UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

ATOMIC SAFETY AND LICENSING BOARD

In the Matter of CROW BUTTE RESOURCES, INC. (Marsland Expansion Area)	Docket No. 40-8943-MLA-2 ASLBP No. 13-926-01-MLA-BD01

Hearing Exhibit

Exhibit Number: OST003

Exhibit Title: Dr. Kreamer Opinion August 16, 2018

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CROW BUTTE RESOURCES, INC. ,	)	Docket No. 40-8943 – MLA - 2
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(Marsland Expansion Area)	)	August 16, 2018

EXPERT OPINION TESTIMONY OF DAVID K. KREAMER

I, David K. Kreamer, do hereby swear that the following written testimony is true to the best of my knowledge:

I. Basis for Testimony as Expert in Field.

I have been involved in hydrogeological studies and reviewed contaminated waste and pollution challenges for over 35 years, have served as an expert witness, and testified before the U.S. Congress on issues of uranium mining. I serve as a professor in the Department of Geoscience at the University of Nevada, Las Vegas, am past President of the Universities Council on Water Resources, and Vice President for Science and program for the International Association of Hydrogeologists. I have been asked by the U.S. EPA and other internationally and nationally recognized professional groups to give short courses and lecture series on issues of groundwater quantity and quality. I have published over 65 professional publications and am co-author of the 3rd Edition of the text, "Contaminant Hydrogeology" Fetter, Boving and Kreamer, 2018, Waveland Press.

II. Expert Opinions and Testimony Concerning OST Contention 2,

Opinion 1: The site characterization by Aqui-Ver, Inc., Marsland Hydrologic Test Report #8, written in 2011, revised in 2015, for the Marsland Expansion Area (MEA) [CBR016] is deficient and mischaracterizes the hydrogeologic environment at the MEA site.

Basis: There are several deficiencies with the Marsland Expansion Area hydrogeologic characterization. Essentially much of the collected pumping test data was selectively ignored, the solitary pumping test covered very little of the of the MEA site leaving the majority of the site hydrogeolologically undefined, and the single pumping test that was analyzed was influenced by conditions outside the site boundary.

A. The Aqui-Ver Inc., Marsland Hydrologic Test Report #8, written in 2011, revised in 2015 only reported one of two pumping tests done on the MEA – a second 19 hour test was not presented and was characterized as "failed". [CBR016 at 10] The "failed" Marsland pumping test that went on for 19 hours had a long enough duration to be possibly analyzed and perhaps could have be included as a second analysis in the reporting of hydrological conditions. This second test could supply additional insight as to the hydrogeological conditions beneath the site. The justification for test failure was a poorly explained pump failure. If this occurred at the end of the test, the information recorded is still valid.

B. The report only analyzed selective portions of the data from the single pumping test. The report did not present analysis of the complete data set. The data the report selectively excluded can demonstrate, if analyzed, the lack of confinement of the Basal Chadron Sandstone Aquifer and production zone.

C. The report stated that Cooper-Jacob semi-logarithmic evaluations were performed on the data. [CBR016 at 15] These analyses did not appear in the report and can identify a recharge boundary which would be consistent with lack of confinement of the aquifer.

D. The report did not include analysis of pumping test data from water level changes at Monitoring Wells 2 or 8 in the analysis, although these wells were reported to be in the radius of influence of the pumping test and those water level changes were used to define an extended radius of pumping well influence.

E. The single pumping test covered only a relatively small portion of the site which is over five miles long. Only one pumping test on so large a site is poor professional practice. The subsurface hydrogeological response of the large majority of the site to pumping remains unknown. The hydrologic response of more of the MEA's subsurface can only be guessed.

