WEST CRANE AQUIFER TEST SUMMARIES, RICHLAND COUNTY, MONTANA

Jon Reiten and Kevin Chandler

Montana Bureau of Mines and Geology
Ground Water Investigation Program

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Cover:Jonsson 2 aquifer test, 12/20/2015. Photo by Kevin Chandler, MBMG.

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ABSTRACT

The West Crane aquifer, located in Richland County, Montana, occupies a buried valley west of the modern Yellowstone River Valley. This productive aquifer extends for 22 mi from Fox Creek in the north to Burns Creek in the south. Fourteen high-yield irrigation wells capable of pumping 500 to 1,500 gpm were permitted in the aquifer between 2011 and 2020. As part of the permitting process, aquifer tests were conducted on each irrigation well. We analyzed the test data using the Cooper–Jacob method and leaky confined models in AQTESOLV 4.5. The aquifer transmissivity (T) estimates ranged from 4,310 ft2/d to 34,240 ft2/d. Aquifer storage (S) coefficient estimates ranged from 0.0001 to 0.03, in the confined to leaky confined aquifer range. Hydraulic conductivity (K) estimates ranged from 360 to 1,300 ft/d.

INTRODUCTION

We evaluated 14 aquifer tests conducted on irrigation wells completed in the West Crane aquifer in Richland County, Montana as part of a Ground Water Investigation Program (GWIP) project. The purposes of these tests were to estimate specific aquifer properties (such as transmissivity, hydraulic conductivity, aquifer storage, anisotropy, etc.), estimate the degree to which this aquifer is confined, estimate aquifer boundaries (recharge and/or barrier), and evaluate groundwater/surface-water connection. Aquifer properties will be used in development of a numerical groundwater model and to evaluate heterogeneity within the aquifer. The aquifer tests fulfilled the Montana Department of Natural Resources and Conservation (DNRC) requirements for water-rights applications. DNRC requires a 72-hr aquifer test on all water-rights applications for over 35 gpm from groundwater sources.

BACKGROUND HYDROGEOLOGY

The West Crane aquifer is part of the Lower Yellowstone Buried Valley (LYBV) aquifer system underlying the Yellowstone River Valley and valley slopes in Richland County, Montana (fig. 1). Test drilling south of Fox Creek confirmed that the West Crane aquifer continues 22 mi southward to Burns Creek and roughly parallels the Yellowstone River (fig. 1). The sand and gravel filling the base of the buried valley supports well yields from 500 to 1,500 gpm. Sediments overlying the aquifer include interbedded clay, silt, silty clay, silty sand, and glacial till (fig. 2). These overlying sediments form confining and leaky confining layers that can slowly release water to the aquifer (Fetter, 2001). Borehole lithology varies greatly over short distances, and locating the most productive zones in the aquifer usually requires test drilling.

High-yield irrigation wells completed in the West Crane aquifer allow farmers to grow a variety of crops in areas that were previously dryland farmed. Rapid development of the West Crane aquifer has prompted the demand for hydrologic data for proactive aquifer management. This aquifer is currently a Ground Water Investigation Program (GWIP) project that aims to define the aquifer size and its properties, water quality, and development potential.

METHODS

MBMG staff conducted or supervised seven of the aquifer tests and consultants conducted the other seven tests. These tests followed guidelines established by DNRC in the 633 Aquifer Test Data Form (http://dnrc.mt.gov/divisions/water/water-rights/docs/forms/633.xls/view, A comprehensive data collection form for reporting aquifer test information). A DNRC-approved aquifer test requires pumping the production well for 72 hr at a constant rate. Scheduled drawdown measurements outlined in the form are collected from the production well and at least one observation well. The information section of the 633 form includes site and scheduling details needed to evaluate the aquifer test.

Prior to each test, background water levels were collected to determine if the test data needed water-level trend corrections before analysis. *In situ* data loggers recorded depth-to-water level measurements every minute. Vented data loggers were used in some of the wells measured. In the cases where non-vented loggers were used, data were corrected for barometric fluctuations using data from a nearby baro-logger. Baro-logger data were also used to correct for barometric efficiency of the wells if needed.

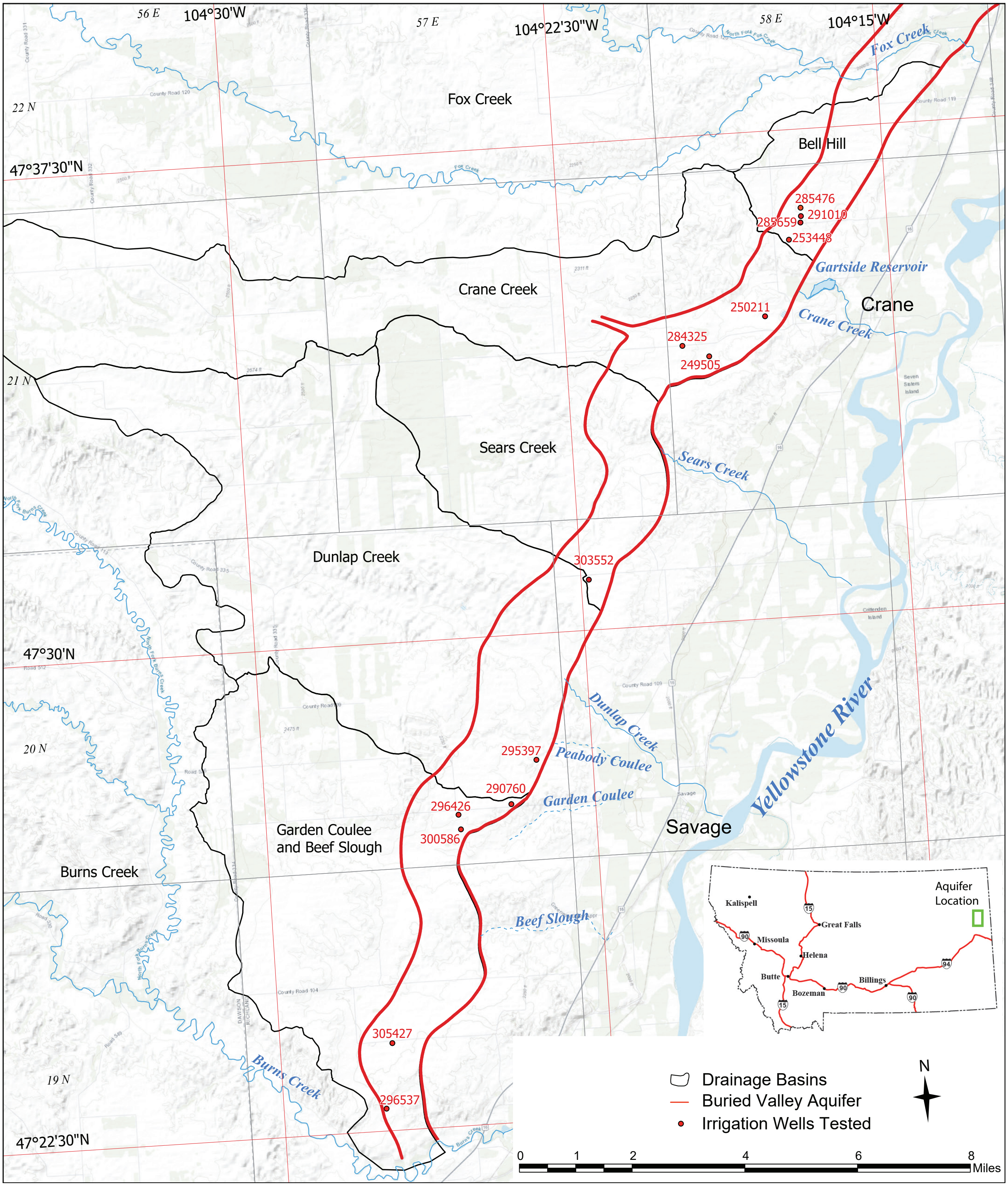

Figure 1. Location of the irrigation wells tested in the West Crane aquifer. Ground Water Information Center identification (GWIC ID) numbers are used to identify the test wells. Information on the well completion, lithology, and aquifer water levels are available online at http://mbmggwic.mtech.edu/.

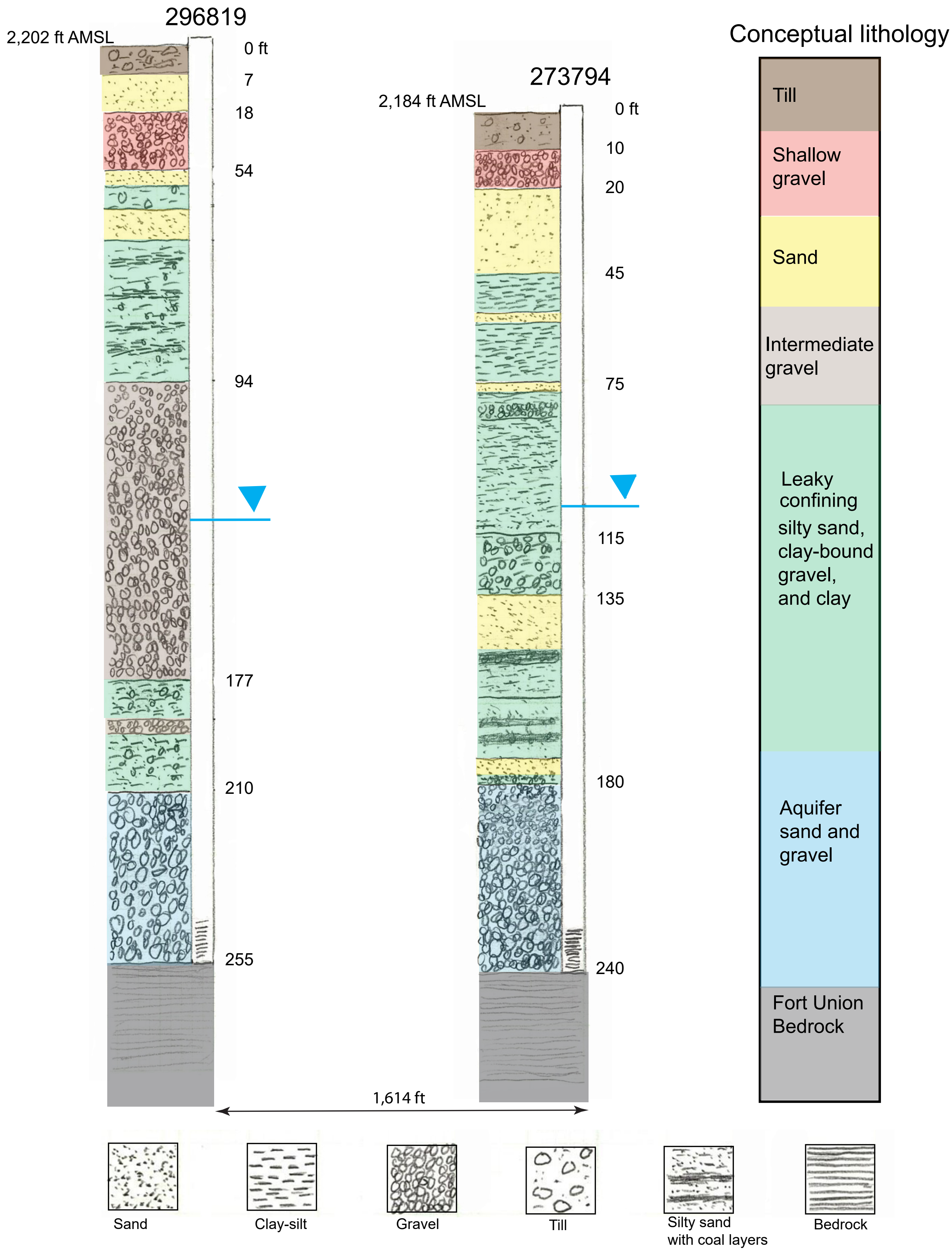

Figure 2. The lithology of the West Crane aquifer varies substantially by location, but in general the most productive gravel deposits are found directly above the Fort Union Formation bedrock and below layers of silty sand and gravel, often interbedded with clay (leaky confining layers). The leaky confining layers provide additional aquifer storage that is released when pumping from the aquifer gravel. The monitoring wells here are due west of irrigation well 284325 (273794 at 0.27 mi, 296819 at 0.57 mi).

Diesel generators powered submersible test pumps installed in the production wells. McCrometer flow meters plumbed in the center of an 8-ft straight section of the discharge line measured pumping rates. The flow meters were located in the middle of the pipe sections to reduce turbulence from fittings and control valves in the discharge line. Piping discharge water to areas sloping away from the test wells prevented the potential of infiltrating water influencing drawdown measurements.

Well locations were either surveyed using a Leica GPS System RX1250 or altitude and location estimated using Google Earth maps. Water-level data collected during the test were initially analyzed using Excel plots and the Cooper–Jacob method (Cooper, 1946). Cooper–Jacob method results provide an initial estimate of aquifer parameters. The data were then input into AQTESOLV 4.5 software for analyses with different models (Duffield, 2007). Several methods were initially applied, but our understanding of the hydrogeologic conditions allowed us to focus on AQTESOLV solutions for leaky confined conditions.

Of the leaky confined solutions available in AQTESOLV, Cooley and Case (1973), Moench, case 3 (1985), and Neuman and Witherspoon (1969) were the most appropriate considering the buried valley lithology and the potential for vertical leakage from silty sand, clay-bound gravel, and sand layers above the aquifer (fig. 2). Only one test site (Bradley, 253450 and 302856) has paired shallow and deep observation wells showing a water-table aquifer above the leaky confining layers, but this condition is likely at the other test sites. All test sites have Fort Union Bedrock for the aquifer base; therefore solutions allowing aquifer leakage from below were excluded. Solutions allowing for boundaries or wedge-shaped aquifers were used for sites thought to be near the edges of the buried valley. Assumptions and description of each solution can be found at http://www.aqtesolv.com/summary_of_solutions.htm.

AQUIFER TEST CONDITIONS

Aquifer tests are field experiments subject to equipment problems and weather conditions that can alter interpretation of the test results. Issues that resulted in variations from the ideal conditions prescribed in the 633 form are noted in table 1. In several of the tests, constant pumping rates were reported, but the water levels in the wells showed recovery or increased drawdown when the generators failed or when valves were changed to increase the pumping rate. When curve matching, we ignored drawdown data affected by fluctuations in the pumping rate.

TEST RESULTS

The aquifer results displayed in table 2 were selected from various leaky confined solutions using AQTESLOV 4.5. Selection was based on the model fit, aquifer conditions at the test site, and our hydrogeologic understanding of the aquifer. Box and whisker plots of the results show the variability observed in the 14 tests (fig. 3). The aquifer tests results agree with our geologic interpretation, indicating confined to leaky confined aquifer conditions. Barometric efficiencies determined from pre-test water-level data also indicate confining conditions (table 1). Leaky confined storage values typically range from 0.001 to 0.03 (Weight and Sonderegger, 2001). Test storage coefficients (S) ranged from 0.0001 to 0.03, with a median value of 0.0007. Transmissivities (T) ranged from 4,310 ft2/day to 34,240 ft^2/day. Nearby barrier boundaries appear to have affected the T values estimated at the Basta 1(296537) and D. Jorgenson (290760) aquifer test sites. Our lithologic mapping places these sites near the aquifer edge (fig. 1). The median aquifer transmissivity is about 24,000 ft^2/day. Hydraulic conductivities (K) ranged from 360 ft/day to 1,300 ft/day. Most K values ranged from 700 ft/day to 1,000 ft/day. Appendix A includes hydrographs showing background water-level trends and levels during the pumping and recovery periods. Appendix A also includes plots constructed using the Cooper–Jacob method and various leaky confined AQTESOLV solutions.

Table 1. Aquifer test locations and conditions.

Well Name GWIC ID	Watershed	Well Type	Distance from PW (ft)	Ground Surface Altitude (ft AMSL)	Total Depth (ft)	Screened Interval (ft)	SWL at Start (ft below mp)	Baro Eff. (%)	Latitude	Longitude	Start Date/Time	Pumping Duration (hr)	Pumping Rate (gal/min)	Drawdown at Test End (ft)	Pumping Rate Variability	Comments
Basta 1	Beef-Garden															
296537		Production		2193	181	171–181	115		47.38126	-104.46094	4/23/18 17:19	72.2	250	43.11	Major	Pump off in middle of test, late test data used, site near aquifer edge. Test conducted by private consultants.
295197		Observation	50	2195	180	170–180	119	32	47.38142	-104.46093				9.07		
Basta 2	Beef-Garden															
305427		Production		2229	226	206–226	154.04	40	47.3986	-104.45836	12/10/19 9:12	72	750	50.44	Minor	Good test, conducted by Agri-Industries.
305422		Observation	100		225	210–220	150.71	45	47.39862	-104.4573				2.33		
Lange 2	Beef-Garden															
300586		Production		2159	142	122–142	73.6	35	47.44659	-104.42627	2/11/19 9:24	72.00	804	41.28	Minor	Good test, conducted by Agri-Industries.
300256		Observation	56	2157	139	115–135	69.5	32	47.44644	-104.42624				4		
Lange 1	Beef-Garden															
296426		Production		2215	223	203–223	127.9		47.45639	-104.42733	11/22/18 10:15	72.00	900	52.77	Very Minor	Good test, conducted by Agri-Industries.
273806		Observation	146	2215	218	204–214	128.4	25	47.45642	-104.42792				3.08		
D Jorgensen 1	Beef-Garden															
290760		Production		2223	230	210–230	139.35		47.45694	-104.40968	12/6/16 14:16	72.0	750	63.94	Minor	Early-time pumping rate 10 % lower, steady after 2.5 hours. Site close to aquifer edge. Good test, supervised by MBMG.
290815		Observation	74	2221	232	212–232	138.19	15	47.45693	-104.40938				10.98		
Ler 1	Dunlap															
295397		Production		2114	130	110–130	37.7		47.46811	-104.3952	11/17/17 12:31	37.3	862	50.51	Moderate	Late-time pumping rate fluctuations. Test ended 1 day early. Fair test, conducted by Agri-Industries.
295396		Observation	73	2116	118	108–118	38.6	27	47.46817	-104.3955				3.69		
J Jorgensen 1	Dunlap															
303552		Production		2131	260	240–260	155.95		47.5132	-104.3747	10/17/19 8:05	72.1	1420	59.93	Stable	Good test, conducted by Agri-Industries.
303550		Observation	65	2131	258	248–258	155.35	30	47.5132	-104.3245				7.62		
K Jonsson 2	Crane															
284325		Production		2173	223	192–223	110.17	50	47.57191	-104.33065	12/19/15 9:23	72.4	715	60.15	Stable	Good test, conducted by MBMG.
283134		Observation	112	2173	220	205–215	117.32	50	47.5719	-104.33109				2.72		

Table 1—*Continued.*

K Jonsson 1	Crane														
249505		Production		2124	170	150–170	67.12		47.56878	-104.32075	4/10/09 11:13	74.0	900	48.01	Stable	Good test, conducted by MBMG.
234024		Observation	618	2115	164	154–164	61.38	23	47.56961	-104.31858				0.61		
Wyman 1	Crane															
250211		Production		2059	118	97–117	20.37		47.57808	-104.29858	12/6/12 18:13	72.0	1020	28.96	Stable	Good test, conducted by MBMG.
263799		Observation 1	82	2060	118	108–118	22.09	22	47.57795	-104.29883				7.49		
234036		Observation 2	1252	2052	105	95–105	19.21		47.5781	-104.29351				1.11		
Bradley 1	Bell															
253448		Production		2114	180	164–174	101.36		47.5973	-104.28761	11/13/09 11:40	72.0	800	9.24	Stable	Good test, supervised by MBMG.
253450		Observation	106	2114	165	155–165	103.18	38	47.59758	-104.28772				2.36		
C Johnson 1	Bell															
285659		Production		2105	170	150–170	94.28		47.60151	-104.28281	12/17/15 9:30	72.0	630	43.04	Stable	Good test, supervised by MBMG.
279891		Observation	153	2102	177	165–175	91.78	12	47.60186	-104.28246				2.36		
C Johnson 3	Bell															
291010		Production		2103	169	149–169	92.62		47.60316	-104.28247	1/11/17 8:33	8.5	1010	54.86	Minor	Rate dropped near end of test.
291009		Observation	104	2104	172	160–170	95.75	20	47.60288	-104.28249				3.28		Fair test, conducted by Agri-Industries.
C Johnson 2	Bell															
285476		Production		2104	180	150–180	95.25		47.6053	-104.28241	9/12/16 16:15	16.7	900	20.36	Stable	Good test, conducted by MBMG.

Table 2. Aquifer test results.

Test Site GWIC ID	Well Type	Pumping Rate/ Analysis Method	Transmissivity (ft^2/d)	Storage Coefficient	Saturated Thickness (ft)	Hydraulic Conductivity (ft/d)	Appendix A Fig. No.
Basta 1							
296537	Production	250 gpm			12		
295197	Observation	Cooley–Case Leaky, no flow barrier at 100 ft	4,310	0.00010		360	A4
Basta 2							
305427	Production	750 gpm			33		
305422	Observation	Neuman–Witherspoon Leaky	24,080	0.0008		730	A10
Lange 2							
300586	Production	804 gpm			20		
300256	Observation	Neman–Witherspoon Leaky	19,480	0.003		970	A13
Lange 1							
296426	Production	900 gpm			27		
273807	Observation	Moench (Case 3) Leaky	24,590	0.03		910	A16
DJorgensen1							
290760	Production	750 gpm			18		
290816	Observation	Cooley–Case Leaky, no-flow boundary 100 ft S	7,580	0.0006		420	A22
Ler 1							
295397	Production	862 gpm			27		
295396	Observation	Cooley–Case Leaky	18,780	0.014		700	A26
JJorgensen 1							
303552	Production	1,420 gpm			24		
303550	Observation	Cooley–Case Leaky	25,010	0.0002		1,040	A32
KJonsson 2							
284325	Production	715 gpm			29		
283134	Observation	Cooley–Case Leaky	32,620	0.0002		1,130	A37
KJonsson 1							
249506	Production	900 gpm			20		
234024	Observation	Cooley–Case Leaky	22,450	0.021		1,120	A40
Wyman 1							
250211	Production	1020 gpm			35		
263799	Observation 1	Cooley–Case Leaky	12,860	0.0002		370	A45
234036	Observation 2	Neuman–Witherspoon Leaky	23,370	0.0018		670	
Bradley 1							
253448	Production	800 gpm			22		
253450	Observation	Neuman–Witherspoon Leaky	28,540	0.0001		1,300	A53
CJohnson 1							
285659	Production	630 gpm			26		
279891	Observation	Cooley–Case Leaky	23,760	0.026		910	A57
CJohnson 3							
291010	Production	1,010 gpm			28		
291009	Observation	Moench (Case 3) Leaky	30,610	0.0002		1,090	A63
CJohnson 2							
285476	Production	900 gpm			28		
285476	Production	Cooley–Case Leaky recovery	34,240	NA		1,220	A66

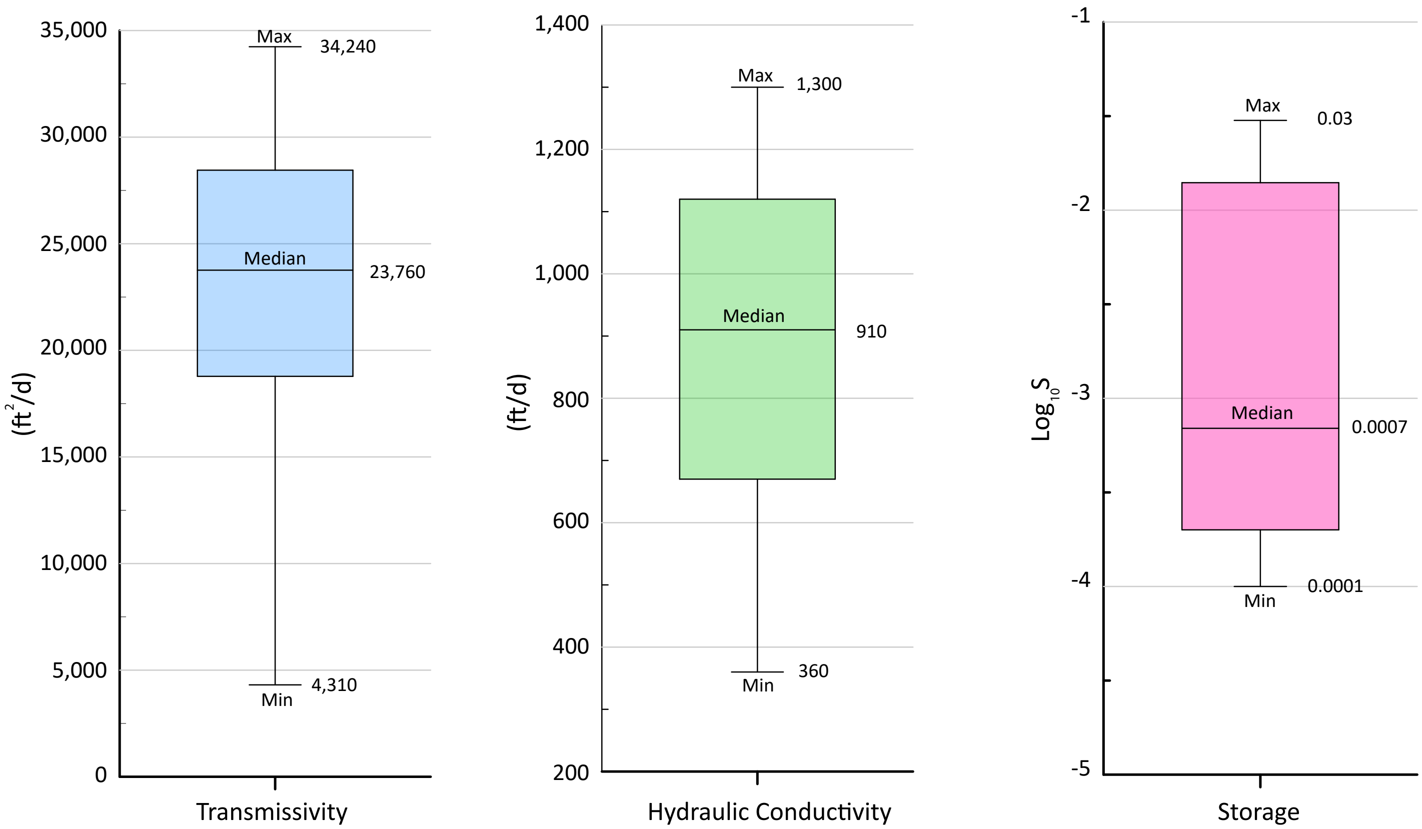

Figure 3. Box plots of the aquifer test results show the ranges of aquifer properties from the 14 aquifer tests.

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Cooper, H.H. Jr., and Jacob, C.E., 1946, A generalized graphical method for evaluating formation constants and summarizing well-field history: Transaction, American Geophysical Union, v. 27, no. 4, p. 526–534.

Fetter, C.W., 2001, Applied Hydrogeology: Upper Saddle River, N.J., Prentice-Hall, 598 p.

Weight, W.D., and Sonderegger, J.L., 2001, Manual of Applied Field Hydrogeology: New York, McGraw-Hill, 608 p.

APPENDIX A:

WEST CRANE AQUIFER TEST CHARTS

BASTA 1 (296537)

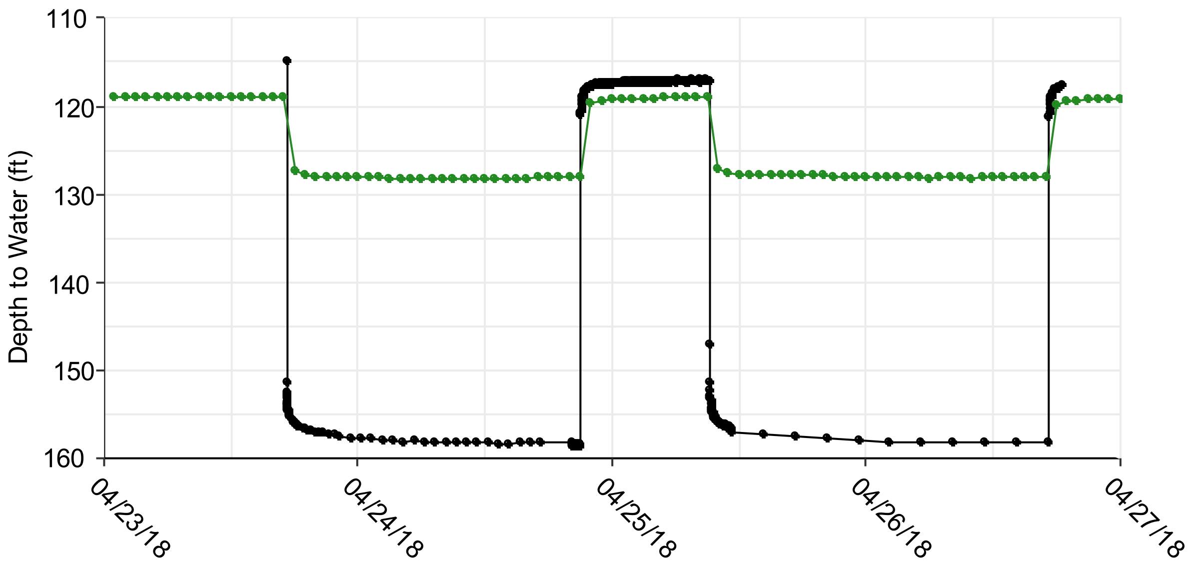

Figure A1. Basta 1 aquifer test background through recovery water levels. No background measurements were collected on the production well. Pump off for about 12 hr.

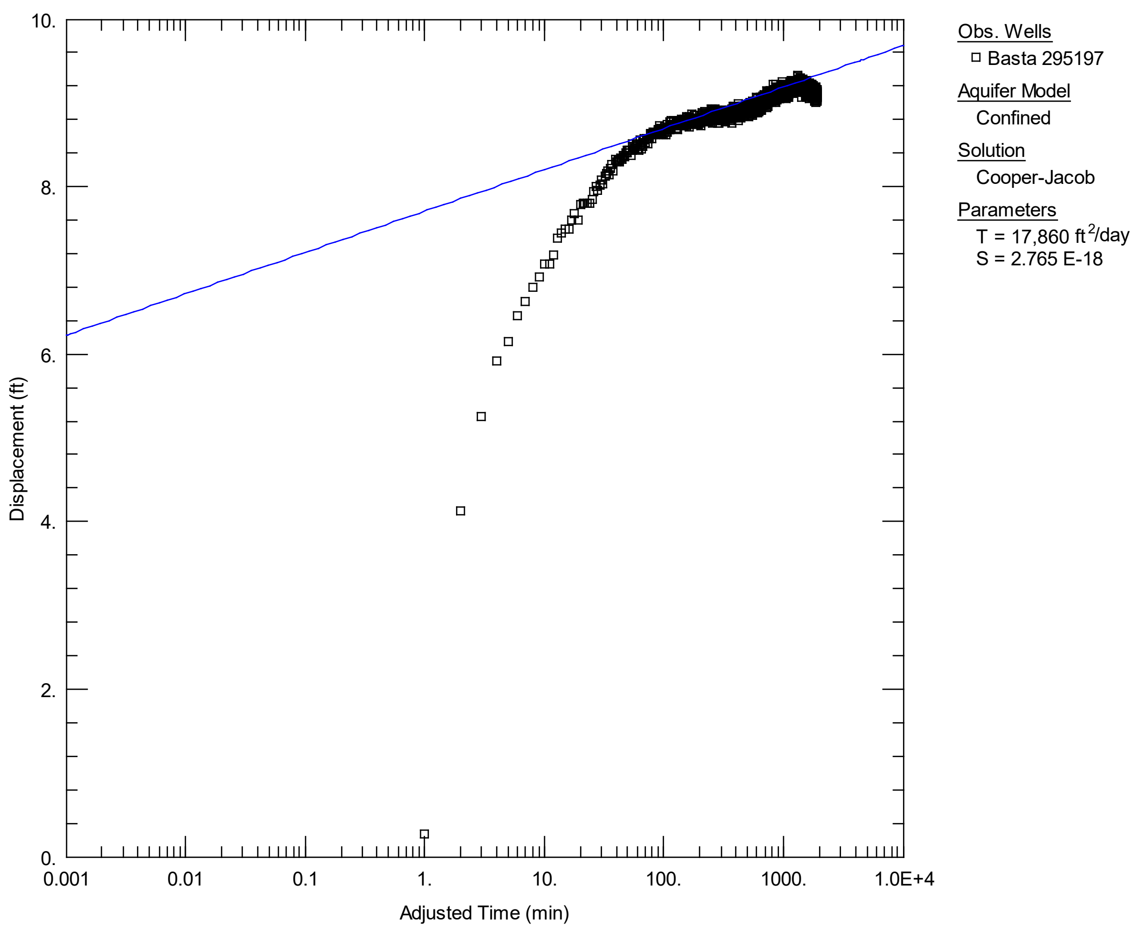

Figure A2. Basta 1 aquifer test showing Cooper–Jacob solution. Storage coefficient values are unrealistic.

