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TECHNICAL MEMORANDUM

TO:	Curtis Koger and Jenny Saltonstall, Associated Earth Sciences Inc.	**DATE:**	March 14, 2008
FR:	Derek Holom and Jim Johnson, L.E.G., Golder Associates Inc.	**OUR REF:**	063-1076.501
RE:	The Villages Aquifer Testing and Sampling Results		

This technical memorandum summarizes the results of the aquifer testing conducted by Golder Associates Inc at The Villages project site in late 2006 and early 2007. Attached are the results of the aquifer testing. In total, there were 11 wells tested by means of a constant rate pumping test or a falling head test. A summary of the methodology of the aquifer testing is described below.

1.0 METHODOLOGY OF AQUIFER TESTING

1.1 Constant Rate Pumping Test

Constant rate pumping tests were conducted in 7 of the 11 wells tested to determine the transmissivity (T) of the aquifer at each well. The pumped wells include MW-6, MW-7, MW-9, MW-10, MW-12, MW-15, and MW-17. Tacoma Pump and Drilling was contracted to install and operate the pump in seven of the wells. Discharge was to the ground at a distance of 50 feet or more. Average flow rates were measured by a totalizer meter by calculating the difference between the readings at the start and end of the test. In some cases, the flow rates were measured with a 5-gallon bucket and stop watch. Manual water-level measurements were recorded using a water-level tape. Automated water-level measurements were recorded using a Solinst® pressure transducer datalogger owned by Associated Earth Sciences Inc. The pumping test data were analyzed using the Cooper-Jacob straight-line method and in some cases using the Uffink method for underdamped responses (oscillations in the water level during recovery). The results of the pumping tests are listed in Table 1 (see attached).

1.2 Falling Head Tests

Falling head tests, or slug tests, consist of adding a known volume (slug) to a well and recording the change in head (water level) versus time. A slug can be a weighted cylinder, such as a capped PVC tube filled with sand, or it can be simply a bucket of water. The wells that were tested or analyzed using the falling head technique were MW-5, MW-8, MW-13, and MW-19. Two 5-gallon buckets of water were simultaneously added to each well while automatically recording water levels with an

INW[1] pressure transducer datalogger. The falling head test data were analyzed using the Hvorslev method. Results of the falling head tests are listed in Table 1.

2.0 METHODOLOGY OF WATER QUALITY SAMPLING

Water quality samples were collected from 11 wells, which included all of the tested wells except for MW-5. DH-3 was not tested for aquifer parameters, but a water quality sample was collected and analyzed. A water quality sample was collected from each of the pumped wells at the end of the aquifer test. Water quality samples were collected with a bailer for the wells that were not pumped. In all cases, three well bore volumes were purged before collecting a sample to obtain a more accurate water sample of the aquifer formation. All samples were submitted to Anatek Labs in Redmond, WA to be analyzed. The lab results are presented in Table 2 (see attached).

[1] INW stands for Instrumentation Northwest, based in Kirkland, WA.

TABLES

Summary of the Aquifer Testing for The Villages at Black Diamond, WA

Well ID	Well Depth (feet)	Depth to Water[3] (feet bgs)	Groundwater Elevation (ft amsl)	Ground Elevation (ft amsl)	Aquifer Unit	Aquifer Test	Water Quality Sample	Average K[a] (ft/day)	Average T[b] (ft^2/day)	Comments
MW-1	59.6	DRY	N/A	?	Shallow	--	No	--	--	Dry, no water available for sample or test
MW-2	66.9	53.46	508.34	561.8	Deep[1]	--	No	--	--	Not completed in Qpogc, Qva, or Qvr aquifer
MW-3	81.6	23.68	537.92	561.6	Deep[1]	--	No	--	--	Not completed in Qpogc, Qva, or Qvr aquifer
MW-4	67	62.45	552.65	615.1	Deep[2]	--	No	--	--	Limited access
MW-5	70	67.15	537.85	605	Deep[2]	SLUG	No	8.7	--	Hvorslev Falling Head Test Method
MW-6	178	98.46	491.54	590	Deep	PUMP	Yes	--	27,000	Cooper-Jacob and Uffink Analysis Methods
MW-7	126	58.28	493.72	552	Deep	PUMP	Yes	--	21,550	Cooper-Jacob Straightline Method
MW-8	27	15.53	536.57	552.1	Shallow	SLUG	Yes	0.24	--	Hvorslev Falling Head Test Method
MW-9	24	2.24	548.86	551.1	Shallow	PUMP	Yes	--	100	Cooper-Jacob Straightline Method
MW-10	173	99.18	480.82	580	Deep	PUMP	Yes	--	44,800	Cooper-Jacob and Uffink Analysis Methods
MW-11	304	69.50	465.5	535	Bedrock	--	No	--	--	Not completed in Qpogc, Qva, or Qvr aquifer
MW-12	79	49.14	485.86	535	Deep	PUMP	Yes	--	2,500	Cooper-Jacob Straightline Method
MW-13	49	43.91	491.09	535	Deep	SLUG	Yes	370	--	Hvorslev Falling Head Test Method
MW-14	110.5	83.62	603.38	687	Deep[1]	--	No	--	--	Not completed in Qpogc, Qva, or Qvr
MW-15	341.5	186.58	490.42	677	Bedrock	PUMP	Yes	--	2	Cooper-Jacob Straightline Method
MW-16	31.6	DRY	N/A	?	Shallow	--	No	--	--	Dry, no water available for sample or test
MW-17	87.5	52.34	484.66	537	Deep	PUMP	Yes	--	108,000	Cooper-Jacob and Uffink Analysis Methods
MW-18	23.8	21.59	515.41	537	Shallow	--	No	--	--	Fallen trees are blocking access
MW-19	176.4	104.70	495.3	600	Deep[1]	PUMP	Yes	0.94	--	Hvorslev Falling Head Test Method

Aquifer Units

[1] Perched zone within Qpo formation

[2] Completed in Qva aquifer

Shallow is recessional outwash deposits (Qvr)

Deep is pre-Olympia coarse-grained glacial outwash of sands and gravels (Qpog-c)

[3] Water level measurements taken in mid-December 2006

Aquifer Parameters

[a] Hydraulic conductivity

[b] Transmissivity

Water Quality Results for The Villages at Black Diamond, WA

Constiuent	Unit	MW-06	MW-07	MW-09	MW-15	MW-19	MW-10	MW-12	MW-17	MW-13	DH-3	MW-08
Aquifer Unit		Qpog	Qpog	Qvr	Thb	Qpon	Qpog	Qpog	Qpog	Qpog	Qvr?	Qvr
pH		6.88	6.45	5.73	8.92	9.03	6.64	6.11	6.62	6.38	6.14	na
Temperature	C°	9.8	9.4	10.1	10.7	14	10	9	8.9	8.7	5.7	na
Conductivity	µs	70.5	62.3	43.1	112.6	74.4	74.8	43.1	66.7	31.9	17.2	na
Turbidity	NTU	0.69	0.84	137	51.3	36.9	1.2	31.1	2.7	200	280.0	na
Fecal Coliforms	CFU/100 ml	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
TOC	mg/l	< 1	< 1	< 1	< 1	< 1	< 1	2.7	4.1	< 1	1.2	< 1
Alkalinity	mg/l	58	52	32	140	90	58	38	54	34	10	30
Cl	mg/l	3.1	2.9	2.3	3.6	1.8	2.5	2	< 1	< 1	7.4	4.5
Hardness (CaCO3)	mg/l	68	59	33	11	69	61	34	55	30	11	28
S(6)	mg/l	9.3	9	3.5	1.1	6.6	7.2	2.1	6.3	1.9	1.6	5.9
Ca	mg/l	20	18	8.9	3	18	18	8.6	14	7.1	3.2	7.6
P	mg/l	0.83	0.69	0.34	0.71	1.3	0.53	1.6	1.1	0.5	0.42	0.78
Mg	mg/l	4.4	3.4	2.6	0.91	5.8	4	3.1	4.8	2.9	0.81	2.1
Na	mg/l	7.8	3.3	5.6	54	12	3.7	4.4	4.9	3.1	1.9	4.5
N(3)	mg/l	<0.005	<0.005	<0.005	0.24	0.22	<0.005	0.05	0.013	0.037	<0.005	0.03
N(5)	mg/l	0.38	1.2	0.39	0.94	1	0.95	0.24	0.46	0.1	0.33	0.42
Total Phosphate	mg/l	<0.005	<0.005	<0.005	0.22	0.13	0.019	0.019	0.048	<0.005	<0.005	<0.005
Fe	mg/l	<0.005	0.005	0.077	0.027	<0.005	0.018	0.029	0.009	<0.005	0.405	0.058
Mn	mg/l	0.0027	0.0039	0.0459	0.0251	0.0947	0.0007	0.0142	0.0008	0.0117	0.0054	0.014
Cu	mg/l	<0.001	0.002	0.004	0.002	0.003	0.004	0.004	0.004	0.004	<0.001	0.003
Pb	mg/l	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Zn	mg/l	0.006	0.009	0.032	0.038	0.083	0.013	0.006	0.003	0.004	0.002	0.002

Notes:
Raw data results from laboratory; not internally checked
na - not available
< indicates non-detect

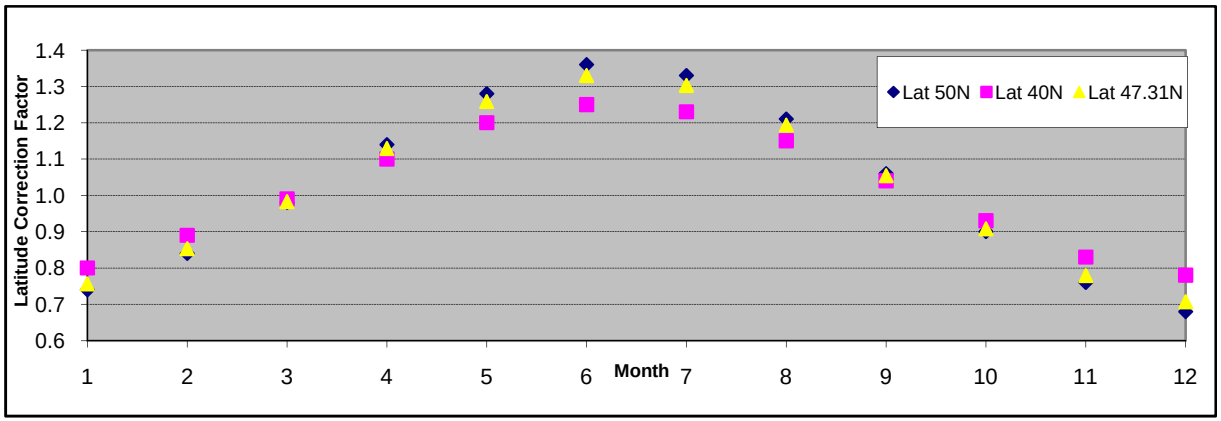
Evapotranspiration Values for Lawson Hills Pre-Development Condition

	Evapotranspiration (in)			Landsburg Station Data									
Method	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Annual**
Thornthwaite	1.557	0.819	0.462	0.774	0.524	1.031	1.754	2.814	3.951	4.547	3.855	2.946	25.033

Thornthwaite method pg. 138 in Water in Environmental Planning by Dunne and Leopold, 1978

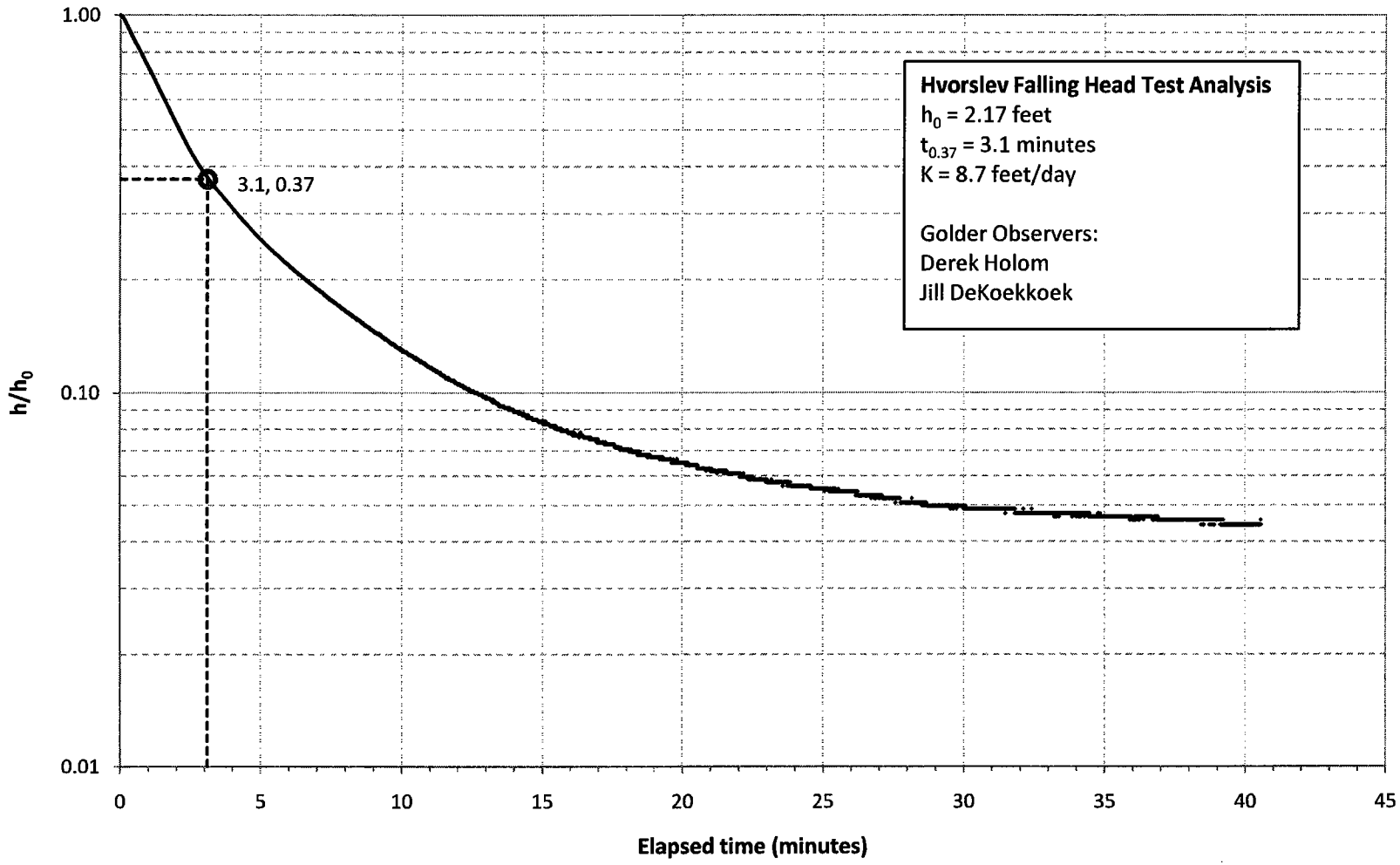
	Temperature (C)			Landsburg Station Data									
	Oct	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Annual**
	9.433	6.044	3.917	5.894	3.700	6.028	8.622	12.017	15.567	18.028	16.800	14.722	10.064