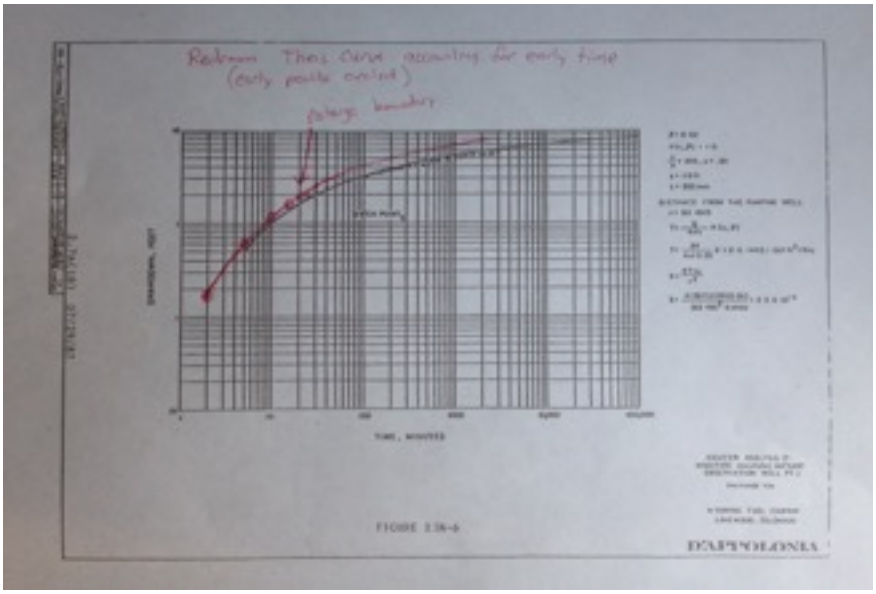
F. The single, solitary pumping test performed at the MEA was impacted by hydrogeologic influences off-site that were not part of the area to be evaluated. Because of the elongated nature of the MEA, the cone of depression's radius of influence for the solitary pumping test extended significantly off-site, well past the boundaries of the narrow portion of the property. The pumping test drew water from these off-site locations. This is significantly impactful as much of the analyses selectively addressed only late time data, which is more influenced by off-site factors.

G. The report does not make it clear if the actual aquifer thicknesses were used to calculate transmissivity or only the average aquifer thickness.

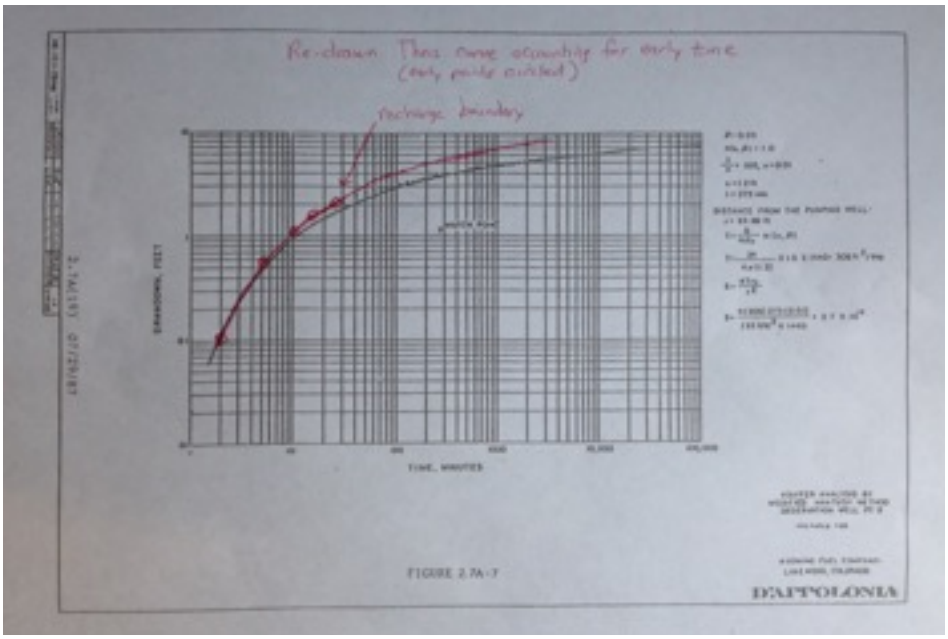
H. From Figure 2.6-9 [CBR008 at 76], the thickness of the Basal Chadron Sandstone varies from 21ft to 91ft across the site; the screened intervals of the monitoring wells varied from 22 to 50 feet giving the possibility that these wells did not measure results solely from the entire thickness of that aquifer, or conversely, in part measured water derived from formations other than the Basal Chadron Sandstone.

Opinion 2: The summary of historical testing results, mischaracterizes results of previous testing of the Basal Chadron Sandstone. Particularly the assertion on page 6 of the Aqui-Ver, Inc., Marsland Hydrologic Test Report #8 that ***"Results of previous testing indicate that the Basal Chadron is relatively homogeneous and isotropic within the current Class III UIC area…"*** is contradicted by previous data. [CBR016 at 10].

Basis: Previous hydrogeologic testing identified non-homogeneous anisotropic conditions in properties adjacent to the MEA. Ten aquifer tests were performed at the or around the Crow Butte Resources (CBR) site and five of those tests were invalidated by CBR because of possible vertical leakage (Tests 5 through 9 in 2004 and 2005). Information on those pumping tests was not provided. For CBR Aquifer Test One the CBR report explicitly states on page 2.7A (15) [OST006 at 16], *"Figures 2.7A-4 through 2.7A-7 give the apparent indication of leakage especially noticeable at late times."* On page 2.7A (8) [OST006 at 9] in the CBR report the authors state that, *"Based on significant deviation of the pump test data from the Theis type curve in the original analysis the USNRC questioned the use of a non-leaky analysis method in the data."* On page 2.7A (22) [OST006 at 23] they state, *"Examination of the drawdown/time curves plotted for observation well indicated that some leakage from confining bed occurred during the pumping test."* Additionally, Dr. David Kreamer in testimony regarding pumping test one showed departure from the classic Theis curve consistent with leakage (See Exhibits 1 and 2 below). [OST005 at 4] This same departure is evident in the MEA pumping test. [CBR016 at 80-96]

