MEMORANDUM
OFFICE OF THE STATE ENGINEER
HYDROLOGY BUREAU

DATE:	November 15, 2022
TO:	David Ohori, Permit Lead, Mining Act Reclamation Program (MARP)/MMD Holland Shepherd, Program Manager, MARP/MMD
THROUGH:	Katie Zemlick, Ph.D., Chief, Hydrology Bureau KZ Laura Petronis, Water Resources Manager 1, Hydrology Bureau
FROM:	Brad Wolaver, Ph.D., Senior Hydrologist, Hydrology Bureau BDW Christopher E. Angel, P.G., Senior Hydrologist, Hydrology Bureau
SUBJECT:	Review and Comments, Revision 22-1 to Mt. Taylor Mine, Permit No. CI002RE, Rio Grande Resources Corporation

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1. Introduction and Conclusions

On July 14, 2022, the Mining and Minerals Division (MMD) of the State of New Mexico Energy, Minerals and Natural Resources Department (EMNRD) requested the New Mexico Office of the State Engineer (NMOSE) Hydrology Bureau (Hydrology) review and comment on the Revision 22-1 application (Revision) for the Mt. Taylor Mine (Mine) Mining Act Permit No. CI002RE from Rio Grande Resources Corporation (RGR, 2022). The permit Revision presents an updated Closeout/Closure Plan (CCP). This Revision differs from the original in that it includes—but is not limited to—an expansion of Waste Rock Pile/Disposal Cell (Disposal Cell), an alternative shaft cap system ("plug") design, and a change in primary post-mining land use from a water supply project to grazing and light industrial. Several CCP activities described in the Revision could potentially affect groundwater and alluvial aquifers associated with surface water. Thus, the purpose of this document is to evaluate hydrogeologic aspects of the CCP, including:

1. Plugging of Mine conduits and shafts,
2. Plugging of Mine wells, and
3. Potential erosion of waste disposal cells and channelized drainages.

Comment Summary

Mine Shafts and Conduits

- Two shafts (fourteen ft and twenty-four ft in diameter) penetrate several aquifers to a total depth (TD) of approximately 3,300 feet below ground level (ft bgl). As outlined in—but not limited to—19.27.4.29, 19.27.4.30.A (Annular seal), and 19.27.4.31 New Mexico Administrative Code (NMAC), the shafts do not conform to NMOSE codes to 1) prevent commingling or inter-aquifer exchange of groundwater, 2) prevent loss of hydraulic head between hydrogeologic zones or units, 3) prevent unintended flood waters, surface water, or groundwater from entering the shafts and contaminating the aquifer, and 4) prevent the flow of contaminated or low-quality water.

- The Administrative Code requires 1) preventing the commingling or inter-aquifer exchange of groundwater, 2) preventing the loss of hydraulic head between hydrogeologic zones or units, 3) preventing unintended flood waters, surface water, or groundwater from entering the shafts and contaminating the aquifer, and 4) preventing the flow of contaminated or low-quality water. Thus, the Westwater Canyon Member of the Morrison Formation (Westwater Canyon) should be sealed off to prevent groundwater with elevated uranium and radium-226 from migrating to other hydrogeologic units. As-is, Hydrology considers the shafts abandoned in-place without a permit. If RGR does not want to plug the shafts from the bottom up to seal off the Westwater Canyon, a variance will need to be submitted through NMOSE per code 19.27.4.37 NMAC. As part of a variance, a Shaft Monitoring Plan would be needed that describes how RGR will demonstrate compliance with the above referenced codes, given the potential for concrete shaft liners break down over time and create leakage paths.
- The Administrative Code also requires that:
    - The near-surface seep in the fourteen-foot shaft be sealed off,
    - Construction debris does not free-fall into shafts,
    - RGR propose a surface completion protecting the PVC vent in the proposed shaft "plugs" from potential migration of surface runoff (19.27.4.29.L NMAC), and
    - Steel utility conduits be plugged per NMAC 19.27.4, RGR submits a request for variance to use proposed grout design, and RGR proposes an approach ensuring grout does not flow out of the bottom into Mine workings during tremie operations.
- Hydrology requests the following information from RGR:
    - Results of tests evaluating the sulfate-resistance of cement, if conducted, in addition to water quality analyses for sulfate, chloride, and hardness of groundwater in the shaft to evaluate shaft liner-groundwater compatibility,
    - Results of effectiveness testing of the grout curtain (i.e., "an "after the fact" evaluation of grouting efficiency…"), if conducted, to understand how effective the grout curtain was in reducing the inflow of groundwater to the shaft and to characterize the rate at which groundwater was flowing into the shaft during post-dewatering Mine operations,
    - An explanation of what type of joint was used to construct the shaft liners to understand the potential for groundwater inflows through shaft liner joints,
    - Shaft liner concrete permeability: results of any permeability tests would help to understand the potential for flow of groundwater through shaft liner concrete, maps of groundwater potentiometric surface for all monitored aquifers for two different time periods (current and pre-dewatering conditions, or the earliest data available), and a narrative interpretation of each map to understand inferred vertical and horizontal groundwater flow conditions and the potential for groundwater inflows to the shafts,
    - Groundwater quality contour maps for all monitored aquifers for two different time periods (current and pre-dewatering conditions, or the earliest data available) for

sulfate, radium-226, and uranium, in addition to a narrative interpretation of each map. In conjunction with mapping of potentiometric surface described above, groundwater quality maps would assist in understanding the potential for 1) shaft liner degradation from interaction with sulfate and 2) the migration of low-quality groundwater, and
    - What method will be used to keep grout from flowing out of the bottom of the conduit.
- Hydrology is concerned about:
    - The observed trend of decreasing radioactivity of radium-226 with decreasing shaft depth (Table 2.1 in RGR 2022),
    - Elevated (but below New Mexico groundwater standards) total radium (radium-226 + radium-228) in Point Lookout wells DW-2A and DW-3 (Table 2.2 in RGR 2022), and
    - The cause of the decrease in uranium values of the samples collected at 855-ft bgl in the fourteen-ft and twenty-four-ft shafts, compared to samples collected at greater depths (Table 2.1 in RGR 2022).

Groundwater: Wells near the Mine and Abandonment of Mine wells

- The Administrative Code requires wells in the CCP to be plugged in accordance with 19.27.4 NMAC and the Well Plugging Plan, which RGR will submit to NMOSE for approval.
- Hydrology requests**:**
    - Construction details for shallow monitoring, remediation, and dewatering wells, and
    - An explanation of how long-term monitoring wells will be plugged when monitoring is complete and, how well integrity will be tested and, if necessary, wells repaired during long-term monitoring.
- Hydrology is concerned about:
    - Groundwater with elevated concentrations of uranium, nitrate, and other analytes potentially moving off the Mine and impacting nearby public water supply wells,
    - Protecting public water supply wells near the Mine from potential contamination, and
    - How remediation system monitoring well and PMCP well integrity will be assessed to demonstrate a competent seal.

Surface Infrastructure: Waste Disposal and Channelized Drainages

- Hydrology is concerned about:
    - The source(s) of contaminated groundwater identified in wells MW-1M and MW-11A,
    - Potential disposal cell leakage and how unintended leakage might be detected, and
    - Potential mobilization of contaminated sediments from stormwater runoff in channelized drainages and how any such erosion would be remediated.

2. Background

Hydrogeologic Setting

The Mine is in the southeast corner of the San Juan Structural Basin (Basin) in the Grants Mineral Belt (McLemore and Chenoweth 2003) (**Figure 1**). The Basin hosts multiple aquifers and aquitards, with groundwater recharging along elevated Basin margins and discharging to Rio Grande tributaries and the San Juan River (Stone et al. 1983; Kelley et al. 2014; Craigg 2001) (**Figure 2**). Subsurface Mine infrastructure, including wells, utility conduits, and shafts interacts with several aquifers, including San Mateo Creek alluvium, Point Lookout (Wright 1986), Tres Hermanos Member of the Mancos Shale (Tres Hermanos; Hook et al., 1985), Dakota Sandstone Member of the Mesaverde Group (Dakota; Craigg, 2001), and the Westwater Canyon (T.W. Kelly 1977) (**Figure 3, Figure 4**).

The Westwater Canyon is an important confined, artesian aquifer (Craigg 2001), and the Basin's primary uranium ore body (McLemore and Chenoweth 2003). Uranium ore in the Westwater Canyon was accessed in mines of the Grants Mineral Belt using dewatering wells prior to and during mining operations (Kelly, Link, and Schipper 1980). Produced water was typically disposed of in surface drainages, such as San Mateo Creek, causing normally dry streams to flow up to sixty miles (Thomson 2021; Gallaher and Cary 1986). In advance of and during mining operations, the Westwater Canyon was dewatered (approximately six million gallons per day from two Kerr-McGee mines along in 1975), resulting in hundreds of feet of localized drawdown (Kelly, Link, and Schipper 1980). However, pumping ceased when mine closures began the 1980s. At the Mine, Westwater Canyon pressure has largely recovered (Thomson 2021). Dewatering discharge caused alluvial aquifer contamination in some parts of the Grant Mineral Belt and necessitated a health advisory for San Mateo Creek Basin wells (NMED 2009; Thomson 2021).

Mt. Taylor Mine Background

The Mine is located at latitude 35.3392° and Longitude -107.6353° (NAD83), or the NE¼ SW¼ NW¼ SE¼ of Section 24 Township 13 North and Range 8 East in Cibola and McKinney counties, approximately seventeen miles northeast of Grants, New Mexico at an elevation of approximately 7,300 feet above mean sea level (amsl; **Figure 1**). Gulf Mineral Resources Company developed the Mine in the 1970s. Production began in 1980 and stopped in 1982 due to market conditions. Later, Chevron produced uranium from 1986 to 1990. RGR acquired the mine in 1991 but never started production. Closeout/closure activities began in 2019 (RGR 2022). During Mine operation, uranium was produced from sandstone of the Westwater Canyon (referred to as "Upper West Water Sandstone" Member of the Morrison Formation or "Upper West Water" by RGR, 2022, Figures 3 and 4). Mine workings used room-and-pillar and stope mining methods and were accessed by two approximately 3,300 ft deep shafts which were started in 1976 and completed in 1979 and required dewatering wells during construction and operation. Two utility conduits were also constructed to the Westwater Canyon. The shafts and conduits penetrated several aquifers.

Surface and subsurface Mine infrastructure could potentially impact aquifers and existing wells of other ownership due to unintended 1) commingling or inter-aquifer exchange of groundwater, 2) loss of hydraulic head between hydrogeologic zones or units, 3) unintended flood waters, surface water, or groundwater entering shafts, conduits, and wells, and 4) flow of contaminated or low-quality water. Two shafts were constructed to access the main ore body in the Westwater Canyon. Wells, including twenty-three onsite and offsite monitoring wells (RGR, 2022), six groundwater remediation wells, and twenty-two dewatering wells were drilled and operated prior to and during Mine activities and to reduce groundwater pressure as construction of shafts progressed (Table 1; RGR, 2022). An approximately four-mile long, twenty-four-inch diameter steel Treated Water Discharge Pipeline (Pipeline; RGR, 2022) formerly flowed north from the Mine and discharged to El Derrame Cañon (also referred to as Cañada las Vacas and San Lucas Canyon) but ceased operation in 1978 (RGR 2022) (**Figure 1**). At the discharge site, sediments have above-background levels of gamma radiation; however, the CCP includes actions to clean up the area downstream of the pipeline discharge point "to meet permitted soil standards" (see Figure 2-3 in RGR, 2022).

Point-source discharge of pollutants from the Mine to surface water (e.g., storm water runoff) is regulated by a National Pollutant Discharge Elimination System (NPDES) permit. Mine surface infrastructure of interest from a perspective of avoiding surface water and groundwater impacts, includes Mine Water Treatment Unit (MWTU) ponds (#2 and #3 will receive contaminated fluids as part of CCP activities), ore pad, and north storm water retention pond (NSWP) (RGR 2022). Despite current environmental controls, paleo-arroyo alluvial aquifers at the Mine have groundwater with elevated uranium and nitrate, likely sourced from an unlined sewage lagoon (also exceeding NMWQCC drinking water standards: arsenic, boron, chloride, iron, manganese, radium, selenium, sulfate, pH, and TDS). Groundwater in the paleo-arroyos flows off-site to the west-northwest along the contact between paleo-arroyos and the Menefee (see Section 5.1.1 in RGR, 2022) and is currently the focus of groundwater remediation operations, which will continue until groundwater meets water quality standards.

Several intermittent surface drainages flow close to or adjacent to Mine surface infrastructure and drain into San Mateo Creek approximately 1.5 miles to the west of the Mine (refer to Figure 1-2 in RGR, 2022). Marquez Arroyo runs between Borrow Areas "A" and "C" (north bank) and the Ore Pad, Ore Pad Retention Pond, and Pond 8 (south bank). The North Diversion Channel is a re-routed, pre-Mine drainage that flows adjacent to the Ore Pad and Old Ore Loading Area. The South Diversion Channel is also a re-routed drainage that flows next to the Existing Waste Rock Pile / Disposal Cell and Disposal Cell Expansion Area. A Storm Drainage System flows into Marquez Arroyo (Sheet No. CL 09 in RGR, 2022). Additional information on surface water bodies near the Mine is provided in U.S. Geological Survey 7.5-minute, 1:24,000 topographic maps and the National Hydrologic Dataset (NHD) (San Mateo, Cerro Pelon, San Lucas Dam, and Cerro Alesna Quadrangles; USGS, 2022).

3. Mine Shafts and Conduits

The fourteen-foot Manway and twenty-four-foot Production shafts and two utility conduits extend approximately 3,300 ft from the surface and penetrate multiple hydrologic units, including, but not limited to, the Point Lookout, Gallup, Dakota, Westwater Canyon, and the Recapture formations. RGR provided proposed designs for using a chemical grout to control water flow from the formations to the shaft. The fourteen-foot and twenty-four-foot shafts are connected by laterals that are labeled as either permanent or temporary pump stations (**Appendix A**). Since dewatering operations using wells and pumps in the shafts ceased in 1978, Westwater Canyon pressure has largely recovered (Thomson 2021). The CCP states groundwater level in the shafts is now approximately 780 ft bgl (approximately 6,566 ft amsl). If shaft concrete liners were to leak, this would place Westwater Canyon groundwater in potential connection with overlying aquifers.

Mine Shafts

The shafts do not conform to NMOSE codes as outlined in, but not limited to 19.27.4.29, 19.27.4.30.A (Annular seal), and 19.27.4.31 NMAC. In their current condition, the shafts are considered by NMOSE to be abandoned in-place without a permit. Thus, Hydrology's interpretation of the Administrative Code indicates that RGR should seal off the Westwater Canyon in the shafts to prevent groundwater with elevated uranium and radium-226 from migrating to other hydrogeologic units, and 1) prevent commingling or inter-aquifer exchange of groundwater, 2) prevent loss of hydraulic head between hydrogeologic zones or units, 3) prevent unintended flood waters, surface water, or groundwater from entering the shafts and contaminating the aquifer, and 4) prevent the flow of contaminated or low-quality water. If RGR does not plan to plug the shafts from the bottom up, the Administrative Code requires that RGR apply for a variance per code 19.27.4.37 NMAC. The Administrative Code also indicates that the seep in the fourteen-foot shaft should be sealed off. Also, concrete shaft liners will break down over time and create the possibility of leakage. Thus, Hydrology's interpretation of the Administrative Code indicates that RGR should provide a Shaft Monitoring Plan that describes how RGR will demonstrate compliance with the above referenced codes. Hydrology's interpretation of the Administrative Code also indicates that RGR should not free-fall construction debris into the shafts to reduce risk of damaging shaft liners and that RGR should propose a design of a lock box or similar fixture to protect the PVC vent and monitoring tube from damage and potential migration of surface runoff into the shafts (including but not limited to Section 27.4.29.K and Section 27.4.29.L NMAC).

Chemical Grouting

Prior to shaft construction, a grout design with permeability of 10^{-9} cm/s was proposed (i.e., Celtite 55 Terraseal; **Appendix A**). However, as-built documentation was not provided by RGR describing if this grout was injected into the formation. A 1977 report on grouting of the Dakota (**Appendix B**) indicates that grouting had already taken place in the Menefee and Point Lookout; however, the report does not specify as-built materials used for the grouting these intervals. The report also reports Dakota fractures up to 3.5-in wide and a seventy-foot head decline from 1972 to 1977, which appears to be from the dewatering program. The report discusses testing to be performed to determine the effectiveness of the grout, but RGR has not provided information regarding any grout effectiveness testing.

