Public Notice

U.S. Army Corps of Engineers, Norfolk District

March 7, 2008

CENAO-REG

Wetland Hydrology Determinations

After reviewing current and historic data as well as drought indices and regional analyses, we conclude that current and antecedent conditions are drier than typical and are unreliable for well data monitoring for wetland determinations. Therefore, we will not consider 2008 well data by itself, to constitute conclusive evidence that a particular property in Hampton Roads vicinity is not a wetland. However, we will continue to make wetland determinations based on the Corps 1987 Manual evaluation of field indicators of vegetation, soils, and wetland hydrology.

Wetlands are defined as "those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that **under normal circumstances** do support, a prevalence of vegetation typically adapted for life in saturated soil conditions" (33 CFR 328.3(b)). Wetland determinations typically entail observation of field indicators of wetland vegetation, hydric soils, and hydrology. Occasionally, property owners or their agents may install and monitor shallow groundwater wells in the spring to determine whether wetland hydrology is present in a particular area in order to clarify the delineation of wetlands. There is no requirement to submit well data to refine wetland delineations. However, the Corps will consider groundwater well data if collected in accordance with proper well installation and monitoring standards and during periods of typical precipitation as described below.

When reviewing shallow well data in order to determine whether wetland hydrology is present, we consider cumulative precipitation totals for the 3-month period prior to well monitoring compared to the cumulative precipitation totals for typical conditions (determined to be between the 30th and 70th percentiles of monthly precipitation totals for a given weather station over a 30 year period). The distribution of rainfall events during this period is also an important consideration.

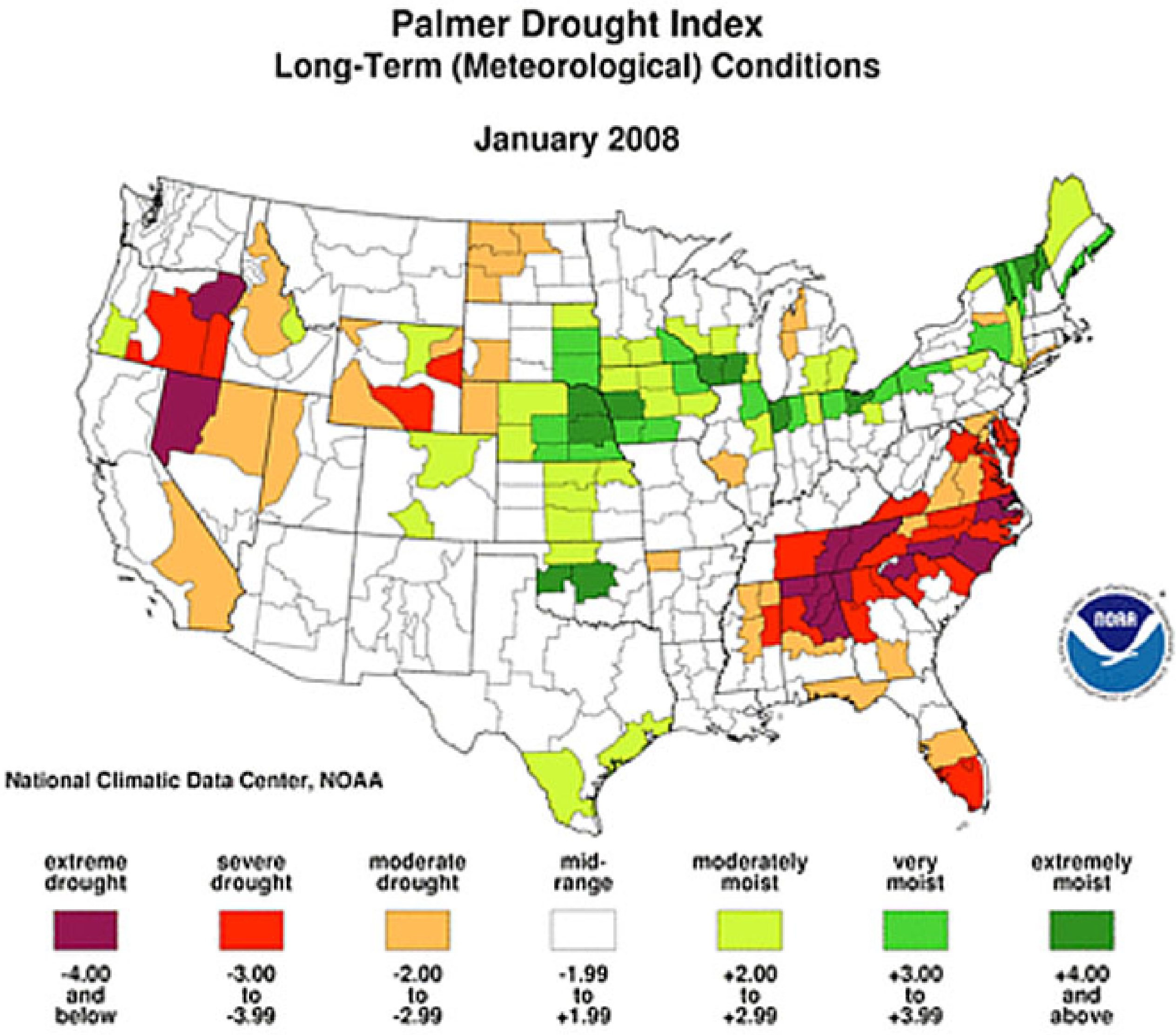
The Norfolk District Regulatory Office has reviewed precipitation data from 2007-2008 with an emphasis on the period December 2007- February 2008 from a number of weather stations in Hampton Roads. We also examined several reference wetlands in the Cities of Hampton, Chesapeake, and Virginia Beach that were studied in some detail from 2002 through 2005. As of February 29, 2008, the majority of the reference sites were far drier than they were during corresponding dates from 2002 through 2005 (see attachments). Analyses prepared by the National Oceanic and Atmospheric Administration and the VA Drought Monitoring Task Force (attached) suggest that southeastern Virginia is experiencing severe meteorologic and hydrologic drought conditions and these drought conditions are likely to persist through the spring of 2008.

The publication entitled "*Technical Standard for Water-Table Monitoring of Potential Wetland Sites*" (USACE 2005) notes that "For many wetlands, water tables in a given year may be affected by precipitation that occurred in previous years, especially if monitoring occurs after an extended period of drought or precipitation excess. After a series of dry years, for example, it may take several years of normal or above-normal rainfall to recharge groundwater and return water tables to normal levels. Therefore, in evaluating wetland hydrology based on short-term monitoring, it is necessary to consider the normality of rainfall over a period of years prior to the groundwater study. Recent precipitation trends can be determined by comparing annual rainfall totals at the monitoring site with the normal range given in WETS tables for two or more years prior to the monitoring study, or by examining trends in drought indices, such as the Palmer Drought Severity Index."

Any monitoring wells used to facilitate wetland hydrology determinations should be installed in accordance with the guidelines in *Technical Standard for Water-Table Monitoring of Potential Wetland Sites*, ERDC-TN-WRAP-05-2, U.S. Army Research and Development Center, Vicksburg, MS (attached). Before we will consider well data for a specified site, we require submittal and approval of a well monitoring plan, which includes a review of the location and installation of the monitoring wells. In addition, during the monitoring season (typically late February through April), the Corps must be allowed reasonable periodic checks without notice to provide proper quality assurance.

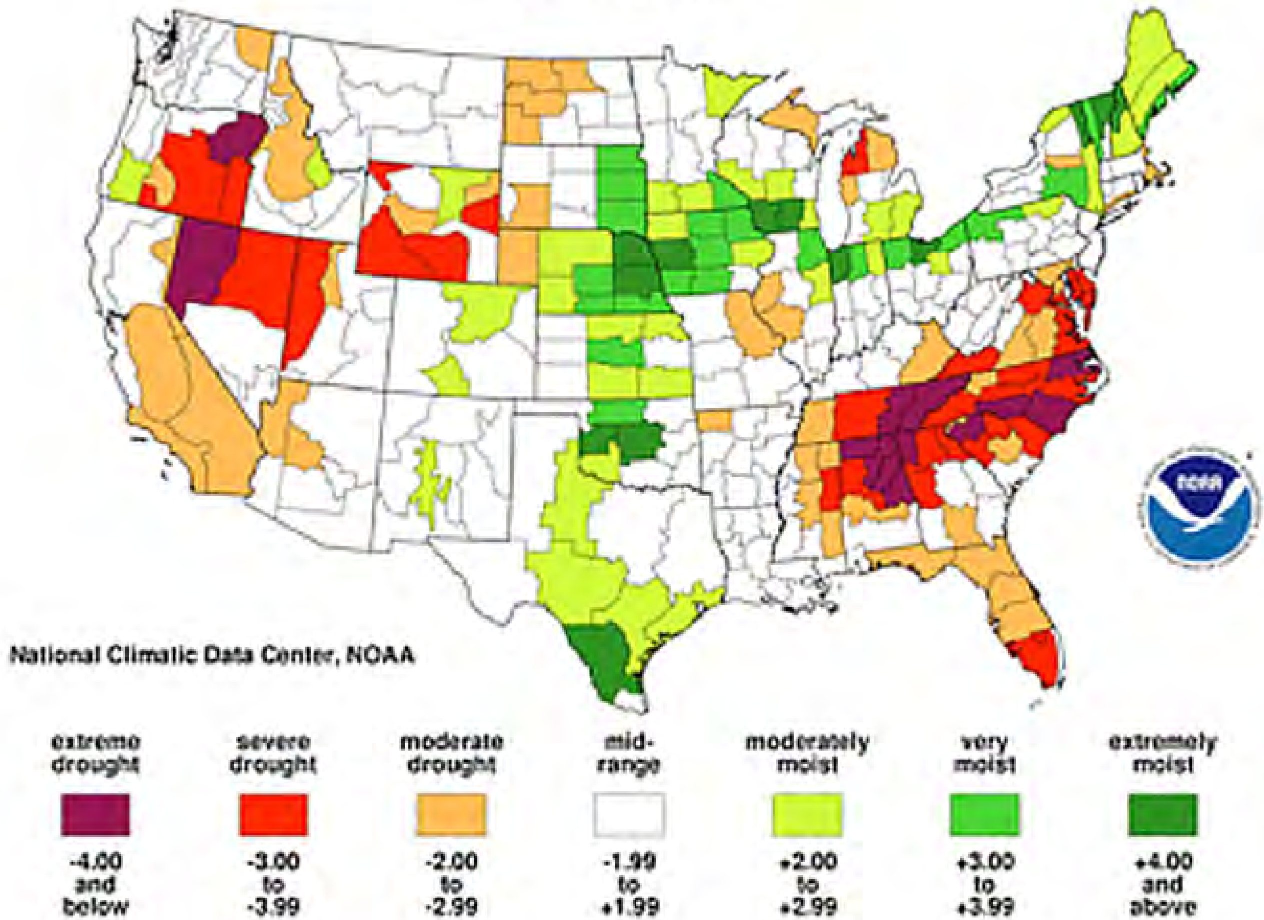
This notice does not relieve those that have constructed wetland mitigation projects from monitoring hydrologic conditions. Monitoring should be conducted in accordance with the associated permit, approved plan, or mitigation banking instrument. Credits will be released from mitigation banks for those areas meeting all applicable performance standards, including hydrologic criteria.

J. Robert Hume, III
Chief, Regulatory Office


Palmer Drought Index
Long-Term (Meteorological) Conditions
January 2008
National Climatic Data Center, NOAA
extreme drought
-4.00 and below
severe drought
-3.00 to -3.99
moderate drought
-2.00 to -2.99
mid-range
-1.99 to +1.99
moderately moist
+2.00 to +2.99
very moist
+3.00 to +3.99
extremely moist
+4.00 and above

Palmer Hydrological Drought Index
Long-Term (Hydrological) Conditions

January 2008



DROUGHT MONITORING TASK FORCE

Drought Status Report

January 22, 2008

Statewide precipitation for the previous water year (October 1, 2006 through September 30, 2007) was below normal (81% of normal). Statewide precipitation for the period from October 1, 2006 until January 17, 2008 was below normal (79% of normal) and statewide precipitation in each successive shorter time period is below normal. Statewide precipitation for the period from January 1, 2008 to January 17, 2008 is 52% of normal. Precipitation greater than 85% of normal is considered to be in the normal range. The following drought evaluation regions are currently below normal for the period beginning October 1, 2006; Big Sandy (73%), New River (80%), Roanoke (78%), Upper James (83%), Middle James (81%), Shenandoah (82%), Northern Virginia (78%), Northern Piedmont (72%), Chowan (84%), Northern Coastal Plain (78%), York-James (76%) and Southeast Virginia (84%). Precipitation deficits across the Commonwealth remained relatively stable in all drought evaluation regions since the last report. All drought evaluation regions now have accumulated precipitation deficits that represent below normal conditions except the Eastern Shore (93%). Appendix A contains precipitation tables for periods dating to October 1, 2006. The long-range monthly climatologic outlook calls for above normal temperatures statewide and below normal precipitation for the eastern half of the Commonwealth through February of 2008. The long-range seasonal outlook calls for above normal temperatures for the entire Commonwealth through April 2008. The long-range seasonal outlook calls for equal chances of below normal, normal and above normal precipitation for the area west of the Blue Ridge and below normal precipitation for the remainder of the Commonwealth through April 2008.

