Cameco

June 5, 2015

CAMECO RESOURCES

Corporate Office
550 N Poplar St. Ste. 100
Casper, WY
82601 USA

Tel: (307) 237-2128
Fax: (307) 237-2142
www.cameco.com

Mr. John Passehl
Wyoming Department of Environmental Quality
Water Quality Division
Herschler Building
122 West 25th Street
Cheyenne, WY 82002

Supplemental Report on Smith Ranch Deep Disposal Well #2

Dear Mr. Passehl,

Power Resources, Inc. d.b.a. Cameco Resources (Cameco) is writing to provide a *Supplemental Report on Smith Ranch DDW # 2 Class I Proposed Workover Procedures*. This report is being submitted to comply with Section M of Permit 99-347 as requested in correspondence submitted by your office on April 15, 2015. Cameco is available to meet at your earliest convenience to discuss this submittal. As always feel free to contact me directly at 307-333-7644 or by email Jeanie_wolford@cameco.com.

Sincerely,
Cameco Resources

Jeanie Wolford
SHEQ

JW/jmw

Attachments:
Supplemental Report on Smith Ranch DDW # 2 Class I Proposed Workover Procedures

Cc: SHEQ Document Management System
Doug Mandeville, Nuclear Regulatory Commission

Supplemental Report on Smith Ranch DDW # 2 Class I Proposed Workover Procedures

This report supplements and, as appropriate, revises the reports, information and statements previously communicated to Water Quality Division (WQD) of the Wyoming Department of Environmental Quality (WDEQ) regarding the movement of fluid from Smith Ranch Deep Disposal Well #2 (SR DDW #2) into an interval above the perforation and below the primary confining layer.

Cameco submitted the Proposed Workover Procedure for SR DDW #2 in February 2015. WQD's approval was received by Cameco on April 23, 2015. To fulfill Cameco's obligation of Section "M" and "O" of the current permit, Cameco is providing additional information for your review prior to completing the workover procedure.

