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April 29, 2005

Via Fedex

Ms. Mary Ann Menetrey
Program Manager
New Mexico Environment Department
Mining Environmental Compliance Section
P. O. Box 26110
Santa Fe, New Mexico 87508

Dear Ms. Menetrey

Re: DP-1341, Condition 84,
Update to the 2001 Assessment of No. 3 Tailing Pond Reclaim Area

Pursuant to DP-1341, Condition 84, Phelps Dodge Tyrone, Inc. submits the following report for the New Mexico Environment Department's approval, titled; Update to the 2001 Assessment of No. 3 Tailing Pond Reclaim Area. Please find attached three hard copies of the subject report, each with an electronic copy included.

If you have any questions, please contact Mr. Mike Jaworski at (505) 538-7181.

Very truly yours,

Ned Hall

E. L. (Ned) Hall, Manager
Environment, Land & Water
New Mexico Operations

ELH:mj
Attachments
20050429-102

c Clint Marshall, NMED - without attachments
Karen Garcia, MMD - without attachments
David Ohori, MMD - without attachments

DP-1341, CONDITION 84, UPDATE TO THE 2001 ASSESSMENT OF THE NO. 3 TAILING POND RECLAIM AREA

Submitted to:
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8 Copies – Phelps Dodge Tyrone, Inc.
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1.0 INTRODUCTION

Phelps Dodge Tyrone, Inc. (Tyrone) operates an open pit copper mine and solution extraction/electrowinning plant 10 miles southwest of Silver City, New Mexico (Figure 1). Tyrone is evaluating reclamation options with respect to meeting applicable requirements of the New Mexico Water Quality Control Act, the Water Quality Control Commission (NMWQCC) Regulations, and the New Mexico Mining Act for the Tyrone Mine. The Tyrone Mine is permitted as an existing mine (No. GR010RE) with the New Mexico Mining and Minerals Division (MMD).

Golder Associates Inc.(Golder) prepared this report on behalf of Tyrone in response to Condition 84 of the Supplemental Discharge Permit 1341 (DP-1341) issued by the New Mexico Environment Department. Condition 84 requires an evaluation of the reclamation activities conducted after the October 14, 1980 tailing spill below the No. 3 Tailing Impoundment. More specifically, the NMED has requested that "the evaluation shall include: location of the spill area and repositories; evaluation of the success of past reclamation; photographs of reclamation areas; past monitoring activities at the affected area and recommendations and schedules for future work if necessary. The evaluation shall be designed to determine whether the reclamation previously preformed achieves the requirements of the WQA and the WQCC regulations." In addition, this report updates pertinent information in the *Assessment of No. 3 Tailing Pond Reclaim Area* report submitted by Tyrone in June 2001.

1.1 Background

On October 14, 1980, approximately 2.6 million cubic yards of tailing escaped from the No. 3 Tailing Impoundment following a breach in the northwestern corner of the impoundment. This event changed the shape of the face and top surface on a portion of the impoundment, and tailing deposition was discontinued. Additional information on the No. 3 Tailing Impoundment break is provided in the *Conceptual Redesign of the Break Area at the No. 3 Tailing Pond* (Daniel B. Stephens & Associates, Inc. [DBS&A], 1998).

The fugitive tailing in the Mangas Valley were consolidated in repositories adjacent to the No. 3 Tailing Impoundment and various downstream locations (Figure 2). Because of the emergency response nature of the project, formal engineering designs and documentation were not prepared. Once consolidated, the repositories were covered with local soil materials and seeded. Anecdotal accounts indicate that the repositories were shaped with dozers, and an 18-inch thick soil cover was placed primarily by scrapers. Trucks and graders may have been used for cover placement in some instances. Seed was applied primarily by hydroseed methods, although some areas may have been seeded using drill or broadcast techniques. The composition of the seed mix is unknown. Seeding was conducted starting in the winter of 1980 and was completed by July 1981. No fences were constructed around the individual repositories, and grazing continued following seeding.

Field assessments conducted between 1999 and 2001 indicated that reclamation of the tailing spill area had generally been successful (Tyrone, 2001). The soil cover over the majority of the reclaimed areas was intact, and areas of exposed tailing were rare and localized. The tailing repository areas had maintained grade with little evidence of subsidence, localized ponding, or the formation of acid spots. Minor areas with erosional features (rills and gullies) were present in situations where no precautions were taken to prevent run-on or where the initial grading of the material was conducted without adequate surface water control. Overall, no systemic vegetation failures were identified suggesting that the soil cover on this site was capable of supporting a viable plant community and grazing post-mining land use. Localized areas of poor plant performance were noted where cattle congregated or fine-textured soils occurred at the surface. Tyrone (2001) recommended that corrective actions be implemented in the areas exhibiting concentrated erosion features and poor plant performance to repair and prevent degradation of the site.

1.2 Objectives

Following issuance of DP-1341, Tyrone agreed to perform additional reclamation work on the tailing repositories in the Mangas Valley under the schedule specified in the Financial Assurance Addendum. The reclamation work involved reconfiguration of the original repositories, cover replacement, and revegetation. This report is intended to document the success of the past reclamation, recognizing that some aspects of Condition 84 are irrelevant given the repository reclamation work that was initiated in 2004. The scope of Condition 84 evolved in collaboration with the NMED and MMD to address changes associated with reconfiguration of the repositories. The changes in scope are documented in a series of letters between the NMED and Tyrone (Tyrone, February 27, 2004; NMED, March 29, 2004; Tyrone, April 30, 2004; and Tyrone, May 24, 2004). The primary objectives of this report are to provide an evaluation of vegetation performance prior to the 2004 reclamation activities, assess of the status of surface and groundwater quality in the vicinity of the repositories, and report on the potential for upward migration of acidity into the soil cover. Section 2.0 provides information regarding the vegetation performance on the major repositories in the Mangas Valley. Section 3.0 compiles and interprets the water quality data from the wells and surface water monitoring stations in the vicinity of the repositories to update the information provided in the 2001 assessment (Tyrone, 2001). Section 4.0 discusses the evaluation of the potential for upward migration of acidity into the soil cover on the repositories conducted in May 2001. Finally, Section 5.0 provides recommendations for future work including a proposed schedule.

The information in this report is limited to the conditions existing prior to the 2004 reconfiguration of the repositories. Documentation of the construction activities conducted in 2004 will be submitted in the Construction Quality Assurance report.

2.0 VEGETATION PERFORMANCE

Construction activities including cover augmentation and tailing relocation in the spring and summer of 2004 destroyed much of the existing vegetation and eliminated the opportunity to quantify vegetation performance over the entire repository area. Thus, qualitative surveys were conducted in the spring of 2004 prior to the initiation of the major construction and reclamation activities (Section 2.1). A quantitative evaluation of the vegetation was performed near the end of the growing season in the newly established reclamation enclosure (Exclusion Area) on the South Main Repository (Section 2.2).

The evaluation of vegetation on the repositories is qualified in consideration of the past climate and management regimes. During the 5 years preceding this assessment, New Mexico was plagued by a severe and protracted drought. The effects on plant communities are quite evident over most of New Mexico and Arizona, and vegetation cover and production have generally suffered during the drought years.

The rangelands in the Mangas Valley, including the repositories, were actively managed for livestock production. The repositories were not fenced, and livestock had access to the original repository areas. Range utilization varied by repository, but was similar to surrounding native pastures and generally ranged from 60 to 100 percent at the time of the assessment. Overall range condition on both the repositories and adjacent native stands could be characterized as fair, but ranged from poor to good. The range condition on the repository areas with coarse-textured surface soils was similar to the surrounding undisturbed lands. Lands that are grazed generally have lower amounts of canopy cover because the annual biomass is removed by the grazing animals (Figure 3). In addition, grazing may result in shifts in species composition. Thus, the climate and management were less than optimal with respect to promoting vegetation performance. These factors should be considered in assessing the inherent capacity of the soil cover system in this region.

2.1 Qualitative Survey

The intent of the qualitative survey was to assess the conditions on the tailing repositories 20 years after construction and provide a forensic analysis of performance. The repositories were evaluated in March and April 2004, following the completion of boreholes to assess soil cover thickness. Field descriptions and photos of the Mangas Valley tailing repositories that were surveyed in the spring of 2004 are included in Appendix A. The field log documents pre-2004 construction conditions of the major repositories, highlighting both successful and problematic areas. The following is a generalized discussion of the vegetation performance on the major repositories and dominant relationships among vegetation response and soil properties (cover depth and texture).

2.1.1 Methods

Estimates of canopy cover, basal cover, shrub density, and plant diversity were made in various locations throughout the repositories. Cover thickness was measured in boreholes by M3 Engineering & Technology Corp. on a nominal 100-foot grid on the repositories in the winter of 2004 prior to construction activities. The soil texture and surface rock fragment cover were determined in the field by Certified Professional Soil Scientists. In areas where the vegetation performance was poor or excessive erosion was noted, a concerted effort was made to diagnose the root causes of the problem. Particular attention was given to plant performance related to cover depth and surface texture, livestock use and erosion.

2.1.2 Results

Cover thickness varied spatially across the repositories. Based on the borehole data, cover thickness ranged from 1 inch at a single location on the MS-10 repository to 31-inches at a single location on the Laney Canyon repository. Average cover thickness across seven major repositories was approximately 17.6 inches, with average thickness ranging from 14.5 inches at the North Main repository to 22.5 inches at the North Main 1 repository. Overall, the cover was greater than or equal to 20-inches thick at 62 percent of the sample locations and greater than or equal to 24-inches thick at 37 percent of the sample locations. The cover was less than 12-inches thick at approximately 3 percent of the sample locations.

Vegetation on the repositories is generally categorized as a grassland plant community dominated by warm season grasses with a moderate to sparse shrub cover. Total vegetation cover generally ranged from 10 to 30 percent, except in problem soil areas where perennial vegetation cover was generally lacking. Plant diversity was judged as adequate given the seed mix, past grazing management, and preceding drought. In total, 42 plant species were identified on the repositories (Table 1). Native shrubs occurred in small patches that were scattered throughout the repositories. The arrangement and composition of the trees and shrubs suggests that they are colonizing the repositories from adjacent native plant communities. Shrub density estimates ranged from 10 to 150 stems per acre. The majority of herbaceous forbs found on the repositories were perennial and represent important plant families in the region including the legume (*Fabaceae*), composite (*Asteraceae*), and figwort (*Scrophulariaceae*) families. Several tree species were documented on three repositories including Emory oak (*Quercus emoryi*), one-seed juniper (*Juniperus monosperma*), and piñon pine (*Pinus edulis*).

Because no apparent relationship existed among vegetation cover and cover thickness, vegetation performance was judged to be qualitatively independent of cover thickness. In contrast, vegetation performance was strongly related to the texture of the surface soil layer. Vegetation cover tended to be higher where coarse- and moderately coarse-textured soils (10 to 25 percent clay) occurred at the surface. In contrast, perennial plant cover tended to be lower where the texture of the surface layer was medium- to fine-textured (greater than 25 to 30 percent clay). Surface rock fragment cover was generally higher on the better performing soils ranging from approximately 25 to 90 percent. The rock fragments were mainly in the gravel (2 to 75 millimeters [mm]) and cobble (7.5 to 25 centimeters [cm]) size classes. The medium- and fine-textured soils tended to have lower rock fragment contents (<5 to 10 percent by volume gravel) and surface cover. The texture of the subsurface materials (either fine or coarse) did not result in discernable differences in vegetation performance.

Surface crusts (2- to 5-mm thick) were commonly observed on the medium and fine-textured soil (Figure 4). Surface crusts reduce the amount of water that infiltrates into the soil during high intensity rainstorms, thereby reducing available soil water and consequent plant performance. Reduced infiltration on the crusted soils increases runoff and erosion. Thus, surface crusting, sheet and rill erosion, run-on, and heavy grazing all contributed to poor performance of the covers with finer-textured surface layers.

On coarse-textured cover materials, perennial canopy cover was estimated to range from 10 to 30 percent across the repositories. Basal cover was estimated to range from 2 to 30 percent on the coarse-textured materials. Plant performance on areas with a fine-textured surface layers was poor to fair. Basal cover was estimated at less than 1 to 3percent and canopy cover ranged from less than 5 to 20 percent. In the places where perennial grass was established on fine-textured materials, the plants were often pedestaled (1 to 6 inches) suggesting moderate rates of soil loss.

Localized erosion features were noted on some repositories, where run-on from adjacent lands was uncontrolled (Appendix A). In other instances, the repositories were not properly graded to prevent the concentration of water and no ditches were constructed to move water off the facility in a controlled manner. As such, minor areas on the repositories were affected by localized erosion. Coarse-textured cover materials were normally quite stable on the sloping and low gradient positions when run-on was not introduced from upgradient areas. Sheet erosion was the dominant process observed on fine-textured cover materials that did not experience additional run-on due to surface crusting and low plant cover.

2.2 Quantitative Vegetation Assessment

Quantitative vegetation data (e.g., canopy cover, basal cover, and frequency) were collected in the Tyrone Reference Area and a 24-year-old revegetated area (Exclusion Area) on the South Main Tailing Repository using the method approved by the MMD (Section 2.2.1). The Exclusion Area is a 27-acre parcel that is part of the original South Main Repository (Figure 5). This area was fenced, but no additional reclamation activities were conducted during 2004. Thus, it represents the long-term performance of the soils and vegetation in this region under the prevailing climate and management regime.

For mine reclamation applications, vegetation performance is typically defined based on canopy cover. Secondary performance criteria are associated with shrub density and some measure of vegetation diversity. Table 2 provides the technical standards for revegetation success for the Tyrone Mine. Vegetation success for the Exclusion Area is compared against the vegetation success criteria in Section 2.2.2

2.2.1 Methods

Fieldwork was conducted at the end of the growing season, but prior to the first killing frost (October 2004). A systematic random sampling procedure employing a transect/quadrat system was used to select sample sites within the two study areas. A 15.25 meter square grid was imposed over each study area to delineate vegetation sample plots, and random coordinates were used to select plots for vegetation sampling. Originating from the southeastern corner of the selected vegetation plot, a 30-meter (m) transect in a dog-leg pattern was established (DBS&A, 1999). Four 1 square-meter (m^2) quadrats were placed at pre-determined intervals along the transect for quantitative vegetation measurements. A total of eight plots (32 quadrats) were sampled in the Tyrone reference area and eight plots (31 quadrats) were sampled at the repository. Appendix B contains plot and quadrat photos taken at the time of the vegetation assessment in 2004. Soil depths in the sampling area ranged from 15 to 25 inches.

Plant frequency was determined on a species-basis by counting the number of individual plants in each quadrat. Relative and total canopy cover, basal cover, surface litter, rock fragments, and bare soil were visually estimated. Percent area cards were used to increase the accuracy and consistency of the cover estimates. In this study, canopy cover was defined as the percentage of the quadrat area included in the vertical projection of the canopy. The canopy cover estimates included the foliage and foliage interspaces of all of the individuals rooted in the quadrat. Basal cover is defined as the portion of the ground occupied by the crowns of grasses and rooted stems of forbs and shrubs. In addition, basal cover estimates were made for surface litter, rock fragments and bare soil. Shrub density was determined using count data from the point-centered quarter (PCQ) method (Bonham, 1989).

2.2.2 Results

Total Canopy Cover

Vegetation cover on the Exclusion Area was similar to the Tyrone Reference Area. Mean total canopy cover for the Exclusion Area was 34.5 percent compared to 40.6 percent for the Reference Area (Table 2). Based on a one-sided Student's ***t***-test ($t[\alpha=0.1,df=61]$) of two independent samples, there was no statistical difference in mean canopy cover for the two areas. Canopy cover in the individual quadrats ranged from 13 to 93 percent in the Exclusion Area and from 6 to 100 percent in the Reference Area. Differences in canopy cover are primarily due to higher shrub cover in the Reference Area compared to the Exclusion area (Table 3). The Exclusion Area had higher grass and forb cover than Reference Area (Table 3). The Exclusion Area met the vegetation success guidelines for total canopy cover using the one-sided ***t***-test ($t[\alpha=0.15,df=61]$).

Diversity

The numerical diversity guidelines for the Tyrone Mine are listed in Table 5. To summarize, the diversity guideline would be met if the reclaimed area contains at least three warm season grasses and two shrubs, with individual cover levels of at least 1 percent, and one perennial, cool season grass with a minimum cover level of 0.5 percent. For the purposes of this guideline, intermediate-season grasses such as plains lovegrass are considered the functional equivalent of the more traditionally defined cool season grasses. In addition, one non-weedy forb species should occur at a minimum cover level of at least 0.1 percent to meet the proposed diversity guideline. The forb guideline is unqualified with respect to the seasonality and could include a perennial, biannual, or annual species.

The Exclusion Area vegetation clearly meets the diversity requirements for warm-season grasses and forbs. Two intermediate-season (*Eragrostis* spp) occurred in the Exclusion Area, at canopy cover levels of 0.3 and 0.4 percent, which are slightly below the 0.5 percent cover level required in the vegetation guidelines. The lack of cool season grasses may be related to selective pressures associated with year round grazing. It should be noted that cool-season grasses were conspicuously absent in the Tyrone Reference Area where only traces of bottlebrush squirreltail (***Sitanion hystrix***) and an unidentified bluegrass (***Poa*** spp) occurred.

Shrub density was significantly lower in the Exclusion Area than the Reference Area (Table 4) and the vegetation success guideline for shrub density of 0.2 shrubs m^2 was not met in the Exclusion Area. From a cover perspective, two shrub species were captured in the vegetation sampling at a combined canopy cover of 1.2 percent, which is below the diversity guideline. The lower shrub density on the Exclusion Area may be related to a lack of shrubs in the original seed mix and/or the developmental stage of the plant community. The progression of shrubs onto the site through natural dispersal processes is expected to be slow in the Exclusion Area given geographic considerations. The South Main Repository is bounded by the County Road on the east on the Mangas Wash on the west and the repository is not contiguous with undisturbed areas that could provide seed sources. Because higher shrub densities were observed in the smaller repositories that were immediately adjacent to native areas, the lack of shrubs in the Exclusion Area is probably related to external factors, rather than the inherent capacity of the cover to support shrubs.

The quantitative data confirmed the poor correlation among of vegetation cover and soil cover thickness noted during the qualitative surveys (Section 2.1). Cover thickness in the randomly selected vegetation plots ranged from 15 to 25 inches and no relationship was observed with measured canopy cover (Figure 6).

3.0 WATER QUALITY ASSESSMENT

The water quality assessment associated with Condition 84 included an evaluation of both surface water and groundwater conditions in the vicinity of the No. 3 Tailing Impoundment repository area. The scope of the surface water and groundwater quality assessments are presented in Section 3.1 and the associated results are presented in Section 3.2.

3.1 Scope of Water Quality Assessment

As part of the water quality assessment associated with Condition 84, a total of two surface water sampling points within Mangas Wash and 15 groundwater wells located in the vicinity of the No. 3 Tailing Impoundment were evaluated. The scope of the surface water and groundwater assessments are provided in Sections 3.1.1 and 3.1.2, respectively

3.1.1 Surface Water Monitoring

Following individual storm flow events, surface water samples are routinely collected from six flow samplers located within Mangas Wash. Two of these samplers (FS-5 and FS-6) are located immediately downgradient of individual tailing repositories (Figure 7). As part of the DP-27 monitoring program, surface water samples have been collected from these two locations since 1990 and analyzed by either ACZ Laboratories, Inc. of Steamboat Springs, Colorado or Inter-Mountain Laboratories, Inc. of Farmington, New Mexico for analysis of total dissolved metals, major anions, and several other parameters. Surface water quality data are available between July 1990 and October 2004 for flow sampler FS-5 and between July 1990 and December 2002 for flow sampler FS-6. As part of the surface water assessment, water quality results for each sampler were compared with New Mexico standards for interstate and intrastate surface water (livestock watering standards) developed by the NMWQCC (NMWQCC, 2002b). These data were also used to evaluate whether surface water impacts from the tailing repositories have occurred.

3.1.2 Groundwater Monitoring

During the initial site survey in March 1999, 15 groundwater wells were identified near the No. 3 Tailing Impoundment reclaim area (Figure 7). Of these wells, nine (Wells 13, 14, 15, 19, 37, 38, 44, 47, and G) are currently part of the DP-27 monitoring network and the remaining six (MS-2, MS-3, MS-4, MS-5, MS-8, and MS-10) are existing/former residential water supply wells located within Mangas Valley. Between January 17 and 21, 2005, Tyrone personnel measured water levels and collected water samples in the DP-27 monitoring wells. Water levels were measured by Tyrone personnel in four of the existing/former residential water supply wells (two of the residential supply wells were accessed through household taps) and water samples collected from all six on February 22 and 23, 2005. The January and February 2005 sampling events were conducted in accordance with DP-27 monitoring requirements. Prior to collecting samples for laboratory analyses, approximately three casing volumes of water were purged from each well using a submersible pump (with the exception of wells MS-8 and MS-10, which were sampled from residential taps). Field water quality parameters (electrical conductivity [EC], temperature, and pH) were repeatedly measured during purging to ensure that representative samples were collected for laboratory analysis. Water samples collected from the individual wells were filtered at Tyrone's environmental laboratory and shipped to either ACZ Laboratories, Inc. or Inter-Mountain Laboratories, Inc. for analysis. The water samples were analyzed for total dissolved metals, major anions, and several other parameters in accordance with the DP-27 monitoring requirements.

Water level elevations were calculated, and regional groundwater flow directions were determined from the water level measurements. Water quality results for each well were compared with NMWQCC groundwater quality standards (NMWQCC, 2002a). Additionally, the most recent water quality results for wells with data prior to the October 1980 tailing spill (i.e., Wells 13, 14, 15, and G) were compared to the average pre-spill concentrations of individual constituents.

3.2 Results of Water Quality Assessment

The results of the surface water and groundwater quality assessment of the No. 3 Tailing Impoundment reclaim area are presented in Sections 3.2.1 and 3.2.2, respectively. A summary of the proposed actions based on the results of the water quality assessment are presented in Section 5.0.

3.2.1 Surface Water Monitoring

As described in Section 3.1.1, two flow samplers are located within Mangas Valley near the individual tailing repositories (Figure 1). One of the flow samplers is located within the Wind Canyon Drainage (FS-6), near (north of) the large South Main Repository situated west/northwest of the No. 3 Tailing Impoundment. The second flow sampler (FS-5) is located downgradient (northwest) of a repository situated west of the No. 3X Tailing Impoundment. Surface water samples have been collected from these two locations as part of the DP-27 monitoring program since 1990.

Historical analytical results for surface water sample points FS-5 and FS-6 are presented in Tables C-1 and C-2, respectively. These data indicate that in general, the surface water has low concentrations of dissolved constituents. Copper was detected at a concentration exceeding the NMWQCC standard for livestock watering of 0.5 milligrams per liter (mg/L) in one sample collected at FS-5 in 1992 (1.17 mg/L). Lead was also detected at a concentration slightly above the NMWQCC standard for livestock watering of 0.1 mg/L in one sample collected at FS-5 in 2000 (0.11 mg/L). No other constituents have been detected in the two flow samplers at concentrations above their associated NMWQCC standards for livestock watering over the past 15 years of monitoring which suggests that there have been no impacts from the reclaim areas. The two exceedances noted above may be due to laboratory errors or cross contamination during sample collection or analysis.

Time-series plots of pH and concentrations of sulfate and TDS in surface water samples collected at FS-5 and FS-6 are presented in Appendix C. An increase in the concentration of several constituents was observed in the October 2004 surface water sample from FS-5. Although the data represent an increase, the values did not exceed applicable water quality parameters. There are no other trends shown in the data for flow samplers FS-5 and FS-6 that may be indicative of impacts from surface drainage off the reclaim areas. Laboratory analytical reports for the surface water samplers are presented in quarterly and biannual DP-27 monitoring reports.

3.2.2 Groundwater Monitoring

The water level map developed from the January and February 2005 sampling events shows that regional groundwater in the No. 3 Tailing Impoundment area generally flows toward the northwest, roughly parallel to the axis of the Mangas Valley (Figure 8). The hydraulic gradient ranges between approximately 0.008 foot per foot (ft/ft) in the northern portion of the study area to 0.02 ft/ft in the vicinity of the No. 3 and 3X Tailing Impoundments.

Field water quality parameters measured immediately prior to the collection of water samples for laboratory analysis are presented in Tables C-3a through C-3i, Table C-4, and Figure 9. These data indicate that regional groundwater near the No. 3 Tailing Impoundment is characterized by pH values ranging between approximately of 6.56 and 7.67 standard units, and EC values ranging between approximately 331 and 1,048 micromhos per centimeter (corrected to 25 degrees Celsius).

The results of the laboratory analyses of the DP-27 wells are presented in Tables C-3a through C-3i along with the related NMWQCC groundwater standards. As shown on Tables C-3a through C-3i, only one constituent was detected in the DP-27 monitoring wells above applicable NMWQCC groundwater quality standards during the most recent sampling events. Manganese was detected above the NMWQCC domestic water supply standard of 0.2 mg/L in Well G with a concentration of 0.427 mg/L. As shown on Table C-3i, no other constituents have been detected in Well G above applicable NMWQCC groundwater quality standards between October 1998 and October 2004 (i.e., the 6-year period analyzed for this report). In fact, manganese has only been detected above its standard once since monitoring began at this well in June 1975.

The samples from the DP-27 wells are characterized by relatively low concentrations of dissolved metals, sulfate at concentrations ranging between 11 and 468 mg/L, and total dissolved solids (TDS) levels between 190 and 900 mg/L. Analytical results for the last 2 years of water quality monitoring in the wells associated with DP-27 (i.e., eight quarters for Wells 13, 14, 15, 19, 37, 44, 47, and four biannual monitoring events for Well G) show that with the exception of Wells 15, 38, and G (previously discussed) no constituents were detected above applicable NMWQCC groundwater quality standards during the most recent monitoring events.

For Well 15, cadmium was detected above the human health standard of 0.01 mg/L in April 2004 (0.0387 mg/L) and July 2004 (0.0267 mg/L); copper was detected above the domestic water supply standard of 1.0 mg/L in April 2004 (2.56 mg/L) and July 2004 (1.6 mg/L); and iron was detected above the domestic water supply standard of 1.0 mg/L in April 2004 (3.81 mg/L). Otherwise, no constituents have been detected above applicable NMWQCC groundwater quality standards during the past two quarterly monitoring events in Well 15.

For Well 38, copper was detected above the domestic water supply standard of 1.0 mg/L in September 2003 (3.39 mg/L) and manganese was detected above the domestic water supply standard of 0.2 mg/L in September 2003 (3.31 mg/L). Otherwise, no constituents have been detected above applicable NMWQCC groundwater quality standards during the past five quarterly monitoring events in Well 38.

The exceedances of NMWQCC standards in Wells 15, 38, and G appear to be anomalous spot exceedances and do not represent a general decrease in water quality in the individual wells associated with potential impacts from the tailing repositories. The historical data for these wells further support this case. For Well 15, cadmium was detected a total of five times, copper a total of three times, and iron a total of two times above their associated water quality standards since sampling began at this well in January 1978. This represents five exceedances out of 113 total samples analyzed for cadmium, three exceedances out of 116 total samples analyzed for copper, and two exceedances out of 84 total samples analyzed for iron. For Well 38, copper has been detected a total of two times above its water quality standard, and manganese has only been detected once above its standard since sampling began at this well in May 1990. This represents two exceedances out of 67 total samples analyzed for copper, and one exceedance out of 34 total samples analyzed for manganese.

The DP-27 water quality data also indicate that individual constituent concentrations are relatively stable in each of the wells. Time-series plots of pH, sulfate, and TDS concentrations in water samples collected from the DP-27 wells over the past 6 years (Appendix C) do not show any trends that may be indicative of impacts from the repositories, and the concentrations of the individual constituents have remained relatively constant through time.

Average pre-spill (i.e., before October 1980) concentrations of individual constituents were calculated for Wells 13, 14, 15, and G (Tables C-3a, C-3b, C-3c, and C-3i, respectively). These data indicate that the concentrations of individual constituents observed recently in these wells are consistent with those observed prior to the tailing spill, indicating that the October 1980 spill had no impact on groundwater quality in the area. Laboratory analytical reports for the individual monitoring wells are presented in quarterly and biannual DP-27 monitoring reports.

Analytical results for the March 1999 and February 2005 monitoring events associated with the current/former residential water supply wells (i.e., Wells MS-2, MS-3, MS-4, MS-5, MS-8, and MS-10) are presented in Table C-4. These data show that with the exception of manganese in well MS-5, no constituents were detected above applicable NMWQCC groundwater quality standards during the 1999 and 2005 sampling events. Manganese was detected at a concentration of 0.301 mg/L, slightly above its domestic water supply standard of 0.2 mg/L during the February 2005 sampling of Well MS-5. The exceedance of the manganese standard in Well MS-5 appears to be an anomalous one-time spot exceedance and does not represent a general decrease in water quality in the well associated with potential impacts from the repositories. The March 1999 and February 2005 analytical data for the former/current domestic wells do not show any trends that are indicative of impacts from the reclaim areas, and the concentrations of the individual constituents have remained relatively constant through time.

4.0 UPWARD MIGRATION OF ACIDITY

The translocation of chemical constituents from mine spoils and tailing to overlying cover soils has been identified as a potential concern in the reclamation of western mines (Sandoval and Gould, 1978; Merrill et al., 1983; Dollhopf et al., 1985; Carlstrom et al.; 1987; Dollhopf et al., 1992; Chammas et al., 1999; and Dollhopf, 2001). The overriding concern is that chemical changes in the soil cover will reduce its ability to support plant growth. Under extreme projections, upward migration of salts would eventually render the soil cover unsuitable for plant growth leading to a cycle of erosion and eventual failure of cover function. Although these concerns exist, evidence is generally lacking that this phenomenon occurs in properly constructed mine land reclamation applications. Section 4.1 is a review of physics and chemistry of solute movement and empirical studies. Section 4.2 presents the methods used in this investigation. Section 4.3 presents the results of the field and laboratory studies, and Section 4.4 discusses the result with respect to the dominant processes and implications to vegetation and cover function. Section 4.5 provides a summary of this work.

4.1 Background

The intent of this section is to provide background information on chemical redistribution and solute movement (Section 4.1.1), chemical considerations associated with soil acidification and aluminum toxicity (Section 4.1.2), and a review of existing literature on upward migration of sodium (Section 4.1.3) and acidity (Section 4.1.4) on reclaimed mine lands.

4.1.1 Chemical Redistribution and Solute Movement

Chemical redistribution in soils results from a combination of diffusive and convective processes (Kemper, 1986). Diffusion is restricted to the movement of dissolved constituents within the water lattice, whereas convection refers to the movement of dissolved constituents with soil water. The magnitude and direction of diffusion in soils is dependent on ion concentration gradients, soil matrix-ion interactions, ion-ion interactions, soil-water content, temperature, and tortuousity. Diffusion is generally considered to be a slow and inefficient transport mechanism compared to convective flow. Furthermore, diffusion is a self-limiting process and the rate of diffusion decreases as the concentration gradient decreases away from the primary source (Carlstrom, et al., 1987). Diffusion typically is considered at a small scale, and manifestations of diffusion are obliterated by the potentially overwhelming magnitude of convective flow. For example, the effects of many years of diffusional transport may be mitigated by an episodic leaching event.

Upward migration of soluble constituents by convective flow is known to occur in soils where a permanent or seasonal water table is near the soil surface. Soil salinization, which results from capillary rise of water and evapoconcentration of salts in the upper soil profile, has long been recognized as a problem in irrigated situations where drainage is inadequate (Israelsen and Hansen, 1950). Under shallow water table conditions, soluble constituents are transported with capillary water and can accumulate in the upper part of the soil. The transport of constituents by convection is typically not a concern when the water table is at depths greater than 1 to 2 m below ground surface. Under similar water table and climatic conditions, the height of capillary rise depends on soil texture, whereby fine-textured soils are more susceptible to convective salinization than coarse-textured soils. Upward convective transport of constituents is not considered to be an important mechanism in well-drained soils where the dominant vector of movement is downward and leaching is the predominant process (Buol et al., 1980).

4.1.2 Soil Acidity and Aluminum Toxicity

Hydrolytic reactions of aluminum and iron are the primary processes that lead to low pH and acidification of soils (Thomas and Hargrove, 1984; Evangelou, 1998). Oxidation of sulfide minerals (e.g., pyrite) in tailing, waste rock, and spoils results in the generation of acidity and the release of iron and sulfate. If not buffered by reactive neutralizing minerals, the acidic conditions associated with pyrite oxidation accelerate weathering of primary and secondary alumino-silicate minerals releasing aluminum and other weathering products. These weathering products may react with charged mineral surfaces, form new minerals and sesquioxides, or dissolve in the soil solution. Weathering products that are not partitioned in solid phases are available for transport. Following the oxidation of sulfide-bearing wastes, the major weathering products expected to be available for transport are iron, aluminum, and sulfate. Trace elements may also be transported but are not expected to change the fundamental chemistry of the soil cover (e.g., promote acidification). Thus, the fate (movement and reactions) of iron and aluminum are of primary concern with respect to understanding cover soil acidification. Because sulfate is relatively mobile and unaffected by secondary reactions, except those involving gypsum, it is important in detecting the movement of constituents.

Besides being a major contributor to acid formation in soils, aluminum is considered the primary toxic constituent in acid soils. Inorganic aluminum is toxic to plants, with the degree of toxicity is best correlated with the Al^{3+} ion, although toxic effects of mono- and polynuclear aluminum hydroxide complexes has been demonstrated (Adams and Lund, 1966; Pavan et al., 1982; and Parker et al., 1987). Aluminum restricts root growth in some plants at soil solution concentrations as low as 1 mg/L (Bohn et al., 1985). The mechanism of toxicity is not well understood, but steric or size considerations may account for the reduced toxicity of the mono- and polynuclear-aluminum hydroxide complexes (Parker et al., 1989). Similarly, complexation by sulfate, fluoride, and organic acid ligands reduces the phytotoxicity of aluminum (Hue et al., 1986 and Parker et al., 1989). In addition, solution calcium and sodium are attributed with decreasing aluminum toxicity through reductions in aluminum activity (ionic strength effect) and direct physiological effects (Adams and Hathcock, 1984; Alva et al., 1986; Kinraide and Parker, 1987; and Parker et al., 1987). Gypsum has been used as an acid soil amendment partially because of the reduced phytotoxicity of the aluminum sulfate complexes and because it may reduce induced calcium deficiencies (Oates and Caldwell, 1985 and Sumner et al., 1986). The use of gypsum as an amendment to ameliorate aluminum toxicity is significant because most sulfidic mine wastes generate gypsum.

