EXHIBIT F

State of Utah
DEPARTMENT OF ENVIRONMENTAL QUALITY
DIVISION OF RADIATION CONTROL

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MEMORANDUM

TO: Dane Finerfrock *DF*

FROM: Loren Morton *Loren B. Morton*

DATE: June 27, 2000

SUBJECT: International Uranium Corporation White Mesa Uranium Tailings Facility: Engineering Design and As-Built Reports; **Staff Findings, Conclusions, and Recommendations**.

Executive Summary

Review of engineering design plans, specifications and as-built reports provided by IUC have lead DRC staff to conclude that:

1. It is unlikely that any leak detection system exists under IUC wastewater disposal Cell 1. Therefore, point of compliance groundwater monitoring wells will be required around Cell 1 in the Permit.

2. Leak detection systems found under IUC Cells 2 and 3 are grossly inadequate. Based on available system design, geometry, and underlying bedrock permeability, DRC staff estimate that flexible membrane liner (FML) leakage would remain undetected by the current system until leakage flows reach a rate of between 2,500 and 840,000 gal/acre/day, with an average of about 200,000 gal/acre/day. This lack of leak detection sensitivity fails to meet Utah Division of Water Quality (DWQ) performance standards for existing facilities (200 gal/acre/day). As a result, the existing design fails to comply with the DWQ Discharge Minimization Technology (DMT) requirements found in the GWQP Rules.

3. Multiple lines of evidence also suggest that the 30-mil PVC membrane used as FML in Cells 1, 2, and 3 is prone to excess leakage due to a number of factors, including: 1) suspect preparation of FML bedding and protective blanket layers, 2) lower PVC puncture strength, 3) higher PVC water vapor transmission, 4) long-term degradation of PVC membranes due to leaching of plasticizer compounds and organic chemical attack, and 5) suspect PVC seam preparation and construction methods.

4. As a result of leak detection system design shortcomings and suspect physical condition and integrity of the PVC FML in Cells 1, 2 and 3, a demonstration of adequate DMT will largely focus on performance of the final cover system, and to a lesser degree on operational improvements. Operational improvements, include, but are not limited to: 1) additional

groundwater characterization and installation of new monitoring wells for each individual disposal cell, 2) additional water quality monitoring parameters, 3) accelerated closure for Cell 2, and 4) head minimization efforts for Cells 2 and 3. Improvements to the final cover include: decreased radon barrier permeability, addition of a high permeability filter zone and a FML/clay composite layer in the cover design, and shorter drainage path lengths.

5. Although the leak detection system design under Cell 4A represents an improvement over previous disposal cells at the facility, its leak detection shortcomings, and current state of neglect and disrepair mandate that this cell be retrofit to meet current Best Available Technology (BAT) standards before any use for tailings or wastewater disposal activities.

6. Lack of separate and independent construction supervision and construction quality control/quality assurance (CQA/QC) may have contributed to an increased rate of construction defects in IUC Tailings Cells 1, 2, 3, and 4. Revisions need to be made to any future IUC CQA/QC efforts and plans to ensure modern construction techniques and provide confidence in the engineering containment of new wastewater and tailings disposal cell construction.

7. An engineering survey error of approximately 900 feet has been discovered at tailings Cell 2, which must be resolved. Resolution of this error can be combined with surveys needed to correct other errors for the groundwater compliance monitoring wells.

8. An unlined sedimentation pond formerly drained the IUC mill site and ore storage pad area and has been used for on-site disposal of fly-ash. This Fly-Ash Pond is a potential source of groundwater pollution that needs to be investigated. Historical and ongoing operation of this Fly-Ash Pond constitutes a potential groundwater contamination source at the IUC facility. Appropriate measures to control groundwater pollution at this facility include, but are not limited to: 1) installation of an engineered cover system followed by point-of-compliance monitoring wells, or 2) removal of the fly-ash material and other contaminants and appropriated disposal at another approved and engineered facility.

9. Compliance with the GWQP Rules for issuance of a Permit to an existing facility at IUC can be achieved as described above. However, if groundwater contamination is discovered near Cells 1, 2, or 3 during additional site characterization or installation of new groundwater monitoring wells, the Executive Secretary will not be able to affirm the lack of impairment of present and beneficial use without additional groundwater remediation measures.

<u>Introduction</u>

The purpose of this memorandum is to summarize DRC staff review and findings regarding five (5) reports provided by the International Uranium Corporation (IUC) regarding engineering design and construction of wastewater and tailings disposal cells at the White Mesa facility near Blanding, Utah. The five engineering reports reviewed by DRC staff are summarized in Table 1, below:

Table 1. Summary of IUC Engineering Design and As-Built Reports

Report Reference	General Description
June, 1979 D'Appolonia Consulting Engineers (DCE)	Cells 1 and 2 (1st Phase) engineering design report
May, 1981 DCE	Cell 3 (2nd Phase) engineering design report
February, 1982 DCE	Cells 1 and 2 (1st Phase) construction "as-built" report
March, 1983 Energy Fuels Nuclear Inc. (EFN)	Cell 3 (2nd Phase) construction "as-built" report
April 10, 1989 Umetco Minerals Corporation (Umetco)	Cells 4A and 4B engineering design report, amended. Includes: 1) responses to NRC questions dated March 15, 1989, and 2) original August, 1998 Umetco report
August, 1988 Umetco	Original Umetco Cells 4A and 4B engineering design report
September, 1996 Titan Environmental	Tailings cover design, Cells 1 thru 4A

Review of these materials shows that engineering plans and construction "as-built" reports were provided by IUC for tailings Cells 1, 2, and 3. Unfortunately, no construction "as-built" report was provided for construction of Cell 4.

After review of the available engineering design plans, specifications, and construction "as-built reports, DRC staff have made the following findings for each of the IUC tailings cells:

General Findings

1. Lack of Construction Documentation: Cell 1 - detailed review shows little information is available for the construction of tailings wastewater Cell 1. The February, 1982 DCE Report states that EFN performed construction on both Cells 1 and 2, while DCE provided construction supervision services for only Cell 2 (ibid., p. 3-1). Further the report goes on to state that the Cell 1 construction information provided in the report was furnished by EFN and not independently collected by DCE (ibid.).

   Unfortunately, Cell 1 construction information provided in the February, 1982 DCE report is limited to: final EFN Cell 1 excavation elevation contours (Figure 12), PVC liner test results (Appendix D), and 2 centerline profile cross-sections for the Cell 1 south and east dikes (Figure 2). No information is provided regarding several important construction elements such as: topsoil removal, soil and rock excavation methods, preparation of flexible membrane liner (FML) bedding materials, installation of leak detection or under drain systems, installation of the FML, or installation of a FML cover or protective blanket layer.

Based on the information available regarding construction of tailings wastewater Cell 1, DRC staff conclude that:

A. If Cell 1 was constructed as per its design, it appears the cell is underlain by a single FML.

B. Without additional information regarding Cell 1 design and construction, DRC staff conclude that:

1) No leak detection system (LDS) exists beneath Cell 1, and
2) Foundation materials found below the FML are likely to be of high permeability, either in the form of mechanically disturbed sandstone or crushed sandstone rubble.

2. Missing Cell 4 As-Built Report - no engineering "as-built" report was provided for the construction of Cell 4. As a result, DRC staff are currently unable to confirm if actual construction conformed to the April 10, 1989 Umetco design. However, this is not an urgent concern, in that IUC has agreed to refrain from using this disposal cell until it is retrofit to meet State requirements. However, in order to review the adequacy of any future IUC retrofit for Cell 4, it will be essential to have a thorough description of the existing construction for this cell.

3. Lack of Independent Construction Quality Assurance/Quality Control - of IUC Cells 1, 2, and 3, only Cell 2 had construction quality assurance/quality control (CQA/QC) performed by an independent party, and then only for earthwork construction (2/82 DEC Report, p.3-1). For Cells 1 and 3, IUC (EFN) personnel performed both earthwork construction and earthwork CQA/QC (Cell 1: ibid.; Cell 3: 3/83 EFN Report, p. 3-1). In a similar manner, FML installation and FML CQA/QC functions were also performed by the same party, i.e., the FML manufacturer for Cells 1 and 2 (2/82 DCE Report, p. 3-5, and Cell 3 (3/83 EFN Report, p. 3-2).

This lack of independent oversight for earthwork construction and FML installation increases the potential for construction flaws or shortcomings to have been overlooked or gone uncorrected. As a result, defects in the FML at Cells 1, 2, and 3 may exist which could cause a release of pollutants to the underlying groundwater and nearby environment.

General Design Findings: Disposal Cells

1. Mechanical Disturbance and Increased Foundation Permeability - the bedrock formation found immediately below the tailings cells is the Dakota Sandstone. IUC field measurements indicate that the permeability of this bedrock formation ranges between 2.8 and 944 ft/yr (2.71E-6 to 9.12E-4 cm/sec), with an average 237 ft/yr (2.29E-4 cm/sec), see Attachment 1, below [DRC spreadsheet HydCond.XLS, tabsheet alldata, geologic formation Kds].

However, foundation preparation techniques used to prepare the final cell floor grade for Cells 2, and 3 included common soil excavation techniques, followed by mechanical ripping of the Dakota Sandstone bedrock for Cell 2 (2/82 DCE Report, p. 3-2), and Cell 3 [3/83 EFN Report, p. 3-3]). It is also presumed that similar means were used to excavate the cell floor for tailings wastewater Cell 1. In some cases blasting was also used to remove excess bedrock materials, e.g. Cell 3, see March, 1983 EFN Report, page 3-3. In both cases, such disturbance will increase the permeability of the bedrock foundation located below the FML. As a result, the Dakota Sandstone permeabilities quoted by IUC must be considered minimum values for the purpose of estimating leak detection efficiency or leachate infiltration.

2. Inadequate Leak Detection System: Cells 1, 2, and 3 - review of the IUC engineering design and as-built reports referenced above has lead DRC staff to the conclude that fluid under drain systems are inadequate as leak detection systems (LDS) at Cells 1, 2, and 3. This conclusion is based on the following facts and observations:

   A. Lack of Engineering Design or Documentation at Cell 1 - none of the engineering design and as-built reports provided by IUC documents any type of permeable fluid collection layer located beneath the FML in tailings Cell 1 (5/79 DCE Report, Sheets 1 thru 16, and 2/82 DCE Report, Figures 1, 2, and 11). Consequently, DRC staff have conclude that no LDS exists at Cell 1.

   B. Poor Cell 2 and 3 LDS Design: Single Drain Pipe - no permeable fluid under drain layer is documented in the Cell 2 engineering design report (5/79 DCE Report, Sheets 1 thru 16). However, brief description is provided in the text of the February, 1982 DCE As-Built Report of an "under drain" system constructed across the interior slope of the Cell 2 south dike (2/82 DCE Report, pp. 3-3 and 4). The most complete engineering design details for the "under drain" system are found in the Cell 3 design report, which states that this "under drain" system is similar to that designed by IUC for Cell 2 and approved by NRC (5/81 DCE Report, p. 3-6). As a result, DRC staff conclude that an "under drain" system likely exists under the FML at both Cells 2 and 3.

   Engineering details for this "under drain" system show it is limited to a narrow layer of gravelly sand installed on the inside slope of the southern dike (5/81 DCE Report, Sheets 3 and 4). Said sand "under drain" layer is 1-foot thick and was constructed with a perforated 3-inch diameter, perforated, PVC pipe at the inside toe of the south dike; hereafter, referred to as the "toe" drain (ibid.). This 3-inch "toe" drain apparently gravity drains to a central collection point where it is connected to a 1 foot diameter PVC riser pipe that extends up the interior slope under the FML. This riser pipe access enables water to be removed from the "toe" drain and sand "under drain" layer by means of a pump.

It is clear from the engineering design drawings that the "under drain" system is confined to only the inside slope of the south dike, and does not extend under any portion of the floor of either Cell 2 or 3. Furthermore, use of a single drain pipe in the LDS limits the detection of leaks to only those that may : 1) occur immediately over the "toe" drain pipe, or 2) flow at a leakage rate great enough to travel a significant horizontal distance to the "toe" drain. Such a design contributes to poor leak detection reporting time and efficiency, see discussions below.