Concrete Specifications

The shafts are lined with cast-in-place concrete liners to isolate the shafts from aquifers and prevent inter-aquifer communication (**Appendix C**). RGR provided NMOSE with concrete specifications for the shaft lining that indicates the cement to sand and rock ratio was approximately twenty percent cement (i.e., 610 lbs cement, 1323 lbs sand, 1643 lbs rock; **Appendix D**). The water-cement ratio of the design is approximately fifty percent. RGR has not specified what as-built Type of cement was used (e.g., ASTM Type I, Type II, etc.). The Type cement may be important based on the concentration of sulfate in groundwater. According to the Bureau of Reclamation Concrete Manual, "hardened concrete is inherently somewhat pervious [i.e., permeable] to water which may enter through capillary pores or forced in by pressure" (BOR 1988) (**Appendix D**). Thus, groundwater would be forced through the concrete by hydrostatic pressure. Also, concrete permeability increases steadily when the water-cement ratio exceeds fifty-five percent by weight and with increase in aggregate size (BOR 1988) (**Appendix E**). In addition, tensile strength seldom exceeds ten percent of the compressive strength (BOR 1988). Thus, a lack of compressive strength allows for the concrete to crack and flake apart. The stressor of water pushing through the concrete may also increase the deterioration. To understand the shafts better and characterize leakage potential, Hydrology requests: 1) Results of grout curtain effectiveness testing (if conducted; **Appendix B**), 2) Results of tests evaluating the sulfate-resistance of cement (if conducted; **Appendix B**), and 3) an explanation of shaft liner spacers and what type of joint between shaft sections was used (**Appendix C**). Hydrology is concerned about the permeability of shaft liner concrete. Results of permeability tests, if conducted, would be useful to evaluate concrete degradation and leakage potential.

Mine Conduits

The Administrative Code states that the conduits should be plugged to avoid inter-aquifer communication and potential groundwater impacts. General technical requirements for well and conduit plugging are provided in Appendix C.6 of the CCP (RGR 2022). Section 4.3.3.3 of the CCP (RGR 2022) states that a Well Plugging Plan of Operation (NMOSE Form WD-80) shall be submitted for approval by the State Engineer before plugging of any wells is initiated. The two 11.5-inch outside diameter (OD), 10.75-inch inner diameter (ID), steel conduits are in 12.5-in diameter boreholes and have a pressure-grouted annulus to isolate the conduits from aquifers penetrated along 3,100-ft (north) and 3,200-ft (south) conduits. The CCP (RGR 2022) states that a 4:1 cement:bentonite grout mix will be used to grout the conduits from bottom to top using the tremie method ("as required by 19.27.4 NMAC"). The Administrative Code indicates that RGR should submit a request for variance to use this grout design, specifying why this grout design is required, or that RGR demonstrates that this grout meets the permeability requirement of less than 10^{-7} cm/sec (per NM OSE Sealant Guidance for Well Construction and Plugging, 2020).

Also, the CCP also states that the "contractor shall top off any casing [conduit, per Section 2.2 Utility Conduit Plugging] that does not have a solid column of grout to the ground surface" after twenty-four hours. Grouting of the conduits should be done according to 19.27.4 NMAC; however, the CCP does not explain how grout will be kept from flowing out of the bottom of the conduits into the Mine workings. Thus, Hydrology requests that RGR specify what method will be used to keep grout from flowing out of the bottom of the conduit.

4. Groundwater: Wells Near the Mine and Abandonment of Mine Wells

Wells Near the Mine

Using the New Mexico Water Right Reporting System (NMOSE 2022a), sixty-six wells were identified within approximately three miles of the Mine (**Appendix F**). Of these, forty-two wells report completion year, fifty-six have TD, and twenty-nine wells have both TD and depth to water (DTW) information. Well TDs range from 32 to 3,535 ft bgl. The reported DTW for the wells range from fourteen to 1,279 ft bgl. Ten wells have pre-1990 TD and DTW. Based upon an evaluation of well logs (NMOSE 2022a), wells drilled less than approximately 100 ft bgl are likely completed in the alluvial aquifer associated with San Mateo Creek, wells from approximately 100 to 400 ft bgl are likely completed in sandstone and interbedded shale of the Menefee, and wells completed to depth up to approximately 700 ft bgl are likely in sandstone of the Point Lookout. None of the wells evaluated appears to be completed in the Westwater Canyon. One well drilled in 1920 and redrilled in 1947 (POD B-01085) to a depth of 476 ft bgl is likely completed in the Menefee and reports a DTW of 90 ft bgl prior to dewatering operations in the Grants Mineral Belt.

The nearest public supply wells identified in this evaluation supply the Village of San Mateo and are completed in the Menefee (POD B-00428, TD=325 ft bgl, 5.5-inch casing, DTW=75 ft bgl) and Point Lookout (POD B-00428-S, TD=703 ft bgl, which was approved in 1977 as conversion of exploratory borehole B-00385 with DTW=196 ft bgl, one mile from Mine; NMOSE 2022b). Logs for wells drilled in the 1970s and later indicate wells are likely screened in only one aquifer (NMOSE 2022b). However, many of the 1970s-vintage wells were constructed with PVC casing, which can potentially be deformed by the heat of hydration of cement causing an imperfect seal and potential inter-aquifer communication. Hydrology is concerned about potential impacts to water quality of these public water supply wells from inter-aquifer communication resulting from poor seals or improper plugging, particularly those perforating the Menefee and Point Lookout.

Plugging of Mine Wells

As proposed in the CCP, twenty Mine wells will be plugged, including eight Westwater Canyon, two Dakota/Westwater Canyon, one Dakota, two Dakota/Tres Hermanos, one Tres Hermanos, two Point Lookout, and three alluvial wells (**Table 1**). Section 1.9 (General Submittals) of the CCP

(RGR 2022) states that a "Well Plugging Plan … shall be submitted for approval by the State Engineer before well plugging begins." The Mine wells to be plugged as part of the CCP—including shallow monitoring, remediation, and dewatering—should be plugged in accordance with NMAC 19.27.4. The Plugging Plan is essential to ensure inter-aquifer communication and potential groundwater impacts do not occur. The Plugging Plan should be submitted to NMOSE for approval. Plugging should also conform to MMD conditions in the project permit.

As part of Mine dewatering activities, twenty-three alluvial and Menefee aquifer monitoring wells were drilled to assess effects of dewatering on shallow groundwater. Of these, six have been used for extraction of contaminated groundwater (including uranium and nitrate) likely originating from an unlined sewage lagoon. In addition, twenty-two dewatering wells were drilled as Mine shafts were constructed (**Figure 4**) (RGR, 2022). Importantly, the dewatering wells penetrated multiple aquifers (**Figure 2, Figure 3**), started pumping in the early 1970s, and ceased operation in 1978 (RGR 2022). Eight dewatering wells were constructed in the Point Lookout, four wells in the Tres Hermanos and/or Gallup, and ten wells Dakota and/or the Westwater Canyon. Hydrology requests RGR provide construction details for shallow monitoring, remediation, and dewatering wells, particularly if PVC was used for casing, which could potentially deform due to cement heat of hydration causing an imperfect seal.

Several wells will not immediately be plugged as part of the CCP. Seven wells screened in the Point Lookout will be retained for post-mine land use (PMLU), which includes livestock grazing and light industry (Section 3.3 in RGR, 2022). Also, when the abatement program results in groundwater meeting water quality standards for uranium and nitrate, the six original and two additional shallow groundwater remediation wells will be plugged (except for four alluvial/Menefee wells to be retained for long-term monitoring program) (RGR 2022). In addition, five "deep wells" (two Point Lookout wells, one Tres Hermanos/Dakota well, and two Westwater Canyon wells) will be used as part of the Post-Closure Monitoring Plan (PMCP; Appendix H and Table 2.3 in RGR, 2022), which could last up to 100 years. It is important to assure the integrity of long-term monitoring wells so that casing degradation does not lead to inter-aquifer communication and groundwater impacts. Post-closure monitoring for groundwater level and groundwater water quality "once every ten years for Years 31–100 for all wells, if required" (Section 2.6.2 of PCMP in RGR, 2022). Water quality monitoring for a given well can cease if the contaminant is "below the applicable standard for eight consecutive sampling periods" (**Table 1**) and up to 100 years. Hydrology is concerned about how post-PMCP well integrity will be assessed. Hydrology is also concerned about contaminated groundwater, particularly 1) the extent and concentration of contaminants the remediation system is treating (i.e., contour maps of contaminant concentration), 2) current and post-remediation system potentiometric surface and how it may affect contaminant transport, 3) potential transport of residual contamination after the remediation system is shut down, and 4) the long-term integrity of the casing and annular seal of monitoring wells belonging to the remediation system and long-term monitoring program.

5. Surface Infrastructure: Waste Disposal and Channelized Drainages

Typical of mines in the Grants Mineral Belt, solid and liquid waste handling at the surface during operation and when mining ceases provides the potential for near-surface water quality issues and mobilization of contaminants due to unintended erosion during stormwater runoff (NMED 2009; Thomson 2021; Kelly, Link, and Schipper 1980; Gallaher and Cary 1986).

Waste Disposal

At the Mine, solid and liquid waste has been handled and stored at the surface. For example, leakage of an unlined sewage lagoon caused groundwater of paleo-arroyos incised into the Menefee to be contaminated with uranium, nitrate, and other constituents (RGR 2022). As a result, a groundwater extraction well network was drilled to remediate groundwater. Fluids from groundwater remediation and other Mine operations outlined in the CCP will be discharged into MWTU Pond #3 (with MWTU Pond #2 as a backup) until the groundwater abatement program meets groundwater quality goals. At the end of abatement operations, sediment contained in the two ponds, in addition to their liners and other associated equipment will be removed and placed in the disposal cell (RGR 2022). Regarding this contaminated groundwater, Hydrology is concerned about the source(s) of contaminants identified in wells MW-1M and MW-11A that requires the drilling of two new extraction wells (Ensero 2021b; 2021a).

The CCP states that an Expanded Disposal Cell (see Sheet No. CL 09 in RGR, 2022) will be constructed to receive radiologically contaminated materials during Mine closure/closeout (e.g., pond sediments, soils, demolition debris). The expanded cell will be up to 13.5 acres in area and will have base of compacted clay at least 1-foot thick. It will be covered with at least two feet of compacted clay and two feet of growing loam for revegetation to act as water infiltration barrier and protection against erosion. Hydrology is concerned about potential disposal cell leaks and how unintended leakage might be detected.

Channelized Drainages

Channelized surface drainages also are of interest, given past impacts to alluvial groundwater from surface water in the Grants Mineral Belt (NMED 2009; Thomson 2021; Gallaher and Cary 1986). For example, RGR plans as part of the CCP to install riprap for erosion protection along the South Diversion Channel because it passes adjacent to the Waste Rock Pile (WRP) and disposal cell. Hydraulic modeling suggests that Marquez Arroyo does not present an erosion risk, but an analysis of the North Diversion Channel is not mentioned (RGR 2022). While stormwater runoff are infrequent events with likely localized impacts, over long periods time, erosion could potentially mobilize contaminated sediments. But during the time horizon of the CCP, if the NPDES permit conditions are followed, surface water quality should be satisfactory and resulting contamination to hydrologically connected groundwater is likely minor. However, Hydrology is concerned about potential erosion and mobilization of contaminated sediments to surface water and how any such erosion will be remediated if it occurs.

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Table 1. Mine dewatering and observation wells

Notes: PMLU = Post-Mining Land Use, PCMP = Post-Closure Monitoring Plan, PL = Point Lookout, TH = Tres Hermanos, D = Dakota, W = Westwater Canyon.

Well	Well Type	Closure Dispostion	State Plane, Northing	State Plane, Easting	Collar Elevation (ft amsl)	Well Depth (ft bgl)	Well Depth (ft amsl)	Depth to GW (ft bc)	GW Elevation (ft amsl)	Date of GW Measurement	Screened Interval (ft bgl)	Screened Interval (ft amsl)	Aquifer, Screened Interval
1	Dewatering	PMLU	1579419	2782626	7340	1118	6222	471	6869	Dec-21	740-890	6600-6450	PL
2	Dewatering	Plug	1579121	2782606	7345	2920	4425	-	-	-	2550-2920	4795-4425	TH/D
2-a(1)	Dewatering	PMLU	1579202	2782709	7347	925	6422	483	6864	Apr-18	750-900	6597-6447	PL
3	Dewatering	Plug	1579008	2782795	7347	1150	6197	595	6752	Dec-21	737-891	6610-6456	PL
4	Dewatering	PMLU	1578965	2783021	7349	1130	6214	-	-	-	750-900	6599-6449	PL
5	Dewatering	PMLU	1579038	2783256	7406	1172	6234	-	-	-	852-1002	6554-6404	PL
6	Dewatering	PMLU	1579210	2783402	7385	1190	6195	598	6787	Dec-13	845-995	6540-6390	PL
7	Dewatering	PMLU	1579455	2783384	7376	1125	6251	568	6808	Dec-21	825-995	6551-6401	PL
8	Dewatering	PMLU	1579672	2783240	7346	1044	6302	-	-	-	791-941	6555-6405	PL
9	Dewatering	Plug	1579723	2782973	7340	2845	4495	616	6724	Dec-21	2538-2840	4802-4500	TH
10	Dewatering	Plug	1579619	2782734	7337	1065	6272	462	6875	Dec-21	738-888	6599-6449	PL
11	Dewatering	Plug	1578845	2783245	7446	3028	4418	906	6540	May-22	2819-3028	4627-4418	TH/D
12	Dewatering	PCMP	1579421	2783439	7419	2940	4479	831	6588	Dec-21	2791-2940	4628-4479	TH/D
13	Dewatering	Plug	1579378	2782065	7317	3185	4132	747	6570	Aug-21	3045-3185	4247-4132	W
14	Dewatering	PCMP	1578847	2782182	7341	3205	4133	761	6580	May-22	3048-3188	4290-4150	W
15	Dewatering	Plug	1578491	2782501	7347	3205	4142	-	-	-	3056-3196	4291-4151	W
16	Dewatering	Plug	1578334	2782995	7393	3275	4118	812	6581	May-22	3105-3245	4288-4148	W
17	Dewatering	Plug	1578570	2783563	7501	3342	4159	915	6586	Dec-21	3209-3342	4291-4159	W
18	Dewatering	Plug	1578902	2783778	7495	3314	4188	919	6576	May-22	3212-3314	4295-4192	W
19	Dewatering	PCMP	1579493	2783781	7453	3274	4179	-	-	-	3166-3274	4287-4179	W
20	Dewatering	Plug	1579945	2783505	7385	3223	4162	811.36	6574	May-22	2938-3223	4447-4162	D-W
21	Dewatering	Plug	1580165	2782966	7316	3184	4132	750	6566	May-22	2873-3173	4443-4143	D-W
22	Dewatering	Plug	1579900	2782460	7305	3195	4110	731	6574	May-22	3019-3159	4286-4146	W

