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Evaluation of the Status of the 1998-2000
"Provisional" Wells in the Annual
Water-well Monitoring Network

by

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EVALUATION OF THE STATUS OF THE 1998-2000 “PROVISIONAL” WELLS IN THE ANNUAL WATER-WELL MONITORING NETWORK

By

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In 1996, the Kansas Geological Survey took over responsibility for the annual water-level measurement program in Kansas from the US Geological Survey. In the course of redesigning the program, it was anticipated that the well network would change over time as some wells were deleted from the network due to plugging or measurement difficulty. It was also recognized that wells would need to be added to the network as replacements or to discern regional patterns of water-level change in a satisfactory manner. Each new well is added provisionally to the network after careful evaluation of its source of water, construction, use, and location with respect to other nearby network wells. A further step in the evaluation process is to assess how water level change in each “provisional” well compared to water-level changes over time in other nearby network wells in the same aquifer. Initially, it was believed that 3 sets of measurements should be sufficient to make these comparisons.

The purpose of this report is (1) to present (a) an evaluation of the historical water-level data for these “provisional” wells, if available, and (b) a comparison the water-level changes in each well with those in other nearby network wells, (2) make recommendations on the status of the 1998-2000 “provisional” wells based on (1) above, and (3) suggest changes in the length of record needed to evaluate which “provisional” wells are to be added to the network.

Procedures

Prior to the 1998 annual water-level survey, 26 “provisional” wells were added to the network. In the 1998-2000 annual surveys, water levels in 19 of the 26 wells were measured once during each annual measurement cycle and in 4 of the 19 wells the depth to water was remeasured once. Water levels were measured in the 1998 and 2000 annual surveys in the other 7 of the 26 wells, and in one case the depth to water was remeasured once. 1999 water levels were not measured in these 7 wells because of weather or some other circumstance.

Data analysis consisted of an assessment of (1) the historical record of water-level fluctuations prior to 1998 and (2) the water-level fluctuations in the “provisional” well relative to other nearby network wells from data collected during the 1998-2000 annual water-level surveys. Initially, the historic water-level data were reviewed for each “provisional” well, if available. The

trends observed in the 1998-2000 water level data were then compared to the trends observed in this longer historical data record. Attention was paid to the magnitude of the water-level fluctuations from year to year in the historical record and in the 1998-2000 data set. A review of the trends and the magnitude of year-to-year fluctuations in the historical data was helpful in assessing the data from the last three annual water-level surveys. Historic water-level data were available for 13 of the 26 “provisional” wells.

In the second phase of the analysis, the net water-level changes in the each “provisional well” were calculated using the 1998 and 2000 annual measurements and compared to the net water-level changes for the same period in nearby network wells in the same aquifer within 9 mi of the “provisional well” (Appendix 1). In this step a determination was made of how consistently the water-levels in “provisional” wells followed the trend and the magnitude of net change in surrounding network wells. The network wells used in this analysis included those in the same township as the “provisional” well and those in surrounding townships.

On the basis of this comparison the “provisional” wells were placed in one of four categories: (1) those showing 1998-2000 net water-level changes that are consistent with changes in surrounding network wells for the same period, (2) those showing net water-level changes between 1998-2000 that slightly exceed changes in surrounding wells for same period, (3) those showing net water-level changes between 1998-2000 that greatly exceed changes in surrounding network wells for the same period, and (4) those showing net water-level changes between 1998-2000 that are opposite to the average trend of changes in surrounding network wells for the same period. Net water-level changes that slightly exceed the range of values in surrounding network wells are less than the algebraic difference between the extreme value of the range and the average change in surrounding wells. Net water-level changes that greatly exceed the range in surrounding network wells are greater than the algebraic difference between the extreme value of the range and the average for nearby wells. The average trend for network wells surrounding each “provisional” well was calculated as the mean net water-level change considering only the 1998 and 2000 depth-to-water measurements.

Out of the 26 1998-2000 “provisional” well records examined, 15 had net water-level changes that were consistent with the changes in surrounding network wells, 1 exhibited a net change that slightly exceeded the net changes in surrounding wells, 3 exhibited net changes that greatly exceeded the range of net changes in surrounding wells, and 7 exhibited trends that were outside the range of net changes and were contrary to the average trend in surrounding network wells.

Table 1. Grouping of the “provisional” wells into classes on the basis of a comparison between water-level change in each “provisional” well and the average and the range of trends in net water-level change in surrounding annual water-level network wells. 31-31W-03ccc01, 24-33W-19dbb01, 24-33W-18bdb01, and 21-12W-06ccb02 are unused wells. All of the other wells are for irrigation.

“Provisional” Wells Showing Water-level Changes Between 1998-2000 That Are Consistent With Water-Level Changes in Surrounding Wells For the Same Period	“Provisional” Wells Showing Water-level Changes Between 1998-2000 That Slightly Exceed Water-Level Changes in Surrounding Wells For the Same Period	“Provisional” Wells Showing Water-level Changes Between 1998-2000 That Greatly Exceed Water-Level Changes in Surrounding Wells For the Same Period	“Provisional” Wells Showing Water-level Changes Between 1998-2000 That Greatly Exceed and Oppose the Average Trend of Water-Level Changes in Surrounding Wells For the Same Period
31-31W-03ccc01 29-42W-27dad01 29-41W-14cdc01 27-07W-03adc02 27-36W-01adb01 26-28W-10acb02 24-32W-25ccb02 15-40W-22adc01 11-27W-08dbb01 09-27W-31abb01 09-27W-20cbd01 09-28W-15cba01 08-29W-01bdd01 05-40W-27bba01 08-27W-18daa01	08-28W-17bad01	27-23W-28aaa01 06-28W-21bcd01 03-35W-18cbb01	24-33W-19dbb01 24-33W-18bdb01 21-12W-06ccb02 06-38W-09abd01 06-38W-18dbd01 04-39W-15cca01 29-34W-11add01

Discussion of the Historic and the 1998-2000 Water-level Data for Each “Provisional” Well
31-31W-03ccc01

31-31W-03ccc01 is an unused well in Seward Co. whose source of water is the High Plains aquifer (QUTO). When the well was initially inventoried in August, 1996, the depth to water was 243.67 ft. The 1998-2000 depth to water measurements show a gradual decline in water level from 1996 to the present; in the 1998-2000 period there has been an overall decline of about 3.2 ft. In comparison, the range of net water-level declines in surrounding network wells was 1-11.7 ft with an average of 5.9 ft. Thus, the water-level decline observed in 31-31W-03ccc01 is consistent with the declines in other nearby network wells for the 1998-2000 period, which indicates that this well should be added to the annual network on a permanent basis.

29-42W-27dad01

29-42W-27dad01 is an irrigation well in Stanton Co. whose sources of water are the High Plains and Dakota aquifers (QUTOKD). Aside from the depth to water measurement taken in the well when it was inventoried in September, 1997, there are no other historic water-level data. During the 1998-2000 period the water level in this well declined approximately 0.1 ft. The net water-level changes in surrounding network wells range from a 6.5 ft rise to a 1.3 ft decline with an average net water-level rise of 1.5 ft during this period. The small water-level decline observed in 29-42W-27dad01 is consistent with the range of net water-level changes in nearby network wells for the past 3 years of annual measurements which indicates that this well should be added to the network on a permanent basis.

29-41W-14cdc01

29-41W-14cdc01 is another irrigation well in Stanton Co. whose source of water is the High Plains and Dakota aquifers (QUTOKD). When the well was initially inventoried on May 31, 1994, the depth to water in this well was 245.50 ft. The depth to water on November 6, 1997 was 292.02 ft or an apparent water-level decline of about 46.5 ft over approximately 2.5 yrs. This net change is misleading because the initial water-level was taken during the time of year when pumping would have had its greatest effect on water-levels, whereas the November, 1997 measurement would have been taken some time after the pumping season during aquifer recovery. In the 1998-2000 period there was a 5.8 ft decline. In nearby network wells, net water-level changes ranged from a rise of 1.9 ft to a decline of 22.6 ft and the average for all of the surrounding wells was a decline of 4.9 ft. Thus the net water-level change observed in 29-41W-14cdc01 is consistent with the net water-level changes in nearby network wells, which indicates that this well should be added permanently to the network.

29-34W-11add01

29-34W-11add01 is an irrigation well in Haskell Co. that is completed in the High Plains aquifer (QUTO). Water levels in this well were measured frequently over a 18 yr period from 1964-1982 (Figure 1). During this period water levels declined approximately 158 ft or at a rate of more than 8 ft/yr. No annual measurements are available for the well from April, 1982, to December, 1997. During the 1998-2000 the pattern of water-level decline has been reversed and water levels have risen approximately 13.8 ft. This is in contrast to the pattern in surrounding network wells where nearly all of the wells have experienced a decline (overall average water-level change of a 3.0 ft decline) except one where the water level rose 2.5 ft during the period. Because the water level changes in this well are neither consistent with historic water-level change in this well nor with the changes in surrounding network wells for the last 3 yrs, 29-34W-11add01 should be maintained in its “provisional” well status for a period long enough to determine if this pattern will continue.

