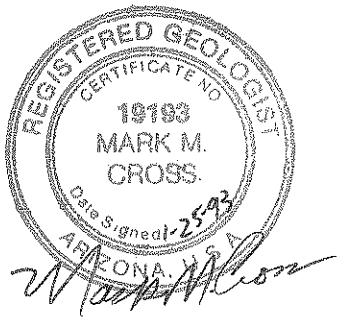
January 25, 1993
REPORT

PHASE B - TUCSON RECHARGE FEASIBILITY ASSESSMENT

ANALYSIS OF GROUNDWATER LEVEL RESPONSE DURING PILOT SURFACE RECHARGE OPERATIONS BRAWLEY WASH PILOT RECHARGE SITE PIMA COUNTY, ARIZONA



Prepared For

TUCSON WATER

by

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January 25, 1993

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Dear Bob:

In accordance with your instructions, we are submitting two copies of our report:

ANALYSIS OF GROUNDWATER LEVEL RESPONSE
DURING PILOT SURFACE RECHARGE OPERATIONS
BRAWLEY WASH PILOT SURFACE RECHARGE SITE
PIMA COUNTY, ARIZONA

If you have questions or require further discussion, please contact us.

Very truly yours,
ERROL L. MONTGOMERY & ASSOCIATES, INC.

Mark M. Cross

Enclosures (2)

cc w/enclosure: Bruce Johnson, Chief Hydrologist, Tucson Water (1)
Joe Babcock, Hydrologist, Tucson Water (1)

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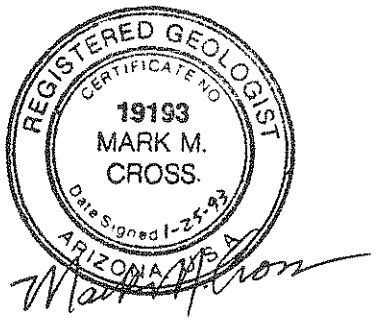
CONTENTS

	Page
SUMMARY AND CONCLUSIONS	1
INTRODUCTION	5
PILOT RECHARGE TESTING PROCEDURES	8
ANALYSIS OF GROUNDWATER LEVEL RESPONSE FOR PERIOD FROM FEBRUARY 12 THROUGH JULY 2, 1990	11
VADOSE ZONE PIEZOMETERS	11
Piezometer WR-170A	12
Piezometer WR-160B	13
Piezometer WR-160C	14
GROUNDWATER MONITOR WELLS	14
Monitor Well (D-16-10)8bcal[WR-160A]	16
Monitor Well (D-16-10)8bdbl[WR-159A]	17
Monitor Well (D-16-10)8bcd[WR-158A]	17
Monitor Well (D-16-10)8bdb2[WR-157A]	18
RESULTS FOR PERIOD FROM DECEMBER 7, 1990, THROUGH FEBRUARY 12, 1991	19
REFERENCES CITED	22



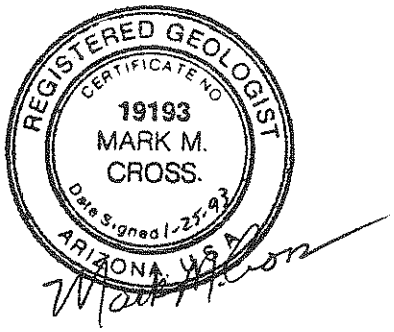
ILLUSTRATIONS

Figure

1 LOCATIONS OF WELLS AND PIEZOMETERS, BRAWLEY WASH PILOT SURFACE RECHARGE SITE

2 WATER LEVEL HYDROGRAPH FOR PIEZOMETERS WR-170A, WR-160B, AND WR-160C, AND MONITOR WELL WR-160A DURING PILOT SURFACE RECHARGE OPERATIONS AT BRAWLEY WASH SITE, FEBRUARY 12 THROUGH JULY 2, 1990

3 WATER LEVEL HYDROGRAPH FOR MONITOR WELLS WR-157A, WR-158A, WR-159A, AND WR-160A DURING PILOT SURFACE RECHARGE OPERATIONS AT BRAWLEY WASH SITE, FEBRUARY 12 THROUGH JULY 2, 1990



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SUMMARY AND CONCLUSIONS

Summary and conclusions for analysis of groundwater level response during pilot surface recharge operations at the Brawley Wash pilot recharge site are as follows:

1. Pilot surface recharge operations were conducted from February 12, 1990, through February 12, 1991. The source of water for pilot recharge operations was Tucson Water well (D-16-10)8bdd[AF-64]. During recharge operations, water level measurements were made in the pumped well AF-64, in four regional aquifer monitor wells, and in nine vadose zone piezometers. Results of water level measurements were used to:

   - Evaluate movement of water from the recharge basins to the regional aquifer during pilot recharge operations.

   - Evaluate the vertical and lateral extent of groundwater mounding during pilot recharge operations.

   - Develop data which could be used to project the magnitude of groundwater mounding from potential long-term full-scale recharge at the Brawley Wash site.

2. From February 12 through July 2, 1990, and from December 7, 1990, through February 12, 1991, water was supplied continuously from well AF-64 to the recharge basins, with the exception of brief and infrequent periods when well AF-64 was not pumping. Based on totalizer measurements obtained from the McCrometer flowmeters by CH2M HILL and Tucson Water, average pumping rate was 590 gallons per minute for the period from February 12 through July 2, and 580 gallons per minute for the period from December 7 through February 12. Groundwater level response was analyzed for these periods. During the period from July 2 through December 7, water was supplied intermittently due to frequent periods when well AF-64 was not pumping; groundwater level response was not analyzed for this period.

3. Design and operation of the recharge basins, infiltration data obtained during pilot recharge operations, and calculated infiltration rates were reported by CH2M HILL (1991). Reported infiltration rates for the period February through October, 1990, ranged from 0.4 to 0.7 feet per day for basin 2 and ranged from 8 to 19 feet per day for basin 4.

