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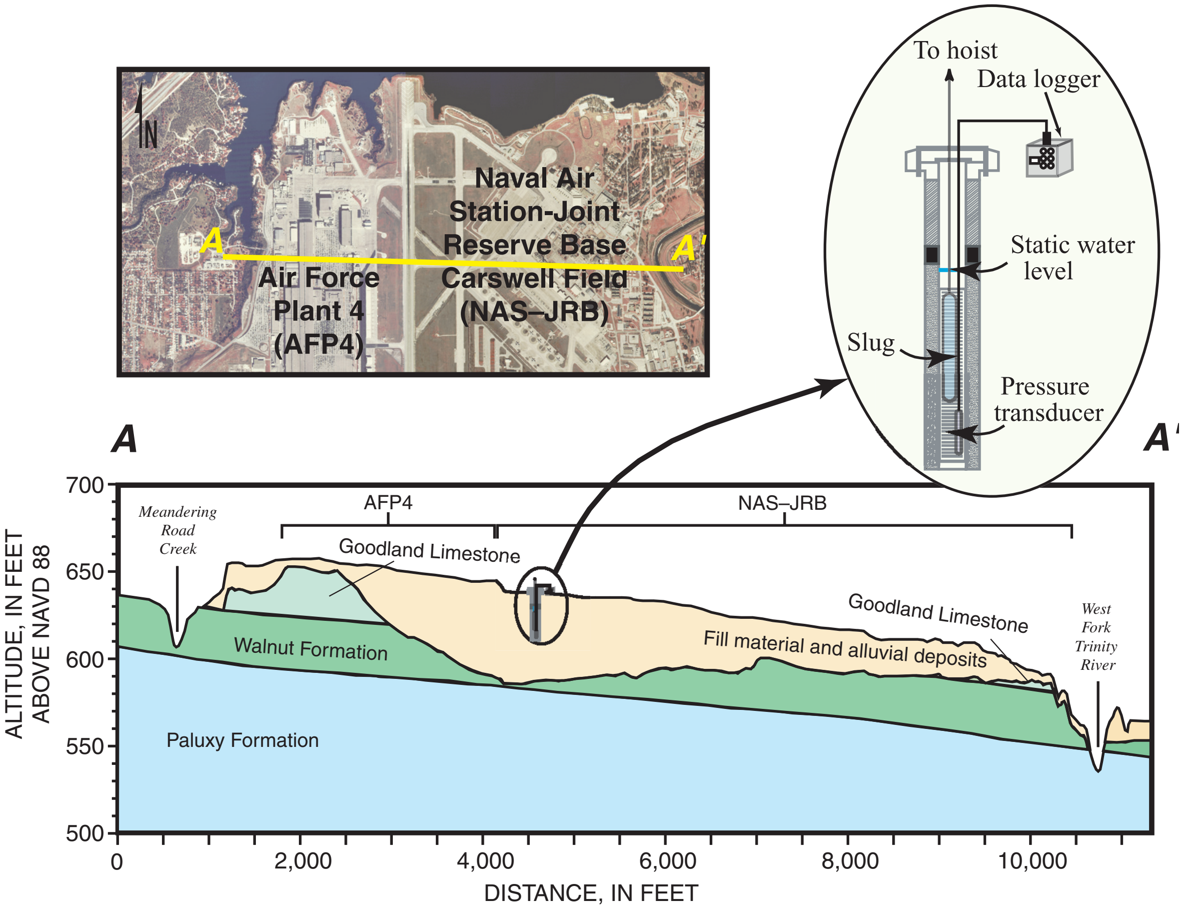
Analyses and Estimates of Hydraulic Conductivity From Slug Tests in Alluvial Aquifer Underlying Air Force Plant 4 and Naval Air Station-Joint Reserve Base Carswell Field, Fort Worth, Texas



Scientific Investigations Report 2004–5225

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By Natalie A. Houston and Christopher L. Braun

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Analyses and Estimates of Hydraulic Conductivity From Slug Tests in Alluvial Aquifer Underlying Air Force Plant 4 and Naval Air Station-Joint Reserve Base Carswell Field, Fort Worth, Texas

By Natalie A. Houston and Christopher L. Braun

Abstract

This report describes the collection, analyses, and distribution of hydraulic-conductivity data obtained from slug tests completed in the alluvial aquifer underlying Air Force Plant 4 and Naval Air Station-Joint Reserve Base Carswell Field, Fort Worth, Texas, during October 2002 and August 2003 and summarizes previously available hydraulic-conductivity data. The U.S. Geological Survey, in cooperation with the U.S. Air Force, completed 30 slug tests in October 2002 and August 2003 to obtain estimates of horizontal hydraulic conductivity to use as initial values in a ground-water-flow model for the site. The tests were done by placing a polyvinyl-chloride slug of known volume beneath the water level in selected wells, removing the slug, and measuring the resulting water-level recovery over time. The water levels were measured with a pressure transducer and recorded with a data logger. Hydraulic-conductivity values were estimated from an analytical relation between the instantaneous displacement of water in a well bore and the resulting rate of head change. Although nearly two-thirds of the tested wells recovered 90 percent of their slug-induced head change in less than 2 minutes, 90-percent recovery times ranged from 3 seconds to 35 minutes. The estimates of hydraulic conductivity range from 0.2 to 200 feet per day. Eighty-three percent of the estimates are between 1 and 100 feet per day.

Introduction

Air Force Plant 4 (AFP4) in Fort Worth, Tex. (fig. 1), was completed in 1942 and used to build military aircraft during World War II. Subsequently, this government-owned, contractor-operated facility was used to manufacture radar units, missile components, and spare parts, in addition to aircraft. Naval Air Station-Joint Reserve Base Carswell Field (NAS–JRB) (fig. 1), adjacent to AFP4, opened as Tarrant Field Airdrome in June 1942, when it was used for flight training and aircraft operations. It now serves as a base and training facility for the U.S. Navy and Marines and reserve forces of the U.S. Air Force and Army.

Manufacturing at AFP4 required various solvents, paints, metals, oils, fuels, and other toxic chemicals; the associated wastes—trichloroethene (TCE) among them—were dumped into on-site landfills during most of the plant's history (Environmental Science and Engineering, Inc., 1994). Ground water containing TCE is known to have leaked downward from the alluvial aquifer into the Paluxy aquifer in at least two areas (Kuniansky and Hamrick, 1998, p. 2). TCE has entered the uppermost ("upper sand") interval of the Paluxy aquifer beneath parts of the east parking lot of AFP4 and flight line of NAS–JRB (pl. 1); and lesser amounts of TCE have reached parts of the upper and middle zones of the Paluxy aquifer on the west side of AFP4 between landfill 3 (west of Bomber Road) and former landfill 1 (now covered by the west parking lot).

The U.S. Geological Survey (USGS), in cooperation with the U.S. Air Force, is studying the hydrogeology beneath AFP4 and NAS–JRB to better understand the ground-water-flow system, particularly as it relates to the subsurface movement of contaminants, including TCE. As a precursor to constructing a ground-water-flow model for the site, the USGS did a series of slug tests to obtain initial estimates of horizontal hydraulic conductivity for use in the model. This report describes the collection, analyses, and distribution of hydraulic-conductivity data obtained from slug tests completed at AFP4 and NAS–JRB during October 2002 and August 2003. Of 30 completed tests, three were done on wells at AFP4 and 27 were done on wells at NAS–JRB. The report also summarizes graphically and in tabular form the results of available aquifer and slug tests done at AFP4 and NAS–JRB, primarily by consultants to the U.S. Air Force, before 2002.

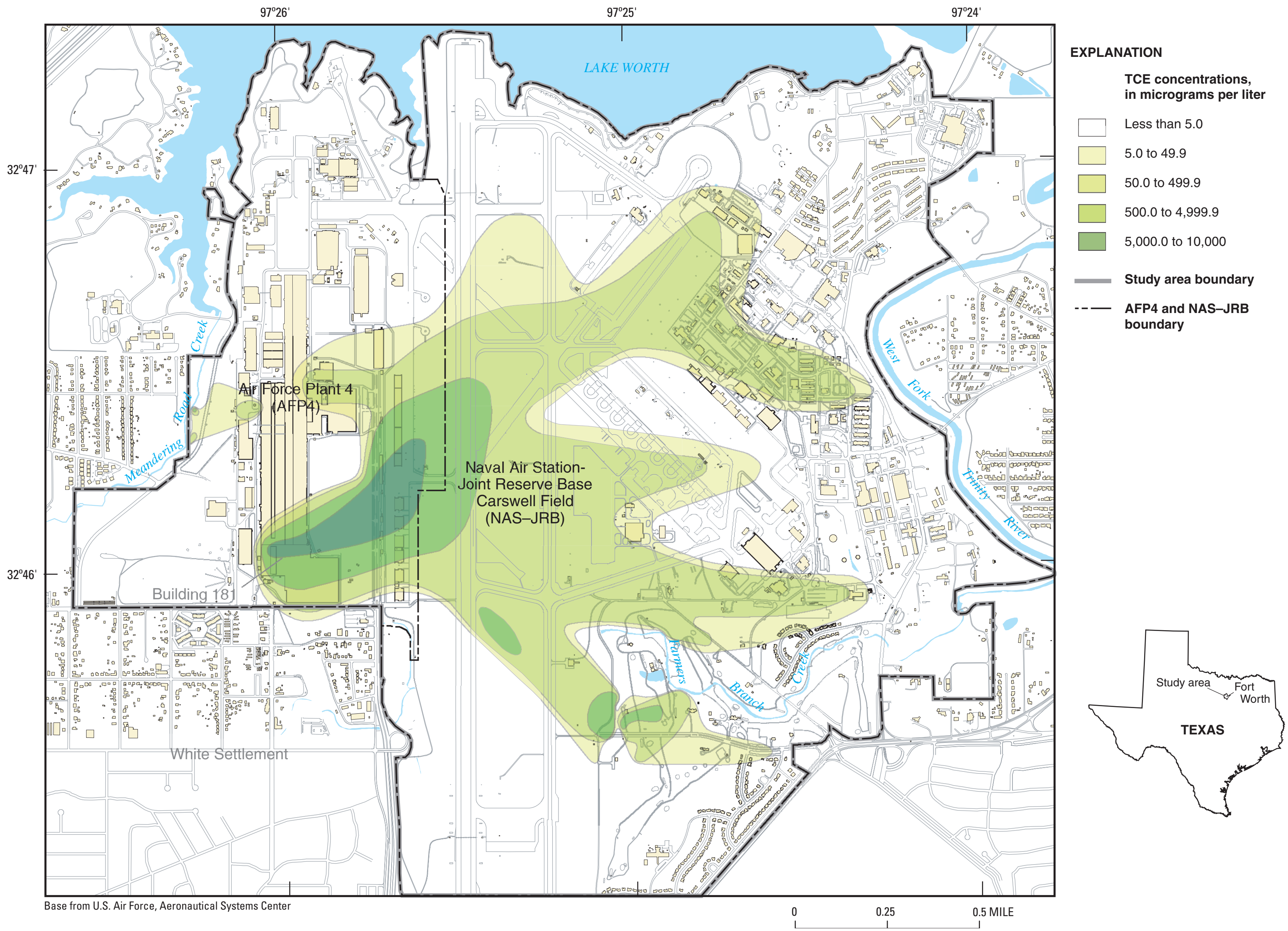


Figure 1. Location of study area and distribution of trichloroethene (TCE) plume in alluvial aquifer underlying Air Force Plant 4 (AFP4) and Naval Air Station-Joint Reserve Base Carswell Field (NAS–JRB), Fort Worth, Texas, August 2003.

