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Ref. No. 09-6209-SC-91.Z3 **This Report Delivered by Email Only**

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Ms. Yolande Norman
Division of Waste Management and Environmental Protection
Office of Federal and State Materials and Environmental Management Programs
U.S. Nuclear Regulatory Commission
Mail Stop T-8F5
11545 Rockville Pike
Rockville, Maryland 20852

Re: Hydrogeologic Analysis of Recent Zone 3 Injection Testing and Proposal for Enhanced Remediation
United Nuclear Corporation's Church Rock Tailings Site, Gallup, New Mexico
Administrative Order (Docket No. CERCLA 6-11-89)
Materials License No. SUA-1475

Dear Mr. Purcell and Ms. Norman:

Introduction

On behalf of United Nuclear Corporation (UNC), Chester Engineers has prepared this analysis of recent injection testing in monitoring well NBL-2, which is located in the northern part of the Zone 3 hydrostratigraphic unit (see Figure 35 within the following report: Chester Engineers, January 2009, Annual Review Report – 2008 – Groundwater Corrective Action, Church Rock Site). UNC proposed to conduct an injection test in NBL-2 as discussed in an email to the agencies from Mark Jancin (Chester Engineers) on August 28, 2009, subject: Description of Church Rock Zone 3 injection testing. EPA, NRC, and NMED approved this proposed workplan. The primary objective of the test is to empirically assess the amount of water a well in the non-impacted, northern part of Zone 3 can accommodate by injection. A secondary objective is to determine an additional estimate of the hydraulic conductivity in this area. The average hydraulic conductivity in this area has previously been determined to be 2.95×10^{-4} cm/s or 0.84 ft/day (N.A. Water Systems, April 25, 2008, Recommendations and Summary of Hydrogeologic Analysis – Evaluation of Groundwater Flow in Zone 3 for the Design of a Pumping System to Intercept and Recover Impacted Groundwater; in reference to northern section line NBL; see p. 8 and Figure 7).

The purpose of this test was to evaluate the potential for creating a hydraulic (or possibly an alkalinity) barrier, using multiple injection wells, to limit further northward advance of the seepage-impacted groundwater in the northern part of Section 36. This potential remedial option was retained in the Revised Submittal, Site-Wide Supplemental Feasibility Study Part II (SWSFS Part II; Chester Engineers, July 2009) with a caveat that the formation may not accept sufficient quantities of fluid to be practicable, as occurred in the Zone 3 in-situ alkalinity stabilization test (Arcadis, June 2007). Secondary permeability restrictions have developed in portions of Zone 3 where the arkosic sandstones have been altered to clays by reaction with the acidic tailings seepage. The new injection test is located outside of the influence of tailings seepage where such secondary permeability restrictions are less likely. Monthly chemical field parameter measurements indicate that the groundwater is non-impacted in well NBL-2. UNC proposed to inject 800 gallons of water obtained from the site's old mill well, which taps the Westwater Canyon Formation. This is the same water source that was used for the previous in-situ alkalinity stabilization pilot test.

The injection water was piped below the water table to minimize the potential for air bubbles to clog the pore spaces around the well. The active injection was expected to be of relatively short duration via gravity flow until the water level rose to the top of the well riser pipe, at which time the flow was to be shut-off. However, the formation accommodated greater than expected flow, and so this condition never occurred. Frequent water-level measurements were made, starting before any water was injected. UNC used a pressure transducer and data logger (the In-Situ Level Troll) to collect these measurements, using a log-time measurement frequency. Manual measurements were made when the transducer was installed prior to the test and at convenient times during the test to verify the initial depth and later accuracy of the transducer measurements. Another reason for the pre-test manual measurement was to determine the position of the water table relative to the top of the Zone 3 hydrostratigraphic unit. This distance and the saturated thickness are factors used in estimating hydraulic conductivity from the test data.

UNC originally expected to conduct and repeat a single-well falling-head test, to be followed by a second, constant head test. As the field program developed we concluded there was little point to conduct a repeat of the first test and, as explained below, the second, constant-head test evolved into a stepped-head test because of the greater than anticipated flow.

Results of the Falling Head Test

Our review of the field testing indicates that quantitative analysis of the second, stepped-head test is very satisfactory and there is little need for such analysis of the first, falling head test.

The falling-head test started at 10:15 on October 27, 2009, with the static water level at a depth of 159.45 ft. The water valve was closed at 12:37 with 1000 gallons having been injected over a period of 2 hrs and 25 min. The average injection rate over the test was approximately 8.3 gallons per minute (gpm). A maximum, nearly constant head condition was obtained for a short period with ~ 55 ft of induced head. After 39 hrs and 52 min, the data logger collection was terminated and the water level had recovered to +0.05 ft above the initial static level.

Results and Analysis of the Stepped Head Test

Summary of Test Data

Well NBL-2 was tested by injection on November 4, 2009. During the test, 3226 gallons of water were injected over a period of 6 hrs and 9 min. The rate of injection was adjusted throughout the test to regulate the water level rise or pressure head induced in the well. Measurements of water level recovery (equilibration) in NBL-2 continued for five days following the injection, until November 9. Test data were recorded manually and with a pressure transducer and automated data logger. Manually recorded data are shown in Table 1; these include manual measurements of depth to water in the well and readings of injected water volume from a totalizing flow meter (Badger).