4. Prior to start of recharge operations, no perched groundwater was detected in the vadose zone piezometers. After recharge operations started, substantial amounts of perched groundwater were detected in piezometers WR-170A, WR-160B, and WR-160C. These three piezometers are located between test basins 2 and 4 near the geometric center of the area of recharge operations. Measurable amounts of perched groundwater were not detected in the remaining six piezometers, located southeast and northeast from basin 2.

5. Height of perched groundwater mounding was largest when infiltration was occurring in basin 4 and the waste basin, and was smallest when infiltration was occurring in basin 2 and the waste basin. As time after recharge started became larger, height of

perched groundwater mounding stabilized or became smaller, and water level rise in the regional aquifer became larger.

6. Piezometer WR-170A was completed to a depth of 34 feet, and was used to monitor occurrence of perched groundwater in the recent alluvium above the interface with the Fort Lowell Formation. Groundwater was detected in piezometer WR-170A beginning about 15 days after the start of recharge operations, or less than 1 day after the start of the first period of recharge testing at basin 4. Maximum height of perched groundwater mounding measured in piezometer WR-170A was 3.0 feet above the base of the piezometer, and occurred 17 days after the start of recharge operations, or 2 days after the start of the first testing period at basin 4.

7. Piezometer WR-160B was completed to a depth of 70 feet and was used to monitor occurrence of perched groundwater above fine-grained unit A in the Fort Lowell Formation. Groundwater was detected in piezometer WR-160B beginning approximately 5 days after start of recharge operations. Maximum height of perched groundwater mounding measured in piezometer WR-160B was 13.6 feet above the base of the piezometer, and occurred about 18 days after the start of recharge operations, or about 3 days after the start of the first period of recharge testing at basin 4.

8. Piezometer WR-160C was completed to a depth of 112.5 feet and was used to monitor occurrence of perched groundwater above fine-grained unit B in the Fort Lowell Formation. Groundwater was detected in piezometer WR-160C beginning approximately 14 days after start of recharge operations. Maximum height of perched groundwater mounding measured in piezometer WR-160C was 4.0 feet above the base of the piezometer, and occurred about 35 days after the start of recharge operations. As recharge operations continued, height of mounding became smaller.

9. Monitor wells WR-157A through WR-160A were used to monitor response of groundwater levels in the regional aquifer during pilot recharge operations. Water levels measured in the monitor wells before start of recharge operations ranged from about 150 to 152 feet below land surface. Beginning approximately 21 days after recharge started, water level rise occurred in the monitor wells due to recharge from the test and waste basins. Maximum water level rise occurred at the end of the 140-day period ending July 2. During the period from 21 to 140 days after recharge started, observed water level rise in the monitor wells was 12.30 feet at well WR-157A, 18.40 feet at well WR-158A, 14.23 feet at well WR-159A, and 23.34 feet at well WR-160A.

10. The principal objective of pilot recharge operations from December 7, 1990, through February 12, 1991, was to further evaluate occurrence of perched groundwater at piezometers located northeast and southeast from basin 2 by promoting larger infiltration rates in basin 2. Larger infiltration rates were promoted by excavating trenches to expose permeable sand and gravel deposits beneath the floor of basin 2.

11. Results of pilot recharge operations during the period from December 7, 1990, through February 12, 1991, indicate that infiltration rate for basin 2 was about twice as large as during previous recharge periods, or about 1 foot per day. The larger infiltration rate for basin 2 did not result in larger height of perched groundwater mounding at piezometers located between basins 2 and 4, and measurable amounts of perched groundwater were not detected at piezometers located northeast and southeast from basin 2. These results indicate that the increase in infiltration rate for basin 2 was not large enough to cause a substantial increase in the height and lateral extent of perched groundwater mounding in the recent alluvium or in the Fort Lowell Formation above fine-grained units A and B.

INTRODUCTION

This report gives results for analysis of groundwater level response during pilot surface recharge operations at the Brawley Wash site. Objectives of the analysis were to:

1. Evaluate movement of water from the recharge basins to the regional aquifer during pilot recharge operations.

2. Evaluate the vertical and lateral extent of groundwater mounding during pilot recharge operations.

3. Develop data which could be used to project the magnitude of groundwater mounding from potential long-term full-scale recharge at the Brawley Wash site.

The source of water for pilot recharge operations was Tucson Water well (D-16-10)8bdd[AF-64]. During recharge operations, water level measurements were made in the pumped well AF-64, in four regional aquifer monitor wells, and in nine vadose zone piezometers. The monitor wells were used to monitor groundwater mounding in the upper Tinaja beds which comprise the regional aquifer at the Brawley Wash site. The vadose zone piezometers were used to monitor occurrence of groundwater: 1) in the recent alluvium above the Fort Lowell Formation; 2) in the Fort Lowell Formation above fine-grained unit A; and 3) in the Fort Lowell Formation above fine-grained unit B. Hydrogeologic conditions, and drilling and construction of the monitor wells and piezometers, were described in a previous report: "RESULTS OF HYDROGEOLOGIC INVESTIGATIONS, BRAWLEY WASH PILOT SURFACE RECHARGE SITE, PIMA COUNTY, ARIZONA" (Montgomery & Associates, 1990a).

Well numbers and identifiers for the monitor wells and piezometers are as follows:

MONITOR WELLS

(D-16-10)8bdb1[WR-157A] — Well Number / Well Identifier

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

PIEZOMETERS

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

Locations for wells and piezometers at the Brawley Wash test site are shown on Figure 1.

Vadose zone piezometers WR-170A, WR-171A, WR-167A, and WR-169A were completed to depths ranging from 31 to 34 feet, and were used to monitor occurrence of groundwater in the recent alluvium above the interface with the underlying Fort Lowell Formation. Piezometers WR-160B and WR-168A were completed to depths of 70 and 69 feet, and were used to monitor occurrence of groundwater above fine-grained unit A. Piezometers WR-159B, WR-160C, and WR-166A were completed to depths ranging from 105 to 123 feet, and were used to monitor occurrence of groundwater above fine-grained unit B.