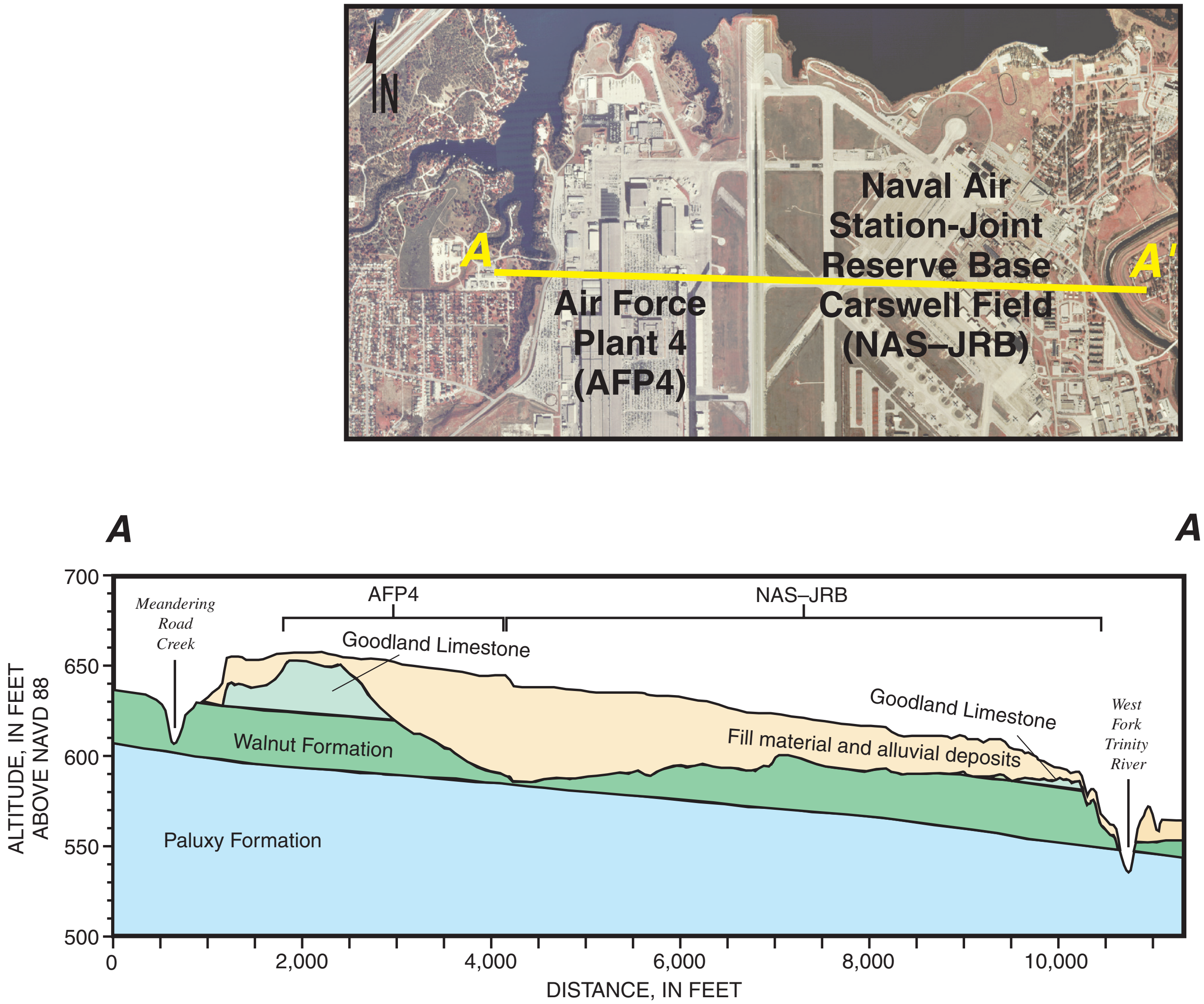


Figure 2. Generalized west-to-east hydrogeologic section through study area, Air Force Plant 4 (AFP4) and Naval Air Station-Joint Reserve Base Carswell Field (NAS–JRB), Fort Worth, Texas.

Study Area

The study area is in northwest Fort Worth, Tex. The area is drained primarily by the West Fork Trinity River (pl. 1; fig. 1). Farmers Branch and Meandering Road Creeks are small, intermittent tributaries to the West Fork Trinity River that locally drain AFP4 and NAS–JRB.

The study area includes AFP4 and NAS–JRB south of the southwestern shoreline of Lake Worth. AFP4 is bounded on the east by NAS–JRB and on the west roughly by Meandering Road Creek (pl. 1) and Bomber Road. NAS–JRB is bounded on the east roughly by State Highway 183 (toward the south) and West Fork Trinity River (toward the north). The community of White Settlement is southwest of both facilities.

Three formations of Cretaceous age crop out in the study area: the Paluxy and Walnut Formations and the Goodland Limestone (fig. 2; table 1). Terrace alluvial deposits of Pleistocene age, recent alluvial deposits of Holocene age, and localized fill material overlie these formations and collectively form the alluvial aquifer in the area. The alluvial deposits are composed of poorly sorted, locally cross-bedded, mostly unconsolidated gravel, sand, silt, and clay. The Goodland Limestone and Walnut Formation together form the Goodland-Walnut confining unit. The Paluxy Formation constitutes the Paluxy aquifer. The alluvial and Paluxy aquifers are hydraulically connected where the intervening confining unit is thin or absent.

Table 1. Geologic and hydrologic characteristics of hydrogeologic units underlying Air Force Plant 4 and Naval Air Station-Joint Reserve Base Carswell Field, Fort Worth, Texas (modified from Kuniansky and others, 1996, table 4).

[mya, million years ago; AFP4, Air Force Plant 4]

Era	System	Series/group	Stratigraphic unit	Hydrogeologic unit	Thickness of hydrogeologic unit (feet)	Lithologic characteristics	Permeability or water-yielding characteristics
Cenozoic	Quaternary (1.8 mya to present)	Holocene	Fill material	Alluvial aquifer	0–65	Construction debris	Permeability varies, gravels and sands permeable
			Recent alluvial deposits			Gravel, sand, silt, and clay	
		Pleistocene	Terrace alluvial deposits			Gravel, sand, silt, and clay	Permeability varies, gravels and sands permeable
Mesozoic	Cretaceous (65 to 140 mya)	Comanchean/ Fredericksburg	Goodland Limestone	Goodland-Walnut confining unit	0–90	Massive white, fossiliferous limestone, interbedded with marl and shale	Very low permeability where not weathered—considered confining unit
			Walnut Formation			Medium to dark gray clay and limestone with shell conglomerates, fossiliferous, *Gryphaea* beds	Very low permeability—considered confining unit
		Comanchean/ Trinity	Paluxy Formation	Paluxy aquifer	130–175	Light gray to greenish-gray fine- to coarse-grained sandstone and dense mudstone	Considered aquifer, yields small to moderate quantities of water
			Glen Rose Formation	Basal confining unit	150, range unknown at AFP4	Brownish-yellow and gray alternating limestone, marl, shale, and sand	Low permeability—considered confining unit in area of AFP4

Previous Studies and Available Data

Before 2002, more than 160 aquifer (pumping/recovery) tests and slug tests are known to have been conducted at AFP4 and NAS–JRB; the locations, methods, and results of most of these tests are listed in table 2. The locations of wells providing pre-2002 hydraulic-conductivity data are shown on plate 1. Table 2 and plate 1 provide information for only those wells with known spatial coordinate data. Most previous authors reported hydraulic-conductivity values to one to three significant figures. For consistency in this report, all hydraulic conductivities are reported to one significant figure.

The USGS completed 11 alluvial aquifer slug tests during August 1996 (E.L. Kuniansky, U.S. Geological Survey, written commun., 1997) as part of an ongoing phytoremediation project (Shah and Braun, 2004). Consulting firms completed the remainder of all previous aquifer and slug tests; those most relevant to the current (2001) study are chronicled below.

Many aquifer and slug tests were completed during the 1980s in wells constructed by Hargis and Montgomery, Inc. (1983). Referring to the alluvial deposits as the "upper zone," these investigators described it as a shallow unit including construction fill and alluvium above the Goodland Limestone and Walnut Formation to a depth of about 40 feet. Subsequent work, however, has shown that many of the Hargis and Montgomery, Inc. (1983) wells are screened in the uppermost, weathered section of the Goodland-Walnut confining unit and thus do not represent solely the alluvial aquifer. Consequently, no data from any Hargis and Montgomery, Inc. (1983) wells known to be mostly or completely screened in Goodland Limestone were used for this report.

During 1986, Intellus Corporation (1986) completed 23 slug tests in wells penetrating areas of potential contamination, or "areas of concern" near AFP4. These wells were completed within old landfills, die yards, chemical pits, chrome pits, and other areas designated as areas of concern. Despite being

Table 2. Locations and results of pre-2002 aquifer and slug tests used to estimate hydraulic conductivity in alluvial aquifer underlying Air Force Plant 4 and Naval Air Station-Joint Reserve Base Carswell Field, Fort Worth, Texas.

[Hydraulic conductivity in feet per day reported to one significant figure; latitude and longitude in degrees/minutes/seconds (DDMMSS.SS); CPB, Cooper-Bredehoeft-Papadopulos method for analyzing confined-aquifer slug-test data; --, unknown]

Well number	Northing[1]	Easting[2]	Latitude	Longitude	Hydraulic conductivity	Test date	Test method or analysis method, or both	Source of test data
GMI–22–02M	6966632.930	2296187.360	324630.79	972601.65	10	1998	Slug test (Bouwer & Rice)	CH2M Hill, Inc. (2000)
GMI–22–03M	6966219.920	2298539.370	324626.46	972534.15	40	1998	Slug test (Bouwer & Rice)	CH2M Hill, Inc. (2000)
GMI–22–04M	6967250.520	2297340.450	324636.78	972548.07	30	1998	Slug test (Bouwer & Rice)	CH2M Hill, Inc. (2000)
GMI–22–05M	6966940.330	2299432.080	324633.50	972523.61	50	1998	Slug test (Bouwer & Rice)	CH2M Hill, Inc. (2000)
GMI–22–06M	6967004.480	2298186.580	324634.26	972538.19	50	1998	Slug test (Bouwer & Rice)	CH2M Hill, Inc. (2000)
GMI–22–07M	6969018.680	2298322.510	324654.18	972536.35	60	1998	Slug test (Bouwer & Rice)	CH2M Hill, Inc. (2000)
USGS04T	6968758.980	2299177.670	324651.52	972526.37	80	1998	Slug test (Bouwer & Rice)	CH2M Hill, Inc. (2000)
WCHMHTA001	6966632.500	2293702.380	324631.03	972630.75	7	1998	Slug test (Bouwer & Rice)	CH2M Hill, Inc. (2000)
WCHMHTA002	6967545.100	2294818.470	324639.95	972617.57	9	1998	Slug test (Bouwer & Rice)	CH2M Hill, Inc. (2000)
WCHMHTA003	6967958.330	2295039.040	324644.02	972614.94	50	1998	Slug test (Bouwer & Rice)	CH2M Hill, Inc. (2000)
WCHMHTA004	6967949.300	2295041.060	324643.93	972614.92	5	1998	Slug test (Bouwer & Rice)	CH2M Hill, Inc. (2000)
WCHMHTA005	6967495.680	2295662.840	324639.37	972607.69	6	1998	Slug test (Bouwer & Rice)	CH2M Hill, Inc. (2000)
WCHMHTA006	6967494.620	2295671.900	324639.36	972607.58	20	1998	Slug test (Bouwer & Rice)	CH2M Hill, Inc. (2000)
WCHMHTA007	6967910.330	2295910.420	324643.46	972604.74	50	1998	Slug test (Bouwer & Rice)	CH2M Hill, Inc. (2000)
WCHMHTA009	6968444.690	2296663.990	324648.66	972555.85	10	1998	Slug test (Bouwer & Rice)	CH2M Hill, Inc. (2000)
WCHMHTA010	6968440.060	2296660.060	324648.62	972555.90	40	1998	Slug test (Bouwer & Rice)	CH2M Hill, Inc. (2000)
WCHMHTA011	6969295.200	2297328.380	324657.01	972547.96	200	1998	Slug test (Bouwer & Rice)	CH2M Hill, Inc. (2000)
WCHMHTA012	6968645.440	2297691.140	324650.55	972543.79	40	1998	Slug test (Bouwer & Rice)	CH2M Hill, Inc. (2000)
WITCTA010	6967694.530	2298753.180	324641.03	972531.47	200	1998	Slug test (Bouwer & Rice)	CH2M Hill, Inc. (2000)
WITCTA024	6965971.780	2298956.020	324623.97	972529.30	20	1998	Slug test (Bouwer & Rice)	CH2M Hill, Inc. (2000)
RW–1U	6965267.600	2292468.700	324617.65	972645.36	30	1997	Hantush Leaky	Duke Engineering and Services, Inc. (1998)
W–151	6964980.930	2292475.310	324614.81	972645.32	40	1997	Hantush Leaky	Duke Engineering and Services, Inc. (1998)
WINTTA048	6965253.000	2292512.000	324617.50	972644.86	20	1997	Hantush Leaky	Duke Engineering and Services, Inc. (1998)
WINTTA049	6965301.000	2292458.000	324617.98	972645.48	30	1997	Hantush Leaky	Duke Engineering and Services, Inc. (1998)
WJEGTA513	6962977.500	2296754.000	324554.56	972555.44	30	1996	Slug test (Bouwer & Rice)	E.L. Kuniansky, U.S. Geological Survey (written commun., 1997)
WJEGTA514	6962864.000	2296751.000	324553.44	972555.49	20	1996	Slug test (Bouwer & Rice)	E.L. Kuniansky, U.S. Geological Survey (written commun., 1997)
WJEGTA515	6962863.000	2296894.000	324553.41	972553.82	3	1996	Slug test (Bouwer & Rice)	E.L. Kuniansky, U.S. Geological Survey (written commun., 1997)
WJEGTA516	6962969.000	2296860.000	324554.46	972554.20	30	1996	Slug test (Bouwer & Rice)	E.L. Kuniansky, U.S. Geological Survey (written commun., 1997)
WJEGTA518	6962950.000	2296714.000	324554.29	972555.92	30	1996	Slug test (Bouwer & Rice)	E.L. Kuniansky, U.S. Geological Survey (written commun., 1997)
WJEGTA520	6962879.000	2296810.000	324553.58	972554.80	20	1996	Slug test (Bouwer & Rice)	E.L. Kuniansky, U.S. Geological Survey (written commun., 1997)
WJEGTA523	6962887.000	2296845.000	324553.65	972554.39	50	1996	Slug test (Bouwer & Rice)	E.L. Kuniansky, U.S. Geological Survey (written commun., 1997)
WJEGTA525	6962800.000	2296820.000	324552.80	972554.69	7	1996	Slug test (Bouwer & Rice)	E.L. Kuniansky, U.S. Geological Survey (written commun., 1997)
WJEGTA527	6962856.000	2296937.000	324553.34	972553.32	10	1996	Slug test (Bouwer & Rice)	E.L. Kuniansky, U.S. Geological Survey (written commun., 1997)
WJEGTA528	6962815.000	2296880.000	324552.94	972553.99	9	1996	Slug test (Bouwer & Rice)	E.L. Kuniansky, U.S. Geological Survey (written commun., 1997)
WJEGTA529	6962759.000	2296997.000	324552.37	972552.62	100	1996	Slug test (Bouwer & Rice)	E.L. Kuniansky, U.S. Geological Survey (written commun., 1997)
FT09–12A	6960549.800	2295439.200	324530.67	972611.13	2	1991	Slug test (Bouwer & Rice)	Environmental Science and Engineering, Inc. (1994)
FT09–12B	6960709.300	2295697.400	324532.22	972608.09	4	1991	Slug test (Bouwer & Rice)	Environmental Science and Engineering, Inc. (1994)
FT09–12C	6960590.300	2295771.500	324531.04	972607.23	8	1991	Slug test (Bouwer & Rice)	Environmental Science and Engineering, Inc. (1994)
LF04–4A	6960300.480	2295852.980	324528.16	972606.31	1	1991	Slug test (Bouwer & Rice)	Environmental Science and Engineering, Inc. (1994)
LF04–4D	6960828.000	2296412.390	324533.32	972559.70	20	1991	Slug test (Bouwer & Rice)	Environmental Science and Engineering, Inc. (1994)

