CBRMarslandPEm Resource

From:	John Schmuck [John_Schmuck@Cameco.com]
Sent:	Tuesday, May 20, 2014 2:58 PM
To:	Lancaster, Thomas
Subject:	FW: Marsland Clarifications from 5/9/14
Attachments:	Confining Layers Revision2.doc; Pine Ridge Fault.doc; MEA_Kozeny-Carmen Calculations.xls

Tom – Attached please find additional documents that Cameco believes are ready for finalization.

Thanks. .john

From: Wade Beins
Sent: Thursday, May 15, 2014 3:25 PM
To: John Schmuck; Larry Teahon; Doug Pavlick
Subject: Marsland Clarifications from 5/9/14

John,

Here are some of the clarifications that Tom and Jose have requested for the Geo-Hydro discussions we had last Friday. Included are:

Kozeny-Carmen Equation calculations and spreadsheet used to determine the Hydraulic Conductivity,
Section 2.7.2.3 Confining Layer edits,
Section 2.6.1.3 Pine Ridge Fault edits,
Further discussion on Pine Ridge Fault.

I have left the word documents pretty plain so that you can cut and paste as needed. Rather than re-send the large cross-sections R0, R1, and R2, they can refer to the "Draft" copies provided for the Niobrara River Fault discussion. I do have final pdfs and prints with pretty legends and title blocks, but will wait to send those when we have fully answered their questions and can determine what the figure numbers will be. We have corrected the Pine Ridge Fault location on the R1 cross-section.
Figure numbers particularly on the discussion of the Pine Ridge Fault are a bit dicey.
Perhaps it is easiest to say that for the Three Crow cross-sections mentioned, they should refer to the Three Crow Technical Report Volume I, dated August 2010, and the figure numbers are 2.6-14, 2.6-15a and 2.6-15b.

Wade A. Beins

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MESSAGE	2362	5/20/2014 2:57:52 PM
Confining Layers Revision2.doc	237632	
Pine Ridge Fault.doc	235584	
MEA_Kozeny-Carmen Calculations.xls	500288	

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For placement in Section 2.7.2.3

Confining Layers

Upper confinement for the basal sandstone of the Chadron Formation within the MEA is represented by 650 to 710 feet of smectite-rich mudstone and siltstones of the upper Chadron and middle Chadron (**Figures 2.6-3a** through **2.6-3n, 2.6-7, and 2.6-8**). Particle grain-size analyses of six core samples from the upper confining layer within the MEA indicate the samples were predominately siltstone. (**Appendix G-1 and G-2**). All MEA core samples were laboratory tested using ASTM D4464 methods for determining particle-size distributions by laser light scattering. The procedure is a modification of ASTM D4464-85 used to measure particle sizes of catalytic material. The procedure has been extended to include measurement of unconsolidated soils and sediments, and is recognized as an alternative to ASTM D422 (hydrometer) and the pipette method. X-Ray Diffraction (XRD) analyses indicate that the chemical compositions of core samples from the middle Chadron are highly similar to the Pierre Shale (e.g., predominantly mixed-layered illite/smectite or montmorillonite with quartz), which would be expected if the Pierre Shale was a contributing source of materials for the overlying middle Chadron (**Appendix G-1**).

The estimated hydraulic conductivities for the upper confining units were developed using the Kozeny-Carmen method (Appendix ???) based on particle grain-size distribution data from the six core samples collected from the upper Chadron and middle Chadron. Use of the Kozeny-Carmen method is acceptable for developing hydraulic conductivity estimates for sands and silts, but not for cohesive clayey soils with a high degree of plasticity. Results of the particle size distribution analyses (Appendix G-1, Appendix G-2) indicate sediments dominated by silts and fine sand with less than 25% clay. Estimated hydraulic conductivities of the four core samples collected within the upper Chadron ranged from 4.3 x 10-5 to 5.9 x 10-5 cm/sec. Estimated hydraulic conductivities of the two core samples collected within the middle Chadron ranged from 1.7 x 10-5 to 2.9 x 10-5 cm/sec. The vertical hydraulic conductivity across the upper and lower confining layers is likely to be even lower due to vertical anisotropy. Additionally, hydraulic resistance to vertical flow is expected to be high due to the significant thickness of the upper confining zone within the MEA, which ranges between 650 and 710 ft. As a result, the Brule Formation and Arikaree Group are vertically and hydraulically isolated from the underlying aquifer proposed for exemption.

