

Umetco Minerals Corporation



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January 22, 2015

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Subject: **Umetco Minerals Corporation, Gas Hills, Wyoming, Site
Groundwater Evaluation and License Amendment Request**

Reference: **Radioactive Materials License SUA-648; Docket No. 40-0299**

Dear Mr. Orlando:

This letter is in response to Nuclear Regulatory Commission (NRC) letters dated March 3, 2014, and November 6, 2014, regarding groundwater concerns at Umetco Minerals Corporation's (Umetco) Gas Hills, Wyoming, site. Specific items addressed herein are as follows:

1. Submittal of the groundwater evaluation that Umetco agreed to provide in Umetco's letter of April 15, 2014.
2. Submittal of well completion information requested by the NRC in its letter of November 6, 2014.
3. License Amendment Request for installation of additional monitoring wells and modification of the groundwater monitoring plan.

Groundwater Evaluation

In Umetco's letter of April 15, 2014, Umetco agreed to perform a groundwater evaluation that, in summary, was inclusive of the results of additional transport model simulations; sampling performed in all the monitoring wells for all Alternate Concentration Limit (ACL) constituents; review of historic operations (waste disposal practices); and detailed evaluation of groundwater chemistry.

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This work has been completed. Attachment 1 of this letter provides the report titled *Western Flow Regime Groundwater Evaluation for Gas Hills, Wyoming, January 2015*, which provides the evaluation discussed in Umetco's letter of April 15, 2014. While this evaluation provides a valuable understanding of Western Flow Regime contaminant migration and attenuation, the need for additional geochemical characterization, monitoring data, and modeling downgradient of MW28 is also necessary to reliably predict future radium 226+228 concentrations at the Point of Exposure. Accordingly, Umetco is proposing installation of three additional wells with concurrent geochemical characterization of aquifer materials. The specific location and rationale for the proposed wells are detailed in Section 6 of Attachment 1.

Well Completion Information

NRC's letter of November 6, 2014, requested well completion information for the currently active wells. This information is provided as Attachment 2 to this letter along with profiles showing how each monitoring well's screened interval relates to each other, the aquifer, and the mudstone aquitard.

License Amendment Request

As noted above, Umetco is requesting a License Amendment for the installation three additional monitoring wells, as described in Section 6 of Attachment 1, and modification of the Groundwater Monitoring Plan referenced in LC 35. The revisions to the Monitoring Plan include:

- Changing the Monitoring Plan to a standalone document, as references to "Appendix M of the ACL Application" in the license have caused confusion in the past.
- Changing the sampling period from June to May through July.
- Changing the sampling parameters to the ACL constituents, plus chloride and sulfate in all wells. In general, the modifications to the monitoring plan terminate the use of sulfate and chloride as indicator and/or model validation constituents in favor of direct monitoring of ACL constituents plus sulfate and chloride.
- Removing the discussion of model validation wells and target concentrations as noted above since monitoring of sulfate and chloride alone in validation wells is not providing reliable indication of contaminate plume migration or attenuation.
- Adding an annual Groundwater Conditions report to be submitted to the NRC.
- Adding the three proposed monitoring wells.

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The revised Groundwater Monitoring Plan is provided as Attachment 3 to this letter and includes the three proposed monitor wells. Due to the extent of edits, the Monitoring Plan is provided as a complete copy as well as a underlined/strike through edit copy to assist in review. Discussion of the three proposed monitor wells is provided in Section 6 of Attachment 1.

Accordingly, Umetco proposes the following modifications (underlined/strike through) to License Condition 35 to accommodate the license amendment request:

35. *The Alternate Concentration Limits (ACL) for ground water contained in Umetco's application dated May 11 and May 18, 2001, as revised by submittals of July 30, 2001, December 3, 2001, ~~and~~ March 4 and October 2, 2002, June 17, 2005, ~~and~~ October 31, 2011, and January 22, 2014 have been approved for this site. The licensee shall implement a ground water compliance monitoring program that includes the following:*
- A. Conduct monitoring as described in the Groundwater Monitoring Plan (ACL application, Appendix M) in the January 5, 2004 submittal, as revised by letter dated October 31, 2011 submitted by letter dated January 22, 2015. ~~The validation of ACL exceedance will be in accordance with Section 4 of Appendix M.~~ The licensee shall submit this monitoring data to the NRC by September 30th of each year and include ground water contour maps, contamination iso-concentration maps, and trend graphs.*
 - B. Comply with the following ACL in the western flow regime at Point of Compliance (POC) wells MW1 and MW21A: arsenic = 1.8 mg/L, beryllium = 1.64 mg/L, lead-210 = 35.4 pCi/L, nickel = 13.0 mg/L, combined radium-226 and 228 = 250 pCi/L, selenium = 0.161 mg/L, thorium-230 = 57.4 pCi/L, and uranium-natural = 11.9 mg/L.*
 - C. Comply with the following ACL in the southwestern flow regime at POC wells GW7 and GW8: arsenic = 1.36 mg/L, beryllium = 1.70 mg/L, lead-210 = 189 pCi/L, nickel = 9.34 mg/L, combined radium-226 and 228 = 353 pCi/L, selenium = 0.53 mg/L, thorium-230 = 44.8 pCi/L, and uranium-natural = 34.1 mg/L.*
 - D. Laboratory reported lower limits of detection for radiological constituents shall be in accordance with Regulatory Guide 4.14, Radiological Effluent and Environmental Monitoring at Uranium Mills, Revision 1 April 1980. Laboratory reported lower limits of detection for non-radiological constituents shall be no greater than 10% of the Alternate Concentration Limit for the constituents.*

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Please contact me at 970-256-8889 or by e-mail at gieckte@dow.com if you, or the staff, have any questions regarding this submittal.

Regards,

A handwritten signature in black ink, appearing to read "Thomas E. Gieck". The signature is fluid and cursive, with the first name "Thomas" being more prominent than the last name "Gieck".

Thomas E. Gieck
Remediation Leader

TEG/ESH/jfc

Enclosures: Attachment 1, *Western Flow Regime Groundwater Evaluation for Gas Hills, Wyoming, January 2015*
Attachment 2, Monitoring Well Logs and Profile
Attachment 3, *Groundwater Monitoring Plan, January 2015*

cc: Tanya King, WDEQ w/enclosures
Scott Surovchak, DOE w/enclosures

UMETCO MINERALS
CORPORATION
GAS HILLS, WYOMING, SITE

GROUNDWATER EVALUATION
AND
LICENSE AMENDMENT REQUEST

January 22, 2015

UMETCO Minerals Corporation
2754 Compass Drive, Suite 280
Grand Junction, CO 81506

**Western Flow Regime Groundwater Evaluation
For
Gas Hills, Wyoming**

Umetco Minerals Corporation
2754 Compass Drive, Suite 280
Grand Junction, Colorado 81506

January 2015

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- Attachment A Modified PHREEQC Files (Original Model with Output at MW28)
- Attachment B Revised PHREEQC Files (Modified Model at 0.33 ft/day with Secondary Radium Source and Output at MW28)

1.0 Introduction

In 2001, Umetco Minerals Corporation (Umetco) submitted an application for Alternate Concentration Limits (ACL) (Umetco, 2001) to address groundwater constituents-of-concern derived from historical milling operations at the East Gas Hills site (Figure 1-1). The ACL application was supported by groundwater flow, solute transport, and geochemical models. To help validate these models and provide an indication of ACL constituent attenuation, Umetco prepared and implemented a groundwater monitoring plan that required comparison of groundwater chloride and sulfate sampling results to corresponding model-predicted concentrations at four model validation wells. This approach suggested that if chloride and/or sulfate concentrations exceeded the model-predicted concentrations at any model validation well (i.e., MW28, MW71B, MW72, and MW82), response actions would be needed, including but not limited to reassessment of the model simulations and assumptions. Therefore, in accordance with the Groundwater Monitoring Plan (Umetco, 2001), the model validation wells were sampled annually for chloride and sulfate, and the sample results were compared to the model predicted concentrations.

Between 2010 and 2012, measured concentrations of chloride and sulfate exceeded model predictions in monitoring well MW28, located along the groundwater flow path between the Western Flow Regime (WFR) Point of Compliance (POC) and Point of Exposure (POE). The WFR occurs in the Lower Wind River aquifer. Subsequent correspondence between the Nuclear Regulatory Commission (NRC) and Umetco resulted in expanded sampling for the ACL constituents at each WFR monitoring well to assess these exceedances. The expanded sampling program revealed elevated radium-226+228 concentrations at monitoring well MW28, which in turn raised concerns that the radium plume was not attenuating as predicted by the geochemical model. The combined radium-226+228 activity at MW28 was 199 picocuries per liter (pCi/L) in June 2013 and 163 pCi/L in June 2014.

To address NRC concerns regarding elevated radium at MW28, Umetco proposed to conduct a technical evaluation as outlined in the April 14th, 2014, letter to the NRC. This report presents Umetco's current assessment and understanding of radium-226+228 sources, migration, and attenuation in the WFR based on an assessment of: (1) geochemical modeling at MW28, (2) major ion geochemical signatures, (3) factors controlling radium-226+228 mobility, and (4) historic and current concentration isopleths for radium-226+228 and indicator constituents. The analysis indicates that: (1) the elevated radium activity currently present at MW28 was derived from tailings-impacted groundwater from the vicinity of monitoring well MWI64 (although it is possible that the highest radium-226+228 activities in the upgradient plume area were not detected by MWI64); (2) the factors controlling radium fate and transport at the site appear to be different than the conceptual model for radium migration presented in the ACL

application; and (3) despite these conceptual model differences, it is still possible that radium-226+228 activities will naturally attenuate to within background levels before reaching the WFR POE. Installation of additional monitoring wells is proposed in the vicinity of MW28 to further evaluate radium-226+228 attenuation upgradient of the POE.

Figure 1-1 shows the locations of the existing and abandoned WFR monitoring wells used in this evaluation.

2.0 Radium-226+228 Evaluation at MW28 Using the 2001 Geochemical Model

The Gas Hills geochemical model for the WFR was originally designed to simulate ACL constituent concentrations at the POE as a function of time for the 1,000-Year compliance period (Umetco, 2001). Consequently, no model results are available from the 2001 model to evaluate whether radium-226+228 activities are being attenuated as predicted at monitoring wells between the POC and POE, such as MW28. Therefore, the 2001 Gas Hills model was modified to generate predicted radium-226+228 activities at a distance from the POC corresponding to the location of monitoring well MW28.

The original geochemical model used the PHREEQC code (Version 2.0) (Parkhurst and Appelo, 1999) to simulate one-dimensional reactive transport of ACL constituents along the groundwater flow path in the WFR (Umetco, 2001). The model flow path extended west from the edge of the Above Grade Tailings Impoundment (AGTI) through POC well MW21A and monitoring well MW28 to the POE, approximately 4,600 feet (ft) from the AGTI. The resulting model grid consisted of 46 cells each representing an aquifer unit 100 ft in length, with model output from Cell No. 46 representing the constituent concentrations at the POE (Figure 2-1). The previous model simulations used a representative groundwater velocity of 0.167 feet per day (ft/day) and an upper velocity limit of 0.33 ft/day.

The modified (2014) geochemical model for MW28 presented here uses the updated version of PHREEQC (3.0.6) (Parkhurst and Appelo, 2013) in conjunction with the same GasHills.dat database used in the original model (Umetco, 2001). The original PHREEQC input files were revised to generate output from Cell No. 25, corresponding to the approximate distance of MW28 from the edge of the AGTI (Figure 2-1). The modified PHREEQC input files are provided in Attachment A.

With the modified model, the maximum predicted radium-226+228 activities at MW28 were very similar to the original POE results (Umetco, 2001) for both groundwater velocities (Table 2.1). The model output for predicted radium-226+228 activities at MW28 and the POE (Figure 2-2) shows that the predicted activities at MW28 are less than the elevated radium-226+228 activities recently observed, and thus radium-226+228 is not being attenuated along the WFR flow path as expected based on the original model assumptions.

Table 2.1 Maximum Predicted Radium-226+228 Activity at MW28 Relative to Original Point of Exposure (POE) Results

Location	Groundwater Velocity	
	0.167 feet/day	0.33 feet/day
MW28	57.1 pCi/L	72.6 pCi/L
POE	58.9 pCi/L	69.5 pCi/L

Picocuries per liter (pCi/L)

The original modeled radium-226+228 source term for the WFR (proposed ACL) of 250 pCi/L was a statistically-derived value selected to provide an upper limit for allowable radium-226+228 activity at the POC monitoring wells. However, radium-226+228 activities at both POC wells (i.e., MW1 and MW21A) have remained within the range of natural background since the 1990s. With the arrival in 2013 of elevated radium-226+228 activity (199 pCi/L) at MW28, it appears that another upgradient radium source area must have existed, because the radium-226+228 ACL was not exceeded in either POC well. Therefore, a detailed investigation of groundwater conditions at the East Gas Hills site was conducted to better understand potential radium-226+228 source areas and to identify the important factors contributing to radium-226+228 migration and attenuation (Section 3.0).

3.0 Investigation into Current Groundwater Conditions

A conceptual model of plume migration in the WFR was previously described (Umetco, 2013) based on the results of additional ACL constituent sampling in June 2013. Radium-226+228 activities at MWI64 decreased as a precursor to the increasing radium-226+228 trends at MW28, suggesting that radium-226+228 has migrated downgradient from MWI64 to MW28. Also noted was the dramatic decrease in constituent concentrations in both MWI64 and POC wells near the AGTI boundary, consistent with the plume passing through these wells and migrating west beyond MWI64. To further refine the conceptual model developed by Umetco (2013), characterization of both historic and recent radium-226+228 activities and major ion chemistry was undertaken to characterize the source, extent, and fate of radium-226+228 in the groundwater migrating west of the AGTI.

3.1 Major Ion Chemical Signatures

The composition of major cations (Ca, Mg, Na, K) and anions (SO_4 , Cl, HCO_3) can be used to define geochemical signatures of mill tailings sources and native groundwater, thus providing potential indicator parameters for identification and monitoring of plume migration. The geochemistry of mill tailings water from the AGTI is represented by average water quality from monitoring wells installed in the AGTI (Umetco, 2001) and from a series of extraction and injection wells which were utilized during earlier groundwater corrective actions. The trilinear diagram on Figure 3-1 shows major ion groupings for: (1) average AGTI tailings fluids (Umetco, 2001), (2) extraction wells which were located west (MWC33, MWC34, and MWC59) or east (MWC45) of the AGTI (Geraghty & Miller, 1996), and (3) historic data (1996 – 2001) for downgradient monitoring wells MWI64, MW28, and MW77. The tailings sources (average AGTI and MWC wells) are primarily Mg- SO_4 type waters, while the downgradient groundwater quality signature (MW28 and MW77) was historically a Ca- SO_4 type water. Monitoring well MWI64 is located just west of the AGTI, and through 2001 had a Mg- SO_4 signature identical to tailings-impacted groundwater extracted in the vicinity of MWC33 and MWC34 (Figure 3-1).

More recent analyses of the monitoring well network for major ions in 2014 shows there has been a significant shift in the major ion chemistry at MWI64 and in the downgradient monitoring wells since 2001. The water composition at MWI64 has shifted from a Mg- SO_4 tailings signature toward a Ca- SO_4 water with higher proportions of HCO_3 (Figure 3-2). However, wells located downgradient from MWI64 presently contain higher proportions of magnesium relative to their historic Ca- SO_4 signatures, which is most pronounced at MW25 and MW28, located west of MWI64. Figure 3-2 illustrates the shift toward higher magnesium proportions at MW28 and MW25 which parallels the decrease in the magnesium proportion observed at MWI64 between 2001 and 2014. This analysis indicates that MWI64 has previously

been affected by impacted groundwater originating from the vicinity of MWC33 and MWC34, which had radium-226+228 activities ranging up to 560 pCi/l and 574 pCi/l, respectively. Decreasing proportions of magnesium at MWI64 followed by increases at downgradient wells is consistent with westward migration of impacted groundwater from the area of MWI64.

Magnesium and sulfate concentrations are sufficiently elevated in the tailings pore water to produce the observed downgradient effects discussed above. Sulfate has been frequently analyzed and is expected to migrate more conservatively relative to magnesium, and therefore is a useful tailings pore water indicator. Figure 3-3 shows that historic sulfate concentrations in MWI64 are consistent with those of MWC extraction wells previously located along the western edge of the AGTI, and are the highest of the wells shown on the figure. Since 2003 there has been a significant decrease in sulfate at MWI64 (Figure 3-3), which corresponds to the major shift in cation proportions noted at MWI64 after 2001 (Figure 3-2). Sulfate concentrations have also been decreasing in MW1 and MW70A to the northwest, but increasing to the west at wells MW21A, MW25, and MW28 (Figure 3-3).

Assuming a hydraulic connection exists between MWI64 and MW28, the travel time for sulfate was calculated using the elapsed time between the first sulfate peak at MWI64 (March 1996) and the corresponding sulfate peak at MW28 (June 2013) (6,288 days). Using a distance of 1,825 feet between MWI64 and MW28, the calculated travel time for sulfate is 0.29 feet/day, which falls within the range of representative groundwater velocities estimated for the site (0.167 to 0.33 feet/day) (Umetco, 2001).

Elevated sulfate concentrations in the tailings pore water resulted from the use of sulfuric acid (pH = 2.0) in the milling process and therefore low pH groundwater may also indicate tailings impacts. The pH trends on Figure 3-4 show that historically, the lowest pH conditions have existed to the north and northwest of the AGTI at MW1 and MW70A; since 2001 the pH has increased significantly at MW1. The lowest pH conditions west of the AGTI have existed at MWI64 (pH = 4.17 in 2003), but since 2003 pH has increased to approximately 7.0, coinciding with the decrease in sulfate concentrations observed at this well (Figure 3-3). Conversely, in recent years pH has decreased at wells MW21A, MW28, and MW25, indicating the possibility of tailings-impacted groundwater migrating into these areas. No impacts from low pH appear to exist at MW71B located southwest of the AGTI, although sulfate concentrations have been increasing at this well since 1998 (Figure 3-3).

The combined sulfate and pH observations agree with prior conceptual models describing neutralization of acidic tailings fluid by reactive minerals (such as calcite) along the flow path (e.g., Geraghty & Miller, 1996). The extent of neutralization depends on factors such as aquifer mineralogy and the acidity/extent of the advancing front of tailings impacted groundwater; however, increases in sulfate concentration may precede decreases in pH as the advancing

front is neutralized. A scatterplot of sulfate and pH (Figure 3-5) shows that MWI64 has historically contained the lowest pH and highest sulfate concentrations, and plots within the upper left of the diagram; conversely, un-impacted wells with higher pH and lower sulfate concentrations (MW77, MW71B, and MW2) plot within the lower right portion of the figure. Monitoring well groupings between these two end-members indicate varying degrees of mixing between native and tailings-impacted groundwater, and provide an indication of the advancing plume front and the most reactive areas of the plume. For example, monitoring well MW28 has displayed the largest shift from lower right to upper left in recent years, while the data for cross-gradient locations (such as MW25 and MW71B) are more tightly grouped. This suggests that the most impacted groundwater is flowing in the general direction of MW28, while MW25 and MW71B are likely situated along the plume periphery.

3.2 Radium-226+228 Source and Mobility Evaluation

Groundwater trends in the East Gas Hills monitoring wells show that past increases in radium-226+228 have been most pronounced at MWI64, whereas recent increases in radium-226+228 are most prominent at MW28 (Figure 3-6). Between 2001 and 2013, radium-226+228 at MW28 increased from 17.9 pCi/L to 199 pCi/L, whereas during the same period radium-226+228 decreased from 215 pCi/L to 15.6 pCi/L at MWI64. As the historical data have shown for sulfate at MWI64 (Figure 3-3), elevated radium-226+228 at MWI64 likely originated from impacted groundwater in the vicinity of former extraction wells MWC33 and MWC34 along the western boundary of the AGTI (Figure 3-7). Radium-226+228 activities have since decreased at MWI64, along with the decrease in sulfate concentrations (Figure 3-3) and increase in pH (Figure 3-4).

The major ion chemistry evaluation (Section 3.1) showed that indicator parameters, such as sulfate, which have migrated beyond MWI64, are currently appearing at MW28. Thus it can be concluded that the recent radium-226+228 increases at MW28 also originate from the arrival of upgradient tailings-impacted groundwater that migrated beyond MWI64. The maximum radium-226+228 activity at MW28 (199 pCi/L) is only slightly lower than that observed at upgradient well MWI64 (215 pCi/L), and thus radium-226+228 is primarily migrating conservatively, similar to sulfate, as long as the pH generally remains below 6.0. Concentration trends for these wells illustrate the simultaneous decrease in radium-226+228 and sulfate at MWI64, followed by the corresponding increase at MW28 (Figure 3-8).

The travel time for radium-226+228 was calculated using the elapsed time between the first radium-226+228 peak at MWI64 (April 1998) and the corresponding peak at MW28 (June 2013) (5,533 days). The calculated radium-226+228 travel time from MWI64 to MW28 (1,825 feet) is 0.33 feet/day, which matches the upper groundwater velocity limit (Umetco, 2001) and is in close agreement with the calculated sulfate travel time of 0.29 feet/day (Section 3.1).

Radium-226+228 activities in groundwater can be controlled by co-precipitation with minerals such as barite or calcite, by ion exchange with clay minerals, or by adsorption to iron oxide mineral surfaces (Ames et al., 1983; Langmuir and Riese, 1985; Bassot et al., 2000). Evaluation of radium-226+228 activities in the East Gas Hills groundwater indicates that the activity increases with decreasing pH, with the greatest effect occurring at a pH of approximately 6.0 and below, as shown on Figure 3-9 for MW28 and MWI64. Previous studies have shown that a similar relationship exists between pH and radium-226+228 when the radium activity is primarily controlled by the extent of adsorption onto iron oxide minerals (Bassot et al., 2000; Denham, et al., 2005). Thus, adsorption to iron oxide minerals appears to be the primary process influencing radium transport in the East Gas Hills groundwater. When the pH is below 6.0, radium at the site does not readily adsorb onto iron oxide minerals, and radium transport approximates that of a conservative tracer. With increasing pH above 6.0, the extent of adsorption increases and radium-226+228 is more strongly attenuated.

3.3 Concentration Isopleth Maps

The relationship between pH, sulfate, and radium in the East Gas Hills groundwater was further evaluated by preparing a series of concentration isopleth maps for these constituents. Umetco selected historical monitoring events for evaluation that had a large number of sample locations in common and where results were available from key wells, such as MW28 and MWI64. Isopleth maps were prepared for the second quarter of 1993, the first quarter of 2001, and the second quarter of 2014. A radium-226+228 isopleth map was also prepared for the second half of 1990 to help delineate the source area of the radium plume.

The first quarter 2001 sampling event was one of the last major sampling events before Umetco's ACL Application was approved and the Appendix M groundwater monitoring plan was implemented (Umetco, 2001). After 2001, sampling was discontinued at all but eight wells in the WFR, and sampling of the ACL constituents was limited to the two WFR POC wells until 2012. Thus, post-2001, there is limited data available to map the groundwater plume.

pH Isopleths

Groundwater pH contours for 1993, 2001, and 2014 are presented on Figures 3-10, 3-11, and 3-12, respectively. Tailings impacts are indicated on the figures by a pH less than 6.0. In 1993, zones of low pH in the WFR occurred to the north and west of the AGTI, with pH values below 5.0 at wells MW1, MWC55, MWC59, and MWC56 (Figure 3-10). A low pH zone was also inferred around well MW70A. Although MW70A was not installed until 1997, the well has had a pH around 4.0 since it was first sampled (Figure 3-4). Figure 3-10 shows that as of 1993, the core of the pH plume had not yet migrated to MWI64, and the pH at downgradient wells MW25 and MW28 were near background levels.

By 2001, the pH plume in the WFR decreased in extent and migrated downgradient (Figure 3-11). The pH at well MWI64 decreased from 5.59 in 1993 to 4.75 in 2001, indicating an increasing influence from tailings-impacted groundwater. However, it is evident that the plume had not yet migrated to MW25 and MW28 in 2001, as the pH values at these wells remained above 6.0.

Current site conditions are represented by pH isopleths developed for 2014 (Figure 3-12). Between 2001 and 2014, the pH plume continued to migrate west along the groundwater flow path, with groundwater quality returning to near background levels at upgradient wells MW1 and MWI64. Conversely, downgradient wells MW25 and MW28 exhibited a decrease in pH after 2001 as the distal edge of the pH plume arrived at these wells.

Sulfate Isopleths

Groundwater sulfate contours for 1993, 2001, and 2014 are presented on Figures 3-13, 3-14, and 3-15, respectively. The minimum contour value used on the figures (1900 milligrams per liter (mg/L)) represents the background sulfate concentration for the WFR (Umetco, 2001). The sulfate plume extents shown on Figures 3-13 through 3-15 correlate visually with the pH plume contours developed for the same time periods. However, the core of the sulfate plume in 1993 (Figure 3-13) appears to have migrated farther downgradient compared to the pH plume. This could be due to the tendency for sulfate to migrate as a conservative tracer, whereas the hydrogen ions driving lower pH travel more slowly due to neutralization by the aquifer matrix. The faster migration rate of the sulfate plume is also evident at downgradient well MW25, where the sulfate concentration was already elevated above background in 1993 (Figure 3-13).

Figure 3-14 shows that by 2001, the sulfate plume had decreased in extent with the core of the plume located around MWI64. Areas of elevated sulfate concentrations also existed around MW70A and in an area downgradient of MW1. The distal edge of the sulfate plume was stable between 1993 and 2001, with sulfate remaining below background at MW28 during the 2001 sampling event.

The current 2014 plume extent (Figure 3-15) is even smaller than the 2001 plume based on data from the eight remaining monitoring wells in the WFR. Between 2001 and 2014, the sulfate plume migrated away from upgradient monitoring wells MW1 and MWI64 and into the area of downgradient well MW28. Overall, the maximum sulfate concentrations measured in 2014 are considerably lower than 2001, showing that the sulfate plume is naturally attenuating.

Radium Isopleths

Combined radium-226+228 activities are plotted on Figures 3-16, 3-17, 3-18, and 3-19 for 1990, 1993, 2001, and 2014, respectively. The minimum contour value shown on the figures (53 pCi/L) represents the background radium-226+228 activity calculated for the WFR (Umetco,

2001). In 1990, a zone of elevated radium-226+228 was present on the west side of the AGTI around wells MWC33 and MWC34 (Figure 3-16). This area represented the core of the radium-226+228 plume which later migrated westward and arrived at MWI64 and then MW28. The activities shown on Figure 3-16 for MWC33 and MWC34 are from samples collected in September 1990; however, higher radium-226+228 values have been recorded at both wells, including a July 1990 sample from MWC33 (560.4 pCi/L) and a December 1991 sample from MWC34 (574 pCi/L) (Figure 3-7). The peak radium-226+228 activities observed at these wells decreased by more than half along the groundwater flow path as they traveled from the source area to monitoring well MWI64.

Figure 3-17 shows that by 1993, the core of the radium plume had migrated to the west but remained upgradient of MWI64. A zone of elevated radium-226+228 activity also likely existed near MW70A during this timeframe based on radium levels measured at the well when it was first installed and sampled in 1997. The downgradient extent of the radium plume in 1993 occurred east of MW25.

By 2001, the core of the radium-226+228 plume had migrated west to MWI64 and DW3 (Figure 3-18). The downgradient plume extent remained stable east of MW25 and MW28. Figure 3-18 also shows that by 2001, the radium-226+228 plume had split into two separate lobes, with a small area of elevated radium-226+228 activity present around well MW26 north of the AGTI.

The 2014 radium-226+228 plume extent is depicted on Figure 3-19. Between 2001 and 2014, the radium-226+228 plume decreased in size and migrated downgradient. As the plume moved west along the groundwater flow path, un-impacted upgradient groundwater flowed into the area of wells MW1 and MWI64, resulting in lower radium activities that are below background levels. Currently, the radium plume is centered on monitoring well MW28.

Overall, the shape and extent of the radium-226+228 plumes in 1993, 2001, and 2014 is similar to both the pH and sulfate plumes for the same time periods. The relative similarities between the radium-226+228 and pH plumes in particular reinforce the concept outlined in Section 3.2 that radium is more mobile when the groundwater pH is below 6.0. This suggests that radium transport at the site is largely controlled by adsorption onto iron oxide minerals. The isopleth maps also show that peak activities within the radium-226+228 plume have attenuated from a high of above 500 pCi/L in 1990 to below 200 pCi/L as observed at MW28 in 2014.

4.0 Revised Geochemical Modeling of Radium-226+228 at MW28 and the Point of Exposure

In the original geochemical transport model, radium-226+228 attenuation was controlled by both ion exchange and adsorption to iron oxide minerals (hydrous ferric oxide, or HFO) (Umetco, 2001). The recent assessment of radium-226+228, however, suggests that adsorption to HFO may be the dominant mechanism for potential radium-226+228 attenuation in the East Gas Hills groundwater (Section 3.2). The original model also assumed an initial AGTI radium-226+228 source of 250 pCi/L predicted to decrease exponentially with time, whereas the current evaluation suggests a potential scenario of locally elevated radium-226+228 above 250 pCi/L in the vicinity east-southeast of MWI64. Possible explanations for the elevated radium-226+228 in this area are that some elevated radium-226+228 migrated west beyond the extraction zone prior to 1990, and/or that elevated radium-226+228 remained in groundwater to a limited extent following the corrective action program. Based on this information, the original model was revised to account for an additional radium-226+228 source west of the AGTI with attenuation controlled by adsorption to HFO under low pH conditions.

In the revised geochemical model, the radium-226+228 activity in Cell 10 (Figure 2-1) was increased to a value of 300 pCi/L, representative of average radium-226+228 levels measured in historic extraction wells and MWI64. In the geochemical database, ion exchange by clays was not allowed as it was in the original model. The pH of the existing groundwater was also decreased to 5.5 based on more recent monitoring data (Figure 3-4); however, neither radium-226+228 activities nor pH values of the initial and decreasing source terms were changed. A corresponding groundwater velocity of 0.33 feet/day was used based on the travel times calculated for radium-226+228 between MWI64 and MW28 (Section 3.2). Revisions to the original model are summarized in Table 4.1 and the revised PHREEQC input file is included in Attachment B.

Table 4.1 Summary of Revisions to the Original Geochemical Model for Radium-226+228

Parameter	Original Model ¹ Umetco (2001) and Section 2.0	Revised Model ²
Radium-226+228 Source Term	Initial Ra-226+228 = 250 pCi/L (decreasing source term)	Additional 300 pCi/L Ra-226+228 in Cell No. 10
Groundwater pH	pH = 6.12 (Cell Nos. 1 - 15) pH = 6.86 (Cell Nos. 16 - 46)	pH = 5.5 (Cell Nos. 1 - 46)
Radium-226+228 Attenuation Mechanisms	Ion Exchange (clays) Surface Complexation (HFO)	Surface Complexation (HFO)

1 See Attachment A for original PHREEQC input file.

2 See Attachment B for revised PHREEQC input file.

The revised modeling results show that transport of an additional single radium-226+228 input of 300 pCi/L west of the AGTI under lower pH conditions produces a peak radium-226+228 activity of 200 pCi/L at MW28 when a flow rate of 0.33 feet/day is simulated (Figure 4-1). The predicted radium-226+228 activity of 200 pCi/L is in good agreement with the measured peak activity at MW28 in June 2013 (199 pCi/L) (Figure 3-6). When the transport simulation is projected to the POE (Figure 4-1), the predicted radium-226+228 activity is lower, but remains above the 0.7 – 79 pCi/L radium-226+228 background range for the WFR (Umetco, 2001). However, because the acidity within the plume is being progressively neutralized, attenuation may not be linear and the majority of radium-226+228 could be attenuated upgradient of the POE if continued neutralization increases the pH to above 6 (Section 3.2).

5.0 Revised Conceptual Model and Radium-226+228 Summary

Evaluation of radium-226+228 source areas associated with the AGTI shows that historic radium-226+228 activities and indicator constituents were most elevated in groundwater at the western boundary of the AGTI, in the approximate vicinity of former extraction wells MWC33 and MWC34. The localized occurrence of elevated radium-226+228 and sulfate in this area relative to remaining AGTI wells may be related to historic variation in tailings water composition among the four separate tailings ponds which comprised the AGTI (1960, 1969, 1972, and 1974 ponds) (Figure 5-1). No information regarding tailings water composition prior to 1977 could be located to evaluate potential differences in radium-226+228 levels in either the 1972 or 1974 ponds which comprised the western portion of the AGTI.

