Department of Energy
Office of Legacy Management

AUG 0 6 2009

Ms. Madeline Roanhorse
Director, Navajo AML
Division of Natural Resources
P.O. Box 1875
Window Rock, AZ 86515

Subject: *Annual Ground Water Report, April 2008 through March 2009, Tuba City, Arizona, Disposal Site, July 2009*

Dear Ms. Roanhorse:

Enclosed is your copy of the *Annual Ground Water Report, April 2008 through March 2009, Tuba City, Arizona, Disposal Site, July 2009*. The report describes the cumulative performance of the Tuba City site ground water remediation system in removing site-related contaminants from the Navajo Sandstone aquifer. Ground water extraction, treatment, and return of treated water to the aquifer continues to operate within the design parameters for this system.

Please call me at (970) 248-6073 if you have any questions.

Sincerely,

Richard P. Bush
Site Manager

Enclosure

cc w/enclosure:
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Annual Groundwater Report April 2008 through March 2009 Tuba City, Arizona, Disposal Site

July 2009

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Annual Groundwater Report
April 2008 through March 2009
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July 2009

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1.0 Introduction

1.1 Background Information

This report evaluates the performance of the groundwater remediation system at the U.S. Department of Energy (DOE) Office of Legacy Management site near Tuba City, Arizona, for the period April 2008 through March 2009, and cumulatively. The site is located in Coconino County, Arizona, within the Navajo Nation and near Hopi Reservation land (Figure 1). A former uranium-ore mill operated at the site from 1956 until 1966. DOE conducted surface remedial actions, consisting of encapsulating all solid waste within an on-site engineered disposal cell, between 1988 and 1990. A remnant plume of groundwater contamination, presumed to have originated from evaporation ponds and slurry-emplaced tailings during mill operation, extends off site to the south and southeast in the underlying bedrock sandstone aquifer. The primary site contaminants in groundwater are nitrate, uranium, and sulfate. DOE constructed a pump-and-treat remediation system, operational by mid-2002, to remove contamination from the aquifer and restore groundwater quality. The progress of water quality restoration is evaluated and reported annually.

1.2 Groundwater Remediation System

The groundwater remediation system currently comprises 37 extraction wells completed within the contaminated region of the aquifer. The extracted water is conveyed in underground piping to an on-site treatment plant, where it is mechanically distilled following ion exchange pretreatment. An engineered solar evaporation pond receives the waste liquid (brine), and an infiltration trench located upgradient of the contaminant plume receives the treated water (distillate), where it is returned to the aquifer to promote the restoration process. Six injection wells (wells 1003 through 1008), originally intended to create a hydraulic barrier at the downgradient limit of contamination, remain unused for that purpose. Of the 37 extraction wells, eight wells (wells 1126 through 1133) were installed in summer 2004 to expand the capture zone of the original 25 wells (wells 1101 through 1125, installed in 1999). Wells 935, 936, 938, and 942, used formerly for monitoring purposes only, were converted to extraction use in summer 2005. Numerous other groundwater monitor wells used to track water quality and water level trends are situated within and surrounding the network of extraction wells. The locations of extraction and monitor wells and the primary features of the site are depicted in Figures 2a through 2c. Figure 2a shows all well locations, Figure 2b shows monitoring wells only, and Figure 2c shows treatment system wells only. (These figures are referred to collectively hereafter as Figure 2.) Corresponding well completion information is provided in Appendix A.

1.3 Groundwater Compliance Strategy

The groundwater compliance strategy for the Tuba City site, as defined in the *Phase I Ground Water Compliance Action Plan for the Tuba City, Arizona, UMTRA Site* (DOE 1999), is to achieve applicable cleanup levels through active remediation of those portions of the aquifer affected by previous site activities. Cleanup levels for the aquifer comprise restoration "standards" (requirements of Title 40 *Code of Federal Regulations* Part 192 [40 CFR 192], "Health and Environmental Protection Standards for Uranium and Thorium Mill Tailings") and restoration "goals" (cleanup levels requested by the Navajo Nation but not required by 40 CFR 192).

Groundwater contaminants requiring active remediation at the site are molybdenum, nitrate, selenium, sulfate, and uranium (DOE 1999). The focus of the figures and data analyses presented in this report are nitrate, uranium, and sulfate, because these contaminants are most widespread and contribute most to potential risk. For all constituents except sulfate, restoration standards correspond to a maximum concentration limit in groundwater established in Table 1 of Subpart A of 40 CFR 192 (see Table 1). Sulfate is not regulated by 40 CFR 192; however, a restoration standard was adopted for this constituent because it is present in groundwater at the site at concentrations that cause excess potential risk (DOE 1999).

Table 1. Groundwater Remediation Targets
(Source: DOE 1999)

Constituent/Property	Cleanup Level	Baseline Concentrations in Plume
Nitrate[a]	10 mg/L as N (44 mg/L as NO_3)	840–1,500 mg/L
Molybdenum[a]	0.10 mg/L	0.01–0.58 mg/L
Selenium[a]	0.01 mg/L	0.01–0.10 mg/L
Uranium[a]	30 pCi/L (0.044 mg/L) U-234 + U-238	0.3–0.6 mg/L
Sulfate[a]	250 mg/L	1,700–3,500 mg/L
TDS[b]	500 mg/L	3,500–10,000 mg/L
Chloride[b]	250 mg/L	20–440 mg/L
pH[b]	6.5–8.5	6.3–7.6
Corrosivity[b]	not corrosive	not applicable

[a]Restoration standard (40 CFR 192)
[b]Restoration goal
mg/L = milligrams per liter
pCi/L = picocuries per liter
TDS = total dissolved solids

1.4 Performance Monitoring and Reporting

The effectiveness of the remediation system in removing contaminants from the aquifer and progressing toward cleanup levels is evaluated yearly, partly on the basis of groundwater monitoring conducted in August and February of each year. During these events, samples are collected at monitor wells for water quality analysis, and water levels are measured. The data are then compared to baseline conditions determined between 1998 and March 2002 (DOE 2003) to evaluate the capture zone of the extraction system, plume movement within the aquifer, and concentration trends. Most of the extraction wells are sampled only during the August events (exceptions this period were wells 935, 938, and 942). This is also the case for several distal and lower terrace wells that have no history of contamination (these too are only sampled during the August events).

Other information used in evaluating the effectiveness of the groundwater remediation system includes the monitoring data collected during routine operation of the treatment plant, such as (1) continuous flow metering for each extraction well, (2) continuous flow metering of the bulk influent and all outflow streams, (3) weekly determination of bulk inflow and distillate composition through composite sampling, and (4) approximately monthly analysis of groundwater composition at each extraction well.

During the current period of observation, the following wells did not have enough water to sample: 1104 and 1127 (August 2008 only), and 0283, 0906, 0936, and 0940 (both August and February events).

1.5 Hydrogeologic Setting

1.5.1 Site Conceptual Model and Groundwater Flow

The Tuba City site lies on the middle of three alluvial terraces formed during ancestral flow in Moenkopi Wash, located about 1.25 miles southeast of the site. The terraces are composed of thin (≤ 20 feet [ft]) surface deposits of coarse, semi-indurated, Quaternary alluvium. Loose dune sand and silt mantle the terraces and terrace gravels at most locations. The terrace and dune deposits unconformably overlie the regionally extensive Navajo Sandstone, a massively cross-bedded, friable, fine-grained to very fine-grained sandstone and siltstone of Jurassic age. Escarpments that separate the terraces are formed by cliffs of the Navajo Sandstone. The regional dip of the bedrock is about 1 degree to the northeast.

At about 200 ft below ground, the massive eolian dune deposits typifying "classic" Navajo Sandstone become interbedded with fine-grained alluvium more typical of the deeper Kayenta Formation. This "intertonguing interval" is 400 to 450 ft thick. Occasional thin (≤ 2 ft), resistant limestone beds, which are relicts of former playa lakes, are interspersed throughout both the classic and intertonguing intervals. The Kayenta Formation consists primarily of 100 ft or more of less resistant, fine-bedded, red silt and fine sand, and lacks the characteristic cross-beds of the Navajo Sandstone. Figure A−1 in Appendix A depicts a conceptual model of the site hydrogeology to illustrate the relationship of surface topography, subsurface geology, and groundwater flow.

Groundwater beneath the Tuba City site occurs in the regionally extensive "N" multiple-aquifer (Cooley et al. 1969), which in the site area comprises the classic and intertonguing intervals of the Navajo Sandstone. Because of the fine-grained nature of the Kayenta Formation locally, it is not water-bearing and is considered the base of the "N" aquifer in this area. The local water table occurs within the Navajo Sandstone; the terrace and dune deposits in the site area are not saturated. Groundwater saturation extends from the water table, about 50 to 60 ft below ground surface on the upper and middle terraces, to the contact with the Kayenta Formation, accounting for a saturated thickness on the order of 500 ft. Groundwater flow beneath the site is south to southeast to Moenkopi Wash. There, regional aquifer discharge is expressed as a laterally extensive (miles) spring zone near the exposed base of the intertonguing interval. Local discharge of groundwater from higher in the formation occurs in some areas, as evidenced by scattered bands of desert phreatophytes that typically occur near the base of the escarpment between the middle and lower terraces. One such area is noted in Figure 2 as the "greasewood area," where the depth to water is only about 20 ft.

1.5.2 Vertical Discretization of the N-Aquifer

In the absence of laterally continuous marker beds in the Navajo Sandstone, for this project the subsurface is discretized into 50-ft intervals, or "horizons," each with a letter designation. These designations are convenient for evaluating the site hydrogeology and depth of contamination. The top of the middle terrace, nominally 5,050 ft in elevation, marks the top of the uppermost

horizon, Horizon A (Figure A–1). Horizons A, B, C, and possibly D span the interval of "classic" Navajo Sandstone beneath the site. The depths of Horizons E through J include the regions of the intertonguing interval. Horizons K, L, and M include the lower intertonguing interval and possibly the upper portion of the Kayenta Formation. Because of surface topography, the uppermost horizon on the lower terrace progresses from Horizon C to D, north to south. The steep topography at Moenkopi Wash intersects Horizons E through G. Because contamination of the aquifer is limited in depth, groundwater remediation at the site focuses primarily on the upper 250 ft of the bedrock aquifer (Horizons A through E).

The stratigraphic relationships to aquifer horizon are shown in Figure A–1 of Appendix A. In Figure 2, color-coding identifies the corresponding horizon in which the mid-point of the screen of each well is located for extraction wells (round symbols) and monitor wells (square symbols). Well screen depth in relation to aquifer horizon and elevation for all project wells is shown schematically in Figure A–2 of Appendix A. Table A–1 of Appendix A includes additional well completion information such as screen length and elevations.

2.0 Treatment and Extraction Systems

2.1 Bulk Treatment Parameters

During the current review period of April 2008 through March 2009, the treatment plant operated for about 318 of 365 total days, for a net on-stream factor of 87 percent. Power failures and scheduled maintenance requiring plant shutdowns account for most of the downtime. About 40.6 million gallons of water were treated during this period, resulting in an average operating rate of 89 gallons per minute (gpm) and an effective rate (downtime included) of 77 gpm. The operating capacity of the treatment plant is about 120 gpm. This rate is not attained because of limited formation yield to the extraction system. Figure 3 indicates that the bulk extraction rate (represented by inflow) has decreased slightly over time, but has stabilized during this reporting period. Total groundwater treatment as of April 1, 2009, was approximately 306.7 million gallons, equivalent to about 25.6 percent of the total estimated volume of uranium-contaminated groundwater prior to remedial action (see Section 4.0 for discussion of contaminant removal rates).

Figure 3 shows the feed rate to the treatment plant and the corresponding concentration of nitrate and sulfate determined from weekly composite samples since the start of remediation. This figure indicates relatively stable concentrations of these constituents entering the treatment system at typical inflows. As shown in Figure 4, uranium concentrations in the bulk feed show a slight downward trend over the same period (concentration trends are addressed further in Section 4.0). The masses of nitrate, sulfate, and uranium extracted during the current review period, estimated from the weekly monitoring of bulk inflow to the treatment plant, are 138,965 pounds (lbs), 365,142 lbs, and 76 lbs, respectively (Table 2).

Table 2. Treatment System Performance Summary, April 2008–March 2009

Contaminant	Typical Feed Concentration (mg/L)	Average Distillate Concentration (mg/L)	Mass Removed During Review Period (lbs)
Nitrate (as NO_3)	400	5.5	138,965
Sulfate	1,060	15	365,142
Uranium	0.22	0.002	76

mg/L = milligrams per liter

2.2 Distillate Quality

Concentrations of nitrate, sulfate, and uranium in the distillate averaged 5.5, 15, and 0.002 milligrams per liter (mg/L), respectively, during this review period (Table 2 and Figure 5). The decrease in these concentrations since the last reporting period (when averages were 17, 59, and 0.01 mg/L, respectively) reflects replacement of the treatment system heat exchanger bags during the week of May 18, 2008 (note decrease in levels plotted in Figures 5a and 5b).

During this reporting period, concentrations of total dissolved solids (TDS) in the distillate ranged from 2 to 220 mg/L (34 mg/L average), and chloride concentrations were generally between 0.5 and 1 mg/L. These results indicate highly effective contaminant removal and a quality of water returned to the aquifer generally well below remediation targets.

2.3 Treatment System Water Budget

Consistent with the last reporting period, about 38 million gallons, or 91 percent, of the total feed to the treatment system was returned to the aquifer at the infiltration trench over the past year. Treatment system wastewater sent to the evaporation pond comprised about 4 percent of the total inflow as brine and about 5 percent as loss for softener regeneration. Water levels in the evaporation pond continue to remain safely below the maximum operating level.

2.4 Extraction Wells

In Figure 2c, the extraction wells labeled 1101 to 1125 are constructed of 6-inch-diameter Schedule 40 PVC solid casing and 6-inch, continuous V-wrap stainless-steel screen (0.017-inch slot). A filter pack of 20–40 mesh silica sand fills the 2-inch annulus to 30 or 40 ft above the screen slots. Screen lengths are 150 ft, extending from the bottom half of Horizon B to the mid-depth of Horizon E, except for wells 1116, 1117, and 1118, which have 100-ft screens to near the base of Horizon D. Extraction wells 1126 to 1133 are constructed of 4-inch-diameter casing and screen. These wells have a 30-ft to 50-ft screen that is placed across most of Horizon B. These wells became operational in August 2005, as did former monitor wells 935, 936, 938, and 942 (4-inch wells). The extraction well pumps are generally positioned 10 to 15 ft above the bottom of the well. Pumps in wells 935, 936, 938, and 942 are at the bottom of the well because these wells are much shallower and so have much less potential drawdown. Refer also to Figure A–2 and Table A–1 in Appendix A.

3.0 Groundwater Capture Analysis

3.1 Extent of Groundwater Contamination

Figures 6a through 14a illustrate the concentrations of nitrate (as NO_3), sulfate, and uranium in groundwater in the respective aquifer horizons before the start of remediation (baseline period). Figures 6b through 14b show contaminant distribution in August 2008 or February 2009 for the respective contaminant and aquifer horizon. Corresponding analytical results are tabulated in Appendix B for August 2008, February 2009, and the baseline period. Most of the baseline period data are from sample collection in March 2002, but data for some locations are from 1999 or 2001. In addition to the primary contaminants, Appendix B also documents analytical results for molybdenum and selenium, the other site contaminants requiring remediation.

Although each well location sampled for the respective period is shown, a concentration value is posted in Figures 6 through 14 only where the applicable remediation goal or standard (Table 1) was exceeded. In map view, the area of contamination in the various horizons does not appear significantly different from the baseline condition, indicating no lateral spreading of the contaminant plume (see also Section 4.1).

Also, except for wells adjacent to the evaporation pond and just south of the disposal cell, the depth of groundwater contamination is generally limited to Horizons A, B, and C beneath the middle terrace. Contamination of Horizon D does not appear widespread or continuous in distribution (see Figures 7b, 10b, and 13b), and the concentration is generally of lesser magnitude than in overlying horizons. Contamination in Horizon E (see Figures 8b, 11b, and 14b) is limited to the occurrence of nitrate in well 268. Nitrate concentrations at this location have risen over the past several years from about 15 mg/L as NO_3 to present values of about 100 mg/L as NO_3 (results were 120 and 75 mg/L for August 2008 and February 2009 events, respectively). Rising concentrations of sulfate and uranium are also observed at this location but do not approach the remediation goals (see Figures E-13 through E-15 in Appendix E). These rising trends may be explained by drawdown of contaminated groundwater from upper horizons to the horizons of the nearby extraction well intakes (refer to Sections 3.2 and 3.3).

On the lower terrace, nitrate continues to exceed the 44 mg/L restoration standard at several locations (Figures 7a and 7b), currently at concentrations between 62 and 230 mg/L as NO_3 (restoration standard is 44 mg/L as NO_3). The maximum (230 mg/L) was measured at Horizon D well 1003; well 1003 is also the only location on the lower terrace where the sulfate restoration goal is presently exceeded (Figure 10b). Between 2006 and 2007, sulfate concentrations had decreased to levels below the restoration goal of 250 mg/L at all lower terrace locations (see Figure E–11). Prior to 2005, uranium was present at several lower terrace wells (e.g., 0691) at concentrations that exceeded the 0.044 mg/L restoration standard. Uranium concentrations have since remained less than this standard at all lower terrace locations. However, as observed for nitrate and sulfate, the uranium concentration also increased at well 1003—from 0.0021 mg/L in 2007 to 0.021 mg/L in 2008. Historically, contaminant trends in this well have not been stable.

Appendix C provides "plume" maps showing the distributions of nitrate, sulfate, and uranium during the current period of review (Figures C–1, C–2, and C–3). The contours shown in the figures were computer-generated using the "natural neighbor" interpolation method based on the posted concentration values. This method provides continuous contours, in contrast to the

"bull's-eye" effect of other interpolators, from data sets containing areas of sparse and dense data, and does not generate contours in areas beyond the data range. One outcome of this method is that contours do not extend far beneath the disposal cell where no data are available.

The plume geometry and magnitude of the contour intervals shown in these figures has not changed significantly during the last several reporting periods—for all constituents, contamination is still generally confined to the middle terrace.

3.2 Water Table Configuration

3.2.1 Water Table Contours

Figure 15 shows the estimated water table for the baseline period (August 2001) using water levels in Horizons A and B monitor wells for the middle terrace, and Horizon C wells for the lower terrace. On the middle terrace, water levels at deeper wells are not representative of water table conditions because of pronounced vertical hydraulic gradients (see Section 3.5) and so are not appropriate for constructing a water table map. On the lower terrace, the water table occurs within Horizon C within the area of interest. The horizontal direction of groundwater flow was predominantly south during the baseline period. A steeper hydraulic gradient at the escarpment (Figure 15) mimics ground surface topography.

Figure 16 shows the estimated water table for February 2009. The monitoring wells and corresponding water table elevations used to generate the water table contours are identified in the figure. The computer-generated, grid-based contours were computed using the "natural neighbor" interpolation method, which does not generate results beyond the input data set. Additional output of the contouring application (SURFER) includes vector analysis as described in Section 3.4.

Comparison of Figures 15 and 16 indicates that operation of the extraction wells has significantly depressed the water table within the central regions of extraction to the south and east of the disposal cell. Also evident in Figure 16 is the development of an elongate groundwater mound and increased hydraulic gradients along the north edge of the disposal cell caused by infiltrating distillate at the trench. Additional analysis of water table drawdown, groundwater flow direction, and groundwater capture, as influenced by groundwater extraction, is provided in Sections 3.3, 3.4, and 3.5. Time trends of water levels for selected wells are provided in Appendix D.

3.2.2 Infiltration Trench

The infiltration trench is constructed into bedrock along the north side of the site (see Figure 2). Distillate enters at the mid-point of the trench from where it flows toward each end in perforated pipe that is embedded in a 3-ft-thick gravel pack. Through mid-2003, nonuniform infiltration caused greater than 20 ft of groundwater mounding beneath the southwest section of the trench, but only about 1 ft of mounding beneath the northeast section. The groundwater mound progressively became more symmetrical after November 2003 when flow valves were installed and all inflowing water was diverted to the northeast section of the trench. In April 2005, a small amount of flow was redirected back to the southwest section of the trench, which again resulted in comparatively greater mounding in that section. Water levels at well 946, located near the southwest section of the trench, reached historical maximums in 2007 but have since decreased

slightly. The groundwater mound at the infiltration currently appears to be symmetrical in shape from the point of water entry to the trench.

Wells 284 and 285 are paired with wells 946 and 943, respectively, to monitor water table conditions at the contact between the terrace deposits and the Navajo Sandstone immediately downgradient of the trench (see Figure 2b). These wells have remained dry since installation in 2004, indicating that mounding has not over-topped the trench to saturate the alluvium. Current water levels are closest to alluvium/sandstone contact at well 946, where the water table is within several feet of that contact. Water level hydrographs for wells completed in the aquifer in the area of the trench are presented as Figure D−1 in Appendix D.

3.3 Water Level Drawdown

Figure 17 further illustrates the effect of groundwater extraction and infiltration by showing the difference in water levels in Horizons A and B between the baseline period and February 2009. Figures 18 and 19 plot the water level differences between the same periods for the deeper horizons. Positive values identify locations where the water level in February 2009 is less than the baseline value. Negative values, such as those at the wells surrounding the infiltration trench (Figure 17), indicate that water levels at the respective locations are presently higher than during the baseline period.

In the area of groundwater extraction, the pattern of water level drawdown illustrated in Figures 17 through 19 reflects three-dimensional converging flow to the extraction wells. The greatest drawdown (as much as 70 ft) is observed at the monitoring wells closest to or within the east and south areas of extraction and screened in either Horizon C, D, or E, which are the horizons spanned by the extraction well intakes. Drawdown is observed to decrease with vertical and horizontal distance from the extraction well intakes. Well hydrographs in Appendix D provide an additional view of water level variation over time at selected monitor wells. The predominantly downward trend in groundwater levels indicates that the capture zone continues to expand and steady-state flow conditions have not been attained since the start of groundwater remediation.

3.4 Horizontal Capture

Figure 20 depicts the estimated zone of groundwater capture in lateral extent in Horizons A and B, where the bulk of contamination resides. All groundwater within the blue line, the approximate extent of plume capture, is predicted to ultimately flow to an extraction well. This prediction is based on slope analysis of the water table depicted in Figure 16. The analysis calculates a vector that describes the direction and magnitude of the water table slope within each user-specified grid cell used in computing the water table contours. The capture line in Figure 20 corresponds to a horizontal flow divide between the vectors that converge on the extraction wells and those that do not.

The slope analysis indicates that the full width of the contaminant plume along the south edge of the disposal cell is within the capture zone, suggesting that flow of contaminated groundwater from the site has been eliminated. The capture zone encompasses the region of greatest contamination; however, much of the area encompassing extraction wells 1126 through 1129 apparently escapes capture. Water level drawdown in this area is significant (Figures 17 and 18)

and continues to increase (Figures D–4, D–5, and D–6 in Appendix D). These data indicate an expanding cone of depression and expanding capture zone in this area. Contamination in this area is limited in vertical extent to Horizons A and B and is generally at lower concentrations than within the capture zone shown in Figure 20.

3.5 Vertical Capture

Hydrographs included in Appendix D for selected sets of co-located monitor wells illustrate that at a given location, the hydraulic head in the aquifer is a function of well-intake depth. This relationship clearly identifies vertical flow components throughout the entire monitored thickness of the aquifer, both before and since the start of groundwater remediation. With few exceptions, vertical flow potentials were downward during the baseline period. Since that time, the magnitude of downward flow in Horizons A, B, and C has increased, as exemplified by the greater vertical separation in the hydrographs for the respective locations of well pairs 265/266, 263/264, 909/932, and 908/912, since about mid-2002 (see Figures D–4 through D–7 in Appendix D). In the main region of contamination, these increased gradients likely imply capture of groundwater from the upper, most contaminated horizons of the aquifer (Horizons A, B, and C).

In the deeper horizons, vertical gradients are now generally upward to the extraction well intakes in response to groundwater extraction. For example, the vertical flow potentials reversed to upward between Horizons M, I, and E at co-located wells 268/256/257 (Figure D–8; wells 256 and 257 were decommissioned in August 2005). A similar result between Horizons E, I, and possibly M is apparent at the location of wells 251/252/253 (see Figure D–9; monitoring well 253 was decommissioned in 2001). A downward flow potential remained between Horizon I and M into 2005 at paired wells 254/255 (Figure D–10; wells 254 and 255 were decommissioned in August 2005). Groundwater elevation data for well 273, installed in August 2004 near the location of former wells 254 and 255, implies vertically upward flow from Horizon I to D under the current pumping condition and downward flow from Horizons A and B (Figure D–10). Groundwater extraction has reduced but not reversed the downward flow gradient between Horizons D and G at wells 915 and 916 (Figure D–11); however, this region of the aquifer is not contaminated.

Because the observed vertical influence of the extraction wells extends deeper than the presumed depth of contamination (Horizons A, B, and C, and to a lesser extent Horizon D), it is likely that the remediation system captures the full vertical extent of the contaminant plume. Downward flow potentials in lower terrace groundwater remain strongly downward, extending possibly through Horizon I, as indicted at the lower terrace well cluster identified in Figure D–12. The effect of pumping at that location has been to increase the downward hydraulic gradient between Horizon C and E and decrease the potential between Horizons E and I (Figure D–10). Despite the downward flow potential remaining on the lower terrace, the slight amount of contamination in lower terrace groundwater is limited primarily to Horizon C.

4.0 Remediation Progress

4.1 Contaminant Concentration Trends at Monitor Wells

Appendix E contains time-series graphs of nitrate, sulfate, and uranium concentrations in groundwater at selected monitor wells located throughout the project area. In the main region of groundwater contamination, obvious or pronounced upward or downward trending is not apparent at most monitor wells (Figures E–1 through E–3). Uranium concentrations in well 262 have increased in recent years (Figure E–3), possibly owing to capture zone expansion with time into areas of relatively high contamination. A more recent increase is evident in nearby well 0906 (see Figure 2b for well locations). Toward the downgradient (south) margin of the plume, contaminant concentrations are relatively stable or slightly decreasing (see Figures E–4 through E–6). Horizon A, B, and C wells 271, 683, 684, 914, and 929 are located beyond but near the downgradient or crossgradient extent of contamination. At most of these "sentinel" wells (271, 683, 684, and 914), groundwater has not been contaminated since monitoring began in 1999. Minor nitrate contamination of about 1.5 times the remediation standard had been measured at well 929 until this reporting period, when nitrate levels were below the 44 mg/L remediation standard for the first time since 2000. These findings indicate that significant lateral expansion of the contaminant plume has not occurred.

Contaminant concentrations remain stable and below remediation standards in Horizon C and D wells 264, 266, 914, 915, and 932 (Figures E–7 through E–9). These results indicate that no southward expansion of the plume is occurring at this depth in the aquifer. In Figures E–7 and E–8, elevated nitrate and sulfate concentrations at well 912 (Horizon C) have trended downward over time, which also indicates that contamination is not spreading farther downgradient.

As presented in Section 3.1, groundwater contamination beneath the lower terrace is generally limited to nitrate. Uranium and sulfate concentrations in lower terrace wells have recently decreased to levels below the respective restoration objectives at all locations except Horizon D well 1003 (sulfate at 310 mg/L). The current extent of nitrate contamination on the lower terrace is limited to well 930 (80 mg/L as NO_3), well 903 (88 mg/L as NO_3), well 691 (80 mg/L as NO_3), well 1003 (234 mg/L as $N0_3$), and well 1004 (66 mg/L as NO_3). Nitrate concentrations have remained relatively stable at wells 692, 903, 930, 1004, and 1006. Definitive trending is not apparent at well 691 and co-located well 1003; in fact, historical trends in this area have been erratic. Contaminant concentration plots for lower terrace monitor wells are included in Figures E–10 through E–12 in Appendix E.

4.2 Breakthrough from the Infiltration Trench

The arrival of water from the infiltration trench to the extraction wells may eventually be important in evaluating the flushing process and time requirement for restoration of the aquifer. Breakthrough of clean water from the infiltration trench is expected to be evident as a relatively abrupt decline in contaminant concentration accompanied by changes in other indicator parameters such as rise in pH and decrease in dissolved silica. Such trending is not yet apparent at monitor wells located along the south side of the disposal cell. Darcy's Law predicts a travel time from the infiltration trench to well 940 of about 17 years, using the observed water table gradient (Figure 16) and a hydraulic conductivity of 1 ft per day (from DOE 1998). This amount

of time exceeds the cumulative remediation period to date, so breakthrough of the distillate is not yet anticipated.

4.3 Contaminant Concentration Trends at Extraction Wells

Figures 21 to 23 illustrate concentration trends at the extraction wells for nitrate, sulfate, and uranium. For each contaminant, the trend at most wells is of decreasing concentration as contaminant mass is removed from the aquifer. Appendix F contains individual concentration plots for each extraction well based on the monthly on-site sampling and analysis.