27-23W-28aaa01

27-23W-28aaa01 is an irrigation well in Ford Co. that is completed in the High Plains aquifer (QUTO). Water-level records are available for this well from 1980-1993 and reveal an overall decline of approximately 25.6 ft or a decline rate of about 2.8 ft/yr (Figure 2). No water-level measurements were taken from 1993 through 1997. In 1998-2000 the water level in 27-23W-28aaa01 declined approximately 18.6 ft or about 9.3 ft/yr, more than 3 times the 1980-1993 annual rate of decline. However, the water-level changes in nearby wells varied from a rise of 1.9 ft to a decline of 3.7 ft over the same period. Inspection of the 1998-2000 and the 1980-1993 data indicates a water-level rise of about 10 ft between 1993 and 1998. This is followed by more than a 10 ft water-level decline in 1999 which was confirmed by remeasurement. This abrupt change in water level over a one-year period suggests the possibility of an error in the 1998 annual measurement. Because of this problematic water-level behavior, 27-23W-28aaa01 should be maintained in its current status as a “provisional” well and reevaluated at a later time before it is included in the annual network on a permanent basis.

27-07W-03adc02

27-07W-03adc02 is an irrigation well in Kingman Co. and is completed in the High Plains aquifer of south-central Kansas (QU). No historic water-level data are available for this well. The 1998-2000 water-level data indicate a water-level decline of 3.4 ft which is consistent with the water-level changes in surrounding network wells (declines of 0.8-4.1 ft) over the same period. Since the water-level trend in this well is consistent with the trends in nearby network wells, this well should be added permanently to the annual well network.

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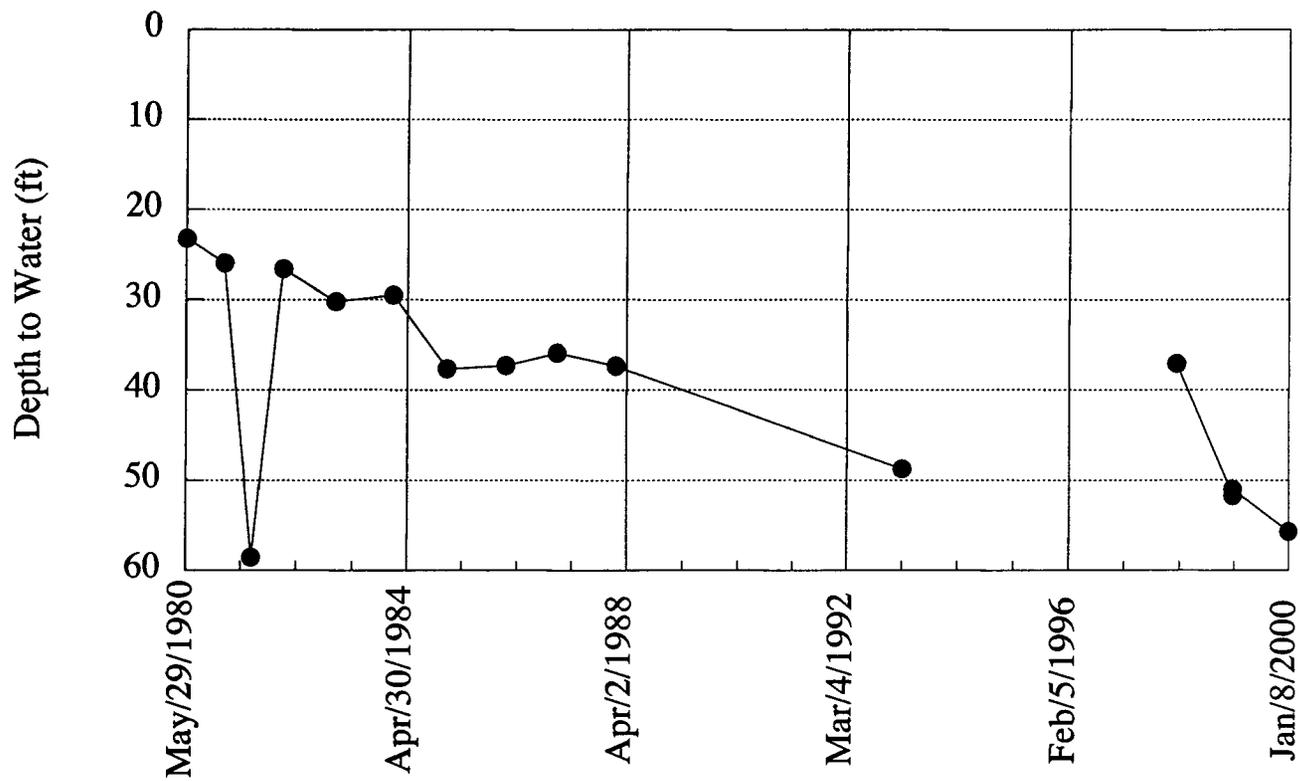


Figure 2. Hydrograph for well 27-23W-28aaa01

27-36W-01adb01

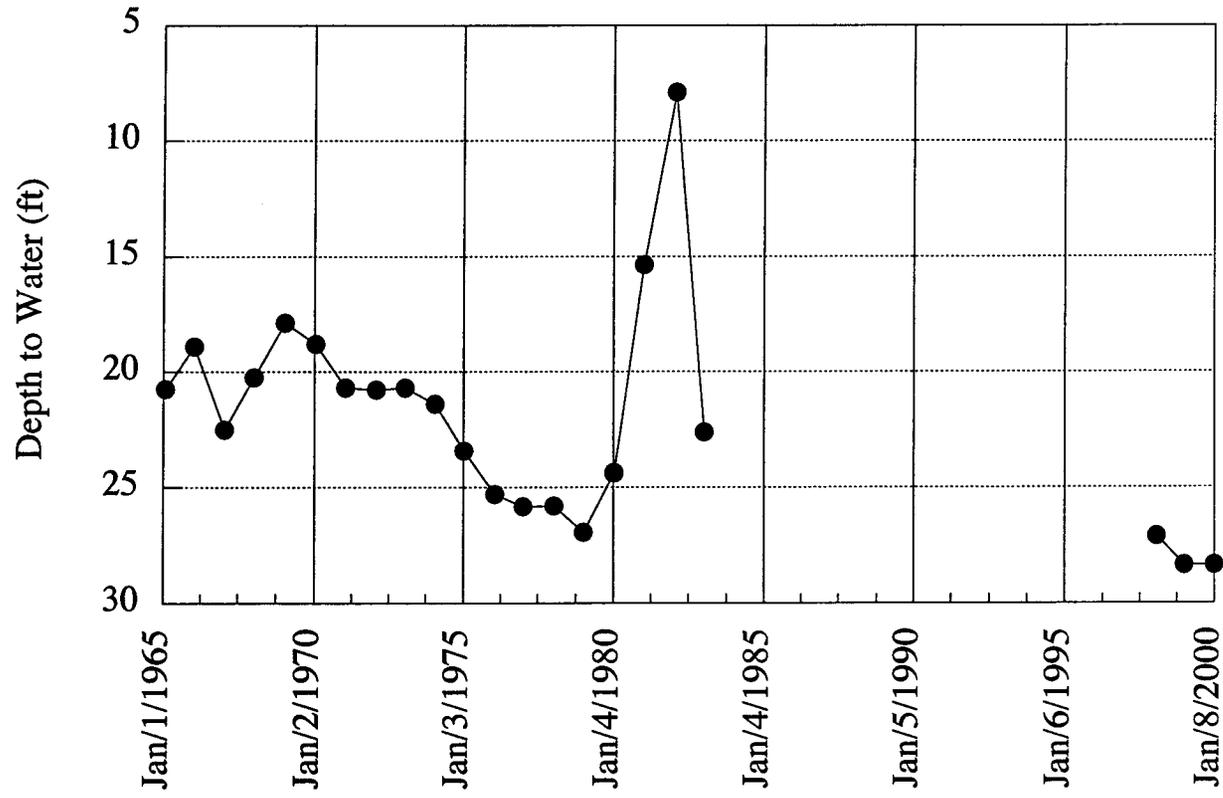
27-36W-01adb01 is an irrigation well in Grant Co. whose source of water is the High Plains aquifer (QUTO). Annual winter water-levels rose steadily in this well from 227.78 ft in 1981 to 222.36 ft in 1984. No water-level data were collected from this well until the 1998 winter water-level measurement. In 1998, the depth to water was 270.52 ft below surface and over the next two years water levels declined approximately 4.4 ft, which is consistent with the declines in nearby network wells (1.7-8.6 ft) for the same period. Because the water-level change in 27-36W-01adb01 is consistent with the water-level changes in surrounding wells, this well should be added to the annual network.