Elevated radium-226+228 activities and sulfate concentrations began to appear at MWI64 in the early 1990s from locally-contaminated groundwater that migrated west beyond the AGTI extraction zone prior to 1990 and/or that remained in groundwater following the corrective action program. At present, the elevated radium-226+228 activities and sulfate concentrations have migrated beyond MWI64 and are being flushed by relatively clean groundwater from upgradient; thus, the source activities and concentrations appear to have diminished. The geochemical groundwater assessment provided in Section 3 indicates that elevated radium-226+228 activities previously observed at MWI64 have arrived at MW28. The observed degree of attenuation at MW28 does not support further attenuation of radium-226+228 to background levels at the POE, but is consistent with a revised model simulating an additional source of radium-226+228 migrating west of the AGTI controlled by pH and iron oxide adsorption.

Relationships between radium-226+228, sulfate, and pH indicate that radium-226+228 will remain elevated and continue to migrate conservatively along with sulfate, as long as the pH generally remains below 6. If the pH increases above 6, radium-226+228 attenuation by iron oxides should exert greater control and reduce soluble radium-226+228. The June (2014) decrease in radium-226+228 activity at MW28 from 199 to 163 pCi/L was accordingly associated with a decrease in sulfate and an increase in pH (Figure 3-9). The recent decreases in radium-226+228 activity and sulfate concentration suggest that the peak plume activities/concentrations have arrived at MW28.

The future extent of radium-226+228 attenuation beyond MW28 should largely be controlled by the rate that pH increases at the plume front as the groundwater acidity is further neutralized. The arrival of background groundwater (pH = 7) at MWI64 indicates a diminished source with limited acidity that is becoming increasingly neutralized with time and distance;

for example the lowest pH observed at MWI64 was 4.17, whereas the minimum pH at MW28 has so far reached 5.20.

To predict the degree of future radium-226+228 migration, Umetco will use data from MWI64 and MW28 to calibrate the revised geochemical model (Section 4.0) to account for pH neutralization by calcite (which was not simulated in the original or revised PHREEQC model). Simulations will be conducted to evaluate the amount of calcite (CaCO_3) required to account for the pH rise between MWI64 and MW28. A second model will then use the calculated calcite content and water quality from MW28 to predict the extent of downgradient radium-226+228 attenuation. Field activities are also planned for concurrent geochemical characterization of aquifer materials and completion of supplemental monitoring wells (Section 6.0); the data collected may be used to guide and/or modify ongoing geochemical concepts and model predictions regarding future radium-226+228 attenuation.

6.0 Proposed Monitoring Wells

Umetco proposes to install three additional WFR monitoring wells to evaluate radium-226+228 attenuation upgradient of the POE. Proposed locations for the new monitoring wells are shown on Figure 6-1. These locations are only approximate and may need to be adjusted based on field conditions or access limitations.

Locations, depths, and objectives for the proposed new wells are provided in Table 6.1.

Table 6.1 Proposed New Monitoring Well Locations

Well Name	Well Location	Estimated Depth	Objective for New Well
MW83	300 feet west of MW28	240 feet	Well is intended to intercept peak radium-226+228 activities from upgradient within one year of installation. Data from the well will be used to evaluate radium attenuation along the groundwater flow path.
MW84	600 feet northwest of MW28	230 feet	Well will be used to refine the groundwater flow direction and provide a second point for evaluating radium-226+228 attenuation.
MW85	1400 feet northwest of MW28	270 feet	Well is intended to intercept the leading edge of sulfate-impacted groundwater from the AGTI, and will provide an early indication of downgradient contaminant movement.

These three well locations were selected based on an estimated groundwater seepage velocity of 0.29 ft/day. By the time the new wells are installed in the summer of 2015, two years will have elapsed since peak radium-226+228 activities arrived at MW28. In those two years, the radium plume will have migrated slightly over 200 feet downgradient. Thus, the plume should begin to appear at proposed well MW83 within one year after the well is installed. MW83 will consequently provide a valuable data point for assessing radium attenuation along the groundwater flow path between MW28 and downgradient well MW77.

Proposed well MW84 would provide a second data point for assessing radium-226+228 attenuation that will be especially useful if the radium plume is migrating faster than expected. By positioning the well slightly to the northwest, MW84 could also be used to refine the groundwater flow direction. Finally, the location of proposed well MW85 was selected to intercept the leading edge of sulfate impacted groundwater from the AGTI, which likely occurs

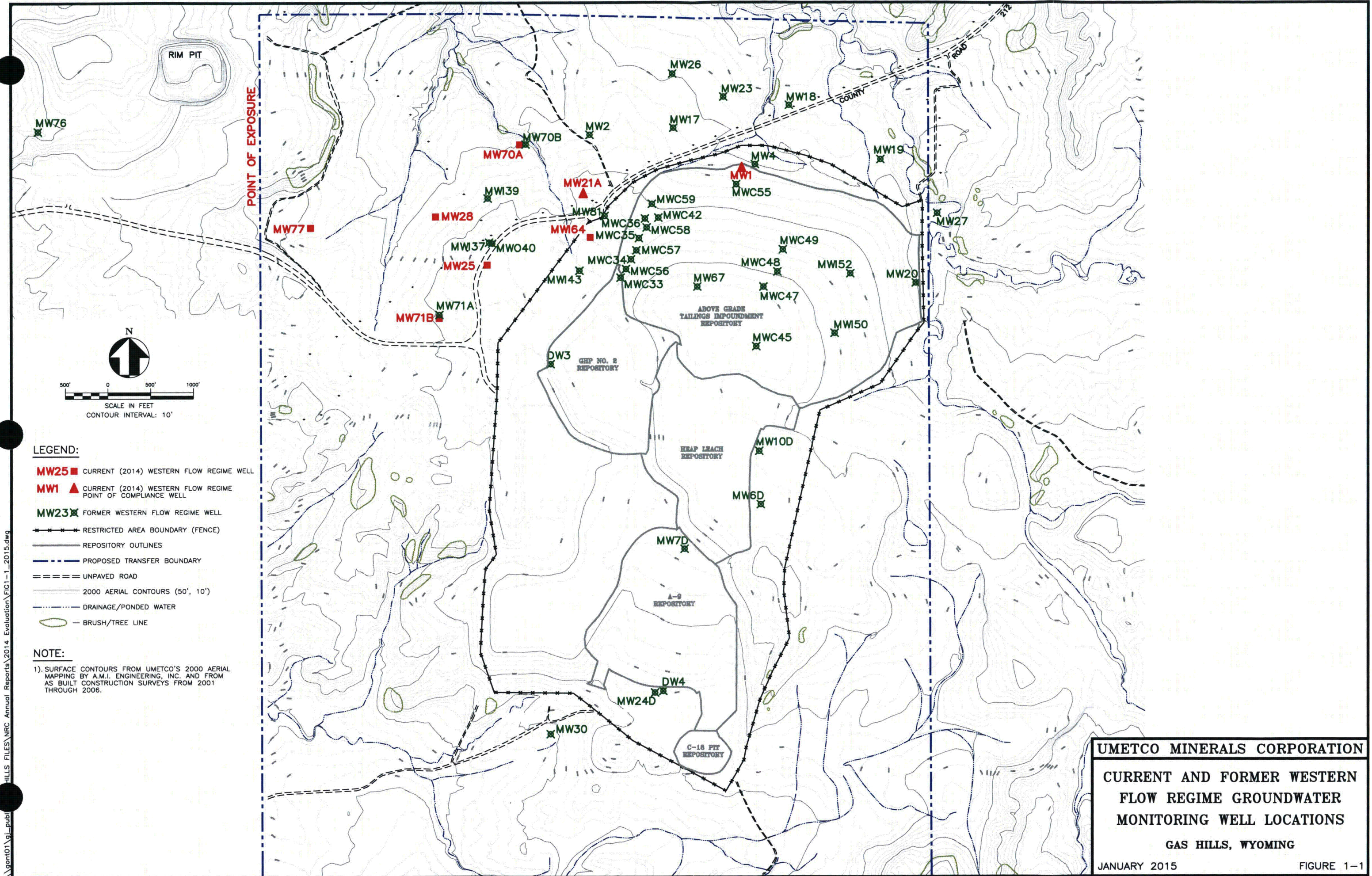
several hundred feet west-north west of MW28 based on the first arrival of elevated sulfate in this well (Figure 3-3). MW85 would be about the same distance from MW28 as MW77, and would serve as an additional sentinel well to detect plume migration before the plume reached the POE. The proposed location of MW85 is also close to an existing road, allowing for easy access to the well site.

The proposed new monitoring wells will be installed in the Lower Wind River aquifer, with the well screens set at approximately the same elevation in each well. To the extent practicable, the well screens will be designed to overlap the existing well screen intervals in monitoring wells MW164, MW28, and MW77. This will likely require Umetco to install longer (i.e., 50- to 60-ft) well screens in the new wells. Based on these requirements and the ground surface elevation at each of the proposed locations, the well depths are expected to range from 230 to 270 feet below ground surface. These depths are preliminary and may need to be refined based on field conditions and input received from NRC.

Samples of the aquifer solids will be collected from the unsaturated and saturated zones as the proposed new wells are drilled. The samples will be characterized with respect to bulk mineralogy, clay and organic carbon content, cation exchange capacity, and amorphous iron oxide content. This information will provide direct measurement of the properties controlling constituent attenuation which will be used to refine Umetco's conceptual and geochemical models of radium fate and transport at the site.

7.0 References

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LEGEND:

- MW25** ■ CURRENT (2014) WESTERN FLOW REGIME WELL
- MW1** ▲ CURRENT (2014) WESTERN FLOW REGIME POINT OF COMPLIANCE WELL
- MW23** ✕ FORMER WESTERN FLOW REGIME WELL
- RESTRICTED AREA BOUNDARY (FENCE)
- REPOSITORY OUTLINES
- - - - PROPOSED TRANSFER BOUNDARY
- ==== UNPAVED ROAD
- 2000 AERIAL CONTOURS (50', 10')
- DRAINAGE/PONDED WATER
- BRUSH/TREE LINE

NOTE:

1). SURFACE CONTOURS FROM UMETCO'S 2000 AERIAL MAPPING BY A.M.I. ENGINEERING, INC. AND FROM AS BUILT CONSTRUCTION SURVEYS FROM 2001 THROUGH 2006.

UMETCO MINERALS CORPORATION

CURRENT AND FORMER WESTERN
FLOW REGIME GROUNDWATER
MONITORING WELL LOCATIONS

GAS HILLS, WYOMING

JANUARY 2015

FIGURE 1-1

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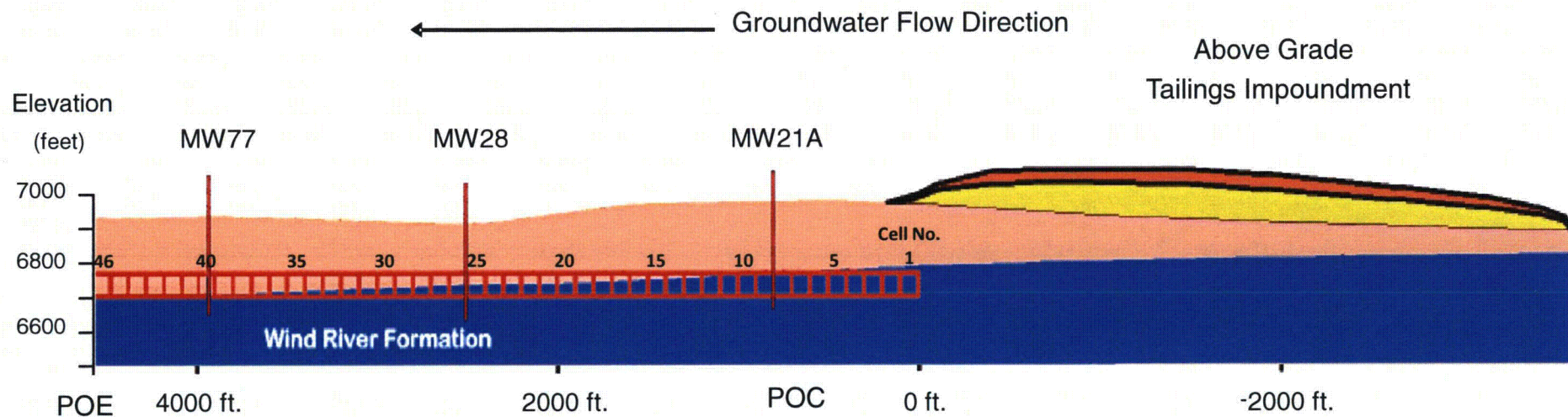


Figure 2-1 Model Grid for the Western Flow Regime.

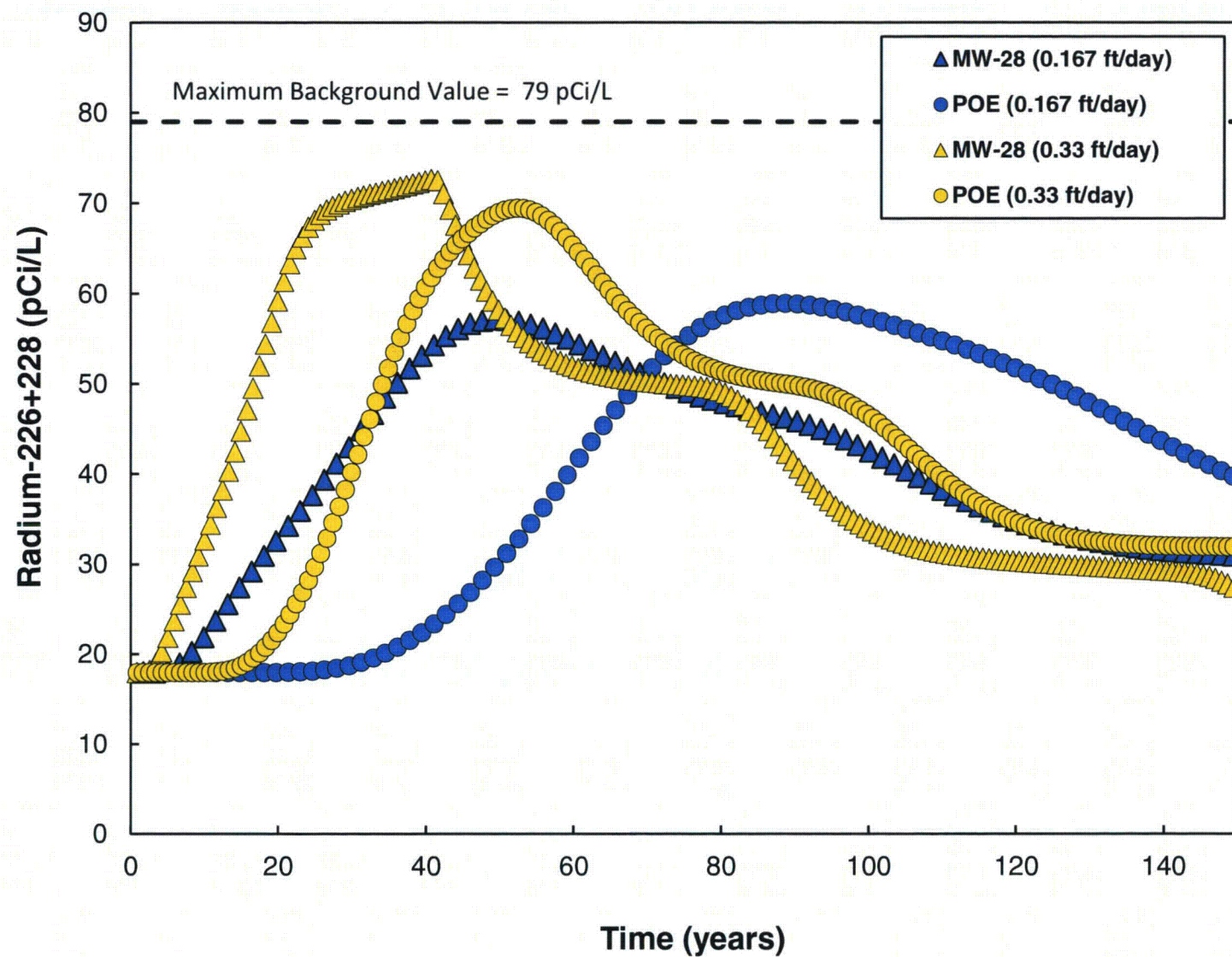


Figure 2-2 Comparison of Predicted Radium-226+228 at MW-28 and the POE.

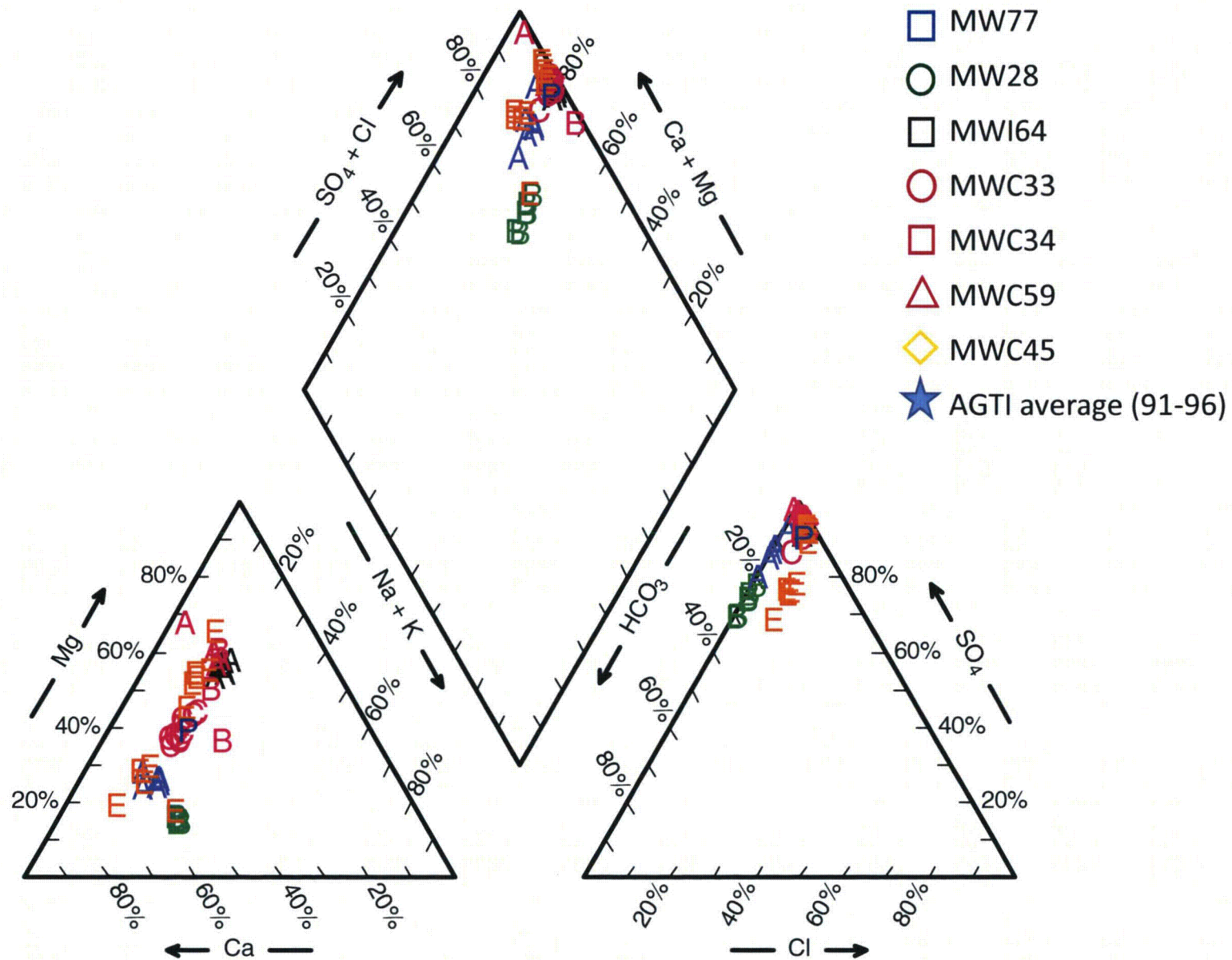


Figure 3-1 Historic Major Ion Comparison (1996 – 2001) Between Selected Monitoring Wells and Potential Sources.

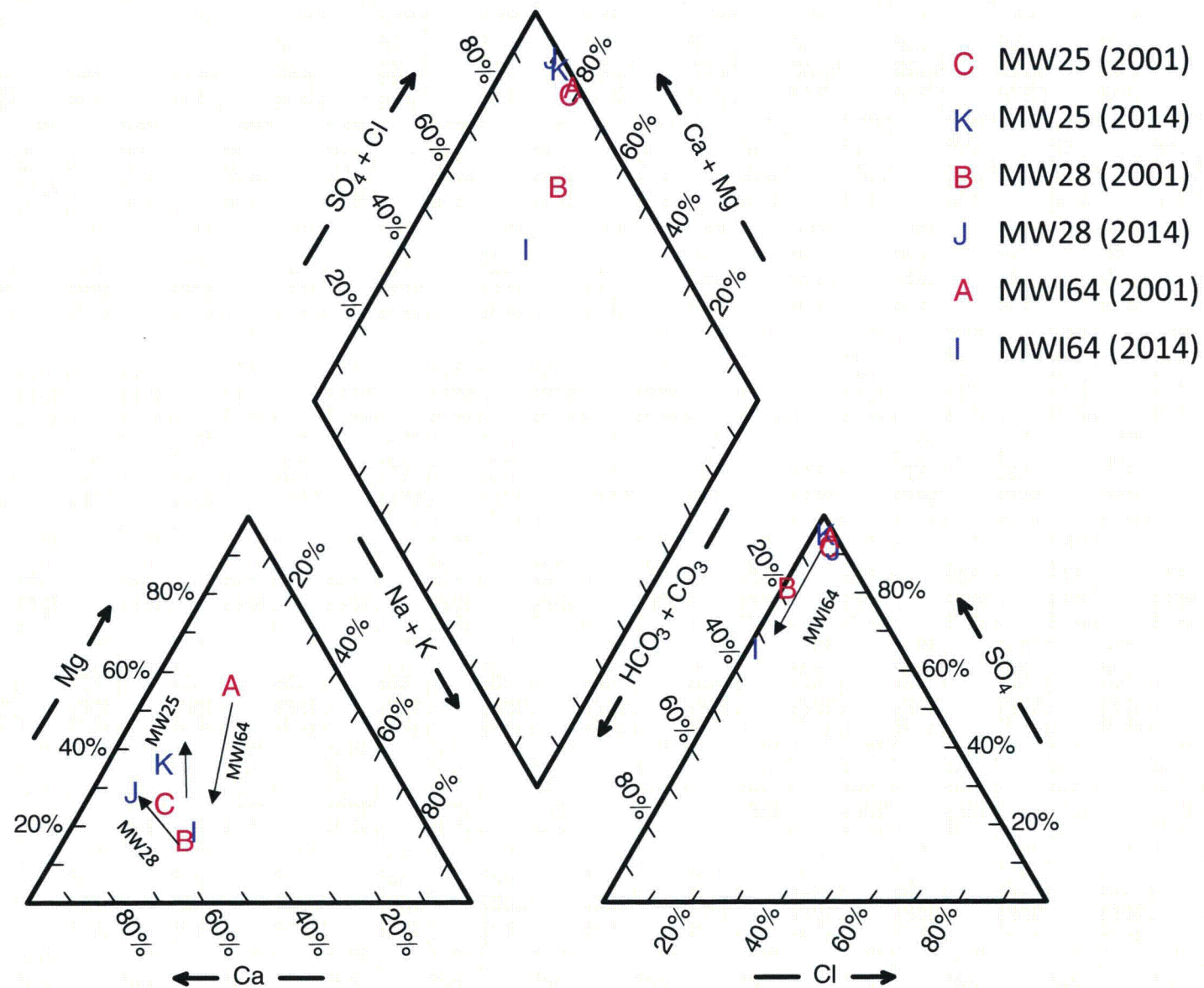


Figure 3-2 Historic Shifts in Major Ion Chemistry: MWI64 vs. MW28 and MW25.

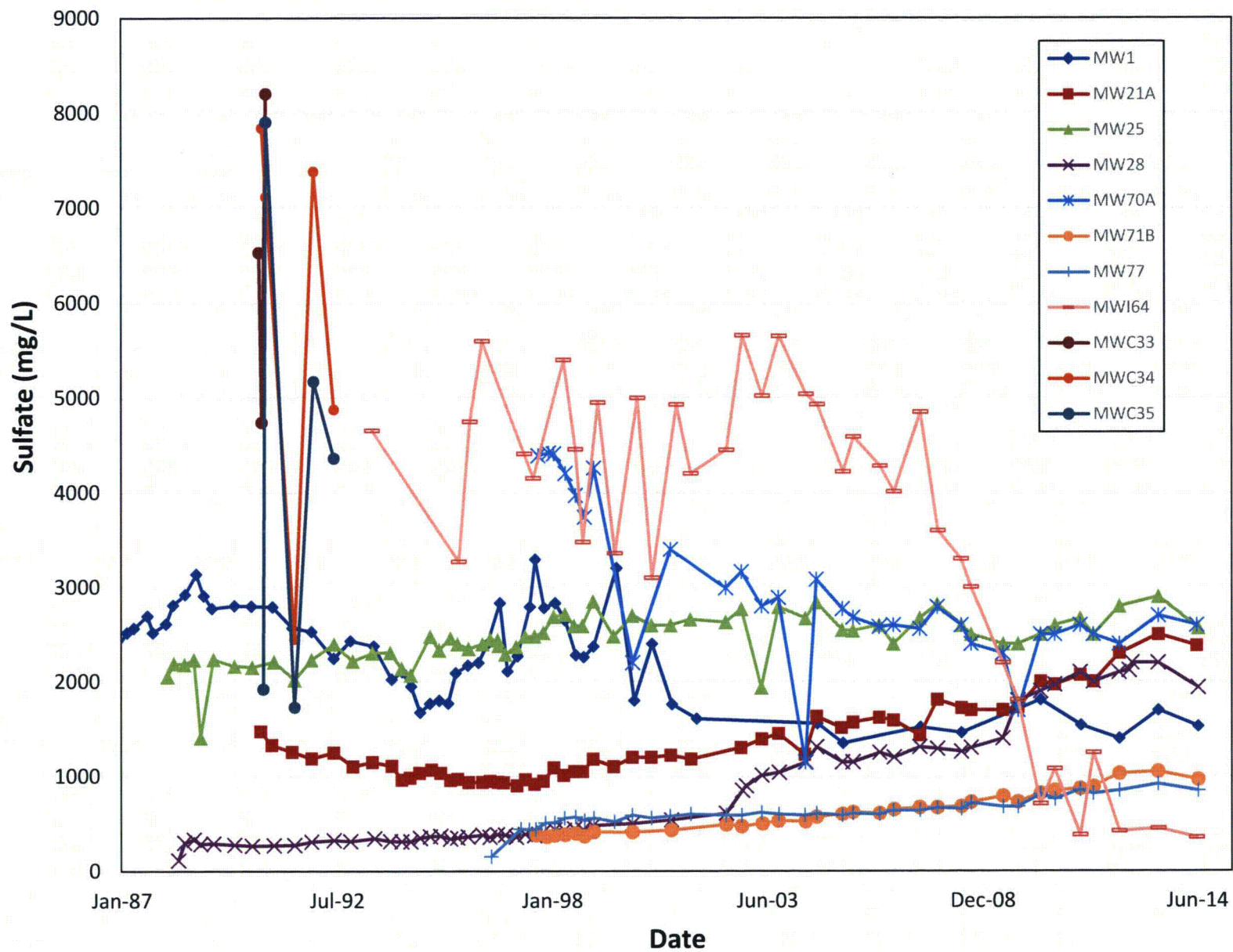


Figure 3-3 Comparison of Sulfate Between Sources and Selected Wells.

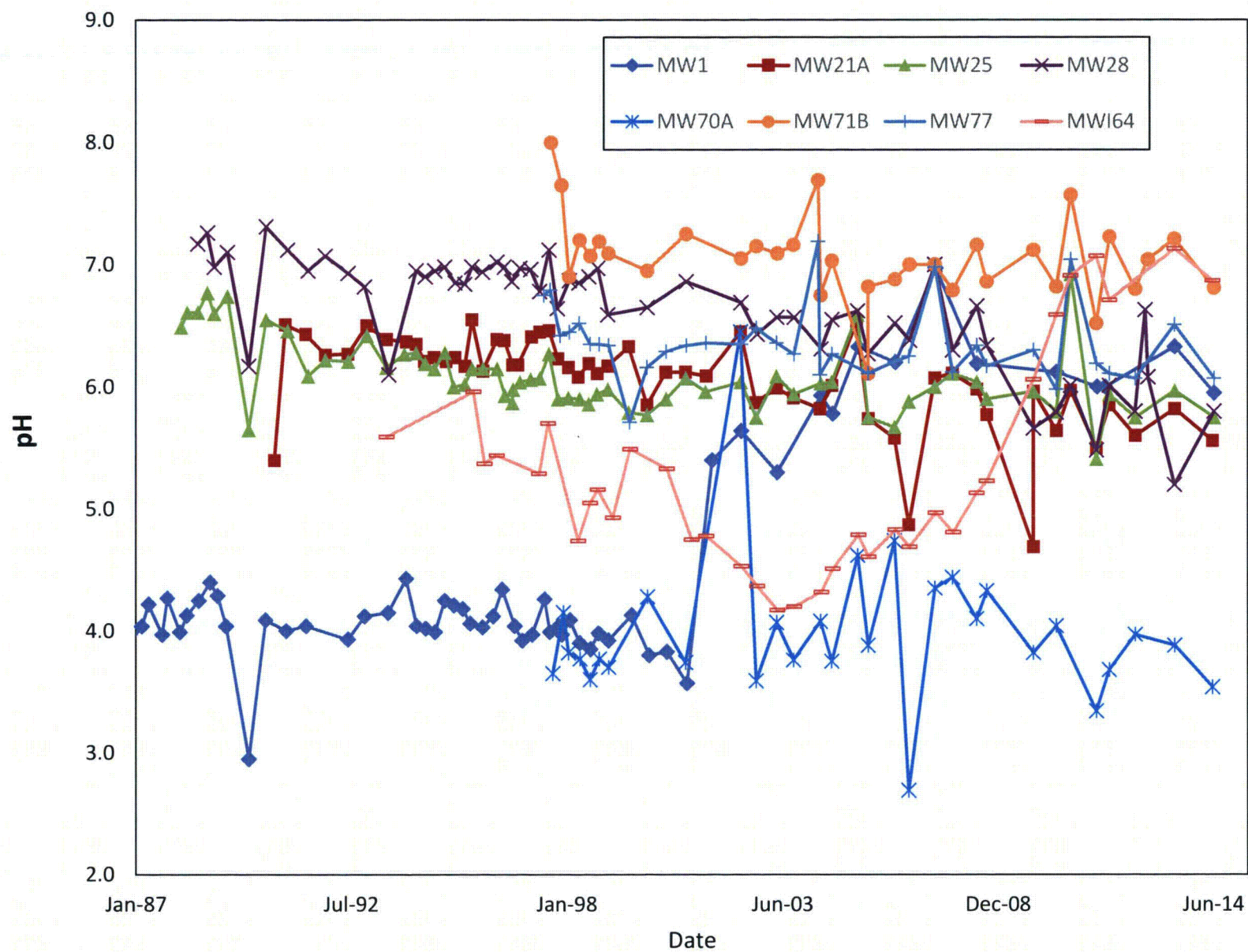


Figure 3-4 pH Trends in WFR Monitoring Wells.

