GJO–2004–550–TAC

Tuba City, Arizona, Land Management Project Site
Semi-Annual Performance Evaluation
March 2003 through August 2003

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1.0 Introduction

This report presents an evaluation of the pump-and-treat ground water remediation system at the U.S. Department of Energy (DOE) Tuba City site, near Tuba City, Arizona (Figure 1), for the period of March through August 2003. The evaluation is based primarily on a comparison of site conditions in July and August 2003 with baseline conditions established during 1999 through February 2002 (DOE 2003a). Cumulative effects, such as treatment volumes and contaminant mass removal since full-time remediation began in mid-2002, are also addressed. The main ground water contaminants requiring remediation are nitrate and uranium, which extend vertically about 100 to 200 feet (ft) below the top of the Navajo Sandstone bedrock aquifer. Ground water contamination, as nitrate, laterally extends a maximum of 2,000 ft to the south and southwest of the 145-acre site to affect an off-site area of approximately 120 acres.

The ground water remediation system comprises (1) 25 ground water extraction wells completed within the most contaminated region of aquifer, (2) ion-exchange pre-treatment and distillation treatment, (3) solar evaporation of waste liquids in engineered ponds, (4) infiltration of treated water via an engineered trench on the upgradient side of the plume, and (5) six injection wells along the downgradient terminus of the contaminant plume to return treated water to the aquifer. To date, the injection wells have not been used; all treated ground water is discharged to the infiltration trench. Primary site features are shown in Figure 2.

1.1 Performance Monitoring

The scope of routine monitoring conducted to evaluate remediation system performance is summarized below.

Treatment System

- Bulk inflow to treatment system is metered continuously and recorded weekly (equivalent to the bulk ground water extraction rate).
- Treatment system effluent flows (waste-stream and distillate) are metered continuously and recorded weekly.
- Bulk inflow composition is analyzed weekly from a composite sample collected over a 5-day period.
- Treatment system effluents/compositions are analyzed weekly from composite samples collected over a 5-day period.

Extraction and Injection System

- Ground water levels in monitoring wells are measured and recorded monthly.
- Ground water levels in extraction wells are measured and recorded twice yearly (February and August; not all extraction wells are currently equipped for water level measurement).
- Monitor wells are sampled twice yearly (February and August) for water quality analysis.
- Extraction wells are sampled monthly for water quality analysis.
- Flow from each extraction well is monitored continuously and flow totals are recorded daily per well.

1.2 Performance Standards

Specific performance standards as established for the Tuba City ground water remediation system (DOE 2003a) are summarized below.

General Performance Standards

- Horizontal hydraulic gradients within contaminated regions should point inward to the extraction wells.
- Vertical hydraulic gradients above and below the extraction well screens should be downward and upward, respectively.
- The extraction system should ultimately reduce contaminant concentrations within the plume to acceptable levels.

Extraction System Design Standards

- The actual cumulative extraction rate should approximate the design cumulative extraction rate of 100 gallons per minute (gpm).
- Actual drawdown in the vicinity of the extraction wells should approximate the design drawdown of 30 ft.
- The existing extraction system should capture those portions of the plume having the greatest dissolved contaminant mass.

Treatment System Design Standards

- The system was designed to treat 100 gpm with an on-stream factor of 85 percent. The actual influent rate will be compared to the design influent rate to verify that the system is performing as expected.
- The system was designed to produce distillate with less than 50 milligrams per liter (mg/L) total dissolved solids (TDS). The actual effluent dissolved solids concentration will be compared to the design effluent concentration to assess treatment effectiveness.
- The system was designed to produce approximately 15 percent of the original volume of influent water as concentrated brine. Deviation from this percentage is an efficiency performance measure of the treatment process.

1.3 Ground Water Remediation Goals

Contaminants requiring active ground water remediation at the Tuba City site are molybdenum, nitrate, selenium, uranium, and sulfate (DOE 1999). Restoration goals for each analyte but sulfate correspond to maximum contaminant levels (MCLs) as established by the U.S. Environmental Agency (EPA) (Table 1). The Navajo Nation proposed the remediation goal for sulfate, which has no MCL. Water quality goals requested by the Navajo Nation for other parameters are also indicated in Table 1.

Table 1. Ground Water Remediation Goals

Constituent/Property	Remediation Goal	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
TDS[b]	500 mg/L	3,500–10,000 mg/L
Sulfate[b]	250 mg/L	1,700–3,500 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]MCL and required remediation goal.
[b]Secondary remediation goal requested by the Navajo Nation.

1.4 Hydrogeologic Setting

Ground water beneath the Tuba City site occurs in the N-Aquifer, which comprises relatively flat-lying sedimentary rocks of the Navajo Sandstone, Kayenta Formation, and Moenave Formation. The Navajo Sandstone consists of fine-to-medium grained massively cross-bedded aeolian sand. It is weakly cemented and friable in the site area. Occasional remnants of former playa lakes are present as resistant, thin limestone beds. Sandstone, siltstone, and mudstone of fluvial origin comprise the Kayenta Formation. A transitional zone ("intertonguing" interval) approximately 250 to 350 ft thick, sharing both aeolian and fluvial features, separates the Navajo Sandstone and Kayenta Formation. Combined thickness the Navajo Sandstone and intertonguing interval is between about 500 and 600 ft at the site.

Little is known about the Moenave Formation in the site area. From a regional perspective, it tends to be a relatively fine-grained unit (Cooley et al. 1969) and, therefore, is not expected to transmit ground water readily. In addition, because the Moenave Formation lies several hundreds of feet below the deepest measured contamination at the site, it is unlikely to provide a medium for contaminant movement. As discussed in the following paragraph, local ground water within this unit may be affected by regional ground water discharge south of the Tuba City site.

Predominantly north to south ground water flow is controlled by regional discharge to Moenkopi Wash located approximately 2 miles south of the site (Figure 2). Significant vertical hydraulic gradients in project monitor wells suggest that vertical flow may be an important process. The site lies on the middle of three alluvial terraces associated with ancestral surface flows in the wash. Locally, ground water in the Navajo Sandstone is discharged as evapotranspiration from a greasewood stand along the base of the escarpment separating the middle and lower terraces (Figure 2).

Under non-pumping conditions, depth to ground water in the Navajo Sandstone under the disposal cell area is generally 50 ft; however, ground water is about 20 ft below ground surface in the greasewood area under pumping and non-pumping conditions. The terraces are mantled with up to about 25 to 30 ft of unconsolidated, unsaturated dune sand and alluvium. The basal alluvium may be locally saturated in the greasewood area, where the depth to water is about 18 to 20 ft below ground surface.

For convenience in evaluating subsurface conditions, the aquifer beneath the site is divided into 50-ft intervals, each of which is assigned a letter designation, beginning with the 5,000−5,050 ft elevation interval (Horizon A) and ending with the 4,400−4,450 ft elevation interval (Horizon M). Horizons A through C approximately comprise the Navajo Sandstone, Horizons D through J are approximately equivalent to the intertonguing interval, and Horizons K through M generally correspond to the upper portion of the Kayenta Formation. Tabulated and graphical information regarding aquifer horizons and the screened intervals of site wells is provided in Appendix A. Well designations are according to the horizon in which the mid-point of the screen is located.

The Tuba City ground water investigation focuses primarily on the upper 250 ft of the bedrock aquifer (Horizons A through E). Ground water extraction wells uniformly screen Horizons C and D entirely, and about one-half of Horizons B and E.

2.0 Six-Month Extraction and Treatment Summary

Between February 28 and August 29, 2003, the treatment unit was in operation for 2,510 hours out of a possible 4,368 hours, resulting in an on-stream factor of 57 percent. The 28 percent difference between the actual on-stream time and design capacity (85 percent on-stream time) was due primarily to unanticipated treatment system shutdown in early April and late May. A total of 15,668,000 gallons of water was treated during the 6-month period, resulting in an average on-stream feed rate of 104 gpm and an effective rate, accounting for all downtime, of about 60 gpm. As of August 29, 2003, approximately sixty million gallons of ground water had been treated, which amounts to about 2 percent of the total estimated volume of the pre-pumping contaminant plume.

The weekly inflow rate and the variation of uranium mass in the bulk feed to the treatment system for the 6-month period is shown in Figure 3. Minimum and maximum uranium concentrations were 0.20 and 0.67 mg/L, respectively. The mean uranium concentration, determined from the weekly average concentration, was 0.35 mg/L, and the mass of uranium removed from the aquifer for the period was 44 pounds. Table 2 presents additional data regarding uranium recovery and analogous recovery data for nitrate and sulfate. Variation in nitrate and sulfate concentrations in the bulk extract is shown in Figure 4. Predicted remediation times as determined from current removal rates are provided in Section 5.3.

Table 2. COPC Mass Removal Summary

COPC	Average Bulk Feed Composition (mg/L)	Six-Month Mass Removal (lb)	Cumulative Mass Removed (lb)	Initial Mass above Remedial Goal (lb)[a]	Initial Volume of Ground Water above Goal (gal)[a]	Cumulative Mass Reduction (%)
Nitrate	458	58,860	218,170	12,400,000	3.4E+09	1.8
Sulfate	1,108	141,640	539,930	17,900,000	2.7E+09	3.0
Uranium	0.35	44	169	2,800	3.0E+09	6.1

[a]Source: DOE 2003a

2.1 Treated Water Quality and Aquifer Injection

The average total dissolved solids (TDS) concentration of the treatment system distillate was 39 mg/L for the review period. This result meets the design requirement of less than 50 mg/L of TDS in the treated water. Average concentrations of nitrate, uranium, and sulfate in the distillate were 6.7, 0.003, and 19.7 mg/L, respectively, indicating highly effective contaminant removal. The treatment system operated to produce 9 percent brine by volume of the system feed. This excludes the volume of ground water that was pumped directly to the evaporation pond without treatment during the weeks of August 15 and 22 when the treatment plant was not operating. In addition, about 9 percent of system influent for the 6-month period was sent to the evaporation pond as waste from the pre-treatment softener (ion exchange). A total of 12,268,600 gallons of treated water, equal to approximately 80 percent of the extracted volume, was returned to the aquifer via the infiltration trench.

3.0 Extent of Ground Water Contamination

Nitrate, uranium, and sulfate are the most widespread contaminants at the site. Figures 5a through 13a illustrate the baseline concentrations of these contaminants in ground water, as determined from water-quality samples collected in spring 2002, or 1999–2001 in the absence of spring 2002 data, prior to pump-and-treat operations. In these figures, three depth intervals are presented, corresponding to Horizons A and B combined, Horizons C and D combined, and Horizon E. Accompanying maps illustrate corresponding concentrations in August 2003 (Figures 5b through 13b). In these figures, each location where a sample was collected for the respective period is identified by well number. Concentration values are posted only at those locations where the remediation goal is exceeded for the respective contaminant. Extraction well locations are included in all figures for reference purposes.

Tabulated analytical results for August 2003 and the baseline period for each contaminant requiring remediation are included in Appendix B. (Erroneous uranium concentrations for wells 1104, 1105, 1106, and 1120, as presented in the baseline report [DOE 2003a] and in DOE 2003b, have been corrected in this document.) Mass removal from the various horizons and removal rates are presented in Section 5.2 and 5.3.

3.1 Horizons A through D

This section describes nitrate, uranium, and sulfate contamination in Horizons A through D. Most of the concentration data for Horizons C and D is from the extraction wells (150 ft screens centered in Horizon D), which are typically in operation when sampled. Extraction pumps are 10 to 15 ft above the bottom of the wells. As a result, concentration data from the extraction wells provide a general indication of the bulk composition of Horizons B through E but is inconclusive in describing vertical contaminant distribution in finer detail. Most monitor wells completed solely in Horizon C or Horizon D are located peripheral to the main plume area.

Nitrate

Nitrate contamination in Horizons A and B is not different in areal extent from the baseline period; however, concentrations have decreased at most locations within and marginal to the main plume (Figures 5a and 5b). An exception to the general decreasing trend occurs at well 943, located at the east section of the infiltration trench, where the nitrate concentration has increased to exceed the remediation goal for this constituent.

Nitrate concentrations in C and D horizon monitor wells have not changed appreciably since the baseline period (Figures 6a and 6b). Wells that were uncontaminated during the baseline period remain uncontaminated (e.g., wells 266, 932, and 264), and concentrations at the remaining locations are similar to baseline values (e.g., nitrate concentrations at well 912 of 403 and 367 mg/L, baseline and August 2003 results, respectively). Nitrate concentrations in the extraction wells are generally less than during the baseline period. However, this latter observation may be due to the fact that since the start of remediation, extraction well samples are more likely mixtures of ground water from multiple horizons, some of which may be uncontaminated (e.g., Horizon E, Figures 7a and 7b).

Uranium

The areal extent of uranium contamination in Horizons A and B during August 2003 is very similar to that observed during the baseline period (Figures 8a and 8b). However, concentrations in these shallow horizons have generally decreased at many locations within and marginal to the main plume. Again, well 943 (located at the east section of the infiltration trench) provides an exception to this observation, as uranium concentrations have increased to exceed the remediation goal of 0.044 mg/L.

Figures 9a and 9b show that uranium concentrations in C and D horizon monitor wells have also not changed appreciably since the baseline period: wells that were uncontaminated during the baseline period remain uncontaminated (e.g., wells 266, 912, 932, and 264), and uranium concentrations at the remaining monitoring locations are similar to baseline values (e.g., uranium concentrations at well 932 of 0.0016 and 0.0017 mg/L, baseline and August 2003 results, respectively). As with nitrate, and for the same reason, uranium concentrations in the extraction wells are generally less than during the baseline period. Uranium contamination in the horizons deeper than Horizon E, as shown in Figures 10a and 10b, is discussed in Section 3.2.

Sulfate

Sulfate contamination in Horizons A and B is also not different in areal extent from the baseline period (Figures 11a and 11b). Since that time however, sulfate concentrations have decreased at some locations and increased at others, including previously mentioned well 943. Sulfate concentration increases are mainly localized within the extraction field and are not suggestive of plume expansion.

Sulfate concentrations in C and D horizon monitor wells have not changed appreciably between the baseline period and August 2003 (Figures 12a and 12b). Wells that were uncontaminated during the baseline period remain uncontaminated (e.g., wells 266, 932, and 264), and sulfate concentrations at the remaining monitor wells are similar to baseline values. Sulfate concentrations in the extraction wells are generally less than during the baseline period.

3.2 Horizons E and Deeper

Baseline sampling results indicated contamination of nitrate, uranium and sulfate at well 251, completed with mid-screen depth in Horizon E (Figures 7b, 10b, and 13b). Since the start of ground water remediation, concentrations of each contaminant in well 251 have decreased to below each respective water quality goal. Contamination levels at the remaining upper terrace E-horizon well (well 268) has remained consistent with background values throughout the baseline and remediation periods. Water quality results for the only Horizon E well on the lower terrace (well 920) indicate that ground water contamination has never reached that location. These data indicate that contamination in Horizon E was minor in lateral extent and magnitude prior to the start of ground water remediation, and that presently Horizon E is not contaminated.

Deep wells 254 (Horizon I), 255 (Horizon M), 256 (Horizon I), and 257 (Horizon M) were installed in May 2000. Each of these wells exhibits contamination of either nitrate, uranium, or sulfate in excess of the remediation goal. Concentrations of these constituents during initial samplings at each location were consistent with background or did not exceed remediation goals. Since the first appearance of contamination in these wells, concentrations have generally been unstable. The origin of this apparent contamination in the deep horizons is uncertain.

A fifth deep well (well 253, Horizon M), installed in May 2000 adjacent to wells 251 and 252, also showed evidence of contamination. Because of extensive grout invasion of the well screen, well 253 was abandoned in April 2001. Since that time, down-hole video images indicate that grout has apparently also invaded the screens of wells 254 and 256 (the camera cable could not reach the screen depths of wells 255 and 257). Material collected from the bottom of well 254 in October 2003 had the appearance and texture of bentonite grout. At that time, the well depth was approximately 15 ft higher than when first installed.

The delayed arrival of contamination in deep wells 253 through 257, combined with evidence of potentially compromised annular seals, as indicated by grout invasion, and the apparent absence of contamination in overlying Horizon E, suggests that monitoring results from these wells may be unrepresentative of the ground water in the formation intercepted by their screens. DOE is preparing a separate report, due in 2004, to specifically address the source of contamination in these wells and determine if subsequent action is warranted.

3.3 Extent of Contamination Summary

- Nitrate, uranium, and sulfate contamination in Horizons A and B is similar in areal extent than that observed in the baseline period. In general, concentrations have decreased at many locations within and marginal to the main plume.

- Nitrate, uranium, and sulfate concentrations in C and D horizon monitor wells have not changed appreciably from those measured under baseline conditions. Wells that were uncontaminated during the baseline period remain uncontaminated, and concentrations at the remaining locations are similar to baseline values.

- Concentrations of nitrate, uranium, and sulfate at well 943 (Horizon B) have increased from relatively low levels in the baseline period to exceed the remediation goals in

August 2003. The cause of the increases is not certain. Ground water at this location is estimated to be within the capture zone of the extraction system.

- On the lower terrace, uranium contamination occurs only in well 691 (Horizon C) but at a concentration that does not greatly exceed the remediation goal. Nitrate and sulfate concentrations remain above the remediation goal at that location and in adjacent well 1003 (Horizon D). Surrounding wells on the lower terrace indicate minor nitrate contamination (less than twice the remediation goal) and no sulfate contamination.

- Ground water contamination in Horizon E slightly exceeded remediation goals in the baseline period. Remediation goals have since been attained in Horizon E.

- Due to potentially compromised annular well seals, low-level contamination in Horizons I and M (wells 254, 255, 256, 257) may be unrepresentative of the ground water in the formation intercepted by the well screens.

4.0 Hydraulic Response of Aquifer to Extraction and Injection

This section evaluates the hydraulic responses of the aquifer to ground water extraction and injection by comparing baseline water levels and hydraulic gradients to those observed during March through August 2003.

4.1 Water Table

The estimated water table associated with baseline conditions is shown in Figure 14a. Water level contours were computer-generated by triangulation with linear interpolation and then manually refined. Water levels in Horizons A and B wells only were used for the middle terrace area because the top of the saturated zone drops several tens of feet between the north end of the disposal cell and the escarpment, and in doing so intersects both of these horizons. The water table beneath the lower terrace was estimated using Horizon C water levels because the A and B horizons are absent there. For both terraces, wells deeper than Horizon C are excluded because vertical gradients observed with depth are not representative of a water table condition. The analysis also did not use pumping well water levels.

Figure 14a indicates generally southward flow during the baseline period. The water table gradient was relatively uniform beneath the area of the disposal cell and became steeper at the escarpment. Figure 14b shows a similarly constructed water table for July 2003. At that time, ground water mounding and locally increased hydraulic gradients in Horizons A and B were evident along the north edge of the disposal cell due to infiltration of treatment system effluent. Additional discussion of ground water mounding at the trench is presented in Section 4.1.1. Comparison of Figures 14a and 14b indicates that operation of the extraction wells has produced a prominent south trending depression in the water tables extending from the southwest corner of the disposal cell to the escarpment.

4.1.1 Ground Water Mounding

Treatment plant distillate enters the infiltration trench at a concrete vault about halfway between its endpoints and is then conveyed in perforated PVC piping to the northeast and southwest by gravity flow. The piping lies in a 3-ft thick gravel bed underlain by bedrock sandstone or unconsolidated alluvium, depending on location. Non-uniform infiltration of the treated water has created the asymmetrical ground water mound along the trench shown in Figure 14b. About 18 ft of mounding, relative to baseline conditions, resulted beneath the west section of the trench in July 2003, whereas only about 1 ft of mounding occurred beneath the eastern section. Mounding is greatest toward the southwest end of the trench either because most treatment effluent enters that end; or, the resistance to flow in Horizon A is larger below the southwest part of the trench. Ground water modeling performed in support of remedial system design predicted approximately 5 ft of mounding distributed uniformly along the length of the trench (DOE 1998).

Ground water mounding at the infiltration trench should be evaluated before any major change is made to the ground water extraction and treatment system to ensure that the water table will not rise to the level of the mill tailings. At present, the sloped base of the tailings, in combination with sustained drawdown along the south edge of the disposal cell, should provide an adequate margin of safety in preventing the water table from intersecting the tailings and further mobilizing contaminants to ground water. As a precaution, and to evaluate hydraulic response, all distillate was discharged to the run-on drain along the north side of the disposal cell from mid-August through late November 2003.

4.2 Water Level Drawdowns

Figures 15, 16, and 17 illustrate computed drawdown in monitor wells during July 2003, relative to baseline water levels, for the various depth horizons. Drawdown calculation data are included in Appendix C. Section 4.2.1 evaluates drawdown and pumping rates in the extraction wells.

Horizons A and B

Figure 15 shows that water level changes have occurred in all A and B-horizon wells between the baseline period and July 2003. However, measured drawdown in a well does not imply that the well is necessarily within the capture zone of the extraction system (see Section 5.1). Monitor wells completed solely in Horizons A or B are absent within and immediately surrounding the extraction well field east of the disposal cell, and therefore drawdown analysis for that area is not possible. Immediately south of the cell, the maximum observed drawdown is 17 to 18 ft, occurring at or near the center of extraction. Extraction well screens intercept about 20 to 25 ft of Horizon B but no portion of Horizon A. Significant drawdown (2 to 7 ft) results on the middle terrace along the escarpment south of the site. Drawdown in the shallow horizons diminishes to 0.2 ft at well 271, located about 2,000 ft southwest of the extraction well field.

Numerical modeling of the site predicted steady-state drawdown of 20 to 30 ft in the immediate area surrounding the extraction wells (DOE 1998) at a total extraction rate of 100 gpm. Ground water extraction during the month preceding the July 2003 water level measurements increased steadily from zero to about 85 gpm. Considering the non-steady pumping during this period, the model result is a close approximation to observed drawdown.

Horizons C and D

All C and D-horizon monitor wells appear to be within the zone of influence of the extraction system (Figure 16). Direct analysis of Horizons C and D drawdown within the extraction well field is not possible due to the lack of monitoring wells; however, significant drawdown (10 to 20 ft) occurs in the immediately surrounding area. Generally, 2 to 3 ft of drawdown is observed on the lower terrace, although the actual capture zone does not extend to these lower terrace locations (see Section 5.1).

Horizon E and Deeper

Extraction well screens extend downward to intercept the upper 25 to 35 ft of Horizon E. Within the extraction well field, drawdowns at Horizon E wells 251 and 268 on July 30, 2003 were about 20 and 30 ft, respectively. Both wells are fully screened across Horizon E and portions of Horizons D and F. Drawdown at the remaining Horizon E well (well 920), located on the lower terrace about 1,200 ft south of the disposal cell, was 9.5 ft. This latter result may indicate relatively high hydraulic conductivity within the horizon. Significant drawdowns observed in Horizons G, I, and M. (up to 8.7, 16.8, and 1.4 ft, respectively; Figure 17) are not necessarily the result of ground water capture from these horizons, but may instead be due to reduced flows to the deep zones from the overlying horizons.

4.2.1 Extraction Well Drawdowns and Pumping Rates

Twenty-four wells were pumped to extract ground water during the period of review. Continuous pumping at many locations is not possible because of well-yield limitations. On-off pump cycling was particularly evident among extraction wells 1112 to 1118 located south of the fence line on the south side of the disposal cell (Figure 2), although on-off cycling affected most locations at some time during the review period. While pumping, the rates at individual wells ranged from about 2.5 to 6.5 gpm, which is consistent with design criteria for the extraction system (Appendix A). However, the effective pumping rate at a given well, which accounts for the time that the pump is idle during the on-off cycles, are generally lower (Table A−4, Appendix A). Sustained pumping tends to increase the incidence of on-off cycling thus decreasing the effective pumping rate.

The available drawdown (height of water column above the pump intake) in a well while being pumped is an indication of whether aquifer properties or pump capacity limit the extraction rate. Water levels in all pumping wells (except well 1105) were measured on June 30 and July 1, 2003 to determine available drawdowns. Figure 18 shows the amount of available drawdown in the extraction wells. East of the disposal cell, available drawdown tended to range from about 100 to 140 ft; the single exception (80 ft) occurred at well 1122. Available drawdown ranged from about 50 to 150 ft in the group of wells near the southwest corner of the cell, and from 10 to 156 ft along the south side of the disposal cell. Uncertainty is introduced into these calculations because, for a given well, it is not known at which point during the on-off pump cycle that the water level was measured.

In July 2003, 0.75-horsepower pumps in wells 1105, 1106, and 1120 were replaced with 1.5-hp pumps to determine if greater extraction rates could be sustained. Results varied. Extraction rates increased by about 10 percent at wells 1106 and 1120; however, available drawdowns at these wells were reduced to 90 percent and 20 percent of the pre-pumping drawdowns, respectively.

Well 1105 was then inoperable through mid-August but has since sustained an extraction rate of 14.5 gpm. Water levels in well 1105 were not measured for the period since pump operation was restored.

Formation yield appears to be rate-limiting in the south group of extraction wells 1112 through 1118 and so current pump capacity is probably adequate for those locations. Mixed results of increasing the pumping capacity at wells 1105, 1106, and 1120 indicates that the potential to achieve greater extraction at other locations by increasing pump capacity is difficult to predict.

4.3 Horizontal Flow Gradients

Water level data for the summer of 2003 were analyzed to estimate ground water flow directions within discrete depth intervals of the aquifer. This was accomplished using a grid-based contouring and surface mapping computer program (Surfer, v. 7) to produce a three-dimensional surface of the hydraulic head in the aquifer, as estimated by triangulation and linear interpolation. Horizons A and B were combined in this analysis, as were Horizons C and D. Horizons E, G, and I were evaluated separately.

In addition to the potentiometric surface, program output included a hydraulic gradient vector at each grid node. Figures 19 through 23 illustrate the hydraulic gradients for the baseline period and July 2003. Within each vertical interval analyzed, vector scaling (symbol length) is proportional to the magnitude of the hydraulic gradient. However, the proportionality is not preserved between depth intervals. Filled arrows are used to represent baseline hydraulic gradient vectors; unfilled arrows are used to represent July 2003 conditions.

Horizons A and B

A comparison of baseline and July 2003 flow directions in Horizons A and B suggests that since the start of remediation, horizontal flow is effected in relatively shallow ground water in the area of the infiltration trench, beneath the disposal cell, and within the extraction field south of the disposal cell. North and northwest of the disposal cell, flow directions in July 2003 indicate radially outward flow from the infiltration trench (Figure 19b). Infiltration at the trench combines with ground water extraction to the south to create steeper hydraulic gradient beneath the cell than occurred under baseline conditions. Convergent flow directed toward extraction wells occurs within the extraction field south of the disposal cell but not significantly beyond. The extent to which ground water extraction influences flow directions in Horizons A and B east of the cell is indeterminate because no monitoring wells are located in that area. Section 5.1 presents contaminant capture information for Horizons A and B using both hydraulic gradient and contaminant data.

Horizons C and D

Figures 20a and 20b illustrate computed horizontal gradient vectors in Horizons C and D. The analysis included water levels in monitor wells and pumping levels in the extraction wells. Without the extraction well data, vector analysis predicted no capture of ground water from these horizons, primarily because there are monitor wells within or adjacent to the extraction field.

The extraction wells have caused a reversal in flow within Horizons C and D for much of the region south of the well field. Capture is not apparent in the area south of extraction wells 1113, 1112, and 1116 because yields from those wells are low, leading to prolonged intervals of water level recovery without pumping. Extremely low yield entirely prevents use of well 1116. Low yields from these wells may not be problematic, however, because Horizons C and D in this area may not be contaminated. As indicated in sample results from wells 266 and 932, measured concentrations of nitrate, uranium, and sulfate in Horizons C and D a short distance south of the extraction field are less than the respective remediation goals (Figures 6, 9, and 12). The influence of the well field east of the disposal cell is to create westward flow toward those extraction wells. Ground water capture does not occur anywhere on the lower terrace or in the southwest area of the middle terrace.

