SEI042

August 25, 2014

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

ATOMIC SAFETY AND LICENSING BOARD

Before Administrative Judges:

G. Paul Bollwerk, III, Chairman
Dr. Richard F. Cole,
Dr. Craig M. White,

In the Matter of:	)	
	)	
Strata Energy, Inc.	)	Docket No. 40-9091-MLA
	)	ASLBP No. 12-915-01-MLA-BD01
	)	
(Ross In Situ Recovery	)	
Uranium Project)	)	

INITIAL WRITTEN TESTIMONY OF RAY MOORES

TABLE OF CONTENTS

1.0 WITNESS BACKGROUND INFORMATION

Q.1. Please state your name, position and employer, including duration of employment.
A.1. Ray Moores. I am a Civil Engineer/Project Manager with WWC Engineering and have been with the company for 12 years. My *curriculum vitae* is included as Exhibit (SEI043).

Q.2. Please state your education, professional registration and memberships.
A.2. I hold both Master of Science (M.S.) and Bachelor of Science (B.S.) degrees in Civil Engineering from the University of Wyoming. I am a registered professional engineer in Wyoming and Colorado.

Q.3. What ISR projects have you been involved with in your career?
A.3. In addition to the Ross ISR Project, I have been involved with Powertech's Dewey-Burdock Project in South Dakota, Uranium One's Christensen Ranch Project in Wyoming, and Anatolia's Temrezli ISR Uranium project in Turkey.

Q.4. Please describe your role in these projects.
A.4. In all of these projects I have offered technical support primarily with respect to groundwater evaluation. At Christensen Ranch I oversaw aquifer pumping tests in Mine Units 8 and 10 that were eventually used as part of their wellfield data packages and I have provided limited technical support for groundwater characterization and surface water containment to support licensing and operations. In addition to providing minor technical support for permit documents associated with the Dewey-Burdock project, I had an instrumental role in preparing the conceptual groundwater model which was included to support the water rights permit application submitted to the State of South Dakota for the project's Madison water supply well. I was the primary author of the Preliminary Economic Assessment (PEA) for the Temrezli ISR Uranium Project and have continued to offer technical support on ongoing hydrologic analyses at the project. I have also provided technical input for various due diligence evaluations on other ISR operations in Wyoming and Texas.

Q.5. What has been your role in the Ross ISR Project?
A.5. My key role with the Ross Project was to prepare the numerical groundwater model. In my role as the groundwater modeler, I helped develop the conceptual groundwater model. I then translated the elements of the conceptual groundwater model into a numerical groundwater model. I was responsible for developing, calibrating, and running operational simulations using the numerical groundwater model for the Ross Project. I also provided technical support for the aquifer tests, assisted with preparation of the approved license application, assisted with geotechnical drilling and analysis within the proposed Central Processing Plant (CPP), and provided general technical support as needed for the project.

Q.6. Please describe what additional groundwater modeling projects have you worked on and your role in those projects.

A.6. I have been involved with several groundwater modeling projects over the course of my career. In addition to the model for the Ross Project, I have worked on numerical groundwater models for coal mines, coal bed methane development, and coal bed methane discharge water management. Specifically some of the projects I have been involved with include:

- The Dry Fork Mine Moyer Springs analysis. This was a numerical groundwater model developed to evaluate the potential impacts of the Dry Fork Coal Mine on Moyer Springs, the only cold water trout fishery in Campbell County, WY. My role was to modify an existing numerical groundwater model to add additional monitoring data collected since the original model was developed and to increase the model resolution (decrease the grid spacing). As part of this project, I recalibrated the model to the additional monitoring data and evaluated alternative mining scenarios that maximized coal recovery while at the same time minimizing impacts to the spring.
- The Atlantic Rim Groundwater model which was a regional numerical groundwater model developed along the east flank of the Washakie Basin, generally located between the towns of Baggs and Rawlins, WY. The numerical groundwater model was developed to assess the potential impacts of coal bed methane development to support an Environmental Impact Assessment prepared by the Rawlins BLM field office. I was responsible for developing the conceptual groundwater model as well as developing and calibrating the numerical groundwater model for this project.
- Alluvial pond evaluations for coal bed methane operators in the Powder River Basin. These models were developed to evaluate how fast water would enter into the shallow groundwater system and the time it would take the water to reach the main drainage after being discharged into alluvial ponds. I was responsible for developing the models and preparing predictive simulations to use in the pond designs.
- Development of the Brook Mine Groundwater model. This numerical groundwater model was developed to assess the potential impacts from the proposed Brook Mine located near Acme, WY. I was the senior engineer over the numerical groundwater model on this project. I oversaw development of the conceptual groundwater model, calibration of the numerical model, and helped develop the simulation scenarios.

