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)	)	

JOINT THIRD DECLARATION OF DR. RICHARD ABITZ AND FIRST DECLARATION OF DR. LANCE LARSON ON BEHALF OF THE NATURAL RESOURCES DEFENSE COUNCIL & POWDER RIVER BASIN RESOURCE COUNCIL

I. INTRODUCTION

We, Dr. Richard Abitz and Dr. Lance Larson, declare the following statements are true and correct to the best of our knowledge.

1. I, Dr. Abitz, previously submitted a declaration in support of Petitioners' motion to intervene and contentions in this proceeding, and that original declaration explains my background and experience relevant to this proceeding. *See* Oct. 23, 2011 and May 2013 Declarations of Dr. Richard Abitz ¶¶ 1-3.
2. I, Dr. Lance Larson, am submitting my first declaration in this proceeding in support of Petitioners' contentions. Attachment A to this exhibit explains my background and experience relevant to this proceeding.
3. The Natural Resources Defense Council has contracted Dr. Abitz's services to supply technical analysis and comments on both Strata the Energy's Ross Project *In Situ* Uranium Recovery[1] License Application before the Nuclear Regulatory Commission (NRC) and on the NRC's Final

[1] *In situ* recovery ("ISR") is also commonly referred to as *in situ* leaching ("ISL"). For the purposes of this declaration, the two phrases are used interchangeably.

Supplemental Environmental Impact Statement (FSEIS) for the Ross Project. Dr. Larson is a Science Fellow at NRDC.

4. Our expert opinions and comments in this declaration are based both on our professional experience and on our independent and combined review of relevant portions of the NRC's FSEIS, Draft Supplemental Environmental Impact Statement (DSEIS), Strata's application, and other documents listed in the References Cited section of this declaration.

5. Our declaration focuses on the technical issues at the foundation of each of Petitioners' admitted contentions in this proceeding. We begin with the overarching observation that in terms of technical presentation and analysis, there are few meaningful differences between Strata's ER, the Staff's DSEIS, and now the FSEIS with respect to the Petitioners' admitted contentions. And what few differences exist are not substantial in this latest iteration of the EIS and do not alter the nature of the dispute between the parties as they relate to the admitted contentions pertaining to baseline water quality, analysis of the environmental impacts of alternative concentration limits, fluid migration, or cumulative impacts.

6. Included in our initial assessment of the lack of substantive difference between the DSEIS and the FSEIS is a review of Strata's Responses to NRC Staff's Requests for Additional Information submitted since the admission of the four contentions and reference to the Declarations submitted by Drs. Moran and Sass.

7. This declaration provides the factual and analytical basis underpinning our identification of the following deficiencies in the FSEIS: (1) It fails to present any empirical characterization of the pre-mining baseline water quality values that will be used to (a) assess the impacts of *in situ* leach uranium mining on the portion of the ore zone aquifer exempted from Safe Drinking Water Act requirements; (b) detect horizontal and vertical migration of lixiviant ("excursions")

outside the exempted portion of the mined aquifer; and (c) establish binding and achievable water-quality values for aquifer restoration. (2) The FSEIS fails to present a consistent and credible sampling methodology to develop water quality values that Strata will employ for the sole purpose of defining, for NEPA documentation purposes, the “Affected Environment” that will be altered as a consequence of the NRC’s proposed licensing action. (3) The FSEIS ignores the mobility of uranium in the oxygen-carbonate rich lixiviant and fails to (a) include uranium with the proposed excursion parameters alkalinity, chloride and conductivity; and (b) propose valid sampling and statistical protocols to establish upper control limits for reporting excursions. (4) The cumulative-impact analysis for groundwater is incomplete in the FSEIS; as it fails to include resource loses in the ore zone, the overlying and underlying aquifers, and the Ross Project expansion into the entire Lance District.

Contention 1 – Baseline Water Quality

NRC’s FSEIS Provides No Description of a Current Baseline

8. The NRC’s FSEIS does not address the Intervenors’ contentions regarding the failure of Strata to establish baseline conditions using proper scientific and statistical protocols. As a technical matter, we find it disconcerting that the term ‘baseline’, as used in the Ross DSEIS has been <u>systematically removed</u> and replaced with the phrase “post-licensing, pre-operational” in the Ross FSEIS, thereby introducing regulatory confusion:

    a. The DEIS stated: “*As part of site-characterization efforts, ground-water monitoring wells are installed and ground-water samples are obtained. These samples are analyzed for certain water-quality constituents, or parameters, that are important to the characterization of existing conditions at a particular site. These concentrations*

are known as the "pre-licensing baseline" values of the respective water-quality constituents."

DSEIS at 2-24

b. However, the FEIS states: "*After the NRC has issued a license to an applicant, the licensee begins construction of its facility as well as installation of its uranium-recovery wellfields. A single wellfield consists of many ground-water wells; when all of these wells have been installed; water-quality samples are obtained 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 this SEIS, "post-licensing, pre-operational." These post-licensing, pre-operational data, after some statistical analysis, are the values to which excursion-detection and/or aquifer-restoration monitoring are compared.*"

FSEIS at 2-25

9. The NRC's four previous FSEIS documents for ISR operations (Moore Ranch, Nichols, Lost Creek, Dewey-Burdock) did not introduce this confusion. Allowing an applicant to establish baseline concentrations after a license is issued and after all wells are placed in a well field ignores the regulatory intent of the word baseline and provides inadequate representation of the water quality in the ore zone and overlying and underlying aquifers. As explained below, inherent biases are introduced into the project's post-license, pre-operational 'baseline' values to establish higher concentrations of contaminants relative to a proper scientific and statistical baseline obtained before the aquifer is mechanically and chemically disturbed by the

installation and development of hundreds to thousands of injection, extraction and monitoring wells.

10. Terminology aside, the FSEIS carries forward the DSEIS's lack of analysis on the pre-industrial baseline water-quality issue. The FSEIS simply presents a range of values for water quality and lacks a thorough technical discussion on how a valid scientific and statistical representation of "baseline" will be developed for the project. Further, the NRC Staff makes it clear that no "baseline" will be developed from the pre-license initial measurements Strata does take and data obtained from this work have no meaning until *after* the license has been issued. Indeed, the text box on p.2-25 of the FSEIS explicitly states "[these] *post-licensing, pre-operational data, after some statistical analysis, are the values to which excursion-detection and/or aquifer-restoration monitoring are compared.*" Thus, the Intervenors' fundamental concern with establishing a valid scientific and statistical, pre-license baseline remains unchanged through each successive stage of this proceeding.[2]

11. In comparison with RCRA and CERCLA sites, the NRC proposed ISR option to establish the baseline post-licensing; pre-operational is only viable if the baseline is established with samples collected from wells hydraulically up gradient of the disturbed area. That is, when baseline is established at disturbed and contaminated RCRA and CERCLA sites, groundwater wells are placed hydraulically up gradient of the contaminated and disturbed areas to establish clean-up standards in the unaffected media. However, the intent of the NRC language is to allow Strata to establish groundwater baseline within the disturbed zone. This clearly violates all scientific and statistical principles behind the definition of groundwater baseline values and it is in

[2] We use pre-license and pre-industrial in this paragraph and define these terms as such: pre-license implies disturbance from exploration boreholes and previous oil and mining activities. Pre-industrial means natural background conditions, which would be difficult to demonstrate due to the thousands of exploration boreholes and ongoing activities in the oil and mining sectors.

conflict with regulations for establishing baseline at RCRA and CERCLA sites hydraulically up gradient of the disturbed area (40 CFR 264.97).

12. Additionally, Section 120(a)(2) of CERCLA provides that all guidelines, rules, regulations, and criteria for preliminary assessments, site investigations, National Priorities List (NPL; *See* 55 FR 8666-8865 [March 8, 1990]) listing, and remedial actions are applicable to Federal facilities to the same extent as they are applicable to other facilities. It states the following: "No department, agency, or instrumentality of the United States may adopt or utilize any such guidelines, rules, regulations, or criteria which are inconsistent with the guidelines, rules, regulations, and criteria established by the Administrator under this Act." In other words, the NRC has no basis to suggest that post-licensing, pre-operational baseline in a disturbed area meets the intent of regulations directed at establishing proper baseline (e.g., 40 CFR 264.97).

