The statewide monitoring network currently contains about 830 wells. Most of the wells are measured by staff at the Montana Bureau of Mines and Geology (MBMG) but some wells in the Paradise, Helena, Gallatin, and Missoula valleys are measured by cooperators under contract to MBMG. Additionally, 10 water-level recorders are operated for the program by the U.S. Geological Survey under a cooperative agreement. Wells in Rosebud and Bighorn counties that are considered part of the network are measured by MBMG under its Coal Hydrology program and made available to the statewide network through data storage in the Ground-Water Information Center (GWIC) data bases.

Most network wells are measured quarterly although those in current Ground-Water Characterization Program study areas (Lolo-Bitterroot Area, and Upper Clark Fork River Area) are being measured monthly. Other programs measuring the same wells but at different times may store the information in the GWIC data base providing additional measurements. Some programs such as MBMG’s Coal Hydrology and Butte Mineflooding programs also collect water-level data and store it in GWIC. The Department of Natural Resources periodically sends water-level data for wells it visits to MBMG for storage in GWIC.

Water-level data collected from the network are available through the GWIC web site at http://mbmiggwic.mtech.edu.
Well construction and terminology

Definitions of Terms

The static water level is the distance from the land surface to the water in a well when the well is not pumping. A pumping water level is a measurement made while a well is being pumped and at a known time after pumping started. Drawdown is the difference between a pumping water level and a static water level. Distances to water (both static and pumping water levels) below land surface in wells are reported as positive numbers. Therefore a water level of 10 ft below land surface is “higher” than a water level of 20 ft below land surface. Increasing distances to water in wells indicates that water levels are “declining”, decreasing distances indicate that water levels are “rising”.

The amount of drawdown required to produce water from a well depends on the yield, the amount of time that the well has been pumped, and the characteristics of the aquifer. Generally, if static water levels in the well decline, pumping water levels must fall accordingly to produce the amount of water desired. Because the pump in a well is set at a constant depth, declining static water levels may cause pumping water levels to fall below the level of submergence required for the pump to operate, and production from the well will be disrupted.

If there is room in the well to lower the pump, one solution to declining water levels may be to lower the pump. However, if the pump is set the maximum depth possible the only recourse may be to limit production or to deepen the well.
A discrete area within an aquifer is similar to the area within the black box in the drawing above. When recharge to the aquifer exceeds discharge (the volume of water represented by the green arrows exceeds that represented by the red arrows), water levels rise as indicated by the upward green arrow to the left of the wells. When discharge exceeds recharge, water levels decline as indicated by the downward red arrow to the left of the wells.

Static water levels may represent the altitude of the water table as shown in this example or may represent pressure in the aquifer. In both cases “higher” water levels show that the aquifer in the area around the well is gaining storage or pressure. “Lower” water levels show that the aquifer is losing storage or pressure.

Springs often represent spill points for aquifers and occur where the current water table intersects the land surface. If water levels rise, spring flow may increase as the aquifer increases discharge to remain in equilibrium. New springs at higher altitudes may also form. If water levels decline, springs at certain altitudes may cease to flow as the aquifer decreases discharge to maintain equilibrium.

Shallow wells may not produce the amount of water they did previously because declining water levels can cause pumping water levels to decline to where the pump ceases to produce water. Deeper wells in the same aquifer may appear unharmed. Conversely, if the shallow well requires very little drawdown, and the deep well a very large drawdown to operate, the deep well may fail at the same time that the shallow well keeps functioning.
How do you decide if a well is responding to climate?

- Compare current water levels to the total period of record
- Compare current water levels to previous seasonal water levels
- Look for record low measurements and consecutive record low measurements
- Compare water levels to climate data

Wells and Climate

Periodic measurement of static water levels in wells provides the basis on which aquifer response to climate can be considered. As noted previously, changes in water levels show change in storage (or pressure) in an aquifer but comparison of the water-level data to other factors is required to evaluate possible causes for the change. For example, factors such as leakage from nearby irrigation ditches, flood irrigation, or pumping in wells can cause water level changes in wells.

Comparison of water levels in wells to climate data requires that similar periods of record are present in the water level and climatic data. Precipitation data are available in Montana for periods of up to 100 years, but periods of record in the water-level monitoring network range from a maximum of about 60 years to less than one. The median period of record is now about 8 years. As the period of water-level record for a well increases, comparisons between its water level data and climatic data become easier and better interpretations of the impact of climate result.
The hydrograph above for a well from the Bitterroot Valley shows that early spring water levels appeared to have declined about 4 feet in the last 4 years. It also appears that highest water levels in this well occur in mid summer.