Pilot surface recharge operations were conducted from February 12, 1990, through February 12, 1991. From February 12 through July 2, 1990, water was supplied continuously from well AF-64 to the recharge basins, with the exception of brief and infrequent periods when well AF-64 was not pumping. From July 2 through October 24, 1990, water was supplied intermittently due to frequent periods when well AF-64 was not pumping. From October 24 through December 7, 1990, well AF-64 was not pumped, and no water was supplied to the recharge basins. This report gives results for analysis of groundwater level response during the period from February 12 through July 2, 1990. Design and

operation of the recharge basins, infiltration data obtained during pilot recharge operations, and calculated infiltration rates were reported by CH2M HILL (1991). Reported infiltration rates for the period February through October, 1990, ranged from 0.4 to 0.7 feet per day for basin 2, and ranged from 8 to 19 feet per day for basin 4.

Rates from December 7, 1990, through February 12, 1991, water was supplied continuously from well AF-64 to the recharge basins, with the exception of brief and infrequent periods when well AF-64 was not pumping. The principal objective of pilot recharge operations during this period was to further evaluate occurrence of perched groundwater at piezometers located northeast and southeast from basin 2 by promoting larger infiltration rates in basin 2. Larger infiltration rates were promoted by excavating trenches to expose permeable sand and gravel deposits beneath the floor of basin 2. Excavation of trenches and results for pilot recharge operations conducted after the trenches were excavated are summarized in this report.

PILOT RECHARGE TESTING PROCEDURES

Prior to pumping well AF-64 for pilot surface recharge operations, water levels at monitor wells WR-157A, WR-158A, WR-159A, and WR-160A were monitored for a period of about 7 months. Analysis of water level hydrographs for the monitor wells indicates that average rate of groundwater level rise was 0.003 feet per day for the period from November 1989 until pumping started on February 8, 1990.

Pumping at well AF-64 started at 13:30 on February 8, 1990. During the first 4 days of pumping, water was discharged into a concrete-lined irrigation canal at well AF-64, conveyed northwest from well AF-64 via the canal, and siphoned from the canal onto retired farmland. Beginning at 10:30 on February 12, water was conveyed via pipeline to the pilot recharge basins approximately 1,450 feet northwest from the pumped well (**Figure 1**).

Pumping rate was measured using a Data Industrial flowmeter installed in the discharge pipeline at pumped well AF-64, a McCrometer flowmeter installed in the water supply pipeline for the pilot recharge test basins, and a McCrometer flowmeter installed in the water supply pipeline for the waste basin. A gate valve installed downstream from the Data Industrial flowmeter was used to maintain constant discharge rate.

During the 140-day period from February 12 through July 2, 1990, water was supplied continuously from well AF-64 to the recharge basins, with the exception of six periods when well AF-64 was not pumping. Duration of these periods ranged from 4 to 33 hours. Based on totalizer measurements obtained from the McCrometer flowmeters by CH2M HILL and Tucson Water personnel, average pumping rate for the period from February 12 through July 2 was computed to be 590 gallons per minute (gpm).

During pilot recharge operations, discharge from well AF-64 was switched manually between test basins 2 and 4 by Tucson Water and CH2M HILL personnel

at approximately two-week intervals (Figure 1). A stilling well was constructed in each test basin and was equipped with high level and low level electronic water level sensors; the vertical distance between the sensors was 1 foot. During a period of recharge testing at either test basin 2 or test basin 4, water was discharged to the test basin until the water level reached the high level sensor, when discharge was diverted automatically to the waste basin. Discharge continued to the waste basin until infiltration from the test basin caused water level to decline to the low level sensor, when discharge was diverted automatically back to the test basin. Infiltration rates for basin 2 were substantially smaller than infiltration rates for basin 4. Therefore, periods of discharge to the waste basin were substantially longer during testing of basin 2 than during testing of basin 4.

Water pumped from well AF-64 was discharged only to the waste basin during the first week of recharge operations, from February 12 through 19. From February 19 through July 2, recharge testing occurred alternately between basin 2 and basin 4, as follows:

PERIOD	BASIN USED FOR RECHARGE TESTING
February 12 - February 19	Waste Basin
February 19 - February 27	Test Basin 2
February 27 - March 5	Test Basin 4
March 5 - March 12	Test Basin 2
March 12 - March 19	Test Basin 4
March 19 - April 2	Test Basin 2
April 2 - April 16	Test Basin 4
April 16 - April 30	Test Basin 2
April 30 - May 14	Test Basin 4
May 14 - May 29	Test Basin 2
May 29 - June 11	Test Basin 4
June 11 - June 19	Test Basin 2
June 19 - July 2	Test Basin 4

Water level measurements were obtained in the pumped well using an electric sounder and were obtained in the monitor wells using electric sounders and GeoKon vibrating wire pressure transducers. Measurements of

change in barometric pressure were obtained using a GeoKon vibrating wire pressure transducer installed at a depth of about 20 feet in piezometer WR-160C. Data from the pressure transducers were recorded automatically by a GeoKon Micro-10 datalogger.

ANALYSIS OF GROUNDWATER LEVEL RESPONSE FOR PERIOD FROM FEBRUARY 12 THROUGH JULY 2, 1990

VADOSE ZONE PIEZOMETERS

The nine vadose zone piezometers were used to monitor occurrence of perched groundwater and height of perched groundwater mounding during pilot recharge operations. Perched groundwater is defined for this report as a body of groundwater separated from an underlying body of groundwater by an unsaturated zone. Height of perched groundwater mounding is defined for this report as the vertical distance from the base of a piezometer to the water level measured in the piezometer. The water level measured in the piezometer indicates the position of the perched water table, where the perched water table is that surface at which the pore-water pressure is atmospheric.