Table 2. Locations and results of pre-2002 aquifer and slug tests used to estimate hydraulic conductivity in alluvial aquifer underlying Air Force Plant 4 and Naval Air Station-Joint Reserve Base Carswell Field, Fort Worth, Texas—Continued.

Well number	Northing[1]	Easting[2]	Latitude	Longitude	Hydraulic conductivity	Test date	Test method or analysis method, or both	Source of test data
LF04–4E	6961036.040	2296407.000	324535.38	972559.74	20	1991	Slug test (Bouwer & Rice)	Environmental Science and Engineering, Inc. (1994)
LF04–4G	6961224.130	2296658.930	324537.22	972556.77	10	1991	Slug test (Bouwer & Rice)	Environmental Science and Engineering, Inc. (1994)
LF05–5C	6961720.050	2295993.730	324542.19	972604.50	5	1991	Slug test (Bouwer & Rice)	Environmental Science and Engineering, Inc. (1994)
LF05–5E	6961177.000	2295546.000	324536.86	972609.81	6	1991	Slug test (Bouwer & Rice)	Environmental Science and Engineering, Inc. (1994)
LF01–1D	6964288.180	2301412.720	324607.05	972500.73	.03	1991	Slug test (Bouwer & Rice)	Environmental Science and Engineering, Inc. (1994)
LF01–1F	6964438.040	2301376.050	324608.54	972501.14	4	1991	Slug test (Bouwer & Rice)	Environmental Science and Engineering, Inc. (1994)
LF04–02	6961113.060	2296309.100	324536.15	972600.88	800	1990	Aquifer test (drawdown)	HydroGeoLogic, Inc. (2002)
LF04–02	6961113.060	2296309.100	324536.15	972600.88	700	1990	Aquifer test (recovery)	HydroGeoLogic, Inc. (2002)
LF04–03	6961063.960	2296305.770	324535.67	972600.92	800	1990	Multiple-well aquifer test (recovery)	HydroGeoLogic, Inc. (2002)
CAR–RW1	6960869.000	2296755.000	324533.70	972555.68	300	1993	Single-well aquifer test	HydroGeoLogic, Inc. (2002)
CAR–RW2	6961223.000	2296673.000	324537.21	972556.60	200	1993	Single-well aquifer test (Neuman)	HydroGeoLogic, Inc. (2002)
CAR–RW10	6961279.060	2296078.880	324537.82	972603.55	100	2000	Multiple-well aquifer test (Cooper-Jacob)	HydroGeoLogic, Inc. (2002)
CAR–RW10	6961279.060	2296078.880	324537.82	972603.55	100	2000	Multiple-well aquifer test (Neuman)	HydroGeoLogic, Inc. (2002)
CAR–RW10	6961279.060	2296078.880	324537.82	972603.55	100	2000	Multiple-well aquifer test (Theis)	HydroGeoLogic, Inc. (2002)
WHGLTA046	6961298.486	2296089.683	324538.01	972603.42	100	2000	Multiple-well aquifer test (Theis)	HydroGeoLogic, Inc. (2002)
WHGLTA047	6961250.473	2296102.197	324537.54	972603.28	200	2000	Multiple-well aquifer test (Cooper)	HydroGeoLogic, Inc. (2002)
WHGLTA047	6961250.473	2296102.197	324537.54	972603.28	200	2000	Multiple-well aquifer test (Neuman)	HydroGeoLogic, Inc. (2002)
WHGLTA047	6961250.473	2296102.197	324537.54	972603.28	200	2000	Multiple-well aquifer test (Theis)	HydroGeoLogic, Inc. (2002)
WP07–10B	6961277.460	2296040.450	324537.81	972604.00	100	2000	Multiple-well aquifer test (Cooper)	HydroGeoLogic, Inc. (2002)
WP07–10B	6961277.460	2296040.450	324537.81	972604.00	100	2000	Multiple-well aquifer test (Neuman)	HydroGeoLogic, Inc. (2002)
WP07–10B	6961277.460	2296040.450	324537.81	972604.00	100	2000	Multiple-well aquifer test (Theis)	HydroGeoLogic, Inc. (2002)
FT08–11A	6962320.500	2295877.800	324548.15	972605.78	20	2001	Slug test (Bouwer & Rice)	HydroGeoLogic, Inc. (2002)
HM–123	6961638.500	2295272.600	324541.46	972612.95	200	2001	Slug test (Bouwer & Rice)	HydroGeoLogic, Inc. (2002)
ITMW–01T	6961062.050	2298967.140	324535.38	972529.75	300	2001	Slug test (Bouwer & Rice)	HydroGeoLogic, Inc. (2002)
LF05–5E	6961177.140	2295546.400	324536.86	972609.80	50	2001	Slug test (Bouwer & Rice)	HydroGeoLogic, Inc. (2002)
WHGLRW016	6961034.950	2299201.470	324535.09	972527.01	100	2001	Slug test (Bouwer & Rice)	HydroGeoLogic, Inc. (2002)
WHGLRW017	6960727.110	2299000.590	324532.06	972529.40	300	2001	Slug test (Bouwer & Rice)	HydroGeoLogic, Inc. (2002)
WHGLRW019	6960684.230	2298620.190	324531.68	972533.86	100	2001	Slug test (Bouwer & Rice)	HydroGeoLogic, Inc. (2002)
WHGLTA002	6962377.910	2296111.390	324548.69	972603.04	10	2001	Slug test (Bouwer & Rice)	HydroGeoLogic, Inc. (2002)
WHGLTA048	6960916.200	2298714.830	324533.96	972532.73	10	2001	Slug test (Bouwer & Rice)	HydroGeoLogic, Inc. (2002)
WHGLTA056	6960787.360	2295827.620	324532.98	972606.56	50	2001	Slug test (Bouwer & Rice)	HydroGeoLogic, Inc. (2002)
WHGLTA701	6961835.730	2295332.860	324543.40	972612.22	40	2001	Slug test (Bouwer & Rice)	HydroGeoLogic, Inc. (2002)
WHGLTA705	6962002.920	2296026.740	324544.99	972604.08	8	2001	Slug test (Bouwer & Rice)	HydroGeoLogic, Inc. (2002)
WHGLTA706	6962146.170	2296030.820	324546.40	972604.01	10	2001	Slug test (Bouwer & Rice)	HydroGeoLogic, Inc. (2002)
WITCTA057	6961308.486	2295952.354	324538.12	972605.03	100	2001	Slug test (Bouwer & Rice)	HydroGeoLogic, Inc. (2002)
WP07–10A	6961289.980	2295807.270	324537.96	972606.73	80	2001	Slug test (Bouwer & Rice)	HydroGeoLogic, Inc. (2002)
WP07–10C	6961575.610	2296062.430	324540.76	972603.71	50	2001	Slug test (Bouwer & Rice)	HydroGeoLogic, Inc. (2002)
F–212	6967838.170	2290527.370	324643.27	972707.80	.05	1986	Cedergen method	Intellus Corporation (1986)
F–214	6966040.040	2289864.000	324625.55	972715.78	.01	1986	Cedergen method	Intellus Corporation (1986)
F–216	6965776.180	2290219.930	324622.90	972711.64	.06	1986	Cedergen method	Intellus Corporation (1986)
F–217	6965959.980	2290109.050	324624.73	972712.92	1	1986	Cooper type-curve method	Intellus Corporation (1986)
F–218	6964024.490	2291474.210	324605.45	972657.15	.1	1986	Cedergen method	Intellus Corporation (1986)

Table 2. Locations and results of pre-2002 aquifer and slug tests used to estimate hydraulic conductivity in alluvial aquifer underlying Air Force Plant 4 and Naval Air Station-Joint Reserve Base Carswell Field, Fort Worth, Texas—Continued.

