analysis involved finding the values of the fitting parameters that produced the best-simulated matches to the pressure data collected during the sinusoidal pressure change, constant-rate test/recovery period, and the slug test pressure recovery. All the nSIGHTS test simulations incorporated pre-test pressure records of various durations as "history" periods where the observed pressures were specified in the simulations. In addition to the formation properties of interest (principally transmissivity (T)), static formation pressure and wellbore skin were also included as fitting parameters in the pumping-test analyses so that nSIGHTS could exactly match the amount of wellbore storage observed during the test.

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 sample the parameter-space minimum that provides the best quantitative fit to the data, measured in terms of the smallest unweighted 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





Figure 2. Location of the IMC-461 Culebra well located on the IMC-461 wellpad designated by a blue star.



parameter-space topography that trap the inverse regression algorithm during its attempt to find the global minimum – the smallest unweighted SSE. If multiple data types are included in the match (e.g., if pressures, pressure derivatives, etc., are matched simultaneously), then the weighted SSE values for each component are combined and the overall goodness-of-fit measure is denoted in nSIGHTS as the *fit value*.

Five hundred perturbation/optimization runs were performed for each of the analyses discussed in this report. A visual assessment of parameter-space plots for each fitting variable and a visual assessment of the fits themselves were all used to determine the value of the "fit discriminant". The fit discriminant is used to reduce the perturbations under consideration to only those within the best-fit minimum, and sufficiently close to be subjectively considered "acceptable" fits. All perturbation results for which the fit value was less than the fit discriminant were deemed acceptable solutions and are included in the final range of reported values for each fitting parameter. In some cases, the original baseline solution may not fall within the global minimum defined through perturbation analysis. The final number of satisfactory perturbation results for each test is reported in the Section 3 figure captions.

3. IMC-461 Analysis Results

Discussions of IMC-461 and associated test analyses are given below. A summary of the T estimates obtained from perturbation analysis of each test is shown in Table 1. The full range of T values from which the statistics in Table 1 are derived is presented as a scatter plot in the sections below and a full listing is contained within the nPost configuration file for each analysis.

		Mean S	Geo. Mean T (m ² /s)				
IMC-461 Testing	Period (min)			Geo. Mean T (m ² /s)	$\begin{array}{l} \text{Min. } T \\ \text{(m}^2\text{/s)} \end{array}$	Max. <i>T</i> (m ² /s)	Variance $(m^2/s)^2$
6/9, Sine	10	6.17E-05	3.28E-04	-3.48	-3.50	-3.42	5.66E-07
6/6, Sine	20	3.16E-04	1.85E-04	-3.73	-3.85	-3.64	5.01E-12
6/9, Sine	40	2.70E-04	1.99E-04	-3.70	-3.71	-3.70	1.26E-15
6/7, Sine	60	3.64E-04	1.43E-04	-3.85	-3.92	-3.76	2.07E-12
6/8, Sine	120		3.56E-05	-4.45	-4.64	-4.29	6.57E-07
6/6, Constant Rate	-	3.53E-04	1.51E-04	-3.82	-3.97	-3.71	3.03E-12
6/7, Constant Rate	-	4.84E-04	1.20E-04	-3.92	-4.02	-3.59	3.37E-12
6/6, Slug	-	2.99E-06	3.56E-04	-3.45	-3.47	-3.43	2.74E-13
6/7, Slug	-	9.57E-10	2.14E-03	-2.67	-5.05	-1.81	2.29E-07
6/8, Slug	-	1.64E-07	3.15E-04	-3.50	-5.52	-2.01	1.41E-08
2005 Slug Test*	-	-	1.92E-04	-3.72	-2.88	-2.82	4.47E-05

Table 1. Culebra Transmissivity and Storativity Estimates.

*Values from Bowman and Roberts, 2009.

3.1. IMC-461

A physical description of the IMC- 461 well is detailed in Figure 3. The well is a 5.125" bore hole with a 2.375" tubing slotted in the Culebra. The pneumatic testing of the well was made possible using a gauged pressure cap, or kapsoid, on the stick-up portion of the well casing. The kapsoid allowed for contained pressure in the well while being able to measure total pressure (gas and water) and gas pressure. Using a DAS system aboard a testing trailer, pressure was able to be maintained and directed for the sinusoidal and constant rate tests. Slug tests were a result of immediately opening a ball valve connected to the kapsoid after a period of pressure stabilization.

Five slug tests were previously conducted on January 25th-26th, 2005 at the IMC-461 well using pneumatics. The results of their analysis can be found in the analysis report "Analysis of Culebra and Magenta Hydraulic Tests Performed Between January 2005 and August 2008" (Bowman and Roberts 2009). A pressure-manifold system was attached to the IMC-461 wellhead so the PVC well casing could be pressurized with compressed nitrogen to depress the water level in the well. After the water level was lowered to the desired depth and all pressures had stabilized, the nitrogen was rapidly vented from the well to initiate a slug test. The pressure changes of those slug tests varied from approximately 20 psi to 45 psi.

Testing of the IMC-461 aquifer was conducted over four days from 6/6/16 to 6/9/16. The first two days of testing started with a constant-rate test, followed by sinusoidal testing, and concluded with a slug test (Figure 4). The third day consisted of sinusoidal testing followed by a slug test. Only sinusoidal testing was conducted on the fourth day. The first sinusoidal test attempted was excluded from analysis as the amplitude was too high for the short (10 min) period, which led to a deformed sinusoid. Pressure changes were logged by measuring the gas pressure via a transducer above water and total pressure via a pressure transducer below the water surface. For modeling purposes, total pressure is the data that is fit using variable aquifer parameters and flow rate. Flow rate is calculated as the derivative of water pressure (gas pressure subtracted from total pressure) translated to a volume/time through wellbore storage.

The IMC-461 nSIGHTS sinusoidal simulations consisted of a pressure change sequence bookended by two history sequences; slug simulations consisted of a recovery sequence book-ended by two history sequences; constant-rate simulations consisted of a paired pressure buildup/pressure release sequences book-ended by two history sequences. Typically, pressure diagnostics (e.g., Bourdet derivatives and Ramey plots) are used to better fit and understand the data. However, the low total pressure changes to data noise ratio made these plots unreliable. They were excluded from these tests as a diagnostic tool. The details of each sequence (i.e., start/end time, pressure, etc.) are specified in the IMC-461.nPre files and are listed in Appendix B.1.

The specified IMC-461 conceptual models were chosen because they were the simplest models consistent with the available information that produced an acceptable fit to the data; acceptable by consensus of the modeler and an associate modeler. The models used were infinite-acting, radial systems with a variable T, wellbore storage, and a negative, time-dependent skin with some of these parameters being excluded if it provided a necessary improvement to the model.



A sand pack surrounding the screened portion of the well warranted the inclusion of skin effects into the model. The magnitude of pressure change during testing versus a model that included skin sometimes allowed the skin to become the dominant hydraulic conductivity effect of the model through skin thickness. The occurrences and their meaning will be discussed on a model-by-model basis in the following sections.



- 2. Not to scale.
- 3. Well info ref. Beauheim (2005)

Figure 3. IMC-461 well configuration during testing.



3.1.1 Pumping Test Analysis and Discussion

Figure 4. Day 2 Testing Regime for pneumatic testing at IMC-461.

3.1.1a Sinusoidal Test Analysis

The Culebra at IMC-461 was tested with sinusoidal pressure tests of multiple amplitudes (10, 20, 40, 60, 120 min). Differing amplitudes allow for a suite of tests to be analyzed and also deters parameter estimate bias due to background or circumstantial harmonics. Test analysis revealed well constrained *T* estimates but poorly constrained *S* estimates. In the case of the 120 min period sinusoid, S was constrained to a value of 1.0E-5 1/m. In some of the cases, we note that skin conductivity becomes partially dominant over formation conductivity through a large value (~5 m) of skin thickness. In the models where this is the case, K_{skin} was very similar in value to $K_{formation}$. The 120 min sinusoid also had the effect of a seemingly superimposed linear decrease in pressure. As the pressure controls mathematically calculate the sinusoidal response that should exist and it is an enclosed system, barometric/earth tide pressure should not be a contributing factor. The most likely explanation is a slight drift in our pressure transducers. The cumulative pressure change from the effect is ~0.05 psi. The effect warranted a second model because the decrease created bimodal minima (i.e., better fits of different parts of the sinusoid). These tests also had a very well constrained static formation pressure which is an effect that is consistent throughout all tests.



Figure 5. Pressure data and 491 model fits of the 10 min period Culebra sinusoidal test in IMC-461.



Figure 6. X-Y scatter plot showing the transmissivity parameter space derived from the IMC-461 10 min period sinusoidal test perturbation analysis with fit discriminant and best fit values.



Figure 7. X-Y scatter plot showing the storativity parameter space derived from the IMC-461 10 min period sinusoidal test perturbation analysis with fit discriminant and best fit values.



Figure 8. Pressure data and 491 model fits of the 20 min period Culebra sinusoidal test in IMC-461.



Figure 9. X-Y scatter plot showing the transmissivity parameter space derived from the IMC-461 20 min period sinusoidal test perturbation analysis with fit discriminant and best fit values.



Figure 10. X-Y scatter plot showing the storativity parameter space derived from the IMC-461 20 min period sinusoidal test perturbation analysis with fit discriminant and best fit values.



Figure 11. Pressure data and 499 model fits of the 40 min period Culebra sinusoidal test in IMC-461.



Figure 12. X-Y scatter plot showing the transmissivity parameter space derived from the IMC-461 40 min period sinusoidal test perturbation analysis with fit discriminant and best fit values.



Figure 13. X-Y scatter plot showing the storativity parameter space derived from the IMC-461 40 min period sinusoidal test perturbation analysis with fit discriminant and best fit values.



Figure 14. Pressure data and 498 model fits of the 60 min period Culebra sinusoidal test in IMC-461.



Figure 15. X-Y scatter plot showing the transmissivity parameter space derived from the IMC-461 60 min period sinusoidal test perturbation analysis with fit discriminant and best fit values.



Figure 16. X-Y scatter plot showing the storativity parameter space derived from the IMC-461 60 min period sinusoidal test perturbation analysis with fit discriminant and best fit values.



Figure 17. Pressure data and 322 model fits of the 120 min period Culebra sinusoidal test in IMC-461.



Figure 18. X-Y scatter plot showing the transmissivity parameter space derived from the IMC-461 120 min period sinusoidal test perturbation analysis with fit discriminant and best fit values.

3.1.1b Constant Rate Test Analysis

The models fit to the constant rate tests performed on IMC-461 had similar results to the sinusoidal tests. They had a well constrained T and static formation pressure. S was, similarly, poorly constrained. Both had extensive skin effects with K_{skin} similar to $K_{formation}$. As stated before, Bourdet diagnostic plots were coarse and relatively unhelpful due to the small pressure changes that accompany these tests.



Figure 19. Pressure data and 491 model fits of the 6/6/16 Culebra constant rate test in IMC-461.





Figure 20. X-Y scatter plot showing the transmissivity parameter space derived from the IMC-461 6/6/16 Culebra constant rate test perturbation analysis with fit discriminant and best fit values.



Figure 21. X-Y scatter plot showing the parameter space derived from the IMC-461 6/6/16 Culebra constant rate test perturbation analysis with fit discriminant and best fit values.



Figure 22. Pressure data and 478 model fits of the 6/7/16 Culebra constant rate test in IMC-461.



Figure 23. X-Y scatter plot showing the transmissivity parameter space derived from the IMC-461 6/7/16 Culebra constant rate test perturbation analysis with fit discriminant and best fit values.



Figure 24. X-Y scatter plot showing the storativity parameter space derived from the IMC-461 6/7/16 Culebra constant rate test perturbation analysis with fit discriminant and best fit values.

3.1.1c Slug Test Analysis

The slug tests at IMC-461 were the most difficult test-type to model due to the relatively low changes in pressure. Static formation pressure was the only parameter that was well constrained in these models. T, while not well constrained, did average to a similar value as the other test type results.





Figure 25. Pressure data and 491 model fits of the 6/6/16 Culebra slug test in IMC-461.



Figure 26. X-Y scatter plot showing the transmissivity parameter space derived from the IMC-461 6/6/16 slug test perturbation analysis with fit discriminant and best fit values.



Figure 27. X-Y scatter plot showing the storativity parameter space derived from the IMC-461 6/6/16 slug test perturbation analysis with fit discriminant and best fit values.



Figure 28. Pressure data and 238 model fits of the 6/7/16 Culebra slug test in IMC-461.



