



INTERNATIONAL  
URANIUM (USA)  
CORPORATION

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November 9, 2001

**VIA OVERNIGHT MAIL**

Mr. William J. Sinclair  
Director, Division of Radiation Control  
Utah Department of Environmental Quality  
P.O. Box 144850  
168 North 1950 West  
Salt Lake City, UT 84114-4850

Re: Update report regarding IUSA's October 4, 2000 report on investigation of elevated Chloroform Concentrations in Perched Groundwater at the White Mesa Uranium Mill. Utah Division of Water Quality Notice of Violation and Groundwater Corrective Action Order; Docket No. UGW20-01.

Dear Mr. Sinclair:

This transmits International Uranium (USA) Corporation's ("IUSA's") Contaminant Investigation report entitled Update to Report - "Investigation of Elevated Chloroform Concentrations in Perched Groundwater at the White Mesa Uranium Mill near Blanding, Utah". This report is an update to the Contaminant Investigation Report (the "CIR") that IUSA submitted to the Utah Department of Environmental Quality ("UDEQ") on October 4, 2000 (IUSA and HGC, 2000), and addresses questions raised by UDEQ's letter to IUSA in response to the CIR dated June 7, 2001. Items addressed in this report are also pursuant to a meeting between IUSA and UDEQ on October 5, 2001.

Please note that this report includes a recommendation for installing two additional temporary wells, for the purpose of additional delineation of the areas of the perched zone containing chloroform, and in the locations discussed during the meeting with UDEQ. IUSA would like to install these two additional wells during the week of

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December 3, 2001, so that the wells can be sampled during the first quarter 2002 sampling event. Should you have any questions or comments concerning this or any other part of this report, please contact me at 303.389.4131.

Sincerely,



Michelle R. Rehmann  
Environmental Manager

cc/att: Larry Mize, UDEQ Division of Water Quality  
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**UPDATE TO REPORT  
“INVESTIGATION OF ELEVATED CHLOROFORM CONCENTRATIONS IN  
PERCHED GROUNDWATER AT THE WHITE MESA URANIUM MILL NEAR  
BLANDING, UTAH”**

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## 1. INTRODUCTION AND SUMMARY

International Uranium (USA) Corporation ("IUSA") submitted a Contaminant Investigation Report entitled "Investigation of Elevated Chloroform Concentrations in Perched Groundwater at the White Mesa Uranium Mill near Blanding, Utah" (the "CIR") to the Utah Department of Environmental Quality ("UDEQ") on October 4, 2000 (IUSA and HGC, 2000). This report has been prepared as an update to the CIR, and to address questions raised by UDEQ's letter to IUSA dated June 7, 2001 in response to the CIR. Items addressed in this report are also pursuant to a meeting between IUSA and UDEQ on October 5, 2001.

This report discusses analytical results to date, trends in chloroform concentrations in the vadose or perched water zones at the site, and additional delineation of the areas of the perched zone containing chloroform. This report also discusses the potential for degradation of chloroform in the perched water and the feasibility of enhancing in-situ reductive dechlorination of chloroform.

Important results of the investigation to date are that:

1. The data do not indicate that chloroform DNAPL exists at the site either in the vadose zone or the perched water zone.
- 2) The data do not indicate that a continuing chloroform source exists.
- 3) Data are consistent with the abandoned scale house leach field as the source for the MW-4 chloroform, and for the chloroform to have entered the perched water as a "slug" over a relatively short period of time (1-2 years).
- 4) Additional wells are needed to delineate the chloroform plume to the west and northwest of MW-4.

- 5) Rapid degradation of chloroform in the perched water is unlikely without enhancement.

Additional delineation of the chloroform in the perched water is proposed to be accomplished by adding two new temporary wells to the west and northwest of MW-4, and by vertical profile sampling in selected wells, to define the chloroform concentrations in three dimensions. Additional characterization of groundwater gradients in the northeast portion of the site, which have been changing and may affect chloroform migration in the perched water, will be accomplished by phased installation of piezometers. In addition, IUSA will continue to perform quarterly monitoring of chloroform and will transmit such data to the UDEQ in accordance with a schedule provided herein.

## 2. DNAPL ISSUES

UDEQ has expressed concern that dense, non-aqueous phase liquid (DNAPL) chloroform may exist in the vadose and perched water zones in the vicinity of MW-4 and the abandoned scale house leach field. This section uses existing soil gas and groundwater data from the site to demonstrate that DNAPL does not exist in either the vadose or perched water zones at the site, and that no evidence for continuing chloroform source exists.

### 2.1 Vertical Profiling of Existing Perched Wells

Initial sampling to evaluate the potential for stratification of chloroform concentrations was conducted in the fall of 1999, and reported in the CIR. As indicated in the CIR, multi-depth sampling of MW-4 was conducted during the week of September 27, 1999. Two samples were collected, one from the top of the water column (approximately 70-73 feet bls) and one from the base of the water column (approximately 117-120 feet bls). The shallow sample was collected first. Both samples were collected using disposable teflon bailers. Samples were collected without purging the well, to prevent disturbance of the water column.

Samples were collected in 40 ml VOA vials, with no headspace, capped, labeled, and stored in a cooler with blue ice at 4°C for shipment to the offsite analytical laboratory (Energy Laboratories, Casper, Wyoming). Chloroform was detected in the shallow sample at a concentration of 6,200 µg/L, and in the deep sample at a concentration of 5,820 µg/L. Because concentrations did not increase with depth, the presence of DNAPL (i.e., free chloroform product) was not indicated in MW-4.

As UDEQ has requested further evaluation of the vertical distribution of chloroform concentrations, a Sampling Plan, with the Data Quality Objective of evaluating the potential for stratification of chloroform concentrations in the Chloroform Investigation wells, will be developed. This Sampling Plan will include the following key features:

- Procedure to collect samples from discrete depths using disposable bailers with double check valves
  - Requirements for field records
  - Methodology for evaluation of results
  - Evaluation of the feasibility of testing experimental USGS procedure using passive diffusion bags in at least one well, to provide comparison to conventional method results
- 
- This sampling will take place in the first quarter of 2002

Appendix A contains manufacturer specifications for disposable bailer designed to collect samples from discrete intervals in groundwater.

## **2.2 Potential for DNAPL to Exist in the Vadose Zone**

Soil gas sampling is a useful means to detect the presence of pure phase volatile organic compounds (VOC) that reside in the vadose zone. This applies to chloroform, which has a vapor pressure of 160 mm Hg. As discussed in Appendix B, soil gas concentrations in excess of 10% of a VOC pure phase saturated vapor pressure are indicative of the presence of the pure phase. For chloroform, soil gas concentrations in excess of 100,000  $\mu\text{g/L}$  would be indicative of pure phase.

The possibility that residual pure phase chloroform exists as a DNAPL within the vadose

zone beneath the abandoned scale house leach field is not supported by the trace level soil gas chloroform concentrations measured in the vicinity in 1999 ( $<1 \mu\text{g/L}$ ). The measured concentrations are indicative of low concentrations of chloroform dissolved in vadose pore waters. Furthermore, the possibility that DNAPL exists within the perched zone is not supported by the relatively low chloroform concentrations detected at wells TW4-5 and TW4-9, which are the temporary wells located closest to the leach field (Figure 1).

### **2.3 Evaluation of the Potential for DNAPL to Exist in the Saturated Zone**

The possibility that chloroform DNAPL may exist in the perched zone beneath the abandoned scale house leach field and/or may traveled downgradient along the Brushy Basin contact toward MW-4 is remote. This possibility is not supported by data collected from the temporary perched wells at the site or from MW-4.

#### **2.3.1 Detected Concentrations with Respect to Chloroform Solubility**

Perched water chloroform concentrations exceeding 1% of the solubility of chloroform (8,000-10,000 mg/l) would have to exist to indicate the presence of DNAPL (Cohen and Mercer, 1993). The highest groundwater concentrations detected at the site ( $<7 \text{ mg/L}$ ) are more than 3 orders of magnitude lower than the solubility of chloroform. While the solubility of chloroform in the perched water may be slightly depressed by the presence of trace concentrations of carbon tetrachloride (500 mg/L dissolved in the pure chloroform used in the ore assay lab as suggested in UDEQ's June 7, 2001 letter to IUSA) and by the presence of inorganic solutes in the perched water, as detailed below, it can be demonstrated that this depression is not significant.

The effect of 500 mg/l carbon tetrachloride contaminant on the solubility of chloroform used at the site would be negligible, potentially lowering the solubility by less than 0.05%, because the mole fraction of carbon tetrachloride in the mixture would be less than 0.05%. The presence of significant concentrations of other solvents in perched groundwater near MW-4, which could potentially lower the solubility of chloroform, is not supported by past analytical results. Furthermore, as detailed below, the impact of salinity on chloroform solubility, which will depend on the concentrations of salts in the water, is also not significant.

The solubility of a neutral organic compound such as chloroform in water containing dissolved inorganic salts is generally lowered as the concentration of the inorganic salts increases (Schwarzenbach, 1993; Garrels and Christ, 1965; and Harned and Owen, 1950). The depression of solubility is generally not significant, unless the concentration of the salts is greater than about 0.1 molar (M). At MW-4, the dominant anion is sulfate, which averages approximately 2,000 mg/l, or 0.021M, based on data presented in TITAN, 1994. The average concentrations of chloride, sodium, calcium, and potassium ions average approximately 0.0013M, 0.014M, 0.010M, and 0.0003M, respectively, at MW-4. These concentrations are too low to have a significant effect on the solubility of chloroform in the perched water, at most reducing solubility by a few percent. Even in seawater, where salt concentrations are orders of magnitude higher than in the perched water, the depression of solubility of neutral organic compounds is typically less than a factor of 2 (Schwarzenbach, 1993).

Schwarzenbach, 1993, provides a methodology for estimating the impact of salinity on the solubility of neutral organic compounds. Salting constants ( $K_s$ ) for various types of salts are provided, with the highest that of sodium sulfate ( $K_s = 0.55$ ). Using the formula provided in Schwarzenbach,

$$C_{w+salt}^{sat} = 10^{-K_s \cdot [salt]} \cdot C_w^{sat}$$

where  $C_{w+salt}^{sat}$  = solubility of neutral organic compound in salty water,

$K_s$  = salting constant,

$C_w^{sat}$  = solubility of neutral organic compound in pure water,

and assuming that

$K_s = 0.55$ , and

$[salt] = [SO_4] = 0.021M$ ,

the solubility of chloroform in perched water is calculated as  $0.975 C_w^{sat}$  or 97.5% of the solubility in pure water, a reduction in solubility of less than 3%.

The actual reduction in solubility is likely to be lower for chloroform, however, because the salting-out effect is lower for polar organic compounds (Schwarzenbach, 1993). Because chloroform is somewhat polar, owing to its asymmetry, which accounts for its high solubility (10 times that of carbon tetrachloride, which is non-polar), the actual depression of chloroform solubility in perched water is likely to be less than 2.5%. Because the estimated reduction in chloroform solubility is so small, and is nearly an order of magnitude lower than typical laboratory analytical error of  $\pm 20\%$ , the effect of perched water salinity on the solubility of chloroform can be ignored.

Furthermore, the assumption that DNAPL is not indicated unless dissolved groundwater concentrations greater than 1% of the solubility of the pure product are detected (Cohen and Mercer, 1993) is considered reliable because the lowering of solubility by other factors such as the presence of other solvents, is taken into account in this assumption.

### 2.3.2 Comparison of MW-4 to Nearby Temporary Wells

Chloroform concentrations in the past have been higher at MW-4 in comparison with nearby temporary wells, although these differences have been slight in recent sampling events. The differences do not indicate DNAPL that may be present at MW-4 or that these differences result from well construction factors, possibilities suggested in UDEQ's June 7, 2001 letter.

Recently measured chloroform concentrations at MW-4 are not significantly higher than at nearby temporary wells. Concentrations at TW4-1 and TW4-2, located immediately downgradient and upgradient, respectively, of MW-4, are within approximately 5% and 12%, respectively, of concentrations at MW-4 as of the June 2001 sampling (Figure 1). Concentrations at MW-4 are within 8% of concentrations at TW4-2 in the September, 2001 sampling. (Concentrations between MW-4 and TW4-1 cannot be compared for the September, 2001 sampling because the TW4-1 sample vial broke in transit to the laboratory and no analysis was performed). These results suggest that differences in concentrations are more likely the result of recovery than well construction factors or the potential presence of DNAPL at MW-4 as suggested by UDEQ. Differences in concentration between MW-4 and nearby temporary wells would be expected to be much larger if DNAPL were present near MW-4. The slightly lower concentrations at the nearby temporary wells, and the reduction in the differences in nearby temporary wells relative to MW-4 over time are consistent with recovery of temporary wells from the air rotary drilling process (as discussed in Section 3). In other words, the reason that MW-4 has had the highest concentrations is more likely due to its age rather than construction.

Furthermore, it is highly unlikely that chloroform DNAPL could have migrated more than 1,200 feet from the source area (the abandoned scale house leach field) to the vicinity of MW-4. The Burro Canyon/Brushy Basin contact is an erosional surface with numerous small-

scale irregularities that would prevent movement of any DNAPL very far from the source area. Even if small scale irregularities did not prevent the movement, the farther the DNAPL moved from the source area, the more spread out it would become, exposing more surface area to the groundwater and making it easier to dissolve. Also, it can be demonstrated that more than sufficient volume of water has passed beneath the abandoned leach field source area to have dissolved all of the chloroform potentially disposed there.

Assuming the following conditions,

Width of abandoned leach field =	20 feet
Average saturated thickness =	30 feet (conservative)
Average hydraulic gradient =	0.016 ft/ft
Average hydraulic conductivity =	1 ft/day

Approximately 520,000 gallons of perched water have passed beneath the leach field over the past 20 years. (The average hydraulic conductivity was based on the results of a pump test at MW-4 in 1999, which yielded a transmissivity of 38.4 ft<sup>2</sup>/day. Dividing this by the saturated thickness of the perched zone at that time, approximately 40 feet based on a depth to the Brushy Basin of 108 feet bls depicted in the geophysical log of MW-4, yields an average hydraulic conductivity of 1 foot/day.) Assuming a solubility of chloroform of 8,000 mg/l, or 5 x 10<sup>-3</sup> gallon chloroform/gallon water, sufficient perched water has flowed beneath the source area to have dissolved more than 10 times the amount potentially used in the ore assay laboratory.

### 2.3.3 Vertical Profiling of MW-4

As stated above under 2.1, previous vertical profile sampling of MW-4 in 1999 did not indicate that concentrations increased with depth, as would be expected if DNAPL existed near MW-4.

Samples were collected from depths of approximately 71 feet bls (approximately 2 feet below the top of the water column) and from near the base of the well (approximately 118 feet bls) using a disposable bailer. The shallow sample was collected first, then the deep sample. If chloroform DNAPL were present at the base of the well, concentrations would be expected to be significantly higher there than at the top of the water column. Instead, sampling results showed no significant difference in concentration between the deep and shallow samples. Chloroform was detected at a concentration of 6,200 µg/L in the shallow sample and a concentration of 5,280 µg/L in the deep sample.

More rigorous vertical profile sampling of MW-4 is proposed to characterize the vertical distribution of chloroform concentrations at the site as discussed above in Section 2.1.

#### **2.4 Brushy Basin Contact**

UDEQ has expressed concern that the Brushy Basin contact at MW-4 may be depressed and may harbor a pool of chloroform DNAPL. This concern is based on a reported contact depth of 125 ft below land surface (bls) at MW-4. However, the Brushy Basin contact at MW-4 is considered to be at a depth of 108 ft bls based on lithologic logs of nearby temporary wells TW4-1, TW4-2, TW4-7 and TW4-8, and on the geophysical log for MW-4 provided in TITAN, 1994.

The geophysical log for MW-4 provided in TITAN, 1994, depicts the Burro Canyon/Brushy Basin contact at 108 ft bls. This depth is consistent with the lithologic logs of nearby temporary perched monitoring wells TW4-1, TW4-2, TW4-7, and TW-4-8, which depict the contact at approximately 103 ft, 105 ft, 98 ft, and 105 ft bls, respectively. This would place the base of the screened interval of MW-4, which extends to 112 ft bls, approximately 4 feet below the contact.

The 125 foot depth that has been previously reported for the Brushy Basin at MW-4 is apparently based on the well completion diagram provided in TITAN, 1994, which depicts a contact between "sandstone" and "claystone" at 125 ft bls. However, no additional lithologic information is provided to indicate whether the "sandstone" is continuous from the surface to 125 ft bls, or whether the "sandstone" is a lens or layer encountered within the Brushy Basin. The formation names are also not designated on the diagram.

During drilling of temporary wells TW4-3 and TW4-7, the borings were extended into the Brushy Basin to characterize the lithology of the uppermost portion of the formation. Thin layers or lenses of sandstone and/or conglomeratic sandstone were found at a depth of approximately 108-112 ft bls in TW4-7, 10 feet below the Brushy Basin contact, and depths of approximately 125-132 ft bls in TW4-3, 25 feet below the contact. These lenses or layers in the Brushy Basin were separated from the base of the Burro Canyon by shales, siltstones and claystones. These low permeability materials would hydraulically isolate the lenses or layers of sandy/conglomeratic material within the Brushy Basin from the Burro Canyon.

With regard to the geophysical log of MW-4, there is a clear response in the natural gamma at 108 ft bls. This response is also consistent with the natural gamma response at the Brushy Basin contact as depicted in other geophysical logs at the site and is consistent with the lithology logged at nearby temporary wells. Because the geophysical log depicts the Brushy Basin contact at 108 ft bls in MW-4 and because this is consistent with lithologic logs of nearby temporary wells, the 108 foot depth is considered reliable.

Therefore, any DNAPL potentially present near MW-4 would be expected to enter the well screen, and to raise the measured chloroform concentrations at MW-4 nearer the solubility

of chloroform (8,000-10,000 mg/l). Because the measured concentrations of chloroform at MW-4 are more than 3 orders of magnitude lower than the solubility, no DNAPL is indicated. Furthermore, if DNAPL were present near MW-4, concentrations should be at least one to two orders of magnitude higher than at TW4-1, TW4-2 and TW4-4, rather than only 5%, 12%, and 48% higher as of the June, 2001 sampling.

Installation of an exploratory boring near MW-4 as suggested by UDEQ to characterize the contact is not considered necessary based on the geophysical log of MW-4 provided in TITAN, 1994, the lithologic logs of nearby temporary wells, and the lack of evidence for DNAPL in the analytical data. The depth to Brushy Basin of 108 feet bls depicted on the geophysical log of MW-4 is consistent with the depths provided in the nearby lithologic logs and is considered reliable.

A contour map of the top of the Brushy Basin, using the 108 ft depth at MW-4, is provided in Figure 2.

### 3. ADDITIONAL PLUME DELINEATION

UDEQ has expressed concern that more temporary perched wells are needed to define the extent of chloroform in the perched water, and that piezometers are needed in the northeast portion of the site to better define changing water level gradients and to identify sources of recharge. This section discussed the distribution of chloroform in the perched water both spatially and temporally, the need for new temporary wells to the west and northwest of MW-4 based on observed trends in the chloroform data, and the relationship of chloroform to nitrate which is consistent with a leach field origin.

#### 3.1 Analytical Results from Temporary Wells

Chloroform analytical results for MW-4 and temporary wells are shown in Figure 1. The chloroform plume is bounded to the south (downgradient) by non-detect results at TW4-6, although the recent detection of 3.6 µg/L chloroform at TW4-6 may indicate arrival of chloroform at that well. The upgradient well (TW4-5) and lateral wells (TW4-7 and TW4-8) show chloroform concentrations in excess of 100 µg/L, although concentrations at these wells are much lower than at MW-4, TW4-1 and TW4-2.

The increases in concentration detected in most of the temporary wells after installation are most likely related to recovery of concentrations that were lowered as a result of the air rotary drilling method, and the generally long recovery times expected when wells are installed in low permeability formations. Temporary wells located downgradient (south) of MW-4 are affected by both the recovery process and by continued southerly migration of the chloroform

plume. These and other temporal trends will be discussed further in Section 3.5. IUSA will continue to monitor and report results to the UDEQ.

### **3.2 Hydraulic Gradient in the Vicinity of MW-4**

The hydraulic gradient in the vicinity of MW-4 has historically been to the south (IUSA and HGC, 2000). Recent water level contour maps are provided in Figures 3 and 4.

The change in water levels and change in hydraulic gradient to a more westerly direction in the vicinity of the abandoned leach field are recent, and the direction of the hydraulic gradient during most of the period of migration of the plume was southerly. A southerly gradient still exists near MW-4 and at the downgradient edge of the plume. The recently detected more westerly hydraulic gradient near the scale house leach field is of no concern unless a residual chloroform source is present, but the assumption of a residual source is not supported by any of the soil gas or groundwater data collected to date. IUSA plans to install piezometers, in a phased fashion, in the northeast portion of the site to further investigate the increase in water levels and change in hydraulic gradient. This work will be described in a report to UDEQ due on November 16, 2001.

The water level map provided by UDEQ in their June 7, 2001 letter to IUSA indicates a concern as to whether or not there may be a possible groundwater mound near MW-4.

This feature is likely not a mound but the result of locally semi-confined conditions related to the stratigraphy of the perched zone. This type of feature is common in water table aquifers even where the hosting lithology consists of unconsolidated layered sands and gravels

with local interbeds of silt and clay. These small-scale fluctuations in the regional flow field can be ignored when considering the large scale flow of groundwater and transport of solutes.

### **3.3 Need for Additional Wells to Delineate Chloroform in the Perched Zone**

The vertical dimension of the chloroform in perched water will be addressed by vertical profile sampling as discussed in Section 2.1. The lateral dimension of the plume is defined in large part by the existing temporary well network but further delineation is likely needed to the west and northwest of MW-4. Additional downgradient delineation may be needed in the future as the plume continues to move to the south.

UDEQ provided a chloroform isoconcentration map in its June 7, 2001 letter to IUSA. While this map indicates that further lateral delineation of the plume is needed, to the west and northwest of MW-4, the chloroform isoconcentration map prepared by UDEQ displays a number of features that are not hydrogeologically reasonable. These features are related to:

- 1) Non-uniform distribution of input data leading to unavoidable errors in computer gridding and contouring unless specific measures are taken to counteract them,
- 2) The impossibility of providing hydrogeologic input to the computer gridding and contouring algorithm such as, for example, historical groundwater gradient information, and
- 3) The assignment of detectable chloroform concentrations to downgradient wells that have always been non-detect for chloroform

Some of the resulting erroneous features displayed in the map include the following:

- 1) The depicted plume extends farther cross-gradient and up-gradient than down-gradient which is not hydrogeologically reasonable.

- 2) The detectable chloroform isoconcentration contours extend up to and beyond wells that have always been non-detect for chloroform, which is not hydrogeologically reasonable.
- 3) "Bulls eye" features occur that are related to the non-uniform distribution of data, choice of gridding parameters, and unavoidable limitations of the gridding and contouring package. There is no hydrogeologic mechanism that can result in such features.
- 4) Unless chloroform is actually detected at the downgradient wells, the downgradient edge of the plume will always be at or just beyond these same wells that are non-detect for chloroform, resulting in a plume whose extent is time independent. This is not hydrogeologically reasonable unless a steady-state condition has been reached.

The apparent northwest trend in the isoconcentration contours in the map produced by UDEQ is an artifact resulting partly from the well density west and northwest of MW-4, and partly from the non-uniform distribution of data, the lack of hydrogeologic input in producing the map, and the assignment of detectable chloroform concentrations to wells that have been non-detect for chloroform.

IUSA proposes to install two new temporary wells to the west and northwest of MW-4, as shown in Figure 5, to help delineate the extent of the plume to the west and northwest where control is poor. Additional wells to the east and south may be considered at a later time based on the results of continued monitoring at the site.

### **3.4 Temporal Trends in Chloroform Concentrations and Relationship to Nitrate**

Figure 1 shows the chloroform concentrations over time measured in MW-4 and temporary wells near MW-4. As discussed in section 3.1, initial increases in most of the temporary wells are likely related to recovery from the drilling process which used primarily air as a drilling fluid, and small amounts of water as needed to maintain circulation. Increases at wells upgradient (north) of MW-4 are most likely due to recovery alone, while downgradient

wells (south of MW-4) are expected to respond to both recovery and continued downgradient (southerly) plume movement. For example, the rapid increase in concentration at TW4-1 after installation could not likely have resulted from recovery alone, but must also have resulted from movement of the leading edge of the plume past that well. Increases in concentration from non-detect to 3,200 µg/L at TW4-4 are also likely to have resulted primarily from continued plume movement to the south.

Concentrations at upgradient wells TW4-5, TW4-9, and TW4-3 have stabilized or decreased after the initial increase related to recovery. Concentrations at lateral wells TW4-7 and TW4-9 are stabilizing. These trends are consistent with the initial interpretation of a "slug" of chloroform entering the perched water over a relatively short period of time (1-2 years) and migrating downgradient toward MW-4, TW4-1, and TW4-4. The width of the plume near MW-4 will be addressed by the installation of two new temporary wells to the west and northwest of MW-4.

Figure 6 is a plot of nitrate concentrations over time at MW-4 and the temporary wells. There is a clear correlation between chloroform and nitrate concentrations which is consistent with a leach field origin. Figure 7 is a scatterplot of chloroform vs. nitrate through the June, 2001 sampling, which illustrates this correlation.

#### **4. COORDINATES REQUESTED BY UDEQ**

A copy of estimated coordinates for the following locations was previously transmitted to UDEQ on September 7, 2001, and was provided during the meeting on October 5. They are also provided in this report in Appendix C.

- Former mill office building sanitary leach field,
- Former mill office building laboratory wastewater holding tank and pipeline to Evaporation Cell 1.
- Former office trash disposal area

## 5. PERCHED ZONE PERMEABILITY

UDEQ has expressed concern about the permeabilities derived from the hydraulic tests at MW-4, and whether chloroform could have migrated from the abandoned scale house leach field to MW-4, and whether chloroform could have migrated from the abandoned scale house leach field to MW-4 via conglomeratic materials logged in temporary wells at the site, as suggested in the CIR. This section discussed the results of hydraulic testing at MW-4, the probable coincidence of a high permeability zone evident in the MW-4 test data with conglomeratic materials logged in nearby temporary wells, and the likelihood that these conglomeratic materials influence the flow of perched water and transport of chloroform near MW-4.

### 5.1 Permeability Distribution of the Perched Zone

An updated perched zone permeability map is provided in Figure 8. The permeabilities plotted on the map are based on the results of pump and slug tests where available, or on constant head packer tests within the perched zone. Test results by Peel were used where available, except the value plotted for MW-4 ( $3.5 \times 10^{-4}$  cm/s), which was based on a transmissivity of 38 ft<sup>2</sup>/day measured during a 1999 pump test by HGC. The saturated thickness at that time was calculated as 39 feet assuming a Brushy Basin contact at 108 ft bls. A detailed discussion of tests at MW-4 will be provided in a report to UDEQ due on November 16.

### 5.2 Conglomeratic Zone Near MW-4

Varying thicknesses of conglomeratic material are present below the water table in all temporary wells north of TW4-1 (Figure 9). The base of this zone is approximately 95 feet bls in TW4-1, and TW4-2, and approximately 88 ft bls in TW4-7. A higher permeability zone with a base at a depth of approximately 95 feet below top of casing (btoc) is evident in the drawdown data collected during a pump test by Peel at MW-4 in 1992 (UMETCO, 1994). During the first

3 hours of pumping at a constant rate of 0.46 gpm, only about 2 ½ feet of drawdown was measured. Then, as water levels dropped below approximately 95 feet btoc, the rate of drawdown increased by about a factor of 30. Similar behavior occurred in a test conducted at 0.92 gpm, except that the break in slope occurred in about half the time. This behavior is consistent with dewatering of a higher permeability zone having a base at 95 feet btoc near MW-4 at about 3 hours into the test. This zone most likely coincides with the conglomeratic zone logged at nearby temporary wells. Because this conglomeratic zone is present below the water table at all wells north (upgradient) of TW4-1, and has a relatively high permeability based on the pump tests at MW-4, it likely influences the flow of the perched water, and therefore the transport of chloroform, in the vicinity. Furthermore, the least productive temporary wells at the site, TW4-4 and TW4-6, have very thin conglomeratic zones that are located above the water table where they cannot at present affect the movement of perched water at the site.

A detailed discussion of tests at MW-4 and interpretation of results will be provided in a report to UDEQ due November 16.

## 6. ONGOING GROUNDWATER MONITORING AND REPORTING

As stated in Section 5.1 of the CIR, the sampling results to date indicate that elevated chloroform concentrations are confined to a relatively narrow zone. Elevated chloroform concentrations have not moved significantly downgradient of TW4-4.

To ensure that samples collected from the temporary wells are representative of the perched groundwater, continued monitoring has been performed on a quarterly basis in the temporary wells (TWs) and in MW-4. Measurements have included depth to water, electrical conductivity, temperature, pH, and chloroform concentration. Nitrate has also been measured in temporary wells TW4-1, TW4-3, and TW4-4.

Continued potential movement of the elevated chloroform concentrations is being monitored using the new temporary wells, TW 4-4 and TW 4-6 located downgradient of TW 4-1. Also, based on hydraulic conductivity estimates at MW-4, and the magnitude of the groundwater gradient, the travel times can be used to estimate the effective porosity of the perched zone in this vicinity.

IUSA will continue to collect chloroform data for all of the wells involved in the chloroform investigation, including well MW-4, all the existing TW-4 series wells, and all future monitoring wells that are installed to delineate the area of chloroform contamination.

Table 1 is a summary of data collected to date from the TW-4 series wells. Quarterly analytical results which were not previously transmitted to UDEQ in split sampling data

packages for data collected since the transmittal of the CIR to the present are included in Appendix D.

To ensure adequate time for sample analysis, laboratory data validation, IUSA data validation, and reporting, IUSA proposes to submit the data, together with the quarterly summary report, to UDEQ in accordance with the following schedule:

<u>Quarter</u>	<u>Submittal Due Date</u>
January - March	May 30
April - June	August 30
July - September	November 30
October - December	February 30

## **7. ADDITIONAL GROUNDWATER MONITORING PARAMETERS**

The primary purpose for measuring additional groundwater parameters within and near the chloroform plume should be to establish the likelihood that chloroform is degrading naturally (either chemically or biologically) within the perched water.

The natural degradation pathway for chloroform is for chlorine atoms to be successively replaced by hydrogen under anaerobic, reducing conditions, via reductive dechlorination. Chloroform will degrade to its daughter product, dichloromethane (DCM) under these conditions, and may ultimately degrade to methane. The presence or absence of DCM would help establish whether or not this process is occurring at a significant rate.

The presence of nitrate concentrations in the perched water near MW-4 that are generally higher than the chloroform concentrations, however, indicates that groundwater conditions are not presently favorable for this process. Under conditions favorable for reductive dechlorination, nitrate will also be expected to degrade, and at a higher rate than chloroform. For this reason, existing analytical data provides an indirect estimate of redox conditions, which do not appear favorable for reductive chlorination.