Water level depths determined from the data logger record are shown in Figure 1. These data show a step down in water level that occurred 114 minutes into the test at 10:45. This step was the result of an injection rate adjustment made at the time the pressure transducer cable slipped to a position several feet lower in the well. The cable was re-secured at the lower position and the injection rate was adjusted so that the pressure transducer reading returned to a value close to that prior to the slippage. The amount of slippage was unknown at the time of these adjustments, but was later determined to be 3.45 ft. This amount of head was subtracted as a correction to the transducer readings after 10:45. The data shown in Figure 1 and all subsequent analyses incorporate this correction. The net consequence of the actions taken at the time is that the planned constant head test became effectively a stepped-head test. This inadvertently produced the potential of gleaning more information than was originally anticipated from the test.

Figure 2 is a time-series graph of the induced height of water above pre-test static (pressure head) and periodic flow rates. These data were calculated from the flow and depth to water measurements described above. The time series illustrate that prior to the step down in pressure head (from 52.7 ft at 10:45) the injection rate had been reduced to 8.9 gpm. The rate of injection during the remainder of the test at the reduced pressure head of approximately 49 ft required little adjustment from the average of 8.1 gpm. Note that the pressure heads in both steps were less than one third of the available 159 ft of freeboard between the static water level and the top of the well casing. This indicates that the well could easily accommodate the flow used during the test and probably significantly more.

Figure 3 is a time series of pressure heads calculated from pressure transducer recordings from the time injection ceased 15:00 November 4 until 8:17 November 6, when full equilibration (return to pre-test water level) was determined to have occurred. The following section describes the analysis made of these recovery data.

Analysis of Hydraulic Conductivity

The Theis recovery method was used to analyze the recovery data. This method is applicable to the unconfined (water table) conditions observed in the Zone 3 water bearing strata screened in well NBL-2. Citing Neumann (1975), Krusemann and deRidder (1990, p. 196) indicate that the Theis recovery method can be used if the analysis is restricted to late time recovery data. They indicate further, that the method can be applied to a constant-head test if the flow rate applied in the analysis is that just prior to the cessation of flow. Accordingly, both of the cited conditions were applied in the analysis of recovery data from the test of well NBL-2.

Figure 4 shows the regressed fit of the Theis recovery function to the test recovery data (for a description of the function, see Krusemann and deRidder, 1990, pp. 194-195). The function was fitted to the data by the method of least squares. The slope of the fitted line is used to estimate transmissivity, the hydraulic parameter quantifying the capacity of the formation to transmit water. Hydraulic conductivity is calculated by dividing transmissivity by the saturated thickness. The saturated thickness was calculated from the static water level measurement prior to the test and determined to be 29.04 ft. This resulted in a calculated hydraulic conductivity of 0.87 ft/day.

Analysis of Head Dependence on Injection Rate

As indicated above, the unplanned modification of the test from a constant-head to a stepped-head test creates the potential of determining more information than originally anticipated. This information has to do with the dependence of the induced pressure head (water level rise) on the rate of injection. The purpose of making such an analysis is to estimate the effects of injection at rates different than those tested. The applicable method of analysis is the same as that used for a well performance test. Typically a well performance test is made with multiple stages of stepped pumping rates. Flow rate adjustments during the early part of the NBL-2 test were more continuous in nature than a typical well performance test. However, the rate changes between the first and second steps (of pressure head, see Figure 2) offered the potential for making an analysis of the dependence of head on the injection rate.

The analysis method is an extension of Hantush-Bierschenk's method (Krusemann and deRidder, 1990, pp. 201-203). The method employs the principle of superposition to fit Jacob's equation (see inset in Figure 5) to the variable rate (of injection) test data. The coefficients, a, b, and c, of the equation are estimated by regression on the adjusted time-head data. Figure 5 shows the fit of the equation to the data and the estimated values of the three coefficients. Coefficient b is the factor in the second term of the equation, which is also dependent on time. This term is typically described as the contribution of the aquifer to head changes, while the first and third terms (multiplied by coefficients a and c) are described as well loss terms.

It is notable that the estimated value of coefficient c is negative. This is probably inaccurate, because well losses (contributions to head change) typically increase with increasing flow rates, and the negative value of c implies the opposite. It is likely that this result is a consequence of most of the earlier, higher flow rates having occurred before the flow rate had neared equilibrium with the head in the first step of the test. Much of the flow during the early part of the test was probably accommodated by filling of the well bore and pore spaces in the immediately surrounding formation. Only later in the test was the flow rate constrained primarily by the capacity of the formation to accommodate lateral flow.

The final part of the analysis of head dependence on flow rate is shown in Figure 6. This graph shows projected pressure head versus time for a range of injection rates from 4 gpm to 10 gpm. The projections are based on the fitted equation described above and shown in Figure 5. Projections were made to a rate (10 gpm) only slightly greater than that tested, because of the caveats described above, which limit the applicability of the analysis to much higher rates.

Discussion

The value of hydraulic conductivity estimated as above, 0.87 ft/day, is very close to the estimate of 0.84 ft/day made for this area of Zone 3 in a report cited above (N.A. Water Systems, April 25, 2008). The latter estimate was based on an analysis of very broadly based groundwater flow rates and hydraulic gradients. Therefore, it is considered to be an accurate estimate of the average hydraulic conductivity of Zone 3 in the region surrounding NBL-2. The nearness of the estimate made from the injection test to this average is probably fortuitous, as the variability of the formation is expected to be greater than implied by this coincidence. Nevertheless, the similarity of the hydraulic conductivity derived from the NBL-2 test data to this average value indicates that the test results are not exceptional. The demonstrated capacity of the formation to accept water at the tested rates should be viewed as expected, on average.

