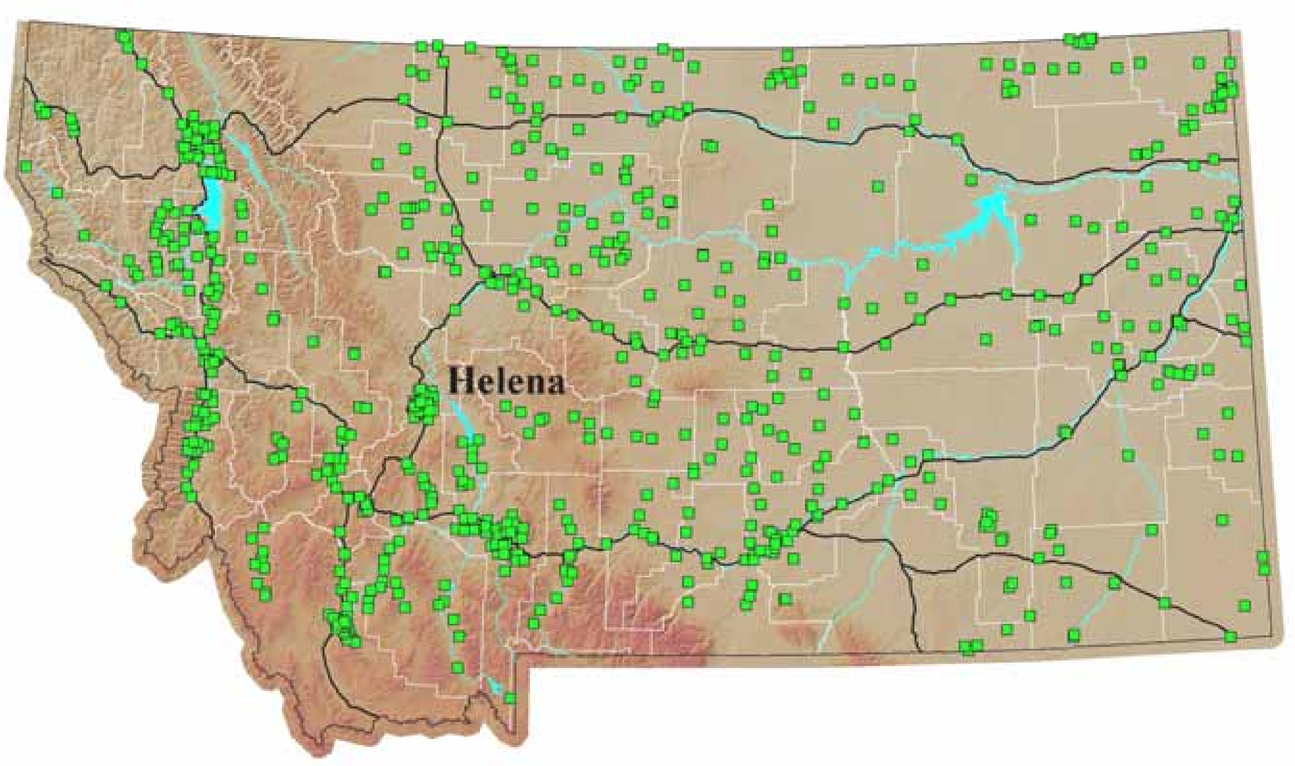
Montana Ground-Water Assessment
Statewide Monitoring Well Network



Montana Ground-Water Assessment

Water-level Monitoring and Drought: July - September 2003

Tom Patton - Montana Bureau of Mines and Geology

Butte, Montana

October 22, 2003

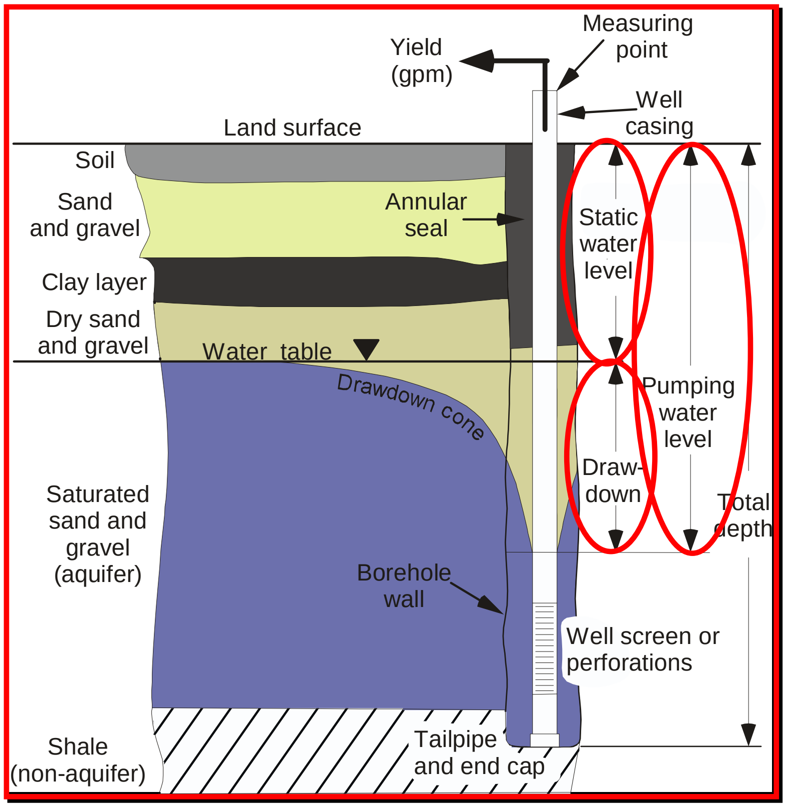
The statewide monitoring network currently contains about 850 wells. Most wells are measured quarterly by staff at the Montana Bureau of Mines and Geology (MBMG) but some in the Paradise, Helena, Gallatin, and Missoula valleys are measured by cooperators at local water quality districts and the universities. In addition to the quarterly measurements, there are about 90 water-level recorders that provide daily water levels, 10 of which are operated by the U.S. Geological Survey under a cooperative agreement. Other cooperators include the Coal Hydrology program at MBMG which measures wells in Rosebud and Big Horn counties, the Ground-Water Characterization Program at MBMG which measures wells in its active study areas, the Confederated Salish and Kootenai Tribes, and the Sheridan County Conservation District's water reservation monitoring program in northeast Montana. Water-level data from all of these efforts are available through the GWIC web site at **http//:mbmggwic.mtech.edu.**

The statewide network is designed to collect water-level and water-quality data that may be used for a variety of purposes. However, in response to current climatic conditions this document focuses on how ground-water levels are responding to drought.

Contents

(A) A water-level recorder on a well in Yellowstone County provides water-level records valuable for assessing the impact of subdivision and climate on near-surface alluvial aquifers.

(B) A stock well in Powder River County is one of about 90 network wells completed in the Fort Union Formation. Water-level measurements from Fort Union Formation wells provide data helpful in evaluating the aquifer's response to drought and development.