Lower confinement for the basal sandstone of the Chadron Formation in the vicinity of the MEA is represented by approximately 750 to more than 1,000 feet of black marine shale deposits of the Pierre Shale. Additional low permeability confining units are represented by the underlying Niobrara Formation, Carlile Shale, Greenhorn Limestone, and Graneros Shale. Together with the Pierre Shale, these underlying low-permeability units hydraulically isolate the basal sandstone of the Chadron Formation from the underlying "D", "G", and "J" sandstones of the Dakota Group by more than 1,000 vertical feet (**Table 2.6-1**). The Pierre Shale is not a water-bearing unit, exhibits very low permeability, and is considered a regional aquiclude.

The Pierre Shale consists primarily of illite and smectite clays as indicated by x-ray diffraction of CBR core samples collected in 2011 and 2013 (**Appendix G-1** and **G-2**). The swelling nature of these clays in the presence of water makes it unlikely that any fractures or penetrations within the Pierre would provide a pathway for loss of confinement through this thick unit. Regional estimates of hydraulic conductivity for the Pierre Shale range from 10^{-7} to 10^{-12} cm/sec (Neuzil and Bredehoeft 1980; Neuzil et al. 1982; Neuzil 1993). The Pierre Shale has a measured vertical hydraulic conductivity at the CPF of less than 1 x 10^{-10} cm/sec (WFC 1983), which is consistent with other studies in the region. Particle grain-size analyses of two samples collected from the Pierre Shale within the MEA indicate low permeability silty clay compositions. Kozeny-Carman estimated hydraulic conductivities for the seven core samples collected within the Pierre Shale were not reported due to significant levels (up to 76 weight percent) of clay.

The upper surface of the Pierre Shale illustrated on **Figure 2.6-10** and cross-section A-A' (**Figure 2.6-3a**) is a gentle, southeasterly-sloping surface consistent with that described by DeGraw (1971). This sloping surface rises northwesterly to the axial crest of the Cochran Arch north of the MEA. Cross-section A-A' does not show evidence of major folding across the axis of the Cochran Arch that could have created significant vertical fractures within the Pierre Shale. Regional studies also indicate that there is no observed transmissivity between vertical fractures in the Pierre Shale, which if present, are short and not interconnected (Neuzil et al. 1982). All oil and gas wells in the area of review which penetrate the Pierre Shale were abandoned in accordance with accepted regulatory practices at that time. Oil and gas well plugging records are provided as **Appendix D-1**.

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Section 2.6.1.3

Pine Ridge Fault

Approximately 5 miles north of the MEA is the inferred Pine Ridge Fault, located along the northern edge of the Pine Ridge Escarpment (Figure 2.6-15). The east-west trending fault is inferred from several lines of evidence, but no detailed study of it has yet been published. The fault was initially proposed by DeGraw (1969) based on subsurface oil and gas test hole data which indicated the possible presence of a normal fault, with north-side down displacement of about 300 feet. The fault is inferred to be sub-parallel to the Cochran Arch as shown in Figure 2.6-15. Souders (1981) inferred the presence of an unnamed fault near the same location proposed by DeGraw, but estimated only 120 feet of displacement on the basis of limited test well data south of the fault and extrapolated measurements of the dip of the Pierre Shale from outcrop several miles to the north. Swinehart et al. (1985) reported normal faulting along the feature that post-dates the Upper Harrison (Arikaree Group), but does not describe the location where the observation was made.

