RIO ALGOM MINING CORP.

SMITH RANCH PROJECT

WDEQ PERMIT #633
NRC LICENSE SUA-1548
DOCKET 40-8964

WELLFIELD 4 ANNEX
VOLUME 2

PRE-OPERATIONAL DATA SUBMITTAL

JUNE 1, 2000

ATTACHMENT K
SMITH RANCH FACILITY
M SAND WELLFIELD 4A
MULTI-WELL PUMP TESTS

FOR:

WDEQ/LQD
PERMIT #633
NRC LICENSE SUA-1548
DOCKET 40-8964

BY:

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FIGURES

K.3.0 WATER-LEVEL ELEVATIONS

The static water levels prior to the start of the pump tests were used to determine the piezometric surface for each of the aquifers in Wellfield 4A. Water levels at the end of the pumping phase of the pump test were also used to develop a piezometric surface for the aquifers at the end of the stress period. Four water-level elevation maps were developed for the M Sand, one prior to the start of each of the two tests and one for the end of the pumping phase for each test. Two water-level elevation maps are presented for the O and K Sands due to the small amount of change in depth to water in these two aquifers.

K.3.1 M SAND

Water-level elevations are presented prior to the start of the PW4-4 pump test on Table K.5-1 for the M Sand wells. These water-level elevations are presented on Figure K.3-1 to portray the piezometric surface of the M Sand aquifer prior to the start of the PW4-4 pump test. This piezometric surface shows that the ground water is flowing to the southeast in the M Sand in the PW4-4 area with an average gradient of 0.0029 ft/ft. The average gradient and average hydraulic conductivity of 0.84 ft/day and an effective porosity of 0.1 indicate that the ground water is moving at a rate of 0.024 ft/day (8.9 ft/year). The gradient in the northwestern one-third of Wellfield 4A is toward Wellfield 4 due to the bleed rate in Wellfield 4.

Figure K.3-2 shows the piezometric surface at the end of the pumping phase of the PW4-4 test. This piezometric surface portrays the depression caused by the PW4-4 pumping and shows that flow lines would converge towards pumping well

PW4-4. The flow at the end of the PW4-4 test in the M Sand was still toward Wellfield 4 in the area of monitoring wells M401, M402 and M434.

Table K.6-1 presents the water-level elevations prior to the start of the PW4-3 pump test. The piezometric surface prior to the start of the PW4-3 pump test is presented in Figure K.3-3. The average gradient prior to the start of this pump test between wells MP423 and M401 was 0.0069 ft/ft. This gradient, along with an average hydraulic conductivity of 0.84 ft/day and an effective porosity of 0.1 indicates that the ground water in this area is flowing at 0.058 ft/day (21 ft/year) toward Wellfield 4. The gradient between wells MP423 and MP425 was 0.003 ft/ft to the southeast.

Figure K.3-4 presents the piezometric surface at the end of the pumping phase for the PW4-3 test. This piezometric map shows the conversions of ground-water flow to pumping well PW4-3, except for gradients to the northwest at wells M402 and M434.

K.3.2 O SAND

Water-level elevation maps were developed for the overlying O Sand, which was monitored during the PW4-4 and PW4-3 multi-well tests. Figure K.3-5 presents the water-level elevations for the O Sand prior to the start of the PW4-4 multi-well test and at the end of pumping. The depth to water did not change significantly between the start and end of pumping in the PW4-4 test and, therefore, the water-level elevations for the O Sand wells are presented for two dates: November 5 and November 8, 1999, on Figure K.3-5. The magenta data shows water levels prior to

the start of the PW4-4 test, while the blue data shows the O Sand water levels that were obtained at the end of the PW4-4 test. Flow in the O Sand was to the southeast during the PW4-4 multi-well test with an average gradient of 0.0011 ft/ft.

The O Sand wells monitored during the PW4-3 test show similar water levels prior to and at the end of the PW4-3 pumping (see Figure K.3-6). The piezometric surfaces shown on Figures K.3-5 and K.3-6 are very similar, showing very similar gradients and water-level elevations slightly greater than one foot higher for the PW4-3 test.

The heads in the O Sand were a few feet higher than heads in the M Sand over the entire Wellfield 4A prior to both of these multi-well tests. This head difference was greatest in the northwest portion of Wellfield 4A, adjacent to Wellfield 4.

K.3.3 K SAND

The water-level elevations in the K Sand prior to and at the end of the PW4-4 pump test are presented on Figure K.3-7. The water levels were essentially the same in the K wells prior to the start of the pump test and at the end of the pumping phase of the test. Only one set of piezometric contours (based on 11/05/1999 data) are drawn on this map due to the lack of variation in these water-level elevations. The ground-water flow in the K Sand is to the southeast with an average gradient of 0.0054 ft/ft. The gradient is steeper in some areas of Wellfield 4A at 0.0096 ft/ft.

The water-level elevation in the K Sand prior to the PW4-4 test was lower than the water-level elevation in the M Sand by several feet except near Wellfield 4 at monitoring wells M401, M402 and M434. Water levels in the K Sand are near the M Sand levels near these three wells.

Figure K.3-8 presents the water-level elevations for the K Sand for the PW4-3 test for November 29, prior to the start of the test, and for December 3 at the end of the pumping phase of the PW4-3 test. This shows that the water-level elevations were slightly higher at the end of the PW4-3 pump test. The piezometric contours for the PW4-3 test for the K Sand (based on the November 29 data) shows a gradient to the southeast with an average gradient of 0.0071 ft/ft in the northwestern half of Wellfield 4A.

THIS PAGE IS AN OVERSIZED DRAWING OR FIGURE,

THAT CAN BE VIEWED AT THE RECORD TITLED:

FIG. K.3-1, REV. NO. 1

SMITH RANCH PROJECT WELLFIELD 4A PATTERNS WATER-LEVEL ELEVATIONS IN THE M SAND PRIOR TO THE PW4-4 PUMP TEST NOVEMBER 5, 1999, FT-MSL,

WITHIN THIS PACKAGE...OR, BY SEARCHING USING THE DOCUMENT/REPORT FIG. K.3-1, REV. NO. 1

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FIG. K.3-2, REV. NO. 1

SMITH RANCH PROJECT WELLFIELD 4A PATTERNS- WATER-LEVEL ELEVATIONS IN THE M SAND AT THE END OF THE PW4-4 PUMP TEST NOVEMBER 8, 1999, FT-MSL,

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FIG. K.3-3, REV. NO. 1

SMITH RANCH PROJECT WELLFIELD 4A PATTERNS WATER-LEVEL ELEVATIONS IN THE M SAND PRIOR TO THE PW4-3 PUMP TEST NOVEMBER 29, 1999, FT-MSL,

WITHIN THIS PACKAGE...OR, BY SEARCHING USING THE DOCUMENT/REPORT FIG. K.3-3, REV. NO. 1

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FIG. K.3-4, REV. NO. 1

SMITH RANCH PROJECT WELLFIELD 4A PATTERNS- WATER-LEVEL ELEVATIONS IN THE M SAND AT THE END OF THE PW4-3 PUMP TEST DECEMBER 3, 1999, FT-MSL,

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FIG. K.3-4, REV. NO. 1

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FIG. K.3-5, REV. NO. 1

SMITH RANCH PROJECT WELLFIELD 4A PATTERNS - WATER-LEVEL ELEVATIONS IN THE O SAND FOR WELLFIELD 4A, NOVEMBER 5, AND NOVEMBER 8, 1999, FT-MSL

WITHIN THIS PACKAGE...OR, BY SEARCHING USING THE DOCUMENT/REPORT FIG. K.3-5, REV. NO. 1

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FIG. K.3-6, REV. NO. 1

SMITH RANCH PROJECT WELLFIELD 4A PATTERNS - WATER-LEVEL ELEVATIONS IN THE O SAND FOR WELLFIELD 4A, NOVEMBER 29, AND DECEMBER 3, 1999, FT-MSL

WITHIN THIS PACKAGE...OR, BY SEARCHING USING THE DOCUMENT/REPORT FIG. K.3-6, REV. NO. 1

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FIG. K.3-7, REV. NO. 1

SMITH RANCH PROJECT WELLFIELD 4A PATTERNS - WATER-LEVEL ELEVATIONS IN THE K SAND FOR WELLFIELD 4A, NOVEMBER 5, AND NOVEMBER 8, 1999, FT-MSL

WITHIN THIS PACKAGE...OR, BY SEARCHING USING THE DOCUMENT/REPORT FIG. K.3-7, REV. NO. 1

NOTE: Because of this page's large file size, it may be more convenient to copy the file to a local drive and use the Imaging (Wang) viewer, which can be accessed from the Programs/Accessories menu.

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FIG. K.3-8, REV. NO. 1

SMITH RANCH PROJECT WELLFIELD 4A PATTERNS - WATER-LEVEL ELEVATIONS IN THE K SAND FOR WELLFIELD 4A, NOVEMBER 29 AND DECEMBER 3, 1999, FT-MSL

WITHIN THIS PACKAGE...OR, BY SEARCHING USING THE DOCUMENT/REPORT FIG. K.3-8, REV. NO. 1

NOTE: Because of this page's large file size, it may be more convenient to copy the file to a local drive and use the Imaging (Wang) viewer, which can be accessed from the Programs/Accessories menu.

SECTION K.4

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K.4.0 PUMP TEST PROCEDURES

K.4.1 AQUIFER TESTS CONDUCTED

Two multi-well aquifer tests were conducted in Rio Algom's Wellfield 4A. Transducers were used to measure water levels in all of the wells used in these two multi-well pump tests. Manual water levels were measured in each well for three days prior to the start of the test and during the pump tests to calibrate and check the transducer levels. The PW4-4 multi-well pump test on the southeastern half of Wellfield 4A was the first test conducted. Well PW4-4 is located in the center portion of the southeastern half of Wellfield 4A and was pumped for three days, followed by three days of recovery measurements. A second pump test was conducted in the northwestern half of Wellfield 4A to define conditions in this region. Well PW4-3 was pumped for the second multi-well test for four days with four days of recovery. Three days of pre-test water levels are presented for the PW4-3 multi-well test.

K.4.2 PUMPING WELLS

Well PW4-4 was used as the pumping well for the three day multi-well pump test which began on November 5, 1999 at 9:30 a.m. and ran through November 8, 1999 at 9:30 a.m. with three days of recovery following the pumping phase. Well PW4-3 was pumped for the second multi-well pump test from 11:00 a.m. on November 29, 1999 through 11:00 a.m. on December 3, 1999.

K.4.3 WATER-LEVEL MEASUREMENTS

Water levels in all of the wells in Wellfield 4A were measured with electric tapes. Water levels were collected with pressure transducers and data loggers in the 29 wells used in the PW4-4 pump test. Water levels were measured with pressure transducers in all of the wells used in the PW4-4 test: O Sand wells MS415, MS416 and MS417; K Sand wells MD415, MD416 and MD417; and M Sand wells PW4-4, MP425, MP426, MP427A, MP428, MP429, MP430, MP431, M439, M440, M441, M442, M443, M444, M445, M446, M447, M448, M449, M450, M451, M452 and M453.

Twenty-nine wells were monitored with pressure transducers and data loggers during the PW4-3 pump test. Transducers were used to measure water levels in all wells during the PW4-3 multi-well pump test: O Sand wells MS412, MS413, MS414 and MS415; K Sand wells MD412, MD413, MD414 and MD415; and M Sand wells PW4-3, MP422, MP423, MP424, MP425, MP426, MP432, M401, M402, M434, M435, M436, M437, M438, M439, M453, M454, M455A, M456, M457 and M458. Monitoring well M401 will become an MP well during operation of Wellfield 4A.

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K.5.0 PW4-4 TEST

As stated in the introduction, this aquifer test was conducted: 1) to demonstrate communication between the area to be mined (production zone) and the surrounding monitor well ring, 2) to determine the degree of hydrologic communication between the production zone and overlying and underlying aquifers, 3) to determine the presence of hydrologic boundaries, and 4) to determine the hydrologic characteristics of the production zone aquifer. The PW4-4 multi-well test was conducted to achieve these objectives for the southeastern half of Wellfield 4A.

In order to achieve the objective of determining the production zone aquifer's hydrologic properties, data on time and drawdown were plotted, and calculations of transmissivity and storage coefficient were made by using the Theis non-leaky aquifer method. See Section E.7 in Attachment E of Volume III in Permit to Mine #633 of Rio Algom and Hydro-Engineering, L.L.C. (1997) in the 1997 PW1 test for aquifer test theory discussion. The straight-line drawdown method (semi-log plot), which approximates the Theis method, and the Theis recovery were also used to analyze these pump tests. The aquifer test theory in Hydro-Engineering, L.L.C. (1997) also presents the equations for both of these methods. The tables and figures in this section present the uncorrected drawdown data, which was used in our analysis of this pump test.

These drawdown plots and data fits were also important in the definition of boundary conditions. Boundary conditions are not important to this pump-test analysis as discussed in Section K.5.4.3. The directional transmissivities were also calculated and the results are presented in Section K.5.4.4.

The test clearly demonstrated communication between the monitor well ring and the production zone, and the lack of hydrologic communication with the overlying O Sand and underlying K Sand aquifers.

Rio Algom's data logger records barometric pressure while it is logging the water levels. The water level change plots (the A set of figure numbers) contain a plot of the barometric pressure, along with the water-level changes. Barometric pressure changed only approximately 0.6 inches of mercury over the pre-test, pumping and recovery phases of the PW4-4 test. This amount of barometric change would result in small water-level correction for changes in barometric pressure. No corrections for barometric pressure were made for the analysis of this pump test.

Water levels prior to the initiation of the pump test were fairly steady prior to the PW4-4 test. A prior trend correction was not used to correct for these very gradual trends in water levels for this test. Water levels are presented for three days before the start of the test in the water-level change plots (A figure numbers). The prior trend may change after the pump test has started, resulting in incorrect corrections for prior trend. Therefore, no correction for prior trend was used in our analysis of this test.

The drawdown and water-level change data presented in the figures and tables have not been corrected for barometric pressure changes or prior trends. These corrections would result in relatively small changes, and they were not considered in analysis of the PW4-4 tests results.

K.5.1 M SAND RESPONSES

Well PW4-4, which is located in the southeastern half of Wellfield 4A, was pumped at an average rate of 16.2 gpm from 9:30 a.m. on November 5, 1999 through 9:30 a.m. on November 8, 1999. The discharge from well PW4-4 was held steady throughout the test (see Table K.5-16C for a tabulation of flow rates).

This sub-section presents a discussion of the drawdown developed by pumping well PW4-4, the demonstration of communication with the monitoring ring wells and a summary of the M Sand aquifer properties developed by this test. The analyses of the M Sand pump test are presented in Section K.5.4.

The pump test figures and tables for each particular well are given the same number with the addition of the letter A, B, C or D to distinguish the different type of figure or table. The manual data is presented in the A series tables, while the transducer data is given in the B series. The A series figures give a linear plot of the pre-test, pumping and recovery data. The B and C series figures contain the semi-log and log-log drawdown plots, while the D series presents the recovery plot.

K.5.1.1 DRAWDOWN IN M SAND

Figure K.5-1 presents the drawdown in the M Sand after three days of PW4-4 pumping. The drawdowns at the end of the pump test from the transducer tables (B series tables) were used to obtain these drawdown values after three days of pumping.

Table K.5-1 presents a tabulation of these drawdowns at the end of the pump test in the fourth column. This figure shows that the drawdowns decrease with

distance away from pumping well PW4-4. A drawdown of at least eight feet was developed in all of the southeastern M Sand wells. This figure also shows that the M Sand was very adequately stressed over the northwestern half of Wellfield 4A, except for the last three wells that are adjacent to Wellfield 4.

Drawdowns of greater than 30 feet extend beyond 450 feet from the pumping well. The twenty-foot contour generally extends out to 1000 feet from the pumping well. A particular drawdown contour extends further to the northeast and southwest of the pumping well indicating higher transmissivities in this direction.

K.5.1.2 MONITOR WELL COMMUNICATION WITH PUMP WELL PW4-4

The drawdown developed at the end of the pump test shows very good communication with all of the southeastern M Sand monitoring wells. Figure K.5-1 presents the drawdown at the end of the test for all of the M Sand wells. The straight-line plots of the drawdown data are also useful in determining whether a consistent pattern of drawdown has developed with respect to the PW4-4 pumping in the outer monitoring ring wells, i.e. those wells with "M" designations. All of the southeastern monitoring wells are in communication with pumping well PW4-4 with the minimum drawdown of eight feet in well M453. This pump test, therefore, adequately demonstrates that the southeast half of the well field monitoring ring is in good communication with the production wells within the M Sand.

Drawdowns of at least one foot were developed in each of the northwestern monitoring ring wells, with the exception of the three most

northwestern wells. The PW4-4 test, therefore, demonstrates good communication with most of the northwestern wells also.

K.5.1.3 SUMMARY OF AQUIFER PROPERTIES FROM THE PW4-4 TEST

Transmissivities varied from the log-log plots of the PW4-4 observation wells from 130 gal/day/ft to 210 gal/day/ft. Figure K.5-2 presents the transmissivity values from the PW4-4 multi-well test. Transmissivities from the log-log drawdown plots are recommended to be used instead of the values from the semi-log drawdown or recovery plots because the pumping time does not meet the straight-line requirements for some of these wells. Changes in water-level trends also affected the recovery plots. A transmissivity of 160 gal/day/ft is thought to best represent the M Sand in the southeastern half of Wellfield 4A.

The hydraulic conductivities, based on an aquifer thickness of 24 feet and the Theis log-log transmissivities, are also tabulated in Table K.5-1, and they vary from 0.72 to 1.17 ft/day (0.22 to 0.35 Darcy) with an average of 0.90 ft/day (0.27 Darcy).

Storage coefficients varied from a low of 1.4E-05 to a high of 7.7E-05 from the log-log plots. A storage coefficient of 3.7E-05 is thought to best represent the M Sand in the southeastern area of Wellfield 4A.

A transmissivity of 160 gal/day/ft and storage coefficient of 3.5E-05 is thought to best represent average conditions for Wellfield 4A, based on both the PW4-4 and PW4-3 multi-well tests. A hydraulic conductivity of 0.84 ft/day (0.26 Darcy) is thought to best represent average conditions in the M Sand in Wellfield 4A.

K.5.2 O SAND RESPONSES

The overlying aquifer in Wellfield 4A is the O Sand. Three O Sand wells were monitored during the PW4-4 multi-well test. The geologic cross-sections in Section K.2 show a continuous overlying N Shale in this area. The water-level responses in the O Sand monitoring wells during the PW4-4 test do not indicate any connection between the M Sand and the O Sand in this area. Table K.5-2 presents the static water levels prior to the start of the PW4-4 test for the O Sand wells.

Table K.5-3 presents the distance to the O Sand (MS) wells from pumping well PW4-4, along with the estimated drawdown in the M Sand, at the end of the test near each of these O Sand wells. The estimated drawdown in the M Sand was used in this table because this is the stress on the N Shale adjacent to these MS wells.

The water-level change plots for the MS wells are presented in Figures K.5-3A through K.5-5A. The tabulation of water levels is presented in Tables K.5-4A through K.5-9B. The three northwestern most O Sand wells were not used in the PW4-4 test but their limited water-level measurements are presented in Tables K.5-4A through K.5-6A, respectively. These water levels were collected for development of the piezometric maps. The single water levels measured at the end of pumping in the three northwestern MS wells indicate a small amount of drawdown. These single water level readings are considered to be slightly in error because the numerous readings of the closer O Sand well, MS415, did not indicate any drawdown. The transducer water levels for the O Sand wells used in the PW4-4 multi-well test are presented in the K.5-7B through K.5-9B tables. The manual data is presented in the A series tables, while the transducer data is given in the B series tables for the O Sand wells also. Only A series linear time plots with all of the water-level change data (pre-test, pumping and recovery) are presented for the adjacent aquifer wells.

Figure K.5-3A presents the water-level change data for O Sand well, MS415. The manual data is shown by blue diamonds on this figure, while the transducer data is shown with magenta dots. The majority of the pre-test water levels in O Sand well MS415 were gradually rising (negative water-level change) prior to the start of the PW4-4 pump on November 5, 1999 due to the general decline of the barometric pressure. The shape of the water-level changes in well MS415 are very similar to the shape of the barometric changes. These small water-level changes are thought to be mainly due to changes in the barometric pressure. These water-level changes for well MS415 do not indicate any drawdown and, therefore, no connection between the M and O Sands in this area.

Figure K.5-4A presents the water-level changes for O Sand well MS416. Water levels in this well rose approximately 0.2 feet during the pumping and recovery phase of this test. The small water-level changes in well MS416 do not indicate connection between the O and M Sands in this area.

Figure K.5-5A presents the water-level change for well MS417. The water-level changes for this observation well indicate a gradual rising trend throughout this pump test. The manual data during recovery indicates slightly less water-level rise than that indicated by the transducer data. The transducer data, in this case, is thought to best represent water-level changes at well MS417. This data indicates no connection between the M and O Sands.

None of the water-level changes in the O Sand wells indicates drawdown from the PW4-4 test. Therefore, the PW4-4 test indicates that there is no connection between the O Sand and the M Sand in the southeastern half of Wellfield 4A.

K.5.3 K SAND RESPONSES

The water-level changes observed in the K Sand wells are presented in Tables K.5-10A through K.5-15B. Although MD wells 412 through 414 were not used in the PW4-4 test, the limited number of manual water levels measured on these three K Sand wells are presented in the first three of these tables. Water levels were measured prior to the start and at the end of the PW4-4 test in these three K Sand wells for use in developing the piezometric surface maps. The remainder of the MD wells contain a manual table (A) and a transducer table (B). The static water levels in the K Sand wells prior to the start of the PW4-4 test are presented in Table K.5-2.

The estimated drawdowns in the M Sand near the K Sand wells are presented in Table K.5-3. The drawdown in the M Sand is the stress on the L Shale. The minimum drawdown in the M Sand adjacent to an MD well was 16 feet at well MD415. This amount of drawdown adequately stresses the L Shale in the area of well MD415.

The water-level changes in the K Sand wells are presented for monitoring wells MD415 through MD417 in Figures K.5-6A through K.5-8A, respectively. Only the A series of plots are presented for the adjacent aquifer K Sand (MD) wells because the pre-test, pumping and recovery water-level changes are presented on one figure. Water-level change plots for these K Sand wells do not indicate drawdown.

Figure K.5-6A presents the water-level changes for K Sand well MD415. Water levels in this well changed very similar to the changes in barometric pressure. Water levels rose approximately two-tenths near the end of the pumping phase of the test but were very near zero at the end of recovery. No trend in the water-level

changes is indicated by the MD415 data. The water-level changes in K Sand well MD415 indicate that the M and K Sands are not connected in this area.

The water-level changes in K Sand monitoring well MD416 are presented in Figure K.5-7A. The water-level change data from this K Sand well is also very similar to the barometric changes with no trend indicated. This data indicates that the M and K Sands are not connected near well MD416.

The other K Sand well (MD417) is presented in Figure K.5-8A. The water-level changes in this K Sand well are similar to those from the other two MD wells. The good agreement of water-level change and barometric change indicates that the K and M Sands are not connected near well MD417.

The K Sand wells in the PW4-4 multi-well test show that the M and K Sands are not connected in the southeastern half of Wellfield 4A.

K.5.4 M SAND PUMP TEST ANALYSIS

This section presents a detailed analysis of the M Sand pumping and observation wells. The drawdowns developed from this multi-well test and a summary of aquifer properties are presented in Section K.5.1 and tabulated in Table K.5-1. Figure K.5-2 presents the transmissivities obtained from the PW4-4 multi-well test.

Tables K.5-16A through K.5-54A present the water-level data collected for the M Sand wells during the PW4-4 multi-well pump test. Transducer data for the pumping well and the M Sand observation wells are also presented in a second table. These tables use the same table number followed with the letter B rather than the letter A. Figure K.5-2 shows which of the monitoring wells were used in this multi-

well pump test. All wells used in the PW4-4 pump test were equipped with a transducer. All wells southeast of the line drawn between monitoring ring wells M453 and M454 and between M438 and M439 were used in the PW4-4 multi-well test.

Tables K.5-17A through K.5-19A are for MP wells 422 through 424, respectively, and Table K.5-27A is for well MP432, and contain only a very few measurements because they are on the northwestern side of the well field and are not included in the PW4-4 test. In addition, monitoring ring wells M401 through M438 are presented in Tables K.5-28A through K.5-34A and wells M454 through M458 are presented in Tables K.5-50A through K.5-54A. Only a few measurements are given for these wells due to their non-use in the PW4-4 multi-well pump test. These measurements were used to develop the piezometric and drawdown maps.

Each of the M Sand observation wells in the PW4-4 pump test contain four plots: a water-level change plot on a linear time basis, a semi-log drawdown plot, a log-log drawdown plot and a semi-log recovery plot. The log-log drawdown plot is not presented for the pumping well because the effective radius of a pumping well can vary significantly and greatly affects the results of a log-log plot. Therefore, only water level change, semi-log drawdown and semi-log recovery plots are presented for pumping well PW4-4. Figures K.5-9A through K.5-31D present the results for the M Sand wells from the PW4-4 pump test.

K.5.4.1 PW4-4 PUMPING WELL

The PW4-4 pumping well was pumped at an average rate of 16.2 gpm from 9:30 a.m. on November 5 to 9:30 a.m. on November 8, 1999. Water levels were

monitored for approximately three days prior to the start of the PW4-4 test (see Tables K.5-16A and K.5-16B). The A series of tables are presented for the manual data for the M Sand wells and the B series are presented for the transducer water-level data. Table K.5-16C present a tabulation of the measured flow rates for pumping well PW4-4. All wells that are southeast of the red line on Figure K.5-2 were used in the PW4-4 test. Water-level changes are presented for approximately three days prior to the pumping of this well and for slightly greater than three days after the pump was turned off (see Figure K.5-9A).

The figures for the M Sand wells consist of "A" (linear water-level change), "B" (semi-log drawdown), "C" (log-log drawdown) and "D" (semi-log recovery) figures. A log-log plot was not developed for the pumping well.

The drawdown in well PW4-4 was approximately 163 feet at the end of pumping (see Figure K.5-9A). The semi-log plot of this drawdown data yields a transmissivity of 120 gal/day/ft (see Figure K.5-9B). The very early drawdown data in pumping well PW4-4 was affected by well storage. The straight-line fit from 20 to 1000 minutes after pumping started is due to the transmitting ability of the M Sand. The deflection of the data below this straight line is due to higher transmissivities in the M Sand away from well PW4-4.

The recovery data of the water levels in pumping well PW4-4 are presented on Figure K.5-9C and Tables K.5-16A and K.5-16BB. The middle portion of the recovery plot is thought to be most representative of the M Sand transmissivity. The flatter slope during late-time recovery (less than t/t' of 4) is a function of the higher transmissivities away from well PW4-4.

K.5.4.2 M SAND OBSERVATION WELLS

The PW4-4 multi-well pump test does not indicate boundary conditions near Wellfield 4A. The results from the semi-log drawdown and recovery plots must be used with caution due to the long time required to meet the straight-line approximation. Also, trend changes caused by Wellfield 4 on the M Sand water levels affected the recovery data. The Theis type curve was fit to the late time drawdown data giving less weight to the very early time data. These aquifer properties should be representative of the M Sand. Table K.5-1 presents the transmissivities obtained from the multi-well test for the straight-line, Theis and recovery.

Figure K.5-2 presents the transmissivities from the log-log fit for the southeastern half of Wellfield 4A. The log-log fits are thought to produce the best aquifer properties from this pump test. The transmissivity and storage coefficient calculated from this log-log fit should be representative of the M Sand in the area of the observation well. A late time, straight-line fit on the semi-log drawdown plots was used but three days was not long enough to meet the straight-line method requirements for some of the larger distance wells. In closer wells, the straight-line values should produce an accurate transmissivity and storage coefficient. In wells at greater distances, the straight-line results should be used with caution and evaluated as to whether the straight-line method is appropriate (u values less than 0.1, see Section E.7.1.1 of Hydro-Engineering L.L.C., 1997). Also, the straight-line fits from the recovery data were generally not used due to changes in water-level trends caused by Wellfield 4.

Well storage affected only the pumping well and the nearest M Sand observation well, MP428. The semi-log plot (Figure K.5-13B) shows typical well storage effects with a steeper straight line being observed prior to reaching the true straight line for the aquifer.

Tables K.5-17A through K.5-54A present the manual and transducer data for the M Sand observation wells. Tables K.5-17A through K.5-19A, K.5-27A through K.5-34A and K.5-50A through K.5-54A present only a few manual water levels because these M Sand wells were not used in the PW4-4 test. No plots are presented for this group of M Sand wells. The A, B, C and D series of plots were developed for each of the M Sand observation wells used in the PW4-4 multi-well test.

The transmissivities from the M Sand observation wells varied from 130 to 210 gal/day/ft. The average transmissivity from the Theis fit is 160 gal/day/ft. The transmissivities from the straight-line method yielded, in general, slightly larger values due to some of these semi-log plots not meeting the straight-line time requirement. The recovery straight-line plots generally were not fit with a straight line because variations in Wellfield 4 affected the recovery.

Table K.5-1 also presents the hydraulic conductivity for the M Sand wells. The transmissivities from the Theis log-log plot were used in calculating the hydraulic conductivities along with an aquifer thickness of 24 feet at pumping well PW4-4. This produced hydraulic conductivities that varied from 0.72 to 1.17 ft/day (0.22 to 0.35 Darcy).

Table K.5-1 also presents a tabulation of storage coefficients obtained from this multi-well pump test. The storage coefficients varied from 1.4E-05 to 7.7E-05

with an average value of 3.7E-05. The storage coefficient derived from the Theis log-log fit is tabulated in Table K.5-1, and it should be the considered the best storage coefficient to use from this multi-well pump test.

The aquifer properties from the PW4-4 multi-well test for the M Sand are fairly consistent with the lower values found in Wellfield 4A. The smaller transmissivities in Wellfield 4A are a function of a thinner and less permeable M Sand in this area.

K.5.4.3 BOUNDARY CONDITIONS

The semi-log and log-log plots of drawdown versus time for the M wells for the PW4-4 pump test do not indicate the effects of a boundary in the M Sand. Some of the variations in the recovery plots could be construed to be due to a boundary. However, this is not consistent with the results from the drawdown plots. The lag in recovery is thought to be due to variations in Wellfield 4 operation because the wells closer to Wellfield 4 showed more lag in recovery. The PW4-4 multi-well pump test did not detect boundaries in this area of the M Sand.

K.5.4.4 DIRECTIONAL TRANSMISSIVITY

Several different combinations of three observation wells were used to analyze the directional transmissivity for the M Sand. The log-log match point values were used in this analysis, along with the observation well locations.[1]

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[1] Papadopulos, 1965, Method for Anisotropic Analysis was used to determine the horizontal anisotropic properties.

Tables K.5-55 through K.5-60 present the results from the different combinations of three monitoring wells that were used to determine the anisotropic ratio. The direction of the major transmissivity axis from these results varied from negative 123 degrees to 26 degrees, relative to the x-axis where positive is counterclockwise. This indicates that the major axis is highly variable depending on the combination of wells used in the analysis.

The drawdown from this pump test (see Figure K.5-1) indicates a little elongation toward the northeast and southwest of pumping well PW4-4. The ratio of the major to minor axis (anisotropic ratio) varied from a 0.49 to 50.3 factor. The varied results of the direction of the major transmissivity axis and the anisotropic ratios make it questionable to use a directional transmissivity analysis for this site.

THIS PAGE IS AN OVERSIZED DRAWING OR FIGURE,

THAT CAN BE VIEWED AT THE RECORD TITLED:

FIG. K.5-1, REV. NO. 1

SMITH RANCH PROJECT WELLFIELD 4A PATTERNS M SAND DRAWDOWN AT THE END OF THE PW4-4 PUMP TEST, IN FEET

WITHIN THIS PACKAGE...OR, BY SEARCHING USING THE DOCUMENT/REPORT FIG. K.5-1, REV. NO. 1

NOTE: Because of this page's large file size, it may be more convenient to copy the file to a local drive and use the Imaging (Wang) viewer, which can be accessed from the Programs/Accessories menu.

THIS PAGE IS AN OVERSIZED DRAWING OR FIGURE,

THAT CAN BE VIEWED AT THE RECORD TITLED:

FIG. K.5-2, REV. NO. 1

SMITH RANCH PROJECT WELLFIELD 4A PATTERNS M SAND TRANSMISSIVITY RESULTS FROM THE PW4-4 TEST, GPD/FT

WITHIN THIS PACKAGE...OR, BY SEARCHING USING THE DOCUMENT/REPORT FIG. K.5-2, REV. NO. 1

NOTE: Because of this page's large file size, it may be more convenient to copy the file to a local drive and use the Imaging (Wang) viewer, which can be accessed from the Programs/Accessories menu.