### **7.1 Dichloromethane Analytical Results From Split Sampling**

Previous split sampling analytical results indicate that DCM is not present in perched water near MW-4 at detectable concentrations (1 µg/L). This is consistent with conditions that are not favorable for reductive dechlorination of chloroform.

## **7.2 Direct Measurement of Redox Conditions in the Field**

At UDEQ's request, IUSA had evaluated the feasibility of obtaining relatively reliable measurements of reduction-oxidation potential (redox, or ORP) for groundwater, using field instruments. As described in the U.S.G.S. Field Manual, Chapter 6.5, in contrast to other field measurements, the determination of redox "should not be considered a routine measurement" and is "not recommended in general because of the difficulties inherent in its theoretical concept and its practical measurement" (see Appendix D). The U.S.G.S. notes that "Eh measurement may show qualitative trends, but generally cannot be interpreted as equilibrium values". Hydrolab Corporation, the supplier of the Hydrolab Surveyor 4a Instrument currently being used at the Mill for field measurement of pH, temperature, and electrical conductivity in groundwater, has indicated that the instrument's available redox electrode, which can be retrofitted to the Mill's instrument, has somewhat improved capability of measuring redox, as compared with earlier models. Hydrolab's Tech Note 204 listing parameter specifications is included in Appendix D. Response time is not specified on Tech Note 204, and IUSA will need to establish a procedure to determine at what point the redox value would be selected. Also, to avoid potential exposure to quinhydrone, the Mill would use Zobell solution to calibrate the new redox electrode, after it has been added to the instrument.

## **7.3 Feasibility of Enhancing Reductive Dechlorination In-Situ**

Reductive dechlorination can be enhanced in-situ by adding substances such as hydrogen release compound, or substances that accomplish the same purpose such as molasses or ethyl alcohol, which release hydrogen during fermentation (Odom, Martin J et al, 1995), and mixing

them with the perched water. The mixing process will be facilitated at the site because temporary wells currently exist along almost the entire extent of the chloroform plume, with a number of wells completed in that portion of the plume with the highest chloroform concentrations. Existing data indicate that this process will be feasible, however additional data will be collected prior to making a final determination of the feasibility and developing a work plan for implementation.

**TABLE 1**  
**MW-4 and Temporary Perched Well Completion and Analytical Parameters**

	TW4-1	TW4-2	TW4-3	TW4-4	TW4-5	TW4-6	TW4-7	TW4-8	TW4-9	MW-4
Approximate screened interval (feet bls)	70-110	80-120	67-97	72-112	80-120	57.5-97.5	80-120	85-125	80-120	92-112
Chloroform (µg/L) (1st sampling)	5.8	2,510	702	NS	29.5	NS	256	<1	4.2	NS
Chloroform (µg/L) (2nd sampling)	1,100	5,520	834	NS	49	NS	616	21.8	1.88	NS
Chloroform (µg/L) (3rd sampling)	1,490	NS	NS	NS	NS	NS	NS	NS	NS	NS
Chloroform (µg/L) (initial sampling of TW4-4 and TW4-6)	NS	NS	NS	<0.5	NS	<0.5	NS	NS	NS	NS
Chloroform (µg/L) (4th Sampling) (2nd sampling of TW4-4 and TW4-6)	2,230	5,220	836	<1	124	<1	698	102	14.2	NS
Chloroform (µg/L) (11/00 sampling)	3,440	4,220	836	3.85	255	<1	684	107	39.4	6,470
Chloroform (µg/L) (03/01 sampling)	2,340	3,890	347	2,260	236	<1	747	116	43.6	4,360
Chloroform (µg/L) (06/01 sampling)	6,000	5,500	390	3,100	240	<1	1,100	180	59	6,300
Chloroform (µg/L) (09/01 sampling)	NA	4,900	300	3,200	240	3.6	1,200	180	19	5,300
Nitrate (mg/L) (11/00 sampling)	7.79	10.7	1.97	1.02	3.16	<0.1	1.99	<0.1	<0.1	9.37
Nitrate (mg/L) (03/01 sampling)	7.15	10.2	1.85	14.5	3.88	0.13	2.46	<0.1	<0.1	8.77
Nitrate (mg/L) (06/01 sampling)	8.81	9.67	2.61	14.0	6.47	<0.1	2.65	<0.1	0.15	9.02

NS = not sampled

NA = not analyzed

## 8. REFERENCES

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- Harned, Herbert S and Benton B Owen. 1950. The Physical Chemistry of Electrolytic Solutions. American Chemical Society Monograph Series. Reinhold Publishing Corp.
- International Uranium (USA) Corporation, and Hydro Geo Chem (HGC), 2000. Investigation of Elevated Chloroform Concentrations in Perched Groundwater at the White Mesa Uranium Mill Near Blanding, Utah. Submitted to UDEQ.
- Odom, J Martin, Jo Ann Tabinowski, Michael D. Lee, and Babu Z. Fathepure, 1995. Anaerobic Biodegradation of Chlorinated Solvents: Comparative Laboratory Study of Aquifer Microcosms. *In Bioremediation of Chlorinated Solvents*. Battelle Press.
- Schwarzenbach, Renee P; Phillip M Gschwend, and Dieter M Imboden. 1993. Environmental Organic Chemistry. John Wiley and Sons.
- Titan, 1994. Hydrogeologic Evaluation of White Mesa Uranium Mill. Submitted to Energy Fuels Nuclear.
- Umetco, 1994. Groundwater Study, 1994 Update. White Mesa Facility, Blanding, Utah Submitted to United States Nuclear Regulatory Commission.
- U.S. Geological Survey, 1998. Reduction-Oxidation Potential (Electrode Method). Chapter 6.5, Field Manual. Available on-line at [http://water.usgs.gov/owq/FieldManual/Chapter6/6.5\\_contents.html](http://water.usgs.gov/owq/FieldManual/Chapter6/6.5_contents.html)

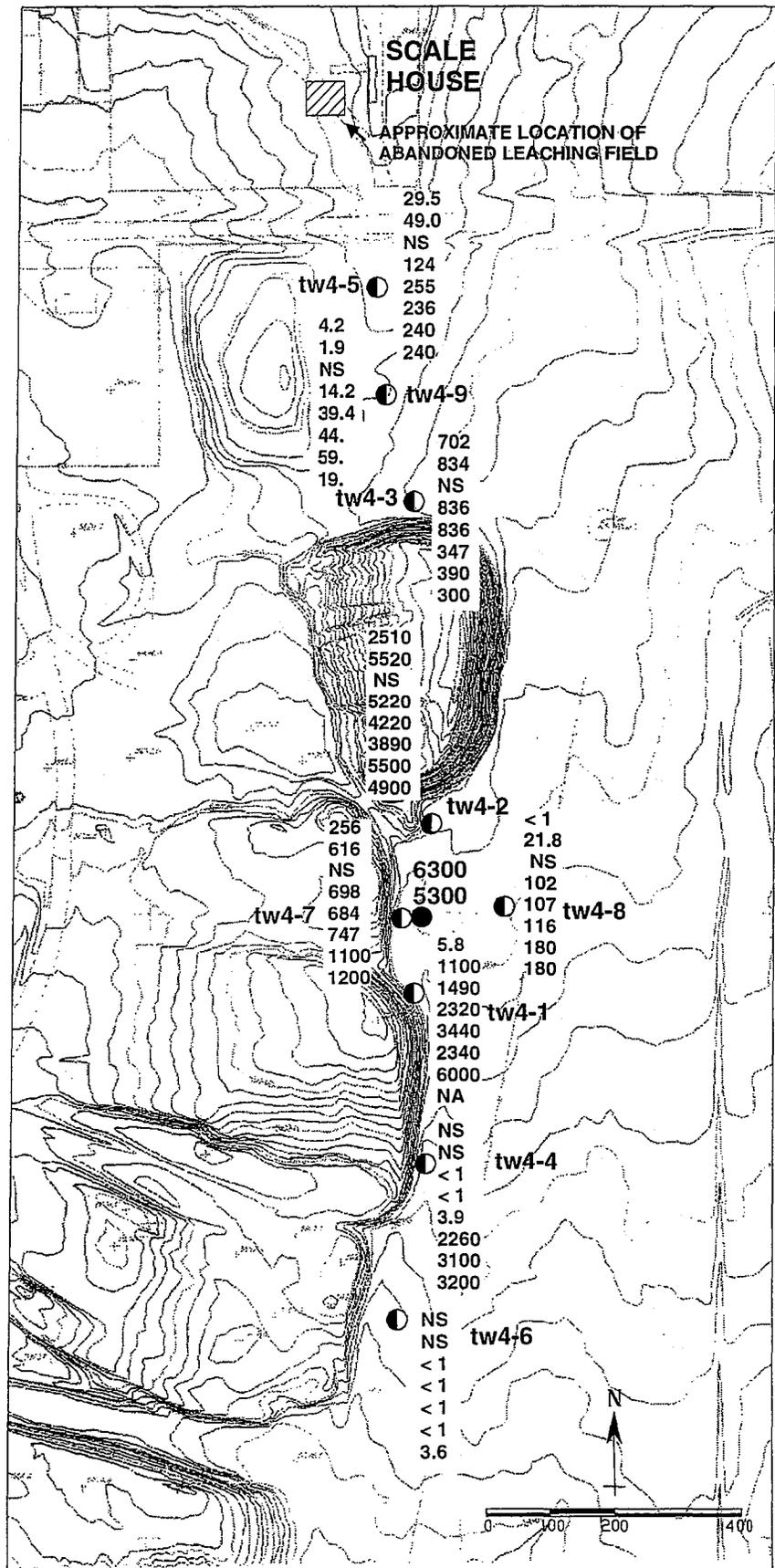
## EXPLANATION

temporary perched well  
showing chloroform (uG/L) in

- 702 initial sampling
- 834 second sampling
- NS third sampling
- 836 fourth sampling
- 836 11/00 sampling
- 347 03/01 sampling
- 390 06/01 sampling
- 300 09/01 sampling

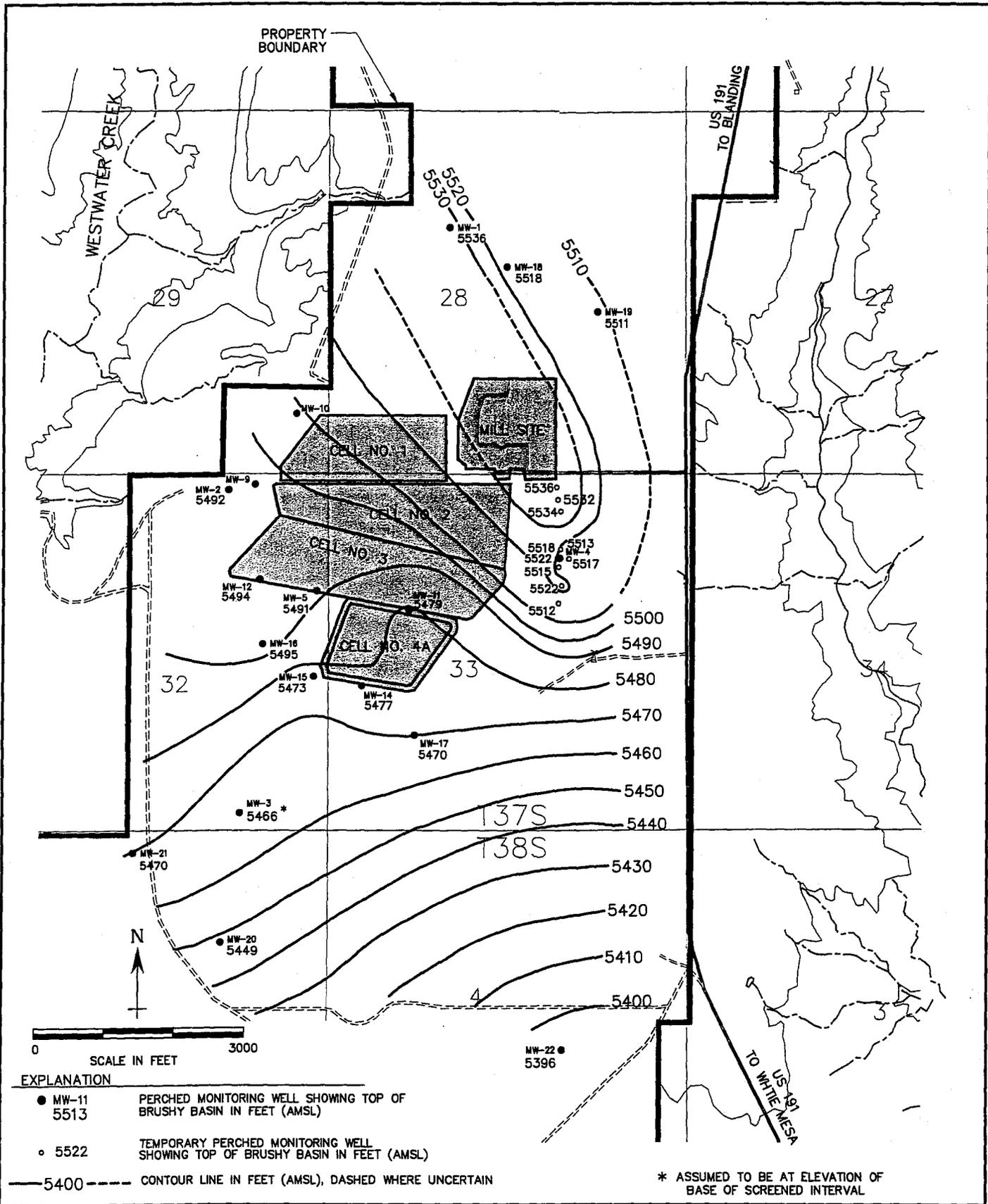
- 6300 perched monitoring well  
MW-4 showing chloroform  
(uG/L) in 6/01 and 9/01  
samplings

NOTE: sample vial for  
tw4-1 broke in  
transit to the  
laboratory so  
no analysis  
was performed  
on 9/01 sample



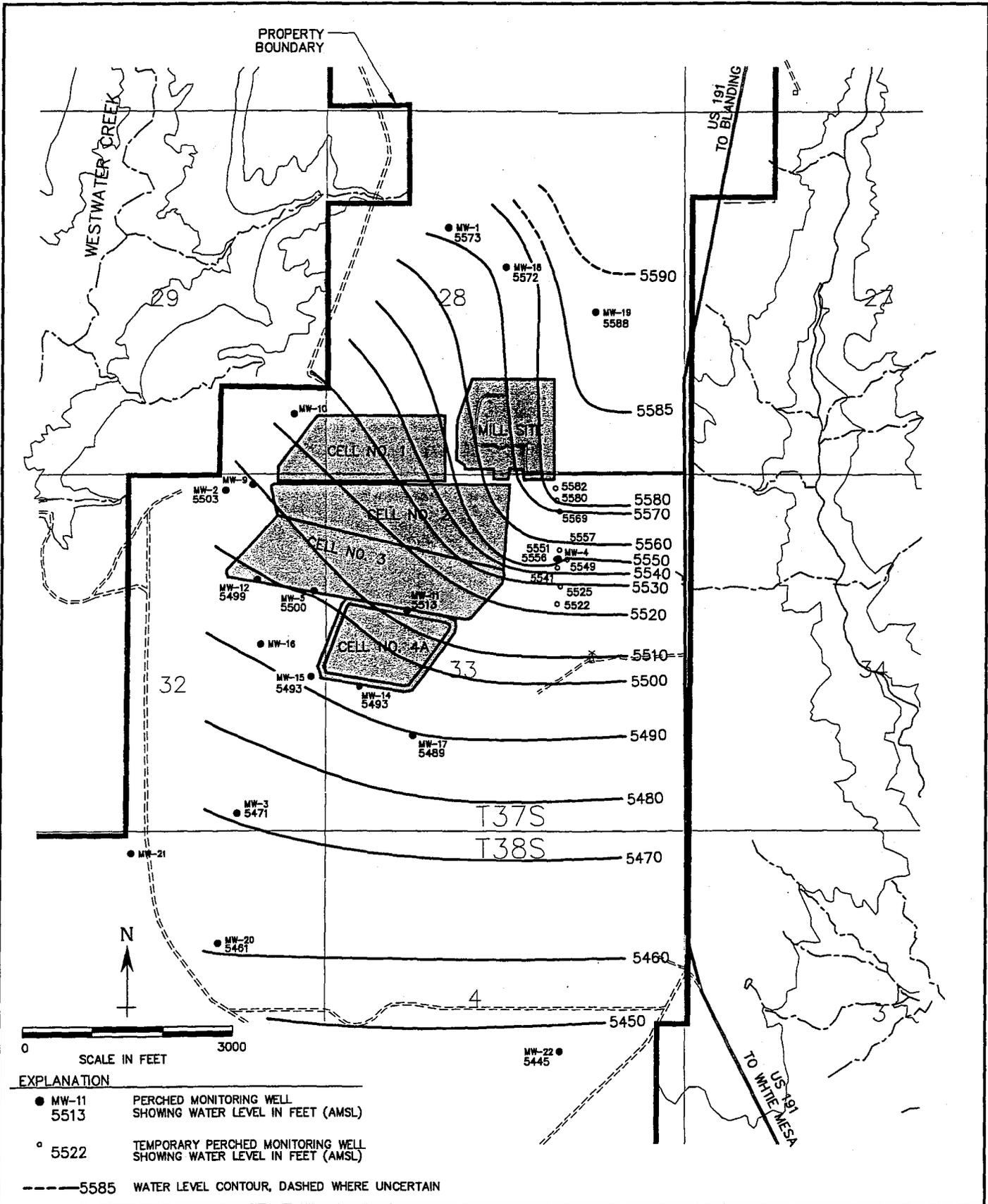
## CHLOROFORM ANALYTICAL RESULTS (uG/L) FOR TEMPORARY PERCHED WELLS (through september, 2001)

Approved	Date	Reference	Figure
			1



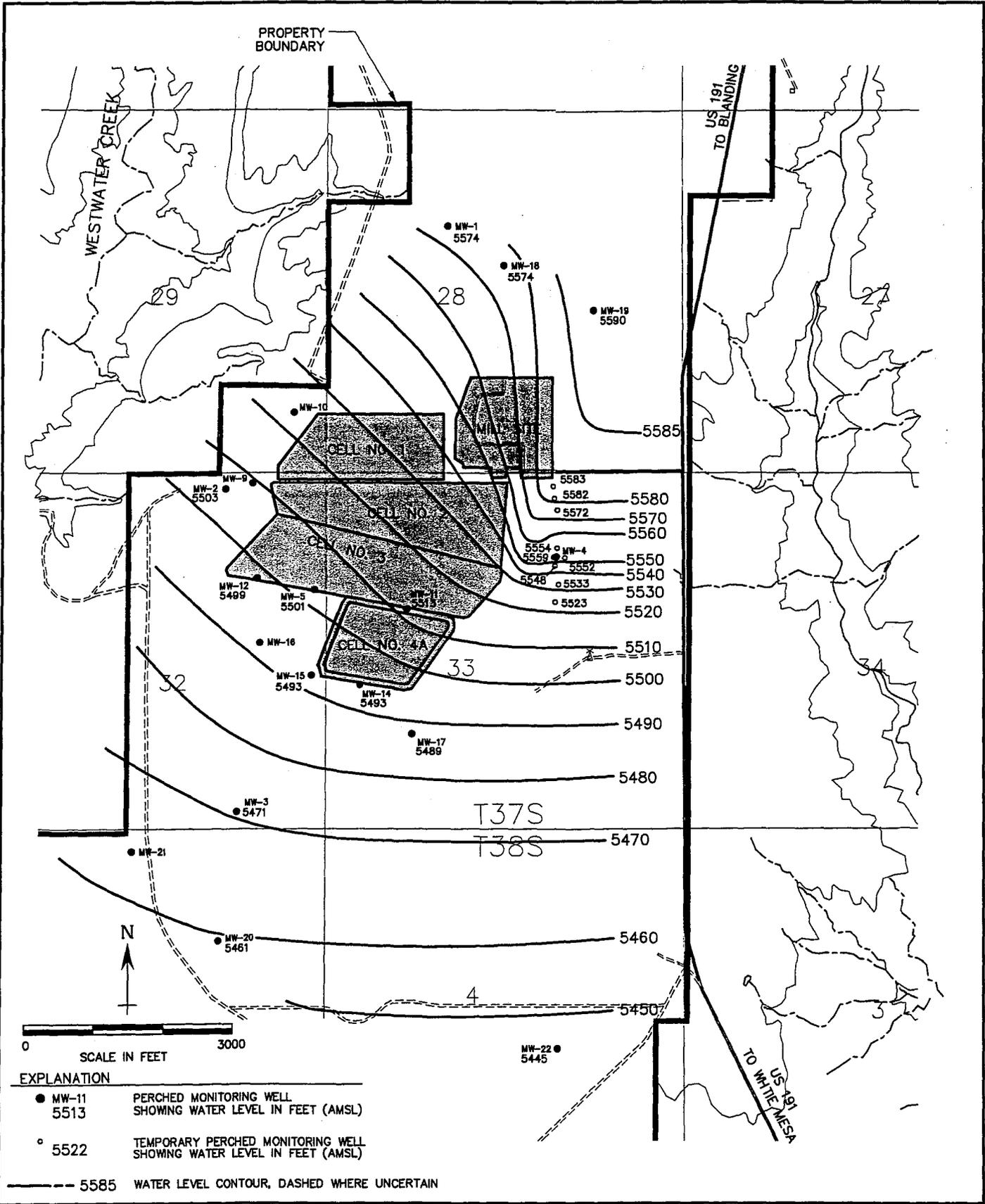
## CONTOUR MAP OF TOP OF BRUSHY BASIN WHITE MESA URANIUM MILL SITE

Approved <b>SS</b>	Date <b>10/30/01</b>	Revised	Date	Reference: <b>71800022</b>	FIG. <b>2</b>
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**WATER LEVEL CONTOUR MAP  
DECEMBER, 2000  
WHITE MESA URANIUM MILL SITE**

Approved <b>SS</b>	Date 10/30/01	Revised	Date	Reference: 71800020	FIG. <b>3</b>
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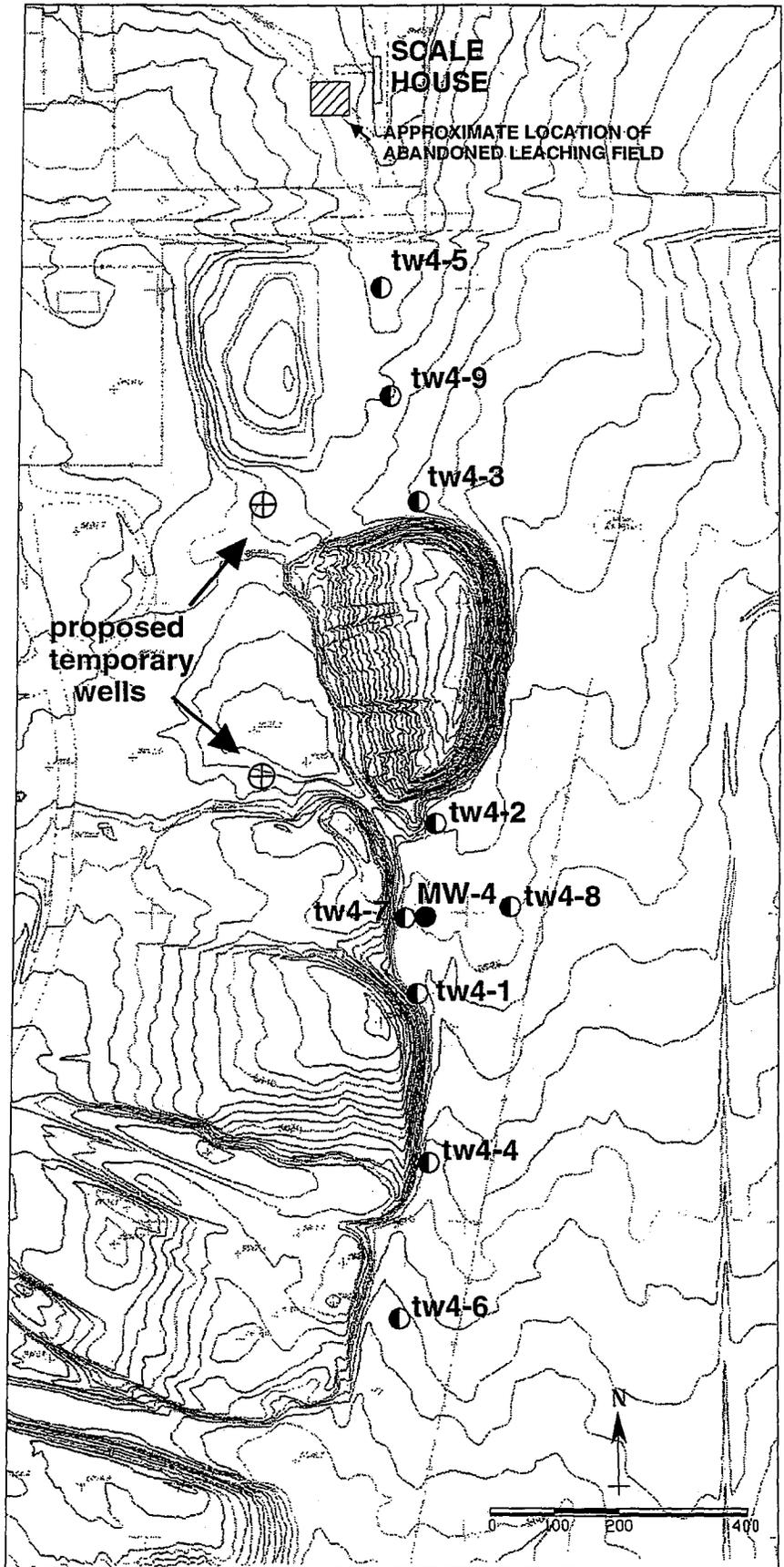


**WATER LEVEL CONTOUR MAP  
SEPTEMBER - OCTOBER, 2001  
WHITE MESA URANIUM MILL SITE**

Approved <b>SS</b>	Date 10/30/01	Revised	Date	Reference: 71800032	FIG. 4
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**EXPLANATION**

- MW-4  
● perched groundwater monitoring well
  
- tw4-1  
○ temporary perched groundwater monitoring well
  
- ⊕ PROPOSED TEMPORARY WELL



**PROPOSED LOCATIONS OF NEW TEMPORARY PERCHED WELLS**

Approved	Date	Reference	Figure
			5

## EXPLANATION

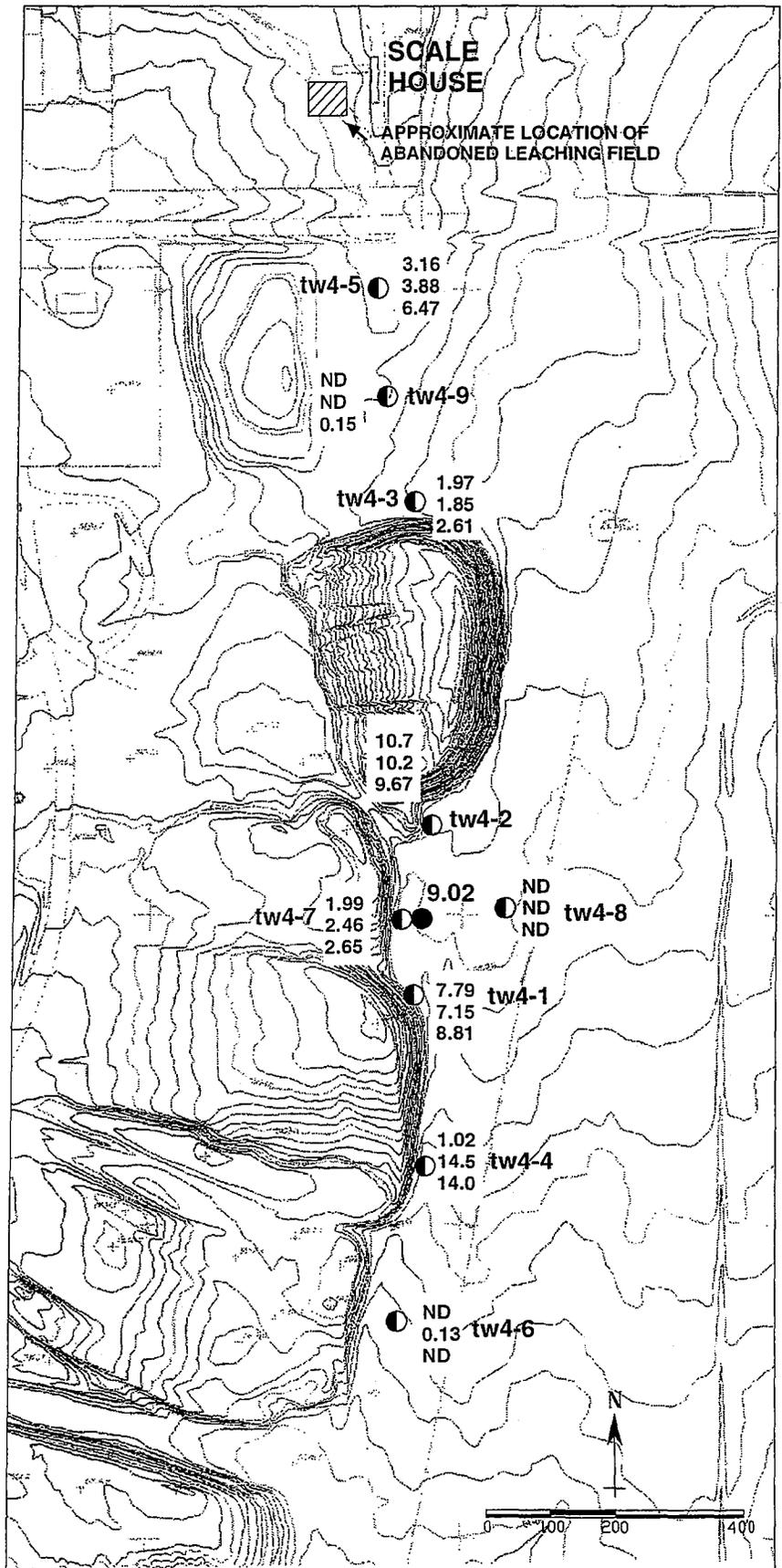
temporary perched well  
showing nitrate (mg/L) in

