UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION
BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

In the Matter of	)	
	)	
STRATA ENERGY, INC.,	)	Docket No. 40-9091-MLA
	)	
(Ross *In Situ* Recovery Uranium Project)	)	

Pre-Filed Direct Testimony of Dr. Richard Abitz
Supporting Joint Intervenors' Contentions 1 and 3

Q.1. Please state your name, current position and employer, including duration of employment.

A.1. My name is Dr. Richard Abitz. For the past eight years I have been the principal geochemist and owner of Geochemical Consulting Services, LLC. Among other tasks, I provide analysis of chemical and radiological data, modeling of soil and water systems, and risk assessments associated with numerous projects involving hazardous and radiological materials. I have been hired by numerous federal agencies for this work over my career, including the Department of Energy and its national laboratories, and the U.S. Environmental Protection Agency. I also am retained by environmental organizations to provide consultation and expert testimony associated with such projects. I have worked with the NRDC on this matter since the fall of 2011.

Q.2. How is your testimony organized?

A.2. My testimony is organized as follows:

1) Background information on my qualifications as an expert witness in these proceedings;
2) Summary of my testimony;

3) Background information on establishing baseline groundwater quality;
4) Testimony supporting Contention 1 – The FSEIS fails to adequately characterize baseline (i.e., original or pre-mining) groundwater quality;
5) Testimony supporting Contention 3 – The FSEIS fails to include adequate hydrological information to demonstrate SEI's ability to contain groundwater fluid migration; and
6) Conclusion.

<u>I. Background Information on Qualifications to be an Expert Witness</u>

Q.3. Please state your educational background, professional experience, and organizational memberships that qualify you to provide testimony in these proceedings.

A.3. I am a geologist and geochemist with more than 25 years of domestic and international experience in conducting and managing environmental work associated with the restoration of groundwater and soil contaminated by uranium and other radionuclides. I received my Ph.D. in Geology from the University of New Mexico in 1989. Among other prior work, from 2003-2006 I served as the Manager for Environmental Services Group, where I oversaw the work of over 50 scientists and technicians who performed water, soil and air sampling; laboratory analyses associated with radionuclide, metals and organic compounds; and other related work. I also worked on remediation strategies for the Great Miami aquifer, which involved uranium contamination. In the 1990s, I worked on geology and geochemical issues associated with groundwater, soil and waste-disposal issues associated with the Fernald Environmental Management Program and the Waste Isolation Pilot Project. I am a member of the Geological Society of America and the International Association of Geochemistry and Cosmochemistry.

My full Curriculum Vitae (CV) is attached at Joint Intervernors' Exhibit 002 (hereinafter "JTI002").

Q.4. Has your work been published in peer-reviewed publications?

A.4. Over my career, I have published more than 20 such papers, on numerous topics. My published works include papers on the need for valid statistical protocols to establish baseline water quality at Uranium ISL facilities, the geochemistry of natural and contaminated groundwater and brines, and the decommissioning of highly contaminated nuclear facilities. A complete list of my publications is at the end of my CV.

Q.5. Have you been admitted to testify in federal or state court, or in prior administrative proceedings?

A.5. Yes. On November 8, 2001, I testified before the NRC on water quality issues related to the Hydro Resources, Inc. application for a license for an ISL facility at Crownpoint, New Mexico. On Februrary 17, 2009, I testified before the New Mexico Mining Commission on revisions to state regulations to protect water quality. On May 10, 2010, I testified before the State of Texas, Goliad County Groundwater Conservation District on the invalid baseline data developed by Uranium Energy Corporation for their permit to perform uranium ISL mining in Goliad, Texas. I have also prepared numerous declarations on water quality issues related to improper well installation and development and invalid aquifer baseline values for proposed and developed uranium ISL facilities in New Mexico, Texas, Colorado, Nebraska and Wyoming.

Q.6. Please summarize your work on ISL matters prior to working for NRDC on this project?

A. 6. I have been evaluating ISL permits and licenses for nearly 20 years. My experience includes work at the proposed Churchrock and Crownpoint sites in New Mexico; the Kingsville Dome and Goliad Projects in Texas; the proposed Centennial Project in Colorado; and the Crow Butte Project in Nebraska. Work executed for the Goliad Project in Goliad, Texas was performed under contract with the Goliad County Groundwater Conservation District and was focused on baseline water quality in the uranium ore zones in the Goliad Formation. Additionally, in the performance of the above work, I have spent a considerable amount of time reviewing records and data from the Smith Ranch- Highland Project and Irigaray and Christensen Ranch Project (the Willow Creek facility) in Wyoming.

Q.7. How many of your projects, ISL uranium mining related or otherwise, have involved groundwater characterization and analysis?

A.7. All of them.

Q.8. Have you been responsible for conducting or overseeing the collection of baseline water quality data at any of these sites, and if so please describe.

A.8. Under a contract between the Goliad County Groundwater Conservation District and Geochemical Consulting Services, LLC, I was responsible for evaluating all the groundwater data collected by Uranium Energy Corporation (UEC) for their Goliad Project.

Q. 9. Have you reviewed the applicant's Environmental Report, DSEIS, FSEIS, and all the associated documentation with the Ross Project?

A. 9. Yes, I have extensively reviewed applicant SEI's Environmental Report (ER), Technical Report (TR), the Draft Supplemental Environmental Impact Statement (DSEIS) for the Ross Project prepared by NRC staff, the Final Supplemental EIS (FSEIS) prepared by NRC staff, and a host of other associated and relevant documents. During the course of these proceedings, I have submitted three declarations detailing concerns with the ER and TR, then the DSEIS, then the FSEIS. All the documents I reviewed in preparing those declarations and in preparing this testimony are noted and referenced in this Direct Testimony. A complete list can be found in at the conclusion of this testimony and in the Joint Intervenors' list of exhibits. My conclusions are my own and based upon the review of the relevant documents and my decades of experience in such matters.

II. Summary of Testimony

Q.10. Please provide a brief summary of your testimony.

A.10. I am providing expert testimony in support of Joint Intervenors' admitted Contentions 1 and 3. I will discuss the foundation behind Contention 1, specifically the FSEIS fails to adequately assess and disclose baseline groundwater. Before addressing specific flaws, I will provide some technical background information on how to properly establish baseline groundwater quality and why it matters in the case of an ISL facility. Then, I will turn to Contention 3 and provide testimony that the FSEIS fails to include adequate hydrological information to demonstrate SEI's ability to contain groundwater fluid migration. I will discuss the numerous unidentified and unplugged abandoned exploration wells in the area and how they can be pathways for fluid migration during the project. I will also discuss SEI's monitoring data and how it was insufficient for the NRC staff to make an informed fluid migration impact assessment given that the applicant's six monitor-well clusters and the 24-hour pump tests at four of these clusters provided insufficient hydrological information to demonstrate satisfactory groundwater control during planned high-yield industrial well operations.

III. Contention 1 – The FSEIS Fails to Adequately Characterize Baseline Groundwater Quality

Q. 11. Please describe what it means to have "baseline" water quality established in an underground aquifer.

A. 11.The use of the word baseline is typically applied to describe water quality parameters at a site prior to the start of any activity that might disturb or contaminate the aquifer.

Q. 12 Is this a common understanding of "baseline" or "background" groundwater quality?

A. 12. Yes. Baseline and background are interchangeable terms when describing water quality in an aquifer that has not been disturbed by human actions. EPA (2009), in Part I, Section 5.1, p. 5-1 of their Unified Guidance (http://www.epa.gov/wastes/hazard/correctiveaction/resources/guidance/sitechar/gwstats/) notes that:

> "The most important quality of background is that it reflects the historical conditions unaffected by the activities it is designed to be compared to." JTI006, at 5-1.

Q.13. Can you please explain the purpose of characterizing baseline water quality?

A.13. Generally, it is important to have a precise knowledge of the baseline water quality for two purposes. First, for remediation efforts aimed at restoring a contaminated aquifer – for example, at a hazardous waste site undergoing cleanup under the Resource Conservation & Recovery Act (RCRA) or the Comprehensive Environmental Compensation and Liabilities Act (CERCLA) – one wants to know the baseline as a guide for appropriate restoration. In other words, the aim is to restore to baseline in order to completely remediate or remove the contamination from the aquifer. Second, and directly relevant to Contention 1 here, one needs a precise knowledge of baseline groundwater quality to understand the environmental impacts at a site where natural resource extraction activities are going to take place, such as will transpire with an ISL uranium facility. In either case, it's important for basic environmental decision making and assessment to understand as best one can the condition of the aquifer before any anthropogenic activity that might cause contamination takes place; so proper monitoring levels can be established to protect the groundwater. Again, as noted by EPA (2009) in Part I, Section 5.1, p. 5-1 of the Unified Guidance:

> "High quality background data is the single most important key to a successful statistical groundwater monitoring program, especially for detection monitoring." JTI006, at 5-1.

Q. 14. Could you explain how baseline or background groundwater quality values are established in the cleanup context?

A. 14. As noted above, for RCRA and CERCLA sites, baseline or background values (as stated above, the terms are used interchangeably) are established for the groundwater horizons by installing wells, under approved procedures and valid statistical sampling plans, *upgradient* of known or suspected contamination zones. NRC's *Standard Review Plan for In Situ Leach Uranium Extraction License Applications*, NUREG 1569, (JTI007 at Section 2.9.3, p. 2.32, also SEI submitted this document, SEI007) (2003; http://www.nrc.gov/reading-rm/doc-collections/nuregs/staff/sr1569/sr1569.pdf), cites NRC Regulatory Guide 4.14, Section 1.1 (JTI008) (NRC, 1980; http://pbadupws.nrc.gov/docs/ML0037/ML003739941.pdf) for guidance on monitoring programs to establish background for radiological constituents. NRC Regulatory Guidance 4.14 (JTI008 at Section 1.1.2, p. 4.14-2) notes that at least one well must be hydrologically upgradient to serve as a source for background samples. There is no such well identified in the FSEIS.

Further, the EPA (2009) Unified Guidance (JTI006 at Part I, Section 5.2.1, p. 5-3) recommends a minimum of 8 to 10 independent samples be collected before running statistical tests. Independent samples are defined as representative samples drawn from randomly located wells in the study area that have been properly installed and developed; and the submission of the samples to a certified and licensed laboratory for analysis of water quality parameters. After receipt and validation of the analytical results, proper scientific and statistical methods are used to establish valid baseline values. The appropriate protocols are outlined in the EPA (2009) Unified Guidance (JTI006) and references therein.

Q. 15. Should baseline groundwater quality values be established the same way for a cleanup site as for a site that is going to become subject to further contamination as a result of a planned project, such as an ISL site?

A.15. Yes, precisely the same rigorous and statistically valid protocols for the collection of baseline water quality are appropriate and necessary for a site where the issue is not cleaning up existing contamination, but establishing the quality of the natural groundwater environment prior to the execution of a project that risks degrading water quality. In summary, it is necessary to collect data from a sufficient number of wells, over a sufficient time period, under conditions that ensure representative samples are collected to produce valid data to establish the baseline values that will be used to monitor the change in groundwater conditions.

Q.16. Is this consistent with the approach to baseline water quality approved by the NRC in the Ross Project FSEIS?