I. Background

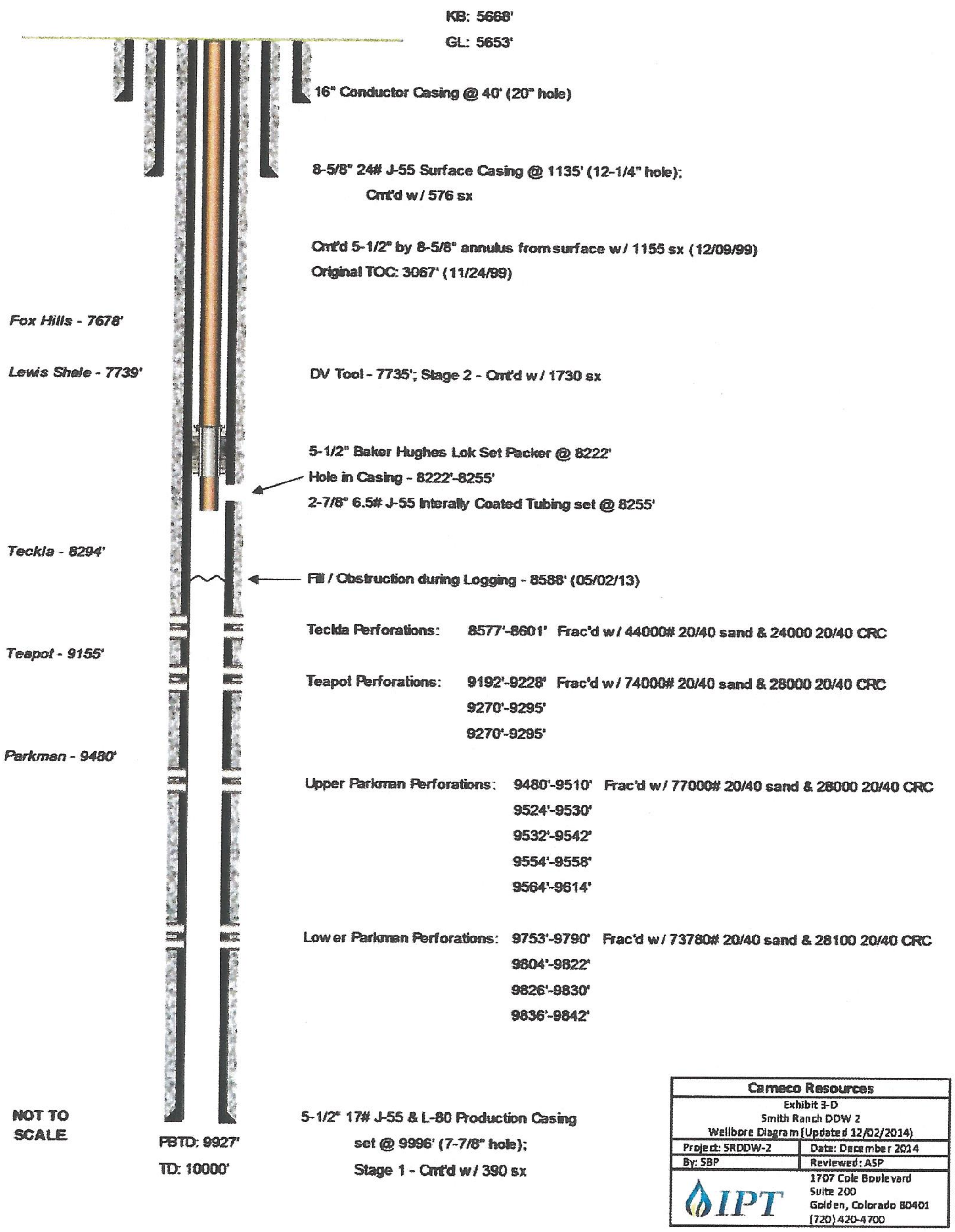
Cameco Resources contracted Petrotek Engineering Corporation (Petrotek) to perform the 5-year mechanical integrity test (MIT) for SR DDW #2 as required under Section M (Mechanical Integrity) of permit 99-347 (currently in renewal). All MIT activity occurred on May 2 and May 3, 2013. Mechanical integrity testing conducted in 2013 consisted of a Standard Annulus Pressure Test (SAPT), post-injection static temperature log conducted approximately 17 hours after shut-in, one- and two- hour static (post-injection) temperature logs and a RAT log. The purpose of the logs is to identify potential movement of fluid along channels that may exist adjacent to the well bore.

The initial temperature log from Part II MIT raised some concerns as it suggested possible fluid storage behind the casing in an interval above the top perforations. Further evaluation of the logs indicate that under test conditions approximately 30% of the injected flow is exiting the casing through a hole above the first perforation, but below the packer in the vicinity of 8,222' - 8,255' KB (see Figure 1). Based on these initial results SR DDW #2 was shut in and WQD was notified on May 6, 2013.

On May 8, 2013 Cameco representatives met with WQD to discuss the potential failure of Part II of the MIT. WQD reviewed the ultrasonic log from the 2008 workover and the original cement bond logs. At this meeting it was determined that WQD did not believe that a failure of the MIT occurred and that if any holes were present in the casing it was most likely due to corrosion but still within the confines of the permitted injection zone. During this meeting WQD requested the following additional information from Cameco:

- Provide a report (by Petrotek) on the MIT by the end of the month which should summarize the phenomena of the upward flow into the sand. The report was submitted as requested on August 14, 2013.