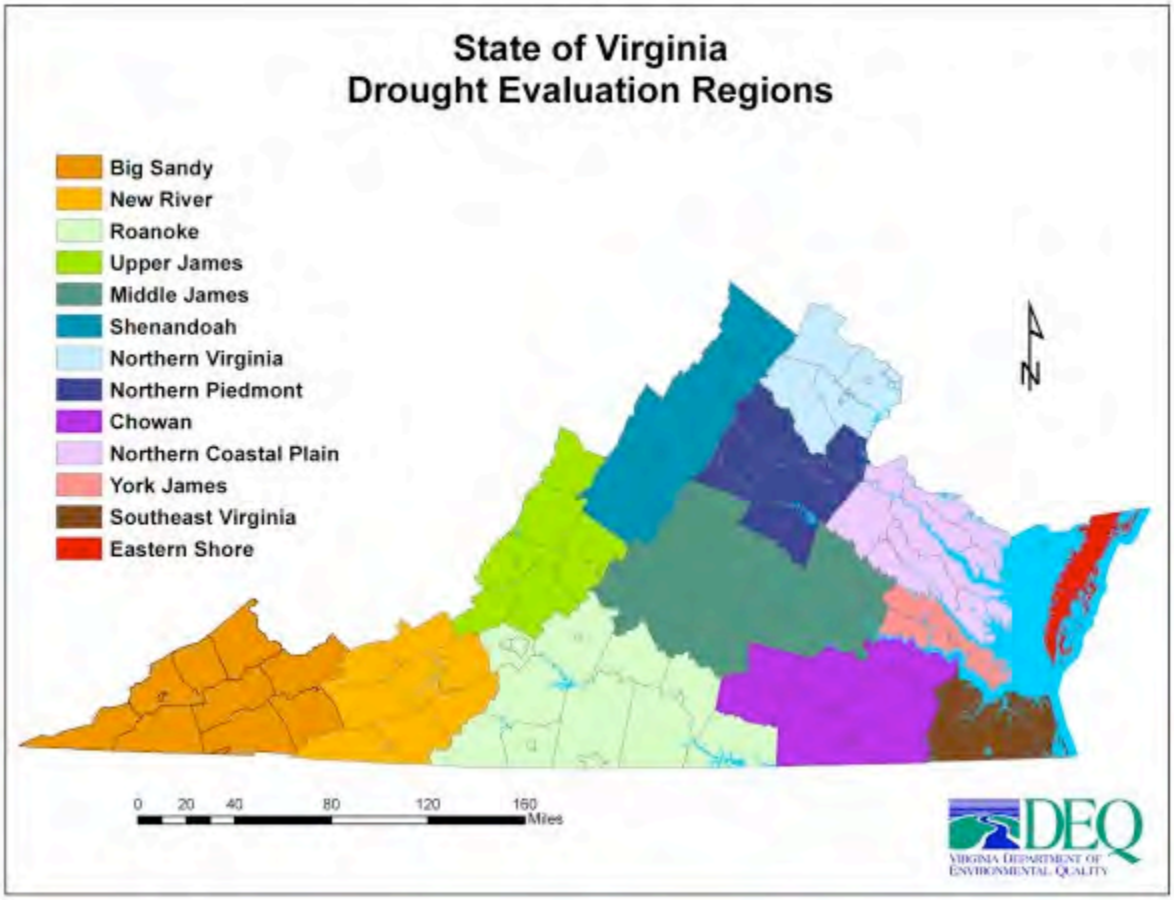
The latest NOAA drought monitor indicates the occurrence of drought conditions throughout the majority of the Commonwealth and is included as Appendix B. Appendix C contains information from the national drought monitor with only Virginia displayed. Drought conditions have remained relatively stable over the Commonwealth during the last month. Areas of exceptional drought in southwest Virginia have improved one drought category and are not rated as extreme drought. The NOAA seasonal drought outlook through April 2008 indicates that drought conditions may improve in the majority of the Commonwealth with the potential for minor improvement in southeast Virginia. The seasonal drought outlook is included as Appendix D.

Seven day average streamflows for January 21 in the majority of the Commonwealth are below normal (10th to 24th percentiles) with some areas in south central Virginia, southeast Virginia, the Middle Peninsula, and Northern Neck in the range of flows indicative of moderate hydrologic drought (6th to 9th percentiles) to severe hydrologic drought (< 5th percentile). Stream flows reacted positively to falling temperatures and the resultant reduction in evapotranspiration and will likely remain stable until the beginning of the growing season.. While drought monitoring ground water levels data is scarce, ground water levels are generally in the lower range of expected water levels in areas east of Route 95 and are generally lower than normal in the area west of Route 95. Five dedicated drought monitoring wells are at levels indicative of moderate hydrologic drought (10th to 24th percentiles) and eight are at levels indicative of severe hydrologic drought (< 10th percentile). More importantly ground water levels in the majority of dedicated monitoring wells have either remained stable of continued to decline during a period when ground water levels are expected to rise indicating ground water recharge. Preliminary indications are that there will be little ground water recharge during the winter of 2007-2008. Levels of most large reservoirs have rebounded over the last month and are expected to fill before spring with the exception of Lake Anna which continues to be significantly lower than normal.

While the Virginia Department of Health has not reported any impacts to public water supplies that have compromised their ability to provide the needs of their customers 31 systems have initiated voluntary water conservation requirements and 13 systems have initiated mandatory water conservation requirements. The reduction in conservation requirements is likely reflective of decrease water demands during the winter season and it is likely Appendix E contains a table of waterworks that have initiated water conservation requirements.

The Department of Forestry reports that light wildfire activity has continued during the month of January. This is above normal wildfire activity and may portend increased activity during the spring wildfire season. Since January 1, 2008 the DOF has responded to 32 wildfires which have burned 194 acres.

The Department of Game and Inland Fisheries reports no significant change in the past month in stream flows or reservoir levels related to recreational activities. Recreation has been impacted minimally however due to the limited seasonal demand. All boat access ramps are open in spite of the lower water levels. Stocking of trout continues on schedule. The trout raised in Department facilities are smaller then average due to the prolonged drought. Significant winter/spring precipitation events are needed to provide adequate recreational opportunity and aquatic habitat during the spring fishing and fish spawning period.


State of Virginia
Drought Evaluation Regions
Big Sandy
New River
Roanoke
Upper James
Middle James
Shenandoah
Northern Virginia
Northern Piedmont
Chowan
Northern Coastal Plain
York James
Southeast Virginia
Eastern Shore
N
0 20 40 80 120 160
Miles
DEQ
VIRGINIA DEPARTMENT OF ENVIRONMENTAL QUALITY

The intensity of drought impacts has continued to decline during the last month due to the end of the active growing season. Current moisture deficits coupled with a dry winter could result in significant drought impacts across all socio-economic sectors in the spring of 2008.

Reports from the Climatology Office of the University of Virginia, the Virginia Department of Agriculture and Consumer Services, the Virginia Department of Environmental Quality, the United States Geological Survey, and the Virginia Department of Forestry follow.

Report of the Climatology Office of the University of Virginia

Continued winter storm activity in late December brought statewide precipitation totals into the normal range for the month. Despite the Commonwealth's first widespread snowfall event of the season, the resulting precipitation amounts were insufficient to push totals for early January much past 50% of normal in all but one Drought Region.

Upper-air circulation has continued to keep winter storms on track for Virginia. Forecasts for the next two weeks indicate a continuation of this trend with above normal precipitation. Longer-range forecasts (February and February through April) indicate below normal precipitation for most of the state.

As has been emphasized in previous reports, precipitation during the colder months of the year is critical to the moisture status throughout the upcoming growing season. An analysis of the long-term climatological records was performed to estimate the probability of receiving threshold statewide average precipitation totals between now and the end of March.

Based upon that analysis, the current probability that the statewide average precipitation total for the period October 2007 through March 2008 will reach a normal level is less than 15 percent. The probability of reaching 85% of normal (low end of the "normal range") is about 60-percent. This does not indicate the likely distribution of precipitation across the individual Drought Regions.

The actual amount of precipitation which would be required to make up for existing deficits and achieve a normal level of moisture reserves is uncertain. Nonetheless, the shrinking probability of reaching even the normal level of precipitation for the period does not bode well for drought impacts during 2008.

Virginia Department of Agriculture and Consumer Services
Status of Agricultural Drought

Overview

According to the USDA crop weather report released on January 7, 2008, topsoil moisture was adequate. Producers are concerned about low subsoil moisture and the dry trend does not help prospects for the 2008 growing season. Hay is still short in supply and farmers continue to struggle with the shift in economics coming from skyrocketing values for hay and fertilizer.

Impact on Crops:

Nursery/Horticulture:

- Virginia's nursery and landscape industry is no longer suffering direct drought damage since most outside plants have gone dormant for the winter. However, the full damage to surviving plants will not become evident until this spring when the plants break dormancy. Drought damage to many plant root systems will not allow for the vigorous spring growth of leaves necessary for sustained plant health. Many plants will die this spring from the drought effects they suffered last fall. Hopefully nurserymen and landscapers will have sufficient healthy plant material to meet the anticipated volume of increased business required to repair or replace homeowner's drought damaged landscaping.

Hay Crop:

- As a result of the hay shortages caused by the 2007 drought, the Virginia Tobacco Indemnification and Community Revitalization Commission has allocated $500,000.00 to livestock producers in the Southwest Virginia counties of Bland, Buchanan, Carroll, Dickenson, Grayson, Lee, Scott, Smyth, Tazewell, Washington, Wise, and Wythe.

Impact on Livestock:

- Snow and ice early in December forced livestock producers to suspend pasture grazing their livestock for about a week. Feed supplies for livestock continue to be tight as stored feed is being depleted and could be non-existent by spring if these supplies are not purchased soon.

Disaster Designations
Due to the extreme agricultural drought, 93 Virginia counties and 34 independent cities have received a Secretarial disaster designation as primary natural disaster areas in 2007. York and Arlington counties and the independent cities of Alexandria, Bristol, Falls Church, Poquoson, and Norton were named contiguous disaster areas.

Waivers for Hauling of Emergency Supplies

At the request of the Department of Agriculture and Consumer Services, the Department of Transportation and Department of Motor Vehicle have jointly authorized a temporary waiver of registration and license requirements along with normal weight and width restrictions for the hauling of hay and feed to the counties that have been designated natural disaster areas by the U.S. Secretary of Agriculture. The waiver also pertains to contiguous counties. In addition, the Department of Emergency Management has authorized appropriate motor carrier exemptions to hours worked as prescribed by the Code of Federal Regulations and corresponding state regulations throughout the Commonwealth for carriers transporting emergency supplies destined for the affected localities. Both waivers became effective at 6 a.m. on August 11 and will remain in effect through April 15, 2008.

Virginia Department of Environmental Quality
Condition of Major Reservoirs

Reservoir conditions have generally improved over the past month and we appear to be on track to bring back major lake levels to their normal elevations by spring. The slowest lake to respond has been Lake Anna due to its relatively small watershed.

Lake Moomaw in western Virginia has gained back 43% of its conservation pool in the past month and now stands at 73% full. The lake is on track to fill before spring. When it does refill, the lake will probably return to normal operations. Inflow during the spring normally exceeds minimum releases because the reservoir passes inflow after it reaches full pool. Variances to the minimum flows remain in place at this time to insure that refilling occurs. The project is releasing only 100 cubic feet of water per second to the Jackson River.

Kerr Reservoir is at 295.9 feet, close to guide curve and 1.2 feet higher than a month ago. The Southeastern Power Administration is making the minimum amount of hydroelectric power to fulfill their contracts. The other Corps of Engineers Lake, Lake Philpott, is at 965.6 feet, still 2 feet below guide curve. Lake Philpott has risen five feet in the past month.

Smith Mountain Lake is at 793.9 feet; 1.1 feet below full. The lake has gained one foot in the past month. The lake level is currently steady. The project is operating under variance and is currently releasing 350 cfs instead of the normal release of 650 cfs. The variance has been in effect for five months, saving about 4.4 feet of water over the normal release. Because of early action by the State, the lake is only one foot down and should refill by spring.

The system of reservoirs owned by Rivanna Water and Sewer Authority is currently 93% full, having gained 5% in the past month. This drought warning has been lifted.

Last week Lake Anna was at 247.8 feet msl, 2.2 feet below full and releasing the drought contingency plan minimum flow of 20 cfs as required by the existing Flow Measurement Design Plan and Operations Manual.

United States Geological Survey
Streamflow and Ground Water Levels

Streamflow in the western portions of the State (Valley and Ridge and Appalachian Plateaus) are generally in the normal to just below normal range. This represents a significant improvement in streamflow conditions for southwest Virginia. Streamflows in the Piedmont and Coastal plain are generally well below normal for this time of year. Water-table wells are a mix with the majority below normal. The disturbing fact is that most well levels have not started their winter recovery that would be expected to begin in early to mid December. This delay of ground water recharge is thought to be due to last fall's warmer than normal temperatures and the resultant late leaf fall. All indications are that recent rainfall has reduced soil moisture deficit and ground-water recharge will not occur until these deficits are eliminated. The monthly and seasonal temperature outlooks indicate higher than normal temperatures for the entire Commonwealth which may result in an early spring green-up and early leaf out. If we experience an early spring there will be little opportunity for ground water recharge to occur.

Precipitation in the next two months will be critical for reducing the effect of drought this spring and summer.

Streamflow conditions based on daily values for January 21 are presented in Appendix F. Area summaries of 7-day average streamflows from the USGS drought watch web page show similar flow conditions and are presented in Appendix G. Current conditions are generally lower than depicted by seven day average stream flows as flows continue to decline. Ground water levels based on conditions on January 21 are presented in Appendix H.

Department of Forestry

The Virginia Department of Forestry reports that through January 17th, the agency has responded to 32 fires which have burned 294 acres. This activity is above average for this time of year and indicative of the drier than normal conditions across the Commonwealth.

The obvious concern is how current conditions may impact wildfire potential during the month of February and what that may mean for Virginia's spring wildfire season. All indications are that the Commonwealth will experience a higher than normal number of fires this spring and the agency is ready to respond as necessary.

The DOF also reports concern over secondary drought effects such as a continued upward trend for forest pest outbreaks such as Gypsy Moth and Southern Pine Beetle and also concerns with higher than normal tree seedling mortality following the spring planting season. More than 18 million seedlings are planted in Virginia each year and poor survival as a result of extended dry conditions can create major economic impacts lasting for many years.