Well number	Northing[1]	Easting[2]	Latitude	Longitude	Hydraulic conductivity	Test date	Test method or analysis method, or both	Source of test data
F–219	6964343.310	2291472.820	324608.60	972657.14	0.05	1986	Cedergen method	Intellus Corporation (1986)
F–220	6964050.320	2290236.600	324605.83	972711.65	.08	1986	Cedergen method	Intellus Corporation (1986)
F–221	6963244.600	2290575.220	324557.82	972707.77	.4	1986	Cedergen method	Intellus Corporation (1986)
HM–10	6965810.910	2290121.800	324623.26	972712.79	.4	1986	Cooper type-curve method	Intellus Corporation (1986)
HM–11	6963091.760	2290932.280	324556.27	972703.61	.4	1986	Cooper type-curve method	Intellus Corporation (1986)
HM–12	6963088.530	2290396.720	324556.29	972709.88	.01	1986	Cooper type-curve method	Intellus Corporation (1986)
HM–25	6963314.260	2290575.870	324558.51	972707.76	.07	1986	Cooper type-curve method	Intellus Corporation (1986)
HM–27	6965727.600	2289864.570	324622.46	972715.81	.5	1986	Cooper type-curve method	Intellus Corporation (1986)
HM–28	6963532.120	2290422.230	324600.68	972709.53	.1	1986	Cooper type-curve method	Intellus Corporation (1986)
HM–30	6964012.620	2289983.860	324605.47	972714.61	.8	1986	Cooper type-curve method	Intellus Corporation (1986)
HM–51	6966666.000	2290329.000	324631.70	972710.26	.02	1986	Cooper type-curve method	Intellus Corporation (1986)
HM–69	6963423.000	2292001.000	324559.44	972651.06	.7	1986	Cooper type-curve method	Intellus Corporation (1986)
HM–80	6967856.000	2290527.000	324643.45	972707.80	.02	1986	Cooper type-curve method	Intellus Corporation (1986)
HM–88	6964479.910	2291919.170	324609.91	972651.89	100	1996	Aquifer test (drawdown)	Intera (1998)
HM–89	6964470.440	2292084.170	324609.80	972649.96	300	1996	Aquifer test (drawdown)	Intera (1998)
HM–89	6964470.440	2292084.170	324609.80	972649.96	100	1996	Aquifer test (recovery)	Intera (1998)
RW–8UR	6964339.000	2291990.600	324608.51	972651.07	100	1996	Aquifer test (drawdown)	Intera (1998)
OW–1–1	6965550.173	2289764.434	324620.71	972717.00	100	1994	Drawdown (Theis)	International Technology Corporation (1994)
OW–1–2	6965548.475	2289789.573	324620.69	972716.71	300	1994	Drawdown (Theis)	International Technology Corporation (1994)
OW–1–3	6965546.001	2289833.225	324620.66	972716.20	100	1994	Drawdown (Theis)	International Technology Corporation (1994)
OW–1–4	6965577.715	2289739.079	324620.98	972717.30	200	1994	Drawdown (Theis)	International Technology Corporation (1994)
OW–1–5	6965602.369	2289739.743	324621.23	972717.28	100	1994	Drawdown (Theis)	International Technology Corporation (1994)
OW–3–2	6966022.931	2289854.960	324625.38	972715.89	1	1994	Drawdown (Theis)	International Technology Corporation (1994)
OW–3–6	6966019.660	2289820.920	324625.35	972716.28	.6	1994	Drawdown (Theis)	International Technology Corporation (1994)
OW–3–7	6966030.345	2289827.893	324625.46	972716.20	.2	1994	Drawdown (Theis)	International Technology Corporation (1994)
T4	6965870.000	2290067.000	324623.85	972713.42	40	2000	Slug test (Bouwer & Rice)	International Technology Corporation (2000)
T6	6965927.000	2290069.000	324624.41	972713.39	20	2000	Slug test (Bouwer & Rice)	International Technology Corporation (2000)
T7	6966050.000	2290097.000	324625.62	972713.05	20	2000	Slug test (Bouwer & Rice)	International Technology Corporation (2000)
HM–89	6964470.440	2292084.170	324609.80	972649.96	30	1996	Slug test (Bouwer & Rice)	Jacobs Engineering Group, Inc. (1999)
HM–89	6964470.440	2292084.170	324609.80	972649.96	100	1996	Slug test (CPB Method)	Jacobs Engineering Group, Inc. (1999)
HM–112	6964218.830	2293142.650	324607.20	972637.59	3	1998	Slug test (Bouwer & Rice)	Jacobs Engineering Group, Inc. (1999)
W–149	6965190.700	2292456.970	324616.89	972645.51	.5	1998	Slug test (Bouwer & Rice)	Jacobs Engineering Group, Inc. (1999)
W–149	6965190.700	2292456.970	324616.89	972645.51	.4	1998	Slug test (CPB Method)	Jacobs Engineering Group, Inc. (1999)
WJETA031	6964012.290	2291516.210	324605.32	972656.66	10	1998	Slug test (CPB Method)	Jacobs Engineering Group, Inc. (1999)
WJETA033	6964003.180	2291520.300	324605.23	972656.62	70	1998	Slug test (CPB Method)	Jacobs Engineering Group, Inc. (1999)
WJETA036	6964011.480	2291538.510	324605.31	972656.40	200	1998	Slug test (CPB Method)	Jacobs Engineering Group, Inc. (1999)
WJETA040	6964020.130	2291534.390	324605.40	972656.45	40	1998	Slug test (CPB Method)	Jacobs Engineering Group, Inc. (1999)
WJETA043	6964667.720	2292227.720	324611.73	972648.25	30	1998	Slug test (CPB Method)	Jacobs Engineering Group, Inc. (1999)
WJETA044	6964591.320	2292172.930	324610.99	972648.90	10	1998	Slug test (CPB Method)	Jacobs Engineering Group, Inc. (1999)
WJETA047	6964393.060	2292176.360	324609.02	972648.89	30	1998	Slug test (CPB Method)	Jacobs Engineering Group, Inc. (1999)
WJETA050	6964218.300	2293120.620	324607.20	972637.85	30	1998	Slug test (Bouwer & Rice)	Jacobs Engineering Group, Inc. (1999)
WJETA052	6964321.270	2292210.750	324608.31	972648.49	40	1998	Slug test (CPB Method)	Jacobs Engineering Group, Inc. (1999)

Table 2. Locations and results of pre-2002 aquifer and slug tests used to estimate hydraulic conductivity in alluvial aquifer underlying Air Force Plant 4 and Naval Air Station-Joint Reserve Base Carswell Field, Fort Worth, Texas—Continued.

Well number	Northing[1]	Easting[2]	Latitude	Longitude	Hydraulic conductivity	Test date	Test method or analysis method, or both	Source of test data
WJETA058	6963890.850	2290868.750	324604.18	972704.26	10	1998	Slug test (CPB Method)	Jacobs Engineering Group, Inc. (1999)
WJETA059	6963915.190	2290869.120	324604.42	972704.26	4	1998	Slug test (CPB Method)	Jacobs Engineering Group, Inc. (1999)
WJETA060	6963891.670	2290888.760	324604.19	972704.03	8	1998	Slug test (Bouwer & Rice)	Jacobs Engineering Group, Inc. (1999)
WJETA063	6963914.990	2290888.600	324604.42	972704.03	30	1998	Slug test (Bouwer & Rice)	Jacobs Engineering Group, Inc. (1999)
WJETA064	6963902.980	2290868.450	324604.30	972704.26	5	1998	Slug test (CPB Method)	Jacobs Engineering Group, Inc. (1999)
WJETA065	6963903.290	2290888.750	324604.31	972704.03	5	1998	Slug test (Bouwer & Rice)	Jacobs Engineering Group, Inc. (1999)
WJETA085	6964032.920	2291528.420	324605.52	972656.52	20	1998	Slug test (CPB Method)	Jacobs Engineering Group, Inc. (1999)
WJETA087	6964207.710	2293100.390	324607.09	972638.09	30	1998	Slug test (Bouwer & Rice)	Jacobs Engineering Group, Inc. (1999)
WL–091JETA	6964267.890	2291919.330	324607.81	972651.91	300	1998	Aquifer test (drawdown)	Jacobs Engineering Group, Inc. (1999)
WL–091JETA	6964267.890	2291919.330	324607.81	972651.91	300	1998	Aquifer test (recovery)	Jacobs Engineering Group, Inc. (1999)
WL–092JETA	6963916.770	2291884.400	324604.34	972652.36	600	1998	Aquifer test (drawdown)	Jacobs Engineering Group, Inc. (1999)
WL–092JETA	6963916.770	2291884.400	324604.34	972652.36	600	1998	Aquifer test (recovery)	Jacobs Engineering Group, Inc. (1999)
WL–093JETA	6964060.090	2291864.930	324605.76	972652.57	300	1998	Aquifer test (drawdown)	Jacobs Engineering Group, Inc. (1999)
WL–093JETA	6964060.090	2291864.930	324605.76	972652.57	300	1998	Aquifer test (recovery)	Jacobs Engineering Group, Inc. (1999)
WL–094JETA	6964126.840	2291827.100	324606.42	972653.01	500	1998	Aquifer test (drawdown)	Jacobs Engineering Group, Inc. (1999)
WL–094JETA	6964126.840	2291827.100	324606.42	972653.01	400	1998	Aquifer test (recovery)	Jacobs Engineering Group, Inc. (1999)
WL–095JETA	6964195.430	2291863.320	324607.10	972652.58	400	1998	Aquifer test (drawdown)	Jacobs Engineering Group, Inc. (1999)
W–149	6965190.700	2292456.970	324616.89	972645.51	.3	1995	Slug test (Bouwer & Rice)	RUST Geotech (1995)
F–208	6968601.960	2290644.230	324650.82	972706.34	.7	1995	Slug test (Bouwer & Rice)	RUST Geotech (1995)
F–212	6967838.170	2290527.370	324643.27	972707.80	.01	1995	Slug test (Bouwer & Rice)	RUST Geotech (1995)
F–216	6965776.180	2290219.930	324622.90	972711.64	6	1995	Slug test (Bouwer & Rice)	RUST Geotech (1995)
F–217	6965959.980	2290109.050	324624.73	972712.92	7	1995	Slug test (Bouwer & Rice)	RUST Geotech (1995)
HM–105	6969064.250	2290972.320	324655.36	972702.44	8	1995	Slug test (Bouwer & Rice)	RUST Geotech (1995)
HM–12	6963088.530	2290396.720	324556.29	972709.88	.1	1995	Slug test (Bouwer & Rice)	RUST Geotech (1995)
HM–27	6965727.600	2289864.570	324622.46	972715.81	3	1995	Slug test (Bouwer & Rice)	RUST Geotech (1995)
HM–28	6963532.120	2290422.230	324600.68	972709.53	20	1995	Slug test (Bouwer & Rice)	RUST Geotech (1995)
W–131U	6963278.410	2290540.830	324558.16	972708.17	30	1995	Slug test (Bouwer & Rice)	RUST Geotech (1995)
W–136	6965214.160	2290716.200	324617.29	972705.89	20	1995	Slug test (Bouwer & Rice)	RUST Geotech (1995)
W–140	6965407.490	2291039.700	324619.17	972702.08	30	1995	Slug test (Bouwer & Rice)	RUST Geotech (1995)
W–141U	6965391.580	2290672.520	324619.05	972706.38	.2	1995	Slug test (Bouwer & Rice)	RUST Geotech (1995)
W–143	6968548.580	2291192.240	324650.24	972659.93	80	1995	Slug test (Bouwer & Rice)	RUST Geotech (1995)
W–144	6965577.000	2290450.000	324620.91	972708.97	300	1995	Slug test (Bouwer & Rice)	RUST Geotech (1995)
W–147	6965823.630	2290710.240	324623.32	972705.89	1	1995	Slug test (Bouwer & Rice)	RUST Geotech (1995)
W–153	6965106.300	2294096.200	324615.89	972626.32	10	1995	Slug test (Bouwer & Rice)	RUST Geotech (1995)
W–156	6964824.120	2292815.020	324613.22	972641.36	.05	1995	Slug test (Bouwer & Rice)	RUST Geotech (1995)
W–158	6963954.830	2291080.820	324604.80	972701.77	9	1995	Slug test (Bouwer & Rice)	RUST Geotech (1995)
W–159	6963922.850	2291370.780	324604.45	972658.38	50	1995	Slug test (Bouwer & Rice)	RUST Geotech (1995)
W–160	6963448.680	2291368.510	324559.76	972658.46	20	1995	Slug test (Bouwer & Rice)	RUST Geotech (1995)
FT08–11A	6962320.500	2295877.800	324548.15	972605.78	10	--	Slug test (Bouwer & Rice)	--
LF05–5E	6961177.140	2295546.400	324536.86	972609.80	70	--	Slug test (Bouwer & Rice)	--

[1] Northing—North State Plane coordinate of the north-south distance, in feet, of a location from a reference location of known State Plane coordinates. In this application, the reference location is N65616666.67.

[2] Easting—North State Plane coordinate of the east-west distance, in feet, of a location from a reference location of known State Plane coordinates. In this application, the reference is E1968500.00.

identified as "upper aquifer" wells, some of these wells are screened in upper parts of the Goodland-Walnut confining unit. Hydraulic-conductivity estimates from 18 of the 23 tests were retained for this report.

During 1991, Radian Corporation completed 17 slug tests on AFP4 (Environmental Science and Engineering, Inc., 1994). Hydraulic-conductivity estimates from 11 of the 17 tests are documented in this report.

During 1994, International Technology Corporation (1994) conducted eight drawdown tests in the alluvial aquifer. The resulting hydraulic-conductivity data were reported as part of pre-construction testing by International Technology Corporation for a vacuum-enhanced pumping system at landfill 3. International Technology Corporation (2000) also completed three slug tests west of the assembly building as part of a subsequent remediation investigation.

RUST Geotech (1995) completed 25 slug tests in the alluvial aquifer in the western part of the study area as part of their preliminary assessment and inspection of AFP4 during 1995. Their report indicates that three of the tests were done in wells with screens extending into the weathered top of the Goodland-Walnut confining unit and thus are not included with the RUST Geotech (1995) results in this report (table 2). Hydraulic-conductivity values from 21 of the 25 tests were retained for this report.

During October 1996, Intera (1998) completed four aquifer tests beneath the east parking lot of AFP4. These tests were a precursor to Intera's "partitioning interwell tracer testing" (PITT) at AFP4 (Intera, 1998).

Jacobs Engineering Group, Inc. (1999), reported the results of 22 slug and nine aquifer tests completed in the east parking lot of AFP4 during 1998. Most of these tests were used to design a pump-and-treat remediation system, which currently (2004) operates in the east parking lot.

During January 1998, CH2M Hill, Inc. (2000), completed 22 slug tests near the northern lobe of the TCE plume beneath NAS–JRB (fig. 1). These tests (20 of which are listed in table 2) were done to augment information about the alluvial aquifer in this area.

During October–November 1997 Duke Engineering and Services, Inc. (1998), conducted four aquifer tests in wells installed in the east parking lot of AFP4. The tests were in wells located where the confining unit beneath the alluvial aquifer is only a few feet thick.

HydroGeoLogic, Inc. (2002) did two aquifer tests in the southern part of NAS–JRB in 1990. In 2000, they did a series of multiple-well aquifer tests in the same general area; and in 2001, 16 slug tests.

Slug Tests

Slug testing (Butler, 1997) is a relatively simple, quick, and inexpensive way to collect data for estimating hydraulic conductivity for small areas of an aquifer. A slug test is done by adding (or removing) an object of known volume, such as a solid slug, to (or from) a static column of water in a well and measuring the resulting changes in water level over time. The changes in water level are recorded until equilibrium is restored—that is, the water level in the well returns to its original static condition. A principal benefit of slug tests as opposed to aquifer tests is that there is no need to dispose of potentially contaminated water. A major limitation of slug tests is that hydraulic conductivity is estimated for only a few feet from the well (Bouwer, 1978, p. 114).