Comparison to precipitation data for the area would help interpret whether or not this well is responding to climatic conditions. Hindering the interpretation would be the short period of record. For example, were the years previous to 1996 a time of rising water levels representing wetter years in 1994-1995?
Consecutive record low water levels
In this well water levels have generally fallen since measurements began in late 1997 although record high levels occurred in the first half of 1999. In mid 2000, consecutive monthly static- water levels fell by 15, to more than 20 feet per month. In late-summer 2000 the well was deepened but no change in water levels resulted from the deepening. During the fall of 2000 and winter 2001, about 40 feet of recovery occurred. The short period of record precludes knowing if water levels rose during 1995 and 1996 prior to when measurements began.
Current Water-Level Status

Although the network currently contains about 830 wells, only 402 have January-March seasonal records of **more than 5 years, more than 5 measurements representing the January-March period, and were measured since January 1, 2001**. Each point on the map shows the difference in feet (departure) between a well’s most recent measurement and the average of all its measurements for the January-March period. Yellow, orange, and red points show wells in which the most recent measurement is below average. Green and blue points indicate wells where water levels are above average. Gray points show where water levels are less than 1 foot above or below average.

The histogram shows the percentages of wells that fall into each departure category. About 45% of the wells have current water levels within +/-1 foot of their long-term averages, although 26% are below their average water level and only 18% above their averages. Wells with water levels between 1 and 5 feet below their seasonal averages populate the largest category at 37%. About 11% of the wells were more than 5 feet below average while only about 3% were more than 5 feet above average.

**Departures** should be only be used as a screening tool to determine which wells may deserve a closer look. Long-term water-level data (hydrographs) evaluated against climatic conditions must be used to help determine whether or not an individual well is responding to drought. The actual impact of water level decline on an individual well depends on the amount of water needed the performance of the well.
Statewide Monitoring Network:
Departures from January-March averages 1996 - 2001

The chart shows the seasonal departures from average for the Monitoring Network for late winter periods since 1996. To be included in the retrievals each well had to have at least 5 years of record, at least 5 measurements, and have a current January-March measurement in the year of the retrieval. The number of wells included by year increases from a minimum of 116 in 1997 to 455 in 2000. Generally, the increasing number of wells meeting the criteria each year reflects the increasing period of record in the overall network, but some variations occur because of wells that do not make the current deadline. For example, about 50 wells in 2001 were measured in early April and did not make the March 31, 2001 cutoff for the retrieval.

The number of wells that are in each negative departure category decreased between 1996 and 1998 and then increased during 1999 to 2001. The number of wells in each positive departure category generally peaked in 1998-1999.

In the upper left corner of the chart is a graph showing statewide Standardized Precipitation Index (SPI) values posted every 3 months, for the previous 3-month period. The dark blue (heavy) line is a 2 year moving average on the SPI. The average on the SPI peaked in late 1996 and has been downward since then. The peak in the average SPI generally corresponds with the lowest number of wells in the negative departure categories and the highest number of wells in the positive departure categories.
Record Low Water Levels - period of record >= 5 years

The map above shows locations of wells where record low water levels were observed during the January-March 2001 period. Departures shown on this map also are from total period of record averages. Because the entire period of record is considered in this retrieval, some network wells may appear here and not on the departures from seasonal average map shown earlier. For example, the initial measurement for well 81636 in the Kalispell Valley was made in May 1996 and therefore that well did not have 5 years of water level data for the January-March period and was not included on the current departures map on page 7. It does have a record low water level in the January-March 2001 period and is included here.