The projections of pressure head versus time for the different flow rates shown in Figure 6 should be viewed as only roughly accurate, because of limitations of the analysis described earlier. However, it is clear that there is ample capacity to accommodate injection at rates similar to or less than those tested.

References

Krusemann, G.P. and N.A. deRidder, 1990, *Analysis and Evaluation of Pumping Test Data*, 2nd ed., International Inst. for Land Reclamation and Improvement, Wageningen, The Netherlands, 377 p.

Neuman, S.P., 1975, Analysis of pumping test data from anisotropic unconfined aquifers

considering delayed gravity response, Water Resources Res., Vol. 11, pp.329-342.

Proposal for Enhancement of the Zone 3 Remedy

In the SWSFS (Part II, Table 6), a potential remedy alternative, Alternative 8, is outlined and consists of a hydraulic barrier from injection wells for containment. Based on the results of the testing at NBL-2, UNC recommends enhancing and testing of this potential remedy alternative with the injection of alkalinity-amended water through an array of new injection wells located to the north of the NW-series of extraction wells and south of the Section 36 property boundary.

The first phase of the injection program will comprise a pilot phase with the installation of one new injection well (at a location suitable for the new well array) that will be subject to injection testing similar to that conducted at well NBL-2. There is likely to be spatial variation in the hydraulic conductivity and injection-take rates, and this pilot well will provide preliminary data on these hydraulic properties along the intended new well array.

We expect to install a linear array of injection wells along a WNW-trending alignment, normal to the predominant groundwater flow direction. Alkalinity-amended injection water will serve two purposes: to neutralize impacted groundwater, and to provide a hydraulic barrier to the northward advance of the impacted water. Some of the alkalinity-amended water will flow to the south toward extraction by the NW-series of wells, while some of the alkalinity-amended water will flow to the north onto Navajo land.

The proposed injection array will lead to a mixing zone of impacted and non-impacted, amended waters along the NW-series wells. Non-impacted background water may also be drawn in locally from the west.

The plan intends to neutralize and geochemically stabilize the impacted water; continue to extract impacted water flowing from the south; and to impede northward advance of the impacted water. The effective life-span of the NW-series of wells is hard to predict, although experience suggests that well fouling from multiple causes will limit the spans to several years. The life-span of the new injection wells is uncertain because such wells have no historic counterparts at the site to serve as examples; however, one should assume that fouling will eventually become an issue.

In conclusion, as with the modifications to the Zone 3 pumping remedy that have taken place over the past several years, the recommended alkalinity injection proposal is intended to mitigate the continued downdip migration of seepage-impacted water for as long as it is beneficial; it is not considered a permanent solution to meeting the groundwater protection standards throughout Zone 3. Nonetheless, it offers the possibility of installing a temporary hydraulic barrier combined with chemical stabilization which together will lessen the migration of seepage-impacted water for as long as the wells function.

Recall that the elevation head on the groundwater system cannot be entirely removed by extraction, and so a hydraulic barrier would be effective only as long as water is injected into Zone 3. By adding alkalinity to the injected water, the seepage-impacted waters may become neutralized in place, preventing further migration. This would be a very desirable outcome although the extent cannot be determined until the further injection is undertaken.

We recommend that this remedial alternative be implemented as soon as practicable and should not wait until the SWSFS is completed and approved. Based on the testing performed at NBL-2, injection of alkalinity-amended water as part of a hydraulic barrier appears to present a favorable opportunity to lessen the migration of seepage-impacted waters. We request your timely concurrence with the recommendation. Upon your approval, we will develop a remedial design report that will specify the proposed number and locations of new injection wells, their construction specifications and their design injection rates.

If you have any questions please contact me (814-231-2170 x 20) or James Ewart (412-809-6719).

Sincerely,

Mark D. Jancin, PG
Project Manager

James A. Ewart, PhD, PG
Technical Consultant

Attachments

email cc:

Earle Dixon, NMED
Lifeng Guo, NRC
Eugene Esplain, Navajo Nation EPA
Buddy Parr, EPA
Roy Blickwedel, GE
Larry Bush, UNC

TABLE 1
Manual Measurements and Observations
Injection Test of Well NBL-02, November 4, 2009