Prior to start of recharge operations, no perched groundwater was detected in the vadose zone piezometers. After recharge operations started, substantial amounts of perched groundwater were detected in piezometers WR-170A, WR-160B, and WR-160C. These three piezometers are located between test basins 2 and 4 near the geometric center of the area of recharge operations (Figure 1). Measurable amounts of perched groundwater were not detected in the remaining six piezometers, located southeast and northeast from basin 2.

Figure 2 is a water level hydrograph for vadose zone piezometers WR-170A, WR-160B, and WR-160C, and monitor well WR-160A, during the period from February 12 through July 2, 1990. The hydrograph was prepared using water level data obtained from the pressure transducers. The periods during which recharge testing was occurring in basin 2 and in basin 4 are shown on Figure 2. During the initial 7 days of recharge, water was discharged only to the waste basin. From 7 to 15 days after recharge started, water was discharged only to basin 2. From 15 to 21 days after recharge started, water was discharged only to basin 4. During the first two periods of recharge testing at basin 4, no water was discharged to the waste basin. Inspection of the

hydrographs for the piezometers indicates that height of perched groundwater mounding was largest when infiltration was occurring in basin 4 and the waste basin, and was smallest when infiltration was occurring in basin 2 and the waste basin (Figure 2). Comparison of the hydrographs for the piezometers to the hydrograph for monitor well WR-160A indicates that as time after recharge started became larger, height of perched groundwater mounding stabilized or became smaller, and water level rise in the regional aquifer became larger.

Six periods during which well AF-64 was not pumping are shown on Figure 2. For these periods, water levels in the piezometers responded to temporary cessation of discharge to the recharge basins. The longest period during which well AF-64 was not pumping was about 33 hours, and began 117 days after recharge started. In response to the 33-hour cessation of pumping at well AF-64, water level declined to below the base of piezometer WR-170A. Water level decline was 6.4 feet in piezometer WR-160B, 1.7 feet in piezometer WR-160C, and 3.6 feet in monitor well WR-160A (Figure 2). At piezometers WR-170A, WR-160B, and WR-160C, initial response to cessation of pumping occurred less than 0.5 days after pumping stopped. At monitor well WR-160A, initial response to cessation of pumping occurred 1.3 days after pumping stopped.

Piezometer WR-170A

Piezometer WR-170A was completed to a depth of 34 feet, and was used to monitor occurrence of perched groundwater in the recent alluvium above the interface with the Fort Lowell Formation. Groundwater was detected in piezometer WR-170A beginning about 15 days after the start of recharge testing on February 12, or less than 1 day after the start of the first period of recharge testing at basin 4 (Figure 2). As recharge operations continued, groundwater was detected in piezometer WR-170A only during, or immediately following, periods of recharge testing at basin 4. During periods of recharge testing at basin 2, most of the water pumped from well AF-64 was diverted to the waste basin because infiltration capacity for basin

2 was substantially smaller than the supply of water from well AF-64. Perched groundwater mounding may have resulted from recharge at the waste basin. However, piezometer WR-170A is located more than 150 feet from the waste basin; this distance may be larger than the lateral extent of perched groundwater mounding resulting from recharge at the waste basin.

Maximum height of perched groundwater mounding measured in piezometer WR-170A was 3.0 feet above the base of the piezometer, and occurred 17 days after the start of recharge operations, or 2 days after the start of the first testing period at basin 4. For each subsequent basin 4 testing period, maximum height of perched groundwater mounding occurred about 2 days after start of infiltration for that period, and was smaller than the maximum height of mounding for the previous basin 4 testing period. Maximum height of mounding during the sixth testing period at basin 4 was about 1 foot above the base of the piezometer (Figure 2).

Piezometer WR-160B

Piezometer WR-160B was completed to a depth of 70 feet and was used to monitor occurrence of perched groundwater above fine-grained unit A in the Fort Lowell Formation. Groundwater was detected in piezometer WR-160B beginning approximately 5 days after start of recharge operations. Maximum height of perched groundwater mounding measured in piezometer WR-160B was 13.6 feet above the base of the piezometer, and occurred about 18 days after the start of recharge operations, or about 3 days after the start of the first period of recharge testing at basin 4. For each subsequent basin 4 testing period, maximum height of mounding occurred near the end of the period, and was smaller than the maximum height of mounding for the previous basin 4 testing period. Maximum height of mounding during the sixth testing period at basin 4 was 9.5 feet above the base of the piezometer.

Height of perched groundwater mounding measured in piezometer WR-160B during periods of testing at basin 2 was substantially smaller than height

of mounding during periods of testing at basin 4. Height of mounding at the end of each basin 2 testing period was approximately 4 to 6 feet smaller than height of mounding at the end of the preceding basin 4 testing period. For each basin 2 testing period, height of mounding was smaller than during the previous basin 2 testing period. Minimum height of perched groundwater mounding in piezometer WR-160B occurred during the sixth period of testing at basin 2, and was 3.4 feet above the base of the piezometer (Figure 2).

Piezometer WR-160C

Piezometer WR-160C was completed to a depth of 112.5 feet and was used to monitor occurrence of perched groundwater above fine-grained unit B in the Fort Lowell Formation. Groundwater was detected in piezometer WR-160C beginning approximately 14 days after start of recharge operations. Maximum height of perched groundwater mounding measured in piezometer WR-160C was 4.0 feet above the base of the piezometer, and occurred about 35 days after the start of recharge operations. As recharge operations continued, height of mounding became smaller. Minimum height of perched groundwater mounding in piezometer WR-160C occurred during the sixth period of testing at basin 2, and was 0.5 feet above the base of the piezometer (Figure 2).