APPENDIX A

Precipitation departures by Drought Evaluation Region.

PRELIMINARY PRECIPITATION SUMMARY

Prepared: 01/19/08

	DROUGHT REGION	OBSERVED	Jan 1, 2008 NORMAL	- Jan 17, 2008 DEPARTURE	% OF NORM.
1	Big Sandy	2.24	2.05	0.19	110%
2	New River	0.97	1.76	-0.79	55%
3	Roanoke	0.81	2.15	-1.34	38%
4	Upper James	1.08	1.80	-0.72	60%
5	Middle James	0.76	2.01	-1.25	38%
6	Shenandoah	0.91	1.56	-0.65	58%
7	Northern Virginia	1.12	1.80	-0.68	62%
8	Northern Piedmont	0.92	1.93	-1.01	48%
9	Chowan	0.68	2.25	-1.57	30%
10	Northern Coastal Plain	1.11	2.06	-0.95	54%
11	York-James	0.93	2.27	-1.34	41%
12	Southeast Virginia	0.65	2.28	-1.63	28%
13	Eastern Shore	1.13	1.95	-0.82	58%
	Statewide	1.03	2.00	-0.97	52%

	DROUGHT REGION	OBSERVED	Dec 1, 2007 NORMAL	- Jan 17, 2008 DEPARTURE	% OF NORM.
1	Big Sandy	5.25	5.69	-0.43	92%
2	New River	3.55	4.47	-0.93	79%
3	Roanoke	4.03	5.40	-1.37	75%
4	Upper James	4.19	4.75	-0.56	88%
5	Middle James	3.49	5.18	-1.69	67%
6	Shenandoah	3.86	4.15	-0.30	93%
7	Northern Virginia	4.16	4.90	-0.74	85%
8	Northern Piedmont	4.12	5.21	-1.09	79%
9	Chowan	4.82	5.27	-0.45	91%
10	Northern Coastal Plain	3.86	5.34	-1.48	72%
11	York-James	5.04	5.66	-0.62	89%
12	Southeast Virginia	4.31	5.46	-1.16	79%
13	Eastern Shore	5.70	5.19	0.51	110%
	Statewide	4.16	5.12	-0.96	81%

	DROUGHT REGION	OBSERVED	Nov 1, 2007 NORMAL	- Jan 17, 2008 DEPARTURE	% OF NORM.
1	Big Sandy	6.93	8.97	-2.04	77%
2	New River	4.20	7.50	-3.30	56%
3	Roanoke	4.50	8.76	-4.26	51%
4	Upper James	4.71	8.11	-3.40	58%
5	Middle James	4.08	8.69	-4.60	47%
6	Shenandoah	4.99	7.20	-2.21	69%
7	Northern Virginia	5.78	8.31	-2.53	70%
8	Northern Piedmont	5.12	9.01	-3.89	57%
9	Chowan	5.33	8.38	-3.06	64%
10	Northern Coastal Plain	5.00	8.48	-3.48	59%
11	York-James	5.86	9.03	-3.17	65%
12	Southeast Virginia	4.87	8.53	-3.66	57%
13	Eastern Shore	6.54	8.13	-1.59	80%
	Statewide	5.01	8.35	-3.34	60%

	DROUGHT REGION	OBSERVED	Oct 1, 2007 NORMAL	- Jan 17, 2008 DEPARTURE	% OF NORM.
1	Big Sandy	8.66	11.85	-3.18	73%
2	New River	8.04	10.67	-2.63	75%
3	Roanoke	8.45	12.47	-4.02	68%
4	Upper James	7.08	11.36	-4.28	62%
5	Middle James	7.99	12.53	-4.54	64%
6	Shenandoah	7.39	10.39	-3.00	71%
7	Northern Virginia	9.44	11.79	-2.35	80%
8	Northern Piedmont	7.62	13.00	-5.38	59%
9	Chowan	8.42	11.96	-3.54	70%
10	Northern Coastal Plain	10.37	11.99	-1.62	87%
11	York-James	9.70	12.56	-2.86	77%
12	Southeast Virginia	10.14	12.19	-2.05	83%
13	Eastern Shore	9.91	11.34	-1.44	87%
	Statewide	8.40	11.85	-3.45	71%

	DROUGHT REGION	OBSERVED	Sep 1, 2007 NORMAL	- Jan 17, 2008 DEPARTURE	% OF NORM.
1	Big Sandy	9.91	15.31	-5.39	65%
2	New River	9.68	14.08	-4.40	69%
3	Roanoke	10.53	16.70	-6.17	63%
4	Upper James	9.33	14.86	-5.53	63%
5	Middle James	8.80	16.66	-7.86	53%
6	Shenandoah	9.34	14.06	-4.72	66%
7	Northern Virginia	10.61	15.86	-5.25	67%
8	Northern Piedmont	8.61	17.28	-8.67	50%
9	Chowan	9.39	16.39	-7.01	57%
10	Northern Coastal Plain	11.61	16.08	-4.46	72%
11	York-James	11.60	17.46	-5.86	66%
12	Southeast Virginia	10.87	16.62	-5.75	65%
13	Eastern Shore	11.47	14.95	-3.49	77%
	Statewide	9.82	15.85	-6.03	62%

	DROUGHT REGION	OBSERVED	Aug 1, 2007 NORMAL	- Jan 17, 2008 DEPARTURE	% OF NORM.
1	Big Sandy	11.10	19.14	-8.04	58%
2	New River	10.87	17.39	-6.52	63%
3	Roanoke	11.36	20.42	-9.06	56%
4	Upper James	10.77	18.19	-7.42	59%
5	Middle James	11.52	20.48	-8.96	56%
6	Shenandoah	12.11	17.39	-5.28	70%
7	Northern Virginia	12.47	19.71	-7.24	63%
8	Northern Piedmont	10.99	21.10	-10.11	52%
9	Chowan	11.40	20.70	-9.31	55%
10	Northern Coastal Plain	13.06	19.94	-6.88	66%
11	York-James	13.93	22.33	-8.41	62%
12	Southeast Virginia	14.35	21.74	-7.40	66%
13	Eastern Shore	13.96	18.82	-4.86	74%
	Statewide	11.69	19.68	-7.99	59%

	DROUGHT		Jul 1, 2007	- Jan 17, 2008	
	REGION	OBSERVED	NORMAL	DEPARTURE	% OF NORM.
1	Big Sandy	15.59	23.62	-8.03	66%
2	New River	13.80	21.18	-7.38	65%
3	Roanoke	14.63	24.81	-10.18	59%
4	Upper James	13.11	22.23	-9.12	59%
5	Middle James	13.87	24.89	-11.01	56%
6	Shenandoah	14.11	21.15	-7.04	67%
7	Northern Virginia	14.94	23.48	-8.54	64%
8	Northern Piedmont	12.52	25.50	-12.98	49%
9	Chowan	14.45	25.21	-10.76	57%
10	Northern Coastal Plain	14.48	24.39	-9.91	59%
11	York-James	17.37	27.43	-10.06	63%
12	Southeast Virginia	17.66	26.81	-9.16	66%
13	Eastern Shore	16.05	22.82	-6.77	70%
	Statewide	14.42	24.02	-9.60	60%

	DROUGHT		Jun 1, 2007	- Jan 17, 2008	
	REGION	OBSERVED	NORMAL	DEPARTURE	% OF NORM.
1	Big Sandy	18.33	27.76	-9.42	66%
2	New River	16.84	25.03	-8.19	67%
3	Roanoke	17.56	28.70	-11.14	61%
4	Upper James	16.87	25.94	-9.07	65%
5	Middle James	17.23	28.40	-11.17	61%
6	Shenandoah	17.39	24.86	-7.48	70%
7	Northern Virginia	16.88	27.34	-10.46	62%
8	Northern Piedmont	14.67	29.51	-14.84	50%
9	Chowan	16.67	28.86	-12.20	58%
10	Northern Coastal Plain	16.33	27.95	-11.61	58%
11	York-James	19.56	30.84	-11.29	63%
12	Southeast Virginia	20.88	30.42	-9.55	69%
13	Eastern Shore	21.30	25.80	-4.50	83%
	Statewide	17.28	27.81	-10.53	62%

	DROUGHT REGION	OBSERVED	May 1, 2007 NORMAL	- Jan 17, 2008 DEPARTURE	% OF NORM.
1	Big Sandy	20.08	32.58	-12.50	62%
2	New River	18.62	29.24	-10.62	64%
3	Roanoke	19.53	33.03	-13.50	59%
4	Upper James	18.89	30.22	-11.33	63%
5	Middle James	19.69	32.64	-12.95	60%
6	Shenandoah	19.57	28.70	-9.13	68%
7	Northern Virginia	18.14	31.68	-13.54	57%
8	Northern Piedmont	16.76	33.73	-16.97	50%
9	Chowan	19.55	32.95	-13.40	59%
10	Northern Coastal Plain	17.58	32.11	-14.53	55%
11	York-James	21.11	35.11	-14.00	60%
12	Southeast Virginia	22.84	34.28	-11.44	67%
13	Eastern Shore	23.04	29.32	-6.28	79%
	Statewide	19.31	32.07	-12.76	60%

	DROUGHT REGION	OBSERVED	Apr 1, 2007 NORMAL	- Jan 17, 2008 DEPARTURE	% OF NORM.
1	Big Sandy	24.55	36.34	-11.79	68%
2	New River	21.74	32.79	-11.05	66%
3	Roanoke	22.74	36.83	-14.09	62%
4	Upper James	22.39	33.62	-11.23	67%
5	Middle James	22.92	35.98	-13.06	64%
6	Shenandoah	23.15	31.62	-8.47	73%
7	Northern Virginia	21.87	34.98	-13.11	63%
8	Northern Piedmont	19.86	37.02	-17.16	54%
9	Chowan	23.99	36.38	-12.40	66%
10	Northern Coastal Plain	21.29	35.20	-13.91	60%
11	York-James	25.15	38.41	-13.26	65%
12	Southeast Virginia	27.36	37.53	-10.18	73%
13	Eastern Shore	27.59	32.24	-4.65	86%
	Statewide	22.95	35.49	-12.54	65%

	DROUGHT REGION	OBSERVED	Mar 1, 2007 NORMAL	- Jan 17, 2008 DEPARTURE	% OF NORM.
1	Big Sandy	27.68	40.59	-12.90	68%
2	New River	25.77	36.46	-10.69	71%
3	Roanoke	26.43	41.10	-14.67	64%
4	Upper James	26.03	37.41	-11.38	70%
5	Middle James	25.97	40.04	-14.06	65%
6	Shenandoah	26.03	34.82	-8.79	75%
7	Northern Virginia	25.02	38.64	-13.62	65%
8	Northern Piedmont	22.29	40.83	-18.54	55%
9	Chowan	26.56	40.75	-14.20	65%
10	Northern Coastal Plain	24.10	39.48	-15.38	61%
11	York-James	26.87	43.10	-16.23	62%
12	Southeast Virginia	29.30	41.73	-12.43	70%
13	Eastern Shore	29.37	36.55	-7.18	80%
	Statewide	26.02	39.53	-13.51	66%

	DROUGHT REGION	OBSERVED	Feb 1, 2007 NORMAL	- Jan 17, 2008 DEPARTURE	% OF NORM.
1	Big Sandy	29.08	44.17	-15.09	66%
2	New River	27.42	39.39	-11.97	70%
3	Roanoke	28.48	44.41	-15.93	64%
4	Upper James	28.48	40.26	-11.78	71%
5	Middle James	27.95	43.16	-15.21	65%
6	Shenandoah	28.08	37.23	-9.15	75%
7	Northern Virginia	27.86	41.31	-13.45	67%
8	Northern Piedmont	24.73	43.80	-19.07	56%
9	Chowan	28.72	43.92	-15.20	65%
10	Northern Coastal Plain	26.60	42.62	-16.01	62%
11	York-James	28.62	46.63	-18.02	61%
12	Southeast Virginia	31.56	45.23	-13.67	70%
13	Eastern Shore	32.16	39.74	-7.58	81%
	Statewide	28.11	42.66	-14.55	66%

	DROUGHT REGION	OBSERVED	Jan 1, 2007 NORMAL	- Jan 17, 2008 DEPARTURE	% OF NORM.
1	Big Sandy	32.26	47.90	-15.63	67%
2	New River	30.38	42.60	-12.22	71%
3	Roanoke	32.36	48.33	-15.97	67%
4	Upper James	31.49	43.54	-12.05	72%
5	Middle James	31.52	46.82	-15.30	67%
6	Shenandoah	29.64	40.08	-10.44	74%
7	Northern Virginia	30.11	44.59	-14.48	68%
8	Northern Piedmont	27.25	47.32	-20.07	58%
9	Chowan	31.25	48.03	-16.79	65%
10	Northern Coastal Plain	30.84	46.37	-15.52	67%
11	York-James	31.23	50.77	-19.55	62%
12	Southeast Virginia	34.73	49.39	-14.66	70%
13	Eastern Shore	34.33	43.30	-8.97	79%
	Statewide	31.17	46.30	-15.13	67%

	DROUGHT REGION	OBSERVED	Dec 1, 2006 NORMAL	- Jan 17, 2008 DEPARTURE	% OF NORM.
1	Big Sandy	34.26	51.54	-17.28	66%
2	New River	32.17	45.31	-13.14	71%
3	Roanoke	34.54	51.58	-17.04	67%
4	Upper James	33.48	46.49	-13.01	72%
5	Middle James	33.11	49.99	-16.88	66%
6	Shenandoah	30.77	42.67	-11.91	72%
7	Northern Virginia	31.77	47.69	-15.92	67%
8	Northern Piedmont	29.00	50.60	-21.60	57%
9	Chowan	33.41	51.05	-17.64	65%
10	Northern Coastal Plain	32.55	49.65	-17.10	66%
11	York-James	33.05	54.16	-21.12	61%
12	Southeast Virginia	37.18	52.57	-15.39	71%
13	Eastern Shore	37.08	46.54	-9.46	80%
	Statewide	33.02	49.42	-16.40	67%

