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U.S. Geological Survey Ground-Water Climate Response Network

The U.S. Geological Survey serves the Nation by providing reliable hydrologic information used by others to manage the Nation's water resources.

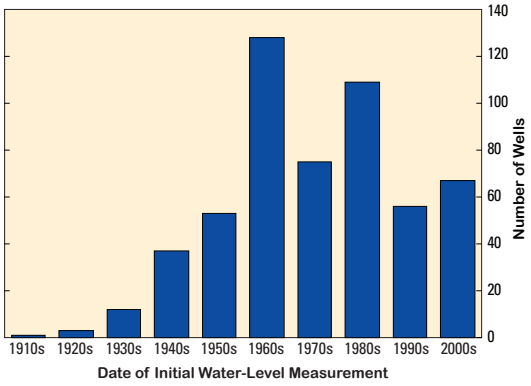
The U.S. Geological Survey (USGS) measures more than 20,000 wells each year for a variety of objectives as part of Federal programs and in cooperation with State and local agencies. Water-level data are collected using consistent data-collection and quality-control methods. A small subset of these wells meets the criteria necessary to be included in a "Climate Response Network" of wells designed to illustrate the response of the ground-water system to climate variations nationwide.

The primary purpose of the Climate Response Network is to portray the effect of climate on ground-water levels in unconfined aquifers or near-surface confined aquifers that are minimally affected by pumping or other anthropogenic stresses. The Climate Response Network Web site (*http://groundwaterwatch.usgs.gov/*) is the official USGS Web site for illustrating current ground-water conditions in the United States and Puerto Rico.

The Climate Response Network Web pages provide information on ground-water conditions at a variety of scales. A **national map** provides a broad overview of water-table conditions across the Nation. **State maps** provide a more local picture of ground-water conditions. **Site pages** provide the details about a specific well.

In 2006, the Climate Response Network contained more than 500 wells. About 140 of the wells are supported by the USGS Ground-Water Resources Program. The remaining wells are managed under a partnership among the USGS and State and local agencies through the Cooperative Water Program. Ideally, wells in the network have many years of measurements. The longest available record in the network is from a Nevada well with measurements collected since 1918. The median measurement starting date for a well in the network is 1983; however, some wells have been measured for only a few years. The value of water-level measurements increases with length of record and frequency of measurement.

As of 2006, the Climate Response Network contains 280 wells instrumented



Distribution of wells in the Climate Response Network, based on initial measurement date.

Types of Data

There are three types of water-level data available from wells measured by the USGS:

- **Periodic data** are ground-water levels measured by hand at selected intervals, usually with a steel or electric tape. These measurements typically are made monthly to quarterly. Thus periodic data displayed in the Climate Response Network may be the most recently measured, but still several months old.

Field measurement with electric tape. *(Photograph by Bill Cunningham, USGS)*

- **Continuous data** are ground-water levels measured by an automatic sensing device, recorded by a data logger, and periodically retrieved from the well. The availability of continuous data may lag current conditions by one to several months because they must be retrieved from the field, processed, and loaded into the USGS database.

Sutron 8400 recorder installation with laptop for data download. *(Photograph by Bill Cunningham, USGS)*

Real-time well. *(Photograph by Jason M. Fine, USGS)*

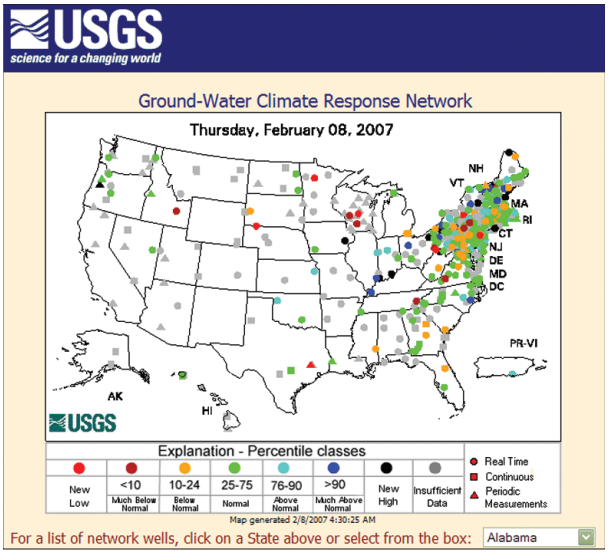
- **Real-time data** are continuous data that are transmitted from the well to the USGS by satellite or telephone at least once per day. Real-time data reflect current ground-water conditions at the well.