Well	Well Type	Closure Dispostion	State Plane, Northing	State Plane, Easting	Collar Elevation (ft amsl)	Well Depth (ft bgl)	Well Depth (ft amsl)	Depth to GW (ft bc)	GW Elevation (ft amsl)	Date of GW Measurement	Screened Interval (ft bgl)	Screened Interval (ft amsl)	Aquifer, Screened Interval
MW 01	-	Plug	1580484	2781541	7275.3	-	-	-	-	-	33.5-38.5	-	A-M
MW 02	-	Plug	1580191	2781538	7278.3	-	-	-	-	-	30.1-36.1	-	A-M
MW 03	-	Plug	1580976	2781545	7273	-	-	-	-	-	33.6-38.6	-	A-M
MW 03A	-	Plug	1580976	2781546	7272	-	-	-	-	-	39.0-49.0	-	A-M
MW 04	-	PCMP	1578580	2781050	7284.2	-	-	-	-	-	31.5-46.5	-	A-M
MW 05	-	Plug	1579062	2781556	7303.4	-	-	-	-	-	22.5-32.5	-	A-M
MW 06	-	Plug	1578620	2782243	7341.5	-	-	-	-	-	15-35	-	A-M
WP 04	-	PCMP	1578330	2781527	7312.7	-	-	-	-	-	38-48	-	A-M
WP 05	-	Plug	1578786	2781546	7303.1	-	-	-	-	-	30-40	-	A-M
WL 02	-	Plug	1578575	2782115	7341.4	-	-	-	-	-	39-49	-	A-M
WL 03	-	Plug	1578651	2782133	7341.1	-	-	-	-	-	39-49	-	A-M
WL 04	-	Plug	1578537	2782171	7342.2	-	-	-	-	-	39-49	-	A-M
WL 05	-	Plug	1578614	2782309	7343	-	-	-	-	-	40-50	-	A-M
MW 1C	-	Plug	1578341	2783120	7395.5	-	-	-	-	-	84-94	-	A-M
MW 1J	-	Plug	1579034	2782712	7347.4	-	-	-	-	-	49.4-59.4	-	A-M
MW 1M	-	PCMP	1579255	2782392	7339	-	-	-	-	-	38-48	-	A-M
MW 2F	-	Plug	1578553	2782577	7348	-	-	-	-	-	42-62	-	A-M
MW 4D	-	Plug	1578849	2782082	7341.4	-	-	-	-	-	42-62	-	A-M
MW 4H	-	Plug	1579335	2782029	7322.5	-	-	-	-	-	51.5-61.5	-	A-M
MW 11A	-	PCMP	1578585	2781928	7355.8	-	-	-	-	-	75-85	-	A-M

Well	Well Type	Closure Dispostion	State Plane, Northing	State Plane, Easting	Collar Elevation (ft amsl)	Well Depth (ft bgl)	Well Depth (ft amsl)	Depth to GW (ft bc)	GW Elevation (ft amsl)	Date of GW Measurement	Screened Interval (ft bgl)	Screened Interval (ft amsl)	Aquifer, Screened Interval
SM-24-38	Monitoring	Plug	1579132	2783007	7349	3535	3814	-	-	-	3107-3247	4324-4184	W
SM-24-43	Monitoring	Plug	1579029	2782948	7347	3535	3812	-	-	-	3064-3204	4283-4143	W
SM-24-89	Monitoring	Plug	1578964	2782908	7348	3121	4227	-	-	-	-	-	W
SM-15-59	Monitoring	Plug	1584519	2771754	7738	-	-	-	-	-	-	-	-
SM-13-74	Monitoring	Plug	1584233	2783313	7480	-	-	1518	5962	Oct-91	-	-	-
SM-31-1-2D	Monitoring	Plug	1584519	2786914	7630	-	-	-	-	-	-	-	-
SM 24-23E	Monitoring	Plug	1579711	2783249	7342	3077	4265	796.41	6550.59	May-22	-	-	D
14-Ft Shaft	Man	-	1579520	2783065	7342	3340	4008	776	6566	Oct-19	-	-	W
24-Ft Shaft	Production	-	1579122	2782964	7346	3300	4043	779	6567	Sep-19	-	-	W

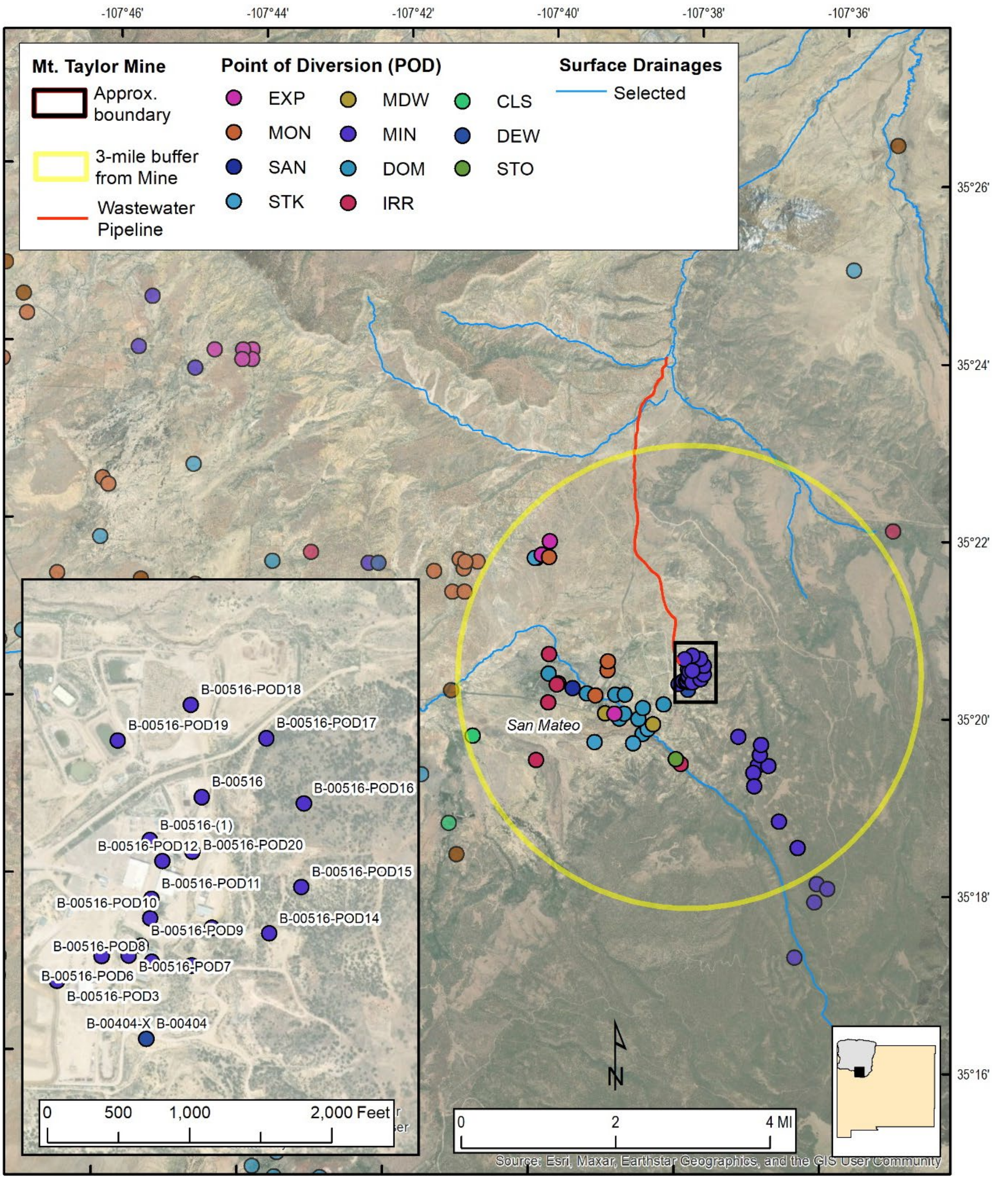


Figure 1. Mount Taylor Mine, surface hydrology, groundwater wells (NMOSE, 2022)

Notes: Large inset map shows wells on the approximate extent of the Mine property. Three-mile buffer around Mine used to identify groundwater wells. Black rectangle shows the approximate extent of the Mine property. Gray polygon of inset map identifies the San Juan Structural Basin. POD types are: EXP = exploration, MON = monitoring, SAN = sanitary (commercial use), STK = stock, MDW = community water supply, MIN = mining, DOM = domestic, IRR = irrigation, CLS = closed file, DEW = dewatering, STO = storage.

Youngest	Formation	Rock type (major rock listed first)	Depositional environment	Resources	Geologic symbol
Cenozoic	San Jose Formation	Sandstone and shale	Continental rivers	Water,gas	Tsj
	Nacimiento Formation	Shale and sandstone	Continental rivers	Water, gas	Tn
	Ojo Alamo Sandstone	Sandstone and shale	Continental rivers	Water, gas	Toa
Cretaceous	Kirtland Shale	Interbedded shale, sandstone	Coastal to alluvial plain	Water, oil, gas	Kk
	Fruitland Formation	Interbedded shale, sandstone and coal	Coastal plain	Coal, coalbed methane	Kf
	Pictured Cliffs Sandstone	Sandstone	Regressive marine, beach	Oil, gas	Kpc
	Lewis Shale	Shale, thin limestones	Offshore marine	Gas	Kls
	Cliff House Sandstone	Sandstone	Transgressive marine, beach	Oil, gas	Kch
	Menefee Formation	Interbedded shale, sandstone and coal	Coastal plain	Coal, coalbed methane, gas	Kmf
	Point Lookout Sandstone	Sandstone	Regressive marine, beach	Oil, gas, water	Kpl
	Crevasse Canyon Formation	Interbedded shale, sandstone and coal	Coastal plain	Coal	Kcc
	Gallup Sandstone	Sandstone, a few shales and coals	Regressive marine to coastal deposit	Oil, gas, water	Kg
	Mancos Shale	Shale, thin sandstones	Offshore marine	Oil, gas	Km
	Dakota Sandstone	Sandstone, shale and coals	Transgressive coastal plain to marine shoreline	Oil, gas, water	Kd
Jurassic	Morrison Formation	Mudstones, sandstone	Continental rivers	Uranium, oil, gas, water	Jm
	Wanakah/Summerville/Cow Springs/Bluff	Siltstone, sandstone	Alluvial plain and eolian		
Oldest	Entrada Sandstone	Sandstone	Eolian sand dunes	Oil, gas, water	Je

Other rock names used in the San Juan Basin

Chacra Mesa is a name applied to the Cliff House Sandstone lenses on the north side of the basin
The La Ventana tongue is a marine sandstone above the main part of the Cliff House Sandstone
Hospah is the uppermost sandstone toungue in the Gallup Sandstone
The lower Hosta tongue is a transgressive phase of the regressive Point Lookout Sandstone
The upper Hosta is another name for the Point Lookout Sandstone
Sanostee is equivalent to the Juana Lopez

Figure 2. Generalized hydrostratigraphy of the San Juan Structural Basin of New Mexico

Source: Kelley et al. (2014)

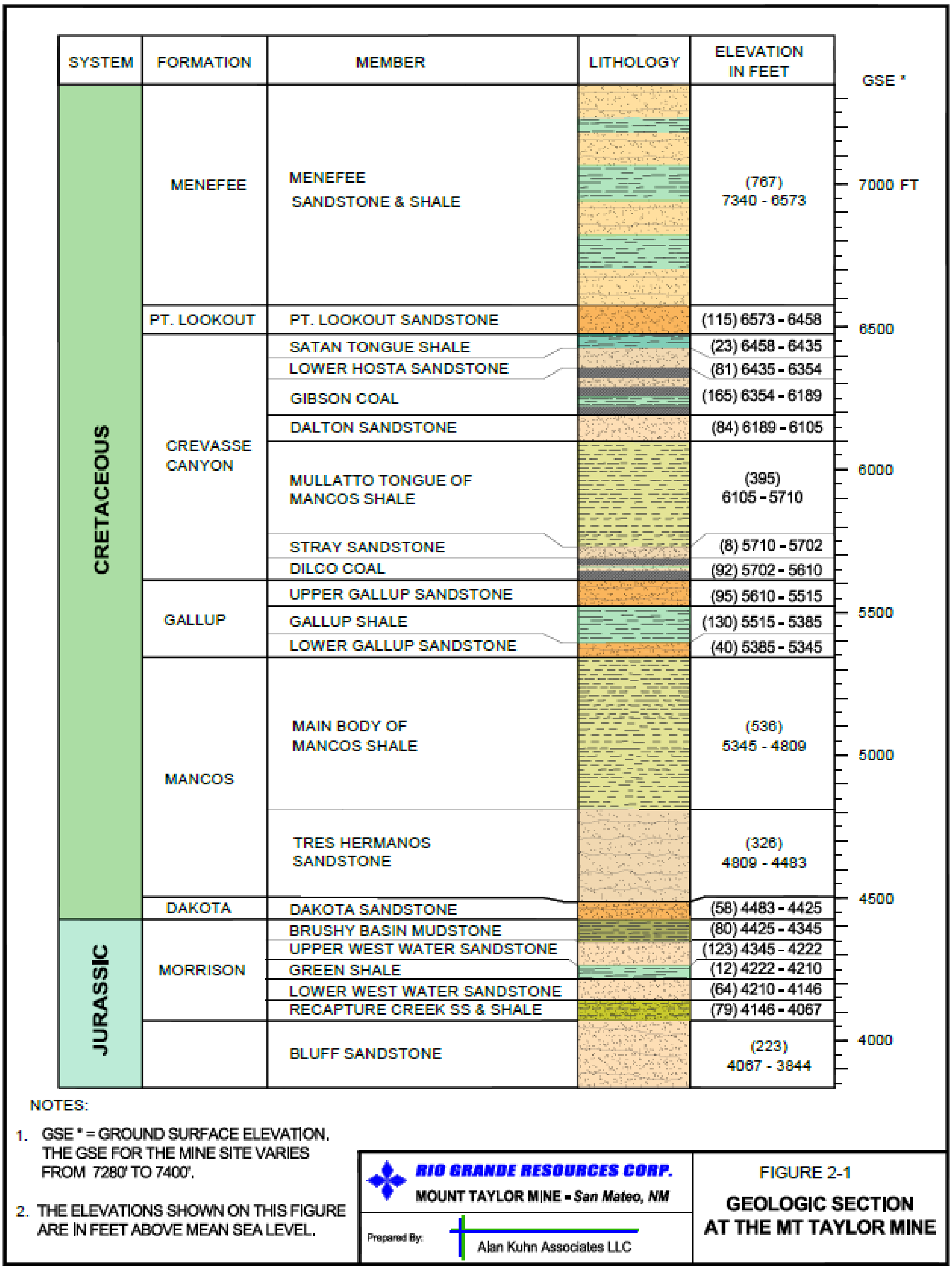


Figure 3. Geologic section at the Mine

Source: RGR (2022).