Horizon E and Deeper

Figure 21 presents the horizontal flow direction calculated for a limited area of Horizon E. The July 2003 flow direction deviated east of the baseline direction and the magnitude of the gradient was less. The E-horizon flow direction in February 2003 was identical to that of the baseline although the magnitude of the gradient was less (DOE 2003a). Relatively greater drawdown in July at well 268, located at the south end of the east group of extraction wells, resulted in the apparent deviation in flow direction. The difference in drawdown and apparent flow direction may be a transient effect of the varied pumping histories preceding analysis.

Although not indicated in Figure 21, ground water capture from Horizon E is probable because all but three of the extraction wells (1116, 1117, and 1118) have screens extending into that horizon. The extent of capture in Horizon E cannot be fully characterized by horizontal flow vectors because the only three monitor wells having screens centered on this interval are too widely spaced. The reduction in the magnitude of the hydraulic gradient suggests, however, that the rate of southward horizontal ground water flow in Horizon E has decreased in response to ground water extraction.

Figure 22 shows no significant change in the direction or magnitude of horizontal gradients between baseline and July 2003 conditions for Horizon G, indicating that current ground water extraction exerts no influence on horizontal flow in this horizon. The lack of response is likely because the deepest screened interval in the extraction wells is Horizon E.

Flow directions in Horizon I implied by the calculated gradients have remained consistent with the baseline condition (Figure 23). However, the magnitudes of the gradients were significantly less in July 2003 than those computed for baseline conditions. This reduction in hydraulic gradient magnitude was not observed during the previous evaluation period (DOE 2003a). It is inconclusive at this time whether the gradient reduction in Horizon I during July 2003 is real or the result of other factors such as a failed annular seal in one of the wells used in this analysis.

4.4 Vertical Hydraulic Gradients

Analysis of vertical flow gradients provides some indication of the capture depth of the extraction system. Table 3 presents a comparison of computed vertical gradients under baseline and July 2003 conditions. Data for wells that screen adjacent horizons is limited to five paired sets within Horizons A through D. No well pairs exist that screen adjacent deeper horizons.

Table 3. Vertical Hydraulic Gradients Between Horizons

Well Pair	Horizons	Date	Gradient[a] (ft/ft)	Date	Gradient[a] (ft/ft)
901−910	A−B	September 1998	0.024	July 2003	0.028
906−938	A−B	February 1999	0.040	July 2003	0.071
908−912	B−C	March 2000	0.019	July 2003	0.057
909−932	B−C	September 2000	0.67	July 2003	0.73
914−915	C−D	February 1999	-0.24	July 2003	-0.011
903−920	C−E	September 2000	0.030	July 2003	0.090
915−916	D−G	February 1999	0.14	July 2003	0.099
251−252	E−I	May 2000	0.040	July 2003	-0.045
268−256	E−I	May 2000	0.10	July 2003	-0.020
920−921	E−I	September 2000	0.060	July 2003	0.04
254−255	I−M	May 2000	0.073	July 2003	0.10
256−257	I−M	May 2000	0.011	July 2003	0.00

[a]Positive gradient indicates downward flow potential; negative gradient indicates upward flow potential.

In Horizons A, B, and C, which are above the screen centers of the majority of the extraction wells, July 2003 vertical gradients indicate downward flow. The downward vertical gradient at upgradient well pair 901/910 (Horizons A and B, respectively) has essentially remained unchanged from the baseline condition. At the remaining locations used to compute vertical gradients in these upper horizons, the magnitude of the downward gradient in July 2003 was larger than baseline equivalents.

At well pair 914/915, flow between Horizons C and D remained upward during the evaluation period, although the vertical gradient at this location had a lower magnitude compared to the baseline value. Contaminant concentrations at these wells during July 2003 are consistent with background levels. Upward flow from mid to upper horizons at this location on the middle terrace may be due to ground water discharge by evapotranspiration along the base of escarpment, where Horizons A, B, and C are exposed and a stand of phreatophytes (greasewood) is present.

Well 916, nested with wells 914 and 915, is screened solely in Horizon G. Contrary to the upward gradient observed in the 914/915 well pair a downward vertical flow potential persists between wells 915 (Horizon D) and 916 (Horizon G). The relatively large gradient (approximately 0.1 ft/ft) remains consistent with the baseline gradient computed for this well pair. The apparent vertical flow divide at this location may signify divergence of a shallow flow system from a deeper regional system that ultimately discharges at Moenkopi Wash.

Since the start of ground water remediation, the vertical flow gradient between the E and I horizons at middle terrace well pairs 251/252 and 268/256 has been upward, in contrast to the downward potential observed at these locations for the baseline period. The reversal in the vertical gradient between these horizons suggests that operation of the extraction system contributes in preventing downward migration of contaminants on the middle terrace. The vertical flow potential between Horizons E and I on the lower terrace, as indicated at well pair 920/921, has remained downward since the baseline period although at a slightly decreased magnitude since the start of pumping. Downward vertical gradients have also persisted between the C and E horizons at the same location as indicated by well pair 903/920.

Computed vertical gradients between Horizons I and M at middle terrace well pair 254/255 have been downward during and since the baseline period. Since the start of remediation, the flow potential between well 256 (I horizon) and 257 (M horizon) changed from downward to neutral. This effect appears to primarily result from pumping, as manifested in extensive drawdown in Horizon E, moderate drawdown in Horizon I, and relatively stable water levels in Horizon M.

5.0 Plume Capture and Contaminant Recovery

5.1 Plume Capture

The estimated capture zone of the extraction system, as it affects contaminant recovery, is illustrated in Figures 24 and 25 for Horizons A and B combined, and C and D combined, respectively. The dashed line in each figure defines the southern extent of the ground water capture zone as determined by analysis of July 2003 water level data described in Section 4.0. Proportionally scaled circles indicate the relative magnitude of contaminant concentration in wells where the respective remediation goal is exceeded.

Figures 24 and 25 suggest that the current configuration and operation of the extraction system effectively captures the region of maximum contamination. Hydraulic containment of all contaminated flow from the site is also achieved. Upward flow potentials from deep zones to Horizon E (Section 4.4) and the absence of contamination in Horizon E (Section 3.0) are indicative of vertical containment of contaminated ground water within the main plume area.

Contamination currently not captured by the extraction system includes moderately high concentrations of uranium and nitrate in wells 262 and 263 located in the southeast portion of the middle terrace area. In the remaining middle terrace area beyond the capture zone, uranium concentrations are less than or marginally exceed the uranium remediation goal. Moderate levels of nitrate and sulfate are also present. Migration of contamination toward Moenkopi Wash within these areas may be hindered by ground water discharge along the escarpment and to the greasewood stand.

Contamination on the lower terrace is generally restricted to dilute concentrations of nitrate, uranium, and sulfate at co-located wells 691 (Horizon C) and 1003 (Horizon D), approximately 1,500 ft south of the site. Contaminant concentrations are lower in the D-horizon than in the C-horizon at this location. Uranium levels are below the standard at well 1003. Low levels of nitrate (50 to 63 mg/L) in wells 903, 1004, and 930 are the only other indications of contamination on the lower terrace.

5.2 Contaminant Recovery from Aquifer Horizons

Monitoring results indicate that contamination is currently restricted to Horizons A through D; however, the relative contribution of contaminated ground water from each of these horizons to the treatment system is difficult to evaluate because the screened intervals of many of the wells used to define contaminant extent intercept more than one horizon. For example, on the basis of uranium concentration data from the pumping wells, Horizon D appears to be highly contaminated; however, pumping well screens generally extend from within Horizon B to within

Horizon E. Because the baseline distribution of contamination with depth in the extraction wells was not determined it is currently not possible to discern which of the intercepted horizons contains the greatest contamination.

Excluding the extraction wells, Horizon C and D monitor wells are located peripheral to the main plume area. Numerous A and B horizon wells that exhibit high levels of contamination define the main portion of the plume near the site; however, there are no co-located C and D wells to indicate the depth to which the contamination extends. There are several locations toward the margins of the contaminant plume where wells completed in either Horizon A or B are near or adjacent to Horizon C or D wells (e.g., wells 935 and 912, B and C horizons, respectively; 265 [B] and 266 [D]; 909 [B] and 932 [C], and 263 [B] and 264 [D]). In each case, contaminant concentrations in the well screened in Horizon A or B exceed those in the corresponding C or D horizon well. For example, nitrate concentrations at wells 265 (B) and 256 (D) in August 2003 were 575 and 14 mg/L, respectively. Where present on the lower terrace, contamination also decreases significantly from Horizon C to Horizon D. Given this apparent reduction in contaminant concentrations with depth, it is possible that Horizons A and B contribute the greater proportion of contamination to the extraction system. Relatively large drawdowns measured in Horizon A and B wells on the middle terrace tend to support this possibility.

5.3 Contaminant Removal Rates

Since the start of remediation in mid-2002, the masses of nitrate, uranium, and sulfate removed from the aquifer total approximately 218,000, 169, and 540,000 pounds, respectively (Table 2). The cumulative removal rates for these contaminants through 1.2 years of full-scale remediation (June 2002 through August 2003) are 182,000; 141, and 450,000 lb/yr, respectively. At these rates, remediation of the nitrate, uranium, and sulfate, plumes will require 68, 20, and 40 years, respectively, since June 2002. This prediction is valid only if volumetric extraction rates increase over time to compensate for decreasing concentrations of contaminants in the ground water, and if the entire plume is captured through expansion of the existing extraction system. By comparison, the estimated volume of contaminated ground water (approximately 3×10^9 gal; Table 2) will require about 67 years to extract at the current, sustained design pumping rate (85 gpm), assuming full plume capture.

Figure 26 displays uranium concentration over time at monitor well locations in Horizons A and B within the most contaminated regions of the ground water plume. Analogous concentration versus time data for selected extraction wells are shown in Figure 27. These plots indicate that uranium concentrations are in general static or slightly decreasing since the start of remediation. Increasing concentrations at well 936 are indicative of southward migration of contamination from near the disposal cell to the extraction wells.

6.0 Summary

- Capture of the main portion of the contaminant plume has been achieved.
- Vertical plume containment has been achieved.
- Ground water remediation goals have been achieved for aquifer horizon E.
- On-stream extraction and treatment flow rates achieve design objectives.
- Distillate quality meets or exceeds remediation objectives.

- Eighty-percent of extracted water has been returned to the aquifer.
- Extraction from Horizon E, although unavoidable with the current system, may no longer benefit remediation objectives.

7.0 Recommendations

Recommendations pertaining to the operation of present remediation system and the future remediation strategy for the site will be addressed in a separate report prepared in March 2004.

8.0 References

U. S. Department of Energy (DOE), 1998. *Final Site Observational Work Plan for the UMTRA Project Site Near Tuba City, Arizona*, MAC-GWTUB1.1, U. S. Department of Energy Grand Junction Office, Grand Junction, Colorado, September.

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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, 61 p.

Figures

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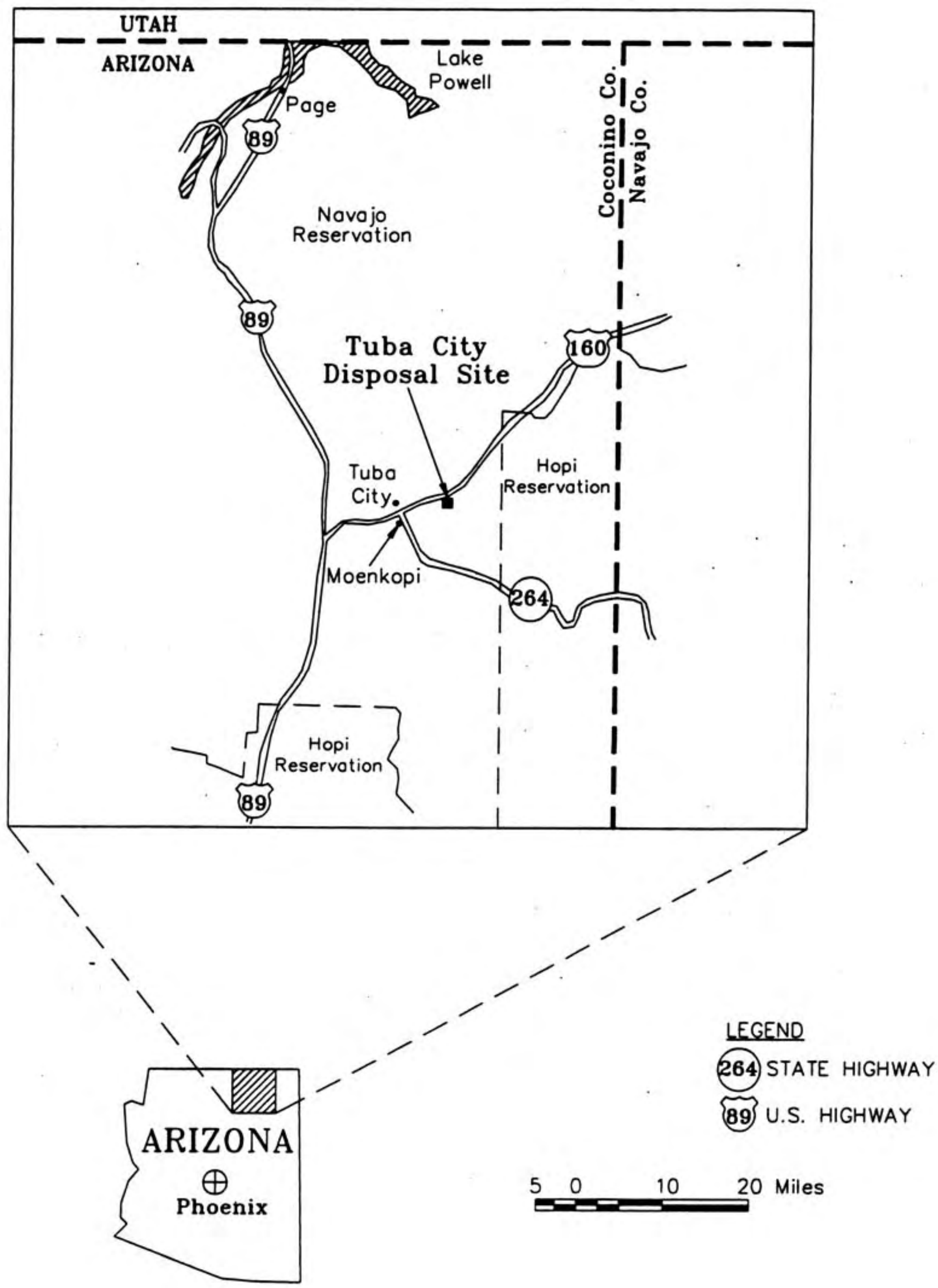

Figure 1. Tuba City Site Location

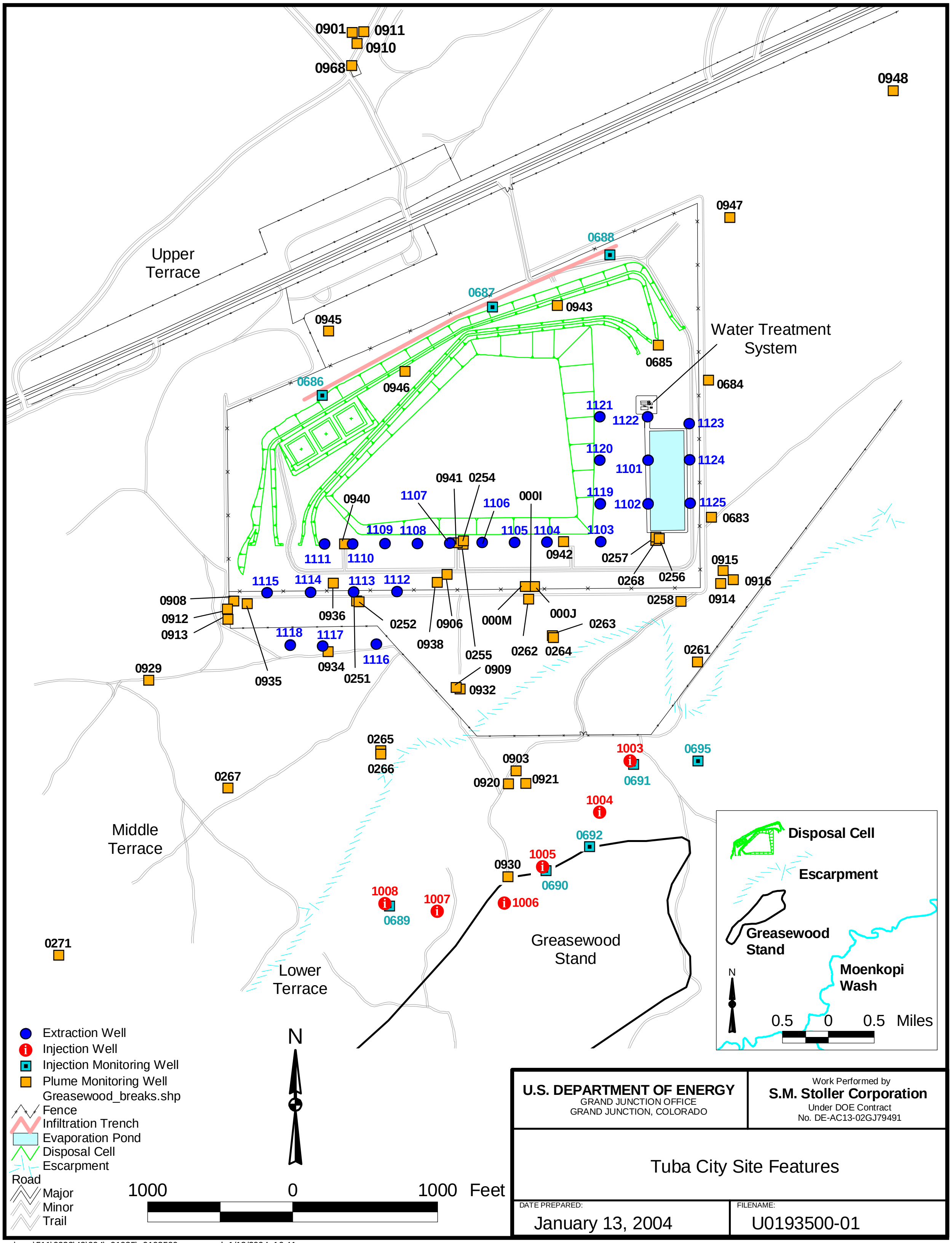

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Figure 2. Tuba City Site Features

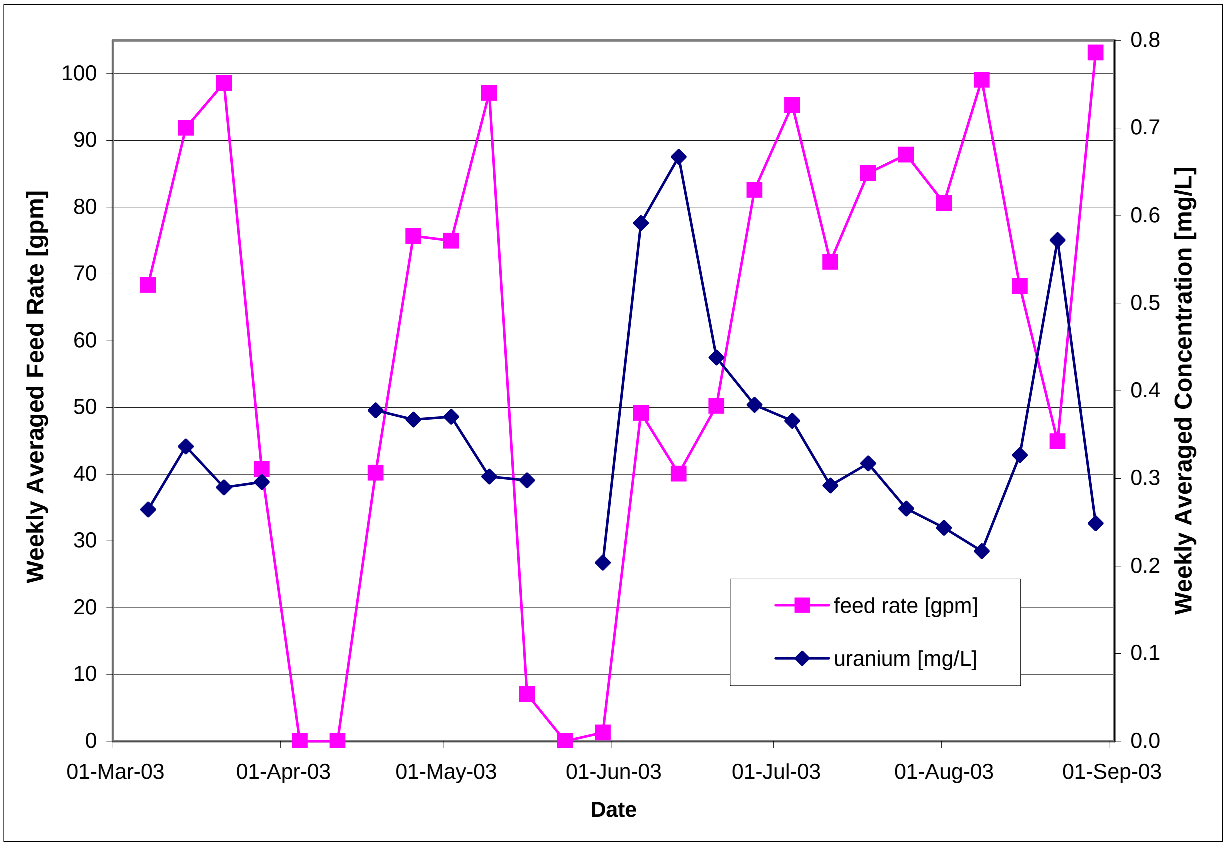

Figure 3. Rate of Uranium Treatment, March through August 2003

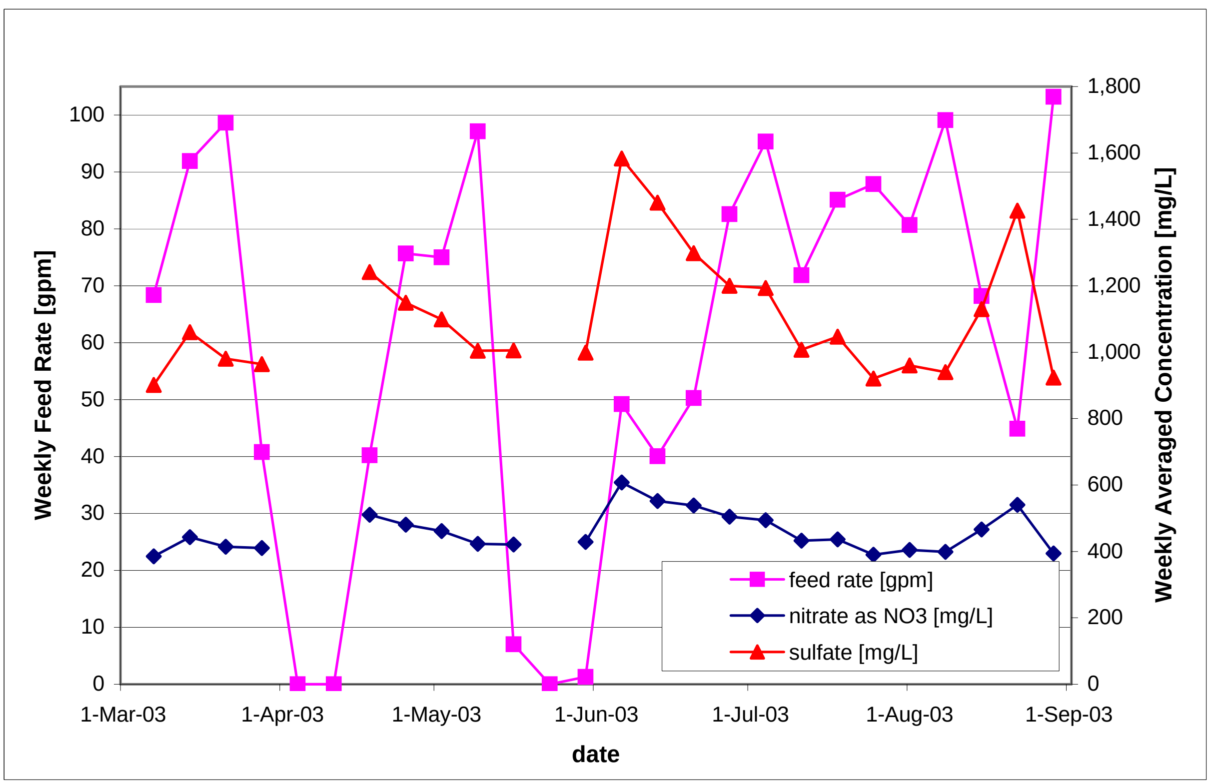

Figure 4. Rate of Nitrate and Sulfate Treatment, March through August 2003

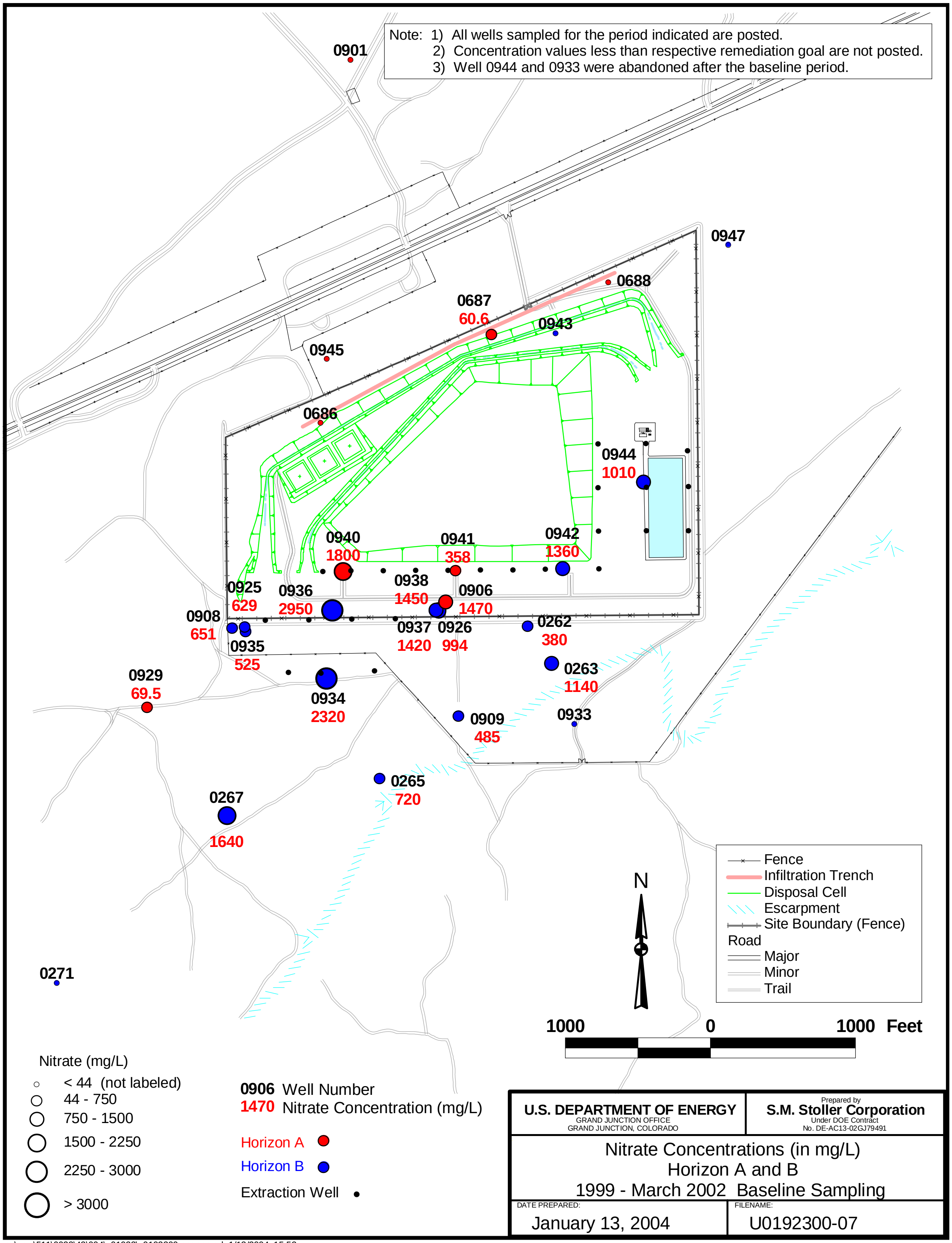

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Figure 5a. Nitrate Concentrations in Ground Water, Horizons A and B, Baseline Period