FIGURE K.5-3A. WATER-LEVEL CHANGES IN ADJACENT AQUIFER WELL MS415

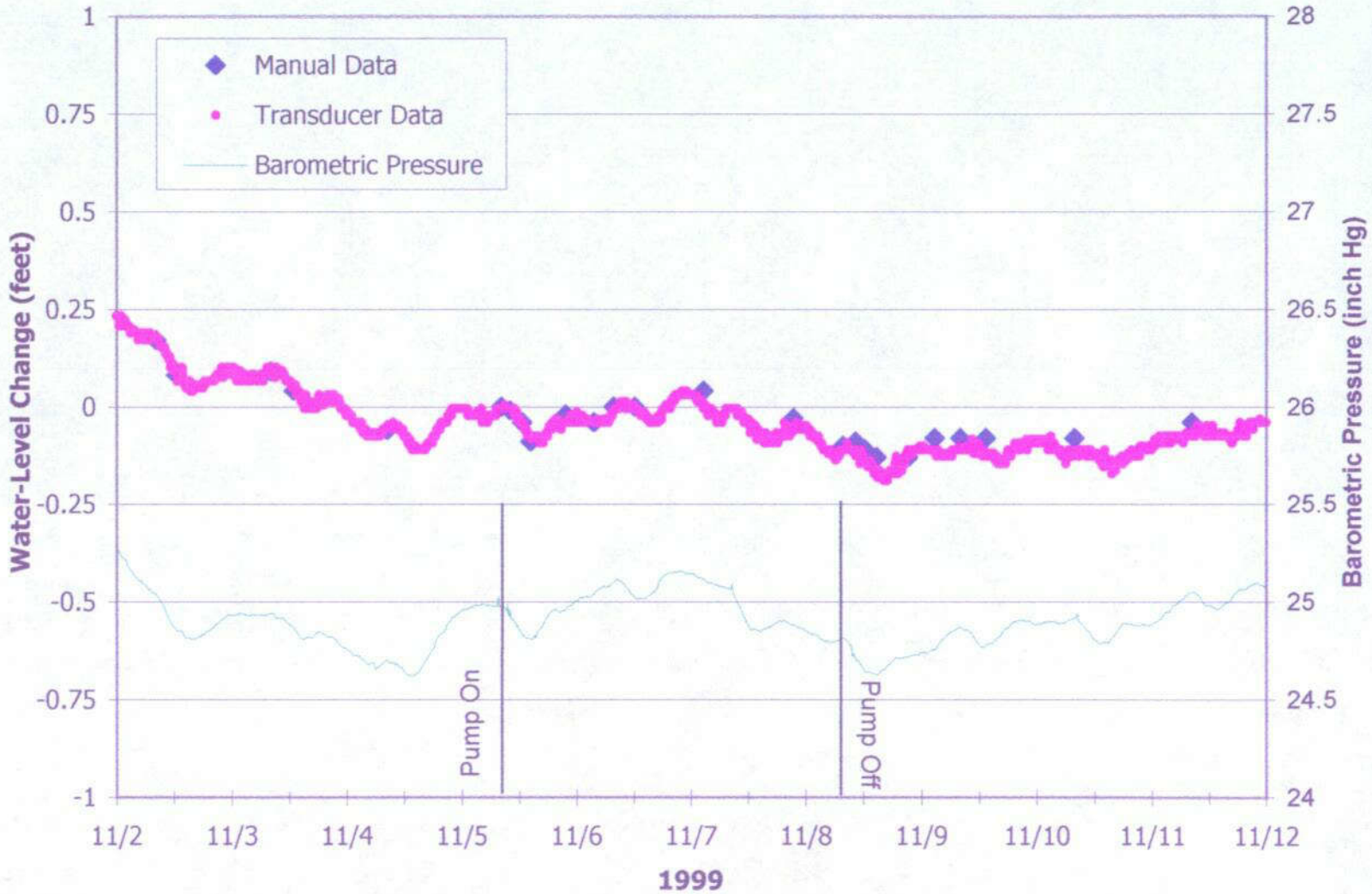


FIGURE K.5-4A. WATER-LEVEL CHANGES IN ADJACENT AQUIFER WELL MS416

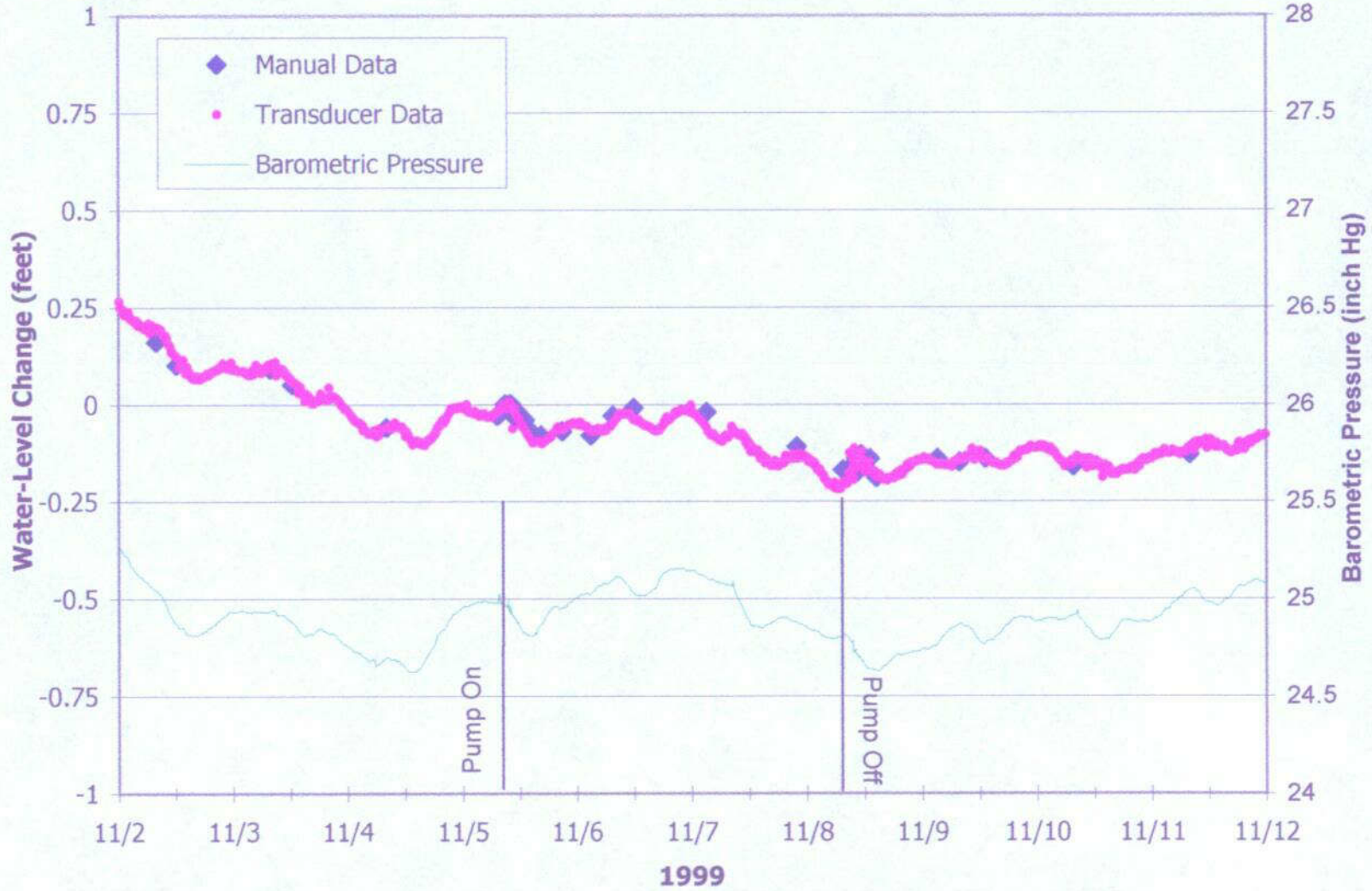


FIGURE K.5-5A. WATER-LEVEL CHANGES IN ADJACENT AQUIFER WELL MS417

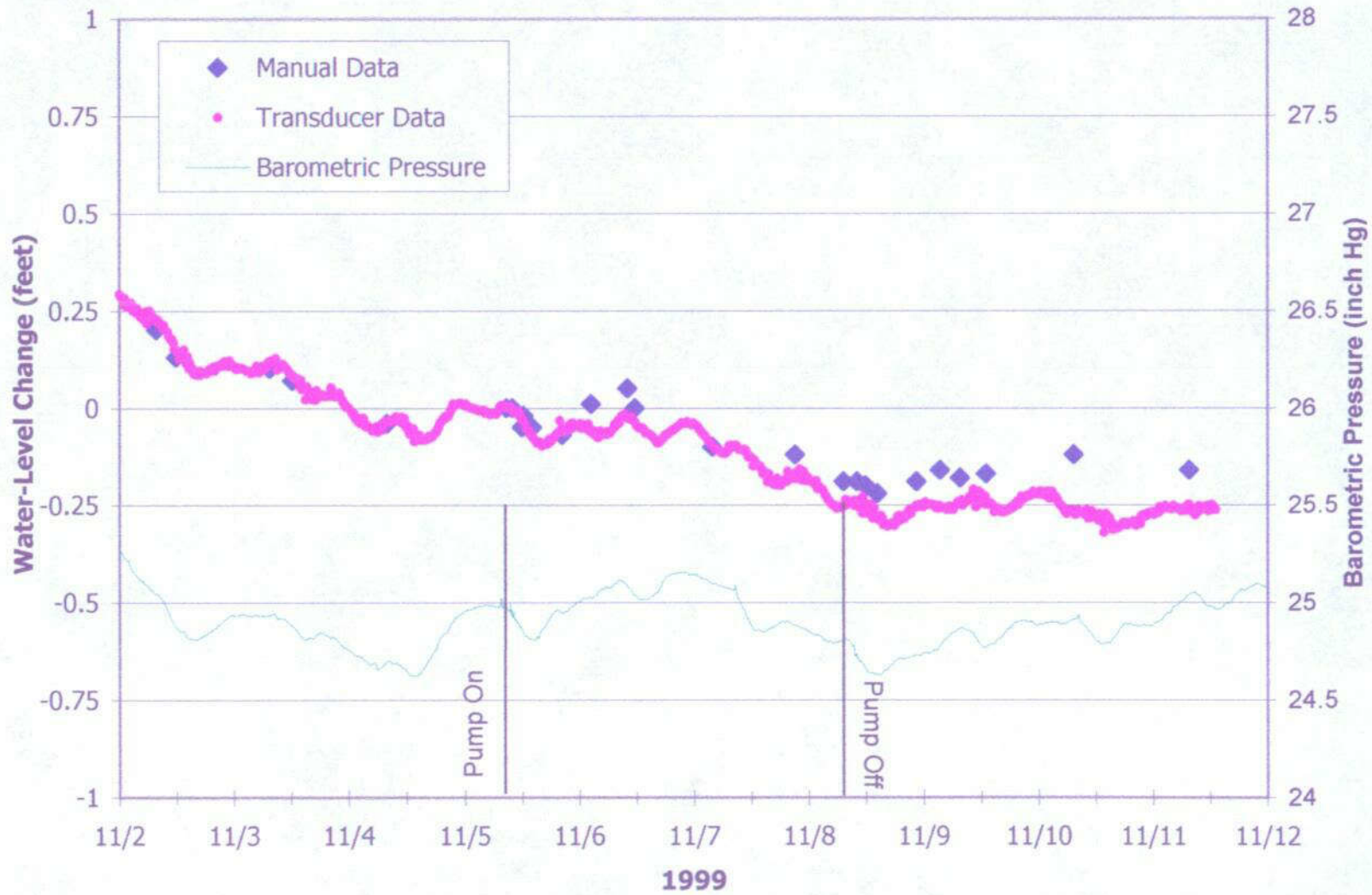


FIGURE K.5-6A. WATER-LEVEL CHANGES IN ADJACENT AQUIFER WELL MD415

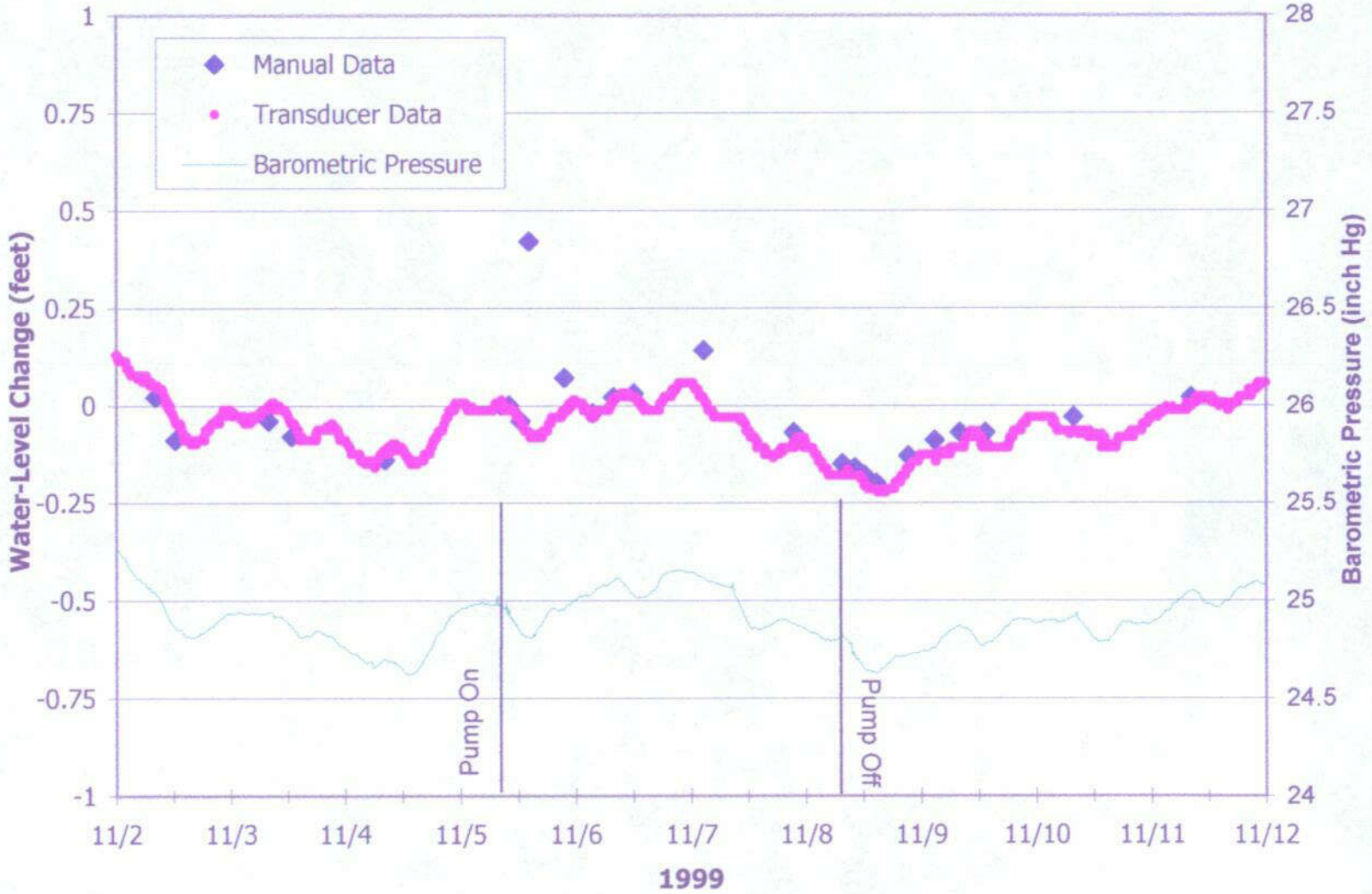


FIGURE K.5-7A. WATER-LEVEL CHANGES IN ADJACENT AQUIFER WELL MD416

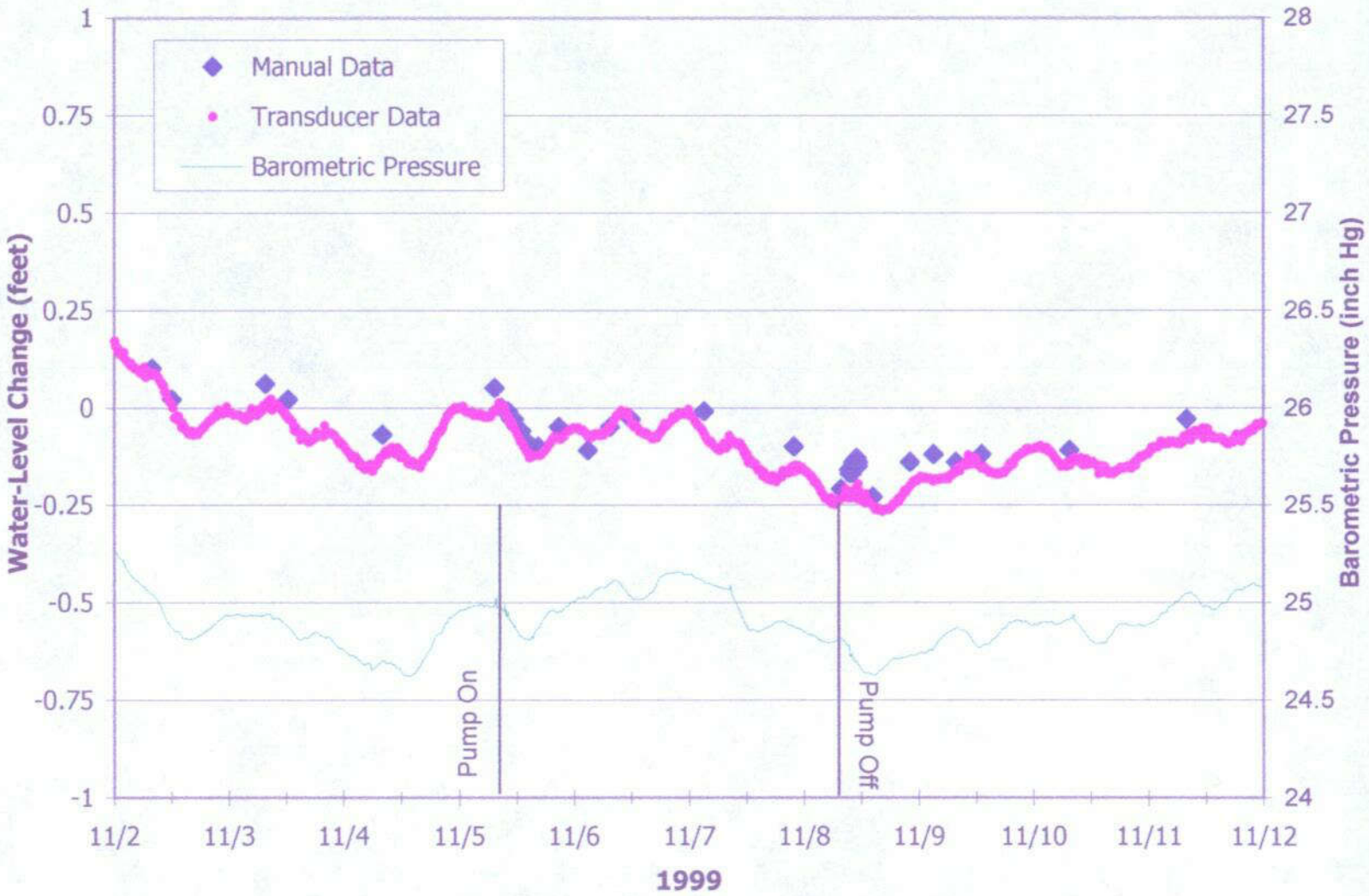


FIGURE K.5-8A. WATER-LEVEL CHANGES IN ADJACENT AQUIFER WELL MD417

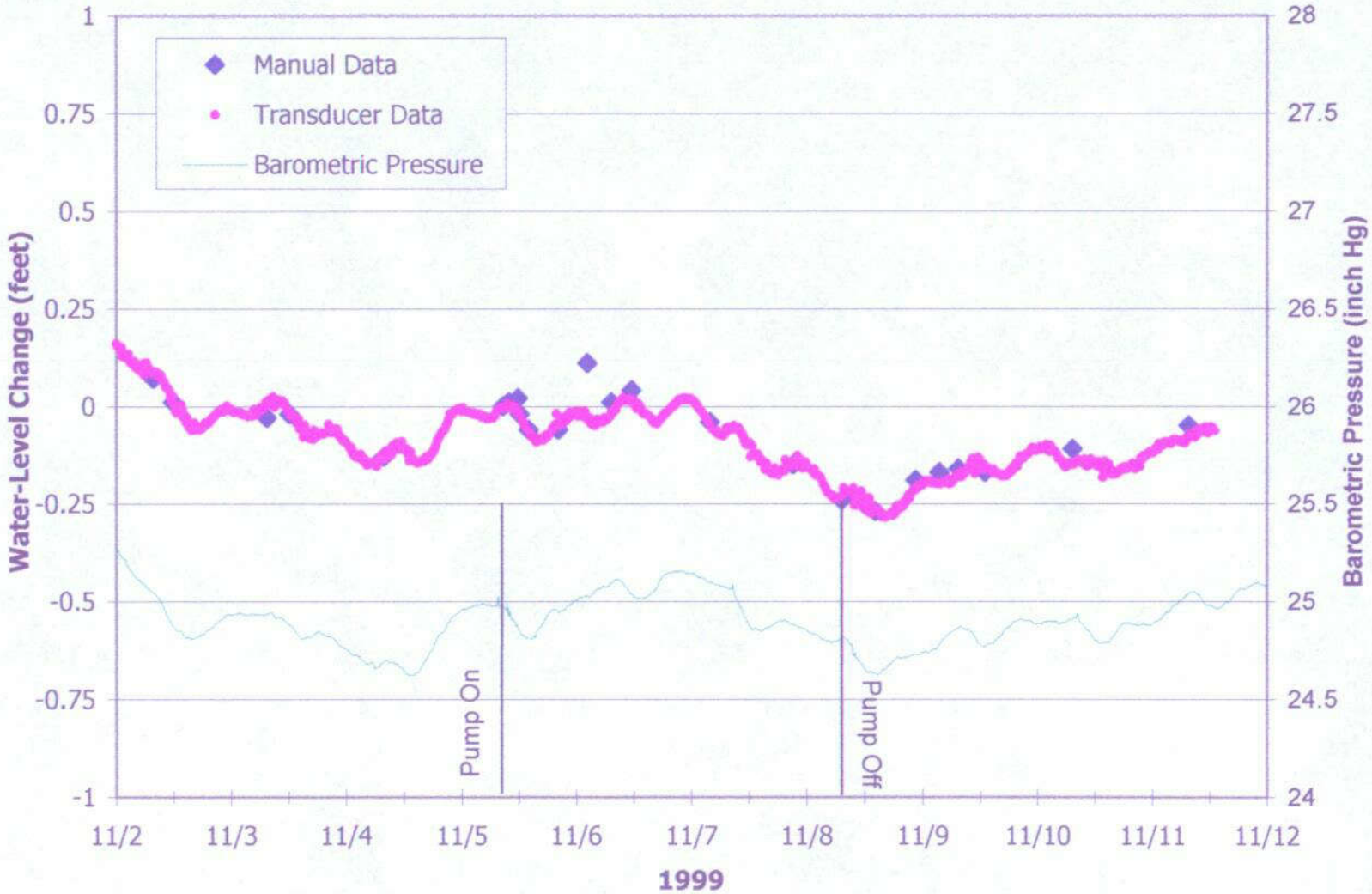
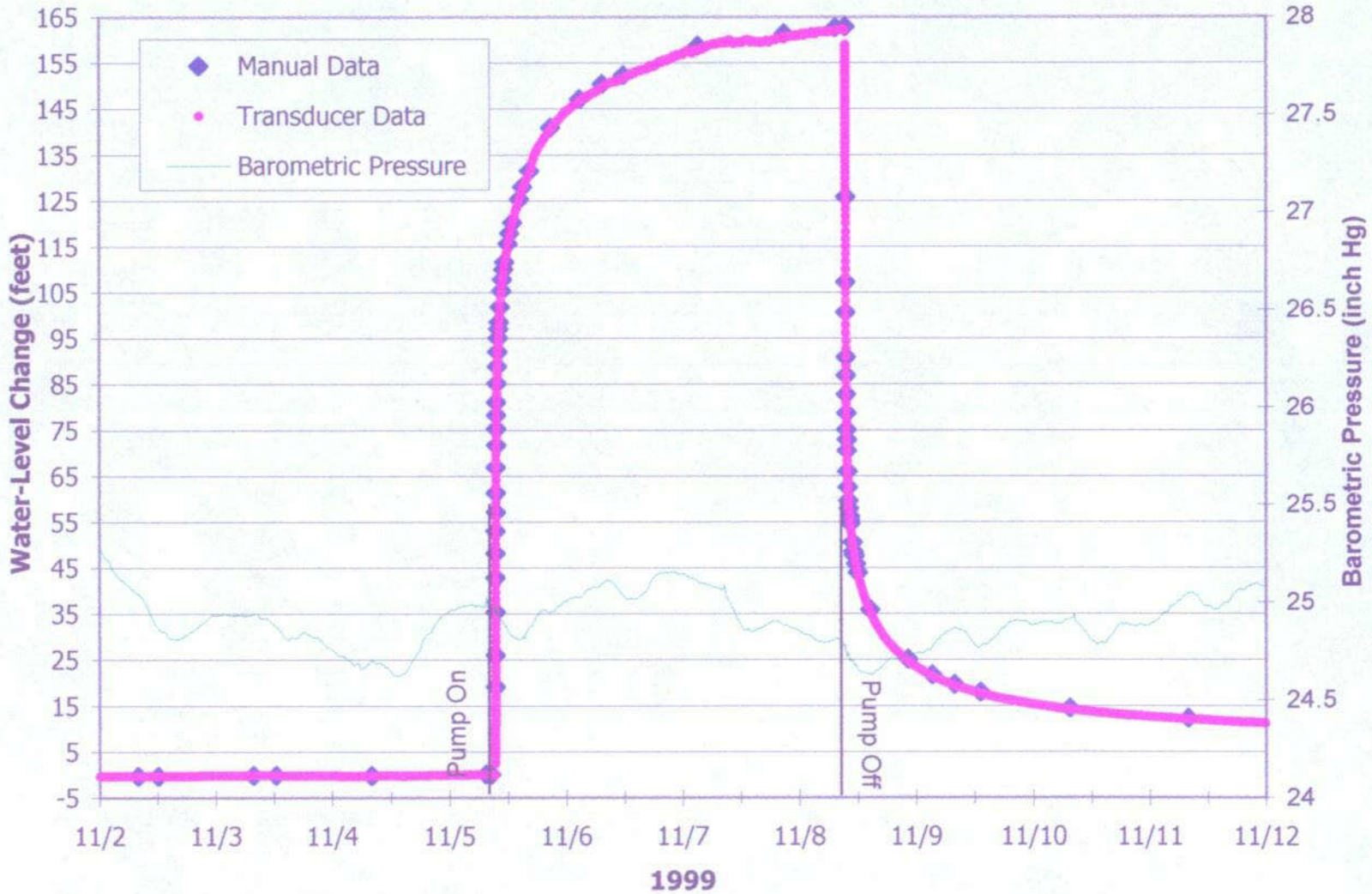


FIGURE K.5-9A. WATER-LEVEL CHANGE IN PUMPING WELL PW4-4



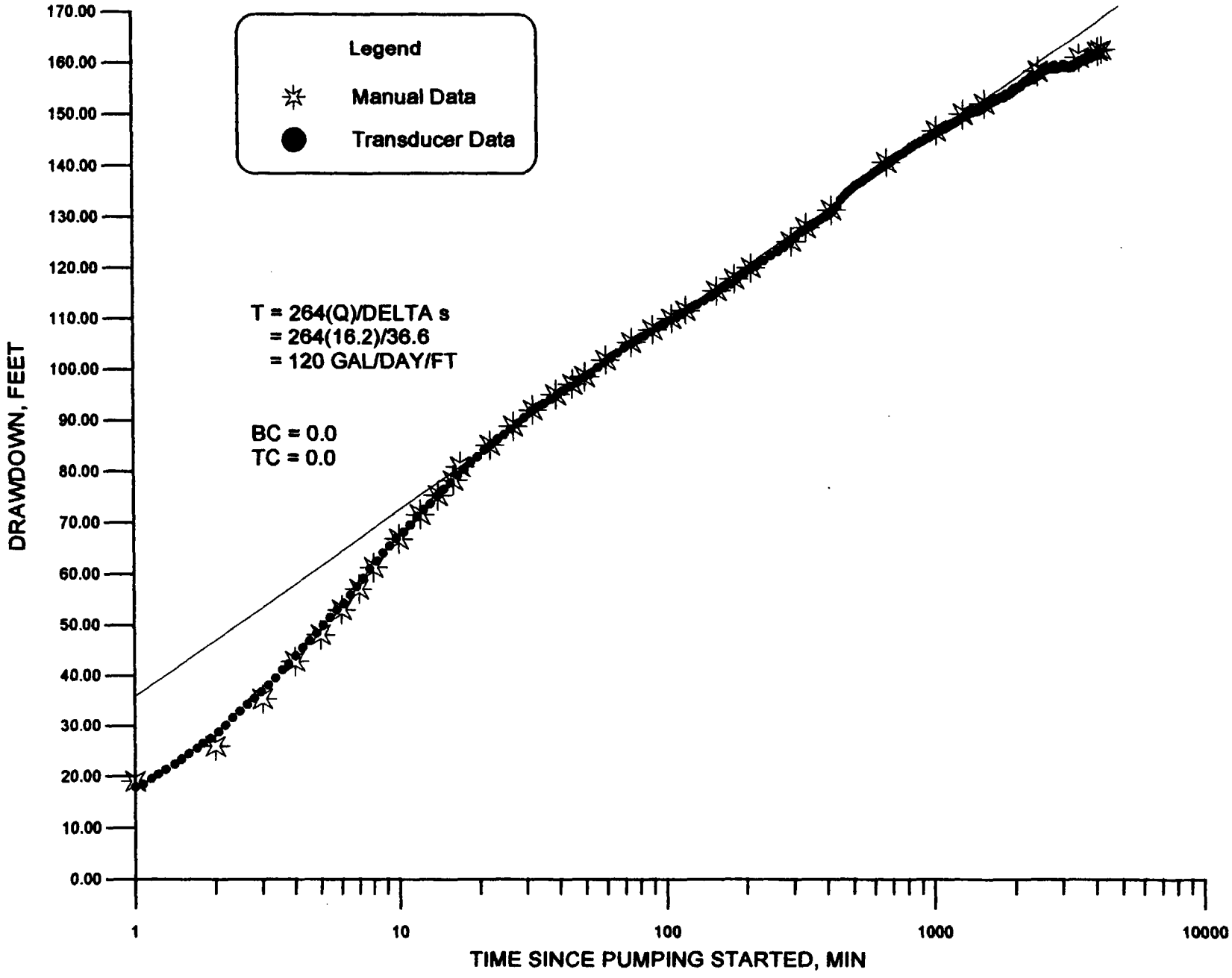


FIGURE K.5-9B. DRAWDOWN IN PUMPING WELL PW4-4, SEMI-LOG.

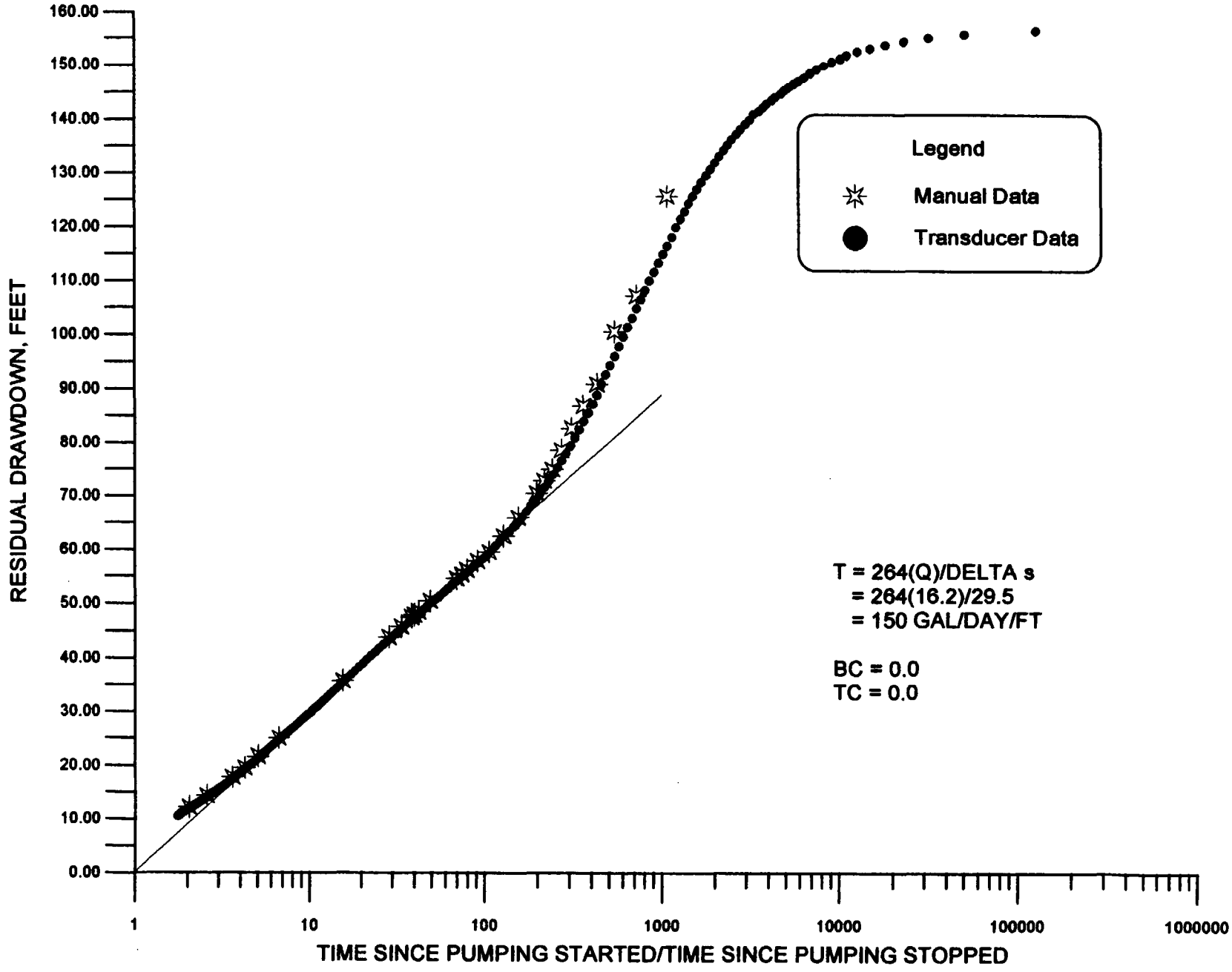
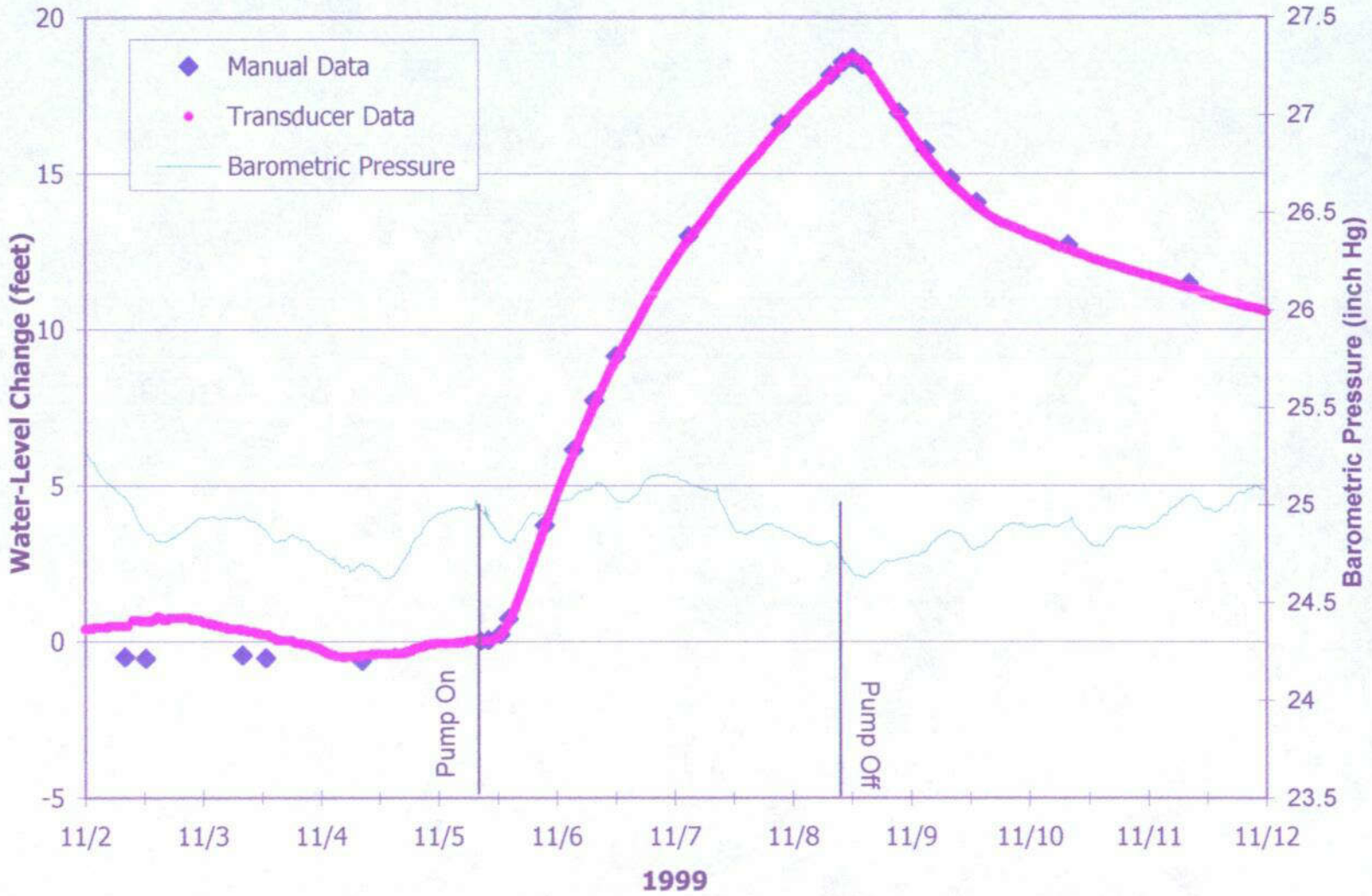


FIGURE K.5-9C. RECOVERY IN PUMPING WELL PW4-4.

FIGURE K.5-10A. WATER-LEVEL CHANGE IN OBSERVATION WELL MP425



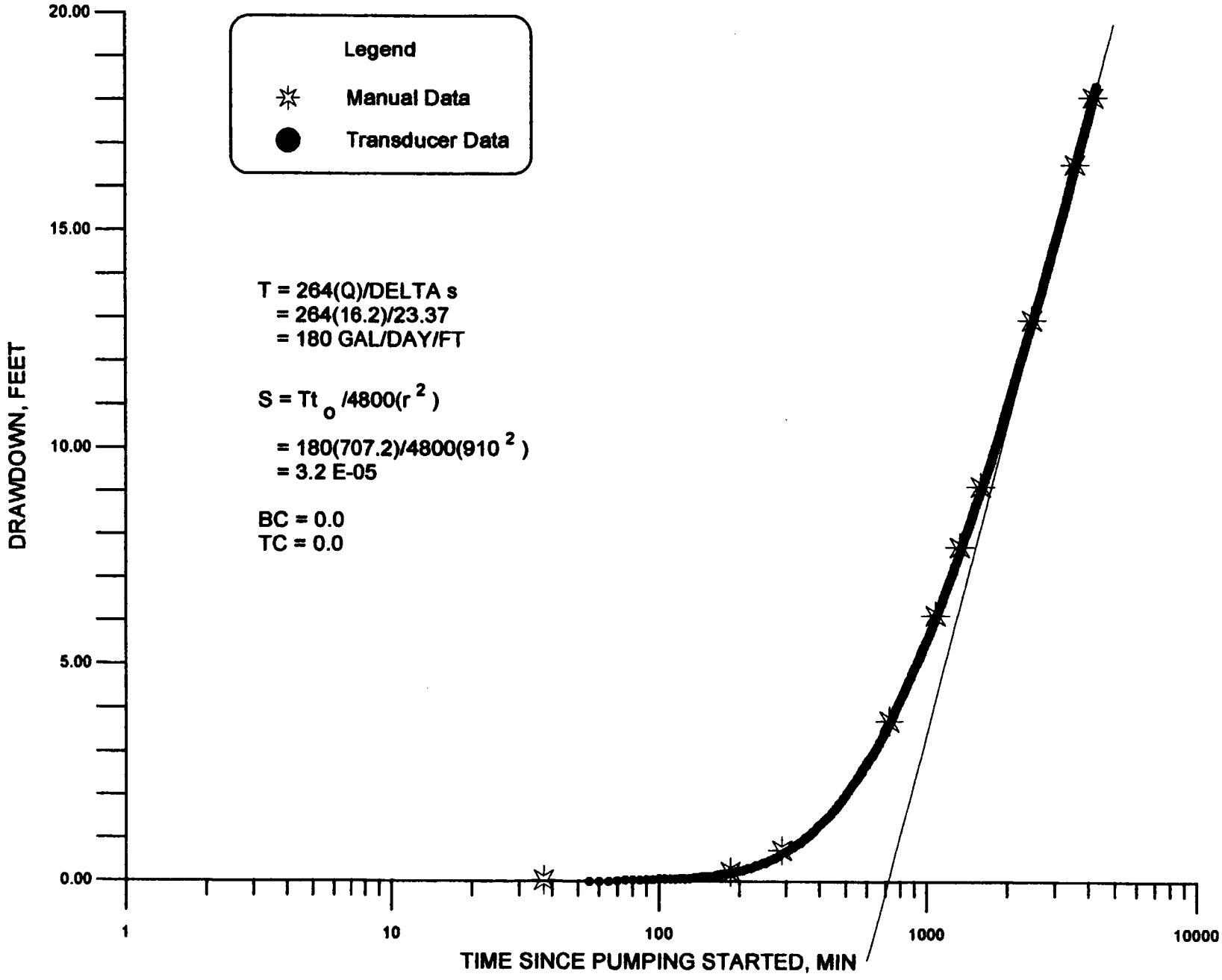
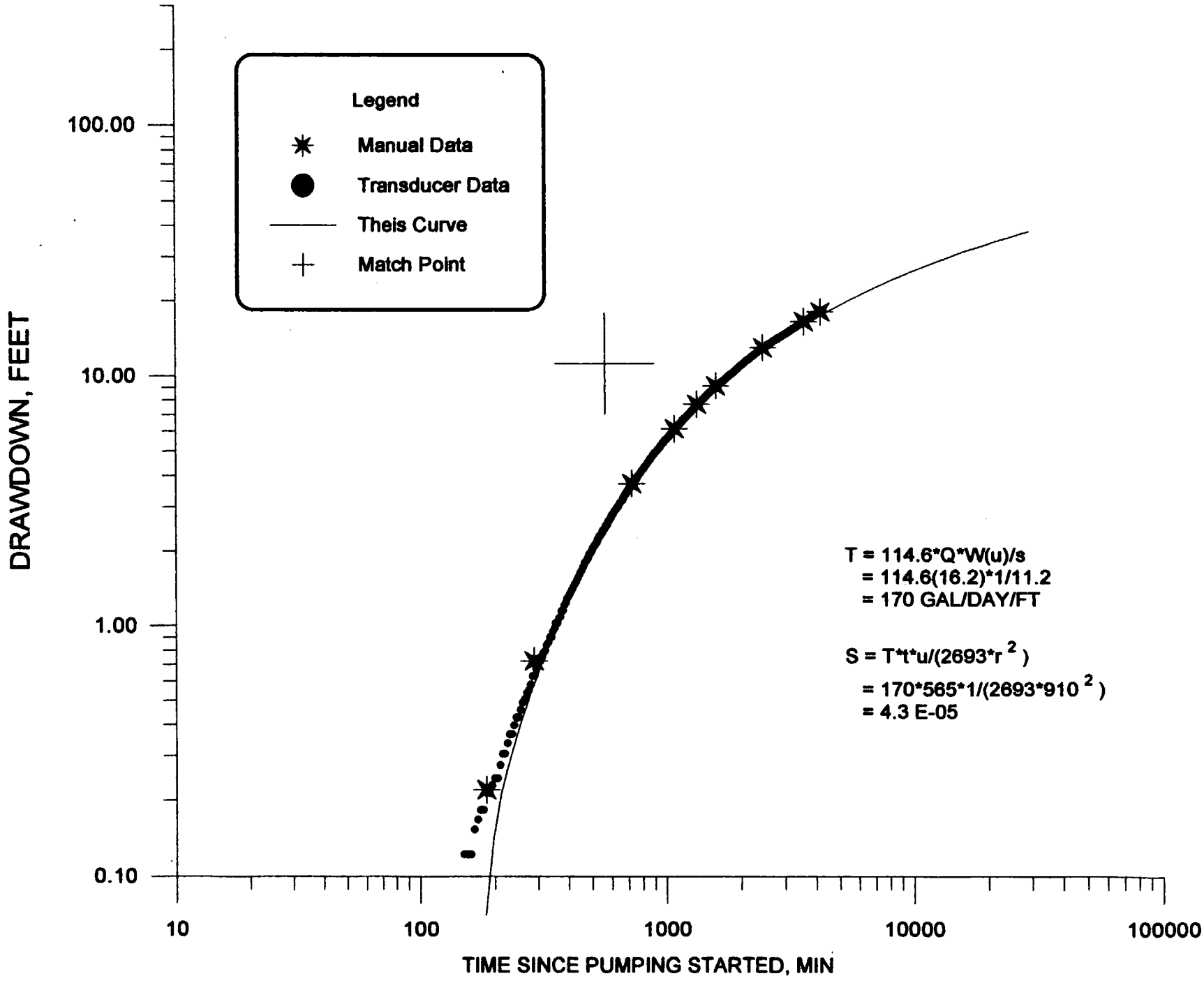


FIGURE K.5-10B. DRAWDOWN IN OBSERVATION WELL MP425, SEMI-LOG.



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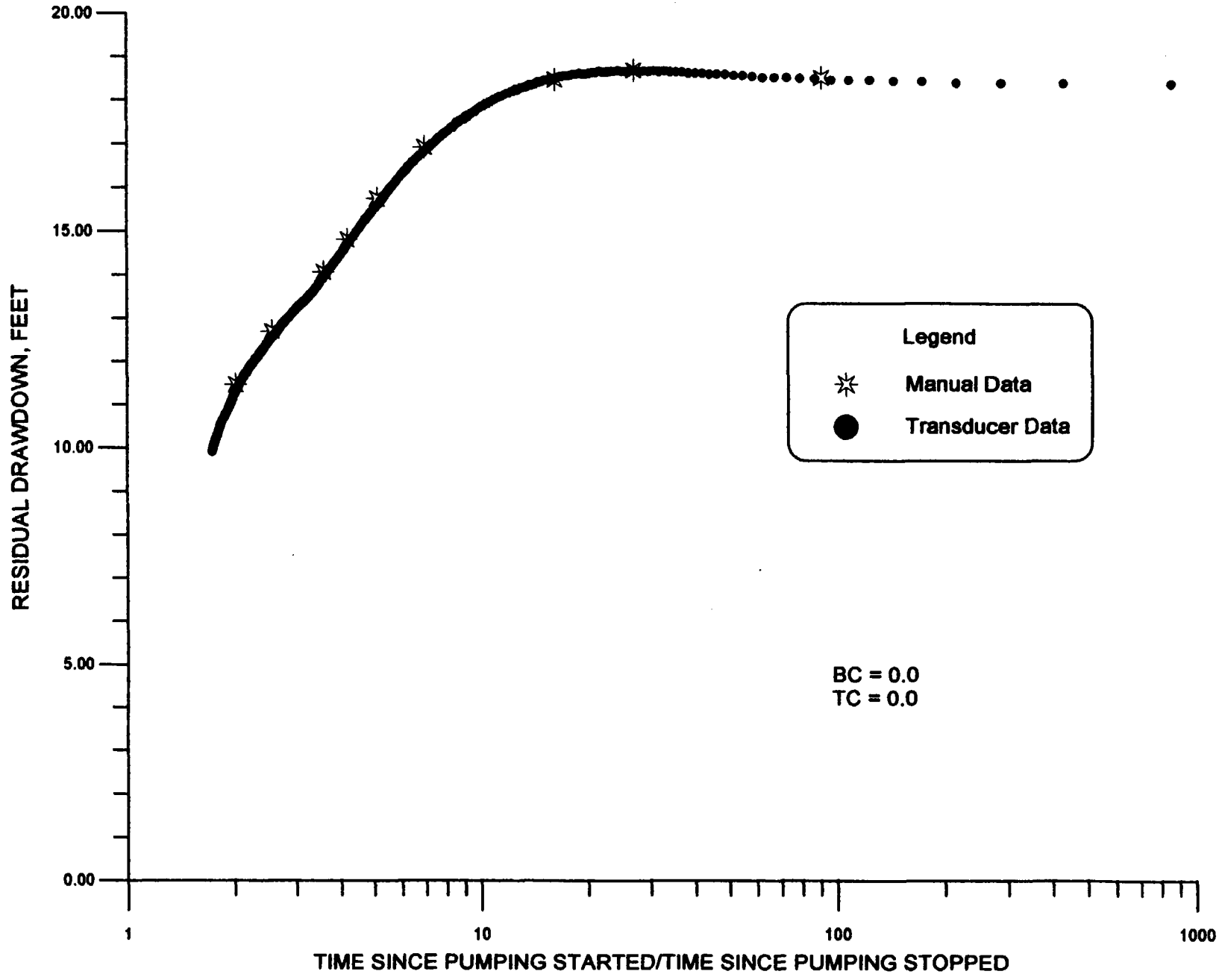
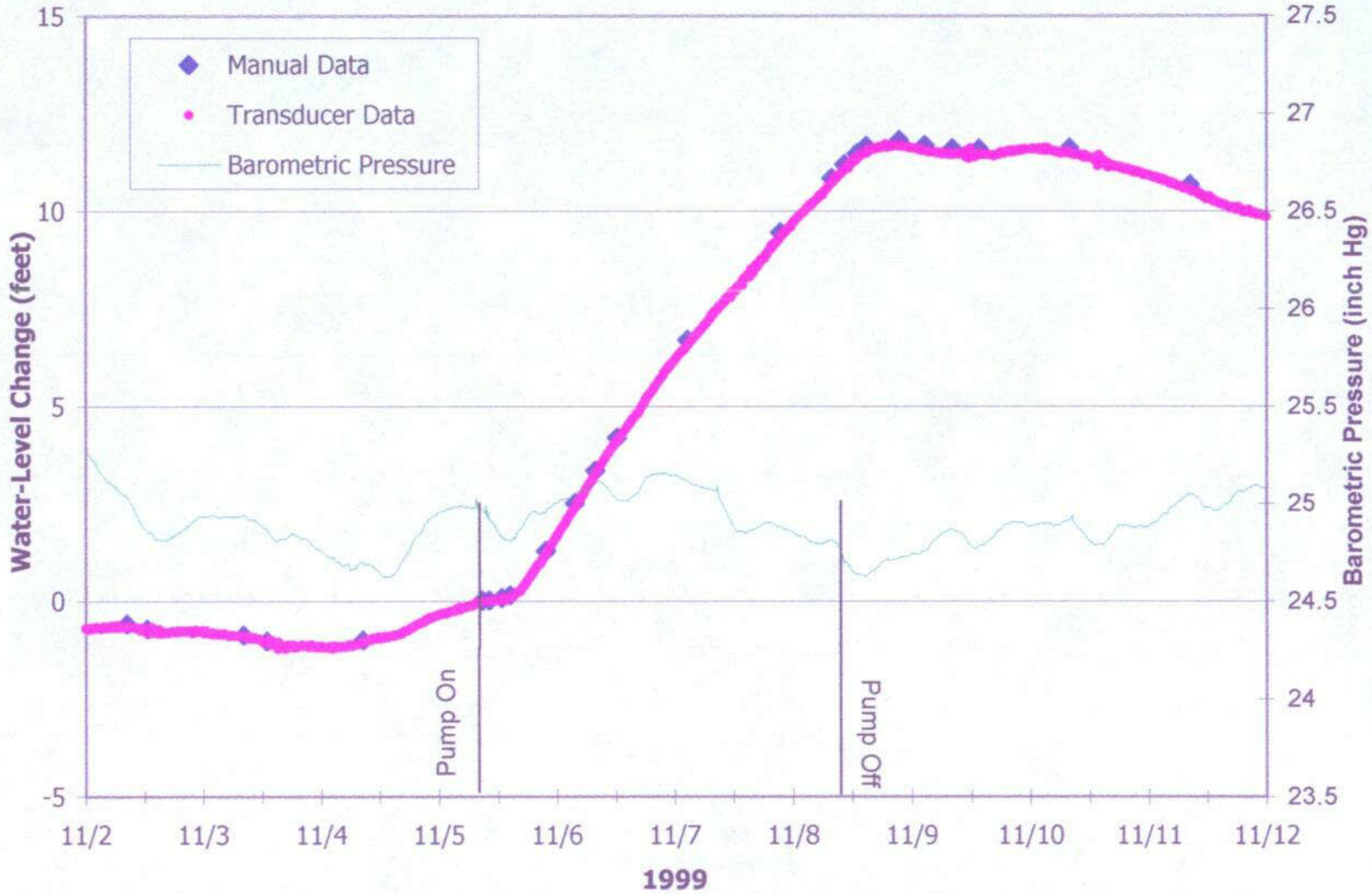


FIGURE K.5-10D. RECOVERY IN OBSERVATION WELL MP425.

FIGURE K.5-11A. WATER-LEVEL CHANGE IN OBSERVATION WELL MP426



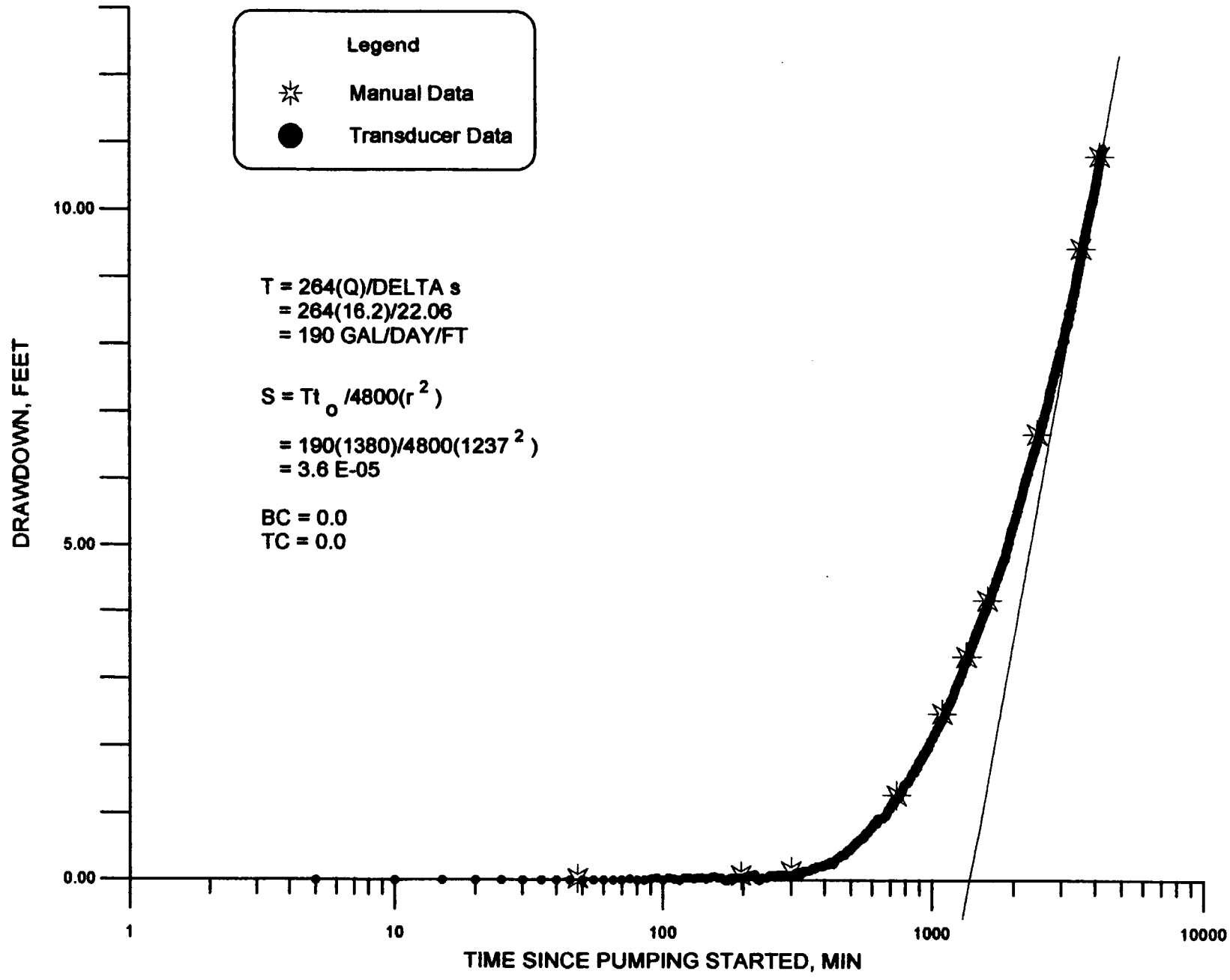


FIGURE K.5-11B. DRAWDOWN IN OBSERVATION WELL MP426, SEMI-LOG.

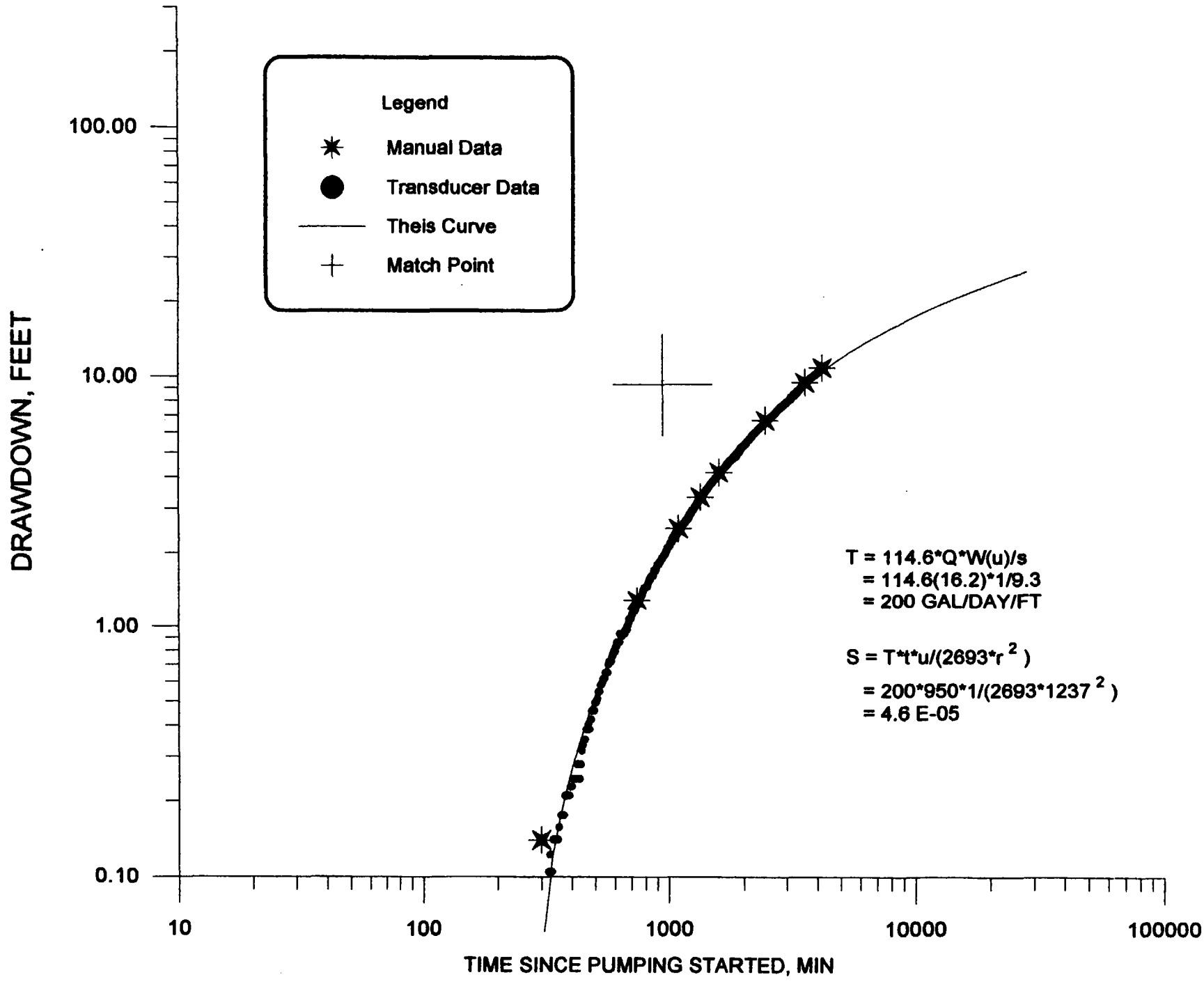


FIGURE K.5-11C. DRAWDOWN IN OBSERVATION WELL MP426, LOG-LOG.

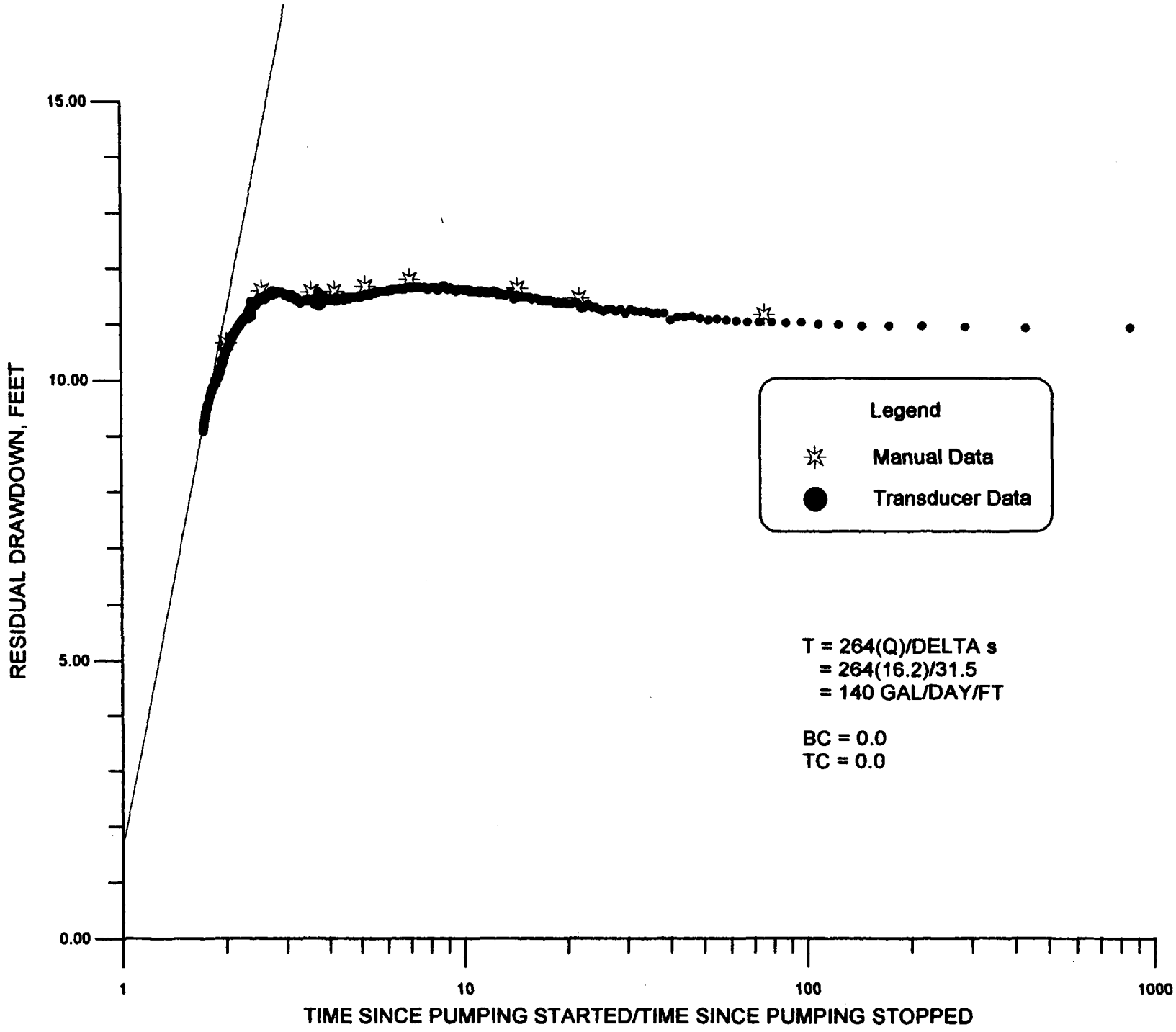
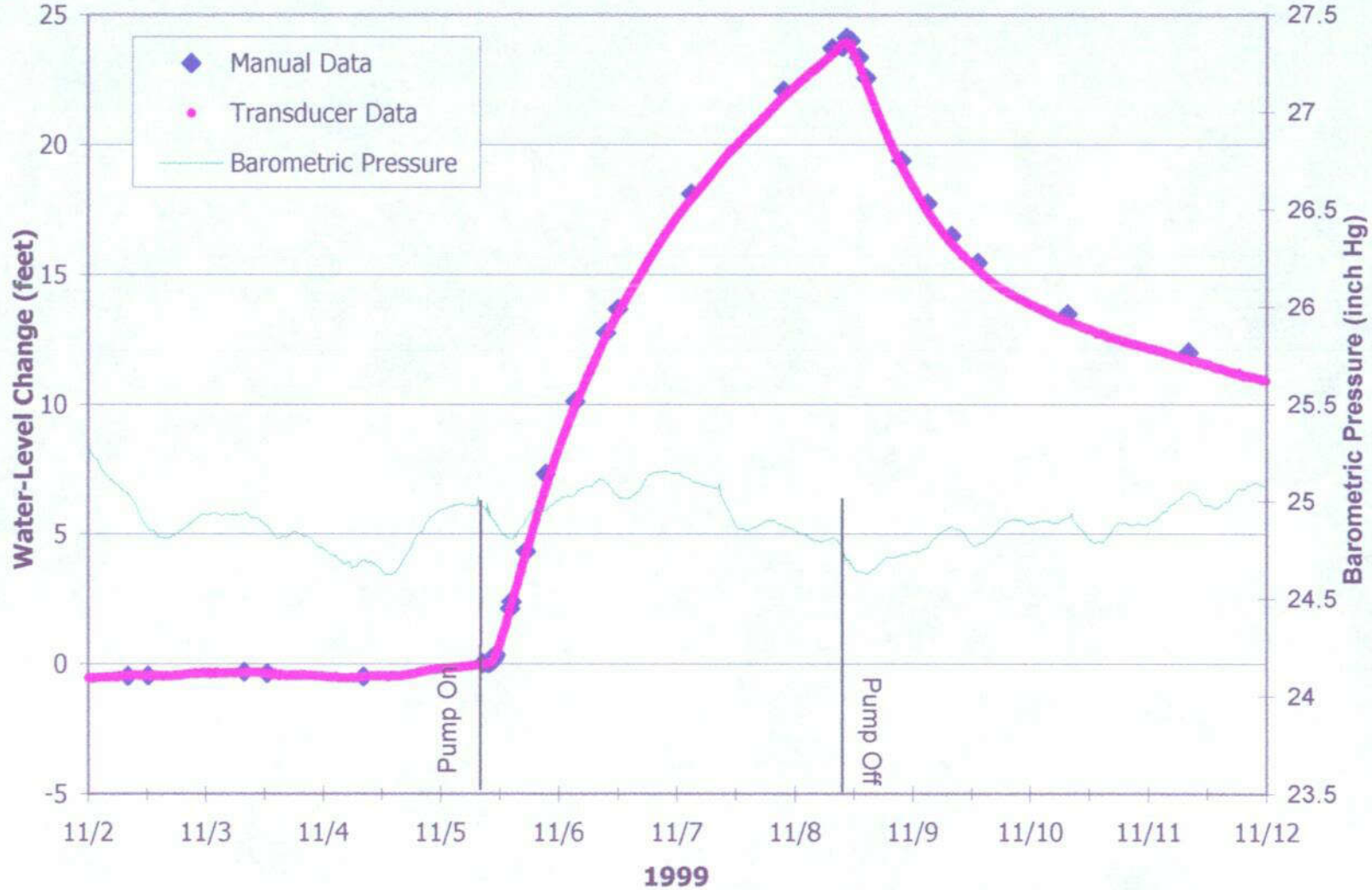


FIGURE K.5-11D. RECOVERY IN OBSERVATION WELL MP426.

