Department of Environmental Quality

To protect, conserve and enhance the quality of Wyoming's environment for the benefit of current and future generations.

Matthew H. Mead, Governor

Todd Parfitt, Director

October 13, 2017

Mr. Scott Schierman
Uranium One Americas, Inc.
907 N. Poplar Street, Suite 260
Casper, WY 82601

RE: LQD Review of 2015 Comment Response Package for Christensen Ranch Mine Units 2 through 6 Groundwater Restoration, Uranium One, Willow Creek ISR Project, Permit No. 478; TFN 5 2/022

Dear Mr. Schierman,

The Wyoming Department of Environmental Quality, Land Quality Division (LQD) has completed a review of the groundwater restoration data provided in Uranium One's September 2015 Response Package associated with groundwater restoration of Christensen Ranch Mine Units 2 through 6 at the Willow Creek ISR Project. The response package was received by LQD District 3 on May 26, 2016.

The enclosed review memoranda contain LQD's review comments. Please see the enclosed review comments and provide LQD with the requested information. Once adequate responses are received, the subject restoration may be recommended for approval. If you have any questions, please contact me at 307-675-5619.

Sincerely,

Luke McMahan, P.G.
Project Geologist
WDEQ-LQD District 3

lm/

Attachments: Luke McMahan Review Memorandum dated October 13, 2017
Reid Brown Review Memorandum dated October 12, 2017

xc: Cheyenne LQD Files (with attach.)
Mr. Ron Linton, U.S. NRC, MS T-8F5, 11545 Rockville Pike, Rockville, MD 20852

NSK 10/16/17

WYOMING

MEMORANDUM

TO: File: **TFN 5 2/022**; PT478, Uranium One, Willow Creek ISR Project, Christensen Ranch Mine Units 2 through 6 Groundwater Restoration

FROM: Luke McMahan, Project Geologist, LQD District 3

DATE: October 13, 2017

SUBJECT: LQD Review of Uranium One's September 2015 Response to Comments from U.S. Nuclear Regulatory Commission Staff Technical Evaluation Report: PT478, Uranium One, Willow Creek ISR Project, TFN 5 2/022.

DISCUSSION

In April 2008, the Wyoming Department of Environmental Quality-Land Quality Division (LQD) received from COGEMA Mining Inc. (Cogema) the groundwater restoration report for Christensen Ranch Mine Units 2 through 6 under Tom Hardgrove's cover letter dated April 8, 2008. The Report contains details of the restoration of Mine Unit 2, Mine Unit 3, Mine Unit 4, Mine Unit 5 and Mine Unit 6 at the Christensen Ranch Satellite Operation of the Willow Creek ISR Project. Currently, the primary restoration reports and agency review documents associated with LQD's review of the subject groundwater restoration consist of the following:

- Cogema Mining Inc., Wellfield Restoration Report, Christensen Ranch Project, Wyoming (prepared by Cogema Mining and Petrotek Engineering Corp. March 5, 2008)
- NRC Technical Evaluation Report, Review of Restoration Report for Mine Units 2 through 6 of the Christensen Ranch Satellite Facility, Uranium One Willow Creek In Situ Recovery Project, Johnson and Campbell Counties, Wyoming, TAC No. J00563 (prepared by NRC Staff October 23, 2012)
- LQD Review of NRC 2012 Technical Evaluation Report (Letter of Concurrence from LQD to Uranium One, January 7, 2013)
- Uranium One USA Inc., Willow Creek ISR Project – Christensen Ranch Mine Units 2 – 6, Response to Comments from NRC Staff Technical Evaluation Report (prepared by Uranium One and ARCADIS September 11, 2015)

Mining of MU2, MU3, MU4 and MU6 took place between 1989 and 2000. Restoration efforts for MU2, MU3, MU4 and MU6 took place between 1997 and 2006. Stability monitoring for MU2, MU3, MU4 and MU6 took place between April 2004 and March 2006.

Although restoration was conducted at Mine Unit 5 between 2000 and 2005, mining was resumed in Mine Unit 5 in 2012 and Uranium One is no longer requesting approval of restoration for Mine Unit 5 per Uranium One's September 11, 2015 Response to the NRC 2012 TER.