- 1.02 11/00 sampling
- 14.5 03/01 sampling
- 14.0 06/01 sampling

9.02

perched monitoring well  
MW-4 showing nitrate  
(mg/L) in 6/01 sampling

ND = not detected at 0.1mg/L



## NITRATE ANALYTICAL RESULTS (mg/L) FOR TEMPORARY PERCHED WELLS

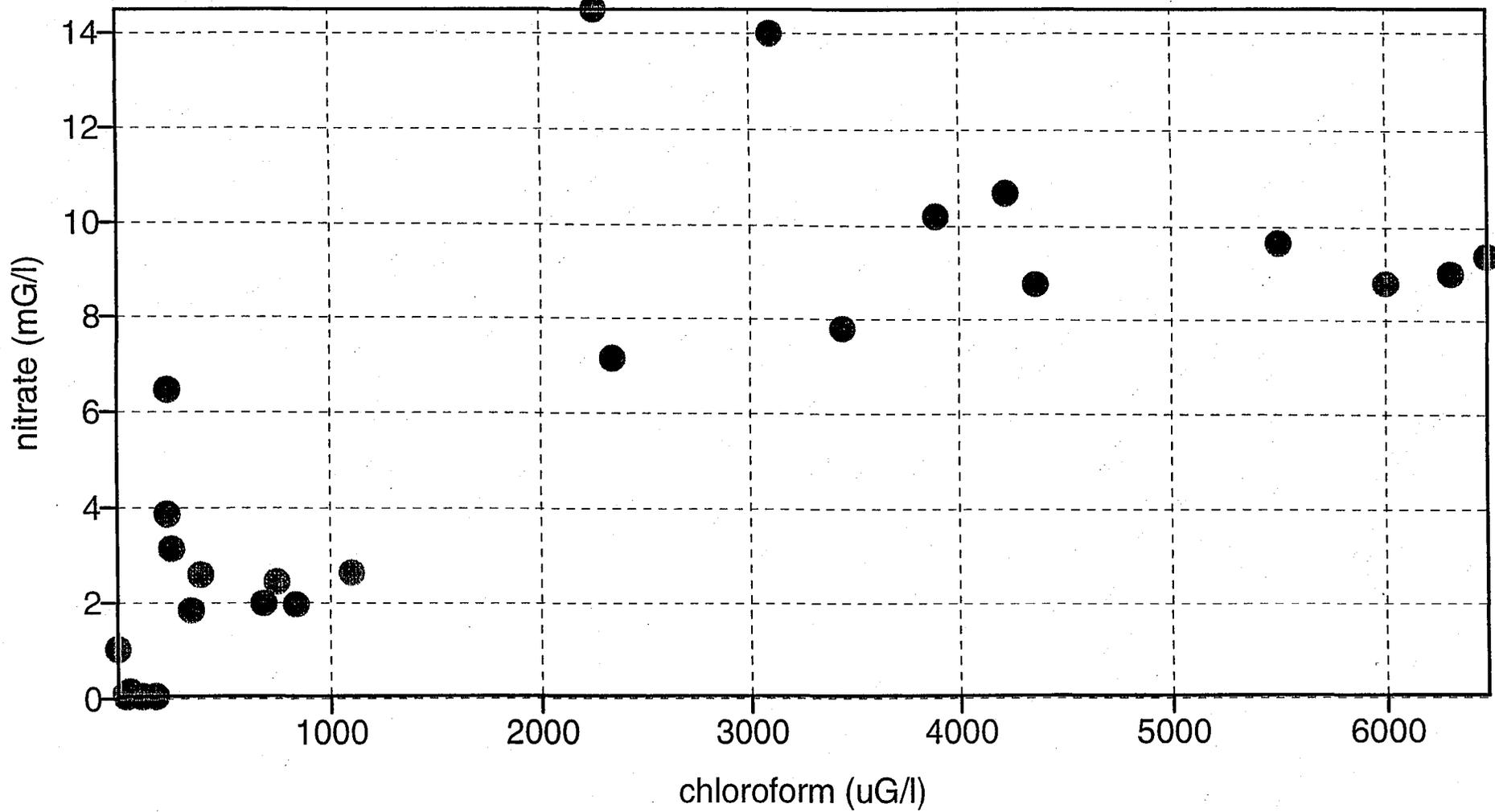
Approved

Date

Reference

Figure

6



SCATTERPLOT OF CHLOROFORM VS NITRATE  
 TEMPORARY PERCHED WELLS AND MW-4

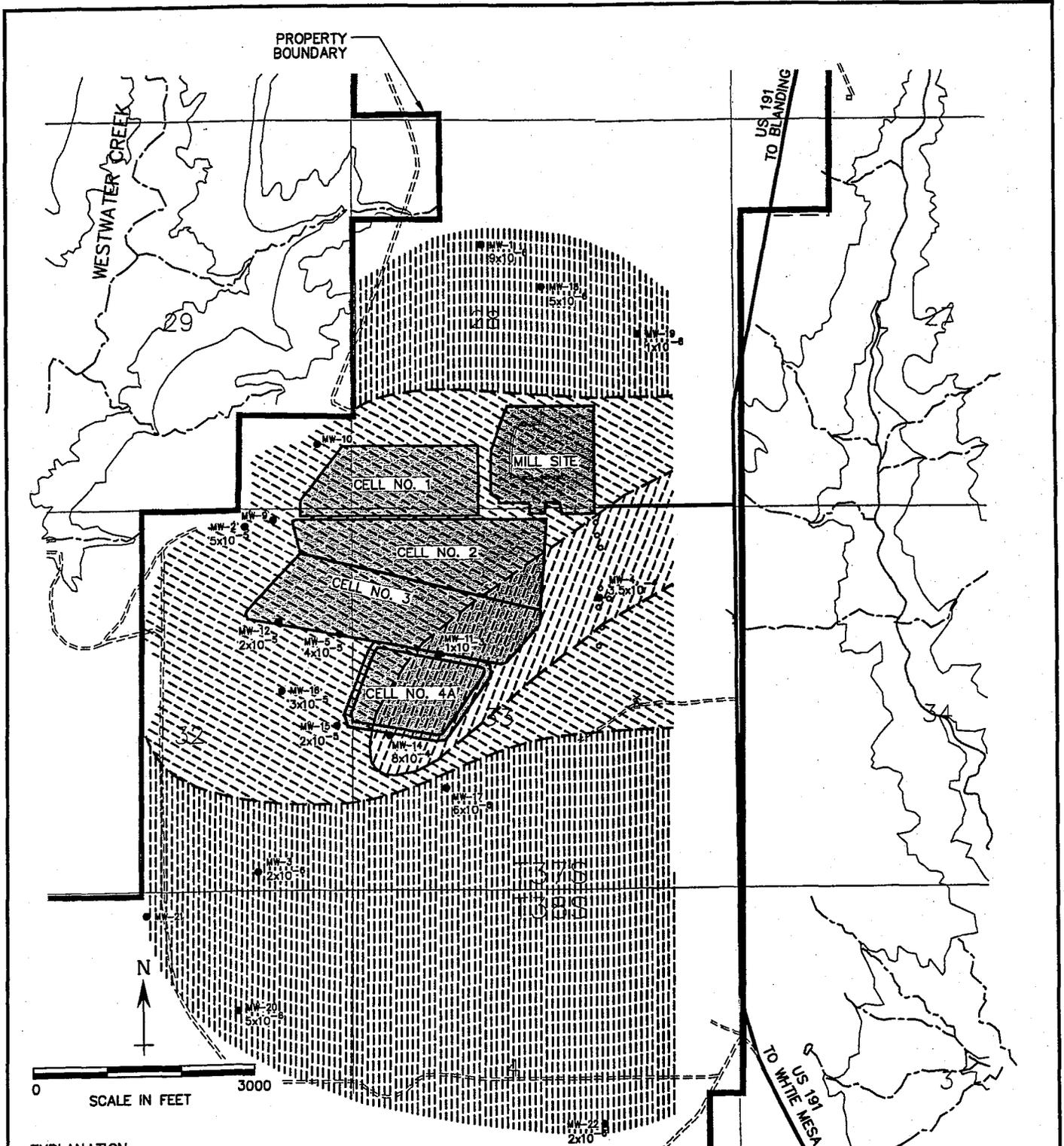
Approved

Date

Reference

Figure

7



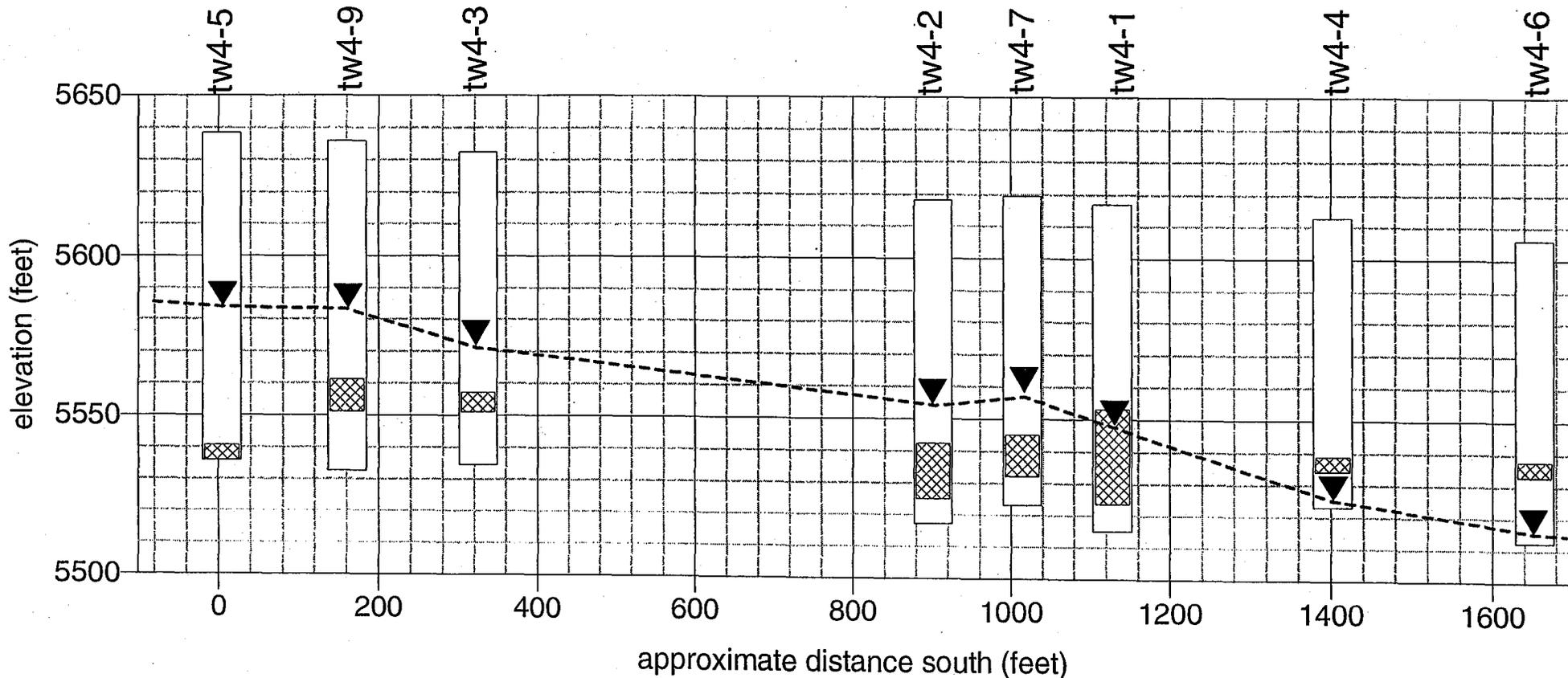
**EXPLANATION**

- MW-11  
1x10<sup>-3</sup> PERCHED MONITORING WELL SHOWING PERCHED ZONE PERMEABILITY IN cm/s
- PERCHED ZONE PERMEABILITY ≥ 10<sup>-4</sup> cm/s
- PERCHED ZONE PERMEABILITY < 10<sup>-5</sup> cm/s
- PERCHED ZONE PERMEABILITY BETWEEN 10<sup>-4</sup> cm/s AND 10<sup>-5</sup> cm/s

NOTE: PUMP TEST (DRAWDOWN OR RECOVERY) RESULTS ARE PLOTTED WHERE AVAILABLE. WHERE NOT AVAILABLE, SLUG TEST OR CONSTANT HEAD PACKER TEST RESULTS ARE PLOTTED

**PERCHED ZONE PERMEABILITY  
BASED ON PUMP AND SLUG TESTS, AND  
CONSTANT HEAD PACKER TESTS  
WHITE MESA URANIUM MILL SITE**

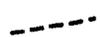
Approved <b>SS</b>	Date 10/30/01	Revised	Date	Reference: 71800024	FIG. <b>8</b>
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**EXPLANATION:**



conglomeratic sandstone



10/01 water table

APPROXIMATE INTERVALS OF  
CONGLOMERATIC SANDSTONE  
LOGGED IN TEMPORARY WELL BORINGS

Approved

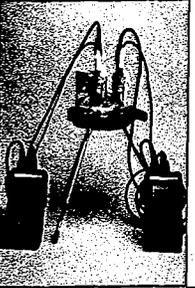
Date

Reference

Figure

**APPENDIX A**

**Vertical Profile Sampling Methods**



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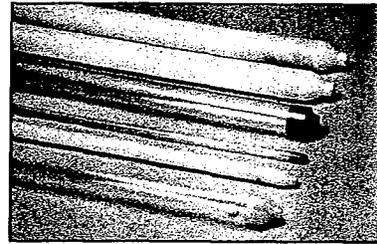
Leaders in manufacturing and distributing  
ground and surface water **sampling, analytical,**  
**filtration, and remediation** equipment.

## Geotech Disposable and Reusable Bailers

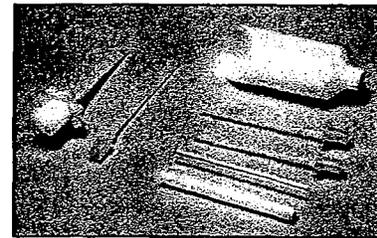
Geotech disposable and reusable bailers are available in many configurations and materials to meet your specific sampling needs.

### DISPOSABLE BAILERS

- **Improved bailer design**
  - Geotech's "Orbit Flux" design fills 33% faster than other bailers
  - V-notch design for trouble free cord attachment, and accurate pouring
- **Weighted disposable bailer as heavy as most double-weighted without the extra cost**
- **Manufactured under strict clean-room conditions**
  - Made of virgin, FDA approved high-density poly resin
  - The polyethylene contains no plasticizers or additives, and no regrinds are accepted
- **Optional double check valve bailers isolate the sample, sealing as the bailer is removed from the well at specific depths**
- **Certified special clean disposable bailers available upon request**



Geotech Disposable Bailers



Disposable Accessories

### DISPOSABLE ACCESSORIES

- **Product sampler for floating hydrocarbons**
- **VOC sampler uses a unique design that allows sample transfer to VOA vials with minimal loss of VOCs**

### REUSABLE BAILERS

- **PVC white and clear**
  - Diameters from .675" to 3.5" in lengths 12" to 60"
  - Recessed check and double check available
- **Stainless Steel Geobailers**
  - 1" and 1.75" diameters are 36" long
  - Rugged and durable for well development
- **Teflon® Geobailers**
  - 1.25" and 1.625" diameters are 36" long
  - Most inert material available



Geotech Reusable Bailers

## SPECIFICATIONS

Geotech Disposable Bailers are available in the following configurations:

Material	Diameter	Length	Configurations	Units/case
Poly	.75"	36", 83"	Weighted/Non Weighted	24 per case
Poly	1.5"	12", 36", 48"	Weighted/Non Weighted/Pressurized	24 per case
Poly	3"	36"	Weighted/Non Weighted	9 per case
Teflon®	1.5"	12", 36"	Weighted/Non Weighted	12 per case
Clear PVC	.46", .75", 1.5"	36"	N/A	30 per case

### Accessories

Poly VOC tips for 1.5" diameter bailers	24 per case
Poly VOC tips for 3" diameter bailers	9 per case
Teflon® VOC tips for 1.5" diameter bailers	12 per case
Poly free product samplers	24 per case

### Geotech Pressurized Disposable Bailers

This special disposable bailer provides the convenience of using in-line dispos-a-filters™ in the field even when pumps are not available. By using a pneumatic hand pump you can filter your samples directly from the bailer, saving time while maintaining sample integrity.

Each bailer comes complete with a barbed hose adapter for attaching the hand pump to the top of the bailer, and a special adapter with a notched thread to be used with a dispos-a-filter™ at the bottom. In order to displace the check ball and establish a smooth flow, an additional large barbed removal device is included for bottom emptying without filtering.



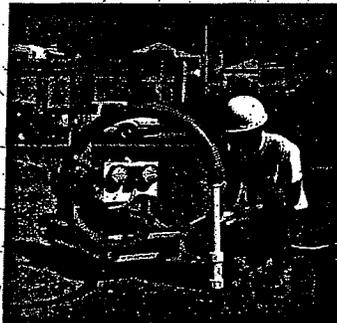
**APPENDIX B**

**Use of Soil Gas to Detect DNAPL**

**GRA Seminar  
Series  
1997**

**Groundwater Resources  
Association Presents**

# **Innovative Soil Gas Monitoring and Remediation Applications**



**GROUNDWATER RESOURCES ASSOCIATION  
OF CALIFORNIA**

**Wednesday, September 24, 1997**  
McClellan Air Force Base, Sacramento, California  
and

**Thursday, September 25, 1997**  
Wyndham Garden Hotel, Costa Mesa, California

**THE USE OF SOIL GAS DATA TO OBTAIN SOIL VOC CONCENTRATIONS**

**AND**

**TO IDENTIFY THE PRESENCE OF NAPL**

**by**

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## THE USE OF SOIL GAS DATA TO OBTAIN SOIL VOC CONCENTRATIONS AND TO IDENTIFY THE PRESENCE OF NAPL

### 1. Conversion of Soil Gas Concentrations to Soil Concentrations

The concentration of a VOC in soil gas can be converted to its total concentration in the soil by considering the equilibrium laws governing the partitioning of the VOC between the gas, liquid, and solid phases. The reasoning and methodology are as follows:

Unless a separate liquid phase of VOC, i.e., a NAPL, is present, the soil gas concentration is controlled by the distribution of the VOC between the soil, water and soil organic matter. If the moisture content in the soil is greater than 5%, normally the case, the vapor phase contaminant concentration will be controlled by its gas-water distribution coefficient, the Henry's Law coefficient (H). The Henry's Law coefficient can be written in its dimensionless form,  $H_D$ . The dimensionless Henry's Law coefficient relates the concentration of a compound in the vapor phase to its concentration in the aqueous phase

$$H_D = C_g/C_w = H/RT \cdot \rho_s/S \quad (1)$$

where  $H$  is the Henry's Law coefficient  
 $R$  is the ideal gas constant  
 $T$  is degrees Kelvin  
 $\rho_s$  is the VOC's vapor density (the vapor pressure of the pure liquid expressed as mass/unit volume).  
 and  $S$  is the water solubility

The aqueous-phase concentration will in turn be controlled by the distribution of contaminants between water and the solid soil matrix. This distribution is governed by  $K_D$ , the water-solid distribution coefficient. Rarely is the direct distribution of contaminants between the gas and solids important.

If the water-solid distribution is controlled by adsorption onto organic carbon, which occurs above organic carbon concentrations of approximately 0.001 (fraction), (Chiou and Shoup, 1985) the water-solid distribution coefficient is

$$K_D = \frac{C_s}{C_w} = \frac{K_{OC} \cdot \%OC}{100} \quad (2)$$

where  $C_s$  is the concentration in the solid [mass VOC/mass solids]  
 $C_w$  is the concentration in the water [mass VOC/volume water]  
 $K_{OC}$  is the water-organic carbon distribution coefficient  
 $f_{OC}$  is the fraction, by weight, of organic carbon in the soil

The total soil VOC concentration ( $M/L^3$ ) is the sum of the mass/unit volume in each of the three phases:

$$C_t = C_s \rho_b + C_w \theta_w + C_g (\theta_T - \theta_w) \quad (3)$$

where

- $C_g$  is the concentration in the gas [M/V air]
- $C_t$  is the total concentration in the soil [M/V (bulk volume soil)]
- $\rho_b$  is the bulk dry soil density [M/V solid]
- $\theta_T$  is the total porosity
- and  $\theta_w$  is the water filled porosity

The ratio of a VOC's total concentration in the soil gas to its concentration in the soil is given by substituting (1) and (2) in (3) and dividing by bulk density ( $\rho_b$ ) to convert soil concentration units from mass/volume to mass/mass:

$$\frac{C_T}{C_g} = \frac{K_D}{H_D} + \frac{\theta_w}{H_D \rho_b} + \frac{(\theta_T - \theta_w)}{\rho_b} \quad (4)$$

where  $C_T$  is the total concentration in the soil (M/M)

Table 1 presents an example of the results of using (4) to relate soil gas and soil concentrations. For each of the compounds listed, a soil gas concentration of 100  $\mu\text{g/L}$  was converted to the equivalent soil VOC concentration in  $\mu\text{g/kg}$ . The soil parameters utilized in the calculation were  $f_{OC}$  (fraction) = 0.005; total porosity (fraction) = 0.40; volumetric moisture content (fraction) = 0.2; and dry soil bulk density ( $\text{gm/cm}^3$ ) = 2.00.

TABLE 1. CONVERSION OF SOIL GAS TO TOTAL SOIL CONCENTRATION

COMPOUND	$K_{oc}$ (ml/g)	Henry's Coeff. (H)	$H_D^*$ (H/RT)	$K_D$ (ml/g)	SGas-Soil Conversion Factor	Soil Gas Conc. ( $\mu\text{g/L}$ )	Soil Conc. ( $\mu\text{g/Kg}$ )
$\text{CCl}_4$	110	$2.41\text{E}^{-2}$	1.0	0.55	0.75	100	75
Chloroform	31	$2.87\text{E}^{-3}$	0.119	0.155	2.24	100	224
1,1 DCA	30	$4.31\text{E}^{-3}$	0.179	0.15	1.50	100	150
1,2 DCA	14	$9.78\text{E}^{-4}$	0.0407	0.07	10.2	100	1020
1,1 DCE	65	$3.40\text{E}^{-2}$	1.41	0.325	0.401	100	40.1
cis 1,2 DCE	49	$7.58\text{E}^{-3}$	0.315	0.245	1.2	100	120
trans 1,2 DCE	59	$6.56\text{E}^{-3}$	0.273	0.295	1.55	100	155
1,1,1 TCA	155	$1.70\text{E}^{-2}$	0.707	0.775	1.33	100	134
TCE	126	$9.10\text{E}^{-3}$	0.379	0.63	2.03	100	203
PCE	364	$2.59\text{E}^{-2}$	1.08	1.82	1.88	100	18
Vinyl Chloride	57	$8.19\text{E}^{-2}$	3.41	0.285	0.212	100	21.2
Benzene	83	$5.59\text{E}^{-3}$	0.233	0.415	2.31	100	232
Ethyl Benzene	1100	$6.43\text{E}^{-3}$	0.267	5.5	19.4	100	1940
Toluene	300	$6.37\text{E}^{-3}$	0.265	1.5	5.86	100	586
Xylene	240	$7.04\text{E}^{-3}$	0.293	1.2	4.53	100	453

\* Roy & Griffin, 1989. - 1,1,1 TCA

\* Montgomery & Welkom, 1990 - all others.

It can be shown by sensitivity analysis of (4) that for all but the most water-soluble compounds, the ratio of soil gas to total soil concentration is most sensitive to  $K_D$ , next to  $H_D$ , and that the other parameters have relatively little effect. Thus, for all but the most quantitative applications, the soil parameter important in calculating the conversion of soil gas concentration to total soil concentration is total organic carbon. Reasonable estimates of moisture content, porosity, and bulk density, the additional soil parameters, will be sufficient for most purposes.



Figure 1

# Solid-Water Distribution Depends on Soil Organic Content

Usually represented as:

$$C_s / C_w = K_{sw} = K_D \approx K_{oc} \cdot f_{oc}$$

where

$K_{oc}$  is organic carbon distribution coefficient

$f_{oc}$  is fraction of organic carbon (by weight) in soil

Examples:

TCE

$$K_{oc} \approx 150 \text{ ml/gm}$$

$$f_{oc} = 0.005$$

$$K_{sw} = 7.5 \times 10^{-1} \text{ ml/gm}$$

Hexachlorobenzene

$$K_{oc} \approx 4 \times 10^3 \text{ ml/gm}$$

$$f_{oc} = 0.005$$

$$K_{sw} = 20 \text{ ml/gm}$$



HYDRO GEO CHEM

# Gas-Water Distribution by Henry's Law

$$C_g/C_w = K_{gw} \equiv H_D \approx e_s/S$$

$H_D$  is dimensionless Henry's Law Constant  
 $e_s$  is saturated vapor density  
 $S$  is aqueous solubility

Examples:

TCE

$$e_s = 415 \text{ gm/m}^3 \text{ (gas)}$$

$$S = 1100 \text{ mg/l (water)}$$

$$C_g/C_w = 0.38$$

Hexachlorobenzene

$$e_s \approx 1 \times 10^{-7} \text{ gm/m}^3$$

$$S = 3.5 \times 10^{-2} \text{ mg/l}$$



# Mass Budget Equation

$C_T = (\text{mass solute}) / (\text{soil sample volume})$

$$C_T = C_g \theta_g = C_l \theta_w + C_{se} b \\ = C_g (\theta_T - \theta_w) + \frac{C_g \theta_w}{K_H} + \frac{C_g k_d e b}{K_H}$$

Figure 4

Let  $C_m = (\text{mass solute}) / (\text{mass soil sample})$

$$C_m = C_T / e_b$$

Then 
$$C_m / C_g = \frac{\theta - \theta_w}{e_b} + \frac{\theta_w}{K_H e_b} + \frac{K_d}{K_H}$$

$C_m / C_g$  is the soil gas factor (SGF)