Figure 1


KB: 5668'
GL: 5653'
16" Conductor Casing @ 40' (20" hole)
8-5/8" 24# J-55 Surface Casing @ 1135' (12-1/4" hole):
Cmt'd w / 576 sx
Cmt'd 5-1/2" by 8-5/8" annulus from surface w / 1155 sx (12/09/99)
Original TOC: 3067' (11/24/99)
Fox Hills - 7678'
Lewis Shale - 7739'
DV Tool - 7735'; Stage 2 - Cmt'd w / 1730 sx
5-1/2" Baker Hughes Lok Set Packer @ 8222'
Hole in Casing - 8222'-8255'
2-7/8" 6.5# J-55 Interally Coated Tubing set @ 8255'
Teckla - 8294'
Fill / Obstruction during Logging - 8588' (05/02/13)
Teckla Perforations: 8577'-8601' Frac'd w / 44000# 20/40 sand & 24000 20/40 CRC
Teapot - 9155'
Teapot Perforations: 9192'-9228' Frac'd w / 74000# 20/40 sand & 28000 20/40 CRC
9270'-9295'
9270'-9295'
Parkman - 9480'
Upper Parkman Perforations: 9480'-9510' Frac'd w / 77000# 20/40 sand & 28000 20/40 CRC
9524'-9530'
9532'-9542'
9554'-9558'
9564'-9614'
Lower Parkman Perforations: 9753'-9790' Frac'd w / 73780# 20/40 sand & 28100 20/40 CRC
9804'-9822'
9826'-9830'
9836'-9842'
NOT TO SCALE
PBTD: 9927'
TD: 10000'
5-1/2" 17# J-55 & L-80 Production Casing
set @ 9996' (7-7/8" hole);
Stage 1 - Cmt'd w / 390 sx
Cameco Resources
Exhibit 3-D
Smith Ranch DDW 2
Wellbore Diagram (Updated 12/02/2014)
Project: SRDDW-2
Date: December 2014
By: SBP
Reviewed: ASP
IPT
1707 Cole Boulevard
Suite 200
Golden, Colorado 80401
(720) 420-4700

- Cameco should have Gene George & Associates (GGA) contact WQD to work out defining the upper boundary of the sandstone and any associated implications for SR DDW #2.

Cameco agreed to provide the additional information. The well was restarted after the meeting concluded.

On July 3, 2013 Cameco representatives met with WQD to present findings from further evaluation, including results from GGA's analysis. A complete geologic review determined that the area in which the fluid had presumably migrated was above the top of the permitted injection zone into the Lewis Shale and a request was put forth to increase the current injection zone to include the lower portion of the Lewis Shale which contains some sandstone members. WQD was agreeable as long as Cameco could provide supporting documentation that the sandstone was still a Teckla Sandstone Member of the Lewis Shale. On September 4, 2013 Cameco submitted a request to increase the injection zone to approximately 8,120' KB and included information to show the sandstone was within the Teckla formation.

On September 2, 2014 WQD requested that Cameco shut in the well as they did not concur that the proposed increase to the injection zone was within the Teckla Sandstone. WQD did not believe that sufficient information had been provided. Cameco requested a meeting to further discuss the evaluation, which was scheduled for September 11, 2014. Cameco met with Kevin Frederick, Mark Thiesse and Kathy Shreve to discuss the history of the well, notification of the potential failure of the MIT in 2013, the determination that WQD did not believe a failure had occurred and the submittal in which Cameco requested increasing the injection zone. The logs were analyzed and a consensual agreement was made to have a petroleum engineer review the logs. WQD asked for Cameco to submit potential engineers and a scope of work. On September 30, 2014 Cameco submitted the scope of work and potential engineers via email to WQD. On October 16, 2014 Cameco retained Integrated Petroleum Technology (IPT) to complete the evaluation.

On January 15, 2015 Cameco determined that SR DDW #2 should be shut-in. A meeting was scheduled with WQD and IPT on January 21, 2015. The following key points were highlighted:

- Injection fluid has flowed outside of the intended discharge zone through a hole in the casing that developed sometime between 2008 and 2013.
- Available data (temperature and RAT logs) indicate that vertical fluid migration is not extending (and is not expected to extend) beyond a depth of 8,025'.
- There is no evidence to suggest contamination of the Fox Hills aquifer at 7,750 below KB.

Cameco informed WQD that they were preparing a workover procedure for approval and that the well would not be placed back in use until this procedure was accepted and completed.

Further investigations and analysis have been conducted to determine if any adverse impact to the environment has taken place due to the unintended fluid movement above the currently permitted injection zone. This supplemental report presents the results of those investigations.

II. Analysis of Unintended Flow above the Perforations

In an attempt to determine the time when the unintended flow began, Cameco evaluated:

1) Previous MIT records for SR DDW#2, and
2) Injection data from 2001-2013.

