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 Testimony of Dr. Lance Larson on
Contentions 2 and 3

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United States Nuclear Regulatory Commission Official Hearing Exhibit
In the Matter of: STRATA ENERGY, INC. (Ross In Situ Recovery Uranium Project)
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Expert Witness Background Information

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

A. 1. Dr. Lance Larson, Science Fellow, Natural Resources Defense Council. I started with the NRDC Science Center in January 2014 and am located in the Washington D.C. office. I work with the Land and Wildlife, Energy, and Water programs to protect U.S. groundwater resources.

Q. 2. Please state your education, professional registration and memberships.

A. 2. I earned a dual doctorate in environmental engineering and biogeochemistry from the Pennsylvania State University (2013). My graduate research focused on modeling acid mine drainage, arsenic and uranium fate and transport, and biogeochemical interactions between surface and groundwater. I've presented research at scientific conferences in the United States and internationally, and published multiple peer-reviewed research articles regarding interactions of redox-sensitive elements, such as iron, arsenic, and uranium. For example, in 2012 I published a peer-reviewed article on surface and pore-water interactions associated with arsenic and uranium transport in northwestern South Dakota, and in 2011 I published another peer-reviewed article on sediment-bound arsenic and uranium within reservoir sediments in North Dakota. My full resume is attached at JTI004.

Q. 3. Have you worked on *in-situ* Leach (ISL) matters prior to arriving at NRDC?

A. 3. Yes. While finishing my undergraduate degree, I worked a summer internship with RESPEC consulting in Rapid City, SD, which supported surface water hydrology and well log characterization of various geological units associated with Powertech/Azarga's proposed ISL mine near Dewey-Burdock, SD.

Q. 4. What, briefly, have you worked on since you have been at NRDC? How many of these projects have involved groundwater characterization and analysis?

A. 4. My time at the NRDC has been spent working on analyzing historical environmental impacts of ISL mines across the United States, examining the current scientific literature concerning uranium transport and sequestration mechanisms, and reviewing the NEPA documents associated with the Ross ISL project. My other projects with the NRDC are associated with researching the current state of regional groundwater supplies in the United States.

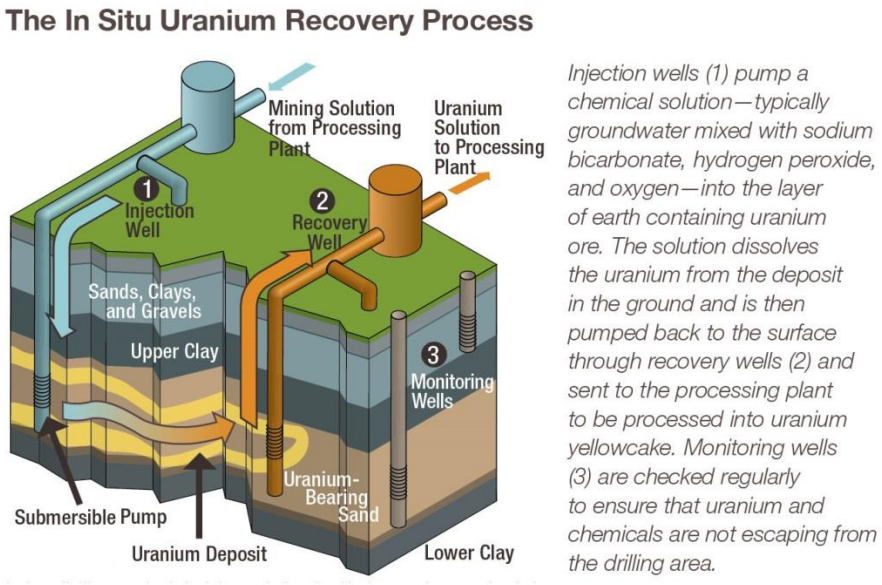
General Background Information Regarding ISL Extraction

Q. 5. Dr. Larson – please describe the ISL uranium recovery process in basic terms.

A. 5. A uranium recovery process has emerged within the last 40 years, termed *in-situ* ("in place") leach (ISL) or *in-situ* recovery (ISR) uranium extraction. This process involves injecting an oxidizing solution into a groundwater aquifer containing naturally occurring uranium ore. The solution dissolves the uranium minerals and the 'pregnant' solution is pumped to the surface, where the uranium is subsequently processed and shipped offsite. The process exploits the redox (oxidation-reduction) characteristics of uranium. This "redox" characteristic matters for the following reason. In the ore body, uranium exists as U^{4+} is a solid, as the mineral uraninite ($UO_2(s)$), formed by natural conditions over geologic time frames. The injection of a lixiviant solution oxidizes the naturally occurring uraninite ore, creating the U^{6+} oxidation state, which is substantially more soluble.

Q. 6. Dr. Larson I would like to draw your attention to the following figure. What is this?

A. 6. This is a figure taken from the NRC's website on ISL recovery provides a basic graphical representation of the ISL recovery process (http://www.nrc.gov/materials/uranium-recovery/extraction-methods/isl-recovery-facilities.html).



SCHEMATIC FIGURE OF GENERAL IN SITU RECOVERY PROCESS.

Q. 7. Please explain the basics of an underground aquifer.

A. 7. An aquifer is a geological unit which is capable of storing and transmitting significant amounts of water. Aquifers are divided into two broad categories, unconfined and confined. An

unconfined aquifer is a shallow aquifer that is 'open' to atmospheric conditions. That is, it is not vertically constrained by an overlying confining unit. An unconfined aquifer's water-level is termed the *water table,* which represents the boundary between the saturated and unsaturated zone. A confined aquifer is overlain by an impervious confining geological unit, *aquiclude* or *aquitard,* which limits vertical transmission of water.

The *potentiometric surface* is the water-level surface for a confined aquifer that is due to the both the elevation and pressure head. When the potentiometric surface exceeds the land elevation, an artesian well or spring will be observed. Internal solid matrix stress and expansion of groundwater in the pore spaces account for the pressure head. Groundwater flows from high-to-low head potential similar to surface water flowing from high to low elevation, due to friction losses within the geological units and reflected with relatively lower potentiometric surfaces.

Q. 8. Have you reviewed the applicant's Environmental Report, DSEIS, FSEIS, and all the associated documentation with the Ross Project?

A. 8. Yes, I have extensively reviewed the applicant's Environmental Report (ER), the Draft Supplemental Environmental Impact Statement (DSEIS) for the Ross Project, the Final Supplemental EIS (FSEIS), and a host of other associated and relevant documents (SEI009A, SEI016A-E). All documents I reviewed are noted and referenced in this Direct Testimony. A complete list can be found at the conclusion of this Direct Testimony and in our referenced exhibits. My conclusions are my own professional opinions and are based upon my review of the relevant documents and my education and experience in such matters.

Contention 2 – The FSEIS fails to analyze the environmental impacts that will occur if the applicant cannot restore groundwater to primary of secondary limits

Q. 9. In your expert opinion, has Strata or NRC Staff analyzed the environmental impacts to groundwater that are likely to exist post-restoration, including what will occur if the applicant cannot restore groundwater to primary of secondary limits, either in the ER, the DSEIS or the FSEIS?

A. 9. No, and I will explain in detail in the pages that follow.

Proposed Aquifer Restoration

Q. 10. Dr. Larson, please explain what it means to "restore" an ISL mining site.

A. 10. According to the FSEIS (SEI009A at p. 2-35), the groundwater restoration at the site will follow the progression

1) Groundwater sweep
2) Reverse osmosis (RO) permeate injection
3) Recirculation
4) Chemical treatment
5) Stability monitoring

Groundwater sweep (1) involves collective recovery pumping in the wellfield to capture elevated constituents in ISL impacted water. Following groundwater sweep, RO permeate injection (2) occurs as a 'pump-and-treat' method where recovered groundwater is treated using RO and the permeate is re-injected into the wellfield. After RO permeate injection, 'hot spots' (where uranium concentrations remain elevated) are focused using recirculation (3), which aims to homogenize elevated groundwater concentrations through dilution. Recirculation is similar RO permeate injection, except the recovered groundwater is not

treated with RO. In certain instances, chemical injection treatment (4), typically hydrogen sulfide gas or NaS, is injected in an attempt to reduce groundwater concentrations further. Upon completion of the restoration phase, 12 months of stability monitoring (5) is required to confirm that wellfield water quality concentrations are stable and water quality parameters of concern are not migrating beyond the permit boundary. The costs of groundwater restoration at ISL sites are significant, typically 40% of the entire project budget (JTI029; p 55 in pdf, p 48 in document).

Q. 11. Now that we have established the concept of what restoration is and how it's supposed to work, how well have restoration efforts worked in the ISL uranium mining industry?

A.11. I have reviewed extensive empirical data and results, published by industry, academia, or regulators on this issue, and these data uniformly suggest groundwater restoration to pre-mining baseline levels for uranium concentrations has been overwhelmingly unsuccessful (JTI030; p.16). I will address the issue of what specific instances of ISL restoration look like several times in the testimony that follows.

<u>NRC Staff/FSEIS Characterization of Aquifer Restorations</u>

Q. 12. NRC Staff included in the FSEIS (SEI009A at 4-46) a discussion of three historical aquifer restoration activities that received NRC approval, including examples of hazardous constituent concentration values that the agency found protective of human health and the environment. The FSEIS relies on these examples to conclude that the impacts of the Ross Project on groundwater quality will be "small," FSEIS at 4-45 to 4-48, and Staff, in their April 14, 2014 Answer to Intervenors' FSEIS Contentions, defended against Joint Intervenors' FSEIS contention on this issue by asserting these examples provide "an idea of what a range of possible ACLs for the Ross Project might look like, and accordingly are representative of the impacts that might result should Strata be unable to restore the Ross

wellfields to post-licensing, pre-operational values." Dr. Larson, can you address the adequacy of Staff's presentation in the FSEIS in this regard?

A.12. Yes I can address Staff's presentation and I will do so in the following paragraphs. But in summary, in the FSEIS (SEI009A at pages 4-45 to 4-48) Staff presented a short discussion and limited data from NRC approved restorations at three sites – a) Crow Butte mine unit 1, b) Smith Highland Ranch ISL mine unit A, and c) the Irigaray ISL site (mine units 1-9). The FSEIS also purports to disclose what happened with d) the Nubeth Project, a 1970s ISL project conducted in the same proposed permit area as the Ross site. Staff's discussion of each of these four sites is inadequate and fails to present any meaningful understanding of what is certain to occur at as a result of the Ross Project: irretrievable and irreversible environmental degradation of groundwater quality, which the FSEIS does not acknowledge or discuss. And it certainly does not constitute a bounding analysis that could inform a decision maker of the likely environmental impacts. I will review in turn each of the three examples listed in the FSEIS sites, as well as issues associated with the Nubeth ISL groundwater restorations.

Q.13. Even though it was the last you mentioned, as it's contained within the Ross Project boundary, let's start with the Nubeth Project. What happened here?

A.13. According to the FSEIS (SEI009A at p. 3-39), the Nubeth project had two separate ISL leach operations which were conducted within the current Ross permit boundary. Project A was a single push-pull (the injection and recovery processes were used with one well) which was located "*1000 ft north of Oshoto Reservoir*" and occurred in 1976. Project B was a research and development project located "*3,000 feet south of Oshoto Reservoir*" which occurred began in 1978.

Q. 14. Can you show the results of the Nubeth project?

A. 14. I created the table below to display the complete results from project B of the Nubeth restoration (SEI009A at 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' (NRC017; p.66 in pdf) and Restoration/Post-Restoration. The NRC Staff presented the highlighted data in Table 5.4 of the FSEIS, and omitted four other 1981 samples taken post-restoration (NRC018; p 47-53 in pdf and JTI031; p. 8-11 pdf). 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 ISL restorations near the applicant's proposed mining activities, yet the FSEIS did not provide a complete analysis with the available data.

	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 ^	19x*	20x*
	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	8	0.094
	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	1.1	0.081
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	1.4	0.088
	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	0.84	0.065
	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	0.48	0.068
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	2.36	0.079
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	8	0.094
									Percent Change (Averages) =	**476**	**196**	**109**	**109**	**122**	**151**	**1993**	**2640**

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)

URANIUM CONCENTRATIONS FROM NUBETH ISL OPERATIONS. "BASELINE" URANIUM CONCENTRATIONS ARE ON THE LEFT AND POST-RESTORATION VALUES ARE ON THE RIGHT

(MG/L). THE HIGHLIGHTED VALUES SHOW THE DATA PRESENTED IN THE SEI009A, P.5-28. PERCENT CHANGE WAS CALCULATED AS (POST-RESTORATION/BASELINE) * 100.

Along with inadequately presenting the restoration data from Nubeth project B, no data or discussion is presented from groundwater restorations from Nubeth project A, which was located within the proposed permit boundary, except for Table 3.7 (SEI009A, p. 3-41) which displays a pre-test sample that does not aid in understanding what happened with the restoration of the aquifer after leaching occurred. However, groundwater restorations at the Nubeth project A were unsuccessful as well (JTI032 p. 14-15; and p. 87).

Q.15. So what do these results from the Nubeth Project mean?

A. 15. In my expert opinion, failure to restore the groundwater after a short six-month pilot-scale single well leaching project should have clearly communicated to the NRC Staff that it will not be possible to restore a full-scale commercial ISL operations in 8 months as the FSEIS claims (SEI009A; p.2-35). I believe the FSEIS seriously underestimates the time necessary to restore groundwater after full-scale ISL operations, such as the Ross Project. Additionally, and perhaps more importantly, the Nubeth Project indicates that at this particular site, Strata will be unlikely to restore groundwater to primary or secondary standards. This conclusion is confounded by the fact that either Nubeth Project used only a single injection well, whereas commercial operations of ISL, like the Ross Project, use hundreds of wells, which means that groundwater restoration at the commercial scale will be even more difficult to obtain. In this regard, I also examined the results from commercial ISL operations in the United States, such as Crow Butte ISL, Smith Highland Mine Units A, and Willow Creek ISL, which serve as additional evidence of the

expected groundwater impacts at the Ross ISL project. The details of groundwater restoration activities at those sites, and subsequent groundwater contamination, will be discussed in depth in the following section.

Q. 16. Let's move to the Crow Butte Wellfield 1. In its FSEIS, what did the NRC allege happened and then what actually happened?

A. 16. 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 ISL groundwater restoration results, radium-226 and uranium concentrations were not restored. In the FSEIS, NRC Staff justified this 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; NRC023 p. 10). 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*." (SEI009A; 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. The NRC staff incorrectly analyzed the groundwater restoration data from Crow Butte mine unit 1 and stated that uranium concentrations increase by only 18% post-restoration, whereas concentrations actually increased 18.8 times baseline concentrations (NRC036; p. 2), as is seen in the chart immediately below this paragraph. I demonstrated this

error in a March 31, 2014 declaration on behalf of the Joint Intervenors (at ¶35). The difference is great, yet even after the NRC acknowledged its error after issuance of the FSEIS, (NRC036; p. 2) the NRC staff asserted the error made no impact on the qualitative aquifer impacts being "SMALL and temporary" (JTI033; p. 18 and p. 19). To the contrary, groundwater concentrations observed at 1.73 mg/L (shown in the figure below) suggest very high contamination relative to the 0.03 mg/L drinking water standards and there is no discussion or demonstration from Staff that the effects on the aquifer are temporary, reversible, or retrievable, yet NRC staff state these levels are "SMALL" (JTI033; p. 18 and p. 19). In sum, this NRC staff example of ISL restoration demonstrates a failure to accurately and thoroughly analyze the significant environmental impacts that arise when ISL operators fail to restore contaminated groundwater at ISL sites.

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.

RESTORATION RESULTS AT CROW BUTTE MINE UNIT 1 COMPARED TO AVERAGE BASELINE CONCENTRATIONS. URANIUM SPECIFICALLY IS HIGHLIGHTED.

Q. 17. Let's turn to the Smith Ranch Highland Wellfield A. In the FSEIS what did the NRC allege happen and what really happened?

A. 17. The NRC next discussed groundwater restoration at Smith Ranch-Highland Wellfield A (SEI009A; p. 4-46). There, the NRC stated 31 of 35 water-quality parameters were restored to 'baseline' concentrations; but again, little analysis was provided with respect to constituents not restored to 'baseline' values. Specifically, the NRC Staff did 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%)(NRC037; p.8 in pdf). Specific spatial and temporal uranium groundwater concentrations from Smith Highland Wellfield A and B will be presented later in this document.

Q. 18. And turning to the third example of "restoration" provided by the NRC in its FSEIS, what happened with Irigaray Mine Units 1-9?

A. 18. Next, the FSEIS referenced the restoration approval at Irigaray Mine Units 1-9 (SEI009A; p.4-46) and stated that even though several water quality parameters were not restored, concentrations in excess of post-licensing, pre-operational levels would not exceed EPA MCLs for groundwater outside the aquifer exemption boundary (SEI009A; p.4-46). In fact, results from the Irigaray Mine Units reflect similar failures as those described above to restore uranium to baseline concentrations. I created the table below to show the restoration results for average baseline and average stability uranium concentrations for each mine unit. This data is not discussed in any detail in the FSEIS (JTI005A-R; p.259-346).

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)

In industry's restoration summary report, industry describes the results as acceptable, saying: "*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.*" (NRC030; p.86 in pdf, p. 4-18).