On the basis of those figures, Table 3 lists the extraction wells where a primary contaminant concentration was below the remediation standard in the extract during this reporting period. As shown in this table, there is no extraction well where all three primary contaminants are below remediation standards. The lowest nitrate concentration in an extraction well was 75 mg/L (well 1125). Sulfate and uranium concentrations in the extracted groundwater are below remediation standards at extraction wells 1113, 1116, and 1125. Although the extraction well samples are likely composites of groundwater from several horizons of variable contamination, the region of the aquifer east of the evaporation pond and encompassing well 1125 is approaching cleanup goals. During this period, nitrate concentrations (as NO_3) exceeded the 44 mg/L standard in all extraction wells.

Table 3. Pumping Wells Where a Contaminant Concentration is Below the Remediation Standard in the Extract, as of February 2009

Nitrate	Sulfate	Uranium
--	1113	1113
--	1116	1116
--	--	1117
--	1125	1125
--	1133	--

4.4 Contaminant Inventory and Removal Rates

4.4.1 Contaminant Mass Removal Rate Projections

Table 4 lists the cumulative amounts of nitrate, sulfate, and uranium removed from the aquifer through March 2009, about 7 years into full-scale groundwater extraction and treatment. For comparison, Table 4 also provides the estimated quantities of contamination initially present in the aquifer and the amount of contaminant removed as a percent of the initial quantity. Calculation methods for these estimates of initial contaminant mass are provided in Appendix G as Calculation Set 1.

By these estimates, at current mass recovery rates of between 1.6 (nitrate) to 4.2 (uranium) percent per year, groundwater restoration will require about 24 to 63 years to complete since the inception of active remediation in mid-2002, assuming total plume capture (see also Figure 24, which projects current mass removal rates to future years). The corresponding volume of groundwater extracted at 24 years, assuming constant withdrawal of 85 gpm (equivalent to about

3.7 percent reduction in plume volume per year [see Table 4]), is 1 billion gallons, or approximately one estimated pore volume of the contaminant plume.

Table 4. Summary of Cumulative Mass and Volume Recovery as of April 1, 2009

Contaminant	Initial Mass (lbs)[a]	Cumulative Mass Removed (lbs)	Cumulative Percent Mass Reduction	Initial Volume (gal)[a]	Volume Treated (gal)	Percent Plume Volume Reduction
Nitrate	9,500,000	1,030,500	10.8	1.2×10^9	3.1×10^8	25.6
Sulfate	20,150,000	2,579,600	12.8	1.2×10^9	3.1×10^8	25.6
Uranium	2,300	650	28.3	1.2×10^9	3.1×10^8	25.6

[a]Source: see Appendix G

4.4.2 Aquifer Restoration Indices

An alternative approach of estimating the restoration period to that presented in Section 4.4.1 is based on concentration trending over time and is independent of mass and volume calculations of the contaminant plumes. By this approach, an average concentration of a contaminant is computed for each sampling event from a selected group of monitor wells. The composition of the groundwater plume is thus represented by a single concentration value, or index, for a given contaminant and time. A time series plot of the index can then provide a measure of bulk trending and restoration progress. Figures 25 and 26 illustrate respectively how the sulfate and uranium indices vary since the start of active remediation. The selected monitor wells in this analysis are those located throughout the contaminant plume and sampled most regularly. Appendix G provides calculation information for this performance metric as Calculation Sets 3 and 4.

Despite the small increment of change and the relatively brief period of observation, the results presented in Figures 25 and 26 depict a developing trend suggesting that remediation is effective in reducing the bulk concentration of uranium and sulfate (nitrate results have not yet been analyzed using this method). Linear projection of the sulfate and uranium indices, disregarding any possible desorption or concentration tailing effects, continues to predict restoration times of about 30 and 60 years, respectively, since the inception of active remediation in mid-2002. This compares to an estimated 24 years to remove one pore volume of the initial contaminant plume (Table 4) at the current cumulative extraction rate of about 3.7 percent per year by volume.

Linear projections of contaminant removal rates as indicators of the aquifer restoration period must be viewed with caution however. This is because such projections ignore geochemical and matrix effects known to prolong water quality improvement (see EPA 1994). Examples of such effects are kinetically controlled desorption of a contaminant from aquifer substrate grains and diffusion controlled transport of a contaminant within dual-domain porosity settings. These effects can lead to concentration tailing, whereby the rate of contaminant release from the substrate decreases with time, or to concentration rebounding following periods of reduced or inactive pumping. Either effect will eventually cause a departure from linear concentration trending and to a longer restoration period than predicted by linear projection.

5.0 Year in Review Summary

- On-stream extraction and treatment flow rates meet design objectives.
- Distillate quality meets or exceeds design objectives.
- Return flow to the aquifer as a percentage of extracted water meets design objectives.
- The current configuration and operation of the extraction system effectively captures the region of maximum groundwater contamination.
- The current configuration and operation of the extraction system likely captures the full vertical extent of groundwater contamination.
- Plume expansion is not significant on either the middle or lower terrace.
- Uranium and sulfate concentrations have decreased to levels less than the restoration standard at most lower terrace monitoring locations. Only minor nitrate contamination remains on the lower terrace.
- Bulk concentration trends indicate measurable progress in water quality restoration.
- Projected cleanup times range between about 25 and 60 years since mid-2002. These projections assume total plume capture, which currently is not achieved, and assume no contaminant tailing or rebound effect.

6.0 Recommendations

- Develop and implement a protocol of pumping and fallow time to evaluate contaminant rebound at extraction well 1125, which is currently extracting groundwater with only minor nitrate contamination and is on the periphery of the extraction well field. Two-week periods of pumping and non-pumping are suggested as a starting point. A water sample would be collected at the start of each pumping cycle after one well casing volume is withdrawn for analysis of nitrate, sulfate, and uranium. This study will assist in evaluating concentration rebounding after pumping is discontinued, and when regions of the aquifer can truly attain cleanup goals. It will also facilitate development of a strategy to implement cyclical pumping at other locations to reduce power consumption.
- Maintain the current distribution of distillate to the infiltration trench. At monitor well 946, where the water table mound is nearest ground surface, the water table position has recently stabilized or decreased slightly from peak levels recorded in August 2007. If a rising trend resumes at this location, injecting a portion of the distillate at the existing injection wells should be considered. The existing injection wells are not currently used for this purpose but all infrastructure is in place. The injection wells (1003 to 1008) are located on the lower terrace in areas of no or very minor groundwater contamination, and so injection of distillate at these wells is not likely to displace contaminants farther downgradient or vertically downward.
- Use February as the more comprehensive semiannual groundwater monitoring event rather than August. This will allow annual reporting of the most current and comprehensive water quality monitoring data.

- Consider implementing a study to determine if the observed decrease in the bulk groundwater extraction rate is an effect of aquifer drawdown and dewatering rather than well fouling by mineral or biologic accumulations. This could be accomplished by removing the pump from selected wells where the effect appears greatest and identifying the mineral or biologic deposits on the down-hole equipment by field and in-house laboratory analysis. The condition of the well screen could then be examined using a down-hole camera. If accumulations are significant, an approach to rehabilitate the selected wells would be developed and implemented. Post-rehabilitation pumping rates would then be compared to pre-rehabilitation pumping rates to determine if this is a cost-effective activity for the remaining extraction wells.

7.0 References

Cooley, M.E., J.W. Harshbarger, J.P. Akers, and W.F. Hardt, 1969. *Regional Hydrogeology of the Navajo and Hopi Indian Reservations, Arizona, New Mexico and Utah*, U.S. Geological Survey Professional Paper 521-A.

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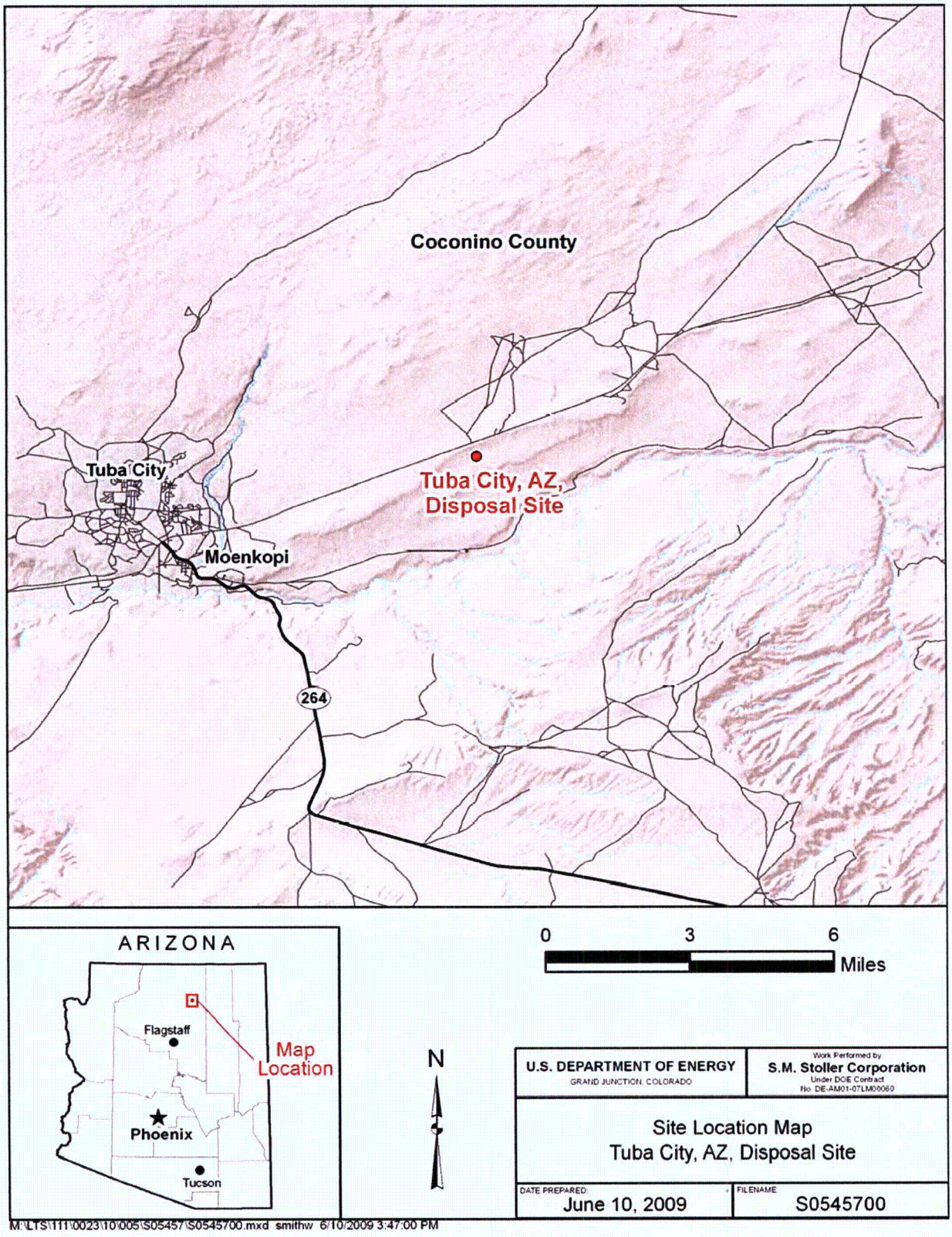

Figure 1. Tuba City Site Location

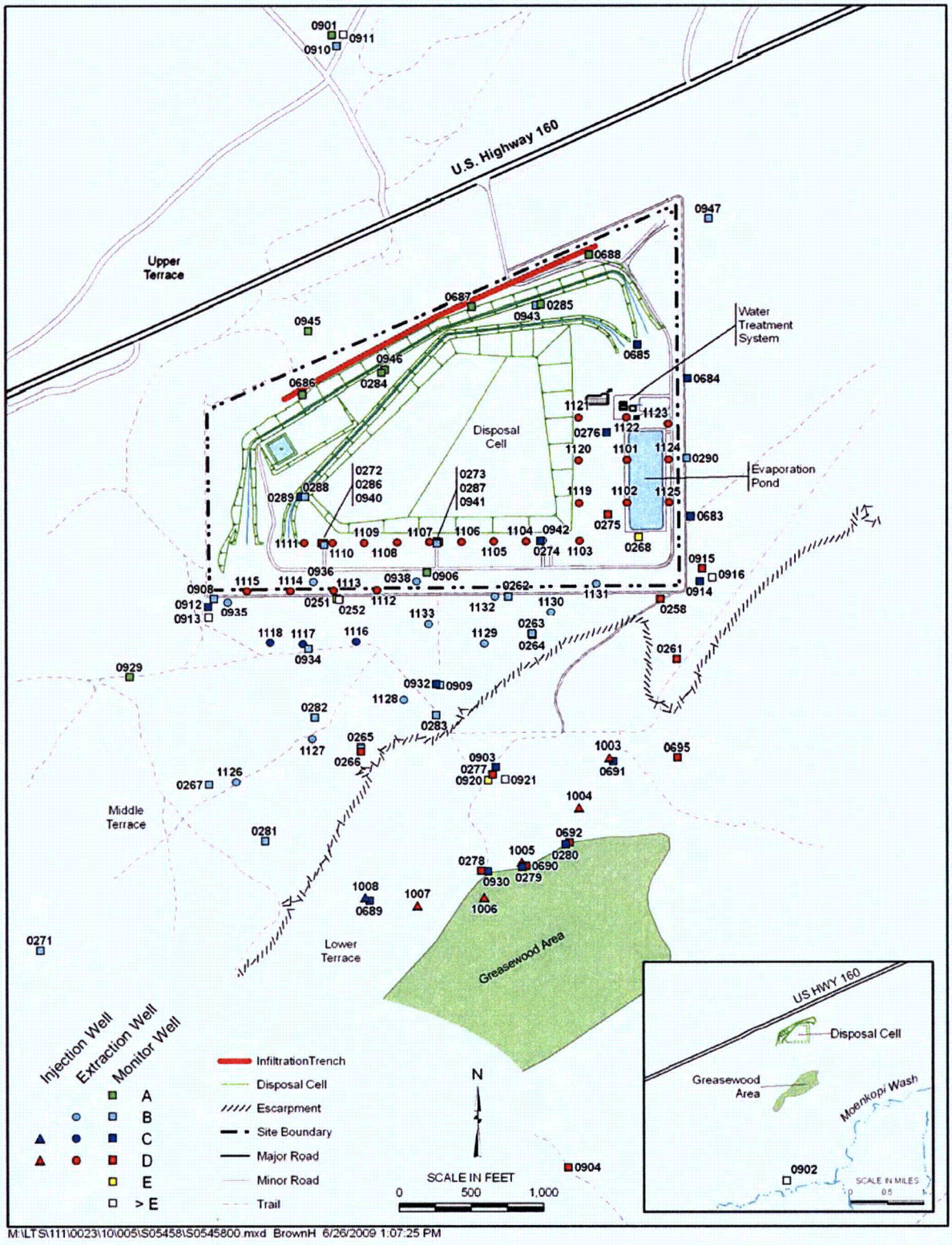

Figure 2a. Tuba City Site Features and Well Locations

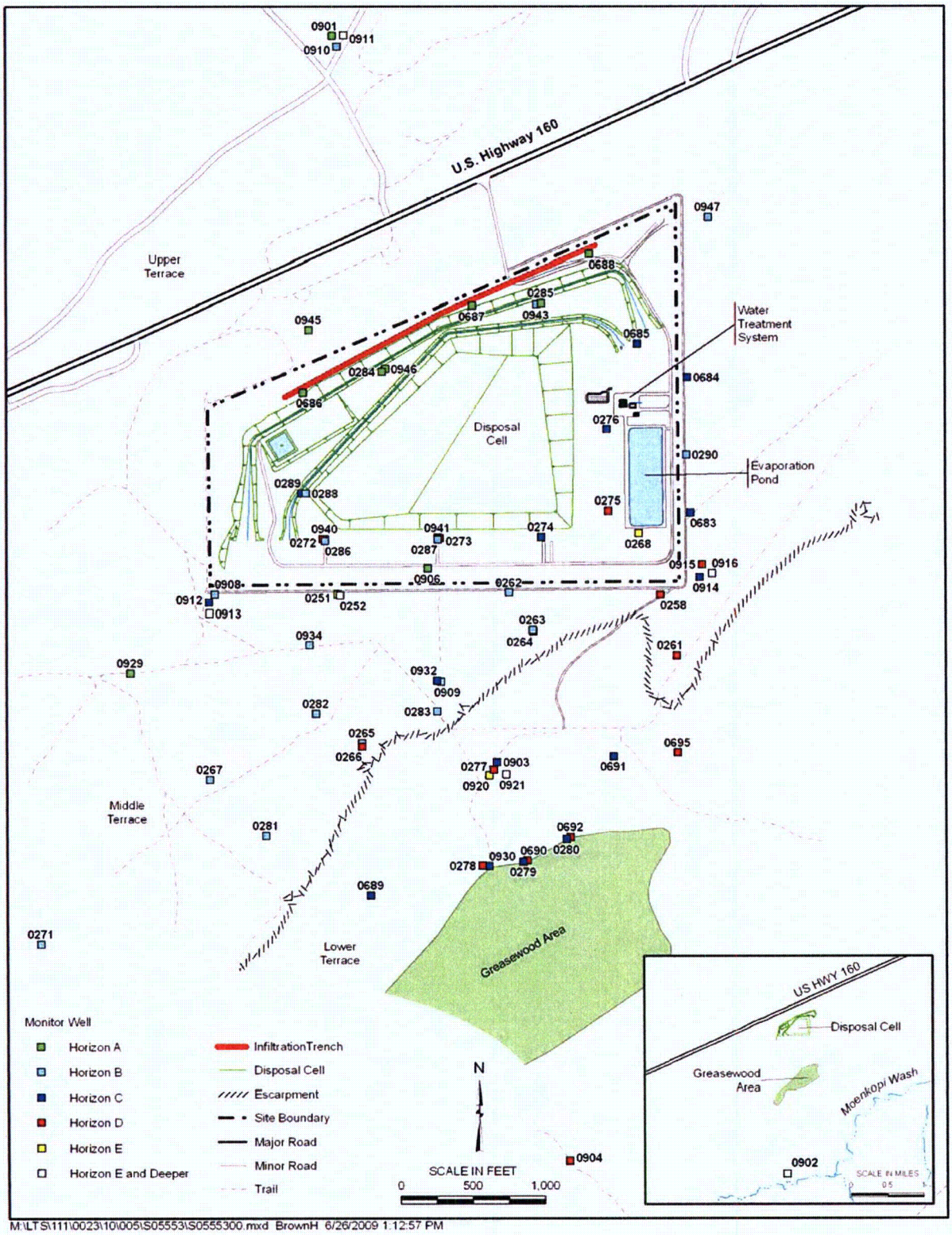

Figure 2b. Tuba City Site Features and Well Locations—Monitor Wells Only

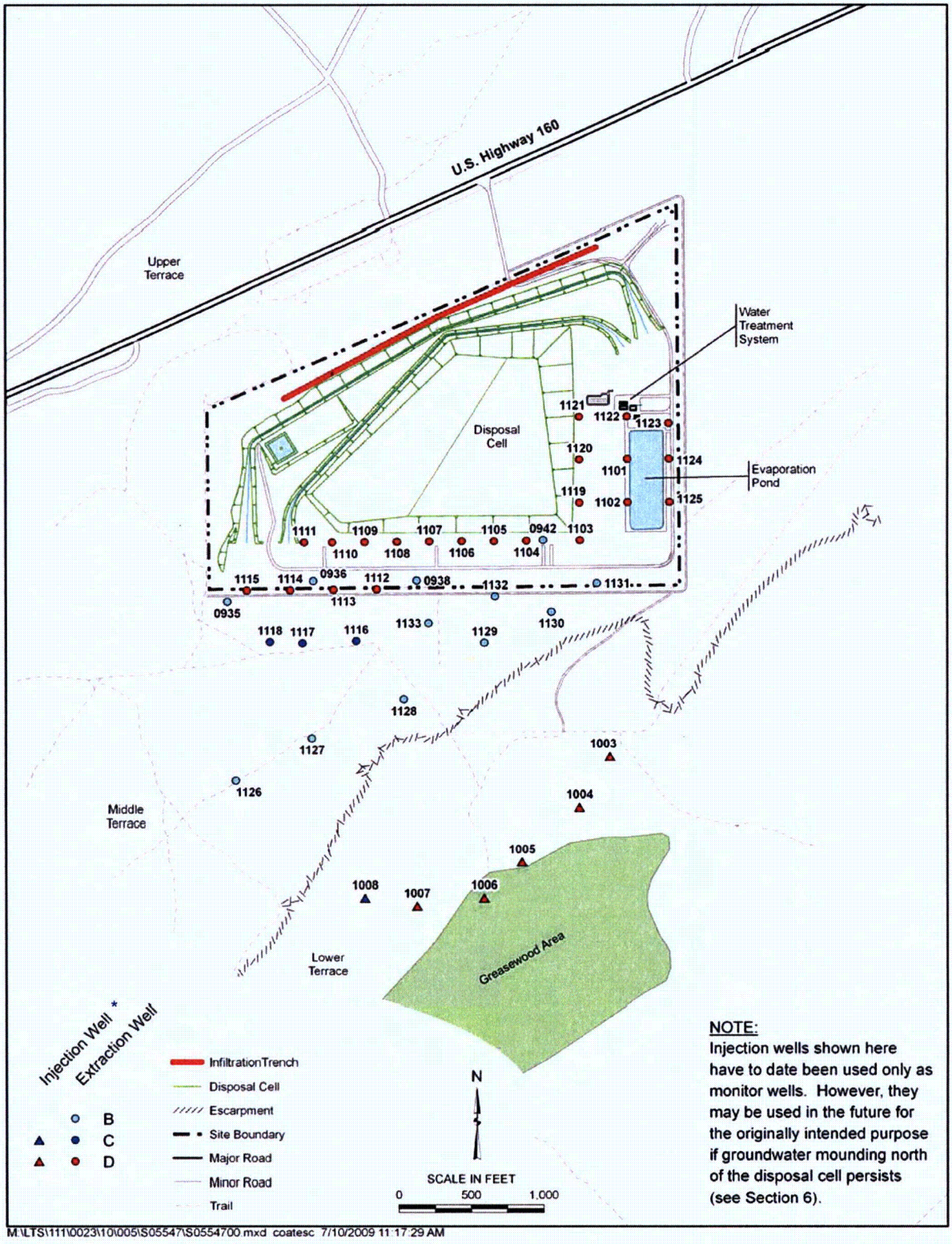

Figure 2c. Tuba City Site Features and Well Locations—Treatment System Wells Only