4.1.3 Upward Migration of Sodium

The potential for upward migration of sodium has been studied to evaluate concerns associated with sodication of soil covers at coal mines. Merrill et al. (1983) studied sodium translocation from sodic spoils to non-sodic soils in sealed and unsealed laboratory columns. They concluded that diffusion was the primary mechanism for sodium redistribution from the spoils to the overlying nonsodic soils. Convective flow associated with evaporative processes and the redistribution of water under unsaturated flow was estimated to account for only about 12 to 16 percent of sodium movement on average. It should be noted that the columns were not leached; thus, the potential overriding effects of downward convective flow on sodium redistribution were not assessed.

In addition to the column studies, Merrill et al. (1983) cited results of field studies from four sites where non-sodic soils were placed over sodic spoils. They concluded that downward convection (leaching) eliminated any evidence of the upward (diffusional) migration of sodium at two of four field test sites. They speculated that mineral weathering and elevated salinity levels contributed to the mitigation of sodicity. At the two sites where sodication of the cover was observed, only the lower 10 to 15 cm of the soil layer was affected. Sodication at these sites occurred within a few years after cover placement, which is inconsistent with the rate of transport that would be predicted in association with diffusion. The potential for mixing of the cover and spoils was not discussed as an alternative mechanism for sodication of the cover soil, but the rapid changes suggest that it may have contributed to the process.

Merrill et al. (1983) speculated that sodication was a concern in situations where the hydraulic conductivity of the spoils is limiting and a significant sodium concentration gradient exists. More specifically, they characterized the problem spoils as those with high clay contents and/or severe compaction that occur in landscape positions that are susceptible to run-on and lateral, subsurface flow. They suggested that dispersion associated with sodicity could reduce the hydraulic conductivity of the spoils, but provided no evidence that the process had occurred. Finally, they hypothesized the degree and magnitude of sodication associated with diffusive upward migration was likely to be accentuated with soil covers that were more than 30-cm (12-inches) thick, because convective leaching was expected to be more prevalent in thinner cover systems.

Sodication of relatively thick cover soils (70 cm or 30 inches) overlying sodic spoils was studied at the Decker Mine in Montana (Dollhopf et al., 1985 and 1992). The study was originally designed to test the effects of various soil amendments (i.e., gypsum, calcium chloride, ammonium nitrate, and ammonium sulfate) and irrigation on soil and plant performance. The spoils were sodic and characteristic of the carbonate-dominated spoils at Decker (Dollhopf et al., 1992). The cover soils in the test plots were sampled in three equal depth increments (each 23-cm thick) and analyzed on an annual or semiannual basis over an 11-year period. Sodium migration was evaluated indirectly using sodium adsorption ratio (SAR) data that were grouped (averaged) for all the treatments.

The test plot results revealed that sodicity in the cover soil profile decreased in the upper third (0 to 23 cm), remained nearly constant in the middle interval (23 to 46 cm), and increased in the lower soil layer (46 to 90 cm). On the basis of these data, Dollhopf et al. (1985 and 1992) concluded that sodication of the cover soil resulted primarily from sodium diffusion from the spoil to the soil. In the 1985 report, using a linear regression model, they predicted that the topsoil could become sodic in 18 to 36 years (Dollhopf et al., 1985). Later, using a more appropriate negative exponential growth model, they indicated that only the lower part of the cover soil profile would be affected, with a maximum SAR near 7 (Dollhopf et al., 1992).

The potential for leaching of sodium in the upper soil layers was recognized in the 1992 report, but was not accounted for in the empirical predictive model (Dollhopf et al., 1992). The decrease in SAR in the upper soil layer, coupled with zero net change in SAR in the middle layer and an increase in SAR in the lower layer, is consistent with the expected sodium distribution that would occur under a leaching regime dominated by the downward translocation of sodium. Thus, the time-transgressive SAR distribution in the cover soil profiles may be interpreted as resulting from the translocation of sodium from the upper soil layers to the lower soil layers. This interpretation does not preclude diffusion as an active process that contributed to sodication of the topsoil; however, it does not change the interpretive significance of the process and the likely trend in sodium distribution that would be expected with time.

Sampling and analysis of the soils and spoils on the non-irrigated test plots at Decker in 1999 revealed little evidence of upward migration of salinity from the spoils into the topsoil layer (Munk et al., 2000). These data were interpreted to indicate that convective leaching and weathering eliminated concerns associated with any possible sodication and salinization that might occur through upward diffusion.

4.1.4 Upward Migration of Acidity

Upward migration of acidity from tailings to cover soils has been studied at sites in the western United States. A short-term study by Chammas et al. (1999) suggested that upward migration was occurring from acidic and neutral (non-acid) copper tailing to the overlying Gila Conglomerate cover soils. The test plot soil covers were sampled approximately 1 year after construction. Their primary evidence for upward migration was increased diethylenetriaminepentaacetic acid (DPTA) extractable iron levels in the lower 2 inches of the soil covers. The changes in DTPA-iron occurred at the base of the soil profiles regardless of the occurrence of lime- or capillary-barrier treatments below the covers. The DPTA-iron results are incongruous as indicators of upward migration as there was no accompanying change in electrical conductivity. Conceptually, any iron transported in solution would have been accompanied by a charge-balancing anion (typically sulfate), which should have resulted in an increase in electrical conductivity of the soil solution. Unfortunately, they did not report soluble salt results for the basal cover soil.

We believe that the increased DTPA-iron observed at the base of the cover may have been associated with fertilizer and irrigation treatments rather than diffusion. Chammas et al. (1999) indicated that all plots were treated with acid-forming fertilizers, a humic acid soil conditioner, and were irrigated. These actions could have resulted in the release and chelation of iron originating from the Gila Conglomerate and downward translocation of organo-iron complexes to the lower profile, rather than upward migration.

Dollhopf (2001) evaluated the long-term changes of a cover soil overlying a lime reject layer and acid tailing. He studied a 10 hectare area near Anaconda Montana that was covered with an 8-cm lime layer and 41-cm cover soil in 1974. The tailing was acidic, with a pH ranging from 2.0 to 2.3. The lime reject was and alkaline waste product that originally contained elevated levels of arsenic, iron, copper, and zinc. After 26 years, chemical changes in the lime layer were restricted to a 0.7-cm zone at the tailing contact. He concluded that acid from the tailing has the potential to migrate upward into earthen covers, but this phenomenon was confined to a thin layer at the base of the cover.

Although not discussed, the data from the Anaconda tailing indicated no enrichment of the basal cover by arsenic, iron, copper, or zinc, even though these constituents were elevated in the reject lime material (Dollhopf, 2001). The lack of evidence for arsenic enrichment in the basal cover layer is particularly significant as the mobility of arsenic should not be inhibited by alkaline conditions to the extent as cationic metals, like copper, iron, or zinc. These data suggest that diffusion is not operating as an important transport mechanism that could affect the cover soils.

4.2 Methods

This section outlines the field (Section 4.2.1) and laboratory (Section 4.2.2) methods used in this investigation.

4.2.1 Field Methods

Five sampling sites were selected on the South Main Repository in the Mangas Valley (Figure 10). The sampling was conducted on May 30, 2001 in collaboration with the MMD. Because positive drainage is required as part of the mine closure process, we chose areas with linear and convex slope configurations to emulate the conditions that would exist on the majority of the future reclamation. The sampling sites were nearly level to gently sloping with gradients that varied from approximately 1 to 2 percent. The vegetation cover, dominated by warm season grasses, reflected heavy grazing and varied from approximately 5 to 25 percent canopy cover.

Four samples of cover soil were collected from each profile using the method described below. Three discrete 2-inch interval samples were collected starting approximately 1 inch above the contact with tailing. The 1-inch zone immediately above the soil-tailing contact was not sampled to avoid mixing of tailing and soil. A single sample was collected from the remainder of the soil profile above the highest 2-inch interval sample. Two samples of tailing were collected from each excavation. One sample represented the 3-inch interval immediately below the contact and other tailing sample represented the next 5- to 6-inch interval. Figure 11 is a photograph of one of the sampling pits.

4.2.2 Lab Methods

The cover soil and tailing samples were analyzed by Energy Laboratories in Billings, Montana. All of the samples were analyzed for particle size distribution; $CaCO_3$ equivalent; saturated paste pH; paste extract EC; and paste extract aluminum, iron, and sulfate. In addition to these analyses, acid-base accounting and sulfur forms were determined on the tailing samples (Sobeck et al., 1978).

4.3 Physiochemical Characteristics of the Cover Soil and Tailing

The source area for the cover soils that were used on the South Main Repository is not precisely known. However, the most likely source areas are the highly dissected fan remnants underlain by Gila Conglomerate Formation west of the repository and younger alluvial deposits north of the South Main Repository. The covers varied in thickness from 16 to 24 inches (Note: the depths on Tables 6 and 7 do not include the 1-inch interval above the tailing contact). The No. 3 Tailing Impoundment was the source for the tailing. The character of the tailing prior to transport is not known, but probably varied in the degree of oxidation and chemical nature at the time of deposition on the repository.

4.3.1 Cover Soils

The physical characteristics of the soils are listed in Table 6. The cover soils varied in texture from loamy sand to silty clay loam, ranging from 6 to 30 percent clay. The rock fragment contents ranged from 2 to almost 30 percent by mass. The cover soils were placed in lifts using scrapers and the materials are assumed to have varied. However, the intra-profile variation in chemical properties of the cover soils is not precisely known because sampling was not conducted at the time of placement. Thus, the original character of the materials is inferred from the data represented by the upper sampling intervals of the test pits recognizing that the basal contact zone may have been affected by diffusion, convection, or construction related mixing (Section 4.4).

Excluding the lower interval samples, the paste pH ranged from 6.0 to 7.7; extract EC ranged from 0.45 to 3.20 deciSiemens per meter (dS/m); paste extract aluminum and iron were not detected at levels above 0.5 mg/L; paste extract sulfate ranged from 40 to 2,290 mg/L; and lime range from 0.9 to 3.7 percent. The paste pH, extract EC, and $CaCO_3$ data are consistent with data for the Gila Conglomerate and associated soils that occur at Tyrone. Based on the analyses of 78 soils samples from undisturbed areas at Tyrone, the pH ranges from 5.0 to 7.9; EC ranges from 0.18 to 3.74 dS/m; and the lime content ranged from 0.4 to 6.0 percent (Appendix C; Table C-3 of DBS&A, 1999). No comparative data are available from the 1999 dataset for extractable aluminum, iron, and sulfate.

4.3.2 Tailing Characteristics

The particle size distribution data for the tailing samples are listed in Table 6. The tailing samples were classified as loams with 15 to 22 percent clay. These textures are approximately equivalent to the textures of the slimes or intermediate tailing that occur at Tyrone. The chemistry of the tailing indicates various degrees of oxidation and weathering have prevailed subsequent to deposition and covering (Table 7). Paste pH ranges from 2.5 to 7.3; extract EC varies from 2.94 to 14.2 dS/m; paste extract aluminum ranged from less than 0.5 mg/L in the circumneutral tailing to 1,850 mg/L in the lowest pH materials; similarly paste extract iron ranged from non-detect to 965 mg/L; extract sulfate ranged 1,890 to 32,000 mg/L; and measurable CaCO3 equivalent was detected in a few samples.

4.3.3 Property Depth Curves

Property depth curves are used to display the distribution of chemical constituents in the cover soils and tailing (Appendix D). Table 7 lists the pH; EC; paste extract iron, aluminum, and sulfate; and $CaCO_3$ equivalent data for the cover and tailing profiles. Paste pH in the basal contact zone of the cover decreased by less than 1 to slightly more than 3 units when compared to the overlying soil layer; otherwise no definitive changes in pH were noted in the cover soils (Figure D-1). Sulfate is the predominant anion in solution in these soils, the sulfate and EC profiles show similar patterns (Figures D-2 and D-3). For each of the five profiles, sulfate concentrations generally increased regularly with depth to the tailing contact. Extractable iron occurred below the detection limits in all cases and extractable aluminum was measured in the basal contact zone in only two profiles (Figures D-4 and D-5). $CaCO_3$ equivalent generally, but not always, decreased with depth (Figure D-6).

4.4 Discussion

The lower 3 inches of the cover soils (basal contact zone) exhibit clear decreases in soil pH and increases in salinity and sulfate concentrations. However, it is difficult to conclude that there were changes in the chemistry of the soil cover above the basal contact zone. Section 4.4.1 discusses potential mechanisms for acidification and provides an interpretation of the chemical processes operating in the basal contact zone. Section 4.4.2 provides an overview of the implications of the chemical changes in the cover with respect to vegetation performance and cover function.

4.4.1 Acidification of the Basal Contact Zone

The basal contact zone represents the interface between the cover and tailing. The reduction in pH in the basal contact zone indicates that some process has caused acidification in the lower part of the cover. Oxidation of tailing physically mixed into the lower part of the cover during construction and diffusion are the two primary mechanisms identified that could contribute to acidification of the basal contact zone. Physical mixing is identified as a potential mechanism based on field observations of tonguing and incorporation of tailing in the cover soils (Figure 12). Although none of the profiles sampled showed gross manifestations of mixing, and a 1-inch zone immediately above the tailing contact was excluded, it is impossible to conclude that mixing did not occur at the interface. The chemical data collected from these profiles does not provide conclusive evidence that upward migration is the causative factor for acidification in the basal contact zone. Incorporation of tailing probably explains at least part of the observed decrease in pH. The chemical data are discussed below with respect to the potential for upward migration.

Sulfate is more conservative with respect to mobility than iron or aluminum, which are strongly affected by adsorption reactions and secondary mineral formation. Sulfate solubility is likely to be controlled primarily by gypsum were free calcium occurs in solution. The regular increase in sulfate concentrations with depth in the cover soils suggests downward translocation (leaching) of sulfate from the surface layers. Diffusion from the underlying tailing, or sulfate generated through oxidation of tailing mixed in the basal cover during construction are other possible causes. It is not possible to distinguish the relative contributions of these processes with respect the sulfate distribution, but it is unlikely that the sulfate in the basal contact zone originated solely from the underlying tailing. Thus, the sulfate distribution is inconclusive with respect to demonstrating upward migration as an active process in these cover-waste systems.

The extractable iron and aluminum data are incongruous with respect to demonstrating upward migration from the tailing. The extractable iron and aluminum concentrations in the tailing are indicative of systems controlled by sulfate salts. In contrast, extractable iron was not detected in any of the cover soils, and extractable aluminum was measured in the basal contact zone in only two profiles, indicating that iron and aluminum in the basal contact zone were generally not associated with more soluble sulfate salts. The strong tendency of iron to hydrolyze and form oxyhydroxides of low solubility at pH <3 may account for the apparent lack of enrichment of iron above the tailing contact. Similarly, aluminum tends to form relatively insoluble oxyhydroxides at pH greater than about 4. The presence of sulfate and other complexing ligands are expected to increase the solubility of iron and aluminum relative to the concentrations that would be predicted solely on the basis of pH.

The extractable aluminum concentration in the basal contact zone of TRT-4 is indicative of control by an aluminum sulfate salt, suggesting upward migration of aluminum and sulfate. However, the lack of measurable iron in this sample suggests that iron was not co-transported, arguing that the underlying tailing was not the source for the aluminum and sulfate in the basal contact zone. Assuming that iron and aluminum did migrate from the underlying tailing, we hypothesize that they must first undergo hydrolysis (lowering the pH of the cover soil) and then be partitioned into insoluble solid phases and/or adsorbed on the exchange complex. A similar chemical signature would be expected in association with weathering of tailing incorporated in the basal contact zone of the cover. Thus, differentiating the causative mechanism is problematic on the basis of these data.

Regardless of the mechanism (mixing or diffusion), partitioning of iron and aluminum into insoluble forms reduces the potential for aluminum toxicity and limits the concentration gradient relative to the overlying layers, thereby restricting the driving force behind diffusion and for future upward migration. Over the long-term, convective leaching in the upper part of the cover will redistribute salts into the accumulation zone near the basal contact at 18 to 24 inches below the soil surface. The 18 to 24 inch zone corresponds to the typical depth of calcium carbonate accumulation in the native soils surrounding Tyrone and is interpreted to represent the average long-term depth of leaching. Infrequent, episodic leaching events are expected to move salts below this depth in association with above normal winter precipitation.

4.4.2 Implications for Revegetation and Cover Function

Cover function at Tyrone is dependant on having adequate vegetation cover to provide erosion control and transpiration demand. Vegetation canopy cover on the repositories ranges from 15 to 30 percent (Section 2.0), which is adequate to control erosion. Mean maximum leaf area index (LAI) measured on the repositories was 0.29, which provided adequate transpiration demand based on unsaturated flow water balance modeling (Golder, 2005). Thus, repository soils similar to those evaluated here support sufficient levels of vegetation to maintain cover functions. The intent of this section is to evaluate the chemical characteristics of the cover 20 years after placement. The primary concerns are related to soil acidity, salinity, and toxic ions with emphasis on aluminum.

Modest changes in the chemistry in the lower part of the cover soils occurred over the 20-year period since construction. The chemical conditions in the basal contact zone are generally deemed non-limiting for plant growth, especially considering that they occur below the primary depth of rooting for vegetation in this region (Peace et al., 2004; Golder, 2005). Specifically, 66 percent of the roots occur in the upper 20 cm (8 inches) and almost 90 percent occur in the upper 50 cm (20 inches) of the soils based on measurements made in both native and reclaimed areas at Tyrone (Golder, 2005).

With the exception of one profile (TRT-4), the pH and salinity in the basal contact zone are suitable for plant growth. For comparison, plant toxicity directly associated with H^+ ions is not likely to occur above pH 3.0 (Bohn et al., 1985). Salinity levels in the basal contact zone are typically in the 2 to 4 dS/m range, which even sensitive plants can tolerate. The highest salinity level (8.5 dS/m) is within the MMD soil suitability guidelines. Furthermore, higher salinity levels are typically tolerated when they occur deep in the soil profile as opposed to at the soil surface (Rhoades et al., 1992).

Extractable aluminum, which is typically the primary constituent of concern in acid soils, generally occurred at low levels. The elevated levels of soluble aluminum measured in the basal contact zone of profile TRT-4 are of limited concern considering the high ionic strength of the solutions and the occurrence of sulfate and other complexing ligands (Section 4.1.2). Like pH and salinity, the high aluminum concentrations occurred below the primary rooting zone for this region and are not expected to impact plant growth.

4.5 Summary

The results of this investigation are consistent with studies conducted at other mine sites involving upward migration of sodium and acidity (Section 4.1). In particular, preliminary concerns of deleterious affects on cover performance based on short term measurements prove to be inconsequential over the long-term. Evidence for time-transgressive upward redistribution of constituents of sufficient magnitude to disrupt biological processes has not been demonstrated and the changes in the chemistry of the cover soil are restricted to the relatively thin zone at the interface between the cover and underlying waste material.

At Tyrone, modest changes in the soil cover have occurred over the 20 years since covering of the repositories. The apparent chemical changes are limited to the reductions of pH and slight increases in salinity in the basal contact zone and downward translocation of salts in the upper part of the cover. The mechanisms leading to acidification of the basal contact zone is difficult to determine with certainty, but probably include physical mixing of tailing during construction and/or a component of upward migration. Regardless of the mechanism, the degree and magnitude of change in chemistry in the cover soils are considered practically insignificant with respect to plant growth and cover function.

The vegetation (Section 2.0) and water quality (Section 3.0) assessments presented herein provide additional evidence of the resilience and functional capacity of earthen covers for achieving the reclamation performance goals at Tyrone.

5.0 RECOMMENDATIONS

Condition 84 requires recommendations for future work. Because cover augmentation and reseeding work conducted in the summer 2004 resulted in nearly complete reconfiguration of the repositories, this section will not deal with corrective actions on the repositories. Instead, the recommendations made herein will focus on cover and vegetation related issues and water quality aspects based on the results of past monitoring efforts discussed in this document.

Vegetation

With the exception of the Exclusion Area, all existing vegetation on the original repositories was destroyed and the areas were reseeded during 2004. The newly reseeded areas should be inspected to determine if vegetation establishment is progressing adequately. Otherwise, no additional vegetation investigations are proposed in the Exclusion Area at this time. However, we recommend that the Exclusion Area be maintained to track the long-term response of this area and its response to reduced grazing pressure.

Cover Soils

Based on the results of the investigation presented herein and studies from other areas, no additional investigations of upward migration are warranted for the cover soils in this region. We recommend that Tyrone reevaluate the need for Conditional requirements in the NMED and MMD permits concerning upward migration on the tailing and stockpile test plots.

Water Quality Monitoring

The groundwater monitoring results associated with the recent sampling of the wells located within the Mangas Valley do not show any indications of impacts from the October 1980 tailing spill and associated reclaimed areas. The DP-27 water quality data also indicate that individual constituent concentrations are relatively consistent in each of the wells. Time-series plots of pH, sulfate, and TDS concentrations in water samples collected from the DP-27 wells over the past 6 years do not show any trends that may be indicative of impacts from the reclaim areas, and the concentrations of the individual constituents have remained relatively constant through time. Additionally, average pre-spill (i.e., before October 1980) concentrations of individual constituents were calculated for Wells 13, 14, 15, and G indicate that the concentrations of individual constituents observed recently in these wells are consistent with those observed prior to the tailing spill, indicating that the October 1980 spill had no observable impact on groundwater quality in the area.

Analytical results for the March 1999 and February 2005 monitoring events associated with the current/former residential water supply wells show that with the exception of one analyte, in one well, for one sampling event, no constituents were detected above applicable NMWQCC groundwater quality standards during the 1999 and 2005 sampling events. As with the DP-27 wells, the analytical data for the former/current residential wells do not show any trends that may be indicative of impacts from the reclaim areas, and the concentrations of the individual constituents have remained relatively constant through time.

As part of the Stage 1 Abatement Plan (DP-1341 Condition 34) for the Tyrone Mine (DBS&A, 2004), four additional regional aquifer monitoring wells are scheduled to be installed in the general vicinity of the No. 3 Tailing Impoundment area (Figure 7). The analytical data from the DP-27 wells and former/current residential water supply wells do not suggest a need for additional wells within the No. 3 Tailing Impoundment area or downstream.

Analytical results from surface water samples collected downgradient of two of the tailing repositories do not show any indications of impacts from surface drainage off the areas. We do not recommend additional surface water quality monitoring beyond that already required under Condition 48 of DP-1341.

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TABLES

TABLE 1
OBSERVED PLANT SPECIES ON MANGAS VALLEY TAILING REPOSITORIES, MARCH AND APRIL 2004

Guild	Common Name	Scientific Name
Grasses	Western wheatgrass	*Agropyron smithii*
	Poverty threeawn	*Aristida divaricata*
	Purple threeawn	*Aristida purpurea*
	Cane bluestem	*Bothriochloa barbinodis*
	Side-oats grama	*Bouteloua curtipendula*
	Black grama	*Bouteloua eriopida*
	Blue grama	*Bouteloua gracilis*
	Hairy grama	*Bouteloua hirsuta*
	Weeping lovegrass	*Eragrostis curvula*
	Fluffgrass	*Erioneuron pulchellum*
	Mat muhly	*Muhlenbergia richardsonis*
	Vine mesquite	*Panicum obtusum*
	Bottlebrush squirreltail	*Sitanion hystrix*
	Alkali sacaton	*Sporobolus airiodes*
	Mesa dropseed	*Sporobolus flexuosus*
	Sixweeks fescue	*Vulpia octoflora*
Forbs	Locoweed	*Astragulas spp.*
	Waterleaf	*Borage spp.*
	False yarrow	*Chaenactis stevioides*
	Trailing fleabane	*Erigeron flagellaris*
	Hog potato	*Hoffmanseggia glauca*
	Summer cypress	*Kochia scoparia*
	Lupine	*Lupine spp.*
	Purple aster	*Mechaeranthera canescens*
	Penstemon	*Penstemon spp.*
	Russian thistle	*Salsola iberica*
	Globemallow	*Sphaeralcea spp.*
Shrubs	Sagewort	*Artemisia carruthii*
	Indigobush	*Dalea formosa*
	Apache plume	*Fallugia paradoxa*
	Broom snakeweed	*Gutierrezia sarothrae*
	Catclaw mimosa	*Mimosa biuncifera*
	Beargrass	*Nolina microcarpa*
	Cholla	*Opuntia imbricata*
	Prickly pear	*Opuntia engelmanii*
	Honey mesquite	*Prosopis glandulosa*
	Threadleaf groundsel	*Senecio douglasii*
	Gray horsebrush	*Tetradymia canescens.*
	Soap tree yucca	*Yucca elata*
Trees	One-seed juniper	*Juniperus monosperma*
	Piñon pine	*Pinus edulis*
	Emory oak	*Quercus emoryi*

TABLE 2
SUMMARY OF TOTAL CANOPY COVER FOR THE EXCLUSION AND REFERENCE AREAS

Plot	Exclusion Area					Reference Area			
	Quadrat					Quadrat			
	A	B	C	D		A	B	C	D
1	22	33	35	33		5.9	21.8	6.6	36.1
2	62	18	12.5	19		34.6	10.6	24	31
3	30	22	20	38		33	55	100	31
4	13.5	10	28	40		85	21	46	83
5	26	47	88	78		22	82	37	27
6	46	17	18	93		35	46	42	46
7	61	58	28	ns		52	37	42	22
8	21.2	13.5	20.9	18.1		50	30	49	55
Mean	**34.5**					**40.6**			
Std. dev.	**22.3**					**22.3**			
90% C.I.	**27.7 – 41.3**					**33.9 – 47.3**			

Notes:
ns - not sampled
90% C.I. – 90% confidence interval of the sample mean.

TABLE 3:
CANOPY COVER AND PLANT DENSITY FOR THE EXCLUSION AND REFERENCE AREAS

Plant Code	Scientific Name	Common Name	Exclusion Area		Reference Area	
			Canopy Cover	Density	Canopy Cover	Density
			%	#/m^2	%	#/m^2
FORBS						
ASNU	*Astragalus nuttallianus*	Nuttall loco	1.1	1.6	-	-
BADI	*Bahia dissecta*	Bahia	-	-	0.3	0.1
CHER	*Chaetopappa ericoides*	Rose heath	-	-	T	0.1
CHPR	*Chamaesyes prostrata*	Spurge	T	0.03	0.5	2.3
CHST	*Chaenactis stevioides*	False yarrow	0.9	0.3	-	-
CIUN	*Cirsium undulatum*	Wavyleaf thistle	-	-	0.1	0.2
CRCR	*Cryptantha crassisepala*	Thicksepal cryptantha	-	-	T	0.5
DALE	*Dalea leporina*	Foxtail prarie clover	1.4	1.2	-	-
DECO	*Desmanthus cooleyi*	Cooley's bundleflower	0.5	1.5	T	0.2
ERFL	*Erigeron flagellaris*	Trailing fleabane	0.1	0.1	0.9	3.0
FAB	*FABACEAE*	unidentified legume	T	0.1	0.6	1.1
EVSE	*Evolvulus sericeus*	Silver dwarf morning-glory	-	-	0.1	0.7
GAPI	*Gallardia pinnatifida*	Red dome blanketflower	0.1	0.2	-	-
HAGR	*Haplopappus gracilis*	Slender goldenweed	0.5	1.5	0.2	0.1
HOGL	*Hoffmannseggia glauca*	Hog potato	T	0.1	-	-
IPCO	*Ipomoea costellata*	Cretrib morning glory	-	-	T	0.1
LEMO	*Lepidium montanum*	Peppergrass	-	-	T	<0.1
MECA	*Machaeranthera canescens*	Purple aster	-	-	T	<0.1
MOPE	*Monarda pectinata*	Pagoda plant	-	-	0.2	2.2
PEBA	*Penstemon barbatus*	Beardlip penstemon	-	-	0.1	0.2
POOL	*Potulaca oleracea*	Purslane	-	-	0.4	4.8
RHSE	*Rhynochosia senna*	Rosary bean	0.4	0.4	-	-
SAIB	*Salsola iberica*	Russian thistle	0.1	0.2	-	-
SASU	*Salvia subincisa*	Indigo sage	-	-	0.1	0.7
SINE	*Sida neomexicana*	New Mexico sida	-	-	T	0.1
SOEL	*Solanum elaeagnifolium*	Silverleaf nightshade	-	-	0.3	0.3
SPFE	*Sphearalcea fendleri*	Scarlet globemallow	T	<0.1	0.2	0.7
STPA	*Stephanpmeria pauciflora*	Skeletonweed	-	-	0.1	0.3
TAAU	*Talinum aurantiacum*	Orange flame-flower	-	-	T	0.1
THME	*Thelesperma megapotamicum*	Greenthread	T	<0.1	-	-
ZIGR	*Zinnia grandiflora*	Rocky Mountain zinnia	-	-	0.6	0.6
		Total (Relative) Forb Cover	**6.2 (18.1)**		**4.7 (11.6)**	

TABLE 3 (CON'T)

Plant Code	Scientific Name	Common Name	Exclusion Area		Reference Area	
			Canopy Cover	Density	Canopy Cover	Density
			%	#/m^2	%	#/m^2
GRASSES						
ARAD	*Aristida adscensionis*	Six-weeks threeawn	T	1.1	0.1	0.2
ARDI	*Aristida divaricata*	Poverty threeawn	0.5	0.5	0.4	0.2
ARHA	*Aristida havardii*	Harvard's threeawn	1.7	1.2	T	<0.1
ARPU	*Aristida purpurea*	Purple threeawn	3.0	4.6	-	-
ARSC	*Aristida schiedeana*	Single-awn threeawn	0.2	0.2	0.7	0.3
BOBA	*Bothriochloa barbinodis*	Cane bluestem	0.1	0.3	0.1	0.1
BOCU	*Bouteloua curtipendula*	Sideoats grama	7.2	20.0	6.4	5.4
BOER	*Bouteloua eripoda*	Black grama	-	-	1.3	1.3
BOGR2	*Bouteloua gracilis*	Blue grama	4.8	6.0	8.1	8.0
BOHI	*Bouteloua hirusta*	Hairy grama	9.3	8.7	0.2	0.3
CAREX	*Carex spp.*	unidentified sedge	T	0.1	-	-
ERCU	*Eragrostis curvula*	Weeping lovegrass	0.4	0.5	-	-
ERLE	*Eragrostis lehmannii*	Lehmann's lovegrass	0.3	0.1	-	-
HIBE	*Hilaria belangeri*	Curly-mesquite	-	-	2.2	5.7
HIMU	*Hilaria mutica*	Tabosa	-	-	0.9	0.3
LEDU	*Leptochloa dubia*	Green sprangletop	-	-	0.1	<0.1
LYPH	*Lycurus phleoides*	Wolftail	-	-	T	<0.1
MURI	*Muhlenbergia richardsonii*	Mat muhly	T	0.4	-	-
MUTO	*Muhlenbergia torreyi*	Ring muhly	0.1	0.3	-	-
PAHA	*Panicum halli*	Hall's panicgrass	-	-	0.1	<0.1
PAOB	*Panicum obtusum*	Vine mesquite	-	-	0.3	<0.1
PAVI	*Panicum virgatum*	Switchgrass	-	-	T	0.1
POA	*Poa spp.*	unidentified bluegrass	-	-	0.1	<0.1
SELE	*Setaria leucophila*	Plains bristlegrass	-	-	T	<0.1
SIHY	*Sitanion hystrix*	Bottlebrush squirreltail	-	-	0.3	<0.1
SPAI	*Sporobolus airoides*	Alkali sacaton	0.3	0.6	-	-
SPCR	*Sporobolus cryptandrus*	Spike dropseed	0.3	0.2	-	-
		Total (Relative) Grass Cover	**28.2 (81.9)**		**21.3 (52.5)**	
SHRUBS						
ACAN	*Acacia angustissima*	Prairie acacia	-	-	2.1	1.6
BRCA	*Brickellia californica*	California brickelbush	-	-	0.1	<0.1
GUSA	*Gutierrezia sarothrae*	Broom snakeweed	-	-	7.0	0.9
JUDE	*Juniperus deppeana*	Alligator juniper	-	-	T	<0.1
MIBI	*Mimosa biuncifera*	Mimosa	0.5	0.2	-	-
NOMI	*Nolina microcarpa*	Beargrass	-	-	4.1	0.1
OPIM	*Opuntia imbricate*	Cholla	-	-	T	<0.1
OPPH	*Opuntia phaecantha*	Tulip pricklypear	-	-	T	0.1
PRGL	*Prosopis glandulosa*	Honey mesquite	0.7	<0.1	4.8	0.3
QUGR	*Quercus emoryi*	Emory oak	-	-	T	<0.1
		Total (Relative) Shrub Cover	**1.2 (3.6)**		**18.2 (44.8)**	

Notes:
lbs/m^2 = pounds per square meter
T – trace cover (<0.1%)

TABLE 4
SHRUB DENSITY DATA ON THE EXCLUSION AND REFERENCE AREAS

Plot	Exclusion Area		Reference Area	
	shrubs per m^2	Shrubs per acre	Shrubs per m^2	Shrubs per acre
1	0.01	24.0	0.18	739.1
2	0.07	295.3	0.07	270.6
3	0.01	45.6	0.21	848.1
4	0.01	38.5	1.09	4401.6
5	0.02	62.8	0.35	1418.4
6	0.02	94.6	0.02	68.3
7	<0.01	10.7	1.59	6423.1
8	0.02	72.7	0.14	574.4
Mean	**0.02**	**81**	**0.46**	**1843**
Std. dev.	**0.02**	**91**	**0.57**	**2001**

Notes:
m^2 = square meters

TABLE 5
DIVERSITY GUIDELINES FOR THE TYRONE MINE

Class	Seasonality	Number	Minimum Occurrence (% cover)
Perennial Grass	Warm	3	1
Perennial Grass	Cool	1	0.5
Shrub	NA	2	1
Forb	NA	2	0.1

Source: DBS&A (1997)

TABLE 6
PHYSICAL PROPERTIES OF THE REPSOITORY SOILS AND TAILING

Site	Depth	Material	Sand	Silt	Clay	USDA Texture	Coarse Fragments
			%	%	%	Class	% wt
TRT-1	0-17	soil	75	15	10	SL	12
	17-19	soil	86	8	3	LS	20
	19-21	soil	82	11	7	LS	23
	21-23	soil	82	11	7	LS	25
	24-27	tailing	46	35	19	L	4
	27-33	tailing	42	43	15	L	2
TRT-2	0-9	soil	68	14	18	SL	11
	9-11	soil	72	12	16	SL	5
	11-13	soil	74	12	14	SL	9
	13-15	soil	52	32	16	L	12
	16-19	tailing	41	41	18	L	4
	19-22	tailing	38	45	17	L	3
TRT-3	0-17	soil	75	10	15	SL	25
	17-19	soil	73	8	19	SL	28
	19-21	soil	76	6	18	SL	27
	21-23	soil	78	8	14	SL	24
	24-27	tailing	41	40	19	L	2
	27-33	tailing	58	28	14	SL	<2
TRT-4	0-17	soil	32	44	24	L	6
	17-19	soil	75	13	12	SL	20
	19-21	soil	76	10	14	SL	23
	21-23	soil	72	13	15	SL	24
	24-27	tailing	30	47	23	L	6
	27-33	tailing	32	47	21	L	5
TRT-5	0-14	soil	22	50	28	Cl	8
	14-16	soil	20	52	28	SiCL	4
	16-18	soil	18	52	30	SiCL	3
	18-20	soil	22	50	28	Cl	2
	21-24	tailing	42	36	22	L	7
	24-30	tailing	43	36	21	L	7