Based on the evaluation Cameco has determined that the unintended flow from the casing began sometime between the 2008 MIT and the 2013 MIT. Review of the injection data pressure and rates was inconclusive as injection pressures and flow varies based on operational needs.

III. Hypothetical Flow Evaluation

Radioactive Tracer Survey (RATS) from the 2013 MIT estimated that the fluid loss through the hole while shut-in at 257 to 334 bpd. As the shut-in pressure was not significantly below the injection pressure, 300 bpd is a reasonable estimate of the rate through the casing leak. The leakage rate was likely progressive and is considered to have begun at 0 bpd increasing linearly over time to the measured rate of 300 bpd. Cameco conservatively assumes that beginning December 11, 2008 through May 2, 2013 the rate increased linearly. After completion of the 5 year MIT on May 3, 2013 the leakage rate is assumed to be constant at 300 bpd. This results in an average rate of approximately 197 bpd through the casing breach over 2,349 days for a total of 462,753 bbls[1].

As there is no conclusive evidence as to when the unintended flow began Cameco conservatively evaluated the estimated flow using a start date of December 11, 2008. This was the date of restart after the 2008 workover and MIT were completed. Note that significant uncertainty exists in the assumed hypothesis, as many variables can influence the calculation. However, to meet the requirements of Section M of UIC permit 99-347, Cameco presents the following analysis:

[1] Calculated volume as of 5/18/15

Volume Calculation

Start Date	12/11/2008
End Date	5/18/2015
Total Days	2349

Average Flow/day	197	bbl/day

Total Volume:

Days X Average Flow/day = Total Volume		
2349 Days x 197 bbl/day =	462,753	bbls

Based on the flow rate and duration assumptions from Section III above, the total radial distance that the centroid of the plume may have migrated from the well can be estimated as follows:

Flow duration	2,349 days	(Assumed)
Assumed leak injection rate	197 bbls./day	(Cameco injection data)
Total leak volume in 2,349 days	462,753 bbls.	(calculated)
Assumed thickness of flow zone	30 feet	(RAT-Temp log)
Assumed effective porosity	12 percent	(OH logs)
Calc. radius of fluid displacement (ULEW)	479 feet	(per DEQ WQRR CH 13.)

To assess potential travel distance including retardation, a simple advective flow analytical calculation is used and discussed below. As historical sampling results indicate, the injected fluid contains low concentrations of dissolved uranium and radium that are transported by the injected water. Chemical processes can affect the rate at which the solutes (uranium and radium) are transported by the solvent (the injected water). The most common chemical process encountered is ion exchange involving clay minerals (e.g., montmorillinite and vermiculite) or zeolites. A measure of the amount of ion exchange which occurs is referred to as the "distribution coefficient" which is a determination of the amount of solute left on matrix after it has been mixed with the injected water, and allowed to reach equilibrium. The distribution coefficient (K_d) is defined by the following equation: $K_d = C/C_o$

Where C = concentration sorbed per gram of soil/matrix

C_o = equilibrium concentration in the injected water

The K_d values found in the literature are 10 ml/g for radium[2], and 1 ml/g for uranium[3].

Ignoring dispersion, one-dimensional theoretical sorption from laboratory studies can be extrapolated to predict the amount of sorption likely to occur in the field. The velocity of the ion transport in the field can then be predicted from Freeze & Cherry (Groundwater, Prentice-Hall International, 1979; Eq. 9.14) and Domineco & Schwartz (Physical and Chemical Hydrogeology, John Wiley & Sons, 1998, Eq. 18.7) and from NRC using the following formulas[1]:

$V_i = v / (1 + (K_d B_d / n))$ – Freeze & Cherry (1979)

Where V_i = ion velocity

v = solution velocity

K_d = distribution coefficient

B_d = bulk density

n = porosity

$V_i = v / (1 + ((1-n)/n)\ \square_m K_d))$ – Domenico & Schwartz (1998)

The ion velocity for radium and uranium can then be calculated using the following values:

K_d = 10 ml/g (radium) or 1 ml/g (uranium)