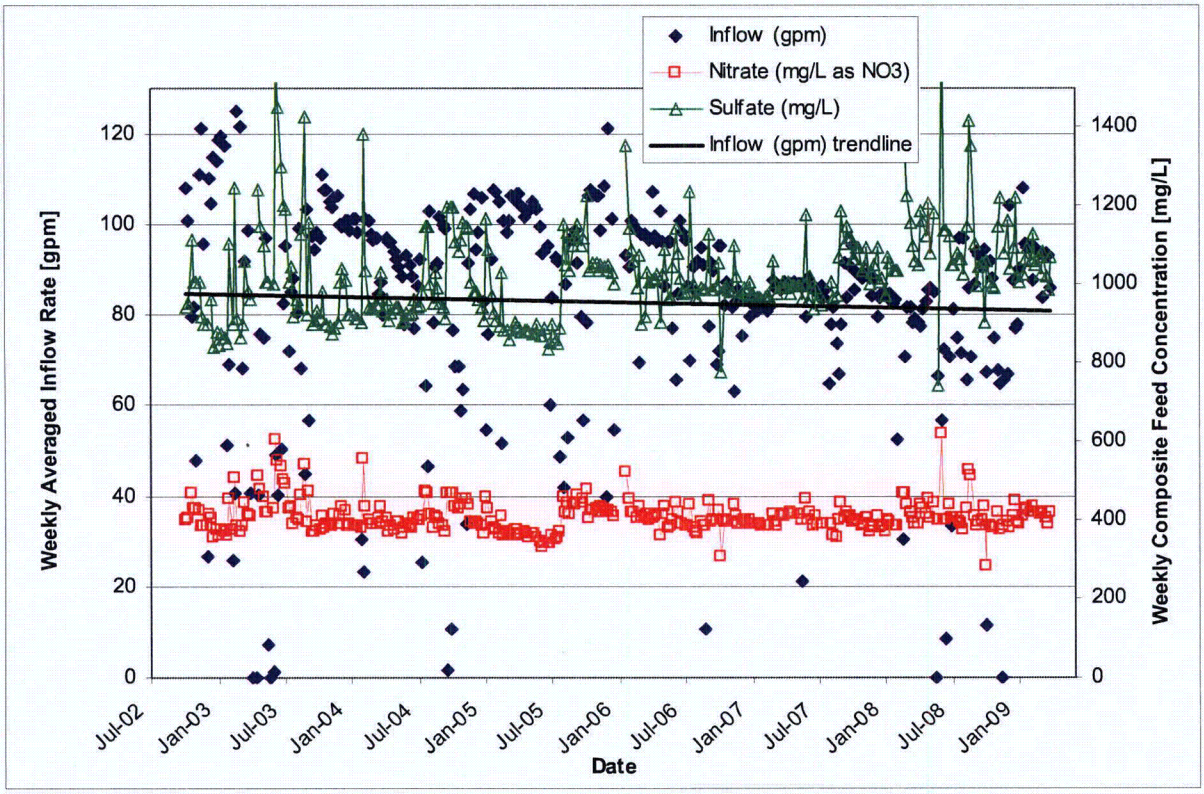

Figure 3. Treatment Plant Inflow Rate and Nitrate and Sulfate Concentrations

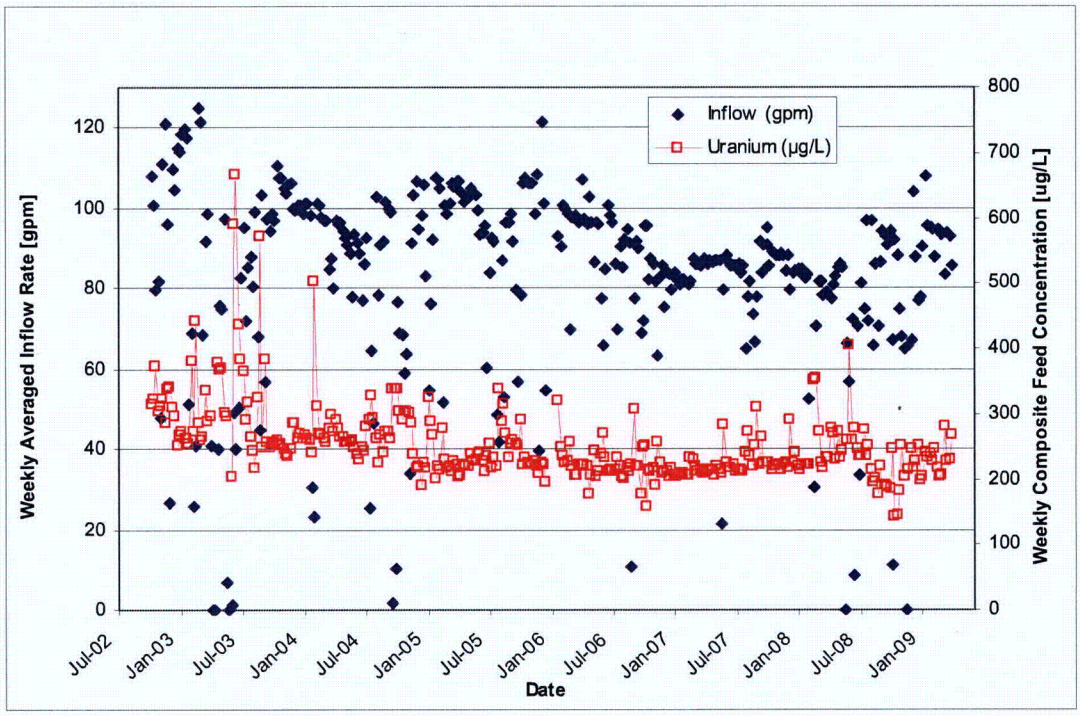

Figure 4. Treatment Plant Inflow Rate and Uranium Concentration

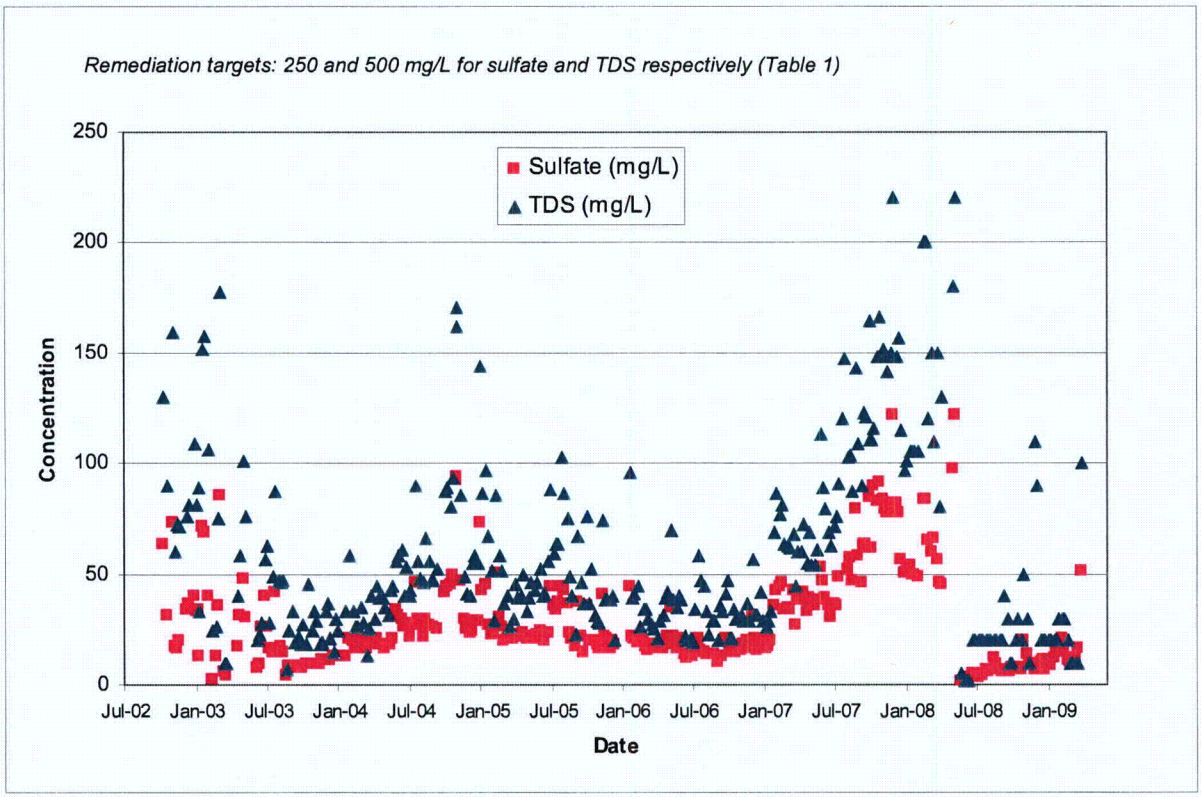

Figure 5a. Treatment Plant Distillate Quality—Sulfate and TDS

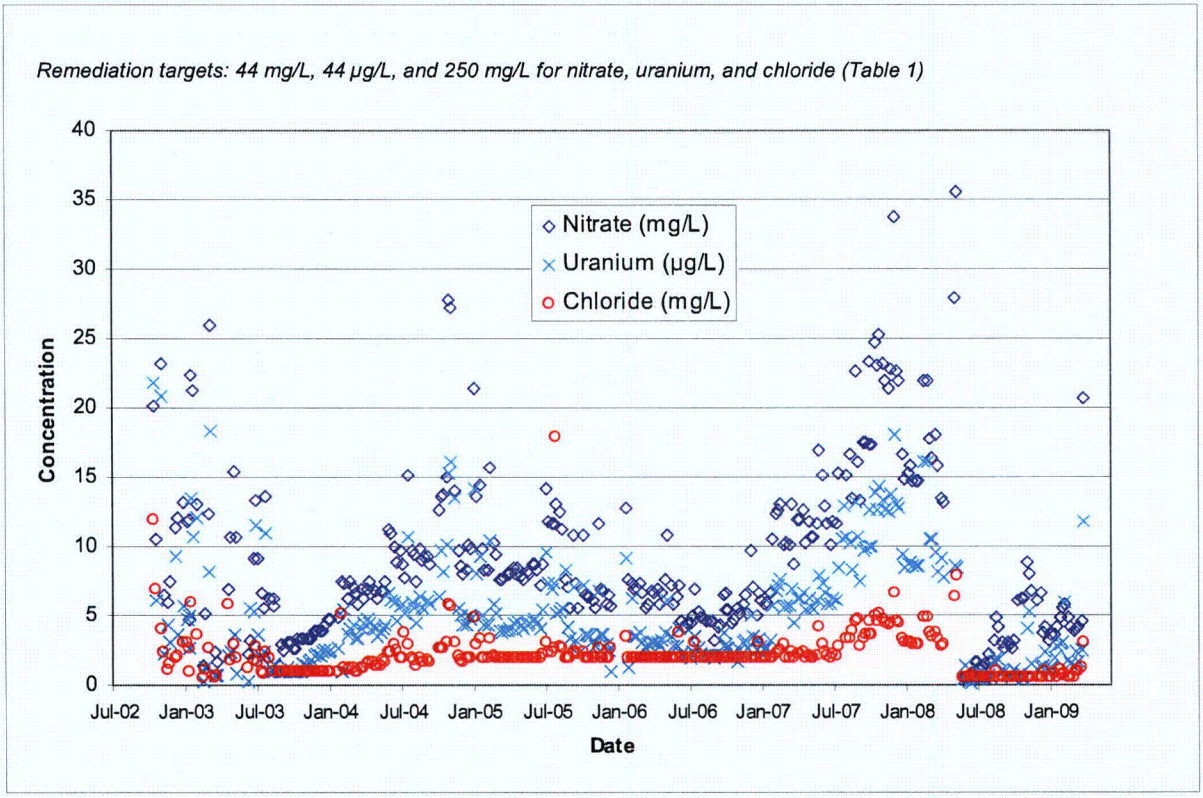

Figure 5b. Treatment Plant Distillate Quality—Nitrate, Uranium, and Chloride

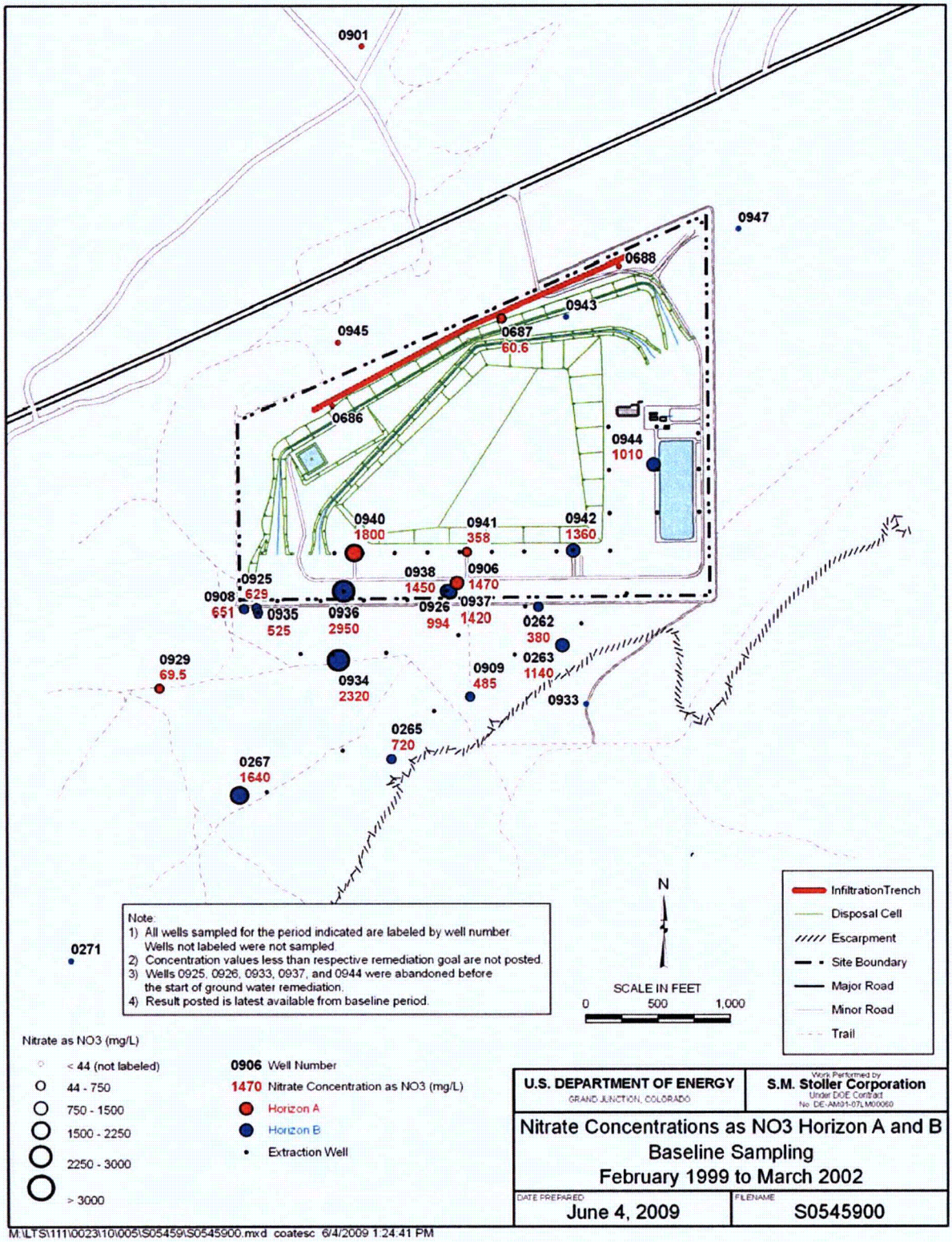

Figure 6a. Nitrate Concentrations as NO_3, Horizons A and B, Baseline Period

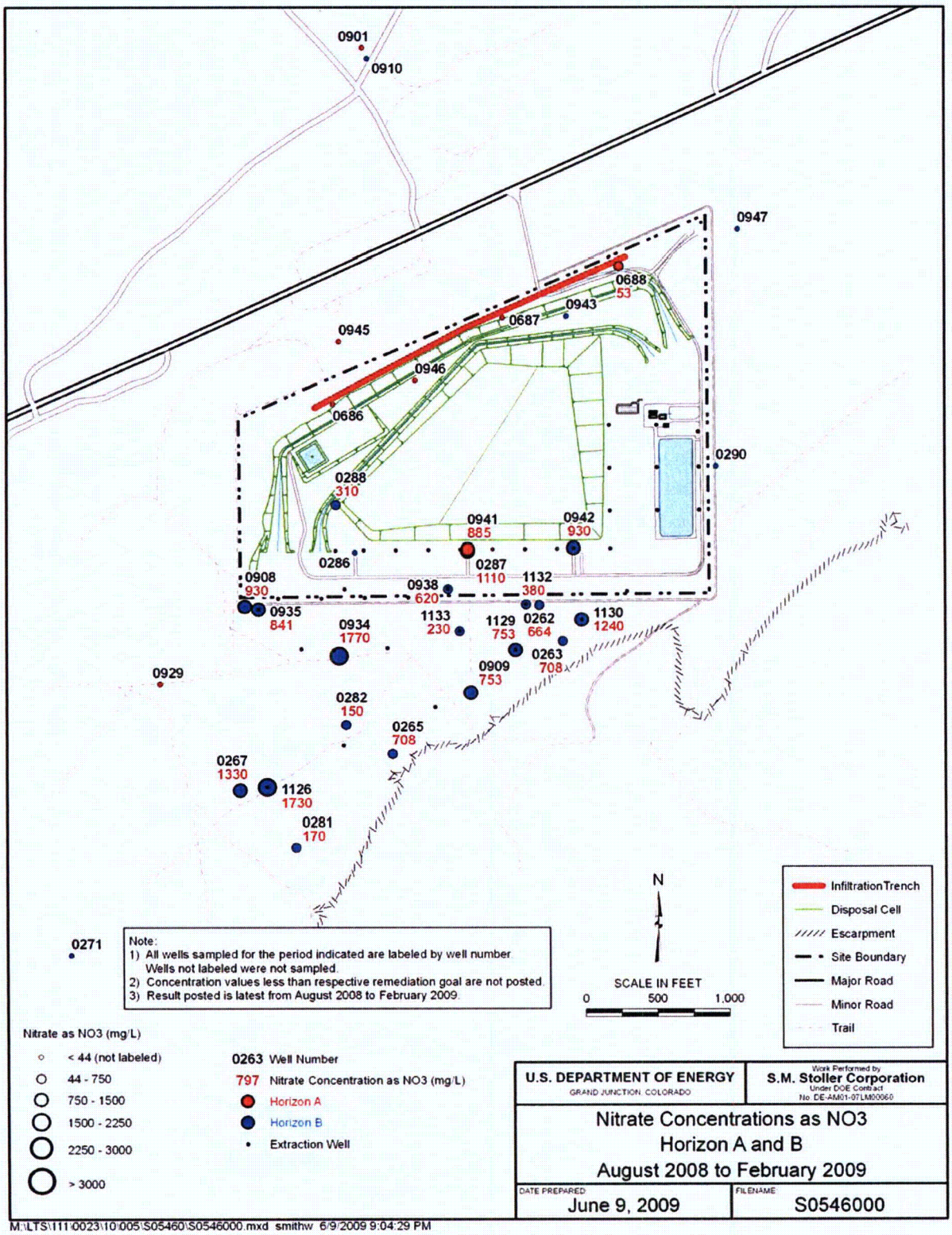

Figure 6b. Nitrate Concentrations as NO_3, Horizons A and B, February 2009

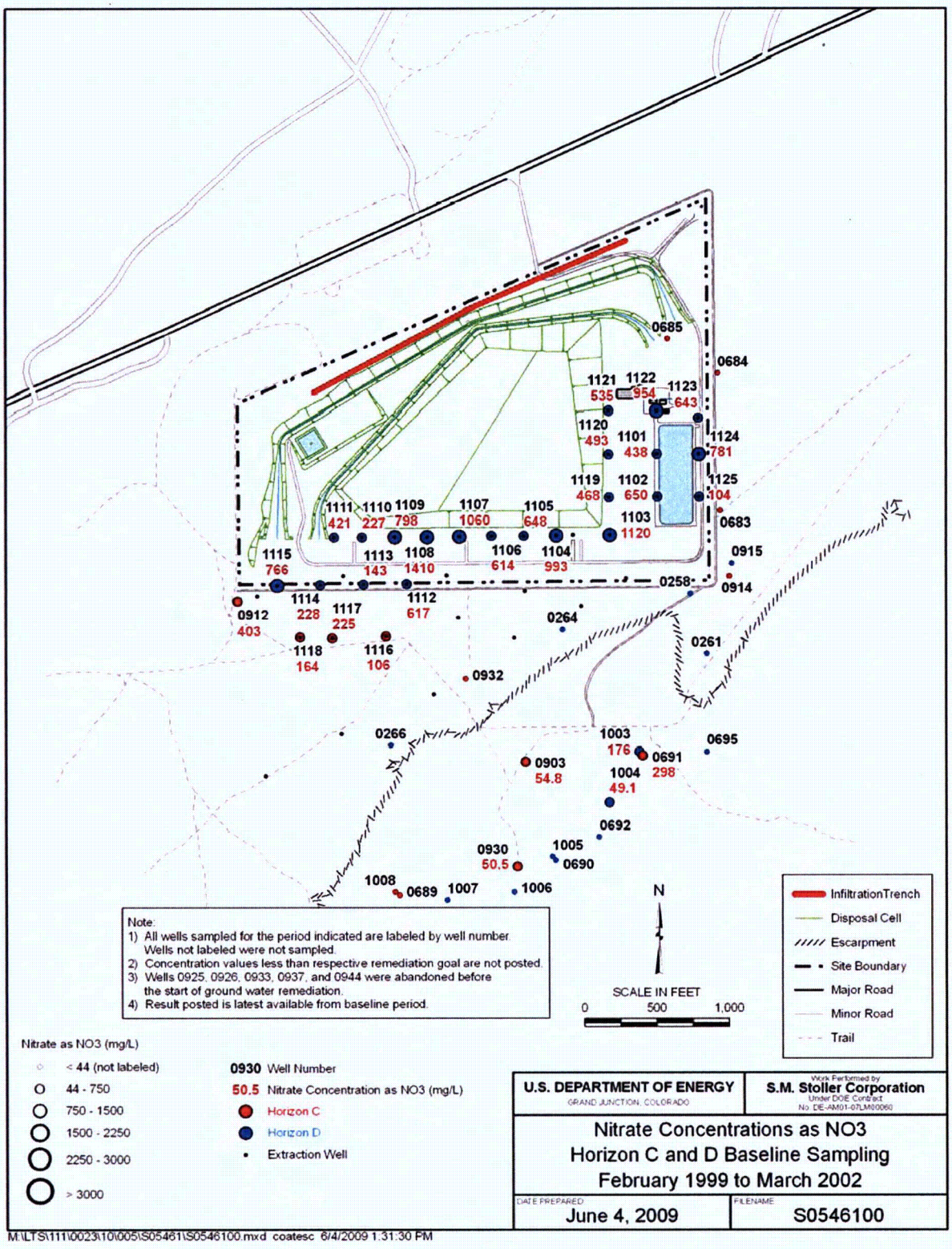

Figure 7a. Nitrate Concentrations as NO_3, Horizons C and D, Baseline Period

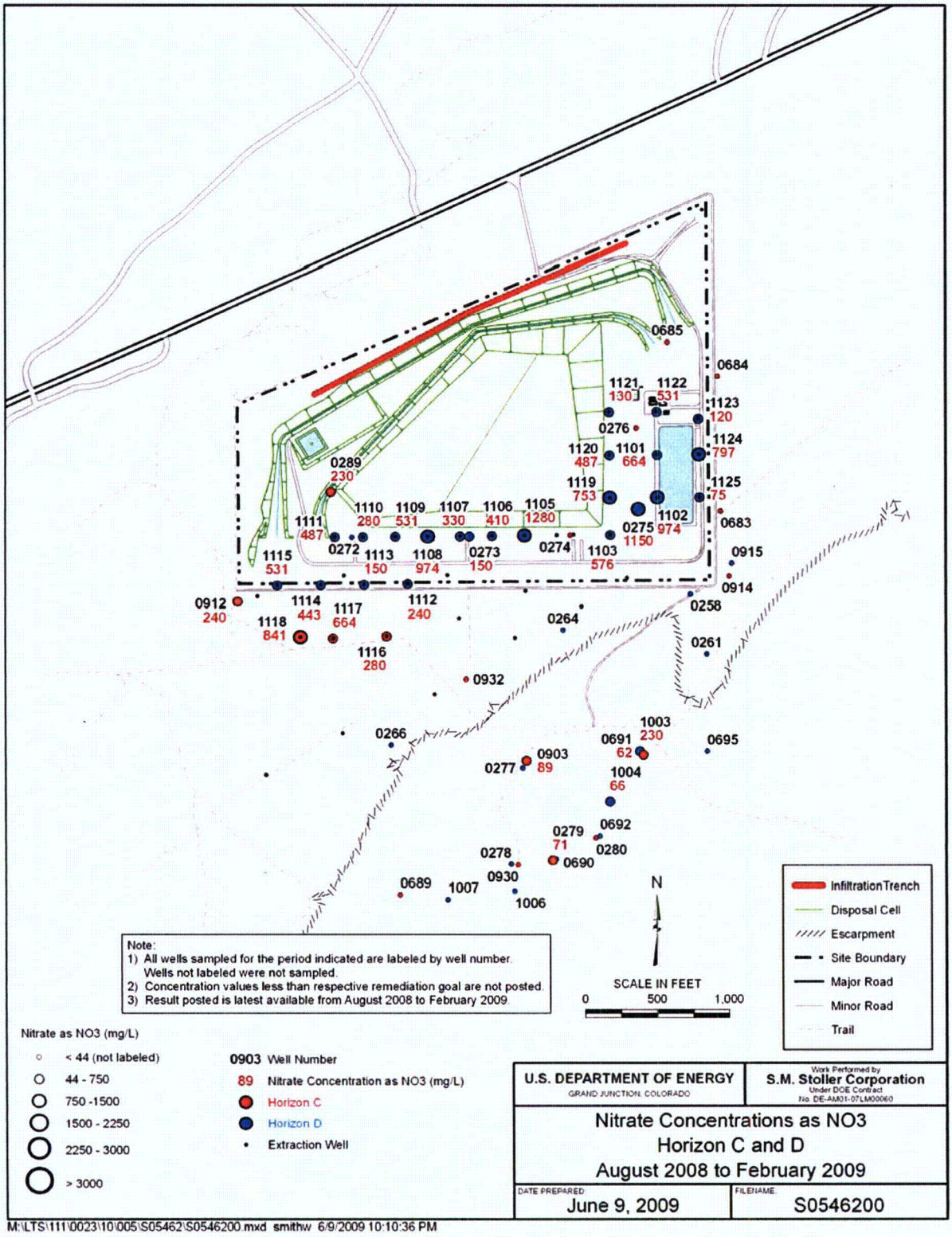

Figure 7b. Nitrate Concentrations as NO_3, Horizons C and D, February 2009

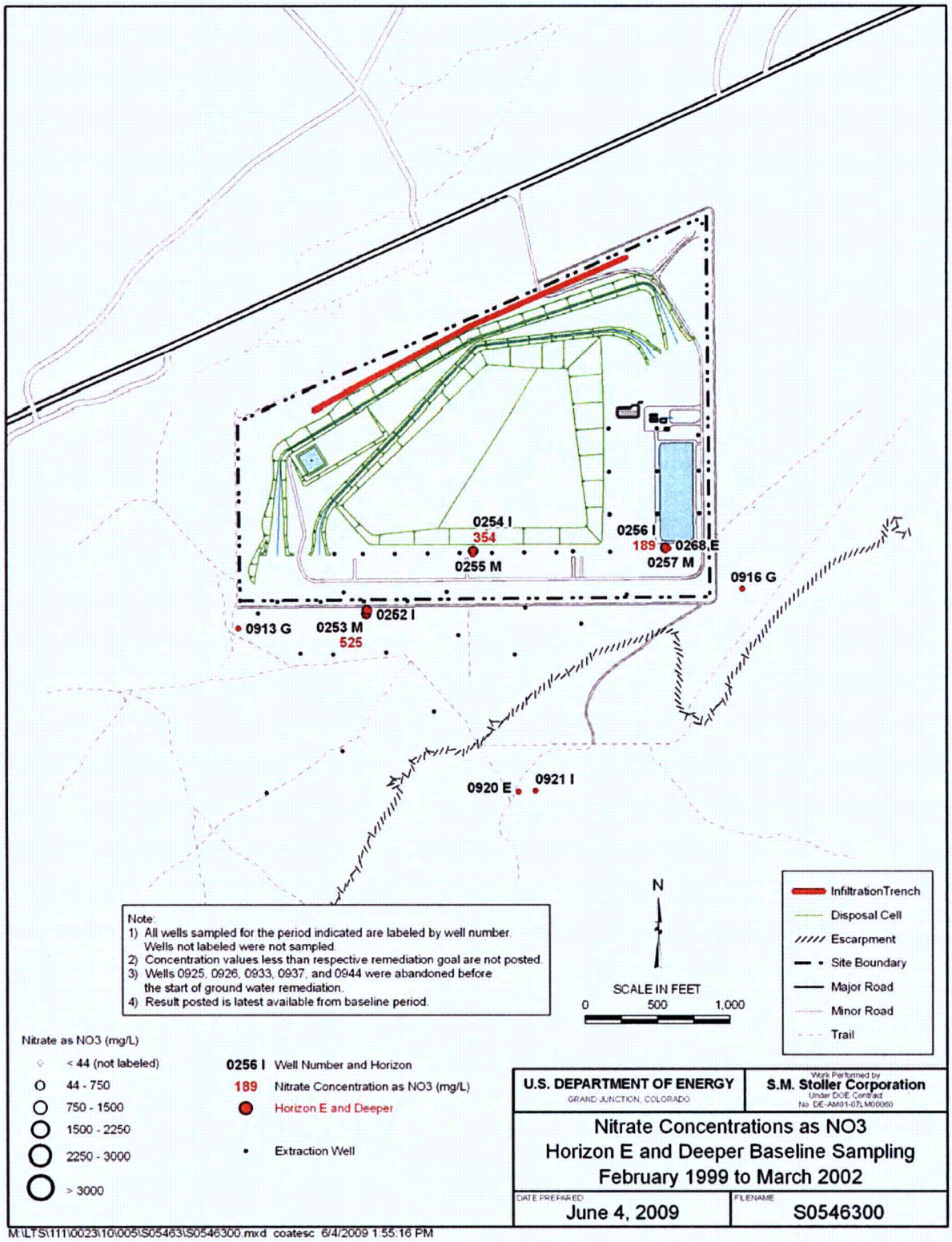

Figure 8a. Nitrate Concentrations as NO_3, Horizons E and Deeper, Baseline Period

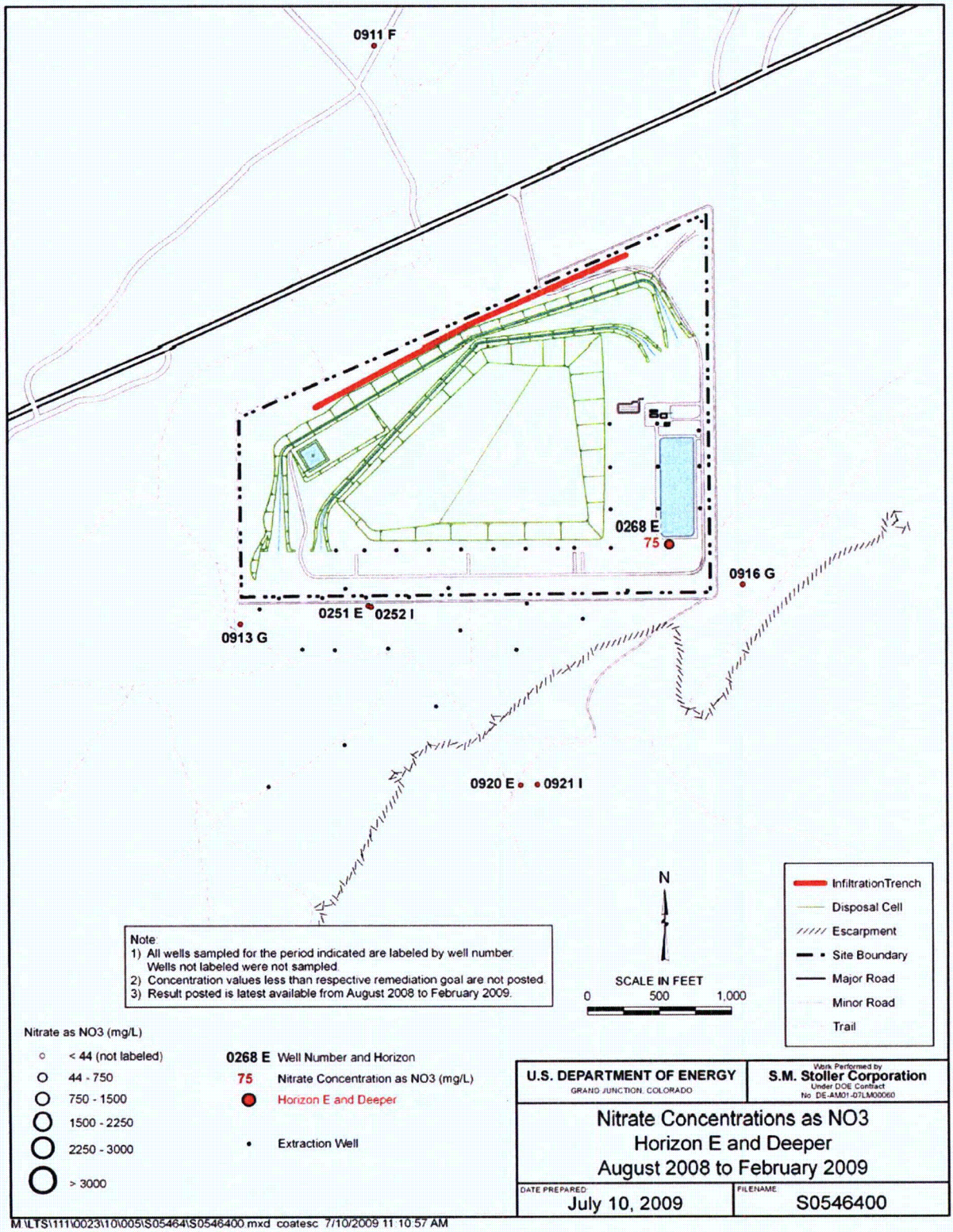

Figure 8b. Nitrate Concentrations as NO_3, Horizons E and Deeper, February 2009

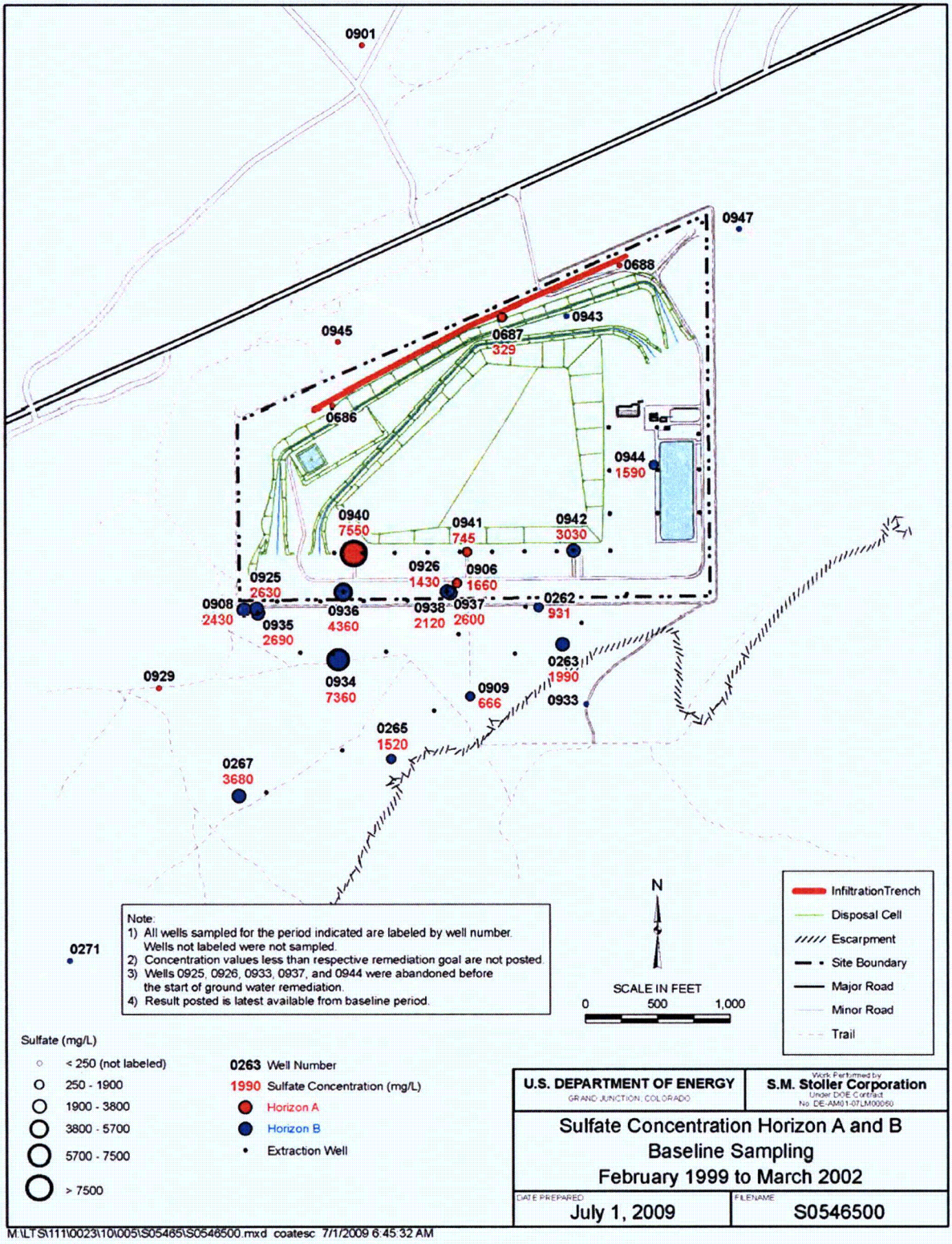

Figure 9a. Sulfate Concentrations in Groundwater, Horizons A and B, Baseline Period