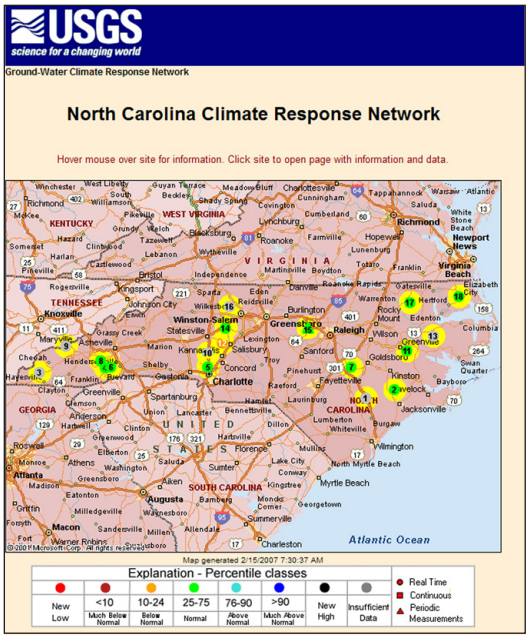
for real-time data; 59 continuous wells measured hourly, but not available in real time; and about 214 wells with periodic measurements made monthly to quarterly.

Each of the 50 States and Puerto Rico have at least one well in the network, and most States have two or more network wells. Massachusetts has 89 wells in the Climate Response Network, the most of any State. Pennsylvania has 65 wells, approximately 1 well in every county, and all wells have real-time instrumentation. It is difficult to identify wells in the western United States that are minimally affected by pumping or other anthropogenic stresses, thus coverage in this part of the Nation is more sparse.

National Page

The Climate Response Network "home" page provides a visual snapshot of the ground-water conditions across the Nation. Site locations and ground-water levels are depicted using color-coded symbols. The symbol defines the type of measurement (periodic, continuous, or real time), and the colors depict the relation between the most recent measurement and the monthly percentiles calculated from the long-term record for the well. Only symbols of wells having at least 10 years of measurements in a given month are color coded to ensure that the calculated percentiles are representative of historical conditions. Eight categories of ground-water levels are shown on the Climate Response Network: a new high for the month (black), greater than the 90th percentile (dark blue), 76th–90th percentile (light blue), 25th–75th percentile (green), 10th–24th percentile (orange), less than 10th percentile (brown), and new record low for the month (red). If the most recent measurement is more than 45 days old or there are less than 10 years of data available, the symbol is gray.





State Page

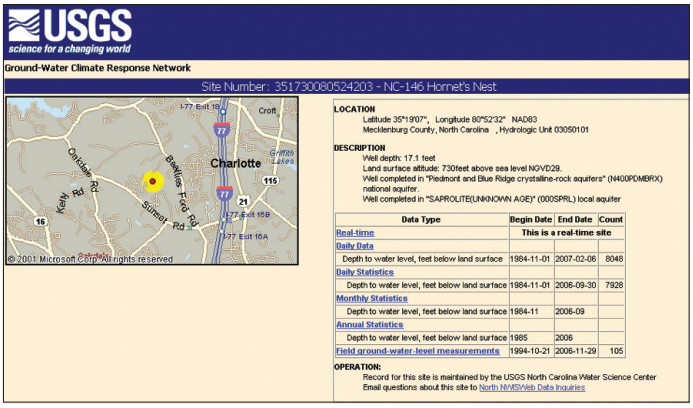
The Climate Response Network State page provides a visual snapshot of the State's ground-water conditions and a list of wells available in the State. Individual wells are assigned an arbitrary sequence number for display on the state map. "Hovering" the cursor over the sequence number will provide well details such as site name, aquifer, and well depth. The colors and symbols used on the state pages are consistent with the national map. The yellow halo around the well symbol is included to help the well symbol stand out from the underlying map.

The user may select an individual well using the well symbol or the table below the image to view the site pages.