$$\frac{\delta(\text{SGF})}{\delta\theta_w} = \frac{1}{2} (1/K_H - 1)$$

$$\frac{\delta(\text{SGF})}{\delta f_{oc}} = \frac{K_{oc}}{K_H}$$

Figure 6

# Soil:Gas Conc. Ratio vs Water Content

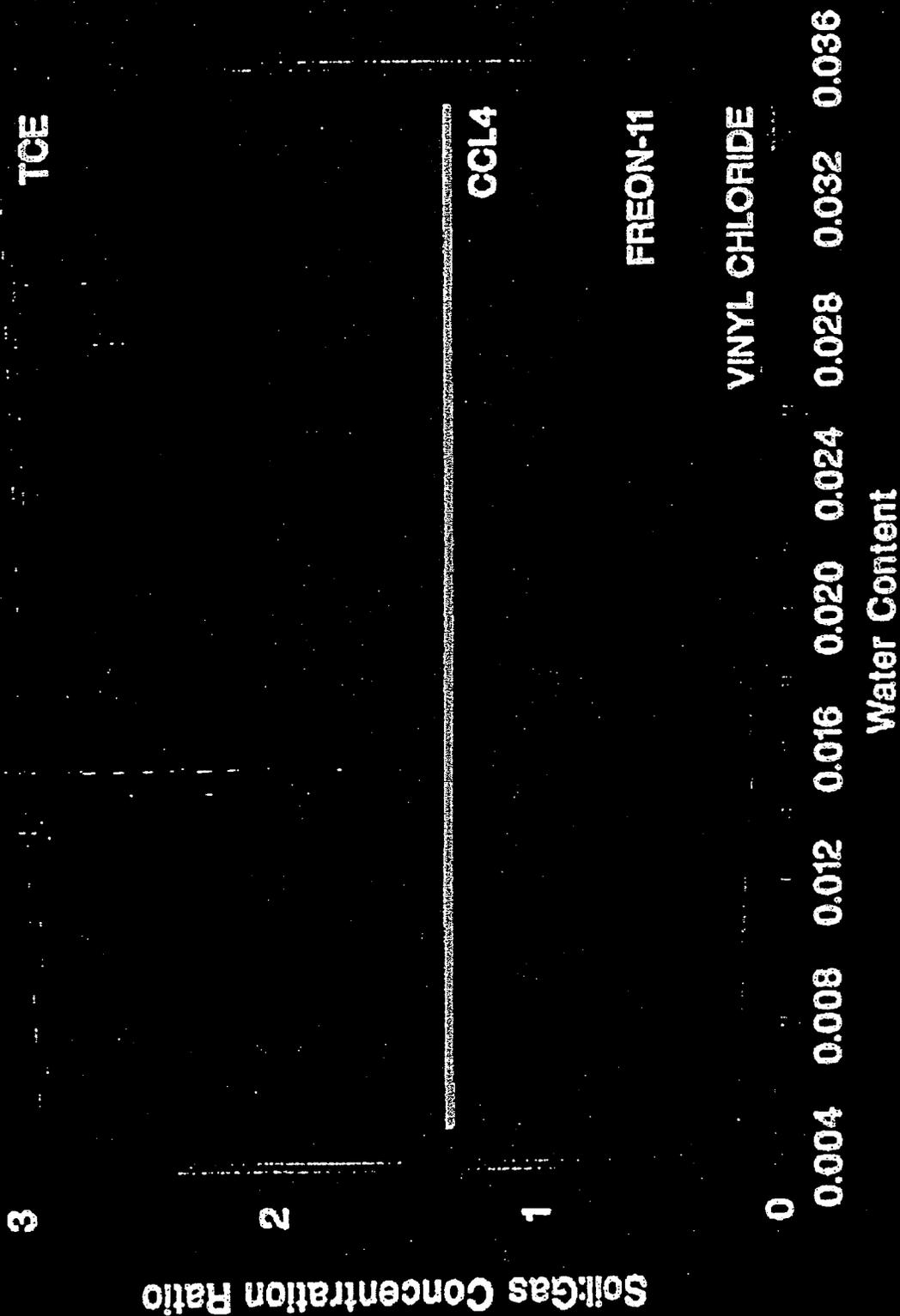


Figure 7

# Soil:Gas Conc. Ratio vs. Water Content

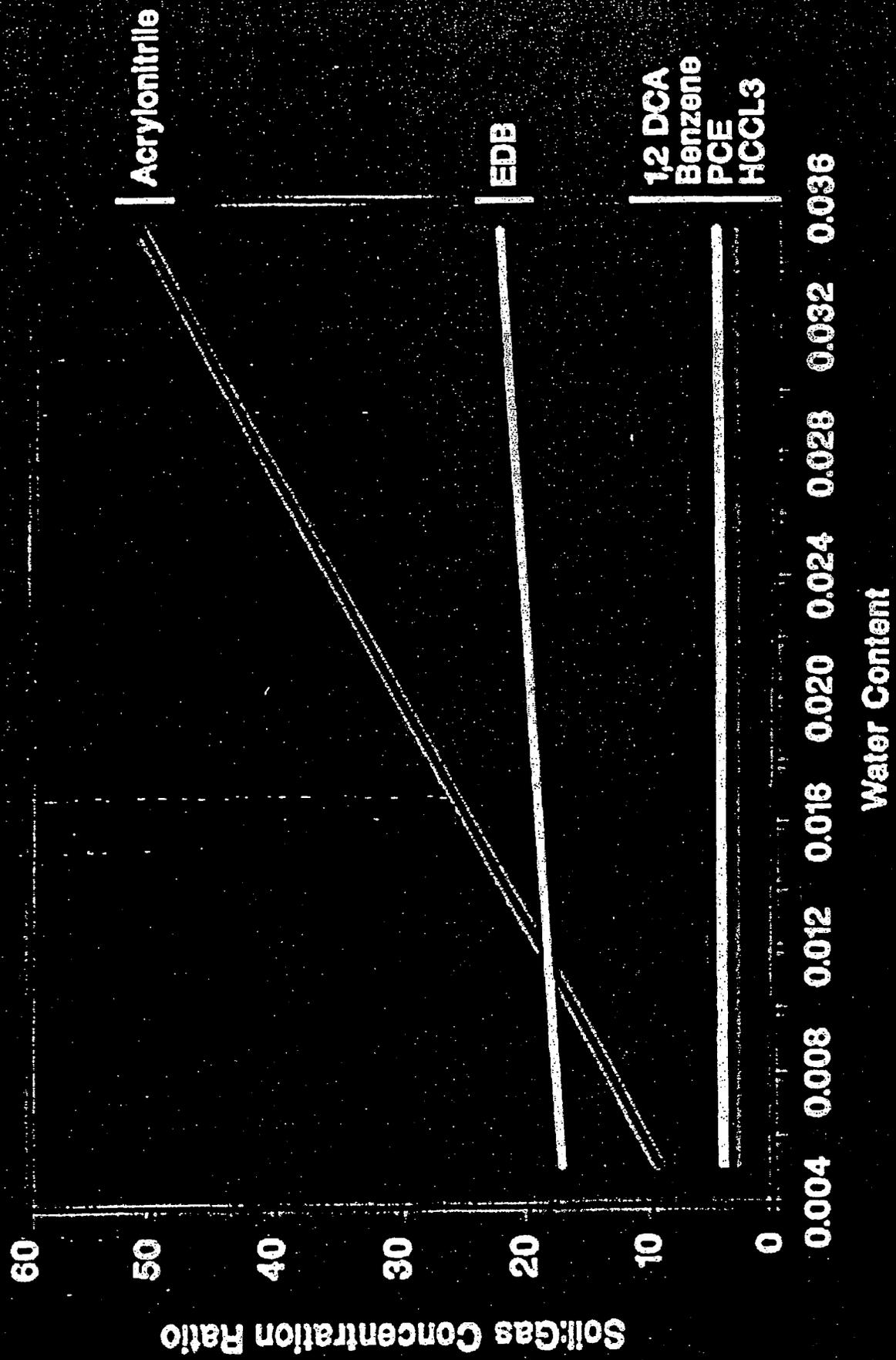


Figure 8

# Soil:Gas Conc. Ratio vs Fraction OC

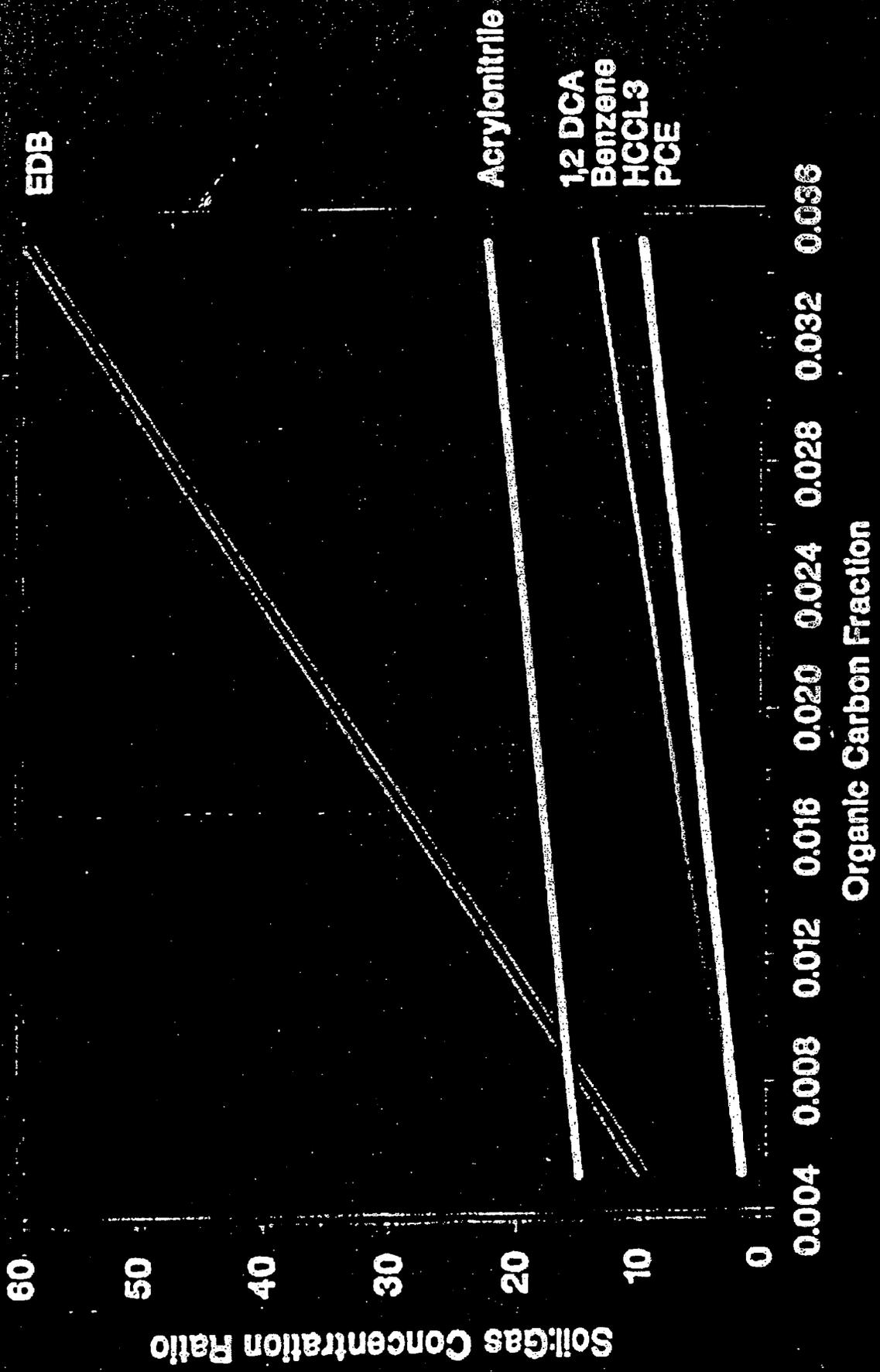


Figure 9

# Soil:Gas Conc. Ratio vs Fraction OC

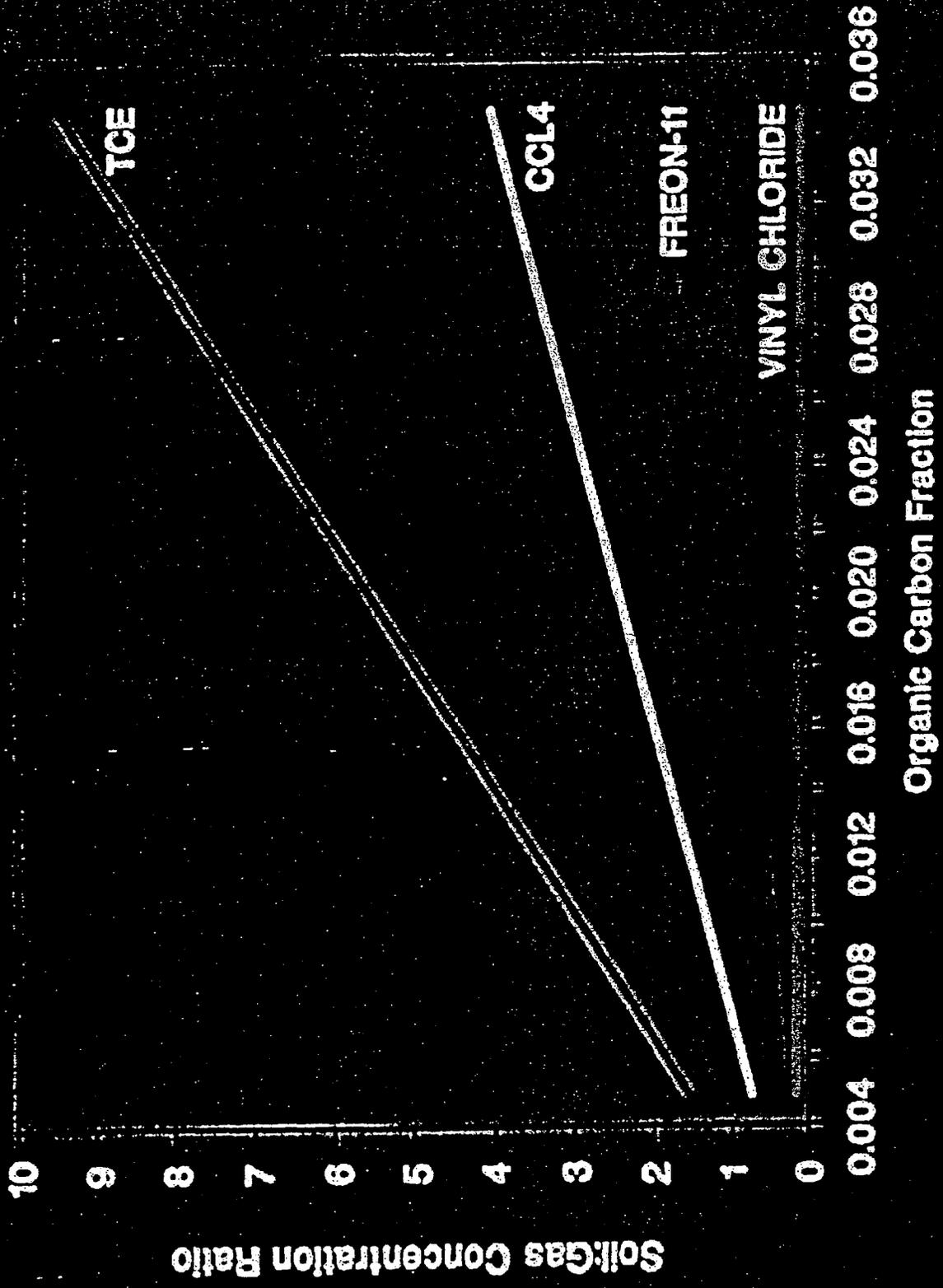
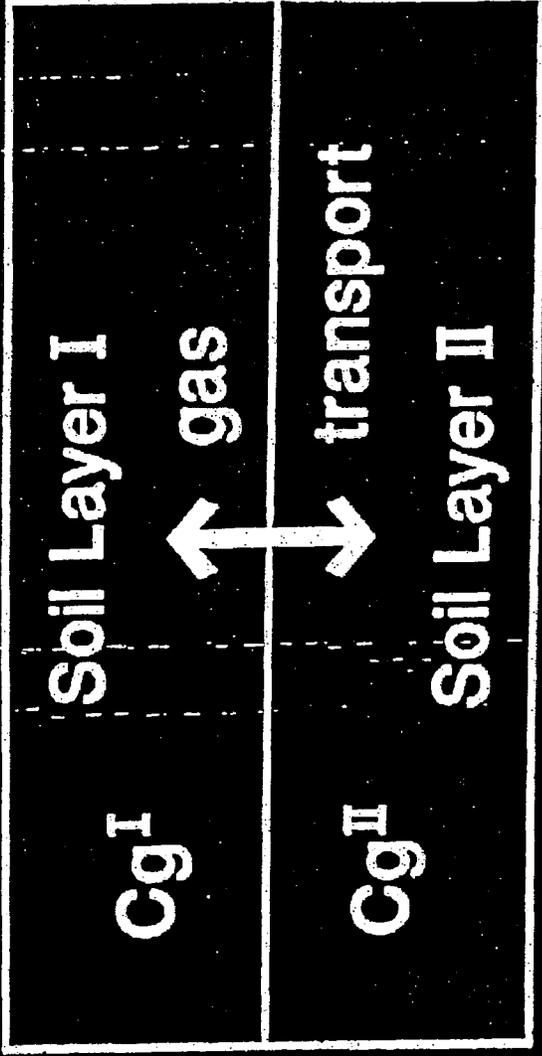


Figure 10



$$\text{Gas Flux} = -D \frac{\delta C_g}{\delta z}$$

At equilibrium, flux = 0

$$\frac{\delta C_g}{\delta z} = 0$$

$$C_{gI} = C_{gII}$$

Figure 11

## 2. Predicting the Presence of NAPL from Soil Gas Concentrations

Equation 4 is valid in most soil gas applications, but can under predict a total soil concentration in cases where a separate non-aqueous liquid phase is present. The total VOC soil concentration is then a function of the VOC concentration in the NAPL and the amount of NAPL in the soil. In such a case, although Equation 4 continues to account for the VOC's partitioned into soil, water, and soil gas, it does not account for the VOCs dissolved in the NAPL. Where NAPL is present, the prediction of VOC soil concentrations from soil gas concentrations is not possible because the vapor pressure of a VOC in the NAPL is a function of its concentration in the NAPL and the amount of NAPL is generally unknown.

When a VOC concentration in the NAPL is high, its distribution between the NAPL and the gas phase can be estimated by Raoult's Law

$$C_g(i) = \rho_s X_i \quad (5)$$

where  $\rho_s$  is the vapor density (pure-compound vapor pressure) of the *i*th VOC  
and  $X_i$  is the mole fraction of the *i*th VOC

The sum of the mole fractions of compounds making up a NAPL (or any liquid) is equal to 1:

$$\sum_{i=1}^n X_i = 1.0 \quad (6)$$

Where *n* is the number of compounds in the NAPL.

Assuming the NAPL is composed of VOCs, that is, each of the dissolved compounds has a reasonable vapor pressure, the substitution of (5) into (6) yields

$$\sum_{i=1}^n \frac{C_g(i)}{\rho_s(i)} = 1 \quad (7)$$

Thus, in a soil NAPL zone where the NAPL is composed entirely of VOCs, the sum of the quotients of soil gas concentrations divided by their respective pure-compound vapor pressure should approach 1. However, a lower than the theoretical value of 1.0 for the summation in (7) should be used to indicate the presence of a NAPL in unsaturated soils. In water saturated soils, because of attenuation by advective and diffusive processes, only 1% of the saturated solubility of a groundwater contaminant is the criterion used to determine the presence of NAPL in groundwater (Feenstra and others, 1991). Soil gas is less likely to be attenuated by advective processes, and the diffusive transport of a gas borne compound is much more effective than that of a compound dissolved in water, both processes leading to a larger zone of detection for soil gas sources. Thus a larger criterion than the 1% of the

theoretical value is appropriate. We suggest, based on observations at a number of soil gas sites, that 10% of the theoretical value be used to determine that a NAPL is present at a soil gas sampling location. The appropriate criterion, therefore, is

$$\sum_{i=1}^n \frac{C_g(i)}{\rho_s(i)} \geq 0.1 \quad (8)$$

As an example of the use of this criterion, suppose that the soil gas data obtained at a point location are

PCE = 2,500 µg/L  
 TCE = 4,200 µg/L  
 Cis 1,2-DCE = 10,000 µg/L

The calculations utilizing Equation 8 are summarized in Table 2.

TABLE 2. EXAMPLE OF USING SOIL GAS TO DETERMINE NAPL PRESENCE

Soil Gas Analyte	Vapor Pressure (mm) (@20 °C)	Molecular Weight (g)	Conversion Factor [µg/(mm·L·g)]	Vapor Density ρ <sub>s</sub> (µg/L)	Observed Concentration C <sub>g</sub> (µg/L)	C <sub>g</sub> /ρ <sub>s</sub>
PCE	14	165.8	54.7	127,000	2,500	0.02
TCE	19	131.4	54.7	137,000	4,200	0.03
1,2 cis DCE	180	97	54.7	955,000	10,000	0.01
SUM of C <sub>g</sub> /ρ <sub>s</sub>						0.06

According to this calculation, the soil gas concentrations divided by their respective pure-solvent vapor pressures sum to less than 0.1. Thus NAPL is not present where this soil gas probe was located, and the concentrations of PCE, TCE, and 1,2 cis DCE at this location can be calculated by the methods summarized in Table 1.

## References

Chiou, C.T. and T.D. Shoup, Environ. Sci. Technol. 1985, 19, 1196.

Feenstra, S., D.M. McKay, and J.A. Cherry, 1991. A method for assessing residual NAPL based on organic concentrations in soil samples

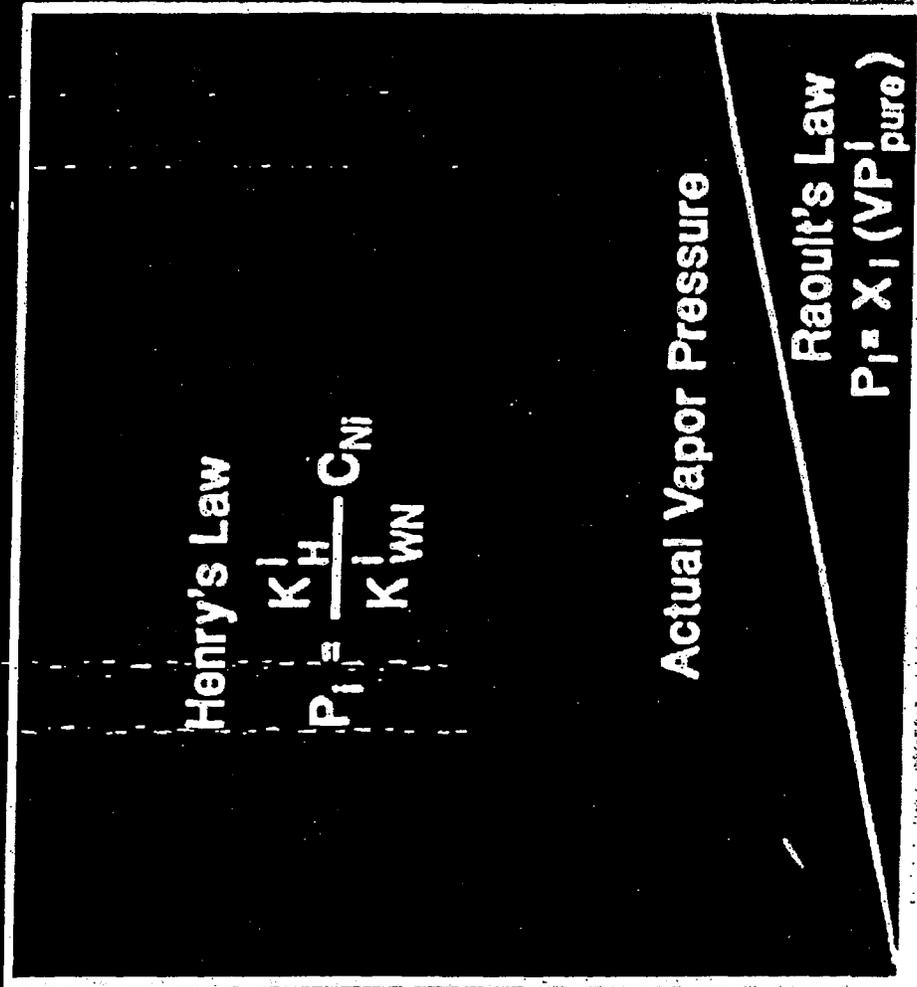
## Use of Soil Gas to Determine The Presence of NAPLs in Soils

When a VOC concentration in the NAPL is high, its distribution between the NAPL and the gas phase is described by Raoult's Law

$$C_g (i) = \rho_s X_i$$

where  $\rho_s$  is the vapor density of the *i*th VOC  
and  $X_i$  is the mole fraction of the *i*th VOC

# Vapor Pressure of Volatile Organic Compound Dissolved in Non-Aqueous Phase Liquid



The sum of the mole fractions of compounds dissolved in a NAPL (or any liquid) is equal to 1:

$$\sum_{i=1}^n X_i = 1.0$$

Where n is the number of compounds in the NAPL.

Assuming the NAPL is composed of VOCs, that is, each of the dissolved compounds has a reasonable vapor pressure, these two equations may be combined as:

$$\sum_{i=1}^n \frac{C_g(i)}{\rho_S(i)} = 1.0$$

A lower value than the theoretical value of 1.0 should be used to determine that a NAPL is present. The lower value is appropriate for much the same reason that only 1% of the saturated solubility of a groundwater contaminant is used to determine the presence of NAPL in groundwater (Feenstra et al., 1992).

The choice of the proper value is somewhat arbitrary. A larger value than the 1% used for groundwater is reasonable because soil gas components are less likely than groundwater solutes to be attenuated by advective processes and because the diffusivity of a gas borne compound, which widens the area of detection, is much greater than that of a compound dissolved in water. We suggest, based on observations at a number of soil gas sites, that 10 % of the theoretical value be used to determine that a NAPL is present at a soil gas sampling location. The appropriate criterion is

$$\textit{The Presence of NAPL Is Indicated By : } \sum_{i=1}^n \frac{C_g (i)}{\rho_s (i)} \geq 0.1$$

Figure 16

**APPENDIX C**

**Coordinates Requested by UDEQ**

**Approximate Coordinates**  
**Misc. Features - White Mesa Mill Site**  
 Revised using 2001 Topographic Map  
 ( all coordinates are approximate )

Feature                      Easting Northing Elevation

Water Well #1	2580084	323314	
Test Well	2580945	322687	
Jones Well	2581252	318910	
Jet Pump	2581250	329460	
Ruin Spring	2574294	310375	5391
Cottonwood Spring	2570024	317880	5238
Westwater Spring	2574166	321692	5493

Former Leach Field (near office)	<u>Dimensions (ft. x ft.)</u>		
NW	2580274	322228	
NE	2580369	322228	95      100
SE	2580369	322128	
SW	2580274	322128	Area (sq.ft.)    9500

Old Leach Field (scale house)	<u>Dimensions (ft. x ft.)</u>		
NW	2580765	322279	
NE	2580786	322279	21      56
SE	2580786	322223	
SW	2580765	322223	Area (sq.ft.)    1176

Current Leach Field (east of Mill yard)	<u>Dimensions (ft. x ft.)</u>		
NW	2581224	322530	
NE	2581324	322530	100     160
SE	2581324	322370	
SW	2581224	322370	Area (sq.ft.)    16000

Land Fill	<u>Dimensions (ft. x ft.)</u>		
NW	2581040	322915	
NE	2581115	322915	75      130
SE	2581115	322785	
SW	2581040	322785	Area (sq.ft.)    9750

Sedimentation Pond			
NW	2579420	322645	
NE	2579465	322645	
A	2579465	322400	
B	2579555	322355	
SE	2579555	322175	
SW	2579420	322175	

Lab Waste Holding Tank			
	2580085	322408	

Tailings Cells - Approximate Boundaries

Cell No.    Easting    Northing

<u>1-I</u>		
NW	2577460	323190
NE	2579365	323145
SE	2579355	322078
SW	2576795	322150
A	2576880	322415

<u>2</u>		
NW	2576795	322150
NE	2580210	322040
SE	2580210	320745
SW	2576845	321680

<u>3</u>		
NW	2576845	321680
NE	2580210	320745
SE	2579593	320100
SW	2576015	320825

<u>4A</u>		
NW	2577883	320411
NE	2579593	320100
SE	2578860	319021
SW	2577469	319266

**Abandoned Monitor Wells, Bore Holes, and Angle Holes**

Feature    Easting Northing Elevation    ( all coordinates are approximate )

MW-13	2577590	319547	5570
MW-6-1	2578895	320530	5588
MW-6-2	2578895	320530	5588
MW-7-1	2578125	320886	5588
MW-7-2	2578125	320886	5588
MW-8-1	2577265	320925	5590
MW-8-2	2577265	320925	5590

D & M 3	2580092	322720	5634.3
D & M 9	2581380	327365	5679.3

GH-94-1	2576459	320549	5597
GH-94-2/	2577257	320385	5585
GH-94-3	2577245	320046	5579
GH-94-4	2577365	319598	5572

D & M 12	2578314	326932	5648.1
D & M 28	2577380	317340	5547.6

**APPENDIX D**

**Analytical Results**



**ENERGY LABORATORIES, INC.**

Billings • Casper • Gillette  
Helena • Rapid City

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E-mail: casper@energylab.com • FAX: (307) 234-1639  
PHONE: (307) 235-0515 • TOLL FREE: (888) 235-0515

**LABORATORY ANALYSIS REPORT**

**Client: INTERNATIONAL URANIUM (USA) CORPORATION**

**Project: White Mesa Mill**

**Contact: Wally Brice**

**Sample Matrix: Liquid, Water**

**Date Received: 04-02-01**

**Report Date: April 9, 2001**

Laboratory ID	Sample Date / Time	Sample ID	Nitrate + Nitrite as N, mg/L
01-31914-1	03-26-2001 14:02	WMMTW4-11	< 0.10
01-31914-2	03-26-2001 15:49	WMMTW4-15	< 0.10
01-31914-3	03-29-2001 11:08	WMMTW4-12	10.0
01-31914-4	03-29-2001 12:38	WMMM4	8.77

*WMMTW4-11 is a field blank (DI Blank).  
WMMTW4-15 is a rinseate of pumpg. syst. prior to collection of CW samples.  
WMMTW4-12 is a Dup. WMMM4-12.*

Quality Assurance Data	
Method	EPA 353.2
Reporting Limit	0.10
RPD <sup>1</sup>	1.0
Spike <sup>2</sup>	96
Analyst	rwk
Date/Time Analyzed	04-04-2001 17:13

**NOTES:**

- (1) These values are an assessment of analytical precision. The acceptance range is 0-20% for sample results above 10 times the reporting limit. This range is not applicable to samples with results below 10 times the reporting limit.
- (2) These values are an assessment of analytical accuracy. They are a percent recovery of the spike addition. ELI performs a matrix spike on 10 percent of all samples for each analytical method.



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toll free 1-888-235-0515  
 voice 307-235-0515  
 fax 307-234-1639

For Sample Tracking Purposes, Please Provide Contact Name and Telephone #'s as Indicated (SEE BACK OF FORM FOR EXAMPLES AND INSTRUCTIONS)

Project Name / Location / Purchase Order # / Bid #				Number of containers Sample Type: A W S V U O Air Water Soils/Solids Vegetation Urine Other	Type of Analyses Requested				Special Requests
Date	Time	composite	grab sample		Nitrates	8260 (CHCl <sub>3</sub> )			Comments, Special Instructions, etc.
White Mesa Mill / 1425 S. Hwy 191 Blanding, UT 84511									50%
Name / Phone # / Fax # Wally Brice / (435) 678-2221 / (435) 678-2224									31914
			Send Invoice to: IUC PO Box 809 Blanding, UT 84511 Attn: Ron Berg						
			Send Report to: Same As Above						
			Sample I.D. WMMTW 1st 1/4 '01						
3/24/01	1402	✓	WMMTW4-11 Nitrate	3W	✓				
3/24/01	1549	✓	WMMTW4-15	↓	↓				
3/29/01	1108	✓	WMMTW4-12	↓	↓				
3/29/01	1238	✓	WMMM4	↓	↓				
3/16/01			<del>WMMTW4-10</del> 8260B (CHCl <sub>3</sub> )	3W	✓				the This is a trip Blank #76 that is on another COC THF 03/16/01

1. Sampler: (signature) Wally Brice	Date 3/30/01	Time 1000	Received by: (signature)	2. Relinquished by: (signature)	Date	Time	Received by: (signature)
3. Relinquished by: (signature)	Date	Time	Received by: (signature)	4. Relinquished by: (signature)	Date	Time	Received at Laboratory by: (signature) 2 April 2001 S. J. Lauren

Energy Laboratories, Inc.  
SAMPLE CONDITION REPORT

This report provides information about the condition of the sample(s), and associated sample custody information on receipt at the laboratory.

Client: International Uranium (USA) Corporation Description: WATER  
Lab ID(s): 01-31914-1 Thru 01-31914-4 Matrix: Liquid  
Delivered by: ups Date&Time Rec'd: 02-APR-01 1000 Date&Time Col'd: 26-MAR-01 1402  
Received by: Sara Hawken Logged In by: Sara Hawken

Chain of custody form completed & signed:	Yes	Comments:
Chain of custody seal:	No	Comments:
Chain of custody seal intact:	N/A	Comments:
Signature match, chain of custody vs. seal:	N/A	Comments:
Sample received Temperature:	5C	Comments:
Samples received within holding time:	Yes	Comments:
Samples received in proper containers:	Yes	Comments:
Samples Properly Preserved:	Yes	Comments:

Bottle Types Received: 4-16oz p nf h2so4

Comments: \_\_\_\_\_

TRACKING NO. PAGE NO.

3191370004

REPORT PACKAGE SUMMARY - FINAL PAGE

Acronyms and Definitions

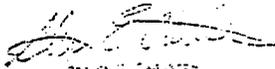
ELI-B Energy Laboratories, Inc. - Billings, Montana  
ELI-G Energy Laboratories, Inc. - Gillette, Wyoming  
ELI-H Energy Laboratories, Inc. - Helena, Montana  
ELI-R Energy Laboratories, Inc. - Rapid City, South Dakota

co - Carry over from previous sample  
ip - Insufficient parameters  
N/A - Not Applicable  
NA - Not Analyzed  
ND - Analyte Not Detected at Stated Limit of Detection  
NR - Analyte Not Requested  
NST - No Sample Time Given  
NSD - No Sample Date Given

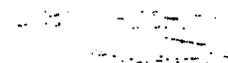
This Package Contains the following Client ID(s) and Lab ID(s)

Client ID: WMMM4 is associated to Lab ID: 01-31914-4  
Client ID: WMMTW-11 is associated to Lab ID: 01-31914-1  
Client ID: WMMTW-12 is associated to Lab ID: 01-31914-3  
Client ID: WMMTW-15 is associated to Lab ID: 01-31914-2

Approved By:

  
REGIONAL MANAGER  
CHEMICAL SERVICES

Reviewed By:

  
REGIONAL MANAGER  
CHEMICAL SERVICES

This is the last page of the Laboratory Analysis Report.  
Additional QC is available upon request.

The report contains the number of pages indicated by the last 4 digits

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LABORATORY ANALYSIS REPORT

Client: INTERNATIONAL URANIUM (USA) CORPORATION

Project: White Mesa Mill

Contact: Wally Brice

Sample Matrix: Liquid, Water

Date Received: 04-02-01

Report Date: April 9, 2001

Table with 4 columns: Laboratory ID, Sample Date / Time, Sample ID, Nitrate + Nitrite as N, mg/L. Contains 10 rows of data.

WMMTW4-10 is a Trip Blank (WMM Chem Lab DI Blank).

Quality Assurance Data table with 2 columns and 6 rows: Method, Reporting Limit, RPD, Spike, Analyst, Date/Time Analyzed.

NOTES:

- (1) These values are an assessment of analytical precision. The acceptance range is 0-20% for sample results above 10 times the reporting limit. This range is not applicable to samples with results below 10 times the reporting limit.
(2) These values are an assessment of analytical accuracy. They are a percent recovery of the spike addition. ELI performs a matrix spike on 10 percent of all samples for each analytical method.