	Latitude Correction Factor											
Latitude (N)	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
50	0.740	0.840	0.980	1.140	1.280	1.360	1.330	1.210	1.060	0.900	0.760	0.680
40	0.800	0.890	0.990	1.100	1.200	1.250	1.230	1.150	1.040	0.930	0.830	0.780
47.31	0.756	0.853	0.983	1.129	1.258	1.330	1.303	1.194	1.055	0.908	0.779	0.707



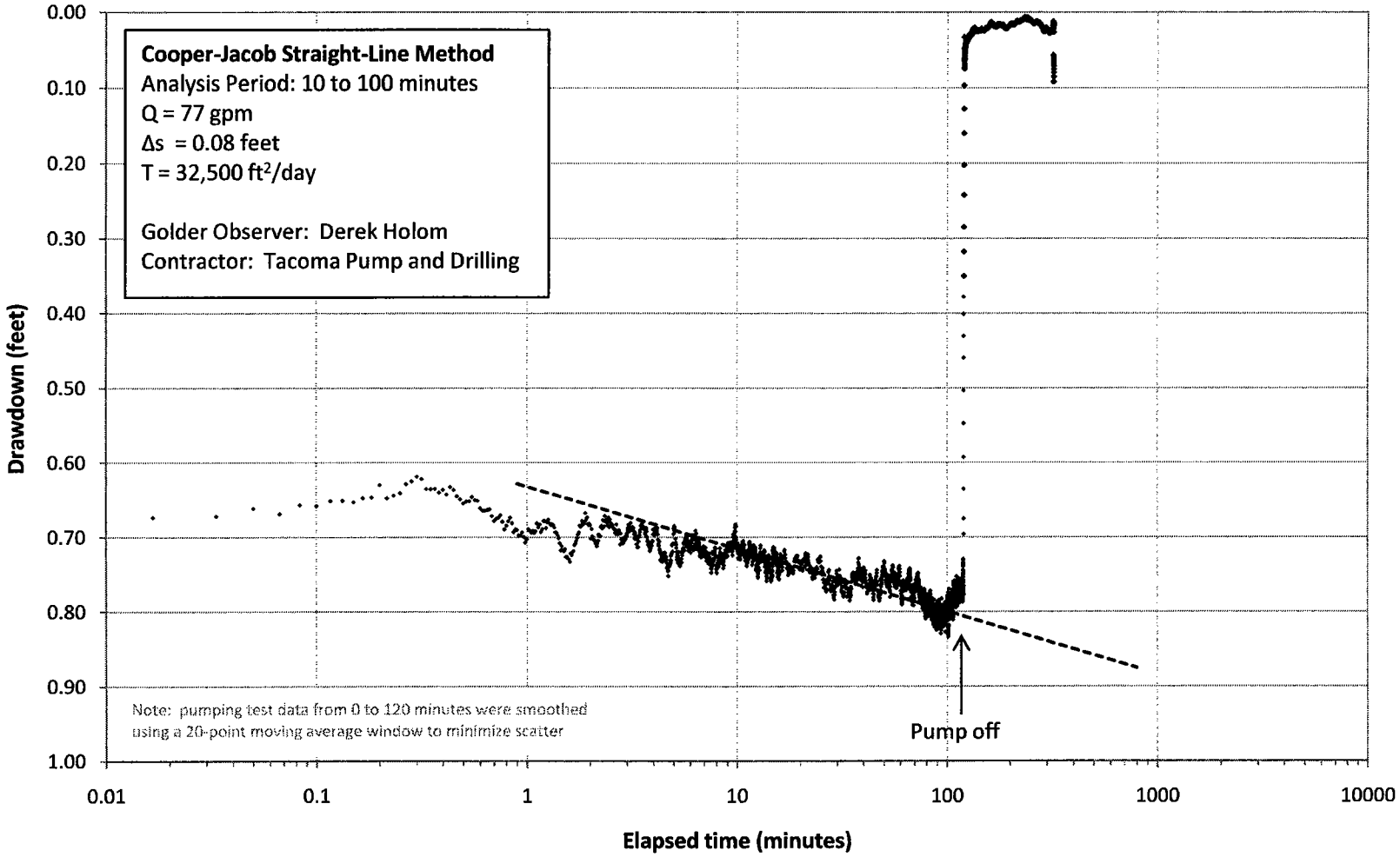
Temperature Data Source: http://www.wrcc.dri.edu/Climsum.html

FIGURES



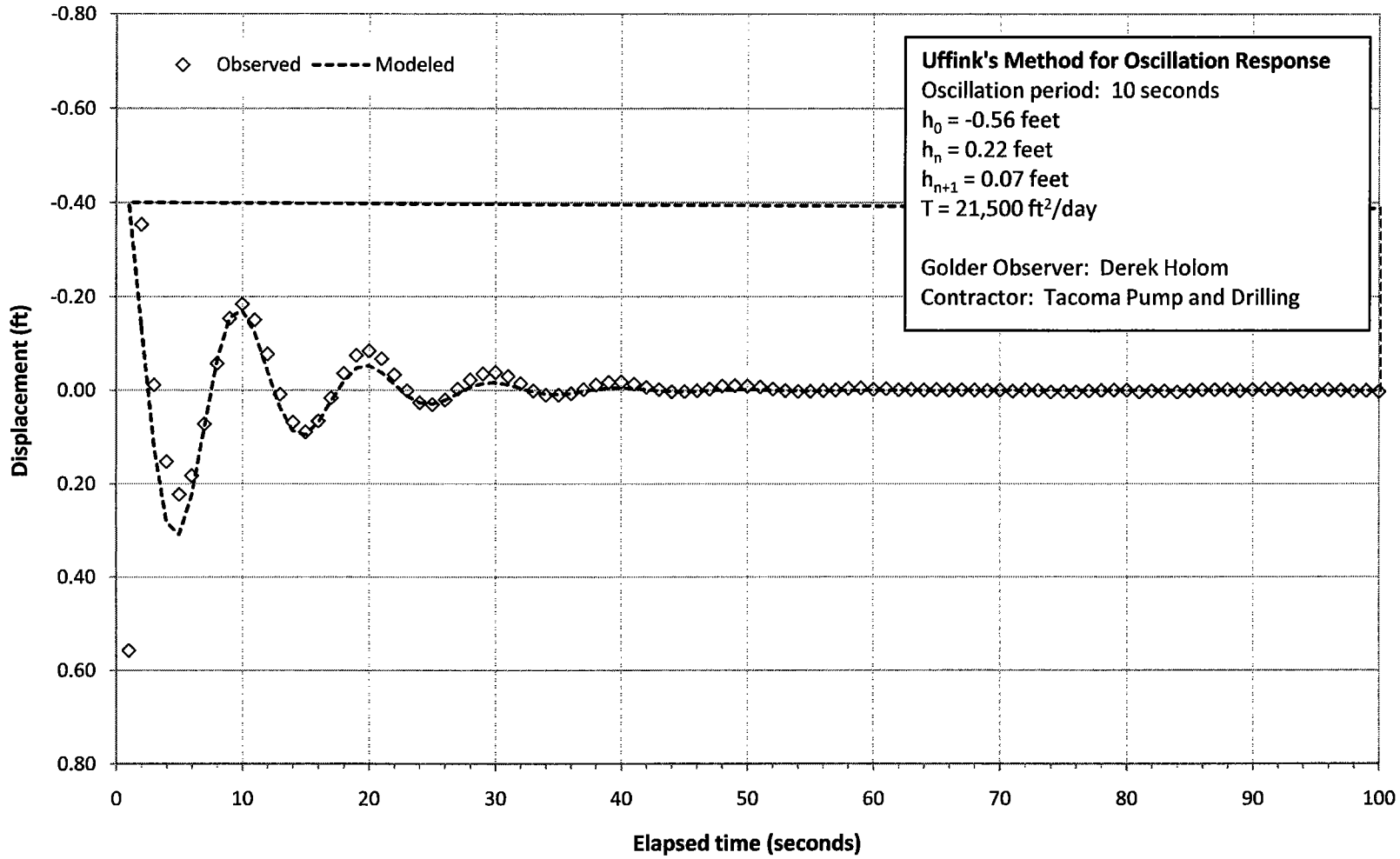
Golder Associates	Title: MW-5 Falling Head Test		Drawn: DH
			Checked: MK
	Project Name: The Villages	Project No.: 063-1076.501	Reviewed: CA
	Client Name: BD Villages, LP	Date: February 26, 2008	FIGURE 1

\\SEA1-S-FS1\Data1\Engineering\PROJECTS\2006\063-1076_BDP_The Villages_Johnson\501 Aquifer Testing and Geophysics\Groundwater Data\Aquifer Test Data\Updated 2008\MW-5 Falling Head Test.xlsx



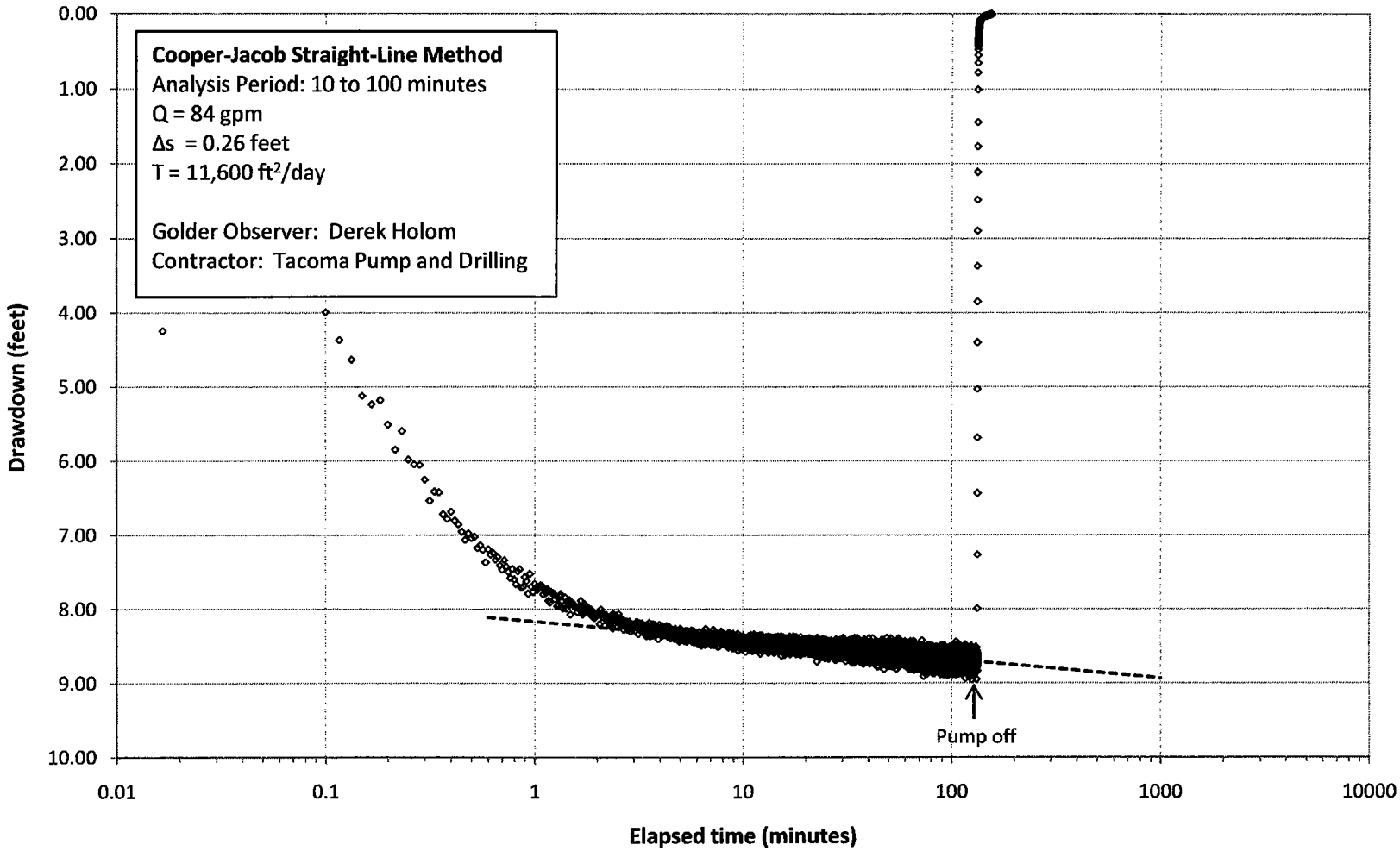
Golder Associates	Title: MW-6 Constant Rate Pumping Test Analysis		Drawn: DH
			Checked: MK
	Project Name: The Villages	Project No.: 063-1076.501	Reviewed: RA
	Client Name: BD Villages, LP	Date: February 26, 2008	FIGURE 2

\\SEA1-S-FS1\Data1\Engineering\PROJECTS\2006\063-1076_BDP_The Villages_Johnson\501 Aquifer Testing and Geophysics\Groundwater Data\Aquifer Test Data\Updated 2008\MW-6 Pumping Test.xlsx