Geophysical data from Cameco Resources exploration test holes have been reviewed to substantiate the presence of the inferred Pine Ridge Fault, and to determine the extent and potential impact of this fault on operations at the MEA. Regional cross-sections prepared as part of clarifying information provided to NRC concerning the Niobrara River Fault are also useful for discussions about the Pine Ridge Fault. These regional cross-sections, Figures X through X3(R0, R1, R2), extend from south of the Niobrara River (south of MEA) northward though the Marsland Expansion Area, across the Crow Butte License Area and the North Trend Expansion Area. Figure X4(Figure 3 of Niobrara Fault comments) of this report shows these cross-sections and a map of their location. Each of the three sections, R0, R1 and R2, cross the Niobrara River Fault, Cochran Arch, Pine Ridge Fault and White River Fault. The principle cross-section, R1 runs from south of the MEA northward through the center of the project along the same transect as A-A' (MEA TR Figure 2.6-3a), and continues to the northwest, intersecting the Crow Butte Project and the North Trend Expansion Area. Sections R0 and R2 are located approximately one mile east and one mile west of R1 respectively. The geophysical logs shown on the figures are vertically exaggerated 10X to accentuate any structural features present. The Pierre Shale, top of Chadron sandstone, and a pair of persistent marker beds have been highlighted.

Cross-Section R0-R0' transects the proposed Pine Ridge Fault at a point about one mile west of where Souders(1981) places the fault. The surface of the Pierre Shale at this point drops 22 vertical feet over a distance of 2.3 miles. On sections R1 and R2, the Pierre Shale rises 24 feet and 29 feet from south to north as the location of the proposed fault is crossed respectively.

These topographic changes in the Pierre surface are likely erosional rather than structural. At no point on the cross-sections with the exception of the White River Fault/Fold, is an offset of ~300 feet observed as reported by DeGraw, nor is an offset of ~120 feet observed that impacts all overlying strata as would be expected by fault movement that post-dates deposition of the overlying strata.

The Three Crow Expansion Area Technical Report also addressed concerns for the presence of the Pine Ridge Fault. These sections are presented as Appendix Z of this application. Five cross-sections were prepared showing the Pierre Shale surface contact with the overlying Chadron Formation as determined on geophysical logs. The surface depicted has been plotted with a 10X vertical scale to visually accentuate any structural features present. These sections do not support the presence of the Pine Ridge Fault within the AOR for the TCEA permit as inferred by DeGraw (1969), nor do they support the presence within the MEA AOR. The cross-sections do not substantiate a reported north side down vertical displacement of 300 feet and in two of the cross-sections, the top of the Pierre Shale surface elevations decrease southward, which is contradictory to a north side down vertical displacement. The sections show gentle increases in the elevation for the top of the Pierre Shale that are most likely a result of topographic lows on the eroded surface of the Pierre Shale or structural dip due to flexing associated with the formation of the Crawford Basin. Given the magnitude of folding observed elsewhere in the Crawford Basin, it is entirely feasible that displacement along an inferred fault would not be required to explain observed elevation changes for the top surface of the Pierre Shale.

While the data presented in these sections refutes the estimated offset of the Pine Ridge Fault, it does not entirely rule out the possibility that a short offset fault may be present. The data clearly shows however, that there is not a large offset fault that could act as a boundary for groundwater flow and movement that would impact production operations at MEA.

Porosity	0.438		
Kozeny-Carman Coeff	4.8	Range 4.5 to 5.1	
Shape Factor	6.5	Range 6 to 8.4	Rounded 6.1 - 6.6
			Medium angular 7
			Very Angular 7.7 -
Effective Grain Size (cm)	0.006494829		
Intrinsic Permeability (cm2)	5.5E-08		
Rho (g/cm3)	1.03		
Viscosity (dyne-sec/cm2)	0.016		
Gravitational Const (cm/sec2)	980		
Hydraulic Conductivity K (cm/sec)	3.5E-03	Arikaree	