Site Page

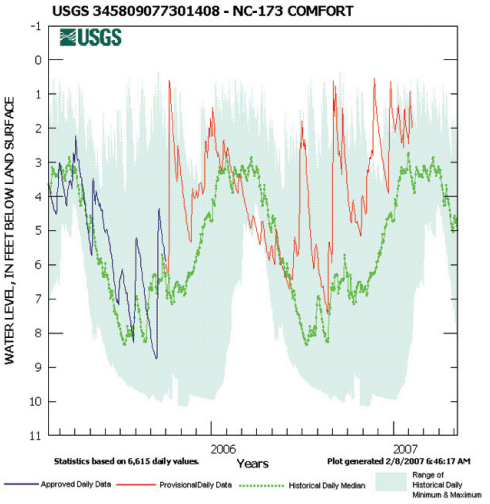
All of the information related to an individual well is available from the site pages. These pages contain a location map and descriptive information such as well location, well depth, and the aquifer screened by the well. An individual site page is segregated by blue bands across the page to differentiate among the types of data available—real time, continuous, and(or) periodic measurements. The site page also has a link to NWISWeb (*http://waterdata.usgs.gov/nwis/gw*), the USGS online interface to more than 100 years of water data collected by the USGS. NWISWeb contains all of the metadata for the well and is the source for the water-level measurements used in the Climate Response Network Web pages.

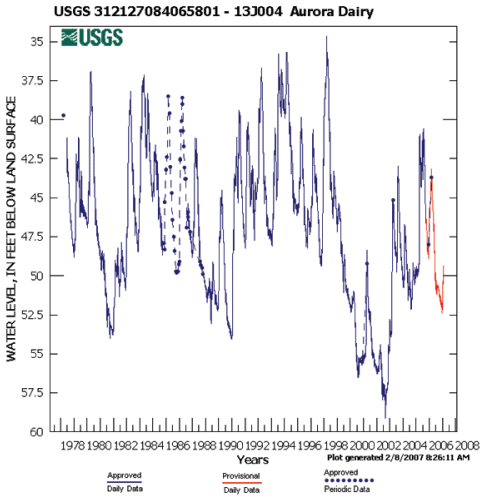
Hydrographs for all data types are presented on the site pages. Depending on the type of measurements available from the well and the length of water-level record, a variety of additional graphics may be presented.



Two-Year Hydrograph

If a well has real-time instrumentation and at least 5 years of continuous data, then a 2-year hydrograph is presented. This hydrograph provides at-a-glance information about the ground-water level recorded over the past 2 years. The hydrograph contains two statistical measures: a cyan shading that represents the historic range of daily minimum and maximum water levels, and a green line that represents the median water level for that day. A blue or red line represents the daily mean water level. The blue line represents daily data that have received final USGS approval, and the red line represents daily data from provisional measurements. This hydrograph illustrates daily fluctuations of water levels compared to daily extremes over the period of daily record. It is used to observe the recent water-level trends and is the only hydrograph in the Climate Response Network pages that includes daily statistical information.





Combined Hydrograph

Ideally, a climate response well has continuous, real-time instrumentation in place and a long history of continuous data. But often the measurement frequency at a well changes over time as project objectives change or as funding priorities change. If multiple data types (periodic, continuous, and real time) are available from a well over different measurement periods, then the data are combined in a single hydrograph that presents the entire measurement history of a well on a single figure. In this "combined hydrograph," periodic measurements are shown as blue dots, continuous measurements are blue lines, and provisional real-time or continuous measurements are red lines.

Statistics Table

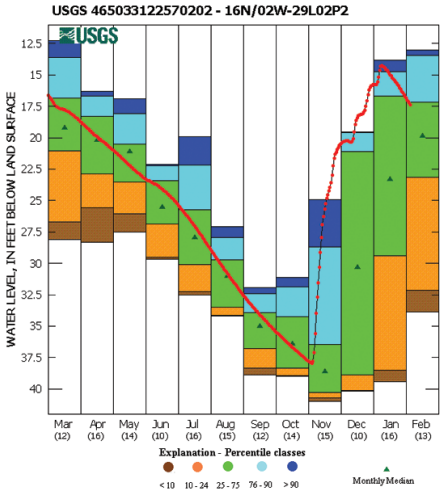
If there is an adequate period of record at a well, a monthly statistics table is presented. Different monthly statistics are presented based on the period of record available. To compute this table, all available data (periodic, continuous, and real time) from an individual well are combined. Data then are grouped by month, and the mean of the grouped value is used to represent a given month in a given year. Provisional data that have not received final USGS approval are not included in the statistical calculations. If there are 4 or less years of data for any given month, no statistics are computed for that month. If there are more than 4 years and less than 10 years of data in a given month, the minimum, median, and maximum water levels are displayed. If there are 10 or more years of data in a given month, water-level percentiles are computed and displayed.