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31913

For Sample Tracking Purposes, Please Provide Contact Name and Telephone #'s as Indicated (SEE BACK OF FORM FOR EXAMPLES AND INSTRUCTIONS)

Project Name / Location / Purchase Order # / Bid #				Number of containers Sample Type: A W S V U O Air Water Soils/solids Vegetation Urine Other	Type of Analyses Requested						Special Requests
Name / Phone # / Fax #											Comments, Special Instructions, etc.
White Mesa Mill / 6425 S. Hwy. #1 Blanding, UT 89511					Nitrates						500
Wally Brice / (435) 678-2221 / (435) 678-2224											
Date	Time	composite	grab sample	Send Invoice to:							
				Send Report to:							
				Sample I.D. WMMTW4-1							
3/29/01	0932	✓		WMMTW4-1	Nitrates						
3/29/01	1108	✓		WMMTW4-2							
3/29/01	1735	✓		WMMTW4-3							
3/27/01	0902	✓		WMMTW4-4							
3/28	1104	✓		WMMTW4-5							
3/26	8:00	✓		WMMTW4-6							
3/27/01	1456	✓		WMMTW4-7							
3/27/01	1654	✓		WMMTW4-8							
3/27/01	1120	✓		WMMTW4-9							
3/27/01	1401	✓		WMMTW4-10							

1. Sampler: (signature) Wally Brice	Date 3/30/01	Time 1000	Received by: (signature)	2. Relinquished by: (signature)	Date	Time	Received by: (signature)
3. Relinquished by: (signature)	Date	Time	Received by: (signature)	4. Relinquished by: (signature)	Date	Time	Received at Laboratory by: (signature)
					2 Apr 01 1000		Jeff Jackson



REPORT PACKAGE SUMMARY - FINAL PAGE

Acronyms and Definitions

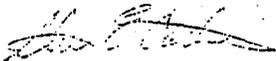
ELI-B Energy Laboratories, Inc. - Billings, Montana  
ELI-G Energy Laboratories, Inc. - Gillette, Wyoming  
ELI-H Energy Laboratories, Inc. - Helena, Montana  
ELI-R Energy Laboratories, Inc. - Rapid City, South Dakota

co - Carry over from previous sample  
ip - Insufficient parameters  
N/A - Not Applicable  
NA - Not Analyzed  
ND - Analyte Not Detected at Stated Limit of Detection  
NR - Analyte Not Requested  
NST - No Sample Time Given  
NSD - No Sample Date Given

This Package Contains the following Client ID(s) and Lab ID(s)

Client ID: WMMTW4-1 is associated to Lab ID: 01-31913-1  
Client ID: WMMTW4-10 is associated to Lab ID: 01-31913-10  
Client ID: WMMTW4-2 is associated to Lab ID: 01-31913-2  
Client ID: WMMTW4-3 is associated to Lab ID: 01-31913-3  
Client ID: WMMTW4-4 is associated to Lab ID: 01-31913-4  
Client ID: WMMTW4-5 is associated to Lab ID: 01-31913-5  
Client ID: WMMTW4-6 is associated to Lab ID: 01-31913-6  
Client ID: WMMTW4-7 is associated to Lab ID: 01-31913-7  
Client ID: WMMTW4-8 is associated to Lab ID: 01-31913-8  
Client ID: WMMTW4-9 is associated to Lab ID: 01-31913-9

Approved By:

  
BRUCE J. LUTHER  
LABORATORY SUPERVISOR

Reviewed By:

  
BRUCE J. LUTHER  
LABORATORY SUPERVISOR

This is the last page of the Laboratory Analysis Report.  
Additional QC is available upon request.

The report contains the number of pages indicated by the last 4 digits.

TRACKING NO. PAGE NO.

31913R00005

### LABORATORY ANALYSIS REPORT

Client: INTERNATIONAL URANIUM (USA) CORPORATION

Project: White Mesa Mill

Contact: Wally Brice

Sample Matrix: Liquid, Water

Date Received: 04-02-01

Report Date: April 9, 2001

Laboratory ID	Sample Date / Time	Sample ID	Nitrate + Nitrite as N, mg/L
01-31913-1	03-29-2001 09:32	WMMTW4-1	7.15
01-31913-2	03-29-2001 11:08	WMMTW4-2	10.2
01-31913-3	03-28-2001 17:35	WMMTW4-3	1.85
01-31913-4	03-27-2001 09:02	WMMTW4-4	14.5
01-31913-5	03-28-2001 11:04	WMMTW4-5	3.88
01-31913-6	03-26-2001 16:20	WMMTW4-6	0.13
01-31913-7	03-27-2001 14:56	WMMTW4-7	2.46
01-31913-8	03-27-2001 16:54	WMMTW4-8	< 0.10
01-31913-9	03-27-2001 11:20	WMMTW4-9	< 0.10
01-31913-10	03-26-2001 14:01	WMMTW4-10	< 0.10

#### Quality Assurance Data

Method	EPA 353.2
Reporting Limit	0.10
RPD <sup>1</sup>	0.8
Spike <sup>2</sup>	94
Analyst	rwk
Date/Time Analyzed	04-04-2001 15:30

#### NOTES:

- (1) These values are an assessment of analytical precision. The acceptance range is 0-20% for sample results above 10 times the reporting limit. This range is not applicable to samples with results below 10 times the reporting limit.
- (2) These values are an assessment of analytical accuracy. They are a percent recovery of the spike addition. ELI performs a matrix spike on 10 percent of all samples for each analytical method.

## LABORATORY ANALYSIS REPORT

Client: INTERNATIONAL URANIUM (USA) CORPORATION

Project: White Mesa Mill

Contact: Wally Brice

Sample Matrix: Liquid, Water

Date Received: 04-02-01

Report Date: April 9, 2001

Laboratory ID	Sample Date / Time	Sample ID	Nitrate + Nitrite as N, mg/L
01-31914-1	03-26-2001 14:02	WMMTW4-11	< 0.10
01-31914-2	03-26-2001 15:49	WMMTW4-15	< 0.10
01-31914-3	03-29-2001 11:08	WMMTW4-12	10.0
01-31914-4	03-29-2001 12:38	WMMM4	8.77

### Quality Assurance Data

Method	EPA 353.2
Reporting Limit	0.10
RPD <sup>1</sup>	1.0
Spike <sup>2</sup>	96
Analyst	rwk
Date/Time Analyzed	04-04-2001 17:13

#### NOTES:

- (1) These values are an assessment of analytical precision. The acceptance range is 0-20% for sample results above 10 times the reporting limit. This range is not applicable to samples with results below 10 times the reporting limit.
- (2) These values are an assessment of analytical accuracy. They are a percent recovery of the spike addition. ELI performs a matrix spike on 10 percent of all samples for each analytical method.





**LABORATORY ANALYSIS REPORT, EPA METHOD 8260**  
**Volatile Organic Compounds**

Client:	International Uranium (USA) Corporation	Date Sampled:	03-28-01
Project:	WHITE MESA MILL	Time Sampled:	17:56
Sample ID:	WMMTW4-3	Date/Time Received:	04-02-01 10:00
Laboratory ID:	01-31916-3	Date Analyzed:	04-04-01
Matrix:	Liquid - WATER	Date Reported:	April 14, 2001
Dilution Factor:	100		

C.A.S. #	TARGET COMPOUNDS	CONCENTRATION (µg/L)	REPORT LIMIT (µg/L)
67-66-3	Chloroform (Trichloromethane)	347	50.0

*ND - Analyte not detected at stated limit of detection*

**RUNTIME QUALITY ASSURANCE REPORT**

INTERNAL STANDARDS	AREA	ICAL / CCAL AREA	PERCENT RECOVERY	ACCEPTANCE RANGE
Pentafluorobenzene	1158619	1150521	101%	50 - 200 %
Fluorobenzene	2404030	2388861	101%	50 - 200 %
1,4 - Difluorobenzene	1745382	1775533	98.3%	50 - 200 %
Chlorobenzene - d5	1175904	1163446	101%	50 - 200 %
1,4 - Dichlorobenzene - d4	472736	458787	103%	50 - 200 %

SYSTEM MONITORING COMPOUNDS	CONCENTRATION	PERCENT RECOVERY	ACCEPTANCE RANGE
Dibromofluoromethane	9.48	94.8%	86 - 118 %
Toluene - d8	10.3	103%	88 - 110 %
4 - Bromofluorobenzene	10.1	101%	86 - 115 %
1,2 - Dichlorobenzene - d4	9.85	98.5%	80 - 120 %

**METHODS USED IN THIS ANALYSIS:**  
EPA 5030B, EPA 8260B



# LABORATORY ANALYSIS REPORT, EPA METHOD 8260

## Volatile Organic Compounds

Client: International Uranium (USA) Corporation Date Sampled: 03-28-01  
Project: WHITE MESA MILL Time Sampled: 11:22  
Sample ID: WMMTW4-5 Date/Time Received: 04-02-01 10:00  
Laboratory ID: 01-31916-5 Date Analyzed: 04-04-01  
Matrix: Liquid - WATER Date Reported: April 14, 2001  
Dilution Factor: 10

C.A.S. #	TARGET COMPOUNDS	CONCENTRATION (µg/L)	REPORT LIMIT (µg/L)
67-66-3	Chloroform (Trichloromethane)	236	5.0

ND - Analyte not detected at stated limit of detection

### RUNTIME QUALITY ASSURANCE REPORT

INTERNAL STANDARDS	AREA	ICAL / CCAL AREA	PERCENT RECOVERY	ACCEPTANCE RANGE
Pentafluorobenzene	1107374	1150521	96.2%	50 - 200 %
Fluorobenzene	2345208	2388861	98.2%	50 - 200 %
1,4 - Difluorobenzene	1698810	1775533	95.7%	50 - 200 %
Chlorobenzene - d5	1159686	1163446	99.7%	50 - 200 %
1,4 - Dichlorobenzene - d4	466834	458787	102%	50 - 200 %

SYSTEM MONITORING COMPOUNDS	CONCENTRATION	PERCENT RECOVERY	ACCEPTANCE RANGE
Dibromofluoromethane	9.46	94.6%	86 - 118 %
Toluene - d8	10.4	104%	88 - 110 %
4 - Bromofluorobenzene	10.1	101%	86 - 115 %
1,2 - Dichlorobenzene - d4	9.76	97.6%	80 - 120 %

### METHODS USED IN THIS ANALYSIS:

EPA 5030B, EPA 8260B





**LABORATORY ANALYSIS REPORT, EPA METHOD 8260**

**Volatile Organic Compounds**

Client: International Uranium (USA) Corporation  
Project: WHITE MESA MILL  
Sample ID: WMMTW4-8  
Laboratory ID: 01-31916-8  
Matrix: Liquid - WATER  
Dilution Factor: 10

Date Sampled: 03-26-01  
Time Sampled: 17:00  
Date/Time Received: 04-02-01 10:00  
Date Analyzed: 04-04-01  
Date Reported: April 14, 2001

C.A.S. #	TARGET COMPOUNDS	CONCENTRATION (µg/L)	REPORT LIMIT (µg/L)
67-66-3	Chloroform (Trichloromethane)	116	5.0

*ND - Analyte not detected at stated limit of detection*

**RUNTIME QUALITY ASSURANCE REPORT**

INTERNAL STANDARDS	AREA	ICAL / CCAL AREA	PERCENT RECOVERY	ACCEPTANCE RANGE
Pentafluorobenzene	1090084	1150521	94.7%	50 - 200 %
Fluorobenzene	2309760	2388861	96.7%	50 - 200 %
1,4 - Difluorobenzene	1664765	1775533	93.8%	50 - 200 %
Chlorobenzene - d5	1119681	1163446	96.2%	50 - 200 %
1,4 - Dichlorobenzene - d4	442367	458787	96.4%	50 - 200 %

SYSTEM MONITORING COMPOUNDS	CONCENTRATION	PERCENT RECOVERY	ACCEPTANCE RANGE
Dibromofluoromethane	9.57	95.7%	86 - 118 %
Toluene - d8	10.4	104%	88 - 110 %
4 - Bromofluorobenzene	10.1	101%	86 - 115 %
1,2 - Dichlorobenzene - d4	9.94	99.4%	80 - 120 %

**METHODS USED IN THIS ANALYSIS:**

EPA 5030B, EPA 8260B

**LABORATORY ANALYSIS REPORT, EPA METHOD 8260**

**Volatile Organic Compounds**

Client: International Uranium (USA) Corporation Date Sampled: 03-27-01  
Project: WHITE MESA MILL Time Sampled: 11:35  
Sample ID: WMTW4-9 Date/Time Received: 04-02-01 10:00  
Laboratory ID: 01-31916-9 Date Analyzed: 04-05-01  
Matrix: Liquid - WATER Date Reported: April 14, 2001  
Dilution Factor: 2

C.A.S. #	TARGET COMPOUNDS	CONCENTRATION (µg/L)	REPORT LIMIT (µg/L)
67-66-3	Chloroform (Trichloromethane)	43.6	1.0

ND - Analyte not detected at stated limit of detection

**RUNTIME QUALITY ASSURANCE REPORT**

INTERNAL STANDARDS	AREA	ICAL / CCAL AREA	PERCENT RECOVERY	ACCEPTANCE RANGE
Pentafluorobenzene	1067998	1150521	92.8%	50 - 200 %
Fluorobenzene	2306313	2388861	96.5%	50 - 200 %
1,4 - Difluorobenzene	1658294	1775533	93.4%	50 - 200 %
Chlorobenzene - d5	1115898	1163446	95.9%	50 - 200 %
1,4 - Dichlorobenzene - d4	447091	458787	97.5%	50 - 200 %

SYSTEM MONITORING COMPOUNDS	CONCENTRATION	PERCENT RECOVERY	ACCEPTANCE RANGE
Dibromofluoromethane	9.50	95.0%	86 - 118 %
Toluene - d8	10.5	105%	88 - 110 %
4 - Bromofluorobenzene	10.1	101%	86 - 115 %
1,2 - Dichlorobenzene - d4	9.80	98.0%	80 - 120 %

**METHODS USED IN THIS ANALYSIS:**

EPA 5030B, EPA 8260B

**LABORATORY ANALYSIS REPORT, EPA METHOD 8260**

**Volatile Organic Compounds**

Client:	International Uranium (USA) Corporation	Date Sampled:	03-23-01
Project:	WHITE MESA MILL	Time Sampled:	12:45
Sample ID:	WMMTW4-10 <b>QA</b>	Date/Time Received:	04-02-01 10:00
Laboratory ID:	01-31916-10	Date Analyzed:	04-05-01
Matrix:	Liquid - WATER	Date Reported:	April 14, 2001
Dilution Factor:	2		

C.A.S. #	TARGET COMPOUNDS	CONCENTRATION (µg/L)	REPORT LIMIT (µg/L)
67-66-3	Chloroform (Trichloromethane)	ND	1.0

*ND - Analyte not detected at stated limit of detection.*

**RUNTIME QUALITY ASSURANCE REPORT**

INTERNAL STANDARDS	AREA	ICAL / CCAL AREA	PERCENT RECOVERY	ACCEPTANCE RANGE
Pentafluorobenzene	1081645	1150521	94.0%	50 - 200 %
Fluorobenzene	2280451	2388861	95.5%	50 - 200 %
1,4 - Difluorobenzene	1630418	1775533	91.8%	50 - 200 %
Chlorobenzene - d5	1103332	1163446	94.8%	50 - 200 %
1,4 - Dichlorobenzene - d4	437754	458787	95.4%	50 - 200 %

SYSTEM MONITORING COMPOUNDS	CONCENTRATION	PERCENT RECOVERY	ACCEPTANCE RANGE
Dibromofluoromethane	9.55	95.5%	86 - 118 %
Toluene - d8	10.6	106%	88 - 110 %
4 - Bromofluorobenzene	10.2	102%	86 - 115 %
1,2 - Dichlorobenzene - d4	9.91	99.1%	80 - 120 %

**METHODS USED IN THIS ANALYSIS:**

EPA 5030B, EPA 8260B





**LABORATORY ANALYSIS REPORT, EPA METHOD 8260**  
**Volatile Organic Compounds**

Client:	International Uranium (USA) Corporation	Date Sampled:	03-23-01
Project:	WHITE MESA MILL	Time Sampled:	14:24
Sample ID:	WMMTW4-13 <i>Rinsate prior to</i>	Date/Time Received:	04-02-01 10:00
Laboratory ID:	01-31916-13 <i>purging and</i>	Date Analyzed:	04-05-01
Matrix:	Liquid - WATER <i>sampling POC wells.</i>	Date Reported:	April 14, 2001
Dilution Factor:	2 <i>(Collected a few wells)</i>		

C.A.S. #	TARGET COMPOUNDS	CONCENTRATION (µg/L)	REPORT LIMIT (µg/L)
67-66-3	Chloroform (Trichloromethane)	16.7	1.0

*ND - Analyte not detected at stated limit of detection*

**RUNTIME QUALITY ASSURANCE REPORT**

INTERNAL STANDARDS	AREA	ICAL / CCAL AREA	PERCENT RECOVERY	ACCEPTANCE RANGE
Pentafluorobenzene	1056010	1150521	91.8%	50 - 200 %
Fluorobenzene	2291350	2388861	95.9%	50 - 200 %
1,4 - Difluorobenzene	1639990	1775533	92.4%	50 - 200 %
Chlorobenzene - d5	1102979	1163446	94.8%	50 - 200 %
1,4 - Dichlorobenzene - d4	429163	458787	93.5%	50 - 200 %

SYSTEM MONITORING COMPOUNDS	CONCENTRATION	PERCENT RECOVERY	ACCEPTANCE RANGE
Dibromofluoromethane	9.56	95.6%	86 - 118 %
Toluene - d8	10.5	105%	88 - 110 %
4 - Bromofluorobenzene	10.1	101%	86 - 115 %
1,2 - Dichlorobenzene - d4	9.85	98.5%	80 - 120 %

**METHODS USED IN THIS ANALYSIS:**  
**EPA 5030B, EPA 8260B**

**LABORATORY ANALYSIS REPORT, EPA METHOD 8260**

**Volatile Organic Compounds**

Client: International Uranium (USA) Corporation Date Sampled: 03-25-01  
Project: WHITE MESA MILL Time Sampled: 12:33  
Sample ID: WMMTW4-14 *Resite prior to* Date/Time Received: 04-02-01 10:00  
Laboratory ID: 01-31916-14 *MW-17* Date Analyzed: 04-05-01  
Matrix: Liquid - WATER Date Reported: April 14, 2001  
Dilution Factor: 2

C.A.S. #	TARGET COMPOUNDS	CONCENTRATION (µg/L)	REPORT LIMIT (µg/L)
67-66-3	Chloroform (Trichloromethane)	ND	1.0

*ND - Analyte not detected at stated limit of detection*

**RUNTIME QUALITY ASSURANCE REPORT**

INTERNAL STANDARDS	AREA	ICAL / CCAL AREA	PERCENT RECOVERY	ACCEPTANCE RANGE
Pentafluorobenzene	1053851	1150521	91.6%	50 - 200 %
Fluorobenzene	2258371	2388861	94.5%	50 - 200 %
1,4 - Difluorobenzene	1603542	1775533	90.3%	50 - 200 %
Chlorobenzene - d5	1090824	1163446	93.8%	50 - 200 %
1,4 - Dichlorobenzene - d4	426403	458787	92.9%	50 - 200 %

SYSTEM MONITORING COMPOUNDS	CONCENTRATION	PERCENT RECOVERY	ACCEPTANCE RANGE
Dibromofluoromethane	9.62	96.2%	86 - 118 %
Toluene - d8	10.6	106%	88 - 110 %
4 - Bromofluorobenzene	10.1	101%	86 - 115 %
1,2 - Dichlorobenzene - d4	9.78	97.8%	80 - 120 %

**METHODS USED IN THIS ANALYSIS:**

EPA 5030B, EPA 8260B

**LABORATORY ANALYSIS REPORT, EPA METHOD 8260**

**Volatile Organic Compounds**

Client:	International Uranium (USA) Corporation	Date Sampled:	03-25-01
Project:	WHITE MESA MILL	Time Sampled:	13:35
Sample ID:	WMMTW4-15 <i>Rinsate prior to</i>	Date/Time Received:	04-02-01 10:00
Laboratory ID:	01-31916-15 <i>Chloroform wells.</i>	Date Analyzed:	04-05-01
Matrix:	Liquid - WATER	Date Reported:	April 14, 2001
Dilution Factor:	2		

C.A.S. #	TARGET COMPOUNDS	CONCENTRATION (µg/L)	REPORT LIMIT (µg/L)
67-66-3	Chloroform (Trichloromethane)	ND	1.0

*ND - Analyte not detected at stated limit of detection*

**RUNTIME QUALITY ASSURANCE REPORT**

INTERNAL STANDARDS	AREA	ICAL / CCAL AREA	PERCENT RECOVERY	ACCEPTANCE RANGE
Pentafluorobenzene	1064856	1150521	92.6%	50 - 200 %
Fluorobenzene	2258935	2388861	94.6%	50 - 200 %
1,4 - Difluorobenzene	1624960	1775533	91.5%	50 - 200 %
Chlorobenzene - d5	1088081	1163446	93.5%	50 - 200 %
1,4 - Dichlorobenzene - d4	419852	458787	91.5%	50 - 200 %

SYSTEM MONITORING COMPOUNDS	CONCENTRATION	PERCENT RECOVERY	ACCEPTANCE RANGE
Dibromofluoromethane	9.47	94.7%	86 - 118 %
Toluene - d8	10.5	105%	88 - 110 %
4 - Bromofluorobenzene	10.1	101%	86 - 115 %
1,2 - Dichlorobenzene - d4	9.98	99.8%	80 - 120 %

**METHODS USED IN THIS ANALYSIS:**

EPA 5030B, EPA 8260B



# LABORATORY ANALYSIS REPORT, EPA METHOD 8260

## Volatile Organic Compounds

Client: International Uranium (USA) Corporation Date Sampled: 03-25-01  
Project: WHITE MESA MILL Time Sampled: 14:48  
Sample ID: WMMM17 Date/Time Received: 04-02-01 10:00  
Laboratory ID: 01-31916-17 Date Analyzed: 04-05-01  
Matrix: Liquid - WATER Date Reported: April 14, 2001  
Dilution Factor: 2

C.A.S. #	TARGET COMPOUNDS	CONCENTRATION (µg/L)	REPORT LIMIT (µg/L)
67-66-3	Chloroform (Trichloromethane)	ND	1.0

ND - Analyte not detected at stated limit of detection

### RUNTIME QUALITY ASSURANCE REPORT

INTERNAL STANDARDS	AREA	ICAL / CCAL AREA	PERCENT RECOVERY	ACCEPTANCE RANGE
Pentafluorobenzene	1055347	1150521	91.7%	50 - 200 %
Fluorobenzene	2270030	2388861	95.0%	50 - 200 %
1,4 - Difluorobenzene	1618320	1775533	91.1%	50 - 200 %
Chlorobenzene - d5	1091563	1163446	93.8%	50 - 200 %
1,4 - Dichlorobenzene - d4	432256	458787	94.2%	50 - 200 %

SYSTEM MONITORING COMPOUNDS	CONCENTRATION	PERCENT RECOVERY	ACCEPTANCE RANGE
Dibromofluoromethane	9.61	96.1%	86 - 118 %
Toluene - d8	10.6	106%	88 - 110 %
4 - Bromofluorobenzene	10.2	102%	86 - 115 %
1,2 - Dichlorobenzene - d4	9.88	98.8%	80 - 120 %

### METHODS USED IN THIS ANALYSIS:

EPA 5030B, EPA 8260B

**LABORATORY ANALYSIS REPORT, EPA METHOD 8260**

**Volatile Organic Compounds**

Client:	International Uranium (USA) Corporation	Date Sampled:	03-30-01
Project:	WHITE MESA MILL	Time Sampled:	07:36
Sample ID:	WMMTW4 COMP	Date/Time Received:	04-02-01 10:00
Laboratory ID:	01-31916-18	Date Analyzed:	04-05-01
Matrix:	Liquid - WATER	Date Reported:	April 14, 2001
Dilution Factor:	100		

C.A.S. #	TARGET COMPOUNDS	CONCENTRATION (µg/L)	REPORT LIMIT (µg/L)
67-66-3	Chloroform (Trichloromethane)	687	50.0

*ND - Analyte not detected at stated limit of detection*

**RUNTIME QUALITY ASSURANCE REPORT**

INTERNAL STANDARDS	AREA	ICAL / CCAL AREA	PERCENT RECOVERY	ACCEPTANCE RANGE
Pentafluorobenzene	1036677	1150521	90.1%	50 - 200 %
Fluorobenzene	2249534	2388861	94.2%	50 - 200 %
1,4 - Difluorobenzene	1598837	1775533	90.0%	50 - 200 %
Chlorobenzene - d5	1072649	1163446	92.2%	50 - 200 %
1,4 - Dichlorobenzene - d4	416945	458787	90.9%	50 - 200 %

SYSTEM MONITORING COMPOUNDS	CONCENTRATION	PERCENT RECOVERY	ACCEPTANCE RANGE
Dibromofluoromethane	9.44	94.4%	86 - 118 %
Toluene - d8	10.6	106%	88 - 110 %
4 - Bromofluorobenzene	10.2	102%	86 - 115 %
1,2 - Dichlorobenzene - d4	9.92	99.2%	80 - 120 %

**METHODS USED IN THIS ANALYSIS:**

EPA 5030B, EPA 8260B

**LABORATORY ANALYSIS REPORT, EPA METHOD 8260**

**Volatile Organic Compounds**

Client:	International Uranium (USA) Corporation	Date Sampled:	03-16-01
Project:	WHITE MESA MILL	Time Sampled:	16:10
Sample ID:	TRIP BLANK	Date/Time Received:	04-02-01 10:00
Laboratory ID:	01-31916-19	Date Analyzed:	04-04-01
Matrix:	Liquid - WATER	Date Reported:	April 14, 2001
Dilution Factor:	1		

C.A.S. #	TARGET COMPOUNDS	CONCENTRATION (µg/L)	REPORT LIMIT (µg/L)
67-66-3	Chloroform (Trichloromethane)	ND	1.0

*ND - Analyte not detected at stated limit of detection*

**RUNTIME QUALITY ASSURANCE REPORT**

INTERNAL STANDARDS	AREA	ICAL / CCAL AREA	PERCENT RECOVERY	ACCEPTANCE RANGE
Pentafluorobenzene	1191328	1150521	104%	50 - 200 %
Fluorobenzene	2452721	2388861	103%	50 - 200 %
1,4 - Difluorobenzene	1788376	1775533	101%	50 - 200 %
Chlorobenzene - d5	1218017	1163446	105%	50 - 200 %
1,4 - Dichlorobenzene - d4	491947	458787	107%	50 - 200 %

SYSTEM MONITORING COMPOUNDS	CONCENTRATION	PERCENT RECOVERY	ACCEPTANCE RANGE
Dibromofluoromethane	9.59	95.9%	86 - 118 %
Toluene - d8	10.2	102%	88 - 110 %
4 - Bromofluorobenzene	9.89	98.9%	86 - 115 %
1,2 - Dichlorobenzene - d4	9.79	97.9%	80 - 120 %

**METHODS USED IN THIS ANALYSIS:**

EPA 5030B, EPA 8260B

**LABORATORY ANALYSIS REPORT, EPA METHOD 8260**  
**Volatile Organic Compounds**

Client:	International Uranium (USA) Corporation	Date Sampled:	N/A
Project:	WHITE MESA MILL	Time Sampled:	N/A
Sample ID:	Method Blank	Date/Time Received:	N/A
Laboratory ID:	MB0404	Date Analyzed:	04-04-01
Matrix:	Water	Date Reported:	April 12, 2001
Dilution Factor:	1		

C.A.S. #	TARGET COMPOUNDS	CONCENTRATION (µg/L)	REPORT LIMIT (µg/L)
67-66-3	Chloroform (Trichloromethane)	ND	1.0

*ND - Analyte not detected at stated limit of detection*

**RUNTIME QUALITY ASSURANCE REPORT**

INTERNAL STANDARDS	AREA	ICAL / CCAL AREA	PERCENT RECOVERY	ACCEPTANCE RANGE
Pentafluorobenzene	1184558	1150521	103%	50 - 200 %
Fluorobenzene	2435440	2388861	102%	50 - 200 %
1,4 - Difluorobenzene	1782379	1775533	100%	50 - 200 %
Chlorobenzene - d5	1183537	1163446	102%	50 - 200 %
1,4 - Dichlorobenzene - d4	464888	458787	101%	50 - 200 %

SYSTEM MONITORING COMPOUNDS	CONCENTRATION	PERCENT RECOVERY	ACCEPTANCE RANGE
Dibromofluoromethane	9.53	95.3%	86 - 118 %
Toluene - d8	10.2	102%	88 - 110 %
4 - Bromofluorobenzene	9.88	98.8%	86 - 115 %
1,2 - Dichlorobenzene - d4	9.85	98.5%	80 - 120 %

**METHODS USED IN THIS ANALYSIS:**

EPA 5030B, EPA 8260B

**LABORATORY ANALYSIS REPORT, EPA METHOD 8260**  
**QC RESULTS - MATRIX SPIKE (MS), MATRIX SPIKE DUPLICATE (MSD)**

**Client:** International Uranium (USA) Corporation  
**Sample Set:** 01-31916-1 through 01-31916-19  
**Laboratory ID:** 01-31916-17 S  
**Matrix:** Liquid - WATER

**Date Sampled:** 03-29-01  
**Date/Time Received:** 04-02-01 10:00  
**Date Analyzed:** 04-05-01  
**Date Reported:** April 12, 2001

**INTERNAL STANDARDS**

	ICAL / CCAL	SPIKED SAMPLE		SPIKE DUPLICATE		ACCEPTANCE
	AREA	AREA	%	AREA	%	RANGE
Pentafluorobenzene	1150521	1025937	89.2%	1034958	90.0%	50 - 200 %
Fluorobenzene	2388861	2213431	92.7%	2237292	93.7%	50 - 200 %
1,4 - Difluorobenzene	1775533	1595730	89.9%	1600008	90.1%	50 - 200 %
Chlorobenzene - d5	1163446	1065324	91.6%	1060181	91.1%	50 - 200 %
1,4 - Dichlorobenzene-d4	458787	425066	92.6%	424488	92.5%	50 - 200 %

**SYSTEM MONITORING COMPOUNDS**

	SPIKED SAMPLE CONCENTRATION	PERCENT RECOVERY	SPIKE DUPLICATE CONCENTRATION	PERCENT RECOVERY	ACCEPTANCE RANGE
Dibromofluoromethane	9.62	96.2%	9.57	95.7%	86 - 118 %
Toluene - d8	10.6	106%	10.6	106%	88 - 110 %
4 - Bromofluorobenzene	10.3	103%	10.4	104%	86 - 115 %
1,2 - Dichlorobenzene-d4	9.95	99.5%	9.97	99.7%	80 - 120 %

**SPIKED SAMPLE RESULTS**

	SPIKED SAMPLE CONCENTRATION	ORIG. CONC. (µg/L) *	SPIKE AMOUNT (µg/L)	PERCENT RECOVERY	ACCEPTANCE RANGE
Chloroform (Trichloromethane)	9.85	ND	10.0	98.5%	70 - 130 %

**SPIKE DUPLICATE SAMPLE RESULTS**

	SPIKE DUP CONCENTRATION	ORIG. CONC. (µg/L)	SPIKE (µg/L)	PERCENT RECOVERY	RPD	RPD LIMITS
Chloroform (Trichloromethane)	10.1	ND	10.0	101%	2.8%	20 %

\* Concentration does include dilution correction

**MATRIX SPIKE:** 0 of 2 Matrix Spike results are outside of established QC Limits  
**MATRIX SPIKE DUPLICATE:** 0 of 1 Matrix Spike Duplicate results are outside of established QC Limits

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**ENERGY LABORATORIES, INC.**

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July 10, 2001

Wally Brice  
International Uranium Corp. (IUC)  
PO Box 809  
Blanding, Utah 84511

Order No: C01060297

**RE: White Mesa Mill**

Mr. Brice:

The following cover letter is a summary of the attached analytical results for the above referenced project.