$B_d = 2.45\ g/cm^3$ (Freeze & Cherry)

$\square_m = 2.65\ g/cm^3$ (Domenico & Schwartz)

$\theta = 0.12$

v = 479 feet in 2,349 days (0.204 ft/d; based on ULEW calculation)

Based on the above values, the horizontal ion velocities for radium and uranium are calculated to be:

V_i (radium) = 2.3 feet in 2,349 days (Freeze & Cherry)
2.5 feet in 2,349 days (Domenico & Schwartz)

V_i (uranium) = 22.4 feet in 2,349 days (Freeze & Cherry)
23.5 feet in 2,349 days (Domenico & Schwartz)

It is noted that the solution velocity used here is a conservative estimate based on the injection solution moving 479 feet in 2,349 days (i.e., a ULEW of 479 feet with an assumed flow rate of 5.7 gpm into only 30 feet of thickness). It is recognized that, due to slower velocities at distance

---

2 USNRC NUREG-0706, Vol. II; Final Generic Environmental Impact Statement on Uranium Milling, September 1980, Appendix E-3.

3 Department of Energy, DOE/LLW-238; Selected Radionuclides Important to Low Level Radioactive Waste Management, Section 15, November, 1996.

due to radial flow, the velocity is higher in the early months and lower in the later time as the displacement radius grows.

To assess possible worst-case scenarios, travel distance was calculated for the entire range of well operation (e.g., assuming the flow from December 11, 2008 to May 2, 2013). The ULEW calculated for this period is 479 feet. In this scenario, the travel distance for uranium is calculated to be approximately 24 feet from the well; the Ra-226 travel distance is calculated as approximately 2.5 feet. It is noted that the same retardation mechanism that limits transport distance during injection would also apply during any fluid recovery efforts. Please see Figure 2 for calculations utilized.

IV. Evidence for Containment and Impact to Injection Zone

Based on the temperature log taken during the 2013 MIT, cooling within the wellbore is evidenced at approximately 8,025' below KB. To better understand the water quality within the Teckla Sandstone Member of the Lewis Shale, Cameco evaluated the formation from below the Fox Hills, 7,750 below KB, through the assumed breach in the casing, 8,222-8,255 below KB.

The Teckla Sandstone Member of the Lewis Shale is an Upper Cretaceous marine sandstone and shale unit that is part of a regressive –transgressive interval within the thick marine Lewis Shale. The Lewis Shale thickens from less than 300 ft. in the northern part of the Powder River Basin (PRB) to more than 1500 ft. in the southern part. The Teckla Sandstone in the southern part of the PRB has good reservoir-quality sandstones[4], and can reach net thickness of approximately 600 feet. SR DDW #2 is located in Converse County within the Southern part of the PRB. The Lewis crops out near the western margin of the PRB in Converse, Natrona, Johnson, and Sheridan Counties and has been recognized in the subsurface of the basin[5].

The evaluation of the Lewis Shale, below the Fox Hills, defined two distinct Teckla Sandstone Members as pictured in Figure 3 of this document; additionally, two Siltstone layers were analyzed. Based on analysis completed by Gooslby, Finely & Associates (Attachment 1) the Fox Hills is protected above the upper most Teckla Sandstone Member with over 160 feet of clay rich strata between the top of the sandstone and the base of the Fox Hills. This upper Teckla Sandstone Member has a calculated average Total Dissolved Solids (TDS) of 7,415 ppm. The lower, already exempted Teckla Sandstone Member, approximately 550 feet below, calculates an average TDS of 7,690 ppm. Water quality samples obtained from this Sandstone calculated the

---

[4] Anna, Lawrence O. *Geologic Assessment of Undiscovered Oil and Gas in the Powder River Basin Province, Wyoming and Montana*. Reston: U.S. Geological Survey, 2009.

[5] . Merewether, E.A. "Stratigraphy and Tectonic Implications of Upper Cretaceous Rocks in the Powder River Basin." *Evolution of Sedimentary Basins - Powder River Basin*. United States Government Printing Office, 1966. T66.