Notes: S = sand(y); Si = silt(y); C = clay; L = loam(y)

TABLE 7
CHEMICAL PROPERTIES OF THE REPOSITORY SOILS AND TAILING

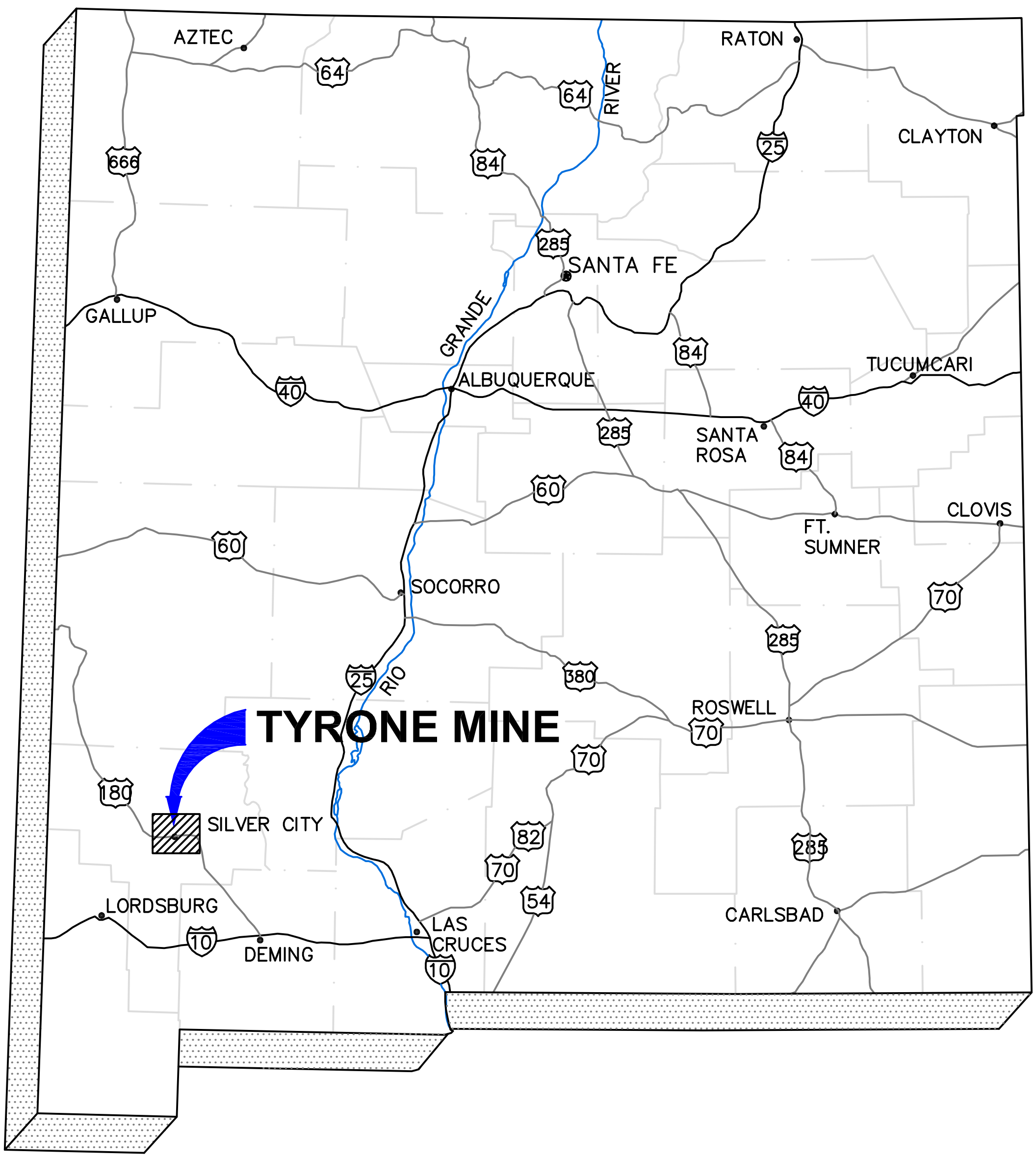
Site	Sample Depth (in)	Sample Material	Saturate Paste Extract					Lime as $CaCO_3$
			pH	EC	Aluminum	Iron	Sulfate	
			(s.u.)	(dS/m)	(mg/l)			(%)
TRT-1	0-17	soil	6.0	3.20	<0.5	<0.5	2290	0.9
	17-19	soil	7.1	3.27	<0.5	<0.5	2330	0.9
	19-21	soil	7.1	3.87	<0.5	<0.5	2830	1.1
	21-23	soil	4.8	3.73	1.5	<0.5	2770	1.2
	24-27	tailing	3.5	4.03	15.5	3.1	3880	0.4
	27-33	tailing	6.6	3.20	<0.5	<0.5	2100	0.4
TRT-2	0-9	soil	7.4	1.07	<0.5	<0.5	336	1.4
	9-11	soil	7.5	1.07	<0.5	<0.5	375	1.2
	11-13	soil	7.5	1.13	<0.5	<0.5	425	1.1
	13-15	soil	6.4	3.36	<0.5	<0.5	2150	0.9
	16-19	tailing	3.6	3.63	36.3	18.1	3380	0.2
	19-22	tailing	7.3	2.94	<0.5	<0.5	1890	0.7
TRT-3	0-17	soil	7.4	0.45	<0.5	<0.5	40	3.7
	17-19	soil	7.5	0.83	<0.5	<0.5	196	1.6
	19-21	soil	7.5	1.13	<0.5	<0.5	418	1.6
	21-23	soil	5.2	2.72	<0.5	<0.5	1790	0.9
	24-27	tailing	2.6	4.45	102	127	2680	<0.1
	27-33	tailing	2.5	6.21	208	463	4750	<0.1
TRT-4	0-17	soil	7.7	0.65	<0.5	<0.5	131	2.5
	17-19	soil	7.4	2.59	<0.5	<0.5	1530	1.2
	19-21	soil	7.0	3.79	<0.5	<0.5	2660	1.1
	21-23	soil	3.8	8.50	342	<0.5	11500	0.6
	24-27	tailing	2.5	13.6	1850	691	29600	<0.1
	27-33	tailing	2.6	14.2	1910	965	32000	<0.1
TRT-5	0-14	soil	7.6	0.57	<0.5	<0.5	72	3.7
	14-16	soil	7.6	1.13	<0.5	<0.5	408	3.0
	16-18	soil	7.6	1.95	<0.5	<0.5	1010	2.7
	18-20	soil	6.7	4.24	<0.5	<0.5	2760	2.5
	21-24	tailing	2.9	7.28	642	22.2	12000	<0.1
	24-30	tailing	3.1	5.41	271	91.5	7010	<0.1

Notes: EC = electrical conductivity

FIGURES

STATE OF NEW MEXICO

NOT TO SCALE



PROJECT

phelps dodge TYRONE Inc.

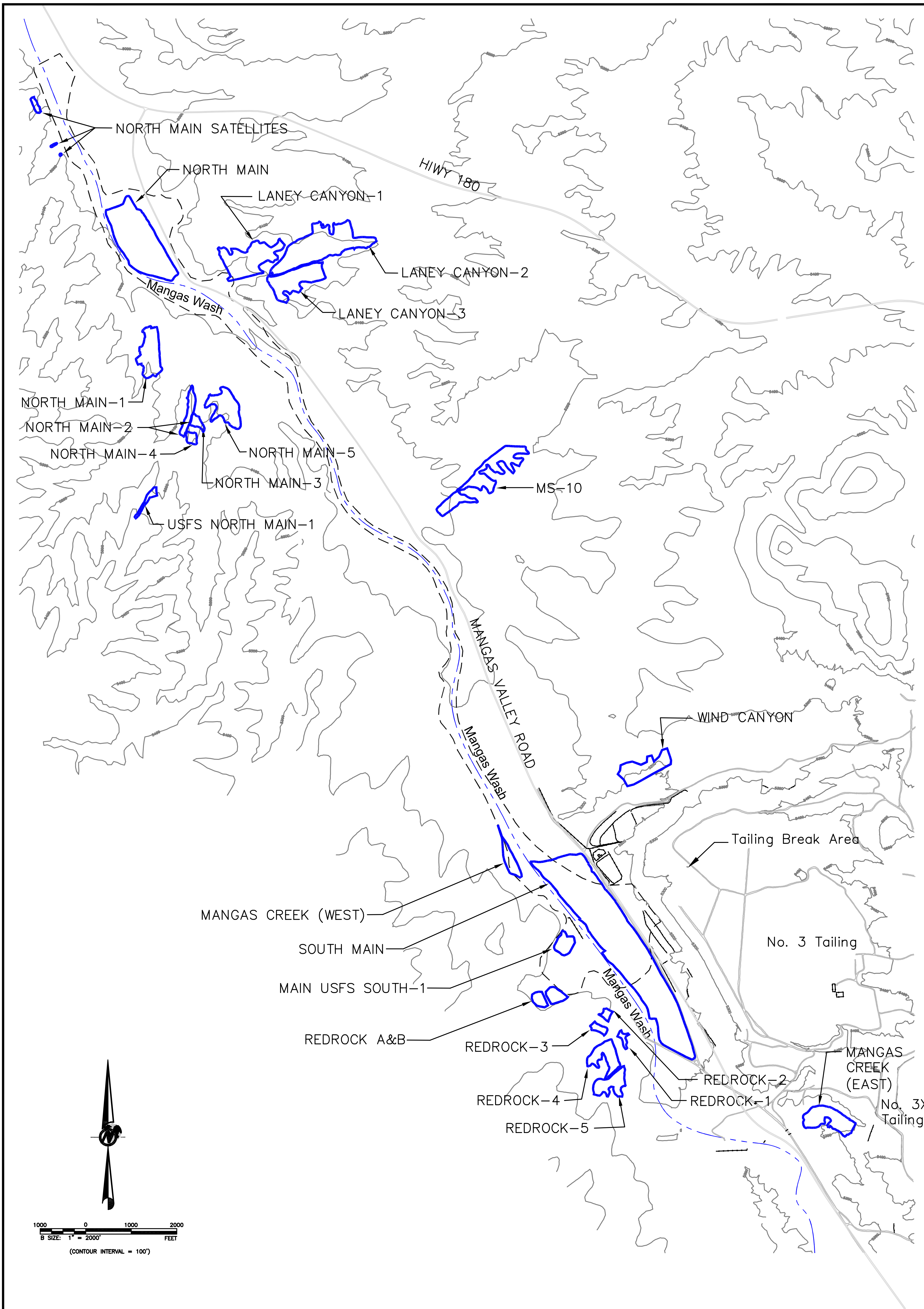
PHELPS DODGE TYRONE INC.
GRANT COUNTY, NEW MEXICO

TITLE

LOCATION OF TYRONE MINE IN SOUTHWESTERN NEW MEXICO

Golder Associates
Albuquerque, New Mexico

PROJECT No.		043-2318	FILE No.	XXXXXXXXX
DESIGN	LM	01/25/05	SCALE AS SHOWN	REV. A
CADD	CM	01/25/05	**FIGURE 1**	
CHECK	DR	04/28/05		
REVIEW	--	DATE		



LEGEND

- Approximate original extent of tailing repositories
- Approximate original extent of tailing spill
- Road
- Mangas Wash

PROJECT

PHELPS DODGE TYRONE INC.
GRANT COUNTY, NEW MEXICO

TITLE

APPROXIMATE EXTENT OF NO.3 TAILING SPILL AND MANGAS VALLEY TAILING REPOSITORIES

Golder Associates
Albuquerque, New Mexico

PROJECT No.		053-2371	FILE No.	Original Extents
DESIGN	DR	04/26/05	SCALE AS SHOWN	REV. A
CADD	CM	04/27/05		
CHECK	DR	04/27/05		
REVIEW	--	DATE		

FIGURE 2

K:\2005 Projects\053-2371\Figure 2.dwg

FIGURE 3
RESPONSE OF VEGETATION COVER TO GRAZING. PHOTO OF FENCE LINE ON THE ORGINAL NORTHERN EXCLOSURE ON THE SOUTH MAIN REPOSITORY. GRAZING HAS BEEN EXCLUDED ON THE RIGHT OF THE FENCE.

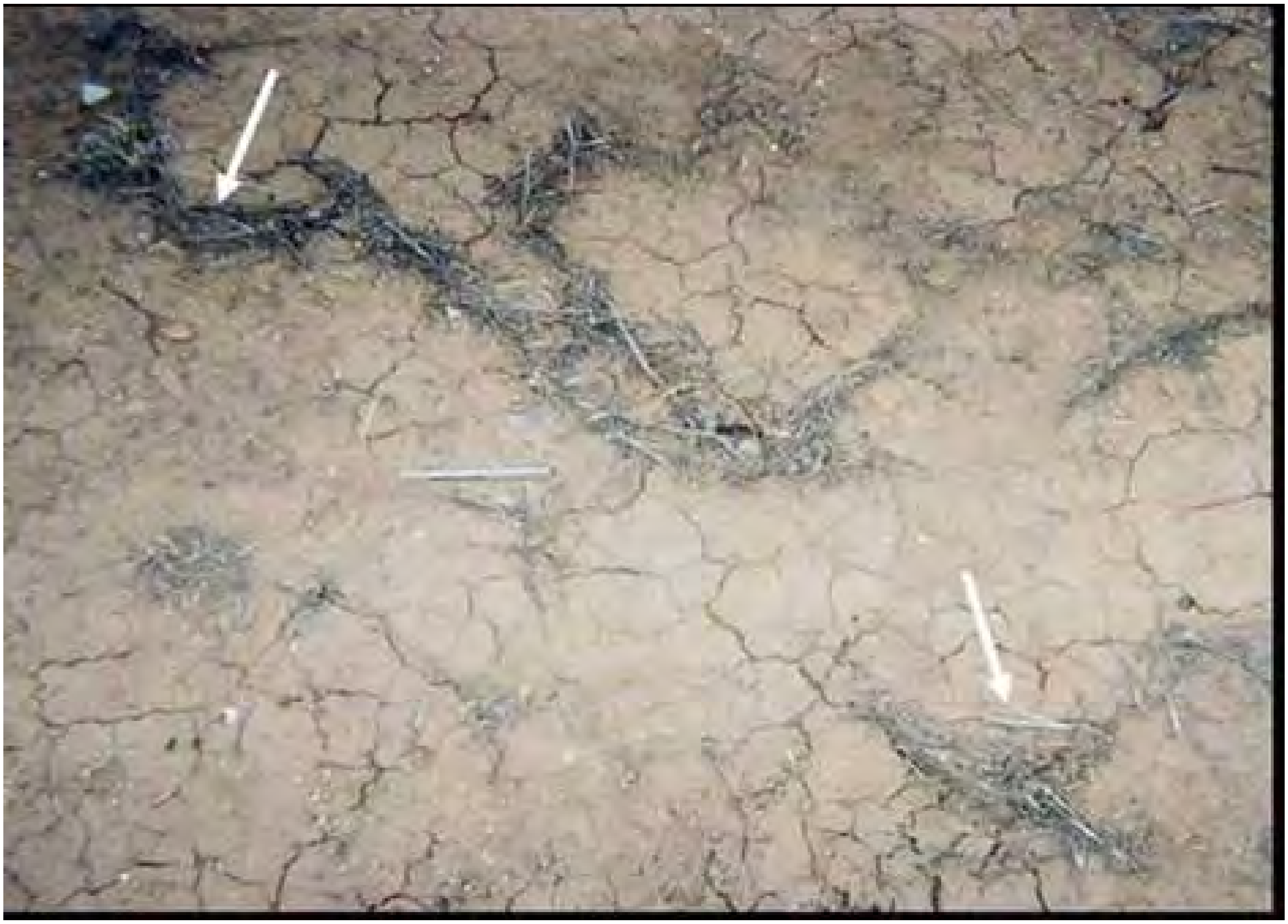
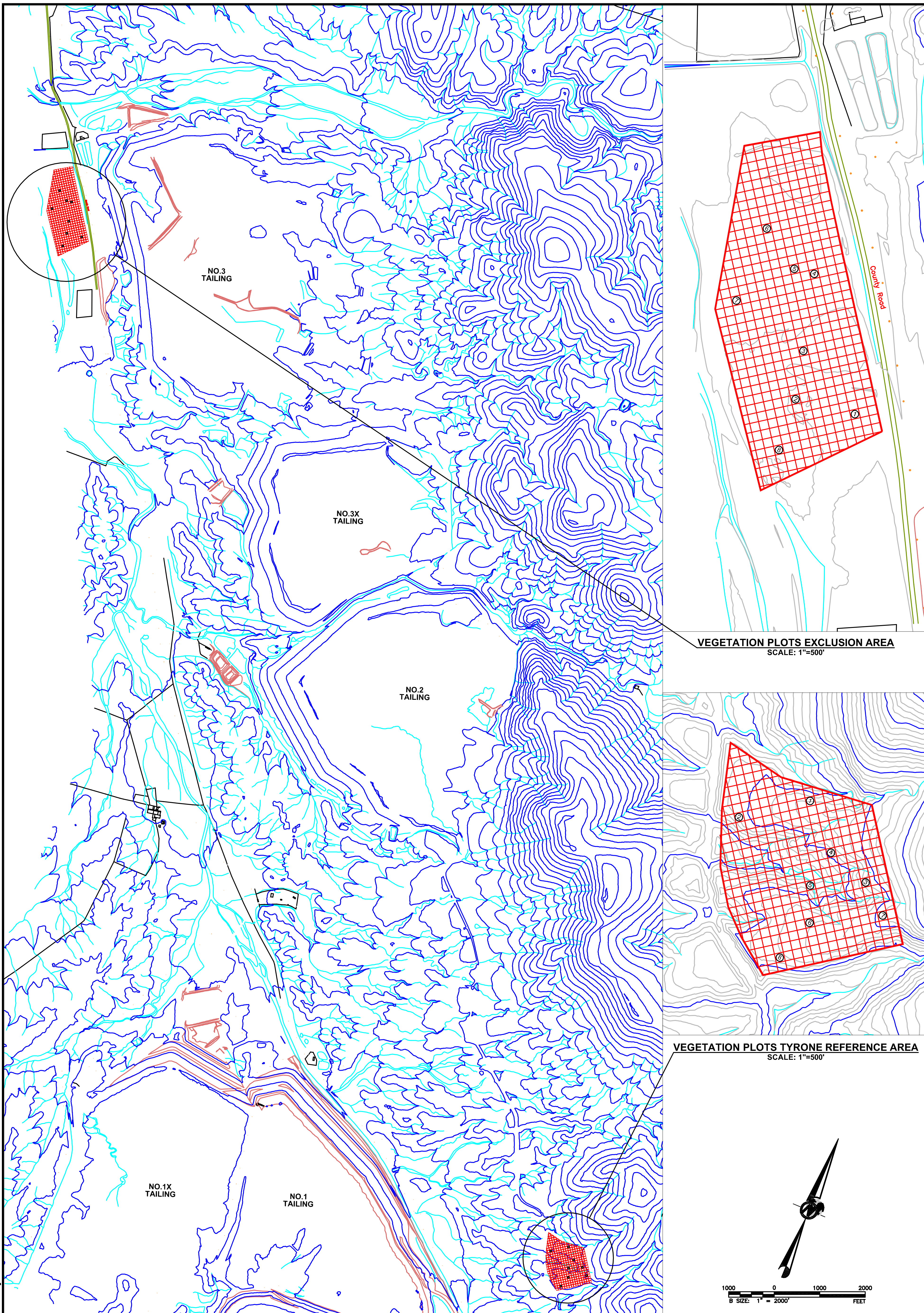


FIGURE 4
SURFACE CRUSTS ON A FINE-TEXTURED COVER SOIL (SILT LOAM). NOTE THE DEBRIS DAMS (ARROWS) INDICTING OVERLAND FLOW AND DEPOSITION OF LITTER. PEN JUST LEFT OF CENTER FOR SCALE.



PROJECT

Phelps Dodge TYRONE Inc.

PHELPS DODGE TYRONE INC.
GRANT COUNTY, NEW MEXICO

TITLE

CONDITION 84 VEGETATION PLOTS MANGAS VALLEY-TYRONE MINE

Golder Associates
Albuquerque, New Mexico

PROJECT No.		053-2371	FILE No.	C_84 sample plots
DESIGN	DR	04/22/05	SCALE AS SHOWN	REV. A
CADD	CM	04/22/05	FIGURE 5	
CHECK	DR	04/22/05		
REVIEW	--	DATE		

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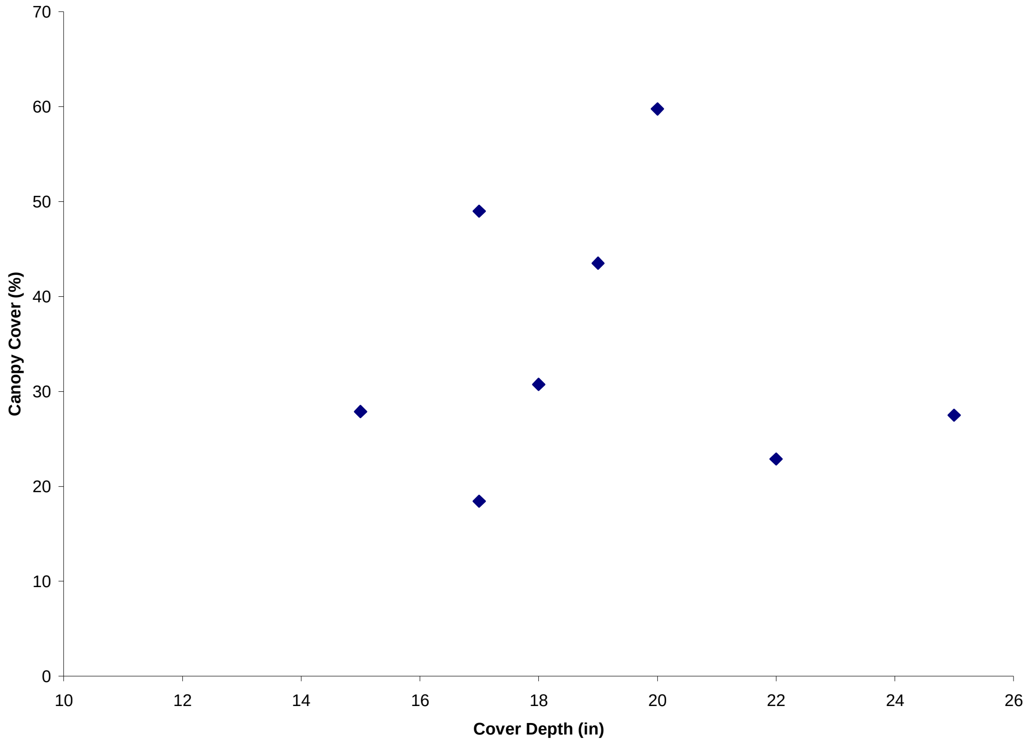
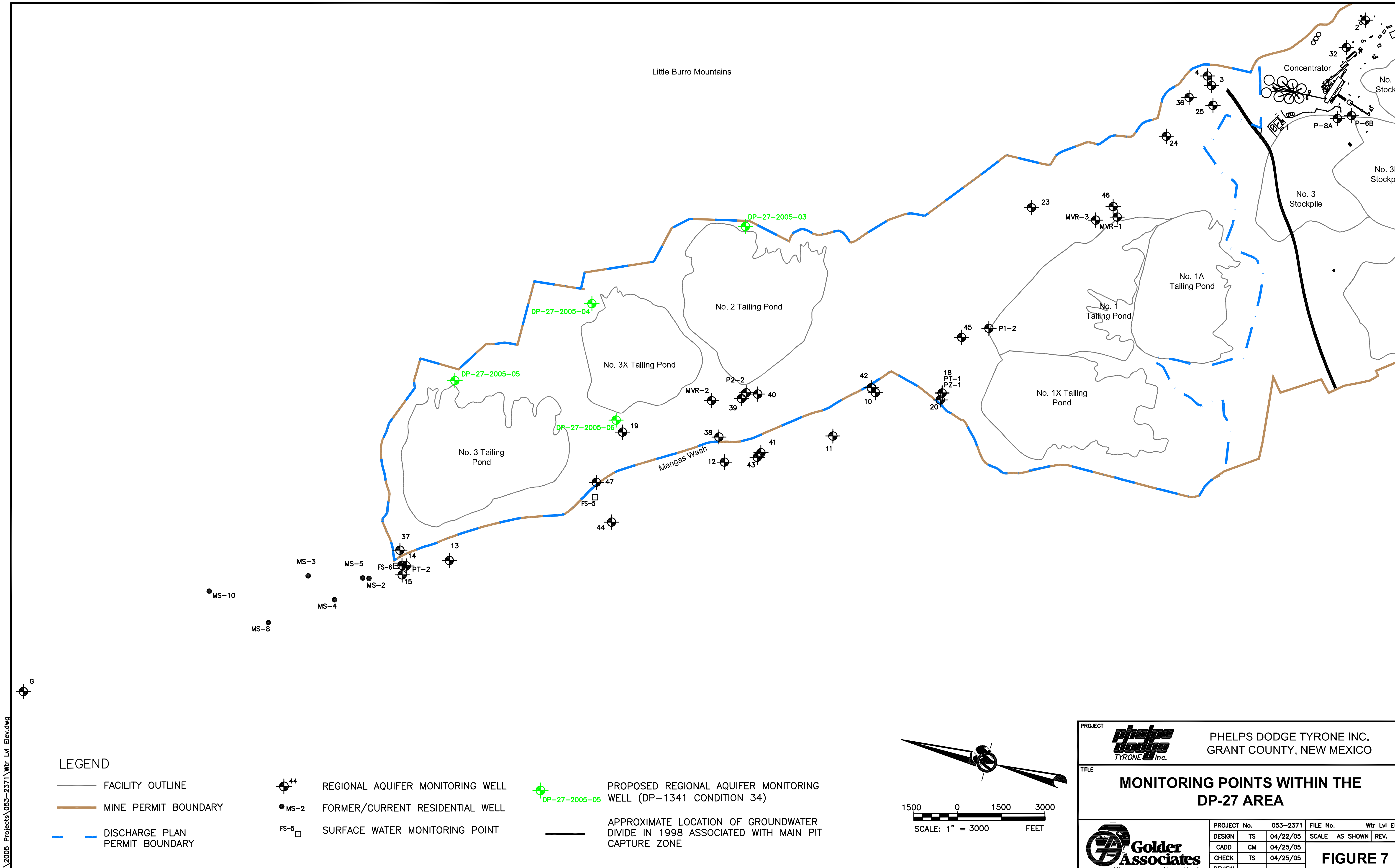


FIGURE 6
RELATIONSHIP BETWEEN COVER THICKNESS AND MEAN PLOT CANOPY COVER. DATA FROM THE RECLAIMED VEGETATION COMMUNITY IN THE EXCLUSION AREA



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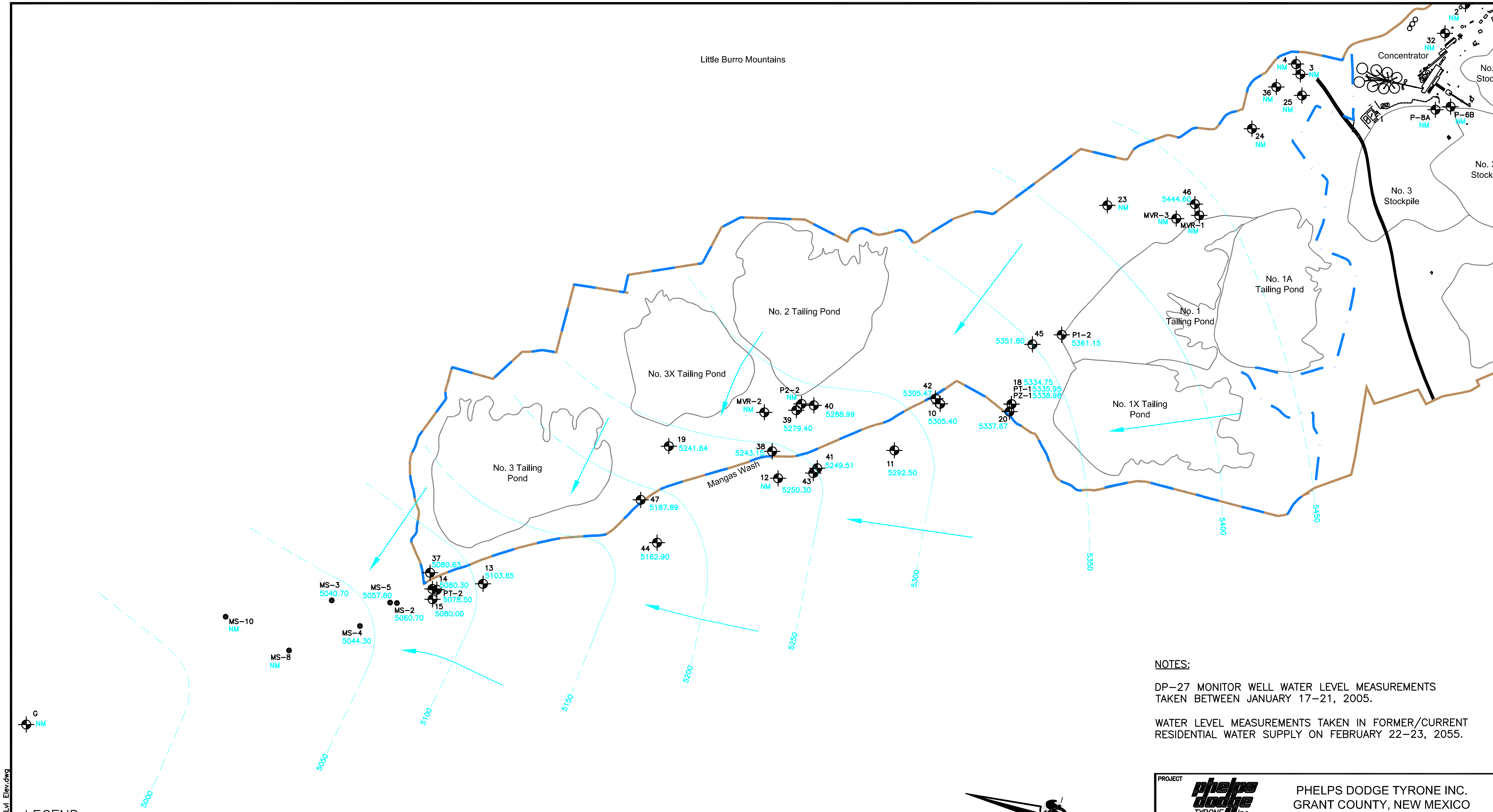


NOTES:

DP-27 MONITOR WELL WATER LEVEL MEASUREMENTS TAKEN BETWEEN JANUARY 17-21, 2005.

WATER LEVEL MEASUREMENTS TAKEN IN FORMER/CURRENT RESIDENTIAL WATER SUPPLY ON FEBRUARY 22-23, 2055.

LEGEND

- FACILITY OUTLINE
- MINE PERMIT BOUNDARY
- DISCHARGE PLAN PERMIT BOUNDARY
- 44 / 5169.87 — REGIONAL AQUIFER MONITORING WELL WITH WATER LEVEL ELEVATION (FEET ABOVE MEAN SEA LEVEL)
- MS-2 / 5060.70 — FORMER/CURRENT RESIDENTIAL WELL WITH WATER LEVEL ELEVATION (FEET ABOVE MEAN SEA LEVEL)
- 5100 — WATER LEVEL ELEVATION CONTOUR (FEET ABOVE MEAN SEA LEVEL) DASHED WHERE APPROXIMATE (CONTOUR INTERVAL 50 FEET)
- REGIONAL GROUNDWATER FLOW DIRECTION
- APPROXIMATE LOCATION OF GROUNDWATER DIVIDE IN 1998 ASSOCIATED WITH MAIN PIT CAPTURE ZONE
- NM — NOT MEASURED

1500 0 1500 3000

SCALE: 1" = 3000 FEET

PROJECT: phelps dodge TYRONE Inc.

PHELPS DODGE TYRONE INC.
GRANT COUNTY, NEW MEXICO

TITLE

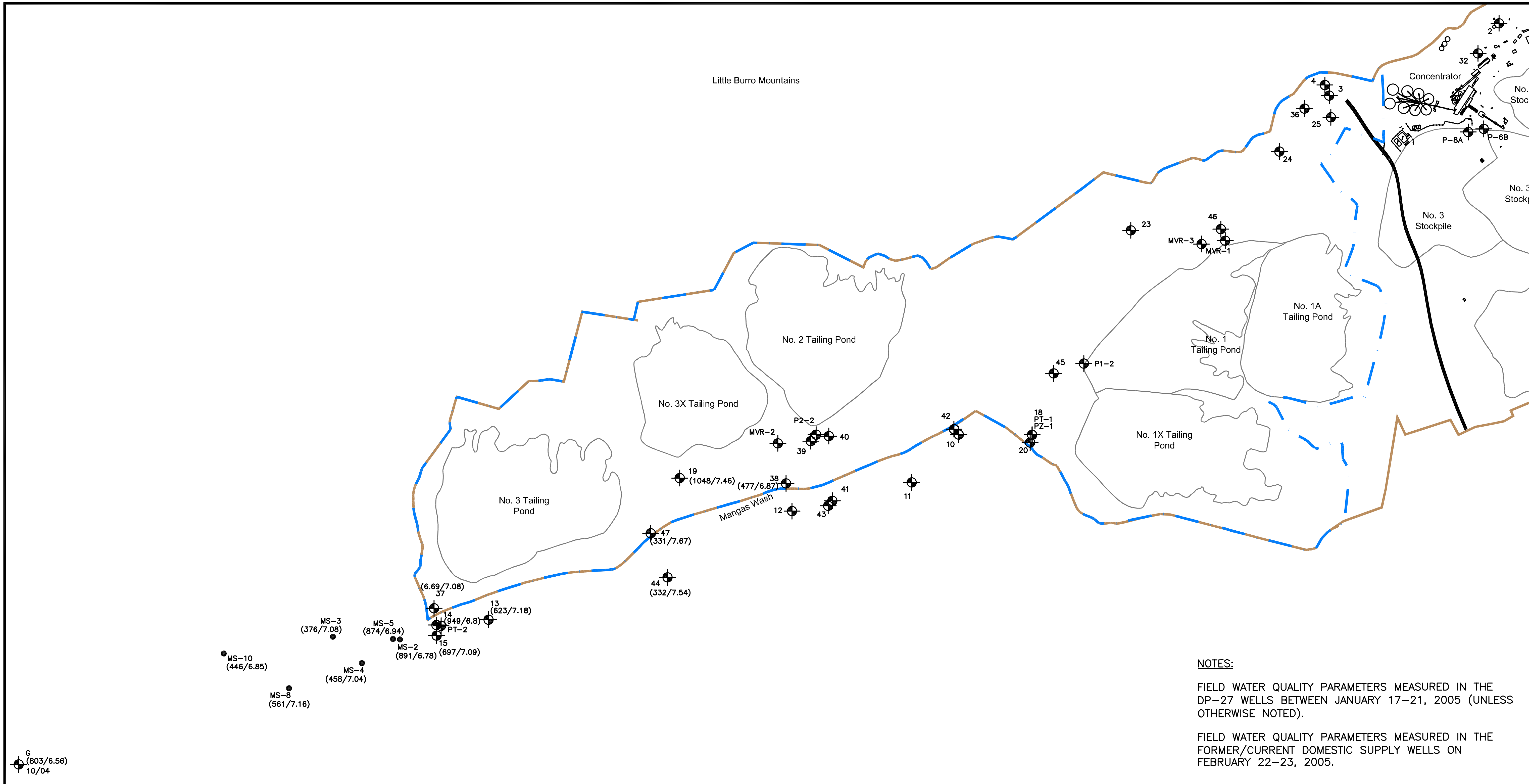
WATER LEVEL ELEVATIONS WITHIN THE DP-27 AREA (JANUARY-FEBRUARY 2005)

Golder Associates, Albuquerque, New Mexico

PROJECT No.	053-2371	FILE No.	Wtr Lvl Elev
DESIGN	TS	04/22/05	SCALE AS SHOWN / REV. A
CADD	CM	04/25/05	
CHECK	TS	04/25/05	
REVIEW			

FIGURE 8

K:\2005 Projects\053-2371\Wtr Lvl Elev.dwg



NOTES:

FIELD WATER QUALITY PARAMETERS MEASURED IN THE DP-27 WELLS BETWEEN JANUARY 17–21, 2005 (UNLESS OTHERWISE NOTED).