LQD has reviewed Uranium One's September 11, 2015 Response Package which was provided to LQD in response to NRC's 2012 TER and LQD's January 7, 2013 Review Letter. The Response Package was reviewed by LQD District 3 Project Geologist Luke McMahan and LQD District 1 Natural Resources Program Principal Reid Brown. Mr. McMahan's comments are provided below. Mr. Brown's comments are provided in the attached review memorandum.

REVIEW COMMENTS (Luke McMahan)

1. **Permit Revision** – Uranium One provided in its 2015 Response to the 2012 NRC TER a reevaluation of the Target Restoration Values (TRV's) for all of the subject Mine Units. The reevaluation resulted in only a slight modification of some of TRV's with the most prominent modification being the reduction of the TRV for radium-226. LQD does not find issue with this reevaluation or the new TRV's provided in Table 2-1 of the 2015 Response. In order to finalize review of the restoration, LQD will require a permit revision which updates the TRV's in the Reclamation Plan and/or the MU2, MU3, MU4, MU5 & MU6 WFDP's. Section 6.1.1 of the Reclamation Plan will need to be revised as applicable. Please update the appropriate permit text regarding how the TRVs are calculated and the appropriate permit tables that list the TRVs. These updates will be incorporated in to the approved permit through LQDs Non-Significant Revision process.

2. **Core Data** – Section 3.2, Page 13 of the 2015 Uranium Response Package provides discussion regarding the presence of pyrite within the formation downgradient of the wellfield production area. This section also provides core data from Mine Unit 7 that demonstrates the presence of pyrite. LQD anticipates that core samples were collected in Mine Units 2, 3 and 4 prior to development of these wellfields and assessment of pyrite distribution in these cores will assist in estimating the reducing capacity of the formation downgradient of the wellfield production area. Please provide an assessment of pyrite distribution in cores collected from the production zone in the area of Mine Units 2, 3 and 4.

3. **MU2S SSI Trend** – A statistically significant increasing (SSI) trend in the uranium concentrations at well 2AF34-1 in Mine Unit 2 South was identified by NRC in their 2012 TER. As a result, NRC requested that Uranium One (U1) demonstrate that this SSI trend is reversed and stable at the subject well. U1 responded to this request by indicating that assessment of constituent trends should not be done on individual wells, but rather, because

(LM review comment #3 continued)

the groundwater protection standards are calculated on a wellfield basis, trend analysis must also be calculated on a wellfield basis. This resulted in the conclusion under Section 2.3.3 of U1's 2015 Response Package that there is an increasing trend in the uranium concentrations on a wellfield basis for Mine Unit 2 South. Please clarify how this supports Uranium One's assessment that uranium concentrations in Mine Unit 2 South are stable when it appears that there is an increasing trend in this mine unit when the data is analyzed on a wellfield basis.

4. **Mine Unit 6** – Currently, active Mine Unit 7 overlaps Mine Unit 6 in the southeast portion of Mine Unit 6. For the purposes of groundwater restoration and surface reclamation, Mine Unit 6 should be redefined in accordance with its reduction in size due to the overlap of Mine Unit 7. Additionally, six (6) of the restoration wells used for the Mine Unit 6 restoration data provided by Cogema in 2008 are now within the northern portion of the Mine Unit 7 monitoring well ring where MU6 and MU7 overlap (7AS65-1, 6AP64-2, 6AT58-1, 6AQ56-1, 6AQ52-1, & 6AT51-1). Please revise the assessment of restoration in Mine Unit 6 excluding the subject wells which are now associated with an active mining unit.

5. **Mine Unit 5** – As indicated in Uranium One's September 11, 2015 Cover Letter under which the 2015 Response Package was provided to NRC, "NRC comments regarding Mine Unit 5 are not being addressed as part of this response as Uranium One has recently conducted mining activities in Module 5-2 within Mine Unit 5". As a result, LQD is not currently addressing Mine Unit 5 in its assessment of the restoration results. The Mine Units applicable to this restoration review include; Christensen Ranch Mine Unit 2, Mine Unit 3, Mine Unit 4, and Mine Unit 6. No response required.