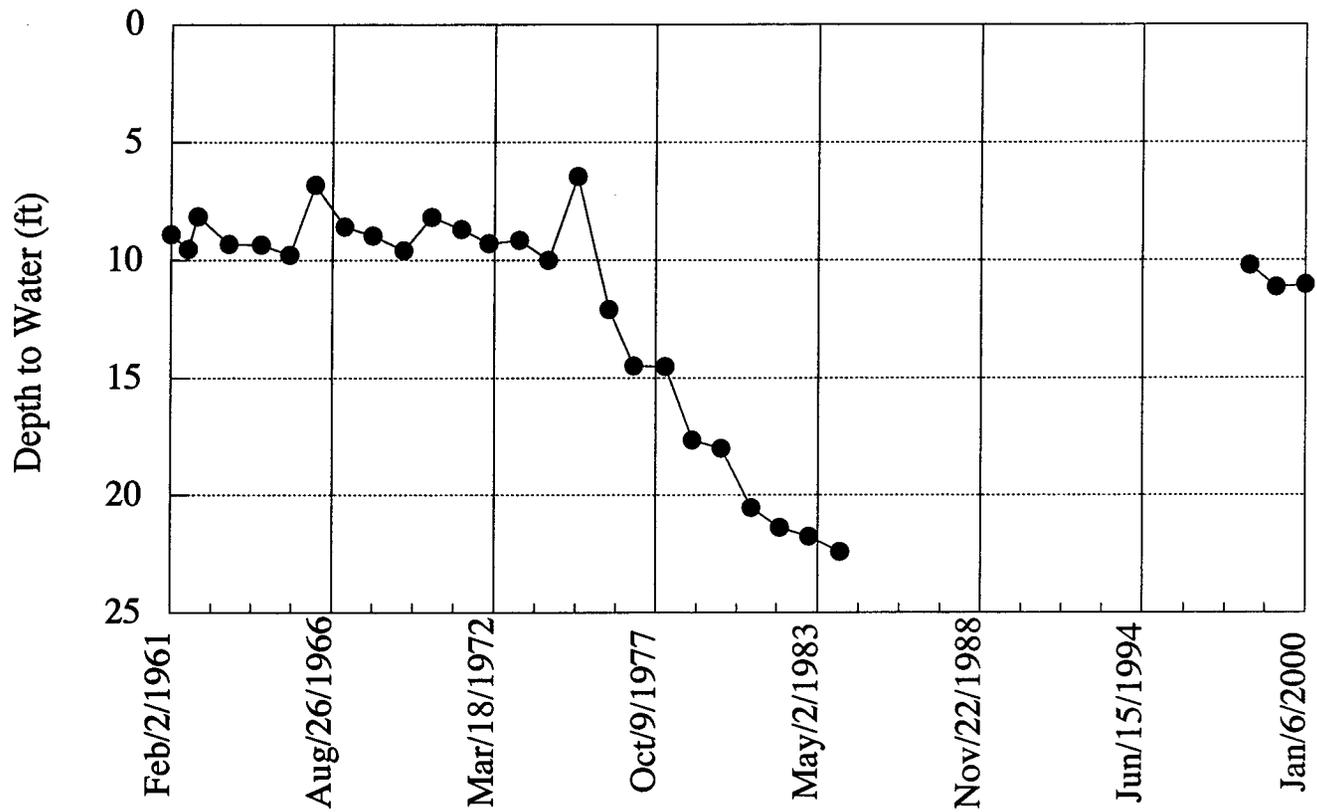
26-28W-10acb02

26-28W-10acb02 is an irrigation in Gray Co. that is completed in the Arkansas River alluvial aquifer approximately 0.5 mi north of the river. Annual winter water-level records are available for this well from 1956-1983 (Figure 3). The historic record shows that water levels have gradually declined in this well with the exception of a brief rise and fall of water level that occurred in 1981-1983. The brief rise and fall could have been associated with a flow event in the river. However, the rise and fall were not recorded in the upstream of "provisional" well 24-32W-25ccb02 hydrograph during that time period (Figure 4). Thus the brief rise and fall are problematic. The 1998-2000 depth to water measurements seem to suggest that the overall trend of decline has been continuing over the last two years. This 1.2 ft net decline is consistent with the 1.4 ft decline in a nearby network well (26-28W-06ddb01) that is also completed in the alluvial aquifer about 3 mi to the west. Consequently, it is appropriate that 26-28W-10acb02 should be added to the network because water levels changes in this well seem to reflect at least local changes of water level in the alluvial aquifer.

24-32W-25ccb02

24-32W-25ccb02 is also an irrigation well in Finney Co. that is completed in the Arkansas River alluvial aquifer approximately 0.3 mi north of the river. Annual winter water-level measurements for the 1961-1984 period show that steep water-level declines did not occur until about 1975 (Figure 4). Between 1975 and 1984 water levels declined to more than 14 ft below the average water levels in the 1960s and early 1970s. In the 1998-2000 period, it is evident that there has been significant recovery of water levels nearly up to the water levels of the 1960s-early 1970s period, presumably as a result of recharge from increased streamflow in the Arkansas River. the 1998-2000 net water-level change is a decline of 0.8 ft which is the same as the decline observed in a nearby network well in 24-33W-9ccd01. 24-32W-25ccb02 should be added to the permanent





network because the water-level changes in this well are consistent with the historical data and with the changes in a nearby network well.

24-33W-19dbb01 and 24-33W-18bdb01

24-33W-19dbb01 is an unused well in Finney Co. that is completed in the Dakota aquifer. Water levels were monitored in 24-33W-19dbb01 periodically from February, 1979, to September, 1996 (Figure 5). Water levels were also measured annually during the winter months in 24-33W-18bdb01 with the exception of a May, 1980 measurement (Figure 6). The historical data for both wells show little if any trend. The depth-to-water measurements from 24-33W-19dbb01 display high-amplitude fluctuations on the order of 30-50 ft over relatively short periods of time. These high-amplitude fluctuations most likely reflect nearby pumping by the Sunflower generating station and nearby irrigation wells since the water-level measurements were taken throughout the year. By comparison, the 1998-2000 annual winter depth-to-water measurements show a net decline of about 2.6 ft. This is consistent with the 0.3 ft decline aquifer for the 1998-2000 period in “provisional” well 24-33W-18bdb01. Interestingly, for the same period, water levels in other nearby network Dakota wells show rises of 25.7 ft (24-33W-18bdb02) and 2.7 ft (24-33W-09ccd03). This local variability in trend and magnitude of water-level change is probably reflective of the local scale heterogeneity in the Dakota aquifer and its effect on ground-water flow patterns under pumping conditions. Both “provisional” wells should be added to the network because the observed water-level changes are consistent with changes in the Dakota aquifer elsewhere in Kansas and because these monitoring wells are located in an area where there is significant use of the Dakota aquifer for water supply.

21-12W-06ccb02

21-12W-06ccb02 is an unused well in Stafford Co. that is completed in the High Plains aquifer (QU). Historic water-level data for the period from March, 1982, to October, 1990, show that water levels fluctuated in the 25-30 ft below surface range with no visually discernible trend (Figure 7). The more recent water levels (1998-2000) are higher than the historic levels and show an upward trend through time (a net rise of 9.0 ft over the 2-yr measurement period). In contrast, the ranges of net water-level changes for the 1998-2000 period in nearby network wells vary from a rise of 1.6 ft to a decline of 4.5 ft with an average trend of 0.4 ft. These departures of net water-level change in the 1998-2000 period from the historical trend in the “provisional” well and from local trends indicates that this well should not be added to the permanent well network. Rather, additional data should be collected and the well should remain in its “provisional” status to be reevaluated at a future time.