FIELD WATER QUALITY PARAMETERS MEASURED IN THE FORMER/CURRENT DOMESTIC SUPPLY WELLS ON FEBRUARY 22–23, 2005.

LEGEND

FACILITY OUTLINE

MINE PERMIT BOUNDARY

DISCHARGE PLAN PERMIT BOUNDARY

44 (332/7.54) REGIONAL AQUIFER MONITORING WELL WITH ELECTRIC CONDUCTIVITY (μmhos/cm@25°C) AND pH (STANDARD UNITS)

MS-2 (891/6.78) FORMER/CURRENT RESIDENTIAL WELL WITH ELECTRIC CONDUCTIVITY (μmhos/cm@25°C) AND pH (STANDARD UNITS)

APPROXIMATE LOCATION OF GROUNDWATER DIVIDE IN 1998 ASSOCIATED WITH MAIN PIT CAPTURE ZONE

1500 0 1500 3000

SCALE: 1" = 3000 FEET

PROJECT

phelps dodge TYRONE Inc.

PHELPS DODGE TYRONE INC.
GRANT COUNTY, NEW MEXICO

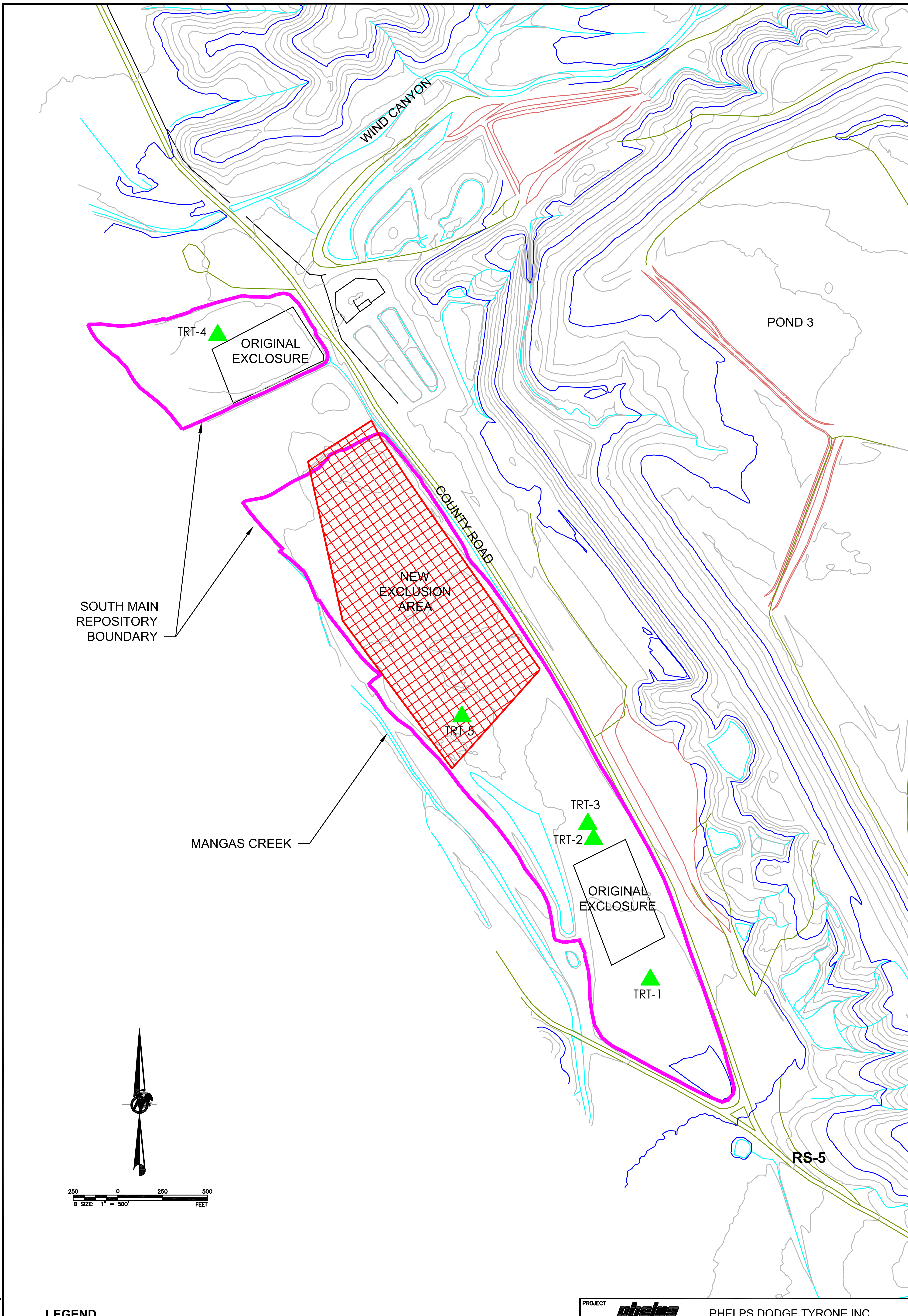
TITLE

FIELD WATER QUALITY WITHIN THE NO.3 TAILING RECLAIM AREA (JANUARY-FEBRUARY 2005)

Golder Associates
Albuquerque, New Mexico

PROJECT No.	053-2371		FILE No.	Wtr Lvl Elev
DESIGN	TS	04/22/05	SCALE AS SHOWN	REV. A
CADD	CM	04/25/05		
CHECK	TS	04/25/05	**FIGURE 9**	
REVIEW				

K:\2005 Projects\053-2371\Wtr Lvl Elev.dwg



PROJECT
phelps dodge TYRONE Inc.
PHELPS DODGE TYRONE INC.
GRANT COUNTY, NEW MEXICO

TITLE
UPWARD MIGRATION SAMPLE PIT LOCATION, MANGAS VALLEY-TYRONE MINE

Golder Associates Albuquerque, New Mexico

PROJECT No.		053-2371	FILE No.	N03-Samp Locs
DESIGN	LM	03/24/05	SCALE AS SHOWN	REV. A
CADD	CM	03/25/05		
CHECK	DR	03/25/05	FIGURE 10	
REVIEW	--	00/00/00		

FIGURE 11
COVER SOIL OVER TAILING AT SITE TRT-1. THE TAILING IS EXPOSED IN THE PIT WALL AT APPROXIMATELY 60 CM BELOW GROUND SURFACE.

FIGURE 12
TONGUING OF TAILING IN THE BASAL CONTACT ZONE OF THE SOIL COVER. WIRE MESH GRID SPACING IS 10 CM.

APPENDIX A

FIELD OBSERVATIONS OF THE MANGAS VALLEY TAILING REPOSITORIES MARCH AND APRIL, 2004

MANGAS EAST

The Mangas East repository occurs below the northwest corner of the No. 3X tailing impoundment. Overall, this repository was in good condition. It is gently sloping with a northwest aspect. The cover soil is generally coarse-textured and plant cover was considered good (25 to 30 percent) over the majority of the area.

There were no upland surface water diversions to prevent runon. Localized erosion features occurred where runon was uncontrolled. Runoff from an access road on the west side of the repository has lead to the formation of a small gully (4 to 5 feet deep) on the western face of the deposit. The arroyo just north of the repository has cut into the slope and exposed a small area of tailing. These erosion features represent about one percent of the area.

Sample Point: Mangas East Coarse-textured soil **Date:** 3/2/04

Cover Soil		**Vegetation**	
Soil Texture	CoSL 15%C	**Canopy Cover**	25-30%
Soil Color	--	**Basal Cover**	3%
Coarse Fragments - Surface	30-50% gravel 0-15% cobble	**Shrub Density**	25/ac (150 half shrubs)
		Grasses*	BOCU, BOER, BOGR, SPFL
Cover Thickness	--	**Shrubs**	SELO, YUEL, GUSA, PRGL
Slope	3 to 5%	**Forbs**	--
		Trees	JUMO
Notes: Lack of upland water diversions resulted in runon and localized erosion.			

* Please see Table 3 for plant codes

SOUTH MAIN

The South Main 2 (SM-2) repository runs between the Mangas Wash and the Mangas Valley Road for about a mile and a half. Cover soils on the SM-2 are primarily coarse textured with 30 to 70 percent coarse fragments on the surface. Vegetation cover was good (15 to 30 percent) over most of this area and signs of severe erosion were rare and localized.

The repository was gently sloping and slightly undulating (top left). Minor areas of slopes longer runs and steeper gradients occurred near the north end of the repository. Slopes along the road on the northern portion of the repository were stable and well vegetated (bottom left). Slopes on the southern portion of the SM-2 repository were rilled with small areas (25 to 50 square feet) of exposed tailing. Erosion in these areas occurred at slope inflection points, where shallow gradients converged with steeper gradient slopes. Cover thickness in these areas appeared to be shallow. On the western edge, Mangas Wash formed a steep embankment and has cut into a small portion (< 0.5 acre) of the repository.

RED ROCK

Five distinct deposits occur in the Red Rock repository; three small fills in upland watersheds and two larger deposits that extend out from native hills. The photo was taken looking south across a small repository towards the larger Red Rock-4 repository. Cover soils were primarily coarse-textured, though there were small areas covered with finer textured materials. All of the repositories deposits were affected to some degree by the runon from the adjacent upland slopes. Over-land flow from the top surfaces of the deposits was also not directed away from the slopes, leading to rill erosion on the side slopes (larger rills on the far repository in center of photo). Vegetative cover was considered good where runon-related erosion did not occur.

Sample Point: Red Rock Coarse-textured soil **Date:** 3/2/04

Cover Soil		**Vegetation**	
Soil Texture	SL 11% clay	**Canopy Cover**	20-25%
Soil Color	--	**Basal Cover**	2-3%
Coarse Fragments - Surface	25-30% gravel 0-5% cobble	**Shrub Density**	5/ac
		Grasses	BOCU, BOER, BOGR
Cover Thickness	--	**Shrubs**	GUSA, YUEL
Slope	3 to 8%	**Forbs**	--
		Trees	--
Notes: Lack of upland water diversions has resulted in runon and rill erosion			

MS-10

The MS-10 repository consists of three small upland watersheds that were filled with tailing (left). Cover soils were primarily fine-textured, dark-colored soils that developed thin, friable surface crusts. Vegetation performance was generally poor.

Vegetation is sparse on the fine-textured soils, limited to places where water concentrates, such as minor depressions and at the toes of slopes. Annual plants (tumbleweed) appears are dominant; although small patches of western wheatgrass, blue grama, mat muhly and dropseeds were observed. Approximately two acres of coarse texture soils in upland portions of the repository were well vegetated. The contrast in vegetation performance as a function of surface soil texture was apparent at this site.

Sample Point: MS-10 Fine-textured soil **Date:** 3/2/04

Cover Soil		**Vegetation**	
Soil Texture	SiCL, 28% clay	**Canopy Cover**	<5%
Soil Color	--	**Basal Cover**	2-3%
Coarse Fragments - Surface	0-5% gravel	**Shrub Density**	None
		Grasses	AGSM, BOGR, SPFL, MURI
Cover Thickness	12-24”	**Shrubs**	--
Slope	1-15%	**Forbs**	KOSC, SAIB, HOGL
		Trees	--
Notes: Surface crust are 1 cm thick and friable. Lack of upland water diversions has resulted in runon and erosion,			

NORTH MAIN

The North Main repository is large deposit near the northern end of the Mangas Valley. The southern half of the repository was primarily covered with coarse-textured soils (left). Plant cover was consistently good on these materials and did not change in response to changes in cover thickness. About three acres of fine-textured cover materials on the southern end also has relatively good plant cover.

The north end of this repository was covered with fine-textured soils and had about 5 percent canopy cover. The vegetation was limited primarily to isolated patches in small depressions and was dominated by grasses. The cover soil was a silt loam or silty clay loam (23 percent clay) with less than 5 percent gravel cover.

Overall, the slopes of this repository were well vegetated and in good condition with little evidence of erosion. Most of the slopes were covered with coarse-textured soils. Occasional rills have formed where water from the top surface concentrated and ran out onto the slope.

Sample Point: Main North Coarse-textured soil **Date:** 3/2/04

Cover Soil		**Vegetation**	
Soil Texture	CoSL, 18% clay	**Canopy Cover**	20%
Soil Color	--	**Basal Cover**	3-4%
Coarse Fragments - Surface	60-70% gravel 5-10% cobble	**Shrub Density**	25/ac
		Grasses	SPAI, BOCU, BOER, BOGR,
Cover Thickness	--	**Shrubs**	GUSA, YUEL, MIBI
Slope	2%	**Forbs**	--
		Trees	--
Notes:			

NORTH MAIN-1

The North Main-1 repository was used as a horse pasture. Vegetation cover was fair, considering that it had experienced high use. Canopy cover tended to increase from north to south with more annuals observed in the northern part of the repository. Despite the grazing pressure, the repository demonstrated excellent shrub and forb recruitment including yucca, desert broom, snakeweed, Emory oak, mimosa, globemallow, lupines (2-3 species), penstemon, beargrass, black grama, and three awns (2 species).

There were minor runon/erosion issues associated with the western edge of the repository. These upland areas appear to have been the source for borrow materials and the slopes are lightly vegetated. Sheet flow starts to rill in the central portion of the repository. There are also three areas (about 1/4 acre each) where the cover appears to be affected by the tailing that was mixed with the cover soil during reclamation.

Sample Point: MN1-1202 **Date:** 4/7/04

Cover Soil		**Vegetation**	
Soil Texture	SCL , 22% clay	**Canopy Cover**	10-15%
Soil Color	7.5 YR 5/4	**Basal Cover**	2%
Coarse Fragments - Surface	65-70% gravel <5% cobble	**Shrub Density**	<5/ac
		Grasses	BOCU, BOGR, ARPU, ARDI, BOER
Cover Thickness	24”	**Shrubs**	NOMI, TECA, MIBI, GUSA, YUEL
Slope	3%	**Forbs**	ARCA, LUPI, SPHA, PENST
		Trees	QUEM
Notes			

NORTH MAIN-2

The North Main-2 is composed of three small repositories. One is covered by a silty clay loam soil (28 percent clay) with 10 percent fine gravels on the surface (top left). Perennial grass cover was marginal (blue grama primarily; 2 percent basal, 10 percent foliar), especially considering that is appears to have been lightly grazed. Plants were pedestaled 6-10 inches, even on a relatively gentle grade (5 percent). Improper grading and lack of upland surface water diversions has resulted in localized incision and the arroyo on the southern edge has exposed tailing.

Two other small repositories occur to the south (bottom left and bottom right). These repositories were covered with coarse-textured soils and had relatively good plant cover. Rills formed where no upland surface water diversions were installed, otherwise the cover was intact. Slopes range from 15 to 25 percent.

NORTH MAIN-3

The North Main-3 repository was covered entirely with fine-textured soils and was sparsely vegetated (top left). The surface had a friable crust and less than 5 percent gravel. Vegetation was mainly annual weeds, though small patches of blue grama occurred.

There were no upland surface water diversions and runon was causing minor rilling. There was also evidence of overland flow on the surface with debris dams along the slope (bottom left). In the places where perennial grasses (10 percent cover) had established, 1 to 3 inches high pedestals were evident indicating moderate sheet erosion (bottom right).

The Laney Canyon repository was composed of two primary deposits separated by an arroyo. Two contrasting soil types were used as cover at this site. The coarser-textured variant supported higher levels of vegetation cover and was generally resilient. The finer-textured variant was poorly vegetated and subject to moderate to severe sheet and rill erosion. Where the finer-textured soils occurred on slopes the erosion was severe and tailing were exposed.

Looking southeast from borehole LC-804. Cover over tailings is 4 inches thick. Cover soil is coarse-textured with 50 percent gravel on the surface. Foliar cover is nearly 25 percent and vegetation shows no signs of physiological stress. Plant diversity is nominal and site dominated by blue, hairy and side-oats gramas, lovegrass and snakeweed. Volunteer acacia, mesquite and yucca occur at about 50 stems per acre, indicating that plant diversity is increasing by natural processes. Plant cover remained fairly uniform as cover soil thickness increased from 4 to 18 and 24 inches thick.

Sample Point: LC-804 **Date:** 3/3/04

Cover Soil		**Vegetation**	
Soil Texture	SL, 19% clay	**Canopy Cover**	25%
Soil Color	7.5 YR 4/2	**Basal Cover**	3%
Coarse Fragments - Surface	50% gravel	**Shrub Density**	<5/ac
		Grasses	BOCU, BOGR, BOHI, ERCU
Cover Thickness	4”	**Shrubs**	GUSA, MIBI, PRGL, YUEL
Slope	1%	**Forbs**	—
		Trees	—
Notes:			

SURFACE WATER CONTROLS

The lack of surface water diversions upgradient of the repositories was the principal cause of rill and gully formation independent of the surface texture of the cover. Uncontrolled runon from adjacent undisturbed uplands in Mangas Creek repository lead to the formation of this small gully in coarse-textured materials (top left). Tailing was not evident in the cut.

Tailing was exposed in the MS-10 repository (bottom left). Runoff from the fine-textured surface conditions of the cover combined with runoff not diverted from the native uplands to produce this small scalped area.

At the Redrock repository, an attempt to stop rilling caused by upland runon was made by creating small berms or check dams across small channels (bottom right). These are judged to be ineffective as water circumvents the berms and continues to erode the cover.

SOIL OBSERVATION (SM2-3768)

Looking north from borehole SM2-3768 across the Exclusion area. Coarse-textured cover thickness is 6 inches thick over tailing at this location. The surface is covered by 60 percent coarse fragments; primarily gravels. Canopy cover is about 20 percent and vegetation shows no signs of physiological stress. Plant diversity is relatively high in the immediate area with several species of volunteer forbs, shrubs and trees. Plant cover increases to about 25 to 30 percent in the slight swale in the background. The increase in canopy cover may be a influenced by several factors including surface water runon, a decrease in rock cover, and an increase in cover thickness from 6 inches to 13 to 16 inches.

Sample Point: SM2-3768 **Date:** 4/7/04

Cover Soil		**Vegetation**	
Soil Texture	SL, 18% clay	**Canopy Cover**	20%
Soil Color	7.5 YR 4/2	**Basal Cover**	4%
Coarse Fragments - Surface	50% gravel 10% cobble	**Shrub Density**	<5/ac
		Grasses	BOCU, BOGR, SPAI
Cover Thickness	6”	**Shrubs**	MIBI, SELO, TECA, PRGL
Slope	2%	**Forbs**	LUPI, MECA, CHST
		Trees	PIED
Notes:			

COVER THICKNESS– VEGETATION RESPONSE (MN-146)

The lack of correlation between cover thickness and vegetation cover was apparent at sample point MN-146 in the North Main Repository. The cover was 9 inches thick in the immediate foreground and increased to 12 to 18 inches thick in the background. This site was representative of the response of vegetation to varying cover thickness.

Sample Point: MN-146 **Date:** 4/7/04

Cover Soil		**Vegetation**	
Soil Texture	SCL, 25% clay	**Canopy Cover**	20%
Soil Color	7.5 YR 3/2	**Basal Cover**	2-3%
Coarse Fragments - Surface	60% gravel <5% cobble	**Shrub Density**	10/ac
		Grasses	BOCU, BOHI, BOGR, VUOC, ARDI, SPAI
Cover Thickness	9”	**Shrubs**	GUSA, YUEL
Slope	1%	**Forbs**	BORA, MECA, ERFL
		Trees	--
Notes			

SOIL-VEGETATION OBSERVATION (SM2-3609)

Scattered within the South Main 2 repository are small areas (2-3 acres) where the surface textures are fine sandy loams and loams with less than 10 percent coarse fragments. Sample point SM2-3609 (left) is representative of this variant in cover texture. These soils do not have surface crusts and the vegetative cover is higher than on the soils with higher silt contents.

Sample Point: SM2-3609 **Date:** 4/7/04

Cover Soil		**Vegetation**	
Soil Texture	SL, 16% clay	**Canopy Cover**	25%
Soil Color	7.5 YR 4/2	**Basal Cover**	4%
Coarse Fragments - Surface	10% gravel	**Shrub Density**	<5/ac
		Grasses	BOGR, SPAI
Cover Thickness	18”	**Shrubs**	MIBI,
Slope	1%	**Forbs**	
		Trees	--
Notes:			

FINE-TEXTURED SOILS IN GRAZING EXCLOSURE

Fine-textured soils generally performed poorly, except where they were grazing was excluded. Surface soil conditions within the northern exclosure on the South Main repository are shown here. The fine-textured cover soil has essentially no coarse fragments and a surface crust is prevalent. Canopy cover is about 30 percent. The area supports a slightly more diverse grass community than is found outside the exclosure. Grasses inside the exclosure include mat muhly, vine mesquite, bottlebrush squirreltail, and western wheatgrass in addition to the gramas. The cool-season species (bottlebrush squirreltail and western wheatgrass) tend to occur rarely outside the exclosure and suggest that cool-season grass may persist with lower grazing pressure.

The area was fenced to exclude livestock, though the date of its installation is unknown. The area provides a indication of the potential performance of this soil to support vegetation. Canopy cover, both live and litter, is markedly better compared to other fine-textured repository covers. There was also no evidence of sheet erosion (i.e. plant pedestaling) .

Sample Point: SM1-3307 **Date:** 4/7/04

Cover Soil		**Vegetation**	
Soil Texture	SiCL, 32% clay	**Canopy Cover**	30%
Soil Color	7.5 YR 3/2	**Basal Cover**	4%
Coarse Fragments - Surface	1% gravel	**Shrub Density**	<5/ac
		Grasses	MURI, BOCU, BOGR, AGSM, PAOB, SPFL, SIHY, ERCU
Cover Thickness	25”	**Shrubs**	OPEN, TECA
Slope	1%	**Forbs**	--
		Trees	--
Notes: Observation taken in original reference area in north section of repository			

APPENDIX B

PHOTOS OF VEGETATION PLOTS
AND QUADRATS
OCTOBER, 2005

Plot EA1; Tyrone Repository (10/05/04)

Quadrat EA1A (10/05/04)

Quadrat EA1B (10/05/04)

Quadrat EA1C (10/05/04)

Quadrat EA1D (10/05/04)

Plot EA2; Tyrone Repository (10/05/04)

Quadrat EA2A (10/05/04)

Quadrat EA2B (10/05/04)

Quadrat EA2C (10/05/04)

Quadrat EA2D (10/05/04)

Quadrat EA3A (10/05/04)

Quadrat EA3B (10/05/04)

Quadrat EA3C (10/06/04)

Quadrat EA3D (10/06/04)

Plot EA4; Tyrone Repository (10/06/04)

Quadrat EA4A (10/06/04)

Quadrat EA4B (10/06/04)

Quadrat EA4C (10/06/04)

Quadrat EA4D (10/06/04)

Plot EA5; Tyrone Repository (10/06/04)

Quadrat EA5A (10/06/04)

Quadrat EA5B (10/06/04)

Quadrat EA5C (10/06/04)

Quadrat EA5D (10/06/04)

Plot EA6; Tyrone Repository (10/06/04)

Quadrat EA6A (10/06/04)

Quadrat EA6B (10/06/04)

Quadrat EA6C (10/06/04)

Quadrat EA6D (10/06/04)

Plot EA7; Tyrone Repository (10/06/04)

Quadrat EA7A (10/06/04)

Quadrat EA7B (10/06/04)

Quadrat EA7C (10/06/04)

NO PHOTO'S AVAILABLE FOR PLOT EA8

Plot TR1; Reference Area

Quadrat TR1A (10/03/04)

Quadrat TR1B (10/03/04)

Quadrat TR1C (10/03/04)

Quadrat TR1D (10/03/04)

Plot TR2; Tyrone Reference Area (10/03/04)

NO PHOTO AVAILABLE

Quadrat TR2A (10/03/04)

Quadrat TR2B (10/03/04)

Quadrat TR2C (10/04/04)

Quadrat TR2D (10/04/04)

Plot TR3; Reference Area (10/04/04)

Quadrat TR3A (10/04/04)

Quadrat TR3B (10/04/04)

Quadrat TR3C (10/04/04)

Quadrat TR3D (10/04/04)

Plot TR4; Reference Area (10/04/04)

Quadrat TR4A (10/04/04)

Quadrat TR4B (10/04/04)

Quadrat TR4C (10/04/04)

Quadrat TR4D (10/04/04)

Plot TR5; Reference Area (10/04/04)

Quadrat TR5A (10/04/04)

Quadrat TR5B (10/04/04)

Quadrat TR5C (10/04/04)

Quadrat TR5D (10/04/04)

Plot TR6; Reference Area (10/05/04)

Quadrat TR6A (10/05/04)

Quadrat TR6B (10/05/04)

Quadrat TR6C (10/05/04)

Quadrat TR6D (10/05/04)

Plot TR7; Reference Area (10/05/04)

Quadrat TR7A (10/05/04)

Quadrat TR7B (10/05/04)

Quadrat TR7C (10/05/04)

Quadrat TR7D (10/05/04)

Plot TR8; Reference Area (10/05/04)

Quadrat TR8A (10/05/04)

Quadrat TR8B (10/05/04)

Quadrat TR8C (10/05/04)

Quadrat TR8D (10/05/04)

APPENDIX C

WATER QUALITY TABULAR DATA
AND TIME SERIES PLOTS
MANGAS VALLEY

Table C-1. Summary of Surface Water Quality Analyses
Sample Point FS-5

Parameter	New Mexico Regulatory Standard [a]	Concentration (mg/L)																								
Sample Date		07/16/90	07/25/90	07/26/90	08/02/90	08/23/90	09/06/90	09/24/90	10/04/90	07/19/91	08/10/91	08/19/91	08/20/92	08/21/92	09/21/92	08/18/93	08/03/94	11/14/94	07/30/97	07/21/99	08/10/99	07/14/00	08/16/01	07/17/02	08/18/03	10/22/04
Al	5.0	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
As	0.2	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
B	5.0	0.02	0.05	0.03	0.02	0.05	0.03	0.01	<0.01	0.06	0.04	<0.01	0.019	<0.01	0.015	<0.02	<0.1	<0.1	<0.05	<0.05	<0.05	0.07	NM	<0.05	0.02	<0.04
Ca	NS	31.8	27.3	30.4	27.8	38.3	37.7	29.9	27.3	29.4	36.6	31.3	33.1	25.8	21.0	20.1	24.0	50.0	58.5	26.8	35.5	78.8	NM	130	29.1	196
Cd	0.05	<0.0006	<0.0006	<0.0006	<0.007	<0.0006	<0.0006	<0.0006	<0.0006	0.002	0.001	<0.0006	<0.0006	<0.0006	<0.0006	0.0007	<0.04	<0.04	<0.004	<0.005	<0.005	0.005	NM	<0.005	<0.001	<0.002
Cl	NS	2.75	2.4	2.4	2	11	2.4	4.6	3.1	1.68	1.83	1.16	2.11	2.58	2.33	1.46	13	2.6	3	7	7	5	NM	15	<5	3.1
Co	1.0	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
Cu	0.5	0.027	0.053	0.064	0.012	0.02	0.035	0.062	0.051	0.092	0.014	<0.004	0.08	1.17	0.042	0.151	0.09	<0.05	0.08	0.04	0.03	0.06	NM	0.04	0.113	0.0651
F	NS	0.9	1	1.1	<0.2	0.7	1.1	0.6	1.3	0.84	0.95	0.47	1.27	1.06	0.86	0.95	0.62	0.84	0.83	0.89	0.25	0.78	NM	0.58	0.99	0.48
HCO_3	NS	66	59	68	64	96	116	85.9	72.7	59	81	123	55	55	51	56	<2	16	170	67	116	286	NM	NM	NM	NM
Hg	0.01	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
K	NS	3.98	3.68	3.35	2.85	3.77	1.99	4.3	7.05	3.24	3.64	3.1	3.3	2.78	3.18	2.52	12	5.5	4.8	3.4	6.7	8.2	NM	7.40	4.3	4.8
Mg	NS	3.85	4.17	4.71	3.84	6.21	6.1	5.71	5.19	4.79	6.11	4.34	5.84	3.73	4.28	3.58	3.8	8.5	9	4.4	5.5	14.2	NM	20.5	4.9	33.6
Mo[b]	1.0	<0.04	<0.04	<0.04	0.017	0.05	<0.04	<0.04	0.003	0.921	0.423	<0.003	0.028	0.026	0.053	0.008	<0.05	<0.05	0.03	0.02	0.01	0.01	NM	0.01	0.02	0.0263
Na	NS	9.65	10.7	10.9	7	11	11.4	7.3	1	9.4	8.6	4.1	10.1	7.5	5.82	8.07	7.8	10	12.8	7.6	1.8	13	NM	10.50	8.3	14.1
Pb	0.1	<0.02	<0.02	<0.02	<0.02	0.046	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.033	<0.02	<0.05	<0.05	<0.05	<0.05	<0.05	0.11	NM	<0.05	<0.005	<0.005
pH[c]	NS	6.3	6.4	6.4	6.5	6.5	6.8	7.4	7	7.2	7.5	7.9	7.3	6.7	6.2	7.6	7.54	8.2	7.7	7.8	7.3	7.3	7.27	6.8	8	6.67
Se	0.05	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
SO_4	NS	59	53.7	71	48.3	48.8	60.1	49.8	26.8	64.5	65.9	8.63	87.8	48.4	30.8	44.6	49	35	50	50	15	56	NM	375	27.8	440
TDS	NS	160	172	184	210	202	226	170	160	162	179	196	187	111	145	110	160	240	290	130	150	380	NM	700	150	778
Zn	25.0	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM

[a] State of New Mexico Standards for Interstate and Intrastate Surface Water, livestock watering standards (NMWQCC, 2002).
[b] Molybdenum - dissolved standard for irrigation. NS for livestock.
[c] pH in standard units.

mg/L = Milligrams per liter
NM = Not measured
NS = No New Mexico regulatory standard set for parameter
shaded cells indicate parameter above applicable regulatory standard

Table C-2. Summary of Surface Water Quality Analyses
Sample Point FS-6

Parameter	New Mexico Regulatory Standard [a]	Concentration (mg/L)												
Sample Date		07/23/90	07/26/90	08/02/90	07/19/91	08/10/91	08/19/91	08/21/92	01/12/93	08/04/93	08/30/94	08/16/01	07/16/02	12/03/02
Al	5.0	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
As	0.2	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
B	5.0	0.02	0.03	0.01	0.038	0.02	0.034	<0.01	<0.5	0.03	<0.1	NM	<0.05	<0.05
Ca	NS	48.5	83.3	43.2	74.5	56.0	22.5	37.1	24.0	23.3	43.0	NM	29.7	125
Cd	0.05	<0.0006	<0.0006	<0.0006	<0.0006	<0.0006	<0.0006	<0.0006	<0.01	<0.0006	<0.04	NM	<0.005	<0.005
Cl	NS	3.2	<1	3.9	<1	<1	1.49	<1	3.1	<1	1.6	NM	3	6
Co	1.0	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
Cu	0.5	0.015	0.028	0.024	0.024	0.024	0.011	0.023	0.07	0.07	<0.05	NM	0.04	0.38
F	NS	0.3	0.4	0.4	0.36	<0.2	<0.2	0.28	0.2	0.4	0.25	NM	0.17	0.1
HCO_3	NS	157	72	79	66	125	86	85	50	47	72	NM	NM	NM
Hg	0.01	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
K	NS	5.47	5.37	2.94	5.01	4.2	2.94	3.23	2.1	4.27	3	NM	7	6.3
Mg	NS	3.88	6.56	3.05	5.5	4.71	2.21	3.18	2.3	1.79	4.1	NM	2.8	13.8
Mo[b]	1.0	<0.04	<0.04	0.021	0.643	0.217	0.009	0.025	<0.05	0.03	<0.05	NM	<0.01	0.01
Na	NS	2.7	2.11	1.92	2	2	2.5	1.1	6.5	2	2.8	NM	1.5	4.7
Pb	0.1	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.05	0.014	<0.05	NM	<0.05	<0.05
pH[c]	NS	6.7	5	7.1	7.4	7.4	7.3	6.8	6.96	7.4	7.74	7.38	7.4	7.7
Se	0.05	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
SO_4	NS	11.7	193	70	160	61.3	5	40.8	18	30.4	56	NM	30	5
TDS	NS	200	348	225	327	211	116	114	150	116	220	NM	150	490
Zn	25.0	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM

[a] State of New Mexico Standards for Interstate and Intrastate Surface Water, livestock watering standards (NMWQCC, 2002).
[b] Molybdenum - dissolved standard for irrigation. NS for livestock.
[c] pH in standard units.
mg/L = Milligrams per liter
NM = Not measured
NS = No New Mexico regulatory standard set for parameter