C. Lack of Permeability Contrast Below FML to Collect and Divert Fluids For Detection: Cells 2 and 3 - no permeability information has been provided by IUC for soil materials constructed below the FML in Cells 2 or 3. However, available IUC soil gradation data allowed DRC staff to estimate the hydraulic conductivity of these materials, see Table 2, below. The average Dakota Sandstone bedrock permeability is also provided below for comparison purposes. Review of this information shows that the "under drain" sand layer constructed along the inside slope of the southern dikes has a lower permeability than the FML bedding layer. Consequently, it is unlikely that FML leakage will be encouraged to flow into this layer unless high head conditions force it horizontally in that direction.

Table 2. Estimated Hydraulic Conductivity of Materials Below FML; IUC Cells 2 and 3

Layer	Permeability [(1)]		Layer	Permeability [(1)]	
	ft/day	cm/sec		ft/day	cm/sec
Cell Floor			*Cell Inside Sideslope (South Dike)*		
FML Bedding	40	1.41E-2	"Under drain" Blanket	20	7.06E-3
Dakota Sandstone	> 0.65	> 2.29E-4			

Footnote:

1. Permeability determined from IUC soil gradation data, as follows:
   - A. FML Bedding Layer - from IUC grain size analysis chart in 2/82 DCE As-Built Report, Figure 13; as determined from a U.S. Department of Transportation filter material permeability nomograph (Moulton, p.51). For details, see Attachment 3, below.
   - B. Dakota Sandstone - average permeability from IUC test data, see Attachment 1, below [DRC spreadsheet HydCond.XLS, tabsheet alldata, geologic formation Kds], where 237 ft/yr = 0.65 ft/day. This value is considered minimum permeability of the Dakota Sandstone bedrock due to mechanical fracturing and disturbance, see DRC discussion above.
   - C. Under drain Blanket - from IUC design specifications provided in the 6/79 DCE Design Report, Appendix B, p. 4-2. No as-built soil gradation data were provided in ; as determined from a U.S. Department of Transportation filter material permeability nomograph (Moulton, p.51). For details, see Attachment 3, below.

D. Long Reporting Time Estimates: Cells 2 and 3 - it is important to consider LDS geometry in the soil layers immediately below the FML, in order to evaluate leak detection reporting time. At IUC Cell 3, FML leakage will first permeate the FML Bedding Layer, and if sufficient flow and head are available, may accumulate on the underlying bedrock. At this point, the time it takes a leak to report to the "toe" drain for detection is a function of: 1) the permeability of these two materials, 2) FML leakage flow rate and head, and 3) length and slope of the travel path the leak may take across the surface of the underlying bedrock material.

To determine leak path length review of must be given to bedrock elevations and slope beneath the FML and "toe" drain location. Unfortunately, IUC has failed to document the total length or horizontal extent of the "toe" drain at Cell 3 (see 5/81 DEC Design Report, Sheets 2 and 3). However, three IUC construction photographs suggests that the "toe" drain may extend across the entire length of the Cell 3 south dike (see 3/83 EFN As-Built Report, Appendix E, 2 photographs entitled "Cell 3 under drain installation", and one entitled "Cell 3 under drain installation and bottom preparation"). This location is less than ideal, in that FML leakage will have to travel across a long expanse of bedrock before reaching the "toe" drain. As explained below, seepage losses across this long travel path will result in undetected leakage from the facility.

Shape and grade of the underlying bedrock formation under Cell 3 suggest that leakage from the eastern portion of Cell 3 will take a long western path followed by a shorter southern path to the "toe" drain; for a total distance of about 1,700 feet from the northeast corner of the cell floor (see 5/81 DCE Design Report, Sheet 2). A leak from the northwest cell floor corner would travel a path with nearly equal eastern and southern legs for a total distance of about 1,100 feet to reach the "toe" drain (ibid.).

One simple method of estimating leak detection reporting time would be to assume: 1) that the FML Bedding Layer is saturated, 2) that fluids in this layer travel at the same rate as the layer's permeability, estimated at 40 ft/day, 3) ignore driving head and gradient for the leak, and 4) ignore seepage losses to the underlying bedrock layer as a result of horizontal travel to the "toe" drain. Using these very simple assumptions, leakage would take about 43 and 28 days to report from the eastern and western leak paths mentioned above, respectively.

Unfortunately, these can only be considered rough minimum estimates, in that for the FML Bedding Layer to become and be maintained saturated, a large and continuous rate of leakage flow would be required thru the FML. Actual or more realistic estimates of leak reporting time may be orders of magnitude greater than 43 days. In any case, even the smallest simple assumption of 28 days is well beyond the EPA RCRA leak detection reporting time performance standard of 1 day (EPA, p. 8).

E. <u>Poor Leak Detection Efficiency</u> - in order for leakage to find its way to the "toe" drain under Cell 3, the leakage flow rates thru the FML have to be greater than the seepage losses into the underlying bedrock. Only then can horizontal flow in the FML Bedding Layer be achieved. FML leakage rates below this value will not report to the "toe" drain, and will hence go undetected.

The lowest FML leakage rate needed for detection can be estimated from the permeability of the underlying Dakota Sandstone bedrock formation. IUC measurements of Dakota Sandstone permeability are listed in Attachment 1, and summarized in Table 3, below:

Table 3. Summary of IUC Dakota Sandstone Permeability

In-situ Borehole Tests	Bedrock Permeability	
	ft/yr [1]	gal/acre/day
Maximum:	944	842,173
Minimum:	2.8	2,498
Average:	237	211,442

Footnote:
1) From DRC spreadsheet HydCond.XLS, tabsheet alldata (see Attachment 1, below).

In this case it is conservative to consider average permeability values in that IUC mechanically disturbed the Dakota Sandstone bedrock by ripping and blasting the foundations of Cells 2 and 3 (see discussion above). Based on the average bedrock permeability, it appears that the FML leakage rate would need to reach about 200,000 gal/acre/day before fluids would appear in the "toe" drain for detection. Even under the lowest Dakota Sandstone permeability, the FML leakage rate would need to be greater than 2,498 gal/acre/day in order for the "toe" drain to detect leakage. Both scenarios are dramatically greater than the EPA RCRA performance standard for leak detection efficiency (or sensitivity) of 1 gal/acre/day (EPA, p. 8).

In conclusion, no as-built documentation for the Cell 1 LDS has been made available, consequently, DRC staff can only conclude that no LDS exists at Cell 1. For Cells 2 and 3, the LDS systems are inadequate, because: 1) use of a single LDS pipe limits the ability of system to detect leaks unless they occur immediately over the pipe, or at high enough leakage rate to travel horizontally to the pipe, 2) diversion of leakage in a horizontal direction towards the "toe" drain is unlikely due to a lack of permeability contrast below the FML Bedding Layer, 3) long travel paths under the FML to the LDS drainage pipe greatly increase the time needed to detect a leak, on the order of at least 28 days or more, and 4) based on these considerations, leakage thru the FML would likely be detected under Cells 2 or 3, only if the FML leakage rate exceeded about 200,000 gal/acre/day.

3. <u>Inadequate Leak Detection System Design: Cell 4A</u> - some improvement was made in the design of the Cell 4A LDS, in that a network of pipes was devised under a larger portion of the cell's floor. This piping system was designed to gravity drain to the Southwest corner of Cell 4A, where a 12 inch access pipe would allow a pump to remove any collected leakage fluid (8/88 Umetco Report, Sheet C4-4). However, detailed review also shows the Cell 4A LDS is also inadequate for the following reasons:

A. Lack of Permeability Contrast to Divert Leachate to Collection Pipes - similar to Cells 1, 2, and 3, there is a lack of permeability contrast to direct or divert FML leakage to the LDS collection pipe network, based on:

1) High Permeability FML Bedding Layer - the FML bedding layer was designed to have a gradation of 70% sand and gravel and 30% fines passing the No. 200 sieve (8/88 Umetco Report, Attachment I, p. 7). IUC claimed this bedding layer was "clayey", suggesting a lower permeability material that could possible force FML leakage horizontally towards the LDS collection pipe network (at the top of the FML bedding layer). However, based on a 70% sand and gravel content, it is likely that this material has a high permeability. Furthermore, close review of the August, 1988 Umetco construction specifications shows that no permeability testing was required to document this material's hydraulic conductivity (ibid., Attachment I). Nor was there any maximum permeability specification defined for this material. Consequently, DRC staff conclude that the permeability of this FML bedding material is likely high.

2) High Permeability Bedrock - the August, 1988 Umetco Report outlines that certain bedrock areas found to be soft will be over-excavated and replaced with ML or CL-type soils (ibid., p. 8). However, this "spot" replacement does not provide a uniform layer of clay material across the final surface of the Cell 4A floor excavation. Further, the August, 1988 Umetco design report also failed to stipulate permeability testing of the foundation materials to confirm hydraulic conductivity before placement of the FML bedding layer. It is also clear that IUC's practice was to mechanically rip and blast bedrock in order to achieve final grade (8/88 Umetco Report, Attachment I, p. 3).

Based on these considerations, it appears that much, if not all, of the bedrock surface under Cell 4A was composed of permeable materials. Consequently, DRC staff also concluded that it is unlikely that a low permeability barrier exists at the base of the FML bedding layer to collect leakage and convey it towards the LDS pipe network.

B. Isolation of LDS Pipes by Secondary FML - the LDS design outlined in the August, 1988 Umetco Report calls for the LDS pipes to be installed in a FML lined trench, the base of which was to be located immediately over the bedrock foundation (ibid., Sheet C4-3). This secondary FML would extend away from the LDS trench a short distance, about 1 foot to either side. Also, the LDS collection pipe was to be installed over a thin granular bedding and under a subsequent backfill of granular material in the trench.

As a result of this geometry, any leakage from the uppermost or primary FML at a distant lateral location, that became perched on the bedrock material, would have to pass thru the secondary FML in order to be collected and removed via the LDS pipe network. Consequently, DRC staff concluded that the ability of the LDS design was limited to detection of leaks in the primary FML at locations that immediately overlie the LDS collection pipe and secondary FML.

C. Poor Leak Detection Efficiency - based on the above arguments, DRC staff concluded that the ability of the Cell 4A LDS to detect leaks is limited to the area immediately above the collection pipes and secondary FML, i.e., LDS area of influence. Taking this as a guide, an estimate of the LDS area of influence was calculated and compared with the total Cell 4A floor area, see Attachment 5, below. Based on these estimates, DRC staff concluded that the Cell 4A LDS design would only allow detection of leaks across about 1.6% of the total floor area.

D. Lack of CQA/QC Testing for Secondary FML - the August, 1988 Umetco Design Report outlines the use of vacuum box testing of FML seams for the primary liner in Cell 4A (ibid., Attachment II, Procedure QC-19-C4WM, p. 2). Unfortunately, this same specification excludes any such testing for the secondary FML in the LDS collection trenches (ibid.). As a result, less testing was performed on the secondary FML. Consequently, higher potential exists for flaws or defects to have gone undetected in the secondary FML, and more leakage to be released undetected from the Cell 4A LDS. Therefore, the leak detection efficiency of the Cell 4A LDS, estimated above, is further reduced.

In conclusion, DRC staff have also determined that the Cell 4A LDS is inadequate based on lack of permeability contrast to force leakage to the detection pipeage network, isolation of the LDS pipes by the limited secondary FML geometry, and poor detection efficiency caused by limited coverage and lesser scrutiny of secondary FML construction. Based on these findings, it appears that across about 98% of the Cell 4A footprint, the sensitivity of the LDS is as equally poor as Cells 2 and 3; ranging from about 2,500 to 840,000 gal/acre/day.

4. Primary Purpose of "Under drain" Layer: Dike Stability - it is clear from the above discussion that the effectiveness of the Cell 2 and 3 leak detection systems is poor. Consequently, it is apparent that these design elements had a different engineering function. Review of the May, 1981 DCE Report suggests that the primary purpose of these design elements was to minimize and control soil pore pressures in the south dike of each tailings cell in order to maximize dike stability (ibid., p. 4-2).