In summary, the Irigary site was not restored to baseline concentrations despite an 11.5 year groundwater restoration period and 13.7 pore volumes recirculated in the aquifer

Q. 19. Does this site raise concerns regarding how baseline and restoration efforts are related?

A. 19. Yes it does. Here, 'baseline' values from Irigaray (Mine Unit 1) were significantly elevated from research and development mining activities prior to 1976 (NRC020; p. A-6, 4th paragraph and subsequent pages). Baseline uranium groundwater concentrations for Irigaray mine unit 1 were collected between 11/9/1976 – 2/24/1977 (JTI034; p.256 in pdf or p. B-4). Therefore, baseline uranium groundwater samples were biased towards high concentrations. These 'baseline' data from Irigaray were presented as the minimum, maximum, and averaged for all wellfields (wellfields 1-9) (NRC032; p. 3). The entire Irigaray restoration results for all wellfields were presented as a single combined wellfield (NRC030; p.71 in pdf, p. 4-3 in document), a COGEMA Mining Report from 2005 that stated as follows:

"*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, a combined baseline data set was compiled from the ore zone baseline wells located in Production Units 1 through 9 and is included in Table 4-2 [original document]*."

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) relative to the composite average 'baseline' value of 0.52 mg/L. Again, see the table I created above for the specific values for each mine unit. 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 (~3.52x 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. This post-operations and post-restoration manipulation of data essentially masks the reality of the groundwater impacts of the mining operations.

In brief, WDEQ approved a restoration and concluded further attenuation monitoring was not required and wells within the wellfield could be abandoned (NRC035; p. 4). The NRC Staff agreed with WDEQ's assessment of the restoration on September 20, 2006 (NRC034; p. 1).

Q. 20. So what's your conclusion from reviewing this example provided by the NRC?

A. 20. With respect to baseline, the examples demonstrate that previous mining activities and operations bias 'baseline' values to high concentrations, and pre-industrial baseline does not exist at these ISL mining sites. These examples and observations support the related nature of

Intervenor's Contentions 1 and 2: in that, the NRC Staff and the applicant have neither established an adequate baseline nor addressed the certain and degrading impact to groundwater resources when alternative concentration limits are set after restoration fails.

Disclosure Of Impacts of the Ross ISL Project

Q. 21. Since the Ross Project has yet to take place, we can't precisely know end results. But in contrast to Staff's presentation, can we look with more detail at sites where similar restoration plans have been approved and what might transpire?

A. 21. Yes. Commercial ISL sites in the United States have used the same restoration techniques as what's being proposed for the Ross ISL groundwater restoration. For example, at Christensen ranch, mine unit 4, the same restoration process was followed as proposed in the Ross FSEIS.

For example: The NRC staff states (JTI035; p. 33):

"*As reported by the licensee, production at MU-4 was initiated in June 1994 at MOD42, August 1994 at MOD43, and December 1994 at MOD41. Operations continued until August 1997. Groundwater sweep phase of the restoration was initiated at all three modules in August 1997 and completed at all modules in July 1998. The volume of water associated with the groundwater sweep activities was 1.93 PVs. After a three year hiatus, the next phase of restoration consisted of the groundwater treatment with RO permeate injection. This phase was initiated at MOD43 in April 2001, and at the other two modules in February-March 2002. The groundwater treatment phase was completed by March 2003. A total of 9.84 PVs is associated with the groundwater treatment phase. Injection of hydrogen sulfide gas as a reductant was initiated during the final stages of the groundwater treatment phase for MOD42 from January 2003 to March 2003. The final phase of restoration consisted of groundwater recirculation to spread the hydrogen sulfide*

reductant to modules MOD41 and MOD43. This phase of restoration was initiated in March 2003 and concluded in April 2004. The total volume of water associated with the groundwater recirculation phase is 1.0 PVs." (*Cf.* SEI009A at p.2-35 and 2-36).

The results from Christensen ranch show severe contamination of uranium occurred while following the standard NRC groundwater restoration plan, which is also being proposed for the Ross ISL operation. Average groundwater uranium concentrations increased from 0.044 mg/L to 3.83 mg/L during the last stability round sampling event, an increase of roughly 87x, as summarized below. I created the table below based solely on the data provided by the NRC at: JTI005A-R; p.65-84). Further, concentrations as high as 16 mg/L were observed in one well, which is 533x the drinking water standard (0.03 mg/L). If this is any indication, similar groundwater degradation at the Ross project is inevitable.

Baseline			Post-restoration, Stability Round 4 Sampling		
Average	0.044	mg/L	Average	3.83	mg/L
Max	0.37	mg/L	Max	16.0	mg/L
Min	0.005	mg/L	Min	0.009	mg/L
n	49		n	15	

COMPARISON OF AVERAGER BASELINE URANIUM GROUNDWATER CONCENTRATIONS AND POST-RESTORATION STABILITY ROUND 4 URANIUM CONCENTRATIONS FOR CHRISTENSEN RANCH ISL, MINE UNIT 4.

Q.22. In light of these examples, what is your professional opinion regarding the likely impact of the Ross Project on groundwater quality?

A.22. Relying on the examples the NRC cites in the FSEIS, the Christensen Ranch results shown above, and the examples I will discuss later in my testimony, it is my professional opinion

that it is inconceivable that the Ross Project will have a "SMALL and Temporary" impact on groundwater quality, as the FSEIS concludes (SEI009A; p. xxx). There is no discussion of the irretrievable and seemingly irreversible impacts of this process. To the contrary, if the FSEIS were to consider the actual baseline conditions on the site and compare those values to the reasonably anticipated conditions post-restoration, the FSEIS would disclose that the Ross Project will have significant environmental impacts. The public, and the agency, should confront this reality before allowing this project to proceed.

Q.23. We have discussed your concerns with the other sites relied upon. In your professional opinion, is there more the FSEIS could have, and should have, disclosed regarding the likely outcome at the Ross Project, other than referring to other sites?

A.23. Absolutely. While it is of course impossible to predict precisely what the post-restoration values are going to be at the site, the experience at these other sites allow the Staff to, at the very least, prepare a bounding analysis disclosing the boundaries of the likely outcomes. Such a meaningful bounding analysis would show quantitatively – derived from a representative number of sites – what the actual groundwater impacts would be rather than a few anecdotal and qualitative conclusions such as Staff presents in the FSEIS. Further, Staff certainly has the resources to visually present and analyze the restoration results for a number of sites. As will be discussed later in my testimony, I have done just such a visual presentation for two sites. By failing to confront the degradation of water quality that is, in my professional opinion, certain to be the result of this project, or to disclose a detailed analysis of what I consider to be the likely outcomes, the FSEIS has fundamentally masked serious and irretrievable degradation of environmental resources.

Discussion of Restoration Criteria

Q. 24. Let's talk about timeframes for restoration and their relationship to the FSEIS's failure to evaluate the virtual certainty an Alternative Concentration Limit (ACL) will be required. Has the NRC done an adequate job of presenting and analyzing how long restoration will take to restore to primary, secondary, or ACL standards and the relationship between the timeline and likely outcomes?

A. 24. No. This is true for several reasons that I will now detail. As an initial matter, the suggested eight-month restoration period is far too short and inadequate to restore to either a baseline or secondary standard given the past history of failed ISL restorations at other ISL sites. Such a short time period inevitably consigns the affected aquifer to even more significant degradation than might occur with a longer effort.

Proposed restoration timeframes are based on the NRC definition of a pore volume as "*a term used by the ISL industry to represent the volume of water that fills the void space in a given volume of rock or sediment* (FSEIS; p. 2-36)". Here, the FSEIS relies on Strata's estimate that 9.5 pore volumes is an acceptable limit (SEI009A; p. B-46). 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 examples from the Irigaray ISL site and Christensen Ranch mine unit 4.

But the FSEIS provides no basis for that prediction other than the claim that it is "*within the range currently used by the uranium-recovery industry*." Given the experience at other ISL sites, where as I have discussed previously, groundwater quality has been seriously degraded; relying upon the pore volume from other sites only further confirms the serious groundwater contamination results are inevitable from this project. Only if the FSEIS disclosed that Strata would pump many *more* pore volumes than has occurred at other ISL sites could the FSEIS have predicted that the results here might be better than at these other sites.

Moreover, the low pore volume estimate ties directly to the likely outcome at the site in light of what has happened elsewhere. As I have explained, one of the bases on which restoration has been deemed adequate elsewhere is that "best efforts" have been made over a long period of time. Here, since NRC has only required a financial security tied to this inadequate pore volume estimate, it is likely that – as has occurred elsewhere – a higher level of remaining groundwater contamination will be permitted than would occur had a scientifically rigorous estimate been prepared as to the pore volume likely to be necessary to restore groundwater to something even approaching true baseline levels.

Storymap visual representations of data which support Contention 2

Willow Creek ISL - Baseline Water Quality and Post-Restoration Water Quality

Dr. Larson, you have created visual representations to illustrate changes in groundwater quality at ISL uranium recovery sites. We have here JTI005B-R, Storymap #1, *A Visual Representation Of The Failure to Restore Contaminated Groundwater at a Selected Portion of the Willow Creek ISL Uranium Mining Site*. We also have JTI005B-R, Storymap #2, *A Visual Representation Of The Failure to Restore Contaminated Groundwater & Depiction of Near-Surface Contamination at a Selected Portion of the Smith Ranch ISL Uranium Mining Site.*

Q. 25. First, what is meant by the term "Storymap"?

A. 25. A Storymap is a visual, interactive representation of spatial data coupled with detailed descriptions of the significance of the data. If a user is shown a static map or a spreadsheet, without context or the ability to interact, it is much more difficult to assimilate the information. Storymaps are a way of allowing any user to understand the data in a meaningful context.

Q. 26. Alright, now let's get started on how you created these visual representations. Is Storymap a computer assisted GIS program that is commercially available? Where would

one be able to purchase it? Does the program rely upon you for all information necessary for the program to generate accurate visual representation?

A. 26. The software package is commercially available by ESRI, termed ArcGIS. ArcGIS is commonly used by engineers, military, academics, community planners, and scientists (http://www.esri.com/). Contained within ArcGIS, ArcMap was specifically used to assimilate, locate, and organize the NRC's spreadsheet data to spatial locations. In certain instances, industry maps were 'georeferenced' to provide increased accuracy of wells and/or approximate locations of uranium ore and wellfields. Georeferencing is the process of calibrating maps (which do not have physical locations in GIS) to known spatial locations. This is a common practice to increase the accuracy of spatial data.

The ArcMap files were converted to an interactive application provided by ESRI, termed 'Storymaps'. Storymaps are ESRI's vehicle for providing ArcMap data into a story format, so that the relevance of the data can be explained to a broad audience. The software program is solely a means of displaying spatial data and has no effect on the data quality or source.

Q. 27. Where can the Board find the Storymap on the web and how can they be accessed?

A. 27. The interactive maps can be accessed by anyone with an internet connection at the following links:

Willow Creek – Christensen Ranch ISL ( ) - http://isl-uranium-recovery-impacts-nrdc.org/Willow-Creek/

Smith Ranch ISL - http://isl-uranium-recovery-impacts-nrdc.org/Smith-Highland/

Importantly, I am the only person that can alter the Storymaps or how the underlying source data can be imported into the program.

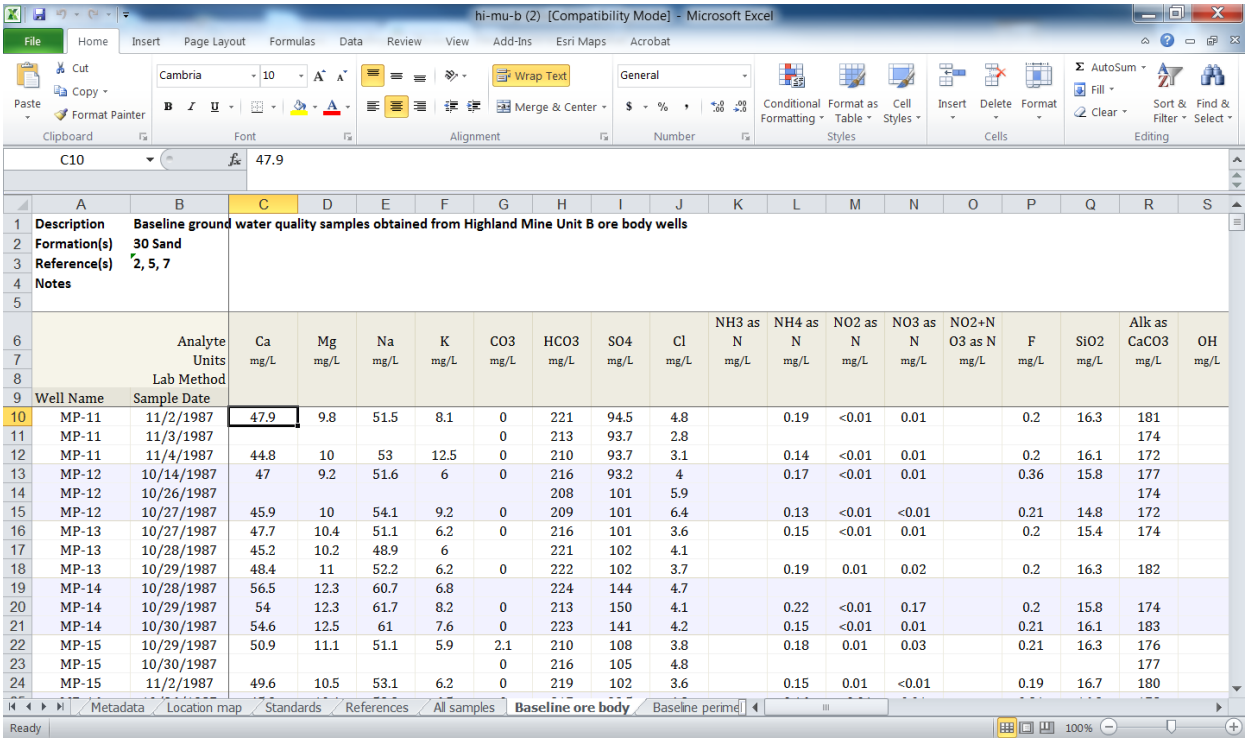
Q. 28. Before we walk through what the Storymaps tell us, where did you obtain the data you used to create these visual representations?

A. 28. The NRC has provided groundwater data for commercial ISL operations in spreadsheet format. The spreadsheets can be found on the NRC website for ISL operations, but are attached at JTI005A-R. However, much of the environmental groundwater data stored in these spreadsheets are in a format that the general public would have a hard time locating, interpreting, and understanding the significance. Therefore, to make the groundwater impacts from ISL operations visual, I created two interactive maps that allow any user to view the results and impacts of ISL recovery. You can click on various wells to learn more information about concentration values, specific well numbers, and the history of excursions. All data is sourced with the original document or spreadsheet locations online. The information is taken from NRC published data and reports, which are all publically available.

Q. 29. So every piece of data you used came from the NRC website?

A. 29. Yes, the data originated from industry reporting baseline water quality in the ore body, overlying, underlying and perimeter monitoring wells. In all of the wells, the term *baseline* (i.e. not the new term "*commission-approved background*") is consistently used to show the data used to assess excursions and compare restoration results. Therefore, while NRC staff has recently changed the terminology of these samples as either "*post-licensing, pre-operational ground-water monitoring*" (SEI009A; p. 2-25) or "*commission-approved background*", the term "baseline" will be used throughout the Storymaps to stay consistent with the NRC staff's terminology used in the NRC staff provided spreadsheets. I have included a screen shot of the Smith Highland Mine Unit B to demonstrate what the NRC spreadsheet displays (see figure

below, all data at JTI005A-R). Any usage of the term 'baseline' within the Storymaps is synonymous with the NRC staff's new definitions "*post-licensing, pre-operational ground-water monitoring*" or "*commission-approved background*", and not the old definition of '*baseline*' as used throughout the NRC staff's provided data.



hi-mu-b (2) [Compatibility Mode] - Microsoft Excel

C10: 47.9

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
1	Description	Baseline ground water quality samples obtained from Highland Mine Unit B ore body wells																	
2	Formation(s)	30 Sand																	
3	Reference(s)	2, 5, 7																	
4	Notes																		
5																			
6		Analyte	Ca	Mg	Na	K	CO3	HCO3	SO4	Cl	NH3 as N	NH4 as N	NO2 as N	NO3 as N	NO2+NO3 as N	F	SiO2	Alk as CaCO3	OH
7		Units	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
8		Lab Method																	
9	Well Name	Sample Date																	
10	MP-11	11/2/1987	47.9	9.8	51.5	8.1	0	221	94.5	4.8		0.19	<0.01	0.01		0.2	16.3	181	
11	MP-11	11/3/1987					0	213	93.7	2.8								174	
12	MP-11	11/4/1987	44.8	10	53	12.5	0	210	93.7	3.1		0.14	<0.01	0.01		0.2	16.1	172	
13	MP-12	10/14/1987	47	9.2	51.6	6	0	216	93.2	4		0.17	<0.01	0.01		0.36	15.8	177	
14	MP-12	10/26/1987						208	101	5.9								174	
15	MP-12	10/27/1987	45.9	10	54.1	9.2	0	209	101	6.4		0.13	<0.01	<0.01		0.21	14.8	172	
16	MP-13	10/27/1987	47.7	10.4	51.1	6.2	0	216	101	3.6		0.15	<0.01	0.01		0.2	15.4	174	
17	MP-13	10/28/1987	45.2	10.2	48.9	6		221	102	4.1									
18	MP-13	10/29/1987	48.4	11	52.2	6.2	0	222	102	3.7		0.19	0.01	0.02		0.2	16.3	182	
19	MP-14	10/28/1987	56.5	12.3	60.7	6.8		224	144	4.7									
20	MP-14	10/29/1987	54	12.3	61.7	8.2	0	213	150	4.1		0.22	<0.01	0.17		0.2	15.8	174	
21	MP-14	10/30/1987	54.6	12.5	61	7.6	0	223	141	4.2		0.15	<0.01	0.01		0.21	16.1	183	
22	MP-15	10/29/1987	50.9	11.1	51.1	5.9	2.1	210	108	3.8		0.18	0.01	0.03		0.21	16.3	176	
23	MP-15	10/30/1987					0	216	105	4.8								177	
24	MP-15	11/2/1987	49.6	10.5	53.1	6.2	0	219	102	3.6		0.15	0.01	<0.01		0.19	16.7	180	

Metadata | Location map | Standards | References | All samples | Baseline ore body | Baseline perime

Ready

Q. 30. And each piece of data on the NRC spreadsheets on the agency's website has an ADAMS accession number associated with it?