	DROUGHT REGION	OBSERVED	Nov 1, 2006 NORMAL	- Jan 17, 2008 DEPARTURE	% OF NORM.
1	Big Sandy	37.01	54.82	-17.81	68%
2	New River	36.12	48.34	-12.22	75%
3	Roanoke	39.93	54.94	-15.01	73%
4	Upper James	37.26	49.85	-12.59	75%
5	Middle James	38.84	53.50	-14.66	73%
6	Shenandoah	34.91	45.72	-10.81	76%
7	Northern Virginia	37.56	51.10	-13.53	74%
8	Northern Piedmont	35.30	54.40	-19.10	65%
9	Chowan	40.79	54.16	-13.38	75%
10	Northern Coastal Plain	37.85	52.79	-14.94	72%
11	York-James	38.71	57.53	-18.82	67%
12	Southeast Virginia	44.80	55.64	-10.84	81%
13	Eastern Shore	41.96	49.48	-7.53	85%
	Statewide	38.18	52.65	-14.47	73%

	DROUGHT REGION	OBSERVED	Oct 1, 2006 NORMAL	- Jan 17, 2008 DEPARTURE	% OF NORM.
1	Big Sandy	41.98	57.70	-15.71	73%
2	New River	41.11	51.51	-10.40	80%
3	Roanoke	45.97	58.65	-12.68	78%
4	Upper James	44.19	53.10	-8.91	83%
5	Middle James	46.53	57.34	-10.81	81%
6	Shenandoah	40.16	48.91	-8.76	82%
7	Northern Virginia	42.35	54.58	-12.23	78%
8	Northern Piedmont	41.83	58.39	-16.56	72%
9	Chowan	48.49	57.74	-9.26	84%
10	Northern Coastal Plain	43.92	56.30	-12.37	78%
11	York-James	46.71	61.06	-14.35	76%
12	Southeast Virginia	49.87	59.30	-9.43	84%
13	Eastern Shore	48.89	52.69	-3.80	93%
	Statewide	44.42	56.15	-11.73	79%

Reference Wells

Wells Read 2/29/08 by Martin, Cotnoir, & Decker

Dates	Depth to water (inches) 2/28/2003	3/1/2003	3/1/2004	3/1/2005	2/29/2008	Notes on 2/29/08
Stumpy Lake Wells						
Well 1	1.4	0.8	-19.5	-1.5	-16	dry
Well 2	1.7	1.8	-6.1	-0.3	-22	0.5" of mud at bottom of w
Well 3	1.2	0.7	-18.6	-1.1	-24	dry
Well 4	0.4	-0.1	-4.3	-1.6	-24	dry
Well 5	-0.2	-0.6	-3.7	-0.9	-21	dry
Well 6	0.2	-0.2	-2.6	-7.2	-22	dry

OGC Wells	3/1/2002	2/19/2003	3/8/2003	2/26/2004	3/3/2004	3/1/2005	2/29/2008
Well 1	dry	-7.5	-8	-15.5	-18.5	-8.5	-25.5
Well 2	-27	-7.5	-7.5	-16.5	-19.5	-8.5	-23
Well 3	dry	-9	-8	-20.5	-23.5	-10.5	-21
Well 4	dry	-14	-13.5	-22	-24	-13.5	-21
Well 5	dry	-13	-13	-19.5	-21	-12.5	-23.5

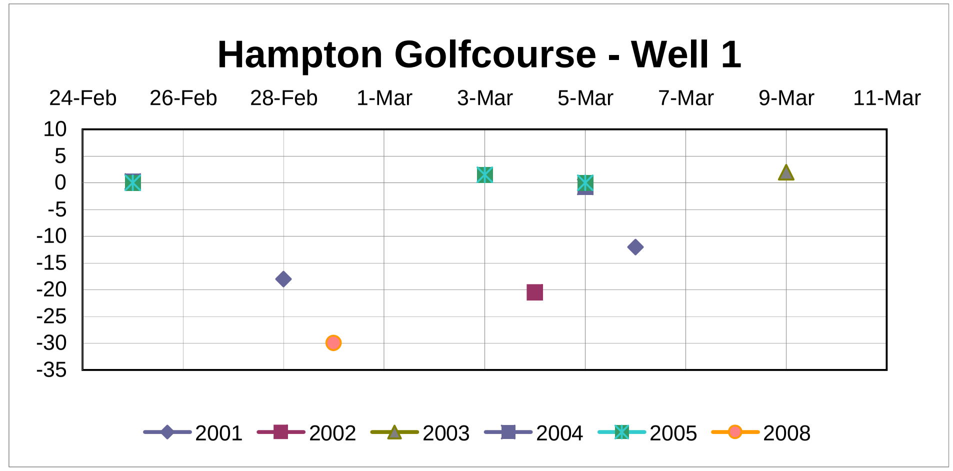
Hampton Golfcourse Shallow Groundwater Monitoring Wells

Values are inches below the soil surface to free water (or the bottom of the well)

Wells read 29 Feb by Nash, Floyd & Knepper

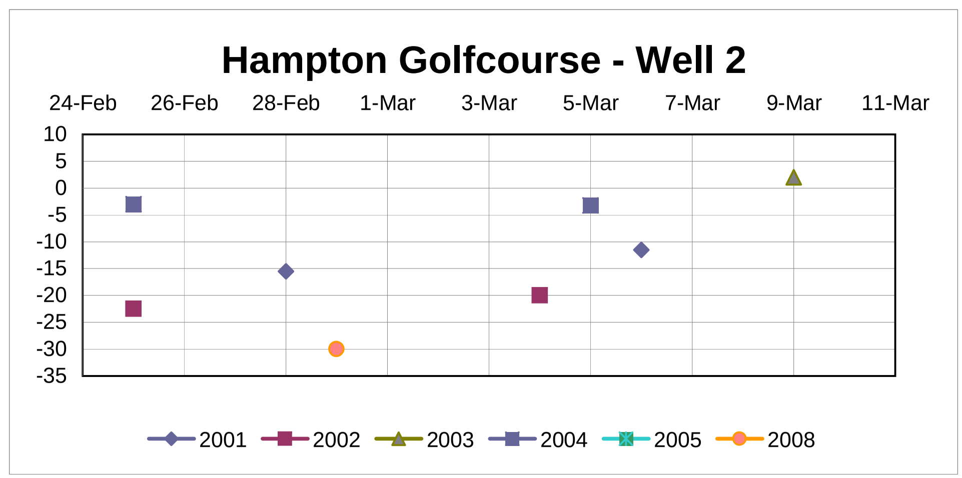
Hampton Golfcourse - Well 1

	YEAR MONITORED					
DAY	2001	2002	2003	2004	2005	2008
25-Feb				0.25		
26-Feb						
27-Feb						
28-Feb	-18					
29-Feb						-30
1-Mar						
2-Mar						
3-Mar					1.5	
4-Mar		-20.5				
5-Mar				-0.75		
6-Mar	-12					
7-Mar						
8-Mar						
9-Mar			2			



Hampton Golfcourse - Well 2

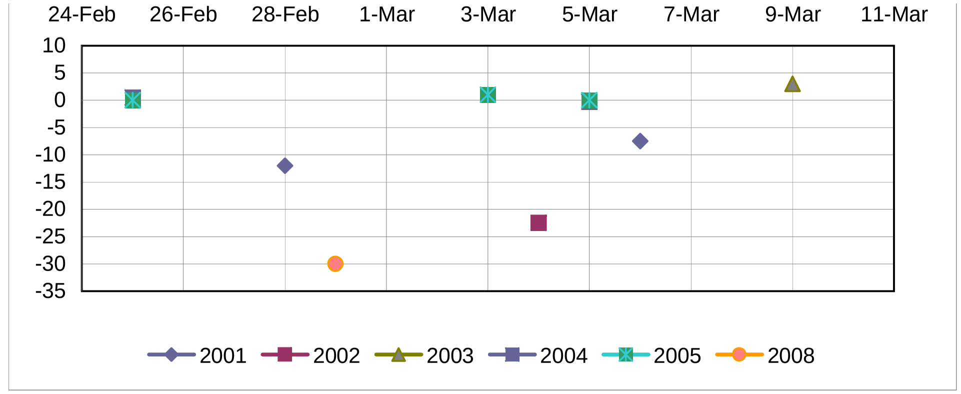
	YEAR MONITORED					
DAY	2001	2002	2003	2004	2005	2008
25-Feb		-22.5		-3		
26-Feb						
27-Feb						
28-Feb	-15.5					
29-Feb						-30
1-Mar						
2-Mar						
3-Mar					-1.75	
4-Mar		-20				
5-Mar				-3.25		
6-Mar	-11.5					
7-Mar						
8-Mar						
9-Mar			2			



Hampton Golfcourse - Well 3

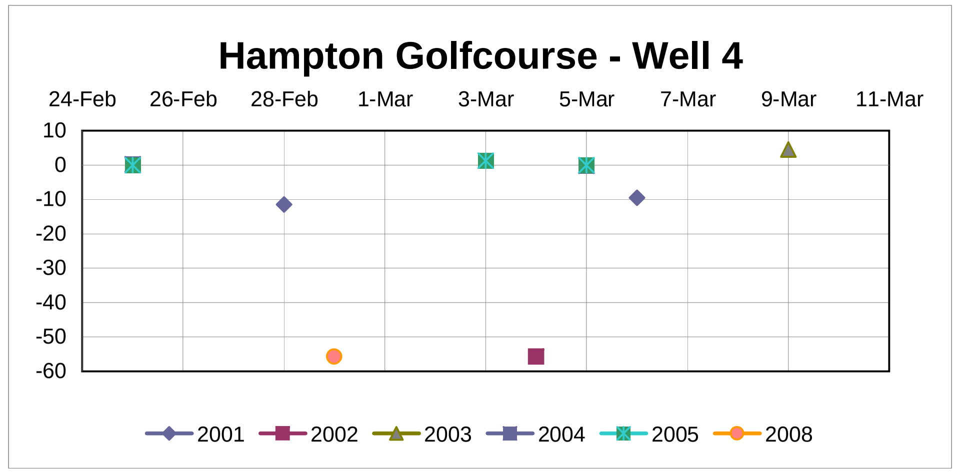
	YEAR MONITORED					
DAY	2001	2002	2003	2004	2005	2008
25-Feb				0.5		

26-Feb						
27-Feb						
28-Feb	-12					
29-Feb						-30
1-Mar						
2-Mar						
3-Mar					1	
4-Mar		-22.5				
5-Mar				-0.25		
6-Mar	-7.5					
7-Mar						
8-Mar						
9-Mar			3			



Hampton Golfcourse - Well 4

DAY	YEAR MONITORED					
	2001	**2002**	**2003**	**2004**	**2005**	**2008**
25-Feb				0.25		
26-Feb						
27-Feb						
28-Feb	-11.5					
29-Feb						-55.8
1-Mar						
2-Mar						
3-Mar					1.25	
4-Mar		-55.75				
5-Mar				-0.25		
6-Mar	-9.5					
7-Mar						
8-Mar						
9-Mar			4.5			



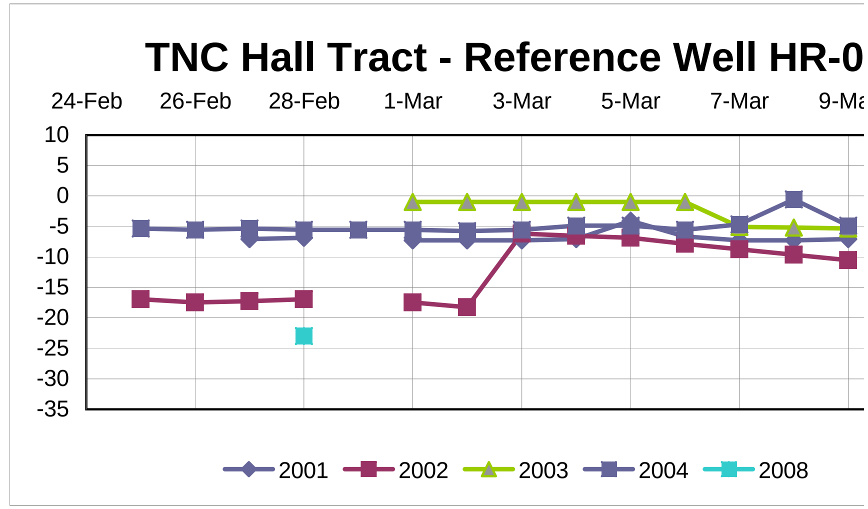
TNC Chesapeake Properties (Su, Hall, Benefits) Groundwater Monitoring Wells

Values are inches below the soil surface to free water (or the bottom of the well)

New boreholes dug & read near reference wells on 28 Feb 2008 by Knepper

Hall Tract - HR-09

	YEAR MONITORED				
DAY	**2001**	**2002**	**2003**	**2004**	**2008**
25-Feb		-16.95		-5.35	
26-Feb		-17.45		-5.55	
27-Feb	-7.05	-17.25		-5.35	
28-Feb	-6.85	-16.95		-5.55	-23
29-Feb				-5.55	
1-Mar	-7.25	-17.45	-0.95	-5.55	
2-Mar	-7.25	-18.25	-0.95	-5.75	
3-Mar	-7.25	-6.15	-0.95	-5.55	
4-Mar	-7.05	-6.55	-0.95	-4.85	
5-Mar	-4.05	-6.85	-0.95	-4.85	
6-Mar	-6.65	-7.85	-0.95	-5.55	
7-Mar	-7.25	-8.75	-5.05	-4.65	
8-Mar	-7.25	-9.65	-5.15	-0.55	
9-Mar	-7.05	-10.55	-5.35	-4.85	