5. Appropriate Points-of-Compliance: Cells 1, 2, 3, and 4 - based on the above findings and evaluations, DRC staff conclude that: 1) no LDS exists under Cell 1, and 2) the existing "toe" drain and "under drain" systems at Cells 2 and 3 are not adequate for purposes of leak detection monitoring. Since these three disposal cells have been in service for an extended period of time, and are full or at near full capacity of tailings and/or wastewater; little can be done to retrofit the existing facilities. Consequently, the Groundwater Discharge Permit

(Permit) must require IUC to install additional groundwater monitoring wells to measure local groundwater quality. In order to provide early warning, minimize both the time needed to detect groundwater pollution and clean it up, IUC must design and install a new groundwater monitoring well network that includes monitoring wells around each and every tailings disposal cell currently in service; i.e., Cells 1, 2, and 3. In order to determine local groundwater flow directions, such wells must be installed both up and downgradient of each of these three tailings cells in question.

Previously, IUC staff have expressed concerns regarding possible difficulty to install new groundwater monitoring wells on the dikes between Cells 1 and 2, and 2 and 3. However, review of the IUC engineering design shows each of these dikes has a 20-foot crest width (6/79 DCE Report, p. 4-15). This is easily enough space for a truck-mounted drilling rig to drill and install the required monitoring wells. To avoid future traffic concerns, the new wells can be completed with a flush protective cover that will allow vehicular traffic to pass over the wellheads. Additional evidence that monitoring wells can be installed on the dikes between the cells is the fact that five (5) IUC monitoring wells have already been constructed on dikes at the facility, including: MW-5, MW-11, and MW-12 (Cell 3 South dike, 3/83 EFN Report, Figure 1), and MW-14 and MW-15 (Cell 4 South dike, 7/94 Titan Environmental Report, Figure 2.1).

6. <u>Unsatisfactory Plugging and Abandonment of Seven Wells Inside Cell 3 Footprint</u> - the May, 1981 DCE Design Report explains how six (6) dry wells installed inside the footprint of Cell 3 will need to be plugged and abandoned before disposal cell construction; well pairs 6-1, 6-2, 7-1, 7-2, 8-1, and 8-2 (ibid., p. 5-2, and Figure 2). This report also calls for each well to be plugged by pumping grout into the well with use of a tremie pipe to ensure an adequate seal and a lack of air voids in the grout (ibid.).

   In contrast, the Cell 3 As-Built Report cites seven (7) wells that were abandoned, including the six (6) mentioned above, and a stockwater supply well (3/83 EFN Report, p. 3-4). Unfortunately, this as-built report also discloses that no tremie pipe was used to plug these seven (7) wells. Instead the report explains how concrete was simply poured down each borehole and vibrated (ibid.). Such plugging and abandonment appears to be a violation of the Utah State Engineers Administrative Rules for Water Well Drillers, which requires initial placement of cement grouts at the bottom of the well with progressive upward placement, i.e., thru a tremie pipe [Utah Administrative Code (UAC) R655-4-12]. As a result, it appears that these wells have the potential to form vertical conduits for groundwater pollution from Cell 3.

   Although it is too late to rectify this mistake, it is all the more reason for individual groundwater quality monitoring to be done around each disposal cell, including Cell 3.

7. <u>Failure to Follow Specification for Dental Grouting of Bedrock Foundation Cracks</u> - the May, 1981 DCE Cell 3 Design Report called for "dental" grouting of cracks in the bedrock that were greater than 0.5 inch wide after cell excavation (ibid., Appendix B, p. 2-3).

However, the March, 1983 as-built report states that no "dental" grouting was undertaken, but instead that fractures in the bedrock were filled with washed sand (3/83 EFN Report, p. 3-5). This failure to follow the prescribed engineering specification reinforces DRC staff interpretation, above, of high bedrock permeability for the Dakota Sandstone.

8. Unknown Plugging and Abandonment of Monitoring Well MW-13: Cell 4A Implications - the March, 1983 EFN As-Built Report for Cell 3 documents the installation of a monitoring well MW-13, located South of Cell 3 (ibid., Figure 1 and Appendix D). Comparison with other IUC drawings suggests this well was located in an area that later became the southwest corner of tailings Cell 4A (8/88 Umetco Report, Figure 2.2-1). In fact, the July, 1994 Titan Environmental Report does confirm that MW-13 was destroyed during construction of Cell 4A (ibid., Table 2.3).

   Although the location of MW-13 is provided in the August, 1988 Umetco Report (Figure 2.2-1), no discussion is provided in the report if or how this well will be plugged and abandoned. No such mention is made in either the text of the Cell 4 Design Report or in the construction specifications regarding this matter (see 8/88 Umetco Report text and Attachment 1 [Plans and Specifications]).

   Consequently, it is not known if or how this well was plugged and abandoned prior to construction of Cell 4A. As a result, the potential exists that well MW-13 could form a vertical conduit for groundwater pollution. To resolve this potential problem, DRC staff recommend the Permit be conditioned to require submittal of a plugging and abandonment report for MW-13 for DRC approval. If this report is found unacceptable, then the Permit should require corrective actions for excavation of the former well site and renewed efforts to adequately plug and abandon this well.

9. Error in Engineering Survey Coordinates: Need for New Survey - a discrepancy in local engineering survey coordinates has been discovered by DRC staff after review of the available engineering plans and as-built reports. Review of the June, 1979 DCE Report shows that the western margin of Cell 2 is located near an Easting grid coordinate of E 2,576,000 feet (ibid., Sheet 4). In contrast, the August, 1988 Umetco Report shows this same edge of Cell 2 has different Easting coordinate of about E 2,576,880 feet; an error of about 880 feet (ibid., Sheet C4-1). It appears this discrepancy can be explained only by an error in design or in construction.

   Consequently, IUC should be required to resolve this error by implementation of a Permit condition, that would require submittal and approval of a new reliable elevation survey of the facility to confirm and document location and elevation of all major features of the facility, including, but not limited to: dikes, pond spillways, monitoring wells, borings, pipelines, sedimentation ponds, nearby drainages, ore storage pads, milling facility, soil stockpiles, etc. This in order to comply with the requirements of the Utah Water Quality Design Requirements for Wastewater Collection, Treatment, and Disposal Systems [UAC

R317-3-1.2(A)(1)], this survey must be completed and sealed by a State licensed engineer or land surveyor.

10. Missing or Illegible Design Documents - review of the March, 1983 EFN Cell 3 As-Built Report found several maps and figures missing or illegible. IUC should be required to provide legible copies of the missing or illegible figures, as follows: 1) illegible Figures 2 (floor final excavation contour map) and 4 (slimes drain pipeage system layout), and 2) missing Figure 5 (screen analysis of tailings used as protective blanket and slimes drain media).

Flexible Membrane Liner Findings

1. FML Bedding and Protective Blanket Concerns / Issues - IUC tailings Cells 1, 2, and 3 were lined with a PVC membrane. Review of available technical literature suggests that leakage may be expected from the PVC materials in question, due to several factors, as follows:

   A. Lack of Gradation Specifications for FML Bedding Materials: Fill Soils - review of two DCE engineering design reports shows that in areas where soil fill materials were to be added to achieve final grade, that no specifications were provided for the maximum bedding particle size for the subgrade below the FML for either Cells 1 and 2 (6/79 DCE Report, Appendix B, pp. 2-9 and 2-5) or Cell 3 (5/81 DCE Report, Appendix B, pp. 2-8 and 2-5). As a result, over-size particles have the potential to cause point stresses that can lead to FML failure after loading; particularly if bedding material particles are angular in shape.

   B. Angular Particles in FML Bedding Materials: Subgrade for Excavated Areas - construction specifications for Cells 1, 2, and 3 call for the Dakota Sandstone bedrock in certain areas to be excavated in order to achieve final design grade. In preparation of these areas, DCE construction specifications call for the following activities before FML installation (Cells 1 and 2: 6/79 DCE Report, Appendix B, pp. 2-5 and 2-10; Cell 3: 5/81 DCE Report, Appendix B, pp. 2-5, 2-6, and 2-9):

      1) Mechanical disturbance of Dakota Sandstone bedrock, including ripping and blasting.
      2) Crushing of subgrade materials with multiple passes of the treads of a crawler-type tractor for subgrade materials (where 20% of the particles exceed 5 inches in diameter).
      3) Specifications for subgrade preparation to ensure:
         a) a final surface free of any particle or rock over 6 inches in diameter.
         b) "smooth" final slope with no pieces or fragments protruding more than 4 inches from the plane of excavation.

   These very liberal IUC specifications allow a subgrade surface with multiple areas of large angular rock fragments that could have easily punctured the PVC liner.

However, as-built records suggest that bedding material particle size may have not been as large as once planned, in that one gradation test of the bedding material beneath Cell 2 indicates that the maximum particle size was less than 1.5 inches (2/82 DCE Report, Figure 13, D_{100} = 1.5 inch, D_{90} = 0.75 inch, etc.). Unfortunately, no other gradation test result have been provided by IUC for the bedding material under any of the other tailings disposal cells at the White Mesa facility.

It is important to note test pad research conducted at another Utah waste disposal landfill facility has shown that angular rocks of a size range of 0.25 to 1.0 inch in diameter, placed on subgrades in intimate contact with FMLs, have caused perforations in the overlying membrane liners under loads of 4,500 to 4,800 lb/ft^2 (personal communication, Blake Robertson, Utah Division of Solid and Hazardous Waste). DRC have estimated static loads on the FML at IUC Cells 2, thru 4, and found they appear to be less than 4,500 lb/ft^2, see Attachment 2, below. However, IUC has provided little information regarding specific types of equipment used to construct the tailings cells. As a result, it is possible that dynamic loads during construction of the IUC tailings cells could have been equivalent to the test pad research in question, and thereby generated equivalent FML damage.

C. <u>Particle Size, Angularity, and Placement Methods for Overlying Protective Blankets</u> - review of the IUC construction specifications shows that after installation of the FML, that a protective soil blanket was installed in Cells 2 and 3 (Cell 2: 6/79 DCE Report, Appendix B, p. 3-7 and 2/82 DCE Report, pp. 3-5 and 3-6; Cell 3: 3/83 EFN Report, p. 3-7 and 3-8). For Cell 2, engineering specifications for this material called for use of soils excavated from the cell, with a maximum diameter of 3 inches (ibid.). For Cell 3, specifications called for use of coarse sand tailings (5/81 DCE Report, Appendix B, pp. 3-7). However the as-built report documents otherwise and explains that excavated soils were also used for soil protective blanket over 70% of the Cell 3 liner (3/83 EFN Report, p. 3-7 and 3-8).

For both cells, the soil protective blankets were installed over the FML after construction of a temporary access ramp, with the use of trucks, front-end loaders, and small dozers (ibid.). However, no information was provided in any of the engineering design or the as-built reports to document the weight of the equipment used to place and spread the soil protective blanket. Nor were any calculations made to estimate any dynamic stress applied to the FML by this equipment. Consequently, the potential damage could have occurred to the Cell 2 FML during placement of these materials without detection by IUC or its construction contractors.

2. <u>FML Puncture Prevention and Performance</u> - currently standardized tests exist to measure the puncture performance of FML materials in response to a load applied over pointed object or probe, e.g. ASTM Method 4833. The purpose of such a test is to determine the maximum load that a FML may be subjected to without puncture, and thereby design and control construction conditions and static and dynamic loads to prevent FML damage.

Review of the IUC engineering design reports shows that no FML puncture tests were conducted on any of the PVC FML materials installed in either Cells 1 and 2 (6/79 DCE Design Report, Appendix B, p. 3-3; and 2/82 DCE As-Built Report, Appendix D) or Cell 3 (5/81 DCE Report, Appendix B, p. 3-3; and 5/83 EFN As-Built Report, Appendix B). Neither was any such testing planned for Cell 4 (8/88 Umetco Design Report, Attachment II, Procedure QC-19-C4WM). As a result, it appears that little effort was employed by IUC to prevent perforations of the FML by static or dynamic loads during tailings cell construction. Consequently, it is reasonable to expect that puncture damage did occur during construction; resulting in a number of imperfections and/or perforations in the PVC liner under all four (4) IUC tailings cells.