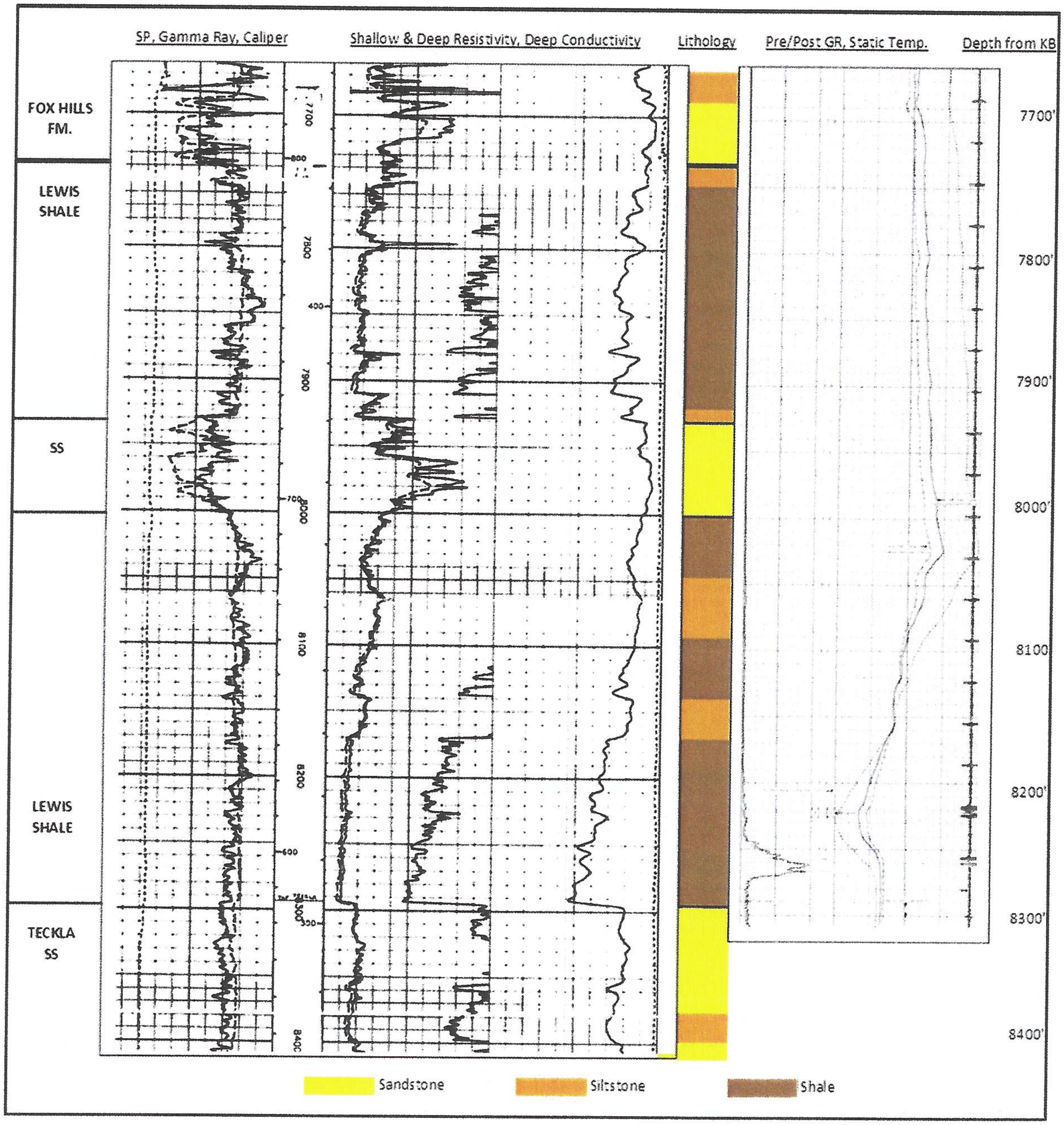
Figure 2

Cameco SRHUP Facility	**SR DDW 2**		
HORIZONTAL FLOW CALCULATION			
Leak Start	12/11/2008		
leak stop	5/18/2015		
leak days	2349		
Ave. leak rate	197	bb/ld	
Ave. leak rate	5.7458333	gpm	
Total leak volume	19,435,626	gal	
Leak percent	100	percent	
Leak volume	19,435,626	gal	
Total formation thickness	65	feet	
Leak formation thickness	30	feet	
Porosity	12	percent	
ULTIMATE LIMIT OF EMPLACED WASTE - Per WDEQ Ch. 13 and GD No. 1)			
R = radius of volumetric fillup (feet)			
R =	$(Qt/\pi H\varnothing)^{1/2}$		
Q = injection rate (ft3/d) =	1106		
t = injection time (days) =	2349		
H = formtion thickness =	30		
Ø = formation porosity=	0.12		
R =	479	feet from well	

RETARDATION					
$V_i = v / (1 + (B_d/n * K_d))$ - Freeze & Cherry, Eqn. 9.14[1]			$V_i = v / (1 + (1\text{-}n)/n * \rho_m * K_d))$ - Domico & Schwartz, Eqn. 18.7[2]		
Where:	V_i = ion velocity		Where:	V_i = ion velocity	
	v = solution velocity			v = solution velocity	
	K_d = distribution coefficient			K_d = distribution coefficient	
	B_d = bulk density			ρ_m = matrix density	
	n = porosity			*n* = porosity	
From ROFD; v =	0.204	feet/d	From ROFD; v =	0.204	feet/d
Kd (Ra) =	10	ml/g^3	Kd (Ra) =	10	ml/g^3
Kd (U) =	1	ml/g4	Kd (U) =	1	ml/g4
Bd =	2.45	g/cm3	ρ_m =	2.65	g/cm3
Porosity =	0.12		Porosity =	0.12	
V1 (Ra) =	2.3	feet	V1 (Ra) =	2.5	feet
V1 (U) =	22.4	feet	V1 (U) =	23.5	feet

References
1- Freeze & Cherry (*Groundwater*, Prentice-Hall International, 1979; Eq. 9.14)
2 - Domineco & Schwartz (*Physical and Chemical Hydrogeology*, John Wiley & Sons, 1998, Eq. 18.7)
3 - USNRC NUREG-0706, Vol. II; Final Generic Environmental Impact Statement on Uranium Milling, September 1980, Appendix E-3.
4 - Department of Energy, DOE/LLW-238; Selected Radionuclides Important to Low Level Radioactive Waste Management, Section 15, Nov. 1996.

Figure 3


SP, Gamma Ray, Caliper
Shallow & Deep Resistivity, Deep Conductivity
Lithology
Pre/Post GR, Static Temp.
Depth from KB
FOX HILLS FM.
LEWIS SHALE
SS
LEWIS SHALE
TECKLA SS
7700'
7800'
7900'
8000'
8100
