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LOST CREEK ISR, LLC

April 22, 2010

Tanya Palmateer Oxenberg, PhD
Project Manager
U.S. Nuclear Regulatory Commission
Mail Stop T8F5
Two White Flint North
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Rockville, MD 20852-2738

Re: Lost Creek Project Responses November and December 2009 Technical Comments
Docket No. 40-9068
TAC No. LU0142

Dear Doctor Oxenberg,

Please find behind this cover, in duplicate, Lost Creek ISR, LLC's responses to the comments posed in the November 9, 2009 and December 18, 2009 memos from the NRC. Additionally, this submittal includes revisions to the Technical Report resulting from historic RAIs. An index sheet, which provides a description of how to update the Technical Report with all the historic and new responses, is also included.

If you have any questions regarding this submittal, please feel free to contact me at the Casper office.

Regards,

Lost Creek ISR, LLC
By its Manager, Ur-Energy USA Inc.

By: _____
John W. Cash, Manager EHS and Regulatory Affairs

Cc: Nancy Fitzsimmons – Ur-Energy USA Inc., Littleton

RESPONSES TO

NRC REQUESTS FOR ADDITIONAL INFORMATION

of

December 2009
and
November 2009

for the
LOST CREEK PROJECT
Wyoming

April 2010

The responses are organized as follows:

The December 2009 and November 2009 Requests for Additional Information (RAIs) are addressed in reverse order chronologically (i.e., the December 2009 RAIs and then the November 2009 RAIs). The responses are listed in the order in which the RAIs were presented in the December 18, 2009 and November 9, 2009 letters from T. Oxenberg (NRC) to W. Heili (LC ISR, LLC).

NRC DECEMBER 2009 RAIs

1. MISCELLANEOUS CONFIRMATORY/ADMINISTRATIVE ITEMS

These items have been resolved.

2. HYDROGEOLOGY OPEN ISSUES

a. Draft SER 2.4 Hydrogeology (TR Section 2.7) (RAI Response 12/12/08 3.2 #7)

LCI described a complex hydrogeology at the site, which includes faults that may act as hydraulic barriers, potentially anisotropic hydraulic conductivities that may result in preferential flowpaths, and abandoned wells that may act as conduit flows to the overlying and underlying aquifers. The staff, through calculations, evaluated the site hydrogeologic conditions and the results of which require additional explanation for the following issues:

(1) Information provided by the applicant indicates that a small degree of hydraulic connection exists potentially through abandoned boreholes. Our calculations indicate that it would be difficult to identify the impact of the abandoned wells on the groundwater quality based on an observation well spacing of 1 well per 4 acres. Please provide specific details regarding the manner in which the monitoring well network will be installed to address the abandoned boreholes. Regulatory Basis: 10 CFR Part 40 Appendix A, Criterion 7A.

NRC Summary of 12/9/09 Conference Call - LCI proposed that the abandoned holes can be adequately addressed in a subsequent response to this issue. LCI questioned staff's concern as the proposed spacing is consistent with spacing currently used at former and existing ISR facilities. The staff emphasized the unique setting at this site is justification for the concern. **This is an open issue.**

LC ISR, LLC (4/10) - LC ISR, LLC has committed to attempt to locate and then properly abandon all historic boreholes within a mine unit. This action should significantly reduce the likelihood that an improperly abandoned borehole could provide a potential conduit for fluid movement between the production zone and overlying and underlying aquifers.

With regard to the density of overlying and underlying monitor wells, a spacing of one monitor well per four acres should be adequate for detection of improperly abandoned boreholes. For Mine Unit 1 there will be 13 monitor well nests each including production zone, underlying, and overlying monitor wells. The distribution of the monitor wells is shown in the Mine Unit 1 Data Package submitted to WDEQ/LQD in December 2009 (with a copy to NRC). One well per four acres within the well pattern area results in a horizontal spacing of between 400 and 500 feet between monitor wells. This would result in a

maximum distance of 200 to 250 feet from any potential abandoned borehole within a mine unit to an overlying or underlying monitor well.

During a hydrologic test conducted in a well completed in the HJ Horizon (production zone) on the north side of the fault in October 2009, significant drawdown (over 20 feet) occurred in an underlying monitoring well completed in the UKM Sand (MU-108). Well MU-108 was located approximately 387 feet from the pumping well (Petrotek, 2009). Further review of drilling records performed after the HJ Horizon pump test for the suspect well indicated that the casing and annular seal were damaged during well completion. Well MU-108 was abandoned and replaced with well KPW-2. A subsequent short-term pump test confirmed that well MU-108 was properly sealed and abandoned and that there was no longer hydraulic communication with the HJ Horizon at that location.

For production well patterns, the spacing between recovery wells will be on the order of 75 to 150 feet. Based on that spacing, any improperly abandoned historic borehole would most likely be located within 150 feet of four recovery wells and within 500 feet of at least two overlying and two underlying monitor wells. Based on the response observed at the underlying well (MU-108) which was located about 400 feet from the pumping well during the North Side Hydrologic Test, one monitor well per four acres should be adequate for detection of hydraulic impacts and water quality to the overlying and underlying aquifers.

If an abandoned borehole creates a pathway for the release of production or recovery fluids into the overlying or underlying aquifer, the proposed monitoring network will detect the excursion. Once detected, the excursion is dealt with in the manner previously described in the permit application.

(2) The staff observed an apparent anisotropy to drawdown based on the October 2007 pumping test. Based on staff's calculations, the anisotropy was determined to be in the vertical direction, i.e., the HJ Horizon is subdivided into the upper, middle and lower subhorizons. Given this anisotropy, perimeter wells screened in the upper HJ Horizon may not provide timely detection of an excursion should the nearby production zone be in the middle or lower HJ Horizon. Please provide an evaluation that wells screened in one HJ Horizon subhorizon will provide timely detection of an excursion for production in the other subhorizons.
Regulatory Basis: 10 CFR Part 40 Appendix A, Criterion 7A.

NRC Summary of 12/9/09 Conference Call - LCI acknowledged that they've encountered this scenario at many sites and will present to staff rationale for screening of the wells. LCI stated that the mine unit package for Mine Unit 1 has the detail and proposed that the package could be submitted at this time. The staff

suggested LCI not submit the package for review and approval at this time as its review would delay the license review process. LCI and staff discussed that this issue may be included as the license condition for NRC review and approval of the mine unit package, pending LCI's response to this comment.

LCI's proposal to resolve this issue as a license condition is acceptable to the NRC staff. **Therefore, this is an open issue pending staff review of the proposed license condition.**

LC ISR, LLC (4/10) - Waiting for license condition, no response required.

(3) The mapping supplied by the applicant indicated a relatively wide zone of low permeability material in conjunction with the Lost Creek Fault, several mine units that are bisected by the Fault, and a schematic of mine units that suggests a homogeneous distribution to the production units within a mine unit. The staff's calculations indicate that the low permeability zone will hinder the applicant's ability to adequately control the migration of fluids for production units located within, straddling or in close proximity to the fault zone. Please provide a plan for the individual mine unit hydrogeologic testings that will ensure safe operations of units in close proximity of the Fault.
Regulatory Basis: 10 CFR Part 40 Appendix A, Criterion 7A.

NRC Summary of 12/9/09 Conference Call - LCI inquired about staff's calculations. The staff explained that a numeric flow model was created by staff to analyze the fault and mine units. LCI requested the ability to review the model; however, staff indicated that it may be logistically difficult to provide this information at this time since NRC's policy is to make all information discussed with an applicant also available to the public. The staff suggested that the concepts of a low permeable zone within a mine unit should be addressed, and that the construction of the model can be discussed during a phone call with the project manager.

LCI acknowledged that the final mine plan will have the patterns and will not include mining across the fault. LCI has had many scenarios where similar stratigraphic variable has been adequately addressed and will provide this information to staff. **This is an open issue.**

LC ISR, LLC (4/10) - The low permeability zone shown on Figure 2.7-11a is a conceptualization to address the large differences in head across the Lost Creek Fault. It has been demonstrated during pump tests that the Fault impedes groundwater movement and acts as a partial hydraulic barrier in the HJ Horizon. Whether that barrier exists as a thin fault line or a wider fault zone is unknown.

Heterogeneity within the production zone has been acknowledged, (as indicated by the identification of at least three major subunits of the HJ Horizon). Such heterogeneity is common to the fluvially deposited sedimentary rocks associated with uranium roll front deposits at other ISR projects. Although the faulting within the mine units may be somewhat unique to the Lost Creek ISR project, horizontal and vertical heterogeneity within the ore bodies and surrounding lithologic units is typical of roll front deposits, and is in fact, a key feature controlling the distribution of uranium as an ore body.

The presence of low permeability zones should not impede LC ISR, LLC's ability to adequately control the migration of fluids for production units located within, straddling, or in close proximity to the fault zone. The spacing between wells in the production well patterns will be close enough to allow for detailed control of fluid movement in the subsurface, regardless of the heterogeneity. LC ISR, LLC will mine the Lost Creek ore deposits using industry-tested well patterns, typically with spacing between recovery wells on the order of 75 to 150 feet. Individual well patterns are completed in discrete zones, typically across intervals of twenty feet or less. The hydraulic response of individual wells within patterns near the fault will provide the best information as to how to control hydraulic flow patterns in that area. Furthermore, LC ISR, LLC has committed that no mining will occur across the fault within specific well patterns.

Additional hydrologic testing has been performed to better characterize the hydraulic behavior and influence of the Lost Creek Fault on the HJ Horizon during pumping. That data is included with the Mine Unit 1 Data Package submitted to WDEQ/LQD in December 2009 (with a copy to NRC).

b. Draft SER 3.1.3 MIT Testing and Well Casing Pressures (TR Section 3.2) (RAI Response 12/12/09 3.2 #5)

LCI reported the minimum fracture gradient for the license area is 0.70 psi. It stated that during operations, injection pressures at the wellheads would not exceed MIT pressures. It also stated that the maximum injection operating pressures will not exceed 90% of the production zone fracture pressure or 95% of the ASTM maximum operation pressure for the well casing. LCI, however, did not provide the MIT pressure or maximum well casing pressures. Without an estimate of these values, NRC staff cannot evaluate if the fracture gradient will be exceeded. Section 3.2.7, NUREG 1569 Section 3.1.3 No. 5 (a).
Regulatory Basis: AEA, as amended Section 84 (c). 10 CFR Part 40 Appendix A

NRC Summary of 12/9/09 Conference Call - LCI acknowledged that information to address this issue can be provided to staff. LCI has the calculations; however, the

maximum pressures will be header-house specific due to hydraulic conditions. As a header house is brought on-line, LCI has procedures to develop and ensure that the maximum pressure for each header house will not be exceeded. In the unlikely event that a header house consists of wells with greatly variable pressure regimes, then the maximum pressure will be based on a well-by-well basis using a pressure switch. **This is an open issue.**

LC ISR, LLC (4/10) - TR Section 3.2.4, Well Completion, specifies the properties for a typical well casing to be installed at the Lost Creek Project. A typical mechanical integrity test (MIT) will begin at 150 psi for injection and production wells. The well will be required to maintain 95% of the MIT start pressure over 10 minutes. An example of the determination of the maximum injection pressure has been added to TR Section 3.2.7.1 (Header House Control).

c. Draft SER 5.7.8 (TR Section 5.7.8) Completion Zone for the Overlying or Underlying Wells

LCI stated that the completion zone for an overlying or underlying well may be within the production zone but did not provide details.
Regulatory basis: 10 CFR Part 40 Appendix A, Criterion 7A.

NRC Summary of 12/9/09 Conference Call - LCI agreed that this scenario is not proper and will review and revised the application accordingly. **This is an open issue.**

LC ISR, LLC (4/10) – LC ISR, LLC affirms that the required overlying and underlying mine unit monitor wells will not be completed within the production zone aquifer. The overlying monitor wells will be completed just above the aquitard above the HJ Sand. The underlying monitor wells will be completed just below the aquitard underlying the HJ Sand. The text in TR Section 5.7.8 (Groundwater and Surface-Water Monitoring Programs) has been revised, under the heading **Monitoring Specific to Mine Units**, to clarify how the overlying and underlying monitor wells will be completed.

d. Draft SER 5.7.8 (TR Section 5.7.8) Lack of Surficial Aquifer Baseline Quality

LCI did not include plans to acquire baseline surficial aquifer water quality for the licensed area. Regulatory basis: 10 CFR Part 40 Appendix A, Criterion 7 and 7A.

NRC Summary of 12/9/09 Conference Call - LCI inquired about the use of the term "surficial aquifer" and whether or not one existed at the proposed setting because of

the clay stringers located within the unsaturated zone that isolated the uppermost aquifer from the near surface. NRC staff acknowledged that the term surficial aquifer may be interpreted as such but staff's concern is to establish proper baseline levels for aquifer(s) at the site that may potentially be impacted by the ISR operations. The staff indicated that the term "uppermost aquifer" may be more appropriate. Although less likely to be impacted by a release or spill originating at ground surface, the uppermost aquifer may impacted by leakage from production wells at shallow depths. The uppermost aquifer is found within the DE Horizon. LCI acknowledged that it has been acquiring data for the uppermost aquifer and will provide the data to staff. **This is an open issue.**

LC ISR, LLC (4/10) - The surficial aquifer (uppermost aquifer) at the Lost Creek Project area is the DE Sand. The original TR contained water quality for a total of three wells completed in the DE Sand (LC29M, LC30M, and LC31M). Since that time three additional regional monitor wells were completed in the DE Sand (MB-1, MB-7, and MB-10). Of these three new wells only MB-1 contained sufficient water for sampling. The water quality data for well MB-1 has been added to Table 2.7-13 of the TR and the text in TR 5.7.8 Groundwater and Surface-Water Monitoring Programs has been updated to reflect the additional well.

Additional regional monitor wells were also installed in the FG, HJ, and KM Sands and the resulting water quality is also included in Table 2.7-13. Figure 2.7-19 has been revised to include the location of the new regional baseline monitor wells.

e. Draft SER 6.1 (TR Section 6.1) Thickness of Ore Body for Surety Calculations

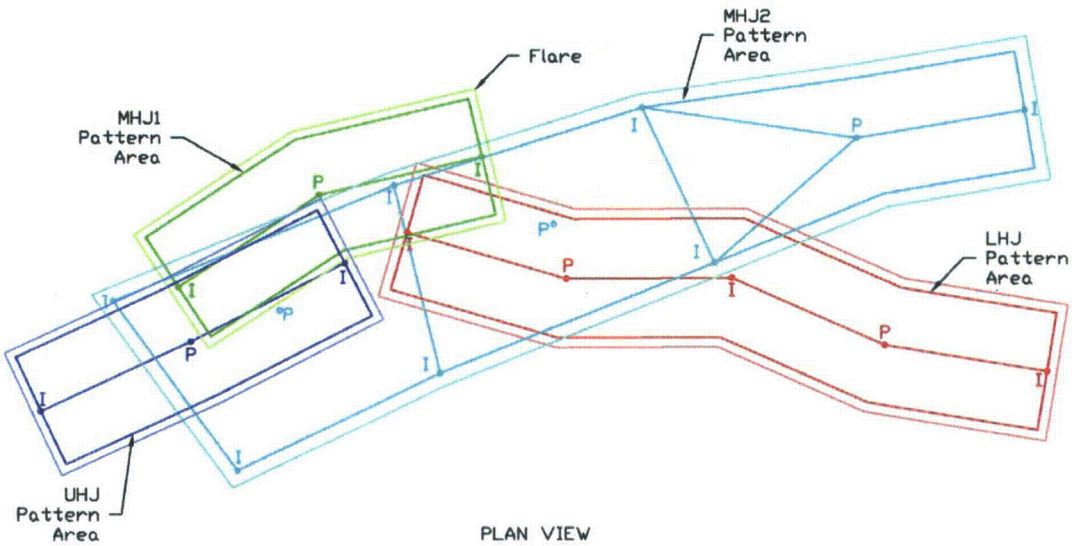
NRC staff needs supporting evidence that the use of average completion thickness in lieu of thickness of the ore sand is appropriate in the pore volume calculation. LCI reports that the thickness of the mineralization varies from 5 to 28 feet, with an average of 16 feet. LCI also indicated that the restoration would only be completed in areas with multiple mineralization zones after production at all zones. If production is done in all zones, it appears the restoration pore volume should account for the thickness of multiple zones (NUREG 1569 6.1.3 (2)).
Regulatory Basis: AEA, as amended Section 84 (c). 10 CFR Part 40 Appendix A, Criterion 9.

NRC Summary of 12/9/09 Conference Call - LCI acknowledged that an adequate response to demonstrate the rationale will be provided to the staff. **This is an open issue.**

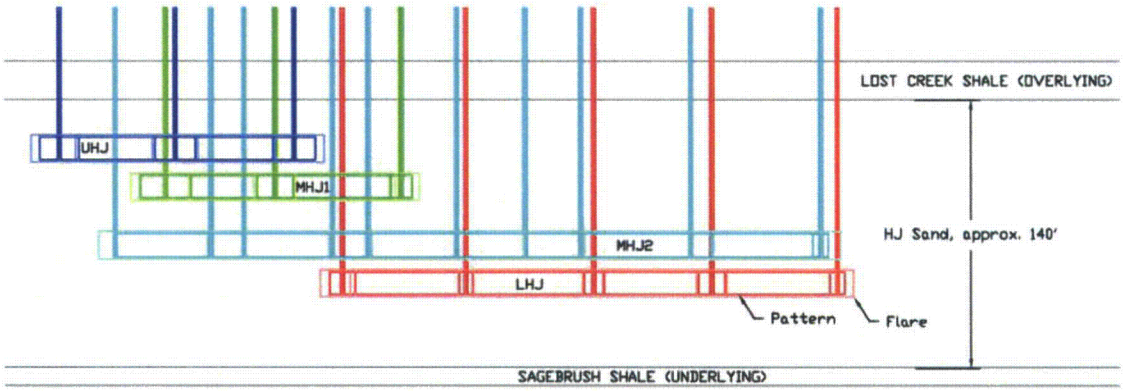
LC ISR, LLC (4/10) -

Average Completion Thickness - With respect to NRC's request for supporting evidence that the use of average completion thickness in lieu of thickness of the ore sand is appropriate in the pore volume calculation:

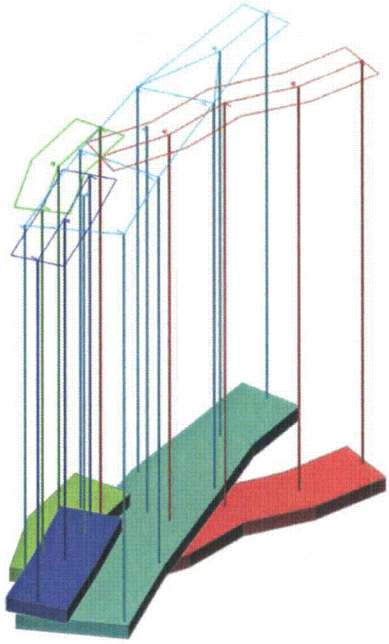
"Groundwater and Wells, Third Edition" states that permeability refers to the ease with which any fluid moves through a geologic material. It is widely accepted that vertical permeability is an order of magnitude less than horizontal permeability in a fluvial system such as the HJ Horizon at the Lost Creek Project. In other words, the injection lixiviant will tend to move horizontally rather than vertically in the production patterns. Each pattern within the production horizon is balanced individually to minimize flare from that pattern. This is done regardless of vertical or horizontal location within the HJ Horizon. The Surety Estimate (Table 6.8-1) includes a cumulative flare factor of 44% (horizontal flare times vertical flare). One portion of the flare is the horizontal component which is 20% of the pattern area. This is accounted for in each pattern in each sand within the HJ horizon (as depicted in the plan view figure below).



The vertical flare component also totals 20% (10% above and 10% below). This is also accounted for in each pattern in each sand within the HJ Horizon as depicted in the cross-section below. This figure also depicts the basis for bonding of individual sands versus the entire production horizon. In addition, currently permitted and operating ISR production facilities bond for only the pattern pore volume plus an approved flare factor; not the entire horizon.



The figure below provides a typical three-dimensional view of how the patterns within the HJ Horizon relate to one another. This figure represents the plan and cross-sectional views provided above.



Restoration Timing - With respect to restoration completion in areas with multiple mineralization zones after production of all zones:

As stated above, the restoration pore volume accounts for the total affected pore space in the production horizon including both horizontal and vertical flare. Restoration

activities can begin in an area once all production activities are complete. This is done so restoration is not competing with production.

f. Draft SER 6.1 (TR Section 5.7.8) Excursion Corrective Actions

LCI did not describe how it will address corrective action at wells which were on excursion status during the restoration and restoration stability monitoring period (NUREG-1569, Section 5.7.8.3 (5)). NRC staff therefore requests that LCI provide NRC with a plan on how it will correct any excursions at monitoring wells during restoration and stability monitoring and restore water quality near these wells to ensure that groundwater outside the exempt zone is protected. Regulatory basis: 10 CFR Part 40 Appendix A, Criterion 5D.

NRC Summary of 12/9/09 Conference Call - LCI acknowledged that an adequate response that demonstrates LCI's rationale will be provided to the staff. **This is an open issue.**

LC ISR, LLC (4/10) - An excursion detected during active restoration will be corrected in the same fashion as during operations. Therefore, TR Section 5.7.8.2 (Operational Monitoring), under the subheading **Excursion Verification and Corrective Action**, has been revised to clarify that corrective actions for excursions during operations are the same as for during active groundwater restoration.

However, the corrective action for an excursion during stabilization may be different since active pumping, and therefore active groundwater control, has been halted. Therefore, text has been added to TR Section 5.7.8.2 to explain the corrective action for an excursion during the restoration stability monitoring period.

g. Draft SER 6.1.2 (TR Section 5.7.8, 6.2.2) Baseline Quality Data for the Perimeter Wells

LCI (Section 6.2.2) stated that to establish baseline water quality, a minimum of four samples would be collected for each well at least fourteen days apart. At least one of these samples will be analyzed for all parameters listed in Table 6.2-1. LCI said other samples may be tested for a reduced list of parameters with WDEQ approval. NRC staff notes that NUREG-1569 Section 5.7.8.3 (1) states that at least four independent sample sets should be collected, with adequate time between sets to represent any preoperational temporal variations. A set of samples is defined as a group of at least one sample at each of the designated baseline monitor wells which are analyzed for all water quality parameters in Table 2.7.3-1. NRC requests that LCI revise their sampling plan to sample for all constituents to meet the guidelines in NUREG -1569. Regulatory basis: 10 CFR Part 40 Appendix A, Criterion 7 and 7A.

NRC Summary of 12/9/09 Conference Call - LCI discussed that the sampling as proposed was in accordance with WDEQ regulations/guidelines and has been making concerted efforts to meet requirements for both regulatory agencies, WDEQ and NRC. The staff acknowledged that there are times that applicants have to meet requirements of various regulatory bodies. The staff will attempt to minimize any duplicative efforts; however, LCI must, at a minimum, meet requirements of NRC regulations if those regulations are more stringent. LCI acknowledged that an adequate response to this issue will be provided to the staff. **This is an open issue.**

LC ISR, LLC (4/10) - LC ISR, LLC has revised the last paragraph of TR Section 6.2.2 (Restoration Requirements) to commit to analyzing for all parameters each sample round.

The list of analytes provided in TR Table 5.7-4 is consistent with the list of analytes found in Table 2.7.3-1 of NUREG 1569 with the exception of silver. LC ISR, LLC requests that silver be removed from the list of required analytes due to the extremely low concentrations of similar heavy metal elements such as copper. Copper was analyzed in each of the regional baseline wells a total of 65 times with no detects. It is very unlikely that silver exists in Tertiary fluvial systems that have not been impacted by hydrothermal fluids. Also, although listed in NUREG-1569, few if any other in situ facilities analyze for silver for the reasons listed above.

h. Draft SER 6.1.7 (TR Section 6.1) Restoration Stability Monitoring Wells

LCI did not state how many wells will be sampled during stability monitoring. NRC Staff notes that NUREG-1569, Section 6.1.3(5) recommends that the number of wells used for stability monitoring be provided.
Regulatory basis: 10 CFR Part 40 Appendix A, Criterion 7 and 7A.
NRC Summary of 12/9/09 Conference Call - LCI acknowledged that it understands this issue but until the mine unit is designed will not have a specific number of wells for a mine unit at this time. LCI committed to include this information in the wellfield hydraulic testing package which will be addressed through a license condition.

LCI's proposal to resolve this issue as a license condition is acceptable to the NRC staff. **Therefore, this is an open issue pending staff review of the proposed license condition.**

LC ISR, LLC (4/10) - Waiting for license condition, no response required.

i. **Draft SER 6.1.7 (TR Section 6.2) Restoration Stability Monitoring Parameters**

LCI stated that during stabilization, monthly samples will be collected to ensure oxidation/reduction conditions do not fluctuate significantly (Section 6.2.4). LCI did not state what constituents will be measured in these samples, but said they would be based on water quality at the end of restoration and agency approval. LCI did state that at the end of the stabilization period, samples will be tested for all parameters listed in Table 6.2-1. NRC staff notes that NUREG-1569, Section 6.1.3 (5) establishes guidelines that describe the purpose of stability monitoring to ensure that all chemical species of concern do not increase in concentration after restoration.
Regulatory basis: 10 CFR Part 40 Appendix A, Criterion 7 and 7A.

NRC Summary of 12/9/09 Conference Call - LCI and NRC staff discussed making this a license condition as part of NRC review of the wellfield hydraulic testing report. LCI committed to include this information in the wellfield hydraulic testing package which will be addressed through a license condition.

LCI's proposal to resolve this issue as a license condition is acceptable to the NRC staff. **Therefore, this is an open issue pending staff review of the proposed license condition.**

LC ISR, LLC (4/10) - Waiting for license condition, no response required.

j. **Draft SER 6.1.7 (TR Section 6.2) Restoration Stability Monitoring Statistical Methods**

In Section 6.2.4, LCI stated that the restoration will be considered stable if the sampling results show there are no significant increasing trends. LCI, however, did not provide a description of how the stability trends will be evaluated statistically or otherwise or describe what actions would be taken if trends are determined to be significantly increasing. NRC requests that LCI provide this information (NUREG-1569, Section 6.1.3 (3)).
Regulatory basis: 10 CFR Part 40 Appendix A, Criterion 7 and 7A.

NRC Summary of 12/9/09 Conference Call - LCI acknowledged that it understands the issue; however, LCI inquired about staff's statistical preference. The staff stated that a regression analysis would be sufficient as long as a fit analysis was reported and LCI defined what actions will be taken if trends are increasing. For their response, the staff suggests that the applicant reviews recent EPA guidance on trend analyses in Chapter 17 of EPA-530-R-09-007, "Statistical Analysis of Groundwater

Monitoring Data at RCRA Facilities: Unified Guidance", dated March 2009. **This is an open issue.**

LC ISR, LLC (4/10) - The last paragraph of Section 6.2.4 (Stabilization Phase) has been replaced with a subsection (Section 6.2.4.1 - Statistical Analyses) which describes the statistical approach.

k. Draft SER 6.1.7 (TR Section 6.2) (RAI Response 12/12/08 6.2 #17) Lost Creek did not provide a strategy for addressing hot spots after restoration

LCI stated they will evaluate the restoration stability for "hot spots" that may require further treatment (RAI Section 6.2 No.17, Dec. 2008). However, it has not proposed a strategy to address how "hot spots" will be identified and how they will be treated during restoration stability monitoring. NRC staff notes that depending on location and groundwater flow direction, these "hot spots" can act as potential sources of contamination and may require specific attention if they remain. NRC requests that LCI provide a method to identify "hot spots" and assess how they will be treated if they are a concern for later contamination outside of the mine unit (NUREG-1569, Section 6.1.3 (6)).
Regulatory basis: 10 CFR Part 40 Appendix A, Criterion 7 and 7A.
Note: NRC staff gave guidance at the November 2009 Workshop in Denver, Colorado, on a definition of a "hot spot" as a concentration greater than the mean value plus 2 standard deviations.

NRC Summary of 12/9/09 Conference Call - LCI acknowledged that it understands the issue and that an adequate response to this issue will be provided to the staff. **This is an open issue.**

LC ISR, LLC (4/10) - A subsection (Section 6.2.4.2 - Identification of 'Hot Spots') has been added which describes how 'hot spots' will be addressed.

l. Draft SER 6.1.8 Lost Creek did not provide a commitment to maintain hydraulic control on a wellfield for the period between operation and restoration

NRC staff requests that LCI commit to maintaining a bleed, which creates a sufficient inward gradient to prevent excursions on all wellfields during all production /restoration operations, including when production/ restoration operations are suspended or the wellfield is put in a standby mode. LCI may only cease this bleed when the wellfield is in its stability monitoring phase or through specific approval by NRC (NUREG1569 3.1.3 (5b, f & i).
Regulatory Basis: AEA, as amended Section 84 (c). 10 CFR 40.31(g)

NRC Summary of 12/9/09 Conference Call - LCI acknowledged that it understands the issue and that an adequate response to this issue will be provided to the staff.
This is an open issue.