WELL #	Date-Time	WATER DEPTH (feet)	BADGER READING (gallons)	FLOW RATE (gpm)	COMMENTS		
NBL-02	11/4/09 8:03	159.04	1030		Water levels are from new measuring point which is .87 ft above the original TOC MP	22.44	
NBL-02	11/4/09 8:51				Open valve A wide		
NBL-02	11/4/09 8:53				Open valve B 50% at about 8 GPM		
NBL-02	11/4/09 8:58				close valve B with Badger B reading 30 gal		
NBL-02	11/4/09 9:00		1177	16.33			
NBL-02	11/4/09 9:07		1264	12.43			
NBL-02	11/4/09 9:13		1329	10.83			
NBL-02	11/4/09 9:18		1390	12.20			
NBL-02	11/4/09 9:26		1467	9.62			
NBL-02	11/4/09 9:33		1537	10.00			
NBL-02	11/4/09 9:45		1653	9.67			
NBL-02	11/4/09 9:51		1710	9.50			
NBL-02	11/4/09 9:53	105.70					
NBL-02	11/4/09 10:00		1794	9.33			
NBL-02	11/4/09 10:10	105.71	1886	9.20		75.01	
NBL-02	11/4/09 10:32		2085	9.05			
NBL-02	11/4/09 10:40		2156	8.87			
NBL-02	11/4/09 10:44				PROBE PROBLEMS???		
NBL-02	11/4/09 10:49	108.60	2230	8.22	Hanger on LevelTROLL slipped about 3.4? Ft - re-secured	75.38	
NBL-02	11/4/09 10:55	108.81	2278	8.00		75.2	
NBL-02	11/4/09 11:08	108.96	2385	8.23		74.99	
NBL-02	11/4/09 11:22		2500	8.21	valve problems		
NBL-02	11/4/09 11:30	109.03	2564	8.00		74.91	8.10
NBL-02	11/4/09 11:37		2621	8.14			
NBL-02	11/4/09 11:48		2709	8.00			
NBL-02	11/4/09 12:00	108.84	2807	8.17		74.85	
NBL-02	11/4/09 12:10		2889	8.20			
NBL-02	11/4/09 12:20		2971	8.20			
NBL-02	11/4/09 12:30		3052	8.10			
NBL-02	11/4/09 12:40	108.81	3135	8.30		74.9	
NBL-02	11/4/09 12:53		3239	8.00			
NBL-02	11/4/09 13:00		3296	8.14			
NBL-02	11/4/09 13:10		3376	8.00			
NBL-02	11/4/09 13:20	108.64	3457	8.10		75.1	
NBL-02	11/4/09 13:30		3538	8.10			
NBL-02	11/4/09 13:50		3697	7.95			
NBL-02	11/4/09 14:10		3858	8.05			
NBL-02	11/4/09 14:30		4016	7.90			
NBL-02	11/4/09 15:00	108.57	4256	8.00	Injection flow stopped	75.05	
NBL-02	11/4/09 15:02				break vaccum drop pipe emptied		
NBL-02	11/4/09 15:10	130.93					
NBL-02	11/4/09 15:20	136.96					
NBL-02	11/5/09 10:46	157.54					
NBL-02	11/6/09 8:05	158.12					
NBL-02	11/9/09 8:43	158.52			Stop logging w/ LevelTROLL		