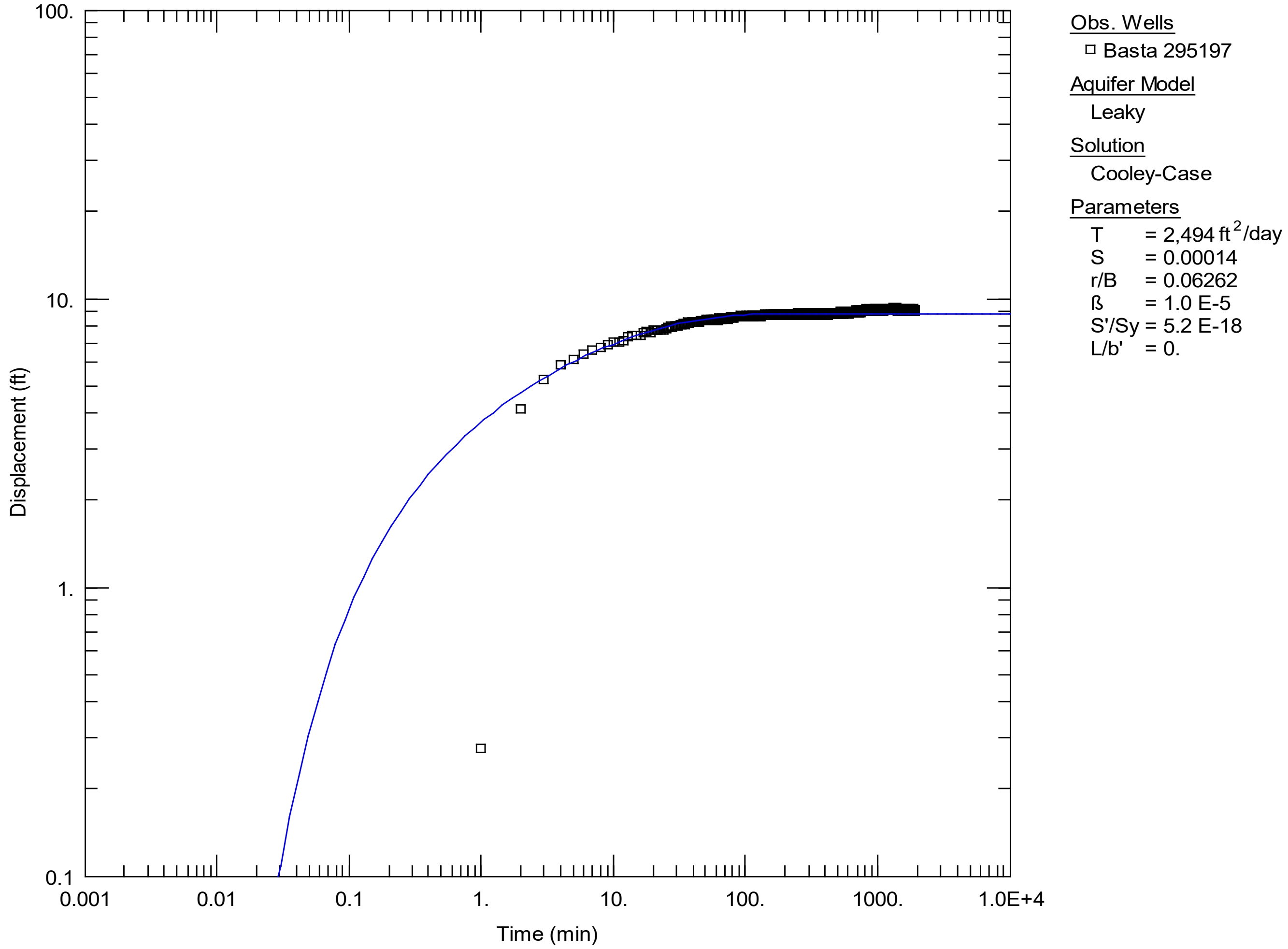

Figure A3. Basta 1 aquifer test showing Cooley–Case leaky confined solution.

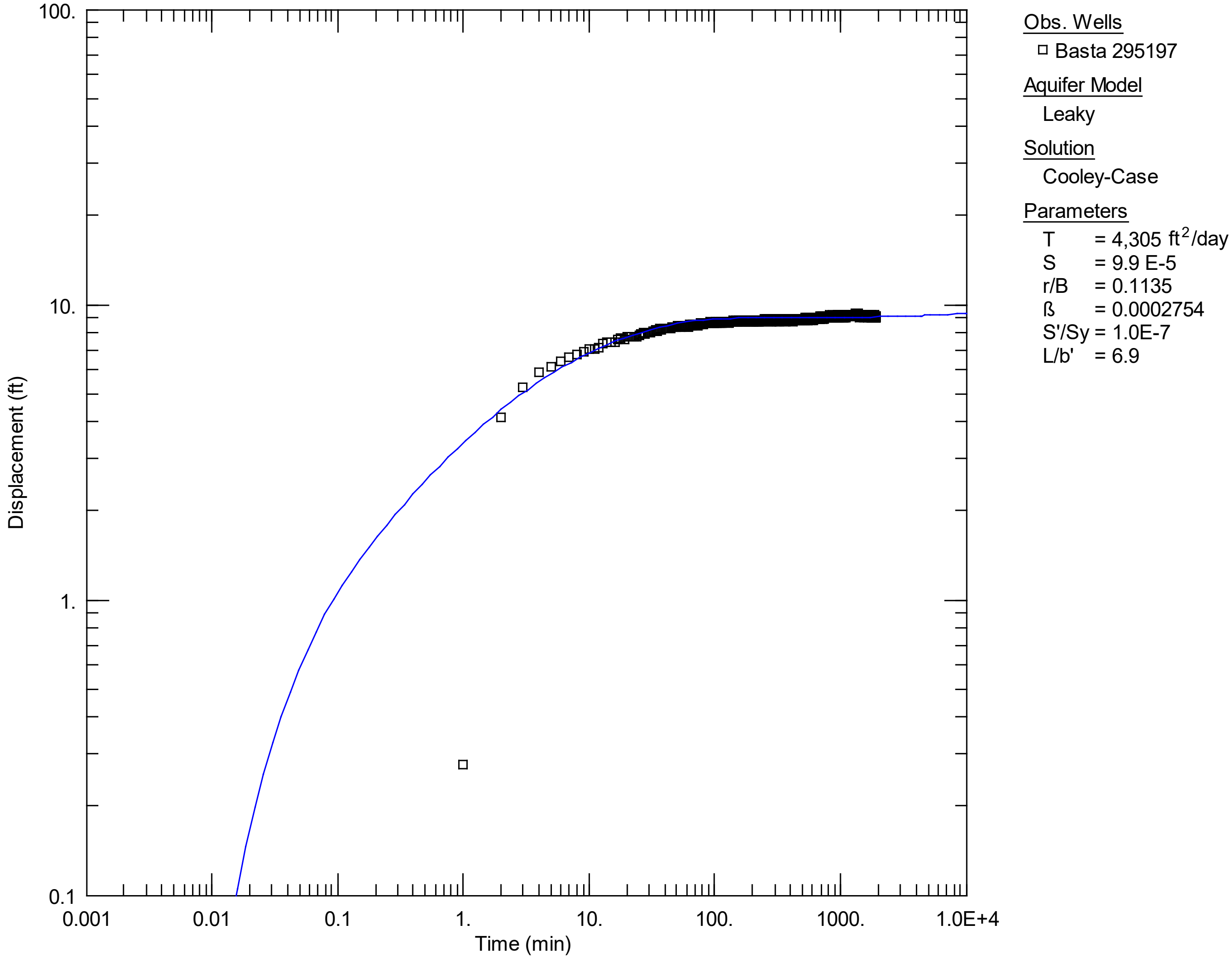

Figure A4. Basta 1 aquifer test showing Cooley–Case leaky confined solution with a barrier boundary located 100 ft west.

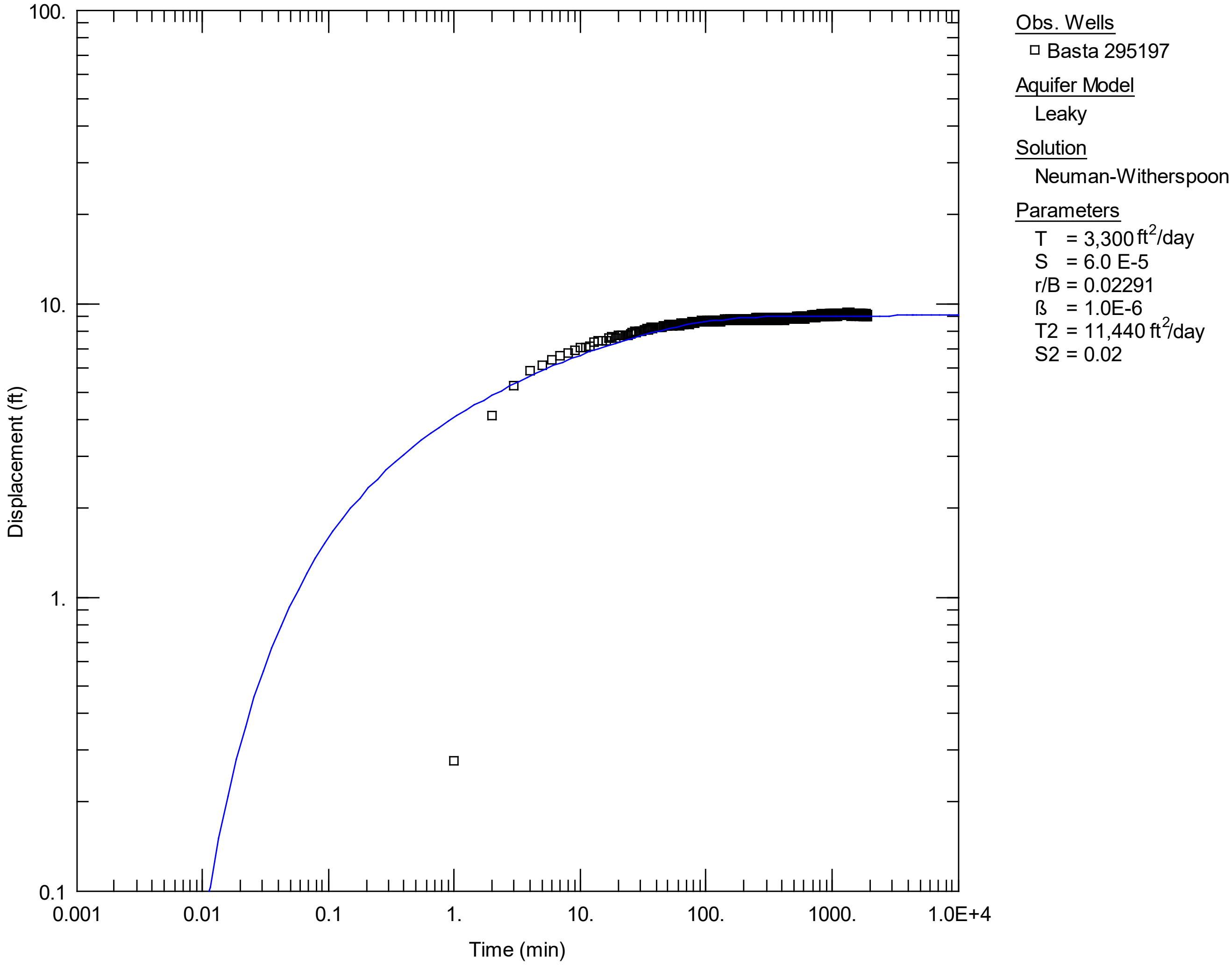

Figure A5. Basta 1 aquifer test showing Neuman–Witherspoon leaky confined solution.

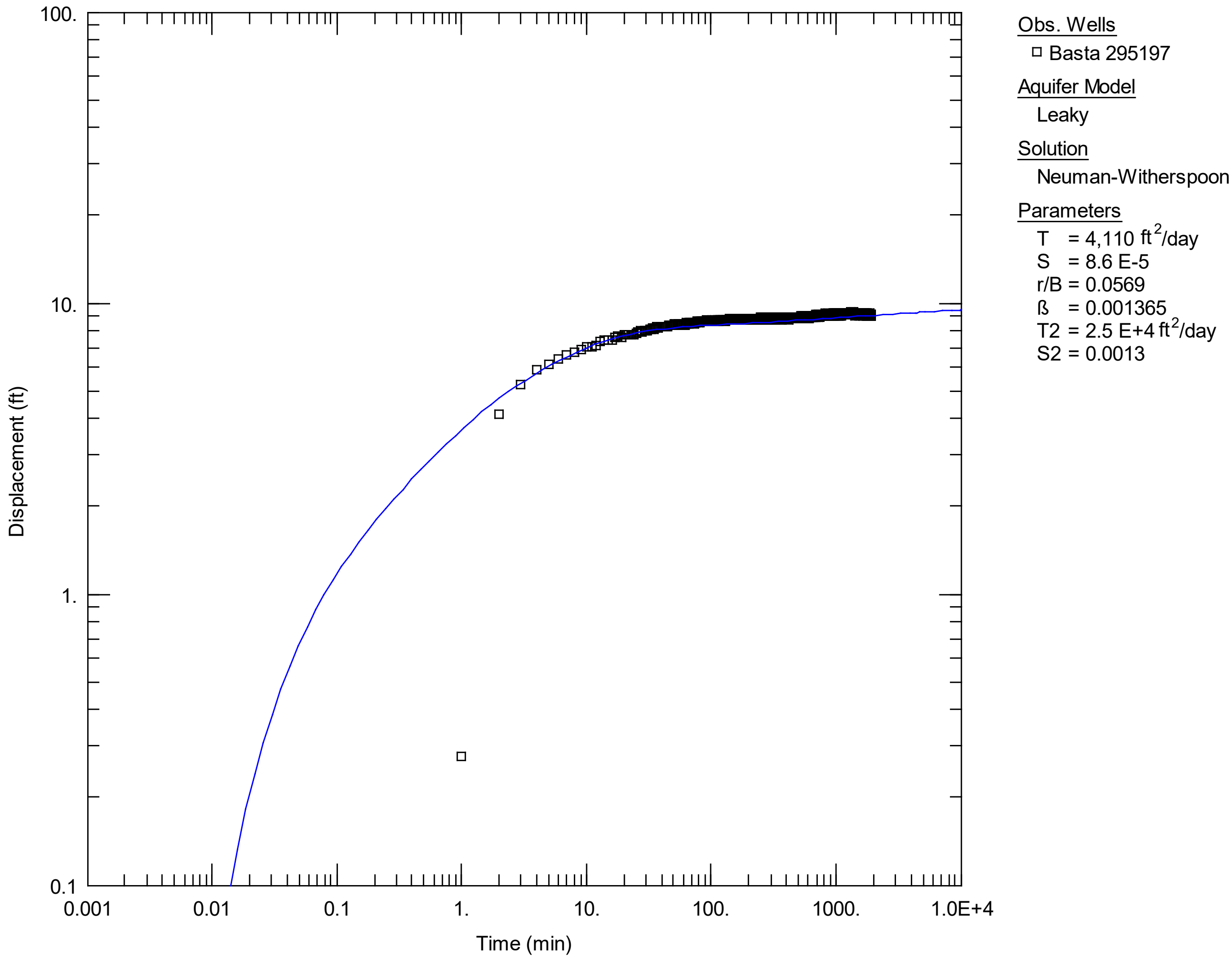

Figure A6. Basta 1 aquifer test showing Neuman–Witherspoon leaky confined solution with a barrier boundary located 100 ft west.

BASTA 2 (305427)

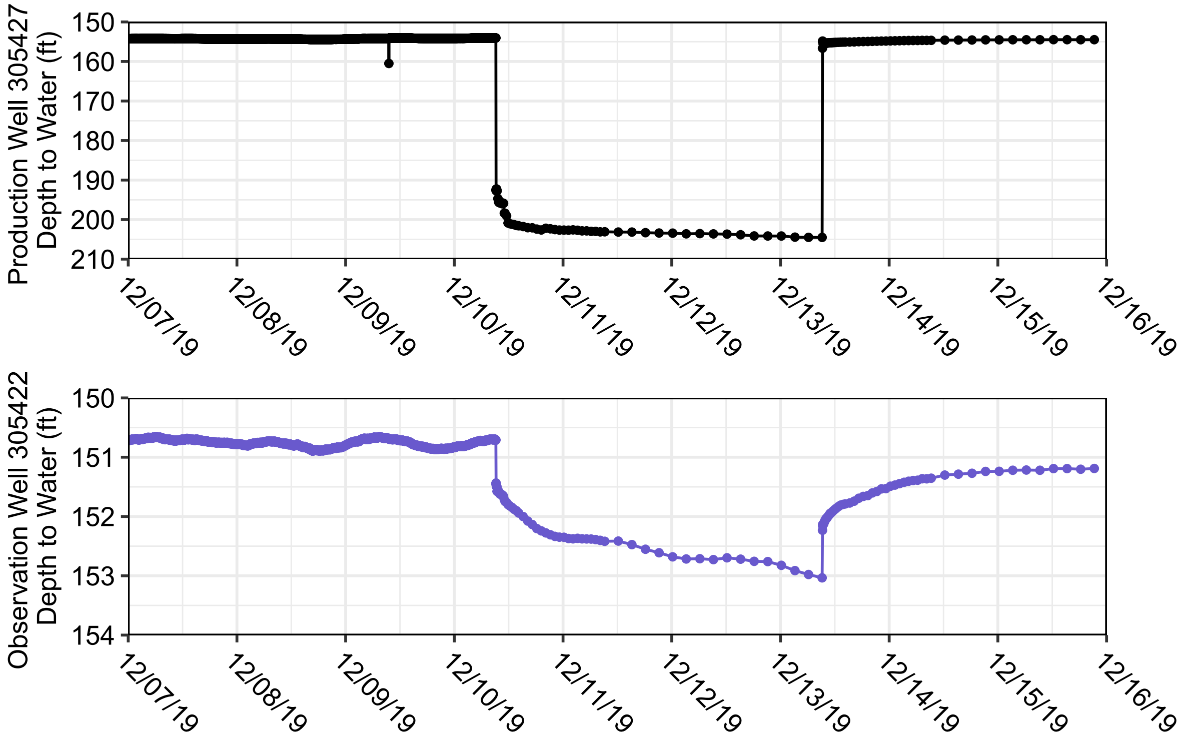

Figure A7. Basta 2 aquifer test background through recovery water levels.

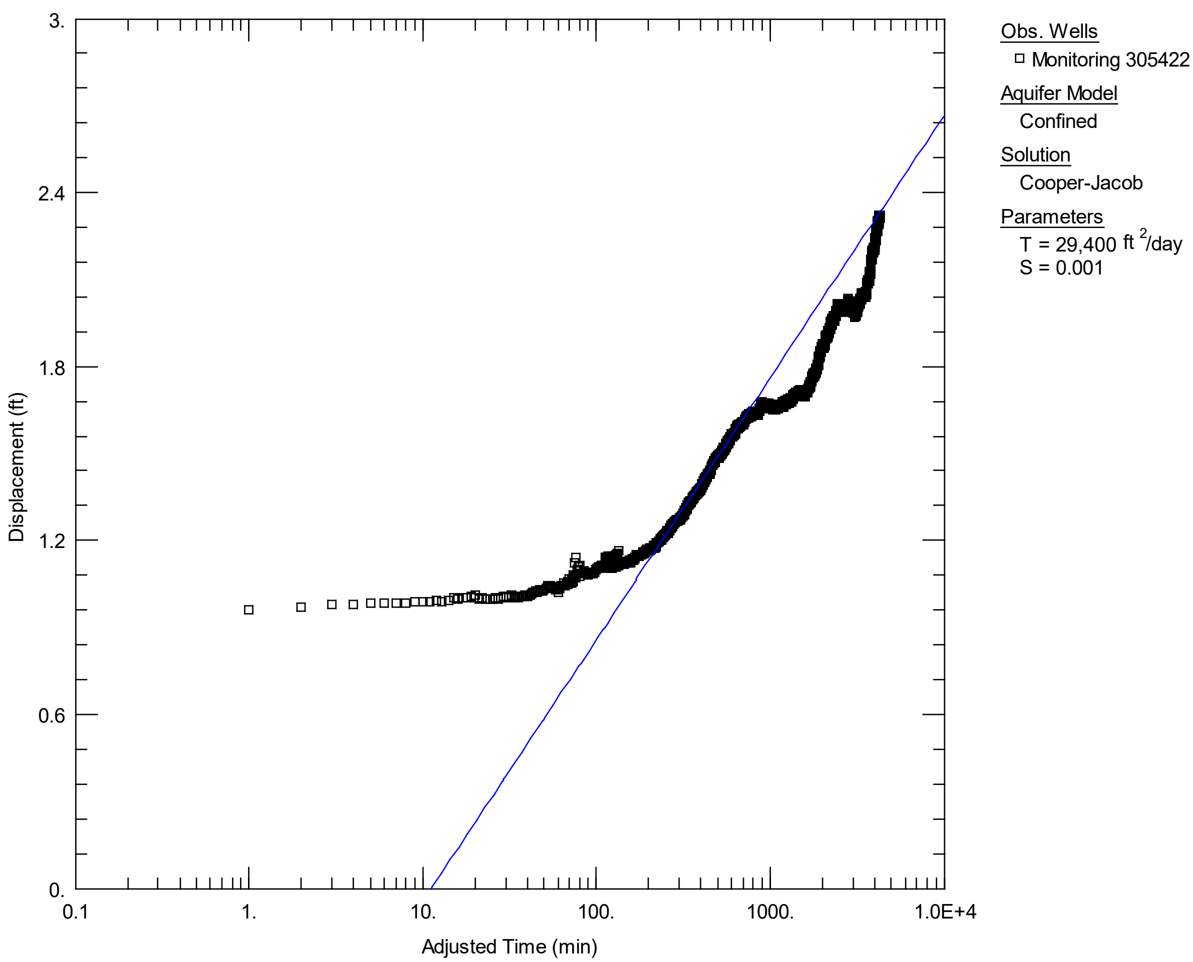

Figure A8. Basta 2 aquifer test showing Cooper–Jacob solution.

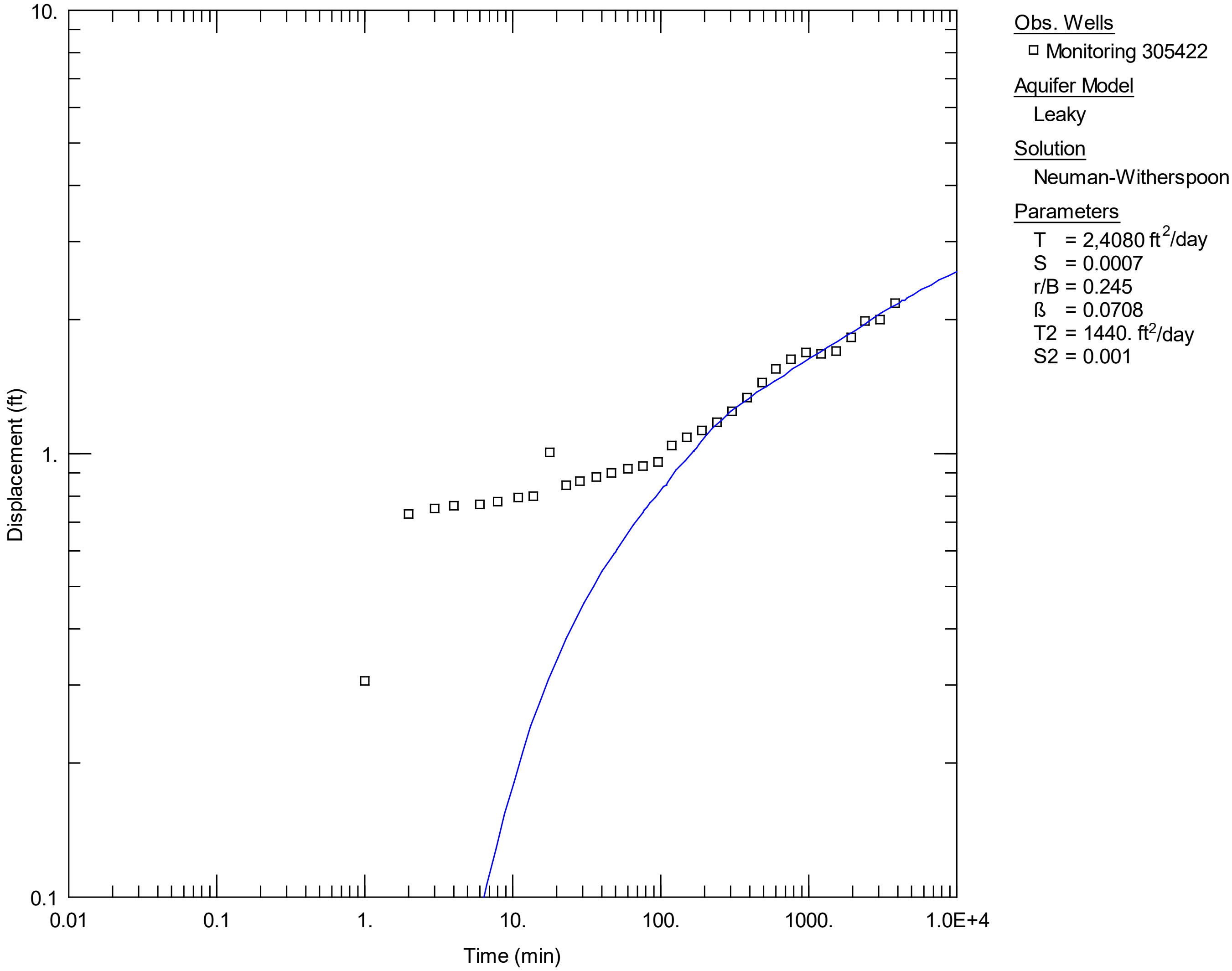

Figure A9. Basta 2 aquifer test showing Neuman–Witherspoon leaky confined solution.

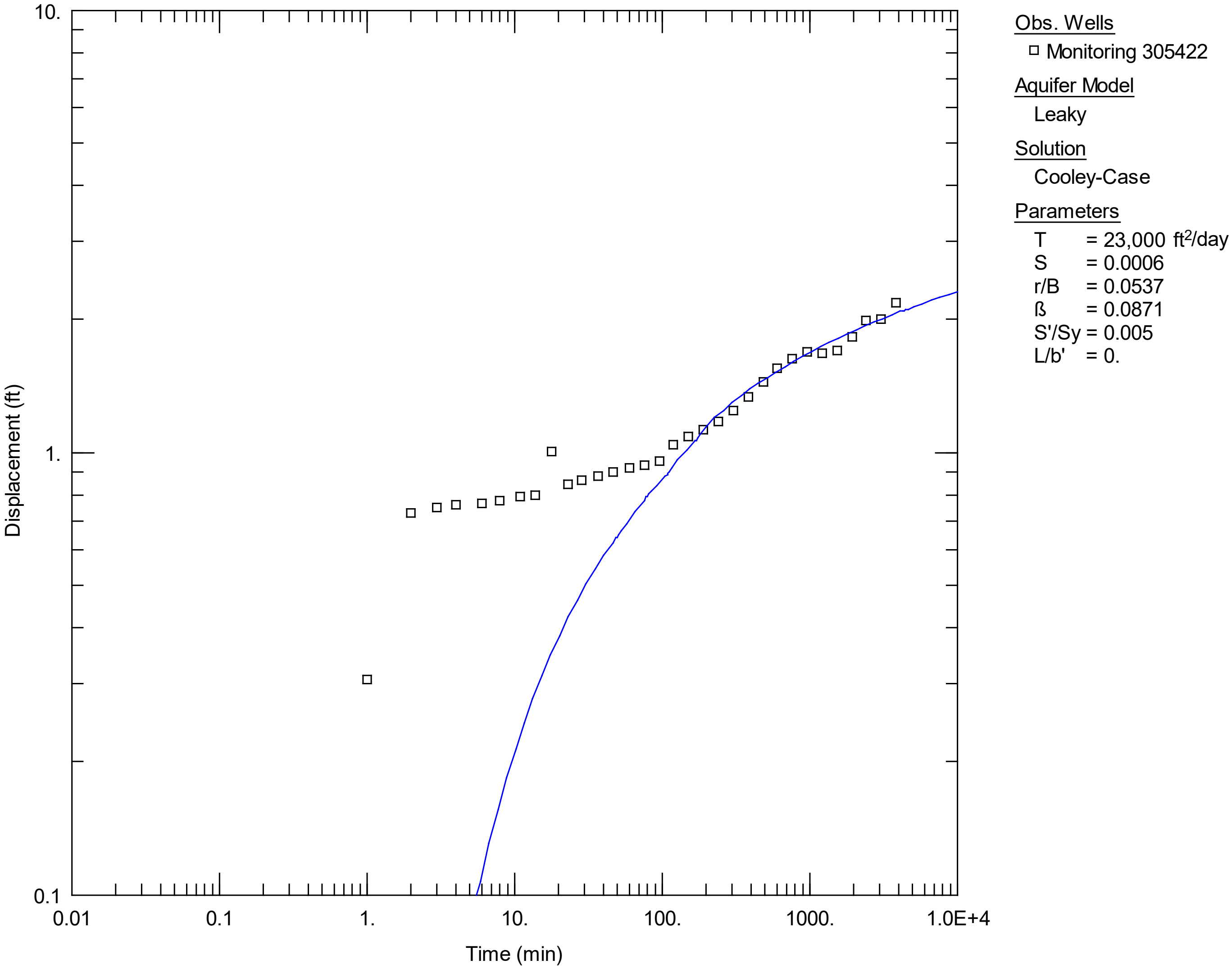

Figure A10. Basta 2 aquifer test showing Cooley–Case leaky confined solution

LANGE 2 (300586)

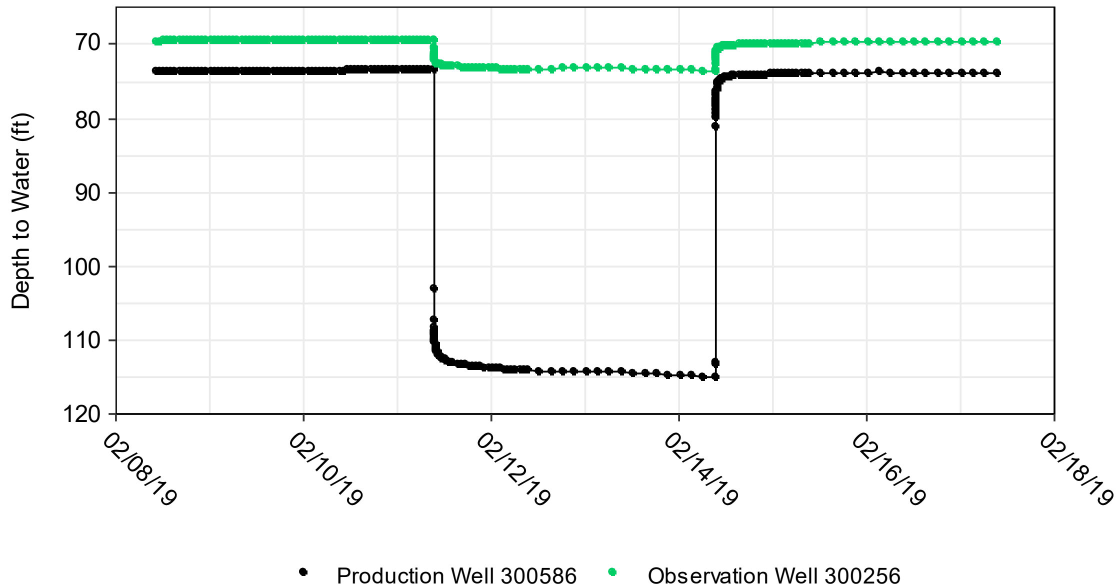

Figure A11. Lange 2 aquifer test background through recovery water levels. Pumping rate appears to have fluctuated in the last part of the test.