LC ISR, LLC (4/10) - TR Section 6.2.2 (Restoration Requirements) has been revised to remove the reference to WDEQ Class of Use and to clarify that a hydrologic bleed will be maintained during all phases of production, approved standby modes, and active groundwater restoration.

3. HYDROGEOLOGY CONFIRMATORY ITEMS

a. Draft SER 2.3 (TR Section 2.6) (RAI Responses 12/12/08 2.6 #3; 01/19/09 2.6 #1 & 2) Inconsistencies in the Geologic Information

In the TR, December 12, 2008 and January 19, 2009 responses, geologic information that was submitted includes revisions to isopach mapping and cross-sections as well as development of structural contour mapping. The information has several inconsistencies, notably, the thicknesses of the units depicted on the cross-sections and isopach mapping as well as thickness determined from the structural contour mapping. Also, the depiction of fault traces is inconsistent on the submitted documents. During the September 25, 2009 tele conference, LCI committed to further discussion and submittal of uniform information. At the request of LCI, the staff provided more detailed information on inconsistencies in the information. In brief, the staff requests that information presented in the report is consistent on cross-sections and various map views. The existing inconsistencies include:

(1) Additional traces of faults other than the Lost Creek Fault on various cross-sections and map view (e.g., the potentiometric surface contour maps).

<u>LC ISR, LLC (4/10)</u> - Revisions have been made to the following figures and plates to include the North Fault, the Lost Creek Fault (subsidiary), and the South Fault:

Figure 2.7-11a DE Potentiometric Surface
Figure 2.7-11c LFG Potentiometric Surface
Figure 2.7-11f HJ Potentiometric Surface
Figure 2.7-11h UKM Potentiometric Surface
<u>Plate 2.6-2a LCS Isopach Map</u>
<u>Plate 2.6-2b HJ Isopach Map</u>
<u>Plate 2.6-2c SBS Isopach Map</u>
<u>Plate 2.6-2d KM Isopach Map</u>
<u>Plate 2.6-4a FG Structure Contour Map</u>
<u>Plate 2.6-4b LCS Structure Contour Map</u>
<u>Plate 2.6-4c HJ Sand Structure Contour Map</u>
<u>Plate 2.6-4d SBS Structure Contour Map</u>
<u>Plate 2.6-4e KM Sand Structure Contour Map</u>

Notes:
The potentiometric surface maps listed above were originally submitted as part of the 1/09 Response to NRC's 11/08 RAI 2.7.2 #1 and are now incorporated into TR Section 2.7 (Hydrology).

The inset maps shown on cross-section plates that trace the location of the cross-section have not been updated with the above listed faults since the faults are now located on several plates and figures. However, the cross sections themselves show the faults.

(2) Possible inaccuracies in the isopach mapping. In response to RAIs, LCI updated cross-section C-D in which an unidentified error was corrected. The initial submittal had a discontinuity in the selection of the sage Brush Shale (SBS) horizon at location P2-19. On the initial and current cross-section B-C the top of the SBS at location P2-19 was at an elevation of approximately 6380 ft-MSL; however on the initial cross section C-D, the top of the SBS at location p2-19 was at an elevation of approximately 6310 ft-MSL. The updated cross-section C-D corrected this apparent error by selecting the stratigraphically overlying shale horizon as the SBS. In essence, the designated lower HJ zone on the initial cross-section C-D is now included in the upper KM horizon.

LC ISR, LLC (4/10) - The observation is correct that the stratigraphic correlation on Cross-Section C-D (Plate 2.6-1c) has been corrected, and the corrected copy included with this submittal. The Lower HJ zone on the initial Cross-Section C-D is now included in the upper KM horizon. However, this did not require any edits of the stratigraphy on the HJ or KM Isopach Maps (Plates 2.6-2b and 2d); because those maps were generated from raw data rather than from the cross-sections.

(3) The thickness of the HJ isopach mapping along this cross section is consistent with the depictions on the updated cross section which suggests may have been clerical in nature. However, the offset of the NNS along the fault line south of the fault between well TT40 and TT34 differs from the offset for the other units both south and north of the fault. Specifically, the offset for the other units is slightly less than 60 feet whereas the offset for the NNS is approximately 120 feet. Furthermore, based on the cross-section, the isopach of the UKM horizon is approximately 20 feet north of the fault and 110 feet south of the fault. This abrupt change in thickness is inconsistent with the isopach contour map for the UKM horizon.

LC ISR, LLC (4/10) – As noted in the previous response, Cross-Section C-D (Plate 2.6-1C) has been corrected.

(4) In reviewing the structural contour maps, another apparent discrepancy was observed. At the location of 743280 (easting) and 534750 (northing), the top of the HJ horizon is at 6600 ft-MSL. At that same location, the top of the overlying LCS unit is less than 6600 ft-MSL. The isopach mapping for the LCS unit indicates a thickness of 10 to 20 feet.

LC ISR, LLC (4/10) - Stratigraphic complexities in the vicinity of the fault resulted in erroneous recordings of the top of the LCS for five holes in vicinity of the coordinates cited above by NRC. As a result, the 6600ft structural contour for the LCS incorrectly plotted sub-parallel to the fault trace in that vicinity. A revised Plate 2.6-4b (Structural Contour Map for the Lost Creek Shale) has been drafted to reflect the necessary corrections. Also note that these complexities require some generalization in terms of depiction of the fault trace. At the current status of data and interpretation, the precision can be considered to be on the order of 50 to 100 feet. As additional drilling information is acquired over time, the precision of the fault location will be refined.

(5) On table 2.7-5, wells LC27M and LC28M are listed as completed in the HJ horizon. In the December 12, 2008 submittal (Volume 2), well LC27M is listed as a HJ Sand well. However, in the January 2009 submittal, wells LC27M and LC28M are depicted on the potentiometric contour map for the KM horizon. Furthermore, the boring logs for those wells in the submittal to WDEQ show the completed horizon within the KM horizon.

LC ISR, LLC (4/10) - Table 2.7-5 has been revised to show that Wells LC27M and LC28M are completed in the UKM Sand. Also, the ground surface elevation for Well LC28M was reported incorrectly and has been corrected.

In LC ISR, LLC's December 2008 RAI Responses, , Volume 2 contained the "Lost Creek Aquifer Test Analyses" report prepared for UR-Energy US, Inc by Hydro-Engineering, LLC. The report presents information on a series of single-well pump tests and one multi-well pump test conducted at the Lost Creek Project in October and November of 2006, and an electronic copy of that report has been incorporated into Section 2.7 (Hydrology) as Attachment 2.7-1. (The existing Attachment 2.7-1 (the LC19M Pump Test Report) was renumbered as Attachment 2.7-2.) At the time of the pump tests, Well LC27M was believed to have been completed in the HJ Horizon. However, since that report was completed, a revised interpretation of the stratigraphy surrounding Well LC27M has been conducted based on more recent drill data. The new interpretation of the stratigraphic sequence for Well LC27M concludes that the well is completed in the UKM Sand as opposed to the HJ Horizon. LC ISR, LLC believes that since the report was written based on the most current data available at that time, the

description of to Well LC27M as completed in the HJ Horizon should not be changed.

(6) In the December 12, 2008 response (Volume 3), the elevation for the top of casing for well HJMP-101 is listed at 6903.70 ft-MSL in Table 3-1 but as 6950.96 ft-MSL in Appendix A. (Also, the elevation is listed as 6903.70 ft-MSL in the boring log in the WDEQ submittal. Through staff's calculation, it is more likely that the 6950.9 FTMSL elevation is correct.

LC ISR, LLC (4/10) - In LC ISR, LLC's December 2008 RAI Responses, Volume 3 contained the LC16M Pump Test Report by Petrotek Engineering Corp. An electronic copy of that report has been incorporated into Section 2.7 (Hydrology) as Attachment 2.7-3. Table 3-1 and Appendix A of that report have been revised to include the correct elevation data for Well HJMP-101. Also, two copies of the revised Well Completion Report has been included to be inserted into NRC's copy of WDEQ submittal.

(7) Staff reviewed the locations of the nearby domestic and stock wells and determined that the information is consistent on the table and figures presented in the December 12, 2008 submittal.

NRC Summary of 12/9/09 Conference Call - LCI acknowledged this confirmatory item and indicated that the technical report will be modified accordingly.
Therefore, this is an open issue.

LC ISR, LLC (4/10) – The information on the domestic and stock wells within five miles of the Permit Area has been incorporated into Section 2.2 (Uses of Adjacent Lands and Waters) as Figure 2.2-6 and Table 2.2-4.

b. Draft SER 2.3 (TR Section 2.6) Proper Seismological Design Criteria

In the TR, LCI proposed using the uniform building code (UBC) design criteria to meet the seismologic criterion in accordance with the then existing Wyoming regulations. However, since submittal of the TR, Wyoming adopted the international building code (IBC) in lieu of the UBC to their regulations. The primary difference with respect to seismological design criterion; the IBC criterion is based on a recurring interval of 2,500 years whereas the UBC criterion was based on a 500-year recurrence interval. During the September 25, 2009 Tele-conference call, LCI committed to adhere to the existing regulations for the design criterion.

NRC Summary of 12/9/09 Conference Call - LCI acknowledged this confirmatory item and indicated that the technical report will be modified accordingly. **Therefore, this is an open issue.**

LC ISR, LLC (4/10) - Sections 2.6.3.2 (Uniform Building Code and International Building Code) and 2.6.3.5 (Probabilistic Seismic Hazard Analysis and IBC) have been updated with the IBC information for Wyoming and Figure 2.6-6 has been updated with the 2,500-year map (replacing the original 500-year). For continuity and comparison, Figure 2.6-4 UBC Seismic Zones was kept in Section 2.6.3.2. The IBC seismic design criteria will be used for facility construction at Lost Creek.

c. **Draft SER 2.4.1 (TR Section 2.7.1) (RAI Responses 12/12/08 2.7.1 #1 through #4) Mitigation efforts for any Surface Water Inundation**
In the TR, LCI included information on surface water flow regime. NRC staff questioned whether or not the estimated flows were representative of the entire proposed licensed area and what measures were to be undertaken to minimize issues related to inundation or erosion from surface water flows.

In the December 12, 2008 responses to RAIs, LCI indicated that the evaluation in the TR represented the worst case and thus applicable for the entire area. LCI committed to installing a berm around the CPP and measures to mitigate erosion in areas in which flooding may occur.

NRC Summary of 12/9/09 Conference Call - LCI acknowledged this confirmatory item and indicated that the technical report will be modified accordingly. **Therefore, this is a confirmatory item.**

LC ISR, LLC (4/10) Information on the berm around the Plant has been added in Section 7.4.1 (with a cross-reference to there from Section 3.3.4). Information on berms around other facilities and on erosion control measures is in Section 7.3.2. More detail on the drainages has been added to Section 2.7.1, and Figure 2.7-1 and Table 2.7-2 have been updated.

d. **Draft SER 3.12; 6.1 (TR Sections 3.3 & 6.2)**
(RAI Responses 12/12/08 3.3 #3, 6.2 #15 &16) Insufficient Disposal Capacity

In the TR, LCI stated that two to four deep injection wells would be installed. LCI estimated in an RAI that the capacity of each disposal well will be 100 gpm. NRC staff notes that if only two wells are installed and there is a failure of a disposal well, one well will not be sufficient to handle the concentrated brine during restoration

(130 gpm). Two wells are not sufficient if there is a pond failure and all liquid waste is sent to the deep disposal well (226 gpm).

In the December 12, 2008 response to RAIs, LCI provided details on the calculation of the maximum liquid disposal capacity. It was estimated that if one well disposal well or one pond was not operational, the remaining facility storage/disposal capacity would be sufficient for two weeks. In the unlikely event that the remaining storage capacity is insufficient, LCI committed to ceasing operations until the disposal capacity is sufficient.

The staff has determined that the response is adequate and needs to be included in the Technical Report. Note that LCI will be required to maintain, at a minimum, hydraulic control of wellfields in which remnant lixiviant exists in the production aquifer. Ceasing operations must not include ceasing hydraulic control. Estimation of disposal capacity during an emergency situation must take into account the waste stream from the minimum hydraulic control.

NRC Summary of 12/9/09 Conference Call - LCI acknowledged this confirmatory item and indicated that the technical report will be modified accordingly. **Therefore, this is a confirmatory item.**

LC ISR, LLC (4/10) - The information in the responses to the December 2008 RAIs 3.3 #3 and 6.1 #15 and #16 has been incorporated into TR Section 4.2.5.4. The two TR sections referenced in the December 2009 RAIs [Section 3.3 (Plant Processes, Instrumentation, and Control) and Section 6.2 (Plans and Schedules for Groundwater Quality Restoration)] do not relate directly to the deep disposal wells. Therefore, the information from the RAI responses has been incorporated into Section 4.0 (Effluent Control Systems), specifically Section 4.2.5.4 (Disposal of 11(e)(2) Byproduct Materials).

e. Draft SER 3.1.2 (TR Section 3.2.2) (RAI Responses 12/12/08 3.2 #11) Approval of Wellfield Packages

In the TR, LCI indicated that individual Mine Unit Hydrogeologic Testing Plans and Reports will be submitted to Wyoming Department of Environmental Quality. The staff requested that the applicant commit to the submittal of those reports to, and approval by NRC prior to operations.

In the December 12, 2008 response, LCI committed to submit wellfield packages to NRC for review and approval until the NRC staff is satisfied with LCIs management experience and the SERP Process.

NRC Summary of 12/9/09 Conference Call - LCI acknowledged this confirmatory item and indicated that a license condition will be required for the submittal and approval of individual Mine Unit Hydrogeologic Testing Plans and Reports (aka Packages) to the NRC. **Therefore, this is an open issue pending staff review of the proposed license condition.**

LC ISR, LLC (4/10) - Waiting for license condition, no response required.

f. Draft SER 3.1.2 (TR Section 3.2.2) (RAI Responses 01/16/09 3.2 #9 & 10) Cumulative Drawdown

In the TR, LCI used an analytical drawdown analysis to estimate the cumulative drawdown by its operations. The staff inquired about the methodology, whether or not it accounted for the effects of the fault, and determine whether or not the cumulative drawdown posed a problem for operations.

In the January, 16, 2009 response, LCI used a transmissivity of 144 ft2/d, storativity of 7e-5 and thickness of the HJ horizon of 120 feet and predicted a drawdown at the end of production and restoration operations at an average pumping rate of 175 gpm would be 177 ft at 2 miles from the centroid of production and 147 ft at 3 miles if all production was done on one side of the fault. With production on both sides of the faults they predicted that drawdown would be 89 feet at 2 miles and 74 feet at 3 miles. LCI provided a figure which showed the magnitude of the drawdown in the mine units near the centroid of about 160 ft which would dewater the production aquifer. LCI provided an analysis of drawdown and a description of how it will operate the mine units near the fault to prevent dewatering.

NRC Summary of 12/9/09 Conference Call - LCI acknowledged this confirmatory item and indicated that the technical report will be modified accordingly. **Therefore, this is a confirmatory item.**

LC ISR, LLC (4/10) - The text under the subheading **Cumulative Drawdown** in Section 3.2.7.3 (Projected Water Balance and Water Level Changes) has been updated and Figure 3.2-6 has been replaced with Figures 3.2-7a and 7b, which illustrate drawdown extent with and without recharge.

g. Draft SER 3.1.2 (TR Section 3.2.2) (RAI Response 12/12/08 3.2 #1) Perimeter Well Spacing

In the TR, LCI proposed perimeter zone monitoring wells for horizontal excursion monitoring be located 500 feet apart on a ring set 500 feet from the nearest production well pattern. The staff requested supporting documentation for the proposed spacing.

In the December 12, 2008 response, LCI provided supporting evidence for the adequacy of the location of these monitoring wells.

NRC Summary of 12/9/09 Conference Call - LCI acknowledged this confirmatory item and indicated that the technical report will be modified accordingly. **Therefore, this is a confirmatory item.**

LC ISR, LLC (4/10) - The December 12, 2008 response to NRC's 11/08 RAI 3.2 #1 has been incorporated into TR Section 3.2.2.2. The text in TR 3.2.2 has also been revised to clarify that when multiple ore horizons are present that they will be mined concurrently instead of one at a time as was originally proposed.

h. Draft SER 3.1.2 (TR Section 3.2.2.2) (RAI Response 12/12/08 3.2 #1) Perimeter Well Screened Interval

In the TR, LCI proposed screening of the perimeter zone monitoring wells at the selected ore zone and not the entire HJ Horizon. The staff requested justification for the selective screened interval.

In the December 12, 2008 response, LCI stated that WDEQ requires that the ring wells only be completed in the "HJ Horizon" sand which is being targeted for extraction and provided supporting evidence for why this completion is sufficient.

NRC Summary of 12/9/09 Conference Call - LCI acknowledged this confirmatory item and indicated that the technical report will be modified accordingly. **Therefore, this is a confirmatory item.**

LC ISR, LLC (4/10) - Please see Response to RAI #3(g) above.

i. Draft SER 3.1.2 (TR Section 3.2) (RAI Response 12/12/08 3.2 #7) Instrumentation, Alarms and Control Systems in Well Fields

In the TR, LCI provided only a general commitment to have the proper instrumentation,
alarms and control systems. The staff requested more specific information.

In the December 12, 2008 responses to RAIs, LCI provided additional detailed information on the instrumentation, alarms and control systems to be used in the process plant and well fields.

NRC Summary of 12/9/09 Conference Call - LCI acknowledged this confirmatory item and indicated that the technical report will be modified accordingly. **Therefore, this is a confirmatory item.**

LC ISR, LLC (4/10) - The information in LC ISR, LLC's Response to the December 2008 RAI 3.2 #7 has been incorporated into TR Section 3.2.6 (Mine Unit Piping and Instrumentation).

j. Draft SER 3.1.2 (TR Section 3.2.2.2) (RAI Response 12/12/08 3.2 #6 and #7) Field Inspection Program

In the December 12, 2008 responses to RAIs, LCI provided additional detailed information on the field inspection program to ensure timely detection of spills or leaks.

NRC Summary of 12/9/09 Conference Call - LCI acknowledged this confirmatory item and indicated that the technical report will be modified accordingly. **Therefore, this is a confirmatory item.**

LC ISR, LLC (4/10) – The December 12, 2008 response has been added to a new TR Section 3.2.7.5 (Spill Prevention and Detection) instead of Section 3.2.2.2 (Monitor Well Locations) in order to present the information in a more orderly fashion.

k. Draft SER 6.1.3 (TR Section 6.2.3) (RAI Response 12/12/08 6.2 #13) Biorestoration as an Alternative Method

In the TR, LCI indicated that the addition of biological reductants may be evaluated as an experimental technology for aquifer restoration. The staff requested more specific details on the use of biological reductants as the technology is still in experimental phases.

In the December 12, 2008 responses to RAIs, LCI indicated that use of biological reductants is only speculative and should be considered an alternative restoration method. LCI committed to providing details on any biorestoration methodology in a decommission plan for a mine unit which will be submitted to NRC for approval prior to the use of biorestoration.

The staff notes that the plan may be a well field restoration plan in lieu of a decommission plan; NRC staff will not accept use of biorestoration methods approved through the SERP process without prior NRC approval.

NRC Summary of 12/9/09 Conference Call - LCI acknowledged this confirmatory item and indicated that the technical report will be modified accordingly. **Therefore, this is a confirmatory item.**

LC ISR, LLC (4/10) - The fourth paragraph of TR Section 6.2.3 (Groundwater Restoration Methods) has been revised to indicate NRC approval must be obtained before use of biorestoration.

l. Draft SER 6.1.3 (TR Section 6.2.3) (RAI Response 12/12/08 6.2 #14) Comprehensive Safety Plan for Use of Reductants

In the TR, LCI indicated that the addition of reductants may be used as part of the groundwater treatment phase of the aquifer restoration. LCI lists examples of typical reductants as hydrogen sulfide or sodium sulfide; their preference was sodium sulfide due to safety concerns for handling and storing hydrogen sulfide. LCI committed to implementing a comprehensive safety plan for use of reductants. The staff requested more details on the safety plan.

In the December 12, 2008 responses to RAIs, LCI indicated that a plan at this time was premature but listed issues to be addressed by a plan and that the plan will be implement on after a review by the SERP.

NRC Summary of 12/9/09 Conference Call - LCI acknowledged this confirmatory item and indicated that the technical report will be modified accordingly. **Therefore, this is a confirmatory item.**

LC ISR, LLC (4/10) - The fourth paragraph of TR Section 6.2.3 (Groundwater Restoration Methods) has been revised to indicate that, prior to use of a reductant, a safety plan for that reductant must be developed, approved by the SERP, and implemented prior to use of the reductant.

m. Draft SER 6.1.3 (TR Section 6.1) (RAI Response 12/12/08 6.2 #11 & #12) Perimeter Well Screened Interval

In the TR, LCI indicated criteria to be used to determine when principal activities at a mine unit are completed. The staff requested more information with respect to requirements for timeliness of decommissioning as outlined in 10 CFR 40.42

In the December 12, 2008 responses to RAIs, LCI indicated that should a mine unit be shut down, decommissioning will commence within 24 months. Furthermore, LCI committed to notify NRC of the transition to restoration.
While meeting one criterion, LCI responses did not completely address all issues. First, for clarification purposes, NRC is using terms well field and mine unit interchangeably. Most importantly, the applicant is directed to the letter dated July 7, 2008 (ML081480293) from NRC to an existing licensee which documents NRC position on compliance with the timeliness of decommissioning regulations. Note that "principal activities" is defined as the last date of lixiviant injection. Four conditions would trigger NRC notification of decommissioning (restoration) activities: the license has expired, the licensee has decided to permanently cease principal activities, no principal activities have been conducted for 24 months under the license, or no principal activities have been conducted in a specific wellfield. Restoration of a wellfield must be completed within 24 months after initiation of restoration unless an alternate schedule is approved.

With respect to LCI reference that a well field may be temporarily shut down for an extended period, the staff's position is that the hydraulic control (i.e., inward hydraulic gradient in each wellfield) and excursion monitoring will be maintained by the licensee during any hiatus between the cessation of principal activities and the start of restoration activities.

NRC Summary of 12/9/09 Conference Call - LCI acknowledged this confirmatory item and indicated that the technical report will be modified accordingly. LCI asked staff whether or not this item was equivalent to prior LCI acknowledgement that the proposed schedule was an alternative schedule. The staff indicated that to a large extent it was but that LCI should use the terminology "principal activities" in the narrative. **Therefore, this is a confirmatory item.**

LC ISR, LLC (4/10) - TR Section 6.1 (Completion of Production Operations) has been revised to incorporate the December 12, 2008 response and to provide clarification as requested above. In addition, to address the criteria to determine the end of production, a sentence has been added at the end of Section 6.2 (Plans and Schedules for Groundwater Quality Restoration). To address the alternate restoration schedule, a sentence has been added at the end of the first paragraph in Section 6.2.

n. Draft SER 6.1.3 (TR Section 6.0) (RAI Response 12/12/08 6.2 #6; RAI Response 02/27/09 6.2 #5) Restoration at Multiple Mineralization Zones

In the TR, LCI proposed that restoration will proceed on the well-head by well-head basis in lieu of the entire wellfield. LCI proposed that once production is completed for wells at a particular wellhead, that portion of the wellfield will immediately start restoration. LCI further states that the production and restoration processes within a wellfield may be buffered by one or two well houses. In Section 3.2.2 Mine Unit Design, LCI proposed sequencing to the restoration process within a wellfield that has multiple mineralizations within the production aquifer. Production will proceed from the lowest mineralization to the uppermost mineralization. Restoration will be initiated after production from the uppermost mineralization is complete and proceeds downward. The staff questioned the viability on a method for partial restoration of the production aquifer.

In the December 12, 2008 response, LCI indicated that the entire HJ Horizon will be treated as a single unit. In the February 2009 reply, LCI indicated that multiple wells will be utilized during production of the first mine unit and that all levels will undergo restoration at the same time. LCI indicated that stacked restoration techniques may be applied to future mine units

NRC Summary of 12/9/09 Conference Call - LCI acknowledged this confirmatory item and indicated that the technical report will be modified accordingly. **Therefore, this is a confirmatory item.**

The staff notes that a change to stacked restoration techniques will require review through the SERP process.

LC ISR, LLC (4/10) - The fourth paragraph in Section 6.0 (Groundwater Quality Restoration, Surface Reclamation, and Facility Decommissioning) and the second paragraph in Section 3.2.2 (Mine Unit Design) have been revised to remove reference to progressive production and restoration of 'stacked' or overlying sands.

o. Draft SER 6.1.4 (TR Section 6.1.4) (RAI Response 12/12/08 6.2 #10) Successful Analog Examples of the Proposed Restoration Methods

In the TR, LCI utilized six (6) pore volumes for restoration in the financial surety calculations. The staff requested justification for the six pore volumes.

In the December 12, 2008 response, LCI provided justification for their PV estimated by providing a technical memorandum that evaluates analogs of restorations at existing facilities where similar restoration methods have been used successfully. In addition, LCI proposed a strategy to adjust the PV estimates as needed as the restoration work proceeds.

NRC Summary of 12/9/09 Conference Call - LCI acknowledged this confirmatory item and indicated that the technical report will be modified accordingly. **Therefore, this is a confirmatory item.**

LC ISR, LLC (4/10) – The technical memorandum mentioned above has been added as Attachment 6.2-1, and a reference to it included in the last paragraph of Section 6.2.3 (Groundwater Restoration Methods). There appears to be an error in the citation listed in the above comment from NRC (TR Section 6.1.4). However, LC ISR, LLC understands the comment and has inserted text from the December 12, 2008 document into the TR in Section 6.2.3.

p. Draft SER 6.1.5 (TR Section 6.1.4) (RAI Response 12/12/08 6.2 #10) Source of Porosity Values used in Surety Calculations

In the TR, LCI used a porosity of 0.26 to calculate the pore volume. The staff requested the applicant to provide the source of that estimate.

In the December 12, 2008 response, LCI reports that the 26 percent value for effective porosity was based on core samples from numerous areas on the property.

NRC Summary of 12/9/09 Conference Call - LCI acknowledged this confirmatory item and indicated that the technical report will be modified accordingly. **Therefore, this is a confirmatory item.**

LC ISR, LLC (4/10) - The last paragraph in Section 6.2.3 (Groundwater Restoration Methods) was revised to indicate that the effective porosity was based on core samples.

q. Draft SER 6.1.5 (TR Section 6.2.3) (RAI Response 01/16/09 6.2 #8) Corrected Pore Volume Calculations

In the TR, LCI stated in the narrative that both horizontal and vertical flare factors were estimated at 20 percent; however, the surety calculations utilized flare factors of 10 percent. The staff asked about this discrepancy.

In the January 16, 2009 response, LCI reiterated their opinion that a flare factor of 20 percent was appropriate based on data for existing facilities and may be less at the LCI site due to the scale of the proposed restorations (on the well house scale). LCI corrected the calculations yielding a PV of 59.97 million gallons for Mine Unit 1.

NRC Summary of 12/9/09 Conference Call - LCI acknowledged this confirmatory item and indicated that the technical report will be modified accordingly. **Therefore, this is a confirmatory item.**

LC ISR, LLC (4/10) - The most current revision of the Surety Estimate (Table 6.8-1) is attached. In addition to revising the flare factor to 20%, several changes were made as outlined below:

Worksheet 1 – Groundwater Restoration:

Technical Assumptions: The Mine Unit 1 (MU-1) pattern count, monitor ring count and mine unit area were originally more conceptual in nature with 180 patterns, 64 monitor wells and a pattern area of 1,784,484 square feet. The current surety estimate is based on MU-1 consisting of 241 patterns, 69 monitor wells and a pattern area of 2,115,594 square feet. LCI anticipates installing 50% of the MU-1 patterns and all the monitor wells during the first bonding calendar year. Therefore, the surety estimate accounts for 120 patterns, 69 monitor wells and a pattern area of 1,057,797 square feet. The associated pore volume for the current surety estimate is 34,181,229 gallons.

III. Recirculation: The original estimate did not break out the cost for recirculation (homogenizing) the groundwater after groundwater sweep and reverse osmosis were complete. This section was added after consultation with the WDEQ-LQD.

VI. Labor: The original groundwater restoration labor estimate allowed for two years with a supervisor, six laborers and two vehicles. The current surety estimate was revised to meet the WDEQ-LQD's requirements for various support staff for up to three and one-half years during restoration and stability.

VII. Restoration Capital Requirements: The original surety estimate of $450,000 for plugging and abandonment of three waste disposal wells was reduced to $306,270 after receiving estimates based on the current proposed well installations.

Worksheet 3 – Plant Building Demolition and Disposal:

Header Houses: The original surety estimate was based on the conceptual header house count of nine buildings. The current surety estimate is based on the installation of 50% of the header houses in MU-1 during the first year, or six buildings.

Plant: The original surety estimate assumed that three inches of soil would be removed from beneath the Plant and disposed at a licensed facility. LC ISR, LLC has planned to install an HDPE liner under the Plant foundation and has consequently reduced its soil removal estimate to one inch.