Most recent real time daily data value: 11.45 on 2/4/2007
Period of Record Monthly Statistics for 431312089475301
Water Level, Feet Below Land Surface

Note: Bold values in the table indicate closest statistic to the most recent data value.

Month	Lowest Level	10th %ile	25th %ile	50th %ile	75th %ile	90th %ile	Highest Level	Number of Years
Jan	11.99	11.51	11.11	10.29	9.45	9.05	8.56	40
Feb	11.99	**11.40**	11.09	10.22	9.74	9.00	8.15	35
Mar	12.00	10.79	10.32	9.87	8.91	7.88	7.05	38
Apr	11.53	10.10	9.58	9.11	7.92	7.64	6.44	36
May	10.55	10.26	9.69	9.05	8.36	8.02	7.69	33
Jun	11.19	10.78	10.02	9.41	8.58	7.96	7.38	41
Jul	11.95	11.32	10.78	10.33	9.30	8.74	7.82	39
Aug	12.21	11.75	11.05	10.58	10.15	9.36	8.08	37
Sep	12.57	11.93	11.28	10.94	10.26	9.50	7.12	35
Oct	12.38	11.80	11.28	10.49	9.95	8.62	7.44	41
Nov	11.90	11.63	11.21	10.48	9.86	9.01	7.66	33
Dec	12.08	11.60	11.15	10.29	9.41	8.93	8.34	36

Note: Months with no computed statistics displayed did not meet the criteria for presentation of monthly water-level statistics.



Bar Chart

When a well has at least 10 years of measurements in any month of the year, a monthly bar chart is produced. This chart is a powerful statistical combination of historical data with recent measurements. The monthly statistical distribution described in the previous section is graphed using colored bands. The years of measurement available in each month are included in parentheses beneath the month label. The percentile color bands in this graph use the same color scheme as other Climate Response Network maps: the water-level distribution greater than the 90th percentile is dark blue, 76th–90th percentile is light blue, 25th–75th percentile is green, 10th–24th percentile is orange, and less than 10th percentile is brown. The monthly median water level is indicated by a green triangle. Water-level measurements from the most recent 12-month period are then plotted on this annual statistical hydrograph, providing current ground-water conditions compared to historical ground-water conditions in any given month.

Retrieving Data From the Climate Response Network

All data presented in the Climate Response Network pages or used in Climate Response Network statistical calculations are available for download. These are available from download icons within the sections for each data type.

Limitations and Opportunities

The Climate Response Network is a partnership among the USGS and State and local agencies. The USGS provides consistent data collection and analysis methods, a National database, and Federal funding for the core network through the Ground-Water Resources Program and the USGS Cooperative Water Program. Cooperating agencies assure relevance to state and local needs, and may provide cooperative matching funds in addition to local knowledge and expertise. This Federal resource provides the only source of timely ground-water conditions across the Nation and is a national source for data from long-term wells available for climate analysis, ground-water modeling, and drought science. Through Federal appropriations and cooperative agreements, the USGS continues to expand the Climate Response Network whenever possible.

The Climate Response Network does have some limitations. The Network is designed to monitor water-table conditions that reflect climate variability alone. Wells monitored for other purposes, such as wells with water levels influenced by nearby pumping, typically are not presented in the Climate Response Network. Data from these wells are available through NWISWeb (*http://waterdata.usgs.gov/nwis/gw*). In its current state (2007), the Climate Response Network has inconsistent coverage of our Nation's aquifers and recharge areas to those aquifers—about 60 percent of the Nation's principal aquifers (U.S. Geological Survey, 2003) are represented in the Climate Response Network. The network is subject to limits in Federal funding and changing funding priorities by cooperators. Moreover, in some areas of the Nation, extensive ground-water use or large depths to the water table make it difficult to identify wells that provide a pristine climate signal, especially in the western United States.

