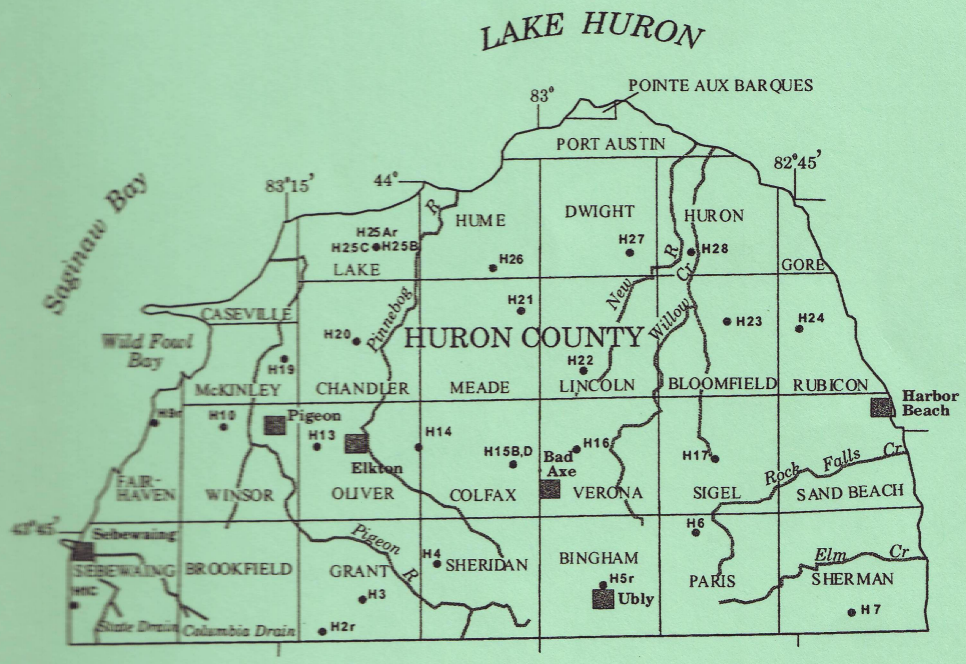
Ground-Water Levels in Huron County, Michigan, 2002-03

U.S. GEOLOGICAL SURVEY

Open-File Report 2005-1082



Prepared in cooperation with Huron County, Michigan

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Ground-Water Levels in Huron County, Michigan, 2002-03

By T.L. Weaver, S.P. Blumer, and S.L. Crowley

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Lansing, Michigan
2005

U.S. DEPARTMENT OF THE INTERIOR

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U.S. GEOLOGICAL SURVEY

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EXECUTIVE SUMMARY

In 1990, the U.S. Geological Survey (USGS) completed a study of the hydrogeology of Huron County, Michigan (Sweat, 1991). In 1993, Huron County and the USGS entered into a continuing agreement to collect water-level altitudes (hereafter referred to as water levels) at selected wells throughout Huron County. As part of the agreement, USGS has operated four continuous water-level recorders, installed from 1988 to 1991 on wells in Bingham, Fairhaven, Grant, and Lake Townships (fig. 1) and summarized the data collected in an annual or bi-annual report. The agreement was altered in 2003, and beginning January 1, 2004, only the wells in Fairhaven and Lake Townships will have continuous water-level recorders, while the wells in Grant and Bingham Townships will revert to quarterly measurement status. USGS has also provided training for County or Huron Conservation District personnel to measure the water level, on a quarterly basis, in 23 wells. USGS personnel regularly accompany County or Huron Conservation District personnel to provide a quality assurance/quality control check of all measurements being made. Water-level data collected from the 23 quarterly-measured wells is also summarized in the annual or bi-annual report. In 1998, the USGS also completed a temporal and spatial analysis of the monitoring well network in Huron County (Holtschlag and Sweat, 1998).

The altitude of Lake Huron and precipitation are good indicators of general climatic conditions and, therefore, provide an environmental context for groundwater levels in Huron County. Figure 2 shows the mean-monthly water-level altitude of Lake Huron, averaged from measurements made by the U.S. Army Corps of Engineers at sites near Essexville and Harbor Beach, and monthly precipitation measured in Bad Axe (National Oceanic and Atmospheric Administration [NOAA], 2002-04; Danny Costello, NOAA hydrologist, written commun., 2003-04). In March 2003, a new low-water level for the period of this study was measured in Lake Huron (National Oceanic and Atmospheric Administration, 2003; 2004). The net decline in the water level of Lake Huron from January 1, 2002 to December 31, 2003 was about 0.3 ft. Annual precipitation in 2002 was about 0.3 inches above normal, with much of it occurring during summer months. The provisional precipitation total for 2003 is about an inch below normal (NOAA, 2003, 2004; Danny Costello, NOAA hydrologist, written commun., 2003, 2004).

Four wells equipped with continuous-data recorders are completed in the glacial, Saginaw, and Marshall aquifers. Water levels in three of the four wells equipped with continuous-data recorders experienced a net decline over the period from January 2002 to December 2003, while the level in well H9r, completed in the Saginaw aquifer in Fairhaven Township adjacent to Saginaw Bay (Lake Huron), rose about 1.3 ft over the same period. Interestingly, the water level in Saginaw Bay declined about 0.3 ft over the same period. A period-of-record maximum depth to water was recorded in September 2003 in well H25Ar, completed in the Marshall aquifer in Lake Township. Hydrographs showing altitude of the water surface are presented for each of four wells equipped with continuous-data recorders.

Twenty three wells were measured on a quarterly basis in 2002-03. These wells are completed in the Saginaw and Marshall aquifers, and Coldwater confining unit. Although each quarterly measurement only provides a “snapshot” water level, the data adequately define the “generalized” water-level trend in the aquifer near the well. The water level in one quarterly-measured well completed in the Saginaw aquifer near Saginaw Bay, had a net rise for the period from January 2002 to December 2003, while levels in the other 22 quarterly-measured wells declined about 0.5 to 2.0 ft during the same period. A period-of-record minimum depth to water (high) was measured in 2002 in two quarterly-measured wells completed in the Saginaw aquifer, although the level in one of those wells had a net decline over the period from January 2002 through December 2003. Conversely, period-of-record maximum depths to water (low) were measured in 2002 in one well completed in the Saginaw aquifer and two wells completed in the Marshall aquifer; and in 2003, in 6 of 16 wells

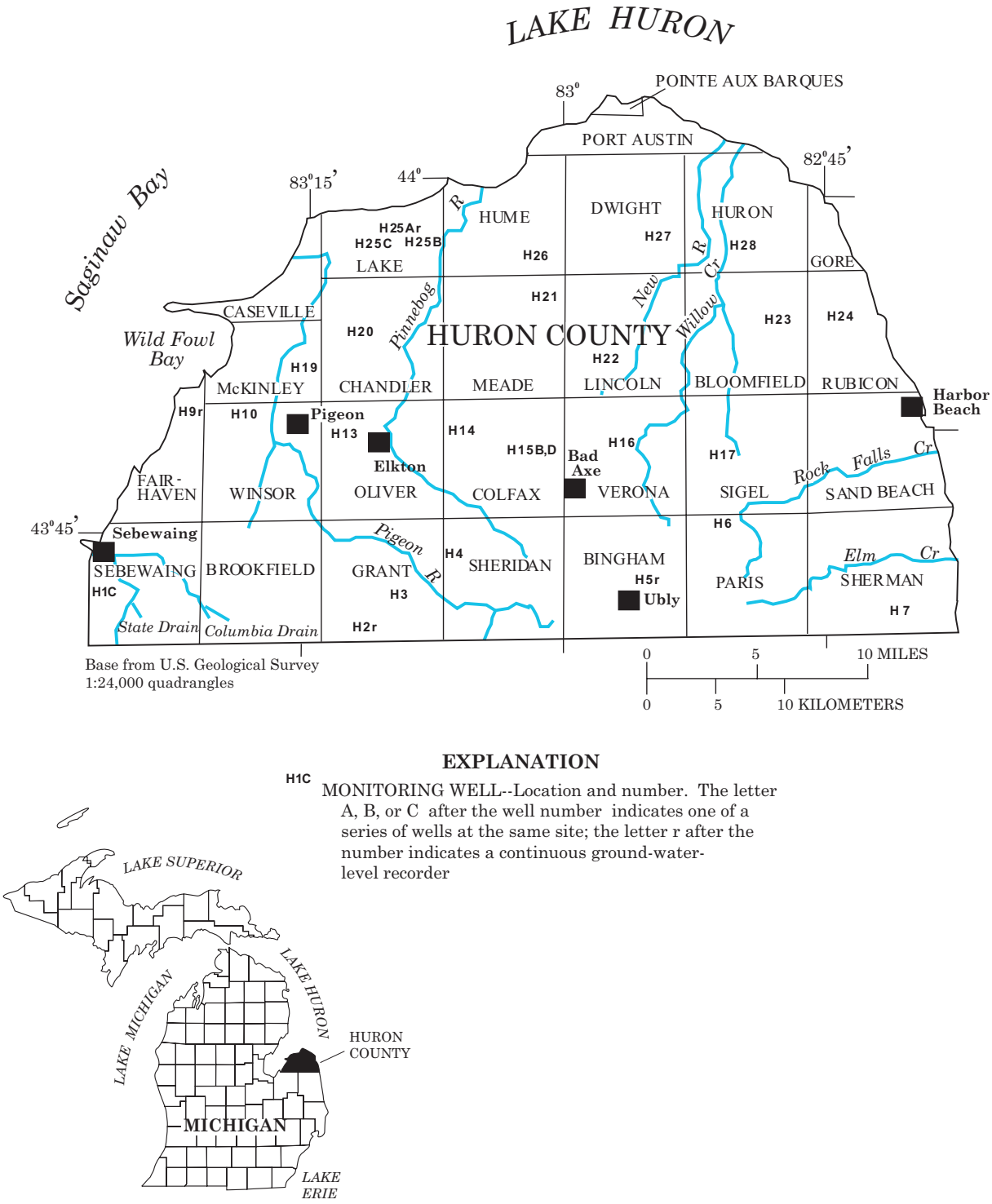


Figure 1. Location of monitoring wells in Huron County, Michigan.