A. 30. Yes, the ADAMS accession numbers are located in the "References" tab in each spreadsheet.

Q. 31. Can you link directly to the original data from either Storymap?

A. 31. Yes. I include on the left hand side of the screen in the text a link to the NRC spreadsheets and their associated data.

Q. 32. Did you modify, alter or change the data in any way?

A. 32. No, I did not modify the data, although I did have to average the data to provide a representative baseline value. Specifically, in each spreadsheet there are four baseline samples taken over time. In the Storymaps I created, the four baseline samples were averaged to create one baseline sample for each well. This is to show representative baseline conditions in the well. I take no position on the adequacy of the baseline concentrations in the NRC spreadsheets. I am simply analyzing the available data. Baseline values were rounded to the nearest hundredth decimal place by the Storymap. When samples measured below detection, the lowest detection limit (rather than using zero, which would bias averages to lower sample magnitudes) was used in the averaging process (i.e. <0.0003 mg/L = 0.0003 mg/L). The color scheme was arbitrarily set by the Storymap template.

Q. 33. And with the display of the post restoration phase and excursion phase (also on the left) – are they displayed the same way?

A. 33. Essentially yes. Again, each well is demarcated by a dot. The post restoration phase has a color scheme associated with it to indicate a range of values. However there, the last round of sampling was used for the color scheme. But, I have ensured exact well concentration magnitudes are presented when specific wells are selected. With respect to the excursions, horizontal excursions are quotes from NRC staff copied directly from the NRC's comments on the Christensen Ranch restoration report (JTI035; various sections throughout). The shallow

uranium and selenium concentrations observed at Smith Highland were selected from the first sample taken from each well (JTI036; p. 57-85).

Q. 34. So in short, from the perspective of the data, this is simply a visual representation of the spread sheets that can be found on NRC's websites?

A. 34. Yes, the Storymaps display NRC's groundwater data in a suitable format for a general audience.

Q. 35. Does the program draw assumptions from data? Or is the data entirely from the sources you import into the program?

A. 35. Again, as I described above, relative color hues are created by the program. The program places or "bins" the ranges of concentrations into groups which it identifies by color hues. The color schemes were held close for baseline and post-restoration samples so as to not mislead the user. However, regardless of relative color schemes, any well can be selected to show the exact baseline concentration magnitude or concentration changes over time.

Q. 36. Are there multiple calculations/manipulations of data?

A. 36. No. The program simply demonstrates the source data provided by the NRC spreadsheets into a spatial, graphical format that any user can visualize the groundwater impacts of ISL. Average values were calculated for baseline and all values were shown for stability rounds 1-4.

Q. 37. So what do we know about the data from the NRC sources – is the spreadsheet data collected by routine and consistent procedures and/or methods?

A. 37. The spreadsheets contain links to original document sources via the 'reference' tab. According to the NRC website which supplied the spreadsheet data (JTI005A-R),

"*The links below contain in-situ recovery (ISR) wellfield baseline and restoration ground water quality data collected from the licensed ISR Smith Ranch site for regulatory purposes. Hard copies of this information are publicly available in ADAMS, ADAMS legacy or in State records, however, to improve public access to the data, standardized MS Excel spreadsheets are being made available. The spreadsheets listed below contain the ISR wellfield ground water quality data for Smith Ranch and Highlands Uranium Project mine units through January 2012*

(Contact: **ISRgroundwaterquality.Resource@nrc.gov***)"*

Note, '*baseline*' was used by NRC staff to describe the pre-mining groundwater data which was used to set monitoring well UCLs and groundwater restoration goals. Therefore, 'baseline' will be used throughout the Storymaps to describe the groundwater data used to set UCLs and assess restoration performance.

Q. 38. Is the spreadsheet data input in a routine matter, with little variation in way data is input into system?

A. 38. Spreadsheets are a similar format, regardless of the ISL operation. The NRC's spreadsheet template appears to be consistent regardless of operation or mine unit.

Q. 39. So, circling back to the finished product of the Storymaps– are your visual depictions verifiable or able to be duplicated?

A. 39. Yes, as long as a user has access to an internet connection, Microsoft Excel, and ArcGIS software package, and a thorough understanding of GIS, any user could replicate these

Storymaps. All of these software packages are very common place for science and engineering consultants. ESRI has provided step-by-step tutorials on how to create Storymaps from ArcGIS files.

Q. 40. So in summary, the Storymaps simply accurately and appropriately reproduce the spreadsheets in such a way as to make them visually intelligible?

A. 40. Yes, in a spreadsheet format, it is very difficult to collect, assimilate, and understand the groundwater impacts. I've simply made the spreadsheet data visual, to make the user able to understand the actual groundwater impacts from measured, quantitative data provided by the NRC staff.

Q. 41. So now that we've established what they are, let's turn to what they show. Let's look at the first screen.

A. 41. The first site we'll investigate is Willow Creek/Christensen Ranch ISL, mine units 2-6. The source groundwater uranium data for these mine units can be found here (JTI005A-R; p. 2-220). I have learned that parts of mine unit 5 have returned to production, and the groundwater chemistry there is considerably altered beyond what concentrations are shown (JTI037; p.1). These data are simply the 'first' baseline and 'first' post-restoration results at Willow Creek/Christensen Ranch ISR after active groundwater restoration and available via the NRC spreadsheets.

Q. 42. First we have to get it loaded up on the screen and working – can you walk us through the simple steps to do that?

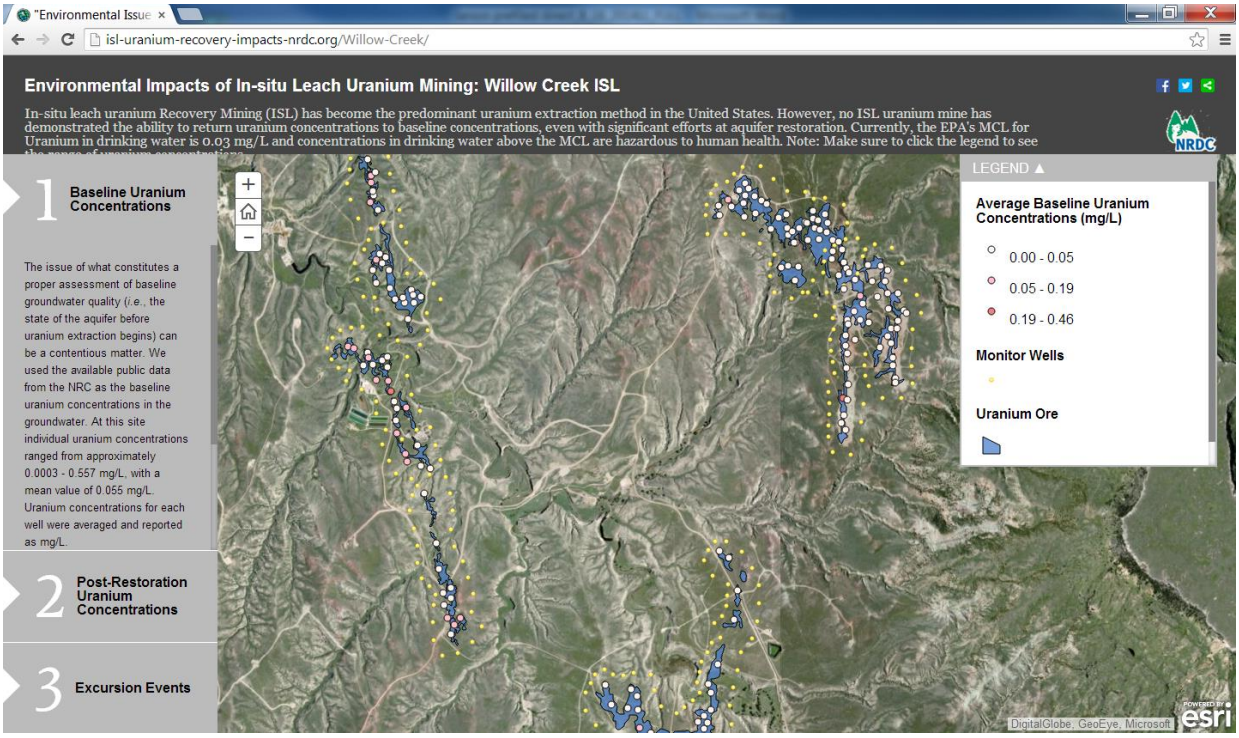
A. 42. The user can type, copy and paste, or 'click' the link http://isl-uranium-recovery-impacts-nrdc.org/Willow-Creek/ to access the storymap (JTI005B-R). Make sure the left hand tabs have

completely loaded before interacting with the map. Once the webpage is loaded, click the 'legend' to expand.

Q. 43. Now, that we are up and loaded, what are we looking at first?

A. 43. The first Storymap is broken into three tabs: 1) the 'baseline' uranium groundwater concentrations, 2) the post-restoration uranium groundwater concentrations, and 3) excursion reports. 1) 'Baseline' (Now termed - "*Commission-approved Background*" or "*Post-Licensing Site Characterization Background*") uranium concentrations are collected before mining occurs and are used to assess the restoration targets values and UCLs. 2) Four samples are collected for one year following restoration activities to determine if groundwater concentrations are not statistically increasing (i.e. 'stable'). 3) Excursions occur when measured excursion parameters exceed baseline UCLs due to escaping mining fluids, either horizontal or vertical.

The first screenshot seen below is the average uranium baseline groundwater concentrations (mg/L) for mine units 2-6 from an aerial viewpoint (below and JTI005B-R; p.2). The yellow dots are horizontal monitoring wells delineating various mine units, the blue regions are uranium ore, and the various interior wells are ore body sampling wells. The 'redness' of the interior wells is proportional to the average baseline uranium concentration observed at that well. A short description of the storymap is located above the map and left hand pane describes the baseline tab specifically.



Q. 44. So first let's understand the picture – you can cursor up and down, just as one would Google Earth or another such program, and then what?

A. 44. The user can fully interact with the map and pan north-south-east-west and to zoom in and out (to a certain extent). When selected, ore zone wells have a 'pop-up' window that displays addition information.

Q. 45. What's the listing on the left?

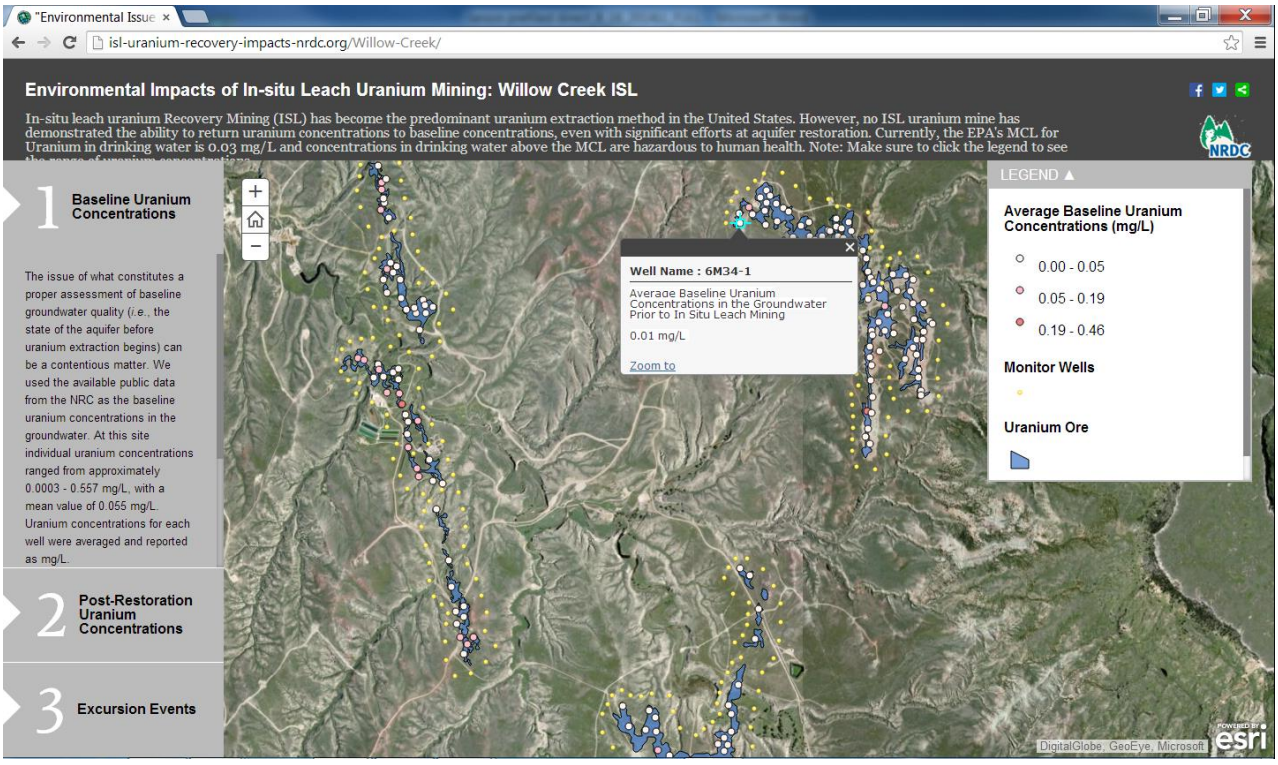
A. 45. The left pane shows three different tabs which display the 'story'. The first tab is already showing, which is the 'Baseline Uranium Concentrations'. A short description is located below the title. The second tab is labeled 'Post-Restoration Uranium Concentrations' and third 'Excursion Events'. If nothing shows on the left, 'refresh' the browser window.

Q. 46. Where is the legend to explain the map?

A. 46. The legend is located in the top right portion of the map. The legend can be 'clicked' to either expand or collapse.

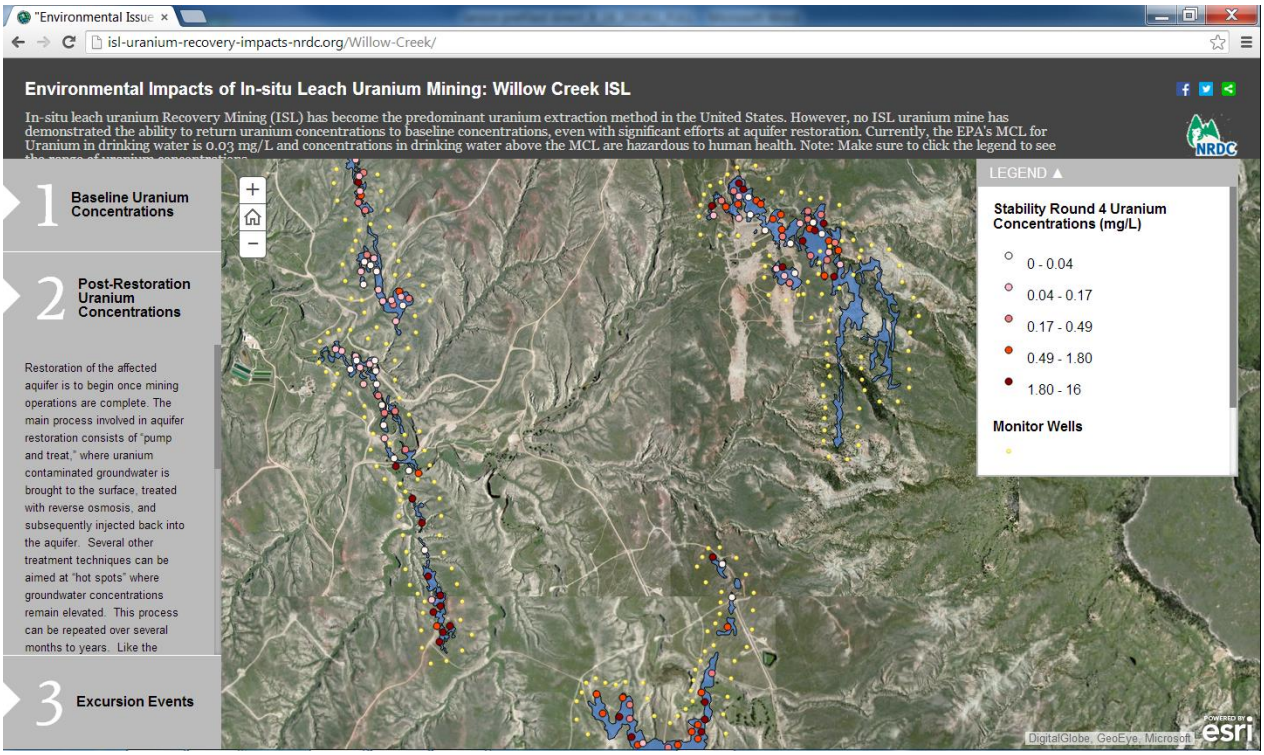
Q. 47. What happens if the user points to a circle on the screen, clicks with his or her mouse or keypad?