13. Next, we find the FSEIS's conclusion that impacts on groundwater resources are SMALL (p. xxxi), and in the case of the confined aquifers SMALL to MODERATE (FSEIS; p. 4-45 to 4-48) are without basis because: (1) pre-license water-quality data reported in Tables 3-6 and 3-7 of the FSEIS will not be used to set baseline (note that the pre-license baseline data in Tables 3-6 and 3-7 remain biased to high values due to improper well installation, development, and previous ISR mining by Nubeth) and (2) there is no discussion of the proper scientific and statistical methods that must be executed to establish valid baseline values. For example:

- The impact of the use of oxidizing fluids during drilling operations, and the impact of air-lifting during well development - processes which can cause uranium ore to be oxidized during the drilling and development of monitoring wells and therefore alter true baseline water quality values (Paragraph 15 in this declaration; Abitz, 2010; Laaksoharju et al., 2008);

- Statistical requirements for inclusion of a sufficient number of randomly located wells to collect representative groundwater samples from the proposed aquifer exemption zone (VSP 2013) prior to wellfield development;
- Assurance that baseline wells are screened through the entire sand interval of the aquifer horizon, in order to eliminate a high bias towards ground-water contamination when the sample is obtained only from the ore-rich interval of the aquifer horizon; and
- Inclusion of proper statistical analysis and methods to establish valid baseline values (Gilbert, 1987; Matzke et al., 2007; ASTM, 1998; EPA, 1989; 1992a; 1992b; 2009; NRC, 2003);

14. The FSEIS (p. 2-34) carries forward the DSEIS's deficiency (see DSEIS; p. 2-32) that groundwater monitoring to determine baseline values and excursion Upper Control Limits (UCLs), parameters that guide individual wellfield aquifer restoration efforts, will be undertaken only when a given wellfield's construction and testing is complete and a perimeter ring of monitoring wells has been established around the wellfield. In our expert judgment, this scenario raises a consistent set of concerns that Intervenors' lodged originally against the ER. The FSEIS offers no valid scientific or technical rationale for using "post-licensing, pre-operational," rather than "pre-licensing baseline" measurements to establish "baseline" water quality data.

NRC's FSEIS Allows Post-Licensing / Pre-Operational Monitoring to Bias Sample Concentrations Towards Higher Baseline Values.

15. The FSEIS fails to explain how the Applicant and/or the terms of its NRC License will prevent such "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 Applicant and 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 for the Kingsville Dome ISR operations in Texas (TWC 1988; TWC 1990)[3], 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."

16. Another example where previous ISR mine operators failed to set an accurate baseline – and the problems that emerge from that failure – is found in the data reported for the Irigaray Project, Mine Unit 1 (NRC, 2013b). The uranium concentrations for well AP-4 in Mine Unit 1 display clear evidence of extensive mechanical and chemical disturbance of the aquifer prior to establishing the baseline uranium value (Table below paragraph 16). The average uranium 'baseline' concentration at well AP-4 is thermodynamically unfeasible for natural groundwater in contact with uranium ore (uraninite) under reducing conditions (Langmuir 1978); and this conclusion is substantiated by the observation that the 'baseline' value is almost 2.5 times higher than the post-mining concentration.

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[3] 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 (PAA1: uranium = 0.164 mg/L; radium-226 = 22 pCi/L. PAA2: uranium = 1.89 mg/L; radium-226 = 92 pCi/L). Note that baseline was established for these Production Area Authorizations (PAA) with invalid statistical methods, as outlined in paragraph 10 of this declaration. (TWC 1988; TWC 1990)

Well AP-4 – Irigaray, Mine Unit 1 – Uranium (mg/L)

'Baseline' Average	Post-Mining
13.57	4.95

17. Further investigation of operational history at Irigaray demonstrates how the invalid 'baseline' was affected by previous mining and exploratory activities. Research and development activities occurred at the Irigaray site in 1975. Specifically, the 517 site and Well Field A (now Mine Unit 1) began pilot operations in 1975 (Staub et al. 1983; p. A-6). Well Field A was ISR mined using an ammonium bicarbonate lixiviant from 1975 to mid-1976 (Staub et al. 1983; p. A-6). According to the 1978 draft environmental impact statement for commercial operations at Irigaray, baseline sample data for Well Field A were taken "from 11/9/76 to 2/24/77" (NRC, 1978). Therefore, the 'baseline' data used for Well Field A were collected immediately after pilot-scale research and development mining activities. The implications of approving high 'baseline' values in an ISR license are discussed in detail in paragraphs 37-41.

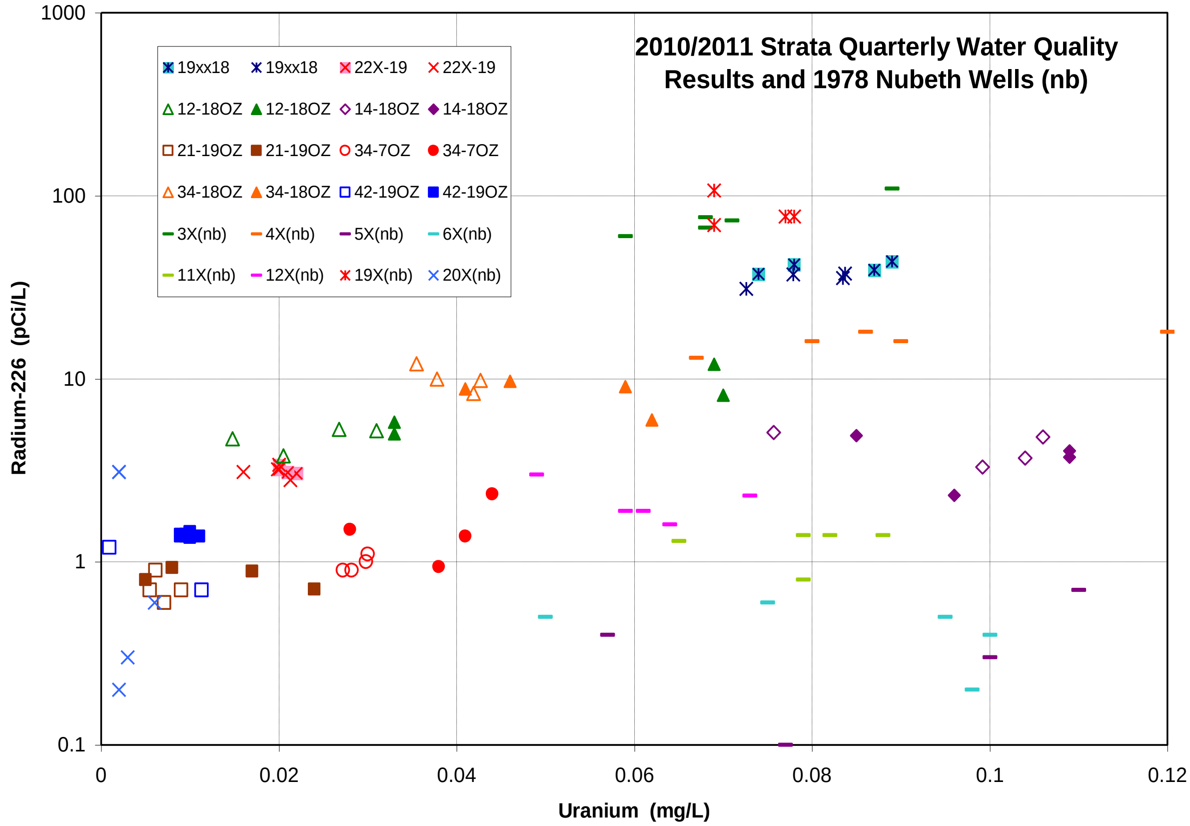
18. The NRC notes that, for each well field in the Ross Project, Strata will re-drill, plug and abandon all open exploration boreholes prior to mining. The plug and abandonment actions will also occur before collecting water-quality samples. Furthermore, the NRC states baseline samples will be collected 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 (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 (FSEIS; B-105). Thus, 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 for this switch from pre-licensing baseline in the DSEIS to post-licensing, pre-operational baseline in the FSEIS is outside the accepted industry and regulatory protocols for establishing baseline water quality. (See paragraph 10, 11; *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.").

19. Pre-operational data are given in Section 3.5.3.3 of the FSEIS (Ground-Water Quality), which references Strata (2011a, 2012) and Nuclear Dynamics (1978) for average concentrations of the major and trace ions (Tables 3.6 and 3.7) for the six monitor-well clusters (SA, SM, OZ, and DM horizons) and for the Nuclear Dynamics data for the 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*." (DEIS at p.3-39, lines 11-12). The late addition of 2011 water-quality data in the FSEIS supports Intervenors' contention that Strata has failed to (and should be required to) establish proper baseline before the aquifer is further disturbed.

20. In Appendix C of the FSEIS, the 2011 data are tabulated and it is disconcerting that the NRC has no comment on the significance of the 2011 results relative to the 2010 values. Plotting the 2011 and 2010 radium-226 and uranium results (below figure) reveals trends that support our conclusions on the 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. The 2011 ore-zone data for Strata's six regional wells (open symbols) 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 by well installation and development activities and it is inaccurate of the NRC Staff to assert that baseline can be developed after hundreds to thousands of wells are drilled in the

well fields (i.e., NRC's definition of post-licensing, pre-operational baseline).