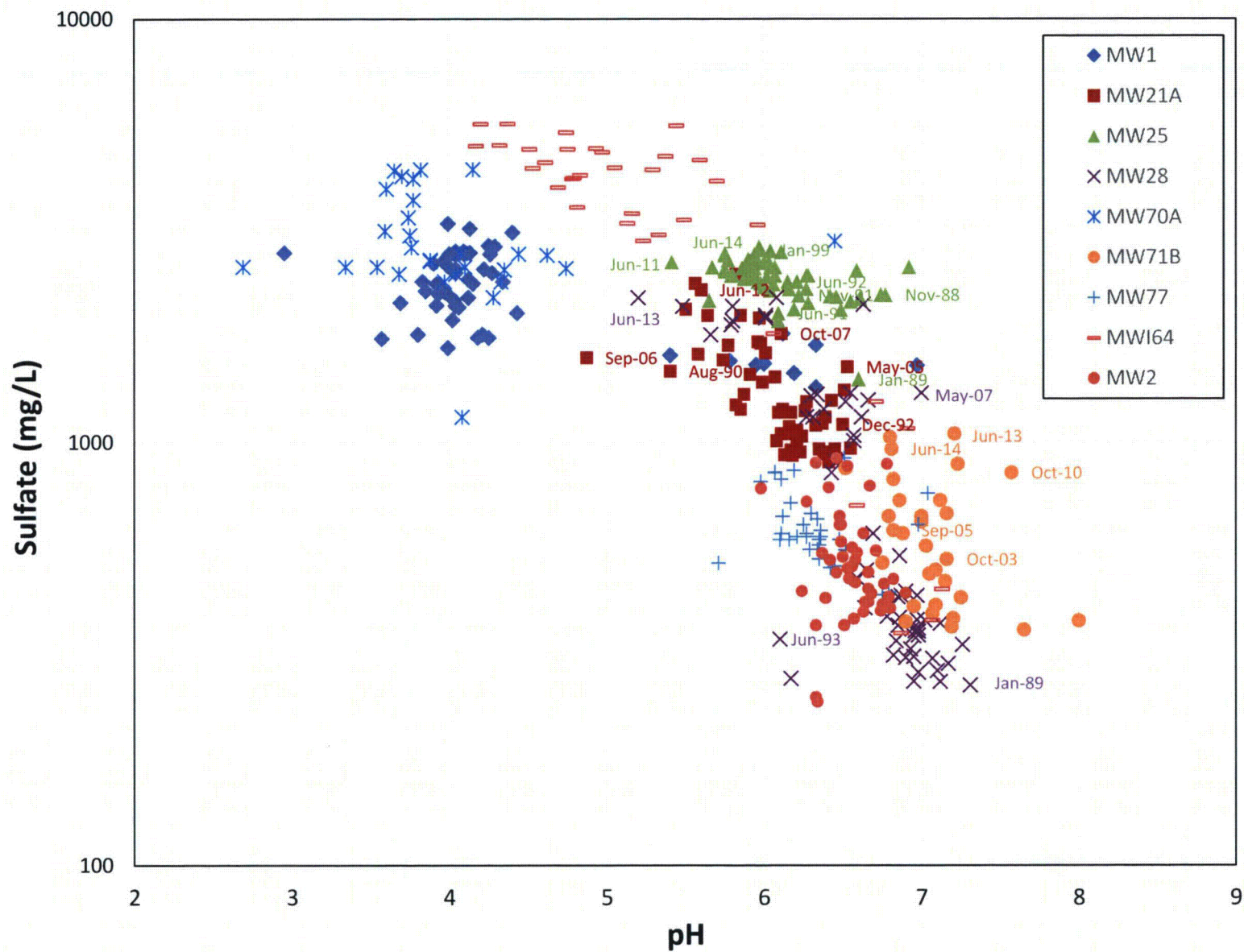


Figure 3-5 Relationship Between Sulfate and pH in WFR Monitoring Wells.

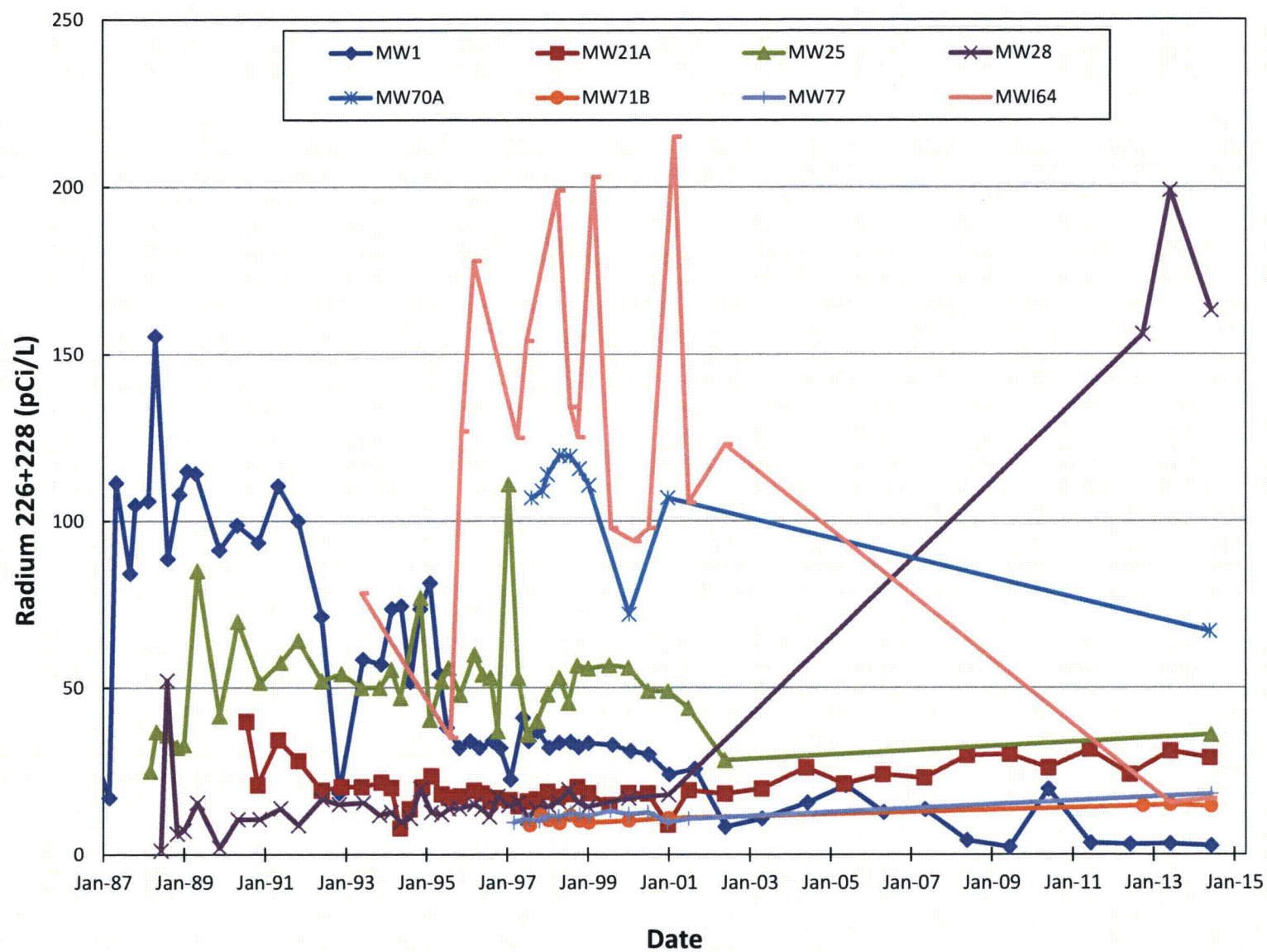


Figure 3-6 Radium226+228 in Gas Hills Monitoring Wells.

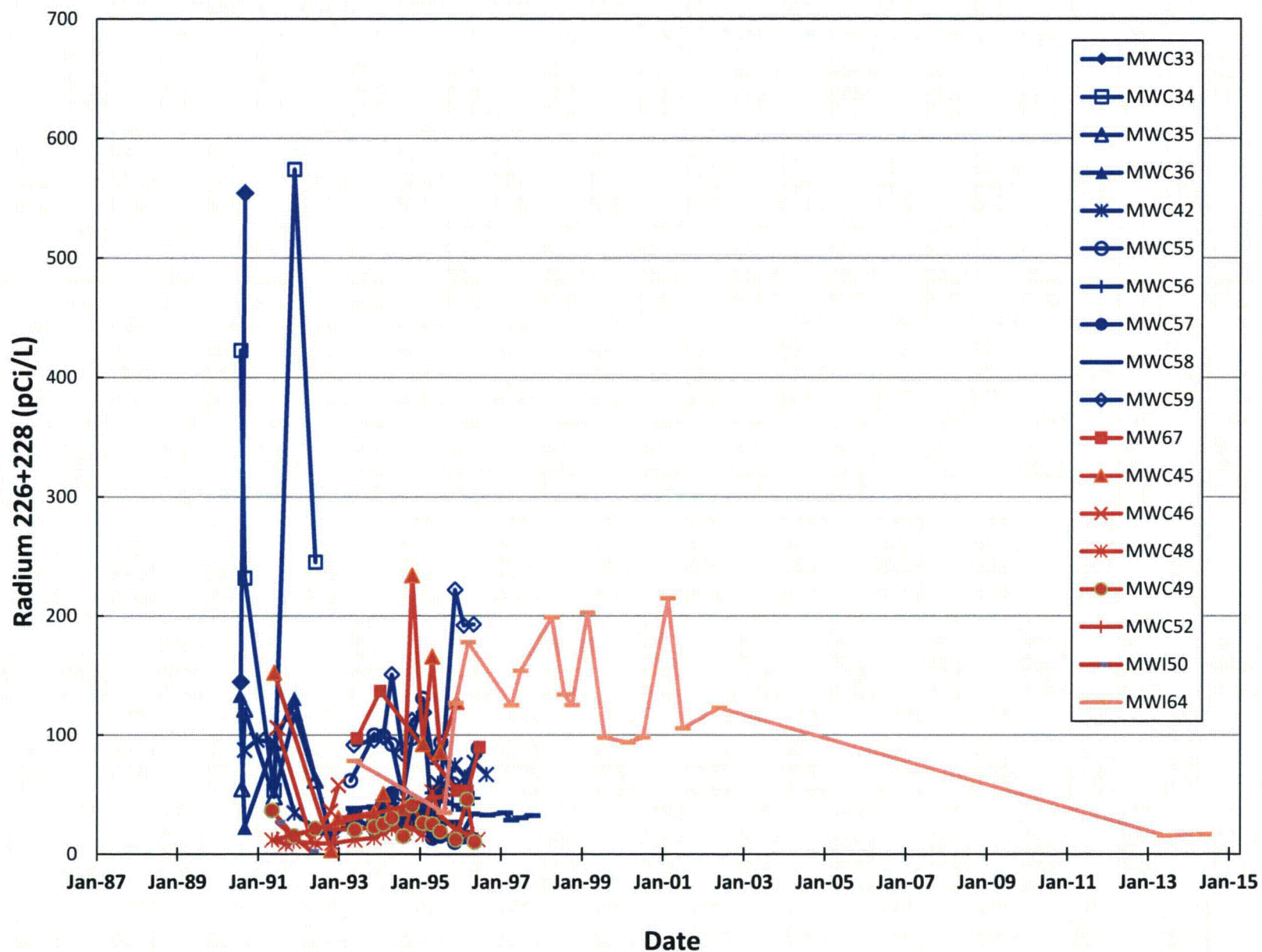


Figure 3-7 Radium226+228 in Gas Hills Monitoring Wells (wells shown in blue were used for groundwater extraction, wells shown in red are monitoring wells installed in the AGTI (average radium226+228 = 53 pCi/L).

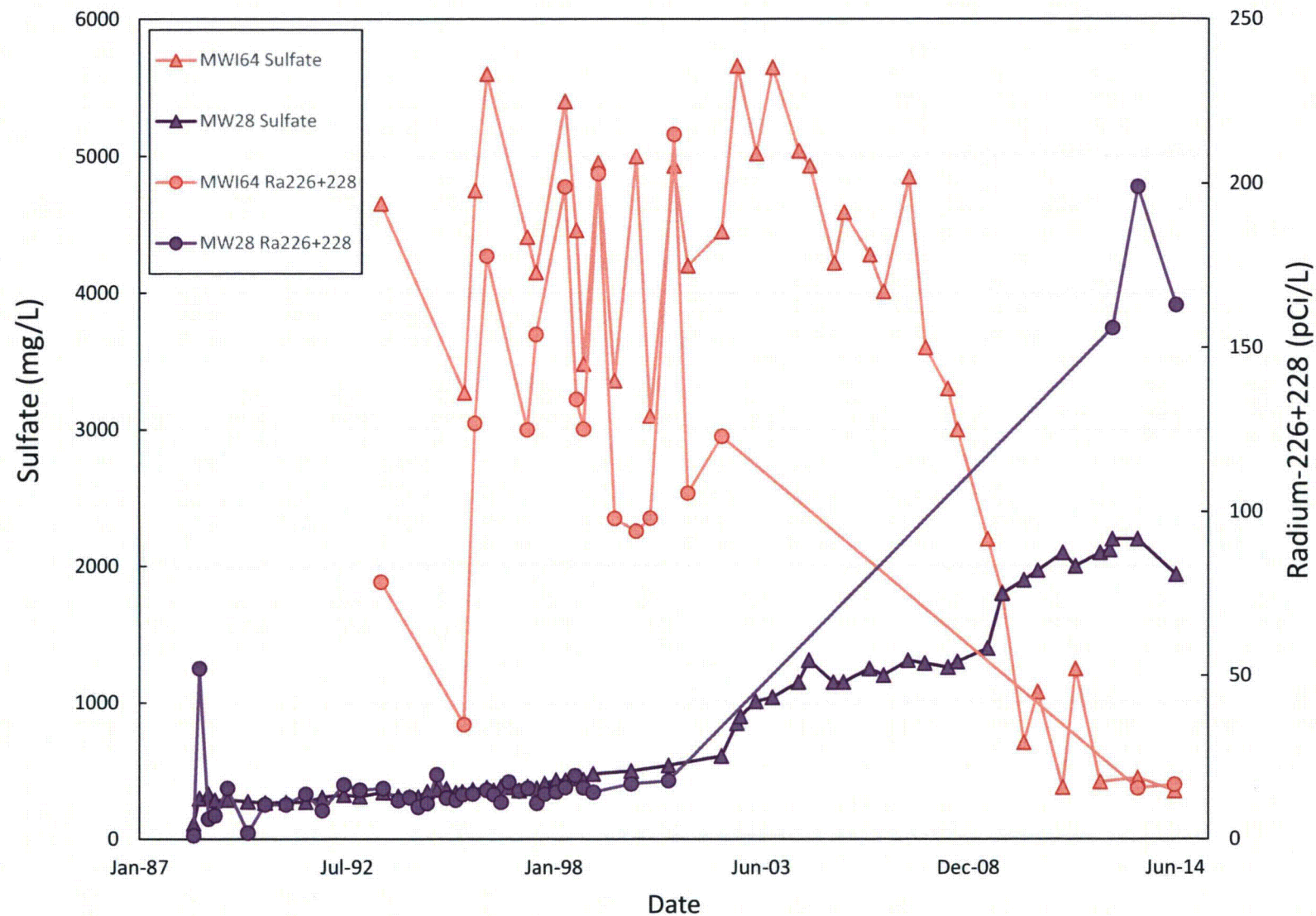


Figure 3-8 Radium226+228 and Sulfate Trends in Monitoring Wells MWI64 and MW28.

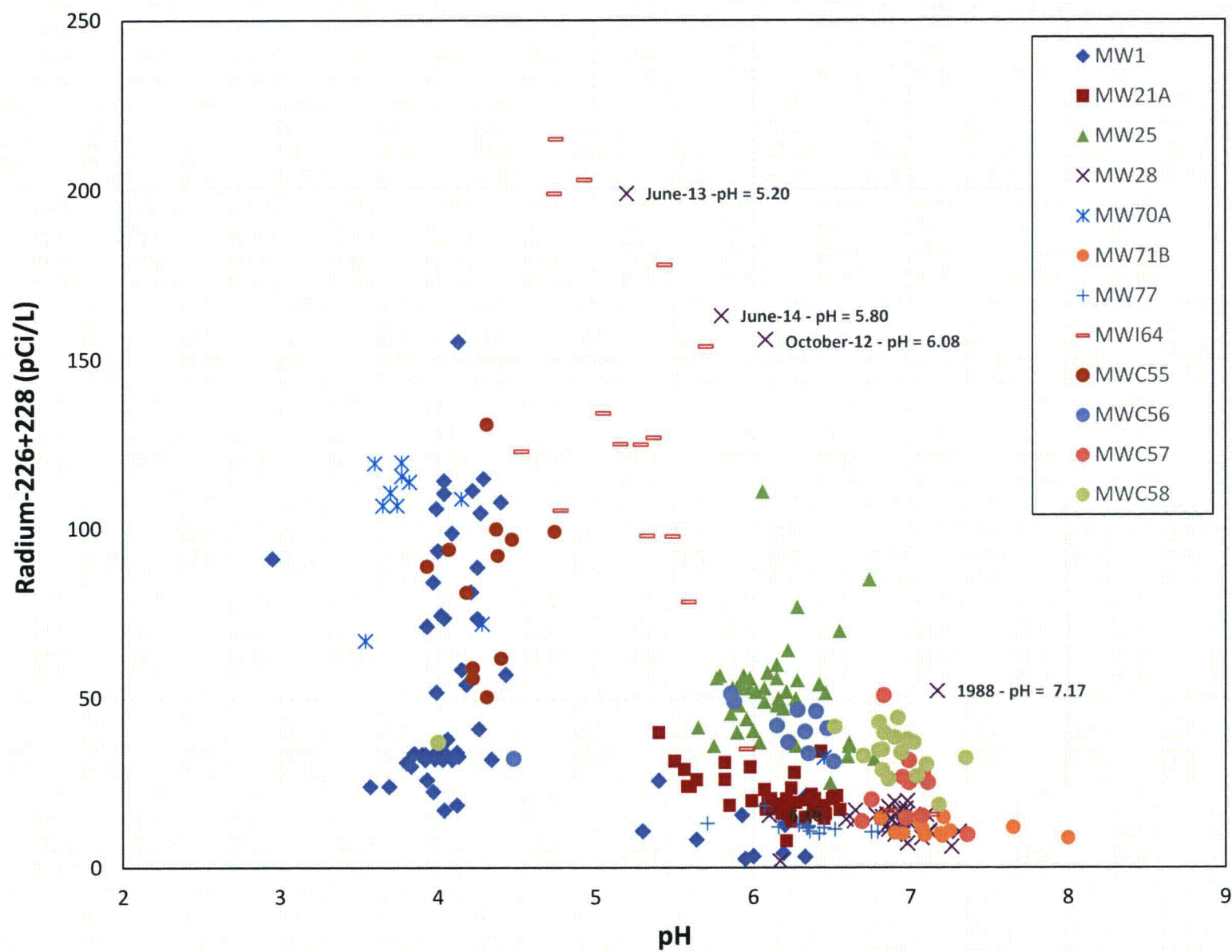
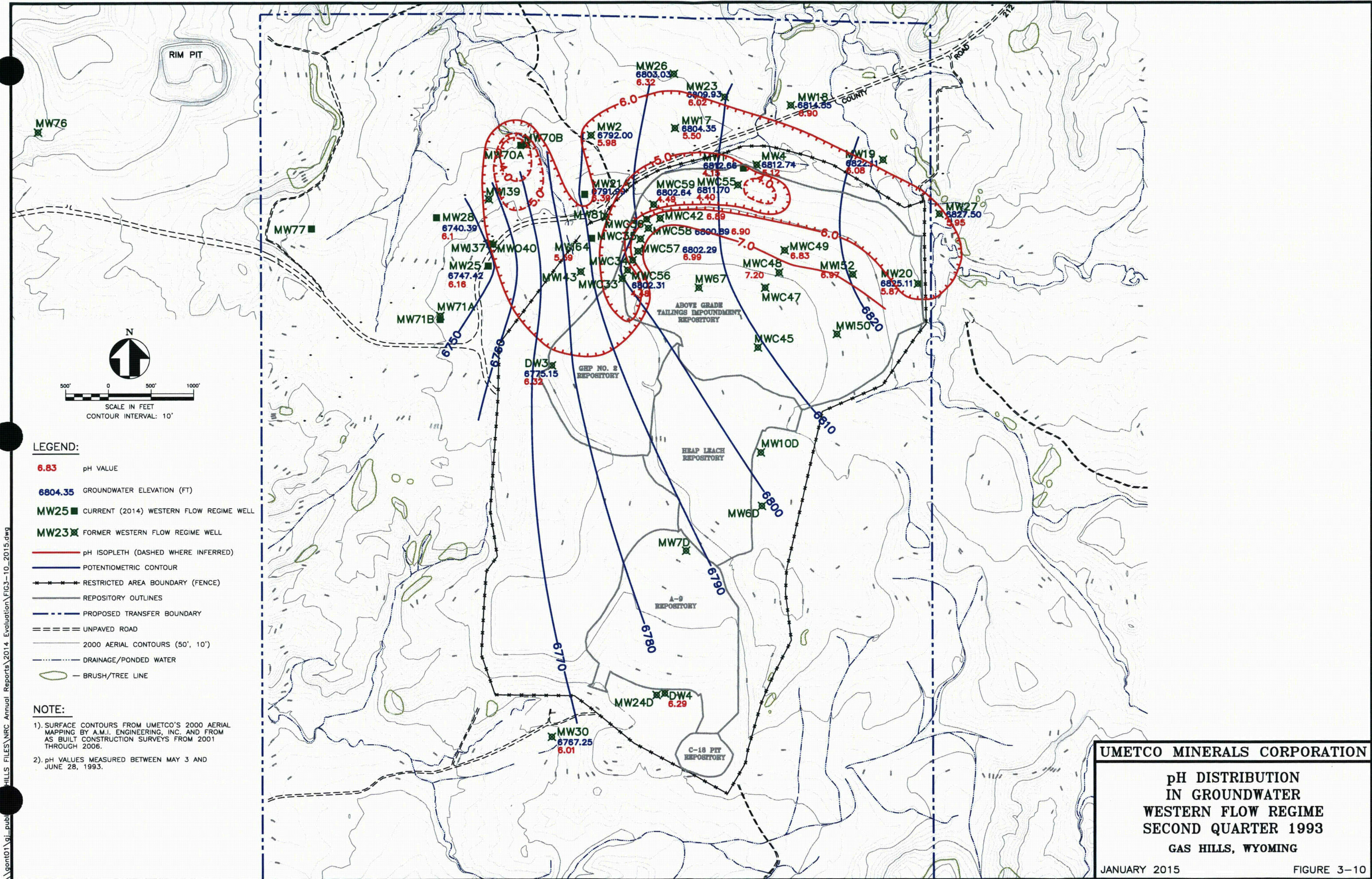
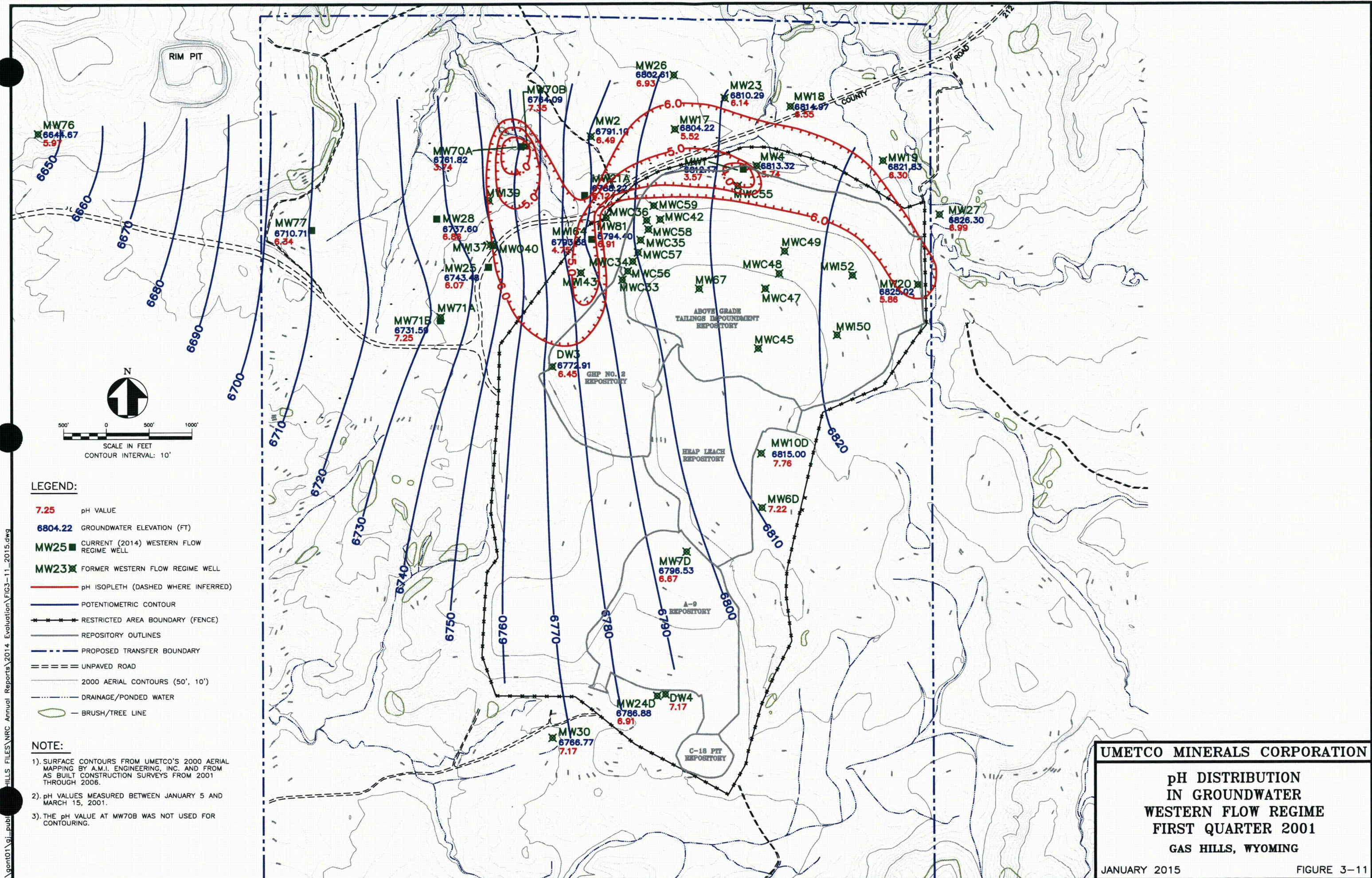


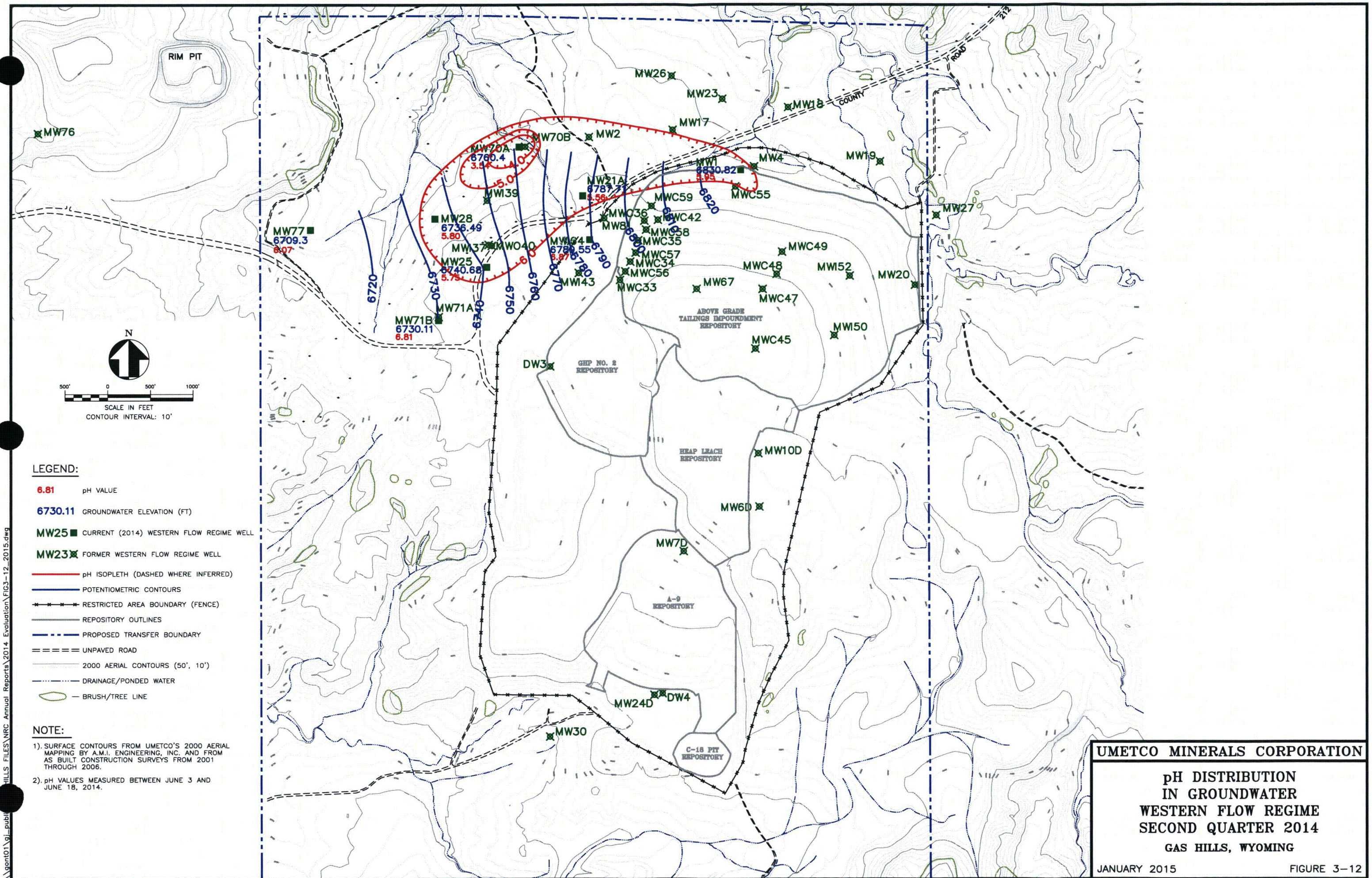
Figure 3-9 Radium226+228 vs. pH for Gas Hills Site Monitoring Wells.