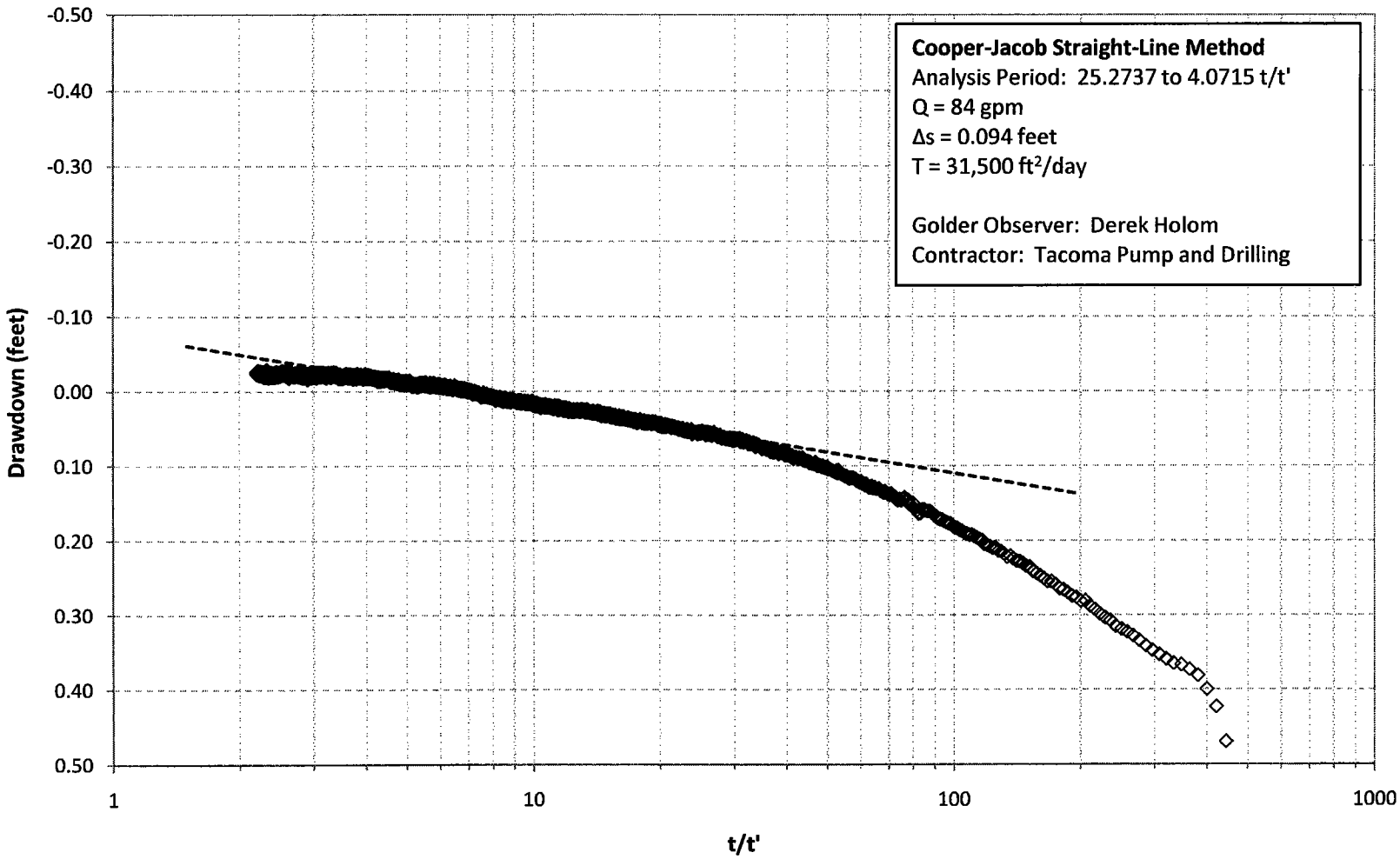
Golder Associates	Title: MW-6 Uffink's Method for Oscillation Response		Drawn: DH
			Checked: MK
	Project Name: The Villages	Project No.: 063-1076.501	Reviewed: MA
	Client Name: BD Villages, LP	Date: February 26, 2008	FIGURE 3

\\SEA1-S-FS1\Data1\Engineering\PROJECTS\2006\063-1076_BDP_The Villages_Johnson\501 Aquifer Testing and Geophysics\Groundwater Data\Aquifer Test Data\Updated 2008\MW-6 Pumping Test.xlsx



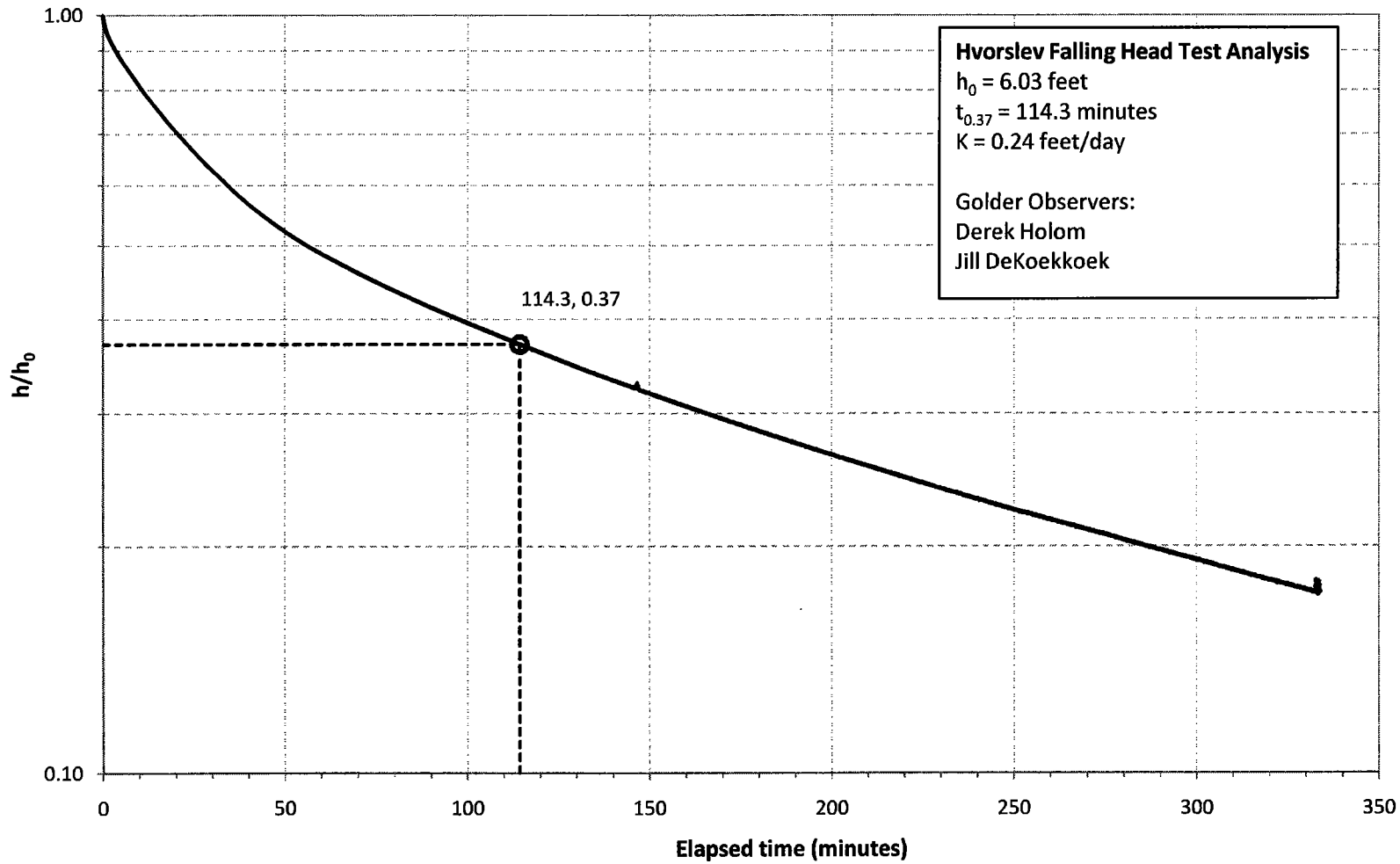
Golder Associates	Title: MW-7 Constant Rate Pumping Test Analysis	Drawn	DH
		Checked	MK
	Project Name: The Villages	Reviewed	CA
	Project No.: 063-1076.501	FIGURE	4
	Client Name: BD Villages, LP		
	Date: February 26, 2008		

\\SEA1-S-FS1\Data1\Engineering\PROJECTS\2006\063-1076_BDP_The Villages_Johnson\501 Aquifer Testing and Geophysics\Groundwater Data\Aquifer Test Data\Updated 2008\MW-7 Pumping Test.xlsx



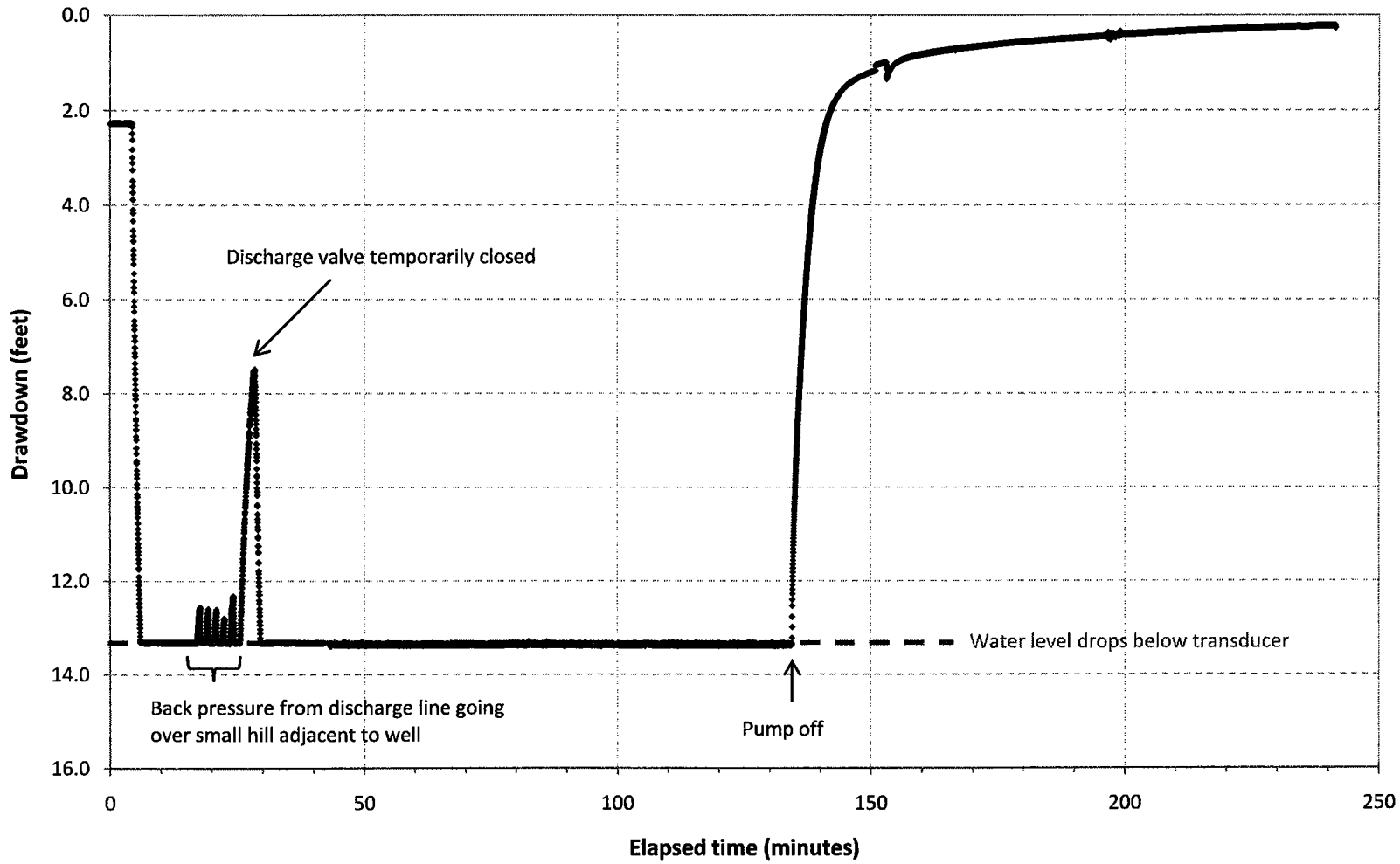
Golder Associates	Title: MW-7 Recovery Analysis		Drawn: DH
			Checked: MK
	Project Name: The Villages	Project No.: 063-1076.501	Reviewed: MA
	Client Name: BD Villages, LP	Date: February 26, 2008	FIGURE 5

\\SEA1-S-FS1\Data1\Engineering\PROJECTS\2006\063-1076_BDP_The Villages_Johnson\501 Aquifer Testing and Geophysics\Groundwater Data\Aquifer Test Data\Updated 2008\MW-7 Pumping Test.xlsx



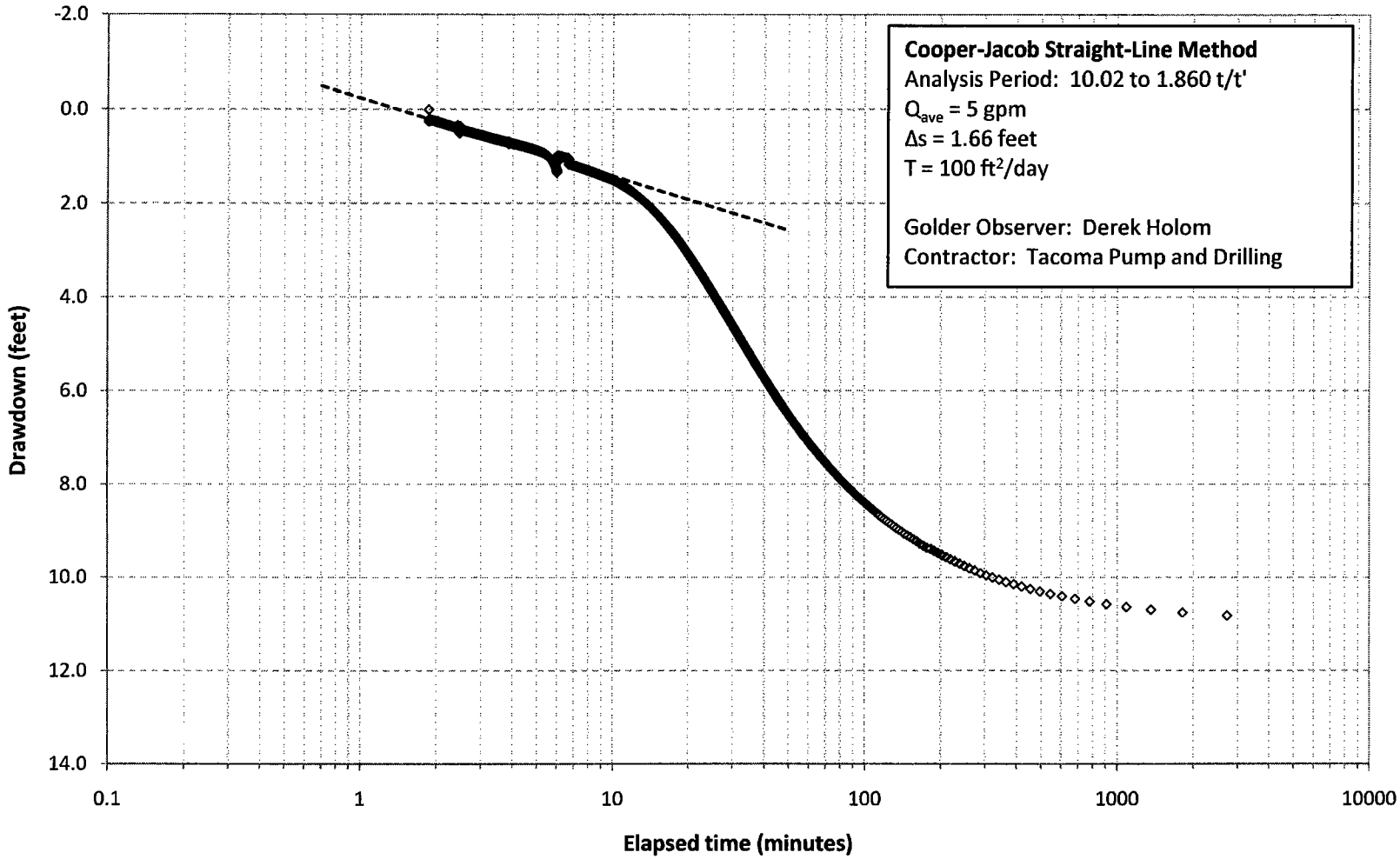
Golder Associates	Title: MW-8 Falling Head Test		Drawn: DH
			Checked: MK
	Project Name: The Villages	Project No.: 063-1076.501	Reviewed: RA
	Client Name: BD Villages, LP	Date: February 26, 2008	FIGURE 6