It is also important to note that in general, PVC membranes exhibit lower puncture strength (2.2 lb/mil) than High Density Polyethylene (HDPE) liners (2.8 lb/mil, see EPA, p. 31, Table 3-2). Consequently, all other factors being equal, a greater degree of FML puncture damage is expected under IUC tailings Cells 1, 2, and 3, in that these facilities were constructed with a 30-mil PVC liner (Cells 1 & 2: 2/82 DCE Report, p.3-5 and Appendix D; Cell 3: 5/83 EFN Report, pp. 3-6 and 7). In contrast, Cell 4 was apparently completed with a 40-mil HDPE liner and may have experienced lesser puncture damage during its construction (8/88 Umetco Design Report, Attachment I, p. 13).

3. <u>PVC Liner Material Design Concerns / Issues</u> - at least three concerns are apparent at the selection of PVC material as the FML of choice at the IUC tailings facility, as follows:

   A. <u>High Water Vapor Permeability and Unmeasured Discharge to Environment</u> - technical literature indicates that a 30-mil PVC membrane without defects will discharge water at a rate of 1.93 gal/acre/day due to water vapor transmission alone (Koerner, p. 369, Table 5.2). Unfortunately, this leakage rate is greater than the EPA RCRA de-minimus leakage rate (1.0 gal/acre/day, see EPA, p. 30). It is also interesting to note that the PVC membrane water vapor permeability is 2-orders of magnitude higher than an equivalent thickness of HDPE liner (Koerner, p. 369, Table 5.2). In fact, PVC membranes have the highest water vapor permeability of the five (5) different FML media cited (ibid.). Consequently, even under the best of circumstances, use of PVC liner technology at the IUC facility is not equivalent to EPA RCRA minimum technology guidance; nor does it constitute a de-minimus type discharge under said regulations.

   B. <u>Long-Term Integrity of PVC Liners</u> - the long-term performance or physical integrity of PVC liners to contain tailings contaminants over long periods of time is a concern, based on at least two (2) concerns listed below:

      1) <u>Effects of Plasticizer Leaching</u> - plasticizer compounds added by the manufacture to PVC membranes leach from the FML over time (Koerner, p. 510). Such leaching leads to progressive brittleness and cracking of PVC membranes (ibid., p. 393). Consequently, the long-term performance of PVC

membranes may deteriorate with time; leading to increased rates of liner failure and leakage to the environment. Other synthetic membranes appear to have longer longevity than PVC materials (ibid., p. 510).

2) <u>Poor Resistance to Chemical Attack by Organic Compounds</u> - one technical reference cites PVC membranes has having generally poor chemical resistance in the presence of: aliphatic and aromatic hydrocarbons, chlorinated solvents, and crude petroleum solvents (Koerner, p. 389). IUC uses large amounts of kerosene fuel in its uranium solvent extraction process, about 1,680 lb/day (5/28/99 IUC Groundwater Information Report, p. A-8). Unfortunately, kerosene contains both aliphatic and aromatic hydrocarbons. Two aromatic hydrocarbons (toluene and naphthalene), and one chlorinated solvent (chloroform) have also been detected in IUC tailings wastewater samples (7/94 Titan Environmental Report, Appendix B, Table 1, slimes drain). As a result, deterioration should be expected in the PVC membranes below IUC tailings Cells 1, 2, and 3 as a result of interaction with these chemicals. Said deterioration could encourage formation of membrane defects and resulting discharge to the environment.

4. <u>PVC Seam Construction Concerns/Issues</u> - although the FML liners were installed by the manufacturer or their representatives, no detailed descriptions are provided by these parties in any of the IUC as-built reports (Cells 1 & 2: 2/82 DCE Report, p. 3-5; Cell 3: 5/83 EFN Report, p. 3-6). Neither are any detailed descriptions provided for PVC liner seam construction in Cells 1, 2, or 3 in the IUC engineering design reports (Cells 1 & 2: 6/79 DCE Report, pp. 4-18 and 19, or Attachment B specifications on p. 3-5; Cell 3: 5/81 DCE Report, pp. 3-4 and 5, or Attachment B specifications on p. 3-5). As a result, little is known about several critical factors related to integrity of the PVC liner system. Also, other issues are of concern regarding liner seam design and construction, as follows:

A. <u>PVC Seam Design and Specifications: Zones of Inherent Weakness</u> - it is common for FML seams to be weaker than the geomembrane itself, largely because field construction techniques cannot match controlled factory conditions used by the liner manufacturer (Koerner, p. 374). At IUC Cells 1, 2, and 3, field seam strength was also found to be lower than the virgin PVC material; where engineering design and specifications that required only an 80% tear strength criteria for field manufactured seams relative to the virgin PVC panel material (Cells 1 & 2: 6/79 DCE Report, Appendix B, p. 3-2; and Cell 3: 5/81 DCE Report, Appendix B, p. 3-2). IUC construction test data confirms this in that the seams constructed were weaker than the virgin PVC material, see Table 4, below.

Contrary to the discussion above, factory manufactured seams in IUC Cells 1, 2, and 3 fared even worse than their field manufactured counterparts. Unfortunately, no explanation was provided in any of the IUC construction as-built reports. DRC staff can only speculate that either different tests were used, thereby rendering the results uncomparable; or that the factory made seams were actually of poor quality. In any case, both types of liner seams in Cells 1, 2, and 3 constitute apparent zones of weakness in the FML system that should have been accounted for in design of the FML system to withstand static and dynamic loads. Apparent failure on the part of IUC to design for and prevent adverse effects of static or dynamic loading suggests that significant defects could exist in the PVC liners; thereby allowing wastewater to be released to the environment.

Table 4. Summary of IUC PVC Liner Seam Test Data

Tailings Cell	No. of Tests	Average Tear Strength (1)	Reference (2)
Field Manufactured Seams			
Cell 1	110	92.8%	A
Cell 2	165	87.3%	B
Cell 3	28	93.3%	C
Factory Manufactured Seams			
Cell 1	25	81.5%	A
Cell 2	90	82.4%	B
Cell 3	13	89.5%	C

Footnotes:

1. Average seam tear strength relative to tear strength of the virgin PVC panel material.
2. Sources of IUC PVC liner seam test data are as follows:
   A. 2/82 DCE As-Built Report, Appendix D, BF Goodrich Company laboratory Reports of February 4, 1981 (factory seams) and September 17, 1981 (field seams).
   B. 2/82 DCE As-Built Report, Appendix C, BF Goodrich Company laboratory reports of February 19, April 30, and May 30, 1980 (factory seams), and May 19, June 4, and June 16, 1980 (field seams).
   C. 3/83 EFN As-Built Report, Appendix B, September 20, 1982 Watersaver Company Inc Report (field seams), and September 3, 1982 Dyanmit Nobel-Harte laboratory results (factory seams).

B. Chemical Resistance of Adhesive - the above cited design reports cite the use of an adhesive to join the PVC liner panels in Cells 1, 2, and 3. As such, this adhesive forms a new component in the liner system. Unfortunately, no information was provided in any of the IUC design or as-built reports about the long-term resistance of the PVC adhesive used to contain contaminants found in the IUC tailings ponds, e.g., acidic solutions, diesel fuel, chlorinated solvents, etc. If the adhesive were to be more prone to chemical attack, the seams would become major points of weakness in the FML system; thereby resulting in a discharge of wastewater to the subgrade environment.

C. Seam Cleaning Method Implications - the above referenced design reports simply state that the "... field seams shall be made only on lining surfaces that are cleaned of dirt, dust, moisture, or other foreign matter." However, no explanation was provided on how this cleaning would be accomplished. If simple mechanical means were used to brush the dirt from the FML, dust and dirt could have easily contaminated the seam areas, easily resulting in weakened PVC seams. Better seams could have been constructed if solvents were used to clean the seam areas before application of the adhesive. However, poor or irregular application of cleaning solvents could also render seam weaknesses. Also, spillage of the cleaning solvent elsewhere on the PVC panels could also form other points of weakness in the FML system. Static or dynamic loading could later open these weak areas into FML perforations during the construction process.

D. FML Wrinkles and Seam Integrity - none of the above referenced design or as-built reports included measures used to eliminate wrinkles in the PVC panels before the seams were constructed. If liner wrinkles were to become incorporated inside a seam area, bypass conduits could be formed thru the seams that would allow wastewater to be discharged from the tailings cells. If no measures were provided in the engineering design, specifications, or as-built reports to prevent wrinkles from forming in or near seams, it is reasonable to expect that some PVC liner leakage may exist as a result of this oversight.

5. Disrepair of Cell 4A; Need for Retrofit Construction - during an inspection of May, 1999, DRC staff discovered that the FML liner in IUC Tailings Cell 4A was in gross disrepair. During this inspection it was observed that at least a portion of one FML panel had separated from the liner and been blown out of the cell by the prevailing winds; thereby leaving the underlying bedding layer exposed to the elements (personal communication, Rob Herbert, DRC). At the same time it was observed that other seam areas of the FML in Cell 4A had been nailed down with steel nails and 2-by-4 inch boards to prevent them from also blowing away (ibid.). During this inspection a green liquid was also observed to be contained in the bottom of Cell 4A (ibid.). During other inspections, IUC staff have explained that this liquid is a vanadium raffinate stored in Cell 4A.

As a result of these observations, DRC staff have concluded that the Cell 4A liner system has been grossly neglected and damaged, and must be repaired before placing the cell in to service. Based on this neglect and the LDS design shortcomings mentioned above, DRC staff recommend that the existing FML in Cell 4A be removed and the tailings cell re-design and re-constructed to provide adequate LDS performance. Because IUC staff have indicated that vanadium raffinate has been stored on the Cell 4A liner, decontamination of the existing FML bedding layer and foundation may also be in order during cell retrofit construction. As a result of these considerations, DRC staff recommend that Cell 4A not be authorized or included in any Permit; but instead that IUC be required to submit and complete a retrofit construction plan for this cell before its re-use for tailings or wastewater disposal at the facility.

General Facility Design Concerns / Issues

1. Mill Facility Area Sedimentation Pond: Potential Groundwater Pollution Source - the June, 1979 DCE design report shows that a sedimentation pond was constructed adjacent to the southeast corner of Cell 1 to receive stormwater drainage from the mill site area and the ore storage piles (ibid., Sheet 4 and p. 6-3). This sedimentation pond was designed with an 11 acre-foot storage capacity, and without an outlet or overflow spillway. More importantly, the pond was designed without any liner. Consequently, water may only exit the pond thru either evaporation or seepage.

   Unfortunately, no "as-built" information has been provided by IUC regarding the Mill Facility Sedimentation (MFS) Pond. Consequently, DRC staff assumed that its construction conformed to the design provided in the June, 1979 DCE Report.

   During a site visit on May 9, 2000, DRC staff inspected the MFS Pond site and found no open surface impoundment at this location. After inquiry, IUC staff explained that: 1) the MFS Pond had been filled with fly-ash waste in about 1990, 2) the company now referred to this pond as the Fly-Ash Pond, and 3) soon after filling the pond with fly-ash the area near the Fly-Ash Pond had been re-graded to direct stormwater runoff from the mill site to Tailings Cell 2. During the May 9 site visit it was apparent that a soil cover had been placed over the fly-ash (5/11/00 DRC memorandum, pp. 5 and 6).

   Based on the available information, it appears that both contact and non-contact stormwater runoff from the mill facility was at one time collected in the MFS Pond and ultimately discharged to groundwater. As a result, mill site area spills of reagents, chemicals, or wastewaters could have been retained by this sedimentation pond and also discharged to local groundwater. From on-site inspection and disclosure by IUC staff it is also apparent that the MFS Pond has also been used by the company for the disposal of fly-ash.

   As a result, the MFS Pond should be considered as a potential source of groundwater contamination at the facility. Source term investigations should be used to confirm or ascertain the presence of contaminants in this pond, and should be included in the ongoing groundwater contaminant investigation report. If contamination is confirmed, IUC should be required to make certain improvements in engineering design to mitigate or prevent any continuing groundwater pollution from this potential pollution source. Appropriate measures would include, but are not limited to: 1) installation of an engineered cover system to minimize infiltration and point-of-compliance monitoring wells to determine any adverse impact to groundwater quality, or 2) removal of the fly-ash material and other contaminants, followed by appropriated disposal at another approved and engineered facility.