In addition the groundwater models described above, I have also conducted in-house model simulations to evaluate the variability of hydraulic conductivity within an ISR wellfield using data from wellfield aquifer tests. I presented the results of this evaluation at the U2013 Conference in Corpus Christi, Texas. All of the numerical groundwater models described above were developed using Groundwater Vistas software, however I have also participated in several groundwater evaluations that utilized other calculation methods. I have conducted groundwater seepage analyses for several large reservoir projects using traditional flow nets and GeoStudio® (GeoStudio® is a software suite used to evaluate seepage and slope stability). I have also conducted and overseen a number of line sink analyses using traditional industry standard drawdown equations. These line sink analyses were primarily used for simple coal mine permit modifications when a more complicated numerical groundwater model was not justified.

2.0 CONTENTION 3 - ALLEGED FAILURE TO INCLUDE ADEQUATE HYDROLOGICAL INFORMATION TO DEMONSTRATE SEI'S ABILITY TO CONTAIN GROUNDWATER FLUID MIGRATION

2.1 The Aquifer Test Durations Are Adequate for Their Intended Purpose

Q.7. Please briefly describe what an aquifer test is and how they were conducted at the Ross Project.

A.7. An aquifer test, which is sometimes also referred to as a pumping test, is conducted by pumping water from a well and observing the response of the aquifer in the pumped well and/or adjacent observation wells. At the Ross Project, aquifer tests were conducted at all six monitor well clusters. During each aquifer test, the well installed within the ore zone aquifer (OZ) was pumped at a constant rate. Pressure transducers, which were programmed to measure and record the water level in each well on one minute increments, were installed within the pumped OZ well and OZ observation wells (if present), the overlying water bearing interval well (SM), and underlying water bearing interval well (DM). After the pumping portion of the test was complete, the transducers continued to record water levels on one minute increments until water levels in the pumped well recovered to within at least 90% of the pre-pumping water levels.

Once the test was complete and sufficient time had passed for the water levels in the pumped wells to recover, the water level data from the transducers was downloaded and graphs of drawdown and recovery versus time were developed. These graphs are key to characterizing the aquifer characteristics. By fitting the graphs measured during the aquifer test to graphs developed from an idealized model, aquifer parameters such as transmissivity and storativity are be calculated. For the aquifer tests conducted at Ross, both the drawdown and recovery curves were evaluated using applicable methods and presented in the final aquifer test report (Exhibit SEI014G at 139-397). Also, by evaluating responses, or lack thereof, recorded in the SM and DM wells it was also possible to measure the integrity of the confining intervals above and below the OZ aquifer in the vicinity of the pumped well.

Q.8. Please respond to the allegation that the aquifer tests conducted for the Ross Project were too short to obtain the needed hydrologic data to assess the control of mining fluids during ISR operations (Abitz and Larson, 2014 ¶62; Abitz, 2013 ¶32).

A.8. As stated in the sampling and analysis plan (Exhibit SEI020A at 92), the goals of the aquifer testing program were to determine the hydrologic parameters of transmissivity, hydraulic conductivity, storativity, measure the horizontal anisotropy within the ore zone, and to determine if there is leakage between the ore zone and the overlying and or underlying water bearing units. The hydraulic parameters were calculated based on the drawdown and recovery curves from the aquifer tests. The drawdown and recovery curves as well as the analyses on these curves are presented in the aquifer test report (Exhibit SEI014G at 139-397). As noted in the report, the data collected during the aquifer tests was sufficient to develop trendlines and curves to be able to successfully analyze the aquifer tests using appropriate empirical methods. Given that the data from the aquifer tests was sufficient to calculate all the hydraulic parameters it is my

professional opinion that the aquifer tests were of sufficient duration to meet their intended purposes.