GROUNDWATER MONITOR WELLS

Figure 3 is a water level hydrograph for monitor wells WR-157A, WR-158A, WR-159A, and WR-160A during the 140-day period from February 12 through July 2, 1990. The hydrograph was prepared using water level data obtained from the pressure transducers. During the 140-day testing period, water levels in the monitor wells responded to the effects of pumping at well AF-64, recharge from infiltration of water in the test and waste basins, and changes in barometric pressure at the site.

Water level drawdown occurred in the monitor wells due to pumping at well AF-64. Maximum drawdown occurred approximately 25 days after pumping started, or 21 days after recharge started, and was 1.02 feet at monitor well WR-157A, 0.49 feet at well WR-158A, 0.92 feet at well WR-159A, and 0.38 feet at well WR-160A. Water level drawdown data obtained for the pumped well AF-64 and the monitor wells were analyzed to compute aquifer transmissivity and storage coefficient. Results of analyses for aquifer parameters were given in a previous report: "RESULTS OF PUMPING TEST, TUCSON WATER WELL (D-16-10)8bdd[AF-64], BRAWLEY WASH PILOT SURFACE RECHARGE SITE, PIMA COUNTY, ARIZONA (Montgomery & Associates, 1990b). Aquifer transmissivity was estimated to be 80,000 gallons per day per foot width of aquifer at 1:1 hydraulic gradient (gpd/ft). Storage coefficient was estimated to be 0.20 (dimensionless; volume of water released from or taken into storage per unit surface area of aquifer per unit decrease or increase in head).

Beginning approximately 21 days after recharge started, water level rise occurred in the monitor wells due to recharge from the test and waste basins. Maximum water level rise occurred at the end of the 140-day testing period. During the period from 21 days to 140 days after recharge started, observed water level rise in the monitor wells was 12.30 feet at well WR-157A, 18.40 feet at well WR-158A, 14.23 feet at well WR-159A, and 23.34 feet at well WR-160A.

During the initial 21 days of recharge, water level response due to changes in barometric pressure was substantial in relation to water level response due to pumping; therefore, water level drawdown in the monitor wells was adjusted for changes in barometric pressure prior to analysis of water level drawdown for aquifer parameters (Montgomery & Associates, 1990b). During the period from 21 to 140 days after recharge started, water level response due to changes in barometric pressure was negligible in relation to water level response due to recharge. Water level rise in the monitor wells for this period was not adjusted for changes in barometric pressure prior to analysis of groundwater mounding.

Based on aquifer transmissivity of 80,000 gpd/ft, storage coefficient of 0.20, and a cumulative average pumping rate of 590 gpm, projected drawdown due to pumping during the period from 21 to 140 days after recharge started ranges from 1.07 feet at well WR-158A, to 1.35 feet at well WR-159A. Water level rise in the monitor wells was adjusted by adding projected drawdown to observed water level rise. Adjusted water level rise was computed to be 13.62 feet at well WR-157A, 19.47 feet at well WR-158A, 15.58 feet at well WR-159A, and 24.58 feet at well WR-160A. For the period from 21 to 140 days after recharge started, projected drawdown due to pumping represents about 10 percent of the adjusted water level rise at well WR-157A, about five percent at well WR-158A, about nine percent at well WR-159A, and about five percent at well WR-160A.

Water levels in the monitor wells responded to temporary cessation of discharge from well AF-64 to the recharge basins. The longest period during which well AF-64 was not pumping was about 33 hours, and occurred 117 days after recharge started. In response to the cessation of pumping at well AF-64, water level decline was 1.27 feet at monitor well WR-157A, 1.49 feet at monitor well WR-158A, 1.73 feet at monitor well WR-159A, and 3.62 feet at monitor well WR-160A (Figure 3). Response to cessation of pumping occurred first at monitor well WR-160A, beginning 1.3 days after pumping stopped. Response to cessation of pumping occurred last at monitor well WR-158A, beginning 1.8 days after pumping stopped.

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

Monitor well WR-160A is located between test basin 2 and test basin 4 (Figure 1), and is near the geometric center of the area of recharge operations. The water level hydrograph for monitor well WR-160A during the period February 12 through July 2 is shown on Figure 3. Pre-pumping water level on February 8 was 151.92 feet below land surface. Maximum water level drawdown due to pumping occurred 21 days after recharge started, and was 0.38 feet. During the period from 21 days to 140 days after recharge started,

projected drawdown at well WR-160A due to pumping at well AF-64 was 1.24 feet, and observed water level rise due to recharge was 23.34 feet. Water level rise, adjusted for the effects of pumping, was 24.58 feet at the end of the 140-day testing period.

Monitor Well (D-16-10)8bdb1[WR-159A]

Monitor well WR-159A is located approximately 400 feet southeast from well WR-160A (Figure 1). The water level hydrograph for monitor well WR-159A during the period February 12 through July 2 is shown on Figure 3. Pre-pumping water level on February 8 was 150.72 feet below land surface. Maximum water level drawdown due to pumping occurred 21 days after recharge started, and was 0.92 feet. During the period from 21 days to 140 days after recharge started, projected drawdown at well WR-159A due to pumping at well AF-64 was 1.35 feet, and observed water level rise due to recharge was 14.23 feet. Water level rise, adjusted for the effects of pumping, was 15.58 feet at the end of the 140-day testing period.

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

Monitor well WR-158A is located approximately 760 feet southwest from well WR-160A (Figure 1). The water level hydrograph for monitor well WR-158A during the period February 12 through July 2 is shown on Figure 3. Pre-pumping water level on February 8 was 151.63 feet below land surface. Maximum water level drawdown due to pumping occurred 21 days after recharge started, and was 0.49 feet. During the period from 21 days to 140 days after recharge started, projected drawdown at well WR-158A due to pumping at well AF-64 was 1.07 feet, and observed water level rise due to recharge was 18.40 feet. Water level rise, adjusted for the effects of pumping, was 19.47 feet at the end of the 140-day testing period.