Operational Issues / Concerns

1. Water Balance Monitoring - the June, 1979 DCE Report lists an aggressive program for water balance monitoring at the White Mesa facility, including: a local precipitation gauge,

evaporation pan, staff gauges, and flow meters (ibid., p. 4-5). Inspections should be done to confirm these devices were installed, that historic measurements were made, and records kept. If such water balance monitoring data are available, review and evaluation of the historic data should be done to determine if it can be an effective tool to measure performance of the discharge minimization technology approved under the Permit.

2. Annual Site Precipitation Rate - the June, 1979 DCE Report cites the average precipitation as 11.8 inches/year. This value is low. More recent information from the Western Regional Climate Center indicates average annual precipitation is 13.38 inches (see Attachment 4, below).

Discharge Minimization Technology (DMT) Considerations

1. Need for DMT Determination: Ground Water Quality Protection Rules - in order for the Executive Secretary to issue a Permit for an existing facility, one that pre-dated the GWQP Rules, the following determination must be made first (UAC R-317-6-6.4.C.1 thru 4):

> "*1. the applicant demonstrates that the applicable class TDS limits, ground water quality standards and protection levels will be met;*
> *2. the monitoring plan, sampling and reporting requirements are adequate to determine compliance with applicable requirements;*
> *3. the applicant utilizes treatment and discharge minimization technology commensurate with plant process design capability and similar or equivalent to that utilized by facilities that produce similar products or services with similar production process technology, and*
> *4. there is no current or anticipated impairment of present and future beneficial uses of the ground water*"

Factors to be considered in arriving at the above listed determinations required of the Executive Secretary are listed in the discussion below.

2. DMT Performance Standard for Existing Facilities - discussions with Utah Division of Water Quality (DWQ) staff have confirmed that the maximum seepage discharge allowed from DWQ permitted existing facilities is 200 gal/acre/day. As a result of this precedence, this 200 gal/acre/day seepage discharge rate should be used as a Dishcarge Minimization Technology (DMT) performance standard for other existing facilities (personal communication, Larry Mize, DWQ). Under this performance criteria, undetected FML leakage from an existing disposal facility should be no greater than 200 gal/acre/day. This criteria is amply reasonable, in that currently available FML technology allows leak detection system sensitivity as low as 1 gal/acre/day (US Environmental Protection Agency [EPA], pp. 8 and 30). This DWQ undetected discharge criteria is also applicable to both the operational phase and closed-cell condition of the facility (personal communication, Dennis Frederick, DWQ).

3. Unacceptable IUC LDS Design and Construction - based on available LDS design and construction information, undetected leakage from IUC Cells 2, 3, and 4A could range from about 2,500 to 840,000 gal/acre/day, with an average of 200,000 gal/acre/day (see discussion above). This possible undetected seepage discharge rate is much greater than the 200 gal/acre/day DWQ criteria cited above.

   Admittedly, this estimate of LDS sensitivity is based on the permeability of the underlying bedrock and the system's resulting failure to force FML leakage horizontally to the leak detection pipeage. Actual seepage discharge thru the FML may be lower, depending on many contributing factors such as: thickness and permeability of the tailings, total effective head on the FML, number and size of defects in the FML, etc.

   However, it is clear that the existing IUC leak detection systems in question are ineffective at measuring leakage in light of the DWQ performance criteria for existing facilities (200 gal/acre/day). Furthermore, the apparent lack of any LDS under Cell 1 is also unacceptable. As a result, DRC staff conclude that none of the existing disposal cells at the IUC facility has an adequate LDS. Nor can any of the existing LDS be used a satisfactory point of compliance for purposes of a Permit

4. Lack of Ability to Objectively Model IUC Cell Seepage - the above DRC leak detection sensitivity seepage rate estimates are worse-case figures. Prediction of actual or more realistic seepage discharge from the existing IUC tailings cell would require infiltration modeling studies. One common model used for such infiltration predictions is the EPA Hydrologic Evaluation of Landfill Performance (HELP) model.

   Because each cell has a separate different design or is in a different stage of its life cycle, separate model simulations would be needed for each disposal cell. For example, Cell 1 is currently used for wastewater storage and has little sediment disposed there. Cell 2 is near the end of its operational life and is being drained and prepared for final cover. Cell 3 is still only partially filled; while Cell 4 awaits retrofit and repair work before it can be used for disposal.

   Any infiltration model used will require determination of a number of engineering design, soil hydraulic properties, and weather variables. While many of these are known or can be deduced from available information, some inputs would be difficult to ascertain, and therefore, would possibly render the model results subjective and open to interpretation. Two (2) important, yet subjective input variables needed in the HELP model are: 1) the number of field defects per acre in the FML, including those created during FML installation (seam defects, punctures, etc.), or develop thereafter in response to loading stress or chemical interactions, and 2) type of FML placement quality or degree of intimate contact between the FML and the over and underlying soil materials.

   Because the IUC disposal cells were constructed over 20 years ago, few people are available to provide input on the number of FML field defects that might have occurred during installation. Furthermore, few or no records are available to confirm such, or provide information on the degree of FML placement quality. In addition, little can be quantified regarding current physical integrity of the FML, particularly with regards to chemical resistance of either the PVC membrane panels or the glues used to seam them. As a result, any assumptions made by IUC or DRC staff regarding these HELP model inputs would be subjective and open to dispute and argument. Certainly, based on the company's past resistance to State regulation, one can expect that any infiltration modeling used to further quantify actual or probable seepage discharge from the IUC disposal cells will be long, argumentative, arduous, and definitely subjective.

5. DRC Staff Recommendations - as a result of the above considerations and findings, DRC staff recommend that the agency forgo infiltration modeling as a means to determine compliance with the DWQ 200 gal/acre/day seepage discharge criteria for the operational phase of the IUC facility. Instead, DRC staff recommend that the following actions be completed:

   A. Necessary Operational Phase Improvements - distinct improvements should be made to groundwater monitoring during the facility's operational life, including, but not limited to:

      1) Additional Monitoring Wells - to allow each disposal cell to be individually monitored with a series of wells located immediately up and downgradient. These wells would be installed on the internal dikes located between each cell.

      2) Additional Head Monitoring and Reporting - including frequent measurement of shallow aquifer water levels in all monitoring wells at the facility, careful characterization and monitoring of the apparent groundwater mound at the facility, and preparation of water table contour maps.

      3) Additional Groundwater Monitoring Parameters - including the addition of new groundwater monitoring analytes to better detect and quantify any seepage discharge that may have been released from the IUC facility.

      4) Accelerated Closure and Compliance Schedule for Cell 2 - IUC is currently in the process of stabilizing and advancing temporary soil cover over Cell 2. Consequently, DRC staff recommend a compliance schedule be included in the Permit that accelerates and makes enforceable closure of this tailings cell in a timely manner.

      5) Retrofit Construction of Cell 4A - because Cell 4A has not yet been used for tailing disposal, and is in a state of disrepair, it is feasible to re-design and re-construct this cell to meet current Best Available Technology requirements under the GWQP Rules. Consequently, DRC staff recommend that the

Permit require Cell 4A to be upgraded to meet current BAT design and technology standards before being placed into service.

B. Possible Operational Improvements - several improvements could be made to disposal cell operations to minimize seepage discharges from the IUC facility, including:

1) Disposal Cell Head Minimization - in the event that the IUC disposal cells were to be operated on a continuing basis, and for an extended period of time, certain improvements to head minimization could yield significant decrease in seepage flux from the facility. This seepage driving head could be minimized at IUC by:

a) Installation of a clay internal liner slurried over the top of the existing tailings surface; thereby reducing vertical seepage to the underlying FML, and

b) Installation and full-time operation of pumps to remove fluids from the existing leachate collection (slimes drainage) system constructed immediately above the FML. This may require installation of automation and backup equipment to ensure full-time operation.

c) Careful measures to minimize the depth of fluids on top of the tailings, or on top of the FML in wastewater Cell 1. Timely efforts to pump and remove these fluids and re-circulate them back to the mill will also help minimize driving head conditions in the cells.

However, if the IUC facility were to be closed soon after issuance of the Permit, these head minimization efforts would do little to reverse any seepage effects caused by 20 years of historic operation.

2) FML Lining for Mill site Stormwater / Sedimentation Pond - an FML liner and leak detection system could be installed for the sedimentation pond found East of Cell 1 that is used for disposal of stormwater runoff from the mill site and contact stormwater runoff from the ore storage pile.

3) Contaminated Groundwater Recovery System - in the event that contaminated groundwater is found at the facility, IUC should install a series of pumping wells to recover and contain said water.

C. Closed-Cell Design Improvements - review of the proposed IUC tailings cells cover design in the September, 1996 Titan Environmental Report, shows that it includes four (4) layers above the waste form, as summarized in Table 5, below (in descending order):

Table 5. Summary of September, 1996 IUC Tailings Cover System Design

Sideslope Areas		Topslope Areas	
Description	Thickness (inch)	Description	Thickness (inch)
Riprap	3.0	Riprap	12.0
Random Fill	24.0	Random Fill	24.0
Radon Barrier	12.0	Radon Barrier	12.0
Random Fill	36.0 *	Random Fill	36.0 *

Footnote:
* Thickness varies in order to make final grade for cover.

Several improvements could be made to the current cover system design to minimize discharge of the facility to groundwater, including, but not limited to:

1) Inclusion of a Filter Drainage Layer Above Radon Barrier - the cover design proposed does not include a filter drainage layer above the radon barrier. Rather, it calls for a 2-foot thick "upper random fill" layer, which is reportedly made of a clay-like material (9/96 Titan Report, p. 5 and Appendix D, HELP model output file "efn-fin2.out", Layer 1, permeability = 8.8E-7 cm/sec). If all or part of this layer were designed and constructed with a higher permeability, infiltration that may accumulate on top of the clay radon barrier could be diverted out of the cover system and prevented from entering the waste in the disposal cells.

2) Reduction of Radon Barrier Permeability - the current cover design simulated by IUC with the EPA HELP model assumed a radon barrier permeability of 3.7E-8 cm/sec (9/96 Titan Report, Appendix D, HELP model output file "efn-fin2.out", Layer 2). This permeability could feasiblely be reduced to 1.0E-8 cm/sec.

3) Addition of FML/Clay Composite Layer - the radon barrier could be converted to a FML / clay composite by addition of a FML immediately above the clay radon barrier. This design change would dramatically reduce the seepage rate thru the tailings waste.

4) Provide Shorter Drainage Path Lengths - in the current IUC cover system design, the "clay-like" random fill layer extends uniformly from the North side of Cell 1 to the South side of Cell 4A, a distance of over 3,300 feet (9/96 Titan Report, Figure 1, East side of Cells 2, 3, and 4A). This provides for a very long path length for seepage to travel horizontally in the riprap layer before it can exit the system. As a result, seepage losses are maximized during the course of this travel path; thereby maximizing infiltration thru the

tailings waste. Redesign of the cover system could allow for shorter horizontal drainage paths; thereby allowing the seepage to exit the system sooner; minimizing seepage thru the underlying waste.

6. Compliance with Required Determinations - determinations required by the GWQP Rules regarding existing facilities (UAC R317-6-6.4.C) can be accomplished as follows:

A. Groundwater Class Limits, Standards and Protection Limits - after completion of site characterization and resolution of the DRC February 7, 2000 request for additional hydrogeological information, the Executive Secretary should be able to confirm groundwater class of the shallow aquifer. After installation of the additional groundwater monitoring wells needed at the facility, the Executive Secretary should also be able to determine if IUC currently meets State Ground Water Quality Standards and Protection Levels in the shallow aquifer around each disposal cell.

B. Monitoring Plan, Sampling and Reporting - improvements will be made to groundwater monitoring at the facility to better characterize local conditions and better detect tailings contaminants in the shallow aquifer (see discussion above). Improvements can also be incorporated for better quality assurance / quality control and reporting for future construction projects at the facility. Thus, these requirements in the GWQP Rules should also be met.