8200'
8300'
8400'
Sandstone
Siltstone
Shale

TDS at 6,210 ppm. Based on this information the characteristics of these two distinct Sandstones is identical. [6]

As defined in ***Permit 99-347,*** classification of these units are Class VI groundwater under WQRR chapter VIII because:

1) "The groundwater in this formation contains between 3,000 and 10,000 mg/l of Total Dissolved Solids, but cannot be reasonably expected to provide a source of drinking water because of its extreme depth of burial", and

2) "The groundwater in this formation is situated at such a depth that recovery of this water and treatment for drinking water purposes is not practical",

Additionally, as defined in Cameco's ***Application for Renewal UIC No. 99-347***, the groundwater could be further classified as Class VI groundwater:

3) "due to its hydrocarbon constituents". (Based on water quality samples obtained for nearby Reynolds Ranch DDW #1)

Therefore, although the injection intervals identified in Permit 99-347 are at different depths than the interval in which there is potential for unintended flow, the formation has similar porosity and TDS values to the exempted area.

When considering potential for adverse environmental impacts the most significant factor is that the interval into which flow potentially occurred is beneath a substantial confining layer of the Lewis Shale that provides protection for the overlying aquifer. Here, the available evidence provides no basis for concern as there is no movement of fluid beyond the confining layer, and no evidence that any fresh or potable groundwater has been impacted by the unintentional flow. The presence of the fluid beyond the permitted zone does not present a potential for further environmental impacts in the current location. Therefore, from an environmental protection standpoint there is no benefit to recovering the fluid that moved above the current injection zone. The fluid that has been displaced is contained just as the fluid injected into the currently permitted injection interval is contained.