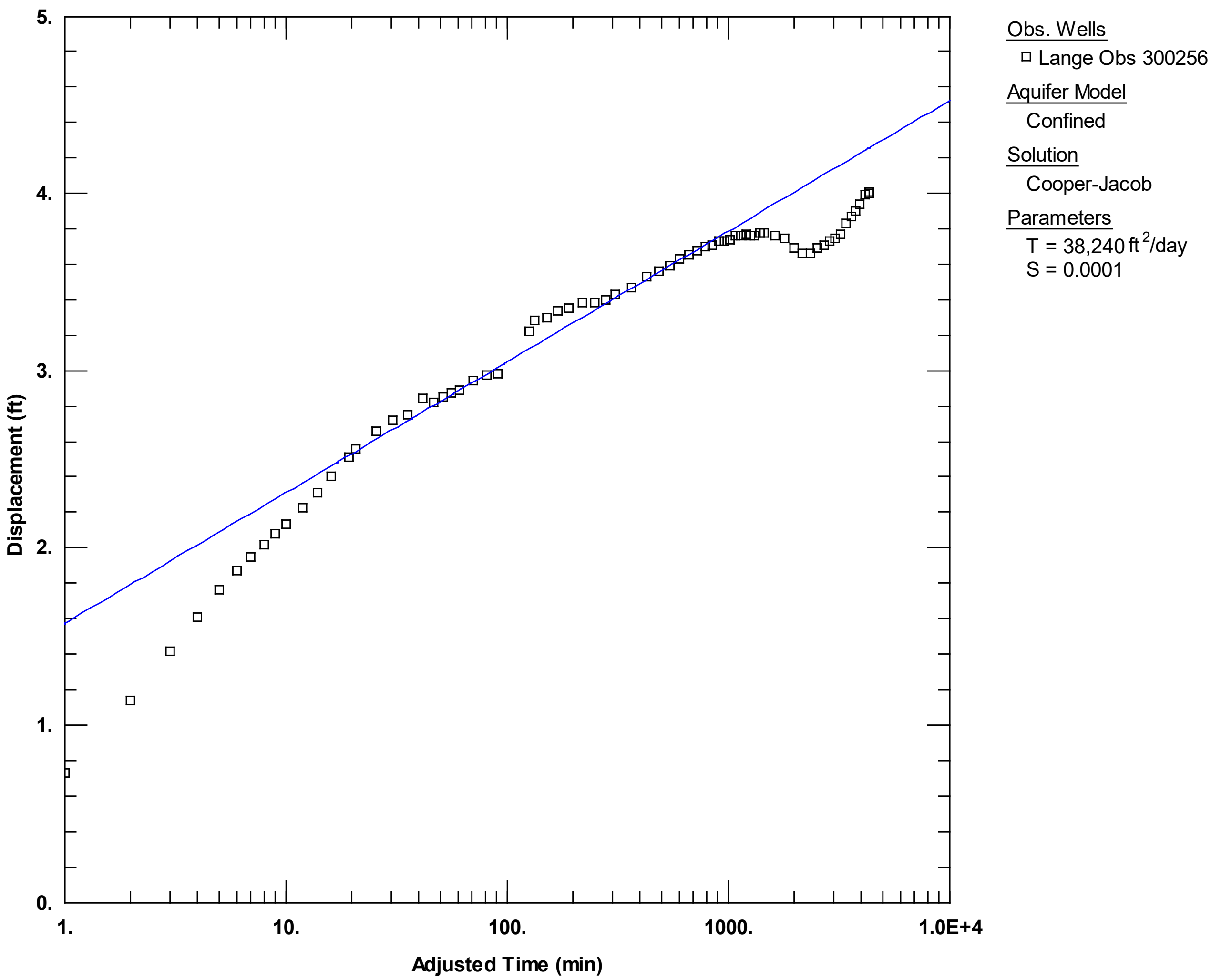

Figure A12. Lange 2 aquifer test showing Cooper–Jacob solution.

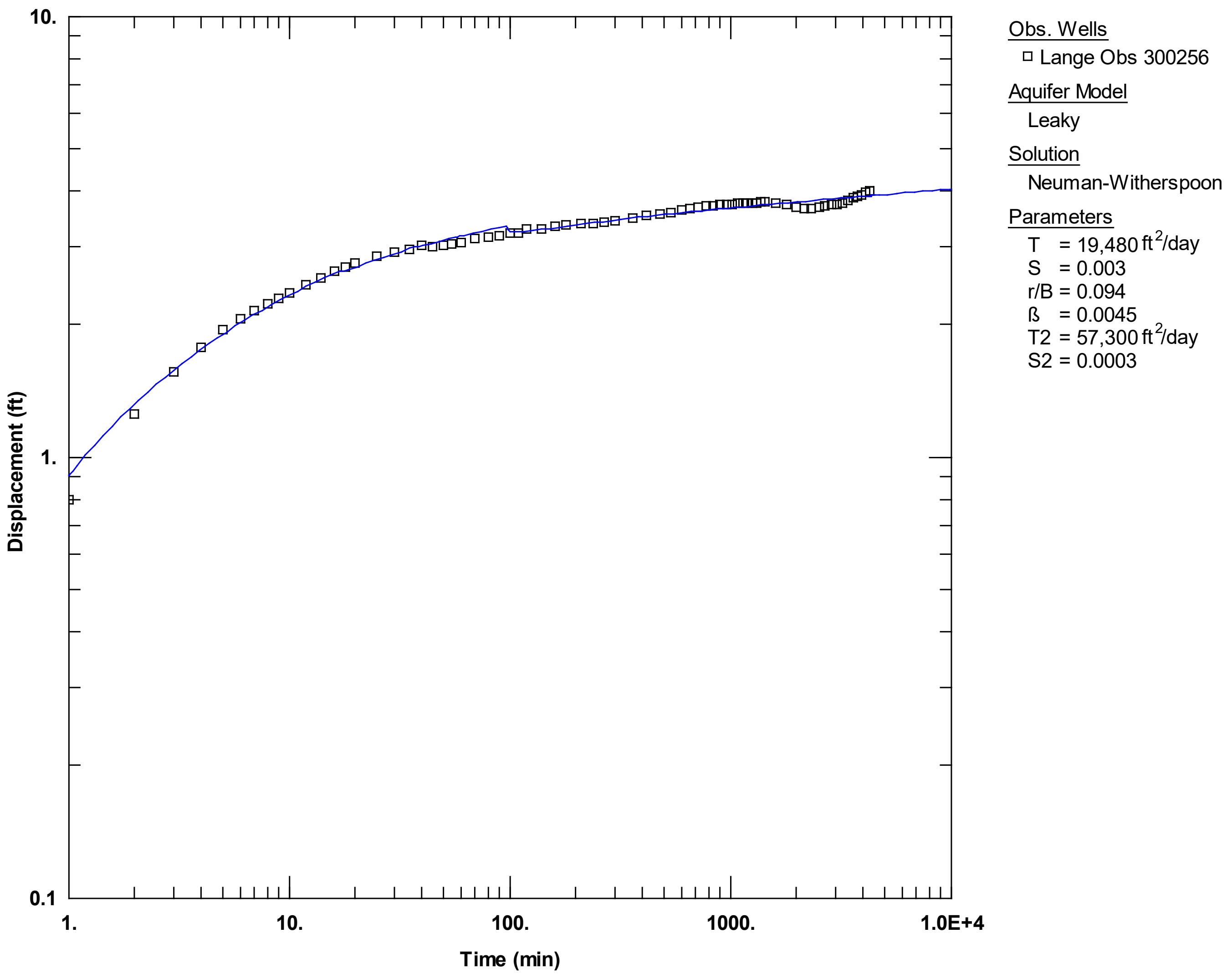

Figure A13. Lange 2 aquifer test showing Neuman–Witherspoon solution.

LANGE 1 (296426)

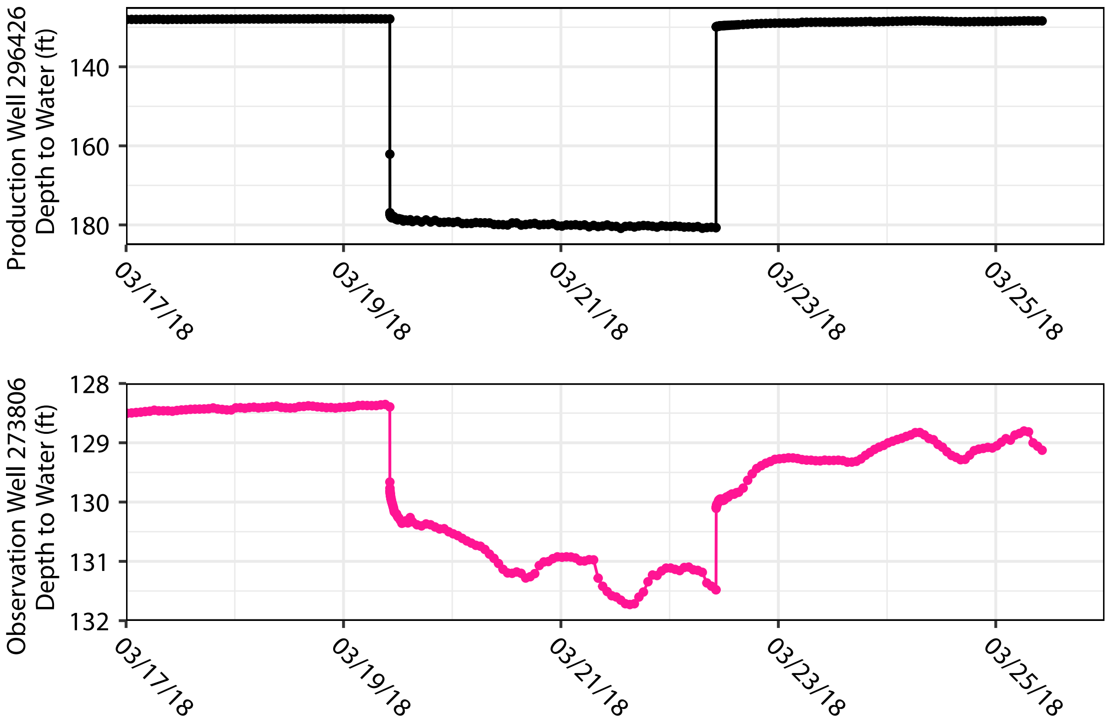

Figure A14. Lange 2 aquifer test background through recovery water levels. Pumping rate appears to have fluctuated in the last part of the test.

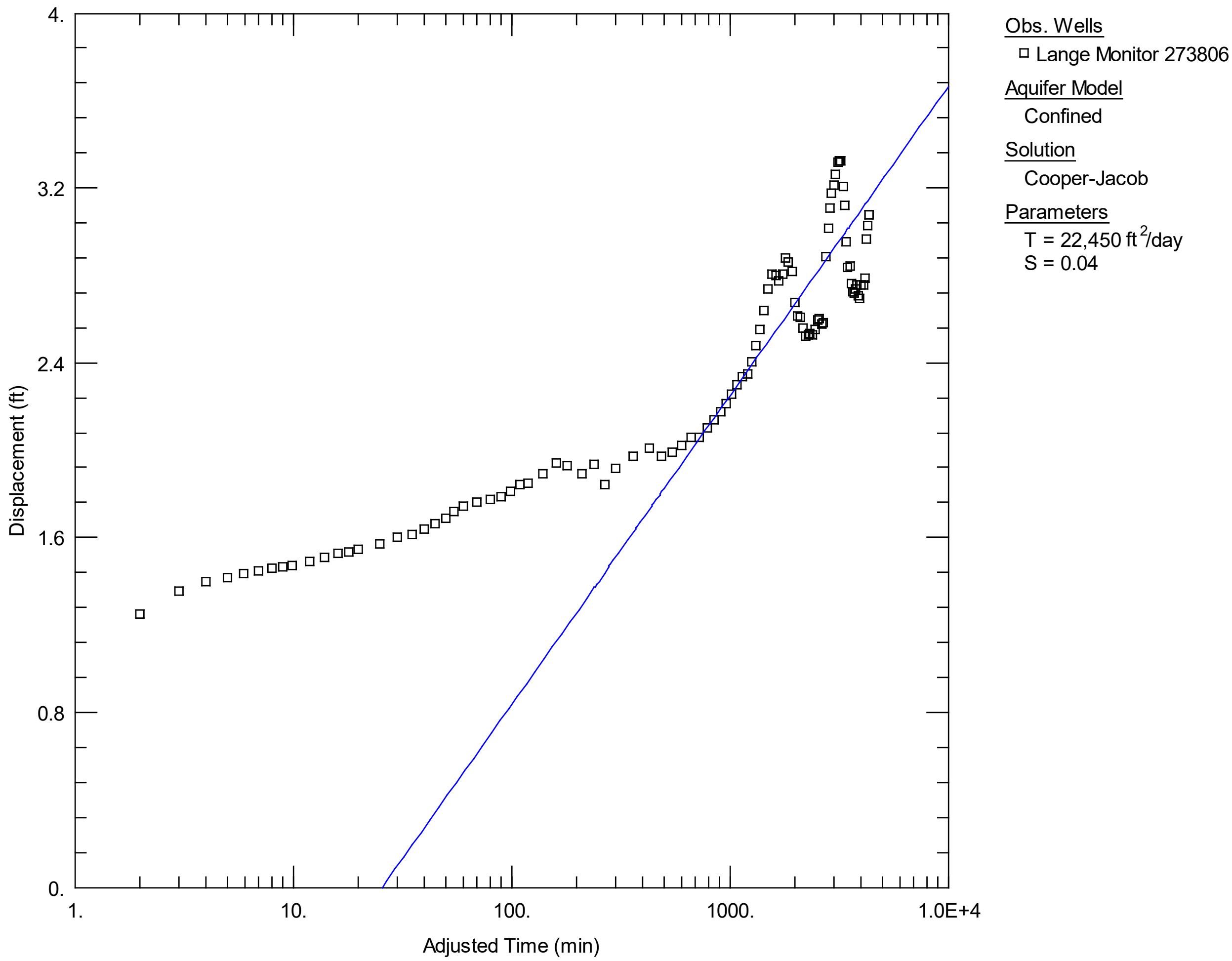

Figure A15. Lange 1 aquifer test showing Cooper–Jacob solution.

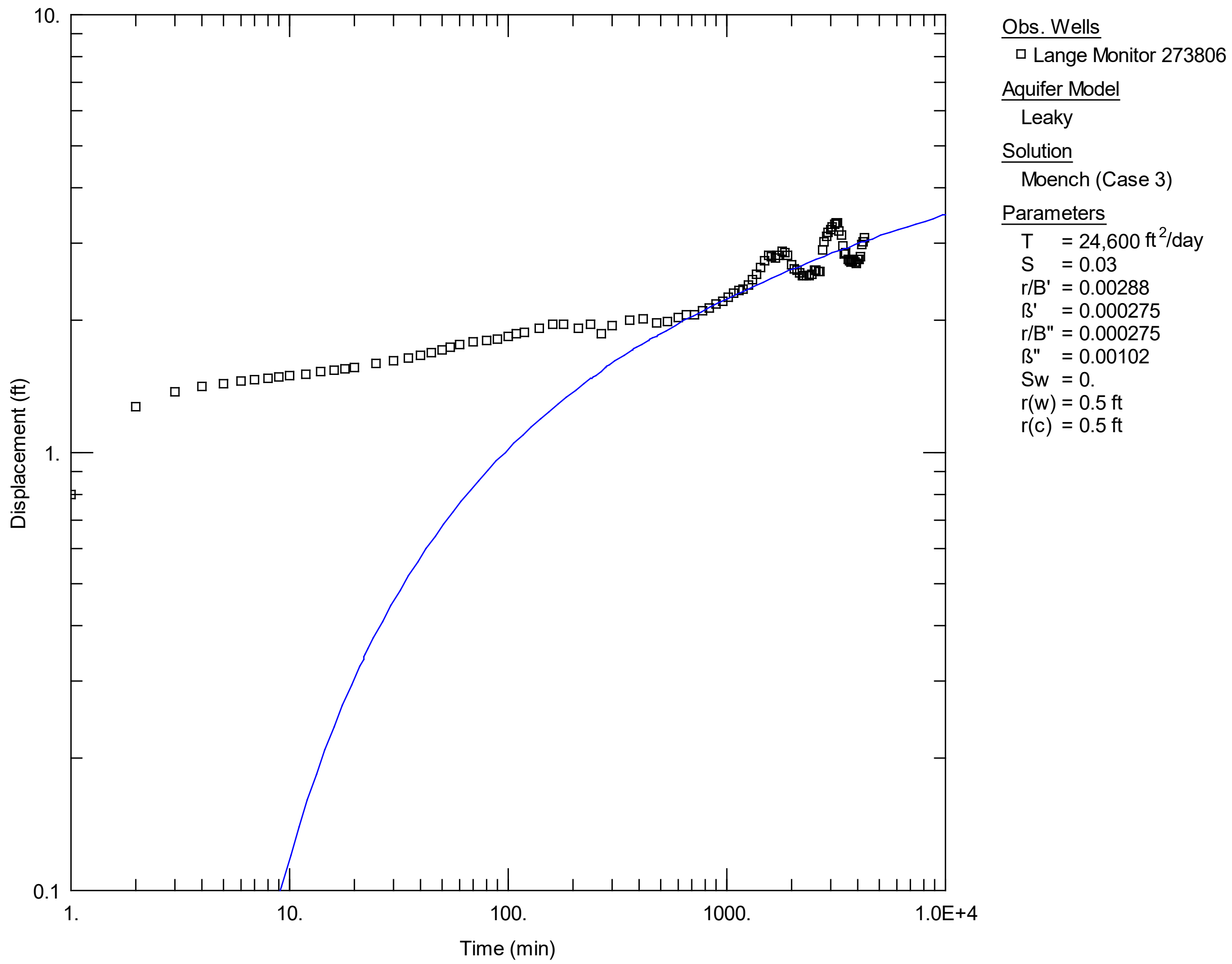

Figure A16. Lange 1 aquifer test showing Moench (Case 3) leaky confined aquifer solution.

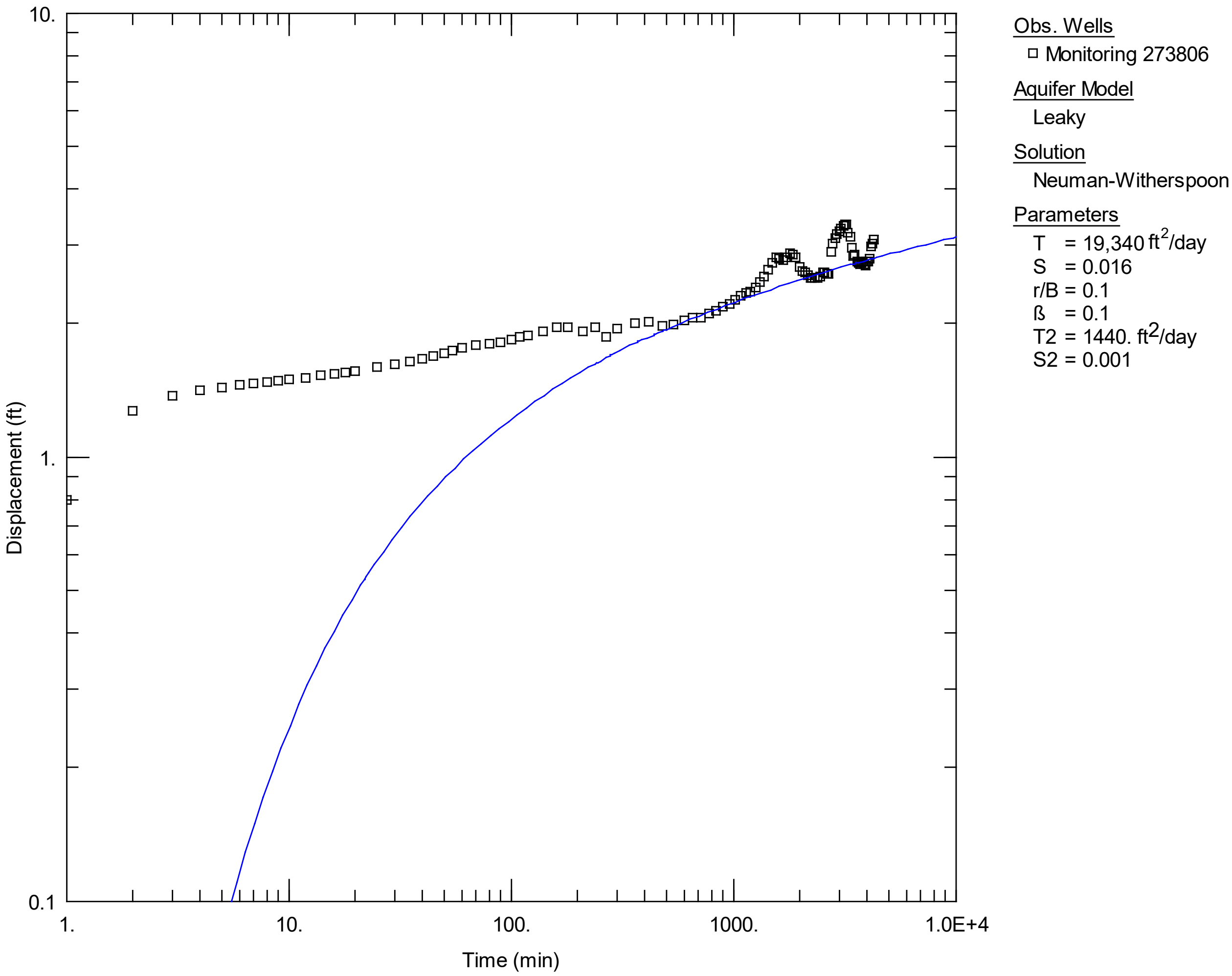

Figure A17. Lange 1 aquifer test showing Neuman–Witherspoon leaky confined aquifer solution.

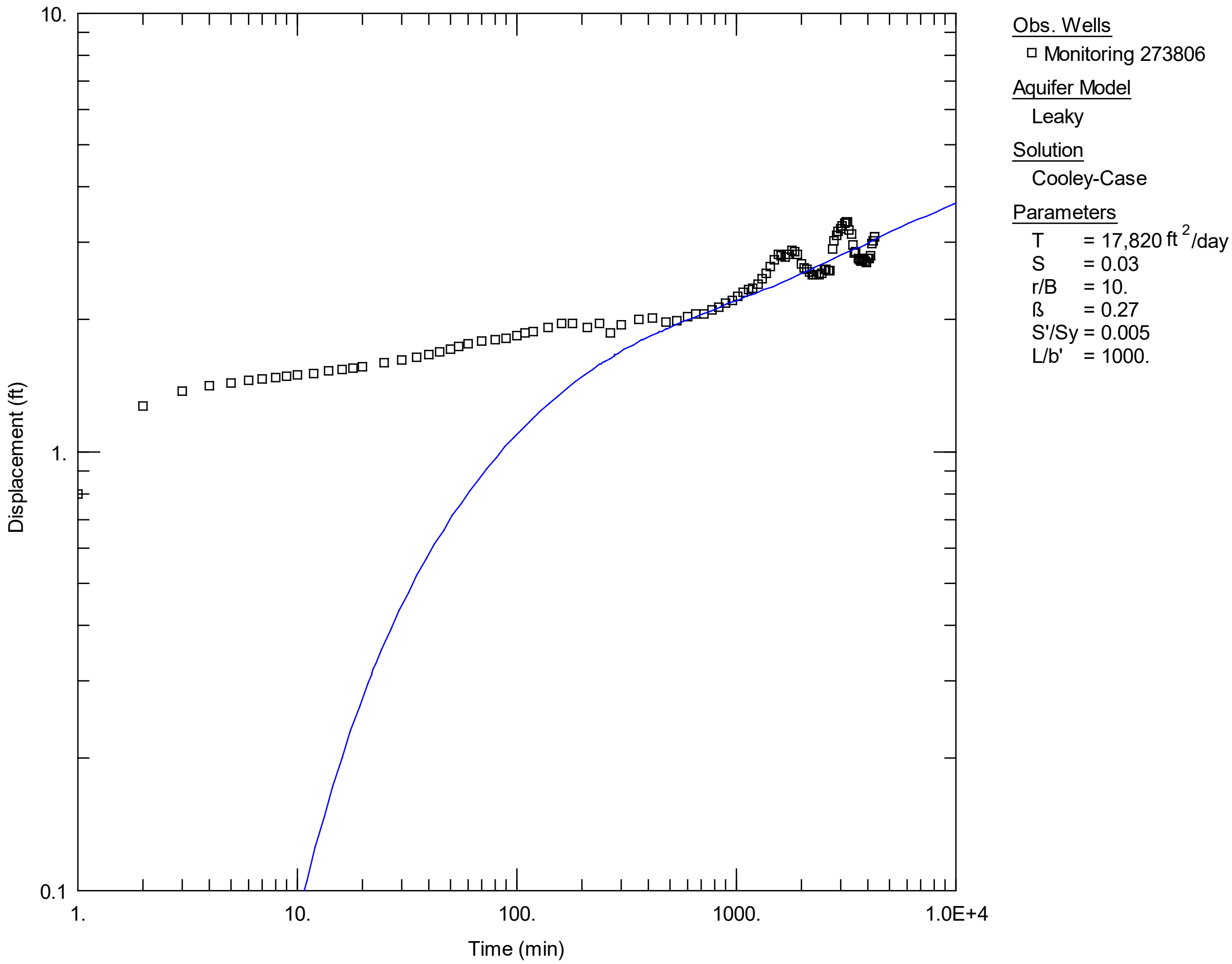

Figure A18. Lange 1 aquifer test showing Cooley–Case leaky confined aquifer solution.

D. JORGENSEN 1 (290760)

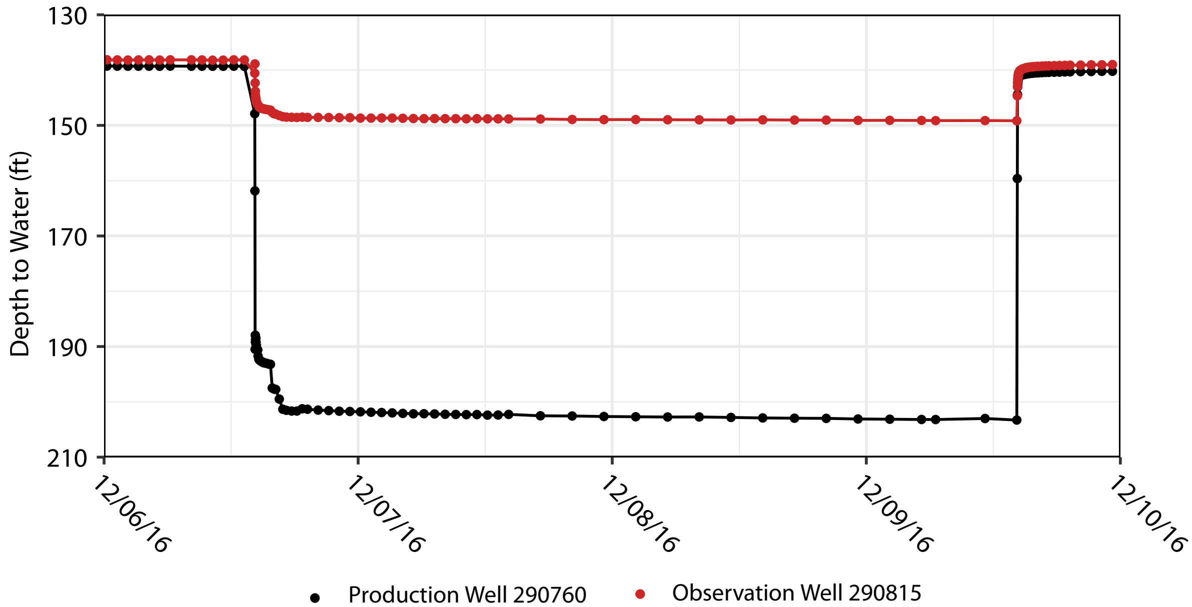

Figure A19. D. Jorgenson 1 aquifer test background through recovery water levels.

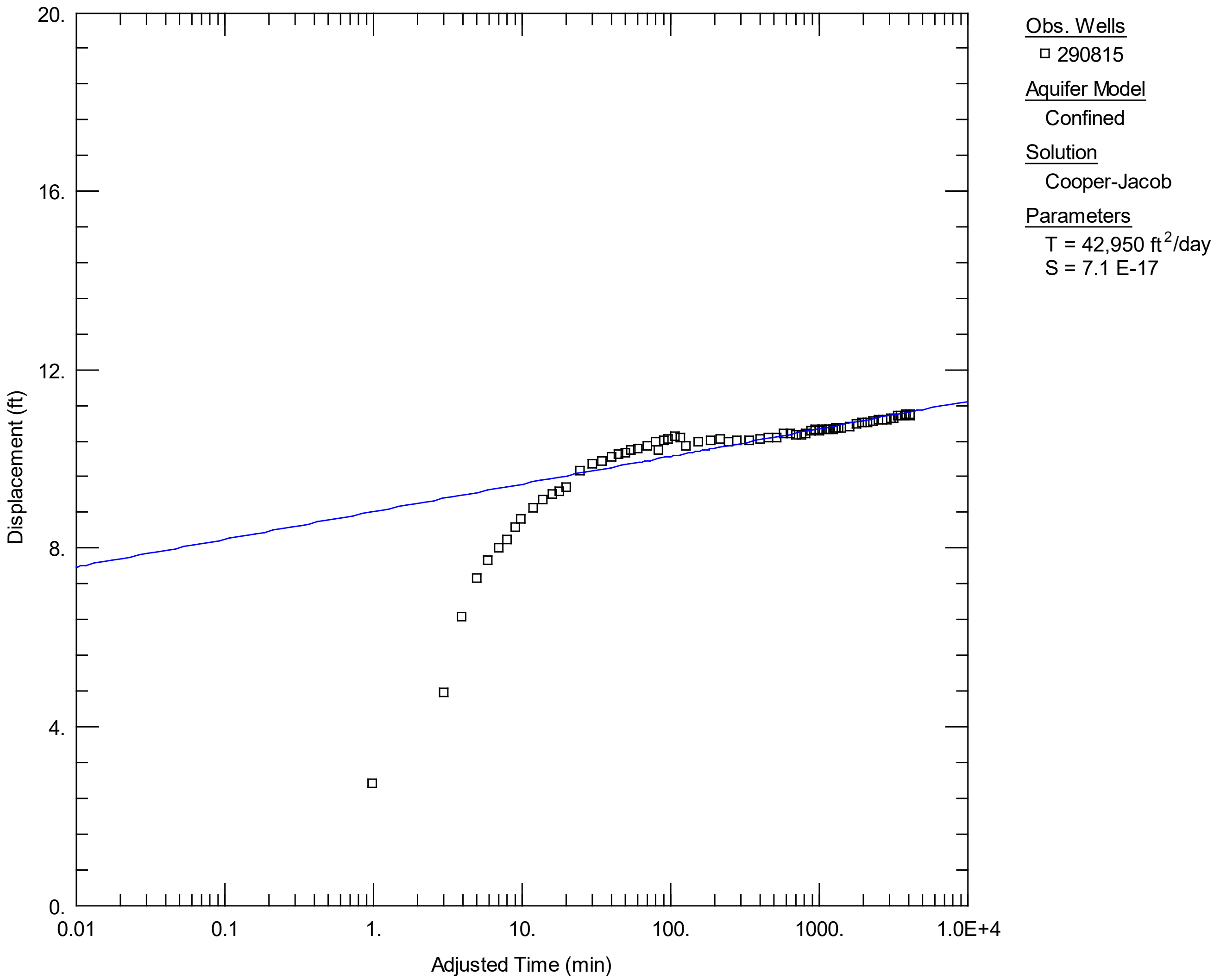

Figure A20. D. Jorgenson 1 aquifer test showing Cooper–Jacob confined aquifer solution. Storage coefficient is unrealistic.

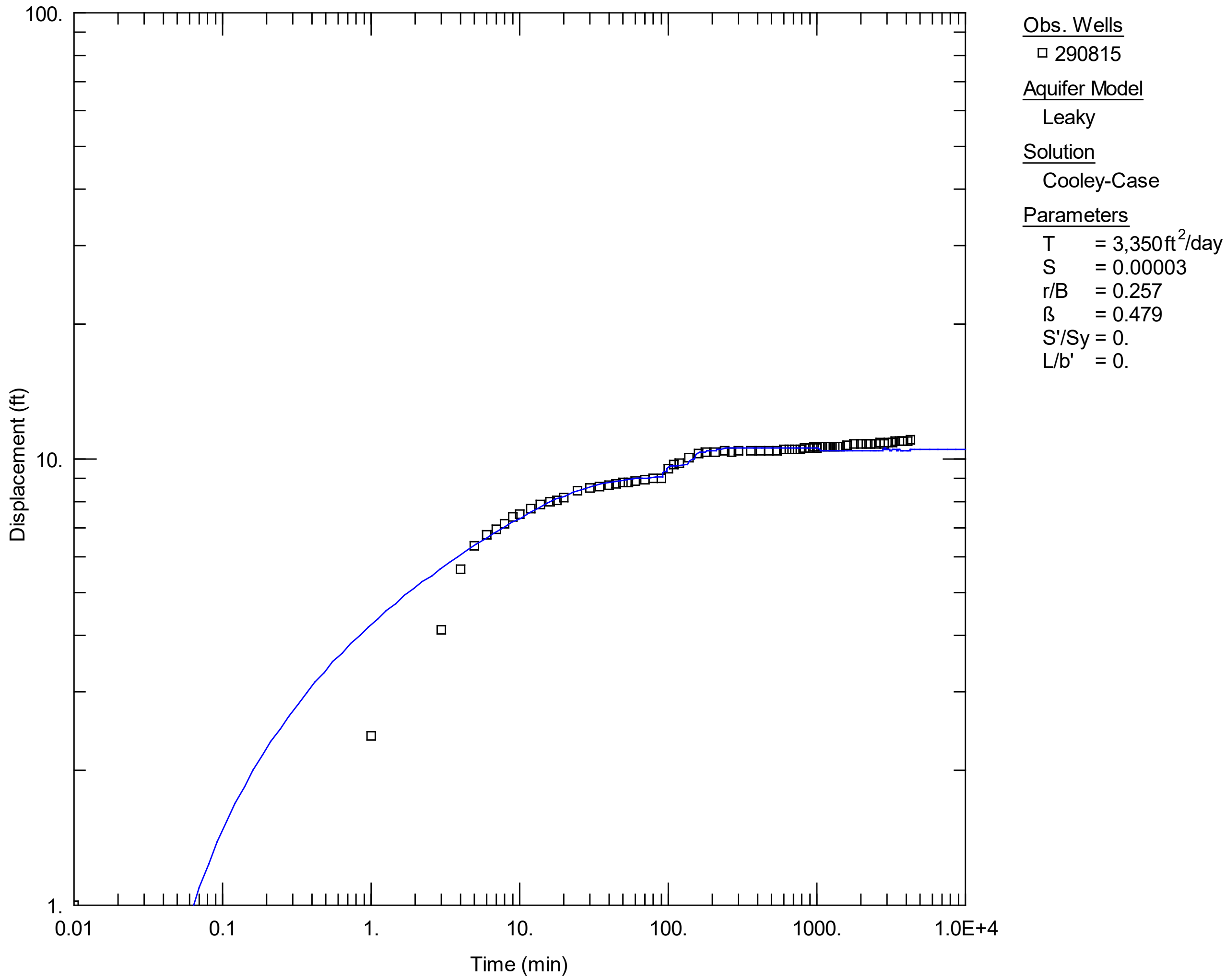

Figure A21. D. Jorgenson 1 aquifer test showing Cooley–Case leaky confined aquifer solution.