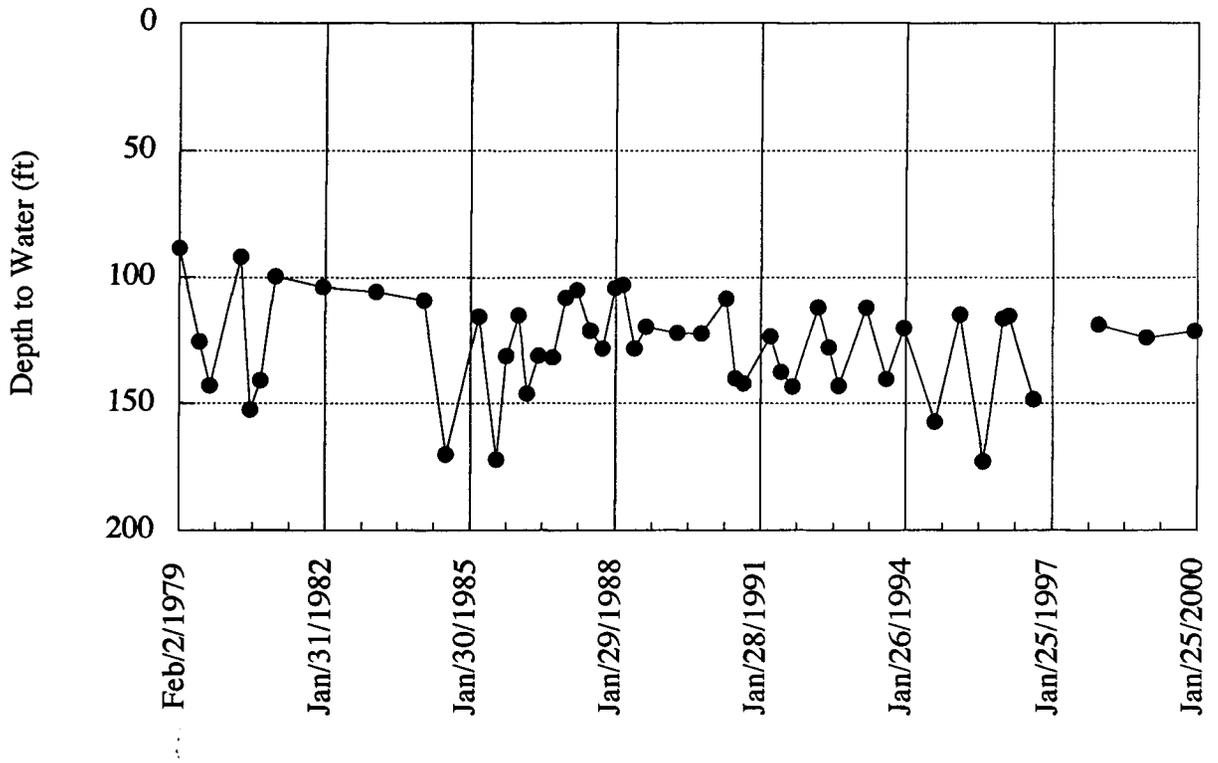
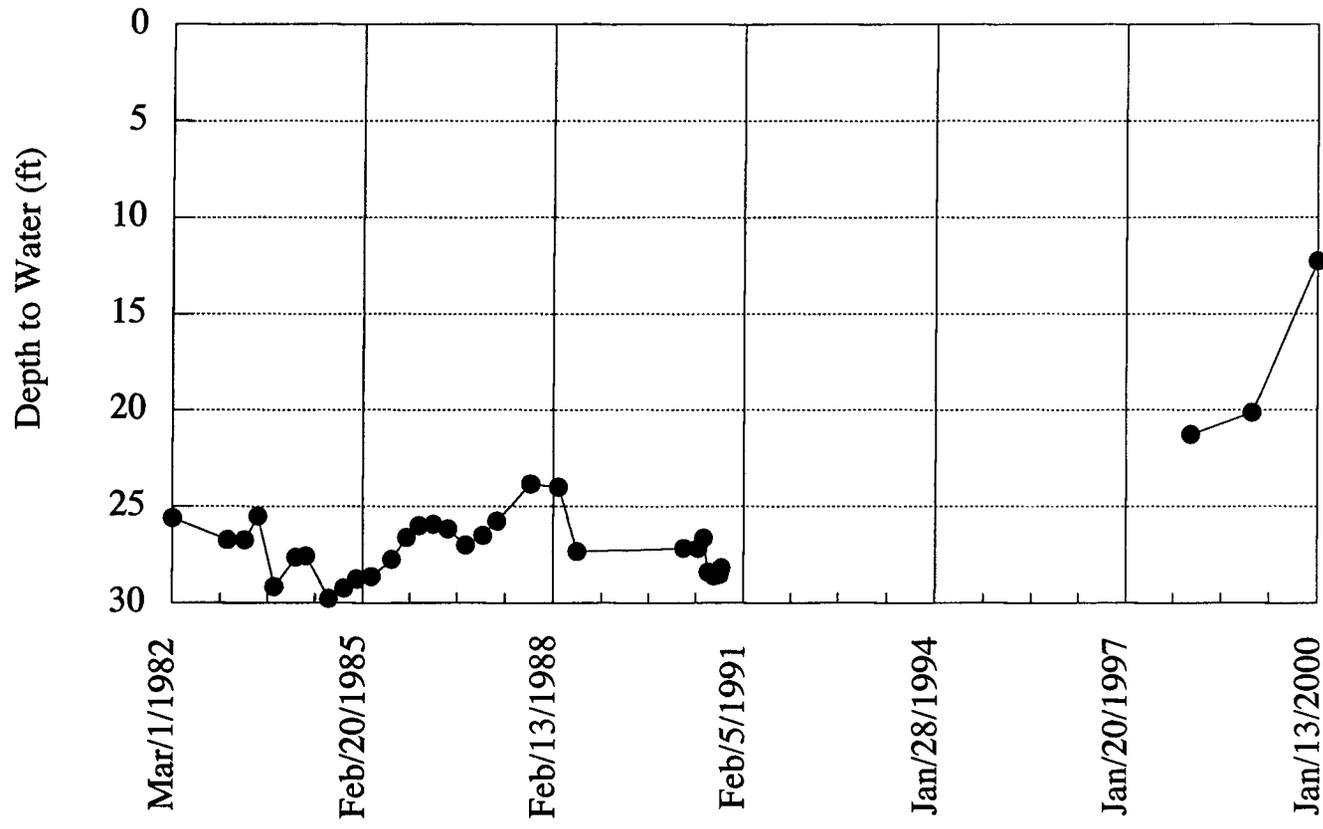


Figure 5. Hydrograph for well 24-33W-19dbb01



15-40W-22adc01

15-40W-22adc01 is an irrigation well in Wallace Co. whose source of water is the High Plains aquifer (TO). Other than a depth to water measurement of 150.07 ft from September, 1997, when the well was initially inventoried, there are no historic water-level data on this well. Taken together with the 1998 and 2000 depth to water measurements, the overall trend is toward higher water levels in this well, and in the 1998-2000 period that amounted to a 0.5 ft water-level rise. All but one of the network wells in township 15-40W and in the surrounding townships show water-level declines ranging from 0.2-9.5 ft for this period. The only well showing a water-level rise is 14-40W-29aba. Nevertheless, the water-level change in 15-40W-22adc01 falls within the range of trends in other network wells and the well should be added permanently to the annual network.

11-27W-08dbb01

11-27W-08dbb01 is an irrigation well in Gove Co. and is completed in the High Plains aquifer (TO). Other than a depth to water measurement of 109.00 ft from November, 1983, when the well was initially inventoried, there are no historic water-level data on this well. Only the 1998 and 2000 depth to water measurements are available from this well and they indicate a net water-level decline of 0.3 ft. In nearby network wells the net water-level changes for the 1998-2000 period range from a rise of 2.6 ft to a decline 6.4 ft. Because the net water-level change in 11-27W-08dbb01 is consistent with the range of net changes in other nearby wells, it should be added permanently to the annual network.

09-27W-31abb01 and 09-27W-20cbd01

09-27W-31abb01 and 09-27W-20cbd01 are irrigation wells in Sheridan Co. and are completed in the High Plains aquifer (TO). There are no historic water-level data from these wells. 09-27W-31abb01 was measured yearly during the 1998-2000 period and shows a net water-level decline of 0.9 ft. 09-27W-20cbd01 was measured in 1998 and in 2000 and shows a net water-level decline of 0.3 ft. The water-level changes for this period in surrounding network wells range from a rise of 5.9 ft to a decline 3.4 ft and the average trend for these wells is a net rise of 1.3 ft. The water-level changes in 09-27W-31abb01 and 09-27W-20cbd01 are consistent with the range of changes in other nearby wells and thus these wells should be added permanently to the annual network.

09-28W-15cba01

09-28W-15cba01 is an irrigation well in Sheridan Co. that is completed in the High Plains aquifer (TO). There are no historic water-level data from this well. The well was measured in

1998 and in 2000 and shows a net water-level rise of 3.1 ft. The net water-level changes for the 1998-2000 period in surrounding wells range from a rise of 5.7 ft to a decline of 0.9 ft and the average trend is a net rise of 0.7 ft. The net water-level change in 09-28W-15cba01 is consistent with the range of trends in nearby wells and thus this well should be added permanently to the annual network.