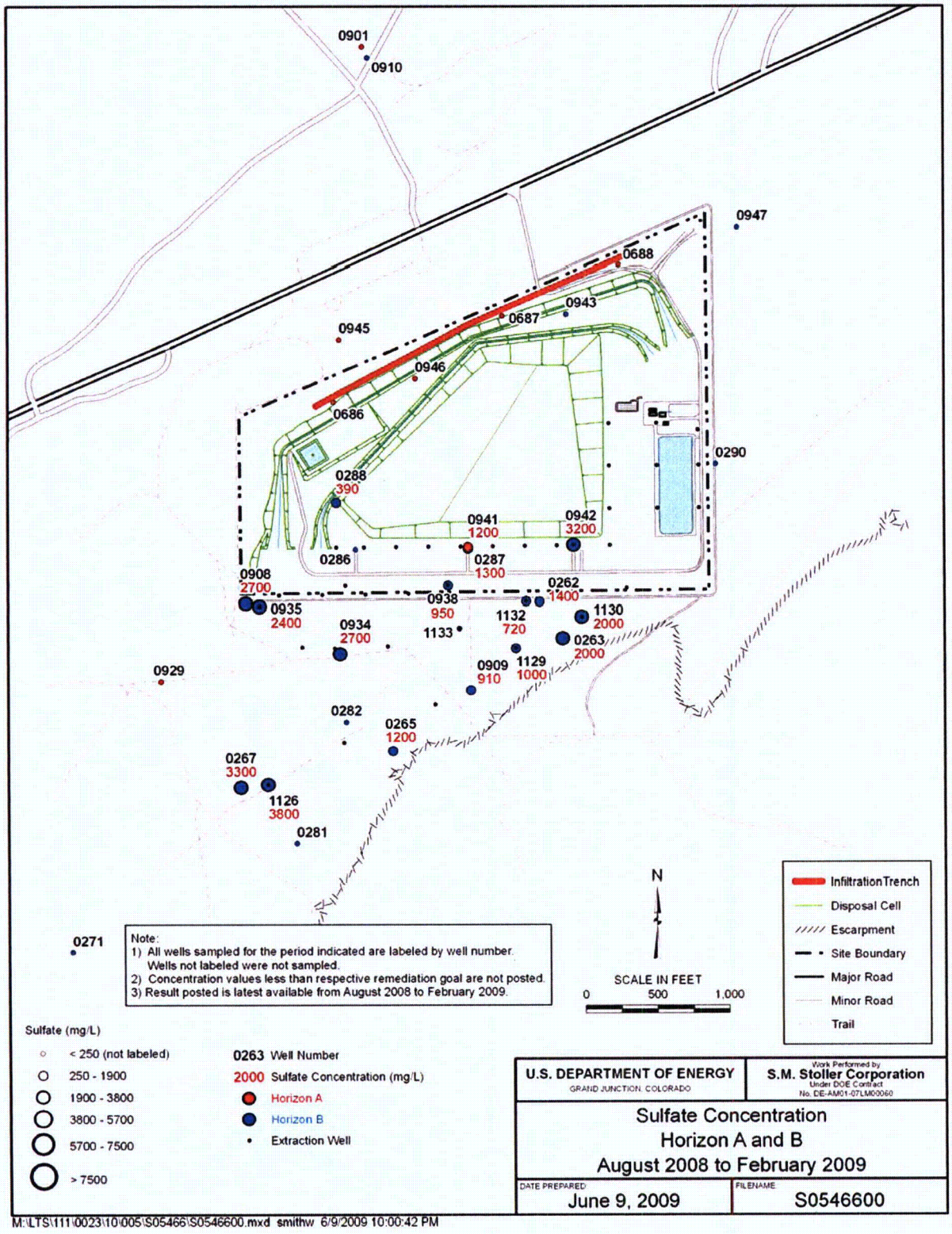

Figure 9b. Sulfate Concentrations in Groundwater, Horizons A and B, February 2009

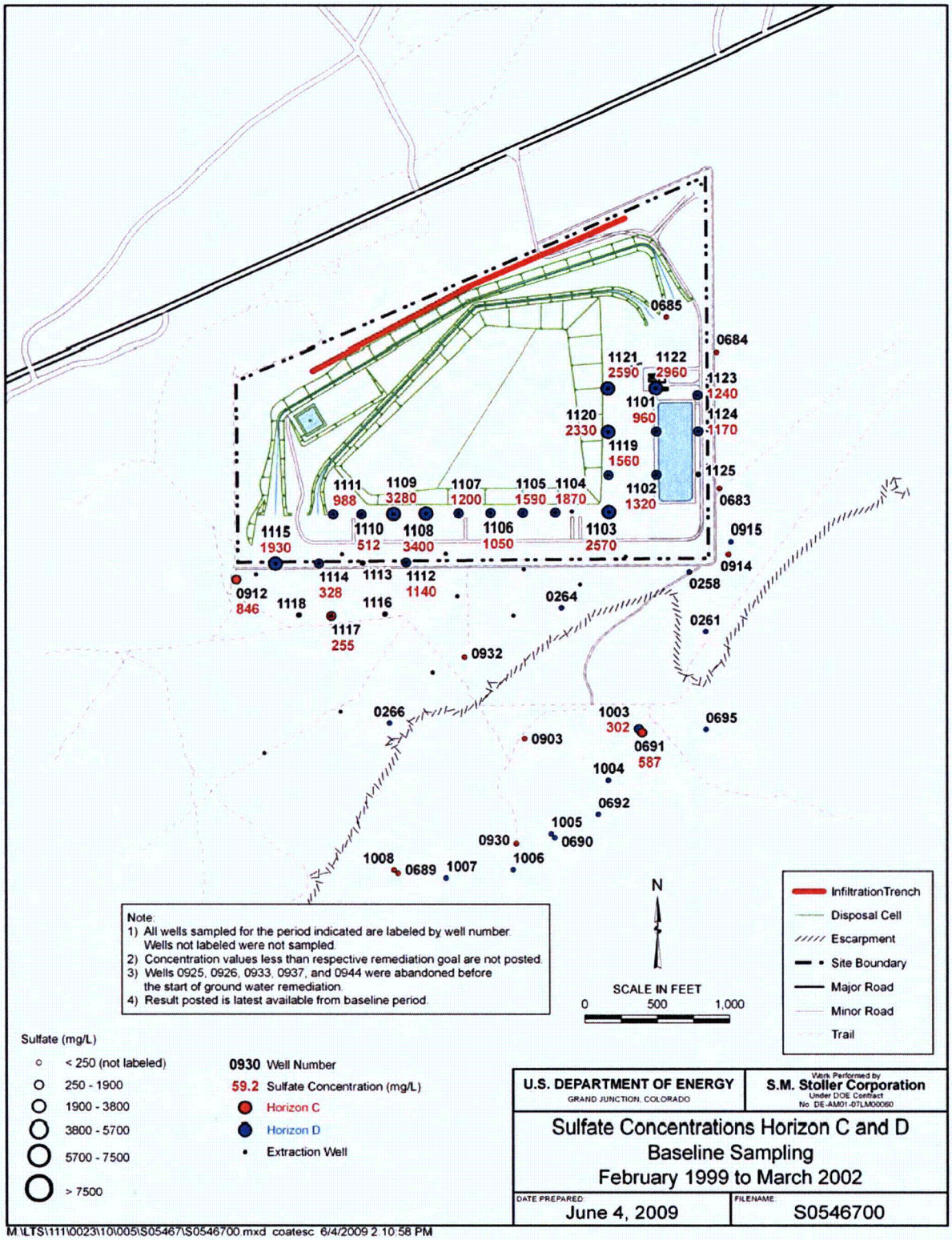

Figure 10a. Sulfate Concentrations in Groundwater, Horizons C and D, Baseline Period

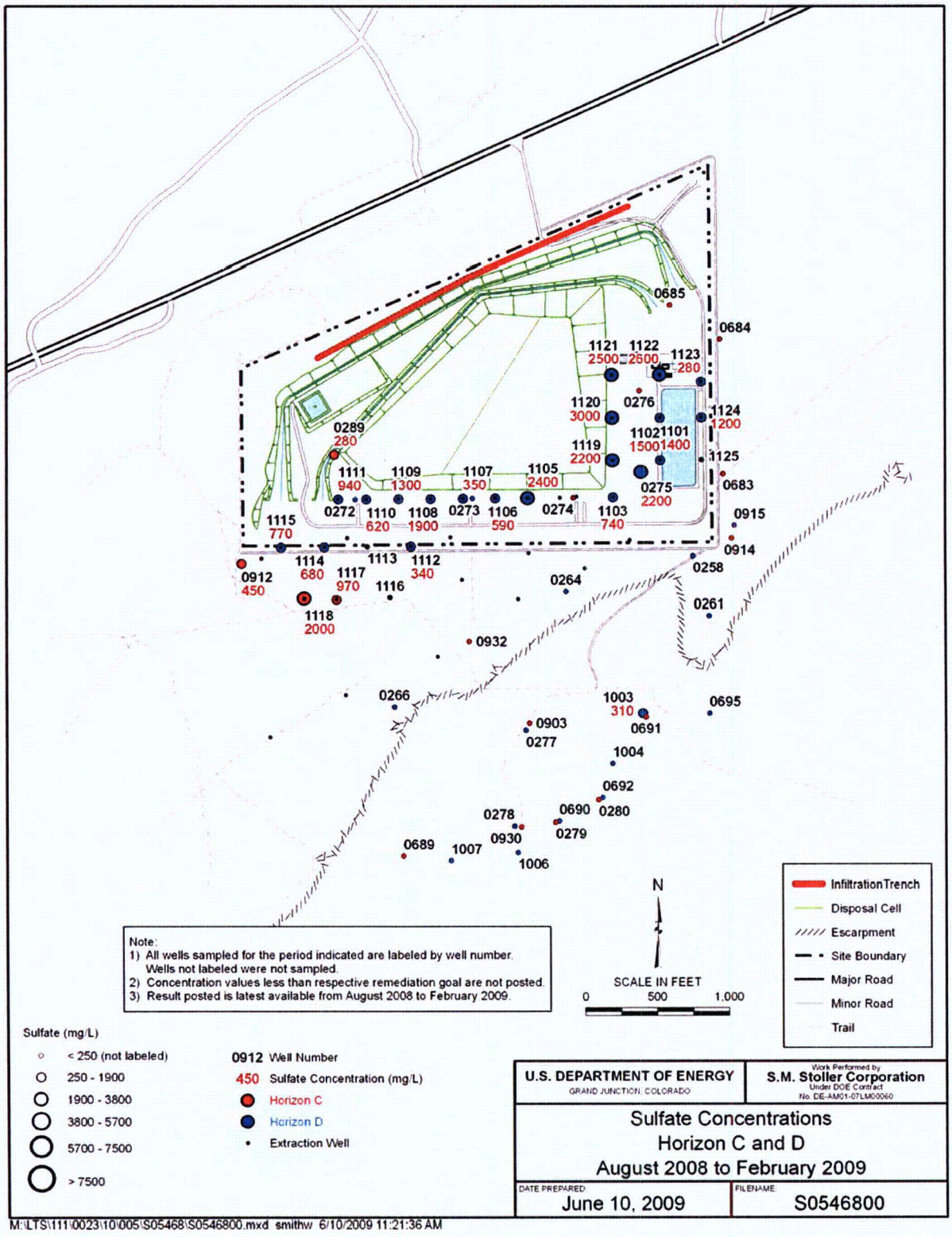

Figure 10b. Sulfate Concentrations in Groundwater, Horizons C and D, February 2009

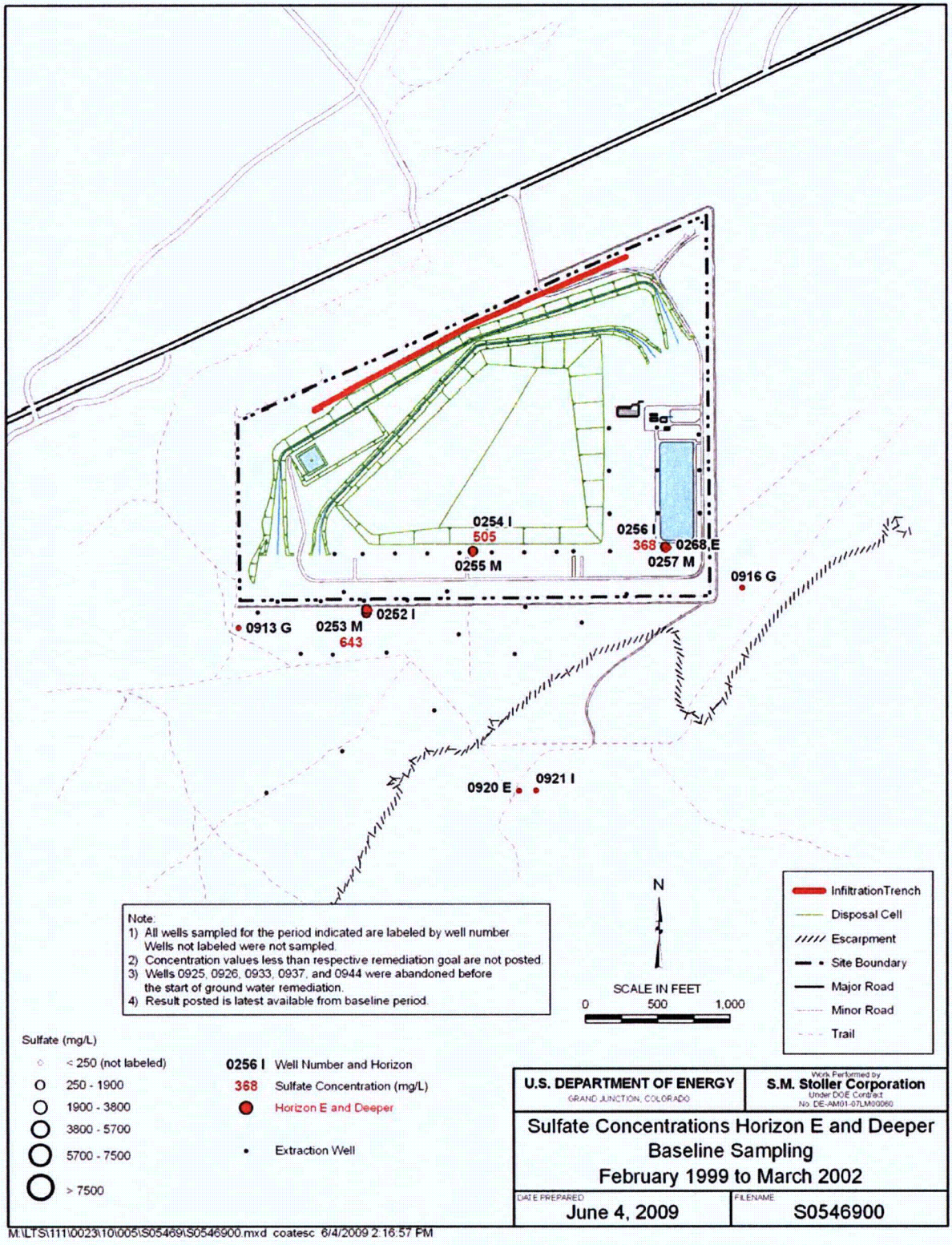

Figure 11a. Sulfate Concentrations in Groundwater, Horizons E and Deeper, Baseline Period

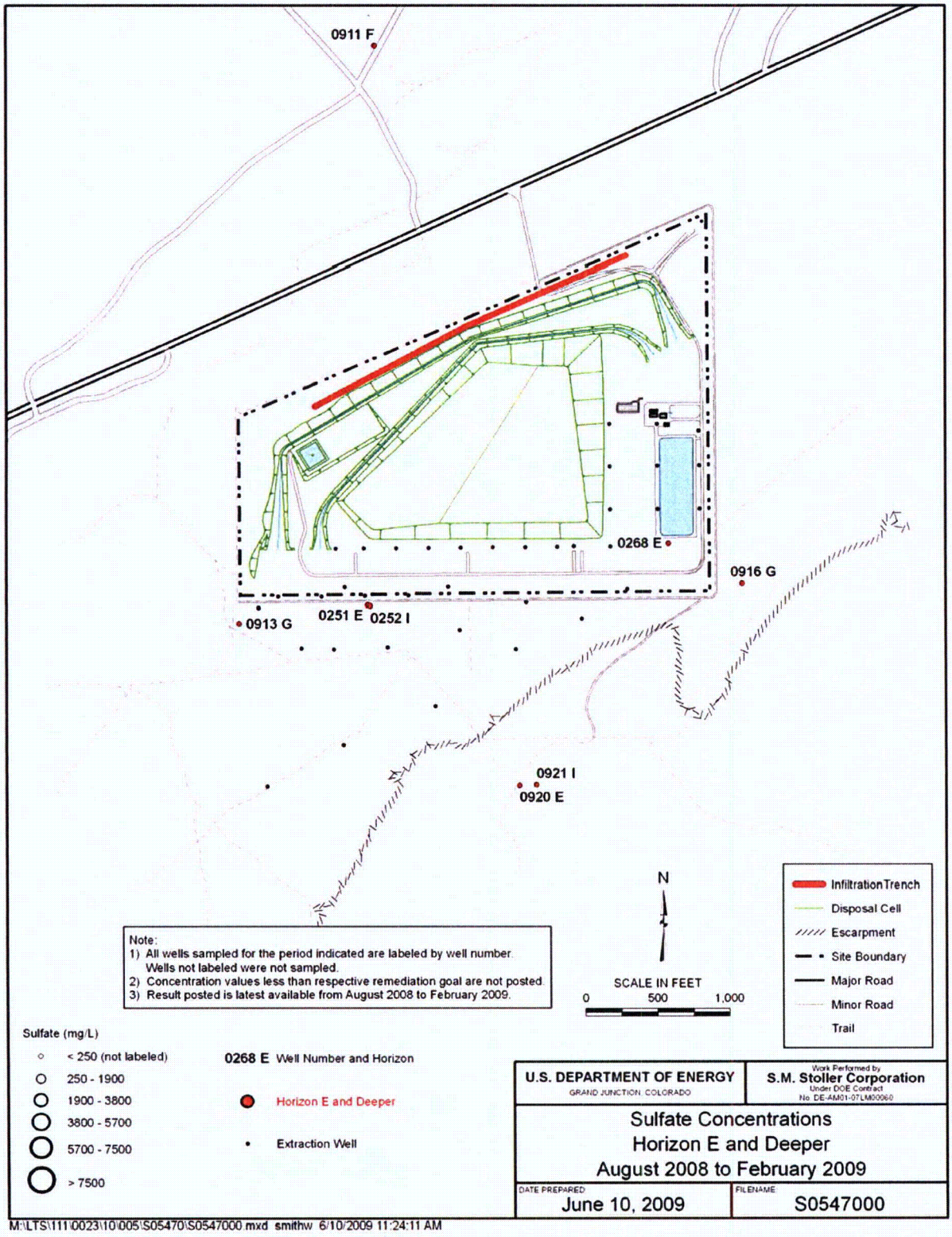

Figure 11b. Sulfate Concentrations in Groundwater, Horizons E and Deeper, February 2009

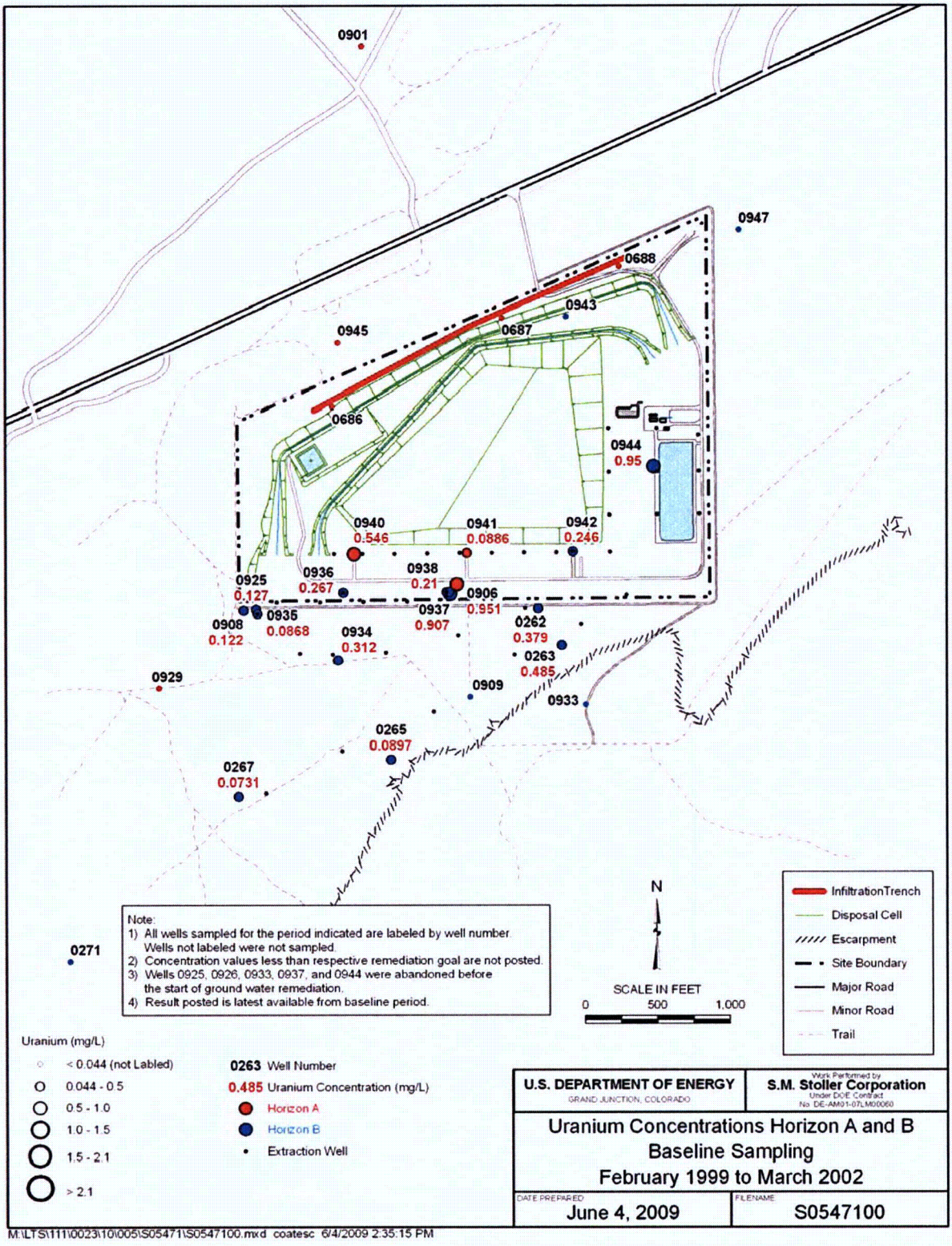

Figure 12a. Uranium Concentrations in Groundwater, Horizons A and B, Baseline Period

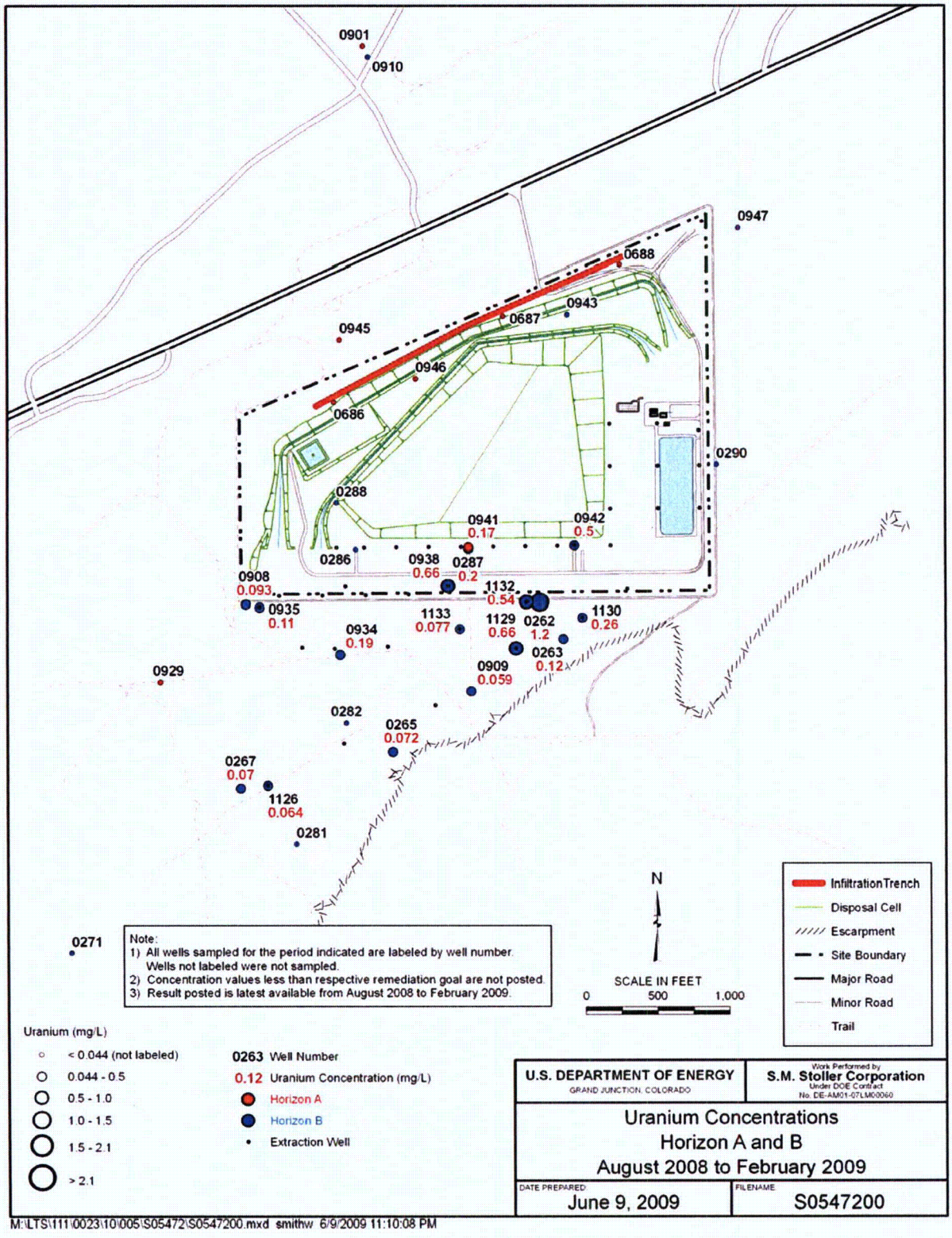

Figure 12b. Uranium Concentrations in Groundwater, Horizons A and B, February 2009