The distribution of wells with record low water levels is generally statewide although clusters of points appear in the Kalispell, Missoula, and Helena valleys and in the Great Falls area.
Kalispell valley: selected hydrographs with record low water levels

West Side Kalispell Valley
Record Low Water Levels

Three hydrographs from the west side of the Kalispell valley with orange and yellow departures are illustrated above. Additionally, the Western Climatic Division 3-month Standardized Precipitation Index (SPI) and a 2-year moving average for the index is shown for reference at the bottom of the chart. Water levels in all three wells show a similar downward trend since 1996 or 1997 and declines have been between 26 and 11 feet. The SPI shows that the 2 years before measurements began were relatively wet and it is unknown what water-level rises occurred in the wells during these earlier years. The period of record is too short to determine if the wells are reacting abnormally to recent climatic conditions or if we are now observing the “dry” side of water-level cycle that has a period of more than 5 years and a magnitude of 10’s of feet.
Great Falls Area: Madison Aquifer

Record Low Water Levels

The hydrographs shown on this chart are for wells that produce water from the Madison Formation or measure leakage from the Madison Formation (Well 2526, bottom line, at Giant Springs). Shown along the bottom of the chart is the Southwest Climatic Division 3-month Standardized Precipitation Index (SPI) and its 2-year moving average. Even though all of the wells are in the Central Climatic district, the Southwest District climatic data correspond more closely to the observed water level changes. The recharge area for the Madison Formation in this part of Montana is in the Little Belt Mountains south of Great Falls and it may be that precipitation in the recharge area may more closely follow southwest Montana patterns than Central Montana patterns.

All of the wells are declining from peaks occurring in 1996-1997. The long-term record (15+ years) for well 2526 adds perspective and shows that water levels rose between 1993 and 1995 after falling between 1985 and 1989. Wells 2247 and 2315 obtain water from the aquifer much closer to the recharge zone and declines in those wells since their peak are about 22 feet. The well at Giant Springs is in the artesian part of the aquifer and declines there have been about 4 feet.
Aquifers

The wells in the Monitoring network are distributed through many of the aquifers that occur within various formations across Montana (see front page). The Fort Union Formation, Foxhills-Hell Creek Formation, Judith River Formation, Eagle-Virgelle formation, and the Kootenai Formation are important in the eastern two-thirds of the state. In western Montana, valley-fill materials in valleys like the Helena, Missoula, and Gallatin are the most important, although encroachment of new wells on the edges of the valleys has increased the importance of the fractured bedrock aquifers surrounding the valleys.

Fort Union Formation Status

The map above shows the distribution of wells currently being measured which are completed in the Fort Union Formation. Hydrographs for selected wells showing negative departures of between 1 and 10 feet from the seasonal average are on the chart. The bottommost trace on the chart is the South Central Climatic District 3-month Standardized Precipitation Index.

Most of the departures show that water levels in these wells are within 1 foot of their seasonal averages. The second most common departure is for wells between 1 and 5 feet below their averages. The orange points in Bighorn and Rosebud counties are for wells impacted by coal mining. The red point near Terry is a data problem.
Foxhills - Hell Creek Formation

The Foxhills - Hell Creek formation extends regionally across eastern Montana. It is deeply buried east of about Treasure County and north of the Yellowstone River, and only outcrops near Poplar, the Cedar Creek area, and the northern part of the Black Hills. North of the Missouri River the formation is near or at land surface as it also is in parts of Golden Valley, Wheatland, and Musselshell counties. Departures from January-March averages are generally small. The orange departure (Well 24862, total depth 1,275 feet) in eastern Prairie county is for water level record dating back into the 1960’s. At that time the Foxhills and Hell Creek formations were being used as a source of water to flood oilfields and large long-term declines in water levels occurred. The orange departure (Well 140128, total depth 63 feet) in southwest Golden Valley county appears to be declining in response to climatic conditions. Most other monitoring wells in the Foxhills - Hell Creek formations are within a few feet of their seasonal averages.
The Judith River Formation is a geologic unit that is extensively used as an aquifer in the Havre, central Montana, and the Billings areas. There are currently 42 wells in the Judith River Formation being measured by the Monitoring Program. Thirty-five of these wells have less than 5 years of January-March records or less than 5 measurements within that time frame. If all measurements are made as planned in 2001, 15 of the 42 wells will have usable departures next year.

The Eagle-Virgelle formation extends across areas similar to that of the Judith River Formation. It is used to supply water in the Havre, central Montana, and Billings areas. There are 36 wells in the network that are completed in the Eagle-Virgelle formation. Only 10 of the wells met the criteria for inclusion in the retrievals. If all measurements are made as planned this year, 16 of the 36 wells will have usable departures next year.