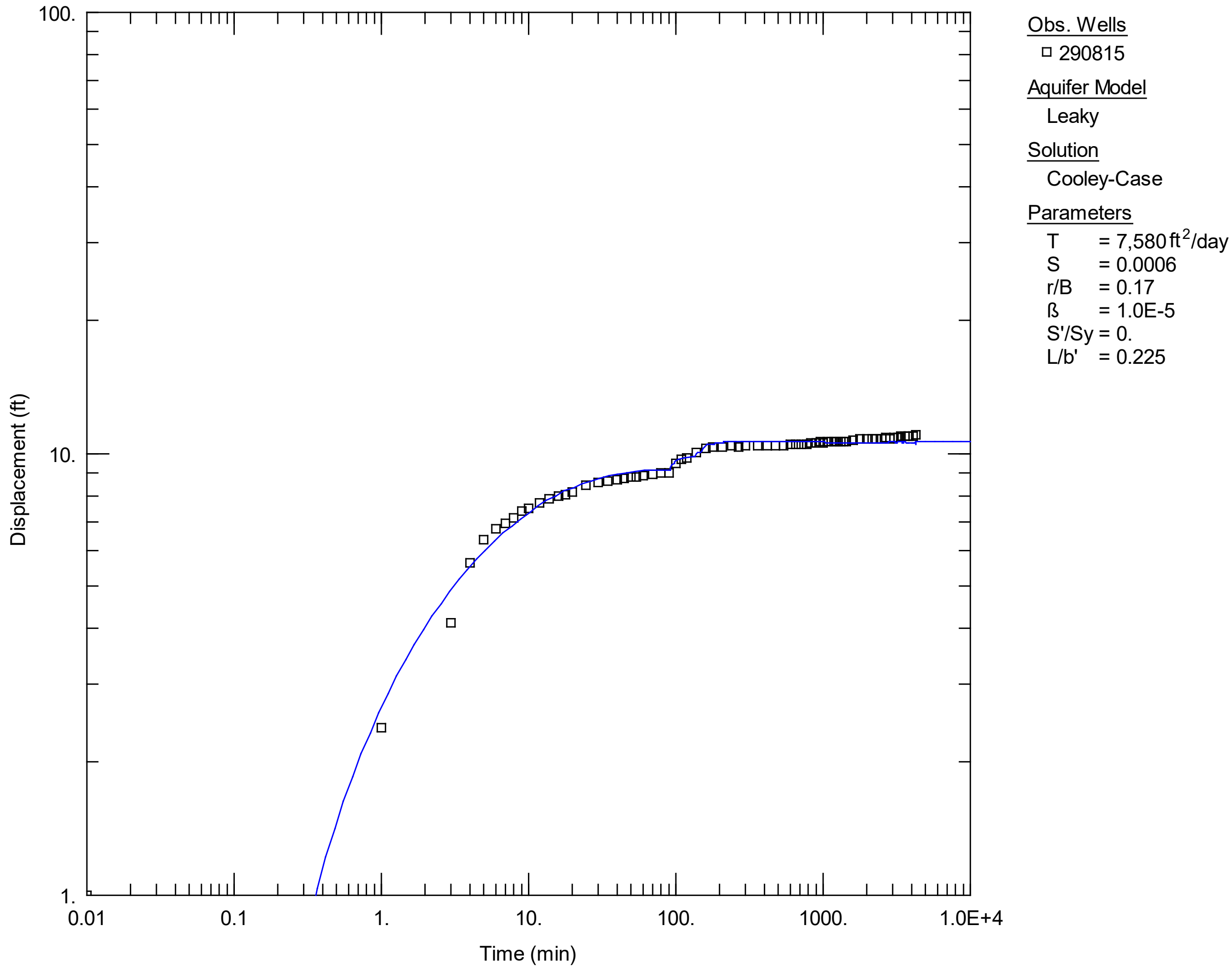

Figure A22. D. Jorgenson 1 aquifer test showing Cooley–Case leaky confined aquifer solution, with barrier boundary 100 ft to the south.

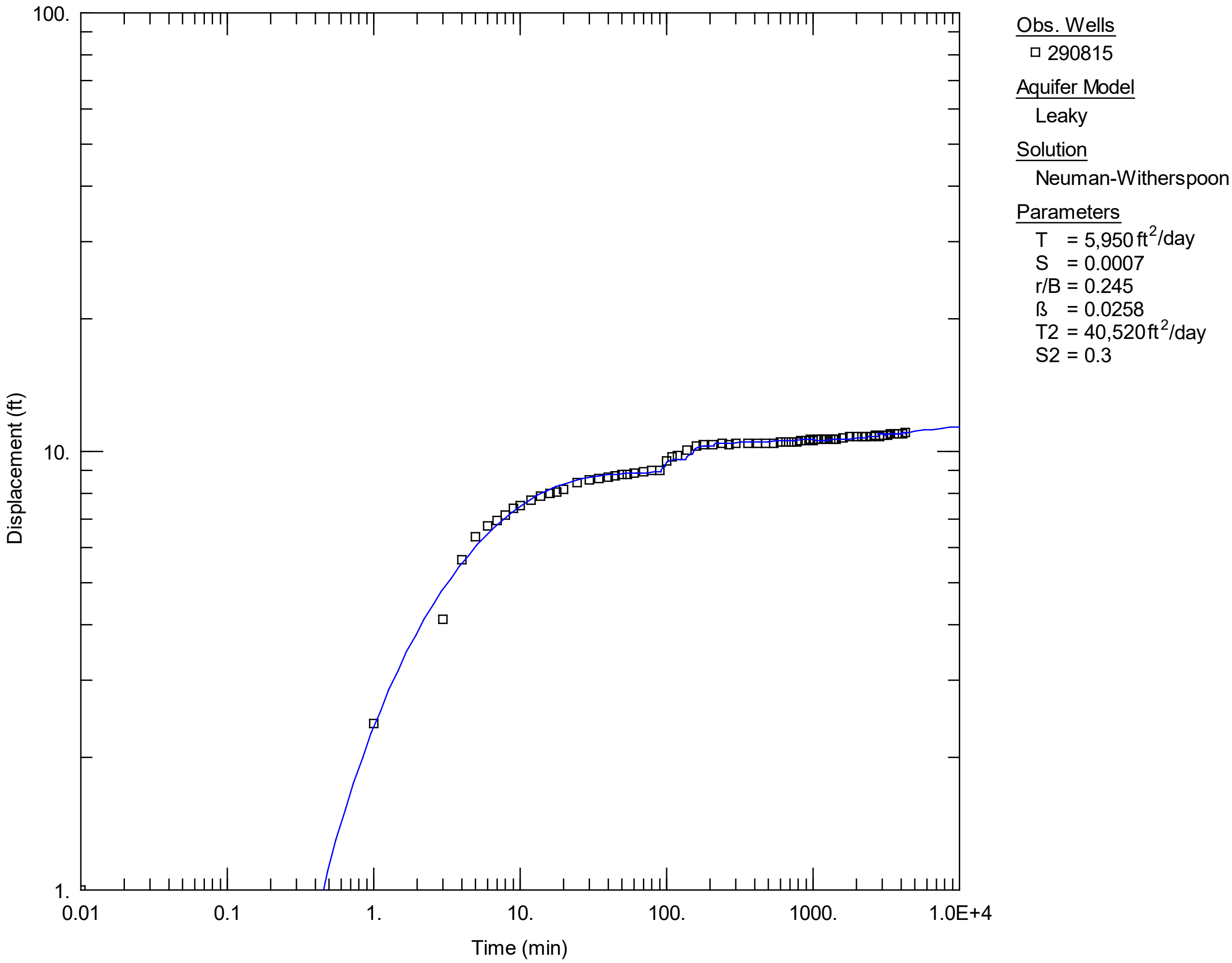

Figure A23. D. Jorgenson 1 aquifer test showing Neuman–Witherspoon leaky confined aquifer solution, with barrier boundary 100 ft to the south.

LER 1 (295397)

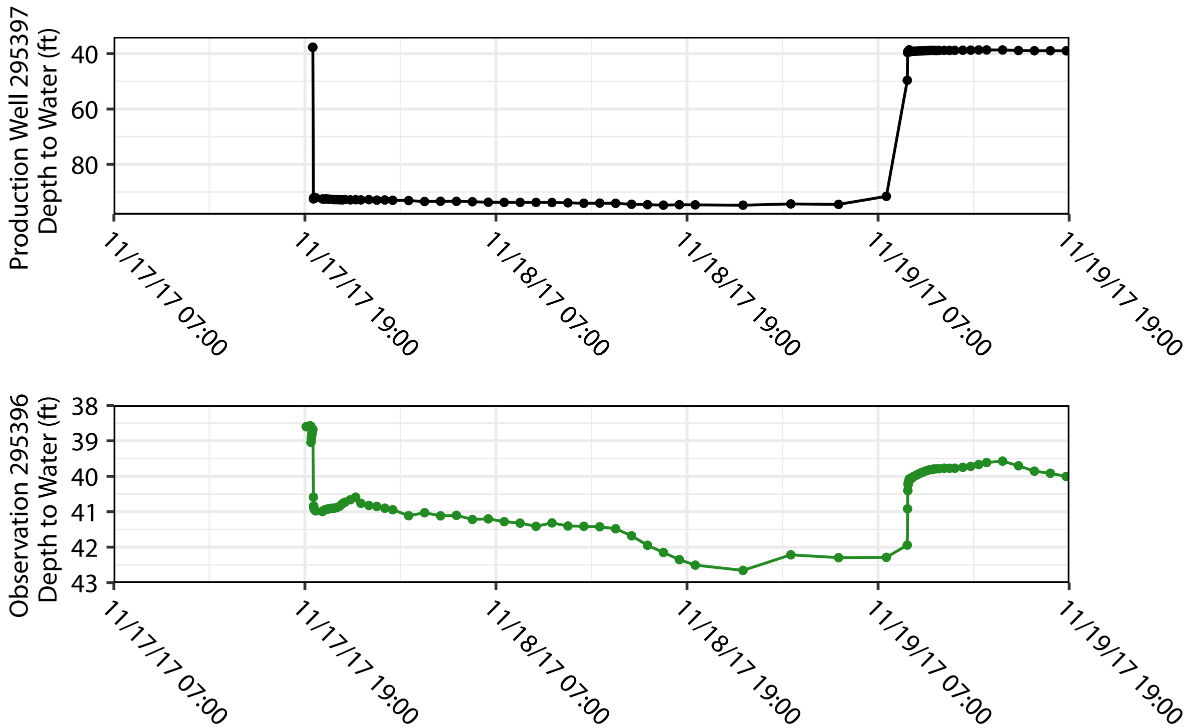

Figure A24. Ler 1 aquifer test background through recovery water levels. Pumping rate fluctuated during last part of the test.

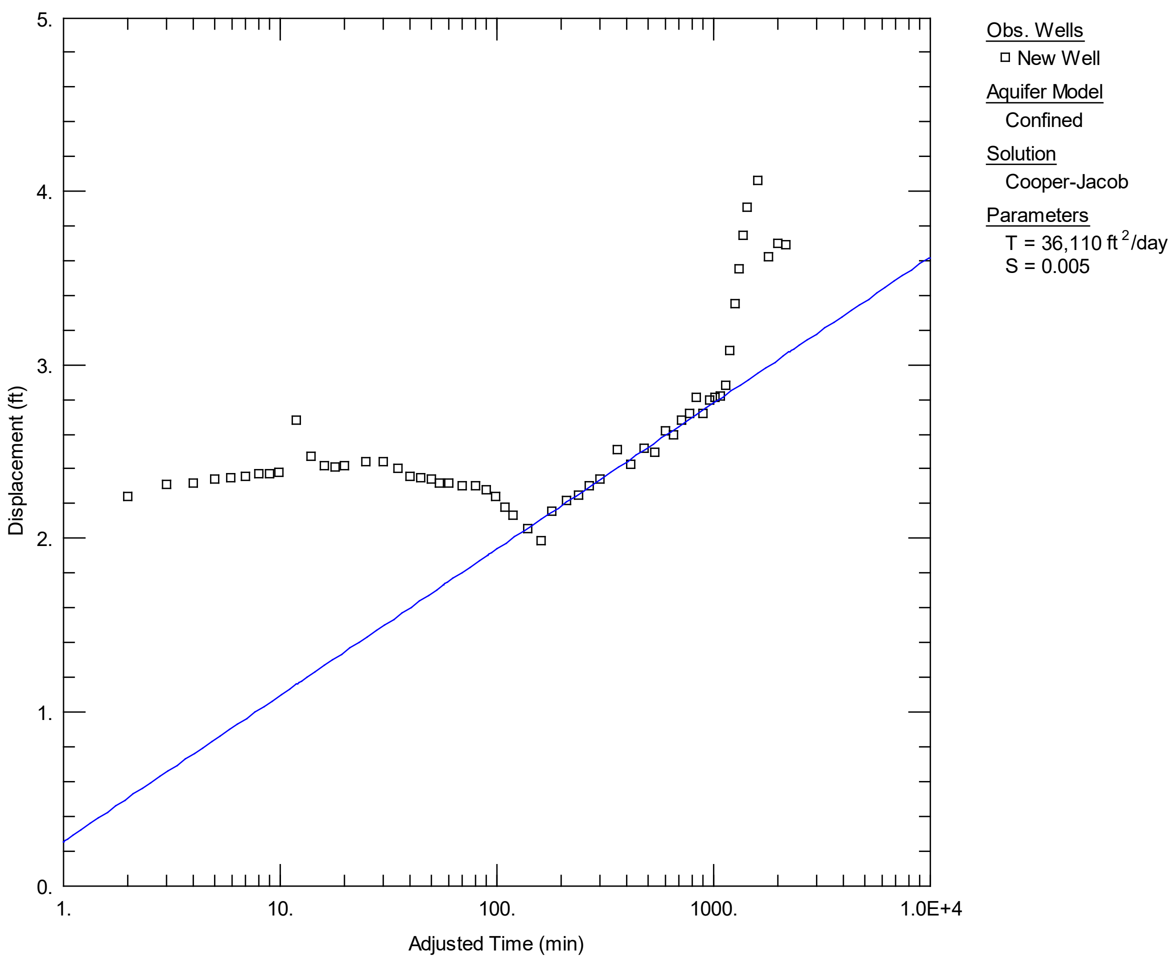

Figure A25. Ler 1 aquifer test showing Cooper–Jacob confined aquifer solution.

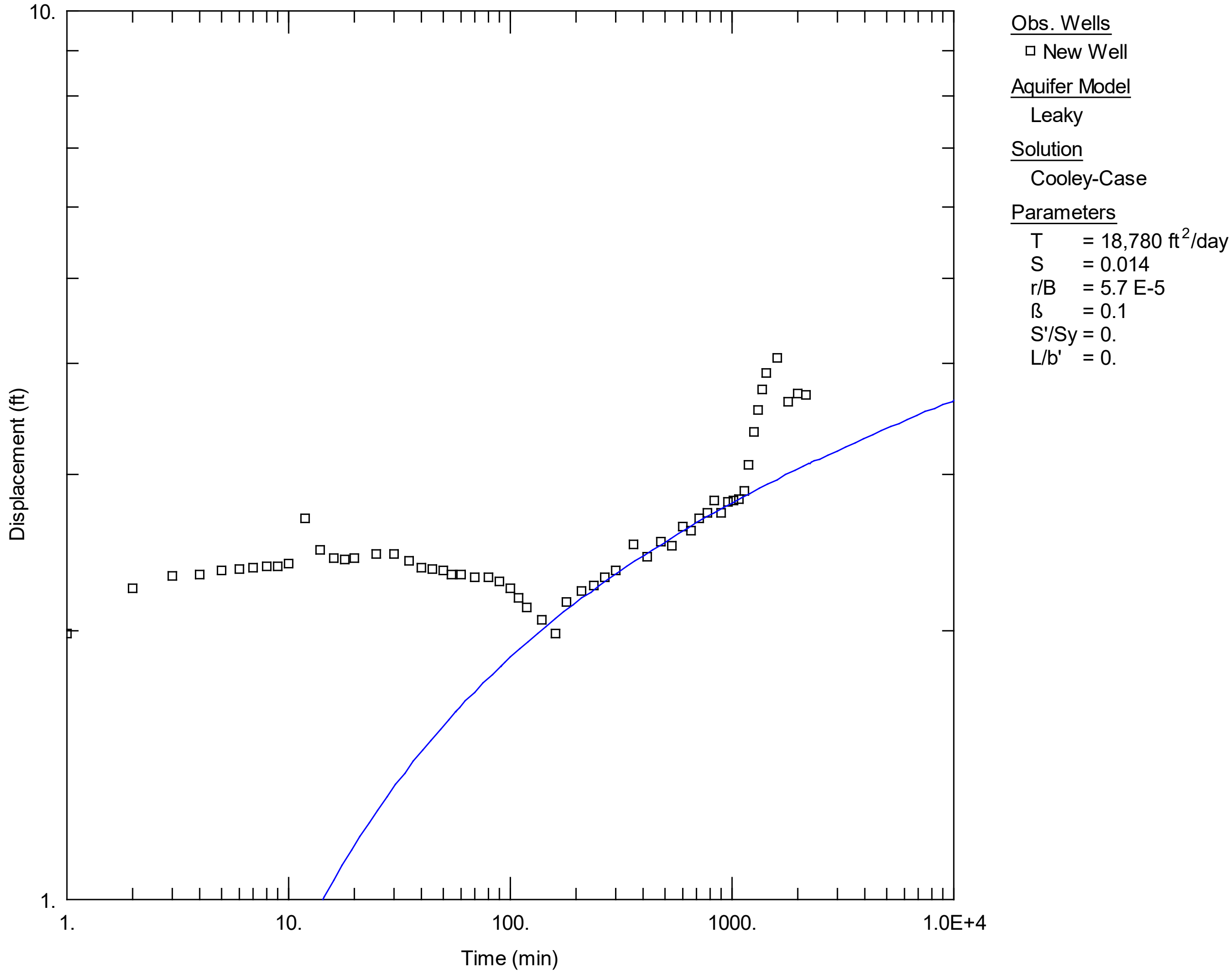

Figure A26. Ler 1 aquifer test showing Cooley–Case leaky confined aquifer solution.

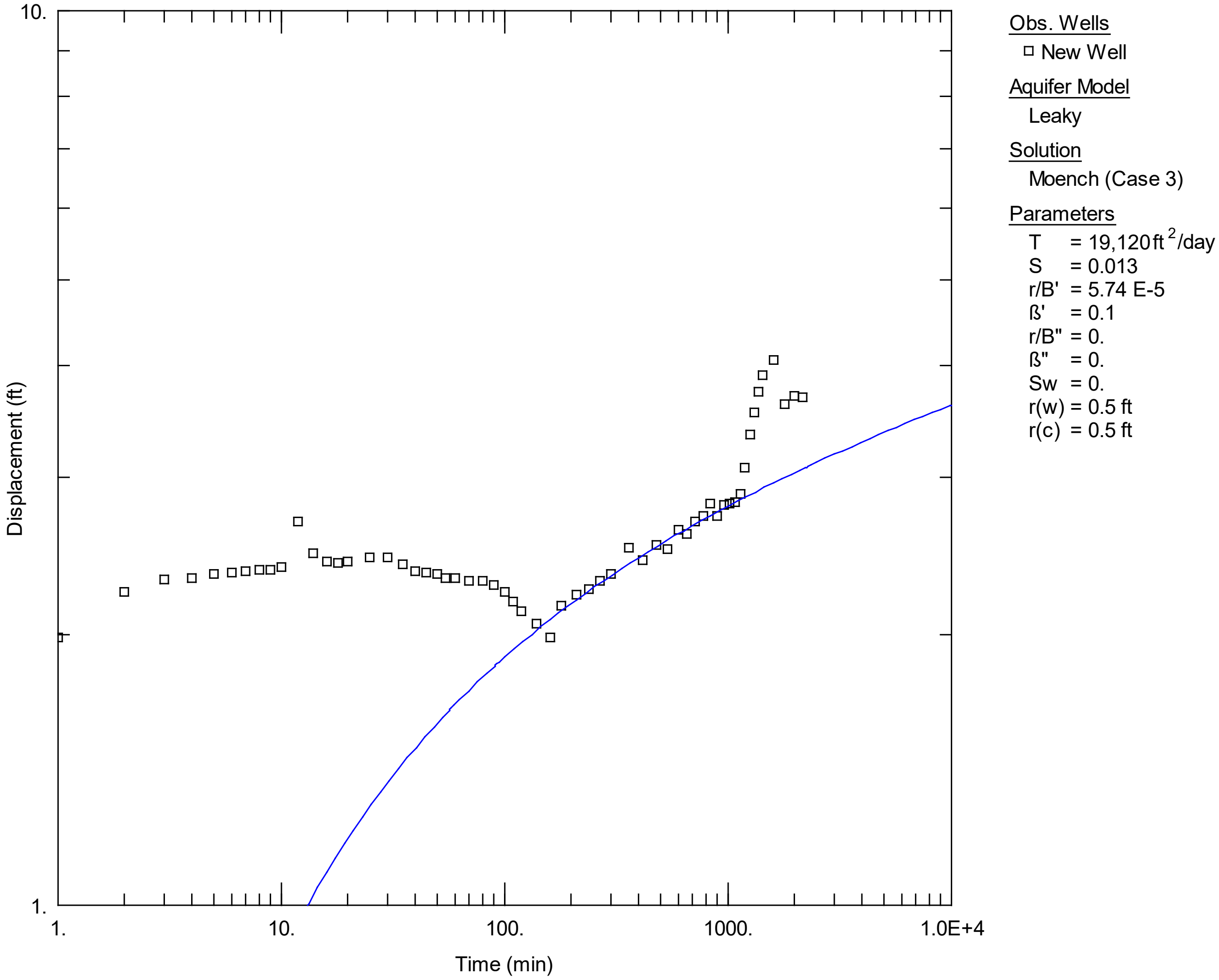

Figure A27. Ler 1 aquifer test showing Moench (Case 3) leaky confined aquifer solution.

J. JORGENSEN 1 (303552)

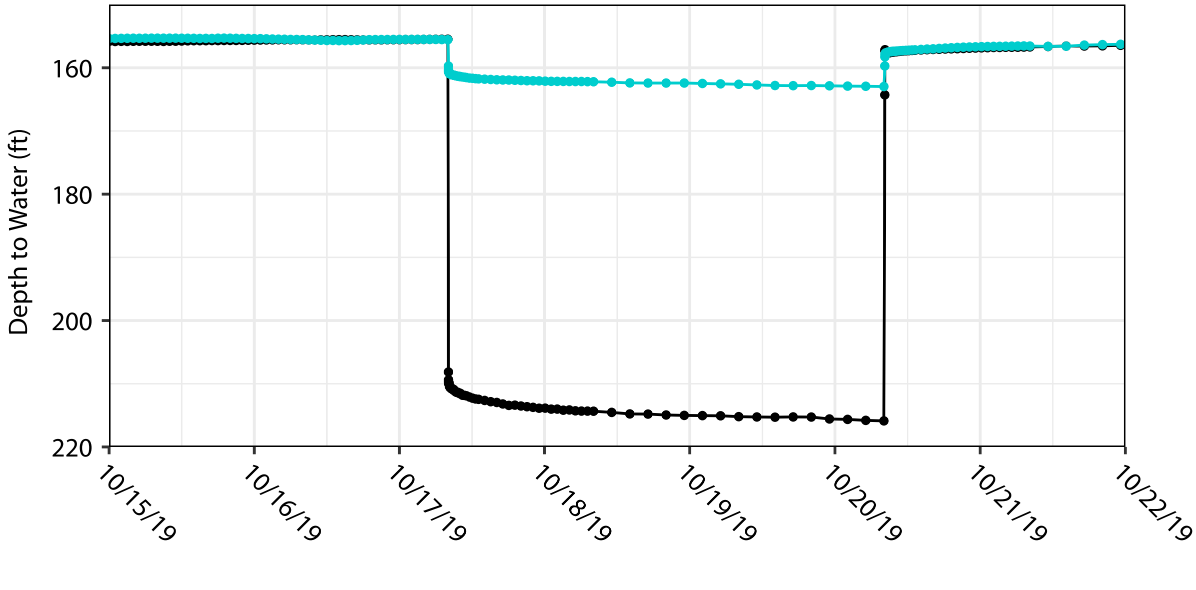

Figure A28. J. Jorgenson 1 aquifer test background through recovery water levels.

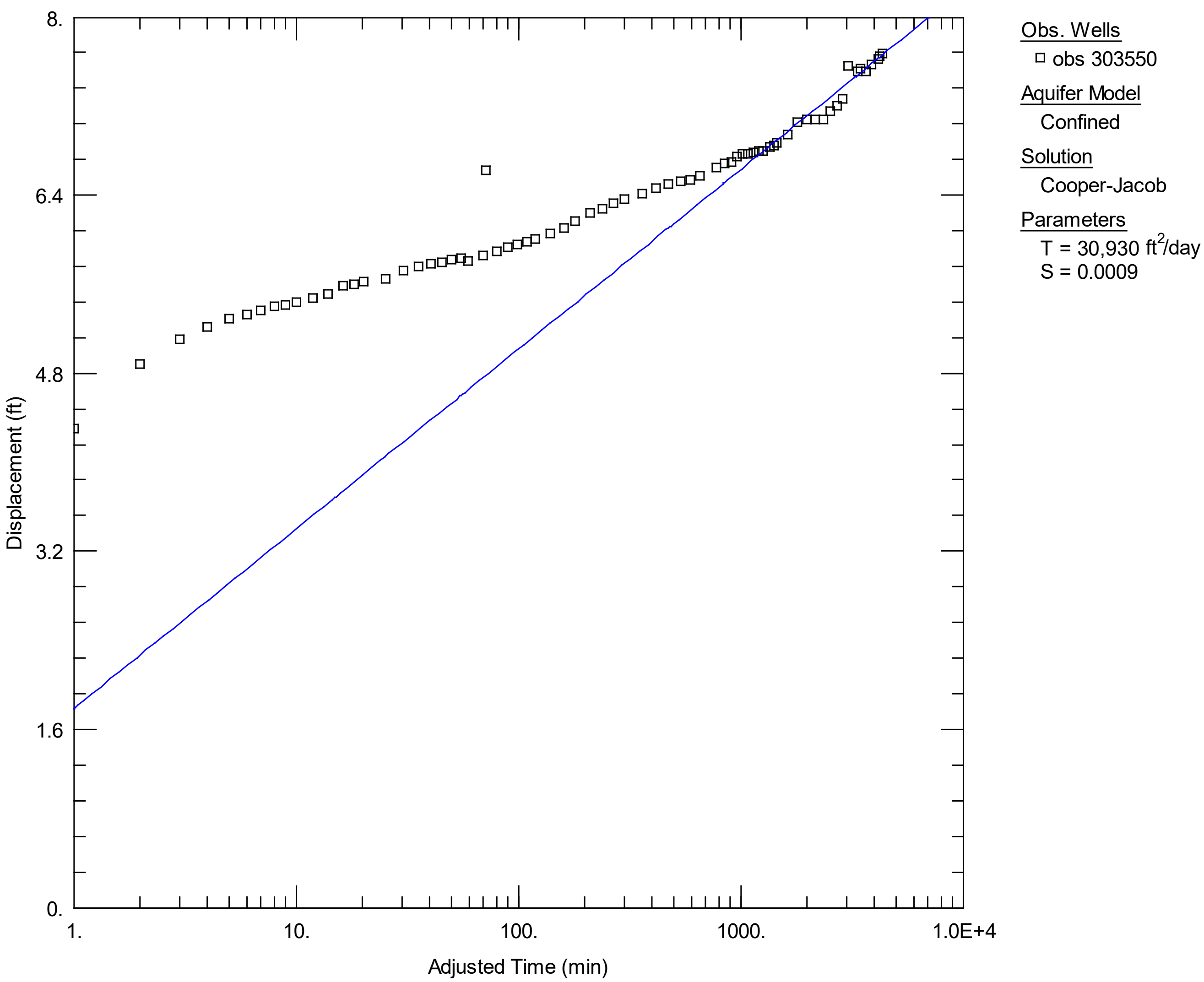

Figure A29. J. Jorgenson 1 aquifer test showing Cooper–Jacob confined aquifer solution.

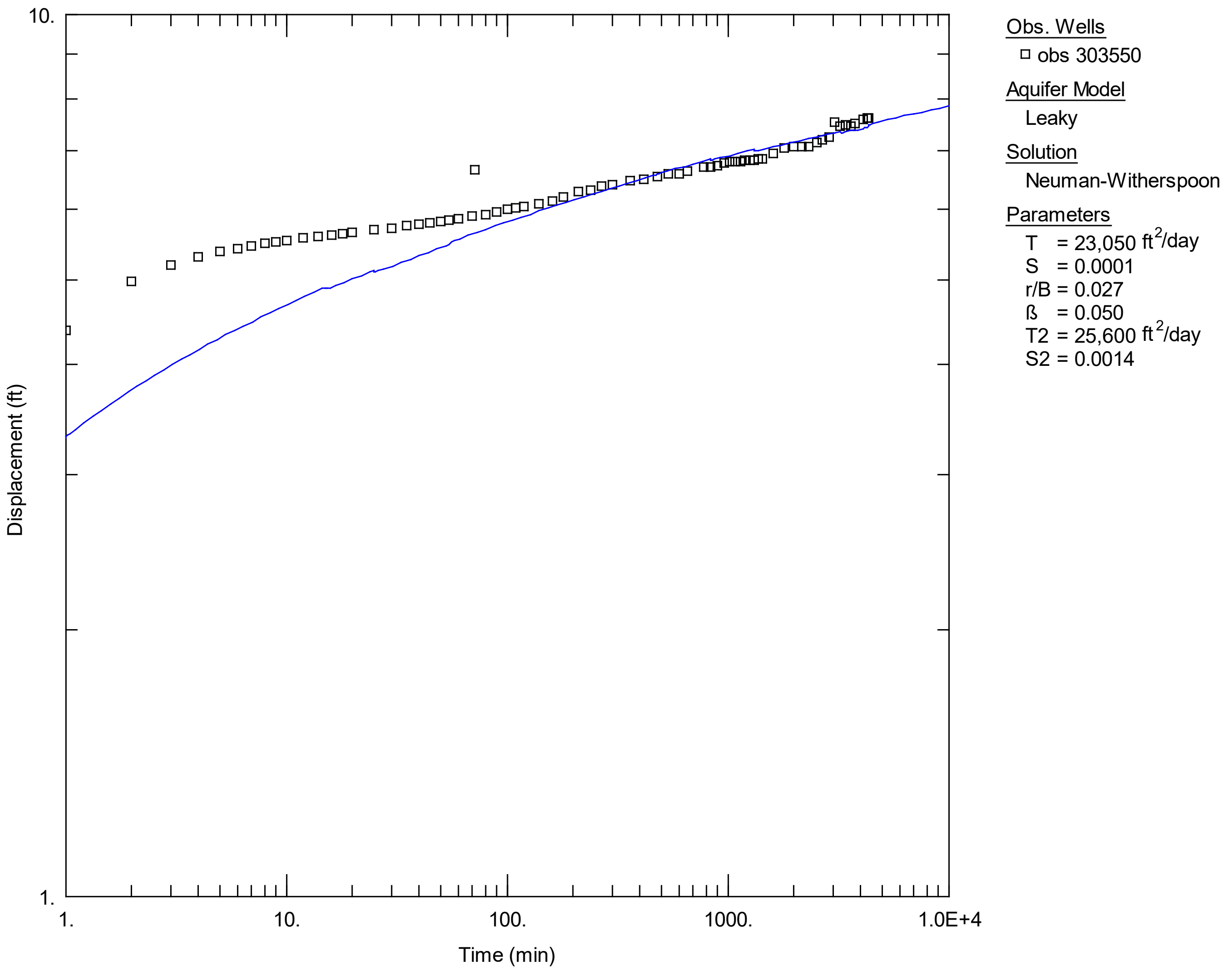

Figure A30. J. Jorgenson 1 aquifer test showing Neuman–Witherspoon leaky confined aquifer solution.