A. 16. No. The FSEIS provides that two separate efforts to evaluate baseline water quality data will occur, one pre-license and another post-license, with almost all the data collection and the actual setting of baselines performed *post*-license. Pre-license baseline data collection is described in Section 6.3 of the FSEIS (SEI009A):

> "Pre-licensing, site-characterization monitoring of surface water and ground water was completed by the Applicant in 2009, 2010, and 2011. The Applicant also provided supplemental environmental-monitoring data in 2012 (Strata, 2012a). The acquired data were then used to characterize the Ross Project area according to the requirements in 10 CFR Part 40, Appendix A, Criterion 7 (Strata, 2011a)."

In contrast, *post*-license baseline data collection is described in Section 6.3.2 of the FSEIS (SEI009A):

> "The Applicant has proposed a ground-water monitoring program to acquire post-licensing, preoperational data in order to establish the constituents and their concentrations that would form the basis to detect excursions outside the ore zone during active uranium-recovery operation and to observe aquifer-restoration performance as restoration proceeds (Strata, 2011b). The post-licensing, pre-operational data would be collected from each individual wellfield as it is completed and installed, but prior to the Applicant's initiating uranium recovery in the respective wellfield. Each wellfield's ground-water monitoring data would be used to establish NRC approved upper control limits (UCLs) in accordance with 10 CFR Part 40, Appendix A, Criterion 5B(5) (i.e., constituent concentration-based values for excursion detection and for aquifer restoration performance assessment). (See SEIS Section 2.1.1 for a further explanation of this type of

monitoring.) Thus, excursion-parameter values and aquifer-restoration target values would be wellfield specific."

Q.17. Why is it so important, from a scientific perspective, to establish baseline water quality prior to licensing and operation of the facility?

A.17. There are fundamental scientific reasons why the baseline water quality effort must occur before the ISL license is issued to the SEI Ross Project. First, to collect samples that represent the true geochemical conditions in the aquifer, the baseline must be established using groundwater samples obtained from an aquifer that has not been contaminated by extensive exploration drilling; with monitoring wells randomly located and installed and developed through the entire sand thickness with non-oxidizing drilling fluids and gases to ensure that the uranium ore zone remains under reducing conditions. Second, the concept of developing post-license baseline for each wellfield prior to its construction allows contamination of the aquifer prior to establishing baseline and this is completely contrary to the scientific definition of baseline and the noted criteria in 10 C.F.R. 40 Appendix A. In addition, because the groundwater quality data necessary to establish baselines were not collected, nor were baselines established, prior to completing the NEPA process and issuing the license, the FSEIS fails to disclose to the agency and the public the actual baseline conditions on the site, a critical element to any meaningful evaluation of the project's likely environmental impacts. Thus, for example, engaging in these activities in pristine groundwater may understandably raise more concerns than if the groundwater is already highly degraded.

Q. 18. What do you see as the impacts to human health and the environment if the agency is permitted to complete the NEPA process based on the consideration and discussion of baseline water quality included in the FSEIS?

A.18. Importantly, as noted under the NRC's approved approach in this FSEIS, baselines are not actually evaluated and established before the decision to go ahead with this project is made. But in addition, under the approach approved in the FSEIS, groundwater quality in the proposed mining area will be characterized improperly, resulting in the establishment of very high excursion values and restoration standards that will preclude the use of the water for future domestic, livestock or agriculture needs. Thus, under the FSEIS, SEI will be allowed to contaminate the aquifer prior to baseline development through extensive exploration programs that use oxidizing fluids during drilling operations and the installation of hundreds of wells with rotary-drill techniques that use oxidizing fluids and air-lifting techniques during well development - processes which oxidize the uranium ore and alter true baseline water quality values ((JTI009) Abitz, 2010 https://gsa.confex.com/gsa/2010AM/finalprogram/abstract_174957.htm; (JTI010) Laaksoharju et al., 2008). Moreover, SEI will be allowed to screen the wells used for the collection of baseline samples only through the narrow ore zone within the aquifer. This ISL industry practice is scientifically and statistically invalid because it allows a company to collect baseline samples from the most disturbed and contaminated portion of the aquifer by screening only through the ore zone that has been oxidized by improper drilling and development techniques.

Additionally, the FSEIS fails to identify proper statistical analysis and methods to establish valid baseline values and excursion limits (e.g., see Parts II, III and IV in the EPA Unified Guidance, 2009; and references therein (JTI006)).

Given these deficiencies approved in the FSEIS, when 'baseline' is discussed in this testimony, it will be emphasized with single quote marks to indicate reference to NRC's view of the baseline, which reflects neither the establishment of a true baseline consistent with appropriate scientific and statistical principles nor the criteria in 10CFR40 Appendix A and NRC Regulatory Guide 4.14.

As discussed in detail below, the failure of the FSEIS to meaningfully address baseline groundwater quality allowed the NRC to fail to disclose the actual environmental impacts of the Ross Project in two respects. First, by relying on only the six well clusters and some other existing data in the FSEIS, rather than undertaking a scientifically and statistically valid baseline water quality effort, the NRC has failed to disclose or consider the *actual* baseline water quality conditions in the area comprising its licensing decision. Second, in light of the fundamental deficiencies associated with the approved plans to collect post-licensing 'baseline' water quality data, the NRC has failed to disclose or consider how much *worse* the water quality in the area is likely to become post-restoration, as compared to baseline conditions. Put another way, only by implementing an invalid approach whereby the 'baseline' will be characterized as significantly more degraded than it is in reality has the NRC been able to avoid confronting and disclosing the inevitable fact that the actual environmental impact of the Ross Project on water quality will be "large" as defined by the NRC – *i.e.,* "clearly noticeable and sufficient to destabilize important attributes of the resource considered." *See* FSEIS xxi (SEI009A).

Q. 19. Are you familiar with specific instances where baseline was improperly or inadequately characterized? And if so, what were the consequences?

A. 19. Yes. During my review of the Goliad Project, described below at Question 28 p. 26, I determined that groundwater data collected by UEC were invalid for establishing baseline values because the uranium ore zone had been oxidized by improper well installation and development techniques and the water samples were collected only from the narrow ore zone horizon (10 to 15 feet) of the aquifer, rather than the entire thickness of sand (50 to 75 feet). Using the results of the invalid samples, which had been biased to high values by oxidation of the ore zone and collection of the sample only from the ore horizon, I followed proper statistical protocols and evaluated the distribution of the data to determine if parametric statistics (e.g., mean, standard deviation, etc) could be applied to the data set. As the data distribution was neither normal nor log normal, non-parametric statistics (e.g., median, percentiles, etc.) had to be applied to the data set to determine if the water quality for uranium and radium-226 met the EPA maximum contaminant limits (MCLs) for drinking water. My analysis showed that the median groundwater values for uranium and radium-226 meet the EPA drinking water MCLs. Results presented by UEC concluded that uranium and radium-226 exceeded the EPA drinking water MCLs because they used a simple average calculation (parametric statistic), but this type of calculation is invalid because the data do not follow a normal distribution.

Extremely high uranium and radium-226 values for several of the groundwater samples biased the estimate of the population mean (UEC's simple average calculation) to high values, and it is because of these very high values that the data do not follow a normal distribution. The improper statistical calculation performed by UEC was incongruous with the fundamental statistical principle to test the data distribution prior to estimating population parameters. In this case, non-parametric estimates were required and the median uranium and radium-226 values met the EPA MCLs for a drinking water aquifer.

This approach is consistent with EPA's unified guidance (EPA 2009) (JTI006 at Part I, Section 2.2.2) on performance standards for the statistical treatment of groundwater samples:

> "Any statistical method chosen under §264.97(h) [or §258.53(g)] for specification in the unit permit shall comply with the following performance standards, as appropriate:
> 1. The statistical method used to evaluate ground-water monitoring data shall be appropriate for the distribution of chemical parameters or hazardous constituents. If the distribution of the chemical parameters or hazardous constituents is shown by the owner or operator to be inappropriate for a normal theory test, then the data should be transformed or a distribution-free test should be used. If the distributions for the constituents differ, more than one statistical method may be needed."

Q. 20. In your expert opinion, has SEI or NRC Staff provided an adequate characterization of baseline groundwater quality, either in the ER, the DSEIS or the FSEIS for this project?

A. 20. No. Now that I have presented the background, I will explain in detail in the paragraphs that follow. But, as a general matter, providing a scientifically and statistically sound sampling regime prior to the issuance of a license and during the course of the public environmental review is an issue we have raised in this proceeding since the outset. As with a number of other issues Joint Intervenors have raised, there were no substantive changes between the ER, the

DSEIS, and now the FSEIS and, in any event, the presentations were inadequate to demonstrate a meaningful assessment of the baseline water quality.

Q. 21. First, describe what SEI and NRC Staff have done to establish what they call "baseline" groundwater quality described in the FSEIS?

A. 21. First, in Section 3.5.3.3 of the FSEIS (SEI009A), the SEI and NRC Staff note that:

> "…groundwater-quality data is the Applicant's own ground-water monitoring network which it constructed in 2009 and 2012 and which consists of six monitoring-well clusters and four piezometers…"

Second, Section 3.5.3.3 of the FSEIS states:

> "The Applicant provided construction details of the wells and methods used for ground-water sampling in its ER (Strata, 2011a)."

These construction methods were traced to the SEI Technical Report ((SEI006A) Section 2, p.2-146):

> "All baseline monitoring wells were constructed using conventional mud rotary drilling techniques……..Following filter pack placement, air-lift development was conducted until turbidity readings stabilized."

Third, Table 3.6 in Section 3.5.3.3 of the FSEIS provides maximum, average, and minimum values for the chemical constituents measured in groundwater samples collected from 2009, 2010, and 2011.

Finally, SEI and the NRC Staff opine in Section 3.5.3.3 of the FSEIS that:

"The data from 2011 are generally consistent with the 2009 and 2010 data; this consistency indicates a representative characterization of ground-water quality." SEI009A, FSEIS at 3-38.

<u>The Necessity of a Valid Statistically Defensible Baseline</u>

Q. 22. What are you over-arching concerns with the SEI methodology, approved by NRC in its FSEIS?

A. 22. First, the statistical justification for the random location of the six monitoring-well clusters across the proposed mining area is absent in the FSEIS, and in the Strata 2011 Technical Report documents, and this issue was noted in my initial 2011 declaration. As discussed below, in my professional opinion the locations are not located and distributed in a manner designed to collect data representative of overall site conditions.

Second, the well installation and development methods oxidized the ore zone by introducing oxygen-rich fluids (relative to the depleted oxygen levels in the aquifer) during drilling and atmospheric air (20% oxygen) during well development and these improper actions contaminated the aquifer prior to collecting baseline water quality samples. Instead, for the oxygen-depleted conditions associated with uranium ore deposits, baseline water quality data should be collected using wells that have not been installed and developed with oxygen-rich fluids and air-purging techniques. This is in accordance with professional standards for well installation recommended by the U.S. Geological Survey (1997; http://water.usgs.gov/owq/pubs/wri/wri964233/wri964233.pdf) (JTI011), which I will expand upon in the next question.

Third, there is no attempt to perform a valid statistical analysis on the data to determine whether there are a sufficient number of wells and samples to conclude with a stated level of confidence that the water exceeds the EPA drinking water MCLs for hazardous metals and radionuclides. Below I will explain the correct scientific approach to determining the correct number of wells used.

Finally, as discussed elsewhere in this testimony, uranium data from 2011 show lower levels relative to 2010 and 2009. This is consistent with reducing conditions returning to the ore zone in the aquifer after anthropogenic oxidation during well installation and development. In reality, the 2011 results are NOT consistent with 2009 and 2010 data. More importantly, it is highly inaccurate to state, as it does in the FSEIS at 3-38 (SEI009A), that similarity in water quality results from round to round indicates representative groundwater quality when all of the fundamental protocols for collecting a representative groundwater sample have been violated on the Ross Project.