FIGURE K.5-12A. WATER-LEVEL CHANGE IN OBSERVATION WELL MP427A



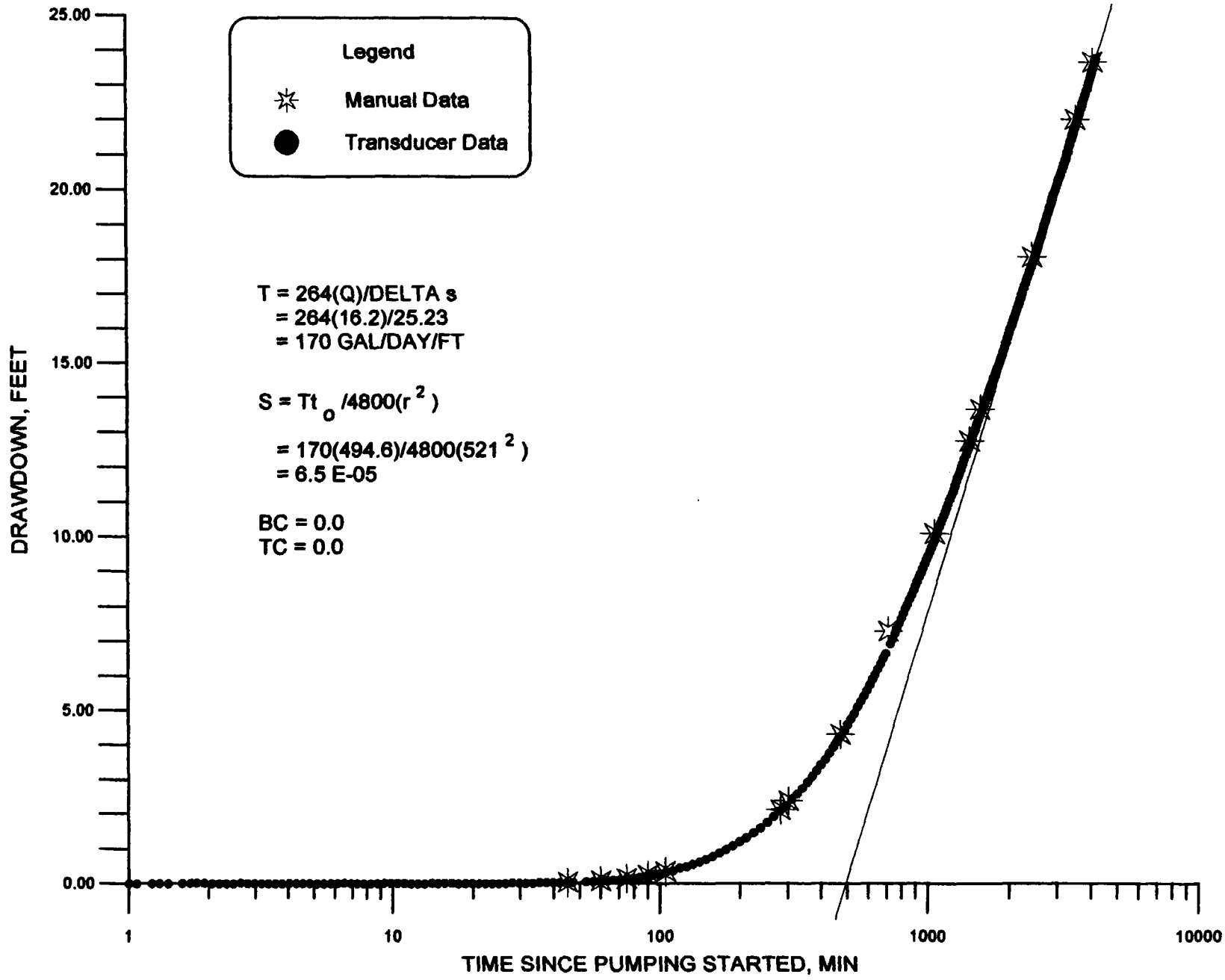


FIGURE K.5-12B. DRAWDOWN IN OBSERVATION WELL MP427A, SEMI-LOG.

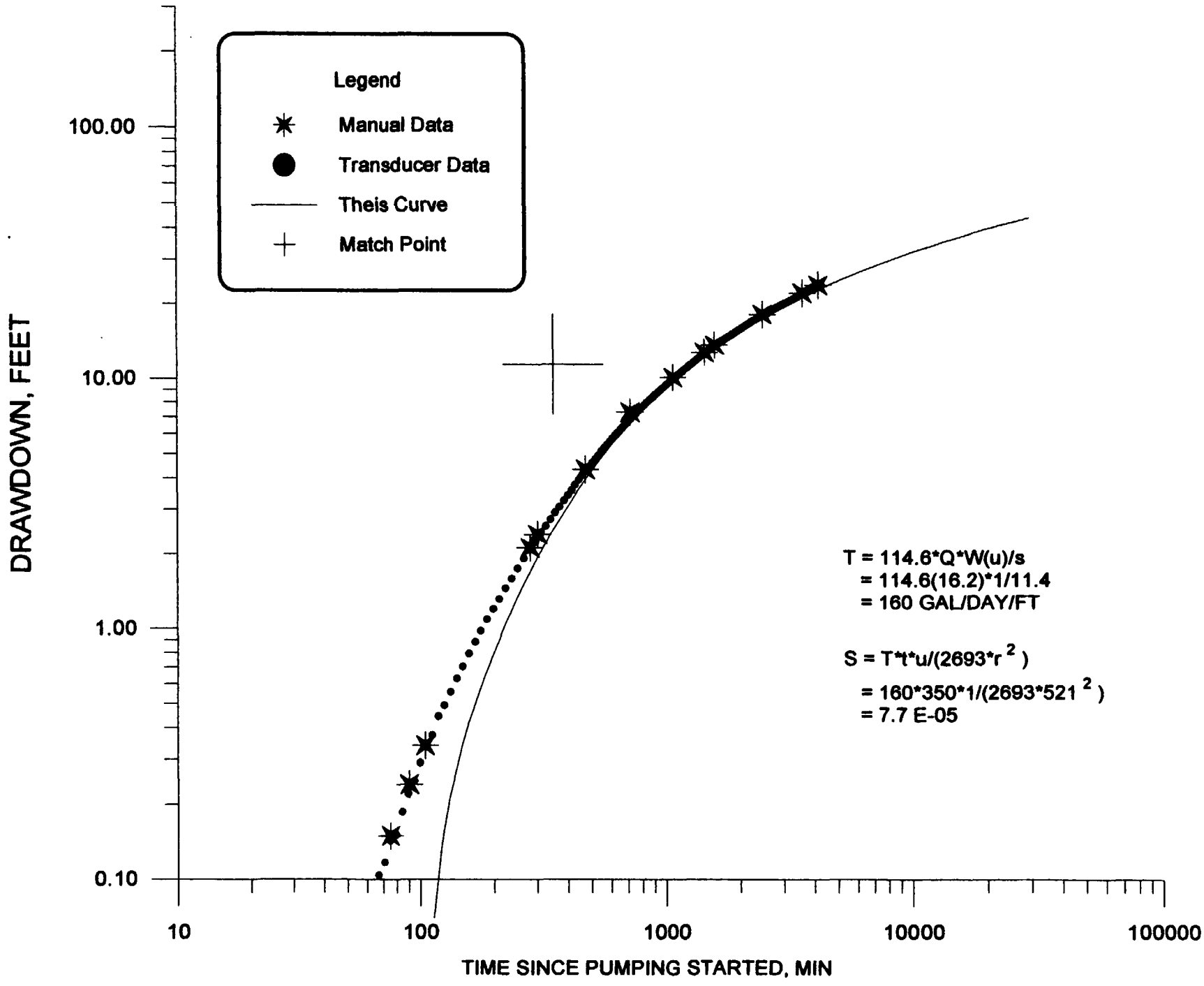


FIGURE K.5-12C. DRAWDOWN IN OBSERVATION WELL MP427A, LOG-LOG.

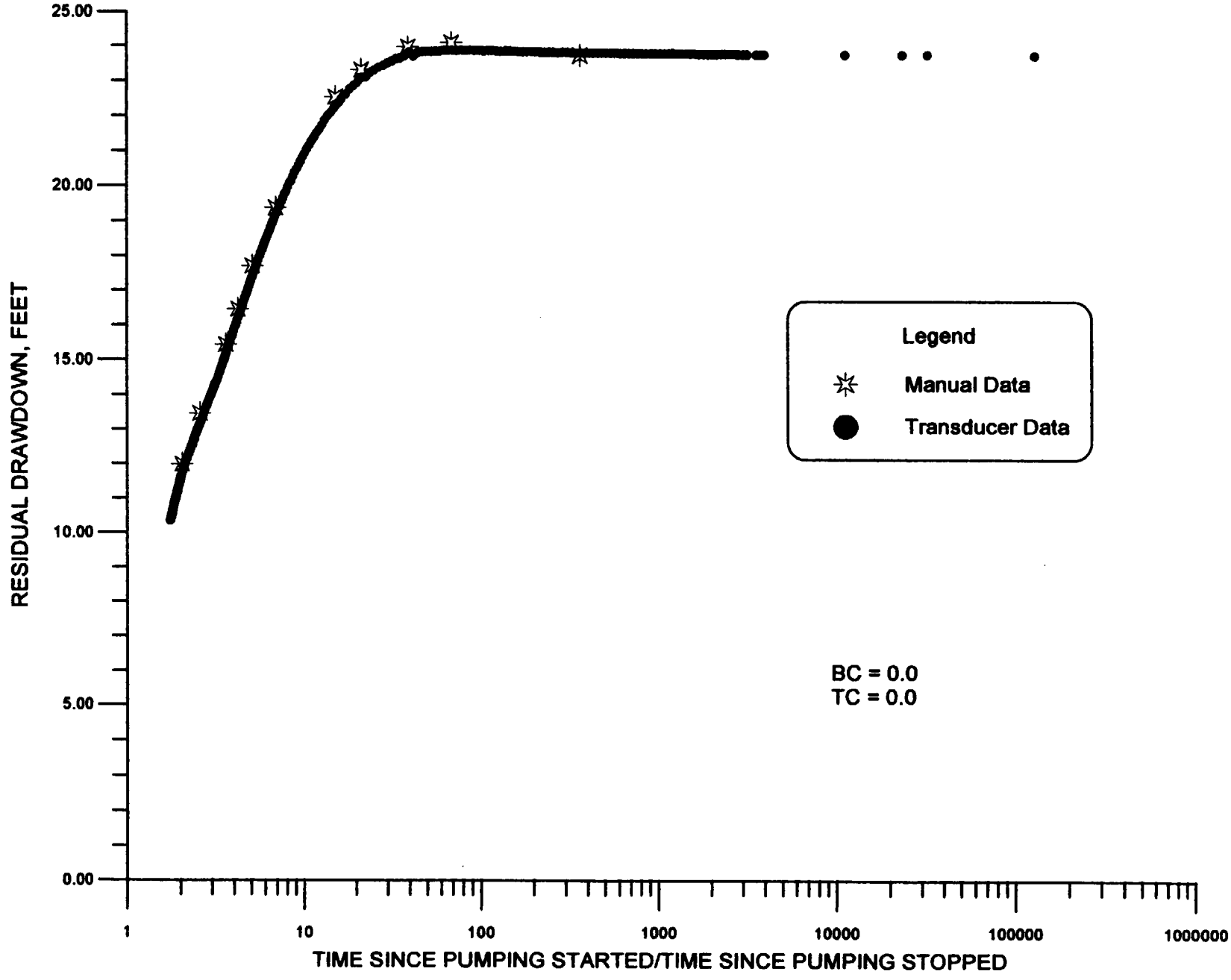
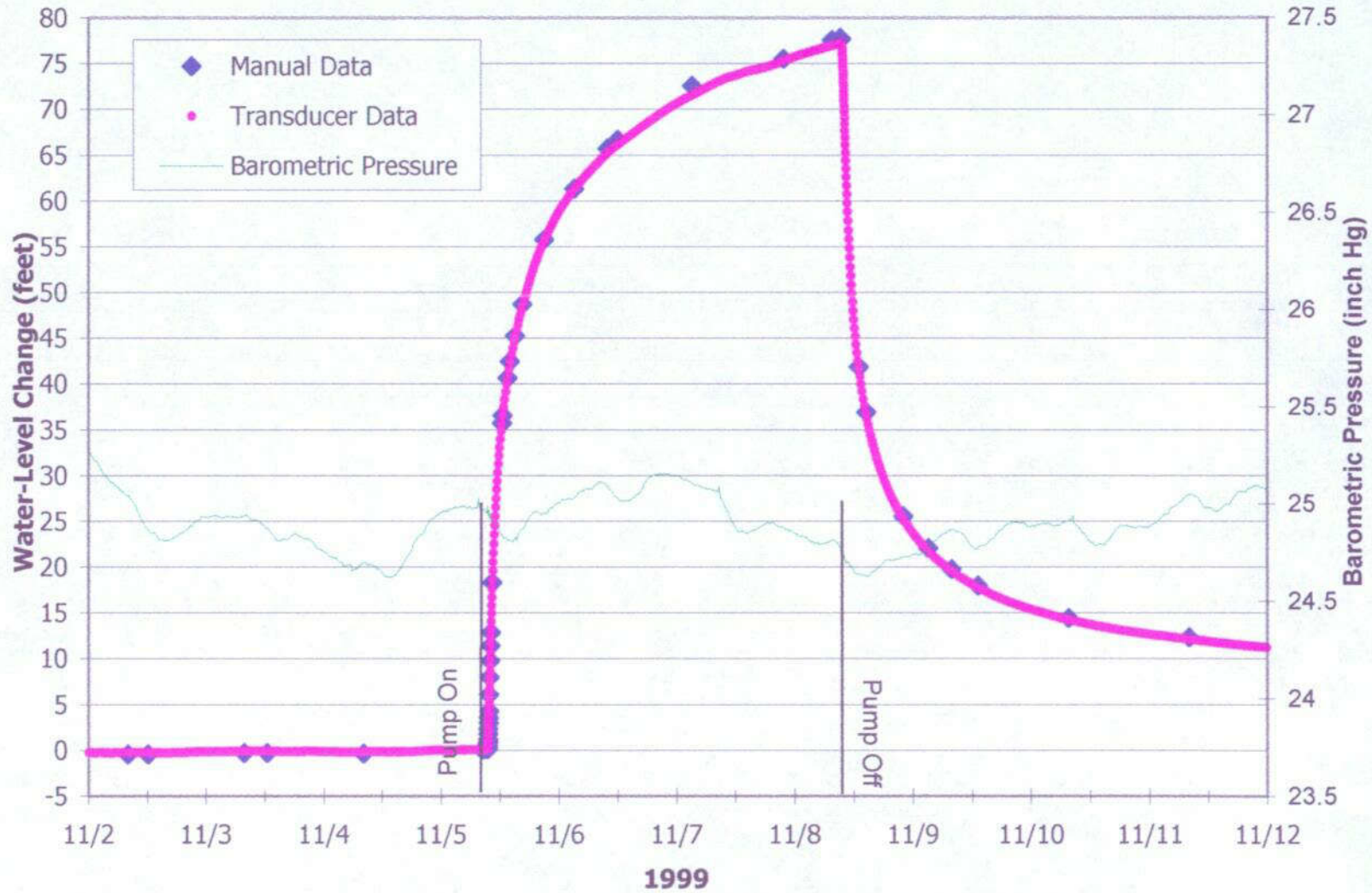


FIGURE K.5-12D. RECOVERY IN OBSERVATION WELL MP427A.

FIGURE K.5-13A. WATER-LEVEL CHANGE IN OBSERVATION WELL MP428



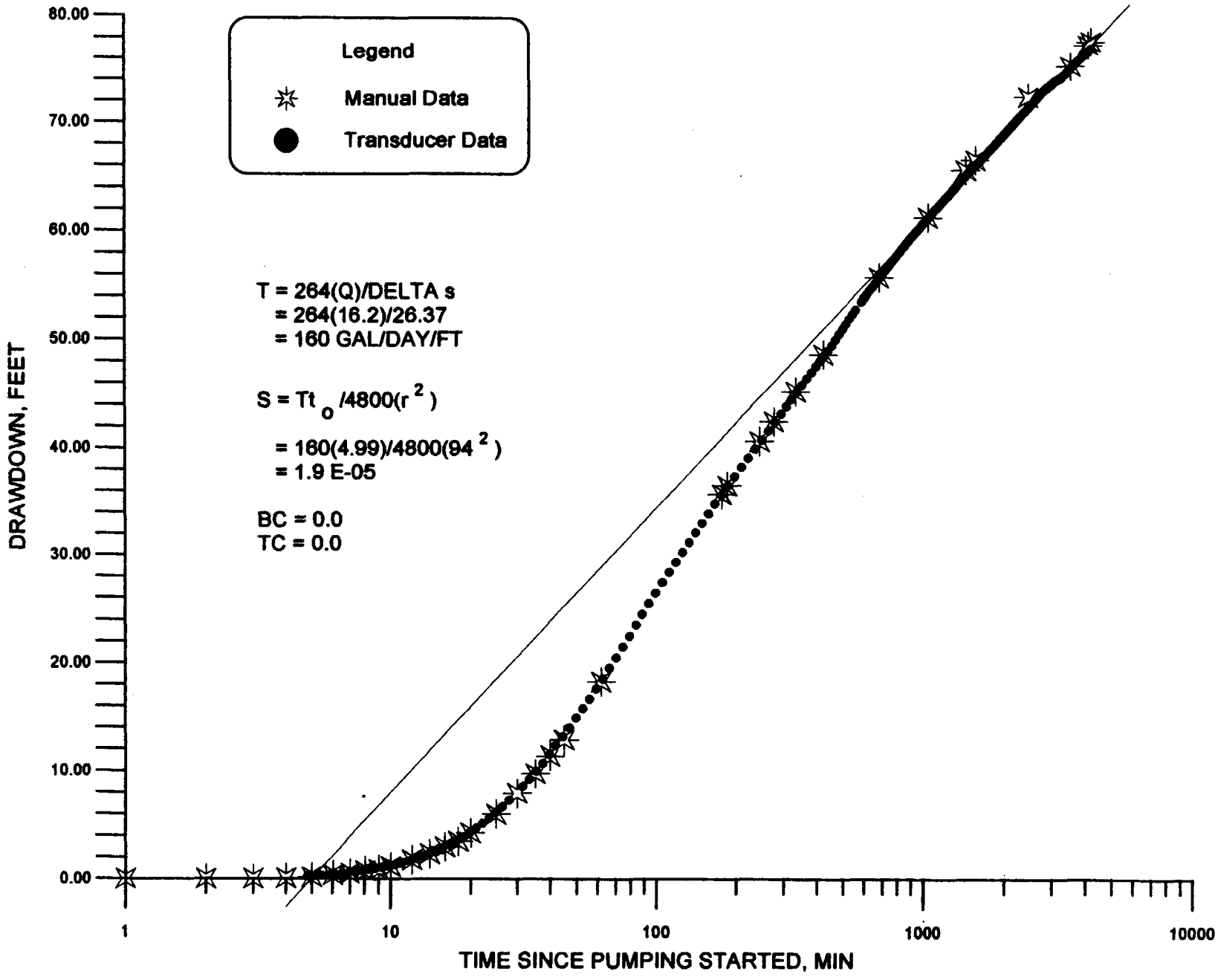
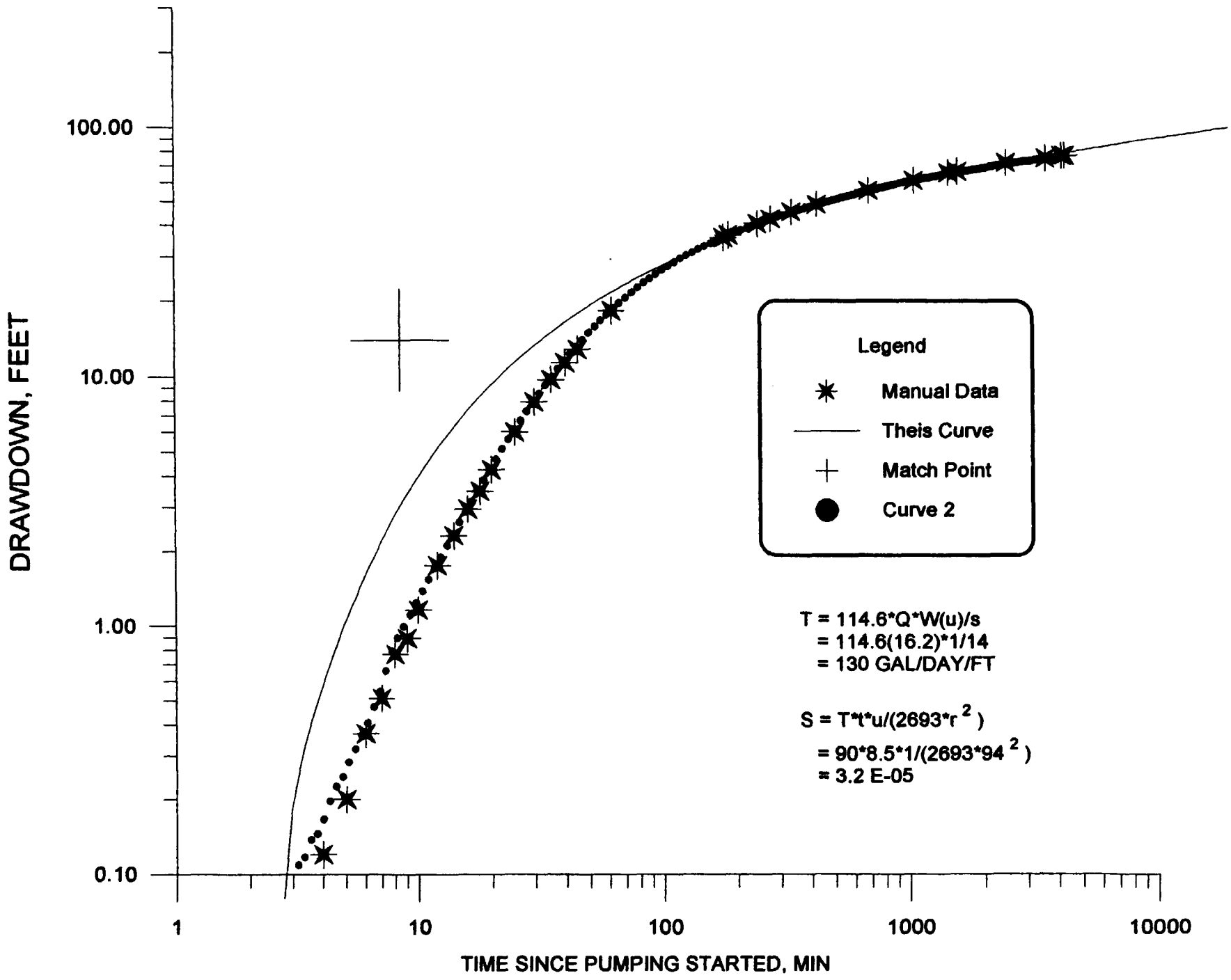


FIGURE K.5-13B. DRAWDOWN IN OBSERVATION WELL MP428, SEMI-LOG.



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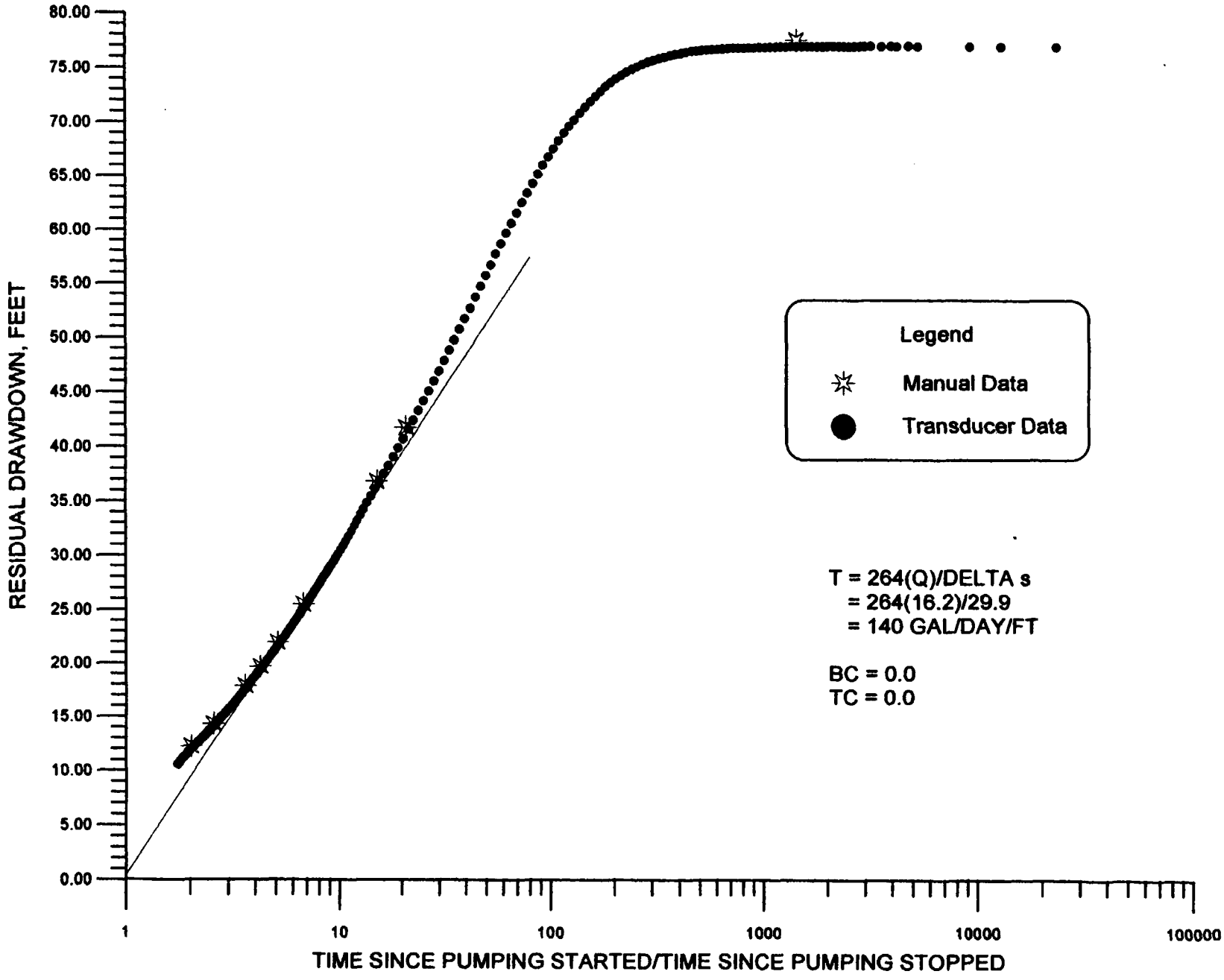
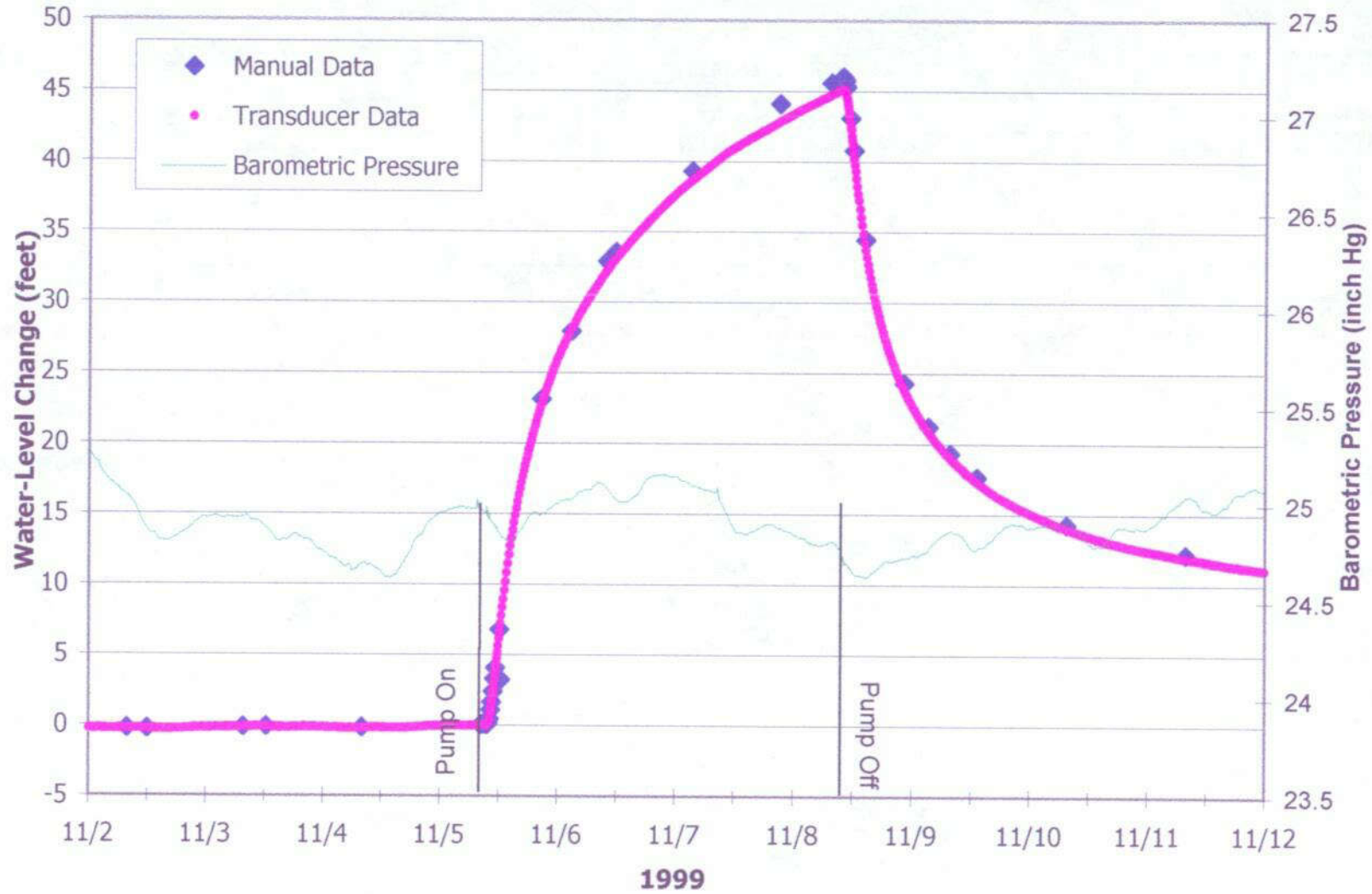


FIGURE K.5-13D. RECOVERY IN OBSERVATION WELL MP428.

FIGURE K.5-14A. WATER-LEVEL CHANGE IN OBSERVATION WELL MP429



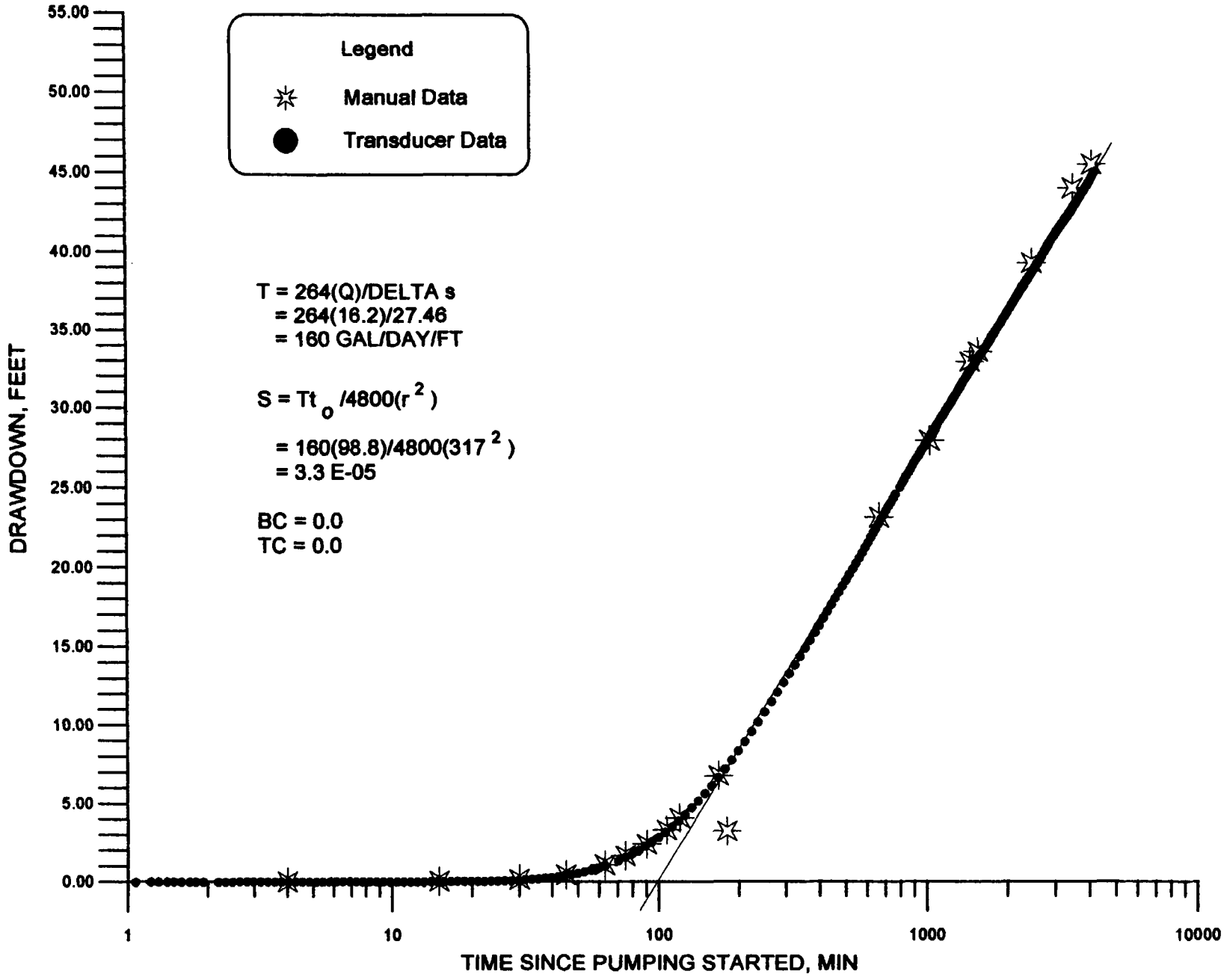


FIGURE K.5-14B. DRAWDOWN IN OBSERVATION WELL MP429, SEMI-LOG.

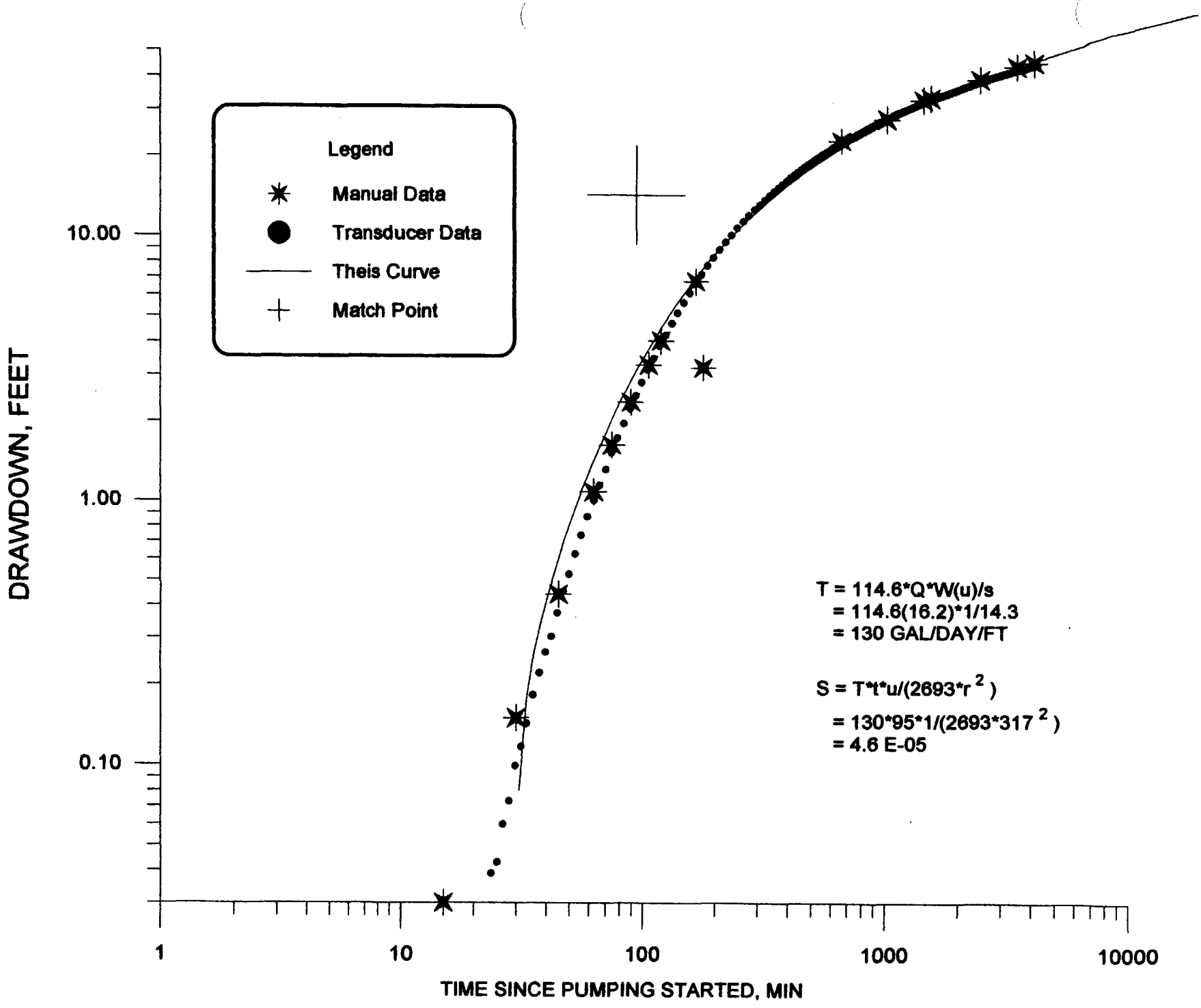


FIGURE K.5-14C. DRAWDOWN IN OBSERVATION WELL MP429, LOG-LOG.

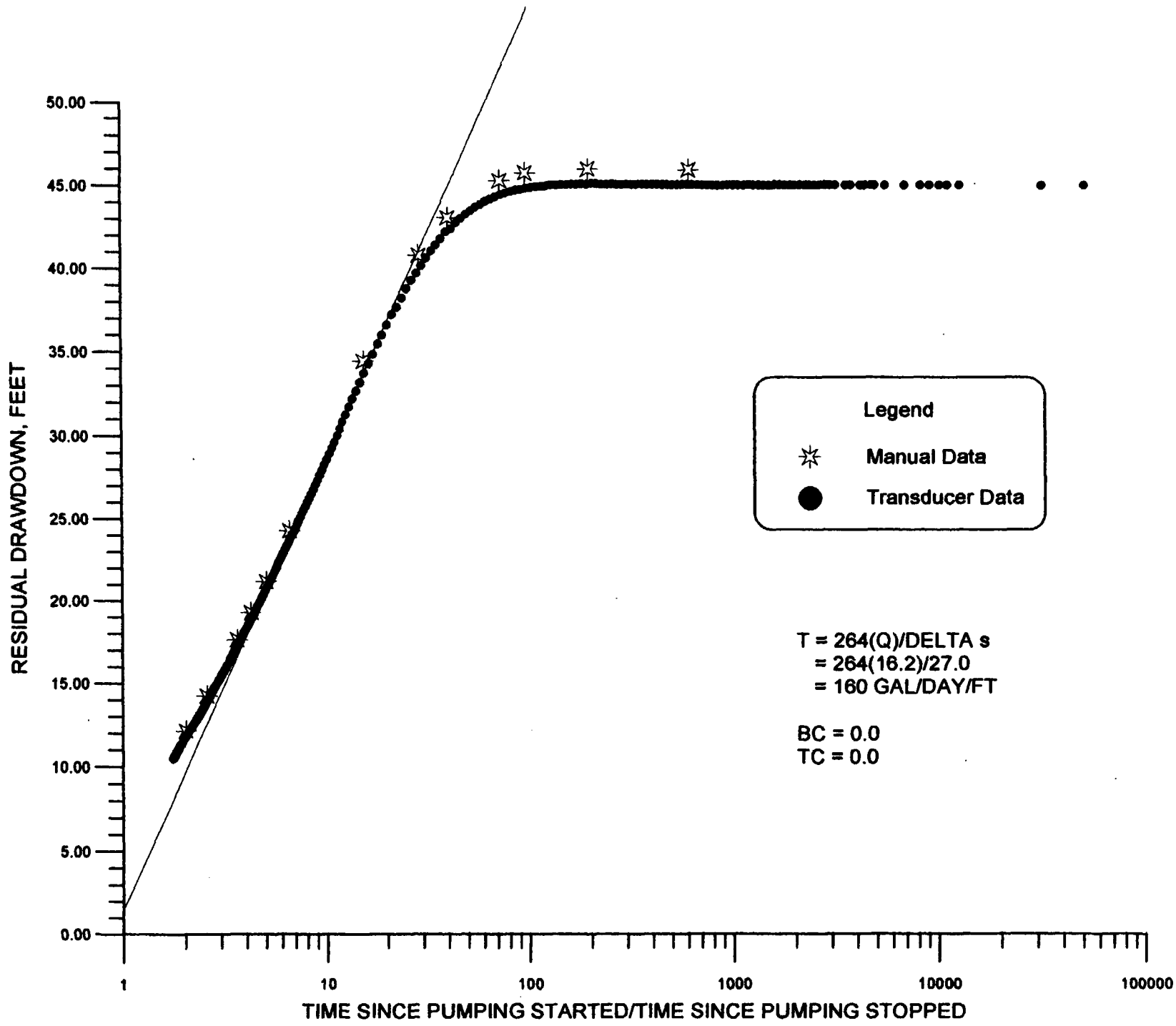
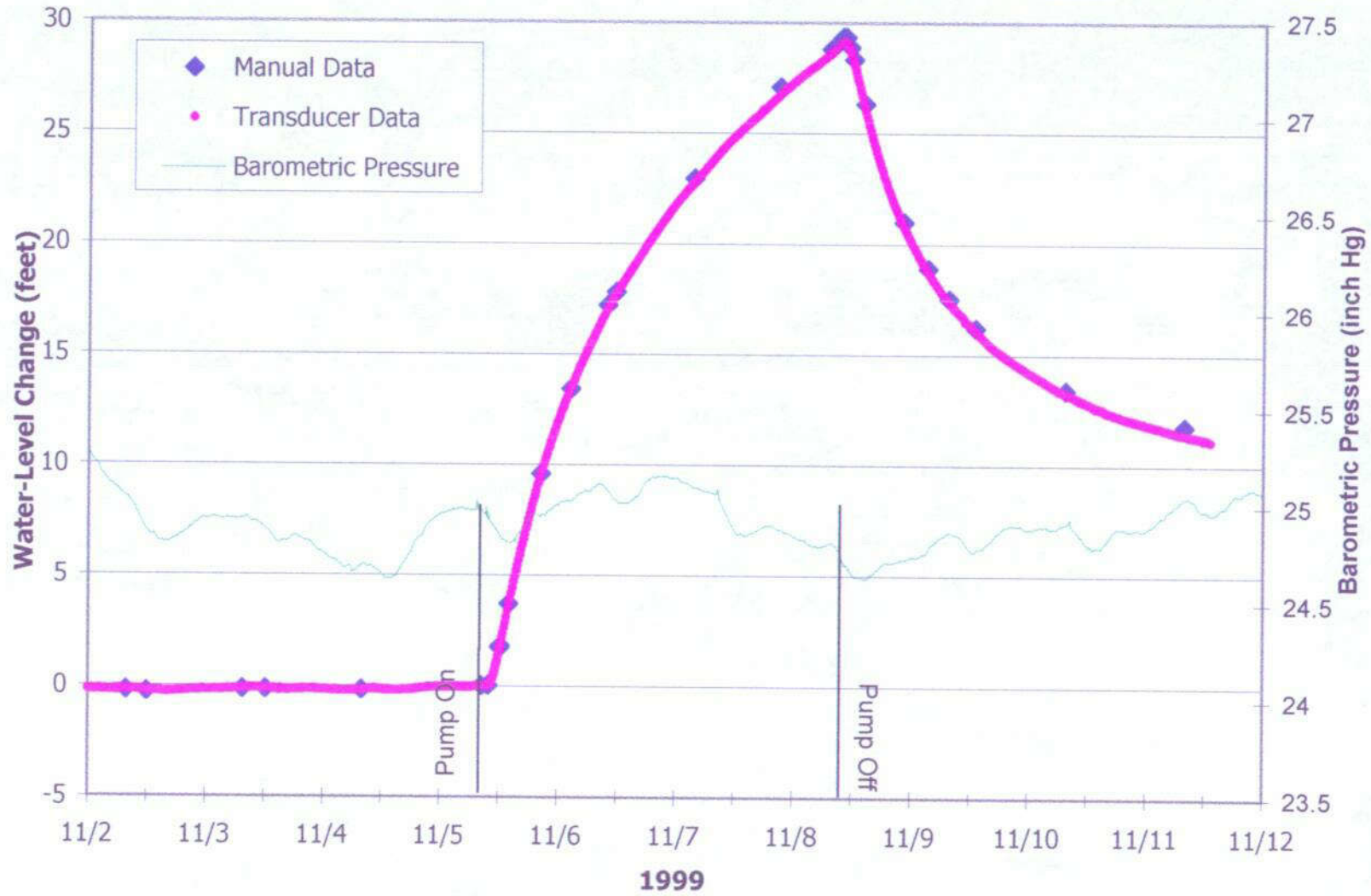


FIGURE K.5-14D. RECOVERY IN OBSERVATION WELL MP429.

FIGURE K.5-15A. WATER-LEVEL CHANGE IN OBSERVATION WELL MP430



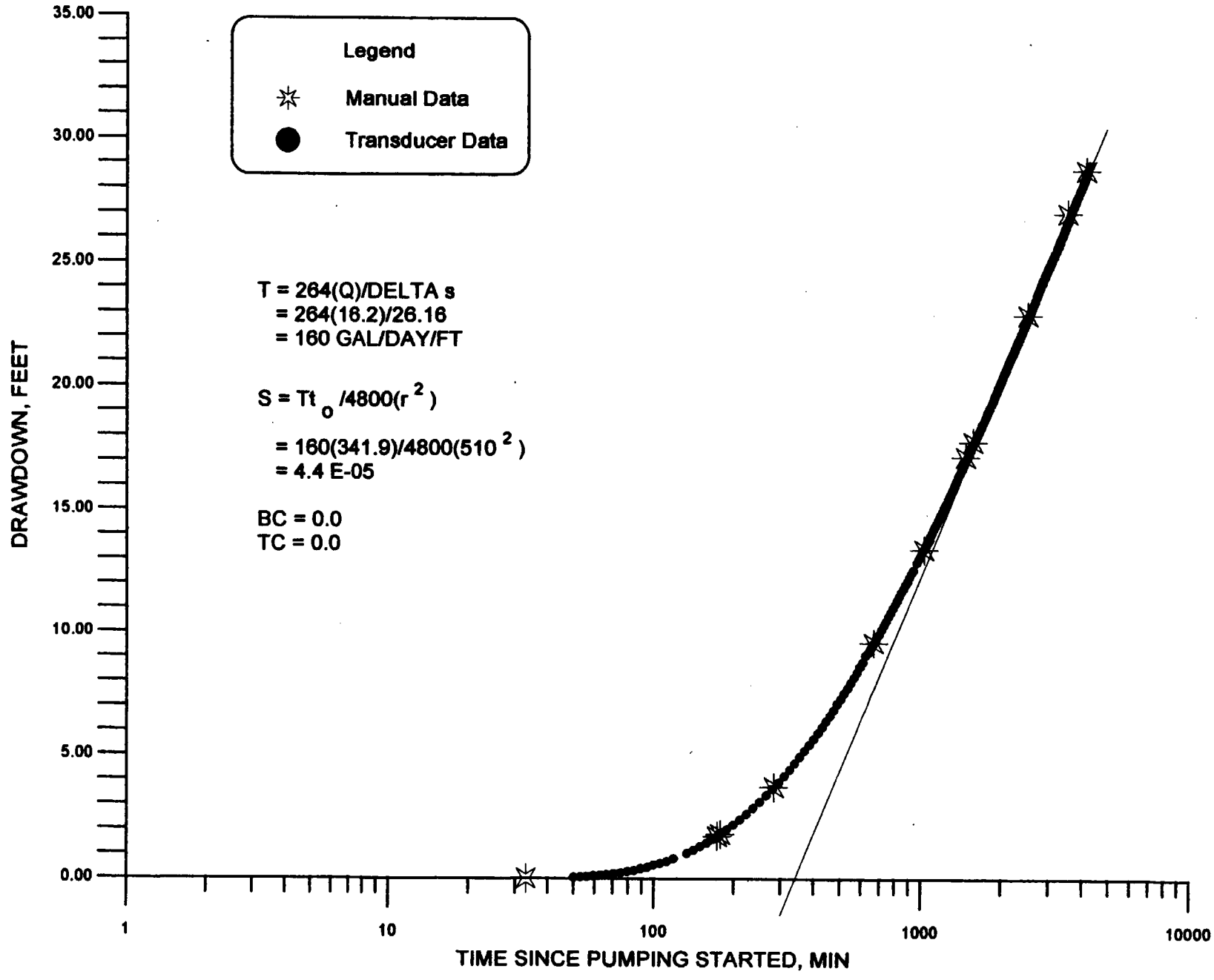


FIGURE K.5-15B. DRAWDOWN IN OBSERVATION WELL MP430, SEMI-LOG.