Worksheet 4 – Pond Reclamation:

Pond Line: The original surety estimate utilized an incorrect conversion factor from mils to inches. The current surety estimate uses the appropriate conversion of 0.001 inches to one mil.

Worksheet 5 – Well Abandonment:

The MU-1 pattern count, monitor ring count, average well depth and casing internal diameter (ID) were originally more conceptual in nature with 180 production wells, 360 injection wells, 64 monitor wells, an average well depth of 500 feet and a casing ID of 4.5 inches. The current surety estimate is based on MU-1 consisting of 241 production wells, 417 injection wells, 69 monitor wells, an average well depth of 410 feet and a casing ID of 4.328 inches. LC ISR, LLC anticipates installing 50% of the MU-1 patterns and all the monitor wells during the first bonding calendar year. Therefore, the surety estimate accounts for 120 production wells, 208 injection wells and 69 monitor wells at an average depth of 410 feet. The cost per sack of cement was also revised to current pricing of $14.43/sack. The labor was accounted for on a per well basis in the original surety estimate. The revised estimate accounts for all project labor under Worksheet 1: Groundwater Restoration.

Worksheet 6 – Mine Unit Equipment Removal and Disposal:

Mine Unit Piping: The MU-1 pattern count was originally more conceptual in nature with 180 production wells and 360 injection wells. The current surety estimate is based on MU-1 consisting of 241 production wells and 417 injection wells. LCI anticipates installing 50% of the MU-1 patterns during the first bonding calendar year. Therefore, the current surety estimate accounts for 120 production wells and 208 injection wells (328 wells total). The cost of piping removal originally included labor on a per unit basis. That labor component was

removed in the current estimate and accounted for under Worksheet 1: Groundwater Restoration.

Production Well Pumps: The Mine Unit 1 (MU-1) pattern count was originally more conceptual in nature with 180 production wells. The current surety estimate is based on MU-1 consisting of 241 production wells. LCI anticipates installing 50% of the MU-1 patterns during the first bonding calendar year. Therefore, the current surety estimate accounts for 120 production wells. The cost of piping removal originally included labor on a per unit basis. That labor component was removed in the current estimate and accounted for under Worksheet 1: Groundwater Restoration. In addition, the original estimate for pump setting depth was 400 feet. That number has also been revised in the current surety estimate to 360 feet as the average well depth is estimated at 410 feet.

Buried Trunkline: The original cost of buried pipeline removal included labor on a per unit basis. That labor component was removed in the current estimate and accounted for under Worksheet 1: Groundwater Restoration.

Manholes: The original cost of manhole removal included labor on a per unit basis. That labor component was removed in the current estimate and accounted for under Worksheet 1: Groundwater Restoration.

Worksheet 8– Miscellaneous Reclamation:

Fence Removal and Disposal: The original cost of fence removal included labor on a per unit basis. That labor component was removed in the current estimate and accounted for under Worksheet 1: Groundwater Restoration.

Booster Pump Assembly Removal and Disposal: The original surety estimate included the disassembly and removal of eight booster pumps. The current surety estimate and design has no booster pumps and therefore requires no removal bond.

Culvert Removal and Disposal: The original cost of culvert removal included labor on a per unit basis. That labor component was removed in the current estimate and accounted for under Worksheet 1: Groundwater Restoration.

DDW Pipeline Removal: The original surety estimate did not include bonding for the removal of the three disposal well pipelines. The current estimate accounts for removal of the lines.

r. Draft SER 6.1.5 (TR Section 6.2.2) (RAI Response 12/12/08 6.2 #2) Standards for Aquifer Restoration

In the TR, LCI stated that the goal of the groundwater restoration is to return the groundwater quality to pre-operational class-of-use. In Section 6.2.5, LCI reported that it will conduct daily, weekly, and monthly analyses to track restoration progress. LCI stated it would sample all monitoring wells at the end of the active restoration phase for parameters listed in Table 6.2-1. It said these values would be compared to the baseline average to help ensure class-of-use criteria have been met. The staff asked the applicant to commit to restoration standards in 10 CFR Part 40 as class-of-use is a state-standard and not promulgated by NRC regulations.

In the December 12, 2008 response, LCI committed to the standards identified in Criterion 5B (5) of 10 CFR Part 40, Appendix A. Those standards are background, the values in the table in Criterion 5C of 10 CFR Part 40, Appendix A, or an alternate concentration limit established by NRC in accordance with Criterion 5B(6).

NRC Summary of 12/9/09 Conference Call - LCI acknowledged this confirmatory item and indicated that the technical report will be modified accordingly. **Therefore, this is a confirmatory** item.

LC ISR, LLC (4/10) - The text in TR Section 6.2 (Plans and Schedules for Groundwater Quality Restoration) has been modified as requested.

s. Draft SER 6.1.5 (TR Section 6.2.2) (RAI Response 01/16/09 6.2 #3) Standards for Aquifer Restoration

In the TR, LCI proposed to set Restoration Target Values (RTVs) for the LC mine units as class-of-use determined from baseline water quality. For wells in the perimeter monitoring ring and in overlying and underlying aquifers, LCI stated that class-of-use would be determined on a well-by well basis. For the mine unit pattern area, the baseline water quality will be averaged to determine the class-of-use for that mine unit. Baseline water quality will be collected from all wells in accordance with a testing proposal submitted to WDEQ for review and approval. NRC staff notes that as LCI has revised its goal of restoration to pre-operational baseline water quality. Therefore the RTVs must be based on baseline water quality and not class-of-use as proposed.

In the January 16, 2009 response, LCI committed to restoration on the perimeter monitoring ring on specific baseline water quality based on a well-by-well basis.

NRC Summary of 12/9/09 Conference Call - LCI acknowledged this confirmatory item and indicated that the technical report will be modified accordingly. **Therefore, this is a confirmatory item.**

LC ISR, LLC (4/10) - The text in TR Section 6.2.2 (Restoration Requirements) has been updated as requested.

t. Draft SER 6.1.6 (TR Section 6.2.2) (RAI Response 01/16/09 6.2 #3)
Ground Water Restoration Monitoring

In Section 6.2.5, LCI reported that it will conduct daily, weekly, and monthly analyses to track restoration progress. LCI stated it would sample all monitoring wells at the end of the active restoration phase for parameters listed in Table 6.2-1. It said these values would be compared to the baseline average to help ensure class-of-use criteria have been met. LCI has committed to meet pre-operational baseline average water quality, the reference to class-of -use should be removed.

NRC Summary of 12/9/09 Conference Call - LCI acknowledged this confirmatory item and indicated that the technical report will be modified accordingly. **Therefore, this is a confirmatory item.**

LC ISR, LLC (4/10) - The text in TR Section 6.2.5 (Reporting) has been updated as requested.

u. Draft SER 6.1.6 (TR Section 6.2.2)
Excursion Monitoring During Restoration/Stability

LCI did not specifically state in Section 6.0 how often it would monitor for excursions in the overlying/underlying and well ring monitoring wells during restoration and stability monitoring. LCI did, however commit to monitoring these wells for excursions on the same schedule used during production operations in Section 5.7.8.2.

NRC Summary of 12/9/09 Conference Call - LCI responded that it thought that monthly not bi-weekly sampling was proposed for the restoration phase in the application. LCI acknowledged this confirmatory item and indicated that the technical report will be modified accordingly. **Therefore, this is an open issue.**

LC ISR, LLC (4/10) - The text in TR Section 6.2.5 (Reporting) has been updated as requested.

v. Draft SER 6.1.7 (TR Section 6.2.4) (RAI Response 01/16/09 6.2 #17) Stability Monitoring Period

In Section 6.2.4, LCI stated that once restoration has been completed, they will begin a six month stability period to demonstrate that the restoration standard has been adequately maintained. In an RAI (Section 6.2, No. 17, Dec. 2008), LCI committed to a nine month monitoring period and provided a basis for the time period based on returning the ore body to pre-operational reducing conditions.

NRC Summary of 12/9/09 Conference Call - LCI acknowledged this confirmatory item and indicated that the technical report will be modified accordingly. **Therefore, this is a confirmatory item.**

LC ISR, LLC (4/10) - The text in Section 6.2.4 (Stabilization Phase) has been updated as requested.

w. Draft SER 6.1.7 (TR Section 6.2.4) (RAI Response 1/16/09 6.1 #6) Well Screen Completions for Stability Monitoring

LCI did not provide the screen location of the wells which would be used to monitor stability in the production zone. As the HJ production zone has three horizons separated by interbedded low permeability units which are not continuous, NRC staff was concerned there may be a difference in water quality in the different horizons during stability monitoring. LCI responded in an RAI (Section 6.1, No. 6, Dec. 2008) that the water quality in the HJ horizon is significantly consistent regardless of vertical position. NRC staff would like this supporting RAI text to be included in the application to justify that stability monitoring data will be representative of the entire HJ zone.

NRC Summary of 12/9/09 Conference Call - LCI acknowledged this confirmatory item and indicated that the technical report will be modified accordingly. **Therefore, this is a confirmatory item.**

LC ISR, LLC (4/10) - Please see Response to Comment #3(v) above.

4. HYDROGEOLOGY ADMINISTRATIVE ITEMS

a. Draft SER 5.7.8 (TR Section 5.7.8) Long-term (60-day) Excursion Monitoring Requirement

The NRC staff will require that LCI terminate lixiviant injection, or, provide additional reclamation surety that is agreeable to the NRC, if an excursion cannot be remediated within 60 days of confirming the excursion. Please provide such a commitment in the application.
Regulatory basis: 10 CFR Part 40 Appendix A, Criterion 5D.

NRC Summary of 12/9/09 Conference Call - LCI acknowledged that this is a NRC requirement and will include in the technical report. **This is an open issue.**

LC ISR, LLC (4/10) - TR Section 5.7.8.2 (Operational Monitoring), under the subheading **Excursion Verification and Corrective Action** has been revised to clarify that LC ISR, LLC will terminate lixiviant injection or provide additional reclamation surety that is agreeable to the NRC if an excursion cannot be remediated within 60 days of confirming the excursion.

b. Draft SER 3.2 (TR Section 3.2) (RAI Response 12/12/09 3.2 #7) Lack of Header House Schematic and Frequency of Inspection

In the December 12, 2008 response, LCI provided details on the instrumentation, alarms and controls but did not include a schematic of header house piping and instrumentation or a statement on the frequency of heard house inspections. The staff has determined that the response is adequate with the additional schematic and statement on the frequency (pending review) which needs to be included in the Technical Report.

NRC Summary of 12/9/09 Conference Call - LCI proposed that a schematic would be considered confidential due to proprietary information. The staff indicated that the schematic can be submitted as confidential if accompanied by a completed affidavit (10 CFR 2.390), which will be reviewed for appropriateness by the staff. If the information meets the criteria for confidentiality, then the information will be reviewed as such. If not, the information will be returned to Lost Creek ISR, LLC. **This is an open issue.**

LC ISR, LLC (4/10) - The requested schematics have been submitted in a separate envelope with a completed affidavit requesting that they be considered confidential due to proprietary information. The schematics are labeled as Figures 3.2-5a, b, and c – Confidential - in the Table of Contents for Section 3.0 (Description of the Proposed Facility) and are referenced in the text.

5. HEALTH PHYSICS OPEN ISSUES

a. Draft SER 2.6 Background Radiation Characteristics (TR Section 2.5.5.2) (RAI Response 12/12/082.9 #1a; 8/5/09 5#2)

10 CFR Part 40 Appendix A, Criterion 7 requires a preoperational monitoring program in place for one year prior to any major site construction to establish a complete baseline. The baseline is required to meet operational requirements of Criterion 7, such as (1) measure/evaluate compliance with applicable standards and regulations, (2) evaluate performance of control systems and procedures, (3) evaluate environmental impacts of operation, and (4) detect potential long-term effects.

(1) The applicant collected radon data for three calendar quarters. These results do not represent a minimum of twelve months of consecutive data as recommended by Regulatory Guide 4.14 nor is there justification from the applicant for collecting less data. Therefore, staff cannot conclude that pre-operational air radon sampling 19 results accurately reflect site-specific conditions. Regulatory Basis: 10 CFR Part 40 Appendix A, Criterion 7. **This is an open issue.**

LC ISR, LLC (4/10) - Table 2.5-6 has been moved to Section 2.9-2 (Passive Gamma and Radon Monitoring) and renumbered as Table 2.9-3. It includes five quarters of data.

(2) It is not clear in the TR what criteria the applicant used in determining where to place the radon monitors and air particulate samplers. The applicant provided criteria in the response dated August 5, 2009.

(a) After reviewing the response, it is still not clear to the staff why the applicant chose location HV5 nor why samplers were only co-located at HV1 and HV4. Without this information, NRC staff cannot determine whether or not the placement of the preoperational radon monitors and air particulate samplers is consistent with Regulatory Guide 4.14. Regulatory Basis: 10 CFR Part 40 Appendix A, Criterion 7. **This is an open issue.**

LC ISR, LLC (4/10) - Section 2.5.5.2 (Passive Gamma and Radon Monitoring) was redrafted to clarify the August 2009 response and moved to Section 2.9.2. Section 2.9.3.7 (Radiological Air Particulate (High-Vol) Sampling) has been added, and it provides additional detail regarding the radon monitor and the air particulate samplers, particularly in the subsection **Locations of Radon, Passive Gamma, and Air Particulate Instrumentation**.

In light of additional information now available, LC ISR, LLC has elected to collect additional radon and passive gamma data. The additional radon and passive gamma sampling is described in Section 2.9.4 (2010-11 Baseline Radiological Studies). Radon and passive gamma will be measured at twelve locations (Figure 2.9-27), including:

the areas with maximum predicted project-related radiological activity (per MILDOS modeling);
all air particulate sampling locations; and
all locations that were monitored from 2006-08.

Sampling begins in April 2010 so that four additional quarters of radon and passive gamma baseline data will be collected prior to commencing Plant operations.

(b) It is not clear that the location of estimated maximum concentrations of radioactive materials was taken into account in selecting the locations of the air particulate samplers. NRC staff cannot determine if the placement of the preoperational air particulate monitors, other than the Bairoil monitor, is consistent with Regulatory Guide 4.14. Regulatory Basis: 10 CFR Part 40 Appendix A, Criterion 7. **This is an open issue.**

NRC Summary of 12/9/09 Conference Call - LCI agreed to provide their rationale for the location of the monitors. Lost Creek will check to make sure that they had not provided basis for not co-locating radon monitors and air particulate samplers. It may be attached to the January 2009 response. If not, they will provide the information.

Note: The [NRC] staff stated an assessment of the background radiation of the site is essential before operations begin because the licensee is only responsible for radiation exposures, releases, and decommissioning of residual radioactivity that is above background. Therefore, it is in the applicant's best interest to assess the type and location of the highest radiation within the permitted area before operations begin. Additionally, LCI must consider dose to the member of the public within the permitted area because the permitted area consists of Bureau of Land Management (BLM) property and hunting areas. Dose assessments to the public must be made within the permit boundaries and to ensure compliance with 10 CFR 20.1101(b); 20.1301, Appendix B, Table 2.

LC ISR, LLC (4/10) - Please refer to the above response for RAI #5.a.(2)(a).

b. Draft SER 2.6.3 Vegetation, Food, and Fish Sampling (TR Section 2.2.1) (RAI Response 12/12/08 2.9 #3, 6; 8/5/09 5 #1)

Regulatory Guide 4.14 recommends collecting (1) vegetation samples from three locations near the site in three different sectors having the highest predicted airborne radionuclide concentrations due to milling operations, (2) three food samples that include crops, livestock etc. within 3 km of the site, and (3) fish samples in each body of water.

The applicant identified three grazing allotments which provide forage for cattle, horses and sheep. The applicant stated that there will be no radiological impact on vegetation based on its operations producing yellowcake slurry. Therefore, the applicant did not initially perform preoperational vegetation sampling. However, NRC staff notes that baseline data is also used to assess the impacts of unusual releases due to spills, accidents, etc. In addition, radon releases can lead to radionuclide foliar deposition and uptake by vegetation of radon daughter products.

Per the August 5, 2009 response, LCI ran the MILDOS computer code to determine the location of maximum contamination deposition. The locations that resulted from this analysis were "closer to the plant site than anticipated". Since previous public dose estimates were arbitrarily analyzed at the permit boundaries, the staff questions if this new analysis changed the predicted maximum expected public dose from operations. MILDOS results need to be provided and reviewed by the NRC staff. **This remains an open issue.**

NRC Summary of 12/9/09 Conference Call - LCI understands the question and agreed to provide information.

LC ISR, LLC (4/10) – The technical memorandum describing the 2008 vegetation sampling, which was submitted in the December 2008 Response to RAI 2.9 #3, has been added to the Technical Report as Attachment 2.9-6. The results are also discussed in Section 2.9.3.2 (Vegetation and Associated Surface Soil Sampling), which is a new section in the Technical Report. A discussion of the 2009 MILDOS modeling, which addressed predicted ground deposition of radon daughter products from the Plant operations, has been added as TR Section 2.9.3.1 (Supplementary MILDOS Modeling). Additional vegetation and surface soil samples were collected in 2009 based on the 2009 MILDOS. The results of this sampling are described the new Section 2.9.3.2 and Attachment 2.9-7.

Neither food crops nor fish are present within 3 km of the Permit Area. Tissue samples were collected from cattle that grazed within 3 km of the Plant site in 2008 and 2009. Section 2.9.3.5 (Food and Fish Sampling) and Attachment 2.9-8 have been added with a description of the sampling and the analytical results.

Regarding the expected public dose, please see Section 7.2.1.2 (Exposures from Air Pathways) under the subheading **Doses to 'Casual' Members of Public Who Enter Permit Area (e.g. a Hunter)**, and page 21 of Attachment 7.2-1. The analysis of dose estimates at the permit boundary was not arbitrary. Even though the entire permit may not be fenced, LC ISR, LLC and BLM have some level of control over activities within the permit boundary. In addition, the isolated location of the site and harsh conditions further reduce the possibility for casual entrance to and use of the area.

c. Draft SER 2.6.4 Direct Radiation (TR Section 2.9)
(RAI Responses 12/12/08 2.9)

(1) The first component of the direct radiation measurement program consisted of placing thermoluminescent dosimetry (TLD) badges in the same locations as the radon samplers. These locations are shown in Figure 2.6-1 of the TR. Results are presented in Table 2.6-1. As stated in Section 2.6.1, NRC staff can not determine if the placement of the radon and particulate air samplers are consistent with Regulatory Guide 4.14. In addition, the locations for the radon and particulate air samplers are not the same. Because of these issues, NRC staff can not determine if the placement of the TLD badges is consistent with Regulatory Guide 4.14. Therefore, staff can not find the placement of TLDs associated with particulate air samples acceptable. **This is an open issue.**

NRC Summary of 12/9/09 Conference Call - LCI thought they actually addressed this issue, agreed to provide information.

LC ISR, LLC (4/10) - Please refer to the above response for RAI #5.a.(2)(a).

d. Draft SER 2.6.5 Background Radiation - Soil Sampling and 5.7.7.2.3 Operational Soil Sampling (TR Section 2.9 and 5.7.7)
(RAI Response 12/12/08 2.9 and 5.7.7 and 8/5/09 #5)

(1) The applicant did not perform preoperational subsurface soil sampling as recommended by Regulatory Guide 4.14. In its January 16, 2009 response to NRC staff's November 6, 2008 request for additional information, the applicant committed to collecting these subsurface soil samples. At this time, staff cannot determine if preoperational subsurface soil sampling is consistent with Regulatory Guide 4.14. Regulatory basis 10 CFR 40, Appendix A, Criterion 7 and 6(6). **This is an open issue.**

NRC Summary of 12/9/09 Conference Call - See RAI 5.d.(2) below.

LC ISR, LLC (4/10) - Section 2.9.3.3 (Soil Profile Sampling) and Attachment 2.9-7 were added to the Technical Report to discuss subsurface soil sampling conducted in 2008.

(2) The applicant has not committed to Pb-210 analysis consistent with Reg Guide 4.14. Regulatory basis 10 CFR 40, Appendix A, Criterion 7. **This is an open issue.**

NRC Summary of 12/9/09 Conference Call - LCI stated they have the subsurface and tissue samples and will provide the data. They collected the Pb-210 and agreed to provide information.

LC ISR, LLC (4/10) - Pre-operational results for Pb-210 in soils are included in Attachment 2.9-7. A commitment to analyze soils for Pb-210 as a component of the radiation monitoring program during operations has been added to Section 5.7.7.1 (Operational Radiation Monitoring) under the Soils subheading.

e. Draft SER 2.6.6 Sediment Sampling and 5.7.8 Surface Water Sampling (TR Section 2.9) (RAI Responses 12/12/08 2.9)

(1) In Section 2.2.1 of the Technical Report, the applicant identifies four BLM stock ponds in the vicinity of the Permit Area. NRC staff cannot conclude whether these stock ponds are subject to drainage from potentially contaminated areas and therefore whether the applicant's approach for preoperational offsite sediment and offsite operational surface water sampling consistent with Regulatory Guide 4.14. **This remains an open issue until resolved.**

NRC Summary of 12/9/09 Conference Call - LCI stated they have the locations identified on a topo map, which indicates elevations. The NRC staff agreed that the map would provide the information needed for the staff's evaluation.

LC ISR, LLC (4/10) - The four BLM 'stock ponds' are associated with the groundwater rights shown in Figure 2.2-4 (Section 2.2.2.2 (Groundwater)). The stock ponds associated with the BLM East Eagle Nest Draw Well and with BLM Boundary Well No. 4775 are in a separate drainage system and upgradient of the Permit Area, respectively; therefore, they are not subject to drainage from the Permit Area. A third well, the BLM Battle Spring Well No. 4777, is shown in Figure 2.2-5b (renumbered from Figure 2.2-5). This site is a stock watering tank

located off the drainage and, therefore, not subject to drainage from the Permit Area.

The fourth stock pond is associated with BLM Battle Spring Draw Well No. 4451. When baseline data were collected, this site consisted of an in-channel berm designed to pond natural runoff during spring snowmelt or rare summer flow events. The site was further developed in spring 2009 to include a solar-powered pump feeding a stock tank, with overflow routed to the in-channel stock pond (new Figure 2.2-5a). As shown in Figures 2.2-4 and 2.7-1, the in-channel stock pond is located in a tributary that enters East Battle Springs Draw from the east. There are no operational activities planned for the southeast corner of T25N, R92W, Section 16, the area drained by this small tributary (Figure 3.1-2). Shipping and receiving for the Project will use the West Access Road, so there is no potential for radiological contamination of this in-channel stock pond. Figure 2.9-24 and Figure 7 of Attachment 2.9-7 show that surface water and sediment samples were collected where East Battle Springs Draw crosses the southern Permit Area boundary. These samples provide baseline data for a theoretical spill occurring in the most eastern portion of the Permit Area.

(2) Note the following was not discussed in the meeting: The applicant stated in section 2.9 in the TR that sediment samples were not collected because there is no perennial surface water (page 2.9-1). Yet the applicant collected storm water samples. Sediments should have been collected in the storm water channels. The applicant should include sediment samples in these areas or an explanation as to why these locations were not included in the baseline and the proposed operational monitoring program. **This is an open issue.**

LC ISR, LLC (4/10) - Sediment samples were collected in 2008. Section 2.9.3.4 and Attachment 2.9-7 have been added to the Technical Report to include these results.

f. DSER 5.7.1 and 4.2.1.3 Dose to public/Release of Pregnant Lixiviant/System Failure (TR 5.7.1.2 and 5.7.1.3, 4.2.5.5)
(RAI Responses 12/12/08 5.7.1 #1 and #3; 1/16/09 5.7.1 #3a.; 8/5/09 #6)

(1) An analysis of the maximum exposed member of the public is at issue. The NRC questions what constitutes the place the time and place where the maximum exposed person resides. Could a hunter or someone else within the permitted area receive the maximum exposure as a member of the public? NRC staff notes that LCI has not presented a basis for relying on modeling alone with no monitoring data to validate the model. **This is an open issue.**

NRC Summary of 12/9/09 Conference Call - LCI agreed to examine the situation. No other resource development will occur within the permit area. LCI agreed to provide additional information.

LC ISR, LLC (4/10) – Information under the subheading **Doses to 'Casual' Members of Public Who Enter Permit Area (e.g. a Hunter)** was added at the end of Section 7.2.1.2 (Exposures from Air Pathways).

(2) Note the following was not discussed in the meeting: In section 4.2.5.5 of the TR, the applicant has stated that no liquids will be stored in the header houses, but the sumps in the buildings will be equipped with fluid detection sensors wired to automatic alarms and shutoffs in the event of a pipeline or pump failure. The CPP will be equipped with concreted containment curbing and sumps to contain and recover any releases within the plant. However, a recent accident at another ISR facility resulted in an event that exceeded the limits and released effluent to the general environment outside the plant. The applicant will need to address the contingency plans for a failure that exceeds the capacity of the sumps and the curbed floor (volume). Potential exposure to members of the public that may be in the exposed area (e.g. a hunter) and verification that the soil is not contaminated must be included in the corrective action and accident scenario. Note that a survey of the area without soil sample analysis is not sufficient to determine the area is free of contamination from the spill. Because of the low energy gammas emitted from U-238 and the low abundance of the U isotopes with higher specific activity, soils in the spill area may contain U that exceeds unrestricted limits, but yield background radiation exposure readings with a survey instrument. **This issue is an open issue.**

LC ISR, LLC (4/10) - A new Section 7.4.10 (Overflow of Sumps or Berms) has been added.

g. Draft SER 5.7.3 Airborne Radiation Monitoring Program and 5.7.7 Airborne Effluent and Environmental Monitoring Program

There has been no commitment to include analysis for Pb-210 in the operational air sampling program in accordance with Regulatory Guide 4.14 nor has there been a commitment to validate model results. **This is an open issue.**

NRC Summary of 12/9/09 Conference Call - LCI agreed to provide additional information.

LC ISR, LLC (4/10) - Bullets have been added in Section 5.7.7 (Airborne Effluent and Environmental Monitoring Programs) committing to analysis for Pb-210.

h. DSER 5.7.4 Worker dose calculations (TR 5.7.4)
(RAI Responses 12/12/08 5.7.4 #5, #6, #7;8/5/09 #3)

This issue is related to the derived air concentration (DAC) issue previously raised by the NRC staff. LCI must demonstrate how they will comply with 10 CFR 20, Subpart C. The Metzger *et al* paper cited described a mixed DAC under various stages in the ISR process. The calculations in the TR do not address calculations in accordance with 10 CFR 1204(c), (d), (e), and (f). **This is an open issue.**
NRC Summary of 12/9/09 Conference Call - LCI agreed to move forward with assuming that the yellowcake is a class W until they analyze the yellow cake, calculate solubility, and will provide the information needed.

The staff notes that not only the yellowcake needs to be addressed. LCI must include methods to determine exposures during routine and non-routine operations, maintenance, and clean-up activities as described in NUREG-1569, section 5.7.4. The class may vary depending on what stage of the process the worker is exposed.

LC ISR, LLC (4/10) - Section 5.7.3.2 (Establishing Derived Air Concentrations) has been added, which includes discussion of methods for DAC determination under both yellowcake and mixed nuclide conditions.

i. DSER 5.7.5 Bioassay (TR 5.7.5)
(RAI Responses 12/12/08 5.7.5 #1; 8/5/09#2)

The applicant stated that it would use urinalysis as the method of bioassay due to the relatively high solubility of the chemical form of yellowcake present at the ISR facility. The applicant has not justified using inhalation class D for the uranium in its facility. Regulatory Guide 8.22 recommends that for exposures to Class W or Y materials alone, in vivo lung counts or alternate sampling times and action levels should be considered.

(1) Without a technical justification of the inhalation class for the uranium that could be encountered during operations, NRC staff cannot conclude that performing urinalysis alone is consistent with Regulatory Guide 8.22. **This is an open issue.**

NRC Summary of 12/9/09 Conference Call - LCI stated this has been discussed previously. Bioassay is really based on NUREG-0874. Low-fired yellowcake could contain Class W, but LCI still maintains the 30-day retention period is

applicable for bioassay. LCI will refer to NUREG-0874, but agreed to provide information.

LC ISR, LLC (4/10) - Discussion of bioassays has been inserted after the first paragraph in Section 5.7.5 (Bioassay Program). Additional considerations are included in the following new sections:
5.7.4.2 (Action Levels Tied to Worker Exposure Calculations); and
5.7.4.3 (Controlling Exposure to Soluble Uranium).

(2) The applicant stated that the bioassay program would follow guidelines set forth in Regulatory Guide 8.22. However, the applicant did not specifically state what frequency specimens will be collected and evaluated for workers in the bioassay program. Since action levels are tied to the frequency that the specimens are collected and evaluated, without this information NRC staff cannot conclude that the frequency of specimen collection and evaluation is consistent with Regulatory Guide 8.22. **This is an open issue.**

NRC Summary of 12/9/09 Conference Call - LCI plans to justify the sampling frequency. May be special cases, as described in NUREG-0874. They plan to justify why Reg Guide 8.22 is appropriate.