Q. 23. Can you go back to the USGS professional standards for well-installation you cite in your previous answer?

A. 23. Yes. Professional standards for well design, installation and development are discussed in detail by the USGS (1997) (JTI011), with the following highlights and recommendations:

"The primary consideration for selecting well-installation methods and materials is to minimize the effects on the chemical and physical properties of the ground-water sample." (JT1011 at 18)

"The goal for water quality studies is to have the well design compatible with requirements to obtain samples that accurately represent the chemical constituents of concern in groundwater. " (JTI011 at 20)

"Additional considerations that influence selection of the well-construction method include:

- Requirements inherent in the chemical constituents targeted for sampling, their anticipated concentrations, and the accuracy needed to meet study objectives." (JTI011 at 45)

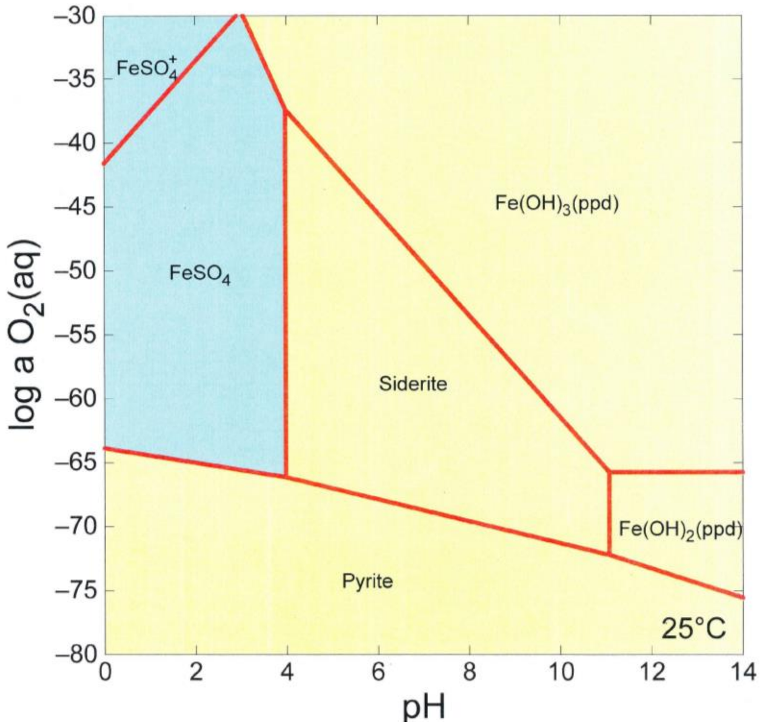
In particular, the bulleted portion of the above quote highlights three important criteria we have repeatedly stressed throughout the review process. First, "requirements inherent in the chemical constituents targeted for sampling" explicitly implies that if you are going to measure uranium concentrations in groundwater in contact with a uranium ore body, you cannot use a well-construction method that introduces oxygen into the ore zone. An appropriate method would be to use air-rotary drilling (JTI011 at 57) with recirculated nitrogen gas instead of air and a foam surfactant that contains organic constituents to eliminate oxygen.

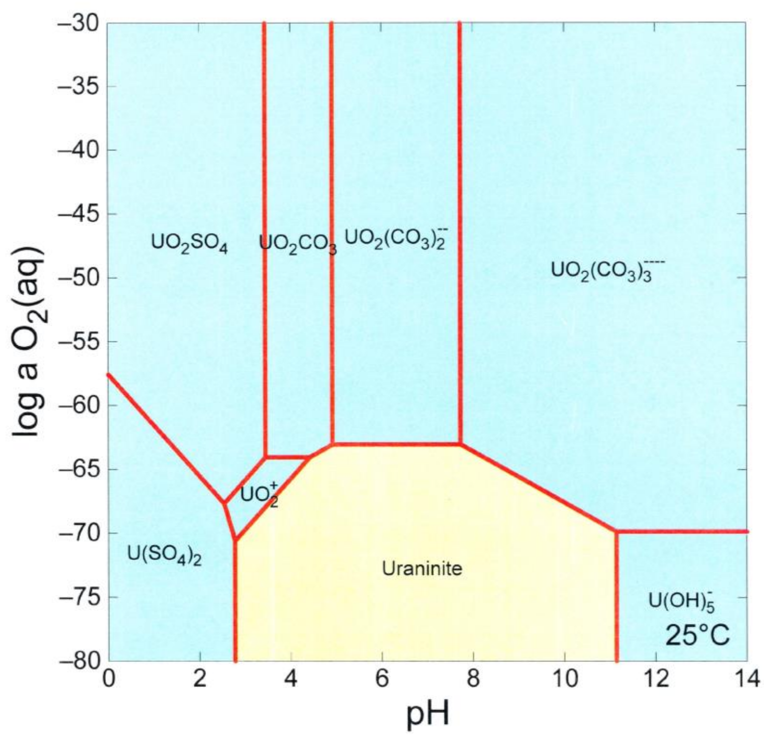
The second part of the above bullet, "their anticipated concentrations", refers to the concentration of uranium in the ore zone. The FSEIS (SEI009A, p. 3-16) states "The presence of pyrite confirms the geochemical conditions necessary for formation of the roll front." This is consistent with the common occurrence of pyrite with uranium ore deposits at extremely low oxygen levels in groundwater (JTI012, Brookins, 1988; p. 153). The levels of oxygen in groundwater contacting pyrite and uranium ore (uraninite) are easily calculated using commercial software, such as the Geochemist's Workbench (http://www.gwb.com/). I calculated the stability field for pyrite (below figure) using the Geochemist's Workbench and the approximate highest groundwater concentrations for iron (0.57 milligrams/liter), carbonate (610 milligrams/liter) and sulfate (920 milligrams/liter), as reported for the ore zone (Appendix C of FSEIS). The thermodynamic calculations indicate that pyrite is stable over the pH range of 6 to 10 only when oxygen levels are below $1x10^{-65}$moles/liter. Next, the uranium concentration in groundwater can be estimated by constraining the uraninite stability field to oxygen levels less than about $1x10^{-65}$moles/liter. I constructed this figure (below) using the same water quality data noted above and when the uraninite stability field is below oxygen levels of $1x10^{-65}$moles/liter, uranium concentrations in groundwater are less than $1x10^{-10}$moles/liter (2.38E-08 grams/liter or 2.38E-14 micrograms liter, which is over 13 orders of magnitude lower than the EPA uranium MCL of 30 micrograms/liter). This analysis shows that the true uranium concentration in groundwater contacting uraninite and pyrite is so low that it cannot be detected with present laboratory methods.

The last criterion in the quoted text under the above bullet states "the accuracy needed to meet study objectives." Given that oxygen levels are extremely low in uranium ore deposits, the well-construction methods must provide the accuracy needed to ensure no oxygen is introduced to the ore zone via drilling fluids and compressed atmospheric air.

Results discussed below clearly indicate that Strata violated the above noted professional standards when constructing their monitoring wells and analytical results on uranium concentrations in the groundwater demonstrate they oxidized the uranium ore prior to collection of the groundwater samples.

Pourbaix diagrams displaying relevant geochemical conditions from Geochemist Workbench®. Top figure shows Iron and bottom figure shows the uranium stability fields.





Q. 24. Let's start with specific problems with the 'baseline' described in the FSEIS. Did the FSEIS provide a thorough and scientifically valid technical discussion on how the pre-licensing 'baseline' required for NEPA analysis purposes was developed for the Ross project?

A. 24. No. First, the information gathered is neither statistically meaningful nor adequate to the task of presenting an accurate picture of original groundwater conditions. The manner in which this data collection was done creates a statistically invalid, biased set of non-representative groundwater samples from improperly located, constructed and developed wells that are screened only through the part of the ore zone (OZ) water horizon that is in contact with the ore zone, rather than the entire column of water in the OZ sand interval. Generally 8 to 10 samples per well are needed to perform a meaningful statistical analysis and the independent samples must be pulled from a sufficient number of random locations across the proposed mining area. (JTI006, EPA, 2009; Part I, Section 5.2.1, p. 5-3) Details on how an accurate baseline should be established for the Ross Project are presented below.

Q.25. Please explain specifically why you don't think SEI and NRC Staff have collected representative groundwater samples.

A. 25. I first raised this issue with respect to the ER in 2011 and the successive iterations of the DSEIS and FSEIS have not altered the inadequacies. SEI failed to collect representative groundwater samples, as the wells were not randomly located across the mining area, the ore zone was oxidized when the wells were installed and developed, and the screen lengths for the existing six monitor wells in the OZ zone are approximately ¼ to ½ the thickness of the OZ sand and centered on the ore zone; as noted in the table below.

OZ Well	OZ well screen length[1]	OZ sand thickness[2]	Uranium (mg/L)[3]	Radium-226 (pCi/L)[3]
12-18	110 feet	200 feet	0.033-0.070	5.00-12.0
14-18	30 feet	180 feet	0.085-0.109	2.31-4.90
21-19	35 feet	160 feet	0.005-0.024	0.71-0.93
42-19	90 feet	180 feet	0.009-0.011	1.36-1.46
34-18	105 feet	180 feet	0.041-0.062	5.97-9.68
34-7	60 feet	150 feet	0.028-0.044	0.94-2.35

[1]data from Addendum 2.7 F, Table 1 (SEI009A)

[2]data from Addendum 2.6 C, Figure 7 (12-18), Figure 9 (14-18), Figure 11 (21-19), Figure 24 (42-19), Figure 16 (34-18), Figure 17 (34-7). (SEI009A)

[3]data from Technical Report, Section 2, Table 2.7-37 (SEI014A-P)

This approach had the effect of biasing the groundwater sample to high values for uranium, radium-226 and other uranium progeny and associated ore metals (e.g., arsenic, molybdenum, vanadium, etc) due to the disturbance and oxidation of the ore during well construction and development. I know NRC Guidance (NRC013, at 5-43) also recognizes this bias and the NRC states that fully screened intervals are more accurate in their representation of the water quality that a user of the water will encounter. Therefore, for all the reasons noted above, in my expert opinion the present monitor wells in the OZ horizon do not collect a representative groundwater sample.

Q. 26. Are there other specific examples of how the FSEIS failed to contain a statistically meaningful assessment of baseline water quality?

A. 26. Yes. In Tables 3.6 and 3.7 of the FSEIS, Strata's six cluster wells are grouped together to report average and ranges for each water horizon, and there is no mention of the proper statistical methods for evaluating individual wells prior to grouping them and calculating an average or range for the aquifer horizon (JTI006, EPA 2009, Parts II, III and IV; and references therein). A simple averaging or reporting a range of the values from all wells does not establish baseline unless it can be shown with proper statistical methods that (i) the samples from the individual wells follow a normal or log-normal distribution, and (ii) an analysis of the data variance of each well demonstrates that the wells can be combined into a single population for statistical calculations. Examination of the reported values is discussed under ¶ 27, where it is clearly shown that the samples from the six cluster wells do not fall into a single population with respect to uranium and radium-226. To this point, standard statistical practices for the environmental industry (random grid sampling, statistically significant number of sampling locations, proper statistical tests, etc) are routinely and easily carried out using statistical software (e.g., JTI013, Visual Sampling Plan, http://vsp.pnnl.gov; and Pro UCL, http://www.epa.gov/osp/hstl/tsc/ProUCL_v4.00.02_user.pdf) available free from Pacific Northwest National Laboratory and the EPA), and I note that the use of these standard industry practices is enforced by EPA when groundwater and soil samples are collected at CERCLA and RCRA sites. (JTI014, DOE 1994, Appendix F; http://www.lm.doe.gov/cercla/documents/fernald_docs/CAT/Revised%20110692.pdf).

