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Technical Memorandum

To: Rick Henry, WWBWC

CC: Stuart Durfee, GFID #13

From: Travis Hammond, Ari Petrides and Kevin Lindsey, GSI Water Solutions, Inc.

Date: January 04, 2012

Re: December 2011 Locher Road Pumping Test Results and Analysis

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The objective of this Technical Memorandum (Tech Memo) is to report the results of aquifer testing conducted in the Test Well built in 2010 at the Locher Road Aquifer Recharge (AR) Site. Testing was done between December 14, 2011 and December 19, 2011. These dates generally corresponded to a period of time when the alluvial aquifer experienced relatively stable conditions; between the pumping and recharge-irrigation seasons.

This Tech Memo: (1) briefly describes the aquifer test, (2) describes water level data collected before, during, and after the pumping phase of the aquifer test, (3) provides our interpretation of the results including the aquifer background noise conditions, and (4) provides recommendations for future work based on the test data and our interpretation. This Tech Memo also includes hydrographs compiled from water level data collected from the Test Well and three observation wells at the Locher Road Site before, during, and after the aquifer test. This Tech Memo does not include detailed site descriptions as that has been reported on in previous documents.

Background

The objective of this aquifer test is to estimate the hydrological properties of the alluvial aquifer in the vicinity of the Locher Road SAR site under conditions when the aquifer was not experiencing significant pumping and recharge stresses in the immediate vicinity of the AR site (other than the test itself). The aquifer test consisted of two stages. The first stage was an approximately 4-hour long step draw-down test. The goal of this stage was to identify a pumping rate for the subsequent constant discharge rate test. The second stage of the test was the constant discharge rate test. The step draw-down test was performed on December 14, 2011. The constant discharge rate test started at approximately 0930 hours on 16 December 2011,

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and ran for approximately 72 hours with pumping being shut down at approximately 0930 hours on 19 December 2011. The data shows that approximately 50 hours after starting the constant pumping rate test the pumping rate decreased due to mechanical issues with the generator. Despite the decrease in pumping rate, steady state conditions were achieved at the pumping and observation wells providing sufficient quality data for aquifer analysis.

The Locher Road Test Well is approximately 260 feet deep, and screened from approximately 70 feet below ground surface (bgs) to the bottom of the well (Figure 1). The screened interval lies predominantly within variably indurated gravel and muddy gravel of the Mio-Pliocene conglomerate unit down to approximately 237 feet bgs. Below that depth the screened interval is in the underlying, weakly indurated claystones of the Mio-Pliocene fine unit (also referred to as the blue clay, or old clay). Within the Mio-Pliocene conglomerate unit, several clayey intervals likely are present within the screened interval, with the thickest one observed during drilling lying at approximately 135 to 140 feet bgs. The Test Well is interpreted to fully penetrate the alluvial aquifer at the Locher Road AR site.

The three observations wells, designated GW70, GW71, and GW72, used during the pumping tests do not fully penetrate the alluvial aquifer. Each only extends 15 to 25 feet into the alluvial aquifer depending on water levels. The locations of the Test Well and the observation wells are shown on Figure 2.

A submersible pump capable of pumping up to approximately 500 gpm was deployed in the Test Well by Purswell Pump of Hermiston, Oregon. Pressure transducers were deployed in the Test Well and the three observation wells. Based previous step draw-down testing conducted in September 2010, step test pumping rates for the December 2011 testing were pre-selected at 100, 200, 300, and 400 gpm. During the December 2011 step draw-down test it was observed that the Test Well could not sustain a 200 gpm rate. Further pumping at reduced rates resulted in the selection of a pumping rate of approximately 190 gpm for the December 2011 constant discharge test.

The constant discharge aquifer test began, at approximately 0930 on 16 December 2011 with an average pumping rate of 190 gpm. Totalizing flow meter data for the test is summarized on Table 1. Total draw-down during the constant discharge rate test was approximately 180 feet (Figure 3) in the Test Well. The post-test recovered water levels in the Test Well and the observation wells were lower than the pre-test levels.

Aquifer Test Data

Data collected before and during the aquifer test show a gently decreasing antecedent water level trend (Figure 3). Following the completion of aquifer testing these water level declines appear to end, and water level rises in at least one observation well. The antecedent trend is interpreted to reflect water level decline in the alluvial aquifer following the shutoff the adjacent Burlingame Canal approximately one week prior to the start of testing. This trend has been observed at the Locher Road AR site every year since the start of AR work at the site. Other than these observations, there appears to be little, or no, other significant external influences on water levels in the three observation wells. Consequently, no data corrections were made to the measured water level observations.

The following sections present specific observations and interpretations in the data collected before and during testing.

Pre-Test Water Level Trends

The pre-test antecedent water level declines in the three observation wells average approximately 0.2 feet over three days prior to the test (Figure 3). The magnitude and general pattern of the antecedent trend in all three observation wells are similar, although the variation seen in MW70 appears to be greater than is seen in the other two observation wells. This variation may be due to interference from other nearby wells. MW70 is located close to several homes situated just east of Locher Road (see Figure 2). Pumping of the domestic wells associated with these homes may have resulted in the small variations seen in MW70, but not seen in the other wells which are located much further away from the homes. The magnitude of potential interference draw-down in GW 70 resulting from influences of other nearby pumping wells is between 0.06 and 0.09 feet.

Water Level Changes During the Pumping Test

Draw-down in the Test Well during the pumping test was approximately 168 feet. Draw-downs in the observation wells that are interpreted to be attributable to the pumping test (as described below) are approximately 0.12 to 0.14 feet. As noted above, the constant rate pumping test was originally planned to last 72 hours. However, problems with the generator supplying power to the test pump lead to erratic pumping in last day of the test. As a result, only data from approximately the first 50 hours of the constant rate test are used in this analysis.