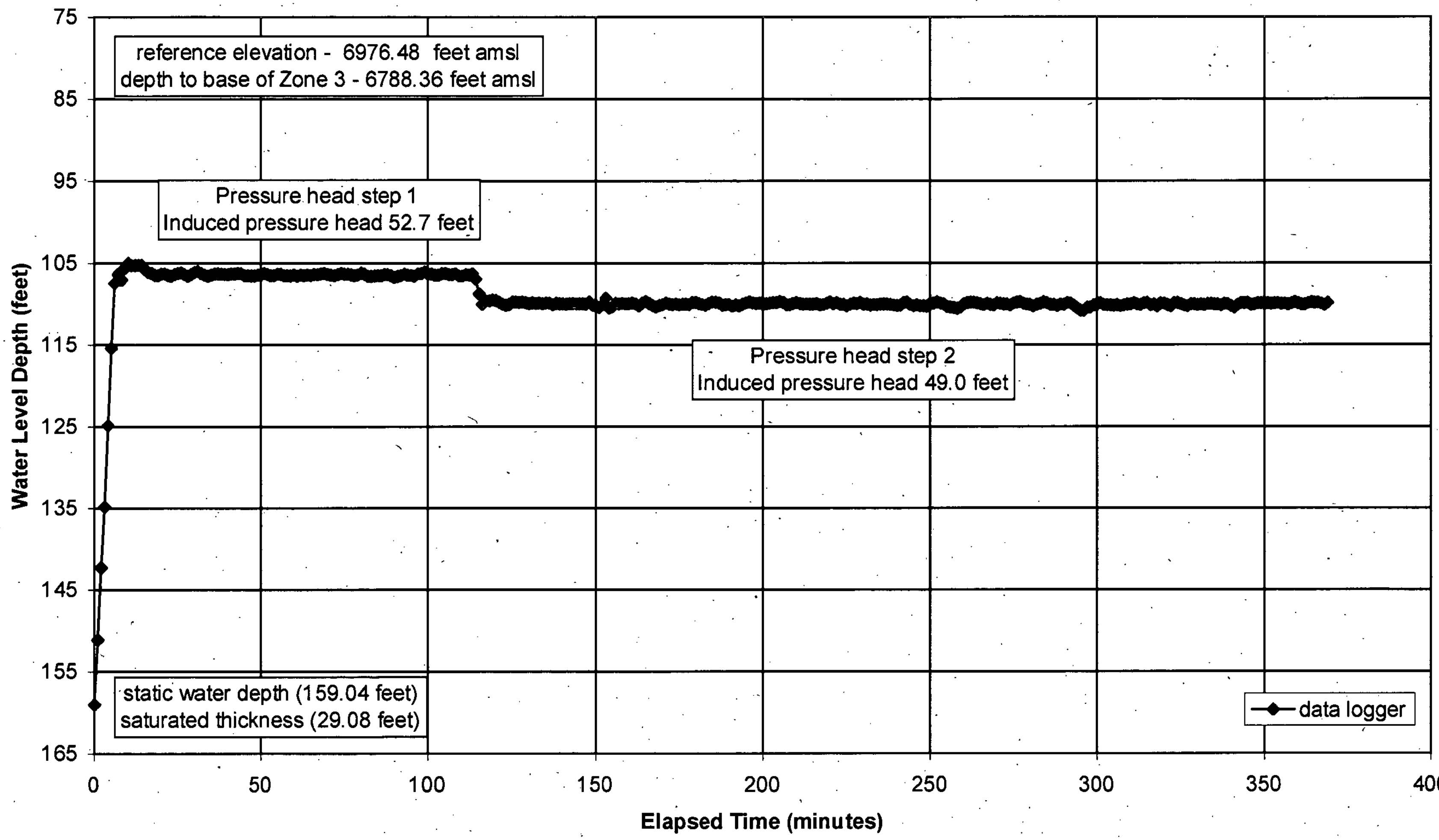

Figure 1
Water-level depths measured in Well NBL-2,
November 4, 2009, injection test of Well NBL-2

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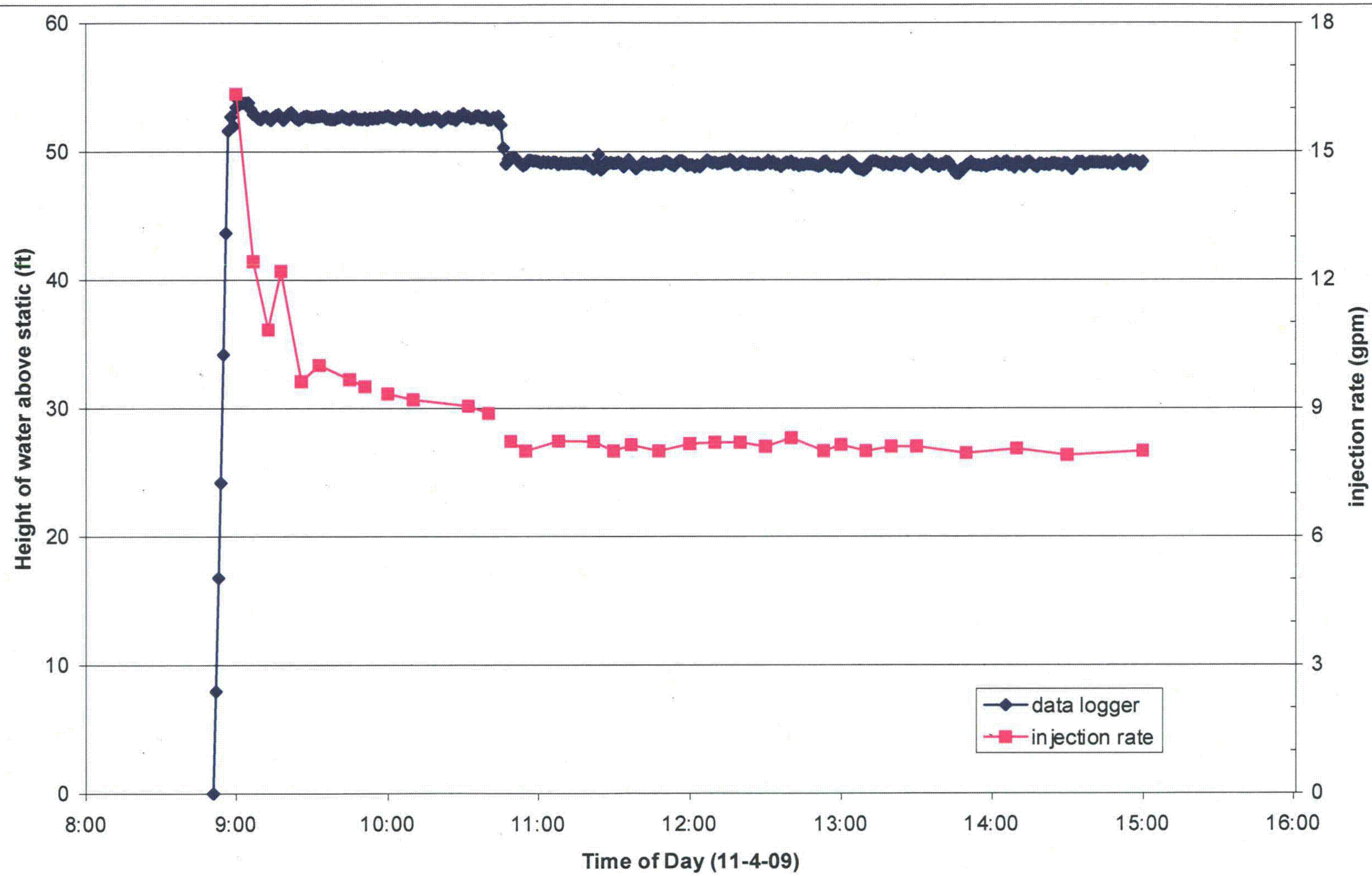

Figure 2
Pressure head and injection rate changes
Injection test of Well NBL-2, November 4, 2009