21. Moreover, the FSEIS does not present the scientific basis to support sequential establishment of baseline water quality and excursion UCLs in new well fields after mining has taken place in adjacent well fields. Based on the data presented in paragraph 19 and 20 of this declaration, it is clear that the ore zone is impacted by well installation and development and it is our finding that the NRC is ignoring these scientific data to allow Strata to bias elevated baseline water-quality data as they develop new well fields.

NRC's FSEIS Fails to Account for the Impacts of the Nubeth Site

22. An element of the first contention addressed the lack of pre-industrial (pre-Nubeth) baseline water quality. *See* Moran Decl. ¶¶ 36-41, at 12 of NRDC's and PRBRC's Petition to Intervene (hereinafter "Petition"); Sass Decl. ¶¶ 22-23, Petition at 14. The DSEIS states "*in the case of the Ross Project, because an earlier uranium-recovery operation was conducted within the Ross Project area, this operation could potentially have impacted background values."* DSEIS at 2-24. But later the DSEIS claimed: "*[t]he similarity between the pre-licensing baseline concentrations in the ore zone and aquifer above the ore zone suggests that Nubeth did not alter the baseline water quality.*" (DSEIS; p. 3-42). This problem is carried over to the FSEIS. Moreover, NRC Staff now explicitly maintain in the FSEIS that the Nubeth Project groundwater restoration was successful and complete (FSEIS; p. 2-11 – 2-12). We explore this assertion in the paragraphs that follow.

23. First, we have noted repeatedly, there are no 'pre-industrial baseline' values from Nuclear Dynamics (1978) or Strata (2011a). Pre-industrial baseline values can only be determined if statistically valid, random groundwater samples are collected from wells that are constructed and developed without the addition of oxidizing fluids and air; and collected before the well field is developed. This was not done by Nubeth or Strata. Second, Buswell (1982, p.25) 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). The impact of this test is evident over the area defined by the monitoring wells that were sampled two years after the testing (see figure under paragraph 20). Therefore, the ore was injected with lixiviant *before* baseline water-quality samples were collected and pre-industrial baseline does not exist for the Nubeth pilot-scale

study (see Paragraphs 15 and 16, where invalid baseline was determined in the same manner for the Irigaray Project).

24. The figure under paragraph 20 also shows the impact of the Nubeth 1976 lixiviant injection prior to establishing the Nubeth 'baseline' values two years after lixiviant injection. 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). Other wells used to define the Nubeth 1978 'baseline' (except 20x(nb)), which appears unaffected by the test) have elevated uranium but low radium-226 (see figure under paragraph 20). These wells are impacted by the transport of uranium in a carbonate lixiviant. 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. Despite the fact that the pre-industrial 'baseline' reported by Nuclear Dynamics (1978) is not representative of pre-industrial conditions and is biased to high values, restoration at this test site was unsuccessful (see paragraph 33).

A Valid Scientific and Statistical Method to Establish Baseline Prior to Licensing and For a Draft NEPA Review

25. Another element of the Petitioners' first contention was the failure of the NRC materials license process to provide a scientifically sound sampling regime prior to the issuance of a license and during the course of the public environmental review. (See 2011 Abitz Decl. ¶¶ 16-19 on ER, Petition at 14). As with a number of other elements in dispute, there has been no substantive change between the ER, the DSEIS, and now the FSEIS. As noted in the first Abitz declaration

(2011), in our expert judgment, 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 eliminate 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.[4] Such an industry-standard, statistical sampling approach (Matzke et al., 2007), 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 MCLs for uranium and radium-226.

26. Another element of the Intervenors' first contention is the statistically invalid, biased collection of non-representative groundwater samples from wells screened only through the part of the OZ water horizon that is in contact with the ore zone, rather than the entire column of water in the OZ sand interval. *See* 2011 Abitz Decl. ¶ 22, Petition at 14. Regarding this element, little has changed in the FSEIS on the issue of collecting representative groundwater samples, as screen lengths for the existing six monitor wells in the OZ zone are approximately ¼ to ½ the thickness of the OZ sand (Table 1 in Abitz 2011) and centered on the ore zone. This has 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. We are

[4] NRC guidance is to place one baseline well in every four acres (NRC, 2003; p. 5-39), but Intervenors are not suggesting that 312 wells (1248 acres proposed for ISL well fields divided by 4) 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.

aware that NRC Guidance (NRC, 2003; p. 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, in our expert opinion, the present monitor wells in the OZ horizon do not collect a representative groundwater sample.

27. We provide an example (using VSP software) and subsequent explanation of how this sampling might look (Abitz May 2013 declaration).

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

28. The statistical summary in paragraph 23 indicates that the six regional monitor wells are an insufficient number of wells to conclude, with a stated level of confidence (90% in this example), that uranium exceeds the EPA MCL in the OZ aquifer. To perform this analysis with parametric statistical tests (e.g., student t test), the data must be evaluated with the Shapiro-Wilk (SW) test to determine if the distribution is normal or lognormal (Shapiro and Wilk, 1965; Shapiro et al. 1965). If the data are neither normal nor lognormal, non-parametric test methods must be used. The SW test statistic is greater than the SW critical value, which indicates that the six results for each quarter follow a normal distribution, and the 95% lower control limit (LCL) of the mean is below the EPA MCL, which indicates that the true uranium mean of the regional aquifer could be below 0.03 mg/L. Because the data are normally distributed, the student t test can be used to test the hypothesis (90% confidence level used in this example) that the true uranium mean is less than the EPA MCL (0.03 mg/L). The results of the student t test

show that the t statistic is above the t critical value, and we have to accept the null hypothesis that the true uranium mean for the groundwater in the OZ horizon is less than the EPA MCL of 0.03 mg/L. If Strata believes the true uranium mean in the OZ horizon is above the EPA MCL, they must collect additional random samples and rerun the SW and Student t tests to determine if the null hypothesis can be rejected, which would demonstrate that the true uranium mean is above the EPA MCL. The sample requirements for different Type II errors and contamination scenarios indicate 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.

29. Further, the lack of analysis found in the FSEIS exemplifies the need for a meaningful environmental review of baseline water-quality data prior to any final licensing decisions. For example, 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 (Gilbert, 1987; Matzke et al., 2007; ASTM, 1998; EPA, 1989; 1992a; 1992b; 2009; NRC, 2003). A simple averaging or simply reporting a range of the values from all wells is inappropriate, 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 figure under paragraph 20 clearly shows samples from the six cluster wells do not fall into a single population with respect to uranium and radium-226. 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 available

statistical software (e.g., Visual Sampling Plan, available free from Pacific Northwest National Laboratory: http://vsp.pnnl.gov), and we 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 (DOE 1998a-e; DOE 1999a-e; DOE 2000a-e; DOE 2001a-e; DOE 2002a-c; DOE 2003a-c; DOE 2004a-f; DOE 2005 a-d; DOE 2006a-o; DOE 2007a-j; DOE 2008a-b; DOE 2009).

30. Presently, the NRC materials license process fails to develop an accurate and independent assessment of water quality in the ore zone (*See* Sass Decl. ¶ 15, Petition at 13). NRC's review of the FSEIS primarily relies on an invalid analysis of the data in the Strata application, which in our expert judgment is insufficient to conclude that the regional water quality in the ore zone exceeds the EPA drinking water Maximum Concentration Limits (MCLs) for uranium and radium-226.

Contention 2 – Failure to Analyze the Environmental Impacts of Alternative Concentration Limits

ISR Restoration Has Failed In Virtually Every Instance

31. It is well established that no pilot-scale or full-scale ISR mining operation has restored their uranium contaminated groundwater to the baseline values cited in the <u>initial</u> license permit (Deutsch et al., 1984; Hall, 2009; Staub et al., 1986). Importantly, ISR operators are unable to restore the groundwater to baseline values, even erroneously poor baseline values that are biased by high by oxidation of the ore zone during drilling and well development, invalid sampling protocols, and improper statistical representations of analytical results. It is apparent, in our expert judgment, that the probability is vanishingly small that ISR-contaminated groundwater can be restored to baseline values when those values are properly determined with valid scientific and statistical techniques.