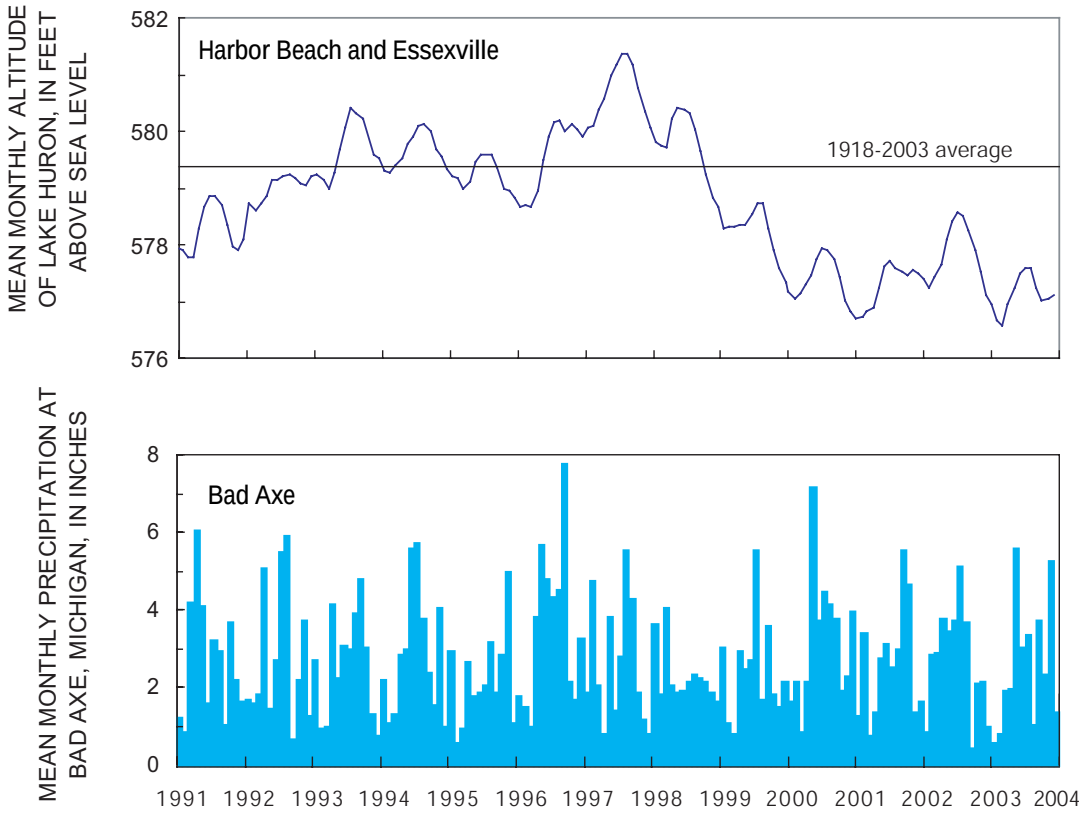


Figure 2. Monthly water-level altitude of Lake Huron averaged from measurements made at Harbor Beach and Essexville and monthly precipitation at Bad Axe, Huron County, Michigan.

completed in the Marshall aquifer. Near period-of-record maximum depths to water were measured in 2003 in two additional wells completed in the Marshall aquifer. No period-of-record minimum or maximum depths to water were measured in 2002-03 in wells completed in the Coldwater confining unit. Hydrographs showing water levels measured in each well are presented for the 23 wells measured on a quarterly basis.

Water-level trends measured in 2002-03 in other wells in Lower Michigan have similarities to those measured in Huron County wells. Several external factors appear to influence water-level trends including proximity to nearby production wells, amount and timing of precipitation events, evapotranspiration and type of prevalent ground cover, proximity of aquifer to the surface, and hydraulic characteristics of overlying geologic materials.

LAKE HURON LEVELS

Figure 2 shows the mean-monthly water-level altitude of Lake Huron, averaged from measurements made by the U.S. Army Corps of Engineers at sites near Essexville and Harbor Beach (NOAA, 2002-04), and monthly precipitation measured in Bad Axe (Danny Costello, NOAA hydrologist, written commun., 2003, 2004). In January 2002, the water level of Lake Huron was 0.70 ft higher than the previous January, and the level rose an additional 1.17 ft from February through June, before declining 1.46 ft from July through December. In January 2003, the water level was 0.44 ft lower than January 2002, and it declined an additional 0.38 ft through March, when a new low for the period of this study was established (NOAA 2003, 2004). The water level rose 1.03 ft from April through August, then declined 0.48 ft from September through December. Overall, the water level in Lake Huron declined about

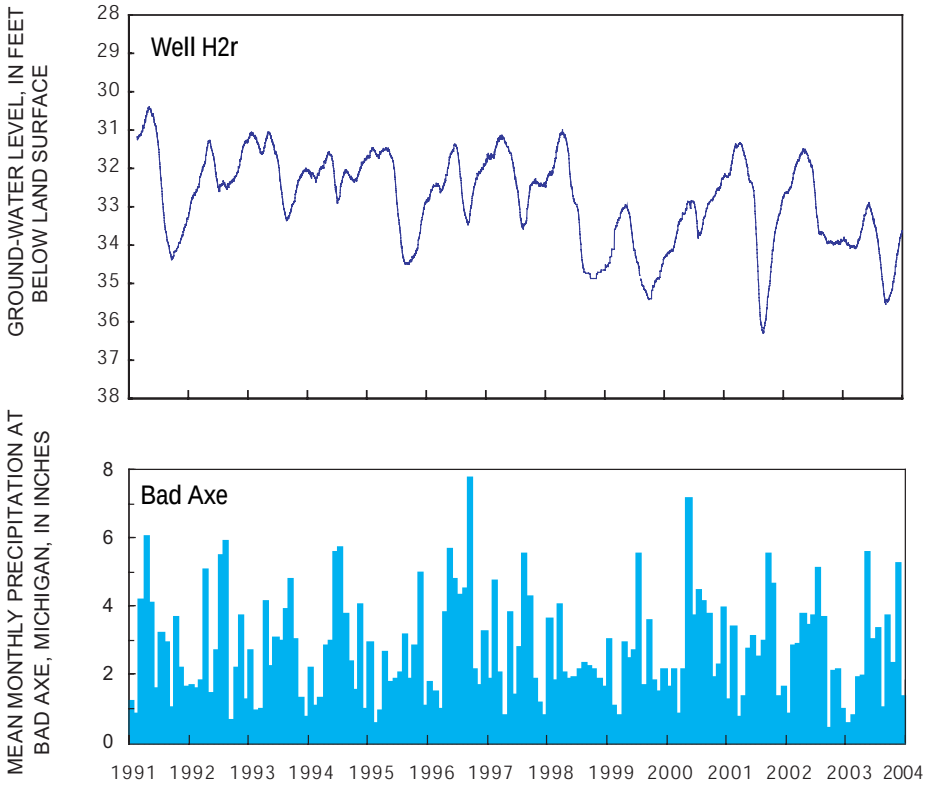


Figure 3. Depth below land surface of water in Grant Township well H2r and monthly precipitation at Bad Axe, January 1991 through December 2003, Huron County, Michigan.

0.3 ft during the period from January 1, 2002 to December 31, 2003.

PRECIPITATION

Average annual precipitation measured at Bad Axe, Michigan is 31.1 inches. Precipitation measured in 2002 was 31.4 inches, and the provisional precipitation total for 2003 is 30.3 inches (NOAA, 2001-03; Danny Costello, NOAA hydrologist, written commun., 2003, 2004). Distribution of precipitation during the growing season is an important factor that influences how much, if any, aquifer recharge occurs during those months. Precipitation during June, July, and August, 2002 was several inches greater than the same months in 2003 (fig. 2). As a consequence, water levels in most of the wells in 2002 were higher than they were in 2003.

GLACIOFLUVIAL AQUIFER WELL

The Grant Township well (H2r) is completed in the glaciofluvial aquifer. The well, which is 91 ft deep, is cased to 87 ft, and screened in unconsolidated sand from 87 to 91 ft. A continuous-data recorder was installed in February 1991 and operated continuously, with the exception of the period from October 1998 through February 1999, until it was discontinued on December 31, 2003.

Figure 3 shows the water level in well H2r compared with monthly precipitation measured at Bad Axe, Michigan. Unlike wells completed in deeper bedrock aquifers, shallow wells completed in unconfined glaciofluvial aquifers like H2r typically respond rapidly to precipitation. The water level is affected mostly by losses due to evapotranspiration and recharge from precipitation. In general, precipitation during the period from fall through early spring exceeds evapotranspira-

tion, allowing infiltrated water to recharge the aquifer and causing the water level to rise. From late spring through summer, evapotranspiration typically exceeds precipitation, and infiltration is minimized, causing the water level to fall.

In 2002, the water level in well H2r (measured in feet below land surface) rose from 32.75 ft on January 1 to a yearly minimum of 31.49 ft on May 2. After early-May, the water level declined about 2.5 ft through the end of September and then remained fairly constant through the remainder of the year. The yearly maximum of 33.99 ft occurred November 4 and 5. In 2003, the water level remained fairly constant until the end of March, before rising to a yearly minimum of 32.86 ft, which occurred June 8 and 9. The water level then declined to the yearly maximum of 35.54 ft, which occurred September 21 and 22. On December 31, the water level of 33.63 ft was about 0.9 ft lower than at year's end in 2001 (Weaver and McGowan, 2002). The period-of-record maximum depth to water in well H2r of 36.29 ft, which occurred August 29 and 30, 2001, was not exceeded in 2002-03.

National Weather Service data indicate that the precipitation deficit in Bad Axe in the fourth quarter of 2002 was about 6 inches (Danny Costello, NOAA hydrologist, written commun., 2003). The water level in the glacial aquifer probably remained stable during the period from fall 2002 through spring 2003, rather than rising which would have been more typical, because of the precipitation deficit. The water level in the glacial aquifer would probably have declined during the same period without the above-average precipitation that fell on Huron County from February through August 2002.