	Porosity	0.35	
		M-533C Run 1, Sample 1	
Sieves Size/Number	Sieve Size (mm)	Retained (%)	
	6.35107	0.00	
	4.75683	0.00	0.000
	3.36359	0.00	0.000
	2.00000	0.00	0.000
Medium Sand	1.18921	3.42	2.110
	0.84090	2.47	2.389
	0.70711	1.42	1.810
	0.59460	2.07	3.137
	0.50000	3.50	6.307
	0.42045	5.55	11.892
Fine Sand	0.35355	6.39	16.280
	0.29730	11.20	33.927
	0.25000	10.90	39.258
	0.21022	10.80	46.250
	0.17678	9.65	49.136
	0.14865	7.85	47.525
	0.12500	5.92	42.614
	0.10511	4.21	36.033
#200	0.08839	2.94	29.919
	0.07433	2.12	25.652
Silt	0.06250	1.60	23.019
	0.05256	1.23	21.040
	0.04419	0.95	19.322
	0.03716	0.74	17.895
	0.03125	0.58	16.677
	0.02503	0.60	20.919
	0.02005	0.49	21.321
	0.01563	0.47	25.812
	0.01105	0.56	41.039
	0.00781	0.48	49.729
	0.00500	0.52	79.319
Clay	0.00195	0.80	232.691
	0.00098	0.39	262.463
	0.00049	0.20	269.006
	0.00038	0.02	45.195
		Sum(fi/(dli^0.404*	1539.687
		Deff (mm)	0.0649
		K (cm/sec)	**1.3E-03**

K (ft/day)	3.77
K (m/day)	1.15
D10 (mm)	0.0649
K Hazen (cm/sec)	4.22E-03
K (ft/day)	11.96
K Hazen (cm/sec)	2.18E-03
K (ft/day)	6.17

Sand (%)	90.37
Silt (%)	8.22
Clay (%)	1.41

Analysis of K results

Formation	**Geomean of K (cm/sec)**	**STD**	**# of Samples**
Arikaree	1.4E-04	9.3E-04	10

.4 - 7.5
8.4

$$\text{Intrinsic Permeability} = \frac{\text{Porosity}^3}{\left(\text{K-C coefficient} \times \left(\frac{\text{Shape Factor}}{\text{Effective Grain Size}}\right)^2 \times \left(1 - \text{Porosity}\right)^2\right)}$$

$$\text{Hydraulic Conductivity (K)} = \frac{\text{Intrinsic Permeability} \times \text{Density} \times \text{Gravity}}{\text{Viscosity}}$$

Arikaree		Arikaree		Arikaree	
0.35		0.35		0.35	
M-533C Run 1, Sample 2		**M-1635C Run 1, Sample 1**		**M-1635C Run 1, Sample 2**	
Retained (%)		Retained (%)		Retained (%)	
0.00		0.00		0.00	
0.00	0.000	0.00	0.000	0.00	0.000
0.00	0.000	0.00	0.000	0.00	0.000
0.00	0.000	0.00	0.000	0.00	0.000
0.00	0.000	0.00	0.000	0.00	0.000
0.00	0.000	0.00	0.000	0.00	0.000
0.00	0.000	0.00	0.000	0.00	0.000
0.00	0.000	0.00	0.000	0.00	0.000
0.00	0.000	0.00	0.000	0.00	0.000
0.00	0.000	0.00	0.000	0.00	0.000
0.00	0.007	0.00	0.000	0.00	0.000
0.11	0.333	0.00	0.000	0.00	0.000
0.41	1.477	0.00	0.005	0.00	0.004
0.83	3.555	0.08	0.343	0.09	0.377
1.24	6.315	0.67	3.413	0.88	4.485
1.75	10.597	1.98	11.993	2.96	17.936
2.41	17.351	3.41	24.558	5.43	39.122
3.35	28.677	5.23	44.785	8.03	68.789
4.59	46.718	7.43	75.648	10.41	105.930
5.84	70.675	9.08	109.920	11.81	142.906
6.64	95.545	9.18	132.135	11.41	164.155
6.82	116.682	7.90	135.202	9.55	163.507
6.51	132.429	6.22	126.570	7.16	145.756
5.84	141.253	4.87	117.828	5.21	126.106
5.09	146.381	3.96	113.920	3.91	112.527
5.57	194.231	4.21	146.852	3.82	133.302
4.80	208.899	3.69	160.642	2.89	125.865
4.61	253.218	3.96	217.583	2.52	138.518
5.64	413.391	5.59	409.855	2.77	203.177
5.27	546.082	5.31	550.399	2.25	233.314
6.26	955.037	5.67	865.297	2.39	364.885
10.50	3054.588	7.19	2092.322	3.82	1112.086
4.34	2921.239	2.79	1878.529	1.80	1212.444
1.49	2004.438	1.43	1924.326	0.80	1076.981
0.11	248.614	0.14	316.517	0.07	162.846
	11617.733		9458.645		5855.019
Deff (mm)	0.0086	Deff (mm)	0.0106	Deff (mm)	0.0171
K (cm/sec)	**2.3E-05**	**K (cm/sec)**	**3.5E-05**	**K (cm/sec)**	**9.2E-05**