Figure 29. X-Y scatter scatter plot showing the transmissivity parameter space derived from the IMC-461 6/7/16 slug test perturbation analysis with fit discriminant and best fit values.



Figure 30. X-Y scatter plot showing the storativity parameter space derived from the IMC-461 6/7/16 slug test perturbation analysis with fit discriminant and best fit values.





Figure 31. Pressure data and 441 model fits of the 6/8/16 Culebra slug test in IMC-461.



Figure 32. X-Y scatter plot showing the transmissivity parameter space derived from the IMC-461 6/8/16 slug test perturbation analysis with fit discriminant and best fit values.



Figure 33. X-Y scatter plot showing the storativity parameter space derived from the IMC-461 6/8/16 slug test perturbation analysis with fit discriminant and best fit values.

4. References

Beauheim, R.L. 2009. Analysis Plan for Hydraulic-Test Interpretations, AP-070, Revision 2. ERMS# 552209. Carlsbad, NM: Sandia National Laboratories, WIPP Records Center.

Beauheim, R.L. 2005. Memo to file (Subject: IMC-461, 462, and 463). 24 October 2005. ERMS# 541654. Carlsbad, NM: Sandia National Laboratories, WIPP Records Center.

Beauheim, R.L., and G.J. Ruskauff. 1998. Analysis of Hydraulic Tests of the Culebra and Magenta Dolomites and Dewey Lake Redbeds Conducted at the Waste Isolation Pilot Plant Site. SAND98-0049. Albuquerque, NM: Sandia National Laboratories.

Beauheim, R.L., R.M. Roberts, T.F. Dale, M.D. Fort, and W.A. Stensrud. 1993. *Hydraulic Testing of Salado Formation Evaporites at the Waste Isolation Pilot Plant Site: Second Interpretive Report*. SAND92-0533. Albuquerque, NM: Sandia National Laboratories.

Bourget, D., J.A. Ayoub, and Y.M. Pirard. 1989. "Use of Pressure Derivative in Well-Test Interpretation," *SPE Formation Evaluation*, 4(2):293-302.

Bowman, D. O., R.M. Roberts. 2009. Analysis of Culebra and Magenta Hydraulic Tests Performed Between January 2005 and August 2008: Ap-070:Analysis Plan for Non-Salado



Hydraulic-Test Interpretations. Carlsbad, NM: Sandia National Laboratories, WIPP Records Center.

DeYonge, Wesley. 2013. WIPP Site Well Testing Notebook 15 (WSWT-15), ERMS #560947, Pkg #540244.

Powers, D.W., R.M. Holt, R.L. Beauheim, and R.G. Richardson. 2006. "Advances in Depositional Models of the Permian Rustler Formation, Southeastern New Mexico." *Caves and Karst of Southeastern New Mexico* (pp. 267–276). L. Land, V.W. Lueth, W. Raatz, P. Boston, and D.L. Love (eds.) 57th Annual Fall Field Conference Guidebook. Socorro, NM: New Mexico Geological Society.

Ramey, H.J., R.G. Agarwal, and I. Martin. 1975. "Analysis of 'Slug Test' or DST Flow Period Data," *Journal of Canadian Petroleum Technology*, 14(3):37-47.

Roberts, R.M., R.L. Beauheim, and P.S. Domski. 1999. *Hydraulic Testing of Salado Formation Evaporites at the Waste Isolation Pilot Plant Site: Final Report*. SAND98-2537. Albuquerque, NM: Sandia National Laboratories.

Salness, R.A. 2006. Basic Data Report for Well Plugging and Abandonment and Reconfiguration Activities for Fiscal Year 2005. DOE/WIPP 05-3326. Carlsbad, NM: U.S. Department of Energy.

Well Testing Trailer 1 Scientific Notebook Supplemental #6 (WTT1-6) 2016. Carlsbad, NM: Sandia National Laboratories, WIPP Records Center.

Appendix A – IMC-461 Hydraulic Test – 6/6/16 to 6/9/16

Well	Borehole Diameter (in)	Inside Tubing or Casing Diamet er (in)	Culebra Interval (ft bgs)	Fluid Density (g/cm³)	Data Source Report(s)	Field Notebook
IMC- 461	5.125	1.913	362-386	1.008	Letter: IMC- 461, 462, and 463(ERMS #541654)	WSWT#5, WTT1-6 Scientific Notebook Supplemental

Date	Start Test Time	Stop Test Time	
6/6/2016	10:37	21:07	
6/7/2016	9:03	18:57	
6/8/2016	7:42	0:00	
6/9/2016	7:13	12:19	

Appendix B - nSIGHTS Listings

B.1 IMC-461 nSIGHTS Listings

Control Settings

Main Settings

Simulation type Simulation subtype Phase to simulate Skin zone ? External boundary	Optimization Normal Liquid yes Fixed Pressure		
Liquid Phase Settings			
Aquifer type Aquifer horizontal permeability System porosity Compensate flow dimension geometry Leakage	Confined Isotropic Single yes None		
Test Zone Settings			
Test zone volume can vary Test zone compressibility can vary Test zone temperature can vary Default test-zone temperature	no no 20.00	[C]	
Solution variable	Pressure		
Allow negative head/pressure	yes		

Parameters

Formation

Formation thickness	24.000	[ft]
Flow dimension	2.0	[]
Static formation pressure	Optimization	

Minimum value	67.000	[psi]
Maximum value	71.000	[psi]
Estimate value	69.759	[psi]
Range type	Linear	
Sigma	1.00000E+00	
External boundary radius	1000000	[m]
Formation conductivity	Optimization	
Minimum value	1.00000E-10	[m/sec]
Maximum value	1.00000E-02	[m/sec]
Estimate value	4.48965E-05	[m/sec]
Range type	Log	
Sigma	1.00000E+00	
Formation spec. storage	Optimization	
Minimum value	1.00000E-08	[1/m]
Maximum value	1.00000E-04	[1/m]
Estimate value	4.89372E-06	[l/m]
Range type	Log	
Sigma	1.00000E+00	

Skin

Radial thickness of skin	Optimization	
Minimum value	0.001	[m]
Maximum value	5.0	[m]
Estimate value	0.0011011	[m]
Range type	Linear	
Sigma	1.00000E+00	
Skin zone conductivity	Optimization	
Minimum value	1.00000E-10	[m/sec]
Maximum value	1.00000E-02	[m/sec]
Estimate value	8.24331E-07	[m/sec]
Range type	Log	
Sigma	1.00000E+00	
Skin zone spec. storage	Optimization	
Minimum value	1.00000E-10	[1/m]
Maximum value	1.00000E-02	[1/m]
Estimate value	8.46114E-07	[1/m]
Range type	Log	
Sigma	1.00000E+00	

Fluid

Fluid density Fluid thermal exp. coeff.	1008.00 0.00000E+00	[kg/m^3] [1/C]
Test-Zone		
Well radius	2.5625	[in]
Numeric		
# of radial nodes # of skin nodes Pressure solution tolerance	250 50 1.45038E-11	[] [] [psi]

Information Only

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Calculated Parameters

Formation

Transmissivity Minimum Maximum Storativity Minimum Maximum Diffusivity Minimum Maximum	min/max 7.31520E-10 7.31520E-02 min/max 7.31520E-08 7.31520E-04 min/max 1.00000E-06 1.00000E+06	[m ² /sec] [m ² /sec] [] [] [m ² /sec] [m ² /sec]
Skin Zone		
Transmissivity Minimum Maximum Storativity Minimum Maximum Diffusivity Minimum Maximum Skin factor Minimum Maximum	<pre>min/max 7.31520E-10 7.31520E-02 min/max 7.31520E-10 7.31520E-02 min/max 1.00000E-08 1.00000E+08 min/max -1.52471E-02 4.35439E+08</pre>	[m ² /sec] [m ² /sec] [] [m ² /sec] [m ² /sec] [] []
Grid Properties		
Grid increment delta Minimum Maximum	min/max 0.06127 0.08308	[] []
First grid increment Minimum Maximum Skin grid increment delta	min/max 3.20053E-01 5.72485E-03 min/may	[m] [m]
Minimum Maximum	0.00031 0.08887	[] []
Skin first grid increment Minimum Maximum	mln/max 2.02561E-05 6.04880E-03	[m] [m]
Skin last grid increment Minimum Maximum	min/max 2.05609E-05 4.30690E-01	[m] [m]
Increment ratio Minimum Maximum	min/max 7.43118E-01 2.78433E+02	[] []

Sequences

Sequence: H_01

of time steps

Wellbore storage

Туре

Sequence type	History		
Start time	42530.262081 [da		
Duration	0.045791 [da		
Time step type	Static		
Static time step	0.000116	[day]	
Туре	Curve		
Wellbore storage	None		
Sequence: F_01			
Comionao timo	Flow		
Start time	12520 207972	[dow]	
Duration	42550.507872	[day]	
Time stop time	0.035551	[uay]	
Static time step	0 000116	[dav]	
Trme	Curve	[uay]	
Wellbore storage	None		
Weithole Scolage	NOILE		
Sequence: H_02			
Sequence type	History		
Start time	42530.343403	[day]	
Duration	0.010764	[day]	
Time step type	Log	_	
First log step	1.15741E-07	[day]	
# of time steps	250	-	
Туре	Curve		
Wellbore storage	None		
Sequence: H_03			
Sequence time	History		
Start time	42530 354167	[dav]	
Duration	0 141782	[day]	
Time step type	Static	[day]	
Static time step	0 000116	[dav]	
Type	Curve	[ddy]	
Wellbore storage	None		
Sequence: H 04			
Sequence type	History		
Start time	42530.495949	[day]	
Duration	0.013079	[day]	
Time step type	Log		
First log step	1.15741E-07	[day]	

250

Curve

None

Sequence: H_05

[day]
[day]
[day]

Test Zone Curves

Curve object to use	P_Curve
Curve type	Pressure
Start sequence	H_01
End sequence	H_05
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	H_01
End sequence	H_05
Curve time base	Test
Curve Y data units	[USgpm]
Curve Y data is log 10	no

Simulation Results Setup

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

OutputFiles

XY Forward Output	
Write file ?	no
Optimization Output	
Write file ?	no

Optimization Setup

Algorithm	Simplex	
Calculate confidence limits ?	yes	
Covariance matrix calculations	1st Order	
Fixed derivative span ?	no	
Fit tolerance	1.0000E-05	
Parameter tolerance	not used	
<pre># of optimized variables</pre>	6	
Formation conductivity	OK	
Skin zone conductivity	OK	
Static formation pressure	OK	
Formation spec. storage	OK	
Skin zone spec. storage	OK	
Radial thickness of skin	OK	
Fits to Optimize		
CompositeFit	OK	
Calculated Parameters Included		
<pre># of calculated variables included</pre>	0	

Suite/Range Setup

of suite/range variables

0




Figure B-1. X-Y scatter plot showing the skin zone conductivity parameter space derived from IMC-461 perturbation analysis for the 10 min period sinusoidal test with the fit discriminant and best fit values.



Figure B-2. X-Y scatter plot showing the skin zone specific storage parameter space derived from IMC-461 perturbation analysis for 10 min period sinusoidal test with the fit discriminant and best fit values.



Figure B-3. X-Y scatter plot showing the skin zone thickness parameter space derived from IMC-461 perturbation analysis for the 10 min period sinusoidal test with the fit discriminant and best fit values.