Monitor Well (D-16-10)8bdb2[WR-157A]

Monitor well WR-157A is located approximately 590 feet northeast from monitor well WR-160A (Figure 1). The water level hydrograph for monitor well WR-157A during the period February 12 through July 2 is shown on Figure 3. Pre-pumping water level on February 8 was 150.02 feet below land surface. Maximum water level drawdown due to pumping occurred 21 days after recharge started, and was 1.02 feet. During the period from 21 to 140 days after recharge started, projected drawdown at well WR-157A due to pumping at well AF-64 was 1.32 feet, and observed water level rise was 12.30 feet. Water level rise adjusted for the effects of pumping was 13.62 feet at the end of the 140-day testing period.

RESULTS FOR PERIOD FROM DECEMBER 7, 1990, THROUGH FEBRUARY 12, 1991

Pilot recharge testing was conducted from December 7, 1990, through February 12, 1991, to further evaluate occurrence of perched groundwater at piezometers located northeast and southeast from basin 2 (Figure 1). During previous recharge testing periods, perched groundwater was detected only at piezometers WR-160B, WR-160C, and WR-170A, located between basin 2 and basin 4; perched groundwater was not detected at piezometers located northeast and southeast from basin 2. The detection of perched groundwater only at piezometers between basins 2 and 4 is believed to result from large infiltration rates for basin 4. The absence of detectable perched groundwater at piezometers located northeast and southeast from basin 2 is believed to result from small infiltration rates for basin 2.

Larger infiltration rates were promoted in basin 2 by excavating two trenches to expose permeable sand and gravel deposits beneath the floor of the basin. The trenches were excavated during the period from November 5 through 7, 1990, using a backhoe owned and operated by Tucson Water. The first trench was excavated from near the west corner of basin 2 to the east corner of the basin. The second trench was excavated from the north corner to the south corner of the basin. Length of each trench was about 230 feet. Average width of each trench was about five feet. During excavation of the trenches, deposits of fine-grained silty sand were encountered to a depth of 7 feet, with some gravel from 5 to 7 feet. Fine- to coarse-grained, silty, gravelly sand was encountered at a depth of about 7 feet. The trenches were excavated to a total depth of 7 to 8 feet. The depth of the trenches prior to start of recharge testing ranged from about 6 to 8 feet due to sloughing of the walls of the trenches after excavation and before start of recharge testing.

Pumping at well AF-64 started at 11:45 on December 8, 1990. Pumping rate was measured using a Data Industrial flowmeter installed in the discharge pipeline at pumped well AF-64 and using two McCrometer flowmeters

installed in the two water supply pipelines for the pilot recharge test basins and the waste basin. A gate valve installed downstream from the Data Industrial flowmeter was used to maintain constant discharge rate. Based on totalizer measurements obtained from the McCrometer flowmeters, average pumping rate for the period from December 8 through February 12 was 580 gpm.

Water pumped from well AF-64 was discharged to basin 2 and the waste basin from December 7, 1990, through January 4, 1991. Water was discharged to basin 2 until the water level in basin 2 reached the high level sensor, when discharge was diverted automatically to the waste basin. Discharge continued to the waste basin until water level in basin 2 declined to the low level sensor, when discharge was diverted automatically back to the test basin. The vertical distance between the high- and low-level sensors in basin 2 was 1 foot. For the first three falling-stage infiltration cycles, during the period from December 8 through December 12, time required for water level to decline from the high-level to the low-level sensor ranged from about 22 to 26 hours. Average infiltration rate for basin 2 during this five-day period was about 1 foot per day. Infiltration rate for basin 2 became smaller as recharge operations continued. Average infiltration rate for the period from December 7 through January 4 was about twice as large as the average infiltration rate of about 0.4 feet per day reported by CH2M HILL for the period August through October, 1990, before the trenches were excavated (CH2M HILL, 1991).

Prior to start of recharge operations, perched groundwater was detected only in piezometer WR-160B, between test basins 2 and 4 near the geometric center of the area of recharge operations (Figure 1). Height of groundwater mounding in this piezometer was less than 1 foot above the base of piezometer. After recharge operations started, perched groundwater was also detected in piezometer WR-160B and WR-170A. During the period from December 7, 1990, through January 4, 1991, when water was being discharged to basin 2 and the waste basin, maximum height of perched groundwater mounding was less than 1 foot above the base of piezometer WR-170A, about 6 feet above the base of piezometer WR-160B, and about 2 feet above the base of piezometer WR-

160C. Measurable amounts of perched groundwater were not detected in the remaining six piezometers, located southeast and northeast from basin 2.

Results of pilot recharge operations from December 7, 1990, through February 4, 1991, indicate that infiltration rate for basin 2 was about twice as large as during previous recharge periods. The larger infiltration rate for basin 2 did not result in larger height of perched groundwater mounding at piezometers located between basins 2 and 4, and measurable amounts of perched groundwater were not detected at piezometers located northeast and southeast from basin 2. These results indicate that the increase in infiltration rate for basin 2 was not large enough to cause a substantial increase in the height and lateral extent of perched groundwater mounding in the recent alluvium or in the Fort Lowell Formation above fine-grained units A and B.