All wells shown have negative departures from seasonal averages of less than 5 ft except for well 85046 (total depth 90 feet) at the Town of Valier which has a seasonal departure of about 7 feet. The hydrograph for this well (bottom line on graph) shows that water levels declines in this well correlate with declines in the 2-year moving average of the North Central Climatic Division 3-month Standardized Precipitation Index shown at the bottom of the chart. The upper hydrograph on the chart is for well 81455 (total depth 100 feet). The more than 15 feet of positive seasonal departure and the rapid rise in water levels during 1993 and 1994 indicates that water levels in this well are influenced by local factors such as nearby irrigation.
Kootenai Formation

The Kootenai Formation is exposed at land surface in a broad band along the north part of the Big Belt Mountains and in the Lewistown area. It is a commonly used aquifer near and south of Great Falls where it outcrops. In Judith Basin County the formation can be deeply buried under the Colorado Shale and wells up to 2,000 feet deep are used to obtain water.

The 9 wells that met the retrieval criteria all had negative departures from their seasonal averages. Wells with departures greater than 10 feet are shown in the hydrographs along with the Central Montana Climatic Division 3-month Standardized Precipitation Index (SPI) and a 2-year moving average on that index. The Central SPI shows a less pronounced decline since 1998-1999 than do other climatic divisions, but the wells generally show strong downward trends during their periods of record beginning in 1994.
Between January 1 and March 31, 2001, water levels had been collected in 195 wells in western Montana valleys. The locations of these wells are shown above. Although the wells look densely packed, each is 2 to 10 miles distant from its neighbor. Clusters of wells are apparent in the Mission, Helena, Bitterroot, Missoula, and Kalispell valleys. A number of wells in the Gallatin, Dillon-Blacktail, and upper Bighole valleys are not represented because their recent measurements were in late December 2000 and in early April 2001, or the data have not been received from cooperators.

Most wells in the Western Montana valleys are within 1 foot of their seasonal averages. or less than 5 feet below their averages.
Western Montana Status

The map above shows the locations of 24 wells in which departures were either more than 5 feet below their seasonal averages (orange squares) or more than 10 feet below their averages (yellow squares). Groups of yellow and orange points occur along the western and eastern edges of the Kalispell Valley. Isolated wells occur in other valleys also. The red on this map is the City of Helena.

The chart contains hydrographs showing typical water level response in 3 wells. Correspondence between the climatic data at the bottom of the chart and the water levels is apparent in wells 123132 and 5612. It also appears that well 133911 peaked in 1997-1998 after wetter than average years in 1996-1997. The long-term decline in the early part of the record for well 133911 does not appear to be explained by climatic conditions and the water-level change may be related to other factors such as development of nearby wells. The bottom line on the chart is Western Montana Climatic Division 3-month Standardized Precipitation Index and a 2-year moving average on the index.
Montana Ground-Water Information Center
On-line Hydrographs
http://mbmwwic.mtech.edu

The Montana Bureau of Mines and Geology and the Ground-Water Assessment Program now offers a direct link to static water-level data from the statewide Monitoring network. To access the data simply click on the hydrograph icon in the lower left part of the page. The icon gives access to water-level data for about 830 wells.

Additional water level data for wells measured by other programs at the Montana Bureau of Mines and Geology can be obtained from the Current Water Levels section of the main website after logging onto the database.
Interactive Map Access

Clicking on the link on the home page link produces this interactive map. Each of the large rectangles is active. Click within one of the rectangles to see an expanded map of that area.
Select a Well

Within your rectangle of choice, select one of the green well locations to obtain static water-level data. In areas where wells are tightly clustered, a list of wells for the immediate area of your selection may be returned. You can then select a well from that list to see the data.
On-Line Hydrograph

A hydrograph for the well you have chosen is produced by the database. The hydrograph is calculated at the time of your query so it is always current. Below the graph, additional information including the period of record, the depth of the well, the dates and altitudes of record lows and highs are reported. At the bottom of the web page (not shown here) is a link that produces the data used to make the graph. That data can be downloaded to your computer.

When you view the hydrograph, remember the aquifer in a box described on page 3. Times when water levels move upward are times when more water is being stored in the aquifer. When water levels are falling, water is being removed from storage near the well. The hydrograph shown above illustrates a well defined annual pattern of mid-summer peaks and late winter lows. This pattern is typical of an aquifer strongly influenced by irrigation practices. Note that the overall, general, shape of the pattern peaks between 1995 and 1998, has fallen since 1999, and is similar to the general shape of the average of the Standardized Precipitation Index for southwest Montana (see page 11 for an example of the southwest Montana Standardized Precipitation Index).