In addition to determining hydrologic parameters in the ore zone aquifer, the aquifer tests also successfully demonstrated confinement of the ore zone aquifer within the vicinity of the monitor well clusters. With the exception of well clusters 34-18 and 14-18, monitor wells completed within the SM and DM water bearing units did not register any water level changes during the aquifer tests. Small water level changes were registered during the aquifer tests in the DM wells installed at 34-18 and 14-18. These small water level changes may be indicative of potential communication between the OZ and DM aquifers. As described in TR Addendum 2.7-F (at 155-156), prior to conducting the aquifer tests all the exploration boreholes within a 522-foot radius of well 12-18 OZ were plugged. No plugging of historic exploration boreholes occurred at the other well clusters (34-7, 14-18, 12-19, 34-18, and 42-19) prior to the aquifer tests. As such, the potential communication between the OZ aquifer and DM water bearing interval at well clusters 34-18 and 14-18 was attributed to improperly plugged exploration boreholes. It is important to note that the aquifer tests at both of these clusters were of sufficient length to see potential water level responses in the DM water bearing interval at 34-18 and 14-18. Also, just as importantly, no apparent responses were observed at the other clusters (even at the clusters where extensive exploration borehole re-abandonment has not been completed).

The transducers used during the aquifer tests are very sensitive to even slight changes in pressure. For example, when the aquifer tests were conducted at the 14-18 monitor well cluster, the transducer installed in the DM well registered a change in head of 0.2 feet which is relatively minimal given the large drawdown in the OZ aquifer. Because the transducers are so sensitive, it is possible to see trends that might indicate a leaky aquifer even over short pumping durations. In my experience overseeing aquifer tests for coal mines and at other ISR operations, we typically see responses very early in the aquifer tests. It is true that these trends become more pronounced the longer the aquifer test continues, but the trend is usually spotted within just a few hours after the test begins.

These aquifer tests demonstrate confinement only over the local area of influence. They were not designed nor intended to demonstrate confinement throughout the entire Ross Project area. As described in the initial testimony of Hal Demuth and Errol Lawrence (Exhibit SEI026), additional wellfield scale aquifer tests will be conducted prior to ISR operations in order to further demonstrate aquifer confinement within specific wellfields. Prior to conducting the wellfield scale aquifer tests, all the historic boreholes that can be located within the wellfield will be properly plugged and abandoned. In addition, monitor well clusters as specified in License Condition 11.3 of Strata's Materials License (Exhibit SEI015) will be installed throughout the proposed wellfield in the OZ, SM, and DM water bearing intervals. During subsequent wellfield scale aquifer tests, multiple monitor wells within each wellfield will be monitored to verify that the confining intervals between the water bearing intervals are intact. Because these additional tests will include monitor wells at a much higher density (4 acre maximum spacing) it will be possible to ascertain with much more certainty if the confining intervals are compromised.

Furthermore, if necessary the extensive wellfield scale monitoring network will allow Strata to pinpoint the location of a potential compromise in the confining interval. For example, if a DM monitor response was identified when an OZ well was being pumped, Strata could compare the response patterns measured at the adjacent DM wells to determine where the potential leak is most likely to be. As necessary, additional aquifer tests could also be conducted at adjacent OZ or DM wells to further pinpoint the location of the potential leak.

In addition to the seven aquifer tests conducted specifically for the Ross ISR Project, historic aquifer test results from two aquifer tests conducted in 1977 and 1978 were also summarized in the aquifer test report. The results of the historic aquifer tests were similar to the results of the more recent aquifer tests. The historic aquifer test results were utilized in the numerical groundwater model to increase the spatial coverage of the measured data.

Q.9. Please describe NRC staff's review of Strata's evaluation of Strata's aquifer tests conducted on the monitor well clusters.