In 2003, Huron County personnel expressed interest in comparing localized-precipitation data and water level in a near-surface aquifer (Greg Renn, Huron Conservation District, written commun., 2003). Figures 4 and 5 show precipitation measured by an observer in Grant Township and the water level in well H2r for the period from May through September 2002, and May through August 2003, respectively. The precipitation totals for the two periods were 14.88 and 11.01 inches, respectively. In 2002, the significant precipitation in July and August appears to have truncated the typical summer decline in water level in H2r (fig. 4). In 2003, when precipitation in July and August was considerably less than in the same months in 2002, the water level in H2r declined throughout the period, and even a 2.4 inch rainfall event on July 11 made no appreciable difference in the trend except for a temporary rise lasting about 48 hours (fig. 5). Figures 4 and 5 illustrate both how rapidly the water level in the glacial aquifer can respond to precipitation events and how even large single precipitation events may have little or no long-term effect on the water level trend.

SAGINAW AQUIFER WELLS

The Fairhaven Township well (H9r) is completed in the Saginaw aquifer and is located on the County's western shore with Saginaw Bay, at the eastern edge of Wild Fowl Bay. The well is cased to 147 ft, and is open to limestone, shale, and sandstone of the Saginaw aquifer between 147 and 180 ft. A continuous-data recorder was installed in February 1991 and has operated since, except for short periods due to equipment malfunctions.

Sweat (1999) noted that the water level in well H9r shows normal seasonal fluctuations (fig. 6) that typically *precede* those of Lake Huron by 3 to 6 months. In 2001, the water level of Lake Huron rose 1.12 ft over the period from March through July and fell 1.46 ft from August through December, while the water level in H9r rose almost continuously from mid-September 2001 to mid-June 2002. Interestingly, the rise in water level in H9r during the very-dry period from October through December 2002 does *proceed* above-normal precipitation that fell from June through August by about 3 months. During the same period, water levels recorded in the other 3 wells equipped with continuous-data recorders stayed relatively constant or declined.

The water level in well H9r (measured in feet below land surface) was quite low during the period from mid-1998 to mid-September 2001. The water level began rising in mid-September 2001 and by December 31, 2002, had recovered about 2.5 ft. In 2002, the yearly maximum of 6.17 ft was recorded on January 31, before rising to a yearly minimum of 4.05 ft, on June 15. After mid-July, the water level remained fairly constant until early-October, when it began to rise again, and on December 31, it was 4.71 ft (the December 31, 2001 reading was 6.18 ft). In 2003, the yearly minimum of 4.33 ft was recorded on January 8. The data recorder failed on January 21 and no data were recorded until the next inspection on March 15. After March 15, the water level rose until mid-June before declining until September 14, when the yearly maximum of 6.75 ft was recorded. The water level rose after mid-September and was 5.25 ft on December 31, 2003. The period-of-record maximum depth to water in well H9r, of 12.30 ft, recorded on June 2, 1998, was not exceeded in 2002-03.

Water levels measured quarterly in four wells completed in the Saginaw aquifer are included in table 1. Wells are listed using the identifier shown in figure 1.

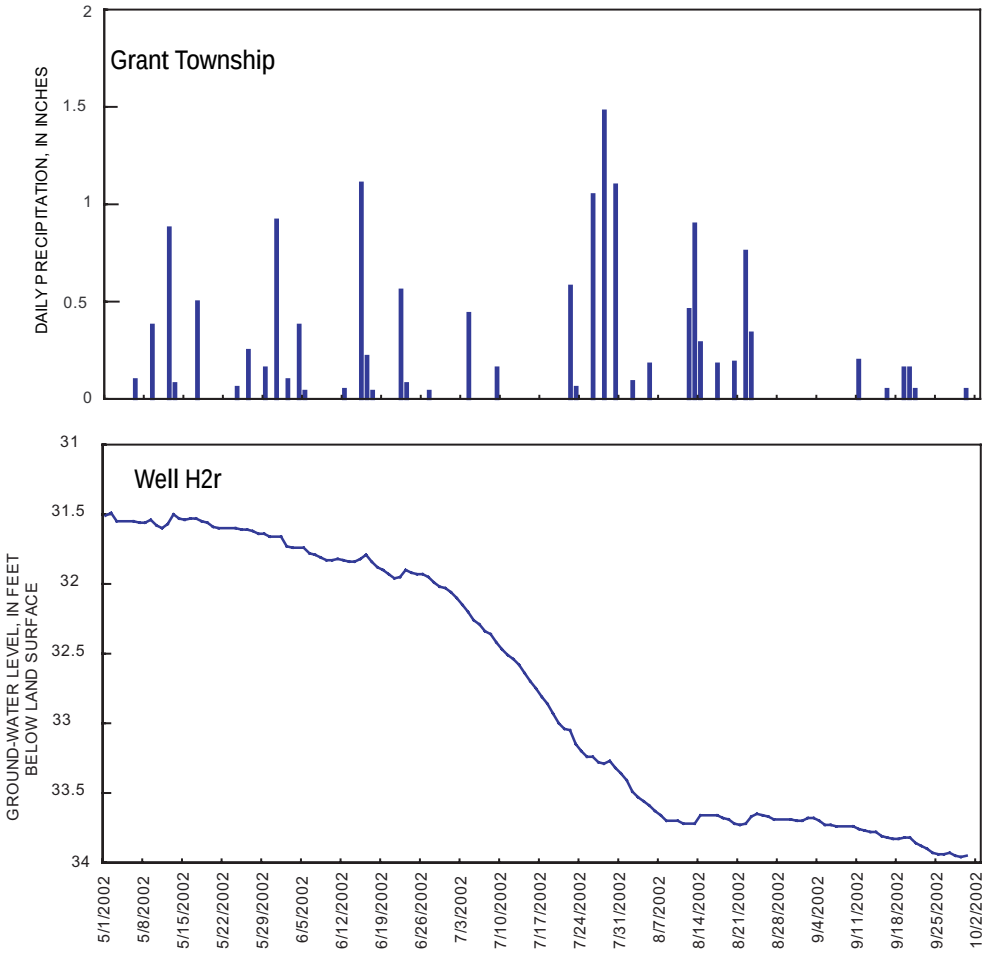


Figure 4. Daily precipitation measured in Grant Township and depth below land surface of water in Grant Township well H2r, May through September 2002.

Water levels are determined by measuring the distance from the top of the well casing (a measuring point with a known elevation with respect to land surface and sea level) to the water surface. The hydrographs in figure 7 illustrate water levels measured quarterly and a generalized water-level trend for the period from 1988 through 2003. Water levels in all four wells rose in the first one or two quarters of 2002, and period-of-record minimum depths to water were measured in well H10 in March, and well H13 in June. Water levels in the wells except H1C, primarily fell throughout the remainder of 2002, and a period-of-record maximum depth to water was measured in well H20 in December. The general water level trend in wells H10, H13, and H20 was stable or downward during the period from January 2002 to September 2003, with some recovery noted in the last quarter, particularly in well H13. Inexplicably, the water level in H1C rose about 2.0 ft during the same period. No period-of-record minimum or maximum depths to water were measured in the wells in 2003.

The water level trend measured in 2002 in well H20, which is located in Chandler Township, is somewhat different than that observed in the other wells completed in the Saginaw aquifer. The water level in H20 declined precipitously from March through December. A decline of similar magnitude also occurred in H20 in 1998, and continued through March 2000. In contrast with the other quarterly-measured wells completed in the Saginaw aquifer, the trend in water level in well H20 has continued to decline since 1998. Notably, Huron County and other governmental agencies expressed interest in the water level in well H20 during the first half of 2003 as a large commercial agricultural operation was being developed in Chandler Township north of the well. This facility withdraws water from the Marshall aquifer, and, the effect of this water withdrawal on

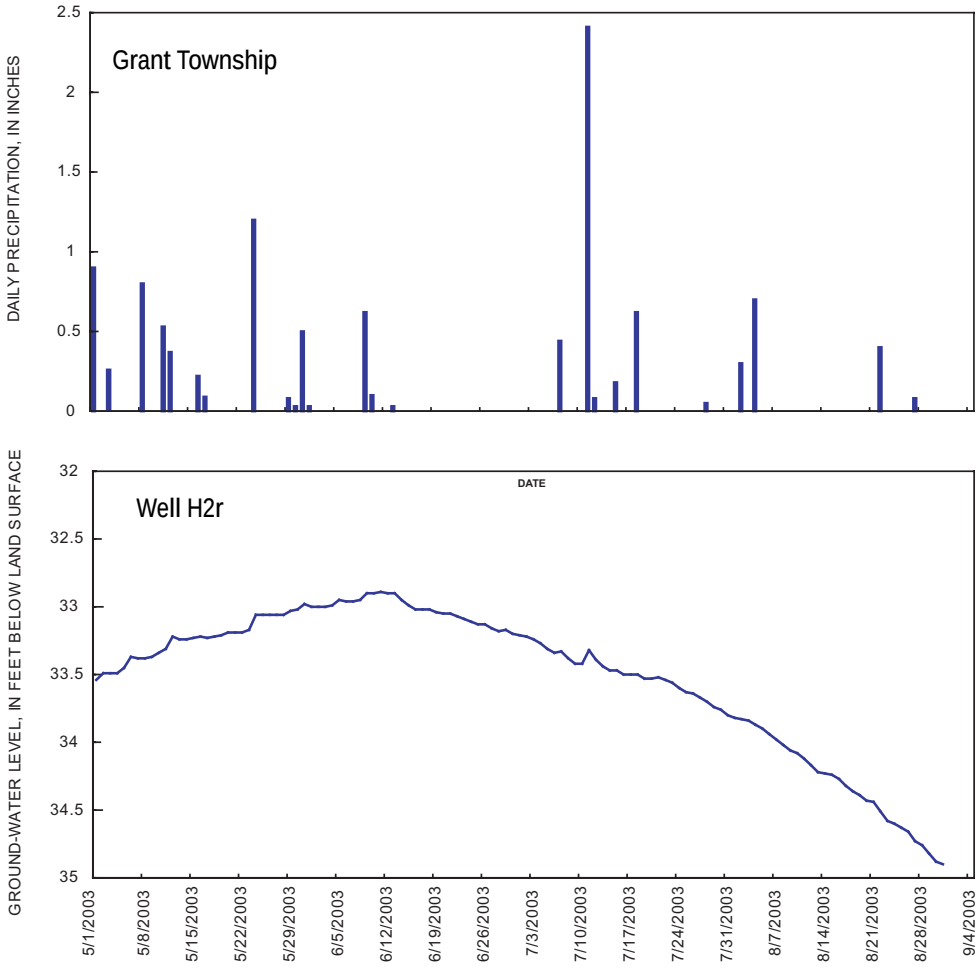


Figure 5. Daily precipitation measured in Grant Township and depth below land surface of water in Grant Township well H2r, May through August 2003.

the water level in well H20 is unknown.