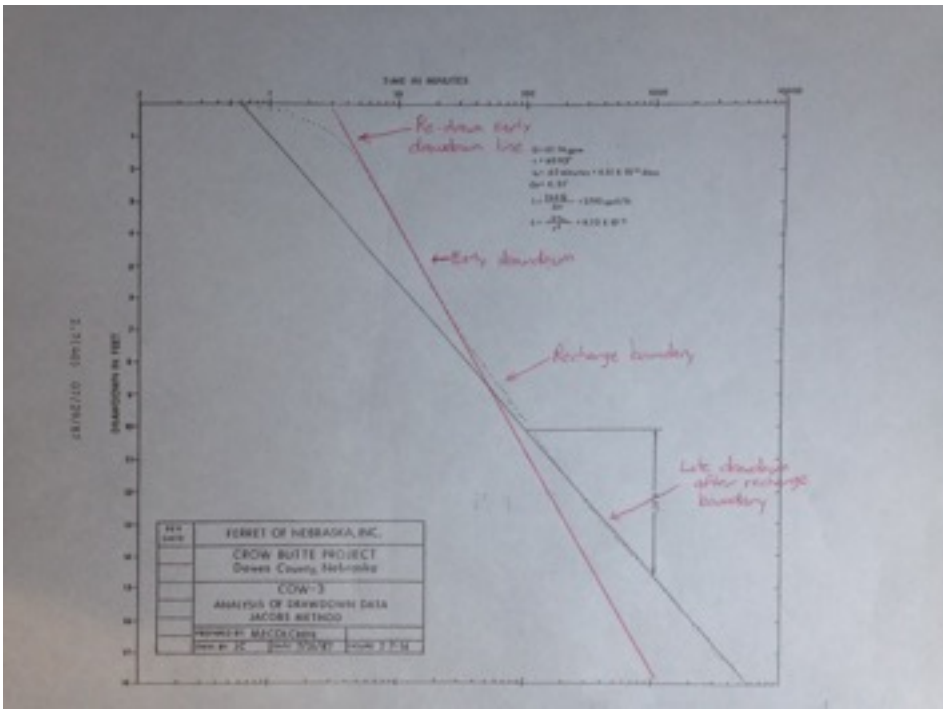


OST005 at 4: Dr. Kreamer re-drawn Figure 2.7A-6, with Theis type-curve matching early time in red. Early data points are circled – late time data below type curve indicates recharge.



OST005 at 4: Dr. Kreamer re-drawn Figure 2.7A-7, with Theis type-curve matching early time in red. Early data points are circled – late time data below type curve indicates recharge.

Historical Aquifer Test 2 from CBR also showed a recharge boundary. [OST007]. Kreamer Testimony September 2015 Exhibit 3 below [OST005 at 7] is Figure 2.7-14 with additional early time interpretation, showing a distinct break point at about 30 minutes, signifying a clear recharge boundary, which can be interpreted as additional vertical flow. Residual time-drawdown data for COW-3 also exhibits this recharge boundary (Figure 2.7-20 on page 2.7 (46)). [OST007 at 33].



OST005 at 7: Cooper Jacob semi-logarithmic plot (Figure 2.7 -14) modified (in red) by Dr. Kreamer to show early drawdown. A recharge boundary appears at approximately 30 minutes, and forms a line of late time data to the right of the red early data trend.

For CBR Pumping test three no vertical leakage analysis was performed, and the report authors document that Test 3 was *"not performed to quantitatively assess the nature of the confining layer above the Chadron Sandstone"*. [OST008 at 13] Similar problems were identified in other CBR pumping tests.

The historic analytical mathematical approaches used by CBR, which are the same used at MEA for interpretation, assume *a priori* homogeneity and isotropy. This presumption by CBR was debunked by the quantification of anisotropy in Pump Test 2 on page 2.7 (53). [OST007 at 40] Note that the major axes of anisotropy reported in CBR Aquifer Test 1 [OST006 at 23] had azimuth difference of 49 degrees from those reported in Test 2 [OST007 at 40] and there are large differences in magnitude of hydraulic conductivity, indicating the complete lack of homogeneity, and the likelihood of preferential flow. This observable but unreported heterogeneity is consistent with unequal distribution of spot contamination during site stabilization process at CBR and the need to utilize more complex numerical modeling to understand preferential flow in the remedial process.