Table C-3a. Summary of Historical Groundwater Quality Analyses
Well 13

Parameter	New Mexico Regulatory Standard [a]	Average Pre-Spill Concentration [h] (mg/L)	Concentration (mg/L)																							
	Sample Date		01/13/99	04/10/99	07/04/99	10/28/99	01/14/00	04/18/00	07/01/00	10/08/00	01/13/01	04/10/01	07/14/01	10/07/01	01/10/02	04/03/02	07/24/02	10/15/02	01/20/03	04/17/03	07/16/03	10/31/03	01/14/04	04/29/04	07/29/04	10/21/04	01/21/05
Al[d]	5.0	0.05(1)	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	<0.05	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
As[b]	0.1	0.008(9)	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
B[d]	0.75	0.089(8)	0.05	<0.05	0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	NM	<0.05	<0.05	<0.05	<0.05	<0.05	0.02	0.03	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Ca	NS	84.5(66)	153	136	132	131	123	120	120	116	112	107	107	NM	125	108	119	120	123	157	129	112	123	113	115	112	125
Cd[b]	0.01	0.002(18)	<0.004	<0.0049	<0.0049	<0.0049	<0.0049	<0.0049	<0.0049	<0.0049	<0.005	<0.005	<0.005	NM	<0.005	<0.005	<0.005	<0.005	<0.005	0.0016	<0.001	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Cl[c]	250	13.3(66)	19	37	21	20	24	23	21	23	21	17	37	NM	17	18	19	17	38	41	16.4	20.4	18.3	20.9	21.1	19.9	17.2
Co[d]	0.05	0.015(1)	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
Cu[c]	1.0	0.058(57)	<0.0049	<0.0099	<0.0099	0.49	<0.0099	<0.0099	0.01	0.03	0.03	0.02	<0.01	NM	0.12	<0.01	0.01	0.01	0.03	0.03	<0.005	0.0125	0.0067	0.0095	0.0032	0.051	0.076
F[b]	1.6	0.56(36)	0.26	0.33	0.24	0.69	0.11	0.26	0.3	0.9	0.19	0.18	0.2	NM	0.3	0.25	0.32	0.43	0.15	<0.1	0.19	NM	0.35	0.29	0.33	0.35	0.324
Fe[c]	1.0	0.142(61)	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	<0.02	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
HCO_3	NS	160(58)	159	165	159	98	146	157	155	169	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	129.0
Hg[b]	0.002	0.001(5)	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
K	NS	2.4(38)	2.2	1.6	1.6	1.7	1.5	1.6	1.5	1.6	1.6	1.5	1.6	NM	1.7	1.5	1.5	1.4	1.8	2	1.4	2.1	1.6	1.7	2	1.7	1.73
Mg	NS	11.6(64)	13.2	13.9	14.5	14.6	13.7	13.7	13.4	13.5	12.7	11.8	12.6	NM	14	12.3	13.4	12.6	13.4	17	14.8	16.2	15.5	14	13.7	14.1	16
Mn[c]	0.2	0.01(23)	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	<0.01	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
Mo[d]	1.0	0.01(22)	0.07	0.06	0.07	0.06	0.06	0.07	0.07	0.06	0.07	0.07	0.07	NM	0.07	0.06	0.07	0.06	0.06	0.057	0.06	0.0505	0.0705	0.0576	0.0639	0.0639	0.0615
Na	NS	18.8(40)	21.3	24	25.1	18.6	24.8	19.2	18.8	23.8	22.6	16.9	24.2	NM	23.3	20.9	22.5	20.2	25.6	24	22.3	22.4	21.1	22.6	21.8	21.4	21.3
Pb[b]	0.05	0.01(16)	<0.0049	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	NM	<0.05	<0.05	<0.05	<0.05	<0.05	<0.003	<0.005	0.0065	<0.005	<0.005	<0.005	<0.005	<0.005
pH[c,e]	>6,<9	7.6(53)	7.3	7.4	7.3	6.4	7.4	7.4	7.3	7.2	7.2	7.1	7.1	7.3	7.2	7.1	7.1	7	7.1	7.4	7.9	7.49	7.67	7.75	7.63	6.53	7.18
Se[b]	0.05	0.004(10)	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
SO_4[c]	600	145(67)	301	269	267	303	289	268	223	255	242	195	200.0	NM	224	240	296	290	255	321	258	239	275	242	247	239	222
Specific Conductance[f]	NS	671(25)	700	600	650	790	700	743	718	720	724	600	734	742	630	681	594	619	648	668	678	624	707	626	669	750	623
Temperature[g]	NS	NM(53)	18.7	16.8	18.4	22	16.6	16.5	21.1	17.6	15.4	17.7	18.7	18.2	17	18.2	19.6	18.1	17.8	18	20.1	17.9	17.8	17.9	22.6	19.2	17.3
TDS[c]	1000	431(40)	600	610	640	590	590	550	620	510	530	680	550	NM	550	510	620	600	620	620	630	508	578	518	541	512	543
Zn[c]	10.0	0.06(23)	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	<0.025	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM

[a] New Mexico Water Quality Control Commission Regulations, 20.6.2 NMAC (NMWQCC, 2002).
[b] Human health standard
[c] Other standard for domestic water supply
[d] Standards for irrigation use
[e] pH in standard units.
[f] Specific conductance in µmhos/cm @ 25° C, measured in the field
[g] Temperature in ℃, measured in the field
[h] Arithmetic mean concentration prior to tailing spill in October 1980. Number of samples collected prior to spill shown in parentheses. One half of detection limit used in calculation for non-detects.

mg/L = Milligrams per liter
NM = Not measured
NS = No New Mexico regulatory standard set for parameter

Table C-3b. Summary of Historical Groundwater Quality Analyses
Well 14

Parameter	New Mexico Regulatory Standard [a]	Average Pre-Spill Concentration [h] (mg/L)	Concentration (mg/L)																								
	Sample Date		01/19/99	04/11/99	07/05/99	10/27/99	01/16/00	04/19/00	07/05/00	10/23/00	01/14/01	04/17/01	07/15/01	10/22/01	01/23/02	04/09/02	07/24/02	10/16/02	01/23/03	04/21/03	07/16/03	11/04/03	01/20/04	04/21/04	07/20/04	10/06/04	01/21/05
Al[d]	5.0	0.025(1)	<0.05	<0.0049	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.16	<0.05	<0.05	NM	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.05	<0.02	<0.02	0.396	0.272	<0.02	0.200
As[b]	0.1	0.004 (6)	<0.0049	<0.05	<0.0049	0.014	<0.0049	<0.0049	<0.0049	<0.0049	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	<0.025
B[d]	0.75	0.03(8)	0.05	0.07	0.06	<0.05	<0.05	0.05	<0.05	0.05	<0.05	<0.05	<0.05	NM	0.05	<0.05	0.05	<0.05	<0.05	0.03	0.03	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Ca	NS	159(9)	146	157	156	138	163	162	152	155	154	147	143	NM	179	163	157	149	163	193	158	159	163	160	157	194	184
Cd[b]	0.01	0.002(8)	<0.0049	0.008	<0.0049	<0.0049	<0.0049	<0.0049	<0.0049	<0.0049	<0.005	<0.005	<0.005	NM	<0.005	<0.005	<0.005	<0.005	<0.005	0.0002	<0.001	<0.002	<0.002	<0.002	0.0022	<0.002	<0.002
Cl[c]	250	36(11)	26	46	30	51	33	35	30	31	30	28	43	NM	37	35	104	35	45	21	25.8	28	26.2	32.3	33.4	26.8	27.3
Co[d]	0.05	0.005(5)	<0.0099	<0.0099	<0.0099	<0.0099	<0.0099	<0.0099	<0.0099	<0.0099	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	<0.006
Cu[c]	1.0	0.01(10)	<0.0099	<0.0099	<0.0099	<0.0099	<0.0099	<0.0099	0.01	0.14	0.05	<0.01	<0.01	NM	<0.01	<0.01	0.03	0.01	<0.01	<0.005	0.012	0.0063	<0.003	0.0832	0.0726	0.0053	0.046
F[b]	1.6	0.91(10)	0.25	0.31	0.22	0.26	0.12	0.22	0.28	0.05	0.25	0.4	0.17	NM	0.4	0.12	0.31	0.35	0.13	<0.1	0.14	0.28	0.21	0.34	0.33	0.48	0.244
Fe[c]	1.0	0.064(8)	<0.0199	<0.0199	<0.0199	<0.0199	<0.0199	<0.0199	<0.0199	<0.0199	<0.02	<0.02	<0.02	NM	<0.02	<0.02	<0.02	<0.02	<0.02	<0.05	<0.03	<0.02	<0.02	0.077	<0.02	<0.02	<0.06
HCO_3	NS	149(7)	176	154	197	121	187	189	187	169	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	152
Hg[b]	0.002	0.001(4)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	<0.0002
K	NS	1.5(8)	2	2	2.1	1.6	2.5	2.1	1.9	1.9	2.1	1.9	2	NM	2.2	2	2.1	1.9	2.1	2	2	2.2	2.2	2.1	2	2.3	2.26
Mg	NS	13.5(11)	16	16.5	17.3	14.8	18.2	18.3	17	18.2	17.2	15.9	16.4	NM	19.6	17.9	17.5	15.1	17.5	20	17.2	17.7	17.9	17.6	17.5	21.3	21.4
Mn[c]	0.2	0.005(2)	<0.0099	<0.0099	<0.0099	<0.0099	<0.0099	<0.0099	<0.0099	<0.0099	0.01	<0.01	<0.01	NM	<0.01	<0.01	0.03	<0.01	<0.01	0.02	0.03	0.0212	<0.002	0.149	0.141	<0.002	0.0669
Mo[d]	1.0	0.24(8)	<0.0099	0.01	<0.0099	<0.0099	<0.0099	<0.0099	<0.0099	<0.0099	<0.01	<0.01	<0.01	NM	<0.01	<0.01	0.01	0.02	<0.01	0.006	<0.02	0.0186	0.008	0.0204	0.0108	0.0137	0.0119
Na	NS	44.9(9)	26.8	27.1	28.5	28.5	30.4	23.2	22.3	37.8	27.8	26.6	27	NM	32	28.9	28	23.4	25.9	27	27.1	26	27.1	26.5	26.6	28.4	26.7
Pb[b]	0.05	0.005(10)	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	NM	<0.05	<0.05	<0.05	<0.02	<0.05	<0.003	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
pH[c,e]	>6,<9	7.5(11)	7.2	7.2	7.2	7.2	7.2	7.1	7.2	7.1	6.5	7.1	7	6.53	7	6.9	6.8	6.8	6.7	7.2	7.8	7.49	7.51	7.46	7.79	6.46	6.8
Se[b]	0.05	0.003(5)	<0.0049	<0.0049	<0.0049	<0.0049	<0.0049	<0.0049	<0.0049	<0.0049	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	<0.04
SO_4[c]	600	378(11)	314	303	308	293	387	338	294	352	346	340	273	NM	295	313	147	311	327	362	283	329	334	348	352	441	413
Specific Conductance[f]	NS	992(7)	790	750	780	950	850	935	903	904	935	801	961	885	869	917	780	791	821	825	772	876	878	894	923	1146	949
Temperature[g]	NS	NM(11)	19.3	17.8	18.7	19	17.7	17.1	20.1	18.8	18.2	19	19.4	18.1	17.3	19.2	19.6	19.3	17.1	18.1	19.7	19.3	18.7	19.3	21.1	19.2	15.6
TDS[c]	1000	805(11)	670	700	740	760	760	730	770	770	720	730	740	NM	780	740	780	770	780	770	760	724	730	783	742	900	864
Zn[c]	10.0	0.005(2)	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	0.034	0.073	<0.025	<0.025	NM	<0.025	0.037	0.03	0.03	<0.025	0.015	0.03	0.0134	<0.005	0.177	0.154	<0.005	0.076

[a] New Mexico Water Quality Control Commission Regulations, 20.6.2 NMAC (NMWQCC, 2002).
[b] Human health standard
[c] Other standard for domestic water supply
[d] Standards for irrigation use
[e] pH in standard units.
[f] Specific conductance in μmhos/cm @ 25° C, measured in the field
[g] Temperature in ℃, measured in the field
[h] Arithmetic mean concentration prior to tailing spill in October 1980. Number of samples collected prior to spill shown in parentheses. One half of detection limit used in calculation for non-detects.

mg/L = Milligrams per liter
NM = Not measured
NS = No New Mexico regulatory standard set for parameter

Table C-3c. Summary of Historical Groundwater Quality Analyses
Well 15

Parameter	New Mexico Regulatory Standard [a]	Average Pre-Spill Concentration [h] (mg/L)	Concentration (mg/L)																								
	Sample Date		01/19/99	04/11/99	07/05/99	10/27/99	01/16/00	04/19/00	07/05/00	10/23/00	01/14/01	04/17/01	07/15/01	10/22/01	01/23/02	04/09/02	07/24/02	10/16/02	01/23/03	04/21/03	07/16/03	11/04/03	01/20/04	04/21/04	07/20/04	10/06/04	01/21/05
Al[d]	5.0	0.025(1)	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
As[b]	0.1	0.005(5)	0.0	<0.0049	<0.0049	<0.0049	<0.0049	<0.0049	<0.0049	<0.0049	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	<0.025
B[d]	0.75	0.04(7)	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	NM	<0.05	<0.05	<0.05	<0.05	<0.05	0.02	0.03	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Ca	NS	139(8)	139	137	134	126	134	132	127	127	125	112	121	NM	136	131	122	116	120	158	142	124	128	131	129	132	108
Cd[b]	0.01	0.002(7)	<0.0049	<0.0049	<0.0049	<0.0049	<0.0049	<0.0049	<0.0049	<0.0049	0.011	<0.005	<0.005	NM	<0.005	<0.005	<0.005	<0.005	<0.005	0.0001	0.005	<0.002	<0.002	0.0387	0.0267	<0.002	<0.002
Cl[c]	250	33(9)	23	42	49	26	29	29	36	28	26	24	41	NM	34	31	31	32	24	22	23.3	24.1	24.4	27	27.8	25.5	23.7
Co[d]	0.05	0.005(5)	<0.0099	<0.0099	<0.0099	<0.0099	<0.0099	<0.0099	<0.0099	<0.0099	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	<0.006
Cu[c]	1.0	0.01(8)	<0.0099	<0.0099	<0.0099	<0.0099	<0.0099	<0.0099	0.01	0.07	0.66	0.01	<0.01	NM	0.09	<0.01	0.03	0.01	<0.01	<0.005	0.138	0.0147	<0.003	2.56	1.6	0.0061	0.102
F[b]	1.6	0.62(8)	0.28	0.39	0.28	0.31	0.17	0.06	0.33	<0.05	1.42	0.4	0.3	NM	0.5	2.18	0.34	0.37	0.38	<0.1	0.18	0.33	0.27	0.38	0.31	0.42	0.264
Fe[c]	1.0	0.24(7)	<0.0199	<0.0199	<0.0199	<0.0199	<0.0199	<0.0199	<0.0199	<0.0199	0.43	<0.02	<0.02	NM	<0.02	<0.02	<0.02	<0.02	<0.02	<0.05	0.31	0.055	<0.02	3.81	0.126	<0.02	0.098
HCO_3	NS	152(6)	170	162	167	157	164	160	167	155	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	142
Hg[b]	0.002	0.001(4)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	<0.0002
K	NS	1.4(7)	1.9	1.9	1.7	1.1	2.1	2.0	1.8	1.8	1.8	1.6	1.8	NM	1.9	1.8	1.9	1.7	1.8	2	2	2	2	2.1	1.9	1.9	1.57
Mg	NS	16.3(9)	14.3	14.1	14.4	13.1	14.4	14.3	13.7	14.4	14.6	11.8	13.5	NM	14.8	14	13.5	12.4	12.9	16	11.9	14.1	14.2	20.5	19.2	14.5	12.5
Mn[c]	0.2	0.005(1)	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
Mo[d]	1.0	0.01(7)	0.04	0.04	0.04	0.02	0.03	0.04	0.03	0.04	0.03	0.03	0.03	NM	0.03	0.03	0.03	0.03	0.03	0.025	0.02	0.0331	0.0256	0.035	0.026	0.0292	0.0219
Na	NS	25.1(9)	25.7	24.8	25.3	26.9	26.0	20.8	21.1	31.8	24.2	22.1	23.6	NM	27.6	25.9	24.3	22.9	22.4	24	25.7	22.1	23.5	24.5	23.9	24.1	18.9
Pb[b]	0.05	0.005(8)	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	NM	<0.05	<0.05	<0.05	<0.05	<0.05	<0.003	<0.005	<0.005	<0.005	0.0052	<0.005	<0.005	<0.005
pH[c,e]	>6,<9	7.4(9)	7.2	7.3	7.3	6.5	7.4	7.3	7.2	7.5	5.8	7.3	7.1	6.71	7.1	7.1	7	7.1	6.9	7.4	7.9	7.57	7.58	7.81	7.9	6.57	7.09
Se[b]	0.05	0.003(4)	<0.0049	<0.0049	<0.0049	<0.0049	<0.0049	<0.0049	<0.0049	<0.0049	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	<0.04
SO_4[c]	600	282(9)	289	263	251	254	299	289	238	258	462	253	231	NM	214	243	207	252	261	289	246	247	257	266	266	259	244
Specific Conductance[f]	NS	868(5)	700	690	700	850	705	806	769	777	768	681	814	724.0	685	757	659	654	665	679	679	735	732	746	764	837	697
Temperature[g]	NS	NM(9)	17.1	18.5	18.6	19	18.2	16.2	19.8	18.3	18.1	19	19.6	18.2	16.8	17.9	19.9	19.2	18.5	18.2	20.6	18.8	18.6	19.7	20.8	19.2	17.4
TDS[c]	1000	675(9)	610	620	530	630	620	570	700	630	700	600	620	NM	600	580	660	640	610	620	260	603	583	662	612	617	593
Zn[c]	10.0	0.005(1)	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM

[a] New Mexico Water Quality Control Commission Regulations, 20.6.2 NMAC (NMWQCC, 2002).
[b] Human health standard
[c] Other standard for domestic water supply
[d] Standards for irrigation use
[e] pH in standard units.
[f] Specific conductance in µmhos/cm @ 25° C, measured in the field
[g] Temperature in ℃, measured in the field
[h] Arithmetic mean concentration prior to tailing spill in October 1980. Number of samples collected prior to spill shown in parentheses. One half of detection limit used in calculation for non-detects.

mg/L = Milligrams per liter
NM = Not measured
NS = No New Mexico regulatory standard set for parameter
shaded cells indicate parameter above applicable regulatory standard

Table C-3d. Summary of Historical Groundwater Quality Analyses
Well 19

Parameter	New Mexico Regulatory Standard [a]	Concentration (mg/L)																								
	Sample Date	01/12/99	04/10/99	07/04/99	10/20/99	01/14/00	04/18/00	07/01/00	10/08/00	01/13/01	04/09/01	07/12/01	10/07/01	01/10/02	04/03/02	07/24/02	10/14/02	01/20/03	03/20/03	07/14/03	10/13/03	01/14/04	04/19/04	07/20/04	10/02/04	01/20/05
Al[d]	5.0	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
As[b]	0.1	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
B[d]	0.75	0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	NM	<0.05	0.060	<0.05	<0.05	<0.05	0.03	0.03	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Ca	NS	149	118	138	144	105	128	143	121	135	139	123	NM	150	172	160	139	147	127	169	158	154	191	182	194	177
Cd[b]	0.01	<0.004	<0.0049	<0.0049	<0.0049	<0.0049	<0.0049	<0.0049	<0.0049	<0.005	<0.005	<0.005	NM	<0.005	<0.005	<0.005	<0.005	<0.005	<0.0001	<0.001	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Cl[c]	250	45	56	48	52	45	51	55	48	52	53	58	NM	51	56	25	53	62	55	48.8	55	53	59.3	61.5	58.6	52.8
Co[d]	0.05	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
Cu[c]	1.0	<0.0049	<0.0099	<0.0099	0.02	<0.0099	0.01	0.02	0.02	0.02	0.02	<0.01	NM	0.06	0.01	<0.01	<0.01	0.02	<0.005	0.007	0.0117	0.0085	0.0707	0.0379	0.0066	0.019
F[b]	1.6	0.31	0.41	0.33	0.36	0.25	0.33	0.38	0.9	0.28	0.32	0.3	NM	<0.01	0.26	0.3	0.43	0.19	<0.1	0.2	0.29	0.34	0.39	0.29	0.33	0.258
Fe[c]	1.0	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
HCO_3	NS	146	146	142	148	143	132	132	135	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	96.0
Hg[b]	0.002	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
K	NS	2.4	1.6	1.9	1.7	1.6	1.9	1.8	1.8	1.8	1.9	1.7	NM	2.1	1.9	1.7	1.5	1.9	1.3	1.5	2.3	1.8	2.2	1.9	2.1	1.84
Mg	NS	10.4	10.2	12.6	12.7	9.2	11.8	12.6	11	11.8	11.8	11.3	NM	13	14.5	13.6	11	11.9	11.9	14.2	14.3	13.8	16.5	16	16.6	15.3
Mn[c]	0.2	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
Mo[d]	1.0	0.02	<0.0099	<0.0099	<0.0099	<0.0099	<0.0099	<0.0099	<0.0099	<0.01	<0.01	<0.01	NM	<0.01	<0.01	<0.01	<0.01	<0.01	<0.005	<0.02	0.0132	0.0174	0.0154	<0.008	0.0097	<0.008
Na	NS	22.2	22.8	28.6	30.2	24.4	21.1	22	26.5	27.5	22.3	27.6	NM	27.8	28	29.1	23.1	28.6	24.9	29.1	28.2	26.8	31.2	31	31.6	28.4
Pb[b]	0.05	<0.0049	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	NM	<0.05	<0.05	<0.05	<0.05	<0.05	<0.003	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
pH[c,e]	>6,<9	7.5	7.6	7.6	7.4	7.6	7.6	7.5	7.5	7	6.9	7.5	7.59	7.5	7.4	7.3	7.4	7.3	7.6	8	7.78	7.77	7.84	7.96	6.49	7.46
Se[b]	0.05	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
SO_4[c]	600	254	204	248	290	202	269	261	252	290	212	233	NM	234	360	365	307	318	356	335	386	354	449	459	468	435
Specific Conductance[f]	NS	690	600	750	880	650	786	835	776	855	761	811	954	757	963	835	778	801	773	861	972	893	1019	1065	1149	1048
Temperature[g]	NS	18.4	17.6	20.4	19.2	19.4	17.8	20.6	18.6	16.9	19.9	20.7	19.4	18.9	19.6	20.5	19.7	18.5	18.8	21.1	20.6	19.5	20.5	21.6	19.6	19
TDS[c]	1000	572	540	650	640	510	560	730	530	620	760	640	NM	670	760	830	730	750	660	840	786	715	891	853	844	874
Zn[c]	10.0	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM

[a] New Mexico Water Quality Control Commission Regulations, 20.6.2 NMAC (NMWQCC, 2002).
[b] Human health standard
[c] Other standard for domestic water supply
[d] Standards for irrigation use
[e] pH in standard units.
[f] Specific conductance in µmhos/cm @ 25° C, measured in the field
[g] Temperature in °C, measured in the field

mg/L = Milligrams per liter
NM = Not measured
NS = No New Mexico regulatory standard set for parameter

Table C-3e. Summary of Historical Groundwater Quality Analyses
Well 37

Parameter	New Mexico Regulatory Standard [a]	Concentration (mg/L)																								
	Sample Date	01/19/99	04/10/99	07/04/99	10/27/99	01/14/00	04/19/00	07/05/00	10/08/00	01/13/01	04/10/01	07/14/01	10/07/01	01/23/02	04/09/02	07/24/02	10/15/02	01/20/03	04/17/03	07/16/03	10/31/03	01/14/04	04/29/04	07/20/04	10/06/04	01/21/05
Al[d]	5.0	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
As[b]	0.1	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
B[d]	0.75	0.07	0.07	0.08	0.06	0.07	0.07	<0.05	0.07	0.07	0.07	0.07	NM	0.07	0.07	0.07	0.06	0.06	0.04	0.06	0.044	0.046	<0.04	<0.04	0.05	0.046
Ca	NS	68.6	78.7	71.8	73.8	74.0	71.6	146	70.8	71.3	68.3	68.6	NM	83	75.4	78.3	76.1	77.2	89	82.6	80.5	81	86.6	83.6	87.3	90.1
Cd[b]	0.01	<0.0049	<0.0049	<0.0049	<0.0049	<0.0049	<0.0049	<0.0049	<0.0049	<0.005	<0.005	<0.005	NM	<0.005	<0.005	<0.005	<0.005	<0.005	0.0004	<0.001	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Cl[c]	250	18	38	22	21	23	22	32	22	21	18	19	NM	19	20	20	20	21	17	19.3	22.8	21.4	24.1	24.2	23.1	22.2
Co[d]	0.05	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
Cu[c]	1.0	<0.0099	<0.0099	0.13	<0.0099	0.01	<0.0099	0.01	0.01	0.02	0.01	<0.01	NM	<0.01	<0.01	<0.01	<0.01	<0.01	0.011	<0.005	0.0083	0.0066	0.0076	0.025	0.0042	0.011
F[b]	1.6	1.2	1.3	1.28	1.24	1.23	1.24	0.31	1.5	1.19	1.26	1.1	NM	1	1.27	1.28	1.46	1.17	0.6	1.29	NM	1.28	1.21	1.23	1.25	1.18
Fe[c]	1.0	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
HCO_3	NS	268	282	267	306	308	267	180	265	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	231.0
Hg[b]	0.002	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
K	NS	3.8	3.7	1.28	1.24	3.9	1.24	1.9	3.9	3.8	3.5	3.7	NM	4.1	3.6	3.8	3.1	3.5	4	3.6	3.7	3.8	3.8	3.6	3.9	3.75
Mg	NS	14	14.5	14.2	14.3	14.2	14.4	16.2	14.2	13.7	12.7	13.3	NM	15.2	13.7	14.2	12	12.7	15	14	13.6	14.7	14.2	14	14.6	15.7
Mn[c]	0.2	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
Mo[d]	1.0	<0.0099	<0.0099	<0.0099	<0.0099	<0.0099	<0.0099	<0.0099	<0.0099	<0.01	<0.01	<0.01	NM	<0.01	<0.01	<0.01	<0.01	<0.01	<0.005	<0.02	0.0137	0.0149	0.0106	<0.008	0.0122	0.0085
Na	NS	50.2	47.5	51.5	42.3	58.2	41.4	20.9	50.6	51.1	37.5	54.2	NM	59.3	53.2	52.8	42.4	51.7	51	50.7	44.6	50.5	52.5	50.9	53.5	49.7
Pb[b]	0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	NM	<0.05	<0.05	<0.05	<0.05	<0.05	<0.003	<0.005	0.0058	<0.005	<0.005	<0.005	<0.005	<0.005
pH[c,e]	>6,<9	7.4	7.4	7.3	7.4	7.4	7.4	7.3	7.4	7.2	7	7.2	7.25	7.3	7.2	7.1	7.1	7.1	7.4	7.9	7.75	7.91	7.92	7.92	6.73	7.08
Se[b]	0.05	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
SO_4[c]	600	88	109	88	80	98	90	271	96	97	69	82	NM	87.0	102	104	106	102	105	89.6	106	108	111	112	111	142
Specific Conductance[f]	NS	590	500	600	700	600	649	634	645	645	564	682	692	602	662	580	585	592	595	617	659	635	648	679	740	669
Temperature[g]	NS	19.6	17.5	19.6	19	18.1	17.5	20.3	18	19.4	19	19.4	19.7	17.2	18.4	20.3	19.3	19	18.3	21.2	19.1	18.5	19	21.3	19.5	16
TDS[c]	1000	430	470	470	440	470	430	730	400	440	530	450	NM	480	480	540	500	490	470	500	487	447	478	478	485	555
Zn[c]	10.0	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM

[a] New Mexico Water Quality Control Commission Regulations, 20.6.2 NMAC (NMWQCC, 2002).
[b] Human health standard
[c] Other standard for domestic water supply
[d] Standards for irrigation use
[e] pH in standard units.
[f] Specific conductance in µmhos/cm @ 25° C, measured in the field
[g] Temperature in ℃, measured in the field

mg/L = Milligrams per liter
NM = Not measured
NS = No New Mexico regulatory standard set for parameter

Table C-3f. Summary of Historical Groundwater Quality Analyses
Well 38

Parameter	New Mexico Regulatory Standard [a]	Concentration (mg/L)																								
	Sample Date	01/12/99	04/09/99	07/04/99	10/20/99	01/14/00	04/18/00	07/01/00	10/07/00	01/13/01	04/09/01	07/12/01	10/06/01	01/10/02	04/02/02	07/24/02	10/02/02	01/20/03	03/14/03	07/14/03	09/30/03	01/13/04	04/19/04	07/19/04	10/02/04	01/18/05
Al[d]	5.0	<0.05	<0.05	0.26	0.34	<0.05	0.09	<0.05	<0.05	<0.05	<0.05	<0.05	NM	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	4.33	<0.02	0.048	0.032	<0.02	<0.02
As[b]	0.1	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
B[d]	0.75	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	NM	<0.05	<0.05	<0.05	<0.05	<0.05	0.03	0.03	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Ca	NS	180	108	98.6	114	73.6	69.1	71	61.5	57.4	59	54.5	NM	68.2	59.5	62.6	67.7	60.2	56.8	67	69.6	66.7	70.6	67.9	89.1	81.3
Cd[b]	0.01	<0.0049	<0.0049	<0.0049	<0.0049	<0.0049	<0.0049	<0.0049	<0.0049	<0.005	<0.005	<0.005	NM	<0.005	<0.005	<0.005	<0.005	<0.005	<0.0001	<0.001	0.0406	<0.002	<0.002	<0.002	<0.002	<0.002
Cl[c]	250	43	30	28	40	26	26	27	25	24	20	22	NM	24	25	27	28	32	37	33.6	43.4	43.2	49.8	53.3	47.3	53.6
Co[d]	0.05	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
Cu[c]	1.0	<0.0099	<0.0099	0.02	0.06	<0.0099	<0.0099	<0.0099	0.02	<0.01	0.02	<0.01	NM	0.04	<0.01	<0.01	<0.01	<0.01	0.011	<0.005	3.39	0.0041	0.0314	<0.003	0.0062	<0.01
F[b]	1.6	0.34	0.5	0.46	0.47	0.41	0.48	0.54	0.7	0.4	0.31	0.47	NM	0.5	0.41	0.51	0.65	0.53	<0.1	0.43	0.47	0.51	0.39	0.53	0.45	0.405
Fe[c]	1.0	<0.0199	0.02	0.25	0.21	<0.0199	0.05	<0.0199	<0.0199	<0.02	<0.02	<0.02	NM	<0.02	<0.02	<0.02	<0.02	<0.02	0.13	<0.03	0.07	<0.02	0.021	<0.02	<0.02	<0.02
HCO_3	NS	181	194	171	176	169	169	168	151	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
Hg[b]	0.002	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
K	NS	2.5	1.7	1.8	2	1.6	1.7	1.5	1.6	1.4	1.5	1.4	NM	1.7	1.5	1.4	1.5	1.4	1.4	1.3	1.9	1.5	1.7	1.5	1.8	1.61
Mg	NS	22.1	12.6	12.4	14.1	8.4	8.2	8.6	7.5	6.7	6.6	6.4	NM	7.6	6.6	7.2	7	6.2	6.2	7.4	14.8	7.47	8.11	7.54	9.2	8.69
Mn[c]	0.2	NM	NM	NM	NM	NM	NM	NM	NM	<0.01	<0.01	<0.01	NM	<0.01	<0.01	<0.01	0.01	<0.01	<0.02	<0.01	3.31	0.0081	0.0281	0.0072	0.0046	<0.004
Mo[d]	1.0	0.01	<0.0099	<0.0099	0.01	<0.0099	<0.0099	<0.0099	<0.0099	0.01	0.01	0.01	NM	0.01	<0.01	0.02	0.01	<0.01	0.01	<0.02	0.0154	0.0192	0.0211	0.0136	0.0165	0.0137
Na	NS	27.1	17.2	18.1	20.5	15.8	11.2	14.6	12.9	12.9	10.2	12.4	NM	13.7	11.7	13.5	12.9	13.6	12.4	13.5	14.2	13	14.3	13.9	16.1	14.3
Pb[b]	0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	NM	<0.05	<0.05	<0.05	<0.05	<0.05	<0.003	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
pH[c,e]	>6,<9	7.4	7.5	7.5	6.8	7.7	7.6	7.6	7.6	7.4	7.2	7.4	7.51	7.6	7.4	7.4	7.5	7.3	7.7	8.1	7.95	7.82	7.91	7.99	6.62	6.87
Se[b]	0.05	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
SO_4[c]	600	353	174	127	201	72	60	64	43	34	25	27	NM	30	30	30	49	37	44	35.3	39.9	39.9	44.4	44.8	106	76.9
Specific Conductance[f]	NS	900	460	500	750	380	441	425	399	386	342	390	402	358	388	340	380	363	366	368	429	421	430	461	582	477
Temperature[g]	NS	18.8	17.5	19.3	18.1	18.7	18.4	21	18.7	17.3	18.5	21.2	19.3	17.5	19.9	19.9	19.6	18.5	19.1	20.4	22.1	19.8	19.7	21.9	19.8	15.4
TDS[c]	1000	794	490	490	530	320	320	330	250	250	340	270	NM	300	300	350	320	300	210	310	294	277	370	313	371	346
Zn[c]	10.0	<0.025	<0.025	0.027	0.1	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	NM	<0.025	0.038	<0.025	<0.025	<0.025	0.021	<0.01	4.54	0.006	0.0185	<0.005	<0.005	<0.01

[a] New Mexico Water Quality Control Commission Regulations, 20.6.2 NMAC (NMWQCC, 2002).
[b] Human health standard
[c] Other standard for domestic water supply
[d] Standards for irrigation use
[e] pH in standard units.
[f] Specific conductance in µmhos/cm @ 25° C, measured in the field
[g] Temperature in °C, measured in the field

mg/L = Milligrams per liter
NM = Not measured
NS = No New Mexico regulatory standard set for parameter
shaded cells indicate parameter above applicable regulatory standard