Figure B-4. X-Y scatter plot showing the static formation pressure parameter space derived from IMC-461 perturbation analysis for the 10 min period sinusoidal test with the fit discriminant and best fit values.

nPre/64 2.50

Version date 25 June 2012
Listing date 01 Aug 2016
QA status non-QA Open Source
Config file C:\SANDIA_PROJECTS\WIPP_wells\Culebra\IMC-461_Sinusoid\IMC461_D1_SINE.nPre

Control Settings

Main Settings

Simulation type Simulation subtype Phase to simulate Skin zone ? External boundary	Optimization Normal Liquid yes Fixed Pressure		
Liquid Phase Settings			
Aquifer type Aquifer horizontal permeability System porosity Compensate flow dimension geometry Leakage	Confined Isotropic Single yes None		
Test Zone Settings			
Test zone volume can vary Test zone compressibility can vary Test zone temperature can vary Default test-zone temperature Solution variable Allow negative head/pressure	no no 20.00 Pressure yes	[C]	

Parameters

Formation

Formation thickness	24.000	[ft]
Flow dimension	2.0	[]
Static formation pressure	Optimization	
Minimum value	67.000	[psi]
Maximum value	71.000	[psi]
Estimate value	69.734	[psi]
Range type	Linear	
Sigma	1.00000E+00	
External boundary radius	1000000	[m]
Formation conductivity	Optimization	
Minimum value	1.00000E-10	[m/sec]
Maximum value	1.00000E-02	[m/sec]

Estimate value Range type Sigma Formation spec. storage Minimum value Maximum value Estimate value Range type Sigma	2.16332E-05 Log 1.00000E+00 Optimization 1.00000E-08 1.00000E-04 7.00372E-05 Log 1.00000E+00	[m/sec] [1/m] [1/m] [1/m]	
Skin			
Radial thickness of skin Minimum value Maximum value Estimate value Range type Sigma Skin zone conductivity Minimum value Maximum value Estimate value Range type Sigma Skin zone spec. storage Minimum value Maximum value Estimate value Range type Sigma	Optimization 0.001 5.0 4.7814313 Linear 1.00000E+00 Optimization 1.00000E-10 1.00000E-02 3.94091E-05 Log 1.00000E+00 Optimization 1.00000E-10 1.00000E-02 2.15531E-09 Log 1.00000E+00	[m] [m] [m] [m/sec] [m/sec] [m/sec] [1/m] [1/m] [1/m]	
Fluid			
Fluid density Fluid thermal exp. coeff.	1008.00 0.00000E+00	[kg/m ³] [1/C]	
Test-Zone			
Well radius	2.5625	[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]	

Calculated Parameters

Formation		
Transmissivity	min/max	
Minimum	7.31520E-10	[m ² /sec]
Maximum	7.31520E-02	[m ² /sec]
Storativity	min/max	
Minimum	7.31520E-08	[]

Maximum	7.31520E-04	[]
Diffusivity	min/max	
Minimum	1.00000E-06	[m^2/sec]
Maximum	1.00000E+06	[m^2/sec]
Skin Zone		
Transmissivity	min/max	
Minimum	7.31520E-10	[m^2/sec]
Maximum	7.31520E-02	[m ² /sec]
Storativity	min/max	
Minimum	7.31520E-10	[]
Maximum	7.31520E-02	[]
Diffusivity	min/max	
Minimum	1.00000E-08	[m ² /sec]
Maximum	1.00000E+08	[m ² /sec]
Skin factor	min/max	
Minimum	-1.52471E-02	[]
Maximum	4.35439E+08	[]
Grid Properties		
Grid increment delta	min/max	
Minimum	0.06127	[]
Maximum	0.08308	
First grid increment	min/max	
Minimum	3.20053E-01	[m]
Maximum	5.72485E-03	[m]
Skin grid increment delta	min/max	
Minimum	0.00031	
Maximum	0.08887	1
Skin first grid increment	min/max	
Minimum	2.02561E-05	[m]
Maximum	6.04880E-03	[m]
Skin last grid increment	min/max	
Minimum	2.05609E-05	[m]
Maximum	4.30690E-01	[m]
Increment ratio	min/max	
Minimum	7.43118E-01	[]
Maximum	2.78433E+02	[]

Sequences

Sequence: H_01

Sequence type	History	
Start time	42527.390046	[day]
Duration	0.057871	[day]
Time step type	Static	
Static time step	0.000116	[day]
Туре	Curve	
Wellbore storage	None	

Sequence: H_02

Sequence type

History

Start time	42527.447917	[day]
Duration	0.020833	[day]
Time step type	Static	
Static time step	0.000116	[day]
Туре	Curve	
Wellbore storage	None	
Saguanaa II 02		
Sequence: H_05		
Sequence type	History	
Start time	42527.468750	[day]
Duration	0.022107	[day]
Time step type	Log	
First log step	1.15741E-07	[day]
# of time steps	250	
Type	Curve	
Wellbore storage	None	
Sequence: H_04		
Sequence type	History	
Start time	42527.490857	[day]
Duration	0.036921	[day]
Time step type	Log	
First log step	1.15741E-07	[day]
# of time steps	250	
Туре	Curve	
Wellbore storage	None	
Sequence: H_05		
Sequence: H_05 Sequence type	History	
Sequence: H_05 Sequence type Start time	History 42527.527778	[day]
Sequence: H_05 Sequence type Start time Duration	History 42527.527778 0.014005	[day] [day]
Sequence: H_05 Sequence type Start time Duration Time step type	History 42527.527778 0.014005 Log	[day] [day]
Sequence: H_05 Sequence type Start time Duration Time step type First log step	History 42527.527778 0.014005 Log 1.15741E-07	[day] [day] [day]
Sequence: H_05 Sequence type Start time Duration Time step type First log step # of time steps	History 42527.527778 0.014005 Log 1.15741E-07 250	[day] [day] [day]
Sequence: H_05 Sequence type Start time Duration Time step type First log step # of time steps Type	History 42527.527778 0.014005 Log 1.15741E-07 250 Curve	[day] [day] [day]
Sequence: H_05 Sequence type Start time Duration Time step type First log step # of time steps Type Wellbore storage	History 42527.527778 0.014005 Log 1.15741E-07 250 Curve None	[day] [day] [day]
Sequence: H_05 Sequence type Start time Duration Time step type First log step # of time steps Type Wellbore storage Sequence: F 01	History 42527.527778 0.014005 Log 1.15741E-07 250 Curve None	[day] [day] [day]
Sequence: H_05 Sequence type Start time Duration Time step type First log step # of time steps Type Wellbore storage Sequence: F_01 Sequence type	History 42527.527778 0.014005 Log 1.15741E-07 250 Curve None Flow	[day] [day] [day]
Sequence: H_05 Sequence type Start time Duration Time step type First log step # of time steps Type Wellbore storage Sequence: F_01 Sequence type Start time	History 42527.527778 0.014005 Log 1.15741E-07 250 Curve None Flow 42527.541782	[day] [day] [day]
Sequence: H_05 Sequence type Start time Duration Time step type First log step # of time steps Type Wellbore storage Sequence: F_01 Sequence type Start time Duration	History 42527.527778 0.014005 Log 1.15741E-07 250 Curve None Flow 42527.541782 0.071065	[day] [day] [day] [day] [day]
Sequence: H_05 Sequence type Start time Duration Time step type First log step # of time steps Type Wellbore storage Sequence: F_01 Sequence type Start time Duration Time step type	History 42527.527778 0.014005 Log 1.15741E-07 250 Curve None Flow 42527.541782 0.071065 Static	[day] [day] [day] [day] [day]
Sequence: H_05 Sequence type Start time Duration Time step type First log step # of time steps Type Wellbore storage Sequence: F_01 Sequence type Start time Duration Time step type Static time step	History 42527.527778 0.014005 Log 1.15741E-07 250 Curve None Flow 42527.541782 0.071065 Static 0.000116	[day] [day] [day] [day] [day]
Sequence: H_05 Sequence type Start time Duration Time step type First log step # of time steps Type Wellbore storage Sequence: F_01 Sequence type Start time Duration Time step type Static time step Type	History 42527.527778 0.014005 Log 1.15741E-07 250 Curve None Flow 42527.541782 0.071065 Static 0.000116 Curve	[day] [day] [day] [day] [day]
Sequence: H_05 Sequence type Start time Duration Time step type First log step # of time steps Type Wellbore storage Sequence: F_01 Sequence type Start time Duration Time step type Static time step Type Wellbore storage	History 42527.527778 0.014005 Log 1.15741E-07 250 Curve None Flow 42527.541782 0.071065 Static 0.000116 Curve None	[day] [day] [day] [day] [day]
Sequence: H_05 Sequence type Start time Duration Time step type First log step # of time steps Type Wellbore storage Sequence: F_01 Sequence type Start time Duration Time step type Static time step Type Wellbore storage Sequence: H 06	History 42527.527778 0.014005 Log 1.15741E-07 250 Curve None Flow 42527.541782 0.071065 Static 0.000116 Curve None	[day] [day] [day] [day] [day]
Sequence: H_05 Sequence type Start time Duration Time step type First log step # of time steps Type Wellbore storage Sequence: F_01 Sequence type Start time Duration Time step type Static time step Type Wellbore storage Sequence: H_06 Sequence type	History 42527.527778 0.014005 Log 1.15741E-07 250 Curve None Flow 42527.541782 0.071065 Static 0.000116 Curve None	[day] [day] [day] [day] [day]
Sequence: H_05 Sequence type Start time Duration Time step type First log step # of time steps Type Wellbore storage Sequence: F_01 Sequence type Start time Duration Time step type Static time step Type Wellbore storage Sequence: H_06 Sequence type Start time	History 42527.527778 0.014005 Log 1.15741E-07 250 Curve None Flow 42527.541782 0.071065 Static 0.000116 Curve None History 42527.612847	[day] [day] [day] [day] [day]
Sequence: H_05 Sequence type Start time Duration Time step type First log step # of time steps Type Wellbore storage Sequence: F_01 Sequence type Start time Duration Time step type Static time step Type Wellbore storage Sequence: H_06 Sequence type Start time Duration	History 42527.527778 0.014005 Log 1.15741E-07 250 Curve None Flow 42527.541782 0.071065 Static 0.000116 Curve None History 42527.612847 0.014583	[day] [day] [day] [day] [day] [day]
Sequence: H_05 Sequence type Start time Duration Time step type First log step # of time steps Type Wellbore storage Sequence: F_01 Sequence type Start time Duration Time step type Static time step Type Wellbore storage Sequence: H_06 Sequence type Start time Duration Time step type	History 42527.527778 0.014005 Log 1.15741E-07 250 Curve None Flow 42527.541782 0.071065 Static 0.000116 Curve None History 42527.612847 0.014583 Log	[day] [day] [day] [day] [day] [day] [day]
Sequence: H_05 Sequence type Start time Duration Time step type First log step # of time steps Type Wellbore storage Sequence: F_01 Sequence type Start time Duration Time step type Static time step Type Wellbore storage Sequence: H_06 Sequence type Start time Duration Time step type First log step	History 42527.527778 0.014005 Log 1.15741E-07 250 Curve None Flow 42527.541782 0.071065 Static 0.000116 Curve None History 42527.612847 0.014583 Log 1.15741E-07	[day] [day] [day] [day] [day] [day] [day] [day]

Information Only

Туре		Curve
Wellbore	storage	None

Sequence: H_07

Sequence type	History	
Start time	42527.627431	[day]
Duration	0.251087	[day]
Time step type	Log	
First log step	1.15741E-07	[day]
# of time steps	250	
Туре	Curve	
Wellbore storage	None	

Test Zone Curves

P_Curve
Pressure
H_01
H_07
Test
[psi]
no
Q_Curve
Flow Rate
H_01
H_07
Test
[TTC crow]
[Usgpiii]

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 ?	no
Optimization Output	
Write file ?	no

Optimization Setup

Algorithm	Simplex	
Calculate confidence limits ?	yes	
Covariance matrix calculations	lst Order	
Fixed derivative span ?	no	
Fit tolerance	1.0000E-05	
Parameter tolerance	not used	
<pre># of optimized variables</pre>	6	
Formation conductivity	OK	
Skin zone conductivity	OK	
Static formation pressure	OK	
Formation spec. storage	OK	
Skin zone spec. storage	OK	
Radial thickness of skin	OK	
Fits to Optimize		
Cart DAT P	OK	
Calculated Parameters Included		
# of galgulated wariables included	0	
+ OF CATCUTACED VALIABLES INCLUDED	0	

Suite/Range Setup

of suite/range variables

0









Figure B-6. X-Y scatter plot showing the skin zone specific storage parameter space derived from IMC-461 perturbation analysis for 20 min period sinusoidal test with the fit discriminant and best fit values.



Figure B-7. X-Y scatter plot showing the skin zone thickness parameter space derived from IMC-461 perturbation analysis for the 20 min period sinusoidal test with the fit discriminant and best fit values.