C. Discharge Minimization Technology - it is clear that the current engineering containment at IUC is not equivalent to what similar uranium mill operators use today. This discrepancy is largely because the White Mesa facility was constructed 20 years ago. Since that time, great improvements have been made in FML materials, design, and construction techniques, that make the IUC facility now appear outdated and obsolete. One example of this disparity is the Plateau Resources uranium mill tailings facility near Ticaboo, Utah. There, double FML liners, full coverage leachate removal systems over the upper FML, and full coverage LDS between the FMLs were designed with multiple observation sumps to minimize driving head, provide rapid reporting, and effect high FML leakage recovery.

However, certain improvements can be made at White Mesa including: 1) point of compliance monitoring wells for each individual cell, 2) head minimization equipment and operation for Cells 1 and 3, 3) accelerated closure of Cell 2, 4) re-design and retrofit construction for Cell 4 before return to service, and 5) improved cover system design for all 4 Cells at the facility.

D. Absence of Current or Anticipated Impairment of Beneficial Use - this requirement can be considered satisfied at IUC if: 1) groundwater is adequately and carefully monitored at the facility, and 2) the current IUC design and construction has not caused any adverse impact on local groundwater quality. Additional site characterization and improvements in the existing groundwater monitoring network can establish if compliance has been met in these areas.

However, in the event that groundwater pollution is discovered and confirmed at the facility, the Executive Secretary would be hard-pressed to make this last affirmation required by the GWQP Rules. In that event, beneficial use of local groundwater could still be protected thru other means, such as implementation of a groundwater recovery or remediation system to protect downstream groundwater users. For this reason, it will be critical to coordinate the Permitting efforts for this facility with ongoing contaminant investigation studies at the IUC facility (see 8/23/99 DRC NOV and Groundwater Corrective Action Order).

Predictions of future degradation of groundwater quality at the facility would be difficult to provide, based on a lack of supporting information, and would be highly subjective, as discussed above.

Conclusions

After review of the engineering design, specifications, and as-built reports provided by IUC, DRC staff have concluded that:

1. It is unlikely that any leak detection system exists under IUC wastewater disposal Cell 1. Therefore, point of compliance groundwater monitoring wells will be required around Cell 1 in the Permit.

2. Leak detection systems found under IUC Cells 2 and 3 are grossly inadequate. Based on available system design, geometry, and underlying bedrock permeability, DRC staff estimate that FML leakage would remain undetected by the current system until leakage flows reach a rate of between 2,500 and 840,000 gal/acre/day, with an average of about 200,000 gal/acre/day. This lack of leak detection sensitivity fails to meet DWQ performance standards for existing facilities (200 gal/acre/day). As a result, the existing design fails to comply with the DWQ Discharge Minimization Technology (DMT) requirements found in the GWQP Rules.

3. Multiple lines of evidence also suggest that the 30-mil PVC membrane used as FML in Cells 1, 2, and 3 is prone to excess leakage due to a number of factors, including: 1) suspect preparation of FML bedding and protective blanket layers, 2) lower PVC puncture strength, 3) higher PVC water vapor transmission, 4) long-term degradation of PVC membranes due to leaching of plasticizer compounds and organic chemical attack, and 5) suspect PVC seam preparation and construction methods.

4. As a result of leak detection system design shortcomings and suspect physical condition and integrity of the PVC FML in Cells 1, 2 and 3, a demonstration of adequate DMT will largely focus on performance of the final cover system, and to a lesser degree on operational

improvements. Operational improvements, include, but are not limited to: 1) additional groundwater characterization and installation of new monitoring wells for each individual disposal cell, 2) additional water quality monitoring parameters, 3) accelerated closure for Cell 2, and 4) head minimization efforts for Cells 2 and 3. Improvements to the final cover include: decreased radon barrier permeability, addition of a high permeability filter zone and a FML/clay composite layer in the cover design, and shorter drainage path lengths.

5. Although the leak detection system design under Cell 4A represents an improvement over previous disposal cells at the facility, its leak detection shortcomings, and current state of neglect and disrepair mandate that this cell be retrofit to meet current Best Available Technology (BAT) standards before any use for tailings or wastewater disposal activities.

6. Lack of separate and independent construction supervision and construction quality control/quality assurance (CQA/QC) may have contributed to an increased rate of construction defects in IUC Tailings Cells 1, 2, 3, and 4. Revisions need to be made to any future IUC CQA/QC efforts and plans to ensure modern construction techniques and provide confidence in the engineering containment of new wastewater and tailings disposal cell construction.

7. An engineering survey error of approximately 900 feet has been discovered at tailings Cell 2, which must be resolved. Resolution of this error can be combined with surveys needed to correct other errors for the groundwater compliance monitoring wells.

8. An unlined sedimentation pond formerly drained the IUC mill site and ore storage pad area and has been used for on-site disposal of fly-ash. This Fly-Ash Pond is a potential source of groundwater pollution that needs to be investigated. Historical and ongoing operation of this Fly-Ash Pond constitutes a potential groundwater contamination source at the IUC facility. Appropriate measures to control groundwater pollution at this facility include, but are not limited to: 1) installation of an engineered cover system followed by point-of-compliance monitoring wells, or 2) removal of the fly-ash material and other contaminants and appropriated disposal at another approved and engineered facility.

9. Compliance with the GWQP Rules for issuance of a Permit to an existing facility at IUC can be achieved as described above. However, if groundwater contamination is discovered near Cells 1, 2, or 3 during additional site characterization or installation of new groundwater monitoring wells, the Executive Secretary will not be able to affirm the lack of impairment of present and beneficial use without additional groundwater remediation measures.

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LBM:lm

attachments (5)

cc: Larry Mize, DWQ

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File: IUC Groundwater Permit P1b

ATTACHMENT 1

Utah Division of Radiation Control

Summary of
Available Permeability Information
for the
IUC White Mesa Uranium Mill Tailings Facility

DRC Spreadsheet HydCond.XLS
Tabsheet alldata

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1	**International Uranium Corporation: Saturated Hydraulic Conductivity**												= calculated fields			
2	*direct data from IUC consultants reports*															
3		Boring or		Depth Interval							Test Zone					
4	Geologic	Well	Test	(ft. bgs)		Data		Hydraulic Conductivity			Formation	K Value	Data			
5	Formation	ID	Type	Top	Bot.	Ref.	gpd/ft^2	(ft/yr)	(cm/sec)	gal/acre/day	Confirmed?	Confirmed?	Source	Comment		
6	**Soil**	6	lab	9	n/a	D&M		12.00	1.20E-05	10,705.59	yes		1	undisturbed core		
7		7	lab	4.5	n/a	D&M		10.00	1.00E-05	8,921.33	yes		1	undisturbed core		
8		10	lab	4	n/a	D&M		12.00	1.20E-05	10,705.59	yes		1	undisturbed core		
9		12	lab	9	n/a	D&M		140.00	1.40E-04	124,898.57	yes		1	undisturbed core		
10		16	lab	4.5	n/a	D&M		22.00	2.10E-05	19,626.92	yes		1	undisturbed core		
11		17	lab	4.5	n/a	D&M		93.00	9.00E-05	82,968.34	yes		1	undisturbed core		
12		19	lab	4	n/a	D&M		70.00	6.80E-05	62,449.29	yes		1	undisturbed core		
13		22	lab	4	n/a	D&M		3.90	3.80E-06	3,479.32	yes		1	undisturbed core		
14																
15																
16						Max.:		140.00	1.40E-04	124,898.57						
17						Min.:		3.90	3.80E-06	3,479.32						
18						Mean:		45.36	4.46E-05	40,469.37						
19						Std.Dev.:		50.11	4.96E-05	44,701.05						
20						Geomean:		24.07	2.37E-05	21,472.09						
21						Count:		8								
22																
23	**Kds**	No. 3	injection	28	33	D&M		568.00	5.49E-04	506,731.35	probable		1			
24		No. 3	injection	33	42.5	D&M		2.80	2.71E-06	2,497.97	probable		1			
25		No. 12	injection	16	22.5	D&M		5.10	4.93E-06	4,549.88	probable		1			
26		No. 12	injection	22.5	37.5	D&M		79.20	7.66E-05	70,656.91	probable		1			
27		MW-18	injection	27	32	Peel		114.00	1.10E-04	101,703.12	probable		1			
28		No. 19	injection	26	37.5	D&M		7.00	6.77E-06	6,244.93	probable		1			
29		No. 19	injection	37.5	52.5	D&M		944.00	9.12E-04	842,173.22	probable		1			
30		GH-94-1	injection	34	40	IUC	0.16	7.81	7.55E-06	6,969.60			3			
31		GH-94-1	injection	40	50	IUC	1.18	57.62	5.56E-05	51,400.80			3			
32		GH-94-2A	injection	34	40	IUC	0.66	32.23	3.11E-05	28,749.60			3			
33		GH-94-2A	injection	32.5	40	IUC	18.72	914.04	8.83E-04	815,443.20			3			
34		GH-94-2A	injection	50	56	IUC	2.3	112.30	1.08E-04	100,188.00			3			
35																
36						Max.:		944.00	9.12E-04	842,173.22						
37						Min.:		2.80	2.71E-06	2,497.97						
38						Mean:		237.01	2.29E-04	211,442.38						
39						Std.Dev.:		358.22	3.46E-04	319,579.57						
40						Geomean:		54.72	5.29E-05	48,816.52						
41						Count:		12								
42																

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1	International Uranium Corporation: Saturated Hydraulic Conductivity												= calculated fields			
2	*direct data from IUC consultants reports*															
3		Boring or		Depth Interval							Test Zone					
4	Geologic	Well	Test	(ft, bgs)		Data	Hydraulic Conductivity				Formation	K Value	Data			
5	Formation	ID	Type	Top	Bot.	Ref.	gpd/ft^2	(ft/yr)	(cm/sec)	gal/acre/day	Confirmed?	Confirmed?	Source	Comment		
43	**Kbc**	No. 3	injection	42.5	52.5	D&M		5.80	5.61E-06	5,174.37	probable		1			
44		No. 3	injection	52.5	63	D&M		16.20	1.57E-05	14,452.55	probable		1			
45		No. 3	injection	63	72.5	D&M		5.30	5.13E-06	4,728.30	probable		1			
46		No. 3	injection	72.5	92.5	D&M		3.20	3.09E-06	2,854.82	probable		1			
47		No. 3	injection	92.5	107.5	D&M		4.90	4.74E-06	4,371.45	probable		1			
48		No. 3	injection	122.5	142	D&M		0.60	5.80E-07	535.28	probable		1			
49		No. 9	injection	27.5	42.5	D&M		2.70	2.61E-06	2,408.76	Kds?		1			
50		No. 9	injection	42.5	59	D&M		2.00	1.93E-06	1,784.27	Kds?		1			
51		No. 9	injection	59	82.5	D&M		0.70	6.77E-07	624.49	probable		1			
52		No. 9	injection	82.5	107.5	D&M		1.10	1.06E-06	981.35	probable		1			
53		No. 9	injection	107.5	132	D&M		0.30	2.90E-07	267.64	Jmb		1			
54		No. 12	injection	37.5	57.5	D&M		0.90	8.70E-07	803.81	Kds?		1			
55		No. 12	injection	57.5	82.5	D&M		1.40	1.35E-06	1,248.99	probable		1			
56		No. 12	injection	82.5	102.5	D&M		10.70	1.03E-05	9,545.82	probable		1			
57		No. 28	injection	76	87.5	D&M		4.30	4.16E-06	3,836.17	probable		1			
58		No. 28	injection	87.5	107.5	D&M		0.30	2.90E-07	267.64	probable		1			
59		No. 28	injection	107.5	132.5	D&M		0.20	1.93E-07	178.43	probable		1			
60		MW-1	recovery	92	112	Peel		3.00	2.90E-06	2,675.40	probable		1			
61		MW-2	SWDD	85	125	Peel		48.83	4.72E-05	43,562.84	probable		2			
62		MW-3	recovery	67	87	Peel		2.97	2.87E-06	2,649.63	no geol. log		1	no log on well completion diagram		
63		MW-4	SWDD	92	112	Peel		9.89	9.55E-06	8,823.19	possible		2			
64		MW-5	recovery	95.5	133.5	H-E		13.10	1.27E-05	11,686.94	possible		1			
65		MW-5	recovery	95.5	133.5	Peel		21.00	2.03E-05	18,734.79	possible		1			
66		MW-11	recovery	90.7	130.4	H-E		1,230.00	1.19E-03	1,097,323.2	possible		1			
67		MW-11	SWDD	90.7	130.4	Peel		1,630.00	1.58E-03	1,454,176.2	possible		1			
68		MW-12	recovery	84	124	H-E		68.40	6.61E-05	61,021.87	possible		1			
69		MW-12	recovery	84	124	Peel		68.40	6.61E-05	61,021.87	possible		1			
70		MW-14	SWDD	90	120	H-E		1,210.00	1.16E-03	1,079,480.5	no diagram		1	no well completion diagram available		
71		MW-14	SWDD	90	120	H-E		402.00	3.88E-04	358,637.33	no diagram		1	no well completion diagram available		
72		MW-14	SWDD	90	120	Peel		767.02	7.41E-04	684,283.59	no diagram		2	no well completion diagram available		
73		MW-15	SWDD	99	129	H-E		36.50	3.53E-05	32,562.84	no diagram		1	no well completion diagram available		
74		MW-15	recovery	99	129	Peel		25.80	2.49E-05	23,017.02	no diagram		1	no well completion diagram available		
75		MW-16	injection	28.5	31.5	Peel		942.00	9.10E-04	840,388.96	probable		1			
76		MW-16	injection	45.5	51.5	Peel		52.80	5.10E-05	47,104.60	probable		1			
77		MW-16	injection	65.5	71.5	Peel		80.70	7.80E-05	71,995.11	probable		1			
78		MW-16	injection	85.5	91.5	Peel		30.00	2.90E-05	26,763.98	probable		1			
79		MW-17	injection	45	50	Peel		3.10	3.00E-06	2,765.61	possible		1			