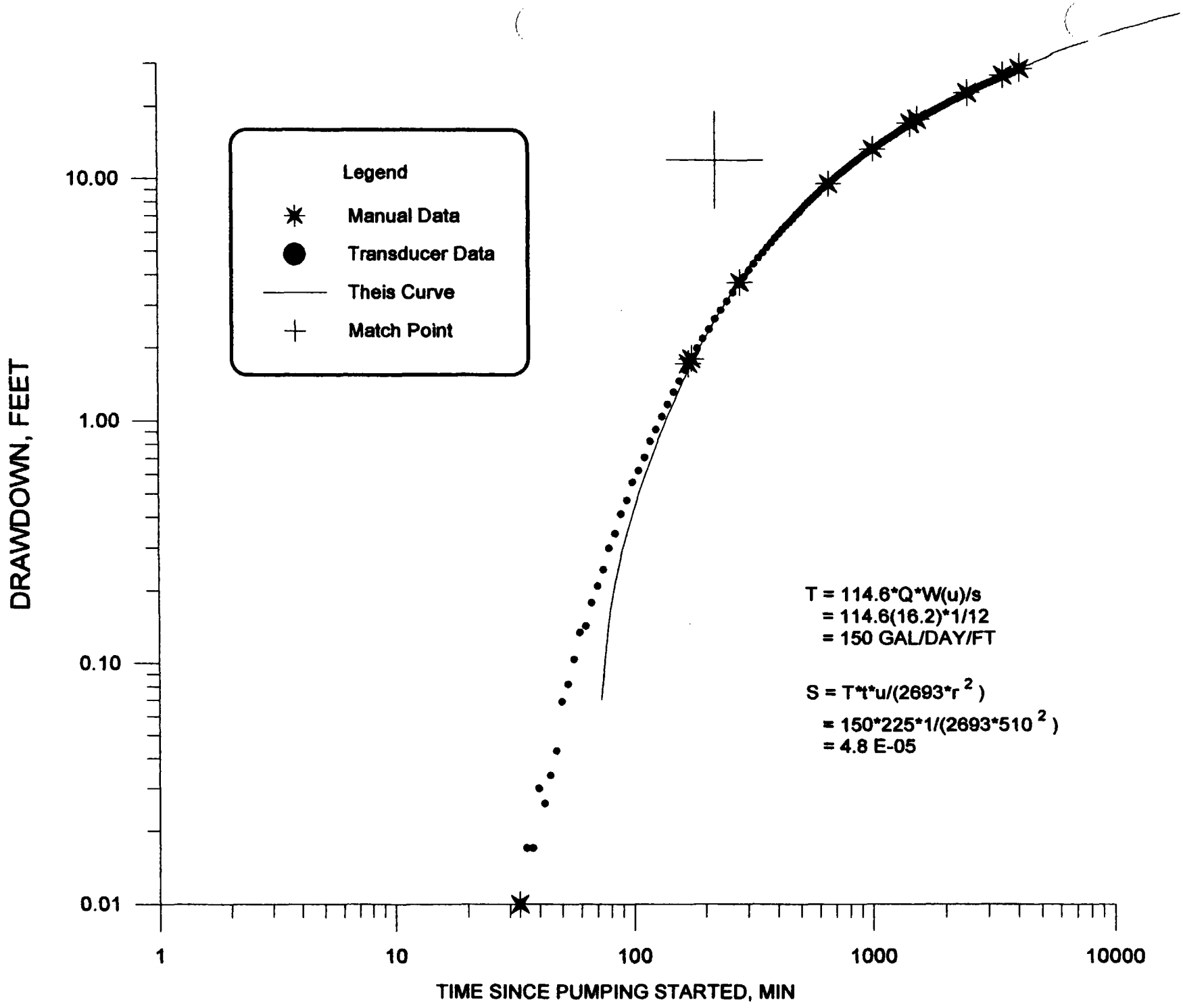


FIGURE K.5-15C. DRAWDOWN IN OBSERVATION WELL MP430, LOG-LOG.

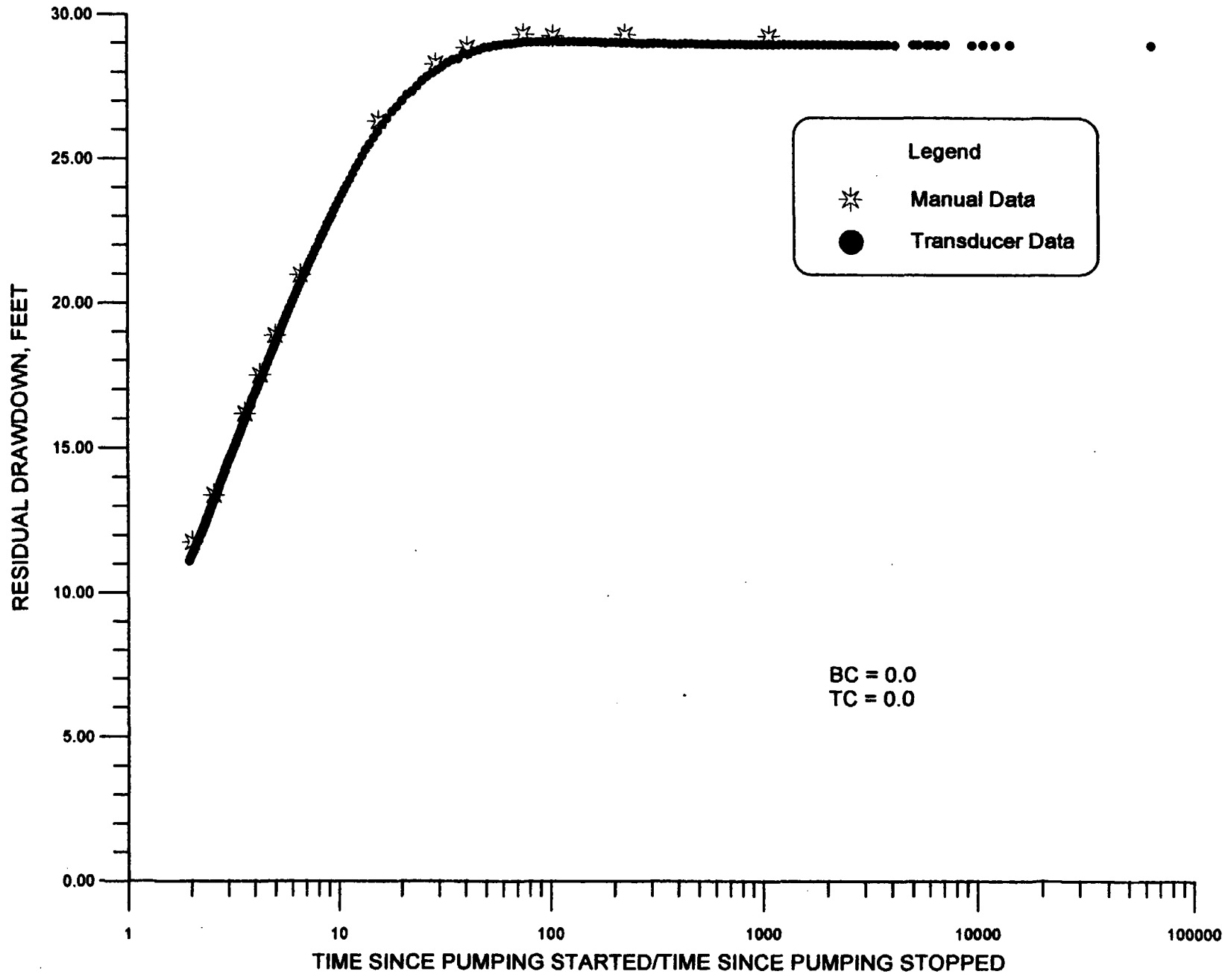
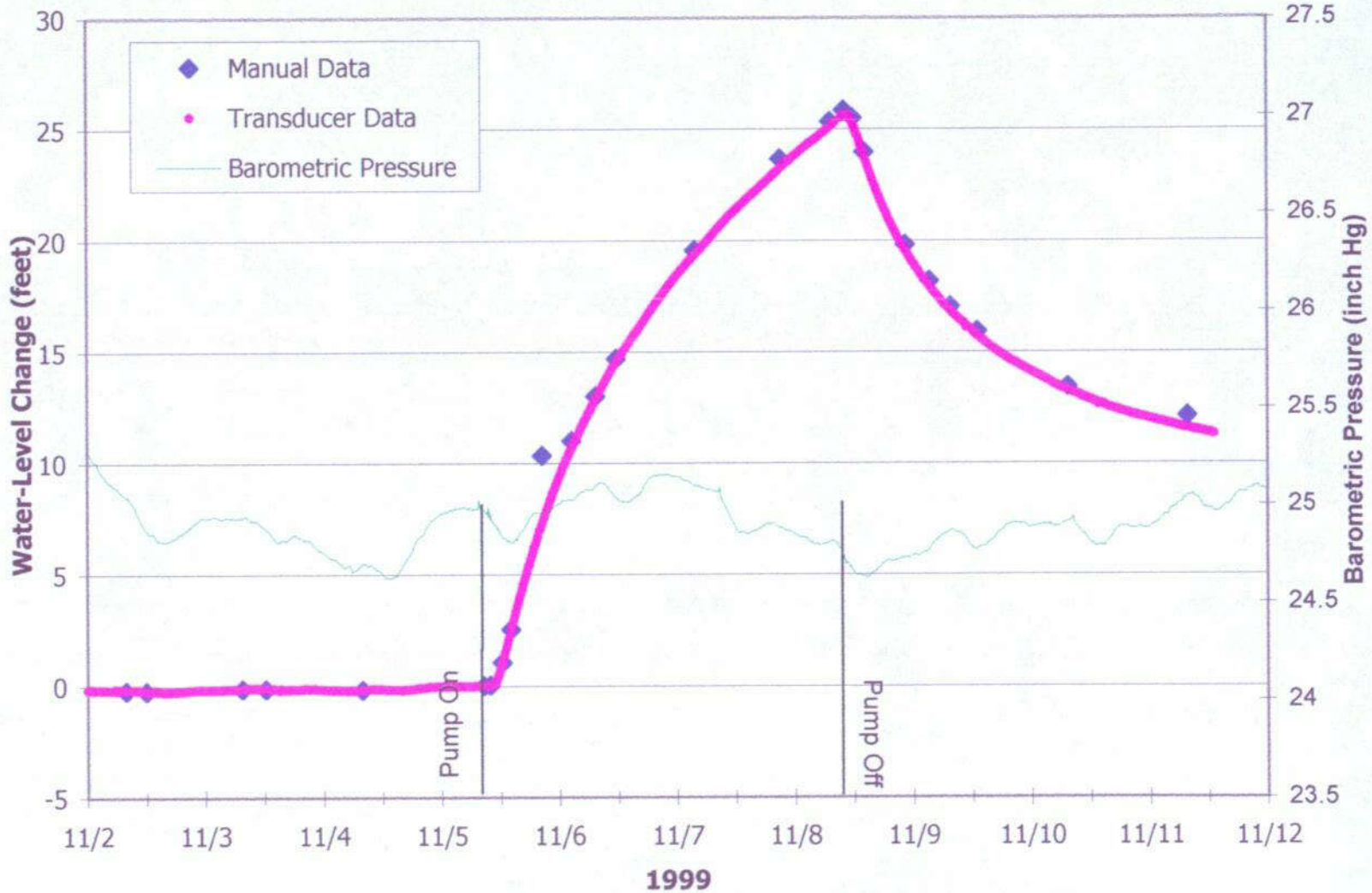


FIGURE K.5-15D. RECOVERY IN OBSERVATION WELL MP430.

FIGURE K.5-16A. WATER-LEVEL CHANGE IN OBSERVATION WELL MP431



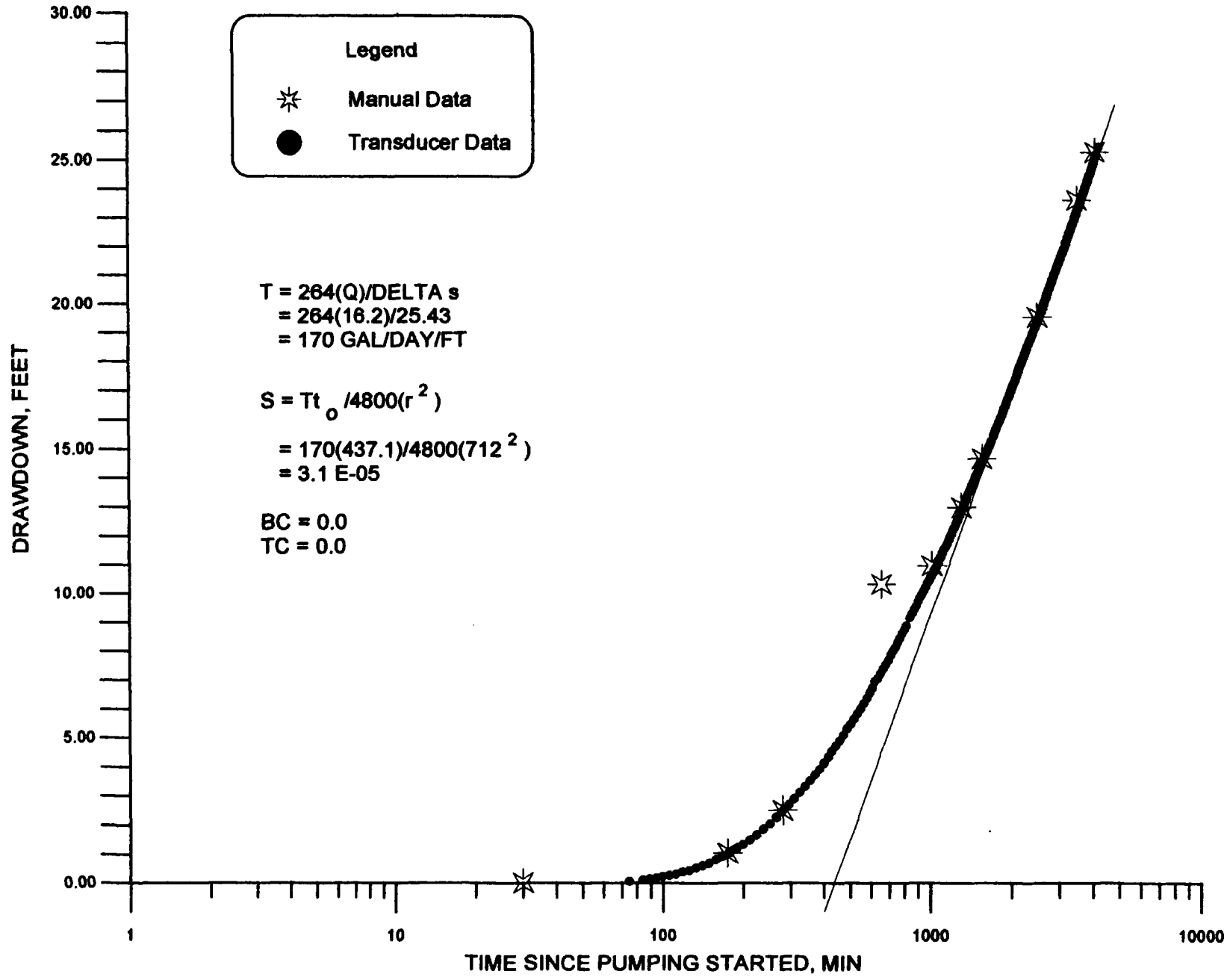


FIGURE K.5-16B. DRAWDOWN IN OBSERVATION WELL MP431, SEMI-LOG.

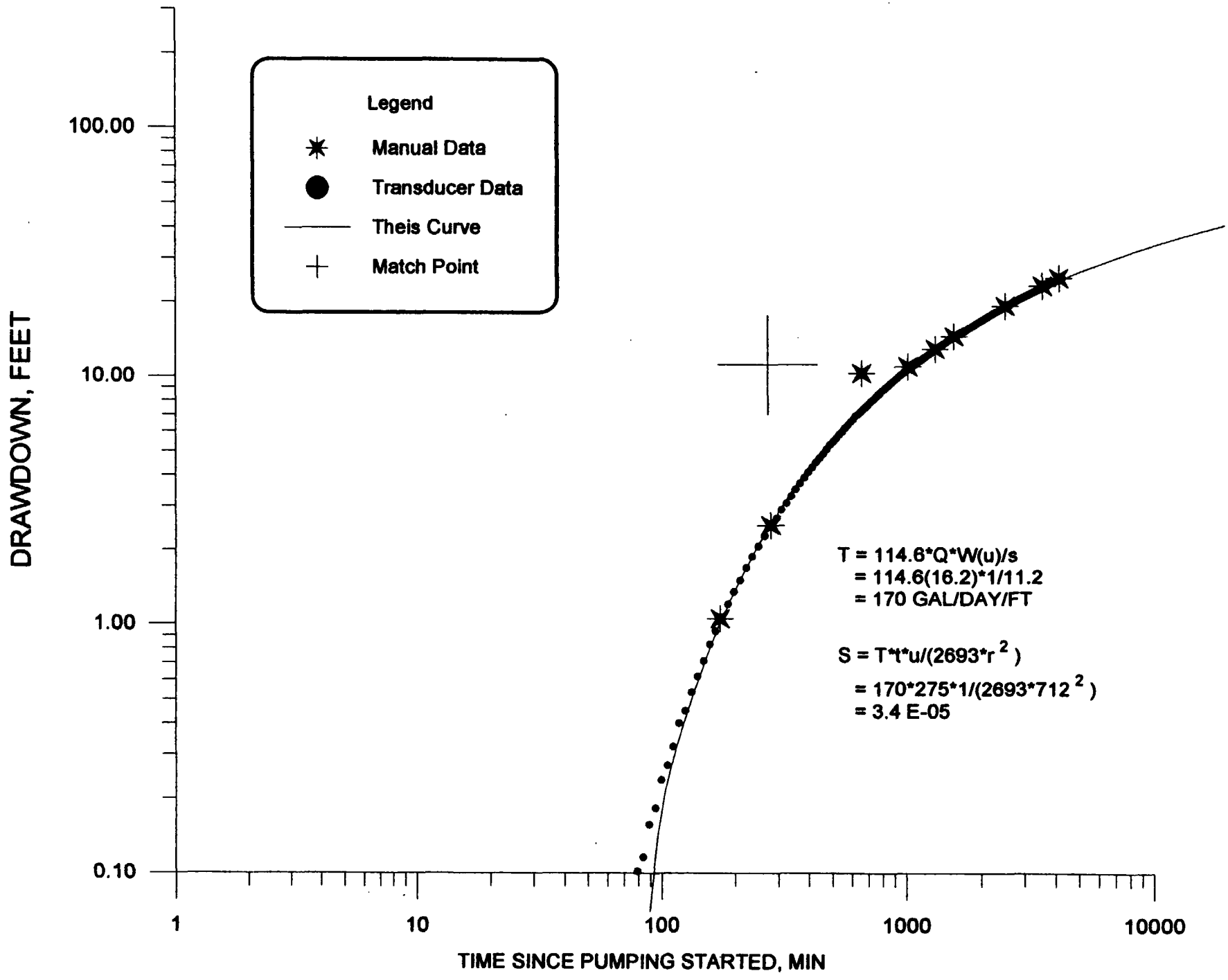


FIGURE K.5-16C. DRAWDOWN IN OBSERVATION WELL MP431, LOG-LOG.

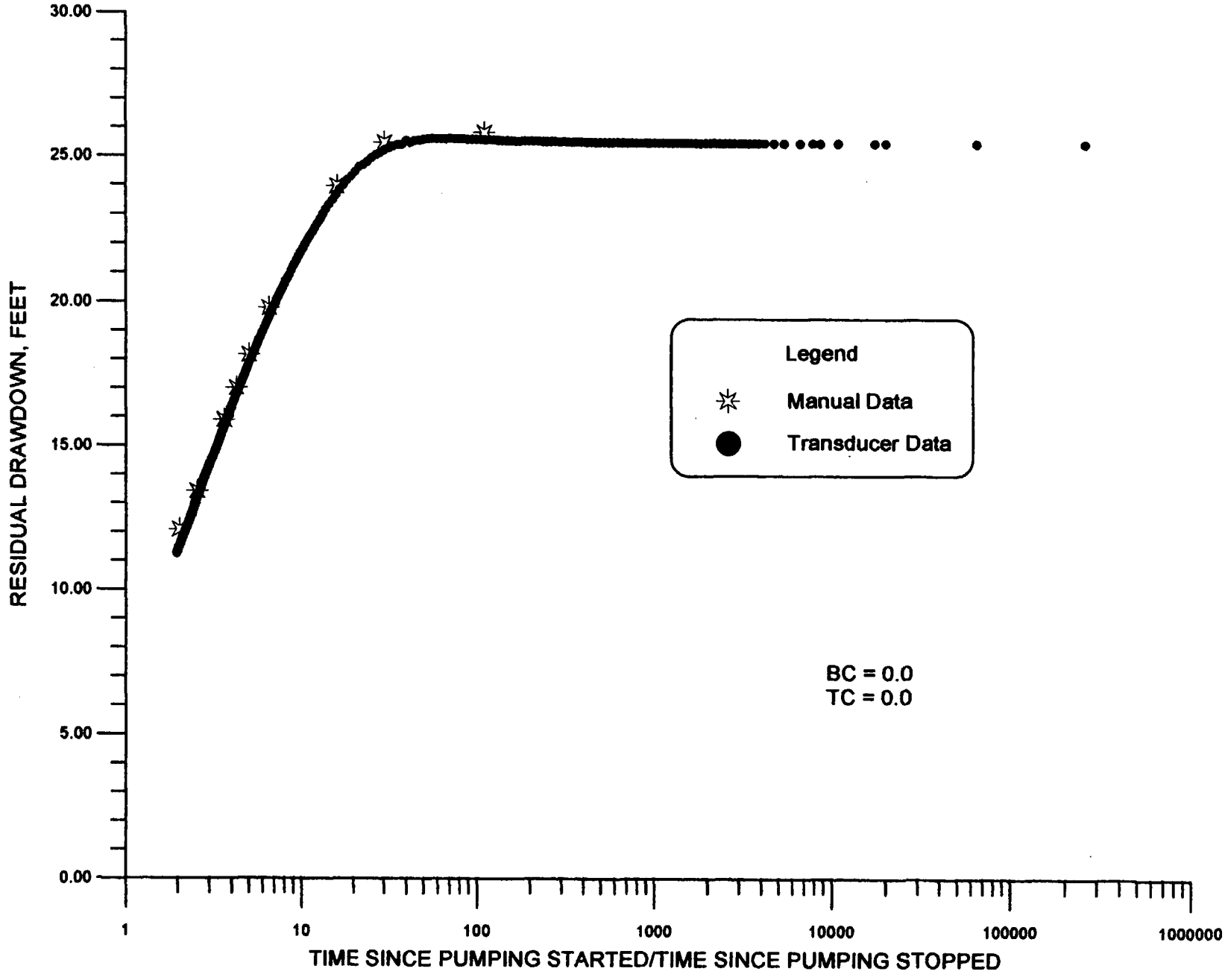
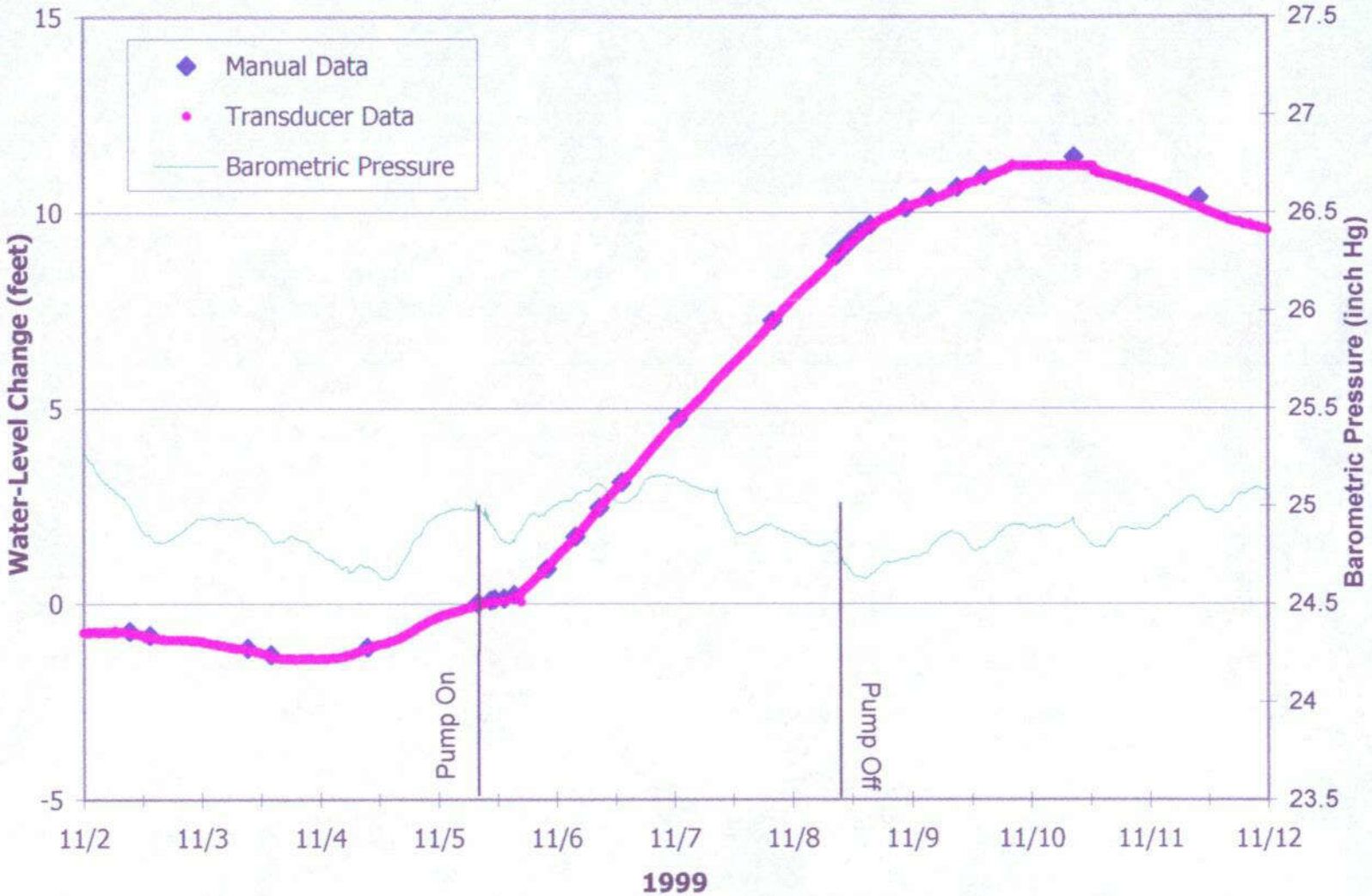


FIGURE K.5-16D. RECOVERY IN OBSERVATION WELL MP431.

FIGURE K.5-17A. WATER-LEVEL CHANGE IN OBSERVATION WELL M439



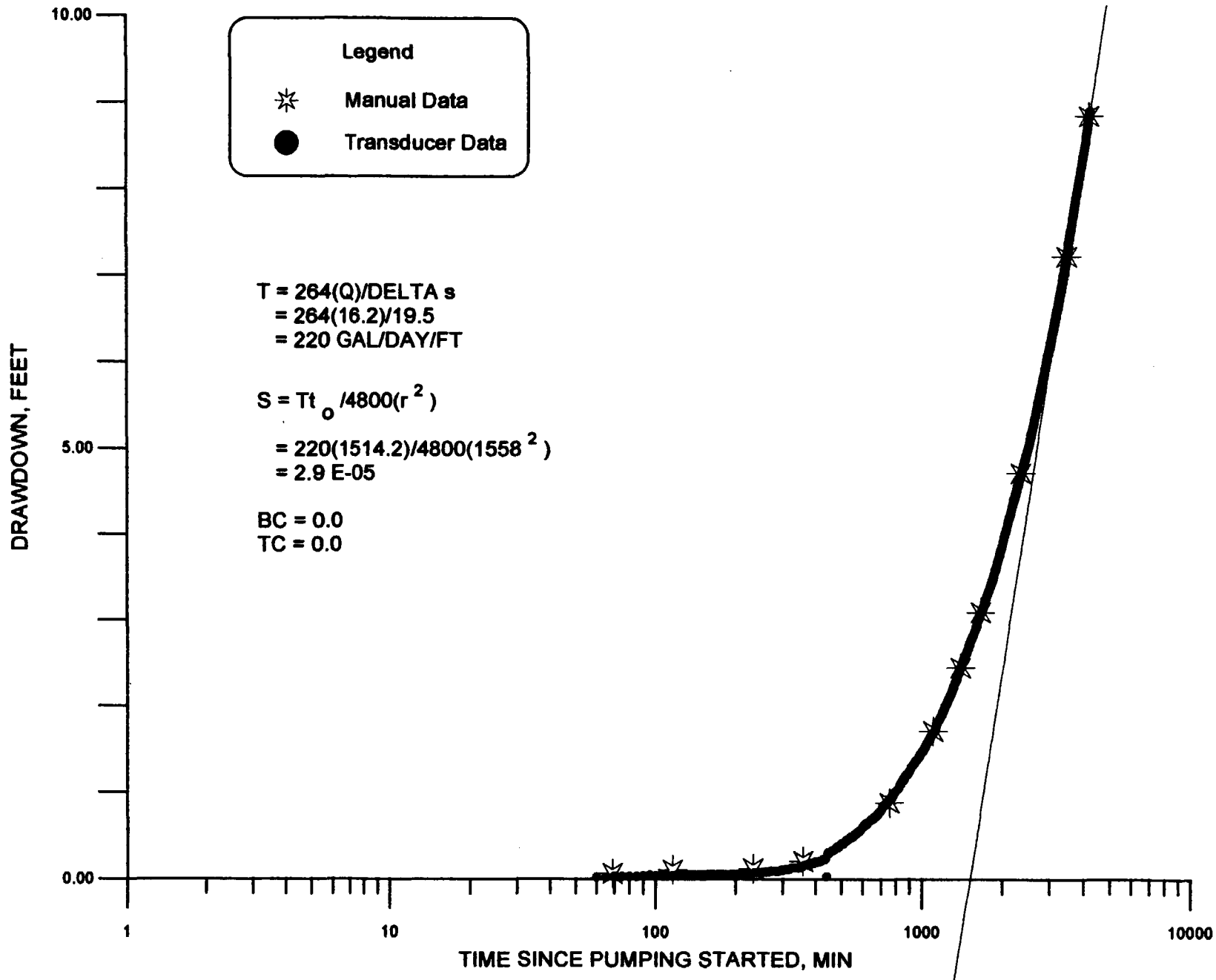


FIGURE K.5-17B. DRAWDOWN IN OBSERVATION WELL M439, SEMI-LOG.

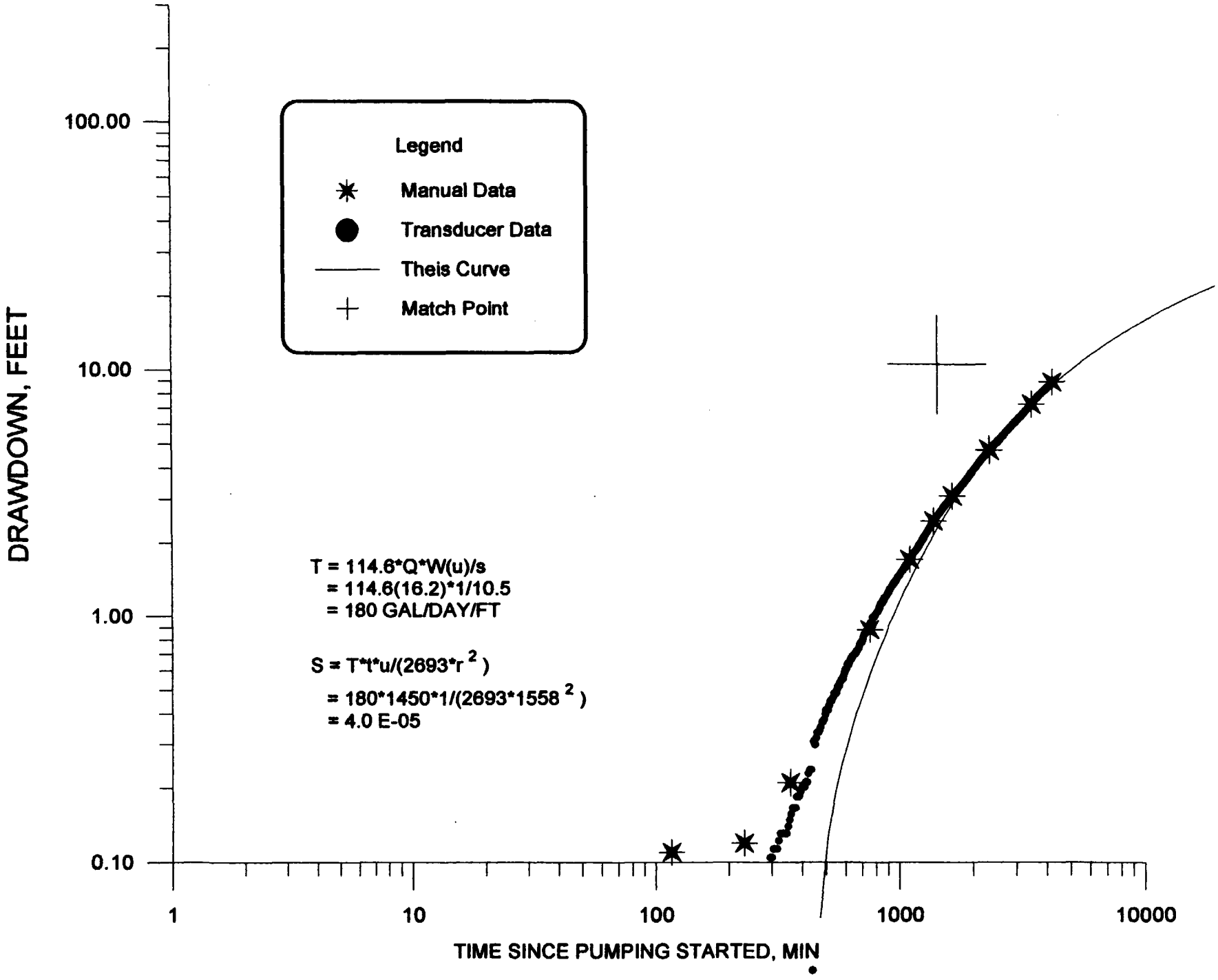


FIGURE K.5-17C. DRAWDOWN IN OBSERVATION WELL M439, LOG-LOG.

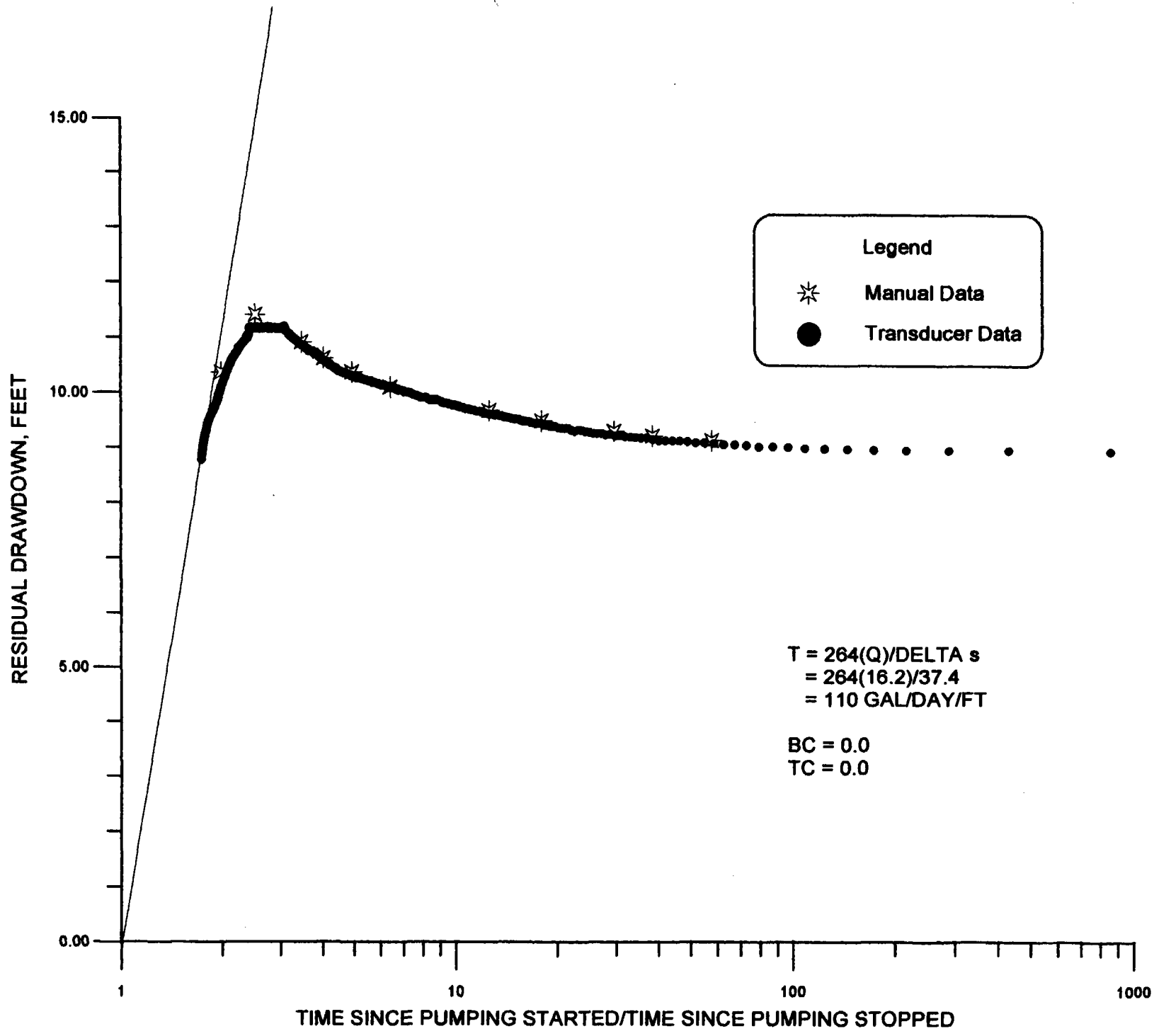
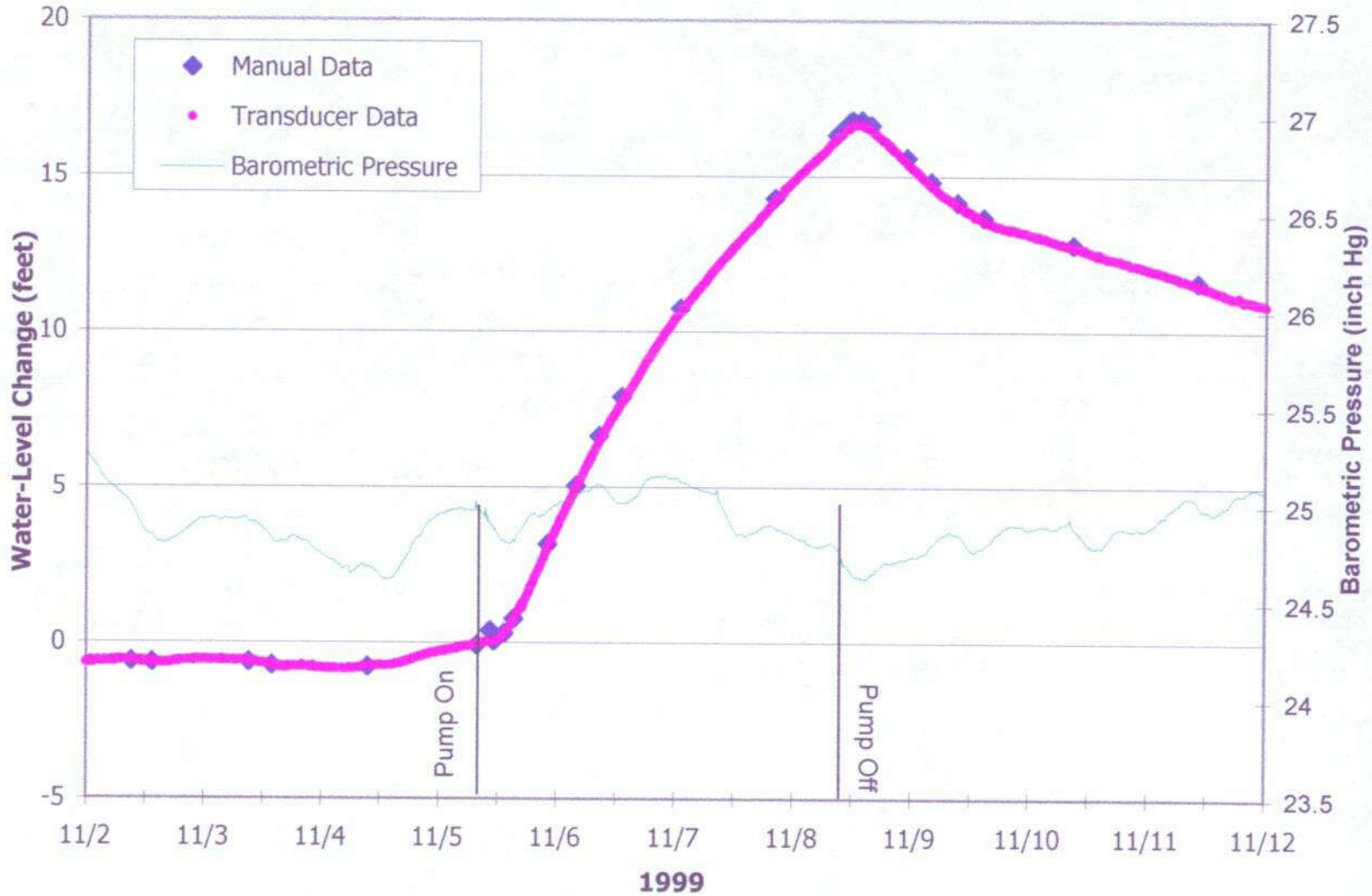


FIGURE K.5-17D. RECOVERY IN OBSERVATION WELL M439.

FIGURE K.5-18A. WATER-LEVEL CHANGE IN OBSERVATION WELL M440



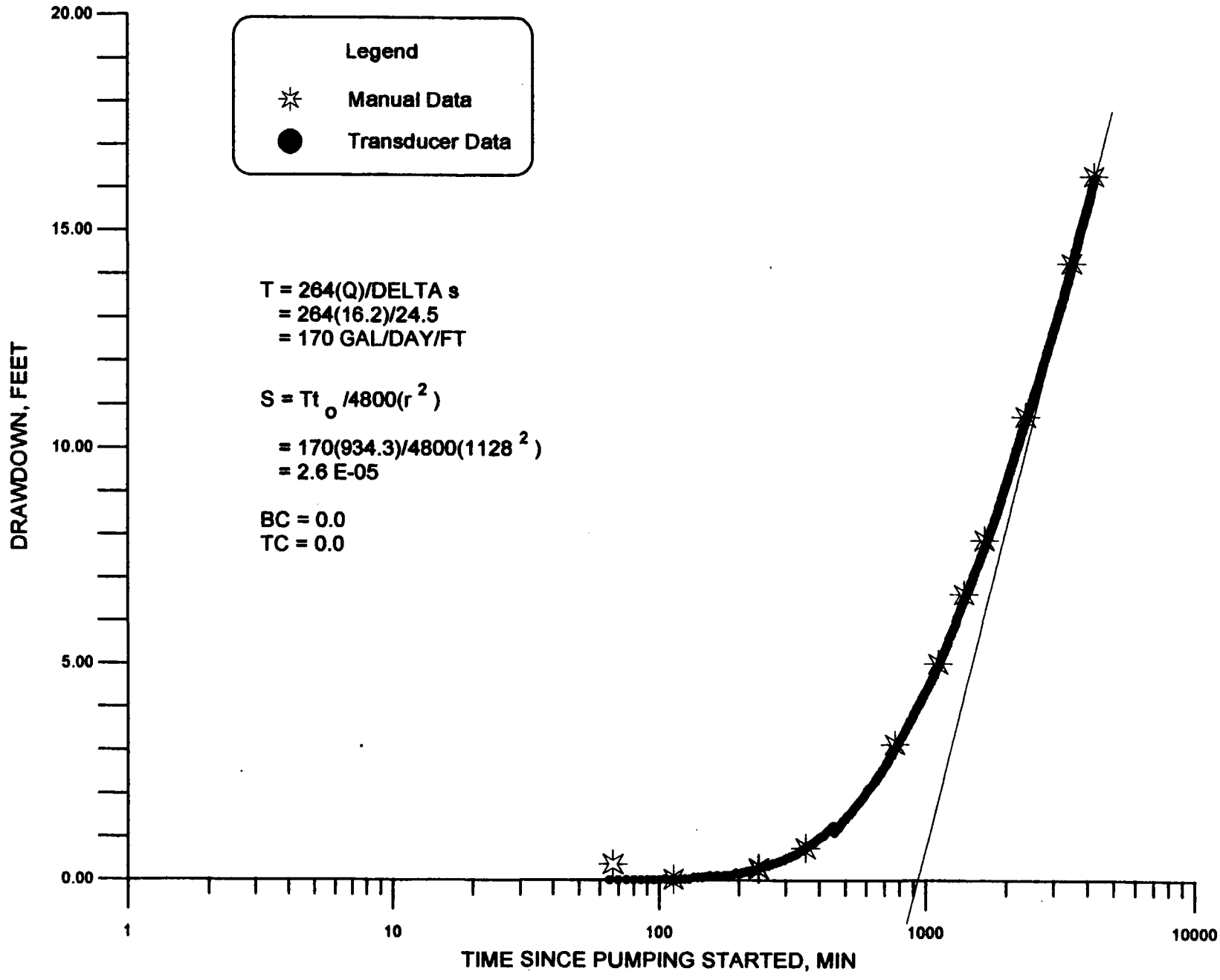


FIGURE K.5-18B. DRAWDOWN IN OBSERVATION WELL M440, SEMI-LOG.

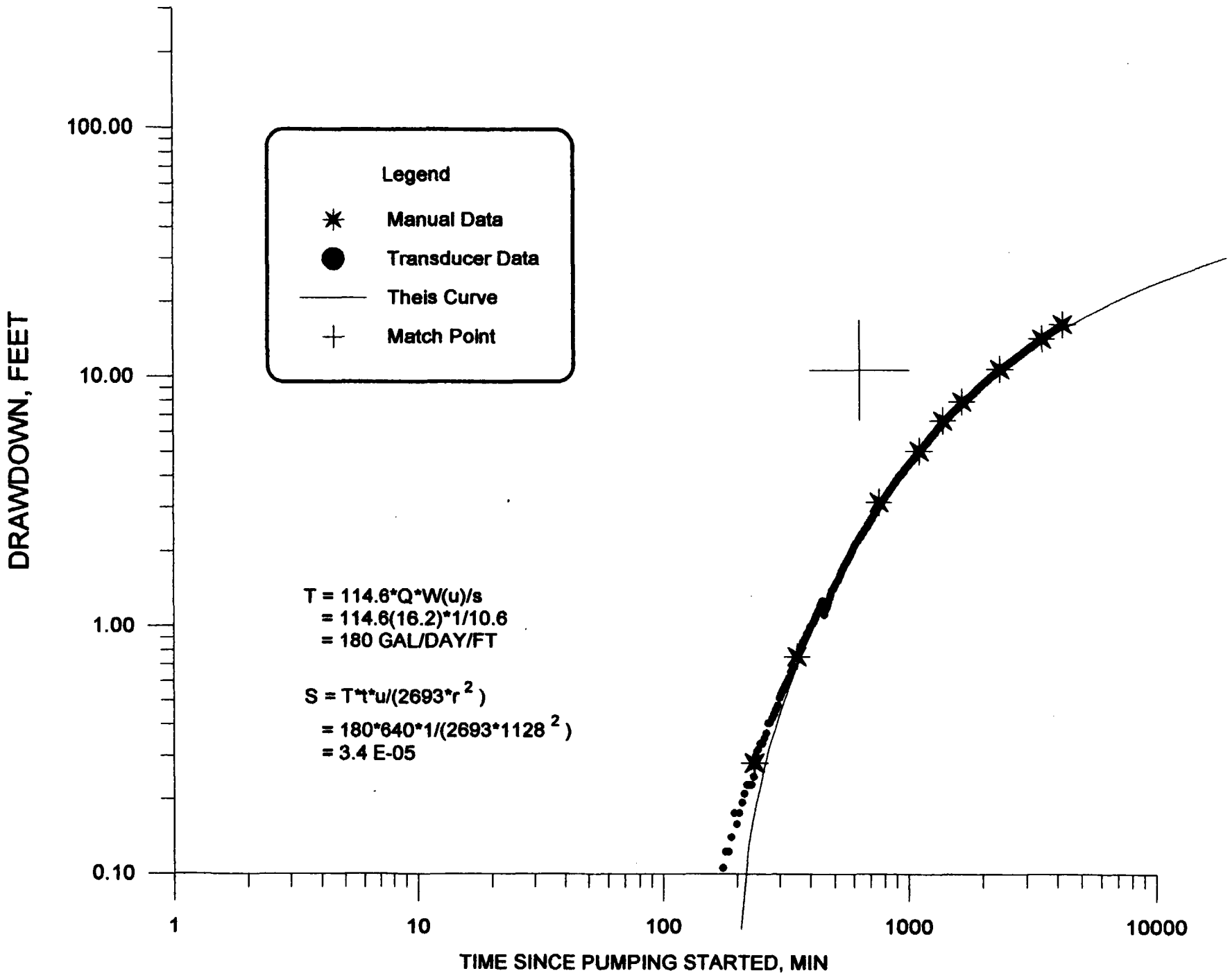


FIGURE K.5-18C. DRAWDOWN IN OBSERVATION WELL M440, LOG-LOG.