In previous years, the water level in H1C, which is located near Saginaw Bay south of Sebewaing, did not appear to behave in the same manner as the other wells completed in the Saginaw aquifer. This behavior is evident during 2002-03 as well. During the period of this study, the water level in H1C has previously appeared to mimic changes in levels of Lake Huron more closely than any other well in the County, albeit with some delay. Interestingly, that pattern does not seem to hold true during 2002-03, as the water level in well H1C rose, while the level of Lake Huron declined about 0.3 ft. Curiously, no known decreases in water withdrawals are taking place near well H1C and no other external factors are known to have changed that would account for the significant rise in water level in the well (Dale Lipar, Huron County Health Department, oral commun., 2004).

Water levels in wells H9r and H1C experienced a net rise during the period from January 2002 to December 2003, while levels in the other 3 wells completed in the Saginaw aquifer declined during the same period.

MARSHALL AQUIFER WELLS

Two wells instrumented with continuous-data recorders are completed in the Marshall aquifer. The Bingham Township well (H5r) is 170 ft deep, cased to 70 ft below land surface, and open to sandstone and shale of the Marshall aquifer from 70 to 170 ft. It is located 1 mile north of the village of Ubly, near a former landfill site. A continuous data recorder was initially installed in December 1988 and was operated until late-March 1990. The recorder was reinstalled in January 1993 and, except for three months in early 1993, operated continuously until December 31, 2003, when it was discontinued. In addition to normal seasonal fluctuation, the water level in well H5r is also affected by withdrawal

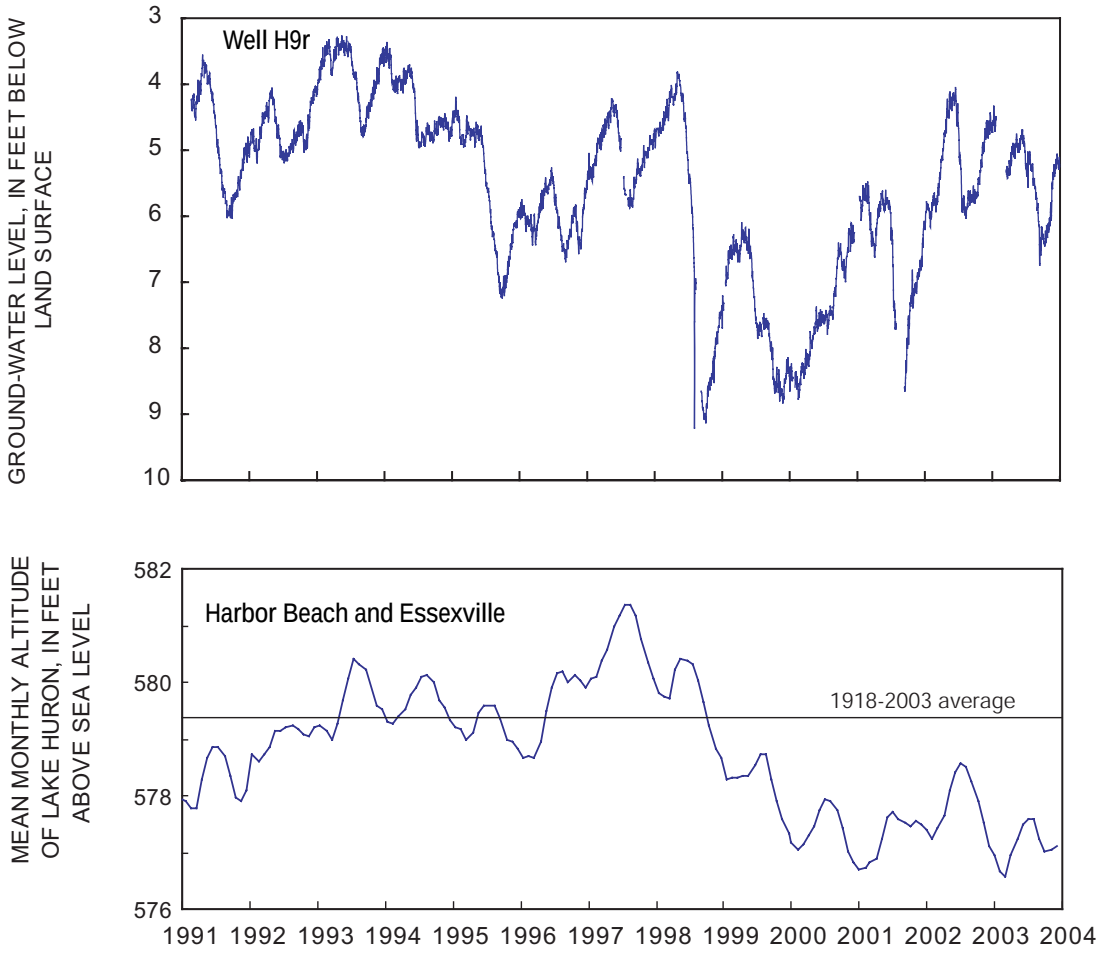


Figure 6. Depth below land surface of water in Fairhaven Township well H9r, and monthly water-level altitude of Lake Huron averaged from measurements made at Harbor Beach and Essexville, January 1991 through December 2003, Huron County, Michigan.

at a nearby public-water-supply well belonging to the Village of Ubly. Rapid, cyclical variations in water levels are typical when large-capacity production wells cycle on and off in response to system demands. These cyclical variations, which are notable in data from H5r for the periods 1989 to 1990 and 1993 to 1994, have been more subdued during recent years (fig. 8).

On January 1, 2002 the water level in well H5r (measured in feet below land surface) was 11.28 ft and remained relatively constant from January through mid-February, after which it rose to a yearly minimum of 9.66 ft on April 15. After mid-April, the water level declined until the yearly maximum of 12.99 ft was recorded on October 2. The water level remained relatively stable for the remainder of 2002, and on December 31 it was 12.94 ft. In 2003, the water level trended downward until mid-March, after which it began to rise. The yearly minimum of 11.26 ft was recorded on June 11. After mid-June, the water level began declining again, and a yearly maximum of 13.54 ft was recorded on September 7, after which it recovered considerably, and on December 31 was 11.62 ft. The period-of-record maximum depth to water of 16.38 ft below land surface, which was recorded on July 26, 1989, was not exceeded in 2002-03.

The Lake Township well (H25Ar) is 200 ft deep, cased to 179 ft, and open to sandstone of the Marshall aquifer from 179 to 200 ft. It is located on the southern shore of Rush Lake in northwestern Huron County, and is the deepest of three adjacent wells at the site. A continuous-data recorder was first installed in September 1988 and began collecting data in October 1988 and operated until September 1989. The recorder was reactivated in December 1992 and has operated continuously since. In addition to normal seasonal variation, the water level in H25Ar is also affected by withdrawals from nearby irrigation wells (fig. 9).

Table 1. Depth to water for wells measured quarterly, Huron County, Michigan, 2002-03. [S, indicates well in Saginaw aquifer; M, indicates well in Marshall aquifer; C, indicates well in Coldwater confining unit; **BOLD** type indicates a new maximum depth to water for period-of-record, ***BOLD Italic*** type indicates a new minimum depth to water for period-of-record].

Well identifier	Aquifer code	Altitude of measuring point, in feet	Depth to water below land surface, in feet								
Date of measurement			Period of record maximum	3/02	6/02	9/02	12/02	3/03	6/03	9/03	12/03
H1C	S	600.00	26.67	16.88	16.18	16.17	15.76	17.91	15.62	17.43	15.74
H3	M	731.70	34.80	27.29	27.54	29.72	29.51	30.15	28.79	31.01	29.59
H4	M	751.60	14.98	11.18	11.72	13.55	14.60	**14.98**	12.84	14.59	13.16
H6	M	781.50	17.48	12.50	12.66	15.51	17.43[a]	17.47	14.12	16.51	14.92
H7	C	726.80	16.94	15.19	15.03	15.55	15.88	16.00	15.87	16.31	15.92
H10	S	617.07	27.50	***21.11***	22.27	23.02	23.07	22.98	22.66	23.41	23.23
H13	S	642.35	36.90	27.37	***26.58***	29.49	28.65	28.54	28.33	32.30	29.33
H14[b]	M	681.30	10.79	6.06	6.06	8.61	8.22	9.17	7.35	10.24	7.72
H15B	M	751.20	22.7	16.67	17.22	19.23	19.88	20.46	17.86	21.89	18.51
H15D[c]	M	unknown	25.34	19.29	19.78	22.64	22.03	22.59	20.71	**25.34**	21.26
H16	M	771.50	34.15	30.23	28.92	32.11	32.46	33.60	31.05	**34.15**	32.23
H17	M	751.00	28.09	6.25	6.22	22.46	11.19	11.21	7.29	9.01	8.34
H19	M	611.90	6.13	3.04	3.61	3.41	3.09	4.29	5.68	5.41	4.88
H20	S	631.00	17.22	13.65	13.79	14.38	**17.22**	15.85	15.23	15.55	16.19
H21	M	702.90	13.21	7.61	8.18	9.89	12.25	13.13	8.46	10.62	10.42
H22	M	695.50	18.68	13.14	13.49	16.06	18.09	**18.68**	14.92	16.54	15.82
H23	C	721.80	10.37	8.87	8.77	8.99	8.96	9.16	9.21	9.88	9.53
H24	C	691.50	29.04	24.92	24.80	25.72	27.15	26.87	26.04	26.19	26.05
H25B	M	601.00	5.70	1.11	1.57	3.45	4.61	5.07	2.67	**5.70**	3.76
H25C	M	602.20	5.28	0.97	1.92	3.46	3.98	4.29	2.19	4.80	3.06
H26	M	662.70	16.1	0.86	1.99	3.65	6.49	6.97	1.75	5.58	3.43
H27	M	716.50	37.66	31.96	32.10	34.66	36.29	37.14	35.23	36.39	34.81
H28	M	691.70	24.30	17.26	18.27	22.12	**23.94**	**24.30**	20.24	21.93	19.88