A. 47. To investigate any given well specifically, move the cursor over the interior well and 'click'. The image below shows the result of clicking on a given well (JTI005B-R; p.3). A small pop-up window appears which shows the average baseline uranium concentration (in mg/L) for that given well and the well name (6M34-1). The average uranium baseline concentration was 0.01 mg/L for this well.



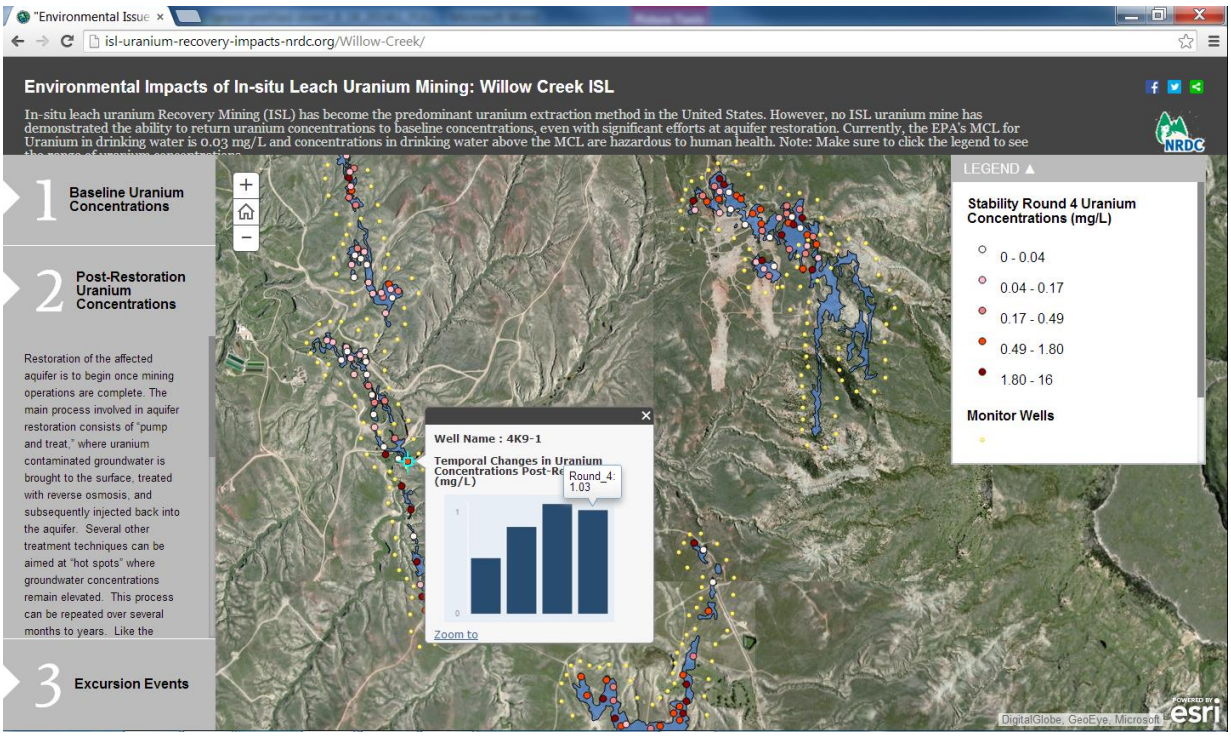
Q. 48. What does the second tab (Post-Restoration Uranium Concentrations) show in relation to the first tab (Baseline Uranium Concentrations)?

A. 48. Upon 'clicking' on the second tab (Post-Restoration Uranium Concentrations), immediately the user notices most wells have darkened considerably, due to contamination of uranium that could not be removed from the aquifer. These data show the measured uranium concentrations in groundwater once mining and groundwater restoration have occurred. Once restorations are completed, four stability measurements are taken to confirm the relative stability of the contaminants of concern.



Q. 49. What happens when a well is selected in the Post-Restoration Uranium Concentrations tab?

A. 49. Different from the baseline tab, all four stability rounds are shown in the pop-up window (see image below, for well 4K9-1) (JTI005B-R; p.5). Only the fourth round sampling concentrations were used to indicate the level of red shade.



Q. 50. What does the vertical axis tell us?

A. 50. The vertical y-axis shows the groundwater uranium concentration (in mg/L) for a given well. The range of values on the y-axis were automatically created by the storymap application based upon the range of minimum and maximum concentrations observed at that given well. However, the user can scroll-over any bar to see the exact concentration of uranium in mg/L (see figure above – 1.03 mg/L or ~34.3x the safe drinking water limit).

Q. 51. And what does the horizontal axis tell us?

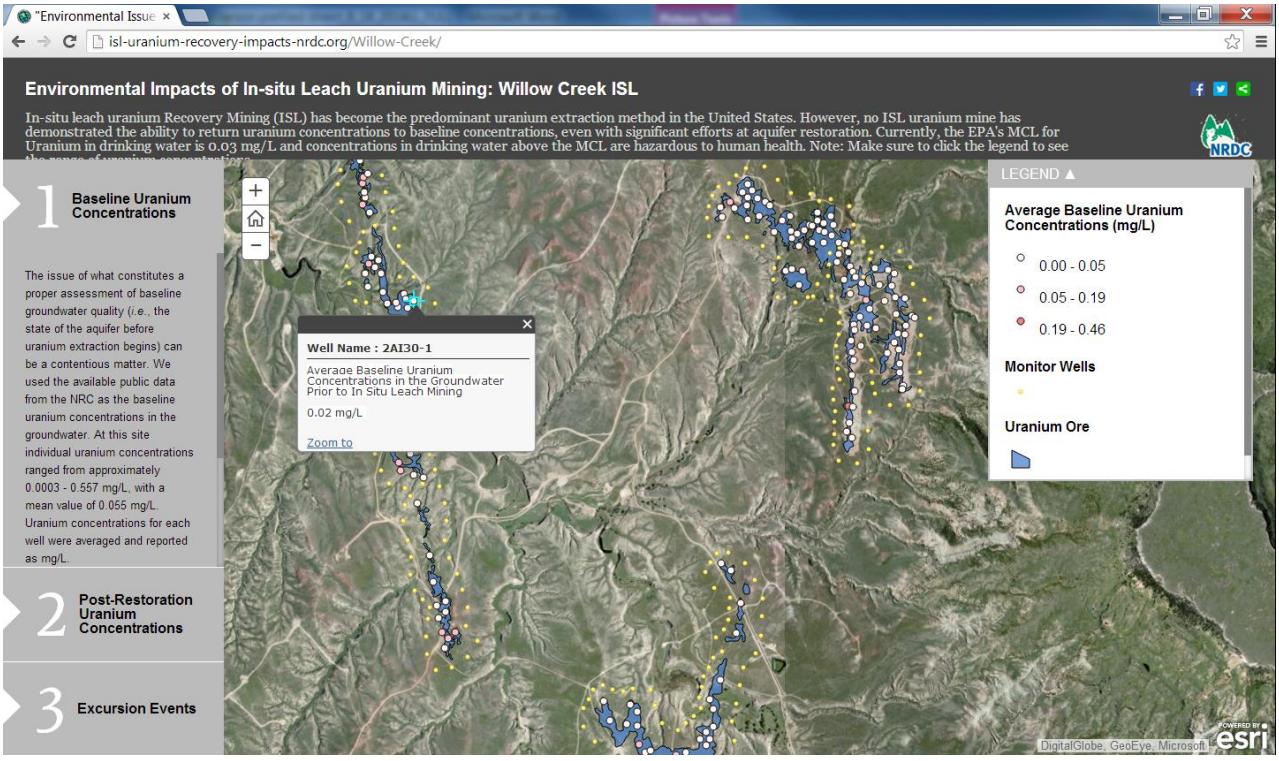
A. 51. No data is located on the x-axis. The x-axis simply shows the temporal sampling events for a given well. In other words, each column was one groundwater stability sample. Exact sampling dates are located in the original spreadsheets.

Q. 52. Now that we've scrolled around the screen a bit, let's start with some examples of what the Willow Creek Storymap shows us. Let's look at a specific well and start with its baseline number.

A. 52. Selecting the 'baseline' tab again: the first well selected was located in mine unit 2, named 2AI30-1.

Q. 53. What is the original baseline here?

A. 53. The NRC staff's spreadsheet data presented for the baseline concentrations as 0.026, 0.037, 0.022, 0.004 mg/L, resulting in an average concentration of 0.0223 mg/L. When 2AI30-1 is selected, the baseline value presented is 0.02 mg/L, which was rounded to the nearest hundredth decimal (JTI005B-R; p.6).

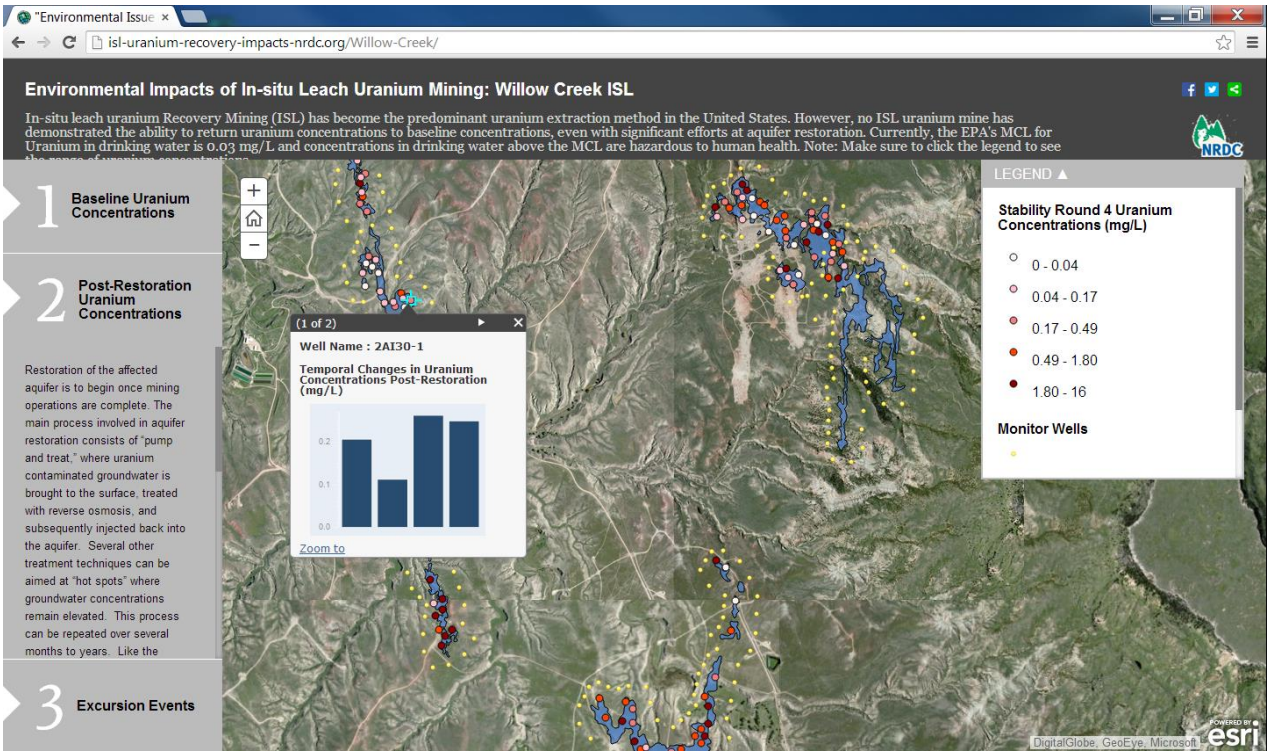


Q. 54. And you can access the data and spreadsheet the information came from?

A. 54. Yes, the original NRC staff's spreadsheet is located at the following link (JTI005A-R; p. 2-220). Or the user can access this well specifically by opening the original excel file titled "Christensen Ranch Mine Unit 2", and selecting the 'Baseline ore body' tab.

Q. 55. Now let's turn to what happened with that well. How do I find that?

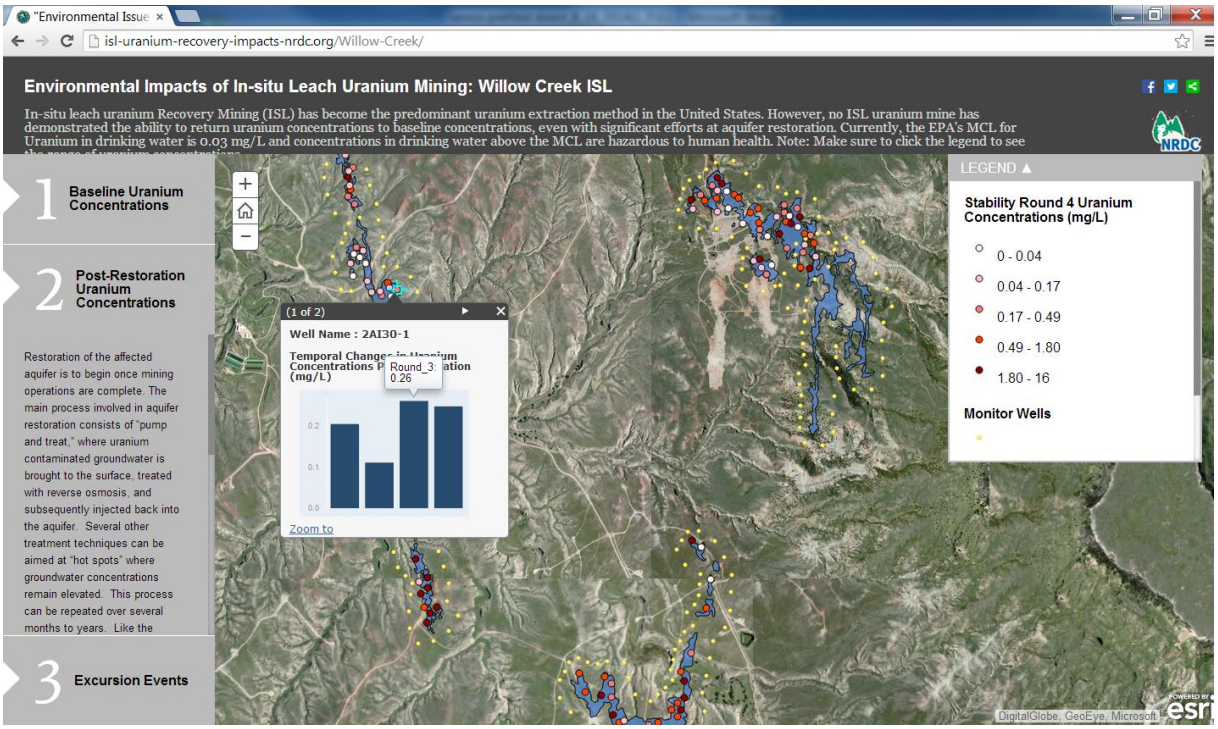
A. 55. Now click the tab on the left side of the screen labeled "Post-Restoration Uranium Concentrations", find well 2AI30-2 in mine unit 2, and click the well again. Notice that the well has a slightly darker red color, indicating the uranium concentration has increased substantially relative to the baseline average.



Q. 56. Let's look to see what happened with the same well. What is meant by "post-restoration" and what does the reader see here? What do each of the columns represent?

A. 56. When well 2AI30-1 is selected, the pop-up window displays four columns instead of a single value. These columns represent the four stability sampling rounds which occurred after

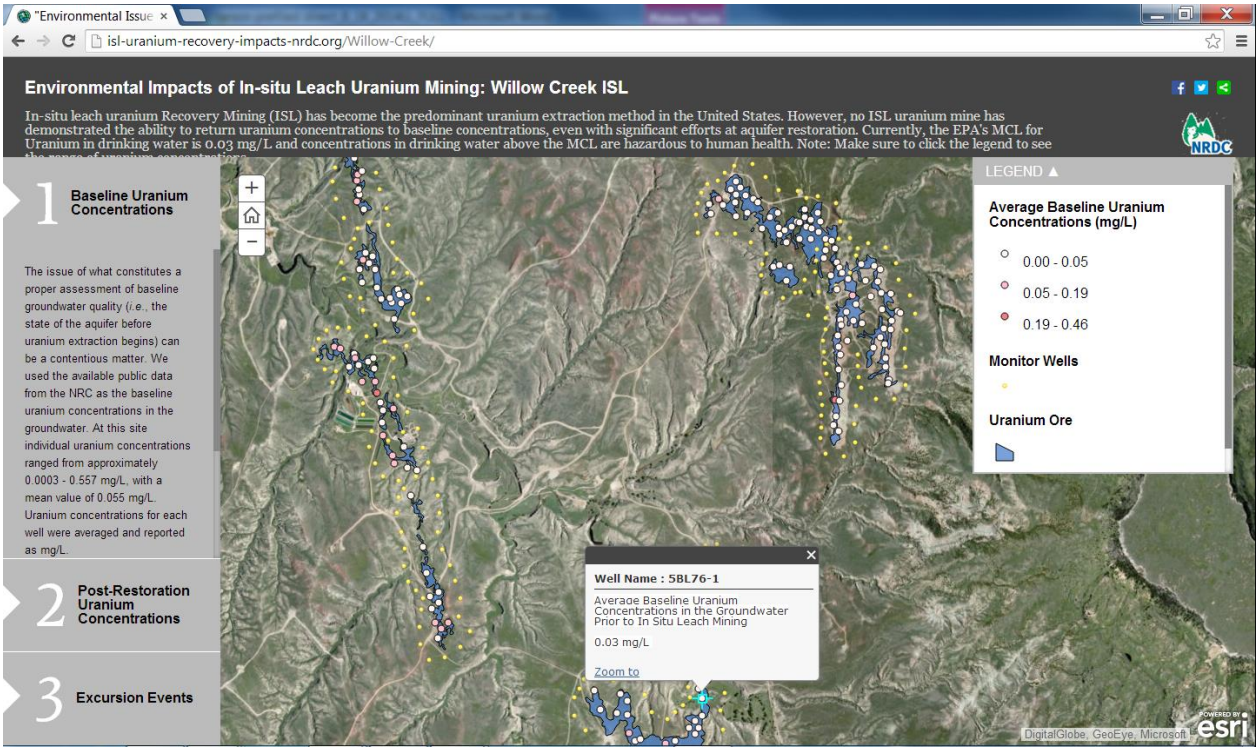
active groundwater restoration. According to the NRC staff's spreadsheet, the sample dates were 4/8/2004, 7/15/2004, 10/12/2004, and 1/4/2005, indicating that the entire stability sampling for this well was approximately nine months. According to the NRC staff's spreadsheet, the corresponding uranium concentrations were as followed, 0.207, 0.113, 0.263, 0.25 mg/L. These values become apparent when you 'scroll' over the columns with the mouse cursor (JTI005B-R; p.8). At this well after active restoration, the lowest observed uranium concentration (0.113 mg/L) was approximately 5x higher than the average baseline concentration (0.0223 mg/L) and approximately 3.8x higher than safe drinking water standards (0.03 mg/L).