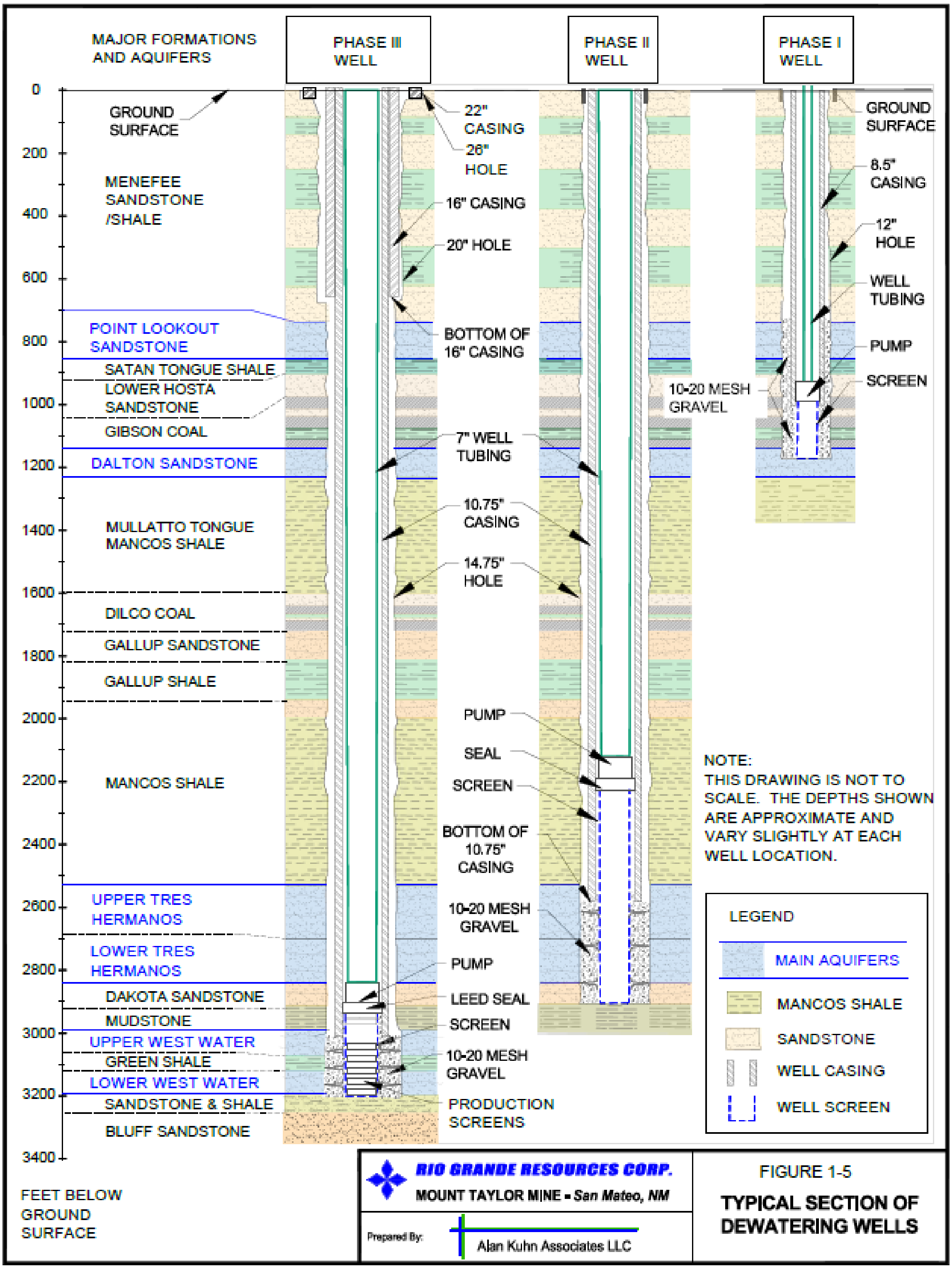
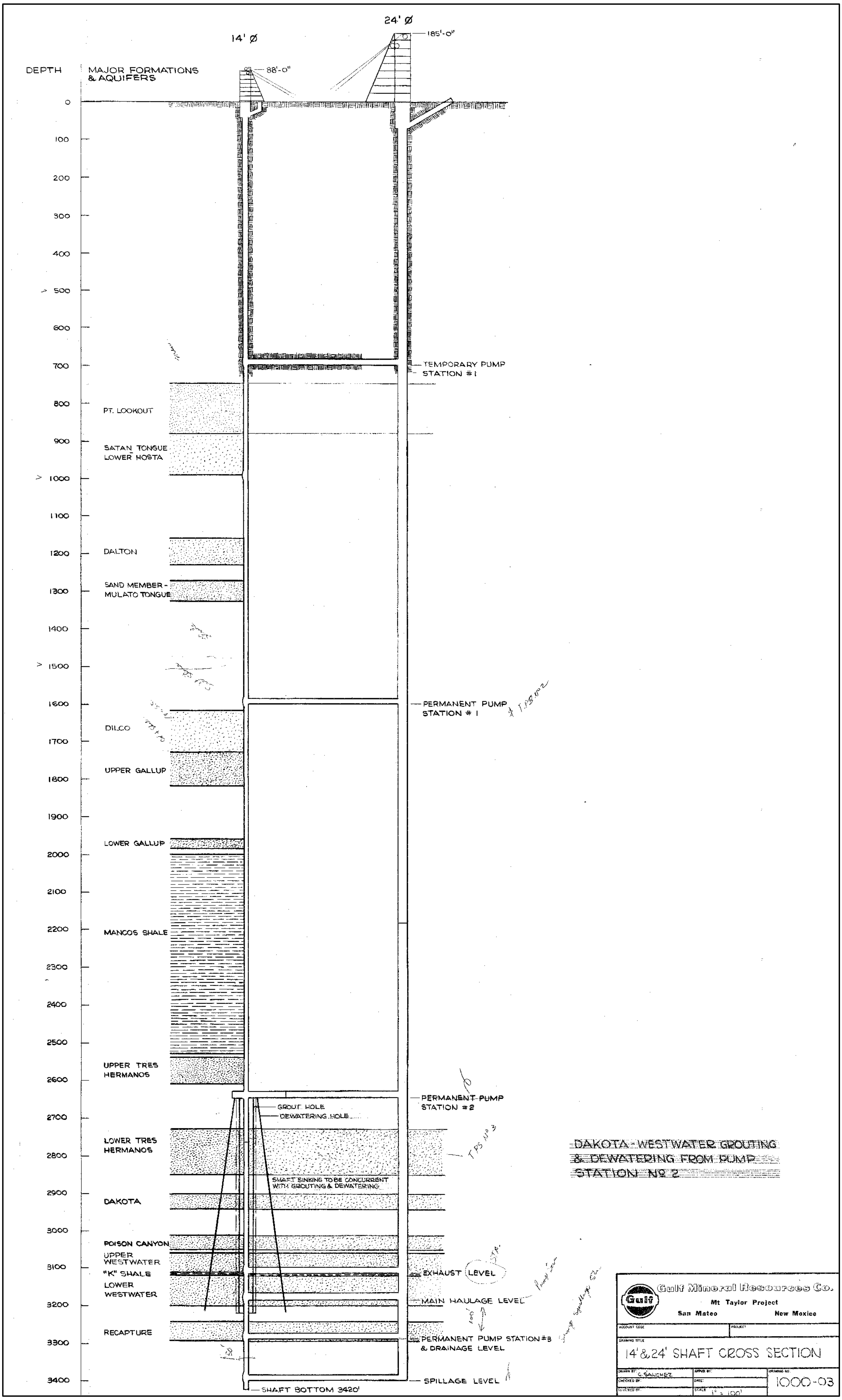


Figure 4. Aquifers penetrated by shafts and dewatering wells

Source: RGR (2022).

Appendix A. Mine Shaft Proposed Design with Pump Stations and Stratigraphy (Drawing No. 1000-03)


24' Ø
185'-0"
14' Ø
88'-0"
DEPTH
MAJOR FORMATIONS & AQUIFERS
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
2100
2200
2300
2400
2500
2600
2700
2800
2900
3000
3100
3200
3300
3400
PT. LOOKOUT
SATAN TONGUE LOWER HOSTA
DALTON
SAND MEMBER - MULATO TONGUE
DILCO
UPPER GALLUP
LOWER GALLUP
MANCOS SHALE
UPPER TRES HERMANOS
LOWER TRES HERMANOS
DAKOTA
POISON CANYON
UPPER WESTWATER
"K" SHALE
LOWER WESTWATER
RECAPTURE
TEMPORARY PUMP STATION #1
PERMANENT PUMP STATION # 1
PERMANENT PUMP STATION #2
GROUT HOLE
DEWATERING HOLE
SHAFT SINKING TO BE CONCURRENT WITH GROUTING & DEWATERING
EXHAUST LEVEL
MAIN HAULAGE LEVEL
PERMANENT PUMP STATION #3 & DRAINAGE LEVEL
SPILLAGE LEVEL
SHAFT BOTTOM 3420'
DAKOTA-WESTWATER GROUTING & DEWATERING FROM PUMP STATION No 2
Gulf Mineral Resources Co.
Gulf
Mt Taylor Project
San Mateo
New Mexico
14'&24' SHAFT CROSS SECTION
C. SANCHEZ
1" = 100'
1000-03

Appendix B. Mt. Dakota Grouting Memo by W.C. Juvkam-Wold

INTERNAL CORRESPONDENCE
GUS 10973 - A

JFM → FILE COPY
JFM

FROM H. C. Juvkam-Wold AT Denver IN REPLY REFER TO

TO Mr. P. M. James AT Mt. Taylor DATE 10-13-77

MT. TAYLOR GROUTING - DAKOTA

SUMMARY

This memorandum discusses a program for grouting the Dakota in the 14-ft shaft. One grout pad with two patterns of grout holes is proposed. Two alternate approaches for grouting the Dakota are also discussed. Cement is recommended as the primary grouting material, because of its high strength and low cost, and because of the large fractures in the Dakota.

The top of the grout pad should be at a depth of about 2,830 ft. The "A" pattern of holes should be drilled with a spin angle of 45° and a dip angle of 74°. The "B" pattern should have a spin of -45°, and a dip of 82°.

Testing of the grout materials with various additives to determine viscosity and gel times is suggested. Emphasis should be placed on safety, and on achieving high grouting rates.

INTRODUCTION

The purpose of injecting grout material into the formation is two-fold: to control water flow from the formation, and/or to consolidate and strengthen the rock. The choice of grout material will depend to a great extent on which of the above criteria is applicable.

A satisfactory grouting program requires that the right amount of the right kind of grouting material be placed in the right place in the least time possible. This statement raises a number of questions that should be answered to the extent possible, before grouting commences.

1. How much grout material should be used?
2. How does one select the right kind of grout material? What should be its properties?
3. What is the best way to assure that the grout material goes where it is supposed to go?

4. What is the optimum grouting rate?
5. How does one measure the degree of success of a grouting job, i.e., what are the performance criteria?

In the subsequent sections an attempt is made to shed some light on the above questions. It should be recognized that no "cook-book" approach is recommended. Each grouting job is different, and the grouting program inevitably will have to be modified as conditions dictate. Nevertheless, an overall plan is essential, and this memo represents one person's view of how such a program may be developed.

HOW MUCH GROUT MATERIAL?

One answer might be: "Just enough". But this answer is not very satisfactory from a planning point of view. A very simplistic method for calculating grout material requirements is demonstrated in Figure 1. Here it is assumed that the shaft will be surrounded by a cylindrical grout curtain as shown. The following equation may be used to calculate grout volumes:

$$Q = \pi \left[(r_x + t)^2 - r_x^2 \right] \phi \times 7.48 \times h \times F \qquad (1)$$

Q (gal)	=	volume of grout material required
r_x (ft)	=	shaft excavation radius
t (ft)	=	desired thickness of grout curtain
ϕ	=	porosity of the formation to be grouted, expressed as a fraction ($\approx$ 0.20)
7.48	=	conversion factor to convert from ft^3 to gal
h (ft)	=	thickness of formation (consider h = 1 ft)
F	=	safety factor, to allow for the fact that some of the material may move outside the grout curtain, or be ineffective in some other way, e.g., by not gelling (assume F = 1.5)

With the above values for ϕ, h and F, Equation (1) reduces to:

$$Q = 7.05 \left[(r_x + t)^2 - r_x^2 \right] \qquad (2)$$

Where Q is now the volume of grout required per foot of shaft depth (or aquifer thickness).

If we further assume that the excavation radius is 9 ft, and the desired grout curtain thickness is 15 ft, then, from Equation (2):

$$Q = 3490 \text{ gal/ft}$$

A 15-ft thick grout curtain may be a reasonable starting point for the Dakota, thereby requiring approximately 3,500 gal of grout material for each ft of depth. The total thickness or height of formation to be grouted in the Dakota was estimated from the SM24-38 logs to be approximately 60 ft. Hence the total Dakota grout requirements in the 14-ft shaft is estimated to be 210,000 gal. The geometry of the three intervals to be grouted is shown in Figure 2.

It may be seen from Equation (2) that a grout curtain thickness of 10 ft would reduce the grout material requirements to approximately 2000 gal/ft or 120,000 gal total for the Dakota. In the subsequent discussion a 15-ft thickness will be assumed.

A second, more detailed method for predicting grout requirements is to take into consideration the fact that the grout holes tend to move further away from the shaft as they get deeper. This is demonstrated in Table I, where the location of the grout hole as a function of depth and dip angle is tabulated.

Consider the grout hole with a spin angle of 45° and a dip angle of 74°, drilled from the shaft bottom at a 6-ft radial distance from the center-line of the shaft. By the time this hole reaches a depth of 54 ft, it will be 20 ft away from the shaft center-line. A 15-ft thick grout curtain at this depth would require:

$$Q = 7.05 \left[(20 + 7.5)^2 - (20 - 7.5)^2\right] = 4{,}230 \text{ gal/ft}$$

Hence the grout requirements can be expected to increase with depth below the grout pad.

If 16 grout holes are used in a particular cover, and a 10-ft depth interval is being treated, then the amount of grout material to be injected in each hole (using 3,490 gal/ft) would be:

$$Q = 3{,}490 \times \frac{10}{16} = 2{,}180 \text{ gal/hole}$$

At a grouting rate of 10 gal/min this would represent 218 minutes of pumping, or approximately 3.6 hours per hole. Obviously, doubling the pumping rate would cut the time in half.

It is quite possible that the above estimates are too high, and that a 10-ft thick curtain would be adequate. It is also possible that the 0.20 porosity fraction is too high for the Dakota. All we can go by here is estimates and past experience. When grouting the Menefee and the Point Lookout, the grout consumption averaged about 2,000 and 8,000 gal/ft respectively, and the above estimates for the Dakota are within this range.

SELECTION OF GROUT MATERIAL

The best material is the one that will do the required job at the minimum overall cost. The Dakota is reported to be highly fractured, with some fractures as wide as 3½" (at Ranchers). Cement would be the material of choice here, since it is the strongest and cheapest grout material available, and it will enter into fractures, even though it will not enter into the small pores in the rock matrix. Reportedly, cement has been used quite sucessfully in grouting the Dakota in the Ambrosia Lake area. Geoseal has also been used (Ranchers), but this material is not recommended for grouting large fractures. At 800 PSIG pressure, it is estimated that a good Geoseal gel can be extruded from a 3½" fracture, 10-ft long!

Once the fractures are filled, either Geoseal or Terraset can be used to fill the matrix, if necessary. Terraset will give a compressive strength three to four times higher than that obtained from Geoseal in a highly unconsolidated sand. However, the Dakota is expected to be very competent, so sand consolidation is certainly not a primary objective. Expected gel times, viscosities and compressive strengths for various mixes of these grouts are reported in a technical memorandum by B. B. McGlothlin.* The effect of temperature on his results need to be evaluated, using techniques described in his report. The temperature in the Dakota is approximately 120°F, but will be reduced somewhat by the injection of colder grout fluids.

There are two types of additives that may be useful in grouting

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*B. B. McGlothlin, "Evaluation of Mine Shaft Grouting Materials" Technical Memorandum #444TG137, GR&DC, November 1976.

with cement. Before discussing these additives it would be of value to have a better understanding of what occurs when a fracture is being grouted with cement. One theory of how this occurs is described pictorially in Figure 3. As the cement mixture enters a fracture, some of the water in the mixture leaks out through the walls of the fracture, depositing some cement on the wall. If the concentration of cement is relatively high, the amount of cement that deposits on the wall may be sufficient to plug the fracture near the entrance, as shown in Figure 3(b), resulting in a plugged grout hole, but not a plugged fracture, as far as the overall grout curtain is concerned. One way to get the cement to travel further is to use a very dilute mixture {Figure 3(a)}, but this approach is very time consuming, since it is not the gallons of grout mix that count in this case, but rather the number of sacks of cement. One sack will yield about 10 gal of cement fill.

A more effective and efficient way to increase the grouting rate is to use a "fluid loss" additive and a higher concentration of cement. This will permit a geometry as shown in (a), even with a moderately high concentration of cement, since the leakage rate of water through the walls of the fracture is reduced.

When grouting with chemical grouts the filtration process discussed above is not part of the grouting mechanism. All the grout fluid would gel wherever it is as shown in (c). Some of the grout would leak into the pores on the sides of the fracture and would gel in the pores {not shown in (c)}. It might be possible to obtain a similar effect in the fracture by using a high concentration of cement and fluid loss additive, and with another additive (e.g. Cal-Seal, $CaCl_2$, Preco Plug, Geoseal Z, etc.) to make the cement mixture gel in place. This type of mix would probably be most useful in finishing off a grout treatment, to plug the grout hole and not have an excessive waiting time, but its application might be more general.

Some concern has been expressed regarding the resistance of the cement to sulfates. This can be tested in accordance with test procedure ASTM C-88-73.

Under separate cover I'll provide you with information on various grout materials and additives.

PLACEMENT OF GROUT MATERIAL

The productive part of the Dakota appears in three separate intervals, as shown in Figure 2. The middle zone appears to be the most prolific, but this will have to be confirmed by actual probing.

The objective of the grouting program will be to place the grout material in a continuous curtain around the shaft, more or less as indicated in Figure 1. This will require a large number of grout holes with adequate spin and dip so that the vertical fractures in the Dakota can be intercepted and filled with grout. The location of the grout holes must be a reasonable distance outside the shaft excavation radius (e.g., 3 ft minimum), and yet not too far out from the shaft center-line (e.g., 20 ft maximum). These suggested limits are indicated with dashed lines in Table I, where it is assumed that a spin angle of 45° will be used.