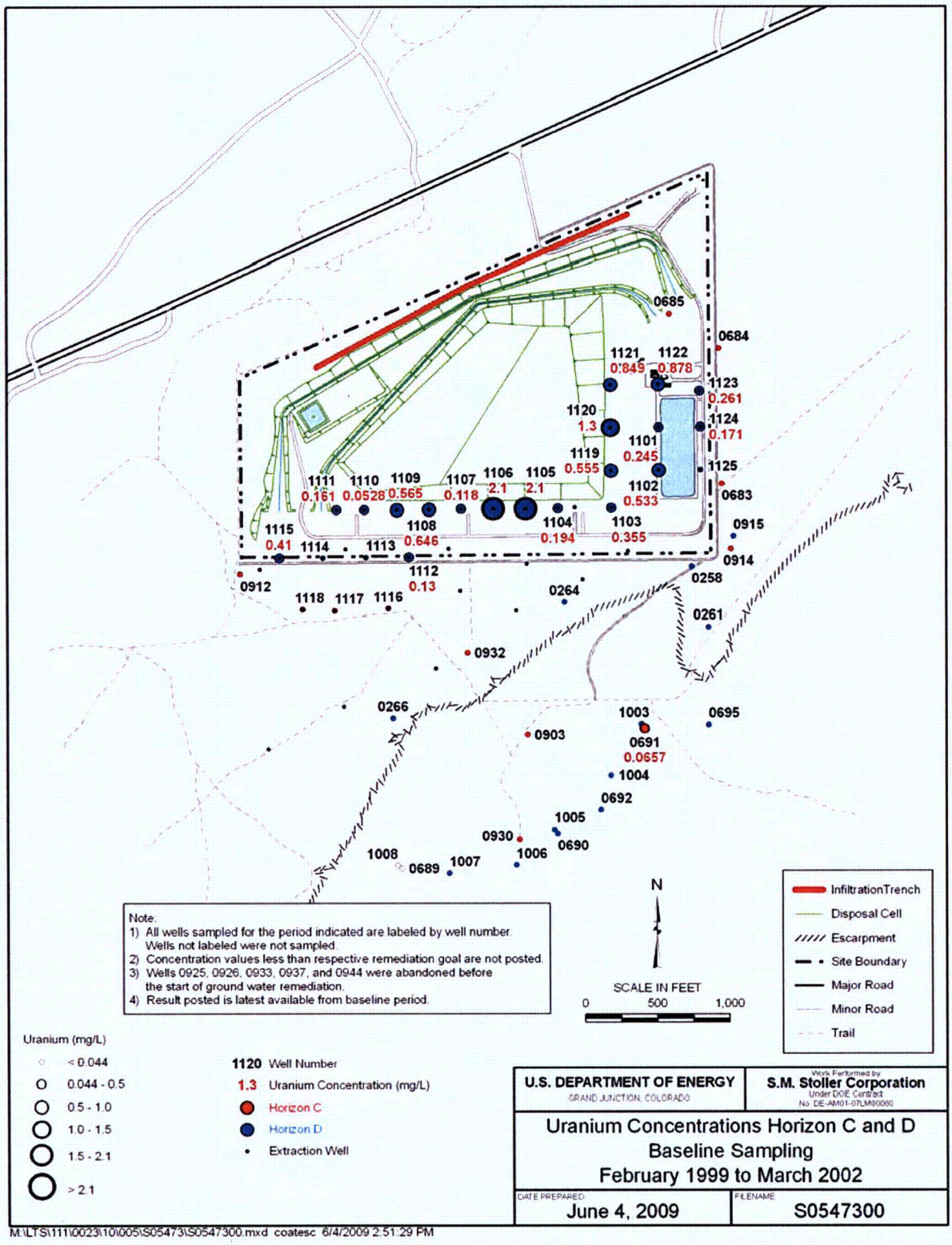

Figure 13a. Uranium Concentrations in Groundwater, Horizons C and D, Baseline Period

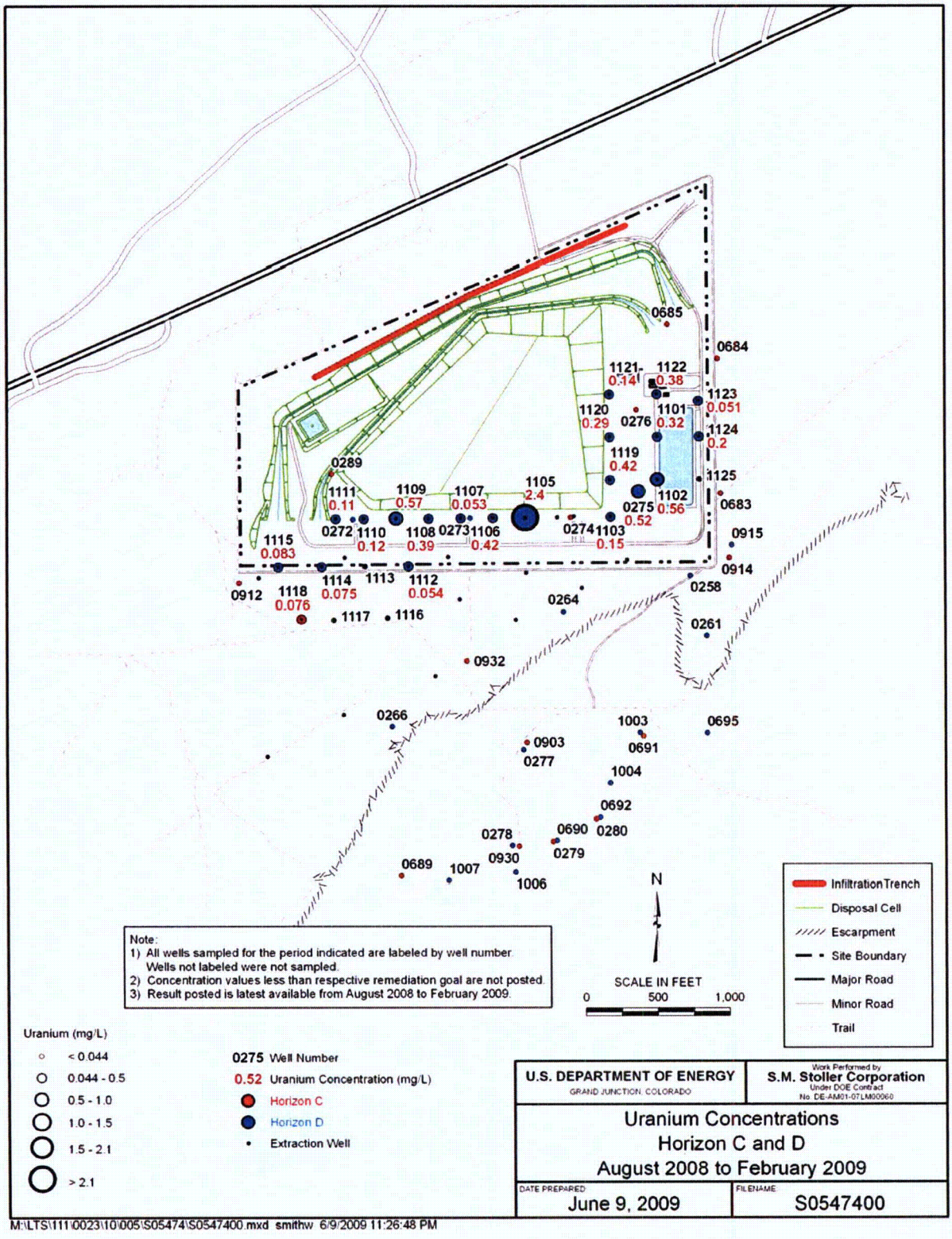

Figure 13b. Uranium Concentrations in Groundwater, Horizons C and D, February 2009

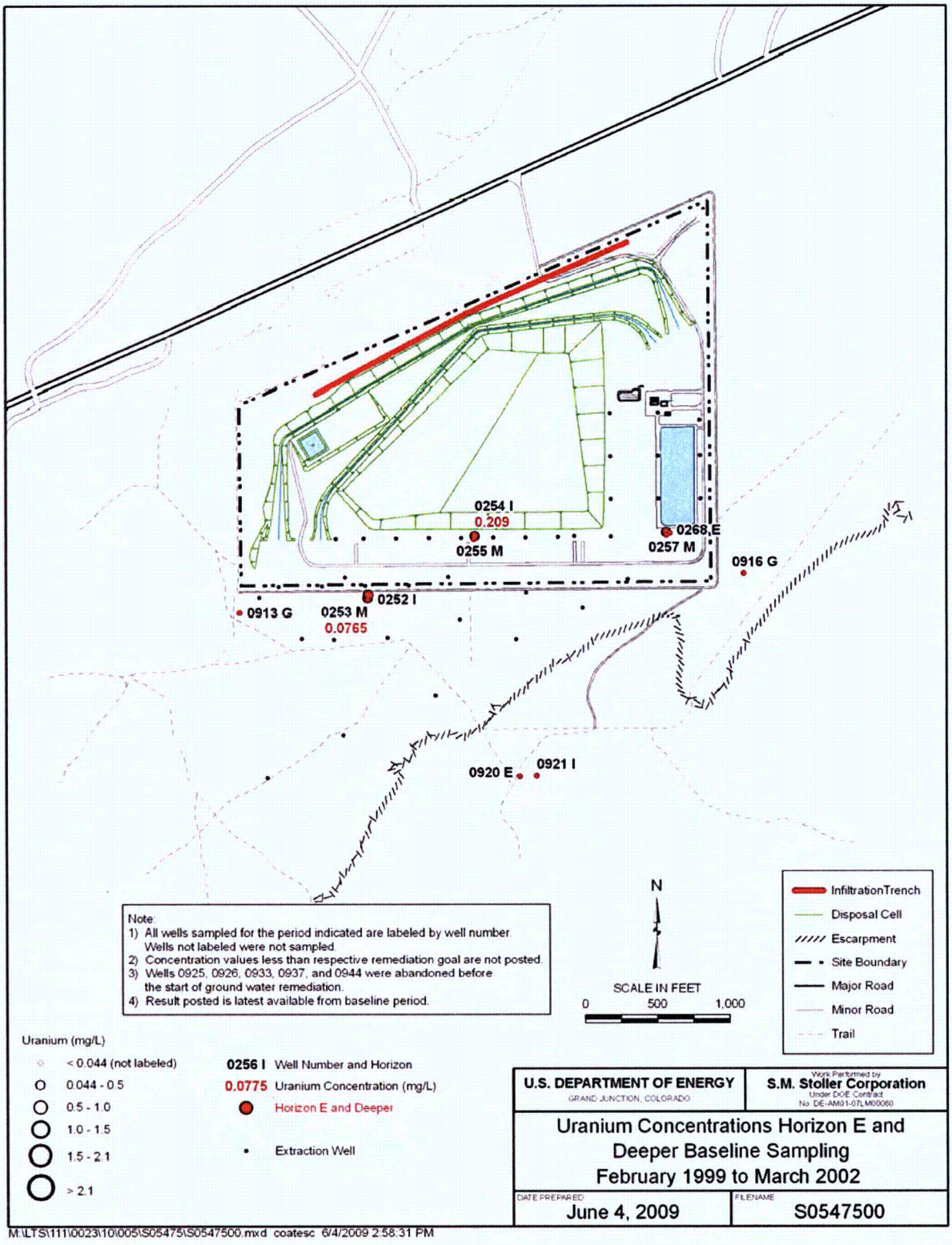

Figure 14a. Uranium Concentrations in Groundwater, Horizons E and Deeper, Baseline Period

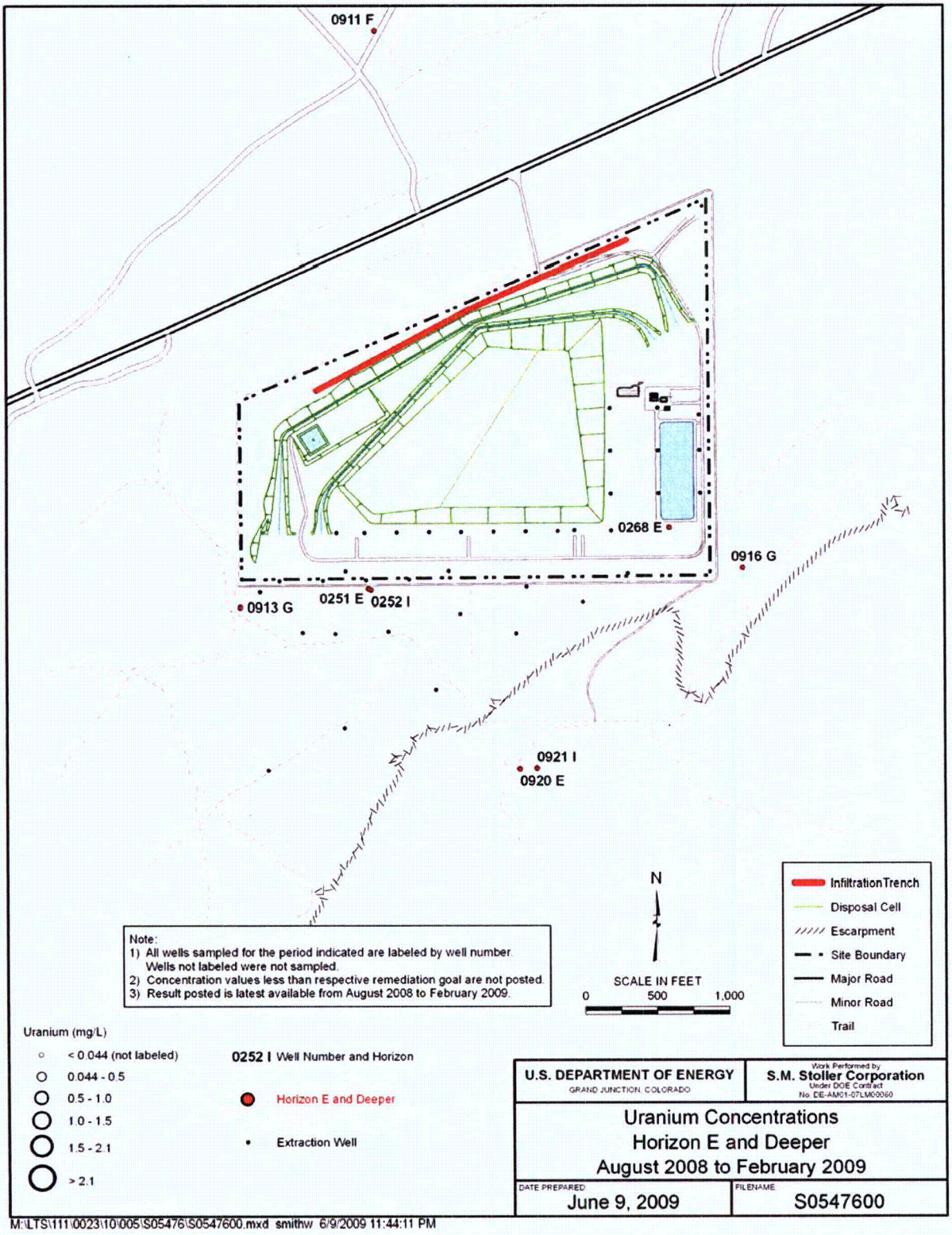

Figure 14b. Uranium Concentrations in Groundwater, Horizons E and Deeper, February 2009

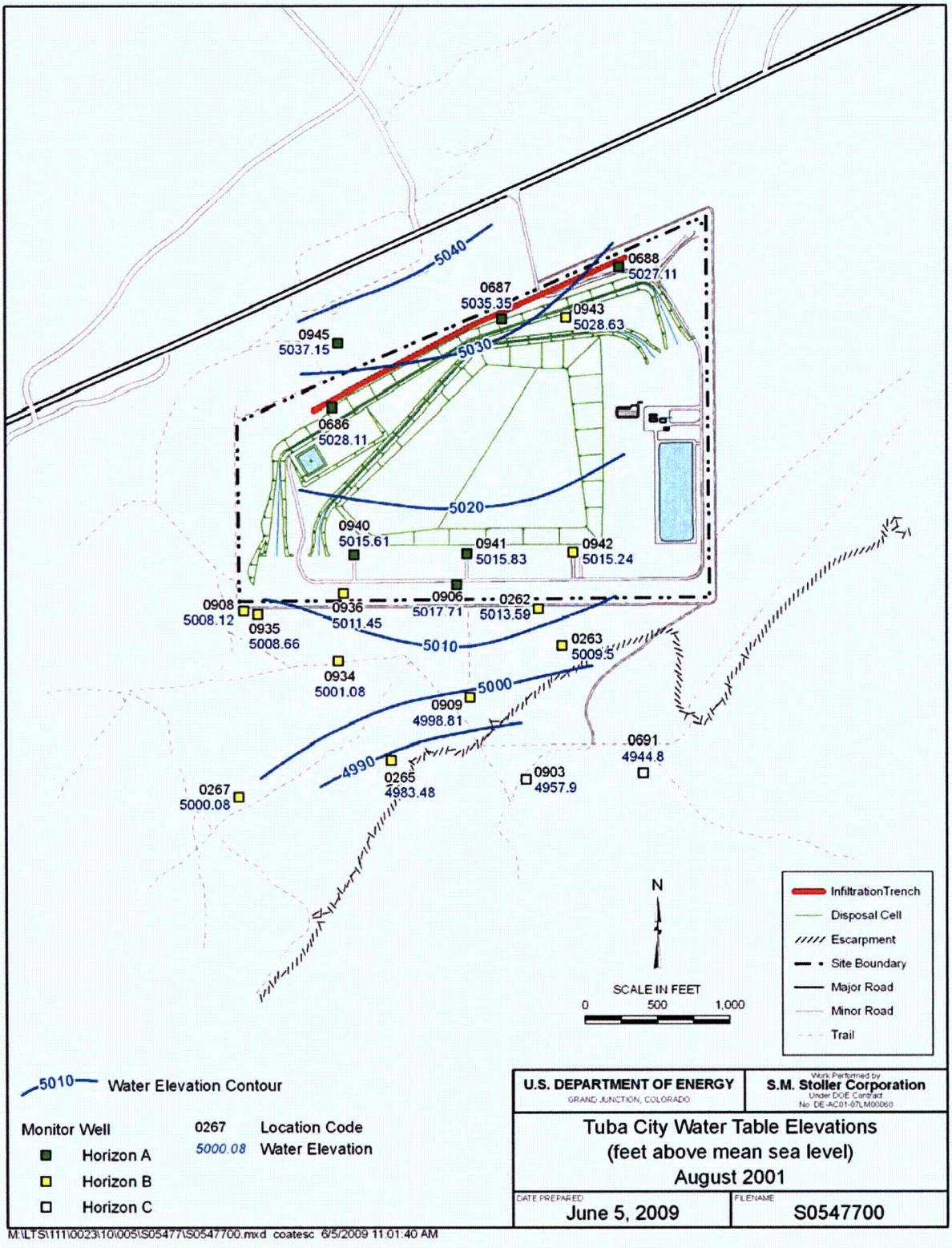

Figure 15. Water Table Elevations (Feet above Mean Sea Level), Tuba City Site, August 2001