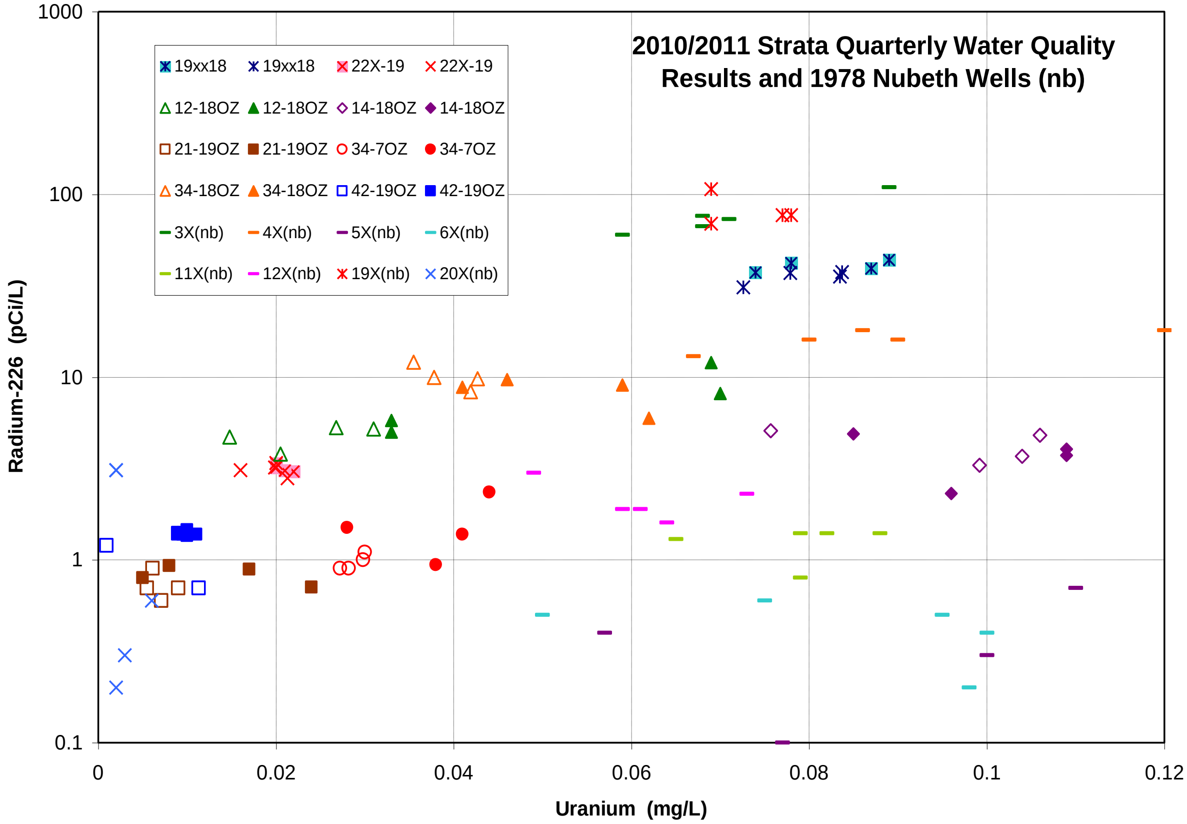
<u>The Impact of Invalid Statistical Sampling and Other Practices That Can Bias the Baseline</u>

Q. 27. You were critical of how SEI gathered the samples, described in the FSEIS. Can you be specific about how the presentation and analysis of the data presents an inaccurate picture of baseline water quality?

A. 27. Yes I can. As discussed above, SEI's methodology for establishing 'baseline' water quality was not statistically sound. This resulting bias in the numbers is significant because it allows for a substantially more degraded aquifer after restoration due to an inaccurate portrayal of baseline groundwater quality. Specifically, the 'baseline' data given in Section 3.5.3.3 of the FSEIS (SEI009A, Tables 3.6 and 3.7) references Strata (2011a, 2012) (SEI005A-E) and Nuclear Dynamics (1978) (NRC017) for average concentrations of the major and trace ions for the six monitor-well clusters completed in four aquifer horizons (SA, SM, OZ, and DM horizons) and for the Nuclear Dynamics Nubeth Pilot Project. These tables now contain the 2011 monitoring data from the six monitor-well clusters. The NRC did not present the 2011 water-quality data in the DSEIS; they noted that "*The data from 2011 are generally consistent with the 2009 and 2010 data, indicating a representative characterization of ground-water quality*." (NRC006A, DSEIS at p.3-39, lines 11-12). This same inaccurate statement has been retained in Section 3.5.3.3 of the FSEIS, as noted above.

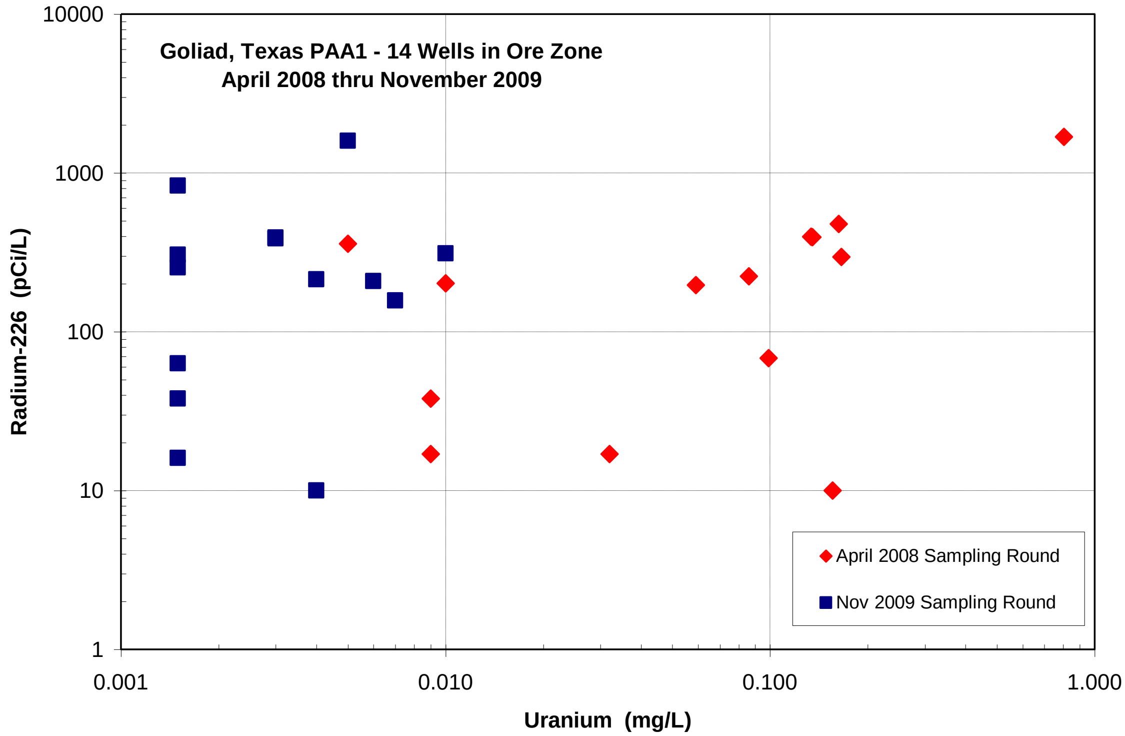
In Appendix C of the FSEIS, the 2011 data are tabulated and it is a fundamental failure of the analysis in the FSEIS that it nowhere confronts the significance of the 2011 results relative to the 2010 values. I have plotted the 2011 and 2010 radium-226 and uranium results (below figure) reported in Appendix C and the Nubeth 'baseline' data to reveal the trends that support our conclusions on the anthropogenic degradation of water-quality parameters from mechanical and chemical disturbance of the ore zone during drilling operations and well development before the license has been issued. I will discuss the Strata wells first and refer to the Nubeth wells later in this testimony.

The 2011 ore-zone data for Strata's six regional wells (open symbols on the figure) show uranium has decreased in 4 of the 6 wells (12-18, 21-19, 34-07, 34-18) and radium-226 is essentially unchanged, relative to the 2010 data (filled symbols). Uranium decreases over this time interval as the aquifer begins to return to reducing conditions following the initial disturbance and oxidation of the uranium ore when the wells were installed and developed. Radium-226 remains at the 2010 levels as radium is insensitive to redox changes once it is released from the uranium bearing ore. The initial magnitude of disturbance and oxidation of the uranium ore varies from location to location, as it is dependent on the time spent in developing the well with air lift and jetting techniques. For well 14-18, the similar results for 2010 and 2011 indicate the ore zone may have been disturbed for a longer period of time during well development. Importantly, the trends for uranium and radium-226 show that the ore zone is disturbed and oxidized by well installation and development activities and it is inaccurate of the NRC Staff to assert that a true baseline can be developed after hundreds to thousands of wells are drilled in the well fields (i.e., Strata's proposed post-licensing, pre-operational 'baseline').



Q. 28. Are there other ISL sites that show the same decreasing trend for uranium when the aquifer attempts to return to reducing conditions after mechanical and chemical oxidation of the ore body during well installation?

A. 28. Yes, this trend is not a coincidental event and it would be captured at all ISL sites if sampling were carried out for two to three years prior to initiation of ISL operations. The same striking decrease in uranium, but not radium-226, is observed for two pre-license sampling events from production wells placed into the uranium ore at Goliad, Texas (JTI015, UEC 2008 Table 5.2 and JTI016, 2009 updates). Again I plotted the uranium and radium results for the site (see figure on next page). Installation of the production wells was performed with improper methods and anthropogenic oxidation of the ore body was captured by the first sampling round in April through September of 2008 (red diamonds in below figure). Fourteen months later, another sampling round was collected in November 2009 for the same wells and all uranium levels had fallen below the EPA uranium MCL of 0.03 mg/L (blue squares); most decreasing by at least an order of magnitude. Again, once the ore body is oxidized during well installation, the radium-226 released from the uranium ore will not drop out of solution because it is insensitive to redox changes. Therefore, allowing improper well installation methods results in contamination of the groundwater prior to any mining activity taking place and the ISL industry 'baseline' values are invalid for uranium, radium-226 and other contaminants associated with the ore (e.g., arsenic, molybdenum, selenium).



As I explained above, with reference to professional standards for well construction and development published by the USGS (JTI011), these problems can be avoided if wells are properly installed and developed without the use of oxidizing fluids and air.

<u>**The Post Licensing Baseline**</u>

Q 29. Let's explore the question of biasing the baseline values further. Are there issues with impacts to the aquifer from potential SEI actions that might bias or affect a scientifically defensible portrayal of the post-licensing "baseline" water quality?