[a] Period-of-record maximum depth was also measured in Dec. 98

[b] Previous listed period-of-record maximum depth was probably measured before well equilibrated after being drilled

[c] Well drilled September 1997

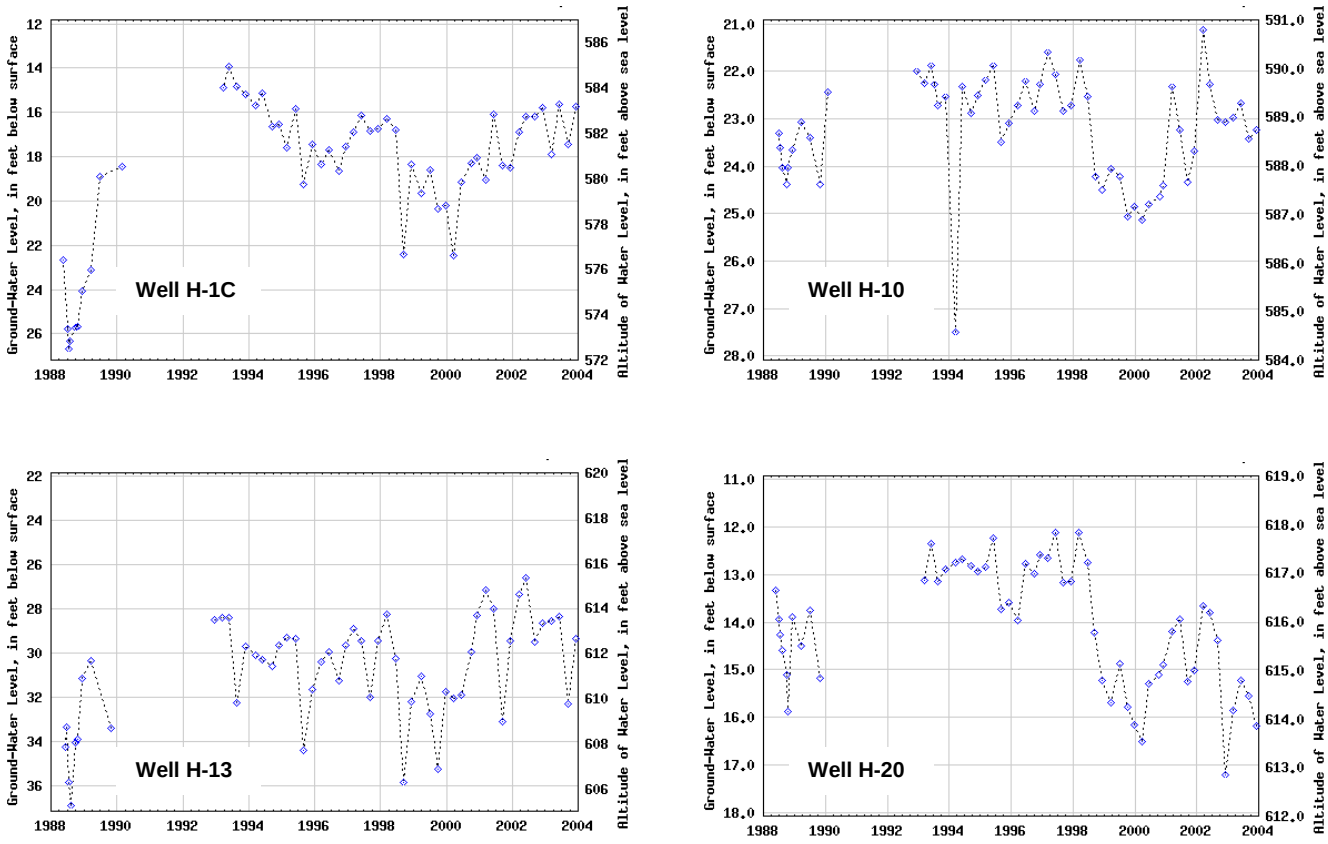


Figure 7. Altitude and depth below land surface of water measured quarterly in wells completed in the Saginaw aquifer for the period 1988 through 2003. Huron County, Michigan. (Dashed lines connecting measurements are included for illustrative purposes only and may not depict the altitude of water in wells between measurements.)

On January 1, 2002, the water level in well H25Ar (measured in feet below land surface) was 7.18 ft and it remained relatively constant throughout January, then decreased to a yearly minimum of 6.14 ft on May 2. After early-May, the water level remained steady, or declined, until December, when the yearly maximum of 9.65 ft was reached several times. The December 31, 2002 reading was 9.61 ft. The water level continued to decline until mid-March 2003, then rose to a yearly peak of 7.87 ft on June 18. After June, the water level declined through early September, although brief rises were recorded in July and August. On September 10, a period-of-record maximum depth to water of 10.96 ft was recorded. After mid-September, the water level recovered considerably, and on December 31, 2003 it was 8.48 ft.

Water levels measured quarterly in 16 wells completed in the Marshall aquifer are included in table 1. Wells are listed by an identifier shown in figure 1. The hydrographs in figures 10a and 10b illustrate water levels measured quarterly and generalized water level trends for the period from 1988 through 2003. In 2002, water levels in all of the wells ranged two or more feet throughout the year. In most of the wells, water level trends were similar, rising through the first quarter in all 16 wells, remaining constant or declining through the second quarter in 15 wells, and falling in the third and fourth quarters in 15 wells and 11 wells, respectively. Well H19 was the exception again in 2002, as it has been in previous years, with rising water levels in the third and fourth quarters. Water levels measured in 12 of the 16 wells in December 2002, were more than 1 ft lower than December 2001 readings. The largest net decline was measured in well H28, where the December 2002 level was 4.65 ft lower than the December 2001 reading, establishing a period-of-record maximum depth

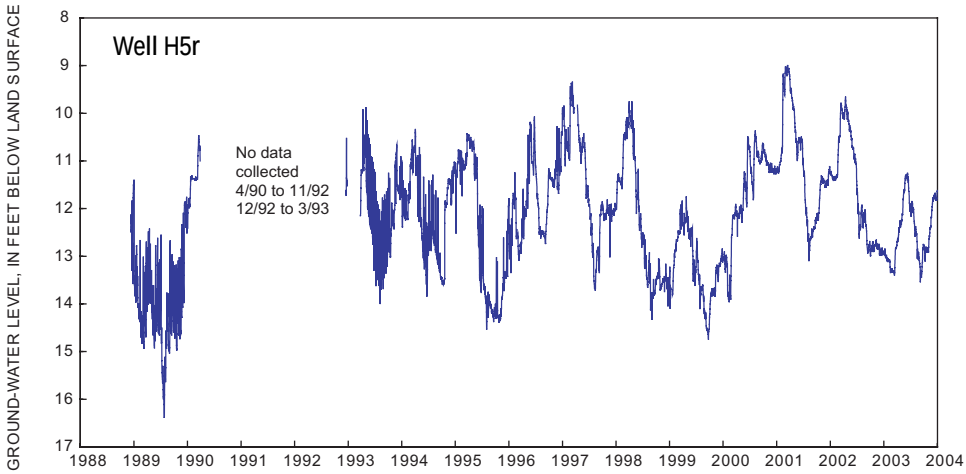


Figure 8. Depth below land surface of water in Bingham Township well H5r, December 1988 through December 2003, Huron County, Michigan. (Recorder not operated from April 1990 to November 1992, December 1992 to March 1993.)

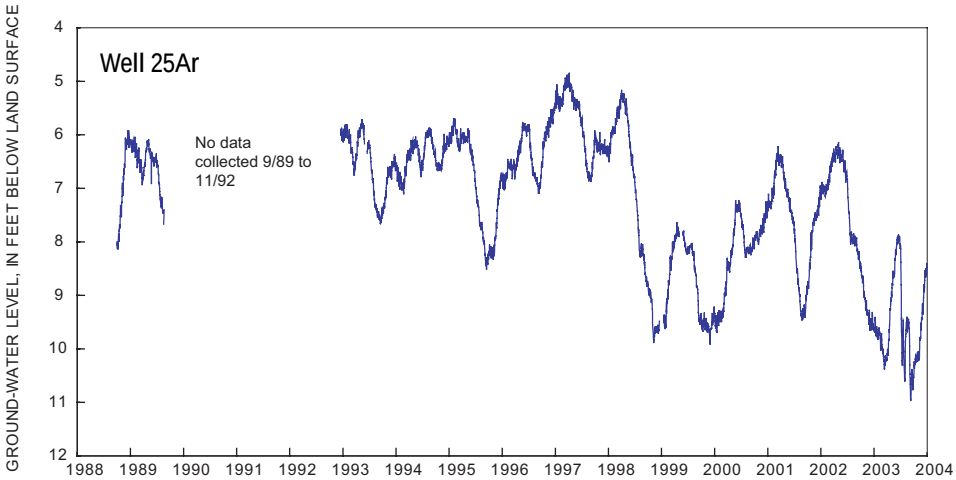


Figure 9. Depth below land surface in Lake Township well H25Ar, October 1988 through December 2003, Huron County, Michigan (Recorder not operated from September 1989 to November 1992.)

to water. The period-of-record maximum depth to water in well H28 was exceeded again in March 2003. Only well H19 had a measured water level in December 2002 that was higher than December 2001. In 2003, water level trends in 12 of 16 wells were similar, declining in the first and third quarters, and rising in the second and last quarters. Water levels in wells H6 and H17, which are located in adjacent Townships, were stable in the first quarter but similar to the larger group in the remaining three quarters. The water level in well H19 declined in the first two quarters, but rose in the final two quarters. The water level in well H27, rose in the first quarter, fell in the second quarter, and rose in the last two quarters.