Figure B-8. X-Y scatter plot showing the static formation pressure parameter space derived from IMC-461 perturbation analysis for the 20 min period sinusoidal test with the fit discriminant and best fit values.

nPre/64 2.50

Version date 25 June 2012
Listing date 01 Aug 2016
QA status non-QA Open Source
Config file C:\SANDIA_PROJECTS\WIPP_wells\Culebra\IMC-461_Sinusoid\IMC461_D4_sine2.nPre

Control Settings

Main Settings

Simulation type Simulation subtype Phase to simulate Skin zone ? External boundary	Optimization Normal Liquid yes Fixed Pressure	
Liquid Phase Settings		
Aquifer type Aquifer horizontal permeability System porosity Compensate flow dimension geometry Leakage	Confined Isotropic Single yes None	
Test Zone Settings		
Test zone volume can vary Test zone compressibility can vary Test zone temperature can vary	no no no	
Default test-zone temperature Solution variable Allow negative head/pressure	20.00 Pressure yes	[C]

Parameters

Formation

Formation thickness	24.000	[ft]
Flow dimension	2.0	[]
Static formation pressure	Optimization	
Minimum value	67.000	[psi]
Maximum value	71.000	[psi]
Estimate value	69.742	[psi]
Range type	Linear	
Sigma	1.00000E+00	
External boundary radius	1000000	[m]
Formation conductivity	Optimization	

Minimum value	1.00000E-10	[m/sec]
Maximum value	1.00000E-02	[m/sec]
Estimate value	2.71813E-05	[m/sec]
Range type	Log	
Sigma	1.00000E+00	
Formation spec. storage	Optimization	
Minimum value	1.00000E-08	[l/m]
Maximum value	1.00000E-04	[1/m]
Estimate value	5.89304E-05	[1/m]
Range type	Log	
Sigma	1.00000E+00	

Skin

Radial thickness of skin	Optimization	
Minimum value	0.001	[m]
Maximum value	5.0	[m]
Estimate value	0.247773	[m]
Range type	Linear	
Sigma	1.00000E+00	
Skin zone conductivity	Optimization	
Minimum value	1.00000E-10	[m/sec]
Maximum value	1.00000E-02	[m/sec]
Estimate value	1.78602E-04	[m/sec]
Range type	Log	
Sigma	1.00000E+00	
Skin zone spec. storage	Optimization	
Minimum value	1.00000E-10	[1/m]
Maximum value	1.00000E-02	[1/m]
Estimate value	2.95586E-10	[1/m]
Range type	Log	
Sigma	1.00000E+00	

Fluid

Fluid	density			1008.00	[kg/m^3]
Fluid	thermal e	xp.	coeff.	0.00000E+00	[1/C]

Test-Zone

1 est zione		
Well radius	2.5625	[in]
Numeric		
<pre># of radial nodes # of skin nodes Pressure solution tolerance STP flow solution tolerance</pre>	250 50 1.45038E-11 1.58503E-11	[] [] [DSi] [USgpm]

Calculated Parameters

Formation

Transmissivity Minimum Maximum Storativity Minimum Diffusivity Minimum Maximum	<pre>min/max 7.31520E-10 7.31520E-02 min/max 7.31520E-08 7.31520E-04 min/max 1.00000E-06 1.00000E+06</pre>	[m ² /sec] [m ² /sec] [] [m ² /sec] [m ² /sec]	
Skin Zone			
Transmissivity Minimum Maximum Storativity Minimum Diffusivity Minimum Maximum Skin factor Minimum Maximum	<pre>min/max 7.31520E-10 7.31520E-02 min/max 7.31520E-10 7.31520E-02 min/max 1.00000E-08 1.00000E+08 min/max -1.52471E-02 4.35439E+08</pre>	[m ² /sec] [m ² /sec] [] [m ² /sec] [m ² /sec] [] []	
Grid Properties			
Grid increment delta Minimum Maximum First grid increment Minimum Maximum Skin grid increment delta Minimum Maximum Skin first grid increment Minimum Maximum Skin last grid increment Minimum Maximum Increment ratio Minimum	min/max 0.06127 0.08308 min/max 3.20053E-01 5.72485E-03 min/max 0.00031 0.08887 min/max 2.02561E-05 6.04880E-03 min/max 2.05609E-05 4.30690E-01 min/max 7.43118E-01	[] [] [m] [] [] [] [m] [m] [m]	
Maximum	2.78433E+02	[]	

Sequences

Sequence: H_01

Sequence type	History	
Start time	42530.262081	[day]
Duration	0.045791	[day]

⁴⁹ Information Only

Time step type	Static	
Static time step	0.000116	[day]
Туре	Curve	
Wellbore storage	None	

Sequence: H_02

Sequence type	History	
Start time	42530.307872	[day]
Duration	0.035531	[day]
Time step type	Static	
Static time step	0.000116	[day]
Туре	Curve	
Wellbore storage	None	

Sequence: H_03

Sequence type	History	
Start time	42530.343403	[day]
Duration	0.010764	[day]
Time step type	Log	
First log step	1.15741E-07	[day]
# of time steps	250	
Туре	Curve	
Wellbore storage	None	

Sequence: F_01

Sequence type	Flow	
Start time	42530.354167	[day]
Duration	0.141782	[day]
Time step type	Static	
Static time step	0.000116	[day]
Туре	Curve	
Wellbore storage	None	

Sequence: H_04

Sequence type	History	
Start time	42530.495949	[day]
Duration	0.013079	[day]
Time step type	Log	
First log step	1.15741E-07	[day]
# of time steps	250	
Туре	Curve	
Wellbore storage	None	

Sequence: H_05

Sequence type	History	
Start time	42530.509028	[day]
Duration	0.004398	[day]
Time step type	Log	
First log step	1.15741E-07	[day]

# of	time	steps	250
Type			Curve
Well	bore	storage	None

Test Zone Curves

Curve	object to	use		P_Curve
Curve	type			Pressure
Start	sequence			H_01
End se	equence			H_05
Curve	time base			Test
Curve	Y data un:	its		[psi]
Curve	Y data is	log	10	no
Curve	object to	use		Q_Curve
Curve	type		F	low Rate
Start	sequence			H_01
End se	equence			H_05
Curve	time base			Test
Curve	Y data uni	lts		[USgpm]
Curve	Y data is	log	10	no

Simulation Results Setup

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OutputFiles

XY Forward Output	
Write file ?	no
Optimization Output	
Write file ?	no

Optimization Setup

Algorithm	Simplex
Calculate confidence limits ?	yes
Covariance matrix calculations	lst Order

Fixed derivative span ?	no	
Fit tolerance	1.0000E-05	
Parameter tolerance	not used	
<pre># of optimized variables</pre>	6	
Formation conductivity	OK	
Skin zone conductivity	OK	
Static formation pressure	OK	
Formation spec. storage	OK	
Skin zone spec. storage	OK	
Radial thickness of skin	OK	
Fits to Optimize		
ris to optimize		
CompositoFit	OF	
Lomposiceric	ŬK.	
Calculated Parameters Included		
	_	
<pre># of calculated variables included</pre>	0	

Suite/Range Setup

of suite/range variables





Figure B-9. X-Y scatter plot showing the skin zone conductivity parameter space derived from IMC-461 perturbation analysis for the 40 min period sinusoidal test with the fit discriminant and best fit values.



Figure B-10. X-Y scatter plot showing the skin zone specific storage parameter space derived from IMC-461 perturbation analysis for 40 min period sinusoidal test with the fit discriminant and best fit values.



Figure B-11. X-Y scatter plot showing the skin zone thickness parameter space derived from IMC-461 perturbation analysis for the 40 min period sinusoidal test with the fit discriminant and best fit values.



Figure B-12. X-Y scatter plot showing the static formation pressure parameter space derived from IMC-461 perturbation analysis for the 40 min period sinusoidal test with the fit discriminant and best fit values.

Version date 25 June 2012 Listing date 01 Aug 2016 QA status non-QA Open Source Config file C:\SANDIA_PROJECTS\WIPP_wells\Culebra\IMC-461_Sinusoid\IMC-461_D2_sine.nPre

Control Settings

Main Settings

Simulation type Simulation subtype Phase to simulate Skin zone ? External boundary Optimization Normal Liquid yes Fixed Pressure

Liquid Phase Settings

Aquifer type Aquifer horizontal permeability Confined Isotropic

System porc	sity			Sir	ıgle
Compensate	flow	dimension	geometry		yes
Leakage				1	Ione

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 Flow dimension	24.000 2.0	[ft] []
Static formation pressure	Optimization	
Minimum value	67.000	[psi]
Maximum value	71.000	[psi]
Estimate value	69.731	[psi]
Range type	Linear	-
Sigma	1.00000E+00	
External boundary radius	1000000	[m]
Formation conductivity	Optimization	
Minimum value	1.00000E-10	[m/sec]
Maximum value	1.00000E-02	[m/sec]
Estimate value	1.67640E-05	[m/sec]
Range type	Log	
Sigma	1.00000E+00	
Formation spec. storage	Optimization	
Minimum value	1.00000E-08	[1/m]
Maximum value	1.00000E-04	[1/m]
Estimate value	9.99867E-05	[1/m]
Range type	Log	
Sigma	1.00000E+00	

Skin

Optimization	
0.001	[m]
5.0	[m]
4.844046	[m]
Linear	
1.00000E+00	
Optimization	
1.00000E-10	[m/sec]
1.00000E-02	[m/sec]
4.85565E-05	[m/sec]
Log	
1.00000E+00	
	Optimization 0.001 5.0 4.844046 Linear 1.00000E+00 Optimization 1.00000E-10 1.00000E-02 4.85565E-05 Log 1.00000E+00

Skin zone spec. storage Minimum value Maximum value Estimate value Range type Sigma	Optimization 1.00000E-10 1.00000E-02 2.86871E-09 Log 1.00000E+00	[1/m] [1/m] [1/m]
Fluid		
Fluid density Fluid thermal exp. coeff.	1008.00 0.00000E+00	[kg/m [*] 3] [1/C]
Test-Zone		
Well radius	2.5625	[in]
Numeric		
<pre># of radial nodes # of skin nodes Pressure solution tolerance STP flow solution tolerance</pre>	250 50 1.45038E-11 1.58503E-11	[] [] [psi] [USgpm]

Calculated Parameters

Formation

Transmissionites		
Transmissivity	min/max	
Minimum	7.31520E-10	[m^2/sec]
Maximum	7.31520E-02	[m^2/sec]
Storativity	min/max	
Minimum	7.31520E-08	[]
Maximum	7.31520E-04	[]
Diffusivity	min/max	
Minimum	1.00000E-06	[m ² /sec]
Maximum	1.00000E+06	[m ² /sec]

Skin Zone

Transmissivity	min/max	
Minimum	7.31520E-10	[m^2/sec]
Maximum	7.31520E-02	[m ² /sec]
Storativity	min/max	
Minimum	7.31520E-10	[]
Maximum	7.31520E-02	[]
Diffusivity	min/max	
Minimum	1.00000E-08	[m ² /sec]
Maximum	1.00000E+08	[m ² /sec]
Skin factor	min/max	
Minimum	-1.52471E-02	[]
Maximum	4.35439E+08	[]

Grid Properties

Grid increment delta	min/max	
Minimum	0.06127	[]
Maximum	0.08308	[]
First grid increment	min/max	
Minimum	3.20053E-01	[m]
Maximum	5.72485E-03	[m]
Skin grid increment delta	min/max	
Minimum	0.00031	[]
Maximum	0.08887	[]
Skin first grid increment	min/max	
Minimum	2.02561E-05	[m]
Maximum	6.04880E-03	[m]
Skin last grid increment	min/max	
Minimum	2.05609E-05	[m]
Maximum	4.30690E-01	[m]
Increment ratio	min/max	
Minimum	7.43118E-01	[]
Maximum	2.78433E+02	[]

Sequences

Sequence: H_01

Sequence type	History	
Start time	42528.250694	[day]
Duration	0.126389	[day]
Time step type	Static	
Static time step	0.000116	[day]
Туре	Curve	
Wellbore storage	None	

Sequence: H_02

Sequence type	History	
Start time	42528.377083	[day]
Duration	0.031366	[day]
Time step type	Log	
First log step	1.15741E-07	[day]
# of time steps	250	
Туре	Curve	
Wellbore storage	None	

Sequence: H_03

Sequence type	History	
Start time	42528.408449	[day]
Duration	0.022107	[day]
Time step type	Log	
First log step	1.15741E-07	[day]
# of time steps	250	
Туре	Curve	

Wellbore storage

None

Sequence: F_01

[day]
[day]
[day]

Sequence: H_04

Sequence type	History	
Start time	42528.599884	[day]
Duration	0.021412	[day]
Time step type	Log	
First log step	1.15741E-07	[day]
# of time steps	250	
Туре	Curve	
Wellbore storage	None	

Sequence: H_05

Sequence type	History	
Start time	42528.621296	[day]
Duration	0.149537	[day]
Time step type	Static	
Static time step	0.000116	[day]
Туре	Curve	
Wellbore storage	None	

Test Zone Curves

Curve object to use	P_Curve
Curve type	Pressure
Start sequence	H_01
End sequence	H_05
Curve time base	Test
Curve Y data units	[psi]
Curve Y data is log 10	no
Curve object to use	Q_Curve
Curve object to use Curve type	Q_Curve Flow Rate
Curve object to use Curve type Start sequence	Q_Curve Flow Rate H_01
Curve object to use Curve type Start sequence End sequence	Q_Curve Flow Rate H_01 H_05
Curve object to use Curve type Start sequence End sequence Curve time base	Q_Curve Flow Rate H_01 H_05 Test
Curve object to use Curve type Start sequence End sequence Curve time base Curve Y data units	Q_Curve Flow Rate H_01 H_05 Test [USgpm]

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 ?	no
Optimization Output	
Write file ?	no

Optimization Setup

Algorithm	Simplex	
Calculate confidence limit:	s? yes	
Covariance matrix calculat:	ions 1st Order	
Fixed derivative span ?	no	
Fit tolerance	1.0000E-05	
Parameter tolerance	not used	
<pre># of optimized variables</pre>	6	
Formation conductivity	OK.	
Skin zone conductivity	OK	
Static formation pressure	OK.	
Formation spec. storage	OK	
Skin zone spec. storage	OK	
Radial thickness of skin	OK	
Fits to Optimize		
CompositeFit	OK	
-		
Calculated Parameters Included		
# of colourated wowichlos	ingluded 0	
# OI CAICUIATED VARIABLES		

Suite/Range Setup

of suite/range variables



Figure B-13. X-Y scatter plot showing the skin zone conductivity parameter space derived from IMC-461 perturbation analysis for the 60 min period sinusoidal test with the fit discriminant and best fit values.