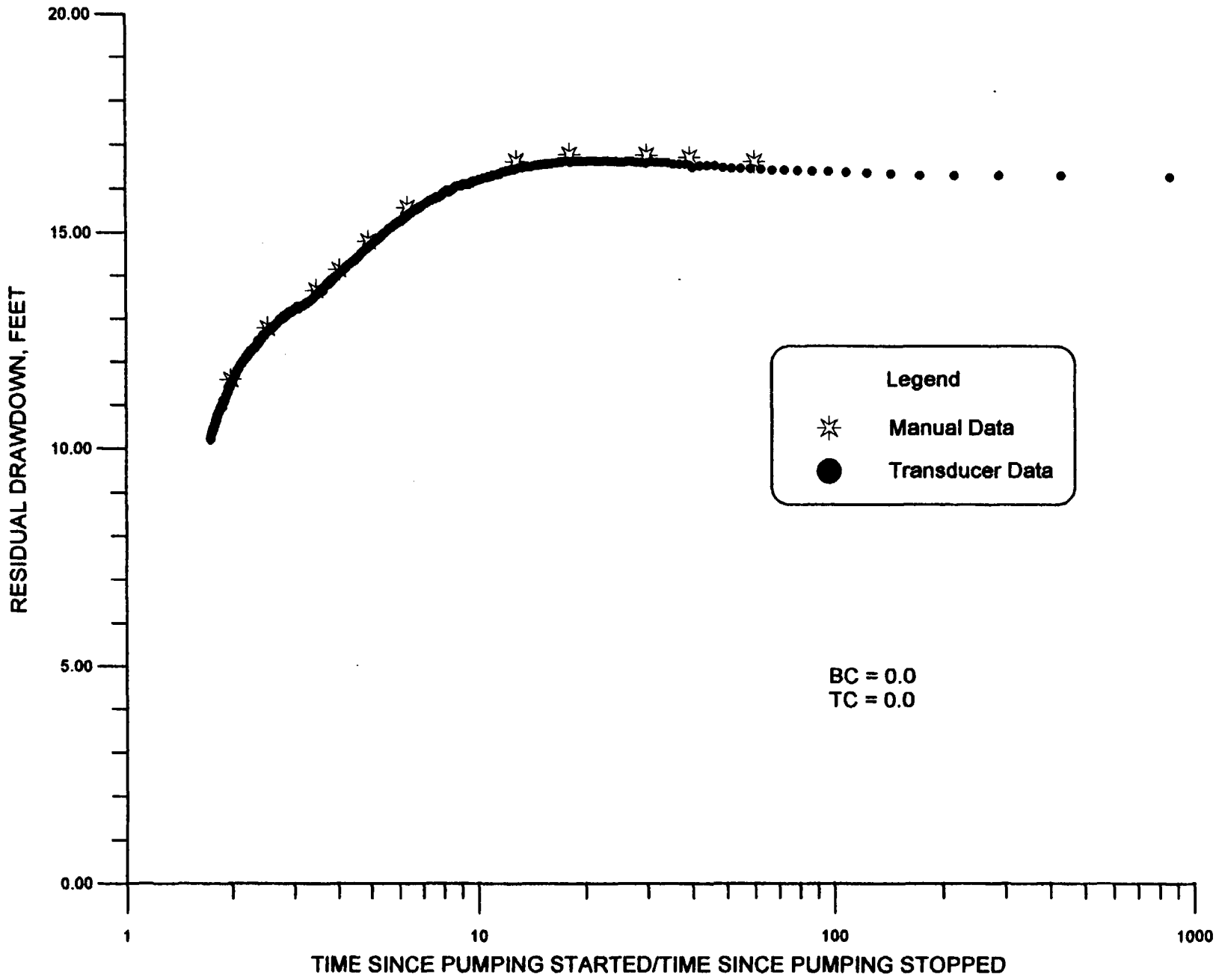
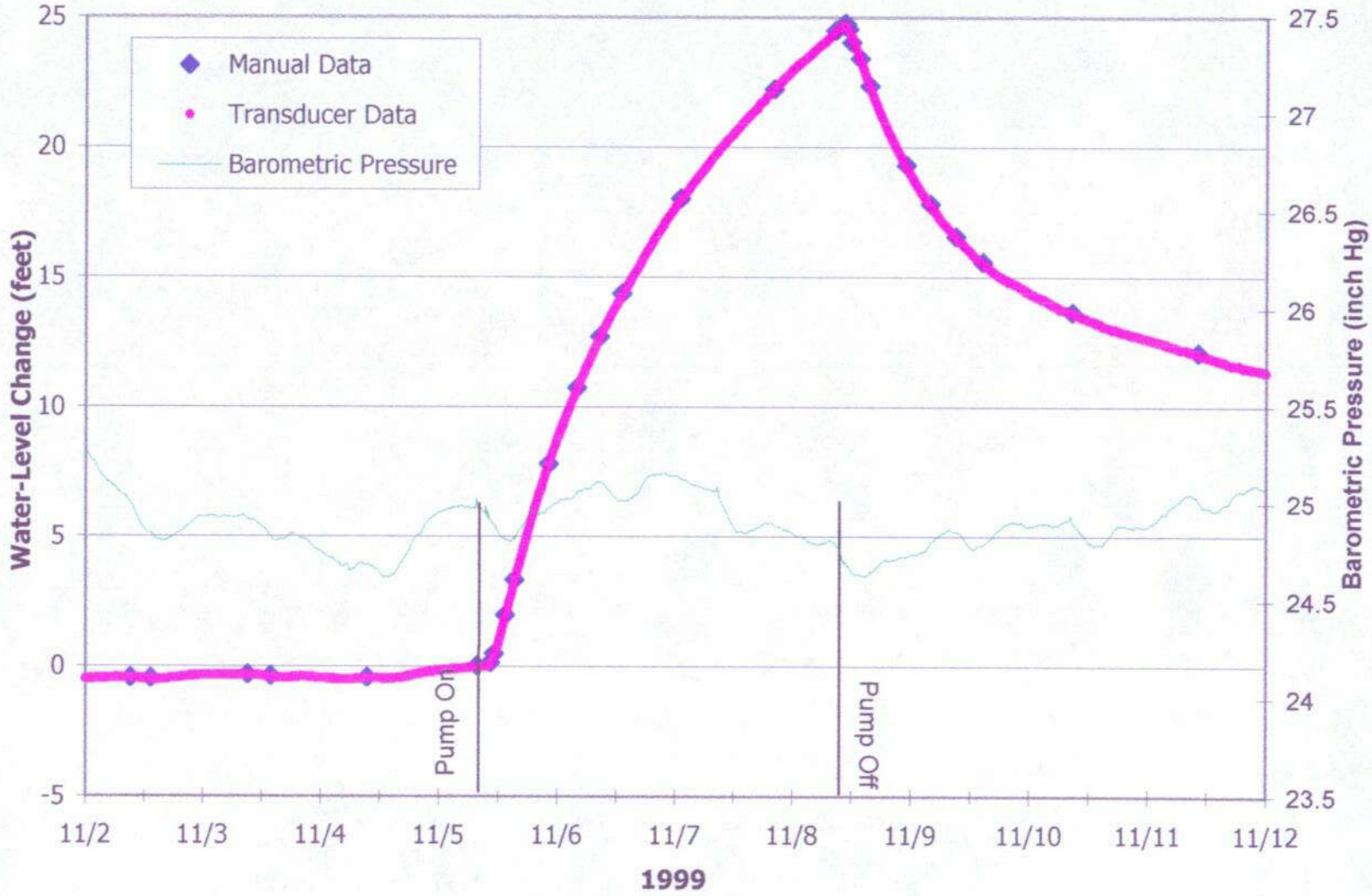


FIGURE K.5-18D. RECOVERY IN OBSERVATION WELL M440.

FIGURE K.5-19A. WATER-LEVEL CHANGE IN OBSERVATION WELL M441



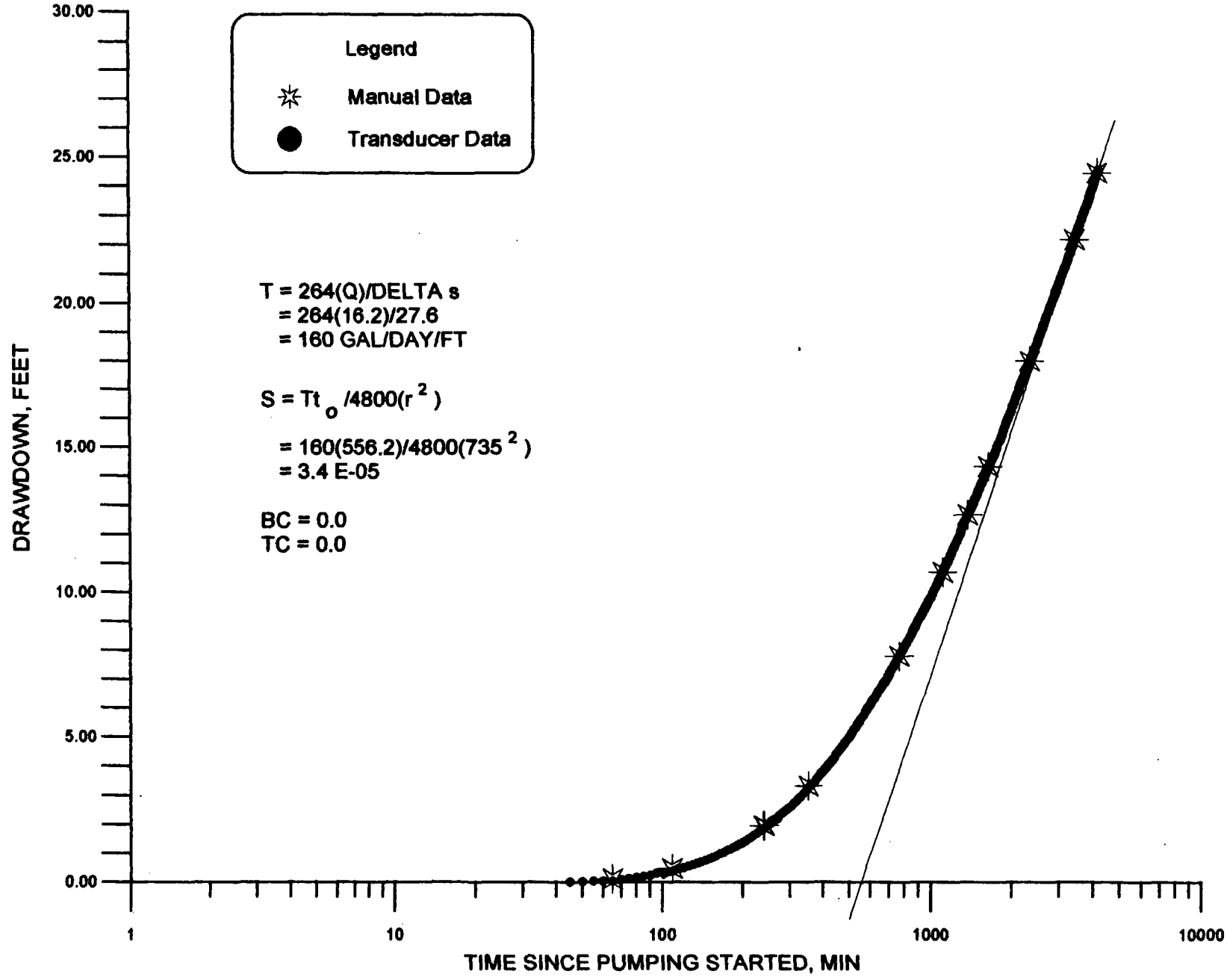


FIGURE K.5-19B. DRAWDOWN IN OBSERVATION WELL M441, SEMI-LOG.

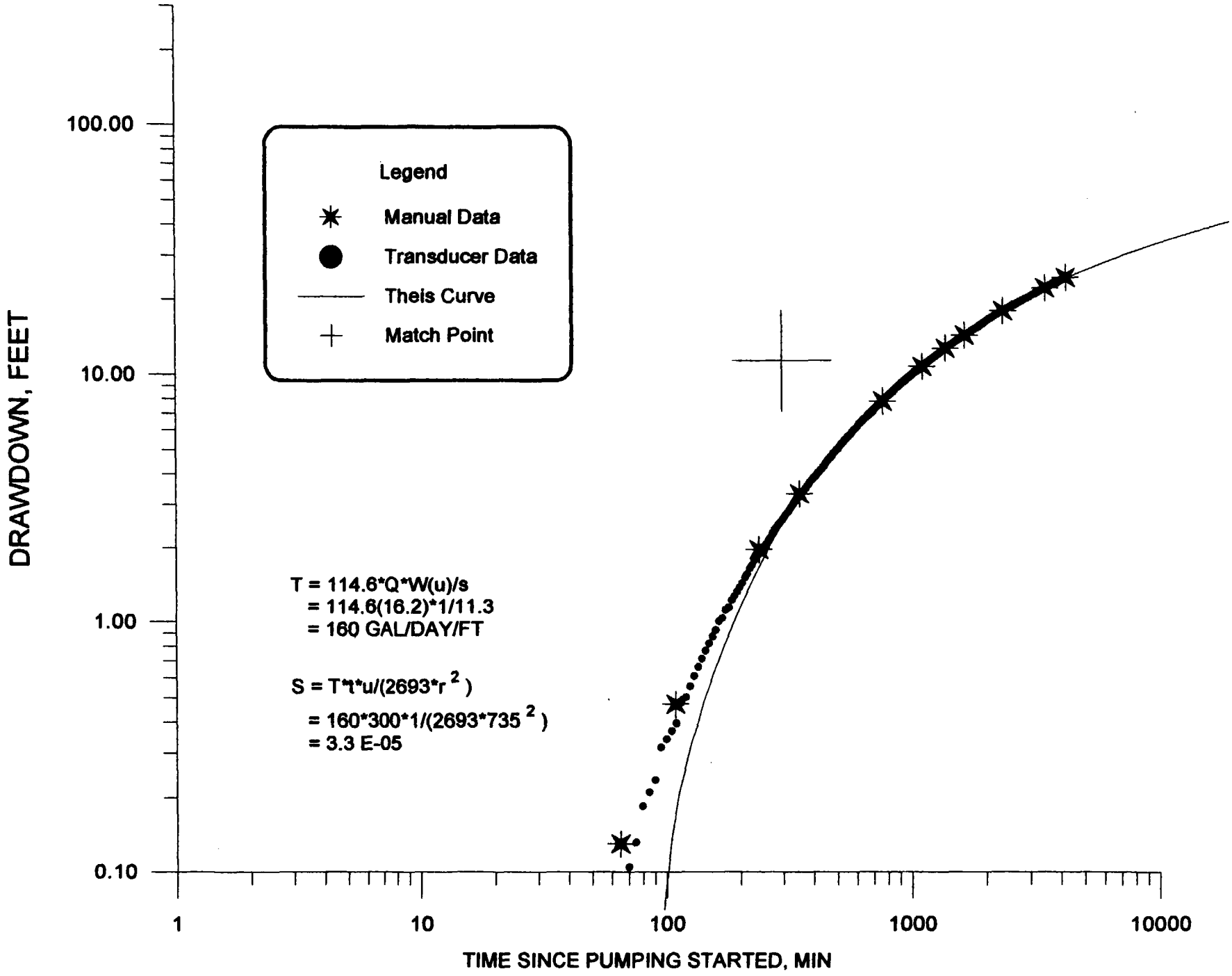


FIGURE K.5-19C. DRAWDOWN IN OBSERVATION WELL M441, LOG-LOG.

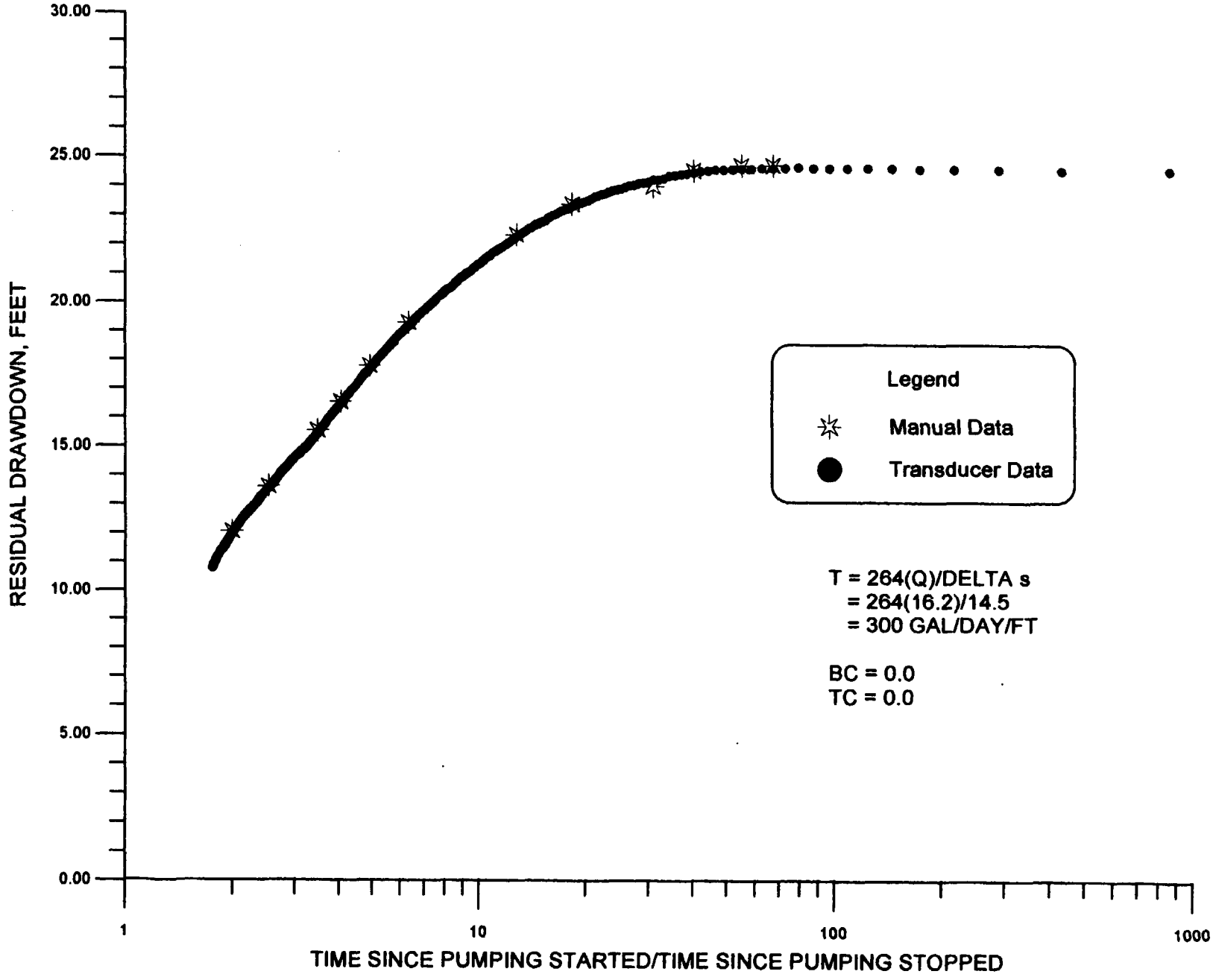
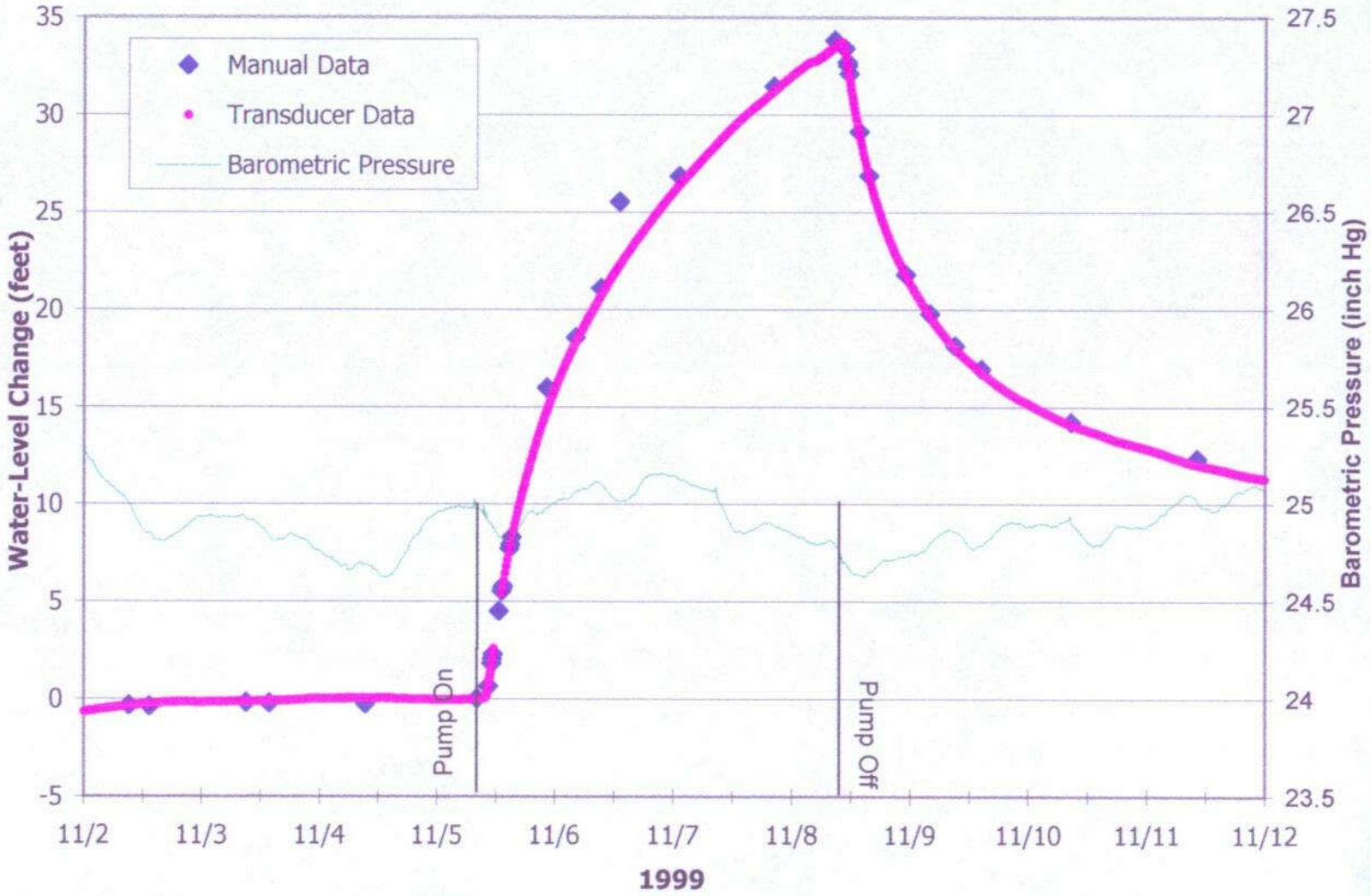


FIGURE K.5-19D. RECOVERY IN OBSERVATION WELL M441.

FIGURE K.5-20A. WATER-LEVEL CHANGE IN OBSERVATION WELL M442



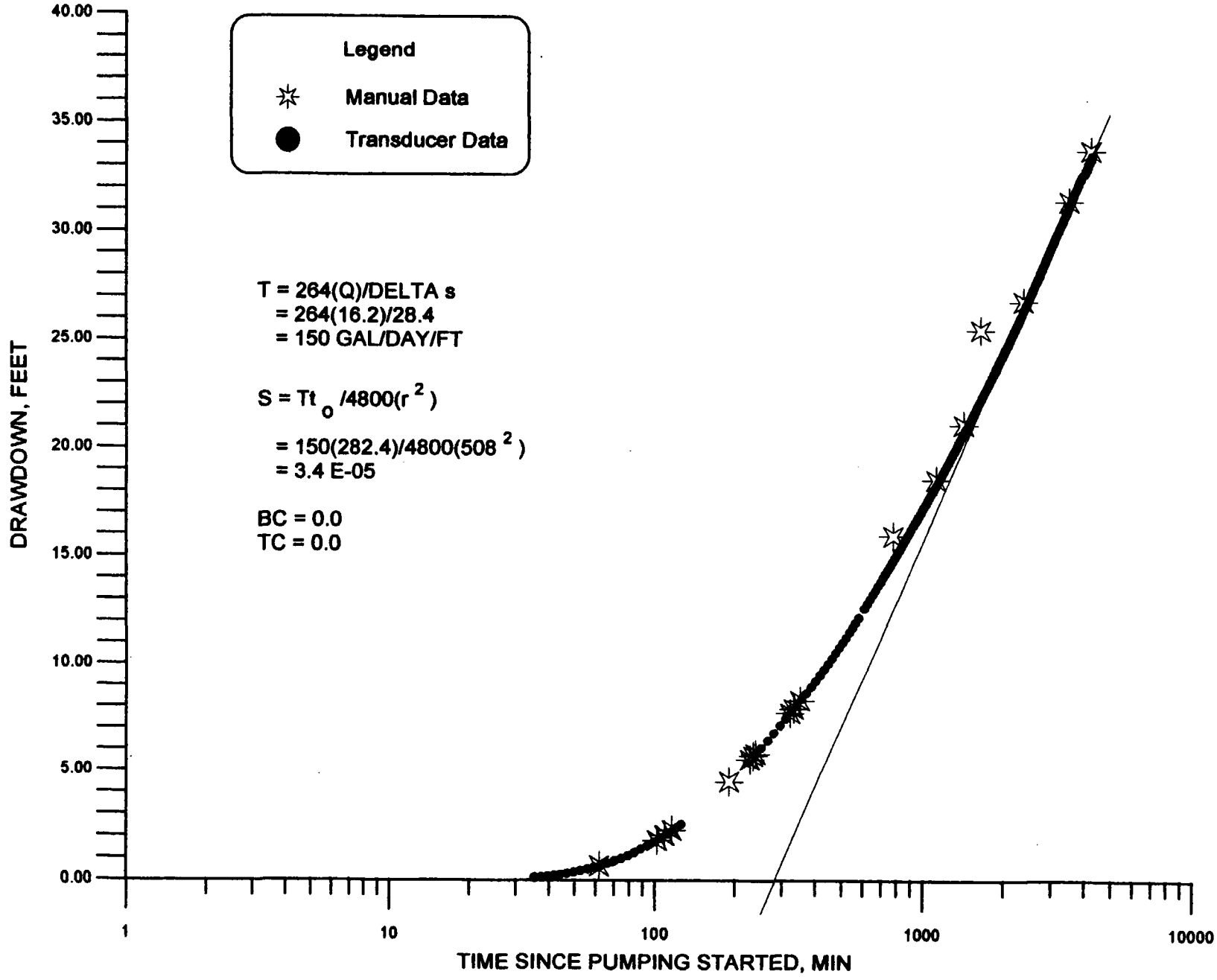


FIGURE K.5-20B. DRAWDOWN IN OBSERVATION WELL M442, SEMI-LOG.

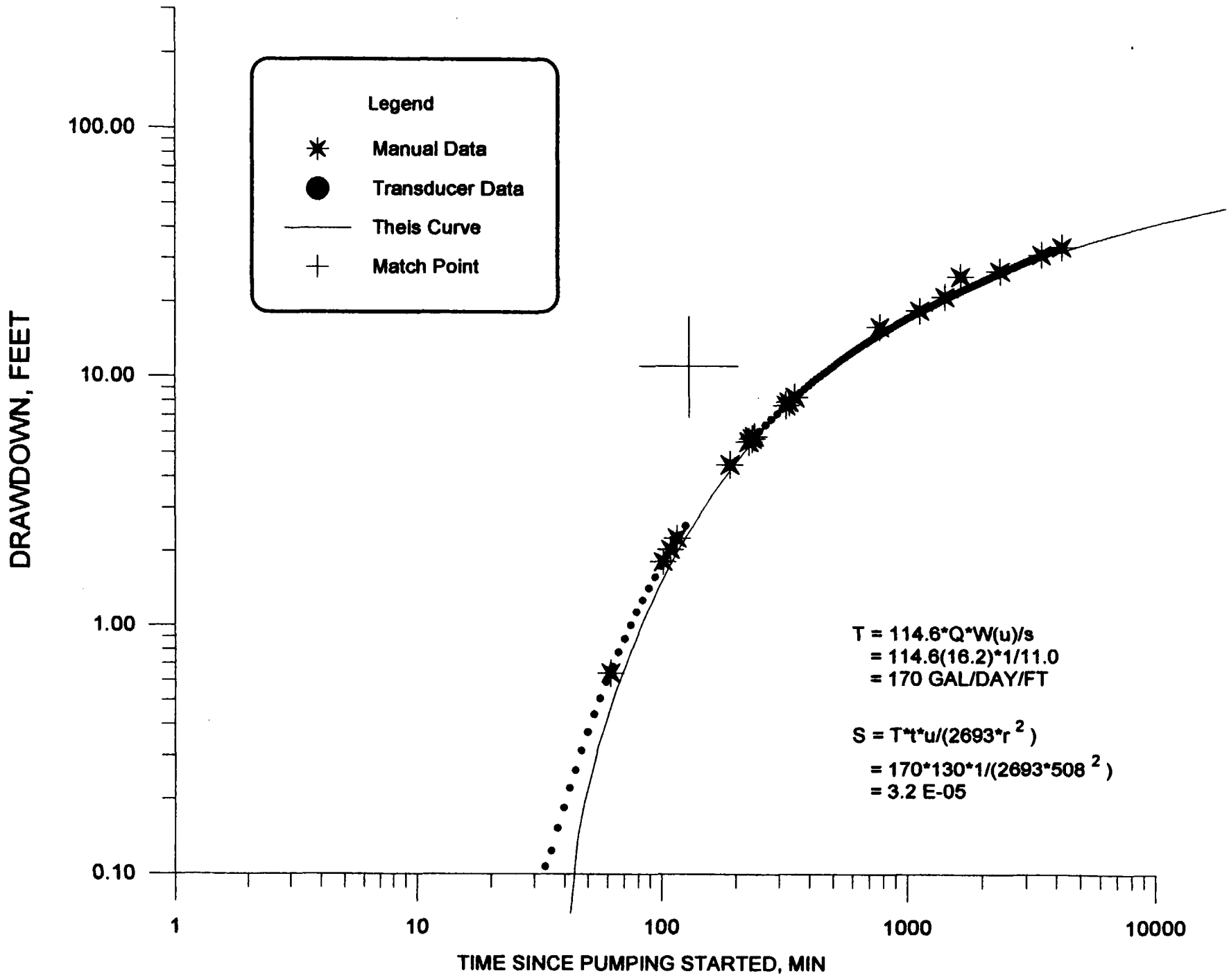


FIGURE K.5-20C. DRAWDOWN IN OBSERVATION WELL M442, LOG-LOG.

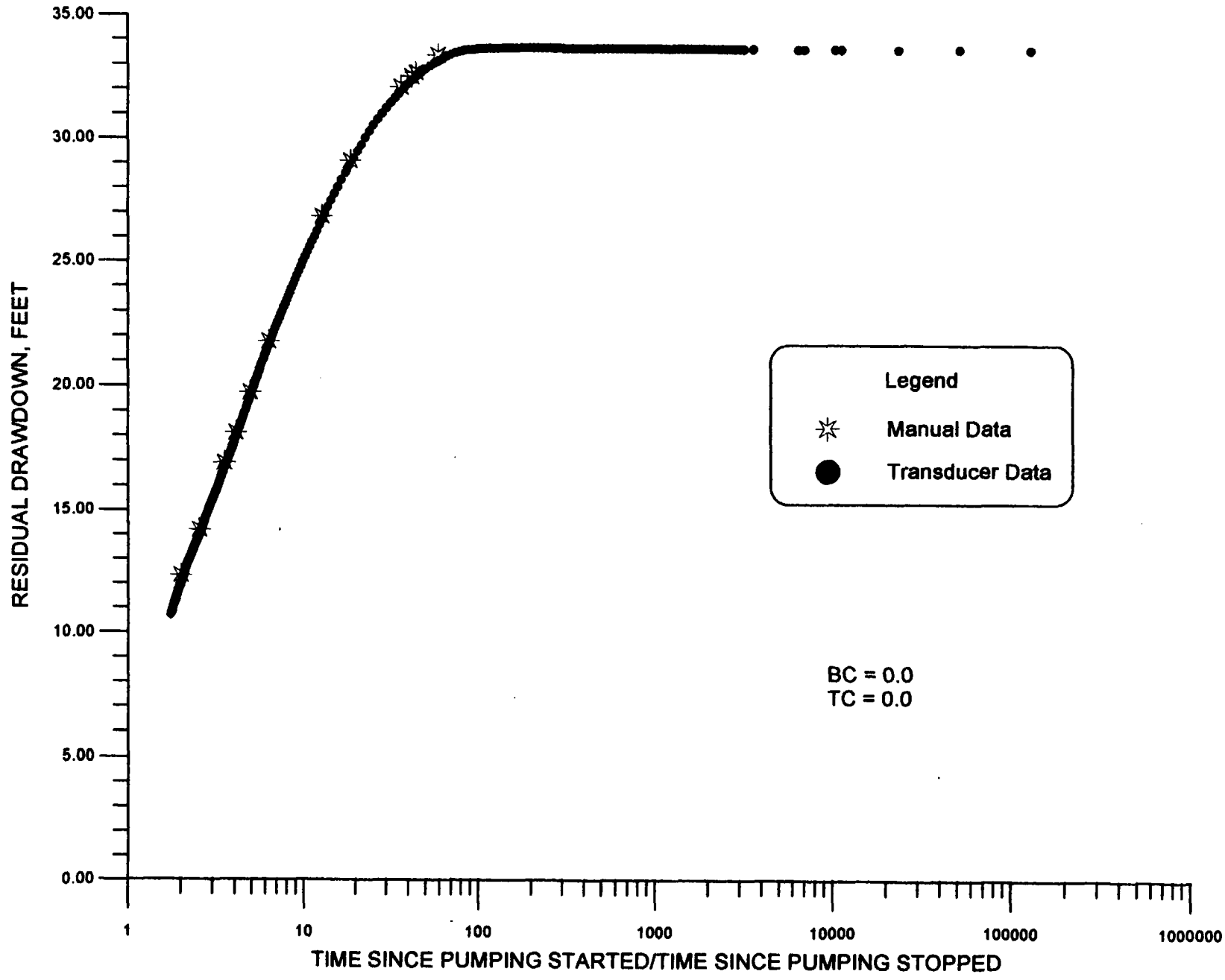
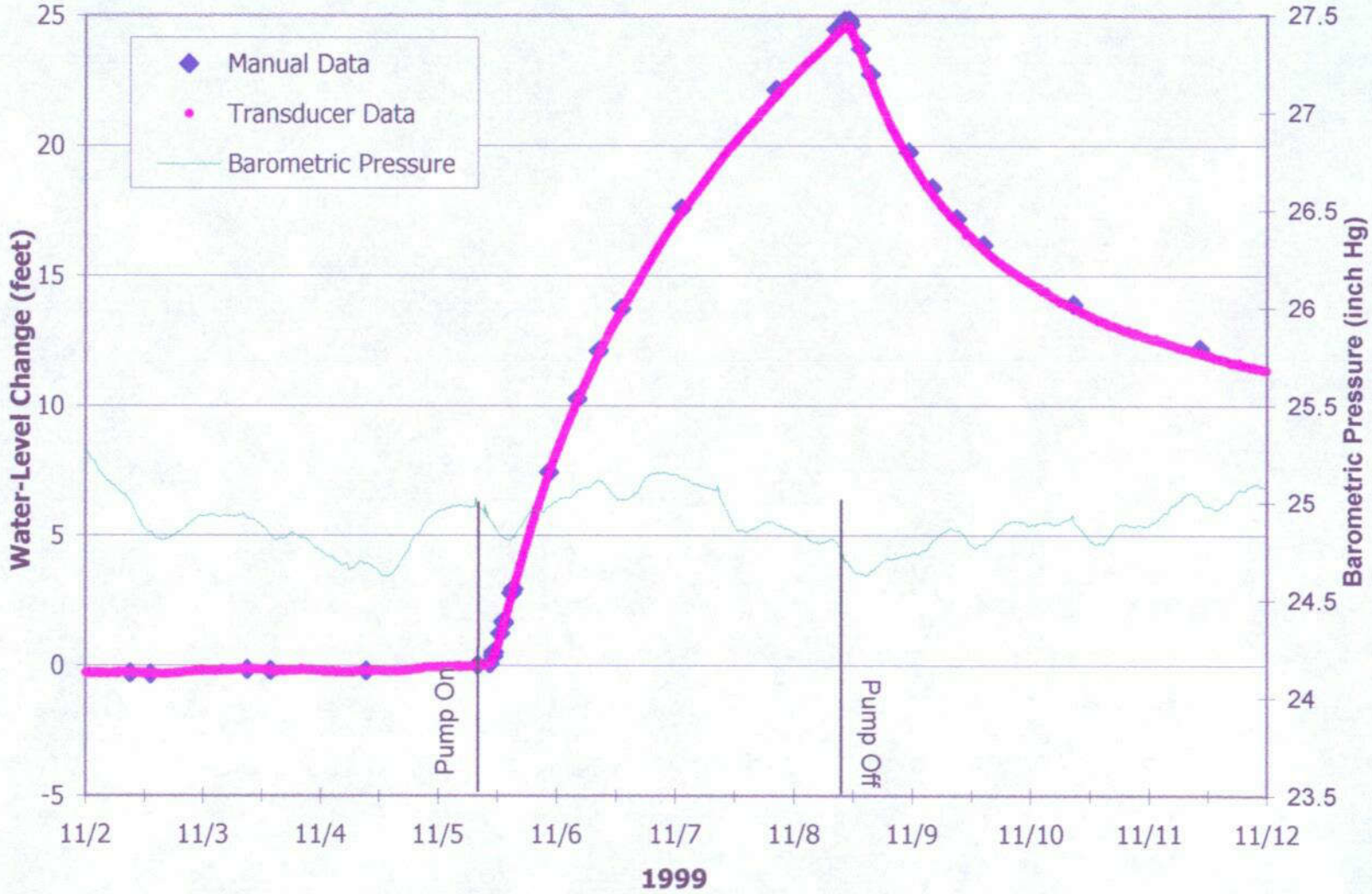


FIGURE K.5-20D. RECOVERY IN OBSERVATION WELL M442.

FIGURE K.5-21A. WATER-LEVEL CHANGE IN OBSERVATION WELL M443



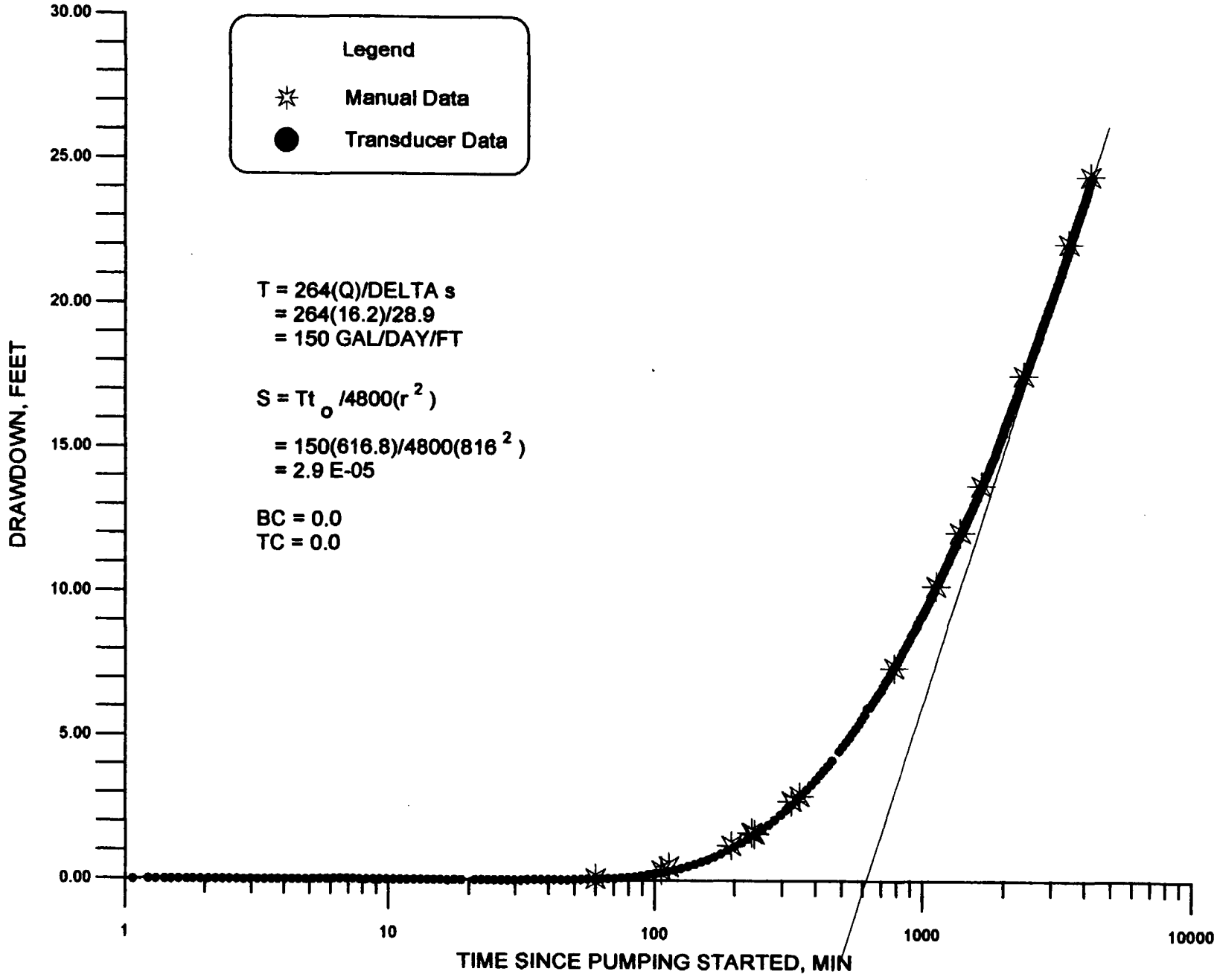


FIGURE K.5-21B. DRAWDOWN IN OBSERVATION WELL M443, SEMI-LOG.

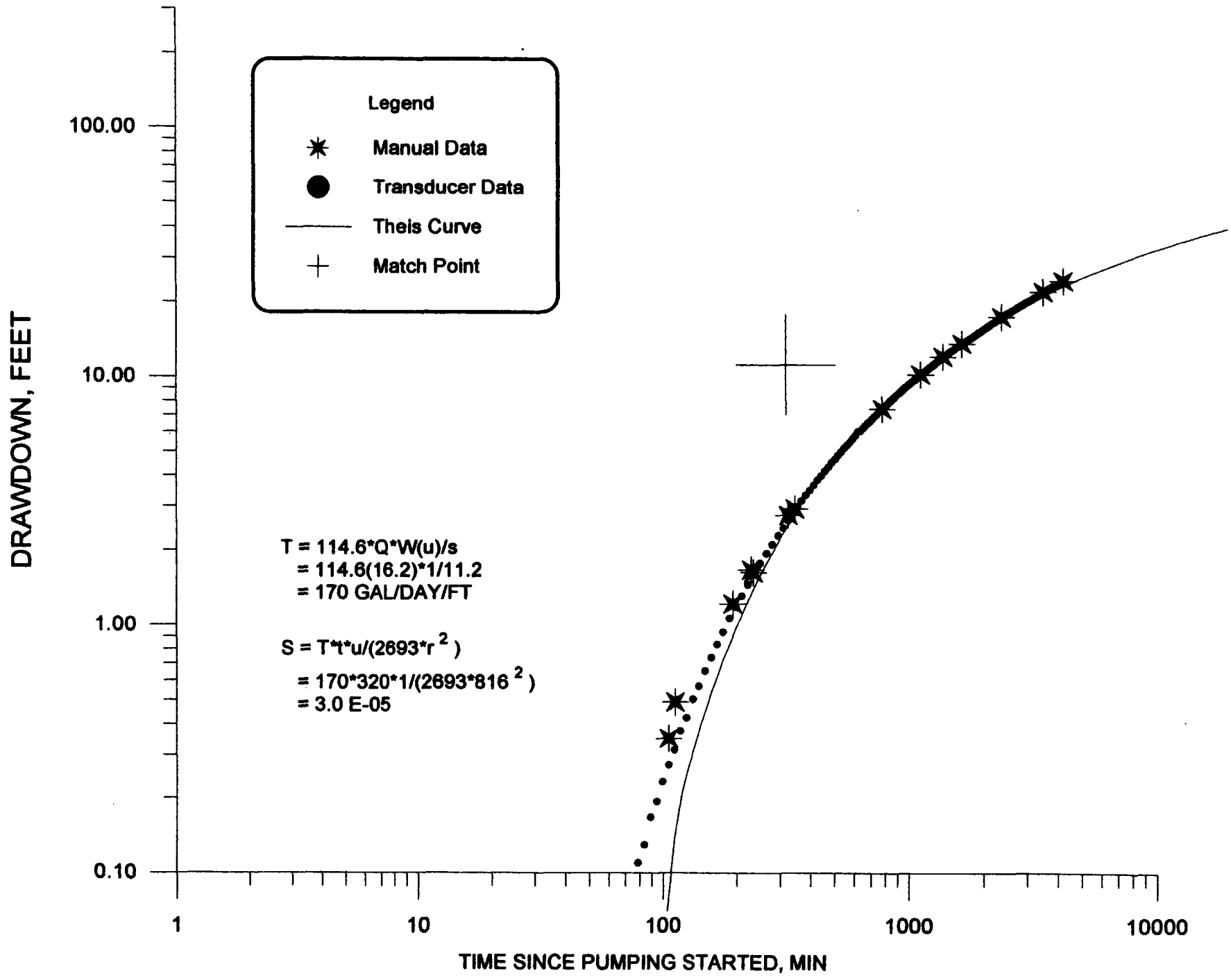


FIGURE K.5-21C. DRAWDOWN IN OBSERVATION WELL M443, LOG-LOG.

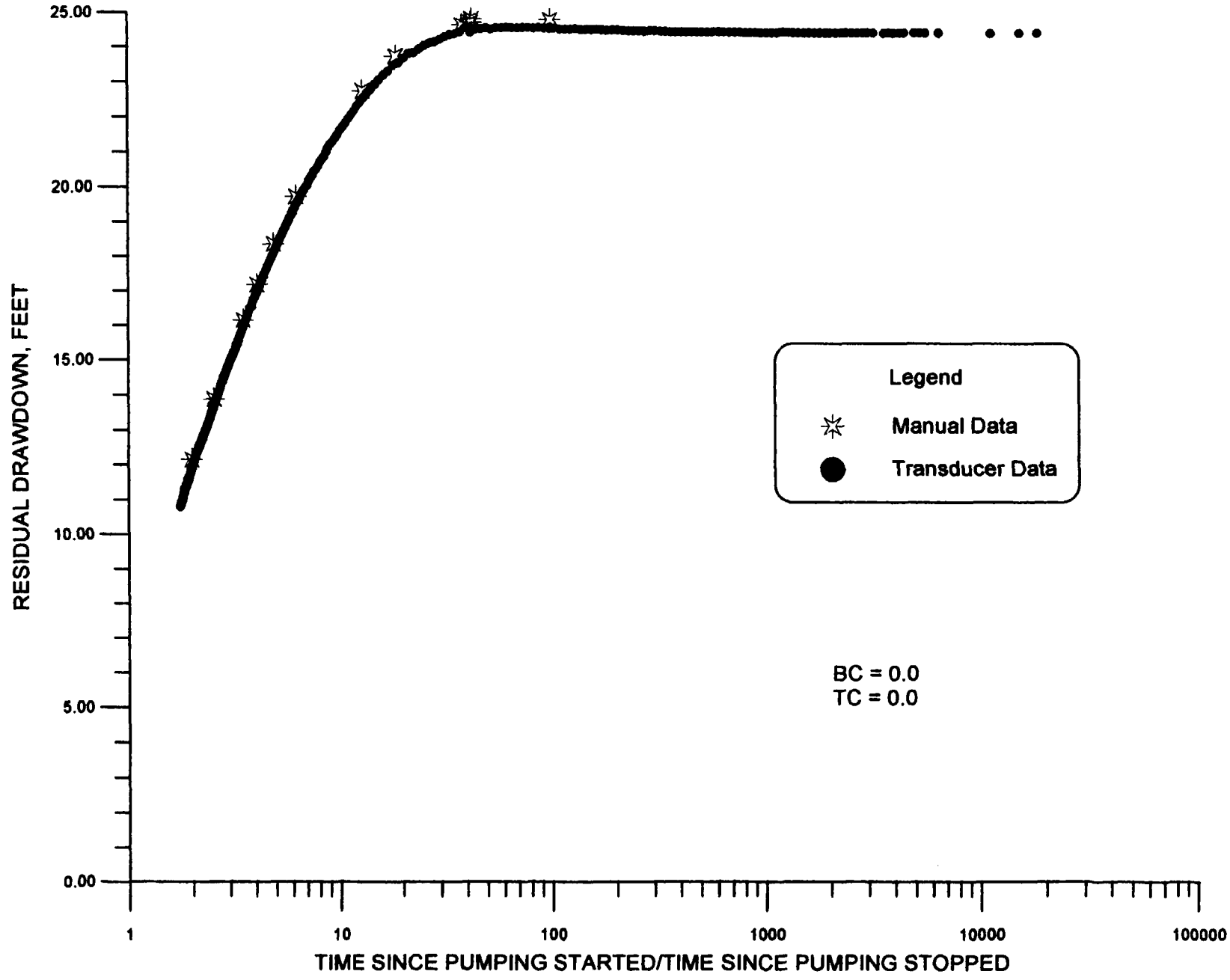
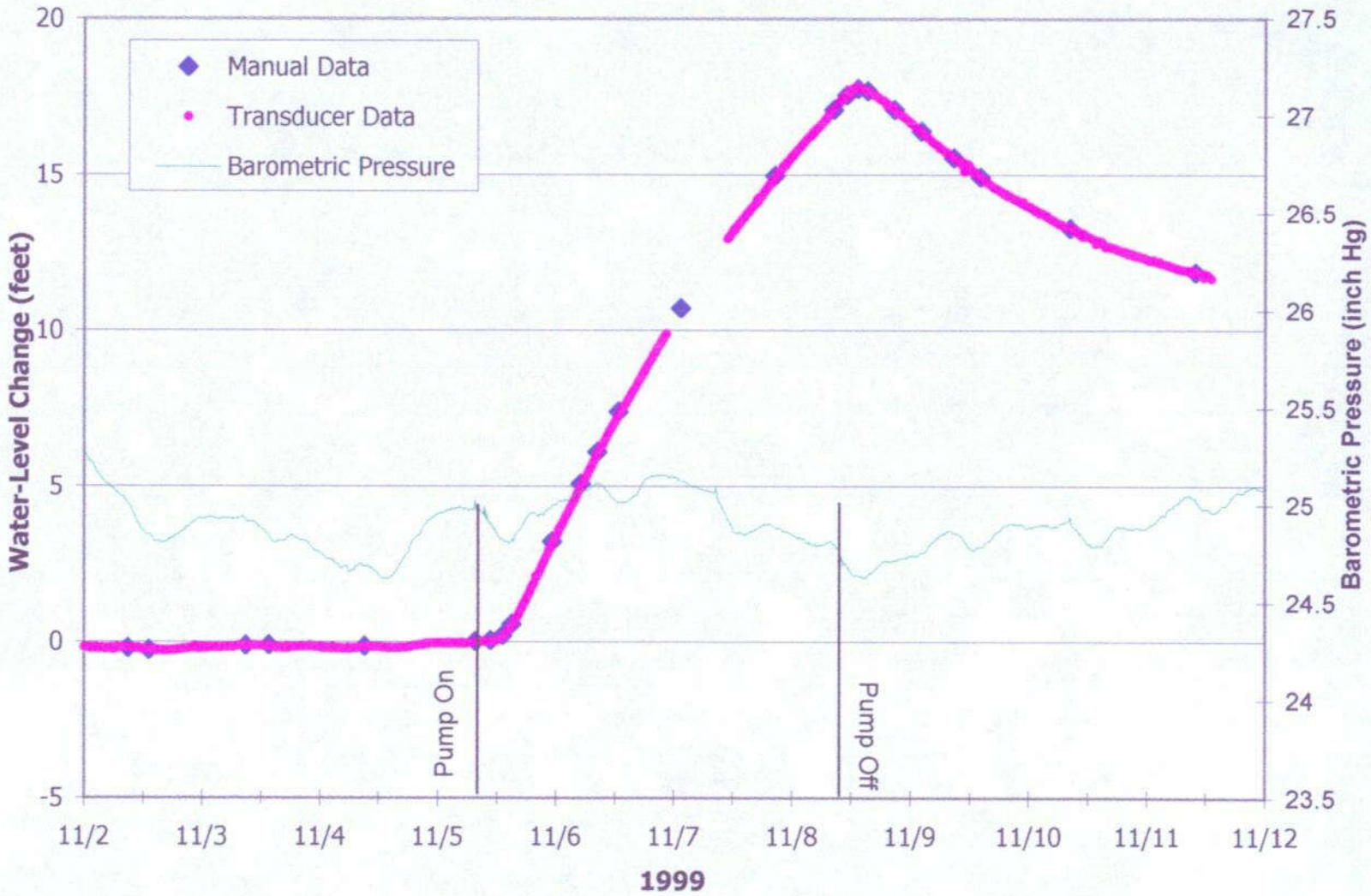


FIGURE K.5-21D. RECOVERY IN OBSERVATION WELL M443.