A. 29. Yes. As noted in my introductory statements, there are significant issues in the FSEIS with respect to defining true baseline water quality. The FSEIS fails to explain how the Applicant and/or the terms of its NRC License will prevent post-licensing, pre-operational 'baseline' water quality measurements from being contaminated by the combined effects, prior to sampling, of drilling, casing, well development and testing of hundreds to thousands of injection and recovery wells; and the FSEIS is silent on the mechanical and chemical effects associated with previous and ongoing exploratory drilling to delineate the boundaries of the economically recoverable uranium resources in the Lance District. Nor does the FSEIS address how, in the course of simultaneously constructing, operating, and "restoring" numerous individual wellfields in sequence over many years, the license terms will avoid the obvious pitfall of operational wellfields degrading the "post-licensing, pre-operational" water quality 'baselines' in subsequent adjacent monitoring wells targeting the same aquifers.

As demonstrated by the statistically invalid 'baseline' values reported in the mining permits for the Kingsville Dome ISR operations in Texas (JTI017, TWC 1988; JTI018, TWC 1990)[1]; this flawed methodology will have the effect of creating a cascading deterioration in nominal 'baseline' water quality measurements from wellfield to wellfield in the course of building-out the Ross Project, and pursuing adjacent Lance District Development.

Q. 30. What is it precisely in the methodology that was used at the Kingsville Dome that concerns you? Can you please describe the details?

A. 30. Yes. Improper 'baseline' was established at the Kingsville Dome site for three Production Area Authorizations (PAA1, PAA2 and PAA3) over a fourteen year period (1983 to 1998). JTI017, JTI018. I will use the data obtained from the permits and modifications to the PAAs to demonstrate my concerns and conclude that there is no scientific or statistical justification to

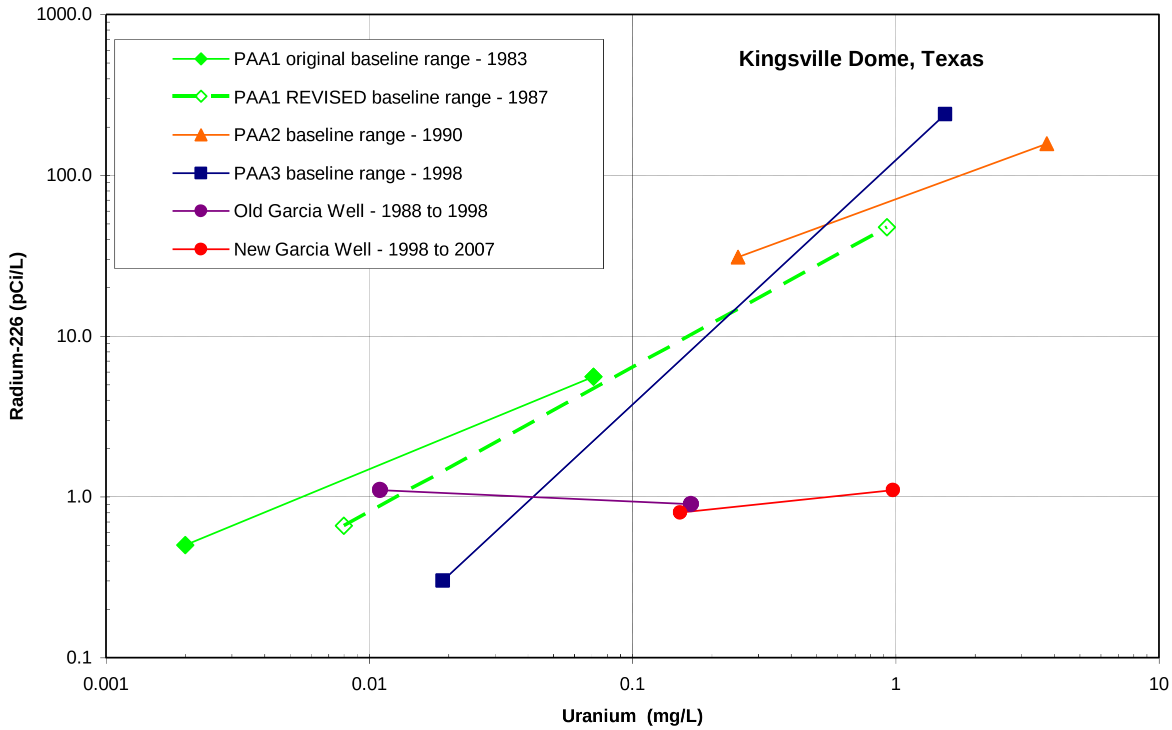
[1] Baseline for Kingsville Dome Production Area Authorization (PAA) 1 and PAA 2 were established two years apart and much higher values were measured for PAA2 (invalid average values - PAA1: uranium = 0.164 mg/L; radium-226 = 22 pCi/L. PAA2: uranium = 1.89 mg/L; radium-226 = 92 pCi/L).

allow post-licensing, pre-operational 'baseline' for each well field as it is built. I created a chart that can be found below to illustrate these concerns.

In August 1983, the initial PAA1 'baseline' was established after the installation of production wells in the ore zone (JTI019, Table 2.7-4 from URI 1983c), and the ranges for uranium and radium-226 for this invalid 'baseline' are shown by the solid green diamonds and bold green line on the below figure. After additional well fields were built out, the Texas Water Commission (JTI017, TWC 1988, p.10) [TWC is now the Texas Commission on Environmental Quality (TCEQ)] allowed the operator to revise the 'baseline' for PAA1 in November 1987 (open green diamonds and fine green line on the figure). In doing so, TWC allowed the operator to increase the 'baseline' for both uranium and radium-226 by using maximum values that were approximately ten times higher relative to the initial 'baseline' established in 1983.

In February 1990, after mining at PAA1 for approximately 6.5 years, TWC (JTI018, 1990, p.9) allowed the operator to establish 'baseline' values at the adjacent PAA2 (solid orange triangles and orange line on the figure), which is located downgradient from the ISL operations in PAA1. This TCEQ action allowed the operator to elevate the uranium 'baseline' value using a maximum value (3.8 mg/L) that is 100 times higher than the maximum uranium value (0.071 mg/L) used to calculate the initial PAA1 'baseline'. Proceeding to PAA3, TWC (JTI020, 2006, p.12) allowed the operator to establish 'baseline' in June of 1998, nearly fifteen years after mining began in PAA1. Therefore, the record at Kingsville Dome clearly shows the deterioration of the nominal invalid 'baseline' values with time when the operator is allowed to develop the 'baseline' for each unit as the well fields are built out.

Moreover, this higher ‘baseline’ allows much higher levels of uranium to pass through the monitor well ring without being reported as an excursion. At Kingsville Dome, this is evident in the significant increase in uranium at the Garcia wells (just outside and downgradient from the monitoring well ring) over the fourteen years of mining. The old Garcia well was sampled in 1988 and the initial water quality met the EPA drinking water MCLs for radium-226 (1.1 pCi/L) and uranium (0.011 mg/L) (Garcia Wells Data Sheets JTI021 at page 2 of the pdf). By 1998, the uranium had increased in the old well by over an order of magnitude (0.17 mg/L) and radium-226 was essentially unchanged (0.9 pCi/L). JTI021 at page 3 of the pdf. This observation is in line with the high mobility of uranium, but not radium-226, in the carbonate lixiviant injected into the ore zone. Due to the impact of uranium on the old well, a new well was installed in 1998. However, the new Garcia well had uranium levels similar to the old well (0.15 mg/L) and the uranium levels continued to increase; reaching a level of 0.98 mg/L in 2007. JTI021 at page 6 of the pdf.



Q. 31. Could you explain the relevance of the Kingsville Dome story to the project at issue here?

A. 31. My conclusion from my extensive review of ISL projects in Texas is that the invalid ISL industry 'baseline' values become progressively more egregious when ISL operators are allowed to establish 'baseline' as they go, which is the post-license pre-operational scenario envisioned by the NRC for the Ross Project. This flawed approach also allows for the establishment of high concentrations of excursion indicators and the potential for significant contamination to migrate beyond the portion of the aquifer that is exempted.

Q. 32. Continuing on the theme of pre-mining impacts biasing an accurate presentation of baseline groundwater quality, are there problems with *prior impacts* that could affect the Ross Site in particular, especially as restoration levels will not be set until after the NEPA process and licensing?

A. 32. Yes, the FSEIS portrayal of 'baseline' water quality at the Ross Site has already suffered some of the effects I noted above.

First, there are no pre-industrial baseline values from Nuclear Dynamics (1978) (NRC017) or Strata (2011a) (SEI005A-E). Pre-industrial baseline values can only be determined if statistically valid, representative groundwater samples are collected from monitoring wells that are randomly located in the mining area prior to drilling hundreds of exploration boreholes and the wells must be constructed and developed without the addition of oxidizing fluids and air. This was not done by Nubeth or Strata.

Second, page 25 of the Buswell MS thesis (found in Strata (2010) TR Addendum 2.6-A, SEI006D) notes that in 1976 Nubeth initiated a single-well, push-pull study (i.e., the injection and extraction of lixiviant from a single well), nearly two years ***before*** the first baseline samples were collected in April 1978 (Nuclear Dynamics 1978, NRC017). The impact of this test is evident over the area defined by the monitoring wells that were sampled two years after the testing (see above figure for Strata 2010/2011 results and 1978 Nubeth results). Nubeth wells 3x, 4x and 19x captured water samples from the aquifer were the lixiviant injection oxidized the ore zone, as they all have high radium-226 values in excess of 10 mg/L. Wells 5x, 6x, 11x and 12x have radium-226 values less than 3 pCi/L, but uranium values as high as wells in the oxidized ore zone. Therefore, because the ore was injected with lixiviant *before* baseline water-quality samples were collected, pre-industrial baseline does not exist for the Nubeth pilot-scale study.

Third, the same figure noted in the above paragraph also shows the impact of the Nubeth 1976 lixiviant injection on the preferential transport of uranium out of the injection zone. Well 19xx(nb) was the injection and extraction location and the elevated uranium and radium-226 indicate the ore was oxidized. Based on similar uranium and radium-226 results for well 3x(nb), and to a lesser extent 4x(nb), these wells were within the zone disturbed by the injection of the lixiviant at 19xx(nb) (Nuclear Dynamics 1978, NRC017). Other wells used to define the Nubeth 1978 'baseline' (except 20x(nb), which appears unaffected by the test due to low radium-226 and uranium values) have elevated uranium but low radium-226. These wells (5x, 6x, 11x and 12x) are impacted by the transport of uranium in a carbonate lixiviant, as would occur in an excursion event. Therefore, the Nubeth wells used to collect water-quality samples were contaminated by the injection of the lixiviant prior to sample collection and there is no pre-industrial baseline for the Nubeth ISR test project.

Finally, there are several problems with the failure to identify and plug the existing exploration boreholes. The NRC notes that, for each well field in the Ross Project, Strata will re-drill, plug and abandon all open exploration boreholes prior to mining. The plug and abandonment actions will also occur before collecting water-quality samples. Furthermore, the NRC states baseline samples will be collected after all of the wells are in place, "*A single wellfield consists of many ground-water wells; <u>when all of these wells have been installed, water-quality samples are obtained</u> from these new wells and are analyzed for the constituents that the NRC specifies in the license, before any uranium-recovery may occur. These sampling* *and analysis efforts, and the data values that are established as a result of these efforts, are called in the SEIS, "post-licensing, pre-operation* (SEI009A, FSEIS; p. 2-25)*."* Specifically, the FSEIS estimates that the total number of injection and recovery wells installed will be between 1,400 – 2,200, not including monitoring wells (*Id*., B-105).