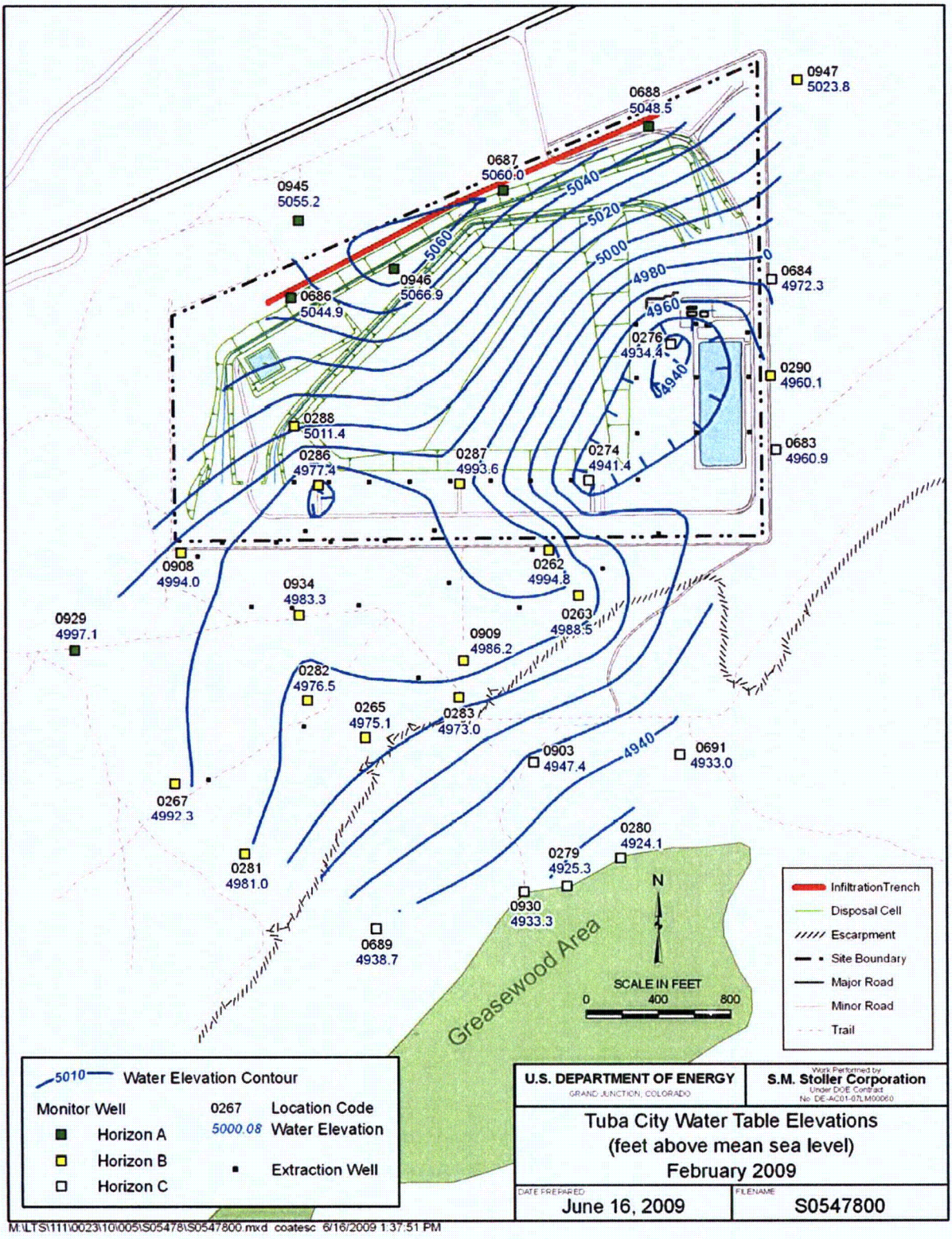

Figure 16. Water Table Contour Map, Tuba City Site, February 2009

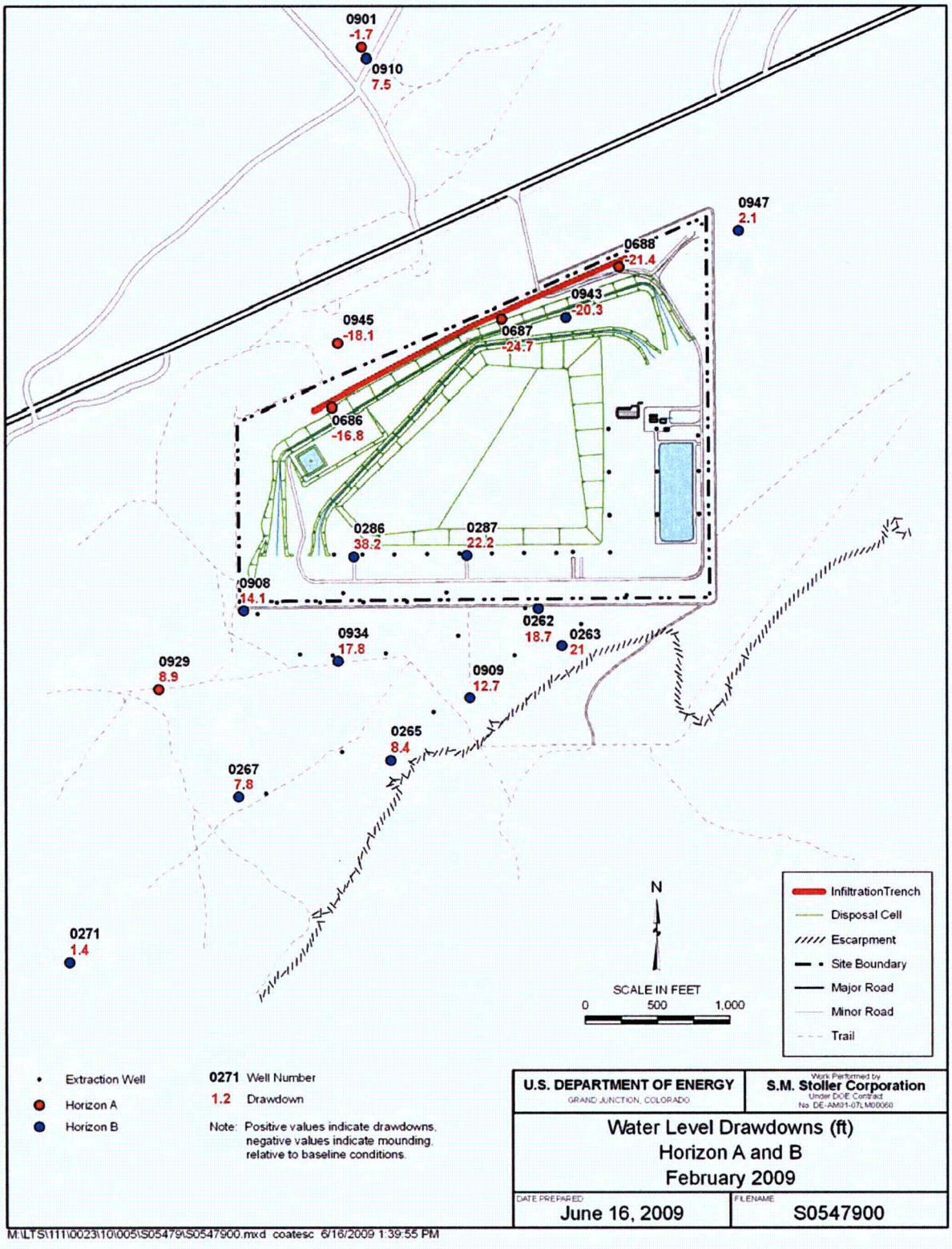

Figure 17. Water Level Drawdowns (Feet), Horizons A and B, February 2009

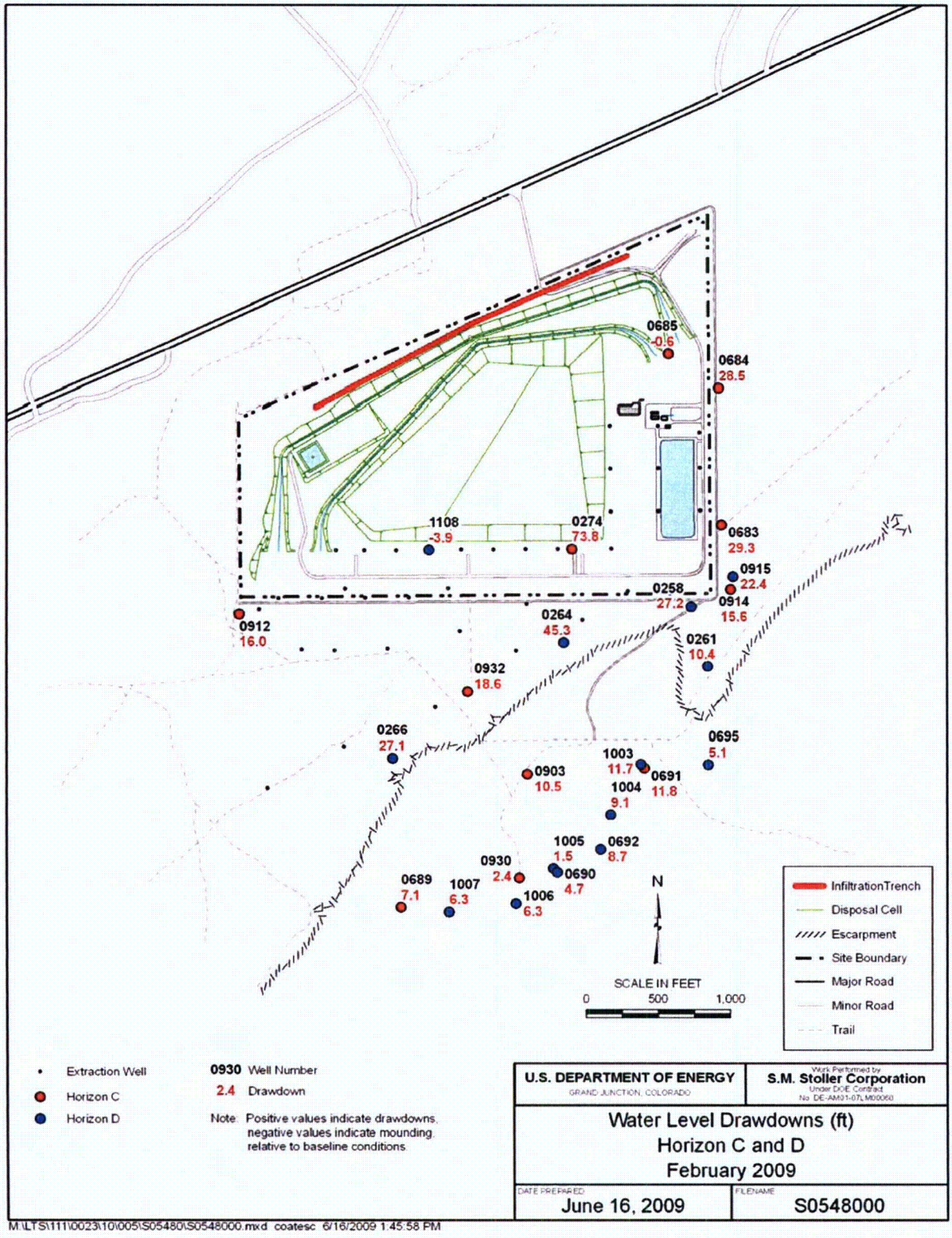

Figure 18. Water Level Drawdowns (Feet), Horizons C and D, February 2009

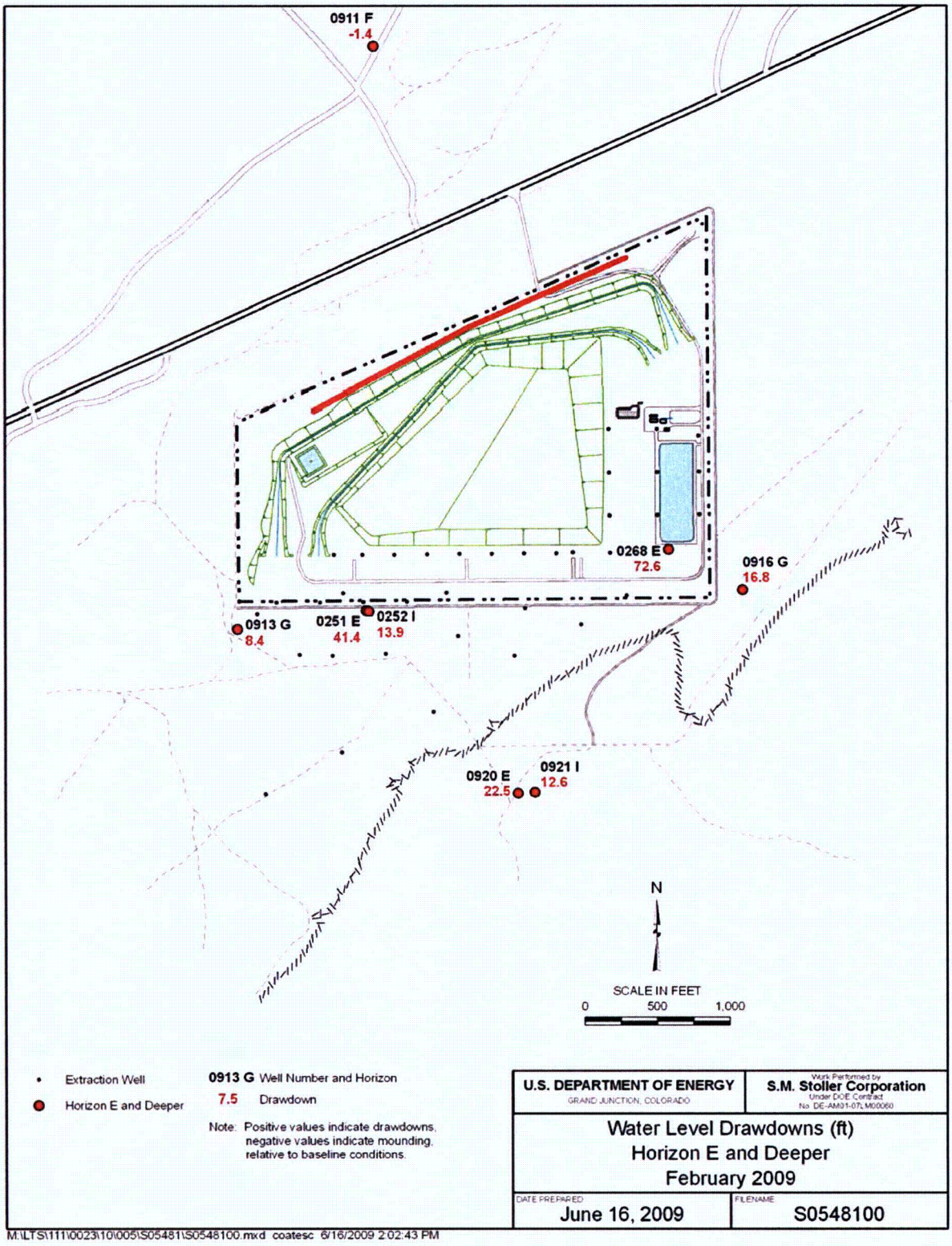

Figure 19. Water Level Drawdowns (Feet), Horizons E, F, G, I, and M, February 2009

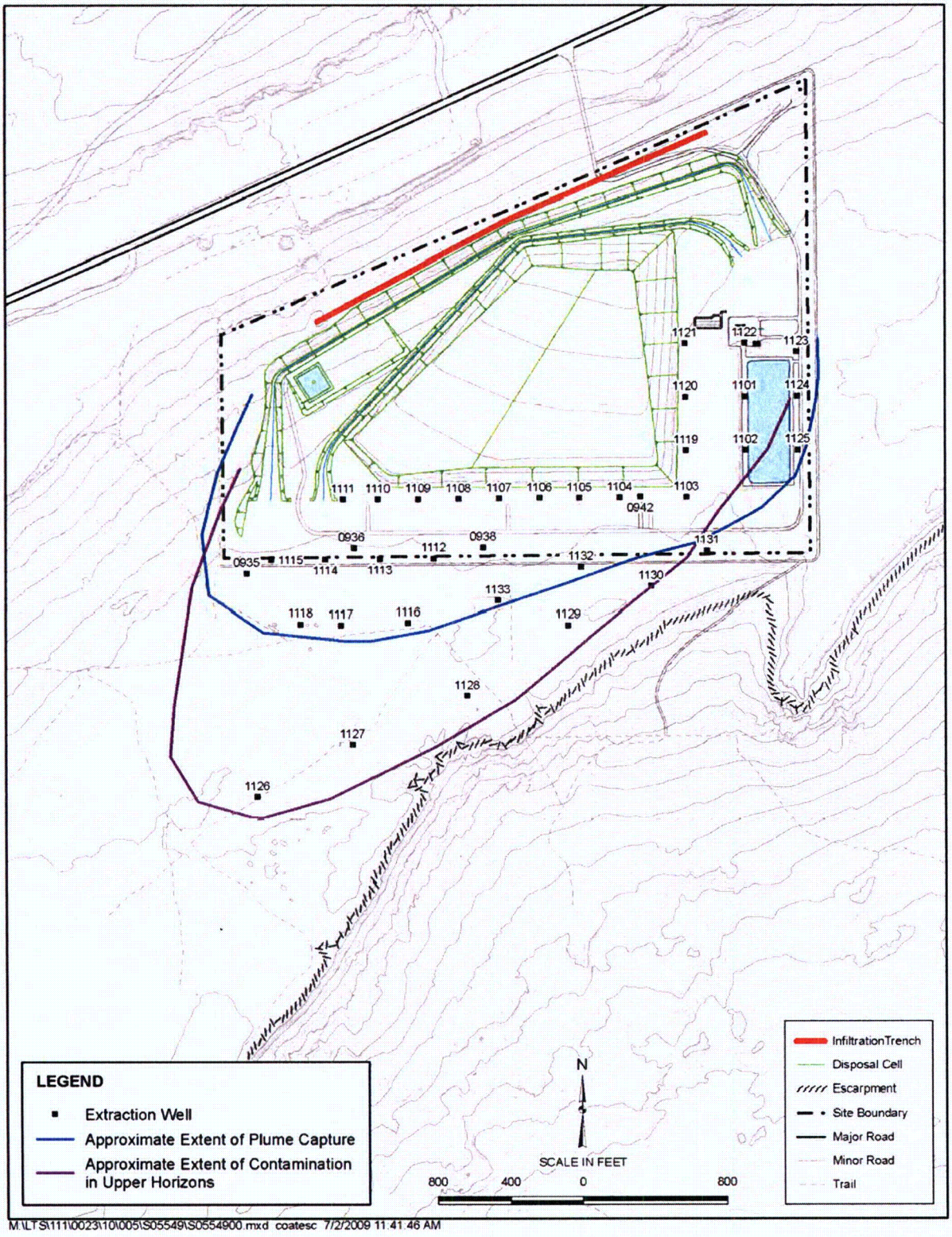

Figure 20. Extent of Groundwater Contamination and Extraction System Capture Zone, Horizons A and B

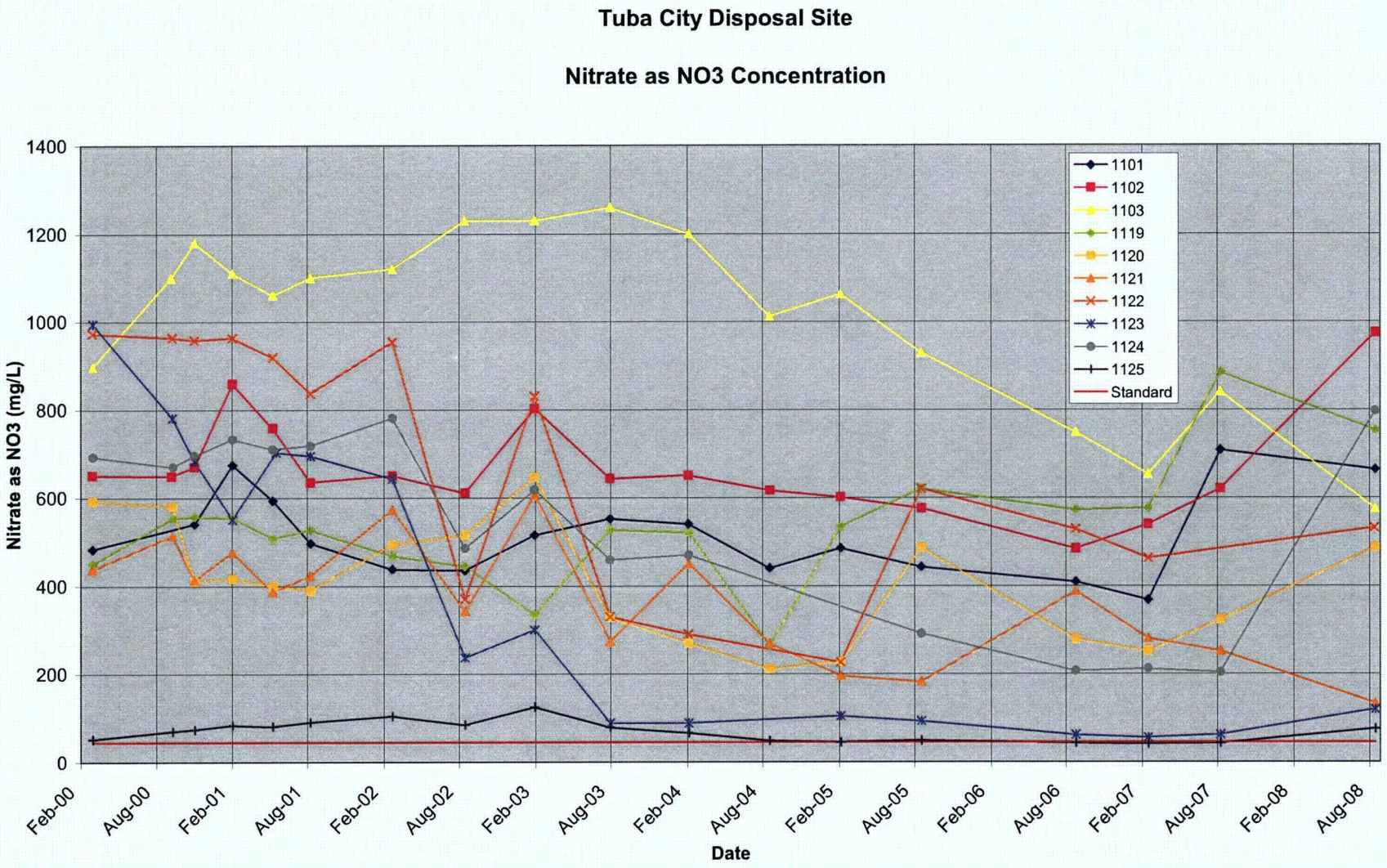

Figure 21a. Nitrate Concentration Trends at Extraction Wells 1101–1103, 1119–1125 (East of Disposal Cell)

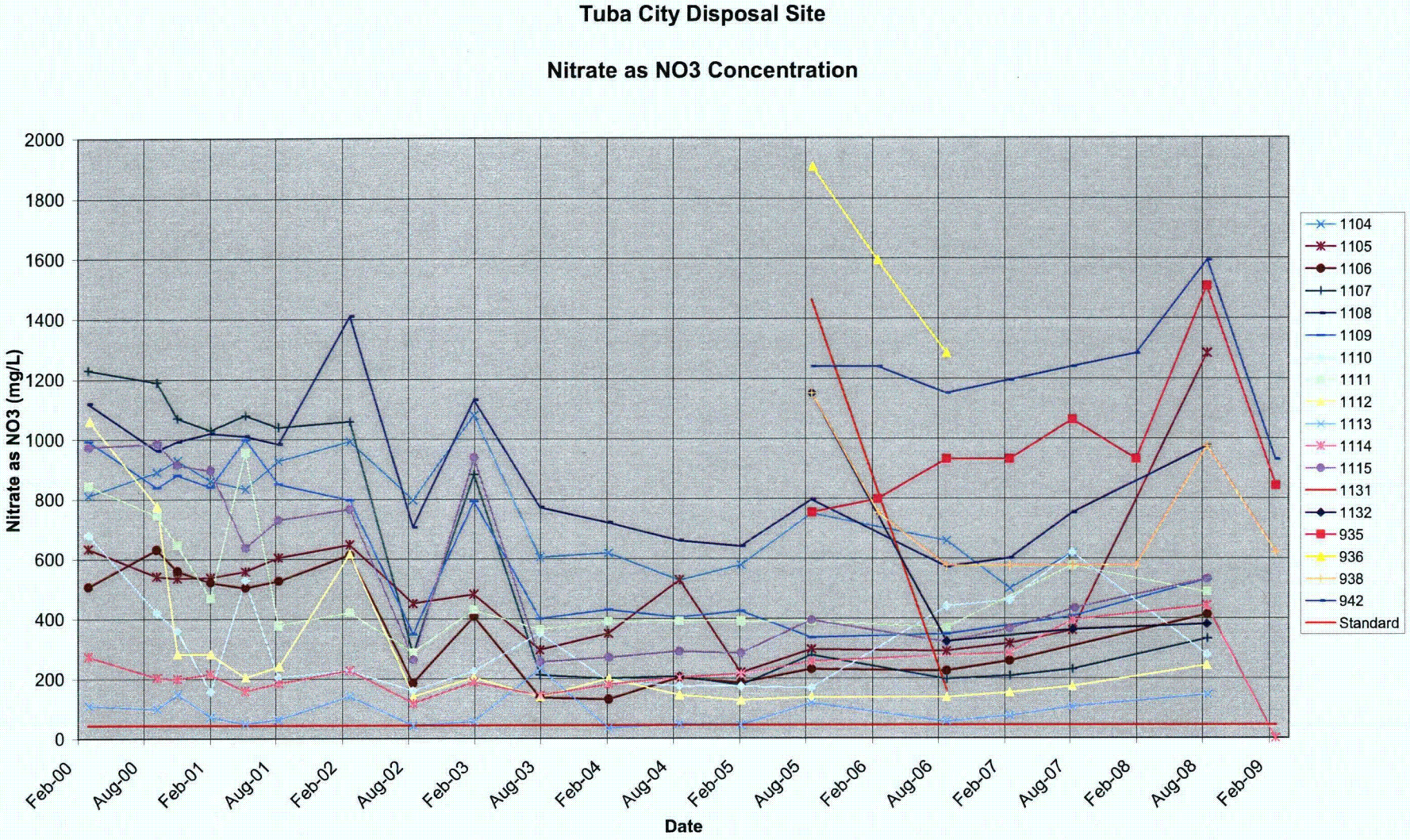

Figure 21b. Nitrate Concentration Trends at Extraction Wells 1104–1115, 1131-1132, 935, 936, 938, 942 (South of Disposal Cell at or within Site Boundary)

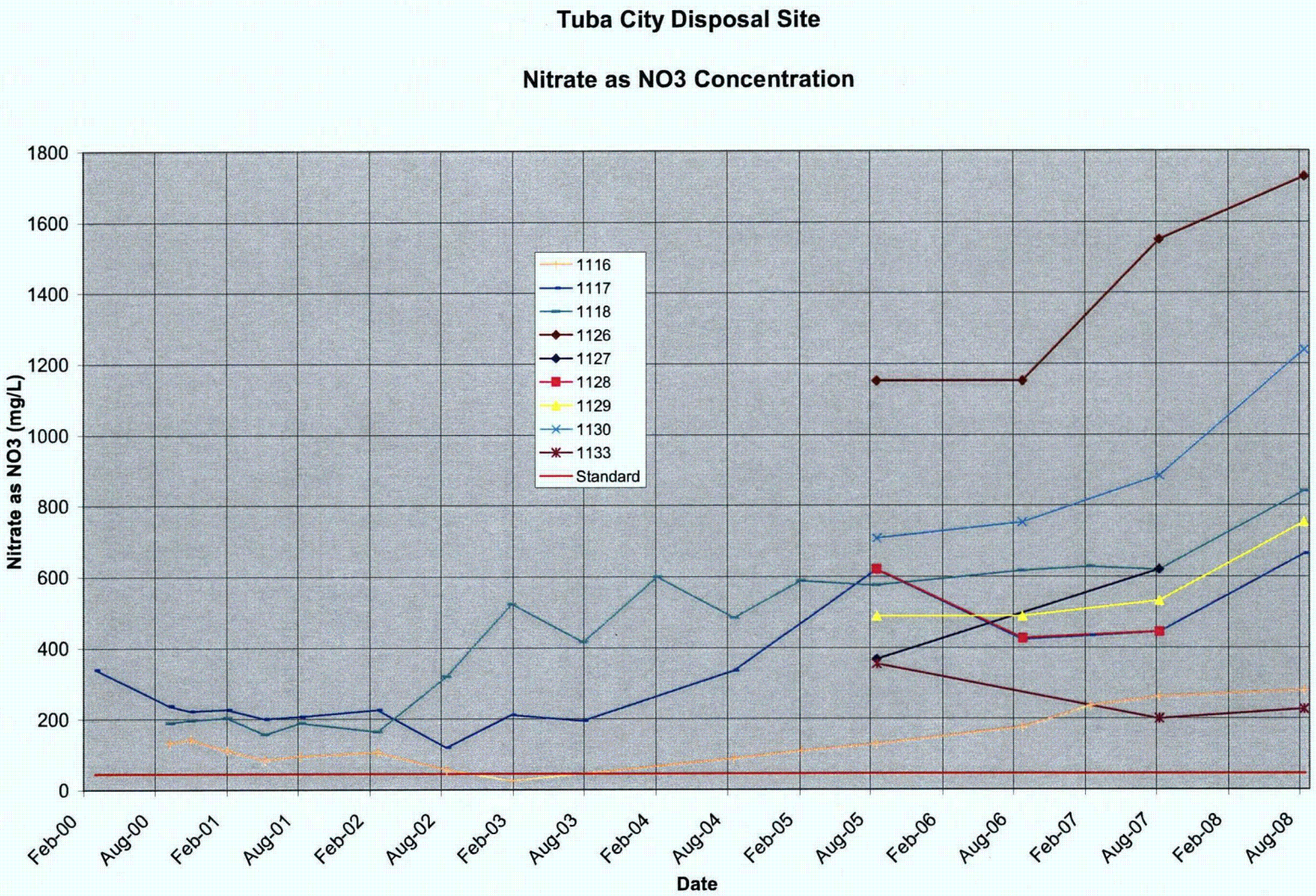

Figure 21c. Nitrate Concentration Trends at Southernmost Extraction Wells 1116–1118, 1126–1130, 1133

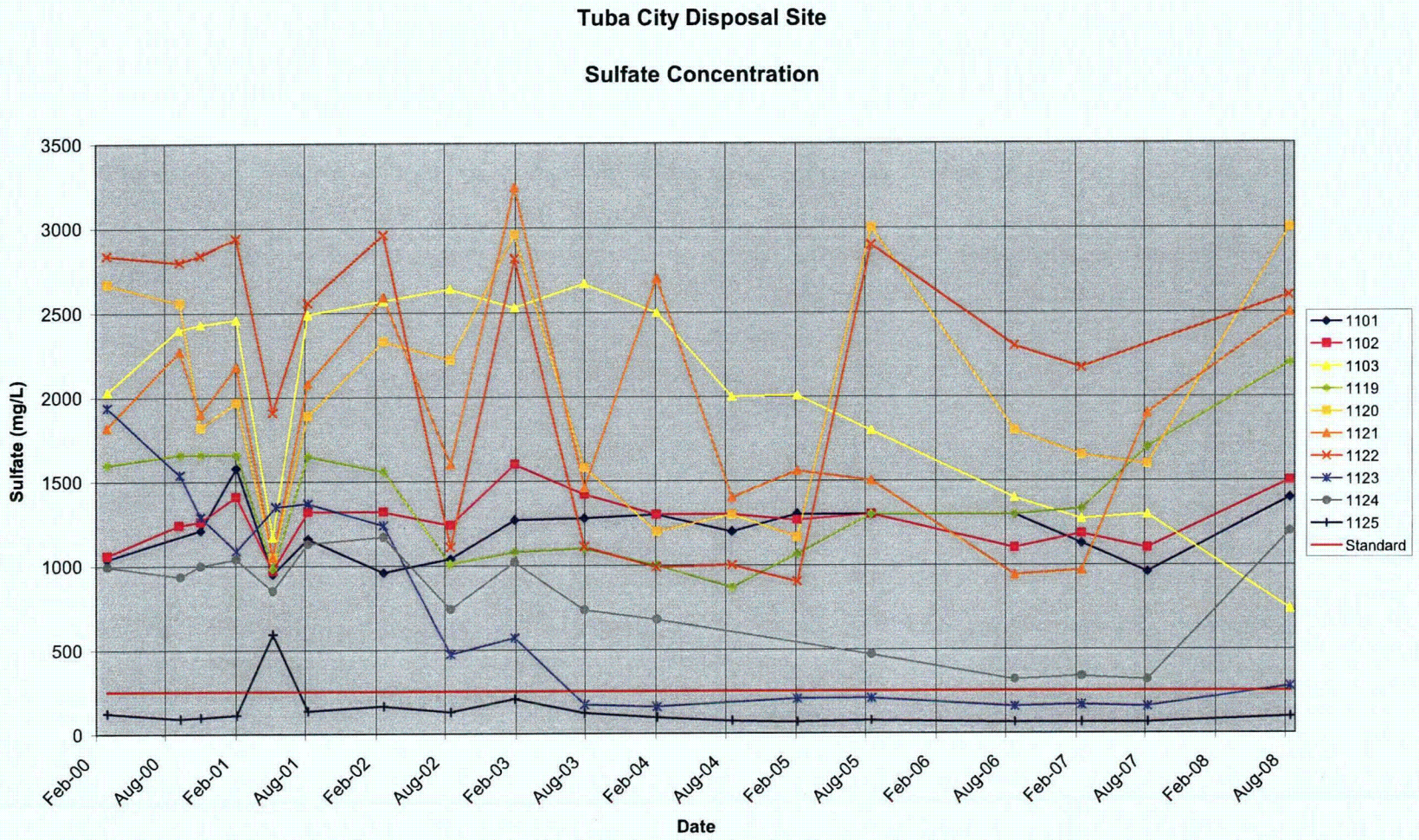

Figure 22a. Sulfate Concentration Trends at Extraction Wells 1101–1103, 1119–1125 (East of Disposal Cell)

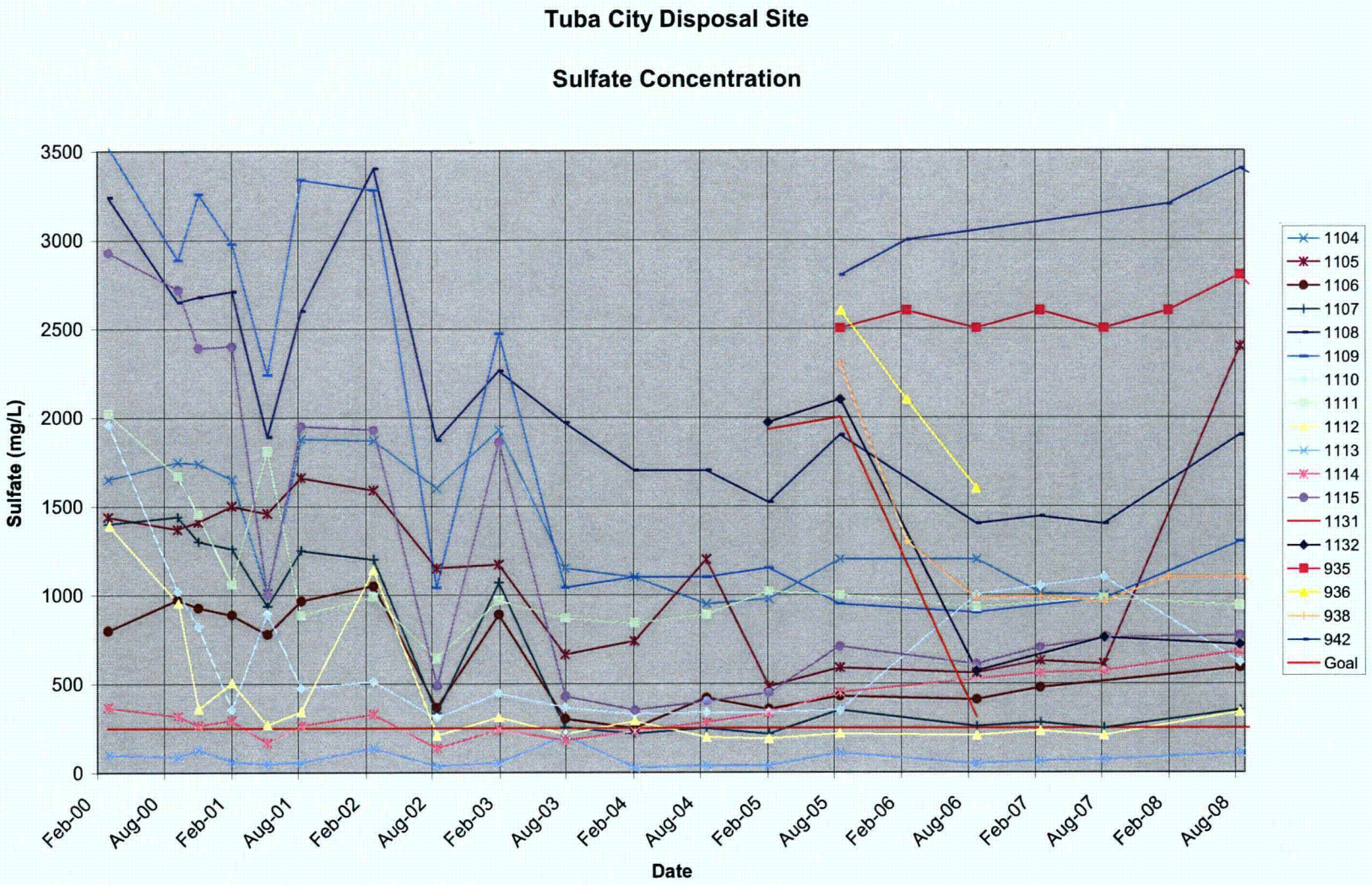

Figure 22b. Sulfate Concentration Trends at Extraction Wells 1104–1115, 1131-1132, 935, 936, 938, 942 (South of Disposal Cell at or within Site Boundary)