This packet contains one invoice, thirteen pages of analytical results, one page of quality assurance data, the project chain of custody, and the sample receipt condition report. This packet contains 20 pages including this cover letter.

There were no problems with the analyses and all data for the batch QC met USEPA or laboratory specifications.

If you have any questions regarding these test results, please feel free to call. Energy Laboratories, Inc. appreciates the opportunity to provide you with analytical services for your projects.

STEVEN E. CAPLAN  
ORGANICS SUPERVISOR

Approved By:

CATHY FORSTING  
PROJECT MANAGER

QAQC - Data Validation:



**CLIENT:** International Uranium (USA) Corp-Blandin  
**Lab Order:** C01060297  
**Project:** White Mesa Mill  
**Lab ID:** C01060297-001 **Matrix:** AQUEOUS

**Report Date:** 07/05/01  
**Collection Date:** 06/21/01 10:34  
**Client Sample ID:** WMMTW4-1

Analyses	Result	Units	Qual	MCL/		Method	Analysis Date / By
				RL	QCL		
<b>VOLATILE ORGANIC COMPOUNDS</b>							
Chloroform	6000	ug/L		200		SW8260B	06/28/01 17:03 / rlo
Surr: 1,2-Dichlorobenzene-d4	99.8	%REC			80-120	SW8260B	06/28/01 17:03 / rlo
Surr: Dibromofluoromethane	111	%REC			80-120	SW8260B	06/28/01 17:03 / rlo
Surr: p-Bromofluorobenzene	102	%REC			80-120	SW8260B	06/28/01 17:03 / rlo
Surr: Toluene-d8	102	%REC			80-120	SW8260B	06/28/01 17:03 / rlo

**Report Definitions:**

ND - Not detected at the reporting limit  
J - Analyte detected below quantitation limits  
B - Analyte detected in the associated method blank  
MCL - Maximum contaminant level  
QCL - Quality control limit

S - Spike recovery outside accepted recovery limits  
R - RPD outside accepted recovery limits  
\* - Value exceeds maximum contaminant level  
RL - Analyte reporting level



**CLIENT:** International Uranium (USA) Corp-Blandin  
**Lab Order:** C01060297  
**Project:** White Mesa Mill  
**Lab ID:** C01060297-002 **Matrix:** AQUEOUS

**Report Date:** 07/05/01  
**Collection Date:** 06/22/01 10:42  
**Client Sample ID:** WMMTW4-2

Analyses	Result	Units	Qual	MCL/		Method	Analysis Date / By
				RL	QCL		
<b>VOLATILE ORGANIC COMPOUNDS</b>							
Chloroform	5500	ug/L		200		SW8260B	06/28/01 17:46 / rio
Surr: 1,2-Dichlorobenzene-d4	101	%REC			80-120	SW8260B	06/28/01 17:46 / rio
Surr: Dibromofluoromethane	114	%REC			80-120	SW8260B	06/28/01 17:46 / rio
Surr: p-Bromofluorobenzene	102	%REC			80-120	SW8260B	06/28/01 17:46 / rio
Surr: Toluene-d8	100	%REC			80-120	SW8260B	06/28/01 17:46 / rio

**Report Definitions:**

ND - Not detected at the reporting limit

J - Analyte detected below quantitation limits

B - Analyte detected in the associated method blank

MCL - Maximum contaminant level

QCL - Quality control limit

S - Spike recovery outside accepted recovery limits

R - RPD outside accepted recovery limits

\* - Value exceeds maximum contaminant level

RL - Analyte reporting level



**CLIENT:** International Uranium (USA) Corp-Blandin  
**Lab Order:** C01060297  
**Project:** White Mesa Mill  
**Lab ID:** C01060297-003 **Matrix:** AQUEOUS

**Report Date:** 07/05/01  
**Collection Date:** 06/21/01 09:04  
**Client Sample ID:** WMMTW4-3

Analyses	Result	Units	Qual	MCL/		Method	Analysis Date / By
				RL	QCL		
<b>VOLATILE ORGANIC COMPOUNDS</b>							
Chloroform	390	ug/L		50		SW8260B	06/28/01 18:28 / rio
Surr: 1,2-Dichlorobenzene-d4	98.8	%REC			80-120	SW8260B	06/28/01 18:28 / rio
Surr: Dibromofluoromethane	113	%REC			80-120	SW8260B	06/28/01 18:28 / rio
Surr: p-Bromofluorobenzene	102	%REC			80-120	SW8260B	06/28/01 18:28 / rio
Surr: Toluene-d8	101	%REC			80-120	SW8260B	06/28/01 18:28 / rio

**Report  
Definitions:**

ND - Not detected at the reporting limit  
J - Analyte detected below quantitation limits  
B - Analyte detected in the associated method blank  
MCL - Maximum contaminant level  
QCL - Quality control limit

S - Spike recovery outside accepted recovery limits  
R - RPD outside accepted recovery limits  
\* - Value exceeds maximum contaminant level  
RL - Analyte reporting level



CLIENT: International Uranium (USA) Corp-Blandin  
Lab Order: C01060297  
Project: White Mesa Mill  
Lab ID: C01060297-004 Matrix: AQUEOUS

Report Date: 07/05/01  
Collection Date: 06/20/01 09:36  
Client Sample ID: WMMTW4-4

Analyses	Result	Units	Qual	MCL/		Method	Analysis Date / By
				RL	QCL		
<b>VOLATILE ORGANIC COMPOUNDS</b>							
Chloroform	3100	ug/L		200		SW8260B	06/28/01 19:11 / rto
Surr: 1,2-Dichlorobenzene-d4	100	%REC			80-120	SW8260B	06/28/01 19:11 / rto
Surr: Dibromofluoromethane	113	%REC			80-120	SW8260B	06/28/01 19:11 / rto
Surr: p-Bromofluorobenzene	103	%REC			80-120	SW8260B	06/28/01 19:11 / rto
Surr: Toluene-d8	101	%REC			80-120	SW8260B	06/28/01 19:11 / rto

**Report  
Definitions:**

ND - Not detected at the reporting limit

J - Analyte detected below quantitation limits

B - Analyte detected in the associated method blank

MCL - Maximum contaminant level

QCL - Quality control limit

S - Spike recovery outside accepted recovery limits

R - RPD outside accepted recovery limits

\* - Value exceeds maximum contaminant level

RL - Analyte reporting level



**CLIENT:** International Uranium (USA) Corp-Blandin  
**Lab Order:** C01060297  
**Project:** White Mesa Mill  
**Lab ID:** C01060297-005 **Matrix:** AQUEOUS

**Report Date:** 07/05/01  
**Collection Date:** 06/20/01 14:14  
**Client Sample ID:** WMMTW4-5

Analyses	Result	Units	Qual	MCL/		Method	Analysis Date / By
				RL	QCL		
<b>VOLATILE ORGANIC COMPOUNDS</b>							
Chloroform	240	ug/L		10		SW8260B	06/28/01 19:53 / rio
Surr: 1,2-Dichlorobenzene-d4	99.3	%REC			80-120	SW8260B	06/28/01 19:53 / rio
Surr: Dibromofluoromethane	117	%REC			80-120	SW8260B	06/28/01 19:53 / rio
Surr: p-Bromofluorobenzene	102	%REC			80-120	SW8260B	06/28/01 19:53 / rio
Surr: Toluene-d8	102	%REC			80-120	SW8260B	06/28/01 19:53 / rio

**Report  
Definitions:**

ND - Not detected at the reporting limit

J - Analyte detected below quantitation limits

B - Analyte detected in the associated method blank

MCL - Maximum contaminant level

QCL - Quality control limit

S - Spike recovery outside accepted recovery limits

R - RPD outside accepted recovery limits

\* - Value exceeds maximum contaminant level

RL - Analyte reporting level



CLIENT: International Uranium (USA) Corp-Blandin  
Lab Order: C01060297  
Project: White Mesa Mill  
Lab ID: C01060297-006 Matrix: AQUEOUS

Report Date: 07/05/01  
Collection Date: 06/20/01 09:58  
Client Sample ID: WMMTW4-6

Analyses	Result	Units	Qual	MCL/		Method	Analysis Date / By
				RL	QCL		
<b>VOLATILE ORGANIC COMPOUNDS</b>							
Chloroform	ND	ug/L		2.0		SW8260B	06/28/01 20:36 / rto
Surr: 1,2-Dichlorobenzene-d4	100	%REC			80-120	SW8260B	06/28/01 20:36 / rto
Surr: Dibromofluoromethane	114	%REC			80-120	SW8260B	06/28/01 20:36 / rto
Surr: p-Bromofluorobenzene	102	%REC			80-120	SW8260B	06/28/01 20:36 / rto
Surr: Toluene-d8	102	%REC			80-120	SW8260B	06/28/01 20:36 / rto

**Report  
Definitions:**

ND - Not detected at the reporting limit

J - Analyte detected below quantitation limits

B - Analyte detected in the associated method blank

MCL - Maximum contaminant level

QCL - Quality control limit

S - Spike recovery outside accepted recovery limits

R - RPD outside accepted recovery limits

\* - Value exceeds maximum contaminant level

RL - Analyte reporting level



CLIENT: International Uranium (USA) Corp-Blandin  
Lab Order: C01060297  
Project: White Mesa Mill  
Lab ID: C01060297-007 Matrix: AQUEOUS

Report Date: 07/05/01  
Collection Date: 06/20/01 12:55  
Client Sample ID: WMMTW4-8

Analyses	Result	Units	Qual	MCL/		Method	Analysis Date / By
				RL	QCL		
<b>VOLATILE ORGANIC COMPOUNDS</b>							
Chloroform	180	ug/L		10		SW8260B	06/28/01 21:19 / rlo
Surr: 1,2-Dichlorobenzene-d4	101	%REC			80-120	SW8260B	06/28/01 21:19 / rlo
Surr: Dibromofluoromethane	112	%REC			80-120	SW8260B	06/28/01 21:19 / rlo
Surr: p-Bromofluorobenzene	103	%REC			80-120	SW8260B	06/28/01 21:19 / rlo
Surr: Toluene-d8	102	%REC			80-120	SW8260B	06/28/01 21:19 / rlo

**Report  
Definitions:**

ND - Not detected at the reporting limit  
J - Analyte detected below quantitation limits  
B - Analyte detected in the associated method blank  
MCL - Maximum contaminant level  
QCL - Quality control limit

S - Spike recovery outside accepted recovery limits  
R - RPD outside accepted recovery limits  
\* - Value exceeds maximum contaminant level  
RL - Analyte reporting level



CLIENT: International Uranium (USA) Corp-Blandin  
Lab Order: C01060297  
Project: White Mesa Mill  
Lab ID: C01060297-008 Matrix: AQUEOUS

Report Date: 07/05/01  
Collection Date: 06/20/01 11:09  
Client Sample ID: WMMTW4-9

Analyses	Result	Units	Qual	MCL/		Method	Analysis Date / By
				RL	QCL		
<b>ORGANIC COMPOUNDS</b>							
Chloroform	59	ug/L		2.0		SW8260B	06/28/01 22:01 / rlo
Surr: 1,2-Dichlorobenzene-d4	98.3	%REC			80-120	SW8260B	06/28/01 22:01 / rlo
Surr: Dibromofluoromethane	112	%REC			80-120	SW8260B	06/28/01 22:01 / rlo
Surr: p-Bromofluorobenzene	103	%REC			80-120	SW8260B	06/28/01 22:01 / rlo
Surr: Toluene-d8	102	%REC			80-120	SW8260B	06/28/01 22:01 / rlo

**Report  
Definitions:**

ND - Not detected at the reporting limit

J - Analyte detected below quantitation limits

B - Analyte detected in the associated method blank

MCL - Maximum contaminant level

QCL - Quality control limit

S - Spike recovery outside accepted recovery limits

R - RPD outside accepted recovery limits

\* - Value exceeds maximum contaminant level

RL - Analyte reporting level



**CLIENT:** International Uranium (USA) Corp-Blandin  
**Lab Order:** C01060297  
**Project:** White Mesa Mill  
**Lab ID:** C01060297-009 **Matrix:** AQUEOUS

**Report Date:** 07/05/01  
**Collection Date:** 06/21/01 09:50  
**Client Sample ID:** WMMTW4-7

Analyses	Result	Units	Qual	MCL/		Method	Analysis Date / By
				RL	QCL		
<b>ORGANIC COMPOUNDS</b>							
Chloroform	1100	ug/L		50		SW8260B	06/28/01 22:44 / rto
Surr: 1,2-Dichlorobenzene-d4	98.5	%REC			80-120	SW8260B	06/28/01 22:44 / rto
Surr: Dibromofluoromethane	113	%REC			80-120	SW8260B	06/28/01 22:44 / rto
Surr: p-Bromofluorobenzene	103	%REC			80-120	SW8260B	06/28/01 22:44 / rto
Surr: Toluene-d8	101	%REC			80-120	SW8260B	06/28/01 22:44 / rto

**Report Definitions:**

ND - Not detected at the reporting limit

J - Analyte detected below quantitation limits

B - Analyte detected in the associated method blank

MCL - Maximum contaminant level

QCL - Quality control limit

S - Spike recovery outside accepted recovery limits

R - RPD outside accepted recovery limits

\* - Value exceeds maximum contaminant level

RL - Analyte reporting level



**CLIENT:** International Uranium (USA) Corp-Blandin  
**Lab Order:** C01060297  
**Project:** White Mesa Mill  
**Lab ID:** C01060297-010 **Matrix:** AQUEOUS

**Report Date:** 07/05/01  
**Collection Date:** 06/22/01 11:25  
**Client Sample ID:** WMMMW-4

Analyses	Result	Units	Qual	MCL/		Method	Analysis Date / By
				RL	QCL		
<b>VOLATILE ORGANIC COMPOUNDS</b>							
Chloroform	6300	ug/L		400		SW8260B	06/28/01 23:26 / rlo
Surr: 1,2-Dichlorobenzene-d4	99.0	%REC			80-120	SW8260B	06/28/01 23:26 / rlo
Surr: Dibromofluoromethane	117	%REC			80-120	SW8260B	06/28/01 23:26 / rlo
Surr: p-Bromofluorobenzene	105	%REC			80-120	SW8260B	06/28/01 23:26 / rlo
Surr: Toluene-d8	101	%REC			80-120	SW8260B	06/28/01 23:26 / rlo

**Report  
Definitions:**

ND - Not detected at the reporting limit  
J - Analyte detected below quantitation limits  
B - Analyte detected in the associated method blank  
MCL - Maximum contaminant level  
QCL - Quality control limit

S - Spike recovery outside accepted recovery limits  
R - RPD outside accepted recovery limits  
\* - Value exceeds maximum contaminant level  
RL - Analyte reporting level



**CLIENT:** International Uranium (USA) Corp-Blandin  
**Lab Order:** C01060297  
**Project:** White Mesa Mill  
**Lab ID:** C01060297-011 **Matrix:** AQUEOUS

**Report Date:** 07/05/01  
**Collection Date:** 06/21/01 09:04  
**Client Sample ID:** WMMTW4-10

Analyses	Result	Units	Qual	MCL/		Method	Analysis Date / By
				RL	QCL		
<b>VOLATILE ORGANIC COMPOUNDS</b>							
Chloroform	320	ug/L		2.0		SW8260B	06/29/01 00:09 / rto
Surr: 1,2-Dichlorobenzene-d4	97.9	%REC			80-120	SW8260B	06/29/01 00:09 / rto
Surr: Dibromofluoromethane	116	%REC			80-120	SW8260B	06/29/01 00:09 / rto
Surr: p-Bromofluorobenzene	102	%REC			80-120	SW8260B	06/29/01 00:09 / rto
Surr: Toluene-d8	102	%REC			80-120	SW8260B	06/29/01 00:09 / rto

**Report  
Definitions:**

ND - Not detected at the reporting limit  
J - Analyte detected below quantitation limits  
B - Analyte detected in the associated method blank  
MCL - Maximum contaminant level  
QCL - Quality control limit

S - Spike recovery outside accepted recovery limits  
R - RPD outside accepted recovery limits  
\* - Value exceeds maximum contaminant level  
RL - Analyte reporting level



CLIENT: International Uranium (USA) Corp-Blandin  
Lab Order: C01060297  
Project: White Mesa Mill  
Lab ID: C01060297-012 Matrix: AQUEOUS

Report Date: 07/05/01  
Collection Date: 06/21/01 12:11  
Client Sample ID: WMMTW4-11

Analyses	Result	Units	Qual	MCL/		Method	Analysis Date / By
				RL	QCL		
<b>VOLATILE ORGANIC COMPOUNDS</b>							
Chloroform	3.0	ug/L		1.0		SW8260B	06/29/01 00:51 / rto
Surr: 1,2-Dichlorobenzene-d4	102	%REC			80-120	SW8260B	06/29/01 00:51 / rto
Surr: Dibromofluoromethane	118	%REC			80-120	SW8260B	06/29/01 00:51 / rto
Surr: p-Bromofluorobenzene	103	%REC			80-120	SW8260B	06/29/01 00:51 / rto
Surr: Toluene-d8	102	%REC			80-120	SW8260B	06/29/01 00:51 / rto

**Report  
Definitions:**

ND - Not detected at the reporting limit  
J - Analyte detected below quantitation limits  
B - Analyte detected in the associated method blank  
MCL - Maximum contaminant level  
QCL - Quality control limit

S - Spike recovery outside accepted recovery limits  
R - RPD outside accepted recovery limits  
\* - Value exceeds maximum contaminant level  
RL - Analyte reporting level



CLIENT: International Uranium (USA) Corp-Blandin  
Lab Order: C01060297  
Project: White Mesa Mill  
Lab ID: C01060297-013 Matrix: AQUEOUS

Report Date: 07/05/01  
Collection Date: 06/22/01 13:50  
Client Sample ID: WMMTW4-Comp

Analyses	Result	Units	Qual	MCL/		Method	Analysis Date / By
				RL	QCL		
<b>VOLATILE ORGANIC COMPOUNDS</b>							
Chloroform	960	ug/L		100		SW8260B	06/29/01 01:34 / rlo
Surr: 1,2-Dichlorobenzene-d4	101	%REC			80-120	SW8260B	06/29/01 01:34 / rlo
Surr: Dibromofluoromethane	118	%REC			80-120	SW8260B	06/29/01 01:34 / rlo
Surr: p-Bromofluorobenzene	103	%REC			80-120	SW8260B	06/29/01 01:34 / rlo
Surr: Toluene-d8	103	%REC			80-120	SW8260B	06/29/01 01:34 / rlo

**Report  
Definitions:**

ND - Not detected at the reporting limit

J - Analyte detected below quantitation limits

B - Analyte detected in the associated method blank

MCL - Maximum contaminant level

QCL - Quality control limit

S - Spike recovery outside accepted recovery limits

R - RPD outside accepted recovery limits

\* - Value exceeds maximum contaminant level

RL - Analyte reporting level



CLIENT: International Uranium (USA) Corp-Blandin  
 Work Order: C01060297  
 Project: White Mesa Mill

## ANALYTICAL QC SUMMARY REPORT

Date: 05-Jul-01

TestCode: VOC-8260-W-SHT

Sample ID: Method Blank #		SampType: MBLK	TestCode: VOC-8260-W-SHT Units: ug/L			Prep Date:			Run ID: GCMS1-C_010628A		
Client ID:		Batch ID: R282	TestNo: SW8260B			Analysis Date: 6/28/2001			SeqNo: 5880		
Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Chloroform	ND	1.0									
Surr: 1,2-Dichlorobenzene-d4	9.99	0	10	0	99.9	80	120	0	0		
Surr: Dibromofluoromethane	11.43	0	10	0	114	80	120	0	0		
Surr: p-Bromofluorobenzene	10.29	0	10	0	103	80	120	0	0		
Surr: Toluene-d8	10.13	0	10	0	101	80	120	0	0		

Sample ID: C01060297-013A		SampType: MS	TestCode: VOC-8260-W-SHT Units: ug/L			Prep Date:			Run ID: GCMS1-C_010628A		
Client ID: WMMTW4-Comp		Batch ID: R282	TestNo: SW8260B			Analysis Date: 6/29/2001			SeqNo: 5894		
Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Chloroform	13330	1000	10000	956	124	70	130	0	0		
Surr: 1,2-Dichlorobenzene-d4	9960	0	10000	0	99.6	80	120	0	0		
Surr: Dibromofluoromethane	11980	0	10000	0	120	80	120	0	0		
Surr: p-Bromofluorobenzene	10390	0	10000	0	104	80	120	0	0		
Surr: Toluene-d8	9890	0	10000	0	98.9	80	120	0	0		

Sample ID: C01060297-013A		SampType: MSD	TestCode: VOC-8260-W-SHT Units: ug/L			Prep Date:			Run ID: GCMS1-C_010628A		
Client ID: WMMTW4-Comp		Batch ID: R282	TestNo: SW8260B			Analysis Date: 6/29/2001			SeqNo: 5895		
Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Chloroform	13570	1000	10000	956	126	70	130	13330	1.78	20	
Surr: 1,2-Dichlorobenzene-d4	10110	0	10000	0	101	80	120	0	0	10	
Surr: Dibromofluoromethane	12070	0	10000	0	121	80	120	0	0	10	S
Surr: p-Bromofluorobenzene	10320	0	10000	0	103	80	120	0	0	10	
Surr: Toluene-d8	10180	0	10000	0	102	80	120	0	0	10	

Qualifiers: ND - Not Detected at the Reporting Limit  
 J - Analyte detected below quantitation limits

S - Spike Recovery outside accepted recovery limits  
 R - RPD outside accepted recovery limits

B - Analyte detected in the associated Method Blank



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**ENERGY LABORATORIES, INC.'S CHAIN OF CUSTODY RECORD**

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 UPS/FedEx Deliveries: 2393 Salt Creek Highway • Casper, WY • 82601

toll free 1-888-235-0515  
 voice 307-235-0515  
 fax 307-234-1639

For Sample Tracking Purposes, Please Provide Contact Name and Telephone #'s as Indicated (SEE BACK OF FORM FOR EXAMPLES AND INSTRUCTIONS)

Project Name / Location / Purchase Order # / Bid #				Number of containers Sample Type: A W S V U O Air Water Soils/solids Vegetation Urine Other	Type of Analyses Requested					Special Requests	
Name / Phone # / Fax #										Comments, Special Instructions, etc.	
2 <sup>nd</sup> Quarter 2601 ciw sampling White Mesa Mill / Blanding, Utah											
David Turk (435) 678-2221 / (435) 678-2224											
Date	Time	composite	grab sample	Send Invoice to:							
				Send Report to:							
				Sample I.D.							
6/21/01	0904		✓	LOC Lon Berg P.O. Box 808 Blanding, Utah 84511	3-W	✓					
6/21/01	1211		✓	same as above	3-W	✓					
6/22/01	1350	-	✓	same as above	3-W	✓					

1. Sampler: (signature) 	Date 6/25/01	Time 11:00	Received by: (signature) UPS	2. Relinquished by: (signature)	Date	Time	Received by: (signature)
3. Relinquished by: (signature)	Date	Time	Received by: (signature)	4. Relinquished by: (signature)	Date	Time	Received at Laboratory by: (signature) 26 JUN 01 1000





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## ENERGY LABORATORIES, INC.

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### LABORATORY ANALYSIS REPORT

**Client: INTERNATIONAL URANIUM (USA) CORPORATION**

**Contact: Wally Brice**

**Sample Matrix: Liquid, Water**

**Date/Time Received: 06/26/2001 10:00**

**Report Date: July 11, 2001**

Laboratory ID	Sample Date / Time	Sample ID	Nitrate + Nitrite as N, mg/L
01-33936-1	06/21/2001 10:31	WMMTW4-1	8.81
01-33936-2	06/22/2001 10:38	WMMTW4-2	9.67
01-33936-3	06/21/2001 08:58	WMMTW4-3	2.61
01-33936-4	06/22/2001 09:34	WMMTW4-4	14.00
01-33936-5	06/20/2001 14:09	WMMTW4-5	6.47
01-33936-6	06/20/2001 09:45	WMMTW4-6	< 0.10
01-33936-7	06/21/2001 09:50	WMMTW4-7	2.65
01-33936-8	06/20/2001 12:51	WMMTW4-8	< 0.10
01-33936-9	06/20/2001 11:00	WMMTW4-9	0.15
01-33936-10	06/22/2001 11:20	WMMM4	9.02
01-33936-11	06/21/2001 08:58	WMMTW4-10	2.96
01-33936-12	06/21/2001 12:15	WMMTW4-11	3.19
01-33936-13	06/21/2001 12:17	WMMTW4-12	0.66

#### Quality Assurance Data

Method	EPA 353.2
Reporting Limit	0.10
RPD <sup>1</sup>	0.0
Spike <sup>2</sup>	97
Analyst	rwk
Date / Time Analyzed	06/27/2001 14:18

#### NOTES:

- (1) These values are an assessment of analytical precision. The acceptance range is 0-20% for sample results above 10 times the reporting limit. This range is not applicable to samples with results below 10 times the reporting limit.
- (2) These values are an assessment of analytical accuracy. They are a percent recovery of the spike addition. ELI performs a matrix spike on 10 percent of all samples for each analytical method.

msh: r:\reports\clients2001\international\_uranium\_corp\liquid\33936-1-13.xls

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**COMPLETE ANALYTICAL SERVICES**

33936R00002





Energy Laboratories, Inc.  
SAMPLE CONDITION REPORT

This report provides information about the condition of the sample(s), and associated sample custody information on receipt at the laboratory.

Client: International Uranium (USA) Corporation                      Description: WATER  
Lab ID(s): 01-33936-1    Thru 01-33936-13                      Matrix: Liquid  
Delivered by: UPS    Date&Time Rec'd: 26-JUN-01 1000    Date&Time Col'd: 21-JUN-01 1031  
Received by: Sara Hawken                      Logged In by: Kerri Schroeder

Chain of custody form completed & signed:	Yes	Comments:
Chain of custody seal:	No	Comments:
Chain of custody seal intact:	N/A	Comments:
Signature match, chain of custody vs. seal:	N/A	Comments:
Sample received Temperature:	5C	Comments:
Samples received within holding time:	Yes	Comments:
Samples received in proper containers:	Yes	Comments:
Samples Properly Preserved:	Yes	Comments:

Bottle Types Received: 12-16OZ P NF H2SO4 (A), 2-12OZ P NF H2SO4 (AB)

---

Comments: \_\_\_\_\_

Energy Laboratories, Inc.  
**REPORT PACKAGE SUMMARY - FINAL PAGE**

**Acronyms and Definitions**

ELI-B Energy Laboratories, Inc. - Billings, Montana  
ELI-G Energy Laboratories, Inc. - Gillette, Wyoming  
ELI-H Energy Laboratories, Inc. - Helena, Montana  
ELI-R Energy Laboratories, Inc. - Rapid City, South Dakota

co - Carry over from previous sample  
ip - Insufficient parameters  
N/A - Not Applicable  
NA - Not Analyzed  
ND - Analyte Not Detected at Stated Limit of Detection  
NR - Analyte Not Requested  
NST - No Sample Time Given  
NSD - No Sample Date Given

**This Package Contains the following Client ID(s) and Lab ID(s)**

Client ID: WMMW4 is associated to Lab ID: 01-33936-10  
Client ID: WMMTW4-1 is associated to Lab ID: 01-33936-1  
Client ID: WMMTW4-10 is associated to Lab ID: 01-33936-11  
Client ID: WMMTW4-11 is associated to Lab ID: 01-33936-12  
Client ID: WMMTW4-12 is associated to Lab ID: 01-33936-13  
Client ID: WMMTW4-2 is associated to Lab ID: 01-33936-2  
Client ID: WMMTW4-3 is associated to Lab ID: 01-33936-3  
Client ID: WMMTW4-4 is associated to Lab ID: 01-33936-4  
Client ID: WMMTW4-5 is associated to Lab ID: 01-33936-5  
Client ID: WMMTW4-6 is associated to Lab ID: 01-33936-6  
Client ID: WMMTW4-7 is associated to Lab ID: 01-33936-7  
Client ID: WMMTW4-8 is associated to Lab ID: 01-33936-8  
Client ID: WMMTW4-9 is associated to Lab ID: 01-33936-9

Approved By:

  
STEVEN E. CARLSON  
CRACKING SUPERVISOR

Reviewed By:

  
JAMES YOCUM  
QUALITY ASSURANCE DIRECTOR

This is the last page of the Laboratory Analysis Report.  
Additional QC is available upon request.  
The report contains the number of pages indicated by the last 4 digits

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33936R00006



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LABORATORY ANALYTICAL REPORT

Client: International Uranium (USA) Corp  
 Project: 3rd Qtr CIW Sampling - White Mesa Mill

Lab Order: C01090685  
 Report Date: 10/16/01

Lab ID: C01090685-001

Collection Date: 09/20/01 10:52

Client Sample ID: WMMTW4-2

Date Received: 09/25/01

Matrix: AQUEOUS

Analyses	Result	Units	Qual	MCL/		Method	Analysis Date / By
				RL	QCL		
<b>VOCS</b>							
Chloroform	4900	ug/L		400		SW8260B	10/04/01 00:56 / rh
Surr: 1,2-Dichlorobenzene-d4	101	%REC			80-120	SW8260B	10/04/01 00:58 / rh
Surr: Dibromofluoromethane	93.5	%REC			80-120	SW8260B	10/04/01 00:56 / rh
Surr: p-Bromofluorobenzene	83.0	%REC			80-120	SW8260B	10/04/01 00:56 / rh
Surr: Toluene-d8	95.6	%REC			80-120	SW8260B	10/04/01 00:56 / rh

Lab ID: C01090685-002

Collection Date: 09/20/01 10:25

Client Sample ID: WMMTW4-3

Date Received: 09/25/01

Matrix: AQUEOUS

Analyses	Result	Units	Qual	MCL/		Method	Analysis Date / By
				RL	QCL		
<b>VOCS</b>							
Chloroform	300	ug/L		100		SW8260B	10/02/01 22:30 / rh
Surr: 1,2-Dichlorobenzene-d4	102	%REC			80-120	SW8260B	10/02/01 22:30 / rh
Surr: Dibromofluoromethane	109	%REC			80-120	SW8260B	10/02/01 22:30 / rh
Surr: p-Bromofluorobenzene	88.8	%REC			80-120	SW8260B	10/02/01 22:30 / rh
Surr: Toluene-d8	96.9	%REC			80-120	SW8260B	10/02/01 22:30 / rh