The Nubeth Project Demonstrates this Failure to Restore Groundwater

32. Failure to restore the groundwater under the Nubeth pilot-scale ISR operation is evident in the consistently elevated uranium and radium-226 concentrations observed in samples from industrial well 19xx18 (Figure under Paragraph 20), which served as the extraction well to the Nubeth pilot-scale test (Figure 3.15 in the FSEIS). The uranium-radium-226 trend observed for all Strata cluster wells from the OZ horizons and industrial well 22x19 lies well below the radium-226 values for 19xx18, and the high radium-226 values can be explained by the capture of the contaminated plume that remains from Nubeth's failure to restore groundwater after their six-month pilot-scale test. Also, note that the water collected from the 19xx18 well is derived from the OZ and SM zones (see paragraphs 59-61), which dilutes the uranium and radium values in the Nubeth OZ zone (i.e., the uranium and radium values in the Nubeth OZ zone are higher than measured in the 19xx18 samples). In our expert opinion, failure to restore the groundwater after a short six-month pilot-scale project should have clearly communicated to the NRC Staff that it will not be possible to restore a full-scale ISR operation in 8 months (DSEIS at 2-33; Fig 2-6 in FSEIS).

33. The table presented below displays the complete results of the Nubeth restoration (FSEIS p. 5-28). Samples for individual wells associated with the Nubeth ore zone operation (3x, 4x, 5x, 6x, 11x, 12x, 19x, and 20x) are shown for 'baseline' and Restoration/Post-Restoration. Issues using the term 'baseline' for this project were discussed previously (Paragraph 20). The NRC Staff presented the highlighted data in Table 5.4 of the FSEIS, and omitted four other 1981 samples taken post-restoration (ND Resources 1980 and Nuclear Resources 1982). When the average restoration/post-restoration values are compared to the average 'baseline', the percent increase for post-restoration, average uranium values (range from 109 – 2640 %) are greater

than the values the NRC Staff provided in Table 5.4. Well 4x, 6x, and 12x were near or below uranium concentrations reported by the NRC Staff, yet all post-restoration sample averages exceeded average ‘baseline’ uranium concentrations. These data are critical to assessing the potential environmental impacts to water quality from previous ISR restorations near the applicant’s proposed mining activities, yet the FSEIS did not provide a complete analysis with the available data. Similarly, average stability concentrations, using the entire dataset, were used to justify restoration efforts at Crow Butte (Crow Resources, 2001; paragraph 35).

	Baseline - (Nuclear Dynamics 1978 - ML12135A358) Nubeth Well - Uranium Concentration (mg/L)									Restoration and Post-Restoration Nubeth Well - Uranium Concentration (mg/L)					
Date	3x	4x	5x	6x	11x	12x	19x	20x		3x*	4x*	5x ^	6x ^	11x ^	12x ^
	0.071	0.08	0.1	0.075	0.079	0.073	0.3	0.006		0.12	0.21	0.1	0.09	0.1	0.09
	0.059	0.067	0.077	0.08	0.065	0.049	0.069	0.002		0.18	0.12	0.09	0.1	0.1	0.09
6/1978	0.068	0.086	0.068	0.1	0.079	0.064	0.069	0.003		0.64	0.16	0.09	0.1	0.1	0.09
	0.089	0.12	0.057	0.098	0.088	0.059	0.077	0.002		0.51	0.16		0.1	0.1	0.09
	0.068	0.09	0.11	0.095	0.082	0.067	0.078	0.002		0.24	0.22	0.08	0.1	0.08	0.11
Average =	0.071	0.089	0.082	0.090	0.079	0.062	0.119	0.003	Average =	0.338	0.174	0.090	0.098	0.096	0.094
Max =	0.089	0.12	0.11	0.1	0.088	0.073	0.3	0.006	Max =	0.64	0.22	0.1	0.1	0.1	0.11
									Percent Change (Averages) =	**476**	**196**	**109**	**109**	**122**	**151**

Highlighted values presented by the NRC staff in Table 5-4, p. 5-28, FEIS

^ - May - September 1979 (Nuclear Dynamics 1980 - ML13274A287)

* - March - October 1981 (ND Resources 1982 - ML13274A178)

NRC’s FSEIS Examples of Restoration Demonstrate A Repeated Failure to Restore Groundwater

34. Given overwhelming scientific evidence of the failure of the ISR industry to restore groundwater to pre-industrial water-quality standards (Hall 2009; and examples below), none of the new information in the selective and limited restoration results provided in the FSEIS demonstrates successful groundwater restoration for uranium and other water quality parameters of concern. The NRC Staff provides analysis of historical ISR restoration results (FSEIS; p. 4-46) regarding ISR restorations at the Crow Butte Wellfield 1, Smith Ranch-

Highland A Wellfield, and Irigaray Mine Units 1-9. We discuss the NRC's misleading analysis and conclusion of "*improvement in water quality*" in detail in the following paragraphs.

35. With respect to Crow Butte Wellfield 1: briefly, the NRC approved the restoration of Wellfield 1 after 30 of 37 water-quality parameters were returned to 'baseline' or Wyoming Class I Domestic Use Standards. Similar to other ISR groundwater restoration results, radium-226 and uranium concentrations were not restored and NRC Staff justified the failure with this statement: "*The NRC determined that the radium-226 and uranium concentrations at 31 percent and 18 percent above post-licensing, pre-operational concentrations were protective of human health and the environment (Crow Butte Resources, 2001). The applicable condition in Crow Butte's NRC license was changed to require stability monitoring beyond the six-month period, as necessary to ensure no increasing concentration trends were exhibited*." (FSEIS; p. 4-46) NRC Staff's justification is flawed. First, there is no risk or dose calculation to support the contention that the elevated radium-226 and uranium concentrations pose no threat to human health and the environment. Second, the NRC states that uranium concentrations remained 18% above baseline concentrations, which is incorrect (Crow Butte Resources, 2001). According to Crow Butte Resources (2001), post-stabilization uranium concentrations were nearly 18.8 times higher than baseline, not 18% percent above baseline (Figure below paragraph 35). The difference is significant. In perspective, a car going 18% over a 55 MPH speed limit would be driving roughly 65 MPH. A car going 18.8 times 55 MPH, would be driving roughly 1,034 MPH. Also of note, average arsenic concentrations went from being non-detectable to exceeding the USEPA MCL (10 ppb). This first NRC example or restoration demonstrates their failure to thoroughly analyze the significant environmental impacts that arise when ISR operators fail to restore contaminated groundwater at ISR sites.

CROW BUTTE RESOURCES, INC.

Mine Unit 1 Groundwater Restoration
Response to Request For Additional Information

Table 3: Parameters Below UIC Permit Standards

Parameter	Baseline Average (Primary Goal)	UIC Permit Standard	Stabilization Average Water Quality
Arsenic (mg/l)	<0.002	0.05	0.017
Calcium (mg/l)	12.5	125	19.9
Total Carbonate (mg/l)	351	609	421
Iron (mg/l)	<0.044	0.30	<0.09
Potassium (mg/l)	12.5	125	13.2
Magnesium (mg/l)	3.2	32	5.3
Molybdenum (mg/l)	<0.069	1.00	0.10
Vanadium (mg/l)	<0.066	0.2	0.11
Radium-226 (pCi/l)	229.7	584	303
Uranium (mg/l)	0.092	5.0	1.73

It should be noted that, of the ten parameters that meet the UIC permit standards but were not returned to baseline concentrations, when standard statistical methods are applied to the baseline data, the concentrations of five of these parameters are statistically the same as baseline. The NRC states in NUREG-1569[2] that "...the baseline average plus three standard deviations is another method for establishing primary restoration targets that has been found acceptable by the NRC." CBR recognizes that this method of determining baseline concentrations is not the method approved in CBR's License. CBR is required to restore the affected groundwater on a mine unit average to the average baseline concentration with no statistical analysis of the data. However, CBR believes that NRC should consider statistical methods when determining whether acceptable efforts have been made to return Mine Unit 1 to baseline condition. Using NRC-accepted methods, five of the ten parameters are statistically at baseline concentration on a mine unit average.

[2] USNRC, NUREG-1569, *DRAFT STANDARD REVIEW PLAN for In Situ Leach Uranium Extraction License Applications*, October 1997.

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36. The FSEIS next discussed restoration at Smith Ranch-Highland Wellfield A (FSEIS; p. 4-46). There, the NRC states 31 of 35 water-quality parameters were restored to 'baseline' concentrations; but again, little analysis is provided with respect to constituents not restored to

‘baseline’ values. Specifically, the NRC Staff does not discuss the post-restoration concentrations of uranium and heavy metals in the ore field. The Smith Ranch-Highland facility observed elevated post-restoration contaminant concentrations, relative to ‘baseline’, for arsenic (3000%), selenium (7000%), and uranium (7060%). All three of these parameters exceeded their respective water quality MCLs (Borch et al. 2012). Furthermore, long-term sampling at two wells in the ore zone (MP-4 and I-21) reveal that groundwater samples had reached peak uranium concentrations in 2012 (17.3 and 2.13 mg/L, respectively)(Cameco Resources 2012). This is evidence that reducing conditions has not re-established in the ore zone at this site and uranium concentrations in the ore zone are increasing over-time.