08-27W-18daa01

08-27W-18daa01 is an irrigation well in Sheridan Co. and is completed in the High Plains aquifer (TO). There are no historic water-level data from this well. The well was measured in 1998 and in 2000 and shows a net water-level decline of 0.2 ft. The net water-level changes for the 1998-2000 period in surrounding wells ranged from a rise of 5.9 ft to a decline of 1.0 ft and the average trend is a net rise of 2.0 ft. Because the water-level change in 08-27W-18daa01 is consistent with the range of trends in nearby wells, it should be added permanently to the annual network.

08-28W-17bad01

08-27W-18daa01 is an irrigation well in Sheridan Co. whose source of water is the High Plains aquifer (TO). There are no historic water-level data from this well except for a depth to water measurement of 101.00 ft on October 1, 1967, that was taken when the well was initially inventoried. The depth to water was measured annually during the 1998-2000 period and the net water-level change was a decline of 2.0 ft. The net water-level change for the 1998-2000 period in surrounding wells ranged from a rise of 5.9 ft to a decline of 1.1 ft and the average trend for nearby network wells was a net rise of 0.4 ft. The water-level decline in this well slightly exceeds the range of declines in the other network wells but not enough to be inconsistent with the range of water-level trends observed in the local area. Consequently, 08-28W-17bad01 should become part of the annual network.

08-29W-01bdd01

08-29W-01bdd01 is an irrigation well in Sheridan Co. that is completed in the High Plains aquifer (TO). There are no historic water-level data from this well with the exception of a depth-to-water measurement of 156.00 ft that was taken when the well was inventoried on November 20, 1995. The depth to water was measured annually during the 1998-2000 period and the net water-level change was a decline of 1.1 ft. The net water-level change for the 1998-2000 period in surrounding wells ranged from a rise of 1.9 ft to a decline of 1.4 ft and the average trend for nearby network wells was a net water-level decline of 0.4 ft. The water-level decline in 08-29W-

01bdd01 is within the range of net water-level changes observed in other nearby wells for this period and thus this well should be added to the permanent annual network.

06-28W-21bcd01

06-28W-21bcd01 is an irrigation well in the High Plains aquifer (TO) in Sheridan Co. When this well was initially inventoried on September 7, 1990, the depth to water was 112.00 ft and in January, 1998, the depth to water was 107.72 ft below surface for a net rise of about 4.3 ft. Only the 1998 and 2000 depth to water measurements are available for this well in this provisional-status period and they show a net water-level decline of 3.4 ft. The net water-level change for the 1998-2000 period in surrounding wells ranged from a rise of 1.3 ft to a decline of 1.2 ft and the average trend for nearby network wells was a water-level decline of 0.4 ft. The 1998-2000 water-level decline in 06-28W-21bcd01 is significantly outside of the range of net water-level changes observed in other nearby wells and is contrary to the trend in the historic water-level data for this well. Consequently, this well should remain as a “provisional” well until more water-level data can be collected.

06-38W-09abd01 and 06-38W-18dbd01

06-38W-09abd01 and 06-38W-18dbd01 are irrigation wells that use the High Plains aquifer (TO) as a source of water in Sherman Co. Historic annual winter water-level data for 06-38W-09abd01 show relatively stable water levels from 1964 to 1975 (Figure 8). This was followed by declining but highly fluctuating water levels through the late 1970s and a period of stable water levels up to 1988, the end of the historic record. In the 1998-2000 period, the annual 1998 measurement suggests a net decline between 1988 and 1998 and recovery back to water levels in 1999 and 2000. The net water-level change for the 1998-2000 period was a rise of 4.5 ft. There are no historic data for 06-38W-18dbd01 except for a February, 1966, depth to water measurement of 130.00 ft when the well was initially inventoried. In the 1998-2000 period water-levels in this well which is located in the same township as 06-38W-09abd01 rose 3.3 ft. In contrast, network wells in surrounding townships declined an average of 2.2 ft in the 1998-2000 period. Both wells should be added to the permanent annual network because of their consistent water-level changes and because there are no other wells in the data base for this township, despite the fact that the water-level changes in these wells are opposite the changes observed in nearby network wells.