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1	**International Uranium Corporation: Saturated Hydraulic Conductivity**												= calculated fields			
2	*direct data from IUC consultants reports*															
3		Boring or		Depth Interval							Test Zone					
4	Geologic	Well	Test	(ft, bgs)		Data	Hydraulic Conductivity				Formation	K Value	Data			
5	Formation	ID	Type	Top	Bot.	Ref.	gpd/ft^2	(ft/yr)	(cm/sec)	gal/acre/day	Confirmed?	Confirmed?	Source	Comment		
80		MW-17	injection	90	95	Peel		3.62	3.50E-06	3,229.52	possible		1			
81		MW-17	Injection	100	105	Peel		5.69	5.50E-06	5,076.23	possible		1			
82		MW-18	Injection	85	90	Peel		25.90	2.50E-05	23,106.24	possible		1			
83		MW-18	Injection	85	90	Peel		26.90	2.60E-05	23,998.37	possible		1			
84		MW-18	Injection	120	125	Peel		4.66	4.50E-06	4,157.34	possible		1			
85		MW-19	injection	55	60	Peel		8.69	8.40E-06	7,752.63	possible		1			
86		MW-19	injection	95	100	Peel		1.45	1.40E-06	1,293.59	possible		1			
87		MW-20	slug	87	90	IUC	0.015	0.73	7.07E-07	653.40			3			
88		MW-22	slug	76	120	IUC	0.06	2.93	2.83E-06	2,613.60			3			
89		GH-94-1	injection	70	80	IUC	0.01	0.49	4.72E-07	435.60			3			
90		GH-94-1	injection	92	100	IUC	13.1	639.63	6.18E-04	570,636.00			3			
91		GH-94-1	injection	103	110	IUC	15.84	773.42	7.47E-04	689,990.40			3			
92		GH-94-2A	injection	60	70	IUC	1.04	50.78	4.90E-05	45,302.40			3			
93		GH-94-2A	injection	70	80	IUC	4.18	204.10	1.97E-04	182,080.80			3			
94		GH-94-2A	injection	80	90	IUC	3.02	147.46	1.42E-04	131,551.20			3			
95																
96																
97						Min.:		0.20	1.93E-07	178.43						
98						Max.:		1,630.00	1.58E-03	1,454,176.2						
99						Mean:		165.43	1.60E-04	147,588.81						
100						Std.Dev.:		369.10	3.57E-04	329,287.90						
101						Geomean:		13.22	1.28E-05	11,789.91						
102						Count:		52								
103																
104	Jmb	MW-20	lab-vert.	92	92.5	IUC		0.00008	7.96E-11	0.07			3			
105		MW-20	lab-vert.	95.4	96	IUC		0.00279	2.69E-09	2.48			3			
106		MW-20	lab-horiz.	95.4	96	IUC		0.11285	1.09E-07	100.68			3			
107		MW-20	lab-vert.	104	104.4	IUC		0.00252	2.43E-09	2.24			3			
108		MW-20	lab-vert.	105	105.5	IUC		0.00008	7.28E-11	0.07			3			
109		MW-20	lab-horiz.	105	105.5	IUC		0.00064	6.14E-10	0.57			3			
110		MW-20	lab-vert.	109.5	110	IUC		0.00106	1.02E-09	0.94			3			
111		MW-20	injection	110.5	114.5	IUC	0.005	0.24	2.36E-07	217.80			3			
112		MW-21	lab-vert.	94.8	95.3	IUC		5.98435	5.78E-06	5,338.83			3			
113		MW-21	lab-horiz.	94.8	95.3	IUC		0.00086	8.31E-10	0.77			3			
114		MW-21	lab-vert.	106.5	107	IUC		0.00066	6.38E-10	0.59			3			
115		MW-21	lab-vert.	114.5	115	IUC		0.15116	1.46E-07	134.86			3			
116		MW-21	injection	109.5	117	IUC	0.17	8.30	8.02E-06	7,405.20			3			

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1	**International Uranium Corporation: Saturated Hydraulic Conductivity**												= calculated fields			
2	*direct data from IUC consultants reports*															
3		Boring or		Depth Interval							Test Zone					
4	Geologic	Well	Test	(ft, bgs)		Data	Hydraulic Conductivity				Formation	K Value	Data			
5	Formation	ID	Type	Top	Bot.	Ref.	gpd/ft^2	(ft/yr)	(cm/sec)	gal/acre/day	Confirmed?	Confirmed?	Source	Comment		
117		MW-22	lab-vert.	122.2	122.7	IUC		1.11818	1.08E-06	997.57			3			
118		MW-22	lab-vert.	126.3	127.2	IUC		0.00072	6.94E-10	0.64			3			
119		MW-22	lab-vert.	133.3	133.7	IUC		0.00218	2.11E-09	1.95			3			
120		MW-22	lab-vert.	137.3	137.8	IUC		616.04	5.95E-04	549,585.68			3			
121		MW-22	lab-horiz.	137.3	137.8	IUC		0.04	3.67E-08	33.90			3			
122		GH-1	lab-vert.	163	163.5	IUC		0.01739	1.68E-08	15.52			3			
123		GH-1	lab-vert.	165	165.5	IUC		0.69990	6.76E-07	624.40			3			
124		GH-2A	lab-vert.	161	161.5	IUC		0.00697	6.73E-09	6.22			3			
125		GH-3	lab-vert.	157	157.5	IUC		0.00098	9.42E-10	0.87			3			
126		GH-4	lab-vert.	158	158.5	IUC		0.00225	2.17E-09	2.00			3			
127		GH-94-1	injection	130	140	IUC	3.6	175.78	1.70E-04	156,816.00			3			
128		GH-94-3	injection	155	161	IUC	0.07	3.42	3.30E-06	3,049.20			3			
129		GH-94-3	injection	138	144	IUC	0.06	2.93	2.83E-06	2,613.60			3			
130																
131																
132						Min.:		0.00008	7.28E-11	0.07						
133						Max.:		616.04	5.95E-04	549,585.68						
134						Mean:		31.34	3.03E-05	27,959.72						
135						Std.Dev.:		124.09	1.20E-04	110,708.85						
136						Geomean:		0.04	3.54E-08	32.69						
137			1			Count:		26								
138																
139	Je-ns	WW-1	recovery	n/a	n/a	D'A		380.00	3.67E-04	339,010.41			1			
140		WW-1	MWDD	n/a	n/a	D'A		466.00	4.50E-04	415,733.82			1			
141		WW-1, 2, 3	MWDD	n/a	n/a	D'A		424.00	4.10E-04	378,264.24			1			
142																
143	Notes:															
144	Soil = alluvium (Quaternary),															
145	Kds = Dakota Sandstone (Cretaceous),															
146	Kbc = Burro Canyon Formation (Cretaceous)															
147	Je-ns = Entrada/Navajo Sandstones (Jurassic)															
148																
149	Data Sources:															
150	1 = 7/94 Titan Environmental Report, Table 2.2															
151	2 = 2/93 Peel Environmental Services, Appendix C and Table 5.1.2-2															
152	3 = 5/28/99 IUC GW Information Report, Tables C-5 and C-6															

Cell: D3
Comment: Depth Interval: values provided derived from intervals tested (laboratory core or injection packer tests) or from screened interval (wells).

Cell: A5
Comment: Geologic Formations: key to abbreviations:
Soil = alluvium (Quaternary),
Kds = Dakota Sandstone (Cretaceous),
Kbc = Burro Canyon Formation (Cretaceous)
Je-ns = Entrada/Navajo Sandstones (Jurassic)

Cell: C5
Comment: Test Types: key as follows:
SWDD = single well drawdown
MWDD = multiple well drawdown
lab = lab permeameter
lab-vert. = lab permeameter across vertical core sample
lab-horiz. = lab permeameter test in horizontal direction across vertical core sample.

Cell: F5
Comment: Data References (7/94 Titan Environmental Report, Table 2.2, footnotes):
D&M = 1/78 Dames & Moore "Environmental Report, White Mesa Uranium Project", Appendix H (1/17/78 Dames & Moore entitled "Report Site Selection and Design Study Tailings Retention and Mill Facilities White Mesa Uranium Project Blanding, Utah for Energy Fuels Nuclear, Inc.", Appendix A, Plates A-3 thru A-11);
Peel = 6/94 Peel Enviromental Services, Umetco Minerals Corp., "Ground Water Study, White Mesa Facility";
H-E = 7/91 Hydro-Engineering, "Ground-Water Hydrology at the White Mesa Tailings Facility";
D'A = 2/81 D'Appolonia Consulting Engineers, "Assessment of the Water Supply System, White Mesa Project"
IUC = 5/28/99 IUC GW Information Report, Tables C-5 and C-6.

Cell: J5
Comment: Gal/acre/day = ft3/ft2/yr * 7.48052 gal/ft3 * 43,560 ft2/acre * 1 yr/365.25 day

(ft3/ft2/yr = ft/yr)

Cell: D27
Comment: MW-18, Test Interval 27 - 32 feet: review of well completion diagram and geologic log indicates this depth interval corresponds to the Dakota Sandstone (Kds). However, the 7/94 Titan Environmental Report, listed it as Burro Canyon Formation (Kbc).

Cell: H30
Comment: ft/yr = gal/day/ft^2 * 1ft^3/7.48052gal * 365.25day/yr = ft/yr

Cell: I30
Comment: cm/sec = ft/yr * 12inch/ft * 2.54cm/inch * 1yr/365.25day * 1day/24hr * 1hr/60min * 1min/60sec = cm/sec

Cell: K53
Comment: Boring No. 9, Injection Test Interval 107.5 - 132 (TD) ft: boring log reports pale green sandy claystone from 107.7 to 108.2 feet. This lithology appears to be the Brush Basin Member of the Morrison Formation (Jmb).

Cell: C60
Comment: MW-1 Recovery Test: Peel data re-analyzed by Titan Environmental

Cell: C62
Comment: MW-3 Recovery Test: Peel data re-analyzed by Titan Environmental

Cell: C64
Comment: MW-5 Recovery Test: H-E data re-analyzed by Titan Environmental

Cell: C65
Comment: MW-5 Recovery Test: Peel data re-analyzed by Titan Environmental

Cell: C66
Comment: MW-11 Recovery Test: H-E data re-analyzed by Titan Environmental

Cell: C67
Comment: MW-3 Recovery Test: Peel data re-analyzed by Titan Environmental

Cell: C68
Comment: MW-12 Recovery Test: H-E data re-analyzed by Titan Environmental

Cell: C69
Comment: MW-12 Recovery Test: Peel data re-analyzed by Titan Environmental

Cell: H70
Comment: MW-14: highest permeability value from early portion of test data. Lowest value from late test data.