LC ISR, LLC (4/10) - See Response to RAI 5.i.(1) above.

(3) NRC staff notes that while the applicant stated that the RSO will be responsible for documenting compliance with the Table 1 "Corrective Actions Based on Monthly Urinary Uranium Results" found in NRC Regulatory Guide 8.22, actual action levels were not specified that will apply for calculating dose as discussed in Section 5.7.4 of the TR and to determine compliance with 10 CFR 20.1201(e) for weekly soluble uranium intake. Without specific action levels tied to the applicant's worker dose calculations, NRC staff cannot conclude that the bioassay program is consistent with Regulatory Guide 8.22. **This is an open issue.**

NRC Summary of 12/9/09 Conference Call - LCI plans to justify action levels per Reg Guide 8.22.

LC ISR, LLC (4/10) - See Response to RAI 5.i.(a) above

(4) The applicant has not provided a description of how bioassay results will be used to confirm results derived from its airborne radiation monitoring program and exposure calculations. Specifically, there is no discussion on the applicant's methods for evaluating bioassay data that result in calculated intakes. Without this

information, NRC staff cannot conclude that the bioassay program is consistent with Regulatory Guide 8.9. **This is an open issue.**

NRC Summary of 12/9/09 Conference Call - LCI stated that typically under most cases, one assigns dose using the 10% DAC rule using DAC-hours and ALI. They do not need to use models or bioassays per NUREG- 0874. LCI plans to justify procedure per NUREG-0874.

LC ISR, LLC (4/10) – See Response to RAI 5.i.(1) above.

j. Draft SER 5.7.6 Contamination Surveys

(1) The applicant's stated goal for no personal contamination above background is a good work practice and consistent with the applicant's ALARA philosophy stated in Section 5.3.3 of the Technical Report. However, NRC staff cannot determine what actions will be taken and what criteria will be used in the case of persons with contamination above background. Without this information, staff cannot determine if the applicant's personnel contamination program is consistent with Regulatory Guide 8.10. **This is an open issue.**

NRC Summary of 12/9/09 Conference Call - LCI stated they understand that the NRC needs to know what happens when personal contamination occurs above background. LCI agreed to provide the information.

LC ISR, LLC (4/10) - Section 5.7.6.1 (Response to Identification of Personnel Contamination in Excess of Background) has been added.

(2) The applicant's program for personnel surveys does not address the potential for other alpha emitting isotopes that may be present. The applicant has not demonstrated that it can account for and detect Ra-226 as well as other naturally occurring daughter products that were separated from the ore as a result of the uranium recovery operations, such as Th-230. Table 5.7-1 indicates that the lower limit of detection (LLD) for personal contamination self surveys will be 100 dpm/100 cm2. Without this information, staff cannot determine if the applicant's personnel contamination program is consistent with 10 CFR 20, Subpart F, Enclosure 2 to Policy and Guidance Directive 83-23 and Regulatory Guide 8.10. Therefore, staff can not find the applicant's personnel contamination program acceptable. **This is an open issue.**

NRC Summary of 12/9/09 Conference Call - LCI understands and agreed to provide the information.

LC ISR, LLC (4/10) - Additional information regarding detection of alpha emitting isotopes is include in Sections 5.7.6.1 and 5.7.6.2 and 5.7.6.3, which address surveys of personnel, areas, and for material release, respectively.

(3) The applicant's program for personnel surveys does not address the potential for beta-gamma contamination that could result from maintenance activities, for example. NRC staff notes that according to Table 5.7-1 the applicant applies beta release limits to equipment contamination. Without this information, NRC staff cannot determine if the applicant's personnel contamination program is consistent with 10 CFR 20, Subpart F and Regulatory Guide 8.10. **This is an open issue.**

Response discussed below.

LC ISR, LLC (4/10) - Additional information regarding detection of beta emitting isotopes is include in Sections 5.7.6.1 and 5.7.6.2 and 5.7.6.3, which address surveys of personnel, areas, and for material release, respectively.

(4) The applicant stated that surface contamination in plant areas would be assessed by visual inspection and measurement. Further, they state that surface contamination in restricted areas will be controlled to minimize the potential for resuspension of uranium dust that can result in inhalation or ingestion intake. The applicant did not propose any limits for surface contamination in restricted areas. Without this information, NRC staff cannot determine if the applicant's contamination program is consistent with 10 CFR 20, Subpart F and Regulatory Guide 8.10. **This is an open issue.**

Response discussed below.

LC ISR, LLC (4/10) - Information regarding limits for surface contamination in restricted areas is provided in TR Section 5.7.6.2 (Area Surveys).

(5) For areas of the plant where work with uranium is not performed, the applicant stated that these areas will be surveyed (spotchecked) weekly for removable contamination (smear surveys). The applicant also stated that the goal for these areas is background and that areas that exceed the contamination limit of 1,000 dpm alpha per 100 cm2 will be cleaned immediately and re-surveyed. Alternatively, total contamination surveys may be performed. If the total

contamination level exceeds the removable contamination limit, the removable contamination level will be determined using smears. In any case, areas showing removable contamination in excess of 25 percent of the contamination limit will be cleaned and resurveyed. For the first criterion, the limit is 1,000 dpm alpha per 100 cm2 removable contamination. In the second criterion, the limit is 250 dpm alpha per 100 cm2 removable contamination. NRC staff finds these criteria for surveying these areas of the plant inconsistent. Without a consistent approach to surveying contamination in parts of the plant where work with uranium is not performed, NRC staff, can not conclude that the applicant's proposed program will be consistent with 10 CFR 20 Subpart F. **This is an open issue.**

LC ISR, LLC (4/10) – The second paragraph of TR Section 5.7.6.2 Area Surveys) has been clarified.

Response for Items 3 through 5:

LCI stated it is controlling worker dose in the restricted areas where uranium work is not performed. LCI understands the NRC staff is interested in what action levels will be used in these areas. LCI agreed to provide the information. LCI stated they need some clarification on the alpha limits and need to address beta. They would like to use Regulatory Guide 8.30. LCI added that they could not have Th-234 and Pa-234 without the uranium present. LCI agreed to provide the information.

The NRC staff notes that the applicant can continue to use Regulatory Guide 8.30 until it is revised, but needs to understand that (1) the NRC staff is expediting the revision of the Regulatory Guide and (2) because the Regulatory Guide is not consistent with 10 CFR 20, the license will require a license condition.

LC ISR, LLC (4/10) - Waiting for license condition, no response required.

k. Draft SER 5.7.7.2 No radon or air particulate effluent monitoring program (TR Section 5.7.7)
(RAI Responses 12/12/08 5.7.7 #1; 8/5/09 #6)

(1) In section 4.1.2, pages 4-3 and 4-4 of the TR, the applicant states that radon present in the bleed fluid may be liberated in the headspaces of tanks and that tanks will be vented to the atmosphere outside the building via a stack. The applicant did not demonstrate that the radon stacks will be monitored consistent with Regulatory Guides 8.37 and 4.14, Table 2 under "other stacks" or demonstrate why it is not necessary to do so. NRC staff cannot determine that the applicant's effluent monitoring program for gaseous effluents is in compliance

with 10 CFR20 1302(a), 10 CFR 40, Appendix A, Criteria 8, and 10 CFR 40.65 nor can it determine that the effluent monitoring program is consistent with Regulatory Guides 4.14 and 8.37. **This is an open issue.**

LC ISR, LLC (4/10) - This item has been addressed with additions to TR Section 5.7.7 (Reports and Records).

LC ISR, LLC and it health physics contractor have made a concerted effort to identify detection equipment that is capable of measuring radon in stack effluent. While at least one instrument has been identified that is designed for radon sampling in stacks, its detection range precludes its use, as currently designed, at an ISR facility. Therefore, LC ISR, LLC contends that it is not technically feasible to measure radon effluent from the stacks.

10 CFR 20.1302 requires the licensee to measure or calculate the maximum total effective dose equivalent to the individual likely to receive the highest dose. 10 CFR 40.65 is worded differently but has the same goal, "...to establish maximum potential annual radiation doses to the public..." LC ISR, LLC intends to comply with these regulations by measuring radon as described in TR Section 5.7.7. In the past, NRC has approved this type of monitoring at ISR facilities and most if not all such facilities currently comply with 10 CFR 40.65 in this manner. Specifically, MILDOS modeling is used to calculate the dose to members of the public before operations begin. Once operations are initiated, alpha track etch detectors are used to measure potential exposure to members of the public.

LC ISR, LLC believes that with respect to 10 CFR 40.65, the intent of the regulation is to determine dose to members of the public and not to determine the total number of curies of radon released. Finally, the concentration of radon within the stack is not directly relevant to public safety since the public does not have access to the stacks. What is relevant is the actual exposure members of the public may receive.

(2) In the response dated August 5, 2009, the staff did not see an analysis of the maximally exposed member of the public nor did LCI address the failure to sample for airborne Pb-210 as recommended by RG 4.14. LCI needs to specifically state 26 whether or not it will perform these airborne samples and analysis in accordance with Regulatory Guide 4.14. **This is an open issue.**

LC ISR, LLC (4/10) - MILDOS analyses are presented in Section 7.1.2 (Exposure from Air Pathways) for potential exposures at the permit boundary and in Section 2.9.3.1 (Supplemental MILDOS Modeling) for exposures near the

Plant. Bullets have been added in Section 5.7.7 (Airborne Effluent and Environmental Monitoring Programs) committing to analysis for Pb-210.

LCI stated they would like to quote chapter and verse, and modern technologies that according to NUREG-1910, radon is the only effluent. For the purpose of effluent measurement and reporting of airborne particulates and radon to meet 10 CFR 40.65, they are not required to make measurements. NRC presents ways to estimate radon effluents. Would like to use the NRC approved effluents. Need to understand the mechanics of ISR. Would like to come back with their position.

Note only part of the following was discussed in the meeting. The NRC is providing additional information in response to the applicant's statements:

The NRC staff notes that although 10 CFR 40.65 allows for calculations to report effluent releases, the applicant has modeled doses based on the dissolved concentration of Ra- 226 for the initial concentration of Rn-222, which may be much less than the actual Rn- 222 source term. Although this method is recommended in by Faillace *et al* in "*MILDOSAREA: An Update with Incorporation of In Situ Leach Uranium Recovery Technology*" (1997), the authors assume that dissolved radon in the groundwater is controlled by the concentration of radium in the host soil/rock and therefore is in equilibrium. Several studies show that Rn-222 concentrations in groundwater exceed Ra-226 concentrations by several orders of magnitude (Cecil *et al* 1991, Torgersen *et al* 1992). The disequilibria indicate that the Rn-222 concentrations are dependent on the characteristics of the aquifer rather than the Ra-226 concentration in the host soil/ore (Cook and Herezeg, ed. (2000)). Therefore, it is important to validate the modeling results with operational sampling.

Additionally, LCI misquoted NUREG-1910 stating that radon is the only effluent. The Lost Creek supplement environmental impact statement in the NUREG is a draft document and states that gaseous emissions are primarily radon. Note that radon, a noble gas having a 3.8-day half-life, is produced by the decay of Ra-226 in the uranium series and is transported from the uranium ore body by gaseous diffusion through soils and groundwater. Rn-222 emanates from soil into the atmosphere. Radon decay produces four short-lived progeny: polonium-218 (Po-218), lead-218 (Pb-218), bismuth- 214 (Bi-214), and Po-214. The progeny have an effective half-life of approximately 30 minutes. Po-214 decay produces Pb-210 that has a 22-year half-life. The radon gas and particulate progeny are subject to dispersion. The particulates will form "attached" and "unattached" fractions that attach to airborne particles or charged surfaces and are subject to "wet" and "dry" deposition, whereas the gas remains in the atmosphere. Dispersion in the atmosphere prevents build-up of the radon and its progeny. However, the progeny can build-up within a few hours to equal the Rn-222 activity within buildings with

poor ventilation. Because of the short-half lives of the progeny and the long air sampling intervals in the proposed environmental monitoring program, the progeny will have decayed, so the air particulate samples analyses should include Pb-210 in accordance with Regulatory Guide 4.14.

Also note that regulatory guides and standard review plans do not promulgate regulatory policy and are not substitutes for legally binding regulatory requirements and thus, compliance with them is not required. Standard review plans provide guidance to the NRC staff on how to evaluate license applications and the regulatory guides provide the applicant/licensee with acceptable methods to perform functions to meet regulatory requirements. Procedures different from those described in the guides are acceptable if they provide a basis for the staff to evaluate and support a conclusion that the procedures meet NRC's regulations.

References:

Cecil L.D., Senior L.A. and Vogel K.L. (1991) Radium-226, radium-228, and radon-222 in groundwater of the Chickies Quartzite, Southeastern Pennsylvania. In *Field Studies of Radon in Rocks, Soils, and Water*, eds. L.C.S. Gundersen and R.B. Wanty, pp. 267- 277. C.K. Smoley, Boca Raton, Florida.

Torgersen T., Benoit J., and Mackie D. (1992) Lithological control of groundwater 222Rn concentrations in fractured rock media. In *Isotopes of Noble Gases as Tracers in Environmental Studies*, pp. 263-287. IAEA, Vienna.

Cecil L.D. and Green J.R. (2000) Radon-222 in groundwater of the Chickies Quartzite, Southeastern Pennsylvania. In *Environmental Tracers in Subsurface Hydrology*, eds. P.G. Cook and A.L. Herezeg, pp. 175-194. Kluwer Academic Publishers, Norwell, Massachusetts.

l. DSER 5.7.7.2.3 Soil Sampling (TR Section 5.7.7) (RAI Response 12/12/08 5.7.7)

In its December 12, 2008 response to NRC staff's November 6, 2008 request for additional information, the applicant committed to cleaning up spills of lixiviant or yellowcake slurry outside the fenced area to decommissioning standards then sampling the affected soil to ensure cleanup was successful. However, the applicant did not develop soil cleanup criteria for uranium or other radionuclides as appropriate. NRC staff cannot conclude that the applicant can meet its commitment to clean up spills to decommissioning standards. **This is an open issue.**

LCI stated they collected the Pb-210 data and agreed to provide information.

LC ISR, LLC (4/10) - Additional baseline soil sampling analyses are presented in Section 2.9.3 (Supplementary Radiological Studies), specifically Attachment 2.9-7. Section 4.2.5.6 (Activity Concentration Cleanup Criteria), which incorporates LC ISR, LLC's response to April 2009 RAI #7 regarding cleanup criteria. TR Section 5.7.7 includes operational soil sampling commitments.

m. Draft SER 7.1 Chemical Accidents and 7.2 Radiological Release Accidents (TR Section 7.4)

(1) The applicant did not address the potential for accidents in the CPP or header houses involving chemicals that will be used on site. The use of the following chemicals was discussed in the TR and included in the effect of potential transportation accidents:

• hydrochloric acid • sulfuric acid • hydrogen peroxide • hydrogen sulfide/sodium sulfide • sodium carbonate/sodium bicarbonate • oxygen • carbon dioxide

The applicant identified that all of the buildings will be adequately ventilated to minimize radon exposure, which will also reduce the opportunity for buildup of explosive gases, such as oxygen in the CPP and header houses. To comply with NUREG-1569, the applicant should address. designs and measures, for each chemical, to prevent the occurrence of an accident and the development of emergency response procedures in the event of an accident. **This is an open issue.**

LC ISR, LLC (4/10) - TR Section 7.5 has been added to discuss the hazards presented by the bulk chemicals proposed for use at the facility, how those hazards will be mitigated, design of facilities, and an assessment of the risks. The risk assessment, which considered mitigations, demonstrates that the bulk hazardous chemicals can be used in a manner that is protective of employees and the environment.

The risk assessment did not consider the hazards presented by sulfuric acid since LC ISR, LLC has decided to use hydrochloric acid exclusively. Nor did the analysis consider the use of groundwater reductants such as hydrogen sulfide or sodium sulfide since, at this point ,it is not clear if these chemicals will be used during groundwater restoration (see discussion in TR Section 6.2.3). If LC ISR, LLC considers the use of a chemical reductant in the future, the associated hazards and mitigations will be reviewed by the SERP. It may be necessary to submit a license amendment request to NRC depending on the proposed nature of reductant use.

(2) The applicant did not address the possibility of scenarios resulting in multiple tank failures such as a failure that would cause a tank to topple into another tank or if the volume of the spill exceeds the capacity of the sumps and the curbed floor. **This is an open issue.**

LCI understands the question and agreed to provide information.

LC ISR, LLC (4/10) - The text of TR Section 7.4.1 (Tank Failure) has been revised to discuss berm capacity versus the largest possible spill resulting from multiple tanks failing or a significant pipeline break. Also, the engineering design criteria discussed above will make the risk of multiple tank failures negligible.

6. HEALTH PHYSICS CONFIRMATORY ITEMS

a. Draft SER 2.6 Background Radiation Characteristics (TR Section 2.5.5.2) (RAI Response 12/12/08 2.9 #1a; 8/5/09 5#2)

(1) The applicant provided additional information on the criteria for selecting radon and air particulate sampling locations in the response dated August 5, 2009. This information and the maps provided need to be in the TR. **This is a confirmatory item.**

LC ISR, LLC (4/10) - Section 2.9.3.7 (Radiological Air Particulate (High-Vol) Sampling) has been added, and it provides additional detail regarding the radon monitor and the air particulate samplers, particularly in the subsection **Locations of Radon, Passive Gamma, and Air Particulate Instrumentation**.

(2) Additional radon and air sampling results described in responses dated December 12, 2008 and January 16, 2009 need to be included in the TR. **This is a confirmatory item.**

NRC Summary of 12/9/09 Conference Call - LCI acknowledged this confirmatory item and indicated that the technical report will be modified accordingly.

LC ISR, LLC (4/10) – Sections 2.9.2 (Passive Gamma and Radon Monitoring) and 2.9.3.7 (Radiological Air Particulate (High-Vol) Sampling) include the required information.

b. Draft SER 2.6.3 Vegetation, Food, and Fish Sampling (TR Section 2.2.1) (RAI Response 12/12/08 2.9 #3, 6; 8/5/09 5#1)

Responses dated January 16 and August 5, 2009 provided sampling data, MILDOS data and results, and locations of samples. All vegetation sampling information as well as the MILDOS data and results included in this correspondence needs to be included in the TR. **This is a confirmatory item.**

NRC Summary of 12/9/09 Conference Call - LCI acknowledged this confirmatory item and indicated that the technical report will be modified accordingly.

LC ISR, LLC (4/10) - The technical memorandum describing the 2008 vegetation sampling, which was submitted in the December 2008 Response to RAI 2.9 #3, has been added to the Technical Report as Attachment 2.9-6. The results are also

discussed in Section 2.9.3.2 (Vegetation and Associated Surface Soil Sampling), which is a new section in the Technical Report. A discussion of the 2009 MILDOS modeling, which addressed predicted ground deposition of radon daughter products from the Plant operations, has been added as TR Section 2.9.3.1 (Supplementary MILDOS Modeling). Additional vegetation and surface soil samples were collected in 2009 based on the 2009 MILDOS. The results of this sampling are described the new Section 2.9.3.2 and Attachment 2.9-7.

c. Draft SER 2.6.4 Direct Radiation (TR Section 2.9)
(RAI Responses 12/12/08 2.9)

Direct radiation information provided in the response dated January 16, 2009 needs to be included in the TR. **This is a confirmatory item.**

NRC Summary of 12/9/09 Conference Call - LCI acknowledged this confirmatory item and indicated that the technical report will be modified accordingly.

LC ISR, LLC (4/10) – LC ISR, LLC's January 2009 Response to RAI 2.9 #7a through 7j is included in the TR as Attachment 2.9-5.

d. Draft SER 2.6.5 Soil Sampling (TR Section 2.9)
(RAI Responses 12/12/08 2.9 and 8/5/09 5)

Additional soil sampling data and the information provided in the response dated December 12, 2008 needs to be in the TR. **This is a confirmatory item.**

NRC Summary of 12/9/09 Conference Call - LCI acknowledged this confirmatory item and indicated that the technical report will be modified accordingly.

LC ISR, LLC (4/10) - Section 2.9.3.3 (Soil Profile Sampling) and Attachment 2.9-7 were added to the Technical Report to discuss subsurface soil sampling conducted in 2008.

e. Draft SER 2.6.6 Sediment Sampling (TR Section 2.9)
(RAI Responses 12/12/08 2.9)

Additional sediment sampling data and the information provided in the response dated December 12, 2009 needs to be in the TR. **This is a confirmatory item.**

NRC Summary of 12/9/09 Conference Call - LCI acknowledged this confirmatory item and indicated that the technical report will be modified accordingly.

LC ISR, LLC (4/10) - Sediment samples were collected in 2008. Section 2.9.3.4 and Attachment 2.9-7 have been added to the Technical Report to include these results.

f. DSER 5.7.4 Worker dose calculations (TR 5.7.4)
(RAI Responses 12/12/08 5.7.4 #5, #6, #7;8/5/09 #3)

Note the following was not discussed in the meeting: On page 5-37 of the TR, the applicant references ICRP report 68 in the exposure calculations. 10 CFR 20 is based on ICRP reports 26 and 30. The applicant must request approval to use ICRP-68. Reference: NUREG 1736, page 51 and Regulatory Guide 8.25, section 4. Regulatory basis: 10 CFR 20.1204(c). **This is a confirmatory item.**

LC ISR, LLC (4/10) - In the fifth paragraph of Section 5.7.4 (Worker Dose Calculations), LC ISR, LLC has committed to obtaining NRC approval prior to using ICRP 68 techniques for worker dose calculations. Until that time LC ISR, LLC will use one of the other alternatives in TR Section 5.7.4.

g. DSER 5.7.5.5 Records and Reporting (TR 5.7.5)

For employees who are monitored for internal and/or external exposure, recording and reporting of monitoring results are required in accordance with 10 CFR 20, Subpart L and 10 CFR 20 Subpart M. The applicant states that records of bioassay results will be maintained until license termination on a form compliant with Regulatory Guide 8.7, Revision 1. In addition, Section 5.2 of the Technical Report describes the recordkeeping and reporting activities proposed by the applicant. NRC staff has determined that the applicant's recordkeeping and reporting activities are consistent with Regulatory Guide 8.30 and meets the requirements for 10 CFR 20, Subparts L and M. Therefore, the staff finds the applicant's program acceptable. However, the current revision of Regulatory Guide 8.7 is Revision 2 and the applicant should use the most current version of this regulatory guide. **This is a confirmatory item.**

LC ISR, LLC (4/10) - The reference to "the most current version" of RG 8.7 has been included throughout Section 5.0 (Operational Organization, Management, Programs, & Training).

h. DSER 5.7.7.2 Environmental Monitoring

(1) In its December 12, 2008 response to NRC staff's November 6, 2008 request for additional information, the applicant stated that the preoperational monitoring location URPA -7 (See Figure 5.7-2) represents background conditions. The 30 URPA-7 location corresponds to monitoring location PR-4 for operations. Based on wind data presented by the applicant (see Section 2.2 of this SER), NRC staff finds the monitoring location PR-4 acceptable for representing background conditions. However, the applicant's description of this monitoring station as the one representing background conditions is not included in the Technical Report. **This is a confirmatory item.**

LC ISR, LLC (4/10) – The numbering of the operational monitoring locations has been changed to correspond to the pre-operational numbering wherever possible (Figure 2.9-27).

(2) Also in its December 12, 2008 response to NRC staff's November 6, 2008 request for additional information, the applicant stated that an additional location will be added for monitoring radon. This location corresponds to SEB1 in Figure 7.7-2. SEB1 represents the receptor location with the maximum calculated potential dose. NRC staff finds the placement of this radon monitor around the Permit Area consistent with Regulatory Guide 4.14. However, the applicant's description of the SEB1 radon monitoring station is not included in the Technical Report. **This is a confirmatory item.**

NRC Summary of 12/9/09 Conference Call - LCI acknowledged this confirmatory item and indicated that the technical report will be modified accordingly.

LC ISR, LLC (4/10) – The sampling locations, including the SEB1 receptor locations, are discussed in Section 2.9.4 and shown on Figure 2.9-27

i. DSER 5.7.7.2.4 Sediment Sampling

The only onsite surface water body identified by the applicant is Crooked Well Reservoir, which is dry for the majority of the year, but fills with snow melt during the months of March and April. In the applicant's December 12, 2008 response to NRC staff's November 6, 2008 request for additional information, they stated that Crooked Well Reservoir is located upstream of any project activities. NRC staff concludes that this reservoir is not subject to drainage from potentially contaminated areas and therefore the applicant's approach for onsite sediment sampling is consistent with Regulatory Guide 4.14. Therefore, the staff finds the applicant's

approach for onsite sediment sampling acceptable. However, the applicant's supporting analysis is not included in the Technical Report. **This is a confirmatory item.**

NRC Summary of 12/9/09 Conference Call - LCI acknowledged this confirmatory item and indicated that the technical report will be modified accordingly.

LC ISR, LLC (4/10) – The requested discussion has been added to Section 2.9.3.4 (Sediment Sampling).

j. DSER 5.7.7.2.5 Food and Fish Sampling

In its December 12, 2008 response to NRC staff's November 6, 2008 request for additional information, the applicant stated that there is insufficient water in the area to support aquatic life so fish sampling will not be performed. NRC staff concludes that the applicant's reason for not collecting fish samples during operations is consistent with Regulatory Guide 4.14. Therefore, staff finds the applicant's reason for not collecting fish samples during operations acceptable. However, the applicant's supporting analysis is not included in the Technical Report. **This is a confirmatory item.**

LC ISR, LLC (4/10) - Neither food crops nor fish are present within 3 km of the Permit Area, and this information has been added to Section 2.9.3.5 . Tissue samples were collected from cattle that grazed within 3 km of the Plant site in 2008 and 2009. Section 2.9.3.5 (Food and Fish Sampling) and Attachment 2.9-8 have been added with a description of the sampling and the analytical results.

k. DSER 5.7.8 Environmental Monitoring - Surface Water Sampling

(1) In Section 2.7.1.1 of the TR, the applicant identified one small (less than one-quarter acre) detention pond within the Permit Area as the Crooked Well Reservoir and acts as an off-channel storage area for stock watering. The applicant further stated that this pond is dry for the majority of the year but fills with snow melt during the months of March and April. According to the applicant, wetland vegetation has not been observed around this impoundment. Lastly, in the applicant's December 12, 2008 response, they stated that Crooked Well Reservoir is located upstream of any project activities. NRC staff concludes that this reservoir is not subject to drainage from potentially contaminated areas and therefore the applicant's approach is consistent with Regulatory Guide 4.14. However, the applicant's supporting analysis is not included in the Technical Report. **This is a confirmatory item.**

NRC Summary of 12/9/09 Conference Call - See RAI #6.k.(2) below.

LC ISR, LLC (4/10) - The reasoning for no routine surface water sampling is now included in Section 5.7.8.2 (Operational Monitoring) under the subheading **Surface Water**.

(2) In its December 12, 2008 response to NRC staff's November 6, 2008 request for additional information, the applicant committed to installing an automatic sampler in the downstream and upstream channel of any drainage impacted by a spill to quantify the radionuclide content of the water during the next precipitation event that results in flow in the channel. NRC staff finds this approach consistent with Regulatory Guide 4.14. However, this commitment is not included in the Technical Report. **This is a confirmatory item.**

NRC Summary of 12/9/09 Conference Call - LCI acknowledged this confirmatory item and indicated that the technical report will be modified accordingly.

LC ISR, LLC (4/10) - This commitment is now included in Section 5.7.8.2 (Operational Monitoring) under the subheading **Surface Water**.

l. DSER 6.4 Methodologies for Conducting Post Reclamation and Decommissioning Radiological Surveys (TR Section 6.5) (RAI Response 12/12/08 6.5 #1-5)

The applicant's response provided to the RAI is consistent with the guidance provided in NUREG-1569, however this information is not included in the Technical Report. **This is a confirmatory item.**

NRC Summary of 12/9/09 Conference Call - LCI acknowledged this confirmatory item and indicated that the technical report will be modified accordingly.

LC ISR, LLC (4/10) - A statement of LC ISR, LLC's commitment to Quality Assurance has been added to the end of TR Section 5.2. A statement of LC ISR, LLC's commitment to submit a decommissioning plan 12 months in advance of each mine unit decommissioning has been added in TR Section 6.0. The methods for determination of radium and uranium cleanup criteria were added to TR Section 6.5.1. A commitment to assuring cleanup with 95 per cent confidence was added to TR Section 6.5.2. The more thorough discussion of the Soil Cleanup Program was included in TR Section 6.5.2. TR Section 6.5.3 (Decommissioning of Non-radiological Hazardous Constituents) was also added.

m. DSER 7.2 Radiological Release Accidents (TR Section 7.4) (RAI Response 12/12/08 7.4 #3)

The applicant stated in the December 12, 2008 response that an Emergency Response Standard Operating Procedure (SOP) will be developed that defines under what circumstances reporting is required and to which agency(ies). The SOP will provide guidance on how to determine the doses, which require reporting under 10 CFR 20.2202 and 2203. However, the applicant's description of the additional emergency stop buttons and the commitment to meet the reporting requirements of 10 CFR 20.2202 and 2203 is not included in the TR. . **This is a confirmatory item.)**

NRC Summary of 12/9/09 Conference Call - LCI acknowledged this confirmatory item and indicated that the technical report will be modified accordingly. 32

LC ISR, LLC (4/10) - A commitment to develop an SOP identifying agency emergency reporting requirements is added at the beginning of Section 7.4 (Effects of Accidents).

n. Note: All information provided in the responses to the RAI dated 12/12/08, 1/16/09, and 8/5/09 not cited above, must be included in the TR. **These are confirmatory items.**

LCI acknowledged the additional confirmatory items and indicated that the technical report will be modified accordingly.