SUMMARY

Please provide responses to the comments listed in the review memoranda provided by Mr. McMahan and Mr. Reid. Upon receipt of adequate responses, this demonstration of groundwater restoration may be recommended for approval.

lm/

cc: LQD Cheyenne

MEMORANDUM

TO: File: **TFN 5 2/022**; PT478, Uranium One, Willow Creek ISR Project, Christensen Ranch Mine Units 2 through 6 Groundwater Restoration

FROM: Reid Brown, Natural Resource Program Principal, URP, Wyoming Department of Environmental Quality, Cheyenne, **WY** RDB

DATE: October 12, 2017

SUBJECT: LQD Review Memorandum; TFN 5 2/022, PT478, Uranium One, Willow Creek ISR Project, Christensen Ranch Mine Units 2 through 6, Response to Comments from U.S. Nuclear Regulatory Commission Staff Technical Evaluation Report, September 2015

DISCUSSION

On June 2, 2016 WDEQ/LQD received Uranium One USA Inc., Willow Creek ISR Project – Christensen Ranch Mine Units 2 – 6, Response to Comments from NRC Staff Technical Evaluation Report (prepared by ARCADIS September 11, 2015). This report included a one-dimensional hydrogeochemical model to predict how groundwater quality changes in the mine units and if they are stable and protective of the aquifers at the permit boundary. ARCADIS created the model using the USGS geochemistry and transport code PhreeqC using the WATEQ4F database.

The goal of this memorandum is to assess the hydrogeochemical transport models used by Uranium One to demonstrate the long-term restoration and stability of MU2, MU3, MU4 and MU6 wellfields at Uranium One's Christensen Ranch. Two model types, redox and no redox, were used to "bookend" a range of possible scenarios. The first transport model did not include redox equations and is not likely to be a realistic scenario but shows a potential worst case. The second transport model type uses the oxidation of pyrite present in the aquifer to reduce and precipitate uranium from solution. Two kinetic controls were tested. The first was the possibility that pyrite might be in small pore spaces and not easily accessible to groundwater flow. ARCADIS used a dual porosity model to represent a mobile zone rich with uranium in solution and an immobile zone with pyrite. A mass transfer coefficient chemically connected the two zones, which restricted access to the pyrite. The second simulated kinetic control was pyrite developing a coating and thereby reducing the effectiveness of pyrite to reduce aqueous uranium. ARCADIS reduced the saturation index of pyrite in the solution to simulate the process of reducing the available mineral surface area for pyrite dissolution.

Several model parameters were estimated, taken from literature or from a different remediation project site. ARCADIS performed a sensitivity analysis to look at the impact changing the surface site concentration and the mass transfer coefficient had on dissolved uranium concentrations in the groundwater at the perimeter well ring. The model responded to the changes in the two parameters in a sensible way. ARCADIS supplied the code that they used to run the base case for each scenario. Using the exact same code, the LQD reviewers should be able to duplicate the ARCADIS results of the sensitivity analysis.

REVIEW COMMENTS (Reid Brown)

General:

Using the code that was supplied in Appendix D of Response to Comments From U.S. Nuclear Regulatory Commission Staff Technical Evaluation Report apart of file: TFN 5 2/022 the reviewer was able to get the model to run without errors. More detail on the methods that ARCADIS used to perform their sensitivity analysis would be helpful. Additional clarifying information about each section of code would both improve and hasten the review process. Of particular interest is how pyrite concentration of 1% by volume was incorporated into the model.

The mineralogy and geology of the system is important and accurate results from the model hinge on getting these parameters right or at least reasonable when assumptions need to be made. The assumed mineral surface area of 3 m^2/g is 2 orders of magnitude below the PhreeqC default value of 600 m^2/g and seems to be a conservative estimate that is based on methods used at the Hanford Site. In addition to mineral surface area and particularly important to the model results is the amount and availability of pyrite for the reduction of mobile uranium especially since this is the only mechanism in the model that is removing uranium from solution.

