INTERIM REPORT
June 28, 1990

RESULTS OF HYDROGEOLOGIC INVESTIGATIONS BRAWLEY WASH PILOT SURFACE RECHARGE SITE PIMA COUNTY, ARIZONA

Prepared For

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CONCLUSIONS

The principal conclusions from hydrogeologic investigations at the Brawley Wash pilot surface recharge site are:

1. Hydrogeologic investigations for the Brawley Wash site included construction of 10 soil borings, four groundwater monitor wells, and nine vadose zone piezometers.

2. Hydrogeologic units identified at the site are recent alluvium, Fort Lowell Formation, and upper Tinaja beds. The recent alluvium and Fort Lowell Formation occur in the vadose zone above groundwater level. Groundwater level occurs at a depth of about 150 feet in the upper Tinaja beds.

3. Results from drilling and from borehole geophysical logging for the monitor wells indicate the occurrence of two fine-grained stratigraphic units that appear to be laterally continuous in the vadose zone beneath the site. Fine-grained unit A is about 25 feet thick and occurs in the Fort Lowell Formation at a depth of about 70 feet. Fine-grained unit B is about five to 15 feet thick and occurs in the upper Tinaja beds at a depth of about 120 feet.

4. Hydraulic conductivity of the Fort Lowell Formation is expected to be substantially smaller than hydraulic conductivity of the recent alluvium. This contrast in hydraulic conductivity may cause downward movement of water through the vadose zone to be impeded at the top of the Fort Lowell Formation during surface recharge operations, and may cause perched groundwater conditions to develop in the recent alluvium. Four piezometers were constructed in the recent alluvium to monitor the potential occurrence of perched groundwater conditions during pilot recharge testing operations.

5. Perched groundwater conditions may develop in the Fort Lowell Formation above fine-grained unit A and above fine-grained unit B. Five piezometers were constructed to monitor the potential occurrence of perched groundwater conditions above these fine-grained units during pilot recharge testing operations.

6. Groundwater level measurements obtained in monitor wells at the site for the period from August 1989 through February 1990 indicate that depth to groundwater at the site is about 150 feet. Direction of groundwater movement is north-northeast; average hydraulic gradient is about 0.0016 or about eight feet per mile.

7. Results of 12-hour pumping tests conducted at the four monitor wells indicate that, for the part of the aquifer penetrated by the monitor wells, representative transmissivity ranges from about 11,000 to 28,000 gallons per day per foot width of aquifer at 1:1 hydraulic gradient. Average hydraulic conductivity for the part of the aquifer penetrated by the monitor wells ranges from 220 to 1,100 gallons per day per square foot of aquifer at 1:1 hydraulic gradient.

8. Results of laboratory chemical analyses for routine and trace constituents for groundwater samples obtained from the monitor wells and production well AF-64 indicate that groundwater is the sodium-bicarbonate type. Herbicides and pesticides were not detected.

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INTRODUCTION

Tucson Water is presently conducting Phase B of a three-phase recharge feasibility project. The goal of the project is to identify the most effective methods for recharging and storing surplus Central Arizona Project water in Tucson basin and Avra Valley aquifers. This report gives results of hydrogeologic investigations conducted for Tucson Water at the Brawley Wash pilot surface recharge site, located about 2-1/2 miles southwest from Three Points, Arizona. Location of the study area is shown on Figure 1. The goals of the hydrogeologic investigations at the Brawley Wash site were to: 1) construct groundwater monitor wells and piezometers for monitoring of groundwater levels and chemical quality of groundwater during pilot recharge testing operations; 2) characterize hydrogeologic conditions in the vadose and saturated zones; 3) determine aquifer hydraulic parameters for the saturated zone; and 4) determine occurrence, movement, and chemical quality of groundwater prior to pilot recharge testing operations.

Phase A of the Tucson Water recharge feasibility assessment project was completed in June 1987 and included: 1) identification and preliminary evaluation of recharge methods, 2) review of water quality requirements for recharge, 3) evaluation of the existing potable water distribution system and of existing wells for recharge, 4) preliminary hydrogeologic assessment of potential recharge sites for long-term storage and recovery, 5) prioriti-

zation of water sources for potential recharge sites, 6) review of institutional and regulatory requirements for recharge projects, and 7) preparation of scope of work for Phase B of the recharge feasibility assessment project. Phase B of the recharge feasibility project is scheduled to be complete in March 1991. Scope of work for hydrogeologic investigations for Phase B includes: 1) evaluation of the potential of existing active and inactive Tucson Water production wells in the Tucson basin for use as injection wells using surplus treated Central Arizona Project water; 2) conduct of a pilot injection recharge testing program at selected wells, analysis of results, and projection of effects of potential long-term injection operations; 3) conduct of vadose and saturated zone flow modeling for potential surface recharge sites, and evaluation of potential groundwater mounding and feasible recharge rates; and 4) hydrogeologic characterization for pilot surface recharge sites.

The upper reach of Brawley Wash was identified during the Phase A investigations as a favorable location for potential recharge by surface methods. The Brawley Wash site was selected as the first site for pilot surface recharge tests during the Phase B investigations. Selection of the site was described in a technical memorandum: "Design of Brawley Wash Pilot Recharge Project", prepared by CH2M Hill, November 27, 1989.

Hydrogeologic investigations for the Brawley Wash site included construction and lithologic sampling of 10 soil borings, four groundwater monitor wells, and nine vadose zone piezometers; conduct of borehole geophysical logging and constant-yield pumping tests at the monitor wells; and collection of groundwater samples for laboratory chemical analyses from the monitor wells. Measurements of groundwater level in the monitor wells have been obtained periodically from September 1989. Locations for monitor wells, piezometers, and soil borings at the pilot recharge site are shown on Figure 2.

Well numbers and identifiers for the Brawley Wash pilot surface recharge site are as follows:

MONITOR WELLS

(D-16-10)8bcd[WR-158A]
(D-16-10)8bdb2[WR-159A]
(D-16-10)8bca1[WR-160A]

PIEZOMETERS

(D-16-10)8bdb2[WR-159B]
(D-16-10)8bca1[WR-160B]
(D-16-10)8bca1[WR-160C]
(D-16-10)8bdb3[WR-166A]
(D-16-10)8bdb4[WR-167A]
(D-16-10)8bdb5[WR-168A]
(D-16-10)8bdb6[WR-169A]
(D-16-10)8bca2[WR-170A]
(D-16-10)8bdb7[WR-171A]

The well numbering system used in this report is given in Appendix A.

REGIONAL HYDROGEOLOGIC CONDITIONS

The Brawley Wash pilot surface recharge site lies in the south part of Avra Valley in the Basin and Range Hydrogeologic Province of southern Arizona. This hydrogeologic province is characterized by alluvial valleys and basins separated by isolated mountain ranges. The Avra Valley basin comprises a tectonically depressed trough that has been filled with several thousand feet of materials eroded from the mountain blocks. A detailed review and analysis of hydrogeologic conditions for the Tucson basin and Avra Valley is given in the Tucson Recharge Phase A, Task 5 Report: Assessment of Potential Recharge Sites for Long-Term Storage and Recovery (CH2M Hill and others, 1988).

The principal geologic units of interest in Avra Valley are recent alluvium related to modern streams and washes, Fort Lowell Formation of Quaternary age, and Tinaja beds of Tertiary age. These units are classified as basin-fill deposits, and are underlain by older sedimentary rocks of the Pantano Formation and by a basement complex.

RECENT ALLUVIUM

The recent alluvium in the Avra Valley basin includes modern stream channel and flood plain deposits, and occurs chiefly along Brawley Wash. The recent alluvium consists mostly of sand and gravel; the silt and clay fraction is commonly small (Davidson, 1973). Review of drillers' logs indicates that average thickness of recent alluvium along Brawley Wash in the vicinity of Three Points may be about 55 feet. Analysis of lithologic samples obtained from soil borings at the Brawley Wash pilot recharge site indicates that average thickness of recent alluvium at the site is about 30 feet.

In the Brawley Wash area, the base of the recent alluvium is above groundwater level and the unit is not saturated. Recent alluvium deposits are porous and permeable, and function as effective infiltration media for ephemeral streamflow.

FORT LOWELL FORMATION

The Fort Lowell Formation consists of a sequence of unconsolidated to weakly-lithified, interbedded, clayey silt, sandy silt, sand, and gravel (Davidson, 1973). Average grain size generally becomes smaller toward the center of the basin. Average silt and clay content of the Fort Lowell Formation in the south part of Avra Valley, near the pilot surface recharge site, ranges from 20 to 40 percent (CH2M HILL and others, 1988).

Thickness of the Fort Lowell Formation generally becomes larger toward the center of the basin. Review of drillers' logs and lithologic logs indicates that average thickness of Fort Lowell Formation in Avra Valley is about 250 feet; average thickness in the south part of Avra Valley near the pilot surface recharge site is less than 100 feet. Analysis of lithologic descriptions, of sieve analyses of drill cuttings samples, and of borehole geophysical logs obtained from monitor wells constructed at the Brawley Wash pilot surface recharge site indicates that the base of the Fort Lowell Formation occurs at a depth of about 120 feet; average thickness of Fort Lowell Formation at the site is about 90 feet. In the area near the pilot surface recharge site, the base of the Fort Lowell Formation is above groundwater level and the unit is not saturated.

TINAJA BEDS

The Tinaja beds are informally classified into the upper, middle, and lower Tinaja beds. The upper Tinaja beds comprise the principal aquifer in Avra Valley.

Upper Tinaja Beds

The upper Tinaja beds consist of a sequence of heterogeneous deposits of unconsolidated to weakly-lithified, interbedded, clayey silts, sandy silts, sands, and gravels (Davidson, 1973). Average silt and clay content of the upper Tinaja beds in the south part of Avra Valley, near the pilot surface recharge site, is less than 20 percent (CH2M HILL and others, 1988).

Thickness of upper Tinaja beds generally becomes larger toward the center of the basin, and where the unit occurs in down-thrown fault blocks. Upper Tinaja beds generally overlie middle Tinaja beds in the north part of Avra Valley, and overlie lower Tinaja beds in the south part of the valley. Analysis of drillers' logs and lithologic logs indicates that average thickness of upper Tinaja beds in Avra Valley is about 350 feet; average thickness near the pilot surface recharge site is about 220 feet. Monitor wells constructed at the Brawley Wash pilot surface recharge site are completed in upper Tinaja beds.

The upper Tinaja beds comprise the principal aquifer in the Avra Valley basin. In much of Avra Valley, including the area near the pilot surface recharge site, groundwater level occurs below the top of the upper Tinaja beds; hence, the unit is not fully saturated. At the pilot surface recharge site, the top of the upper Tinaja beds occurs at a depth of about 120 feet; depth to groundwater is about 150 feet.

Middle Tinaja Beds

The middle Tinaja beds underlie upper Tinaja beds in the north central part of Avra Valley. Middle Tinaja beds consist chiefly of moderately-lithified, gypsiferous and anhydritic, clayey silt and mudstone. The middle Tinaja beds are not believed to be present in the area of the pilot surface recharge site.

Lower Tinaja Beds

The lower Tinaja beds underlie middle Tinaja beds in the north central part of Avra Valley, and underlie upper Tinaja beds in the south part of Avra Valley. The unit consists of a thick sequence of clayey silt, mudstone, gravel, and moderately-lithified conglomerate. Lower Tinaja beds are more firmly cemented than upper or middle Tinaja beds. Most wells and boreholes were not drilled sufficiently deep to completely penetrate lower Tinaja beds. Groundwater level occurs above the top of the lower Tinaja beds at all locations in Avra Valley; hence, the unit is fully saturated.

SOIL BORINGS

Soil borings were drilled at 10 locations in the area near the Brawley Wash pilot surface recharge site during the period March 6 through 10, 1989, under the supervision of CH2M Hill. Montgomery & Associates personnel prepared lithologic sample descriptions for five of the 10 soil borings. Soil borings were drilled to characterize near-surface hydrogeologic conditions for preliminary assessment of technical feasibility of potential long-term surface recharge operations at the site.

The soil borings were drilled by Western Technologies, Inc., Tucson, Arizona, with a CME-55 auger drilling rig, using a 7-inch outside diameter hollow-stem auger. Soil boring SB-C, located near the center of the recharge basins, and soil boring SB-H, located about one-half mile north from the basins were drilled to depths of about 95 feet. Total depth of the remaining eight soil borings was 50 feet. Locations of the four soil borings near the recharge basins at the pilot surface recharge site are shown on **Figure 2**. Locations for the remaining six soil borings drilled north from the area shown on **Figure 2** are given in a technical memorandum: "Design of Brawley Wash Pilot Recharge Project", prepared by CH2M Hill, November 27, 1989.

Soil samples for lithologic descriptions were obtained at five- and 10-foot intervals using split-spoon and brass-ring bearing drive samplers. At each sampling depth, the sampler was driven into the soil using a 140-pound hammer, and standard penetration blow counts were recorded for each six-inch interval penetrated. After drilling and sampling operations were completed, the soil borings were back-filled with drill cuttings.

Lithologic descriptions for samples from the four soil borings in the immediate vicinity of the recharge basins are given in **Appendix B**. Thickness of recent alluvium encountered in these four soil borings ranged from 26 to 30 feet. The contact between the recent alluvium and the Fort Lowell Formation was determined based on silt and clay content, penetration rate of

the drill bit, and standard penetration blow counts for the drive samplers. Silt and clay content, and standard penetration blow counts, were typically larger for the Fort Lowell Formation than for the recent alluvium. Penetration rate of the drill bit was smaller for the Fort Lowell Formation than for the recent alluvium. Recent alluvium consisted chiefly of unconsolidated silty sand and gravel with cobbles. Fort Lowell Formation consisted of silty sand and gravel bound in a clayey matrix, with lenses of silt and clay. Clayey silt was encountered in the Fort Lowell Formation at a depth of 40 feet in soil boring SB-A and at a depth of 80 feet in soil boring SB-C (Appendix B).

CONSTRUCTION OF MONITOR WELLS AND PIEZOMETERS

The hydrogeologic investigations for the Brawley Wash pilot surface recharge site included construction of four groundwater monitor wells and nine vadose zone piezometers during the period May through September 1989. Well construction details for the monitor wells and piezometers are summarized in Table 1. Schematic diagrams of well construction, results of sieve analyses for drill cuttings, and summary borehole geophysical logs for the monitor wells are shown on Figures 3, 4, 5, and 6. The monitor wells were completed in the upper Tinaja beds aquifer. Monitor wells were constructed to obtain water level measurements and groundwater samples, to conduct short-term pumping tests to estimate aquifer parameters before start of recharge operations, and to obtain water level measurements and groundwater samples during pilot recharge operations. Because water levels are expected to rise in response to recharge operations, casing perforations for the monitor wells extend above the regional groundwater level (Figures 3, 4, 5, and 6). Casing perforations for monitor wells WR-157A, WR-158A, and WR-159A extend to a depth of about 200 feet below land surface, or about 50 feet below groundwater level (Figures 3, 4, and 5). Because downward movement of groundwater will occur directly beneath the recharge basins during pilot recharge operations, the perforated interval for monitor well WR-160A was limited to the interval from 141 to 176 feet (Figure 6), to minimize downward movement of groundwater via the wellbore.

Boreholes for surface casing for each monitor well were drilled by Desert Earth, Inc., Tucson, Arizona, using a 24-inch diameter auger. The monitor wells were drilled and constructed by Western Well & Pump, Inc., Phoenix, Arizona, with a Failing JED-A drilling rig, using reverse-circulation rotary drilling methods. Drilling fluids were water and formation derived mud; no drilling fluid additives were used. For each well, lithologic descriptions of drill cuttings samples were prepared by Montgomery & Associates during drilling, and sieve analyses of drill cuttings samples were conducted by Tucson Water. Lithologic descriptions of drill cuttings samples

are given in Appendix C. Locations for the monitor wells are shown on Figure 2.

Following completion of drilling operations, borehole geophysical logs were obtained for monitor wells WR-157A, WR-158A, WR-159A, and WR-160A (Figures 3, 4, 5, and 6). Borehole geophysical logging operations were conducted by Montgomery & Associates personnel, using equipment leased from Century Geophysical Corporation, Tulsa, Oklahoma. Borehole geophysical logs obtained include natural gamma-ray, single point resistivity, guard log resistivity, long and short normal resistivity, spontaneous potential, and temperature. Borehole caliper logs were also obtained for wells WR-157A, WR-158A, and WR-160A (Figures 3, 4, and 6). Stratigraphic position of hydrogeologic units was determined from analysis of borehole geophysical logs and lithologic descriptions of drill cuttings samples.

Piezometers were installed above the groundwater level in the annular space between the 6-inch casing and the borehole wall for monitor wells WR-159A and WR-160A, to monitor the potential occurrence of perched groundwater above fine-grained units in the vadose zone during recharge operations.

After construction was completed, the monitor wells were developed by air-lift pumping and surging. Observations were made of approximate air-lift pumping rates and appearance of fluids discharged from the well. Field measurements of temperature, specific electrical conductance, and pH of pumped water were made periodically during air-lifting operations. Sediment load in pumped water was measured using an Imhoff cone. Air-lift pumping rate ranged from about five to 10 gallons per minute (gpm). Groundwater yielded near the end of development operations for all monitor wells was relatively clear and sand free.

MONITOR WELL (D-16-10)8bdb1[WR-157A]

The initial borehole for monitor well WR-157A was drilled using a 24-inch diameter auger. The borehole was drilled to a depth of 24 feet and 16-inch surface casing was set and cemented (Figure 3). After cementing the surface casing, a 12-inch borehole was drilled to a depth of about 36 feet where caving conditions were encountered. The borehole was stabilized by cementing the interval from 24 to 36 feet. After cementing, a 12-inch borehole was drilled to 220 feet and borehole geophysical logs were obtained. Following completion of borehole geophysical logging operations, 6-inch blank and perforated steel casing was set to 210 feet. Perforated interval extends from 130 to 200 feet. Perforations are 1/8- by 3-inch saw-cut slots, eight slots per round with two rounds per foot.

After the 6-inch casing was set in monitor well WR-157A, a gravel pack was placed via tremie pipe in the annular space between the 6-inch casing and the borehole wall from the bottom of the borehole to a depth of 109 feet, 21 feet above the uppermost perforations (Figure 3). Following installation of the gravel pack, sand was placed via tremie pipe in the interval from 109 to 105 feet, and cement was tremied from the top of the sand to land surface (Table 1). After construction of monitor well WR-157A was complete, the well was developed by air-lift pumping for a period of four hours.

Analysis of borehole geophysical logs and drill cuttings samples for monitor well WR-157A indicates alternating sand, gravel, and clayey sand and gravel strata in the interval from land surface to 210 feet (Figure 3). Several zones with substantial clay content were encountered in the vadose zone. A 16-foot zone having silt and clay content ranging from eight to 75 percent occurs in the interval from about 71 to 87 feet, and a 23-foot zone having silt and clay content ranging from 11 to 33 percent occurs in the interval from 124 to 147 feet. Below 160 feet, silt and clay content is about 11 percent and is relatively uniform.

MONITOR WELL (D-16-10)8bcd[WR-158A]

The initial borehole for monitor well WR-158A was drilled using a 24-inch diameter auger. The borehole was drilled to a depth of 26 feet and 16-inch surface casing was set and cemented (Figure 4). After cementing the surface casing, a 12-inch borehole was drilled to 40 feet where caving conditions were encountered. The borehole was stabilized by cementing the interval from 28 to 40 feet. After cementing, a 12-inch borehole was drilled to 215 feet and borehole geophysical logs were obtained. Following completion of borehole geophysical logging operations, 6-inch blank and perforated steel casing was set to 211 feet. The perforated interval extends from 131 to 201 feet. Perforations are 1/8- by 3-inch saw-cut slots, eight slots per round with two rounds per foot.

After the 6-inch casing was set in monitor well WR-158A, a gravel pack was placed via tremie pipe in the annular space between the 6-inch casing and the borehole wall from the bottom of the borehole to a depth of 109 feet, 22 feet above the uppermost perforations (Figure 4). Following installation of the gravel pack, sand was placed via tremie pipe in the interval from 109 to 105 feet, and cement was tremied from the top of the sand to land surface (Table 1). After construction of monitor well WR-158A was complete, the well was developed by air-lift pumping for a period of about 5-1/2 hours.

Analysis of borehole geophysical logs and drill cuttings samples for monitor well WR-158A indicates chiefly sand and gravel to 64 feet, and alternating sand, gravel, and clayey sand and gravel strata in the interval from 64 to 213 feet (Figure 4). Several zones with substantial clay content were encountered in the vadose zone. A six-foot zone having clay content of 42 percent occurs in the interval from 64 to 70 feet, and a 25-foot zone having clay content ranging from seven to 83 percent occurs in the interval from about 121 to 146 feet. Below 150 feet, silt and clay content is about eight percent and is relatively uniform.

MONITOR WELL (D-16-10)8bdb2[WR-159A]

The initial borehole for monitor well WR-159A was drilled using a 24-inch diameter auger. The borehole was drilled to a depth of 21.5 feet and 16-inch surface casing was set and cemented (**Figure 5**). After cementing the surface casing, a 12-inch borehole was drilled to 40 feet where caving conditions were encountered. The borehole was stabilized by cementing the interval from 21.5 to 40 feet. After cementing, a 12-inch borehole was drilled to 215 feet and borehole geophysical logs were obtained. Following the completion of borehole geophysical logging operations, 6-inch blank and perforated steel casing was set to 210 feet. The perforated interval extends from 145 to 200 feet. Perforations are 1/8- by 3-inch saw-cut slots, eight slots per round with two rounds per foot.

After the 6-inch casing was set in monitor well WR-159A, a gravel pack was placed via tremie pipe in the annular space between the 6-inch casing and the borehole wall from the bottom of the borehole to a depth of 140 feet, five feet above the uppermost perforations (**Figure 5**). Following installation of the gravel pack, sand was placed via tremie pipe in the interval 140 to 137 feet, and cement was tremied from the top of the sand to about 123 feet below land surface (**Table 1**).

After the cement was installed, a piezometer consisting of 1-1/4-inch blank and perforated steel pipe was set in the annular space between the 6-inch casing and the borehole wall from a depth of 123 feet to land surface (**Figure 5**). The perforated interval for piezometer WR-159B extends from 115 to 123 feet. Perforations are 1/8-inch diameter drilled holes, two holes per round, two rounds per foot. After the piezometer casing was set, gravel pack was placed via tremie pipe in the annular space from 123 feet to 109 feet. Following installation of the gravel pack, sand was placed via tremie pipe in the interval 109 to 106 feet, and cement was tremied from the top of the sand to land surface. After construction of monitor well WR-159A and piezometer WR-159B was complete, the well was developed by air-lift pumping for a period of about 5-1/2 hours.

Analysis of borehole geophysical logs and drill cuttings samples for monitor well WR-159A indicates chiefly sand and gravel to a depth of 72 feet, and alternating sand, gravel, and clayey sand and gravel strata in the interval from 72 to 213 feet (**Figure 5**). A 4-1/2 foot zone having clay content of five percent occurs in the interval from 72 to 76 feet, an eight-foot zone having clay content of eight percent occurs in the interval from 87 to 95 feet, and a 29-foot zone having clay content ranging from 23 to 76 percent occurs in the interval from 120 to 149 feet. Below 149 feet, silt and clay content is about 13 percent and is relatively uniform.

MONITOR WELL (D-16-10)8bca1[WR-160A]

The initial borehole for monitor well WR-160A was drilled using a 24-inch diameter auger. The borehole was drilled to a depth of 25 feet and 16-inch surface casing was set and cemented (**Figure 6**). After cementing the surface casing, a 12-inch borehole was drilled to 50 feet where caving conditions were encountered. The borehole was stabilized by cementing the interval from 25 to 50 feet. After cementing, a 12-inch borehole was drilled to 185 feet and borehole geophysical logs were obtained. Following the completion of borehole geophysical logging operations, 6-inch blank and perforated steel casing was set to 181 feet. The perforated interval extends from 146 to 176 feet. Perforations are 1/8- by 3-inch saw-cut slots, eight slots per round with two rounds per foot.

After the 6-inch casing was set in monitor well WR-160A, a gravel pack was placed via tremie pipe in the annular space between the 6-inch casing and the borehole wall from the bottom of the borehole to a depth of 141 feet, five feet above the uppermost perforations (**Figure 6**). Following installation of the gravel pack, sand was placed via tremie pipe in the interval 141 to 137 feet, and cement was tremied from the top of the sand to 112.5 feet below land surface (**Table 1**).

After the cement was installed, a piezometer consisting of 1-1/4-inch blank and perforated steel pipe was set in the annular space between the 6-inch casing and the borehole wall from a depth of 112.5 feet to land surface (Figure 6). The perforated interval for piezometer WR-160B extends from 108.5 to 112.5 feet. Perforations are 1/8-inch diameter drilled holes, two holes per round, two rounds per foot. After the piezometer casing was set, gravel pack was placed via tremie pipe in the annular space from 112.5 to 107.5 feet. Following installation of the gravel pack, sand was placed via tremie pipe in the interval 107.5 to 105 feet, and cement was tremied from the top of the sand to 70 feet below land surface.

After the cement was installed, a second piezometer consisting of 1-1/4-inch blank and perforated steel pipe was set in the annular space between the 6-inch casing and the borehole wall from a depth of 70 feet to land surface. The perforated interval for piezometer WR-160C extends from 66 to 70 feet. Perforations are 1/8-inch diameter drilled holes, two holes per round, two rounds per foot. After the piezometer casing was set, gravel pack was placed via tremie pipe in the annular space from 70 to 64 feet. Following installation of the gravel pack, sand was placed via tremie pipe in the interval 64 to 61 feet, and cement was tremied from the top of the sand to land surface. After construction of monitor well WR-160A and piezometers WR-160B and WR-160C was complete, the well was developed by air-lift pumping for a period of about six hours.

Analysis of borehole geophysical logs and drill cuttings samples for monitor well WR-160A indicates alternating sand, gravel, and clayey sand and gravel strata in the interval from 50 to 185 feet (Figure 6). A nine-foot zone having clay content ranging from five to 34 percent occurs in the interval from 72 to 81 feet, a five-foot zone having clay content of seven percent occurs in the interval from 90 to 95 feet, a four-foot zone having clay content of 18 percent occurs in the interval from 100 to 104 feet, and a 25-foot zone having clay content ranging from nine to 76 percent occurs in the occurs in the interval from 112 to 137 feet. Below 137 feet, silt and clay content is about 14 percent and is relatively uniform.

PIEZOMETERS WR-166A, WR-167A, WR-168A, WR-169A, WR-170A, AND WR-171A

In addition to the piezometers installed in the annular space of monitor wells WR-159A and WR-160A, six piezometers were drilled and constructed at the site to monitor perched groundwater conditions which may develop in the vadose zone during pilot recharge operations. Construction details for the piezometers are given in **Table 1** and are shown on **Figures 7 through 12.** Piezometers WR-166A, WR-167A, WR-168A, WR-169A, WR-170A, and WR-171A were drilled and constructed during September 1989 by Western Technologies, Inc., with a CME-75 auger drilling rig, using a 10-inch outside diameter hollow-stem auger. The piezometers were completed to depths ranging from 31 to 105 feet. Locations for the piezometers are shown on **Figure 2.**

Soil samples for lithologic descriptions were obtained at five- and 10-foot intervals using split-spoon and brass-ring bearing drive samplers. Lithologic descriptions for samples obtained during drilling of the piezometers are given in **Appendix D.**

After each piezometer was drilled to total depth, 2-inch blank and perforated steel casing was set in the borehole via the inside of the auger stem, with perforations in the lower 10 feet of casing. Perforations are 1/4-inch drilled holes, with two holes per round, and two rounds per linear foot of casing. After the piezometer casing was set, gravel pack, a sand cap, and a cement seal were installed via the inside of the auger stem.

PUMPING TESTS FOR MONITOR WELLS

PUMPING TEST PROCEDURES

After well development operations were complete, a submersible electric test pump and water level access tube were installed and constant-yield pumping tests of 12 hours duration were conducted at each of the upper Tinaja beds monitor wells. During the pumping periods, measurements were made of depth to water, pumping rate, and temperature, specific electrical conductance, and pH of the pumped water. Hydrologic data from pumping tests at the groundwater monitor wells are summarized in **Table 2.**

Pumping rate was measured using a totalizing flow meter, installed in the discharge line approximately 10 feet downstream from the well head, and also by recording the time required to fill a calibrated 15-gallon container. A gate valve was installed about 10 feet downstream from the flow meter in the discharge line to control pumping rate and to assure full pipe flow for proper meter operation. After pumping stopped, depth to water at each well was measured for a period equal to the pumping period.

During the pumping test for each monitor well, measurements of water level were also made in the other three monitor wells. Groundwater samples for laboratory chemical analyses were obtained near the end of the pumping period for monitor wells WR-157A, WR-158A, and WR-160A, and after about 4-1/2 hours of pumping for monitor well WR-159A.

ANALYSIS OF PUMPING TEST RESULTS

The water level drawdown data obtained during the pumping tests were analyzed for transmissivity using the modified non-equilibrium equation semi-

logarithmic graphical procedure given by Cooper and Jacob (1946). Water level recovery data were analyzed for transmissivity by plotting residual drawdown versus the ratio t/t', where "t" is time after pumping started and "t'" is time after pumping stopped. Residual drawdown is the magnitude of drawdown remaining at any time after pumping stopped. Transmissivity values determined from analysis of data from the pumping tests are summarized in Table 3. The drawdown and recovery graphs for the pumping tests are shown on Figures 13 through 20. Because the pumping tests were of short duration with small pumping rates, results for transmissivity are approximate. Because water level response did not occur in non-pumping wells, storage coefficient could not be computed.

Monitor Well (D-16-10)8bdb1[WR-157A]

The 12-hour pumping test for monitor well WR-157A started at 07:00 on June 27, 1989. Pre-pumping water level was 150.05 feet below land surface. Pumping rate ranged from 32 to 46 gpm; average was 33 gpm. Maximum water level drawdown occurred near the end of the pumping period and was 12.84 feet. Specific capacity at the time of maximum drawdown was 2.6 gallons per minute per foot of drawdown (gpm/ft). Specific capacity was computed by dividing the average pumping rate by the maximum drawdown at that rate. Average temperature of the pumped water was 24 degrees Celsius (°C). Average specific electrical conductance measured in the field was about 600 micromhos per centimeter (μmho/cm). Specific electrical conductance is defined as the conductance of a cube of water, one centimeter on a side, at 25°C and has units of μmho/cm. Average pH of the pumped water was 7.8 (Table 2).

Figure 13 is a semi-logarithmic drawdown graph for monitor well WR-157A during the pumping test. Analysis of the trend of drawdown data for the period from 20 to 75 minutes after pumping started indicates transmissivity of about 8,000 gallons per day per foot width of aquifer at 1:1 hydraulic gradient (gpd/ft) (Table 3).

Figure 14 is a semi-logarithmic recovery graph for monitor well WR-157A. Analysis of the trend of recovery data for t/t' from 6.8 to 2.0 (from 124 to 720 minutes after pumping stopped) indicates transmissivity of about 16,000 gpd/ft (Table 3).

Monitor Well (D-16-10)8bcd[WR-158A]

The 12-hour pumping test for monitor well WR-158A started at 07:00 on July 5, 1989. Pre-pumping water level was 151.44 feet below land surface. Pumping rate ranged from 56 to 72 gpm; average was 61 gpm. Maximum water level drawdown occurred near the end of the pumping period and was 3.66 feet. Specific capacity at the time of maximum drawdown was 16.7 gpm/ft. Average temperature of the pumped water was 25°C. Average specific electrical conductance measured in the field was about 500 μmho/cm. Average pH of the pumped water was 7.9 (Table 2).

Figure 15 is a semi-logarithmic drawdown graph for monitor well WR-158A during the pumping test. Analysis of the trend of data for the period from 95 to 280 minutes after pumping started indicates transmissivity of about 55,000 gpd/ft (Table 3).