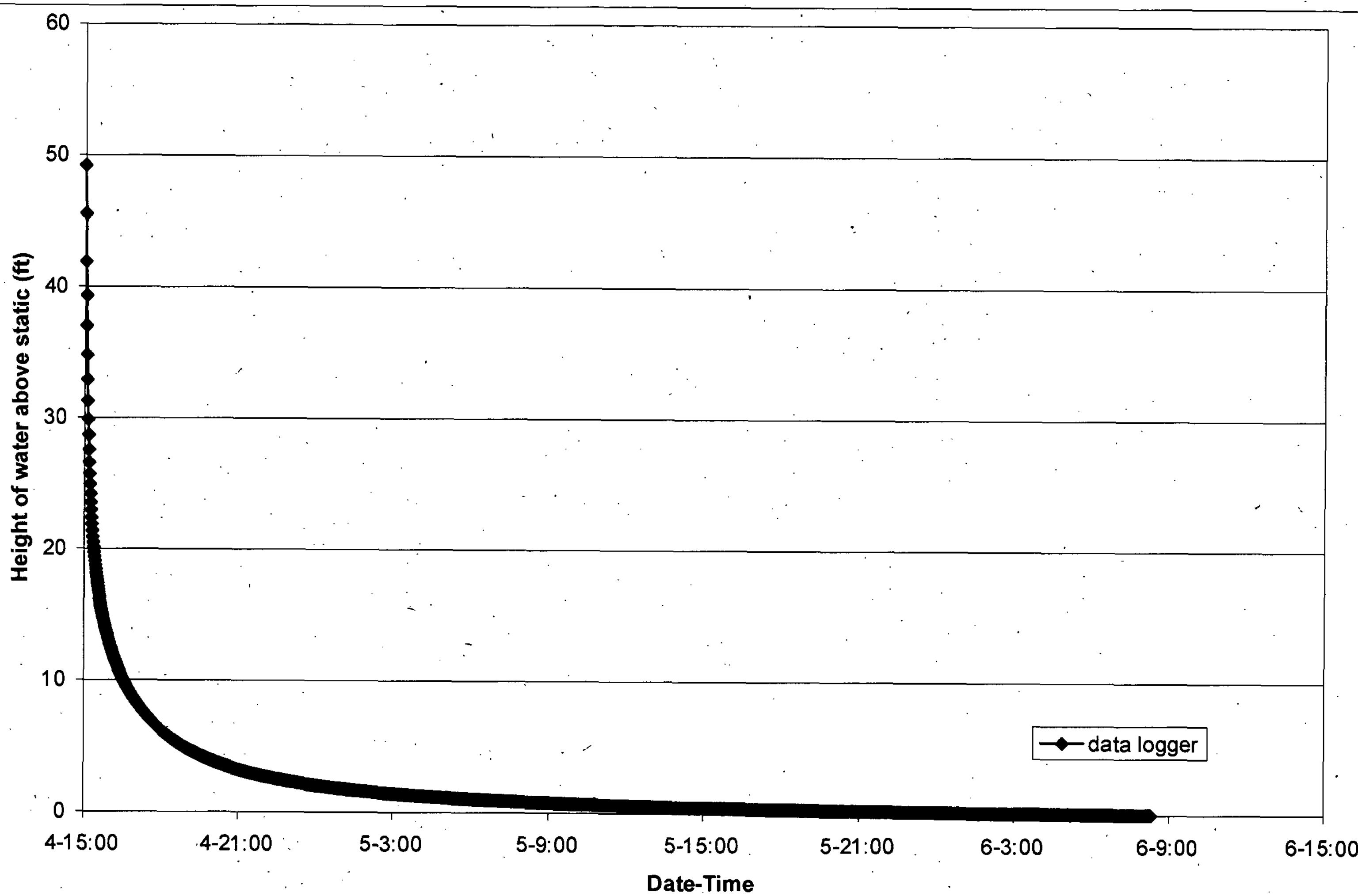

Figure 3
Pressure head changes during recovery
Injection test of Well NBL-2, November 4-6, 2009