37. Next, the FSEIS referenced the restoration approval at Irigaray Mine Units 1-9 (FSEIS; p.4-46). Results from the Irigaray Mine Units reflect similar failures to restore uranium to baseline concentrations. The table below shows the restoration results for average baseline and average stability uranium concentrations. Data were provided from (NRC, 2013b). Issues associated with the elevated ‘baseline’ concentrations at Mine Unit 1, due to research and development mining prior to collection of ‘baseline’ samples, were discussed in paragraphs 16 and 17. In the restoration summary report, the results are described as acceptable due to a best-effort approach: “*COGEMA has expended significant effort to restore the groundwater quality within the Irigaray wellfield to baseline conditions. At the completion of the Irigaray groundwater restoration program, the ore zone aquifer has been restored to standards consistent with Best Practicable Technology (BPT) and NRC’s ALARA (As Low As Reasonably Achievable) principle. In this regard, over 840 million gallons of water were processed over an 11.5-year period, and an average of 13.7 pore volumes were treated for the entire wellfield. Treatment*

volumes exceeded the amounts included in the approved treatment plan." (COGEMA Mining, Inc. 2005)

Irigaray Mine Unit	Average Baseline	Average Stability Rounds 1-4	% Change Average Stability 1-4
Mine Unit 1	3.042	0.988	32%
Mine Unit 2	0.130	3.782	2908%
Mine Unit 3	0.023	2.878	12515%
Mine Unit 4	0.046	2.420	5292%
Mine Unit 5	0.020	1.493	7467%
Mine Unit 6	0.112	1.854	1663%
Mine Unit 7	0.119	1.456	1226.8%
Mine Unit 8	0.041	1.591	3923%
Mine Unit 9	0.066	1.825	2751%

Uranium Concentrations (mg/L)

38. Furthermore, 'baseline' values from Irigaray (Mine Unit 1), which were elevated from research and development mining activities prior to 1976 (paragraphs 16, 17), were presented as the minimum, maximum, and average for all wellfields (wellfields 1-9) (Figure below paragraph 39). This was not coincidental; as industry and Wyoming state regulators agreed to present the entire Irigaray restoration results for all wellfields as a single combined wellfield.

"*In May 2003, COGEMA Mining, Inc. met with WDEQ personnel to discuss the restoration status of the Irigaray and Christensen Ranch projects. At that time, it was proposed and agreed that one restoration report package (this report [referring to the original document]) would be submitted for the Irigaray project. This would entail combining all baseline data from Units 1 through 9 together for a larger database. It was recognized that the data from Units 1 through 9 are more meaningful when combined as a whole than if presented as several individual packages. Thus, <u>a combined baseline data set was compiled</u>*

from the ore zone baseline wells located in Production Units 1 through 9 and is included in Table 4-2 [original document]." (COGEMA Mining, Inc. 2005b)[5]

39. Subsequently, the table of restoration data (below paragraph 39) was presented to the NRC, which includes the elevated 'baseline' uranium concentrations that were determined after research and development activities (COGEMA Mining Inc, 2006). All wellfields (1-9) were combined for a composite average 'baseline' and compared to restoration composite concentrations, as determined by COGEMA and WDEQ. However, 8 of the 9 wellfields (Wellfields 2 through 9) have significantly lower average 'baseline' uranium concentrations (range 0.023 – 0.13 mg/L) (table under paragraph 34) relative to the composite average 'baseline' value of 0.52 mg/L. Thus, the elevated 'baseline' samples collected after research and development activities at Wellfield 1 skewed the composite wellfield average uranium concentration to a higher average value of 0.52 mg/L. Consequently, the new restoration table gives the illusion that the overall post-restoration average uranium concentrations increased from only 0.52 to 1.83 mg/L (352% increase). However, when compared to the initial average 'baseline' uranium concentrations for each wellfield, the average post-restoration uranium increases for Wellfields 1 through 9 are substantially higher (table under paragraph 39). This post-operations and post-restoration manipulation of data essentially masks the reality of the groundwater impacts of the mining operations.

[5] We assume this meeting occurred on 5/27/03, as public reports show - "*Meeting in Casper among industry representatives (COGEMA, PRI and WMA), Land Quality and Water Quality representatives to discuss restoration progress and alternatives.*" (COGEMA Mining Inc. 2009)

Table 1. Comparison of 4th Round Stability Data Range to Baseline Range, Irigaray, Wyoming

IRIGARAY DESIGNATED RESTORATION WELLS - WATER QUALITY SUMMARY

	Unit 1-9 Baseline				Unit 1-9 Round 4			No of Samples Exceeding Baseline Range	Comments
	Minimum	Maximum	Mean		Minimum	Maximum	Mean		
Major Ions mg/l:									
Ca	1.6	27.1	7.8		11.6	65	28.8	17	No groundwater standard
Mg	0.02	9	0.9		2.8	13	7.0	7	No groundwater standard
Na	95	248	125		107	275	185.6	2	No groundwater standard
K	0.92	17.5	2.4		1.1	4.9	2.9	0	
CO3	0	96	13.2		< 1.0	< 1.0	0.8	0	
HC03	5	144	88.3		5.1	631	409.0	31	No groundwater standard
SO4	136	504	188.1		62.8	237	132.0	0	
Cl	5.3	15.1	11.3		0.1	117	39.4	32	All values below WDEQ Standard
NH4	0.05	1.88	0.3		0.05	36.1	8.5	13	NH3 equivalent is below WDEQ Standard
NO2 (N)	< 0.1	1	< 0.4		< 0.1	< 0.1	< 0.1	0	
NO3 (N)	0.2	1	0.9		< 0.1	0.12	0.1	0	
F	0.11	0.68	0.29		0.1	0.22	0.12	0	
SiO2	3.2	17.2	8.3		2.5	7.3	4.99	0	
TDS	308	784	404		343	968	626	5	Exceeds WDEQ and EPA secondary standard
Cond. (mmho/cm)	535	1343	658		604	1970	1094	5	No groundwater standard
Alk. (as CaC03)	67.8	232	104		127	518	345	30	No groundwater standard
pH (units)	6.6	11.00	9.00		7.07	8.40	7.76	0	
Trace Metals mg/l:									
Al	0.05	4.25	0.160		< 0.1	0.140	0.102	0	
As	< 0.001	0.105	0.007		< 0.001	0.029	0.005	0	
Ba	< 0.01	0.12	0.060		0.03	0.200	0.095	1	All values below WDEQ and EPA standard
B	< 0.01	0.225	0.110		<0.05	0.100	0.088	0	
Cd	< 0.002	0.013	0.005		< 0.002	0.005	0.004	0	
Cr	< 0.002	0.063	0.020		< 0.005	0.050	0.039	0	
Cu	< 0.002	0.04	0.011		< 0.01	0.020	0.010	0	
Fe	0.019	11.8	0.477		< 0.03	0.500	0.113	0	
Pb	< 0.002	0.05	0.020		< 0.001	0.090	0.039	1	One sample exceeds WDEQ and EPA standard
Mn	< 0.005	0.19	0.014		0.060	0.950	0.215	13	Exceeds WDEQ and EPA secondary standard
Hg	< 0.0002	0.001	0.0004		< 0.0002	< 0.001	< 0.001	0	
Mo	< 0.02	0.1	0.060		< 0.01	<0.1	0.069	0	
Ni	< 0.01	0.2	0.100		< 0.05	< 0.05	< 0.05	0	
Se	< 0.001	0.416	0.013		< 0.001	0.086	0.019	0	
V	< 0.05	0.55	0.070		< 0.05	< 0.1	0.088	0	
Zn	0.009	0.07	0.016		< 0.01	< 0.01	< 0.01	0	
Radiometric pCi/l:									
U (mg/l)	0.0003	18.60	0.52		0.08	6.03	1.83	0	
Ra 226	0	247.7	39.6		23.50	521.0	130.7	3	Exceeds WDEQ and EPA standard

40. The post-stabilization data were submitted and accepted by the WDEQ in 2005. Recall, this occurred after the 2003 meeting between COGEMA and WDEQ to discuss combining the restoration results for all wellfields. In other words, WDEQ had prior knowledge of COGEMA's intent to submit a combined wellfield restoration package (COGEMA Mining, Inc. 2005b). In brief, WDEQ approved a restoration and concluded further attenuation monitoring was not required and wells withing the wellfield may be abandoned (COGEMA Mining, Inc. 2005a). Unfortunately, the NRC Staff agreed with WDEQ's assessment of the restoration on September 20, 2006 (NRC, 2006).