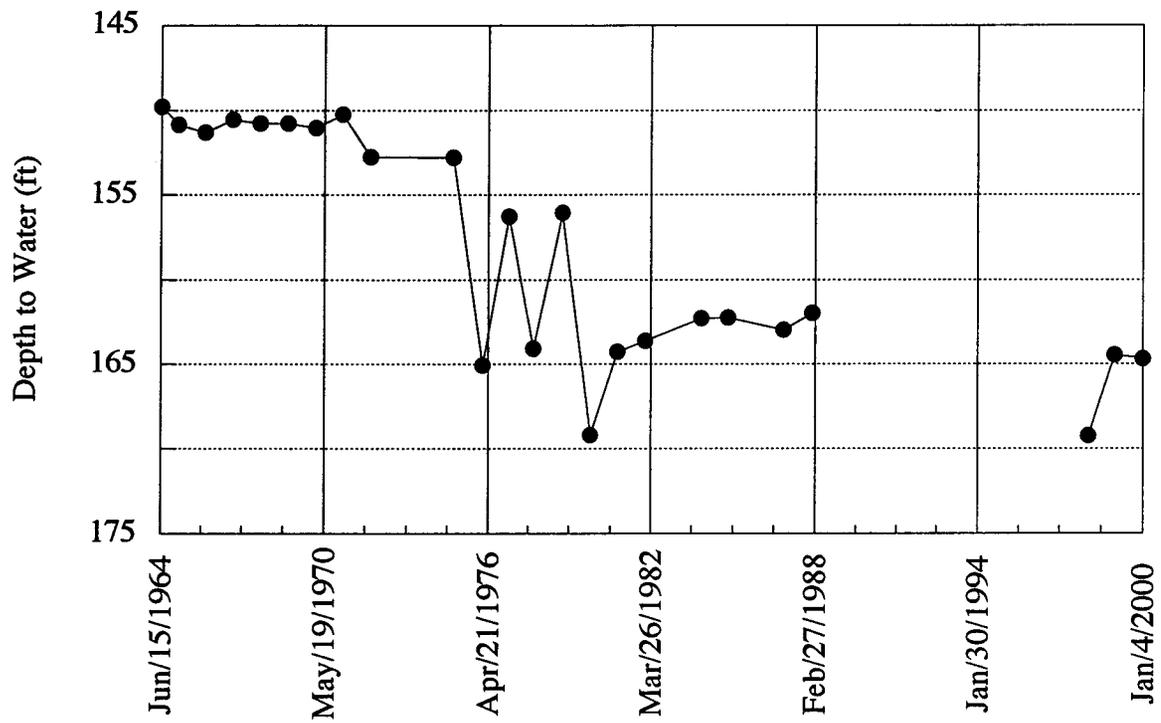


Figure 8. Hydrograph for well 06-38W-09abd01

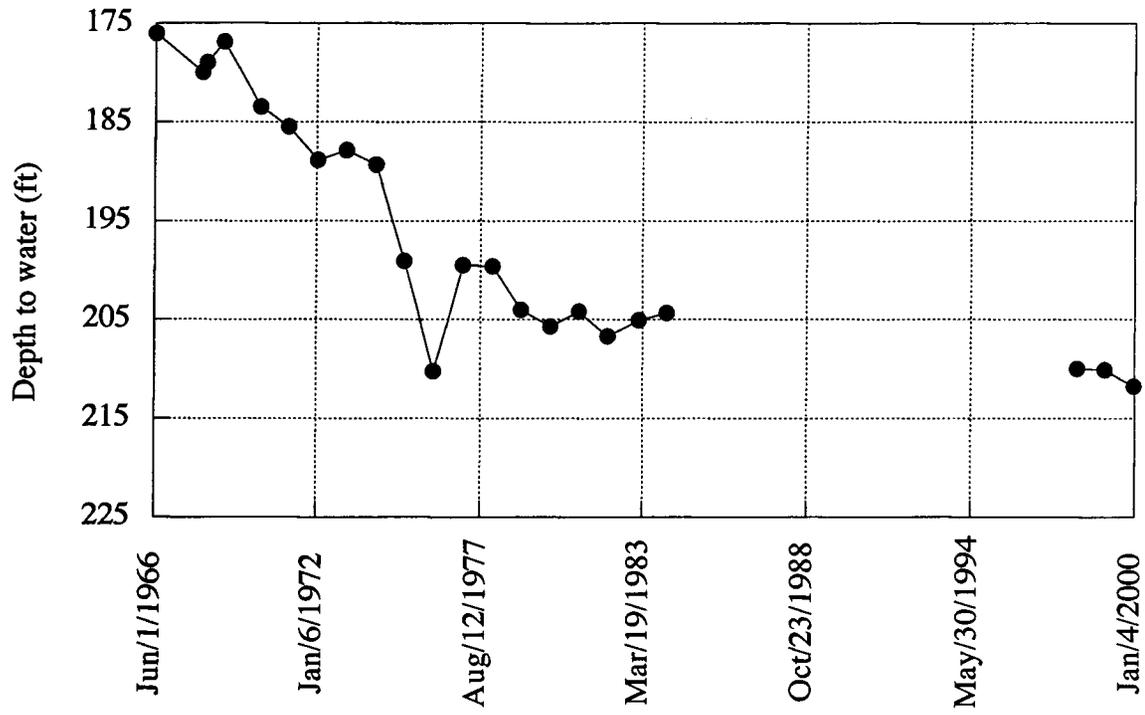


Figure 9. Hydrograph for well 05-40W-27bba01

05-40W-27bba01

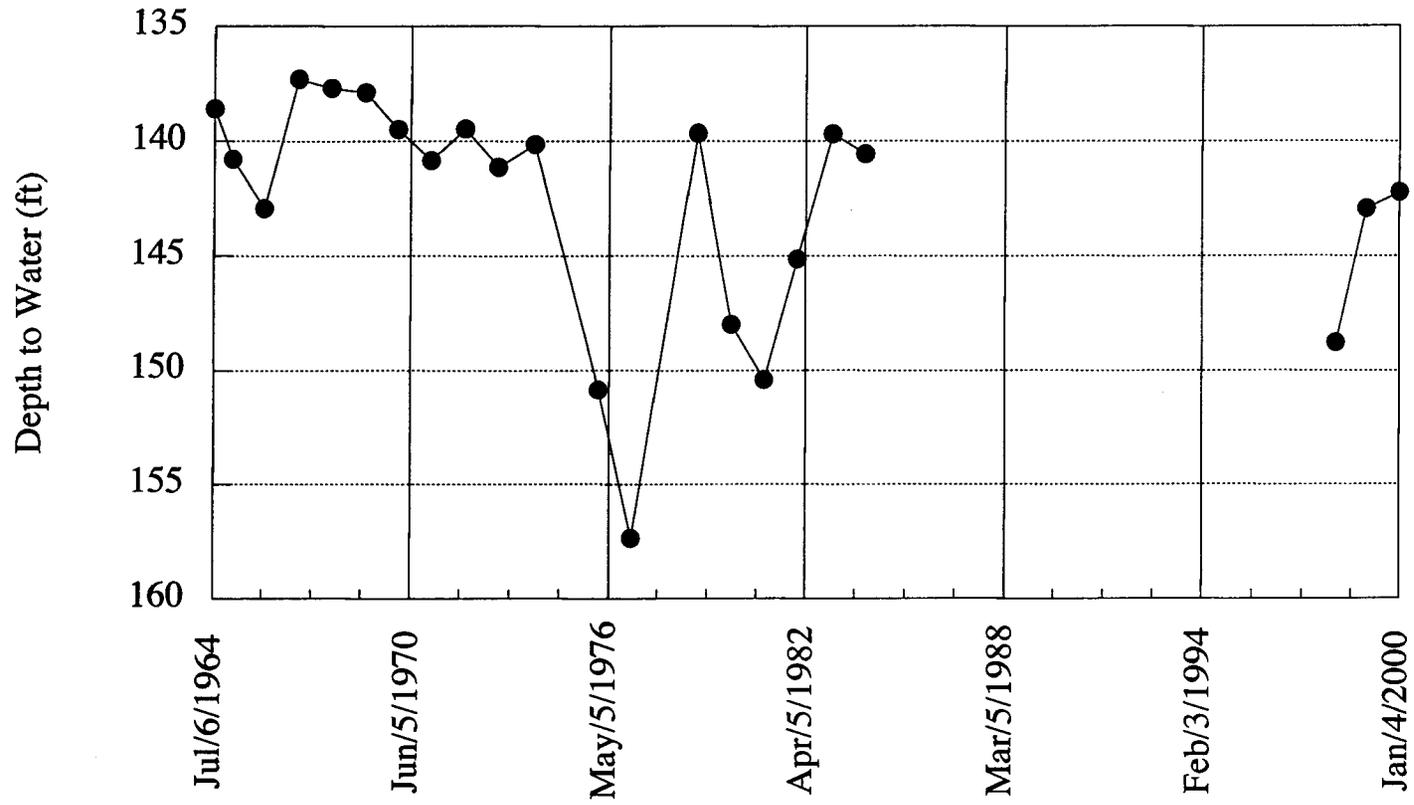
05-40W-27bba01 is an irrigation well in Cheyenne Co. that is completed in the High Plains aquifer (TO). The historic water-level data from this well consist mostly of annual winter water-level measurements from 1966-1984 (Figure 9). The data show a long-term pattern of decline that was relatively steep initially and then gradually tapered to much lower rates with time. The 1998-2000 water-level data indicate a continuation of this decline trend that is consistent with the declines other nearby network wells (2.6-0.2 ft range in water-level change with an average water-level change of 0.8 ft). 05-40W-27bba01 should be added permanently to the annual network because the water-level changes in 1998-2000 are consistent with historic declines and the pattern of declines in other nearby wells.

04-39W-15cca01

04-39W-15cca01 is an irrigation well in Cheyenne Co. whose water source is the High Plains aquifer (TO). The historic water-level data from this well consist almost entirely of annual winter water-level measurements from 1964-1984 (Figure 10). The data show water level fluctuations of varying amplitude throughout the period of record. The 1998-2000 water-levels seem to reflect this behavior of fluctuating water levels and indicate a net rise of 6.5 ft. No other network wells are present in this township that can be used to make water-level change comparisons. However, network wells in surrounding townships generally show a pattern of decline for the 1998-2000 period (range of water level change: 0.1 rise to 1.0 ft decline with an average decline 0.6 ft). The lack of consistency in the direction of water-level change and the uncertain relation between the water-levels of the past three measurement seasons and the historic data indicates that 05-40W-27bba01 should remain as a "provisional" until more water-level data can be collected and evaluated.

03-35W-18cbb01

03-35W-18cbb01 is an irrigation well in Rawlins Co. whose water source is the High Plains aquifer (TO). No historic water-level data are available for this well. In the 1998-2000 period water levels were measured three times, twice for the 1998 winter measurement (January 29 by KGS and December 29 by the Division of Water Resources, Kansas Department of Agriculture) and once for the 2000 winter measurement. The net water-level change is a 5.1 ft decline which greatly exceeds the range of water-level changes in nearby network wells (from a rise of 1.9 ft to a decline of 1.4 ft) but does follow the average local trend of change (a 0.1 ft decline). In a nearby network well in the same township approximately 6 mi away, the net water-level change is a rise of 0.8 ft. This inconsistency in the trend of water-level change in 03-35W-18cbb01 suggests that



further data should be collected and evaluated before adding this well to permanent annual network.

Water-Level Changes in the “Provisional” and Network Wells in the High Plains Aquifer Region

Figure 11 shows the 1998-2000 winter water-level change for each “provisional” well and the range and the arithmetic mean of water-level changes in the nearby network wells in the High Plains aquifer for the same period. Some of the water-level changes in the “provisional” wells are much greater than the range of changes in the existing network wells. These pronounced departures from the local norms have been discussed in the earlier part of this paper.

What is noteworthy about the overall water-level changes in the “provisional” and in the annual network wells is the wide range of local values over the two-year period between the winters of 1998 and 2000. The local water-level fluctuation over the two-year period ranges from 1.1-12.5 ft for this sample of wells and the average value is 6.9 ± 1.6 ft (assuming a confidence interval of ± 2 standard errors). In comparison, the average water-level change for all of the annual network wells used in this analysis is a decline of 1.0 ± 0.8 ft. This average decline rate is consistent with the estimated regional rate of ground-water level decline in the High Plains aquifer in Kansas of approximately 0.9 ft/yr in 1988-1999 period (Woods et al., 2000).

Woods et al. (2000) examined the water-level data from network wells where multiple measurements had been made during the winter season. They found that uncertainties caused by incomplete water-level recovery from previous pumping were large relative to the annual decline rates. From the 1999 water-level surveys, water-level recovery rates greater than 0.25 ft/month were found in 90% of the wells where multiple-measurement data were available during the winter season (December-February). Table 2 lists the rates of water-level rise in the “provisional” wells where multiple water-level measurements were taken 1999 and 2000 annual winter surveys. The

Table 2. Rates of water-level recovery based on multiple measurements of depth to water during the winter survey of the “provisional” wells in the High Plains aquifer.