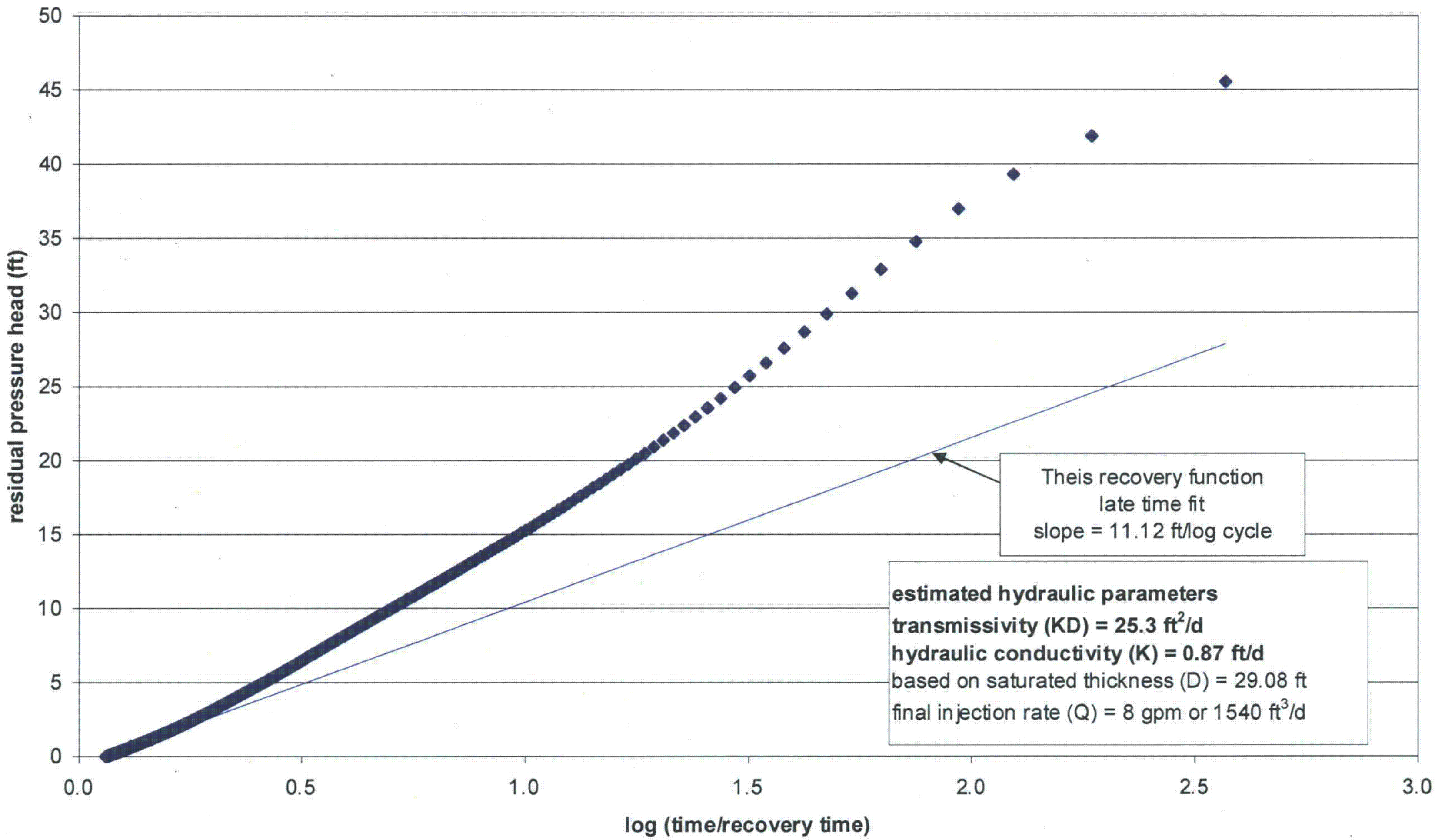

Figure 4
Theis Recovery Analysis
Injection test of well NBL-2, November 4-6, 2009