Pumping Well

The hydrograph for the Test Well is shown on Figure 4. Basic observations and interpretations from this hydrograph are as follows:

1. The Test Well displayed borehole storage effects in the first 13 minutes.

2. The slope of the semi-log plot for the test well is significantly greater than seen in the observation wells (see Figures 5, 6, 7 and 8). This can be interpreted in one of two basic ways. It can indicate a relatively low transmissivity (T) in the alluvial aquifer surrounding the Test Well. Alternatively, the well could be very inefficient, with the screen and/or filter pack restricting flow into the well during pumping.

3. Based on the late-time drawdown data from the pumped well, the calculated alluvial aquifer T is approximately 7,600 ft^2/day with a hydraulic conductivity (K) of 38 ft/day. Hydrogeologic reasons for the low K are interpreted to center on induration in the conglomerate comprising the Mio-Pliocene conglomerate unit and the silt/clay interbeds present in the tested interval.
    a. The Test Well pumps from the full extent of the alluvial aquifer which at this location contains one notable weakly indurate claystone around 140 feet bgs, and possibly several other thinner (less than 1 foot thick) intervals layers.

b. Variable induration seen in outcrops of the unit throughout the area indicates some very well cemented intervals are present. Such intervals would tend to restrict groundwater flow, and hence yield lower K.

c. The lowermost 20 feet of the well penetrates into the Mio-Pliocene Fines unit. During maximum draw-down the dynamic water level in the well is within 30 to 40 feet of this interval. Being that aquifer properties were calculated for late-time steady-state conditions, a significant portion of the water producing interval in the well would correspond to these likely low yield strata.

Since K is estimated across the full saturated thickness of the well, the fine strata and indurated horizons will influence estimate of hydrologic properties, resulting in lower K than if the well was pumping exclusively from coarser intervals.

Observation Wells

Because the noise to signal ratio in the observation wells was low, corrections made for the antecedent decreasing water level trend resulted in greater variance than was seen in the uncorrected data. Thus the uncorrected data was used for analysis. Despite the antecedent decreasing water level trend, water level changes attributable to drawdown response were seen in the observation wells.

The observation wells, which only penetrate 15 to 25 feet into the alluvial aquifer, do not fully penetrate the Mio-Pliocene conglomerate unit and did not encounter any fine strata. Nevertheless, drawdown curves for these wells are suggestive of semi-confined conditions. This is interpreted to due to the presence of indurated strata and finer intervals within the Mio-Pliocene conglomerate unit in the immediate vicinity of the wells.

The Cooper-Jacob straight line method was used with the curve fit from late-time steady state pumping conditions to estimate aquifer hydraulic properties at the observation wells. These estimates, which are only for the upper few tens of feet of the alluvial aquifer, are as follows:

- K = 132 – 397ft/day.
- T = 52,660 – 62,710 ft^2/day.
- S = 0.2 – 0.4.

These aquifer property estimates are higher than those generated from Test Well draw-down data. This difference is interpreted to be related to: (1) only partial penetration of the alluvial aquifer in the observations wells, and the lack of fine and indurated strata in the open intervals for these wells and (2) the presence of several indurated and fine intervals in the fully penetrating Test Well. Nevertheless, the aquifer properties estimated here compare well with those previously estimated by Newcomb (1965), Barker and MacNish (1976), and Petrides (2008).

Observations from the individual monitoring wells are as explained below:

- GW 70: The greatest amount of interference from nearby pumping wells occurs during late time drawdown (Figure 6). This did not affect hydraulic property estimates because the curve from the steady state period between the elapsed pumping times of 1560 and 2400 minutes. During this period, data noise was at its least at this well.

- GW 71: Interference in the data for this well was very low allowing, definition of a distinct drawdown curve (Figure 7). The same steady-state period as mentioned for GW 70 was used to estimate aquifer properties

- GW 72: Interference in the data for this well was very low allowing, definition of a distinct drawdown curve (Figure 8). The same steady-state period between the elapsed pumping times of 1500 and 2670 minutes was used to estimate aquifer properties.

Water levels in all monitoring wells continued to decline for approximately 12 hours after pumping stopped at which time water levels began to recover (Figure 3). Water levels in the observation wells did not return to pre-test levels during the period of observation. This is likely to be in-part attributable to the antecedent conditions and the very small pumping draw-induced in the observation wells.

Conclusions

This test presents a range of hydraulic parameter values for the entire thickness of the alluvial aquifer, as would be expected given its lithologic variability. Based on the data collected during the December 2011 aquifer test, we interpret that the alluvial aquifer system hosted by the Mio-Pliocene conglomerate unit has K ranging from approximately 40 ft/day, up to approximately 400 ft/day. The lower K estimates are from the Test Well draw-down data. These estimates likely saw significant influence from intercalated fines and indurated strata in this well which fully penetrates the alluvial aquifer. The higher K estimates are from the shallow observation wells, and likely reflects only partially penetration of the alluvial aquifer and the absence of fines in the intervals intersected by the observation wells.

Generally it appears that water declines in the observation wells are genuine responses to Test Well pumping rather than artifacts of data noise similar to the responses seen in the previous pumping test conducted in September 2010. Despite an antecedent decreasing water level trend no corrections to the observation data was considered in the analysis. More variability seen in the water level data for GW 70, when compared to the other two observation wells, is interpreted to reflect interference from nearby alluvial aquifer wells associated with the homes just east of the well.

Recommendations

Recommendations derived from this analysis focus on aquifer properties and follow-up aquifer pumping tests as the hydrologic conditions in the vicinity of Locher Road go through their normal seasonal variation.