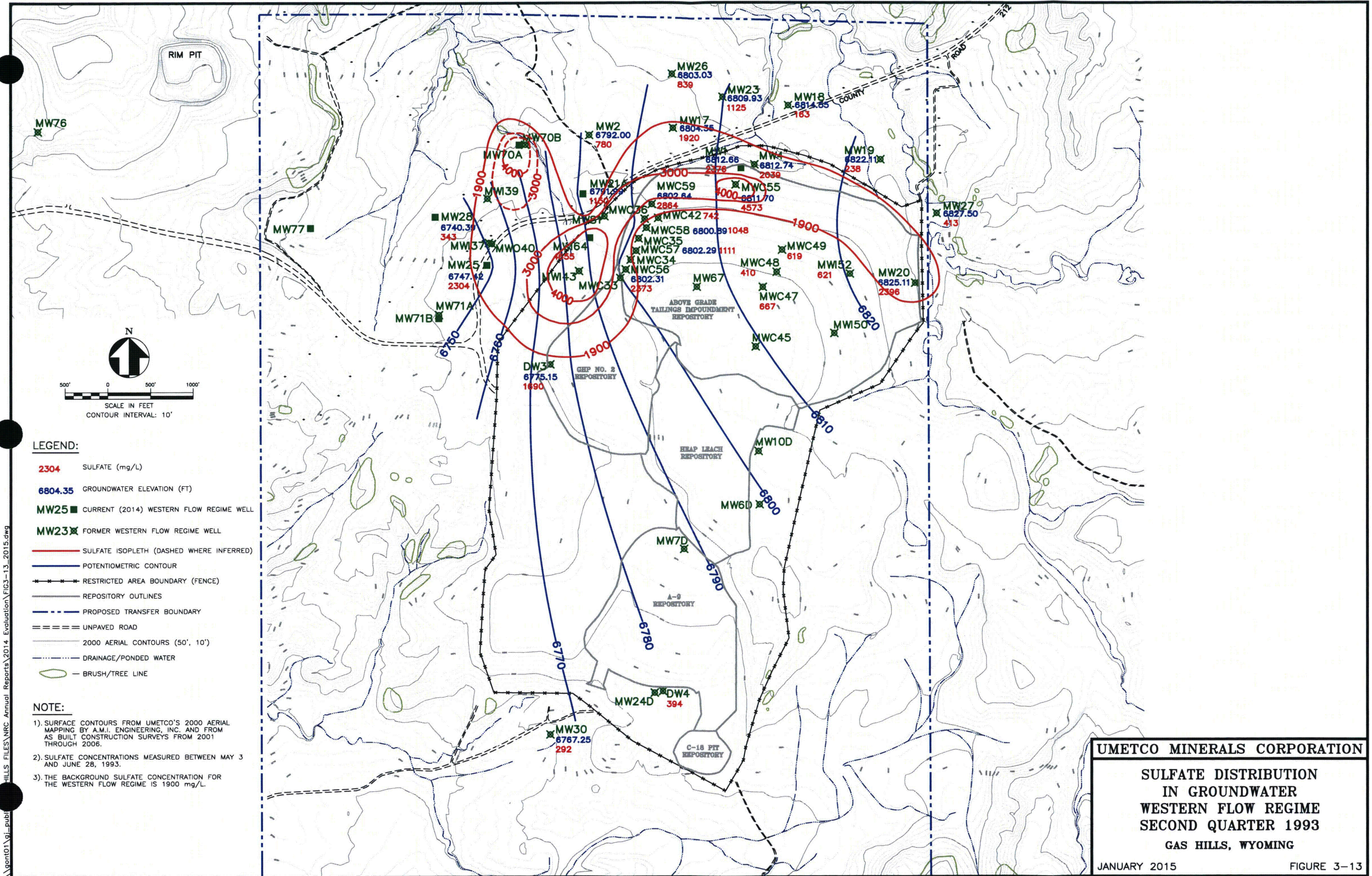


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\\goat01\gl_public\HILLS FILES\NRC Annual Reports\2014 Evaluation\FIG3-12_2015.dwg



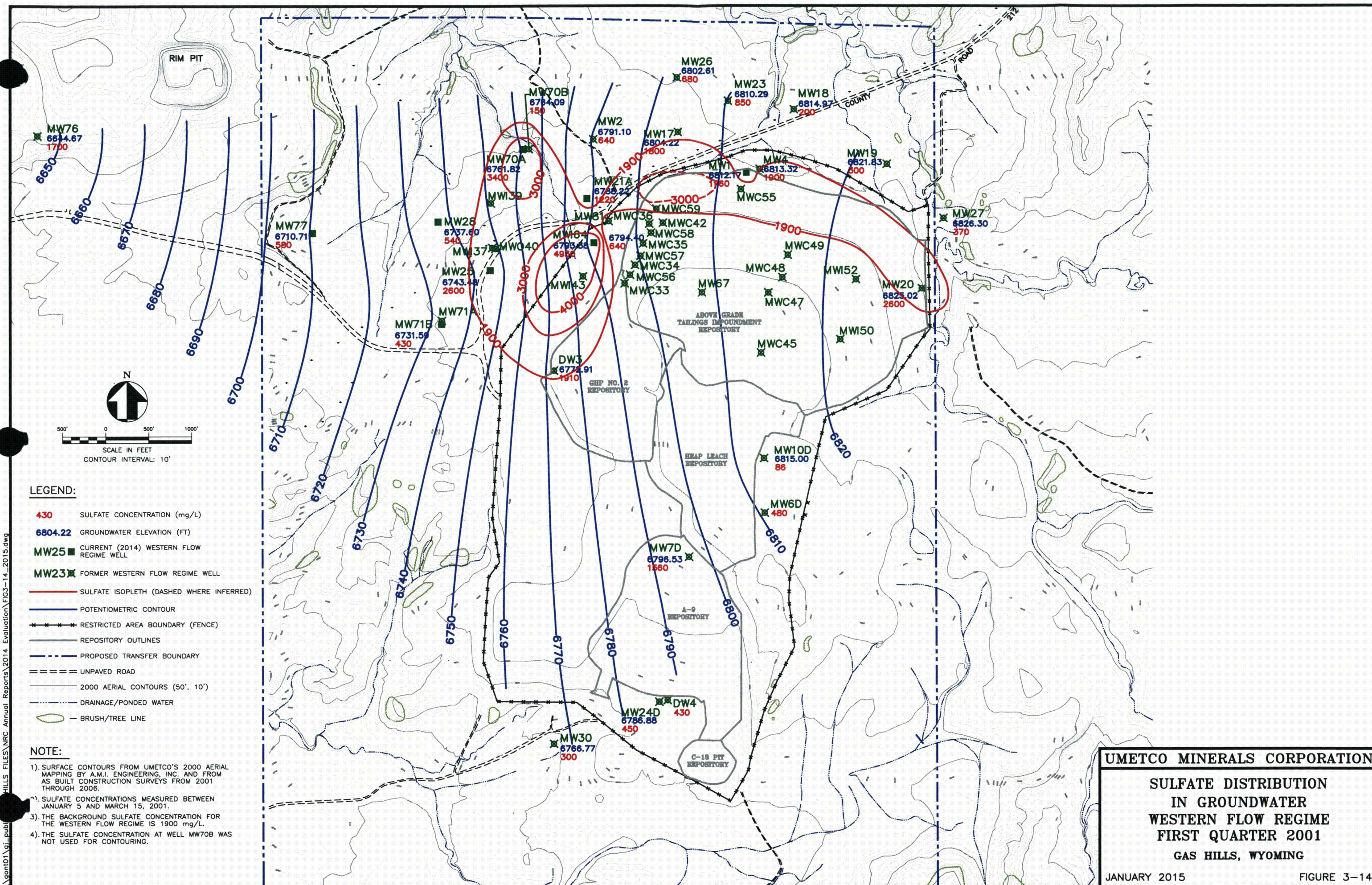


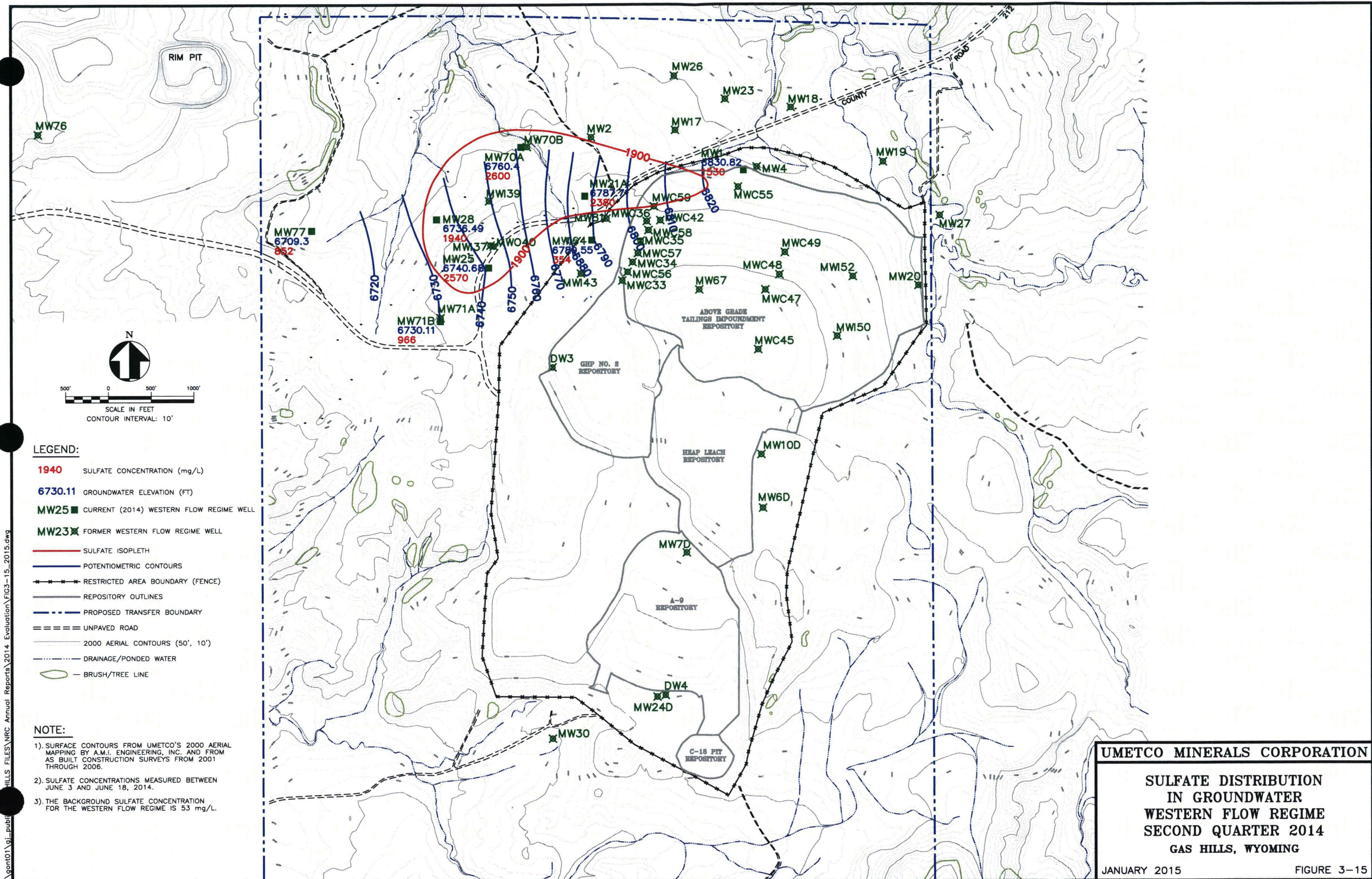
UMETCO MINERALS CORPORATION

**SULFATE DISTRIBUTION
IN GROUNDWATER
WESTERN FLOW REGIME
SECOND QUARTER 1993
GAS HILLS, WYOMING**

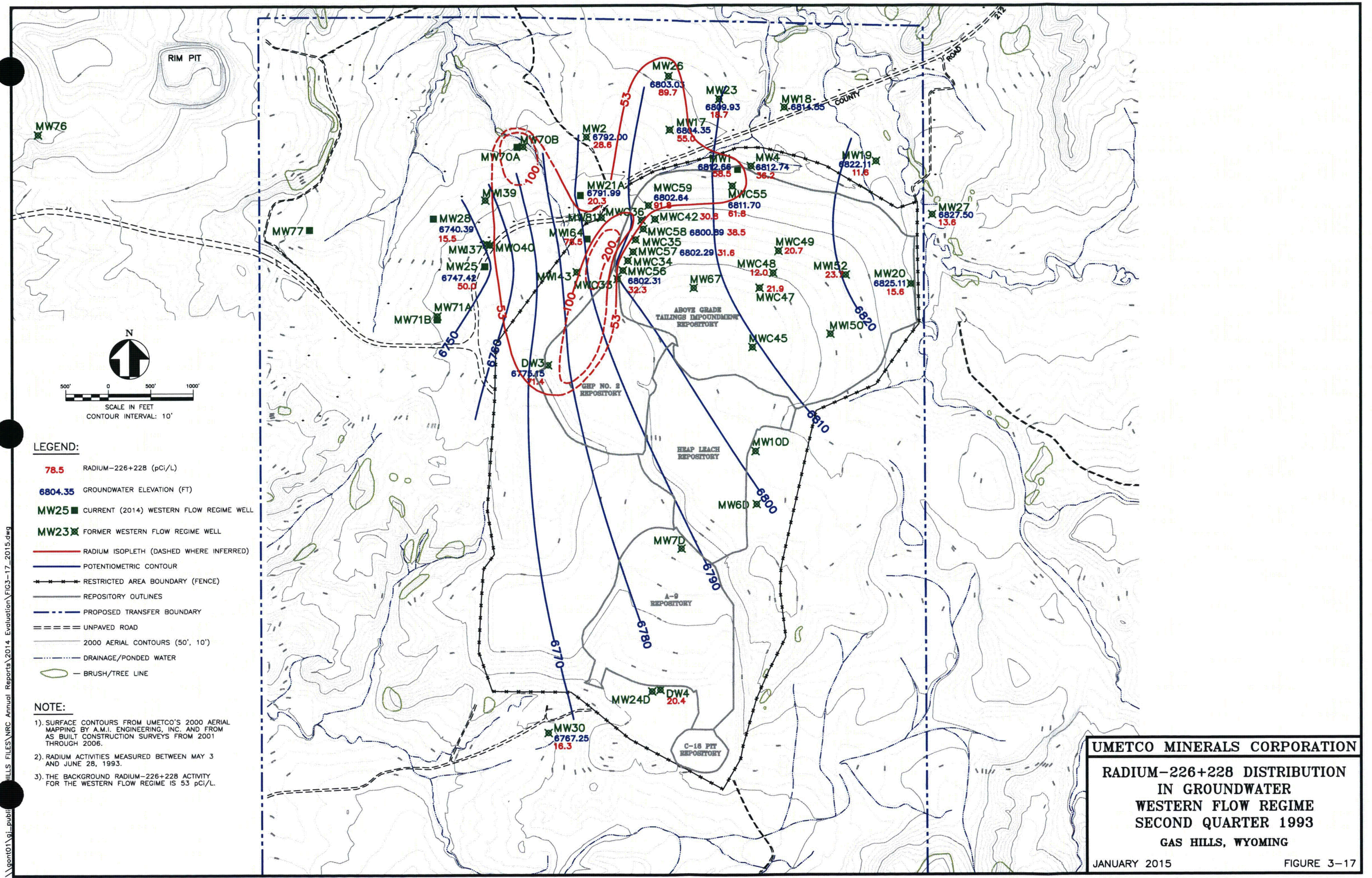
JANUARY 2015 FIGURE 3-13

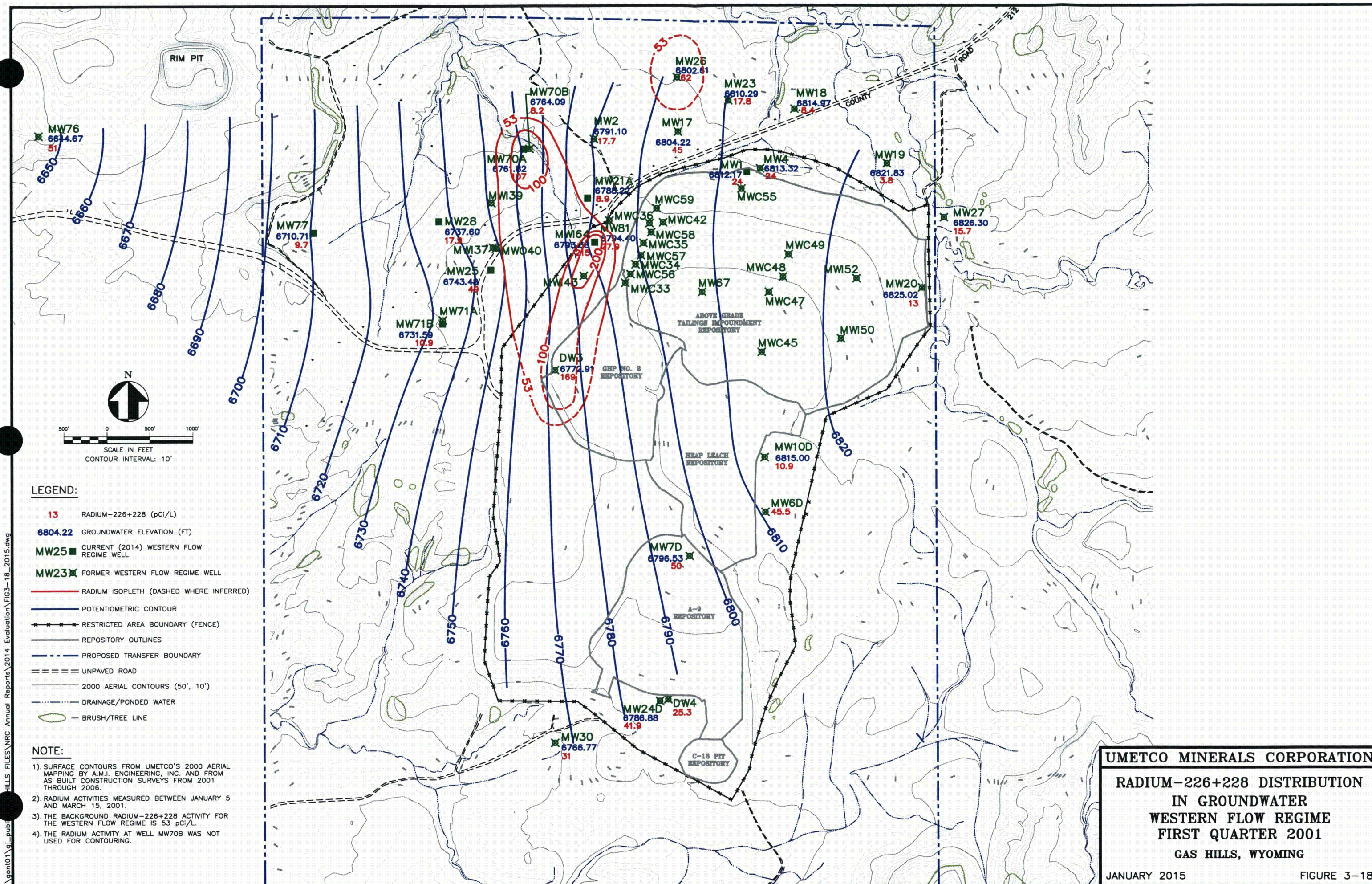
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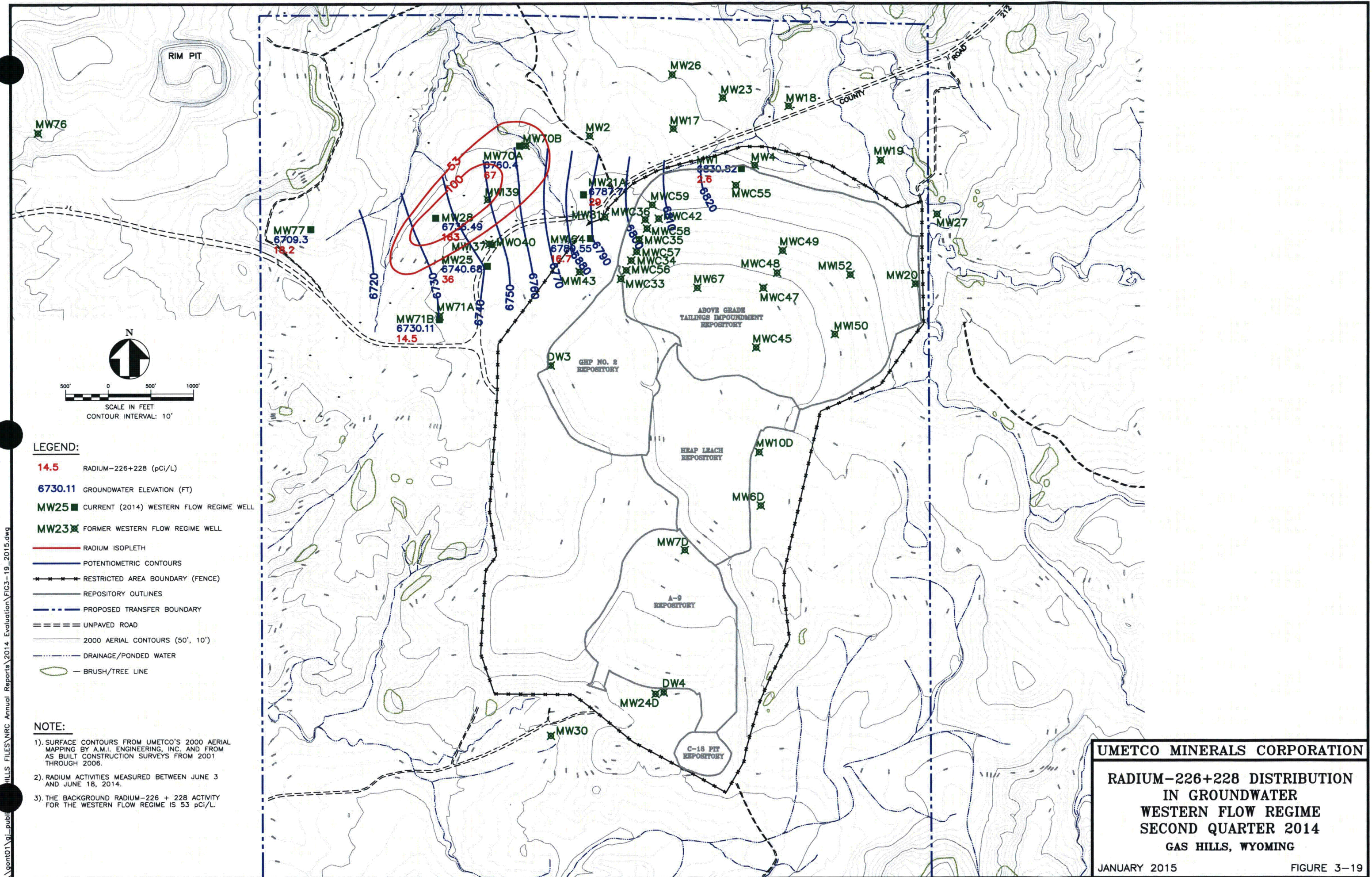




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LEGEND:

- 14.5 RADIUM-226+228 (pCi/L)
- 6730.11 GROUNDWATER ELEVATION (FT)
- MW25 ■ CURRENT (2014) WESTERN FLOW REGIME WELL
- MW23 ✕ FORMER WESTERN FLOW REGIME WELL
- RADIUM ISOPLETH
- POTENTIOMETRIC CONTOURS
- RESTRICTED AREA BOUNDARY (FENCE)
- REPOSITORY OUTLINES
- PROPOSED TRANSFER BOUNDARY
- == UNPAVED ROAD
- 2000 AERIAL CONTOURS (50', 10')
- DRAINAGE/PONDED WATER
- BRUSH/TREE LINE

NOTE:

- 1). SURFACE CONTOURS FROM UMETCO'S 2000 AERIAL MAPPING BY A.M.I. ENGINEERING, INC. AND FROM AS BUILT CONSTRUCTION SURVEYS FROM 2001 THROUGH 2006.
- 2). RADIUM ACTIVITIES MEASURED BETWEEN JUNE 3 AND JUNE 18, 2014.
- 3). THE BACKGROUND RADIUM-226 + 228 ACTIVITY FOR THE WESTERN FLOW REGIME IS 53 pCi/L.

UMETCO MINERALS CORPORATION

RADIUM-226+228 DISTRIBUTION
IN GROUNDWATER
WESTERN FLOW REGIME
SECOND QUARTER 2014
GAS HILLS, WYOMING

JANUARY 2015

FIGURE 3-19

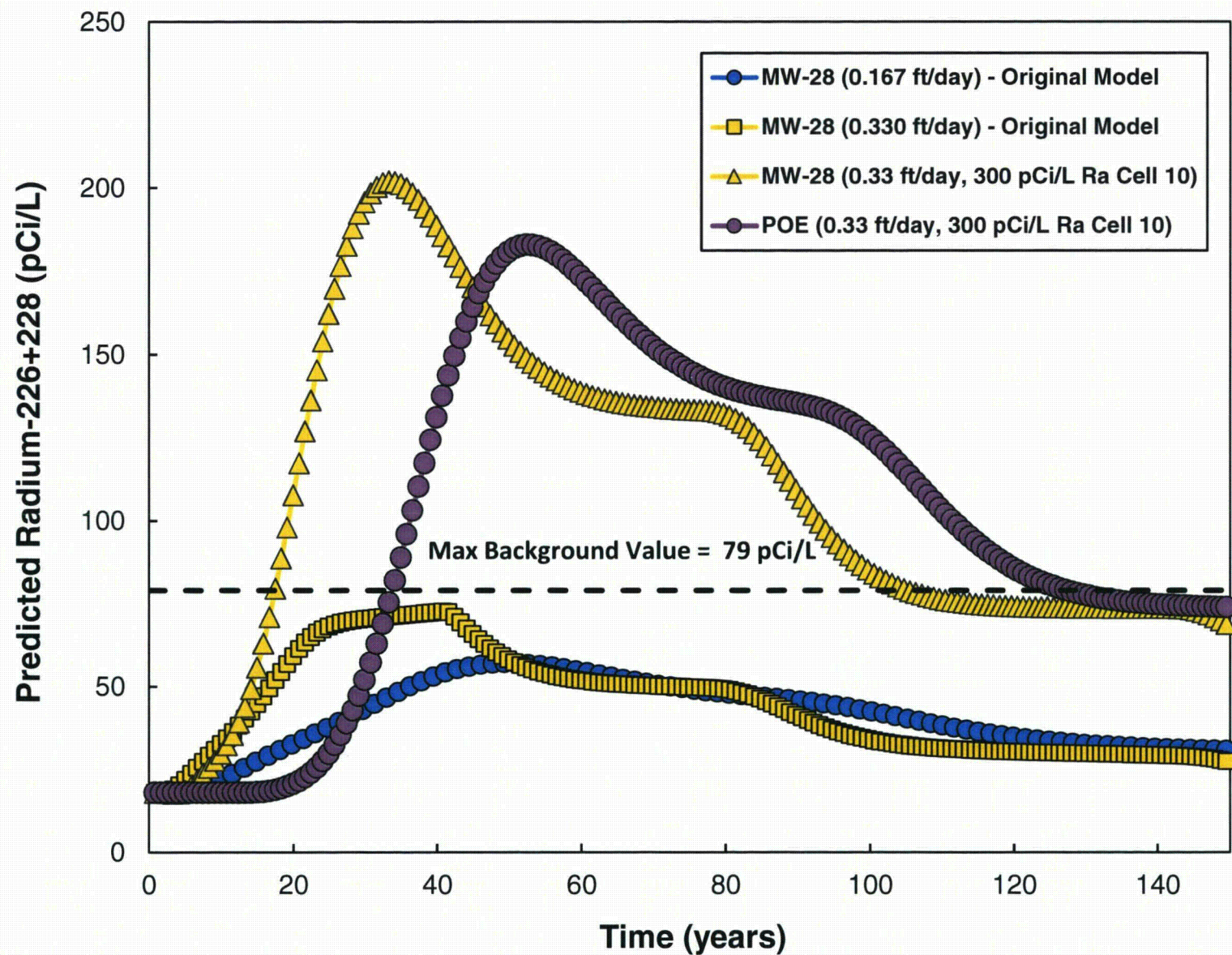


Figure 4-1 Revised Predictions for Radium226+228 at MW28 and the POE Compared to the Original Model.

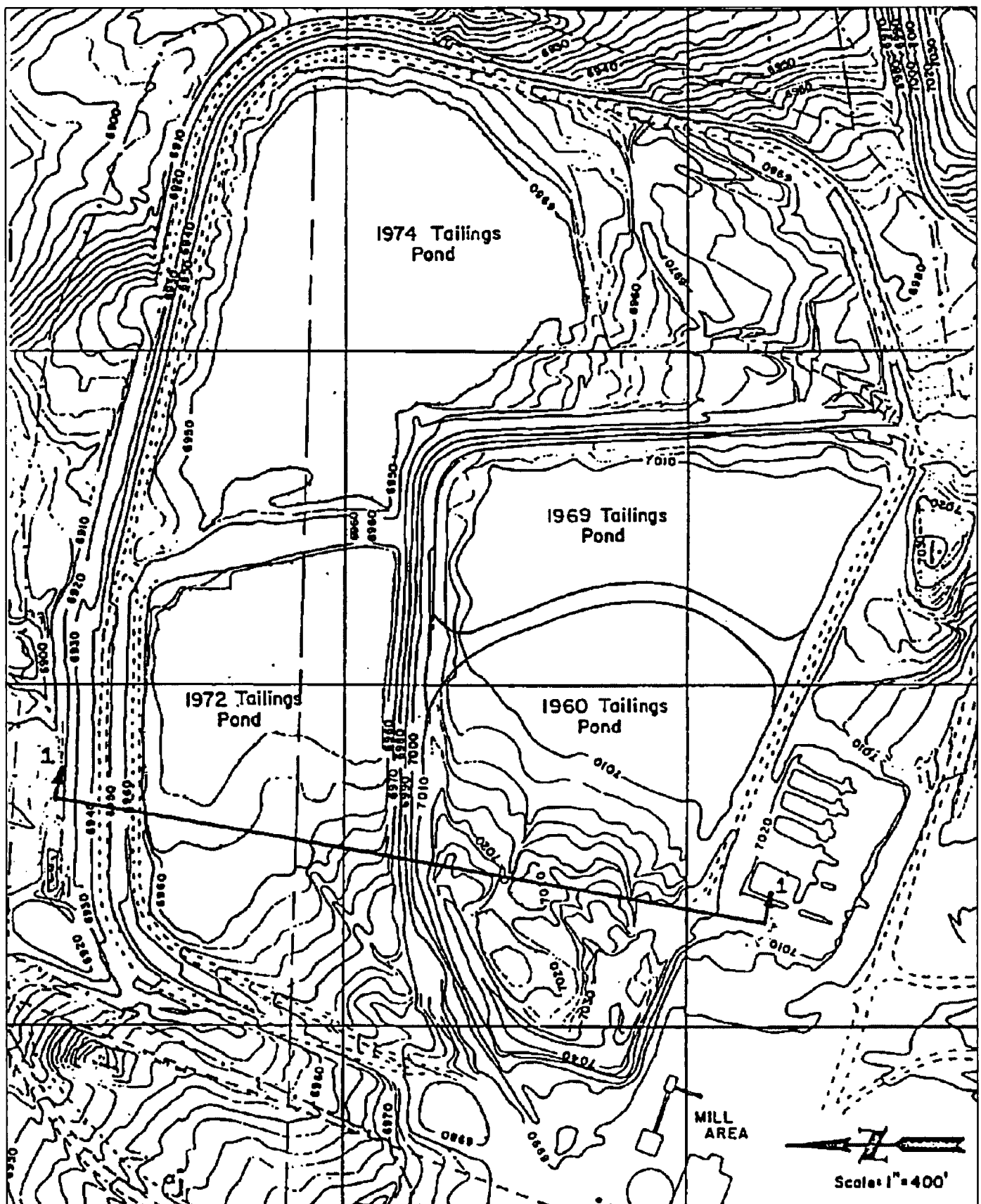
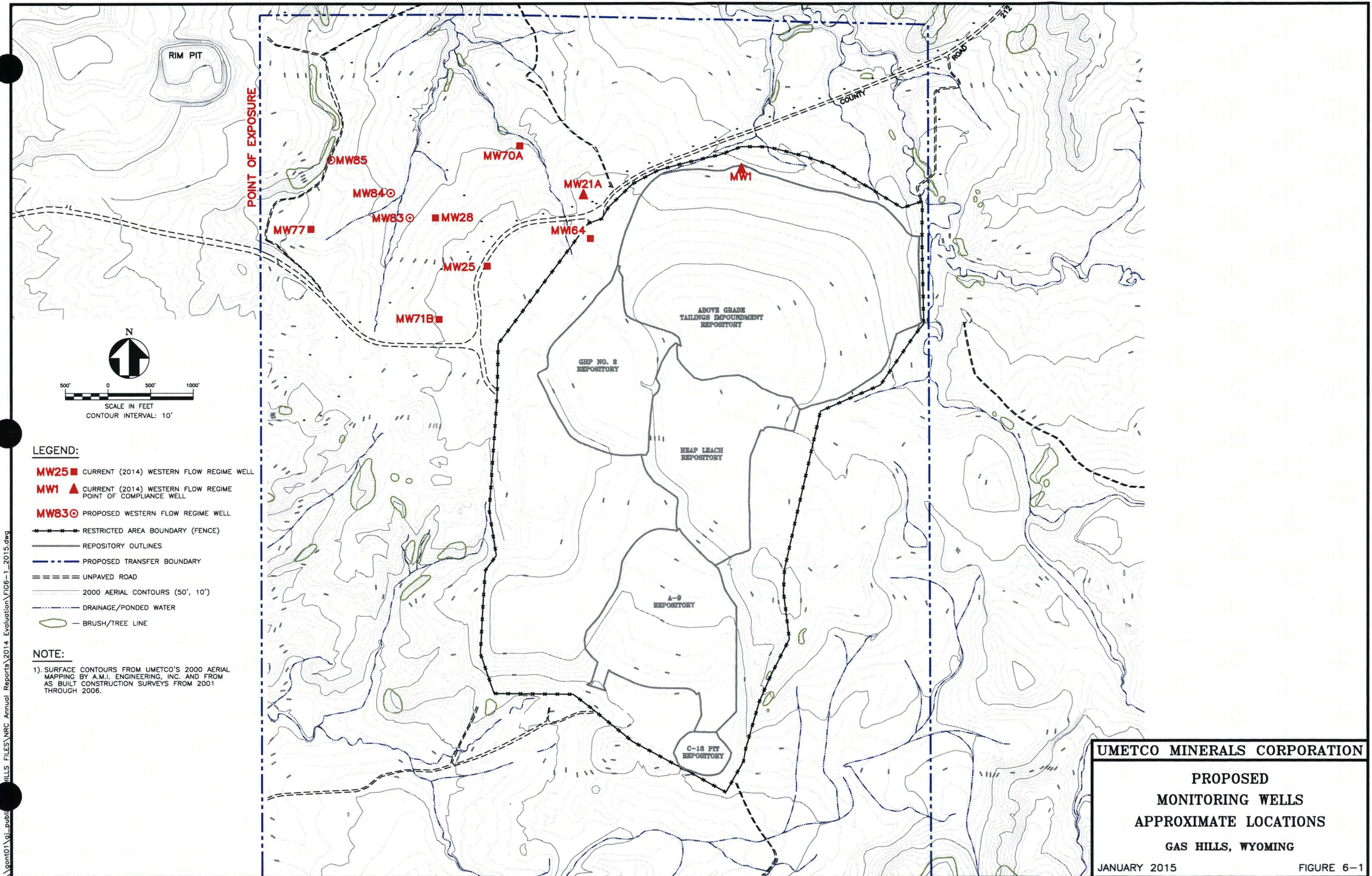


Figure 5-1 Historic AGTI Pond Locations.