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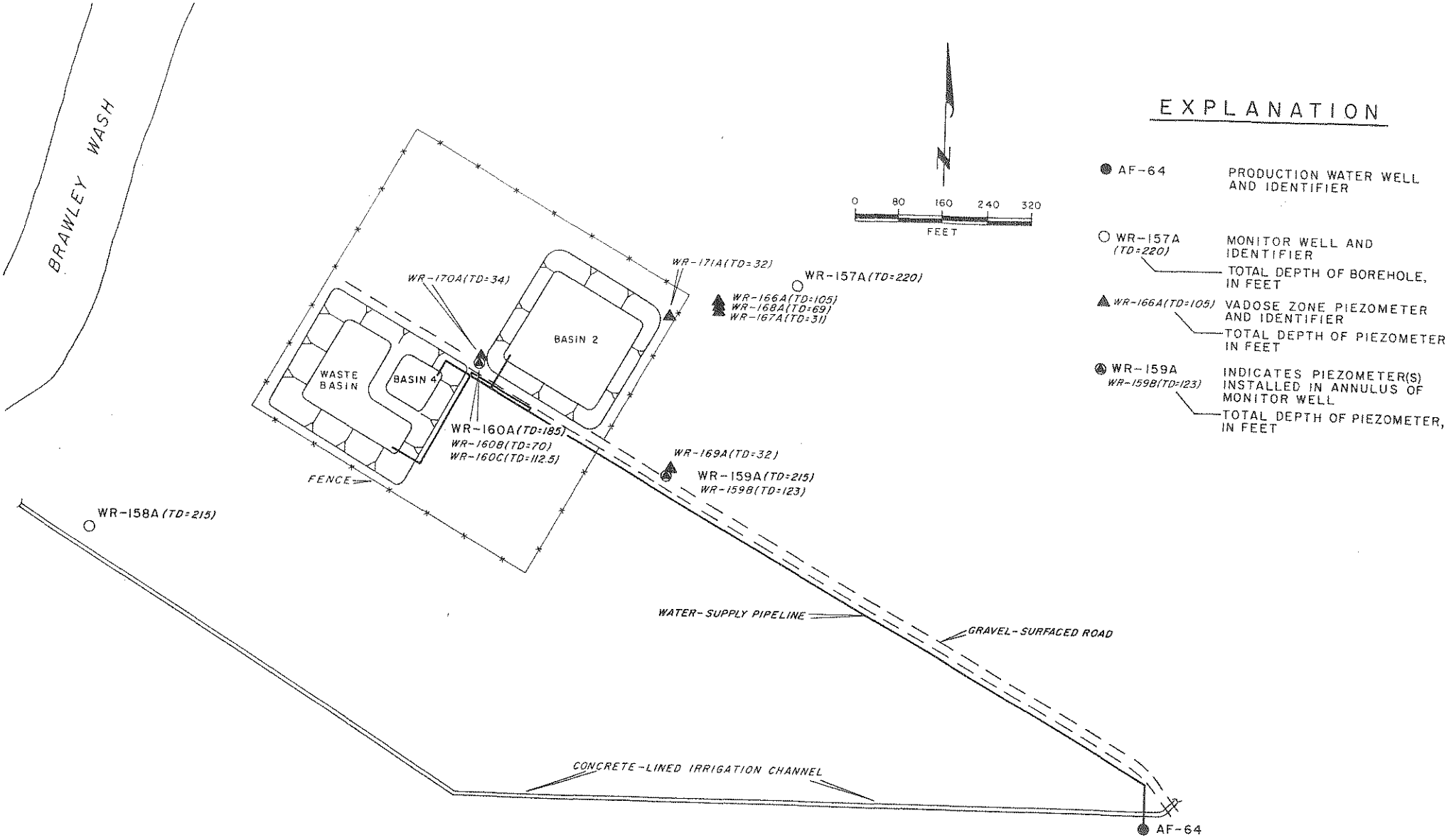