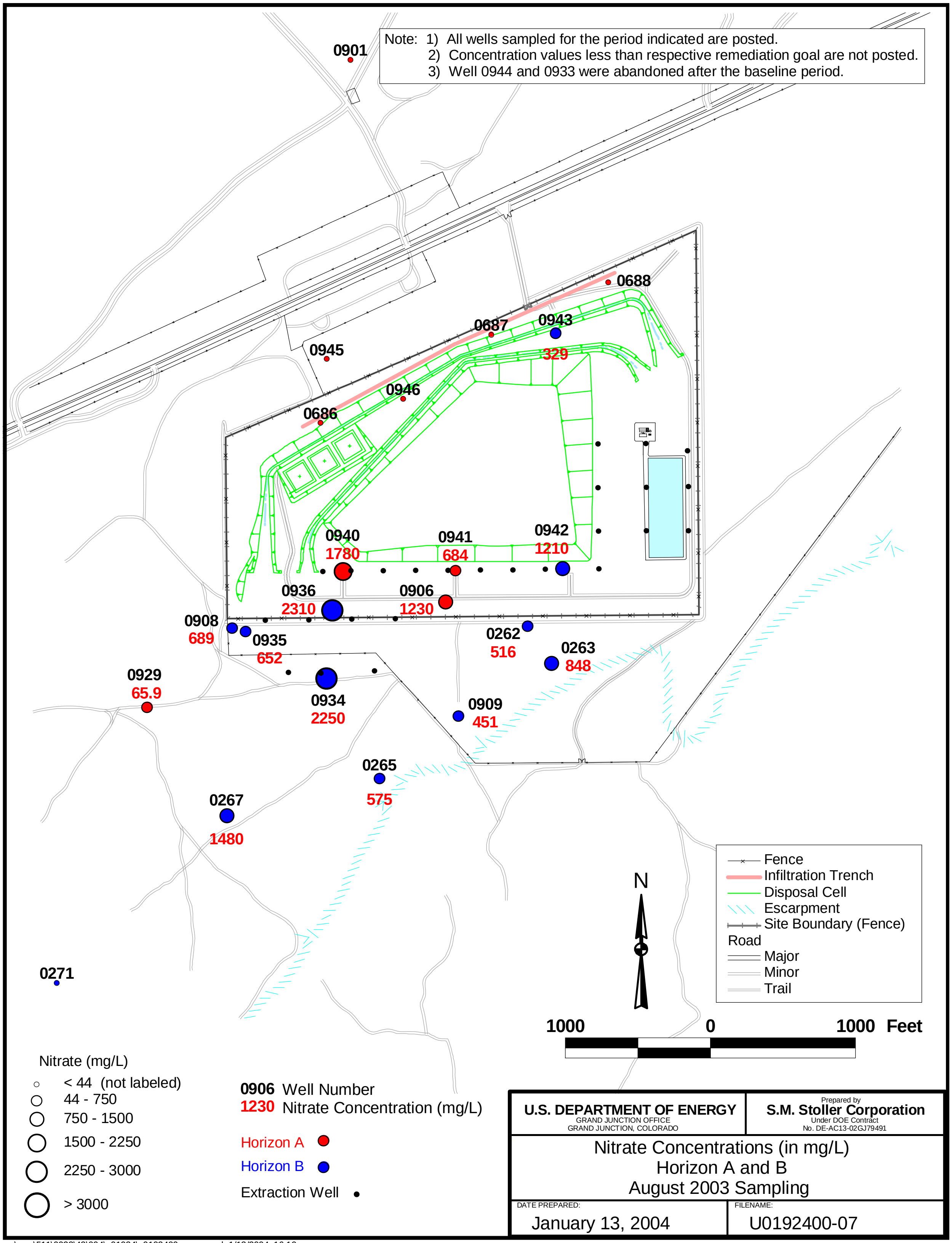

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Figure 5b. Nitrate Concentrations in Ground Water, Horizons A and B, August 2003

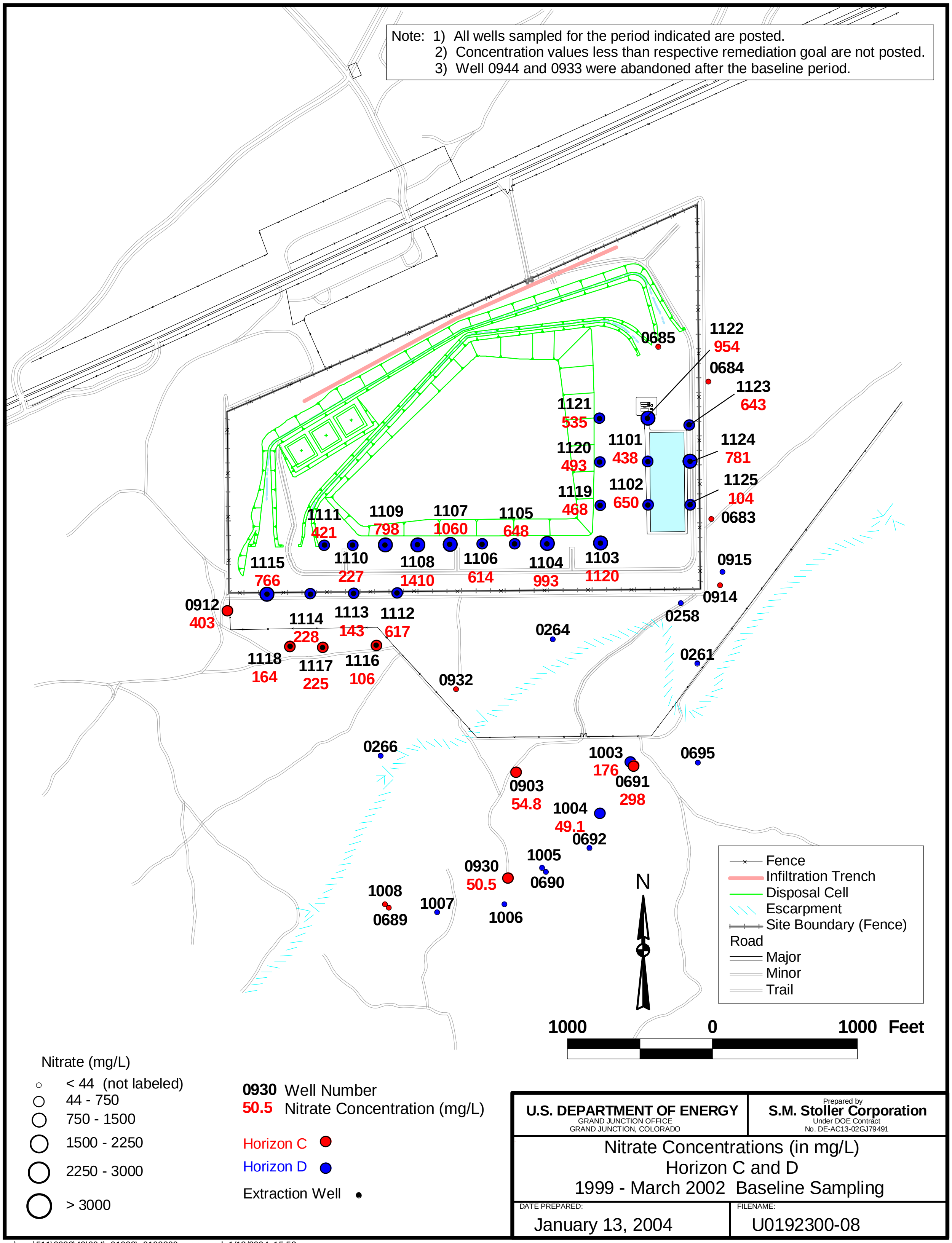

Figure 6a. Nitrate Concentrations in Ground Water, Horizons C and D, Baseline Period

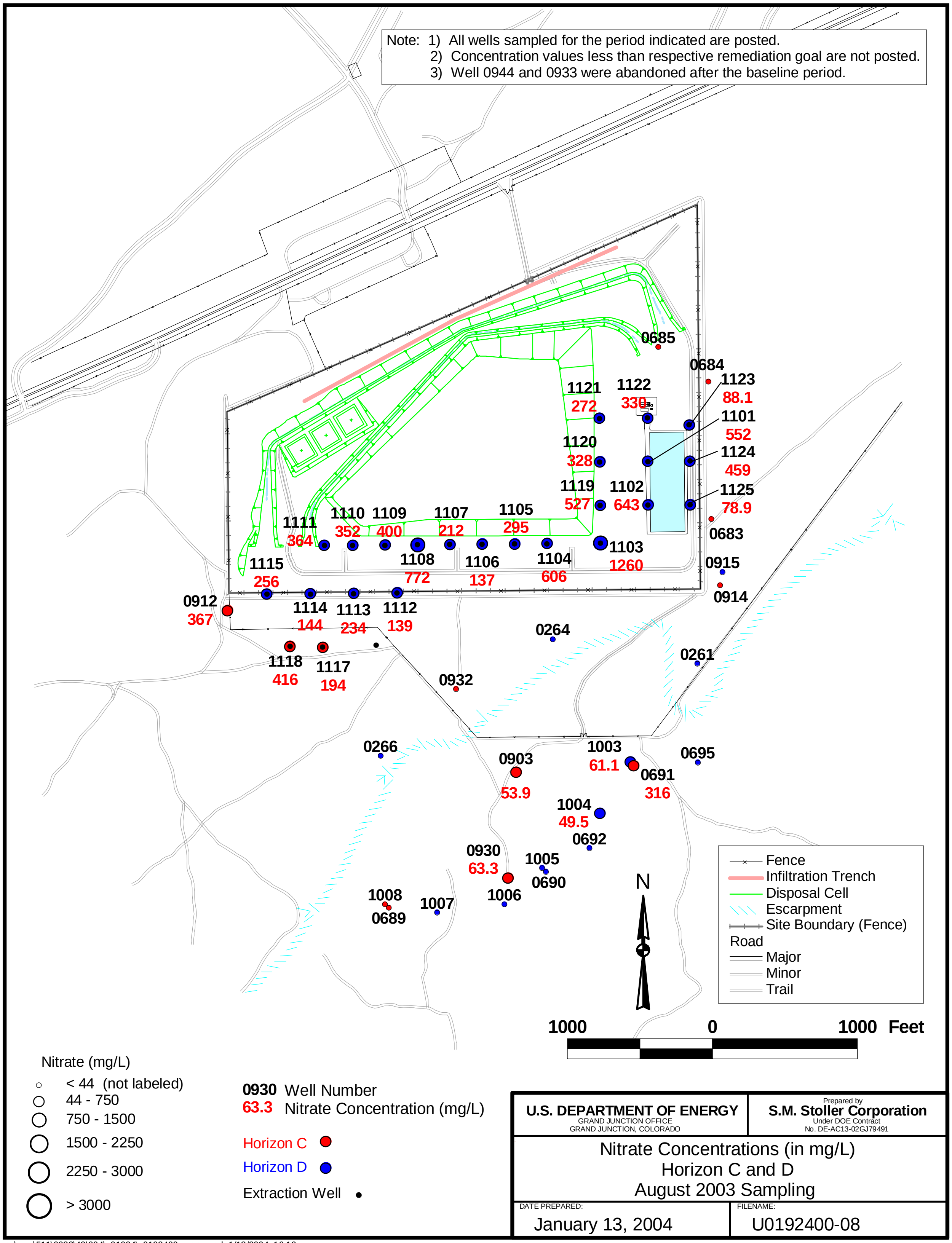

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Figure 6b. Nitrate Concentrations in Ground Water, Horizons C and D, August 2003

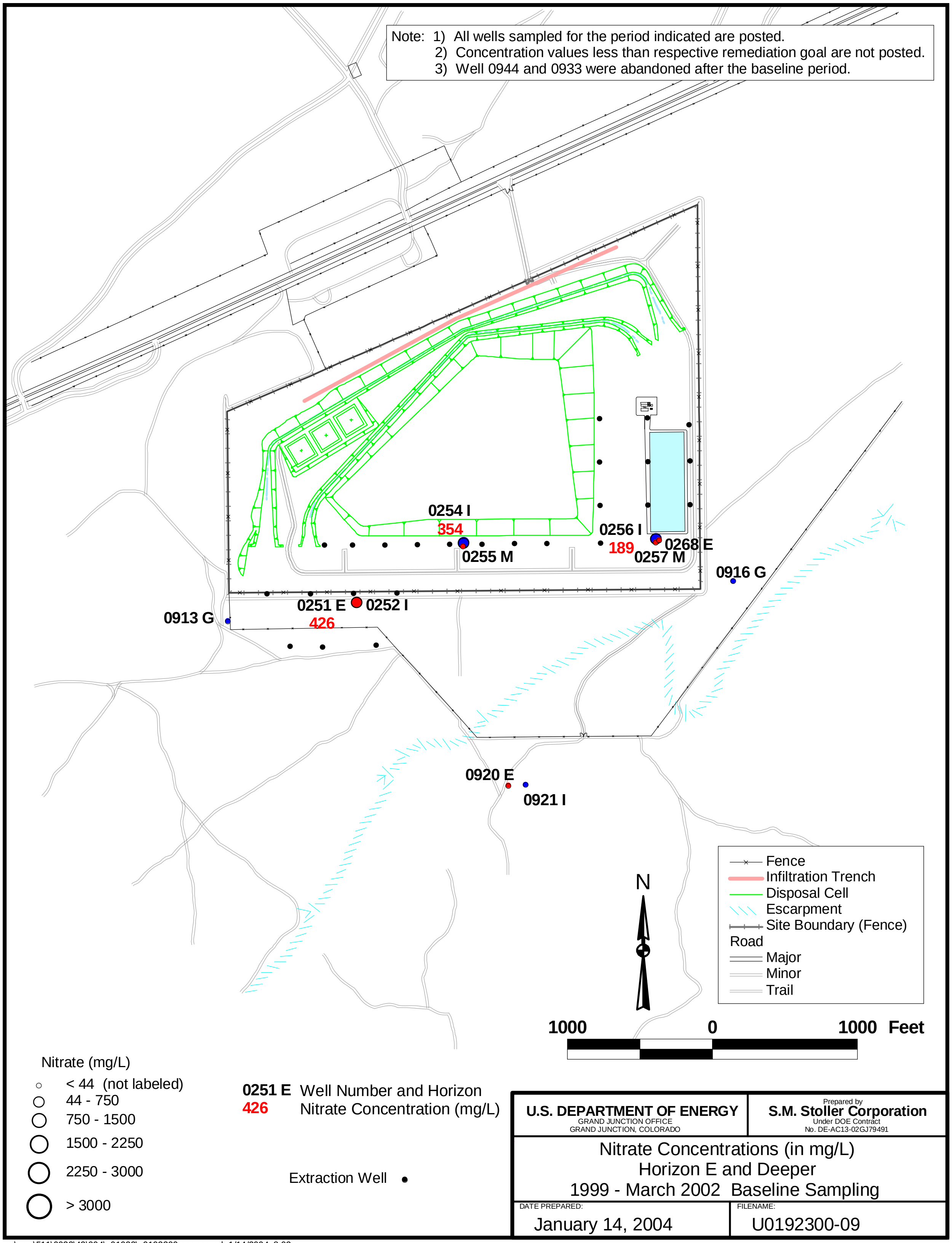

Figure 7a. Nitrate Concentrations in Ground Water, Horizons E and Deeper, Baseline Period

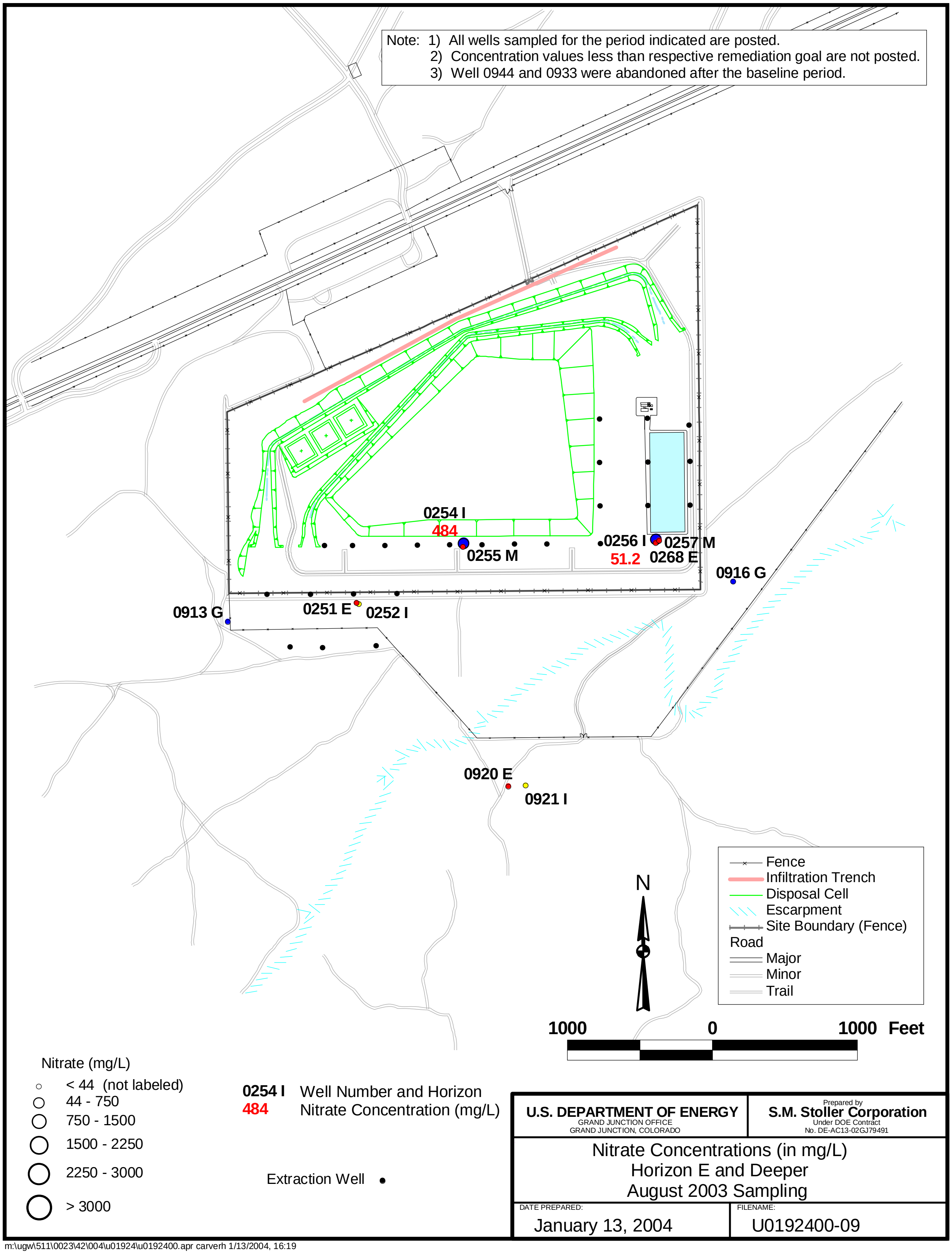

Figure 7b. Nitrate Concentrations in Ground Water, Horizons E and Deeper, August 2003

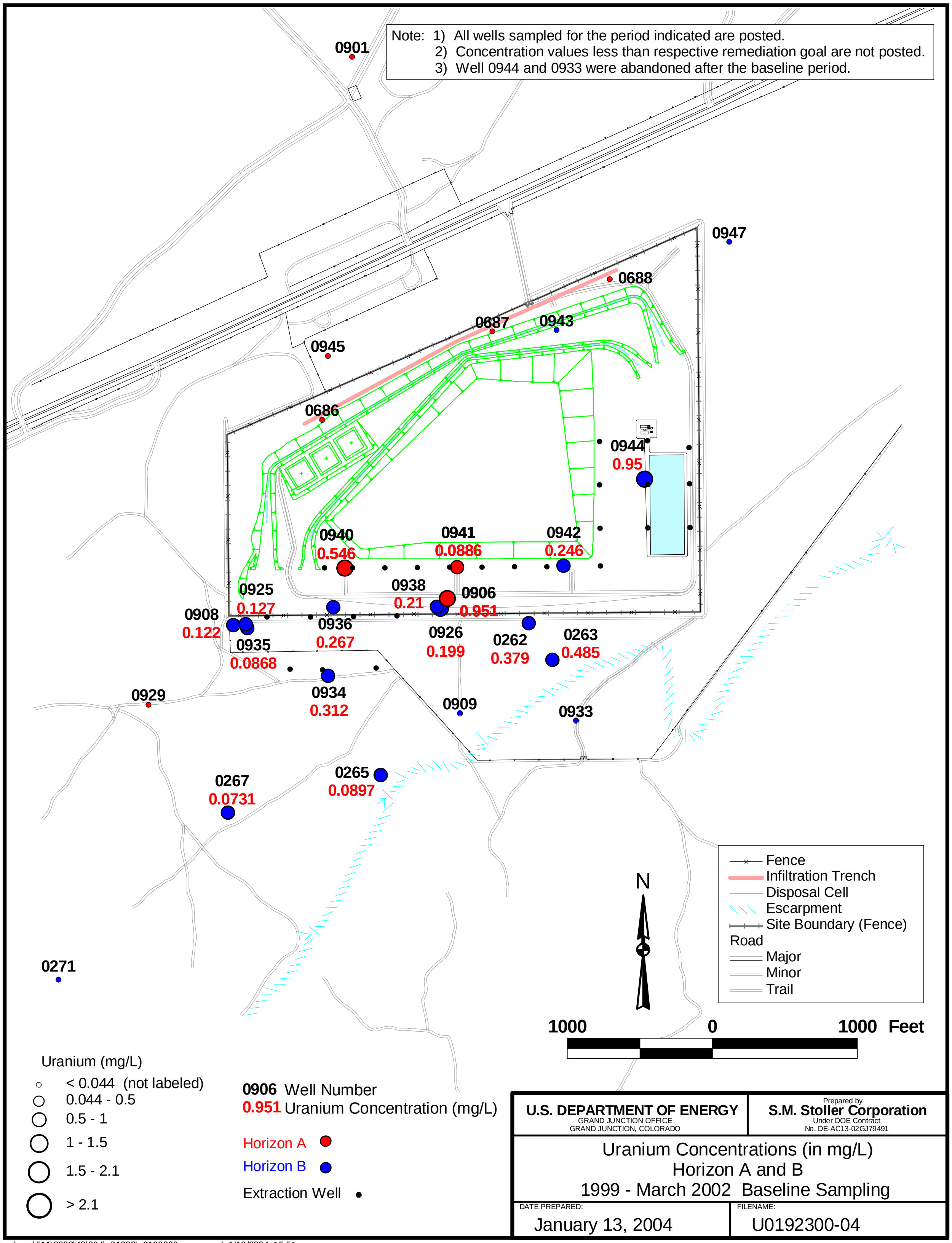

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Figure 8a. Uranium Concentrations in Ground Water, Horizons A and B, Baseline Period