ATTACHMENT A

MODIFIED PHREEQC FILES (ORIGINAL MODEL WITH OUTPUT AT MW28)

```
#TITLE  AGTI area (Western flow regime)
#FILE:  WFRltd_2014.pqi
#Concentration vs. Time at MW-28 (Cell No. 25)
#Using flow rate of 0.167 ft/d - Decreasing Source Term to 90% Reduction
#Dispersion = 50
```

KNOBS

```
-iterations 200
-tolerance 1.00E-13
-step_size 100
-pe_step_size 10
-diagonal_scale TRUE
-debug_prep FALSE
-debug_set FALSE
-debug_model FALSE
-debug_inverse FALSE
-logfile FALSE
```

PRINT

```
-reset      false
```

SELECTED_OUTPUT

```
-file  c:\output\wfrltd_2014.dat
```

USER_PUNCH

```
-headings As Be Cl Pb U Ni Se SO4 Th Ra sOPb+
-headings wOPb+ PbX2 Anglesite sOHUO2+2
-headings wOUO2+ USiO4(C) Uraninite sONi+ wONi+
-headings NiSe sOHra+2 wORa+ RaX2 RaSO4 wSeO4-
-headings wOHSeO4-2 wSeO3- wOHSeO3-2 Se(A)
-headings FeSe2 sSO4- wSO4- sOHSO4-2 wOHSO4-2
-headings gypsum wOTh+3 wOTh(OH)+2 wOTh(OH)2+
-headings wOTh(OH)3 wOTh(OH)4- sH2AsO3 wH2AsO3
-headings sH2AsO4 wH2AsO4 sHAsO4- wHAsO4- sAsO4-2
-headings wAsO4-2 sOHasO4-3 wOHasO4-3 sOBe+ wOBe+
-headings Calcite Ca Mg Na K HCO3 SO4 Cl TDS
-start
10  REM Convert to ppm and show molalities
20  PUNCH TOT("As")*74.9216*1000
30  PUNCH TOT("Be")*9.0122*1000
40  PUNCH TOT("Cl")*35.453*1000
50  PUNCH TOT("Pb")*207.19*1000/1.29e-11
60  PUNCH TOT("U")*238.029*1000
70  PUNCH TOT("Ni")*58.71*1000
80  PUNCH TOT("Se")*78.96*1000
90  PUNCH TOT("S(6)")*96.0616*1000
100 PUNCH TOT("Th")*232.038*1000/4.96e-8
110 PUNCH TOT("Ra")*226*1000/1.01e-9
120 PUNCH MOL("Hfo_sOPb+")
130 PUNCH MOL("Hfo_wOPb+")
140 PUNCH MOL("PbX2")
150 PUNCH EQUI("Anglesite")
160 PUNCH MOL("Hfo_sOHUO2+2")
170 PUNCH MOL("Hfo_wOUO2+")
```

```

180 PUNCH EQUI("USiO4(C)")
190 PUNCH EQUI("Uraninite")
200 PUNCH MOL("Hfo_sONi+")
210 PUNCH MOL("Hfo_wONi+")
220 PUNCH EQUI("NiSe")
230 PUNCH MOL("Hfo_sOHRa+2")
240 PUNCH MOL("Hfo_wORa+")
250 PUNCH MOL("RaX2")
260 PUNCH EQUI("RaSO4")
270 PUNCH MOL("Hfo_wSeO4-")
280 PUNCH MOL("Hfo_wOHSeO4-2")
290 PUNCH MOL("Hfo_wSeO3-")
300 PUNCH MOL("Hfo_wOHSeO3-2")
310 PUNCH EQUI("Se(A)")
320 PUNCH EQUI("Ferroselite")
330 PUNCH MOL("Hfo_sSO4-")
340 PUNCH MOL("Hfo_wSO4-")
350 PUNCH MOL("Hfo_sOHSO4-2")
360 PUNCH MOL("Hfo_wOHSO4-2")
370 PUNCH EQUI("gypsum")
380 PUNCH MOL("Hfo_wOTh+3")
390 PUNCH MOL("Hfo_wOTh(OH)+2")
400 PUNCH MOL("Hfo_wOTh(OH)2+")
410 PUNCH MOL("Hfo_wOTh(OH)3")
420 PUNCH MOL("Hfo_wOTh(OH)4-")
430 PUNCH MOL("Hfo_sH2AsO3")
440 PUNCH MOL("Hfo_wH2AsO3")
450 PUNCH MOL("Hfo_sH2AsO4")
460 PUNCH MOL("Hfo_wH2AsO4")
470 PUNCH MOL("Hfo_sHAsO4-")
480 PUNCH MOL("Hfo_wHAsO4-")
490 PUNCH MOL("Hfo_sAsO4-2")
500 PUNCH MOL("Hfo_wAsO4-2")
510 PUNCH MOL("Hfo_sOHAAsO4-3")
520 PUNCH MOL("Hfo_wOHAAsO4-3")
530 PUNCH MOL("Hfo_sOBe+")
540 PUNCH MOL("Hfo_wOBe+")
550 PUNCH EQUI("Calcite")
560 PUNCH TOT("Ca")*40.08*1000
570 PUNCH TOT("Mg")*24.312*1000
580 PUNCH TOT("Na")*22.9898*1000
590 PUNCH TOT("K")*39.102*1000
600 PUNCH MOL("HCO3-")*61.018*1000
610 PUNCH TOT("S(6)")*96.0616*1000
620 PUNCH TOT("Cl")*35.453*1000
630 A = (TOT("Ca")*40.08*1000)+(TOT("Mg")*24.312*1000)
640 B = (TOT("Na")*22.9898*1000)+(TOT("K")*39.102*1000)
650 C = MOL("HCO3-")*61.018*1000
660 D = TOT("S(6)")*96.0616*1000
670 E = TOT("Cl")*35.453*1000
680 PUNCH A+B+C+D+E
-end

```

SOLUTION 0 # SOURCE (ACL's) AGTI

```

pH          5.5
pe          6
units       mg/l

```

density	1
S(6)	3480 charge
Cl	274
Alkalinity	3.1 as HCO ₃
Ca	456
Na	182
Mg	112
K	24
As	1.8
Fe	86
Be	1.64
Ni	13.0
Se	0.16
Si	24
U	11.9
Th	2.85e-6
Pb	4.57e-10
Ra	2.48e-7

SOLUTION 1-15 #MW-21A January 2001

units	ppm
pe	5.8
pH	6.12
S(6)	1220
Cl	50
Alkalinity	2.4 as HCO ₃
Ca	272
Na	79.6
Mg	80.4
K	13.2
Fe	95
As	0.0463
Be	0.014
Th	9.92e-10
Pb	2.19e-11
Ra	8.99e-9
Ni	0.30
Se	0.002
U	0.00112

SOLUTION 16-46 #MW-28 January 2001

units	ppm
pe	3.9
pH	6.86
S(6)	540
Cl	7.5
Alkalinity	2.8 as HCO ₃
Ca	150
Na	82
Mg	29
K	9.6
Fe	14
As	0.012
Be	0.005 #1/2 DL

Th 5e-9 #this value estimated
Pb 1.55e-11
Ra 1.81e-8
Ni 0.062
Se 0.0025 #1/2 DL
U 0.0045

EQUILIBRIUM_PHASES 1-46

Calcite	0.0	0.0
Gypsum	0.0	0.0
Uraninite	0.0	0.0
USiO4(c)	0.0	0.0
Ferroselite	0.0	0.0
Se(A)	0.0	0.0
RaSO4	0.0	0.0
NiSe	0.0	0.0
Anglesite	0.0	0.0

SURFACE 1-15

-equilibrate 1
Hfo_wOH 0.086 600 45.9
Hfo_sOH 0.0021

SURFACE 16-46

-equilibrate 16
Hfo_wOH 0.086 600 45.9
Hfo_sOH 0.0021

EXCHANGE 1-15

-equilibrate 1
X 1.2

EXCHANGE 16-46

-equilibrate 16
X 1.2

TRANSPORT

-lengths 46*30.5
-dispersivities 46*50
-cells 46
-shifts 10
-punch_cells 25 #MW-28

PRINT

-selected_output true

END

PRINT

-selected_output false

SOLUTION 0 #33% REDUCTION

units ppm
pH 5.66
pe 3.9
Ca 360.2

Mg 80.40
Na 136.0
K 19
Cl 183.0
Alkalinity 3.14 as HCO3
S(6) 2434 charge
Fe 61.50
Th 1.89E-06
Pb 3.69E-10
Ra 1.70E-07
U 7.89
As 1.20
Se 0.11
Ni 8.64
Be 1.09
Si 15.90

TRANSPORT

-lengths 46*30.5
-dispersivities 46*50
-cells 46
-shifts 5
-punch_cells 25 #MW-28

PRINT

-selected_output true

END

PRINT

-selected_output false

SOLUTION 0 #50% Reduction

units ppm
pH 5.80
pe 3.6
Ca 314.1
Mg 65.30
Na 114.0
K 17
Cl 140.0
Alkalinity 3.16 as HCO3
S(6) 1933 charge
Fe 49.70
Th 1.43E-06
Pb 2.84E-10
Ra 1.33E-07
U 5.98
As 0.91
Se 0.08
Ni 6.56
Be 0.83
Si 12.10

TRANSPORT

-lengths 46*30.5

```
-dispersivities 46*50
-cells 46
-shifts 27
-punch_cells 25 #MW-28
```

```
PRINT
  -selected_output true
```

```
END
```

```
PRINT
  -selected_output false
```

```
SOLUTION 0 #75% Reduction
```

```
units ppm
pH 6.18
pe 3.0
Ca 242.1
Mg 41.60
Na 79.5
K 13
Cl 72.4
Alkalinity 3.18
S(6) 1152 charge
Fe 31.40
Th 7.20E-07
Pb 1.50E-10
Ra 7.42E-08
U 2.99
As 0.46
Se 0.04
Ni 3.30
Be 0.42
Si 6.03
```

```
TRANSPORT
  -lengths 46*30.5
  -dispersivities 46*50
  -cells 46
  -shifts 40
  -punch_cells 25 #MW-28
```

```
PRINT
  -selected_output true
```

```
END
```

```
PRINT
  -selected_output false
```

```
SOLUTION 0 #90% Reduction
```

```
units ppm
pH 6.57
pe 2.2
Ca 198.9
```

Mg 27.50
Na 58.8
K 11
Cl 31.8
Alkalinity 3.19 as HCO3
S(6) 682.8 charge
Fe 20.40
Th 2.92E-07
Pb 7.02E-11
Ra 3.92E-08
U 1.20
As 0.19
Se 0.02
Ni 1.35
Be 0.17
Si 2.41

TRANSPORT
-lengths 46*30.5
-dispersivities 46*50
-cells 46
-shifts 527
-punch_cells 25 # (MW-28)

PRINT
-selected_output true

END

PRINT
-selected_output false


```
#TITLE  AGTI area (Western flow regime)
#FILE:  WFR2td_2014.pqi
#Concentration vs Time at MW-28 (Cell No. 25)
#Using flow rate of 0.330 ft/d - Decreasing Source Term to 90% Reduction
#Dispersivities  = 50
```

KNOBS

```
-iterations 200
-tolerance 1.00E-13
-step_size 100
-pe_step_size 10
-diagonal_scale TRUE
-debug_prep FALSE
-debug_set FALSE
-debug_model FALSE
-debug_inverse FALSE
-logfile FALSE
```

PRINT

```
-reset      false
```

SELECTED_OUTPUT

```
-file c:\output\WFR2td_2014.dat
```

USER_PUNCH

```
-headings As Be Cl Pb U Ni Se SO4 Th Ra sOPb+
-headings wOPb+ PbX2 Anglesite sOHUO2+2
-headings wOUO2+ USiO4(C) Uraninite sONi+ wONi+
-headings NiSe sOHRa+2 wORa+ RaX2 RaSO4 wSeO4-
-headings wOHSeO4-2 wSeO3- wOHSeO3-2 Se(A)
-headings FeSe2 sSO4- wSO4- sOHSO4-2 wOHSO4-2
-headings gypsum wOTh+3 wOTh(OH)+2 wOTh(OH)2+
-headings wOTh(OH)3 wOTh(OH)4- sH2AsO3 wH2AsO3
-headings sH2AsO4 wH2AsO4 sHAsO4- wHAsO4- sAsO4-2
-headings wAsO4-2 sOHasO4-3 wOHasO4-3 sOBe+ wOBe+
-headings Calcite Ca Mg Na K HCO3 SO4 Cl TDS
-start
10  REM Convert to ppm and show molalities
20  PUNCH TOT("As")*74.9216*1000
30  PUNCH TOT("Be")*9.0122*1000
40  PUNCH TOT("Cl")*35.453*1000
50  PUNCH TOT("Pb")*207.19*1000/1.29e-11
60  PUNCH TOT("U")*238.029*1000
70  PUNCH TOT("Ni")*58.71*1000
80  PUNCH TOT("Se")*78.96*1000
90  PUNCH TOT("S(6)")*96.0616*1000
100 PUNCH TOT("Th")*232.038*1000/4.96e-8
110 PUNCH TOT("Ra")*226*1000/1.01e-9
120 PUNCH MOL("Hfo_sOPb+")
130 PUNCH MOL("Hfo_wOPb+")
140 PUNCH MOL("PbX2")
150 PUNCH EQUI("Anglesite")
160 PUNCH MOL("Hfo_sOHUO2+2")
170 PUNCH MOL("Hfo_wOUO2+")
180 PUNCH EQUI("USiO4(C)")
```

```

190 PUNCH EQUI("Uraninite")
200 PUNCH MOL("Hfo_sONi+")
210 PUNCH MOL("Hfo_wONi+")
220 PUNCH EQUI("NiSe")
230 PUNCH MOL("Hfo_sOHRa+2")
240 PUNCH MOL("Hfo_wORa+")
250 PUNCH MOL("RaX2")
260 PUNCH EQUI("RaSO4")
270 PUNCH MOL("Hfo_wSeO4-")
280 PUNCH MOL("Hfo_wOHSeO4-2")
290 PUNCH MOL("Hfo_wSeO3-")
300 PUNCH MOL("Hfo_wOHSeO3-2")
310 PUNCH EQUI("Se(A)")
320 PUNCH EQUI("Ferroselite")
330 PUNCH MOL("Hfo_sSO4-")
340 PUNCH MOL("Hfo_wSO4-")
350 PUNCH MOL("Hfo_sOHSO4-2")
360 PUNCH MOL("Hfo_wOHSO4-2")
370 PUNCH EQUI("gypsum")
380 PUNCH MOL("Hfo_wOTh+3")
390 PUNCH MOL("Hfo_wOTh(OH)+2")
400 PUNCH MOL("Hfo_wOTh(OH)2+")
410 PUNCH MOL("Hfo_wOTh(OH)3")
420 PUNCH MOL("Hfo_wOTh(OH)4-")
430 PUNCH MOL("Hfo_sH2AsO3")
440 PUNCH MOL("Hfo_wH2AsO3")
450 PUNCH MOL("Hfo_sH2AsO4")
460 PUNCH MOL("Hfo_wH2AsO4")
470 PUNCH MOL("Hfo_sHAsO4-")
480 PUNCH MOL("Hfo_wHAsO4-")
490 PUNCH MOL("Hfo_sAsO4-2")
500 PUNCH MOL("Hfo_wAsO4-2")
510 PUNCH MOL("Hfo_sOHAsO4-3")
520 PUNCH MOL("Hfo_wOHAsO4-3")
530 PUNCH MOL("Hfo_sOBe+")
540 PUNCH MOL("Hfo_wOBe+")
550 PUNCH EQUI("Calcite")
560 PUNCH TOT("Ca")*40.08*1000
570 PUNCH TOT("Mg")*24.312*1000
580 PUNCH TOT("Na")*22.9898*1000
590 PUNCH TOT("K")*39.102*1000
600 PUNCH MOL("HCO3-")*61.018*1000
610 PUNCH TOT("S(6)")*96.0616*1000
620 PUNCH TOT("Cl")*35.453*1000
630 A = (TOT("Ca")*40.08*1000)+(TOT("Mg")*24.312*1000)
640 B = (TOT("Na")*22.9898*1000)+(TOT("K")*39.102*1000)
650 C = MOL("HCO3-")*61.018*1000
660 D = TOT("S(6)")*96.0616*1000
670 E = TOT("Cl")*35.453*1000
680 PUNCH A+B+C+D+E
-end

```

SOLUTION 0 # SOURCE (ACL's) AGTI

```

pH          5.5
pe          6
units       mg/l
density     1

```

S(6)	3480
Cl	274
Alkalinity	3.1 as HCO3
Ca	456
Na	182
Mg	112
K	24
As	1.8
Fe	86
Be	1.64
Ni	13.0
Se	0.16
Si	24
U	11.9
Th	2.85e-6
Pb	4.57e-10
Ra	2.48e-7

SOLUTION 1-15 #MW-21A January 2001

units	ppm
pe	5.8
pH	6.12
S(6)	1220
Cl	50
Alkalinity	2.4 as HCO3
Ca	272
Na	79.6
Mg	80.4
K	13.2
Fe	95
As	0.0463
Be	0.014
Th	9.92e-10
Pb	2.19e-11
Ra	8.99e-9
Ni	0.30
Se	0.002
U	0.00112

SOLUTION 16-46 #MW-28 January 2001

units	ppm
pe	3.9
pH	6.86
S(6)	540
Cl	7.5
Alkalinity	2.8 as HCO3
Ca	150
Na	82
Mg	29
K	9.6
Fe	14
As	0.012
Be	0.005 #1/2 DL
Th	5e-9 #this value estimated

Pb	1.55e-11		
Ra	1.81e-8		
Ni	0.062		
Se	0.0025	#1/2 DL	
U	0.0045		

EQUILIBRIUM_PHASES 1-46

Calcite	0.0	0.0
Gypsum	0.0	0.0
Uraninite	0.0	0.0
USiO4(c)	0.0	0.0
Ferroselite	0.0	0.0
Se(A)	0.0	0.0
RaSO4	0.0	0.0
NiSe	0.0	0.0
Anglesite	0.0	0.0

SURFACE 1-15

-equilibrate 1			
Hfo_wOH	0.086	600	45.9
Hfo_sOH	0.0021		

SURFACE 16-46

-equilibrate 16			
Hfo_wOH	0.086	600	45.9
Hfo_sOH	0.0021		

EXCHANGE 1-15

-equilibrate 1	
X	1.2

EXCHANGE 16-46

-equilibrate 16	
X	1.2

TRANSPORT

-lengths	46*30.5
-dispersivities	46*50
-cells	46
-shifts	20
-punch_cells	25 #MW-28

PRINT

-selected_output	true
------------------	------

END

PRINT

-selected_output	false
------------------	-------

SOLUTION 0 #33% REDUCTION

units	ppm
pH	5.66
pe	3.9
Ca	360.2
Mg	80.40

Na 136.0
K 19
Cl 183.0
Alkalinity 3.14 as HCO3
S(6) 2434
Fe 61.50
Th 1.89E-06
Pb 3.69E-10
Ra 1.70E-07
U 7.89
As 1.20
Se 0.11
Ni 8.64
Be 1.09
Si 15.90

TRANSPORT

-lengths 46*30.5
-dispersivities 46*50
-cells 46
-shifts 10
-punch_cells 25 #MW-28

PRINT

-selected_output true

END

PRINT

-selected_output false

SOLUTION 0 #50% Reduction

units ppm
pH 5.80
pe 3.6
Ca 314.1
Mg 65.30
Na 114.0
K 17
Cl 140.0
Alkalinity 3.16 as HCO3
S(6) 1933
Fe 49.70
Th 1.43E-06
Pb 2.84E-10
Ra 1.33E-07
U 5.98
As 0.91
Se 0.08
Ni 6.56
Be 0.83
Si 12.10

TRANSPORT

-lengths 46*30.5
-dispersivities 46*50

```
-cells          46
-shifts         54
-punch_cells    25 #MW-28
```

```
PRINT
  -selected_output  true
```

```
END
```

```
PRINT
  -selected_output  false
```

```
SOLUTION 0 #75% Reduction
```

```
units ppm
pH      6.18
pe       3.0
Ca     242.1
Mg     41.60
Na      79.5
K       13
Cl     72.4
Alkalinity  3.18
S(6)   1152
Fe     31.40
Th     7.20E-07
Pb     1.50E-10
Ra     7.42E-08
U       2.99
As      0.46
Se      0.04
Ni      3.30
Be      0.42
Si      6.03
```

```
TRANSPORT
  -lengths       46*30.5
  -dispersivities 46*50
  -cells         46
  -shifts        78
  -punch_cells   25 #MW-28
```

```
PRINT
  -selected_output  true
```

```
END
```

```
PRINT
  -selected_output  false
```

```
SOLUTION 0 #90% Reduction
```

```
units ppm
pH      6.57
pe       2.2
Ca     198.9
Mg     27.50
```


Na 58.8
K 11
Cl 31.8
Alkalinity 3.19 as HCO3
S(6) 682.8
Fe 20.40
Th 2.92E-07
Pb 7.02E-11
Ra 3.92E-08
U 1.20
As 0.19
Se 0.02
Ni 1.35
Be 0.17
Si 2.41

TRANSPORT

-lengths 46*30.5
-dispersivities 46*50
-cells 46
-shifts 1042
-punch_cells 25 #MW-28

PRINT

-selected_output true

END

PRINT

-selected_output false

ATTACHMENT B

**REVISED PHREEQC FILE (MODIFIED MODEL AT 0.33 FT/DAY WITH SECONDARY
RADIUM SOURCE AND OUTPUT AT MW28)**

```
#TITLE AGTI area (Western flow regime)
#FILE: WFR2td_2014_withRa_MW28.pqi
#Concentration vs. Time at MW-28 (Cell No. 25)
#300 pCi/L Ra in Cell No. 10
#Using flow rate of 0.33 ft/d - Decreasing Source Term to 90% Reduction
#Dispersion = 50
```

KNOBS

```
-iterations 200
-tolerance 1.00E-13
-step_size 100
-pe_step_size 10
-diagonal_scale TRUE
-debug_prep FALSE
-debug_set FALSE
-debug_model FALSE
-debug_inverse FALSE
-logfile FALSE
```

PRINT

```
-reset      false
```

SELECTED_OUTPUT

```
-file c:\output\wfr2td_2014_withRa_MW28.dat
```

USER_PUNCH

```
-headings As Be Cl Pb U Ni Se SO4 Th Ra sOPb+
-headings wOPb+ PbX2 Anglesite sOHUO2+2
-headings wOUO2+ USiO4(C) Uraninite sONi+ wONi+
-headings NiSe sOHRa+2 wORa+ RaX2 RaSO4 wSeO4-
-headings wOHSeO4-2 wSeO3- wOHSeO3-2 Se(A)
-headings FeSe2 sSO4- wSO4- sOHSO4-2 wOHSO4-2
-headings gypsum wOTh+3 wOTh(OH)+2 wOTh(OH)2+
-headings wOTh(OH)3 wOTh(OH)4- sH2AsO3 wH2AsO3
-headings sH2AsO4 wH2AsO4 sHAsO4- wHAsO4- sAsO4-2
-headings wAsO4-2 sOHasO4-3 wOHasO4-3 sOBe+ wOBe+
-headings Calcite Ca Mg Na K HCO3 SO4 Cl TDS
-start
10 REM Convert to ppm and show molalities
20 PUNCH TOT("As")*74.9216*1000
30 PUNCH TOT("Be")*9.0122*1000
40 PUNCH TOT("Cl")*35.453*1000
50 PUNCH TOT("Pb")*207.19*1000/1.29e-11
60 PUNCH TOT("U")*238.029*1000
70 PUNCH TOT("Ni")*58.71*1000
80 PUNCH TOT("Se")*78.96*1000
90 PUNCH TOT("S(6)")*96.0616*1000
100 PUNCH TOT("Th")*232.038*1000/4.96e-8
110 PUNCH TOT("Ra")*226*1000/1.01e-9
120 PUNCH MOL("Hfo_sOPb+")
130 PUNCH MOL("Hfo_wOPb+")
140 PUNCH MOL("PbX2")
150 PUNCH EQUI("Anglesite")
160 PUNCH MOL("Hfo_sOHUO2+2")
```

```

170 PUNCH MOL("Hfo_wOUO2+")
180 PUNCH EQUI("USiO4(C)")
190 PUNCH EQUI("Uraninite")
200 PUNCH MOL("Hfo_sONi+")
210 PUNCH MOL("Hfo_wONi+")
220 PUNCH EQUI("NiSe")
230 PUNCH MOL("Hfo_sOHRa+2")
240 PUNCH MOL("Hfo_wORa+")
250 PUNCH MOL("RaX2")
260 PUNCH EQUI("RaSO4")
270 PUNCH MOL("Hfo_wSeO4-")
280 PUNCH MOL("Hfo_wOHSeO4-2")
290 PUNCH MOL("Hfo_wSeO3-")
300 PUNCH MOL("Hfo_wOHSeO3-2")
310 PUNCH EQUI("Se(A)")
320 PUNCH EQUI("Ferroselite")
330 PUNCH MOL("Hfo_sSO4-")
340 PUNCH MOL("Hfo_wSO4-")
350 PUNCH MOL("Hfo_sOHSO4-2")
360 PUNCH MOL("Hfo_wOHSO4-2")
370 PUNCH EQUI("gypsum")
380 PUNCH MOL("Hfo_wOTh+3")
390 PUNCH MOL("Hfo_wOTh(OH)+2")
400 PUNCH MOL("Hfo_wOTh(OH)2+")
410 PUNCH MOL("Hfo_wOTh(OH)3")
420 PUNCH MOL("Hfo_wOTh(OH)4-")
430 PUNCH MOL("Hfo_sh2AsO3")
440 PUNCH MOL("Hfo_wh2AsO3")
450 PUNCH MOL("Hfo_sh2AsO4")
460 PUNCH MOL("Hfo_wh2AsO4")
470 PUNCH MOL("Hfo_sHAsO4-")
480 PUNCH MOL("Hfo_wHAsO4-")
490 PUNCH MOL("Hfo_sAsO4-2")
500 PUNCH MOL("Hfo_wAsO4-2")
510 PUNCH MOL("Hfo_sOHAAsO4-3")
520 PUNCH MOL("Hfo_wOHAAsO4-3")
530 PUNCH MOL("Hfo_sOBe+")
540 PUNCH MOL("Hfo_wOBe+")
550 PUNCH EQUI("Calcite")
560 PUNCH TOT("Ca")*40.08*1000
570 PUNCH TOT("Mg")*24.312*1000
580 PUNCH TOT("Na")*22.9898*1000
590 PUNCH TOT("K")*39.102*1000
600 PUNCH MOL("HCO3-")*61.018*1000
610 PUNCH TOT("S(6)")*96.0616*1000
620 PUNCH TOT("Cl")*35.453*1000
630 A = (TOT("Ca")*40.08*1000)+(TOT("Mg")*24.312*1000)
640 B = (TOT("Na")*22.9898*1000)+(TOT("K")*39.102*1000)
650 C = MOL("HCO3-")*61.018*1000
660 D = TOT("S(6)")*96.0616*1000
670 E = TOT("Cl")*35.453*1000
680 PUNCH A+B+C+D+E
-end

```

SOLUTION 0 # SOURCE (ACL's) AGTI

pH 5.5
pe 6

units	mg/l
density	1
S(6)	3480 charge
Cl	274
Alkalinity	3.1 as HCO3
Ca	456
Na	182
Mg	112
K	24
As	1.8
Fe	86
Be	1.64
Ni	13.0
Se	0.16
Si	24
U	11.9
Th	2.85e-6
Pb	4.57e-10
Ra	2.48e-7

SOLUTION 1-9 #MW-21A January 2001

units	ppm
pe	5.8
pH	5.5 #6.12
S(6)	1220
Cl	50
Alkalinity	2.4 as HCO3
Ca	272
Na	79.6
Mg	80.4
K	13.2
Fe	95
As	0.0463
Be	0.014
Th	9.92e-10
Pb	2.19e-11
Ra	8.99e-9
Ni	0.30
Se	0.002
U	0.00112

SOLUTION 10 #MW-21A January 2001

units	ppm
pe	5.8
pH	5.5 #6.12
S(6)	1220
Cl	50
Alkalinity	2.4 as HCO3
Ca	272
Na	79.6
Mg	80.4
K	13.2
Fe	95
As	0.0463
Be	0.014

Th	9.92e-10
Pb	2.19e-11
Ra	3.03e-7 #8.99e-9
Ni	0.30
Se	0.002
U	0.00112

SOLUTION 11-15 #MW-21A January 2001

units	ppm
pe	5.8
pH	5.5 #6.12
S(6)	1220
Cl	50
Alkalinity	2.4 as HCO3
Ca	272
Na	79.6
Mg	80.4
K	13.2
Fe	95
As	0.0463
Be	0.014
Th	9.92e-10
Pb	2.19e-11
Ra	8.99e-9
Ni	0.30
Se	0.002
U	0.00112

SOLUTION 16-46 #MW-28 January 2001

units	ppm
pe	3.9
pH	5.5 #6.86
S(6)	540
Cl	7.5
Alkalinity	2.8 as HCO3
Ca	150
Na	82
Mg	29
K	9.6
Fe	14
As	0.012
Be	0.005 #1/2 DL
Th	5e-9 #this value estimated
Pb	1.55e-11
Ra	1.81e-8
Ni	0.062
Se	0.0025 #1/2 DL
U	0.0045

EQUILIBRIUM_PHASES 1-46

Calcite	0.0	0.0
Gypsum	0.0	0.0
Uraninite	0.0	0.0
USiO4(c)	0.0	0.0
Ferroselite	0.0	0.0

Se (A)	0.0	0.0
RaSO4	0.0	0.0
NiSe	0.0	0.0
Anglesite	0.0	0.0

SURFACE 1-9

-equilibrate 1		
Hfo_wOH	0.086	600 45.9
Hfo_sOH	0.0021	

SURFACE 10

-equilibrate 10		
Hfo_wOH	0.086	600 45.9
Hfo_sOH	0.0021	

SURFACE 11-15

-equilibrate 11		
Hfo_wOH	0.086	600 45.9
Hfo_sOH	0.0021	

SURFACE 16-46

-equilibrate 16		
Hfo_wOH	0.086	600 45.9
Hfo_sOH	0.0021	

#EXCHANGE 1-9

# -equilibrate 1	
# X 1.2	

#EXCHANGE 10-15

# -equilibrate 10	
# X 1.2	

#EXCHANGE 16-46

# -equilibrate 16	
# X 1.2	

TRANSPORT

-lengths	46*30.5
-dispersivities	46*50
-cells	46
-shifts	20
-punch_cells	25 #MW-28

PRINT

-selected_output	true
------------------	------

END

PRINT

-selected_output	false
------------------	-------

SOLUTION 0 #33% REDUCTION

units	ppm
pH	5.66
pe	3.9

Ca 360.2
Mg 80.40
Na 136.0
K 19
Cl 183.0
Alkalinity 3.14 as HCO3
S(6) 2434 charge
Fe 61.50
Th 1.89E-06
Pb 3.69E-10
Ra 1.70E-07
U 7.89
As 1.20
Se 0.11
Ni 8.64
Be 1.09
Si 15.90

TRANSPORT

-lengths 46*30.5
-dispersivities 46*50
-cells 46
-shifts 10
-punch_cells 25 #MW-28

PRINT

-selected_output true

END

PRINT

-selected_output false

SOLUTION 0 #50% Reduction

units ppm
pH 5.80
pe 3.6
Ca 314.1
Mg 65.30
Na 114.0
K 17
Cl 140.0
Alkalinity 3.16 as HCO3
S(6) 1933 charge
Fe 49.70
Th 1.43E-06
Pb 2.84E-10
Ra 1.33E-07
U 5.98
As 0.91
Se 0.08
Ni 6.56
Be 0.83
Si 12.10

```
TRANSPORT
  -lengths          46*30.5
  -dispersivities   46*50
  -cells            46
  -shifts           54
  -punch_cells      25 #MW-28
```

```
PRINT
  -selected_output  true
```

```
END
```

```
PRINT
  -selected_output  false
```

```
SOLUTION 0 #75% Reduction
```

```
units ppm
pH      6.18
pe      3.0
Ca      242.1
Mg      41.60
Na      79.5
K       13
Cl      72.4
Alkalinity 3.18
S(6)    1152 charge
Fe      31.40
Th      7.20E-07
Pb      1.50E-10
Ra      7.42E-08
U       2.99
As      0.46
Se      0.04
Ni      3.30
Be      0.42
Si      6.03
```

```
TRANSPORT
  -lengths          46*30.5
  -dispersivities   46*50
  -cells            46
  -shifts           78
  -punch_cells      25 #MW-28
```

```
PRINT
  -selected_output  true
```

```
END
```

```
PRINT
  -selected_output  false
```

```
SOLUTION 0 #90% Reduction
```

```
units ppm
pH      6.57
```

pe 2.2
Ca 198.9
Mg 27.50
Na 58.8
K 11
Cl 31.8
Alkalinity 3.19 as HCO3
S(6) 682.8 charge
Fe 20.40
Th 2.92E-07
Pb 7.02E-11
Ra 3.92E-08
U 1.20
As 0.19
Se 0.02
Ni 1.35
Be 0.17
Si 2.41