1. For the modeling and analysis of alluvial aquifer hydrologic properties in the Locher Road vicinity we recommend that k values on the order of 132 to 397 ft/day be used.

2. Conduct a pumping test during the early summer when the aquifer is at its highest water levels to aid in understanding aquifer response to canal operations and the potential effects of the canal on the local antecedent water level trend prior to the pumping test.

3. Look for opportunities to test pump wells having construction different than that seen in the Test Well. If the Test Well is inefficient, additional testing of wells with larger slot size screens, larger well bores, and/or larger filter pack would be instructive.

References

Barker, R.A., and MacNish, R.D., 1976, Digital model of the gravel aquifer, Walla Walla River basin, Washington and Oregon: State of Washington, Department of Ecology Water-Supply Bulletin no. 45, 49 p.

GSI, 2007, Geologic Framework of the Suprabasalt Sediment Aquifer System in the Columbia Basin Ground Water Management Area of Adams, Franklin, Grand and Lincoln Counties, Washington, Prepared Groundwater Solutions, Inc. and Franklin Conservation District.

Lindsey, K.A., and Tolan, T.L., 2004, Alluvial stratigraphy, distal sources, and induration in suprabasalt sediments in the Walla Walla Basin, Washington and Oregon – revisiting and revising a layer-cake stratigraphic model: Geological Society of America Abstracts with Programs, v. 36, no. 4, 78 p.

Newcomb, R.C., 1965, Geology and ground-water resources of the Walla Walla River Basin, Washington and Oregon: Washington Department of Conservation, Division of Water Resources Water-Supply Bulletin 21, 151 p, 3 plates.

Petrides, A., 2008, Modeling Surface Water and Groundwater Interactions near Milton-Freewater, Oregon: masters Thesis, 116 p.

Table 1. Pumping Test Manual Measurements

Date	Time	psi	DTW (feet bgs)	Drawdown (feet)	Totalizer (gal)	Gal. pumped	Flow Rate (gpm)	Specific Capacity	Comments
12/13/2011	1102	83	31	0	4018100	0	0		Step Test
12/15/2011	930	83	31	0	4019300	1200	100		Pump on at ~0930.
12/15/2011	945	46	117	85.5	4021800	3700	90	1.1	Pump oscillating between 70 and 110 GPM.
12/15/2011	1000	44	121	90.1	4025500	7400	100	1.1	
12/15/2011	1015	43	124	92.4	4028200	10100	100	1.1	
12/15/2011	1030	34	144	113.2	4032100	14000	200	1.8	
12/15/2011	1045	7	207	175.6	4036200	18100	185	1.1	Pump oscillating between 170 and 200 GPM. Cavitation present. Much air in effluent.
12/15/2011	1105	12	195	164.1	4042900	24800	155	0.9	Pump oscillating between 150 and 160 GPM.
12/15/2011	1130	12.5	194	162.9	4049000	30900	160	1.0	
12/15/2011	1205	12	195	164.	4059200	41100	160	1.0	
12/15/2011	1206	10	200	168.7	4059600	41500	175	1.0	
12/15/2011	1248	9.5	201	169.9	4071700	53600	160	0.9	Pump oscillating between 140 and 180 GPM.
12/15/2011	1300	9	202	171.0	4075700	57600	175	1.0	Pump oscillating between 150 and 200 GPM.
12/16/2011	925	83	31	0	4080400	62300	0		Constant Rate Test
12/16/2011	1002	10	200	168.7	4091600	73500	190	1.1	Pump on at ~0930.
12/16/2011	1007	10	200	168.7	4093100	75000	190	1.1	
12/16/2011	1800	10	200	168.7			190		psi taken by pump operator
12/17/2011	1200	10	200	168.7			190		psi taken by pump operator
12/18/2011	1230	10	200	168.7			190		psi taken by pump operator
12/19/2011	930		28.09 (e-tape)	-3.1			0		pump went down the previous day. Post test measurement.

Log of Borehole: Locher Test Well

Project: WWBWC **Well ID: APL054**

Location: Locher Road SAR Site

Logged By: Travis Hammond

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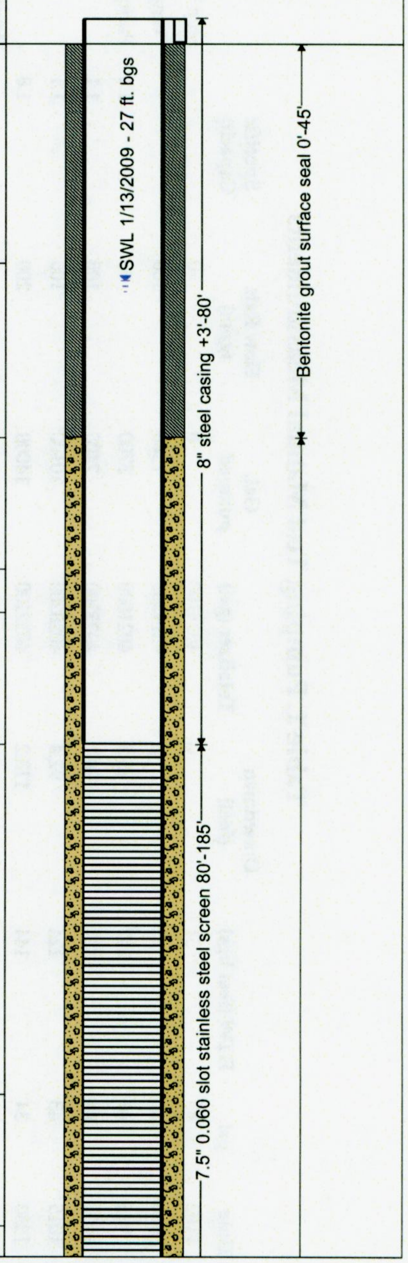
Depth (ft.)	Symbol	Lithologic Description	Elevation (ft. amsl)	Well Construction
-3				
		Ground Surface	672.3	
2		**Mio-Pliocene Coarse Unit**		
		fine to very fine basalt pebble gravel		
7		few coarse pebble clasts		
12				
17				
22				
			647.3	
27		clayey sandy gravel with a high content of		
		very-fine pebble gravel (<4mm - 2mm)		
32				
		sand and increasing clay to 45 ft.		
37				
42				
			627.3	
47		fine to very fine basalt pebble gravel		
		few coarse pebble gravel calsts		
52				
57				
			612.3	
62		clay		
			607.3	
67		sandy fine basalt gravel		
		some sandstone clasts present		
72				
77				
			592.3	
82		mixed basalt and sandstone		
		clayey, sandy, gravel		
87		many clast have coating of "conglomerate like" matrix material		
		some chert and quartz grains in sand fraction		
92				
97				
102				
107				
112				
117				
			552.3	
122		clayey, gravelley, sand containing both basalt and sandstone		
		clay matrix is brown and darker than other clays		
127				
132				
			537.3	
137		light tan colored clay containing a small sand fraction		