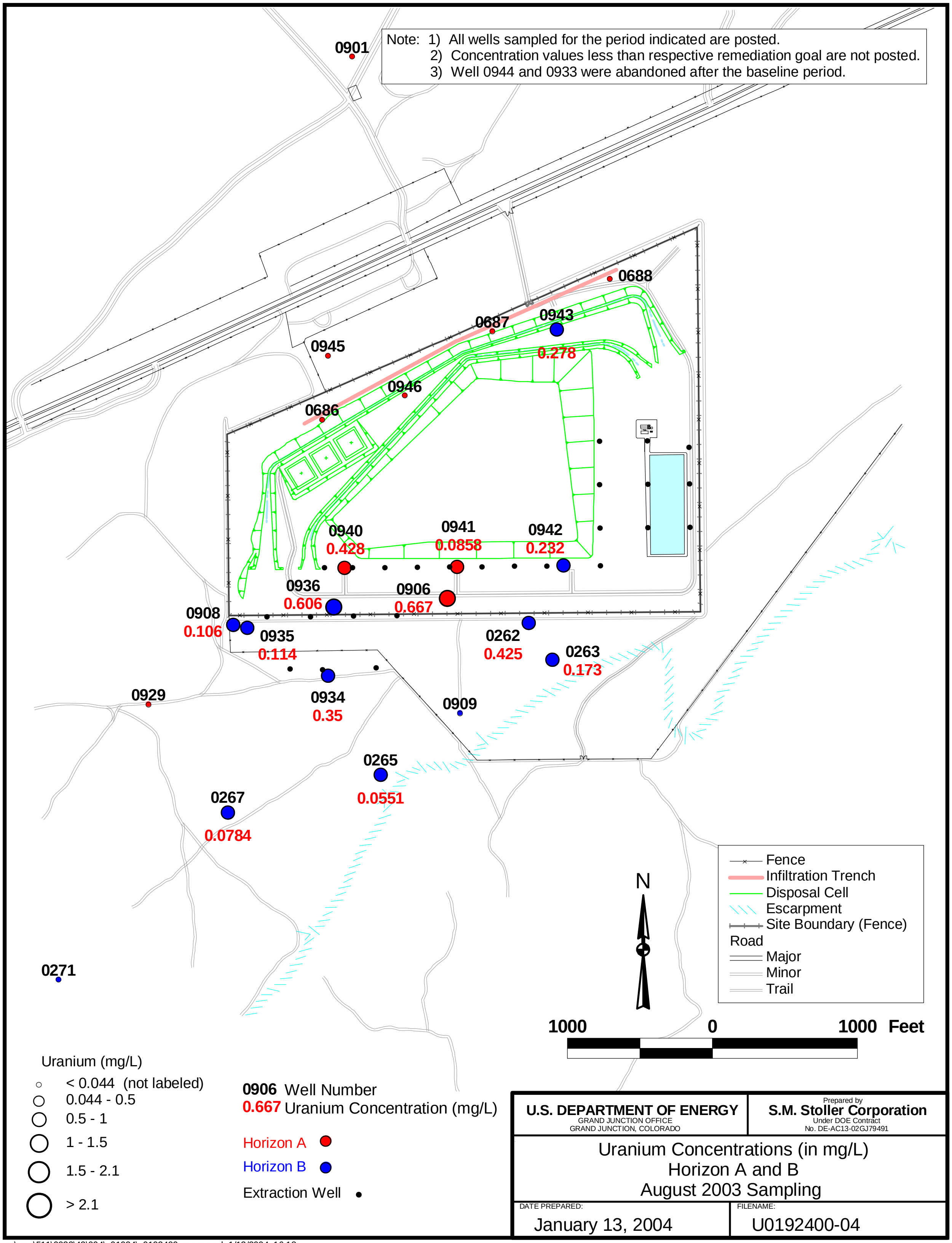

Figure 8b. Uranium Concentrations in Ground Water, Horizons A and B, August 2003

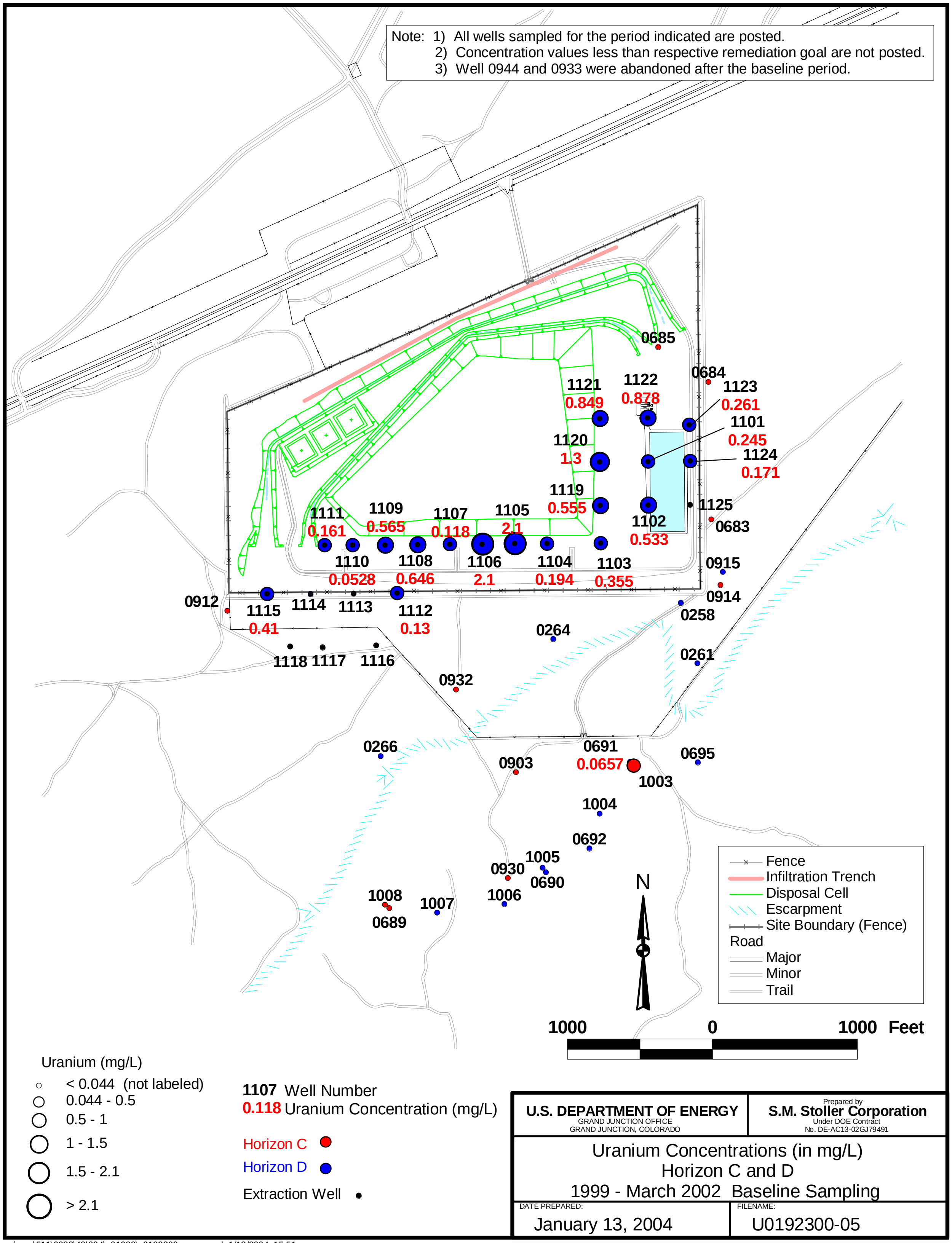

Figure 9a. Uranium Concentrations in Ground Water, Horizons C and D, Baseline Period

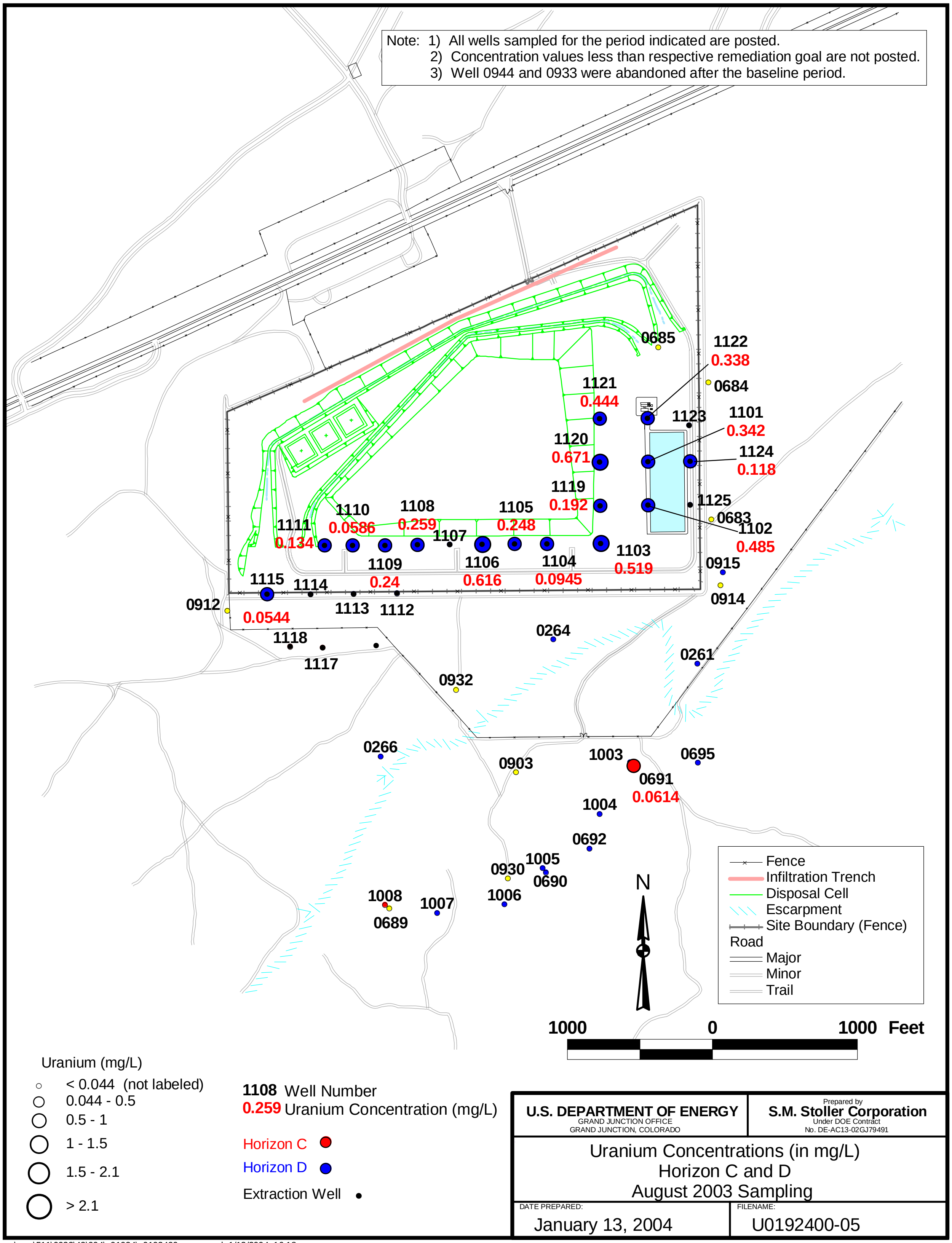

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Figure 9b. Uranium Concentrations in Ground Water, Horizons C and D, August 2003

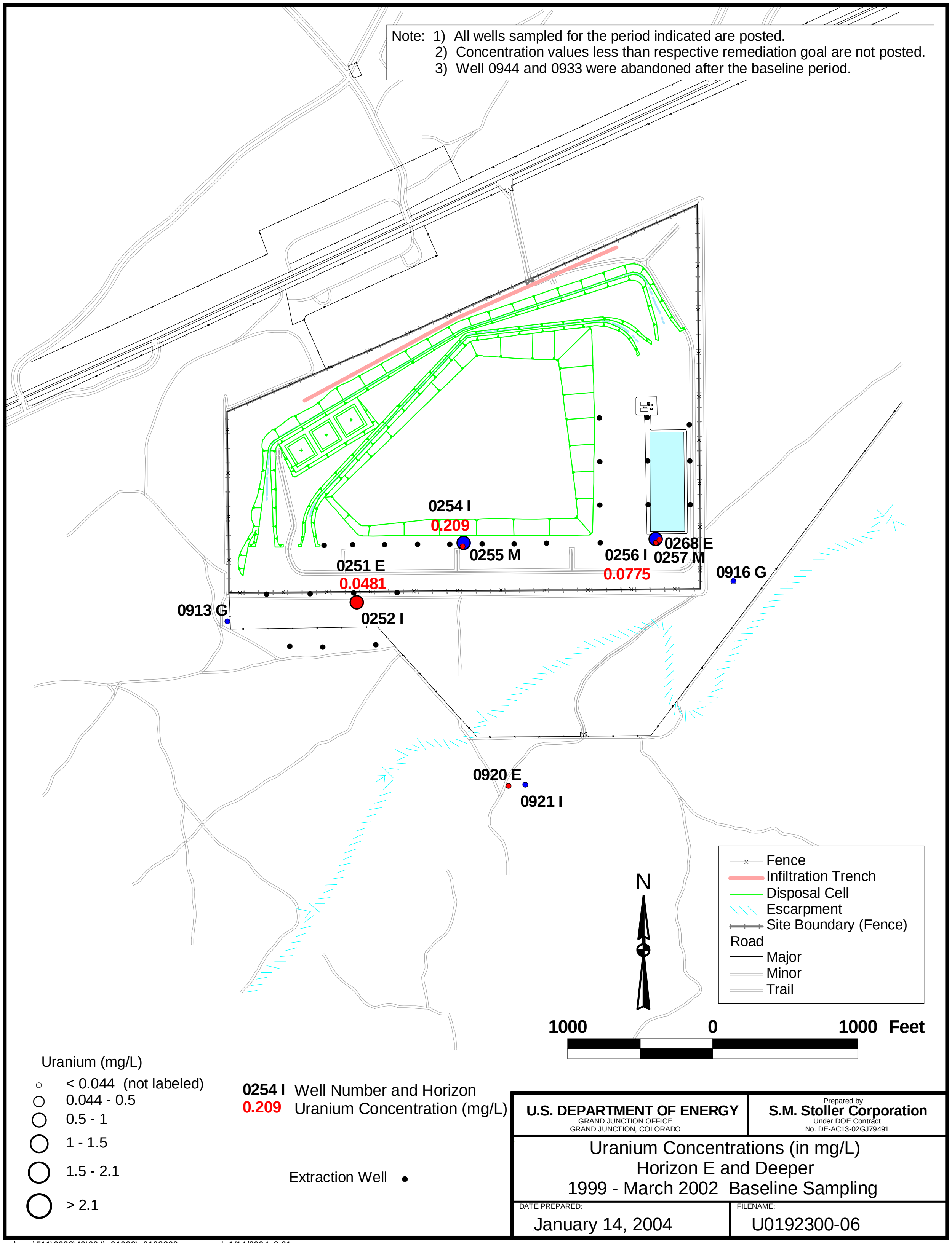

Figure 10a. Uranium Concentrations in Ground Water, Horizons E and Deeper, Baseline Period

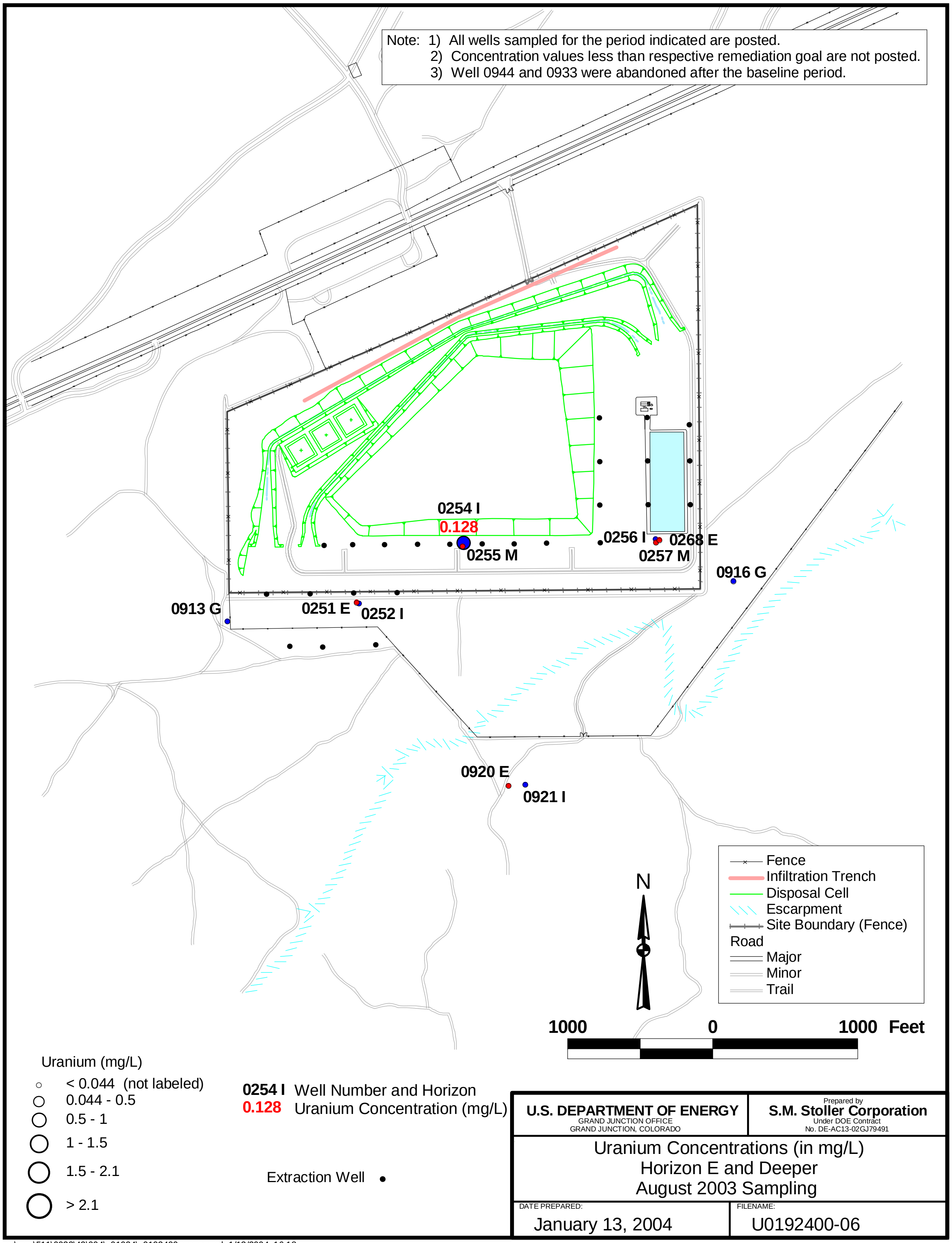

Figure 10b. Uranium Concentrations in Ground Water, Horizons E and Deeper, August 2003

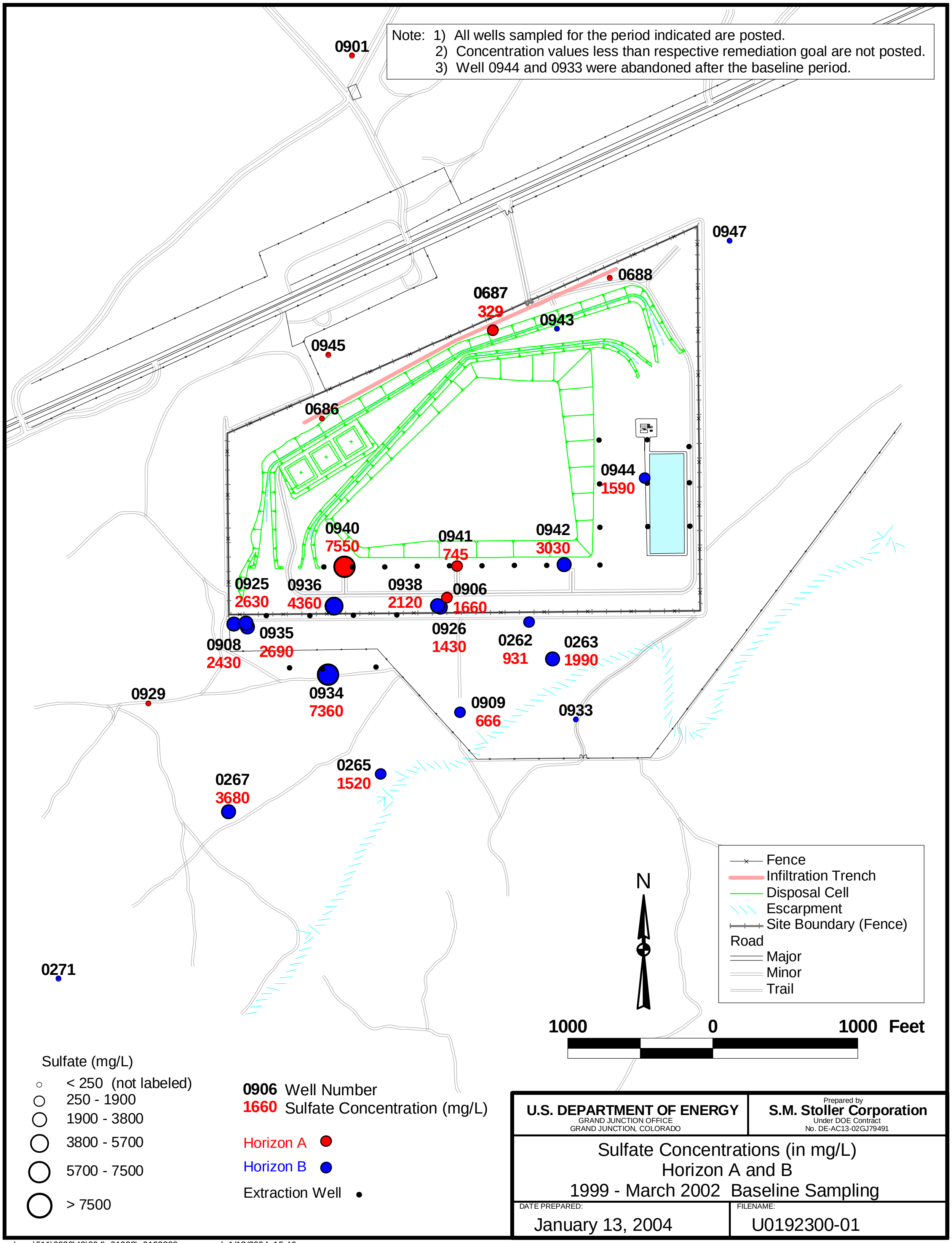

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Figure 11a. Sulfate Concentrations in Ground Water, Horizons A and B, Baseline Period

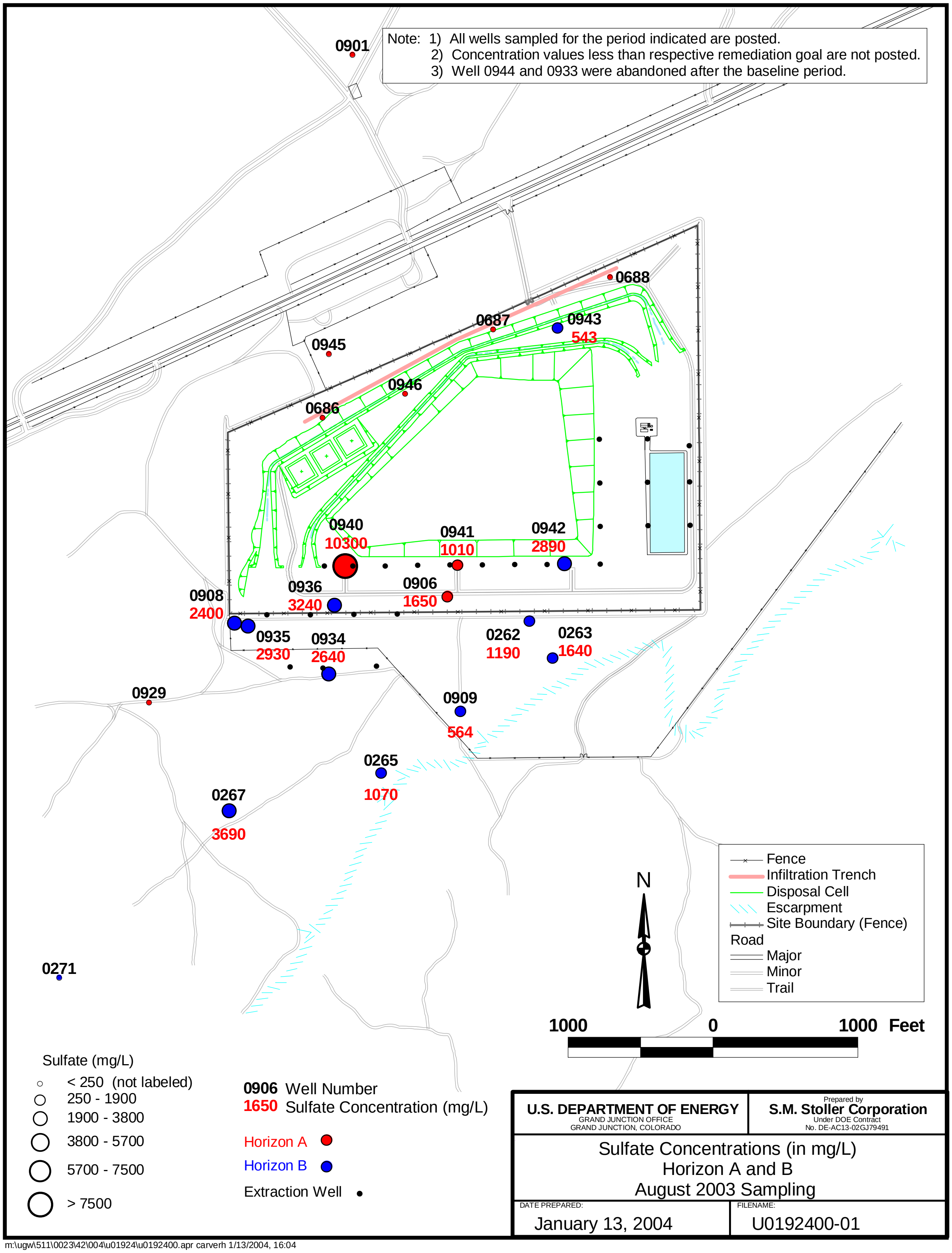

Figure 11b. Sulfate Concentrations in Ground Water, Horizons A and B, August 2003

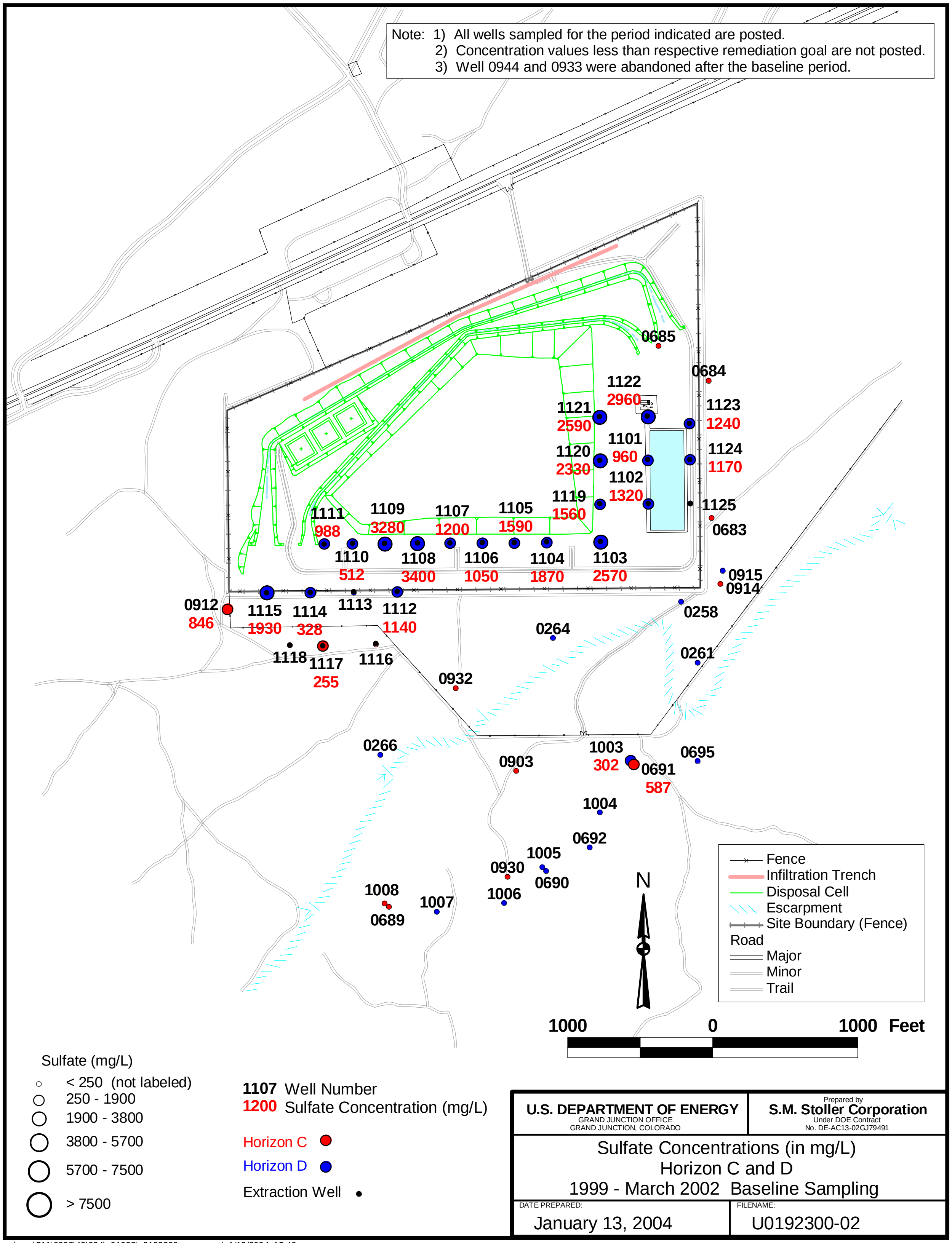

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Figure 12a. Sulfate Concentrations in Ground Water, Horizons C and D, Baseline Period