Table C-3g. Summary of Historical Groundwater Quality Analyses
Well 44

Parameter	New Mexico Regulatory Standard [a]	Concentration (mg/L)																										
	Sample Date	01/13/99	04/10/99	07/04/99	10/20/99	01/07/00	01/14/00	04/18/00	07/01/00	10/08/00	01/13/01	04/08/01	04/09/01	07/13/01	10/07/01	01/10/02	04/03/02	07/24/02	10/14/02	01/20/03	03/20/03	07/16/03	10/31/03	01/14/04	04/29/04	07/20/04	10/02/04	01/21/05
Al[d]	5.0	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
As[b]	0.1	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
B[d]	0.75	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	NM	<0.05	NM	<0.05	<0.05	NM	<0.05	<0.05	<0.05	<0.05	<0.05	0.02	0.03	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Ca	NS	55.5	53.8	46.9	48	47	49.5	49.6	65.6	NM	46.1	NM	45.8	46.6	NM	52.0	46.6	48.5	9	47.2	45	48.5	46.7	48.8	46.1	47.6	49.4	56.2
Cd[b]	0.01	<0.004	<0.0049	<0.0049	<0.0049	<0.0049	<0.0049	<0.0049	<0.0049	NM	<0.005	NM	<0.005	<0.005	NM	<0.005	<0.005	<0.005	<0.005	<0.005	<0.0001	<0.001	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Cl[c]	250	9	12	13	12	13	13	13	10	NM	10	NM	9	10	NM	10	10	9	55	10	<1	8.3	10.6	8.67	10.5	9.39	10.1	9.73
Co[d]	0.05	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
Cu[c]	1.0	<0.0049	<0.0099	<0.0099	0.04	<0.0099	<0.0099	<0.0099	<0.0099	NM	<0.01	NM	<0.01	<0.01	NM	0.04	<0.01	<0.01	0.01	<0.01	<0.005	<0.005	0.0044	0.0091	0.0039	0.0156	0.0095	0.015
F[b]	1.6	0.5	0.64	0.6	0.55	0.7	0.47	0.5	0.71	NM	0.61	NM	0.5	0.5	NM	0.5	0.5	0.57	0.71	0.57	<0.1	0.49	NM	0.59	0.57	0.6	0.56	0.599
Fe[c]	1.0	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
HCO_3	NS	168	170	149	157	167	173	167	173	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	136.0
Hg[b]	0.002	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
K	NS	2.3	1.8	1.6	1.7	1.7	1.6	1.8	1.8	NM	1.7	NM	1.7	1.5	NM	1.9	1.8	1.6	1.4	1.7	1.1	1.5	1.8	1.7	1.8	1.7	1.9	1.7
Mg	NS	9.6	10.8	10	10.6	10.6	10.2	10.9	17	NM	9.9	NM	9.7	10.4	NM	11.1	10	10.3	8.6	9.4	9.8	10	9.9	10.6	9.83	10.1	10.7	11
Mn[c]	0.2	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
Mo[d]	1.0	0.01	<0.0099	0.01	0.01	<0.0099	<0.0099	<0.0099	<0.0099	NM	<0.01	NM	0.01	<0.01	NM	<0.01	<0.01	<0.01	0.01	<0.01	<0.005	<0.02	0.0114	0.0145	0.0103	0.0092	0.0118	0.0101
Na	NS	18.1	22.4	23	27.8	19.4	22.7	17.3	24.4	NM	20.7	NM	16.2	21.6	NM	24.5	21	21.5	18	21.5	19.7	20.6	22.3	20.8	23.1	22.5	21.7	20.9
Pb[b]	0.05	<0.0049	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	NM	<0.05	NM	<0.05	<0.05	NM	<0.05	<0.05	<0.05	<0.05	<0.05	<0.003	<0.005	0.0053	<0.005	<0.005	<0.005	<0.005	<0.005
pH[c,e]	>6,<9	7.8	7.7	7.8	7.6	7.6	7.6	7.8	7.6	7.84	6.7	7.24	7.5	7.4	7.24	7.7	7.5	7.5	7.5	7.3	7.8	8.1	7.93	7.88	7.94	7.98	6.6	7.54
Se[b]	0.05	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
SO_4[c]	600	59	69	64	59	57	59	61	115	NM	71	NM	39	47	NM	57	64	54	56	52	<1	49.9	64	54.6	65.7	59.6	65	64.6
Specific Conductance[f]	NS	340	320	350	329	390	330	397	384	390	388	336	336.3	402	412	343	381	334	329	334	336	330	344	352	346	366	411	332
Temperature[g]	NS	18.1	16.9	19	17.4	15.8	18.7	17.6	18.4	15.8	17.6	18.3	18.3	19.5	17.9	16.5	18.1	19.3	18.3	17.4	18.1	19.3	17.9	17.1	18.1	19.5	19.8	12.9
TDS[c]	1000	260	300	300	270	220	270	280	400	NM	270	NM	330	270	NM	290	260	330	280	280	270	270	271	245	282	267	239	270
Zn[c]	10.0	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM

[a] New Mexico Water Quality Control Commission Regulations, 20.6.2 NMAC (NMWQCC, 2002).
[b] Human health standard
[c] Other standard for domestic water supply
[d] Standards for irrigation use
[e] pH in standard units.
[f] Specific conductance in μmhos/cm @ 25° C, measured in the field
[g] Temperature in ℃, measured in the field

mg/L = Milligrams per liter
NM = Not measured
NS = No New Mexico regulatory standard set for parameter

Table C-3h. Summary of Historical Groundwater Quality Analyses
Well 47

Parameter	New Mexico Regulatory Standard [a]	Concentration (mg/L)																								
	Sample Date	01/13/99	04/10/99	07/04/99	10/20/99	01/14/00	04/18/00	07/01/00	10/08/00	01/13/01	04/09/01	07/13/01	10/07/01	01/10/02	04/03/02	07/24/02	10/14/02	01/20/03	03/20/03	07/14/03	10/31/03	01/14/04	04/29/04	07/20/04	10/02/04	01/18/05
Al[d]	5.0	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
As[b]	0.1	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
B[d]	0.75	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	NM	<0.05	<0.05	<0.05	<0.05	<0.05	0.02	0.02	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Ca	NS	56.6	54.2	51.5	47.5	48.3	49.1	50.8	47.9	47	47.1	47.1	NM	56.7	51.8	53.5	46.7	49	37.8	49.6	47.4	46.4	48.8	49.4	52.8	50.2
Cd[b]	0.01	<0.004	0.008	<0.0049	<0.0049	<0.0049	<0.0049	<0.0049	<0.0049	<0.005	<0.005	<0.005	NM	<0.005	<0.005	<0.005	<0.005	<0.005	<0.0001	<0.001	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Cl[c]	250	7	9	10	9	11	11	7	11	7	9	10	NM	8	9	8	8	10	8	7.3	8.64	8.61	7.67	8.32	7.94	9.61
Co[d]	0.05	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
Cu[c]	1.0	<0.0049	<0.0099	0.01	0.01	<0.0099	<0.0099	<0.0099	<0.0099	<0.01	0.02	<0.01	NM	0.03	<0.01	<0.01	0.01	<0.01	<0.005	<0.005	0.0061	0.0056	0.0049	0.0123	0.0042	<0.01
F[b]	1.6	0.5	0.54	0.5	0.56	0.38	0.48	0.49	0.7	0.42	0.42	0.5	NM	0.4	0.48	0.53	0.65	0.53	<0.1	0.43	NM	0.52	0.54	0.51	0.45	0.431
Fe[c]	1.0	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
HCO_3	NS	192	189	195	188	192	182	182	178	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
Hg[b]	0.002	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
K	NS	2.2	1.7	1.6	1.6	1.6	1.7	1.6	1.7	1.5	1.5	1.5	NM	1.9	1.7	1.7	1.3	1.6	1	1.5	2.7	1.6	1.8	1.6	1.8	1.59
Mg	NS	5.9	7.4	8.1	7.2	6.4	7	7	6.8	6.5	6.3	6.6	NM	7.7	7	7.1	5.9	6.3	5.7	6.7	7.31	6.67	6.73	6.96	7.16	6.68
Mn[c]	0.2	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
Mo[d]	1.0	0.01	<0.0099	<0.0099	<0.0099	<0.0099	<0.0099	<0.0099	0.01	<0.01	0.01	<0.01	NM	0.01	<0.01	<0.01	<0.01	<0.01	<0.005	<0.02	0.0118	0.0128	0.0104	0.0086	0.011	0.0097
Na	NS	9.5	11.4	14.4	15.7	13.1	10.4	9.7	11.7	12.8	9.1	13	NM	13.9	11.8	13	11.2	13.3	10.1	12.3	13	12	14.1	12.8	13.2	11.8
Pb[b]	0.05	<0.0049	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	NM	<0.05	<0.05	<0.05	<0.05	<0.05	<0.003	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
pH[c,e]	>6,<9	7.5	7.7	7.7	7.6	7.7	7.8	7.7	7.7	7	7.4	7.6	7.65	7.51	7.69	7.69	7.42	7.25	7.51	7.74	7.48	7.79	7.61	7.52	7.15	7.67
Se[b]	0.05	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
SO_4[c]	600	12	22	18	16	18	19	12	25	14	13	15	NM	19	19	11	12	14	12	<10	11.1	11.5	11.7	12.6	11.8	14.2
Specific conductance[f]	NS	290	280	305	282	290	336	329	329	330	300	318	344.0	312	328	293	290	291	292	295	289	314	293	326	344	331
Temperature[g]	NS	18.4	18.1	20.6	18.1	17.7	18.8	21	18.7	18.3	19	20.9	19.3	18.4	19.5	21	19.5	19	19.4	22.2	18.1	19.1	18.7	21.2	19.8	20.3
TDS[c]	1000	212	250	240	220	230	220	260	190	200	280	220	NM	270	230	280	230	230	210	240	234	227	303	221	211	214
Zn[c]	10.0	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM

[a] New Mexico Water Quality Control Commission Regulations, 20.6.2 NMAC (NMWQCC, 2002).
[b] Human health standard
[c] Other standard for domestic water supply
[d] Standards for irrigation use
[e] pH in standard units.
[f] Specific conductance in µmhos/cm @ 25° C, measured in the field
[g] Temperature in ℃, measured in the field

mg/L = Milligrams per liter
NM = Not measured
NS = No New Mexico regulatory standard set for parameter

Table C-3i. Summary of Historical Groundwater Quality Analyses
Well G

Parameter	New Mexico Regulatory Standard [a]	Average Pre-Spill Concen-tration [h] (mg/L)	Concentration (mg/L)												
	Sample Date		10/12/98	04/11/99	10/28/99	04/19/00	04/17/01	07/15/01	10/23/01	04/09/02	10/15/02	03/24/03	10/23/03	04/21/04	10/21/04
Al[d]	5.0	NM(0)	0.18	<0.0049	0.07	<0.05	<0.05	0.06	NM	<0.05	<0.05	0.07	0.464	0.058	1.27
As[b]	0.1	0.003(2)	<0.0049	<0.05	<0.0049	<0.0049	NM	NM	NM	NM	NM	NM	NM	NM	NM
B[d]	0.75	0.12(2)	0.06	0.05	<0.05	0.05	<0.05	<0.05	NM	<0.05	<0.05	0.04	<0.04	<0.04	<0.04
Ca	NS	99(16)	134	141	135	132	114	110	NM	125	120	104	122	124	124
Cd[b]	0.01	0.002(3)	<0.004	<0.0049	<0.0049	<0.0049	<0.005	<0.005	NM	<0.005	<0.005	<0.0001	0.0025	<0.002	0.0046
Cl[c]	250	22(16)	30	41	23	26	21	38	NM	21	19	13	22	23.0	21.8
Co[d]	0.05	NM(0)	0.01	<0.0099	<0.0099	<0.0099	NM	NM	NM	NM	NM	NM	NM	NM	NM
Cu[c]	1.0	0.02(18)	0.03	<0.0099	0.08	0.01	<0.01	<0.01	NM	<0.01	0.04	<0.005	0.126	0.0115	0.145
F[b]	1.6	0.61(16)	0.62	0.45	0.37	0.36	0.5	0.36	NM	0.16	0.62	<0.1	0.42	0.48	0.41
Fe[c]	1.0	0.06(16)	0.03	<0.0199	<0.0199	<0.0199	<0.02	<0.02	NM	<0.02	<0.02	<0.05	0.038	<0.02	0.065
HCO_3	NS	168(15)	176	171	209	169	NM	NM	NM	NM	NM	NM	NM	NM	NM
Hg[b]	0.002	0.001(2)	<0.001	<0.001	<0.001	<0.001	NM	NM	NM	NM	NM	NM	NM	NM	NM
K	NS	2.6(17)	2	2.2	2	2	1.7	1.7	NM	1.8	1.7	1.3	2.3	1.8	1.9
Mg	NS	13.8(16)	16.3	16.1	15.7	15.8	14	14.5	NM	15.5	13.8	13.5	14.9	16.4	16.2
Mn[c]	0.2	0.003(3)	0.092	<0.0099	0.03	<0.0099	<0.01	<0.01	NM	<0.01	0.03	<0.02	0.19	0.0432	0.427
Mo[d]	1.0	0.005(4)	0.03	0.01	0.01	0.02	0.01	0.01	NM	0.01	0.04	0.012	0.0224	0.0285	0.0234
Na	NS	24.0(17)	24.6	25.5	19.4	26.8	24.4	23.7	NM	28	23.4	22.8	22.9	24.5	24.7
Pb[b]	0.05	0.01(3)	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	NM	<0.05	<0.02	<0.003	<0.005	<0.005	<0.005
pH[c,e]	>6,<9	7.7(17)	7.1	7.4	7.6	7.4	7.5	7.2	6.82	7.3	7.2	7.7	7.72	7.9	6.56
Se[b]	0.05	0.003(2)	<0.0049	<0.0049	<0.0049	<0.0049	NM	NM	NM	NM	NM	NM	NM	NM	NM
SO_4[c]	600	159	318	272	251	285	241	211	NM	251	245	100	223	255.0	248
Specific conductance[f]	NS	667(15)	790	700	820	787	641	780	649	720	595	606	692	664	803
Temperature[g]	NS	NM(17)	18.6	18.4	20.5	17.1	17.5	23.1	17.8	17.5	17	17.7	18.2	15.5	16.8
TDS[c]	1000	466(17)	660	630	580	600	580	600	NM	550	570	560	540	644	583
Zn[c]	10.0	0.10(3)	0.15	0.044	0.128	<0.025	<0.025	0.11	NM	0.194	0.157	0.144	0.32	0.131	0.685

[a] New Mexico Water Quality Control Commission Regulations, 20.6.2 NMAC (NMWQCC, 2002).
[b] Human health standard
[c] Other standard for domestic water supply
[d] Standards for irrigation use
[e] pH in standard units.
[f] Specific conductance in μmhos/cm @ 25° C, measured in the field
[g] Temperature in °C, measured in the field
[h] Arithmetic mean concentration prior to tailing spill in October 1980. Number of samples collected prior to spill shown in parentheses. One half of detection limit used in calculation for non-detects.

mg/L = Milligrams per liter
NM = Not measured
NS = No New Mexico regulatory standard set for parameter
shaded cells indicate parameter above applicable regulatory standard

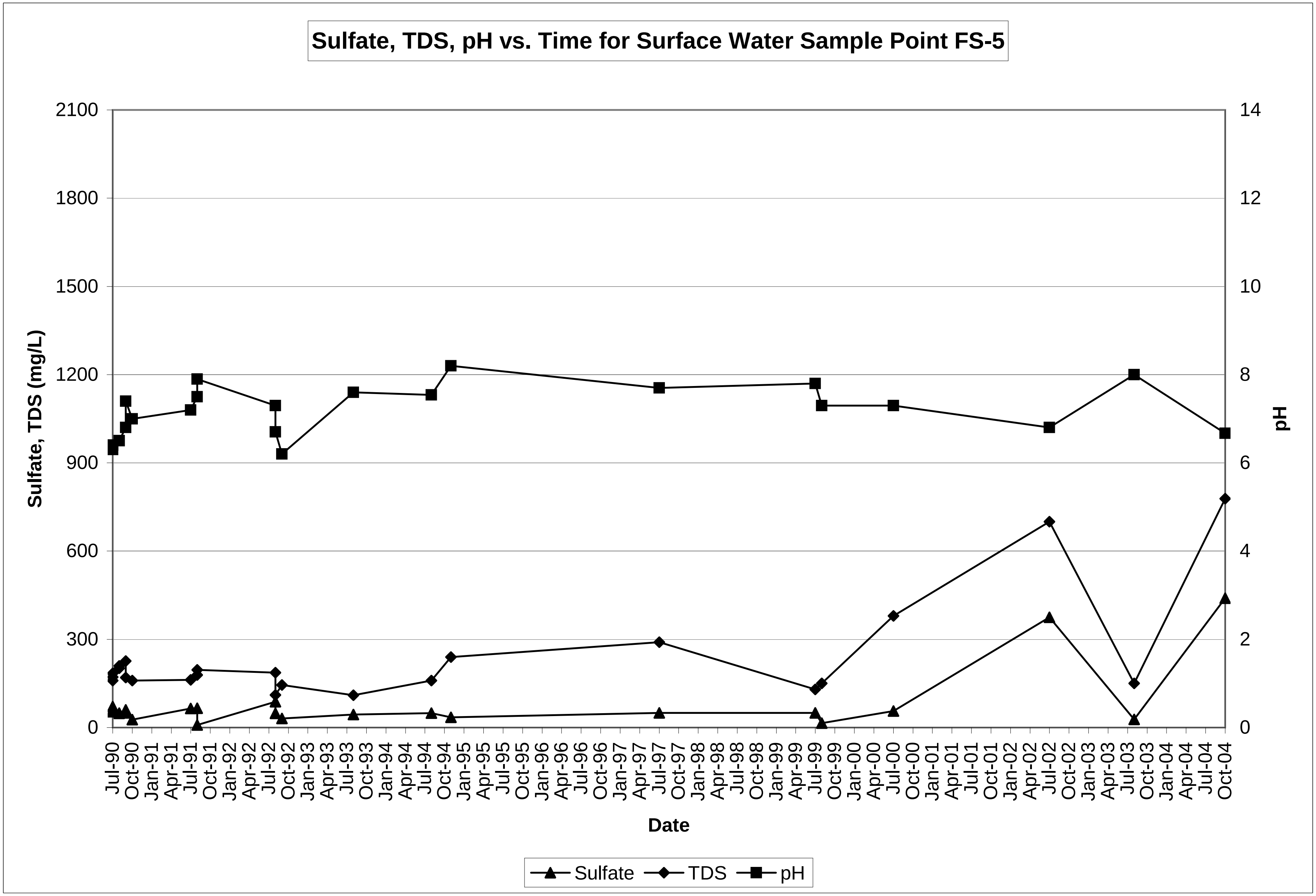
Table C-4. Summary of Groundwater Quality Analyses
March 1999 and February 2005
No. 3 Tailing Pond Reclaim Area

Parameter	New Mexico Regulatory Standard [a]	Concentration (mg/L)											
	Well	MS-2		MS-3		MS-4		MS-5		MS-8		MS-10	
	Sample Date	Mar-99	Feb-05	Mar-99	Feb-05	Mar-99	Feb-05	Mar-99	Feb-05	Mar-99	Feb-05	Mar-99	Feb-05
Al[d]	5.0	0.10	<0.030	<0.03	<0.030	<0.03	<0.030	<0.03	<0.030	<0.03	<0.030	<0.03	<0.030
As[b]	0.1	NM	<0.0250	NM	<0.0250	NM	<0.0250	NM	<0.0250	NM	<0.0250	NM	<0.0250
B[d]	0.75	0.02	<0.040	0.02	<0.040	0.02	<0.040	0.03	<0.040	0.02	<0.040	0.02	<0.040
Ca	NS	67.3	132	42.0	49.6	52.0	58.8	109	127	68.3	67.0	37.2	53.2
Cd[b]	0.01	<0.003	<0.0020	<0.003	<0.0020	<0.003	<0.0020	<0.003	<0.0020	<0.003	<0.0020	<0.003	<0.0020
Cl[c]	250	14	22.3	17	15.8	14	15.4	30	23.4	22	19.9	14	19
Co[d]	0.05	NM	<0.0060	NM	<0.0060	NM	<0.0060	NM	<0.0060	NM	<0.0060	NM	<0.0060
Cu[c]	1.0	0.12	<0.010	0.03	<0.010	0.03	0.013	0.02	<0.010	0.02	0.027	0.05	0.012
F[b]	1.6	0.5	0.40	0.3	0.39	0.4	0.47	0.3	0.40	0.3	0.37	0.5	0.46
Fe[c]	1.0	0.19	<0.060	0.04	<0.060	0.03	<0.060	0.05	<0.060	0.03	<0.060	0.03	<0.060
HCO_3	NS	141	149	138	137	155	149	149	145	188	183	161	140
Hg[b]	0.002	NM	<0.00020	NM	<0.00020	NM	<0.00020	NM	<0.00020	NM	<0.00020	NM	<0.00020
K	NS	1.7	2.21	1.4	1.75	1.3	1.61	1.9	2.07	2.2	2.40	2.1	2.3
Mg	NS	9.1	14.9	7.5	8.47	8.3	8.68	12.9	13.7	13.0	11.7	9.1	10.8
Mn[c]	0.2	0.037	0.0388	0.006	0.0103	0.023	0.0551	0.020	0.301	<0.005	0.0083	<0.005	0.0044
Mo[d]	1.0	<0.01	0.0201	<0.01	<0.0080	<0.01	<0.0080	0.01	0.027	<0.01	<0.0080	<0.01	<0.0080
Na	NS	17.7	26.4	11.6	13.5	16.2	18.3	24.8	25.1	19.7	19.3	20.7	16.6
NO_3-N[b]	10.0	NM	3.75	NM	4.57	NM	5.11	NM	2.72	NM	5.13	NM	5
Pb[b]	0.05	<0.04	<0.0050	<0.04	<0.0050	<0.04	<0.0050	<0.04	<0.0050	<0.04	<0.0050	<0.04	<0.0050
pH[c,e]	>6,<9	7.1	6.78	7.3	7.08	7.3	7.04	7.0	6.94	7.5	7.16	7.3	6.85
Se[b]	0.05	NM	<0.040	NM	<0.040	NM	<0.040	NM	<0.040	NM	<0.040	NM	<0.040
SO_4[c]	600	120	262	20	15.6	50	37.5	290	255	50	48.3	30	31
Specific conductance[f]	NS	538	891	386	376	453	458	863	874	528	561	398	446
Temperature[g]	NS	21.2	NM	21.4	NM	19.8	NM	20.4	NM	16.3	NM	16.4	NM
TDS[c]	1000	390	624	240	244	300	265	660	597	360	327	260	275
Zn[c]	10.0	0.08	<0.010	<0.01	<0.010	0.02	<0.010	0.01	<0.010	0.06	0.152	0.07	0.17

Note: Analytical results for samples collected March 27-28, 1999, except for Well G sample, which was collected April 11, 1999

[a] New Mexico Water Quality Control Commission Regulations, 20.6.2 NMAC (NMWQCC, 2002).
[b] Human health standard
[c] Other standard for domestic water supply
[d] Standards for irrigation use
[e] pH in standard units.
[f] Specific conductance in µmhos/cm @ 25° C, measured in the field
[g] Temperature in ℃, measured in the field

mg/L = Milligrams per liter
NM = Not measured
NS = No New Mexico regulatory standard set for parameter
shaded cells indicate parameter above applicable regulatory standard



Sulfate, TDS, pH vs. Time for Surface Water Sample Point FS-5
Sulfate, TDS (mg/L)
pH
Date
0
300
600
900
1200
1500
1800
2100
0
2
4
6
8
10
12
14
Jul-90
Oct-90
Jan-91
Apr-91
Jul-91
Oct-91
Jan-92
Apr-92
Jul-92
Oct-92
Jan-93
Apr-93
Jul-93
Oct-93
Jan-94
Apr-94
Jul-94
Oct-94
Jan-95
Apr-95
Jul-95
Oct-95
Jan-96
Apr-96
Jul-96
Oct-96
Jan-97
Apr-97
Jul-97
Oct-97
Jan-98
Apr-98
Jul-98
Oct-98
Jan-99
Apr-99
Jul-99
Oct-99
Jan-00
Apr-00
Jul-00
Oct-00
Jan-01
Apr-01
Jul-01
Oct-01
Jan-02
Apr-02
Jul-02
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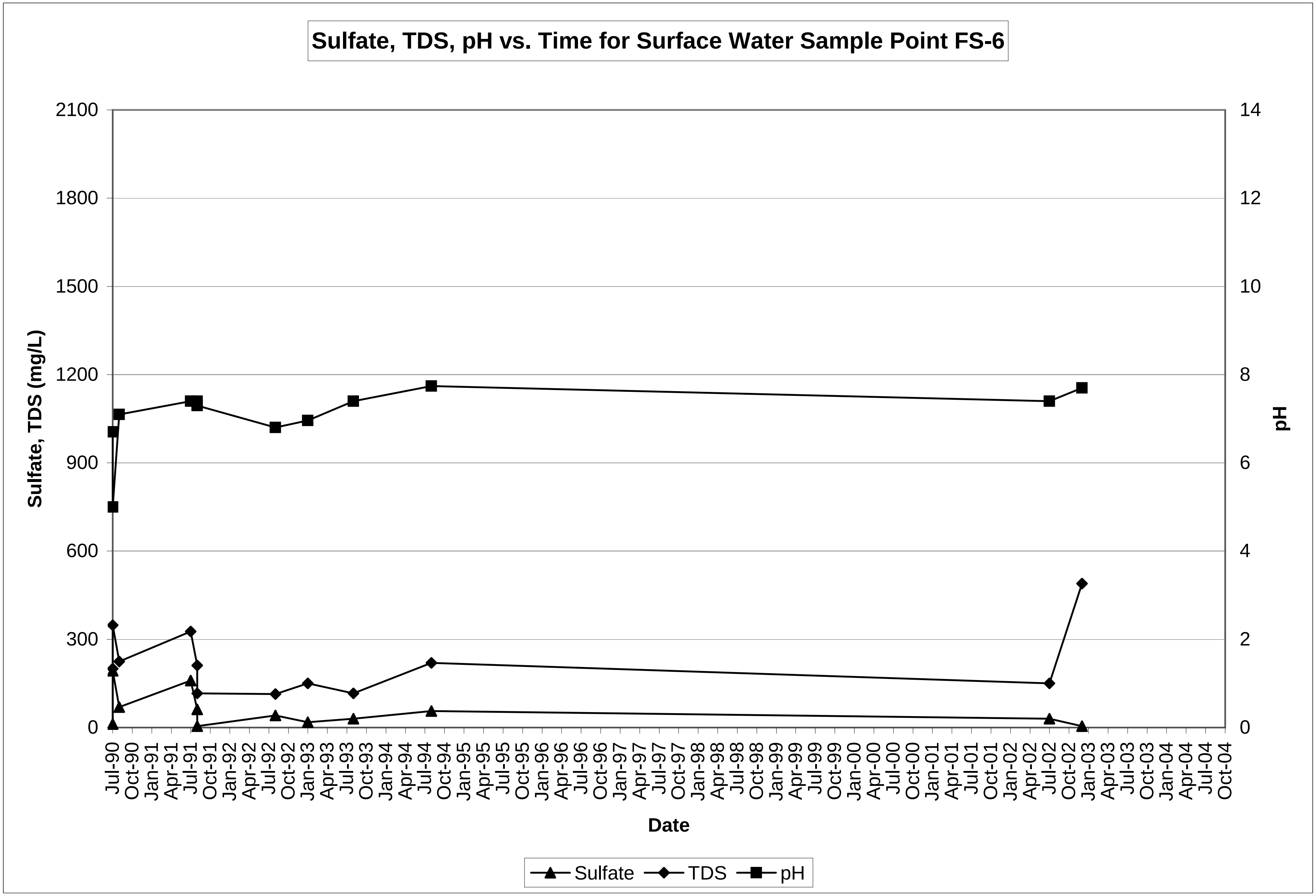
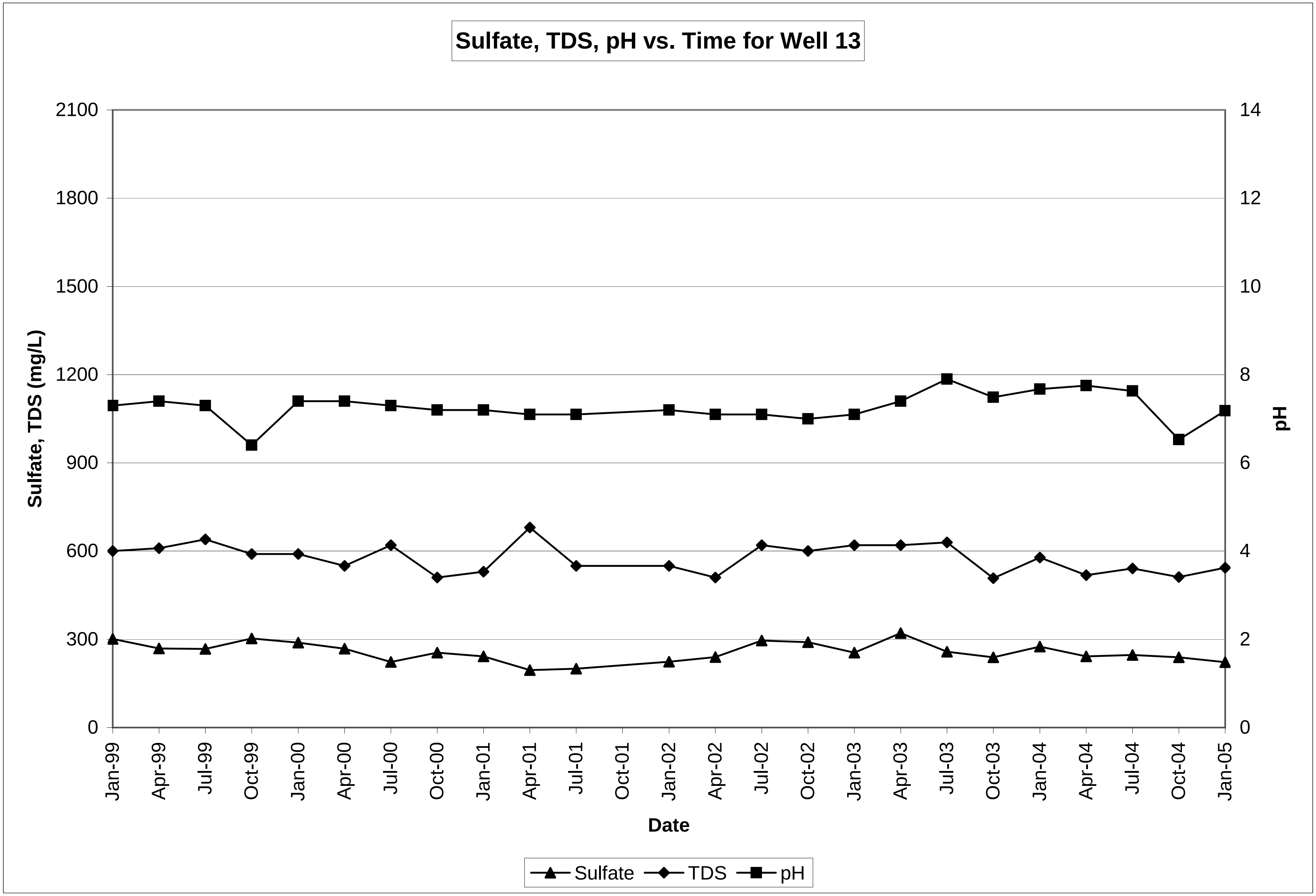
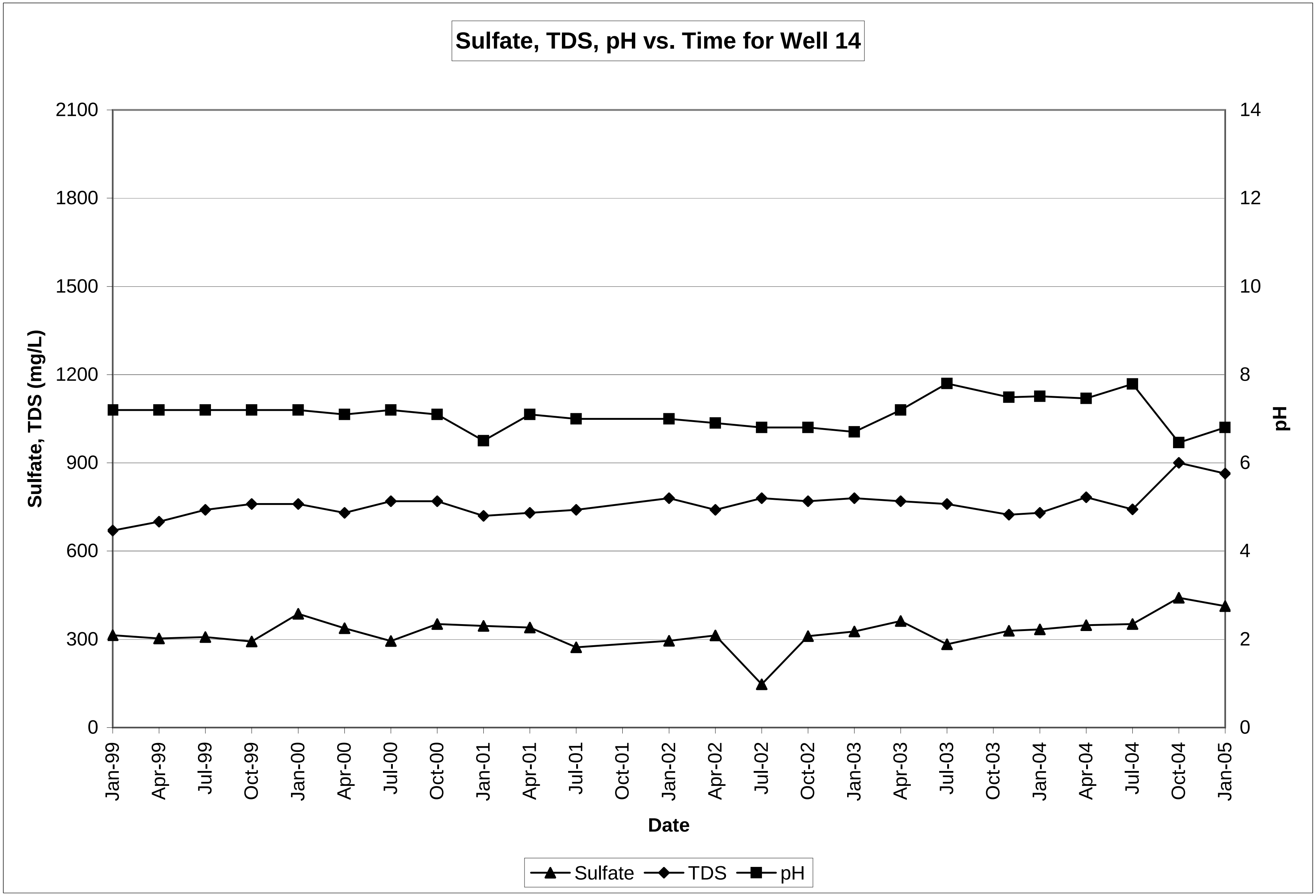
Apr-03
Jul-03
Oct-03
Jan-04
Apr-04
Jul-04
Oct-04
Sulfate
TDS
pH