Drilled By: United Crown Pump and Drilling
Drill Method: Air Rotary
Drill Date: 11-9-2009

Total Depth: 260 ft.
Nominal Borehole Diameter: Locher Test Well

Log of Borehole: Locher Test Well

Project: WWBWC **Well ID: APL054**

Location: Locher Road SAR Site

Logged By: Travis Hammond

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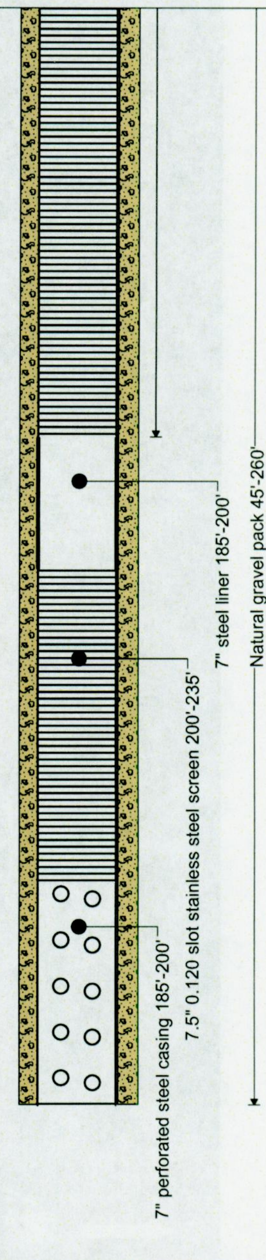
Depth (ft.)	Lithologic Description	Elevation (ft. amsl)
		532.3
142	clayey gravel clasts coated in "conglomerate like" matrix	527.3
147–167	clayey fine to very-fine pebble gravel with a small sand fraction clasts coated with "conglomerate like" matrix coating clay matrix is same color as 135-140 ft	502.3
172–212	fine to coarse basalt gravel with a few sandstone clasts very small sand fraction moderate amount of clay matrix some clasts coated with "conglomerate like" matrix coating	457.3
217–227	fine basalt gravel grading into coarse basalt gravel small sand fraction significan clay fraction increasing with depth	442.3
232	coarse basalt sandy gravel containing more clay with depth	435.3
237–257	**Mio-Ploicene Fines Unit** clay containing sparse pebble, gravel, and sand fractions	412.3
262	End of Log	

Depth scale (ft.): 142, 147, 152, 157, 162, 167, 172, 177, 182, 187, 192, 197, 202, 207, 212, 217, 222, 227, 232, 237, 242, 247, 252, 257, 262, 267, 272, 277

Well Construction



Drilled By: United Crown Pump and Drilling
Drill Method: Air Rotary
Drill Date: 11-9-2009

Total Depth: 260 ft.
Nominal Borehole Diameter: Locher Test Well

Figure 2. Locher Road Test Well Area.