Figure 16 is a semi-logarithmic recovery graph for monitor well WR-158A. Analysis of the trend of recovery data for t/t' from 10 to 2.0 (from 80 to 720 minutes after pumping stopped) indicates transmissivity of about 26,000 gpd/ft (Table 3).

Monitor Well (D-16-10)8bdb2[WR-159A]

The 12-hour pumping test for monitor well WR-159A started at 07:00 on July 7, 1989. Pre-pumping water level was 150.51 feet below land surface. Pumping rate ranged from 33 to 34 gpm; average was 34 gpm. Maximum water level drawdown occurred near the end of the pumping period and was 15.41

feet. Specific capacity at the time of maximum drawdown was 2.2 gpm/ft. Average temperature of the pumped water was 25°C. Average specific electrical conductance measured in the field was about 540 μmho/cm. Average pH of the pumped water was 7.9 (Table 2).

Figure 17 is a semi-logarithmic drawdown graph for monitor well WR-159A during the pumping test. Analysis of the trend of drawdown data for the period from 34 to 200 minutes after pumping started indicates transmissivity of about 5,000 gpd/ft (Table 3).

Figure 18 is a semi-logarithmic recovery graph for monitor well WR-159A. Analysis of the trend of recovery data for t/t' from 5.4 to 2.0 (from 164 to 720 minutes after pumping stopped) indicates transmissivity of about 11,000 gpd/ft (Table 3).

Monitor Well (D-16-10)8bca1[WR-160A]

The 12-hour pumping test for monitor well WR-160A started at 07:00 on June 29, 1989. Pre-pumping water level was 150.50 feet below land surface. Pumping rate ranged from 38 to 43 gpm; average was 40 gpm. Maximum water level drawdown occurred near the end of the pumping period and was 12.25 feet. Specific capacity at the time of maximum drawdown was 3.3 gpm/ft. Average temperature of the pumped water was 25°C. Average specific electrical conductance measured in the field was about 550 μmho/cm. Average pH of the pumped water was 7.8 (Table 2).

Figure 19 is a semi-logarithmic drawdown graph for monitor well WR-160A during the pumping test. Analysis of the trend of drawdown data for the period from 32 to 280 minutes after pumping started indicates transmissivity of about 60,000 gpd/ft (Table 3).

Figure 20 is a semi-logarithmic recovery graph for monitor well WR-160A. Analysis of the trend of recovery data for t/t' from 5.0 to 2.0 (from 180 to

720 minutes after pumping stopped) indicates transmissivity of about 28,000 gpd/ft (Table 3).

SUMMARY OF PUMPING TEST RESULTS

Magnitude of aquifer transmissivity and average hydraulic conductivity estimated from data obtained during pumping test operations conducted at Brawley Wash monitor wells is given in Table 3. Because effects of variation of pumping rate during the pumping period and effects of changing saturated interval due to water level drawdown at the well are smaller during the recovery period, transmissivity computed for the recovery period is believed to be more reliable than transmissivity computed for the drawdown period.

Computed transmissivity for saturated strata opposite the perforated interval in monitor well WR-157A was 8,000 gpd/ft for the drawdown period and 16,000 gpd/ft for the recovery period (Table 3). Transmissivity computed for the late recovery period is believed to be most reliable. Representative transmissivity for saturated strata opposite the perforated interval is judged to be about 16,000 gpd/ft. Immediately prior to the pumping test, penetrated saturated thickness of the upper Tinaja beds at monitor well WR-157A was 50 feet. These relations indicate that magnitude of average hydraulic conductivity for this 50-foot zone at the well may be about 320 gallons per day per square foot of aquifer at 1:1 hydraulic gradient (gpd/ft^2) (Table 3).

Computed transmissivity for saturated strata opposite the perforated interval in monitor well WR-158A was 55,000 gpd/ft for the drawdown period and 26,000 gpd/ft for the recovery period (Table 3). Transmissivity computed for the late recovery period is believed to be most reliable. Representative transmissivity for saturated strata opposite the perforated interval is judged to be about 26,000 gpd/ft. Immediately prior to the pumping test, penetrated saturated thickness of the upper Tinaja beds at monitor well WR-

158A was 50 feet. These relations indicate that magnitude of average hydraulic conductivity for this 50-foot zone at the well may be about 520 gpd/ft^2 (Table 3).

Computed transmissivity for saturated strata opposite the perforated interval in monitor well WR-159A was 4,900 gpd/ft for the drawdown period and 11,000 gpd/ft for the recovery period (Table 3). Transmissivity computed for the late recovery period is believed to be most reliable. Representative transmissivity for saturated strata opposite the perforated interval is judged to be about 11,000 gpd/ft. Immediately prior to the pumping test, penetrated saturated thickness of the upper Tinaja beds at monitor well WR-159A was 49 feet. These relations indicate that magnitude of average hydraulic conductivity for this 49-foot zone at the well may be about 220 gpd/ft^2 (Table 3).

Computed transmissivity for saturated strata opposite the perforated interval in monitor well WR-160A was 60,000 gpd/ft for the drawdown period and 28,000 gpd/ft for the recovery period (Table 3). Transmissivity computed for the late recovery period is believed to be most reliable. Representative transmissivity for saturated strata opposite the perforated interval is judged to be about 28,000 gpd/ft. Immediately prior to the pumping test, penetrated saturated thickness of the upper Tinaja beds at monitor well WR-160A was 26 feet. These relations indicate that magnitude of average hydraulic conductivity for this 26-foot zone at the well may be about 1,100 gpd/ft^2 (Table 3).

HYDROGEOLOGIC CHARACTERIZATION

Hydrogeologic conditions at the Brawley Wash pilot recharge site have been characterized based on inspection of lithologic samples obtained during drilling of exploratory soil borings, groundwater monitor wells, and vadose zone piezometers, and on analysis of borehole geophysical logs, pumping test results, and measurements of groundwater level in monitor wells.

HYDROGEOLOGIC UNITS

Hydrogeologic section A-A', which gives subsurface relations for the hydrogeologic units at the Brawley Wash pilot recharge site, is shown on Figure 21. Location of the hydrogeologic section is shown on Figure 2. The vadose zone and saturated zone comprise a heterogeneous sequence of coarse- and fine-grained basin-fill deposits. Groundwater level occurs at a depth of about 150 feet in the upper Tinaja beds (Figure 21).

Two fine-grained units consisting chiefly of silt and clay, and which may be laterally continuous beneath the site, were identified in the vadose zone. Fine-grained unit A occurs in the Fort Lowell Formation and fine-grained unit B occurs in the upper Tinaja beds (Figure 21). No laterally extensive fine-grained units were encountered in the saturated part of the upper Tinaja beds to the depth penetrated by the monitor wells.

Recent Alluvium

Analysis of lithologic samples from soil borings, monitor wells, and piezometers indicates that thickness of recent alluvium encountered at the Brawley Wash pilot recharge site ranges from 26 feet at soil boring SB-A, to 33 feet at soil boring SB-C (Appendix B; Figure 21); average is about 30

feet. At the site, the upper 10 feet of the recent alluvium consists chiefly of sandy silt and silty sand. Below a depth of about 10 feet the recent alluvium is composed of silty, gravelly sand, and silty, sandy gravel with cobbles.

The contact between recent alluvium and Fort Lowell Formation was determined by inspection of samples obtained during auger drilling of soil borings and piezometers. Deposits above the contact are unconsolidated, with rounded to subrounded granules, pebbles, and cobbles. Deposits below the contact are weakly- to moderately-consolidated, with subangular to subrounded granules and pebbles, bound in a clayey matrix.

Because the recent alluvium is more porous and permeable than the underlying Fort Lowell Formation, perched groundwater conditions may develop at the interface between these units during recharge operations. Piezometers WR-167A, WR-169A, WR-170A, and WR-171A (Figures 8, 10, 11, and 12) were constructed to monitor the occurrence and development of perched groundwater conditions at the interface between recent alluvium and Fort Lowell Formation.

Fort Lowell Formation

Analysis of lithologic samples from soil borings, monitor wells, and piezometers indicates that the thickness of the Fort Lowell Formation at the Brawley Wash pilot recharge site ranges from about 80 feet at monitor well WR-160A, to about 97 feet at monitor well WR-157A (Figure 21). At the site, Fort Lowell Formation consists chiefly of weakly- to moderately-consolidated clayey, silty, gravelly sand, with interbeds of sandy clay and silt. Silt and clay content for the coarse-grained deposits is generally less than 10 percent.

The contact between Fort Lowell Formation and upper Tinaja beds was determined from inspection of lithologic descriptions and results of sieve

analyses of drill cuttings from monitor wells, and from analyses of borehole geophysical logs. Deposits of Fort Lowell Formation generally have smaller silt and clay content and are less consolidated than those of upper Tinaja beds.

Results from drilling and borehole geophysical logging of the four groundwater monitor wells indicate that fine-grained unit A consists chiefly of sandy silt and clay. The top of the unit occurs at depths ranging from 64 feet at monitor well WR-158A, to 72 feet at monitor wells WR-159A and WR-160A (Figure 21). Thickness of the unit ranges from about 4-1/2 feet at monitor well WR-159A, to about 16 feet at monitor well WR-157A. Because fine-grained unit A may be poorly permeable, downward movement of recharge water to the regional aquifer may be retarded, and perched groundwater conditions may develop at the top of the unit during surface recharge operations. Piezometer WR-160B, installed in the annular space of monitor well WR-160A, and piezometer WR-168A were constructed to monitor the occurrence and development of perched groundwater conditions above fine-grained unit A.

Upper Tinaja Beds

Inspection of lithologic samples from monitor wells indicates that the upper Tinaja beds at the Brawley Wash pilot recharge site consist chiefly of moderately- to well-consolidated clayey, silty, gravelly sand, with interbeds of sandy clay and silt. Silt and clay content for the coarse-grained deposits is generally about 10 to 20 percent. Monitor wells drilled at the site penetrate approximately the upper 100 feet of upper Tinaja beds.

Results from drilling and borehole geophysical logging of the four groundwater monitor wells indicate that fine-grained unit B consists chiefly of sandy silt and clay. The top of the unit occurs at depths ranging from about 112 feet at monitor well WR-160A, to 124 feet at monitor well WR-157A (Figure 21). Thickness of the unit ranges from about 23 feet at monitor well WR-157A, to about 29 feet at monitor well WR-159. Because fine-grained unit

B may be poorly permeable, downward movement of recharge water to the regional aquifer may be retarded, and perched groundwater conditions may develop at the top of the unit during surface recharge operations. Piezometer WR-159B, installed in the annular space of monitor well WR-159A, piezometer WR-160C installed in the annular space of monitor well WR-160A, and piezometer WR-166A (Figures 5, 6, and 7) were constructed to monitor the occurrence and development of perched groundwater conditions above fine-grained unit B.

HYDRAULIC AQUIFER PARAMETERS

Aquifer transmissivity and hydraulic conductivity were computed from results of pumping tests at the monitor wells (Table 3). Representative transmissivity for the saturated strata opposite the perforated interval of the monitor wells is judged to range from about 11,000 to 28,000 gpd/ft and hydraulic conductivity is judged to range from about 220 to 1,100 gpd/ft^2 (Table 3). Hydraulic conductivities given are believed to be representative for lateral groundwater movement in the part of the aquifer where monitor wells are completed. Because of effects of stratification in the basin-fill deposits, magnitude of vertical hydraulic conductivity is believed to be substantially smaller than the magnitude of horizontal hydraulic conductivity.

Results of pumping tests for monitor wells WR-157A and WR-159A indicate that hydraulic conductivity of the upper 50 feet of the aquifer is about 200 to 300 gpd/ft^2. Results of pumping tests for monitor wells WR-158A and WR-160A indicate hydraulic conductivities of about 500 to 1,000 gpd/ft^2. These results are interpreted to indicate that hydraulic conductivity for the upper 50 feet of the aquifer may be larger for the area of the recharge basins and west from the basins than for the area east from the basins (Figure 2).

MOVEMENT OF GROUNDWATER

Regional groundwater level contours for December 1988 are shown on Figure 22. Direction of groundwater movement is to the northeast, approximately parallel to the direction of surface water flow in Brawley Wash. Regional hydraulic gradient is about 0.0051 or about 27 feet per mile.

Groundwater level measurements were obtained in monitor wells WR-157A, WR-158A, WR-159A, and WR-160A beginning in August 1989. Water level hydrographs for the monitor wells are shown on Figure 23. During the period from August 11 through October 11, 1989, water level decline in monitor wells ranged from 0.07 to 0.20 feet; average was 0.15 feet. During the period from October 11, 1989 through February 7, 1990, water level rise in monitor wells ranged from 0.37 to 0.48 feet; average was 0.44 feet. Contours of groundwater level altitude at the site for November 1989 are shown on Figure 24. Direction of groundwater movement at the site is north-northeast. For the part of the aquifer penetrated by monitor wells at the site, hydraulic gradient east from the recharge basins appears to be larger than hydraulic gradient west from the recharge basins; average hydraulic gradient is about 0.0016 or about eight feet per mile. Larger hydraulic gradient east from the recharge basins indicates smaller aquifer transmissivity, verifying results of pumping tests for monitor wells WR-157A and WR-159A.

SUMMARY

Results of hydrogeologic investigations at the Brawley Wash pilot recharge site indicate the occurrence of recent alluvium to an average depth of about 30 feet. Fine-grained unit A in the Fort Lowell Formation and fine-grained unit B in the upper Tinaja beds may be laterally continuous beneath the site. These fine-grained units occur in the vadose zone above the groundwater level. Groundwater level at the site occurs at a depth of about 150 feet below land surface.

During surface recharge operations, water would be expected to move chiefly downward in the recent alluvium until encountering the Fort Lowell Formation at a depth of about 30 feet. Because vertical hydraulic conductivity of the Fort Lowell Formation is expected to be substantially smaller than vertical hydraulic conductivity for the recent alluvium, downward movement of recharge water may be impeded, perched groundwater conditions may develop, and lateral movement of water in the recent alluvium may occur. If hydraulic conductivity of the recent alluvium is sufficiently large, then the development of perched groundwater conditions in the recent alluvium would not adversely affect long-term infiltration rates. However, if hydraulic conductivity of the recent alluvium is sufficiently small, then development of perched groundwater conditions in the recent alluvium could cause the perched groundwater mound to intercept land surface at the recharge site. If the perched groundwater mound would intercept land surface, long-term infiltration rates would become smaller.

Downward movement of recharge water in the vadose zone may be further impeded by the occurrence of fine-grained units A and B at depths of about 70 feet and 120 feet, respectively. If hydraulic conductivity of the coarse-grained deposits overlying fine-grained units A and B is sufficiently large, then development of perched groundwater conditions in the Fort Lowell Formation would not adversely affect long-term infiltration rates. However, the occurrence of fine-grained units A and B may cause substantial lateral movement of water in the vadose zone, which would cause recharge to the aquifer to occur over a relatively large area.

CHEMICAL QUALITY OF GROUNDWATER

Groundwater samples for laboratory chemical analyses for routine constituents, trace constituents, herbicides, pesticides, and other parameters were obtained near the end of the 12-hour pumping test at monitor wells WR-157A, WR-158A, and WR-160A, and after about 4-1/2 hours of pumping at monitor well WR-159A, in June and July 1989. A second round of groundwater samples was obtained from the monitor wells on October 27, 1989, after pumping five borehole volumes or more of groundwater from each monitor well. Groundwater samples were also obtained from Tucson Water production well AF-64 on May 12, 1989. During sampling operations, field measurements were made for temperature, specific electrical conductance, and pH of the pumped water. Laboratory chemical analyses for routine and trace constituents in groundwater samples from monitor wells were conducted by Tucson Water and by Arizona Testing Laboratories, Phoenix, Arizona. Results of these analyses are summarized in Tables 4 and 5.

A classification of water salinity suggested by Winslow and Kister (1956), based on total dissolved solids content, is used in this report as follows:

SALINITY CLASS	TOTAL DISSOLVED SOLIDS CONTENT (milligrams per liter)
Fresh	0 - 1,000
Slightly saline	1,000 - 3,000
Moderately saline	3,000 - 10,000
Very saline	10,000 - 35,000
Brine	>35,000

Results of laboratory chemical analyses for routine constituents for groundwater samples obtained from the monitor wells and from production well AF-64 indicate that the water is the sodium-bicarbonate type. Concentrations of total dissolved solids range from 238 milligrams per liter (mg/l) at well AF-64, to 396 mg/l at well WR-157A; average is about 330 mg/l (Table 4). The

groundwater is classified as fresh. Results of analyses for routine constituents indicate that concentrations of all chemical constituents analyzed for were less than maximum contaminant levels mandated by the U. S. Environmental Protection Agency (1975).

Concentrations of trace constituents in groundwater samples obtained from the monitor wells and from production well AF-64 are summarized in Table 5. With the exception of groundwater samples obtained from monitor well WR-157A on June 27, and from monitor well WR-159A on October 27, 1989, no unusual concentrations of trace constituents were found in the groundwater samples. Iron concentrations in the samples from WR-157A and WR-159A were 0.360 and 1.52 mg/l (Table 5) and exceed the U. S. Environmental Protection Agency (1975) secondary maximum contaminant level of 0.3 mg/l.

Concentrations of total organic carbon and total organic halides in groundwater samples obtained from the monitor wells are summarized in Table 5. Results of analyses indicate that concentrations of total organic carbon ranged from 0.18 to 0.32 mg/l. With the exception of 10 μg/l detected in the sample collected on July 7 from monitor well WR-159A, total organic halides were not detected in the groundwater samples from the monitor wells. Laboratory analyses indicate that coliform bacteria were not detected in the groundwater samples from the monitor wells. However, the laboratory reported that, with the exception of the sample from well WR-157A, the presence of other bacteria in the samples interfered with accurate quantification of coliform bacteria.

Groundwater samples obtained from the monitor wells during the pumping tests in June and July 1989 were analyzed for chlorinated pesticides and polychlorinated biphenyls (EPA Method 608), organophosphate pesticides (EPA Method 614), triazine pesticides (EPA Method 619), carbamates and urea pesticides (EPA Method 632), and chlorinated herbicides (EPA Method 8150) by Analytical Technologies, Inc., Tempe, Arizona. Results of analyses indicate that no herbicides, pesticides, or polychlorinated biphenyls were detected in the groundwater samples. Groundwater samples obtained from the monitor wells

on October 27, 1989, were analyzed for chlorinated pesticides and polychlorinated biphenyls (EPA Method 608) and for chlorinated herbicides 2,4-D and 2,4,5-TP (EPA Method 8150) by Tucson Water. Results of analyses indicate that no herbicides, pesticides, or polychlorinated biphenyls were detected in the groundwater samples.

REFERENCES CITED

CH2M Hill, Errol L. Montgomery & Associates, Inc., and Dr. L. G. Wilson, 1988. Assessment of potential recharge sites for long-term storage and recovery. Prepared for Tucson Water Planning Division, Hydrology Section, March 18, 1988.

Cooper, H. H., Jr., and Jacob, C. E., 1946. A generalized graphical method for evaluating formation constants and summarizing well-field history. American Geophysical Union Transactions, Vol. 27, No. IV, August 1946, pp. 526-534.

Davidson, E. S., 1973. Geohydrology and water resources of the Tucson Basin, Arizona. U.S. Geological Survey Water Supply Paper 1939-E.

U. S. Environmental Protection Agency, 1975. Water programs: national interim primary drinking water regulations. Federal Register, Vol. 40, No. 248.

Winslow, A. G., and Kister, L. R., Jr., 1956. Saline-water resources of Texas. U. S. Geological Survey Water Supply Paper 1365.

TABLE 1. SUMMARY OF CONSTRUCTION DETAILS FOR MONITOR WELLS AND PIEZOMETERS
BRAWLEY WASH PILOT SURFACE RECHARGE SITE
TUCSON WATER, PIMA COUNTY, ARIZONA

WELL OR PIEZOMETER NUMBER	IDENTIFIER	DATE COMPLETED	BOREHOLE DIAMETER (inches)	BOREHOLE DEPTH (feet)	CASING DIAMETER (inches)	CASING DEPTH (feet)	PERFORATED INTERVAL (feet,bls)[b]	WELL ANNULUS GRAVEL PACK (interval, in feet,bls)[b]	WELL ANNULUS SAND (interval, in feet,bls)[b]	WELL ANNULUS CEMENT GROUT (interval, in feet,bls)[b]	WELL ANNULUS CEMENT AND CAL-SEAL (interval, in feet,bls)[b]	ANNULAR PIEZOMETERS[a] IDENTIFIER	ANNULAR PIEZOMETERS[a] DIAMETER (inches)	ANNULAR PIEZOMETERS[a] DEPTH (feet)	ANNULAR PIEZOMETERS[a] PERFORATED INTERVAL (feet,bls)[b]
WELL (D-16-10)8bca1	WR-160A	06-13-89	24	25	16	25		64-70	61-64	0-61	70-105	WR-160B	1-1/4	70	66-70
			12	185	6	181	146-176	107.5-112.5	105-107.5		112.5-137	WR-160C	1-1/4	112.5	108.5-112.5
								141-185	137-141						
PIEZOMETER (D-16-10)8bca2	WR-170A	09-20-89	10	35	2	34	24-34	22-35	20-22	0-20					
WELL (D-16-10)8bcd	WR-158A	05-31-89	24	26	16	26		109-215	105-109	0-105					
			12	215	6	211	131-201								
WELL (D-16-10)8bdb1	WR-157A	05-25-89	24	24	16	24		109-220	105-109	0-105					
			12	220	6	210	130-200								
WELL (D-16-10)8bdb2	WR-159A	06-06-89	24	22	16	21.5		109-123	106-109	0-106	123-137	WR-159B	1-1/4	123	115-123
			12	215	6	210	145-200	140-215	137-140						
PIEZOMETER (D-16-10)8bdb3	WR-166A	09-15-89	10	108	2	105	95-105	92-108	89-92	0-89					
PIEZOMETER (D-16-10)8bdb4	WR-167A	09-18-89	10	32	2	31	21-31	20.5-32	20-20.5	0-20					
PIEZOMETER (D-16-10)8bdb5	WR-168A	09-19-89	10	70	2	69	59-69	57.5-70	54-57.5	0-54					
PIEZOMETER (D-16-10)8bdb6	WR-169A	09-19-89	10	33	2	32	22-32	21-33	20-21	0-20					
PIEZOMETER (D-16-10)8bdb7	WR-171A	09-20-89	10	33	2	32	22-32	21-33	20-21	0-20					

[a] Piezometers installed within annular space between well casing and borehole wall.

[b] feet,bls - Feet below land surface

TABLE 2. SUMMARY OF HYDROLOGIC DATA FROM PUMPING TESTS FOR MONITOR WELLS
BRAWLEY WASH PILOT SURFACE RECHARGE SITE
TUCSON WATER, PIMA COUNTY, ARIZONA

WELL NUMBER	DATE PUMPING TEST STARTED	DURATION OF PUMPING PERIOD (hours)	PRE-PUMPING WATER LEVEL (feet below land surface)	AVERAGE PUMPING RATE (gpm)[a]	MAXIMUM WATER LEVEL DRAWDOWN DURING PUMPING PERIOD (feet)	SPECIFIC CAPACITY (gpm/ft)[b]	AVERAGE TEMPERATURE OF PUMPED WATER (°C)[c]	AVERAGE SPECIFIC ELECTRICAL CONDUCTANCE (µmho/cm)[d]	AVERAGE pH OF PUMPED WATER
(D-16-10)8bdb1[WR-157A]	06-27-89	12	150.05	33	12.84	2.6	24	600	7.8
(D-16-10)8bcd[WR-158A]	07-05-89	12	151.44	61	3.66	16.7	25	500	7.9
(D-16-10)8bdb2[WR-159A]	07-07-89	12	150.51	34	15.41	2.2	25	540	7.9
(D-16-10)8bca1[WR-160A]	06-29-89	12	150.50	40	12.25	3.3	25	550	7.8

[a] gpm - Gallons per minute

[b] gpm/ft - Gallons per minute per foot of drawdown

[c] °C - Degrees Celsius

[d] µmho/cm - Micromhos per centimeter

TABLE 3. SUMMARY OF AQUIFER PARAMETERS FROM PUMPING TESTS FOR MONITOR WELLS BRAWLEY WASH PILOT SURFACE RECHARGE SITE TUCSON WATER, PIMA COUNTY, ARIZONA

WELL NUMBER	.....TRANSMISSIVITY[a]..... DRAWDOWN PERIOD SEMI-LOG GRAPHICAL PROCEDURE	RECOVERY PERIOD SEMI-LOG GRAPHICAL PROCEDURE	REPRESENTATIVE TRANSMISSIVITY[a]	REPRESENTATIVE AVERAGE HYDRAULIC CONDUCTIVITY[b]
(D-16-10)8bdb1[WR-157A]	8,000	16,000	16,000	320
(D-16-10)8bcd[WR-158A]	55,000	26,000	26,000	520
(D-16-10)8bdb2[WR-159A]	5,000	11,000	11,000	220
(D-16-10)8bca1[WR-160A]	60,000	28,000	28,000	1,100

[a] gpd/ft - Gallons per day per foot width of aquifer at 1:1 hydraulic gradient

[b] gpd/ft^2 - Gallons per day per square foot of aquifer at 1:1 hydraulic gradient

TABLE 4. SUMMARY OF ROUTINE CONSTITUENTS IN GROUNDWATER SAMPLES
BRAWLEY WASH PILOT SURFACE RECHARGE SITE
TUCSON WATER, PIMA COUNTY, ARIZONA

WELL NUMBER		(D-16-10)8bdb1 [WR-157A]		(D-16-10)8bcd [WR-158A]		(D-16-10)8bdb2 [WR-159A]		(D-16-10)8bce1 [WR-160A]		(D-16-10)8bdd [AF-64]
DATE SAMPLED		06-27-89	10-27-89	07-05-89	10-27-89	07-07-89	10-27-89	06-29-89	10-27-89	05-12-89
CONSTITUENT	Detection Limit									
Cations (mg/l)[a]										
Calcium	0.5	50	49	27	27	41	39	42	38	30
Magnesium	0.05	6.9	7.1	3.7	3.9	5.6	5.9	5.6	5.8	4.0
Sodium	0.1	77	76	68	67	71	71	73	73	52
Potassium	0.1	1.8	1.8	1.4	1.4	1.7	1.7	1.7	1.7	1.5
Anions (mg/l)										
Bicarbonate (as HCO_3)	3	234	259	217	218	237	244	216	228	170
Chloride	1.0	37.8	28.2	15	14.4	14.8	22.2	32.5	26.7	18.6
Sulfate	5.0	41	37	11	12	11	24	26	29	20
Nitrate (as NO_3)	1.0	43.4[e]	35.9	16.8	17.3	16.8	26.1	41.2	31.9	15.9[e]
Fluoride	0.10	0.38	0.34	0.74	0.72	0.74	0.36	0.44	0.43	0.53
Bromide	0.10	0.44	0.31	0.21	0.18	0.21	0.26	0.43	0.32	0.19
Orthophosphate (as P)	0.5	ND[e]	---	ND	---	ND	---	ND	---	ND[e]
Kjeldahl Nitrogen[b] (mg/l)	0.2	---	ND	---	ND	---	ND	---	ND	---
Kjeldahl Ammonia[b] (mg/l)	0.1	---	ND	---	ND	---	ND	---	ND	---
Total Alkalinity (mg/l as $CaCO_3$)	20	192	212	178	179	194	200	177	187	139
Total Hardness (mg/l as $CaCO_3$)	3.0	151	158	79	81	121	124	125	120	91
Total Dissolved Solids (mg/l)	20	375	396	258	296	325	374	328	376	238
Total Suspended Solids (mg/l)	0.4	---	0.7	---	ND	---	0.5	---	ND	---
Turbidity (NTU)[c]	0.1	---	0.7	---	0.5	---	1.6	---	1.4	---
pH (field)	---	7.7	7.6	7.9	7.7	7.9	7.6	7.8	7.7	7.9
Electrical Conductance[d] (field)	---	610	520	560	415	525	495	550	520	414
Temperature (degrees Celsius)	---	23.9	24	25.3	24.9	24.5	24	25.3	24.7	26

[a] mg/l - milligrams per liter

[b] Analyses by Arizona Testing Laboratories, Phoenix, Arizona

[c] NTU - Nephelometric Turbidity Units

[d] Specific electrical conductance in micromhos per centimeter

[e] Holding time exceeded

ND - Not Detected or detected below practical quantitation limit
--- Not analyzed

(Laboratory analyses by Tucson Water, unless noted otherwise)

TABLE 5. SUMMARY OF TRACE CONSTITUENTS IN GROUNDWATER SAMPLES
BRAWLEY WASH PILOT SURFACE RECHARGE SITE
TUCSON WATER, PIMA COUNTY, ARIZONA

WELL NUMBER		(D-16-10)8bdb1 [WR-157A]		(D-16-10)8bcd [WR-158A]		(D-16-10)8bdb2 [WR-159A]		(D-16-10)8bca1 [WR-160A]		(D-16-10)8bdd [AF-64]
DATE SAMPLED		06-27-89	10-27-89	07-05-89	10-27-89	07-07-89	10-27-89	06-29-89	10-27-89	05-12-89
CONSTITUENT (milligrams per liter)	Detection Limit									
Iron	0.1	0.360	ND	ND	ND	ND	1.52	ND	0.253	ND
Manganese	0.05	ND	ND	ND	ND	ND	ND	ND	ND	ND
Copper	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND
Zinc	0.02	ND	0.153	ND	0.120	0.029	0.199	ND	0.129	ND
Arsenic	0.005	ND	ND	ND	ND	ND	ND	ND	ND	ND
Barium	0.0005	0.0934	0.0997	0.0551	0.0509	0.0733	0.0626	0.0802	0.0665	0.0517
Boron[a]	0.05	---	ND	---	0.056	---	ND	---	ND	---
Cadmium	0.0002	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chromium	0.001	0.0018	0.0017	0.0013	0.0014	0.0016	0.0015	0.0015	0.0013	0.0012
Lead	0.002	0.0050	ND	ND	ND	0.0035	ND	ND	0.0030	ND[f]
Mercury (total)	0.0005	ND	0.0005	ND	0.0006	ND	ND	ND	0.0006	ND
Selenium	0.005	ND	ND	ND	ND	ND	ND	ND	ND	ND
Strontium[a]	0.1	---	0.39	---	0.21	---	0.35	---	0.35	---
Silver	0.0005	ND	---	ND	---	ND	---	ND	---	ND
Silica[a]	1	---	22	---	22	---	22	---	22	---
TOC[b]	0.1	---	0.31	0.18	0.19	0.29	0.29	0.27	0.32	---
TOX[c]	6	ND	ND	ND	ND	10	ND	ND	ND	---
Coliform[d]	---	---	0	---	0[e]	---	0[e]	---	0[e]	---

[a] Analyses by Arizona Testing Laboratories, Phoenix, Arizona
[b] TOC - Total Organic Carbon, as C, in milligrams per liter
[c] TOX - Total Organic Halides, as Cl, in micrograms per liter
[d] Coliform - total coliform bacteria, in CFU (Colony-Forming Units) per 100 milliliters
[e] Failed quality control due to interference from other bacteria
[f] Detection limit for this analysis was 0.005 milligrams per liter

ND - Not Detected or detected below practical quantitation limit
--- Not analyzed

(Laboratory analyses by Tucson Water, unless noted otherwise)