\\SEA1-S-FS1\Data1\Engineering\PROJECTS\2006\063-1076_BDP_The Villages_Johnson\501 Aquifer Testing and Geophysics\Groundwater Data\Aquifer Test Data\Updated 2008\MW-8 Falling Head Test.xlsx



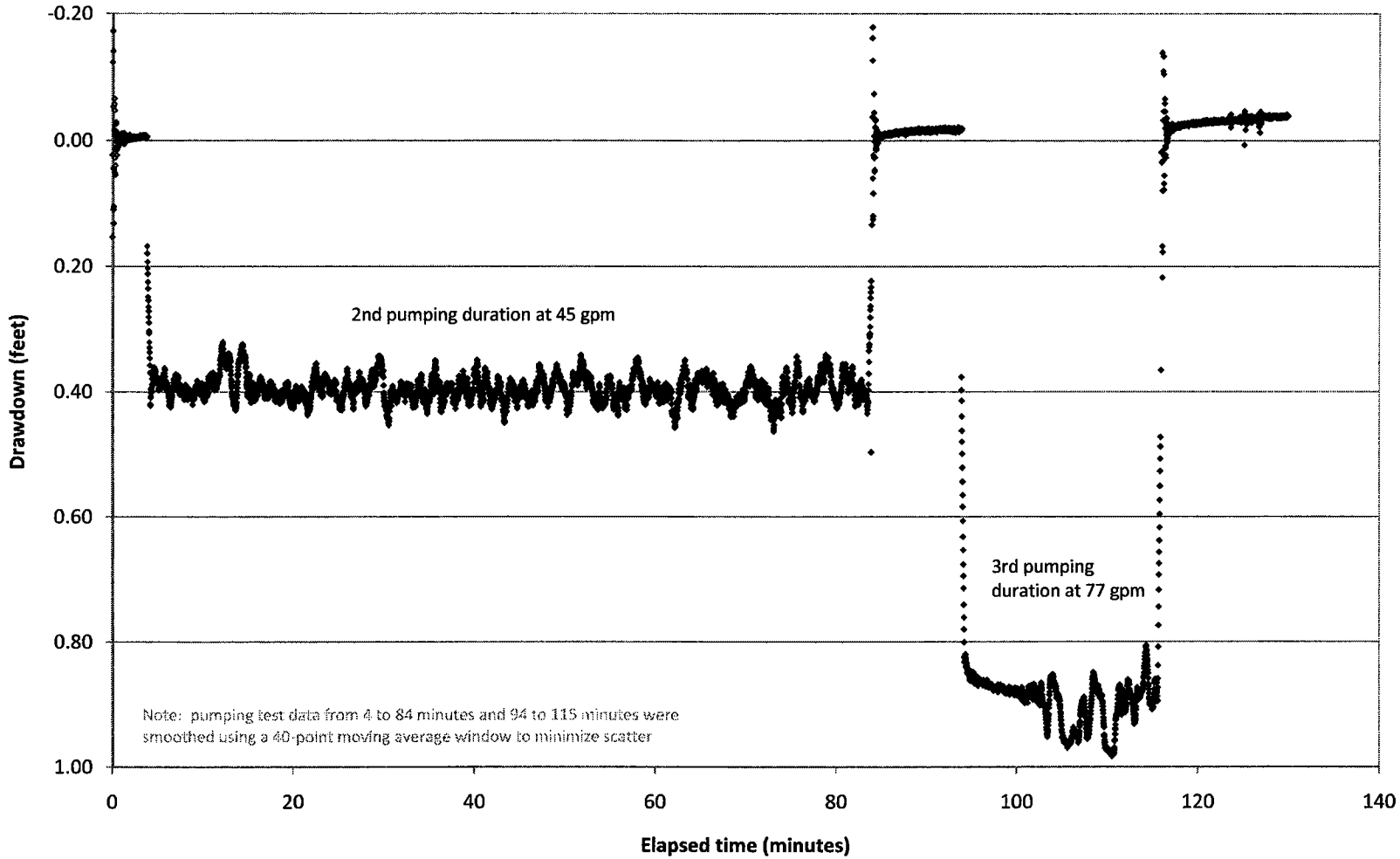
Golder Associates	Title: MW-9 Hydrograph (Pumping Test and Recovery Data)		Drawn: DH
			Checked: MK
	Project Name: The Villages	Project No.: 063-1076.501	Reviewed: CA
	Client Name: BD Villages, LP	Date: February 26, 2008	FIGURE 7

\\SEA1-S-FS1\Data1\Engineering\PROJECTS\2006\063-1076_BDP_The Villages_Johnson\501 Aquifer Testing and Geophysics\Groundwater Data\Aquifer Test Data\Updated 2008\MW-9 Pumping Test.xlsx



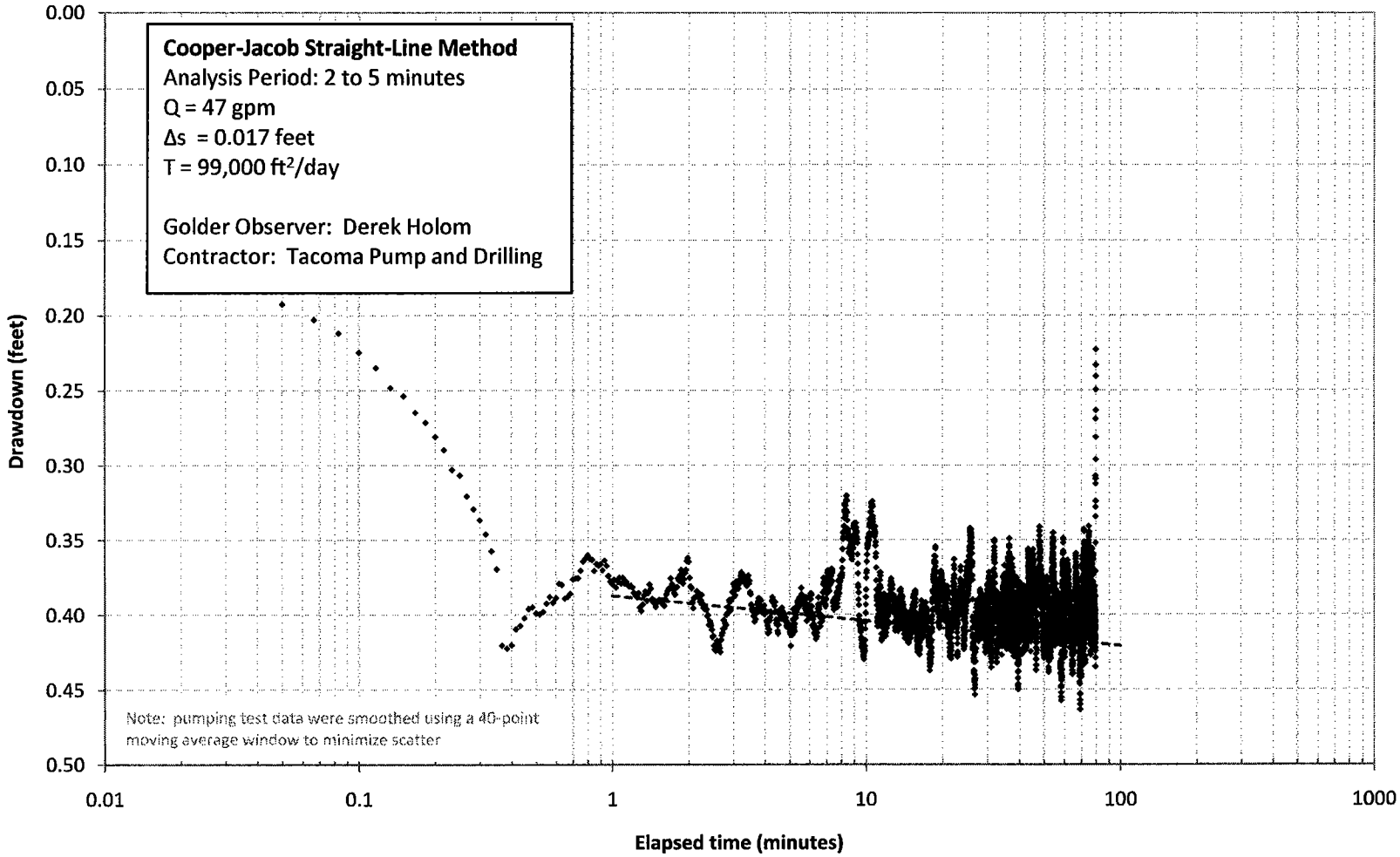
Golder Associates	Title: MW-9 Recovery Analysis		Drawn: DH
			Checked: MK
	Project Name: The Villages	Project No.: 063-1076.501	Reviewed: RA
	Client Name: BD Villages, LP	Date: February 26, 2008	FIGURE 8

\\SEA1-S-FS1\Data1\Engineering\PROJECTS\2006\063-1076_BDP_The Villages_Johnson\501 Aquifer Testing and Geophysics\Groundwater Data\Aquifer Test Data\Updated 2008\MW-9 Pumping Test.xlsx



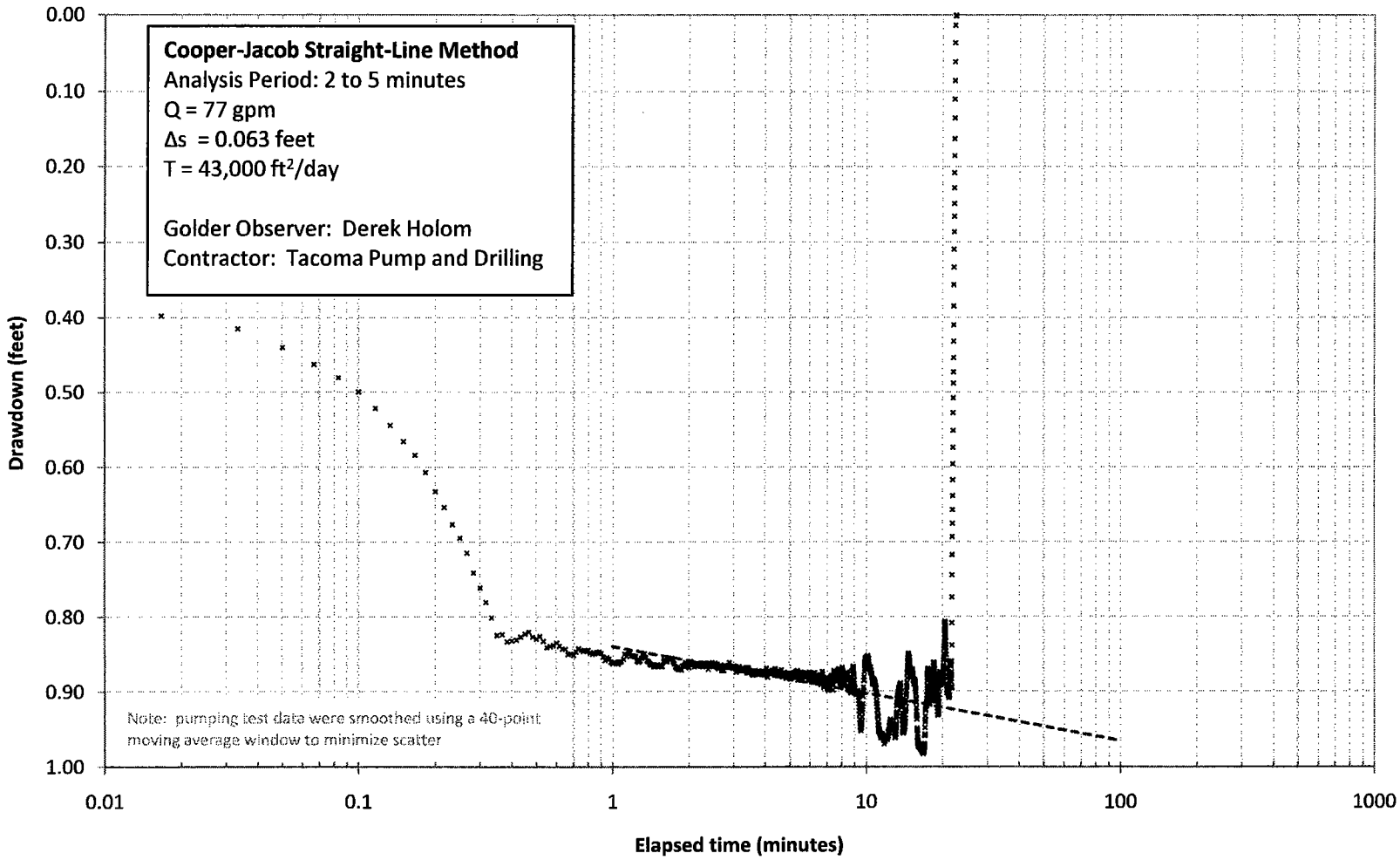
Golder Associates	Title: MW-10 Pumping Tests Hydrograph		Drawn: DH
			Checked: MPK
	Project Name: The Villages	Project No.: 063-1076.501	Reviewed: BL
	Client Name: BD Villages LP	Date: March 13, 2008	FIGURE 9