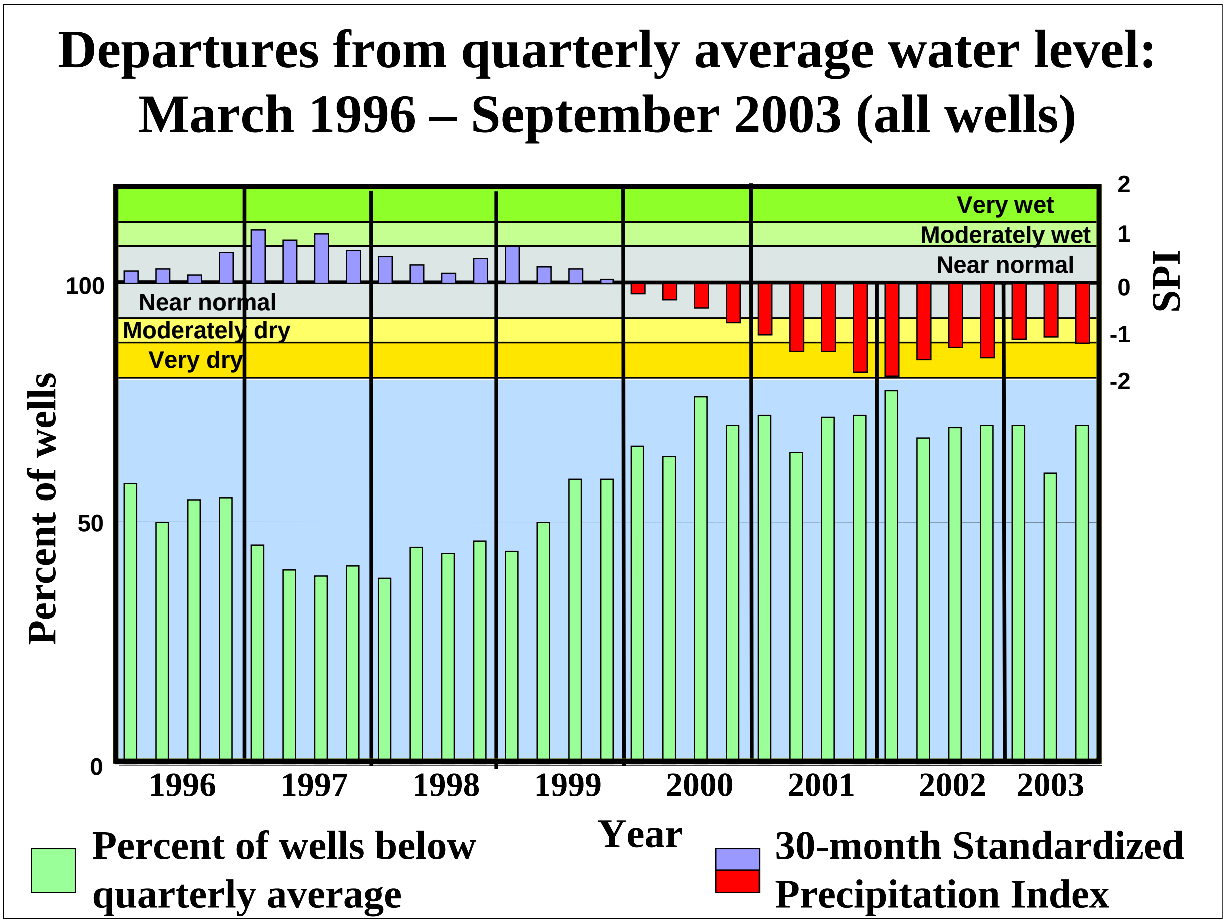


Well construction and terminology

Typical water well construction and Terminology

The **static water level** is the distance *from the land surface to the water in a well* when the well is not being pumped. A **pumping water level** is a measurement made while a well is being pumped and at a known time after pumping began. **Drawdown** is the difference between the pumping water level and the static water level. Distances to water (both static and pumping) 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 sustain a given yield depends on 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, there is less available drawdown. Because pumps are set at specific depths, declining static water levels may cause pumping water levels to fall to the pump intake, and disrupt production from the well. The amount of water-level decline that can be tolerated depends on the individual well and the aquifer in which it is completed. For example, a shallow well that requires only inches of drawdown may continue producing, while nearby deep wells that require several feet of drawdown fail. Other deep wells in the same aquifer may appear unharmed because they require less drawdown to operate. Conversely, deep wells often can tolerate larger total water-level declines than can shallow wells. Ten feet of water-level decline in a deep well may impact yield, but a shallow well that only contained three feet of water to begin with would have long since been dry.

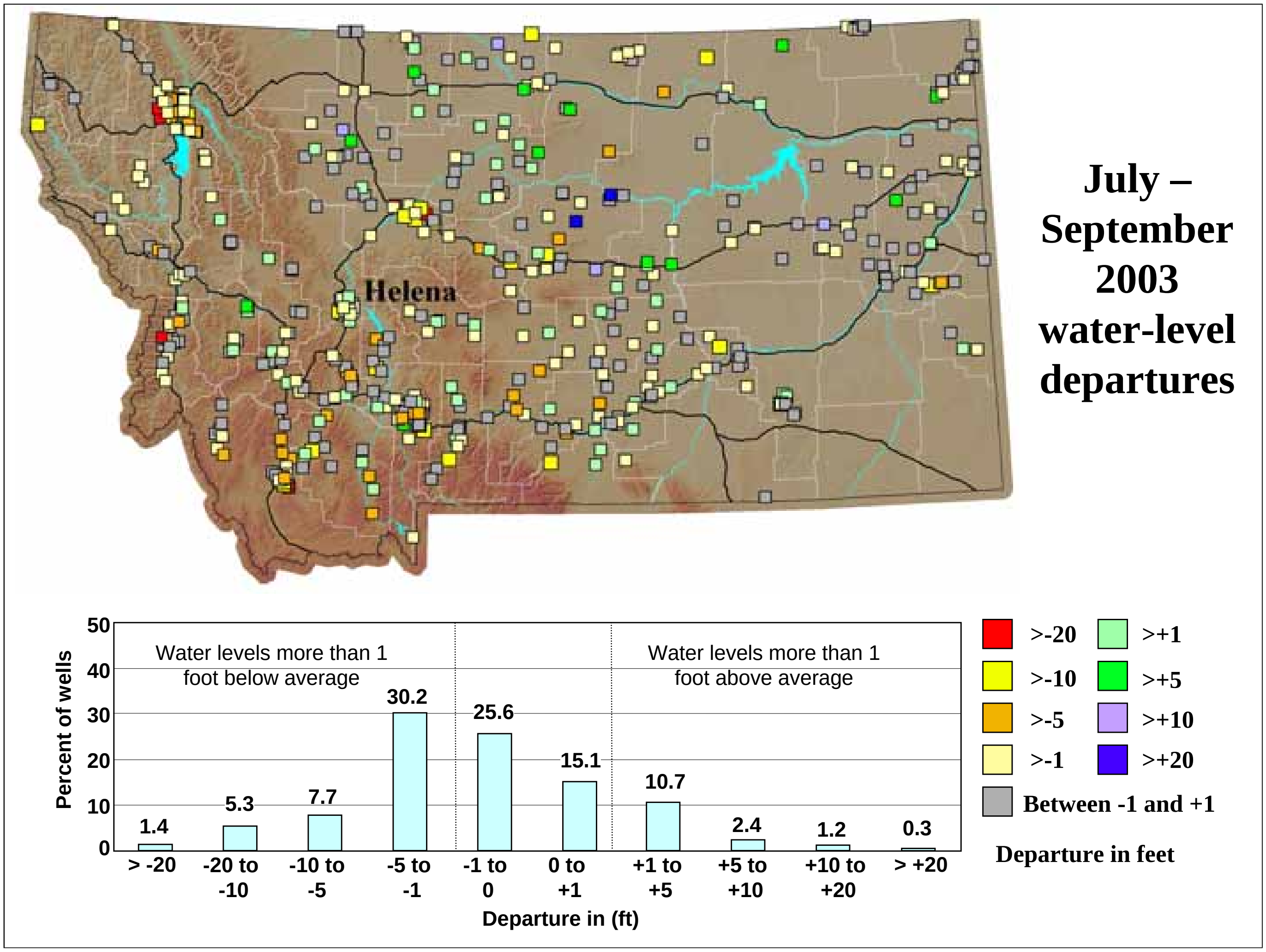


Departures from quarterly average water level: March 1996 - September 2003

The graph compares the percentage of wells in the statewide network with static water levels that were below their long-term quarterly averages. Quarterly postings of the 30-month statewide Standardized Precipitation Index (SPI) are in the upper part of the chart. Between the first quarter of 1996, and the last quarter of 1999, the SPI was mostly wetter than normal. During this “wet” period, most of the water levels in the network wells were close to or above their long-term averages.

