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AUG 20 1982

Mr. Fred Ross
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7915 Eastern Avenue
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Dear Fred:

This letter constitutes my response to your request to analyze the Mine Unit #2 pump test and associated data.

Introduction

Ogle Petroleum Inc. is proposing to mine a 10 to 15 foot thick sandstone layer (ore sand) in Mining Unit #2. According to Hydro-Engineering (1982), a lower non-ore bearing sandstone (lower sand) is separated from the ore sand by 15 to 30 feet of claystone; the lower sand consists of siltstone, and sandstone that fills a poorly developed sandstone channel. The lower sand ranges in thickness from zero feet to 15 feet within mining unit #2 and is underlain by blue-gray shale (Hydro-Engineering, 1980).

The ore sand is overlain by 100 to 150 feet of shale. A 10 to 15 foot thick, "upper sand" aquifer is present above the shale. This "upper sand" aquifer is utilized by the Bison Basin mine as a domestic and mill water supply.

Mining Unit #2 is bounded to the north by the east-west trending north fault. According to Hydro-Engineering (1982), the south side of the fault has been displaced approximately 30 feet upward relative to the south side of the fault. Another fault, the middle fault, trends

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east-west through the middle of Mining Unit #2. The north side of this fault has been displaced approximately 30 feet upward relative to the south side of the fault (Hydro-Engineering, 1982).

Description of Pump Test

Well C-70, completed into the ore sand, was used as the pumping well. Well C-70 is located approximately 225 feet north of the middle fault and approximately 650 feet south of the north fault. According to Hydro-Engineering ore sand wells C-48, C-63, C-71, C-73, C-84, C-101 and C-G were chosen as observation wells between the two faults; ore sand wells B-135 and C-28 were chosen as observation wells to the south of the middle fault, and ore sand well C-F was used as an observation well to the north of the north fault. Three observation wells (M-48, M-52, and M-47) were completed into the "upper sand" aquifer. Well M-48 is located south of the middle fault and wells M-52 and M-47 are located between the faults. The lower sand observation wells were M-50 (south of the middle fault) and M-51 (between the faults).

According to Hydro-Engineering (1982, p.4),

> water levels in the ore sand aquifer in Mining Unit #2 have been impacted due to the mining operation currently in progress in Mining Unit #1 located south-east of Mining Unit #2. Due to the apparent retarding nature of the middle fault, water levels south of the fault have been affected considerably more than those north of the fault. On May 23, 1982, the day before the aquifer test began, the water-level-elevation in well C-28, located south of the middle fault, was approximately 45 feet less than that in well C-48.

Analysis of Pump Test

The pump test began at 9:00 a.m. on May 24, 1982. Well C-70 was pumped for 4445 minutes (3.087 days) at an average discharge rate of

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5.3 gallons per minute.

Hydro-Engineering (1982) analyzed the pump test data for most of the observation wells by using both the Jacob straight line method of analysis and image well theory. Hydro-Engineering (1982) tries to justify a "u assumption" of $u \leq 0.2$ instead of the customary value of $u \leq 0.01$ by stating that " a plot of the Theis curve data on semi-log paper shows that the Theis data for a values less than 0.2 form a straight line. The u value must be ≤ 0.01 in order to justify the use of the Jacob technique. The use of a larger than normally acceptable u value (0.2) by Hydro-Engineering allows them to use the data for early times (before the cone of depression reaches the middle fault) to calculate transmissivity and storativity values. This procedure is not valid. It clearly violates standard theory and practice as can be verified in any textbook on ground water hydrology (see for example Davis and Dewiest, 1966, Hydrogeology, p. 219).

It is estimated (by using Hydro-Engineering's approximate values for transmissivity = 150 gpd/ft and storativity = 5×10^{-5}) that the cone of depression, from pumpage of well C-70, reached the middle fault after approximately 10 minutes of pumping and the north fault after about 90 minutes of pumping. This invalidates the calculation of transmissivity and storativity by the Jacob Straight line method for all wells except the pumping well if the u assumption of u = 0.01 is adhered to properly.

Hydro-Engineering (1982) used image well theory to generate type curves (log-log) for most of the observation wells assuming that both the middle fault and north fault are impermeble boundaries. Hydro-Engineering used the technique of summing the effects of the pumping well, plus one

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primary image well for each fault and one secondary image well for each primary image well. This technique should yield adequate results assuming that correct values were input into the equations and that no errors were made during the calculations. However, it is not possible to analyze development of the type curves because the data used to generate the curves are not available. The technique should yield correct results if the two faults are the only boundaries that are present at the site and if leakage between aquifers and aquitards is not occurring.

A major deficiency with respect to the aquifer pump test is the fact that drawdown data were not collected at several observation wells for the first five to eight minutes of the test. Early drawdown measurements taken to an accuracy of 0.01 feet are crucial with respect to analysis for boundary conditions and potential leakage. Without early drawdown data, it is possible to force fit the remaining data to a type curve while falsely concluding that leakage is not occurring and additional boundaries do not exist. Also, by force fitting data to a type curve in the absence of early data when maximum curvature occurs it is possible also to overestimate or underestimate the transmissivity and storativity for the aquifer.

