AG-7924

November 27, 1979

MEMORANDUM

TO: Distribution

FROM: J. Hanson

SUBJECT: PRELIMINARY EXAMINATION OF TIDAL PRESSURE RESPONSE DATA FROM SIX WELLS AT THE RAFT RIVER KGRA

Over the past several weeks, approximately 3000 hours of downhole pressure data from Raft River, Idaho, have been analyzed for the presence and nature of tidal strain induced pressure fluctuations. These data consist of short (136 hours) to relatively long (888 hours) records removed from archived pump test data taken between 9/29/75 and 6/1/79. A total of six wells (RRGE-1, RRGE-2, RRGE-3, RRGE-4, RRGI-6, and RRGI-7) are represented in the data analyzed. Due to the fact that the tidal response of a well may be influenced by the presence of other wells in the vicinity that are hydraulically connected, the results presented here do not necessarily reflect the responses that would be measured in the present well array. Furthermore, as of the period of September/October, 1979, wells 4 and 5 have undergone hydraulic fracturing. Post-stimulation well response to tides is likely to be different than the pre-stimulation response. One should treat the usefulness of the enclosed information, regarding evaluation of reservoir hydrologic parameters, accordingly.

The spectral analysis method used yields the least squares best estimates of the pressure response amplitude and phase. Prior to spectral analysis, data detrending using polynomial regression followed by appropriate high-pass filtering was applied to the data to remove as much of the non-tidal signal present as possible. On the short length records, only detrending was done since the recursive filter shortens the usable record by approximately 3 days. An error analysis of the spectral amplitudes and phases was then done based on the assumption that the signal noise is a stationary ergodic time series with uniform energy density (i.e., "white"). With these assumptions, the variances of the real and imaginary constituents of the spectral estimates can be computed. Assuming that the real and imaginary parts of the estimate obey a bivariate normal distribution, uncertainties in both amplitude and phase at a given confidence level can be computed. A Fisher statistics test was also applied to the detrended and filtered data to facilitate the determination of which spectral peaks were significant at a given confidence level. The analysis of a set of random data will yield some spectral peaks larger than others. The Fisher test allows for the decision of the reliability of a given spectral amplitude by comparing with spectral amplitudes that can be produced by harmonic analysis on the assumption that the time series are from a random fluctuation and do not have physical meaning.

The procedure outlined above was applied to both the pressure response data and the theoretical tidal gravity perturbation over the same period of time. The latter was computed using Harrison's spherical harmonic formulation and is accurate to 0.1% in amplitude and 0.1° in phase. The sign of the gravity perturbation was reversed so that a high in Δg is associated with a high in Δp for more convenient visual comparison.

Continuous spectra were computed in addition to the discrete spectra approach outlined above. The primary purpose of evaluating continuous spectra was to help determine where the noise was distributed and, in general, allow for a rough estimate of the signal/noise ratio. The continuous spectra are relative--no significance should be attached to the ordinate scale. This is a direct consequence of using an unnormalized data window for sharpening the spectra.

The tidal admittance ($\Delta p/\Delta g$) was computed for each well for each spectral line that was resolved at the 90% confidence level. The phase lag of the pressure response relative to the tidal strain was computed for each line resolved at the 90% confidence level for two wells (RRGE-1 and RRGE-2). Error bars representing the 90% confidence level were placed on all admittance and phase shift estimates.

The results of this preliminary examination of pressure response to tidal strain can be summarized as follows.

1. Tidal response is observed in all wells for which data were available.
2. Relative noise level is quite low on all records, and the signal/noise ratio is somewhat better for deep measurements compared with shallow measurements.
3. On most records, the O_1 and K_1 lines in the diurnal band and the M_2 and S_2 lines in the semidiurnal band are resolved at the 90% confidence level.
4. The terdiurnal line M_3 is seen on the continuous spectra of RRGE-4, RRGI-6, and RRGI-7 (and possibly on RRGE-3). This line is not seen in either RRGE-1 or RRGE-2.
5. Tidal admittances at the O_1 and K_1 lines in the diurnal band differ at the 90% confidence level on the RRGE-1 and RRGI-6 records. This indicates the signal is contaminated by barometric and/or temperature effects and points out the necessity of correcting for these effects in the future.
6. The theory of well pressure response to tidal strain for a homogeneous isotropic porous aquifer of infinite extent indicates that the phases of the pressure response and dilatation are related by the relationship $\pi/2 < \phi_p - \phi_b < \pi$ where ϕ_p is the phase of the pressure response and ϕ_b

is the phase of the tidal dilatation. The lower bound corresponds with zero fluid permeability and the upper bound with infinite permeability. Since tidal dilatation is in phase with the tidal gravity perturbation, it is out of phase by π with a "reversed sign" gravity perturbation. We have used the latter in all calculations. Therefore, for the ideal well-aquifer case, $\pi/2 > \phi_g^* - \phi_p > 0$ always, where ϕ_g^* is the phase of the tidal gravity with reversed sign. Again, the lower bound corresponds with infinite permeability and the upper with zero permeability. Phase shifts observed in RRGE-1 indicate the presence of some mechanism inconsistent with an ideal reservoir model. The phase shifts on all spectral lines do not fall in the allowed range for the ideal case. We can probably attribute this behavior to the presence of structural control (e.g., a nearby fault). A conventional well interference test (Narasimhan and Witherspoon, 1977) indicates the existence of a barrier boundary within 6000 feet of RRGE-1.

JH/bh

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COMMENTS ON INTERPRETING THE COMPUTER OUTPUT

1. all pressures are in psi
2. gravity is in microgals
3. the notation E-02 means 10^{-2}, and so on.
4. 8 tidal lines were analyzed for in the computation. On the left hand side of the computer output pages, numbers 1 through 8 are seen. These identify spectral lines M_m, M_f, O_1, K_1, N_2, M_2, S_2, and M_3 respectively.
5. "Uncorrected" estimates are simply the result of applying the Fourier integration to a finite data length. ie these results are the convolution of the true spectrum with the data window transfer function.
6. "Corrected" estimates account for the finite data window. ie these results are the deconvolved solution and are the best estimates in the least squares sense.
7. phases are given in radians.
8. Fisher statistics: any amplitude greater than these are significant at the corresponding confidence level.
9. RMS noise amplitudes are a measure of the variation between the raw data and the reconstructed signal. That is, the square root of the mean squared residuals.
10. Varr and Vari are the variances of the real and imaginary parts, respectively, of the spectral estimates.