“Provisional” Well	County	Year of the Multiple Measurement	Measured Water-Level Rise (ft)	Normalized Water-Level Rise (ft/mo)
31-31W-03ccc01	Seward	2000	0.13	4.03
27-23W-28aaa01	Ford	1999	0.67	20.77
27-36W-01adb01	Grant	2000	0.01	-

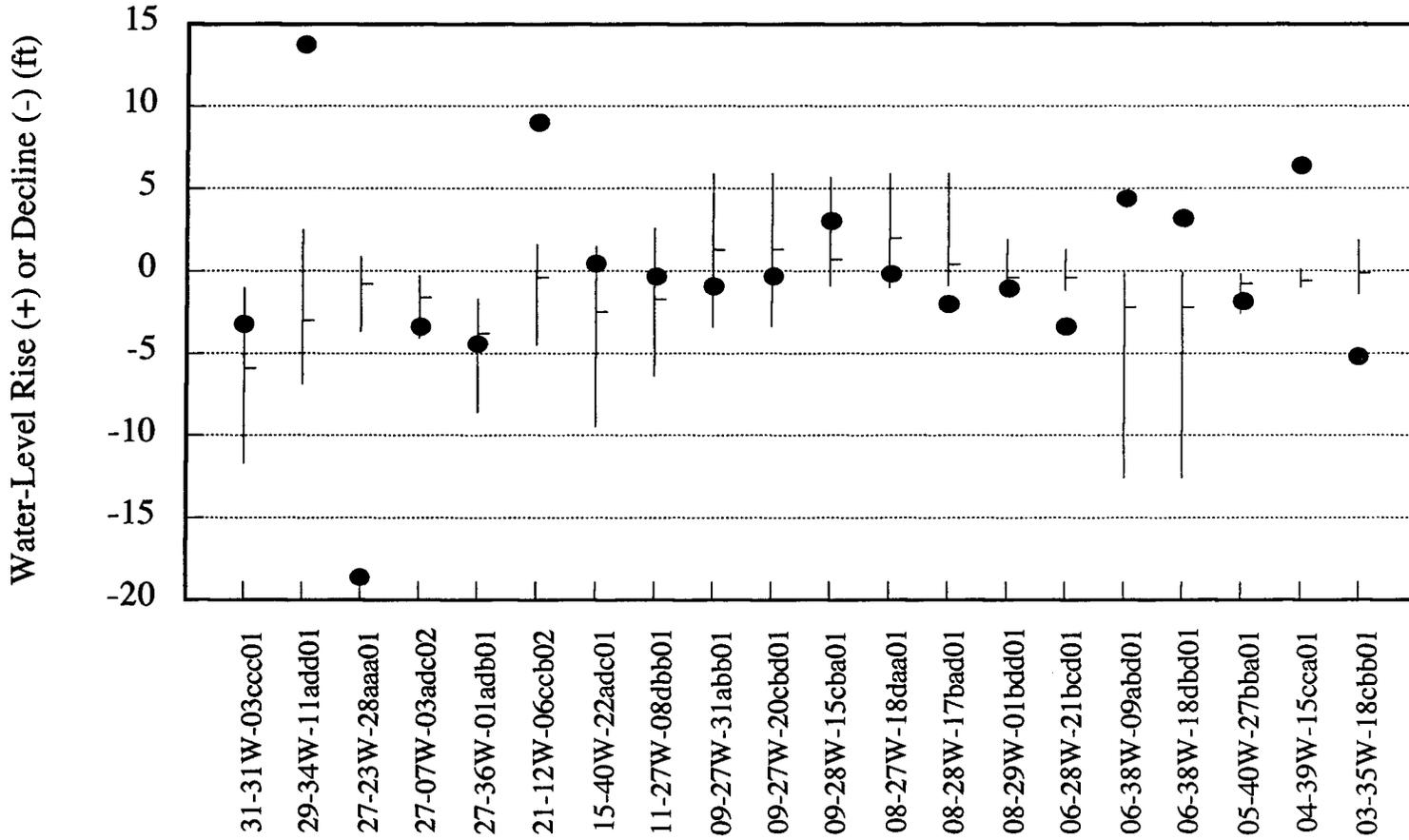


Figure 11. Comparison of water level changes in the "provisional" wells with nearby network wells. The vertical bar represents the range in water-level fluctuations in nearby wells and the horizontal bar, the mean water-level change. The dots represent the water-level change in the "provisional" well.

authors suggest that water-level recovery rates are likely to be higher later in the winter season in areas where the wheat crop is irrigated in the late fall.

High rates of water-level recovery due to late fall irrigated wheat may explain at least some of the local variability in water-level changes in the “provisional” and the network wells presented in this paper. In other areas, where irrigated wheat is not significant factor, slow recovery of water-levels may be caused by more intense or extended pumping during the summer irrigation season or to continuous pumping nearby public water supply or industrial wells.

The results of Woods et al. (2000) suggest that (1) annual surveys of water levels in the High Plains aquifer should be conducted later in the winter season than they are at present, perhaps even as late as early March, and (2) more attention should be paid to rates of recovery from pumping during the summer irrigation season and fall irrigation of the wheat. A water-level survey conducted later in the winter season would allow more recovery of water table from pumping in the High Plains region back to a new equilibrium level. More importantly, the influence of recovery rates on water levels and, consequently, on determining rates of decline from year to year would be reduced. With regard to the second point in the previous paragraph, water-level data from the continuous monitoring of selected wells distributed over the High Plains region during and after the annual survey of network wells could be used as a way to “standardize” the raw depth to water measurements so that a more accurate “instantaneous” regional snapshot of the water table configuration can be generated. The information from the short-term hydrographs would also be useful for the assessment and integration of multiple-measurement data from resurveys that are often conducted at a later time after the main data collection effort. It is often difficult to determine if the difference between depth to water measurements in the same well taken at different times is due primarily to error or recovery.

Summary and Recommendations with Regard to Wells in the “Provisional” Status

Table 3 lists which of the 26 wells should be added to the permanent annual water-level monitoring network and which wells should maintained in their current provisional status.

The length of time that a well is considered provisional should be extended to allow for more annual water-level measurements for the evaluation process. Many of the “provisional” wells did not have three consecutive annual measurements that could be used to evaluate year-to-year fluctuations as well as overall trend. Several of the “provisional” wells displayed water-level trends that were contrary to historic trends, but since only the 1998 and 2000 depth to water measurements were available, it was difficult to determine if error might have caused the apparent disparity in trend. Consequently, it is recommended that the “provisional” well period be extended to a minimum of 4 years (5 consecutive annual water-level surveys) to insure that the data needed to evaluate trends are available.

Table 3. Summary table listing the wells to be added to the permanent annual water-level monitoring network and those whose provisional status should be maintained.

Wells To Be Added To the Permanent Annual Well Network	Wells To Be Maintained In Their Current Provisional Status
31-31W-03ccc01	29-34W-14cdc01
29-42W-27dad01	27-23W-28aaa01
29-41W-14cdc01	21-12W-06ccb02
27-07W-03adc02	04-39W-15cca01
27-36W-01adb01	03-35W-18cbb01
26-28W-10acb02	06-28W-21bcd01
24-32W-25ccb02	
24-33W-19dbb01	
24-33W-18bdb01	
15-40W-22adc01	
11-27W-08dbb01	
09-27W-31abb01	
09-27W-20cbd01	
09-28W-15cba01	
08-27W-18daa01	
08-28W-17bad01	
08-29W-01bdd01	
06-38W-09abd01	
06-38W-18dbd01	
05-40W-27bba01	

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REFERENCES CITED

Woods, J.J., Schloss, J.A., Mosteller, J., Buddemeier, R.W., Maxwell, B.A., Bartley, J.D., and Whittemore, D.O., 2000, Water level decline in the Ogallala aquifer -a report on KGS-KWO Contract 99-132: Kansas Geological Survey Open-file Report 2000-29B, CD-ROM.

**APPENDIX 1: COMPARISON OF NET WATER-LEVEL CHANGES(1998-2000) IN THE
“PROVISIONAL” WELLS WITH WATER LEVEL CHANGES IN SURROUNDING
NETWORK WELLS.**

“Provisional” Well /Aquifer Code	“Provisional” Well Water-level Change 1998-2000 (ft)	Surrounding Network Well Locations	Water-level Change Surrounding Wells 1998-2000 (ft)
31-31W-03ccc01 (QUTO)	-3.2	30-31W-26abb	-11.7
		30-30W-6ccc	-5.6
		31-30W-16bbc	-5.3
		31-32W-31bbb	-1.0
		Ave. = -5.9	
29-42W-27dad01 (QUTOKD)	-0.1	28-42W-32bbb	-1.3
		30-41W-23ddb	0
		30-43W-34bba	+6.5
		30-43W-36bb	+1.7
		30-41W-13ccc	+0.2
		29-42W-08cdc	+1.9
Ave. = +1.5			
29-41W-14cdc01 (QUTOKD)	-5.8	28-40W12ddd	-4.1
		28-41W-02ccc	-2.3
		28-42W-06dbb	-22.58
		28-42W-20bcc	-1.0
		28-42W-32bbb	-1.3
		29-42W-08cdc	+1.95
Ave. = -4.9			
29-34W-11add01 (QUTO)	+13.8	29-33W-01aab	-1.7
		29-33W-28bcb	-6.8
		29-33W-34ddd	-3.7
		30-34W-05bbb	-2.2
		28-34W-14ccc	-2.4
		29-35W-28acc	-6.9
		29-35W-07cbd	+2.5
Ave. = -3.0			
27-23W-28aaa01 (QUTO)	-18.6	27-23W-24bcb	-3.7
		27-23W-36ccc	-0.4
		27-24W-03bbd	+0.9
		27-24W-03cdd	-0.1
		27-24W-04bbc	-1.8
		27-24W-09aad	-0.6
		27-24W-16bdb	+0.2
		27-24W-26daa	-1.1
		28-23W-18bab	-0.7
		28-23W-24abb	-0.7
Ave. = -0.8			