By the first quarter of 2000, the SPI had become negative, and since the last quarter of 2000 to the present (2003) conditions have been moderately to very dry. During this “dry” period there has been a corresponding increase in the number of wells with water levels below their long-term average. Water levels in 70 to 80 percent of the network wells have been below their quarterly averages each first, third, and fourth quarter since 2000. Only 60 to 70 percent of wells have below-average water levels in the second quarter in these years, most likely because of short-term recharge from spring run off and irrigation practices.

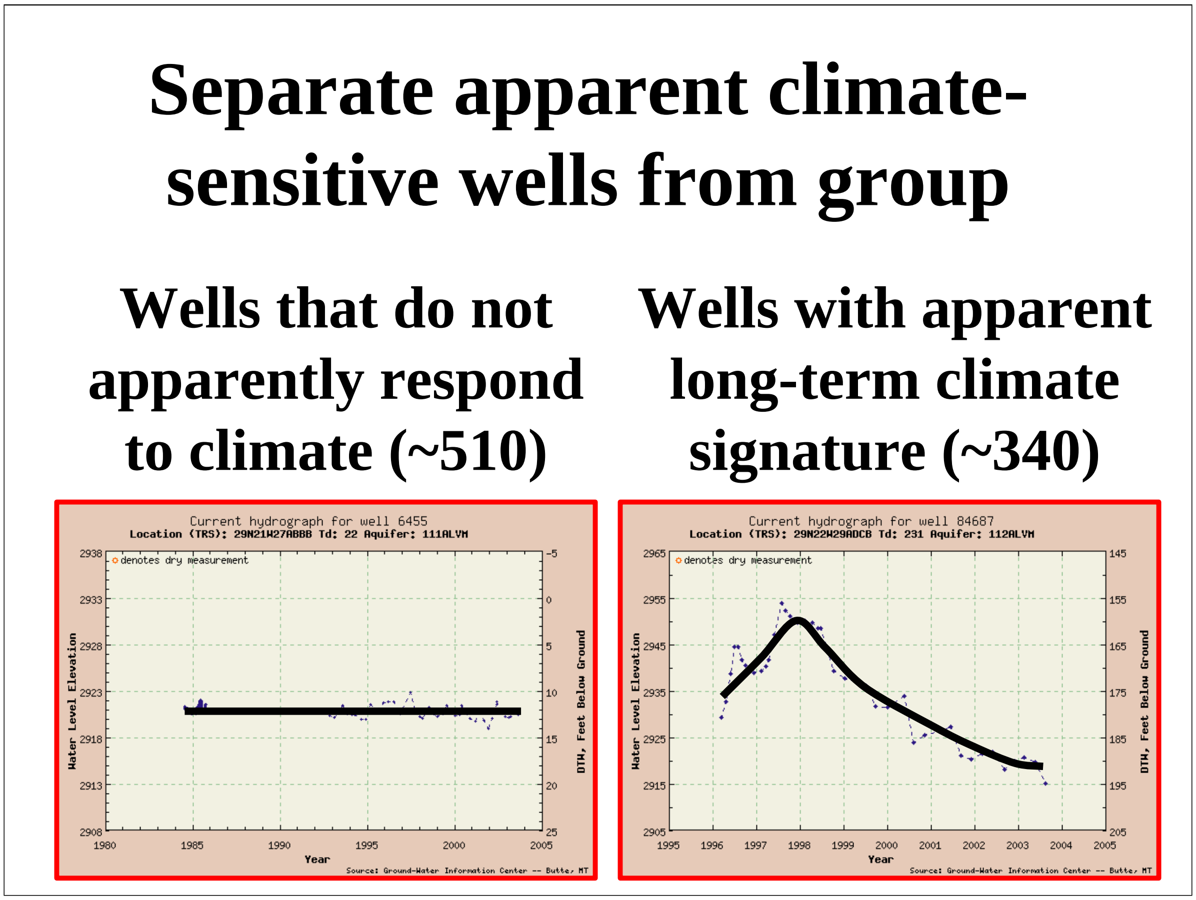
The illustration shows that although more wells are below their quarterly averages in response to the current dry climatic conditions than during 1997-1998, there is a substantial percentage of wells (between 30 and 40 percent) that were below their quarterly averages even when climatic conditions were relatively wet. Other factors influence water levels in wells and examination of water-level records (hydrographs) in conjunction with climatic, pumping, and other data is essential to determine what may be happening in specific areas.



Third quarter 2003 seasonal water-level departures

Although the monitoring network currently contains about 850 wells, only 582 have third quarter (July –September) measurements for 5 or more years. The locations of these wells are shown above. Each point on the map shows the difference in feet (departure) between the well's most recent measurement and the average of all its measurements for the July-September 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 within 1 foot of the quarterly average.

The histogram shows the percentage of wells that are in each departure category. Forty-one percent of the wells have water levels within +/-1 ft of their long-term quarterly averages. Most of the remaining wells (44 percent of total) have water levels more than 1 foot below their long-term averages; only 15 percent of the wells have water levels more than 1 foot above their long-term averages.



Separate apparent climate-sensitive wells from group

Wells that do not apparently respond to climate (~510)

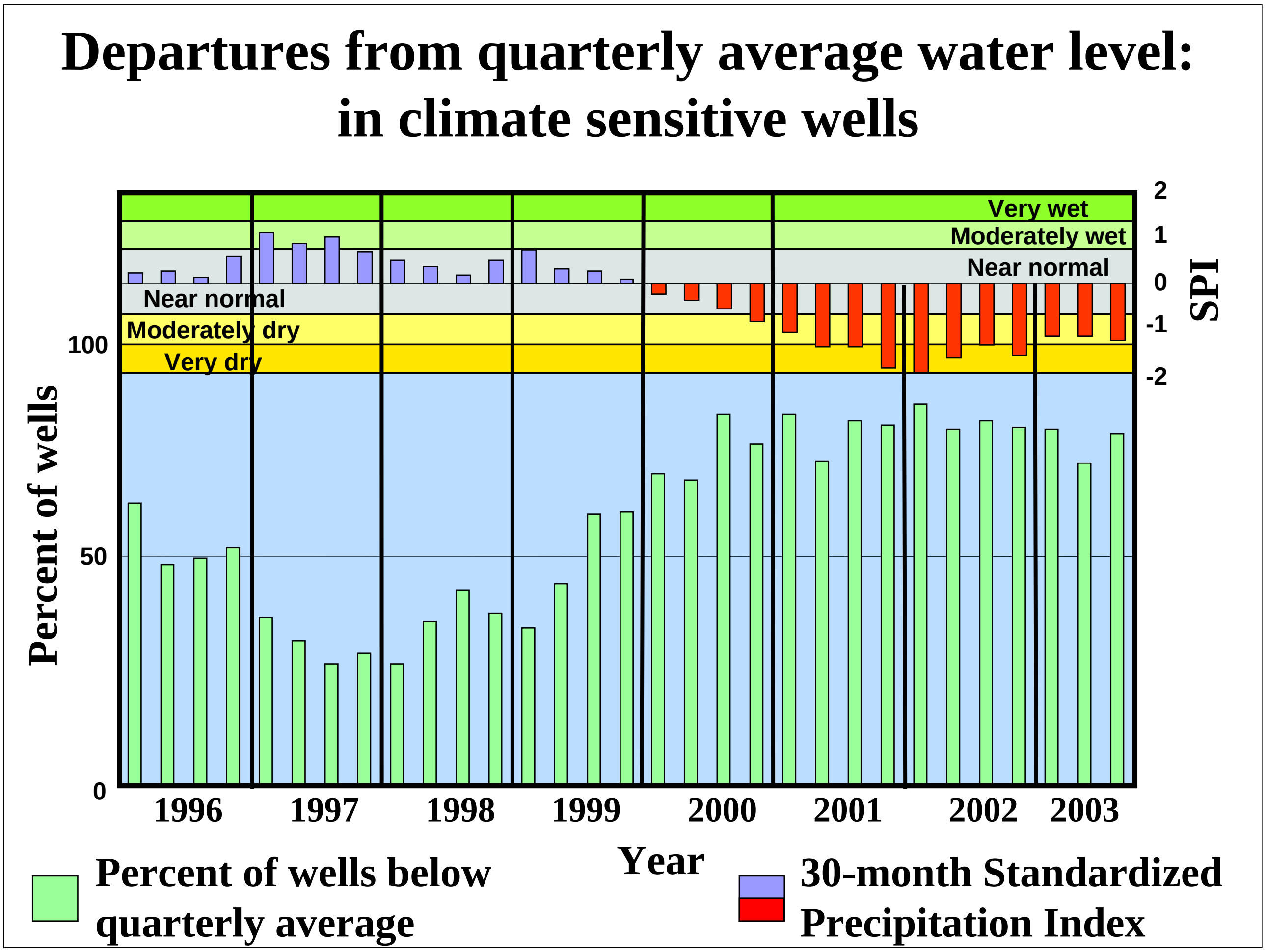
Wells with apparent long-term climate signature (~340)