The water level in well H17 typically responds to nearby irrigation well withdrawals in Sigel Township, ranging as much as 25 ft in a year (Solley and others, 1990, p. 37; Solley and others, 1995, p. 35; Jim LeCureux, Michigan State University Extension Service, Huron County, oral communication, 1997, 1998;

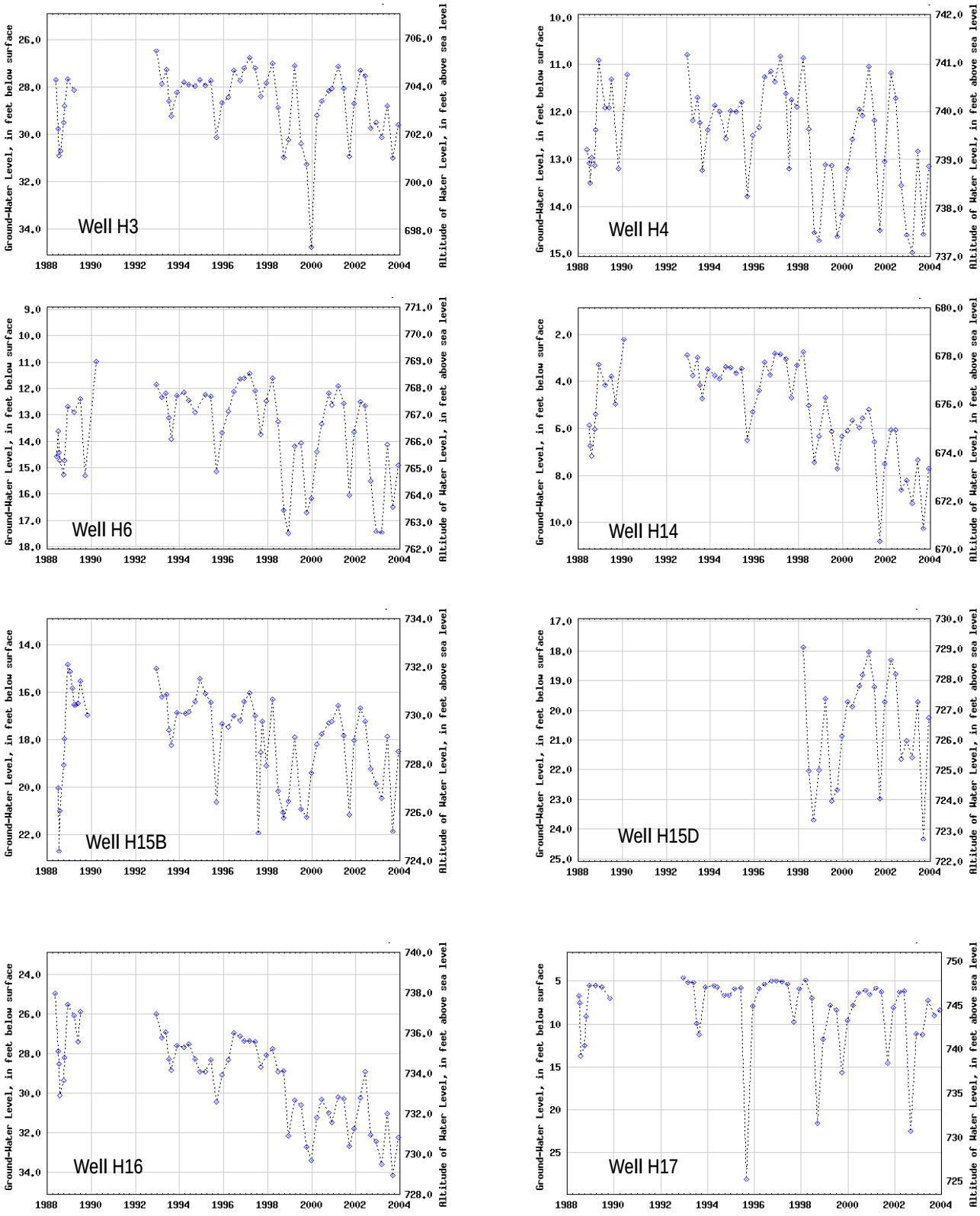
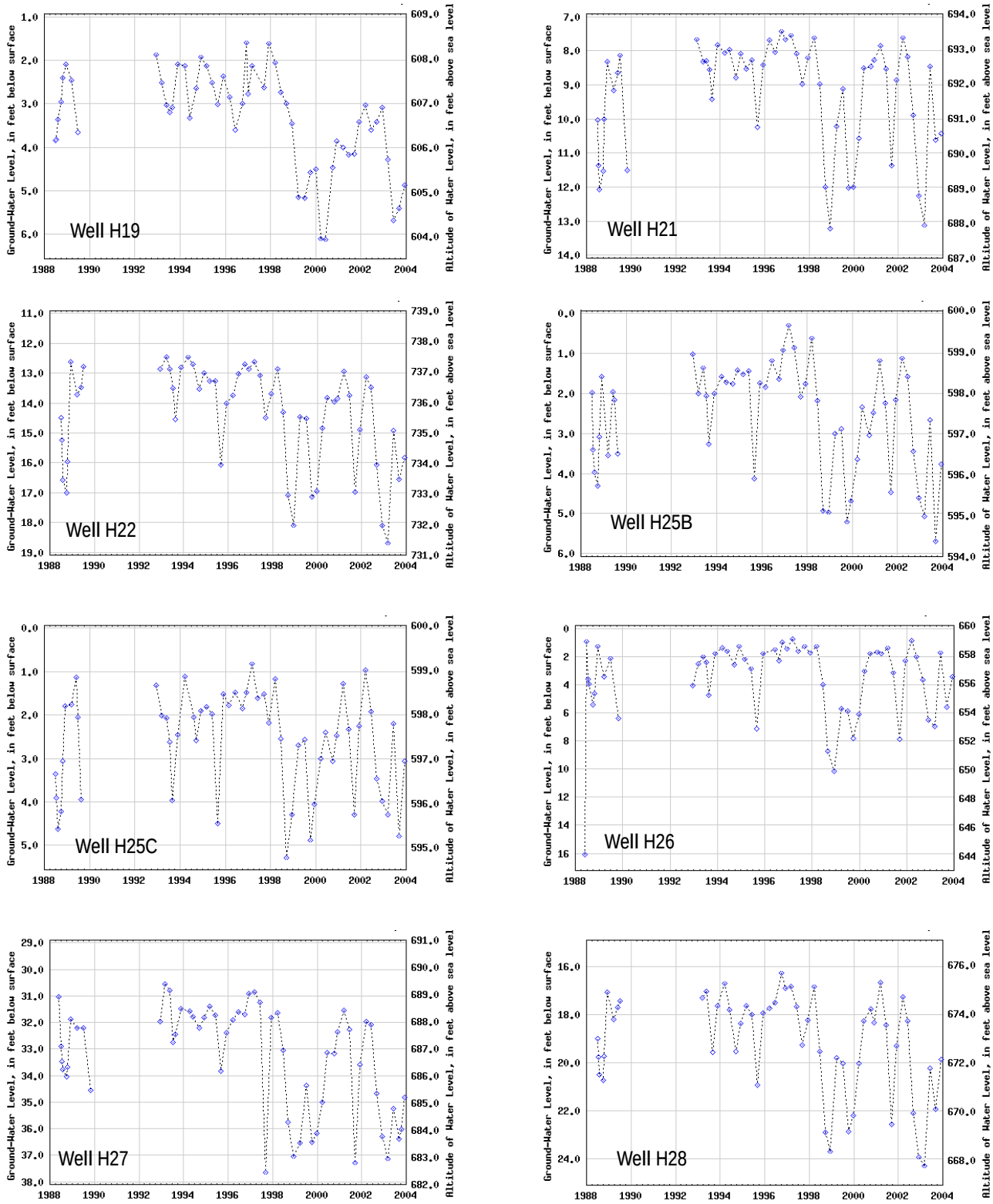


Figure 10a. Altitude and depth below land surface of water measured quarterly in wells completed in the Marshall aquifer for the period 1988 through 2003, Huron County, Michigan. (Dashed lines connecting measurements are included for illustrative purposes only and may not depict the altitude of water in wells between measurements.)



10b. Altitude and depth below land surface of water measured quarterly in wells completed in the Marshall aquifer for the period 1988 through 2003, Huron County, Michigan. (Dashed lines connecting measurements are included for illustrative purposes only and may not depict the altitude of water in wells between measurements.)

Sweat, 1999; Weaver, Luna, and Sweat, 2000; Weaver, 2001; Weaver and McGowan, 2002). In 2002, irrigation withdrawals continued and water levels declined about 16 ft between the second- and third-quarterly measurements. In contrast, the decline in water levels in the other wells completed in the Marshall aquifer over the same period was always less than 4 ft, and typically less than 3 ft. In 2003, much of the year's precipitation fell during the agricultural growing season (Danny Costello, NOAA hydrologist, written commun., 2004), lessening the need for irrigation withdrawals, and the range in water level in well H17 was only about 4 ft.