More importantly, there is no environmental benefit in attempting to recover fluid that flowed into Class VI groundwater. Efforts to recover the fluid would at a minimum increase the volumes of wastewater to be re-injected into the current injection intervals following recovery and increase the risk of an adverse environmental impact. This would amount to attempting to move these fluids from one unit that provides safe and effective containment to another virtually identical unit that essentially provides identical safe and effective containment. Moving fluids

[6] Lemaster, Julia R. *Analysis of DDW2 Injection Zone*, Letter to Cameco Resources, May 19, 2015.

from one Class VI groundwater to another therefore would not provide any environmental benefit. Ultimately, it would not be reasonable to increase risk of environmental harm or incur such costs absent evidence of any need to do so to prevent adverse environmental impacts.

Overall, the results of the investigations and analyses that have been completed to date demonstrate that the unintended flow has not caused any environmental impacts and that recovery of fluids or other remedial action is not necessary to prevent adverse environmental impacts that could result from the unintended flow.

I. Plan of Action

Cameco has submitted and had approved a Well Workover Plan. Cameco will commence well repair as soon as acceptance of this Supplemental Report has been received.

GF&A
JIMMY GOOLSBY-ANDREW FINLEY
MELANIE PETERSON-WALLY REAVES-JULIA LEMASTER
SANDY LEOTTA-ANNE MARQUARD-DAVID TYLER

GOOLSBY, FINLEY & ASSOCIATES, LLC
CONSULTANTS TO THE ENERGY INDUSTRY
1551 THREE CROWNS DRIVE, SUITE #300
CASPER, WY 82604
O 307 266 3199
F 307 268 8466
WWW.GOOLSBYFINLEY.COM

May 19, 2015

Jeanie Wolford
Cameco Resources
550 North Poplar, Suite 100
Casper, WY 82601

RE: Analysis of DDW2 injection zone

Ms. Wolford,

Per your request, Goolsby, Finley, and Associates, LLC has performed an evaluation of Cameco's DDW2 injection well located in the SENW of Section 27, Township 36 North, Range 74 West. Based on a temperature survey and log analysis from the well, injected water appears to be finding a pathway into a permeable sandstone within the Lewis Shale located between 7,930 and 8,000 feet below KB level.

Porosity logs were not run over the interval of interest within the DDW2. Log analysis was performed on the nearby Federal 34-1 well which is located 0.75 miles southwest of the DDW2 in the NWNW of Section 34, Township 36 North, Range 74 West. Their proximity and the depositional environment of the Lewis Shale indicates reservoir characteristics from the Federal 34-1 are a reasonable proxy for conditions in the DDW2. The sandstone in question has a calculated average TDS of 7,415 ppm. Another Teckla sandstone within the Lewis Shale that has already been exempted for injection is located approximately 550 feet below the interval of interest calculates an average TDS of 7,690 ppm. Based on this analysis and a water sample from the already exempted zone of 6,210 ppm, these two sandstones are nearly identical in character. The overlying Fox Hills sandstone calculates a TDS between 2,400 and 4,000 ppm. This is consistent with the character of the Fox Hills Formation water and supports the validity of the log analysis.

The sandstone has similar porosity and TDS values to the already exempted section of the Teckla. Additionally, there is over 160 feet of clay rich strata (upwards of 90% clay) between the top of the sandstone and the base of the Fox Hills which serves as a barrier to fluid flow. If this sandstone is developed in future Class I applications, Goolsby, Finley and Associates, LLC would recommend this zone as a potential receiving zone on the basis of TDS, confinement and depth.

Respectfully submitted,

Julia Rausch Lemaster

Julia Rausch Lemaster
WYPG #3894

PROFESSIONAL GEOLOGIST
JULIA RAUSCH LEMASTER
PG-3894
5/19/2015
WYOMING