Figure B-14. X-Y scatter plot showing the skin zone specific storage parameter space derived from IMC-461 perturbation analysis for 60 min period sinusoidal test with the fit discriminant and best fit values.



Figure B-15. X-Y scatter plot showing the skin zone thickness parameter space derived from IMC-461 perturbation analysis for the 60 min period sinusoidal test with the fit discriminant and best fit values.



Figure B-16. X-Y scatter plot showing the static formation pressure parameter space derived from IMC-461 perturbation analysis for the 60 min period sinusoidal test with the fit discriminant and best fit values.

nPre/64 2.50

Version date 25 June 2012
Listing date 01 Aug 2016
QA status non-QA Open Source
Config file C:\SANDIA_PROJECTS\WIPP_wells\Culebra\IMC-461_Sinusoid\IMC461_D3_sine.nPre

Control Settings

Main Settings

Optimization
Normal
Liquid
yes
Fixed Pressure

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	24.000	[ft]
Flow dimension	2.0	[]
Static formation pressure	Optimization	
Minimum value	67.000	[psi]
Maximum value	71.000	[psi]
Estimate value	69.729	[psi]
Range type	Linear	
Sigma	1.00000E+00	
External boundary radius	1000000	[m]
Formation conductivity	Optimization	

Minimum value	1.00000E-10	[m/sec]
Maximum value	1.00000E-02	[m/sec]
Estimate value	1.53646E-05	[m/sec]
Range type	. Log	
Sigma	1.00000E+00	
Formation spec. storage	1.00000E-05	[1/m]

Skin

Radial thickness of skin	Optimization	
Minimum value	0.001	[m]
Maximum value	5.0	[m]
Estimate value	3.6191182	[m]
Range type	Linear	
Sigma	1.00000E+00	
Skin zone conductivity	Optimization	
Minimum value	1.00000E-10	[m/sec]
Maximum value	1.00000E-02	[m/sec]
Estimate value	4.29044E-04	[m/sec]
Range type	Log	
Sigma	1.00000E+00	
Skin zone spec. storage	Optimization	
Minimum value	1.00000E-10	[1/m]
Maximum value	1.00000E-02	[1/m]
Estimate value	8.69173E-06	[1/m]
Range type	Loq	
Sigma	1.00000E+00	
Fluid		
Fluid density	1008.00	[kg/m^3]
Fluid thermal exp. coeff.	0.00000E+00	[1/C]
Test-Zone		
Well radius	2.5625	[in]
Numeric		
# of radial nodes	250	П

1 of tootot Hogeo		200	
# of skin nodes		50	[]
Pressure solution	tolerance	1.45038E-11	[psi]
STP flow solution	tolerance	1.58503E-11	[USgpm]

Calculated Parameters

Formation

Transmissivity	min/max	
Minimum	7.31520E-10	[m^2/sec]
Maximum	7.31520E-02	[m ² /sec]
Storativity	7.31520E-05	[]

⁶³ Information Only

Diffusivity	min/max	
Minimum	1.00000E-05	[m^2/sec]
Maximum	1.00000E+03	[m ² /sec]

Skin Zone

Transmissivity	min/max	
Minimum	7.31520E-10	[m^2/sec]
Maximum	7.31520E-02	[m ² /sec]
Storativity	min/max	
Minimum	7.31520E-10	[]
Maximum	7.31520E-02	[]
Diffusivity	min/max	
Minimum	1.00000E-08	[m ² /sec]
Maximum	1.00000E+08	[m ² /sec]
Skin factor	min/max	
Minimum	-1.52471E-02	[] `
Maximum	4.35439E+08	[]

Grid Properties

Grid increment delta	min/max		
Minimum	0.06127	[]	
Maximum	0.08308	[]	
First grid increment	min/max		
Minimum	3.20053E-01	[m]	
Maximum	5.72485E-03	[m]	
Skin grid increment delta	min/max		
Minimum	0.00031	[]	
Maximum	0.08887	[]	
Skin first grid increment	min/max		
Minimum	2.02561E-05	[m]	
Maximum	6.04880E-03	[m]	
Skin last grid increment	min/max		
Minimum	2.05609E-05	[m]	
Maximum	4.30690E-01	[m]	
Increment ratio	min/max		
Minimum	7.43118E-01	[]	
Maximum	2.78433E+02	[]	

Sequences

Sequence: H_01

Sequence type	History	
Start time	42529.278745	[day]
Duration	0.047958	[day]
Time step type	Static	
Static time step	0.000116	[day]
Туре	Curve	
Wellbore storage	None	

Sequence: F_01

Sequence type Start time Duration Time step type Static time step Type Wellbore storage	Flow 42529.326703 0.338343 Static 0.000116 Curve None	[day] [day] [day]
Sequence: H_02		
Sequence type Start time Duration Time step type First log step # of time steps Type Wellbore storage	History 42529.665046 0.017130 Log 1.15741E-07 250 Curve None	[day] [day] [day]
Sequence: H_03		
Sequence type Start time Duration Time step type Static time step Type Wellbore storage	History 42529.682176 0.097890 Static 0.000116 Curve None	[day] [day] [day]
Test Zone Curves		
Curve object to use Curve type Start sequence End sequence Curve time base Curve Y data units Curve Y data is log 10	P_Curve Pressure H_01 H_03 Test [psi] no	
Curve object to use Curve type Start sequence End sequence Curve time base Curve Y data units Curve Y data is log 10	Q_Curve Flow Rate H_01 H_03 Test [USgpm] 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 ?	no
Optimization Output	
Write file ?	no

Optimization Setup

Algorithm	Simplex	
Calculate confidence limits ?	yes	
Covariance matrix calculation	s 1st Order	
Fixed derivative span ?	no	
Fit tolerance	1.0000E-05	
Parameter tolerance	not used	
<pre># of optimized variables</pre>	5	
Formation conductivity	OK	
Skin zone conductivity	OK	
Static formation pressure	OK	
Skin zone spec. storage	OK	
Radial thickness of skin	ОК	
Fits to Optimize		
CompositeFit	OK	
Calculated Parameters Included		
<pre># of calculated variables inc.</pre>	luded 0	

Suite/Range Setup

of suite/range variables

0



Figure B-17. X-Y scatter plot showing the skin zone conductivity parameter space derived from IMC-461 perturbation analysis for the 120 min period sinusoidal test with the fit discriminant and best fit values.



Figure B-18. X-Y scatter plot showing the skin zone specific storage parameter space derived from IMC-461 perturbation analysis for 120 min period sinusoidal test with the fit discriminant and best fit values.



Figure B-19. X-Y scatter plot showing the skin zone thickness parameter space derived from IMC-461 perturbation analysis for the 120 min period sinusoidal test with the fit discriminant and best fit values.

nPre/64 2.50

Version date 25 June 2012
Listing date 01 Aug 2016
QA status non-QA Open Source
Config file C:\SANDIA_PROJECTS\WIPP_wells\Culebra\IMC-461_Sinusoid\IMC461_D1_CR.nPre

Control Settings

Main Settings

Simulation type		Forward
Simulation subtype		Normal
Phase to simulate		Liquid
Skin zone ?		yes
External boundary	Fixed	Pressure

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		
Rear Martin Barton - La Carta Barton - Carta Martin Carta Barton - Carta Barton - Carta Barton - Carta Barton -	THEORY AND A STATE OF A		
Devenerators			
rarameters			
Formation			
Formation thickness	24.000	[ft]	
Flow dimension	2.0	[]	
Static formation pressure	69.748	[psi]	
External boundary radius	1000000	[m]	
Formation conductivity	1.61609E-05	[m/sec]	
Formation spec. storage	9.80494E-05	[1/m]	
Skin			
Radial thickness of skin	4.9962433	[m]	
Skin zone conductivity	4.37856E-05	[m/sec]	

3.95170E-09 [1/m]

2.5625

[in]

Fluid

Fluid	density			1008.00	[kg/m^3]
Fluid	thermal e	exp.	coeff.	0.00000E+00	[1/C]

Test-Zone

Well radius

Numeric

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

Calculated Parameters

Skin zone spec. storage

Formation		
Transmissivity	1.18220E-04	[m^2/sec]
Storativity	7.17251E-04	[]
Diffusivity	1.64824E-01	[m ² /sec]
Skin Zone		
Transmissivity	3.20300E-04	[m ² /sec]
Storativity	2.89075E-08	[]

Diffusivity Skin factor	1.10802E+04 -2.74676E+00	[m ² /sec] []
Grid Properties		
Grid increment delta	0.06128	[]
First grid increment	3.19836E-01	[m]
Skin grid increment delta	0.08885	[]
Skin first grid increment	6.04772E-03	[m]
Skin last grid increment	4.30300E-01	[m]
Increment ratio	7.43286E-01	[]

Sequences

Sequence: H_01		
Sequence type	History	
Start time	42527.390046	[day]
Duration	0.057871	[day]
Time step type	Static	
Static time step	0.000116	[day]
Туре	Curve	
Wellbore storage	None	
Sequence: F_01		
Sequence type	Flow	
Start time	42527.447917	[day]
Duration	0.020833	[day]
Time step type	Static	
Static time step	0.000116	[day]
Туре	Curve	
Wellbore storage	None	
Sequence: F_02		

Sequence type	Flow	
Start time	42527.468750	[day]
Duration	0.022107	[day]
Time step type	Log	
First log step	1.15741E-07	[day]
# of time steps	250	
Туре	Curve	
Wellbore storage	None	

Sequence: H_02

Sequence type	History	
Start time	42527.490857	[day]
Duration	0.036921	[day]
Time step type	Log	
First log step	1.15741E-07	[day]
# of time steps	250	
Туре	Curve	
Wellbore storage	None	

Sequence: H_03

Sequence type	History	
Start time	42527.527778	[day]
Duration	0.014005	[day]
Time step type	Log	
First log step	1.15741E-07	[day]
# of time steps	250	
Туре	Curve	
Wellbore storage	None	

Sequence: H_04

Sequence type	History	
Start time	42527.541782	[day]
Duration	0.071065	[day]
Time step type	Static	
Static time step	0.000116	[day]
Туре	Curve	
Wellbore storage	None	

Sequence: H_05

Sequence type	History	
Start time	42527.612847	[day]
Duration	0.014583	[day]
Time step type	Log	
First log step	1.15741E-07	[day]
# of time steps	250	
Туре	Curve	
Wellbore storage	None	

Sequence: H_06

Sequence type	History	
Start time	42527.627431	[day]
Duration	0.251087	[day]
Time step type	Log	
First log step	1.15741E-07	[day]
# of time steps	250	
Туре	Curve	
Wellbore storage	None	

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	H_01
End sequence	H_06
Curve time base	Test

Curve	Y	data	un	its	
Curve	Y	data	is	log	10

[USgpm] 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 ?	no	
Profile Output		
Write file ?	no	

Suite/Range Setup

of suite/range variables

0




Figure B-20. X-Y scatter plot showing the skin conductivity parameter space for the first constant rate test derived from IMC-461 perturbation analysis with the fit discriminant and best fit values.