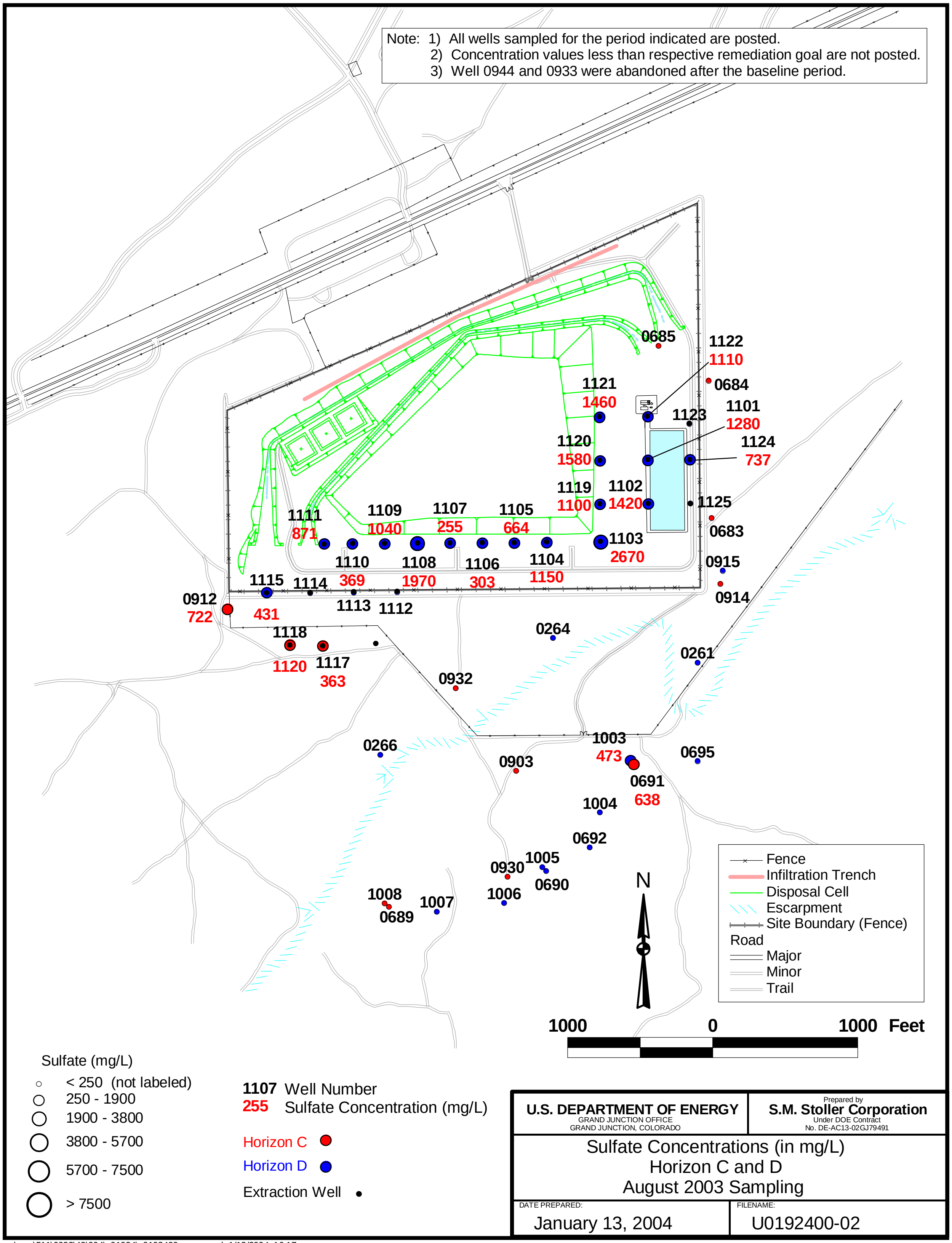

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Figure 12b. Sulfate Concentrations in Ground Water, Horizons C and D, August 2003

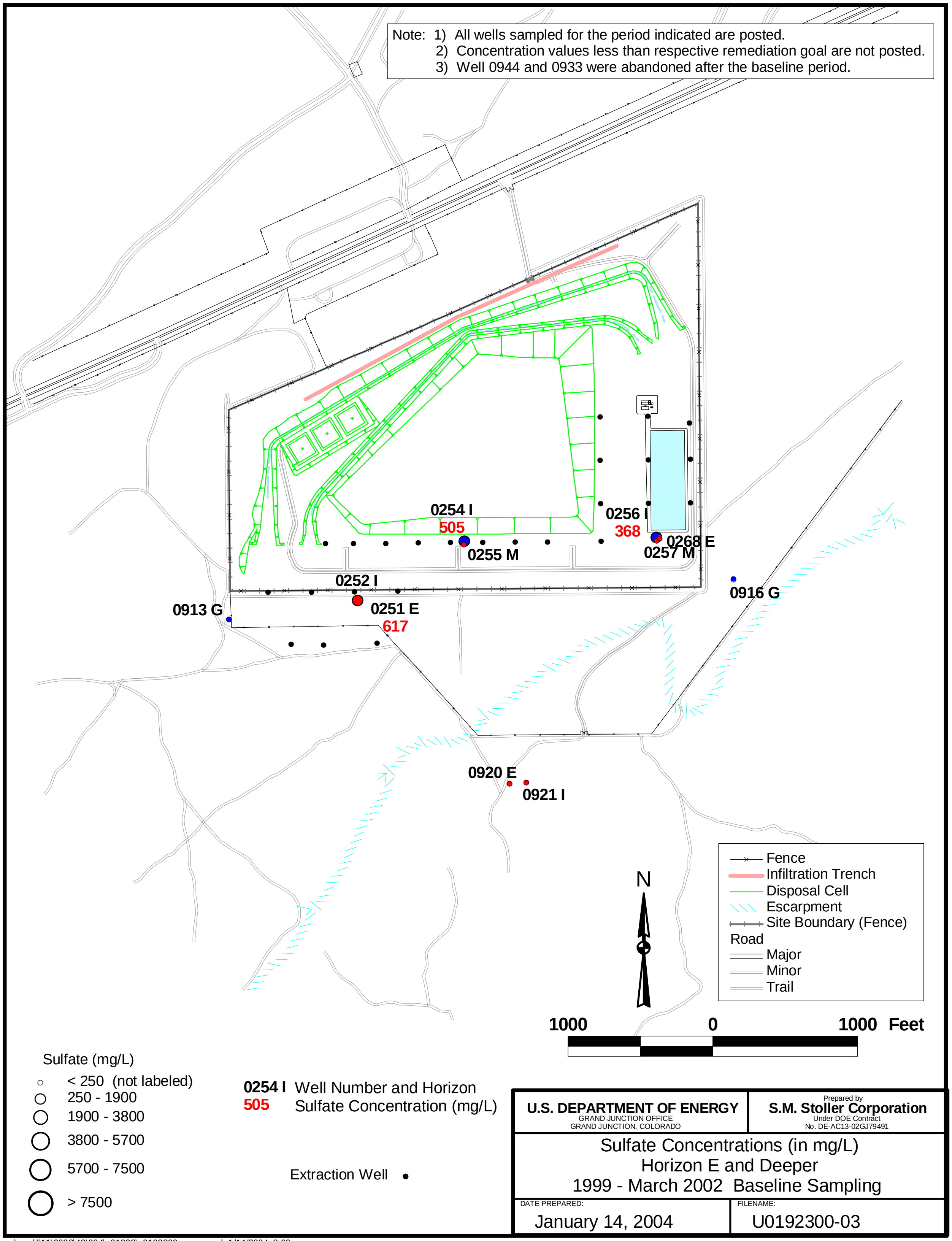

Figure 13a. Sulfate Concentrations in Ground Water, Horizons E and Deeper, Baseline Period

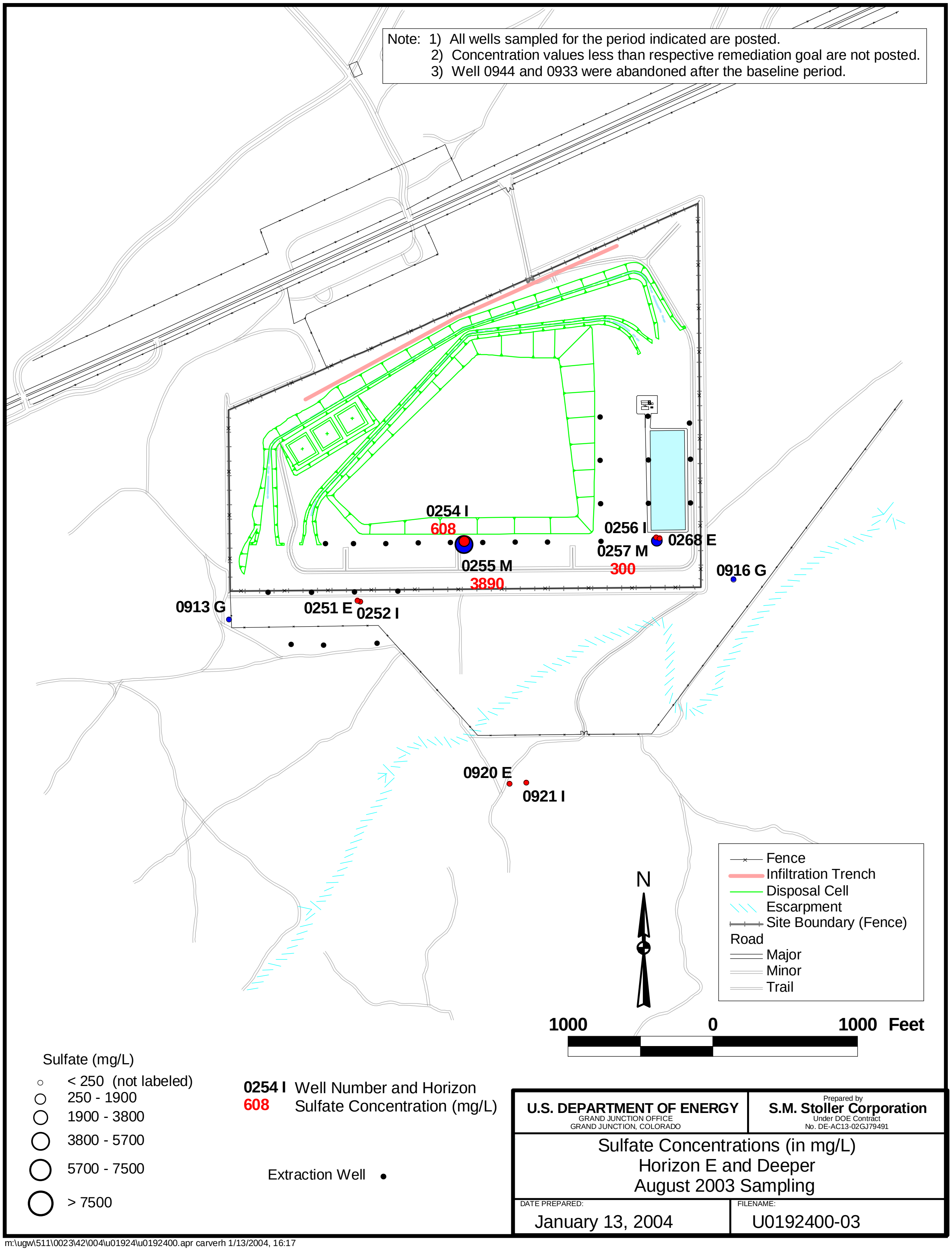

Figure 13b. Sulfate Concentrations in Ground Water, Horizons E and Deeper, August 2003

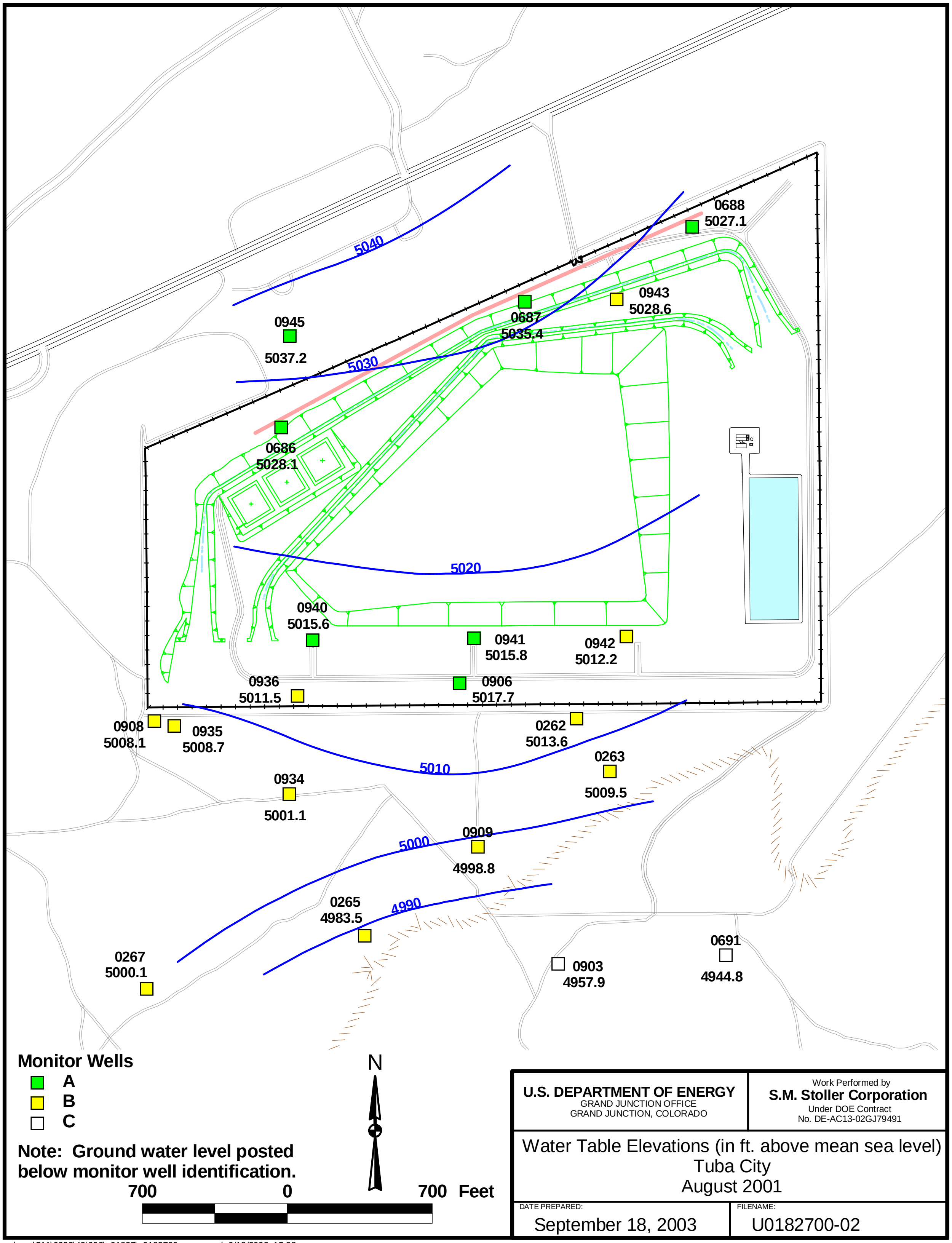

Figure 14a. Water Table Contour Map, Baseline Period

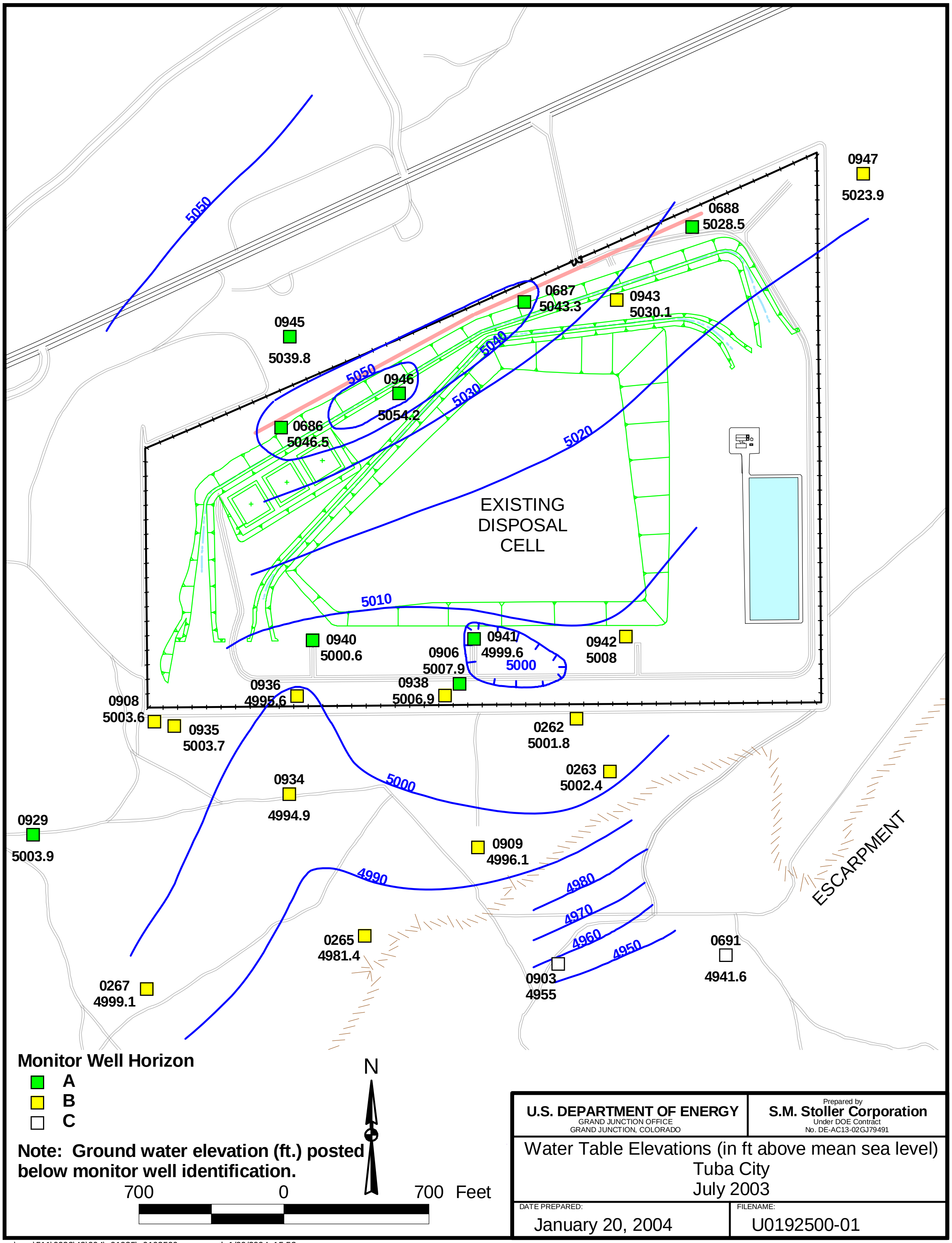

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Figure 14b. Water Table Contour Map, July 2003

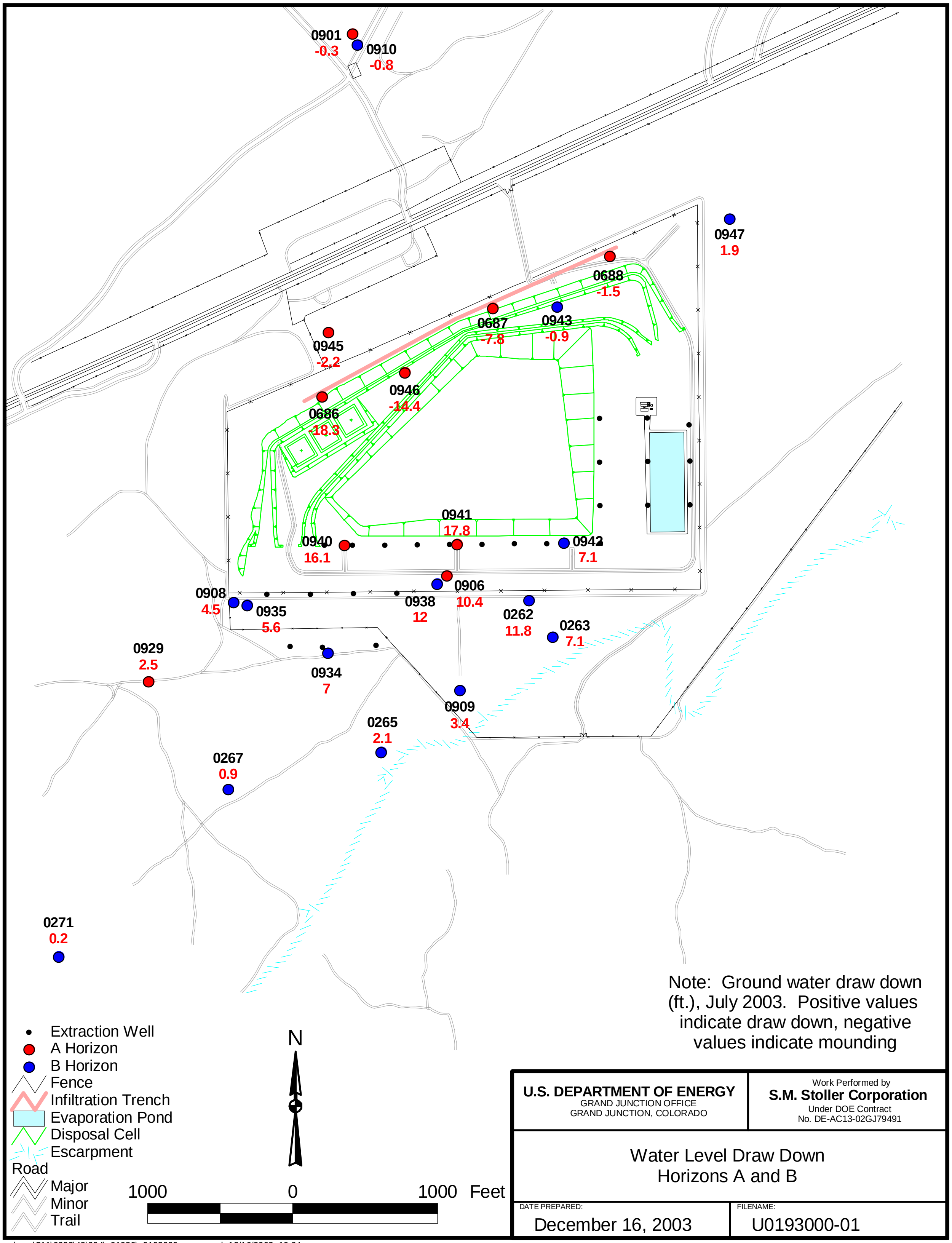

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Figure 15. Water Level Drawdowns, Horizons A and B, July 2003

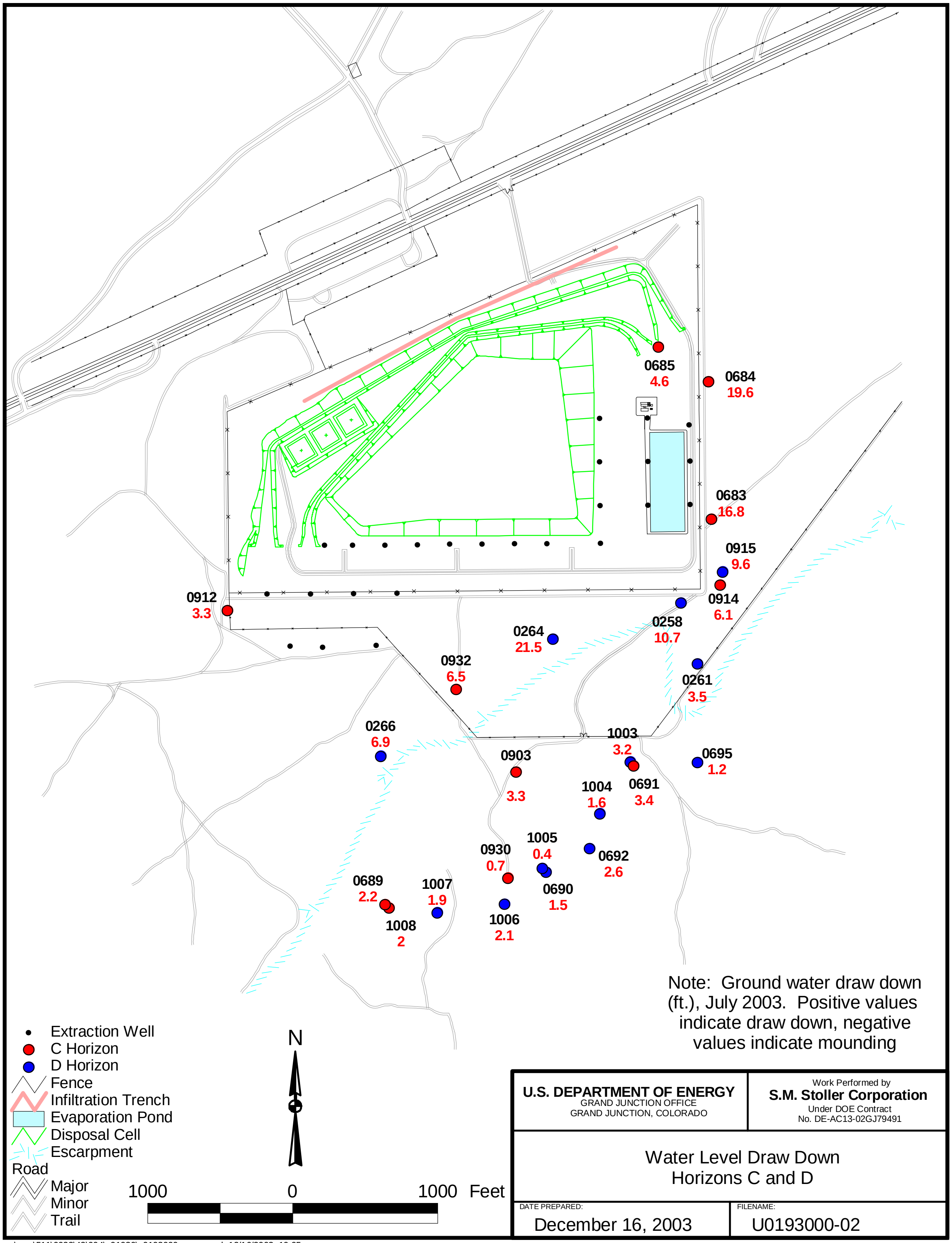

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Figure 16. Water Level Drawdowns, Horizons C and D, July 2003