From Table I and Figure 4, if the top of the grout pad is 30 ft above the top of the Dakota, then a 74° dip angle would be satisfactory between depths below the pad of 30 and 50 ft. This should be adequate for sealing off the upper zone in Figure 2. A total of 16 grout holes is suggested. A second pattern of holes, with a spin of -45° (in the opposite direction to the holes in the first pattern), and with a dip angle of 82° should be adequate for grouting the middle zone. It is possible that some extra holes will be nessary in the second pattern, since hole deviation becomes more severe at this depth.

Note that the first ("A") pattern of holes, is much too far out from the shaft to be effective in the middle zone, whereas the second ("B") pattern is too close to the shaft to be effective in the upper zone.

In general it is more effective to use short grout covers ($\leq$ 70 ft) rather than long ones. This is because of the reduced grouting effectiveness as the grout holes get too far below the grout pad. There are several factors that contribute to this reduced effectiveness.

1. Holes have to be close to vertical (dip angle in excess of 80°) thereby reducing the probability of intersecting all the vertical fractures.
2. Hole deviation becomes excessive when the holes are drilled with the Watson drills. A deviation of only 2° would cause an

uncertainty of ±3.5 ft in the location of the grout hole at a depth of 100 ft! This greatly increases grout requirements and grouting time.

3. Grout holes get further away from the shaft with increasing depth. This further increases grout requirements.
4. Drilling time, and time to drill out for repeated hole treatment increases dramatically with depth. Failures of drill rods is also more common at greater depth.

In view of the above, one grout cover might be insufficient for grouting all three intervals in the Dakota. However, the lowest of the three intervals to be grouted is only about 10 ft thick, and probably not very prolific, so it might be possible to grout it with the "B" pattern of holes from the 2,830-ft grout pad. Improved coverage in the middle and lower zones can be achieved by using a "C" pattern with +45° spin and 82° dip. This approach would increase the probability of intersecting all the fractures in the Dakota.

A possible alternative to the program outlined above would be to plan on two grout pads in the Dakota, and to use a 70° "A" pattern followed by an 80° "B" pattern for each grout cover. This approach would allow the pad to be somewhat further removed from the top of the zone to be grouted, and would therefore allow longer standpipes (casings) through the grout pad (eg., 30 ft instead of ∿20 ft). This approach would be safer, but slower. However, if reasonable depressurization is achieved, the first system with only one grout pad, would probably be adequate.

A third possibility is that it may be feasible to grout the uppermost zone in the Dakota from the 2,782-ft grout pad in the Lower Tres Hermanos. If this were achieved, then the Dakota grout pad could be placed at ∿2,850 ft, and one pad would then almost certainly be adequate for grouting the remainder of the Dakota, and it would also be closer to the middle zone which is likely to be the biggest producer in this aquifer. Two options for a combined grouting program in the Lower Tres and the Dakota are shown in Figure 6.

TESTING THE EFFECTIVENESS OF A GROUT COVER

One of the main drawbacks of grouting as a method of water control is the difficulty in determining the effectiveness of the grout cover. The only true test is after the shaft has been sunk through the aquifer. If the sinking was accomplished without undue diffuculty, then the grout cover was adequate.

The only other way to evaluate the effectiveness of a grout cover is to probe the aquifer below the shaft bottom before and after grouting. This method is fairly reliable if several probe holes are utilized, and if "ring" grouting around the shaft is utilized. For example, if a particular probe hole makes 1,000 gal/min of water before grouting, and 50 gal/min after grouting, then the grouting efficiency can be defined to be 95%, since 95% of the water was shut out. However, it is not at all certain that the grouting efficiency ascribed to the probe hole would be the same for the whole shaft. One problem with a single probe hole is that the rock it penetrates is not necessarily representative of all the rock within the excavation diameter of the shaft. Utilizing several probe holes tends to overcome this objection, except where there are vertical fractures, and all the probe holes are essentially vertical. Inclined probe holes may be used to overcome this objection. For example, a probe pattern such as the one described in Figure 5 may be utilized.

An "after the fact" evaluation of grouting efficiency would be to compare the actual water flow to the shaft during sinking with the estimated water inflow rate calculated from the hydraulic properties of the aquifer (transmissibility, storage factor, and pressure).

Grouting an aquifer from the inside (starting near the center-line of the shaft) and grouting outwards, conceivably might be a more effective method of grouting, but it would eliminate the possibility of testing the effectiveness of the grout cover before sinking resumes. It is therefore not recommended.

GROUTING RATE

In view of the very large quantities of grout material that will be required, it is essential that high grouting rates be utilized. When grouting commenced in the Menefee in the 14-ft shaft, the overall average grouting rate was approximately 1.4 gal/min. By the time the 24-ft shaft was grouting in the Point Lookout, the average rate had increased to about 5 gal/min, with instantaneous rates often in excess of 10 gal/min.

In our previous grouting experience there were two factors that limited the injection rates, one was pump size, and the other was maximum allowable pressure. It was agreed in an earlier planning meeting that larger pumps would be acquired. In grouting the Dakota the required and allowable pressures are much higher than they were in the Point Lookout. The water pressure at the mid-point of the Dakota was 817 PSIG during the 1972 drill stem tests. This corresponds to a piezometric level of about 1,010-ft shaft depth. During the Dakota pump test performed on Well #2B earlier this year, the pressure was found to be 710 PSIG at a depth of 2,714 ft, corresponding to a piezometric surface of approximately 1,080-ft shaft depth, or approximately 787 PSIG at the mid-point of the Dakota.

The pressure will be less when grouting commences, due to the depressurization program. The actual pressure will depend on the level of the depressurization effort that is directed towards the Dakota.

From a grouting effectiveness point of view, it might be desirable to inject grout at pressures above the fracturing pressure of the rock in order to establish communication between the grout holes and the major fractures in the Dakota. Dames and Moore calculated the fracturing pressure in the Dakota to be approximately 2,200 PSIG (2100 PSIG in the Lower Tres Hermanos). The danger in attempting to fracture the formation is that fracturing is more likely to occur above the formation, immediately below the casings, and the grout pad will probably not be designed to tolerate this level of pressure.

For the above reasons the grouting rate should be as high as possible, consistent with staying below pressures that can be dangerous to the pad and shaft. Past experience would lead us to expect an effective grouting rate of ∿1.5 ft/day. It should be possible to improve on this rate.

SAFETY

The main advantage of depressurizing the Dakota is that the grouting can be accomplished in a safer and quicker manner. However, even though theoretical calculations indicate that the Dakota can effectively be depressurized using a combination of Phase II and Phase III wells, it should be recognized that such depressurization has not yet been demonstrated. This means that we may be grouting against a pressure of almost 800 PSIG, with a potential inflow rate into the shaft through the grout hole of approximately 1,000 gal/min! For this reason all possible safety measures should be performed to assure that such flows are not encountered. Also, contingency plans must be developed to handle such a situation in the event that it should occur. If flows were to occur around one of the casings, erosion could enlarge the hole to where the flow might increase to possible 1,500 gal/min.

In order to accomplish a safe grouting operation, it is recommended that the following practices be observed (this list should not be considered to be complete):

1. The grout pad should be at least 30 ft above the formation to be grouted.
2. Holes for casings should never be drilled deeper than 10 ft above the depth where the probe holes indicate significant water to be present.
3. The interval to be grouted should be thoroughly probed, using at least four probe holes.
4. Each casing should be tested to a pressure 1.5 times the maximum intended grouting pressure.
5. Drilling of grout or probe holes should always be done through blowout preventors.
6. There should always be adequate pumping capacity on hand to handle any potential water inflow rate.
7. Standby pumping capacity should be readily available.
8. Great care should be taken to assure that all grouting equipment, pipes, connections, etc., have a pressure rating well in excess of the maximum pressures expected.
9. Serious consideration should be given to monitoring and recording the grouting pressure and injection rate on at least one of the grouting pumps.

Hans C. Juvkam-Wold

H. C. Juvkam-Wold

HCJ:sn
Attachments

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J. Gilmour

(K. S. Barnhill, S. R. Smith, J. A. Heron, J. E. Hanley, J. Gilmour: Mt. Taylor Project)

TABLE I

LOCATION OF GROUT HOLE VS. DEPTH AND DIP ANGLE

IN 14-FT SHAFT (SPIN ANGLE = 45°)

DEPTH (ft)		Dip=65°	70°	74°	77°	80°	82°	84°	86°
10	r	9.865	8.952	8.280	7.805	7.353	7.064	6.784	6.513
	β	19.527	16.709	14.175	12.073	9.762	8.087	6.289	4.354
15	r	12.011	10.589	9.539	8.796	8.089	7.638	7.202	6.782
	β	24.316	21.381	18.592	16.163	13.368	11.255	8.905	6.278
20	r	14.217	12.278	10.842	9.823	8.852	8.231	7.633	7.059
	β	27.637	24.785	21.964	19.412	16.362	13.973	11.230	8.054
30	r	18.719	15.744	13.528	11.947	10.434	9.463	8.526	7.629
	β	31.900	29.367	26.722	24.200	21.007	18.363	15.159	11.212
40	r	23.285	19.274	16.275	14.129	12.066	10.738	9.452	8.219
	β	34.502	32.284	29.889	27.526	24.414	21.727	18.331	13.924
50	r	27.883	22.839	19.058	16.346	13.731	12.042	10.402	8.826
	β	36.248	34.294	32.137	29.957	27.002	24.370	20.930	16.268
60	r	32.499	26.424	21.863	18.585	15.418	13.366	11.370	9.445
	β	37.499	35.760	33.810	31.804	29.027	26.493	23.091	18.307
70	r		30.022	24.682	20.840	17.120	14.706	12.351	10.074
	β		36.876	35.102	33.253	30.651	28.232	24.910	20.094
80	r			27.511	23.105	18.833	16.057	13.343	10.713
	β			36.129	34.419	31.981	29.679	26.461	21.669
90	r			30.348	25.378	20.555	17.416	14.344	11.358
	β			36.964	35.376	33.088	30.901	27.796	23.066
100	r				27.657	22.283	18.782	15.351	12.010
	β				36.176	34.024	31.945	28.956	24.313

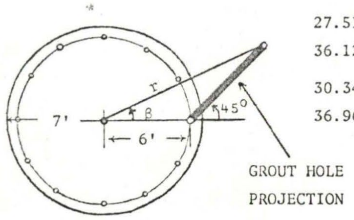
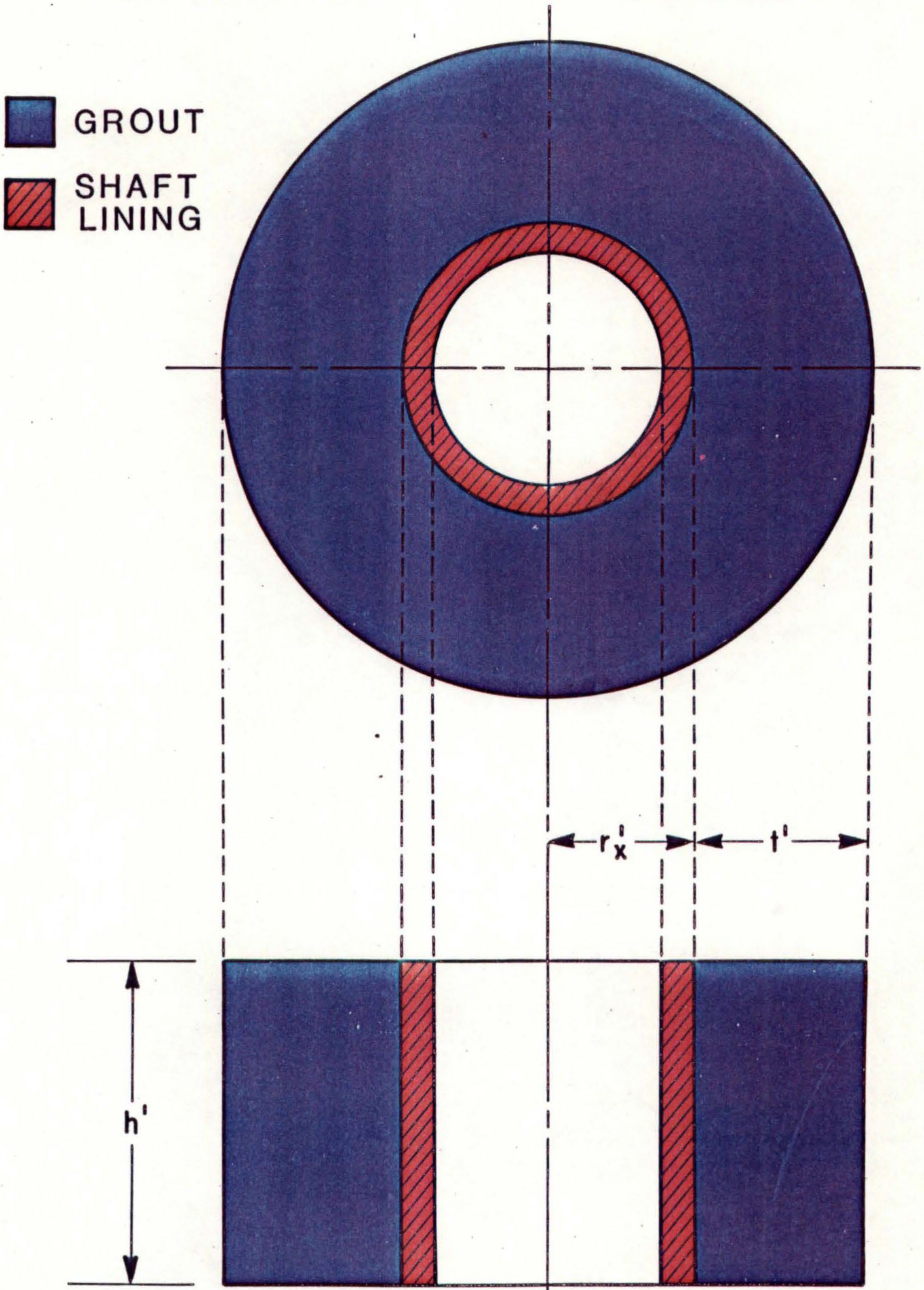