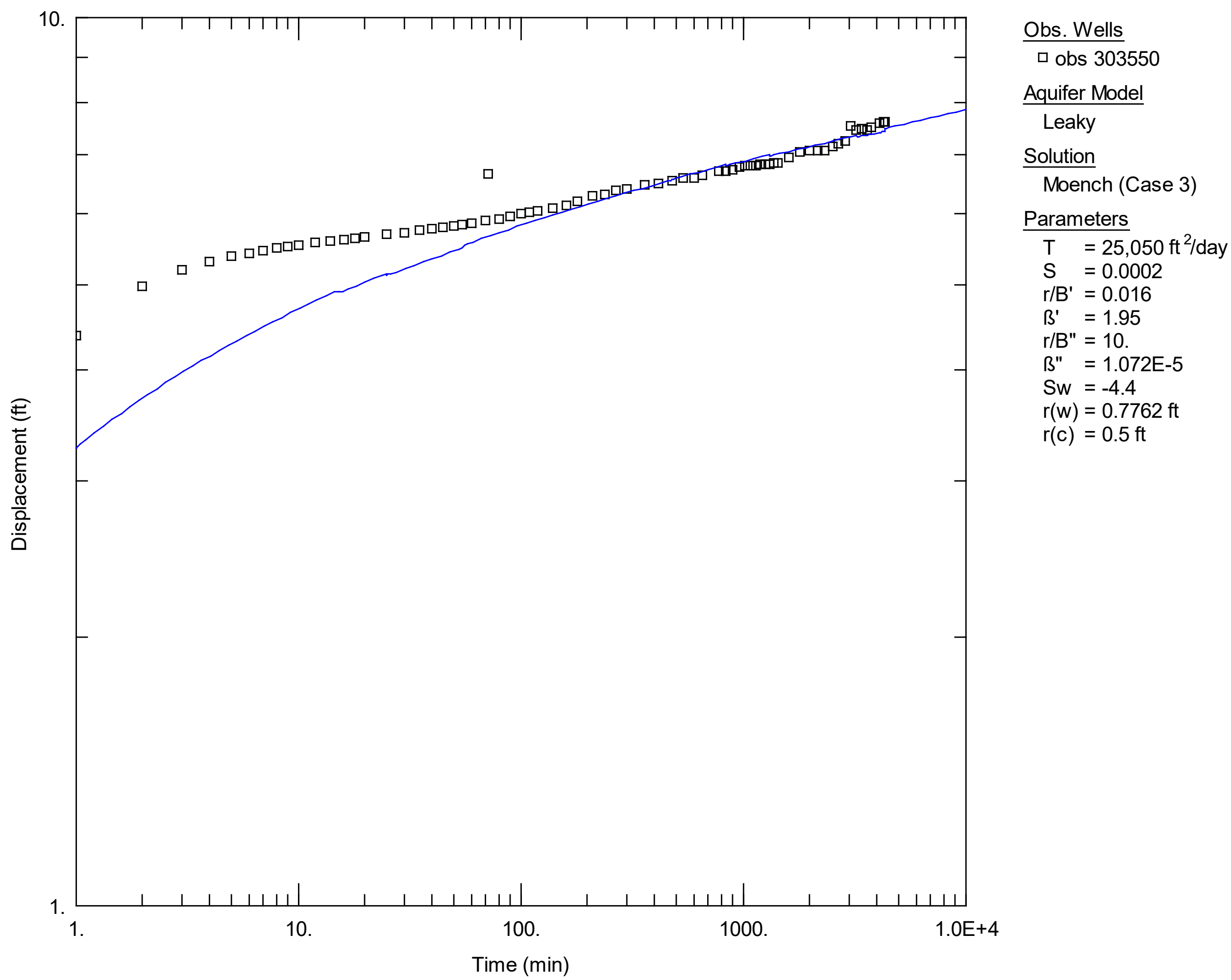

Figure A31. J. Jorgenson 1 aquifer test showing Moench (Case 3) leaky confined aquifer solution.

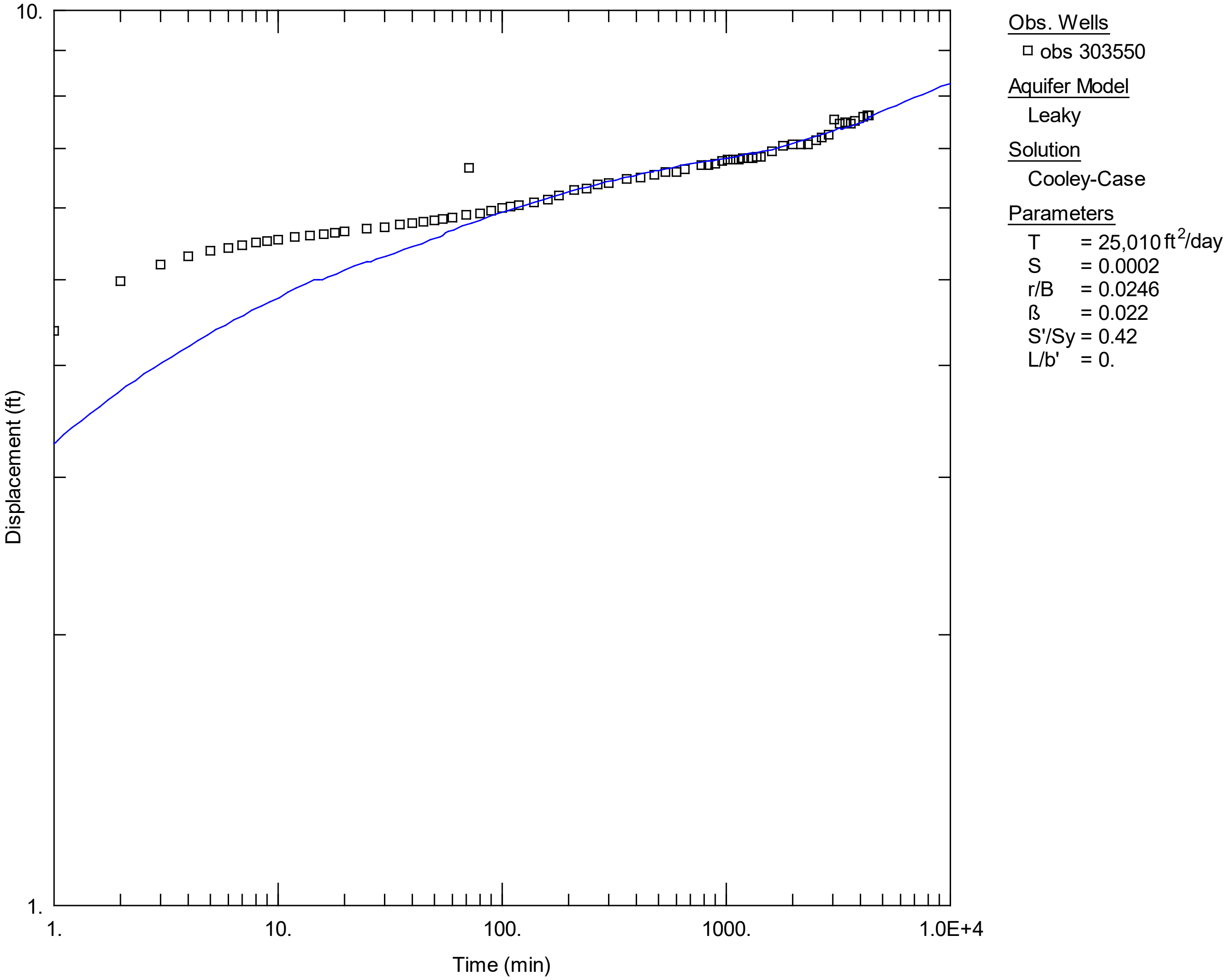

Figure A32. J. Jorgenson 1 aquifer test showing Cooley–Case leaky confined aquifer solution.

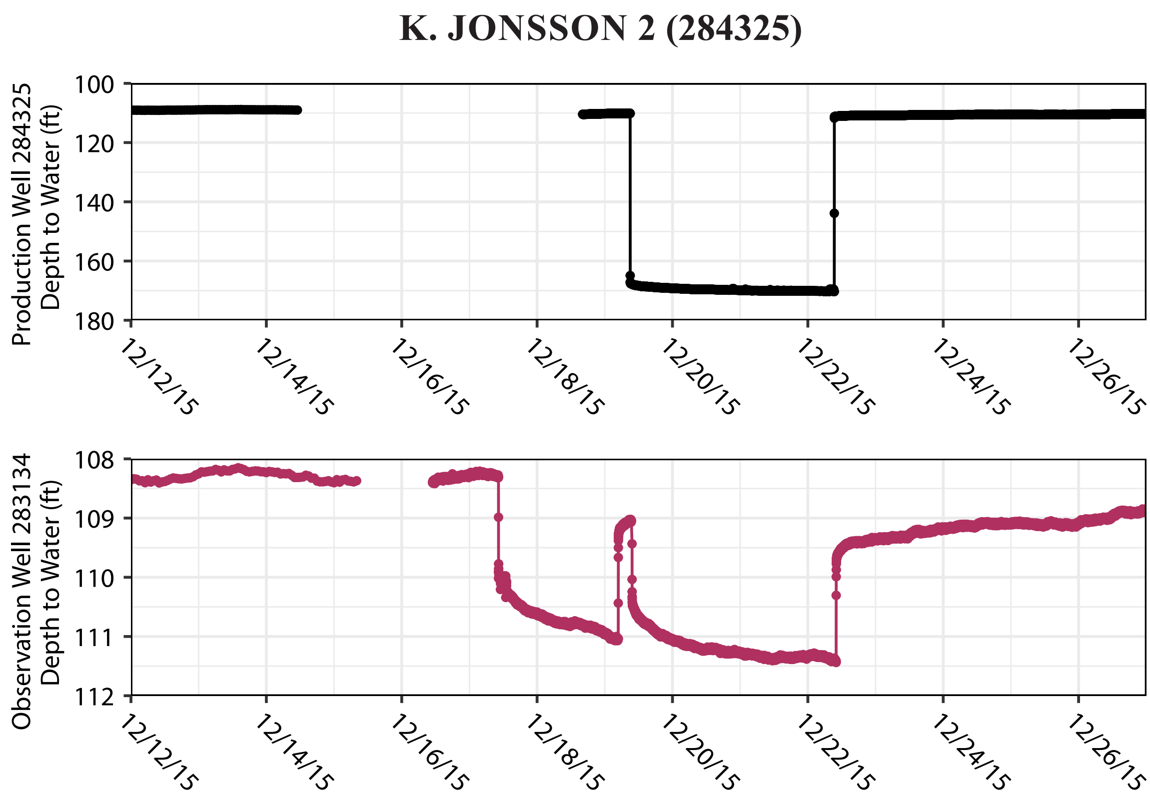

Figure A33. K. Jonsson 2 aquifer test background through recovery water levels. Pump shut down and was restarted after 28 hr of recovery. Test evaluation based on second pumping period.

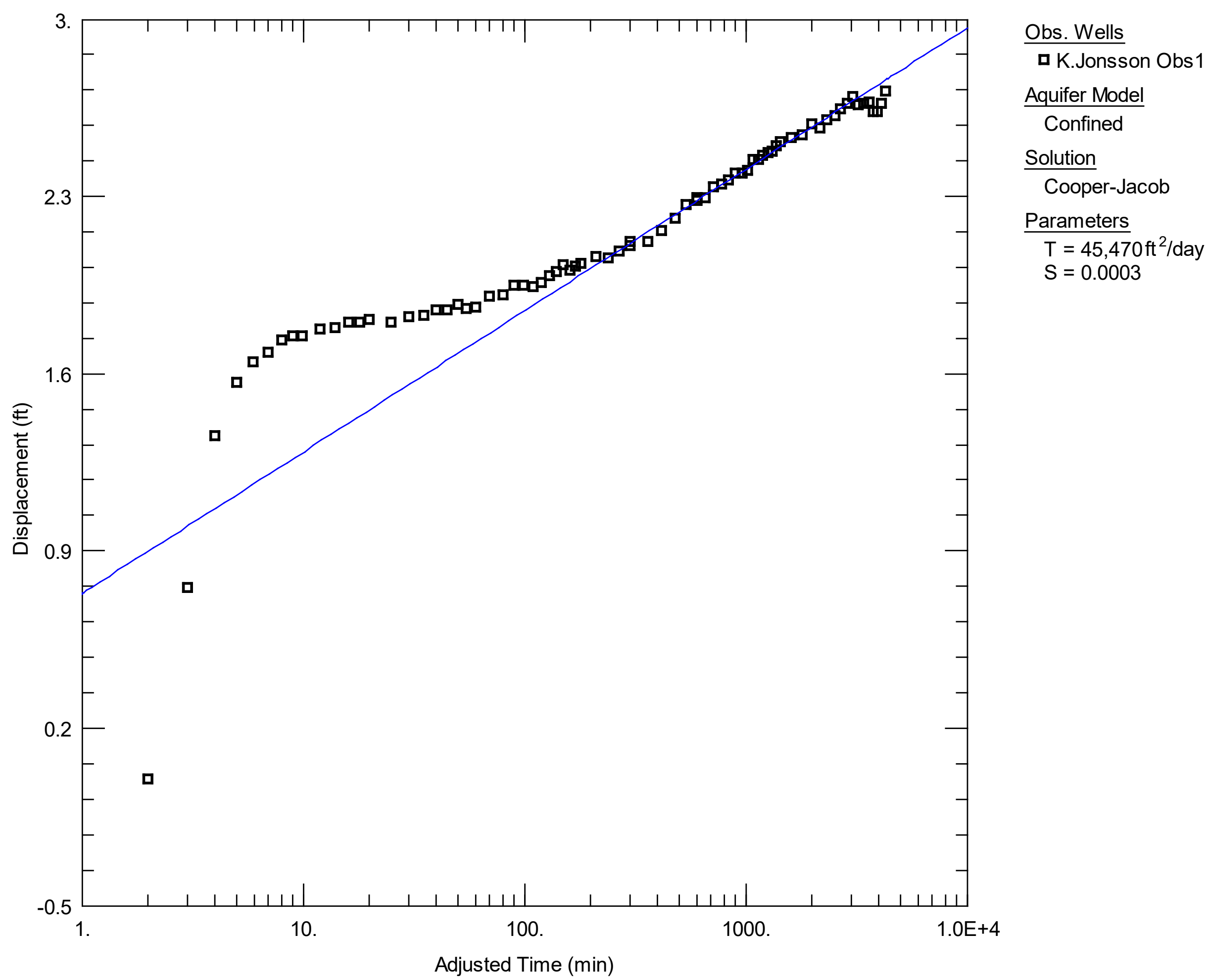

Figure A34. K. Jonsson 2 aquifer test showing Cooper–Jacob confined aquifer solution.

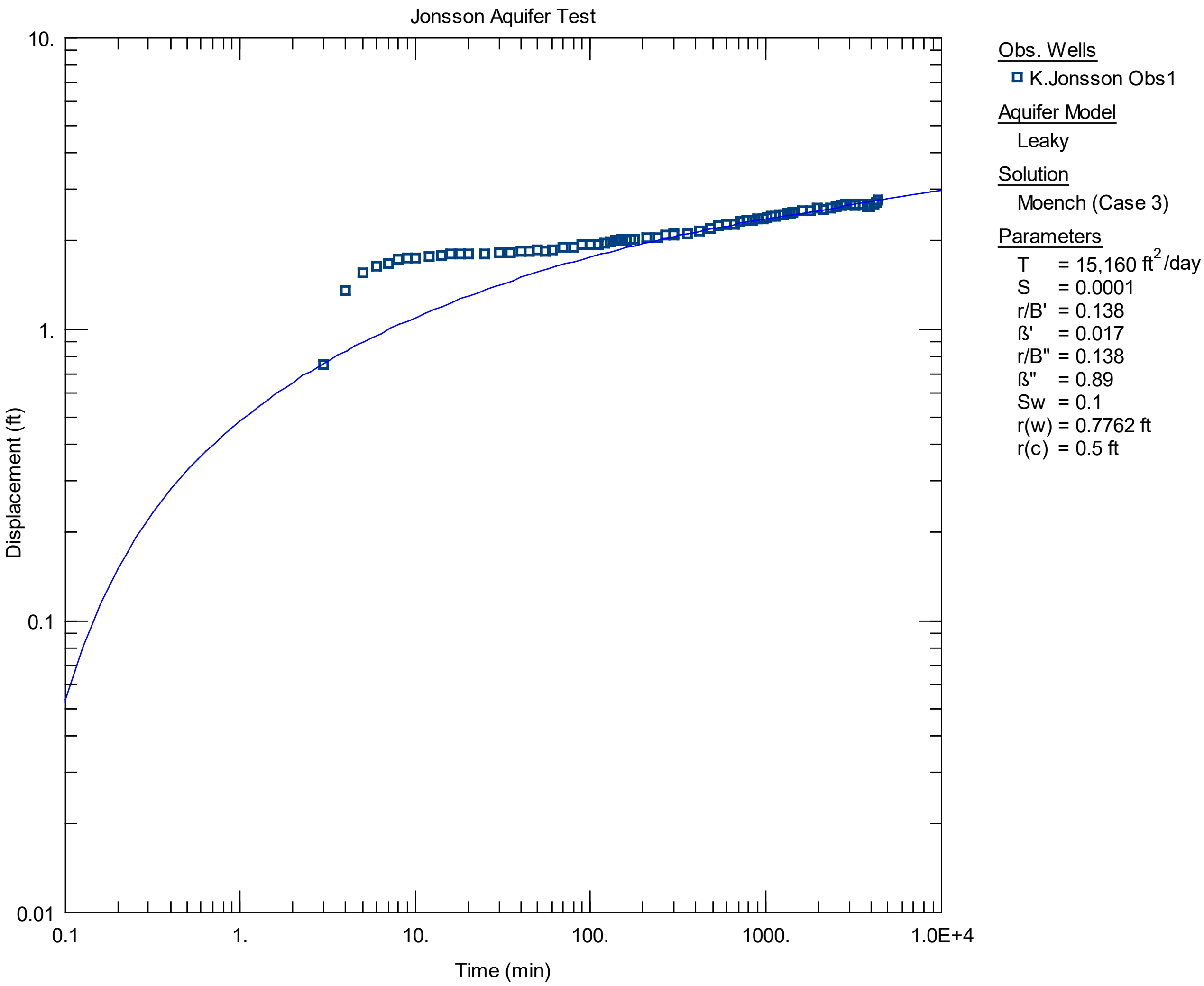

Figure A35. K. Jonsson 2 aquifer test showing Moench (Case 3) leaky confined aquifer solution.

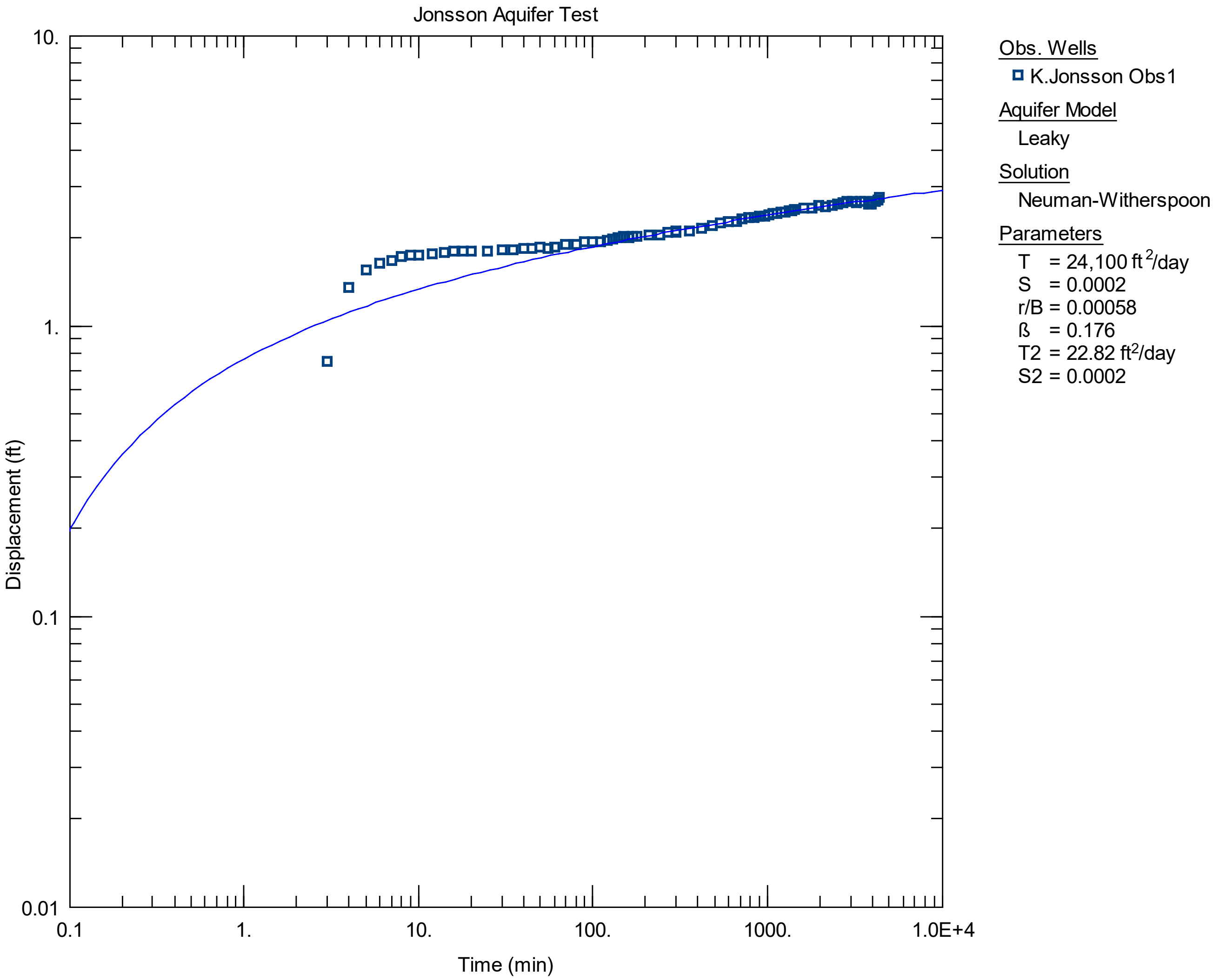

Figure A36. K. Jonsson 2 aquifer test showing Neuman–Witherspoon leaky confined aquifer solution.

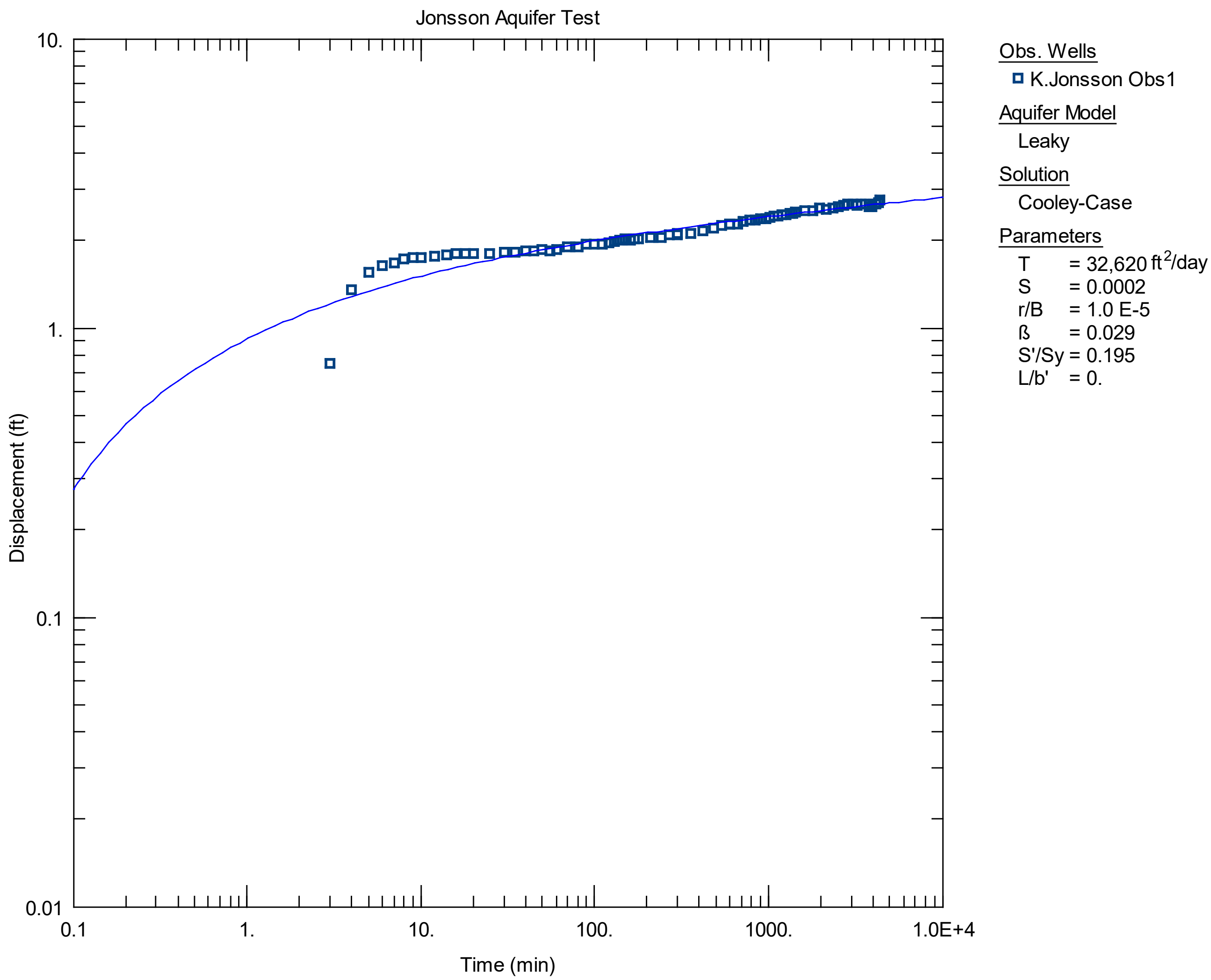

Figure A37. K. Jonsson 2 aquifer test showing Cooley–Case leaky confined aquifer solution.

K. JONSSON 1 (249505)

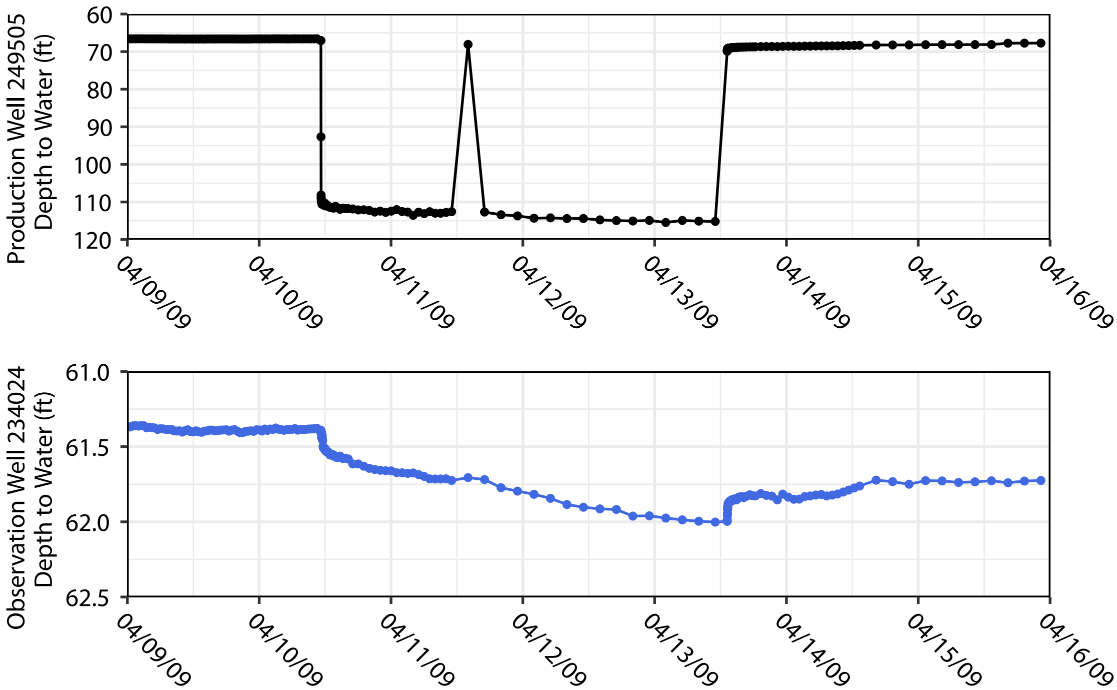

Figure A38. K. Jonsson 1 aquifer test background through recovery water levels. Pump was off for a short time after the first day of pumping. This did not affect interpretations.

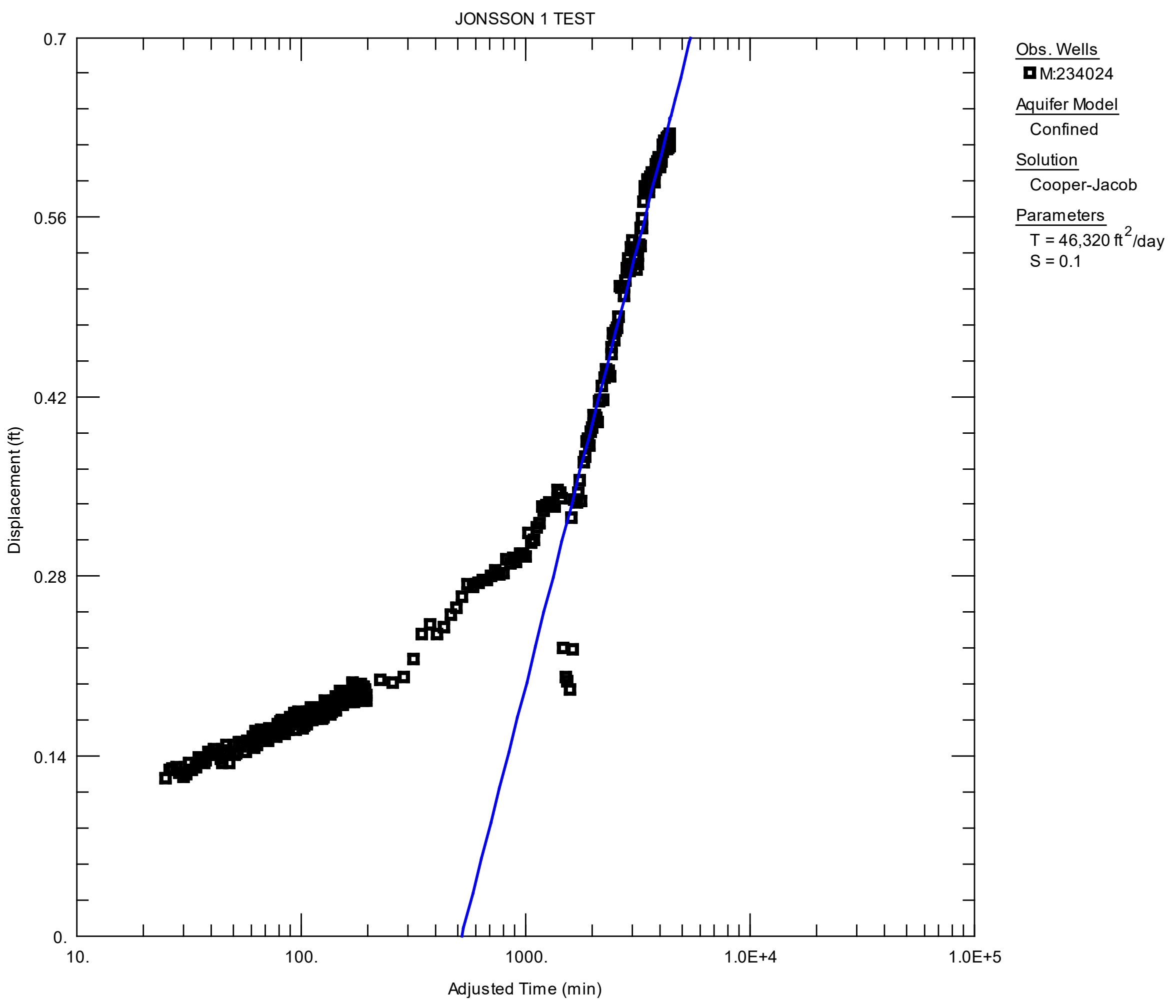

Figure A39. K. Jonsson 1 aquifer test showing Cooper–Jacob confined aquifer solution.