FIGURE 1. LOCATIONS OF WELLS AND PIEZOMETERS, BRAWLEY WASH PILOT SURFACE RECHARGE SITE

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

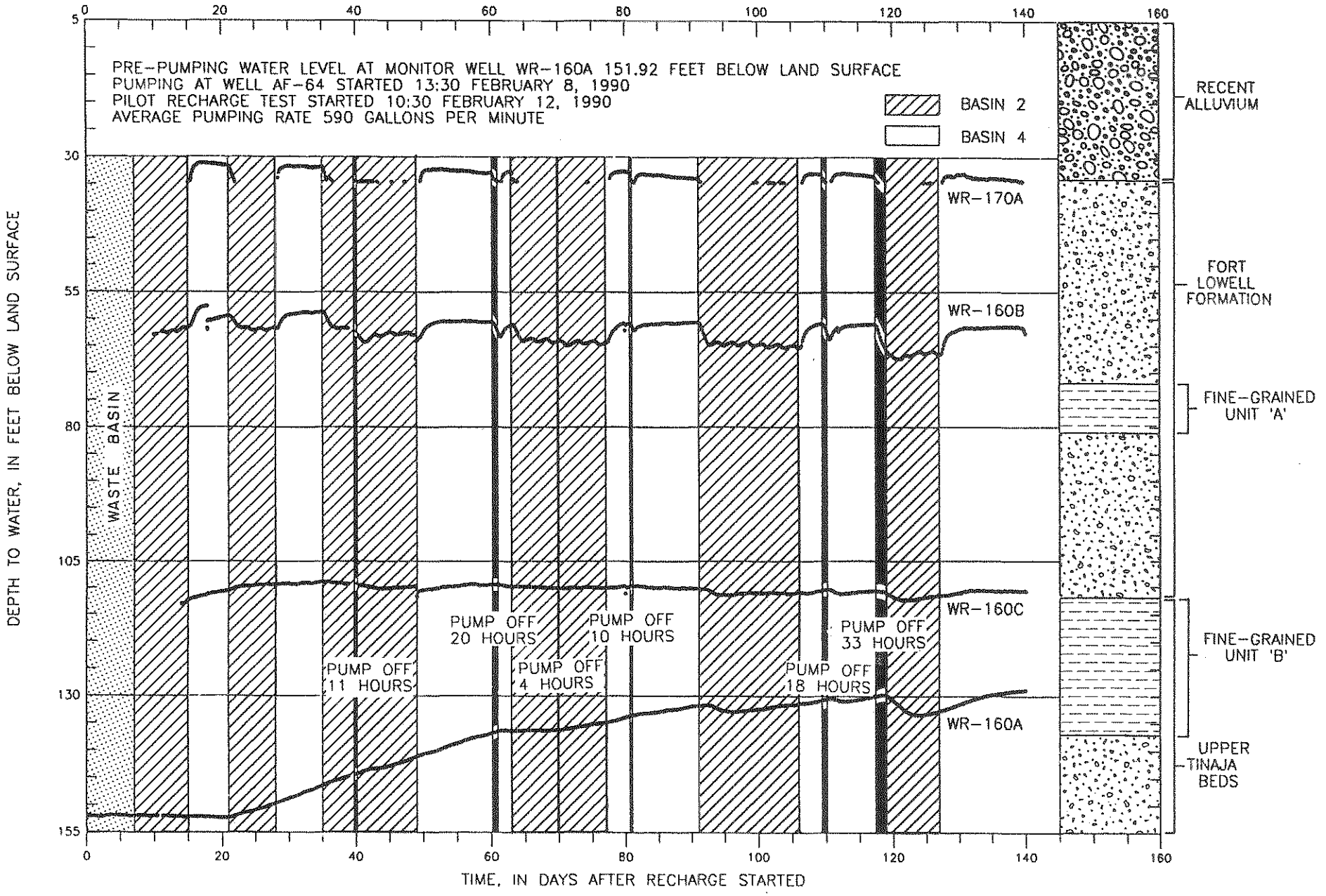

FIGURE 2. WATER LEVEL HYDROGRAPH FOR PIEZOMETERS WR-170A, WR-160B, AND WR-160C, AND MONITOR WELL WR-160A DURING PILOT SURFACE RECHARGE OPERATIONS AT BRAWLEY WASH SITE, FEBRUARY 12 THROUGH JULY 2, 1990

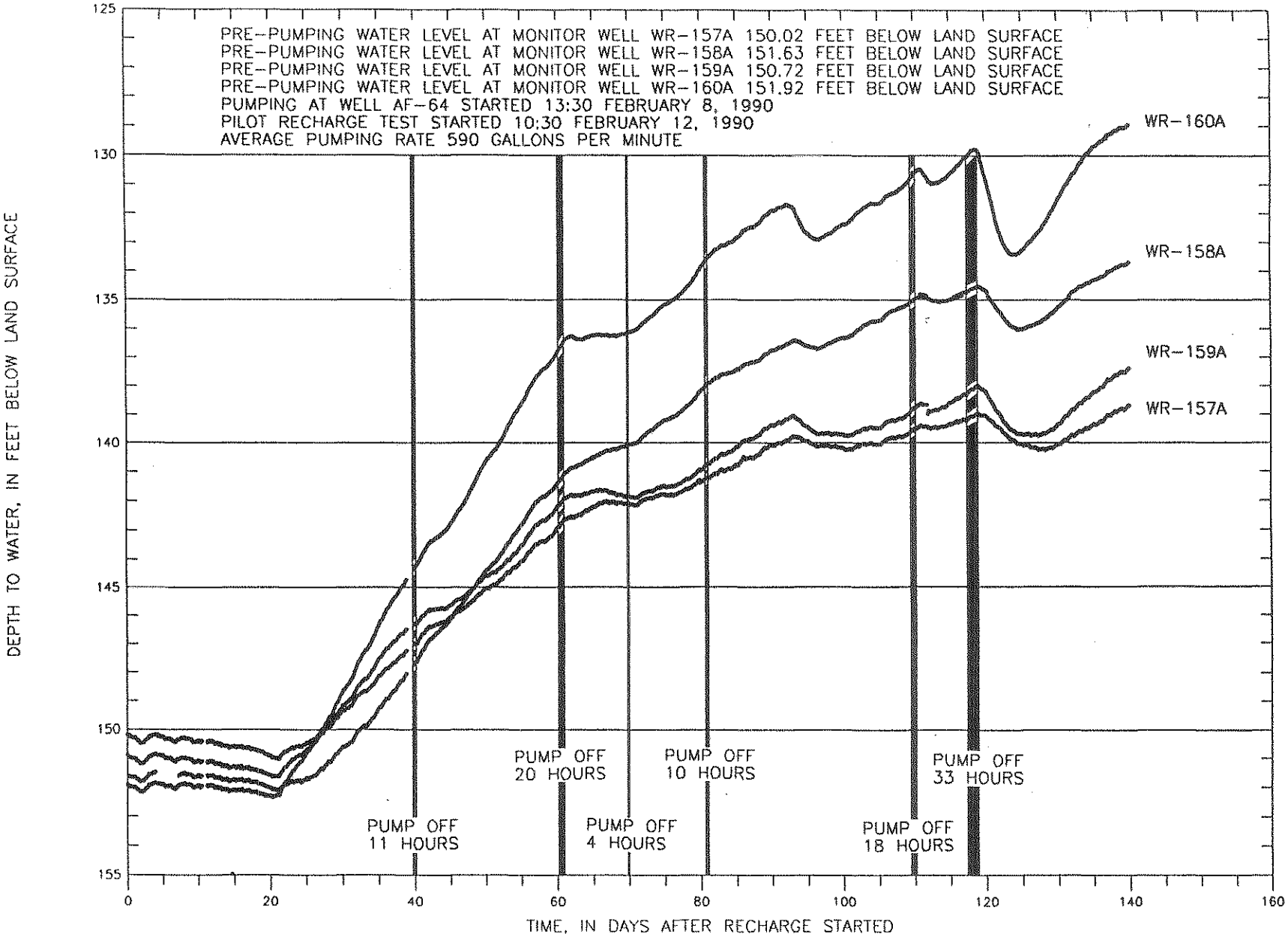

FIGURE 3. WATER LEVEL HYDROGRAPH FOR MONITOR WELLS WR-157A, WR-158A, WR-159A, AND WR-160A DURING PILOT SURFACE RECHARGE OPERATIONS AT BRAWLEY WASH SITE, FEBRUARY 12 THROUGH JULY 2, 1990