Thus, historical impacts and FSEIS's plan for extensive mechanical and chemical disturbance of the aquifer *prior* to collecting baseline water-quality samples demonstrates a lack of statistical and scientific rigor; replaced with actions that bias baseline values to high concentrations. NRC Staff's permissive allowance in the FSEIS for the meaningful baseline (i.e., the restoration mark) to be set after NEPA and licensing processes have concluded is outside the accepted industry and regulatory protocols for establishing baseline water quality. (*see also* 10 CFR 40 Appendix A Criterion 7 – "At least one full year prior to any major site construction, a preoperational monitoring program must be conducted to provide complete baseline data on a milling site and its environs.").

<u>Baseline Groundwater Can Be Accurately Portrayed</u>

Q. 33. Please describe how Strata and the NRC might develop a valid scientific and statistical method to establish baseline prior to licensing and for a NEPA review?

A. 33. In my expert judgment, presenting a scientifically and statistically valid baseline can be done, but it has not been done thus far for this project. To present such a scientifically defensible baseline, Strata must lay out a systematic grid of the proposed project area, and select at random points in that grid to locate baseline wells. Existing water-quality data from Strata's six regional wells can be used to estimate the approximate standard deviation of the population (which must be done for each quarter to evaluate temporal trends), and this methodology can be used to estimate the number of wells needed to reach the stated statistical confidence for obtaining a representative number of samples from the regional project area aquifer. Such an industry-standard, statistical sampling approach (easily executed using the JTI013, Visual Sampling Plan software, http://vsp.pnnl.gov), with a stated level of decision confidence, is the only valid scientific method available to Strata if they wish to conclude that the water quality in the ore zone does not meet the EPA drinking-water MCLs for uranium and radium-226. Indeed, NRC guidance is to place one baseline well in every four acres (JTI007, NRC 2003; Standard Review Plan for In Situ Leach Uranium Extraction License Application, p.5-39; http://www.nrc.gov/reading-rm/doc-collections/nuregs/staff/sr1569/sr1569.pdf), but Interveners are not suggesting that 312 wells (1,248 acres proposed for ISL well fields divided by four)are strictly necessary to obtain representative water samples. Fewer locations can be achieved with good statistical design, but no such effort has been made or suggested by the NRC Staff. In any event, a systematic grid and well-designed statistical sampling plan is necessary.

Q. 34. With all of the above in mind, how might Strata and NRC have gone about presenting a valid and statistically defensible baseline for the affected groundwater aquifer?

A. 34. A valid and statistically defensible baseline can be produced. I first provided an example (using VSP software) and subsequent explanation of how this sampling might look more than one year ago (Abitz 2013) and now reproduce it here.

	2010 Uranium Results (mg/L)			
	1st Q	2nd Q	3rd Q	4th Q
22-18OZ	0.070	0.033	0.069	0.033
14-18OZ	0.096	0.109	0.109	0.085
21-19OZ	0.017	0.008	0.024	0.005
34-7OZ	0.041	0.038	0.044	0.028
34-18OZ	0.062	0.059	0.046	0.041
42-19OZ	0.011	0.010	0.010	0.009
Median	0.052	0.036	0.045	0.031
Mean	0.050	0.043	0.050	0.034
Std dev	0.033	0.038	0.035	0.029
SW test statistic 95% conf	0.952	0.883	0.948	0.892
SW critical value 95% conf	0.788	0.788	0.788	0.788
95% LCL mean	0.023	0.012	0.021	0.010
95% UCL mean	0.076	0.074	0.080	0.057
t stat	1.46	0.837	1.42	0.298
t critical value 90% conf	1.48	1.48	1.48	1.48
Conclusion	accept null hypothesis because t stat < t crit value			
Null hypothesis	regional groundwater < 0.03 mg/L			
Type I error (alpha)	0.1; 90% confident we will accept null hypothesis when it is true			
gray area	0.005 above uranium MCL (0.035 mg/L)			
Type II error (beta)	0.5; 50% chance to accept null hypothesis if the true mean is 0.035			

	mg/L			
Sample Requirements	73	96	82	57
Null hypothesis	regional groundwater < 0.03 mg/L			
Type I error (alpha)	0.1; 90% confident we will accept null hypothesis when it is true			
gray area	0.01 above uranium MCL (0.04 mg/L)			
Type II error (beta)	0.5; 50% chance to accept null hypothesis if the true mean is 0.04 mg/L			
Sample Requirements	19	25	21	15
Null hypothesis	regional groundwater < 0.03 mg/L			
Type I error (alpha)	0.1; 90% confident we will accept null hypothesis when it is true			
gray area	0.01 above uranium MCL (0.04 mg/L)			
Type II error (beta)	0.2; 20% chance to accept null hypothesis if the true mean is 0.04 mg/L			
Sample Requirements	50	66	57	39

Q. 35. Can you please explain the statistical summary you have just presented?

A. 35. The statistical summary in the above table demonstrates that the six regional monitor wells developed by Strata are an insufficient number of wells to draw a meaningful conclusion, with a stated level of confidence (90% in this example), that uranium exceeds the EPA MCL in the OZ aquifer. To explain the statistics in lay terms is complicated so I'll briefly summarize what I conclude. It is my estimation the true uranium mean of the regional aquifer could be below 0.03 mg/L. A valid statistical analysis like the above indicates a minimum of 15 and maximum of 96 locations would be needed to test the alternative hypothesis that the true uranium mean is above the EPA MCL.

Q. 36. Why is presenting such a statistically defensible and meaningful baseline water quality assessment so important?

A. 36. On the most fundamental level, using a sound statistical approach to establish baseline water quality maintains scientific integrity in the process and ensures vital groundwater resources are protected. Only through a rigorous statistical approach, applied to groundwater samples collected from random wells installed and developed properly, prior to extensive disturbance of the aquifer by exploration drilling, can a valid baseline be established to serve as the true reference point to compare subsequent post-disturbance water-quality results. Thus, the statistical analysis is necessary for the NRC, in a final EIS, to evaluate the actual baseline conditions in the area in an objective scientific manner, and to then disclose the extent to which SEI's operations are likely to degrade water quality conditions above the true baseline values. Again, to the extent that the NRC Staff allows inappropriate well installation and development protocols and sampling methods to portray the FSEIS 'baseline' as degraded far below actual conditions, the FSEIS's conclusion that the site's post-restoration status will approach 'baseline' conditions is inaccurate and misleading; and the FSEIS thereby fails to disclose the impacts the Ross Project will have on the environment.

Second, best-practice industry standards must be followed to protect human health and the environment. By concluding that the groundwater at the Ross site is contaminated after collecting samples from wells that were improperly located, installed and developed, and applying improper statistical methods to the results, SEI – and Staff in the FSEIS – has engaged in an approach analogous to the false conclusion that one would pull a black marble out of a jar of green and black marbles every time when that jar is filled with 990 green marbles and 10 black marbles.

Let me explain this concept. SEI and Staff understand probability, and know thousands of exploratory borings must be placed on systematic grids to locate ore deposits that form a tiny fraction of a percent of the total volume of the rock in the aquifer. Given this understanding, they know that the approach taken in the FSEIS will bias the baseline to high values by sampling after the ore zone in the aquifer has been disturbed and oxidized by the drilling of thousands of exploration boreholes and monitoring, injection and extraction wells. In brief, SEI (with Staff approval in the FSEIS) is allowed to replace green marbles with black marbles before they sample the jar to increase the probability that it will pull out a black marble.

V. Contention 3 – The FSEIS fails to include adequate hydrological information to demonstrate SEI's ability to contain groundwater fluid migration.

Q. 37. In your expert opinion, have SEI or NRC Staff in the ER, the DSEIS, or the FSEIS presented adequate hydrological information to demonstrate SEI's ability to contain groundwater fluid migration?

A. 37. No. I have several areas of significant concern. First, I have fundamental disagreements with the NRC over how they interpret basic geochemical interactions that will take place in the subsurface when efforts to establish baseline are commenced and, more important, when mining commences. Second, the FSEIS fails to account for the potential for contaminant excursions.

Third, the FSEIS fails to provide a sufficient analysis of the potential for and impacts associated with fluid migration and communication between aquifer units. I will explain each of these concerns in detail below.

<u>The Failure to Analyze Subsurface Geochemistry and Account for Excursions.</u>

Q. 38. Can you explain your conclusion that the NRC has failed to analyze something as fundamental to fluid migration as the basic subsurface geochemistry?

A. 38. As I noted above, the NRC has failed to analyze and consider the improper methods used to calculate baseline values (anthropogenic oxidation of the ore zone during exploration and well installation) and the historic record on excursions at ISL sites.

This is demonstrated in the FEIS at p.4-41, "*As described in Section 2.1.1.2 of this SEIS, chloride, conductivity, and total alkalinity would be measured twice monthly in the monitoring wells to detect excursions. These constituents move through the aquifer faster than other water-quality parameters, and therefore levels above these would indicate excursions before radionuclides and other elements move outside the production (i.e., uranium-recovery) zone.*" (SEI009A). On this basis the FSEIS provides that uranium will not be included as an excursion parameter, and thus the detection equipment will not be measuring whether uranium is leaking from the aquifer. FSEIS 4-41; FSEIS Section 2.1.1.2 (discussing approach to selecting excursion parameters, which will not include uranium).

The quoted statement from page 4-41 above is inaccurate and presents an oversimplification of the dominant geochemical mechanisms which dictate subsurface transport of soluble uranium (i.e., uranium in the plus-six oxidation state, or U(VI)). Without the presence of carbonate anions, U(VI) as the uranyl ion (UO_2^{+2}) is readily adsorbed to the surfaces of various iron oxides and clays. However, with the introduction of an oxidizing, carbonate-rich lixiviant to enhance U(VI) solubility and mobility in the aquifer, uranium adsorption to iron oxide surfaces decreases, as relatively non-reactive uranyl-carbonate complexes ($UO_2(CO_3)_2^{-2}$ and $UO_2(CO_3)_3^{-4}$) form in solution (Curtis et al. 2006, p. 1; JTI022; JTI023; ExxonMobil, 2010, p. 41;; JTI024, Zhou and Gu, 2005, p. 1). Thus, the aqueous uranium-carbonate species formed from lixiviant injection during ISL operations will be highly mobile in the groundwater. As a result the FSEIS is inaccurate in concluding that other contaminants will serve as more accurate excursion parameters than uranium itself. Rather, since the uranium-carbonate will be highly mobile in groundwater, the environmental analysis should take account of such a fact, which it does not.

Q. 39. But why is it so important for uranium to be used an excursion parameter? Does it relate to the "mobility" of uranium in the aquifer?

A. 39. As noted in the FSEIS citation above, SEI and the NRC Staff believe chloride, alkalinity and TDS are adequate indicators of lixiviant mobility in the aquifer. However, SEI and the NRC Staff know that the oxygen- and carbonate-rich lixiviant increase the concentration and mobility of uranium in the aquifer. Therefore, the debate is not over the mobility of uranium but whether uranium should be included as one of the excursion indicators. The analysis below demonstrates that the answer is unequivocally yes, and thus by not including it the FSEIS skews the analysis and likelihood for detected excursions in a manner that fundamentally undermines the conclusions about the environmental impacts of the project on groundwater quality.