Climate-response wells

The statewide monitoring network includes about 850 wells that are completed in many different hydrogeologic regimes, some of which apparently are not sensitive to current climatic conditions. An example would be deep wells in the eastern Montana regional Foxhills-Hell Creek aquifer. Wells completed in aquifers that receive most of their recharge from sources other than direct infiltration of precipitation also may not be impacted as severely by climatic conditions. Examples include aquifers connected to large rivers or heavily recharged by leakage from irrigation practices.

Two examples are shown above. Both wells are located in the Flathead valley. Water levels from the well on the left are from an aquifer connected to and recharged by the Flathead River. These water levels have not responded to the recent wet 1996-97 or dry periods (1999-03). Water levels from an aquifer that receives recharge from precipitation, snow melt, and spring run off are shown on the right. These water levels generally rose prior to the end of the wet period but have fallen since the dry period began. The rate of fall was relatively rapid initially but in recent years has slowed.

Upon initial examination of their hydrographs, about 340 of the 850 wells in the network show recognizable climatic response.

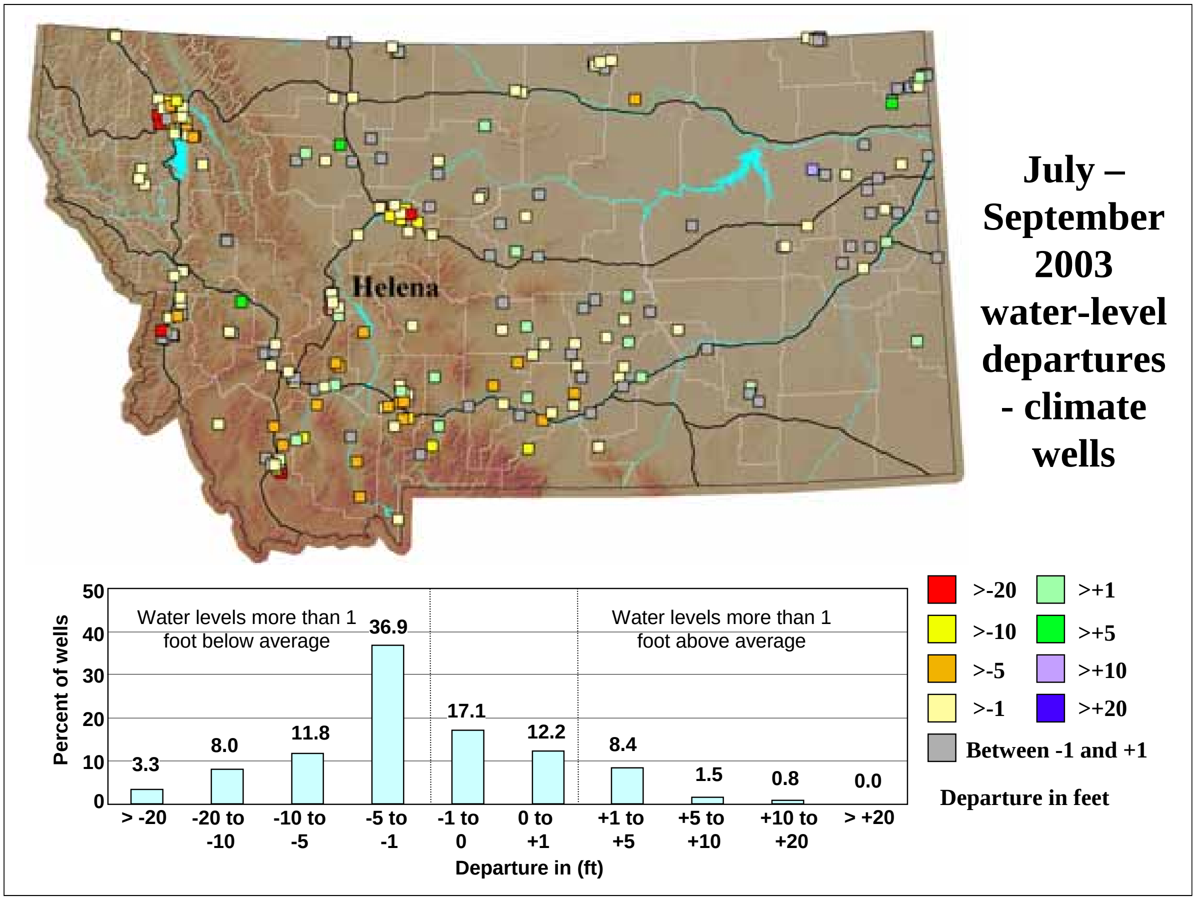


Departures from quarterly average water level: March 1996 - September 2003: Climate-response wells

The graph compares the percentage of climate-response wells in the statewide network that were below their long-term quarterly averages for each calendar quarter between January 1, 1996 and September 30, 2003 with quarterly postings of the 30-month statewide Standardized Precipitation Index (SPI).

Since the third quarter of 2000, except for the second quarters of 2001 and 2003, between 70 and 80 percent of the wells have been below their quarterly averages. The relatively low percentages in the second quarters of 2001 and 2003 likely result from measurements influenced by short-term surface water runoff. At the time of the measurement the water levels were above their average but fell to below average again by the time of the third quarter measurement.

As would be expected, the response to climate in the climate-response wells is more extreme than that observed from the complete network. During the wet period ending in 1997, about 10 percent fewer wells were below their average than in the entire network. During the dry period, between 5 and 10 percent more wells were below their averages than in the entire network. Wells that do not respond directly to climate within the entire network dampen the apparent response of the network to climatic conditions.