FIGURE K.5-22A. WATER-LEVEL CHANGE IN OBSERVATION WELL M444



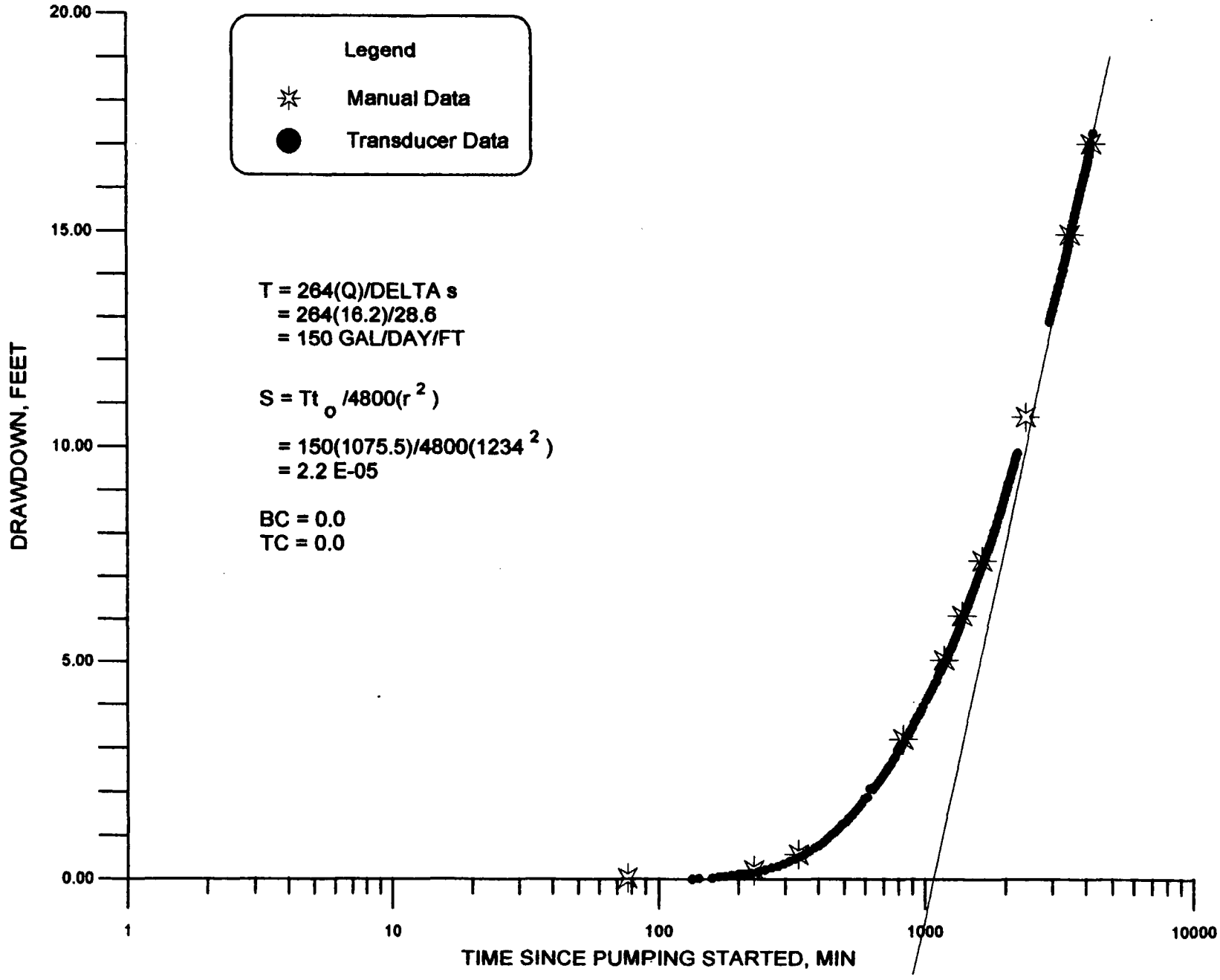


FIGURE K.5-22B. DRAWDOWN IN OBSERVATION WELL M444, SEMI-LOG.

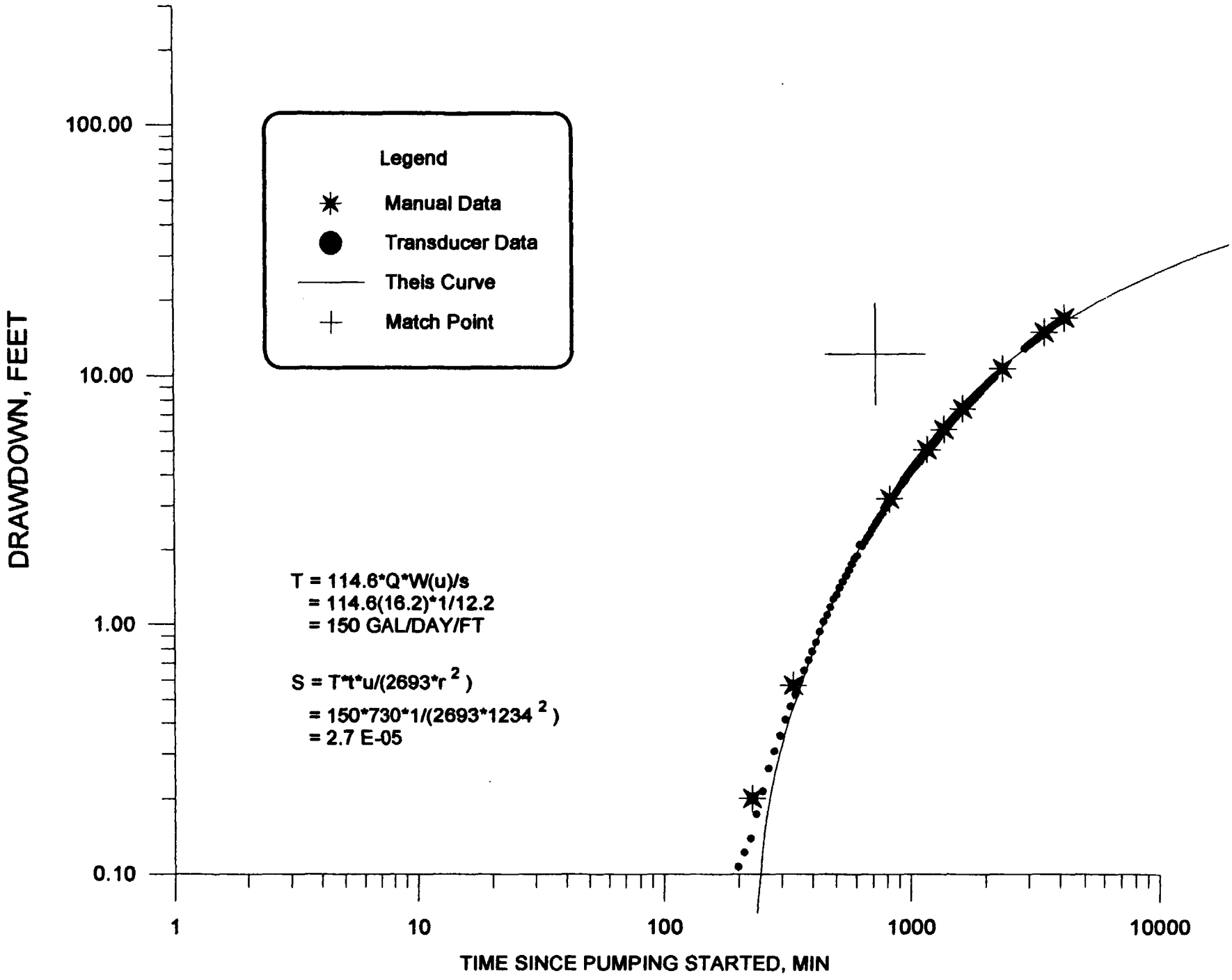


FIGURE K.5-22C. DRAWDOWN IN OBSERVATION WELL M444, LOG-LOG.

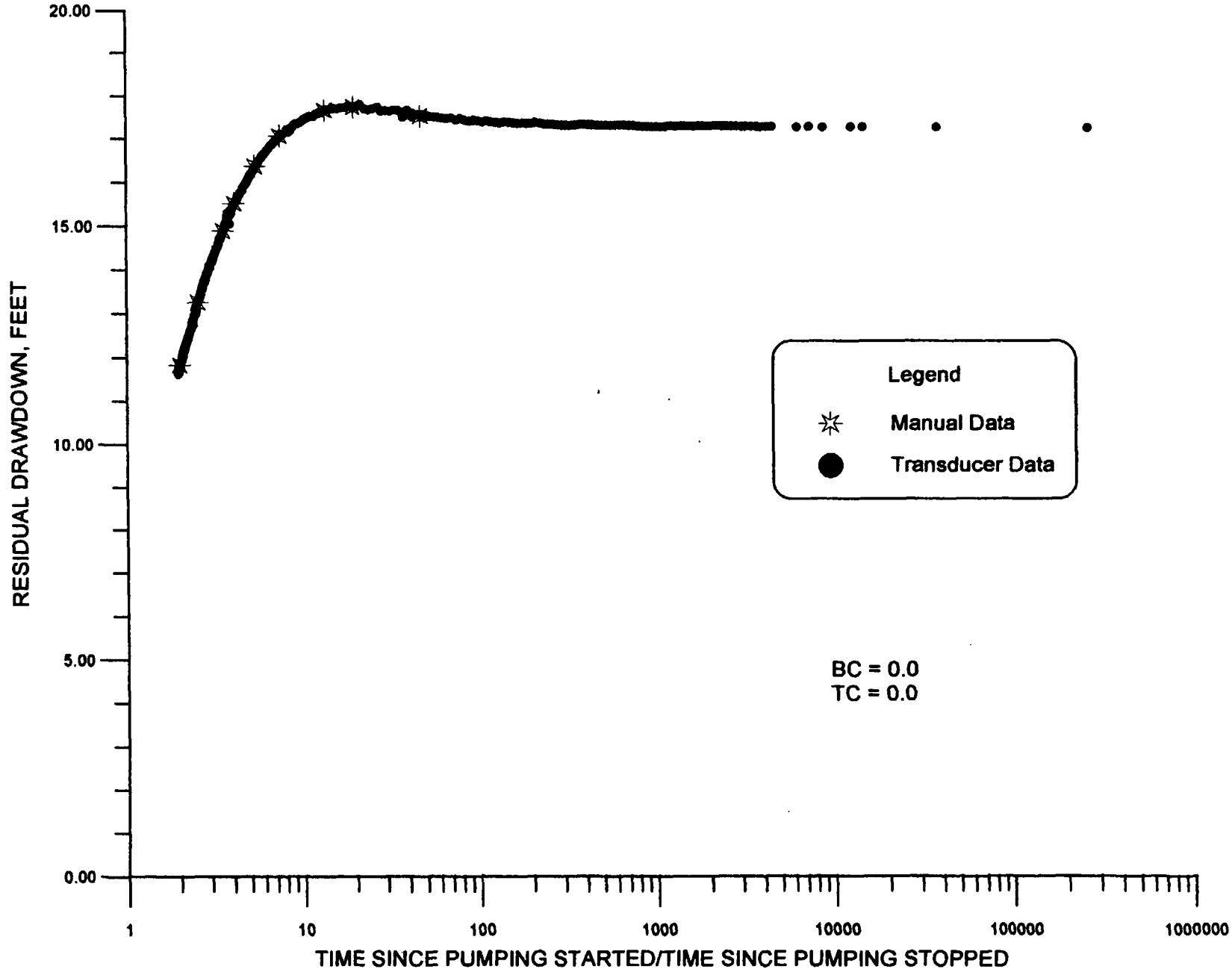
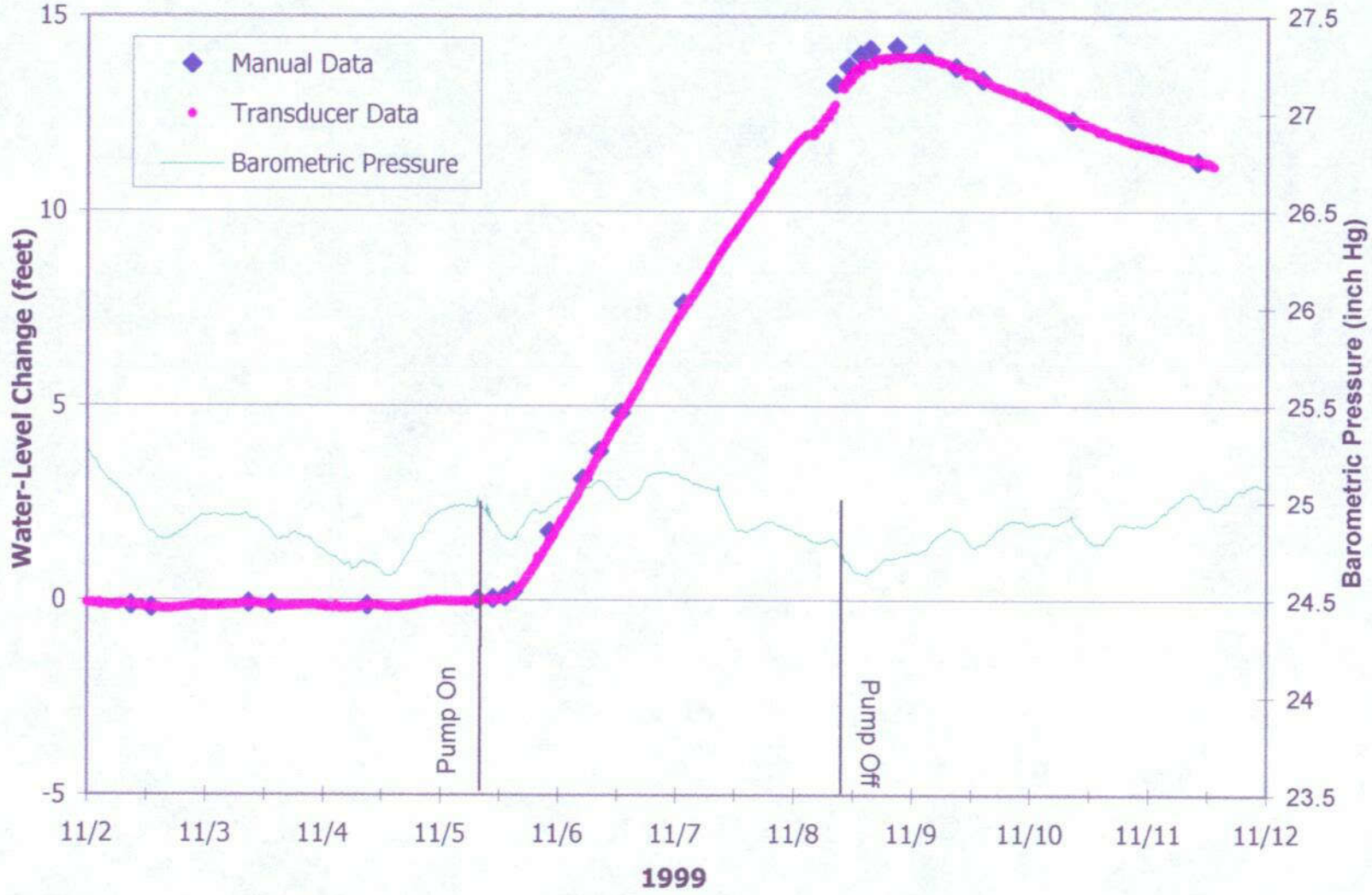


FIGURE K.5-22D. RECOVERY IN OBSERVATION WELL M444.

FIGURE K.5-23A. WATER-LEVEL CHANGE IN OBSERVATION WELL M445



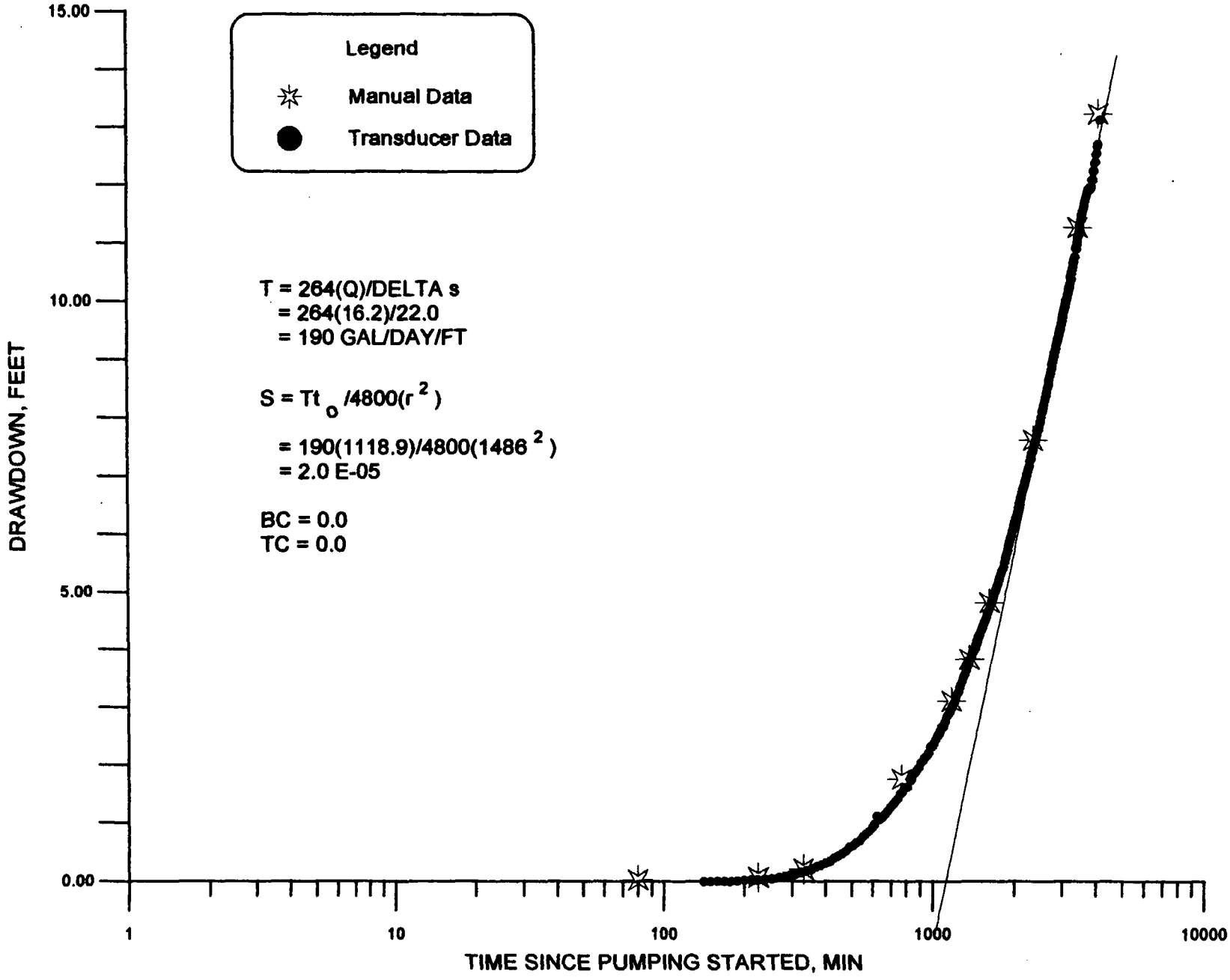


FIGURE K.5-23B. DRAWDOWN IN OBSERVATION WELL M445, SEMI-LOG.

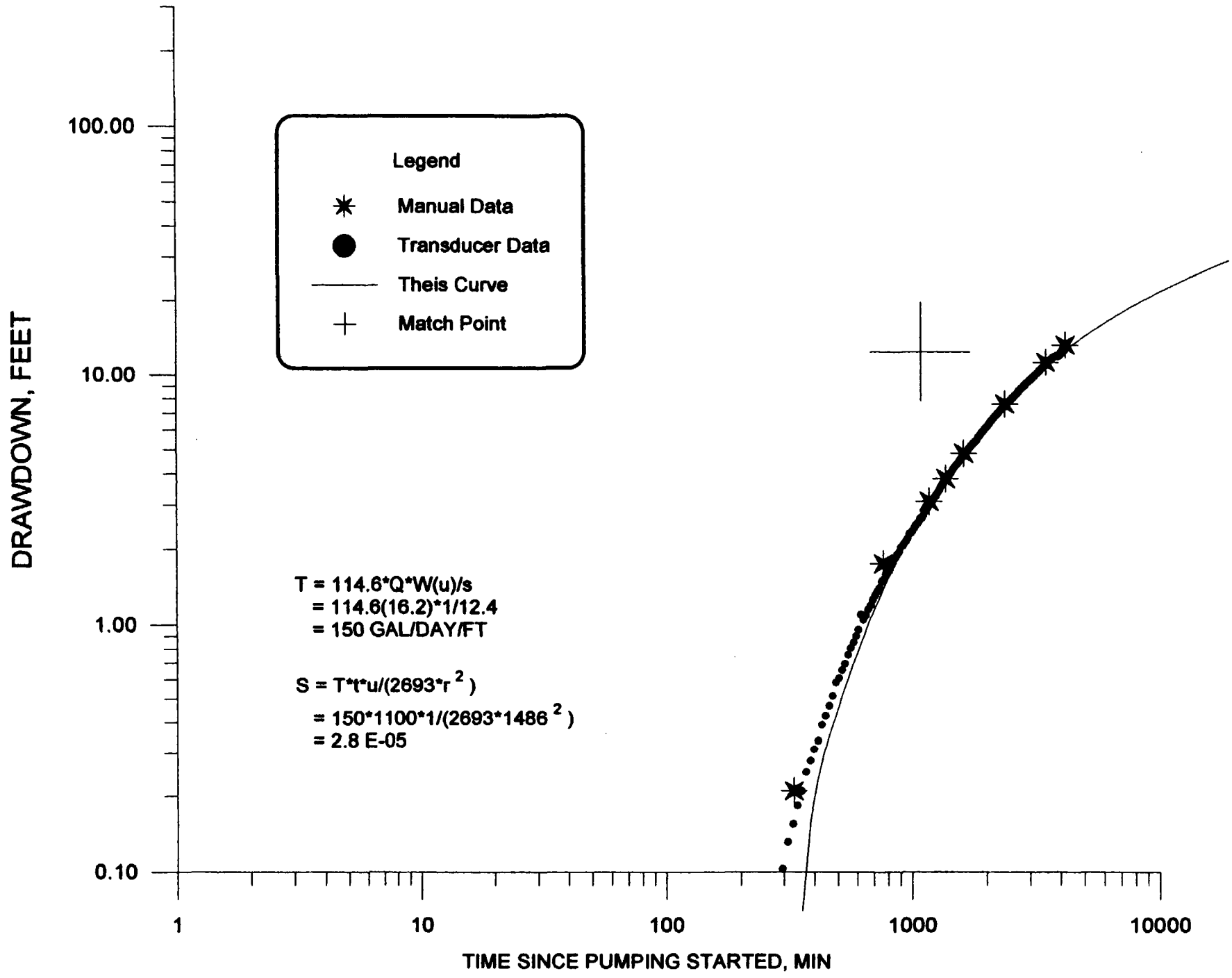


FIGURE K.5-23C. DRAWDOWN IN OBSERVATION WELL M445, LOG-LOG.

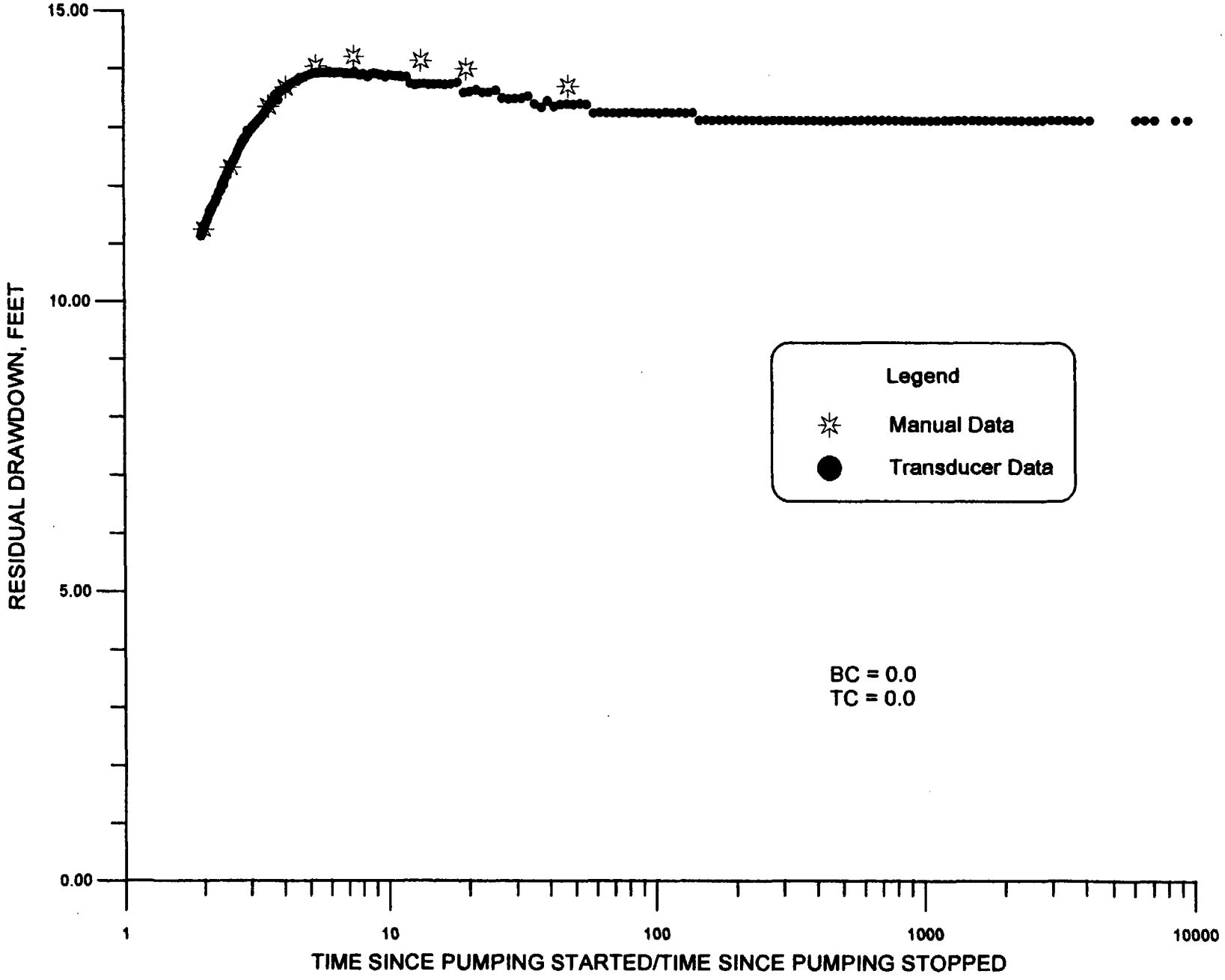
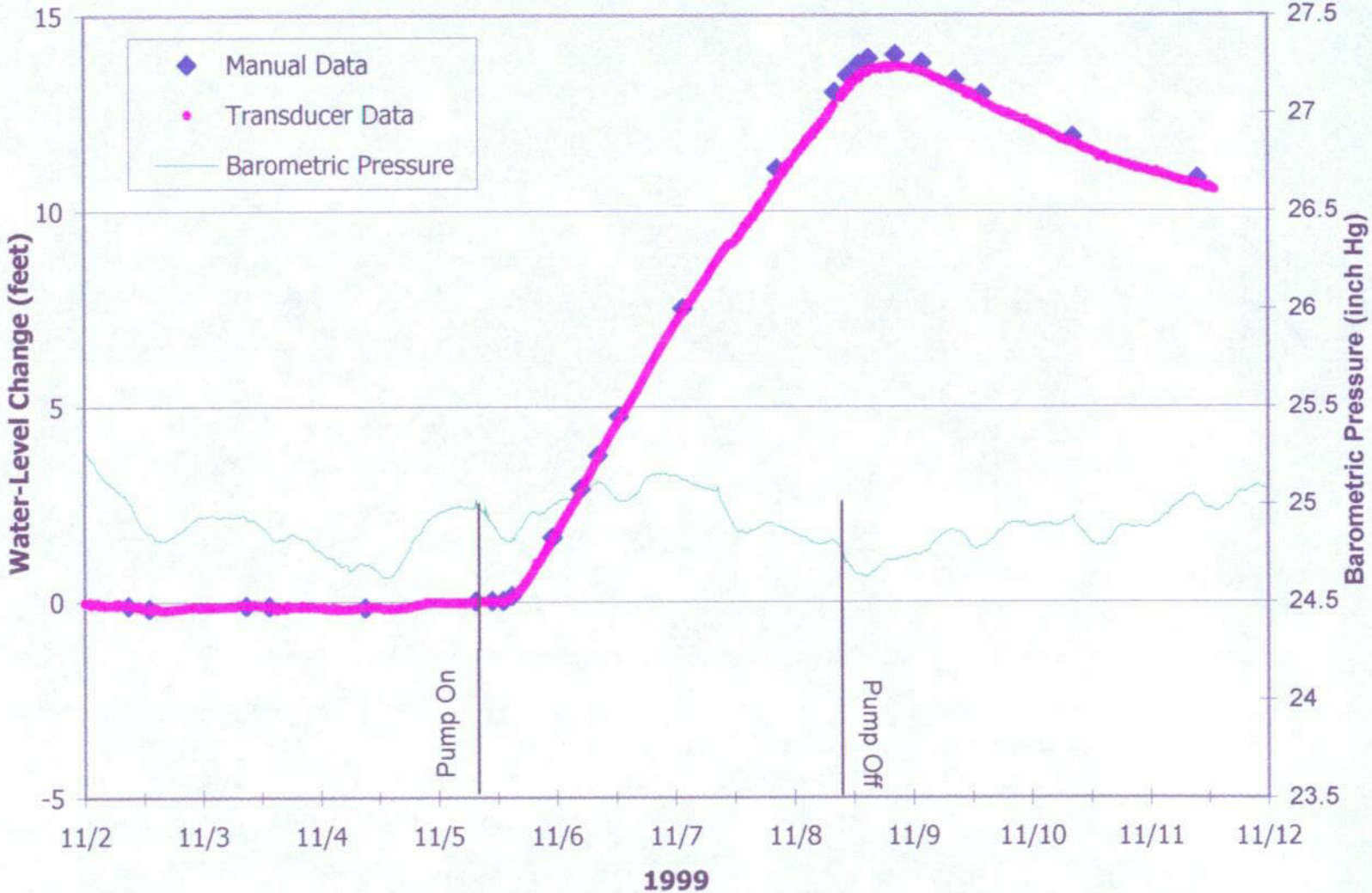


FIGURE K.5-23D. RECOVERY IN OBSERVATION WELL M445.

FIGURE K.5-24A. WATER-LEVEL CHANGE IN OBSERVATION WELL M446



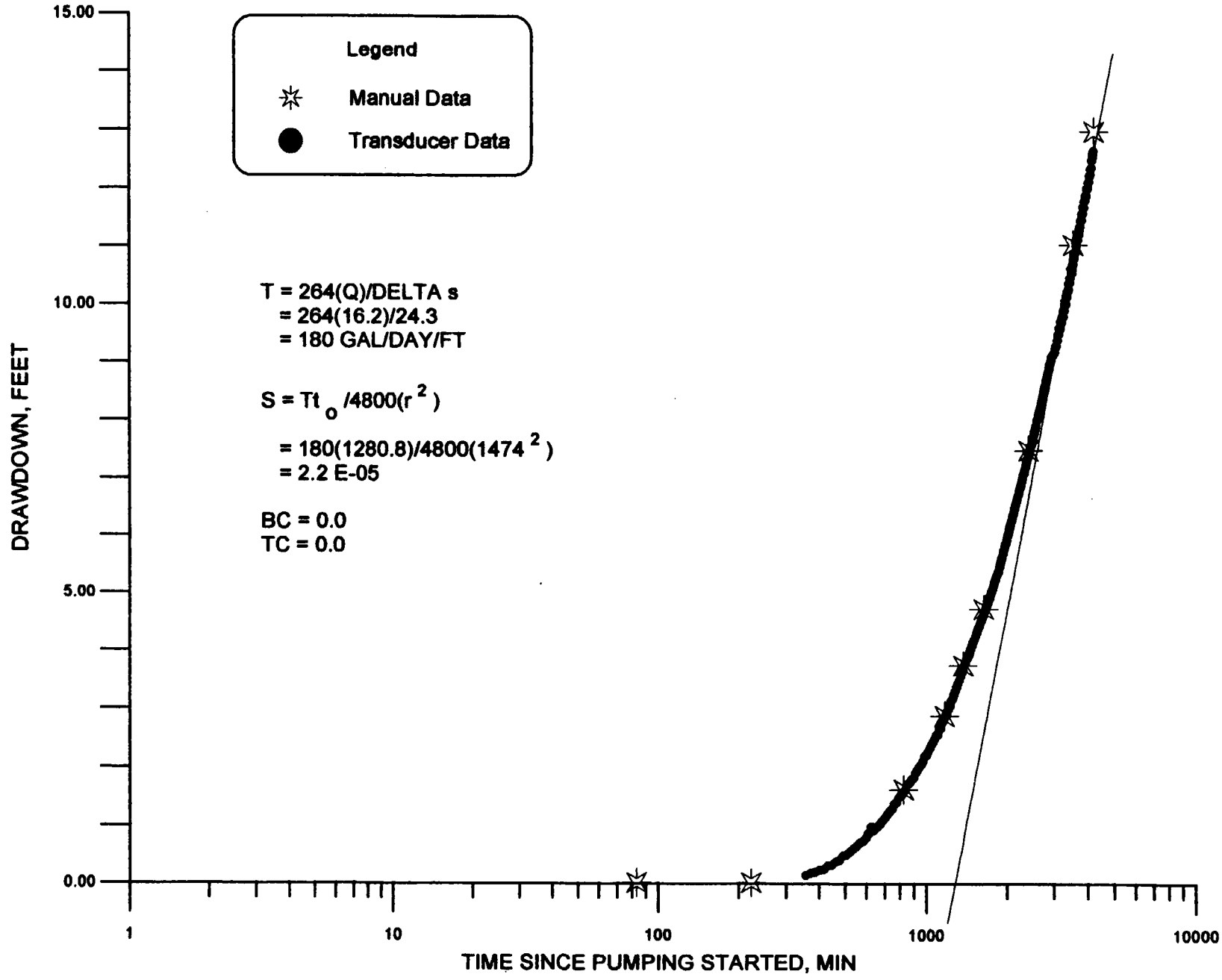


FIGURE K.5-24B. DRAWDOWN IN OBSERVATION WELL M446, SEMI-LOG.

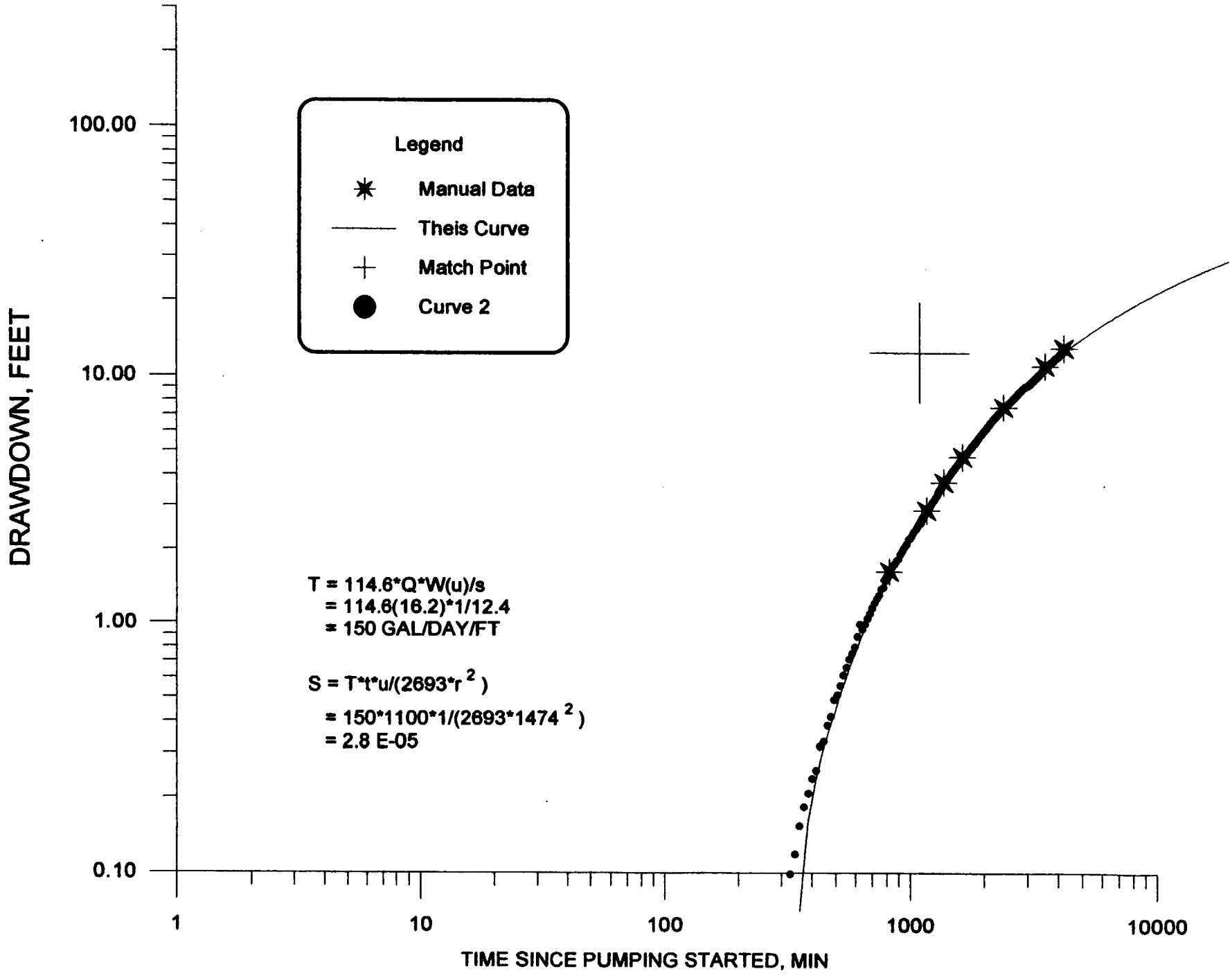


FIGURE K.5-24C. DRAWDOWN IN OBSERVATION WELL M446, LOG-LOG.

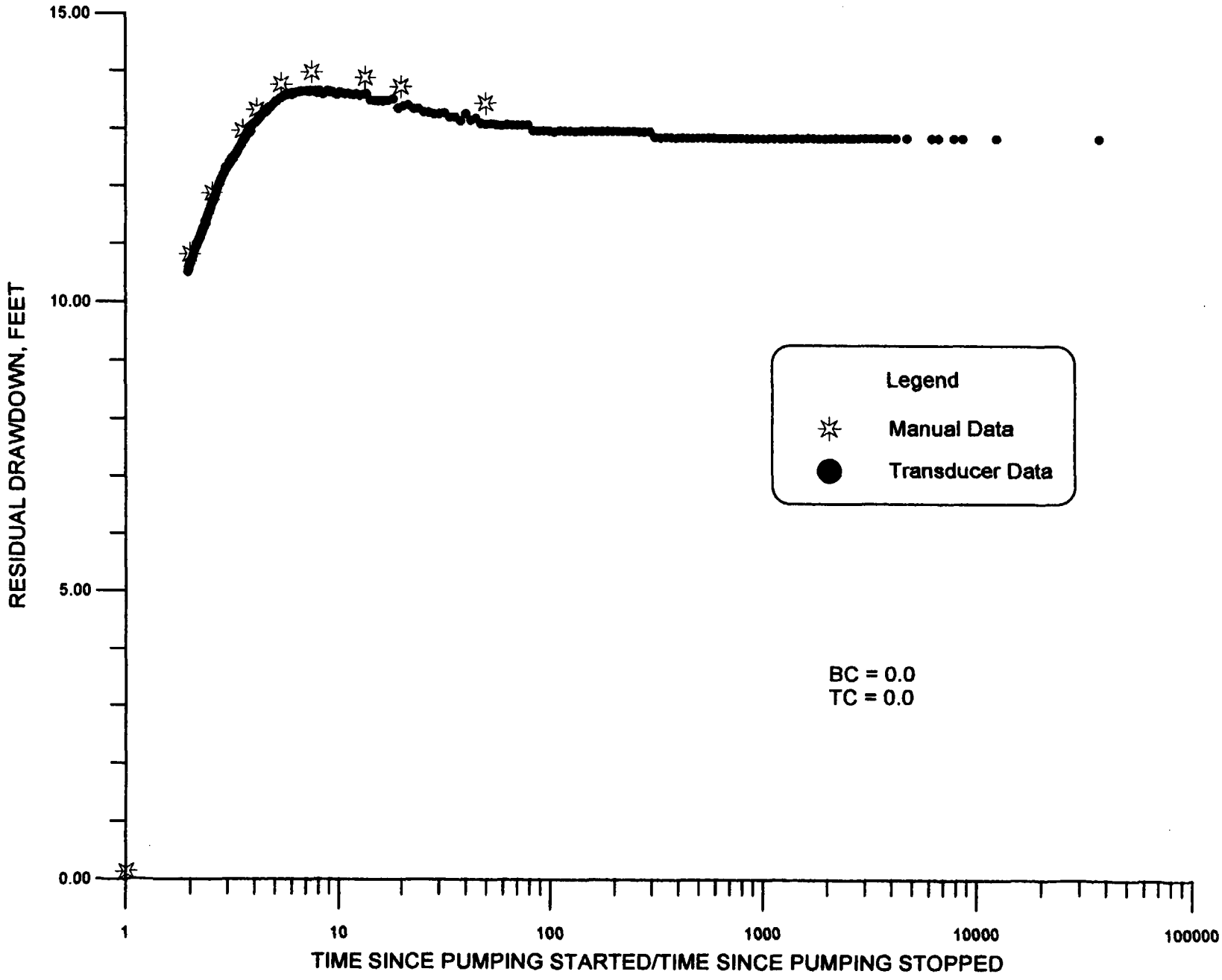
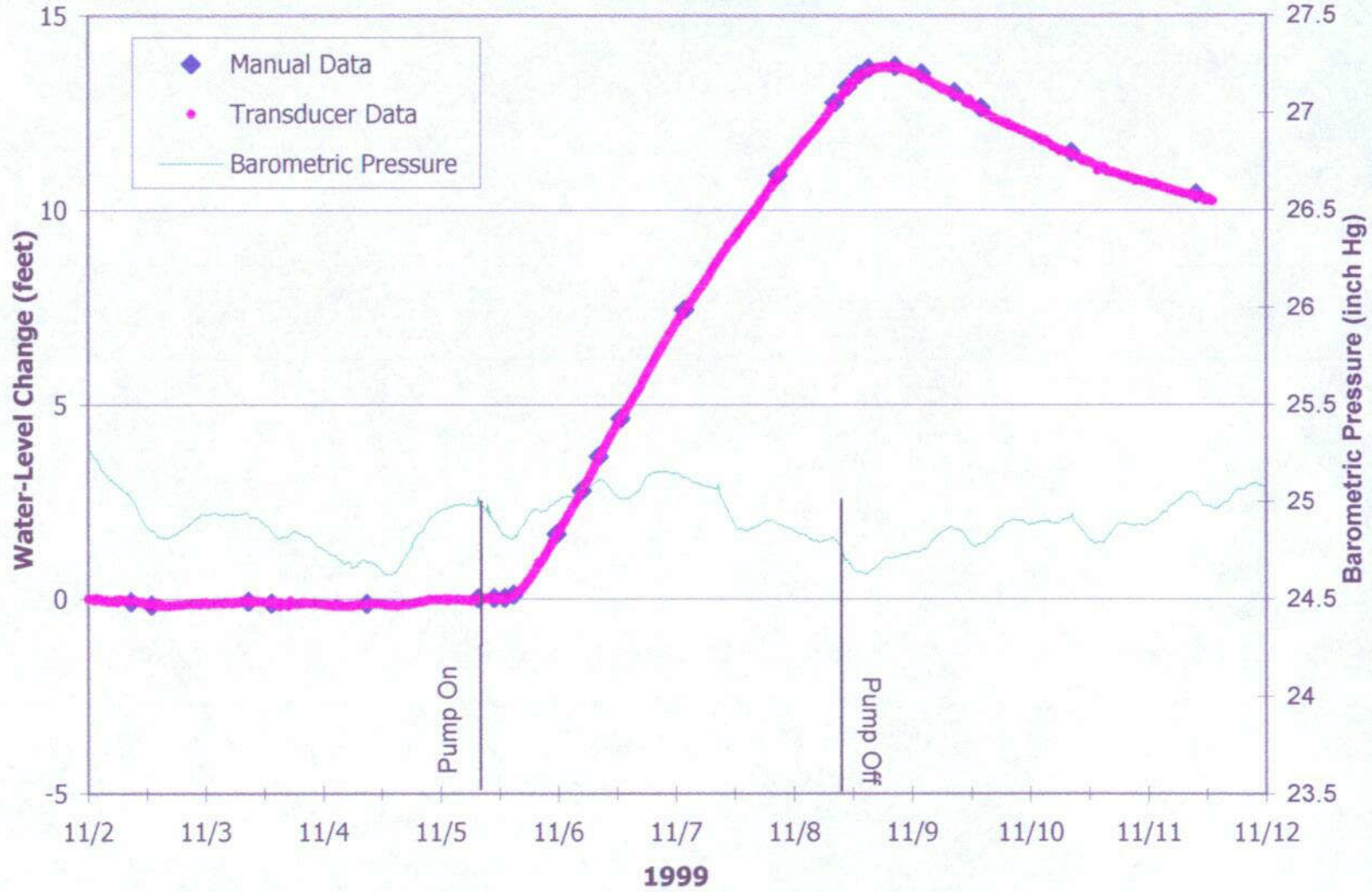


FIGURE K.5-24D. RECOVERY IN OBSERVATION WELL M446.

FIGURE K.5-25A. WATER-LEVEL CHANGE IN OBSERVATION WELL M447



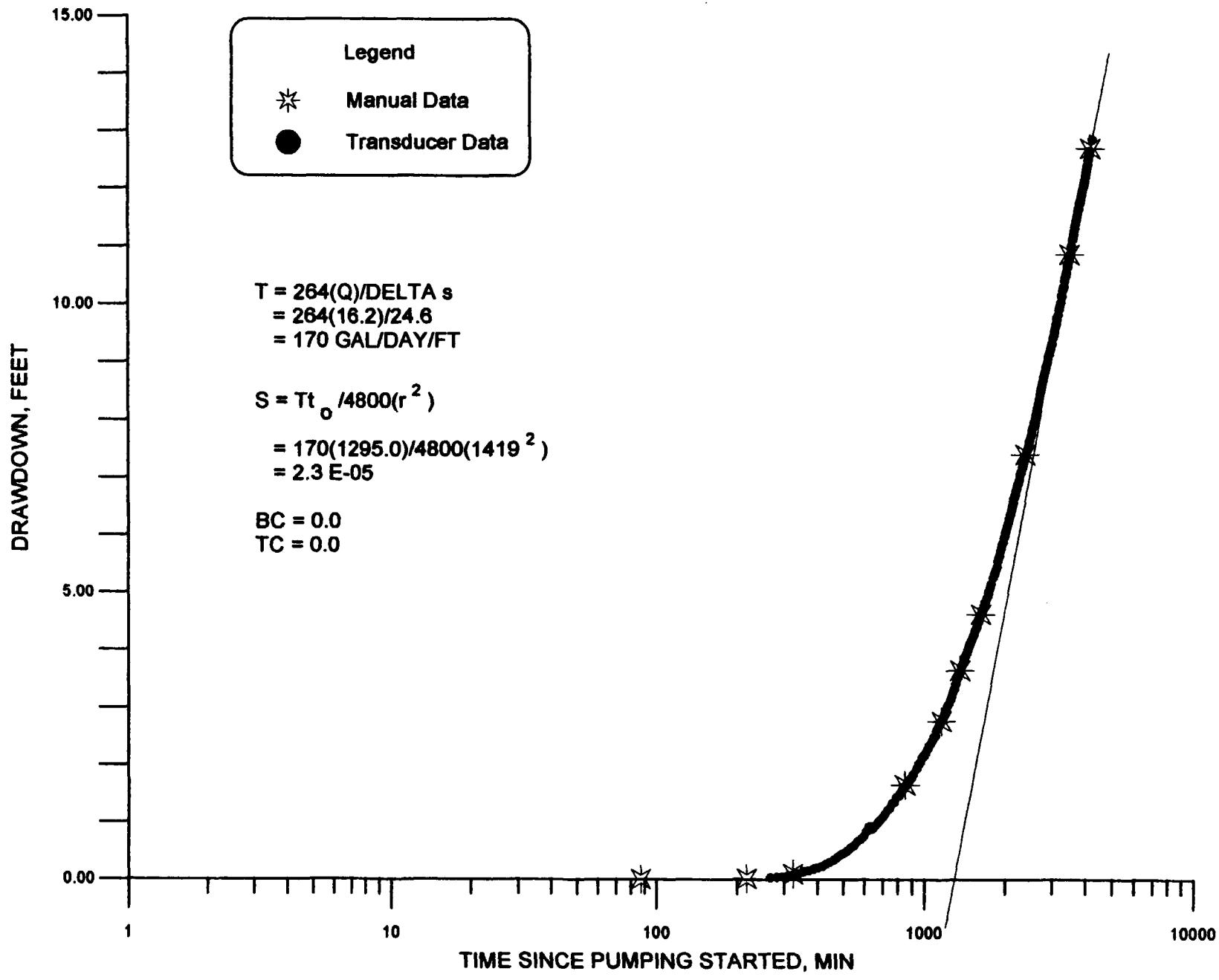


FIGURE K.5-25B. DRAWDOWN IN OBSERVATION WELL M447, SEMI-LOG.