Lab ID: C01090685-003

Collection Date: 09/20/01 10:50

Client Sample ID: WMMTW4-4

Date Received: 09/25/01

Matrix: AQUEOUS

Analyses	Result	Units	Qual	MCL/		Method	Analysis Date / By
				RL	QCL		
<b>VOCS</b>							
Chloroform	3200	ug/L		200		SW8260B	10/02/01 23:11 / rh
Surr: 1,2-Dichlorobenzene-d4	101	%REC			80-120	SW8260B	10/02/01 23:11 / rh
Surr: Dibromofluoromethane	107	%REC			80-120	SW8260B	10/02/01 23:11 / rh
Surr: p-Bromofluorobenzene	88.9	%REC			80-120	SW8260B	10/02/01 23:11 / rh
Surr: Toluene-d8	96.5	%REC			80-120	SW8260B	10/02/01 23:11 / rh

Report Definitions: ND - Not detected at the reporting limit  
 MCL - Maximum contaminant level

RL - Analyte reporting level  
 QCL - Quality control limit



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LABORATORY ANALYTICAL REPORT

Client: International Uranium (USA) Corp  
 Project: 3rd Qtr CIW Sampling - White Mesa Mill

Lab Order: C01090685  
 Report Date: 10/16/01

Lab ID: C01090685-004  
 Client Sample ID: WMMTW4-5

Collection Date: 09/20/01 10:05  
 Date Received: 09/25/01  
 Matrix: AQUEOUS

Analyses	Result	Units	Qual	MCL/		Method	Analysis Date / By
				RL	QCL		
<b>VOCS</b>							
Chloroform	240	ug/L		20		SW8260B	10/04/01 01:37 / rh
Surr: 1,2-Dichlorobenzene-d4	100	%REC			80-120	SW8260B	10/04/01 01:37 / rh
Surr: Dibromofluoromethane	92.5	%REC			80-120	SW8260B	10/04/01 01:37 / rh
Surr: p-Bromofluorobenzene	82.8	%REC			80-120	SW8260B	10/04/01 01:37 / rh
Surr: Toluene-d8	94.3	%REC			80-120	SW8260B	10/04/01 01:37 / rh

Lab ID: C01090685-005  
 Client Sample ID: WMMTW4-6

Collection Date: 09/20/01 09:16  
 Date Received: 09/25/01  
 Matrix: AQUEOUS

Analyses	Result	Units	Qual	MCL/		Method	Analysis Date / By
				RL	QCL		
<b>VOCS</b>							
Chloroform	3.6	ug/L		2.0		SW8260B	10/03/01 13:21 / rh
Surr: 1,2-Dichlorobenzene-d4	99.0	%REC			80-120	SW8260B	10/03/01 13:21 / rh
Surr: Dibromofluoromethane	100	%REC			80-120	SW8260B	10/03/01 13:21 / rh
Surr: p-Bromofluorobenzene	86.9	%REC			80-120	SW8260B	10/03/01 13:21 / rh
Surr: Toluene-d8	98.1	%REC			80-120	SW8260B	10/03/01 13:21 / rh

Lab ID: C01090685-006  
 Client Sample ID: WMMTW4-7

Collection Date: 09/20/01 10:43  
 Date Received: 09/25/01  
 Matrix: AQUEOUS

Analyses	Result	Units	Qual	MCL/		Method	Analysis Date / By
				RL	QCL		
<b>VOCS</b>							
Chloroform	1200	ug/L		100		SW8260B	10/03/01 14:02 / rh
Surr: 1,2-Dichlorobenzene-d4	98.9	%REC			80-120	SW8260B	10/03/01 14:02 / rh
Surr: Dibromofluoromethane	98.6	%REC			80-120	SW8260B	10/03/01 14:02 / rh
Surr: p-Bromofluorobenzene	88.7	%REC			80-120	SW8260B	10/03/01 14:02 / rh
Surr: Toluene-d8	96.2	%REC			80-120	SW8260B	10/03/01 14:02 / rh

Report Definitions: ND - Not detected at the reporting limit  
 MCL - Maximum contaminant level

RL - Analyte reporting level  
 QCL - Quality control limit



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## LABORATORY ANALYTICAL REPORT

Client: International Uranium (USA) Corp  
Project: 3rd Qtr CIW Sampling - White Mesa Mill

Lab Order: C01090685  
Report Date: 10/16/01

Lab ID: C01090685-007

Collection Date: 09/20/01 09:46

Client Sample ID: WMMTW4-8

Date Received: 09/25/01

Matrix: AQUEOUS

Analyses	Result	Units	Qual	MCL/		Method	Analysis Date / By
				RL	QCL		
<b>VOCS</b>							
Chloroform	180	ug/L		10		SW8260B	10/03/01 14:43 / rh
Surr: 1,2-Dichlorobenzene-d4	99.4	%REC			80-120	SW8260B	10/03/01 14:43 / rh
Surr: Dibromofluoromethane	102	%REC			80-120	SW8260B	10/03/01 14:43 / rh
Surr: p-Bromofluorobenzene	87.8	%REC			80-120	SW8260B	10/03/01 14:43 / rh
Surr: Toluene-d8	95.9	%REC			80-120	SW8260B	10/03/01 14:43 / rh

Lab ID: C01090685-008

Collection Date: 09/20/01 09:31

Client Sample ID: WMMTW4-9

Date Received: 09/25/01

Matrix: AQUEOUS

Analyses	Result	Units	Qual	MCL/		Method	Analysis Date / By
				RL	QCL		
<b>VOCS</b>							
Chloroform	19	ug/L		2.0		SW8260B	10/04/01 02:27 / rh
Surr: 1,2-Dichlorobenzene-d4	99.2	%REC			80-120	SW8260B	10/04/01 02:27 / rh
Surr: Dibromofluoromethane	92.1	%REC			80-120	SW8260B	10/04/01 02:27 / rh
Surr: p-Bromofluorobenzene	84.8	%REC			80-120	SW8260B	10/04/01 02:27 / rh
Surr: Toluene-d8	97.3	%REC			80-120	SW8260B	10/04/01 02:27 / rh

Lab ID: C01090685-009

Collection Date: 09/20/01 11:20

Client Sample ID: WMMMMW4

Date Received: 09/25/01

Matrix: AQUEOUS

Analyses	Result	Units	Qual	MCL/		Method	Analysis Date / By
				RL	QCL		
<b>VOCS</b>							
Chloroform	5300	ug/L		400		SW8260B	10/03/01 16:04 / rh
Surr: 1,2-Dichlorobenzene-d4	102	%REC			80-120	SW8260B	10/03/01 16:04 / rh
Surr: Dibromofluoromethane	102	%REC			80-120	SW8260B	10/03/01 16:04 / rh
Surr: p-Bromofluorobenzene	87.2	%REC			80-120	SW8260B	10/03/01 16:04 / rh
Surr: Toluene-d8	96.7	%REC			80-120	SW8260B	10/03/01 16:04 / rh

Report Definitions: ND - Not detected at the reporting limit  
MCL - Maximum contaminant level

RL - Analyte reporting level  
QCL - Quality control limit

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LABORATORY ANALYTICAL REPORT

Client: International Uranium (USA) Corp  
 Project: 3rd Qtr CIW Sampling - White Mesa Mill

Lab Order: C01090685  
 Report Date: 10/16/01

Lab ID: C01090685-010  
 Client Sample ID: Trip Blank

Collection Date: 08/22/01 10:20  
 Date Received: 09/25/01  
 Matrix: AQUEOUS

Analyses	Result	Units	Qual	MCL/		Method	Analysis Date / By
				RL	QCL		
<b>VOCS</b>							
Chloroform	ND	ug/L		1.0		SW8260B	10/02/01 16:59 / rh
Surr: 1,2-Dichlorobenzene-d4	101	%REC			80-120	SW8260B	10/02/01 16:59 / rh
Surr: Dibromofluoromethane	102	%REC			80-120	SW8260B	10/02/01 16:59 / rh
Surr: p-Bromofluorobenzene	86.7	%REC			80-120	SW8260B	10/02/01 16:59 / rh
Surr: Toluene-d8	96.7	%REC			80-120	SW8260B	10/02/01 16:59 / rh

Report Definitions: ND - Not detected at the reporting limit  
 MCL - Maximum contaminant level

RL - Analytic reporting level  
 QCL - Quality control limit

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CLIENT: International Uranium (USA) Corp

Work Order: C01090685

Project: 3rd Qtr CIW Sampling - White Mesa Mill

### ANALYTICAL QC SUMMARY REPORT

Date: 18-Oct-01

TestNo: SW8260B

Sample ID: C01090685-009A	SampType: MS	TestCode: VOC-8260-W-SHT	Units: ug/L	Prep Date:	Run ID: GCMS1-C_011003C						
Client ID: WMMM4	Batch ID: R2461	TestNo: SW8260B		Analysis Date: 10/3/2001	SeqNo: 49763						
Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual

Chloroform	16180	1000	10000	5280	109	70	130	0	0		
Surr: 1,2-Dichlorobenzene-d4	9980	0	10000	0	99.8	80	120	0	0		
Surr: Dibromofluoromethane	9770	0	10000	0	97.7	80	120	0	0		
Surr: p-Bromofluorobenzene	8730	0	10000	0	87.3	80	120	0	0		
Surr: Toluene-d8	9620	0	10000	0	96.2	80	120	0	0		

Sample ID: C01090695-012A	SampType: MS	TestCode: VOC-8260-W-SHT	Units: ug/L	Prep Date:	Run ID: GCMS1-C_011003C						
Client ID:	Batch ID: R2461	TestNo: SW8260B		Analysis Date: 10/5/2001	SeqNo: 49770						
Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual

Chloroform	1047	50	1000	0	105	70	130	0	0		
Surr: 1,2-Dichlorobenzene-d4	996	0	1000	0	99.6	80	120	0	0		
Surr: Dibromofluoromethane	982	0	1000	0	98.2	80	120	0	0		
Surr: p-Bromofluorobenzene	875	0	1000	0	87.5	80	120	0	0		
Surr: Toluene-d8	970	0	1000	0	97	80	120	0	0		

Sample ID: C01090685-009A	SampType: MSD	TestCode: VOC-8260-W-SHT	Units: ug/L	Prep Date:	Run ID: GCMS1-C_011001A						
Client ID: WMMM4	Batch ID: R2449	TestNo: SW8260B		Analysis Date: 10/1/2001	SeqNo: 49730						
Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual

Chloroform	15750	1000	10000	5280	105	70	130	16180	2.69	20	
Surr: 1,2-Dichlorobenzene-d4	10030	0	10000	0	100	80	120	0	0	10	
Surr: Dibromofluoromethane	9850	0	10000	0	99.5	80	120	0	0	10	
Surr: p-Bromofluorobenzene	8790	0	10000	0	87.9	80	120	0	0	10	
Surr: Toluene-d8	9650	0	10000	0	96.5	80	120	0	0	10	

Qualifiers:

ND - Not Detected at the Reporting Limit

S - Spike Recovery outside accepted recovery limits

B - Analyte detected in the associated Method Blank

J - Analyte detected below quantitation limits

R - RPD outside accepted recovery limits

005052000000

QCE NO.

Nov-09-01 10:41am From: IUC BLANDING

801 678 2224

T-555 P.008/012 F-725





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LABORATORY ANALYTICAL REPORT

Client: International Uranium (USA) Corp  
 Project: 3rd Quarter 2001 Sampling Event White MESA Mill

Lab Order: C01090647  
 Report Date: 10/04/01

Lab ID: C01090647-001  
 Client Sample ID: WMMTW4-1

Collection Date: 09/20/01 11:02  
 Date Received: 09/25/01  
 Matrix: AQUEOUS

Analyses	Result	Units	Qual	MCL/		Method	Analysis Date / By
				RL	QCL		
<b>NON-METALS</b>							
Nitrogen, Nitrate+Nitrite as N	12.8	mg/L		0.50		E353.2	09/26/01 19:27 / rwk

Lab ID: C01090647-002  
 Client Sample ID: WMMTW4-2

Collection Date: 09/20/01 10:55  
 Date Received: 09/25/01  
 Matrix: AQUEOUS

Analyses	Result	Units	Qual	MCL/		Method	Analysis Date / By
				RL	QCL		
<b>NON-METALS</b>							
Nitrogen, Nitrate+Nitrite as N	11.4	mg/L		0.50		E353.2	09/26/01 19:29 / rwk

Lab ID: C01090647-003  
 Client Sample ID: WMMTW4-3

Collection Date: 09/20/01 10:30  
 Date Received: 09/25/01  
 Matrix: AQUEOUS

Analyses	Result	Units	Qual	MCL/		Method	Analysis Date / By
				RL	QCL		
<b>NON-METALS</b>							
Nitrogen, Nitrate+Nitrite as N	3.06	mg/L		0.10		E353.2	09/26/01 19:33 / rwk

Lab ID: C01090647-004  
 Client Sample ID: WMMTW4-4

Collection Date: 09/20/01 10:50  
 Date Received: 09/25/01  
 Matrix: AQUEOUS

Analyses	Result	Units	Qual	MCL/		Method	Analysis Date / By
				RL	QCL		
<b>NON-METALS</b>							
Nitrogen, Nitrate+Nitrite as N	14.8	mg/L		1.00		E353.2	09/26/01 19:39 / rwk

Report Definitions: ND - Not detected at the reporting limit  
 MCL - Maximum contaminant level

RL - Analyte reporting level  
 QCL - Quality control limit



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LABORATORY ANALYTICAL REPORT

Client: International Uranium (USA) Corp  
 Project: 3rd Quarter 2001 Sampling Event White Mesa Mill

Lab Order: C01090647  
 Report Date: 10/04/01

Lab ID: C01090647-005  
 Client Sample ID: WMMTW4-5

Collection Date: 09/20/01 10:10  
 Date Received: 09/25/01  
 Matrix: AQUEOUS

Analyses	Result	Units	Qual	MCL/		Method	Analysis Date / By
				RL	QCL		
<b>NON-METALS</b>							
Nitrogen, Nitrate+Nitrite as N	2.10	mg/L		0.50		E353.2	09/28/01 19:41 / rwk

Lab ID: C01090647-006  
 Client Sample ID: WMMTW4-6

Collection Date: 09/20/01 09:17  
 Date Received: 09/25/01  
 Matrix: AQUEOUS

Analyses	Result	Units	Qual	MCL/		Method	Analysis Date / By
				RL	QCL		
<b>NON-METALS</b>							
Nitrogen, Nitrate+Nitrite as N	ND	mg/L		0.10		E353.2	09/26/01 19:43 / rwk

Lab ID: C01090647-007  
 Client Sample ID: WMMTW4-7

Collection Date: 09/20/01 10:43  
 Date Received: 09/25/01  
 Matrix: AQUEOUS

Analyses	Result	Units	Qual	MCL/		Method	Analysis Date / By
				RL	QCL		
<b>NON-METALS</b>							
Nitrogen, Nitrate+Nitrite as N	3.38	mg/L		0.20		E353.2	09/26/01 19:45 / rwk

Lab ID: C01090647-008  
 Client Sample ID: WMMTW4-8

Collection Date: 09/20/01 09:48  
 Date Received: 09/25/01  
 Matrix: AQUEOUS

Analyses	Result	Units	Qual	MCL/		Method	Analysis Date / By
				RL	QCL		
<b>NON-METALS</b>							
Nitrogen, Nitrate+Nitrite as N	0.35	mg/L		0.10		E353.2	09/26/01 19:47 / rwk

Report Definitions: ND - Not detected at the reporting limit  
 MCL - Maximum contaminant level

RL - Analyte reporting level  
 QCL - Quality control limit



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LABORATORY ANALYTICAL REPORT

Client: International Uranium (USA) Corp  
 Project: 3rd Quarter 2001 Sampling Event White Mesa Mill

Lab Order: C01090647  
 Report Date: 10/04/01

Lab ID: C01090647-009  
 Client Sample ID: WMMTW4-9

Collection Date: 09/20/01 09:33  
 Date Received: 09/25/01  
 Matrix: AQUEOUS

Analyses	Result	Units	Qual	MCL/		Method	Analysis Date / By
				RL	QCL		
<b>NON-METALS</b>							
Nitrogen, Nitrate+Nitrite as N	0.40	mg/L		0.10		E353.2	09/25/01 19:53 / rwk

Lab ID: C01090647-010  
 Client Sample ID: WMMTW4

Collection Date: 09/20/01 11:22  
 Date Received: 09/25/01  
 Matrix: AQUEOUS

Analyses	Result	Units	Qual	MCL/		Method	Analysis Date / By
				RL	QCL		
<b>NON-METALS</b>							
Nitrogen, Nitrate+Nitrite as N	9.45	mg/L		0.50		E353.2	09/26/01 19:55 / rwk

Lab ID: C01090647-011  
 Client Sample ID: WMMTW4-10

Collection Date: 09/20/01 10:10  
 Date Received: 09/25/01  
 Matrix: AQUEOUS

Analyses	Result	Units	Qual	MCL/		Method	Analysis Date / By
				RL	QCL		
<b>NON-METALS</b>							
Nitrogen, Nitrate+Nitrite as N	2.32	mg/L		0.20		E353.2	09/26/01 20:01 / rwk

Report Definitions: ND - Not detected at the reporting limit  
 MCL - Maximum contaminant level

RL - Analyte reporting level  
 QCL - Quality control limit

**APPENDIX E**

**U.S.G.S Manual Chapter 6.5 and Hydrolab Parameter Specifications**



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# 6.5 REDUCTION-OXIDATION POTENTIAL (ELECTRODE METHOD)

Reduction-oxidation potential (as Eh): a measure of the equilibrium potential, relative to the standard hydrogen electrode, developed at the interface between a noble metal electrode and an aqueous solution containing electroactive redox species.

In contrast to other field measurements, the determination of the reduction-oxidation potential of water (referred to as redox) should not be considered a routine determination. Measurement of redox potential, described here as Eh measurement, is not recommended in general because of the difficulties inherent in its theoretical concept and its practical measurement (see "Interferences and Limitations," [section 6.5.3.A](#)).

- ▶ Eh measurement may show qualitative trends but generally cannot be interpreted as equilibrium values.
- ▶ Determinations of redox using the platinum (or other noble metal) electrode method (Eh) are valid only when redox species are (a) electroactive, and (b) present in the solution at concentrations of about  $10^{-5}$  molal and higher. Redox species in natural waters generally do not reach equilibrium with metal electrodes.

Procedures for equipment calibration (test procedures) and Eh measurement are described in this section for the platinum electrode only. Although the general guidance given here applies to other types of redox electrodes (such as gold and glassy carbon electrodes), it is necessary to consult the manufacturer's instructions for correct use of the specific electrode selected. Concentrations of redox species can be determined by direct chemical analysis instead of using the electrode method (Baedecker and Cozzarelli, 1992).

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### 6.5.1 EQUIPMENT AND SUPPLIES

The equipment and supplies needed for making Eh measurements using the platinum electrode method are listed in table 6.5-1. Eh equipment must be tested before each field trip and cleaned soon after use. Every instrument system used for Eh measurement must have a log book in which all the equipment repairs and calibrations or equipment tests are recorded, along with the manufacturer make and model numbers and serial or property number.

**Electrodes.** Select either a redox-sensing combination electrode or an electrode pair (a platinum and reference electrode). **Use of the correct electrolyte filling solution is essential to proper measurement and is specified by the electrode manufacturer.** Orion Company, for example, recommends selection of a filling solution to best match the ionic strength of the sample solution, in order to minimize junction potentials.

**Table 6.5-1.** Equipment and supplies used for Eh measurements<sup>1</sup>

[mV, millivolt; ±, plus or minus;  $\mu\text{S}/\text{cm}$ , microsiemens per centimeter at 25 degrees Celsius]

- ✓ Millivolt meter or pH meter with millivolt reading capability, preferably with automatic temperature compensator; 0.1-mV sensitivity; scale to at least  $\pm 1,400$  mV; BNC connector (see instrument specifications for pH meters, 6.4.1 in NFM 6.4)
- ✓ Redox electrodes, either (a) platinum and reference electrode (calomel or silver:silver-chloride) or (b) combination electrode
- ✓ Electrode filling solutions (refer to manufacturer's specifications)
- ✓ Thermometer (liquid-in-glass or thermistor type), calibrated (see NFM 6.1 for selection and calibration criteria)—for use with millivolt meters without temperature compensator
- ✓ Flowthrough cell with valves, tubing, and accessories impermeable to air (for use with pump system)
- ✓ Sampling system: (1) in situ (downhole) measurement instrument, or (2) submersible pump (used with closed-system flowthrough cell). Pump tubing must be "impermeable" to oxygen.
- ✓ ZoBell's solution
- ✓ Aqua regia or manufacturer's recommended electrode-cleaning solution
- ✓ Liquid nonphosphate laboratory-grade detergent
- ✓ Mild abrasive: crocus cloth or 400- to 600-grit wet/dry Carborundum™ paper
- ✓ Deionized water (maximum conductivity of 1.0  $\mu\text{S}/\text{cm}$ )
- ✓ Bottle, squeeze dispenser for deionized water
- ✓ Safety equipment: gloves, glasses, apron, chemical spill kit
- ✓ Paper tissues, disposable, lint free
- ✓ Waste-disposal container

<sup>1</sup>Modify this list to meet specific needs of the field effort.

**CAUTION: The standard hydrogen reference electrode (SHE) can be dangerous and is not recommended for field use.**

- ▶ Silver:silver-chloride or calomel reference electrodes are the redox electrodes in common use.
- ▶ The Orion™ combination electrodes are platinum redox and silver: silver-chloride reference electrodes in one body (the Orion™ brand is used for purposes of illustration only).

**ZoBell's solution.** ZoBell's is the standard solution for testing redox instruments. ZoBell's solution can be obtained from the QWSU in Ocala, Fla., or it can be prepared fresh (see below). Quinhydrone solution is sometimes used but is not recommended because it is significantly less stable above 30°C and its temperature dependence is not as well defined as that of ZoBell's.

ZoBell's solution consists of a 0.1 molal KCl solution containing equimolal amounts of  $K_4Fe(CN)_6$  and  $K_3Fe(CN)_6$ . ZoBell's is reported stable for at least 90 days if kept chilled at 4°C. To prepare ZoBell's solution:

1. Weigh the chemicals (dry chemicals should be stored overnight in a desiccator before use).
  - 1.4080 g  $K_4Fe(CN)_6 \cdot 3H_2O$  (Potassium ferrocyanide)
  - 1.0975 g  $K_3Fe(CN)_6$  (Potassium ferricyanide)
  - 7.4557 g KCl (Potassium chloride)
2. Dissolve these chemicals in deionized water and dilute solution to 1,000 mL.
3. Store the solution in a dark bottle, clearly labeled with its chemical contents, preparation date, and expiration date. Keep the solution chilled.

**CAUTION: ZoBell's solution is toxic—handle with care.**

**Aqua regia.** Aqua regia can be used for cleaning the Eh electrode (check the electrode manufacturer's recommendations). Prepare the aqua regia at the time of use--do not store it. To prepare the aqua regia, mix 1 volume concentrated nitric acid with 3 volumes of concentrated hydrochloric acid.

### 6.5.1.A MAINTENANCE, CLEANING, AND STORAGE

Refer to 6.4.1 of NFM 6.4 on pH for general guidelines on meter and electrode maintenance, cleaning, and storage. Follow the manufacturer's guidelines on the operation and maintenance of the meters and electrodes, and keep a copy of the instruction manual with each instrument system. Keep the meters and electrodes clean of dust and chemical spills, and handle them with care.

#### *Maintenance*

Keep the surface of noble electrodes clean of coatings or mineral deposits. A brightly polished metal surface prevents deterioration of electrode response. The billet tip is more easily cleaned than the wire tip on the platinum electrode. Condition and maintain the Eh electrodes as recommended by the manufacturer.

## Cleaning

Keep the O-ring on electrodes moist during cleaning procedures.

- ▶ To remove precipitate that forms on the outside wall or tip of the reference or combination electrode, rinse the outside of the electrode with deionized water.
- ▶ If particulates or precipitates lodge in the space between the electrode sleeve and the inner cone of sleeve-type electrode junctions, clean the chamber by flushing out the filling solution (the precise procedure to be followed must come from the electrode manufacturer).
- ▶ To remove oily residues, use a liquid nonphosphate detergent solution and polish the surface with mild abrasive such as coarse cloth, a hard eraser, or 400- to 600-grit wet/dry Carborundum™ paper (Bricker, 1982).
- ▶ To recondition the Eh electrode, immerse the electrode in warm aqua regia (70°C) for about 1 minute. **Do not immerse the electrode for longer than 1 minute** because aqua regia dissolves the noble metal as well as foreign matter and leads to an erratic electrode response (Bricker, 1982). Soak the electrode several hours in tap water before use.

**TECHNICAL NOTE:** Disassembly of the electrode is not recommended for routine cleaning and should only be used when absolutely needed. Additional cleaning and reconditioning procedures are discussed in [NFM 6.4](#) and in American Public Health Association and others (1992), American Society for Testing and Materials (1990), Edmunds (1973), Adams (1969), and Callame (1968).

## Storage

For short-term storage, immerse the electrode in deionized water to above the electrode junction and keep the fill hole plugged to reduce evaporation of the filling solution. The recommended procedures for long-term storage of electrodes vary with the type of electrode and by manufacturer. The Orion™ combination electrodes are stored dry after rinsing precipitates from outside of the electrode, draining the filling solution from the chamber, and flushing it with water (consult the manufacturer's cleaning instructions). The electrode connector ends must be kept clean. Clean them with alcohol, if necessary. Store the connector ends in a plastic bag when not in use.

**Some of the procedures recommended herein for equipment operation may be out of date if the equipment being used is different from that described or incorporates more recent technological advances—follow the manufacturer's instructions.**

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## 6.5.2 EQUIPMENT TEST PROCEDURE

Eh measuring systems can be tested for accuracy but they cannot be adjusted. Eh equipment must be tested, either in the laboratory or in the field, against a ZoBell's standard solution before making field measurements. In general, field testing with ZoBell's is not required, but the protocol used will depend on study needs.

- ▶ Before using, check that the ZoBell's solution has not exceeded its shelf life.
- ▶ Test the Eh equipment using the ZoBell's solution **before and after** field use.
- ▶ Be aware that:
  - ZoBell's is toxic and needs to be handled with care.
  - ZoBell's reacts readily with minute particles of iron, dust, and other substances, making field use potentially difficult and messy.

The Eh measurements are made by inserting a platinum electrode coupled with a reference electrode into the solution to be measured. The resulting potential, read directly in millivolts from a potentiometer (such as a pH meter), is corrected for the difference between the standard potential of the reference electrode being used at the solution temperature and the potential of the standard hydrogen electrode (table 6.5-2).

**TECHNICAL NOTE:**  $E_{ref}$  is the whole-cell potential of the reference electrode in ZoBell's solution.

$E_{ref} = 238$  mV (saturated KCl, immersed with the platinum electrode in ZoBell's at 25°C) is the measured potential of the silver:silver-chloride (Ag:AgCl) electrode;

$E_{ref} = 185.5$  mV (saturated KCl, immersed with the platinum electrode in ZoBell's at 25°C) is the measured potential of the calomel (Hg:HgCl<sub>2</sub>) electrode;

$E^{\circ} = 430$  mV is the standard electrode potential of ZoBell's solution measured against the hydrogen electrode at 25°C.

Half-cell potentials for the calomel, silver:silver chloride, and combination electrodes are shown in [table 6.5-2](#). [Table 6.5-3](#) provides the theoretical Eh of ZoBell's solution as a function of temperature. For those temperatures not shown on [tables 6.5-2](#) and [6.5-3](#), interpolate the values. Add the value corresponding to the solution temperature to the measured potential electromotive force (emf measurement).

**Table 6.5-2.** Standard half-cell potentials of selected reference electrodes as a function of temperature and potassium chloride reference-solution concentration, in volts

[Liquid-junction potential included—multiply volts by 1,000 to convert to millivolts; KCl, potassium chloride; Temp °C, temperature in degrees Celsius; M, molar; —, value not provided in reference]

Temp °C	Silver-silver chloride			Calomel <sup>1</sup>				Orion™ 96-78 combination electrode <sup>2,4</sup>
	3M KCl <sup>1</sup>	3.5M KCl <sup>2</sup>	Saturated KCl <sup>2</sup>	3M KCl <sup>2</sup>	3.5M KCl <sup>2</sup>	4M KCl <sup>2</sup>	KCl saturated <sup>2</sup>	
10	0.220	0.215	0.214	0.250	0.258	—	0.254	0.256
15	0.216	0.212	0.209	—	—	—	0.251	0.253
20	0.213	0.208	0.204	0.257	0.252	—	0.248	0.249
25	0.209	0.205	0.199	0.255	0.250	0.246	0.244	0.246
30	0.205	0.201	0.194	0.253	0.248	0.244	0.241	0.242
35	0.202	0.197	0.189	—	—	—	0.238	0.238
40	0.198	0.193	0.184	0.249	0.244	0.239	0.234	0.234

<sup>1</sup>Modified from Langmuir (1971).

<sup>2</sup>Modified from Bates (1973).

<sup>3</sup>Nordstrom (1977) and D.K. Nordstrom, U.S. Geological Survey, written commun., 1996; the half-cell potentials calculated from Nordstrom (1977) are recommended rather than the values from Chateau (1964) cited in the instrument manual provided by the Orion Company because Nordstrom's values were developed specifically for the Orion™ 96-78 redox electrode and provide greater accuracy and precision.

<sup>4</sup>Orion™ manufacturer recommends that for sample solutions with total ionic strength exceeding 0.2 molar (for example, seawater), use a 4M KCl-saturated filling solution (usually supplied with the Orion™ model 97-78 electrode) and the half-cell potentials shown above for the silver-silver chloride saturated KCl reference electrode.

**Table 6.5-3.** Eh of ZoBell's solution as a function of temperature

[From Nordstrom (1977); °C, degrees Celsius; mV, millivolts]

Temperature °C	Eh (mV)	Temperature °C, (continued)	Eh (mV), (continued)
10	467	26	428
12	462	28	423
14	457	30	418
16	453	32	416
18	448	34	407
20	443	36	402
22	438	38	397
24	433	40	393
25	430		

To test Eh equipment, complete the following 7 steps and record results on the Eh data record form for the equipment test procedure (fig. 6.5-1):

- Follow the manufacturers' recommendations for instrument warm up and operation.
  - Set the scale to the desired millivolt range.
  - Record the type of reference electrode being used.
- Unplug the fill hole. Shake the electrode gently to remove air bubbles from the sensing tip of the electrode. Check the level of the filling solution and replenish to the bottom of the fill hole.
  - The filling solution level must be at least 1 in. above the level of solution being measured.
  - Use only the filling solution specified by the manufacturer.
- Rinse the electrode, thermometer, and measurement beaker with deionized water. **Blot (do not**

wipe) excess moisture from the electrode.