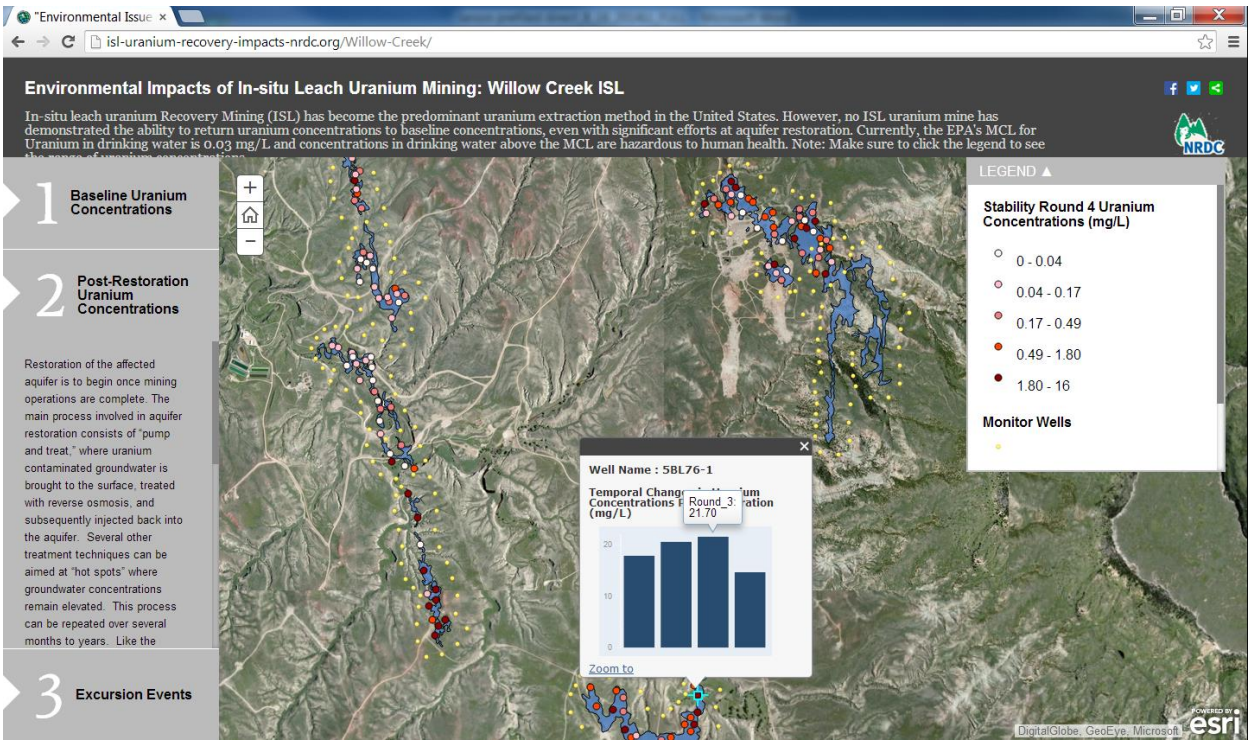
Q. 57. What about the restoration results at other wells?

A. 57. Let's examine another example of groundwater contamination. Select the 'Baseline Uranium Concentrations' tab and select well 5BL76-1 in mine unit 5 (JTI005B-R; p.9). According to the NRC staff's spreadsheet, the average baseline uranium concentration was ~0.03

mg/L (0.027, 0.031, 0.021, and 0.024 mg/L taken 9/1/1994, 9/15/1994, 9/28/1994, and 10/12/1994, respectively).



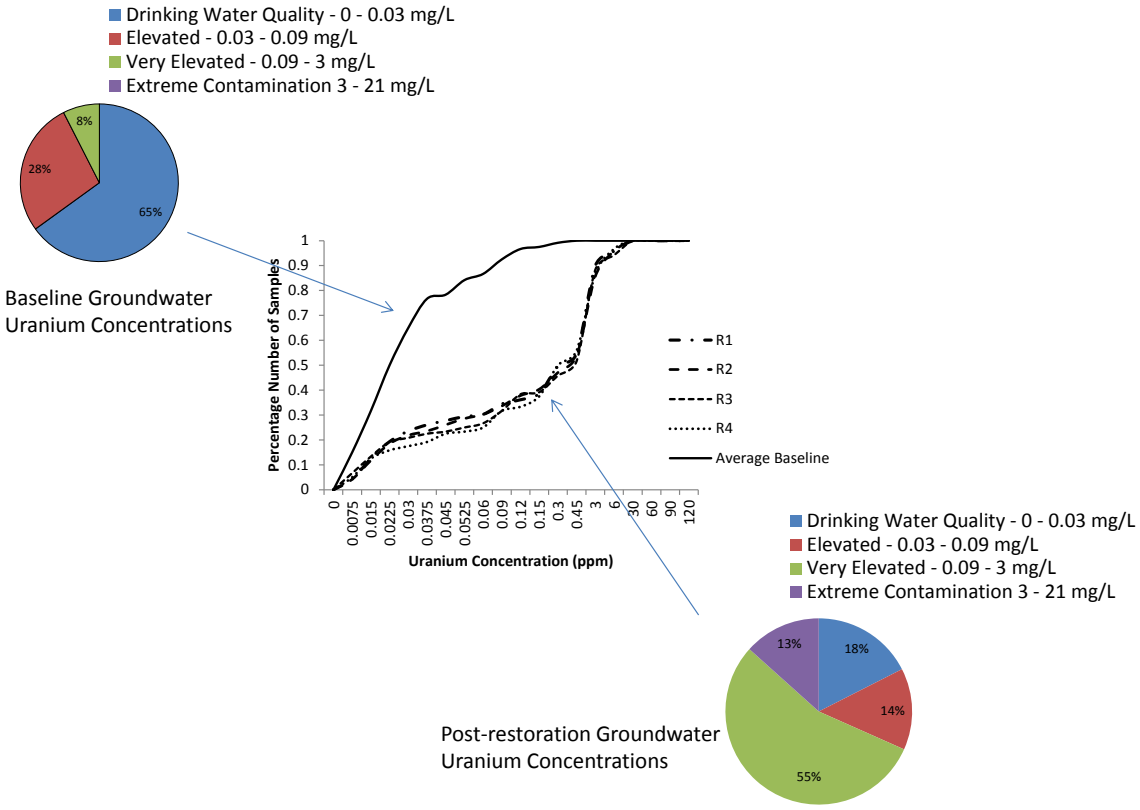
To observe the impacts of ISL mining, select the 'Post-Restoration Uranium Concentration' tab and select well 5BL76-1 (JTI005B-R; p.10). Scroll over the various blue columns to view the groundwater uranium concentration values after active restoration was complete. The observed groundwater uranium concentrations can only be described as extreme: 18.0, 20.7, 21.7, and 14.8 mg/L which were 600x, 690x, 723x, and 493x average baseline and safe drinking water standards. This well represents the highest concentrations of uranium in groundwater observed from the Christensen Ranch ISL operation from this data set. I encourage the reader to select various wells to observe specific impacts (JTI005B-R).



Q. 58. Is there a way to look at this data set holistically? That is, can we see the entirety of the impact to the aquifer? For example, what is the difference for all samples, between average baseline and post-restoration uranium concentrations?

A. 58. Yes we can look at the data as a whole and I have analyzed the sample well distributions between average baseline and post-restoration uranium concentrations due to ISL and groundwater restorations. Using the entire wellfield data set from Christensen Ranch MU2-6, I created a cumulative histogram for average baseline and each post restoration phase sampling round concentrations (denoted as "R1, R2, R3, R4"). The figure below shows the results of the analysis, displaying the distribution of data, in this case, cumulative distribution of data. The y-axis shows the percent number of samples which observe uranium concentrations at various magnitudes. To interpret the figure, choose a concentration of uranium (for example: 0.03 mg/L), and read the corresponding value on the y-axis. For pre-mining baseline conditions, the

percentage of samples with concentrations of 0.03 mg/L or less is approximately 65%, while post-restoration samples show the percentage of samples at or below 0.03 mg/L was approximately 18%. The pie charts summarize these distributions, for average baseline conditions (top left) and post-restoration conditions (bottom right).



Q. 59. In light of what this chart show us, how do ISL activities change the groundwater quality distribution of uranium concentrations?

A. 59. Elevated uranium concentrations (0.03-0.09 mg/L) were observed in 28% of the baseline samples and very elevated (0.09 – 3.0 mg/L) represented 8% of the baseline samples, however the majority of the average baseline groundwater samples were below the MCL for uranium of 0.03 mg/L (~65%, n = 120).

Upon mining and restoration activities, the groundwater quality sample distribution shows significant changes to these observed percentages. For example, a new category termed 'extreme contamination' was created to describe samples >3.0 mg/L (>100x safe drinking water standards). These 'extreme contamination' samples represented roughly 13% of all observed post-restoration groundwater wells. Further, the 'very elevated' uranium concentrations increased from 8% (Baseline) to 59% (Post-restoration). Finally the drinking water quality samples decreased from approximately 2/3 of all samples, to roughly 18% of the observed samples. This analysis demonstrates, quantitatively, the severe water quality degradation which occurs as a result of ISL mining, which is not disclosed or discussed in the FSEIS.

The total amount of groundwater affected from ISL mining at Christensen Ranch mine unit 2-6 was estimated by industry as 1.04 billion gallons of groundwater (JTI038, p.21).

Q. 60. What do these results tell us about the potential impacts to the groundwater from the Ross project and the need to evaluate information regarding the reasonable range of hazardous constituent concentration values that are likely to be applicable if the applicant is required to implement an Alternative Concentration Limit (ACL)?

A. 60. As discussed previously, Willow Creek/Christensen ranch, mine unit 4 (located in the bottom left of the Storymap, wells start with the number 4), the same restoration process was followed as proposed in the Ross FSEIS.

For example: The NRC staff states (JTI035; p. 33):

"*As reported by the licensee, production at MU-4 was initiated in June 1994 at MOD42, August 1994 at MOD43, and December 1994 at MOD41. Operations continued until August 1997. Groundwater sweep phase of the restoration was initiated at all three modules in August 1997 and completed at all modules in July 1998. The volume of water associated with the groundwater*

sweep activities was 1.93 PVs. After a three year hiatus, the next phase of restoration consisted of the groundwater treatment with RO permeate injection. This phase was initiated at MOD43 in April 2001, and at the other two modules in February-March 2002. The groundwater treatment phase was completed by March 2003. A total of 9.84 PVs is associated with the groundwater treatment phase. Injection of hydrogen sulfide gas as a reductant was initiated during the final stages of the groundwater treatment phase for MOD42 from January 2003 to March 2003. The final phase of restoration consisted of groundwater recirculation to spread the hydrogen sulfide reductant to modules MOD41 and MOD43. This phase of restoration was initiated in March 2003 and concluded in April 2004. The total volume of water associated with the groundwater recirculation phase is 1.0 PVs."

It's also important to note that the complete active restoration for this mine unit only, was roughly 11 months for groundwater sweep, 1-2 years for RO permeate injection, and roughly 13 months for groundwater recirculation.

Groundwater restoration techniques and pore volume requirements at this mine unit followed the same progression as described by the NRC staff for Ross (SEI009A; p.2-35 – p. 2-37) with a far shorter active groundwater restoration time frame of 8 months (SEI009A; p.2-35). Similar or worse, groundwater degradation at the Ross project is virtually inevitable and such impacts have not been meaningfully analyzed in the FSEIS.

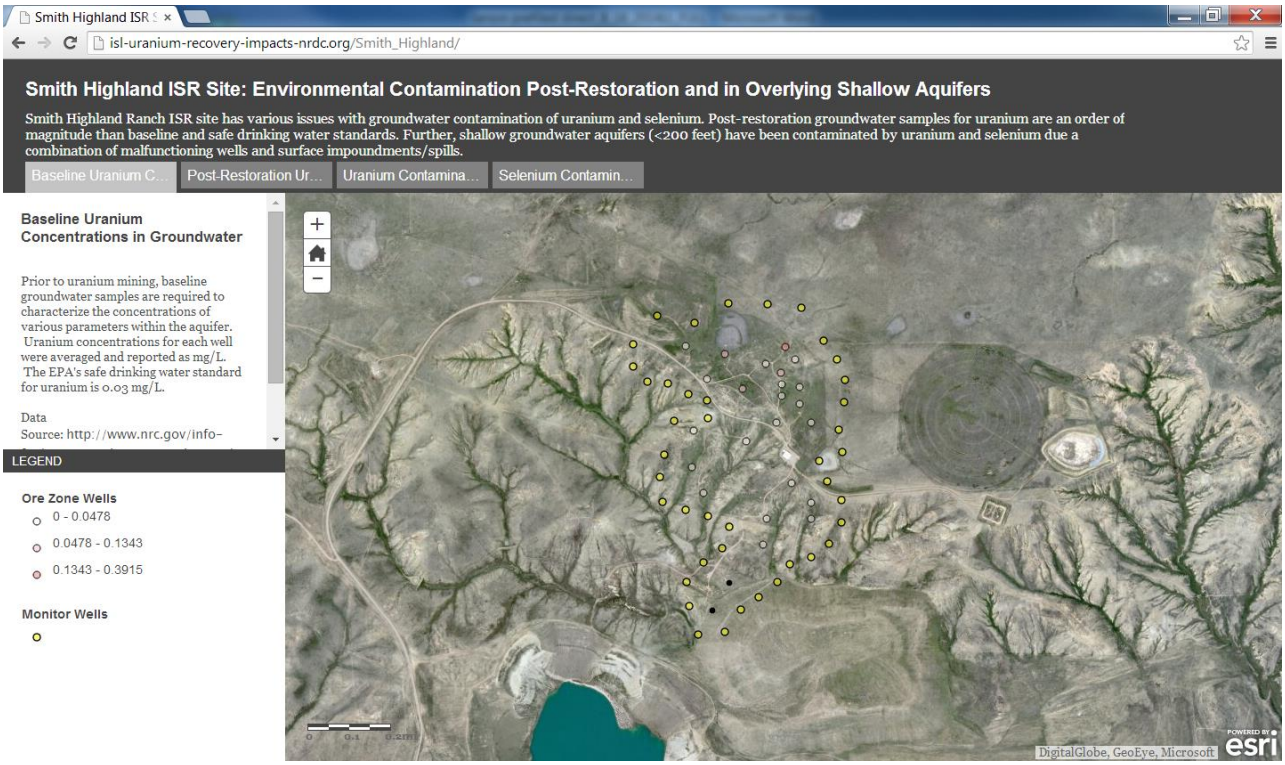
Smith Highland Mine Units A and B - Baseline/Post-restoration

Q. 61. Let's now turn to the second Storymap – Smith Ranch. We don't need to walk through all the steps we did before as it basically works the same –

A. 61. Yes, it works the same way. Follow the link http://isl-uranium-recovery-impacts-nrdc.org/Smith_Highland/. (JTI005B-R; p.1, 21-31). While fundamentally the same as the Willow Creek ISL Storymap, this Storymap has four tabs which are located below the header text (instead of three on the left hand side) and the legend is located in the bottom left hand corner (JTI005B-R; p.21). The monitor wells are in yellow and the ore zone wells are for both Smith Highland mine unit A and B. Mine unit A wells are MP-1, MP-2, MP-3, MP-4, and MP-5. Mine unit B wells are MP-11 through MP-31 (excluding MP-17; which was not included in the original NRC Staff's spreadsheet). Wells MP-26 and MP-27 do not have publically available baseline data, therefore are represented as black dots. However, post-restoration data was available for these wells, though comparison to baseline is not possible. While spatially overlapping, the difference between mine units A and B is the depth to the uranium ore was variable for either operation. The screen shot below is an overview shot of Smith Highland A and B. And again, I take no position on the adequacy of the NRC's baseline information. I am simply working with the available data from the agency.