A.9. NRC staff reviewed Strata's aquifer test results and Strata's evaluation of previous aquifer tests in Sec. 2.4.4 of the SER. The results of the review are summarized as follows (Exhibit SEI010 at 93):

> "In summary, the applicant provided a description of the site-specific hydrogeologic units, included pumping test data that were acquired using acceptable methodologies, and performed data analyses using appropriate analytical models to estimate site-specific hydraulic properties of the subsurface strata. Although the data submitted and analyses performed by the applicant in the application are consistent with guidance in the SRP [NUREG-1569], the analyses included a degree of uncertainty due to the use of numeric groundwater flow models for the complexities of the subsurface setting. Based upon the review conducted by the staff, discussed above, and information that will be provided by the applicant in accordance with the above license conditions, staff finds that the applicant will be able to control the migration of production fluids in the subsurface and thus meets the applicable acceptance criteria for this section and thus meets requirements of 10 CFR 40.31(b) and will meet requirements of 10 CFR 40.41(c), if issued a license."

NRC staff noted in the SER excerpt above that there is a "degree of uncertainty due to the use of numeric flow models for the complexities of the subsurface setting." I would caution that this should not be taken to mean that numerical models do not provide reasonable approximations or more specifically that the numerical model prepared for Ross does not provide reasonable approximations of impacts resulting from proposed ISR operations. As described in more detail within A.13, there is always a degree of uncertainty associated with a numerical groundwater model due to the fact a numerical model is designed to model real world conditions and it is impossible to account for every real world variation in a numerical model. Furthermore, in Section 2.4.3.4.4 of the SER NRC Staff provide a review of the numerical model which is

described in A.12 that concludes the numerical groundwater modeling efforts are appropriate and drawdown estimates are reasonable.

2.2 The Numerical Groundwater Model Provides a Reasonable Representation of Site Hydrologic Conditions

Q.10. Please describe the primary purpose of the numerical groundwater model.

A.10. The numerical groundwater model was designed to serve as a site-wide, predictive model to estimate drawdown, recovery and wellfield specific behavior of the subsurface hydrology at the Ross ISR Project. The objectives of the model as described on Exhibit SEI014H (at 28) were to:

1) On a regional basis:

- Identify impacts (if any) to adjacent water rights,
- estimate long term impacts from ISR operations, and
- estimate potential impacts to the surficial aquifer and surface impoundments.

2) On a localized (wellfield scale basis):

- Estimate adequate perimeter well offset/setback distances for the wellfield,
- demonstrate the ability to identify and remedy a lateral excursion (i.e., lixiviants moving to the monitor wells), and
- provide wellfield optimization.

The numerical groundwater model utilized the USGS MODFLOW computer code with Groundwater Vistas as the pre/post processor. Groundwater Vistas and MODFLOW were chosen for this modeling effort because they are widely used and accepted by both industry and regulatory agencies (SEI014H at 31).

Q.11. Please describe the numerical groundwater model calibration and verification procedures.

A.11. The numerical groundwater model was calibrated using pre-1980 potentiometric surfaces from historic data, 2010 potentiometric surfaces from the monitor well clusters, and pumping rates from 1980 to 2010 from industrial water supply wells within the project area. Using the pre-1980 potentiometric surface as a starting point, water removal from each industrial well was simulated over the 30+ year period. Adjustments were then made to model parameters (primarily hydraulic conductivity) in order to match the 2010 predicted potentiometric surface to the 2010 measured potentiometric surface. Calibration details are described in detail within Exhibit SEI014H (at 108-120).

Verification of the model was completed by comparing model predicted changes in water levels from 1980 to 2010 to measured water levels in Strata's monitor wells. The calibration and verification process was an iterative process. During each successive run of the model, minor changes were made to the hydraulic conductivity distribution within the modeled area to decrease the difference between the measured water surface and the modeled water surface at each monitor well. As noted in Exhibit SEI014H (at 118) in the OZ layer the

correlation between predicted and measured water levels in the calibrated model is very high (the difference between predicted and measured water levels varies from 0.6 to -4.9 feet). Given the fact that the total estimated drawdown at the various cluster wells varies from approximately 40 feet to over 150 feet over the simulated period, the fit between the modeled and measured water surface is very good.