The areal distribution of hydraulic-conductivity data from previous studies was reviewed, and on the basis of the findings of this review, wells in the alluvial aquifer were selected for the two series of slug tests, October 2002 and August 2003 (pl. 1). The following three sections describe the conditions and procedures for the two series of slug tests.

Theory

Data obtained from the October 2002 and August 2003 slug tests were used to estimate hydraulic conductivity from an analytical relation between the instantaneous displacement of water in a well bore and the resulting rate of head change. These analyses are based on a procedure developed by Bouwer and Rice (1976) for fully or partially penetrating wells in unconfined aquifers. Bouwer and Rice use a modified version of the Theim equation (Lohman, 1972) to estimate hydraulic conductivity:

$$K = \frac{r_c^2 1n(R_e/r_w)}{2L}\frac{1}{t}1n\frac{y_0}{y_t}, \qquad (1)$$

where

- K = hydraulic conductivity [L/T];
- r_c = radius of the well casing [L];
- R_e = effective radial distance over which the head difference is dissipated [L];
- r_w = radial distance between well center and undisturbed aquifer [L];
- L = screened interval [L];
- y_0 = difference between static (undisturbed pre-test) and slug-displaced water levels at time 0 [L];
- y_t = difference between static (undisturbed pre-test) and slug-displaced water levels at time t [L]; and
- t = time [T].

This solution for hydraulic conductivity assumes that (1) the aquifer is homogeneous and isotropic, (2) water-level change around the well is negligible, and (3) no water flows through any unsaturated material above the water table (Bouwer, 1978, p. 115).

Equipment

Relative to the amount of equipment required for aquifer testing, little equipment is needed for slug testing. In addition to the required solid object (slug), a pressure transducer and data logger are useful for measuring and recording the resulting water-level changes (Butler, 1997, p. 29–44).

The slugs used for this study were hand-built from different diameters and lengths of polyvinyl-chloride (PVC) pipe, which were filled with sand and capped at both ends. Because the casings of wells selected for testing during October 2002 had inner diameters of either 2 or 4 inches (table 3), four slugs were built initially for this series of tests, two for each casing size. As testing proceeded, however, it became obvious that a greater choice of slugs was needed to handle the wide variations in well construction (table 4) and the large differences in water levels. Therefore, nine slugs were built and used for the August 2003 series of tests.

A 261 QC pressure transducer was used to measure the changes in water levels in all wells tested. A Hermit 3000 data logger was used to record the measured water-level changes during October 2002. Although that equipment performed competently, a MiniTroll data-logging probe was used in conjunction with an IPAQ pocket PC to measure and record the August 2003 water-level data.

Table 3. Diameters of wells and dimensions of slugs used to estimate hydraulic conductivity in alluvial aquifer underlying Air Force Plant 4 and Naval Air Station-Joint Reserve Base Carswell Field, Fort Worth, Texas.

Well number	Casing diameter (inches)	Slug		Date of slug test
		Diameter (inches)	Length (feet)	
BGSMW06	4	2.25	3.17	October 2002
GMI–22–08M	2	1.25	1.00	August 2003
HM–100	2	1.25	5.08	August 2003
HM–119	4	2.25	3.17	October 2002
HM–124	4	2.25	3.17	October 2002
HM–125	4	2.25	3.17	October 2002
HM–126	4	2.25	5.13	October 2002
HM–14	4	2.25	3.17	August 2003
HM–23	4	2.25	3.17	August 2003
LF03–3D	2	1.25	2.58	October 2002
MW–12	4	2.25	3.17	October 2002
ST14–03	2	1.25	5.13	October 2002
ST14–W23	2	1.25	1.00	August 2003
USGS06T	2	1.25	1.58	October 2002
WHGLTA009	2	1.25	2.58	October 2002
WHGLTA010	2	1.25	2.58	October 2002
WHGLTA034	2	1.25	2.58	October 2002
WHGLTA044	2	1.25	1.58	October 2002
WHGLTA049	2	1.25	1.00	August 2003
WITCTA001	2	1.25	2.00	August 2003
WITCTA019	2	1.25	2.58	October 2002
WJEGTA514	6	2.25	1.08	August 2003
WJEGTA515	6	2.25	2.00	August 2003
WJEGTA516	4	2.25	2.00	August 2003
WJEGTA523	4	2.25	1.08	August 2003
WJEGTA525	4	2.25	2.00	August 2003
WJEGTA527	4	2.25	1.08	August 2003
WJEGTA527	4	2.25	1.58	October 2002
WJEGTA529	4	2.25	1.08	August 2003
WSAICTA027	2	1.25	5.13	October 2002

Data Collection

The specific procedures used in this study were refined largely through trial-and-error experimentation in tests at the first three wells during October 2002 and at the first well during August 2003. Attempts were made to make both falling-head (slug inserted into well) and rising-head (slug removed from well) tests; however, the water levels resulting from the falling-head experiments either oscillated excessively or were considered anomalous or inconsistent. Owing to the possibility of interference from the unsaturated zone above the water table, previous investigators recommended making only rising-head tests if the water table is below the top of the screen (Dominico and Schwartz, 1990; Bouwer, 1989). Because water levels were below the top of the screen in 15 of the 16 wells tested during October 2002 and in 12 of 14 wells tested during August 2003, only rising-head data were used to estimate the hydraulic-conductivity values (table 5).

Although attempts were made to record the rates of water-level change on a linear scale, the linear counters of the data loggers did not always record at frequent enough intervals to adequately track water levels through the first few seconds of response. Gaps in the recorded early-time response were most prevalent for wells penetrating the more permeable parts of the alluvial aquifer. Consequently, all water-level responses recorded during this study were stored on logarithmic time scales.

Readings that initially were recorded during October 2002 at the rate of six every 5 seconds were decreased logarithmically to one reading every 10 seconds for later parts of the tests. During August 2003, readings that initially totaled 10 every 3 seconds were, likewise, reduced logarithmically over the course of each test.

In addition to the above-mentioned adjustments to ensure the most accurate results possible, all subsequent testing was done in the following manner:

1. An electric line (e-line) was used to measure well depths and static water levels for computing saturated thicknesses;
2. When possible, the pressure transducer was placed 1 foot or more above the bottoms of wells;

Table 4. Location and site-characteristic data for wells used to estimate hydraulic conductivity in alluvial aquifer underlying Air Force Plant 4 and Naval Air Station-Joint Reserve Base Carswell Field, Fort Worth, Texas.

[Latitude and longitude in degrees/minutes/seconds (DDMMSS.SS); depths in feet below land surface]

Well number	Northing[1]	Easting[2]	Latitude	Longitude	Depth to water	Depth to top of screen	Depth to bottom of screen	Depth of well	Depth to base of alluvial aquifer
BGSMW06	6964981.310	2299910.090	324614.07	972518.24	10.85	7.40	17.40	20.22	20.22
GMI–22–08M	6970323.600	2298971.500	324707.02	972528.59	15.47	10.00	22.50	22.50	22.50
HM–100	6963697.000	2289679.000	324602.38	972718.22	37.05	33.50	48.50	49.00	49.00
HM–119	6968726.000	2294271.800	324651.69	972623.84	15.21	9.00	29.00	32.00	32.00
HM–124	6963957.770	2295223.260	324604.41	972613.26	15.53	9.00	24.00	25.00	23.50
HM–125	6965892.460	2295220.140	324623.56	972613.06	20.43	13.00	33.00	33.00	33.00
HM–126	6963121.000	2294300.200	324556.22	972624.16	16.38	16.00	36.00	37.00	37.00
HM–14	6963092.560	2289243.300	324556.44	972723.39	29.15	28.50	38.30	38.30	42.50
HM–23	6963113.580	2288752.310	324556.70	972729.14	35.14	37.10	46.40	46.40	42.00
LF03–3D	6962056.650	2293269.120	324545.79	972636.37	9.06	7.50	14.40	15.40	15.50
MW–12	6966149.320	2300142.000	324625.60	972515.38	8.82	6.94	26.94	28.00	28.00
ST14–03	6964079.970	2299891.620	324605.15	972518.57	7.41	7.85	17.60	17.90	18.20
ST14–W23	6962949.060	2300410.370	324553.91	972512.63	7.75	5.54	9.54	10.50	10.50
USGS06T	6963763.040	2297542.160	324602.25	972546.12	18.58	12.00	22.00	22.50	21.00
WHGLTA009	6965211.650	2297528.700	324616.59	972546.10	20.87	15.00	25.00	25.00	25.00
WHGLTA010	6965580.030	2296770.930	324620.31	972554.94	24.02	18.00	28.00	28.00	28.50
WHGLTA034	6963889.660	2301060.210	324603.15	972504.90	8.93	5.00	15.00	15.00	15.00
WHGLTA044	6961721.400	2297347.370	324542.07	972548.65	5.60	3.50	8.50	9.00	8.00
WHGLTA049	6962329.240	2299269.360	324547.89	972526.07	7.05	4.50	14.50	14.60	14.80
WITCTA001	6969592.010	2296447.730	324700.04	972558.24	16.53	9.50	21.75	22.00	22.00
WITCTA019	6963107.250	2298838.010	324555.63	972531.02	14.90	9.90	19.65	19.90	20.00
WJEGTA514	6962864.000	2296751.000	324553.44	972555.49	8.39	5.35	9.35	9.85	10.00
WJEGTA515	6962863.000	2296894.000	324553.41	972553.82	8.29	7.50	11.50	12.00	13.00
WJEGTA516	6962969.000	2296860.000	324554.46	972554.20	12.70	11.53	15.53	16.03	16.03
WJEGTA523	6962887.000	2296845.000	324553.65	972554.39	8.59	7.18	9.18	9.74	10.00
WJEGTA525	6962800.000	2296820.000	324552.80	972554.69	10.03	7.59	11.59	12.09	12.09
WJEGTA527 (Aug. 2003)	6962856.000	2296937.000	324553.34	972553.32	10.66	7.28	11.28	11.78	12.00
WJEGTA527 (Oct. 2002)	6962856.000	2296937.000	324553.34	972553.32	8.91	7.28	11.28	11.78	12.00
WJEGTA529	6962759.000	2296997.000	324552.37	972552.62	8.86	9.06	11.06	11.56	12.00
WSAICTA027	6962284.321	2294391.604	324547.94	972623.19	19.59	16.50	31.50	34.00	34.00

[1] Northing—North State Plane coordinate of the north-south distance, in feet, of a location from a reference location of known State Plane coordinates. In this application, the reference location is N65616666.67.

[2] Easting—North State Plane coordinate of the east-west distance, in feet, of a location from a reference location of known State Plane coordinates. In this application, the reference is E1968500.00.

3. Readings from the pressure transducer were allowed to stabilize (usually 10 to 15 minutes) before slugs were introduced;
4. When possible, slugs were positioned with their bottoms 1 foot or more above the top of transducer and with their tops 1 foot or more below the static water levels (before slugs were introduced);
5. Once slugs were introduced, readings from the transducer were allowed to stabilize before tests were initiated;
6. The data logger was started a few seconds before slugs were removed from the well bores;
7. The resulting rising-head data were collected until readings from the pressure transducers stabilized.

Analyses and Estimates of Hydraulic Conductivity

The hydraulic-conductivity estimates provided herein were analyzed with a spreadsheet program (Halford and Kuniansky, 2002) that solves the Bouwer and Rice (1976) algorithm (eq. 1) using well and water-level data collected (figs. 3, 4; tables 3, 4). Figure 5 and table 5 summarize the results of these analyses. Figure 5 is a frequency distribution of hydraulic-conductivity values obtained during this study. The values range from 0.2 to 200 feet per day, and 83 percent are within the range from greater than 1 to 100 feet per day. Although the hydraulic-conductivity values from the study represent only a small sample of all possible values, the results appear consistent with a statistical analysis of possible values (Halford and Kuniansky, 2002). According to Halford and Kuniansky (2002, p. 9), the likely minimum and likely maximum values of hydraulic conductivity are 1 and 100 feet per day, respectively, while the extreme possibilities range from 0.01 to 300 feet per day.

Table 5. Summary of hydraulic-conductivity estimates, slug discrepancies, and 90-percent recovery times for wells in alluvial aquifer underlying Air Force Plant 4 and Naval Air Station-Joint Reserve Base Carswell Field, Fort Worth, Texas.

Well number	Hydraulic conductivity (feet per day)	Slug discrepancy[1] (percent)	Time for 90-percent recovery (seconds)
BGSMW06	10	7	81
GMI–22–08M	.2	49	962
HM–100	4	10	35
HM–119	200	48	3
HM–124	2	26	329
HM–125	.8	10	692
HM–126	60	14	6
HM–14	200	19	3
HM–23	10	29	80
LF03–3D	10	10	19
MW–12	7	40	66
ST14–03	5	4	33
ST14–W23	10	51	25
USGS06T	50	8	7
WHGLTA009	2	16	183
WHGLTA010	.2	21	2,096
WHGLTA034	20	24	16
WHGLTA044	9	40	35
WHGLTA049	8	51	30
WITCTA001	50	11	5
WITCTA019	60	48	4
WJEGTA514	7	35	257
WJEGTA515	2	41	813
WJEGTA516	9	27	135
WJEGTA523	30	46	34
WJEGTA525	4	6	318
WJEGTA527 (Aug. 2003)	2	38	483
WJEGTA527 (Oct. 2002)	2	7	737
WJEGTA529	100	19	11
WSAICTA027	4	7	28

[1] Slug discrepancy is difference between theoretical displacement of water and observed displacement of water.