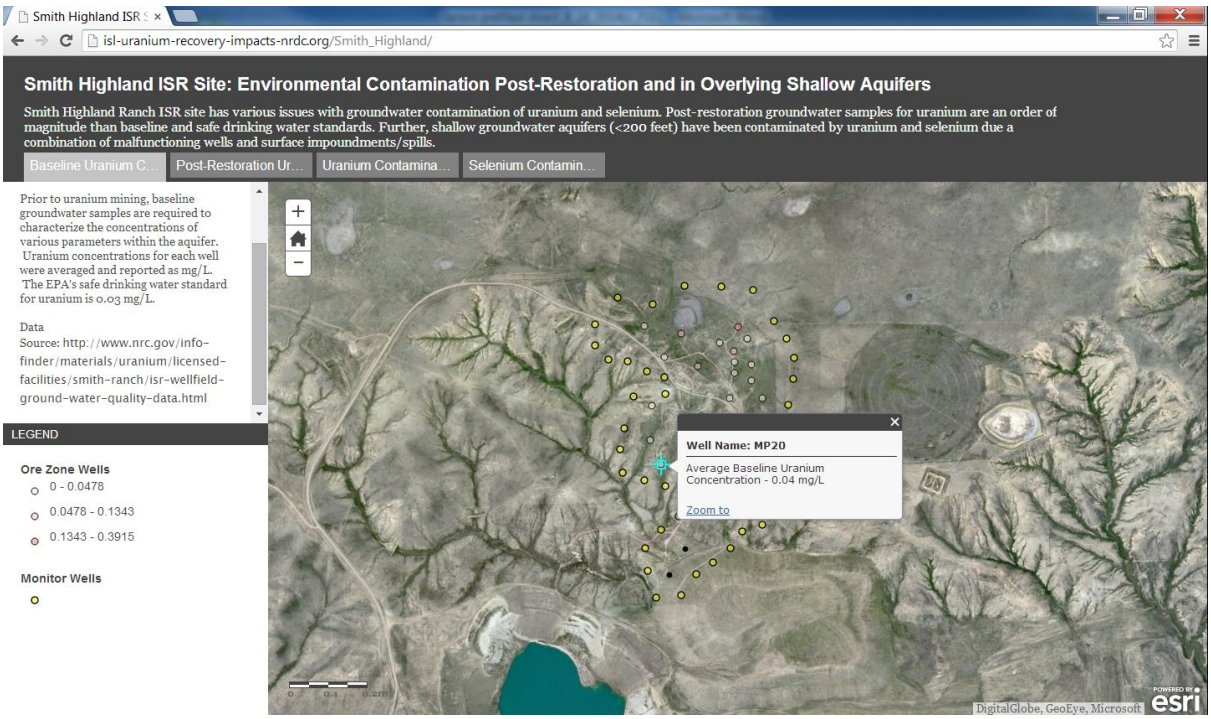
According to the NRC Staff's spreadsheet, for Smith Highlands mine unit A (Mine unit A and mine unit B are separate uranium ore bodies located at different depths, though spatial locations are overlapping), the start of restoration period was 7/1/1991 and the end of restoration period was 12/1/1998, which was approximately 6.5 years of active restoration. For mine unit B, the start of restoration period was 7/1/1991 and the end of restoration period was 6/1/2004, which was approximately 13 years (JTI039; p. 25 in pdf; p.16 in document). Due to the spatial proximity, Smith Highland mine units A and B will be displayed together. However, it should be noted that the groundwater ISL processes and restoration attempts occurred at different depths.

It should also be noted that the groundwater restoration from Smith Highland mine unit A has been approved by the NRC (SEI009A; p. 4-46).



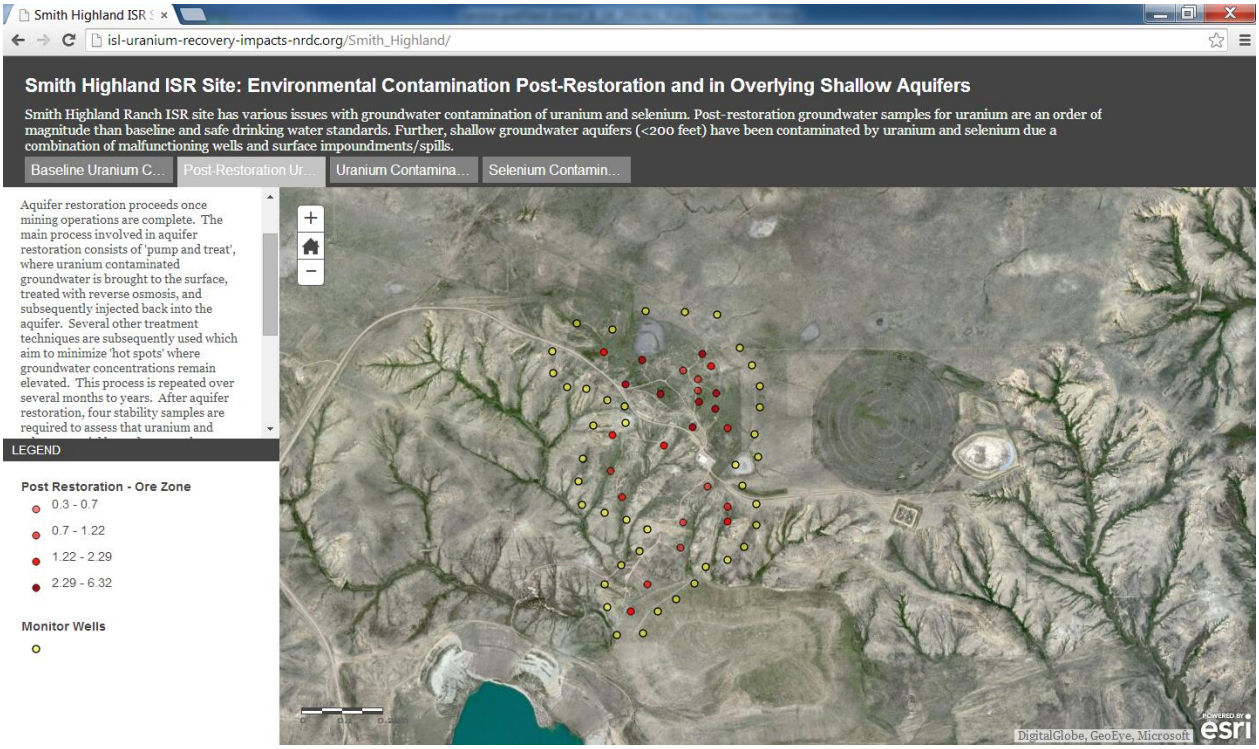
Q. 62. What happens when you select an ore body well under the 'Baseline Uranium Concentrations in Groundwater' tab (inside the monitor wells)?

A. 62. Similar to the Willow Creek Storymap, a 'pop-up' window displays the average baseline uranium concentration in mg/L. For well MP20, included in the screen shot below, the average baseline uranium concentration was approximately 0.04 mg/L, slightly above EPA's drinking water standard (0.03 mg/L). The range of average uranium baseline concentrations were roughly 0 – 0.39 mg/L.



Q. 63. How successful was groundwater restoration at Smith Highland, mine units A and B?

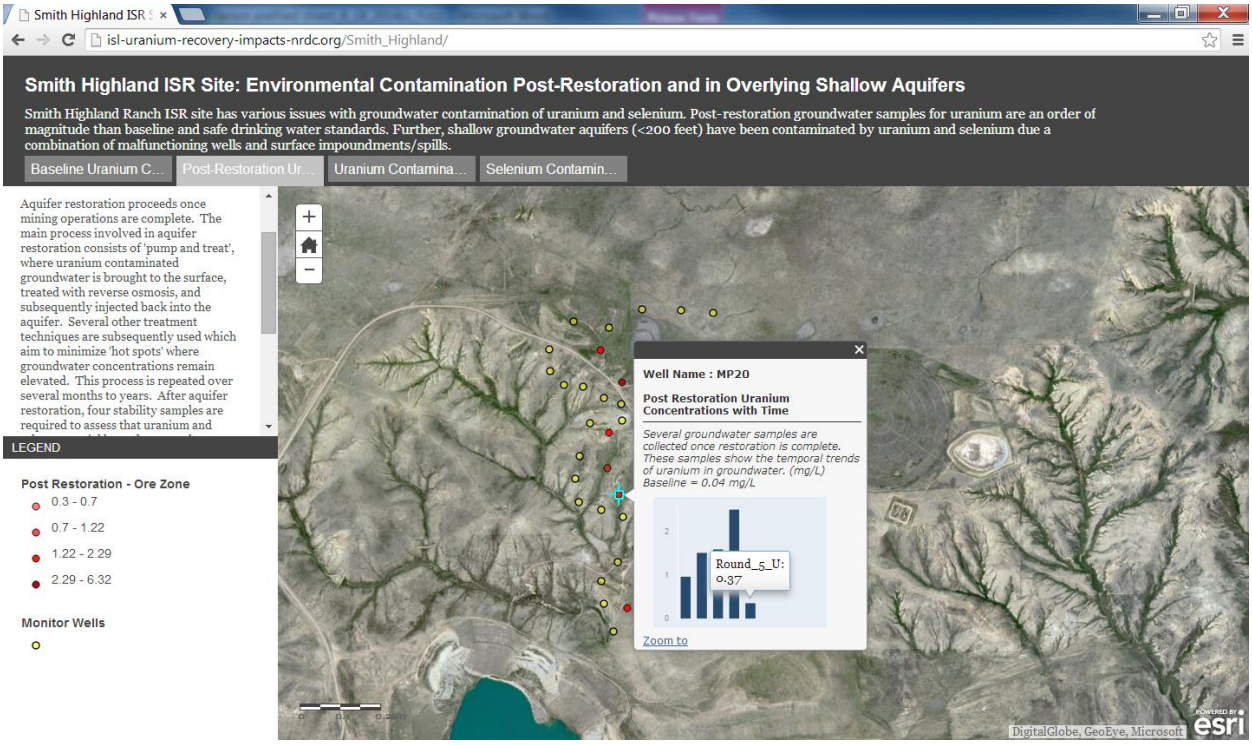
A. 63. Select the 'Post-Restoration Uranium Groundwater Concentrations" tab. Notice the immediate change in darkness of the ore body wells. Also notice the legend has changed to reflect the range of observed uranium concentrations has drastically darken to represent an increase in groundwater uranium concentrations. Uranium concentrations for the first sample post-restoration were 0.3 – 6.32 mg/L. I've included an overview shot of post restoration below (JTI005B-R; p.23).



Q. 64. Let's talk briefly about some wells when "Post-Restoration Uranium Groundwater Concentration" well is selected?

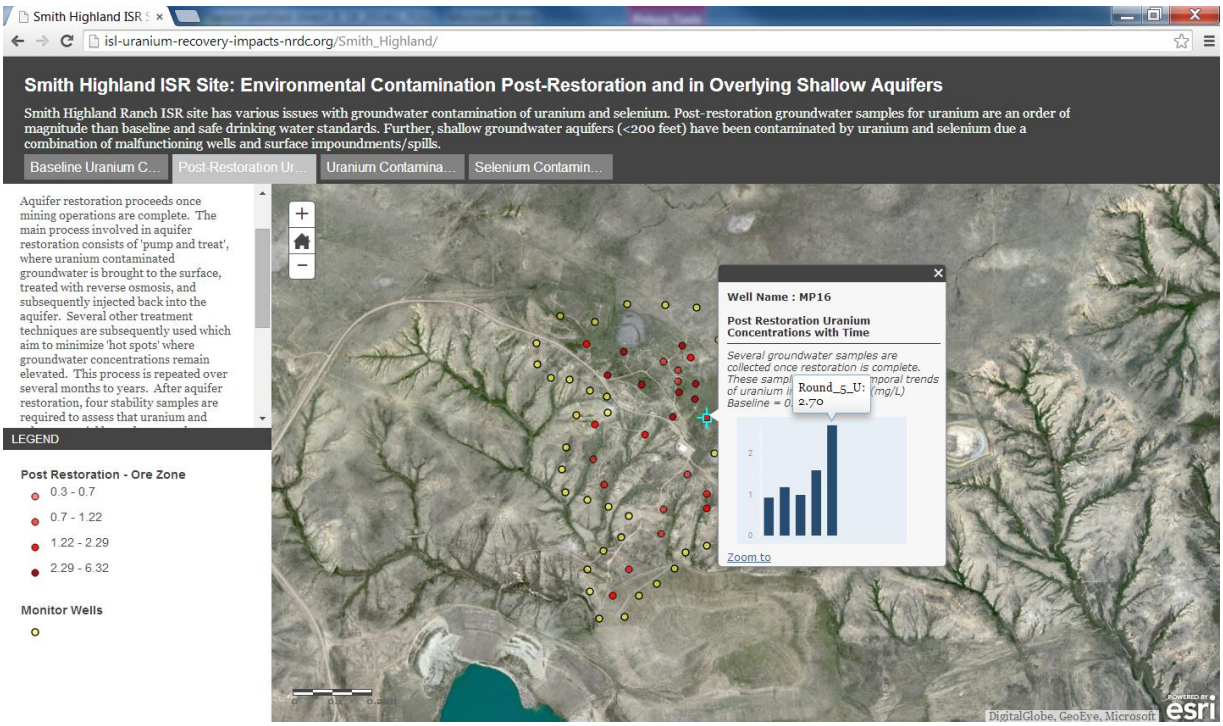
A. 64. Similar to the Willow Creek ISL Storymap, upon selection of a well the measured uranium concentrations over time are displayed in the 'pop-up' window. The actual concentrations are displayed when the cursor is placed on the vertical bars (Figure Below).

Once again I selected well MP20. The cursor shows the results of the 5th sampling round, which was the last and lowest uranium concentration measured (0.37 mg/L). In the text box above the vertical columns, the average uranium baseline concentration is present for comparative purposes. In this case the average uranium baseline concentration was 0.04 mg/L, suggesting the last and lowest uranium concentration observed post-restoration was 10x higher than the baseline and roughly 12x higher than safe drinking water standards (0.03 mg/L). Here is a representative screen shot (JTI005B-R; p.24).



Q. 65. What about another well? Are most wells elevated post-restoration?

A. 65. Yes, the user is encouraged to select various wells and examine and compare the post-restoration and baseline uranium concentrations in the groundwater. Well MP16 (JTI005B-R; p.25) shows a sharp increase in uranium concentrations at the last sampling event (2.70 mg/L), which exceeded the average baseline uranium concentration by ~270x.



Q. 66. Again, why is the failure to restored groundwater at Smith Highland Ranch ISL mine units A and B relevant for the Ross ISL project and its failure to evaluate the virtual certainty that the applicant will be unable to restore groundwater and the need to analyze the range of hazardous constituent concentration values that are likely to be applicable if the applicant is required to implement an Alternative Concentration Limit (ACL) in accordance with 10 C.F.R. Part 40, App. A, Criterion 5B(5)(c)?

A. 66. Relying on the examples the NRC cites in the FSEIS, the Christensen Ranch results I discussed at 21, and the clear visual representation that are the Storymaps, it is my professional opinion that it is inconceivable that the Ross Project will have a "SMALL and Temporary" impact on groundwater quality (SEI009A concludes at xxx and at 4-34 to 4-50). To the contrary, if the FSEIS were to consider the actual baseline conditions on the site and compare those values to the reasonably anticipated conditions post-restoration as evidenced by the Storymaps and the underlying NRC data, the FSEIS would disclose that the Ross Project will have significant and irreversible environmental impacts.

Contention 3: The FSEIS fails to include adequate hydrological information to demonstrate Strata's ability to contain groundwater fluid migration.

Q. 67. In your expert opinion, have Strata or NRC Staff in the ER, the DSEIS, or the FSEIS presented adequate hydrological information to demonstrate Strata's ability to contain groundwater fluid migration?

A. 67. No. I have several areas of significant concern. First, I have fundamental disagreements with the NRC over how they either 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 in light of an inadequate assessment of aquifer confinement. Specifically, the FSEIS has failed to sufficiently analyze the potential for and impacts associated with vertical fluid migration, and unidentified or unsealed drillholes between aquifer units. This is directly relevant to the FSEIS's failure to analyze sufficiently the potential for and impacts associated with fluid migration associated with unplugged exploratory boreholes, including the adequacy of applicant's plans to mitigate possible borehole-related migration impacts by monitoring wellfields surrounding the boreholes and/or plugging the boreholes. Further, the early detection systems will be inadequate to capture potential for fluid migration and there is a failure to understand the aquifer geochemistry. I explain in detail below.

Q. 68. Let's start with your first point so I can understand your concerns about the failure to analyze sufficiently the potential for and impacts associated with fluid migration associated with unplugged exploratory boreholes. What is your dispute with the FSEIS's presentation of basic geochemical interactions that will take place in the subsurface when efforts to establish baseline are commenced and, more important, when mining commences?

A. 68. The fact that Strata will be unable to restore wellfields to pre-mining, scientifically and statistically defensible baseline concentrations is associated with the NRC Staff and Strata's failure to acknowledge the reaction kinetics and thermodynamics of uranium ore geochemistry. Strata and NRC staff 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. Strata and the NRC staff 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 months.