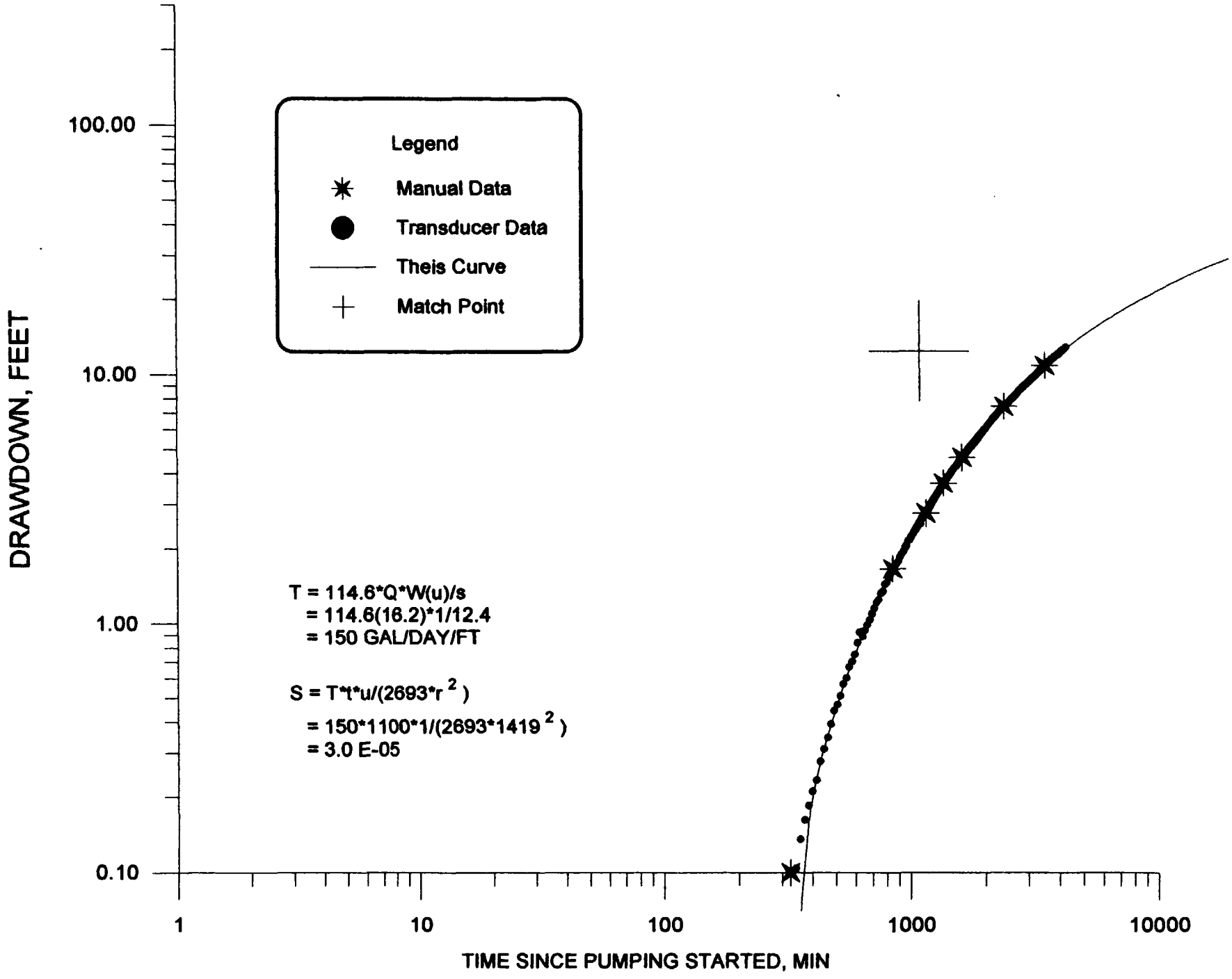


FIGURE K.5-25C. DRAWDOWN IN OBSERVATION WELL M447, LOG-LOG.

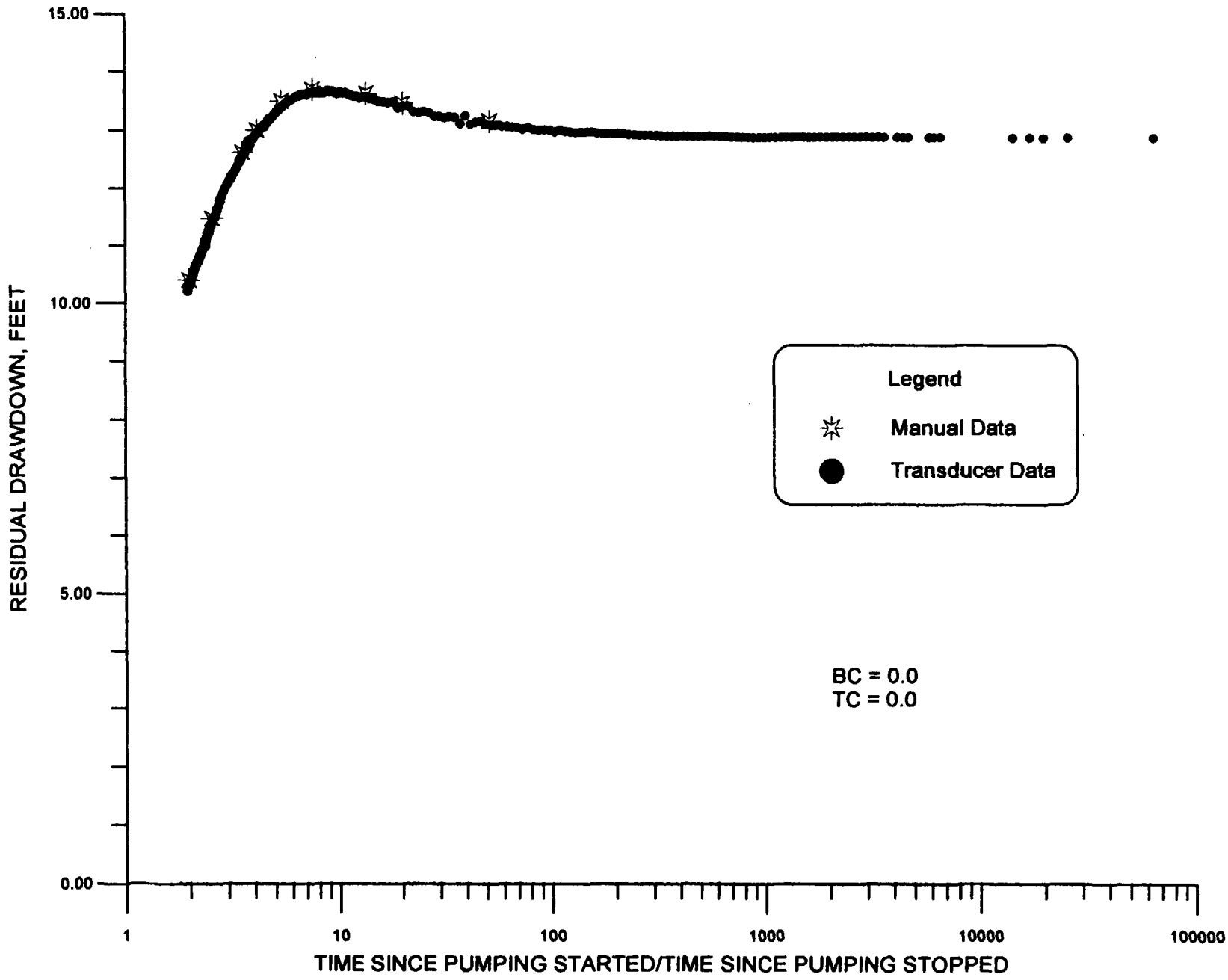
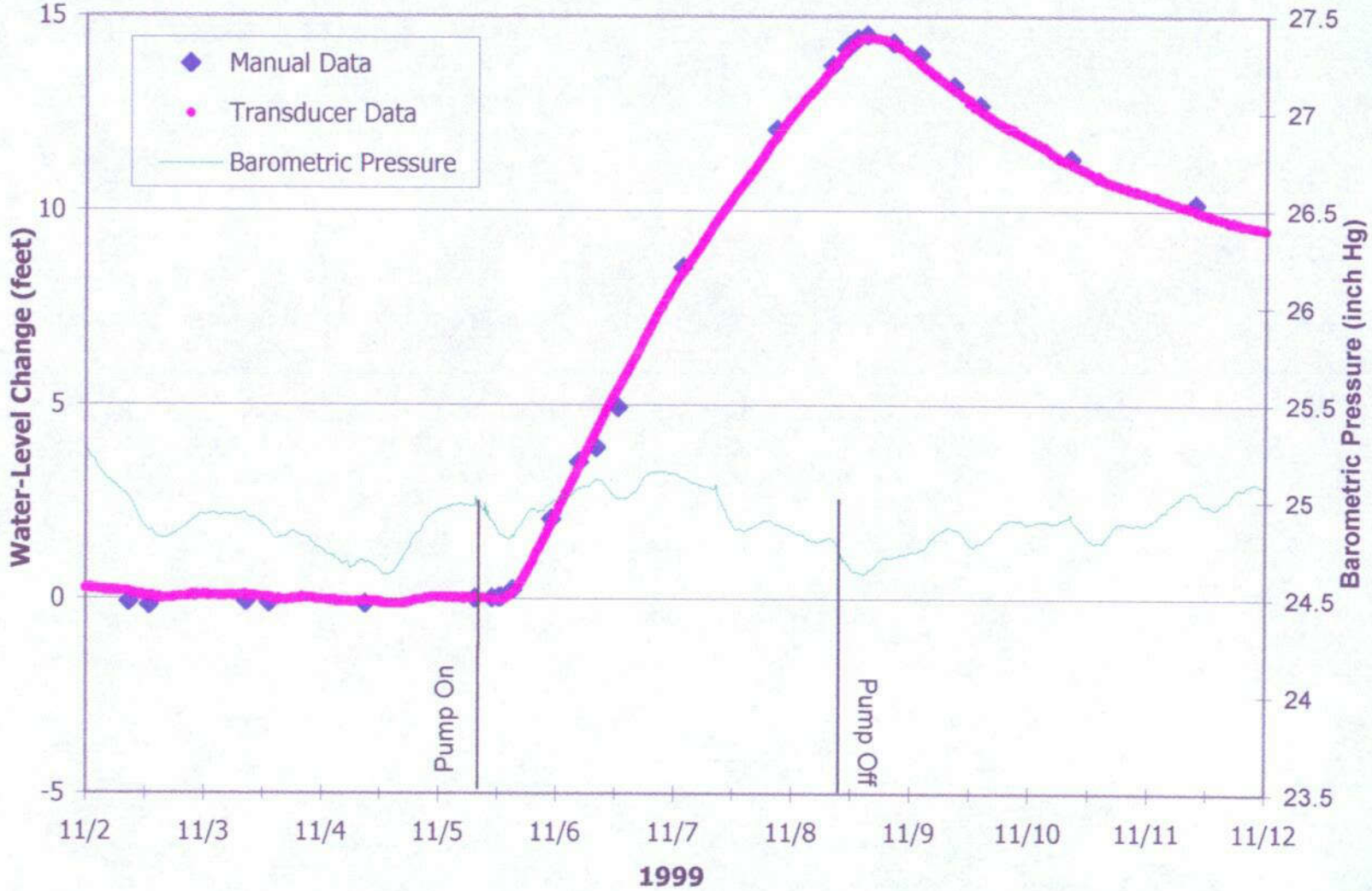


FIGURE K.5-25D. RECOVERY IN OBSERVATION WELL M447.

FIGURE K.5-26A. WATER-LEVEL CHANGE IN OBSERVATION WELL M448



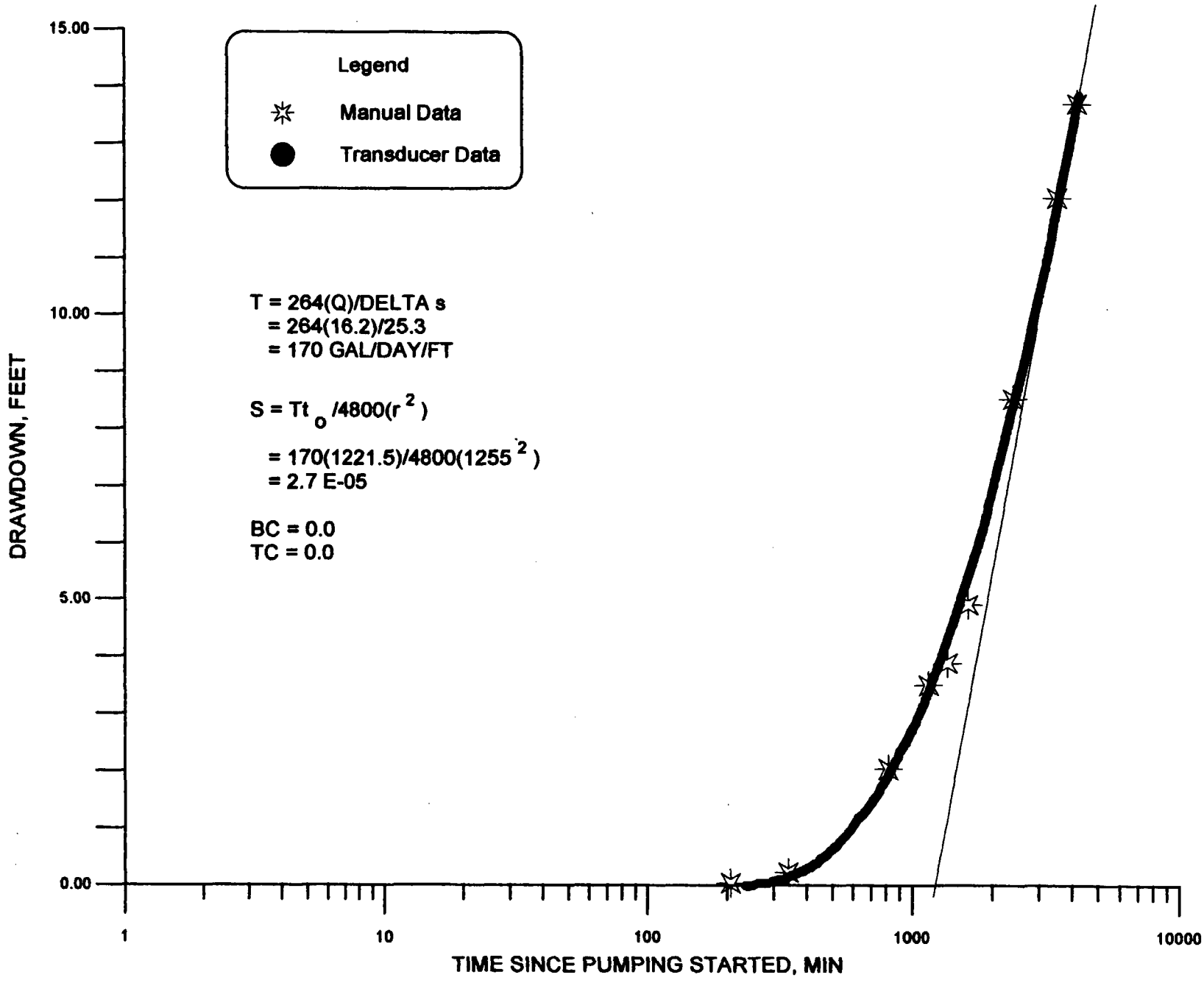


FIGURE K.5-26B. DRAWDOWN IN OBSERVATION WELL M448, SEMI-LOG.

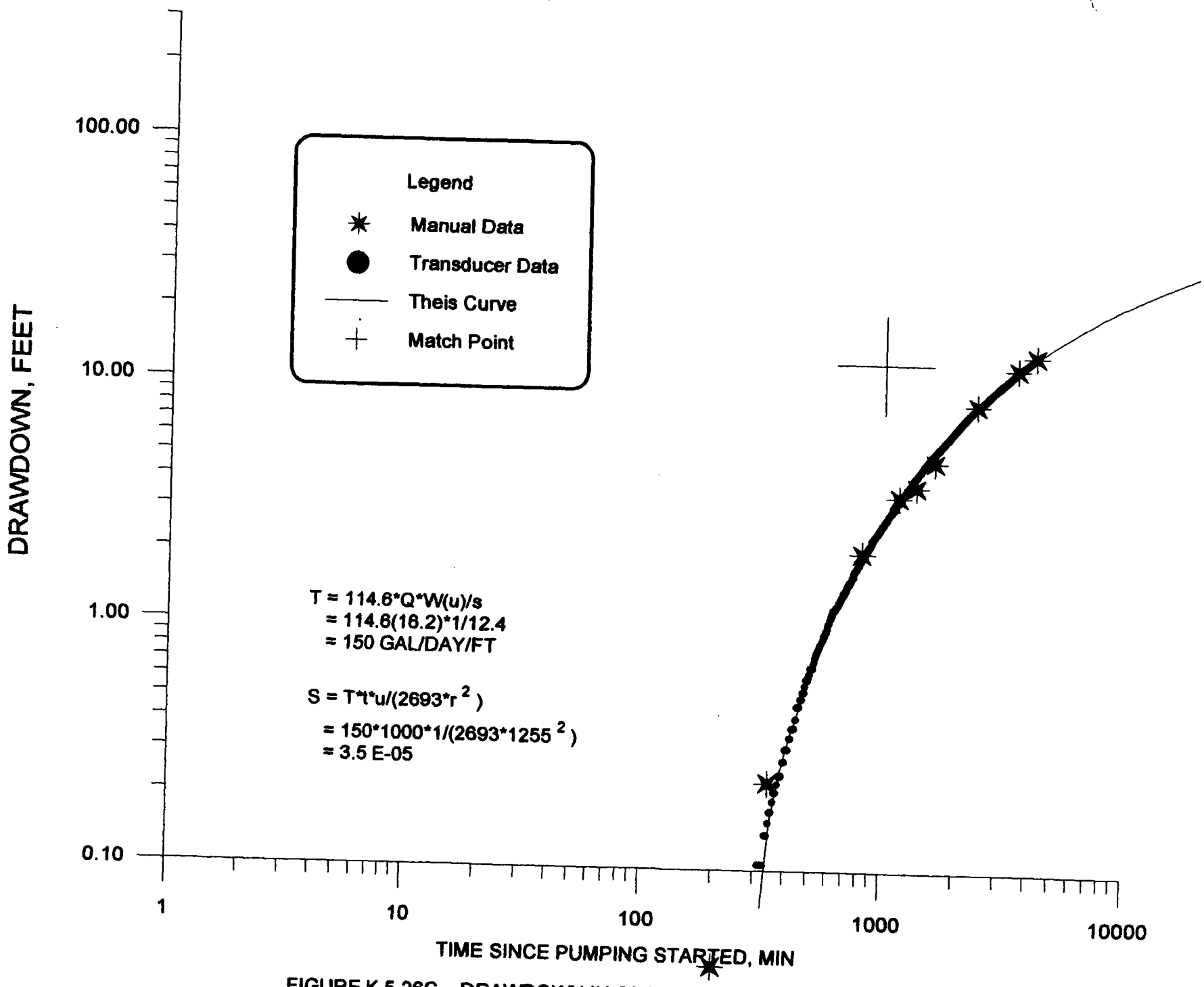


FIGURE K.5-26C. DRAWDOWN IN OBSERVATION WELL M448, LOG-LOG.

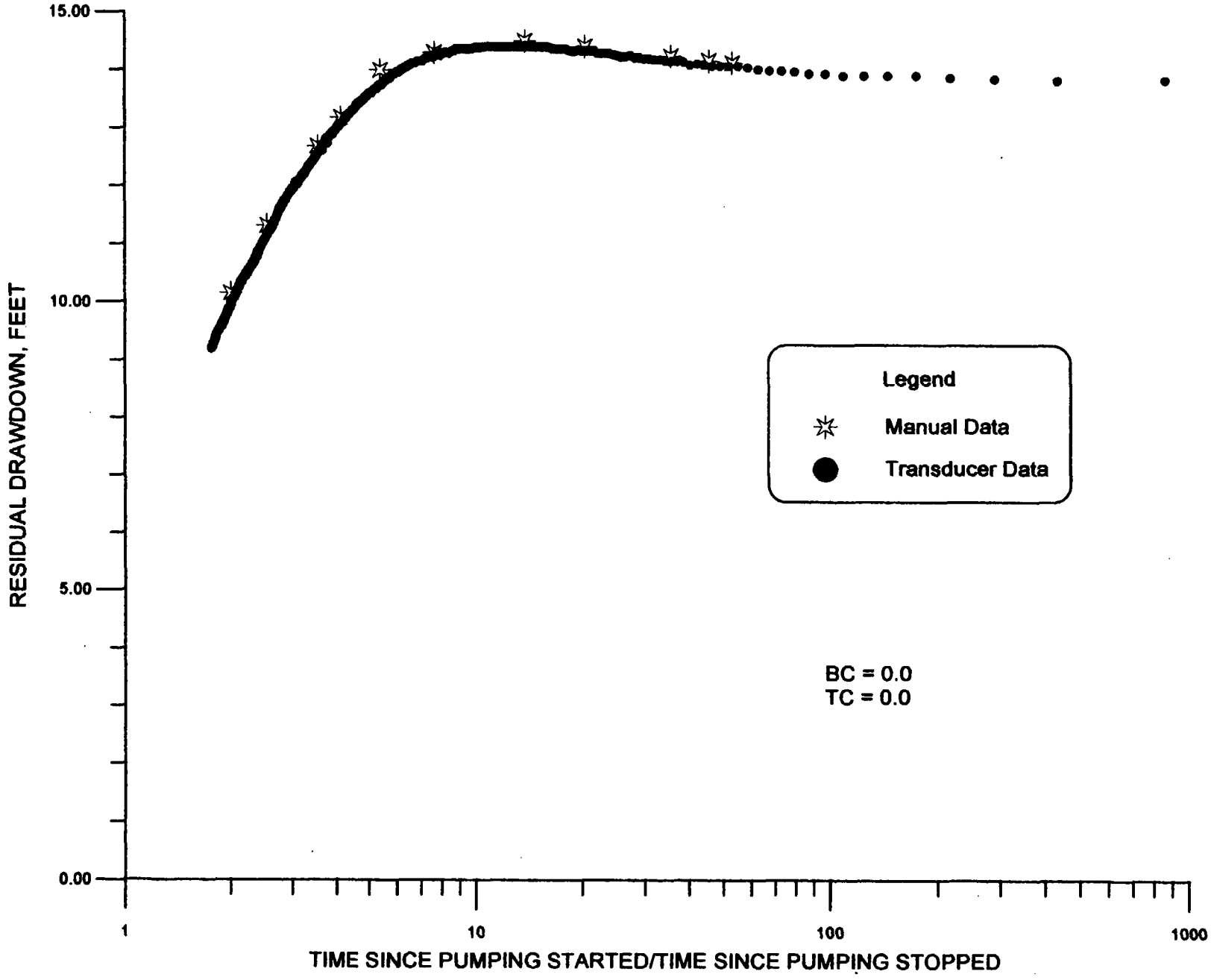
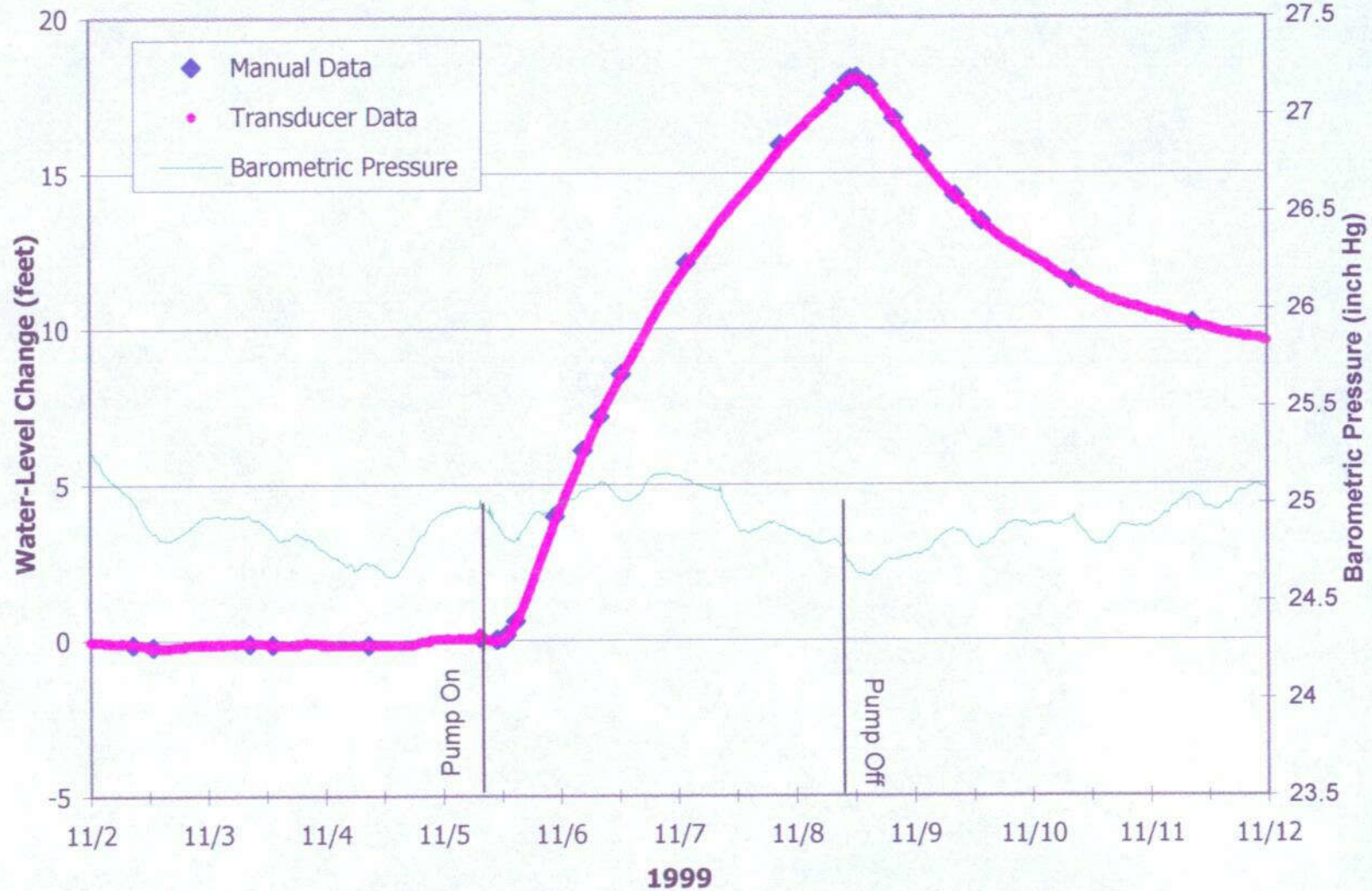


FIGURE K.5-26D. RECOVERY IN OBSERVATION WELL M448.

FIGURE K.5-27A. WATER-LEVEL CHANGE IN OBSERVATION WELL M449



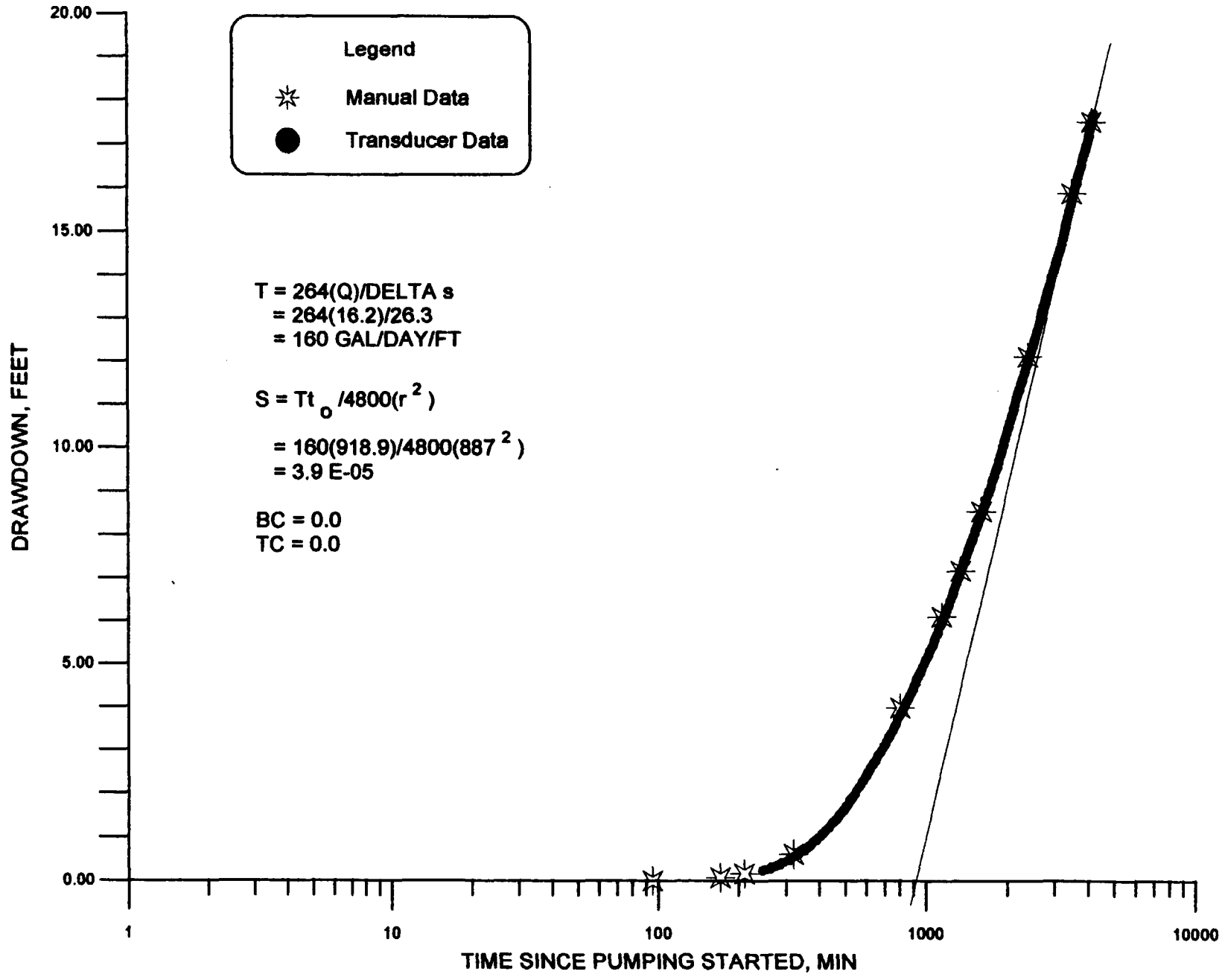


FIGURE K.5-27B. DRAWDOWN IN OBSERVATION WELL M449, SEMI-LOG.

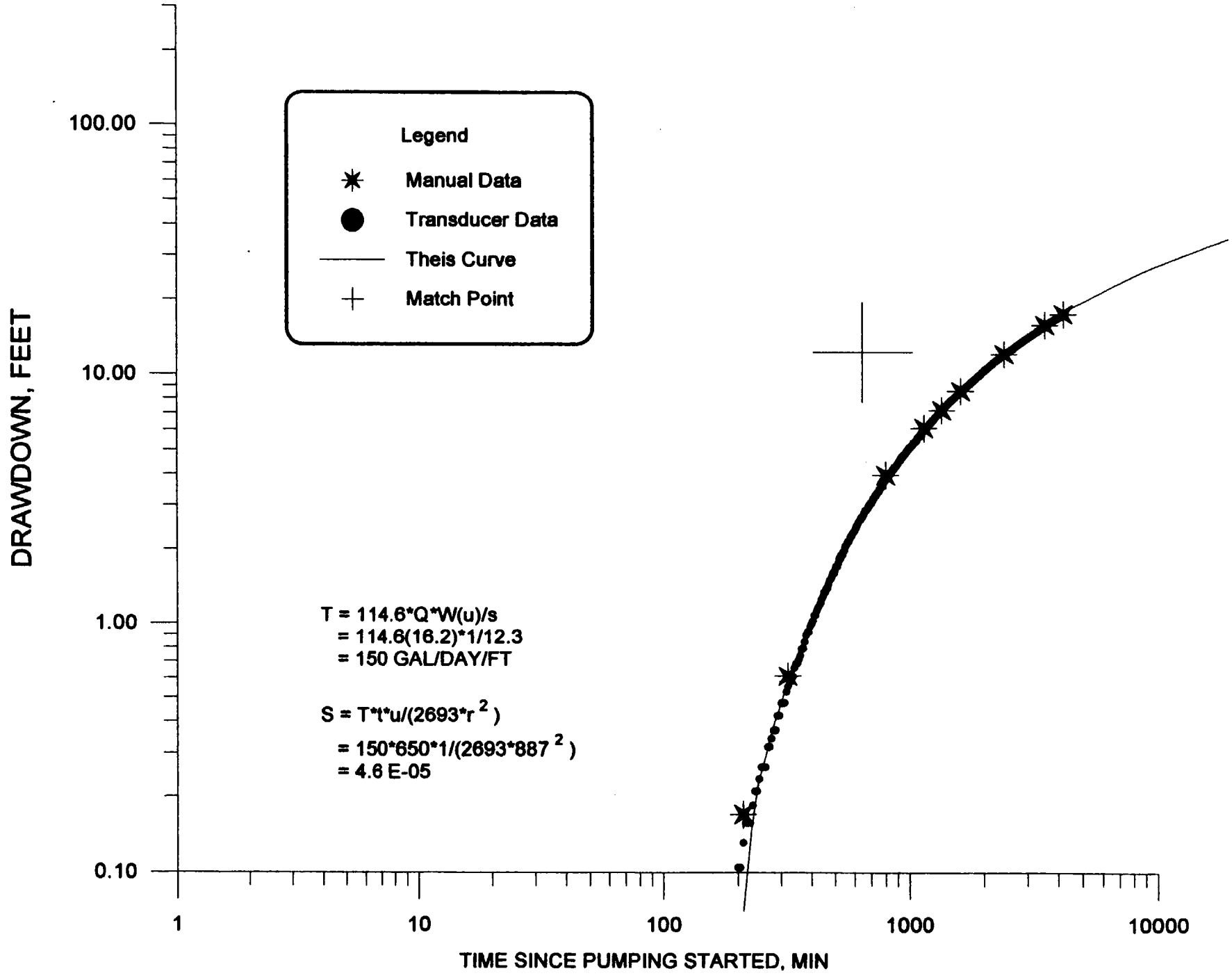


FIGURE K.5-27C. DRAWDOWN IN OBSERVATION WELL M449, LOG-LOG.

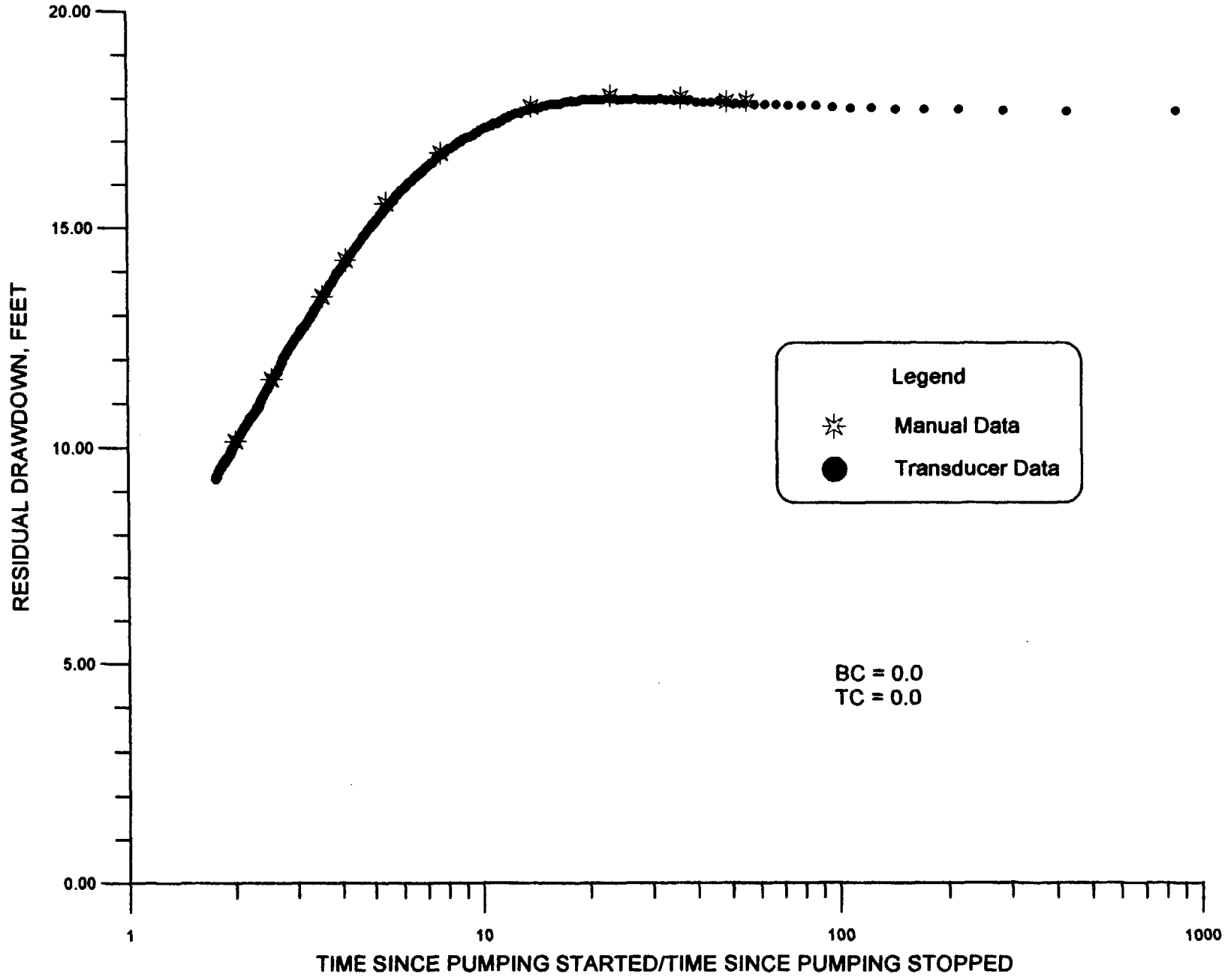
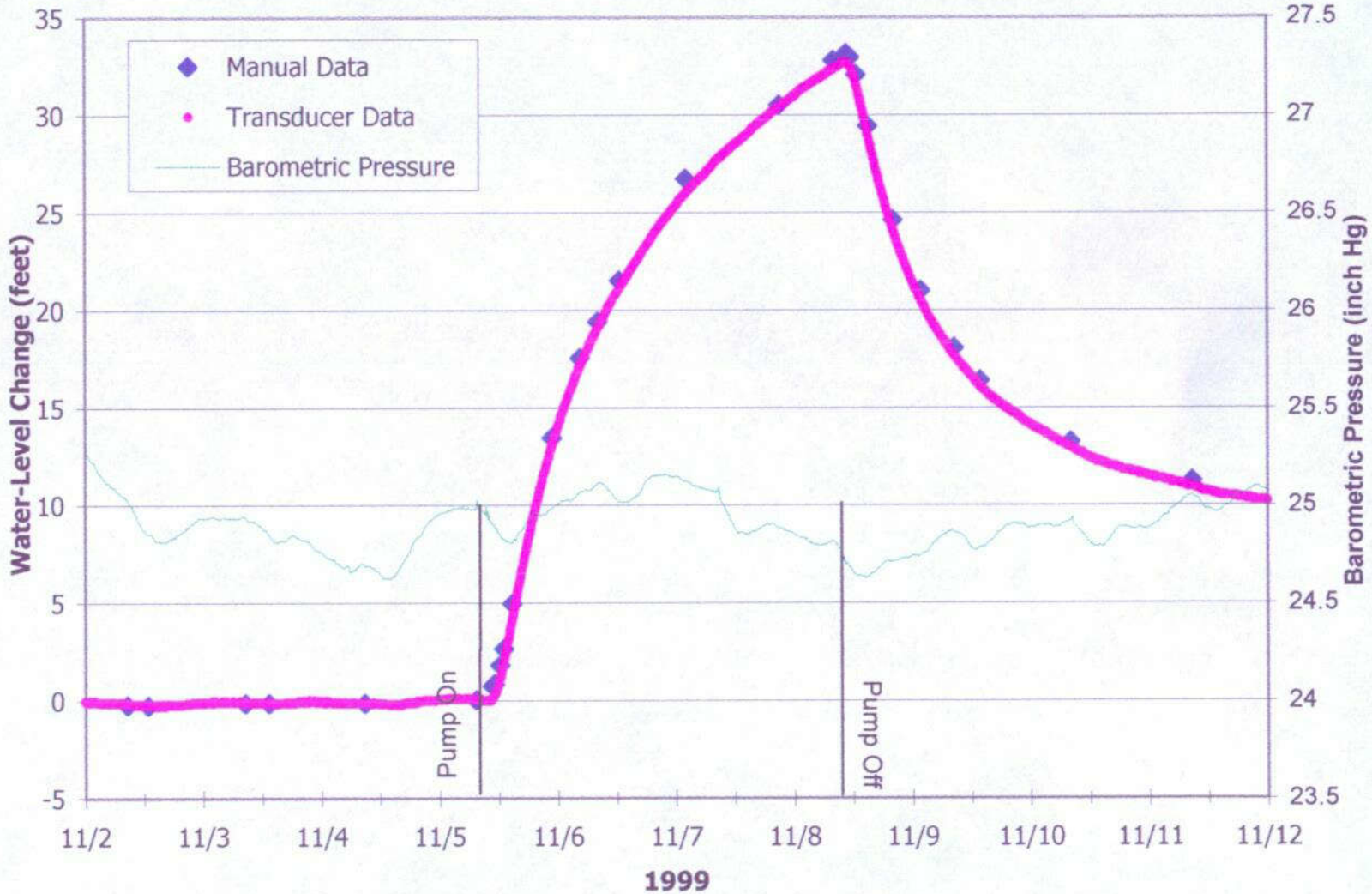


FIGURE K.5-27D. RECOVERY IN OBSERVATION WELL M449.

FIGURE K.5-28A. WATER-LEVEL CHANGE IN OBSERVATION WELL M450



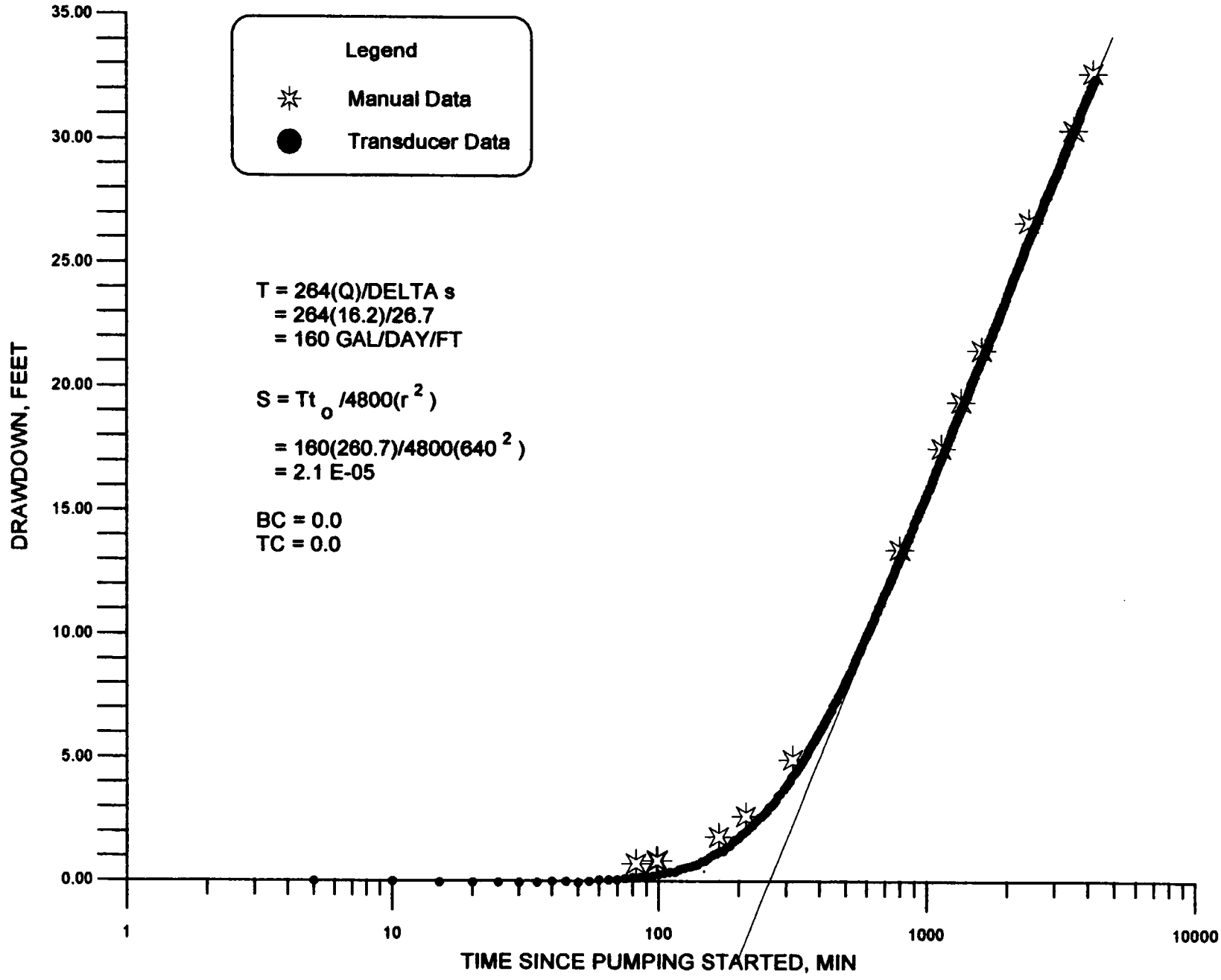


FIGURE K.5-28B. DRAWDOWN IN OBSERVATION WELL M450, SEMI-LOG.

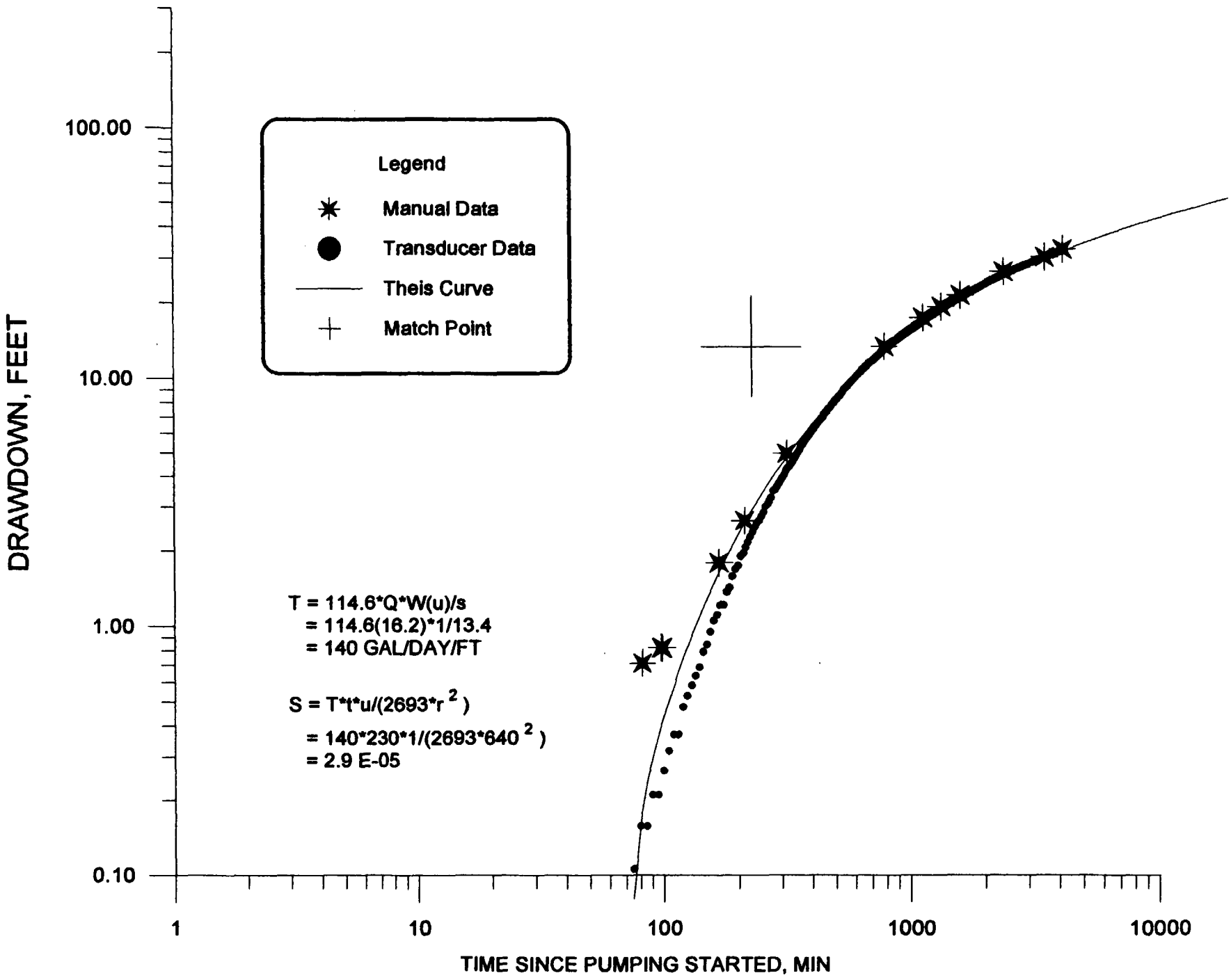


FIGURE K.5-28C DRAWDOWN IN OBSERVATION WELL M450, LOG-LOG.