TRANSPORT

-lengths 46*30.5
-dispersivities 46*50
-cells 46
-shifts 1042
-punch_cells 25 # (MW-28)

PRINT

-selected_output true

END

PRINT

-selected_output false

WESTERN FLOW REGIME

CONTENTS

Western Flow Regime Hydrological Cross Section

MW1 Installation Log

MW21A Installation Log

MW25 Installation Log

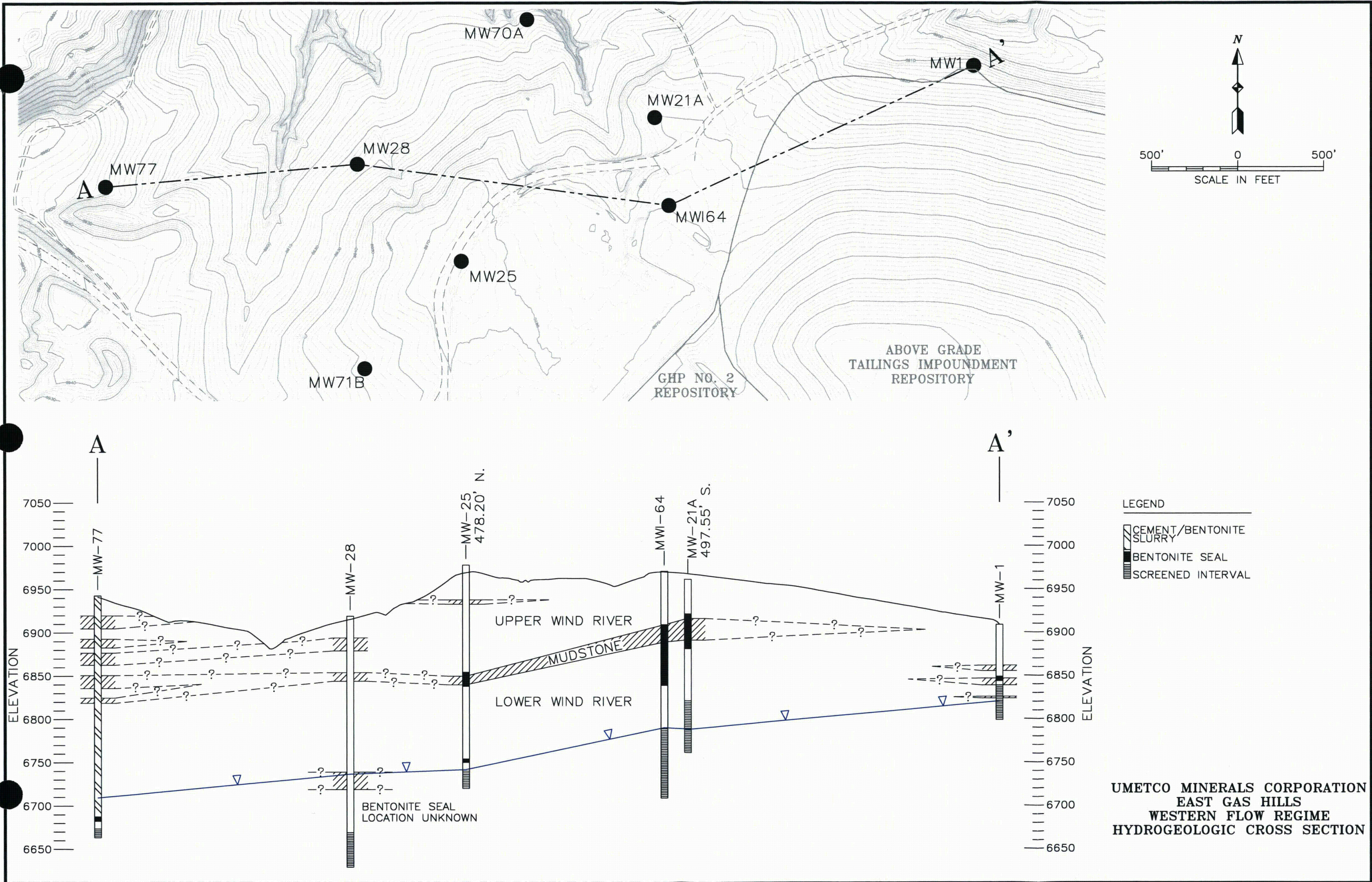
MW28 Installation Log

MWI64 Installation Log

MW70A Installation Log

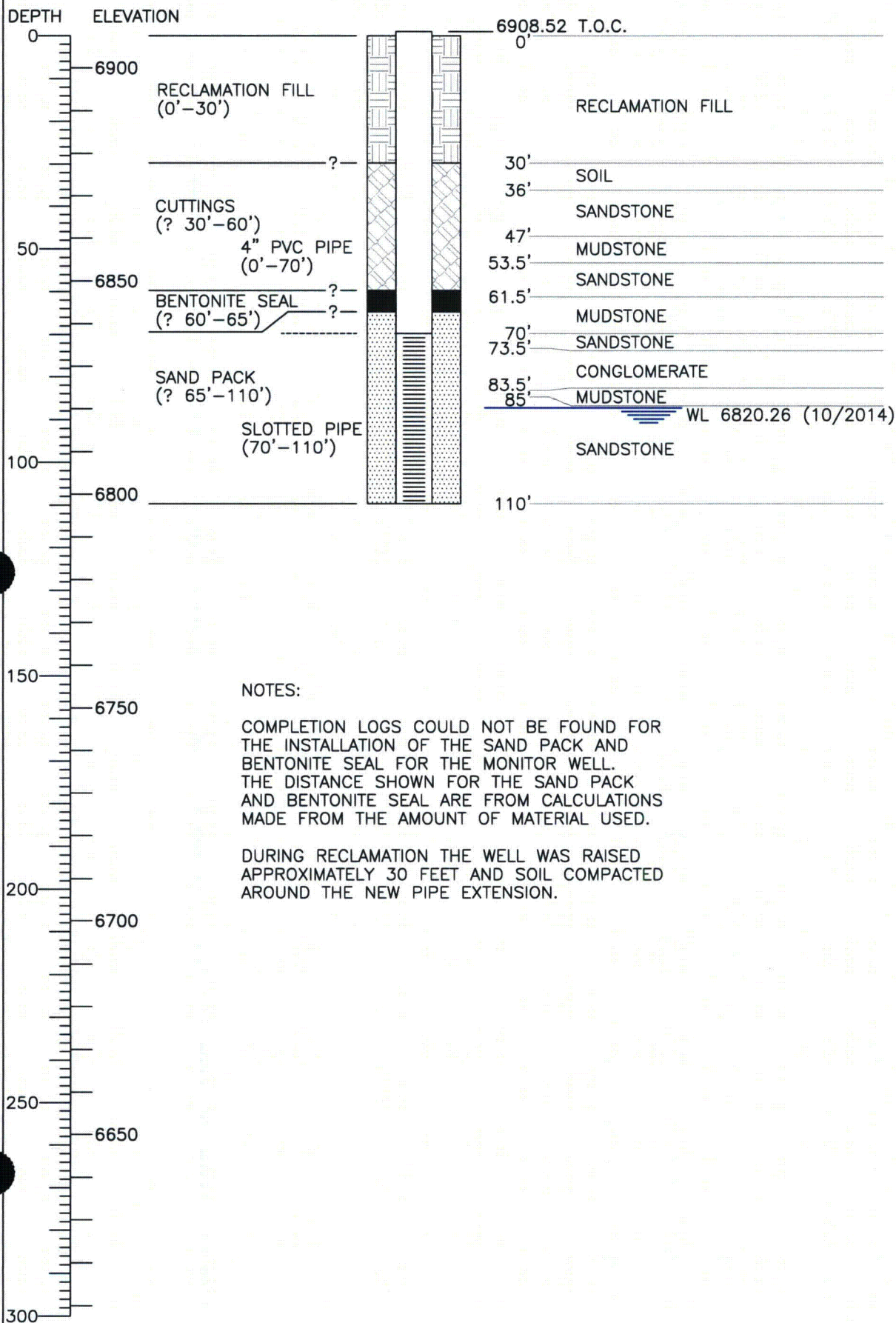
MW71B Installation Log

MW77 Installation Log



UMETCO MINERALS CORPORATION
EAST GAS HILLS
MONITOR WELL INSTALLATION

HOLE NO. MW-1
COORD. N. 795,025.01 E. 838,108.40
ELEVATION TOP OF WELL 6908.52



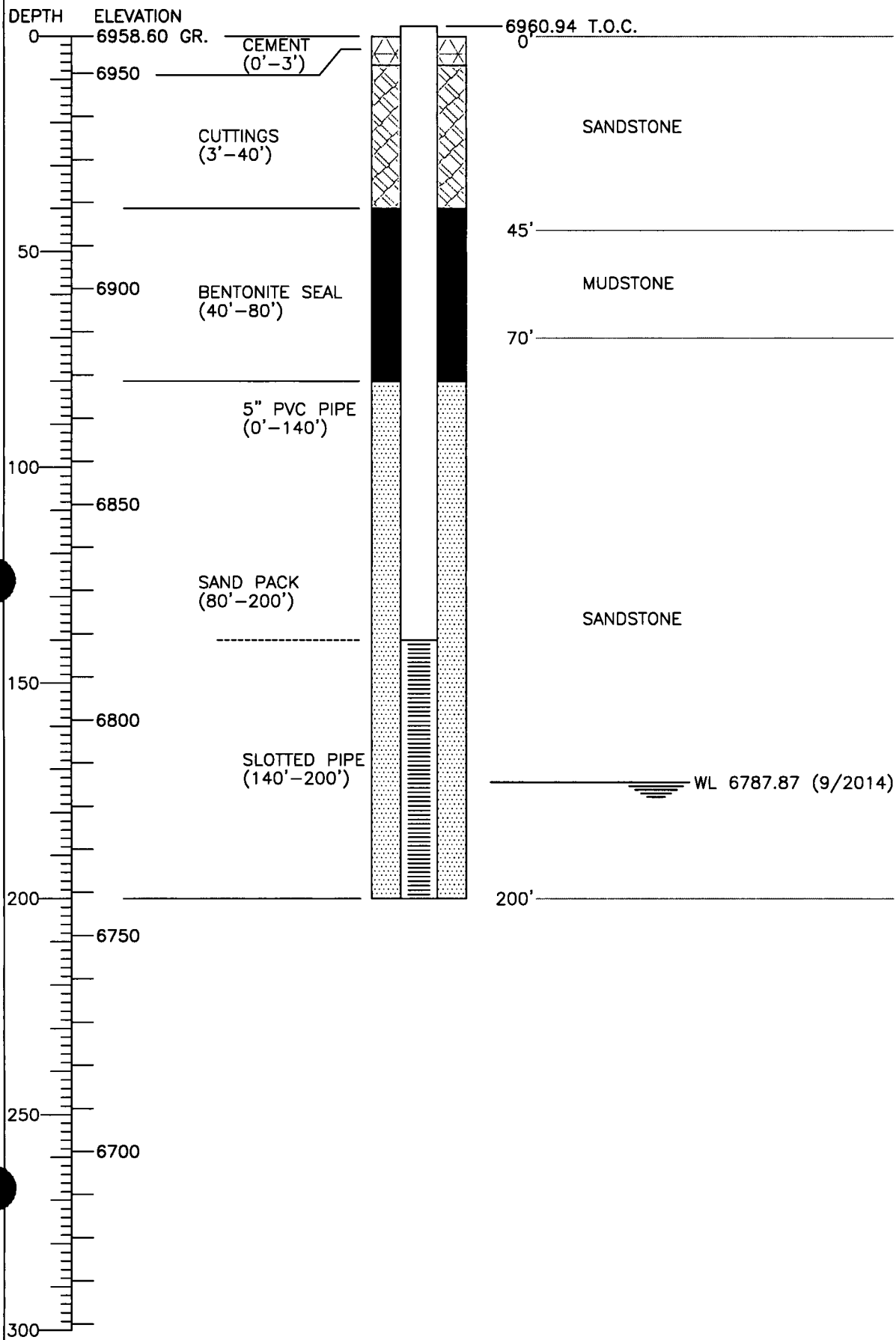
NOTES:

COMPLETION LOGS COULD NOT BE FOUND FOR THE INSTALLATION OF THE SAND PACK AND BENTONITE SEAL FOR THE MONITOR WELL. THE DISTANCE SHOWN FOR THE SAND PACK AND BENTONITE SEAL ARE FROM CALCULATIONS MADE FROM THE AMOUNT OF MATERIAL USED.

DURING RECLAMATION THE WELL WAS RAISED APPROXIMATELY 30 FEET AND SOIL COMPACTED AROUND THE NEW PIPE EXTENSION.

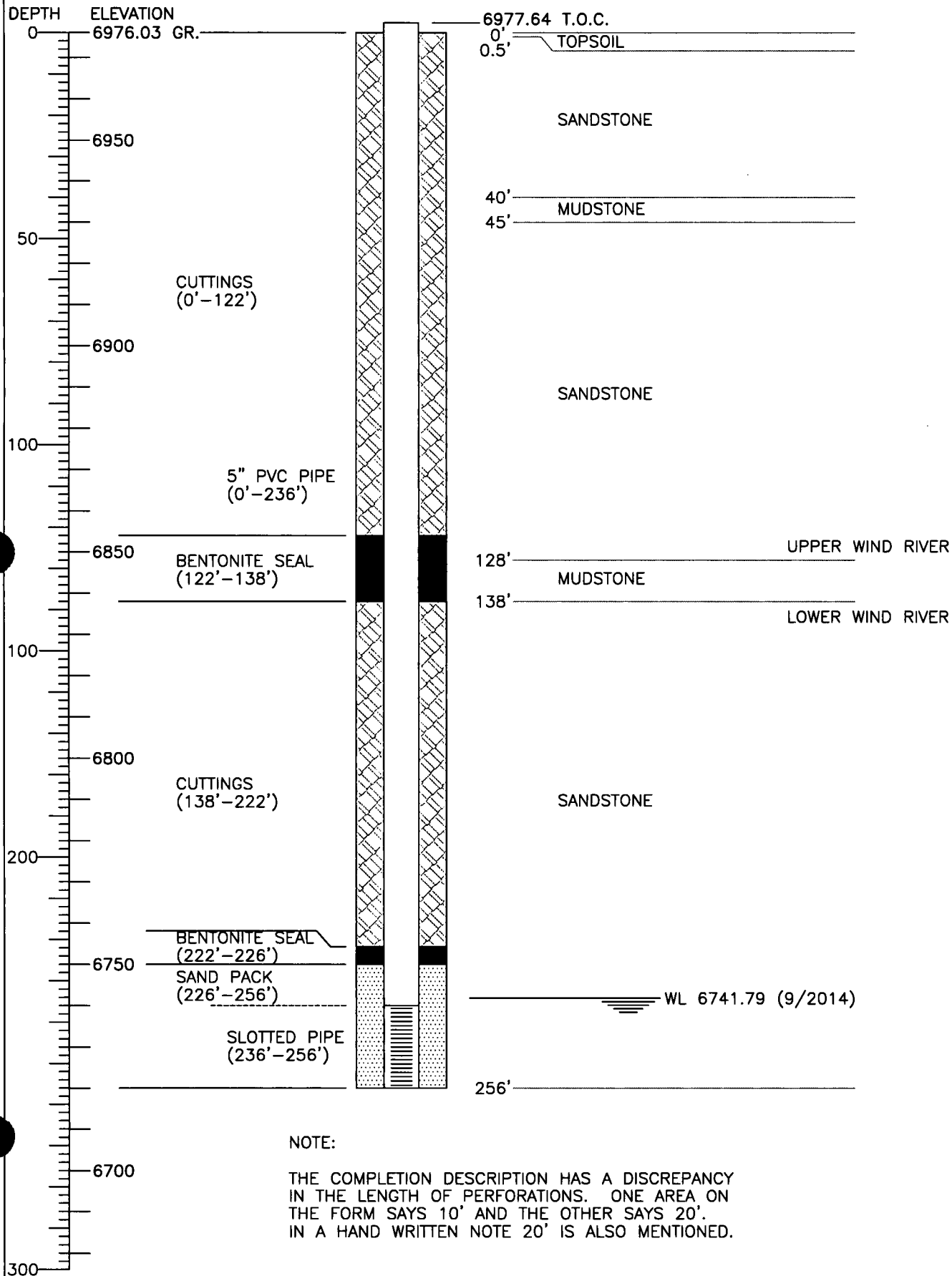
UMETCO MINERALS CORPORATION
EAST GAS HILLS
MONITOR WELL INSTALLATION

HOLE NO. MW-21A
COORD. N. 794,721.04 E. 836249.44
ELEVATION TOP OF WELL 6960.94



UMETCO MINERALS CORPORATION
EAST GAS HILLS
MONITOR WELL INSTALLATION

HOLE NO. MW-25
COORD. N. 793,882.55 E. 835,127.91
ELEVATION TOP OF WELL 6977.64

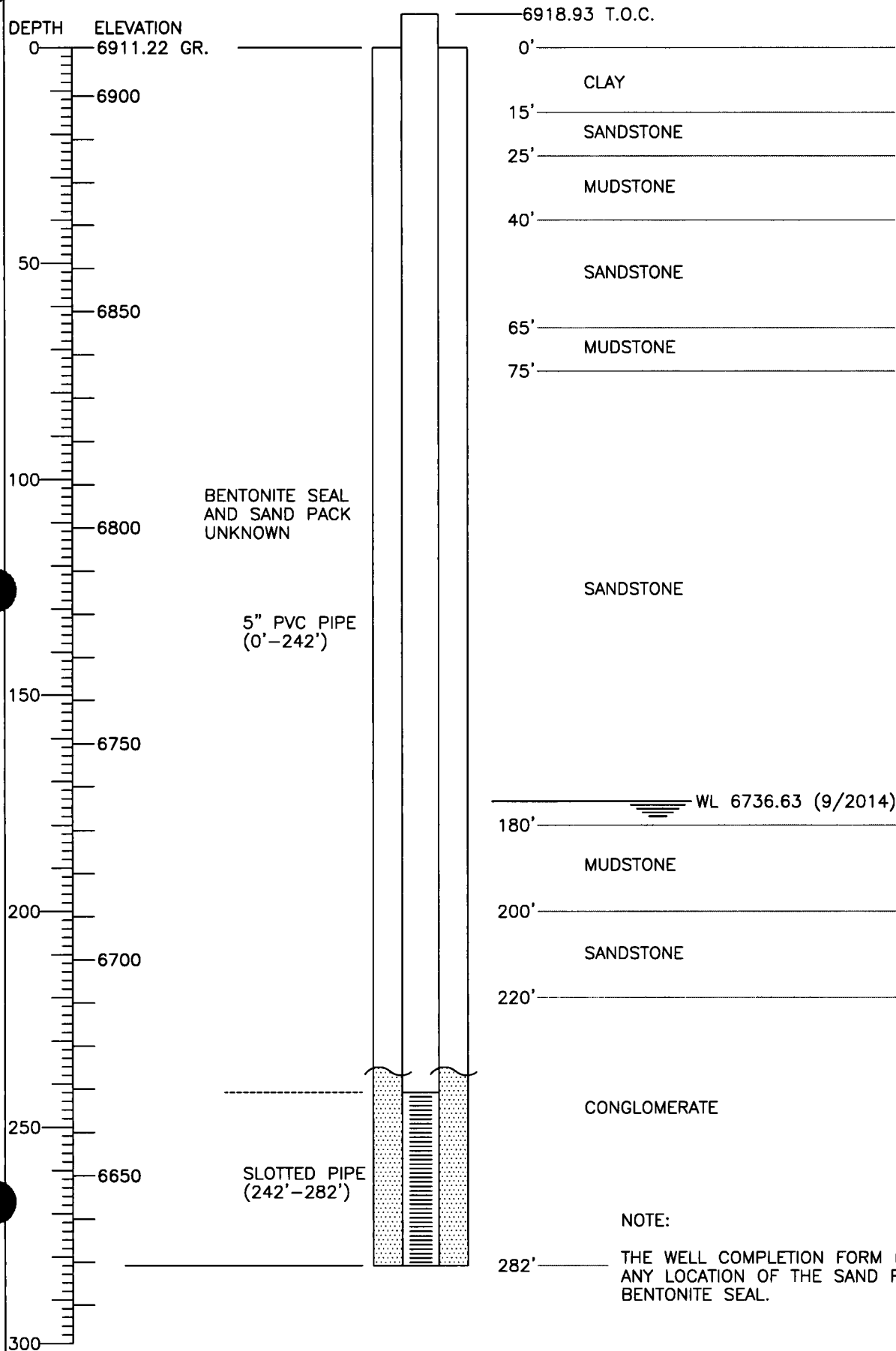


NOTE:

THE COMPLETION DESCRIPTION HAS A DISCREPANCY
IN THE LENGTH OF PERFORATIONS. ONE AREA ON
THE FORM SAYS 10' AND THE OTHER SAYS 20'.
IN A HAND WRITTEN NOTE 20' IS ALSO MENTIONED.