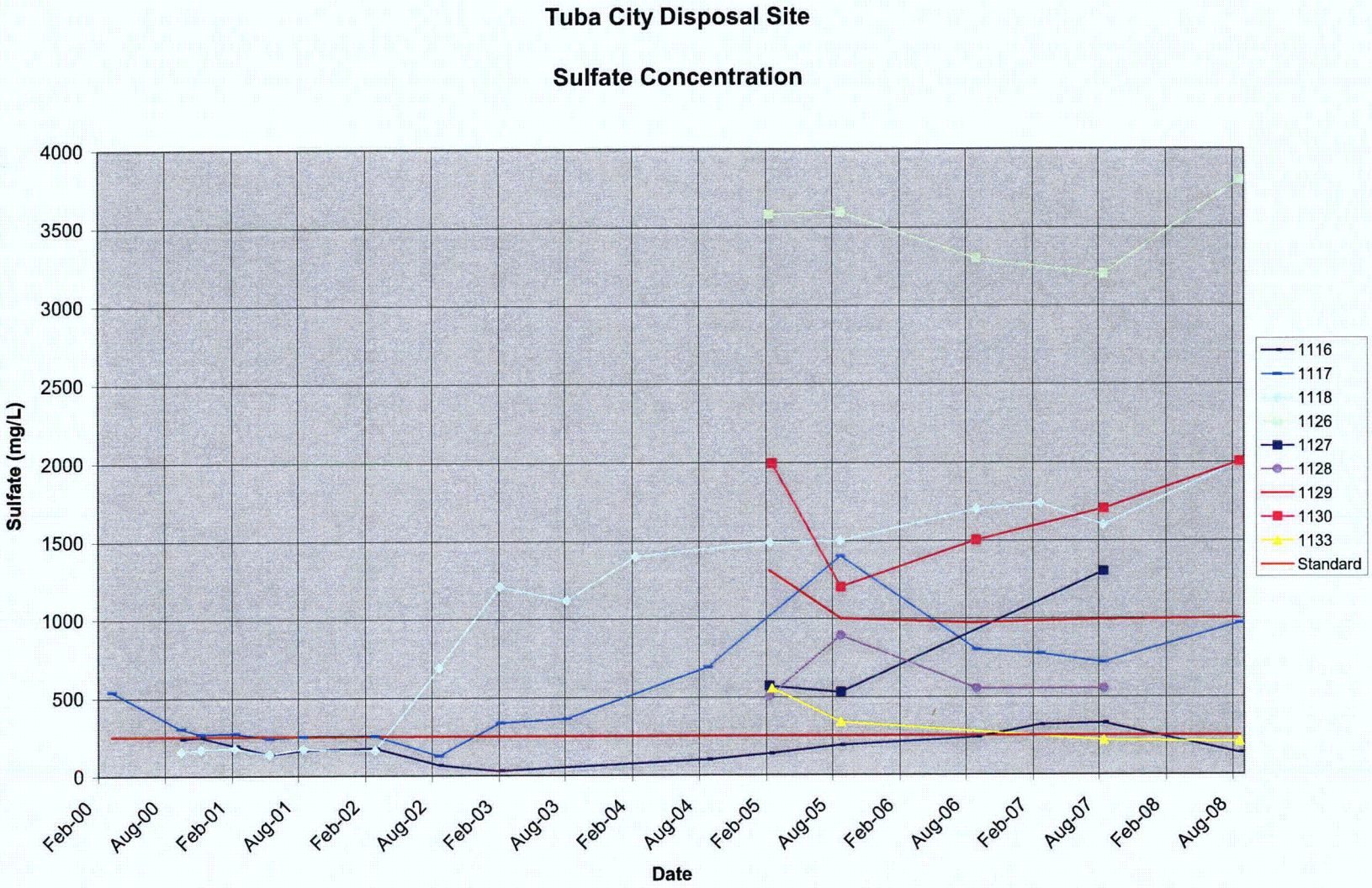

Figure 22c. Sulfate Concentration Trends at Southernmost Extraction Wells 1116–1118, 1126–1130, 1133

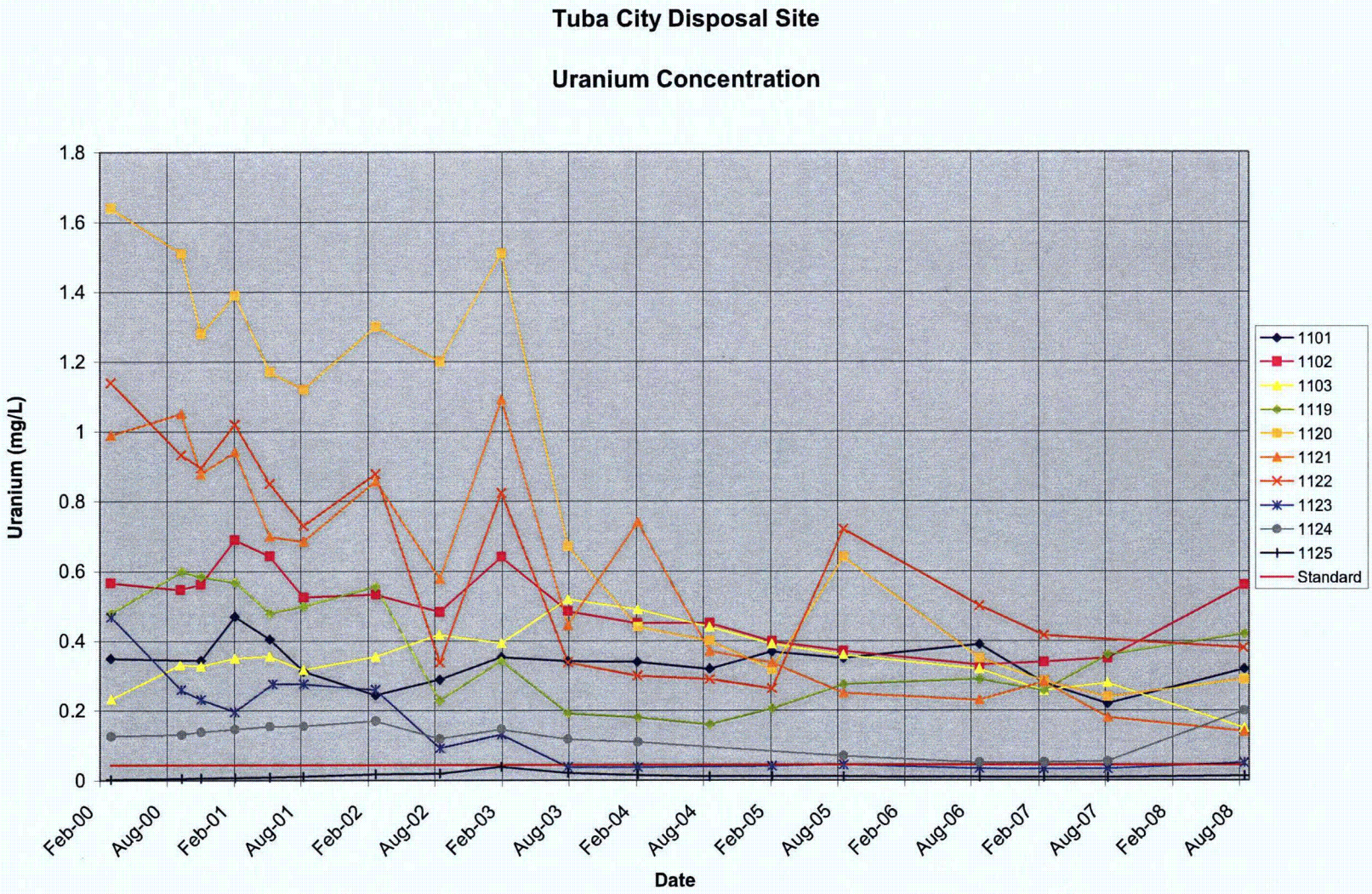

Figure 23a. Uranium Concentration Trends at Extraction Wells 1101–1103, 1119–1125 (East of Disposal Cell)

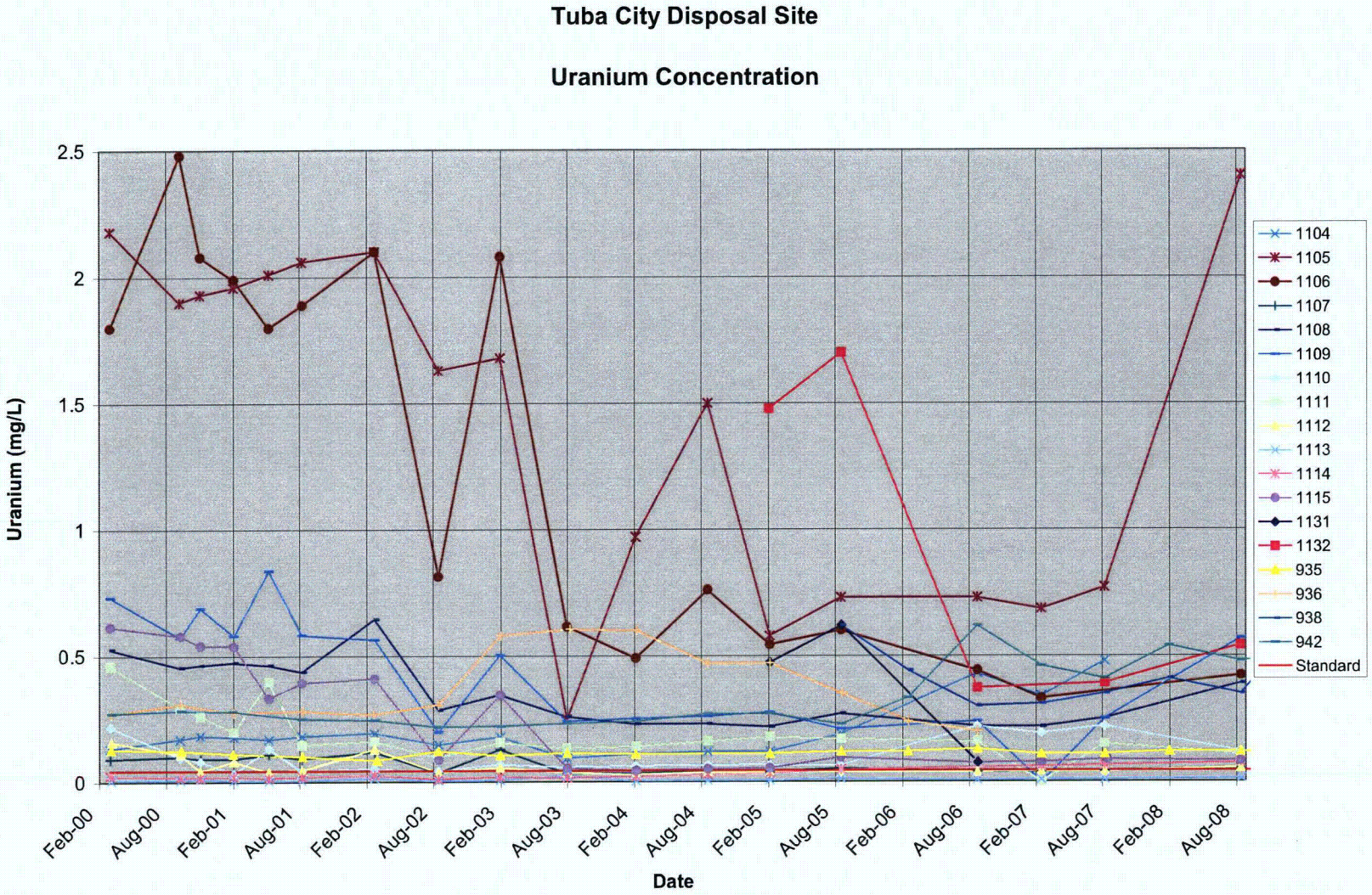

Figure 23b. Uranium Concentration Trends at Extraction Wells 1104–1115, 1131-1132, 935, 936, 938, 942
(South of Disposal Cell at or within Site Boundary)

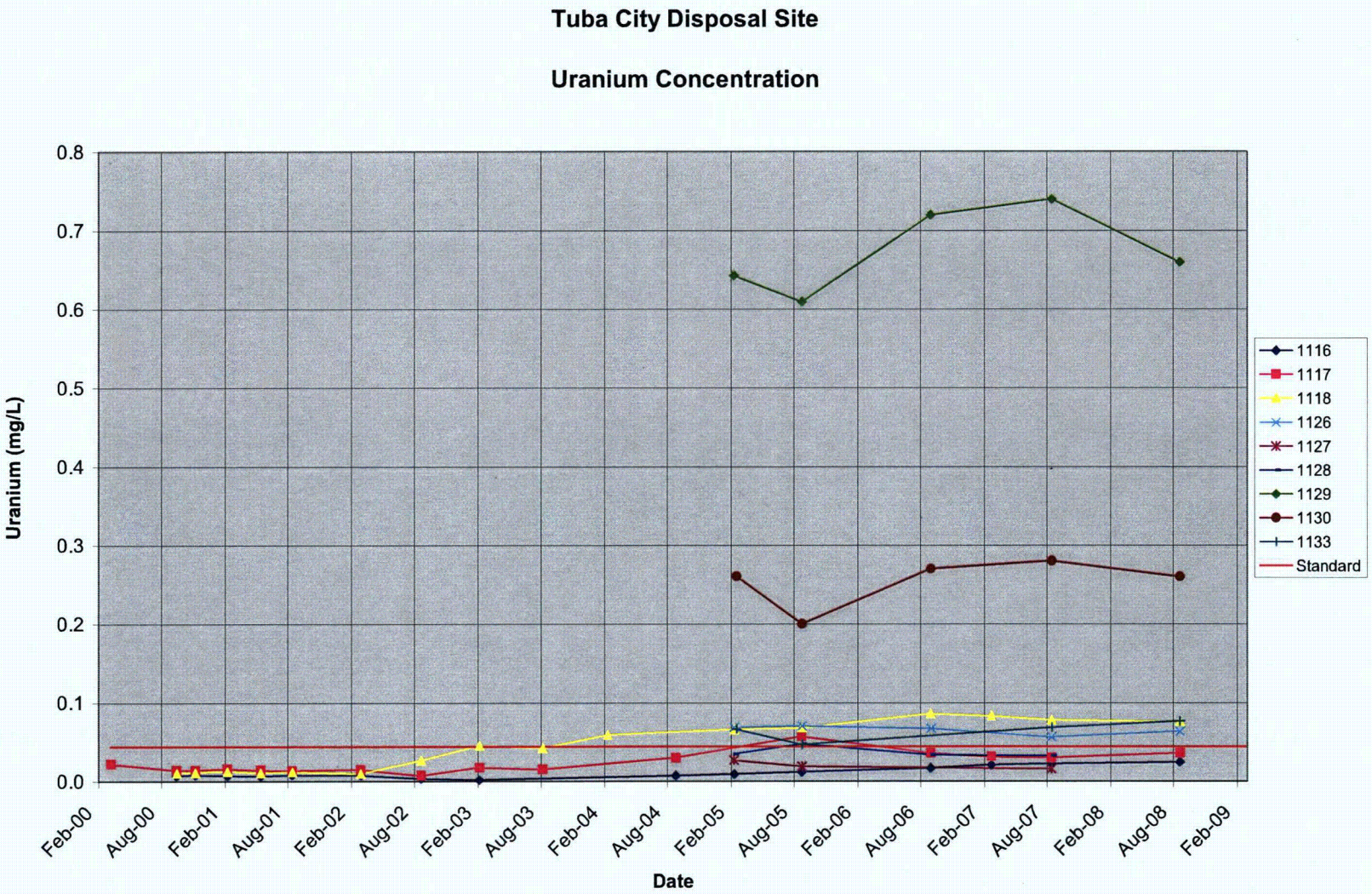

Figure 23c. Uranium Concentration Trends at Southernmost Extraction Wells 1116–1118, 1126–1130, 1133

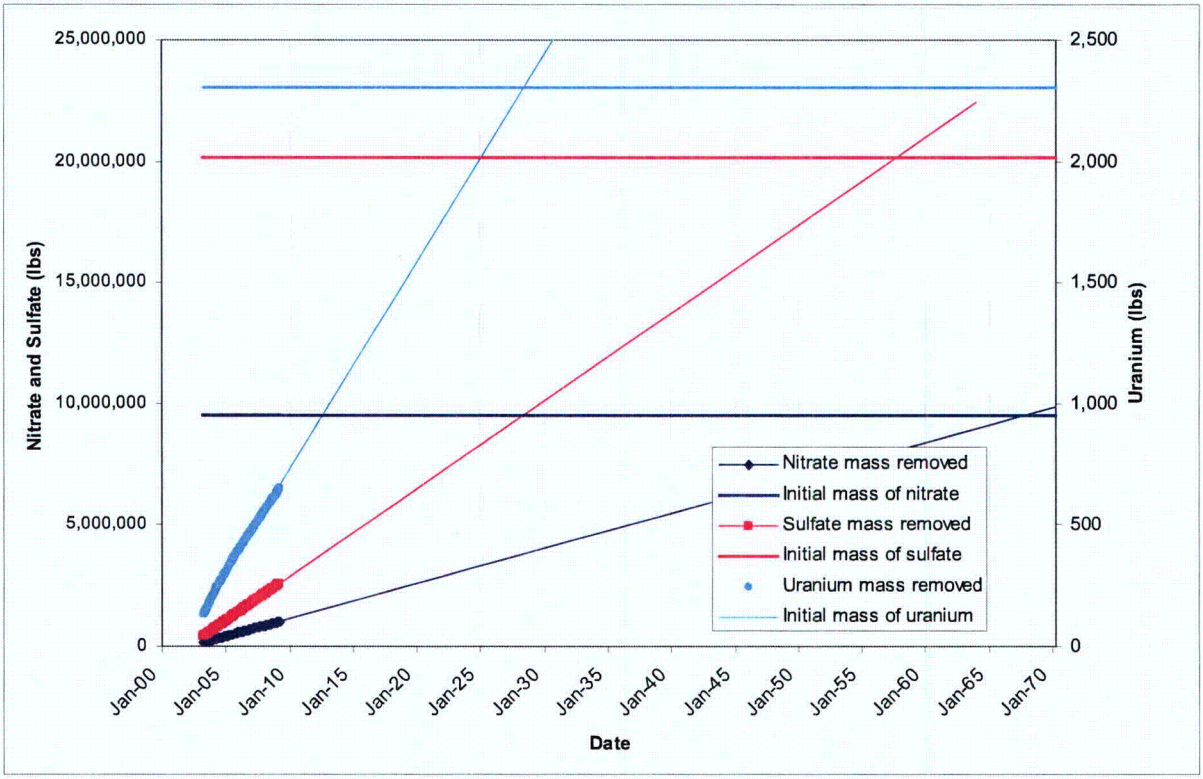

Figure 24. Nitrate, Sulfate, and Uranium Mass Removal Rate Projections

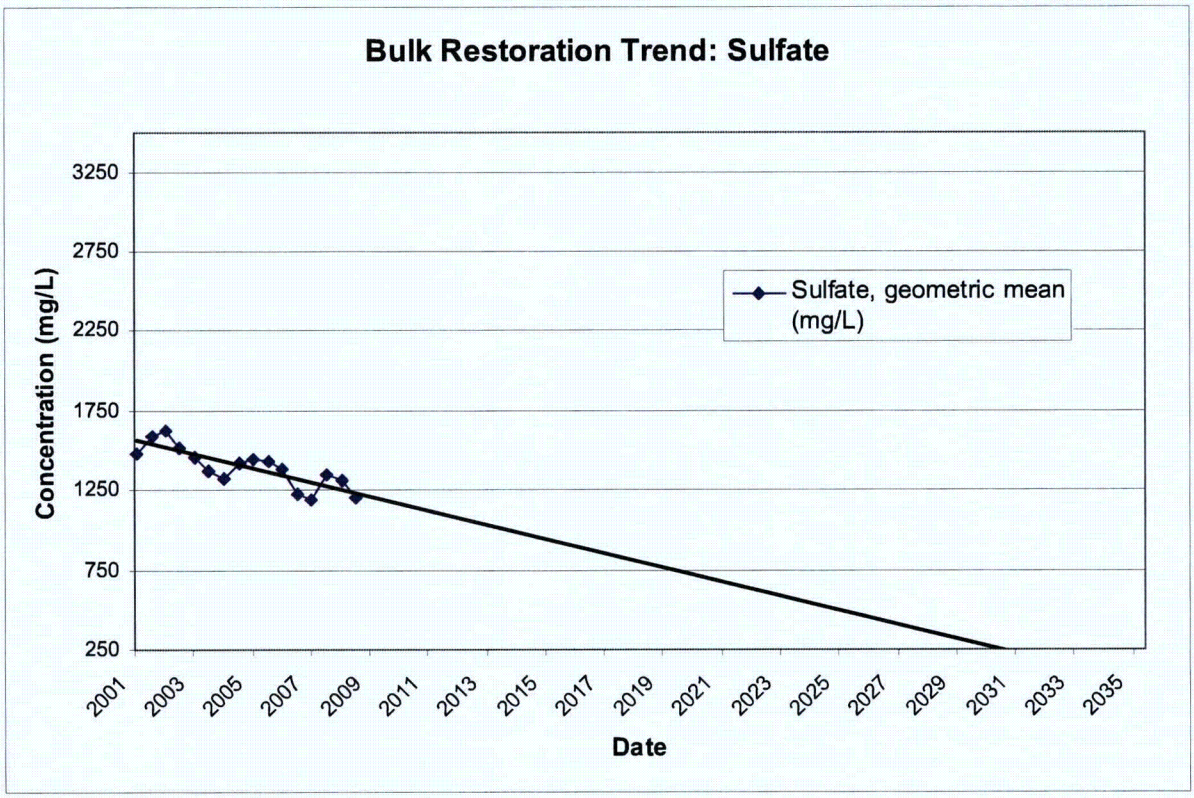

Figure 25. Bulk Restoration Trend for Sulfate

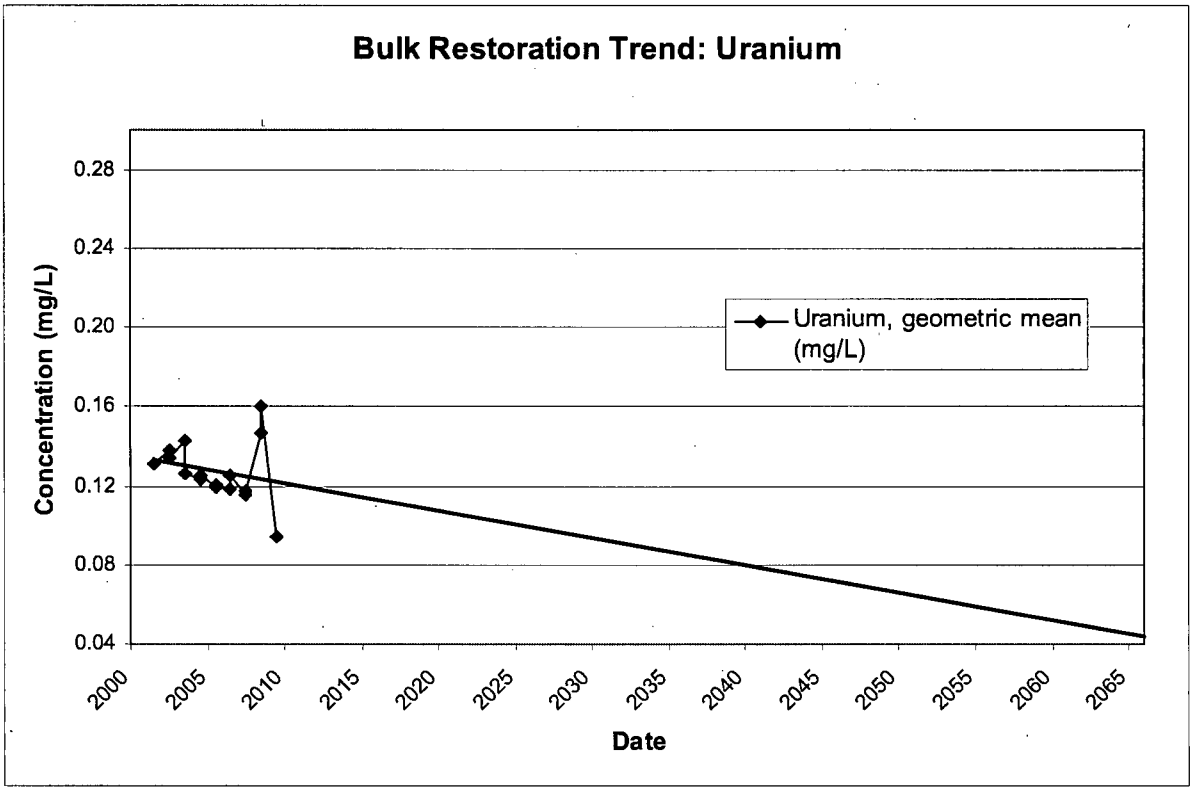

Figure 26. Bulk Restoration Trend for Uranium

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Appendix A

Well Completion Information and Conceptual Site Model

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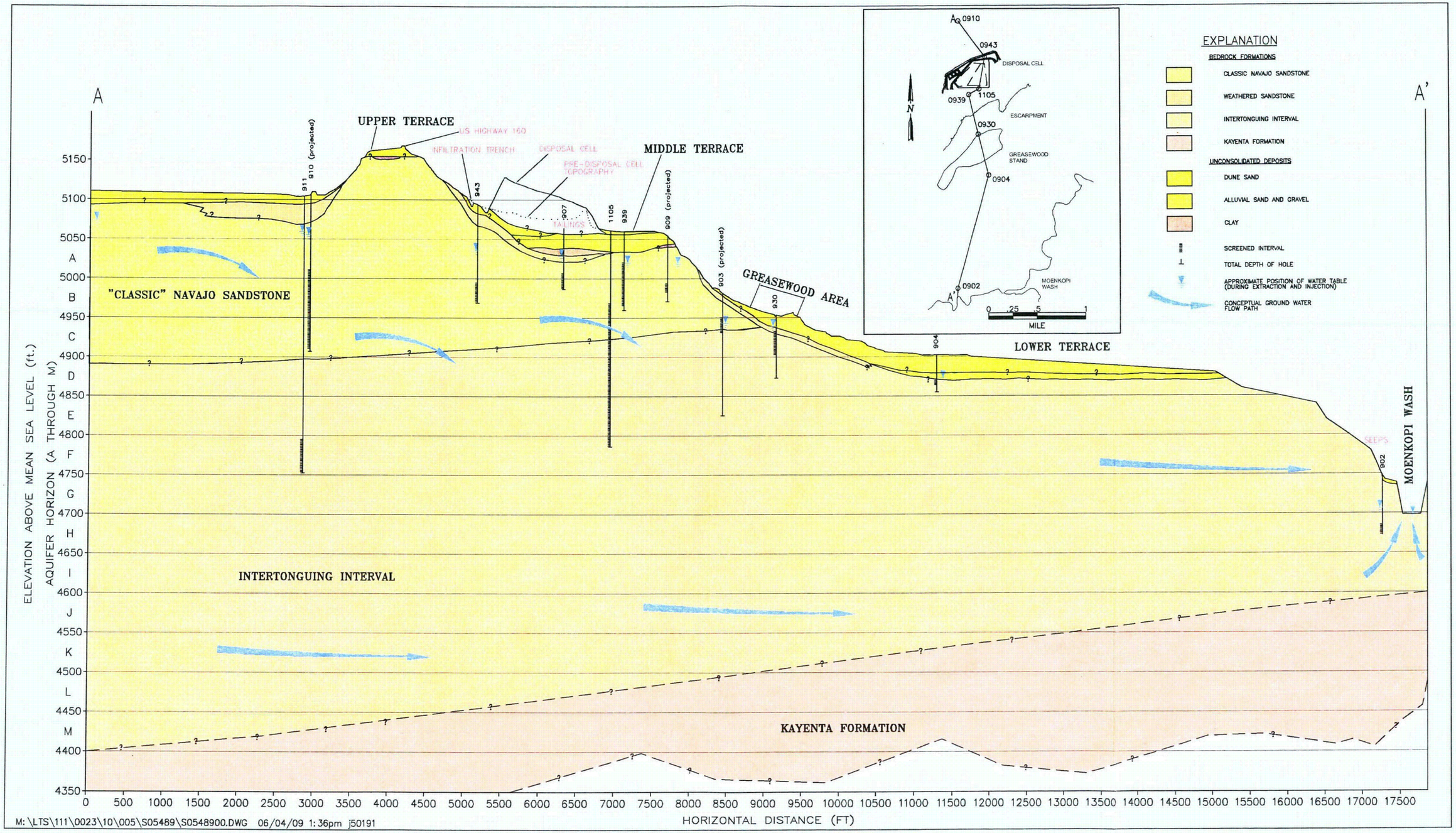