LC ISR, LLC (4/10) - Please see attached Table RAI-1 for a correlation of the NRC RAIs of December 2008, January 2009, February 2009, August 2009, November 2009, and December 2009 and LC ISR, LLC responses, in order of the TR sections.

7. HEALTH PHYSICS ADMINISTRATIVE ITEMS

a. DSER 1.1 Schedule

The applicant has proposed daily inspections of the plant by the RSO, HPT, or trained worker to check for proper containment of yellowcake and mining solutions, proper storage of PPE, radiation protection signage, access control, and security measures. It is not clear if these inspections are the same as those described under Radiation Safety Inspections in Section 5.3. Daily radiation safety inspections performed by workers other than the RSO or HPT is not consistent with Regulatory Guide 8.31. **This is an administrative item.**

NRC Summary of 12/9/09 Conference Call - LCI agreed to provide clarification in the technical report.

LC ISR, LLC (4/10) - Section 2.5.5.2 (Passive Gamma and Radon Monitoring) was redrafted for clarification and moved to Section 2.9.2. Section 2.9.3.7 (Radiological Air Particulate (High-Vol) Sampling) has been added, and it provides additional detail regarding the radon monitor and the air particulate samplers, particularly in the subsection **Locations of Radon, Passive Gamma, and Air Particulate Instrumentation**.

b. DSER 5.7.6.3 Inspections

The applicant has proposed daily inspections of the plant by the RSO, HPT, or trained worker to check for proper containment of yellowcake and mining solutions, proper storage of PPE, radiation protection signage, access control, and security measures. It is not clear if these inspections are the same as those described under Radiation Safety Inspections in Section 5.3. Daily radiation safety inspections performed by workers other than the RSO or HPT is not consistent with Regulatory Guide 8.31. **This is an administrative item.**

NRC Summary of 12/9/09 Conference Call - LCI agreed to provide clarification in the technical report.

LC ISR, LLC (4/10) - The use of the term 'daily inspections' in Section 5.3 (Management Audit and Inspection Program) is consistent with the daily inspections by the RSO, HPT, or trained worker described elsewhere in the TR.

The text in TR has been revised to include a discussion of:

- Circumstances under which the RSO may designate an individual, other than the HPT, to perform daily inspections,
- The qualifications of the designee,
- The authority of the designee,
- Review of inspection reports by the RSO or HPT upon return to work
- Number of consecutive days a designee may perform daily inspections
- Coverage of health physics issues during the absence of the RSO and HPT

Specifically, a new Section 5.4.3.2 (Designee) has been added to provide the qualifications of a "Designee." These qualifications include: a minimum of a high school diploma; training as a radiation worker pursuant to Section 5.5 (Radiation Safety Training) and RG 8.31, Section 2.5; on the job training on how to use the daily inspection checklist, and at least three months experience working as a radiation worker at the Lost Creek Facility.

Section 5.3.1.1 (Daily Inspections) has been revised to clarify that the RSO may only designate an individual to perform daily inspections if that individual meets the training qualifications outlined in Section 5.5 (Radiation Safety Training). A Designee may only be appointed to perform daily inspections that occur on weekends, holidays, and times when both the RSO and HPT(s) are gone at the same time (illness or offsite training). In no case shall a Designee perform daily inspections for more than three consecutive days. The Designee has no authority to perform health physics duties outside the scope of his/her regularly assigned duties. For example, the Designee will not have authority to release materials for unrestricted use or to approve a RWP. On the first day the RSO or an HPT returns to work, the daily inspection checklist used by the Designee must be reviewed by the RSO or an HPT. During periods when a Designee is used to complete daily inspections, either the RSO or an HPT must be reachable by telephone to provide assistance.

c. DSER 5.7.7 Operational Environmental Monitoring Program (TR Section 5.7.7) (RAI Response 8/5/09 5#2)

Attachment 4 in the response dated August 5, 2009 did not include the Bairoil sampling location. An inset showing the scale and location of the Bairoil location needs to be included as presented in Attachment 3 in the response. The updated figures need to be in the TR. **This is an administrative item.**

NRC Summary of 12/9/09 Conference Call - LCI agreed to provide updated map in the technical report.

LC ISR, LLC (4/10) – Figure 2.9-27 includes the Baroil sampling location.

d. DSER 6.5 and 7.2 Spill Clean-up Criteria (TR Section 5.7.1, 5.7.7, 7.4) (RAI Response 8/5/09 #7)

LCI should submit the RESRAD analysis (input and output files) that was used to provide the response dated August 5, 2009. **This is an administrative item.**

NRC Summary of 12/9/09 Conference Call - LCI agreed to provide updated RESRAD files in the technical report.

LC ISR, LLC (4/10) – An electronic copy of the RESRAD files is included in Attachment 5.7-4.

NRC NOVEMBER 2009 RAIs

METEOROLOGY OPEN ISSUES

Draft SER (DSER) 2.2 (Agenda item 1.)
Applicant did not demonstrate that meteorological data from Lost Soldier is representative of the Lost Creek Permit Area.

The applicant installed a meteorological station within the Permit Area in May 2007 to collect onsite data. This station is known as the Lost Creek Station. However, the applicant did not use the Lost Creek Station to describe onsite meteorological conditions. Instead the applicant proposed using data from a nearby meteorological station installed near Bairoil in 2006. This station is known as the Lost Soldier Station and is located approximately 12 miles northeast from the Permit Area (see Figure 2.2-1). The applicant did not provide sufficient data to establish that the data from the Lost Soldier station adequately represents the conditions for the Lost Creek Permit Area. **This is an open issue.**

<u>LC ISR, LLC (4/10)</u> – The Lost Soldier meteorological station has been operational since April 2006, and the Lost Creek station has been operational since May 2007. When the application was initially submitted to NRC in October 2007, a full year of data was only available from the Lost Soldier station; therefore, that data used to describe the site conditions and used for MILDOS input. More data is now available from both stations and is presented in tandem in Section 2.5 (Meteorology, Climatology, and Air Quality). As a check, MILDOS was rerun using the Lost Creek data (last paragraph in Section 7.2.2 (Exposure from Air Pathways)), and the results using the data from both stations are side-by-side on Figure 7.2-3b. The difference in the results are minimal.

Draft SER (DSER) 2.2 (Agenda item 2.)
Applicant did not compare concurrent data from NWS station to demonstrate that data taken for Permit Area is representative of long-term meteorological data.

To determine whether the period that meteorological data was collected is representational of long-term meteorological conditions in the site vicinity, Regulatory Guide 3.63 recommends comparing a concurrent period of meteorological data from a National Weather Service (NWS) station with the long-term meteorological data from that NWS station. The NWS station selected for this comparison should be in a similar geographical and topographical location and be reasonably close (preferably within 50 miles to the site). For this comparison, the applicant chose the NWS station in Muddy Gap, Wyoming (see Figure 2.2-1). This NWS station is located 28 miles northwest of the Permit Area and data has been collected since 1949. According to the applicant, only data

through 2005 were available for the Muddy Gap station when they submitted information related to this application. The applicant did not compare concurrent meteorological data from the Muddy Gap station during the timeframe of collecting Permit Area meteorological data and compare it to the long-term meteorological data from the Muddy Gap station to demonstrate that the data obtained for the Permit Area is representative of long-term meteorological conditions. **This is an open issue.**

LC ISR, LLC (4/10) – When the application was initially submitted in October 2007, the data from Muddy Gap (the closest NWS station (28 miles away)) was only available through 2005, so direct comparison was not possible. More recent data from Muddy Gap is now available and has been incorporated into Section 2.5 along with data from other stations. Because of sporadic nature of precipitation in this climate, direct comparison of short-term and long-term data for some parameters (e.g., precipitation) is difficult. In addition, as noted in Section 2.5.1.2, the area has been in a drought recently.

Draft SER (DSER) 2.2 (Agenda item 3.)
Specify the height at which the data was collected (2 meters or at other heights). Also, no joint frequency distribution data was provided.

In Section 2.5 of the Technical Report, the applicant stated that all data were measured at a height of 6.6 feet (two meters). However, in Section 2.5.4 of the Technical Report and in its December 12, 2008 response to NRC staff's request for additional information dated November 6, 2008, the applicant stated that wind and other measurements were made at various other heights. Regulatory Guide 3.63 recommends that for atmospheric dispersion assessments, wind speed and wind direction be monitored at approximately 10 meters (33 feet) above the ground. **This is an open issue.**

The joint frequency distribution shows how frequently each stability class occurs over a given time period. The joint frequency distribution is developed from wind speed and wind direction. The stability class will determine how well a released contaminant will disperse in the atmosphere and it is used to determine the concentration of the contaminant at some receptor point away from the facility. The stability class can vary from extremely unstable to extremely stable and can be determined by temperature differences between two heights or the fluctuation of horizontal wind direction at a given height. The applicant stated that atmospheric stability was classified according to Pasquill. According to the applicant, calculations were made using wind speed and solar radiation. Regulatory Guide 3.63 suggests a suitable format for data compilation and reporting purposes for the joint frequency data. The applicant did not provide joint frequency data. **This is an open issue.**

LC ISR, LLC (4/10) - More detail about the instrumentation at the Lost Creek and Lost Soldier meteorological stations was provided in LC ISR, LLC's December 2008

Response to RAI 2.5 #2, and that information has been added to Section 2.5.1 (Meteorology and Climatology). The statement that all data was collected at a height of two meters was incorrect and has been removed.

The joint frequency distributions for the Lost Soldier meteorological station are shown as part of the MILDOS printouts submitted in Volume 4 of the March 2008 Revision 1 of the Technical Report. As noted in the Response to Agenda Item 1, differences in the MILDOS results using Lost Creek or Lost Soldier data are minimal.

Draft SER (DSER) 2.2 (Agenda item 4.)
NRC staff can not determine when the wind data was collected.

The applicant reported that the annual average wind speed between April 2006 and April 2007, was 23 feet per second (7.0 meters per second) at the Lost soldier Station. However, Figure 2.5-3 of the Technical Report and Section 3.7.1.4 of the Environmental Report indicate that wind data was collected between May 2006 and April 2007. The prevailing monthly wind direction is from the west-northwest and west for most of the year. See Figure 2.2-3. **NRC staff cannot determine when the wind data was collected. This is a confirmatory item.**

LC ISR, LLC (4/10) - Wind data from both the Lost Soldier and Lost Creek meteorological stations for the period of record available through the fall of 2009 have been incorporated into the Technical Report, and both stations are still operational.

Draft SER (DSER) 2.2 (Agenda item 4.)
NRC staff cannot determine if mixing height data is representative of the Lost Creek site.

The mixing height is the height to which the air near the earth's surface is well mixed due to turbulence caused by the interaction between the surface and the atmosphere. Mixing height, also known as inversion, are data parameters used in atmospheric dispersion models to calculate the concentration of the contaminant and the radiation dose at a receptor point that is not near the facility. In its December 12, 2008 response to NRC staff's request for additional information dated November 6, 2008, the applicant stated that data for mixing height was collected for Lander/Riverton, Wyoming. The data reported by the applicant indicates that the average annual mixing height is 348 meters in the morning and 2300 meters in the afternoon. LCI did not provide sufficient justification that the mixing height in Lander/Riverton is representative of the Lost Creek site. **This is an open issue.**

LC ISR, LLC (4/10) - Two articles are attached (Fearon and Brown (2000) and Martner and Marwitz (1982)), which illustrate the similarity of mixing heights and discuss overall wind conditions in this part of Wyoming, respectively. Although the figures in the Fearon and Brown article are for a single point in time, comparison of the figures illustrates the correspondence of wind and mixing height in southwest Wyoming. There is limited upper air data available for Wyoming (much of it being collected in relation to forest fire studies), with the Lander/Riverton site being the closest site, having the longest period of record, and in a more representative location.

Draft SER (DSER) 2.2 (Agenda item 5.)
No calibration or maintenance data for meteorological instruments. No specific recovery data for wind and stability measurements.

The applicant provided a description of the types and specifications for the meteorological instrumentation in its December 12, 2008, response to NRC staff's request for additional information dated November 6, 2008. The applicant did not provide threshold information for wind direction and wind speed instruments. This information is needed to determine whether this wind direction and speed information is consistent with Regulatory Guide 3.63. **This is a an open issue.**

Regulatory Guide 3.63 provides recommendations on meteorological systems calibration and maintenance to ensure recommended system accuracies are met. The applicant did not provide any data on systems calibration or maintenance. This information is needed to determine if the system accuracies recommended by Regulatory Guide 3.63 were met over the time period used to describe onsite meteorological conditions. **This is an open issue.**

Regarding data recovery, the applicant reported only that all data had "a recovery rate of over 90 percent." Regulatory Guide 3.63 recommends at least 90% annual recovery for each individual parameter measured with at least an annual 75% joint data recovery for wind speed, wind direction, and atmospheric stability. This information is needed to determine if the data is consistent with Regulatory Guide 3.63. **This is an open issue.**

LC ISR, LLC (4/10) - The threshold information for the wind instruments is provided in instrument description in Section 2.5.1 (Meteorology and Climatology).

Both the Lost Solider and Lost Creek meteorological stations were purchased new and calibrated from the factory. Because of the remoteness of the stations and limited accessibility during bad weather, the stations include satellite links for data retrieval. The data is periodically downloaded, either in the field or by satellite link, and checked for accuracy after downloading (e.g., a temperature data point outside appropriate range). Calibration sheets for the Lost Creek station are attached, and no changes to the

equipment were necessary as a result of the calibration. All of the instruments have the same data recovery rate. The only lapse was due to battery failure during extremely cold temperatures one winter, when the site was not accessible. The batteries were replaced once the site was accessible, and once the ground thawed, the batteries were buried deeper to help reduce the potential for recurrence.

The data recovery rate for all the instruments is the same because of the way in which the station is installed.

GEOTECHNICAL OPEN/CONFIRMATORY ISSUES

Draft SER (DSER) 3.2 (Agenda item 21.)
Shipment and processing of third party ion exchange resins from other LC satellites or other producers.

In its application, LCI indicated that it plans to accept ion exchange resins from other satellite facilities operated by LCI or other producers. The application does not appear to include a discussion of transportation related accidents associated with the shipping of resins or how the resins will be handled. LCI has not provided the information necessary for the NRC staff to evaluate the safety and aspects of this activity. The staff indicated that if this is not addressed in the application, LCI might need to obtain an amendment to be able to receive and process third party ion exchange resin from other satellites or producers. **This is an open issue.**

[Note: The letter includes a long discussion of regulatory requirements which has not been included here.]

LC ISR, LLC (4/10) - The Lost Creek ISR LLC facility will produce wet yellowcake slurry that will be sent to another facility for final drying and packaging. Also, LC ISR, LLC has designed the Plant to receive and process resin from other facilities for toll processing. At this time, LC ISR, LLC does not have a contract in place with any other uranium producers to toll process resin or slurry. However, LC ISR, LLC, in anticipation of toll processing material from other companies or handling product from satellite facilities owned by Ur-Energy USA Inc., has designed the Plant to be able to receive and process resin or slurry from other facilities. A new Section 5.8 (Transport of Radioactive Materials) has been inserted to discuss the risks of shipping resins and slurry and how those risks will be managed. The new text includes a discussion on compliance with applicable Department of Transportation Hazardous Material regulations for proper packaging, labeling, placarding, shipping papers, emergency response, security, and employee training.

DSER 3.3 (Agenda item 22.)
Instrumentation and controls related to radiation safety monitoring.

The applicant does not appear to have addressed instrumentation and controls related to radiation safety monitoring in Section 3 of the report. This information should be provided so the NRC staff can evaluate the ability of the proposed instrumentation and control techniques to identify potential radiological issues such as elevated radon in the CPP.

LCI indicated that Table 5.7-2 lists every instrument that will be used in the facility. LCI has indicated that they have included significant discussions on instrumentation and controls in Section 5.7. The staff agrees that instrumentation and controls are described in section 5.7.6 and in their responses dated December 12, 2008 and August 5, 2009 to the NRC's requests for additional information.

LC ISR, LLC (4/10) - The November 9, 2009 letter from NRC indicates that the information already provided addresses this item.

DSER 4.2 (Agenda item 23.)
Baseline groundwater monitoring for storage ponds.

Lost Creek does not appear to have adequately characterized the baseline groundwater quality in the vicinity of the storage ponds as no groundwater samples of the uppermost aquifer have been obtained. Additionally, the groundwater monitoring wells for the storage ponds may not have been completed at a depth that would allow for the detection of leaks. Note that section 5.3.2.3 of the application identifies that the shallowest aquifer is isolated from the storage ponds by aquitards and that two monitoring wells will be completed immediately above the "shallowest aquitard downgradient of the storage ponds." The location of the screened interval of the monitoring wells with respect to the location of the aquitards is not well described in the application. Note that section 4.2.5.4 indicates that four groundwater monitoring wells will be installed and quarterly samples will be obtained before the pond is put into use. **This is an open issue.**

Lost Creek indicated that this issue is described in Section 4.2.5.4 of the technical report. LCI indicated that they have drilled four wells and that no surface aquifer was encountered before hitting the aquitard.

LC ISR, LLC (4/10) - A total of three shallow wells were drilled in the immediate area of the proposed holding ponds in order to characterize the groundwater (Wells MW-1, MW-2, B-2, and MW-4). Well MW-1 is at the northeast corner of the ponds,

well MW-3 is at the southwest corner of the pond and well MW-4 is at the northwest corner of the ponds. Wells MW-3 and MW-4 are believed to be in hydrologically downgradient from the holding ponds. The engineering firm hired to drill the wells was instructed to stop drilling upon intercepting a significant aquitard. Wells MW-1, MW-3, and MW-4 each encountered a significant aquitard without encountering any groundwater. Drill hole B-2 did not encounter a significant aquitard or groundwater so a well was not installed. An additional well will be installed at the location of the B-2 drill hole to determine the depth of the uppermost aquitard and to serve as a point for monitoring during operations. Uranium exploration drill holes in the area indicate the presence of numerous aquitard layers between surface and the groundwater table which is at least 180 feet below ground level.

The surficial aquifer (uppermost aquifer) at the Lost Creek Project area is the DE Sand. The original Technical Report contained water quality for a total of three wells completed in the DE Sand (LC29M, LC30M, and LC31M). Since that time three additional regional monitor wells were completed in the DE Sand (MB-1, MB-7, and MB-10). Of these three new wells, only MB-1 contained sufficient water for sampling. The water quality data for well MB-1 has been added to Table 2.7-13 and the text in Section 5.7.8 (Groundwater and Surface Water Monitoring Programs) has been updated to reflect the additional well.

DSER 4.2 (Agenda item 24.)
Plan view and cross section view of storage pond not consistent grade. Cannot verify freeboard requirement and ability to transfer liquids back and forth in the event of a leak.

The staff noted that the cross section view drawing of the storage ponds does not appear to accurately reflect the plan view. The cross sections show the top of the embankments at 6,975 ft and just under 6,972 ft above mean sea level (MSL), but the plan view shows the pond embankment elevations at 6,970 ft. This discrepancy should be corrected so that the availability of freeboard can be verified and so that sufficient pond capacity is available to be able to transfer the contents of one pond to another should a pond be found to be leaking. **This is an open issue.**

LCI agreed with the NRC staff that the drawings are not always clear and easy to read. LCI indicated that these drawings have been revised and will be sent to the NRC staff to address this issue.

LC ISR, LLC (4/10) - The engineering drawings of the storage ponds have been revised and are included in Attachment 4.2-1. In particular, drawing 0802.103 entitled "Embankment Details" and Section 3.0 of the Design Report provide details on the availability of freeboard.

DSER 4.2 (Agenda item 25.)
Chemical compatibility between synthetic liner and pond liquids.

The applicant does not appear to have addressed the chemical compatibility between the polypropylene liner and the liquids that will be stored in the ponds. This issue was raised in RAI section 4.2, number 3d. This information is necessary to verify that the geosynthetic will be able to fulfill its intended function in a potentially harsh environment. **This is an open issue.**

LCI indicated that a Professional Engineer with experience in pond design selected the liner material. LCI has contacted the liner manufacturer and requested confirmation on the chemical compatibility of the liner and pond liquids. LCI will send the NRC staff the results of the chemical compatibility issue.

LC ISR, LLC (4/10) - A discussion of the chemical compatibility of the pond liner and liquids has been included in Section 4.2.5.4 (Disposal of Liquid 11(e)(2) Byproduct Materials) under the subheading **Storage Ponds.**

DSER 4.2 (Agenda item 26.)
Daily vs. weekly leak detection system inspections.

LCI has proposed performing weekly inspections of the storage pond leak detection system. The NRC staff's experience has indicated that daily inspections of the leak detection system provide operators an adequate ability to detect problems with the liner system. This is discussed in the November 2008 version of NRC Regulatory Guide 3.11 "Design, Construction, and Inspection of Embankment Retention Systems at Uranium Recovery Facilities." The applicant should provide justification for the reduced frequency at the LCI site, or propose conducting daily inspections of the leak detection system. **This is an open issue.**

Lost Creek indicated that they reviewed the practices at other facilities and used that as a basis for the inspection frequency.

LC ISR, LLC (4/10) - The descriptions of the holding pond inspections found in Section 5.3.2.1 and 5.3.2.2 of the Technical Report (TR) were written in early 2007 when an earlier version of Regulatory Guide 3.11 was still in place. A year after the TR was submitted, NRC Regulatory Guide 3.11 was revised with the new requirement of daily inspections of the leak detection system. LC ISR, LLC has revised Section 5.3.2.1 (Daily Storage Pond Inspections) to include a commitment to install an automated leak detection system in the leak detection standpipe. If the

automated system detects a leak it will notify the operator with an alarm. The leak detection standpipe and automated leak detection system will be inspected on a weekly basis to ensure it is operating properly (Section 5.3.2.2 (Weekly Storage Pond Inspections)).

DSER 4.2 (Agenda item 27.)
Evaluation parameters for leak detection system liquids and groundwater monitoring.

Sections 4.2.5.5 and 5.3.2.3 of the application discuss the evaluation parameters for the leak detection system and groundwater monitoring. For leak detection monitoring, the applicant proposes testing for specific conductance, chloride, alkalinity, sodium, and sulfate. For the storage pond groundwater monitoring wells, the applicant proposes monitoring for natural uranium, pH, chloride, bicarbonate, and conductivity. It appears that the applicant will be testing for different parameters in the leak detection water and groundwater monitoring wells. Ideally, these parameters should be the same to allow for a direct comparison of the leak detection liquids and surrounding groundwater, if a leak does occur. **This is an open issue.**

LCI indicated that the chemistry of the water located in the storage ponds is dramatically different from what would be encountered in the groundwater. LCI reiterated that no groundwater was encountered during the installation of the four groundwater monitoring wells for the storage ponds. LCI indicated they chose the parameters based on practices at other ISR facilities.

LC ISR, LLC (4/10) - Section 5.3.2.3 (Quarterly Storage Pond Inspections) has been revised so the parameters analyzed from samples taken from the leak detection standpipe and the shallow monitor wells are the same.

DSER 4.2 (Agenda item 28.) Subgrade preparation techniques.

The applicant does not appear to address the subgrade preparation techniques that will be used for the foundation soils beneath the liner system. Proper preparation of the subgrade is critical to maintaining the performance characteristics of the geomembrane. Items such as the largest particle size allowed and the compaction requirements in the soil layer that will be in contact with the geomembrane should be discussed. Given the information provided, the staff cannot be assured that the storage ponds will be protective of public health once constructed. **This is an open issue.**

LCI indicated that they would address this issue in a submittal to the NRC.

LC ISR, LLC (4/10) - The complete holding pond engineering report has been added to the Technical Report as Attachment 4.2-1. The report specifically addresses soil preparation and compaction in the Technical Specifications Sections 3.2.2, 3.3.4, 3.3.5, and 3.3.7. The attachment also includes a geotechnical report of soil characteristics.

DSER 4.2 (Agenda item 29.)
Number of storage ponds that will be constructed.

The applicant appears to have included two sets of drawings related to storage ponds at the facility. One set of drawings immediately follows the specifications and shows two ponds located adjacent to the Central Processing Plant (CPP) building. The second set of drawings is located at the end of the binder containing Volume 2 of January 16 responses to NRC questions and there is no clear location of these two ponds. The topography and grading plans in both sets of drawings does not appear to match and the CPP is not shown in both sets of drawings. Additionally, Figure 3.2-5 appears to show more than one set of storage ponds. **This is an open issue.**

LCI confirmed that only two storage ponds are proposed for the facility and that they will be located adjacent to the CPP. LCI indicated that Figure 3.2-5 does not reflect the proposed pond locations; that figure is schematic flow diagram.

LC ISR, LLC (4/10) - The complete holding pond engineering report has been added to the Technical Report as Attachment 4.2-1. Additionally, the location of the holding ponds can be seen on the Plant Site Plan on Plate 3.1-1. A total of two holding ponds are being proposed as described in Sections 3.0 (Description of the Proposed Facility) and 4.2.5.4 (Disposal of Liquid 11(e)(2) Byproduct Materials). Figure 3.2-5 shows a schematic of water balance and does not necessarily reflect the number of proposed storage ponds.

Since the submittal of the initial Technical Report in October of 2007, additional work has been performed on the engineering design of the holding ponds. As a result, a few changes to Section 4.2.5.4 are necessary and include the following:

- The pond dimensions have been changed from 160' x 260' to 155' x 260';
- The leak detection pipe has been changed from 2.5" slotted pipe to 4" slotted pipe;
- Instead of having several leak detection standpipes, the herringbone leak detection system will feed only one leak detection standpipe;
- The amount of freeboard has been changed from five feet to thee feet; and
- Since no water was encountered in any of the shallow monitor wells only three monitor wells have been installed to date. A fourth monitor well will be

installed as soon as possible, however, it is extremely unlikely that any groundwater will be encountered.

DSER 4.2 (Agenda item 30.)
Quality assurance plan for soil and liner installation.

The applicant does not appear to present a quality assurance plan addressing installation of soil and geomembrane components of the storage ponds. A quality assurance plan for soil and geomembrane installation would identify testing frequencies for items such as: in-place density, maximum dry density, geosynthetic seams, and submission of geosynthetic manufacturer quality control data. Given the information provided, the staff cannot be assured that the storage ponds will be protective of public health once constructed. **This is an open issue.**

These issues are addressed in the report and will be forwarded to the NRC staff for review.

LC ISR, LLC (4/10) - The complete holding pond engineering report has been added as Attachment 4.2-1. Specifically, the technical specifications address the quality assurance for the liner installation in Section TS-4 and list appropriate ASTM standards that will be used to ensure the quality of the installation. The report specifically addresses soil preparation and compaction in the Technical Specifications Sections 3.2.2, 3.3.4, 3.3.5, and 3.3.7. The attachment also includes a geotechnical report of soil characteristics.

DSER 5.2 (Agenda item 31.)
Reporting of leaks, spills, excursions to NRC

The applicant does not appear to have addressed notification procedures for spills in wellfields, header houses, pipelines, or buildings. Section 5.7.6.6 identifies reports and records that will be maintained for the life of the license. Table 5.2-1 identifies a list of internal and external reports, the responsibility for preparing the report and the applicable regulations. Excursions do not appear to be identified in Section 5.7.6.6 or in Table 5.2-1. The technical report identifies that a spill assessment will be prepared, but it does not appear that this will be submitted to the NRC. **This is an open issue.**

LCI indicated that the NRC staff should review section 5.7.6.6 and Table 5.2-1 of the technical report. LCI also indicated that as well as regulations contained in 10 CFR 20.2202 to 2203, and 10 CFR 40.65 apply.

LC ISR, LLC (4/10) - Section 5.7.6.6 (Plant and Mine Unit Control) and Table 5.2-1 have been revised to include notification of excursions. Also, the procedure for assessing and reporting of mining solution spills can be found in Section 5.7.6.5 (Standard Operating Procedures).

Section 5.7.8.2 (Operational Monitoring) addresses the analysis of and reporting of excursions under the subheading **Excursion Verification and Corrective Action**.

DSER 5.2 (Agenda item 32.)
Meeting requirements of 20 CFR 1902(e).

The applicant does not appear to have provided a discussion related to the requirements of 20 CFR 1902(e). This regulation addresses posting requirements at licensed facilities.