\\SEA1-S-FS1\Data1\Engineering\PROJECTS\2006\063-1076_BDP_The Villages_Johnson\501 Aquifer Testing and Geophysics\Groundwater Data\Aquifer Test Data\Updated 2008\MW-10 Pumping Test.xlsx



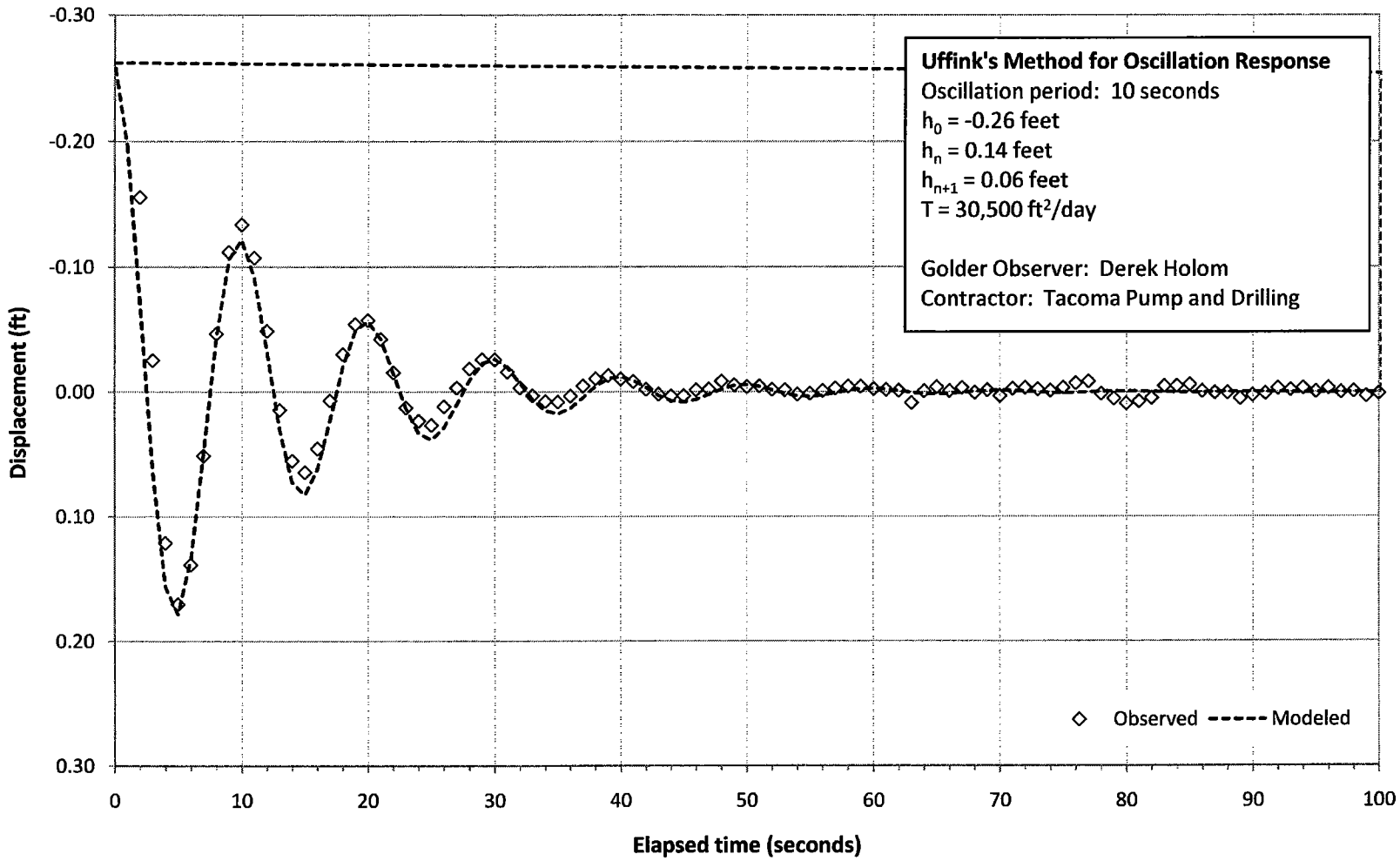
Golder Associates	Title: MW-10 2nd Constant Rate Pumping Test Analysis		Drawn: DH
			Checked: MPK
	Project Name: The Villages	Project No.: 063-1076.501	Reviewed: RA
	Client Name: BD Villages LP	Date: March 13, 2008	FIGURE 10

\\SEA1-S-FS1\Data1\Engineering\PROJECTS\2006\063-1076_BDP_The Villages_Johnson\501 Aquifer Testing and Geophysics\Groundwater Data\Aquifer Test Data\Updated 2008\MW-10 Pumping Test.xlsx



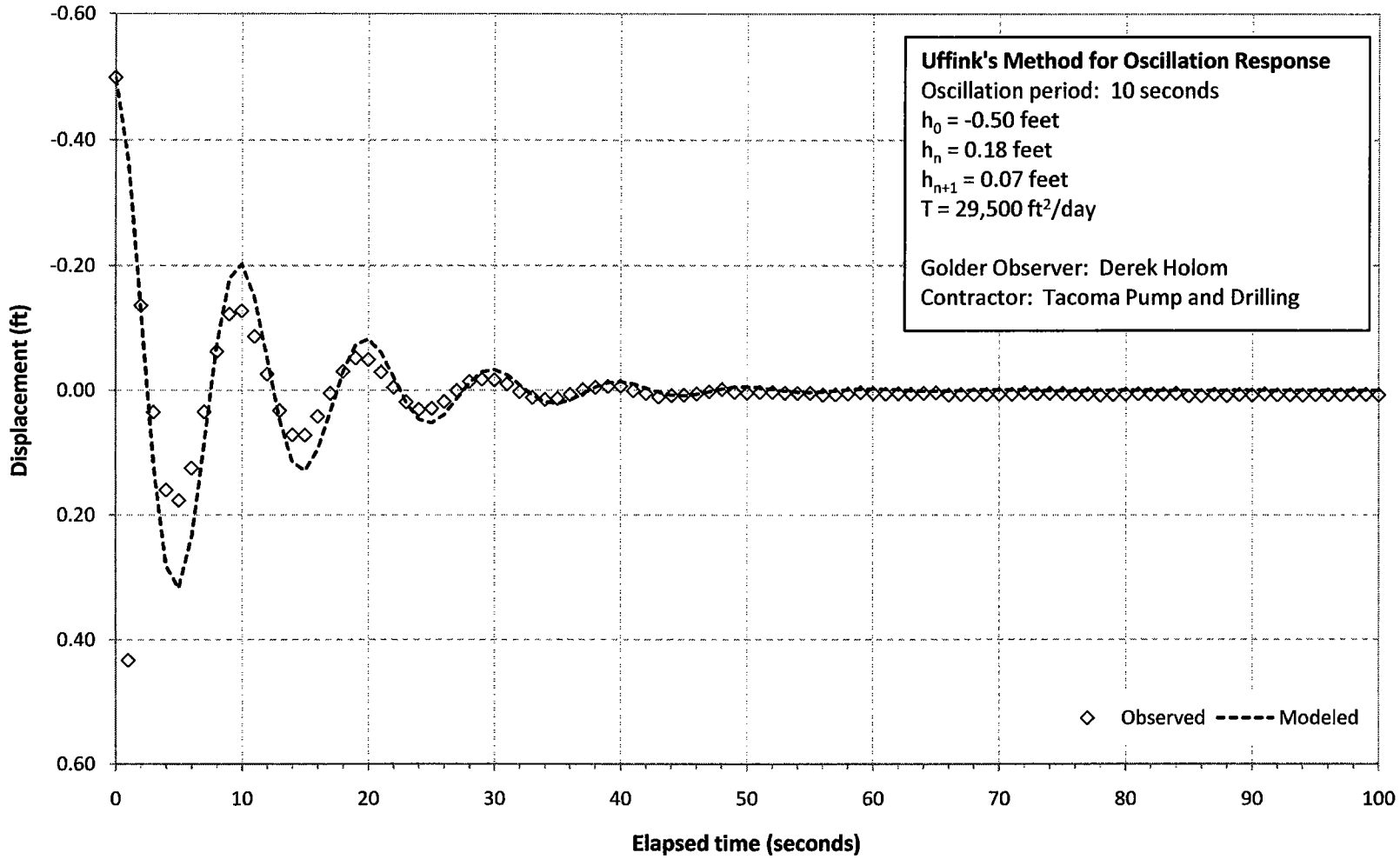
Golder Associates	Title: MW-10 3rd Constant Rate Pumping Test Analysis		Drawn: DH
			Checked: MPK
	Project Name: The Villages	Project No.: 063-1076.501	Reviewed:
	Client Name: BD Villages LP	Date: March 13, 2008	FIGURE 11

\\SEA1-S-FS1\Data1\Engineering\PROJECTS\2006\063-1076_BDP_The Villages_Johnson\501 Aquifer Testing and Geophysics\Groundwater Data\Aquifer Test Data\Updated 2008\MW-10 Pumping Test.xlsx



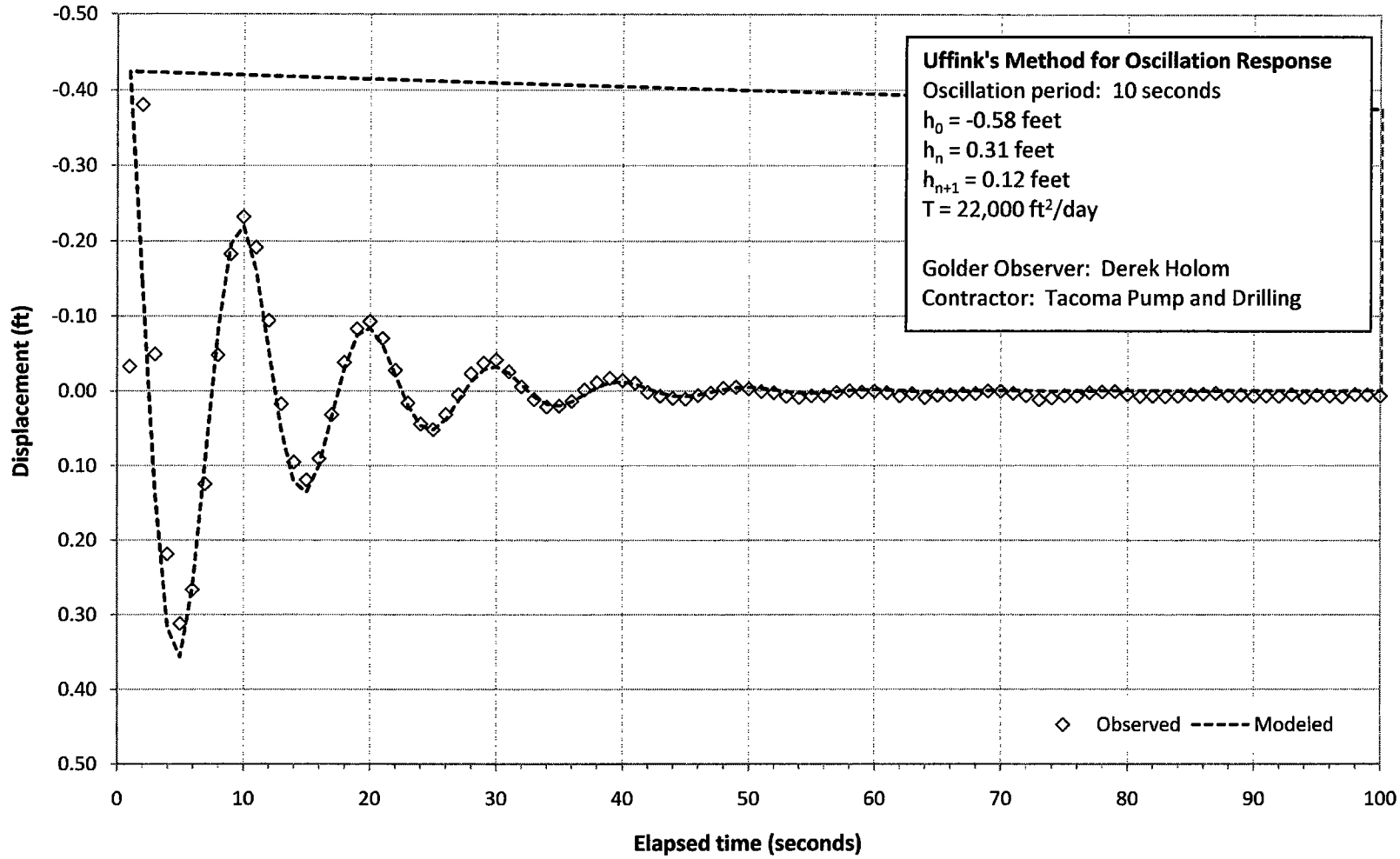
Golder Associates	Title: MW-10 Oscillation Response #1		Drawn: DH
			Checked: MPK
	Project Name: The Villages	Project No.: 063-1076.501	Reviewed:
	Client Name: BD Villages LP	Date: March 13, 2008	FIGURE 12

\\SEA1-S-FS1\Data1\Engineering\PROJECTS\2006\063-1076_BDP_The Villages_Johnson\501 Aquifer Testing and Geophysics\Groundwater Data\Aquifer Test Data\Updated 2008\MW-10 Pumping Test.xlsx