Cell: H71
Comment: MW-14: highest permeability value from early portion of test data. Lowest value from late test data.

Cell: C74
Comment: MW-15: Recovery Test: Peel data re-analyzed by Titan Environmental

Cell: H87
Comment: ft/yr = gal/day/ft^2 * 1ft^3/7.48052gal * 365.25day/yr = ft/yr

Cell: I87
Comment: cm/sec = ft/yr * 12inch/ft * 2.54cm/inch * 1yr/365.25day * 1day/24hr * 1hr/60min * 1min/60sec = cm/sec

Cell: H104
Comment: ft/yr = cm/sec * 1inch/2.54cm * 1ft/12inch * 60sec/min * 60min/hr *24hr/day * 365.25day/yr = ft/yr

Cell: H111
Comment: ft/yr = gal/day/ft^2 * 1ft^3/7.48052gal * 365.25day/yr = ft/yr

Cell: I111
Comment: cm/sec = ft/yr * 12inch/ft * 2.54cm/inch * 1yr/365.25day * 1day/24hr * 1hr/60min * 1min/60sec = cm/sec

Cell: H116
Comment: ft/yr = gal/day/ft^2 * 1ft^3/7.48052gal * 365.25day/yr = ft/yr

Cell: I116
Comment: cm/sec = ft/yr * 12inch/ft * 2.54cm/inch * 1yr/365.25day * 1day/24hr * 1hr/60min * 1min/60sec = cm/sec

Cell: H127
Comment: ft/yr = gal/day/ft^2 * 1ft^3/7.48052gal * 365.25day/yr = ft/yr

Cell: I127
Comment: cm/sec = ft/yr * 12inch/ft * 2.54cm/inch * 1yr/365.25day * 1day/24hr * 1hr/60min * 1min/60sec = cm/sec

ATTACHMENT 2

Utah Division of Radiation Control

Summary of
Estimated Static Loads
on Flexible Membrane Liners
at IUC White Mesa Uranium Mill
Tailings Cells Nos. 1 thru 4

DRC Spreadsheet CellEng.XLS
Tabsheet StaticLoad

IUC Tailings Cells: Static Load on FML

design data from 2/82 D'Appolonia Design Report, Sheet 8 of 16

Tailings Cell	Tailings Elevations @ Hinge Point: Top (ft, amsl)	Tailings Elevations @ Hinge Point: Floor (ft, amsl)	Tailings Height (ft)	Reported Dry Bulk Density (lb/ft^3)	Dry Load on FML (lb/ft2)	Estimated Saturated Porosity (vol/vol)	Water Load on FML (lb/ft2)	Total Load on FML (lb/ft2)
dry density from 2/82 D'Appolonia Design Report (Cells 1 & 2), p. 2-2								
1	n/a	n/a						
2	5,614	5,583	31	92	2,852	0.44	851	3,703
3	5,608	5,573	35	92	3,220	0.44	961	4,181
4	5,593	5,556	37	92	3,404	0.44	1,016	4,420
dry density from 5/81 D'Appolonia Engineering Design Report (Cell 3), p. 1-2								
1	n/a	n/a						
2	5,614	5,583	31	80	2,480	0.44	851	3,331
3	5,608	5,573	35	80	2,800	0.44	961	3,761
4	5,593	5,556	37	80	2,960	0.44	1,016	3,976

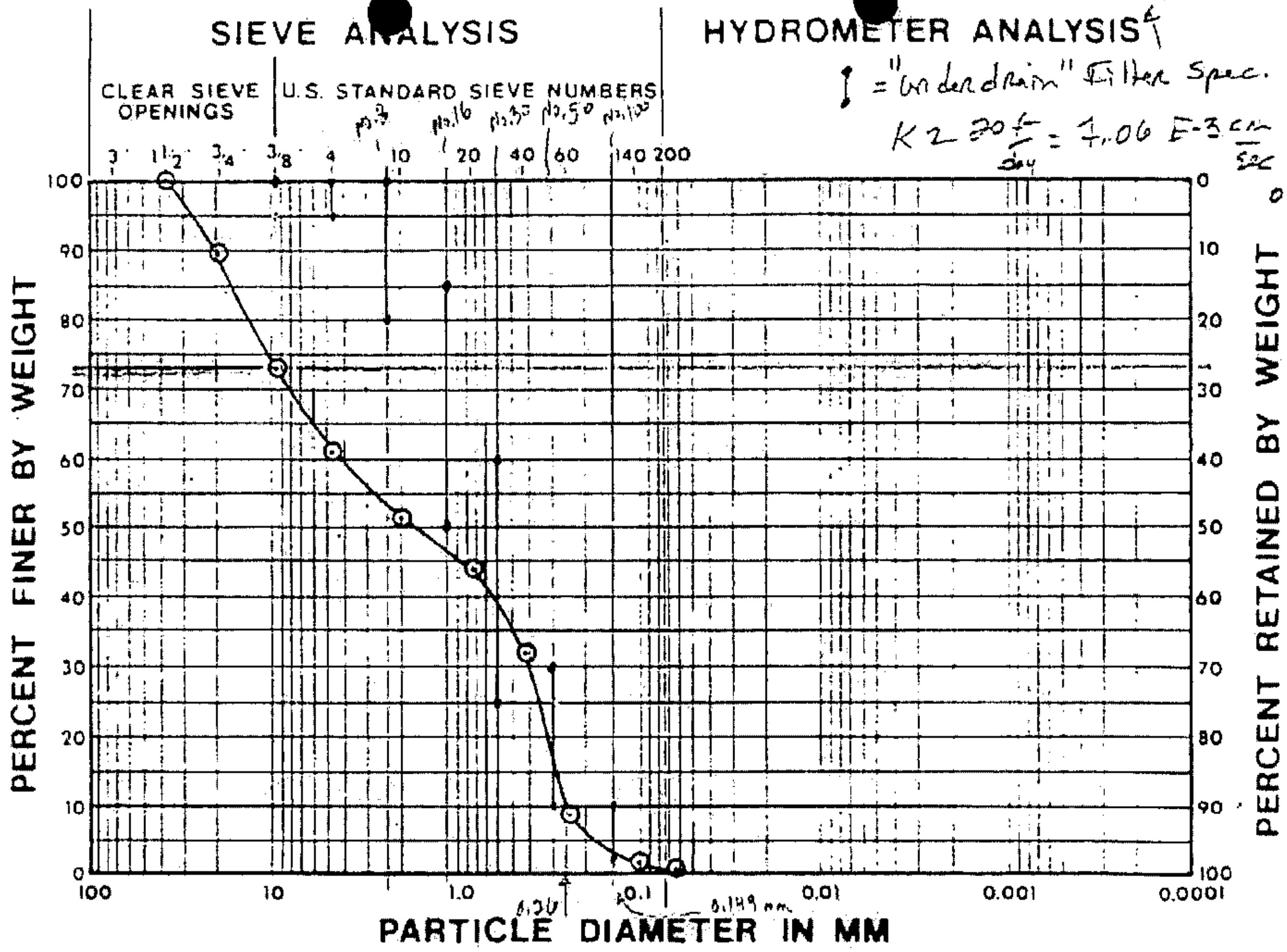
ATTACHMENT 3

Utah Division of Radiation Control

Plot of IUC Tailings Cells 2 and 3
Under drain Filter Gradation
and Comparison with IUC Reported
FML Bedding Layer Gradation

Modified from
2/82 D'Appolonia Consulting Engineers Report
Figure 13.

Bldg D'Appolonia Report
Appendix E p. E-5



COBBLES	GRAVEL		SAND			SILT AND CLAY FRACTION
	coarse	fine	coarse	medium	fine	

SYMBOL	BORING	SAMPLE	DEPTH	SOIL DESCRIPTION	U.S.C.S.	L.L.	P.L.	W.%
—⊙—	—	—	—	SAND, SOME GRAVEL	SP	0.25	16	—

K ≈ 40 ft/day = 1.41 E-2 cm/sec
4

(from U.S. DOT "Highway Subdrainage Design, July 1990, Fig. 28, from:
1) % passing No. 200 sieve = 1%
2) D_{10} = 0.26 mm
3) Dry Density = 114.5 lb/ft³ (9x9)

In-place bedding material (p. 3-3)

FIGURE 13

GRAIN SIZE ANALYSIS
BEDDING MATERIAL

PREPARED FOR

ENERGY FUELS NUCLEAR, INC.
DENVER, COLORADO

D'APPOLONIA

DRAWN BY C... 2/10/82 | CHECKED BY CEY 2/11/82 | APPROVED BY WJ 2/11/82 | DRAWING NUMBER RM78-682-A41

Drain Filter k = estimated from U.S. DOT "Highway Subdrainage Design", Fig. 28

based on: 1) 1% passing No. 200 sieve

2) D_{10} = No. 100 sieve (0.149 mm)

3) Dry Density = 114 $\frac{lb}{ft^3}$ (see 3/83 EFN Cell 3 As-Built Report, p. 3-5)

ATTACHMENT 4

Climate Summary Data for
Blanding, Utah
from the
Western Regional Climate Center

Internet Webpage Address:
http://www.wrcc.dri.edu/cgi-bin/cliRECtM.pl?utblan

BLANDING, UTAH (420738)

Period of Record Monthly Climate Summary

Period of Record : 12/8/1904 to 12/31/1999

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average Max. Temperature (F)	38.7	44.7	52.5	61.9	71.9	83.0	88.3	86.0	78.1	65.9	51.3	41.0	63.6
Average Min. Temperature (F)	16.6	22.0	27.5	34.0	41.7	50.4	57.6	55.9	48.0	37.7	26.4	18.9	36.4
Average Total Precipitation (in.)	1.37	1.18	1.01	0.88	0.73	0.47	1.19	1.40	1.26	1.46	1.05	1.37	13.38
Average Total SnowFall (in.)	11.2	7.5	4.3	2.0	0.2	0.0	0.0	0.0	0.0	0.3	3.4	10.3	39.3
Average Snow Depth (in.)	4	3	0	0	0	0	0	0	0	0	0	1	1

Percent of possible observations for period of record.
Max. Temp.: 96% Min. Temp.: 96.5% Precipitation: 96.8% Snowfall: 91.7% Snow Depth: 69.5%
Check Station Metadata or Metadata graphics for more detail about data completeness.

Western Regional Climate Center, wrcc@dri.edu

ATTACHMENT 5

Utah Division of Radiation Control

Estimate of IUC Cell 4A
Leak Detection System Efficiency

DRC Spreadsheet CellEng.XLS
Tabsheet Cell4aLDS

	A	B	C	D	E	F	G	H	I
1	**Cell 4A Leak Detection System Coverage**								
2	*8/88 Umetco Report, Western Engineers Drawing Sheet C4-4*								
3		Leak Detection System Coverage							
4				Design					
5			Approx.	Diam. Of	Area of		Approximate Cell 4A Floor Area		
6		LDS	Length	Influence	Influence		Length	Width	Area
7	No.	Drain Arm	(ft)	(ft)	(ft^2)		(ft)	(ft)	(ft^2)
8	1	West Outer	905	3.5	3,167.5		1,250	1,000	1,250,000
9	2	West Middle	720	3.5	2,520.0				
10	3	West Inner	450	3.5	1,575.0				
11	4	South Outer	1,165	3.5	4,077.5				
12	5	South Middle	930	3.5	3,255.0				
13	6	South Inner	610	3.5	2,135.0				
14	7	Central Lateral	1,000	3.5	3,500.0				
15									
16				Total:	20,230.0				
17									
18									
19			Ratio of Leak Detection Coverage to Floor Area:						0.016

Cell: C6

Comment: Approximate Drain Arm Length: from 8/88 Umetco Report, Western Engineers Design Drawing Sheet C4-4.

Cell: D6

Comment: Cell 4A Leak Detection System Pipeage Diameter of Influence: cross-section plans provided by IUC show that each LDS pipe was to be installed inside an 18 inch wide trench, lined with an FML (40 mil HDPE or 30 mil PVC). Engineering plan shows FML to extend a distance of 1 foot to either side of the pipe's trench. Consequently, total width across which leaks could be directed to the LDS collection pipe = 3.5 feet.