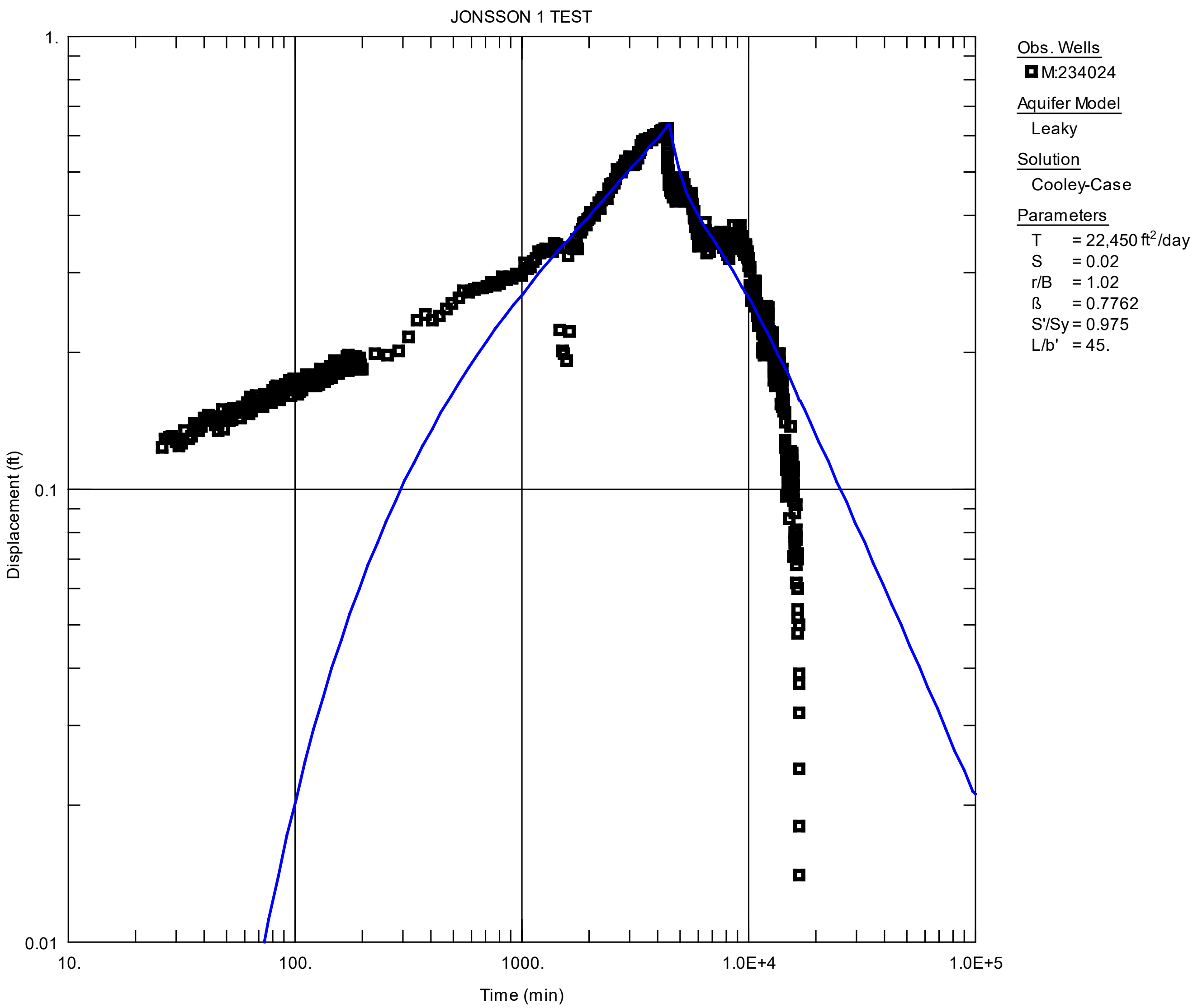

Figure A40. K. Jonsson 1aquifer test showing Cooley–Case leaky confined aquifer solution.

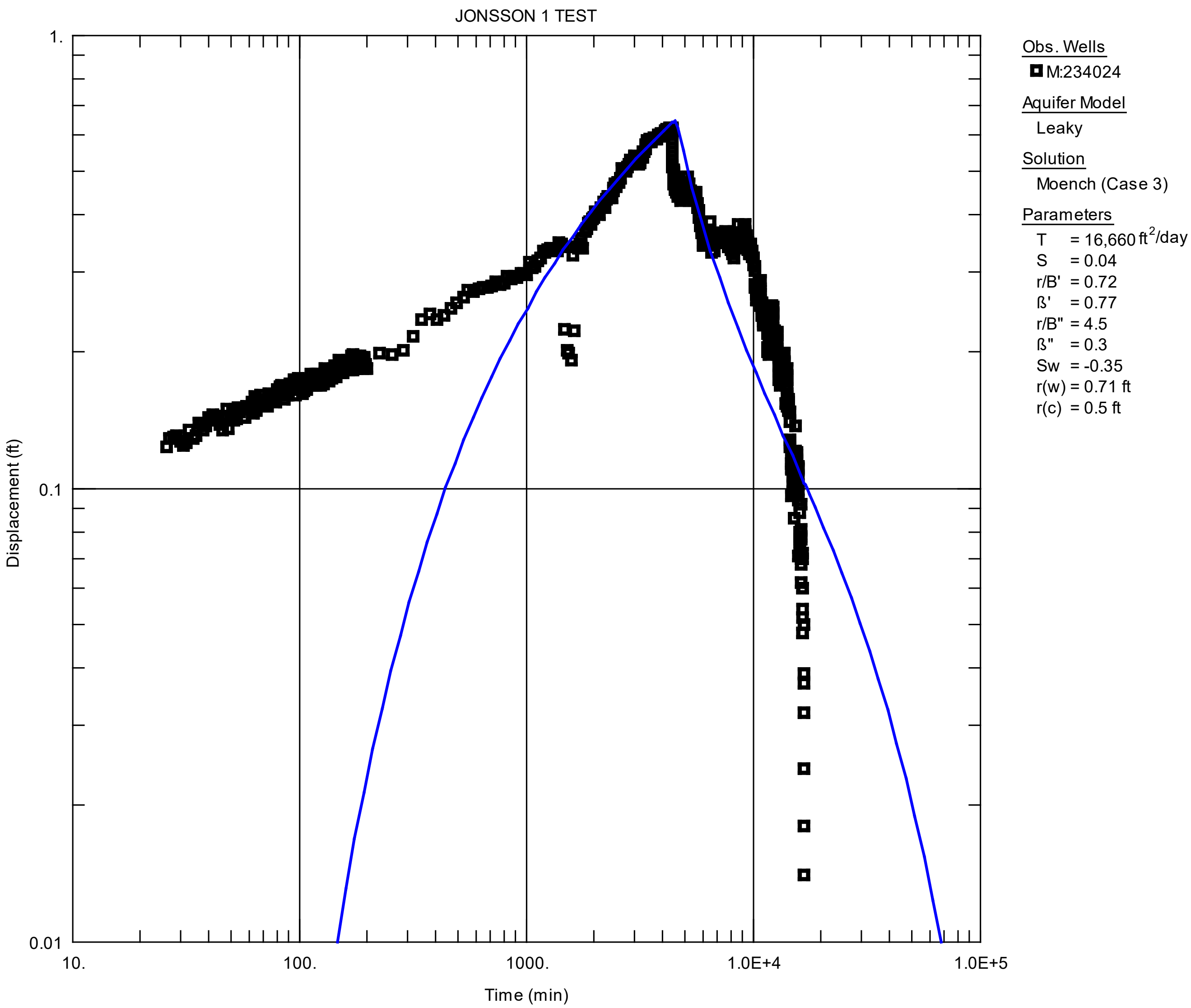

Figure A41. K. Jonsson 1 aquifer test showing Moench (Case 3) leaky confined aquifer solution.

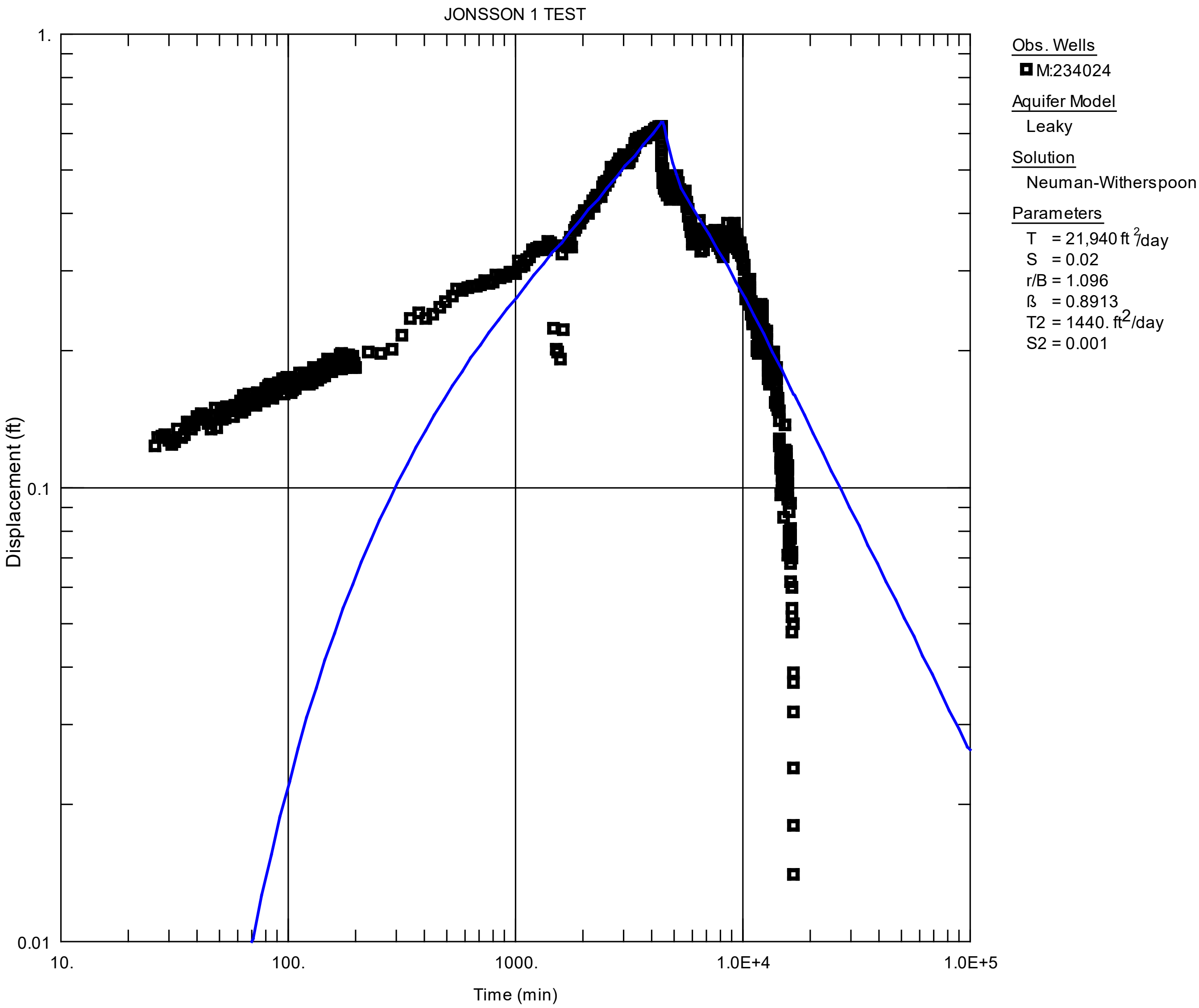

Figure A42. K. Jonsson 1 aquifer test showing Neuman–Witherspoon leaky confined aquifer solution.

WYMAN 1 (250211)

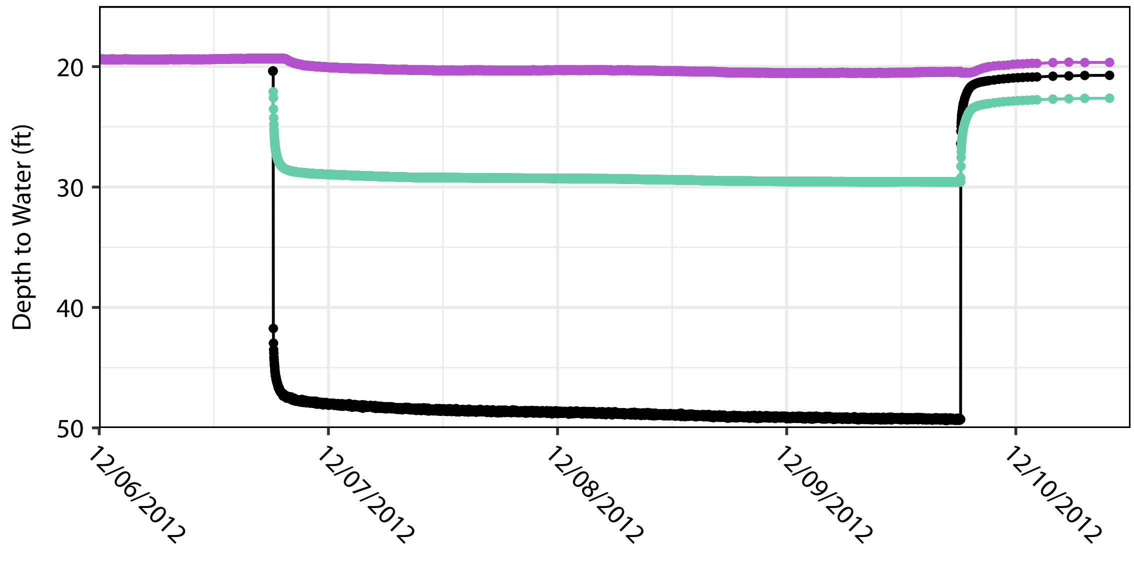

Figure A43. Wyman 1 aquifer test background through recovery water levels.

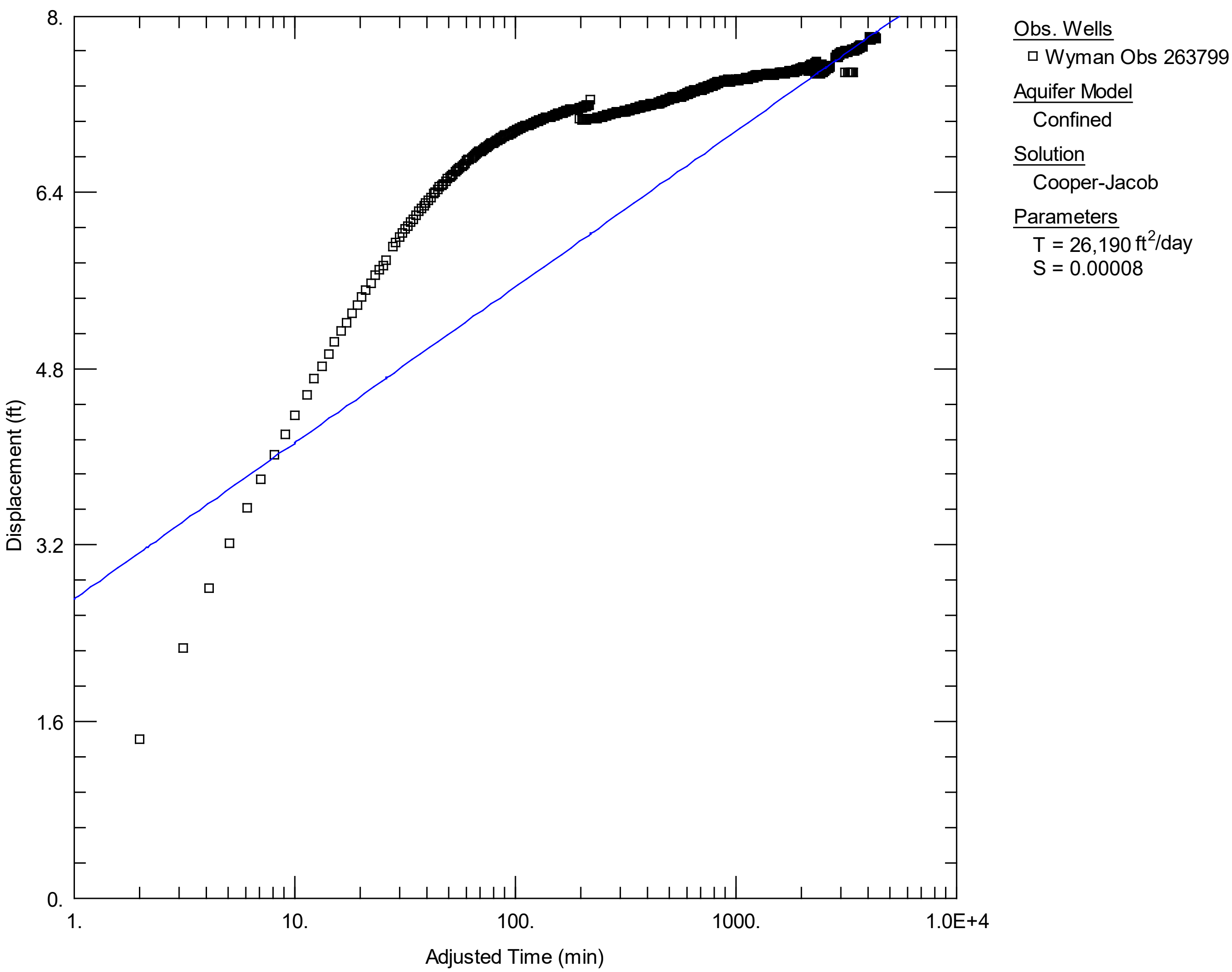

Figure A44. Wyman 1 aquifer test showing Cooper–Jacob confined aquifer solution.

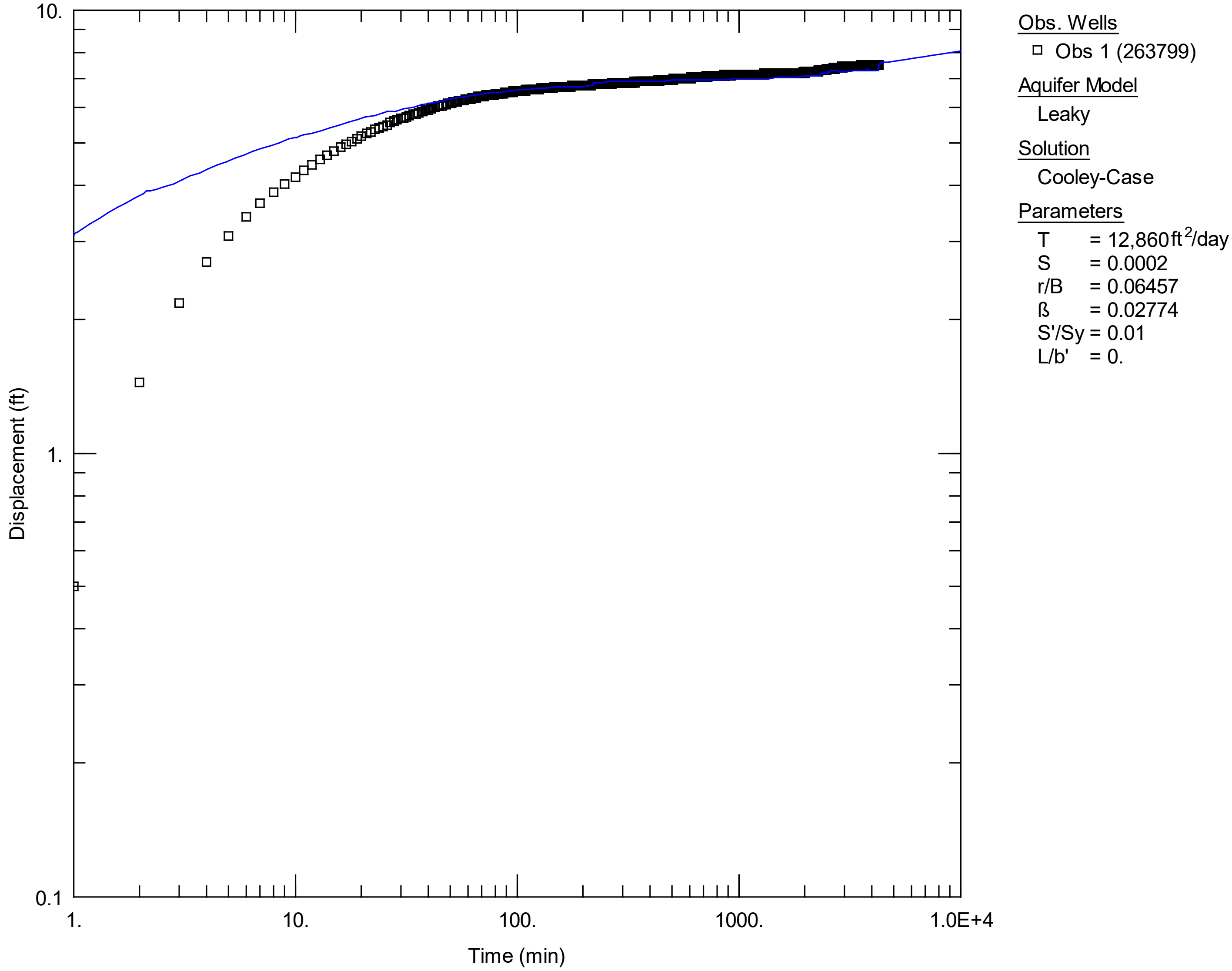

Figure A45. Wyman 1 aquifer test showing Cooley–Case leaky confined aquifer solution.

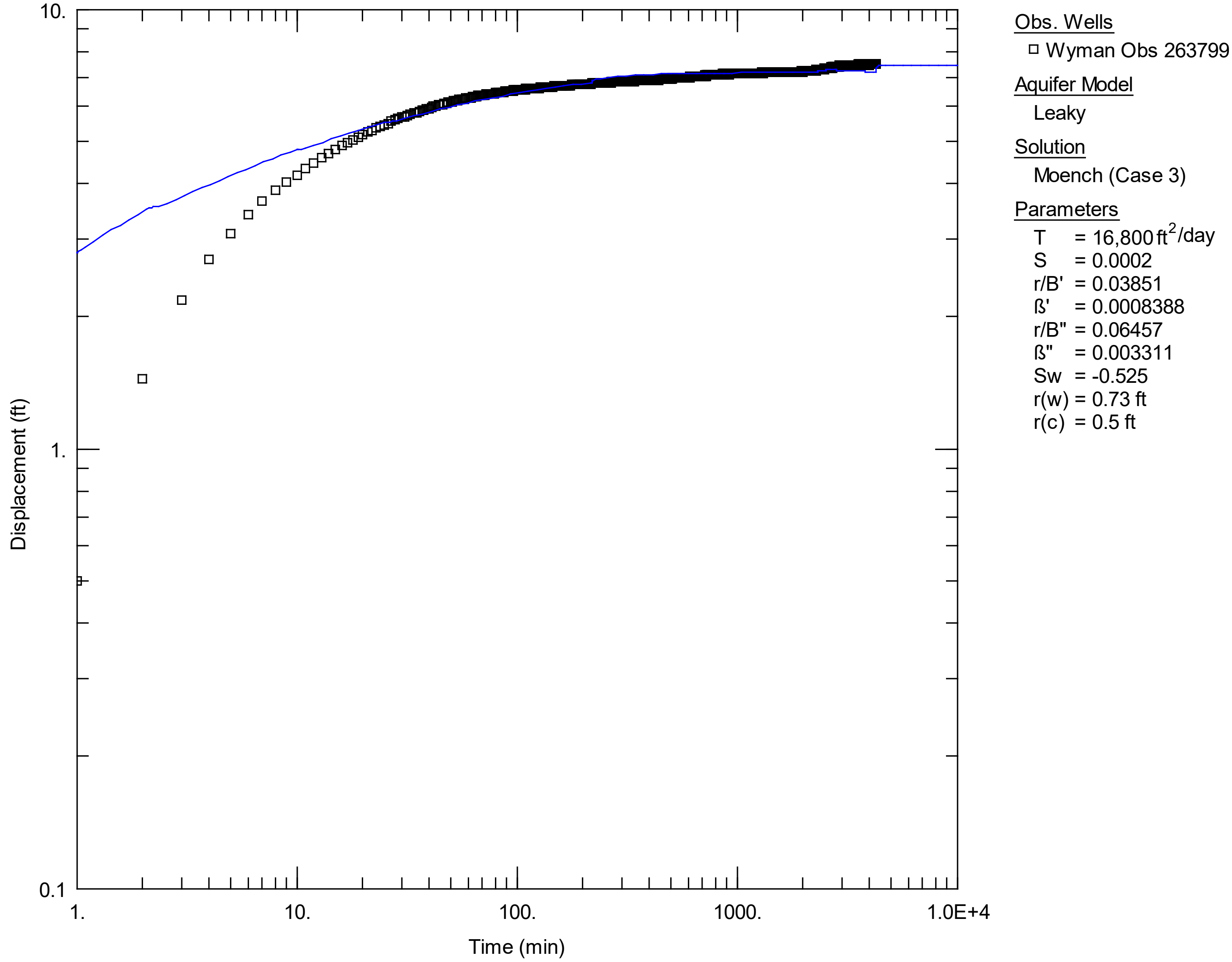

Figure A46. Wyman 1 aquifer test showing Moench (Case 3) leaky confined aquifer solution.

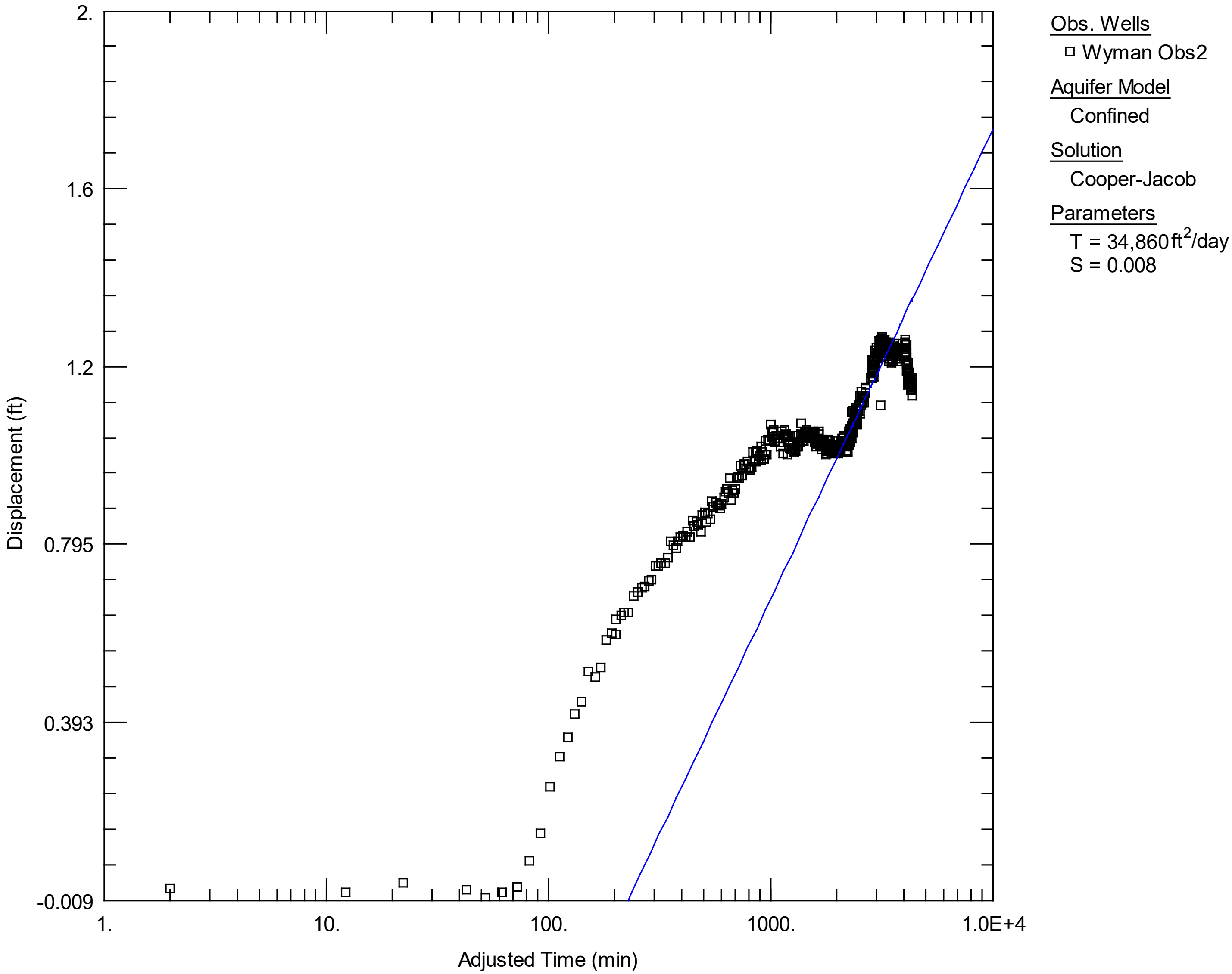

Figure A47. Wyman 1 aquifer test observation well 2 showing Cooper–Jacob confined aquifer solution.

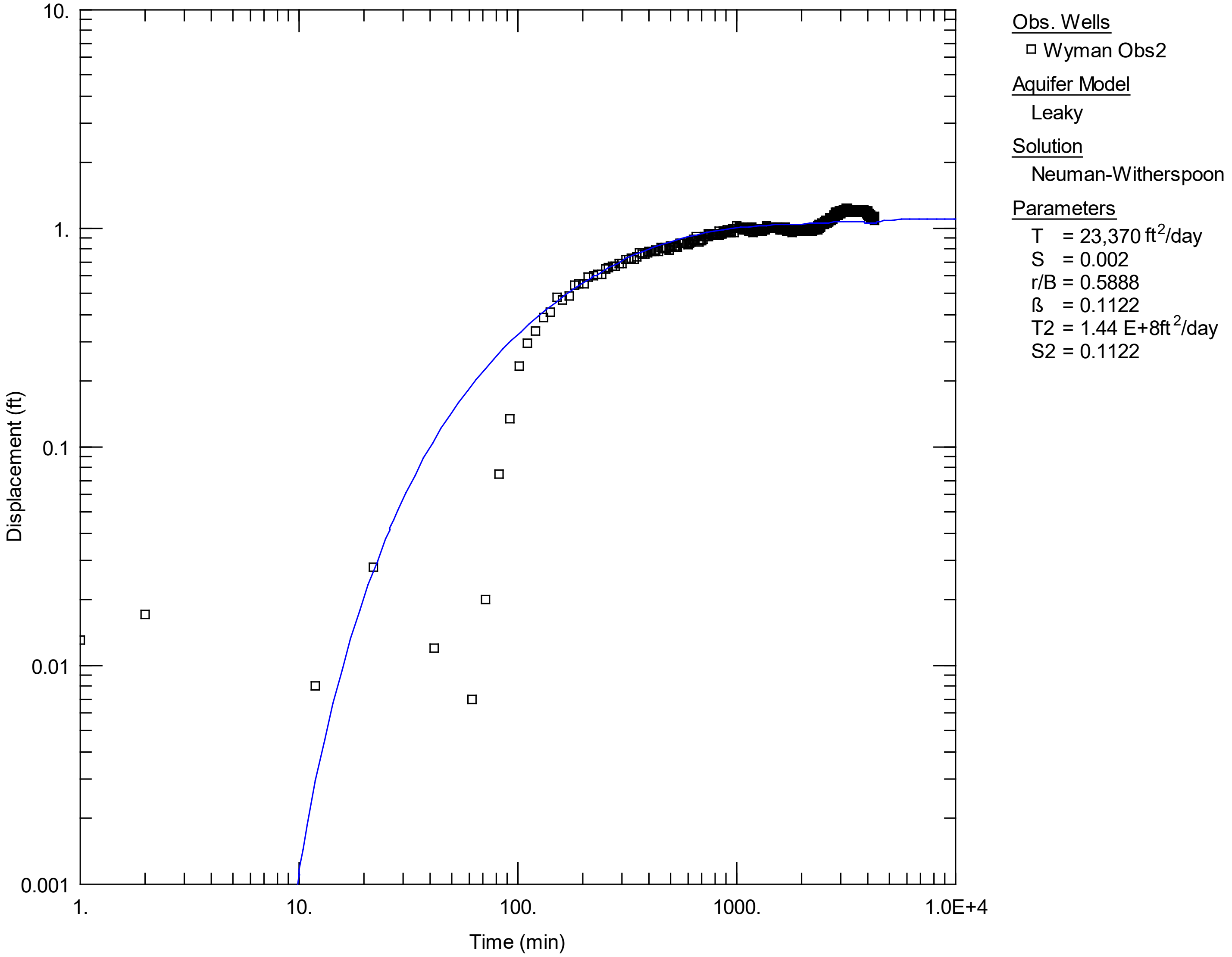

Figure A48. Wyman 1 aquifer test observation well 2 showing Neuman–Witherspoon leaky confined aquifer solution.