Hall Tract - HR-10

	YEAR MONITORED				
DAY	**2001**	**2002**	**2003**	**2004**	**2008**
25-Feb				-3.3	
26-Feb				-4.7	
27-Feb	-8			-5.2	
28-Feb	-7.3			-6.6	-22
29-Feb				-8.1	
1-Mar	-8			-8.3	
2-Mar	-6.9			-8.3	
3-Mar	-7.5			-7.9	
4-Mar	-7.5			-8.3	
5-Mar	-9.1			-8.6	
6-Mar	-8			-8.6	
7-Mar	-9.3			-7.9	
8-Mar	-8.8			-0.1	
9-Mar	-8.2			-1.5	

Su Tract - R1

	YEAR MONITORED				
DAY	**2002**	**2003**	**2004**	**2005**	**2008**
25-Feb	-32.4		-2.7	1	
26-Feb	-32.4		-4	-0.5	
27-Feb	-32.4		-4.5	-1	
28-Feb	-32.4		-6.2	1.9	-25
29-Feb			-7.3		
1-Mar	-32.4	0.6	-7.8	1.5	
2-Mar	-32.4	2.1	-7.8	0.4	
3-Mar	-32.2	0.8	-7.8	-0.3	
4-Mar	-32.2	0.2	-8.6	-1	
5-Mar	-32.4	2.1	-9.5	-0.9	
6-Mar	-32.4	2.6	-8.6	-1.2	
7-Mar	-32.4	1.2	-9.8	-1.4	
8-Mar	-32.4	1.2	0.1	0.1	
9-Mar	-32.6	0.8	-1.8	0.2	

Su Tract - R2

	YEAR MONITORED				
DAY	**2002**	**2003**	**2004**	**2005**	**2008**
25-Feb	-33.2				
26-Feb	-33.2				
27-Feb	-33.2				
28-Feb	-33.2				-26
29-Feb					
1-Mar	-33.2				
2-Mar	-33.3				
3-Mar	-27.3				
4-Mar	-30.9				
5-Mar	-31.8				
6-Mar	-33.2				
7-Mar	-33.2				
8-Mar	-33.2				
9-Mar	-33.2				

Su Tract - R3

	YEAR MONITORED				
DAY	**2002**	**2003**	**2004**	**2005**	**2008**
25-Feb	-30.9				

26-Feb	-30.9				
27-Feb	-30.7				
28-Feb	-30.7				-7
29-Feb					
1-Mar	-30.3				
2-Mar	-30.3				
3-Mar	-3.3				
4-Mar	-9.1				
5-Mar	-15.3				
6-Mar	-18.1				
7-Mar	-20				
8-Mar	-21.5				
9-Mar	-22.8				

Su Tract - R4

	YEAR MONITORED				
DAY	**2002**	**2003**	**2004**	**2005**	**2008**
25-Feb	-32.15		1	2.7	
26-Feb	-31.95		0.8	1.9	
27-Feb	-31.95		0.8	1.7	
28-Feb	-30.25		0.2	3.4	-25.5
29-Feb			-0.1		
1-Mar	-30.3	2.3	-0.1	2.8	
2-Mar	-31.8	3.6	0.2	2.3	
3-Mar	-8.1	2.5	0.4	1.5	
4-Mar	-13.6	1.9	-0.1	1.3	
5-Mar	-18.3	3.4	-0.1	1.5	
6-Mar	-22.1	3.6	-0.3	1.5	
7-Mar	-24.5	2.5	0.2	1.5	
8-Mar	-26.6	2.5	2.5	2.5	
9-Mar	-28.6	2.3	1.9	2.3	

Su Tract - R5

	YEAR MONITORED				
DAY	**2002**	**2003**	**2004**	**2005**	**2008**
25-Feb	-31		-0.5	0	
26-Feb	-31		-0.9	0.8	
27-Feb	-31.2		-0.9	0.6	
28-Feb	-29.6		-1.1	0.4	-26.5
29-Feb			-0.9		

1-Mar	-30.4	-0.3	-0.5	1.5	
2-Mar	-31	0.6	-0.5	1.4	
3-Mar	-17.8	0	0.2	1	
4-Mar	-19.5	-0.7	0	0.6	
5-Mar	-21.6	-0.1	0.2	0.4	
6-Mar	-23.1	1.2	-0.1	0.4	
7-Mar	-24.2	0.4	0.8	0	
8-Mar	-25.3	0	0.2	0.2	
9-Mar	-26.3	-0.1	-0.1	0.8	

Wetlands Regulatory Assistance Program

ERDC TN-WRAP-05-2
June 2005

Technical Standard for Water-Table Monitoring of Potential Wetland Sites

by U.S. Army Corps of Engineers

PURPOSE: This technical note describes national standards for the collection, analysis, interpretation, and reporting of hydrologic data, which may be used to help determine whether wetlands are present on disturbed or problematic sites that may be subject to Clean Water Act regulatory jurisdiction. These standards may be supplemented or superseded by locally or regionally developed standards at the discretion of the appropriate Corps of Engineers District.

BACKGROUND: Wetland determinations in the majority of cases are based on the presence of readily observable field indicators of hydrophytic vegetation, hydric soils, and wetland hydrology, according to procedures given in the *Corps of Engineers Wetlands Delineation Manual* (Environmental Laboratory 1987) (hereafter called the Corps Manual). These three characteristics are the best available evidence that an area has performed in the past, and continues to perform, the functions associated with wetland ecosystems.

The Corps Manual (Part IV, Section F, Atypical Situations) recognizes that wetland determinations on some sites may be difficult because of human disturbance that may have altered or destroyed wetland indicators. In addition, some naturally occurring wetland types may lack indicators or may have indicators present only at certain times of year or during certain years in a multi-year cycle (Part IV, Section G, Problem Areas). Wetland determinations in these atypical and problem situations increasingly involve the use of direct hydrologic monitoring to confirm the presence of wetlands in cases where soils or vegetation have been significantly disturbed or are naturally problematic, or where the hydrology of the site has been altered recently such that soil and vegetation indicators may give a misleading impression of the site's current wetland status.

The Corps Manual provides only a general discussion of wetland hydrology concepts and does not provide a suitable standard that can be used to design a hydrologic monitoring study or interpret hydrologic data, particularly in cases where groundwater is an important water source. Therefore, the purpose of this Technical Standard is to provide a minimum standard for the design, construction, and installation of water-table monitoring wells, and for the collection and interpretation of groundwater monitoring data, in cases where direct hydrologic measurements are needed to determine whether wetlands are present on highly disturbed or problematic sites.

USE OF THE TECHNICAL STANDARD: The Technical Standard is intended for use in atypical and problem situations as described in the Corps Manual. Atypical situations are broadly defined as any wetlands where indicators of hydrophytic vegetation, hydric soil, or wetland hydrology may be lacking due to recent human activities or natural events. Problem areas are wetlands that may lack wetland indicators at certain times due to normal variations in environmental conditions. This standard is designed to determine a site's current hydrologic status and may not be appropriate for evaluating past or pre-disturbance conditions.

This standard should not be used to overrule a wetland determination based on indicators of hydrophytic vegetation, hydric soil, and wetland hydrology on sites that are not significantly disturbed or problematic. Wetland indicators reflect natural processes that occur in wetlands and generally provide the best evidence that functioning wetlands are present on a site. The actual hydrologic regime required to produce and maintain a wetland may vary locally and regionally due to climate, landforms, geology, soils, and plant and animal adaptations. Therefore, any wetland hydrologic standard is necessarily an approximation and should be used only when an indicator-based wetland determination is not possible or would give misleading results.

In addition, this standard is not intended to overrule other scientific evidence that particular regional or local wetland types may be associated with hydrologic conditions different from those described here, including the seasonal timing, depth, duration, and frequency of saturation. Standards used to verify wetland hydrology in such cases should be based on the best available scientific information concerning a particular local or regional wetland type.

The Technical Standard is designed solely to determine the location of the water table for wetland jurisdictional purposes. It should not be used for water-quality monitoring or other purposes. This national standard may be supplemented or superseded by locally or regionally developed standards at the discretion of the District, and well-documented and justified deviations from the standard are acceptable with the approval of the District. It is always good practice to discuss the goals and design of the monitoring study with Corps regulatory personnel before initiating work. This may help to avoid disagreements and problems of interpretation later. This standard is subject to periodic review and revision as better scientific information becomes available.

SITE CHARACTERIZATION: A detailed site characterization should be completed before initiating the groundwater monitoring program. Site information is needed to determine appropriate well locations, installation depths, and other design features. The site characterization should begin with a review of all pertinent off-site information including county soil surveys, topographic maps, aerial photographs, and National Wetland Inventory (NWI) maps, if available. This review should be followed by a field investigation to verify the off-site information and gather additional data. At a minimum, the following site information should be collected (see Warne and Wakeley (2000) for detailed guidance):

- Detailed site map showing the location of property and project-area boundaries (determine coordinates of boundary points and landmarks, if possible).
- Topographic map showing the watershed boundary, water features (e.g., lakes, streams, minor drainages), and direction of water movement across the site.
- Current vegetation and land use.
- Detailed description of any modifications to site hydrology (e.g., water diversions or additions including ditches, subsurface drains, dams, berms, channelized streams, irrigation, modified surface topography, etc.).
- Soil profile descriptions including locations of soil test pits (indicate on site map and determine coordinates, if possible).

Soil profile descriptions are an important part of the site characterization because they may dictate appropriate depths for installation of water-table monitoring wells. Of critical importance is the identification of soil strata that can restrict downward water movement and create a perched water table. Examples of soil strata that may produce perched water tables include fragipans, spodic horizons, argillic horizons, and shallow bedrock. If a shallow restrictive soil layer is identified, care must be taken during well installation to ensure that the layer is not penetrated. Penetration of the restrictive layer may result in misleading water-level readings.

Soil profile descriptions should include horizon depths and (for each horizon) information about texture, color, induration (cementation), redoximorphic features, and roots, so that significant differences in permeability can be evaluated (Sprecher 2000). A blank Soil Characterization Data Form is provided for this purpose (Appendix A). Soil profiles must be described at least to the anticipated installation depth of the wells; profile descriptions to 24 in. or more are recommended. Several soil characteristics indicate that downward water flow may be impeded and that perched water tables may exist. Features to note include the following (Sprecher 2000):

- Abrupt change from many roots to few or no roots.
- Abrupt change in soil texture.
- Abrupt change in ease of excavation.
- Abrupt change in water content, such as presence of saturated soil horizons immediately above soil horizons that are dry or only moist.
- Redoximorphic features at any of the distinct boundaries listed above.

WELL PLACEMENT: A detailed discussion of monitoring well placement within the project site is beyond the scope of this Technical Standard. In general, well placement depends on the objectives of the investigation and characteristics of the site. If the objective is to determine whether wetland hydrology is present at a particular point, a single well may be sufficient. However, multiple wells may be necessary to determine if wetland hydrology occurs on a complex site where topography and human alterations (e.g., road construction, ditching) have produced considerable hydrologic variation. Well locations and depths are dictated by site conditions including topographic relief and the depth and continuity of restrictive soil layers. Portions of a site that are most likely to meet wetland hydrology standards (e.g., low-lying areas such as depressions, floodplain backwaters, swales and washes, fringes of lakes and ponds, toes of slopes, or other areas with shallow restrictive soil layers) should be identified during site characterization and considered for well placement.

If the objective is to confirm wetland boundaries based on groundwater measurements, then multiple wells installed along transects perpendicular to the expected wetland boundary are needed (Figure 1). The number and spacing of wells along each transect depend on the topographic gradient and the precision needed in defining the wetland boundary. Other site information that may help in placing wells and identifying boundaries includes changes in topographic gradient, proximity to hydrologic alterations (e.g., ditches), and changes in soil characteristics or vegetation.

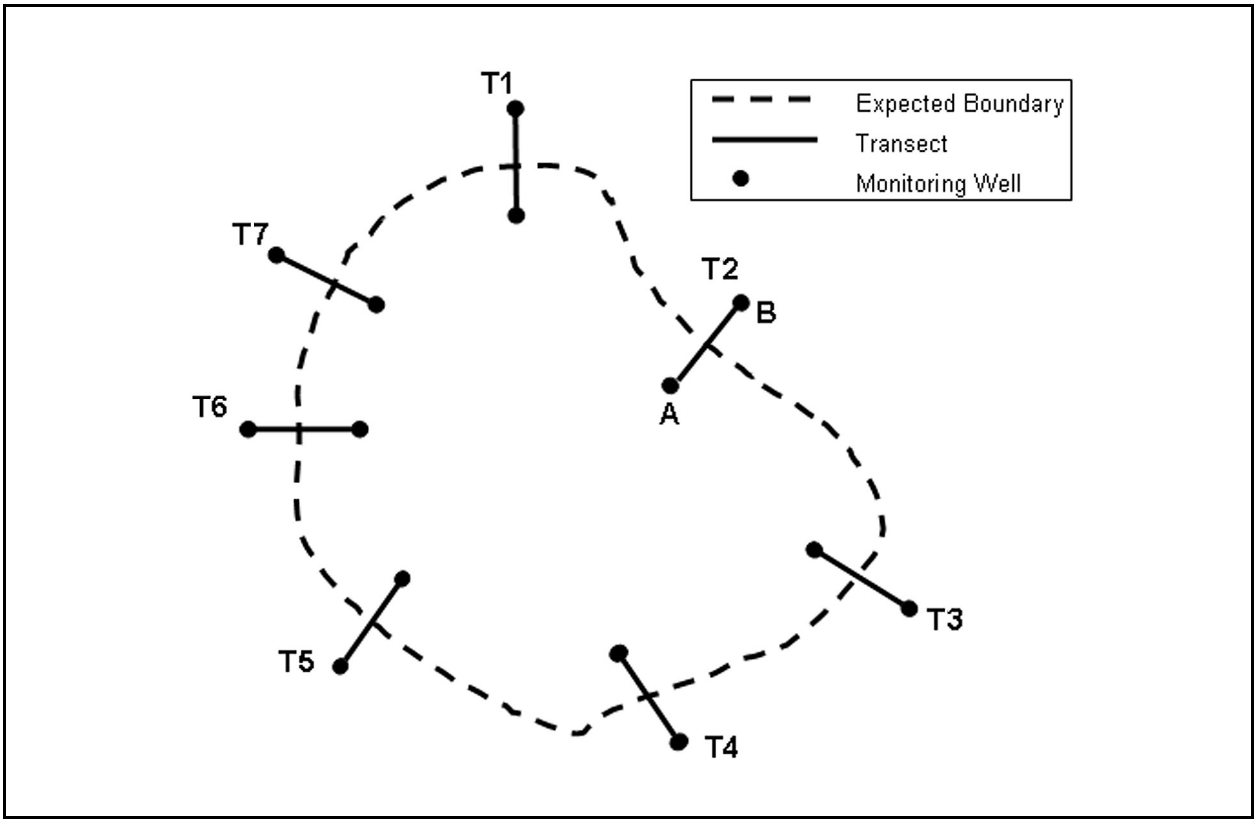


Figure 1. Example of monitoring wells located along transects across the expected wetland boundary. Transects extend from obvious upland to obvious wetland. Two or more wells are needed along each transect (e.g., at locations A and B).