FIGURE 1

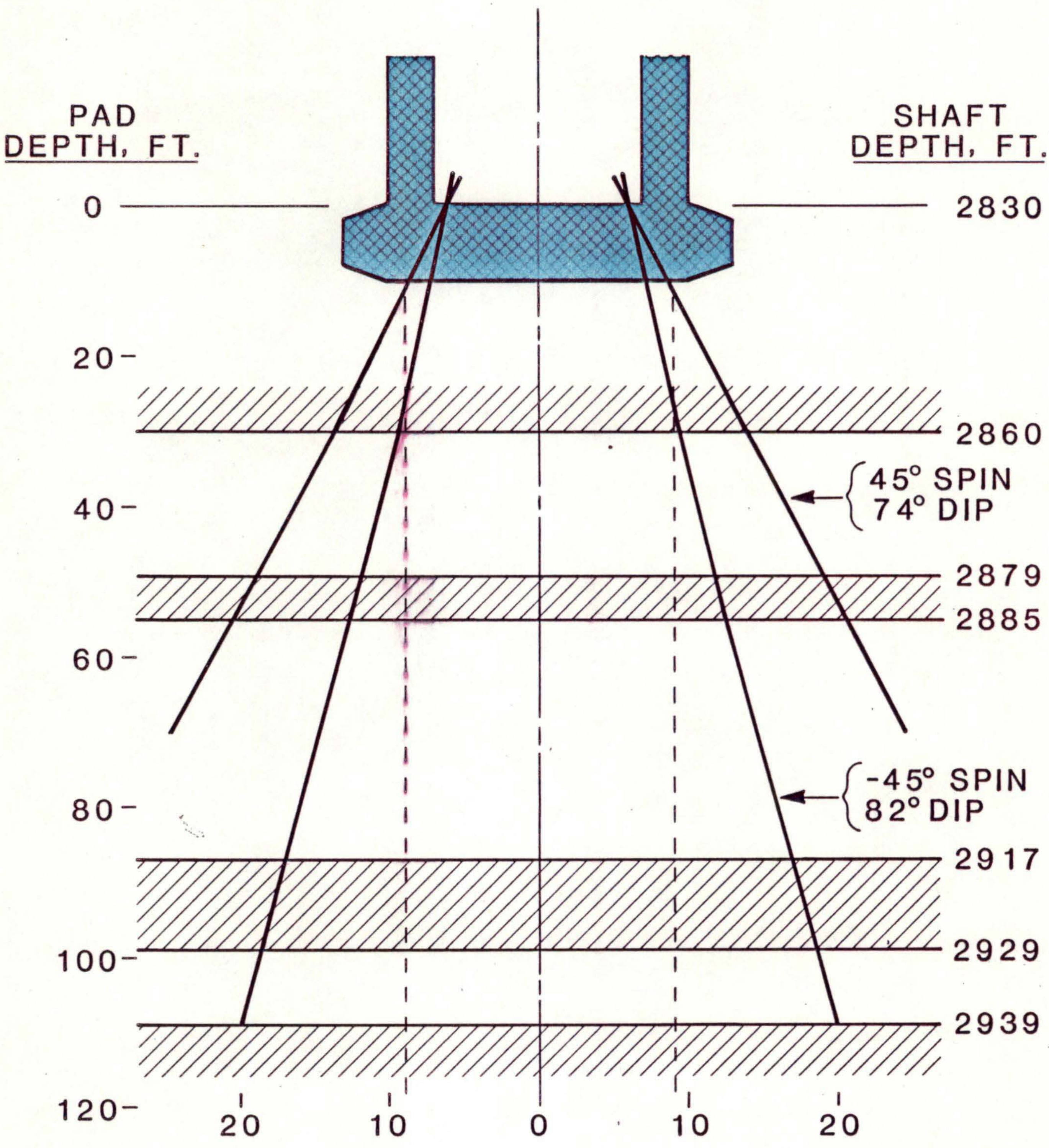
GROUT MATERIAL VOLUME REQUIREMENTS



$$Q = 7.05\,h\left[(r_x + t)^2 - r_x{}^2\right] \text{ gal}$$

FIGURE 2

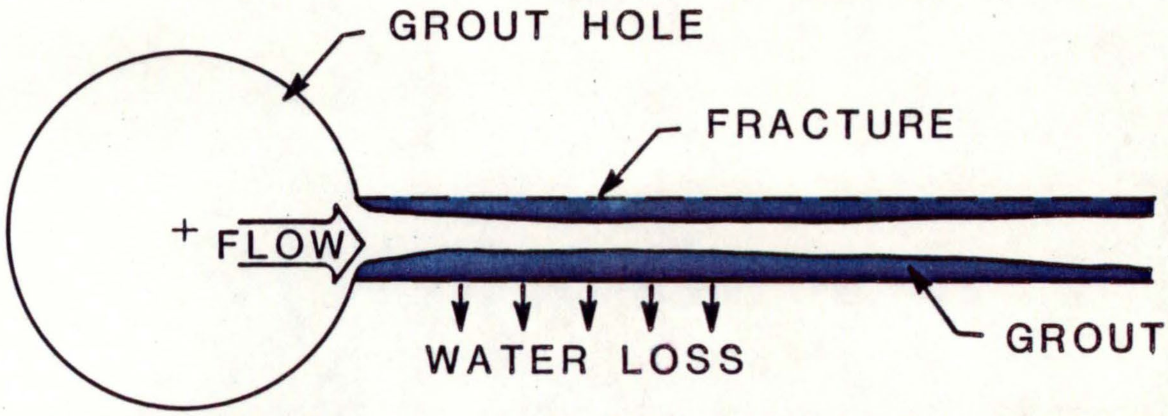
GROUTING THE DAKOTA



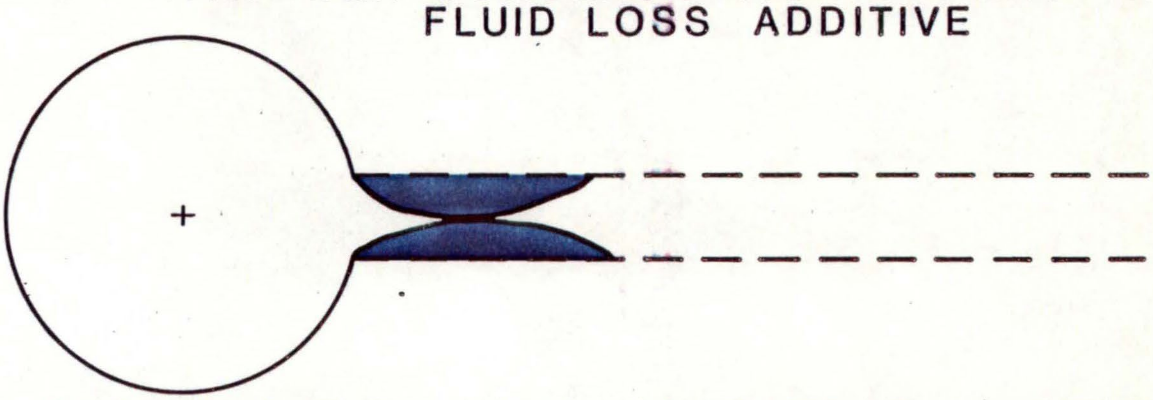
RADIAL DISTANCE FROM SHAFT CENTERLINE, FT.

FIGURE 3

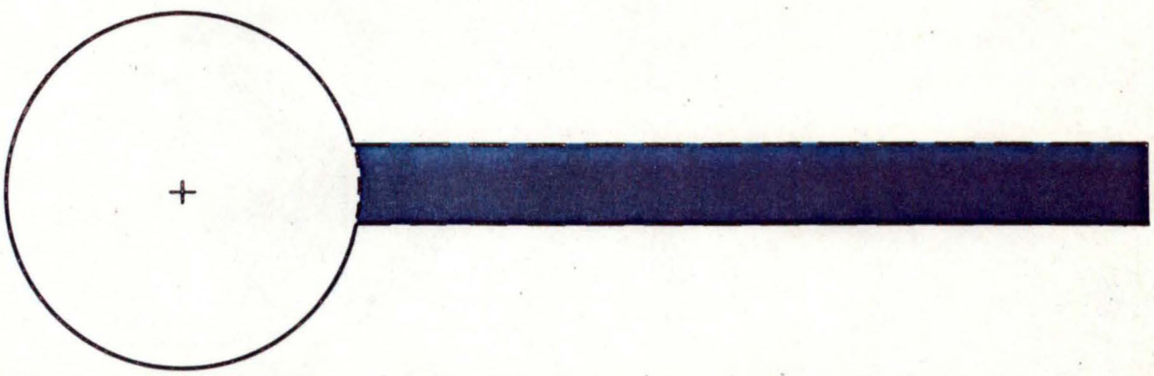
GROUTING A FRACTURED FORMATION



(A) GROUTING WITH LOW CONCENTRATION CEMENT OR WITH HIGH CONCENTRATION CEMENT AND FLUID LOSS ADDITIVE



(B) GROUTING WITH HIGH CONCENTRATION CEMENT AND NO FLUID LOSS ADDITIVE



(C) GROUTING WITH CHEMICAL GROUT OR WITH VERY HIGH CONCENTRATION CEMENT WITH FLUID LOSS AND GELLING ADDITIVES

FIGURE 4

LOCATION OF GROUT HOLE VS. DEPTH AND DIP ANGLE

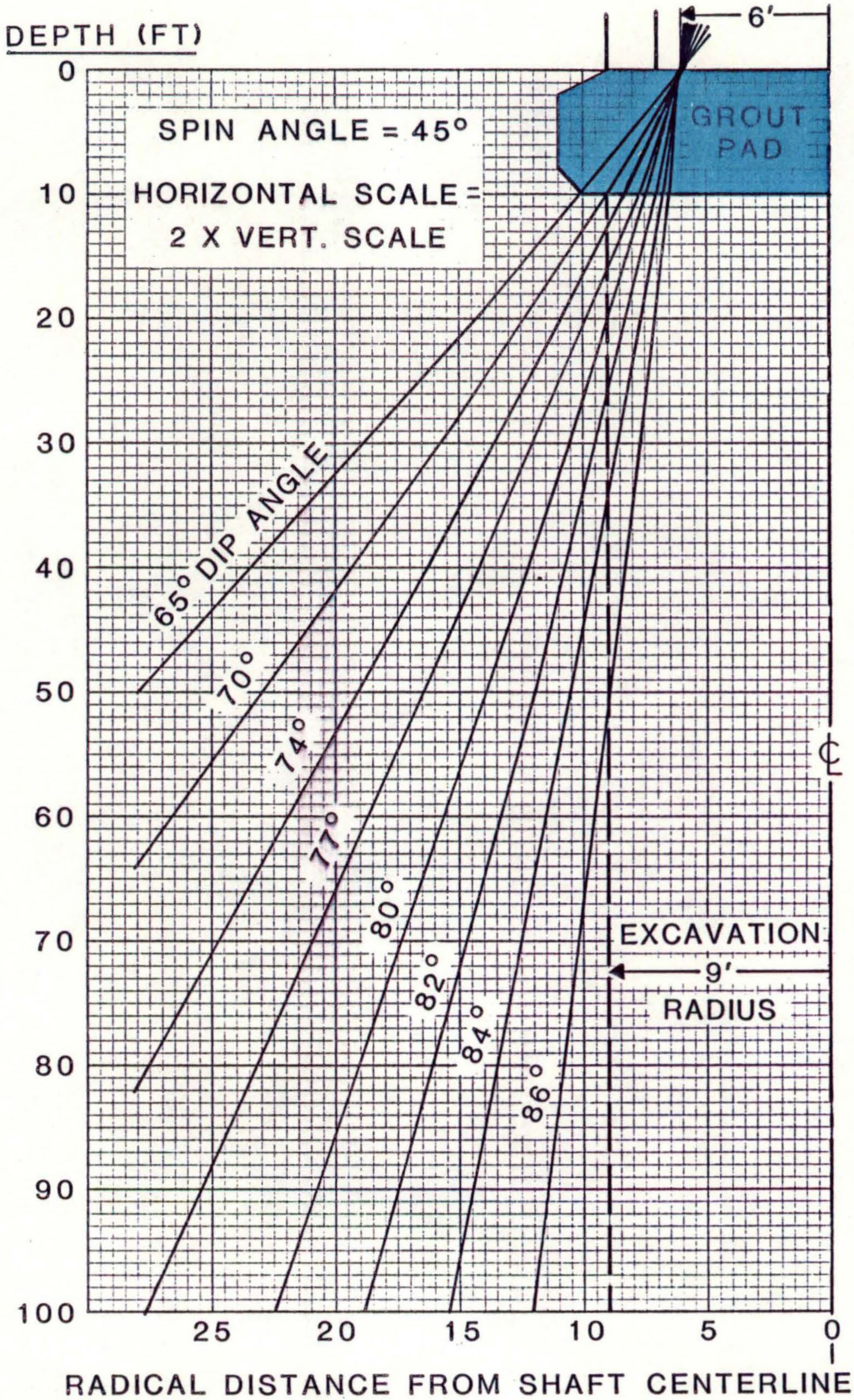


FIGURE 5

PROBE PATTERN IN FRACTURED FORMATION
(4 SLANTED PROBE HOLES)