K (ft/day)	0.07	K (ft/day)	0.10	K (ft/day)	0.26
K (m/day)	0.02	K (m/day)	0.03	K (m/day)	0.08
D10 (mm)	0.0086	D10 (mm)	0.0106	D10 (mm)	0.0171
K Hazen (cm/sec)	7.41E-05	K Hazen (cm/sec)	1.12E-04	K Hazen (cm/sec)	2.92E-04
K (ft/day)	0.21	K (ft/day)	0.32	K (ft/day)	0.83
K Hazen (cm/sec)	3.82E-05	K Hazen (cm/sec)	5.77E-05	K Hazen (cm/sec)	1.50E-04
K (ft/day)	0.11	K (ft/day)	0.16	K (ft/day)	0.43
20.53		27.88		39.61	
63.04		60.57		53.90	
16.44		11.55		6.50	

Arikaree		Arikaree		Arikaree	
0.35		0.35		0.35	
M-1912C Run 1, Sample 1		**M-1912C Run 2, Sample 1**		**M-1956C Run 1, Sample 1**	
Retained (%)		Retained (%)		Retained (%)	
0.00		0.00		0.00	
0.00	0.000	0.00	0.000	0.00	0.000
0.00	0.000	0.00	0.000	0.00	0.000
0.00	0.000	0.00	0.000	0.00	0.000
0.82	0.506	0.74	0.457	1.37	0.845
0.69	0.668	2.75	2.661	1.79	1.731
0.32	0.408	0.96	1.224	1.31	1.670
0.35	0.531	0.89	1.350	2.02	3.061
0.56	1.010	1.17	2.109	3.82	6.883
1.11	2.381	1.33	2.851	6.67	14.289
1.76	4.488	0.98	2.498	8.24	20.989
4.49	13.615	1.10	3.334	15.19	46.034
6.17	22.245	1.17	4.216	14.79	53.294
8.16	34.937	2.13	9.126	13.69	58.657
9.53	48.523	3.87	19.714	10.59	53.962
10.31	62.421	6.15	37.250	7.02	42.492
10.51	75.660	8.05	57.974	4.36	31.379
10.00	85.591	9.01	77.152	2.69	23.019
8.75	89.034	8.83	89.901	1.72	17.500
6.87	83.211	7.73	93.576	1.08	13.065
4.77	68.695	6.16	88.664	0.62	8.918
2.95	50.514	4.63	79.238	0.34	5.815
1.73	35.222	3.46	70.406	0.22	4.474
1.11	26.871	2.74	66.293	0.18	4.352
0.83	23.890	2.34	67.315	0.15	4.312
0.92	32.108	2.67	93.133	0.17	5.926
0.88	38.331	2.44	106.222	0.18	7.831
0.97	53.325	2.50	137.361	0.19	10.432
1.28	93.899	3.19	233.885	0.23	16.852
1.09	113.043	2.85	295.408	0.21	21.752
1.06	161.853	3.12	476.135	0.26	39.651
1.22	355.216	4.56	1326.961	0.47	136.678
0.49	330.098	1.77	1191.737	0.32	215.311
0.27	363.529	0.65	874.681	0.13	174.819
0.03	63.337	0.05	119.823	0.00	0.000
	2335.161		5632.654		1045.993
Deff (mm)	0.0428	Deff (mm)	0.0178	Deff (mm)	0.0956
K (cm/sec)	**5.8E-04**	**K (cm/sec)**	**1.0E-04**	**K (cm/sec)**	**2.9E-03**