MONITORING WELL CONSTRUCTION: In most cases, a standard monitoring well installed to a depth of 15 in. below the soil surface should be used to measure water-table depth on potential wetland sites. Shallower installation depths may be needed if restrictive soil layers exist within 15 in. of the surface. Monitoring wells must not penetrate any such restrictive layer. The standard design is for a well installed by augering. Depending upon site conditions, wells installed by driving may also be acceptable (see the section on Monitoring Well Installation). Installation of one or more additional deeper (4-5 ft) wells at each site is also encouraged to help in interpreting water-table fluctuations and warn of sudden changes in water-table depth. Deeper wells are not required but, if used, should not penetrate any restrictive soil layers. The performance of all wells must be tested and verified before use.

Monitoring Well Components. A standard monitoring well installed by augering is shown in Figure 2 and consists of the following main components: well screen, riser, well caps, sand filter pack, and bentonite sealant. Specifications for each of these components are given below.

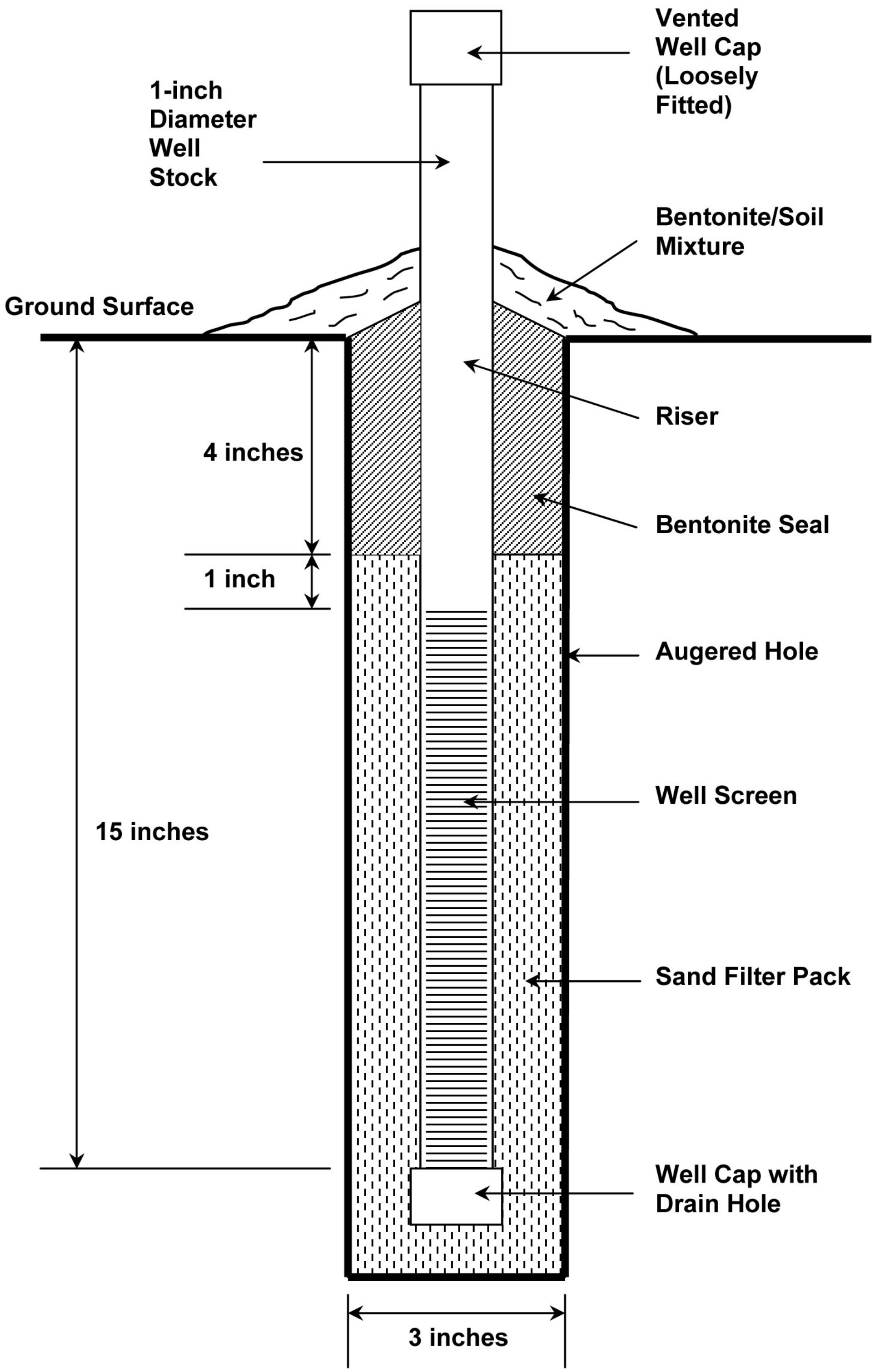


Figure 2. Standard 15-in. monitoring well installed by augering

Well Stock. Shallow monitoring wells should be made from commercially manufactured well stock. Schedule 40, 1-in. inside diameter PVC pipe is recommended. The diameter of the pipe allows sufficient room for hand measurement of water levels while minimizing well volume and maximizing responsiveness to water-table changes. The small diameter also minimizes auger hole diameter, volume of the filter pack, and the quantity of bentonite needed to seal the bore hole. However, if required by automated water-level recorders, then 2-in.-diam pipes can be substituted. Well stock larger than 2 in. in diameter should be avoided.

Well Screen and Bottom Cap. Recommended slot opening and slot spacing for the well screen are 0.010 in. and 0.125 in., respectively. The slotted screen should extend from approximately 5 in. below the ground surface down to the bottom of the well. Hand-slotted or drilled well screens should not be used.

One problem with the use of commercial well screen for very shallow monitoring wells is that there often is a length of unslotted pipe and joint or threads below the screen. In shallow monitoring situations, this extra length often must be inserted into underlying soil material that should be left undisturbed. In combination with a commercial well point, this extra length also provides a reservoir where water can remain trapped after the outside groundwater has dropped, resulting in the potential of misleading or incorrect readings during water-table drawdown. To avoid this problem, commercial well screen should be cut to the desired length within the slotted portion of the pipe. A PVC cap should be glued at the bottom of the screen and a small drain hole should be drilled in the bottom cap (Figure 2).

Riser. The riser is the unslotted PVC pipe that extends from the top of the well screen to above the ground surface (Figure 2). The riser should extend far enough above the ground to allow easy access but not so high that the leverage of normal handling will crack below-ground seals. In locations that do not pond or flood, 9 to 12 in. above the ground surface is usually sufficient. A longer riser may be needed on inundated sites or where automatic recording devices are used.

Well Top Cap. A well cap is required to protect the top of the well from contamination and rainfall. Caps should be attached loosely so they can be removed easily without jarring or dislodging the well, or cracking the bentonite seal. Tight-fitting caps, either threaded or unthreaded, should be avoided because they may seize to the riser and require rough handling to remove. A suitable well cap can be constructed from a short length of PVC pipe of a larger diameter than the riser, with a glued PVC cap at one end (Sprecher 2000). The constructed well cap can be attached loosely to the riser by drilling a hole through both the cap and the riser and connecting the two with a wire lock pin. The cap should be vented to allow equilibration of air pressure inside and outside of the well.

Filter Pack. A filter pack is placed around the well screen to remove fine particles and provide a zone of high hydraulic conductivity that promotes water movement toward the well (Figure 2). Filter packs can be classified into two major categories, natural and artificial. Natural packs are created by manually repacking any excavated soil around the well screen, ensuring that large voids are absent. Natural packs are recommended in coarse-textured, sandy soils. In fine-textured soils, an artificial pack should be used. See Table 1 for recommendations on the use of filter packs for soils of different textures.

Commercially available silica sand is recommended for use as artificial pack material and is usually well-sorted, well-rounded, clean, chemically inert, and free of all fine-grained clays, particles, and organic material. Silica sand is available from water-well supply houses in uniformly graded sizes. Sand that passes a 20-mesh screen and is retained by a 40-mesh screen (20-40 sand) is recommended with a 0.010-in. well screen.

Table 1
USDA Soil Texture Classes and Recommendations for Sand Filter Packs

USDA Soil Texture	Sand Pack
Muck, Mucky Peat, Peat	None
Coarse Sand	None
Medium Sand	None
Fine Sand	None
Loamy Sand	None
Sandy Loam	Recommended
Loam	Recommended
Silt Loam	Recommended
Silt	Recommended
Sandy Clay Loam	Required
Silty Clay Loam	Required
Clay Loam	Required
Sandy Clay	Required
Silty Clay	Required
Clay	Required

Bentonite Sealant. Bentonite is a type of clay that absorbs large quantities of water and swells when wetted. It is used in well installation to form a tight seal around the riser to prevent water from running down the outside of the pipe to the well screen. With this protective plug, only groundwater enters the slotted well screen.

When installing a monitoring well, 4 in. of bentonite should be placed around the riser immediately at and below the ground surface (Figure 2). This 4-in. ring of bentonite rests directly on top of the filter pack around the well screen. Above the bentonite ring, additional bentonite mixed with natural soil material should be mounded slightly and shaped to slope away from the riser so that surface water will run away from the pipe rather than pond around it at the ground surface.

Bentonite is available from well drilling supply companies in powder, chip, or pellet form. Chips are easiest to use in the field. They can be dropped directly down the annular space above the sand filter pack. If this zone is already saturated with water, the chips will absorb water in place, swell tight, and seal off the sand filter from above. If the bentonite chips are dropped into a dry annular space, they should be packed dry and then water should be added down the annular space so the clay can swell shut.

Modified Well Design for Clay Soils. In heavy clay soils, such as Vertisols, water movement occurs preferentially along cracks and interconnected large pores. These cracks may deliver water to a standard monitoring well through its vertical, slotted walls. Even when the surrounding soil is unsaturated, water may remain in the well for days due to impeded drainage into the slowly permeable clay. This problem can be reduced, but not eliminated, by using a well that is slotted or open only at the bottom. In addition, the sand filter pack should be installed only around the immediate well opening and should not extend up the riser. The annular space around the riser should be packed with the natural clay soil material or filled with bentonite.

Because Vertisols in wetland situations tend to be episaturated (i.e., they perch water at or near the surface but may remain unsaturated below), monitoring should focus on detection of surface ponding and saturation in the upper few inches of the soil. For this purpose, wells shorter than 15 in. may be needed.

MONITORING WELL INSTALLATION

Installation Methods. The recommended method for installing shallow monitoring wells involves the use of a bucket auger with an outside diameter 2 in. greater than the well diameter (e.g., 3 in. for a standard 1-in. well). As an alternative, wells may be installed by driving them into the ground. Driven wells may be preferred in areas with noncohesive coarse-grained (sandy) soils, rocky soils (e.g., glacial tills), or in saturated organic materials (i.e., mucks or peats). Procedures for both installation methods are given below. No matter which installation method is selected, wells must be tested for performance before being used. These procedures assume that the soil profile at the well location has already been described and that the appropriate well depth (i.e., 15 in. or less) has been determined based on the presence or absence of restrictive soil layers. A Monitoring Well Installation Data Form (Appendix B) should be completed to document the design and installation of each well (Sprecher 2000).

Augering. Recommended equipment includes a bucket auger 2 in. larger than the diameter of the well being installed, a tamping tool (e.g., wooden or metal rod), bentonite chips, silica sand, and the constructed monitoring well. A pump or bailer may be needed to test the well after installation. The following procedure is used to install the well:

1. Auger a hole in the ground to a depth approximately 2 in. deeper than the bottom of the well. Be sure the hole is vertical.
2. Scarify the sides of the hole if it was smeared during augering.
3. Place 2 to 3 in. of silica sand in the bottom of the hole.
4. For a 15-in. well with 10 in. of well screen, make a permanent mark on the well riser 5 in. above the top of the screen. Insert the well into the hole to the proper depth; the permanent mark on the riser should be even with the soil surface. Do not insert through the sand.
5. Pour and gently tamp more of the same sand in the annular space around the screen and 1 in. above the screen.
6. Pour and gently tamp 4 in. of bentonite chips above the sand to the ground surface. If necessary, add water to cause the bentonite sealant to expand.
7. Form a low mound of a soil/bentonite mixture on the ground surface around the base of the riser to prevent surface water from puddling around the pipe.