Figure A–1. Conceptual Model of the Site Hydrogeology

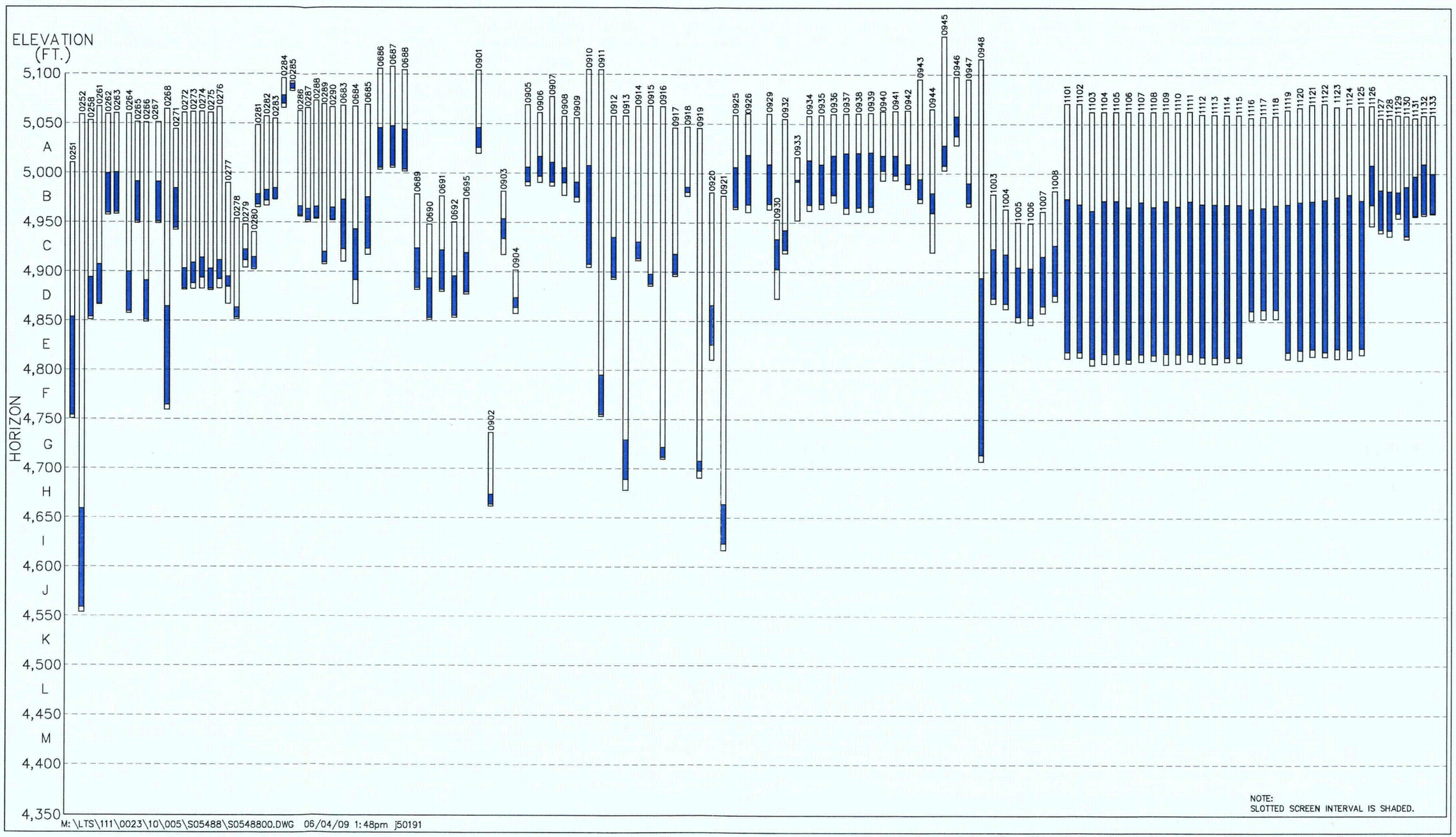

Figure A–2. Well Completions Schematic

Table A–1. Well Completion Information

Well	Type	Horizon	Top Of Screen Elev	Mid Screen Elev	Bottom of Screen Elev	Top of Screen Depth	Mid Screen Depth	Bottom of Screen Depth	Screen Length	Sump Length	Well Depth	Top of Casing Elev		Ground Elev		Well Diameter	Boring Started	Decommission Date	State Plane East	State Plane North
0284	MW	A	5079.8	5074.8	5069.8	16.5	21.5	26.5	10.0	1.5	28.0	5098.72		5096.3		2	16-Aug-04		730525	1873562
0285	MW	A	5090.8	5088.3	5085.8	3.0	5.5	8.0	5.0	0.1	8.1	5096.47		5093.8		2	16-Aug-04		731629	1874042
0686	MW	A	5045.5	5025.5	5005.5	60.0	80.0	100.0	40.0	0.3	100.3	5107.97		5105.5		2	28-Mar-00		729978	1873416
0687	MW	A	5047.6	5027.6	5007.6	60.0	80.0	100.0	40.0	0.3	100.3	5109.82		5107.6		2	29-Mar-00		731152	1874024
0688	MW	A	5044.1	5024.1	5004.1	60.0	80.0	100.0	40.0	0.3	100.3	5106.98		5104.1		2	29-Mar-00		731961	1874385
0901	MW	A	5045.8	5035.8	5025.8	58.0	68.0	78.0	20.0	2.0	80.0	5105.46		5103.8		2	16-Oct-84		730185	1875918
0906	MW	A	5016.9	5006.9	4996.9	44.0	54.0	64.0	20.0	2.0	66.0	5062.10		5060.9		2	19-Nov-84		730838	1872181
0907	MW	A	5010.7	5000.7	4990.7	66.5	76.5	86.5	20.0			5079.17		5077.2		2	30-Nov-84	19-Apr-88	731252	1872920
0928	MW	A	5022.1	5009.6	4997.1	30.0	42.5	55.0	25.0	3.0	58.0	5053.99		5052.1		4	20-Oct-95	24-May-00	729401	1870814
0929	MW	A	5010.4	4990.4	4970.4	48.2	68.2	88.2	40.0			5060.82		5058.6		4			728780	1871453
0940	MW	A	5017.9	5010.4	5002.9	45.0	52.5	60.0	15.0	3.0	68.0	5064.77		5062.9		4	01-Nov-95		730130	1872391
0941	MW	A	5018.0	5008.0	4998.0	45.0	55.0	65.0	20.0	3.0	68.0	5065.97		5063.0		4	10-Nov-95		730908	1872398
0945	MW	A	5028.1	5018.1	5008.1	110.0	120.0	130.0	20.0	3.0	133.0	5140.49		5138.1		4	11-Oct-95		730019	1873857
0946	MW	A	5057.6	5047.6	5037.6	40.0	50.0	60.0	20.0	3.3	63.3	5100.50		5097.6		4	02-Nov-95		730547	1873582
0262	MW	B	4999.2	4979.2	4959.2	60.0	80.0	100.0	40.0	0.3	100.3	5061.99		5059.2		2	03-Apr-00		731402	1872012
0263	MW	B	5000.2	4980.2	4960.2	60.0	80.0	100.0	40.0	0.3	100.3	5063.10		5060.2		2	04-Apr-00		731565	1871757
0265	MW	B	4991.1	4971.1	4951.1	60.0	80.0	100.0	40.0	0.3	100.3	5053.88		5051.1		2	16-Apr-00		730382	1870964
0267	MW	B	4990.8	4970.8	4950.8	60.0	80.0	100.0	40.0	0.3	100.3	5053.40		5050.8		2	14-Apr-00		729329	1870707
0271	MW	B	4984.0	4964.0	4944.0	60.0	80.0	100.0	40.0	0.3	100.3	5046.72		5044.0		2	29-Apr-00		728160	1869555
0281	MW	B	4977.8	4972.8	4967.8	70.5	75.5	80.5	10.0	1.5	82.0	5051.00		5048.3		2	11-Aug-04		729714	1870315
0282	MW	B	4983.3	4978.3	4973.3	74.1	79.1	84.1	10.0	1.5	85.6	5060.04		5057.4		2	10-Aug-04		730062	1871168
0283	MW	B	4984.8	4979.8	4974.8	70.5	75.5	80.5	10.0	1.5	82.0	5057.97		5055.3		2	03-Aug-04		730901	1871185
0286	MW	B	4968.84	4963.8	4958.84	93.2	98.2	103.2	10.0	0.4	103.6	5063.99		5062.0		2	13-Mar-07		730128	1872377
0287	MW	B	4962.29	4957.3	4952.29	100.7	105.7	110.7	10.0	0.4	111.1	5065.65		5063.0		2	15-Mar-07		730908	1872386
0288	MW	B	4965.86	4960.9	4955.86	104.0	109.0	114.0	10.0	0.5	114.5	5072.54		5069.9		2	18-Mar-07		729995	1872709
0290	MW	B	4964.33	4959.3	4954.33	102.7	107.7	112.7	10.0	0.4	113.1	5068.91		5067.0		2	17-Mar-07		732633	1872979
0905	MW	B	5006.0	4998.5	4991.0	63.0	70.5	78.0	15.0	2.0	80.0	5072.80		5069.0		2	14-Nov-84	24-May-00	732933	1873200
0908	MW	B	5005.3	4997.8	4990.3	52.0	59.5	67.0	15.0	2.0	69.0	5058.14		5057.3		2	17-Nov-84		729366	1871999
0909	MW	B	4990.8	4983.3	4975.8	65.0	72.5	80.0	15.0	2.0	82.0	5057.17		5055.8		2	18-Nov-84		730927	1871393
0910	MW	B	5007.6	4957.6	4907.6	97.0	147.0	197.0	100.0	1.0	198.0	5106.70		5104.6		4	26-Jul-85		730219	1875840
0918	MW	B	4986.2	4983.7	4981.2	61.0	63.5	66.0	5.0	2.0	68.0	5049.63		5047.2		4	15-Aug-85		727294	1868724
0925	EXT	B	5005.8	4985.8	4965.8	53.0	73.0	93.0	40.0	0.5	93.5	5060.87		5058.8		6	21-Oct-95	24-May-00	729452	1872006
0926	EXT	B	5018.3	4993.3	4968.3	42.2	67.2	92.2	50.0	3.0	95.2	5062.85		5060.5		6	25-Oct-95	17-May-00	730790	1872126
0933	MW	B	4993.3	4992.3	4991.3	23.0	24.0	25.0	2.0			5018.03		5016.3		4	18-Oct-95	24-May-00	731727	1871341
0934	MW	B	5013.0	4990.5	4968.0	45.0	67.5	90.0	45.0	3.0	93.0	5059.73		5058.0		4	02-Nov-95		730018	1871649
0935	MW/EXT	B	5008.8	4988.8	4968.8	50.0	70.0	90.0	40.0	3.0	93.0	5061.50		5058.8		4	28-Oct-95	*	729461	1871978
0936	MW/EXT	B	5017.9	4997.9	4977.9	42.0	62.0	82.0	40.0	3.0	85.0	5062.30		5059.9		6	26-Oct-95	*	730055	1872121
0937	MW	B	5020.2	4992.7	4965.2	40.0	67.5	95.0	55.0	3.0	98.0	5062.80		5060.2		4	09-Nov-95	24-May-00	730790	1872116
0938	MW/EXT	B	5020.4	4992.9	4965.4	40.0	67.5	95.0	55.0	3.0	98.0	5063.64		5060.4		4	26-Oct-95	*	730769	1872124
0939	EXT	B	5021.1	4993.6	4966.1	40.0	67.5	95.0	55.0	3.0	98.0	5063.23		5061.1		6	23-Oct-95	16-May-00	731403	1872132
0942	MW/EXT	B	5009.5	4999.5	4989.5	54.0	64.0	74.0	20.0	3.0	77.0	5066.45		5063.5		4	03-Nov-95	*	731642	1872409
0943	MW	B	4994.1	4984.1	4974.1	101.0	111.0	121.0	20.0	3.0	124.0	5098.05		5095.1		4	13-Oct-95		731596	1874034
0944	MW	B	4979.9	4969.9	4959.9	85.0	95.0	105.0	20.0	2.0	107.0	5067.00		5064.9		4	04-Nov-95	28-Jul-99	732199	1873007

Table A–1 (continued). Well Completion Information

Well	Type	Horizon	Top Of Screen Elev	Mid Screen Elev	Bottom of Screen Elev	Top of Screen Depth	Mid Screen Depth	Bottom of Screen Depth	Screen Length	Sump Length	Well Depth	Top of Casing Elev		Ground Elev		Well Diameter	Boring Started	Decommission Date	State Plane East	State Plane North
0947	MW	B	4990.0	4980.0	4970.0	105.0	115.0	125.0	20.0	3.3	128.3	5097.01		5095.0		4	03-Nov-95		732786	1874642
1126	EXT	B	4991.9	4971.9	4951.9	60.0	80.0	100.0	40.0	3.3	103.3	*5051.9*	**	*5051.9*	**	4	09-Sep-04		729517	1870728
1127	EXT	B	4984.2	4964.2	4944.2	72.7	92.7	112.7	40.0	3.3	116.0	*5056.9*	**	*5056.9*	**	4	11-Sep-04		730044	1871022
1128	EXT	B	4982.3	4962.3	4942.3	72.7	92.7	112.7	40.0	3.3	116.0	*5055.0*	**	*5055.0*	**	4	12-Sep-04		730679	1871294
1129	EXT	B	4990.9	4975.9	4960.9	68.2	83.2	98.2	30.0	3.3	101.5	*5059.1*	**	*5059.1*	**	4	30-Aug-04		731237	1871690
1130	EXT	B	4987.3	4962.3	4937.3	71.7	96.7	121.7	50.0	3.3	125.0	*5059.0*	**	*5059.0*	**	4	29-Jul-04		731699	1871907
1131	EXT	B	4998.1	4978.1	4958.1	59.7	79.7	99.7	40.0	3.3	103.0	*5057.8*	**	*5057.8*	**	4	08-Sep-04		732011	1872106
1132	EXT	B	5009.1	4984.1	4959.1	49.7	74.7	99.7	50.0	3.3	103.0	*5058.8*	**	*5058.8*	**	4	31-Aug-04		731310	1872015
1133	EXT	B	4999.4	4979.4	4959.4	59.7	79.7	99.7	40.0	3.3	103.0	*5059.1*	**	*5059.1*	**	4	02-Sep-04		730850	1871827
0274	MW	C	4913.6	4903.6	4893.6	149.0	159.0	169.0	20.0	1.5	170.5	5064.42		5062.6		2	30-Aug-04		731623	1872403
0276	MW	C	4910.0	4900.0	4890.0	154.5	164.5	174.5	20.0	1.5	176.0	5067.55		5064.5		2	01-Sep-04		732081	1873158
0279	MW	C	4922.1	4917.1	4912.1	26.5	31.5	36.5	10.0	1.5	38.0	4951.04		4948.6		2	15-Aug-04		731494	1870132
0280	MW	C	4922.6	4917.6	4912.6	26.5	31.5	36.5	10.0	1.5	38.0	4951.52		4949.1		2	15-Aug-04		731794	1870289
0289	MW	C	4920.3	4915.3	4910.3	148.3	153.3	158.3	10.0	0.4	163.0	5070.82		5068.6		6	28-Mar-07		729965	1872709
0683	MW	C	4973.2	4948.2	4923.2	95.0	120.0	145.0	50.0	3.0	148.0	5070.64		5068.2		6	31-Aug-99		732661	1872574
0684	MW	C	4943.1	4917.4	4891.8	124.2	149.9	175.5	51.3	2.5	178.0	5070.05		5067.3		6	20-Aug-99		732642	1873521
0685	MW	C	4975.6	4949.7	4923.8	93.7	119.6	145.5	51.8	2.5	148.0	5072.44		5069.3		6	19-Aug-99		732295	1873760
0689	MW	C	4923.9	4903.9	4883.9	55.0	75.0	95.0	40.0	0.3	95.3	4981.63		4978.9		2	31-Mar-00		730439	1869893
0691	MW	C	4921.9	4901.9	4881.9	55.0	75.0	95.0	40.0	0.3	95.3	4979.41		4976.9		2	30-Mar-00		732124	1870872
0903	MW	C	4953.5	4943.5	4933.5	28.0	38.0	48.0	20.0	2.0	50.0	4983.33		4981.5		2	30-Oct-84		731314	1870829
0912	MW	C	4934.7	4914.7	4894.7	123.0	143.0	163.0	40.0	2.0	165.0	5059.97		5057.7		4	12-Aug-85		729324	1871942
0914	MW	C	4930.3	4921.8	4913.3	137.2	145.7	154.2	17.0	2.0	156.2	5070.10		5067.5		4	16-Aug-85		732723	1872119
0917	MW	C	4917.8	4907.8	4897.8	128.0	138.0	148.0	20.0	2.0	150.0	5048.02		5045.8		4	14-Aug-85		727255	1868642
0930	MW	C	4933.0	4918.0	4903.0	20.0	35.0	50.0	30.0	3.0	53.0	4954.96		4953.0		4	23-Oct-95		731257	1870099
0932	MW	C	4942.3	4932.3	4922.3	112.5	122.5	132.5	20.0	2.7	135.2	5057.32		5054.8		4	29-Oct-95		730900	1871401
1008	INJ	C	4926.8	4901.6	4876.4	55.6	80.8	106.0	50.4	2.5	108.5	4980.52		4982.3		6	23-Jul-99		730410	1869916
1116	EXT	C	4964.1	4912.5	4861.0	92.4	143.9	195.5	103.1	2.5	198.0	5053.74		5056.5		6	08-Aug-99		730350	1871702
1117	EXT	C	4965.3	4913.7	4862.1	92.3	143.9	195.5	103.2	2.5	198.0	5054.95		5057.6		6	11-Aug-99		729981	1871688
1118	EXT	C	4967.9	4915.1	4862.3	89.9	142.7	195.5	105.6	2.5	198.0	5055.11		5057.8		6	12-Aug-99		729756	1871695
0258	MW	D	4894.0	4874.0	4854.0	159.0	179.0	199.0	40.0	0.3	199.3	5055.56		5053.0		2	13-Apr-00		732452	1871996
0261	MW	D	4907.0	4887.0	4867.0	160.0	180.0	200.0	40.0	0.3	200.3	5069.69		5067.0		2	01-Apr-00		732565	1871578
0264	MW	D	4899.6	4879.6	4859.6	160.0	180.0	200.0	40.0	0.3	200.3	5062.19		5059.6		2	03-Apr-00		731569	1871746
0266	MW	D	4890.6	4870.6	4850.6	160.0	180.0	200.0	40.0	0.3	200.3	5053.32		5050.6		2	15-Apr-00		730380	1870941
0272	MW	D	4902.8	4892.8	4882.8	159.1	169.1	179.1	20.0	1.5	180.6	5064.24		5061.9		2	28-Aug-04		730112	1872389
0273	MW	D	4909.4	4899.4	4889.4	153.0	163.0	173.0	20.0	1.5	174.5	5064.74		5062.4		2	29-Aug-04		730922	1872397
0275	MW	D	4903.0	4893.0	4883.0	158.2	168.2	178.2	20.0	1.5	179.7	5062.64		5061.2		2	01-Sep-04		732092	1872586
0277	MW	D	4884.0	4879.0	4874.0	95.7	100.7	105.7	10.0	1.5	107.2	4982.35		4979.7		2	12-Aug-04		731290	1870777
0278	MW	D	4862.9	4857.9	4852.9	90.5	95.5	100.5	10.0	1.5	102.0	4956.09		4953.4		2	14-Aug-04		731210	1870104
0690	MW	D	4893.3	4873.3	4853.3	55.0	75.0	95.0	40.0	0.3	95.3	4950.87		4948.3		2	30-Mar-00		731521	1870140
0692	MW	D	4895.6	4875.6	4855.6	55.0	75.0	95.0	40.0	0.3	95.3	4953.31		4950.6		2	05-Apr-00		731821	1870303
0695	MW	D	4919.3	4899.3	4879.3	55.0	75.0	95.0	40.0	0.3	95.3	4976.83		4974.3		2	06-Apr-00		732566	1870896
0904	MW	D	4873.8	4868.8	4863.8	28.0	33.0	38.0	10.0	2.0	40.0	4904.11		4901.8		2	07-Nov-84		731808	1868036
0915	MW	D	4897.8	4892.8	4887.8	170.0	175.0	180.0	10.0	2.0	182.0	5070.84		5067.8		4	24-Aug-85		732740	1872209
1003	INJ	D	4923.4	4898.4	4873.4	55.5	80.5	105.5	50.0	2.5	108.0	4976.58		4978.9		6	26-Jul-99		732101	1870898

Table A–1 (continued). Well Completion Information

Well	Type	Horizon	Top Of Screen Elev	Mid Screen Elev	Bottom of Screen Elev	Top of Screen Depth	Mid Screen Depth	Bottom of Screen Depth	Screen Length	Sump Length	Well Depth	Top of Casing Elev		Ground Elev		Well Diameter	Boring Started	Decommission Date	State Plane East	State Plane North
1004	INJ	D	4918.1	4893.1	4868.1	45.5	70.5	95.5	50.0	2.5	98.0	4961.55		4963.6		6	27-Jul-99		731892	1870544
1005	INJ	D	4904.7	4879.7	4854.7	45.5	70.5	95.5	50.0	2.5	98.0	4947.83		4950.2		6	25-Jul-99		731496	1870168
1006	INJ	D	4903.7	4878.7	4853.7	45.7	70.7	95.7	50.0	2.5	98.2	4947.08		4949.5		6	24-Jul-99		731233	1869918
1007	INJ	D	4915.6	4890.5	4865.4	45.8	70.9	96.0	50.2	2.5	98.5	4958.56		4961.4		6	23-Jul-99		730770	1869861
1101	EXT	D	4974.2	4896.5	4818.9	96.1	173.8	251.5	155.4	2.5	254.0	5067.29		5070.4		6	24-Aug-99		732223	1872970
1102	EXT	D	4968.8	4893.8	4818.8	101.5	176.5	251.5	150.0	2.5	254.0	5066.76		5070.3		6	24-Aug-99		732225	1872670
1103	EXT	D	4962.3	4887.3	4812.3	100.0	175.0	250.0	150.0	2.5	252.5	5059.56		5062.3		6	30-Jul-99		731896	1872407
1104	EXT	D	4972.3	4894.8	4817.3	90.0	167.5	245.0	155.0	3.0	248.0	5059.57		5062.3		6	01-Aug-99		731527	1872404
1105	EXT	D	4972.1	4894.6	4817.1	90.0	167.5	245.0	155.0	3.0	248.0	5059.33		5062.1		6	02-Aug-99		731304	1872401
1106	EXT	D	4966.0	4888.7	4811.4	96.5	173.8	251.1	154.6	2.9	254.0	5059.73		5062.5		6	03-Aug-99		731081	1872400
1107	EXT	D	4971.2	4894.0	4816.8	91.1	168.3	245.5	154.4	2.5	248.0	5059.51		5062.3		6	03-Aug-99		730858	1872398
1108	EXT	D	4966.1	4891.1	4816.1	96.3	171.3	246.3	150.0	2.5	248.8	5059.62		5062.4		6	03-Aug-99		730634	1872396
1109	EXT	D	4972.1	4894.7	4817.3	90.3	167.7	245.1	154.8	2.9	248.0	5059.64		5062.4		6	04-Aug-99		730410	1872394
1110	EXT	D	4966.8	4891.8	4816.8	95.5	170.5	245.5	150.0	2.5	248.0	5059.47		5062.3		6	07-Aug-99		730187	1872392
1111	EXT	D	4971.9	4894.7	4817.5	90.7	167.9	245.1	154.4	2.5	247.6	5059.87		5062.6		6	06-Aug-99		729993	1872392
1112	EXT	D	4969.1	4891.6	4814.1	90.5	168.0	245.5	155.0	2.5	248.0	5057.08		5059.6		6	17-Aug-99		730494	1872064
1113	EXT	D	4968.7	4891.2	4813.7	90.5	168.0	245.5	155.0	2.5	248.0	5058.54		5059.2		6	17-Aug-99		730196	1872061
1114	EXT	D	4968.5	4891.0	4813.6	90.6	168.0	245.5	154.9	2.5	248.0	5056.25		5059.1		6	11-Aug-99		729896	1872057
1115	EXT	D	4968.6	4891.2	4813.7	90.5	168.0	245.5	155.0	2.5	248.0	5056.36		5059.2		6	07-Aug-99		729596	1872055
1119	EXT	D	4968.7	4893.7	4818.7	95.3	170.3	245.3	150.0	2.5	247.8	5061.19		5064.0		6	31-Jul-99		731894	1872667
1120	EXT	D	4971.0	4896.0	4821.0	95.5	170.5	245.5	150.0	2.5	248.0	5063.60		5066.5		6	28-Jul-99		731891	1872967
1121	EXT	D	4972.0	4897.0	4822.0	97.5	172.5	247.5	150.0	2.5	250.0	5066.61		5069.5		6	28-Jul-99		731889	1873267
1122	EXT	D	4973.4	4896.3	4819.2	96.9	174.0	251.1	154.2	2.9	254.0	5067.31		5070.3		6	26-Aug-99		732221	1873269
1123	EXT	D	4976.2	4899.2	4822.2	91.0	168.0	245.0	154.0	3.0	248.0	5064.54		5067.2		6	02-Sep-99		732508	1873222
1124	EXT	D	4978.7	4899.9	4821.1	87.9	166.7	245.5	157.6	2.5	248.0	5063.86		5066.6		6	23-Aug-99		732512	1872972
1125	EXT	D	4972.8	4897.8	4822.8	95.5	170.5	245.5	150.0	2.5	248.0	5065.47		5068.3		6	25-Aug-99		732515	1872671
0251	MW	E	4858.9	4808.9	4758.9	200.0	250.0	300.0	100.0	0.3	300.3	5061.25		5058.9		2	28-Apr-00		730215	1871999
0268	MW	E	4864.5	4814.5	4764.5	200.0	250.0	300.0	100.0	0.3	300.3	5067.24		5064.5		2	15-May-00		732301	1872430
0920	MW	E	4866.0	4846.0	4826.0	114.4	134.4	154.4	40.0	2.0	156.4	4982.97		4980.4		4	30-Jul-85		731262	1870737
0948	EXDS	E	4893.9	4803.9	4713.9	221.5	311.5	401.5	180.0	5.0	406.5	5117.80		5115.4		4	17-Oct-95		733915	1875516
0911	MW	F	4795.2	4775.2	4755.2	309.4	329.4	349.4	40.0	2.0	351.4	5106.96		5104.6		4	18-Jul-85		730265	1875920
0913	MW	G	4729.2	4709.2	4689.2	328.7	348.7	368.7	40.0	2.0	370.7	5060.16		5057.9		4	02-Aug-85		729327	1871871
0916	MW	G	4721.7	4716.7	4711.7	345.7	350.7	355.7	10.0	2.0	357.7	5070.00		5067.4		4	22-Aug-85		732811	1872146
0919	MW	G	4707.9	4702.9	4697.9	337.7	342.7	347.7	10.0	2.0	349.7	5048.56		5045.6		4	26-Aug-85		727353	1868654
0902	MW	H	4673.7	4668.7	4663.7	63.0	68.0	73.0	10.0	2.0	75.0	4737.42		4736.7		2	02-Dec-84		730179	1862292
0252	MW	I	4658.9	4608.9	4558.9	400.0	450.0	500.0	100.0	0.4	500.4	5061.30		5058.9		4	26-Apr-00		730232	1871993
0254	MW	I	4662.7	4612.7	4562.7	400.0	450.0	500.0	100.0	0.4	500.4	5065.38		5062.7		4	03-May-00	13-Aug-05	730951	1872411
0256	MW	I	4664.0	4614.0	4564.0	400.0	450.0	500.0	100.0	0.4	500.4	5066.58		5064.0		4	13-May-00	14-Aug-05	732277	1872437
0921	MW	I	4663.7	4643.7	4623.7	313.2	333.2	353.2	40.0	2.0	355.2	4979.08		4976.9		4	22-Jul-85		731379	1870742
0253	MW	M	4458.8	4408.8	4358.8	600.0	650.0	700.0	100.0	0.4	700.4	5061.11		5058.8		4	18-Apr-00	11-Apr-01	730213	1871974
0255	MW	M	4462.3	4412.3	4362.3	600.0	650.0	700.0	100.0	0.4	700.4	5064.89		5062.3		4	01-May-00	12-Aug-05	730947	1872387
0257	MW	M	4463.4	4413.4	4363.4	600.0	650.0	700.0	100.0	0.4	700.4	5066.40		5063.4		4	11-May-00	11-Aug-05	732278	1872414
0968	EXDS		5000.4	4699.9	4399.4	106.0	406.5	707.0	601.0	0.0	707.0	5107.00		5106.4		10			730180	1875689
0970	EXDS		5007.7	4705.2	4402.7	100.0	402.5	705.0	605.0	0.0	705.0	5109.53		5107.7		10			730653	1876567

Table A–1 (continued). Well Completion Information

Well	Type	Horizon	Top Of Screen Elev	Mid Screen Elev	Bottom of Screen Elev	Top of Screen Depth	Mid Screen Depth	Bottom of Screen Depth	Screen Length	Sump Length	Well Depth	Top of Casing Elev		Ground Elev		Well Diameter	Boring Started	Decommission Date	State Plane East	State Plane North
0971	EXDS		4985.3	4693.8	4402.3	117.0	408.5	700.0	583.0	0.0	700.0	5104.00		5102.3		10			731590	1878306
0972	EXDS		5039.7	4724.7	4409.7	100.0	415.0	730.0	630.0	0.0	730.0	5141.07		5139.7		10			728031	1877986

All Dimensions in Feet Except Well Diameter in Inches
All Depths are Relative to Ground Surface
* = Converted To Extraction Well in August 2005
MW = Monitor Well
EXT = Groundwater Remediation Extraction Well
INJ = Groundwater Remediation Injection Well
EXDS = Other Supply Well
** = Approximate