Thus, while the FSEIS assumes that the restoration phase will simply involve efforts to remove the contamination that remained in the groundwater as a result of the operations phase, NRC Staff ignores that uranium and other materials disrupted by the ISL process will continue to remain obstinately elevated into the groundwater long after operations have been completed. Several hypotheses have been proposed to explain these severely elevated uranium concentrations, post-restoration. Researchers have suggested that lixiviant is stored in confining units, or at least geological units of relatively lower hydraulic conductivity, and provides a continual source of oxidizing capacity to the ore (JTI040; p. 8 in pdf, p. 36 in document). The USGS has suggested that the continual re-introduction of dissolved oxygen in the RO permeate injection process may be further degrading the aquifer's reducing capacity (JTI041; p.2 in pdf). Finally, our understanding of uranyl-carbonate complexes has greatly increased over the past

decade, which reveals that uranyl-carbonate complexes are relatively unreactive, and hence stubbornly mobile compared to uranyl-hydroxide complexes (JTI042; Figures 3 and Figure 4, p. 4. JTI043; Abstract).

Regardless, empirical data show the ISL process will create substantial contamination into the groundwater that will continue to degrade water quality, and a significant component for the post-restoration efforts will be remediating the ongoing contamination that will occur long after operations are over. None of this is disclosed or discussed in the FSEIS. And further, the failure to analyze all of the above sufficiently in conjunction with the potential for and impacts associated with fluid migration associated with unplugged exploratory boreholes exacerbates the likely results and makes this oversight more troubling.

Q. 69. Let's turn to the next issue – aquifer confinement. First explain what it is and why it matters for the conclusions related to fluid migration and the failure to analyze sufficiently the potential for and impacts associated with unplugged exploratory boreholes made in the FSEIS.

A.69. Aquifer confinement occurs when an aquifer is bounded by an overlying and underlying geologic unit of relatively lower permeability. If an aquifer used for ISL is confined, then the lixiviant solution and associated contaminants of concern are prevented from moving vertically.

Q. 70. Have previous ISL sites proven aquifer confinement? Have vertical fluid excursions occurred under confined aquifer conditions?

A. 70. There are several examples of vertical excursions in aquifers that were allegedly confined. The NRC staff has determined previous ISL sites were confined aquifers and therefore would not allow for vertical fluid excursions. For example, the NRC stated in 1988, in the Environmental Assessment (EA) for Malapai Resources, Christensen Ranch In Situ Leach Satellite operation:

"*This data [aquifer testing characterizations] would theoretically indicate that ground-water flow would be contained by the aquitards and concentrated within the production zone. Further evidence of the confining characteristics associated with the units bounding the production zone has been evidence by the successful operation of the Christensen Ranch Research and Development operation*. (JTI044; p. 26)"

However analysis of the Christensen Ranch Restoration Technical Evaluation Report (TER), in 2008, shows that vertical excursions were an environmental issue. To quote (JTI035; p. 11), "*First, excursions in the shallow aquifer in the vicinity of the southern area of MU-2 and the northern area of MU-3 indicate an impact greater than a single well.*" At this same site, NRC Staff included a comment about how the groundwater monitoring parameter values, called upper control limits (UCLs), in an overlying aquifer were set extremely high, not allowing them to detect a fluid migration:

"*The staff evaluated the setting and found spatial nexus between the wells that were, or have been reported, on excursion. The relations are: (1) well 2MW-89 is located between MU-2 South and MU-3, (2) three (2MW-68S, 3MW-46S, and 3MW-48S) of five wells in the shallow aquifer overlying the southernmost portion of MU-2 South and northernmost of MU-3 have been on excursion either during operations (3MW-48S and 3MW-46S), or during or subsequent to restoration (2MW-68S and 3MW-48S); and (3), established UCLs for two other wells in the shallow aquifer in that area (2MW-70S and 2MW-72S) are extremely high, limiting their potential to detect an excursion*." (JTI035; p. 22)

Like many reported excursion events, the precise source of the vertical excursions was unclear. The NRC confirmed this uncertainty with the following statement:

"*Furthermore, the staff notes that the documentation by the licensee on the source of the excursions for wells in the overlying aquifer is inconclusive. For example, for the 1991 excursion at well 3MW-48S, the licensee noted that the excursion in the overlying aquifer could be through well completions, exploration boreholes or hydraulic communication between aquifers*." (JTI035; p. 23)

Q. 71. Have the NRC staff or other regulators made the same erroneous assumption about confined aquifers at other sites?

A. 71. Yes, it was found that "*aquifer testing procedures have had more limited success in determining the potential for vertical excursions*" (*citing* Staub et al., NRC020, p.32). Staub further supported this statement with an analysis of vertical excursions at Irigaray in the late 1970s:

"*WMC investigated possible reasons for the excursions in wells SM-1, SM-6, and SM-7 beginning in April, 1979. Geologic and hydrologic data were studied, including geophysical logs, core data, geologic cross sections, and pump test data. WMC (1980) [original document] could find no evidence of natural hydraulic connection between the Upper Irigaray Sandstone and the Coal Unit* (Staub et al. 1986, NRC020, p.A-28, 2nd paragraph)*." As a result of these diagnostic tests, WMC (1980) concluded that the most likely pathways for lixiviant migration to the Coal Unit in Production Units 4 and 5 during 1980 were unplugged exploration boreholes* (NRC020; p.29, 4th paragraph)*."*

In other words, the standard methods for proving aquifer confinement could not predict nor explain vertical excursions.

Q. 72. Could unidentified, unsealed abandoned boreholes affect aquifer confinement?

A. 72. Absolutely, the consensus for vertical excursions appears to be directly related to the number of abandoned, unidentified exploration drillholes, or failed well casings (NRC020; p.29, last paragraph; p.30, 2nd paragraph). In other words, "*vertical excursions are directly related to the intensity of drilling activity*" (NRC020; p.48 in pdf., p. 30 in doc, 1st paragraph). Even where an aquifer was naturally confined, a drillhole or abandoned well creates preferential vertical flow paths. And many such drillholes create many pathways for those contaminants.

Q. 73. What is your concern with the FSEIS's discussion of abandoned boreholes at the Ross project site?

A. 73. The principal issue is that in order to justify its conclusion of a confined OZ aquifer, the FSEIS assumed that the more than 1,682 abandoned Nubeth drillholes in the project area would all be plugged prior to Strata's operations, thereby removing these holes as a source of contaminant migration (SEI009A; p. 3-37). However, the FSEIS disclosed that only 759 of those drillholes – or less than 50% – had even been identified, FSEIS at 2-28, and the FSEIS did not explain the basis for assuming that the remaining more than 800 holes would be located. Further troubling, the FSEIS stated that of the 759 drillholes, only 55 of them had been sealed (FSEIS; p. 2-48, 3rd paragraph). However, as of May 9, 2013 625 Nubeth exploratory drillholes have been located and 86 have been plugged by Strata (SEI009A, p.85, response to RP032-060).

These drillhole numbers, while inconsistent, demonstrate an alarming potential for uranium bearing lixiviant to migrate to overlying or underlying aquifers. According to the most recent well abandonment numbers, Strata has yet to find 1,057 Nubeth wells (1,682 – 625) and has yet to plug and abandon 1,596 Nubeth drillholes (1,682 – 86). Further, these numbers do not

include the proposed wellfield development proposed for ISL activities in the Ross permit boundary, ranging from "*1,400-2,200 recovery and injection wells in addition to 34 to 140-250 monitoring wells*" (SEI009A; p.5-54, 5th paragraph).

Q. 74. In light of these experiences at previous ISL sites, what is your professional opinion regarding the likelihood of vertical excursions of contaminants at the Ross site?

A. 74. Vertical excursions are likely given experience at other sites. As is evident from the examples above, it is difficult to assess whether an aquifer is truly confined. The lack of well plugging and not identifying hundreds of abandoned wells show that Strata and the NRC staff have not adequately demonstrated ability to maintain vertical fluid migrations from the ore zone aquifers.

Q.75. What, in your view, should the FSEIS have included to address this issue?

A.75. The FSEIS should have disclosed that excursions are likely, and then addresses the steps that will be taken to address them when detected. Instead, based on the assumption that the aquifer is confined the FSEIS presumes excursions are unlikely.

A Storymap visual representation of data which support Contention 3 – Fluid Migration

Horizontal and Vertical Excursions at Willow Creek/Christensen Ranch ISL

Q. 76. Dr. Larson, we've focused on the FSEIS's failure to sufficiently explore the potential for and impacts associated with fluid migration associated with unplugged exploratory boreholes, including the adequacy of applicant's plans to mitigate possible borehole-related migration impacts by monitoring wellfields surrounding the boreholes and/or plugging the boreholes. What can excursion events tell us about problems related to fluid migration and how might those problems be exacerbated by the failure thus far at the proposed Ross Site

to identify and seal the boreholes? In short, why is understanding fluid migration important at ISL operations, especially in light of the possible borehole-related migration impacts?

A. 76. It is important because the groundwater can be affected by vertical or horizontal excursions and boreholes play a significant role. The NRC acknowledges the potential for this problem ("*Excursions can be caused by an improper water balance between injection and recovery wells, undetected high-permeability geological strata or faults,* ***improperly plugged or abandoned drillholes****, discontinuity with the confining layers, poor well integrity, or unintended fracturing in the uranium-recovery zone or surrounding geological strata*." SEI009A document at 2-30 see also, ("*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, p.4-37.

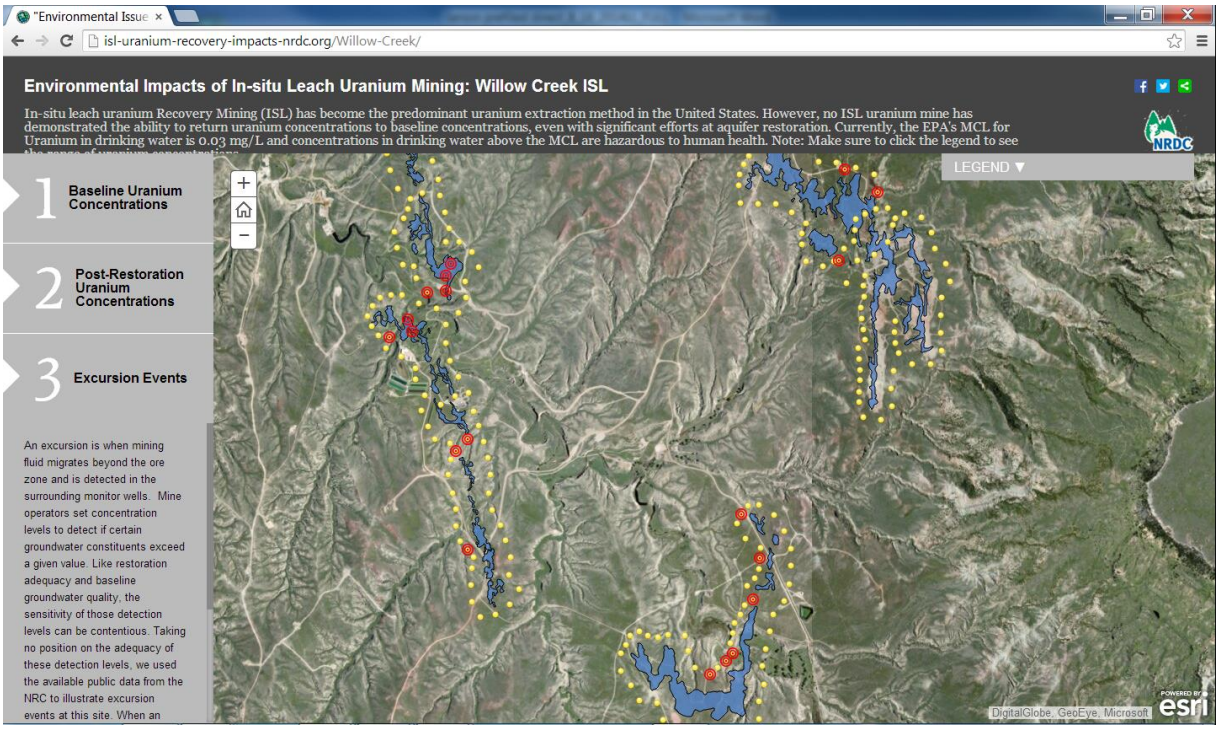
However, the NRC dismisses the possibility of fluid migration and associated excursions via the boreholes at the Ross site by asserting "*[b]reaches to the integrity of the confining unit from historical exploration and delineation drillholes will be minimized by the applicant's locating and abandoning the drillholes within the wellfields (citing License Condition 10.12* ." SEI009A; p.4-42.

With the number of unfilled and unlocated boreholes, the potential for problematic vertical migration is significant, notwithstanding a license condition that assures us the holes will be filled. The Texas example cited by Dr. Abitz in his testimony filed this day (at ¶ 41) illustrates this point precisely. There, the Texas regulator issued a "Notice of Violation" that detailed losing

track of the boreholes and failing to properly manage them (JTI026; p. 3-8) – all in direct violation of express license conditions.

Q. 77. So turning back to the Storymaps, what can they show us about fluid migration and excursions?

A. 77. Repeated excursions are examples of unwanted fluid migration and the Storymaps and the underlying NRC data shed some light on how they can impact ISL sites. Excursion data was not examined in detail the FSEIS. Open the Willow Creek ISL storymap (http://isl-uranium-recovery-impacts-nrdc.org/Willow-Creek/; (JTI005B-R; p.1, 32-34), and select the 'Excursion Events' tab on the left hand side of the screen to view groundwater issues associated with fluid migrations (See figure below. JTI005B-R; p.32).



Q. 78. So what are the big red cross hairs?

A. 78. The red crosshairs are monitoring wells where a horizontal or vertical excursion was reported. The link is found on left side of the page in the text.

Q. 79. Again, just as with the baseline numbers and the post restoration numbers, from where did this information come?

A. 79. These data were taken from the NRC staff's Technical Evaluation Report (TER) concerning the groundwater restorations at Christensen Ranch (JTI035, various paragraphs throughout).

Q. 80. And where did the text in the box that comes up when one clicks the link?

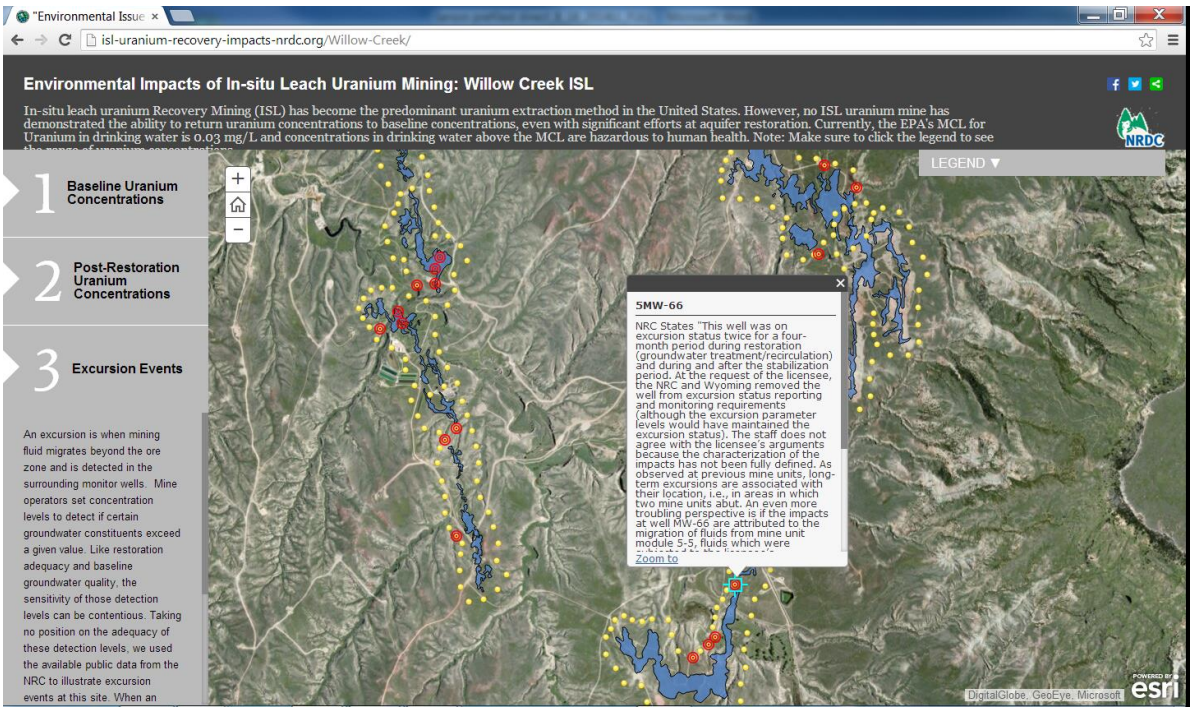
A. 80. The text reprints the NRC staff's Technical Evaluation Report (JTI035, various paragraphs throughout). In other words, it was the NRC staff's direct assessment for each individual excursion event.