U(VI) subsurface modeling has reported that adsorption of uranium in the subsurface is highly complex and varies spatially and temporally (Curtis et al. 2006, JTI022 at p. 41). Outside of reporting water-quality parameters and the slight mention of uranium minerals and pyrite in the fluvial deposits, the FSEIS presents very little about the current subsurface geochemical zonation and, more importantly, is silent on the extent to which mining activities will destroy the reducing geochemical conditions in the exempted aquifer. For example, the FSEIS is silent on the total reductive capacity of the aquifer and fails to estimate the reductive capacity of the aquifer and compare it to the expected amount of oxygen that will be injected into the aquifer to destroy the reducing conditions. This is a fundamental oxygen-balance analysis that would indicate whether sufficient reducing capability remains in the exempted aquifer after restoration to remove U(VI) carbonate species from solution by reductive precipitation to insoluble U(IV). Without this analysis, there is no logical basis to omit uranium as an excursion indicator, as the levels of uranium in the lixiviant are generally three to four orders of magnitude greater than true baseline; and increases in chloride, alkalinity and TDS in the aquifer will be less than one or two orders of magnitude.

Even without the oxygen-balance analysis the NRC Staff should have required that SEI include uranium as an excursion parameter. Many publications (Staub et al., 1986 at p. 123, NRC020; Uranium One, 2010, NRC040; WDEQ, 2011 at p. 4, NRC039 have shown that excursions occur at all ISL sites and uranium does migrate past the monitoring-well ring. These documents summarize cases where monitoring wells go on excursion status for periods of months to years, and operators could not decrease elevated parameters by adjusting pumping rates. At the Bison Basin ISL mine, they observed "*significant increases*" in sodium, sulfate, uranium, and conductivity when the M-2 monitoring well went on excursion status, February 4, 1981 (Staub et al. 1986, NRC020 at A-57). In certain cases, uranium concentrations in monitoring wells were measured as high as 5.5 mg/L (WDEQ, 2011, NRC039, at p. 2). Other horizontal excursions had little or no hydraulic explanation for observed uranium concentrations at a monitoring well; uranium ranged from 1.8 – 2.7 mg/L (Uranium One, 2010, NRC040 at p. 7 of the PDF). I have also presented the uranium excursion evidence for the Kingville Dome site, where ISL excursions transported uranium beyond the monitor-well ring and impacted a residential well outside the monitor-well ring. Finally, the USGS has studied and modeled U(VI) transport processes specifically to assist the NRC Staff with the evaluation of uranium subsurface transport at ISL sites (Davis and Curtis 2007, JTI025 at Sections 6, 7 and 8).

Q. 40. Do you have any other concerns regarding the FSEIS approach to this issue?

A. 40. Yes. The FSEIS is vague and contradictory (SEI009A, FSEIS; p. 4-41) when it states: "*Temporary increases in concentrations of TDS outside the production zone would occur in the event of an excursion. <u>Levels of radionuclides and elements such as arsenic, selenium, and vanadium that are mobilized with the uranium may increase in aquifers outside the production zone if excursions were to occur</u>, but corrective actions in response to increased TDS would likely prevent increases of these elements.*"

First, the NRC acknowledges that uranium and other metals will migrate during excursions, which agrees with our previous statements and examples provided in this proceeding and with numerous observations from other sites (Staub et al. 1986, NRC020 at A-26, A-58, A-81, A-115, A-192, and A-216; Uranium One, 2010, NRC040; WDEQ, 2011, NRC039).

Second, we assume NRC Staff is alluding to the corrective action of changing pumping rates to recapture the lixiviant plume defined by increased TDS. However, the proposed corrective actions do not have a credible scientific basis because the FSEIS fails to address the needed detailed analysis on the hydrological properties in the exempted aquifer, redox conditions in the aquifer, the availability of various complexing anions, microbial community structure, and structural heterogeneity of the fluvial deposits.

I am left to conclude that the NRC Staff's assertion that uranium is a poor indicator of transport during ISL operations demonstrates a failure to understand the changing geochemical subsurface environment when lixiviant is injected and a less than careful manner toward both the historic record of ISL excursions and recent research on geochemical and hydrological data one can assess to establish a sound scientific basis to predict contaminant transport. The result is that by not utilizing uranium as an excursion parameter the FSEIS skews the environmental impact analysis, failing to disclose information vital to the agency and the public that must be disclosed and confronted before the licensing decision is made.

Fluid Migration And Communication Between Aquifer Units Resulting from Improperly Abandoned Exploration Wells

Q. 41. Has the NRC, in its FSEIS, sufficiently analyzed the potential for and impacts associated with fluid migration and communication between aquifer units?

A. 41. No. The FSEIS notes that there are thousands of abandoned wells, but it does not disclose any total amount beyond information SEI has relayed to the agency. Indeed, the FSEIS discloses that hydrologic connection between the OZ aquifer and DM aquifer exists "*due to improperly plugged previous exploration drillholes that have not yet been properly abandoned*." (DSEIS at 4-35; FSEIS at 4-34. SEI009A).

Additionally, the FSEIS does not consider the water quality impacts of these wells in relation to the Ross Project because NRC says groundwater impacts would be "*minimized by the*

Applicant locating the drillholes within the wellfields beneath the Proposed Action as well as plugging and abandoning them." (NRC006,A DSEIS at 4-36; FSEIS at 4-30, SEI009A).

In short, both the DSEIS and now the FSEIS simply assume the feasibility of locating and plugging these thousands of drillholes and relies on the applicant to correctly perform these actions; stating that, "*[t]o prevent communication between aquifers during uranium-recovery operation, the Applicant proposes to actively locate and plug all exploration drillholes prior to beginning wellfield operations.*" (DSEIS at 3-38, NRC006A).[2] "…*the applicant will attempt to locate and properly abandon all historical drillholes located within the ring of perimeter-monitoring wells in each wellfield*…" (FSEIS at 3-37, SEI009A).

The NRC Staff states in the FSEIS (p. 2-48, SEI009A) that, of the 1682 abandoned holes from Nubeth operations, the applicant had located 759 and plugged 55 wells. This was the exact number of wells presented in the DSEIS (p. 2-44, NRC006A); indicating from October 2010 to the FSEIS publication (February 2014), the applicant had not properly plugged a single abandoned exploratory wellhole. As the NRC is asking only for an 'attempt' by the applicant to locate and plug the holes, there is absolutely no assurance that any further boreholes will be plugged and abandoned. Old exploratory wells are very difficult to locate, let alone properly plug and abandon, because records of their precise location may be missing and the uncased holes tend to collapse and fill in overtime. It is highly unlikely that SEI's commitment will be little more than a promise left unfulfilled.

[2] However, "As of October 2010, the Applicant has located 759 of the 1682 holes thought to exist from Nubeth exploration activity and has plugged 55 of them." DSEIS at 2-44. These numbers were the same in the FSEIS (p. 2-48).

The fact that the applicant has plugged roughly 3.3% (55/1682) of what they now report to be the known historical exploration boreholes in the permit boundary (96.7% of the known boreholes in the permit boundary have <u>not been properly sealed</u>), indicates that they may never be filled because unconsolidated sediments on the surface tend to collapse and fill in the old boreholes and there may be no accurate records available to locate the original borehole. This type of event has been a recurrent problem for ISL sites, regardless of whether or not there have been license conditions requiring the proper filling of old boreholes or proper treatment of boreholes from the current operation. As an example, in March 2007, the Texas Railroad Commission described its Notice of Violation to Uranium Energy Corporation: "[t]he Permittee failed to complete surface plugging and drill site reclamation as specific in Section IV of as specified in Section IV of Uranium Exploration Permit No. 123. Specifically, the permittee failed to segregate and replace topsoil, and/or properly install a cement surface plug, and/or allow pits to dry before backfilling and/or compact backfilled materials and topsoil above grade in the reclaimed mud pits to compensate for settling, and/or mark the exact location of each borehole." (JTI026 at p. 8). Note also in the same Notice of Violoation (NOV) the comments of the Texas regulator, citing difficulty with locating the majority of the boreholes even though significant efforts were taken to identify them. *Id*. at 3.

Indeed, the scope of the problem could actually be much worse than is disclosed in the FSEIS. The 1,682 figure in the FSEIS contrasts with the over 2,000 exploration boreholes drilled in the area identified at the ER stage of this proceeding (SEI005B at 5-35). Whether the figure is more than 2,000 or 1,682 there should be a full accounting of all improperly abandoned boreholes in the FSEIS; and the FSEIS must also present a clear discussion of the time table and requirements to locate, plug and abandon the boreholes before any wellfield is developed.

Alternatively, the FSEIS could have (and should have, given its discussion of plans for these abandoned boreholes) disclosed that in light of the likelihood that these wells will not all be located and filled, there are significant risks of excursions, and disclosed the environmental impacts posed therefrom. What Staff cannot do – but did in the FSEIS – is discount those environmental impacts altogether by inappropriately *assuming* these wellholes will be filled.

Q. 42. Why is failure to fully account for all of the improperly abandoned boreholes a problem?

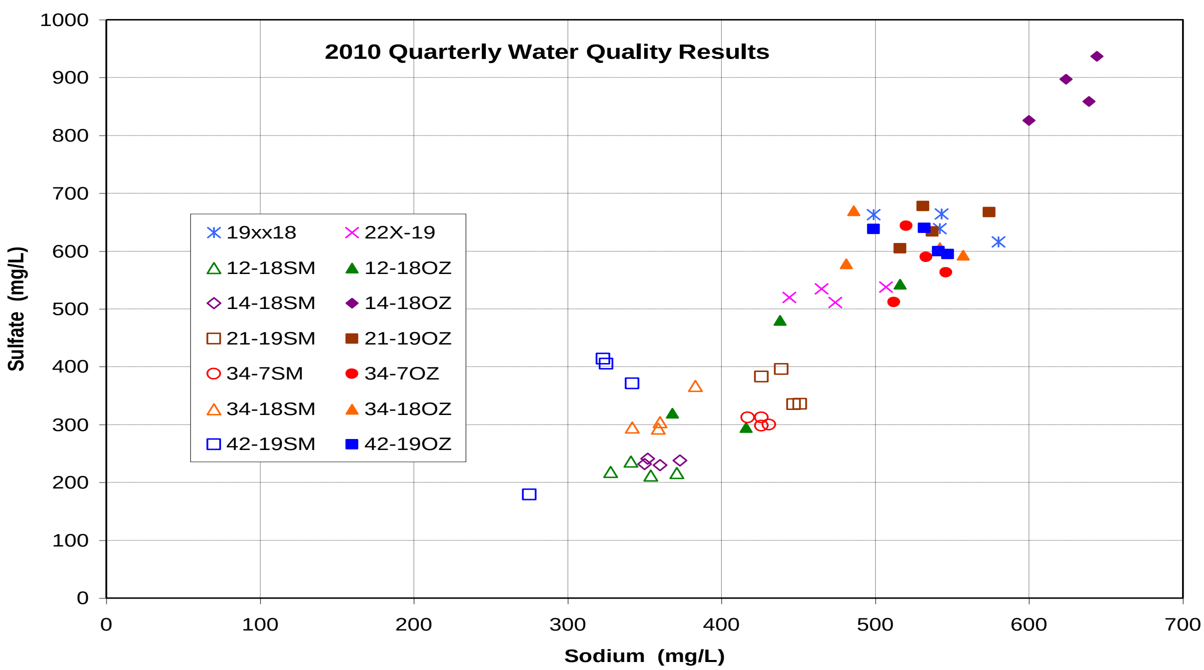
A. 42. It's a problem that the NRC acknowledges, even though they have yet to analyze the potential impacts in any meaningful way. The historical records at ISL sites indicate nearly all vertical excursions in the overlying aquifer were "*directly related to the intensity of drilling activities*" (NRC020 at p. 30, Staub et al. 1986). That is, thinning of the fluvial confining unit, unidentified malfunctioning of equipment, or unsealed bore-holes into the ore zone aquifer have largely been responsible for vertical excursion into overlying ore bodies. The NRC Staff agrees and states, "*Vertical excursions tend to be more difficult to recover than horizontal excursions, and in a few cases, remained on excursion status for as long as eight years. The vertical excursions were traced to thinning of the confining geologic unit below the ore zone and improperly abandoned drillholes from earlier exploration activities*." (SEI009A, FSEIS, p. 4-37, emphasis supplied). Control, prevention, and remediation of vertical excursions were largely unsuccessful at previous ISL sites in the United States (NRC020 at p. 29, Staub et al. 1986). In other words, when a vertical excursion occurs in the SM aquifer, the applicant will have limited options to correct the excursion.