Expansion of the Climate Response Network into a fully functional national network will provide the long-term records that are needed to continually evaluate precious ground-water resources. The long-term data necessary for such a network cannot be created instantaneously. The availability of long-term data sets requires a disciplined data-collection program whereby water levels are collected for their intrinsic long-term value rather than meeting an immediate need. For example, a fully functional network would have at least one well within each of the 366 National Weather Service climate divisions in the United States and Puerto Rico (National Oceanic and Atmospheric Administration, 2006). The Climate Response Network currently (2007) covers 167 of these climate divisions, so expansion of the Federal and cooperative efforts into unmonitored climate divisions would advance this network toward fully functioning status. Multiple wells may be needed when multiple aquifers are present in a given climate division, and additional wells would be needed for other U.S. territories. To expand most efficiently, the national network should be supplemented by wells managed cooperatively for regional and local interests, as it is in many places today. A fully functioning, national-scale Climate Response Network would have real-time, continuous data collection to enable improved drought management; long-term records that provide a statistical framework for evaluating trends in our Nation's ground-water resources; and adequate areal coverage of our Nation's principal aquifers and recharge areas to these aquifers.

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References

National Oceanic and Atmospheric Administration, 2006, U.S. climate divisions: Climate Diagnostics Center; accessed August 14, 2006, at *http://www.cdc.noaa.gov/usclimate/map.html*

U.S. Geological Survey, 2003, Principal aquifers: National Atlas of the United States of America; accessed August 14, 2006, at *http://nationalatlas.gov/mld/aquifrp.html*

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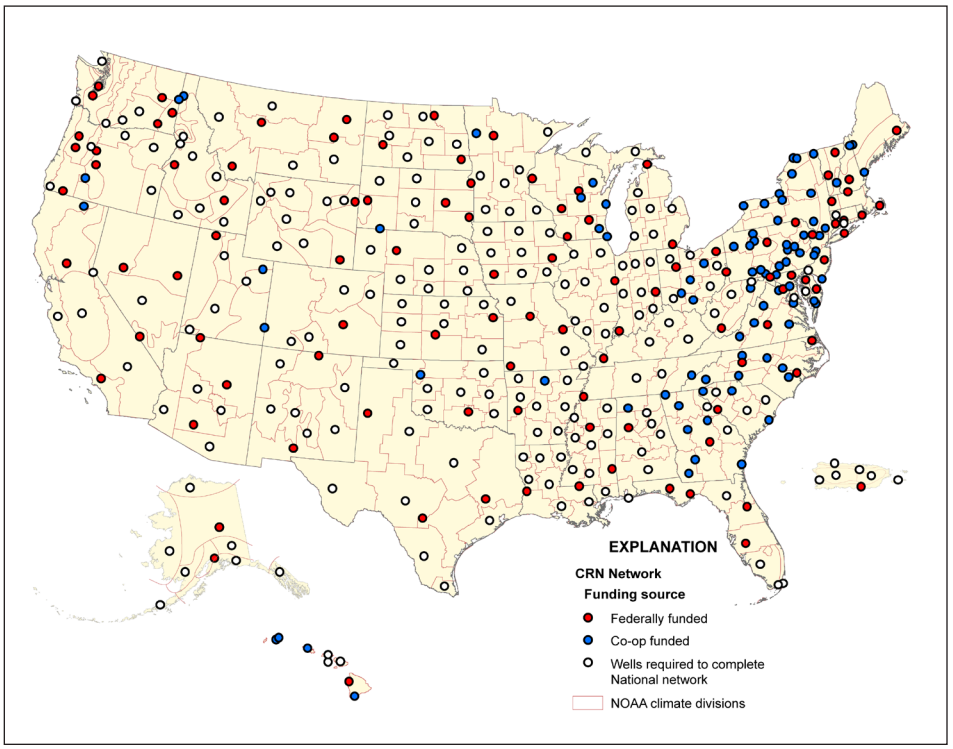
http://water.usgs.gov/ogw