In my experience, it is rare that during model development we have as much data as we had to work with at Ross to calibrate the model. Typically, calibration of a model is limited to a short term aquifer test which only affects a small portion of the modeled area so the calibration is much less robust. However, the industrial water supply wells at Ross have impacted water levels over a large area (approximately 1 mile radius). This means that calibration of the model takes into account real aquifer characteristics over a much greater area than it would using a short term drawdown test. One example of how this model takes into account real world aquifer characteristics is if the shape of the estimated drawdown after 30 years of pumping is considered. Our monitor well data demonstrates that the drawdown is not perfectly concentric around the industrial wells. This is likely due to variability in aquifer characteristics (likely due to variations in hydraulic conductivity throughout the aquifer). With the model we are able to add variability in the hydraulic conductivity distribution throughout the modeled area and then "check" this distribution to see if the shape of the resulting modeled surface matches the shape of the measured surface. By continuously adjusting the hydraulic conductivity distribution we were able to calibrate the model such that the measured and predicted water levels at each monitor well matched as closely as possible.

In previous models I have worked on, we have developed numerical groundwater models and conducted aquifer simulations with little to no verification data. In my experience, we sometimes recalibrate to include additional operational data when it becomes available to increase the accuracy of our model predictions. This is how the modeling was done for the Dry Fork Mine Model I mentioned in A.6. In the case of the Dry Fork model, we found that our initial numerical groundwater model predictions overestimated impacts from the mining operations on the spring. We refined the model with additional data from mining operations and were able to improve upon the model calibration. In the case of the Ross model we have the advantage of already incorporating 30 years of industrial impacts into the model. While there will always be room for improvement as more data becomes available, the Ross model is the best estimate that we have at this time regarding potential impacts from ISR uranium operations. The current model considers all available information including measured hydraulic parameters throughout the project area, pre-1980 and present day water levels, aquifer data from all the industrial water wells in the model domain, and geologic interpretations garnered from some 2,000+ boreholes. Given the large amount of data incorporated into the model development and the level of calibration that went into the model, my confidence in this model and its predictions is much higher than many other numerical groundwater models I have been involved with.

Q.12. Did NRC staff document their review of the site wide numerical groundwater model developed for this project?

A.12. Yes. NRC staff documented their review of the numerical groundwater model in Section 2.4.3 of the SER (Exhibit SEI010 at 92). The results of staff's review are summarized as follows:

> "Staff finds that the applicant's numeric groundwater modeling efforts is appropriate for the data quality objectives of the application. Given the geologic setting where the boundary of the Lance-Fox Hills aquifer is immediately east of the Ross Project, the numeric model permits the incorporation of the limitations due the boundary. In addition, staff finds that the numeric model provides a reasonable estimate of current drawdown from the combined effects of the nearby industrial water supply wells as well as predicted mutual interference should concurrent operations of the industrial water supply wells and ISR wellfields at the Ross Project occur in the future."

Q.13. Please respond to the allegation that there is a great deal of error in the use of computer models and their assumptions (Moran 2011 ¶63 and 94).

A.13. A numerical groundwater model consists of a compilation of all available background hydrologic data in one place and to that extent the model typically provides the best possible estimate of project impacts. Unfortunately, there will always be some error in a numerical groundwater model due to the fact that it is modeling real world conditions and it is impossible to account for every real world variation. However, as is described in A.10, a great deal of effort has been put into calibrating the numerical groundwater model prepared for the Ross ISR Project. Since changes that have occurred over the last 30 years in the project area have been simulated with reasonable accuracy, our confidence in the model predictions of impacts from operations is high because we have incorporated a significant amount of geologic and hydrologic data into the model and our calibration is robust. In fact, based on my experience with several other groundwater models I believe that this numerical groundwater model has less error than many others I have worked with. At this point, the model represents the best possible estimate of impacts that may occur due to in-situ recovery of uranium within the project area.