Figure B-21. X-Y scatter plot showing the skin zone specific storage parameter space derived from IMC-461 perturbation analysis for the first constant rate test with the fit discriminant and best fit values.



Figure B-22. X-Y scatter plot showing the skin zone thickness parameter space derived from IMC-461 perturbation analysis for the first constant rate test with the fit discriminant and best fit values.



Figure B-23. X-Y scatter plot showing the static formation pressure parameter space derived from IMC-461 perturbation analysis for the first constant rate test with the fit discriminant and best fit values.

nPre/64 2.50

Version date 25 June 2012
Listing date 01 Aug 2016
QA status non-QA Open Source
Config file C:\SANDIA_PROJECTS\WIPP_wells\Culebra\IMC-461_Sinusoid\IMC461_D2_CR.nPre

Control Settings

Main Settings

Optimization		
Normal		
Liquid		
yes		
Fixed Pressure		
Confined		
Isotropic		
Single		
yes		
None		
no		
no		
no		
20.00	[C]	
Pressure		
yes		
	Optimization Normal Liquid yes Fixed Pressure Confined Isotropic Single yes None no no 20.00 Pressure yes	Optimization Normal Liquid yes Fixed Pressure Confined Isotropic Single yes None no 20.00 [C] Pressure yes

Parameters

Formation

Formation thickness	24.000	[ft]
Flow dimension	2.0	[]
Static formation pressure	Optimization	
Minimum value	67.000	[psi]
Maximum value	71.000	[psi]
Estimate value	69.764	[psi]
Range type	Linear	
Sigma	1.00000E+00	
External boundary radius	1000000	[m]
Formation conductivity	Optimization	

Minimum value Maximum value Estimate value Range type Sigma Formation spec. storage Minimum value Maximum value Estimate value Range type Sigma	1.00000E-10 1.00000E-02 1.42018E-05 Log 1.00000E+00 Optimization 1.00000E-08 1.00000E-08 1.00000E-04 9.97534E-05 Log 1.00000E+00	[m/sec] [m/sec] [m/sec] [1/m] [1/m] [1/m]
Skin		
Radial thickness of skin Minimum value Maximum value Estimate value Range type Sigma Skin zone conductivity Minimum value Maximum value Estimate value Range type Sigma Skin zone spec. storage Minimum value Maximum value Estimate value Range type Sigma	Optimization 0.001 5.0 4.9853544 Linear 1.00000E+00 Optimization 1.00000E-10 1.00000E-02 5.18556E-05 Log 1.00000E+00 Optimization 1.00000E-10 1.00000E-02 2.39879E-08 Log 1.00000E+00	[m] [m] [m] [m/sec] [m/sec] [1/m] [1/m] [1/m]
Fluid		
Fluid density Fluid thermal exp. coeff.	1008.00 0.00000E+00	[kg/m ³] [1/C]
Test-Zone		
Well radius	2.5625	[in]
Numeric		
<pre># of radial nodes # of skin nodes Pressure solution tolerance STP flow solution tolerance</pre>	250 50 1.45038E-11 1.58503E-11	[] [] [psi] [USgpm]

Calculated Parameters

Formation

nsmissivity	min/max	
Minimum	7.31520E-10	[m ² /sec]
Maximum	7.31520E-02	[m ² /sec]
orativity	min/max	
Minimum	7.31520E-08	[]
Maximum	7.31520E-04	[]
fusivity	min/max	
Minimum	1.00000E-06	[m^2/sec]
Maximum	1.00000E+06	[m^2/sec]
Maximum orativity Minimum Maximum fusivity Minimum Maximum	7.31520E-02 min/max 7.31520E-08 7.31520E-04 min/max 1.00000E-06 1.00000E+06	[m^2/se [] [] [m^2/se [m^2/se

Skin Zone

Transmissivity	min/max	
Minimum	7.31520E-10	[m^2/sec]
Maximum	7.31520E-02	[m ² /sec]
Storativity	min/max	
Minimum	7.31520E-10	[]
Maximum	7.31520E-02	[]
Diffusivity	min/max	
Minimum	1.00000E-08	[m ² /sec]
Maximum	1.00000E+08	[m ² /sec]
Skin factor	min/max	
Minimum	-1.52471E-02	[]
Maximum	4.35439E+08	[]

Grid Properties

Grid increment delta	min/max	
Minimum	0.06127	[]
Maximum	0.08308	[]
First grid increment	min/max	
Minimum	3.20053E-01	[m]
Maximum	5.72485E-03	[m]
Skin grid increment delta	min/max	
Minimum	0.00031	[]
Maximum	0.08887	[]
Skin first grid increment	min/max	
Minimum	2.02561E-05	[m]
Maximum	6.04880E-03	[m]
Skin last grid increment	min/max	
Minimum	2.05609E-05	[m]
Maximum	4.30690E-01	[m]
Increment ratio	min/max	
Minimum	7.43118E-01	[]
Maximum	2.78433E+02	[]

Sequences

Sequence: H_01

Sequence type	History	
Start time	42528.250694	[day]
Duration	0.126389	[day]

Time step type	Static	
Static time step	0.000116	[day]
Туре	Curve	
Wellbore storage	None	

Sequence: F_01

Sequence type	Flow	
Start time	42528.377083	[day]
Duration	0.031366	[day]
Time step type	Log	
First log step	1.15741E-07	[day]
# of time steps	250	
Туре	Curve	
Wellbore storage	None	

Sequence: F_02

Sequence type	Flow	
Start time	42528.408449	[day]
Duration	0.022107	[day]
Time step type	Log	
First log step	1.15741E-07	[day]
# of time steps	250	
Туре	Curve	
Wellbore storage	None	

Sequence: H_02

Sequence type	History	
Start time	42528.430556	[day]
Duration	0.169329	[day]
Time step type	Static	
Static time step	0.000116	[day]
Туре	Curve	
Wellbore storage	None	

Sequence: H_03

Sequence type	History	
Start time	42528.599884	[day]
Duration	0.021412	[day]
Time step type	Log	
First log step	1.15741E-07	[day]
# of time steps	250	
Туре	Curve	
Wellbore storage	None	

Sequence: H_04

Sequence type	History	
Start time	42528.621296	[day]
Duration	0.149537	[day]
Time step type	Static	

Information Only

Static time step	0.000116	[day]
Туре	Curve	
Wellbore storage	None	

Test Zone Curves

Curve object to use	P_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
Curve object to use	Q_Curve
Curve type	Flow Rate
Start sequence	H_01
End sequence	H_04
Curve time base	Test
Curve Y data units	[IISgrow]
	[opabili]
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 ?	no
Optimization Output	
Write file ?	no

Optimization Setup

Algorithm	Simplex
Calculate confidence limits ?	yes
Covariance matrix calculations	1st Order

Fixed derivative span ? Fit tolerance Parameter tolerance # of optimized variables Formation conductivity Skin zone conductivity Static formation pressure Formation spec. storage Skin zone spec. storage Radial thickness of skin	no 1.0000E-05 not used 6 OK OK OK OK OK	
Fits to Optimize		
CompositeFit	OK	
Calculated Parameters Included		
# of calculated variables included	0	

Suite/Range Setup

of suite/range variables

0



Figure B-24. X-Y scatter plot showing the skin conductivity parameter space for the second constant rate test derived from IMC-461 perturbation analysis with the fit discriminant and best fit values.



Figure B-25. X-Y scatter plot showing the skin zone specific storage parameter space derived from IMC-461 perturbation analysis for the second constant rate test with the fit discriminant and best fit values.



Figure B-26. X-Y scatter plot showing the skin zone thickness parameter space derived from IMC-461 perturbation analysis for the second constant rate test with the fit discriminant and best fit values.



Figure B-27. X-Y scatter plot showing the static formation pressure parameter space derived from IMC-461 perturbation analysis for the second constant rate test with the fit discriminant and best fit values.

nPre/64 2.50

Version date 25 June 2012
Listing date 01 Aug 2016
QA status non-QA Open Source
Config file C:\SANDIA_PROJECTS\WIPP_wells\Culebra\IMC-461_Sinusoid\IMC461_D1_Slug.nPre

Control Settings

Main Settings

Simulation type Simulation subtype Phase to simulate Skin zone ? External boundary Optimization Normal Liquid no Fixed Pressure

Liquid Phase Settings

Aquifer type Aquifer horizontal permeability Confined Isotropic

System porc	sity			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	24.000	[ft]
Flow dimension	2.0	[]
Minimum value	optimization 67.000	Ingil
Maximum value	71 000	[psi]
Ratimoto value	71.000	[psr]
Estimate value	69.714 Linoar	[bar]
Range cype	1 00000E:00	
Sigma	1.00000E+00	[m]
External boundary radius		[m]
Formation conductivity	Optimization	r / 7
Minimum value	1.00000E-10	[m/sec]
Maximum value	1.00000E-02	[m/sec]
Estimate value	4.86758E-05	[m/sec]
Range type	Log	
Sigma	1.00000E+00	
Formation spec. storage	Optimization	
Minimum value	1.00000E-08	[1/m]
Maximum value	1.00000E-04	[1/m]
Estimate value	3.84190E-07	[1/m]
Range type	Log	
Sigma	1.00000E+00	
Fluid		
Fluid density	1008.00	[kg/m^3]
Fluid thermal exp. coeff.	0.0000E+00	[1/C]
Test-Zone		
Well radius	2.5625	[in]
Numeric		
# of radial nodes	250	[]

4.47242E-03

[m]

Formation

Transmissivity	min/max	
Minimum	7.31520E-10	[m^2/sec]
Maximum	7.31520E-02	[m ² /sec]
Storativity	min/max	
Minimum	7.31520E-08	[]
Maximum	7.31520E-04	[]
Diffusivity	min/max	
Minimum	1.00000E-06	[m^2/sec]
Maximum	1.00000E+06	[m^2/sec]
Grid Properties		
Grid increment delta	0.06646	[]

Sequences

Sequence: H_01

First grid increment

Sequence type	History	
Start time	42527.390046	[day]
Duration	0.057871	[day]
Time step type	Static	
Static time step	0.000116	[day]
Туре	Curve	
Wellbore storage	None	

Sequence: H_02

Sequence type	History	
Start time	42527.447917	[day]
Duration	0.020833	[day]
Time step type	Static	
Static time step	0.000116	[day]
Туре	Curve	
Wellbore storage	None	

Sequence: H_03

Sequence type	History	
Start time	42527.468750	[day]
Duration	0.022107	[day]
Time step type	Log	
First log step	1.15741E-07	[day]

# of time steps	250
Туре	Curve
Wellbore storage	None

Sequence: H_04

Sequence type	History	
Start time	42527.490857	[day]
Duration	0.036921	[day]
Time step type	Log	
First log step	1.15741E-07	[day]
# of time steps	250	
Туре	Curve	
Wellbore storage	None	

Sequence: H_05

Sequence type	History	
Start time	42527.527778	[day]
Duration	0.014005	[day]
Time step type	Log	
First log step	1.15741E-07	[day]
# of time steps	250	
Туре	Curve	
Wellbore storage	None	

Sequence: H_06

Sequence type	History	
Start time	42527.541782	[day]
Duration	0.071065	[day]
Time step type	Static	
Static time step	0.000116	[day]
Туре	Curve	
Wellbore storage	None	

Sequence: H_07

Sequence type	History	
Start time	42527.612847	[day]
Duration	0.014703	[day]
Time step type	Static	
Static time step	0.000116	[day]
Туре	Curve	
Wellbore storage	None	

Sequence: F_01

Sequence type	Flow	
Start time	42527.627550	[day]
Duration	0.032450	[day]
Time step type	Log	
First log step	1.15741E-07	[day]
# of time steps	250	

Information Only

Туре		Curve
Wellbore	storage	None

Test Zone Curves

Curve object to use	P_Curve
Curve type	Pressure
Start sequence	H_01
End sequence	F_01
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	H_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	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 ?	no
Optimization Output	
Write file ?	no

Optimization Setup

Algorithm	Simplex
Calculate confidence limits ?	yes
Covariance matrix calculations	1st Order
Fixed derivative span ?	no

Fit tolerance Parameter tolerance # of optimized variables Formation conductivity Static formation pressure Formation spec. storage	1.0000E-05 not used 3 OK OK OK	
Fits to Optimize		
CompositeFit	OK	
Calculated Parameters Included		
# of calculated variables included	0	

0

Suite/Range Setup

of suite/range variables



Figure B-28. X-Y scatter plot showing the static formation pressure parameter space derived from IMC-461 perturbation analysis for the first slug test with the fit discriminant and best fit values.