LCI indicated that it would comply with the requirements of 20 CFR 1902(e).

LC ISR, LLC (4/10) Response: NRC indicated in their November 9, 2009 letter that this was no longer an Open Item or Confirmatory.

DSER 5.2 (Agenda item 33.)
Submittal of reports to NRC (ALARA, semi annual effluent monitoring, etc.); reporting of leaks, spills, excursions to NRC.

The applicant has not completely identified which reports will be submitted to the NRC. The licensee should submit the ALARA audit report, land use survey, monitoring data, corrective action program report, semi-annual effluent monitoring reports, and the SERP information to the NRC on an annual basis. **This is an open issue.**

LCI indicated that these reports have been identified in Table 5.2-1. However, land use surveys as described in 5.2.3 are not listed in Table 5.2.-1.

LC ISR, LLC (4/10) - Both Section 5.7.6.6 (Plant and Mine Unit Control) and Table 5.2-1 have been revised to include reports not previously included (ALARA audit report, land use survey, monitoring data, corrective action program report, semi-annual effluent monitoring report, and SERP information).

DSER 5.3(Agenda item 34.)
Qualifications of RSO designee who will perform daily walk through inspections.

Lost Creek plans on performing a series of inspections related to radiation safety and the
storage ponds. In addition, Lost Creek will perform an annual audit of the radiation safety and ALARA programs. Daily walk through inspections of the facility will be performed by the RSO, a health physics technician, or by a qualified person designated by the RSO. The purpose of this inspection is to observe radiation safety practices, SOPs, and to identify the need for corrective actions. The Lost Creek RSO will conduct a weekly inspection (with the Operations Manager) of all facility areas where radioactive materials or radiation levels above background may exist. The RSO will prepare a monthly written summary of the daily and weekly inspections, with a focus on the personnel exposure data at Lost Creek. The monthly summary will include an evaluation of trends related to the ALARA program along with recommendations for corrective actions and improvements. The applicant has not identified the criteria for a qualified person designated by the RSO to perform the daily walk through inspections. **This is an open issue.**

LCI indicated that they would address this issue.

LC ISR, LLC (4/10) - Please see LC ISR, LLC's Response to NRC's December 2009 RAI #7b.

HYDROGEOLOGY OPEN/CONFIRMATORY ISSUES

DSER 2.3 (Agenda item 7.)

Inconsistencies in the site-specific geologic mapping (isopach, cross-sections, and faults). NRC staff indicated that the geologic information in the application and other submittals contained apparent discrepancies. For example, cross-section H-H has traces of three faults, but the isopach mapping (map view) depicts only the Lost Creek Fault, the potentiometric surface contour map for the DE Horizon depicts a splay off of the Lost Creek fault which differs from faulting on the isopach mapping, and the structural contour mapping for the bottom elevation of the Lost Creek Shale (LCS) was above the elevation of the top of the LCS in at least one location. **This is an open issue.**

LCI proposed discussing this issue with the staff on a separate call with more specific information on which figures/mapping are at issue. The issue stems from the fact that

the geologic interpretations by the applicant have evolved during the application process as additional information is gathered. LC and NRC staff agreed that a date should be established that completes the data gathering for purposes of the application.

LC ISR, LLC (4/10) Response: Please see LC ISR, LLC's Response to NRC's December 2009 RAI #3a.

DSER 2.3 (Agenda item 8.)
Adequate abandonment procedures for historic borings.

NRC staff indicated that the April 2009 submittal to the State for the mine permit included documents on the historical (per-1980's) well abandonment procedures by a former owner (TexasGulf). The procedures include filling the screened horizon, which may include the entire Battle Spring Formation, with drilling mud with a density slightly greater than water, and only sealing the upper 25 feet. The staff's concern is the wells being a preferred migration path especially for older wells near a proposed wellfield.

Lost creek replied that the proof would be in the pudding; the pumping tests conducted to date have shown that there is little communication between the overlying and production aquifer. For the pumping test at Mine Unit 1, drawdown in the underlying and overlying is less than 1 percent of the drawdown at the pumping well which was 100 feet, or maximum 10 to 20 percent of the drawdown based on distance from the pumping well. The apparent drawdown did not appear to be point source from a leaky source material. Results of the regional tests are the same as that conducted at Mine Unit 1 where 3 to 4 feet of drawdown was observed at the pumping test rate. Lost Creek indicated that the pumping test data would be performed on a mine unit scale after the license is issue, which will address this concern.

LC ISR, LLC (4/10) Response: NRC acknowledged LC ISR LLC's response to this item and did not indicate that it remains an Open or Confirmatory item.

DSER 2.3 (Agenda item 9.)
UBC or IBC Criterion for Seismology Design.

NRC staff indicated that the application was completed at a time the Wyoming Regulations were based on the UBC criterion but the regulations have adopted the IBC subsequently.

LCI proposed discussing this issue with the staff on a separate call with more specific information on which figures/mapping are at issue. The issue stems from the fact that the geologic interpretations by the applicant have evolved during the application process as additional information is gathered. LC and NRC staff agreed that a date should be established that completes the data gathering for purposes of the application.

LC ISR, LLC (4/10) - Please see LC ISR, LLC's Response to NRC's December 2009 RAI #3b.

Proceedings American Meteorological Society
3rd Symposium on Fire and Forest Meteorology
Long Beach, CA, 9-14 January 2000, 139-140.

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1. INTRODUCTION

The availability of operational forecast guidance describing characteristics of atmospheric boundary layer behavior is extremely beneficial to decision-makers who monitor smoke dispersion resulting from wildland fire and prescribed burning. Currently, many National Weather Service Forecast Offices provide a 12-hour forecast of mixing height (the top level of a layer that begins just above the earth's surface and consists of strong vertical mixing) and mean transport wind flow (the mean horizontal wind speed and direction within the mixing layer). These forecasts are typically based upon sounding information or derived soundings from model output. However, prediction beyond 12 hours can also be of value to decision-makers requiring planning for one or more days ahead. Another advantage of model output is that it can account for temperature and moisture advection and synoptic scale lift or subsidence.

This paper describes a method utilizing 6-hourly National Centers for Environmental Prediction (NCEP) Eta model forecasts to produce gridded smoke management forecast products of mixing height and mean transport wind speed and direction. These products are being computed in an experimental mode at the Desert Research Institute Program for Climate, Ecosystem and Fire Applications (CEFA) in conjunction with the SCRIPPS Institution of Oceanography Experimental Climate Prediction Center's California Applications Project. Though the products are being generated for the entire U.S., results are currently being analyzed only for the West.

2. BACKGROUND

Mixing height represents the height or top of the atmospheric boundary layer, and can be thought of as a cap or lid to buoyant air (Stull, 1988). When buoyancy is minimal, the mixing height is low and particulants entrained in the boundary layer flow will remain near the surface. But higher mixing tops imply increased buoyancy and therefore, greater lift for particulants.

Wind plays an important role in the boundary layer in terms of particulant transport and dispersion. Mean transport wind represents a vertical average of zonal and meridional wind components (u and v components) from the surface up to the calculated mixing height.

The mixing level tends to be well defined in the afternoon hours (typically during times of maximum heating). However, the mixing layer can undergo significant diurnal and seasonal variability, and its location during night and early morning hours can be complex. For example, the mixing layer can decouple and become displaced above the ground during the nighttime hours due to localized radiational cooling and or low-level temperature advection.

The most commonly used method for calculating mixing height is based upon thermodynamic profiles (NWS, 1999). For example, the morning mixing height is defined as the level above ground at which the dry adiabatic ascent of the morning minimum surface temperature plus 5°C intersects the vertical temperature profile measured at 1200 UTC. The afternoon mixing height is based on the level above ground at which the adiabatic ascent of the afternoon maximum surface temperature intersects the 0000 UTC temperature profile. This latter method is applied to obtain a daily forecast of the afternoon mixing height utilizing the daily forecast maximum surface temperature and 1200 UTC sounding.

3. METHOD

In order to generate the experimental products on a daily basis, potential temperature (Θ), geopotential height (z) and zonal and meridional wind (u and v components) are extracted at each grid point (40 km) from the Eta model 00 UTC and 12 UTC runs. This is done for the initialization and each 6-hourly forecast out to 48 hours. Mixing height is then determined using a computer algorithm that checks for regions where Θ remains constant with increasing altitude. This signifies adiabatic conditions that in turn suggests the air is well mixed. The altitude at which Θ departs from constancy by one degree K signifies the top of the mixing layer.

Calculations are performed on sigma surfaces based on a non-dimensional coordinate system where the pressure at any particular level is normalized by the surface pressure. In the Eta model computations for mixing height, sigma levels range from .995 to .955 in increments of .005 and .950 to .450 in increments of .05. The .995 sigma represents the level closest to the surface.

Once the calculations of mixing height and mean transport wind for each model grid point are completed, graphical displays for the western U.S. are generated using the GrADS software package. For both mixing height and wind speed displays, the model grid points are interpolated to a .25 by .25 degree uniform grid using a Cressman analysis scheme incorporated into GrADS, and mean wind direction is simply shown by constant length vectors. However, for forecasters and users desiring actual numerical results, values can be provided for any of the original model grid points.

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4. EXAMPLES

Figure 1 provides an example graphic of mixing heights over the western U.S. using the 1 October 1999 00 UTC Eta initialization. In this example, the cooler colors represent higher mixing heights. The highest mixing heights are indicated in an area across Nevada, southern Utah, western Colorado and most of New Mexico. The lowest mixing heights, represented by warmer coolers, occur along all of the west coast and inland over the California central valley.

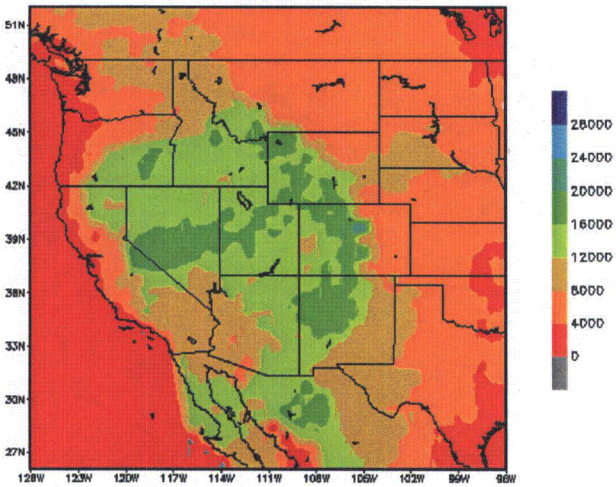

Figure 1. Example mixing height in feet above ground level for the 1 October 1999 00 UTC Eta initialization. Cooler colors indicate higher mixing heights.

Figure 2 shows the mean wind speed associated with the mixing heights in Figure 1. The strongest wind speeds are seen across eastern Oregon, southern Idaho and western Wyoming.

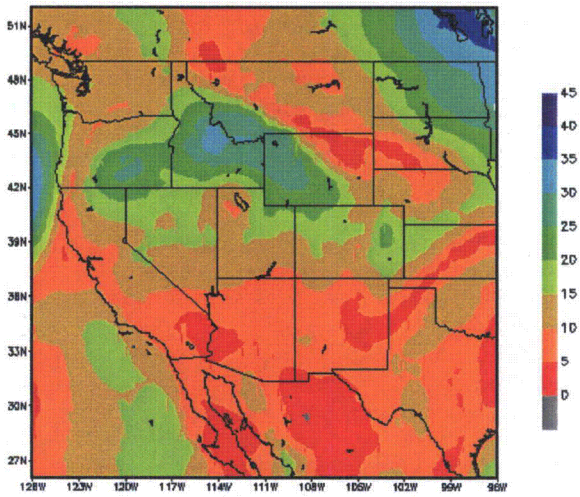

Figure 2. Example mixing height mean wind speed in mph for the 1 October 1999 00 UTC Eta initialization. Cooler colors indicate greater wind speeds.

Figure 3 shows the corresponding mean wind direction or mean transport flow. Except for the Pacific Northwest region, most of the West is generally under westerly flow in this example.

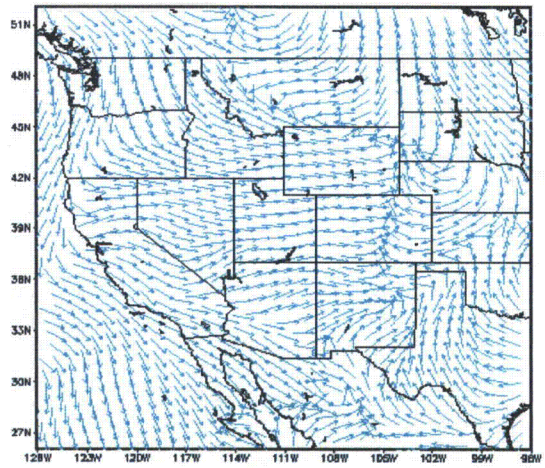

Figure 3. Example mixing height mean wind direction for the 1 October 1999 00 UTC Eta initialization.

5. SUMMARY

Even though the project is in the early stages of evaluation and verification, fire weather forecasters and smoke managers are finding immediate value and usefulness from these products. The primary advantages are that they provide an indication of boundary layer conditions in between sounding locations, and offer forecast guidance over large spatial scales and shorter time intervals. These operational products are not limited to 48 hour Eta forecasts; MRF forecasts could be used to produce mixing height guidance products out to 10 days. In this case, actual daily values may not be as important as mixing height trends.

Anticipated future work will focus on evaluation and verification. Though some basic verification has been undertaken, a more complete statistical analysis of mixing height and transport wind for the initialization and forecasts using sounding observations is needed to assess the quantitative skill of the forecasts. For longer term planning of smoke management, it would be desirable to determine seasonal and diurnal climatologies of mixing height and transport wind. This could be developed using the Eta initialization runs. Another relevant study would be relating mixing height behavior to synoptic scale patterns.

The products described in this paper are currently available in an experimental and semi-operational mode at http://www.dri.edu/Programs/CEFA.

6. REFERENCES

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Wind Characteristics in Southern Wyoming

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ABSTRACT

Measurements of wind from a network of surface anemometers and a 107 m tower have been analyzed for southern Wyoming where a project for large-scale generation of electricity from wind power is underway. Topographically forced channeling of stable air flow across a low region of the Continental Divide is mainly responsible for very high mean wind speeds especially in winter. The seasonal cycle of wind speed exhibits a maximum in winter and minimum in summer. Mean wind speeds are approximately 50% greater in winter months than in summer, and the available wind power density is a factor of ~4.0 greater in winter than in summer. The diurnal cycle is characterized by minimum speed near sunrise and maximum in afternoon hours. Wind directions are narrowly confined from the west-southwest by topographic channeling of the flow, particularly in winter. Wind speed increases sharply with height at night but the profile becomes much more uniform during daylight hours in response to mixing of the lower atmosphere initiated by surface heating.

1. Introduction

Recent studies and engineering tests of large wind turbines indicate these machines offer a promising method of economical generation of electricity (e.g., Hewson, 1975; Metz and Hammond, 1978). This is especially true in regions of high wind speeds. Climatological inventories of available wind energy have shown that southern Wyoming has one of the greatest wind power potentials of any sizeable region in the United States (e.g., Reed, 1974; Elliott and Barchet, 1980). This has prompted the Bureau of Reclamation to proceed with plans for construction of a large array of giant multi-megawatt wind turbines for electricity generation near Medicine Bow, Wyoming. The unique plan which will integrate electricity produced by the wind turbines with power from existing federal hydroelectric systems is described by Hightower and Watts (1977) and the Bureau of Reclamation (1981). The first two giant turbines have currently been erected at Medicine Bow (Fig. 1).

Detailed studies of wind characteristics in southern Wyoming have been conducted by the University of Wyoming (UW) in support of the Medicine Bow wind-hydroelectric project. The objectives of the studies were to measure and document the wind speed, direction and frequency distributions and to ascertain the manner in which the wind varies with season, time of day, height above ground and location. Moreover, the studies investigated the interaction of meteorological and topographical factors which in combination govern the airflow across southern Wyoming.

The wind characteristics studies had four related facets: 1) surface wind measurements from a network of anemometers including vertical profile investigations using data from a tall instrumented tower, 2) airflow case studies using measurements from research aircraft, 3) numerical simulations of the three-dimensional flow, and 4) flow pattern inferences from geomorphology studies of aeolian terrain features. The first facet is the subject of this paper which presents climatological analyses of the anemometer data. Case study analyses have been reported by Dawson and Marwitz (1978) and by Karacostas and Marwitz (1980) for the aircraft data and by Seaman (1982) for the numerical simulations. The geomorphology studies have been reported by Kolm (1977). A brief summary of all four facets is given by Martner and Marwitz (1981).

2. Measurements

The map in Fig. 2 shows major topographic features and the location of wind measurement sites in southern Wyoming. The town of Medicine Bow is located just north of site MA, and the first giant wind turbines have been erected 9 km southwest of town at site MT in an area called Spade Flats. Table 1 identifies the sites and their characteristics. The period of record for data analyzed by UW is given in the last column. Only one station had less than a full year of hourly wind data. Thus, data from almost every site meet the recommendations of Corotis *et al.* (1977) and Justus *et al.* (1979) for at least one year of data to improve the statistical likelihood that the

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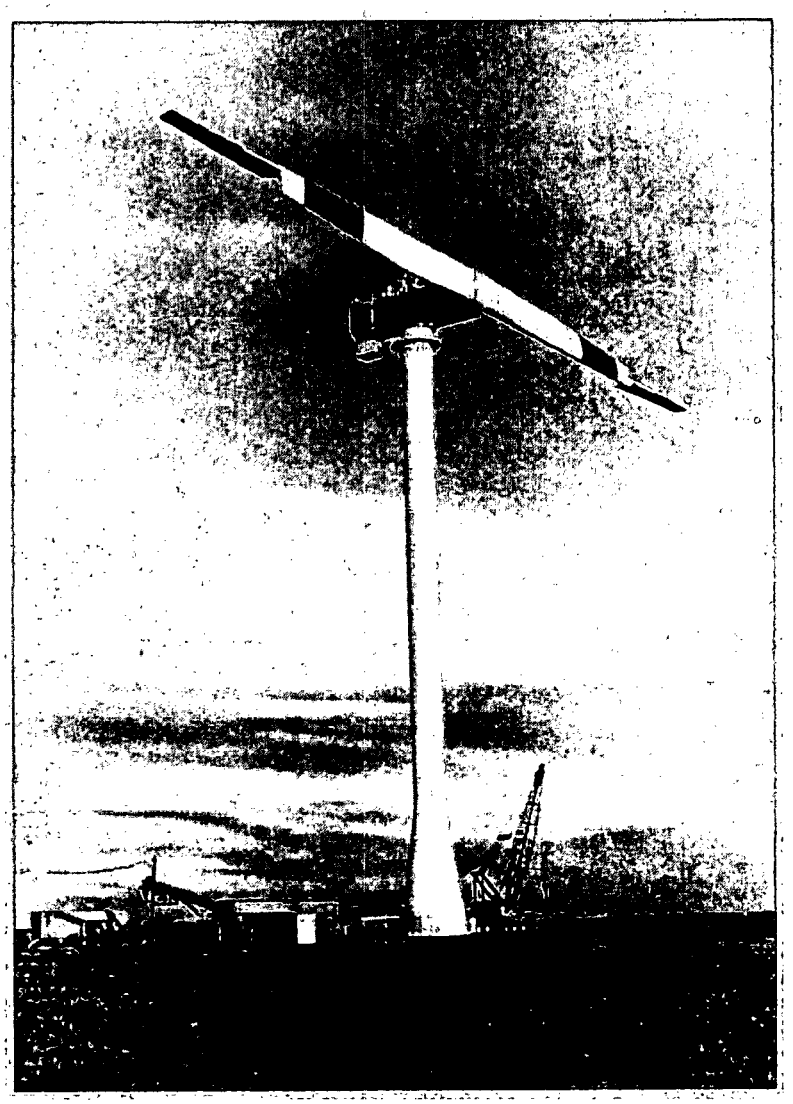

FIG. 1. Photograph of a Boeing MOD-2 wind turbine near Medicine Bow, Wyoming. The hub height is 61 m, rotor diameter is 91.5 m, and the output rated power is 2.5 MW at wind speeds of 14 m s^{-1}. A Hamilton Standard 4 MW turbine is located 1.4 km away.

averages from the limited short-term measurements are accurate estimates of true long-term wind speed averages.

Instruments operated by UW recorded wind speed and direction and are commercially available from Meteorology Research Inc., and Lambrecht Co. Each anemometer underwent a wind tunnel calibration test prior to installation in the field. Most of the UW instruments were mounted on poles at 4 m above ground level (AGL), and a few were co-located on towers at 4 and 12 m AGL. All data were digitized in discrete units of 1 h averages.

Most of the UW anemometers were clustered in the Medicine Bow vicinity. Sites were selected on the basis of a number of criteria, including proximity to aeolian features of the terrain. Each was located in flat open expanses. The terrain within at least 1 km of each anemometer was devoid of trees and had only low prairie grass and sparse sagebrush for vegetation. Roughness lengths of about 10 cm or less would be appropriate for these locations.

A 107 m meteorological tower instrumented at three levels was operated at site MT. The tower anemometers were calibrated every six months in a wind tunnel facility. Wind speed and temperature data from the tower are presented in Section 8.

3. Topographical and meteorological factors

A combination of meteorological and topographical factors is reponsible for the high wind speeds near

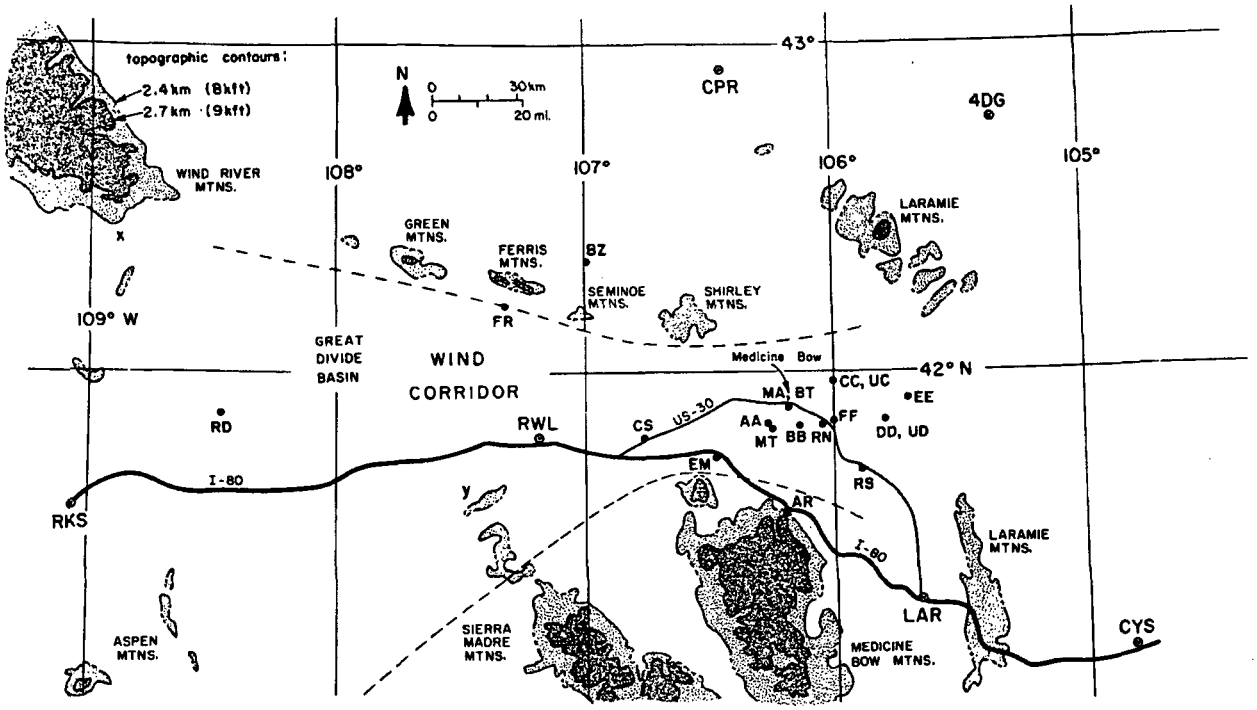

FIG. 2. Map of southern Wyoming showing the higher topography (shaded). The Continental Divide crosses the wind corridor between points x and y. Dots indicate the location of wind measurement stations which are identified in Table 1.

Medicine Bow, especially in winter. The Great Divide Basin or Red Desert area in southern Wyoming between the towns of Rock Springs (RKS) and Rawlins (RWL) is the lowest region of the Continental Divide between Montana and New Mexico. It therefore constitutes a natural passageway for stable air from the Great Basin region of Nevada and Utah to drain eastward across the Divide. Furthermore, the mountain ranges in southern Wyoming are aligned in a funnel-like orientation which forces the air to converge into a narrower, faster stream as it flows eastward across the state. This natural topographic venturi called the "wind corridor" by Kolm (1977) is shown by the dashed lines in Fig. 2. The corridor is about 110 km wide upwind near Rock Springs and narrows to about 45 km downstream between the Shirley and Medicine Bow Mountains. Surface frictional effects in the corridor are minimized by the relatively flat terrain and virtual absence of trees. The town of Medicine Bow lies near the center of the narrowest part of the corridor, and is therefore subjected to strong westerly winds, especially in winter.

Synoptic meteorological conditions which produce the most prolonged strong winter winds in the region are illustrated by the example shown in the maps of Fig. 3. The upper air pattern is characterized by a strong ridge over the West Coast and a trough over the midwestern states. This produces strong northwest winds aloft in the Wyoming area. It most often represents a post-storm condition in Wyoming. At the surface the situation is characterized by an intense high pressure system centered in the Nevada-Utah-Idaho region and much lower pressure in the Dakotas with a large pressure gradient across Wyoming. Strong east–west pressure gradients across Wyoming are not uncommon in winter. During a seven-year period spanning the UW anemometer measurements the surface pressure (reduced to sea level) at Salt Lake City exceeded the pressure at Cheyenne by at least 10 mb on 20% of the winter days and by 15 mb 6% of the time.

The surface pressure gradient forces stable air across the low rim of the Continental Divide and into the wind corridor. Subsidence inversions associated with the high pressure system frequently cap the flow at near the mountain top level. Since the vertical displacement of the flow is limited, the air is constrained to flow through the corridor rather than rising over the mountainous barriers. Part of the flow from the corridor drains northeastward toward Casper (CPR) through mountain gaps (Dawson and Marwitz, 1978).

Pressure gradient and friction forces are dominant. The Coriolis force is relatively small and has little time to significantly affect the motion of air parcels which move rapidly through the corridor. Hence, the flow is essentially antitriptic. Topographically forced confluence accelerates the air, producing the greatest surface wind speeds at the neck of the funnel near Medicine Bow. Other synoptic situations (e.g., frontal passages) also produce strong winds in winter, but

TABLE 1. Wind station site characteristics.

Map code	Station name	Operator	Height (m AGL)	Latitude (°N)	Longitude (°W)	Elevation (m MSL)	Length of record (months)	Period of record
Data compiled by University of Wyoming								
AR	Arlington	WHD	8	41.619	106.239	2356	81	02/74–04/81
BT	Beacon Tower	BOR	17	41.887	106.189	2024	7	10/80–04/81
BZ	Buzzard Ranch	UW	4	42.302	106.993	1815	12	12/76–11/77
CS	Coyote Springs	UW	4	41.808	106.682	2118	50	10/76–04/81
EM	Elk Mountain	WHD	7	41.727	106.467	2223	63	01/75–04/81
FR	Ferris	UW	4	42.184	107.261	2149	12	03/78–02/79
CC	Fish Hatchery	UW	4	41.962	106.008	2079	35	01/78–04/81
MA	Medicine Bow Airport	UW	4	41.886	106.187	2024	50	12/76–04/81
BB	Medicine Bow–SE	UW	4	41.836	106.129	2080	35	01/78–04/81
AA	Medicine Bow–SW	UW	4	41.840	106.253	2056	37	01/78–04/81
MT	Meteorological Tower	WSSI	*	41.837	106.247	2060	28	11/78–04/81
RD	Red Desert	UW	4	41.860	108.480	2009	22	12/76–02/79
RN	Rock River North	UW	4	41.831	106.014	2117	41	10/76–05/80
RS	Rock River South	UW	4	41.704	105.866	2155	51	10/76–04/81
UC	Upper Fish Hatchery	UW	12	41.962	106.008	2079	19	10/79–04/81
UD	Upper Wheatland Reservoir #1	UW	12	41.845	105.808	2085	20	09/79–04/81
FF	Vortac	UW	12	41.831	105.976	2112	20	09/79–04/81
DD	Wheatland Reservoir #1	UW	4	41.845	105.808	2085	34	01/78–04/81
EE	Wheatland Reservoir #2	UW	4	41.912	105.693	2125	17	01/78–05/79
Data compiled by the National Climatic Center								
CPR	Casper Airport	NWS	7	42.901	106.470	1630	196	09/64–04/81
CYS	Cheyenne Airport	NWS	10	41.150	104.820	1871	283	10/57–04/81
4DG	Douglas Airport	FAA	18	42.740	105.344	1486	84	01/48–12/54
LAR	Laramie Airport	FAA	20	41.313	105.670	2214	84	01/48–12/54
RWL	Rawlins Airport	FAA	9	41.804	107.205	2068	120	01/55–12/64
RKS	Rock Springs Airport	FAA	15	41.600	109.070	2056	84	01/48–12/54

* 10, 43, 58 m first 13 months; 10, 61, 107 m thereafter at MT. FAA = Federal Aviation Administration, NWS = National Weather Service, UW = University of Wyoming, WHD = Wyoming Highway Dept., BOR = Bureau of Reclamation, WSSI = Western Scientific Services, Inc.

these are usually of much shorter duration. In summer the wind speeds are considerably lower due to much less vigorous synoptic patterns in mid-latitudes and the less frequent and weaker drainage of stable air.