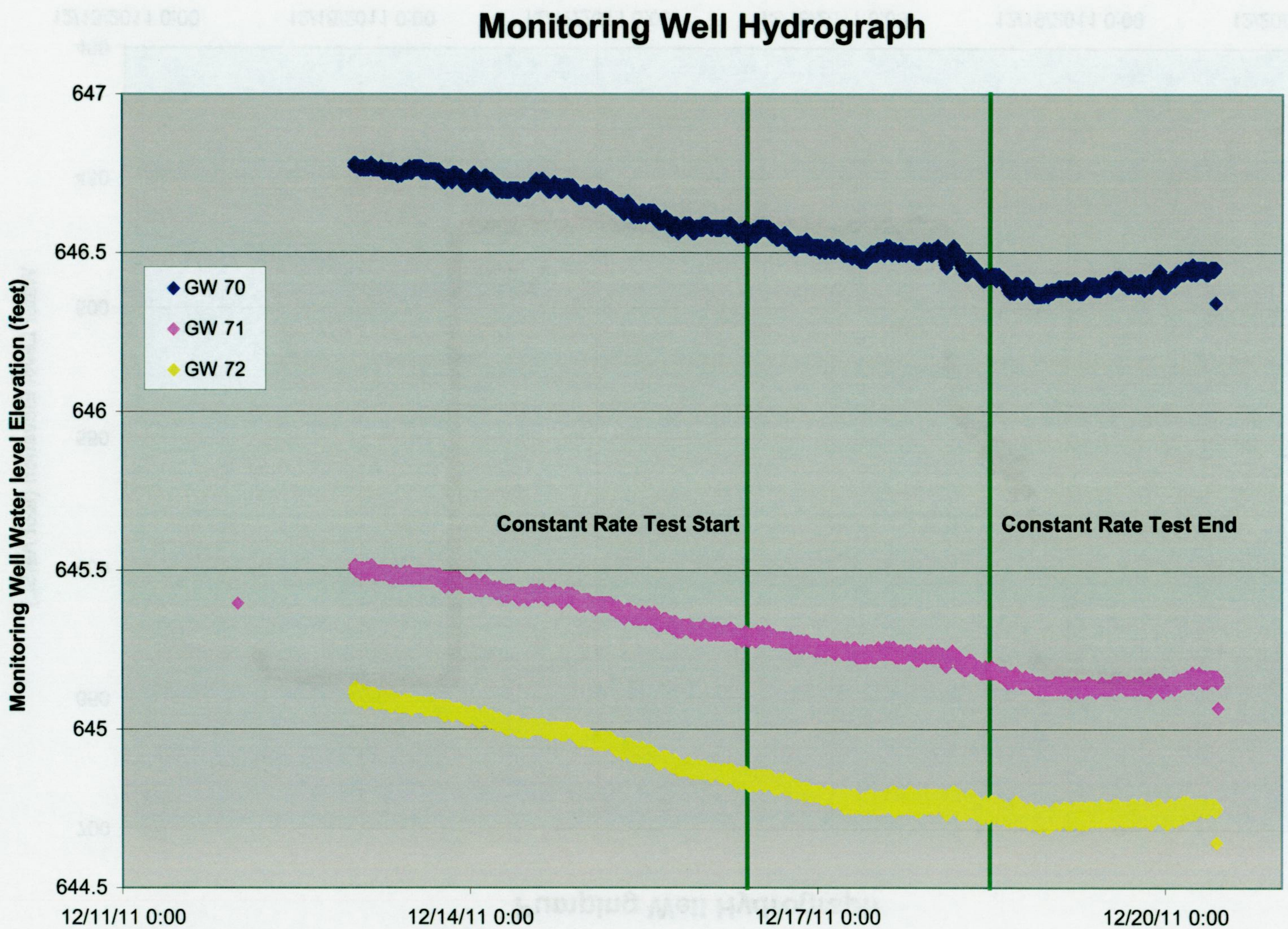


Figure 3. Monitoring well Hydrographs.

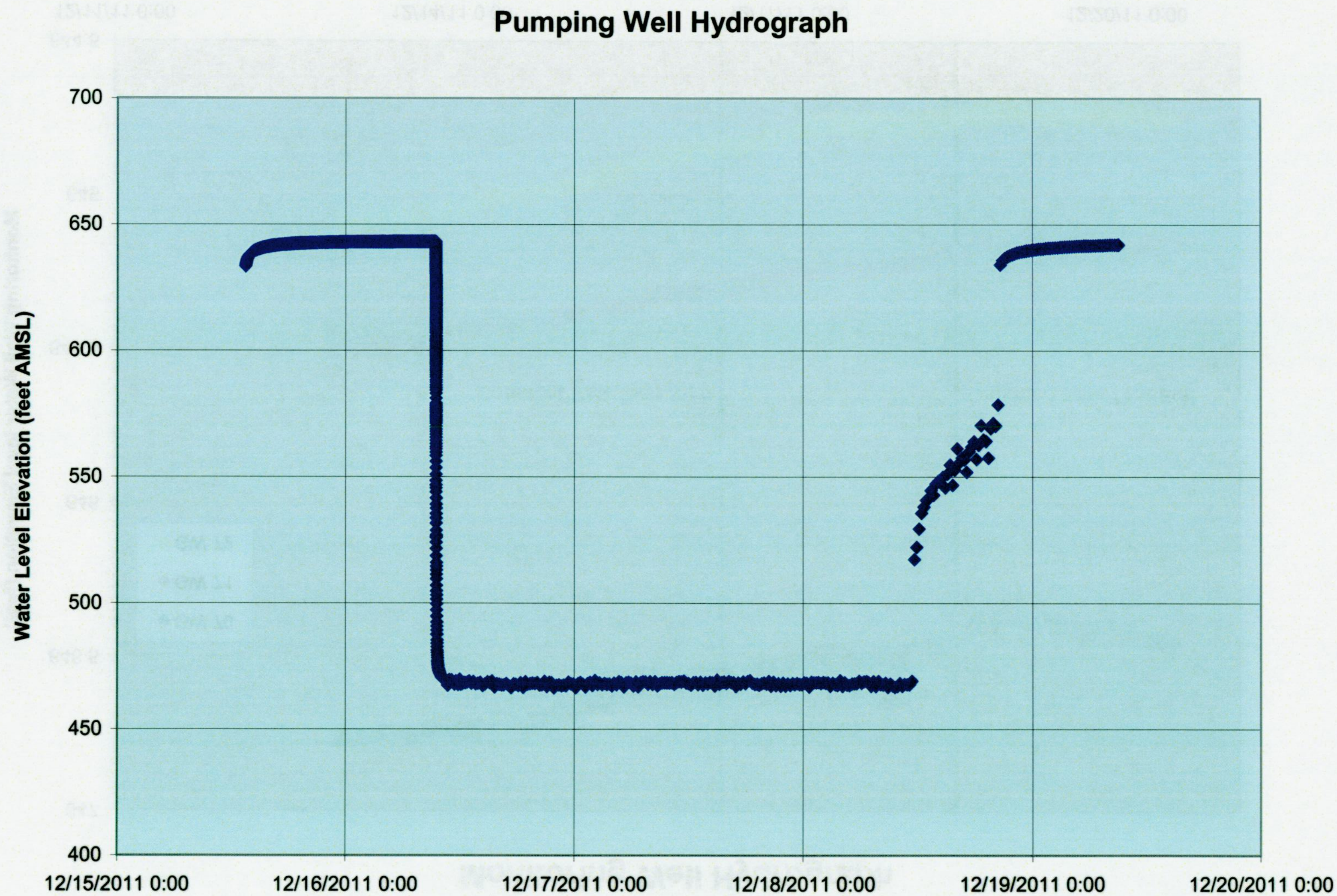


Figure 4. Pumping well hydrograph.