nPre/64 2.50

Version date 25 June 2012
Listing date 01 Aug 2016
QA status non-QA Open Source
Config file C:\SANDIA_PROJECTS\WIPP_wells\Culebra\IMC-461_Sinusoid\IMC461_D2_slug.nPre

Control Settings

Main Settings

Simulation type	Forward	
Simulation subtype	Normal	
Phase to simulate	Liquid	
Skin zone ?	yes	
External boundary	Fixed Pressure	
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	

no	
no	
20.00	[C]
ressure	
yes	
	no 20.00 ressure yes

Parameters

Formation

24.000	[ft]
2.0	[]
69.721	[psi]
1000000	[m]
3.30119E-06	[m/sec]
1.00015E-10	[1/m]
	24.000 2.0 69.721 1000000 3.30119E-06 1.00015E-10

Skin

Information Only

Radial thickness of skin Skin zone conductivity Skin zone spec. storage	0.3759119 9.93246E-03 7.78883E-05	[m] [m/sec] [1/m]
Fluid		
Fluid density Fluid thermal exp. coeff.	1008.00 0.00000E+00	[kg/m^3] [1/C]
Test-Zone		
Well radius	2.5625	[in]
Numeric		
# of radial nodes # of skin nodes Pressure solution tolerance STP flow solution tolerance	250 50 1.45038E-11 1.58503E-11	[] [] [psi] [USgpm]

Calculated Parameters

Fo	rm	ati	on

Transmissivity	2.41489E-05	[m ² /sec]
Storativity	7.31630E-10	[]
Diffusivity	3.30069E+04	[m ² /sec]
Skin Zone		
Transmissivity	7.26579E-02	[m ² /sec]
Storativity	5.69768E-04	[]
Diffusivity	1.27522E+02	[m ² /sec]
Skin factor	-1.91267E+00	[]
Grid Properties		
Grid increment delta	0.07354	[]
First grid increment	3.36528E-02	[m]
Skin grid increment delta	0.03905	[]
Skin first grid increment	2.59175E-03	[m]
Skin last grid increment	1.68879E-02	[m]
increment ratio	I.992/IE+00	LJ

Sequences

Sequence: H_01

Sequence type

History

Start time	42528,250694	[dav]
Duration	0.126389	[day]
Time step type	Static	
Static time step	0.000116	[day]
Туре	Curve	
Wellbore storage	None	
Sequence: H_02		
Sequence time	History	
Start time	42528 377083	[dav]
Duration	0.031366	[day]
Time step type	Loq	r mont 1
First log step	1.15741E-07	[day]
# of time steps	250	
Туре	Curve	
Wellbore storage	None	
Sequence: H_03		
Companyon turne	III at a second	
Start time	ASESS ADSA4S	[dout]
Duration	42528.408449	[day]
Time step type	U.022107	[uay]
First log step	1.15741E-07	[dav]
# of time steps	250	[dial]]
Туре	Curve	
Wellbore storage	None	
Sequence: H_04		
Semience time	History	
Start time	42528 430555	[dav]
Duration	0.169329	[day]
Time step type	Static	
Static time step	0.000116	[day]
Туре	Curve	
Wellbore storage	None	
Sequence: H_05		
Sequence type	History	
Start time	42528.599884	[dav]
Duration	0.021416	[dav]
Time step type	Static	1
Static time step	0.000116	[day]
Туре	Curve	
Wellbore storage	None	
Sequence: F_01		
Sequence type	Flow	
Start time	42528.621300	[dav]
Duration	0.060180	[day]

⁹⁰ Information Only

Time step type Static time step	Static 0.000116	[day]
Туре	Fixed	
Fixed value	0.0	[USgpm]
Wellbore storage	None	

Test Zone Curves

P_Curve
Pressure
H_01
F_01
Test
[psi]
no
Q_Curve
Flow Rate
H_01
F_01
Test
[USgpm]
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 ?	no	
Profile Output		
Write file ?	no	

Suite/Range Setup

of suite/range variables



Figure B-29. X-Y scatter plot showing the skin conductivity parameter space for the second slug test derived from IMC-461 perturbation analysis with the fit discriminant and best fit values.



Figure B-30. X-Y scatter plot showing the skin zone specific storage parameter space derived from IMC-461 perturbation analysis for the second slug test with the fit discriminant and best fit values.



Figure B-31. X-Y scatter plot showing the skin zone thickness parameter space derived from IMC-461 perturbation analysis for the second slug test with the fit discriminant and best fit values.

```
**********
nPre/64 2.50
**********
Version date 25 June 2012
Listing date 01 Aug 2016
QA status non-QA Open Source
Config file C:\SANDIA_PROJECTS\WIPP_wells\Culebra\IMC-461_Sinusoid\IMC-
461_D3_slug.nPre
```

Control Settings

Main Settings

Simulation type		Forward
Simulation subtype		Normal
Phase to simulate		Liquid
Skin zone ?		yes
External boundary	Fixed	Pressure

Liquid Phase Settings

Aquifer	type	
Aquifer	horizontal	permeability

Confined 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 Flow dimension Static formation pressure External boundary radius Formation conductivity Formation spec. storage	24.000 2.0 69.705 1000000 4.97129E-06 1.28089E-08	[ft] [] [psi] [m] [m/sec] [1/m]
Skin		
Radial thickness of skin Skin zone conductivity Skin zone spec. storage	0.1976759 6.90783E-05 2.40869E-04	[m] [m/sec] [1/m]
Fluid		
Fluid density Fluid thermal exp. coeff.	1008.00 0.00000E+00	[kg/m ³] [1/C]
Test-Zone		
Well radius	2.5625	[in]
Numeric		
# of radial nodes # of skin nodes Pressure solution tolerance STP flow solution tolerance	250 50 1.45038E-11 1.58503E-11	[] [] [psi] [USgpm]

Calculated Parameters

Formation

Transmissivity Storativity Diffusivity	3.63660E-05 9.36999E-08 3.88111E+02	[m ² /sec] [] [m ² /sec]
Skin Zone		
Transmissivity Storativity Diffusivity Skin factor	5.05322E-04 1.76200E-03 2.86788E-01 -1.29509E+00	[m ² /sec] [] [m ² /sec] []
Grid Properties		
Grid increment delta First grid increment Skin grid increment delta Skin first grid increment Skin last grid increment Increment ratio	0.07614 2.07884E-02 0.02848 1.88034E-03 7.37795E-03 2.81764E+00	[] [m] [m] [m] []

Sequences

Sequence: H_01

Sequence type	History	
Start time	42529.278745	[day]
Duration	0.047958	[day]
Time step type	Static	
Static time step	0.000116	[day]
Туре	Curve	
Wellbore storage	None	

Sequence: H_02

Sequence type	History	
Start time	42529.326703	[day]
Duration	0.338343	[day]
Time step type	Static	
Static time step	0.000116	[day]
Туре	Curve	
Wellbore storage	None	

Sequence: H_03

History	
42529.665046	[day]
0.017134	[day]
Static	
0.000116	[day]
Curve	
None	
	History 42529.665046 0.017134 Static 0.000116 Curve None

Information Only

Sequence: F_01

Sequence type	Flow	
Start time	42529.682180	[day]
Duration	0.047820	[day]
Time step type	Log	
First log step	1.15741E-07	[day]
# of time steps	250	
Туре	Fixed	
Fixed value	0.0	[USgpm]
Wellbore storage	None	

Test Zone Curves

Curve typePressurStart sequenceH_0End sequenceF_0Curve time baseTesCurve Y data units[psi]Curve Y data is log 10ndCurve object to useQ_CurveCurve typeFlow RateStart sequenceH_0End sequenceF 0	Pressure H_01 F_01 Test
Start sequenceH_0.End sequenceF_0.Curve time baseTesCurve Y data units[psi.Curve Y data is log 10ndCurve object to useQ_CurveCurve typeFlow RateStart sequenceH_0.End sequenceF 0.	H_01 F_01 Test
End sequenceF_0.Curve time baseTesCurve Y data units[psi.Curve Y data is log 10ndCurve object to useQ_CurveCurve typeFlow RateStart sequenceH_0.End sequenceF 0.	F_01 Test
Curve time baseTesCurve Y data units[psi]Curve Y data is log 10ndCurve object to useQ_CurveCurve typeFlow RateStart sequenceH_00End sequenceF 00	Test
Curve Y data units[psi.Curve Y data is log 10ndCurve object to useQ_CurveCurve typeFlow RateStart sequenceH_00End sequenceF 00	
Curve Y data is log 10ndCurve object to useQ_CurveCurve typeFlow RateStart sequenceH_0End sequenceF 0	[psi]
Curve object to useQ_CurveCurve typeFlow RateStart sequenceH_0End sequenceF 0	10 no
Curve typeFlow RateStart sequenceH_0End sequenceF 0	Q Curve
Start sequenceH_0End sequenceF 0	Flow Rate
End sequence F 0.	H_01
	F_01
Curve time base Tes	
Curve Y data units [USgpm]	Test
Curve Y data is log 10 no	Test [USgpm]

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 For	ward O	utput				
Write	file	?				no

Profile Output

Write file ?

no

Information Only

Suite/Range Setup

of suite/range variables

0



Figure B-32. X-Y scatter plot showing the skin conductivity parameter space for the third slug test derived from IMC-461 perturbation analysis with the fit discriminant and best fit values.



Figure B-33. X-Y scatter plot showing the skin zone specific storage parameter space derived from IMC-461 perturbation analysis for the third slug test with the fit discriminant and best fit values.



Figure B-34. X-Y scatter plot showing the skin zone thickness parameter space derived from IMC-461 perturbation analysis for the third slug test with the fit discriminant and best fit values.



Figure B-35. X-Y scatter plot showing the static formation pressure parameter space derived from IMC-461 perturbation analysis for the third slug test with the fit discriminant and best fit values.

Appendix C – File Directories

These files are located in server file-path: /nfs/data/CVSLIB/WIPP_EXTERNAL/ap070

Table C-1. The descriptions.				
File Extension	Function/Use			
<filename>.nPre</filename>	Files used for initial well test analysis.			
<filename>X.nPre</filename>	Files used to generate perturbation analysis of .nPre results.			
	Post-processing files used to visualize .nPre and perturbation			
.nPost	analysis.			
.nOpt	Optimization data used for post processing in .nPost files.			
<filename>.nXYSim</filename>	Simulation data used for post processing in .nPost files.			
<filename>FieldData.nXYS</filename>				
im	Field data used for post processing in .nPost files.			
.jpg	Graphic output from .nPost files.			
.csv,.xls, .dat	Data files used as input for .nPre files.			

Table C-1. File descriptions

Computer	Removable Disk (F:) > IMC-461_Sinusoid	•		▼ Search IMC-461_Sinuso	id .
Organize - Share with -	Burn New folder			£• ⊡	0
🔶 Favorites	Name	Date modified	Туре	Size	
E Desktop	🗼 jpegs	7/29/2016 11:34 AM	File folder		
🐞 Downloads	📕 pert_files	7/14/2016 5:04 AM	File Folder		
E Recent Places	J. Post	7/18/2016 10:30 AM	File folder		
	🗼 pressure_data	6/21/2016 3:30 PM	File folder		
🙀 Libraries	MC-461_DJ_all.nPre	6/14/2016 2:43 PM	NPRE File	58 KB	
Documents	MC-461_D1_CR.nPre	6/28/2016 1:41 PM	NPRE File	58 KB	
a) Music	MC-461_D1_CR_pert.nPre	6/28/2016 3:24 PM	NPRE File	35 KB	
Pictures	MC-461_D1_SINE.nPre	6/22/2016 11:24 AM	NPRE File	58 KE	
🔄 Videos	MC-461_DI_sine_pert.nPre	6/29/2016 12:28 PM	NPRE File	35 KB	
	MC-461_D1_Slug.nPre	7/1/2016 12:58 PM	NPRE File	39 KB	
Computer	MC-461 D1 Slug pert.nPre	7/4/2016 10:09 AM	NPRE File	39 KB	
A DriveC (C:)	MC-461_D2_all.nPre	7/26/2016 2:43 PM	NPRE File	47 KB	
DVD RW Drive (D:) Audi	MC-461_D2_CR.nPre	6/22/2016 12:04 PM	NPRE File	39 KB	
Removable Disk (F:)	MC-461_D2_CR_pert.nPre	6/29/2016 12:32 PM	NPRE File	23 KB	
Ca My Book (G:)	MC-461_D2_sine.nPre	6/23/2016 10:35 AM	NPRE File	39 KB	
	MC-461_D2_sine_pert.nPre	6/30/2016 9:39 AM	NPRE File	23 KB	
Network	MC-461 D2 slug.nPre	7/11/2016 8:43 AM	NPRE File	28 KB	
GRIGRIKE	MC-461 D2 slug pert.nPre	7/4/2016 11:08 AM	NPRE File	23 KB	
SDAVIS	BIMC-461_D3_all.nPre	6/15/2016 2:08 PM	NPRE File	37 KB	
	MC-461 D3 sine.nPre	6/27/2016 1:12 PM	NPRE File	37 KB	
	MC-461 D3 sine pert.nPre	6/30/2016 1:44 PM	NPRE File	22 KB	
	MC-461 D3 sine pert mk2.nPre	7/14/2016 9:19 AM	NPRE File	22 KB	
	MC-461 D3 slug.nPre	7/10/2016 11:48 AM	NPRE File	26 KB	
	MC-461 D3 slug pert.nPre	7/10/2016 11:50 AM	NPRE File	22 KB	
	MC-461 D4 all.nPre	6/15/2016 2:12 PM	NPRE File	38 KB	
	MC-461 D4 sineL.nPre	6/27/2016 1:22 PM	NPRE File	39 KB	
	MC-461 D4 sinel pert.nPre	6/28/2016 7:08 AM	NPRE File	23 KB	
	MC-461_D4_sine2.nPre	6/28/2016 7:11 AM	NPRE File	39 KB	
	MC-461 D4 sine2 pert.nPre	7/13/2016 9:08 AM	NPRE File	23 KB	
	MC-461_D4_stug.nPre	6/27/2016 1:57 PM	NPRE File	39 KB	
	MC-461 sinusoid.nPre	6/14/2016 1:46 PM	NPRE File	54 KB	