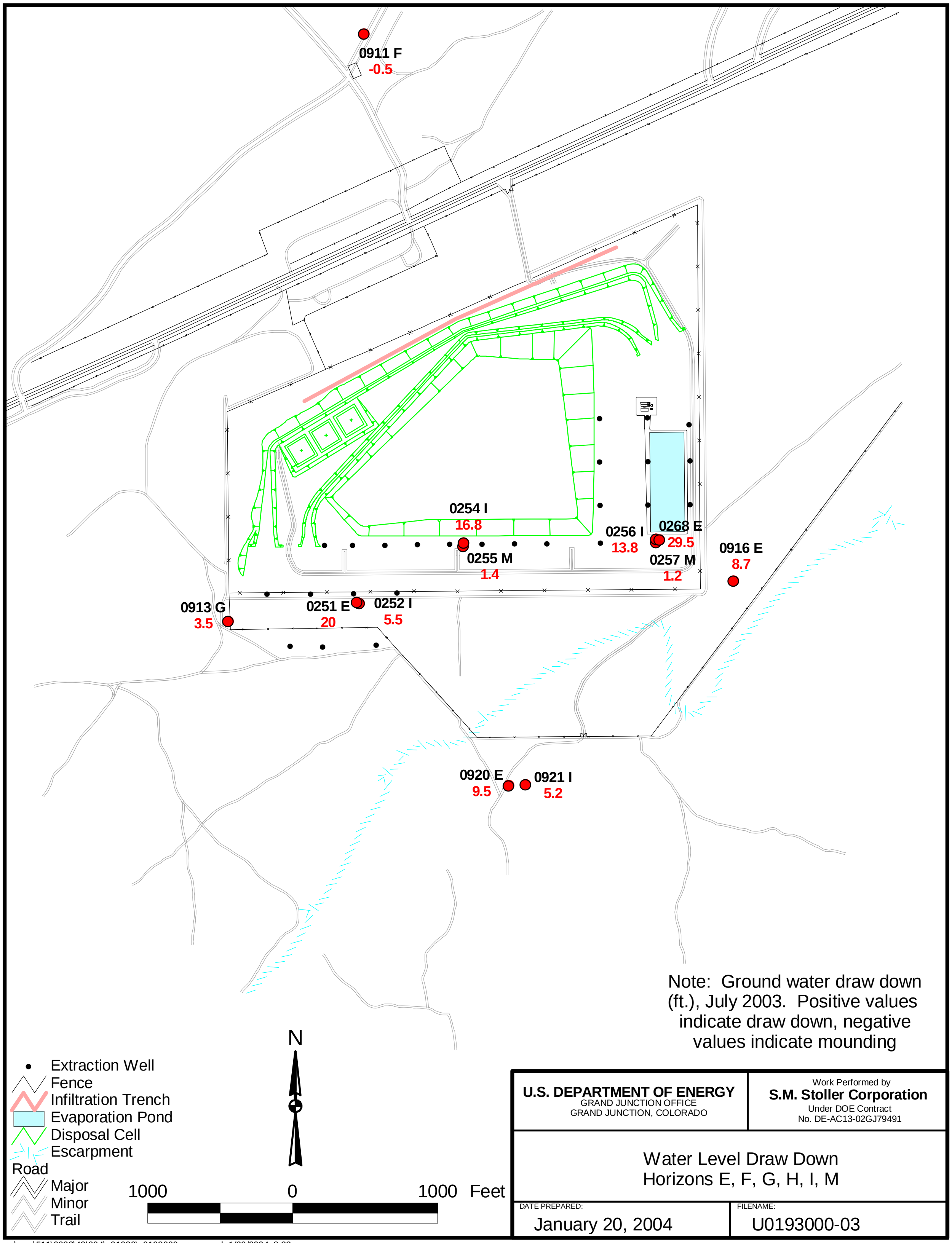

Figure 17. Water Level Drawdowns, Horizons E and Deeper, July 2003

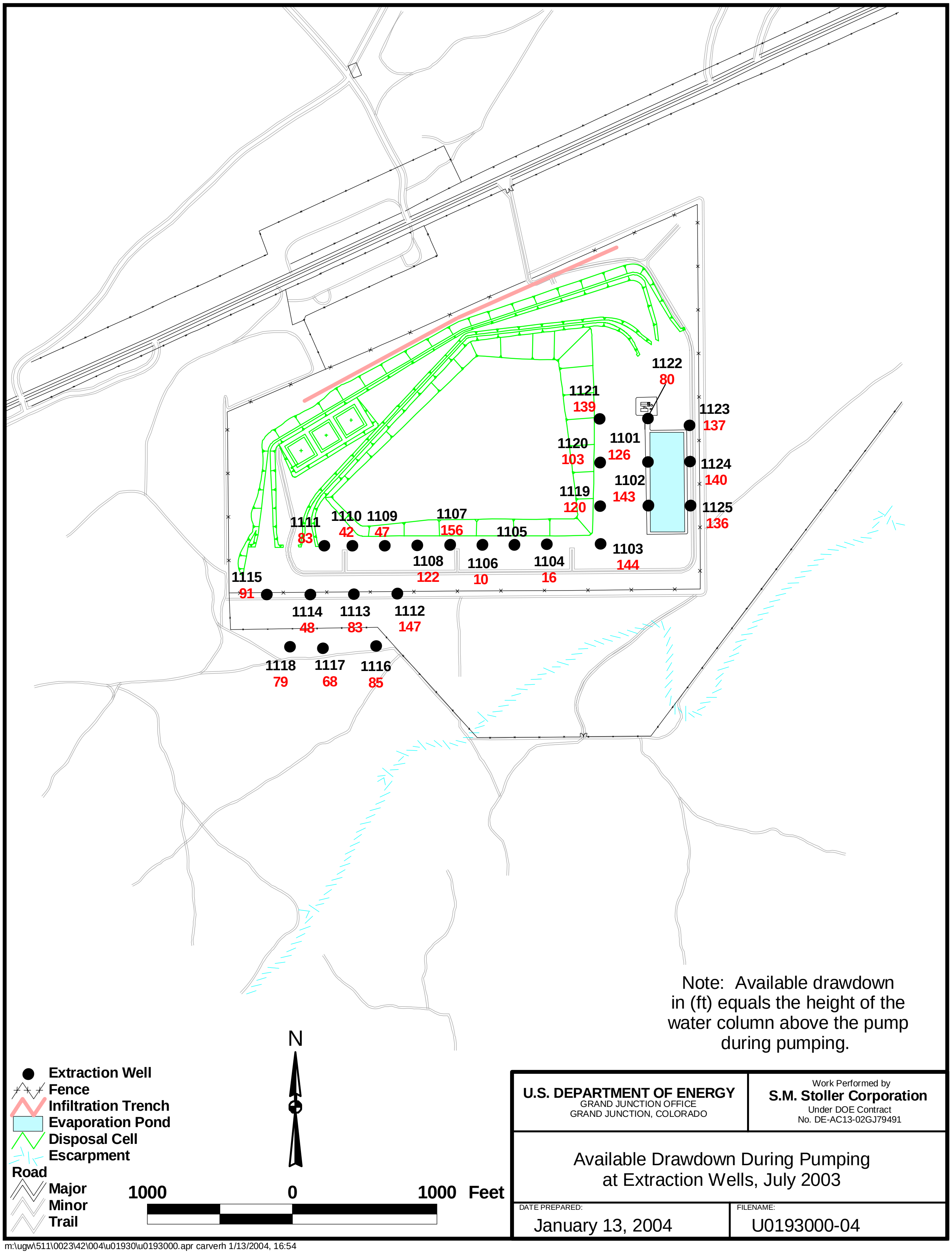

Figure 18. Available Drawdown in Extraction Wells, July/August 2003

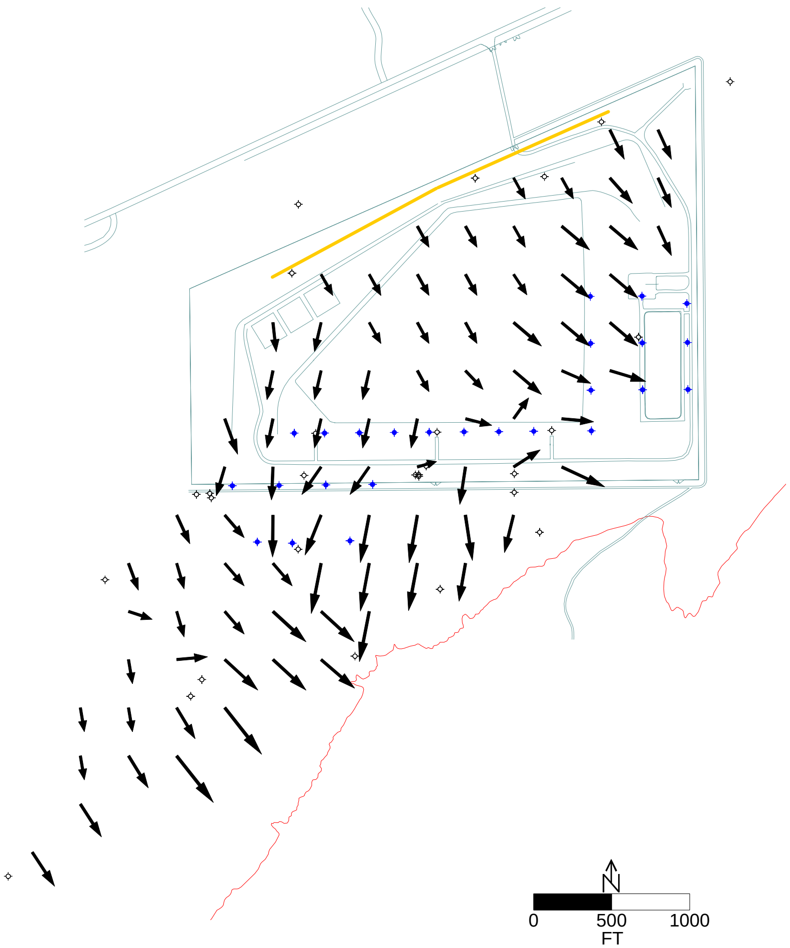

Figure 19a. Horizontal Hydraulic Gradient Direction and Relative Magnitude, Horizons A and B, Baseline Period

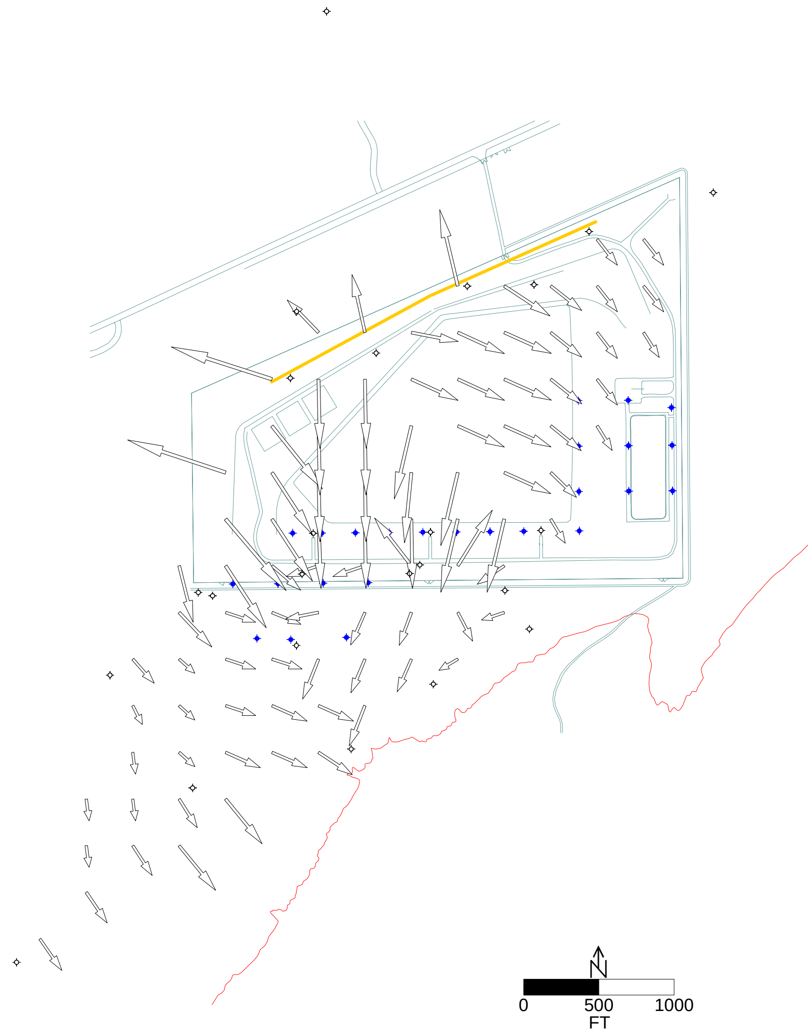

Figure 19b. Horizontal Hydraulic Gradient Direction and Relative Magnitude, Horizons A and B, July 2003

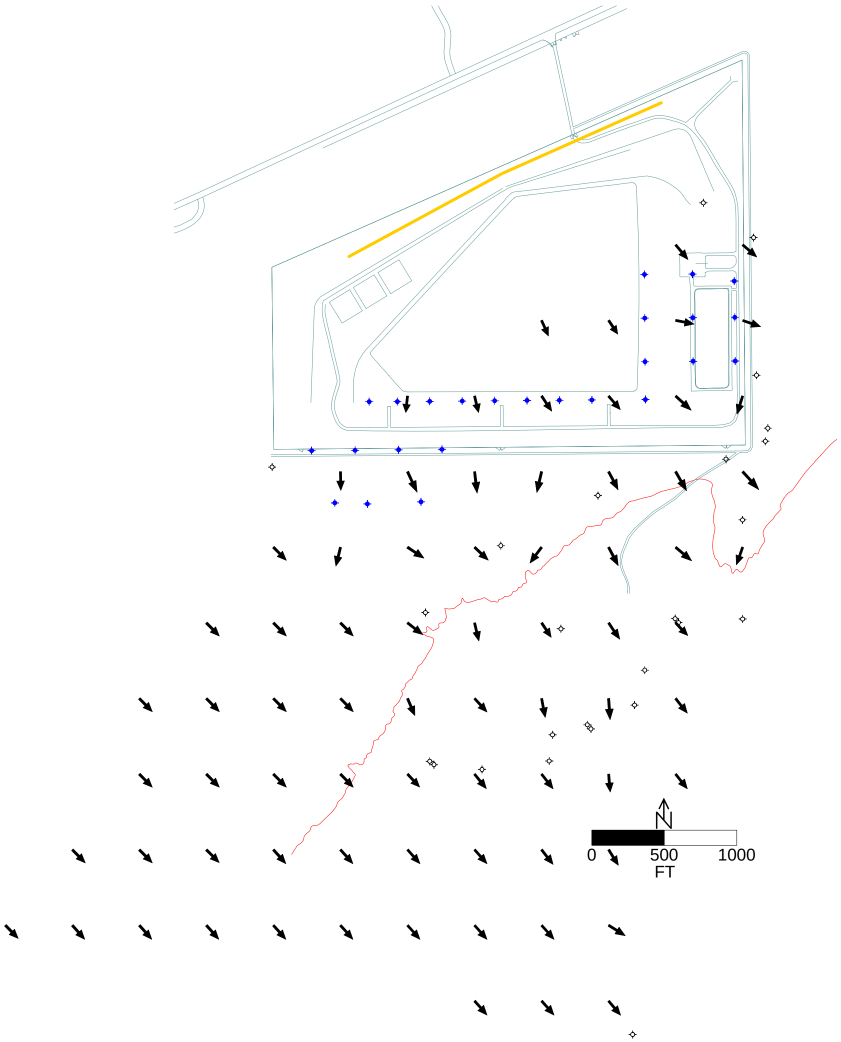

Figure 20a. Horizontal Hydraulic Gradient Direction and Relative Magnitude, Horizons C and D, Baseline Period

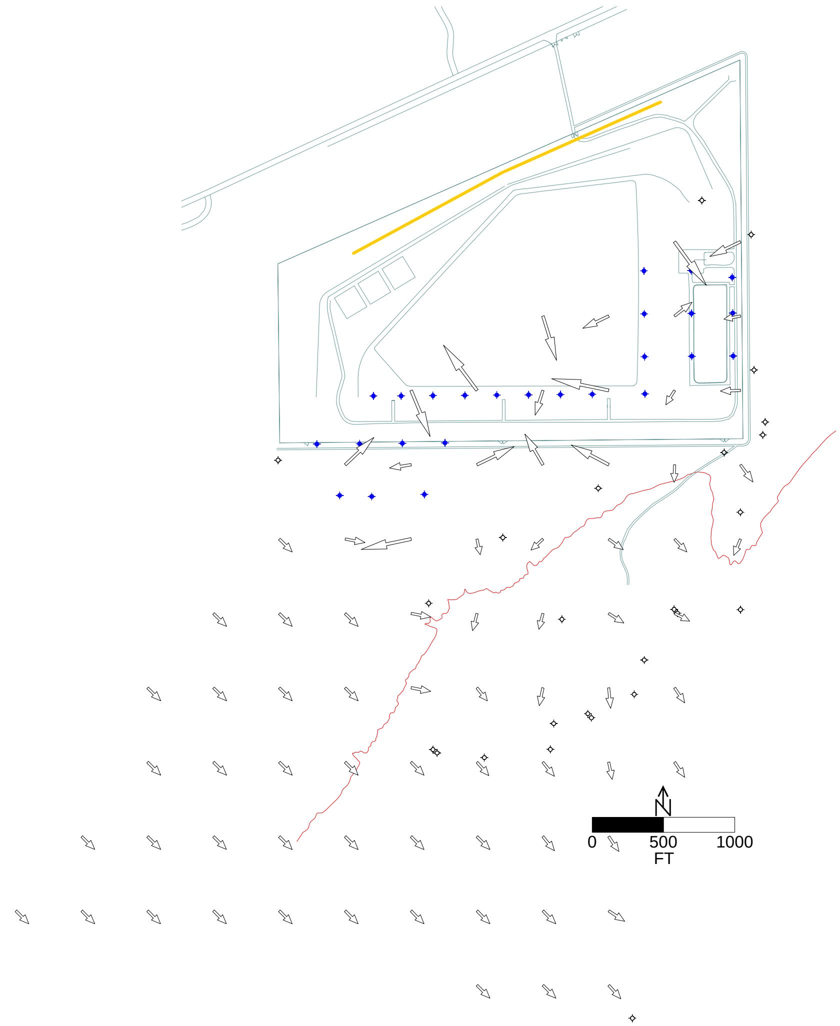

Figure 20b. Horizontal Hydraulic Gradient Direction and Relative Magnitude, Horizons C and D, July 2003

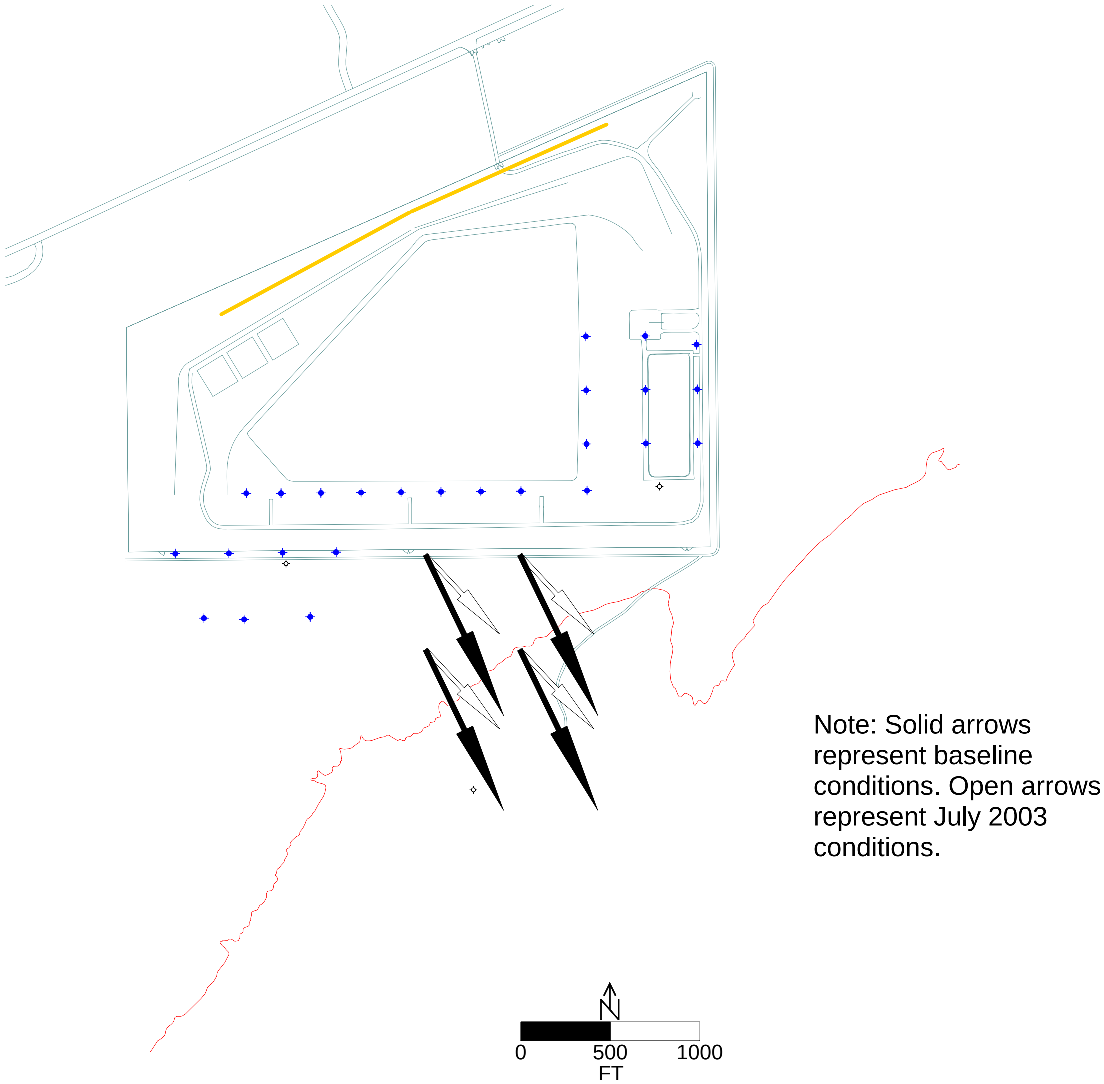

Figure 21. Horizontal Hydraulic Gradient Direction and Relative Magnitude, Horizon E, July 2003 and Baseline Period

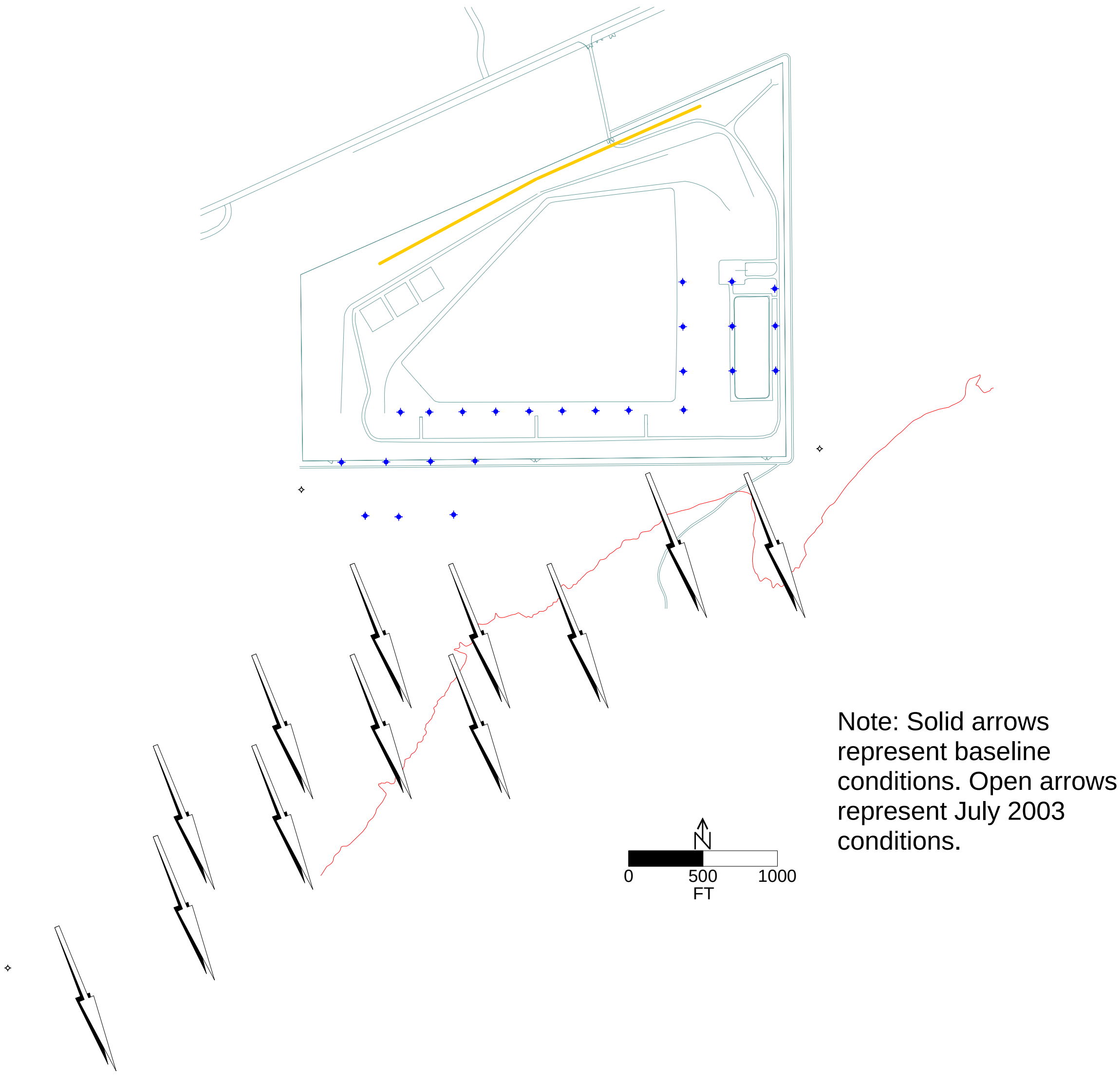

Figure 22. Horizontal Hydraulic Gradient Direction and Relative Magnitude, Horizon G, July 2003 and Baseline Period

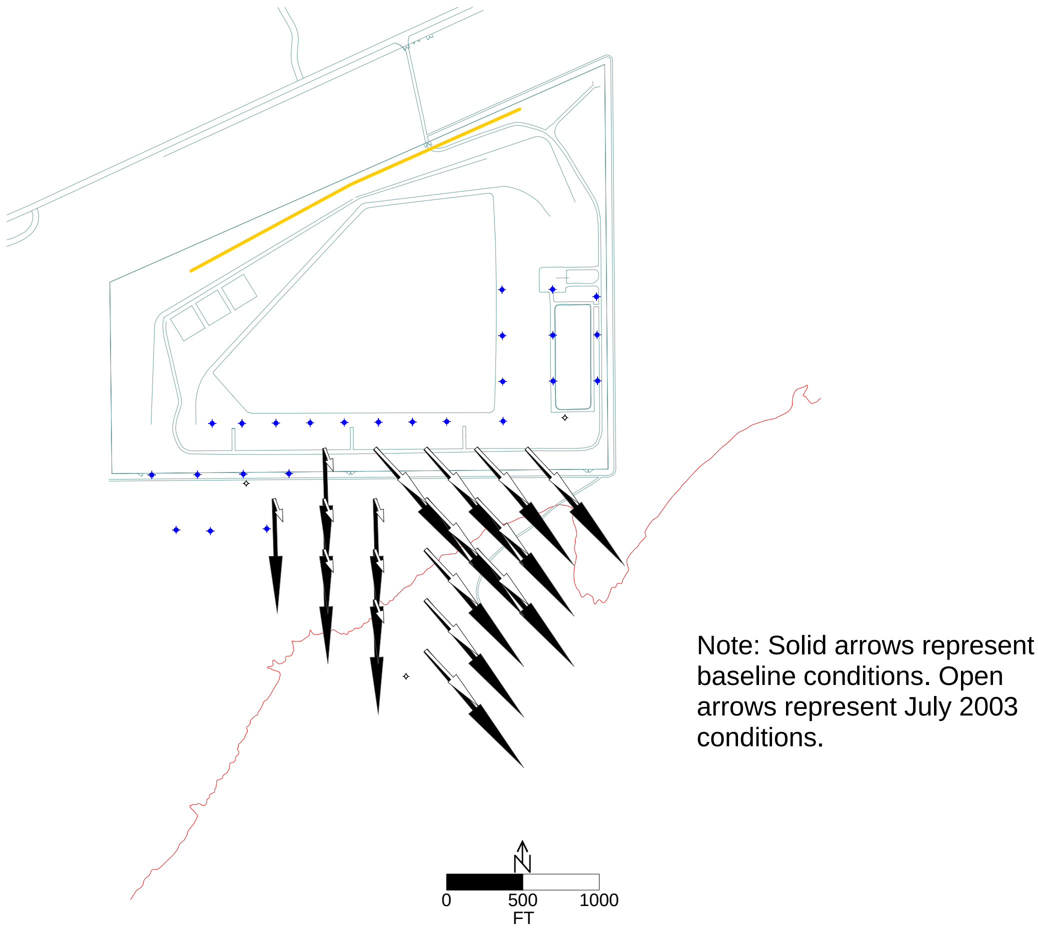

Figure 23. Horizontal Hydraulic Gradient Direction and Relative Magnitude, Horizon I, July 2003 and Baseline Period