"Provisional" Well /Aquifer Code	"Provisional" Well Water-level Change 1998-2000 (ft)	Surrounding Network Well Locations	Water-level Change Surrounding Wells 1998-2000 (ft)
27-07W-03adc02 (QU)	-3.4	27-06W-12ccd	-4.1
		27-06W-16ccb	-1.8
		27-07W-23bcc	-0.8
		27-08W-17dab	-1.1
		27-08W-35cbc	-0.3
			Ave. = -1.6
27-36W-01adb01 (QUTO)	-4.4	27-35W-17add	-6.6
		27-35W-25bdc	-7.8
		27-36W-21dcc	-5.2
		27-37W-04abb	-3.4
		27-37W-16aad	-1.7
		27-37W-21bdd	-8.6
		28-36W-18abc	-2.4
		26-36W-22cca	-4.9
			Ave. = -3.8
26-28W-10acb02 (QA)	-1.2	26-28W-6ddb	-1.4
24-32W-25cbb02 (QA)	-0.8	24-33W-09ccd	-0.8
24-33W-19dbb01 (KD)	-2.6	24-33W-18bdb02	+25.7
		24-33W-09dbb	+2.7
24-33W-18bdb01 (KD)	-0.3	24-33W-18bdb02	+25.7
		24-33W-09ccd03	+2.7
21-12W-06ccb02 (QU)	+9.0	20-12W-23cca	+0.4
		21-11W-07bbb	+0.8
		21-13W-05cbd	-4.5
		21-13W-27ddd02	+1.0
		22-12W-05bbd	+1.6
		22-12W-36bbd01	0.0
		22-12W-36bbb02	-2.4
		20-12W-03dac	-0.6
		20-12W-06aac	-0.1
			Ave. = -0.4

“Provisional” Well /Aquifer Code	“Provisional” Well Water-level Change 1998-2000 (ft)	Surrounding Network Well Locations	Water-level Change Surrounding Wells 1998-2000 (ft)
15-40W-22adc01 (TO)	+0.5	15-40W-03bab	-5.5
		15-40W-09dcb	-2.1
		15-41W-05acb	-3.5
		15-41W-27cbc	-2.8
		15-41W-36bda	-2.3
		15-39W-06cbc	-9.5
		15-39W-02acb	-0.7
		15-39W-08acc	-2.1
		15-39W-26acc	-2.5
		14-40W-14ccc	-2.6
		14-40W-29aba	+1.5
		16-40W-05acc	-1.1
		16-40W-17cbc	-1.9
16-40W-26ada	-0.2		
			Ave. = -2.5
11-27W-08dbb01 (TO)	-0.3	11-27W-36bcc	-1.0
		11-26W-04cdc	+2.6
		11-26W-19aaa	+1.1
		11-28W-08aaa	-4.9
		11-28W-26abb	-6.4
		10-27W-20cbc	-3.3
		10-27W-22dba	-0.1
			Ave. = -1.7
09-27W-31abb01 (TO)	-0.9	09-26W-22bbb	+1.1
		09-27W-12ccc	+5.7
		09-27W-27daa	+0.6
		09-28W-31bcc	-0.9
		10-27W-20cbc	-3.4
		10-27W-22dba	-0.1
		08-27W-35cbb	+5.9
			Ave. = +1.3
09-27W-20cbd01 (TO)	-0.3	09-26W-22bbb	+1.1
		09-27W-12ccc	+5.7
		09-27W-27daa	+0.6
		09-28W-31bcc	-0.9
		10-27W-20cbc	-3.4
		10-27W-22dba	-0.1
		08-27W-35cbb	+5.9
			Ave. = +1.3

“Provisional” Well /Aquifer Code	“Provisional” Well Water-level Change 1998-2000 (ft)	Surrounding Network Well Locations	Water-level Change Surrounding Wells 1998-2000 (ft)
09-28W-15cba01 (TO)	+3.1	08-28W-11daa	-0.4
		09-27W-27daa	+0.6
		09-27W-12ccc	+5.7
		09-28W-04bcc	-0.9
		09-29W-17bcb	-0.9
		09-29W-26baa	-0.9
		10-28W-05ddb	+0.4
		10-28W-29daa	+2.3
			Ave. = +0.7
08-27W-18daa01 (TO)	-0.2	09-27W-12ccc	+5.8
		08-28W-11daa	-0.4
		08-26W-14daa	-1.0
		08-27W-35cbb	+5.9
		07-27W-22dac	-0.3
			Ave. = +2.0
08-28W-17bad01 (TO)	-2.0	08-27W-35cbb	+5.9
		08-28W-11daa	-0.4
		07-28W-08dcc	-0.7
		07-28W-21abb	-1.1
		07-28W-36aba	-0.3
			Ave. = +0.4
08-29W-01bdd01 (TO)	-1.1	08-28W-11daa	-0.4
		08-30W-13daa	-1.4
		08-30W-30abc	+0.4
		07-29W-05bbb	-1.1
		07-29W-27ccc	-0.7
		07-29W-30aba	+1.9
		09-29W-17bcb	-0.9
09-29W-26bbb	-0.9		
			Ave. = -0.4

“Provisional” Well /Aquifer Code	“Provisional” Well Water-level Change 1998-2000 (ft)	Surrounding Network Well Locations	Water-level Change Surrounding Wells 1998-2000 (ft)
06-28W-21bcd01 (TO)	-3.4	07-28W-21abb	-1.1
		07-28W-36aba	-0.3
		06-29W-10dbc	0
		06-29W-24abb	-1.2
		06-29W-33cda	-1.0
		06-27W-05cbb	+1.3
		06-27W-08dca	-0.7
		06-27W-19adc	-0.4
		05-28W-7bbc	-0.2
		05-28W-10bbb	-0.8
		05-28W-17dac	-0.2
		05-28W-14add	+0.1
			Ave. = -0.4
06-38W-09abd01 (TO)	+4.5	06-37W-07bba	-0.2
		06-37W-16cdd	-0.1
		06-37W-19abb	-0.4
		06-39W-09ddd	-12.6
		07-38W-28daa	-1.6
		05-38W-13bad	-0.2
		05-38W-22acb	-0.4
06-38W-18dbd01 (TO)	+3.3	06-37W-07bba	-0.2
		06-37W-16cdd	-0.1
		06-37W-19abb	-0.4
		06-39W-09ddd	-12.6
		07-38W-28daa	-1.6
		05-38W-13bad	-0.2
		05-38W-22acb	-0.4

“Provisional” Well /Aquifer Code	“Provisional” Well Water-level Change 1998-2000 (ft)	Surrounding Network Well Locations	Water-level Change Surrounding Wells 1998-2000 (ft)
05-40W-27bba01 (TO)	-1.8	05-40W-14bad	-0.8
		05-39W-25cda	-0.7
		05-39W-11cbc	-0.3
		05-39W-06daa	-0.6
		05-38W-13bad	-0.2
		05-38W-22acb	-0.4
		04-40W-22bcb	-0.8
		06-40W-10aac	-1.0
		06-40W-13cbc	-2.6
		06-40W-30dcc	-0.7
			Ave. = -0.8
04-39W-15cca01 (TO)	+6.5	04-38W-04bac	-0.9
		04-38W-21adc	-1.0
		04-38W-20ccc	-0.7
		04-40W-22bcb	-0.8
		03-39W-04ccc	-0.2
		03-39W-20cac	-0.6
		03-39W-24ddd	-0.5
		03-39W-32bdb	+0.1
		05-39W-06daa	-0.6
		05-39W-11cbc	-0.9
		05-39W-25cda	-0.7
			Ave. = -0.6
03-35W-18cbb01 (TO)	-5.1	03-35W-24cbb	+0.8
		03-36W-14cbb	-0.1
		03-36W-17ccc	-1.3
		03-36W-21dbc	-1.4
		03-34W-03abb	-0.9
		03-34W-26bac	+0.3
		02-35W-13caa	+1.9
		04-35W-29ddd	-0.2
			Ave. = -0.1