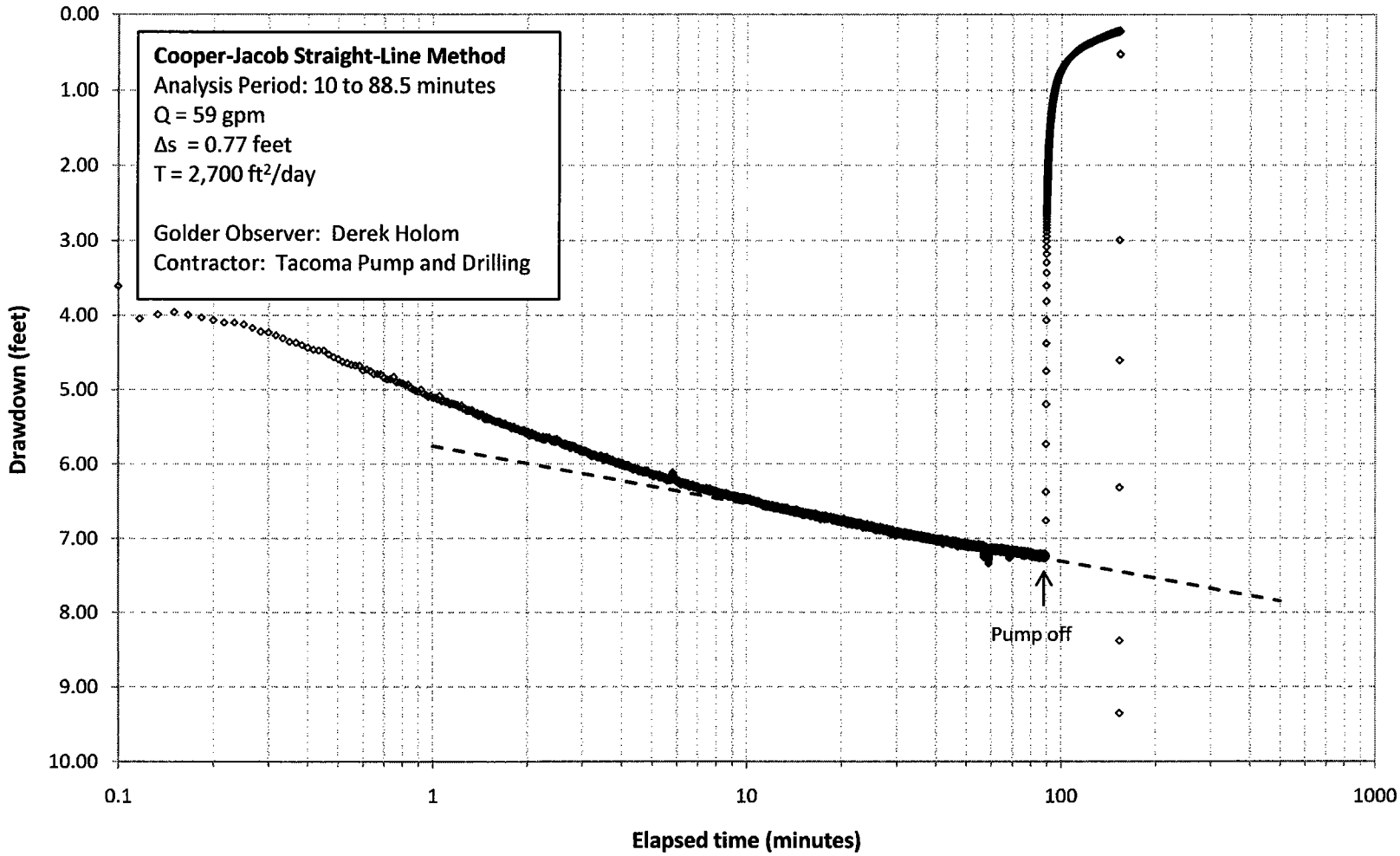
Golder Associates	Title: MW-10 Oscillation Response #2		Drawn: DH
			Checked: MPK
	Project Name: The Villages	Project No.: 063-1076.501	Reviewed: RA
	Client Name: BD Villages LP	Date: March 13, 2008	FIGURE 13

\\SEA1-S-FS1\Data1\Engineering\PROJECTS\2006\063-1076_BDP_The Villages_Johnson\501 Aquifer Testing and Geophysics\Groundwater Data\Aquifer Test Data\Updated 2008\MW-10 Pumping Test.xlsx



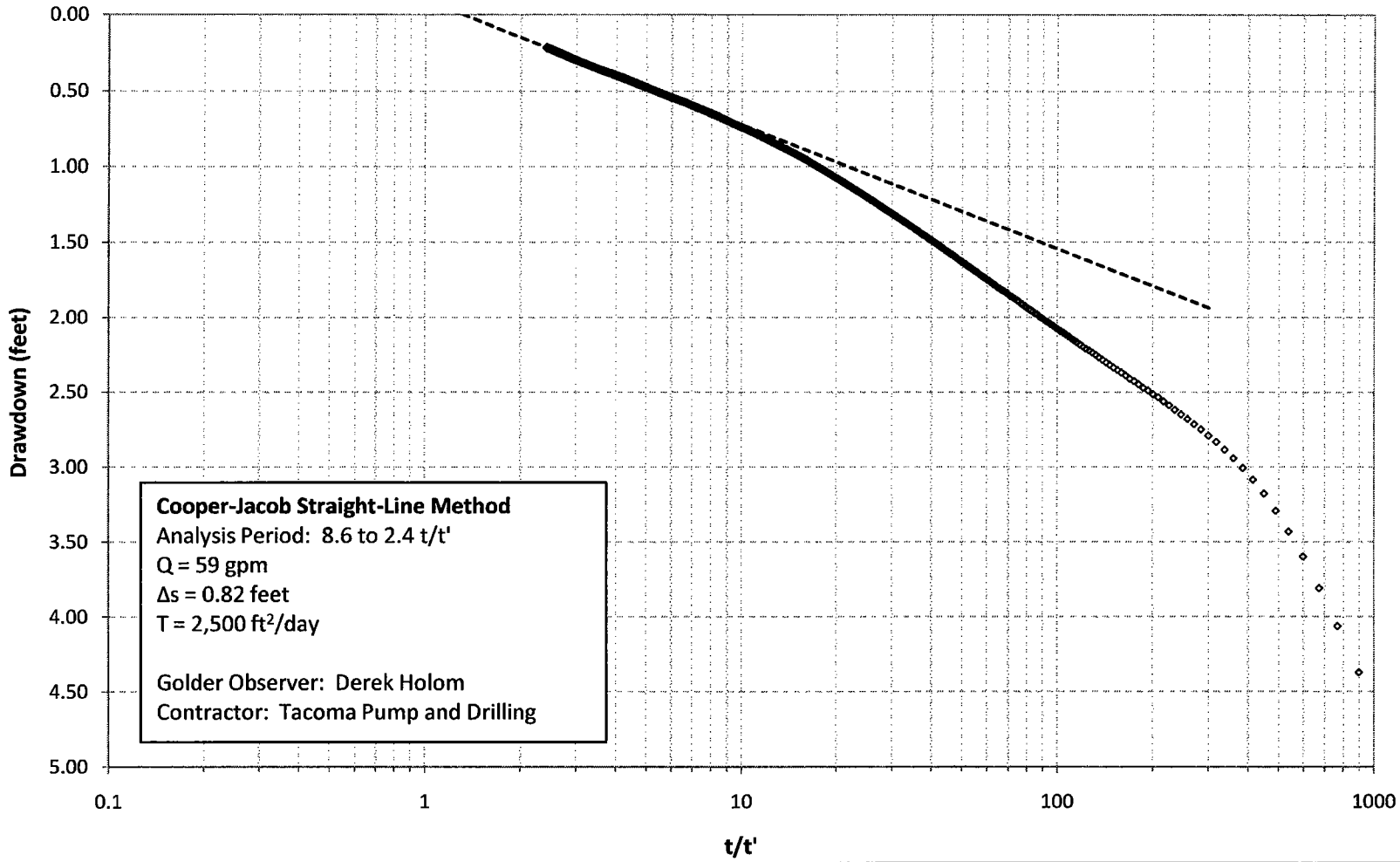
Golder Associates	Title: MW-10 Oscillation Response #3		Drawn: DH
			Checked: MPK
	Project Name: The Villages	Project No.: 063-1076.501	Reviewed: KA
	Client Name: BD Villages LP	Date: March 13, 2008	FIGURE 14

\\SEA1-S-FS1\Data1\Engineering\PROJECTS\2006\063-1076_BDP_The Villages_Johnson\501 Aquifer Testing and Geophysics\Groundwater Data\Aquifer Test Data\Updated 2008\MW-10 Pumping Test.xlsx



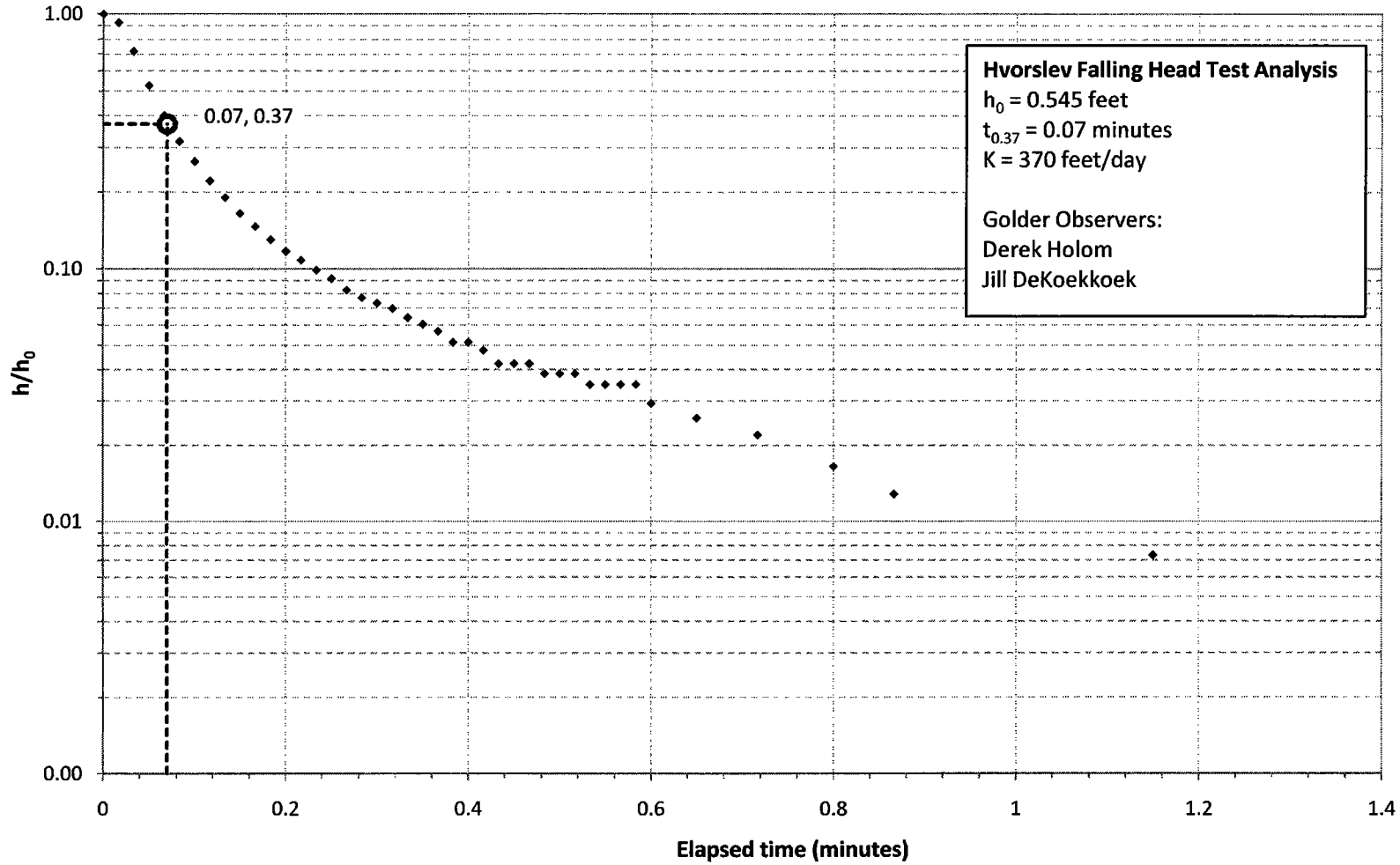
Golder Associates	Title: MW-12 Constant Rate Pumping Test Analysis		Drawn: DH
			Checked: MK
	Project Name: The Villages	Project No.: 063-1076.501	Reviewed: RA
	Client Name: BD Villages, LP	Date: February 26, 2008	FIGURE 15

\\SEA1-S-FS1\Data1\Engineering\PROJECTS\2006\063-1076_BDP_The Villages_Johnson\501 Aquifer Testing and Geophysics\Groundwater Data\Aquifer Test Data\Updated 2008\MW-12 Pumping Test.xlsx



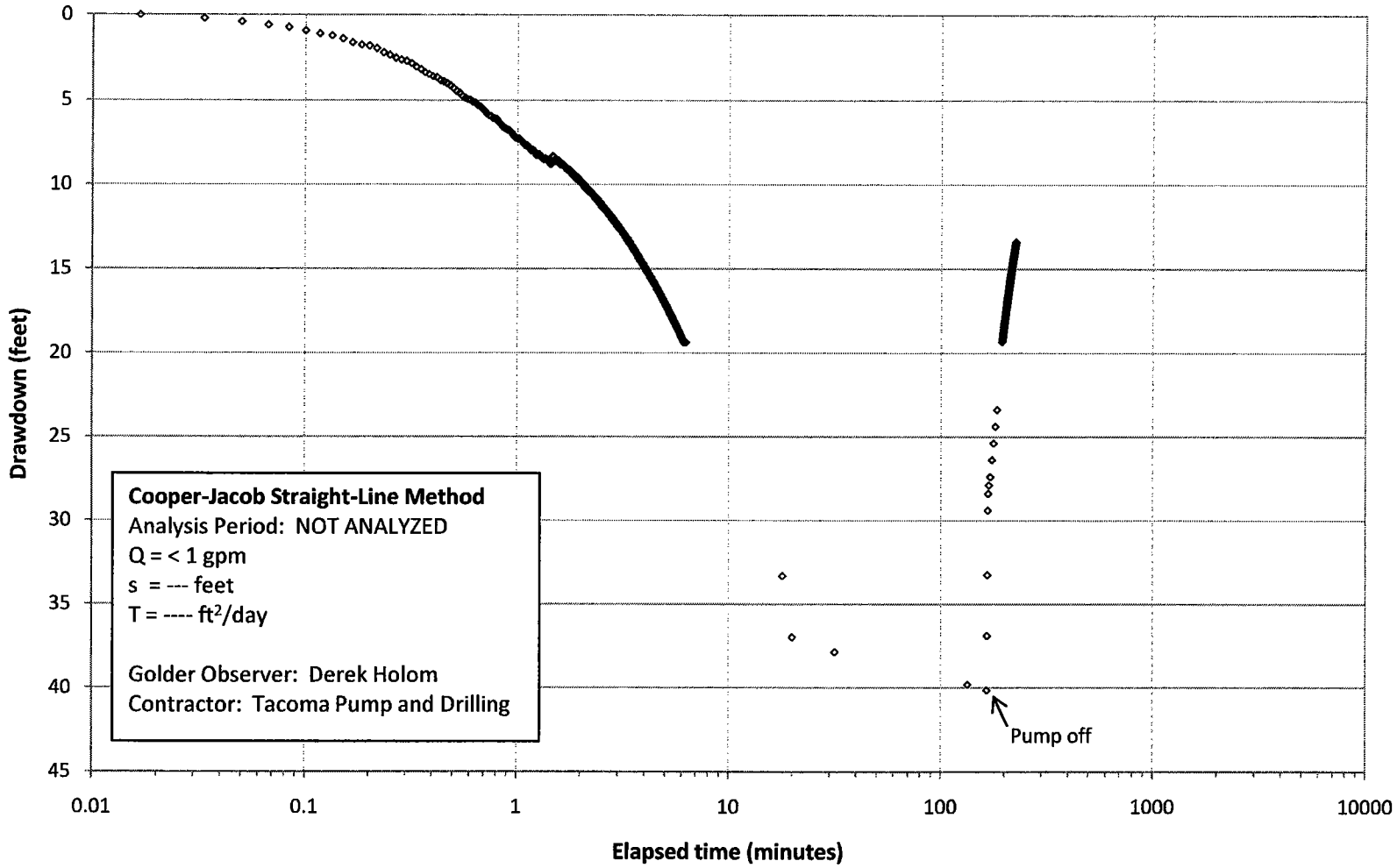
Golder Associates	Title: MW-12 Recovery Analysis		Drawn: DH
			Checked: MK
	Project Name: The Villages	Project No.: 063-1076.501	Reviewed: RA
	Client Name: BD Villages, LP	Date: February 26, 2008	FIGURE 16