Driving. Well installation by driving is recommended when site conditions prevent augering (e.g., noncohesive sandy soils, soils with many coarse fragments, saturated organic soils). In addition, driven wells are acceptable whenever their performance can be shown to be equivalent to that of an augered well. Plans to use driven wells for regulatory purposes should be discussed in advance with the appropriate Corps of Engineers District office.

A driven well is similar in design and construction to the augered well described previously, with the addition of a well point in place of the bottom cap (Figure 3). Well points are commercially available and can be vented to permit draining by drilling a hole in the bottom. A special driving tool may be needed to install the well without damaging the PVC pipe.

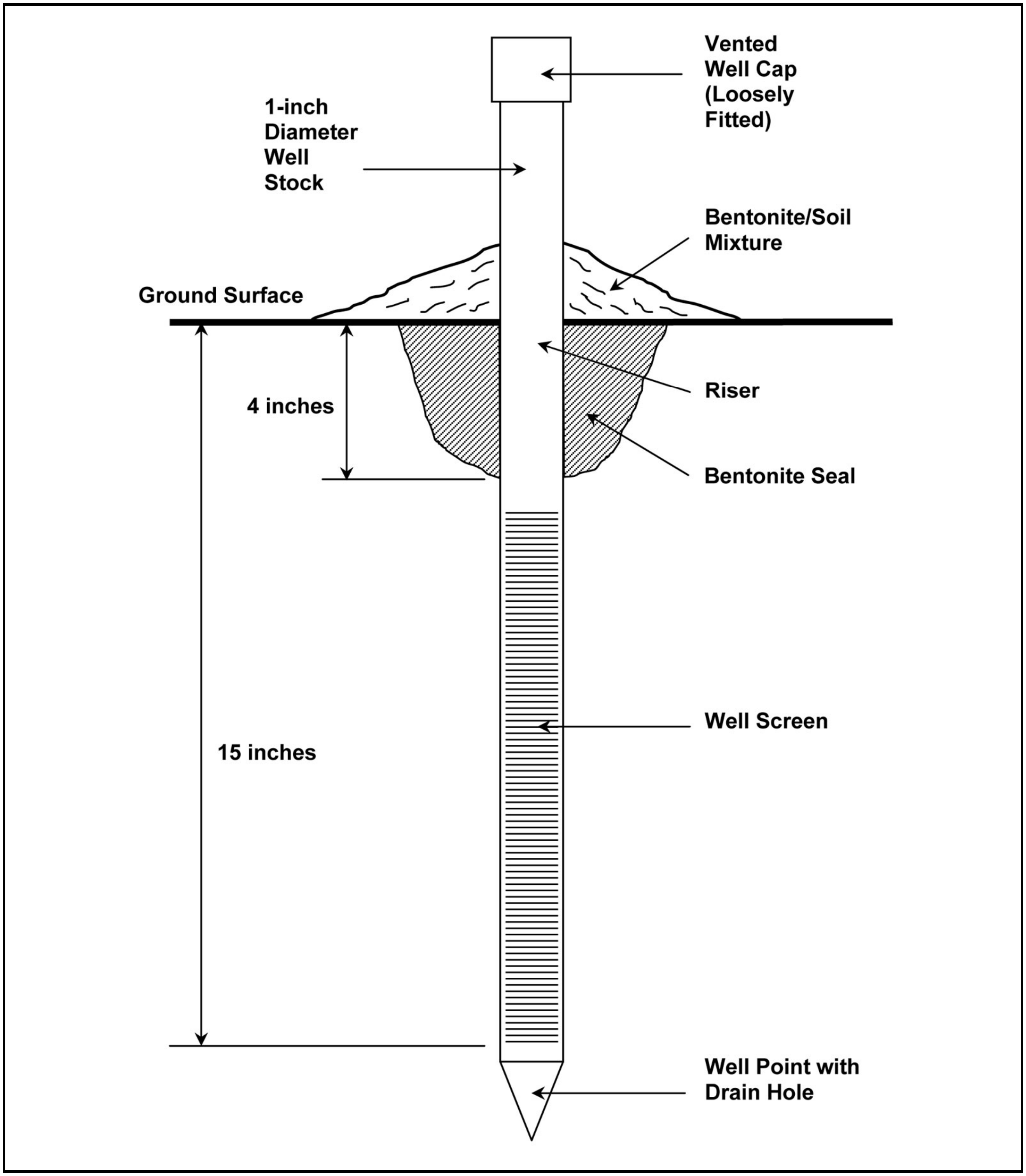


Figure 3. Standard 15-in. monitoring well installed by driving

Required materials include bentonite chips and the constructed monitoring well with vented well point. A pump or bailer may be needed to test the well after installation and, depending on site conditions, a driving device may be required. The following procedure is used to install the well:

1. For a standard 15-in. well, make a permanent mark on the riser 15 in. above the bottom of the well screen. With the well cap removed, use a driving device to drive the well vertically into the ground until the mark is at the ground surface. In organic soil materials, the well may simply be pushed into the ground.

2. Dig out a ring of soil around the well riser to a depth of 4 in. Fill this space with bentonite chips and add water, if necessary, to form a tight seal.

3. Form a low mound of a soil/bentonite mixture on the ground surface around the base of the riser to prevent surface water from puddling around the pipe.

Establishing Riser Height. Water-level measurements are typically recorded as the "depth to water" from the top of the well riser. The depth of the water table below the ground surface is determined by subtracting the riser height from the "depth to water" measurement. Therefore, after installing the well, measure and permanently record the height of the riser above the ground surface. If automated water-level recording devices are used, follow the manufacturer's instructions for calibration of water-level readings relative to the ground surface. Riser height should be checked after soils have thawed in spring, and should be re-checked periodically when water-table measurements are taken or electronic data are downloaded.

Surface Water. In areas subject to flooding or ponding, a separate staff gauge or automated device is required to measure the depth of surface water.

MONITORING WELL TESTING AND MAINTENANCE: During well installation, particularly with driven wells, fine soil particles may clog the well screen, impeding water flow and increasing the response time of the well. The performance of the well should be tested by (1) emptying the well by pumping or bailing and monitoring how quickly the water level returns to the initial level, or (2) if the well is dry, filling it with water and monitoring the rate of outflow. The water level in the well should reestablish itself at approximately the same rate as it would in a freshly dug hole without any pipe. In soils with a high percentage of clay, this could require several hours. If the water does not return to the initial level in a reasonable amount of time, pull the instrument out of the ground, clean it, reinstall it, and retest it. If water-table readings are questionable at any time during the monitoring period, one option is to move some distance away from the well location, auger to the depth in question, and determine whether the water level in the auger hole is the same as that indicated by the monitoring well.

Routine Maintenance. Monitoring well responsiveness should be tested at the beginning of the monitoring period and at least every 2-3 months thereafter by the procedure described above, because wells can plug over time due to bacterial growth and movement of fine soil particles. Well performance can also be affected by cracking of the bentonite seal, sediment deposition in the well, and movement of the ground surface and/or monitoring well due to frost heaving or shrink-swell action. To ensure accurate water-level readings, check for vertical displacement of the well after spring thaw and periodically during sampling by re-measuring the height of the riser above the ground surface and adjusting water-table measurements or resetting the well, as needed.

MAKING WATER-LEVEL MEASUREMENTS: Water levels in monitoring wells should be measured with an accuracy of ±0.25 in., if possible. Measurements may be made manually or with automated equipment. The use of automated water-level recorders is recommended unless an uninterrupted schedule of frequent site visits can be maintained. Automated recorders are also recommended in areas with highly variable or flashy hydrology. Whichever method is selected, it should be used consistently throughout the duration of the monitoring study.

Manual Readings. Water-level measurements can be made easily with a steel measuring tape marked with chalk or a water-soluble marker. Another approach is to use an electric device that sounds or flashes when the sensor, attached to the end of a graduated tape, makes contact with the water. Measurement devices that displace large amounts of water (e.g., dowel rods) should not be used.

Automated Readings. Automated recording devices record water levels with down-well transducers or capacitance-based sensors. An important consideration when purchasing automatic recording devices is the ability to compensate internally for variations in barometric pressure. These variations can be significant in wetland determinations. Automated equipment is more costly than hand measurement, but the devices can be used again in future studies. The credibility of monitoring results is enhanced with the high frequency of water-level readings that automated wells allow. Automated water-level recorders should be checked frequently for accuracy by comparison with manual readings. If automated readings are not within instrument specifications, the device should be recalibrated.

Required Timing, Frequency, and Duration of Readings. Water-level measurements must be taken at least once each day, beginning 5-7 days before the first day of the growing season and continuing until the end of the growing season or until the minimum standard for wetland hydrology is met that year. If automated recorders are used, readings four times per day are recommended (use the lowest reading each day). On sites subject to flooding or ponding, depth of surface water must be measured each day that water-table readings are made.

Growing season beginning and ending dates shall be based on the median dates (i.e., 5 years in 10, or 50 percent probability) of 28 °F air temperatures in spring and fall as reported in WETS tables provided by the USDA-NRCS National Water and Climate Center. WETS tables are based on long-term temperature data collected at National Weather Service (NWS) cooperative weather stations throughout the United States and are available on the Internet at http://www.wcc.nrcs.usda.gov/climate/wetlands.html. For a particular project site, growing season information from the nearest available weather station should be used unless, due to elevation or other factors, a more distant weather station is considered to be more representative of conditions at the project site. Alternative local or regional procedures for determining growing season dates may be used at the District's discretion.

Because hydrologic conditions are naturally variable, many years of groundwater monitoring data may be needed to establish what is typical for a given site. This is particularly true in the arid western United States where rainfall can be sparse, unpredictable, and highly localized. In general, ten or more years of water-table monitoring data may be needed to determine whether minimum standards for water-table depth, duration, and frequency in wetlands are met. However, because long-term monitoring is often impractical in a regulatory context, short-term studies may provide sufficient information if the normality of precipitation during the monitoring period is considered. Determining "normal" rainfall is addressed in the following section.

ANALYSIS AND INTERPRETATION OF MONITORING DATA

Technical Standard for Wetland Hydrology. Wetland hydrology is considered to be present on an atypical or problem site if the following standard is met:

> *The site is inundated (flooded or ponded) or the water table is ≤12 inches below the soil surface for ≥14 consecutive days during the growing season at a minimum frequency of 5 years in 10 (≥50% probability). Any combination of inundation or shallow water table is acceptable in meeting the 14-day minimum requirement. Short-term monitoring data may be used to address the frequency requirement if the normality of rainfall occurring prior to and during the monitoring period each year is considered.*

The Corps Manual discusses wetland hydrology in general, but does not provide a wetland hydrology criterion suitable for use in interpreting monitoring well data. The standard given above is based on recommendations by the National Academy of Sciences (National Research Council 1995). By requiring a water table within 12 in. of the surface, this standard ensures that saturation by free water or the capillary fringe occurs within the "major portion of the root zone" described in the Manual. A 14-day minimum duration standard is assumed to apply nationwide unless Corps Districts have adopted a different standard at the local or regional level. The Corps Manual addresses the need for long-term data (10 or more years) in analyses of stream-gauge data but does not consider the use of short-term data in wetland determinations, nor does it address the frequency issue in relation to water-table monitoring. This Technical Standard allows the use of short-term monitoring data to address the frequency requirement for wetland hydrology, if the normality of rainfall is considered.

The depth to saturation depends both on the position of the water table and the height of the tension-saturated capillary fringe (National Research Council 1995). While its presence has an influence on both plant growth and soil features, the upper limit of the capillary fringe is difficult to measure in the field and impractical as a basis for hydrologic monitoring. The Technical Standard for Wetland Hydrology is based on the depth of the water table because, in most cases, water-table depth can be monitored readily and consistently through the use of shallow wells with either manual or automated data collection. Water-table measurements should not be corrected for a capillary fringe unless other evidence, such as tensiometer readings, laboratory analysis of soil water content, or evidence of soil anoxia, indicates that the height of the saturated capillary fringe is greater than a few inches.

Determining Normal Precipitation. Short-term water-table monitoring data (i.e., <10 years) must be interpreted in relation to the amount of precipitation that fell during and for at least 3 months prior to the monitoring period each year. This is done by comparing the precipitation record for a given year with the normal range of precipitation based on long-term records collected at the nearest appropriate NWS cooperative weather station. The USDA-NRCS National Water and Climate Center calculates normal precipitation ranges for each month (defined as between the 30^{th} and 70^{th} percentiles of monthly precipitation totals) for NWS stations throughout the United States. The information is published in WETS tables available on the Internet (http://www.wcc.nrcs.usda.gov/climate/wetlands.html).

Sprecher and Warne (2000, Chapter 4) describe three methods for evaluating precipitation normality within a given year. The first method is taken from the NRCS Engineering Field Handbook (Natural Resources Conservation Service 1997) and involves the direct application of WETS tables in relation to monthly rainfall totals at the project site. At a minimum, this method shall be used to determine whether rainfall was normal immediately before and during a groundwater monitoring study. The analysis should focus on the period leading up to and during the time when water tables are usually high in that climatic region. In many parts of the country, this is at the beginning of the growing season, when precipitation is abundant and evapotranspiration is relatively low. The second method described by Sprecher and Warne (2000) evaluates daily precipitation data on the basis of 30-day rolling sums, and the third method combines the two procedures. If daily precipitation data are available, the combined method is recommended. The evaluation of precipitation normality should include the three months prior to the start of the growing season and extend throughout the entire monitoring period each year.

For many wetlands, water tables in a given year may be affected by precipitation that occurred in previous years, especially if monitoring occurs after an extended period of drought or precipitation excess. After a series of dry years, for example, it may take several years of normal or above-normal rainfall to recharge groundwater and return water tables to normal levels. Therefore, in evaluating wetland hydrology based on short-term monitoring, it is necessary to consider the normality of rainfall over a period of years prior to the groundwater study. Recent precipitation trends can be determined by comparing annual rainfall totals at the monitoring site with the normal range given in WETS tables for two or more years prior to the monitoring study, or by examining trends in drought indices, such as the Palmer Drought Severity Index (Sprecher and Warne 2000). This issue may not be important in soils with perched water tables that respond to the current year's rainfall and dry out seasonally.