In addition to listing the values of hydraulic conductivity, table 5 provides the associated slug-discrepancy values (difference between theoretical and recorded displacement of water) and 90-percent recovery times (time for well to recover 90 percent of difference between static and slug-displaced water levels). Slug discrepancy is an indicator of slug-test validity (Halford and Kuniansky, 2002). The smaller the slug discrepancy, the more likely the slug-displaced water levels reflect properties of the aquifer rather than extraneous well conditions. Although slug-discrepancy values less than about 20 percent are optimum, values of about 50 percent are considered acceptable for relatively permeable areas of the aquifer (E.L. Kuniansky, U.S. Geological Survey, oral commun., 2003). In the two instances of a 51-percent discrepancy (table 5), the authors decided to retain the associated estimates of hydraulic conductivity because no other conductivity data are available for the extreme southeastern part of the study area (pl. 1). The decision to retain these hydraulic-conductivity values (as well as others from tests with slug discrepancies less than but close to 50 percent) is supported by the fact that these data are to be initial values for a ground-water-flow model and thus likely will be revised during model calibration.

Recovery time is inversely related to aquifer hydraulic conductivity. The 90-percent recovery times range from 3 seconds to 35 minutes (2,096 seconds). Nineteen, or nearly two-thirds, of the tested wells recovered 90 percent of their slug-induced water-level change in less than 2 minutes. The 3-second recovery times were recorded for wells HM–14 and HM–119, which are open to parts of the aquifer composed mostly of relatively permeable, well-sorted sand or sandy gravel, or both. The longest recovery time of 2,096 seconds was recorded in well WHGLTA010 for which a lithologic log indicates a saturated zone composed mostly of fine, silty sand. Not surprisingly, the estimate of hydraulic conductivity from that well (0.2 foot per day) is the smallest reported for the study.

For wells with static water levels below the top of the well screen (27 of the 30 wells tested), graphs of slug-displaced water levels relative to time (figs. 3, 4) sometimes display two straight-line segments of different slopes (Bouwer, 1989). This “double straight-line effect” is especially evident for gravel-packed or highly developed wells, or both, in sediments of

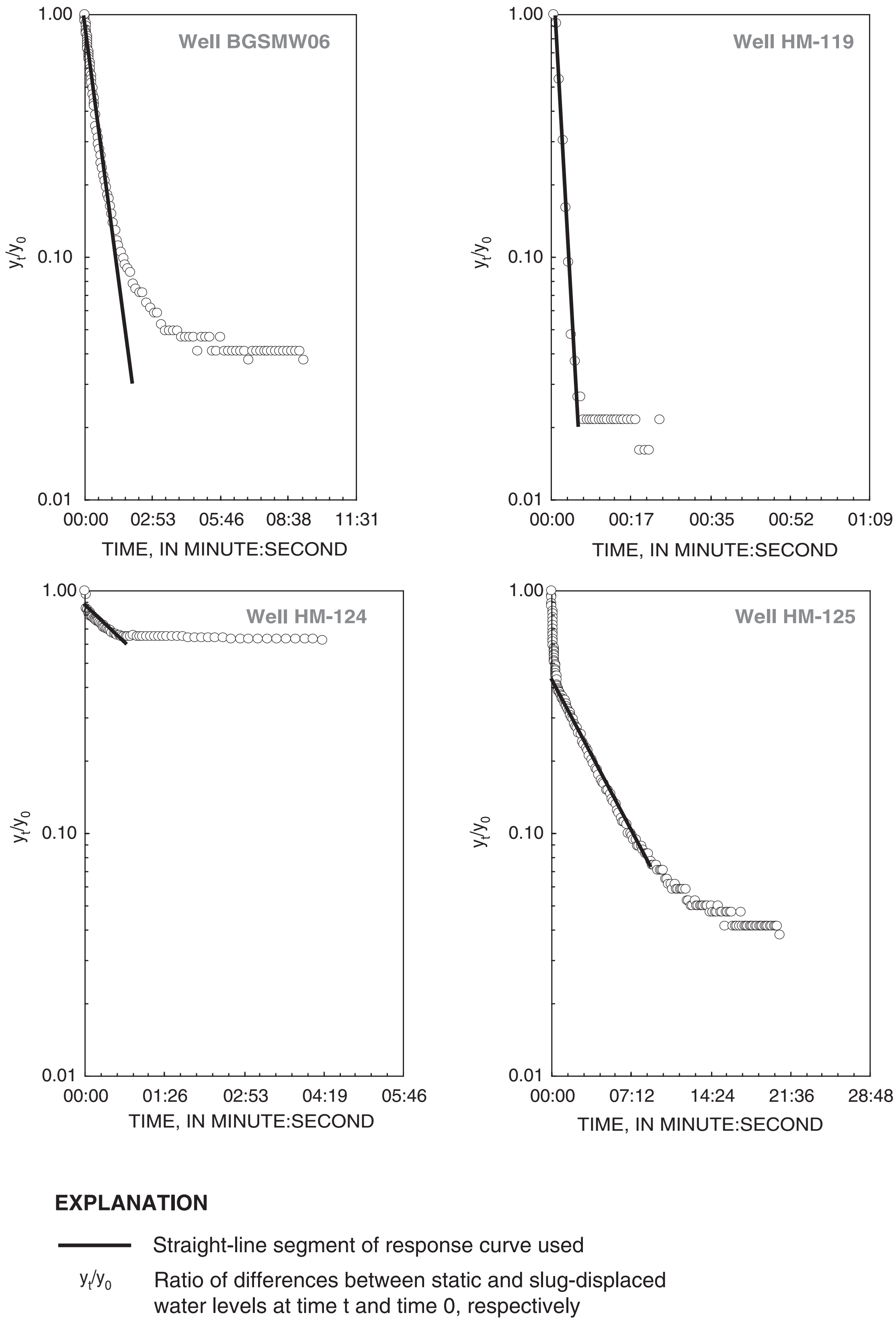


Figure 3. Slug-induced water-level change (normalized) relative to time from slug-test data collected at Air Force Plant 4 (AFP4) and Naval Air Station-Joint Reserve Base Carswell Field (NAS–JRB), Fort Worth, Texas, October 2002.

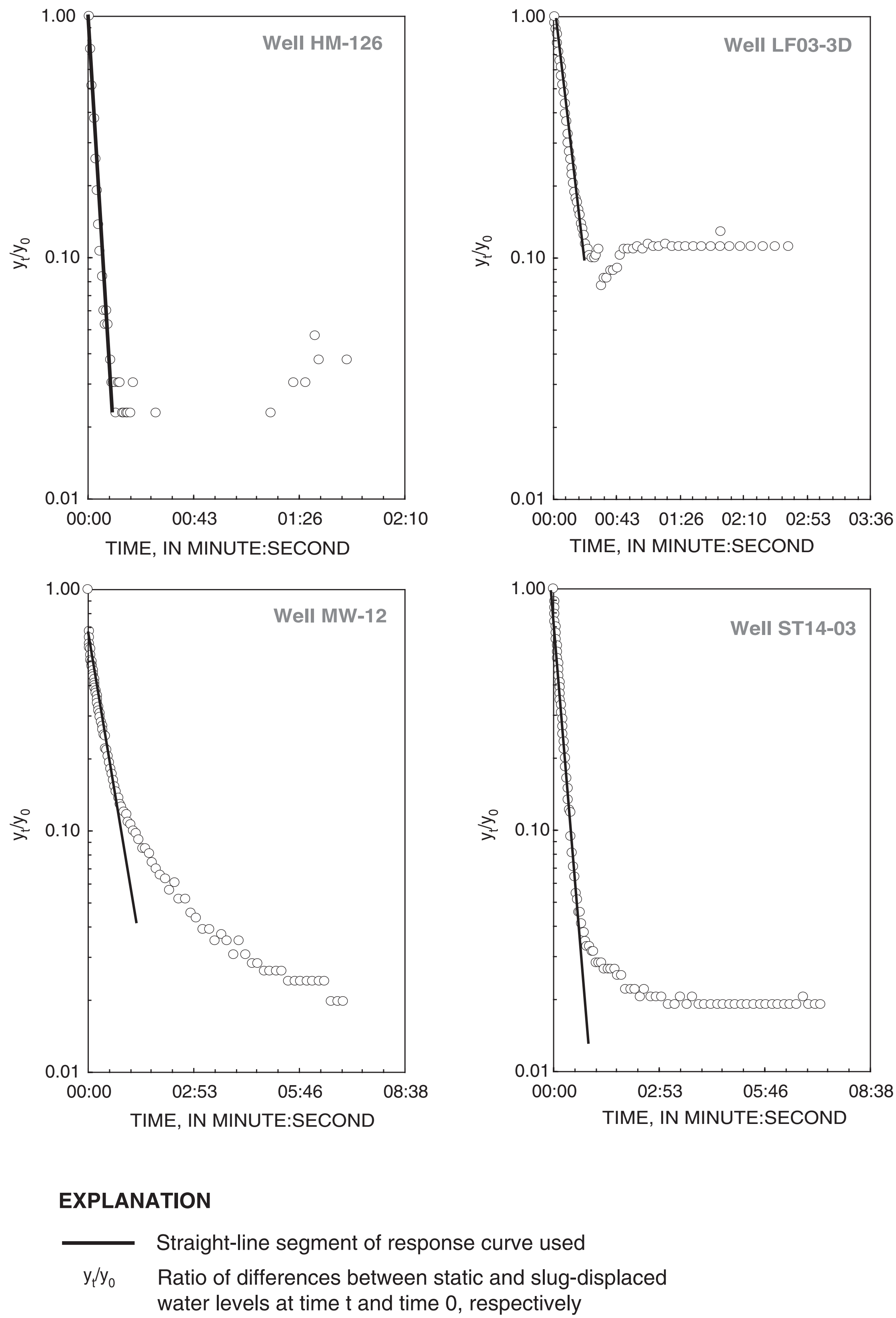
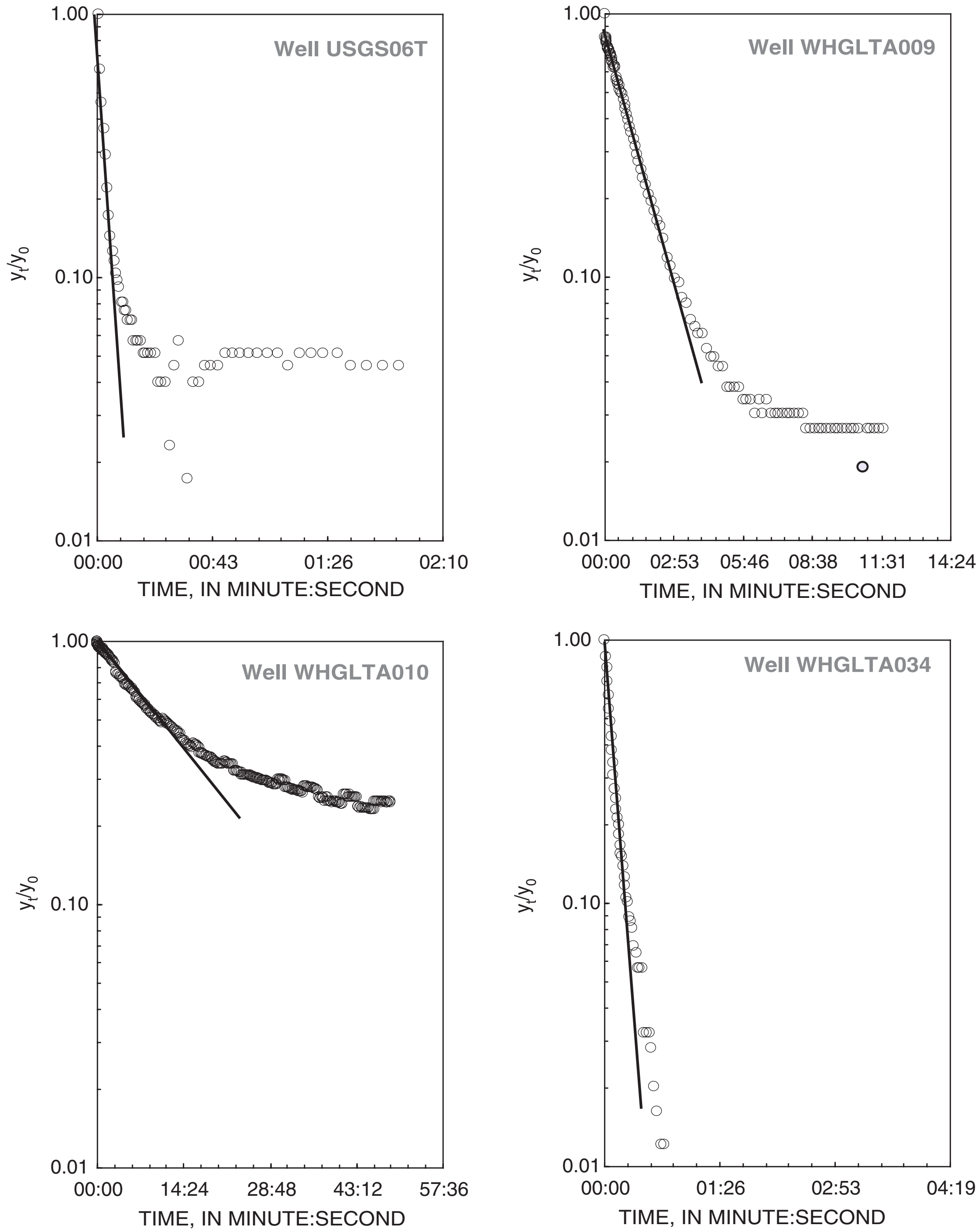


Figure 3—Continued.