Third quarter 2003 seasonal water-level departures:

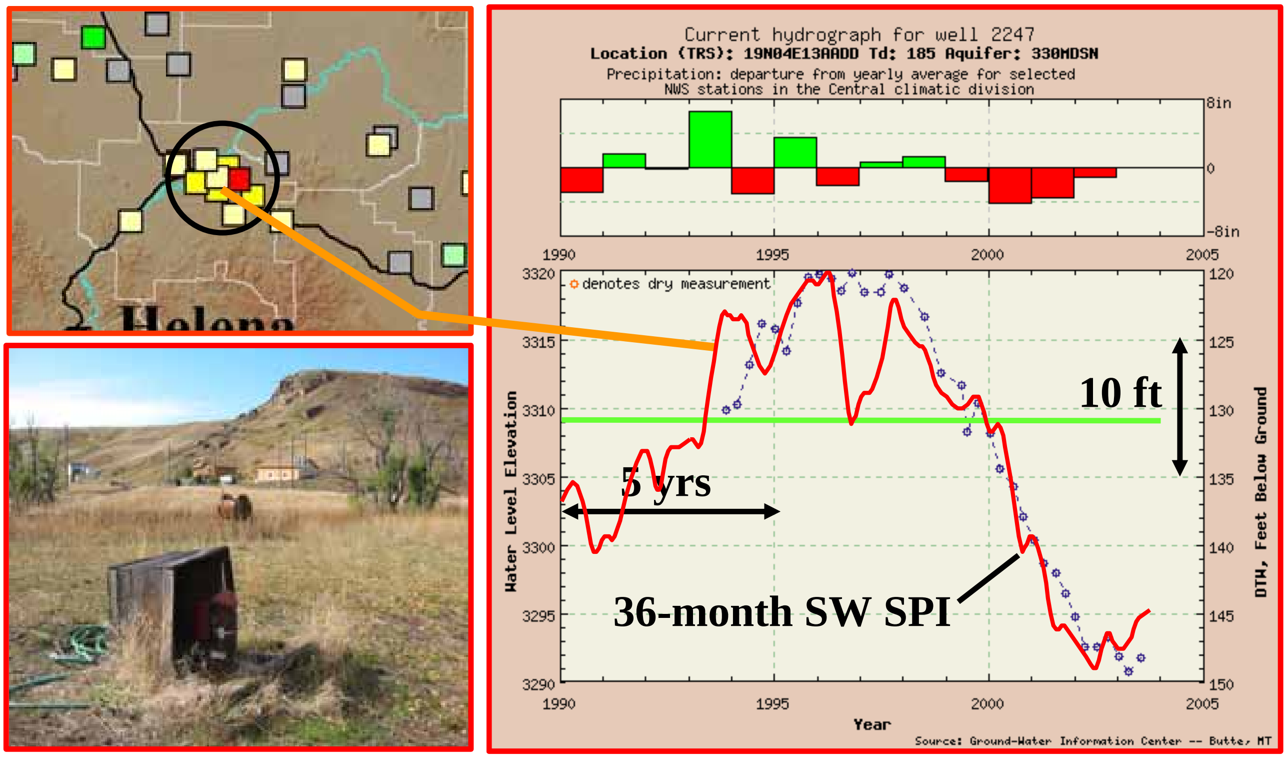
Climate-response wells

Of the 340 wells that show apparent climatic response, only 263 have third-quarter records of at least 5 years including 2003. Each point on the map shows the difference in feet (departure**)** between the well's most recent measurement and the average of all its measurements for the July-September 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 within 1 foot of the quarterly average.

The histogram shows the percentage of wells that are in each departure category. Twenty-nine percent of the wells have water levels within +/-1 ft of their long-term quarterly averages. Most of the remaining wells (60 percent of total) have water levels more than 1 foot below their long-term averages; only about 11 percent of the wells have water levels more than 1 foot above their long-term averages.

The histogram for the climate-response wells contains the same relative distribution of departures as does the histogram for the entire network (see page 5) but the it is more extreme. Water levels in only about 30 percent of the climate-response wells are within one foot of their averages compared to about 40 percent in the entire network. Sixty percent of water levels in the climate-response wells are more than one foot below their averages compared to 44 percent of water levels in wells from the entire network.

Madison Limestone: Great Falls Area



Source: Ground-Water Information Center -- Butte, MT

Madison Limestone: Great Falls Area

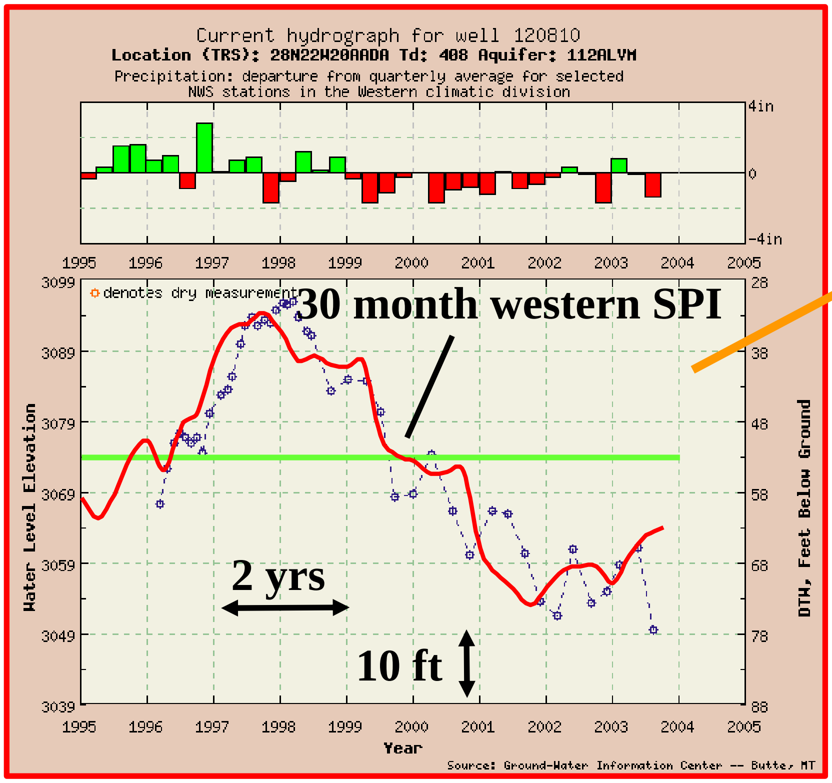
The Madison Limestone aquifer provides water to many wells in the Great Falls area and is the source for Giant Springs. Four monitored wells, completed in the Madison Limestone near Great Falls, have surprisingly similar water-level records. Water levels in three of the wells have dropped about 30 feet since about 1997. The fourth well near Giant Springs has seen a decline of about 6 feet. The hydrograph for well 2247 is typical of the recent water-level response in wells completed in the Madison Formation between Great Falls and the Little Belt Mountains.

The Madison Limestone is at the land surface in extensive areas of the Little Belt Mountains (above the word Helena on the map). The general water-level decline in the Madison Limestone aquifer likely result from lack of snow pack and low run off in streams across areas on the northern flank of the mountains where the formation is in outcrop.

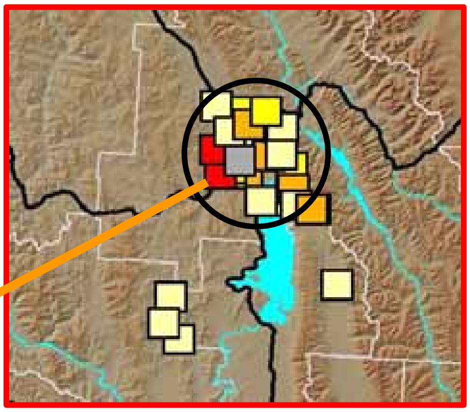
Although the well is located in the Central Montana Climate Division, the division's Standardized Precipitation Index (SPI) for various accumulation periods does not correspond well with the hydrograph. The Central Montana climate division data includes mostly low-altitude precipitation accumulations which may not accurately reflect the climate in the mountainous location of the Madison Limestone's recharge area.