Illustrative of the hydraulic differences between geologic formations, with known external factors minimized, the water level trends in well H19, completed in the Marshall aquifer, and well H20 (fig. 7), interpreted as being completed in an outlier of the Saginaw aquifer several miles to the east, are largely the inverse of one another through the second half of 2002 and all of 2003. The water level in H20 appears to mimic precipitation, while trends in H19 lag 3 to 6 months behind. This observation was not unexpected, but at this location the physical connection between the Saginaw aquifer, which conformably (directly) overlies the Marshall aquifer, would seem to provide a direct conduit between the two aquifer units. An impediment to water flow between the two aquifer units, such as a confining layer, must be present at this location, leading to the observed differences in water level trends.

In general, in 2002, water levels in most wells completed in the Marshall aquifer were similar to those measured in 2001 (Weaver and McGowan, 2002). Period-of-record maximum depths to water were measured in wells H20, and H28 in December 2002. Additionally, the water level in well H6 was less than 0.1 ft above the period-of-record maximum depth to water when measured in December 2002 and March 2003. In 2003, water levels in many of the wells declined somewhat compared to 2001-02, and period-of-record maximum depths to water were measured in wells H4, H15D, H16, H22, H25Ar, H25B, and H28, and near period-of-record maximum depths to water were also measured in wells H6 and H21 in the first quarter. *Water levels in all wells completed in the Marshall aquifer experienced a net decline during the period from January 2002 to December 2003*.

COLDWATER CONFINING UNIT WELLS

There are no wells completed in the Coldwater confining unit with continuous-data recorders because water levels are not expected to vary rapidly in this unit. Relatively stable or slowly changing water levels are typical of wells completed in low-hydraulic conductivity rocks from which little, if any, water is produced, and into, or through which, only small amounts of water can pass under non-stress conditions.

Water levels measured quarterly in three wells completed in shale, sandstone, and sandy shale of the Coldwater confining unit are included in table 1. Wells are listed by an identifier shown in figure 1. The hydrographs in figure 11 illustrate water levels and generalized water level trends for the period from 1988 through 2003. Water levels in all three wells rose in the first two quarters of 2002, but primarily fell throughout all but the second and last quarters of 2003. Interestingly, the variations in water levels in these wells closely mimics variations in the water level of Lake Huron. No period-of-record minimum or maximum depths to water were measured in 2002-03 in wells completed in the Coldwater confining unit. *Water levels in all three wells completed in the Coldwater confining unit experienced a net decline during the period from January 2002 to December 2003*.

COMPARISON WITH REGIONAL GROUNDWATER TRENDS

USGS has recently completed water-resources investigations in Ingham, Kalamazoo, and Monroe Counties, largely in response to declining water levels. USGS maintains a number of observation wells for purposes of monitoring ground-water levels across the state. Many of the wells are equipped with continuous-data recorders including Petersburg Deep well in Monroe County (figure 12) and Portage School 4 well in Kalamazoo County (figure 13). The Petersburg Deep well is completed at a depth of 72 ft in Devonian carbonate rocks, while the Portage School 4 well is completed at a depth of 102 ft in glacial sand and gravel. Quarries in Monroe County have impacted water levels in the region, but the Petersburg Deep well appears to define generalized ground-water levels in the far-southeastern part of Michigan. Although the water level in Portage School 4 is affected somewhat by nearby public and industrial water supply well withdrawals, it appears to define generalized ground-water levels in southwestern Michigan. Figure 14 shows the depth below land surface of water in Petersburg Deep, Portage School 4, and Huron County H2r and H5r wells normalized to Huron County well H25Ar for the period from January 2002 through December 2003. Normalization of the water-level trends of the five wells is necessary because water levels in the wells typically range from about 6 to 53 ft, making comparison of the raw data difficult. The water-level trends of Petersburg Deep, Portage School 4, and Huron County H2r and H5r wells were altered to have a range similar to well H25Ar by subtracting the amount necessary to make the water levels equal on January 1, 2002. In 2002, the trend of water levels measured in Petersburg Deep, Portage School 4, and Huron County wells H2r and H5r were quite similar, particu-

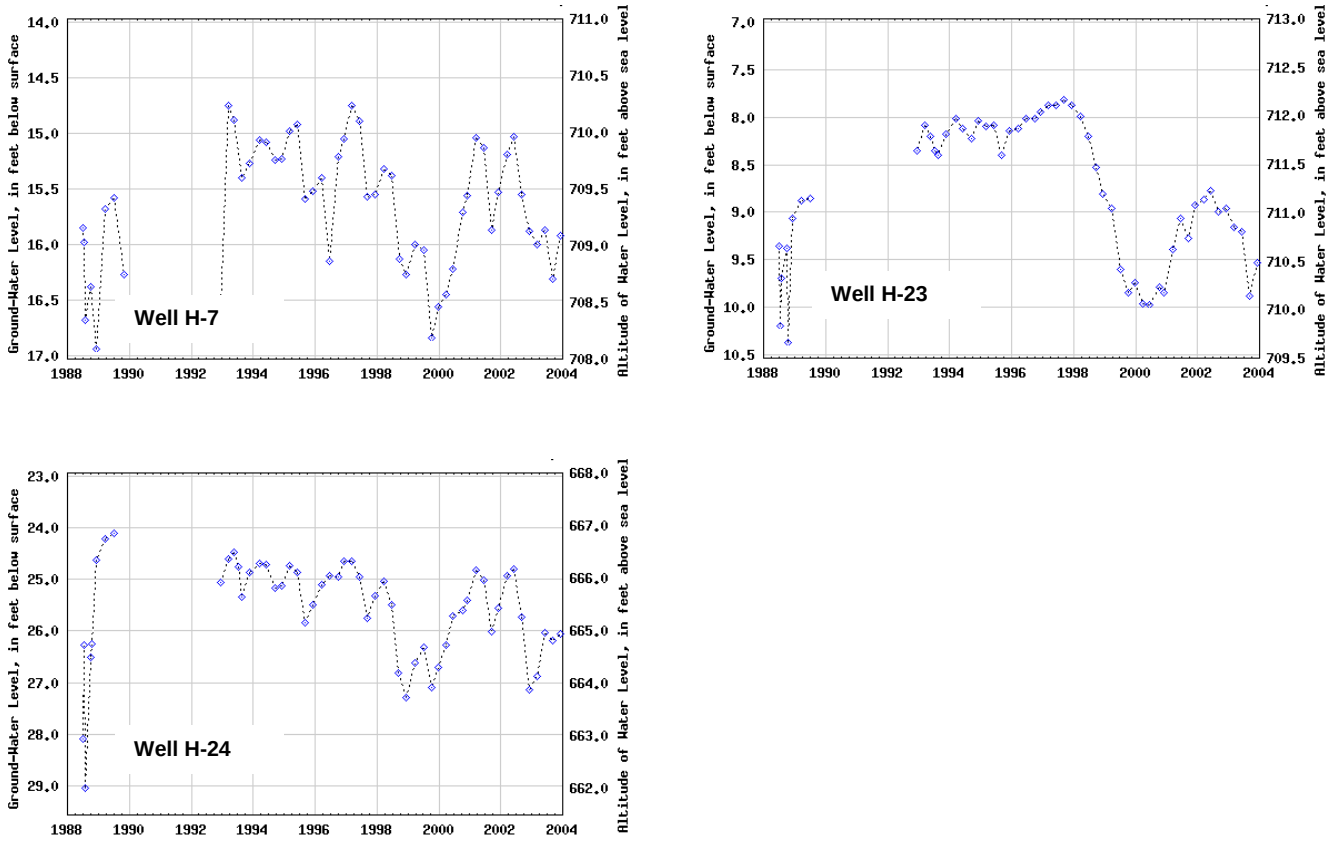


Figure 11. Altitude and depth below land surface of water measured quarterly in wells completed in the Coldwater confining unit for the period 1988 through 2003, Huron County, Michigan. (Dashed lines connecting measurements are included for illustrative purposed only and may not depict the altitude of water in wells between measurements.)

larly after the first quarter; levels in all three of the wells rose through early summer and then fell in the third quarter, before stabilizing in the last quarter, except Portage School 4, where the stabilization appears to lag by several months behind the other wells. The water level trend of well H9r is dissimilar to the trends of the other Huron County wells and the Petersburg Deep and Portage School 4 wells and was not considered for this part of the report. In 2003, water level in the Petersburg Deep well diverges from the above-listed wells and continues a general decline through the entire year even though levels recovered somewhat by June in Portage School 4, and Huron County wells H2r, H5r, and H25Ar.

Note that the water level trends measured in some wells completed in various aquifers throughout the state are somewhat similar, while others that might be predicted to behave similarly due to physical characteristics, are dissimilar. This is one reason why additional statewide ground-water-level monitoring is needed.

It is also notable that ground-water levels have recovered somewhat from period-of-record or near period-of-record maximums in 1998-early 2000 in some wells in Huron and Kalamazoo Counties, while levels in other wells including the Petersburg Deep well in Monroe County have continued to decline. External factors that may affect water levels include proximity to nearby

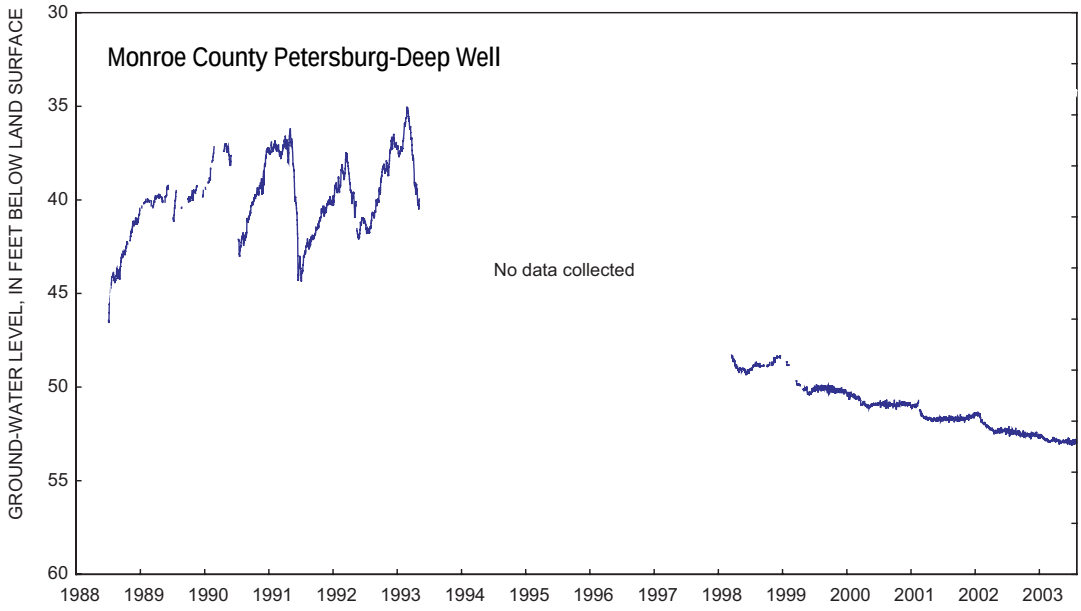


Figure 12. Depth below land surface of water in Petersburg Deep well, Monroe County, January 1988 through December 2003.