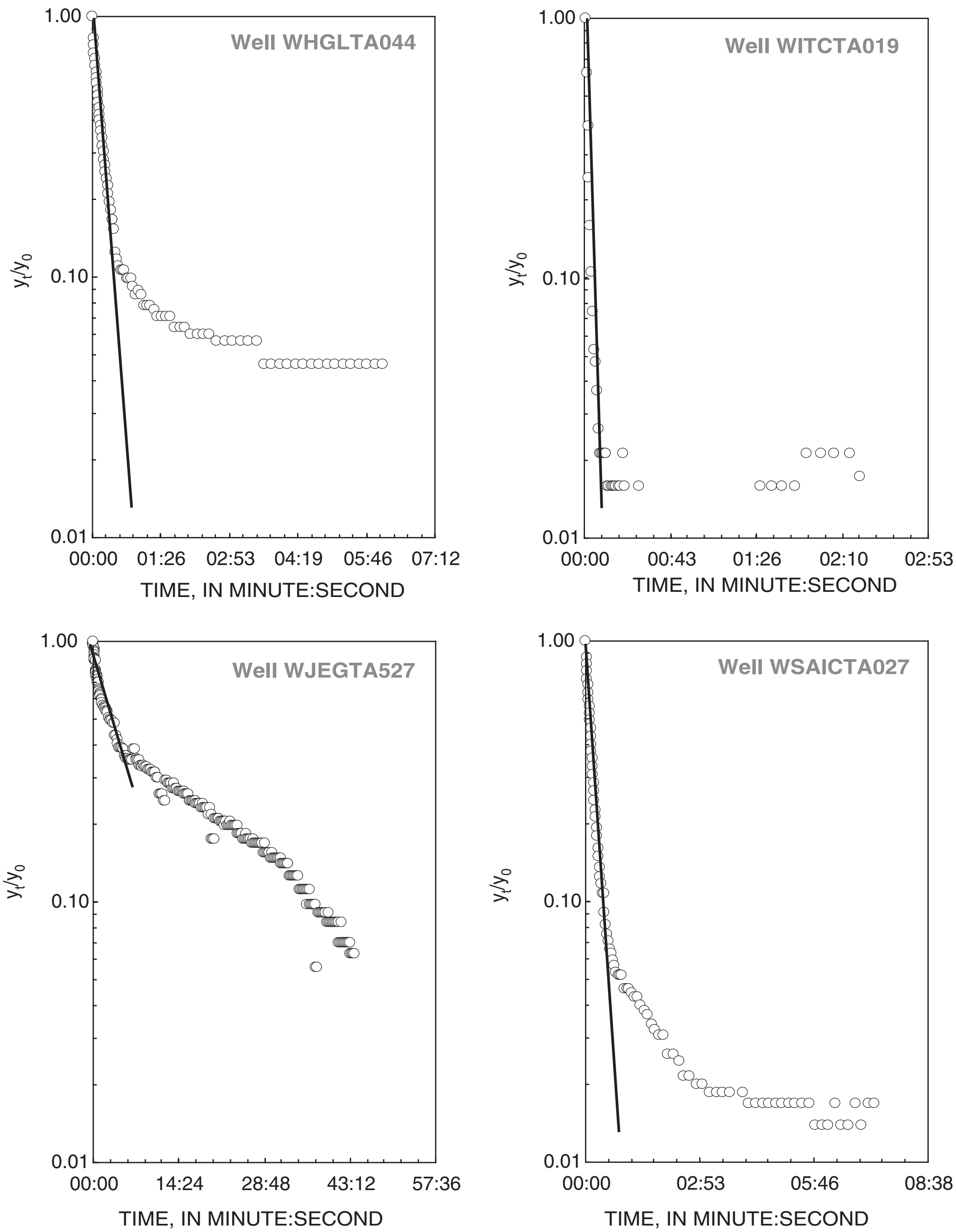


EXPLANATION

Straight-line segment of response curve used

y_t/y_0 Ratio of differences between static and slug-displaced water levels at time t and time 0, respectively

Figure 3—Continued.



EXPLANATION

—— Straight-line segment of response curve used

y_t/y_0 Ratio of differences between static and slug-displaced water levels at time t and time 0, respectively

Figure 3—Continued.

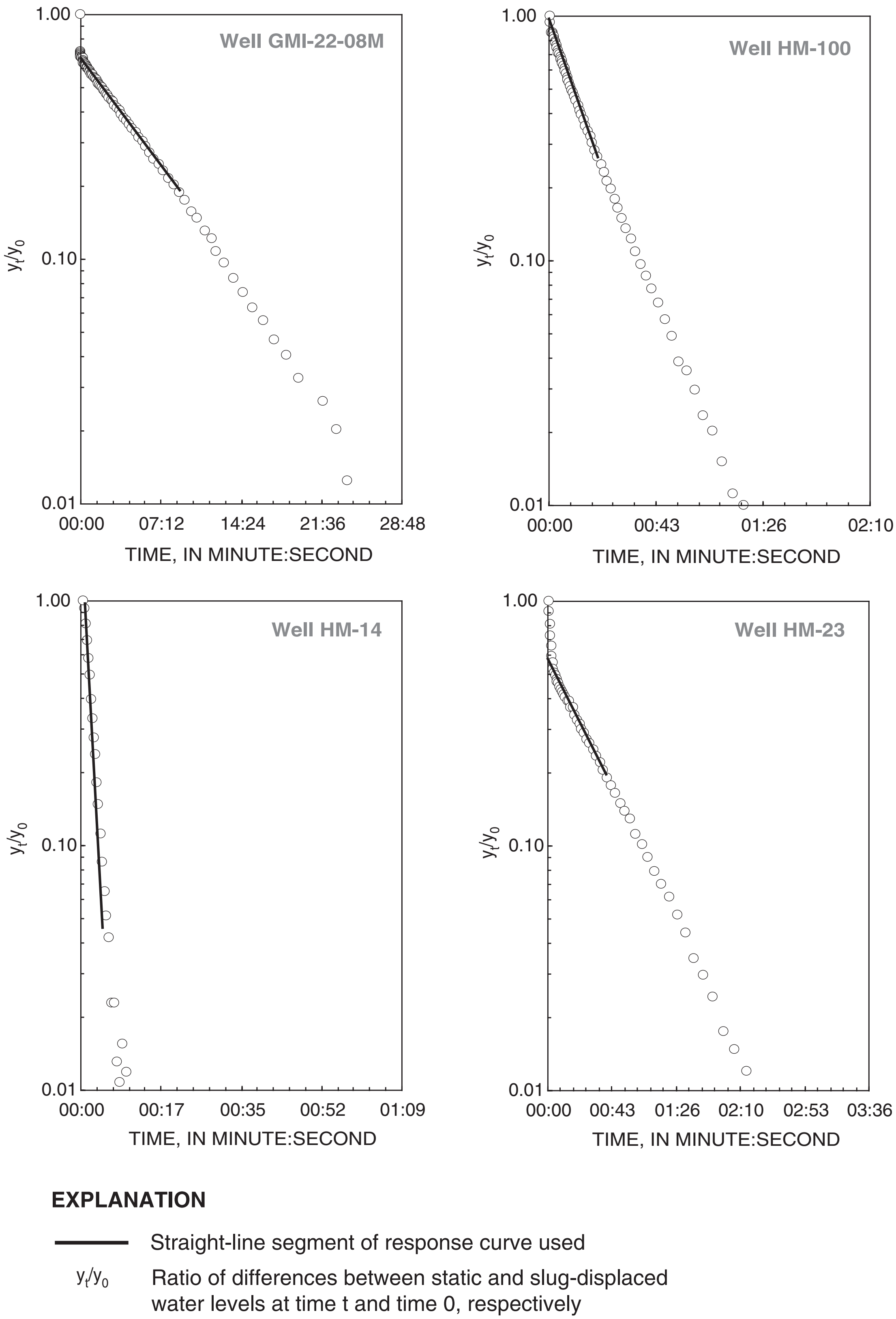


Figure 4. Slug-induced water-level change (normalized) relative to time from slug-test data collected at Air Force Plant 4 (AFP4) and Naval Air Station-Joint Reserve Base Carswell Field (NAS–JRB), Fort Worth, Texas, August 2003.