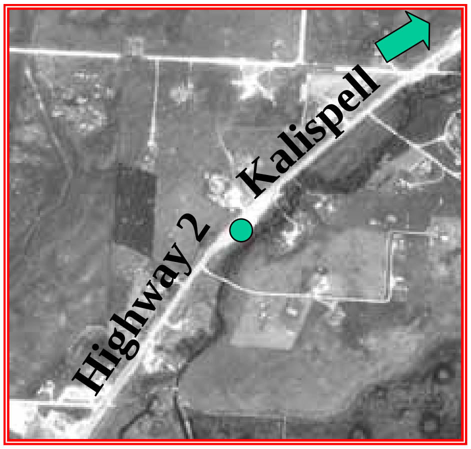
The red trace on the hydrograph is the 36-month Southwest Climatic Division SPI. The green line marks the long-term average precipitation for the climatic division. The distance the SPI is from the average designates how wet (above) or dry (below) each 36-month-period's precipitation has been when compared to the average precipitation for all of the same periods. The shape of the Southwest Climatic Division SPI curve closely corresponds with the hydrograph indicating that wells in the Madison Limestone respond to the amount of precipitation received during 36-month accumulation periods.

Kalispell valley: deep alluvium/fractured bedrock



Source: Ground-Water Information Center -- Butte, MT

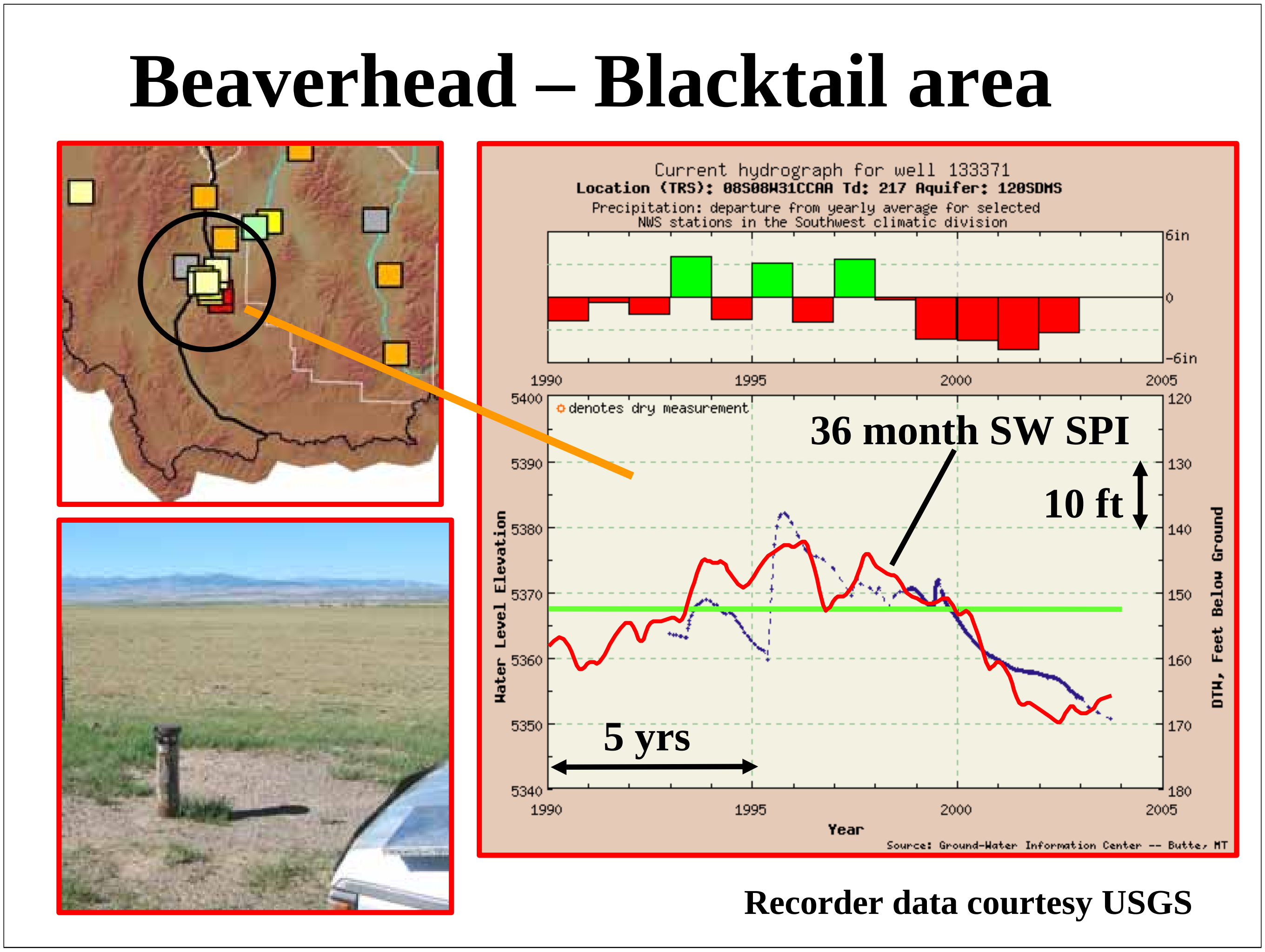




Kalispell valley: deep alluvium/fractured bedrock

Water levels in deep alluvium and fractured bedrock near Highway 2 southwest of Kalispell in the Ashley Creek valley are shown here. The shape of the hydrograph is typical of hydrographs from wells in the Kalispell area that are completed in bedrock. Water levels in this well rose rapidly in 1996-97 to a peak in 1998. Water levels began to fall rapidly in 1998-2000 but the rate of decline appears to have decreased since 2002.

The correspondence between the shape of the 30 month standardized precipitation index and the hydrograph shows that water levels in this well relate to precipitation accumulation periods of about 30 months. Superimposed on the general curve of the hydrograph are annual cycles that peak in the second quarter of each year. The annual water-level cycle likely follows snowmelt-run off patterns in the Ashley Creek drainage.