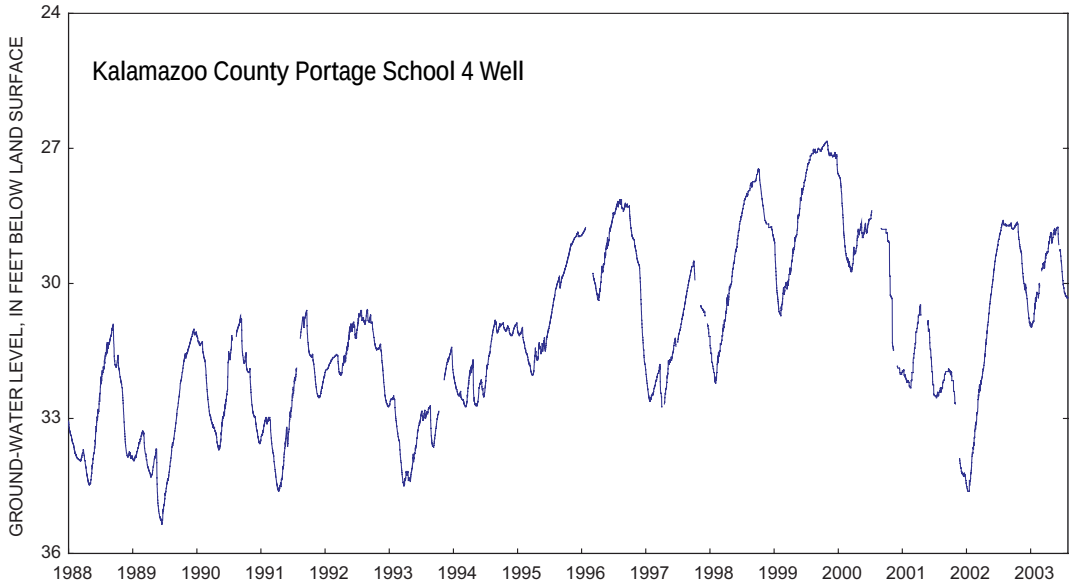


Figure 13. Depth below land surface of water in Portage School 4 well, Kalamazoo County, January 1988 through December 2003.

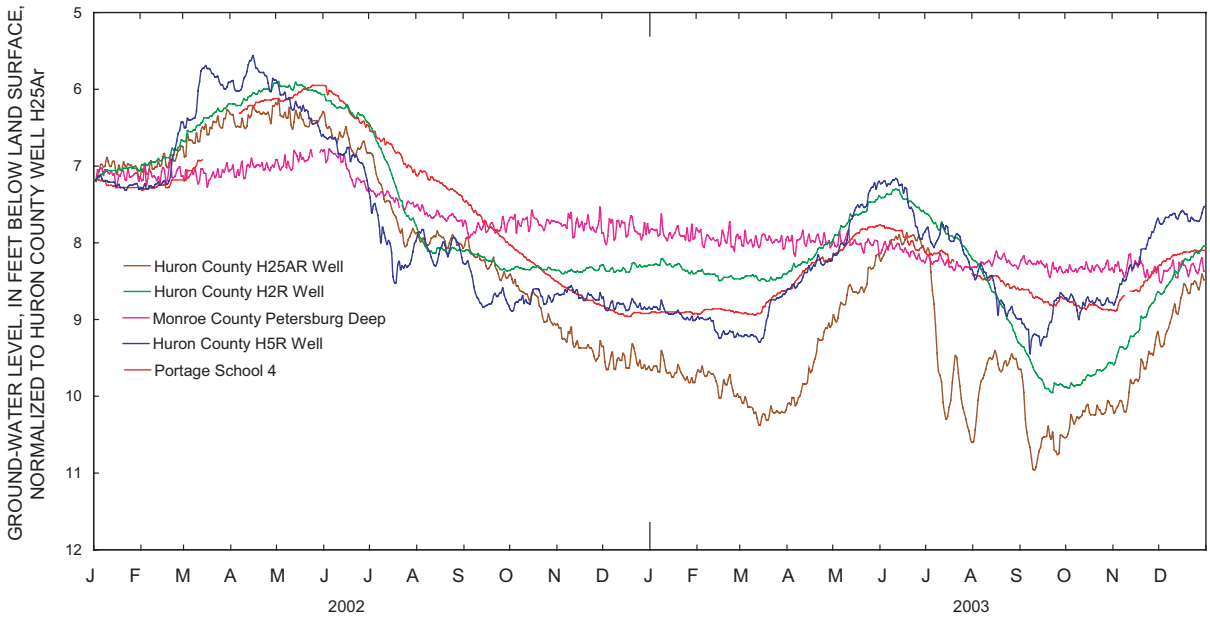


Figure 14. Depth below land surface in Petersburg Deep well, Portage School 4 well, and Huron County well H2r and H5r wells normalized to Huron County well H25Ar, January 2002 through December 2003. Water-level trends of Petersburg Deep, Portage School 4, and Huron County H2r and H5r wells have been altered to have the same initial water level as well H25Ar for illustrative purposes and do not display actual water levels in those wells.

production wells, variation in the amount and timing of precipitation and evapotranspiration, and proximity of the aquifer to either land surface or conductive overlying materials. One or more localized external factor apparently is causing the continuing decline of the water level in the Petersburg Deep well in Monroe County, since wells in Kalamazoo and Huron Counties are not affected similarly.

SUMMARY

Most wells in Huron County had similar water level trends in 2002-03, with an overall decline in levels ranging from about 0.5 to 2.0 ft. These affected wells include the single well completed in the glacial aquifer, 3 of 5 wells completed in the Saginaw aquifer, all 18 wells completed in the Marshall aquifer, and the 3 wells completed in the Coldwater confining unit. The trend of water levels in many, if not most, of the wells in 2002-03 was typical, but dry conditions in fall and early winter 2002 appear to have impacted wells completed in the Marshall aquifer most dramatically in 2003.

Water-level trends in several wells were notable because they differ from those of nearly all the others. Period-of-record minimum depths to water were measured in 2002 in wells H10 and H13, completed in the Saginaw aquifer. Water levels in H13 may still be recovering due to changes in regional ground-water withdrawals (Village of Pigeon is no longer using ground-water for it's municipal water supply). Period-of-record maximum depths to water were measured in 2002 in wells H6, H20, and H28; and in 2003 in wells H4, H15D, H16, and H22, H25Ar, H25B, and H28 which are all completed in the Marshall aquifer, with the exception of H20. In 2003, near period-of-record maximum depths to water were measured in wells H6 and H21, which are also completed in the Marshall aquifer. Interestingly, the two wells with rising water-level trends, H1C and H9r, are located close to Saginaw Bay (Lake Huron), which had a slightly-declining water level over the period from January 2002 to December 2003.

Water-level trends in wells completed throughout Lower Michigan are affected by several external factors, including proximity to nearby production wells, amount

and timing of precipitation events, evapotranspiration and type of prevalent ground cover, proximity of aquifer to the surface, and hydraulic characteristics of overlying geologic materials. Water level trends in some wells in Huron, Kalamazoo, and Monroe Counties are similar, although the long-term trend of the water level in the Petersburg Deep well located in Monroe County differs somewhat.

Notably, water levels in 25 of 27 wells measured as part of the Huron County study experienced a net decline during the period from January 2002 to December 2003.

SELECTED REFERENCES

Holtschlag, D.J. and Sweat, M.J., 1998, A temporal and spatial analysis of ground-water levels for effective monitoring in Huron County, Michigan: U.S. Geological Survey Open-File Report 98-629, 24 p.

National Oceanic and Atmospheric Administration, 1988-2003 Climatological Data, Michigan: U.S. Department of Commerce, v. 103-117, nos. 1-13.

-----, 2001-04, Verified/historical water level data, selected Great lakes sites, U.S. Department of Commerce, Available on the internet at: http://Co-ops.nos.noaa.gov/data_res.html.

Solley, W.B., Pierce, R.R., and Perlman, H.A., 1990, Estimated use of water in the United States in 1990: U.S. Geological Survey Circular 1081, 76 p.

-----, 1995, Estimated use of water in the United States in 1995: U.S. Geological Survey Circular 1200, 71 p.

Sweat, M.J., 1991, Hydrogeology of Huron County, Michigan: U.S. Geological Survey Water-Resources Investigations Report 91-4133, 68 p.

-----, 1999, Ground-Water Levels in Huron County, Michigan, 1997-1998: U.S. Geological Survey Open-File Report 99-186, 10 p.

Weaver, T.L., Luna, J.P., and Sweat, M.J., 2000, Ground-Water Levels in Huron County, Michigan, 1999: U.S. Geological Survey Open-File Report 00-257, 11 p.

Weaver, T.L., 2001, Ground-Water Levels in Huron County, Michigan, 2000: U.S. Geological Survey Open-File Report 01-430, 12 p.

Weaver, T.L. and McGowan, R.M., 2002, Ground-Water Levels in Huron County, Michigan, 2001: U.S. Geological Survey Open-File Report 02-289, 12 p.

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