By making the unsupported statement, "***Results of previous testing indicate that the Basal Chadron is relatively homogeneous and isotropic within the current Class III UIC area"***, [CBR016 at 10] the Aqui-Ver report for MEA misrepresents past aquifer testing results and wrongly implies the local geology is simple. It further mistakenly presumes an overly simplified and inappropriate mathematical analytical approach which assumes homogeneous, isotropic subsurface conditions is appropriate.

Opinion 3: Aqui-Ver, Inc. in its Marseland Hydrologic Test Report #8 only presented one form of analysis for the MEA site, that is, the Theis methodology, although in their report they refer to **also using the semilogrithmic Cooper- Jacob technique** which was not presented. [CBR016 at 15] Both mathematical forms of analysis are considered the simplest forms of aquifer pumping test analysis. They require the same fundamental assumptions to be fulfilled for accurate results. The first major assumption inherent in these analytical, mathematical approaches employed in the MEA hydrology report [CBR016 at 15], is that the Basal Chadron Sandstone aquifer is *"confined and has apparent infinite extent"*. The presumption by the authors is not consistent with the data and evidence. This main foundation for the analytical approach was presumed, but is inconsistent with the test data.

Basis: This explanation that the analytical work with semi-logarithmic Cooper Jacob was done is in the Aqui-Ver Report, but no analysis appears, or is omitted. The measured water levels in the MEA aquifer test monitoring wells break significantly from the expected Theis curve. [CBR016 at 80-96] This change in the level of water from the Theis curve is consistent with a lack of confinement of the aquifer. The authors of the report acknowledge this flattening of the data, but present only one possible explanation and do not discuss or analyze the possibility of lack of confinement. The variation in the horizontality and thickness of the Basal Chadron is documented in the Report [CBR016 at 9] and the qualifying assumptions for the stated mathematical approach are not consistent with the field site.

Opinion 4: The second major assumption inherent in this analytical, mathematical Theis approach employed in the MEA hydrology report, is that the Basal Chadron Sandstone aquifer is, ***"homogeneous and isotropic, and of uniform effective thickness over the area influenced by pumping".*** [CBR016 at 15] This foundational requirement is violated and is not consistent with the data and evidence. Again, this fundamental condition for accurate use of the Theis methodologies is presumed, but is inconsistent with the evidence.

Basis: Transmissivities that range from 230 ft^2/day to 1780 ft^2/day and values of Storage Coefficient from $1.7x10^{-3}$ to $8.32x10^{-5}$ are not consistent with homogeneous conditions. Homogeneity also means that the thickness of the formation is uniform – it is not. Conjecture in the EA [NRC006 at 67] that the lack of continual thickness of the Basal Chadron Formation is due to the formation of paleo channels as the sediment was being deposited seems not to be an explanation for the upper surface of the Pierre Shale and lower boundary of the Basal Chadron because that boundary is rather flat, whereas the upper boundary of the Basal Chadron changes elevation repeatedly and fairly abruptly. This is illustrated in the Figures presented in CBR008 at 68-70 and also in Pump Test #8. [CBR016 at 35-40]

Opinion 5 – Rigorous analyses for anisotrophy were not demonstrated or undertaken for the EA or hydrologic report, and the nature of directional hydraulic conductivity differences remains undefined and not quantified, particularly in the vertical direction.

Basis – The argument put forth in the Aqui-Ver Report [CBR016 at 18], and accepted in the EA [NRC006 at 70 & 255], that no anisotrophy exists in the small area of the MEA which underwent a pumping test was based on a 2-dimensional, hand-drawn visual rendering with very few data points [CBR016 at 48] rather than a standard, serious, data based evaluation. This is not consistent with professional practice.

Opinion 6: Significant discontinuities in the thickness of the Basal Chadron Sandstone aquifer invalidate the simplified mathematical approach used to characterize the hydrological properties of the formation.

Basis: The Basal Chadron Formation is not entirely horizontal nor of equal thickness as required by the Theis assumptions (see above).

Opinion 7: There is no justifiable basis for arbitrary analyzing only a selected portion of the pumping data and not the entire test information.

Basis: Selecting just portions of the measured data is not consistent with getting a complete picture of the pumped region, which in turn is just a small area of the site. It can greatly basis the results. In some well response analysis by Aqui-Ver late time data was chosen for analysis, for other wells late time was disregarded and the middle time period was analyzed.

Pursuant to 10 CFR 2.304(d) and 28 USC 1746, I declare under penalty of perjury, that the foregoing is true and correct to the best of my knowledge and belief.

Signed in Cairo, Egypt, on 8/16/2018, 2018.

DocuSigned by:
David Kreamer
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DAVID K. KREAMER