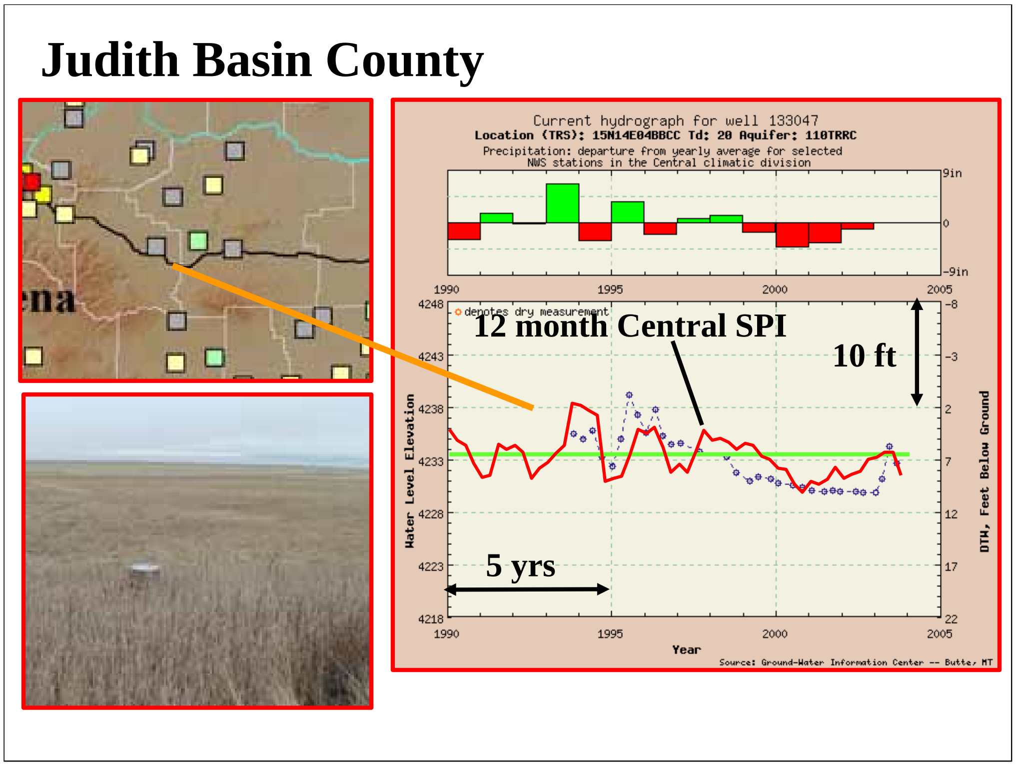


Beaverhead – Blacktail area

Recorder data courtesy USGS

Water-level change: Beaverhead/Blacktail area

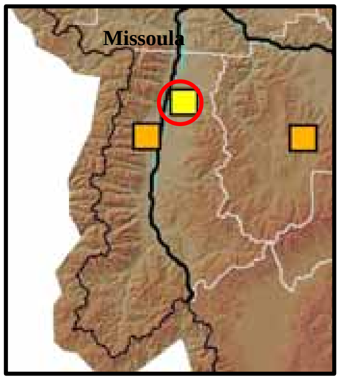
Ground water is used extensively for irrigation in the Blacktail Deer creek valley southeast of Dillon. Two periods of rapid water-level rise occurred in 1993 and 1995. In 1995 water levels rose about 20 feet in a few months. Since 1995 water levels have generally declined. The wet year in 1997 did not cause water-level recovery but the rate of water-level decline decreased to near zero in 1998-99. Since 2000, the rate of water-level decline has increased and water levels are now about 15 feet below those measured at the beginning of the record. Water levels are currently about 10 feet below the previous record-low measurements of early 1995. Gross water-level movement in this well matches best with the 36-month Southwest Climate Division SPI.

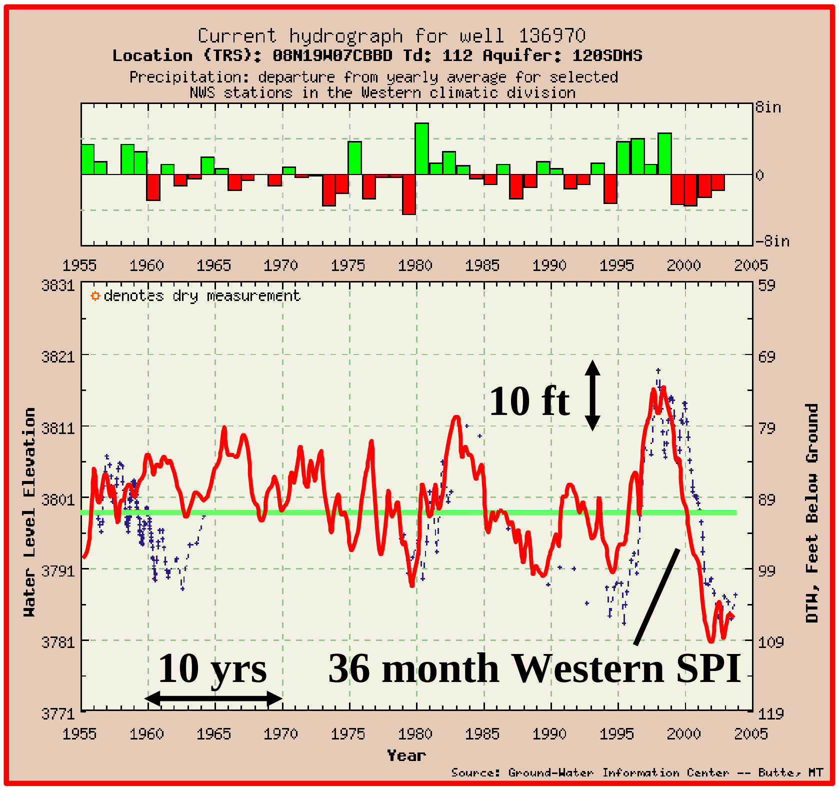


Judith Basin County

Judith Basin County – shallow gravel aquifer

Water levels in a dry-land farming area about 3 miles north of the Moccasin Agricultural experiment station are shown in this hydrograph from a shallow well that monitors an extensive unconfined gravel aquifer. The 12-month Central SPI shows general correspondence between wet periods and rising water levels. The water table is close to land surface (< 10 ft) and recharge events are related to individual precipitation or snowmelt events where large volumes of water are concentrated near or on the land surface.



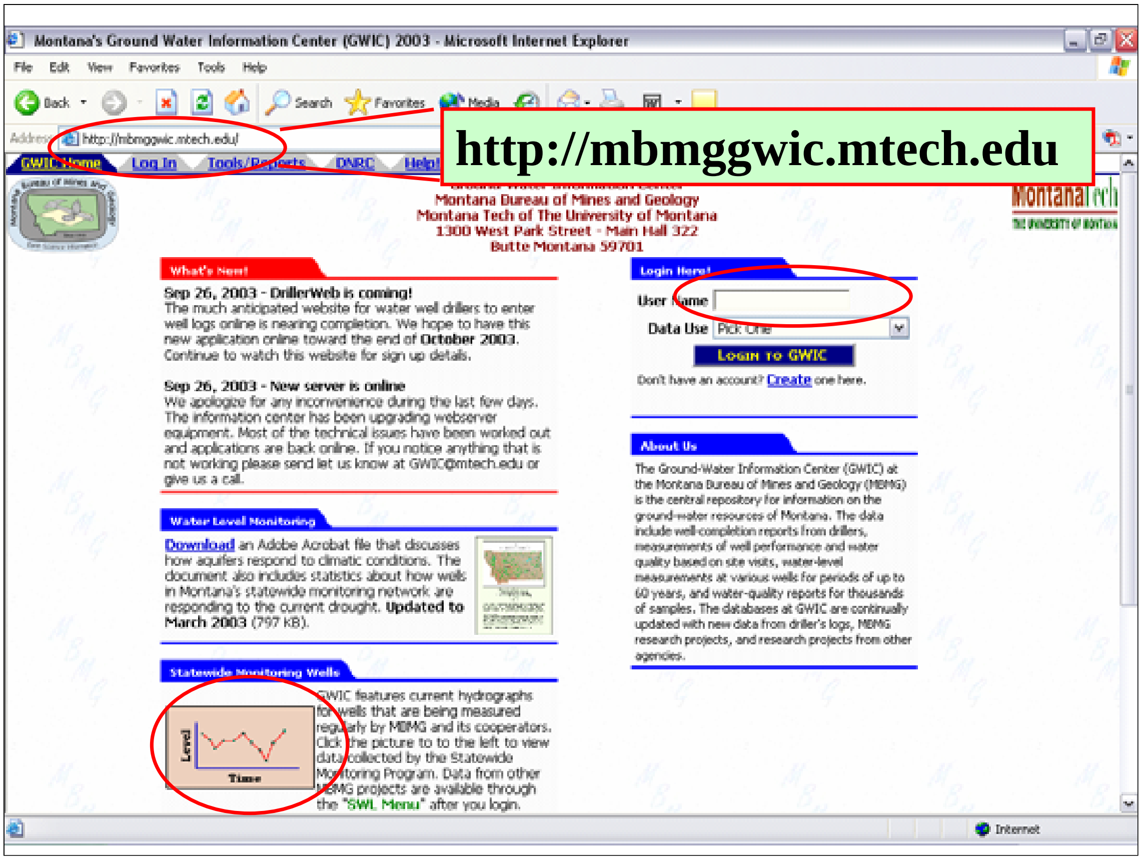


Long-term record and climate

Long-term record and climate

Water-levels in east-side benches in the Bitterroot valley correlate with, but lag behind, recorded precipitation for the Western Montana Climatic Division. Peaks in water levels (dashed line) occurred in 1956, 1984, and 1997 during or shortly after periods of wetter than average annual precipitation. Change in the 36-month Western Climate District SPI matches water-level change closely except during 1960-65 when the SPI remained positive (slightly wet) at the same time as water levels declined.