\\SEA1-S-FS1\Data1\Engineering\PROJECTS\2006\063-1076_BDP_The Villages_Johnson\501 Aquifer Testing and Geophysics\Groundwater Data\Aquifer Test Data\Updated 2008\MW-12 Pumping Test.xlsx



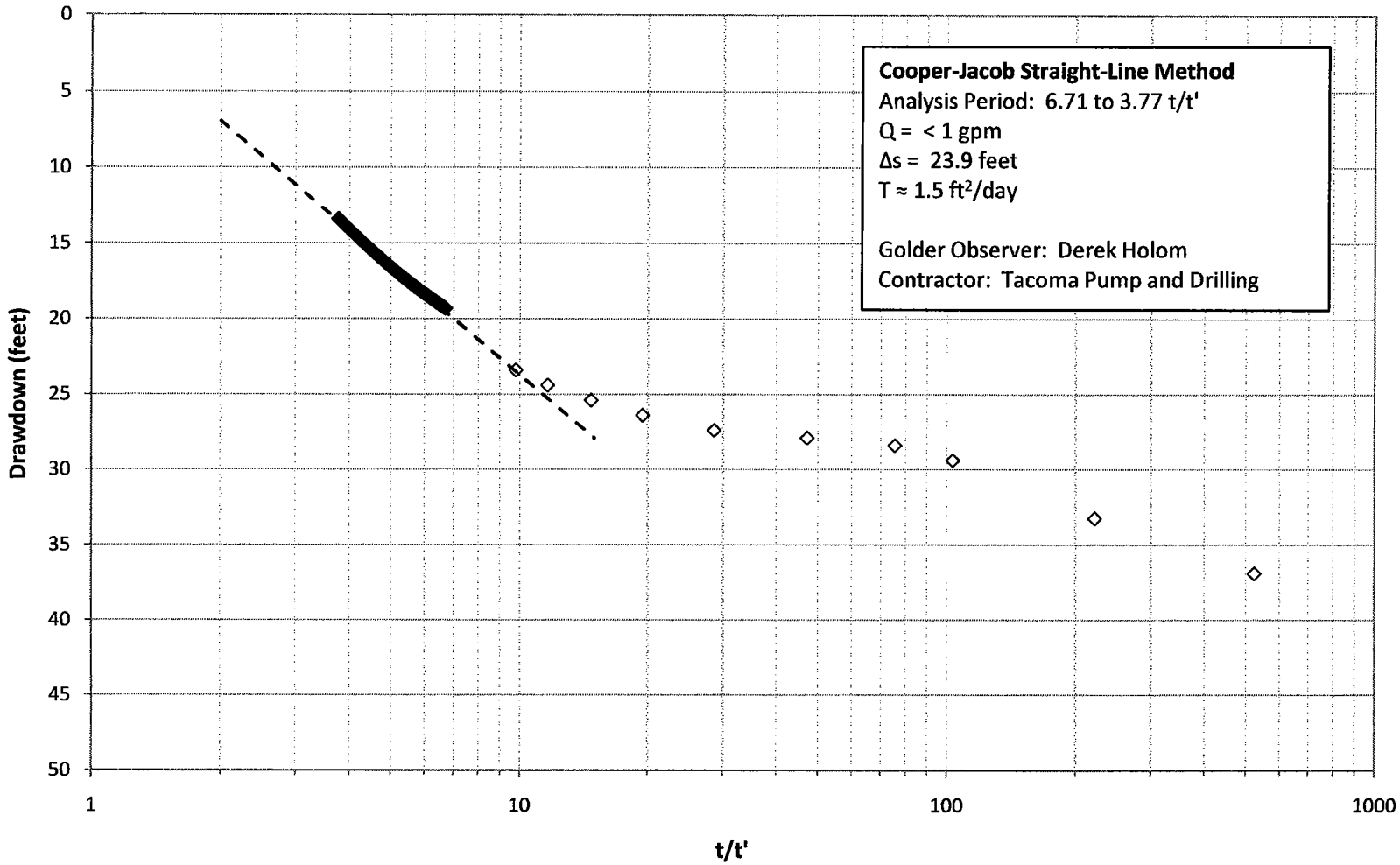
Golder Associates	Title: MW-13 Falling Head Test		Drawn: DH
	Project Name: The Villages	Project No.: 063-1076.501	Checked: MK
	Client Name: BD Villages, LP	Date: February 26, 2008	Reviewed: KA
			FIGURE 17

\\SEA1-S-FS1\Data1\Engineering\PROJECTS\2006\063-1076_BDP_The Villages_Johnson\501 Aquifer Testing and Geophysics\Groundwater Data\Aquifer Test Data\Updated 2008\MW-13 Falling Head Test.xlsx



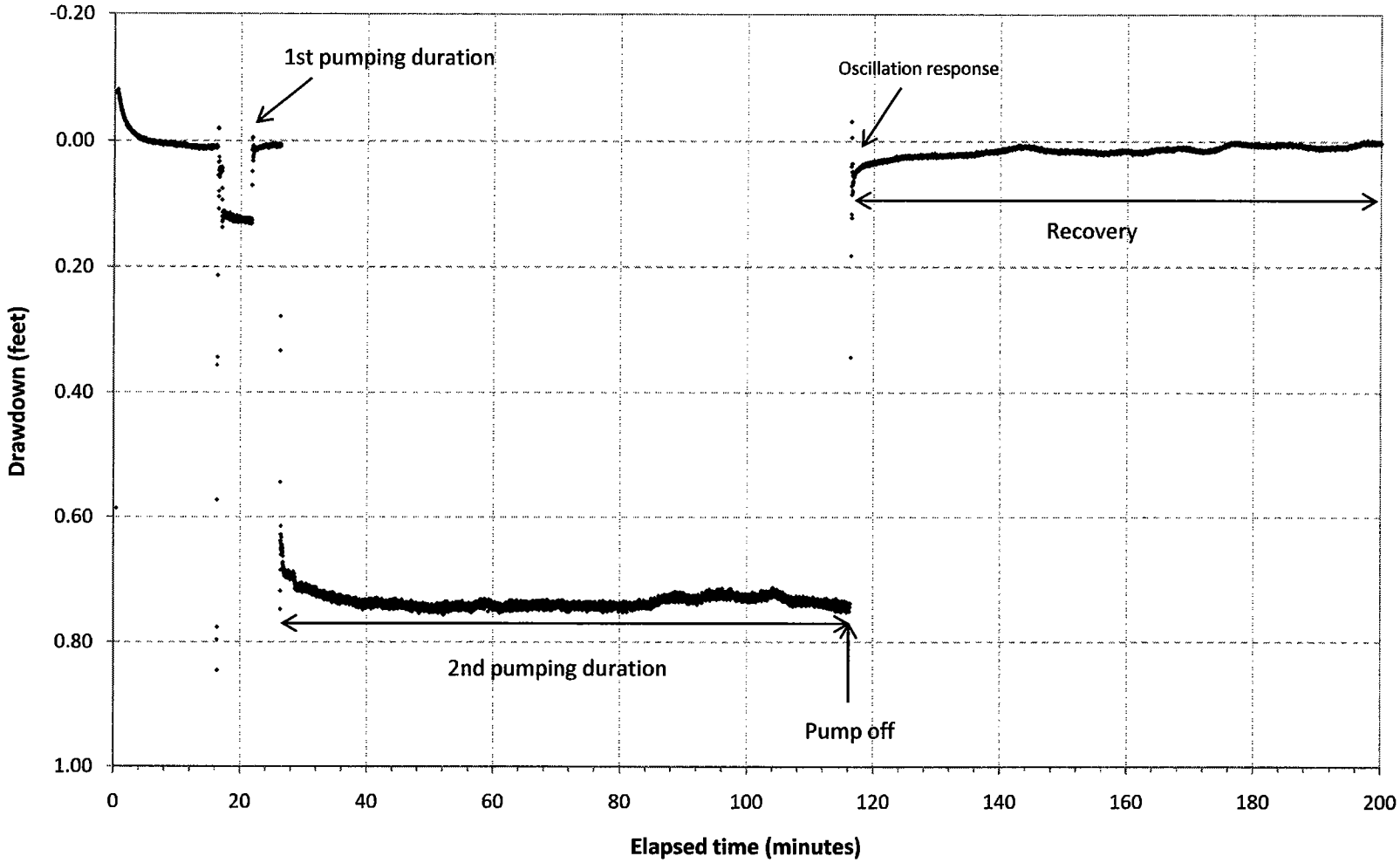
Golder Associates	Title: MW-15 Constant Rate Pumping Test		Drawn: DH
			Checked: MK
	Project Name: The Villages	Project No.: 063-1076.501	Reviewed: RA
	Client Name: BD Villages, LP	Date: February 26, 2008	FIGURE 18

\\SEA1-S-FS1\Data1\Engineering\PROJECTS\2006\063-1076_BDP_The Villages_Johnson\501 Aquifer Testing and Geophysics\Groundwater Data\Aquifer Test Data\Updated 2008\MW-15 Pumping Test.xlsx



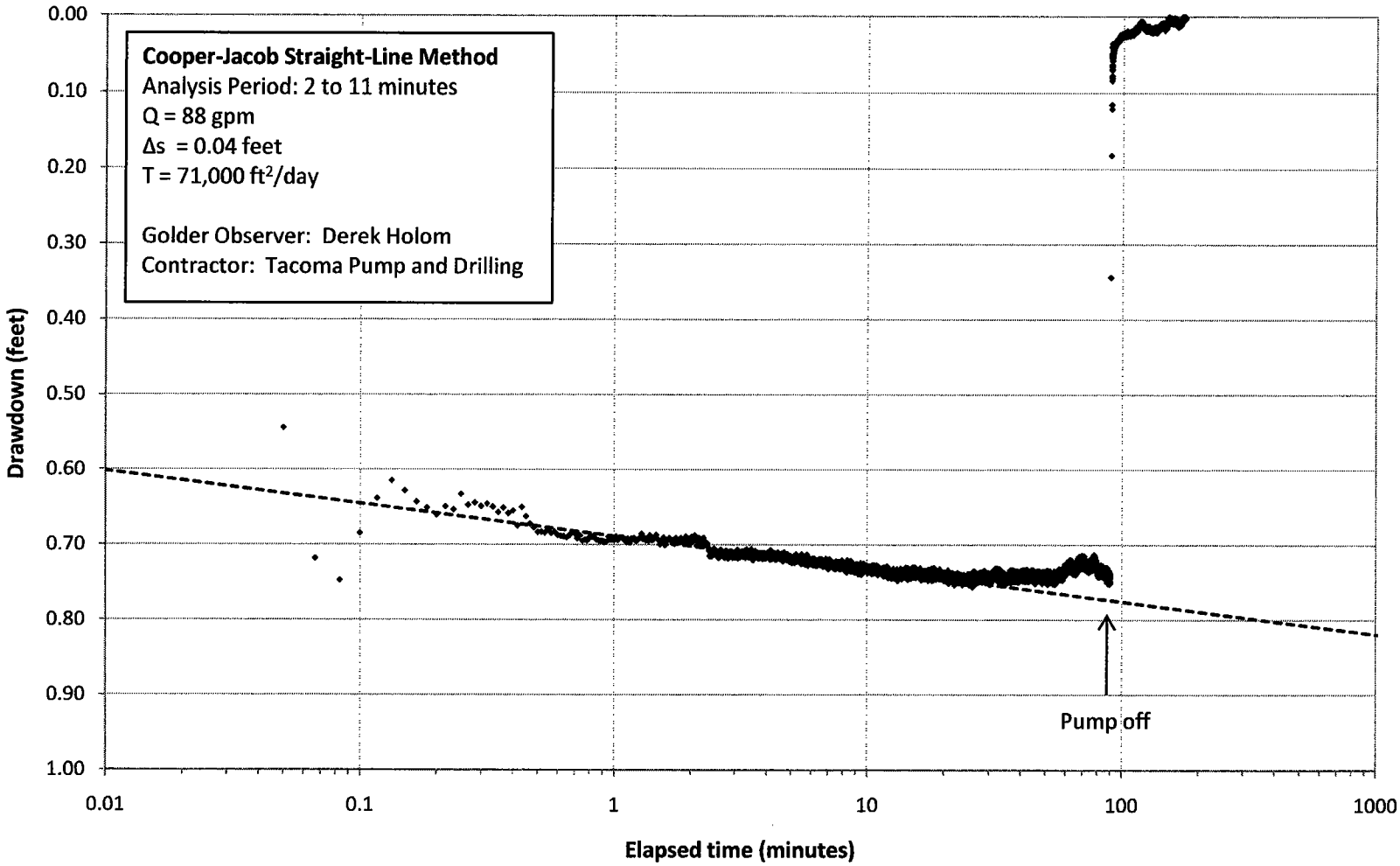
Golder Associates	Title: MW-15 Recovery Analysis		Drawn: DH
			Checked: MK
	Project Name: The Villages	Project No.: 063-1076.501	Reviewed: RA
	Client Name: BD Villages, LP	Date: February 26, 2008	FIGURE 19