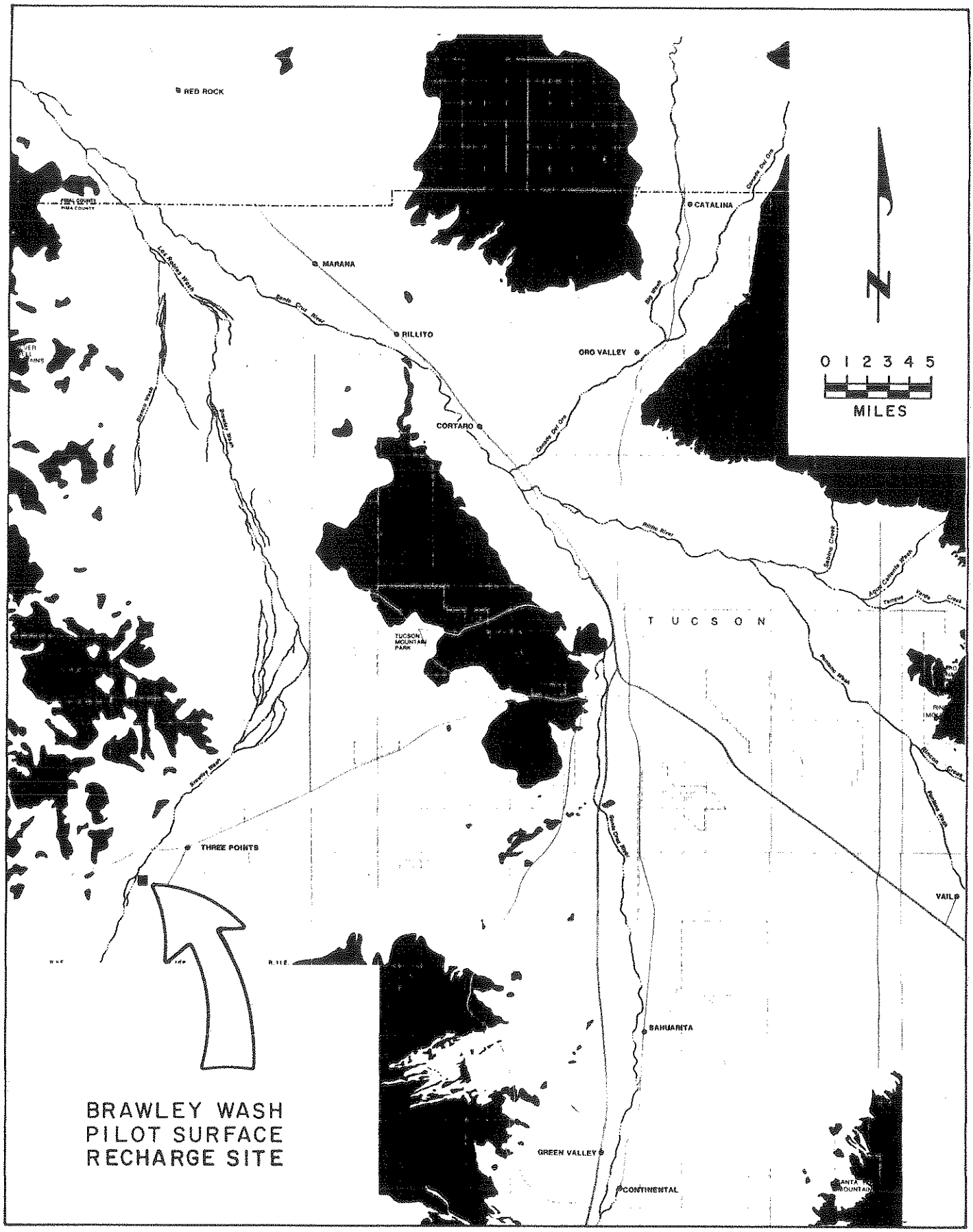

FIGURE 1. LOCATION OF BRAWLEY WASH PILOT SURFACE RECHARGE SITE

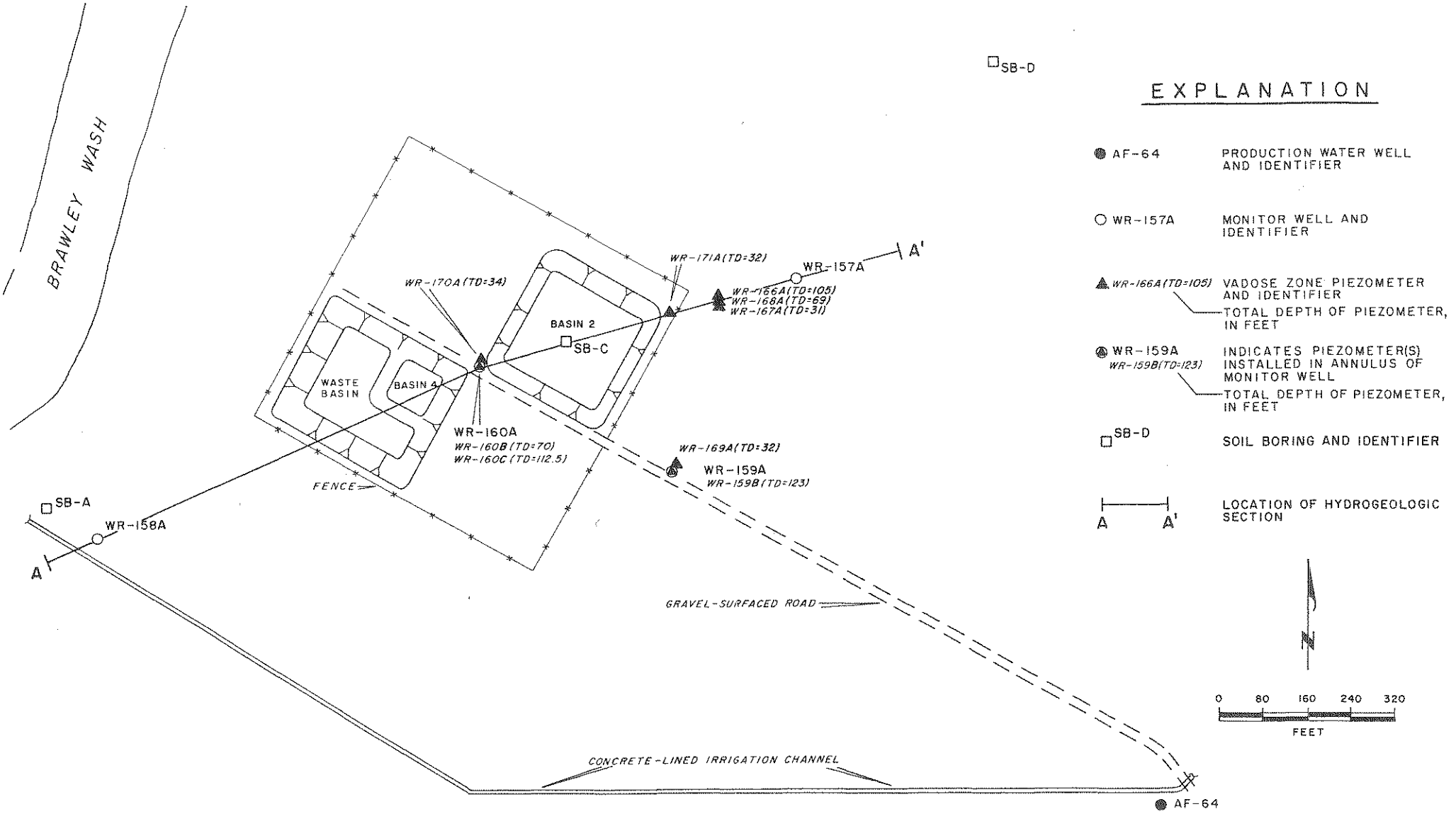

FIGURE 2. LOCATIONS OF SOIL BORINGS, MONITOR WELLS, AND PIEZOMETERS, BRAWLEY WASH PILOT SURFACE RECHARGE SITE

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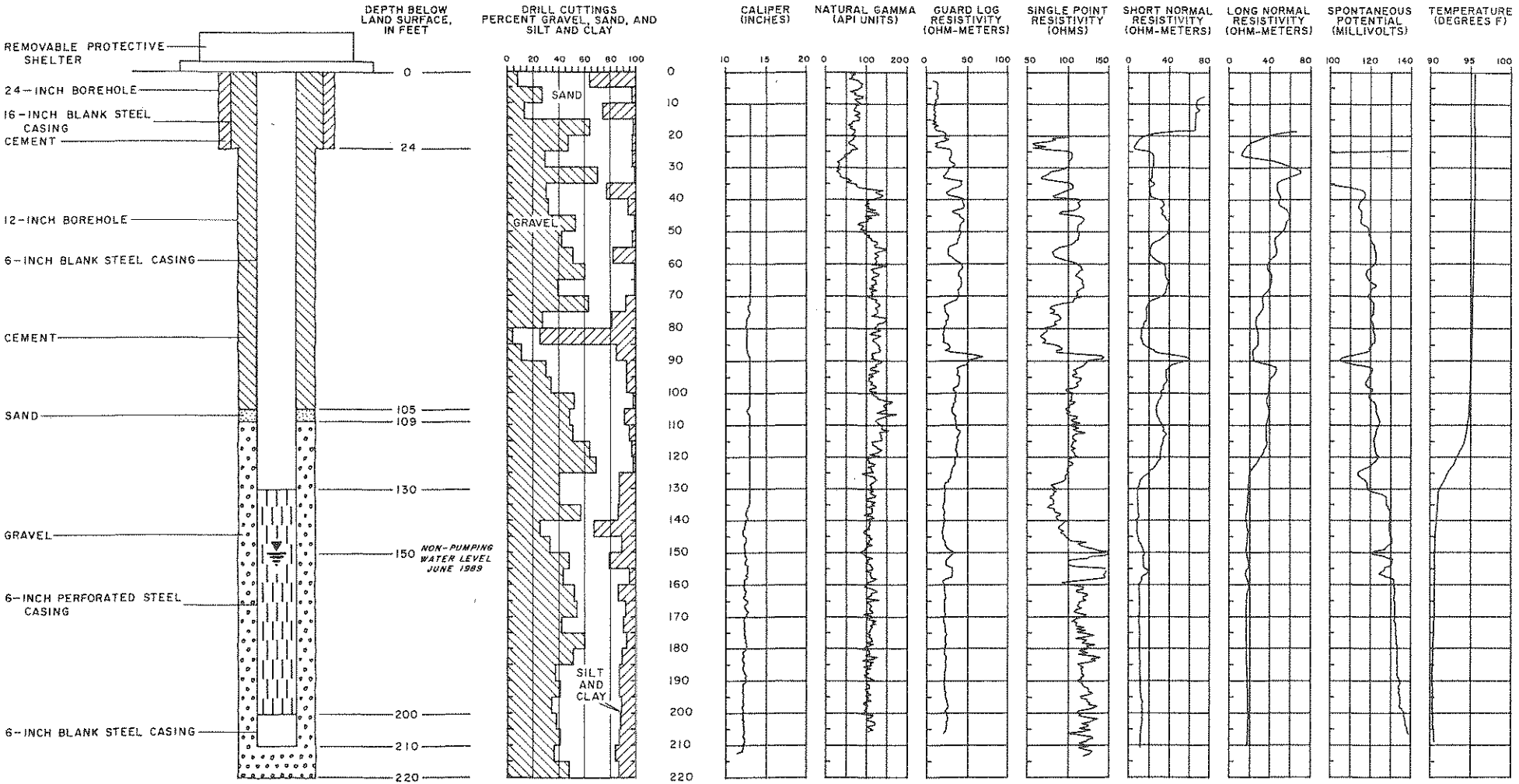

FIGURE 3. SCHEMATIC DIAGRAM OF WELL CONSTRUCTION, DRILL CUTTINGS LOG, AND BOREHOLE GEOPHYSICAL LOGS FOR MONITOR WELL (D-16-10)8bdbl [WR-157A]

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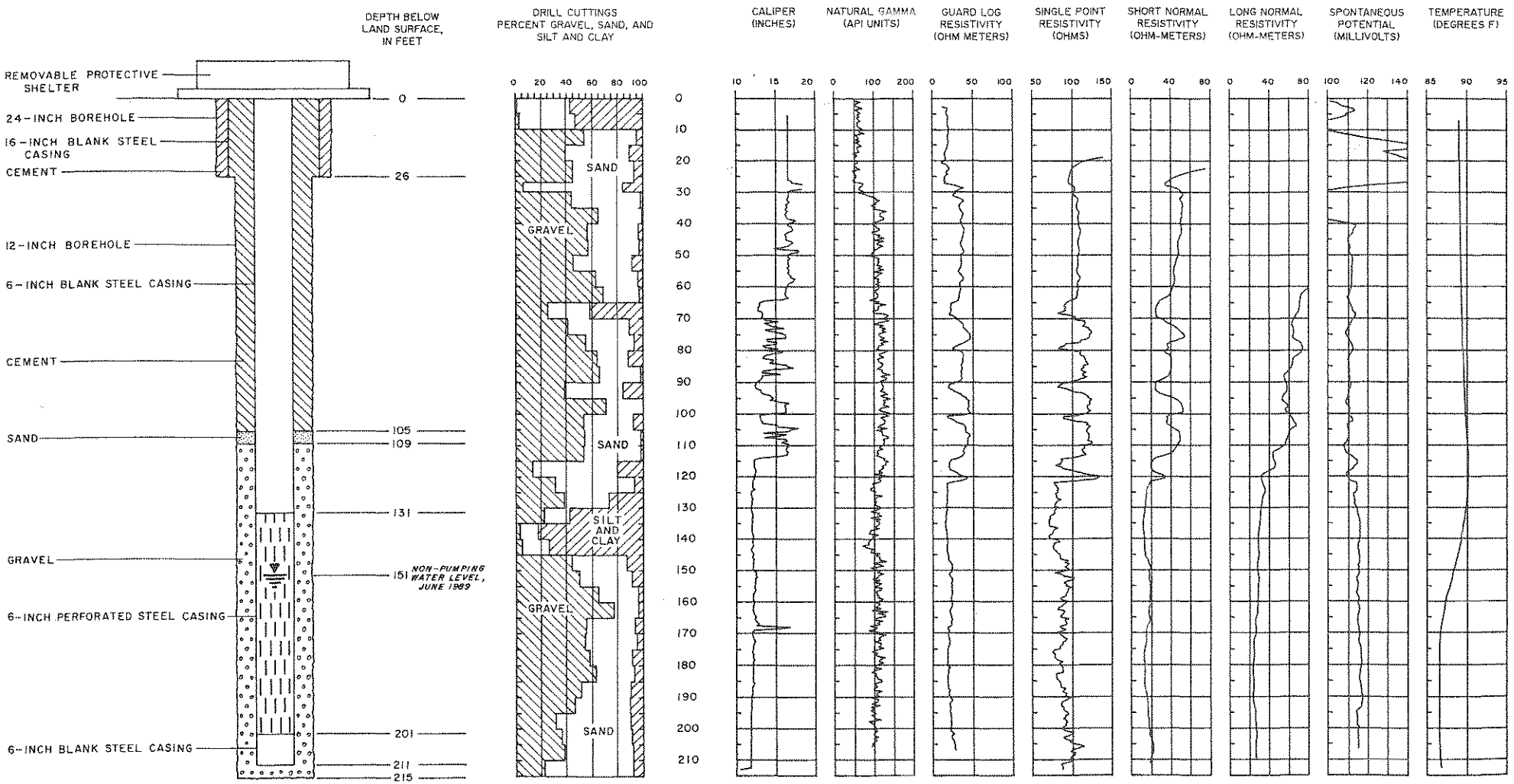

FIGURE 4. SCHEMATIC DIAGRAM OF WELL CONSTRUCTION, DRILL CUTTINGS LOG, AND BOREHOLE GEOPHYSICAL LOGS FOR MONITOR WELL (D-16-10)8bcd[WR-158A]

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TUCSON, ARIZONA

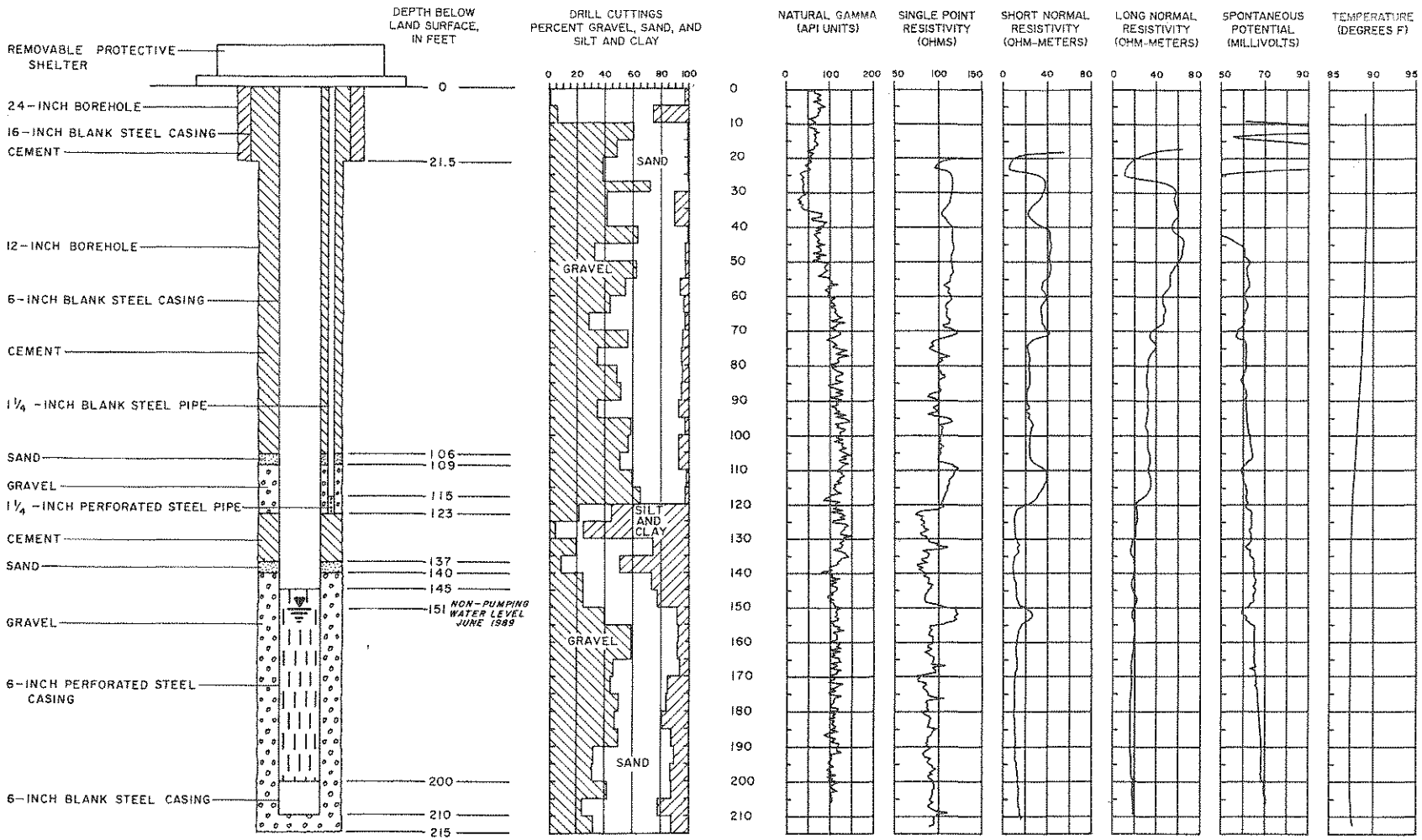


FIGURE 5. SCHEMATIC DIAGRAM OF WELL CONSTRUCTION, DRILL CUTTINGS LOG, AND BOREHOLE GEOPHYSICAL LOGS FOR MONITOR WELL (D-16-10)8bdb2 [WR-159A]

ERROL L. MONTGOMERY & ASSOCIATES, INC.
TUCSON, ARIZONA

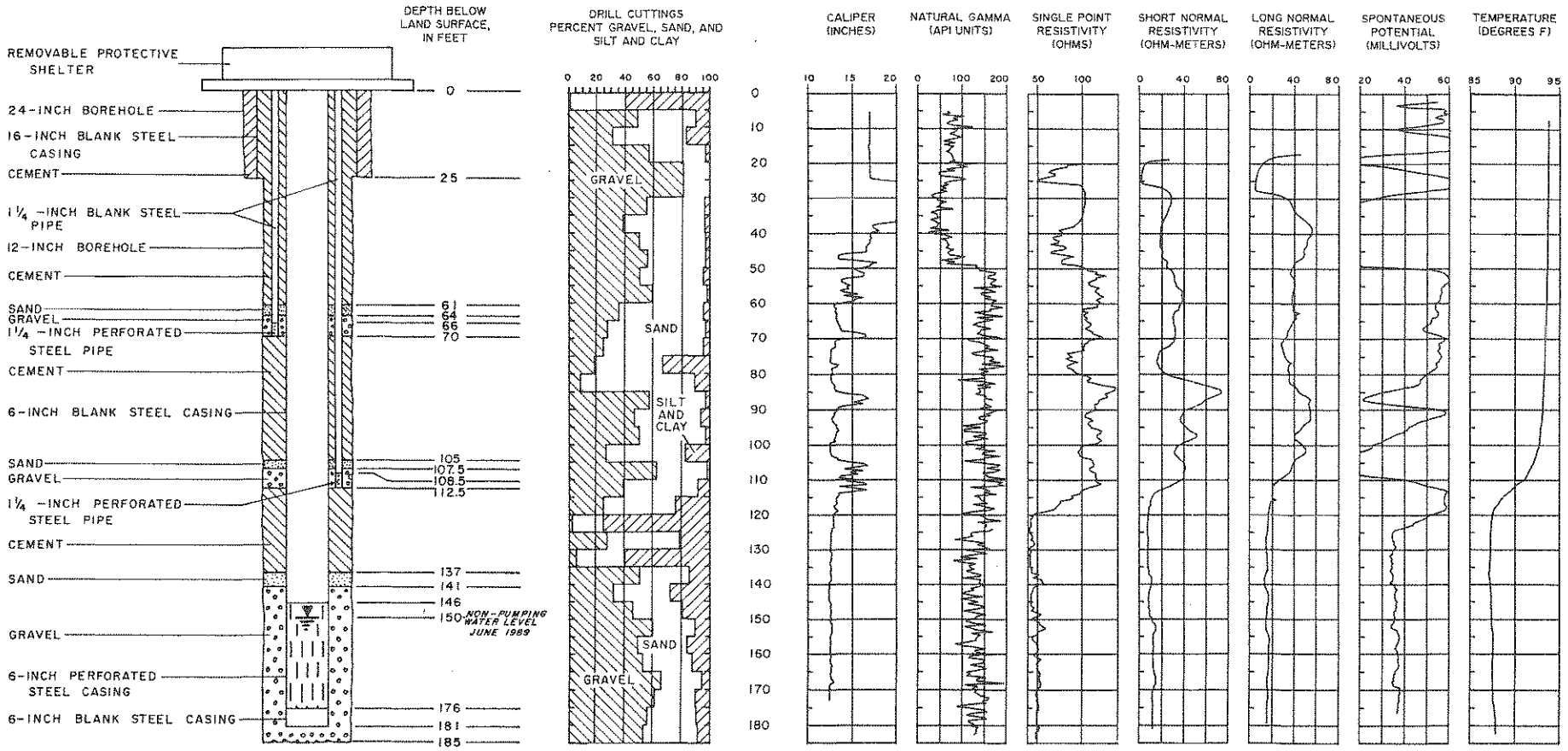


FIGURE 6. SCHEMATIC DIAGRAM OF WELL CONSTRUCTION, DRILL CUTTINGS LOG, AND BOREHOLE GEOPHYSICAL LOGS FOR MONITOR WELL (D-16-10)8bcal[WR-160A]

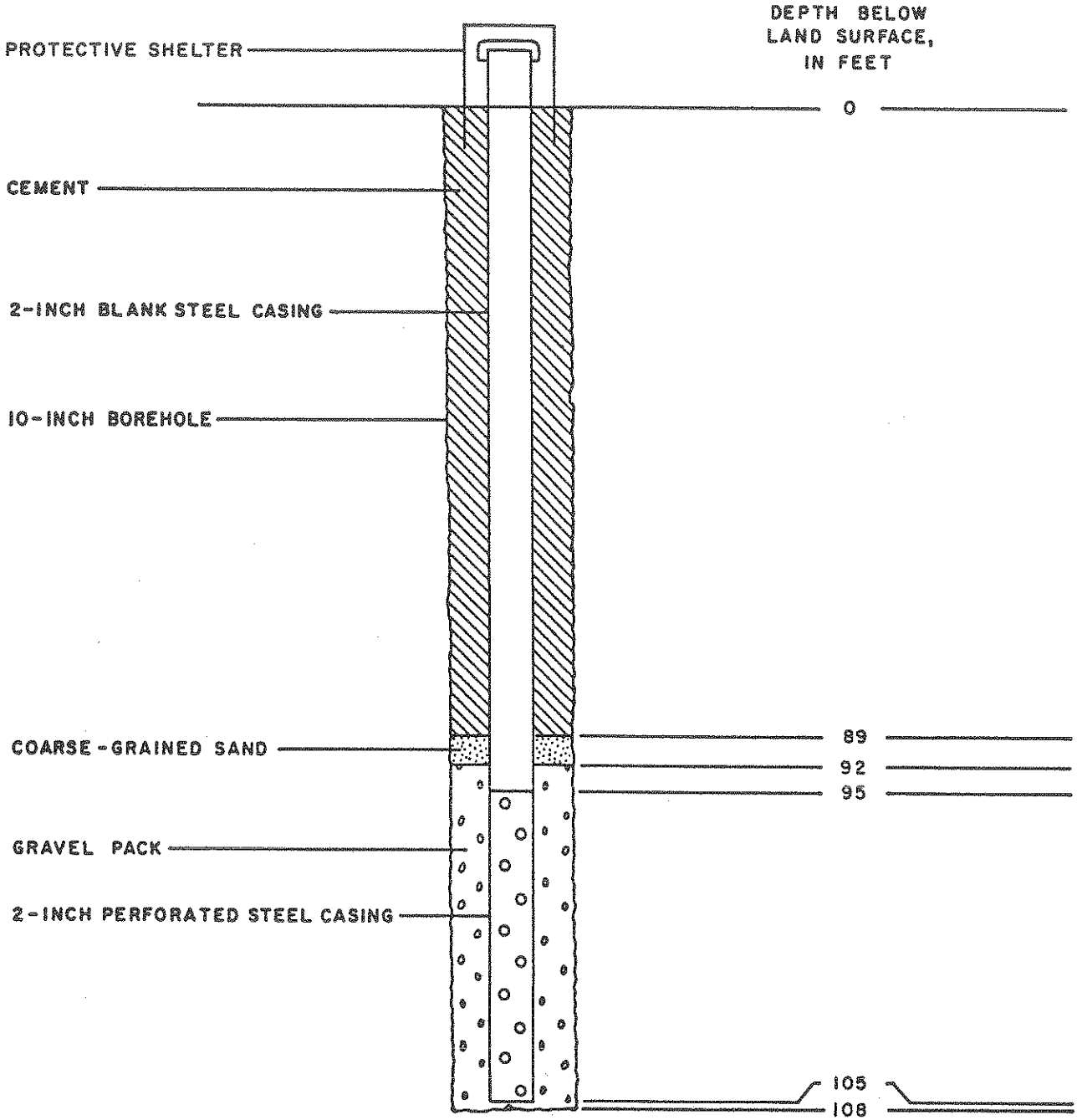


FIGURE 7. SCHEMATIC DIAGRAM OF CONSTRUCTION FOR PIEZOMETER (D-16-10)8bdb3[WR-166A]

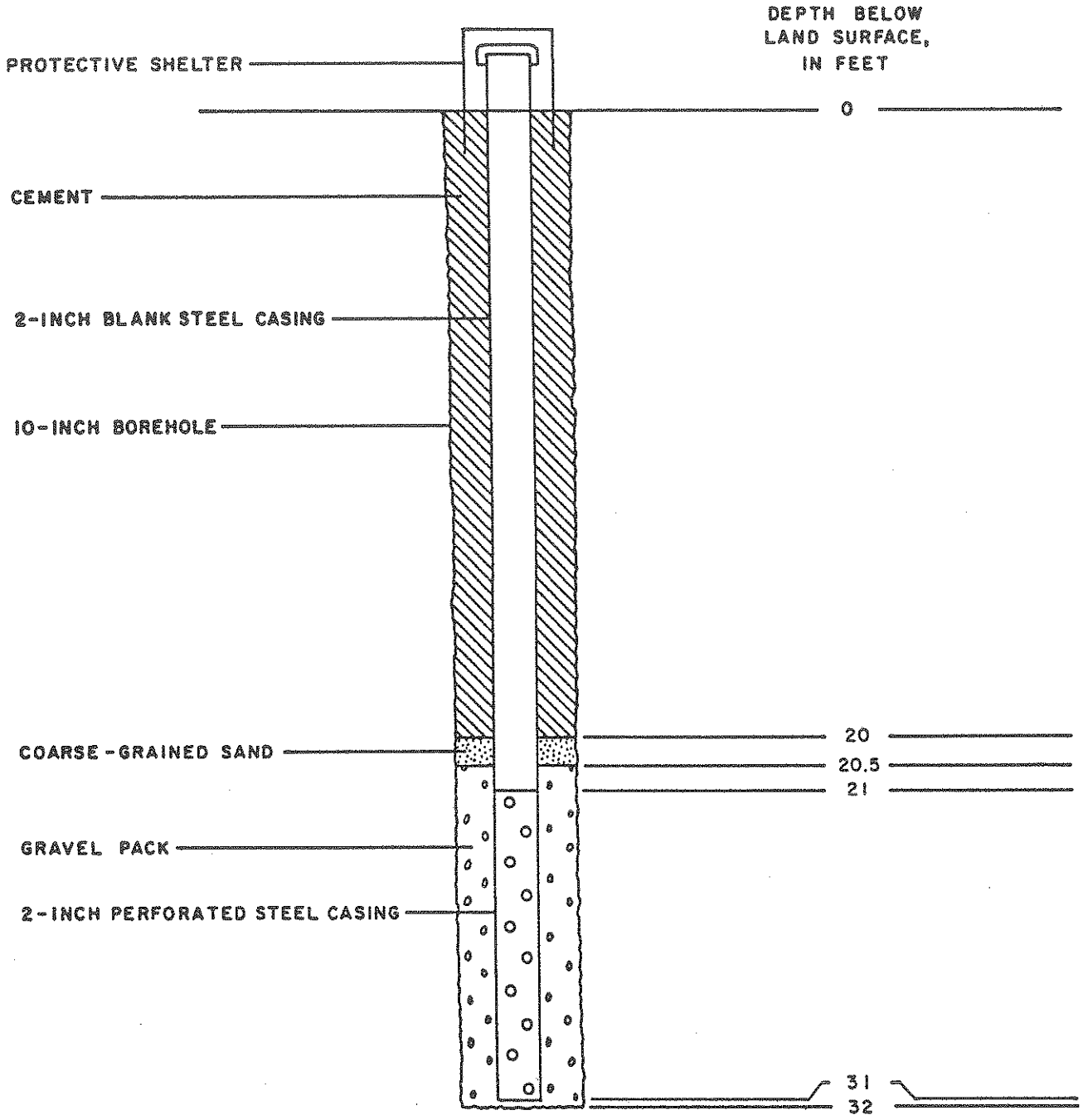


FIGURE 8. SCHEMATIC DIAGRAM OF CONSTRUCTION FOR PIEZOMETER (D-16-10)8bdb4[WR-167A]