If one disregards these inadequacies, and accepts the type curve matching analysis by Hydro-Engineering (1982), it appears that the range of values that are given for transmissivity and storativity are reasonable for the ore sand aquifer. These are:

Transmissivity = 110 gal/day/ft to 190/gal/day/ft

Storativity = 1.9×10^{-4} to 2.0×10^{-5}

Analysis of Potential Leakage

Water levels were measured during the pump test in three observation wells that are completed into the upper sand aquifer (M-47, M-48 and M-52). Water levels also were measured in two observation wells that are completed into the lower sand aquifer. The water level data for these wells do not indicate that drawdown occurred as a result of the aquifer pump test. Water levels in each well showed a rising water level trend during and after the pump test.

According to Hydro-Engineering (1982, p.26),

> because neither the prior water level trend nor barometric efficiency are well quantified for lower sand aquifer well M-51, calculations were made for worst-case conditions assuming that one foot of drawdown occurred as a result of the ore-sand aquifer test by the time pumping ceased in the well C-70....
>
> A method for determining aquitard vertical permeability described by Neuman and Witherspoon (1971) and Neuman and Witherspoon (1972) was used in the analysis of vertical permeability of the aquitard separating the ore-sand and the lower sand aquifers.

Application of the "ratio method" of pump test analysis requires measuring drawdown (s) in the pumped aquifer and drawdown (s') in either one or both of the underlying and overlying aquitards at the same time and at the same radial distance from the pumping well open in the aquifer. This requires observation wells to be constructed and sealed properly in the aquifer and in the aquitards in question. The entire reason for measuring drawdowns in the aquitards is that measureable drawdown may not occur in the overlying or underlying aquifer for a long period of time after pumpage begins (more than 3.087 days), if ever, depending upon the transmissivity of the overlying or underlying aquifers and on the properties of the aquitards. Measurement of drawdown in the aquitards is the only way to obtain data pertaining to pressure changes that occur in the aquitard in response to pumpage of the aquifer.

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The manner in which Hydro-Engineering (1982), attempted to use the "ratio method" to determine the vertical hydraulic conductivity of the lower aquitard is not valid. Hydro-Engineering estimated what drawdown should be in an imaginary nonexistent well, completed in the ore-sand aquifer at a distance of 10.3 feet from the pumping well, after 3.087 days of pumping using values for transmissivity and storativity of 145 gal/day/ft and 5×10^{-5}, respectively (first invalid step). The imaginary well was located 10.3 feet from the pumping well because well M-51, completed in the lower sand, is 10.3 feet from the pumping well. Because no observation well was completed in the lower aquitard at this distance (or any other distance from the pumping well), Hydro-Engineering (1982) made the assumption that the lower aquitard (20 feet thick) and the lower sand aquifer (15 feet thick) were the same hydrostratigraphic unit (second invalid step). They then made the assumption that they could treat the lower 20 foot thick aquitard and the 15 foot thick aquifer as a 35 foot thick lower aquitard with well M-51 completed into the lower half of the aquitard (third invalid step). By assuming what it called a "worst case" scenario (that one foot of drawdown occurred in well M-51), Hydro-Engineering was able to "create" a fictitous ratio of drawdown in the so called aquitard (s') to drawdown in the aquifer (s) at the same radial distance from the pumping well as required by the ratio method (fourth invalid step).

Application of the "ratio method" to the Ogle Petroleum Inc., well design and locations used in the analysis is completely invalid and does not merit further discussion. Hydro-Engineering's conclusion that at least three years of travel time are needed for the movement of water

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from the ore sand to the lower sand aquifer is equally invalid. It is not possible to estimate vertical leakage between the upper sand-ore sand-lower sand with the data that are available. The pump test could easily have been conducted properly by properly locating and properly designing the wells, so that the requirements of the ratio method are met.

Conclusions

1) Values of transmissivity and storativity that were estimated by use of the Jacob Straight line method of analysis are not valid.
2) The middle fault and north fault definitely are flow retarding boundaries. However, hydraulic connection does exist across the north fault.
3) Actual values for transmissivity and storativity for the ore sand aquifer probably fall within the range of values that were estimated by Hydro-Engineering (1982) by use of image well theory. Transmissivity probably ranges between approximately 100 gal/day/ft and 200 gal/day/ft. Storativity probably ranges between 10^{-4} and 10^{-5}.
4) The fact that early drawdown data simply were not measured (or were not presented) for several observation wells is a deficiency with respect to analysis for boundary conditions and potential leakage. The case for boundaries and the absence of leakage could have been strengthened if these measurements had been taken and analyzed.
5) The "ratio method" as utilized by Hydro-Engineering to estimate the vertical hydraulic conductivity of the lower aquitard is

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invalid. The wells used in the test are not located properly nor screened in the correct hydrostratigraphic units to qualify for use in the ratio method.

6) Very little can be determined with respect to potential leakage between aquifers with the data that are available.

Sincerely,

Roy E. Williams

Roy E. Williams,
President

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cc: Joyce Fields

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