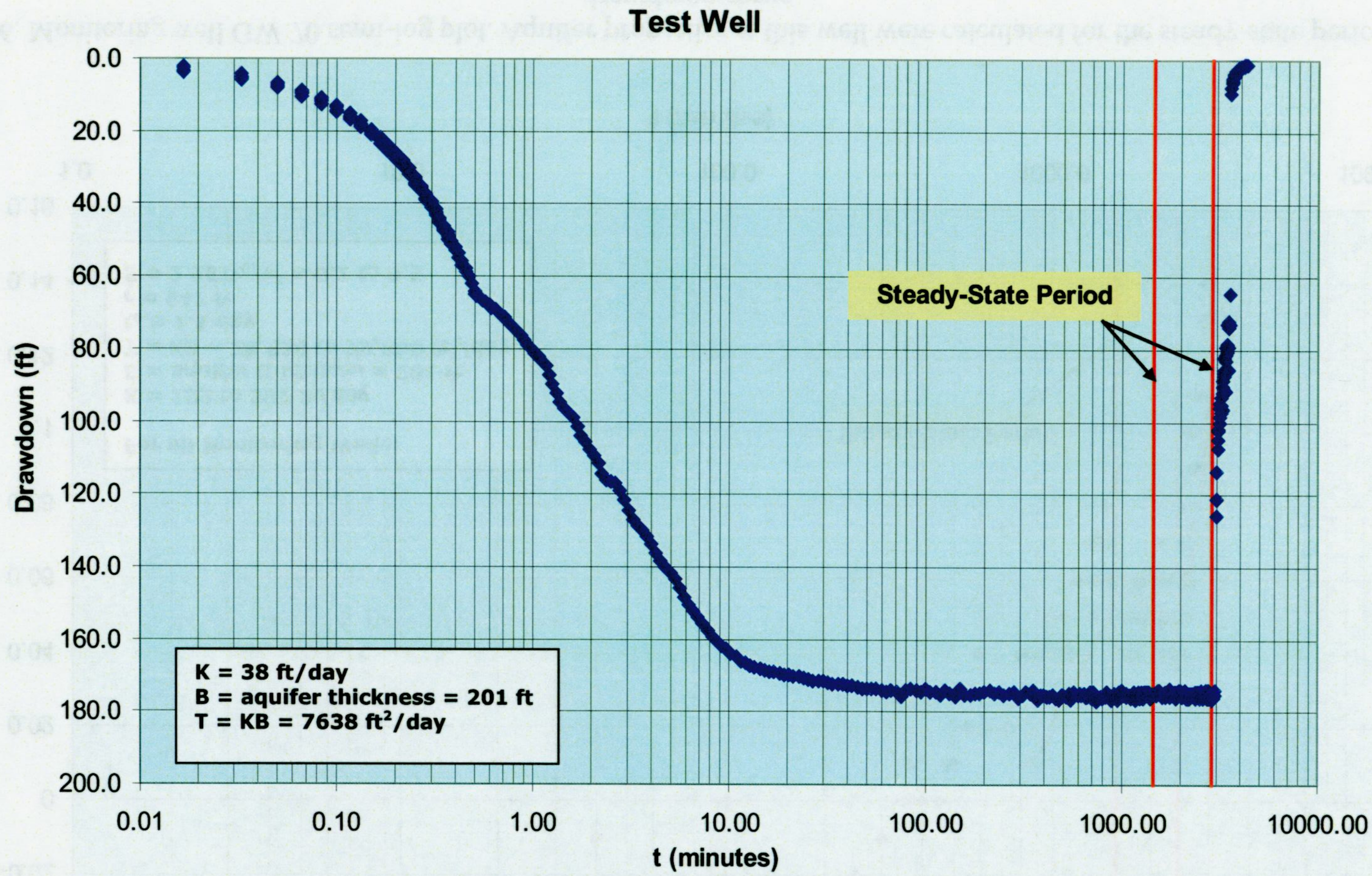


Figure 5. Pumping well (test well) semi-log plot. Aquifer properties at this well were calculated for the steady-state period of the drawdown curve.