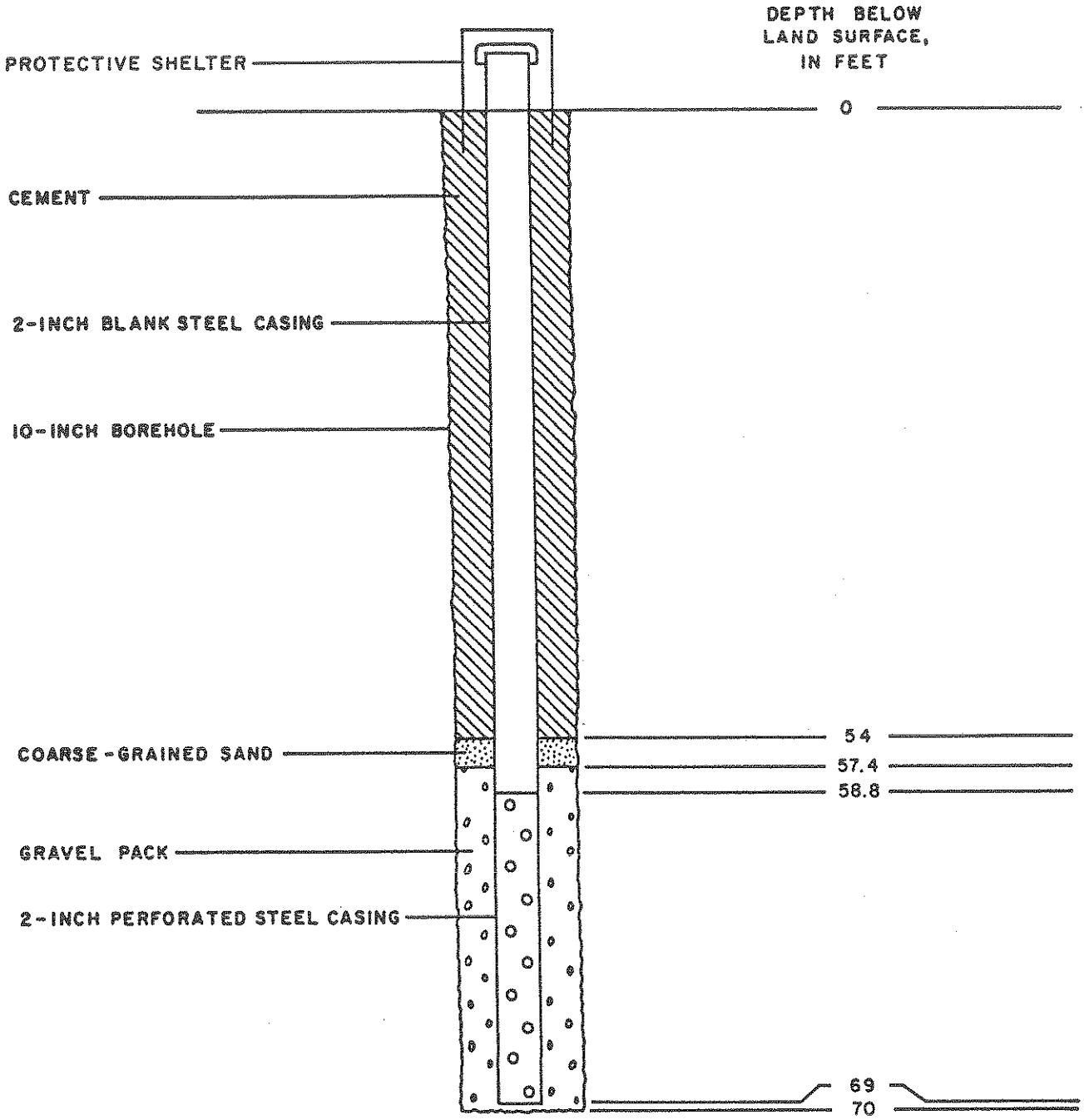


FIGURE 9. SCHEMATIC DIAGRAM OF CONSTRUCTION FOR PIEZOMETER (D-16-10)8bdb5[WR-168A]

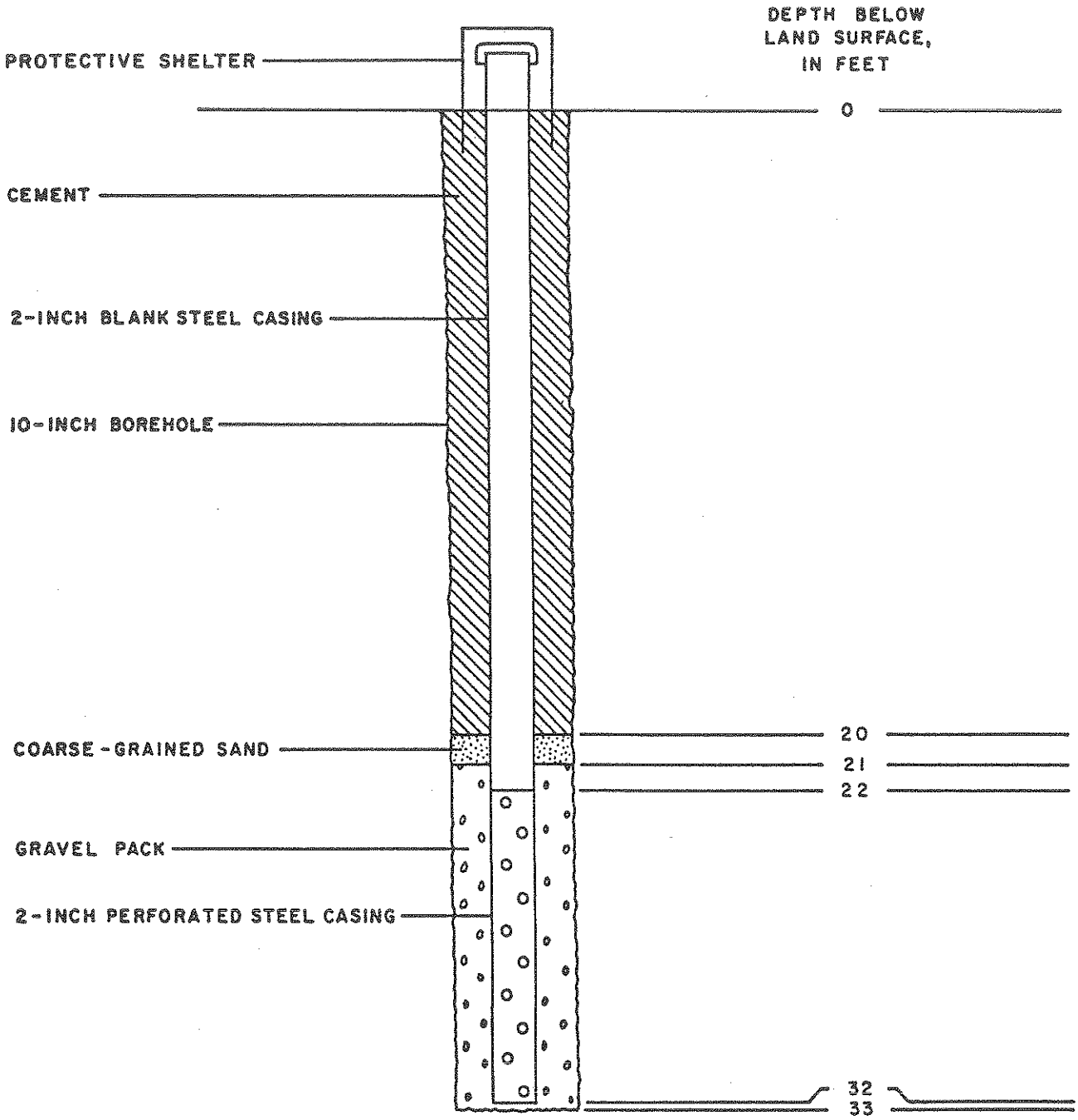


FIGURE 10. SCHEMATIC DIAGRAM OF CONSTRUCTION FOR PIEZOMETER (D-16-10)8bdb6[WR-169A]

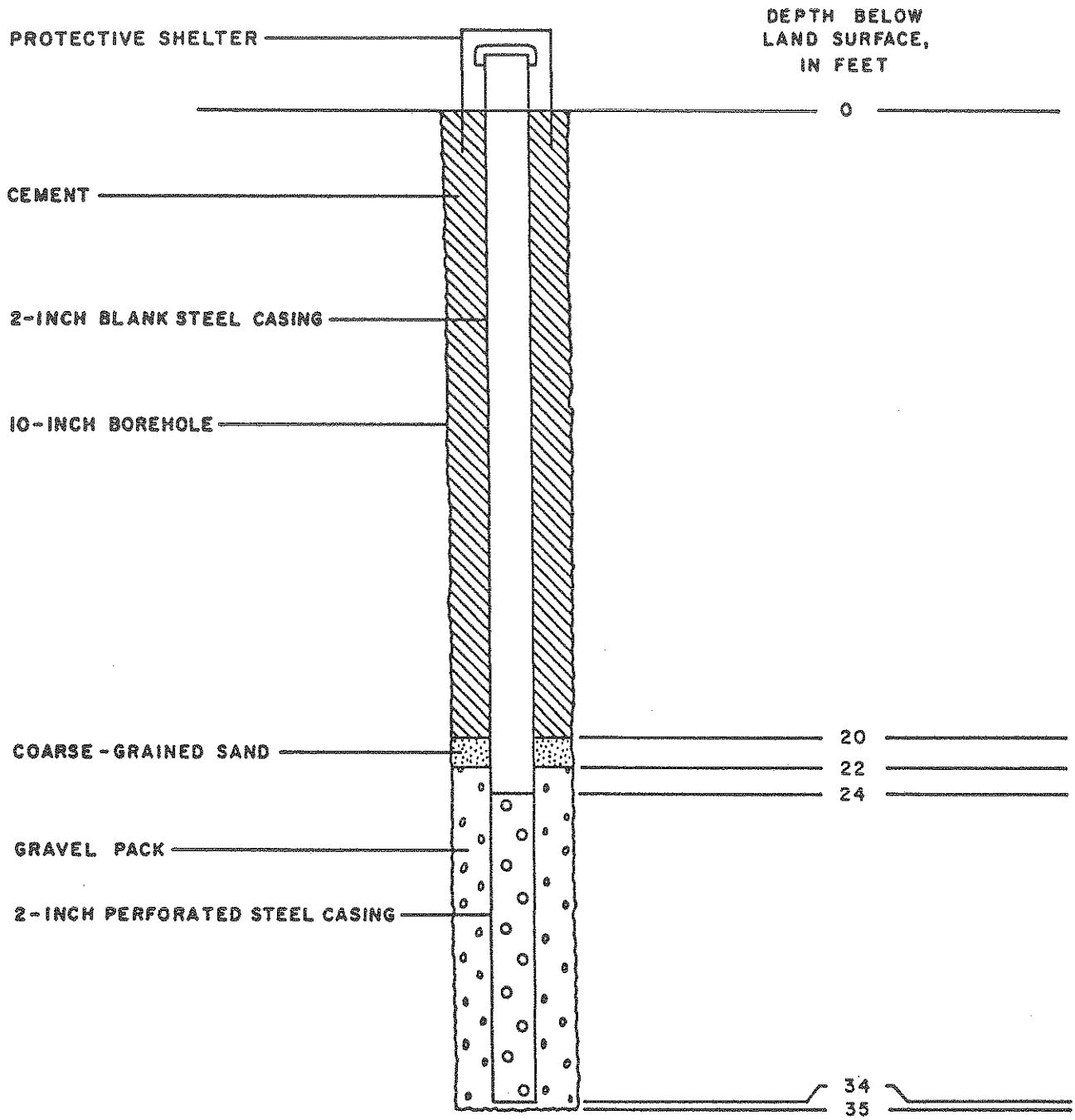


FIGURE 11. SCHEMATIC DIAGRAM OF CONSTRUCTION FOR PIEZOMETER (D-16-10)8bca2[WR-170A]

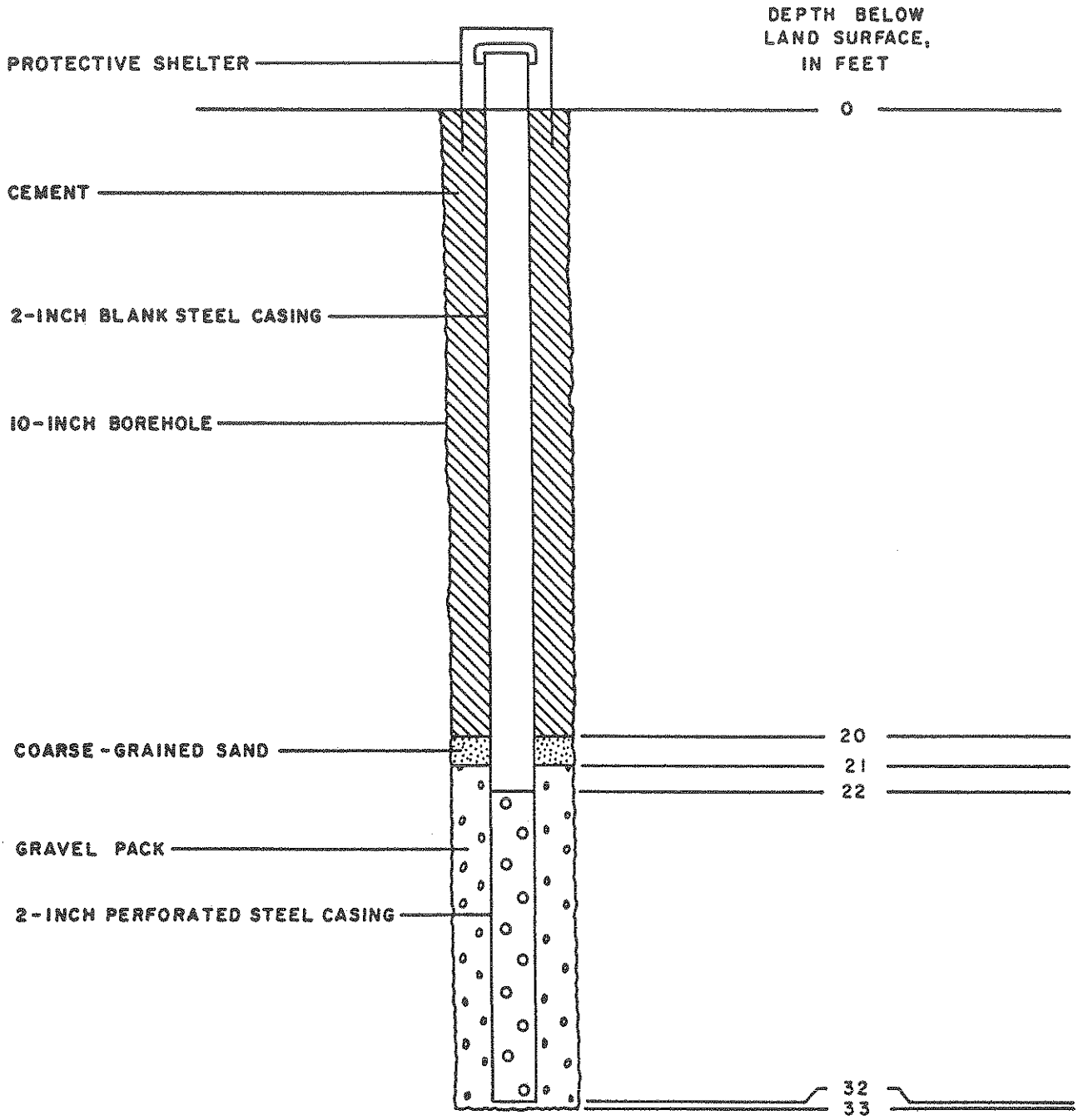


FIGURE 12. SCHEMATIC DIAGRAM OF CONSTRUCTION FOR PIEZOMETER (D-16-10)8bdb7[WR-171A]

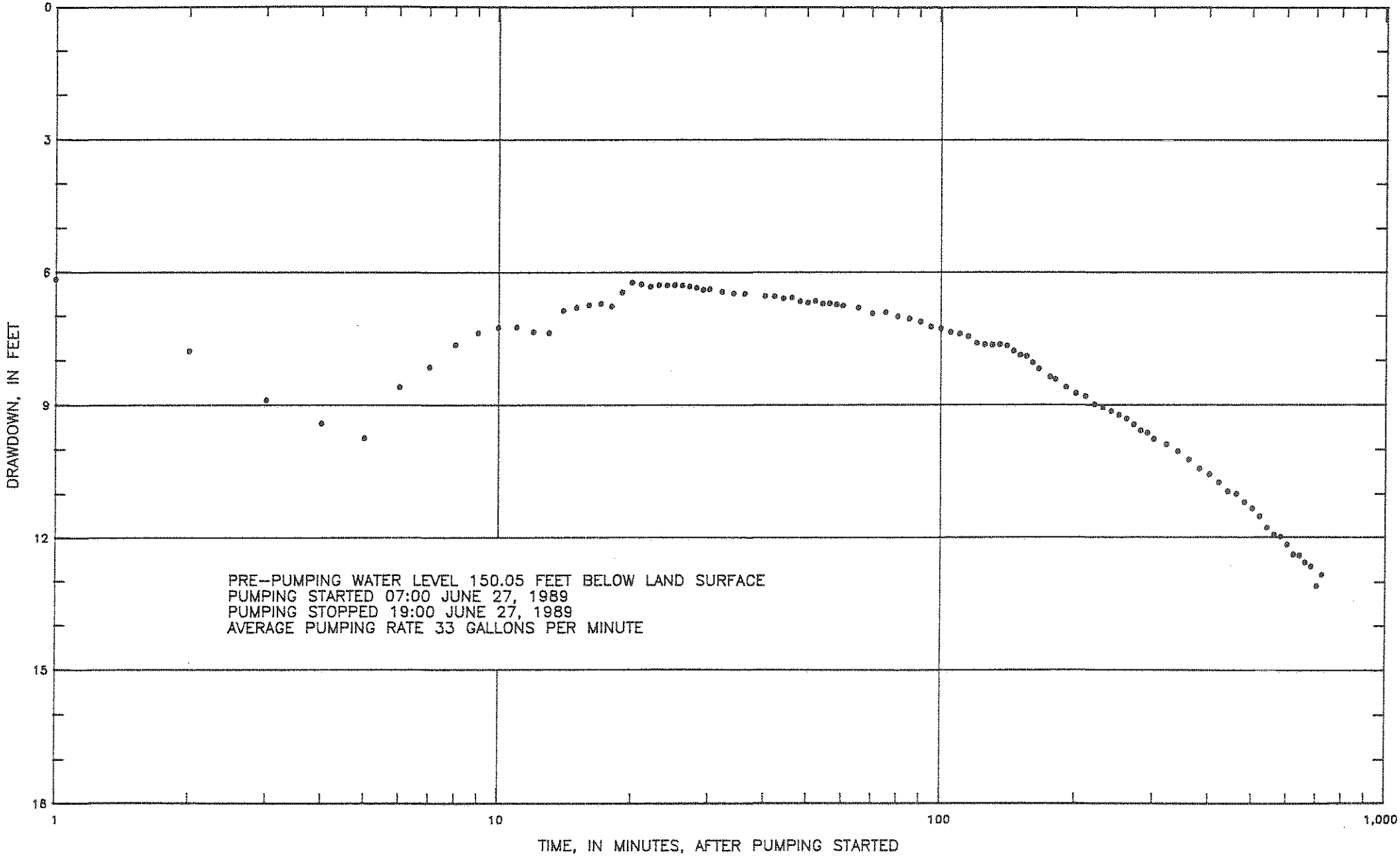


FIGURE 13. DRAWDOWN GRAPH FOR PUMPED WELL (D-16-10)8bdb1[WR-157A]

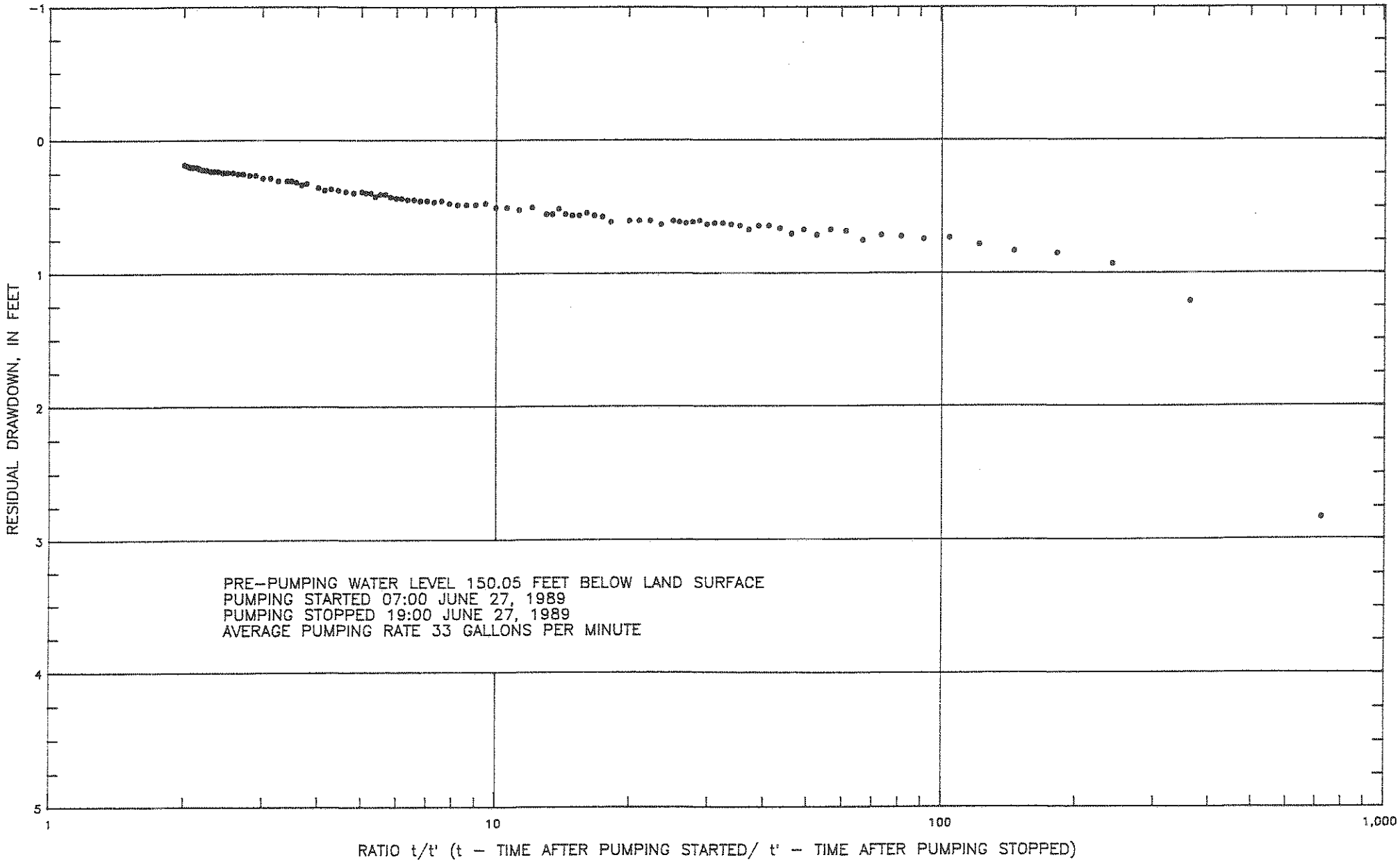


FIGURE 14. RECOVERY GRAPH FOR PUMPED WELL (D-16-10)8bdb1[WR-157A]

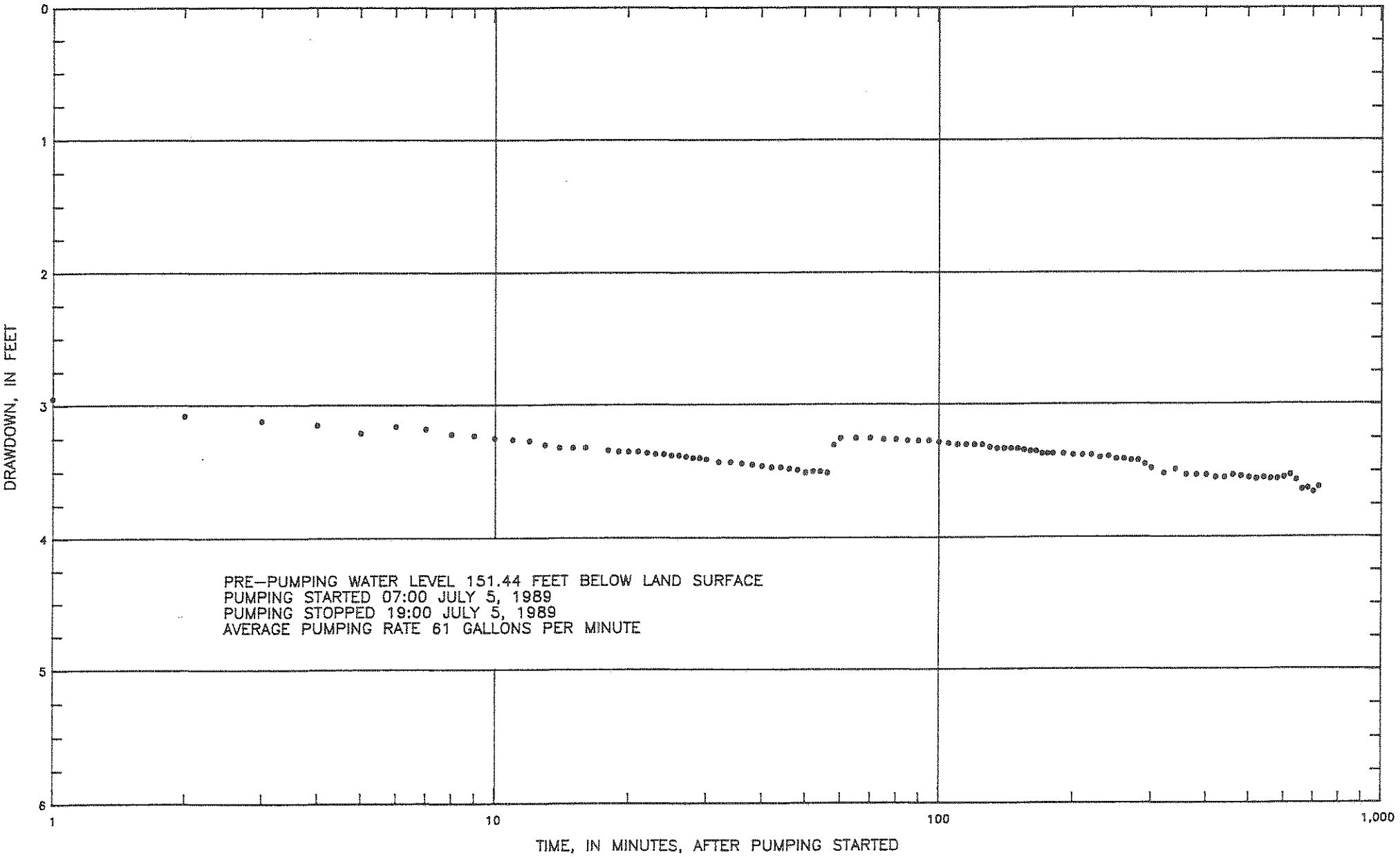


FIGURE 15. DRAWDOWN GRAPH FOR PUMPED WELL (D-16-10)8bcd[WR-158A]

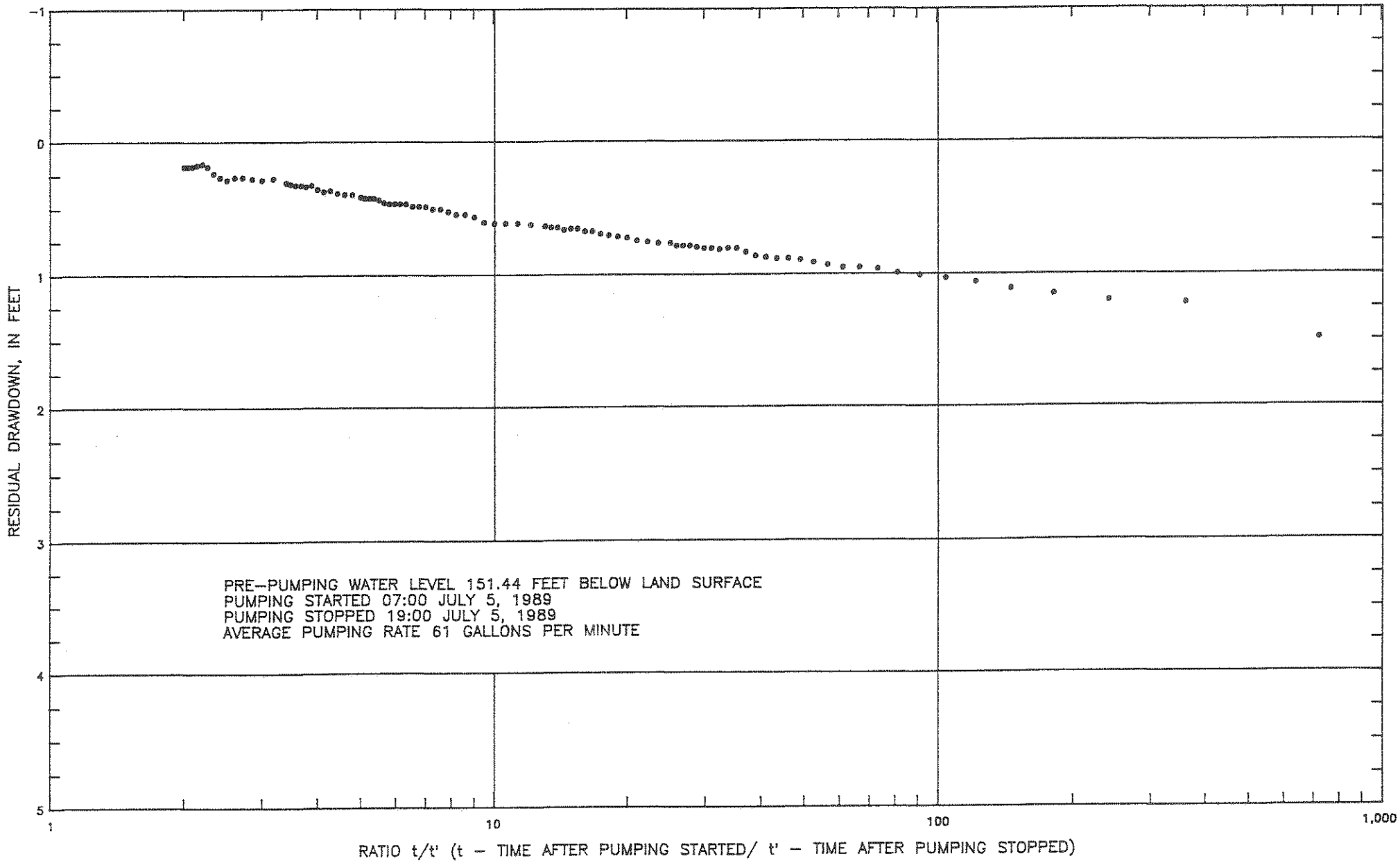


FIGURE 16. RECOVERY GRAPH FOR PUMPED WELL (D-16-10)8bcd[WR-158A]