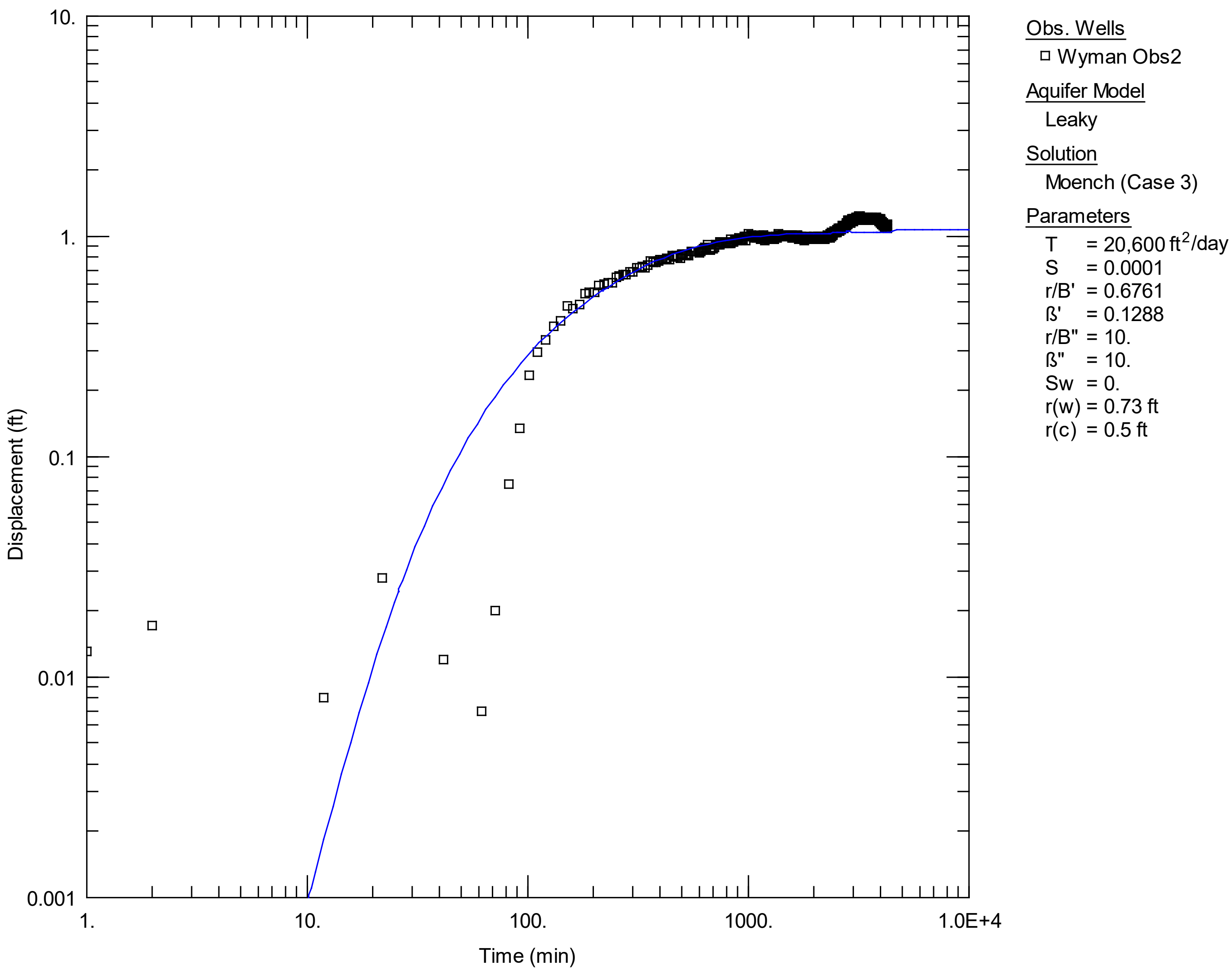

Figure A49. Wyman 1 aquifer test observation well 2 showing Moench (Case 3) leaky confined aquifer solution.

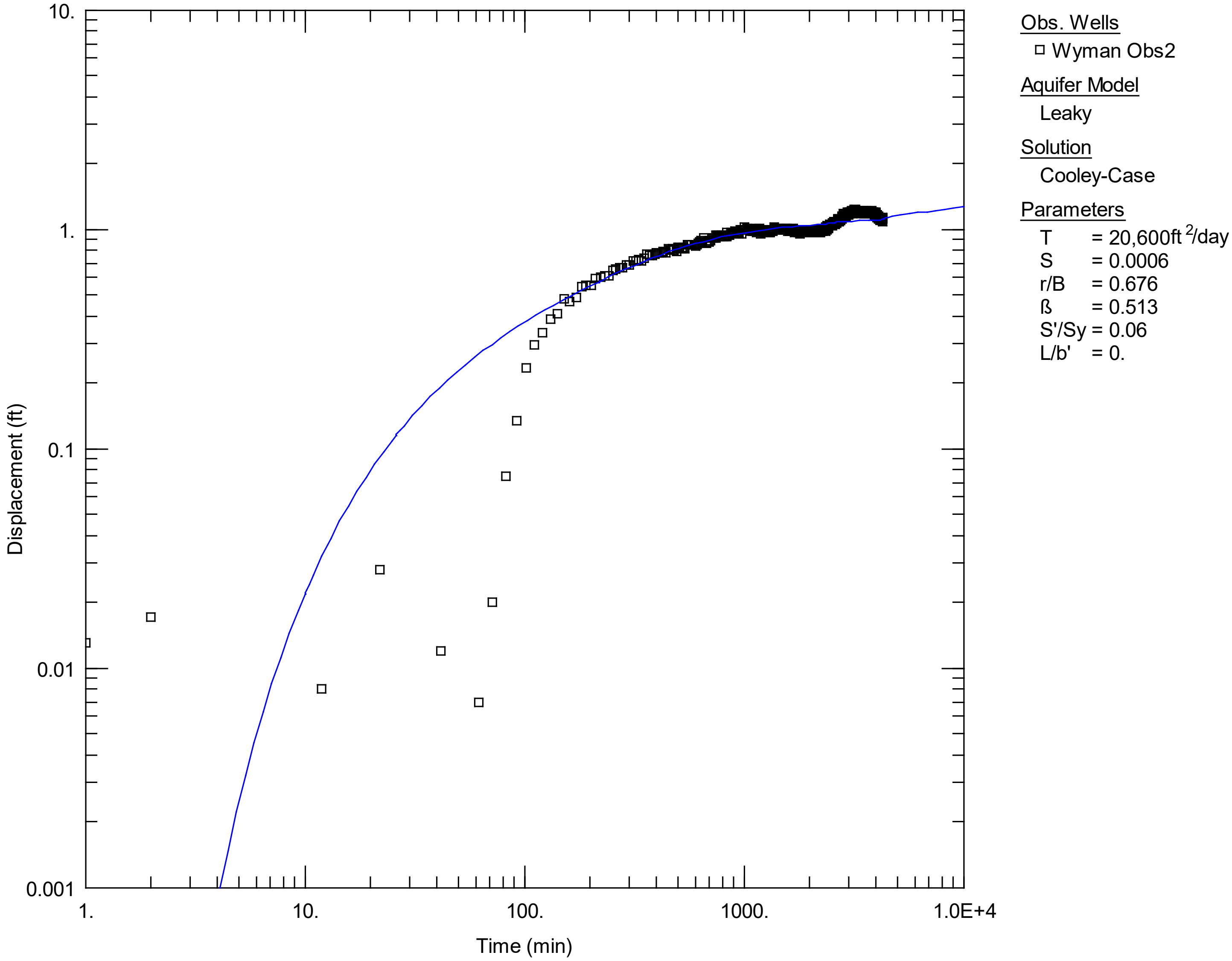

Figure A50. Wyman 1 aquifer test observation well 2 showing Cooley–Case leaky confined aquifer solution.

BRADLEY 1 (253448)

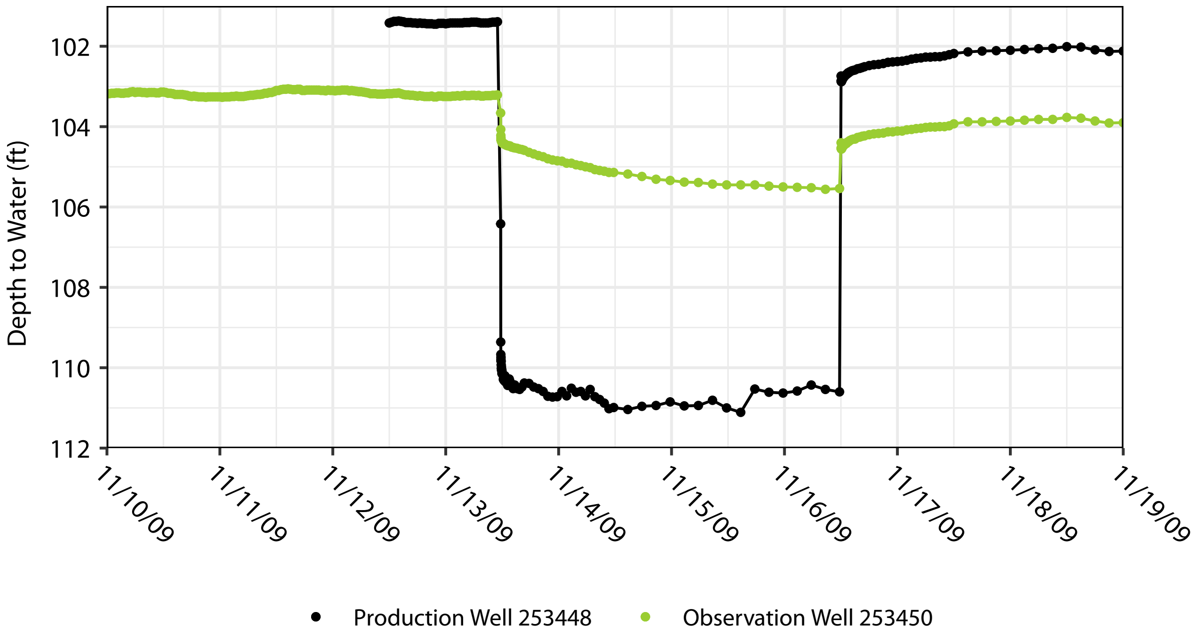

Figure A51. Bradley 1 aquifer test background through recovery water levels.

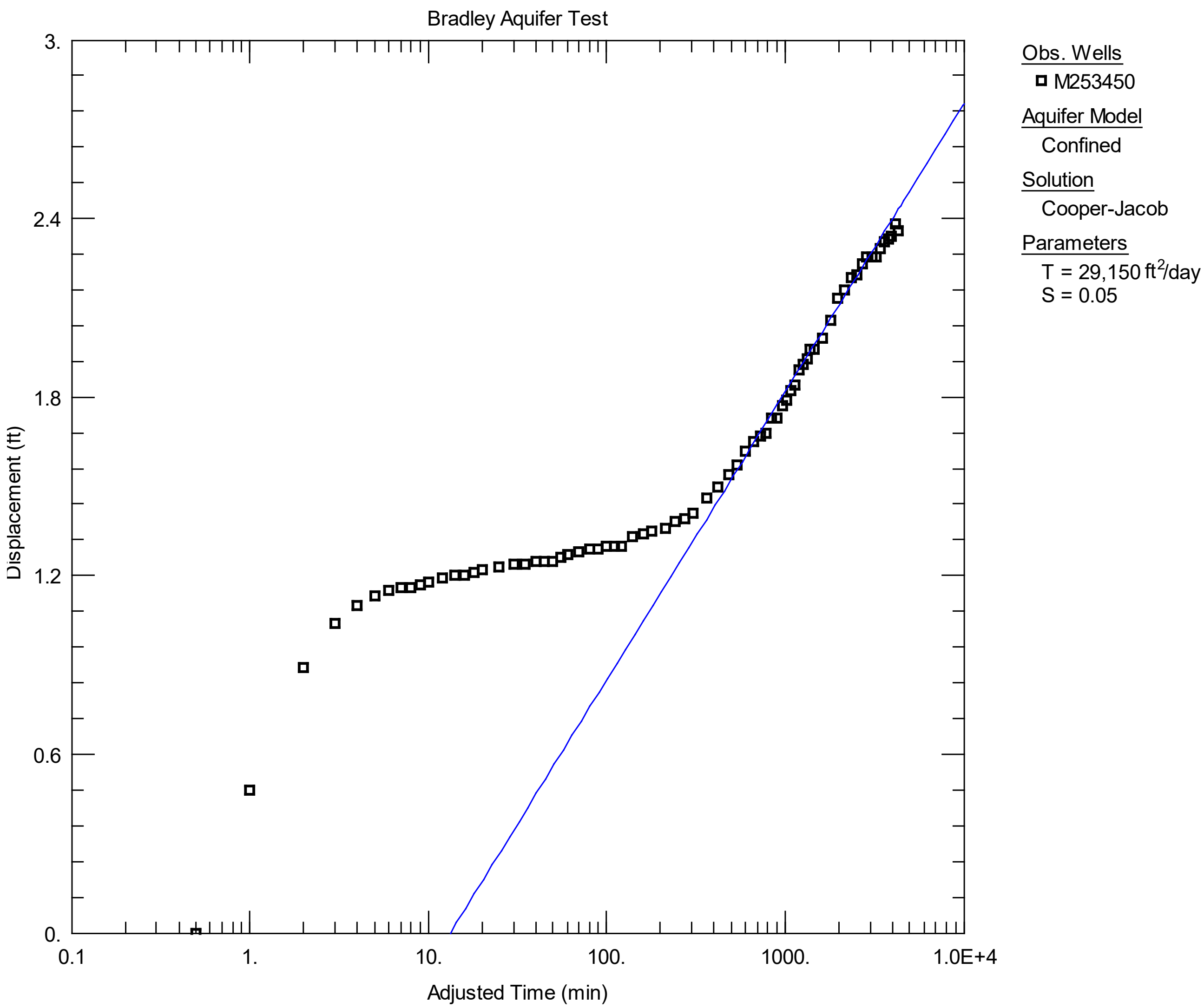

Figure A52. Bradley 1 aquifer test showing Cooper–Jacob confined aquifer solution.

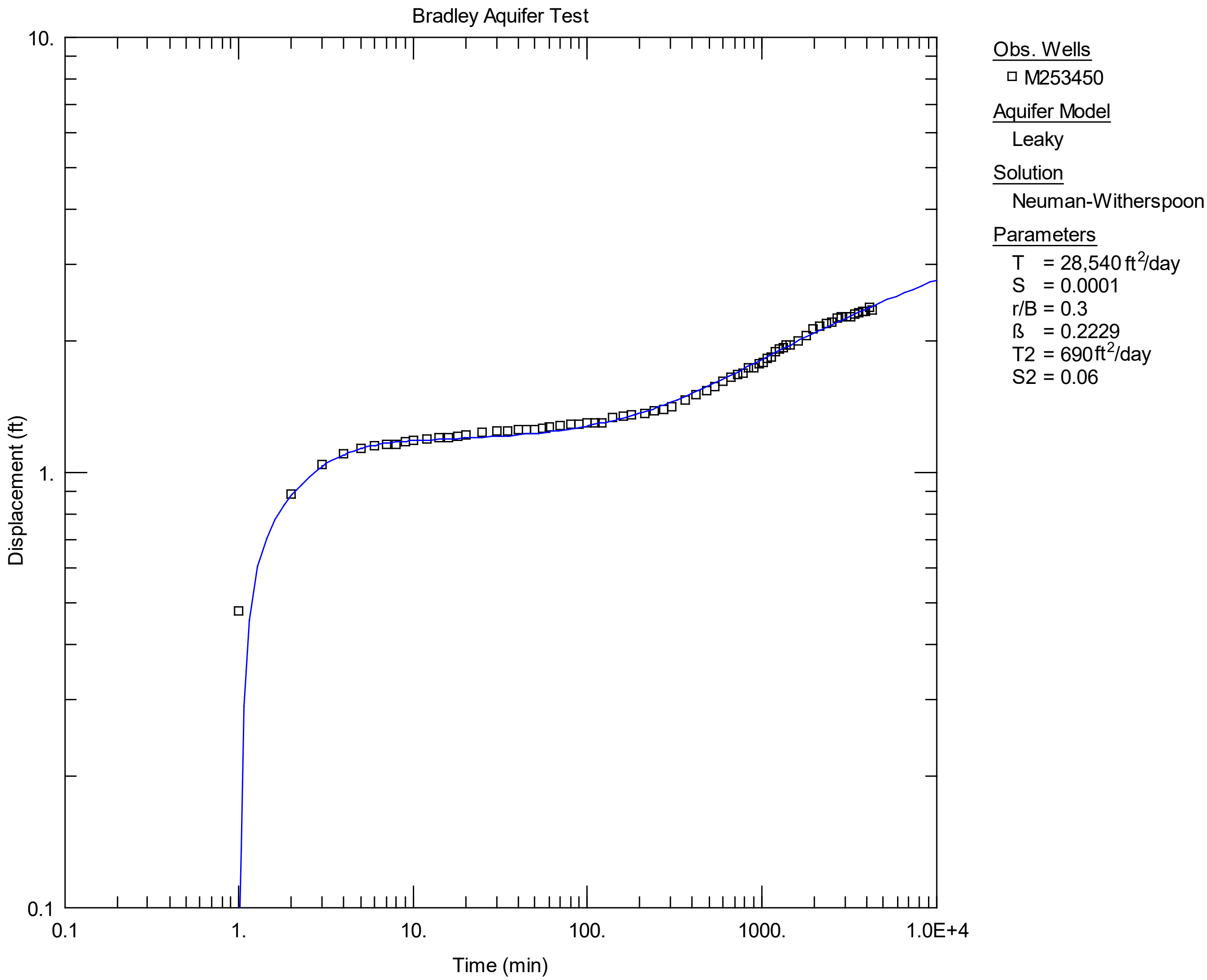

Figure A53. Bradley 1 aquifer test showing Neuman–Witherspoon leaky confined aquifer solution.

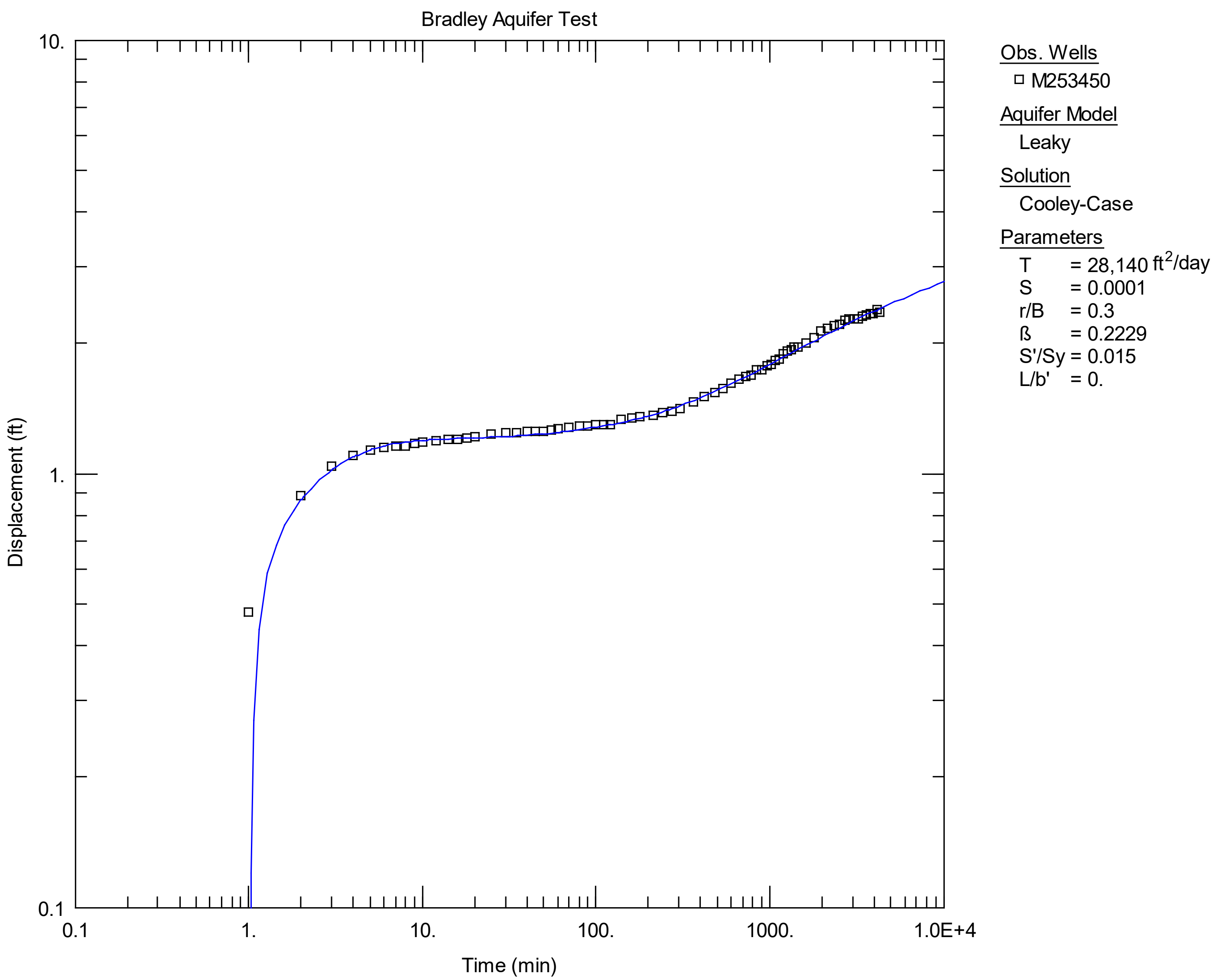

Figure A54. Bradley 1 aquifer test showing Cooley–Case leaky confined aquifer solution.

C. JOHNSON 1 (285659)

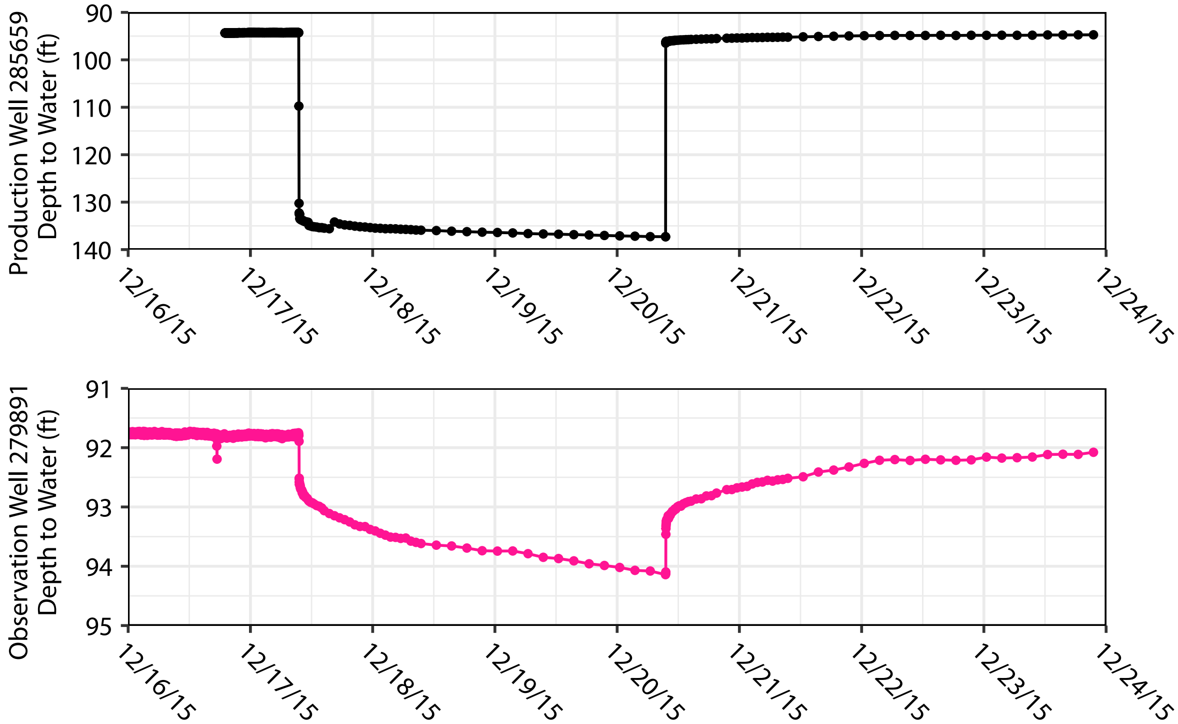

Figure A55. C. Johnson 1 aquifer test background through recovery water levels.

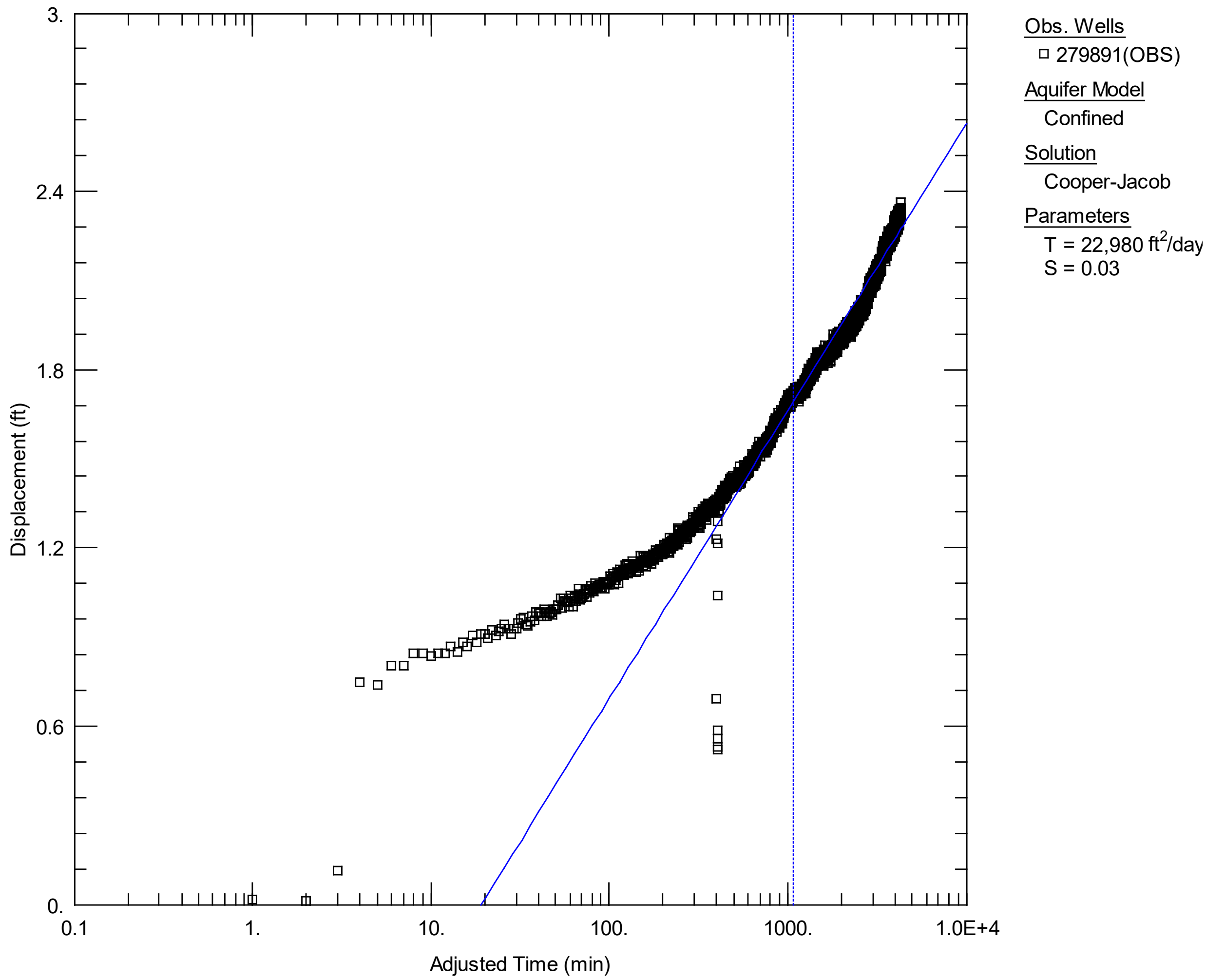

Figure A56. C. Johnson 1 aquifer test showing Cooper–Jacob confined aquifer solution.

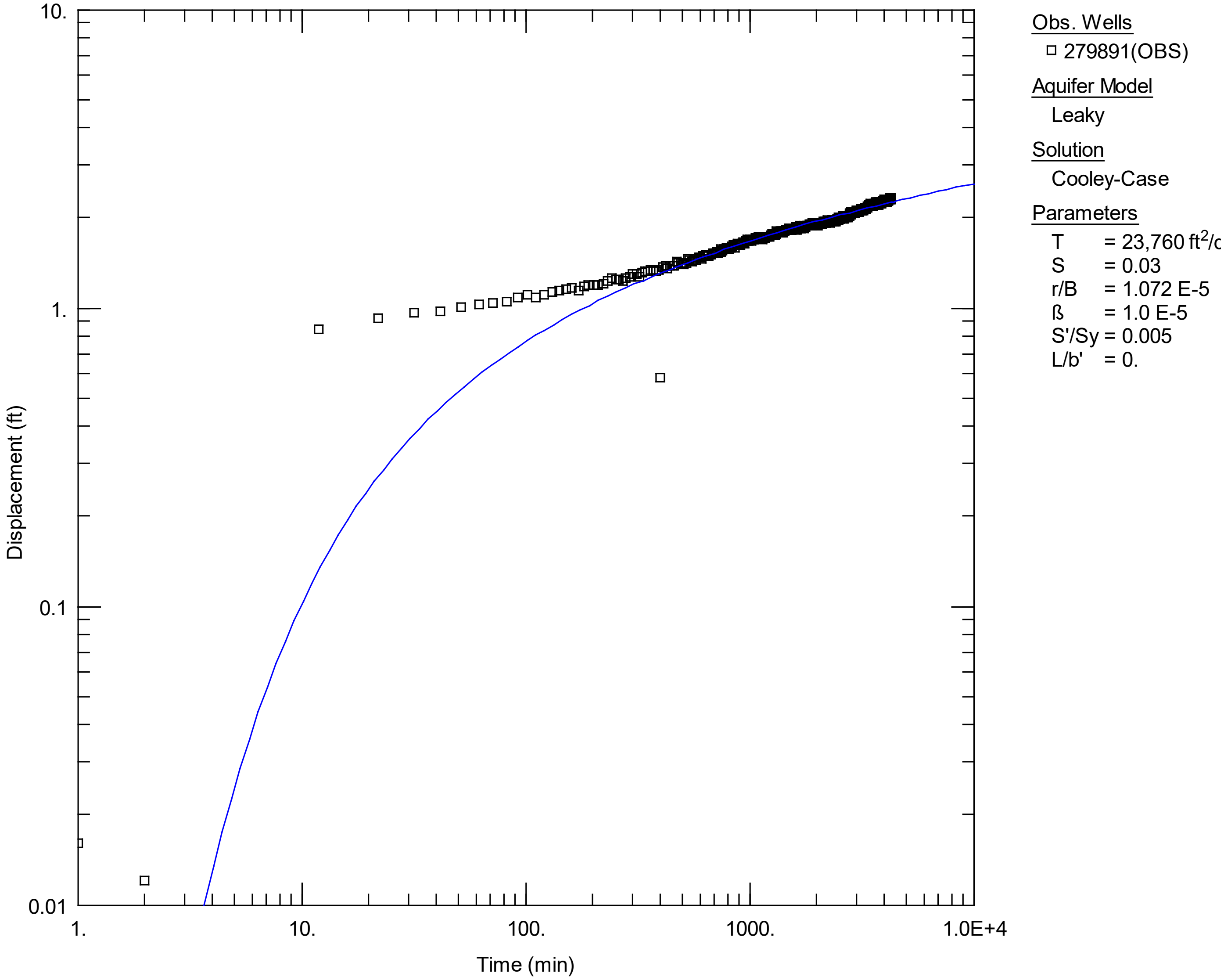

Figure A57. C. Johnson 1 aquifer test showing Cooley–Case leaky confined aquifer solution.

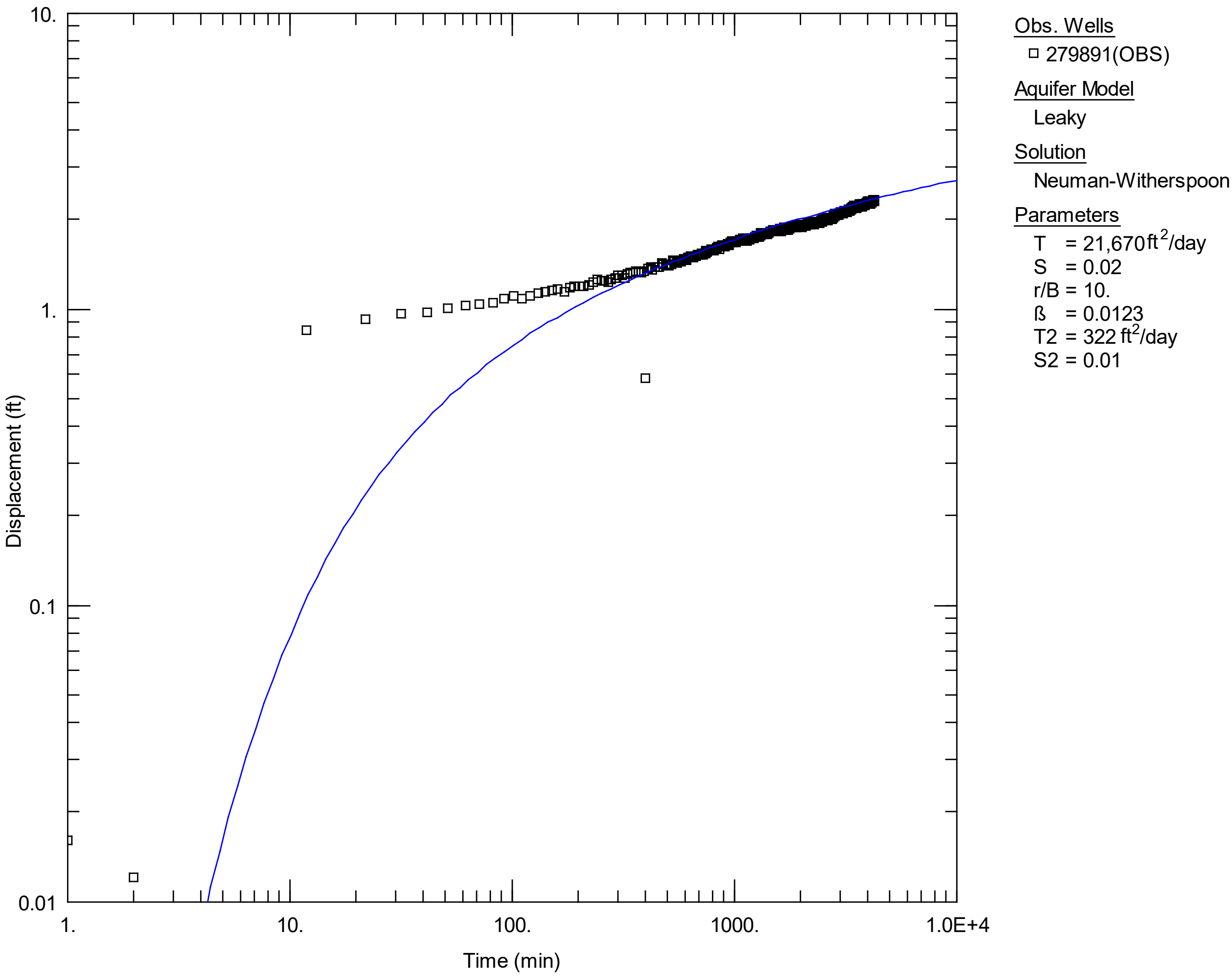

Figure A58. C. Johnson 1 aquifer test showing Neuman–Witherspoon leaky confined aquifer solution.