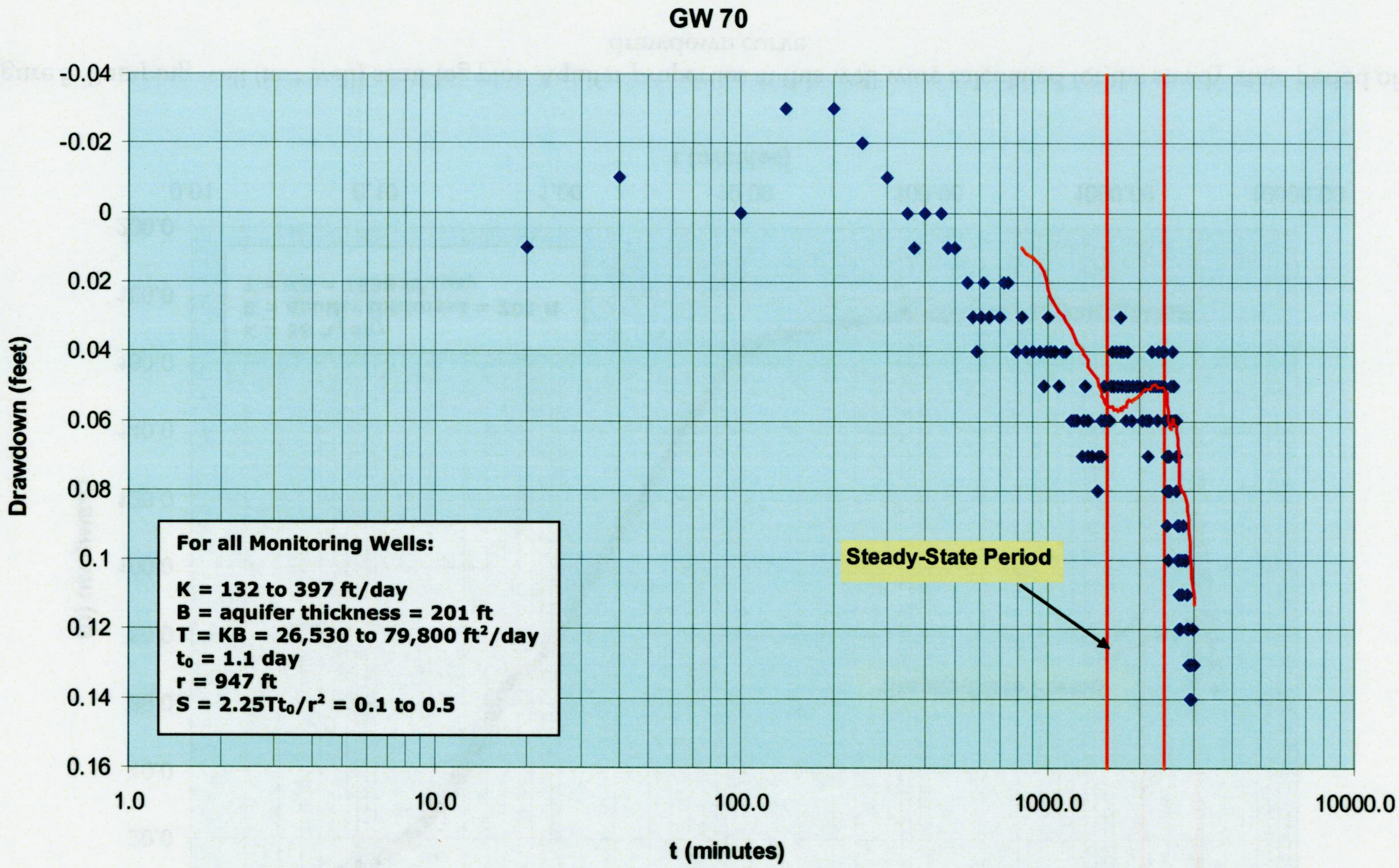


Figure 6. Monitoring well GW 70 semi-log plot. Aquifer properties at this well were calculated for the steady-state period of the drawdown curve.