K (ft/day)	1.64	K (ft/day)	0.28	K (ft/day)	8.18
K (m/day)	0.50	K (m/day)	0.09	K (m/day)	2.49
D10 (mm)	0.0428	D10 (mm)	0.0178	D10 (mm)	0.0956
K Hazen (cm/sec)	1.83E-03	K Hazen (cm/sec)	3.15E-04	K Hazen (cm/sec)	9.14E-03
K (ft/day)	5.20	K (ft/day)	0.89	K (ft/day)	25.91
K Hazen (cm/sec)	9.46E-04	K Hazen (cm/sec)	1.63E-04	K Hazen (cm/sec)	4.72E-03
K (ft/day)	2.68	K (ft/day)	0.46	K (ft/day)	13.37
80.39		56.86		96.33	
17.60		36.10		2.75	
2.01		7.03		0.92	

Arikaree		Arikaree		Arikaree	
0.35		0.35		0.35	
M-1956C Run 3, Sample 1		**M-2169C Run 1, Sample 1**		**M-2169C Run 2, Sample 3**	
Retained (%)		Retained (%)		Retained (%)	
0.00		0.00		0.00	
0.00	0.000	0.00	0.000	0.00	0.000
0.00	0.000	0.00	0.000	0.00	0.000
0.00	0.000	0.00	0.000	0.00	0.000
0.00	0.000	0.00	0.000	0.00	0.000
0.00	0.000	0.00	0.000	0.00	0.000
0.01	0.018	0.00	0.000	0.00	0.000
0.14	0.212	0.00	0.000	0.00	0.000
0.39	0.703	0.00	0.000	0.00	0.000
0.46	0.986	0.00	0.000	0.00	0.000
0.27	0.688	0.00	0.000	0.00	0.000
0.19	0.576	0.00	0.008	0.00	0.000
0.25	0.901	0.06	0.213	0.00	0.003
0.78	3.341	0.32	1.371	0.07	0.308
1.77	9.015	0.85	4.330	0.73	3.716
3.04	18.410	1.60	9.690	2.55	15.435
4.33	31.178	2.43	17.499	4.98	35.840
5.74	49.142	3.54	30.310	7.70	65.890
7.32	74.513	5.07	51.615	10.09	102.761
8.67	104.935	6.71	81.221	11.09	134.281
9.27	133.403	7.79	112.116	10.19	146.715
8.89	152.114	7.92	135.531	8.29	141.949
7.85	159.705	7.37	149.956	6.38	129.735
6.58	159.169	6.51	157.492	5.02	121.373
5.41	155.600	5.65	162.520	4.11	118.153
5.49	191.461	6.07	211.711	4.26	148.493
4.19	182.371	4.94	215.038	3.36	146.174
3.60	197.762	4.56	250.525	3.06	168.016
3.74	274.158	5.32	390.020	3.52	257.905
2.78	288.097	4.59	475.721	2.95	305.565
2.64	402.806	5.01	764.497	3.15	480.387
3.67	1067.766	8.07	2348.169	5.08	1477.277
1.71	1151.118	3.87	2605.438	2.41	1621.546
0.76	1022.507	1.61	2166.330	0.95	1277.512
0.07	153.705	0.14	316.486	0.08	176.223
	5986.360		10657.807		7075.259
Deff (mm)	0.0167	Deff (mm)	0.0094	Deff (mm)	0.0141
K (cm/sec)	**8.8E-05**	**K (cm/sec)**	**2.8E-05**	**K (cm/sec)**	**6.3E-05**

K (ft/day)	0.25	K (ft/day)	0.08	K (ft/day)	0.18
K (m/day)	0.08	K (m/day)	0.02	K (m/day)	0.05
D10 (mm)	0.0167	D10 (mm)	0.0094	D10 (mm)	0.0141
K Hazen (cm/sec)	2.79E-04	K Hazen (cm/sec)	8.80E-05	K Hazen (cm/sec)	2.00E-04
K (ft/day)	0.79	K (ft/day)	0.25	K (ft/day)	0.57
K Hazen (cm/sec)	1.44E-04	K Hazen (cm/sec)	4.54E-05	K Hazen (cm/sec)	1.03E-04
K (ft/day)	0.41	K (ft/day)	0.13	K (ft/day)	0.29
33.36		20.58		37.21	
60.43		65.73		54.28	
6.21		13.69		8.51	