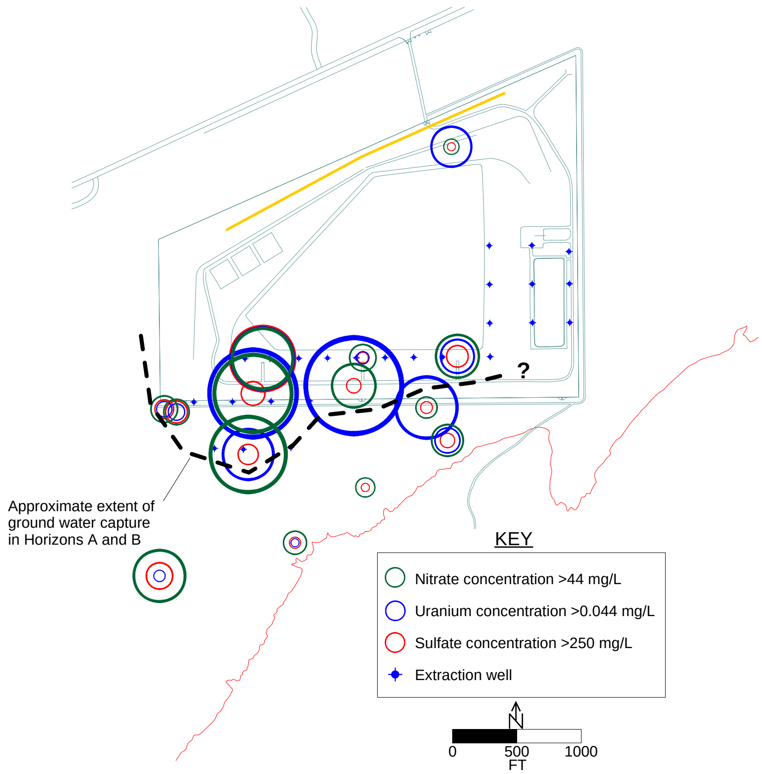

Figure 24. Contaminant Plume Capture Zone, Horizons A and B

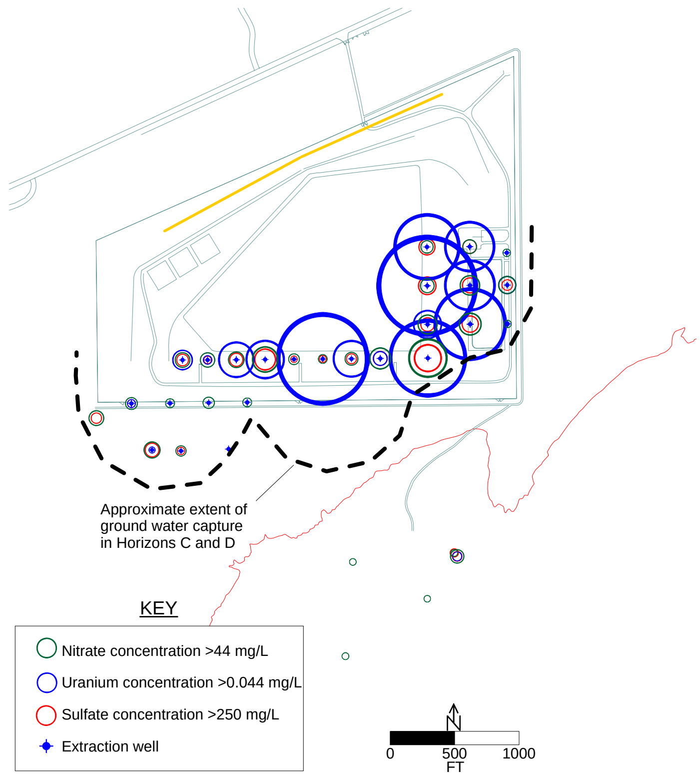

Figure 25. Contaminant Plume Capture Zone, Horizons C and D

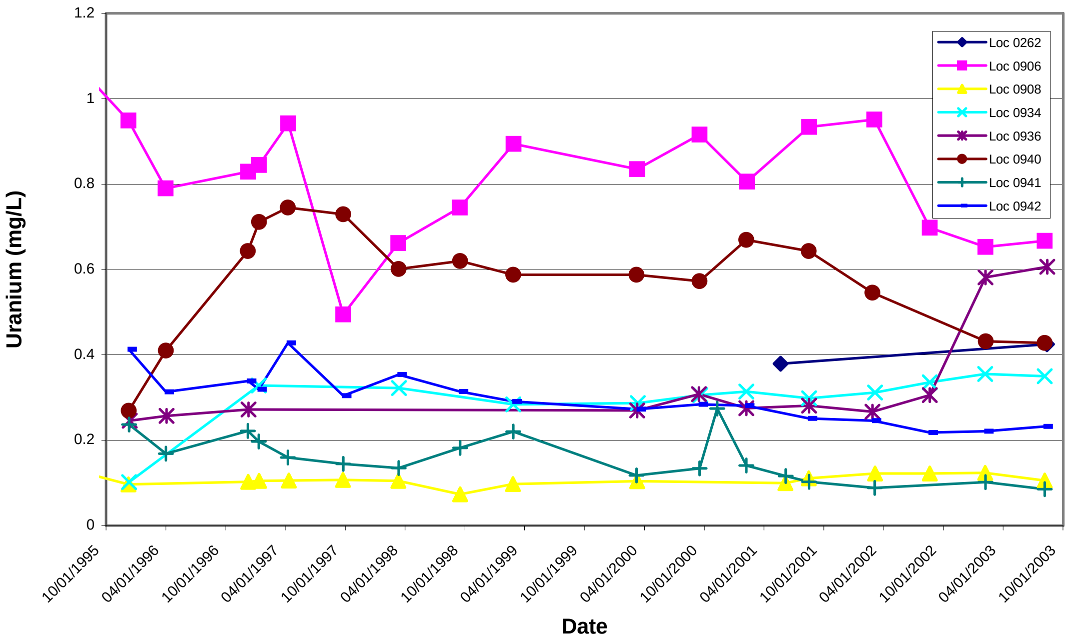

Figure 26. Uranium Concentration versus Time, Horizons A and B Monitor Wells

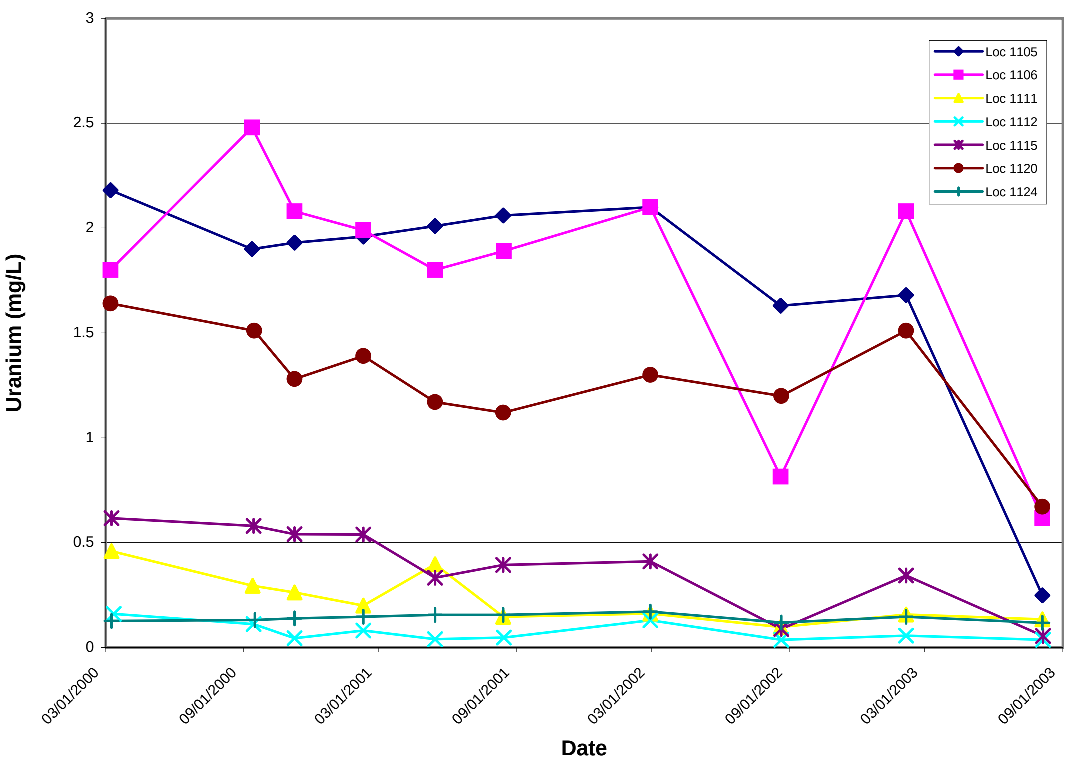

Figure 27.Uranium Concentration versus Time, Horizons C and D Extraction Wells

Appendix A

Tuba City Project Well Data

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Table A−1. Aquifer Horizon Elevations

Horizon	Depth Interval, ft above msl[a]	Number of Wells	Geologic Unit
A	5,000−5,050	10	Navajo Sandstone
B	4,950−5,000	21	Navajo Sandstone
C	4,900−4,950	15	Navajo Sandstone
D	4,850−4,900	36	Intertonguing Interval
E	4,800−4,850	4	Intertonguing Interval
F	4,750−4,800	1	Intertonguing Interval
G	4,700−4,750	3	Intertonguing Interval
H	4,650−4,700	1	Intertonguing Interval
I	4,600−4,650	4	Intertonguing Interval
J	4,550−4,600	0	Intertonguing Interval
K	4,500−4,550	0	Kayenta Formation
L	4,450−4,500	0	Kayenta Formation
M	4,400−4,450	3	Kayenta Formation

[a]msl = mean sea level

Table A−2. Well Screen Intervals

Well ID	Mid-Screen Horizon	Screen Depth (ft)		Screen Length [ft]	Screen Elevation (ft)			Well Type
		Top	Bottom		Top	Mid	Bottom	
0686	A	60	100	40	5,045.5	5,025.5	5,005.5	monitor
0687	A	60	100	40	5,047.6	5,027.6	5,007.6	monitor
0688	A	60	100	40	5,044.1	5,024.1	5,004.1	monitor
0901	A	58	78	20	5,045.8	5,035.8	5,025.8	monitor
0906	A	44	64	20	5,016.9	5,006.9	4,996.9	monitor
0928	A	30	55	25	5,022.1	5,009.6	4,997.1	monitor
0929	A	No data	90	No data	No data	No data	No data	monitor
0940	A	45	60	15	5,017.9	5,010.4	5,002.9	monitor
0941	A	45	65	20	5,018.0	5,008.0	4,998.0	monitor
0945	A	110	130	20	5,028.1	5,018.1	5,008.1	monitor
0946	A	40	60	20	5,057.6	5,047.6	5,037.6	monitor
0262	B	60	100	40	4,999.2	4,979.2	4,959.2	monitor
0263	B	60	100	40	5,000.2	4,980.2	4,960.2	monitor
0265	B	60	100	40	4,991.1	4,971.1	4,951.1	monitor
0267	B	60	100	40	4,990.8	4,970.8	4,950.8	monitor
0271	B	60	100	40	4,984.0	4,964.0	4,944.0	monitor
0905	B	63	78	15	5,006.0	4,998.5	4,991.0	monitor
0908	B	52	67	15	5,005.3	4,997.8	4,990.3	monitor
0909	B	65	80	15	4,990.8	4,983.3	4,975.8	monitor
0910	B	97	197	100	5,007.6	4,957.6	4,907.6	monitor
0918	B	61	66	5	4,986.2	4,983.7	4,981.2	monitor
0925	B	53	93	40	5,005.8	4,985.8	4,965.8	monitor
0926	B	42	92	50	5,018.3	4,993.3	4,968.3	monitor
0934	B	45	90	45	5,013.0	4,990.5	4,968.0	monitor
0935	B	50	90	40	5,008.8	4,988.8	4,968.8	monitor
0936	B	42	82	40	5,017.9	4,997.9	4,977.9	monitor
0937	B	40	95	55	5,020.2	4,992.7	4,965.2	monitor
0938	B	40	95	55	5,020.4	4,992.9	4,965.4	monitor
0939	B	40	95	55	5,021.1	4,993.6	4,966.1	monitor
0942	B	54	74	20	5,009.5	4,999.5	4,989.5	monitor
0943	B	101	121	20	4,994.1	4,984.1	4,974.1	monitor
0947	B	105	125	20	4,990.0	4,980.0	4,970.0	monitor
0683	C	95	145	50	4,973.2	4,948.2	4,923.2	monitor
0684	C	124	176	51	4,943.1	4,917.4	4,891.8	monitor
0685	C	94	146	52	4,975.6	4,949.7	4,923.8	monitor
0689	C	55	95	40	4,923.9	4,903.9	4,883.9	monitor
0691	C	55	95	40	4,921.9	4,901.9	4,881.9	monitor
0903	C	28	48	20	4,953.5	4,943.5	4,933.5	monitor
0912	C	123	163	40	4,934.7	4,914.7	4,894.7	monitor
0914	C	137	154	17	4,930.3	4,921.8	4,913.3	monitor
0917	C	128	148	20	4,917.8	4,907.8	4,897.8	monitor
0930	C	20	50	30	4,933.0	4,918.0	4,903.0	monitor
0932	C	113	133	20	4,942.3	4,932.3	4,922.3	monitor

Table A−2 (continued). Well Screen Intervals

Well ID	Mid-Screen Horizon	Screen Depth (ft)		Screen Length [ft]	Screen Elevation (ft)			Well Type
		Top	Bottom		Top	Mid	Bottom	
1008	C	56	106	50	4,926.8	4,901.6	4,876.4	injection
1116	C	92	196	104	4,964.1	4,912.5	4,861.0	extraction
1117	C	92	196	104	4,965.3	4,913.7	4,862.1	extraction
1118	C	90	196	106	4,967.9	4,915.1	4,862.3	extraction
0258	D	159	199	40	4,894.0	4,874.0	4,854.0	monitor
0261	D	160	200	40	4,907.0	4,887.0	4,867.0	monitor
0264	D	160	200	40	4,899.6	4,879.6	4,859.6	monitor
0266	D	160	200	40	4,890.6	4,870.6	4,850.6	monitor
0690	D	55	95	40	4,893.3	4,873.3	4,853.3	monitor
0692	D	55	95	40	4,895.6	4,875.6	4,855.6	monitor
0695	D	55	95	40	4,919.3	4,899.3	4,879.3	monitor
0904	D	28	38	10	4,873.8	4,868.8	4,863.8	monitor
0915	D	170	180	10	4,897.8	4,892.8	4,887.8	monitor
1003	D	56	106	50	4,923.4	4,898.4	4,873.4	injection
1004	D	46	96	50	4,918.1	4,893.1	4,868.1	injection
1005	D	46	96	50	4,904.7	4,879.7	4,854.7	injection
1006	D	46	96	50	4,903.7	4,878.7	4,853.7	injection
1007	D	46	96	50	4,915.6	4,890.5	4,865.4	injection
1101	D	96	252	156	4,974.2	4,896.6	4,818.9	extraction
1102	D	102	252	150	4,968.8	4,893.8	4,818.8	extraction
1103	D	100	250	150	4,962.3	4,887.3	4,812.3	extraction
1104	D	90	245	155	4,972.3	4,894.8	4,817.3	extraction
1105	D	90	245	155	4,972.1	4,894.6	4,817.1	extraction
1106	D	97	251	154	4,966.0	4,888.7	4,811.4	extraction
1107	D	91	246	155	4,971.2	4,894.0	4,816.8	extraction
1108	D	96	246	150	4,966.1	4,891.1	4,816.1	extraction
1109	D	90	245	155	4,972.1	4,894.7	4,817.3	extraction
1110	D	96	246	150	4,966.8	4,891.8	4,816.8	extraction
1111	D	91	245	154	4,971.9	4,894.7	4,817.5	extraction
1112	D	91	246	155	4,969.1	4,891.6	4,814.1	extraction
1113	D	91	246	155	4,968.7	4,891.2	4,813.7	extraction
1114	D	91	246	155	4,968.5	4,891.0	4,813.6	extraction
1115	D	91	246	155	4,968.6	4,891.2	4,813.7	extraction
1119	D	95	245	150	4,968.7	4,893.7	4,818.7	extraction
1120	D	96	246	150	4,971.0	4,896.0	4,821.0	extraction
1121	D	98	248	150	4,972.0	4,897.0	4,822.0	extraction
1122	D	97	251	154	4,973.4	4,896.3	4,819.2	extraction
1123	D	91	245	154	4,976.2	4,899.2	4,822.2	extraction
1124	D	88	246	158	4,978.7	4,899.9	4,821.1	extraction
1125	D	96	246	150	4,972.8	4,897.8	4,822.8	extraction
0251	E	200	300	100	4,858.9	4,808.9	4,758.9	monitor
0268	E	200	300	100	4,864.5	4,814.5	4,764.5	monitor
0920	E	114	154	40	4,866.0	4,846.0	4,826.0	monitor

Table A−2 (continued). Well Screen Intervals

Well ID	Mid-Screen Horizon	Screen Depth (ft)		Screen Length [ft]	Screen Elevation (ft)			Well Type
		Top	Bottom		Top	Mid	Bottom	
0948	E	222	402	180	4,893.9	4,803.9	4,713.9	monitor
0911	F	309	349	40	4,795.2	4,775.2	4,755.2	monitor
0913	G	329	369	40	4,729.2	4,709.2	4,689.2	monitor
0916	G	346	356	10	4,721.7	4,716.7	4,711.7	monitor
0919	G	338	348	10	4,707.9	4,702.9	4,697.9	monitor
0902	H	63	73	10	4,673.7	4,668.7	4,663.7	monitor
0252	I	400	500	100	4,658.9	4,608.9	4,558.9	monitor
0254	I	400	500	100	4,662.7	4,612.7	4,562.7	monitor
0256	I	400	500	100	4,664.0	4,614.0	4,564.0	monitor
0921	I	313	353	40	4,663.7	4,643.7	4,623.7	monitor
0253	M	600	700	100	4,458.8	4,408.8	4,358.8	monitor
0255	M	600	700	100	4,462.3	4,412.3	4,362.3	monitor
0257	M	600	700	100	4,463.4	4,413.4	4,363.4	monitor

Table A−3. Extraction and Injection Well Design Rates and Screened Horizons

Well Number	Well Type	Design Pumping Rate (gpm)	Screen Length (ft)	Horizon Top of Well Screen	Horizon Bottom Of Well Screen
1003	Injection	1.0	50	C	D
1004	Injection	1.0	50	C	D
1005	Injection	1.0	50	C	D
1006	Injection	1.0	50	C	D
1007	Injection	1.0	50	C	D
1008	Injection	1.0	50	C	D
Infiltration Trench	Infiltration Trench	57.0	NA	NA	NA
1101	Extraction	4.0	155	B	D
1102	Extraction	3.0	150	B	E
1103	Extraction	4.0	150	B	E
1104	Extraction	4.0	155	B	E
1105	Extraction	5.0	155	B	E
1106	Extraction	5.1	155	B	E
1107	Extraction	5.1	154	B	E
1108	Extraction	5.1	150	B	E
1109	Extraction	5.1	155	B	E
1110	Extraction	5.0	150	B	E
1111	Extraction	8.6	154	B	E
1112	Extraction	3.1	155	B	E
1113	Extraction	2.0	155	B	E
1114	Extraction	3.5	155	B	E
1115	Extraction	3.5	155	B	E
1116	Extraction	2.0	103	B	D
1117	Extraction	2.0	103	B	D
1118	Extraction	3.2	106	B	D
1119	Extraction	2.6	155	B	E
1120	Extraction	2.6	150	B	E
1121	Extraction	3.1	150	B	E
1122	Extraction	2.6	154	B	E
1123	Extraction	3.1	154	B	E
1124	Extraction	2.6	158	B	E
1125	Extraction	2.6	150	B	E

Table A−4. Extraction Well Pumping Rate Summary

Well	Pump On [days] [1]	Pump Off [days] [2]	On-Stream Factor [percent] [3]	Gallons Pumped	Design Rate [gpm]	On-Stream Rate [gpm]	Effective Rate [gpm]	Effective minus Design [gpm]
August-03 Treatment Plant Total Time On: 27.9 days								
1101	17.56	10.38	63%	159,183	4.0	6.3	4.0	0.0
1102	17.53	10.42	63%	164,034	3.0	6.5	4.1	1.1
1103	27.93	0.01	100%	265,102	4.0	6.6	6.6	2.6
1104	22.06	5.88	79%	153,715	4.0	4.8	3.8	-0.2
1105	7.93	20.01	28%	166,161	5.0	14.5	4.1	-0.9
1106	20.30	7.64	73%	142,418	5.1	4.9	3.5	-1.6
1107	18.89	9.05	68%	132,371	5.1	4.9	3.3	-1.8
1108	19.91	8.03	71%	148,520	5.1	5.2	3.7	-1.4
1109	19.91	8.03	71%	89,975	5.1	3.1	2.2	-2.9
1110	15.91	12.03	57%	101,257	5.0	4.4	2.5	-2.5
1111	18.83	9.11	67%	127,781	8.6	4.7	3.2	-5.4
1112	12.90	15.04	46%	63,682	3.1	3.4	1.6	-1.5
1113	5.88	22.06	21%	34,849	2.0	4.1	0.9	-1.1
1114	18.48	9.46	66%	140,379	3.5	5.3	3.5	0.0
1115	18.83	9.11	67%	145,429	3.5	5.4	3.6	0.1
1116	0.00	27.94	0%	0	2.0	0.0	0.0	-2.0
1117	18.52	9.42	66%	163,616	2.0	6.1	4.1	2.1
1118	18.66	9.28	67%	99,855	3.2	3.7	2.5	-0.7
1119	21.58	6.37	77%	155,340	2.6	5.0	3.9	1.3
1120	27.87	0.07	100%	192,762	2.6	4.8	4.8	2.2
1121	27.85	0.09	100%	198,266	3.1	4.9	4.9	1.8
1122	27.88	0.06	100%	160,676	2.6	4.0	4.0	1.4
1123	10.32	17.62	37%	9,266	3.1	0.6	0.2	-2.9
1124	18.84	9.10	67%	137,877	2.6	5.1	3.4	0.8
1125	18.67	9.27	67%	117,782	2.6	4.4	2.9	0.3
Cumulative				3,270,296	92.5	122.8	81.4	-11.1

Table A-4 (continued). Extraction Well Pumping Rate Summary

Well	Pump On [days] [1]	Pump Off [days] [2]	On-Stream Factor [percent] [3]	Gallons Pumped	Design Rate [gpm]	On-Stream Rate [gpm]	Effective Rate [gpm]	Effective minus Design [gpm]
July-03 Treatment Plant Total Time On: 22.1 days								
1101	21.46	0.67	97%	199,607	4.0	6.5	6.3	2.3
1102	21.46	0.67	97%	207,012	3.0	6.7	6.5	3.5
1103	21.46	0.67	97%	208,074	4.0	6.7	6.5	2.5
1104	21.38	0.75	97%	161,103	4.0	5.2	5.1	1.1
1105	16.66	5.47	75%	132,411	5.0	5.5	4.2	-0.8
1106	20.28	1.85	92%	119,674	5.1	4.1	3.8	-1.3
1107	20.01	2.12	90%	152,051	5.1	5.3	4.8	-0.3
1108	22.09	0.04	100%	169,142	5.1	5.3	5.3	0.2
1109	22.12	0.01	100%	110,268	5.1	3.5	3.5	-1.6
1110	19.69	2.44	89%	129,500	5.0	4.6	4.1	-0.9
1111	22.12	0.01	100%	157,752	8.6	5.0	5.0	-3.6
1112	16.18	5.95	73%	81,751	3.1	3.5	2.6	-0.5
1113	8.96	13.17	40%	53,762	2.0	4.2	1.7	-0.3
1114	19.81	2.32	90%	159,302	3.5	5.6	5.0	1.5
1115	22.11	0.02	100%	174,614	3.5	5.5	5.5	2.0
1116	0.00	22.13	0%	0	2.0	0.0	0.0	-2.0
1117	19.93	2.20	90%	174,888	2.0	6.1	5.5	3.5
1118	20.54	1.59	93%	125,025	3.2	4.2	3.9	0.7
1119	20.67	1.46	93%	163,680	2.6	5.5	5.1	2.5
1120	21.18	0.95	96%	160,085	2.6	5.2	5.0	2.4
1121	22.12	0.01	100%	166,450	3.1	5.2	5.2	2.1
1122	22.11	0.02	100%	129,463	2.6	4.1	4.1	1.5
1123	20.65	1.48	93%	18,373	3.1	0.6	0.6	-2.5
1124	22.12	0.01	100%	162,634	2.6	5.1	5.1	2.5
1125	18.52	3.61	84%	116,258	2.6	4.4	3.6	1.0
Cumulative				3,432,873	92.5	117.5	107.7	15.2

[1] Computed as the total time during the 27.9 day period that the pump is discharging ground water.
[2] Computed as the total time during the 27.9 day period that the pump is idle due to low water level.
[3] Computed as the percent of the 27.9 day period that the pump is discharging ground water. On-stream factors less than 100% imply on/off pump cycling due to low water levels.