Current water levels are about 4 feet above the record low water level observed in 1995. Long gaps in the record for the years 1964-1978 and 1984-1994 and periods when the well was not included in monitoring programs. A much stronger correlation between climate and water level might be drawn if the water-level record were more complete.



http://mbmggwic.mtech.edu

Montana Bureau of Mines and Geology
Montana Tech of The University of Montana
1300 West Park Street - Main Hall 322
Butte Montana 59701

What's New!

Sep 26, 2003 - DrillerWeb is coming!
The much anticipated website for water well drillers to enter well logs online is nearing completion. We hope to have this new application online toward the end of **October 2003**. Continue to watch this website for sign up details.

Sep 26, 2003 - New server is online
We apologize for any inconvenience during the last few days. The information center has been upgrading webserver equipment. Most of the technical issues have been worked out and applications are back online. If you notice anything that is not working please send let us know at GWIC@mtech.edu or give us a call.

Water Level Monitoring

Download an Adobe Acrobat file that discusses how aquifers respond to climatic conditions. The document also includes statistics about how wells in Montana's statewide monitoring network are responding to the current drought. **Updated to March 2003** (797 KB).

Statewide Monitoring Wells

GWIC features current hydrographs for wells that are being measured regularly by MBMG and its cooperators. Click the picture to to the left to view data collected by the Statewide Monitoring Program. Data from other MBMG projects are available through the "SWL Menu" after you login.

Don't have an account? Create one here.

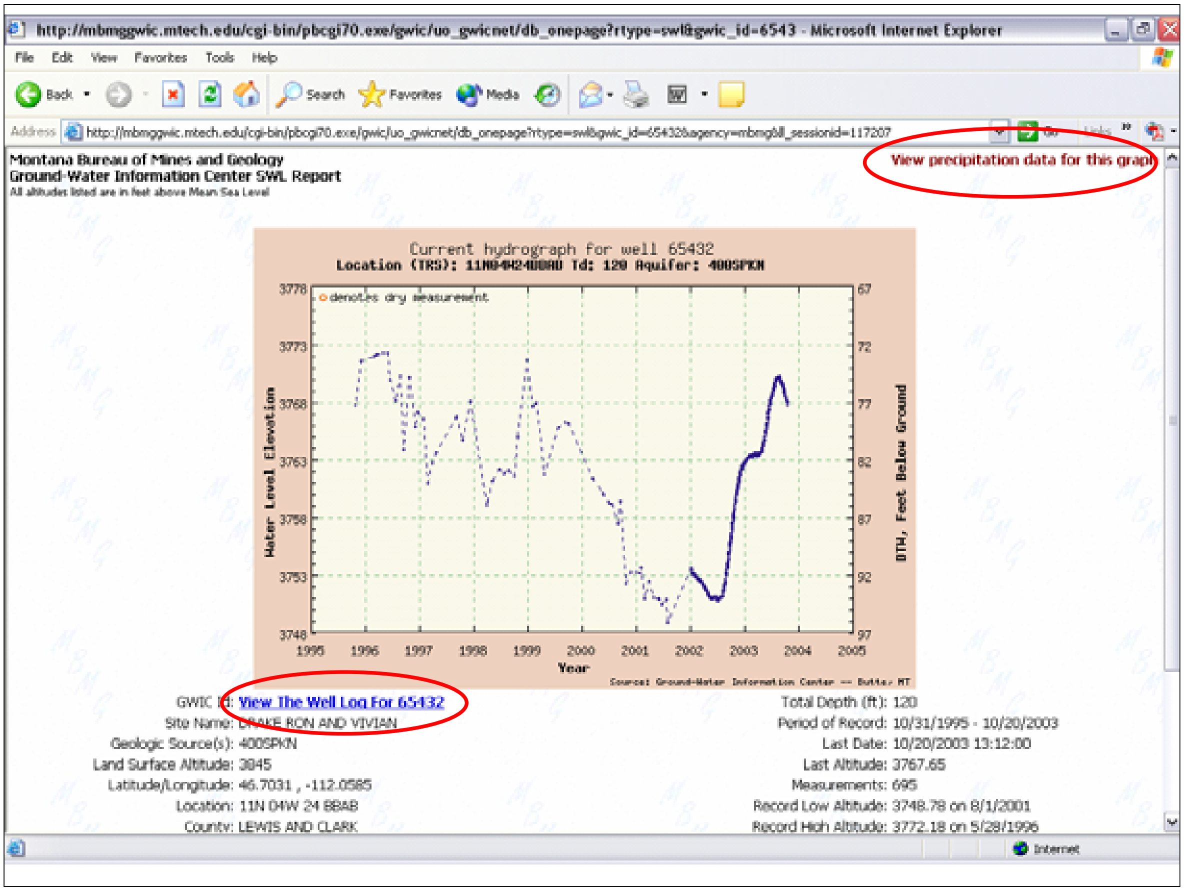
About Us

The Ground-Water Information Center (GWIC) at the Montana Bureau of Mines and Geology (MBMG) is the central repository for information on the ground-water resources of Montana. The data include well-completion reports from drillers, measurements of well performance and water quality based on site visits, water-level measurements at various wells for periods of up to 60 years, and water-quality reports for thousands of samples. The databases at GWIC are continually updated with new data from driller's logs, MBMG research projects, and research projects from other agencies.

Ground-Water Information Center:
Accessing water-level information

Use your internet browser to view the the GWIC website at http://mbmggwic.mtech.edu. You can see water-level data for Ground-Water Monitoring Program statewide network wells by clicking on the hydrograph in the lower left corner of the page. The website will produce a map on which well locations are shown. Clicking on a well location with your computer's mouse will cause the hydrograph for that well to appear.

Water-level data for wells being measured by other projects can be viewed by logging into the database and selecting the "*SWL Menu*" tab.



Montana Bureau of Mines and Geology
Ground-Water Information Center SWL Report
All altitudes listed are in feet above Mean Sea Level

View precipitation data for this graph

GWIC Id: View The Well Log For 65432
Site Name: DRAKE RON AND VIVIAN
Geologic Source(s): 400SPKN
Land Surface Altitude: 3845
Latitude/Longitude: 46.7031 , -112.0585
Location: 11N 04W 24 BBAB
County: LEWIS AND CLARK

Total Depth (ft): 120
Period of Record: 10/31/1995 - 10/20/2003
Last Date: 10/20/2003 13:12:00
Last Altitude: 3767.65
Measurements: 695
Record Low Altitude: 3748.78 on 8/1/2001
Record High Altitude: 3772.18 on 5/28/1996

Ground-Water Information Center:

On-line hydrograph

An example hydrograph is shown above. Each hydrograph is calculated at the time of the query so the image always shows the well’s most current measurements.

Below the graph, additional information such as 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 page is a link that produces the data used to make the graph. Those data can be downloaded to your computer.

You can also select a link to display the well log and from the well log you can link to any existing water-quality information or to the Natural Resource Information System’s *Topofinder* application. The *Topofinder* allows you to see the well’s location plotted on a topographic map or on an orthophotoquad.

Another feature of the hydrograph is a link (upper right hand corner of the image) that will show precipitation data for the climatic division in which the well is located.