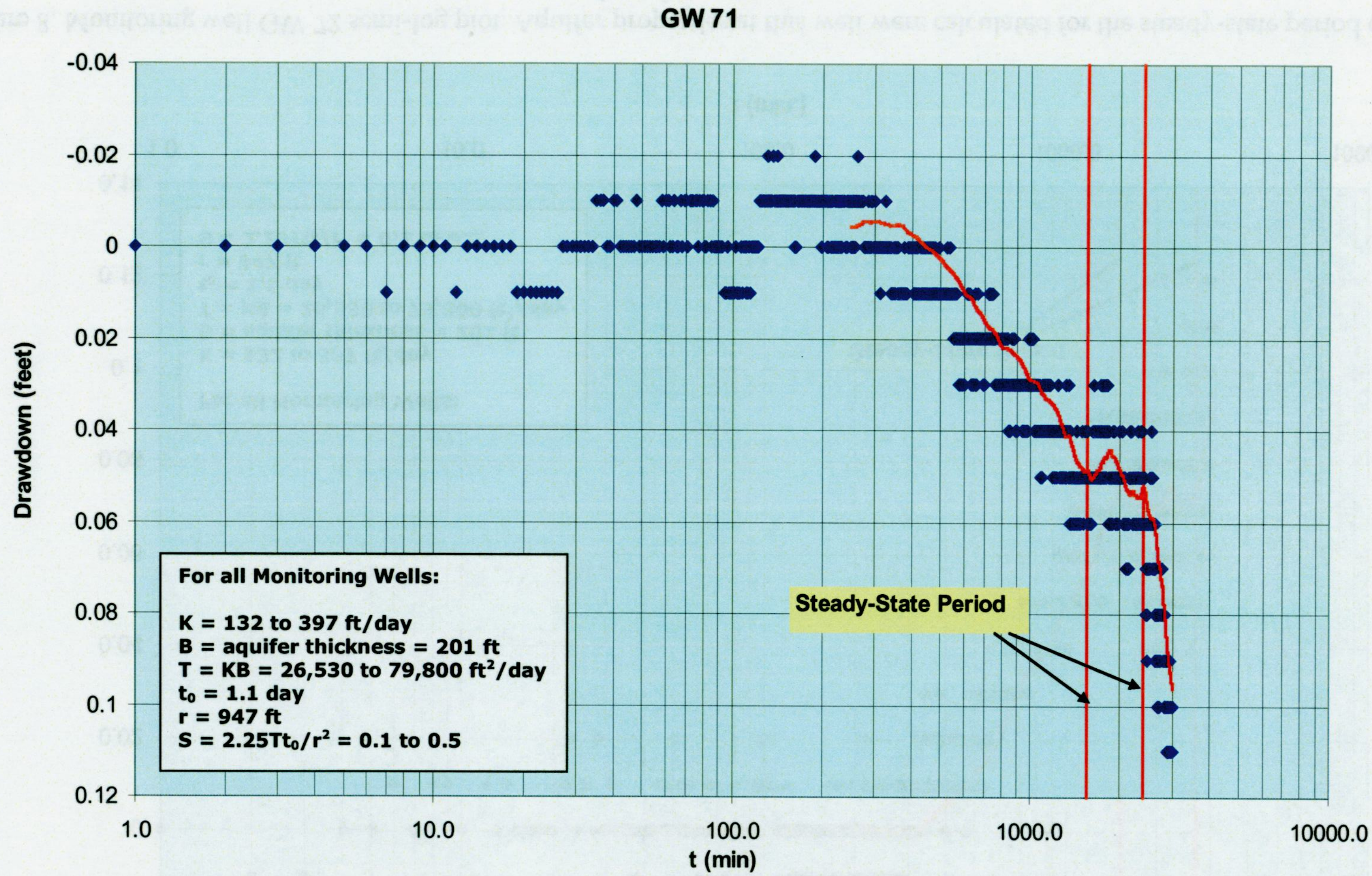


Figure 7. Monitoring well GW 71 semi-log plot. Aquifer properties at this well were calculated for the steady-state period of the drawdown curve.

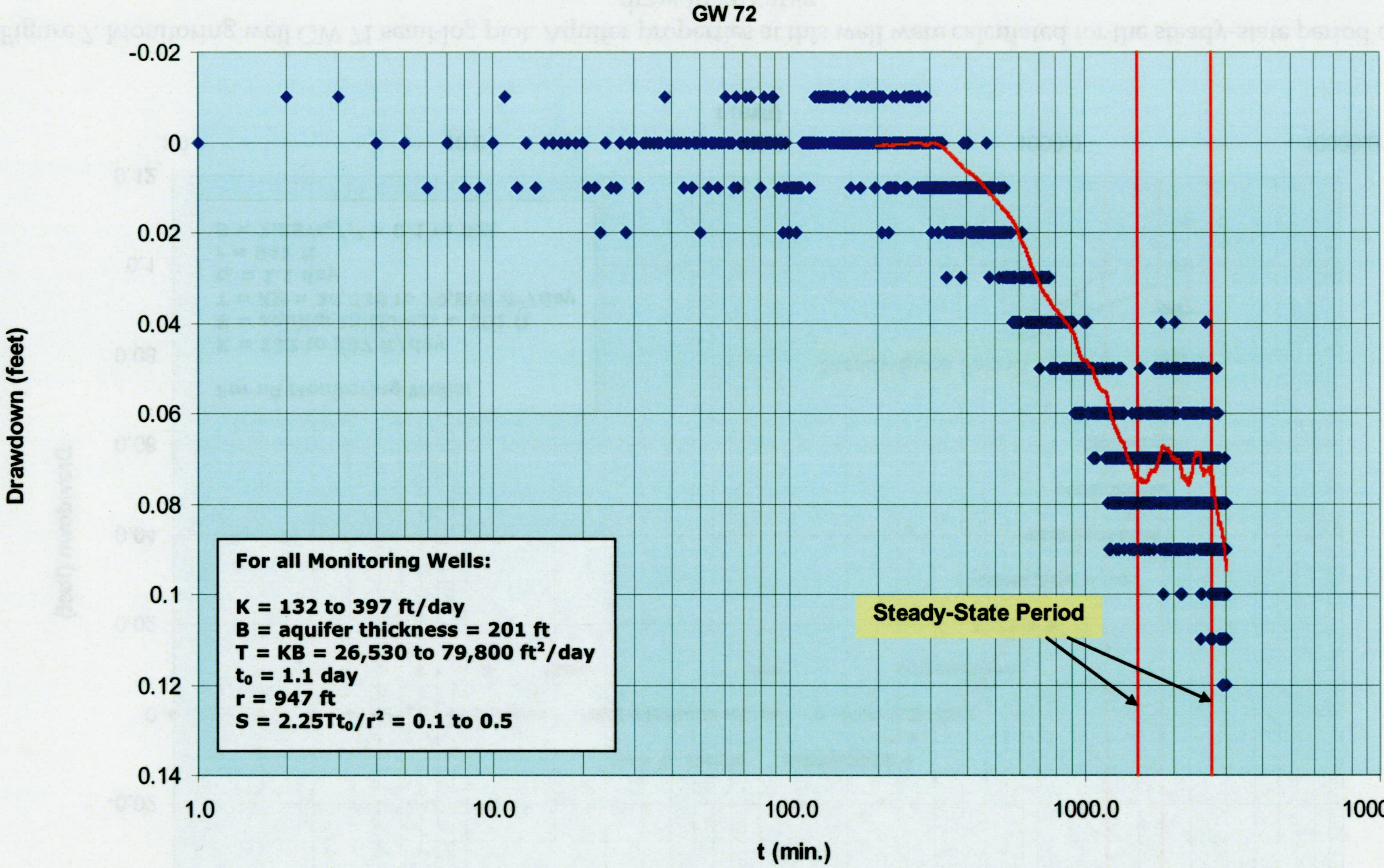


Figure 8. Monitoring well GW 72 semi-log plot. Aquifer properties at this well were calculated for the steady-state period of the drawdown curve.