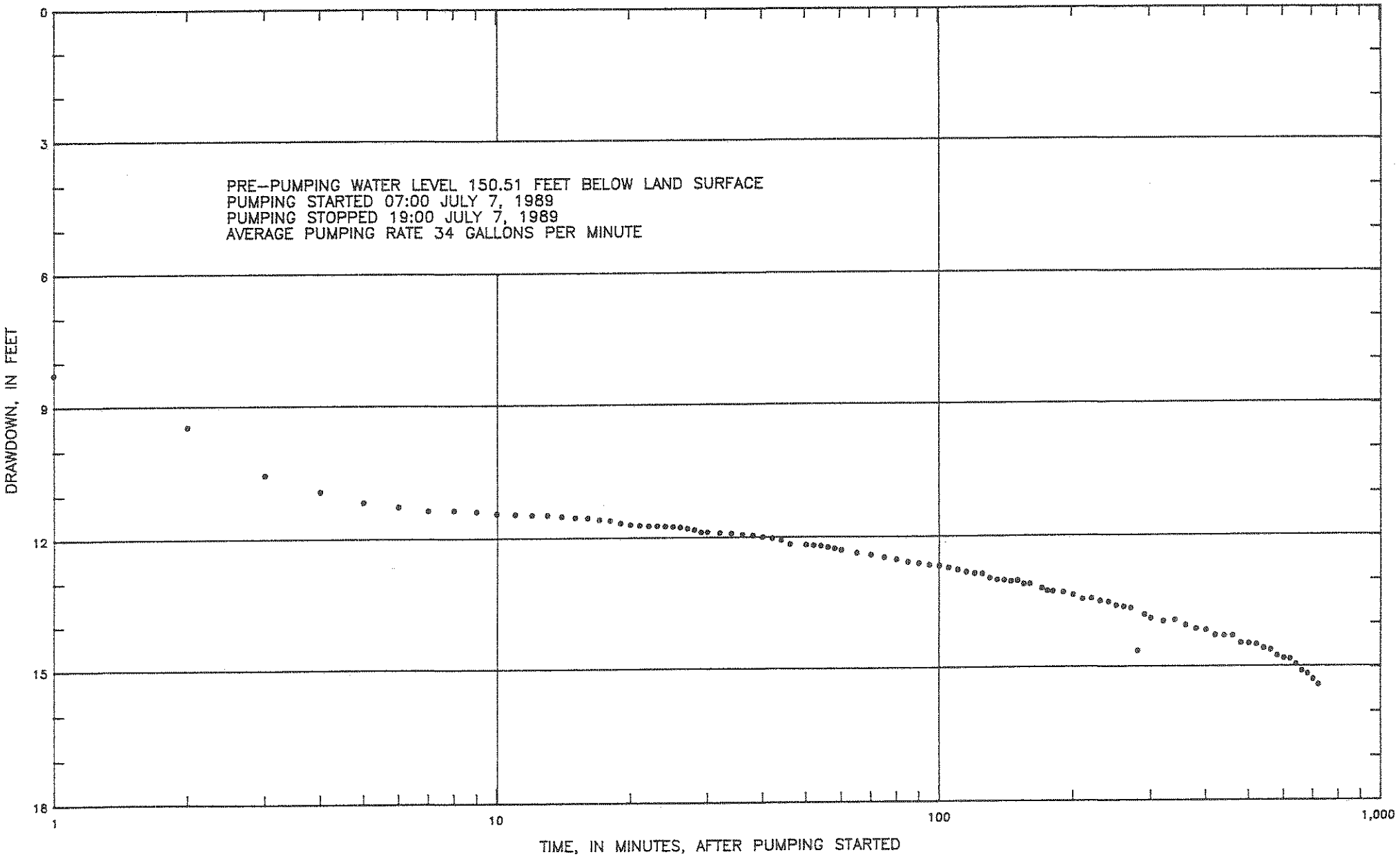


FIGURE 17. DRAWDOWN GRAPH FOR PUMPED WELL (D-16-10)8bdb2[WR-159A]

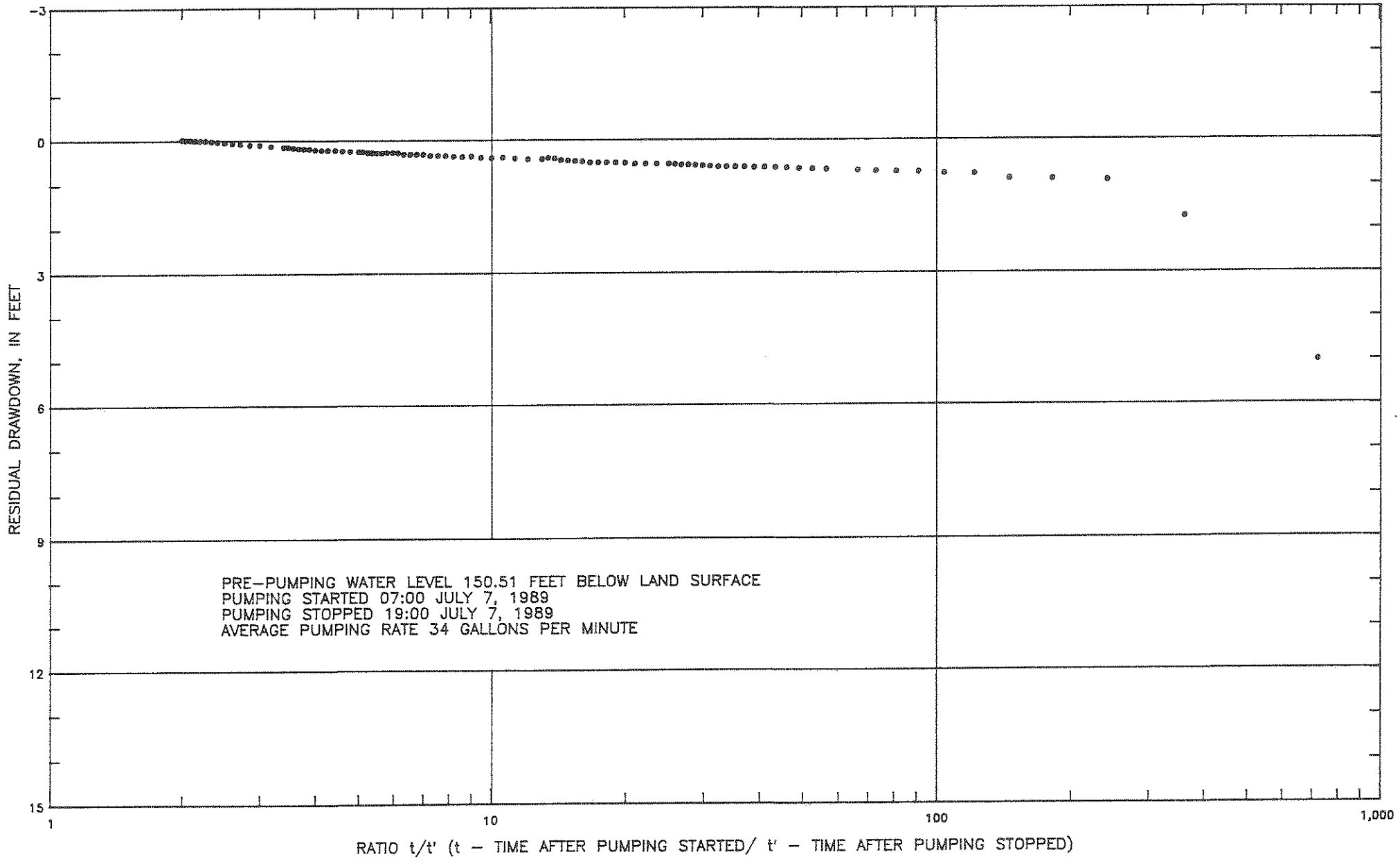


FIGURE 18. RECOVERY GRAPH FOR PUMPED WELL (D-16-10)8bdb2[WR-159A]

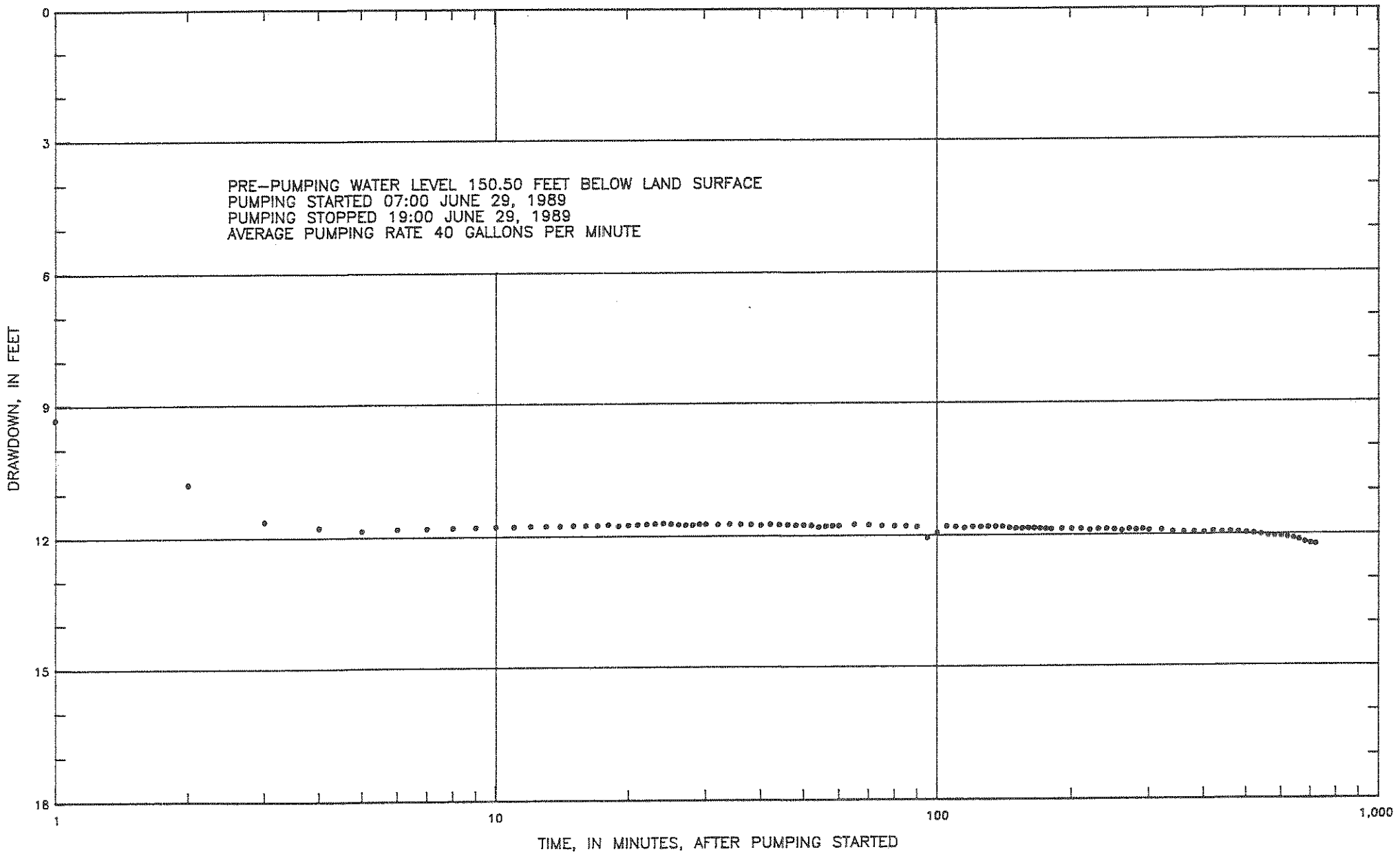


FIGURE 19. DRAWDOWN GRAPH FOR PUMPED WELL (D-16-10)8bca1[WR-160A]

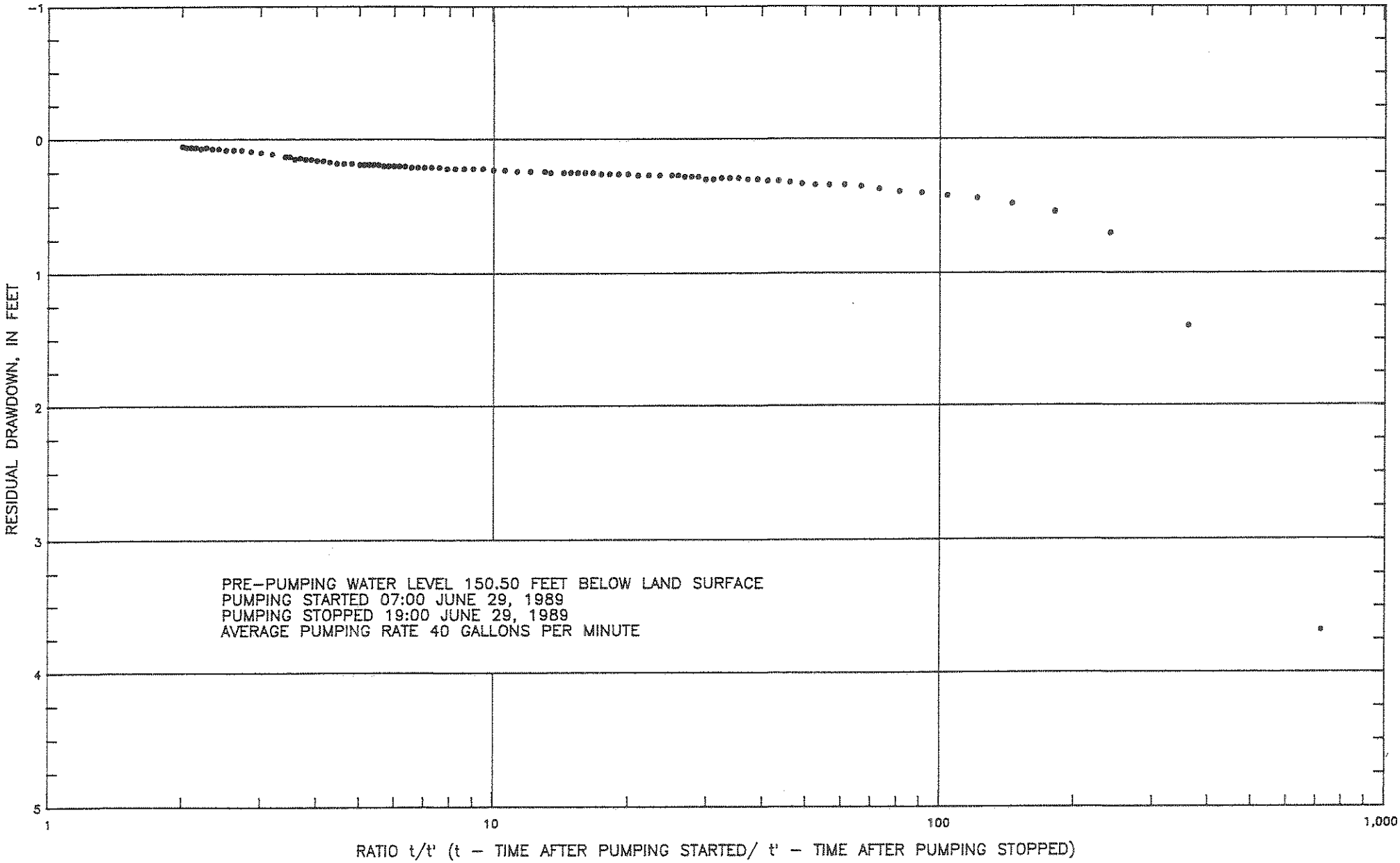
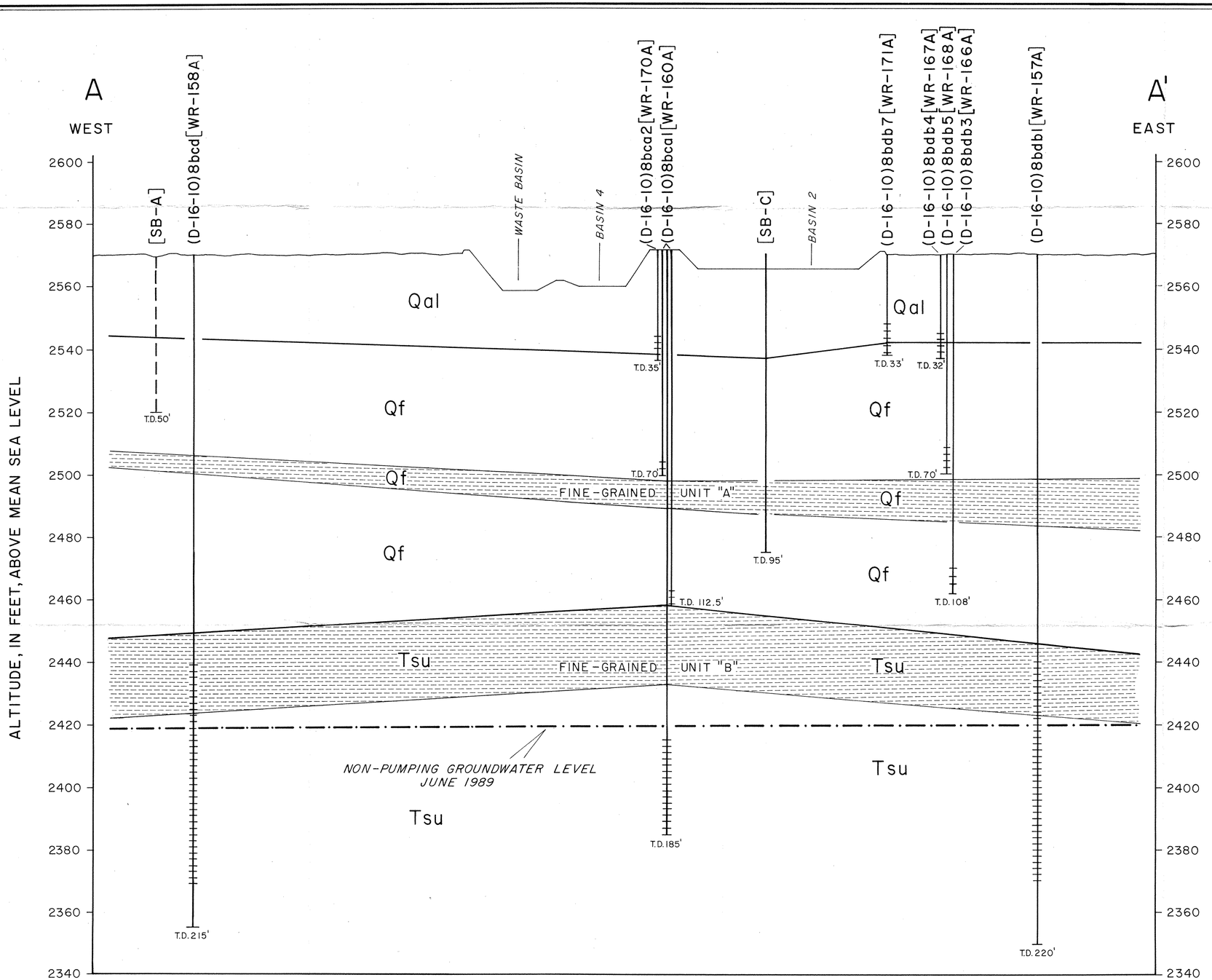


FIGURE 20. RECOVERY GRAPH FOR PUMPED WELL (D-16-10)8bca1[WR-160A]



EXPLANATION

- Qal — RECENT ALLUVIUM
- Qf — FORT LOWELL FORMATION
- Tsu — UPPER TINAJA BEDS

(D-16-10)8bca1[WR-160A]
- WELL OR PIEZOMETER IDENTIFIER
- WELL OR PIEZOMETER NUMBER
- PIEZOMETER IN ANNULAR SPACE FOR WELL WR-160
- PERFORATED INTERVAL FOR PIEZOMETER IN ANNULAR SPACE
- PERFORATED INTERVAL FOR WELL OR PIEZOMETER
- T.D.185' — TOTAL DEPTH DRILLED, IN FEET

[SB-C]
- SOIL BORING IDENTIFIER
- SOIL BORING (UNCASED) (Dashed where projected to plane of section)
- T.D.95' — TOTAL DEPTH DRILLED, IN FEET

HORIZONTAL SCALE
0 100 200 300
FEET

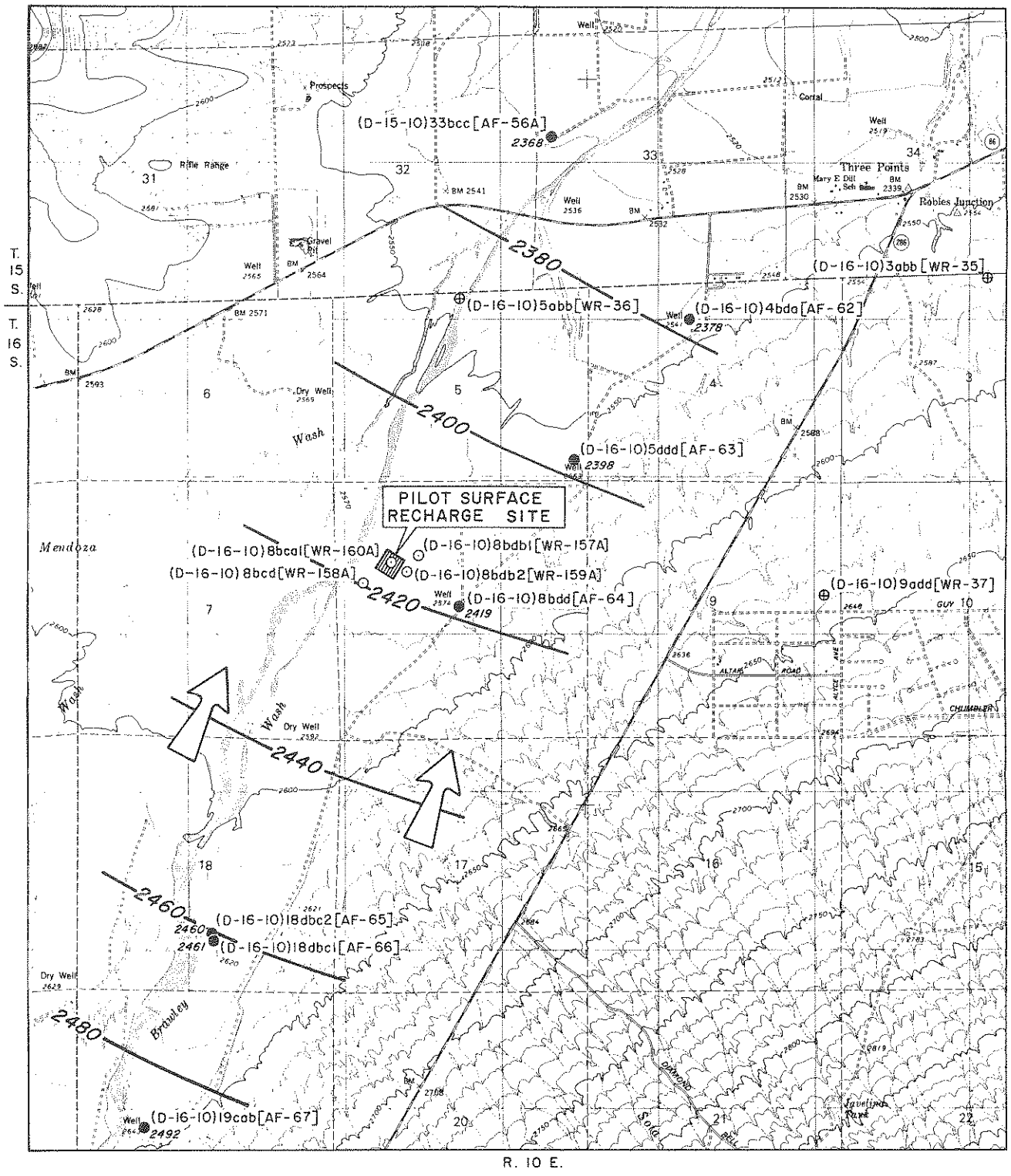
VERTICAL EXAGGERATION 5:1

RECHARGE FEASIBILITY ASSESSMENT PROJECT
TUCSON WATER PROJECT NO. 0945
CITY OF TUCSON CONTRACT NO. 0405-88

BRAWLEY WASH
HYDROGEOLOGIC SECTION
A – A'

ERROL L. MONTGOMERY & ASSOCIATES, INC.
CONSULTANTS IN HYDROGEOLOGY
TUCSON, ARIZONA
1990
CH2MHILL Engineers Planners Economists Scientists
L.G. WILSON
RECHARGE SPECIALIST

FIGURE 21



EXPLANATION

○ (D-16-10)8bdb2[WR-159A]	GROUNDWATER MONITOR WELL AND IDENTIFIER
● (D-16-10)8bdd[AF-64] 2419	PRODUCTION WATER WELL AND IDENTIFIER ALTITUDE OF GROUNDWATER LEVEL, in feet above mean sea level
⊕ (D-16-10)5abb[WR-36]	TEST HOLE AND IDENTIFIER
2440	GROUNDWATER LEVEL CONTOUR, December 1988, in feet above mean sea level
	INDICATES DIRECTION OF GROUNDWATER MOVEMENT

0 1,000 2,000 3,000 4,000
FEET

FIGURE 22. GROUNDWATER LEVEL CONTOURS, DECEMBER 1988, BRAWLEY WASH AREA

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CONSULTANTS IN HYDROGEOLOGY
TUCSON, ARIZONA

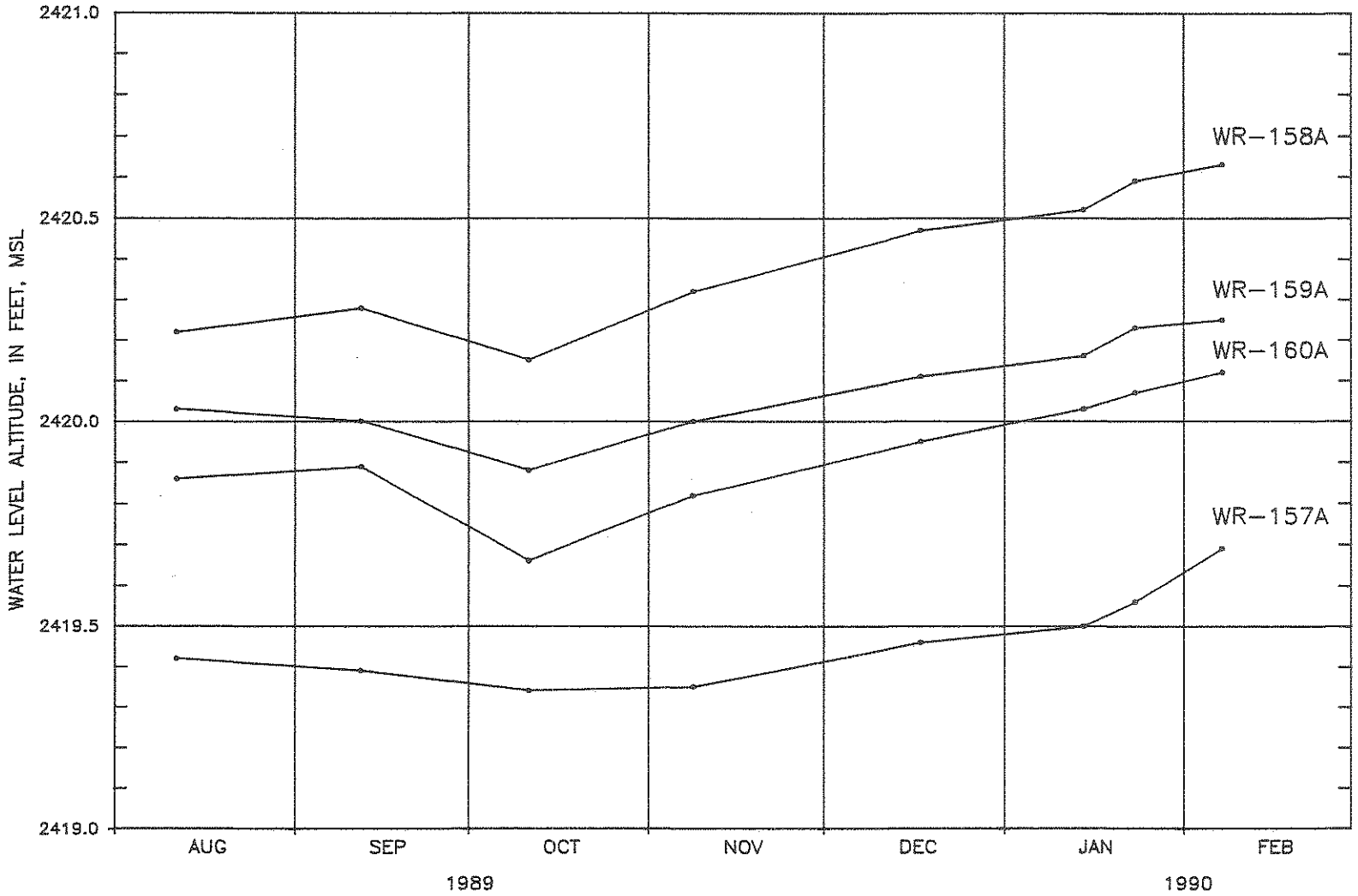

FIGURE 23. WATER LEVEL HYDROGRAPH FOR MONITOR WELLS WR-157A WR-158A, WR-159A, AND WR-160A

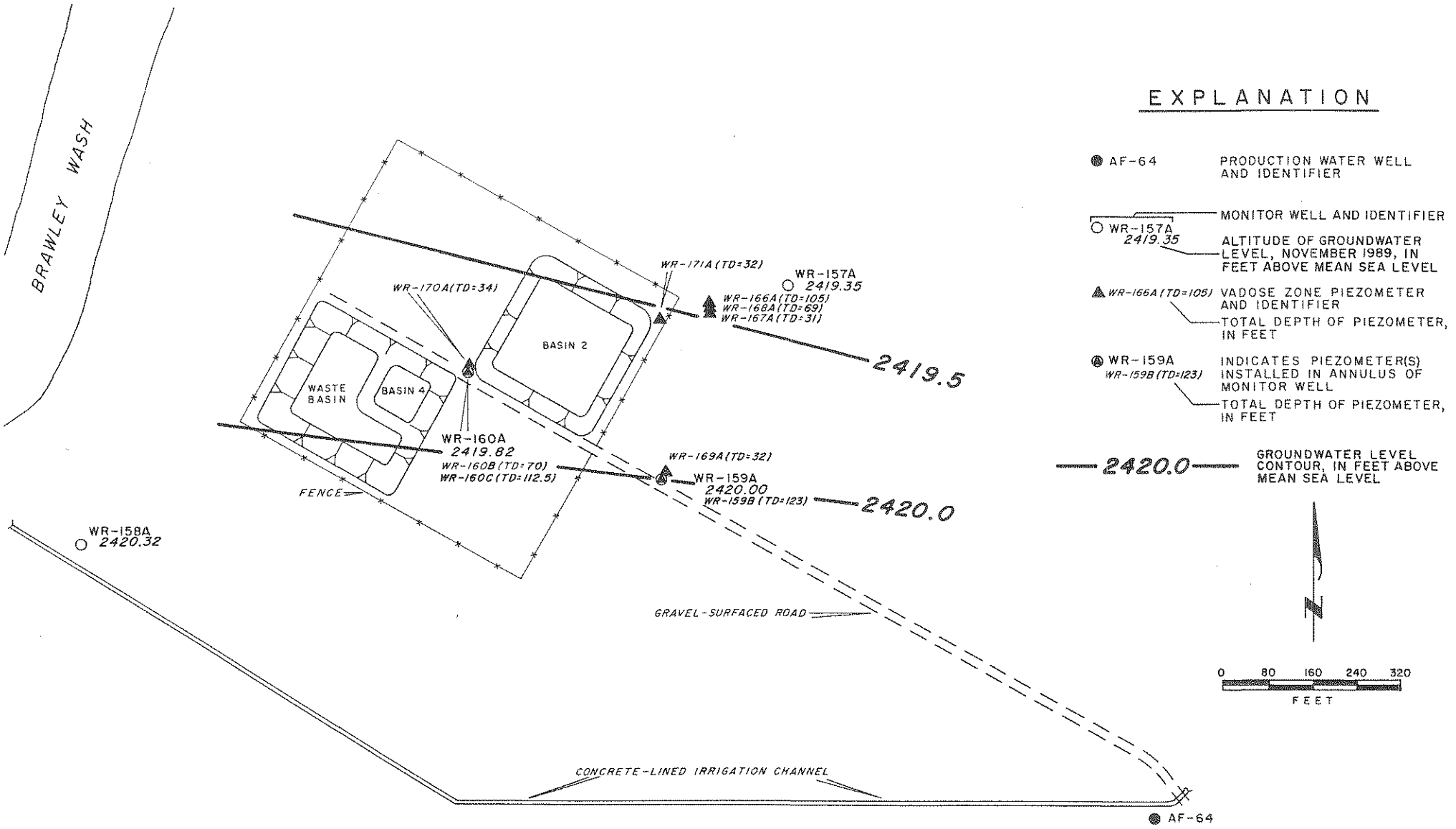

FIGURE 24. GROUNDWATER LEVEL CONTOURS, NOVEMBER 1989, BRAWLEY WASH PILOT SURFACE RECHARGE SITE

ERROL L. MONTGOMERY & ASSOCIATES, INC.
TUCSON, ARIZONA

APPENDIX A

WELL NUMBERING SYSTEM

APPENDIX A

WELL NUMBERING SYSTEM

The well numbers used in this study are in accordance with the Bureau of Land Management's system of land subdivision. The land survey in Arizona is based on the Gila and Salt River meridian and base line, which divide the state into four quadrants. These quadrants are designated, counter-clockwise, by the capital letters A, B, C, and D. All land north and east of the point of origin is in quadrant A, all land north and west of the origin is in quadrant B, all land south and west is in quadrant C, and all land south and east is in quadrant D. The first digit of a well number indicates the township, the second digit the range, and the third digit the section in which the well is located. The lowercase letters, a, b, c, and d after the section number indicate the well location within the section, the first letter denotes a particular 160-acre tract or quarter section, the second letter denotes the 40-acre tract or quarter-quarter section, and the third letter denotes the 10-acre tract or quarter-quarter-quarter section. These letters are also assigned in counter-clockwise direction, beginning the northeast quarter. As Figure A-1 shows, well number (D-16-10)8bcd designates the well as being located in the SE 1/4 of the SW 1/4 of the NW 1/4 of section 8, Township 16 South, Range 10 East. Where more than one well is within a 10-acre tract, consecutive numbers beginning with "1" are added as suffixes. For this study, additional well identifiers enclosed in brackets are added as suffixes, as is shown on Figure A-1.