Q. 43. Could you explain why you think the pump tests performed by SEI, and relied upon by NRC in the FSEIS, provided insufficient hydrological information to demonstrate satisfactory groundwater control during planned high-yield industrial well operations?

A. 43. In my expert opinion, neither the number of wells tested for hydrological parameters nor the short duration of the pump tests run to date establish adequate hydrological information to demonstrate control of groundwater over 1,866 acres of complex fluvial stratigraphy, as depicted in the geological cross sections in Addendum 2.6-C of the Strata Technical Report. Strata constructed and developed six monitor-well clusters within the project boundary and performed 24-hour pump tests on four of these wells in July 2010 (12-18OZ, 21-19OZ, 34-7OZ, 42-19OZ; Strata 2011b, Addendum 2.7-J, SEI006D). The FSEIS does not at all address any of the significant data gaps in the conceptual and numerical hydrologic models put forward to support Strata's license application. This silence is inappropriate because the FSEIS does note that horizontal and vertical excursions of mining fluids occur at all ISL operations, and the vertical excursions were traced to thinning of the confining layer in the complex fluvial stratigraphy and improperly abandoned exploration bore holes (SEI009A, FSEIS; p. 4-37).

Q. 44. What are the consequences of NRC's failure to properly assess hydrologic control in the FSEIS?

A. 44. Demonstration of adequate hydrologic control is not a trivial matter because groundwater communication between the SM and OZ horizons is evident in the 24-hour pump test data from well 12-18OZ and the water-quality results for sodium and sulfate (see my figure below, constructed from data in Appendix C of the FSEIS (SEI009A). Groundwater from the ore horizon (OZ; solid symbols) generally has higher sodium and sulfate, relative to the overlying groundwater (SM). However, mixing of the groundwater from these two horizons is clearly indicated by the linear trace of the sodium and sulfate trend on Figure 2. In my expert opinion, this is unquestionably demonstrated by the mid-location of plotted samples from 22X-19, a well that is screened through the OZ and SM zones (SEI006A, Section 2.7.3.3.1, p.2-169, Strata TR). If 14-18OZ is taken as the unmixed groundwater from the ore horizon, all other OZ samples are shown to have a component of SM water, as they lie between 14-18OZ and 22x-19. Note that the strong mixing between the horizons is unequivocal for samples from 12-18OZ, which plot with the samples from 22x-19 and the SM horizon.



Q. 45. **In addition to showing mixing between the OZ and SM aquifers, what does the above figure indicate with respect to vertical excursions when lixiviant is injected in the OZ aquifer?**

A. 45. The above figure illustrates that the closer a pair of samples plots for a given cluster well (e.g., 12-18SM and 12-18OZ), the higher the probability for groundwater contamination by communication between the two groundwater zones during ISL operations. In contrast to mixing between the 12-18 horizons, 14-18SM and 14-18OZ samples cluster tightly and are well separated on the plot. An explanation for the distinct separation of the 14-18 horizons on the sodium-sulfate plot may be that the density of exploration boreholes is lower around this cluster well and less communication between the SM and OZ horizons has occurred (*i.e.*, 14-18 may provide a snapshot of the distinct major-ion chemistry of the horizons prior to the drilling of thousands of exploration boreholes).

Additionally, it is also known that 22x-19 is screened through the SM and OZ zones, and the FSEIS presents no detailed engineering analysis to show the effect of the industrial well operation on the ISR operations. The complexity of the stratigraphy coupled with thousands of unplugged boreholes, established mixing between the SM and OZ zones, and the operation of the high-yield industrial wells requires many more test wells over the 1,866 acres and much longer pump test intervals to obtain the needed hydrologic data to assess the control of mining fluids during ISL operations. The FSEIS is silent on these complexities and provides no convincing hydrologic data to support Strata's contention that mining fluids will be controlled to prevent groundwater pollution.

Q. 46. Is this type of analysis supported by information in the historical record?

A. 46. Yes. The above analysis is supported by the discussion and figure from (Staub et al.1986; NRC020 at p. 24), which provides evidence for alternative interpretations to aquifer tests and the complexities in adequately defining aquifer confinement:

> "*Conventional exploration methods as describe above seldom provide enough detail to determine whether an ore zone aquifer is sufficiently isolated from other aquifers. The complex stratigraphy of alluvial sediments is a serious obstacle to projection of lithologic units between boreholes even at short distances. Figure 2.8 [original document; see below] presents several interpretations of the same data. In the absence of proof of the contrary, stratigraphic units are often projected as continuous layers between boreholes which may lead to a false sense of security with respect to aquifer isolation. Furthermore, two-dimensional cross-sections do not necessarily portray accurate relationships between aquifers in three dimensions. Thus, an aquitard may be continuous in one direction and discontinuous in another*." (Staub et al. 1986) (page 24).

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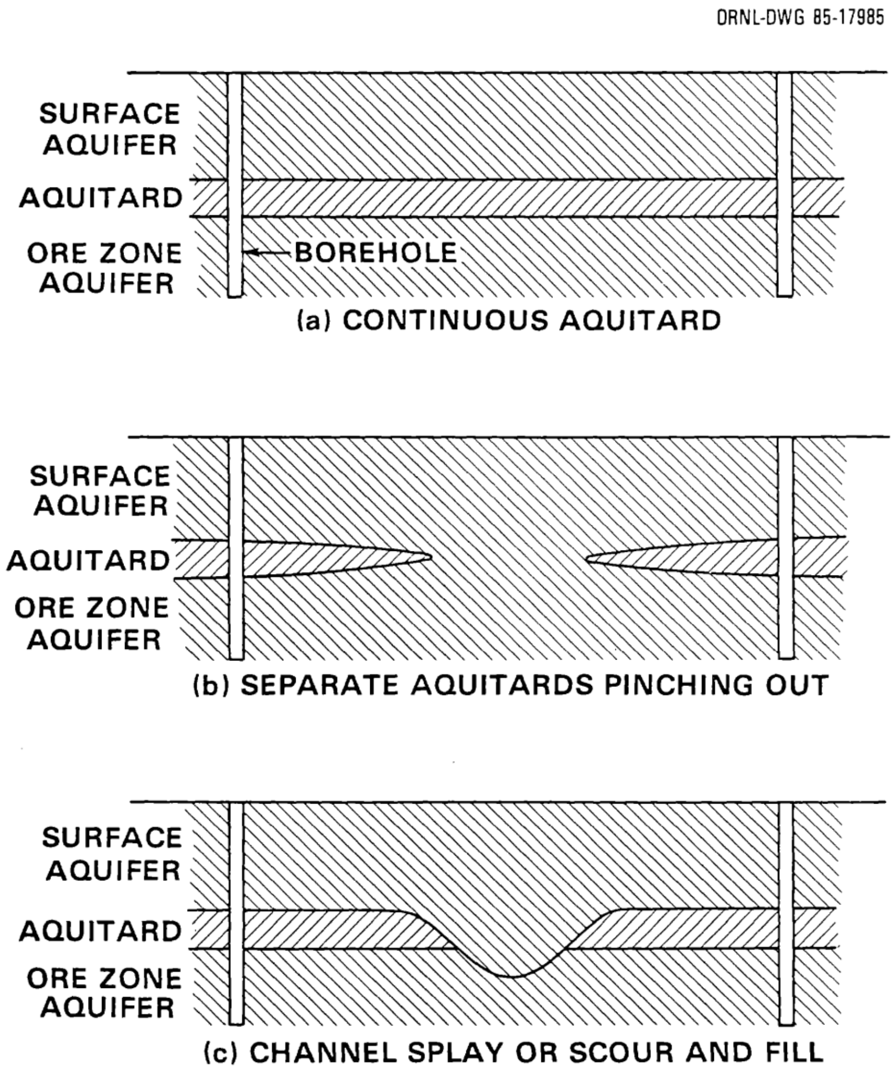

Fig. 2.8. Alternate interpretations of the same borehole data.

Conclusion

Q. 47. Given your concerns with this specific project, why does properly establishing baseline groundwater quality and including adequate hydrological information to

demonstrate SEI's ability to contain groundwater fluid migration matter so much in the American West?

A. 47. The United States Geological Survey's (USGS) publication *Groundwater Depletion in the United States (1900 – 2008)* (JTI027, http://pubs.usgs.gov/sir/2013/5079/SIR2013-5079.pdf) brings attention to the importance of groundwater as drinking water to western communities and, to a lesser extent, the support of agriculture and industry. The conclusions reached in this report are worth noting:

> "This large volume of depletion represents a serious problem in the United States because much of this storage loss cannot be easily or quickly recovered and affects the sustainability of some critical water supplies and base flow to streams, among other effects……In addition to widely recognized adverse environmental effects of groundwater depletion, the depletion also impacts communities dependent on groundwater resources in that the continuation of depletion at observed rates makes the water supply unsustainable in the long term." *Id*. at 50.

In a response to a request from the U.S House of Representatives Subcommittee on Interior Appropriations, the USGS (1998) issued their report to Congress on *Strategic Directions for the U.S Geological Survey Ground-Water Resources Program* (*http://water.usgs.gov/ogw/gwrp/stratdir/*,. JTI028). This report identifies groundwater as one of most important resources in the United States and indicates 57 percent of Wyoming residents rely on groundwater for their drinking supply. *Id*. at 1.

Use of groundwater for drinking water is the highest priority for western states and its protection must be part of any credible sustainability policy. Agriculture and industry interests must be minimized and set aside to ensure adequate drinking water for future generations. The proper scientific analyses must be made to determine those groundwater resources that are unfit for human consumption and industry markets should be carefully scrutinized to determine if the use of groundwater by the industry truly benefits the State and Nation. In the case of the uranium ISL industry and with respect to the environmental analysis of this project in particular, there has yet to be transparent examination of the purported benefits to the State of Wyoming and the United States by the extraction of uranium when that extraction inevitably degrades that scarce source of Western groundwater. Such benefits and harms would also need to be analyzed with a firm understanding of whether uranium produced in the United States would have an appreciable difference on the world uranium market. I am not persuaded domestic sources would make any difference, but that analysis is missing from the review of this project entirely.

Q.48. Does this conclude your testimony.

A. 48. Yes.

I, Dr. Richard J. Abitz, do hereby declare under penalty of perjury that my statements in the foregoing testimony and my statement of professional qualifications are true and correct to the best of my knowledge and belief.

Executed in Accord with 10 C.F.R. § 2.304(d).

/(electronic signature approved)/
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