Q.14. Please respond to the allegation that the numerical groundwater model should address the potential impact of 30 years of transport of groundwater from the Nubeth R&D site to the 14-18 and 12-18 locations (Abitz, 2011 ¶23).

A.14. The numerical groundwater model does address the potential impact of groundwater movement from the Nubeth R&D site to the 14-18 and 12-18 cluster well locations. The potentiometric data provided in the model demonstrates that groundwater is actually moving from the 14-18 and 12-18 cluster wells to the Nubeth R&D site. Exhibit SEI019 presents the estimated potentiometric surface in the OZ aquifer in 2010. Within the ore zone, the water level at the 12-18 location is over 100 feet higher than the water level at wells 789V and 19xx. Both 789V and 19xx are historic wells that were used for the Nubeth R&D. Almost immediately after

restoration of the pilot site was complete, both of these wells were turned over to an oil company for use as water supply wells to supply water for enhanced oil recovery. As a result, groundwater will flow from the 14-18 and 12-18 cluster wells towards the Nubeth R&D site. In light of the groundwater flow gradient, it is not plausible (or even physically possible) for water from the Nubeth R&D to move away from the site.

Based on data compiled in Exhibit SEI014H (at 173), it has been estimated that since 1979 the combined volume of water removed from 22x-19, 19xx, and 789V is approximately 1,167,252,000 gallons. All of this water has been removed from the aquifer and re-injected into underlying aquifers to support enhanced oil recovery in the Deadman oilfield. All three of these wells are either historic Nubeth R&D wells or are in close vicinity to the Nubeth R&D site. The anthropogenic induced groundwater gradient in the project area has virtually eliminated the possibility that any water from Nubeth R&D site has left the immediate vicinity. In fact, given the large volume of water removed from the aquifer over the last 30 plus years, it is unrealistic to assume that any of the water from the Nubeth R&D site still exists within the aquifer.

3.0 REFERENCES

Abitz, R., 2013, Second Declaration of Dr. Richard Abitz on Behalf of the Natural Resources Defense Council and Powder River Basin Resource Council, ADAMS Accession No. ML13126A402, May 6, 2013, Exhibit 2 to Natural Resources Defense Council's and Powder River Basin Resource Council's Joint Motion to Resubmit Contentions and Admit One New Contention in Response to Staff's Supplemental Draft Environmental Impact Statement.

Abitz, R., 2011, Declaration of Dr. Richard Abitz on Behalf of the Natural Resources Defense Council and Powder River Basin Resource Council, ADAMS Accession No. ML11300A191, October 23, 2011, Attachment to the Petition to Intervene and Request for Hearing by the Natural Resource Defense Council and Powder River Basin Resource Council, PDF pages 106 to 132.

Abitz, R. and L. Larson, 2014, Joint Third Declaration of Dr. Richard Abitz and First Declaration of Dr. Lance Larson on Behalf of the Natural Resource Defense Council and Powder River Basin Resource Council, ADAMS Accession No. ML14091A004, March 31, 2014, Exhibit 1 to Natural Resource Defense Council's and Powder River Basin Resource Council's Joint Motion to Migrate or Amend Contentions, and to Admit Contentions in Response to Staff's Final Supplemental Draft Environmental Impact Statement.

Moran, R.E., 2011, Declaration of Robert E. Moran on Behalf of the Natural Resources Defense Council and Powder River Basin Resource Council, ADAMS Accession No. ML11300A191, October 24, 2011, Attachment to the Petition to Intervene and Request for Hearing by the Natural Resource Defense Council and Powder River Basin Resource Council, PDF pages 12 to 69.

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NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

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Strata Energy, Inc.	)	Docket No.	40-9091-MLA
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AFFIDAVIT OF RAY MOORES

I declare under penalty of perjury that my statements in prefiled Exhibits Ray Moores Initial Testimony (Exhibit SEI042) and Ray Moores CV (Exhibit SEI043) are true and correct to the best of my knowledge and belief.

Ray Moores

Executed in Sheridan, WY
this 25th day of August, 2014