Interpreting Results. If ten or more years of water-table monitoring data are available for a site, the long-term record probably includes years of normal, below normal, and above normal precipitation and thus reflects the average hydrologic conditions on the site. Therefore, wetland hydrology can be evaluated directly by the following procedure:

1. For each year, determine the maximum number of consecutive days that the site was either inundated or the water table was ≤12 in. from the ground surface during the growing season. Wetland hydrology occurred in a given year if the number of consecutive days of inundation or shallow water tables was ≥14 days.

2. The Technical Standard for Wetland Hydrology was met if wetland hydrology occurred in at least 50 percent of years (i.e., ≥5 years in 10).

This procedure may not be appropriate during extended periods of drought or precipitation excess. Furthermore, in some regions with highly variable precipitation patterns (e.g., the arid West) more than ten years of groundwater monitoring data may be needed to capture the typical hydrologic conditions on a site.

If fewer than ten years of water-table data are available, then the normality of precipitation preceding and during the monitoring period must be considered. One option is to apply the procedures described in the section on "Determining Normal Precipitation" for each year that water tables were monitored. In addition, annual precipitation or drought severity indices should be evaluated for two or more years prior to the monitoring period on any site that lacks a perched water table. Wetland hydrology can then be evaluated by the following procedure:

1. Select those years of monitoring data when precipitation was normal, or select an equal number of wetter-than-normal and drier-than-normal years.

2. If wetland hydrology (i.e., any combination of inundation or water table ≤12 in. from the surface for ≥14 consecutive days during the growing season) occurred in ≥50 percent of years (e.g., 3 years in 5), then the site most likely meets the Technical Standard for Wetland Hydrology.

It is important to remember that, even in normal rainfall years, many wetlands will lack wetland hydrology in some years due to annual differences in air temperatures (which affect evapotranspiration rates) and the daily distribution of rainfall that are not considered in this analysis. This is particularly true of borderline wetlands that may have shallow water tables in only 50-60 percent of years. Therefore, this procedure may fail to identify some marginal wetlands.

Another option, particularly for very short-duration monitoring studies (e.g., ≤3 years), is to evaluate water-table measurements in conjunction with groundwater modeling. Hunt et al. (2001) described one such approach, called the Threshold Wetland Simulation (TWS), which uses the DRAINMOD model. Actual water-table measurements in a given year are compared with those of a simulated, threshold wetland (i.e., one that meets wetland hydrology requirements in exactly 50 percent of years). The TWS approach requires detailed long-term precipitation and temperature data, soil characteristics, and considerable expertise with the DRAINMOD program.

No method to determine wetland hydrology based on short-term water-table measurements is entirely reliable or free of assumptions. Therefore, ultimate responsibility for the interpretation of water-table monitoring data rests with the appropriate Corps District.

REPORTING OF RESULTS: Warne and Wakeley (2000) provided a comprehensive checklist of information that should be included in the report of a groundwater monitoring study. The report should also include a justification for any deviations from procedures given in this Technical Standard.

The report should include a clear, graphical presentation of daily water-table levels at each well plotted over time and shown in relation to the soil surface and the 12-in. depth, the depth of the monitoring well, growing season starting and ending dates, local precipitation that year, and normal precipitation ranges based on WETS tables. Another useful feature is a diagram of the soil profile at the well location including depths and textures of each major horizon. An example graph with many of these features is shown in Figure 4 (Sprecher 2000).

ACKNOWLEDGMENTS: The initial outline for this Technical Standard was developed at a workshop in Decatur, GA, in September 2003. Participants (in alphabetical order) were Mr. William Ainslie, U. S. Environmental Protection Agency (USEPA), Region 4; Mr. Bradley Cook, Minnesota State University, Mankato; Mr. Jason Hill, Tennessee Tech University (TTU); Ms. Julie Kelley, Geotechnical and Structures Laboratory (GSL), U. S. Army Engineer Research and Development Center (ERDC); Dr. Barbara Kleiss, Environmental Laboratory (EL), ERDC; Dr. Vincent Neary, TTU; Mr. Chris Noble, EL-ERDC; Dr. Bruce Pruitt, Nutter and Associates, Inc.; Dr. Thomas Roberts, TTU; Mr. Paul Rodrigue, USDA Natural Resources Conservation Service (NRCS);

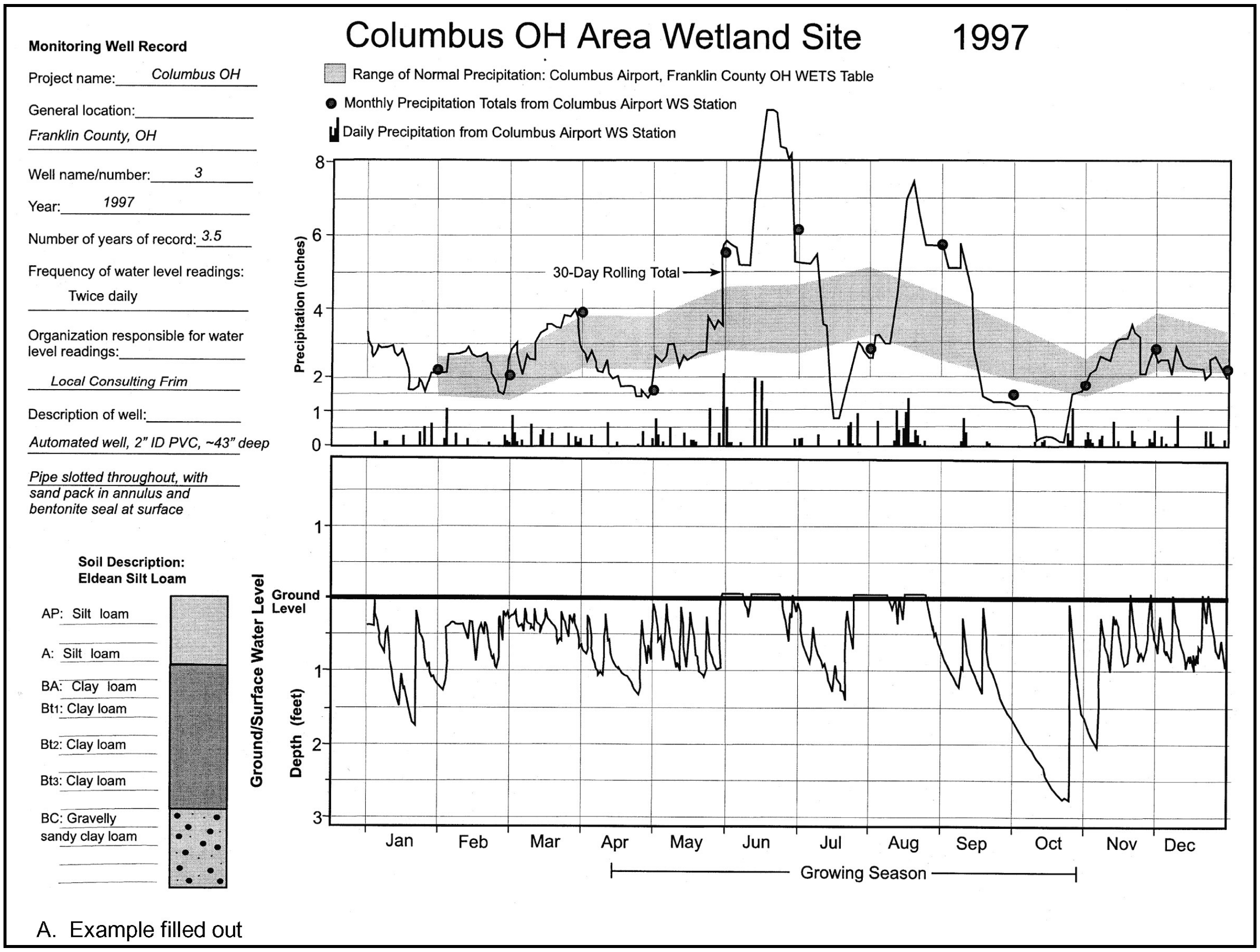


Figure 4. Example of graphical presentation of water-table monitoring data (Note that this example uses a deeper well than the 15 in. specified in this Technical Standard)

Dr. Steven Sprecher, U. S. Army Engineer (USAE) District, Detroit; and Dr. James Wakeley, EL-ERDC. The first draft was written by Drs. Neary and Wakeley and Messrs. Hill and Noble. Technical reviewers included Harry Baij, Jr., USAE District, Anchorage; Mark Clark, NRCS; David D'Amore, U. S. Forest Service (USFS); Jackie DeMontigny, USFS; Michiel Holley, USAE District, Anchorage; Wesley Miller, NRCS; James Miner, Illinois State Geological Survey; Joe Moore, NRCS; Dr. Chien-Lu Ping, University of Alaska, Fairbanks; Ann Puffer, USFS; and Ralph Rogers, USEPA Region 10. A subcommittee of the National Technical Committee for Hydric Soils (NTCHS) provided an independent peer review in accordance with Office of Management and Budget guidelines. The authors are grateful to NTCHS members Drs. Michael Vepraskas and R. Wayne Skaggs, North Carolina State University; and Mr. Ed Blake, Mr. P. Michael Whited, Ms. Lenore Vasilas, and Mr. G. Wade Hurt, NRCS, for their comments and suggestions. The work was supported by Headquarters, U. S. Army Corps of Engineers through the Wetlands Regulatory Assistance Program (WRAP).

POINTS OF CONTACT: For additional information, contact Dr. James S. Wakeley, U. S. Army Engineer Research and Development Center (ERDC), Vicksburg, MS, (601-634-3702, *James.S.Wakeley@erdc.usace.army.mil*) or the Program Manager of the Wetlands Regulatory

Assistance Program, Mr. Bob Lazor (601-634-2935, *Bob.L.Lazor@erdc.usace.army.mil*). This technical note should be cited as follows:

> U. S. Army Corps of Engineers. (2005). "Technical Standard for Water-Table Monitoring of Potential Wetland Sites," *WRAP Technical Notes Collection* (ERDC TN-WRAP-05-2), U. S. Army Engineer Research and Development Center, Vicksburg, MS.

REFERENCES

Environmental Laboratory. (1987). "Corps of Engineers Wetlands Delineation Manual," Technical Report Y-87-1, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS. (Annotated on-line version available at http://el.erdc.usace.army.mil/elpubs/pdf/wlman87.pdf)

Hunt, W. F., III, Skaggs, R. W, Chescheir, G. M., and Amatya, D. M. (2001). "Examination of the Wetland Hydrologic Criterion and its Application in the Determination of Wetland Hydrologic Status," Report No. 333, Water Resources Research Institute of the University of North Carolina, North Carolina State Univ., Raleigh.

National Research Council. (1995). "Wetlands: Characteristics and Boundaries," National Academy Press, Washington, DC.

Natural Resources Conservation Service. (1997). "Hydrology tools for wetland determination," Chapter 19, *Engineering field handbook*, Donald E. Woodward, ed., USDA-NRCS, Fort Worth, TX. (http://www.info.usda.gov/CED/ftp/CED/EFH-Ch19.pdf)

Sprecher, S. W. (2000). "Installing monitoring wells/piezometers in wetlands," WRAP Technical Notes Collection, ERDC TN-WRAP-00-02, U.S. Army Engineer Research and Development Center, Vicksburg, MS. (http://el.erdc.usace.army.mil/elpubs/pdf/tnwrap00-2.pdf)

Sprecher, S. W., and Warne, A. G. (2000). "Accessing and using meteorological data to evaluate wetland hydrology," Technical Report TR-WRAP-00-1, U.S. Army Engineer Research and Development Center, Vicksburg, MS. (http://el.erdc.usace.army.mil/elpubs/pdf/wrap00-1/wrap00-1.pdf)

Warne, A. G., and Wakeley, J. S. (2000). "Guidelines for conducting and reporting hydrologic assessments of potential wetland sites," *WRAP Technical Notes Collection*, ERDC TN-WRAP-00-01, U.S. Army Engineer Research and Development Center, Vicksburg, MS. (http://el.erdc.usace.army.mil/elpubs/pdf/tnwrap00-1.pdf)

APPENDIX A. SOIL CHARACTERIZATION DATA FORM

Soil Characterization Data Form

Project Name________________________________ Date________________________
Personnel___________________________________ Soil Pit ID____________________

Horizon Depths (inches)	Texture	Matrix Color (Munsell moist)	Redoximorphic Features		Induration (none, weak, strong)	Roots
			Color	Abundance		

Comments:

APPENDIX B. MONITORING WELL INSTALLATION DATA FORM

Monitoring Well Installation Data Form

Project Name ______________________________ Date of Installation _______________
Project Location ____________________________ Personnel _______________________
Well Identification Code _____________________
Attach map of project, showing well locations and significant topographic and hydrologic features.

Characteristics of Instrument:
Source of instrument/well stock____
Material of well stock ______________________ Diameter of pipe _________________
Slot width______________________________ Slot spacing _____________________
Kind of well cap __________________________ Kind of well point/end plug _________
Installation:
Was well installed by augering or driving? ____
Kind of filter sand_________________________ Kind of bentonite_________________
Depth to lowest screen slots _______________ Riser height above ground _________
Was bentonite wetted for expansion? ____
Method of measuring water levels in instrument ____
How was instrument checked for clogging after installation?________________________________

Instrument Diagram[a]	Soil Characteristics					
	Texture	Matrix Color	Redoximorphic Features		Induration (none, weak, strong)	Roots
			Color	Abundance		

[a]Show depths (heights) of riser, well screen, sand pack, and bentonite in relation to soil horizons.