4. Pour ZoBell's solution into a measurement beaker containing the electrode and temperature sensor.
  - The Eh electrode must not touch the bottom or side of the container.
  - Add enough solution to cover the reference junction.
  - Allow 15 to 30 minutes for the solution and sensors to equilibrate to ambient temperature.
5. Stir slowly with a magnetic stirrer (or swirl manually) to establish equilibrium between the electrode(s) and solution. Switch the meter to the millivolt function, allow the reading to stabilize ( $\pm 5$  mV), and record the temperature and millivolt value.
6. Look up the half-cell reference potential for the electrode being used (table 6.5-2). Add this value to the measured potential to obtain the Eh of ZoBell's at ambient temperature.
  - If the value is within 5 mV of the ZoBell Eh given on table 6.5-3, the equipment is ready for field use. (See the example below.)
  - Refer to section 6.5.4 if the value is not within 5 mV of the ZoBell Eh.
7. Rinse off the electrodes and the thermometer thoroughly with deionized water. Store the test solution temporarily for possible verification.

#### EXAMPLE:

Example of the equipment test procedure using a silver:silver chloride-saturated KCl (Ag:AgCl) electrode.

$$Eh = emf + E_{ref}$$

where:

$Eh$  is the potential (in millivolts) of the sample solution relative to the standard hydrogen electrode,

$emf$  or  $E_{measured}$  is the electromotive force or potential (in millivolts) of the water measured at the sample temperature,

$E_{ref}$  is the reference electrode potential of the ZoBell's solution corrected for the sample temperature (table 6.5-2).

- a. Follow steps 1-5 (above). For this example,
  - Measured temperature = 22°C
  - $emf = 238$  mV.
- b. Check table 6.5-2. The interpolated reference potential = 202 mV for Ag:AgCl-saturated KCl at 22°C.
- c. From  $Eh = emf + E_{ref}$

$$Eh \text{ (ZoBell's)} = 238 \text{ mV} + 202 \text{ mV} = 440 \text{ mV.}$$

- d. Check [table 6.5-3](#). The test value of 440 mV is within  $\pm 5$  mV of 438 mV from [table 6.5-3](#). Thus, the equipment is functioning well and ready for field use.

**Check the date on Zobell's solution—do not use solution past its expiration date.**

<b>Eh Data Record</b>		
<b>Equipment Test Procedure</b>		
Equipment description and identification (model and serial and/or W number):		
Meter	_____	
Eh electrode	_____	Reference electrode _____
ZoBell's solution: Lot #	_____	Date: prepared _____ expired _____
	Before sample Eh:	After sample Eh:
1. Temperature of ZoBell's solution: (after equilibration to ambient temperature)	T = _____	_____
2. Observed potential (in millivolts) of ZoBell's relative to measuring electrode, at ambient temperature ( $E_{\text{measured}}$ or <i>emf</i> ):	<i>emf</i> = _____	_____
3. Reference electrode potential (in millivolts) at ambient temperature from <a href="#">table 6.5-2</a> ( $E_{\text{ref}}$ ):	$E_{\text{ref}}$ = _____	_____
4. Calculate Eh of ZoBell's: $E_h = \text{emf} + E_{\text{ref}}$	$E_h$ = _____	_____
5. Theoretical potential (in millivolts) of ZoBell's at ambient temperature from <a href="#">table 6.5-3</a> :	$E_h$ (theoretical) = _____	_____
6. Subtract calculated Eh from Eh theoretical (ZoBell's)(step 4 minus step 5)	$\Delta E_h$ = _____	_____
7. Check: is $\Delta E_h$ within $\pm 5$ mV?	Observations: _____	_____

**Figure 6.5-1.** Eh data record: equipment test procedure.

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### 6.5.3 MEASUREMENT

To obtain accurate results, it is necessary to prevent losses and gains of dissolved gases in solution. Consult [NFM 6.0](#) for information on precautions and general procedures used in sample collection and [NFM 6.2](#) for a description of the flowthrough cell used in dissolved-oxygen determination (the spectrophotometric method).

- ▶ Chemical, physical, and biological reactions can cause the Eh of water to change significantly within minutes or even seconds after the collection of a sample.
- ▶ Water samples cannot be preserved and stored for the Eh measurement.
- ▶ Use equipment that eliminates sample aeration and operate the equipment to meet this goal. If using a flowthrough chamber or cell:
  - Use tubing that is impermeable (relatively) to oxygen.
  - Channel the sample flow through an airtight cell (closed system) constructed specifically to accommodate redox or ion-specific electrodes, temperature, and other sensors.
  - Connections and fittings must be airtight.
  - Purge atmospheric oxygen from the sample tubing and associated flow channels before measuring Eh.

**Do not use pumping systems in which inert gas contacts and lifts the sample to the surface: the gas could strip gaseous redox species from the water.**

Measure Eh in situ with a submersible instrument or use an airtight flowthrough system.

**First:**

1. Record the type of reference-electrode system being used ([fig. 6.5-1](#)).
2. Check for the correct electrode filling solution. If working in very hot or boiling waters, change the reference electrode filling solution daily.
3. Keep the electrode surface brightly polished.

**TECHNICAL NOTE:** Temperature determines the Eh reference potential for a particular solution and electrode pair, and may affect the reversibility of the redox reactions, the magnitude of the exchange current,

and the stability of the apparent redox potential reading. The observed potential of the system will drift until thermal equilibrium is established. **Thermal equilibrium can take longer than 30 minutes but it is essential before beginning the measurements.**

*Next, measure the Eh and complete the field form (fig.6.5-2):*

1. Select an in situ or closed-system sampling method. Immerse the electrodes and temperature sensors in the sample water.
  - **In situ (or downhole)**--Lower the sensors to the depth desired and follow the manufacturer's recommendations.
  - **Closed-system flow cell**--Check that the connections and sensor grommets do not leak, and that the water being pumped fills the flowthrough cell.
2. Allow the sensors to reach thermal equilibrium with the aqueous system being measured and record the time lapsed.
  - It is essential that platinum electrodes be flushed with large volumes of sample water to obtain reproducible values.
  - Record the pH and temperature of the sample water.
3. Switch the meter to the millivolt function.
  - Allow the reading to stabilize ( $\pm 5$  mV).
  - Record the value and temperature (see the technical note that follows step 7, below).
  - **Stabilization should occur within 30 minutes.**
4. Take readings of the sample temperature and potential (in millivolts) every few minutes for the first 15 to 20 minutes.
  - It is best to stop the flow of the sample while the reading is being taken to prevent streaming-potential effects.
  - After 15 to 20 minutes, begin to record the time, temperature, and potential in plus or minus millivolts about every 10 minutes. Continue until 30 minutes have passed from the initial measurement and until the measurements indicate a constant potential.
5. After the measurements have been completed for the day, rinse the electrode(s) thoroughly with deionized water.

If field calibration is required for a study,

- a. Place the electrode(s) and other sensors in ZoBell's solution that has been equilibrated to the temperature of the aqueous system to be measured. The electrode(s) must not touch the container, and the solution must cover the reference junction.
  - b. Allow the electrode to reach thermal equilibrium (15 to 30 minutes).
  - c. Record the potential reading.
  - d. Follow steps 5-7 of the equipment test procedure in section 6.5.2.
6. Record all data and calculate Eh (see EXAMPLE, (section 6.5.2)).

Fill out the Eh data record form for field measurements (fig. 6.5-2).

<b>Eh Data Record</b>		
<b>Field Measurements</b>		
	Field Eh	Field Eh <sup>1</sup>
1. Temperature and pH of system measured: T = _____		
pH = _____		
2. Time to thermal equilibration:		
Measurement began at _____		
Measurement ended at _____		
3. Measured potential of water system (mV): <i>emf</i> = _____		
4. Reference electrode potential mV of ZoBell's at sample temperature: $E_{ref}$ = _____		
5. Calculate sample Eh: $emf + E_{ref}$ (add step 3 + step 4): Eh = _____		
6. Field measurements should agree within about 10 mV. Observations: _____		

<sup>1</sup>The second measurement is necessary for quality control.

**Figure 6.5-2.** Eh data record: field measurements.

### 7. Quality control--Repeat the measurement.

**TECHNICAL NOTE:** The response of the Eh measurement system may be considerably slower than that of the pH system and that response also may be asymmetrical: the time required for stabilization may be longer when moving from an oxidizing to reducing environment or vice versa. If the readings do not stabilize within about 30 minutes, record the potential and its drift; assume a single quantitative value is not possible. If an estimate of an asymptotic final (hypothetical) potential in such a drifting measurement is desired, refer to the method used by Whitfield (1974) and Thorstenson and others (1979).

## 6.5.3.A INTERFERENCES AND LIMITATIONS

Measurements should not be carried out without an awareness of the interferences and limitations inherent in the method.

- ▶ Organic matter and sulfide may cause contamination of the electrode surface, salt bridge, or internal electrolyte, which can cause drift or erratic performance when reference electrodes are used (American Public Health Association and others, 1992).
- ▶ Hydrogen sulfide can produce a coating on the platinum electrode that interferes with the measurement if the electrode is left in sulfide-rich water for several hours (Whitfield, 1974; Sato, 1960).
- ▶ The platinum single and combination redox electrodes may yield unstable readings in solutions containing chromium, uranium, vanadium, or titanium ions and other ions that are stronger reducing agents than hydrogen or platinum (Orion Research Instruction Manual, written commun., 1991).
- ▶ Do not insert redox electrodes into iron-rich waters directly after electrode(s) contact with ZoBell's. An insoluble blue precipitate coats the electrode surface because of an immediate reaction between ferro- and ferricyanide ions in ZoBell's with ferrous and ferric ions in the sample water, causing erratic readings.

Many elements with more than one oxidation state do not exhibit reversible behavior at the platinum electrode surface and some systems will give mixed potentials, depending on the presence of several different couples (Barcelona and others, 1989; Bricker, 1982, p. 59-65; Stumm and Morgan, 1981, p. 490-495; Bricker, 1965, p. 65). Methane, bicarbonate, nitrogen gas, sulfate, and dissolved oxygen generally are not in equilibrium with platinum electrodes (Berner, 1981).

**TECHNICAL NOTE:** Misconceptions regarding the analogy between Eh (pe) and pH as master variables and limitations on the interpretation of Eh measurements are explained in Hostettler (1984), Lindberg and Runnells (1984), Thorstenson (1984), and Berner (1981). To summarize:

(1) Hydrated electrons do not exist in meaningful concentrations in most aqueous systems--in contrast, pH represents real activities of hydrated protons. Eh may be expressed as pe, the negative logarithm of the electron activity, but conversion to pe offers no advantage when dealing with measured potentials.

(2) Do not assume that redox species coexist in equilibrium. Many situations have been documented in which dissolved oxygen coexists with hydrogen sulfide, methane, and ferrous iron.

- The practicality of Eh measurements is limited to iron in acidic mine waters and sulfide in waters under-going sulfate reduction.
- Other redox species are not sufficiently electroactive to establish an equilibrium potential at the surface of the conducting electrode.

(3) A single redox potential cannot be assigned to a disequilibrium system, nor can it be assigned to a water sample without specifying the particular redox species to which it refers. Different redox elements (iron, manganese, sulfur, selenium, arsenic) tend not to reach overall equilibrium in most natural water systems; therefore, a single Eh measurement generally does not represent the system.

### 6.5.3.B INTERPRETATION

A rigorous quantitative interpretation of a measurement of Eh requires interactive access to an aqueous speciation code. Exercise caution when interpreting a measured Eh using the Nernst equation. The Nernst equation for the simple half-cell reaction ( $M^I_{(aq)} = M^{II}_{(aq)} + e^-$ ) is

$$Eh = E^{\circ} + 2.303RT/nF \log (a_{M^{II}(aq)}^{II} / a_{M^{I}(aq)}^{I})$$

where:

$R$  = gas constant;

$T$  = temperature, in degrees kelvin;

$n$  = number of electrons in the half-cell reaction;

$F$  = Faraday constant; and

$a_{M^{I}(aq)}^{I}$  and  $a_{M^{II}(aq)}^{II}$  = thermodynamic activities of the free ions  $M^{I(aq)}$  and  $M^{II(aq)}$  and not simply the analytical concentrations of total  $M$  in oxidation states I and II, respectively.

Measurements of Eh are used to test and evaluate geochemical speciation models, particularly for suboxic and anoxic ground-water systems. Eh data can be useful for gaining insights on the evolution of water chemistry and for estimating the equilibrium behavior of multivalent elements relative to pH for an aqueous system. Eh can delineate qualitatively strong redox gradients; for example, those found in stratified lakes and rivers with an anaerobic zone, in an oxidized surface flow that becomes anaerobic after passing through stagnant organic-rich systems, and in mine-drainage discharges.

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[Chapter 6.5.4.pdf](#)

### 6.5.4 TROUBLESHOOTING

Contact the instrument manufacturer if the suggestions in [table 6.5-4](#) fail to resolve the problem.

- ▶ Check the voltage of the batteries.
- ▶ Always start with good batteries in the instruments and carry spares.

**Table 6.5-4.** Troubleshooting guide for Eh measurement

[ $\pm$ , plus or minus; mV, millivolts; *emf*, electromotive force]

Symptom	Possible corrective action
Eh of ZoBell's solution exceeds theoretical by $\pm 5$ mV Excessive drift Erratic performance Poor response when using paired electrodes	<p style="text-align: center;"><u>Check meter operation:</u></p> <ul style="list-style-type: none"> <li>• Use shorting lead to establish meter reading at zero mV.</li> <li>• Check/replace batteries.</li> <li>• Check against backup meter.</li> </ul> <p style="text-align: center;"><u>Check electrode operation:</u></p> <ul style="list-style-type: none"> <li>• Check that electrode reference solution level is to the fill hole.</li> <li>• Plug questionable reference electrode into reference electrode jack and another reference electrode in good working order of the same type into the indicator electrode jack of the meter; immerse electrodes in a potassium chloride solution, record mV, rinse off and immerse electrodes in ZoBell's solution. The two mV readings should be <math>0 \pm 5</math> mV. If using different electrodes (Ag:AgCl and Hg:HgCl<sub>2</sub>), reading should be <math>44 \pm 5</math> mV for a good reference electrode.</li> <li>• Polish platinum tip with mild abrasive (crocus cloth, hard eraser, or a 400-600-grit wet/dry Carborundum™ paper), rinse thoroughly with deionized water. Use a Kimwipe™ if these abrasives are not available.</li> <li>• Drain and refill reference electrolyte chamber.</li> <li>• Disconnect reference electrode. Drain and refill electrolyte chamber with correct filling solution. Wipe off connectors on electrode and meter. Use backup electrode to check the <i>emf</i>.</li> <li>• Read <i>emf</i> with fresh aliquot of ZoBell's solution; prepare fresh ZoBell's solution if possible.</li> <li>• Recondition electrode by cleaning with aqua regia and renewing filling solution—<b>this is a last resort.</b></li> </ul>

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# 6.5.5 REPORTING

Report the calculated Eh in mV to two significant figures.

Potentials are reported to the nearest 10 mV, along with the temperature at which the measurement was made, the electrode system employed, and the pH at time of measurement.

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- (1) Response time is the time required for a measurement to accomplish 95% of a step-change in only that measurement. For instance, if the temperature changed suddenly from 25°C to 35°C, temperature's time response would be the time required for the reading to change to 95% (34.25) → 25 = 34.5°C.
- (2) Stability is a multiprobe's ability to read within its accuracy specifications in the same standard used for calibration. Certain situations can adversely affect stability. For example, a reference electrode soaked for a month in very low Specific Conductance water cannot ordinarily be expected to produce accurate pH (or Redox or ISE) readings. Similarly, a DO probe covered with active algae is not likely to produce accurate DO readings. The stability specifications are based on an analysis of the sensor electronics and not on direct testing, because of the difficulty in applying such a test to specific field conditions.
- (3) Hydrolab's standard thermistor provides ± 0.15°C accuracy worst case and ± 0.10°C using 95% Certainty (most probable error) method for calculating accuracy. This means that more than 95 out of 100 multiprobes will meet the ± 0.10°C specification.
- (4) The four ranges (0 to 0.1999, 0.2 to 1.5, 1.5 to 15, and 15 to 100 mS/cm) are changed automatically (autoranged) to provide the most digits available.
- (5) The 4 digit resolution for Specific Conductance depends on which of the four automatically selected ranges are in use. For instance, a reading of 0.13 mS/cm would be displayed as .1300; resolution would be ten thousandths of mS/cm. A Specific Conductance of 10.157 mS/cm would be displayed as 10.16; resolution would be to hundredths of mS/cm. If the optional output, µS/cm, is chosen, the resolution for Specific Conductance over 9999 µS/cm will be four digits, with a zero added as the last (fifth) digit.
- (6) The Temperature compensation for Specific Conductance can be disabled easily if "raw" Conductivity readings are needed.
- (7) The Salinity accuracy is enhanced when the system is calibrated for Salinity (instead of Specific Conductance) near the expected field values.
- (8) Although the multiprobe will measure the full 0 to 14 unit pH range, it is not recommended that the sensors be exposed to pH extremes outside the 2 to 12 unit range.
- (9) The pH accuracy is valid for waters of Specific Conductance greater than 0.2 mS/cm, when using Hydrolab's standard, rebuildable reference electrode. This accuracy can be ordinarily met in very fresh waters (Specific Conductance less than 0.2 mS/cm) if you use Hydrolab's optional LISREF (low ionic strength) reference electrode and follow very particular maintenance and calibration procedures. The LISREF reference electrode is not refillable.
- (10) When operated at temperature of calibration and calibrated with turbid-free water and a Formazin standard of 75% of range. Typical temperature coefficient is -0.26 NTU/C°.
- (11) Response time is less than ten seconds with averaging disabled, but requires thirty seconds after power-up. The maximum moving average time is 60 seconds for a worst case response time of 90 seconds from power-up.
- (12) Turbidity measurement is divided into two ranges: 0 to 100 and 100 to 1000 NTU. Readings are more accurate in the range in which calibration is made, as shown in the chart below. The chart also shows the readings are more accurate when made at the temperature of calibration.

	% range on cal range	% range on non-cal range
at cal temp	± 5	± 10
not at cal temp	± 10	± 15

- (13) The Redox accuracy refers to true electrode voltage. Actual readings are subject to slow electrode equilibration times and uncertainty in measurement theory and calibration. A typical as-measured accuracy might be ± 50mV. Accuracy is aided in very fresh waters (Specific Conductance is less than 0.2 mS/cm) by Hydrolab's optional LISREF reference electrode (see footnote 9).
- (14) A transfer standard is a calibration solution or standard graded by another measurement method, such as chemical titration (e.g. Winkler). In the case of Redox, a transfer standard might be a solution measured by a trusted laboratory pH-mV meter. For many purposes, it is not necessary to calibrate Redox at all.
- (15) The time required for a Redox sensor to respond to a step-change in Redox is highly variable and depends on the condition of the surface of the platinum electrode and on the direction of the step-change. Because response time is little affected by non-Redox sensor items, such as electronic design or the effects of other sensors, the response time of Hydrolab's Redox sensor is virtually the same as that of other Redox-measurement instruments.
- (16) Typical Accuracy, Ammonium: ± 5% of reading, or ± 2 mg/L-N, whichever is greater. Minimum Accuracy: ± 10% of reading, or ± 2 mg/L-N, whichever is greater. Both accuracy specifications are at temperature of calibration with no interfering ions. Interfering ions artificially increase the ammonium reading as follows:

Interfering Ion	1 mg/L-N Interference
K+	13 mg/L
Na+	1,300 mg/L

Typical Accuracy, Ammonia:  $\pm 27\%$  of reading, or  $\pm 2$  mg/L-N, whichever is greater. Minimum Accuracy:  $\pm 70\%$  of reading, or  $\pm 2$  mg/L-N, whichever is greater. Ammonia is calculated from the sensor's ammonium output according to pH, and the inherent uncertainty in pH is 0.2 units, which means an uncertainty in ammonia of  $\pm 60\%$  when mathematically converted from ammonium to ammonia. Both accuracy specifications are at temperature of calibration with no interfering ions and pH less than 10. Interfering ions artificially increase the ammonium reading and hence the ammonia reading.

- (17) Typical Accuracy, Nitrate  $\pm 6\%$  of reading, or  $\pm 2$  mg/L-N, whichever is greater. Minimum Accuracy:  $\pm 10\%$  of reading, or  $\pm 2$  mg/L-N, whichever is greater. Both accuracy specifications are at temperature of calibration with no interfering ions. Interfering ions can artificially increase the nitrate reading as follows:

Interfering Ion	1 mg/L-N Interference
ClO <sub>2</sub>	0.0071 mg/L
I <sup>-</sup>	0.45 mg/L
CN <sup>-</sup>	2.6 mg/L
Br <sup>-</sup>	39.7 mg/L
NO <sub>2</sub> <sup>-</sup>	23 mg/L
HS <sup>-</sup>	23 mg/L
HCO <sub>3</sub> <sup>-</sup>	433 mg/L
CO <sub>3</sub> <sup>2-</sup>	852 mg/L
Cl <sup>-</sup>	755 mg/L

- (18) Typical Accuracy, Chloride  $\pm 5\%$  of reading, or  $\pm 2$  mg/L, whichever is greater. Minimum Accuracy:  $\pm 10\%$  of reading or  $\pm 2$  mg/L, whichever is greater. Both accuracy specifications are at temperature of calibration with no interfering ions and pH less than 12.4. Interfering ions can artificially increase the chloride reading as follows:

Interfering Ion	1 mg/L Interference
CN <sup>-</sup>	$1.6 \times 10^{-6}$ mg/L
I <sup>-</sup>	$1.8 \times 10^{-6}$ mg/L
S <sup>2-</sup>	$9.0 \times 10^{-6}$ mg/L
Br <sup>-</sup>	$6.7 \times 10^{-2}$ mg/L

- (19) Chloride resolution varies with the magnitude of the reading as follows:

Reading	Resolution
0.00 to 99.99 mg/L	0.01 mg/L
100.0 to 999.9 mg/L	0.1 mg/L
1,000 to 18,000 mg/L	1 mg/L

- (20) The 95% response change to a change in total dissolved gas pressure less than 180 seconds at  $\pm 1^\circ\text{C}$ .
- (21) Typical accuracy is  $\pm 5\%$  of reading, or  $\pm 1 \mu\text{mol s}^{-1} \text{m}^{-2}$ , whichever is greater. Minimum accuracy:  $\pm 10\%$  of reading, or  $\pm 2 \mu\text{mol s}^{-1} \text{m}^{-2}$ , whichever is greater. Manufacturer recommends factory sensor recalibration at least one every two years.
- (22) It is important to note that the fluorescent yield observed in the natural environment can deviate widely over varying conditions. Given this, the Rhodamine standard should not be directly compared to chlorophyll. The standard is used in tuning of fluorometers as a reference, not as a calibration. We encourage our users to perform field calibrations in the locale of their sampling if they are interested in more than relative trends.
- (23) The 10m Depth accuracy is the 95% Certainty (most probable error) accuracy, based on the worst-case errors such as drift, temperature compensation, tilt error, etc. The 10m Depth transducer is atmospherically vented to eliminate the very large errors possible from barometric pressure shifts caused, for instance, by changing weather).

- (24) The Depth readings are compensated for Salinity (that is, water density) so that readings are accurate whether made in fresh or salt waters.
- (25) The 25m, 100m, and 200m Depth accuracy are the 95% Certainty (most probable error) accuracy, based on the worst-case errors such as drift, temperature compensation, bit error, etc. This accuracy requires that the user employ atmospheric correction if changes in barometric pressure are to be considered. The accuracy is much better in situations where temperature changes are small and changes in Depth, rather than the exact Depth, are of primary interest.
- (26) Salinity is calculated from conductivity and temperature based on USGS WS Paper 2511 or Section 2525 of Standard Methods for the Examination of Water and Wastewater. The Standard Methods function is also commonly referred to as the Practical Salinity Scale or UNESCO Method.

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# Parameter Specifications

PARAMETER	RANGE	ACCURACY	RESOLUTION	SENSOR	COMPENSATIONS	CALIBRATION	RESPONSE TIME <sup>1</sup>	STABILITY <sup>2</sup>	OUTPUT OPTIONS
TEMPERATURE	-5 to 50°C	±0.10°C <sup>3</sup>	0.01°C	thermistor	none required	none required	< 1 minute	three years	°C, °F, or °K
SPECIFIC CONDUCTANCE	0.0000 to 0.1999 mS/cm 0.200 to 1.500 mS/cm 1.45 to 15.00 mS/cm 14.5 to 100.0 mS/cm (autoranged) <sup>4</sup>	± 1% of reading ± 1 count ± 1µS/cm	4 digits <sup>5</sup>	0.25" x 1" oval bore with four graphite electrodes	automatic to 25°C <sup>6</sup>	KCl or other standards	< 10 seconds	six months	mS/cm, µS/cm, conductivity, TDS, or resistivity
SALINITY	0 to 70 PSS <sup>7</sup>	± 1% of reading ± 0.01 PSS	0.01 PSS	calculated from specific conductance	none required	Uses calibration from sp. cond. Or calibrate directly with salinity standards	< 10 seconds	one month	PSS
DISSOLVED OXYGEN	0 to 50 mg/L	± 0.2 mg/L (<20) ± 0.6 mg/L (>20)	0.01 mg/L	rebuildable polarographic; 1 m <sup>2</sup> Teflon <sup>TM</sup> membrane	automatic for temperature and salinity	water-saturated air, Winkler, or air-saturated water	< 1 minute	one month	mg/L, % saturation, or mg/L without salinity correction
pH	0 to 14 units <sup>8</sup>	± 0.2 units <sup>9</sup>	0.01 unit	glass pH; rebuildable or low ionic strength reference electrode <sup>9</sup>	automatic for temperature	pH 7 buffer, plus one slope buffer	< 1 minute	one month	pH units
SHUTTERED TURBIDITY (DataSonde 4a only)	0 to 100 NTU or 0 to 1000 NTU (user selectable)	± 2.6% of range <sup>10</sup>	0.1 NTU 1 NTU	ISO 7027 compliant nephelometer with fouling resistant shutter (US Patent #6,111,249)	automatic ambient light rejection	dilutions of Formazin or AEPA-1 polymer beads	< 10 seconds <sup>11</sup>	one month	NTU or volts
NON-SHUTTERED TURBIDITY (DataSonde 4a and MiniSonde 4a)	0 to 100 NTU 100 to 1000 NTU (autoranged)	± 5% of range <sup>12</sup>	0.1 NTU 1 NTU	ISO 7027-based nephelometer	must be operated at depth > 1m or shielded from sunlight	dilutions of Formazin or AEPA-1 polymer beads	< 1 minute	one month	NTU
REDOX	-999 to 999 mV	± 20 mV <sup>13</sup>	1 mV	Pt electrode	none required	quinhydrone, Zobell, Light's, or transfers <sup>14</sup>	varies <sup>15</sup>	one month	mV
AMMONIUM/AMMONIA	0 to 100 mg/L-N	greater of ± 5% of reading or ± 2 mg/L-N <sup>16</sup>	0.01 mg/L-N	ion-specific electrode	activity coefficient computed from specific conductance; and ammonia derived from ammonium temperature, pH, and specific conductance	2-, 3-, or 4-point calibration with Hydrolab or user-produced standards	< 1 minute	one month	mg/L-N, mV, or mg/L-N of total NH <sub>3</sub>

Parameter Specifications – Series 4a DataSonde® 4a & MiniSonde® 4a & Surveyor® 4a Display  
(Continued from Page 1)

PARAMETER	RANGE	ACCURACY	RESOLUTION	SENSOR	COMPENSATIONS	CALIBRATION	RESPONSE TIME <sup>1</sup>	STABILITY <sup>2</sup>	OUTPUT OPTIONS
NITRATE	0 to 100 mg/L-N	greater of $\pm 5\%$ of reading or $\pm 2$ mg/L-N <sup>17</sup>	0.01 mg/L-N	ion-specific electrode	activity coefficient computed from specific conductance	2-, 3-, or 4-point calibration with Hydrolab or user-produced standards	< 1 minute	one month	mg/L-N or mV
CHLORIDE	0.5 to 18,000 mg/L	greater of $\pm 5\%$ of reading or $\pm 2$ mg/L-N <sup>18</sup>	4 digits <sup>18</sup>	ion-specific electrode	activity coefficient computed from specific conductance	2-, 3-, or 4-point calibration with Hydrolab or user-produced standards	< 1 minute	> 1 year with occasional polish	mg/L or mV
TOTAL DISSOLVED GAS	400 to 1300 mmHg (max immersion depth: 30 meters)	$\pm 0.1\%$ of span	0.1 mmHg	membrane-covered pressure transducer	none required	set in air	< 3 minutes <sup>20</sup>	one month	mmHg, mV, or PSI
AMBIENT LIGHT (PAR)	0 to 10,000 $\mu\text{mol s}^{-1}\text{m}^{-2}$	$\pm 5\%$ of reading or $\pm \mu\text{mol s}^{-1}\text{m}^{-2}$ <sup>21</sup>	$1 \mu\text{mol s}^{-1}\text{m}^{-2}$	photovoltaic cell	rejection of ambient light outside the 400-700 nm bandwidth	none required	< 10 seconds	two years <sup>21</sup>	$1 \mu\text{mol s}^{-1}\text{m}^{-2}$
CHLOROPHYLL	0.03 to 150 $\mu\text{g/L}$	$\pm 3\%$ of reading $\pm 0.1 \mu\text{g/L}$ <sup>22</sup>	0.1 $\mu\text{g/L}$	fluorometric	none required	dilutions of rhodamine (or secondary calibration cube) with user correlation to field samples	< 10 seconds	one month	$\mu\text{g/L}$ or volts
DEPTH/0-10M vented	0 to 10 m	$\pm 0.03 \text{ m}^{23}$	0.001 m	strain-gage transducer	automatic for salinity <sup>24</sup>	set zero in air	< 10 seconds	one month	m, ft, or PSI
DEPTH/0-25M non-vented	0 to 25 m	$\pm 0.06 \text{ m}^{25}$	0.01 m	strain-gage transducer	automatic for salinity <sup>24</sup>	set zero in air	< 10 seconds	one month	m, ft, or PSI
DEPTH/0-100M non-vented	0 to 100 m	$\pm 0.3 \text{ m}^{24}$	0.1 m	strain-gage transducer	automatic for salinity <sup>24</sup>	set zero in air	< 10 seconds	one month	m, ft, or PSI
DEPTH/0-200M non-vented	0 to 200 m	$\pm 0.8 \text{ m}^{25}$	0.1 m	strain-gage transducer	automatic for salinity <sup>24</sup>	set zero in air	< 10 seconds	one month	m, ft, or PSI
BAROMETRIC PRESSURE	500 to 850 mmHg	$\pm 10$ mmHg	0.1 mmHg	strain-gage transducer	none required	set in air	< 10 seconds	six months	mmHg, inHg, kPA, mbar, atm, or PSI

Note: These specifications apply over the operating temperature range of  $-6$  to  $50^\circ\text{C}$  (non-freezing), and over the operating voltage range of 8 to 16VDC, for well maintained sensors in clean, unchanging waters. There are many situations, such as biofouling, that will negate extrapolation of these specifications to field conditions.