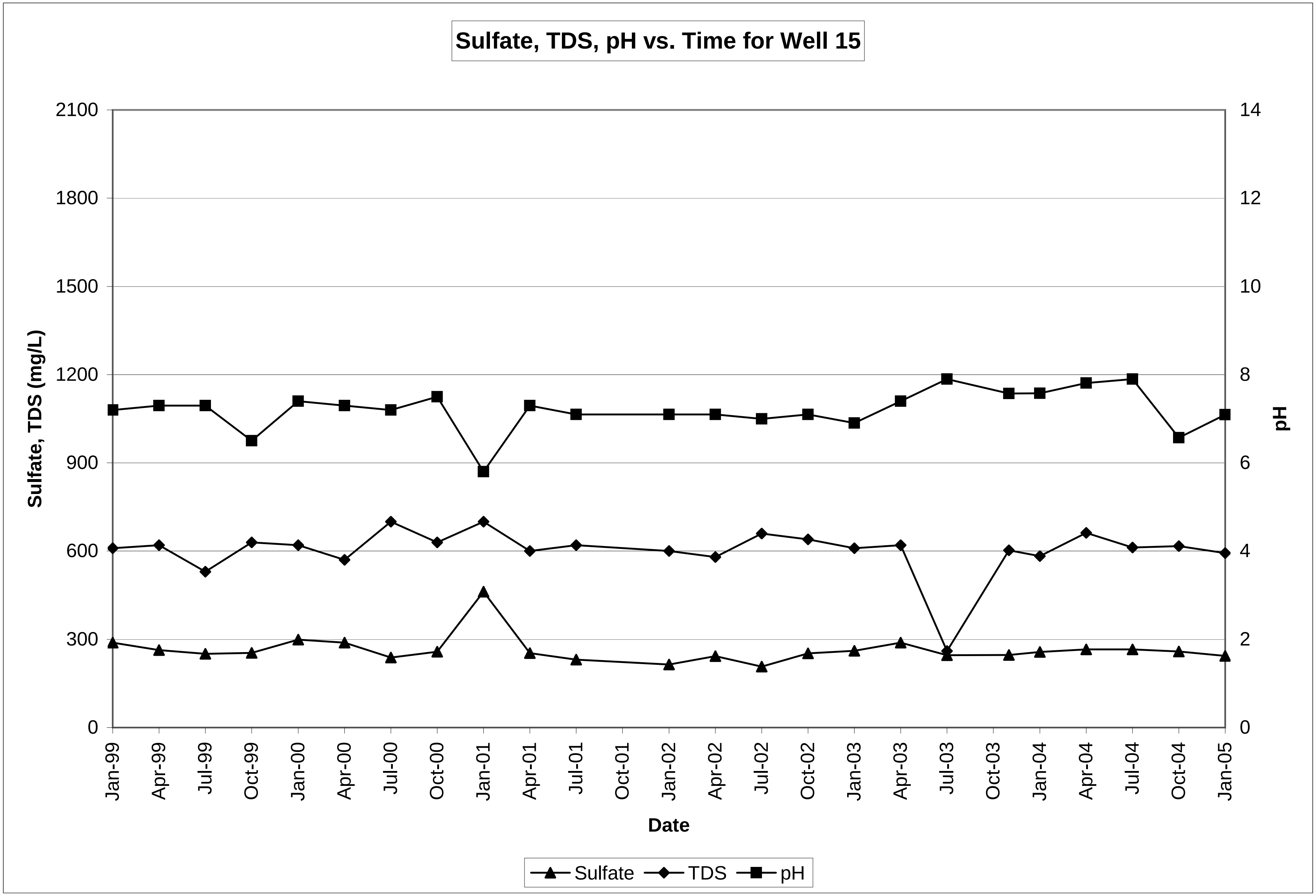

Sulfate, TDS, pH vs. Time for Surface Water Sample Point FS-6
Sulfate, TDS (mg/L)
2100
1800
1500
1200
900
600
300
0
pH
14
12
10
8
6
4
2
0
Jul-90 Oct-90 Jan-91 Apr-91 Jul-91 Oct-91 Jan-92 Apr-92 Jul-92 Oct-92 Jan-93 Apr-93 Jul-93 Oct-93 Jan-94 Apr-94 Jul-94 Oct-94 Jan-95 Apr-95 Jul-95 Oct-95 Jan-96 Apr-96 Jul-96 Oct-96 Jan-97 Apr-97 Jul-97 Oct-97 Jan-98 Apr-98 Jul-98 Oct-98 Jan-99 Apr-99 Jul-99 Oct-99 Jan-00 Apr-00 Jul-00 Oct-00 Jan-01 Apr-01 Jul-01 Oct-01 Jan-02 Apr-02 Jul-02 Oct-02 Jan-03 Apr-03 Jul-03 Oct-03 Jan-04 Apr-04 Jul-04 Oct-04
Date
Sulfate
TDS
pH

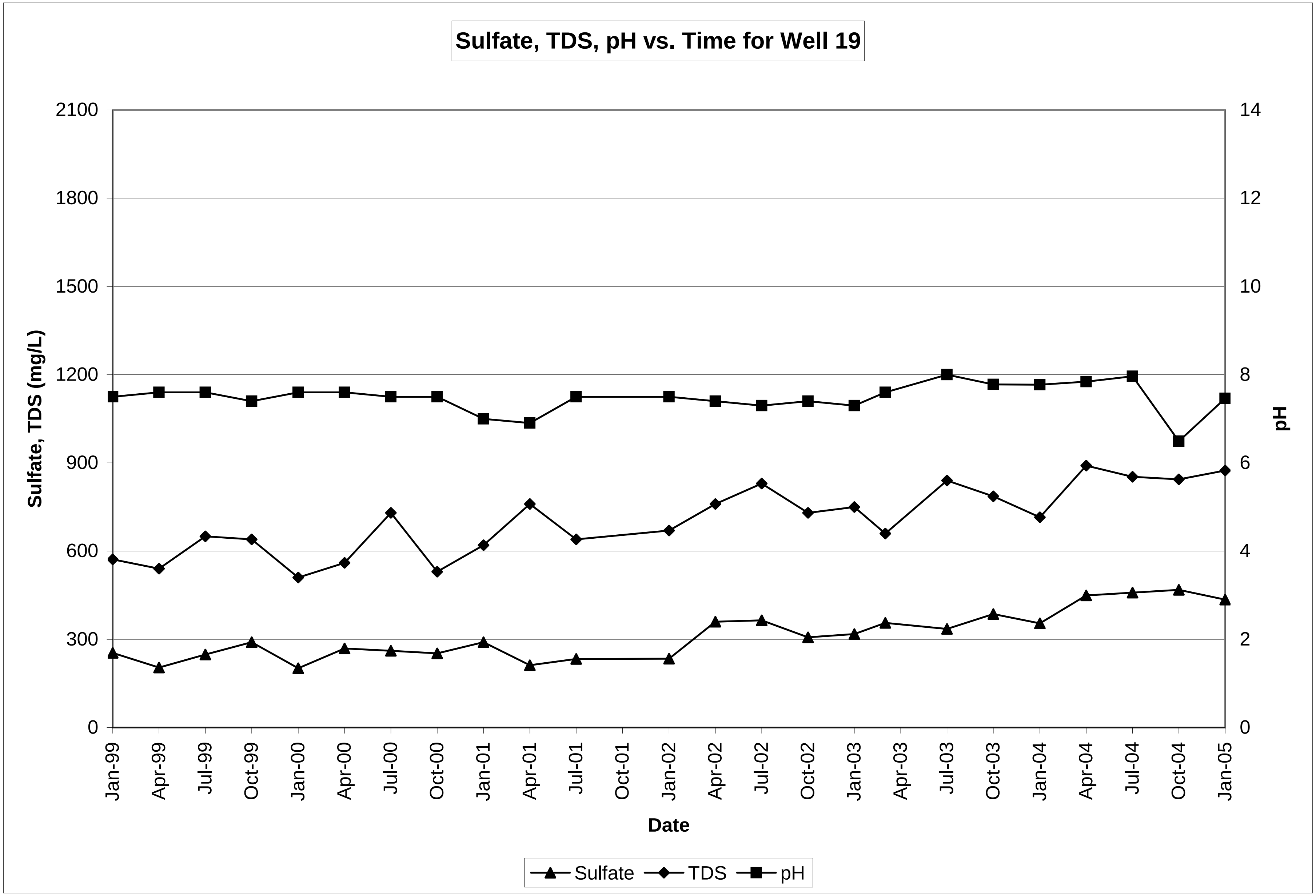


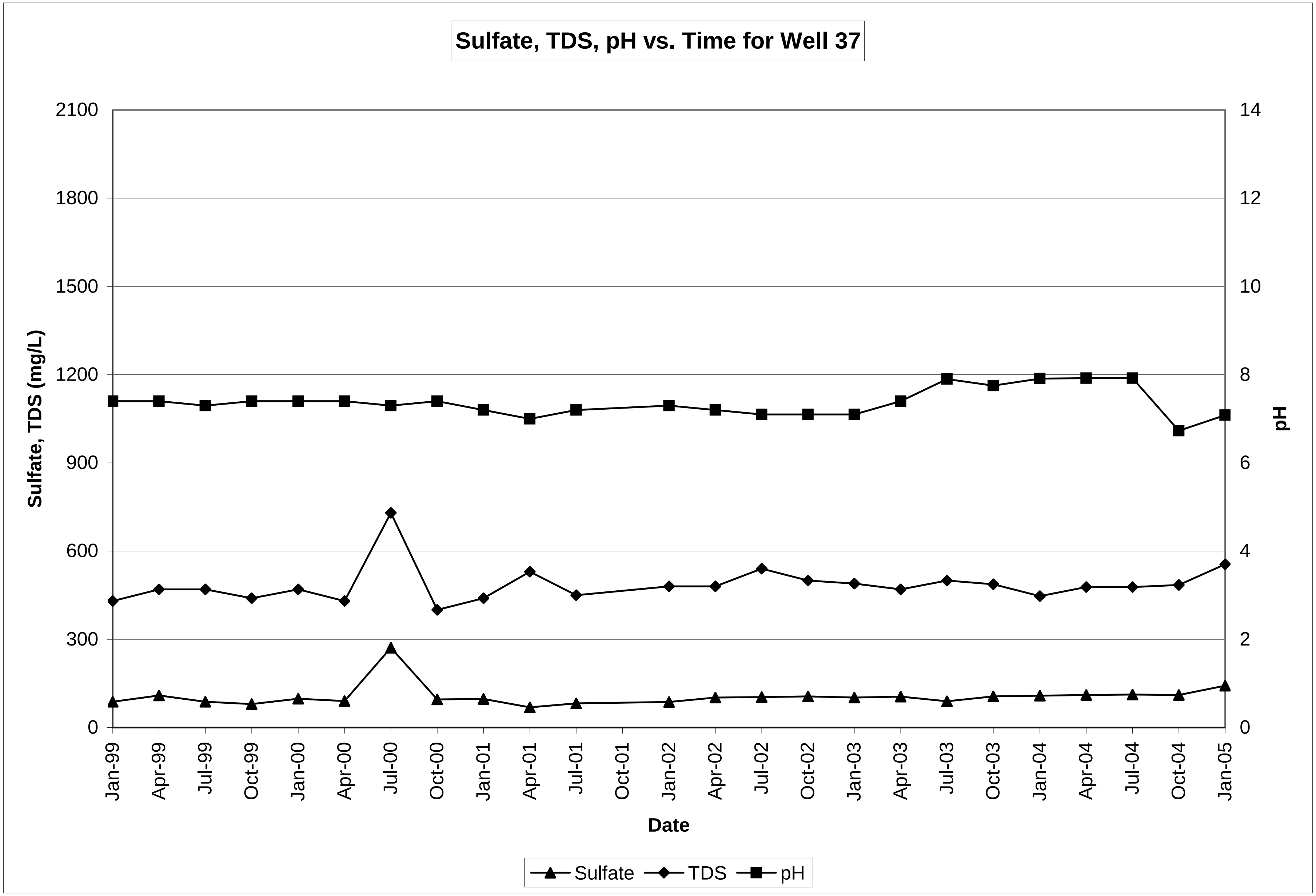
Sulfate, TDS, pH vs. Time for Well 13
Sulfate, TDS (mg/L)
pH
Date
2100
1800
1500
1200
900
600
300
0
14
12
10
8
6
4
2
0
Jan-99
Apr-99
Jul-99
Oct-99
Jan-00
Apr-00
Jul-00
Oct-00
Jan-01
Apr-01
Jul-01
Oct-01
Jan-02
Apr-02
Jul-02
Oct-02
Jan-03
Apr-03
Jul-03
Oct-03
Jan-04
Apr-04
Jul-04
Oct-04
Jan-05
Sulfate
TDS
pH



Sulfate, TDS, pH vs. Time for Well 14
Sulfate, TDS (mg/L)
2100
1800
1500
1200
900
600
300
0
pH
14
12
10
8
6
4
2
0
Jan-99
Apr-99
Jul-99
Oct-99
Jan-00
Apr-00
Jul-00
Oct-00
Jan-01
Apr-01
Jul-01
Oct-01
Jan-02
Apr-02
Jul-02
Oct-02
Jan-03
Apr-03
Jul-03
Oct-03
Jan-04
Apr-04
Jul-04
Oct-04
Jan-05
Date
Sulfate
TDS
pH


Sulfate, TDS, pH vs. Time for Well 15
Sulfate, TDS (mg/L)
2100
1800
1500
1200
900
600
300
0
pH
14
12
10
8
6
4
2
0
Jan-99
Apr-99
Jul-99
Oct-99
Jan-00
Apr-00
Jul-00
Oct-00
Jan-01
Apr-01
Jul-01
Oct-01
Jan-02
Apr-02
Jul-02
Oct-02
Jan-03
Apr-03
Jul-03
Oct-03
Jan-04
Apr-04
Jul-04
Oct-04
Jan-05
Date
Sulfate
TDS
pH


Sulfate, TDS, pH vs. Time for Well 19
Sulfate, TDS (mg/L)
pH
Date
2100
1800
1500
1200
900
600
300
0
14
12
10
8
6
4
2
0
Jan-99
Apr-99
Jul-99
Oct-99
Jan-00
Apr-00
Jul-00
Oct-00
Jan-01
Apr-01
Jul-01
Oct-01
Jan-02
Apr-02
Jul-02
Oct-02
Jan-03
Apr-03
Jul-03
Oct-03
Jan-04
Apr-04
Jul-04
Oct-04
Jan-05
Sulfate
TDS
pH



Sulfate, TDS, pH vs. Time for Well 37
Sulfate, TDS (mg/L)
pH
Date
2100
1800
1500
1200
900
600
300
0
14
12
10
8
6
4
2
0
Jan-99
Apr-99
Jul-99
Oct-99
Jan-00
Apr-00
Jul-00
Oct-00
Jan-01
Apr-01
Jul-01
Oct-01
Jan-02
Apr-02
Jul-02
Oct-02
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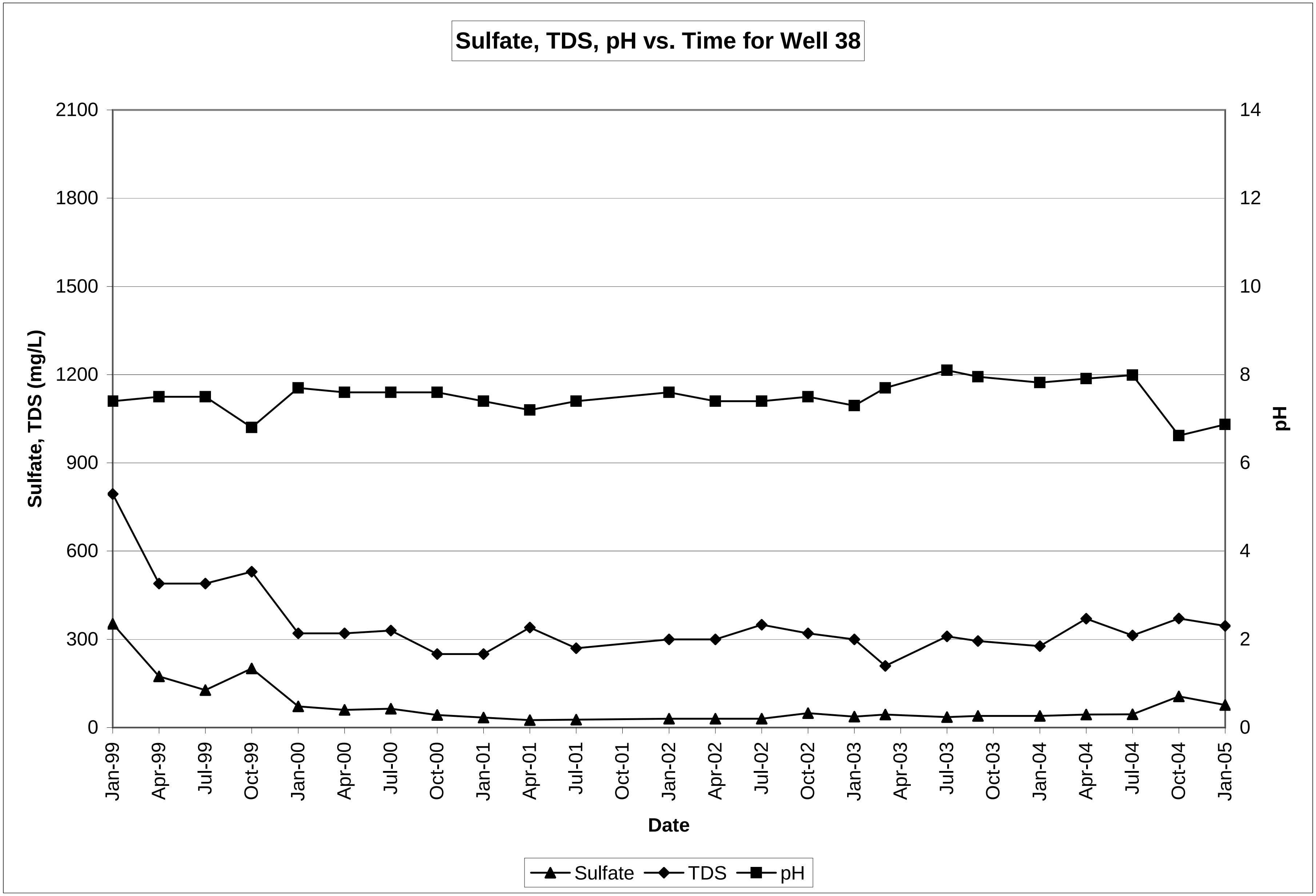
Jul-03
Oct-03
Jan-04
Apr-04
Jul-04
Oct-04
Jan-05
Sulfate
TDS
pH



Sulfate, TDS, pH vs. Time for Well 38
Sulfate, TDS (mg/L)
pH
2100
1800
1500
1200
900
600
300
0
14
12
10
8
6
4
2
0
Jan-99
Apr-99
Jul-99
Oct-99
Jan-00
Apr-00
Jul-00
Oct-00
Jan-01
Apr-01
Jul-01
Oct-01
Jan-02
Apr-02
Jul-02
Oct-02
Jan-03
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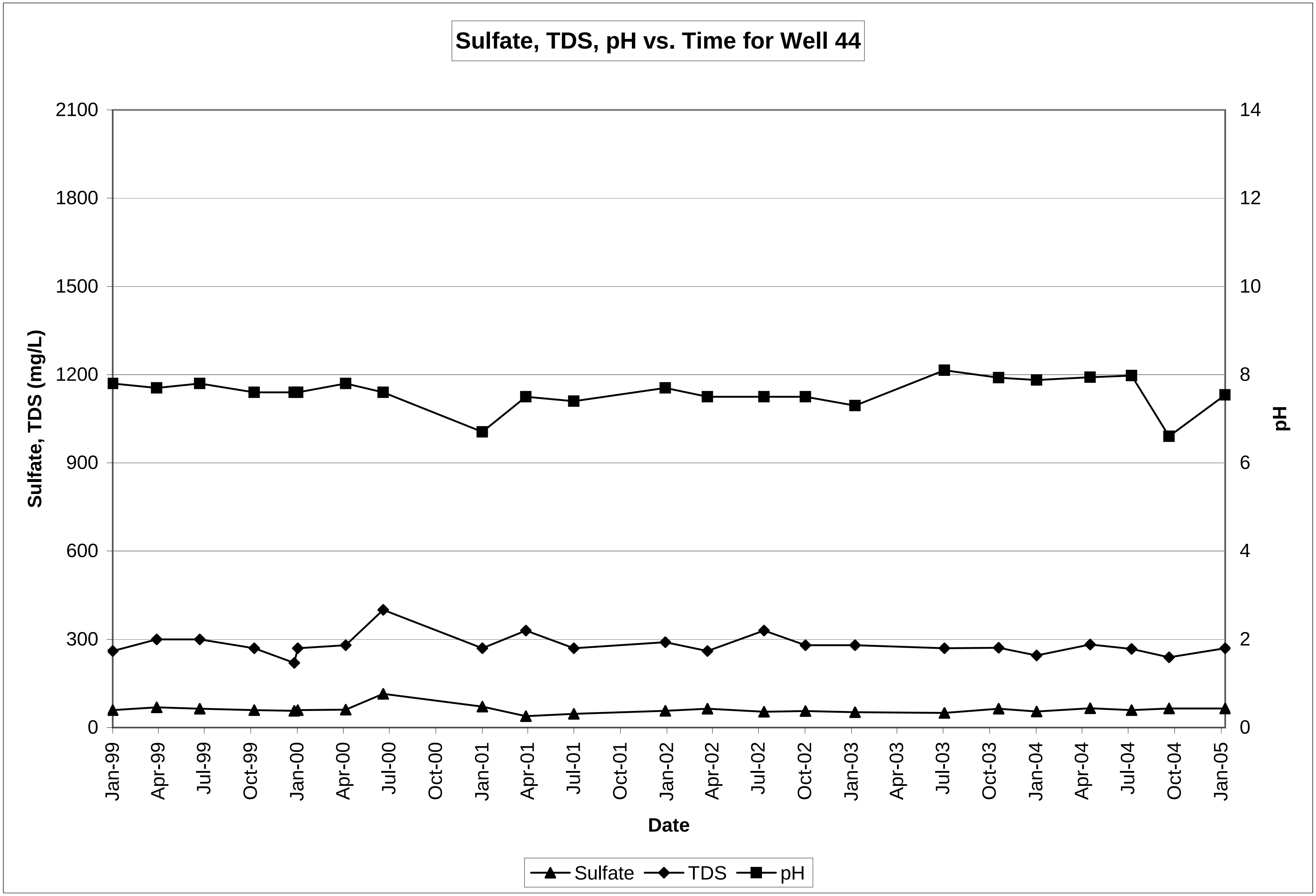
Oct-03
Jan-04
Apr-04
Jul-04
Oct-04
Jan-05
Date
Sulfate
TDS
pH



Sulfate, TDS, pH vs. Time for Well 44
Sulfate, TDS (mg/L)
pH
Date
2100
1800
1500
1200
900
600
300
0
14
12
10
8
6
4
2
0
Jan-99
Apr-99
Jul-99
Oct-99
Jan-00
Apr-00
Jul-00
Oct-00
Jan-01
Apr-01
Jul-01
Oct-01
Jan-02
Apr-02
Jul-02
Oct-02
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Jul-03
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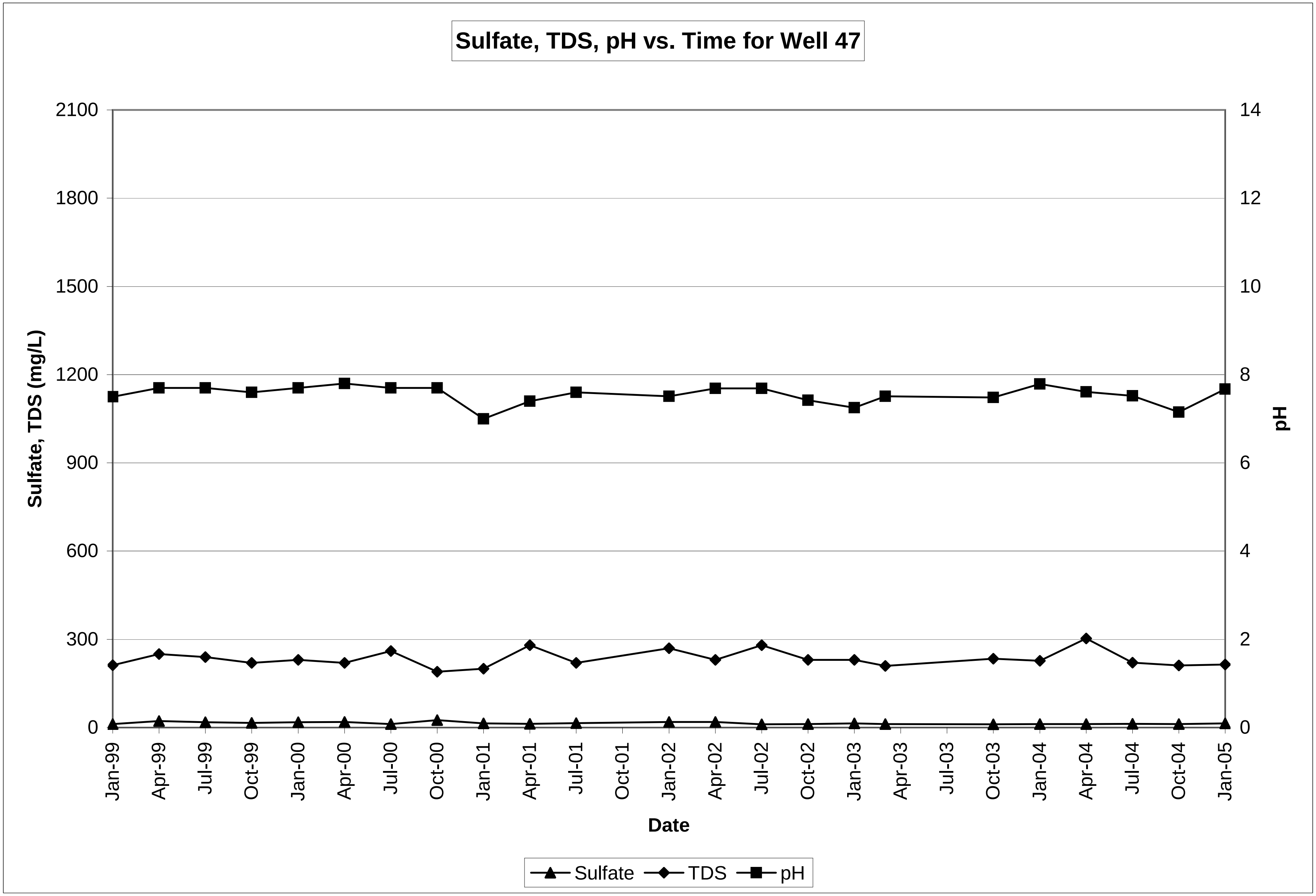
Apr-04
Jul-04
Oct-04
Jan-05
Sulfate
TDS
pH



Sulfate, TDS, pH vs. Time for Well 47
Sulfate, TDS (mg/L)
2100
1800
1500
1200
900
600
300
0
pH
14
12
10
8
6
4
2
0
Jan-99
Apr-99
Jul-99
Oct-99
Jan-00
Apr-00
Jul-00
Oct-00
Jan-01
Apr-01
Jul-01
Oct-01
Jan-02
Apr-02
Jul-02
Oct-02
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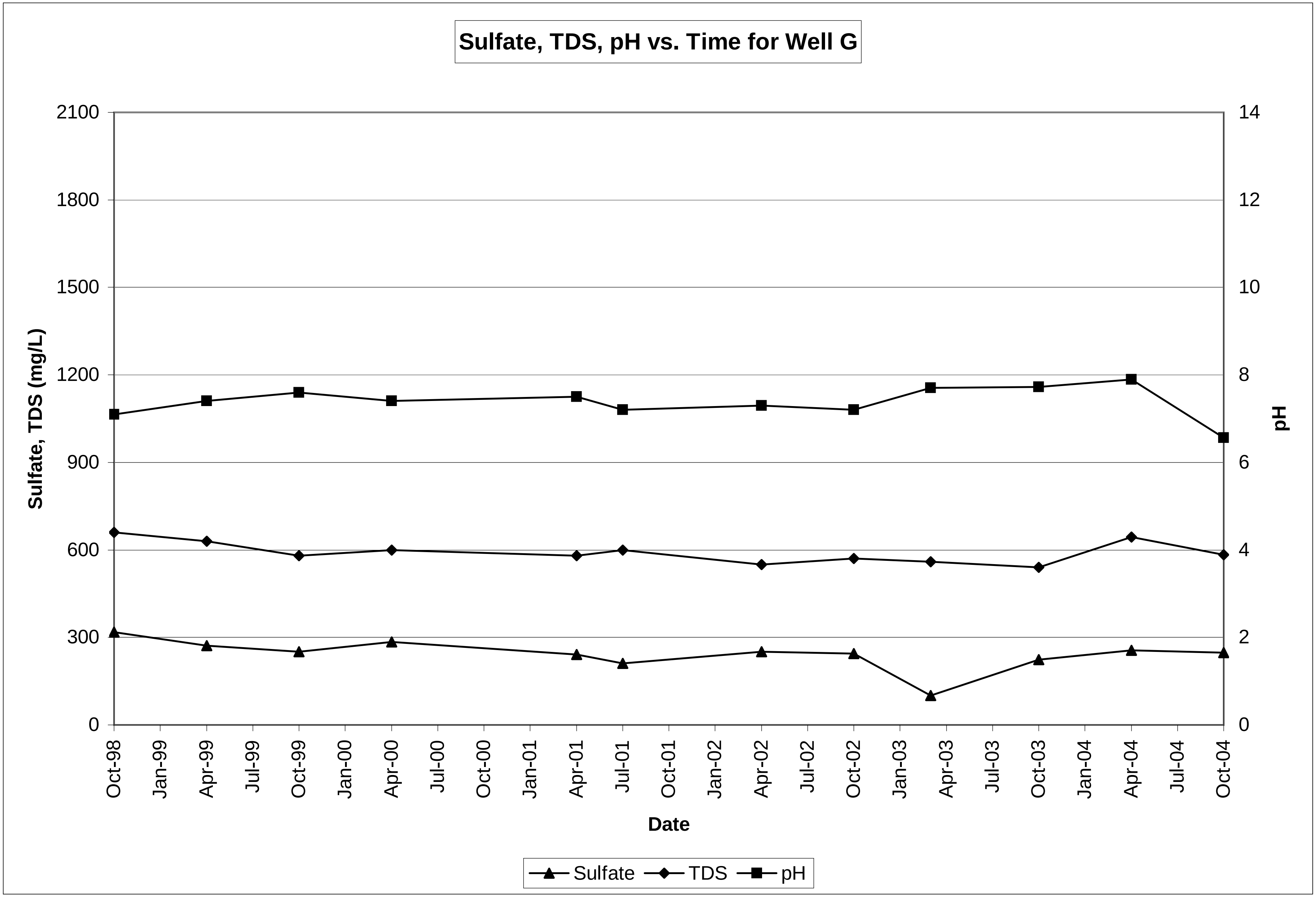
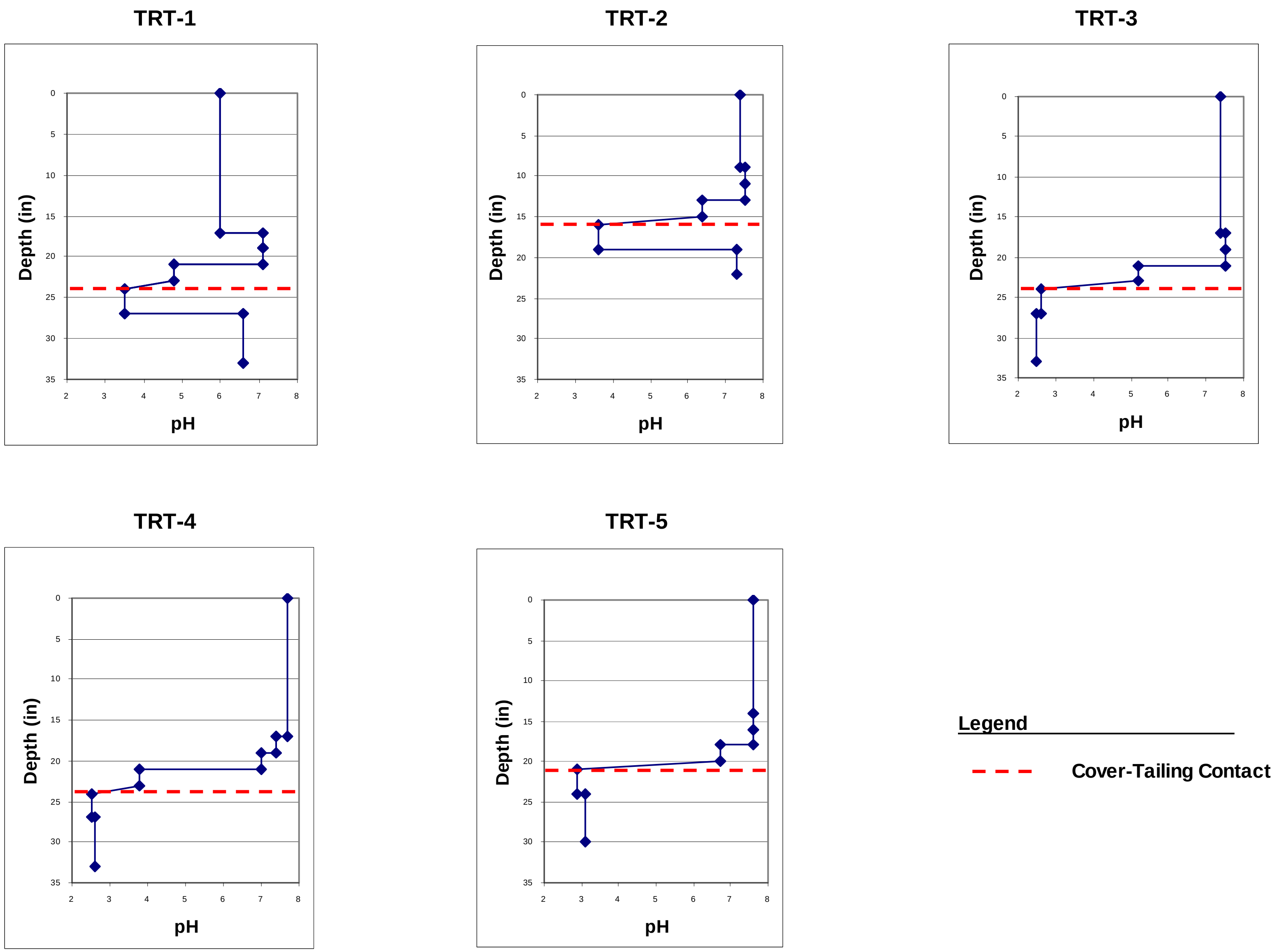
Apr-04
Jul-04
Oct-04
Jan-05
Date
Sulfate
TDS
pH