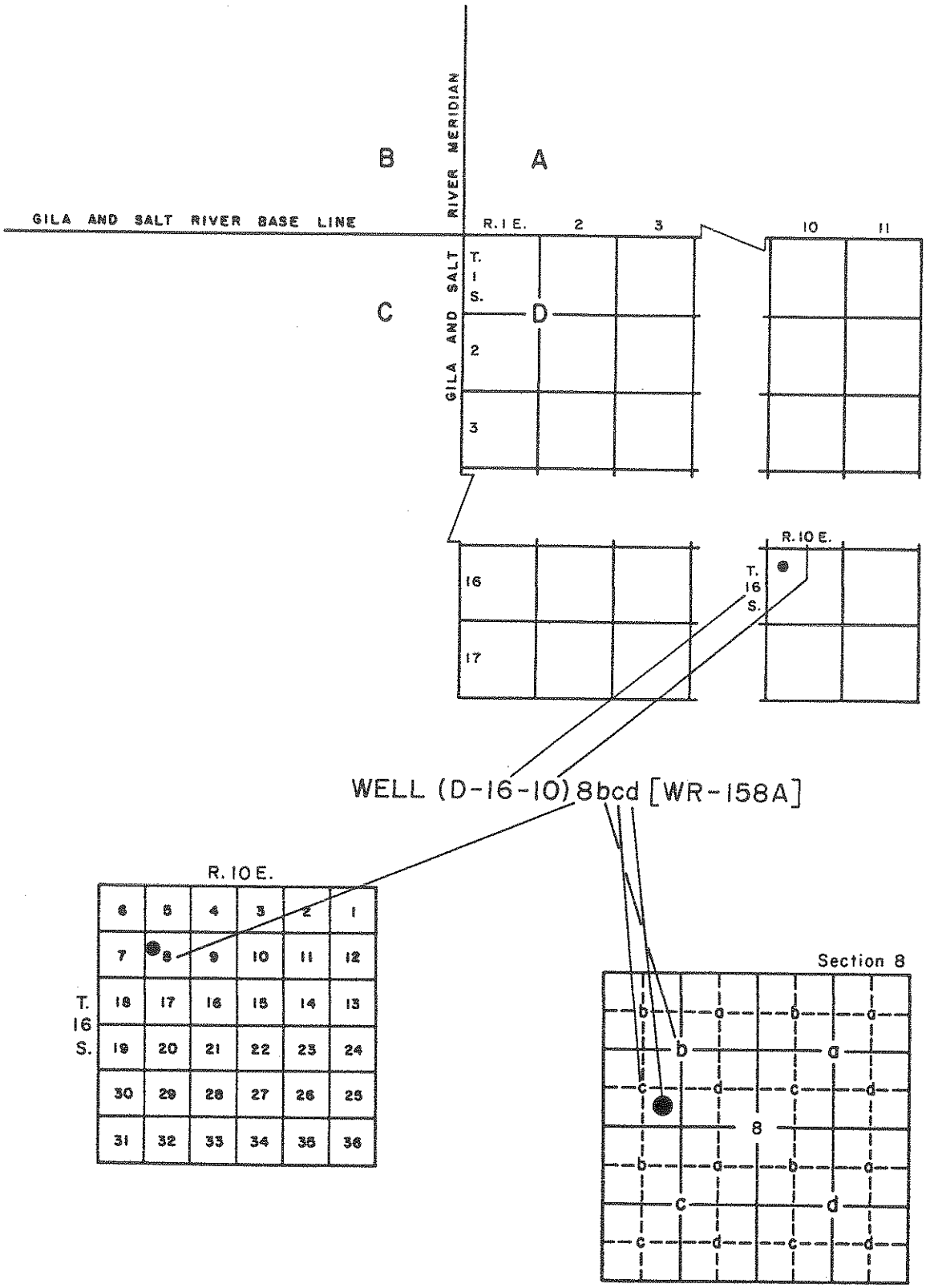

FIGURE A-1. WELL NUMBERING DIAGRAM

APPENDIX B

LITHOLOGIC DESCRIPTION
FOR SAMPLES FROM SOIL BORINGS
BRAWLEY WASH PILOT SURFACE RECHARGE SITE
PIMA COUNTY, ARIZONA

APPENDIX B

CONTENTS

LITHOLOGIC DESCRIPTION FOR SAMPLES FROM SOIL BORING SB-A

DEPTH (Feet)	SAMPLE TYPE	BLOWS PER SIX-INCH PENETRATION	DESCRIPTION
			RECENT ALLUVIUM
5	Split-spoon[a]	4/6/7	**SILTY SAND**; tan; silt 30%, sand 70%. Sand is fine to medium. Reaction to acid: none.
10	Split-spoon	14/27/33	**GRAVELLY, SANDY SILT**; tan; silt 60%, sand 20%, gravel 20%. Sand is fine to medium. Gravel fraction: subangular granules; quartz 80%, rhyolite 20%. Reaction to acid: strong.
15	Split-spoon	26/15/9	**GRAVELLY SAND**; tan-gray; sand 60%, gravel 40%, trace silt. Sand is fine to medium. Gravel fraction: subangular to subrounded granules and small pebbles; quartz 40%, sandstone 30%, granite 20%, rhyolite 10%. Reaction to acid: none.
20	Split-spoon	17/16/12	**GRAVELLY SAND**; tan-gray; sand 55%, gravel 45%. Sand is medium to coarse. Gravel fraction: subangular to subrounded granules and small pebbles; quartz 40%, sandstone 30%, granite 20%, rhyolite 10%. Reaction to acid: none.
25	Split-spoon	37/42/47	**SANDY GRAVEL**; tan-gray; gravel 70%, sand 30%. Sand is fine to medium. Gravel fraction: angular to subrounded granules and large pebbles; rhyolite 60%, sandstone 30%, quartz 10%. Reaction to acid: none.
26			FORT LOWELL FORMATION
30	Split-spoon	17/26/27	**CLAYEY, SILTY, SANDY GRAVEL**; red-brown; gravel 50%, sand 30%, silt and clay 20%; moderately consolidated. Sand is fine to coarse. Gravel fraction: subangular to rounded granules and small pebbles; quartz 40%, sandstone 20%, rhyolite 20%, granite 20%. Reaction to acid: none.

LITHOLOGIC DESCRIPTION
FOR SAMPLES FROM
SOIL BORING SB-A

DEPTH (Feet)	SAMPLE TYPE	BLOWS PER SIX-INCH PENETRATION	DESCRIPTION
37	Brass-ring[b]	63/72	**CLAYEY, SILTY, SANDY GRAVEL**; red-brown; gravel 60%, sand 20%, silt and clay 20%; moderately consolidated. Sand is fine to coarse. Gravel fraction: subangular to rounded granules and small pebbles; quartz 40%, sandstone 20%, rhyolite 20%, granite 20%. Reaction to acid: none.
40	Brass-ring	9/10	**CLAYEY SILT**; red-brown; silt 60%, clay 40%; well consolidated, moist. Reaction to acid: none.
45	Split-spoon	100-(6")[c]	**CLAYEY, SILTY, SANDY GRAVEL**; red-brown; gravel 40%, sand 30%, silt and clay 30%; weakly consolidated, moist. Sand is fine to coarse. Gravel fraction: subangular to subrounded granules and small pebbles; quartz 50%, granite 30%, rhyolite 20%. Reaction to acid: none.
50	Split-spoon	100-(3")	**SILTY, SANDY GRAVEL**; red-brown; gravel 60%, sand 30%, silt and clay 10%; weakly consolidated, moist. Sand is fine to coarse. Gravel fraction: subangular to rounded granules and small pebbles; granite 60%, quartz 30%, rhyolite 10%. Reaction to acid: none.

TOTAL DEPTH OF SOIL BORING: 50 FEET

[a] From split-spoon sampler driven 18 inches using 140 pound hammer

[b] From brass-ring bearing sampler driven 12 inches using 140 pound hammer

[c] Number of blows limited to 100 per sample; number in parentheses indicates penetration after 100 blows

LITHOLOGIC DESCRIPTION FOR SAMPLES FROM SOIL BORING SB-C

DEPTH (Feet)	SAMPLE TYPE	BLOWS PER SIX-INCH PENETRATION	DESCRIPTION
			RECENT ALLUVIUM
5	Split-spoon[a]	6/6/17	**SANDY SILT**; brown; silt 85%, sand 15%; unconsolidated. Sand is fine to medium. Reaction to acid: none.
10	Split-spoon	3/6/11	**GRAVELLY, SILTY SAND**; tan; sand 60%, silt 30%, gravel 10%; unconsolidated. Sand is fine to coarse. Reaction to acid: none.
15	Split-spoon	15/44/25	**SILTY, GRAVELLY SAND**; brown; sand 75%, gravel 15%, silt 10%; unconsolidated. Sand is fine to coarse. Gravel fraction: subangular to subrounded granules and pebbles; granite 80%, sandstone 20%. Reaction to acid: weak.
20	Split-spoon	16/19/11	**SILTY, GRAVELLY SAND**; tan; sand 60%, gravel 30%, silt 10%; unconsolidated. Gravel fraction: subangular to subrounded granules and pebbles; granite 60%, sandstone 40%. Reaction to acid: none.
25	Split-spoon	16/15/16	**SANDY GRAVEL**; brown; gravel 70%, sand 30%; unconsolidated. Sand is fine to coarse. Gravel fraction: subangular to subrounded granules and pebbles; granite 80%, sandstone 20%. Reaction to acid: none.
30	Split-spoon	33/30/55	**SANDY GRAVEL**; brown; gravel 80%, sand 20%; unconsolidated. Sand is fine to coarse. Gravel fraction: angular to subrounded granules and pebbles; granite 40%; sandstone 30%, rhyolite 30%. Reaction to acid: none.

LITHOLOGIC DESCRIPTION
FOR SAMPLES FROM
SOIL BORING SB-C

DEPTH (Feet)	SAMPLE TYPE	BLOWS PER SIX-INCH PENETRATION	DESCRIPTION
33			FORT LOWELL FORMATION
35	Split-spoon	52/48	**CLAYEY, SILTY SAND AND GRAVEL**; gray-brown; sand 40%, gravel 40%, silt and clay 20%; moderately consolidated. Sand is fine to coarse. Gravel fraction: subangular granules and pebbles; rhyolite 40%, sandstone 40%, granite 20%. Reaction to acid: none.
40	Brass-ring[b]	100-(6")[c]	**CLAYEY, SILTY SAND AND GRAVEL**; red-brown; sand 40%, gravel 40%, silt and clay 20%; weakly consolidated. Sand is fine to coarse. Gravel fraction: subrounded to rounded granules and pebbles; granite 50%, sandstone 30%, rhyolite 20%. Reaction to acid: none.
45	Brass-ring	36/47	**SILTY SAND AND GRAVEL**; red-brown; gravel 35%, sand 35%, silt and clay 30%, weakly consolidated. Sand is fine to coarse. Gravel fraction: subangular to subrounded granules and pebbles; sandstone 40%, granite 30%, rhyolite 30%. Reaction to acid: none.
50	Split-spoon	33/58	**CLAYEY, SILTY SANDY GRAVEL**; red-brown; gravel 50%, sand 30%, silt and clay 20%; moderately consolidated. Sand is fine to coarse. Gravel fraction: subangular to subrounded granules and pebbles; sandstone 40%, granite 30%, rhyolite 30%. Reaction to acid: none.
60	Split-spoon	39/61	**SILTY, GRAVELLY SAND**; red-brown; sand 50%, gravel 30%, silt 20%; moderately consolidated. Sand is fine to coarse. Gravel fraction: angular to subrounded granules and pebbles, granite 50%, sandstone 40%, rhyolite 10%. Reaction to acid: none.

LITHOLOGIC DESCRIPTION
FOR SAMPLES FROM
SOIL BORING SB-C

DEPTH (Feet)	SAMPLE TYPE	BLOWS PER SIX-INCH PENETRATION	DESCRIPTION
70	Brass-ring	40/90	**GRAVELLY SAND**; red-brown; sand 60%, gravel 40%, trace silt; moderately consolidated. Sand is fine to coarse. Gravel fraction: subangular to subrounded granules and pebbles; granite 70%, sandstone 20%, rhyolite 10%. Reaction to acid: none.
80	Split-spoon	10/18/21	**CLAYEY SILT**; dark red-brown; silt 70%, clay 30%; moderately consolidated. Reaction to acid: none.
85	Brass-ring	40/43	**SILTY SAND**; red-brown; sand 80%, silt 15%, gravel 5%; weakly consolidated. Sand is medium to coarse. Reaction to acid: none.
95	Brass-ring	50/70	**SILTY, GRAVELLY SAND**; red-brown; sand 70%, gravel 20%, silt 10%; weakly consolidated. Sand is fine to coarse. Gravel fraction: subangular to subrounded granules and pebbles; granite 40%, rhyolite 30%, sandstone 30%. Reaction to acid: none.

TOTAL DEPTH OF SOIL BORING: 95 FEET

[a] From split-spoon sampler driven 18 inches using 140 pound hammer

[b] From brass-ring bearing sampler driven 12 inches using 140 pound hammer

[c] Number of blows limited to 100 per sample; number in parentheses indicates penetration after 100 blows

LITHOLOGIC DESCRIPTION FOR SAMPLES FROM SOIL BORING SB-D

DEPTH (Feet)	SAMPLE TYPE	BLOWS PER SIX-INCH PENETRATION	DESCRIPTION
			RECENT ALLUVIUM
5	Split-spoon[a]	5/7/8	**SANDY SILT**; light red-brown; silt 60%, sand 40%, trace granules; unconsolidated. Sand is fine to coarse, granules subrounded. Reaction to acid: weak.
10	Split-spoon	7/7/8	**GRAVELLY, SILTY SAND**; light red-brown; sand 70%, silt 20%, gravel 10%; unconsolidated. Sand is fine to coarse. Gravel fraction: subangular to subrounded granules and pebbles; granite 60%, sandstone 40%. Reaction to acid: none.
15	Split-spoon	6/8/10	**SAND**; light brown; unconsolidated. Sand is fine to medium. Reaction to acid: none.
20	Split-spoon	20/20/72	**GRAVELLY SAND**; light brown; sand 60%, gravel 40%; unconsolidated. Sand is fine to coarse. Gravel fraction: subangular to subrounded granules and pebbles; granite 60%, sandstone 40%. Reaction to acid: none.
25	Split-spoon	20/37/19	**SANDY GRAVEL**; light brown; gravel 60%, sand 40%, trace silt; unconsolidated. Sand is fine to coarse. Gravel fraction: subangular to rounded, granules and pebbles; granite 60%, sandstone 40%. Reaction to acid: none.
27			FORT LOWELL FORMATION
30	Split-spoon	24/18/23	**CLAYEY, SILTY, SANDY GRAVEL**; red-brown; gravel 60%, sand 30%, silt and clay 10%; weakly consolidated. Sand is fine to coarse. Gravel fraction: angular to subrounded granules and pebbles; rhyolite 60%, granite 40%. Reaction to acid: none.

LITHOLOGIC DESCRIPTION
FOR SAMPLES FROM
SOIL BORING SB-D

DEPTH (Feet)	SAMPLE TYPE	BLOWS PER SIX-INCH PENETRATION	DESCRIPTION
35	Split-spoon	30/40/28	**CLAYEY, SILTY, SANDY GRAVEL**; red-brown; gravel 40%, sand 30%, silt and clay 30%; weakly consolidated. Sand is fine to coarse. Gravel fraction: angular to subrounded granules and pebbles; granite 70%, sandstone 30%. Reaction to acid: none.
40	Split-spoon	27/66	**SILTY, GRAVELLY SAND**; red-brown; sand 60%, gravel 30%, silt 10%, trace clay; weakly consolidated. Sand is fine to coarse. Gravel fraction: angular to subrounded granules and pebbles; quartz 40%, sandstone 30%, diorite 30%. Reaction to acid: none.
45	Brass-ring[b]	60/90	**CLAYEY, SILTY SAND AND GRAVEL**; red-brown; gravel 40%, sand 40%, silt and clay 20%; weakly consolidated. Sand is fine to coarse. Gravel fraction: subangular to subrounded granules and pebbles; quartz 60%, sandstone 30%, diorite 10%. Reaction to acid: none.
50	Split-spoon	32/25/27	**CLAYEY, GRAVELLY SAND**; red-brown; sand 40%, gravel 30%, silt and clay 30%, moderately consolidated. Sand is fine to coarse. Gravel fraction: subangular to subrounded granules and pebbles; quartz 50%, sandstone 30%, granite 10%, diorite 10%. Reaction to acid: none.

TOTAL DEPTH OF SOIL BORING: 50 FEET

[a] From split-spoon sampler driven 18 inches using 140 pound hammer

[b] From brass-ring bearing sampler driven 12 inches using 140 pound hammer

LITHOLOGIC DESCRIPTION FOR SAMPLES FROM SOIL BORING SB-J

DEPTH (Feet)	SAMPLE TYPE	BLOWS PER SIX-INCH PENETRATION	DESCRIPTION
			RECENT ALLUVIUM
5	Split-spoon[a]	5/6/5	**SANDY SILT**; tan; silt 70%, sand 30%. Sand is fine to medium. Reaction to acid: none.
10	Split-spoon	5/7/9	**SANDY SILT**; tan; silt 70%, sand 30%. Sand is fine to medium. Reaction to acid: none.
15	Split-spoon	66/35	**SILTY, SANDY GRAVEL**; tan-gray; gravel 50%, sand 30%, silt 20%. Gravel fraction: angular to subrounded granules and small pebbles; granite 60%, rhyolite 40%. Reaction to acid: none.
20	Split-spoon	11/13/19	**GRAVELLY SAND**; tan-gray; sand 60%, gravel 40%. Sand is fine to coarse. Gravel fraction: angular to subrounded granules and small pebbles; granite 60%, rhyolite 20%, quartz 20%. Reaction to acid: none.
25	Split-spoon	9/10/11	**SANDY GRAVEL**; tan-gray; gravel 60%, sand 40%. Sand is fine to coarse. Gravel fraction: angular to subrounded granules and small pebbles; granite 60%, rhyolite 20%, quartz 20%. Reaction to acid: none.
30			FORT LOWELL FORMATION
30	Split-spoon	34/62	**CLAYEY, SILTY, SANDY GRAVEL**; red-gray; gravel 60%, sand 30%, silt and clay 10%; weakly consolidated. Sand is fine to coarse. Gravel fraction: subangular to subrounded granules and pebbles; granite 40%, quartz 30%, rhyolite 30%. Reaction to acid: none.

LITHOLOGIC DESCRIPTION
FOR SAMPLES FROM
SOIL BORING SB-J

DEPTH (Feet)	SAMPLE TYPE	BLOWS PER SIX-INCH PENETRATION	DESCRIPTION
35	Split-spoon	52/64	**CLAYEY, SILTY, SANDY GRAVEL**; red-gray; gravel 60%, sand 30%, silt and clay 10%; weakly consolidated. Sand is fine to coarse. Gravel fraction: subangular to subrounded granules and pebbles; granite 40%, quartz 30%, rhyolite 30%. Reaction to acid: none.
40	Brass-ring[b]	45/60	**CLAYEY, SILTY, SANDY GRAVEL**; red-brown; gravel 50%, sand 30%, silt and clay 20%; weakly consolidated. Sand is fine to coarse. Gravel fraction: subangular to subrounded granules and pebbles; quartz 40%, granite 30%, rhyolite 30%. Reaction to acid: none.
45	Split-spoon	53/48	**CLAYEY, SILTY, SANDY GRAVEL**; red-brown; gravel 50%, sand 30%, silt and clay 20%; weakly consolidated. Sand is fine to coarse. Gravel fraction: subangular to subrounded granules and pebbles; quartz 40%, granite 30%, rhyolite 30%. Reaction to acid: none.
50	Split-spoon	79/79	**CLAYEY, SILTY, SANDY GRAVEL**; red-brown; gravel 50%, sand 30%, silt and clay 20%; weakly consolidated. Sand is fine to coarse. Gravel fraction: subangular to subrounded granules and pebbles; quartz 40%, granite 30%, rhyolite 30%. Reaction to acid: none.

TOTAL DEPTH OF SOIL BORING: 50 FEET

[a] From split-spoon sampler driven 18 inches using 140 pound hammer

[b] From brass-ring bearing sampler driven 12 inches using 140 pound hammer

APPENDIX C

LITHOLOGIC DESCRIPTION
FOR DRILL CUTTINGS SAMPLES FROM MONITOR WELLS
BRAWLEY WASH PILOT SURFACE RECHARGE SITE
PIMA COUNTY, ARIZONA

APPENDIX C

CONTENTS

ERROL L. MONTGOMERY & ASSOCIATES, INC.

LITHOLOGIC DESCRIPTION
FOR DRILL CUTTINGS SAMPLES
TUCSON WATER MONITOR WELL (D-16-10)8bdb1[WR-157]

DEPTH (Feet)	DESCRIPTION
0-5	**SANDY SILT AND CLAY**; dark brown; clay and silt 80%, sand 20%, trace gravel. Gravel fraction: subrounded granite 40%, subrounded rhyolite 60%. Reaction to acid: nil.
5-10	**GRAVELLY, SILTY, CLAYEY SAND**; brown; sand 80%, clay and silt 15%, gravel 5%. Gravel fraction: subrounded quartz 60%, subrounded rhyolite 20%, subrounded basalt 20%. Reaction to acid: nil.
10-15	**GRAVELLY, SILTY, CLAYEY SAND**; dark brown; sand 60%, clay and silt 35%, gravel 5%. Gravel fraction: subrounded quartz 40%, subrounded feldspar 30%, subrounded diorite 20%, subrounded granite 10%. Reaction to acid: moderate. Minor clay balls.
15-20	**SILTY, CLAYEY, GRAVELLY SAND**; brown; sand 60%, gravel 25%, clay and silt 15%. Gravel fraction: subrounded quartz 40%, subrounded feldspar 30%, subrounded granite 20%, subrounded basalt 10%. Reaction to acid: weak.
20-25	**CLAYEY, SILTY, GRAVELLY SAND**; brown; sand 70%, gravel 20%, clay and silt 10%. Gravel fraction: subrounded rhyolite 40%, subrounded granite 25%, subrounded basalt 20%, subrounded quartz 15%. Reaction to acid: very weak.
25-30	**CLAYEY, SILTY, GRAVELLY SAND**; brown; sand 65%, gravel 25%, clay and silt 10%. Gravel fraction: subrounded rhyolite 70%, subrounded granite 20%, subrounded drusy and bull quartz 5%, angular feldspar 5%. Reaction to acid: very weak.
30-35	**CLAYEY, SILTY, GRAVELLY SAND**; brown; sand 70%, gravel 20%, clay and silt 10%. Gravel fraction: subrounded granite 50%, subrounded rhyolite 30%, subrounded bull quartz 10%, subrounded basalt 5%, subangular feldspar 5%. Reaction to acid: nil.
35-40	**GRAVELLY, SANDY SILT AND CLAY**; brown; clay and silt 60%, sand 30%, gravel 10%. Gravel fraction: subrounded rhyolite 70%, subrounded granite 15%, subangular drusy quartz 10%, angular feldspar 5%. Reaction to acid: nil. Abundant clay balls.
40-45	**GRAVELLY, SANDY SILT AND CLAY**; brown; clay and silt 70%, sand 25%, gravel 5%. Gravel fraction: subrounded rhyolite 60%, subangular bull and drusy quartz 30%, subrounded granite 10%, trace angular feldspar. Reaction to acid: very weak.

LITHOLOGIC DESCRIPTION
FOR DRILL CUTTINGS SAMPLES
TUCSON WATER MONITOR WELL (D-16-10)8bdb1[WR-157A]

DEPTH (Feet)	DESCRIPTION
45-50	**GRAVELLY, SANDY SILT AND CLAY**; brown; clay and silt 60%, sand 30%, gravel 10%. Gravel fraction: subrounded granite 50%, subangular rhyolite 30%, subrounded bull quartz 15%, subangular feldspar 5%. Reaction to acid: none.
50-55	**GRAVELLY, SANDY SILT AND CLAY**; brown; clay and silt 50%, sand 25%, gravel 25%. Gravel fraction: subangular rhyolite 60%, subangular granite 30%, subrounded to angular quartz 10%. Reaction to acid: none.
55-60	**GRAVELLY, SANDY SILT AND CLAY**; brown; clay and silt 70%, sand 20%, gravel 10%. Gravel fraction: subrounded rhyolite 60%, subangular granite 30%, subrounded bull and drusy quartz 10%. Reaction to acid: none. Abundant clay balls.
60-65	**GRAVELLY, SANDY SILT AND CLAY**; brown; clay and silt 60%, sand 25%, gravel 15%. Subangular granite 40%, subrounded rhyolite 40%, angular bull quartz 15%, subangular feldspar 5%. Reaction to acid: none.
65-70	**GRAVELLY, CLAYEY, SILTY SAND**; reddish-brown; sand 50%, clay and silt 40%, gravel 10%. Subangular rhyolite 50%, subangular granite 40%, subangular quartz 10%, trace subangular feldspar. Reaction to acid: none.
70-75	**GRAVELLY, SANDY CLAY AND SILT**; brown; clay and silt 60%, sand 25%, gravel 15%. Gravel fraction: subangular granite 50%, subangular rhyolite 40%, subangular bull quartz 10%, trace subrounded feldspar. Reaction to acid: none.
75-80	**SANDY CLAY AND SILT**; tan; clay and silt 70%, sand 30%, trace gravel. Gravel fraction: subrounded to angular bull quartz 90%, subrounded granite 10%. Reaction to acid: none. Moderate amount of clay balls.
80-85	**SANDY SILT AND CLAY**; tan; clay and silt 75%, sand 25%, trace gravel. Gravel fraction: subrounded granite 90%, subangular bull quartz 10%. Reaction to acid: none. Abundant clay balls.
85-90	**GRAVELLY, SANDY CLAY AND SILT**; dark tan; clay and silt 70%, sand 25%, gravel 5%. Gravel fraction: subangular rhyolite 85%, subangular bull quartz 10%, subangular granite 5%, trace well rounded chert. Reaction to acid: none. Some clay balls.

LITHOLOGIC DESCRIPTION
FOR DRILL CUTTINGS SAMPLES
TUCSON WATER MONITOR WELL (D-16-10)8bdb1[WR-157A]

DEPTH (Feet)	DESCRIPTION
90-95	**GRAVELLY, CLAYEY, SILTY SAND**; brown; sand 50%, clay and silt 40%, gravel 10%. Gravel fraction: subangular granite 40%, subangular to angular rhyolite 30%, subrounded bull quartz 20%, angular basalt 10%, trace subrounded feldspar. Reaction to acid: none. Trace of clay balls.
95-100	**GRAVELLY, CLAYEY, SILTY SAND**; brown; sand 60%, clay and silt 30%, gravel 10%. Gravel fraction: subangular granite 50%, subangular rhyolite 30%, subangular bull quartz 15%, subangular basalt 5%. Reaction to acid: none.
100-105	**GRAVELLY, CLAYEY, SILTY SAND**; brown; sand 60%, clay and silt 25%, gravel 15%. Gravel fraction: subrounded granite 40%, subangular rhyolite 30%, subrounded quartz 20%, subrounded feldspar 5%, subangular basalt 5%. Reaction to acid: none.
105-110	**GRAVELLY, CLAYEY, SILTY SAND**; brown; sand 55%, clay and silt 35%, gravel 10%. Gravel fraction: Subangular rhyolite 40%, subangular granite 30%, subangular bull quartz 20%, subangular basalt 10%. Reaction to acid: none. Trace of clay balls.
110-115	**GRAVELLY, CLAYEY, SILTY SAND**; brown; sand 50%, clay and silt 30%, gravel 20%. Gravel fraction: subangular rhyolite 30%, subangular granite 20%, subangular to rounded bull and drusy quartz 20%, subangular basalt 15%, subrounded tuff 10%, subrounded feldspar 5%. Reaction to acid: none.
115-120	**GRAVELLY, CLAYEY, SILTY SAND**; brown; sand 60%, clay and silt 30%, gravel 10%. Gravel fraction: subangular rhyolite 40%, subrounded granite 30%, subrounded quartz 20%, subangular basalt 10%, trace subrounded feldspar. Reaction to acid: none.
120-125	**CLAYEY, SILTY, GRAVELLY SAND**; tan; sand 60%, clay and silt 20%, gravel 20%. Gravel fraction: subangular rhyolite 30%, subangular granite 20%, subangular quartz 20%, angular basalt 15%, subrounded tuff 10%, subrounded feldspar 5%. Reaction to acid: none.
125-130	**GRAVELLY, SANDY, CLAYEY SILT**; tan; clay and silt 60%, sand 30%, gravel 10%. Gravel fraction: subrounded rhyolite 40%, subrounded granite 30%, subangular quartz 20%, subangular to angular basalt 10%. Reaction to acid: none. Some clay balls.

LITHOLOGIC DESCRIPTION
FOR DRILL CUTTINGS SAMPLES
TUCSON WATER MONITOR WELL (D-16-10)8bdb1[WR-157A]

DEPTH (Feet)	DESCRIPTION
130-135	**GRAVELLY, SANDY, CLAYEY SILT**; tan; clay and silt 60%, sand 30%, gravel 10%. Gravel fraction: subrounded rhyolite 40%, subrounded granite 30%, subrounded quartz 20%, subangular basalt 10%, trace subrounded feldspar. Reaction to acid: none. Some clay balls.
135-140	**GRAVELLY, SANDY, CLAYEY SILT**; brown; clay and silt 70%, sand 20%, gravel 10%. Gravel fraction: subrounded rhyolite 40%, subrounded granite 20%, subrounded tuff 20%, subangular to angular basalt 10%, subrounded quartz 10%. Reaction to acid: none. Trace of clay balls.
140-145	**GRAVELLY, SANDY, CLAYEY SILT**; brown; clay and silt 70%, sand 20%, gravel 10%. Gravel fraction: subrounded rhyolite 40%, subrounded granite 30%, subrounded bull and drusy quartz 20%, subangular to angular basalt 10%. Reaction to acid: none. Trace of clay balls.
145-150	**GRAVELLY, SANDY, CLAYEY SILT**; brown; clay and silt 70%, sand 25%, gravel 5%. Gravel fraction: subrounded rhyolite 40%, subrounded granite 25%, subrounded to angular quartz 20%, subrounded tuff 10%, subangular basalt 5%. Reaction to acid: none. Some clay balls.
150-155	**GRAVELLY, SANDY, CLAYEY SILT**; tan; clay and silt 70%, sand 15%, gravel 15%. Gravel fraction: subangular rhyolite 40%, subangular to rounded granite 30%, subangular bull quartz 20%, subangular to angular basalt 10%. Reaction to acid: none. Trace of clay balls.
155-160	**GRAVELLY, CLAYEY, SILTY SAND**; brown; sand 75%, clay and silt 20%, gravel 5%. Gravel fraction: subrounded rhyolite 40%, subrounded granite 30%, subrounded quartz 20%, subrounded tuff 5%, subangular to angular basalt 5%. Reaction to acid: none.
160-165	**CLAYEY, SILTY, GRAVELLY SAND**; brown; sand 55%, gravel 25%, clay and silt 20%. Gravel fraction: subangular to angular rhyolite 50%, subrounded granite 10%, subangular to angular basalt 40%, trace subangular quartz. Reaction to acid: none.
165-170	**GRAVELLY, CLAYEY, SILTY SAND**; brown; sand 70%, clay and silt 20%, gravel 10%. Gravel fraction: subangular to angular rhyolite 70%, subangular to angular basalt 20%, subangular to angular quartz 10%. Reaction to acid: very weak.