4. Diurnal and seasonal cycles of wind speed

The diurnal and seasonal cycles of wind speed have been examined by computing the mean wind speed for each hour of day for each month at every station. An example of the diurnal trend is displayed in Fig. 4 for the Medicine Bow Airport station (MA in Fig. 2). This station consistently has the lowest wind speeds of the several stations in the Medicine Bow area (annual average values are ~10% below the others). Therefore the values at MA must be regarded as *conservative* indicators of wind speed at 4 m AGL across the region. It has been selected for additional analysis because it had the longest and most complete record of the UW stations in the wind corridor. Seasonal and diurnal trends at other stations parallel those at MA.

Four years of data are incorporated in Fig. 4. The figure reveals that the diurnal trend of wind speed follows the diurnal cycle of solar insolation; minimum speed occurs just before sunrise and maximum occurs in the afternoon. The greatest mean hourly speeds occur in December at ~1400 MST, and average about 10 m s^{-1}. The lowest hourly speeds occur in July at ~0500 MST, and are about 2 m s^{-1}.

We suggest that the diurnal cycle is primarily a consequence of buoyant mixing of frictionally retarded flow near the surface with faster airflow from aloft. The downward transport of momentum increases as solar insolation intensifies during the day. Once heating initiates vertical mixing, the resulting increased surface winds reinforce the mixing process by mechanical turbulence. The amplitude of the cycle is considerably smaller in winter than in summer at Medicine Bow (Fig. 4) probably because solar heating is less by virtue of shorter daylight periods, lower sun angles, and the high albedo of snow cover in winter. The diurnal trend of winds aloft is discussed in Section 8.

Fig. 5 presents the mean wind speed for each hour of day by months in matrix form for the Medicine Bow Airport station. More than four years of hourly measurements are represented. From the figure it is clear that the greatest speeds usually occur in the

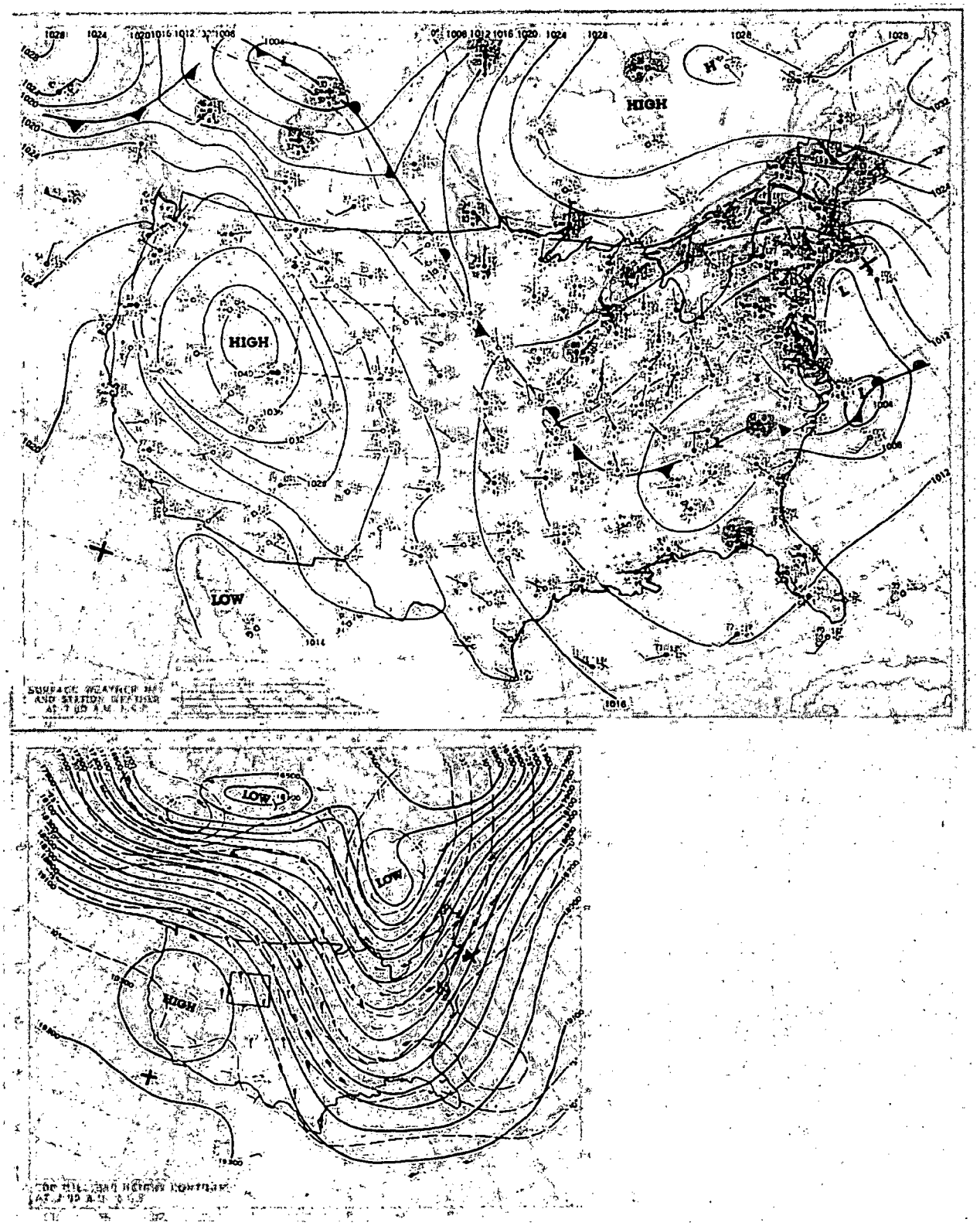

FIG. 3. Synoptic surface (upper) map and 500 mb map (lower) for 16 December 1980.

winter months and in the afternoon hours of all months. The average speed in winter exceeds the summer average by about 50%. Evidence that the higher winter speeds are a consequence of drainage across the Continental Divide and topographically forced confluence in the wind corridor is given in Fig.

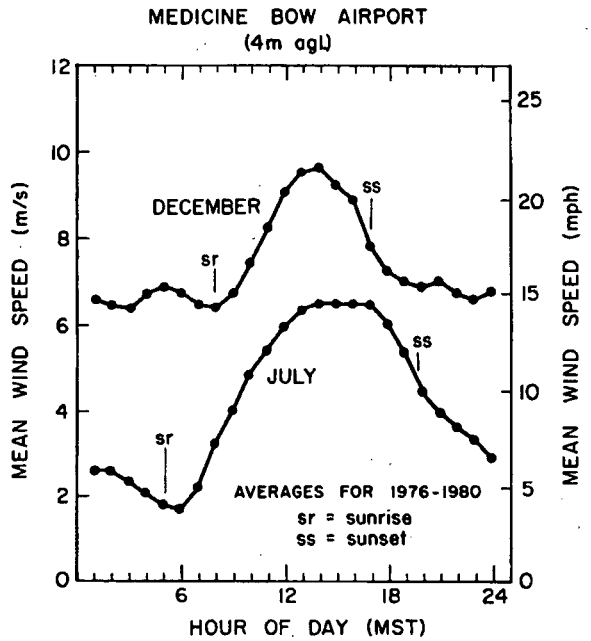

FIG. 4. Diurnal pattern of wind speed at the Medicine Bow Airport station.

6 where Medicine Bow data are compared with four Wyoming stations located outside of the corridor. (Here the speeds for all stations have been extrapolated to a common height of 10 m using the power law discussed in Section 8.) In most months the wind speeds at Medicine Bow are similar to those at nearby stations outside the corridor, such as Casper and Cheyenne. In winter, however, the Medicine Bow speeds excell due to the confluence in the neck of the wind corridor. Lander and Sheridan in northern Wyoming have much lower speeds because they are in the lee of massive mountain ranges.

MEDICINE BOW AIRPORT
(4 m agl.)
Mean Wind Speed (m/s)
DEC 1976 - APR 1981

HOUR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1	5.3	5.4	4.4	3.7	3.7	3.1	2.6	2.7	3.0	3.3	4.7	6.6	4.0
2	5.5	5.3	4.2	3.7	3.5	2.8	2.6	2.6	2.8	3.3	4.5	6.5	3.9
3	5.5	5.3	4.4	3.7	3.3	2.5	2.3	2.6	2.6	3.3	4.5	6.4	3.9
4	5.4	5.5	4.2	3.7	3.2	2.5	2.1	2.5	2.6	3.4	4.5	6.7	3.9
5	5.2	5.7	4.3	3.6	3.2	2.3	1.8	2.3	2.5	3.3	4.8	6.9	3.8
6	5.2	5.6	4.4	3.6	3.1	2.2	1.7	2.2	2.4	3.1	4.6	6.7	3.7
7	5.3	5.9	4.6	3.9	3.6	2.6	2.2	2.4	2.5	3.1	4.7	6.5	3.9
8	5.5	5.9	5.1	4.7	4.6	3.4	3.2	2.8	3.0	3.4	5.2	6.4	4.4
9	5.6	6.3	5.9	5.6	5.2	4.3	4.0	3.5	4.1	4.3	5.7	6.7	5.1
10	6.2	6.9	6.7	6.2	5.5	4.8	4.8	4.3	5.4	5.5	6.4	7.4	5.8
11	6.9	7.7	7.1	7.1	6.0	5.7	5.4	5.5	6.5	6.2	7.2	8.2	6.6
12	7.6	7.9	7.6	7.3	6.2	6.3	5.9	6.2	7.5	7.0	7.8	9.0	7.2
13	8.0	8.3	7.9	7.6	6.7	6.5	6.3	6.7	7.7	7.0	8.4	9.5	7.6
14	8.0	8.5	8.1	7.7	6.9	6.7	6.5	7.1	7.7	7.8	8.4	9.6	7.8
15	7.7	8.4	7.7	7.9	7.1	6.8	6.5	7.1	7.6	7.5	7.8	9.2	7.6
16	7.3	8.1	7.5	7.8	7.1	6.9	6.5	7.0	7.5	7.4	7.1	8.9	7.4
17	6.5	7.3	6.8	7.5	6.8	6.8	6.5	6.9	7.2	6.4	6.1	7.8	6.9
18	5.6	6.3	6.0	6.7	6.6	6.6	6.0	6.7	5.8	4.8	5.4	7.2	6.1
19	5.4	5.7	4.9	5.4	5.9	5.7	5.3	5.8	4.3	4.0	5.4	7.0	5.4
20	5.3	5.7	4.6	4.7	5.0	4.3	4.4	4.8	3.6	3.5	5.4	6.9	4.9
21	5.2	5.7	4.4	4.3	4.5	3.8	3.9	4.0	3.6	3.5	5.2	7.0	4.6
22	5.1	5.5	4.4	4.1	4.0	3.7	3.6	3.5	3.4	3.5	5.1	6.7	4.4
23	5.1	5.5	4.4	4.0	3.8	3.6	3.3	3.3	3.3	3.3	4.9	6.6	4.3
24	5.2	5.6	4.3	3.9	3.6	3.2	2.9	3.0	3.2	3.3	4.8	6.7	4.1
TOTAL	6.0	6.4	5.6	5.4	5.0	4.4	4.1	4.4	4.6	4.6	5.8	7.4	5.3

FIG. 5. Mean wind speed for each hour of day and month at Medicine Bow Airport. Contours are drawn at intervals of 2 m s^{-1}.

The seasonal and diurnal cycles of wind speed have characteristics which are particularly attractive for the Bureau of Reclamation's wind-hydroelectric power integration concept. Wind speeds are greatest in winter when replenishment of the hydroelectric dam reservoirs is at a minimum. When wind speeds are lower in summer, reservoir levels have been boosted by spring snowmelt. Thus, the wind power and hydro power seasonal cycles complement each other. The diurnal wind speed cycle is also convenient because it matches electric load requirements well: low at night, high in daytime.

5. Variability

Interannual variation of monthly mean wind speed in southern Wyoming is illustrated by the example for Casper shown in Fig. 7. The average, standard deviation and extreme range of mean monthly speeds are plotted for 16 years of measurements at a constant anemometer height of 6.7 m. Although Casper is not located within the wind corridor it was selected for this analysis because its period of record is much longer than the Medicine Bow stations. Thus, a more definite assessment of wind variability is possible for Casper. Such plots for the UW stations near Medicine Bow show similar trends but are less smooth and sym-

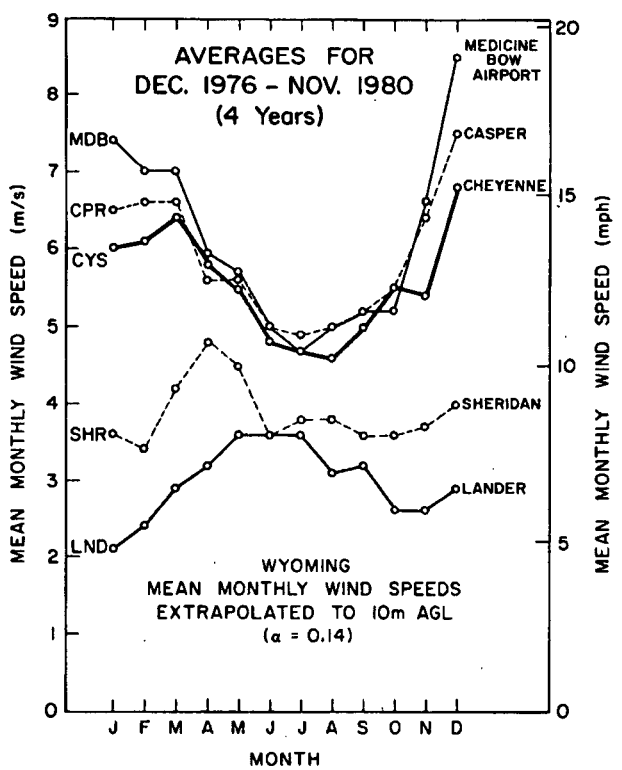

FIG. 6. Mean monthly wind speeds (extrapolated to 10 m AGL) for four years of simultaneous data at Medicine Bow Airport and the four first order National Weather Service Stations in Wyoming. All four NWS stations are outside the wind corridor.

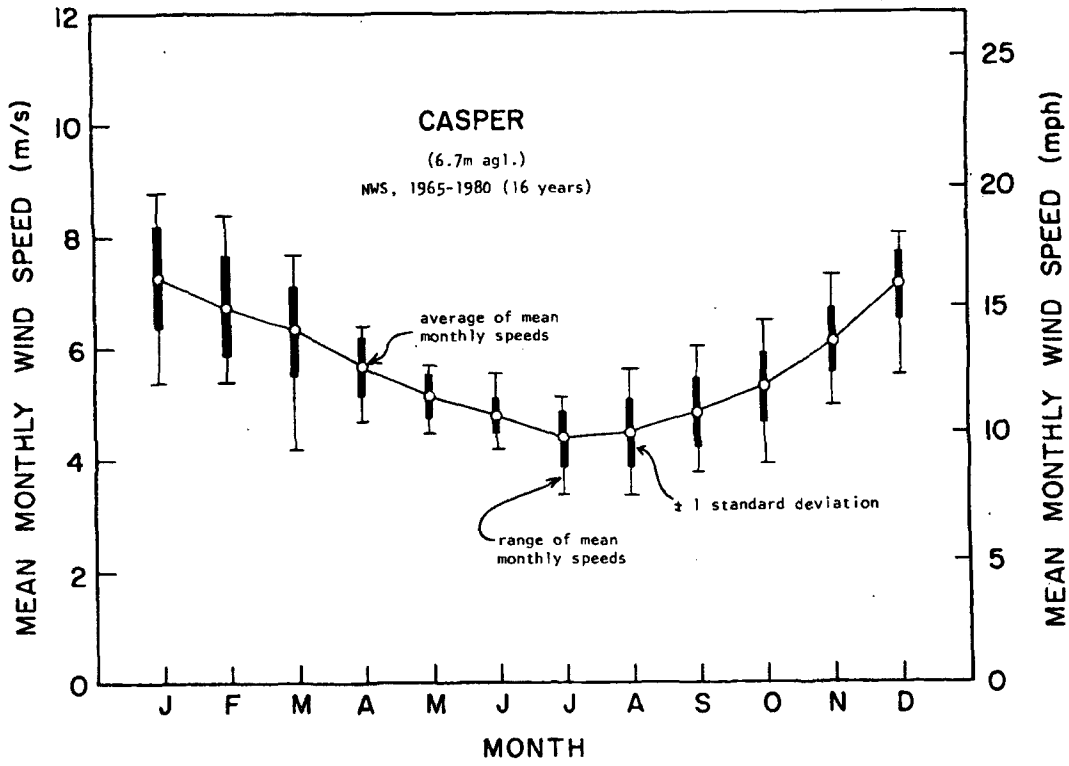

FIG. 7. Average, standard deviation and extreme range of mean monthly wind speeds at the Casper National Weather Service station.

metric because of the much shorter periods of record. The diagram shows that variations of mean monthly speed for individual months can be large and have in the extreme spanned a range of almost a factor of 2 for certain months, although the standard deviations indicate the variations are generally much smaller.

Considering mean annual values of wind speed, the ratio of the standard deviation to the long-term climatological average ($\sigma/\bar{v}$) is 0.05 at Casper. This ranks Casper at the 50 percentile level among the 40 stations across the United States examined by Justus *et al.* (1979) for wind speed variability. From conclusions of that statistical study one may be 90% confident that the mean speed for any individual year at Casper will be within 10% of the climatological mean value. The corresponding average of monthly values of ($\sigma/\bar{v}$) at Casper is 0.11. According to Justus *et al.* (1979), this implies the mean speed for an individual month will be within 18% of the long-term mean for that month with 90% certainty. Occasional extreme departures do occur, however. These values may be representative for southern Wyoming, although similar analyses for most other stations are precluded by the short periods of record.

6. Speed-frequency distributions

Power available in the wind is proportional to the cube of the instantaneous wind speed. While mean annual and mean monthly values of wind speed allow useful estimations of the wind power resource of a location, an accurate calculation of wind power for a period of time requires knowledge of the wind speed-frequency distribution among other variables (Hennessey, 1977; Justus, 1978). Speed-frequency distributions have been documented for every month of operation for all UW stations in southern Wyoming.

Histograms in Fig. 8 present seasonal[1] wind speed-frequency distributions at 4 m AGL for the Medicine Bow-SW site (AA in Fig. 2). Speeds at this location slightly exceed those at all other sites. On that basis the Bureau of Reclamation decided to construct the tall meteorological tower and the first two giant wind turbines adjacent to this location (at site MT). Fig. 8 shows the speed distribution is very broad in winter, extending to large hourly average values. In summer when flow of cold stable air is weaker and less frequent the distribution is much narrower. The available wind power computed from these distributions was a factor of 4.5 greater in winter than in summer.

The smooth curves in Fig. 8 represent analytic Weibull distribution function approximations of the actual distributions (the histograms). The Weibull

[1] Seasons are arbitrarily defined as: winter = Dec + Jan + Feb; spring = Mar + Apr + May; summer = Jun + Jul + Aug; autumn = Sep + Oct + Nov.

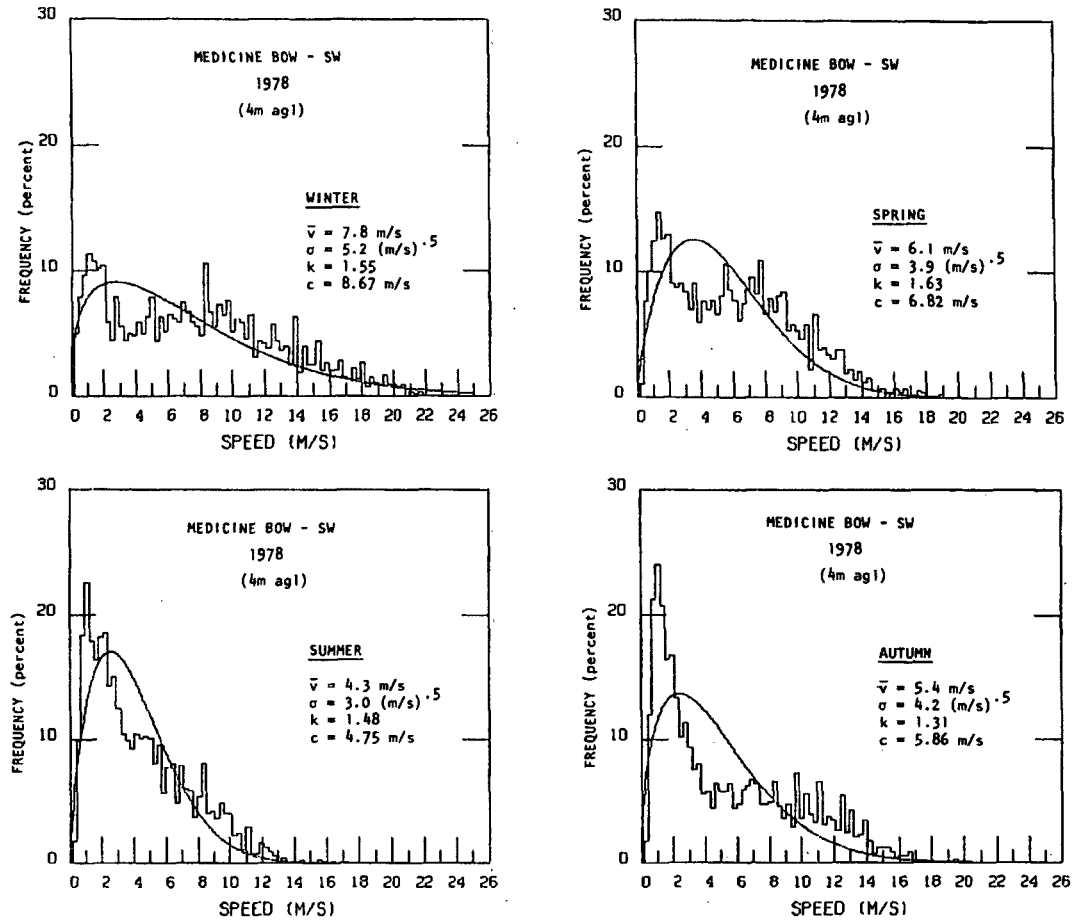

FIG. 8. Seasonal wind speed frequency distributions at the Medicine Bow-SW station. The actual distributions are shown by the histograms. Weibull approximations are given by the smooth curves. The mean, standard deviation and Weibull parameters are listed for each season.

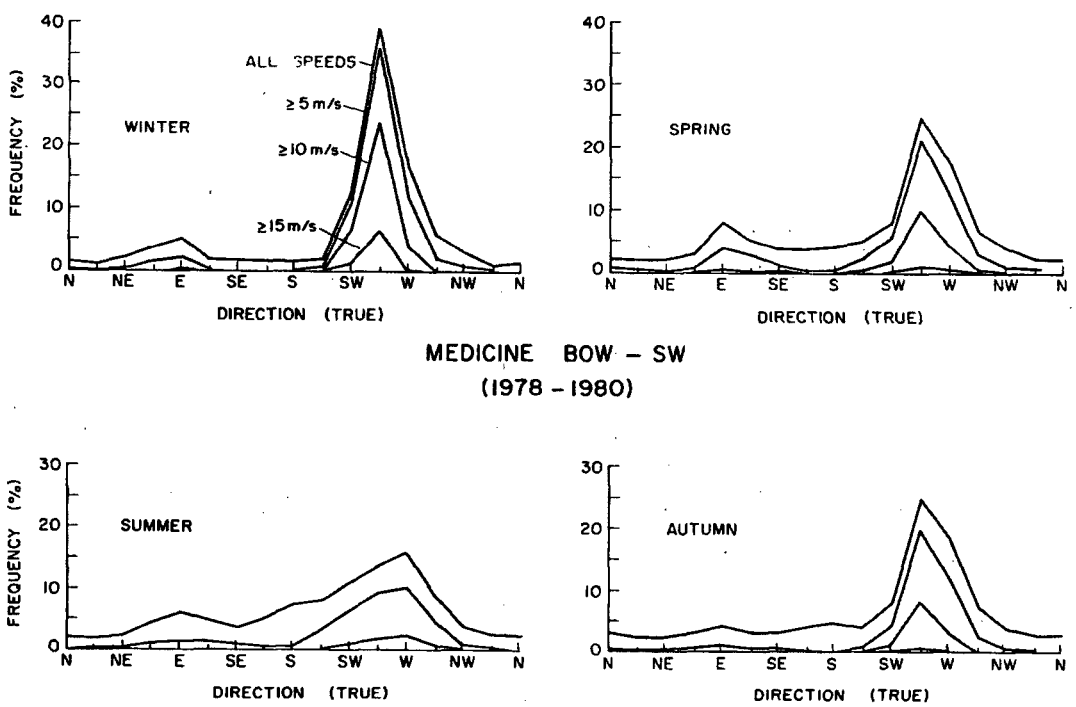

FIG. 9. Seasonal wind direction frequency distributions at the Medicine Bow-SW station.