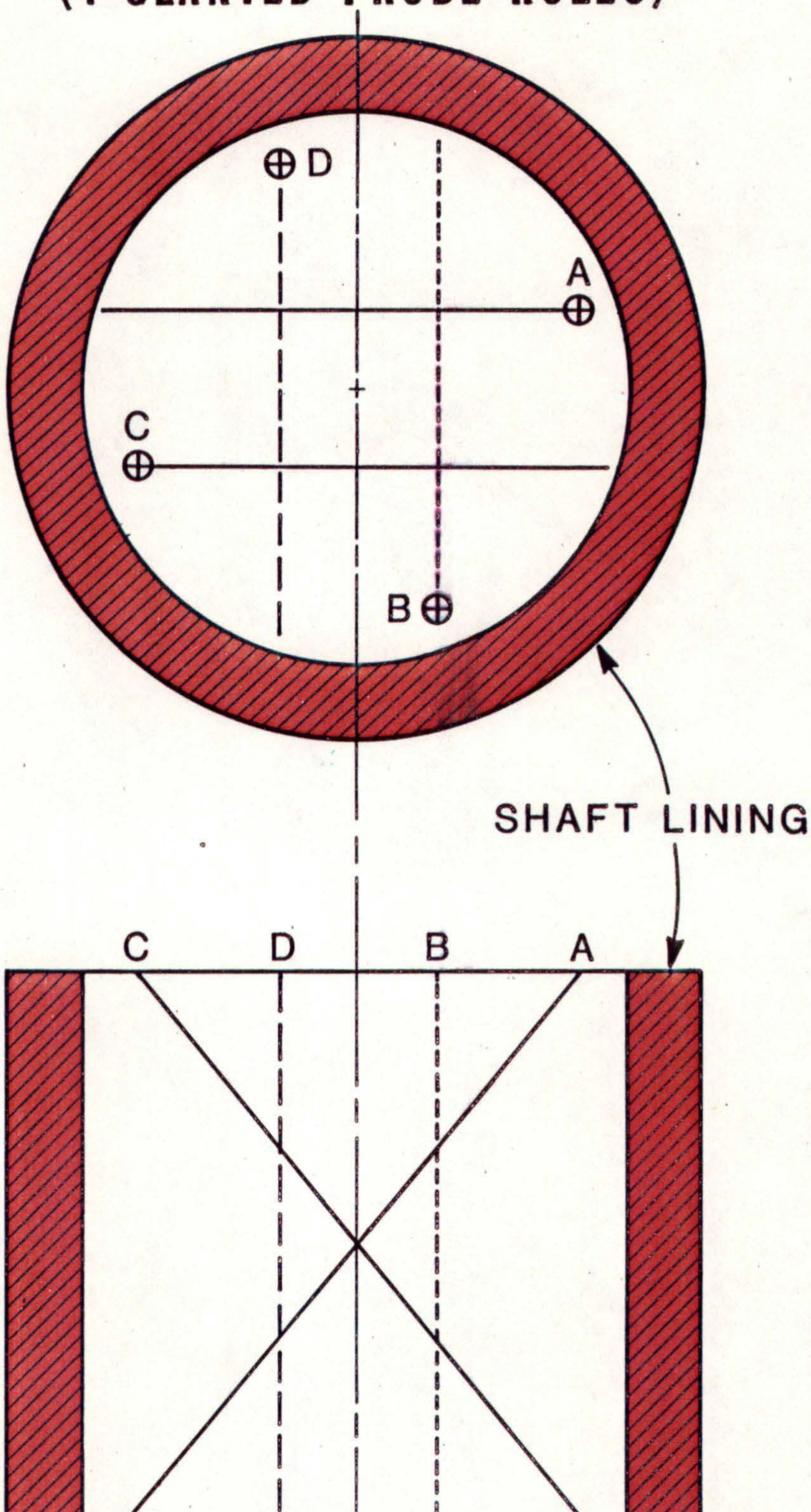
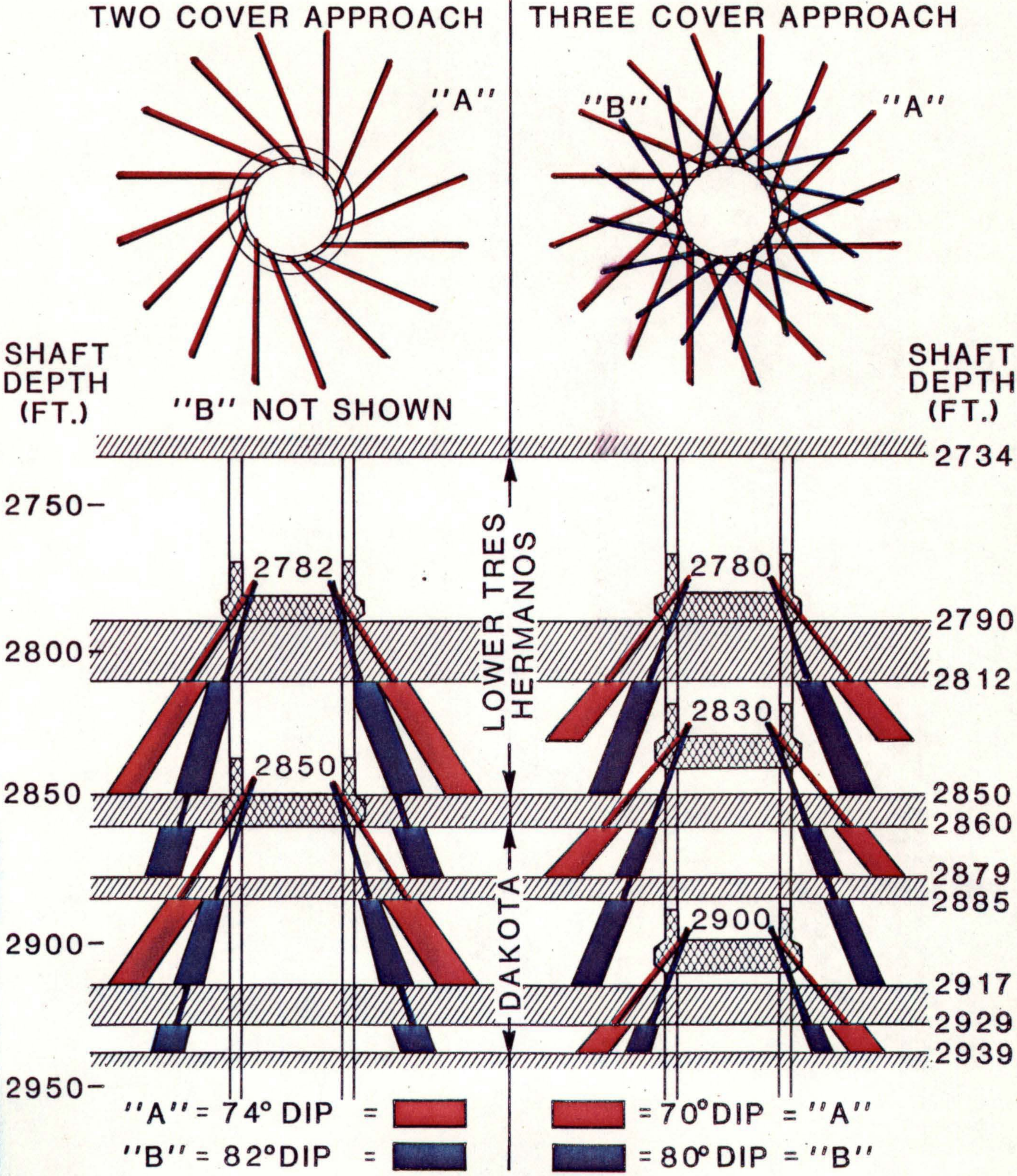
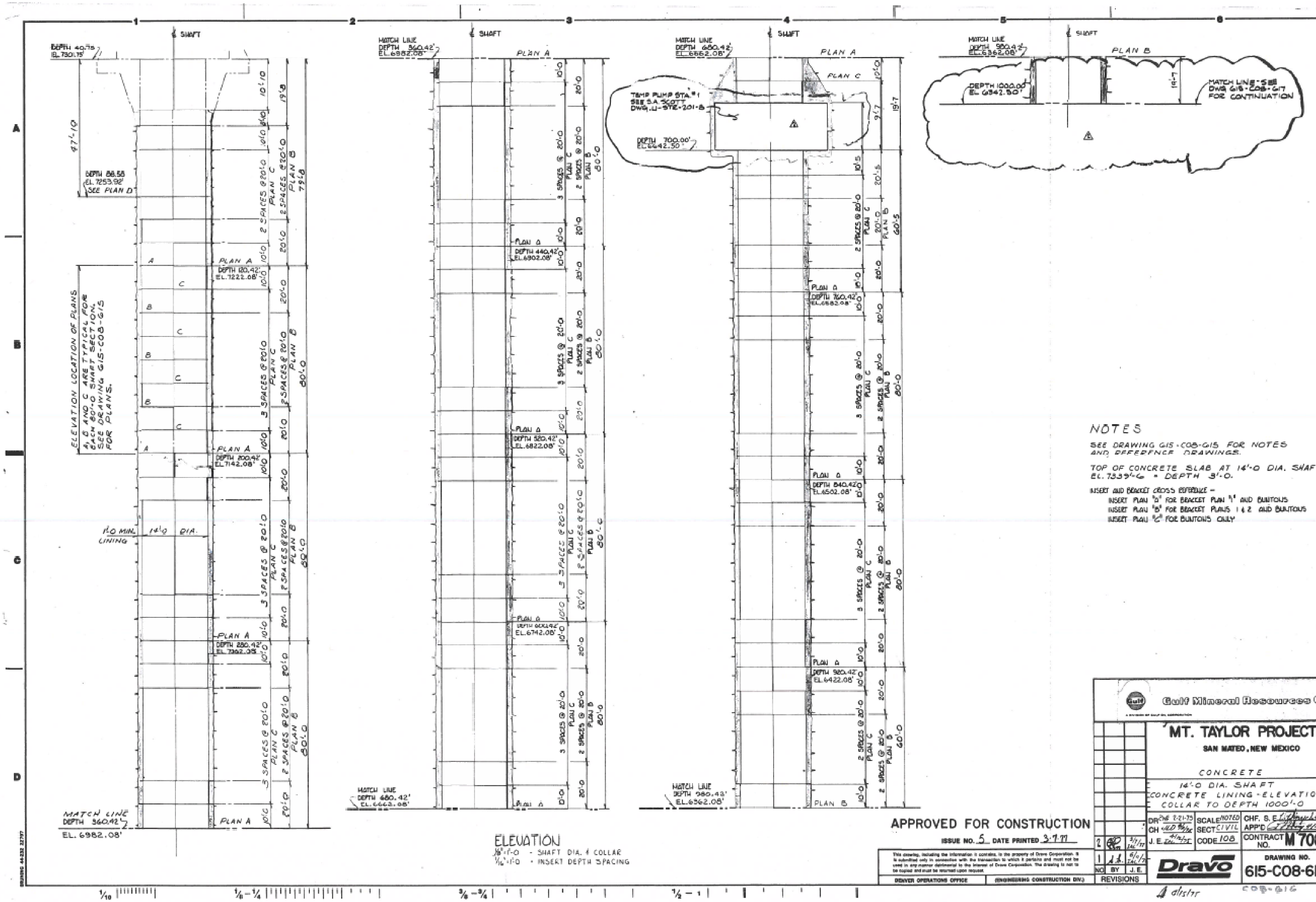


FIGURE 6

COMBINED GROUT PROGRAM FOR THE LOWER TRES HERMANOS AND THE DAKOTA



Appendix C. Proposed Shaft Lining Design (Drawing No. 615-C08-616)



SHAFT
MATCH LINE DEPTH 360.42' EL. 6982.08'
MATCH LINE DEPTH 680.42' EL. 6662.08'
MATCH LINE DEPTH 980.42' EL. 6362.08'
TEMP PUMP STA. #1 SEE S.A. SCOTT DWG. U-STE-201-B
DEPTH 700.00' EL. 6642.50'
DEPTH 1000.00' EL. 6342.50'
MATCH LINE-SEE DWG 615-C08-617 FOR CONTINUATION
ELEVATION LOCATION OF PLANS A, B AND C ARE TYPICAL FOR EACH 80'-0 SHAFT SECTION. SEE DRAWING 615-C08-615 FOR PLANS.
ELEVATION
NOTES
SEE DRAWING 615-C08-615 FOR NOTES AND REFERENCE DRAWINGS.
TOP OF CONCRETE SLAB AT 14'-0 DIA. SHAFT EL. 7339'-6 = DEPTH 3'-0.
INSERT AND BRACKET CROSS REFERENCE -
INSERT PLAN "A" FOR BRACKET PLAN "1" AND BUNTONS
INSERT PLAN "B" FOR BRACKET PLANS 1 & 2 AND BUNTONS
INSERT PLAN "C" FOR BUNTONS ONLY
APPROVED FOR CONSTRUCTION
ISSUE NO. 5 DATE PRINTED 3-7-77
DENVER OPERATIONS OFFICE
(ENGINEERING CONSTRUCTION DIV.)
REVISIONS
Gulf Mineral Resources C
MT. TAYLOR PROJECT
SAN MATEO, NEW MEXICO
CONCRETE
14'-0 DIA. SHAFT
CONCRETE LINING-ELEVATION
COLLAR TO DEPTH 1000'-0
SCALE NOTED
SECT CIVIL
CODE 108
CONTRACT NO. M 708
Dravo
DRAWING NO. 615-C08-616

Appendix D. Proposed Concrete Specifications for Mine Shaft Lining

TABLE 1. Concrete Specifications

Concrete design strength	5000 psi
Cement/yd	610 lb
Rock/lms)/yd	1643 lb
Sand*/yd	1323 lb
Water**/yd	308 lb
Air entraining agent ***/yd	1.5 lb
Water reducing agent****/yd	36.6 lb

Unit weight	145 lb/ft^3
Air percent	3.4%
Slump	4.5-in.
Temperature	65^oF

7 day strength	4440 psi
28 day strength	6190-5995 psi

* Albuquerque River sand

** Water net, excluding moisture in aggregate

*** Masterbuilders air agent

**** Pozzolith M.B.

Information supplied by Ivo Lange April 11, 1978

1.0 C.Y.

MT. TAYLOR, SHAFT LINING CONCRETE

	7000 psi	5000 psi (G88)
CEM.	775	610
ROCK (LIMST.)	1697	1643
SAND *)	1138	1323
xx) WATER (NET)	308	308
xxx AEA	1.5 ounc/c.y	1.5
xxxx WRA	46.5 ounc/c.y	36.6
UNIT. W.	145.8 #/cf	145.0
AIR %	3.2	3.4
SLUMP	6.0 IN.	4.5
TEMP.	65° F	65°F
3 DAY STR.	4000 (+) PSI	~~[illegible]~~
7 DAY STR		4440 PSI
28 "		6190 + 5995 PSI

x) ALBUQ. RIVER SAND
xx) (NET) EXCLUDING MOISTURE IN AGGREG.
xxx AEA MASTER BUILD. — AIR AGENT
xxxx WRA WATER REDUC. + POZZOLITH M.B.

APR. 11, 1978

Lange

Appendix E. Cement Permeability (BOR 1988)

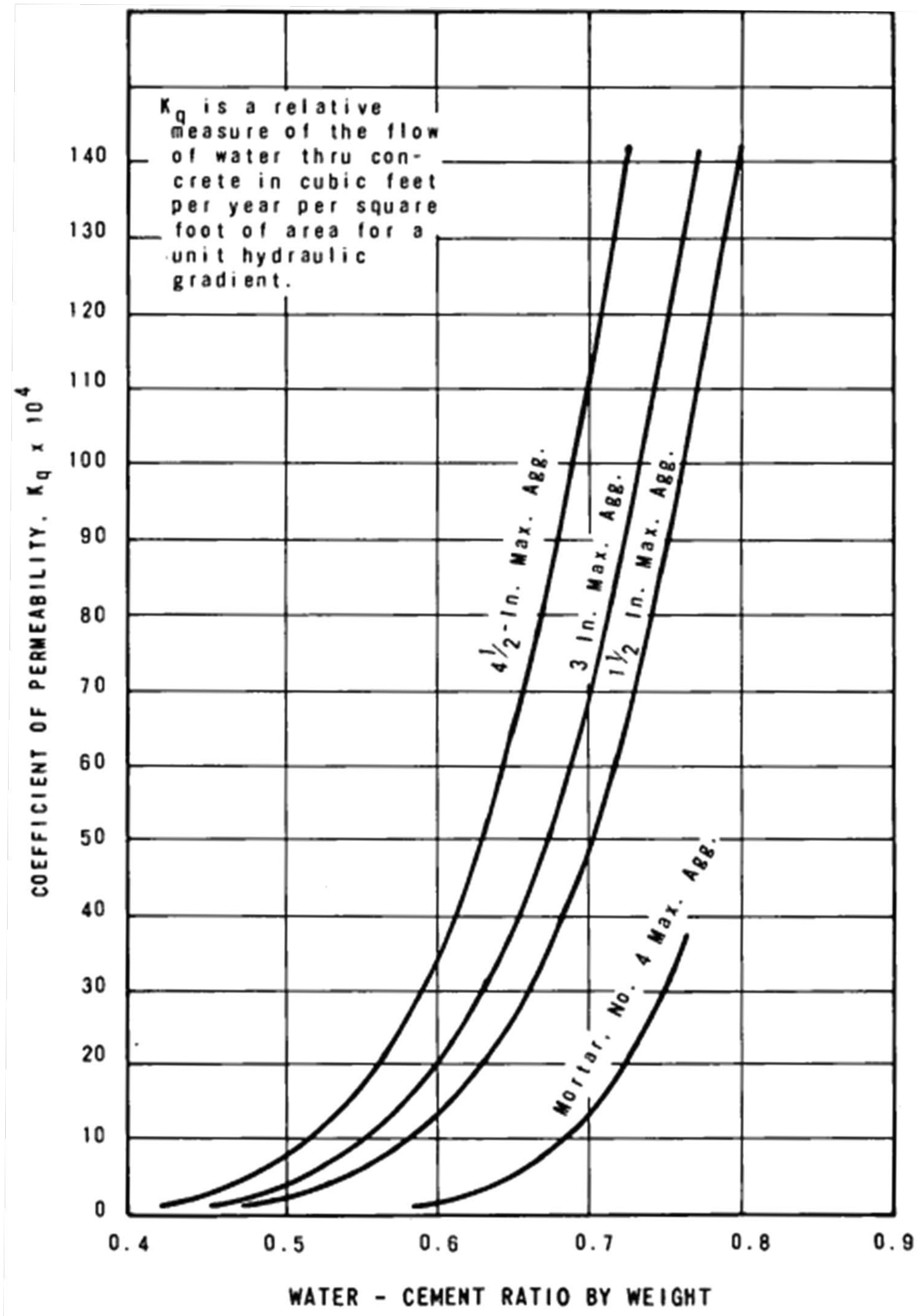


Figure 17.—Relationship between coefficient of permeability and water-cement ratio, for mortar and concrete of three maximum sizes. Relatively low water-cement ratios are essential to impermeability of concrete. 288–D–1522.