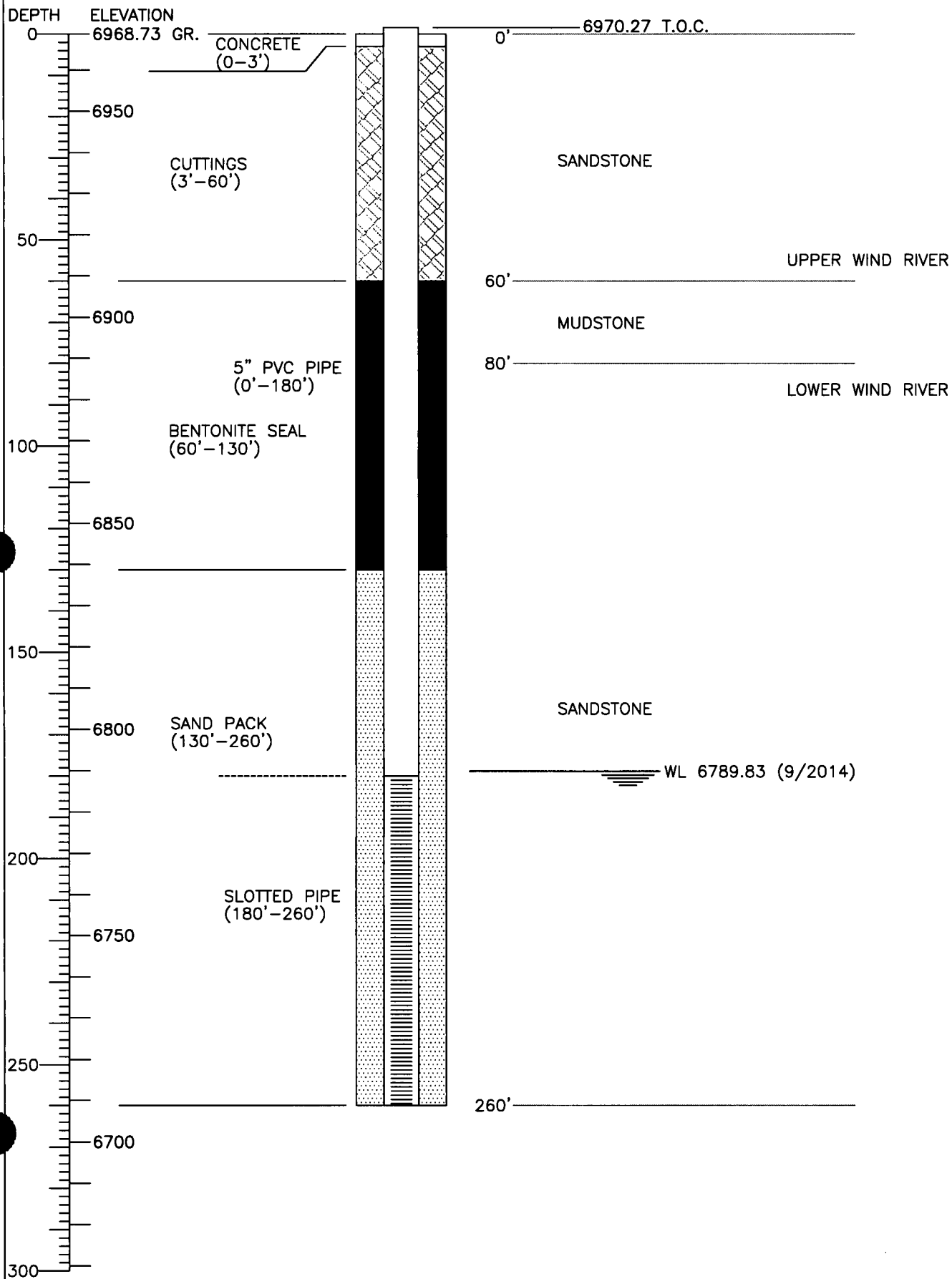
UMETCO MINERALS CORPORATION
EAST GAS HILLS
MONITOR WELL INSTALLATION

HOLE NO. MW-28
COORD. N. 794,441.90 E. 834,525.30
ELEVATION TOP OF WELL 6918.93



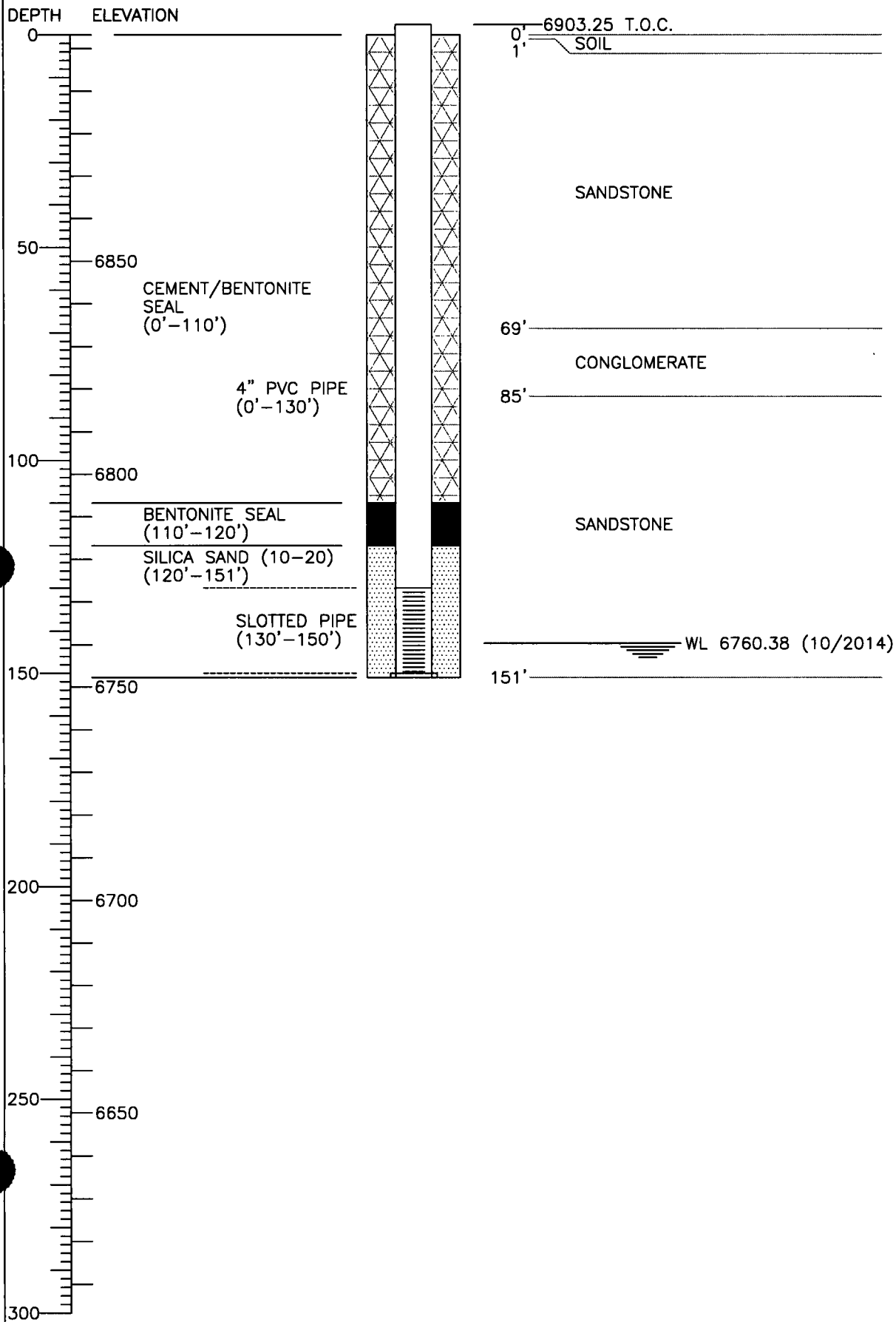
UMETCO MINERALS CORPORATION
EAST GAS HILLS
MONITOR WELL INSTALLATION

HOLE NO. MWI-64
COORD. N. 794,209.11 E. 836,331.01
ELEVATION TOP OF WELL 6970.27



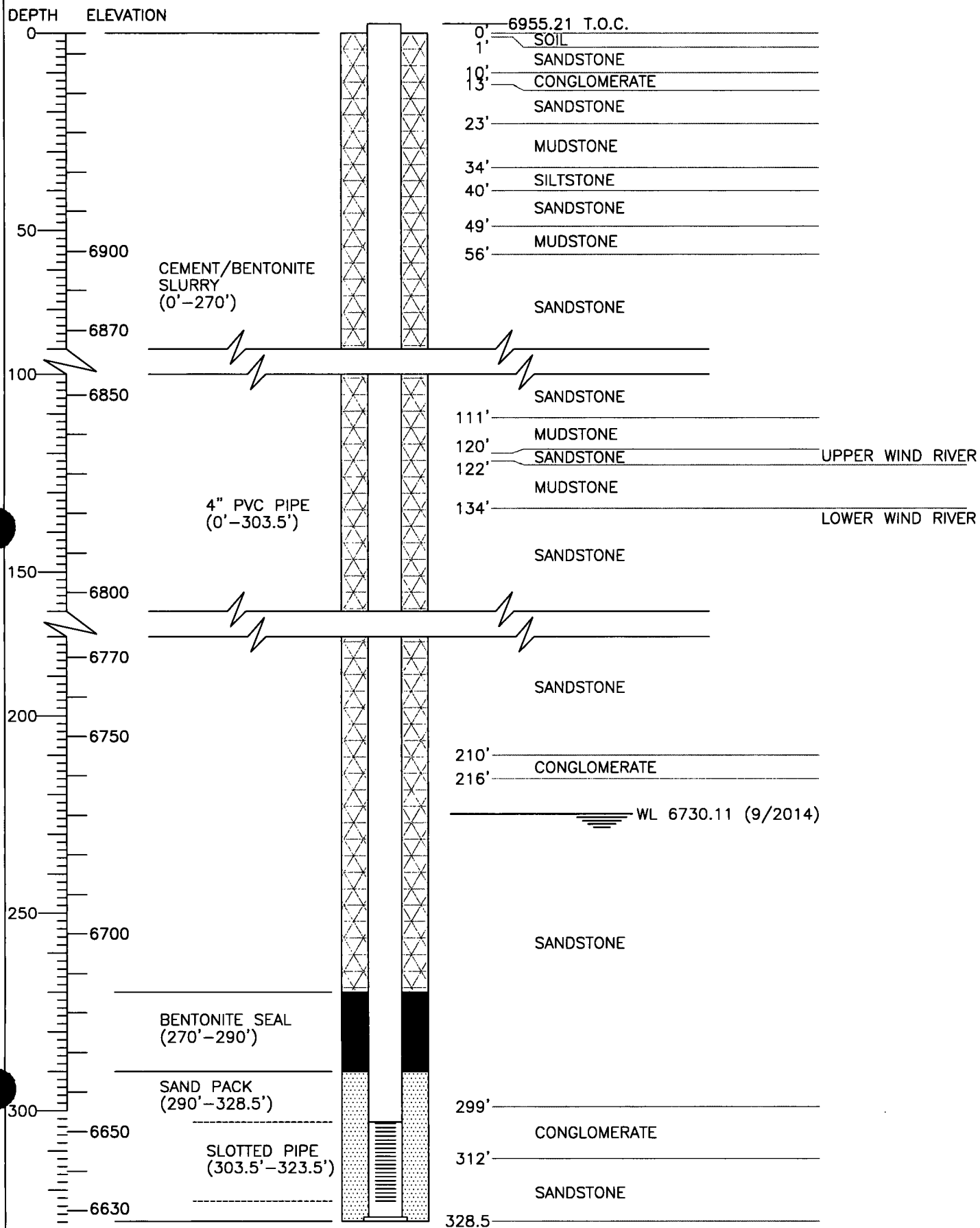
UMETCO MINERALS CORPORATION
EAST GAS HILLS
MONITOR WELL INSTALLATION

HOLE NO. MW-70A
COORD. N. 795,395.73 E. 835,568.07
ELEVATION TOP OF WELL 6903.25



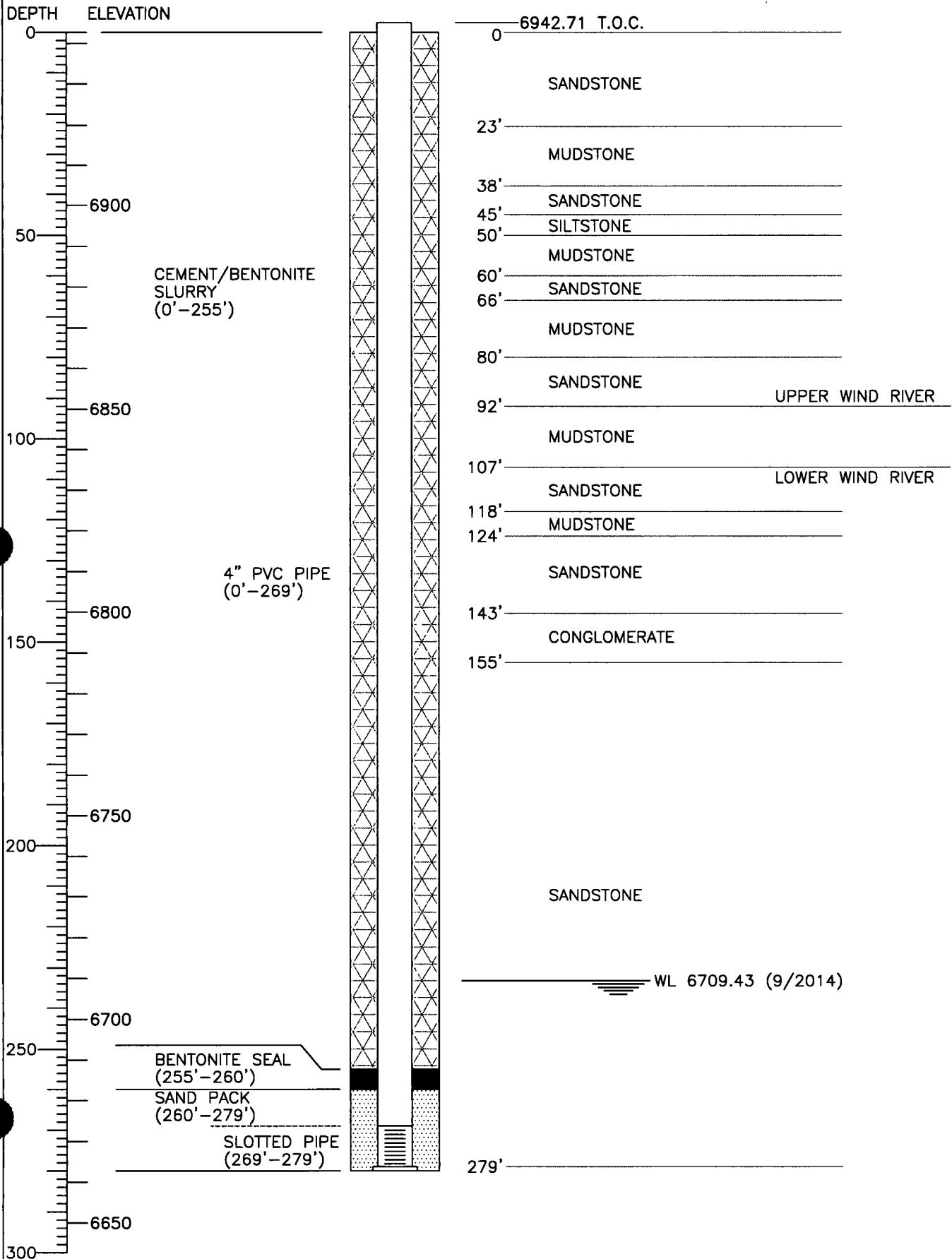
UMETCO MINERALS CORPORATION
EAST GAS HILLS
MONITOR WELL INSTALLATION

HOLE NO. MW-71B
COORD. N. 793,294.93 E. 834,563.68
ELEVATION TOP OF WELL 6955.21



UMETCO MINERALS CORPORATION
EAST GAS HILLS
MONITOR WELL INSTALLATION

HOLE NO. MW-77
COORD. N. 794,323.68 E. 833,060.24
ELEVATION TOP OF WELL 6942.71



SOUTHWESTERN FLOW REGIME

CONTENTS

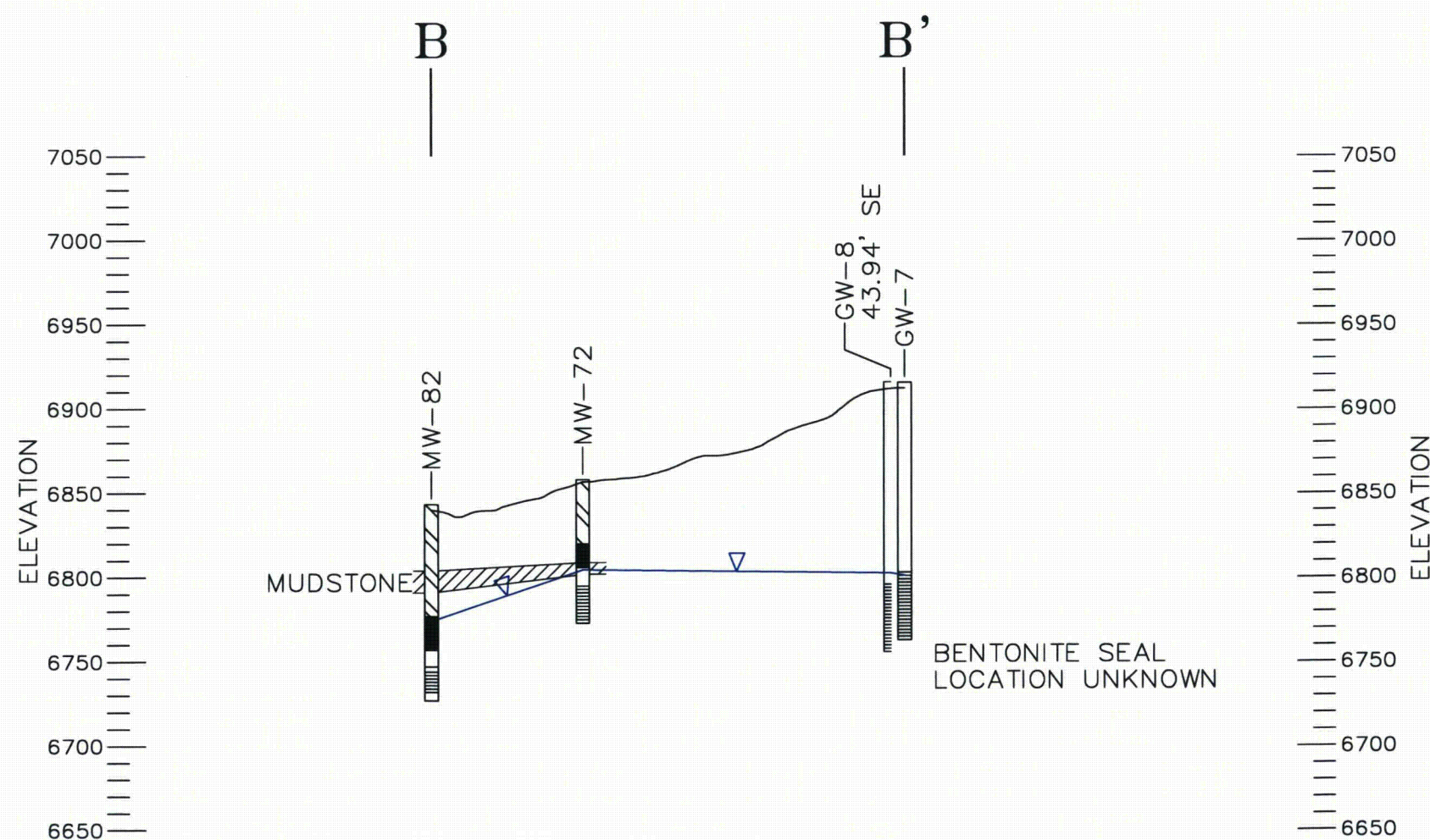
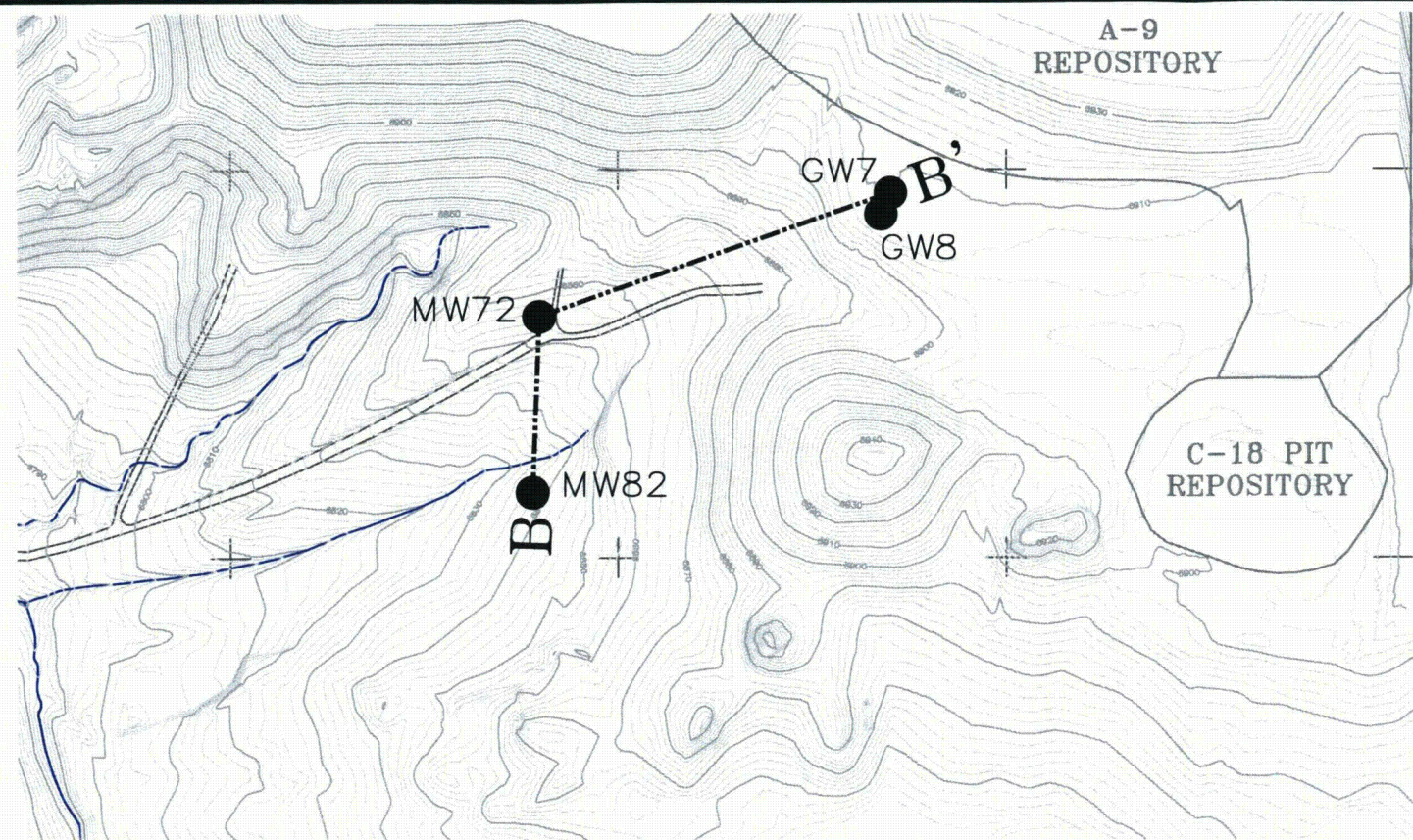
Southwestern Flow Regime Hydrological Cross Section

GW7 Installation Log

GW8 Installation Log

MW72 Installation Log

MW82 Installation Log



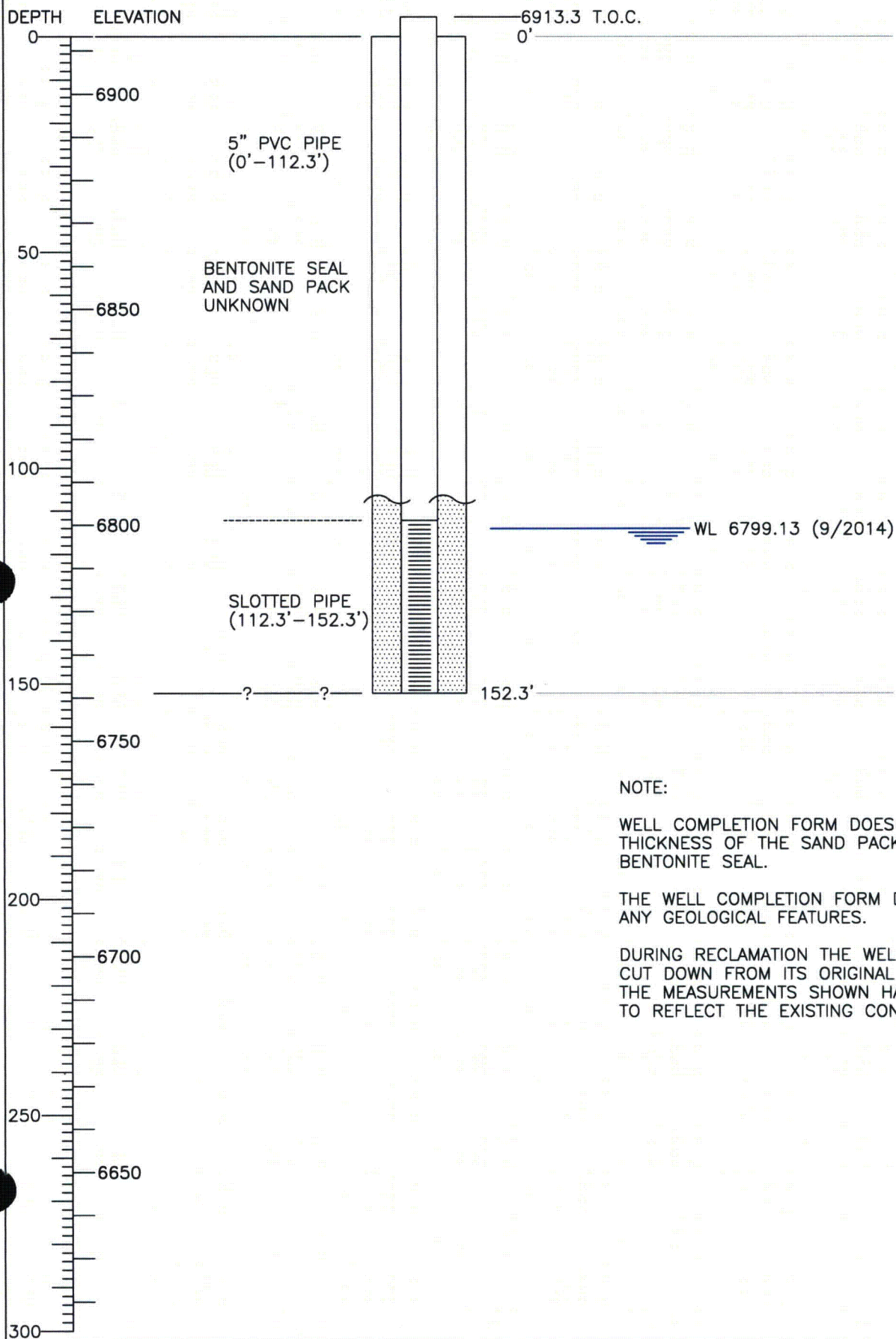
LEGEND

- CEMENT/BENTONITE SLURRY
- BENTONITE SEAL
- SCREENED INTERVAL

UMETCO MINERALS CORPORATION
EAST GAS HILLS
SOUTHWESTERN FLOW REGIME
HYDROGEOLOGIC CROSS SECTION

UMETCO MINERALS CORPORATION
EAST GAS HILLS
MONITOR WELL INSTALLATION

HOLE NO. GW-7
COORD. N. 788,939.73 E. 836,700.60
ELEVATION TOP OF WELL 6913.3



NOTE:

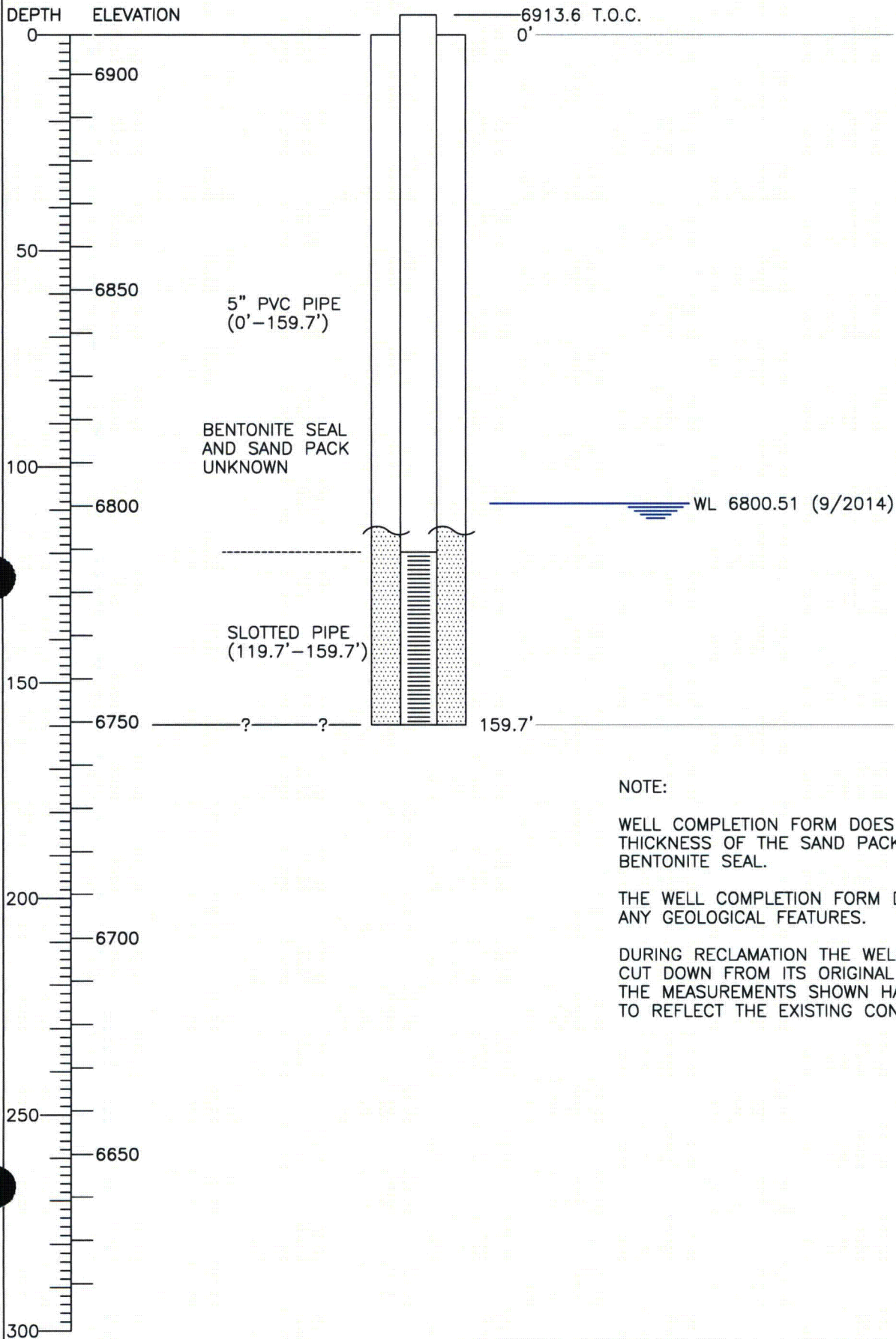
WELL COMPLETION FORM DOES NOT INDICATE THICKNESS OF THE SAND PACK OR THE BENTONITE SEAL.

THE WELL COMPLETION FORM DOES NOT SHOW ANY GEOLOGICAL FEATURES.

DURING RECLAMATION THE WELL CASING WAS CUT DOWN FROM ITS ORIGINAL 1983 ELEVATION. THE MEASUREMENTS SHOWN HAVE BEEN CHANGED TO REFLECT THE EXISTING CONDITIONS.

UMETCO MINERALS CORPORATION
EAST GAS HILLS
MONITOR WELL INSTALLATION

HOLE NO. GW-8
COORD. N. 788,884453 E. 836,676.20
ELEVATION TOP OF WELL 6913.6



NOTE:

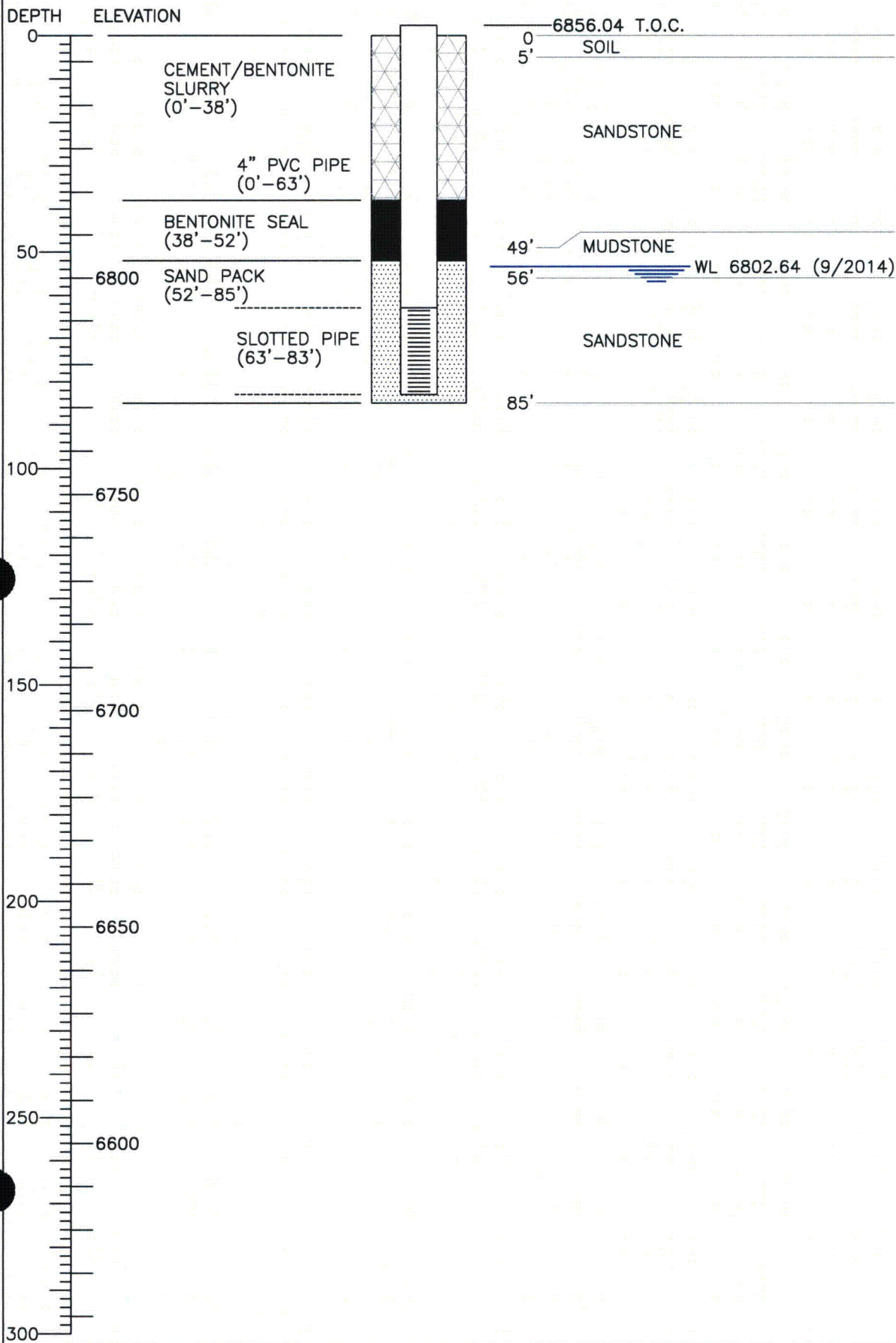
WELL COMPLETION FORM DOES NOT INDICATE THICKNESS OF THE SAND PACK OR THE BENTONITE SEAL.

THE WELL COMPLETION FORM DOES NOT SHOW ANY GEOLOGICAL FEATURES.

DURING RECLAMATION THE WELL CASING WAS CUT DOWN FROM ITS ORIGINAL 1983 ELEVATION. THE MEASUREMENTS SHOWN HAVE BEEN CHANGED TO REFLECT THE EXISTING CONDITIONS.

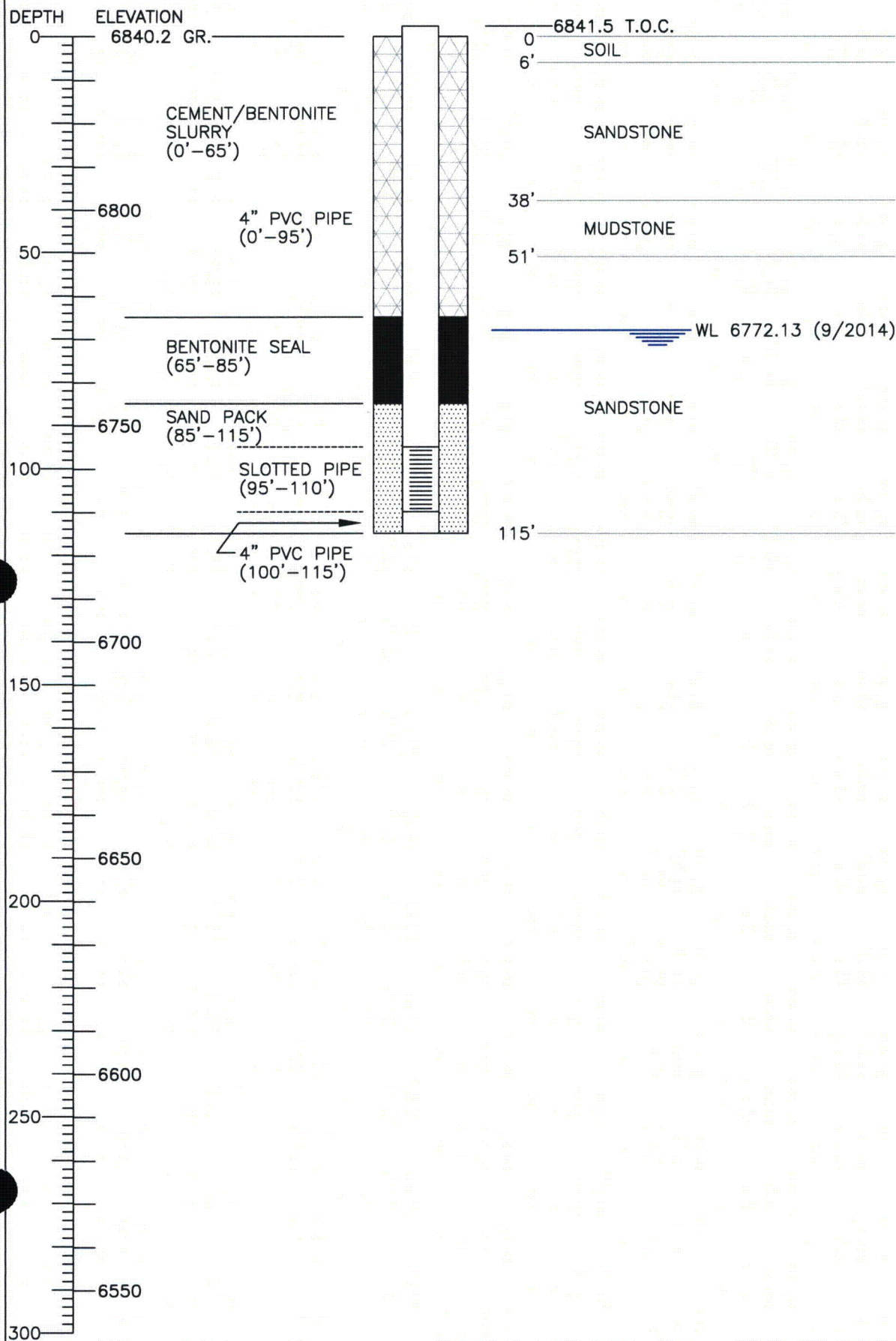
UMETCO MINERALS CORPORATION
EAST GAS HILLS
MONITOR WELL INSTALLATION

HOLE NO. MW-72
COORD. N. 788,620.62 E. 825,796.05
ELEVATION TOP OF WELL 6856.04



UMETCO MINERALS CORPORATION
EAST GAS HILLS
MONITOR WELL INSTALLATION

HOLE NO. MW-82
COORD. N. 788,168 E. 835,779
ELEVATION TOP OF WELL 6841.5



Groundwater Monitoring Plan Gas Hills, Wyoming

Umetco Minerals Corporation
2754 Compass Drive, Suite 280
Grand Junction, Colorado 81506

January 2015

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1.0 INTRODUCTION

This plan has been developed by Umetco Minerals Corporation (Umetco) to detail a groundwater compliance monitoring program as required by License Condition (LC) 35 of U.S. Nuclear Regulatory Commission (NRC) Materials License SUA-648 (license). This plan identifies the monitoring locations for each groundwater flow regime and associated monitoring requirements, and describes how Umetco will define and address potential exceedances of Alternate Concentration Limits (ACLs). This plan was developed from recommendations and commitments described in NRC and Umetco correspondence dated between September 2012 and May 2014 (i.e., NRC letter of September 24, 2012, Umetco letter of March 7, 2013, NRC letter of April 24, 2013, Umetco letter of September 17, 2013, NRC letter of March 11, 2014, Umetco letter of April 15, 2014, and NRC letter of May 8, 2014).

2.0 MONITORING APPROACH

Two types of monitoring locations are to be sampled as part of the Gas Hills groundwater compliance monitoring program:

- (1) Point Of Compliance (POC) wells required by the license; and
- (2) Non-POC wells and spring used to ensure that ACL constituents will meet background concentrations at the Point Of Exposure (POE).

Table 1 lists the POC and non-POC monitoring locations and details their corresponding monitoring requirements. Groundwater monitoring locations are shown on Figure 1 for both the Western and Southwestern flow regimes.

2.1 Point of Compliance Wells

The four POC monitoring wells, specified in LC 35B and LC 35C (i.e., Western Flow Regime (WFR) wells MW1 and MW21A and Southwestern Flow Regime (SWFR) wells GW7 and GW8), will be sampled annually, between May 1st and July 31st, for the ACL constituents (i.e. arsenic, beryllium, lead-210, nickel, combined radium-226 and -228, selenium, thorium-230 and uranium-natural). Concentrations of the ACL constituents in these wells must meet the levels dictated in LC 35B and LC 35C. These wells will also be sampled annually for sulfate and chloride.

2.2 Non-POC Monitoring Locations

The non-POC monitoring location (eleven wells and one spring), listed in Table 1 by flow regime, will be sampled for the ACL constituents annually at the same time that sampling is performed at the POC wells. Sampling will be conducted with analyses for the ACL constituents, sulfate and chloride as indicated in Table 1. These wells were selected to provide early detection of downgradient or vertical contaminant migration, to verify predicted groundwater flow and geochemical attenuation modeling presented in the ACL application, and to ensure that ACL constituent concentrations will be reduced to background levels at the POE.

These locations were selected on the basis of one or more of the following criteria, with input from the NRC:

- location within the plume and in “hot spot” locations;
- location proximal to historic extraction wells;
- location at the downgradient edge of the plume;
- downgradient of site impacts; and/or
- discharge points for groundwater (e.g., springs).

Rationales supporting their selection are documented in Table 2.