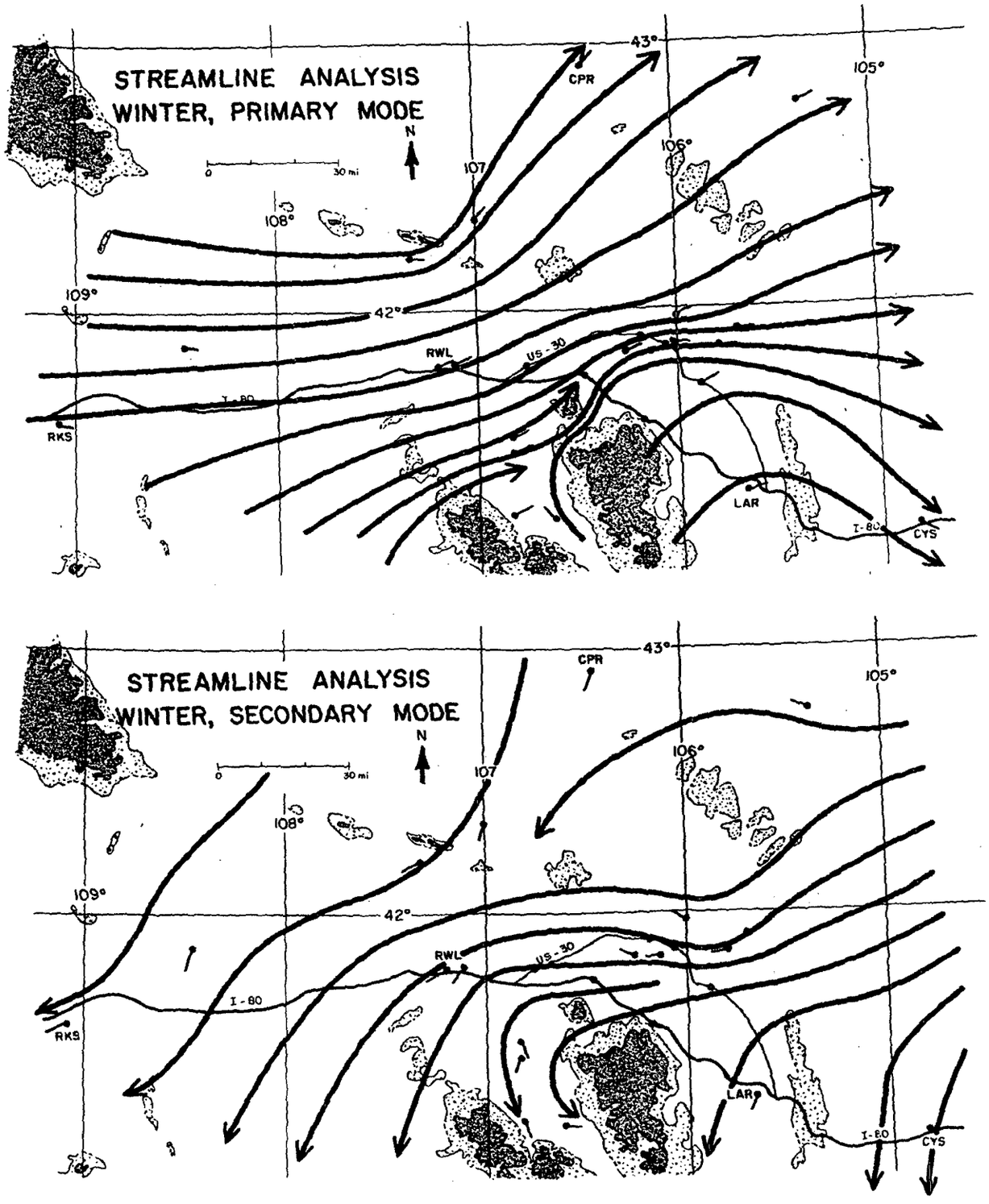

FIG. 10. Maps of generalized primary (upper) and secondary (lower) winter airflow patterns in southern Wyoming.

distributions were computed by the third technique of Justus *et al.* (1978) with the modification suggested by Takle and Brown (1978). Actual distributions in the wind corridor, typified by the case in Fig. 8, are slightly bimodal with the primary peak at 2–4 m s^{-1} and a secondary peak near 8–10 m s^{-1}. This feature

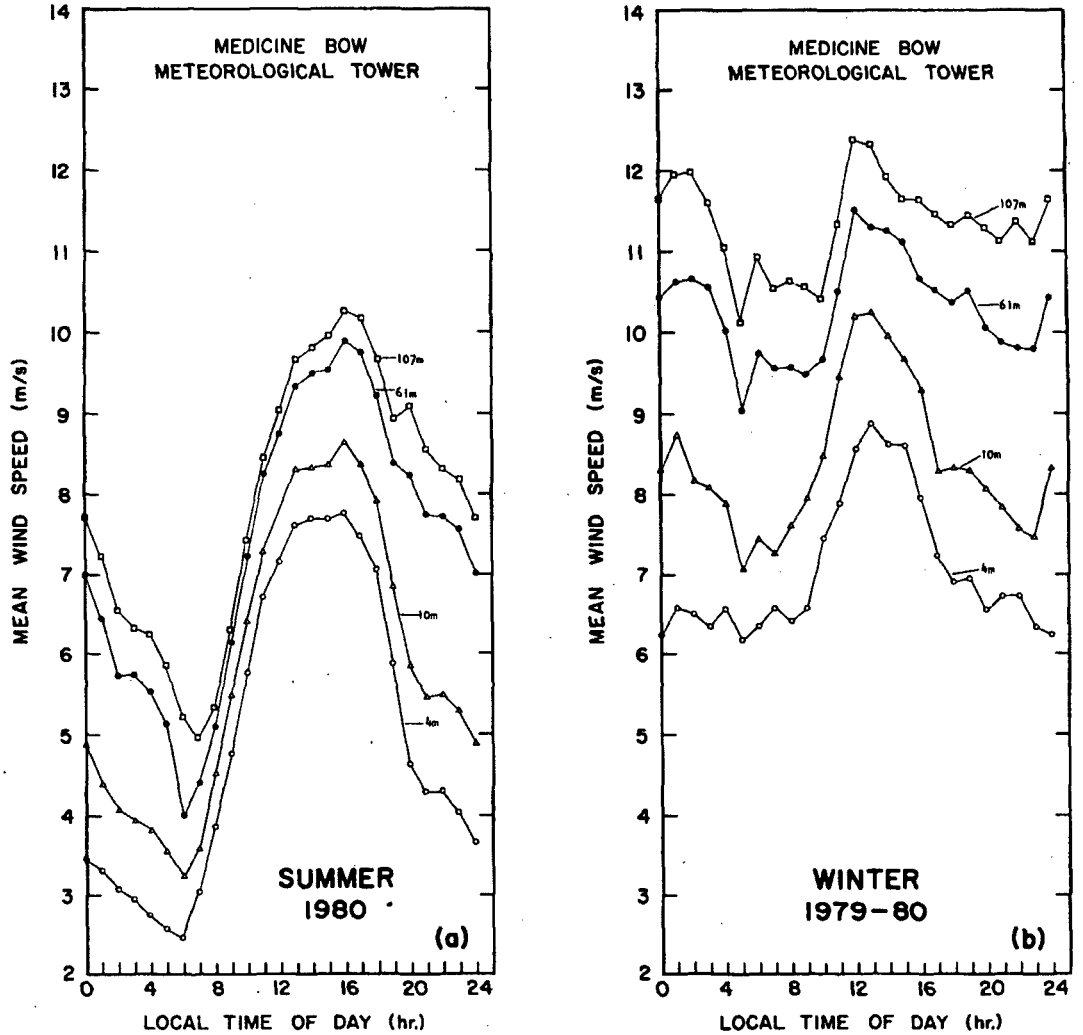

FIG. 11. Diurnal patterns of wind speed at four heights at Medicine Bow in summer (a) and winter (b).

cannot be simulated by the analytic Weibull distributions. Therefore, wind power values computed from the Weibull function parameters may be in substantial error and generally result in an underestimation of the actual power in these locations.

7. Wind direction and flow patterns

Hourly averages of wind direction were recorded and used to compute direction-frequency distributions at each site. Seasonal distributions which are typical of most locations in the wind corridor are shown in Fig. 9 for the Medicine Bow-SW site. Speed threshold contours at 5 m s^{-1} intervals are indicated on the figure. The most common direction (the primary mode) is from the west-southwest for all seasons and speed levels, except in summer when it shifts slightly to become due westerly. The secondary peak of winds from the east is usually produced when low pressure systems are located in the vicinity of eastern Colorado. The east winds are seldom strong, but often bring upslope precipitation to much of southeastern Wyoming in winter and spring.

The wind direction-distributions exhibit a seasonal trend from a broader, more uniform spectrum in summer to a very narrow spectrum in winter. For example, the wind is from between southwest and northwest 52% of the time in summer compared to 77% of the time in winter at Medicine Bow-SW. Narrowness of the winter spectrum is caused by channeling of air through the wind corridor. Year-to-year variations of the distributions are slight. Distributions are broader for stations outside the wind corridor boundaries.

Generalized airflow patterns have been constructed from a synthesis of the primary and secondary peaks of the wind direction distributions of all available measurement stations. Such an analysis is shown in Fig. 10 for winter months; the upper map presents the primary flow regime and the lower map shows

the less common secondary regime. The primary and secondary modes from the wind direction distributions are plotted at each station location on the respective maps. Streamlines have been superimposed on the figures by following the station wind direction indicator marks. The analysis implicitly assumes the primary (or secondary) directions occur simultaneously at all stations. Aircraft case studies support this assumption (Dawson and Marwitz, 1978).

The upper map displays the most common flow pattern in southern Wyoming. Several features are notable. Confluence near Medicine Bow is indicated by confluence of the streamlines there. Downwind of Medicine Bow the flow diverges as it approaches the Laramie Mountains and fans out on the High Plains. A portion of the main airflow from the wind corridor diverts northeastward toward Casper (CPR) through gaps between mountain ranges along the northern boundary of the corridor. Basic features of the primary winter pattern are substantiated by other research including aircraft and aeolian geomorphology studies and numerical simulations summarized by Martner and Marwitz (1981). The secondary flow regime which occurs approximately 10–15% of the time is illustrated in the lower map in Fig. 10. It represents the general upslope storm situation for the region.

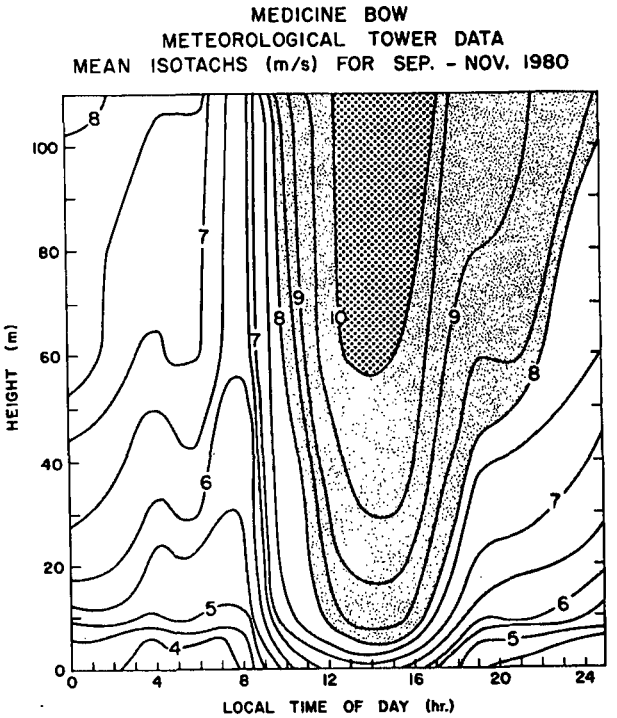

FIG. 12. Wind speed as a function of height and time of day at Medicine Bow in autumn. Isotachs are drawn at 0.5 m s^{-1} contours. Values of 8 m s^{-1} or greater are shaded.

8. Vertical profiles

A tall meteorological tower was operated at site MT by Western Scientific Services, Inc., under contract with the Bureau of Reclamation. Wind measurements were made at 10.0, 61.0 and 106.7 m AGL and temperature was recorded at the top and bottom levels. The data were digitized in blocks of 1 h averages. An adjacent UW anemometer (site AA) mounted at 4 m AGL provided a fourth measurement level. Data from the tower have been used by the Bureau of Reclamation to compute the available wind power at the turbine hub heights and by UW to investigate characteristics of the vertical profile of wind speeds.

Diurnal variations of wind speed at four heights are illustrated in Fig. 11a for the summer season and in Fig. 11b for winter. The speeds increase monotonically with height and are greatest in winter at all levels and hours. The diurnal trends at all levels are essentially the same as those discussed in Section 4 for the surface observations.

It is expected that above some height the diurnal trend must reverse (to minimum speeds at midday) as faster flow aloft is diluted by mixing with lower momentum air from the surface. Crawford and Hudson (1970) show the height of this reversal occurs between 45 and 90 m AGL in Oklahoma City. The Medicine Bow tower data do not show the reversal at any height. Thus the level at which wind speed minimizes at midday must be above 107 m, the top of the tower. In winter the diurnal variations at the upper levels of the tower are weak. This may represent a transition between lower and upper airflow regimes in this season when the planetary boundary layer is shallower than in summer.

The diurnal trend for autumn is portrayed in an alternate format in Fig. 12. Downward transport of momentum from aloft by buoyant mixing is dramatically illustrated by the isotachs which dip sharply toward the surface in the daylight hours.

Several mathematical representations of the variation of wind speed with height have been proposed. Reviews of the topic are given by Sellers (1965) and Justus (1978). One representation of climatological wind profiles which has been used extensively by virtue of its simplicity and versatility is the power law equation

$$V_2/V_1 = (Z_2/Z_1)^\alpha, \qquad (1)$$

where V_2 and V_1 are the wind speeds at heights Z_2 and Z_1, respectively. The value of the dimensionless exponent α depends on the height interval, atmospheric stability and the surface roughness of each site.

Eq. (1) was inverted and applied to the Medicine Bow tower data to examine some of the features which affect the value of α. The exponent was found to have a weak inverse correlation with surface wind speed and a strong correlation with temperature lapse

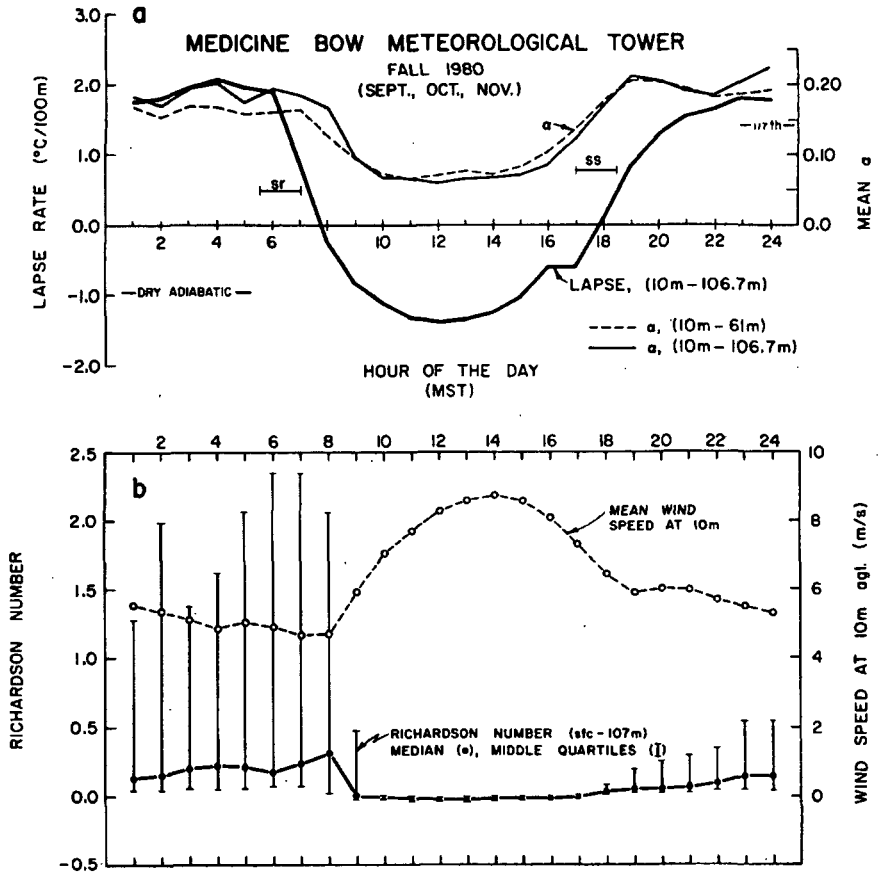

FIG. 13. Temperature lapse rate and power law exponent (α) diurnal patterns at Medicine Bow in autumn are shown in (a). The times of sunrise (sr) and sunset (ss) are indicated. In (b) the median and middle quartiles of hourly Richardson number are shown with the mean wind speed at 10 m.

rate. Fig. 13a illustrates the latter correlation in the diurnal cycles of α and lapse rate for the autumn season. Corresponding diagrams for other seasons are similar. Buoyant mixing creates a more uniform profile (hence, smaller α value) during the day than at night when temperature inversions persist and momentum transport between layers may be decoupled. Thus, the trend of α keeps in step with the lapse rate trend. The amplitude of the cycle is greatest for both parameters in summer and smallest in winter. In Fig. 13b the diurnal trend of stability is further represented by the hourly values of the Richardson number (computed by the method of Heald and Mahrt, 1981).

Extrapolation of wind power values from one height to another using the power law has been investigated by Justus and Mikhail (1976), Doran and Verholek (1978), Sedefain (1980) and others. Peterson and Hennessey (1978) conclude that the commonly used value of $\alpha = 0.14$ (the $1/7$ power law) usually yields conservative yet reasonable wind power estimates where the surface roughness length is relatively small. Touma (1977) and Sisterson and Frenzen (1978), however, emphasize the errors which can accrue in some situations, especially at night, if the $1/7$ value is used.

The Medicine Bow measurements in Fig. 13a show that the value of α dips significantly below the $1/7$ level during the day and rises above it by approximately the same amount at night. Thus, using $\alpha = 0.14$ in (1) results in overestimates of the wind speed aloft during the day and underestimates at night. However, because wind speeds are generally greater in the day, the daytime overestimates of wind power (proportional to the cube of speed) aloft generally exceed the nighttime underestimates, if a constant value of $\alpha = 0.14$ is used.

9. Conclusions

Characteristics of the wind in southern Wyoming have been examined as part of a project to produce large amounts of electricity from wind turbines at Medicine Bow, Wyoming. Several years of hourly surface wind data from a network of anemometers and data from three levels on a 107 m tower have been analyzed.

High winter wind speeds in the region are frequently produced by topographically forced chan-

neling of stable airflow which drains under the influence of a strong pressure gradient force across a low region of the Continental Divide. The flow exhibits marked confluence as it approaches Medicine Bow and diffluence downstream of there. Average winds in the winter season are ~50% greater than in summer; wind power density is at least a factor of 4.0 greater in winter than in summer.

One can infer from the climatological averages that buoyant mixing is the primary modulator of the diurnal cycle of wind speed which is characterized by a minimum near sunrise and an afternoon maximum. The amplitude of the diurnal cycle is greatest in summer and smallest in winter. The same diurnal trend persists at levels up to at least 107 m above the ground. Wind speed-frequency distributions are much broader in winter and directions are more narrowly confined from the west in winter than in summer.

The vertical profile of wind speed is more uniform in the day than at night when speed increases sharply with height. At any given moment the value of the power law exponent α depends on a number of factors including surface roughness and wind speed. However, the diurnal trend of α is on a climatological basis primarily a function of atmospheric stability.

Acknowledgments. The wind characteristics studies were funded by the Department of Interior under Contract 9-07-70-S0104. Earlier parts of the work were funded by the Department of Energy and Pacific Northwest Laboratories. Some of the anemometers were provided by the Wyoming Highway Department. Extensive data processing assistance from Kraig Gilkey and Julia Gilmer is gratefully acknowledged.

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WIND SPEED SENSOR CALIBRATION REPORT

PART A: ANCILLARY INFORMATION

Project: AATA / UR ENERGY
Site ID: LOST CREEK MET
Location: NW of RAWLINS, WY

Date: 14 OCT 2009
Start Time: 1215 MST
End Time: 1230 MST

Technician: D. JOHNSON
Witness: D. ECCLESTON
C. KELSEY

- ***STATION WIND SPEED SENSOR IDENTIFICATION and APPLICATION***

Make: MET ONE
Model: 034B
SN: G2432

Range, mps: 0 to 75
Height, m: 10

Calibrated: UNK

- ***CALIBRATION EQUIPMENT IDENTIFICATION and DESCRIPTION***

Item: R.M.Young, 18811 (20 to 990 rpm), variable rpm motor — **SN:** CA02444-A
Item: R.M.Young, Model 18312, torque disk device — **SN:** NA

PART B: CALIBRATION TEST RESULTS

- ***KNOWN INPUT vs. OBSERVED STATION RESPONSE***

Starting Torque Threshold: 0.2 gm-cm, or 0.38 mps.

Known Inputs		Stn. Response	
Motor rpm	Known mps	Stn. mps	Error mps
0.0	0.00	0.00	0.00
150	4.27	4.27	0.00
300	8.27	8.27	0.00
700	18.92	19.00	0.08
850	22.92	23.00	0.08

- ***COMMENTS or OBSERVATIONS***

Anemometer drive motor was not able to spin the WS shaft more than 850 rpm.

Tower lowered at 1045 MST
Tower raised at 1530 MST

	As Found	As Left
Calibration results are ⇨	X	X

	YES	NO
Instrument adjustments needed? ⇨		X

- ***CALIBRATION LIMIT CRITERIA and PASS/FAIL RESULTS***

Test Category	To PASS, the observed response must be....	Pass/Fail
Accuracy	≤ ±(0.20 mps + 5% of known input) per test point	PASS
Starting torque threshold	≤ 0.5 mps.	PASS

WIND DIRECTION SENSOR CALIBRATION REPORT

PART A: ANCILLARY INFORMATION

Project: AATA / UR ENERGY
Site ID: LOST CREEK MET
Location: NW of RAWLINS, WY

Date: 14 OCT 2009
Start Time: 1115 MST
End Time: 1215 MST

Technician: D. JOHNSON
Witness: D. ECCLESTON
C. KELSEY

- ***STATION WIND DIRECTION SENSOR IDENTIFICATION and APPLICATION***

Make: MET ONE
Model: 034B
SN: G2432

Range: 0 to 360 deg.
Height, m: 10

Calibrated: UNK

- ***CALIBRATION EQUIPMENT IDENTIFICATION and DESCRIPTION***

Item: Ushikata, Model S-25, tranist compass — **SN:** 179887
Item: R.M.Young, Model 18331, vane torque measurement device — **SN:** NA

PART B: CALIBRATION TEST RESULTS

- ***KNOWN INPUT vs. OBSERVED STATION RESPONSE***

Starting Torque Threshold: 4.0 gm-cm, or 0.37 mps.
Local Magnetic Declination: 10.8 deg. east (from Geomag 10/09)

ACCURACY TEST		
Known Input Degrees	Stn. Response: Stn. Degrees	Stn. Response: Error Degrees
90	88	-2
270	268	-2
0	0	0
180	178	-2

LINEARITY TEST (Degree Change Test)					
Change Input Degrees	Stn. Response: Stn. Degrees	Stn. Response: Change* Error	Change Input Degrees	Stn. Response: Stn. Degrees	Stn. Response: Change* Error
10	13	NA	180	182	-1
30	33	0	210	212	0
60	63	0	240	243	1
90	92	-1	270	273	0
120	122	0	300	303	0
150	153	1	330	333	0

* Input change error in degrees.

- ***COMMENTS or OBSERVATIONS***

None

Calibration results are ⇨	X	X
	YES	**NO**
Instrument adjustments needed? ⇨		X

- ***CALIBRATION LIMIT CRITERIA and PASS/FAIL RESULTS***

Test Category	To PASS, the observed response must be....	Pass/Fail
Accuracy	≤ ±5 degrees error per direction input.	PASS
Linearity	≤ ±3 degrees change error per test point.	PASS
Starting torque threshold	≤ 0.5 mps.	PASS

TEMPERATURE / ΔTEMPERATURE CALIBRATION REPORT

PART A: ANCILLARY INFORMATION

Project: AATA / UR ENERGY
Site ID: LOST CREEK MET
Location: NW of RAWLINS, WY

Date: 14 OCT 2009
Start Time: 1330 MST
End Time: 1412 MST

Technician: D. JOHNSON
Witness: D. ECCLESTON
C. KELSEY

- ***STATION TEMP/ Δ TEMP PROBE IDENTIFICATION and APPLICATION***

Make: MET ONE
Model: 062 MP
SN: G2675 (1of 2)
SN: G2675 (2of 2)

Range: -50 to +50 C.
Probe Type: Thermister
Height, m: 2.0
Height, m: 10.0

Calibrated: UNK
Housing Type: Power aspirated (downward pointed inlet)

- ***CALIBRATION EQUIPMENT IDENTIFICATION and DESCRIPTION***

Item: Digital thermometer (0.01 deg C). YSI, Model 4600 — **SN:** 101290 (base)
Item: RTD probe. YSI series 400 — **SN:** 99B0447-403 (probe)
Item: Insulated water bath (3.75 liters) with mechanical stirring. — **SN:** NA

PART B: CALIBRATION TEST RESULTS

- ***KNOWN INPUT vs. OBSERVED STATION RESPONSE***

(Note: Water baths were mechanically stirred to assure uniform temperature within the insulated flask.)

Known Inputs		2-Meter Probe		10-Meter Probe		Δ T Response	
Water Bath	Input Deg. C	Stn. Deg. C	Error Deg. C	Stn. Deg. C	Error Deg. C	Stn. Deg. C	Error Deg. C
Ice	0.44	0.49	0.05	0.51	0.07	0.02	0.02
Cool	24.08	24.05	-0.03	24.05	-0.03	0.00	0.00
Hot	44.35	44.35	0.00	44.42	0.07	0.07	0.07
	Mean Absolute Error⇒		0.03		0.06		0.03

- ***COMMENTS or OBSERVATIONS***

None

Calibration results are ⇨	X	X
	YES	**NO**
Instrument adjustments needed? ⇨		X

- ***CALIBRATION LIMIT CRITERIA and PASS/FAIL RESULTS***

Test Category	To PASS, the observed response must be....	Pass/Fail
Accuracy (2-meter probe)	≤ ±0.50 degrees C error per test point.	PASS
Accuracy (10-meter probe)	≤ ±0.50 degrees C error per test point.	PASS
Accuracy (ΔT system)	≤ ±0.10 degrees C error per test point.	PASS

RELATIVE HUMIDITY SENSOR CALIBRATION REPORT

PART A: ANCILLARY INFORMATION

Project: AATA / UR ENERGY
Site ID: LOST CREEK MET
Location: NW of RAWLINS, WY

Date: 14 OCT 2009
Start Time: 1130 MST
End Time: 1235 MST

Technician: D. JOHNSON
Witness: D. ECCLESTON
C. KELSEY

- ***STATION RELATIVE HUMIDITY SENSOR IDENTIFICATION and APPLICATION***

Make: VAISALA
Model: HMP45 AC
SN: B4850033

Range: 0-100% RH
Probe Height, m: 2.0

Last Calibrated: UNK

- ***CALIBRATION EQUIPMENT IDENTIFICATION and DESCRIPTION***

Item: Digital RH meter. TESTO, Model 635 **SN:** 9769/803
Item: Dual probe RH chamber. **SN:** NA

PART B: CALIBRATION TEST RESULTS

- ***KNOWN INPUT vs. OBSERVED STATION RESPONSE***

Known Inputs		Stn. Response	
Test Environ.	Known %RH	Stn. %RH	Error %RH
Ambient	57.6	59.0	1.4
Chamber	91.9	87.3	-4.6

- ***COMMENTS or OBSERVATIONS***

None

Calibration results are ⇨	X	X
	YES	**NO**
Instrument adjustments needed? ⇨		X

- ***CALIBRATION LIMIT CRITERIA and PASS/FAIL RESULTS***

Test Category		To PASS, the observed response must be....	Pass/Fail
Accuracy (Ambient)		≤ ±7% RH error per test point. (> 5% error = WARN)	PASS
Accuracy (Chamber)		≤ ±7% RH error per test point. (> 5% error = WARN)	PASS

SOLAR RADIATION SENSOR CALIBRATION REPORT

PART A: ANCILLARY INFORMATION

Project: AATA / UR ENERGY
Site ID: LOST CREEK MET
Location: NW of RAWLINS, WY

Date: 14 OCT 2009
Start Time: 1122 MST
End Time: 1427 MST

Technician: D. JOHNSON
Witness: D. ECCLESTON
C. KELSEY

- ***STATION SOLAR RADIATION SENSOR IDENTIFICATION and APPLICATION***

Make: LI-COR
Model: 200X
SN: PY6053

Range: 0 - 1400W/m^2
Sensor Height, m: 10.0
Last Calibrated: UNK

- ***CALIBRATION EQUIPMENT IDENTIFICATION and DESCRIPTION***

Item: Pyranometer transfer standard
Make: KIPP & ZONEN
Model: CM21
Certification Date: 7/9/09
SN: 020991

PART B: CALIBRATION TEST RESULTS

- ***KNOWN INPUT vs. OBSERVED STATION RESPONSE***

(Note: Test pyranometer is placed immediately next to station solar radiation sensor during the test period.)

Report Period hrmm	Input Value W/m^2	Station Response Stn. W/m^2	Error W/m^2	Error %
Covered	0	0	0	NA
1125	756	736	-20	-2.6
1130	747	726	-21	-2.8
1236	705	688	-17	-2.4
1350	154	148	-6	-3.9
1400	812	792	-20	-2.5
1415	148	142	-6	-4.1
1427	129	123	-6	-4.7
	Mean Absolute Errors ⇒		12.0	3.3

- ***COMMENTS or OBSERVATIONS***

Test day was mostly cloudy with occasional brief periods of sunshine.

SR sensor passed but is near ±5% calibration acceptance limit at low sunlight vlaues.
Plan to make adjustment on sensor gain (multiplier in data logger).

Calibration results are ⇨	X	X

	YES	NO
Instrument adjustments needed? ⇨	X	

- ***CALIBRATION LIMIT CRITERIA and PASS/FAIL RESULTS***

Test Category		To PASS, the observed response must be....	Pass/Fail
Accuracy		≤ ±5% error per test point.	PASS

PRECIPITATION GAUGE CALIBRATION REPORT

PART A: ANCILLARY INFORMATION

Project: AATA / UR ENERGY
Site ID: LOST CREEK MET
Location: NW of RAWLINS, WY

Date: 14 OCT 2009
Start Time: 1402 MST
End Time: 1430 MST

Technician: D. JOHNSON
Witness: D. ECCLESTON
C. KELSEY

- ***STATION TIPPING BUCKET RAIN GAUGE IDENTIFICATION and APPLICATION***

Make: TEXAS ELECTRONICS **Range:** NA **Last Calibrated:** UNK
Model: TE252WS **Gauge Height, m:** 1.0
SN: 41936-307

- ***CALIBRATION EQUIPMENT IDENTIFICATION and DESCRIPTION***

Item: Distilled water, graduated cylinders, drip device **SN:** NA

PART B: TEST RESULTS

- ***KNOWN INPUT vs. OBSERVED STATION RESPONSE***

(Note: Distilled water was dripped into the gauge at a constant rate equal to ~0.5 inch per hour)

	Known Inputs			Station Response				
	ml	tip	inch	Stn. tip	Stn. inch	Error tip	Error inch	Error %
Manual Tips ⇒	0.0	5	0.05	5	0.05	0	0.00	NA
Distilled H_2O Tips ⇒	250	30	0.30	30	0.30	0	0.00	0.0

- ***COMMENTS or OBSERVATIONS***

None

Calibration results are ⇨	X	X
	YES	**NO**
Instrument adjustments needed? ⇨		X

- ***CALIBRATION LIMIT CRITERIA and PASS/FAIL RESULTS***

Test Category		To PASS, the observed response must be....	Primary
Accuracy		≤ ±10% error	PASS