LITHOLOGIC DESCRIPTION
FOR DRILL CUTTINGS SAMPLES
TUCSON WATER MONITOR WELL (D-16-10)8bdb1[WR-157A]

DEPTH (Feet)	DESCRIPTION
170-175	**GRAVELLY, SILTY, CLAYEY SAND**; brown; sand 50%, clay and silt 30%, gravel 20%. Gravel fraction: subangular to angular rhyolite 70%, subrounded granite 10%, subangular to angular basalt 10%, subrounded bull quartz 10%. Reaction to acid: none. Trace of clay balls.
175-180	**GRAVELLY, CLAYEY, SILTY SAND**; brown; sand 70%, clay and silt 20%, gravel 10%. Gravel fraction: subangular to angular rhyolite 70%, subangular basalt 20%, subrounded quartz 10%. Reaction to acid: none.
180-185	**GRAVELLY, SILTY, CLAYEY SAND**; brown; sand 55%, clay and silt 30%, gravel 15%. Gravel fraction: subangular to angular rhyolite 70%, subangular to angular basalt 20%, subrounded bull quartz 10%. Reaction to acid: none. Trace of clay balls.
185-190	**GRAVELLY, SILTY, CLAYEY SAND**; brown; sand 60%, clay and silt 30%, gravel 10%. Gravel fraction: subangular to angular rhyolite 50%, subangular to angular basalt 40%, subrounded granite 10%, trace subrounded bull quartz. Reaction to acid: none. Trace of clay balls.
190-195	**GRAVELLY, CLAYEY, SILTY SAND**; brown; sand 60%, clay and silt 30%, gravel 10%. Gravel fraction: subangular to angular rhyolite 70%,k subangular to angular basalt 30%, trace subrounded quartz. Reaction to acid: none. Trace of clay balls.
195-200	**GRAVELLY, CLAYEY, SILTY SAND**; brown; sand 65%, clay and silt 30%, gravel 5%. Gravel fraction: subangular to angular rhyolite 60%, subangular to angular basalt 30%, subangular to angular quartz 10%. Reaction to acid: none. Trace of clay balls.
200-205	**GRAVELLY, CLAYEY, SILTY SAND**; brown; sand 65%, clay and silt 20%, gravel 15%. Gravel fraction: subangular to angular rhyolite 60%, subrounded granite 20%, subangular to angular basalt 20%, trace subrounded bull quartz. Reaction to acid: none.
205-210	**GRAVELLY, CLAYEY, SILTY SAND**; brown; sand 60%, clay and silt 20%, gravel 20%. Gravel fraction: subangular to angular rhyolite 50%, subangular to angular basalt 40%, subrounded bull quartz 10%, trace subrounded tuff. Reaction to acid: very weak.

LITHOLOGIC DESCRIPTION
FOR DRILL CUTTINGS SAMPLES
TUCSON WATER MONITOR WELL (D-16-10)8bdb1[WR-157A]

DEPTH (Feet)	DESCRIPTION
210-215	**GRAVELLY, CLAYEY, SILTY SAND**; brown; sand 70%, clay and silt 20%, gravel 10%. Gravel fraction: subangular to angular rhyolite 60%, subangular to angular basalt 30%, subrounded bull quartz 10%. Reaction to acid: weak.
215-220	**GRAVELLY, SILTY, CLAYEY SAND**; dark brown; sand 50%, clay and silt 30%, gravel 20%. Gravel fraction: subangular to angular rhyolite 70%, subangular to angular basalt 20%, subrounded bull and drusy quartz 10%, trace subrounded feldspar. Reaction to acid: moderate. Moderate clay balls.

TOTAL DEPTH DRILLED: 220 FEET

LITHOLOGIC DESCRIPTION
FOR DRILL CUTTINGS SAMPLES
TUCSON WATER MONITOR WELL (D-16-10)8bcd[WR-158A]

DEPTH (Feet)	DESCRIPTION
0-5	**SILTY, CLAYEY SAND**; dark brown; fine sand 60%, clay and silt 40%. Reaction to acid: very weak. Moderate clay balls.
5-10	**SILTY, CLAYEY SAND**; brown; fine to medium sand 70%, clay and silt 30%. Reaction to acid: very weak. Moderate clay balls.
10-15	**GRAVELLY, CLAYEY, SILTY SAND**; brown; sand 80%, clay and silt 10%, gravel 10%. Gravel fraction: subrounded to rounded granite 85%, subrounded to rounded bull quartz 10%, subrounded to rounded rhyolite 5%. Reaction to acid: weak.
15-20	**GRAVELLY, CLAYEY, SILTY SAND**; brown; sand 60%, clay and silt 30%, gravel 10%. Gravel fraction: subrounded to rounded granite 40%, subrounded to rounded rhyolite 30%, subrounded bull quartz 20%, subrounded andesite 10%, trace subrounded to rounded basalt. Reaction to acid: very weak.
20-27	**CLAYEY, SILTY, GRAVELLY SAND**; tan; sand 65%, gravel 20%, clay and silt 15%. Gravel fraction: subrounded granite 50%, subrounded rhyolite 30%, subrounded bull quartz 15%, subrounded feldspar 5%, trace subrounded to rounded basalt. Reaction to acid: none.
27-30	**SANDY, CLAYEY SILT**; tan; clay and silt 90%, sand 10%. Reaction to acid: none.
30-35	**CLAYEY, SILTY, GRAVELLY SAND**; tan, brown; sand 65%, gravel 25%, clay and silt 10%. Gravel fraction: subrounded to rounded granite 40%, subrounded rhyolite 30%, subrounded to subangular basalt 20%, subrounded to rounded bull quartz 10%, trace subrounded to rounded feldspar. Reaction to acid: none.
35-40	**GRAVELLY, CLAYEY, SILTY SAND**; brown; sand 55%, clay and silt 30%, gravel 15%. Gravel fraction: subrounded granite 50%, subangular to angular rhyolite 30%, subangular to angular basalt 10%, subrounded bull quartz 5%, subrounded feldspar 5%. Reaction to acid: none.
40-45	**CLAYEY, SILTY, GRAVELLY SAND**; brown; sand 55%, gravel 25%, clay and silt 20%. Gravel fraction: subrounded to subangular granite 40%, subangular rhyolite 25%, subangular bull and drusy quartz 20%, subangular basalt 10%, subrounded feldspar 5%. Reaction to acid: none.

LITHOLOGIC DESCRIPTION
FOR DRILL CUTTINGS SAMPLES
TUCSON WATER MONITOR WELL (D-16-10)8bcd[WR-158A]

DEPTH (Feet)	DESCRIPTION
45-50	**CLAYEY, SILTY, GRAVELLY SAND**; brown; sand 55%, gravel 25%, clay and silt 20%. Gravel fraction: subrounded to angular rhyolite 45%, subrounded granite 35%, subrounded to subangular bull and drusy quartz 10%, subrounded basalt 5%, subrounded feldspar 5%. Reaction to acid: none.
50-55	**CLAYEY, SILTY, GRAVELLY SAND**; brown; sand 55%, gravel 25%, clay and silt 20%. Gravel fraction: subrounded rhyolite 60%, subrounded granite 30%, subrounded bull quartz 10%. Reaction to acid: none. Trace of clay balls.
55-60	**CLAYEY, SILTY, GRAVELLY SAND**; tan, brown; sand 55%, gravel 25%, clay and silt 20%. Gravel fraction: subrounded to subangular rhyolite 60%, subrounded granite 20%, subrounded to subangular bull quartz 15%, subrounded basalt 5%. Reaction to acid: none. Trace of clayey siltstone fragments.
60-65	**CLAYEY, SILTY, GRAVELLY SAND**; tan, brown; sand 60%, clay and silt 20%, gravel 20%. Gravel fraction: subrounded rhyolite 40%, subrounded granite 30%, subrounded bull quartz 20%, subrounded basalt 10%. Reaction to acid: none.
65-70	**GRAVELLY, SANDY, SILTY CLAY**; tan; clay and silt 70%, sand 25%, gravel 5%. Gravel fraction: subrounded to subangular rhyolite 80%, subrounded bull quartz 20%. Reaction to acid: very weak. Abundant clay balls. Clay unit extends from about 64 - 70 feet.
70-75	**GRAVELLY, CLAYEY, SILTY SAND**; tan, brown; sand 55%, clay and silt 40%, gravel 5%. Gravel fraction: subrounded rhyolite 40%, subrounded granite 30%, subangular to angular basalt 10%, subrounded to subangular bull quartz 20%. Reaction to acid: very weak. Some clay balls.
75-80	**GRAVELLY, CLAYEY, SILTY SAND**; tan, brown; sand 60%, clay and silt 30%, gravel 10%. Gravel fraction: subrounded granite 40%, subangular rhyolite 30%, subrounded bull quartz 20%, subangular to angular basalt 10%. Reaction to acid: very weak. Some clay balls.
80-85	**GRAVELLY, CLAYEY, SILTY SAND**; tan, brown; sand 45%, clay and silt 30%, gravel 25%. Gravel fraction: subrounded granite 40%, subangular to angular rhyolite 30%, subrounded bull quartz 20%, subrounded to subangular basalt 10%. Reaction to acid: none. Some clay balls.

LITHOLOGIC DESCRIPTION
FOR DRILL CUTTINGS SAMPLES
TUCSON WATER MONITOR WELL (D-16-10)8bcd[WR-158A]

DEPTH (Feet)	DESCRIPTION
85-90	**GRAVELLY, CLAYEY, SILTY SAND**; brown; sand 65%, clay and sand 20%, gravel 15%. Gravel fraction: subrounded granite 40%, subrounded rhyolite 30%, subrounded to subangular bull quartz 20%, subrounded to rounded basalt 10%. Reaction to acid: none.
90-95	**GRAVELLY, CLAYEY, SILTY SAND**; tan, brown; sand 55%, clay and silt 40%, gravel 5%. Gravel fraction: subrounded to subangular rhyolite 40%, subrounded granite 30%, subrounded bull quartz 20%, subangular to angular basalt 10%. Reaction to acid: none. Moderate amount of clay balls.
95-100	**GRAVELLY, CLAYEY, SILTY SAND**; brown; sand 65%, clay and silt 20%, gravel 15%. Gravel fraction: subrounded rhyolite 30%, subrounded granite 40%, subrounded to subangular bull and drusy quartz 20%, subrounded basalt 10%, trace of rounded sandy siltstone fragments. Reaction to acid: none.
100-105	**CLAYEY, SILTY, GRAVELLY SAND**; tan, brown; sand 55%, gravel 25%, clay and silt 20%. Gravel fraction: subrounded granite 40%, subrounded to angular rhyolite 30%, subrounded bull and drusy quartz 20%, subrounded basalt 10%, trace subangular sandy siltstone fragments. Reaction to acid: none.
105-110	**GRAVELLY, CLAYEY, SILTY SAND**; brown; sand 65%, clay and silt 20%, gravel 15%. Gravel fraction: subrounded to angular granite 60%, subrounded rhyolite 20%, subrounded bull quartz 15%, subrounded basalt 5%. Reaction to acid: none.
110-115	**GRAVELLY, CLAYEY, SILTY SAND**; brown; sand 70%, clay and silt 20%, gravel 10%. Gravel fraction: subrounded rhyolite 60%, subrounded bull and drusy quartz 30%, subrounded to subangular granite 10%, trace subrounded sandy siltstone fragments. Reaction to acid: very weak.
115-120	**CLAYEY, SILTY SAND**; tan, brown; sand 70%, clay and silt 30%, trace gravel. Gravel fraction: subrounded rhyolite 60%, subrounded bull quartz 40%, trace subangular to angular basalt. Reaction to acid: none. Trace of clay balls.
120-125	**GRAVELLY, CLAYEY, SILTY SAND**; brown; sand 70%, clay and silt 20%, gravel 10%. Gravel fraction: subangular to angular rhyolite 40%, subangular to angular granite 30%, subrounded to rounded bull and frosted quartz 20%, subrounded basalt 5%, sandy siltstone fragments 5%. Reaction to acid: none.

LITHOLOGIC DESCRIPTION
FOR DRILL CUTTINGS SAMPLES
TUCSON WATER MONITOR WELL (D-16-10)8bcd[WR-158A]

DEPTH (Feet)	DESCRIPTION
125-130	**GRAVELLY, CLAYEY, SILTY SAND**; brown, tan; sand 55%, clay and silt 40%, gravel 5%. Gravel fraction: subrounded to subangular rhyolite 50%, subrounded granite 30%, subrounded bull and frosted quartz 15%, sandy siltstone fragments 5%, trace metamorphics. Reaction to acid: none.
130-135	**SANDY, SILTY CLAY**; tan; clay and silt 75%, sand 25%, trace gravel. Gravel fraction: trace subrounded rhyolite. Reaction to acid: none.
135-140	**SANDY, SILTY CLAY**; tan; clay and silt 60%, sand 40%, trace gravel. Gravel fraction: trace subrounded to subangular rhyolite. Reaction to acid: none.
140-145	**SANDY, SILTY CLAY**; brown; clay and silt 60%, sand 40%, trace gravel. Gravel fraction: trace subangular to angular rhyolite. Reaction to acid: none.
145-150	**GRAVELLY, CLAYEY, SILTY SAND**; brown; sand 50%, clay and silt 40%, gravel 10%. Gravel fraction: subangular to angular rhyolite 70%, subrounded granite 20%, subrounded to subangular basalt 10%, trace subrounded bull and drusy quartz. Reaction to acid: none. Some clay balls.
150-155	**GRAVELLY, CLAYEY, SILTY SAND**; brown; sand 55%, clay and sand 30%, gravel 15%. Gravel fraction: subangular to angular rhyolite 70%, subrounded granite 20%, subrounded basalt 5%, subrounded to subangular bull quartz 5%, trace sandy siltstone fragments. Reaction to acid: very weak. Trace of clay balls.
155-160	**CLAYEY, SILTY, GRAVELLY SAND**; brown; sand 55%, gravel 25%, clay and silt 20%. Gravel fraction: subrounded to angular rhyolite 50%, subrounded granite 40%, subrounded to subangular drusy and bull quartz 10%. Reaction to acid: none. Trace of clay balls.
160-165	**GRAVELLY, CLAYEY, SILTY SAND**; red, brown; sand 50%, clay and silt 30%, gravel 20%. Gravel fraction: subangular to angular rhyolite 60%, subrounded granite 30%, subrounded bull quartz 10%, trace sandy siltstone fragments. Reaction to acid: very weak. Trace of clay balls.

LITHOLOGIC DESCRIPTION
FOR DRILL CUTTINGS SAMPLES
TUCSON WATER MONITOR WELL (D-16-10)8bcd[WR-158A]

DEPTH (Feet)	DESCRIPTION
165-170	**GRAVELLY, CLAYEY, SILTY SAND**; red, brown; sand 50%, clay and silt 30%, gravel 20%. Gravel fraction: subangular to angular rhyolite 80%, subrounded to subangular bull and drusy quartz 15%, subangular granite 5%, trace of claystone fragments. Reaction to acid: none. Trace of clay balls.
170-175	**GRAVELLY, CLAYEY, SILTY SAND**; brown; sand 45%, clay and silt 30%, gravel 25%. Gravel fraction: subangular to angular rhyolite 60%, subangular to angular granite 30%, subrounded bull quartz 10%. Reaction to acid: none. Trace of clay balls.
175-180	**GRAVELLY, CLAYEY, SILTY SAND**; brown; sand 45%, clay and silt 30%, gravel 25%. Gravel fraction: subangular to angular rhyolite 70%, subrounded granite 20%, subrounded drusy and bull quartz 10%, trace subrounded feldspar. Reaction to acid: none.
180-185	**CLAYEY, SILTY, GRAVELLY SAND**; brown; sand 40%, clay and silt 30%, gravel 30%. Gravel fraction: subangular to angular rhyolite 60%, subrounded to angular granite 30%, subrounded bull quartz 10%. Reaction to acid: very weak.
185-190	**GRAVELLY, CLAYEY, SILTY SAND**; brown; sand 45%, clay and silt 30%, gravel 25%. Gravel fraction: subangular to angular rhyolite 60%, subrounded to angular granite 30%, subrounded bull quartz 10%, trace sandy siltstone fragments. Reaction to acid: weak.
190-195	**GRAVELLY, CLAYEY, SILTY SAND**; brown; sand 50%, clay and silt 30%, gravel 20%. Gravel fraction: subangular to angular rhyolite 70%, subrounded to angular granite 20%, subrounded to subangular bull quartz 10%. Reaction to acid: moderate.
195-200	**GRAVELLY, CLAYEY, SILTY SAND**; brown; sand 70%, clay and silt 20%, gravel 10%. Gravel fraction: subangular to angular rhyolite 70%, subrounded granite 20%, subrounded bull quartz 10%, trace sandy siltstone fragments, trace subrounded feldspar. Reaction to acid: weak. Trace of clay balls.
200-205	**GRAVELLY, CLAYEY, SILTY SAND**; brown; sand 65%, clay and silt 20%, gravel 15%. Gravel fraction: subangular to angular rhyolite 60%, subangular to angular granite 30%, subrounded frosted and bull quartz 10%. Reaction to acid: moderate.

LITHOLOGIC DESCRIPTION
FOR DRILL CUTTINGS SAMPLES
TUCSON WATER MONITOR WELL (D-16-10)8bcd[WR-158A]

DEPTH (Feet)	DESCRIPTION
205-210	**CLAYEY, SILTY, GRAVELLY SAND**; brown; sand 60%, clay and silt 20%, gravel 20%. Gravel fraction: subangular to angular rhyolite 50%, subangular to angular granite 40%, subrounded to angular bull quartz 10%, trace sandy siltstone fragments. Reaction to acid: moderate.
210-215	**GRAVELLY, CLAYEY, SILTY SAND**; brown; sand 65%, clay and silt 25%, gravel 10%. Gravel fraction: subangular to angular rhyolite 50%, subangular to angular granite 40%, subrounded drusy, frosted and bull quartz 5%, sandy siltstone fragments 5%. Reaction to acid: moderate.

TOTAL DEPTH DRILLED: 215 FEET

LITHOLOGIC DESCRIPTION
FOR DRILL CUTTINGS SAMPLES
TUCSON WATER MONITOR WELL (D-16-10)8bdb2[WR-159A]

DEPTH (Feet)	DESCRIPTION
0-5	**CLAYEY, SILTY SAND**; brown; sand 90%, clay and silt 10%, trace gravel. Gravel fraction: subrounded bull and drusy quartz 100%. Reaction to acid: very weak.
5-10	**GRAVELLY, SILTY, CLAYEY SAND**; dark brown; sand 65%, clay and silt 30%, gravel 5%. Gravel fraction: subrounded granite 70%, subangular rhyolite 30%. Reaction to acid: weak. Moderate clay balls.
10-15	**CLAYEY, SILTY, GRAVELLY SAND**; brown; sand 85%, gravel 10%, clay and silt 5%. Gravel fraction: subrounded granite 70%, subrounded rhyolite 20%, subrounded basalt 5%, subrounded bull quartz 5%. Reaction to acid: very weak.
15-20	**CLAYEY, SILTY, GRAVELLY SAND**; brown; sand 80%, gravel 15%, clay and silt 5%. Gravel fraction: subrounded rhyolite 60%, subrounded granite 25%, subrounded bull and drusy quartz 10%, subrounded basalt 5%. Reaction to acid: none.
20-25	**CLAYEY, SILTY, GRAVELLY SAND**; tan; sand 85%, gravel 10%, clay and silt 5%. Gravel fraction: subrounded granite 50%, subrounded to rounded rhyolite 40%, subrounded to rounded bull and frosted quartz 10%, trace sandy siltstone fragments, trace rounded basalt. Reaction to acid: very weak.
25-30	**CLAYEY, SILTY, GRAVELLY SAND**; tan; sand 75%, gravel 20%, clay and silt 5%. Gravel fraction: subrounded to subangular granite 40%, subrounded to angular rhyolite 30%, subrounded to rounded bull and drusy quartz 20%, subrounded to rounded andesite 10%, trace subrounded feldspar, trace subangular basalt. Reaction to acid: very weak.
30-35	**CLAYEY, SILTY, GRAVELLY SAND**; tan; sand 65%, gravel 30%, clay and silt 5%. Gravel fraction: subrounded to subangular rhyolite 50%, subrounded granite 40%, subrounded bull and frosted quartz 10%, trace sandy siltstone fragments, trace subrounded weathered feldspar. Reaction to acid: none.
35-40	**GRAVELLY, CLAYEY, SILTY SAND**; brown, tan; sand 60%, clay and silt 30%, gravel 10%. Gravel fraction: subrounded to subangular rhyolite 40%, subrounded granite 30%, subrounded bull and frosted quartz 25%, subrounded sandy siltstone fragments 5%, trace rounded andesite. Reaction to acid: none. Moderate clay balls.

LITHOLOGIC DESCRIPTION
FOR DRILL CUTTINGS SAMPLES
TUCSON WATER MONITOR WELL (D-16-10)8bcd[WR-159A]

DEPTH (Feet)	DESCRIPTION
40-45	**CLAYEY, SILTY, GRAVELLY SAND**; brown, tan; sand 55%, gravel 25%, clay and silt 20%. Gravel fraction: subrounded granite 50%, subrounded andesite 40%, subrounded to angular milky quartz 10%, trace angular basalt, trace sandy siltstone fragments. Reaction to acid: none. Trace of clay balls.
45-50	**GRAVELLY, CLAYEY, SILTY SAND**; brown, tan; sand 60%, clay and silt 30%, gravel 10%. Gravel fraction: subrounded to subangular rhyolite 50%, subrounded to subangular granite 40%, subrounded to angular clear and milky quartz 10%, trace subrounded andesite, trace sandy siltstone fragments. Reaction to acid: very weak.
50-55	**GRAVELLY, CLAYEY, SILTY SAND**; brown, tan; sand 55%, clay and silt 30%, gravel 15%. Gravel fraction: subrounded to angular rhyolite 50%, subrounded to angular granite 30%, subrounded clear and milky quartz 15%, sandy siltstone fragments 5%. Reaction to acid: very weak.
55-60	**GRAVELLY, CLAYEY, SILTY SAND**; tan; sand 45%, clay and silt 40%, gravel 15%. Gravel fraction: subrounded to angular rhyolite 50%, subrounded to angular granite 30%, subrounded milky quartz 15%, sandy siltstone fragments 5%. Reaction to acid: none. Some clay balls.
60-65	**GRAVELLY, CLAYEY, SILTY SAND**; tan; sand 60%, clay and silt 30%, gravel 10%. Gravel fraction: subrounded granite 50%, subrounded to subangular andesite 30%, subrounded to angular rhyolite 10%, subrounded clear and milky quartz 10%, trace sandy siltstone fragments. Reaction to acid: none. Trace of clay balls.
65-70	**GRAVELLY, CLAYEY, SILTY SAND**; tan; sand 65%, clay and silt 30%, gravel 5%. Gravel fraction: subrounded rhyolite 50%, subrounded granite 40%, subrounded to angular milky quartz 10%, trace subrounded andesite, trace sandy siltstone fragments. Reaction to acid: very weak. Trace of clay balls.
70-75	**GRAVELLY, CLAYEY, SILTY SAND**; tan; sand 60%, clay and silt 30%, gravel 10%. Gravel fraction: subrounded to angular rhyolite 40%, subrounded granite 30%, subrounded to subangular andesite 10%, subrounded milky quartz 20%, trace sandy siltstone fragments. Reaction to acid: none. Some clay balls.

LITHOLOGIC DESCRIPTION
FOR DRILL CUTTINGS SAMPLES
TUCSON WATER MONITOR WELL (D-16-10)8bcd[WR-159A]

DEPTH (Feet)	DESCRIPTION
75-80	**GRAVELLY, CLAYEY, SILTY SAND**; tan; sand 65%, clay and silt 30%, gravel 5%. Gravel fraction: subrounded rhyolite 60%, subrounded granite 20%, subrounded clear and milky quartz 15%, subangular andesite 5%, trace sandy siltstone fragments. Reaction to acid: none. Trace of clay balls.
80-85	**GRAVELLY, CLAYEY, SILTY SAND**; tan; sand 50%, clay and silt 30%, gravel 20%. Gravel fraction: subrounded to subangular rhyolite 50%, subangular granite 30%, subrounded milky quartz 15%, subrounded andesite 5%, trace sandy siltstone fragments. Reaction to acid: none.
85-90	**GRAVELLY, CLAYEY, SILTY SAND**; tan; sand 50%, clay and silt 40%, gravel 10%. Gravel fraction: subrounded rhyolite 60%, subrounded clear and milky quartz 25%, subrounded basalt 5%, subrounded andesite 5%, sandy siltstone fragments 5%. Reaction to acid: none. Moderate clay balls.
90-95	**GRAVELLY, CLAYEY, SILTY SAND**; tan; sand 50%, clay and silt 40%, gravel 10%. Gravel fraction: subrounded rhyolite 40%, subrounded granite 30%, subrounded clear and milky quartz 25%, subrounded andesite 5%, trace sandy siltstone fragments. Reaction to acid: none. Some clay balls.
95-100	**GRAVELLY, CLAYEY, SILTY SAND**; brown, tan; sand 40%, clay and silt 40%, gravel 20%. Gravel fraction: subrounded granite 40%, subrounded to angular rhyolite 30%, subrounded clear and milky quartz 20%, subrounded to angular andesite 10%. Reaction to acid: none. Trace of clay balls.
100-105	**GRAVELLY, CLAYEY, SILTY SAND**; brown, tan; sand 55%, clay and silt 30%, gravel 15%. Gravel fraction: subrounded to angular rhyolite 40%, subrounded granite 30%, subrounded milky quartz 20%, subrounded to angular andesite 10%, trace sandy siltstone fragments. Reaction to acid: none. Trace of clay balls.
105-110	**GRAVELLY, CLAYEY, SILTY SAND**; tan; sand 45%, clay and silt 40%, gravel 15%. Gravel fraction: subrounded to angular rhyolite 50%, subrounded to subangular granite 30%, subrounded milky quartz 20%, trace sandy siltstone fragments. Reaction to acid: none. Some clay balls.

LITHOLOGIC DESCRIPTION
FOR DRILL CUTTINGS SAMPLES
TUCSON WATER MONITOR WELL (D-16-10)8bcd[WR-159A]

DEPTH (Feet)	DESCRIPTION
110-115	**GRAVELLY, CLAYEY, SILTY SAND**; brown, tan; sand 65%, clay and silt 20%, gravel 15%. Gravel fraction: subrounded to angular rhyolite 50%, subrounded granite 30%, subrounded milky quartz 20%, trace subrounded andesite, trace sandy siltstone fragments. Reaction to acid: none. Trace clay balls.
115-120	**GRAVELLY, CLAYEY, SILTY SAND**; brown, tan; sand 70%, clay and silt 20%, gravel 10%. Gravel fraction: subrounded to angular granite 50%, subrounded to angular rhyolite 40%, subrounded milky and clear quartz 10%, trace sandy siltstone fragments. Reaction to acid: none. Trace clay balls.
120-125	**GRAVELLY, SANDY, CLAYEY SILT**; tan; clay and silt 60%, sand 35%, gravel 5%. Gravel fraction: subrounded rhyolite 50%, subrounded granite 30%, subrounded to subangular milky quartz 20%. Reaction to acid: none. Abundant clay balls.
125-130	**SANDY, SILTY CLAY**; tan; clay and silt 75%, sand 25%, trace gravel. Reaction to acid: none.
130-135	**CLAYEY, SILTY SAND**; tan; sand 60%, clay and silt 40%, trace gravel. Gravel fraction: subrounded rhyolite 60%, subrounded milky quartz 40%. Reaction to acid: very weak. Moderate number of clay balls.
135-140	**SANDY, CLAYEY SILT**; tan; clay and silt 50%, sand 50%, trace gravel. Gravel fraction: subrounded to subangular rhyolite 60%, subrounded to angular milky quartz 40%. Reaction to acid: none. Abundant clay balls.
140-145	**GRAVELLY, CLAYEY, SILTY SAND**; brown; sand 50%, clay and silt 40%, gravel 10%. Gravel fraction: subrounded to subangular rhyolite 70%, subrounded to subangular milky quartz 30%, trace sandy siltstone fragments. Reaction to acid: none. Moderate clay balls.
145-150	**GRAVELLY, CLAYEY, SILTY SAND**; brown; sand 60%, clay and silt 30%, gravel 10%. Gravel fraction: subrounded to angular rhyolite 50%, subrounded granite 30%, subrounded quartz 20%. Reaction to acid: none. Moderate clay balls.
150-155	**GRAVELLY, CLAYEY, SILTY SAND**; brown; sand 60%, clay and silt 30%, gravel 10%. Gravel fraction: subangular to angular rhyolite 50%, subrounded granite 30%, subrounded to angular clear and milky quartz 20%, trace sandy siltstone fragments, trace angular basalt. Reaction to acid: none. Some clay balls.

LITHOLOGIC DESCRIPTION
FOR DRILL CUTTINGS SAMPLES
TUCSON WATER MONITOR WELL (D-16-10)8bcd[WR-159A]

DEPTH (Feet)	DESCRIPTION
155-160	**GRAVELLY, CLAYEY, SILTY SAND**; brown; sand 60%, clay and silt 20%, gravel 20%. Gravel fraction: subrounded to angular rhyolite 70%, subrounded to subangular milky quartz 20%, subrounded granite 10%. Reaction to acid: none. Trace clay balls.
160-165	**CLAYEY, SILTY, GRAVELLY SAND**; brown; sand 55%, gravel 30%, clay and silt 15%. Gravel fraction: subrounded to angular rhyolite 75%, subrounded to angular milky quartz 20%, sandy siltstone fragments 5%. Reaction to acid: none. Some clay balls.
165-170	**GRAVELLY, CLAYEY, SILTY SAND**; brown; sand 60%, clay and silt 30%, gravel 10%. Gravel fraction: subrounded to angular rhyolite 65%, subrounded to angular milky quartz 20%, subrounded granite 10%, sandy siltstone fragments 5%. Reaction to acid: none. Some clay balls.
170-175	**GRAVELLY, CLAYEY, SILTY SAND**; brown; sand 60%, clay and silt 30%, gravel 10%. Gravel fraction: subrounded to angular rhyolite 75%, subrounded to angular clear and milky quartz 20%, siltstone fragments 5%. Reaction to acid: none. Moderate clay balls.
175-180	**GRAVELLY, CLAYEY, SILTY SAND**; brown; sand 55%, clay and silt 30%, gravel 15%. Gravel fraction: subrounded to angular rhyolite 70%, subrounded milky quartz 20%, subrounded granite 5%, siltstone fragments 5%. Reaction to acid: none. Moderate clay balls.
180-185	**GRAVELLY, CLAYEY, SILTY SAND**; brown; sand 60%, clay and silt 30%, gravel 10%. Gravel fraction: subrounded to angular rhyolite 65%, subrounded to angular milky quartz 20%, subrounded granite 10%, siltstone fragments 5%. Reaction to acid: very weak. Moderate clay balls.
185-190	**GRAVELLY, CLAYEY, SILTY SAND**; brown; sand 55%, clay and silt 30%, gravel 15%. Gravel fraction: subrounded to angular rhyolite 80%, subrounded to angular milky quartz 10%, angular basalt 5%, siltstone fragments 5%. Reaction to acid: very weak. Some clay balls.
190-195	**GRAVELLY, CLAYEY, SILTY SAND**; brown; sand 60%, clay and silt 30%, gravel 10%. Gravel fraction: subrounded to angular rhyolite 80%, subrounded milky quartz 15%, siltstone fragments 5%. Reaction to acid: none. Some clay balls.