Table 1 Summary of Groundwater Compliance Monitoring

Well Type	Western Flow Regime Wells ¹	Southwestern Flow Regime Wells ²	Monitoring Requirements ³
Point of Compliance (POC) Wells	MW1 MW21A	GW7 GW8	Wells to be sampled annually for Alternate Concentration Limit (ACL) constituents ^{1,2} . Sampling to be conducted between May 1st and July 31st until license termination. The results to be used in tandem with results from non-POC wells in a groundwater conditions report submitted to the NRC, annually. Wells to be sampled annually for sulfate and chloride.
Non-POC Wells	MW25 MW28 MWI64 MW70A MW71B MW77 MW83 MW84 MW85 Iron Springs ⁴	MW72 MW82	Wells to be sampled annually for ACL constituents ^{1,2} , chloride and sulfate. Sampling to be conducted between May 1 st and July 31 st until license termination. The results to be used in tandem with results from POC wells in a groundwater conditions report submitted to the NRC, annually.

¹ Alternate Concentration Limits (ACLs) established for the Western Flow Regime Point of Compliance (POC) wells MW1 and MW21A are as follows: arsenic = 1.8 milligrams per liter (mg/L); beryllium = 1.64 mg/L; lead-210 = 35.4 picocuries per liter (pCi/L); nickel = 13.0 mg/L; combined radium-226 and -228 = 250 pCi/L; selenium = 0.161 mg/L; thorium-230 = 57.4 pCi/L; and uranium-natural = 11.9 mg/L.

² ACLs established for the Southwestern Flow Regime POC wells GW7 and GW8 are as follows: arsenic = 1.36 mg/L; beryllium = 1.70 mg/L; lead-210 = 189 pCi/L; nickel = 9.34 mg/L; combined radium-226 and -228 = 353 pCi/L; selenium = 0.53 mg/L; thorium-230 = 44.8 pCi/L; and uranium-natural = 34.1 mg/L.

³ Results of monitoring to be provided to the Nuclear Regulatory Commission (NRC) by September 30 of the same year as required by License Condition 35A of Materials License SUA-648.

⁴ Iron Springs is the surface water sample point required by Wyoming Department of Environmental Quality.

Table 2
Wells

Rationales Supporting Selection of Non-Point of Compliance Monitoring

WESTERN FLOW REGIME	
Monitoring Location	Basis for Selection
MWI64	This well is located at the downgradient edge of the Above-Grade Tailings Impoundment (AGTI). Since 2000, concentrations of the ACL constituents in this well have declined and are all below background concentrations, indicating that the tailings-impacted groundwater has migrated past the well. Continued sampling of this well will verify that groundwater in this area is uncontaminated and remains uncontaminated, thus confirming that there is no leakage from the AGTI to the west, and demonstrate that only uncontaminated groundwater is moving in from upgradient.
MW70A	This location is approximately 1,700 feet to the northwest of the restricted area. This well is screened in the upper portion of the Western Flow Regime and will monitor radial flow from the AGTI. Since 2000, concentrations of most ACL constituents in this well have stayed the same or declined, however several ACL constituents are above background concentrations. Monitoring at this well will be continued to verify generally decreasing trends in groundwater to the northwest of the AGTI.
MW25	Water quality data and isoconcentration plots indicate this well, located approximately 1,500 feet hydraulically downgradient of the AGTI, is appropriately located to monitor the leading edge of the plume. Since 2000, only concentrations of arsenic and nickel have increased in this well and are above background concentrations.
MW71B	This well is approximately 2,500 feet downgradient of the AGTI. It is screened in the lower portion of the Western Flow Regime and will indicate potential vertical migration. Since 2000, concentrations of the ACL constituents in this well have stayed the same or declined and are all below background concentrations. Continued sampling of this well will monitor the increasing trends in sulfate which are currently within the range of background concentrations.
MW28	This well is located 2,500 feet hydraulically downgradient of the AGTI. This location appears to be at the leading edge of the groundwater plume. Since 2000, concentrations of most ACL constituents in this well have increased however most are still below background concentrations with the exception of radium 226+228.
MW77	This location is near the proposed land transfer boundary, 4,000 feet hydraulically downgradient of the AGTI, and is representative of water quality at the Point of Exposure (POE). Since this well is the furthest downgradient, continued monitoring will provide an indication of ACL concentrations and indicate constituent attenuation upgradient of the POE.
MW83	This well is located 300 feet downgradient (west) of MW28. This well is intended to intercept peak radium-226+228 activities from upgradient within one year of installation. Data from the well will be used to evaluate radium attenuation along the groundwater flow path.
MW84	This well is located 600 feet northwest of MW28. This well will be used to refine the groundwater flow direction and provide a second point for evaluating radium-226+228 attenuation.
MW85	This well is located 1400 feet northwest of MW28. This well is intended to intercept the leading edge of sulfate-impacted groundwater from the AGTI, and will provide an early indication of downgradient contaminant movement.

Table 2 Rationales Supporting Selection of Non-Point of Compliance Monitoring Wells, continued

WESTERN FLOW REGIME	
Monitoring Location	Basis for Selection
Iron Spring	This spring, approximately 10,000 feet from the AGTI, is the closest discharge point for groundwater migrating from the site. Groundwater modeling indicates no significant impacts to water quality resulting from site-derived constituents.
SOUTHWESTERN FLOW REGIME	
Monitoring Location	Basis for Selection
MW72	Water quality data and isoconcentration plots indicate this well, located 1,000 feet southwest of the A-9 Repository, may be impacted from site derived constituents and is located near the downgradient edge of the groundwater plume migrating from the site.
MW82	This well is the furthest downgradient location from the A-9 repository (approximately 1,300 feet). The well location was selected based on its position along the modeled axis of the plume and also because it is upgradient of Power Resources, Inc.'s proposed Mine Unit 5.

3.0 EXCEEDANCE IDENTIFICATION AND VERIFICATION RESAMPLING

The monitoring approach described above and in Table 1 was developed to ensure that the groundwater ACLs are met, as well as to provide early detection of downgradient or vertical migration of site contaminants. As such, a mechanism for identifying exceedances and implementing appropriate responses to those exceedances must be identified.

3.1 General Approach to Identifying Exceedances

In identifying exceedances, the overall intent is to allow early detection of potential ACL exceedances, while minimizing the probability of false positive results—e.g., exceedances attributable to laboratory error or transient anomalous increases. Prediction limits are already built into the ACLs. Therefore, comparison of the single values (e.g., ACL vs. monitoring result) should suffice. However, several factors must be accounted for when evaluating results and identifying exceedances. These factors are discussed below.

Significant Figures

Significant figures must be accounted for when comparing predicted values with measured values. The following general approach should be employed. For results less than 1,000 mg/L, comparisons between measured values and predicted values should be based on 2 significant figures. For results exceeding 1,000 mg/L, comparisons should be made on the basis of 3 significant figures.

Verification Sampling

Verification sampling is an integral component of exceedance identification. To avoid "false positives" due to laboratory error and/or transient increases, a statistically significant exceedance

will not be declared or reported until the results of verification sampling are known. Umetco's proposed approach to verification sampling is discussed below and in Table 3.

3.2 ACL Constituents at Point of Compliance Wells

If any POC sample exceeds the ACL for one or more constituents, a second (verification) sample will be collected and analyzed within 3 months of obtaining the original sample to rule out laboratory error or transient increase. Analysis will only be necessary for constituents that exceed their ACLs. If the analyses of this first verification sample also results in an exceedance of the same ACL, Umetco will notify the NRC within 30 days of receiving the verification result. Contingent upon NRC approval, a second verification sample may be collected before corrective action measures are considered; this sample will be collected within 3 months of obtaining the results from the first verification sample.

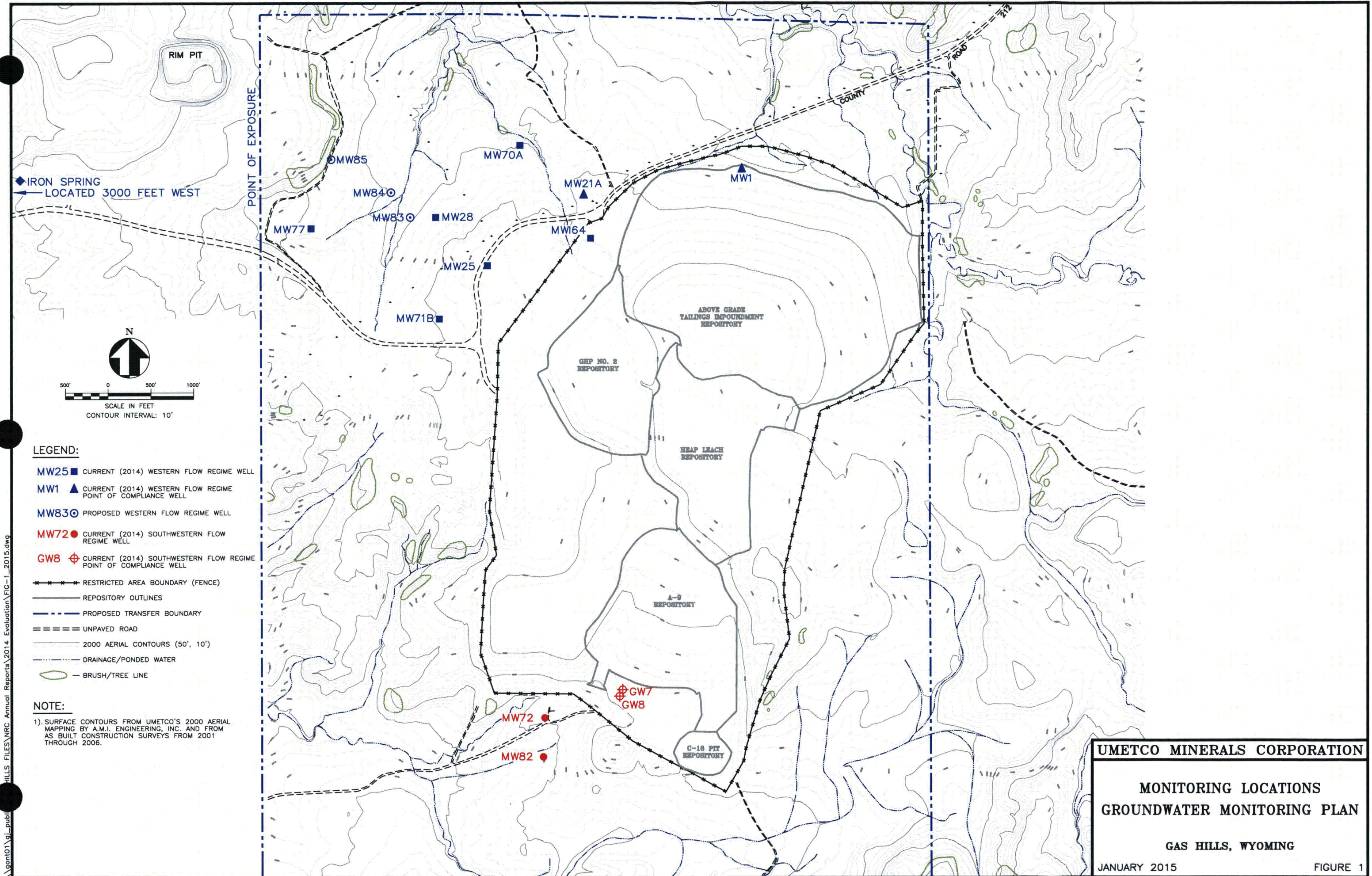
If the second verification sample also results in an exceedance, Umetco will provide an "action plan" to the NRC within 60 days of receiving the results of the second verification sample. This action plan will describe appropriate corrective action(s), if necessary, and/or further analysis to ensure that no risk will be incurred at the POE. Such an analysis may require reassessment of model simulations and assumptions. This approach is detailed in Table 3.

3.3 ACL Constituents at Non-POC Wells

If any Non-POC sample exceeds the ACL for one or more constituents, the exceedance will be handled on a case-by-case basis through correspondence with NRC.

Table 3 Exceedance Identification and Action Approaches

Monitoring Endpoint	Exceedance Identification and Verification Sampling Approach	Actions to be Implemented if Exceedances are Verified
ACL Constituents at POC Wells	<p>If any POC sample exceeds the ACL for one or more constituents (accounting for significant figures), a verification sample will be analyzed <u>within 3 months</u> of obtaining the initial exceedance result(s).</p> <p><i>[Re-analysis is only necessary for the constituent(s) exceeding the ACLs.]</i></p>	<p>If the first verification sample also results in an exceedance of the same ACL, Umetco will notify the NRC within 30 days of receiving the first verification result. Contingent upon NRC approval, a second verification sample may be collected before corrective action measures are considered. The second verification sample will be analyzed within 3 months of obtaining the result(s) of the first verification sample.</p> <p>If the second verification sample also results in an exceedance, Umetco will provide an "action plan" to the NRC within 60 days of receiving the results of the second verification sample. This action plan will describe appropriate corrective action(s), <i>if necessary</i>, and/or further analysis to ensure that no risk will be incurred at Point of Exposure (POE) locations. Such an analysis may require reassessment of model simulations and assumptions.</p>



UMETCO MINERALS CORPORATION

MONITORING LOCATIONS
GROUNDWATER MONITORING PLAN

GAS HILLS, WYOMING

JANUARY 2015

FIGURE 1

Appendix M

Groundwater Monitoring Plan Gas Hills, Wyoming

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**Sulfate and chloride target levels for non-POC model validation wells are provided in Attachment M-1, Tables 2 through 5.*

Figures

<u>M-Figure</u> 1 Monitoring Locations

Also see Attachment M-1 Figures 1.a through 8.b.

Attachments

Attachment M-1	Target Level Derivation and Model Validation Approach for Chloride and Sulfate
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1.0 INTRODUCTION

This groundwater monitoring plan was developed in support of (revised) License Condition (LC) 35, which stipulates that Umetco implement a groundwater compliance monitoring program and identify appropriate actions to be taken if the Alternate Concentration Limits (ACLs) for groundwater are exceeded. In accordance with LC 35, this appendix identifies the groundwater monitoring locations for each flow regime, presents the associated monitoring plan, and describes how Umetco will define and address potential exceedances of ACLs and/or target levels established for non-licensed indicator constituents.

This plan has been developed by Umetco Minerals Corporation (Umetco) to detail a groundwater compliance monitoring program as required by License Condition (LC) 35 of U.S. Nuclear Regulatory Commission (NRC) Materials License SUA-648 (license). This plan identifies the monitoring locations for each groundwater flow regime and associated monitoring requirements, and describes how Umetco will define and address potential exceedances of Alternate Concentration Limits (ACLs). This plan was developed from recommendations and commitments described in NRC and Umetco correspondence dated between September 2012 and May 2014 (i.e., NRC letter of September 24, 2012, Umetco letter of March 7, 2013, NRC letter of April 24, 2013, Umetco letter of September 17, 2013, NRC letter of March 11, 2014, Umetco letter of April 15, 2014, and NRC letter of May 8, 2014).

2.0 MONITORING APPROACH

~~Three~~Two types of monitoring ~~wells~~locations are ~~included in~~to be sampled as part of the Gas Hills ~~site~~-groundwater compliance monitoring program:

- (1) ~~the existing~~Point Of Compliance (POC) wells required by the license; and
- (2) Non-POC wells and spring used to ensure that ACL constituents will meet background concentrations at the Point Of Exposure (POE) for the purposes of tracking any future (unexpected) downgradient and/or vertical contaminant migration; and
- (3) ~~a subset of the downgradient non POC wells defined above, for the purposes of validating the site geochemical and groundwater flow model and to ensure that sulfate and chloride non licensed constituents regulated by the Wyoming Department of Environmental Quality (WDEQ) do not exceed model predictions and/or WDEQ standards.~~

Table ~~M-1~~ ~~defines~~lists the POC and non-POC monitoring ~~wells~~locations and ~~summarizes the details their~~ corresponding monitoring ~~approach, including the sampling frequency and the specific analytes to be monitored~~requirements. Groundwater monitoring locations are shown on Figure ~~M-1~~ for both the Western and Southwestern flow regimes.

2.1 Point of Compliance Wells

The four ~~existing~~POC monitoring wells—, specified in LC 35B and LC 35C (i.e., Western Flow Regime (WFR) wells MW1 and MW21A and Southwestern Flow Regime (SWFR) wells GW7

and GW8—), will be sampled annually ~~with analysis, between May 1st and July 31st, for the ACL constituents. In addition, MW21A and GW7—located at or near the leading edge (i.e. arsenic, beryllium, lead-210, nickel, combined radium-226 and -228, selenium, thorium-230 and uranium-natural). Concentrations of the plume in their respective flow regimes—ACL constituents in these wells must meet the levels dictated in LC 35B and LC 35C. These wells will also be sampled annually with analysis for sulfate and chloride. GW7 has consistently had the highest observed concentrations of several licensed constituents, and is considered a “hot spot” within the SWFR contaminant plume.~~

2.2 Non-POC Wells Monitoring Locations

The non-POC monitoring locations (eleven wells and one spring), listed in Table 1 by flow regime, will be sampled for the ACL constituents annually at the same time that sampling is performed at the POC wells. Sampling will be conducted with analyses for the ACL constituents, sulfate and chloride as indicated in Table 1. These wells were selected to provide early detection of ~~any future~~ downgradient or vertical contaminant migration, ~~and/or~~ to verify ~~the predicted~~ groundwater flow and geochemical attenuation modeling ~~results~~ presented in the ACL application, and to ensure that ACL constituent concentrations will be reduced to background levels at the POE. These locations ~~listed in Table M-2~~ were selected on the basis of one or more of the following criteria, with input from the ~~U.S. Nuclear Regulatory Commission (NRC); NRC:~~

- location within the plume and in “hot spot” locations;
- location proximal to historic extraction wells;
- location at the downgradient edge of the plume;
- downgradient of site impacts; and/or
- discharge points for groundwater (e.g., springs).

Sampling Rationales supporting their selection are documented in Table 2.

Table M-1 Summary of Groundwater Compliance Monitoring Gas Hills Site Groundwater Compliance Monitoring Wells

Well Type	Western Flow Regime Wells ¹	Southwestern Flow Regime Wells ²	Monitoring Approach <u>Requirements</u> ³
Point of Compliance (POC) Wells	MW1 MW21A*	GW7* GW8	Wells to be sampled annually for <u>Alternate Concentration Limit (ACL)</u> constituents ^{1, 2} . Sampling to be conducted every June <u>between May 1st and July 31st</u> until license termination, with <u>The</u> results to be <u>used in tandem with results from non-POC wells in a groundwater conditions report</u> submitted to the NRC, <u>annually by September 30 of the same year.</u> <u>Wells to be sampled annually for sulfate and chloride.</u>

			*Asterisked wells—MW21A and GW7—to be sampled annually for sulfate and chloride.
Non-POC Wells	<u>MW25</u> <u>MW28</u> <u>MWI64</u> <u>MW70A</u> <u>MW71B</u> <u>MW77</u> <u>MW83</u> <u>MW84</u> <u>MW85</u> <u>Iron Springs</u> ⁴	MW72** MW82**	<p><u>Wells to be sampled annually for ACL constituents ^{1,2}, chloride and sulfate. Sampling to be conducted between May 1st and July 31st until license termination.</u></p> <p><u>The results to be used in tandem with results from POC wells in a groundwater conditions report submitted to the NRC, annually.</u></p> <p><u>Sampling of these non-POC wells will be conducted annually with analyses for sulfate, chloride, and uranium-natural. Except for chloride and sulfate monitoring at the four model validation wells (explained below), this sampling will be conducted for information and tracking purposes only—i.e., results will not be assessed for exceedances.</u></p> <p><u>**Results for asterisked wells—MW71B, MW28, MW72, and MW82—will be used to verify model results (see below).</u></p>
Model Validation Wells (subset of above non-POC wells)	MW71B MW28	MW72 MW82	Annual sampling for chloride and sulfate as described above. Results will be compared with the target levels derived for the applicable timeframe. See Section 3.0 and Attachment M-1 Tables 2 through 5.

- 1 Alternate Concentration Limits (ACLs) established for the Western Flow Regime Point of Compliance (POC) wells MW1 and MW21A are as follows: arsenic = 1.8 milligrams per liter (mg/L); beryllium = 1.64 mg/L; lead-210 = 35.4 picocuries per liter (pCi/L); nickel = 13.0 mg/L; combined radium-226 and -228 = 250 pCi/L; selenium = 0.161 mg/L; thorium-230 = 57.4 pCi/L; and uranium-natural = 11.9 mg/L. ~~—Action levels for chloride and sulfate are listed in Table M-3.~~
- 2 ACLs established for the Southwestern Flow Regime POC wells GW7 and GW8 are as follows: arsenic = 1.36 mg/L; beryllium = 1.70 mg/L; lead-210 = 189 pCi/L^{*}; nickel = 9.34 mg/L; combined radium-226 and -228 = 353 pCi/L; selenium = 0.53 mg/L; thorium-230 = 44.8 pCi/L; and uranium-natural = 34.1 mg/L. ~~*The Pb-210 ACL of 189 pCi/L reflects the findings presented in the June 2005 report entitled *Determination of Lead-210 for the Southwestern Flow Regime* was approved by the Nuclear Regulatory Commission in the Finding of No Significant Impact dated January 20, 2006 and subsequent License Amendment No. 56 dated March 24, 2006.~~
- 3 Results of monitoring ~~will to~~ be provided to the Nuclear Regulatory Commission (NRC) by September 30 of the same year as required by License Condition 35A of Materials in the Groundwater Monitoring Review as required by License SUA-648.
- 4 Iron Springs is the surface water sample point required by Wyoming Department of Environmental Quality.

3.0 MODEL VALIDATION COMPONENT OF COMPLIANCE MONITORING: CHLORIDE AND SULFATE

A subset of the non-POC wells defined above—WFR wells MW71B and MW28 and SWFR wells MW72 and MW82—will be compared with target levels established for chloride and sulfate (see Attachment M-1). Although chloride and sulfate are not licensed constituents, they do have groundwater protection standards set by the WDEQ. More importantly, these constituents are minimally attenuated and therefore should provide the earliest indication of site-derived contaminant migration along groundwater flowpaths. As such, target levels were derived for the purposes of validating the sulfate and chloride model simulations. The monitoring approach is summarized in Table M-1, and detailed supporting information is provided in Attachment M-1. Target levels established for individual model validation wells are documented in Attachment M-1, Tables 2 through 5.

Table M-2 Rationales Supporting Selection of Non-POC Point of Compliance Monitoring Wells

WESTERN FLOW REGIME	
Monitoring Well Location	Basis for Selection
MWI64	This well is located at the downgradient edge of the Above-Grade Tailings Impoundment (AGTI) and exhibits some of the highest observed values for beryllium, nickel, lead-210, radium-226+228, uranium-natural, gross-alpha, chloride and sulfate. This well is within the "hot spot" area of the plume. Since 2000, concentrations of the ACL constituents in this well have declined and are all below background concentrations, indicating that the tailings-impacted groundwater has migrated past the well. Continued sampling of this well will verify that groundwater in this area is uncontaminated and remains uncontaminated, thus confirming that there is no leakage from the AGTI to the west, and demonstrate that only uncontaminated groundwater is moving in from upgradient.
MW70A	This location is approximately 1,700 feet to the northwest of the restricted area. This well is screened in the upper portion of the Western Flow Regime and will monitor radial flow from the AGTI. Since 2000, concentrations of most ACL constituents in this well have stayed the same or declined, however several ACL constituents are above background concentrations. Monitoring at this well will be continued to verify generally decreasing trends in groundwater to the northwest of the AGTI.
MW25	Water quality data and isoconcentration plots indicate this well, located approximately 1,500 feet hydraulically downgradient of the AGTI, would be appropriately located to monitor the leading edge of the plume. Since 2000, only concentrations of arsenic and nickel have increased in this well and are above background concentrations.
MW71B**	This well is approximately 2,500 feet downgradient of the AGTI. It is screened in the lower portion of the Western Flow Regime and will indicate potential vertical migration. Since 2000, concentrations of the ACL constituents in this well have stayed the same or declined and are all below background concentrations. Continued sampling of this well will monitor the increasing trends in sulfate which are currently within the range of background concentrations.
MW28**	This well is located 2,500 feet hydraulically downgradient of the AGTI. Water quality data and isoconcentration plots indicate that there has been no impact from site-derived constituents. This location is a few hundred feet in advance of the groundwater plume and will provide the earliest indication of migration. This location appears to be at the leading edge of

	<u>the groundwater plume. Since 2000, concentrations of most ACL constituents in this well have increased however most are still below background concentrations with the exception of radium 226+228.</u>
MW77	<u>This location is near the proposed land transfer boundary, 4,000 feet hydraulically downgradient of the AGTI, and is representative of water quality at the Point of Exposure (POE). Modeling indicates that site derived constituents will reach this location in 70 to 80 years but will not degrade water quality to less than its current Class III status. Since this well is the furthest downgradient, continued monitoring will provide an indication of ACL concentrations and indicate constituent attenuation upgradient of the POE.</u>
<u>MW83</u>	<u>This well is located 300 feet downgradient (west) of MW28. This well is intended to intercept peak radium-226+228 activities from upgradient within one year of installation. Data from the well will be used to evaluate radium attenuation along the groundwater flow path.</u>
<u>MW84</u>	<u>This well is located 600 feet northwest of MW28. This well will be used to refine the groundwater flow direction and provide a second point for evaluating radium-226+228 attenuation.</u>
<u>MW85</u>	<u>This well is located 1400 feet northwest of MW28. This well is intended to intercept the leading edge of sulfate-impacted groundwater from the AGTI, and will provide an early indication of downgradient contaminant movement.</u>

Table 2 Rationales Supporting Selection of Non-Point of Compliance Monitoring Wells, continued

WESTERN FLOW REGIME	
<u>Monitoring Location</u>	<u>Basis for Selection</u>
Iron Springs	This spring, approximately 10,000 feet from the AGTI, is the closest discharge point for groundwater migrating from the site. Groundwater modeling indicates no significant impacts to water quality resulting from site-derived constituents.
SOUTHWESTERN FLOW REGIME	
<u>Monitoring Well Location</u>	<u>Basis for Selection</u>
MW72**	Water quality data and isoconcentration plots indicate this well, located 1,000 feet southwest of the A-9 Repository, may be impacted from site derived constituents and is located near the downgradient edge of the groundwater plume migrating from the site.
MW82**	This well is the furthest downgradient location from the A-9 repository (approximately 1,300 feet). The well location was selected based on its position along the modeled axis of the plume and also because it is upgradient of Power Resources, Inc.'s proposed Mine Unit 5.

Note: All wells listed above will be sampled annually for analysis of sulfate, chloride, and uranium natural. Sulfate and chloride results for asterisked (**) wells — MW71B, MW28, MW72, and MW82 — will also be used to verify model results.

3.0 EXCEEDANCE IDENTIFICATION AND VERIFICATION RESAMPLING

The monitoring approach described above and in Table M-1 was developed to ensure that the groundwater ACLs are met, as well as to provide early detection of downgradient or vertical

migration of site contaminants. As such, a mechanism for identifying exceedances and implementing appropriate responses to those exceedances, must be identified.

43.1 General Approach to Identifying Exceedances

In identifying exceedances, the overall intent is to allow early detection of potential ACL ~~or target level~~ exceedances, while minimizing the probability of false positive results—e.g., exceedances attributable to laboratory error or transient anomalous increases. Prediction limits are already built into ~~both the ACLs and the target levels established for non-ACL (indicator) constituents; the ACLs.~~ Therefore, comparison of the single values (e.g., ACL vs. monitoring result) should suffice. However, several factors must be accounted for when evaluating results and identifying exceedances. These factors are discussed below.

Significant Figures

Significant figures must be accounted for when comparing predicted values with measured values. The following general approach should be employed. For results less than 1,000 mg/HL, comparisons between measured values and predicted values should be based on 2 significant figures. For results exceeding 1,000 mg/HL, comparisons should be made on the basis of 3 significant figures. ~~[Refer to Attachment M-1, Table 2 for a useful example.]~~

Verification ~~Resampling~~ Sampling

Verification ~~resamplingsampling~~ is an integral component of exceedance identification. To avoid "false positives" due to laboratory error and/or transient increases, a statistically significant exceedance will not be declared or reported until the results of verification ~~resamplingsampling~~ are known. Umetco's proposed approach to verification sampling is discussed below and in Table ~~M-3~~.

43.2 ACL Constituents at Point of Compliance Wells

If any POC sample exceeds the ACL for one or more constituents, ~~another~~ a second (verification) sample will be collected and analyzed within 3 months of obtaining the ~~results, for the constituent(s), original sample~~ to rule out laboratory error or transient increase. Analysis will only be necessary for constituents that exceed their ACLs. If the analyses of this first verification ~~(re)~~ sample also results in an exceedance of the same ACL, Umetco will notify the NRC within 30 days of receiving the second verification result. Contingent upon NRC approval, ~~an additional~~ a second verification sample may be collected before corrective action measures are considered ~~(; this sample will be collected~~ within 3 months of obtaining the ~~second result); results from the first verification sample.~~

If the second verification ~~(re)~~ sample also results in an exceedance, Umetco will provide an "action plan" to the NRC within 60 days of receiving the results of the second verification sample ~~results~~. This action plan will describe appropriate corrective action(s), if necessary, and/or further analysis to ensure that no risk will be incurred at ~~Point of Exposure (POE) locations; the POE.~~ Such an analysis may require reassessment of model simulations and assumptions. This approach is detailed in Table ~~M-3~~.

4.3 Chloride and Sulfate.3 ACL Constituents at Model Validation Non-POC Wells

As discussed above, chloride and sulfate are included in the monitoring plan for a subset of the non-POC wells to evaluate the predictions made by modeling and/or to track the downgradient migration of site-related constituents. As described in Table M-3, exceedance of the chloride and/or sulfate target levels will trigger additional response, including, but not limited to, confirmation sampling and/or reassessment of the model simulations and assumptions. Consideration will be given to the degree of the exceedance and the potential impacts to water quality at the POE. The potential for non-site related factors (e.g., mining impacts) must also be considered when identifying potential exceedances for these indicator parameters, in particular for sulfate. Response actions for exceedance of these parameters will be less rigorous than those discussed above for ACL constituents due to the conservatism already built into the model and the low probability that target level exceedances would adversely impact potential risks at POE locations.

If any Non-POC sample exceeds the ACL for one or more constituents, the exceedance will be handled on a case-by-case basis through correspondence with NRC.

Table M-3 Exceedance Identification and Action Approaches

Monitoring Endpoint	Exceedance Identification and Verification Resampling Sampling Approach	Actions to be Implemented if Exceedances are Verified
ACL Constituents at POC Wells	<p>If any POC sample exceeds the ACL for one or more constituents (accounting for significant figures), another <u>a verification</u> sample will be analyzed <u>within 3 months</u> of obtaining the <u>results for the constituent initial exceedance result</u>(s).</p> <p><i>[Re-analysis is only necessary for the constituent(s) exceeding the ACLs.]</i></p>	<p>If the first verification (re)sample also results in an exceedance of the same ACL, Umetco will notify the NRC within 30 days of receiving the <u>second-first verification</u> result. Contingent upon NRC approval, an additional <u>a second</u> verification sample may be collected before corrective action measures are considered -. The second verification sample will be analyzed within 3 months of obtaining the <u>second result</u>-(s) of the <u>first verification sample</u>.</p> <p>If the second verification (re)sample also results in an exceedance, Umetco will provide an "action plan" to the NRC within 60 days of receiving the <u>results of the</u> second verification sample result. This action plan will describe appropriate corrective action(s), <i>if necessary</i>, and/or further analysis to ensure that no risk will be incurred at Point of Exposure (POE) locations. Such an analysis may require reassessment of model simulations and assumptions.</p>
Chloride and Sulfate in Model Validation Wells MW71B, MW28, MW72, and MW82	<p>If any sample exceeds the corresponding target level for chloride or sulfate (see Attachment M-1 tables), another sample will be analyzed <u>within 3 months</u> of obtaining the results. If the first</p>	<p>Exceedance of three consecutive samples—the annual sample, followed by two verification samples—is required before an exceedance of sulfate and chloride target levels is declared. NRC reporting requirements are the same as</p>

	<p>verification sample also exceeds the target level(s), another verification sample will be collected (within 3 months of the first).</p>	<p>those identified above. Exceedances of chloride and/or sulfate target levels will trigger additional response, including but not limited to reassessment of the model simulations and assumptions.</p> <p>Corrective actions are not anticipated for these parameters, however, as exceedance of the target levels is expected to have a negligible impact on potential risks at the POE.</p>
<p>Chloride, Sulfate, and Uranium-natural at Remaining Non-POC Wells</p>	<p>None required. As indicated in Table M-2, this sampling will be conducted for information and tracking purposes only—i.e., results will not be assessed for exceedances.</p>	<p>Not Applicable.</p>