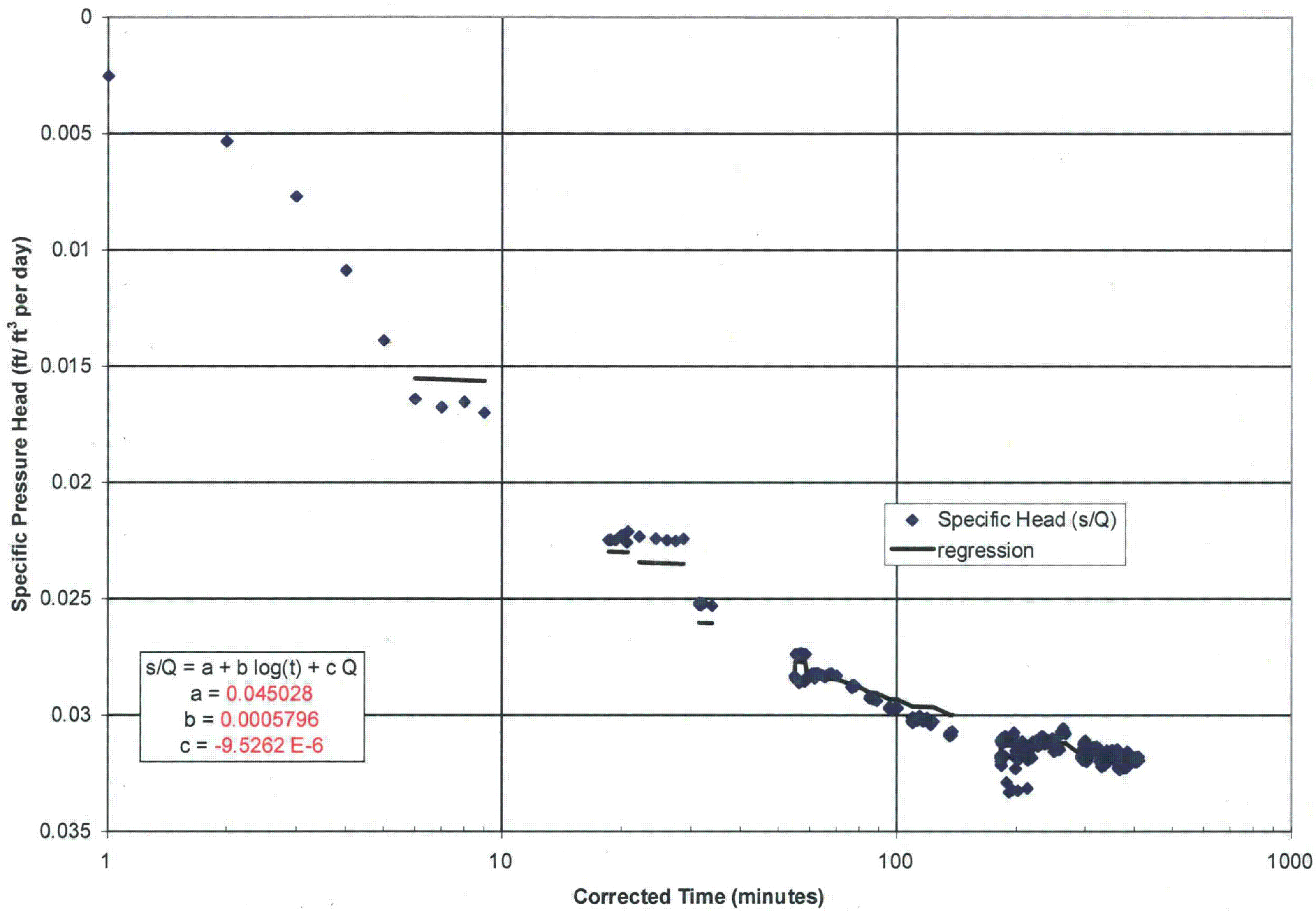

Figure 5
Well performance analysis of pressure head measured in Well NBL-2,
November 4, 2009, injection test of Well NBL-2

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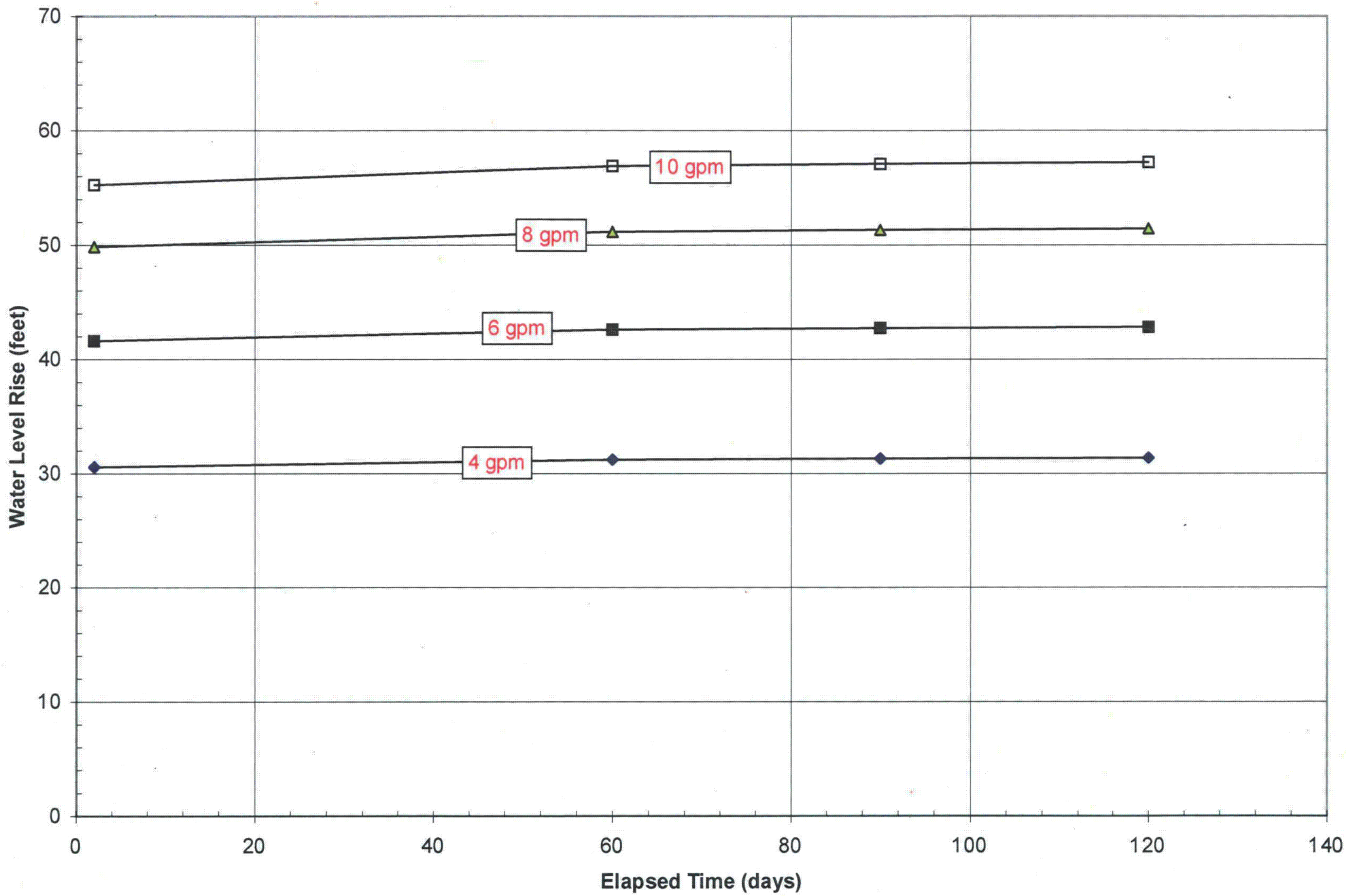

Figure 6
Projected pressure head (water level rise) in Well NBL-2,
Based on analysis of stepped-level injection test of Well NBL-2, November 4, 2009

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