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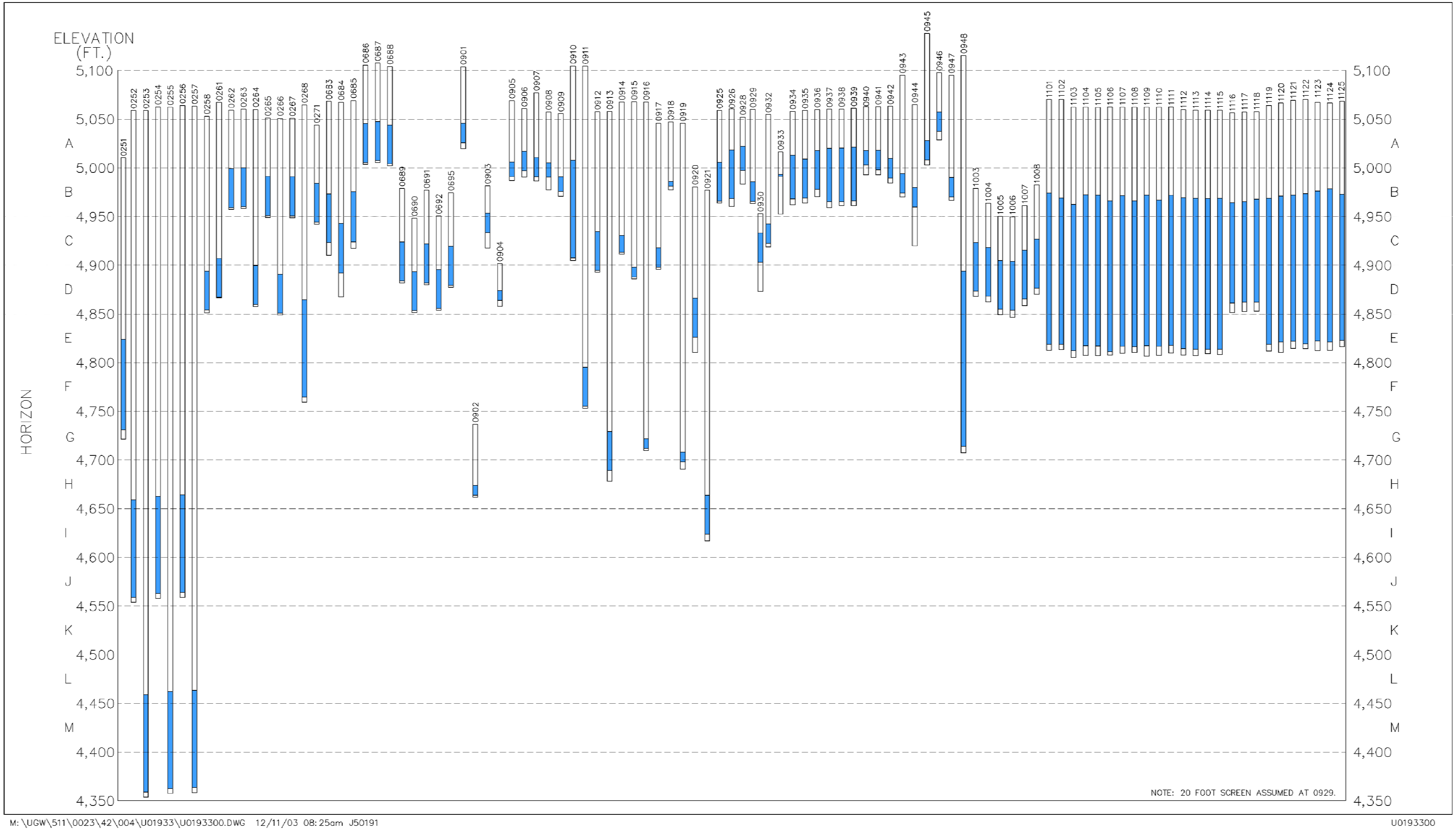

Figure A−1. Well Screen Intervals and Horizons

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Appendix B

Ground Water Sample Results for August 2003 and the Baseline Period for Contaminants Requiring Remediation

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Table B−1. Baseline and August 2003 Nitrate Concentrations

Well Number	Horizon	Baseline Nitrate Concentration (mg/L)	Year Sampled, Baseline	August 2003 Nitrate Concentration (mg/L)
		MCL=44.0 mg/L		
0686	A	32.2	2002	13.9
0687	A	60.6	2002	14.9
0688	A	35.1	2002	35.4
0901	A	13	2001	13.2
0906	A	1470	2002	1230
0929	A	69.5	2002	65.9
0940	A	1800	2002	1780
0941	A	358	2002	684
0945	A	12.7	2002	12
0946	A	NS		34.1
0262	B	380	2001	516
0263	B	1140	2001	848
0265	B	720	2001	575
0267	B	1640	2002	1480
0271	B	15.6	2002	15.5
0908	B	651	2002	689
0909	B	485	2002	451
0910	B	NS		NS
0918	B	NS		NS
0934	B	2320	2002	2250
0935	B	525	2002	652
0936	B	2950	2002	2310
0938	B	1450	1999	NS
0942	B	1360	2002	1210
0943	B	22.1	2002	329
0947	B	12.5	2002	NS
0683	C	14.1	2002	14
0684	C	13.9	2002	13.8
0685	C	14.3	2002	13.7
0689	C	14.3	2002	14.2
0691	C	298	2002	316
0903	C	54.8	2002	53.9
0912	C	403	2001	367
0914	C	13	2001	12.1
0917	C	15.7	2001	82.6
0930	C	50.9	2002	63.3
0932	C	25.3	2002	23.8
1008	C	15.7	2000	15.1
1116	C	106	2002	NS
1117	C	225	2002	194
1118	C	164	2002	416
0258	D	15	2000	NS
0261	D	14	2001	14.3
0264	D	24.3	2001	38

Table B−1 (continued). Baseline and August 2003 Nitrate Concentrations

Well Number	Horizon	Baseline Nitrate Concentration (mg/L)	Year Sampled, Baseline	August 2003 Nitrate Concentration (mg/L)
		MCL=44.0 mg/L		
0266	D	14	2001	14.1
0690	D	12.5	2002	12
0692	D	12.5	2002	13.6
0695	D	25.4	2002	25.3
0904	D	5.13	2001	4.97
0915	D	14.1	2001	12.6
1003	D	176	2000	61.1
1004	D	49.1	2000	49.5
1005	D	14.5	2000	14.1
1006	D	14.1	2000	13.4
1007	D	15.3	2000	14.6
1101	D	438	2002	552
1102	D	650	2002	643
1103	D	1120	2002	1260
1104	D	993	2002	606
1105	D	648	2002	295
1106	D	614	2002	137
1107	D	1060	2002	212
1108	D	1410	2002	772
1109	D	798	2002	400
1110	D	227	2002	352
1111	D	421	2002	364
1112	D	617	2002	139
1113	D	143	2002	234
1114	D	228	2002	144
1115	D	766	2002	256
1119	D	468	2002	527
1120	D	493	2002	328
1121	D	573	2002	273
1122	D	954	2002	330
1123	D	643	2002	88.1
1124	D	781	2002	459
1125	D	104	2002	78.9
0251	E	426	2002	12.8
0268	E	15.4	2002	13.9
0920	E	14.8	2001	15.1
0948	E	NS		NS
0911	F	NS		NS
0913	G	12.4	2001	13.2
0916	G	11.6	2001	10.8
0919	G	NS		NS
0902	H	NS		NS
0252	I	15.3	2002	10.5
0254	I	354	2002	484

Table B−1 (continued). Baseline and August 2003 Nitrate Concentrations

Well Number	Horizon	Baseline Nitrate Concentration (mg/L)	Year Sampled, Baseline	August 2003 Nitrate Concentration (mg/L)
		MCL=44.0 mg/L		
0256	I	189	2002	51.2
0921	I	11	2001	11.1
0255	M	9.6	2000	0.0191
0257	M	6.9	2000	0.0191

NS = Not sampled

Table B−2. Baseline and August 2003 Molybdenum Concentrations

Well Number	Horizon	Baseline Molybdenum Concentration (mg/L)	Year Sampled, Baseline	August 2003 Molybdenum Concentration (mg/L)
		MCL=0.1 mg/L		
0686	A	0.0015	2002	0.0026
0687	A	0.0113	2002	0.0041
0688	A	0.0015	2002	0.0017
0901	A	0.00078	2001	0.0017
0906	A	0.0137	2002	0.031
0929	A	0.0015	2002	0.0017
0940	A	0.0015	2002	0.0017
0941	A	0.0284	2002	0.141
0945	A	0.0015	2002	0.0017
0946	A	NS		0.0017
0262	B	0.432	2001	0.472
0263	B	0.192	2001	0.0363
0265	B	0.00046	2001	0.0017
0267	B	0.0015	2002	0.0017
0271	B	0.0015	2002	0.0017
0908	B	0.0015	2002	0.0017
0909	B	0.0015	2002	0.0017
0910	B	NS		NS
0918	B	NS		NS
0934	B	0.0015	2002	0.0017
0935	B	0.0015	2002	0.0017
0936	B	0.0015	2002	0.0017
0938	B	0.001	1999	NS
0942	B	0.021	2002	0.0083
0943	B	0.0015	2002	0.0017
0947	B	0.0015	2002	NS
0683	C	0.0015	2002	0.0017
0684	C	0.0015	2002	0.0017
0685	C	0.0015	2002	0.0017
0689	C	0.0015	2002	0.0017
0691	C	0.0015	2002	0.0017
0903	C	0.0015	2002	0.0017
0912	C	0.0003	2001	0.0017
0914	C	0.00081	2001	0.0017
0917	C	0.0013	2001	0.0017
0930	C	0.0015	2002	0.0017
0930	C	0.0015	2002	0.0017
0932	C	0.0018	2002	0.0017
1008	C	0.0004	2000	0.0017
1116	C	0.0015	2002	NS
1117	C	0.0015	2002	0.0017
1118	C	0.0015	2002	0.0017
0258	D	0.00063	2000	NS

Table B−2 (continued). Baseline and August 2003 Molybdenum Concentrations

Well Number	Horizon	Baseline Molybdenum Concentration (mg/L)	Year Sampled, Baseline	August 2003 Molybdenum Concentration (mg/L)
		MCL=0.1 mg/L		
0261	D	0.0026	2001	0.0017
0264	D	0.0031	2001	0.0017
0266	D	0.00058	2001	0.0017
0690	D	0.0015	2002	0.0017
0692	D	0.0015	2002	0.0017
0695	D	0.0015	2002	0.0017
0904	D	0.00077	2001	0.0017
0915	D	0.00054	2001	0.0017
1003	D	0.0004	2000	0.0017
1004	D	0.0004	2000	0.0017
1005	D	0.0004	2000	0.0017
1006	D	0.0004	2000	0.0017
1007	D	0.0004	2000	0.0017
1101	D	0.0015	2002	0.0017
1102	D	0.0015	2002	0.0017
1103	D	0.0015	2002	0.0017
1104	D	0.0916	2002	0.038
1105	D	2.96	2002	0.203
1106	D	1.26	2002	0.382
1107	D	0.16	2002	0.0237
1108	D	0.0015	2002	0.0017
1109	D	0.0015	2002	0.0017
1110	D	0.0015	2002	0.0017
1111	D	0.0015	2002	0.0017
1112	D	0.0015	2002	0.0017
1113	D	0.0015	2002	0.0017
1114	D	0.0027	2002	0.0017
1115	D	0.0015	2002	0.0017
1119	D	0.0053	2002	0.0017
1120	D	0.0815	2002	0.0258
1121	D	0.105	2002	0.0475
1122	D	0.0015	2002	0.0017
1123	D	0.0015	2002	0.0017
1124	D	0.0015	2002	0.0017
1125	D	0.0015	2002	0.0017
0251	E	0.0015	2002	0.0017
0268	E	0.0015	2002	0.0017
0920	E	0.0003	2001	0.0017
0911	F	NS		NS
0913	G	0.0003	2001	0.0017
0916	G	0.00096	2001	0.0017
0919	G	NS		NS
0902	H	NS		NS

Table B−2 (continued). Baseline and August 2003 Molybdenum Concentrations

Well Number	Horizon	Baseline Molybdenum Concentration (mg/L)	Year Sampled, Baseline	August 2003 Molybdenum Concentration (mg/L)
		MCL=0.1 mg/L		
0252	I	0.0015	2002	0.0017
0254	I	0.164	2002	0.0535
0256	I	0.0015	2002	0.0017
0921	I	0.0003	2001	0.0017
0255	M	0.0043	2000	0.0482
0257	M	0.00041	2000	0.0316

NS = Not sampled

Table B−3. Baseline and August 2003 Selenium Concentrations

Well Number	Horizon	Baseline Selenium Concentration (mg/L)	Year Sampled, Baseline	August 2003 Selenium Concentration (mg/L)
		MCL=0.01 mg/L		
0686	A	0.0088	2002	0.002
0687	A	0.0145	2002	0.00095
0688	A	0.0033	2002	0.0033
0901	A	0.0024	2001	0.0025
0906	A	0.0335	2002	0.0298
0929	A	0.0028	2002	0.0038
0940	A	0.105	2002	0.0716
0941	A	0.0348	2002	0.0781
0945	A	0.0035	2002	0.0016
0946	A	NS		0.0092
0262	B	0.0621	2001	0.0607
0263	B	0.0632	2001	0.0459
0265	B	0.0071	2001	0.0054
0267	B	0.0532	2002	0.0487
0271	B	0.0016	2002	0.0017
0908	B	0.0163	2002	0.0171
0909	B	0.0224	2002	0.0215
0910	B	NS		NS
0918	B	NS		NS
0934	B	0.0116	2002	0.0108
0935	B	0.0195	2002	0.0228
0936	B	0.0869	2002	0.0566
0938	B	0.0432	1999	
0942	B	0.0348	2002	0.0331
0943	B	0.0021	2002	0.0084
0947	B	0.0019	2002	
0683	C	0.0022	2002	0.0019
0684	C	0.0019	2002	0.0019
0685	C	0.0017	2002	0.0017
0689	C	0.0014	2002	0.0014
0691	C	0.0046	2002	0.0048
0903	C	0.0023	2002	0.0022
0912	C	0.0137	2001	0.0113
0914	C	0.0016	2001	0.0013
0917	C	0.0017	2001	0.0015
0930	C	0.002	2002	0.0022
0932	C	0.0019	2002	0.0016
1008	C	0.0015	2000	0.0015
1116	C	0.0018	2002	NS
1117	C	0.0028	2002	0.0054
1118	C	0.0028	2002	0.013
0258	D	0.0018	2000	NS
0261	D	0.0021	2001	0.0001
0264	D	0.0018	2001	0.0018

Table B−3 (continued). Baseline and August 2003 Selenium Concentrations

Well Number	Horizon	Baseline Selenium Concentration (mg/L)	Year Sampled, Baseline	August 2003 Selenium Concentration (mg/L)
		MCL=0.01 mg/L		
0266	D	0.0013	2001	0.0012
0690	D	0.0014	2002	0.0014
0692	D	0.0022	2002	0.0025
0695	D	0.0019	2002	0.0021
0904	D	0.0131	2001	0.014
0915	D	0.0019	2001	0.0016
1003	D	0.003	2000	0.0036
1004	D	0.0021	2000	0.0021
1005	D	0.0014	2000	0.0014
1006	D	0.0013	2000	0.0014
1007	D	0.0013	2000	0.0014
1101	D	0.0188	2002	0.0284
1102	D	0.0121	2002	0.0219
1103	D	0.0613	2002	0.0545
1104	D	0.0344	2002	0.0182
1105	D	0.0871	2002	0.0177
1106	D	0.0925	2002	0.0319
1107	D	0.0903	2002	0.0131
1108	D	0.0704	2002	0.0364
1109	D	0.0372	2002	0.0144
1110	D	0.0081	2002	0.0071
1111	D	0.0172	2002	0.0141
1112	D	0.0154	2002	0.0043
1113	D	0.0025	2002	0.0039
1114	D	0.0035	2002	0.0031
1115	D	0.0362	2002	0.0076
1119	D	0.029	2002	0.0216
1120	D	0.0563	2002	0.0331
1121	D	0.0455	2002	0.025
1122	D	0.0558	2002	0.0234
1123	D	0.0449	2002	0.0048
1124	D	0.0186	2002	0.0135
1125	D	0.0025	2002	0.0026
0251	E	0.0035	2002	0.0012
0268	E	0.0018	2002	0.0016
0920	E	0.0014	2001	0.0014
0948	E	NS		NS
0911	F	NS		NS
0913	G	0.00063	2001	0.00093
0916	G	0.001	2001	0.0012
0919	G	NS		NS
0902	H	NS		NS
0252	I	0.00092	2002	0.00077
0254	I	0.0531	2002	0.0519

Table B−3 (continued). Baseline and August 2003 Selenium Concentrations

Well Number	Horizon	Baseline Selenium Concentration (mg/L)	Year Sampled, Baseline	August 2003 Selenium Concentration (mg/L)
		MCL=0.01 mg/L		
0256	I	0.0031	2002	0.0013
0921	I	0.00091	2001	0.00098
0255	M	0.0011	2000	0.0001
0257	M	0.0013	2000	0.00045

NS = Not sampled

Table B−4. Baseline and August 2003 Sulfate Concentrations

Well Number	Horizon	Baseline Sulfate Concentration (mg/L)	Year Sampled, Baseline	August 2003 Sulfate Concentration (mg/L)
		No MCL for sulfate		
0686	A	98.6	2002	52.2
0687	A	329	2002	48.7
0688	A	40	2002	44.9
0901	A	26.2	2001	28.6
0906	A	1660	2002	1650
0929	A	28.1	2002	29.1
0940	A	7550	2002	10300
0941	A	745	2002	1010
0945	A	32.1	2002	15.3
0946	A	NS		161
0262	B	931	2001	1190
0263	B	1990	2001	1640
0265	B	1520	2001	1070
0267	B	3680	2002	3690
0271	B	16.4	2002	15.9
0908	B	2430	2002	2400
0909	B	666	2002	564
0910	B	NS		NS
0918	B	NS		NS
0934	B	7360	2002	2640
0935	B	2690	2002	2930
0936	B	4360	2002	3240
0938	B	2120	1999	NS
0942	B	3030	2002	2890
0943	B	29	2002	543
0947	B	18.7	2002	NS
0683	C	21.6	2002	19.1
0684	C	18	2002	16.8
0685	C	26.2	2002	16
0689	C	13.7	2002	14.2
0691	C	587	2002	638
0903	C	76.5	2002	71.9
0912	C	846	2001	722
0914	C	15.6	2001	14.4
0917	C	13.9	2001	15.2
0930	C	59.8	2002	75.4
0932	C	30.2	2002	26.6
1008	C	13	2000	14
1116	C	176	2002	NS
1117	C	255	2002	363
1118	C	163	2002	1120
0258	D	17.4	2000	NS
0261	D	18.2	2001	19.4
0264	D	37.7	2001	57.9

Table B−4 (continued). Baseline and August 2003 Sulfate Concentrations

Well Number	Horizon	Baseline Sulfate Concentration (mg/L)	Year Sampled, Baseline	August 2003 Sulfate Concentration (mg/L)
		No MCL for sulfate		
0266	D	10.9	2001	10.9
0690	D	13.8	2002	13
0692	D	20.8	2002	21.9
0695	D	50.4	2002	51.4
0904	D	96.5	2001	87.9
0915	D	17.8	2001	17.4
1003	D	302	2000	473
1004	D	66.2	2000	74.3
1005	D	12.7	2000	13.1
1006	D	12.2	2000	12.5
1007	D	11.7	2000	12.1
1101	D	960	2002	1280
1102	D	1320	2002	1420
1103	D	2570	2002	2670
1104	D	1870	2002	1150
1105	D	1590	2002	664
1106	D	1050	2002	303
1107	D	1200	2002	255
1108	D	3400	2002	1970
1109	D	3280	2002	1040
1110	D	512	2002	369
1111	D	988	2002	871
1112	D	1140	2002	217
1113	D	136	2002	205
1114	D	328	2002	183
1115	D	1930	2002	431
1119	D	1560	2002	1100
1120	D	2330	2002	1580
1121	D	2590	2002	1460
1122	D	2960	2002	1110
1123	D	1240	2002	173
1124	D	1170	2002	737
1125	D	165	2002	123
0251	E	617	2002	11.7
0268	E	17.4	2002	18.9
0920	E	12.7	2001	13.5
0948	E	NS		NS
0911	F	NS		NS
0913	G	8.43	2001	9.11
0916	G	13.5	2001	11.8
0919	G	NS		NS
0902	H	NS		NS
0252	I	19.2	2002	8.03
0254	I	505	2002	608

Table B−4 (continued). Baseline and August 2003 Sulfate Concentrations

Well Number	Horizon	Baseline Sulfate Concentration (mg/L)	Year Sampled, Baseline	August 2003 Sulfate Concentration (mg/L)
		No MCL for sulfate		
0256	I	368	2002	90.9
0921	I	8.52	2001	8.83
0255	M	102	2000	3890
0257	M	13.4	2000	300

NS = Not sampled

Table B−5. Baseline and August 2003 Uranium Concentrations

Well Number	Horizon	Baseline Uranium Concentration (mg/L)	Year Sampled, Baseline	August 2003 Uranium Concentration (mg/L)
		MCL=0.044 mg/L		
0686	A	0.0021	2002	0.00036
0687	A	0.0208	2002	0.00048
0688	A	0.002	2002	0.0023
0901	A	0.0026	2001	0.0027
0906	A	0.951	2002	0.667
0929	A	0.0012	2002	0.0018
0940	A	0.546	2002	0.428
0941	A	0.0886	2002	0.0858
0945	A	0.0031	2002	0.0013
0946	A	NS		0.001
0262	B	0.379	2001	0.425
0263	B	0.485	2001	0.173
0265	B	0.0897	2001	0.0551
0267	B	0.0731	2002	0.0784
0271	B	0.0014	2002	0.0016
0908	B	0.122	2002	0.106
0909	B	0.0389	2002	0.0279
0910	B	NS		NS
0918	B	NS		NS
0934	B	0.312	2002	0.35
0935	B	0.0868	2002	0.114
0936	B	0.267	2002	0.606
0938	B	0.21	1999	NS
0942	B	0.246	2002	0.232
0943	B	0.0049	2002	0.278
0947	B	0.0024	2002	NS
0683	C	0.0012	2002	0.0014
0684	C	0.0019	2002	0.0014
0685	C	0.0012	2002	0.0016
0689	C	0.0011	2002	0.0013
0691	C	0.0657	2002	0.0614
0903	C	0.0022	2002	0.0024
0912	C	0.0342	2001	0.0318
0914	C	0.0013	2001	0.00093
0917	C	0.0013	2001	0.0011
0930	C	0.0023	2002	0.0031
0932	C	0.0016	2002	0.0017
1008	C	0.001	2000	0.0014
1116	C	0.0081	2002	NS
1117	C	0.0151	2002	0.0154
1118	C	0.0098	2002	0.0422
0258	D	0.0018	2000	NS
0261	D	0.0018	2001	0.0014
0264	D	0.0033	2001	0.0037

Table B−5 (continued). Baseline and August 2003 Uranium Concentrations

Well Number	Horizon	Baseline Uranium Concentration (mg/L)	Year Sampled, Baseline	August 2003 Uranium Concentration (mg/L)
		MCL=0.044 mg/L		
0266	D	0.0019	2001	0.0017
0690	D	0.0018	2002	0.0024
0692	D	0.0015	2002	0.0017
0695	D	0.002	2002	0.0024
0904	D	0.0044	2001	0.0037
0915	D	0.0017	2001	0.0001
1003	D	0.0205	2000	0.0351
1004	D	0.0053	2000	0.0082
1005	D	0.0013	2000	0.0016
1006	D	0.0014	2000	0.0015
1007	D	0.0012	2000	0.0015
1101	D	0.245	2002	0.342
1102	D	0.533	2002	0.485
1103	D	0.355	2002	0.519
1104	D	0.194	2002	0.0945
1105	D	2.1	2002	0.248
1106	D	2.1	2002	0.616
1107	D	0.118	2002	0.0343
1108	D	0.646	2002	0.259
1109	D	0.565	2002	0.24
1110	D	0.0528	2002	0.0586
1111	D	0.161	2002	0.134
1112	D	0.13	2002	0.0372
1113	D	0.0149	2002	0.0258
1114	D	0.0277	2002	0.0151
1115	D	0.41	2002	0.0544
1119	D	0.555	2002	0.192
1120	D	1.3	2002	0.671
1121	D	0.857	2002	0.444
1122	D	0.878	2002	0.338
1123	D	0.261	2002	0.0384
1124	D	0.171	2002	0.118
1125	D	0.0176	2002	0.0218
0251	E	0.0481	2002	0.0016
0268	E	0.0014	2002	0.0023
0920	E	0.0017	2001	0.0016
0948	E	NS		NS
0911	F	NS		NS
0913	G	0.0016	2001	0.0014
0916	G	0.0014	2001	0.0001
0919	G	NS		NS
0902	H	NS		NS
0252	I	0.0024	2002	0.0023
0254	I	0.209	2002	0.128

Table B−5 (continued). Baseline and August 2003 Uranium Concentrations

Well Number	Horizon	Baseline Uranium Concentration (mg/L)	Year Sampled, Baseline	August 2003 Uranium Concentration (mg/L)
		MCL=0.044 mg/L		
0256	I	0.0775	2002	0.0186
0921	I	0.0047	2001	0.0028
0255	M	0.0029	2000	0.0025
0257	M	0.0037	2000	0.0154

NS = Not sampled

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Appendix C

Water Levels and Drawdown Information

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Table C−1. August 2003 Drawdown from Baseline Ground Water Levels

Monitor Well Number	Baseline Water-Level Elevation (ft above msl[a])	July 2003 Water-Level Elevation (ft above msl[a])	Drawdown[b] (ft)
Horizon A			
686	5,028.17	5,046.5	-18.33
687	5,035.41	5,043.26	-7.85
688	5,026.99	5,028.45	-1.46
901	5,054.93	5,055.22	-0.29
906	5,018.29	5,007.93	10.36
929	5,006.39	5,003.94	2.45
940	5,016.62	5,000.55	16.07
941	5,017.32	4,999.56	17.76
945	5,037.57	5,039.76	-2.19
946	5,039.74	5,054.17	-14.43
Horizon B			
262	5,013.59	5,001.77	11.8
263	5,009.50	5,002.36	7.1
265	4,983.48	4,981.37	2.1
267	4,999.98	4,999.11	0.9
271	4,993.48	4,993.31	0.2
908	5,008.05	5,003.55	4.5
909	4,998.56	4,996.12	3.4
910	5,052.26	5,053.04	-0.8
934	5,001.91	4,994.87	7.0
935	5,009.25	5,003.65	5.6
936	5,012.58	4,995.6	17.0
938	5,018.89	5,006.94	12.0
942	5,015.05	5,007.98	7.1
943	5,029.14	5,030.05	-0.9
947	5,025.86	5,023.94	1.9
Horizon C			
683	4,994.44	4,977.66	16.8
684	5,004.28	4,984.72	19.6
685	5,018.81	5,014.22	4.6
689	4,946.10	4,943.91	2.2
691	4,945.01	4,941.64	3.4
903	4,958.20	4,954.95	3.3
912	5,002.07	4,998.77	3.3
914	4,969.30	4,963.17	6.1
917	4,979.19	4,979.08	0.1
930	4,935.84	4,935.12	0.7
932	4,965.52	4,959.04	6.5
Horizon D			
258	4,975.64	4,964.91	10.7
261	4,948.85	4,945.31	3.5
264	4,988.39	4966.92	21.5
266	4,967.32	4,960.42	6.9
690	4,928.64	4,927.1	1.5

Table C−1 (continued). August 2003 Drawdown from Baseline Ground Water Levels

Monitor Well Number	Baseline Water-Level Elevation (ft above msl[a])	July 2003 Water-Level Elevation (ft above msl[a])	Drawdown[b] (ft)
692	4,932.22	4,928.49	2.6
695	4,931.53	4,930.38	1.2
904	4,882.49	4,882.26	0.2
915	4,975.79	4,966.21	9.6
1003	4,944.75	4,941.55	3.2
1004	4,943.02	4,941.4	1.6
1005	4,926.81	4,926.38	0.4
1006	4,933.19	4,931.14	2.1
1007	4,939.61	4,937.74	1.9
Horizon E			
251	4,999.75	4,979.79	20.0
268	4,986.44	4,956.95	29.5
920	4,955.57	4,946.09	9.5
Horizon F			
911	5,057.28	5,057.78	-0.5
Horizon G			
913	4,995.04	4,991.56	3.5
916	4,957.55	4,948.86	8.7
919	4,903.39	4,902.58	0.8
Horizon I			
252	4,994.30	4,988.82	5.5
254	5,009.88	4,993.08	16.8
256	4,974.68	4,960.86	13.8
921	4,943.98	4,938.74	5.2
Horizon M			
255	4,974.49	4,973.11	1.4
257	4,962.07	4,960.87	1.2

[a]msl = mean sea level
[b]Drawdown = Baseline water level—July 2003 water level. Positive values indicate drawdown; negative values indicate mounding.