Directory of E:\ IMC-461_Sinusoid

Nemovable D	ISK (T:) IMC-401_SINUSOIO > Jpegs	• • search jpegs
Organize	Burn New folder	
🚖 Favorites	D1_CR_BsvsFV0010.JPG	D1_CR_CART0005JPG
📃 Desktop	D1_CR_KsvsFV0010.JPG	D1_CR_SFPvsFV0005JPG
Jownloads	D1_CR_SssvsFV0010.JPG	D1_CR_SvsFV0006.JPG
Recent Places	D1_CR_TvsFV0006.JPG	D1_SINE_BsvsFV0010JPG
	D1_SINE_Cart.JPG0005.JPG	D1_SINE_KsvsFV0010JPG
🔰 Libraries	D1_SINE_SFPvsFV0005.JPG	D1_SINE_SssvsFV0010.JPG
Documents	D1_SINE_SvsFV0006JPG	D1_SINE_TvsFV0006JPG
J Music	D1_Slug_CART0005.JPG	D1_Slug_SFPvsFV0005.JPG
Pictures	D1_Stug_SvsFV0006.JPG	D1_Slug_TvsFV0006.JPG
H Videos	D2_SINE_BsvsFV0010JPG	D2_SINE_Cart0005.JPG
	D2_SINE_KsvsFV0010.JPG	D2_SINE_SFPvsFV0005JPG
Somputer	D2_SINE_SssFV0010.JPG	D2_SINE_SvsFV0006.JPG
A DriveC (C:)	D2_SINE_TvsFV0007.JPG	D2_Slug_BsvsFV0010.JPG
DVD RW Drive (D:) Audi	D2_Slug_CART0005.JPG	C2_Slug_KsvsFV0010.JPG
Removable Disk (F:)	D2_Slug_SssvsFV0010JPG	D2_Slug_SvsFV0006.JPG
My Book (G:)	D2_Slug_TvsFV0006.JPG	D3_SINE_BsvsFV0010.JPG
	D3_SINE_Cart0005.JPG	D3_SINE_KsvsFV0010.JPG
Vetwork	SINE_SFPvsFV0005.JPG	D3_SINE_SssvsFV0010.JPG
SRKIRKE	D3_SINE_TvsFV0007.JPG	D3_Slug_BsvsFV0005.JPG
SDAVIS	Slug_CART0005.JPG	D3_Slug_KsvsFV0005JPG
	D3_Slug_SFPvsFV0005.JPG	D3_Slug_SssvsFV0005.JPG
	D3_Slug_SvsFV0006.JPG	D3_Slug_TvsFV0006JPG
	D4_SINE1_BsvsFV0011JPG	D4_SINEL_Cart0005.JPG
	D4_SINE1_KsvsFV0010.JPG	D4_SINEL_SFPvsFV0005.JPG
	D4_SINE1_SssvsFV0010.JPG	D4_SINE1_SvsFV0006.JPG
	D4_SINE1_TvsFV0007.JPG	D4_SINE2_BsvsFV0010.JPG
	D4_SINE2_Cart0005.JPG	D4_SINE2_KsvsFV0010.JPG
	D4_SINE2_SFPvsFV0005.JPG	D4_SINE2_SssvsFV0010.JPG
	D4_SINE2_SvsFV0006.JPG	D4_SINE2_TvsFV0007.JPG
	D2_CR_CART0005JPG	D2_CR_KsvsFV0010.JPG
	D2_CR_SFPvsFV0005JPG	D2_CR_SssvsFV0010.JPG
	D2_CR_SvsFV0006.JPG	D2_CR_TvsFV0006JPG

Directory of E:\ IMC-461_Sinusoid \jpegs

- Computer a	Parmetushia Dick (E) + 1840, 451 Cinum	iet a most filme	- 4	Search nort files				
Comparer +	Removable Disk (F:) INC-401_Sinuso	ia i pert_mes	* * *	Search perc_fues				
Organize 🔻 Share with 👻 Burn New folder 📰 🔮								
Favorites	Name	Date modified	Туре	Size				
E Desktop	d1_CR.nOpt	6/28/2016 4:39 PM	NOPT File	6,016 KB				
🙀 Downloads	d1_CR_field.nXYSim	6/28/2016 3:23 PM	NXYSIM File	124 KB				
Secent Places	d1_CR_sim.nXYSim	6/28/2016 4:39 PM	NXYSIM File	42,016 KB				
	dl_sine.nOpt	6/29/2016 12:18 PM	NOPT File	6,016 KB				
Libraries	d1_sine_field.nXVSim	5/29/2016 11:07 AM	NXYSIM File	124 KB				
Documents	d1_sine_sim.nXVSim	6/29/2016 12:18 PM	NXYSIM File	42,016 KB				
J Music	d1_slug.nOpt	7/4/2016 11:02 AM	NOPT File	6,016 KB				
Pictures	d1_slug_field.nXVSim	7/4/2016 10:08 AM	NXYSIM File	124 KB				
Videos	d1_slug_sim.nXYSim	7/4/2016 11:02 AM	NXYSIM File	40,016 KB				
	d2_CR.nOpt	6/29/2016 4:40 PM	NOPT File	6,016 KB				
Computer	d2_CR_field.nXYSim	6/29/2016 12:31 PM	NXYSIM File	124 KB				
ShiveC (C:)	d2_CR_sim.nXVSim	6/29/2016 4:40 PM	NXYSIM File	38,016 KB				
IVD RW Drive (D:) Audi	d2_sine.nOpt	6/30/2016 1:29 PM	NOPT File	6,016 KB				
Removable Disk (F:)	d2_sine_field.nXYSim	6/30/2016 9:38 AM	NXYSIM File	124 KB				
My Book (G:)	d2_sine_sim.nXYSim	6/30/2016 1:29 PM	NXYSIM File	38,016 KB				
	d2_slug.nOpt	7/4/2016 2:46 PM	NOPT File	6,016 KB				
Network	d2_slug_field.nXYSim	7/4/2016 11:07 AM	NXYSIM File	124 KB				
GRIXIRKE	d2_slug_sim.nXYSim	7/4/2016 2:46 PM	NXYSIM File	30,016 KB				
SDAVIS	d3_sine.nOpt	6/30/2016 8:48 PM	NOPT File	6,016 KB				
	d3_sine_field.nXYSim	6/30/2016 1:43 PM	NXYSIM File	152 KB				
	d3_sine_mk2.nOpt	7/14/2016 5:04 AM	NOPT File	6,016 KB				
	d3_sine_sim.nXYSim	6/30/2016 8:48 PM	NXYSIM File	36,016 KB				
	d3_sine_sim_mk2.nXVSim	7/14/2016 5:04 AM	NXYSIM File	36,016 KB				
	d3_slug.nOpt	7/10/2016 5:55 PM	NOPT File	6,016 KB				
	d3_slug_field.nXYSim	7/10/2016 11:49 AM	NXYSIM File	152 KB				
	d3_slug_sim.nXYSim	7/10/2016 5:55 PM	NXYSIM File	30,016 KB				
	d4_sinel_nOpt	6/27/2016 5:38 PM	NOPT File	6,016 KB				
	d4_sine1_field.nXYSim	6/27/2016 3:16 PM	NXYSIM File	S2 KB				
	d4_sine1_sim.nXYSim	6/27/2016 5:38 PM	NXYSIM File	22,016 KB				
	d4_sine2.nOpt	7/12/2016 5:32 PM	NOPT File	6,016 KB				
	d4 sine2 field.nXYSim	6/28/2016 7:13 AM	NXYSIM File	52 KB				
	d4 sine2 sim nXVSim	7/12/2016 5:32 PM	NXVSIM File	22 016 KR				

Directory of E:\ IMC-461_Sinusoid\pert_files



Computer 1	Removable UISK (P:) MC-461_Sinusoid	Post	• ++ 2	earch Post
rganize Share with	Burn New folder			# • 🖬
Favorites	Name	Date modified	Туре	Size
Mesktop	IMC-461_d1_cr.nPost	7/29/2016 9:48 AM	NPOST File	27 KB
🐞 Downloads	IMC-461_d1_sine_nPost	8/1/2016 1:06 PM	NPOST File	27 KB
S Recent Places	MC-461_d1_slug.nPost	7/29/2016 2:57 PM	NPOST File	19 KB
	MC-461_d2_cr.nPost	7/29/2016 10:12 AM	NPOST File	27 KB
Libraries	BMC-461_d2_sine.nPost	7/28/2016 2:33 PM	NPOST File	27 KB
Documents	IMC-461_d2_slug.nPost	7/29/2016 11:28 AM	NPOST File	25 KB
J Music	MC-461_d3_sine_nPost	7/14/2016 10:04 AM	NPOST File	28 KB
Pictures	MC-461_d3_sine_mk2.nPost	7/29/2016 3:10 PM	NPOST File	24 KB
Videos	IMC-461_d3_slug.nPost	7/29/2016 2:43 PM	NPOST File	27 KB
	MC-461_d4_sine1.nPost	7/28/2016 1:02 PM	NPOST File	27 KB
Computer	IMC-461_d4_sine2.nPost	7/28/2016 2:22 PM	NPOST File	27 KB
DriveC (C:)	IMC-461_template.nPost	7/10/2016 10:17 AM	NPOST File	57 KB
🛃 DVD RW Drive (D:) Audi				
Removable Disk (F:)				

Directory of E:\ IMC-461 Sinusoid\Post

Directory of E:\ IMC-461_Sinusoid\pressure_data

	Removable Disk (F:) MC-461 Sinusoid	b pressure data	- A Sear	ch pressure data
Organize • Share with •	Burn New folder	r pressure_aoto	- Josef	
Favorites	Name	Date modified	Туре	Size
E Desktop	MC461_GP_20160606.csv	6/10/2016 1:44 PM	Microsoft Excel C	685 KB
🙀 Downloads	IMC-461_GP_nsights.csv	6/10/2016 1:46 PM	Microsoft Excel C	685 KB
Lecent Places	MC461_TP_20160606.csv	6/10/2016 1;42 PM	Microsoft Excel C	992 KB
	MC-461_TP_nsights.csv	5/10/2016 1:46 PM	Microsoft Excel C	686 KB
🙀 Libraries	MC-461_TP_nsights_D1.csv	6/21/2016 3:22 PM	Microsoft Excel C	83 KB
Documents	MC-461_TP_nsights_D2.csv	6/21/2016 3:25 PM	Microsoft Excel C	132 KB
J Music	MC-461_TP_nsights_D3.csv	6/21/2016 3:30 PM	Microsoft Excel C	168 KB
Se Pictures	MC-461_TP_nsights_D4.csv	6/21/2016 3:24 PM	Microsoft Excel C	44 KB
😸 Videos				

Acknowledgements

The author of this report would like to acknowledge Jeff Palmer and Patricia Johnson of Intera, Inc. for contributing the well configuration plot and well location map to this report.