LITHOLOGIC DESCRIPTION
FOR DRILL CUTTINGS SAMPLES
TUCSON WATER MONITOR WELL (D-16-10)8bcd[WR-159A]

DEPTH (Feet)	DESCRIPTION
195-200	**GRAVELLY, CLAYEY, SILTY SAND**; brown; sand 50%, clay and silt 40%, gravel 10%. Gravel fraction: subrounded to angular rhyolite 75%, subrounded to angular clear and milky quartz 20%, siltstone fragments 5%, trace subrounded granite. Reaction to acid: very weak. Moderate clay balls.
200-205	**GRAVELLY, CLAYEY, SILTY SAND**; brown; sand 55%, clay and silt 30%, gravel 15%. Gravel fraction: subrounded to angular rhyolite 75%, subrounded to angular milky quartz 20%, subrounded granite 5%, trace siltstone fragments. Reaction to acid: very weak. Some clay balls.
205-210	**GRAVELLY, CLAYEY, SILTY SAND**; brown; sand 65%, clay and silt 30%, gravel 5%. Gravel fraction: subrounded to angular rhyolite 85%, subrounded to angular milky quartz 15%, trace subangular granite, trace siltstone fragments. Reaction to acid: weak. Trace of clay balls.
210-215	**GRAVELLY, CLAYEY, SILTY SAND**; brown; sand 60%, clay and silt 30%, gravel 10%. Gravel fraction: subrounded to angular rhyolite 70%, subrounded granite 10%, subrounded to subangular quartz 15%, sandy siltstone fragments 5%. Reaction to acid: moderate. Some clay balls.

TOTAL DEPTH DRILLED: 215 FEET

LITHOLOGIC DESCRIPTION
FOR DRILL CUTTINGS SAMPLES
TUCSON WATER MONITOR WELL (D-16-10)8bca1[WR-160A]

DEPTH (Feet)	DESCRIPTION
0-5	**CLAYEY, SILTY, SAND**; dark brown; sand 70%, clay and silt 30%. Reaction to acid: very weak.
5-10	**GRAVELLY, CLAYEY, SILTY SAND**; dark brown; sand 75%, clay and silt 20%, gravel 5%. Gravel fraction: subrounded granite 70%, subrounded rhyolite 20%, subrounded drusy and milky quartz 10%, trace subrounded feldspar. Reaction to acid: very weak.
10-15	**GRAVELLY, CLAYEY, SILTY SAND**; dark brown; sand 75%, clay and silt 20%, gravel 5%. Gravel fraction: subrounded granite 80%, subrounded rhyolite 10%, subrounded milky quartz 10%, trace subrounded feldspar. Reaction to acid: very weak.
15-20	**GRAVELLY, CLAYEY, SILTY SAND**; brown; sand 80%, gravel 10%, clay and silt 10%. Gravel fraction: subrounded granite 80%, subrounded basalt 10%, subrounded drusy and milky quartz 10%, trace subrounded feldspar. Reaction to acid: very weak.
20-25	**NO SAMPLE**
25-30	**CLAYEY, SILTY, GRAVELLY SAND**; tan; sand 70%, gravel 20%, clay and silt 10%. Gravel fraction: subrounded to angular rhyolite 40%, subrounded to angular granite 30%, subrounded to subangular clear and milky quartz 30%, trace subrounded basalt, trace sandy siltstone fragments. Reaction to acid: none.
30-35	**CLAYEY, SILTY, GRAVELLY SAND**; tan; sand 60%, gravel 25%, clay and silt 15%. Gravel fraction: subrounded to angular rhyolite 50%, subrounded to angular granite 30%, subrounded to angular clear and milky quartz 20%, trace sandy siltstone fragments. Reaction to acid: none.
35-40	**GRAVELLY, CLAYEY, SILTY SAND**; tan; sand 65%, clay and silt 25%, gravel 10%. Gravel fraction: subrounded to angular rhyolite 40%, subrounded to subangular granite 30%, subrounded to subangular clear and milky quartz 25%, subrounded to angular andesite 5%, trace sandy siltstone fragments. Reaction to acid: none.
40-45	**GRAVELLY, CLAYEY, SILTY SAND**; brown, tan; sand 55%, clay and silt 30%, gravel 15%. Gravel fraction: subrounded granite 40%, subrounded to angular rhyolite 30%, subrounded to angular clear and milky quartz 25%, subrounded andesite 5%, trace sandy siltstone fragments. Reaction to acid: none. Some clay balls.

LITHOLOGIC DESCRIPTION
FOR DRILL CUTTINGS SAMPLES
TUCSON WATER MONITOR WELL (D-16-10)8bca1[WR-160A]

DEPTH (Feet)	DESCRIPTION
45-50	**GRAVELLY, CLAYEY, SILTY SAND**; tan, brown; sand 55%, clay and silt 30%, gravel 15%. Gravel fraction: subrounded granite 45%, subrounded to angular rhyolite 35%, subrounded milky quartz 20%, trace subrounded quartzite fragments, trace sandy siltstone fragments. Reaction to acid: none. Some clay balls.
50-55	**GRAVELLY, CLAYEY, SILTY SAND**; tan, brown; sand 45%, clay and silt 40%, gravel 15%. Gravel fraction: subrounded to angular rhyolite 40%, subrounded granite 35%, subrounded clear and milky quartz 25%, trace subrounded to subangular basalt. Reaction to acid: very weak. Some clay balls.
55-60	**GRAVELLY, CLAYEY, SILTY SAND**; tan, brown; sand 55%, clay and silt 30%, gravel 15%. Gravel fraction: subrounded to subangular granite 40%, subrounded to angular rhyolite 30%, subrounded to angular milky quartz 25%, subrounded andesite 5%, trace sandy siltstone fragments. Reaction to acid: none. Trace of clay balls.
60-65	**GRAVELLY, CLAYEY, SILTY SAND**; tan; sand 50%, clay and silt 40%, gravel 10%. Gravel fraction: subrounded to angular rhyolite 50%, subrounded granite 30%, subrounded milky quartz 15%, subrounded andesite 5%, trace subrounded basalt. Reaction to acid: very weak. Some clay balls.
65-70	**GRAVELLY, CLAYEY, SILTY SAND**; tan; sand 65%, clay and silt 30%, gravel 5%. Gravel fraction: subrounded rhyolite 40%, subrounded granite 30%, subrounded milky quartz 25%, subrounded andesite 5%, trace subrounded basalt. Reaction to acid: very weak. Some clay balls.
70-75	**GRAVELLY, CLAYEY, SILTY SAND**; brown, tan; sand 55%, clay and silt 40%, gravel 5%. Gravel fraction: subrounded granite 40%, subrounded to angular rhyolite 30%, subrounded clear and milky quartz 30%, trace subangular basalt, trace subrounded to angular andesite. Reaction to acid: very weak.
75-80	**GRAVELLY, SANDY, SILTY CLAY**; tan; clay and silt 60%, sand 40%, trace gravel. Gravel fraction: subrounded to angular rhyolite 60%, subrounded clear and milky quartz 40%, trace subrounded andesite. Reaction to acid: none. Abundant clay balls.

LITHOLOGIC DESCRIPTION
FOR DRILL CUTTINGS SAMPLES
TUCSON WATER MONITOR WELL (D-16-10)8bca1[WR-160A]

DEPTH (Feet)	DESCRIPTION
80-85	**GRAVELLY, CLAYEY, SILTY SAND**; tan; sand 65%, clay and silt 30%, gravel 5%. Gravel fraction: subrounded to angular rhyolite 50%, subrounded clear and milky quartz 40%, subrounded granite 10%. Reaction to acid: none. Some clay balls.
85-90	**GRAVELLY, CLAYEY, SILTY SAND**; brown, tan; sand 45%, clay and silt 30%, gravel 25%. Gravel fraction: subrounded to angular granite 40%, subrounded to angular rhyolite 30%, subrounded to angular clear and milky quartz 30%, trace, sandy siltstone fragments, trace subrounded basalt. Reaction to acid: none. Trace of clay balls.
90-95	**GRAVELLY, CLAYEY, SILTY SAND**; brown, tan; sand 50%, clay and silt 30%, gravel 20%. Gravel fraction: subrounded to angular rhyolite 40%, subrounded granite 30%, subrounded to subangular clear and milky quartz 30%, trace subrounded basalt, trace sandy siltstone fragments. Reaction to acid: none.
95-100	**GRAVELLY, CLAYEY, SILTY SAND**; brown, tan; sand 50%, clay and silt 30%, gravel 20%. Gravel fraction: subrounded to subangular rhyolite 40%, subrounded granite 35%, subrounded clear and milky quartz 25%, trace sandy siltstone and siltstone fragments. Reaction to acid: none.
100-105	**GRAVELLY, CLAYEY, SILTY SAND**; tan; sand 50%, clay and silt 40%, gravel 10%. Gravel fraction: subrounded rhyolite 40%, subrounded granite 30%, subrounded to angular milky quartz 25%, subrounded andesite 5%, trace sandy siltstone fragments. Reaction to acid: none. Moderate clay balls.
105-110	**GRAVELLY, CLAYEY, SILTY SAND**; tan, brown; sand 50%, clay and silt 30%, gravel 20%. Gravel fraction: subrounded to angular rhyolite 45%, subrounded to angular granite 35%, subrounded milky quartz 20%, trace sandy siltstone fragments. Reaction to acid: none.
110-115	**GRAVELLY, CLAYEY, SILTY SAND**; tan, brown; sand 50%, clay and silt 30%, gravel 20%. Gravel fraction: subrounded to angular rhyolite 40%, subrounded to angular granite 30%, subrounded to angular milky quartz 25%, subrounded to subangular andesite 5%, trace claystone fragments. Reaction to acid: none.

LITHOLOGIC DESCRIPTION
FOR DRILL CUTTINGS SAMPLES
TUCSON WATER MONITOR WELL (D-16-10)8bca1[WR-160A]

DEPTH (Feet)	DESCRIPTION
115-120	**GRAVELLY, CLAYEY, SILTY SAND**; brown; sand 55%, clay and silt 40%, gravel 5%. Gravel fraction: subrounded rhyolite 50%, subrounded granite 25%, subrounded milky quartz 20%, subrounded andesite 5%, trace subrounded basalt, trace siltstone fragments. Reaction to acid: none. Moderate clay balls.
120-125	**SANDY, SILTY CLAY**; brown; clay and silt 80%, sand 20%, trace gravel. Gravel fraction: Subrounded to rounded rhyolite 100%. Reaction to acid: none.
125-130	**SANDY, SILTY CLAY**; brown; clay and silt 60%, sand 40%, trace gravel. Gravel fraction: subrounded to angular rhyolite 70%, subrounded to subangular milky quartz 30%. Reaction to acid: none. Abundant clay balls.
130-135	**SANDY, SILTY SAND**; brown; clay and silt 70%, sand 30%, trace gravel. Gravel fraction: subrounded rhyolite 50%, subrounded to subangular granite 40%, subrounded milky quartz 10%. Reaction to acid: none. Abundant clay balls.
135-140	**GRAVELLY, SANDY, CLAYEY SILT**; brown; clay and silt 50%, sand 30%, gravel 20%. Gravel fraction: subrounded to angular rhyolite 60%, subrounded granite 30%, subrounded clear and milky quartz 10%. Reaction to acid: none. Moderate clay balls.
140-145	**GRAVELLY, SANDY, SILTY CLAY**; brown; clay and silt 50%, sand 45%, gravel 5%. Gravel fraction: subrounded rhyolite 70%, subrounded granite 20%, subrounded milky quartz 10%. Reaction to acid: none. Abundant clay balls.
145-150	**GRAVELLY, SANDY, CLAYEY SILT**; brown; clay and silt 50%, sand 40%, gravel 10%. Gravel fraction: subrounded to angular rhyolite 70%, subrounded milky quartz 15%, subrounded granite 10%, subrounded to angular basalt 5%. Reaction to acid: none. Abundant clay balls.
150-155	**GRAVELLY, CLAYEY, SILTY SAND**; brown; sand 55%, clay and silt 30%, gravel 15%. Gravel fraction: subrounded to angular rhyolite 75%, subrounded granite 10%, subrounded milky quartz 10%, subangular to angular basalt 5%, trace siltstone fragments. Reaction to acid: none. Some clay balls.

LITHOLOGIC DESCRIPTION
FOR DRILL CUTTINGS SAMPLES
TUCSON WATER MONITOR WELL (D-16-10)8bca1[WR-160A]

DEPTH (Feet)	DESCRIPTION
155-160	**GRAVELLY, SILTY, CLAYEY SAND**; brown; sand 45%, clay and silt 40%, gravel 15%. Gravel fraction: subangular to angular rhyolite 80%, subrounded milky quartz 15%, siltstone fragments 5%. Reaction to acid: none. Moderate clay balls.
160-165	**GRAVELLY, CLAYEY, SILTY SAND**; brown; sand 50%, clay and silt 30%, gravel 20%. Gravel fraction: subangular to angular rhyolite 70%, subrounded granite 20%, subrounded milky quartz 10%, trace sandy siltstone fragments. Reaction to acid: none. Some clay balls.
165-170	**GRAVELLY, CLAYEY, SILTY SAND**; brown; sand 55%, clay and silt 30%, gravel 15%. Gravel fraction: subangular to angular rhyolite 70%, subrounded to angular granite 15%, subrounded milky quartz 10%, siltstone fragments 5%. Reaction to acid: none. Some clay balls.
170-175	**GRAVELLY, CLAYEY, SILTY SAND**; brown; sand 45%, clay and silt 30%, gravel 25%. Gravel fraction: subrounded to angular rhyolite 75%, subrounded milky quartz 15%, subrounded granite 5%, siltstone fragments 5%. Reaction to acid: none. Some clay balls.
175-180	**GRAVELLY, CLAYEY, SILTY SAND**; brown; sand 50%, clay and silt 30%, gravel 20%. Gravel fraction: subrounded to angular rhyolite 85%, subangular milky quartz 10%, claystone fragments 5%. Reaction to acid: none. Some clay balls.
180-185	**GRAVELLY, CLAYEY, SILTY SAND**; brown; sand 50%, clay and silt 30%, gravel 20%. Gravel fraction: subrounded to angular rhyolite 90%, subrounded milky quartz 10%, trace subrounded granite, trace siltstone fragments. Reaction to acid: none. Some clay balls.

TOTAL DEPTH DRILLED: 185 FEET

APPENDIX D

LITHOLOGIC DESCRIPTION
FOR SAMPLES FROM PIEZOMETERS
BRAWLEY WASH PILOT SURFACE RECHARGE SITE
PIMA COUNTY, ARIZONA

APPENDIX D

CONTENTS

LITHOLOGIC DESCRIPTION FOR SAMPLES FROM TUCSON WATER PIEZOMETER (D-16-10)8bdb3[WR-166A]

DEPTH (Feet)	SAMPLE TYPE	BLOWS PER SIX-INCH PENETRATION	DESCRIPTION
			RECENT ALLUVIUM
5	Split-spoon[a]	5/5/4	**SANDY SILT AND CLAY**; light tan; silt and clay 80%, sand 20%; unconsolidated, slightly moist. Reaction to acid: moderate.
10	Split-spoon	2/3/3	**SAND**; light brown; fine to medium, unconsolidated, slightly moist. Reaction to acid: none.
15	Split-spoon	2/3/4	**SANDY SILT**; dark brown; silt and clay 80%, sand 20%; unconsolidated, moist. Reaction to acid: strong.
20	Split-spoon	5/13/14	**GRAVELLY SAND**; gray-brown; sand 95%, gravel 5%; unconsolidated, slightly moist. Sand is fine to coarse. Gravel fraction: subrounded granules and coarse pebbles; quartz 60%, granite 30%, andesite 10%. Reaction to acid: none.
25	Brass-ring[b]	9/18	**SANDY GRAVEL**; gray-brown; gravel 60%, sand 40%; unconsolidated, slightly moist. Gravel fraction: subrounded granules and coarse pebbles; quartz 30%, granite 40%, andesite 30%. Reaction to acid: none.
			FORT LOWELL FORMATION
30	Split-spoon	9/15/25	**CLAYEY, SILTY, SANDY GRAVEL**; red-gray; gravel 70%, sand 20%, silt and clay 10%; moderately consolidated, moist. Gravel fraction: angular to subrounded granules and pebbles; granite 40%, andesite 40%, quartz 20%. Reaction to acid: none.

LITHOLOGIC DESCRIPTION
FOR SAMPLES FROM
TUCSON WATER PIEZOMETER (D-16-10)8bdb3[WR-166A]

DEPTH (Feet)	SAMPLE TYPE	BLOWS PER SIX-INCH PENETRATION	DESCRIPTION
35	Split-spoon	21/30/43	**SANDY, SILTY GRAVEL**; red-gray; gravel 70%, silt and clay 20%, sand 10%; moderately consolidated, moist. Gravel fraction: angular to subrounded granules and pebbles; granite 40%, andesite 40%, quartz 20%. Reaction to acid: none.
40	Split-spoon	9/35/42	**CLAYEY, SILTY, SANDY GRAVEL**; red-gray; gravel 70%, sand 15%, silt and clay 15%; moderately consolidated, moist. Gravel fraction: angular to subrounded granules and pebbles; andesite 70%, granite 30%. Reaction to acid: none.
45	Split-spoon	28/49/21(4")[c]	**SANDY, SILTY GRAVEL**; red-gray; gravel 70%, silt and clay 20%, sand 10%; well consolidated, moist. Gravel fraction: well rounded granules and pebbles; andesite 40%, granite 30%, quartz 30%. Reaction to acid: none.
55	Brass-ring	28/24	**SILTY SAND AND GRAVEL**; gray; sand 40%, gravel 40%, silt and clay 20%; weakly consolidated, moist. Gravel fraction: subrounded granules and coarse pebbles; quartz 70%, granite 20%, andesite 10%. Reaction to acid: none.
65	Split-spoon	27/28/29	**SILTY SAND**; red-brown; sand 70%, silt and clay 30%, trace gravel; moderately consolidated, moist. Gravel fraction: subangular to subrounded granules and pebbles; quartz 40%, granite 30%, andesite 30%. Reaction to acid: none.
70	Brass-ring	80(6")	**NO SAMPLE RECOVERY**
72	Split-spoon	21/32/34	**SILTY, GRAVELLY SAND**; red-brown; sand 40%, gravel 40%, silt and clay 20%; weakly consolidated, moist. Gravel fraction: subangular to subrounded granules and pebbles; gravel 50%, quartz 40%, andesite 10%. Reaction to acid: none.

ERROL L. MONTGOMERY & ASSOCIATES, INC.

LITHOLOGIC DESCRIPTION
FOR SAMPLES FROM
TUCSON WATER PIEZOMETER (D-16-10)8bdb3[WR-166A]

DEPTH (Feet)	SAMPLE TYPE	BLOWS PER SIX-INCH PENETRATION	DESCRIPTION
75	Split-spoon	9/16/25	**SILT AND CLAY**; red-brown; trace sand; well consolidated, very moist. Reaction to acid: none.
80	Split-spoon	9/13/12	**SILT AND CLAY**; red-brown; trace sand; well consolidated, very moist. Reaction to acid: none.
85	Split-spoon	47/57(5")	**SILTY, SANDY GRAVEL**; red-gray; gravel 60%, sand 30%, silt and clay 10%; weakly consolidated, moist. Gravel fraction: angular to sub-rounded granules and pebbles; rhyolite 70%, andesite 30%. Reaction to acid: none.
95	Split-spoon	29/105(4.5")	**SILTY, SANDY GRAVEL**; red-gray; gravel 50%, sand 30%, silt and clay 20%; weakly consolidated, moist. Gravel fraction: angular to sub-rounded granules and pebbles; rhyolite 60%, andesite 40%.
105	Split-spoon	34/45/33(3")	**NO SAMPLE RECOVERY.**
108	Split-spoon	100(4")	**GRAVELLY, SANDY SILT AND CLAY**; gray-brown; silt and clay 50%, sand 30%, gravel 20%; well consolidated, slightly moist. Gravel fraction: subangular to subrounded granules and pebbles; quartz 30%, granite 40%, volcanic rocks 30%. Reaction to acid: none.

AUGER REFUSAL
TOTAL DEPTH DRILLED: 108 FEET

[a] From split-spoon sampler driven 18 inches using 140 pound hammer

[b] From brass-ring bearing sampler driven 12 inches using 140 pound hammer

[c] Number of blows limited to 100 per sample; number in parentheses indicates penetration after 100 blows

LITHOLOGIC DESCRIPTION
FOR SAMPLES FROM
TUCSON WATER PIEZOMETER (D-16-10)8bdb4[WR-167A]

DEPTH (Feet)	SAMPLE TYPE	BLOWS PER SIX-INCH PENETRATION	DESCRIPTION
			RECENT ALLUVIUM
5	Auger[a]	---	**SANDY SILT**; tan; silt and clay 60%, sand 40%; unconsolidated, slightly moist. Reaction to acid: moderate.
10	Auger	---	**SILTY SAND**; tan; sand 60%, silt and clay 40%, trace gravel; unconsolidated, slightly moist. Gravel fraction: subrounded to rounded granules and pebbles; quartz, feldspar, and granite. Reaction to acid: moderate.
15	Auger	---	**GRAVELLY SAND**; brown; sand 85%, gravel 10%, silt and clay 5%; unconsolidated, slightly moist. Gravel fraction: subrounded to rounded granules and pebbles; quartz, feldspar, and granite. Reaction to acid: none.
20	Auger	---	**GRAVELLY SAND**; brown; sand 85%, gravel 10%, silt and clay 5%; unconsolidated, slightly moist. Gravel fraction: subrounded to rounded granules and coarse pebbles; quartz, feldspar, and granite. Reaction to acid: none.
25	Auger	---	**SILTY, GRAVELLY SAND**; brown; sand 60%, gravel 30%, silt and clay 10%; unconsolidated, slightly moist. Gravel fraction: rounded to subrounded granules, pebbles, and cobbles; quartz, granite, and andesite. Reaction to acid: none.

LITHOLOGIC DESCRIPTION
FOR SAMPLES FROM
TUCSON WATER PIEZOMETER (D-16-10)8bdb4[WR-167A]

DEPTH (Feet)	SAMPLE TYPE	BLOWS PER SIX-INCH PENETRATION	DESCRIPTION
			FORT LOWELL FORMATION
30	Split-spoon[b]	15/14/12	**SILTY, SANDY GRAVEL**; brown-gray; gravel 50%, sand 30%, silt and clay 20%; moderately consolidated, moist. Gravel fraction: angular to subangular granules and pebbles; quartz, feldspar, rhyolite and andesite. Reaction to acid: none.

TOTAL DEPTH DRILLED: 32 FEET

[a] From auger flights

[b] From split-spoon sampler driven 18 inches

LITHOLOGIC DESCRIPTION
FOR SAMPLES FROM
TUCSON WATER PIEZOMETER (D-16-10)8bdb5[WR-168A]

DEPTH (Feet)	SAMPLE TYPE	BLOWS PER SIX-INCH PENETRATION	DESCRIPTION
			RECENT ALLUVIUM
5	Auger[a]	---	**SANDY SILT**; tan; silt and clay 70%, sand 30%; unconsolidated, slightly moist. Reaction to acid: strong.
10	Auger	---	**SILTY SAND**; tan; sand 60%, silt and clay 40%, trace gravel; unconsolidated, slightly moist. Reaction to acid: moderate.
15	Auger	---	**SILTY SAND**; red-tan; sand 80%, silt and clay 20%, trace gravel; unconsolidated, slightly moist. Reaction to acid: none.
20	Split-spoon[b]	7/13/12	**GRAVELLY SAND**; gray; sand 80%, gravel 20%; unconsolidated, slightly moist. Gravel fraction: rounded to subrounded granules and pebbles; quartz 40%, volcanic rocks 40%, granite 20%. Reaction to acid: none.
			FORT LOWELL FORMATION
30	Split-spoon	8/6/8	**SILTY, SANDY GRAVEL**; gray; gravel 60%, sand 20%, silt and clay 20%; moderately consolidated, moist. Gravel fraction: angular to subangular granules and coarse pebbles; granite 80%, quartz 20%, trace volcanic rocks. Reaction to acid: none.
50	Split-spoon	27/31/40	**SILTY, GRAVELLY SAND**; red-brown; sand 40%, gravel 30%, silt and clay 30%; well consolidated; moist. Gravel fraction: angular to subangular granules and pebbles; volcanic rocks 80%, quartz 10%, granite 10%. Reaction to acid: none.

LITHOLOGIC DESCRIPTION
FOR SAMPLES FROM
TUCSON WATER PIEZOMETER (D-16-10)8bdb5[WR-168A]

DEPTH (Feet)	SAMPLE TYPE	BLOWS PER SIX-INCH PENETRATION	DESCRIPTION
70	Split-spoon	12/10/16	**SANDY SILT AND CLAY**; red-brown; silt and clay 80%, sand 20%; well consolidated, moist. Reaction to acid: none.

TOTAL DEPTH DRILLED: 70 FEET

[a] From auger flights

[b] From split-spoon sampler driven 18 inches

LITHOLOGIC DESCRIPTION
FOR SAMPLES FROM
TUCSON WATER PIEZOMETER (D-16-10)8bdb6[WR-169A]

DEPTH (Feet)	SAMPLE TYPE	BLOWS PER SIX-INCH PENETRATION	DESCRIPTION
			RECENT ALLUVIUM
5	Auger[a]	---	**SANDY SILT**; tan; silt and clay 90%, sand 10%; unconsolidated, slightly moist. Reaction to acid: strong.
10	Auger	---	**GRAVELLY, SILTY SAND**; tan; sand 50%, silt and clay 30%, gravel 20%; unconsolidated, slightly moist. Gravel fraction: rounded to subrounded granules and coarse pebbles; granite 80%, volcanic rocks 20%. Reaction to acid: moderate.
15	Auger	---	**GRAVELLY SAND**; brown; sand 70%, gravel 30%, trace silt and clay; unconsolidated, slightly moist. Gravel fraction: subangular to subrounded granules and pebbles; quartz 30%, granite 40%, volcanic rocks 30%. Reaction to acid: none.
20	Split-spoon[b]	14/13/11	**GRAVELLY SAND**; gray; sand 60%, gravel 40%, trace silt and clay; unconsolidated, slightly moist. Gravel fraction: angular to subrounded granules and pebbles; granite 60%, quartz 30%, volcanic rocks 10%. Reaction to acid: none.
25	Split-spoon	5/5/10	**GRAVELLY SAND**; gray; sand 60%, gravel 40%, trace silt and clay; unconsolidated, slightly moist. Gravel fraction: subangular to subrounded granules and coarse pebbles; granite 60%, quartz 30%, volcanic rocks 10%. Reaction to acid: none.

LITHOLOGIC DESCRIPTION
FOR SAMPLES FROM
TUCSON WATER PIEZOMETER (D-16-10)8bdb6[WR-169A]

DEPTH (Feet)	SAMPLE TYPE	BLOWS PER SIX-INCH PENETRATION	DESCRIPTION
			FORT LOWELL FORMATION
33	Split-spoon	24/34/30	**CLAYEY, SANDY GRAVEL**; red-gray; gravel 50%, sand 30%, silt and clay 20%; mderately consolidated, moist. Gravel fraction: angular to subangular granules and coarse pebbles; granite 50%, quartz 30%, volcanic rocks 20%. Reaction to acid: none.

TOTAL DEPTH DRILLED: 33 FEET

[a] From auger flights

[b] From split-spoon sampler driven 18 inches

LITHOLOGIC DESCRIPTION
FOR SAMPLES FROM
TUCSON WATER PIEZOMETER (D-16-10)8bca2[WR-170A]

DEPTH (Feet)	SAMPLE TYPE	BLOWS PER SIX-INCH PENETRATION	DESCRIPTION
			RECENT ALLUVIUM
5	Auger[a]	---	**SANDY SILT**; tan; silt and clay 60%, sand 40%; unconsolidated, slightly moist. Reaction to acid: moderate.
10	Auger	---	**SANDY SILT**; tan; silt and clay 80%, sand 20%; unconsolidated, slightly moist. Reaction to acid: moderate.
15	Auger	---	**GRAVELLY, SILTY SAND**; tan; sand 60%, silt and clay 30%, gravel 10%; unconsolidated, slightly moist. Gravel fraction: subangular to subrounded granules and pebbles; quartz, feldspar, granite and rhyolite. Reaction to acid: moderate.
20	Auger	---	**SILTY, SANDY GRAVEL**; brown; gravel 45%, sand 35%, silt and clay 20%; unconsolidated, slightly moist. Gravel fraction: subangular to rounded granules and coarse pebbles; quartz, feldspar, granite and rhyolite. Reaction to acid: weak.
25	Split-spoon[b]	11/16/24	**SANDY GRAVEL**; gray; gravel 60%, sand 40%, trace silt and clay; unconsolidated, slightly moist. Gravel fraction: subangular to subrounded granules, pebbles, and cobbles; granite 80%, volcanic rocks 20%. Reaction to acid: none.
30	Split-spoon	14/14/15	**GRAVELLY SAND**; brown; sand 60%, gravel 40%, trace silt and clay; unconsolidated, slightly moist. Gravel fraction: subrounded to rounded granules and pebbles; quartz 50%, granite 30%, volcanic rocks 20%. Reaction to acid: none.

LITHOLOGIC DESCRIPTION
FOR SAMPLES FROM
TUCSON WATER PIEZOMETER (D-16-10)8bca2[WR-170A]

DEPTH (Feet)	SAMPLE TYPE	BLOWS PER SIX-INCH PENETRATION	DESCRIPTION
			FORT LOWELL FORMATION
35	Split-spoon	16/26/27	**CLAYEY, SANDY GRAVEL**; red-brown; gravel 50%, sand 30%, silt and clay 20%; well consolidated, moist. Gravel fraction: angular to subangular granules and pebbles; rhyolite 80%, granite 20%. Reaction to acid: none.

TOTAL DEPTH DRILLED: 35 FEET

[a] From auger flights

[b] From split-spoon sampler driven 18 inches

LITHOLOGIC DESCRIPTION
FOR SAMPLES FROM
TUCSON WATER PIEZOMETER (D-16-10)8bdb7[WR-171A]

DEPTH (Feet)	SAMPLE TYPE	BLOWS PER SIX-INCH PENETRATION	DESCRIPTION
			RECENT ALLUVIUM
5	Auger[a]	---	**SANDY SILT**; tan; silt and clay 80%, sand 20%; unconsolidated, slightly moist. Reaction to acid: moderate.
10	Auger	---	**SILTY, SANDY GRAVEL**; tan; gravel 65%, sand 20%, silt and clay 15%; unconsolidated, slightly moist. Gravel fraction: subangular to subrounded granules and pebbles; granite 50%, quartz 30%, volcanic rocks 20%. Reaction to acid: weak.
15	Auger	---	**GRAVELLY SAND**; red-brown; sand 80%, gravel 20%, trace of silt and clay; unconsolidated, slightly moist. Gravel fraction: subangular to subrounded granules and coarse pebbles; granite 35%, volcanic rocks 35%, quartz 30%. Reaction to acid: none.
20	Auger	---	**SILTY, GRAVELLY SAND**; red-brown; sand 50%, gravel 30%, silt and clay 20%; unconsolidated, slightly moist. Gravel fraction: subangular to subrounded granules and coarse pebbles; granite 40%, quartz 30%, volcanic rocks 30%. Reaction to acid: none.
			FORT LOWELL FORMATION
30	Split-spoon	---	**SILTY, SANDY GRAVEL**; red-gray; gravel 50%, sand 30%, silt and clay 20%; well consolidated, moist. Gravel fraction: angular to subangular granules and coarse pebbles; volcanic rocks 70%, quartz 20%, granite 10%. Reaction to acid: none.

LITHOLOGIC DESCRIPTION
FOR SAMPLES FROM
TUCSON WATER PIEZOMETER (D-16-10)8bdb7[WR-171A]

DEPTH (Feet)	SAMPLE TYPE	BLOWS PER SIX-INCH PENETRATION	DESCRIPTION

TOTAL DEPTH DRILLED: 33 FEET

[a] From auger flights

[b] From split-spoon sampler driven 18 inches