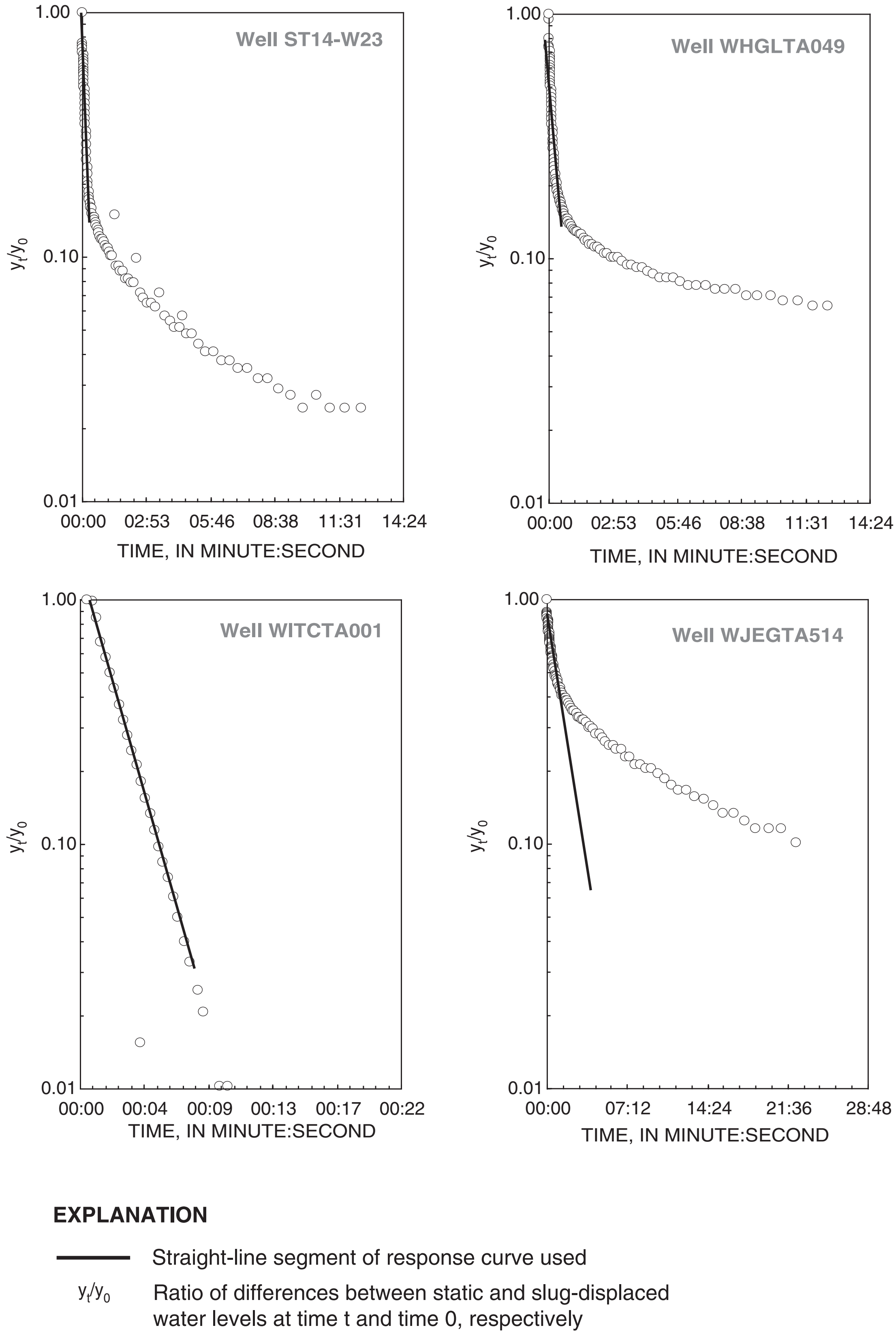
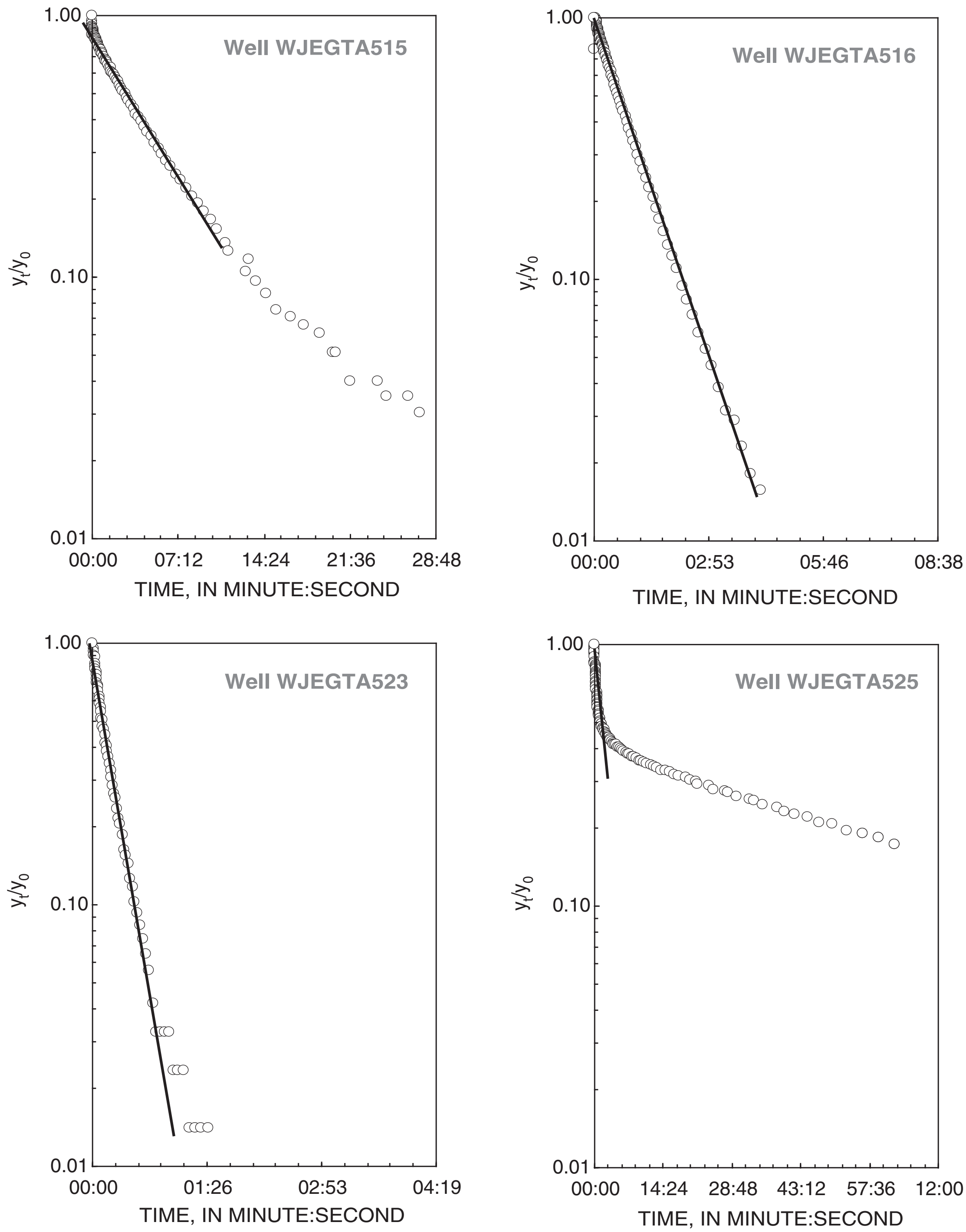


Figure 4—Continued.

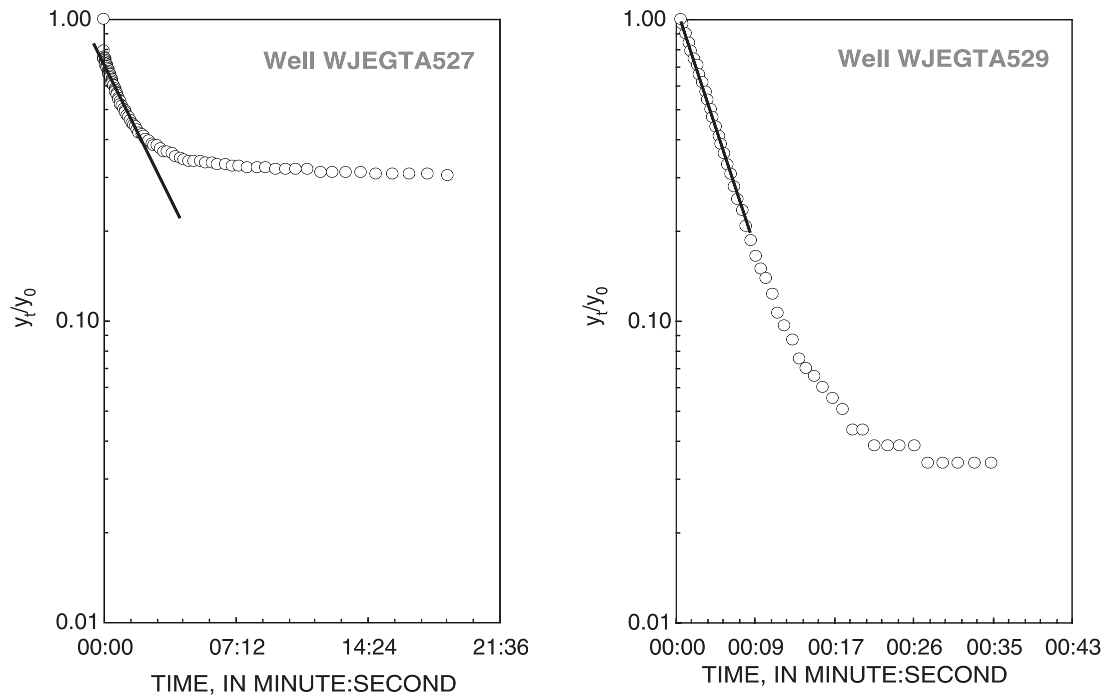


EXPLANATION

Straight-line segment of response curve used

y_t/y_0 Ratio of differences between static and slug-displaced water levels at time t and time 0, respectively

Figure 4—Continued.



EXPLANATION

Straight-line segment of response curve used

y_t/y_0 Ratio of differences between static and slug-displaced water levels at time t and time 0, respectively

Figure 4—Continued.

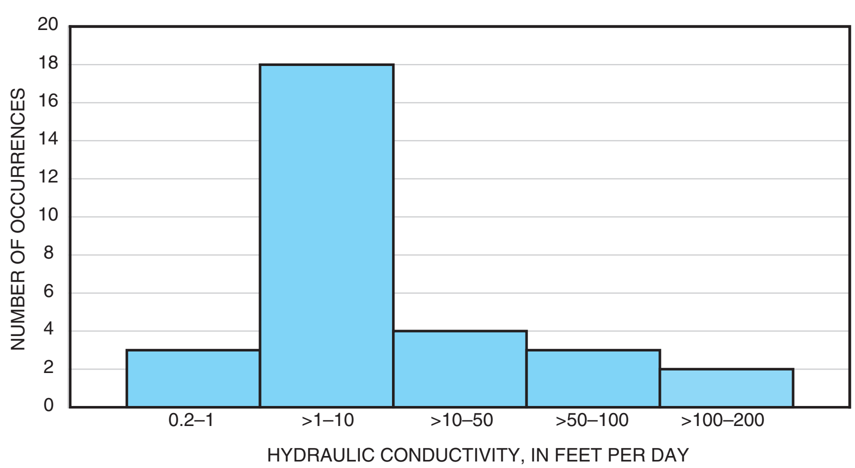


Figure 5. Frequency distribution of hydraulic-conductivity values obtained from analyses of slug-test data collected from wells in alluvial aquifer, Air Force Plant 4 (AFP4) and Naval Air Station-Joint Reserve Base Carswell Field (NAS–JRB), Fort Worth, Texas.

relatively low hydraulic conductivity. According to Bouwer (1989, p. 306–307), the first (upper) slope is most likely associated with drainage from a gravel pack or developed zone whereas the second (lower) slope represents flow from undisturbed parts of the aquifer. For example, the double-line effect is apparent in the graphs for wells HM–124, HM–125, MW–12 (fig. 3), GMI–22–08M, and HM–23 (fig. 4). Whether a graph shows a true double straight line is a matter of judgment. In fact, many of the graphs do not show distinct single straight-line responses, thus considerable judgment commonly is required to select the best-fit line.

Other noteworthy conditions encountered during the October 2002 and August 2003 tests that might have some effect on the resulting estimates of hydraulic conductivity include (1) readings from the data logger might have been too infrequent to record the maximum water-level displacements in wells HM–119, HM–14, and WITCTA019; (2) transducer signals were unstable in well USGS06T, owing to nearby aircraft activity; and (3) slugs were incompletely submerged in wells USGS06T, WHGLTA044, and WJEGTA527. Although precautions were taken to minimize and correct for all known effects of problems related to the slug-testing procedures, it is impossible to know whether, or to what extent, the resulting estimates of hydraulic conductivity are affected. For the three wells in which the slugs were not completely submerged, the variables (eq. 1) were adjusted during analysis to account for the reduced length of slug.

The slug-test results indicate that the alluvial aquifer might be clogging locally (presumably with organic matter) as the result of recent bioremediation on NAS–JRB. Some of the wells that were tested are on the site of a phytoremediation demonstration project that was initiated in 1996 (Shah and Braun, 2004). Data from four of seven wells inside the tree stands or within 125 feet downgradient from the tree stands (WJEGTA[514, 515, 516, 523, 525, 527, 529]) indicate a decrease in hydraulic conductivity compared to those from 1996 slug tests (table 2, table 5). The possibility of clogging is particularly evident with respect to well WJEGTA527. The hydraulic-conductivity estimate for this well (2.0 feet per day)—verified by the tests in both October 2002 and August 2003—is five times less than that estimated from pre-remediation, 1996 data collected from WJEGTA527.

Summary

Disposal of hazardous chemicals, including trichloroethene (TCE), at Air Force Plant 4 (AFP4) in Fort Worth, Tex., associated with the manufacture of military aircraft and other equipment since 1942 has resulted in TCE entering the groundwater-flow system beneath AFP4 and migrating to the subsurface beneath adjacent Naval Air Station-Joint Reserve Base Carswell Field (NAS–JRB). The U.S. Geological Survey, in cooperation with the U.S. Air Force, did a series of slug tests at AFP4 and NAS–JRB to obtain estimates of horizontal hydraulic conductivity to use as initial values in a ground-water-flow model for the site.

During October 2002 and August 2003, after reviewing aquifer- and slug-test data from previous investigations, the USGS completed slug tests in 30 wells penetrating the alluvial aquifer. This report describes the collection, analyses, and distribution of hydraulic-conductivity data obtained from slug testing three wells at AFP4 and 27 wells at NAS–JRB and summarizes previously available hydraulic-conductivity data. The testing procedures were refined largely through trial-and-error experimentation at the first three wells tested during October 2002 and at the first well tested during August 2003.

The slug tests were done by placing a slug of known volume beneath the water level in selected wells, removing the slug, and measuring the resulting water-level recovery over time. The rates of water-level recovery were measured with a pressure transducer and recorded with a data logger until the water levels returned to their original static condition. The slugs were made from different diameters and lengths of polyvinylchloride pipe, which were filled with sand and capped at both ends. Although attempts were made to make both falling-head (slug inserted into well) and rising-head (slug removed from well) tests, only the rising-head data were used to estimate hydraulic conductivity. The resulting water-level responses were recorded on logarithmic time scales.

Data obtained from the slug tests were used to estimate hydraulic conductivity from an analytical relation between the instantaneous displacement of water in a well bore and the resulting rate of water-level change. The analyses are based the Bouwer and Rice algorithm, which accounts for fully or partially penetrating wells in unconfined aquifers. The resulting hydraulic-conductivity values range from 0.2 to 200 feet per day. Eighty-three percent are within the (previously determined) statistical likely minimum and maximum values of 1 and 100 feet per day, respectively. Ninety-percent recovery times ranged from 3 seconds to 35 minutes. Nearly two-thirds of the tested wells recovered 90 percent of their slug-induced water-level change in less than 2 minutes.

Although precautions were taken to minimize and correct for all known effects of problems related to the slug-testing procedures, it is impossible to know whether, or to what extent, the resulting estimates of hydraulic conductivity are affected.

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