Q. 81. What are some examples of the excursions?

A. 81. When horizontal excursions occur, pumping rates are adjusted to capture the contaminant plume. In most cases, this is an effective technique to recover horizontal excursions; however some wells remain on excursion status for months or even years. I have selected an excursion example that would be classified as a MODERATE to LARGE environmental impact according to the NRC staff's qualitative assessment. Select the monitor well 5MW-66 in mine unit 5 (JTI005B-R; p.33). The NRC staff's assessment in the TER of this excursion event from the TER is displayed in the pop-up window:

"*NRC States: This well was on excursion status twice for a four-month period during restoration (groundwater treatment/recirculation) and during and after the stabilization period.*

At the request of the licensee, the NRC and Wyoming removed the well from excursion status reporting and monitoring requirements (although the excursion parameter levels would have maintained the excursion status). The staff does not agree with the licensee's arguments because the characterization of the impacts has not been fully defined. As observed at previous mine units, long-term excursions are associated with their location, i.e., in areas in which two mine units abut. An even more troubling perspective is if the impacts at well MW-66 are attributed to the migration of fluids from mine unit module 5-5, fluids which were subjected to the licensee's restoration. The staff notes that several excursions have been noted at several wells along the downgradient edge of this module (eg wells 5MW-52 and 5MW-54 located south of 5MW-66 and wells 5MW-8 and 5MW-16 located north of 5MW-66). If the impacts at 5MW-66 reflect the migration from a restored aquifer, similar impacts may be expected at the downgradient perimeter in the future. <u>The licensee's argument that the transport will remain within the boundaries of MU-5 is questionable</u>." (JTI035; p.42,43)

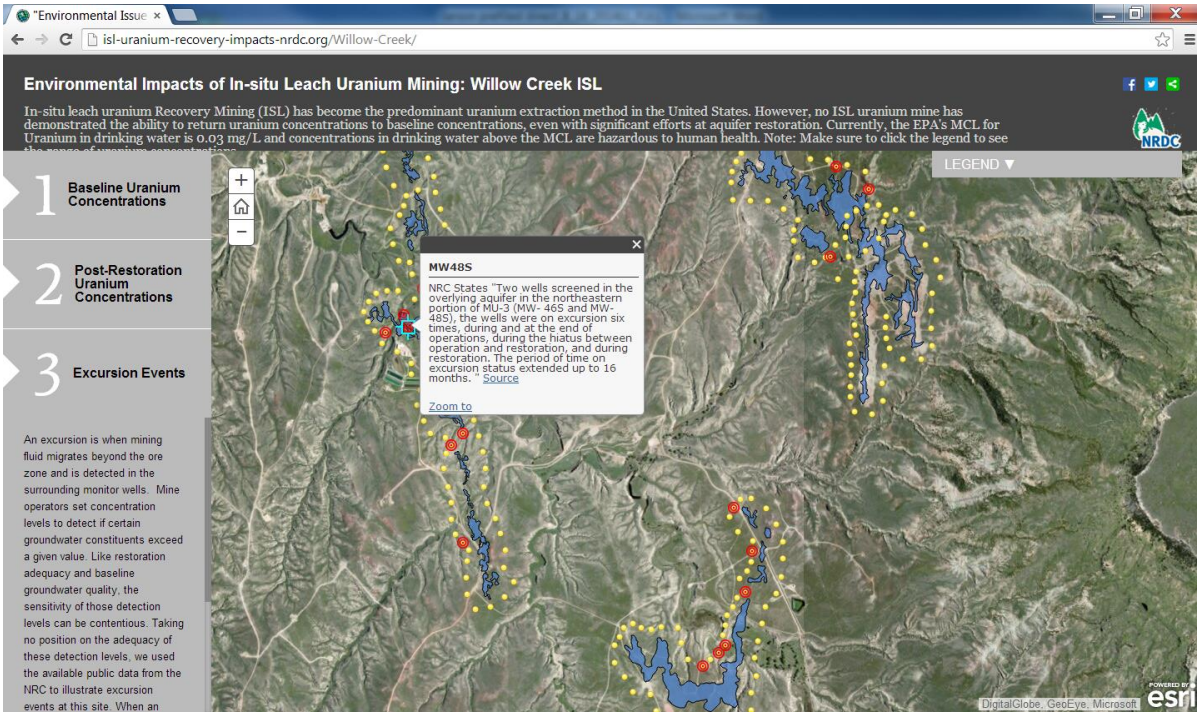


This example of a horizontal fluid migration shows that adjusting pumping rates is not a 'one-size-fits-all' solution for correcting fluid migrations. Monitor well 5MW-66 first went on excursion status on 8/21/2001 and has been on-and-off excursion status for over a decade (from JTI062). Uranium concentrations up to 2.0 mg/L have been observed at well 5MW66, and there was little explanation for the source of the excursion, based on which direction the groundwater was flowing (i.e., potentiometric surface) and the source ore locations (JTI045; p.8 and figures 5,7).

According to the NRC staff, vertical excursions are difficult to resolve as well, observed by selecting well MW48S (S – stands for shallow monitoring well; (JTI005B-R; p.34)).

The NRC staff state *"Two wells screened in the overlying aquifer in the northeastern portion of MU-3 (MW- 46S and MW-48S), the wells were on excursion six times, during and at the end of*

operations, during the hiatus between operation and restoration, and during restoration. The period of time on excursion status extended up to 16 months."



Finally, and importantly, regardless of the exact cause of any of these reported excursions (i.e. unfilled or unlocated boreholes, imbalanced wellfield operations, well failure, thinning or discontinuous confining units, etc.), these fluids migrations not only occur regularly at ISL operations, but have significant groundwater impacts if uncorrected. Corrective actions, such as adjusting pumping rates, can recover horizontal excursions. However this solution is incapable of solving every horizontal excursion and has very little value for recovering vertical excursions, the kind most likely to occur in the event of analyze sufficiently the potential for and impacts associated with fluid migration associated with unplugged exploratory boreholes, including the adequacy of applicant's plans to mitigate possible borehole-related migration impacts by monitoring wellfields surrounding the boreholes and/or plugging the boreholes.

Q. 82. Have fluid excursions occurred at the Smith Highland Ranch ISL operation?

A. 82. Yes, horizontal and vertical excursions (as well as failed well casings and surface leaks) have been documented at various mine units at the Smith Highland ISL operation (ML14202A113; p. 21). Like the Willow Creek ISL project, those aquifers for mine units C, E, and F were allegedly confined (JTI046; p. 17 – 20).

According to NRC staff's spreadsheet, wells of the overlying aquifer at Smith Highland mine unit F were located at depths ranging from 435 – 570 ft. However, much of the contamination was observed in sand aquifers located <200 feet deep. Therefore, the observed groundwater contamination in the shallow aquifers was unable to be detected by overlying excursion monitoring wells.

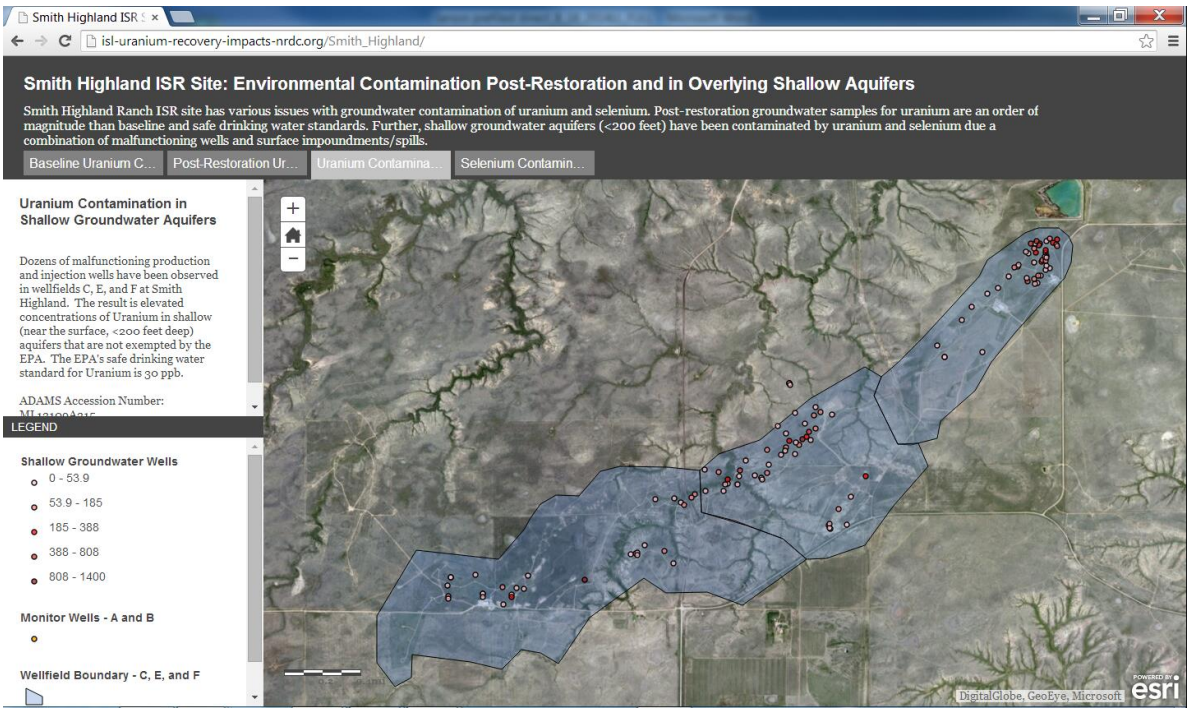
Q. 83. What data is presented in the Smith Highland Excursion Storymap?

A. 83. The data from the Smith Highland ISL map shows extensive elevated groundwater concentrations of uranium and selenium in the shallow (~<200 ft depth), non-uranium ore bearing aquifers. These elevated concentrations of uranium and selenium were reportedly the result of dozens of failed ISL injection well casings in mine units C, E, and F (JTI036; p. 8). It's possible that leaky surface impoundments and vertical fluid migration through high preferential flow paths such as abandoned/unidentified drillholes could have contributed to elevated concentrations at Smith Ranch. Therefore, similar results could transpire at the Ross Project if there is a failure to identify and seal the unplugged exploratory boreholes. Again, regardless of

the exact pathway of contamination, severe concentrations of contaminants of concern are observed in the shallow (<200 feet deep) aquifer.

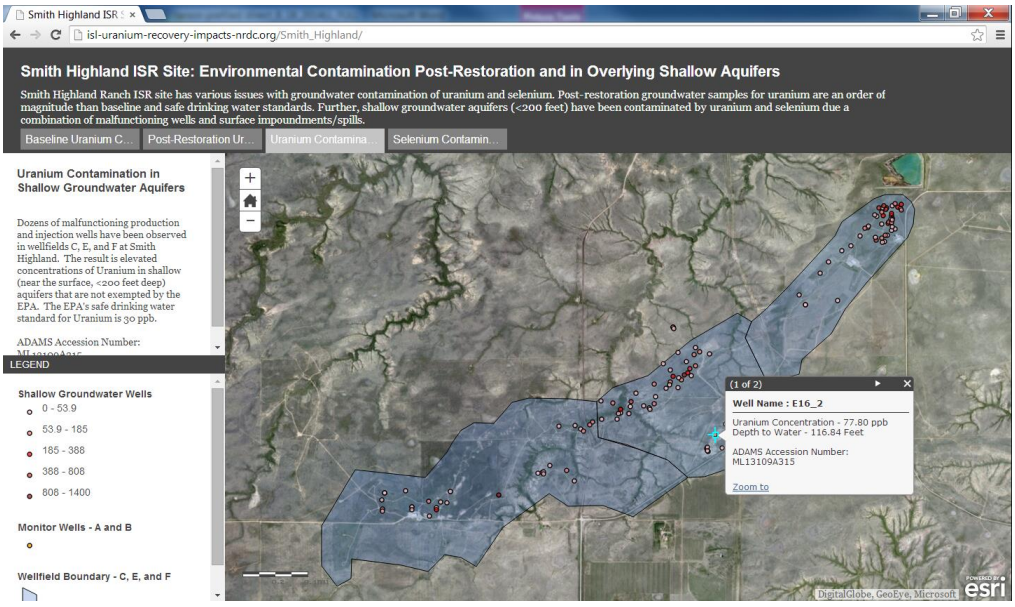
Q. 84. How do you visualize these shallow groundwater impacts using the Smith Highland storymap?

A. 84. Open the Smith Highland storymap URL (http://isl-uranium-recovery-impacts-nrdc.org/Smith_Highland/; (JTI005B-R; p.1, 35-36), and select the third tab labeled "Uranium Contamination in Shallow Groundwater Aquifers". See the image below for the initial view. The blue regions represent the wellfield boundary for mine units C, E, and F. The dots indicate groundwater wells sampled and the color is proportional to the concentration of uranium in the groundwater.



Q. 85. What information does selecting a well present?

A. 85. When a well is selected, the 'pop-up' window displays the well name, groundwater uranium concentration (ppb), the measured depth to water (feet), and the ADAMS accession number. I've selected well E16_2 as an example (JTI005B-R; p.36). The groundwater uranium concentration was 77.80 ppb and the depth to water was 116.84 feet deep. The total depth for well E16_2 was 130 feet (JTI036, p.54).



The impacts from Selenium contamination in the shallow groundwater can be observed in a similar fashion by selecting the fourth tab "Selenium Contamination in Shallow Groundwater Aquifers". The EPA MCL for selenium is 50 ppb (or 0.05 mg/L). As is apparent, the environmental impacts are significant. None of this sort of analysis of irretrievable and irreversible impacts are present in SEI009A.

Conclusion

Q. 86. Dr. Larson, you've explained and demonstrated extensively how the FSEIS fails to analyze the environmental impacts that will occur if the applicant cannot restore groundwater to primary or secondary limits and how the FSEIS fails to include adequate

hydrological information to demonstrate SEI's ability to contain groundwater fluid migration. Can you please briefly summarize why it is so important the FSEIS addresses these issues in the context of groundwater protection in the American West?

A. 86. Groundwater is a significant source of drinking water supply for municipalities and also a source for agricultural irrigation in this part of the country. Groundwater is an attractive water source to meet these demands because it is accessible in areas without substantial surface water availability, requires relatively less treatment compared to surface water, and is less susceptible to drought conditions. According to the USGS, groundwater is the source of drinking water for half the United States. Furthermore, groundwater contributes the largest percentage of source water for agriculture irrigation, which consumes roughly 80% of all US water consumption (JTI047).

Water demands in the future will increase (JTI048), therefore groundwater resources will be increasingly relied upon as a consistent, reliable, source of fresh water. However due to overreliance on groundwater, significant groundwater depletion has been observed by the United States Geological Survey over the past decade. The Central Valley Aquifer, Ca and High Plains Aquifer (Ogallala), have already observed shocking groundwater volume losses from 1960-2008 (JTI027).

The current drought crises in these regions are causing many communities to scrounge and save for water. For example, a community in Texas (Wichita Falls) recently began using treated, recycled wastewater (sewage water), for municipal drinking water, as few available options for water sources could be used to meet demands (http://www.npr.org/2014/05/06/309101579/drought-stricken-texas-town-turns-to-toilets-for-water). California communities are currently enacting strict water usage fines for community

members to deal with a record drought. Future water issues will be compounded significantly, suggesting water supplies will be increasingly scarce and using fresh water sources wastefully, for any means, is shortsighted.

Q. 87. Turning toward the issue before the Board, why does groundwater matter so much in this regional area of the West? In this particular area of Wyoming?

A. 87. Population increases over the last decade in northeastern Wyoming have put increasing stress on the available water supplies. The city of Gillette, Wyoming depends on drinking water from the Fort Union Aquifer and other local aquifers, to provide municipal water supplies. However, water availability in these aquifers are dwindling and the population is projected to substantially increase from 37,000 to 57,000 by 2030. To meet increasing water demands, the city is enacting the Gillette Madison Pipeline Project, a 217.6 million dollar project, which will route water from the Madison aquifer, north of Keyhole Reservoir to Gillette via pipeline (http://www.gillettewy.gov/index.aspx?page=902). The project is intended to meet growing water demands for the next 20 years. This example demonstrates the specific vulnerability of this region to increased water demands and the scarce options to meet those demands.

Q. 88. Would significant groundwater contamination or long-term degradation of a groundwater aquifer really matter, even if no one has is currently accessing that groundwater for water right now?

A. 88. If the groundwater which has contaminant levels above the US EPA's drinking water standards is used directly as a primary source of drinking water it carries a risk of detrimental

health impacts. Groundwater that does not meet drinking water standards would require "at the end of the pipe" treatment to return water to acceptable drinking water standards, which is costly and carries numerous logistical issues (waste disposal, energy requirements, O&M costs, etc.).

In general, financial limitations prompt municipalities to utilize the highest quality source water which requires the least amount of treatment. When relatively high quality (low treatment) source water is unavailable, the next economically available source of water is used. This general trend explains why desalination of sea water is used as a last resort, due to significantly high economical treatment costs. Therefore, preventing water contamination in the first place is regarded by many water resources and environmental engineers as the 'best treatment option'.

Q. 89. And what about the groundwater affected by the Lance District projects? Are there specific impacts in the near or long term?

A. 89. In the FSEIS and license for the Ross ISL project the NRC Staff has approved the same groundwater restoration methods which have failed to meet baseline and/or safe drinking water standards at every previous ISL site, and for technical and scientific reasons, will not result in groundwater quality meeting primary or secondary standards. As demonstrated throughout this document, it's common for 'restored' post-mining groundwater at ISL operations to exceed that value, and in some wells by an order of magnitude or more.

The volume of contaminated water within the ore zone is not trivial, and the impacted water volumes can be (depending on the site specific geology and aquifer properties) in the hundreds of millions of gallons groundwater per mine unit. For example, industry estimated the

total affected volume for Christensen Mine Units 2-6 was approximately 1.04 billion gallons of groundwater (JTI038, p.21).

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

Q.90. Does this conclude your testimony.

A. 90. Yes.

I, Dr. Lance N. Larson, 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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