41. The examples from the Irigaray and Nubeth ISR projects demonstrate that previous mining activities and operations bias ‘baseline’ values to high concentrations, and pre-industrial baseline does not exist at any ISR mining site. These examples and observations support Intervenor’s Contentions 1 and 2: in that, the NRC Staff and the applicant have neither established an adequate baseline nor addressed the almost certain impact to groundwater resources when alternative concentration limits are set after restoration fails. Based on the events which transpired between industry and state regulators at the Irigaray restoration described above, it is our concern that the creation of artificially elevated uranium baseline concentrations could mask restoration failures and the actual groundwater impacts.

The FSEIS Merely Relies on Failed Industry Restoration Efforts

42. Another element of the Intervenors’ second contention, the failure to adequately define the specific aquifer restoration criteria/standards during the NEPA process and prior to licensing the facility (see Moran Decl. ¶ 70, Petition at 17), is also unaltered by treatment in the FSEIS. Here, NRC Staff admits the restoration criteria are not known at this time. *See* contention 1 above: “*The purpose of aquifer restoration is to restore the ground-water quality in the wellfield to the ground-water protection standards specified at 10 CFR Part 40, Appendix A,Criterion 5B(5) so as to ensure no hazard to human health or the environment*” (FSEIS; p. 2-34)

43. The FSEIS treatment of restoration is based on what Strata informed the agency, and not on an NRC independent analysis of a successful restoration timeframe. The FSEIS provides a general description of aquifer restoration techniques: (1) groundwater transfer, (2) ground-water sweep, (3) RO treatment with permeate injection, (4) groundwater recirculation, and (5) stabilization

monitoring, but does not say which would be deployed in what wellfield and for how long and why. Also, there is no differentiation in aquifer restoration techniques between the 15-25 estimated wellfields. This is demonstrated in the vague wording used by the NRC Staff: "*Not all five aquifer restoration activities would be used for restoration of a specific wellfield if determined by the Applicant to be unnecessary to achieve the applicable ground-water protection standards; however, should Strata submit a request for application of an Alternate Concentration Limit (ACL) at a designated wellfield, the NRC staff will review the aquifer-restoration activities to ensure that an approriate (sp) level of effort has been performed.*" (FSEIS; p. 2-35)

44. The suggested eight-month restoration period is far too short; given the past history of failed ISR restorations at other ISR sites (see Abitz Decl. ¶ 28, Petition at 18). Proposed restoration timeframes are based on the NRC definition of a pore volume as "*a term used by the ISR industry to represent the volume of water that fills the void space in a given volume of rock or sediment* (FSEIS; 2-36)". Unfortunately, there is neither discussion nor analysis of the restoration dependency on anthropogenic-induced geochemistry, rather than the restoration techniques listed in paragraph 43; leaving little credibility in the FSEIS's estimated restoration timeframe given the industry's failed restoration history (See paragraphs 35-41 of this declaration).

45. The NRC Staff has not met the agency's obligations under NEPA to perform an adequate environmental impacts analysis of a proposed action and alternatives. The examples from unsuccessful restoration efforts at ISR sites (paragraphs 35-41) indicate the difficulty of predicting the number of pore volumes required for adequate restoration of uranium in the groundwater. Results from restoration failures at the Irigaray Project (paragraph 37) indicated

13.7 pore volumes (840 million gallons) were extracted and treated prior to approving the failed restoration. Yet, the FSEIS provides no analysis of the pore volume numbers for the Irigaray failed restoration and simply agrees with the arbitrary restoration timeframe or pore volume estimate provided by Strata: "*The NRC staff found that the Applicant's estimate of 9.5 pore volumes was acceptable because the estimate is within the range currently used by the uranium-recovery industry, and the Applicant commits to minimizing inefficiencies and adjusting the decommissioning estimate based upon its future experience (FSEIS, p. B-46).*" That is, the NRC Staff has agreed with Strata on using a pore volume estimation and arbitrary pore volume selection approach similar to the demonstrated failed restoration at numerous other mine units, including the Irigaray site.

46. As a further matter, the inability of the ISR industry to restore a wellfield to baseline uranium concentrations (even concentrations that are biased high with invalid sampling and statistical methods) is associated with the NRC Staff and industry failure to acknowledge the reaction kinetics and thermodynamics of uranium ore geochemistry. The ISR industry and NRC understand that ore deposits form over the period of hundreds of thousands to millions of years. During these immense time intervals, the fluvial deposits accumulate uranium where reducing conditions are favorable for precipitation of uranium. The ISR industry and NRC also understand that injection of an oxidizing-bicarbonate lixiviant destroys the natural balance in the ore-zone geochemical conditions over a period of a few years by pumping very high levels of oxidants and complexing agents through the ore zone. Under these anthropogenic induced changes, materials along the lixiviant flow path are oxidized and the reducing capacity built up in the sediments over hundreds of thousands to millions of years is substantially altered in a matter of years.

47. For all the reasons above and based on review of the relevant data, it is our professional opinion that no ISR mine site has ever fully restored the groundwater to 'baseline' conditions. And equally important, the FSEIS fails to consider and acknowledge this likelihood and any subsequent environmental impacts of permanently contaminated groundwater.

Contention 3 – Fluid Migration

NRC's FSEIS Provides Insufficient and Potentially Inaccurate Information to Make an Informed Analysis of Fluid Migration

48. The NRC has failed to analyze and model the subsurface geochemistry and potential for contaminant excursions. 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.*" The quoted statement is inaccurate and an oversimplification of the dominant geochemical mechanisms which dictate subsurface transport of soluble uranium (U(VI)). Without the presence of carbonate anions, U(VI) is readily adsorbed to the surfaces of various iron oxides and clays. However, with the introduction of an oxidizing carbonate-rich lixiviant to artificially enhance U(VI) solubility, uranium adsorption to iron oxide surfaces decreases, as relatively non-reactive uranyl-carbonate complexes form in solution (Curtis et al. 2006; p. 41 ExxonMobil, 2010; Zhou and Gu, 2005). Thus, the aqueous uranium-carbonate species formed from ISR operations process will be highly mobile in the groundwater.

49. Furthermore, 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). 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 how mining activities will disturb reducing geochemical conditions.

50. Another mechanism which could potentially remove U(VI) from solution is reductive precipitation to insoluble U(IV). This would require the presence of strongly reducing conditions in the subsurface; however the introduction of oxidizing agents during the ISR operation and restoration activities would disturb the reducing potential of the aquifer. Therefore, the NRC Staff's subjective assertion about constituent transport demonstrates a failure to adequately collect and analyze the amount of geochemical and hydrological data required to predict contaminant transport.

51. Furthermore, the FSEIS is vague and contradictory (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 made in paragraphs 48-50 and with numerous observations from other sites (Staub et al. 1983; Uranium one, 2010; WDEQ, 2011). There are many documented cases of monitoring wells on excursion status for periods of months to years, where operators could not decrease elevated parameters

by adjusting pumping rates (Staub et al. 1983). In certain cases, uranium concentrations in monitoring wells were measured as high as 5.5 mg/L (WDEQ, 2011). 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). Second, we assume NRC Staff is alluding to the corrective action of changing pumping rates to recapture the lixiviant plume. However, the proposed corrective actions do not have a credible scientific basis and analysis that addresses 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.

52. In addition, empirical evidence from the Bison Basin ISR mine 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. 1983). This example uses collected data to dispute the NRC assertion that the excursion monitoring constituents, alkalinity, chloride and conductivity are sufficient for establishing the excursion UCLs.

53. The USGS has studied and modeled U(VI) transport processes specifically to assist the NRC Staff with the evaluation of subsurface transport at ISR sites (Davis and Curtis 2007). Yet none of these considerations are discussed and applied by the NRC Staff in the FEIS. The aforementioned citation "*Consideration of Geochemical Issues in Groundwater Restoration at Uranium In-Situ Leach Mining Facilities*" is not used or cited within the FSEIS.

The FSEIS Fails To Analyze Sufficiently The Potential For And Impacts Associated With Fluid Migration And Communication Between Aquifer Units

54. The FSEIS notes that there are thousands of abandoned wells, but it does not disclose any total amount beyond information Strata 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. But, 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.*" (DSEIS at 4-36; FSEIS at 4-30). 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.[6] "…*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).

55. The NRC Staff states in the FSEIS (p. 2-48) 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); indicating from October 2010 to the FSEIS publication (February 2014), the applicant had not properly plugged a single abandoned Nubeth wellhole.

56. We find this disconcerting as the historical records at ISR mine sites indicate nearly all vertical excursions in the overlying aquifer were "*proportional to the intensity of mining activities*"

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[6] 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).