\\SEA1-S-FS1\Data1\Engineering\PROJECTS\2006\063-1076_BDP_The Villages_Johnson\501 Aquifer Testing and Geophysics\Groundwater Data\Aquifer Test Data\Updated 2008\MW-15 Pumping Test.xlsx



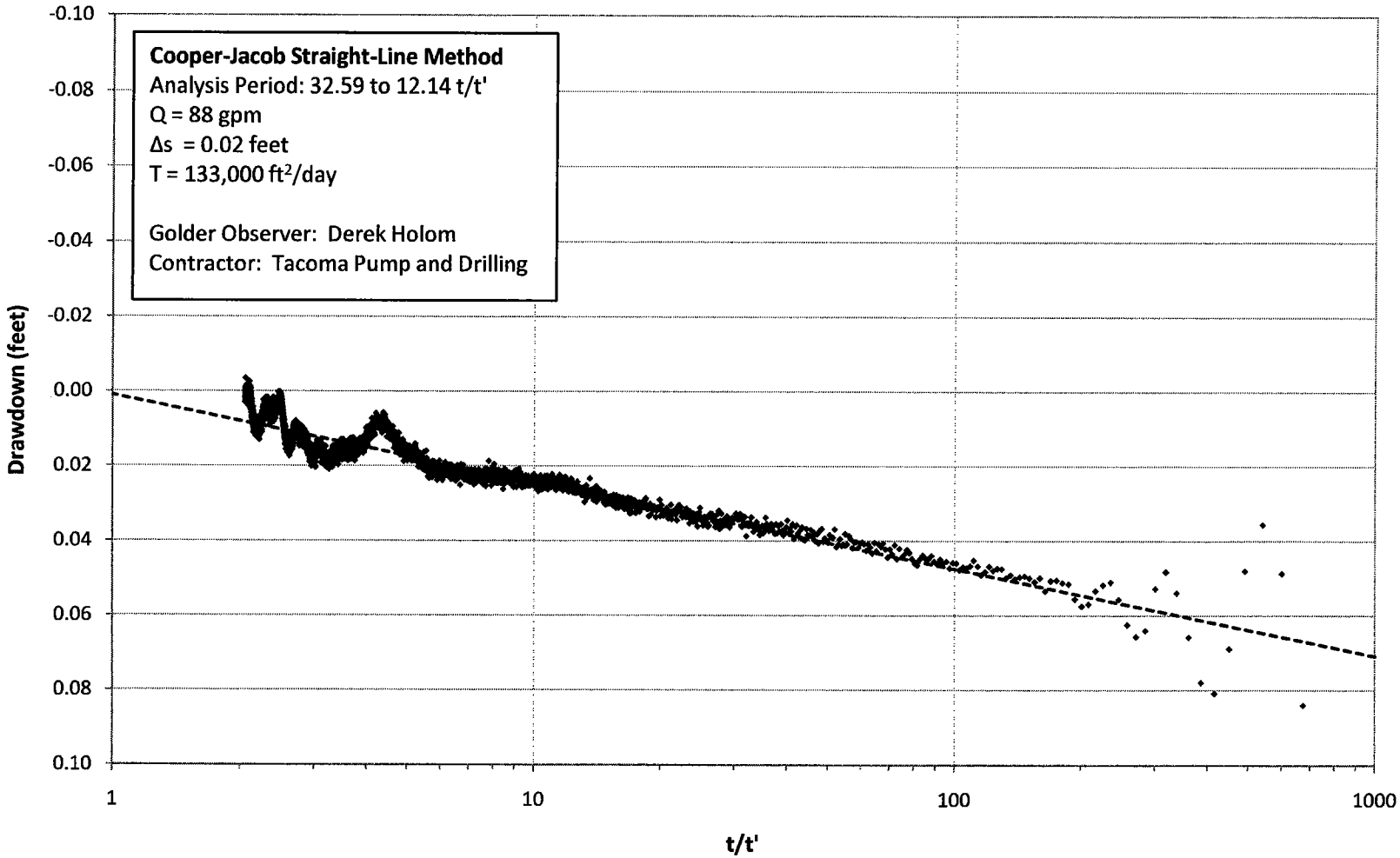
Golder Associates	Title: MW-17 Pumping Tests Hydrograph		Drawn: DH
			Checked: MK
	Project Name: The Villages	Project No.: 063-1076.501	Reviewed: RA
	Client Name: BD Villages, LP	Date: February 26, 2008	FIGURE 20

\\SEA1-S-FS1\Data1\Engineering\PROJECTS\2006\063-1076_BDP_The Villages_Johnson\501 Aquifer Testing and Geophysics\Groundwater Data\Aquifer Test Data\Updated 2008\MW-17 Pumping Test.xlsx



Golder Associates	Title: MW-17 Constant Rate Pumping Test Analysis	Drawn	DH
		Checked	MK
	Project Name: The Villages	Reviewed	RA
	Project No.: 063-1076.501	FIGURE	21
	Client Name: BD Villages, LP		
	Date: February 26, 2008		

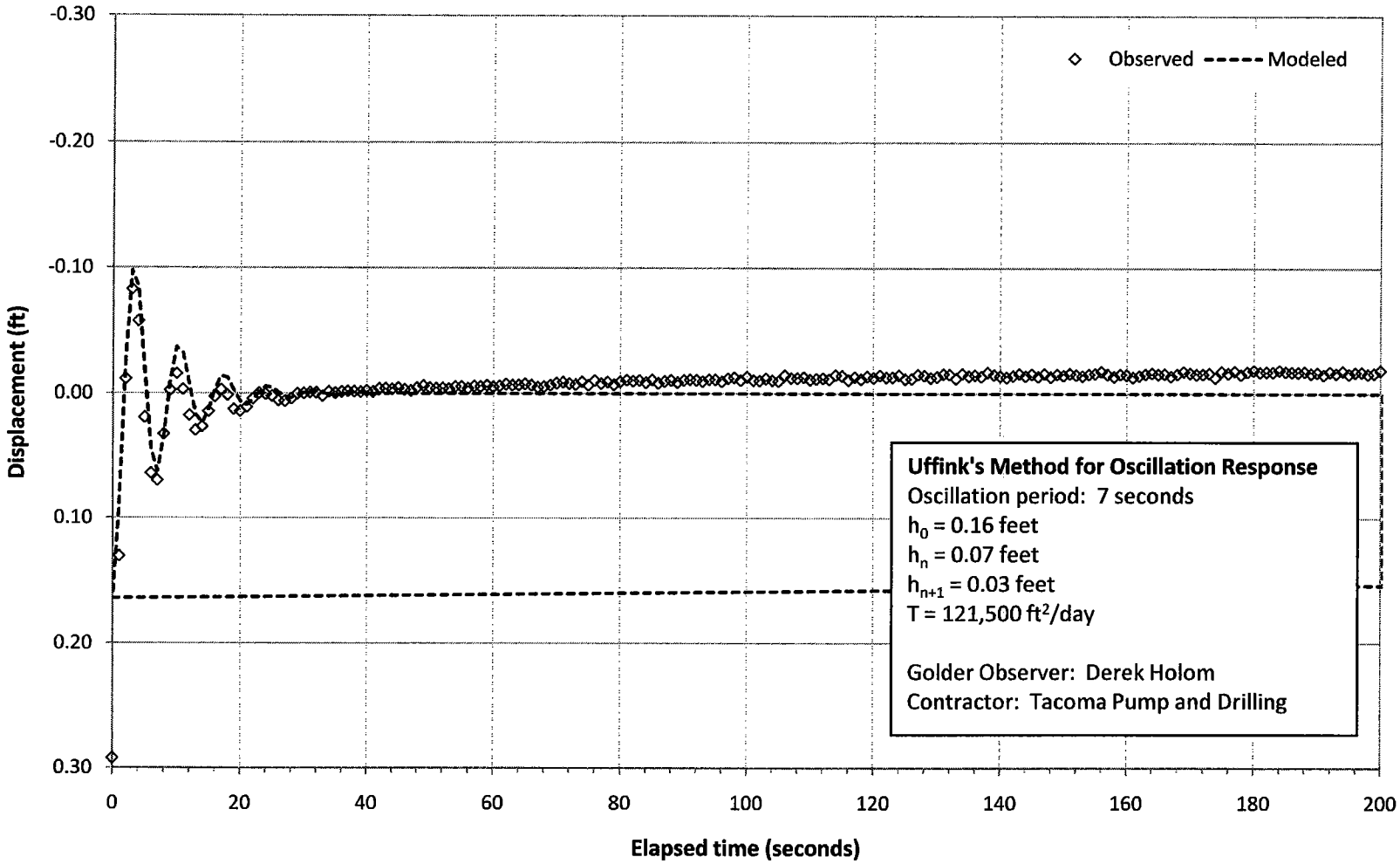
\\SEA1-S-FS1\Data1\Engineering\PROJECTS\2006\063-1076_BDP_The Villages_Johnson\501 Aquifer Testing and Geophysics\Groundwater Data\Aquifer Test Data\Updated 2008\MW-17 Pumping Test.xlsx



Golder Associates

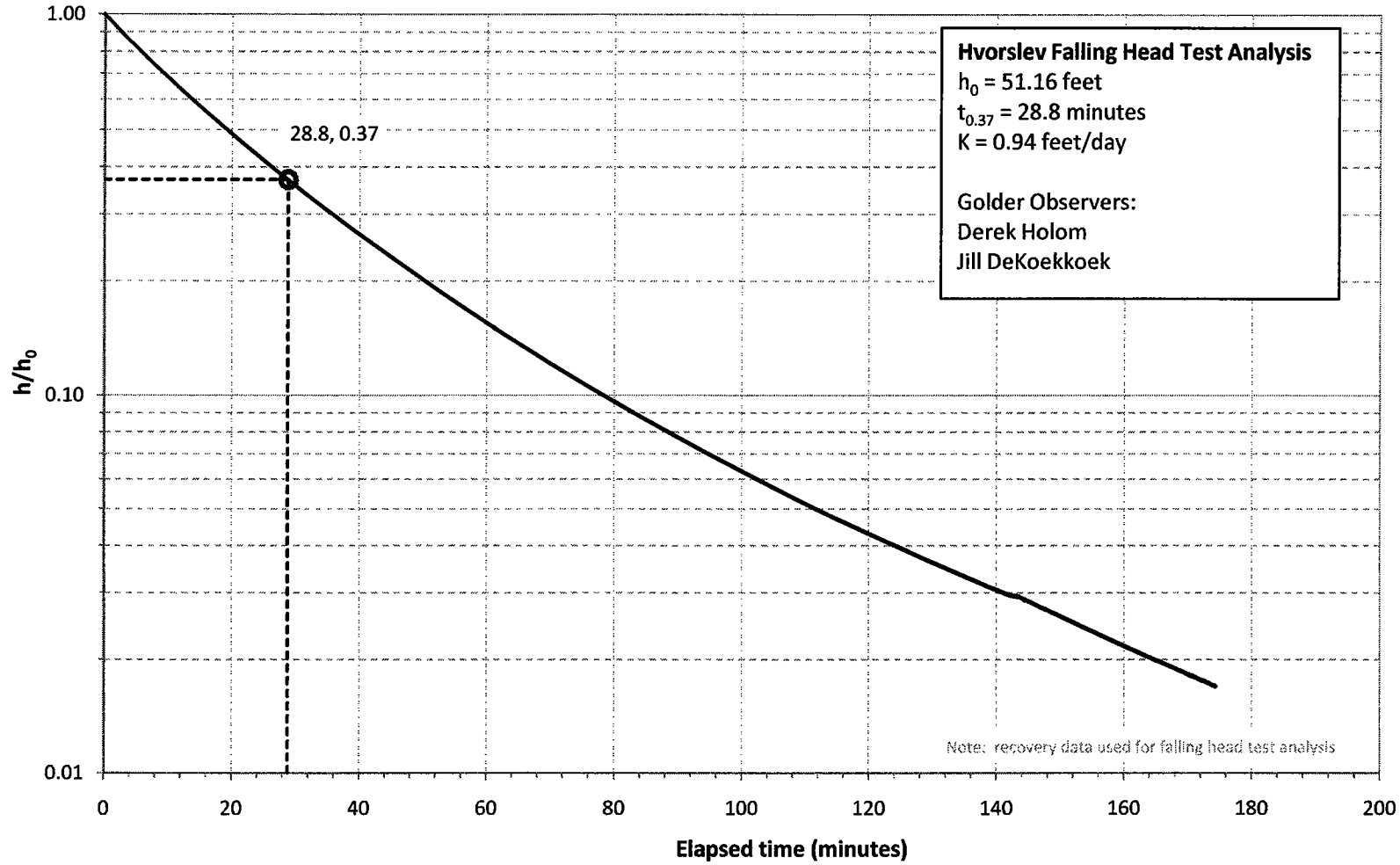
Title	MW-17 Recovery Analysis	Drawn	DH
		Checked	MK
Project Name	The Villages	Reviewed	RA
Project No.	063-1076.501	FIGURE	22
Client Name	BD Villages, LP		
Date	February 26, 2008		

\\SEA1-S-FS1\Data1\Engineering\PROJECTS\2006\063-1076_BDP_The Villages_Johnson\501 Aquifer Testing and Geophysics\Groundwater Data\Aquifer Test Data\Updated 2008\MW-17 Pumping Test.xlsx



Golder Associates	Title: MW-17 Uffink's Method for Oscillation Response	Drawn	DH
		Checked	MK
	Project Name: The Villages / Project No.: 063-1076.501	Reviewed	MA
	Client Name: BD Villages, LP / Date: February 26, 2008	FIGURE	23

\\SEA1-S-FS1\Data1\Engineering\PROJECTS\2006\063-1076_BDP_The Villages_Johnson\501 Aquifer Testing and Geophysics\Groundwater Data\Aquifer Test Data\Updated 2008\MW-17 Pumping Test.xlsx



Golder Associates	Title: MW-19 Falling Head Test		Drawn: DH
			Checked: MK
	Project Name: The Villages	Project No.: 063-1076.501	Reviewed:
	Client Name: BD Villages, LP	Date: February 26, 2008	FIGURE 24

\\SEA1-S-FS1\Data1\Engineering\PROJECTS\2006\063-1076_BDP_The Villages_Johnson\501 Aquifer Testing and Geophysics\Groundwater Data\Aquifer Test Data\Updated 2008\MW-19 Falling Head Test.xlsx