Sulfate, TDS, pH vs. Time for Well G
Sulfate, TDS (mg/L)
pH
Date
2100
1800
1500
1200
900
600
300
0
14
12
10
8
6
4
2
0
Oct-98
Jan-99
Apr-99
Jul-99
Oct-99
Jan-00
Apr-00
Jul-00
Oct-00
Jan-01
Apr-01
Jul-01
Oct-01
Jan-02
Apr-02
Jul-02
Oct-02
Jan-03
Apr-03
Jul-03
Oct-03
Jan-04
Apr-04
Jul-04
Oct-04
Sulfate
TDS
pH

APPENDIX D

SOIL AND TAILING LABORATORY DATA

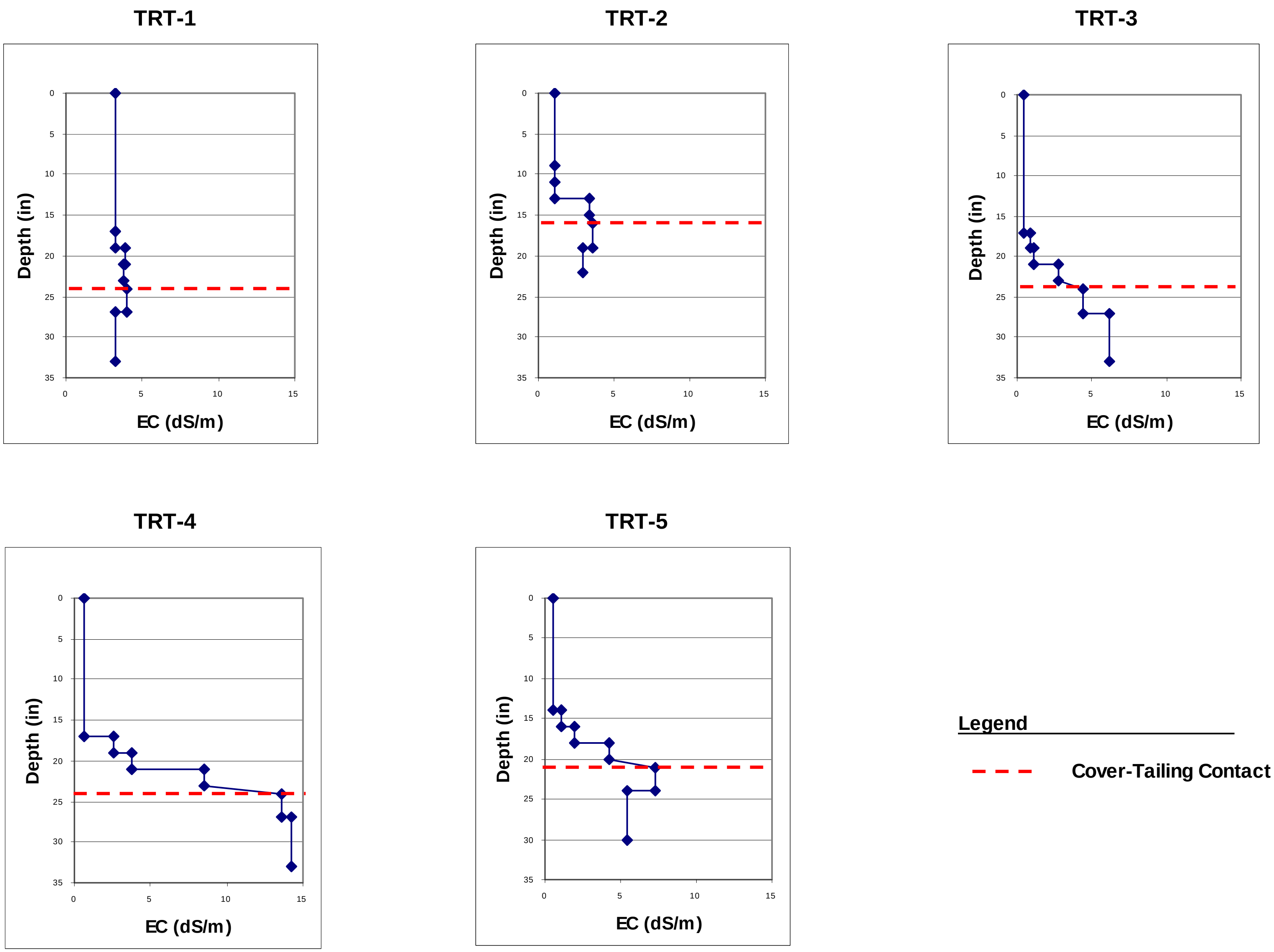


Golder Associates

Date: April 25, 2005 Drawn: DR
Project: 053-2371 Chkd: LM

Paste pH with Depth
South Main Tailing Repository Investigation
Tyrone Mine, June 2001

FIGURE D-1



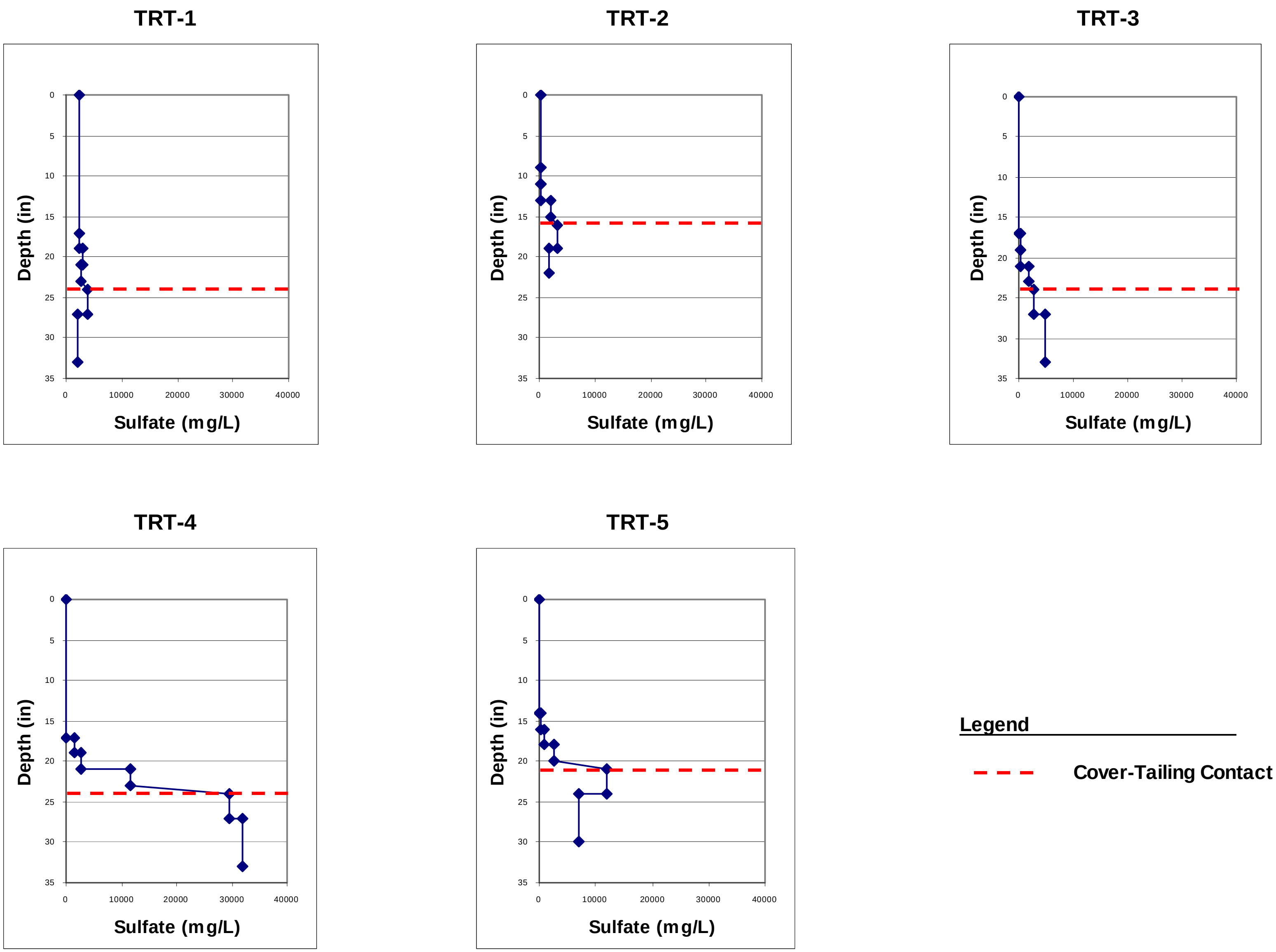
Golder Associates

Date: April 25, 2005 Drawn: DR

Project: 053-2371 Chkd: LM

Extract EC with Depth
South Main Tailing Repository Investigation
Tyrone Mine, June 2001

FIGURE D-2

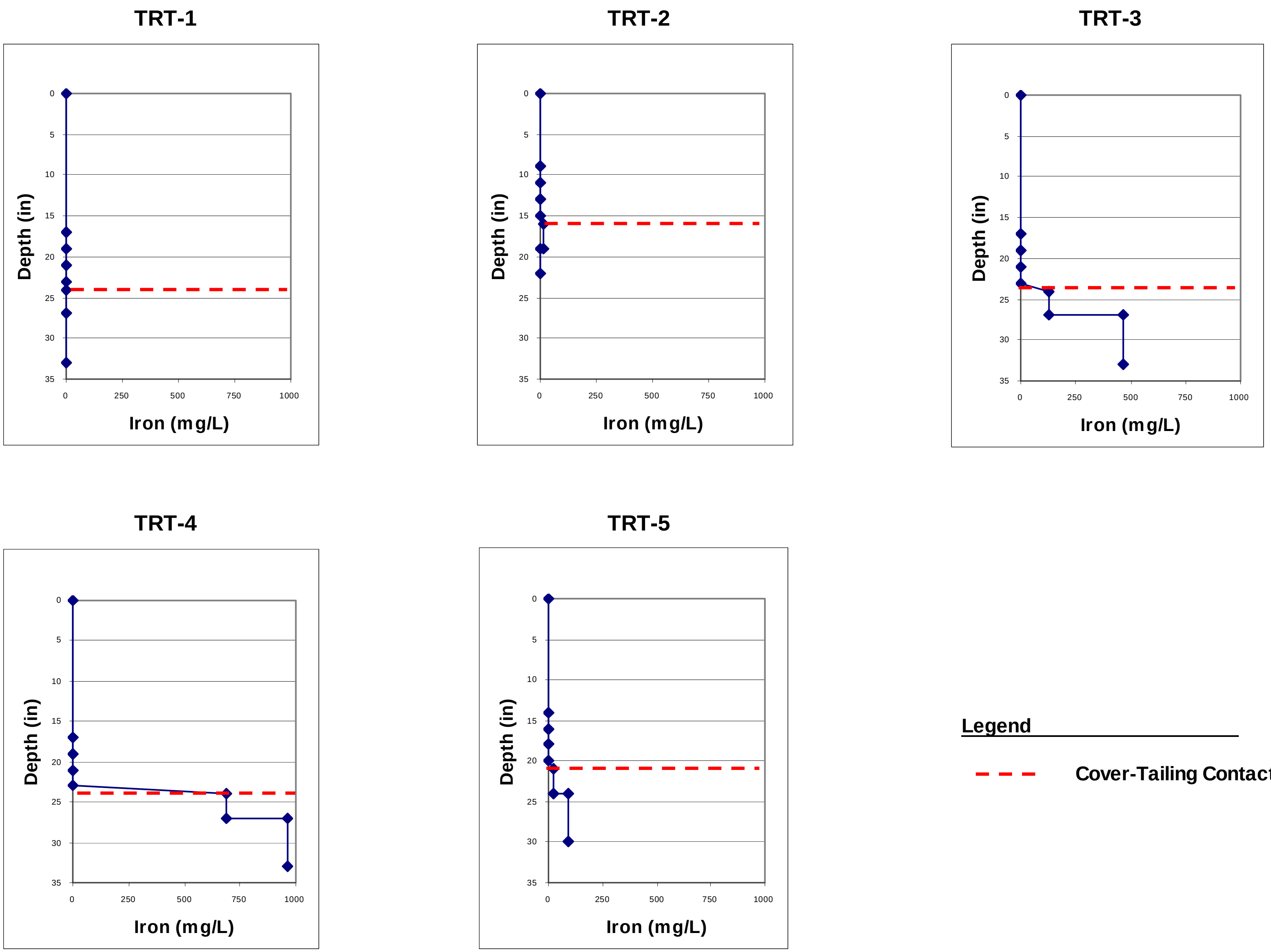


Date: April 25, 2005 Drawn: DR

Project: 053-2371 Chkd: LM

Extract Sulfate Concentration with Depth
South Main Tailing Repository Investigation
Tyrone Mine, June 2001

FIGURE D-3



Golder Associates

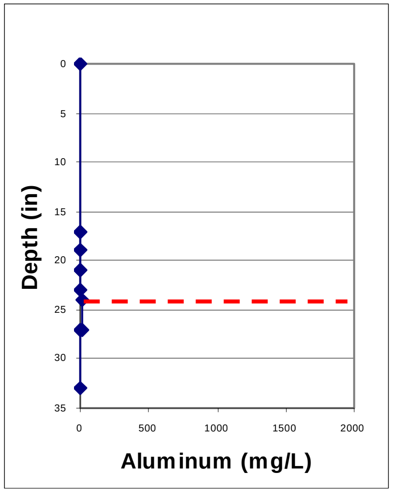
Date: April 25, 2005 Drawn: DR

Project: 053-2371 Chkd: LM

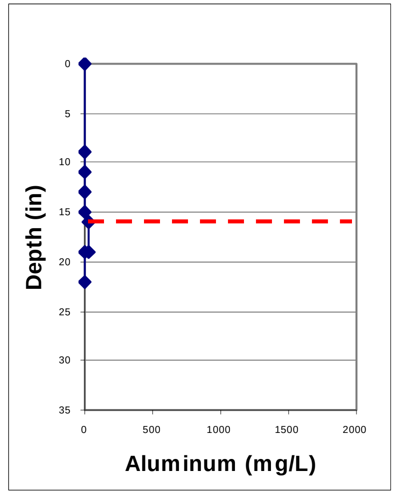
Extract Iron Concentration with Depth
South Main Tailing Repository Investigation
Tyrone Mine, June 2001

FIGURE D-4

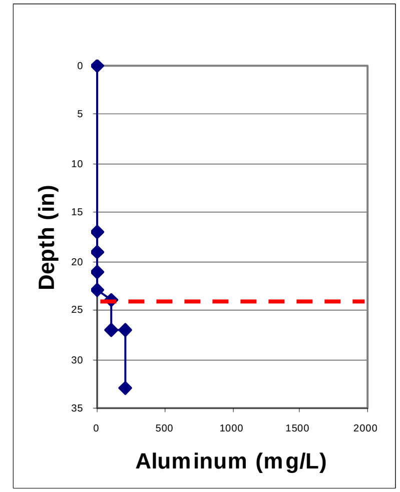
TRT-1



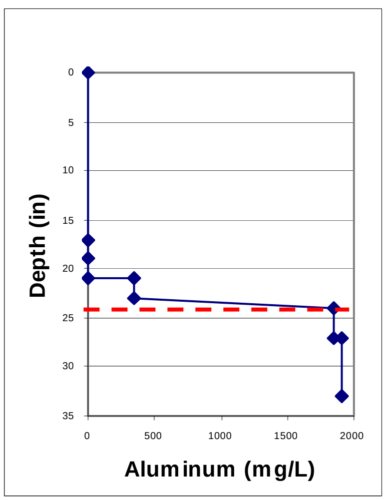
TRT-2



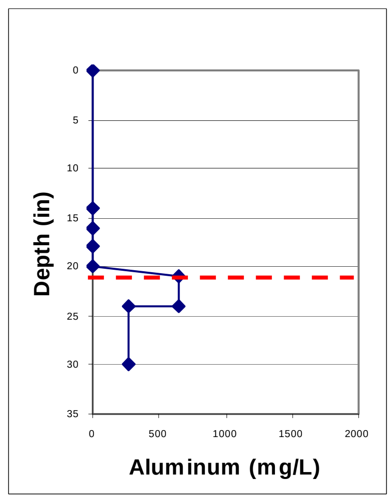
TRT-3



TRT-4



TRT-5



Legend

- - - Cover-Tailing Contact

Golder Associates

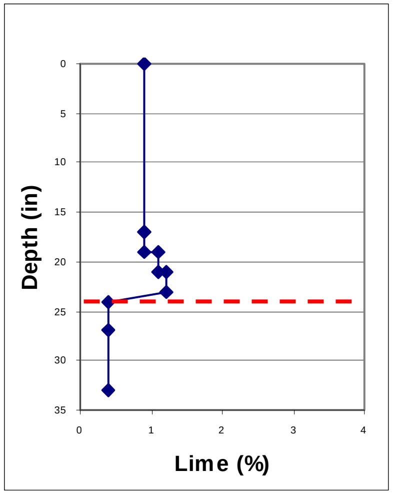
Date: April 25, 2005 Drawn: DR

Project: 053-2371 Chkd: LM

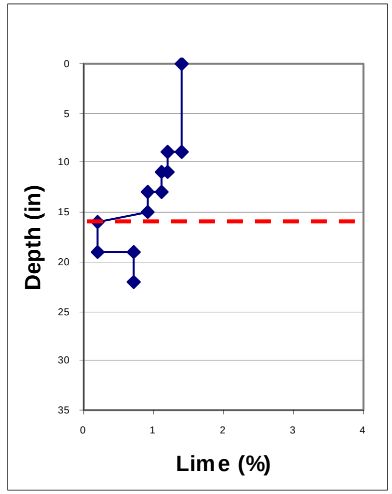
Extract Aluminum Concentration with Depth
South Main Tailing Repository Investigation
Tyrone Mine, June 2001

FIGURE D-5

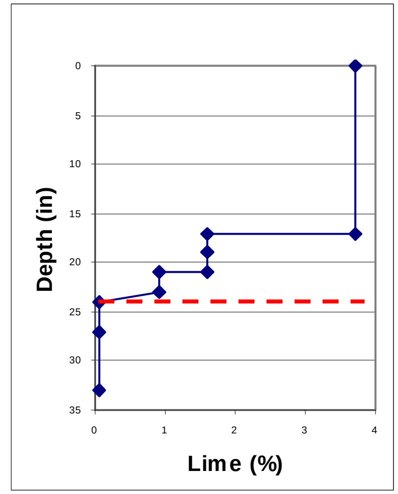
TRT-1



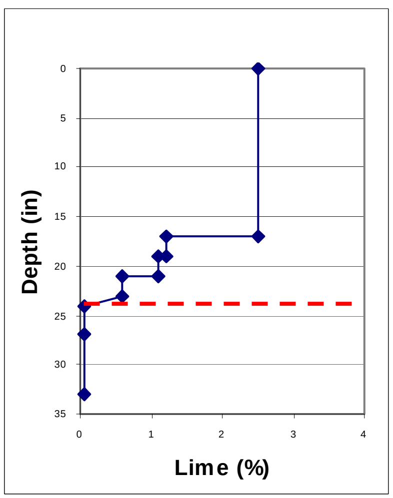
TRT-2



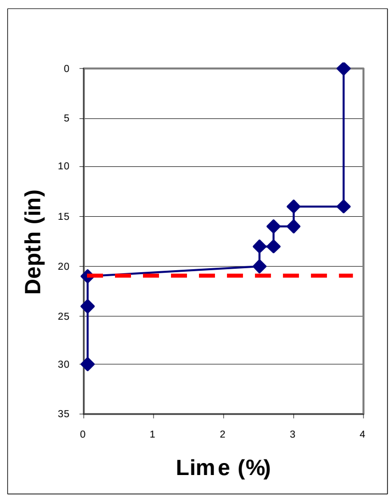
TRT-3



TRT-4



TRT-5



Legend

Cover-Tailing Contact

Golder Associates

Date: April 25, 2005 Drawn: DR

Project: 053-2371 Chkd: LM

CaCO3 Equivalent Percent with Depth
South Main Tailing Repository Investigation
Tyrone Mine, June 2001

FIGURE D-6

ENERGY LABORATORIES, INC.
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LABORATORY REPORT

TO: Jeff Peace
ADDRESS: Phelps Dodge Tyrone Inc.
PO Drawer 571
Tyrone, NM 88065

LAB NO.: 001-020-01-54549
DATE: 06/28/01 bb

SOIL ANALYSIS
NO. 3 TAILING SPILL
Submitted 06/11/01

Sample Number	Identification	pH, s.u. Sat. Paste	Cond., mmhos/cm Sat. Paste	Aluminum mg/l Sat. Paste	Iron mg/l Sat. Paste	Sulfate mg/l Sat. Paste
01-54549-001	TRT-1, 0-17"	6.0	3.20	<0.5	<0.5	2290
01-54549-002	TRT-1, 17-19"	7.1	3.27	<0.5	<0.5	2330
01-54549-003	TRT-1, 19-21"	7.1	3.87	<0.5	<0.5	2830
01-54549-004	TRT-1, 21-23"	4.8	3.73	1.5	<0.5	2770
01-54549-005	TRT-2, 0-9"	7.4	1.07	<0.5	<0.5	336
01-54549-006	TRT-2, 9-11"	7.5	1.07	<0.5	<0.5	375
01-54549-007	TRT-2, 11-13"	7.5	1.13	<0.5	<0.5	425
01-54549-008	TRT-2, 13-15"	6.4	3.36	<0.5	<0.5	2150
01-54549-009	TRT-3, 0-17"	7.4	0.45	<0.5	<0.5	40
01-54549-010	TRT-3, 17-19"	7.5	0.83	<0.5	<0.5	196
01-54549-011	TRT-3, 19-21"	7.5	1.13	<0.5	<0.5	418
01-54549-012	TRT-3, 21-23"	5.2	2.72	<0.5	<0.5	1790
01-54549-013	TRT-4, 0-17"	7.7	0.65	<0.5	<0.5	131
01-54549-014	TRT-4, 17-19"	7.4	2.59	<0.5	<0.5	1530
01-54549-015	TRT-4, 19-21"	7.0	3.79	<0.5	<0.5	2660
01-54549-016	TRT-4, 21-23"	3.8	8.50	342	<0.5	11500
01-54549-017	TRT-5, 0-14"	7.6	0.57	<0.5	<0.5	72
01-54549-018	TRT-5, 14-16"	7.6	1.13	<0.5	<0.5	408
01-54549-019	TRT-5, 16-18"	7.6	1.95	<0.5	<0.5	1010
01-54549-020	TRT-5, 18-20"	6.7	4.24	<0.5	<0.5	2760
DUPLICATE ANALYSIS						
01-54549-009	TRT-3, 0-17"	7.5	0.46	<0.5	<0.5	39
01-54549-020	TRT-5, 18-20"	6.8	4.16	<0.5	<0.5	2800
CONTROL SOIL	**	6.9	3.96	<0.5	<0.5	2200
TARGET RANGE	**	(6.4-7.1)	(2.85-4.90)	N/A	N/A	(1590-2450)
DATE ANALYZED	**	06/19/01	06/19/01	06/21/01	06/21/01	06/20/01
BLANK	**	N/A	N/A	<0.5	<0.5	<1
SPIKE, %	**	N/A	N/A	89	99	N/A
DET. LIMIT	**	0.1	0.01	0.5	0.5	1
METHOD #	**	ASA Mono #9 Method 10-3.1	ASA Mono #9 Method 10-3.3	ASA Mono #9 Method 10-2.3.1 EPA 200.7	ASA Mono #9 Method 10-2.3.1 EPA 200.7	ASA Mono #9 Method 10-2.3.1 EPA 300.0

ENERGY LABORATORIES, INC.
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LABORATORY REPORT

TO: Jeff Peace
ADDRESS: Phelps Dodge Tyrone Inc.
PO Drawer 571
Tyrone, NM 88065

LAB NO.: 001-020-01-54549
DATE: 06/28/01 bb

SOIL ANALYSIS
NO. 3 TAILING SPILL
Submitted 06/11/01

Sample Number	Identification	Sand %	Silt %	Clay %	Texture	Coarse Fragments %	Lime as CaCO3 %
01-54549-001	TRT-1, 0-17"	75	15	10	SL	12	0.9
01-54549-002	TRT-1, 17-19"	86	8	6	LS	20	0.9
01-54549-003	TRT-1, 19-21"	82	11	7	LS	23	1.1
01-54549-004	TRT-1, 21-23"	82	11	7	LS	25	1.2
01-54549-005	TRT-2, 0-9"	68	14	18	SL	11	1.4
01-54549-006	TRT-2, 9-11"	72	12	16	SL	5	1.2
01-54549-007	TRT-2, 11-13"	74	12	14	SL	9	1.1
01-54549-008	TRT-2, 13-15"	52	32	16	L	12	0.9
01-54549-009	TRT-3, 0-17"	75	10	15	SL	25	3.7
01-54549-010	TRT-3, 17-19"	73	8	19	SL	28	1.6
01-54549-011	TRT-3, 19-21"	76	6	18	SL	27	1.6
01-54549-012	TRT-3, 21-23"	78	8	14	SL	24	0.9
01-54549-013	TRT-4, 0-17"	32	44	24	L	6	2.5
01-54549-014	TRT-4, 17-19"	75	13	12	SL	20	1.2
01-54549-015	TRT-4, 19-21"	76	10	14	SL	23	1.1
01-54549-016	TRT-4, 21-23"	72	13	15	SL	24	0.6
01-54549-017	TRT-5, 0-14"	22	50	28	CL	8	3.7
01-54549-018	TRT-5, 14-16"	20	52	28	SiCL	4	3.0
01-54549-019	TRT-5, 16-18"	18	52	30	SiCL	3	2.7
01-54549-020	TRT-5, 18-20"	22	50	28	CL	2	2.5
DUPLICATE ANALYSIS							
01-54549-009	TRT-3, 0-17"	76	9	15	SL	N/A	3.8
01-54549-020	TRT-5, 18-20"	22	50	28	CL	N/A	2.4
CONTROL SOIL	**	44	35	21	L	N/A	6.5
TARGET RANGE	**	(41-53)	(31-41)	(12-22)	N/A	N/A	(3.5 - 7.3)
DATE ANALYZED	**	06/21/01	06/21/01	06/21/01	06/21/01	06/15/01	06/25/01
BLANK	**	N/A	N/A	N/A	N/A	N/A	N/A
SPIKE, %	**	N/A	N/A	N/A	N/A	N/A	N/A
DET. LIMIT	**	1	1	1	N/A	2	0.1
METHOD #	**	ASA Mono #9 Part 1 Method 15-5	ASA Mono #9 Part 1 Method 15-5	ASA Mono #9 Part 1 Method 15-5	ASA Mono #9 Part 1 Method 15-5	ASA Mono #9 Part 1 Method 15-5	USDA Handbook 60 Method 26

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LABORATORY REPORT

TO: Jeff Peace
ADDRESS: Phelps Dodge Tyrone Inc.
PO Drawer 571
Tyrone, NM 88065

LAB NO.: 001-010-01-54551
DATE: 06/29/01 rb

SOIL ANALYSIS
NO 3 Tailing Spill
Submitted: 06/11/01

Sample Number	Identification	pH, s.u. Sat. Paste	Cond., mmhos/cm Sat. Paste	Aluminum mg/l Sat. Paste	Iron mg/l Sat. Paste	Sulfate mg/l Sat. Paste
01-54551-001	TRT-1, 24-27"	3.5	4.03	15.5	3.1	3880
01-54551-002	TRT-1, 27-33"	6.6	3.20	<0.5	<0.5	2100
01-54551-003	TRT-2, 16-19"	3.6	3.63	36.3	18.1	3380
01-54551-004	TRT-2, 19-22"	7.3	2.94	<0.5	<0.5	1890
01-54551-005	TRT-3, 24-27"	2.6	4.45	102	127	2680
01-54551-006	TRT-3, 27-33"	2.5	6.21	208	463	4750
01-54551-007	TRT-4, 24-27"	2.5	13.6	1850	691	29600
01-54551-008	TRT-4, 27-33"	2.6	14.2	1910	965	32000
01-54551-009	TRT-5, 21-24"	2.9	7.28	642	22.2	12000
01-54551-010	TRT-5, 24-30"	3.1	5.41	271	91.5	7010
DUPLICATE ANALYSIS						
01-54551-010	TRT-5, 24-30"	3.1	5.41	286	97.1	7070
CONTROL SOIL	**	6.9	3.96	<0.5	<0.5	2200
TARGET RANGE	**	(6.4-7.1)	(2.85-4.90)	N/A	N/A	(1590-2450)
DATE ANALYZED	**	06/19/01	06/19/01	06/21/01	06/21/01	6/20,26/01
BLANK	**	N/A	N/A	<0.5	<0.5	<1
SPIKE, %	**	N/A	N/A	89	99	101
DET. LIMIT	**	0.1	0.01	0.5	0.5	1
METHOD #	**	ASA Mono #9 Method 10-3.1	ASA Mono #9 Method 10-3.3	ASA Mono #9 Method 10-2.3.1 EPA 200.7	ASA Mono #9 Method 10-2.3.1 EPA 200.7	ASA Mono #9 Method 10-2.3.1 EPA 300.0

ABP Calculated from Non-Sulfate Sulfur, %

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LABORATORY REPORT

TO: Jeff Peace
ADDRESS: Phelps Dodge Tyrone Inc.
PO Drawer 571
Tyrone, NM 88065

LAB NO.: 001-010-01-54551
DATE: 06/29/01 rb

SOIL ANALYSIS
NO 3 Tailing Spill
Submitted: 06/11/01

Sample Number	Identification	Sand %	Silt %	Clay %	Texture	Coarse Fragments %
01-54551-001	TRT-1, 24-27"	46	35	19	L	4
01-54551-002	TRT-1, 27-33"	42	43	15	L	2
01-54551-003	TRT-2, 16-19"	41	41	18	L	4
01-54551-004	TRT-2, 19-22"	38	45	17	L	3
01-54551-005	TRT-3, 24-27"	41	40	19	L	2
01-54551-006	TRT-3, 27-33"	58	28	14	SL	<2
01-54551-007	TRT-4, 24-27"	30	47	23	L	6
01-54551-008	TRT-4, 27-33"	32	47	21	L	5
01-54551-009	TRT-5, 21-24"	42	36	22	L	7
01-54551-010	TRT-5, 24-30"	43	36	21	L	7
DUPLICATE ANALYSIS						
01-54551-010	TRT-5, 24-30"	43	36	21	L	N/A
CONTROL SOIL	**	44	35	21	L	N/A
TARGET RANGE	**	(41-53)	(31-41)	(12-22)	N/A	N/A
DATE ANALYZED	**	06/22/01	06/22/01	06/22/01	06/22/01	06/15/01
BLANK	**	N/A	N/A	N/A	N/A	N/A
SPIKE, %	**	N/A	N/A	N/A	N/A	N/A
DET. LIMIT	**	1	1	1	N/A	2
METHOD #	**	ASA Mono #9 Part 1 Method 15-5	ASA Mono #9 Part 1 Method 15-5	ASA Mono #9 Part 1 Method 15-5	ASA Mono #9 Part 1 Method 15-5	ASA Mono #9 Part 1 Method 15-5

ABP Calculated from Non-Sulfate Sulfur, %

ENERGY LABORATORIES, INC.
P.O. BOX 30916 • 1120 SOUTH 27TH STREET • BILLINGS, MT 59107-0916
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LABORATORY REPORT

TO: Jeff Peace
ADDRESS: Phelps Dodge Tyrone Inc.
PO Drawer 571
Tyrone, NM 88065

LAB NO.: 001-010-01-54551
DATE: 06/29/01 rb

SOIL ANALYSIS
NO 3 Tailing Spill
Submitted: 06/11/01

Sample Number	Identification	Lime as CaCO3 %	Neut. Pot. T/1000T as CaCO3	Acid Pot. T/1000T as CaCO3	Acid/Base Pot. T/1000T as CaCO3	Non-Sulfate Sulfur %	Total Sulfur %	H2O Extr. Sulfur %	HCL Extr. Sulfur %	HNO3 Extr. Sulfur %	Residual Sulfur %
01-54551-001	TRT-1, 24-27"	0.4	4	32	-28	1.03	1.34	0.31	0.02	0.89	0.12
01-54551-002	TRT-1, 27-33"	0.4	4	57	-53	1.82	1.95	0.13	0.07	1.55	0.20
01-54551-003	TRT-2, 16-19"	0.2	2	37	-35	1.17	1.50	0.33	<0.01	1.01	0.16
01-54551-004	TRT-2, 19-22"	0.7	7	54	-47	1.74	1.77	0.03	0.03	1.51	0.20
01-54551-005	TRT-3, 24-27"	<0.1	<1	15	-15	0.49	0.56	0.07	0.17	0.21	0.11
01-54551-006	TRT-3, 27-33"	<0.1	<1	11	-11	0.36	0.43	0.07	0.11	0.17	0.08
01-54551-007	TRT-4, 24-27"	<0.1	<1	23	-23	0.72	1.26	0.54	0.19	0.34	0.19
01-54551-008	TRT-4, 27-33"	<0.1	<1	37	-37	1.19	1.63	0.44	0.12	0.83	0.24
01-54551-009	TRT-5, 21-24"	<0.1	<1	13	-13	0.43	1.02	0.59	0.19	0.16	0.08
01-54551-010	TRT-5, 24-30"	<0.1	<1	34	-34	1.08	1.47	0.39	0.08	0.82	0.18
DUPLICATE ANALYSIS											
01-54551-010	TRT-5, 24-30"	<0.1	<1	33	-33	1.05	1.45	0.40	0.06	0.83	0.16
CONTROL SOIL	**	6.5	65	7	58	0.22	0.24	0.02	0.01	0.16	0.05
TARGET RANGE	**	(3.5 - 7.3)	(37-88)	(0-11)	(34-79)	(0.08-0.30)	(0.09-0.33)	(0.01-0.06)	(0.01-0.06)	(0.05-0.27)	(0.01-0.06)
DATE ANALYZED	**	06/25/01	06/25/01	06/26/01	06/26/01	06/26/01	06/26/01	06/26/01	06/26/01	06/26/01	06/26/01
BLANK	**	N/A	N/A	N/A	N/A	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
SPIKE, %	**	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
DET. LIMIT	**	0.1	1	1	1	0.01	0.01	0.01	0.01	0.01	0.01
METHOD #	**	USDA Handbook 60 Method 23C	USDA Handbook 60 Method 23C	EPA Method 670/2-74-070	EPA Method 670/2-74-070	EPA Method 600/2-78/084 Modified Sobek	EPA Method 600/2-78/084 Modified Sobek	EPA Method 600/2-78/084 Modified Sobek	EPA Method 600/2-78/084 Modified Sobek	EPA Method 600/2-78/084 Modified Sobek	EPA Method 600/2-78/084 Modified Sobek

ABP Calculated from Non-Sulfate Sulfur, %