Specific:

1. **Model Sensitivity Analysis Methods** – The reviewer was able to run the models supplied in Appendix D. However due to the fact that little information was provided with the code as to which model was used and how the model was changed for the sensitivity analysis performed by ARCADIS, the reviewer was unable to replicate the results ARCADIS presented. Detailed instruction as to how the model was changed for each different scenario in the sensitivity analysis would hasten the review process.
2. **Surface Complexation Model (SCM)** – PhreeqC's default SCM is a diffuse double layer model. No explanation was provided as to why the default setting did not apply to ARCADIS's model of mine units 2-6. In addition to the default diffuse double layer model there are additional SCMs that could be used. Please explanation why the "-no_edl" SCM which neglects the surface electrostatic charge is the best choice for this model.
3. **Model Input Data** – In the model, pyrite is arguably the most important parameter to determine if the restoration efforts in the mine units will be protective of the surrounding aquifers. The core analysis of MU7 indicates that pyrite is highly variable in the system even over short distances ranging from 40% to 0.3% in three feet of core. Removing the high and likely an outlier value of 40% and averaging the remaining values in the two cores yields an average of 0.51% by volume of pyrite. Please expound as to why the use of the value of 1% by volume pyrite is justified and why that is representative of all the mine units. It is unclear how 1% pyrite by volume is converted into the model input of 8.096 mol. Is 8.096 mol pyrite applied to each cell of each zone for which pyrite is assumed to be present?

   Likely, due to hot spots present, many of the uranium, selenium and radium production zone well sample data sets appear skewed and non-normal. Please explain why averaging the data (which assumes a normal distribution) is the best choice for the model inputs.

4. **Hydrological Parameters** – Hydrologic parameters have to be estimated especially when limited solids characterization is available. However both the immobile zone porosity and dispersion may be important parameters that impact the uranium concentration at the perimeter monitoring wells. How were the parameters determined? If not from direct solids characterization what is the justification for their estimated values used in the model?
5. **Dissolved Oxygen and Redox Reactions** – In the model the initial solution chemistry for zone 3 (perimeter well ring) used a dissolved oxygen value of 0 mg/kgw (oxygen redox couple with 8.0 mg/kgw is commented out with a '#'). However, figure 4-5 shows measurable dissolved oxygen levels at the perimeter well ring. Please expound upon the assumption of 0 mg/kgw dissolved oxygen in zone 3 of the models with redox.

   Both iron and sulfur oxidation can reduce uranium. In the models with redox, the sulfur redox couple was used exclusively. What was the reasoning behind using only the sulfur redox couple?
6. **Redox model response to changes in Pyrite concentration** – Within the redox model type two models were presented: a dual porosity model and a uniform porosity model. In both the dual porosity model (Appendix D, pg 1-2 & 93-101) and the uniform porosity model (Appendix D, pg 1-2 & 30-36) reducing the amount of pyrite allowed to dissolve into solution (for example: Appendix D pg 33, line 28) did not change the U(VI) in solution compared to the base case presented in the model submitted by ARCADIS. This trend of being exactly the same as the base case held even when the amount of pyrite allowed to dissolve decreased by two orders of magnitude for the uniform porosity model and when pyrite decreased by four orders of magnitude for the uniform porosity and dual porosity model. This model response does not appear to be realistic. When initial concentrations of a reactant are decreased by multiple orders of magnitude some response should be measured in the concentration of the products unless it can be shown that a specific reactant (in this case pyrite) is not limiting until extremely low concentrations.

   In the uniform porosity and the dual porosity models different amounts of pyrite were allowed to dissolve. In the uniform porisity model 0.4048 mol (Appendix D pg 33, line 28 and pg 34 line 14) was allowed to dissolve and in the dual porosity and redox model 8.096 mol (Appendix D pg 97, line 40 and pg 99, line1) was allowed to dissolve, which is 20 times larger. Why was a different value used for pyrite in each model?

7. **Adjusting the Pyrite Saturation Index (SI)** – The Pyrite Equilibrium Limitation model (Appendix D, pg 102) attempted to address the issue of mineral coating by testing several different scenarios by reducing the SI of pyrite. There are a few issues to this approach. The first is that the SI remains constant over time compared to the surface area of the pyrite minerals decreasing through time as more coatings form. Secondly adjusting the SI does not permanently lock away pyrite like a mineral coating, it just makes it more difficult to dissolve pyrite. Consequently, even at low SI, pyrite can continue to dissolve into solution if the products of dissolution are removed via other reactions. Are there other ways to model mineral coatings with PhreeqC? Why is adjusting the SI the best option?