(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 <u>improperly abandoned drillholes from earlier exploration activities</u>*." (FSEIS, p. 4-37). 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>). However, this 1682 figure contrasts with the over 5,000 exploration boreholes drilled in the area identified at the ER stage of this proceeding. *See* Moran Decl. ¶¶ 22,31; Abitz ¶13 Petition 21-23. Whether the figure is more than 5,000 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.

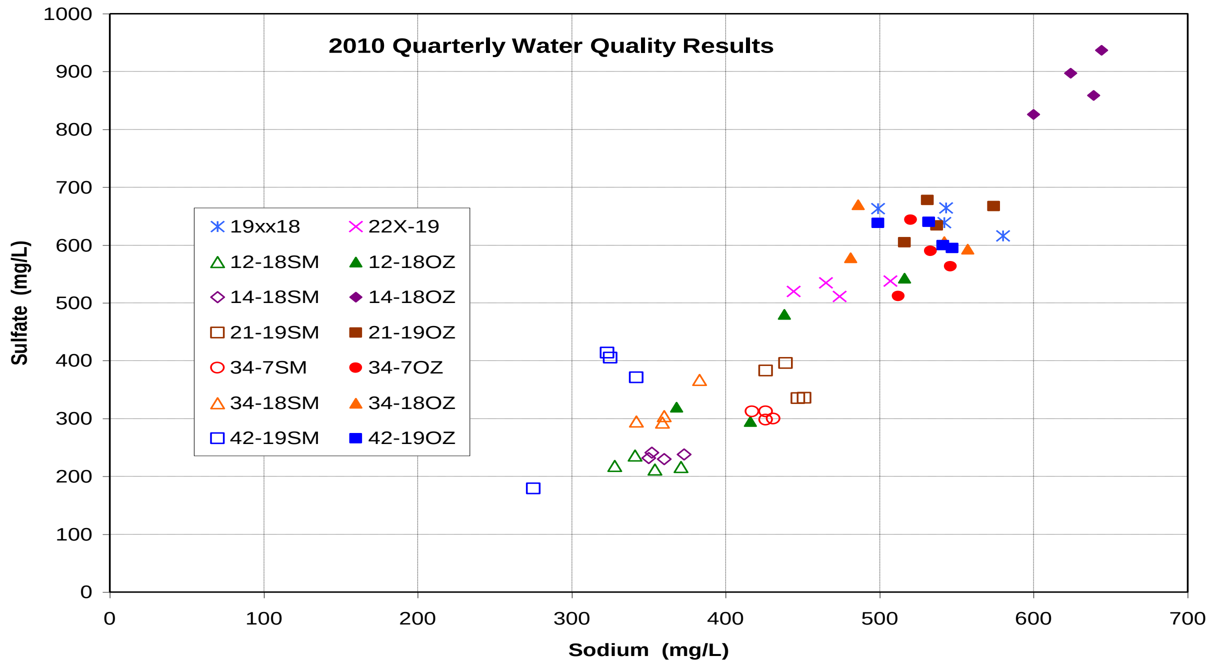
57. The FSEIS states that environmental impacts from horizontal and vertical excursions could be "MODERATE to LARGE" (FSEIS; p. 4-37). Control, prevention, and remediation of vertical excursions were largely unsuccessful at previous ISR sites in the United States (Staub et al. 1983). In other words, when a vertical excursion occurs in the SM aquifer, the applicant will have limited options to correct the excursion.

58. In our 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 (Strata,

2011b, Addendum 2.6-C) -- 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). 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 ISR operations, and the vertical excursions were traced to thinning of the confining layer in the complex fluvial stratigraphy and improperly abandoned exploration bore holes (FSEIS; p. 4-37).

59. 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 (Below paragraph 60). 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 our 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 (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.

60. Water-quality results for sodium and sulfate indicate groundwater mixing of the ore zone (OZ) and overlying horizon (SM).



61. The above figure also illustrates that, the closer that 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 ISR 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).

62. 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. <u>The complexity of the stratigraphy coupled with thousands of unplugged boreholes, established mixing between the SM and OZ zones, and the high-yield</u>

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 ISR 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.

63. Paragraph 62 is supported by the discussion and figure from (Staub et al.1983; 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. 1983) (page 24).

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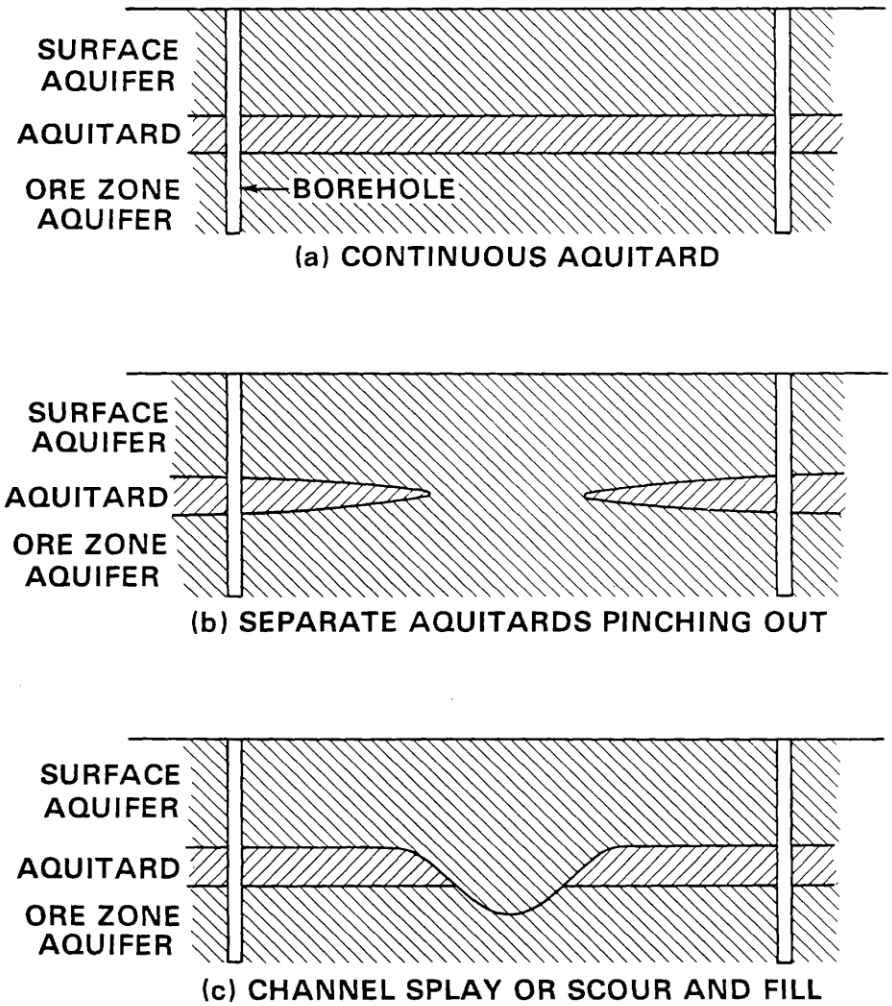

Fig. 2.8. Alternate interpretations of the same borehole data.

Contention 4 – Cumulative Impacts

64. With respect to the Intervenors' fourth admitted contention, the failure to sufficiently describe cumulative groundwater quantity impacts and the failure to quantitatively evaluate impacts of the proposed Lance District expansion and the project as a whole is technically unjustified. While the FSEIS acknowledges cumulative impacts will occur from ISR mining projects (see FSEIS at xxxviii), there is a dearth of meaningful analysis in the agency's document and the Intervenors' concerns remain unaddressed. Remarkably, the NRC notes that cumulative impacts are limited only to the OZ horizon because it is not in contact with aquifers above and below it. FSEIS at 5-23. This contradicts the numerous statements made by the NRC throughout the FSEIS on unplugged exploration boreholes and thinning confining units and ignores the hydrologic data on the 24-hr pump test from well 12-18, and water-quality data form 12-18, that indicates connection with the SM and OZ aquifer horizons (Paragraphs 54-63).
65. The FSEIS briefly notes cumulative impacts to water drawdown from future "satellite" projects: stating consumption could increase to 356 gal/min from the 122 gal/min estimated for the Ross Project. FSEIS at 5-25. This estimate is based on aquifer yield that is proportional to uranium recovery amount, and the FSEIS lacks specific analysis about projected drawdown amounts. The FSEIS also lacks analysis about irreversible trends - it simply estimates that quantity "*would be essentially restored within 24 years after the issuance of the Source and Byproduct Materials License to the Applicant*" (FSEIS; p. 5-27) and therefore suggests impacts would be small. But the FSEIS is contradictory in the analysis concerning groundwater recharge. Initially, the NRC Staff states that increased precipitation will replenish lost groundwater quantities "*There could be an increase in recharge to aquifers underlying the Ross Project area in future years, which would result from the predicted increased precipitation (i.e. higher*

precipitation would consequently increase infiltration in to the ground-water regime)."(FSEIS; p. 5-37). However, the NRC Staff later states that soil and runoff conditions, not precipitation, are the main drivers of aquifer recharge. "*The Applicant's ground-water model determined that infiltration from the land surface to the aquifer is only approximately 0.2-0.56 cm/yr [0.07 – 0.22 in/yr]. Most of that precipitation is lost to runoff, evaporation, and transpiration. The amount of precipitation available for recharge to the aquifer is primarily controlled by soil type and runoff conditions, and it could be little affected by the variation in the amount of precipitation.*"(FSEIS; p. B-102) In other words, the FSEIS presents a vague analysis of the water budget over the entire project and the 24 year recovery appears arbitrary.