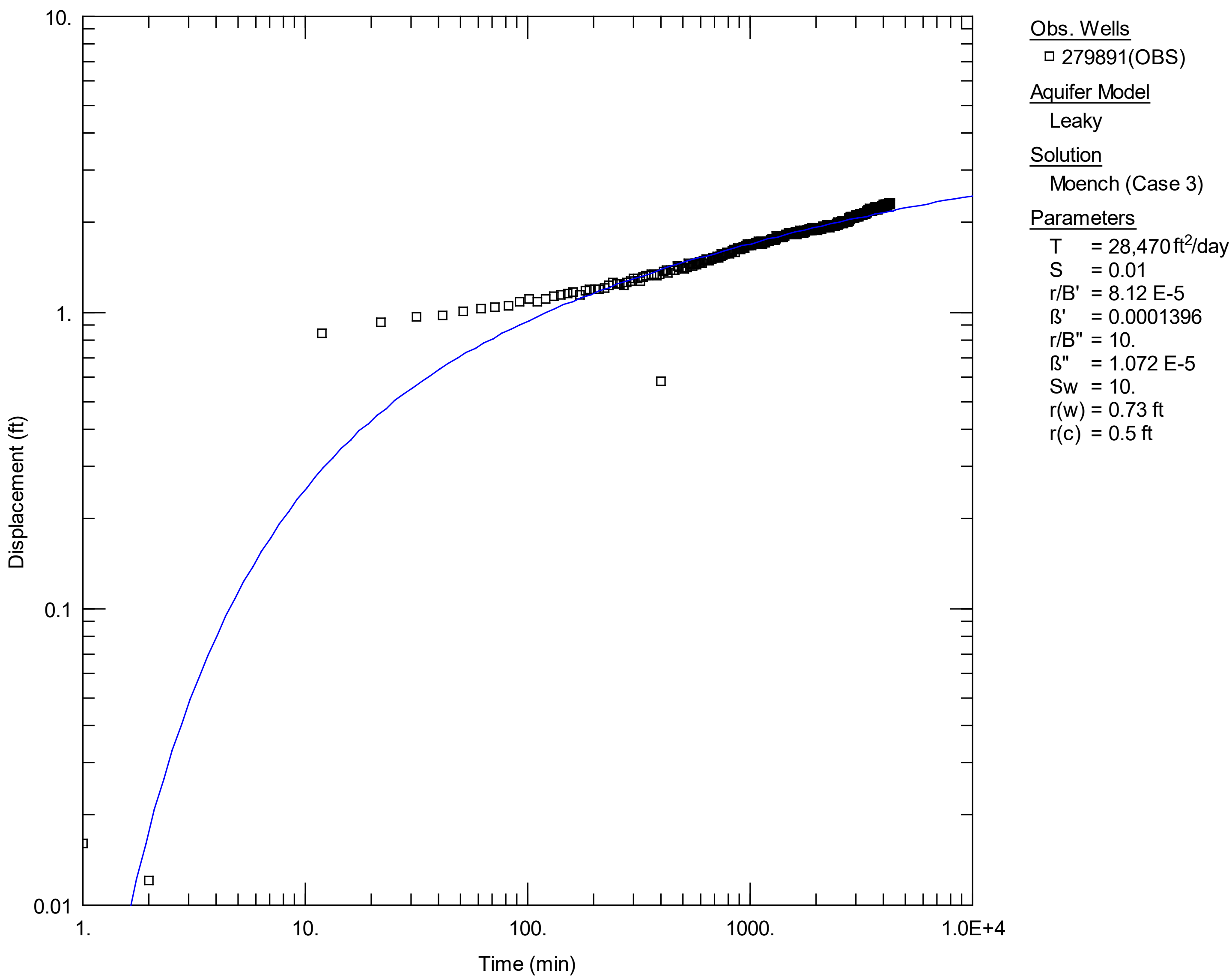

Figure A59. C. Johnson 1 aquifer test showing Moench (Case 3) leaky confined aquifer solution.

C. JOHNSON 3 (291010)

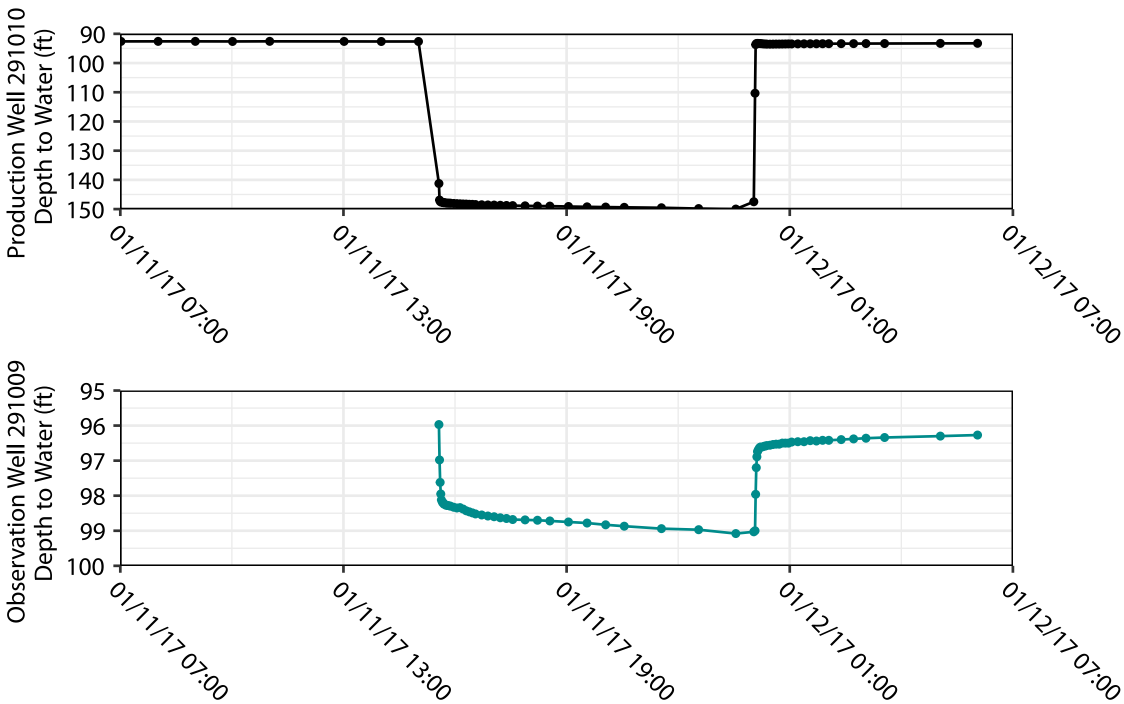

Figure A60. C. Johnson 3 aquifer test background through recovery water levels.

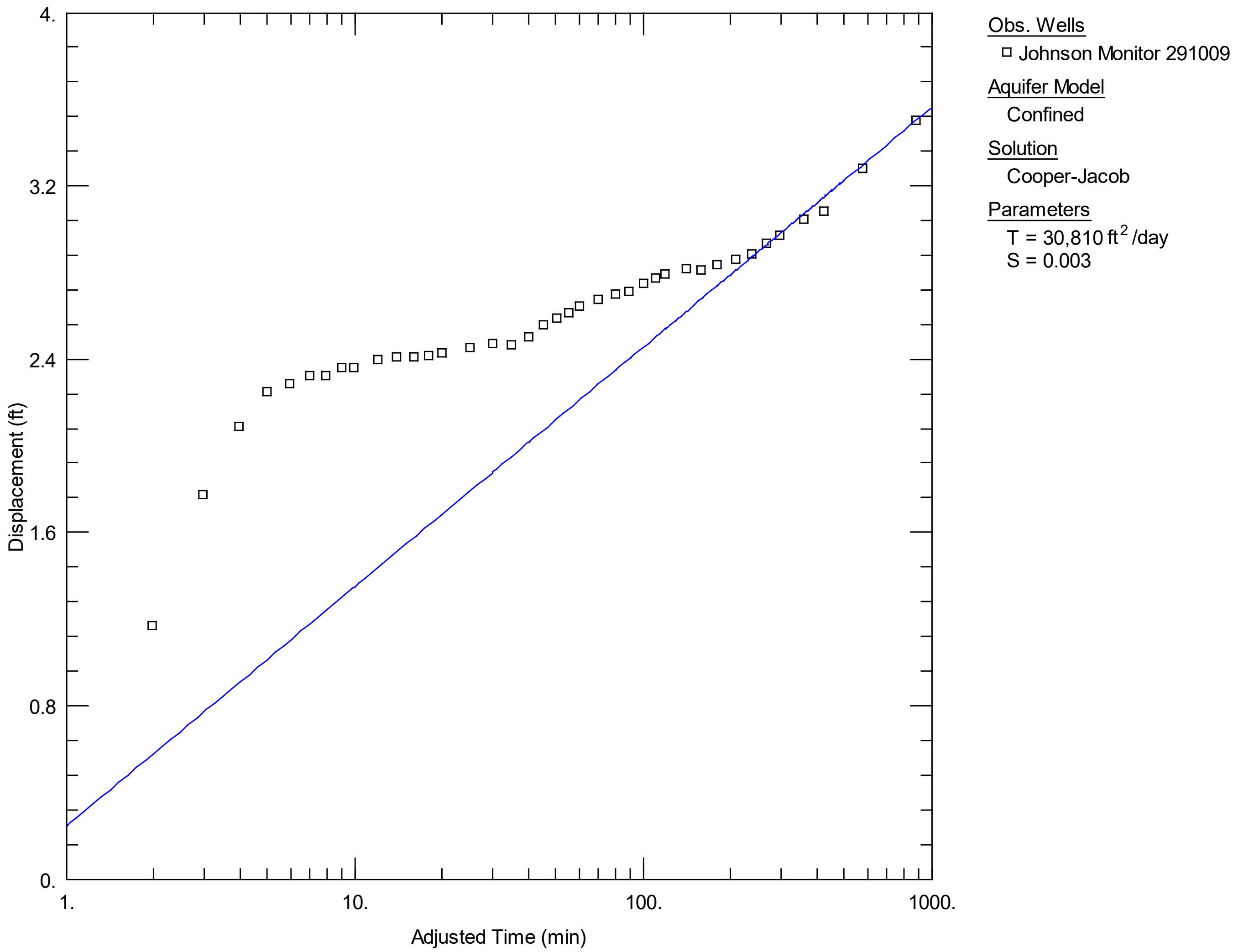

Figure A61. C. Johnson 3 aquifer test showing Cooper–Jacob confined aquifer solution.

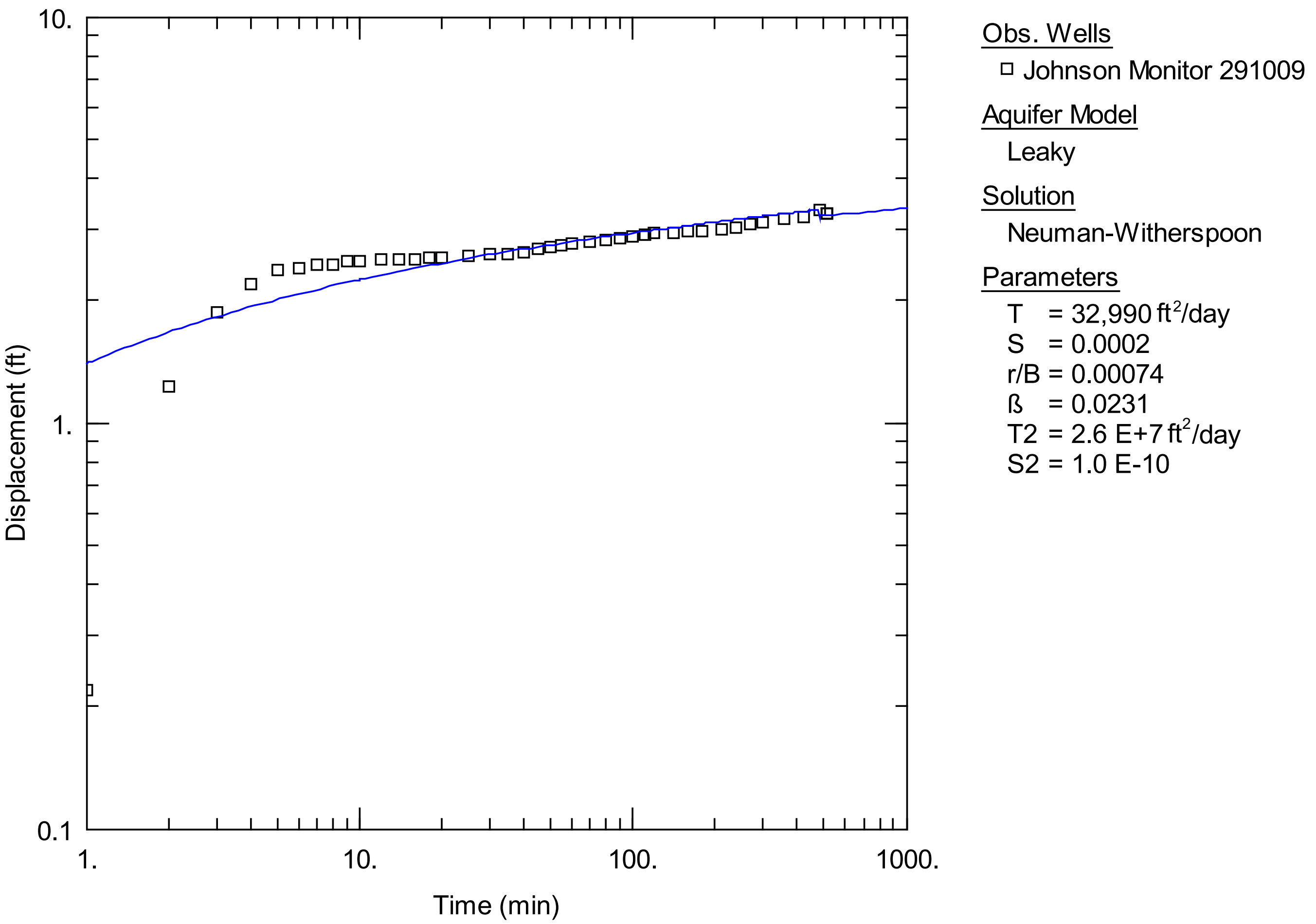

Figure A62. C. Johnson 3 aquifer test showing Neuman–Witherspoon leaky confined aquifer solution.

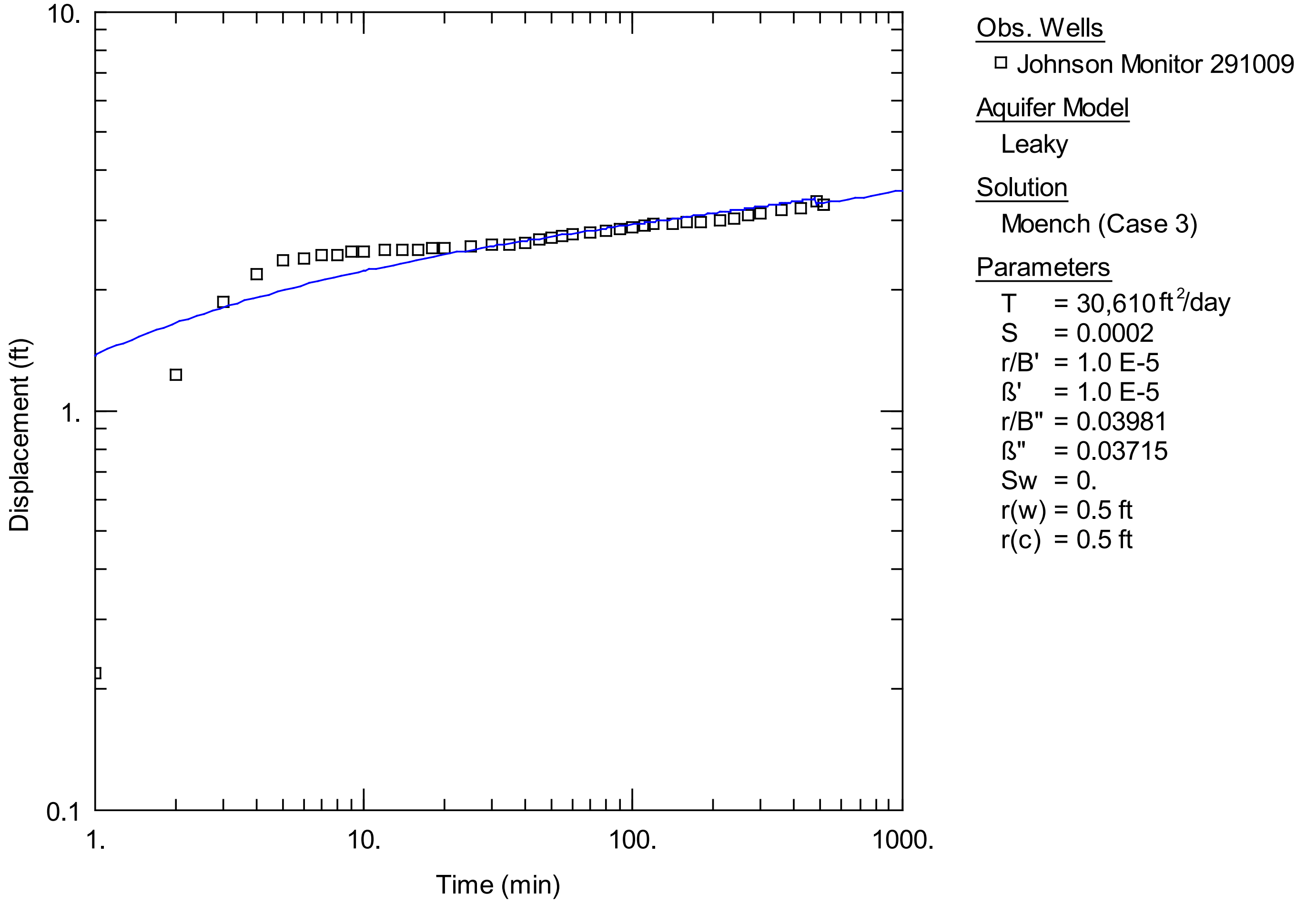

Figure A63. C. Johnson 3 aquifer test showing Moench (Case 3) leaky confined aquifer solution.

C. JOHNSON 2 (285476)

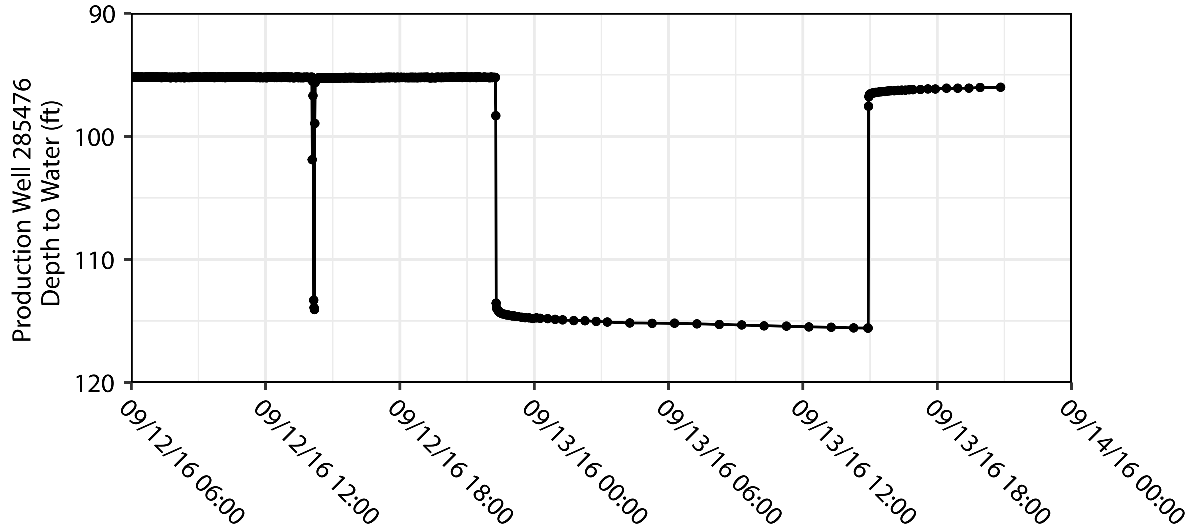

Figure A64. C. Johnson 2 aquifer test background through recovery water levels.

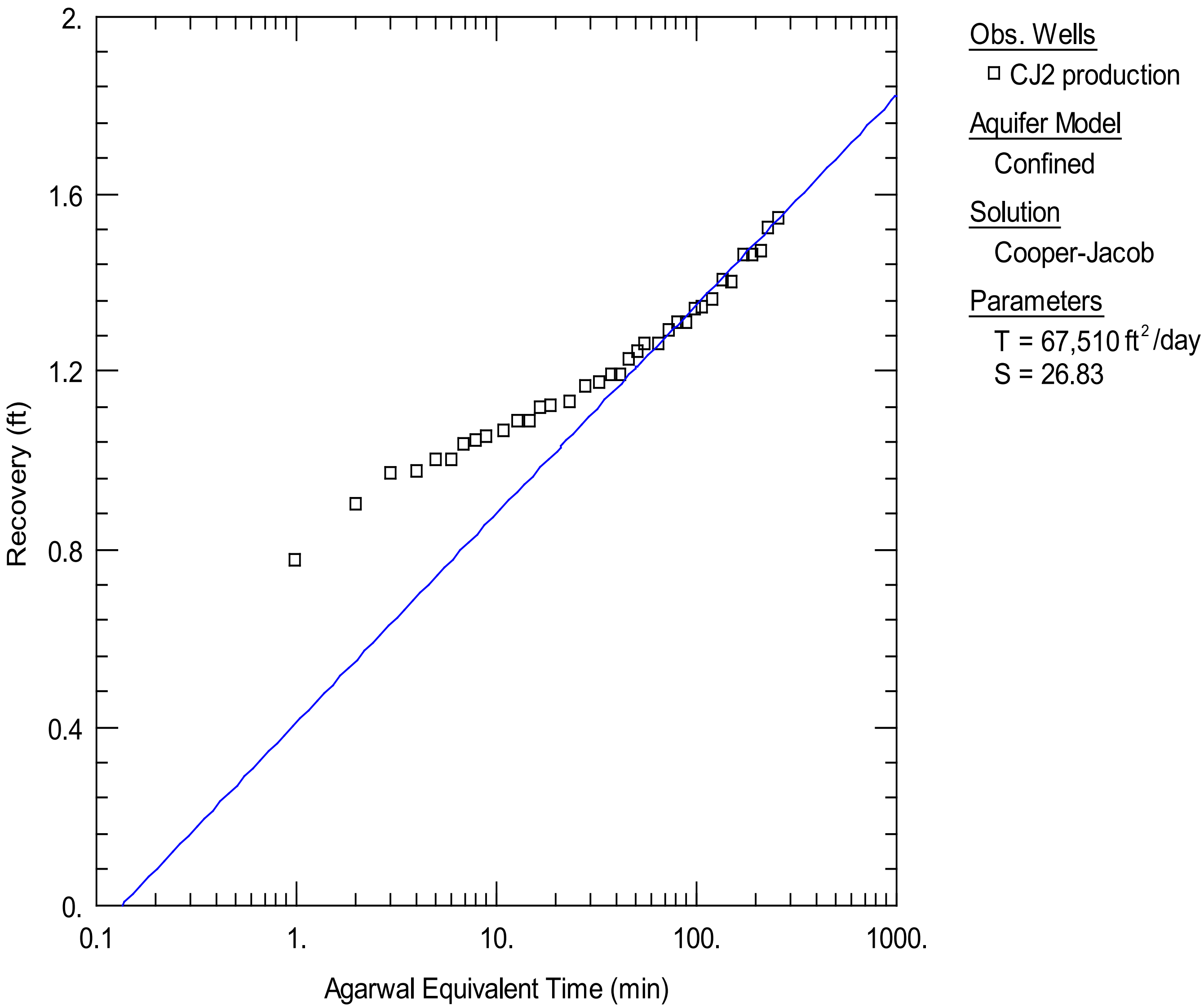

Figure A65. C. Johnson 2 aquifer test showing Cooper–Jacob confined aquifer recovery solution.

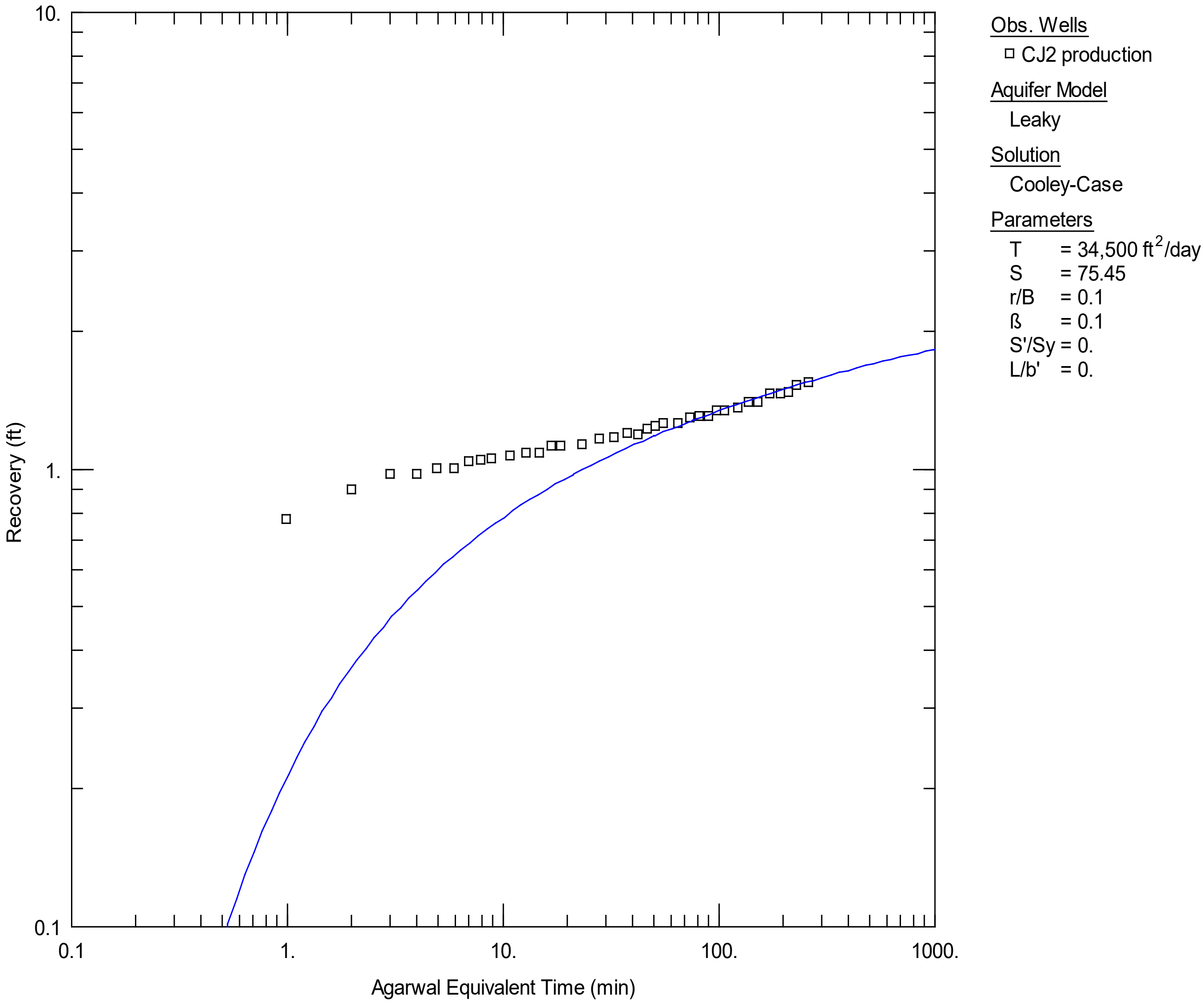

Figure A66. C. Johnson 2 aquifer test showing Cooley–Case leaky confined aquifer recovery solution.

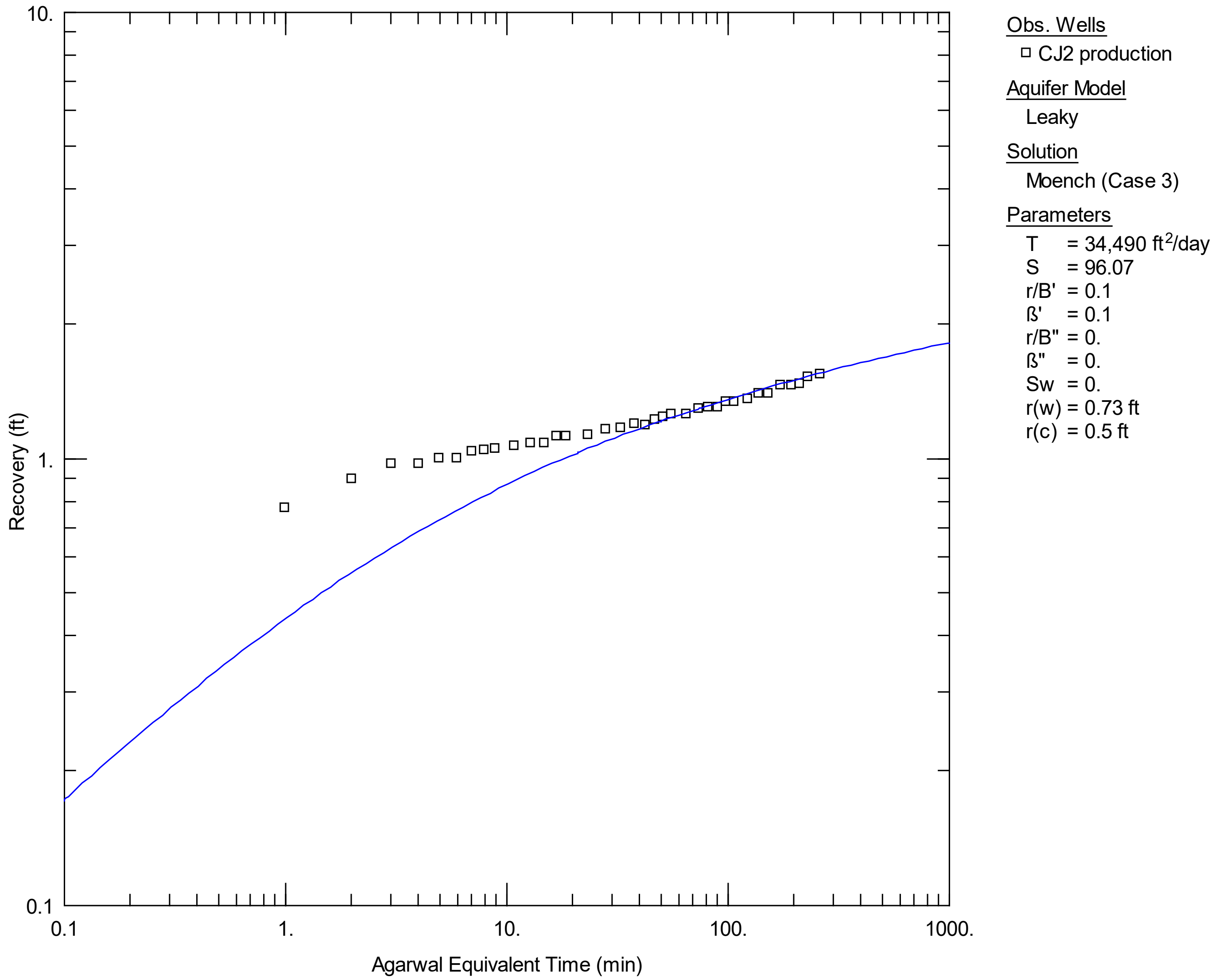

Figure A67. C. Johnson 2 aquifer test showing Moench Case 3 leaky confined aquifer recovery solution.