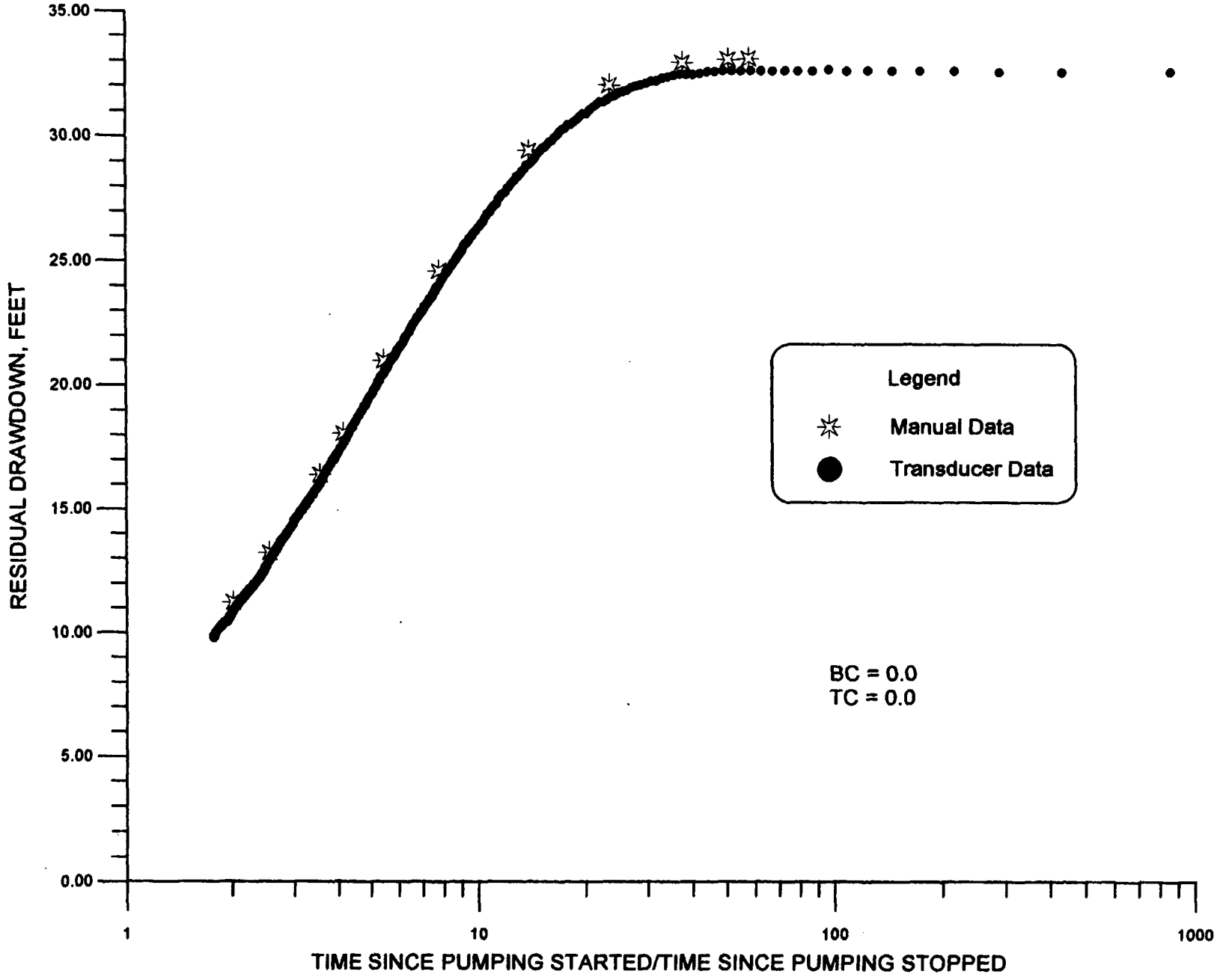
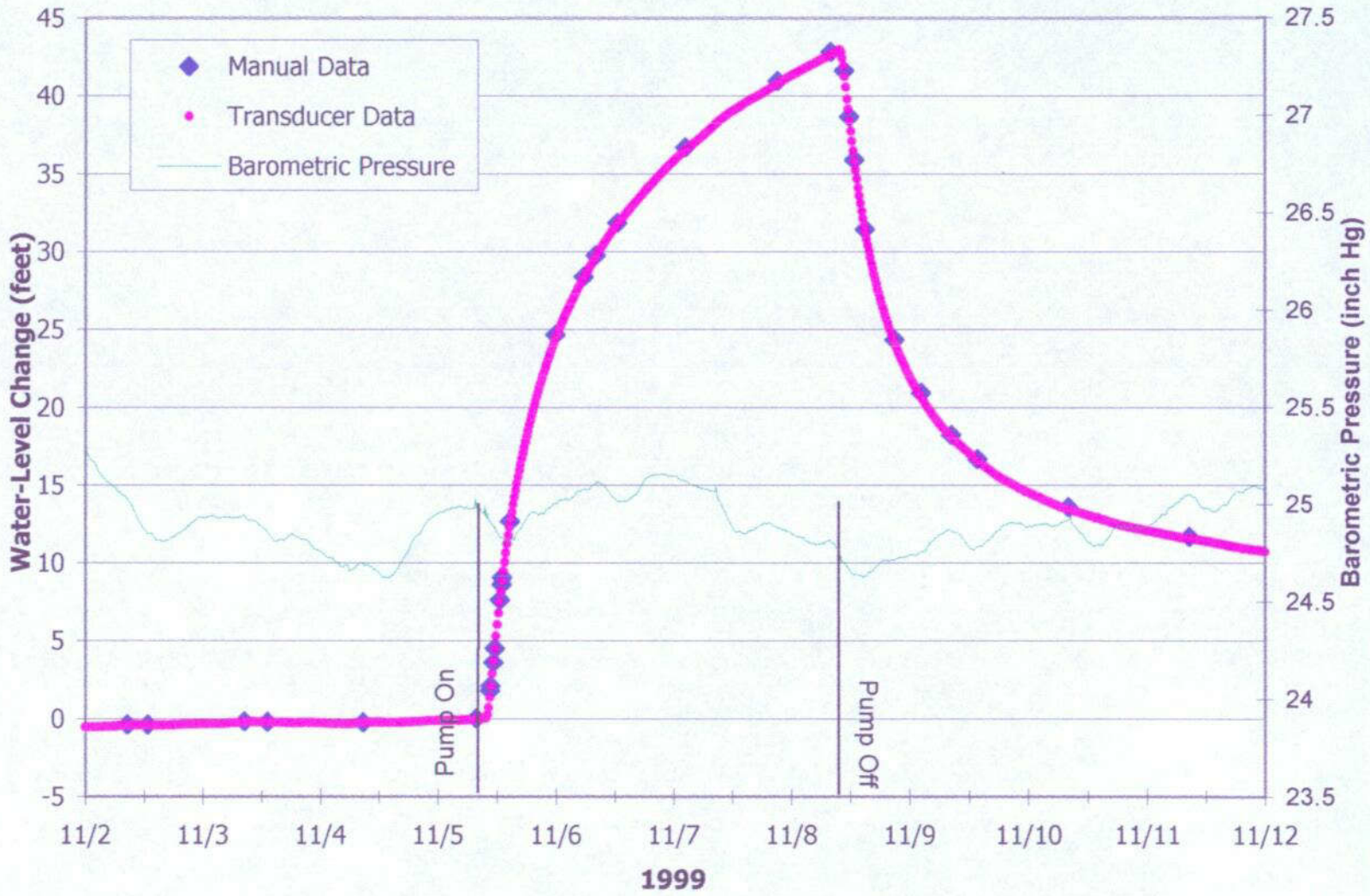


FIGURE K.5-28D. RECOVERY IN OBSERVATION WELL M450.

FIGURE K.5-29A. WATER-LEVEL CHANGE IN OBSERVATION WELL M451



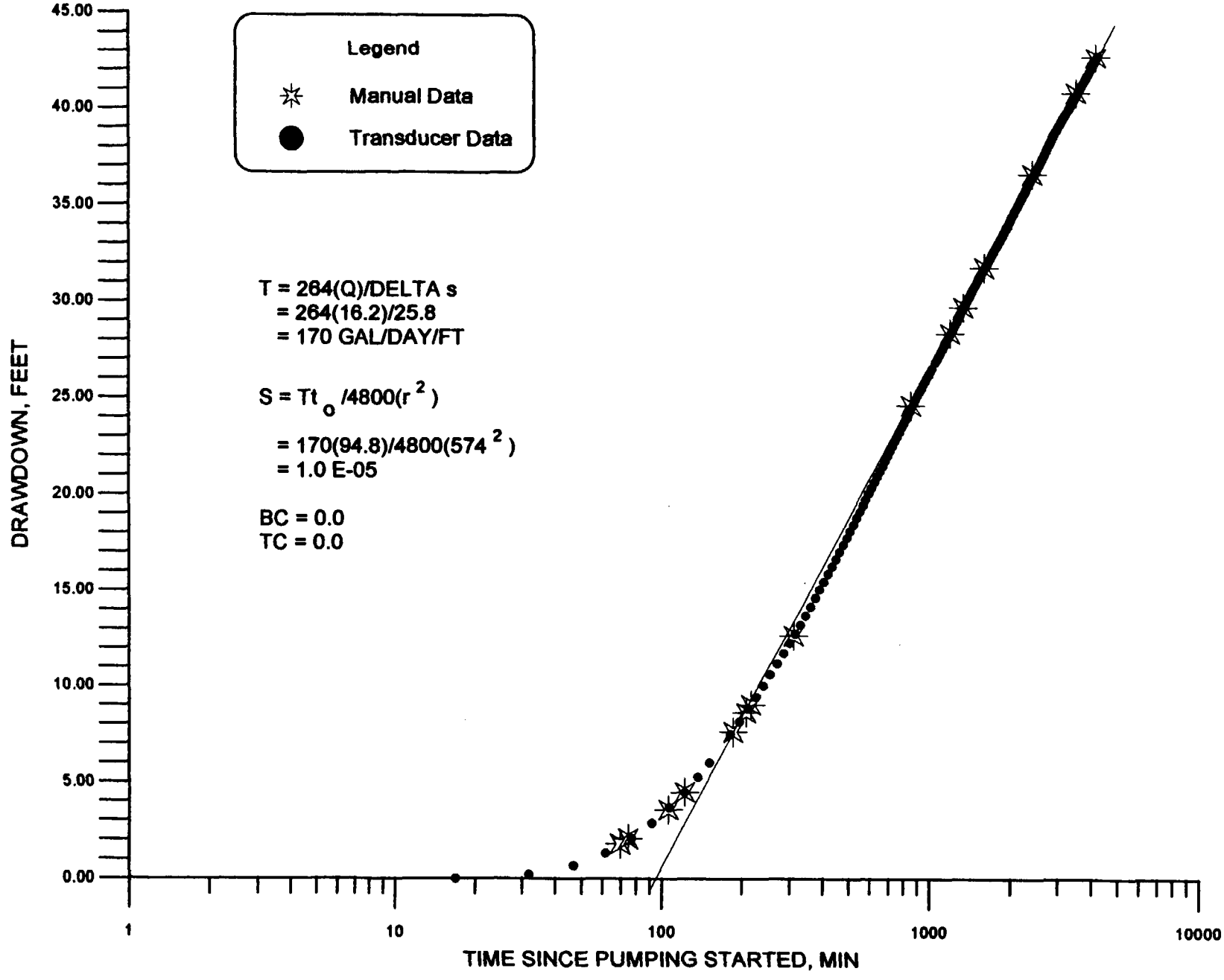


FIGURE K.5-29B. DRAWDOWN IN OBSERVATION WELL M451, SEMI-LOG.

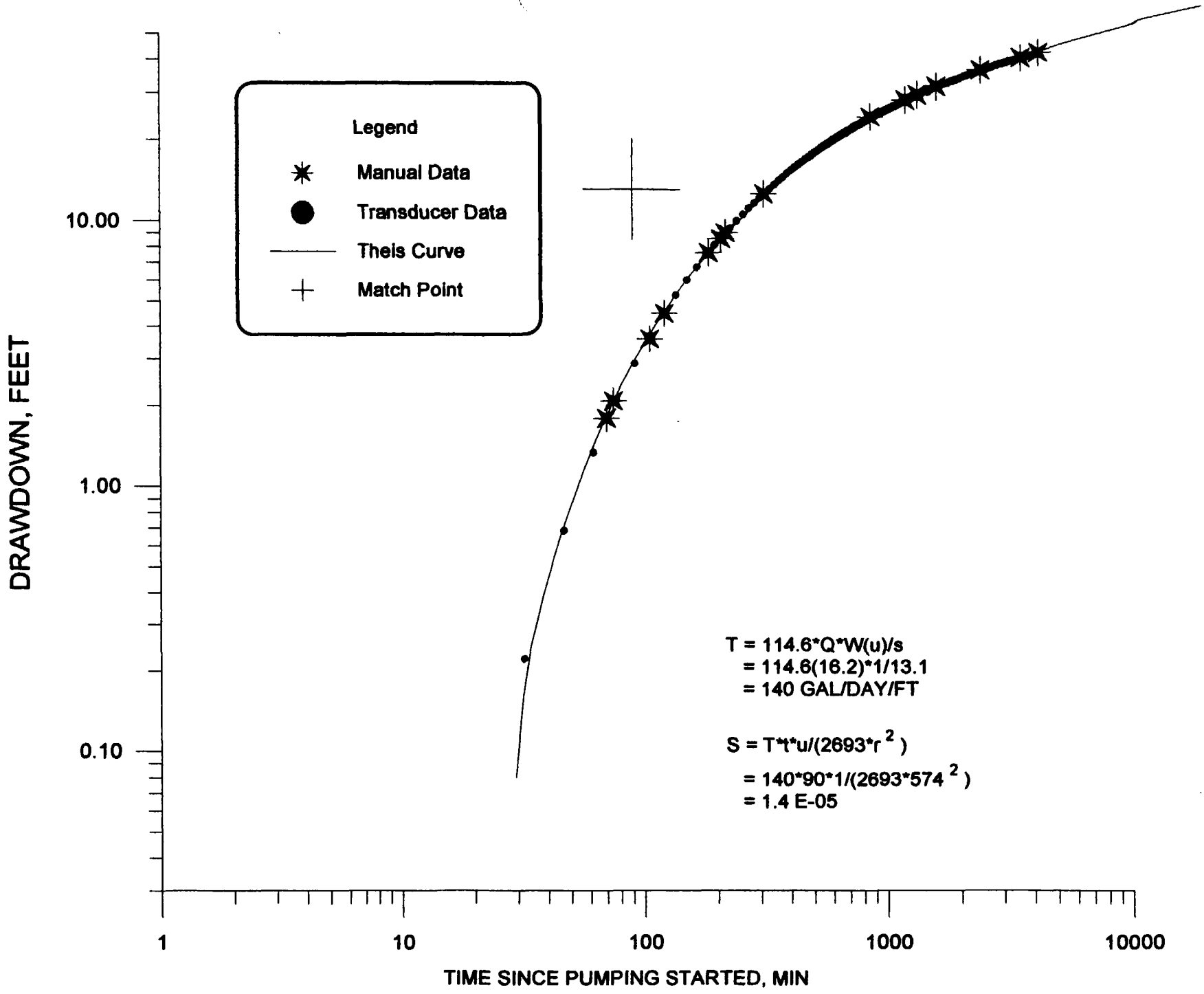


FIGURE K.5-29C. DRAWDOWN IN OBSERVATION WELL M451, LOG-LOG.

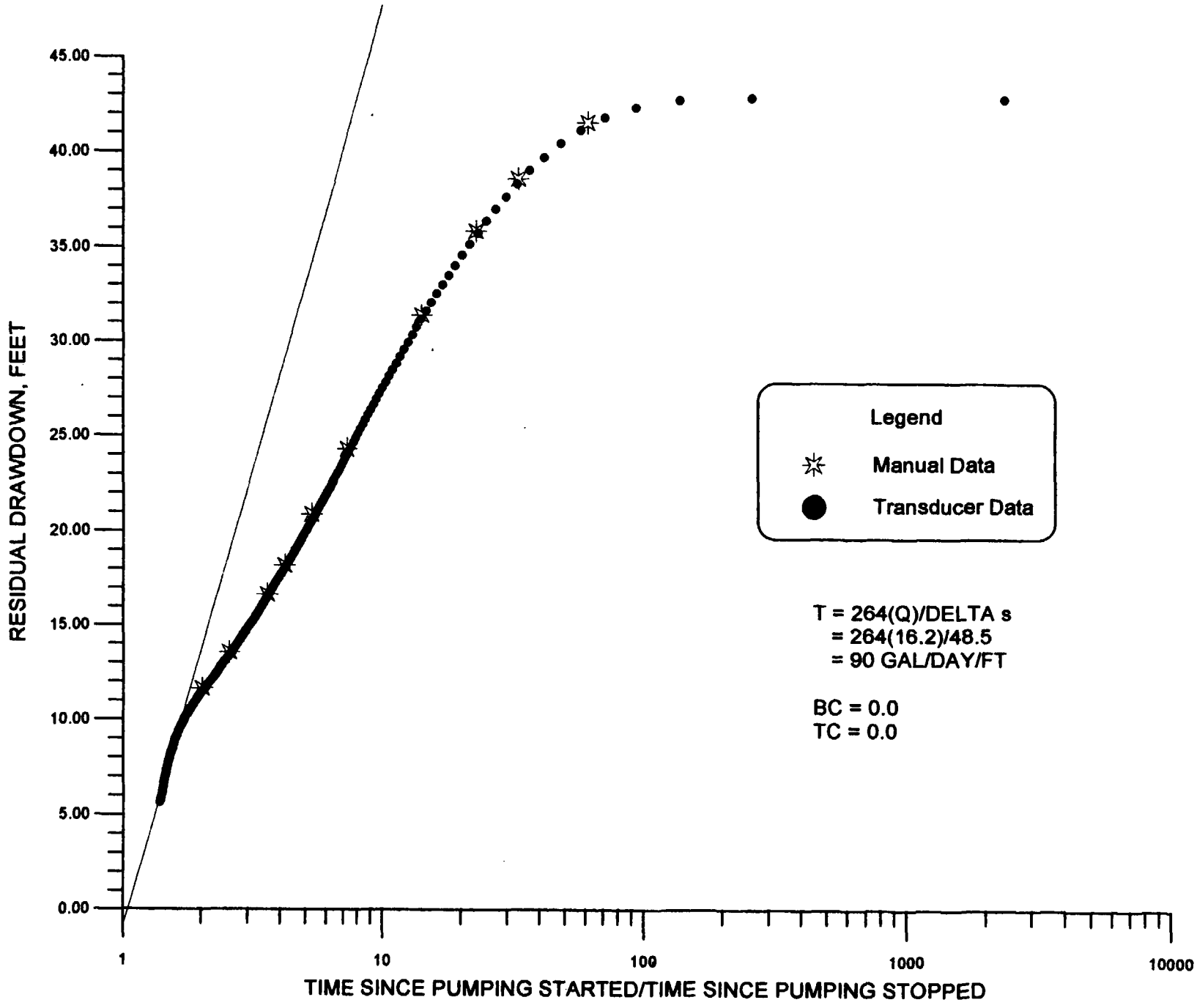
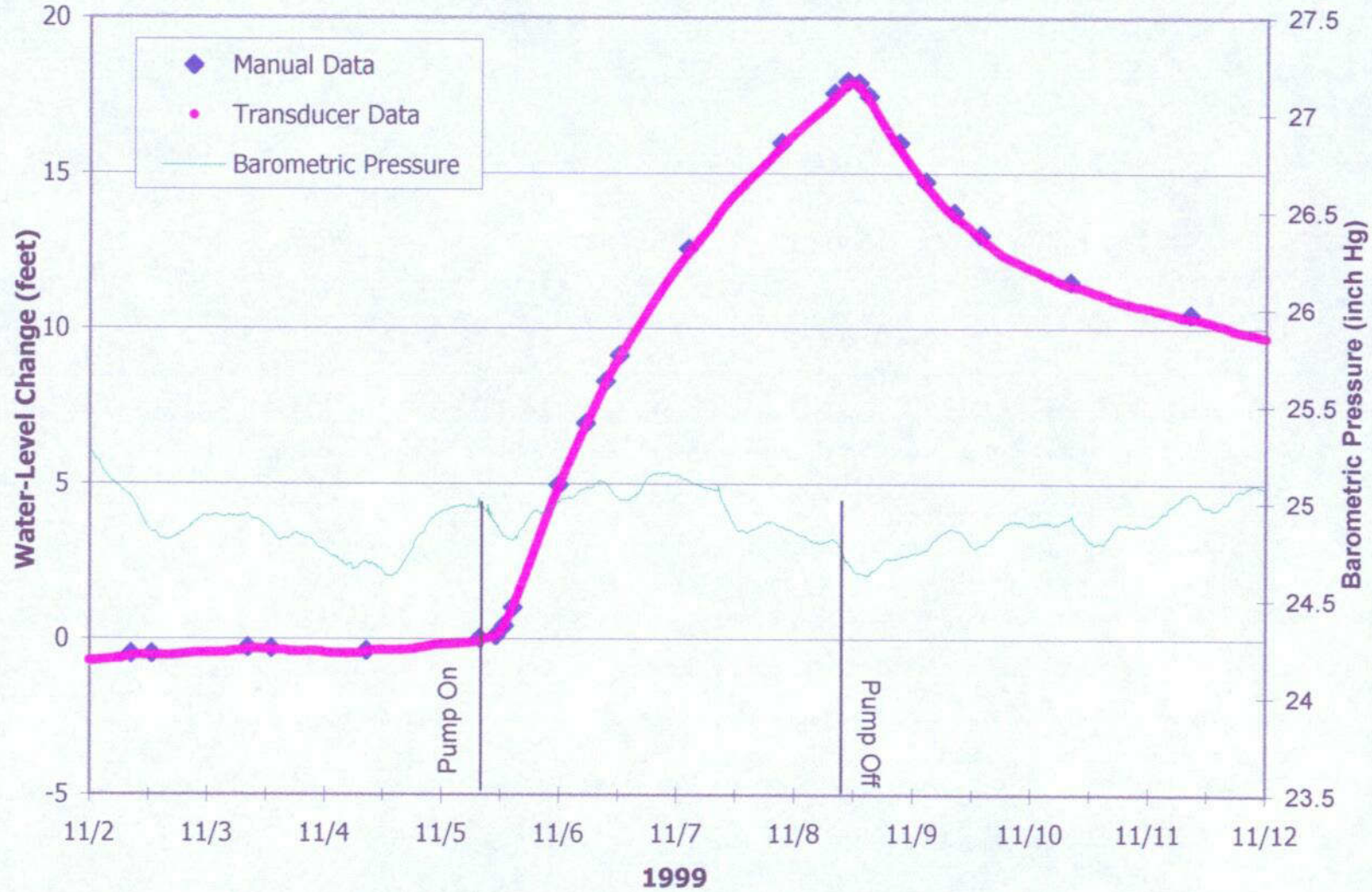


FIGURE K.5-29D. RECOVERY IN OBSERVATION WELL M451.

FIGURE K.5-30A. WATER-LEVEL CHANGE IN OBSERVATION WELL M452



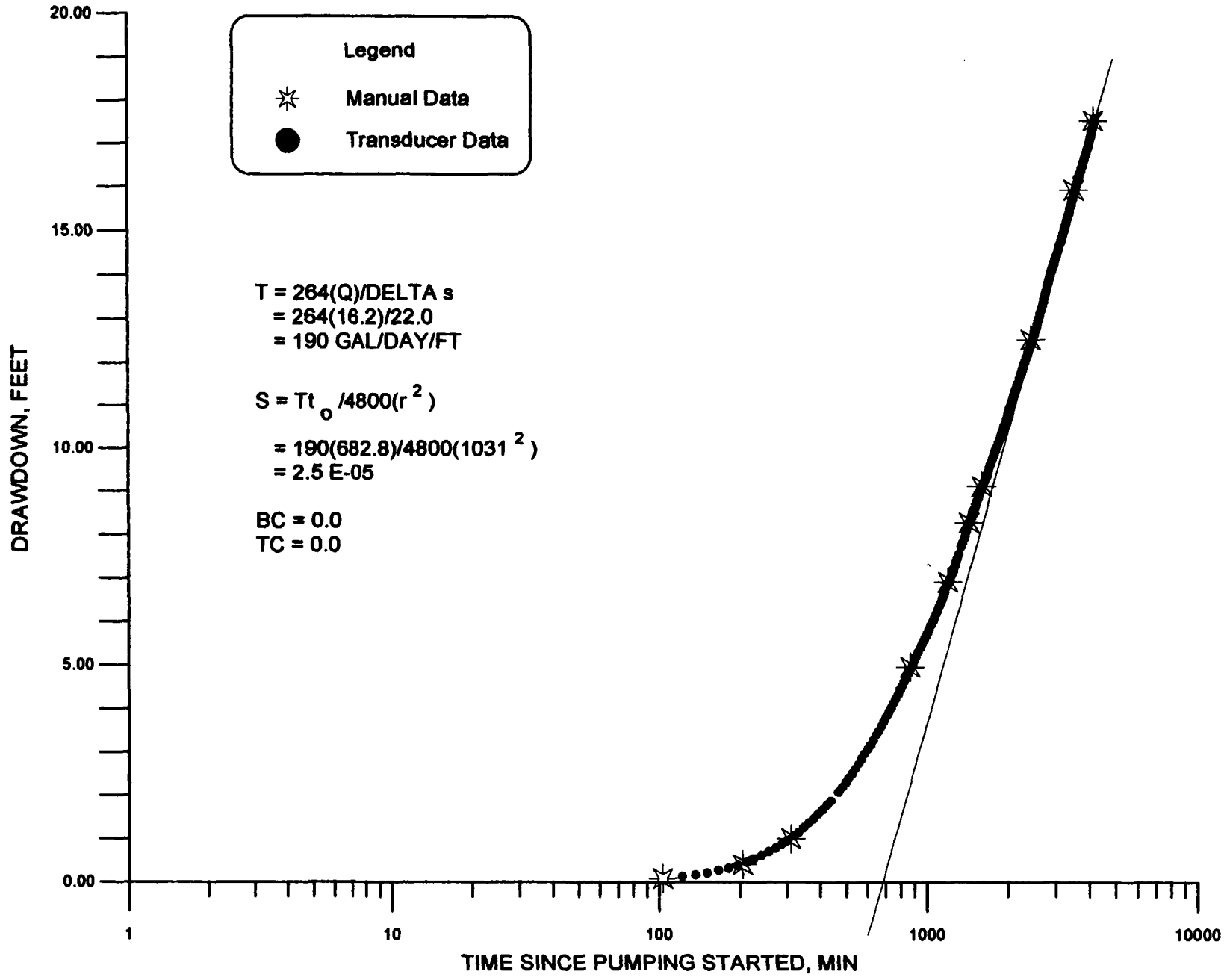


FIGURE K.5-30B. DRAWDOWN IN OBSERVATION WELL M452, SEMI-LOG.

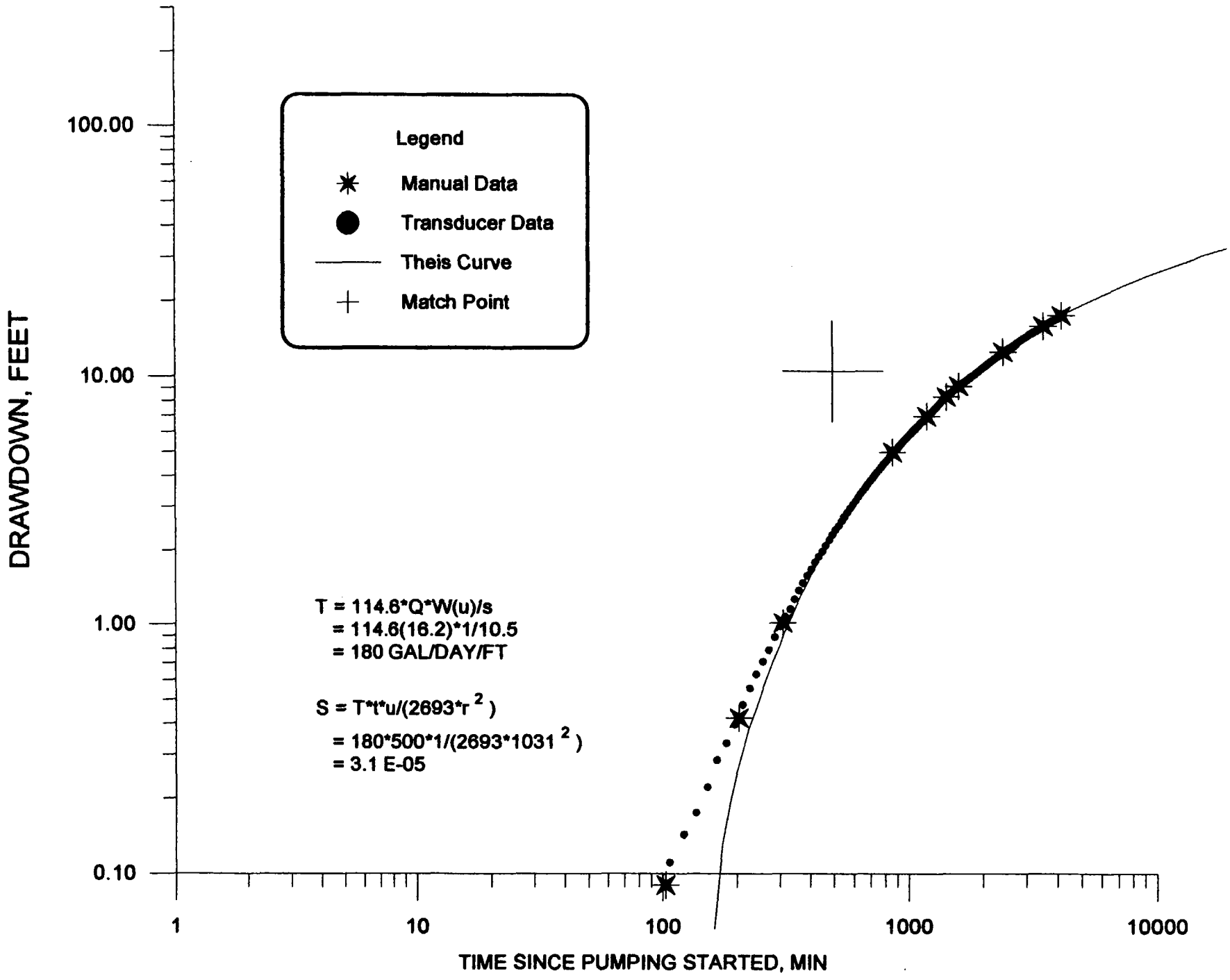


FIGURE K.5-30C. DRAWDOWN IN OBSERVATION WELL M452, LOG-LOG.

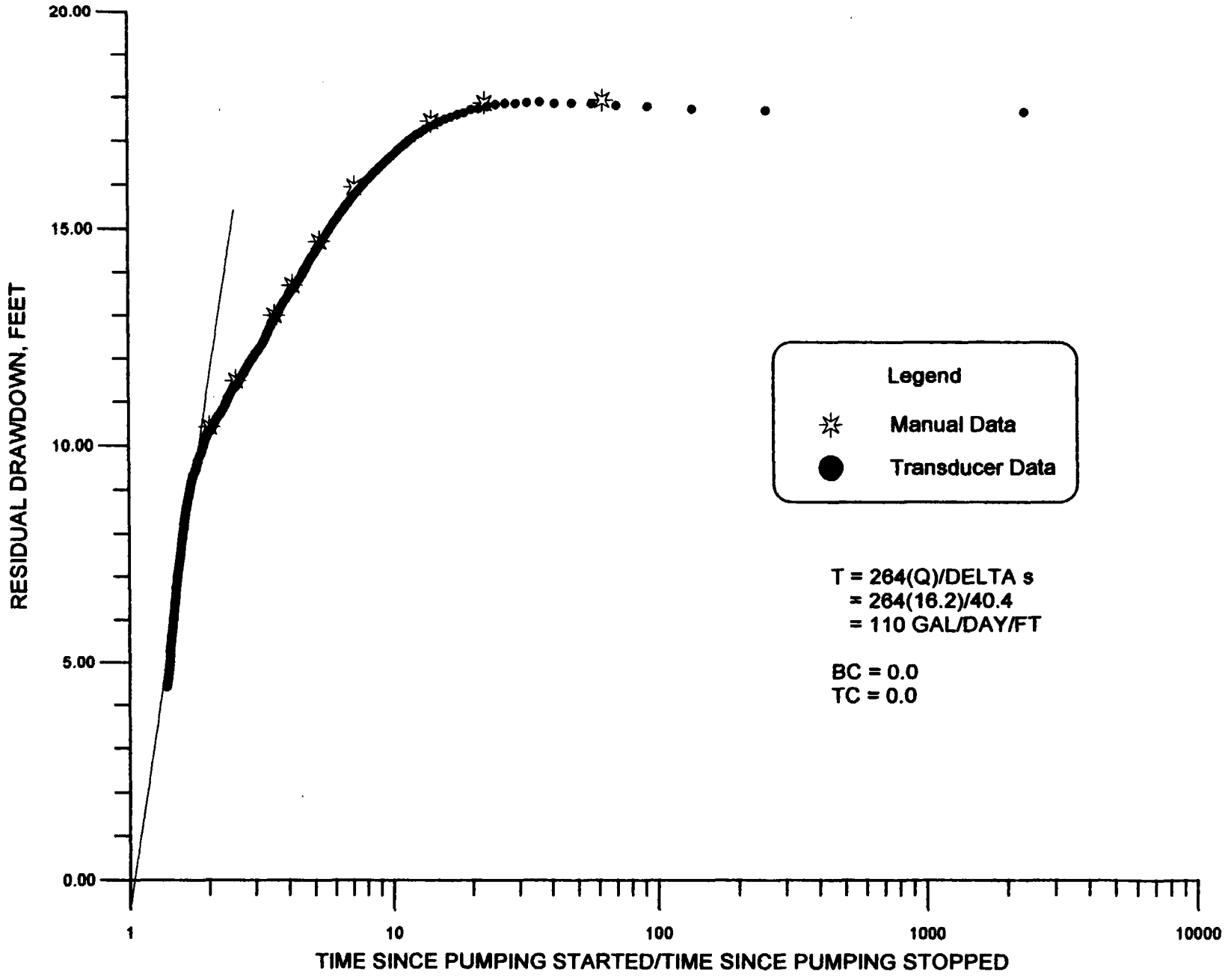
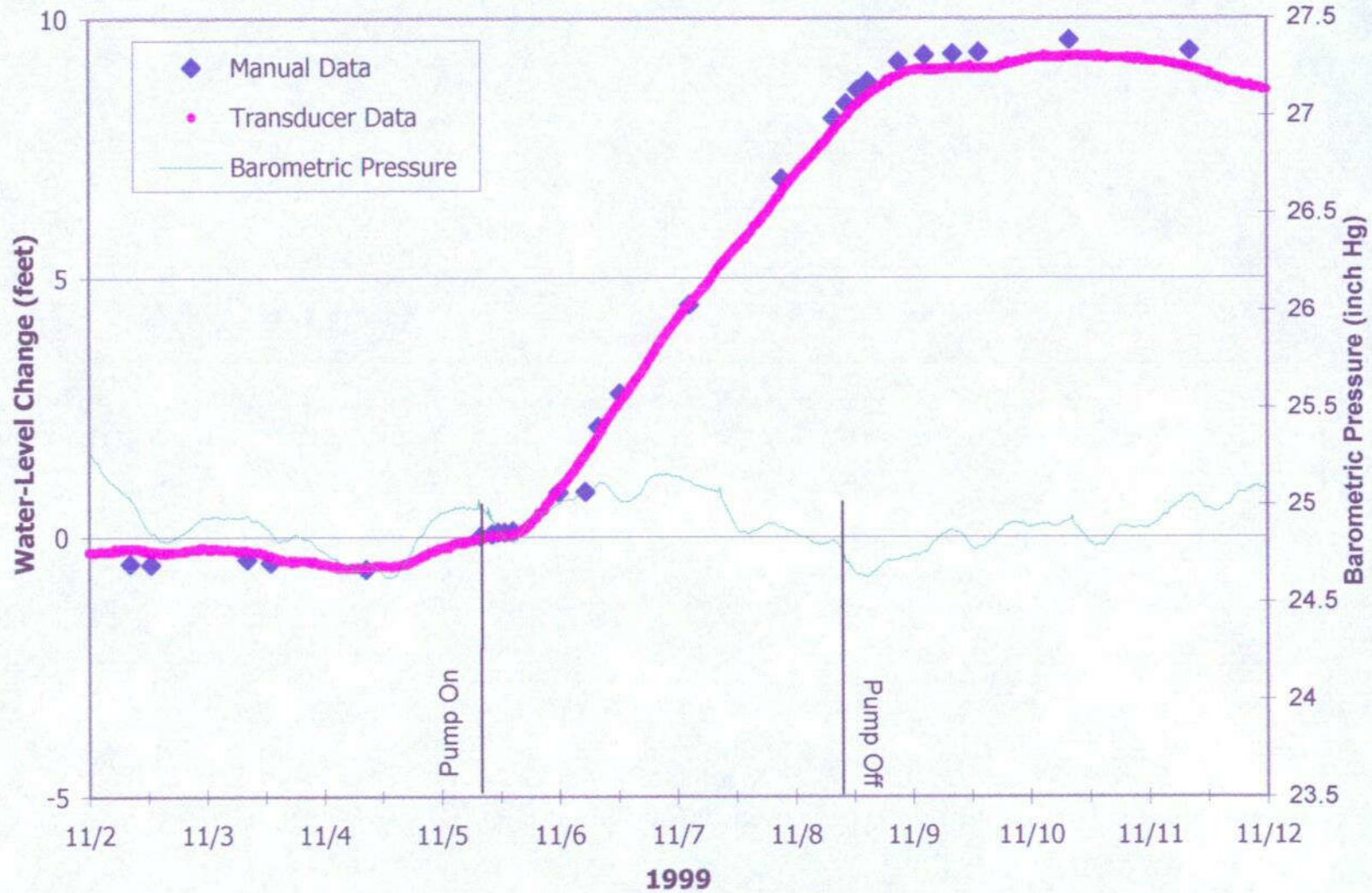


FIGURE K.5-30D. RECOVERY IN OBSERVATION WELL M452.

FIGURE K.5-31A. WATER-LEVEL CHANGE IN OBSERVATION WELL M453



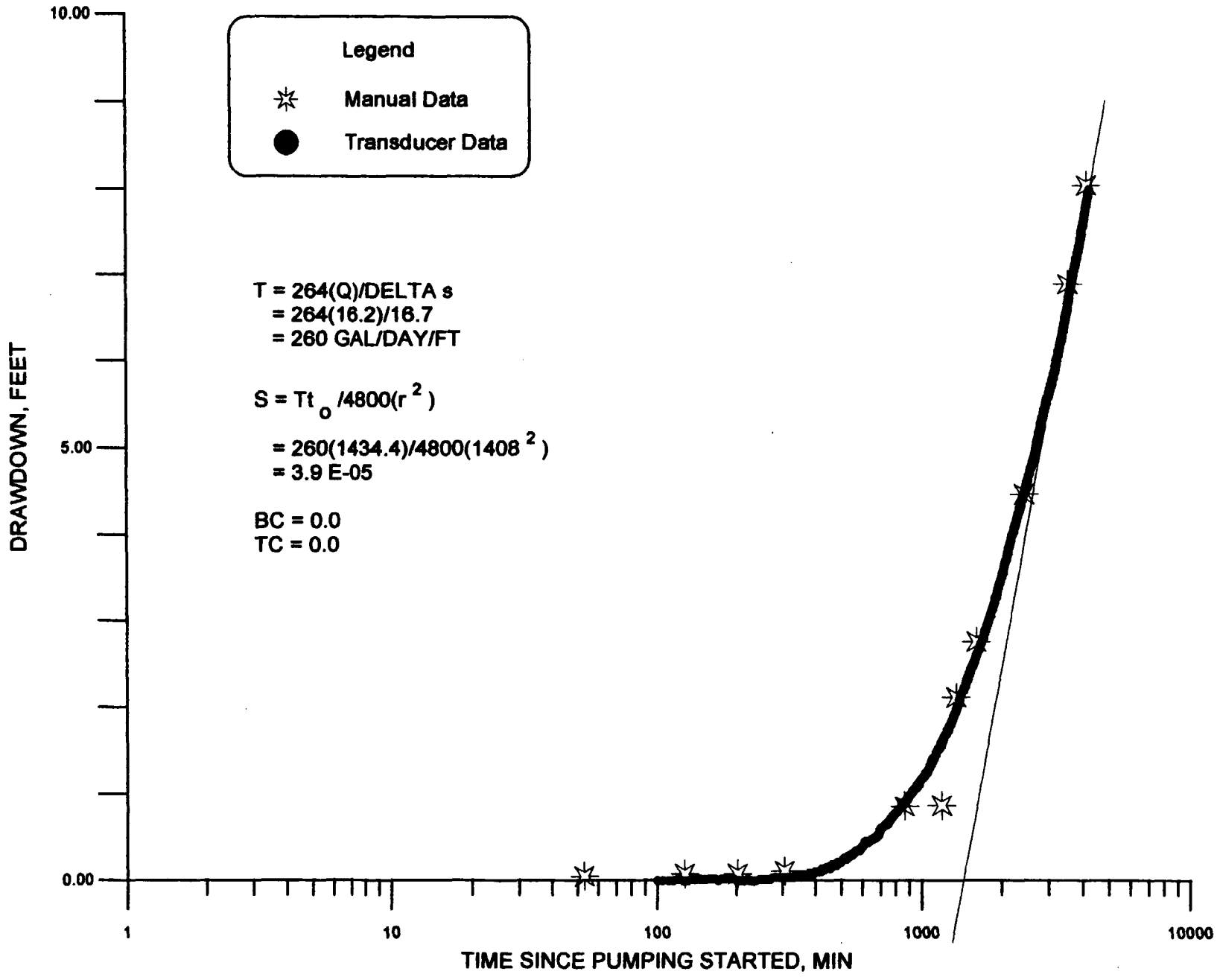


FIGURE K.5-31B. DRAWDOWN IN OBSERVATION WELL M453, SEMI-LOG.

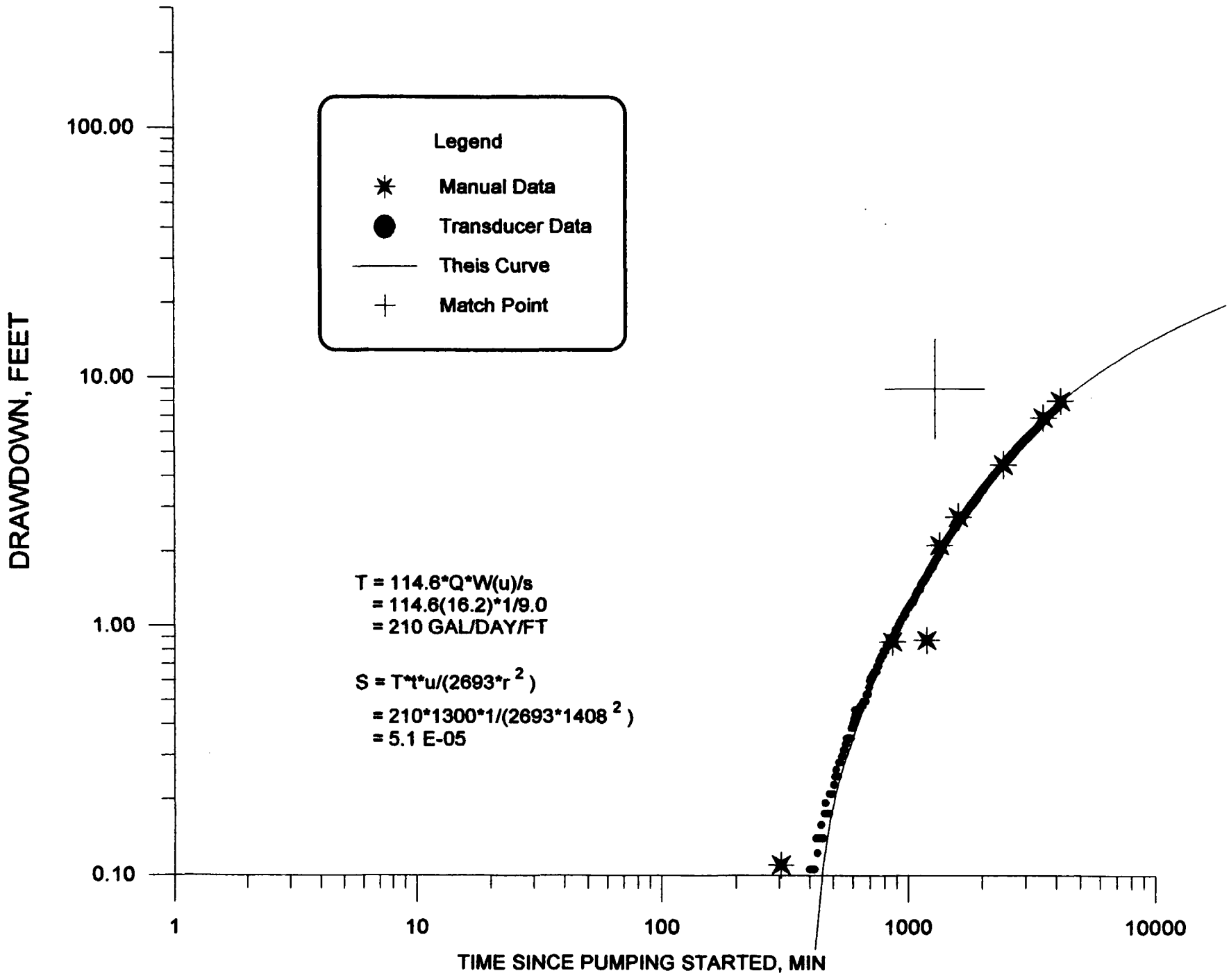


FIGURE K.5-31C. DRAWDOWN IN OBSERVATION WELL M453, LOG-LOG.

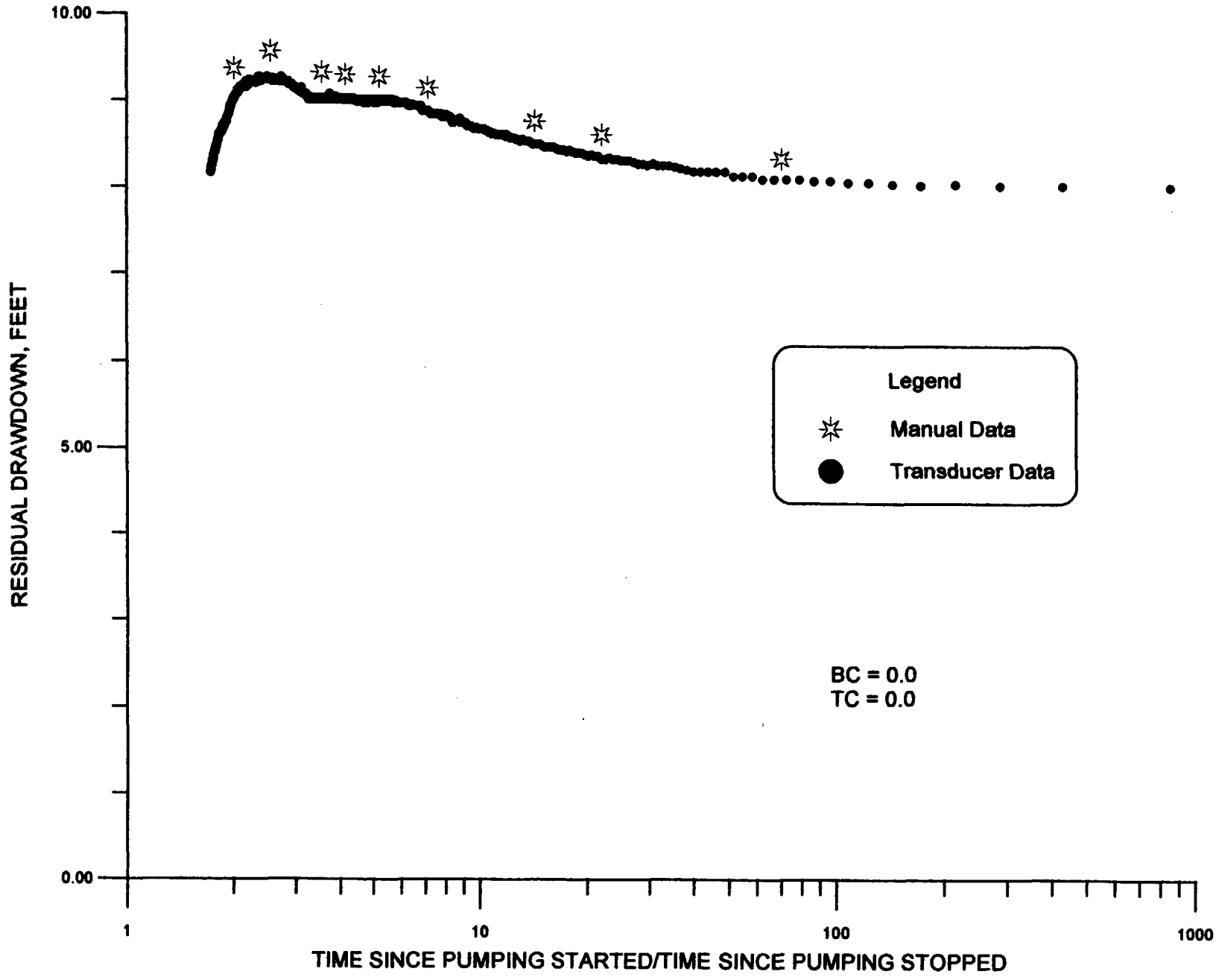


FIGURE K.5-31D. RECOVERY IN OBSERVATION WELL M453.