66. The agency notes average consumption of 122 gal/min over 6 years for the Ross Project; but the basis and calculation to derive the quantity of groundwater over this period is absent (DSEIS p. 5-24, lines 12-14). NRC then states the average increases to 356 gal/min (FSEIS p. 5-25) when including the Kendrick, Richards, and Barber satellite areas; based on scaling water consumption to uranium production between Ross Project and all satellite operations, but no period of consumption is given by the agency. It is perplexing why there is a lack of mass balance calculations, because information is given to estimate total gallons consumed (i.e., 356 gal/min over 24 years equates to 4.5 billion gallons of groundwater, or enough water to cover 13,800 acres to a depth of 1 foot). Note that NRC Staff and Strata are mute on groundwater loss due to failure to restore aquifers to true baseline conditions, which could be another 56,000 acre-ft (assuming 1866 acres multiplied by 100 feet of sand thickness with a porosity of 0.3).

67. Further, there is no analysis of cumulative water quality impacts - just the Nubeth pilot-scale ISR operation, but no analysis of the prospective parts of the entire Ross project or even the greater Lance District project. Indeed, what FSEIS does examine is essentially limited to the

OZ aquifer in the Ross Area, due to the proposed confining layers (FSEIS; p.5-22, lines 44-46). This conflicts with scientific data and NRC statements that horizontal and vertical excursions of mining fluids occur at all ISR operations, and that the vertical excursions were traced to thinning of the confining layer in the complex fluvial stratigraphy and improperly abandoned exploration bore holes (DSEIS, p. 4-32, lines 41-43; FSEIS at 4-34). The layers are not confining due to complex fluvial stratigraphy (Strata 2011b; Addendum 2.6-C), hundreds (if not thousands) unplugged boreholes (Strata 2011b; Addendum 2.6-B), alternative interpretations of pump tests, and water quality analyses that demonstrate mixing between SM and OZ (see figure below paragraph 60).

68. The FSEIS states that Strata cannot estimate the current withdrawal of groundwater from the Lance and Fox Hills formations because the geological interval is not recorded by the Wyoming engineer's office (DSEIS p. 5-24, lines 23-28; FSEIS p. 5-25). It is our finding that this conclusion is inaccurate, as location and depth of wells are given (line 24) and both the NRC Staff and Strata have intimate knowledge of the regional geology to correlate these locations and depths with the geological interval.

69. Again, without independent analysis, NRC cites Strata on concluding that the OZ horizon is unattractive as a groundwater source due to depth (400 fbgs), and due to the presence of overlying aquifers (DSEIS p. 5-24, lines 31-33; FSEIS at p.5-25 & 5-26). This statement contradicts the NRC statement (DSEIS p.5-24, lines 1-4; FSEIS p.5-24) on the city of Gillette, which extracts groundwater from the Fox Hills Formation at a depth of 500 fbgs and mixes this high TDS water with groundwater of lower TDS to produce potable water for the city. The use of Fox Hills groundwater by the city of Gillette also exposes the weakness of the NRC/Strata assertion that the groundwater in the OZ is unsuitable for human consumption. Clearly, the

groundwater from the OZ horizon can be blended with lower TDS water to produce potable water for human consumption.

/s/ Dr. Richard Abitz (electronic signature approved)

/s/ Dr. Lance Larson (electronic signature approved)

Dated: March 31, 2014

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Attachment A

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EDUCATION

Ph.D.	Fall 2013	Environmental Engineering and Biogeochemistry, Pennsylvania State University
M.Sc.	2010	Civil and Environmental Engineering, South Dakota School of Mines and Technology
B.Eng.	2008	Environmental Engineering, California Polytechnic State University, SLO

POSITIONS

2014-present	Post-Doctoral Science Fellow, Natural Resources Defense Council (NRDC), Washington, DC.
2010-2013	Graduate Research Assistant, Pennsylvania State University, University Park, Pa
2008-2010	Graduate Research Assistant, South Dakota School of Mines and Technology

PUBLICATIONS

***Larson L.N.,** Miller C., Macalady J.L., Borch T., Gorski C., Burgos W.D. (2013). Biogeochemical transformation of schwertmannite to goethite under a coal mine drainage impacted stream.

***Larson L.N.,** Burgos W.D.**,** Sánchez-España J. (2013). Thermodynamic constraints of kinetic rates of low-pH biological Fe^{2+} oxidation. Submitted to *Environmental Science and Technology*, 2014.

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Larson L. N., Kipp G. G., Mott H. V. and Stone J. J. (2012). Sediment pore-water interactions associated with arsenic and uranium transport from the North Cave Hills mining region, South Dakota, USA. *Applied Geochemistry*, 27, 879-891.

Burgos W. D., Borch T., Troyer L. D., Luan F., **Larson L. N.**, Brown J. F., Lambson J. and Shimizu M. (2012). Schwertmannite and Fe oxides formed by biological low-pH Fe(II) oxidation versus abiotic neutralization: Impact on trace metal sequestration. *Geochimica et Cosmochimica Acta*, 76, 29-44.

Larson L. N., Stone J. J. (2011). Sediment-bound arsenic and uranium within the Bowman–Haley Reservoir, North Dakota. *Water, Air, Soil Pollution,* 219, 27-42.

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Lupo C. Stone J.J. Bulk Atmospheric Mercury Fluxes for the Northern Great Plains, USA. Water, Air, Soil Pollution. 224, 1-12, 2013

TEACHING EXPERIENCE

2012, spring	Guest Lecturer, Pennsylvania State University. Water Quality Chemistry, CE 475.
2012, fall	Teaching Assistant, Pennsylvania State University. Environmental Engineering Capstone Design, CE 472W
2010, fall	Teaching Assistant, Pennsylvania State University. Introduction to Environmental Engineering, CE 370
2010, spring	Teaching Assistant, South Dakota School of Mines and Technology. Physical/Chemical Process Design and Laboratory, ENVE 426.
2006-2008	Multicultural Engineering Program Tutor, Cal Poly, San Luis Obispo, Ca.

CONFERENCE PRESENTATIONS AND ABSTRACTS

Larson, L.N., Comparison of field and laboratory low-pH Fe(II) oxidation rates. Presented at 14th annual Abandoned Mine Reclamation Conference, State College, Pa, August 2012

Borch, T., Troyer, L., **Larson, L.N.**, Stone, J.J., Impact of biogeochemical redox processes on U and As dynamics within a U mining impacted watershed. Presented at the International Workshop on Uranium Biogeochemistry: transformations and applications, Ascona Switzerland, March 2012.

Burgos, W., Fitzgerald, M., **Larson, L.N.**, Herwehe, L., Singha, K., Gooseff, M., Electrical resistivity imaging of a deep coal mine discharge. Presented at the 21st Annual Goldschmidt Geochemistry Conference, Prague, Czech Republic, August 2011.

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Larson, L.N., Stone, J.J., Stetler, L., Troyer, L., Borch, T., Sediment pore-water equilibrium interactions associated with arsenic and uranium transport within a historical uranium mining impacted watershed, Harding County, SD. Presented at the joint meeting of the Rocky Mountain Section, Geologic Society of America 62nd Annual Meeting and the 2010 Western South Dakota Hydrology Conference, Rapid City, SD, April 2010.

Larson, L.N., Stone, J.J., Stetler, L., Arsenic and uranium impacted sediment behavior within the Bowman-Haley Reservoir, Bowman County, North Dakota. Presented at the joint meeting of the Rocky Mountain Section, Geologic Society of America 62nd Annual Meeting and the 2010 Western South Dakota Hydrology Conference, Rapid City, SD, April 2010.

Larson, L.N., Stone, J.J., Stetler, L.D., Development of an arsenic and uranium fate and transport model for historical uranium mining impacts from Custer National Forest, Harding County, South Dakota. Presented at 2009 Western South Dakota Hydrology Conference, Rapid City, SD, April 2009.