Appendix F. Wells Within Three Miles of Mine

POD	Use	Status1	Status2	Year	TD (ft bgl)	DTW (ft bgl)	Casing Diam. (in)	Diversion (AF)	UTM Easting	UTM Northing	Owner Last Name	Owner City	Other Location Information
B-00385	EXP	PMT	ACT	1976	707	196	14.00		259182	3913161	GULF ENERGY & MINERALS COMPANY	GRANTS	
B-00404	DEW	PMT							260709	3913660	SMALL	GRANTS	
B-00404-X	DEW	PMT							260709	3913660	SMALL	GRANTS	
B-00415-O-3	DOM, OBS	PMT	ACT	1978	32	15	5.00	3	257806	3914005	NEW MEXICO E.I.A.	SANTA FE	FLOYD LEE RANCH, SAN MATEO, NM
B-00428	MDW	PMT		1971	325	75	5.50	26	259987	3912945	SAN MATEO MUCA	SAN MATEO	
B-00428-S	MDW	PMT	ACT	1976	703		6.63	26	258981	3913173	SAN MATEO MUCA	SAN MATEO	
B-00516	MIN	DCL		1974	3535			640	260829	3914179	RIO GRANDE RESOURCES CORP.	GRANTS	
B-00516-(1)	MIN, DOM, SA	DCL		1971	925	260	8.63	640	260716	3914086	RIO GRANDE RESOURCES CORP.	GRANTS	
B-00516-POD3	MIN	DCL	ACT	2011	35	14	2.00	640	260518	3913784	RIO GRANDE RESOURCES CORP.	GRANTS	
B-00516-POD4	MIN, MON	DCL	ACT	2017	1725	1279	8.10	640	262173	3912079	RIO GRANDE RESOURCES CORP.	GRANTS	WELL 1.5
B-00516-POD5	MIN	DCL	ACT	2020	85	69	3.00	640	260850	3913898	RIO GRANDE RESOURCES CORP.	GRANTS	MT-DLMW-01
B-00516-POD6	MIN	DCL	ACT	2020	95	85	3.00	640	260613	3913837	RIO GRANDE RESOURCES CORP.	GRANTS	MT-DLM-02
B-00516-POD7	MIN	DCL			2845		9.63	640	260672	3913838	RIO GRANDE RESOURCES CORP.	GRANTS	9
B-00516-POD8	MIN	DCL	ACT	2020	59	44	3.00	640	260721	3913825	RIO GRANDE RESOURCES CORP.	GRANTS	MT-DLTW-01
B-00516-POD9	MIN	DCL	ACT	2020	65	39	3.00	640	260697	3913859	RIO GRANDE RESOURCES CORP.	GRANTS	MT-DLTW-02
B-00516-POD10	MIN	DCL	ACT	2020	63	62	3.00	640	260717	3913918	RIO GRANDE RESOURCES CORP.	GRANTS	MT-DLTW-04
B-00516-POD11	MIN	DCL	ACT	2020	50	33	3.00	640	260721	3913960	RIO GRANDE RESOURCES CORP.	GRANTS	MT-DLTW-04
B-00516-POD12	MIN	DCL	ACT	2020	64	63	3.00	640	260744	3914041	RIO GRANDE RESOURCES CORP.	GRANTS	MT-DLTW-05
B-00516-POD13	MIN	DCL			3275		10.75	640	260806	3913817	RIO GRANDE RESOURCES CORP.	GRANTS	16
B-00516-POD14	MIN	DCL			3342		10.75	640	260973	3913886	RIO GRANDE RESOURCES CORP.	GRANTS	17
B-00516-POD15	MIN	DCL			3314		10.75	640	261042	3913985	RIO GRANDE RESOURCES CORP.	GRANTS	18
B-00516-POD16	MIN	DCL			3274		10.75	640	261047	3914165	RIO GRANDE RESOURCES CORP.	GRANTS	19
B-00516-POD17	MIN	DCL			3223		10.75	640	260967	3914305	RIO GRANDE RESOURCES CORP.	GRANTS	20
B-00516-POD18	MIN	DCL			3184		10.75	640	260805	3914377	RIO GRANDE RESOURCES CORP.	GRANTS	21
B-00516-POD19	MIN	DCL			3184		10.75	640	260648	3914300	RIO GRANDE RESOURCES CORP.	GRANTS	22
B-00516-POD20	MIN	DCL			3535		9.63	640	260808	3914061	RIO GRANDE RESOURCES CORP.	GRANTS	24-43
B-00516-POD21	MIN	DCL		1970	1660		8.63	640	262080	3911929	RIO GRANDE RESOURCES CORP.	GRANTS	HU3-2
B-00516-POD22	MIN	DCL		1970	1676		8.63	640	262390	3912070	RIO GRANDE RESOURCES CORP.	GRANTS	HU6-1
B-00516-POD23	MIN	DCL		1970	1787		7.63	640	262208	3912298	RIO GRANDE RESOURCES CORP.	GRANTS	HU7-1
B-00516-POD24	MIN	DCL		1970	675		8.63	640	262237	3912515	RIO GRANDE RESOURCES CORP.	GRANTS	HU10-1
B-00516-POD25	MIN	DCL		1971	1769		8.63	640	261763	3912678	RIO GRANDE RESOURCES CORP.	GRANTS	HU26-2
B-00516-POD26	MIN	DCL		1971	1661		7.63	640	262092	3911646	RIO GRANDE RESOURCES CORP.	GRANTS	BK292-1
B-00516-POD27	MIN	DCL		1973	1053		7.63	640	262608	3910911	RIO GRANDE RESOURCES CORP.	GRANTS	BK277-2
B-00516-POD28	MIN	DCL		1972	1919		8.63	640	263001	3910363	RIO GRANDE RESOURCES CORP.	GRANTS	Z013-1
B-00524	DOM	PMT	ACT		520	260	5.56	3	260202	3913357	CHAVEZ	GRANTS	NW1/4
B-00544	SAN, DOM	PMT	ACT	1978	68	30	6.63	3	258306	3913695	MARQUEZ	SAN MATEO	
B-00728	STK	EXP							258762	3912571	SANDOVAL	SAN MATEO	

POD	Use	Status1	Status2	Year	TD	DTW	Casing Diam.	Diversion	UTM Easting	UTM Northing	Owner Last Name	Owner City	Other Location Information
B-00729	STK	PMT						3	259568	3912542	SANDOVAL	SAN MATEO	
B-00734	DOM	PMT	ACT	1979	73			3	259198	3913565	CANDELARIA	SAN MATEO	
B-00735	DOM	PMT	ACT	1980	65	30		3	259198	3913565	CANDELARIA	SAN MATEO	
B-00736	DOM	EXP							259398	3913565	CANDELARIA	SAN MATEO	
B-00737	DOM	PMT	ACT	1979	80			3	259398	3913565	CHAVEZ	SAN MATEO	
B-00738	DOM	PMT	ACT	1979	80	36		3	259382	3913161	GONZALES	SAN MATEO	
B-00815	DOM, STK	PMT	ACT		300	260	8.63	3	258602	3913584	ORTEGA	SAN MATEO	
B-00829	DOM	PMT	ACT	1980	210	50	5.00	3	259768	3912742	SANDOVAL	SAN MATEO	
B-00839	STK, DOM	PMT	ACT	1980	420	120	6.00	3	259870	3912844	HOBBS	SAN MATEO	
B-00839-X	STK	PMT						3	259870	3912844	HOBBS	SAN MATEO	
B-00906	DOM	PMT	ACT	1981	230	50		3	259683	3913050	PADILLA	SAN MATEO	
B-01085	IRR, DOM	DCL		1920	476	90	10.00	16	257817	3914407	FERNANDEZ COMPANY, LTD.	SAN MATEO	
B-01185	DOM	PMT	ACT	1989	185	70	4.00	3	259283	3913062	SANDOVAL SIFREDO	SAN MATEO	
B-01442	IRR	PMT	PEN						257975	3913774	FERNANDEZ COMPANY, LTD.	SAN MATEO	
B-01442-EXPL	IRR, EXPL	PMT	ACT	2000	620	87	12.75		257796	3913403	FERNANDEZ COMPANY, LTD.	SAN MATEO	
B-01442-EXPL-2	IRR	PMT	ACT	2002	1150	107	8.63		258013	3913795	FERNANDEZ COMPANY, LTD.	SAN MATEO	
B-01762-POD1	STK	EXP	PEN		900		7.00		257521	3916416	FERNANDEZ COMPANY LTD	SAN MATEO	
B-01763-POD1	STK	EXP	PEN		400		7.00		257561	3916416	FERNANDEZ COMPANY LTD	SAN MATEO	
B-01786-POD1	EXP	PMT	ACT	2010	1420		8.00		257834	3916765	FERNANDEZ COMPANY, LTD.	SAN MATEO	
B-01787-POD1	EXP	PMT	PEN		110		4.50		257667	3916482	FERNANDEZ COMPANY LTD.	SAN MATEO	
B-01809-POD1	MON	PMT	PEN		3000		8.63		257816	3916434	FERNANDEZ COMPANY, LTD.	SAN MATEO	
B-01877-POD12	MON	PMT	ACT	2014	58	48	2.05		258784	3913542	ENVIRONMENTAL PROTECTION AGEN.	DALLAS	BG03
B-01877-POD13	MON	PMT	ACT	2014	51	41	2.05		259038	3914072	ENVIRONMENTAL PROTECTION AGEN.	DALLAS	BG04
B-01877-POD14	MON	PMT	ACT	2014	53	43	2.05		259043	3914253	ENVIRONMENTAL PROTECTION AGEN.	DALLAS	BG05
B-01905-POD1	CLS, STK	CLS		1935	300		10.00		256228	3912702	FERNANDEZ COMPANY LTD	MCKINLEY	C.C.C WELL
B-01975-POD1	DOM	PMT	ACT	2021	300	160	4.50	1	259775	3913281	MARQUEZ	GRANTS	93 SAN MATEO ST
SD-00966	IRR	PMT							260560	3912111	FERNANDEZ COMPANY, LTD.	SAN MATEO	SAN MATEO COMMUNITY IRRIGATION
SD-00971	IRR	DCL						353	257549	3912202	THE FERNANDEZ COMPANY	SAN MATEO	EL RITO FARM DITCH
SP-02528	STO	LIC	ACT	1935				50	260461	3912212	SAN MATEO COMMUNITY DITCH	SAN MATEO	STORAGE RESERVOIR

Source; NMOSE (2022). Notes: TD = well total depth (ft bgl). DTW = depth to water (ft) bgl or top of casing. 1. Gray shading indicates wells associated with Mine. 2. Yellow shading indicates wells with pre-1990 TD and DTW. 3-miles measured from approximate centroid of Mine.

Appendix G. Celtite 55 Chemical Grouts

CELTITE 55
GROUTING APPLICATIONS

13670 YORK ROAD • CLEVELAND, OHIO 44133 • PHONE 216/237-3232

CELTITE 55 CHEMICAL GROUTS

CELTITE 55 CHEMICAL GROUTS are designed to solve a wide range of problems related to Foundation Engineering. The following are a list of typical applications for Celtite 55 Terraset and Terraseal Grouts.

	TERRASET	TERRASEAL
• PREVENTION OF EROSION AND SCOURING OF LOAD BEARING SUB-SOIL BY FLOWING WATER CONDITIONS.		*
• CONTROL OF FAST WATER FLOWS IN HIGHLY FISSURED ROCK	*	*
• STABILIZATION OF FOUNDATIONS AND FOOTINGS, e.g. HOUSES, BUILDINGS, FACTORIES, LOCATED ON FINE TO MEDIUM SANDS AND UNSTABLE FILL MATERIAL.	*	
• FORMATION OF WATER-IMPERVIOUS CUT-OFF WALLS		*
• PREVENTION OF WATER LOSS FROM RESERVOIRS USING *NON-TOXIC MATERIALS*	*	*
• WATER SHUT-OFF IN DEEP SHAFT EXCAVATION	*	*
• WATERPROOFING OF CONCRETE JOINTS IN SHAFTS AND TUNNELS		*
• PREVENTION OF CAVE-IN DURING EXCAVATION OF UNSTABLE SANDS AND GRAVELS	*	*
• SEALING BASEMENT AREAS		*
• SEALING WATER SEEPAGE THROUGH CONCRETE FLOOR SLABS		*
• UPGRADING THE LOAD BEARING CAPACITY OF FOUNDATIONS PRIOR TO THE INSTALLATION OF HEAVY MACHINERY, BUILDING EXTENSIONS, STORAGE TANKS, ETC.	*	
• WATERPROOFING OF PEDESTRIAN TUNNELS		*
• ELIMINATION OF WATER INGRESS INTO UNDERGROUND PARKING LOTS.		*
• ABATEMENT OF LAND SLIDES	*	
• TREATMENT OF FOUNDATIONS OF MACHINERY AND COMPRESSORS TO REDUCE VIBRATION.	*	
• CONSTRUCTION OF A GROUT CURTAIN INTO ALLUVIAL DEPOSITS ON DAM SITES.	*	*
• SEALING LEAKS INTO DRY DOCKS		*

PRODUCTS FOR MINING, CONSTRUCTION AND INDUSTRY

CELTITE, INC. Products for Mining, Construction and Industry

October 5, 1976

Mr. Bruce B. McGlothlin
Houston Technical Services Center
11111 South Wilcrest Drive
P. O. Box 36506
Houston, Texas 77036

Dear Bruce:

In accordance with your request, we recently sent you two parcels via U.P.S. containing a total of five gallons of Terraset Part A, two gallons of Terraset Part B and ten pounds of Terraseal. A further parcel containing three gallons of Terraset Part A and one gallon of Part B is now on its way to you.

I don't think you have a data sheet on Celtite 55 Terraseal so I have enclosed a copy with this letter. The addition of a catalyst considerably reduces the gel time if this is desirable. Let me know if you want any.

Kindest regards.

Very truly yours,

CELTITE, INC.

Tony Plaisted.

A. C. Plaisted
Development Manager

ACP.jb
enclosure

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CELTITE 55 TERRASEAL

DESCRIPTION

Celtite 55 Terraseal is a polyphenolic resin powder, which is freely water soluble, forming a solution of very low viscosity. This solution will gel after a few hours imparting impermeability and cohesion to grouted soils. Where faster gel times are required, a catalyst is available which will give controllable gel times down to a few minutes. The catalyst can be supplied in liquid or powder form.

Preweighed 50# bags make between 24 and 40 gallons of working solution (i.e. between 15% and 25%) depending on application. Where maximum penetration is required, for example, into fine grained sands, a 15% solution is recommended. Otherwise a 25% solution will satisfy most requirements relative to water cut-off and ground consolidation.

MIXING PROCEDURE

The resin powder dissolves readily in water; however, to avoid lumping, the powder should be added slowly to the water with good agitation. Use the following table as a guide for grout preparation, which indicates the quantity of water necessary per 50# bag of Terraseal.

GROUT CONCENTRATION (%)	QUANTITY OF WATER (GALS)	FINAL VOLUME (GALS)	GEL TIME @ 70°F (HOURS)
15	37	40	5
20	27	30	4
25	21	24	3

SCOPE

Terraseal forms solutions of very low viscosity which, when injected into fine sands and incompetent ground, result in a very marked reduction in permeability (down to 10^{-9} cm/sec.) and a significant gain in bearing capacity. In conjunction with the catalyst, these results are achieved within a very short time after treatment.

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Appendix H. NMOSE Regulation of Drilling and Plugging of Wells

General Concerns

Well drilling activities and well plugging, are regulated in part under 19.27.4 NMAC (New Mexico Administrative Code). Most recently promulgated in 6/30/2017, these regulations require any person engaged in the business of well drilling within New Mexico to obtain a Well Driller License issued by the NMOSE (New Mexico Office of the State Engineer). Therefore, a New Mexico licensed Well Driller shall perform the drilling and plugging of exploratory boreholes that encounter groundwater.

Drilling where any form of groundwater is encountered will be subject to pertinent sections of 19.27.4 NMAC, including but not limited to Sections 19.27.4.30.C NMAC for plugging and abandonment of non-artesian wells / borings; and 27.4.31 NMAC for artesian wells / borings, including but not limited to Section 27.4.31.J and Section 27.4.31.K for repair and plugging of artesian wells. A complete version of the NMOSE 19.27.4 NMAC regulations can be found on the New Mexico OneSource website at: https://nmonesource.com/nmos/nmac/en/nav_date.do . The Mining and Mineral Division (MMD) will likely place additional conditions on the plugging of all wells via the MMD project permit.

All onsite plugging activities where groundwater is encountered shall be conducted under the supervision of the New Mexico-licensed Well Driller or a NMOSE-registered Drill Rig Supervisor under the direction of the licensed Well Driller. Special plugging conditions may be necessary to stop the migration of contaminants in the wellbore. These conditions may include perforating the casing, specialty cements and other conditions depending on the water quality, style, and conditions of the wellbore.

Additional NMOSE filings will be required where it is requested that a well be converted to a monitoring well. The well design and construction shall be subject to the provisions of 19.27.4 NMAC Regulations. Appropriation of water from such a conversion may require a water right. The MMD may disallow the conversions of existing wells to monitoring wells if not permitted specifically in the MMD permit.

Well Plugging

Terms of well plugging will be established jointly by the evaluation of the NMOSE *Well Plugging Plan of Operations* and the review of the relevant MMD application for wells. Approved high-solids bentonite abandonment-grade sealants and/or approved cement slurries will be required for plugging as deemed hydrogeologically appropriate by the agencies. NMOSE-authorized cement slurries will be required for the decommissioning of wells.

NMOSE well plugging regulations require tremie placement of the column of well sealant, which shall extend from the bottom of the borehole to ground surface. By regulation, pumping decommissioning sealants into the top of the borehole is not allowed. The NMOSE defers to the discretion of the MMD for the choice of sealant versus natural fill in the uppermost portion of a borehole plug to facilitate site restoration.

Required plugging of wells shall occur within the timeframe specified by either the NMOSE or MMD.

Drill Rig Fuels, Oils and Fluids

Drill rigs contain and consume fuels, oil, and hydraulic fluids, and are subject to leaks. Drill rigs often remain in-place longer than other pieces of equipment onsite, are frequently running, and are positioned immediately above and adjacent to the open borehole. As a standard practice to prevent contamination and reduce site cleanup activities, it may be beneficial to use bermed, impermeable ground sheeting under the drill rig. Consideration of bermed containment volume sufficient to accommodate a high-intensity precipitation event and use of oil- and water-absorbent mats under the drill rig is also a good practice.