# Water Table Monitoring Project Design

***by Chris V. Noble***

**PURPOSE:** This document provides guidance for planning and implementing a wetland hydrology monitoring project for wetland regulatory purposes. It is intended to address situations commonly encountered in areas where the *Technical Standard* for Water-Table Monitoring of Potential Wetland Sites (U.S. Army Corps of Engineers 2004) (hereafter call the Corps Tech Standard) might be applied. It is not intended to be all-inclusive, or to supersede wetland determinations based on indicators of hydric soils, hydrophytic vegetation, and wetland hydrology. Hydrology studies designed to combine additional information about hydric soils or water quality are beyond the scope of this document.

**INTRODUCTION:** The Technical Standard for Wetland Hydrology describes the specifics of water table well design, installation, and monitoring but does not describe well placement, number of wells needed, or other information necessary to locate the wetland boundary or presence of wetland hydrology. This document provides guidance for planning a wetland hydrology study.

**NUMBER OF WELLS:** The number of wells necessary to provide adequate documentation for determining wetland hydrology depends on several factors, such as (a) objectives of the study, (b) wetland size, (c) site complexity, (d) soil type(s), (e) vegetative communities, and (f) wetland type. As the number of wells increases, the cost of materials, time and cost of well installation and maintenance, and the time required to collect and analyze the data also increase. Fortunately, a hydrology study does not always require a large number of wells. Nesting or duplication of wells at the same depth and location is usually not necessary if wells are properly installed and maintained. The objectives of the study and site characteristics will dictate the number of wells that are needed.

**OBJECTIVES:** If the question being addressed is whether a particular site has wetland hydrology or not, then one well may be adequate for the purpose. However, if the question involves determination of a boundary between an area with wetland hydrology and an area without wetland hydrology, or the area in question is more than a few acres in size, then additional wells become necessary. In many instances the Corps Technical Standard will be applied in a regulatory setting as part of section 404 permit action. Most of these cases involve Corps District personnel and an applicant. In more complex cases, consultants and others may also be involved. It is important for the principal parties to understand what questions will be answered by a wetland hydrology study.

**SITE COMPLEXITY:** The complexity of the site will greatly influence the number and placement of monitoring wells because of the number of different hydrologic situations that may need to be monitored. By considering hydrogeomorphic wetland class, topographic relief, vegetative communities, soil types, and site disturbance or alterations present, a sufficient number of wells can be appropriately located to address most hydrology issues.

**Topographic Relief.** Topographic relief is one of the most obvious reasons for special variations in hydrology. Drier areas tend to be higher in the landscape than wet areas. Sites with complex topographic relief may need to have monitoring wells installed at the boundary of each topographic change.

**Vegetative Communities.** Vegetative communities can provide clues to differences in hydrology and the need for additional monitoring wells, even on disturbed sites. Differences in species, percent cover, or growth characteristics can be indicators of differences in hydrology and may require additional wells.

**Soil Types.** Any hydrology study should include an examination of available soils information, such as can be found in a county or area soil survey. Identify the soil types and inclusions predicted for the site to be monitored. Soils that contrast in characteristics such as depth to water table, depth to restrictive layer, and soil texture may dictate the placement of wells within each soil type. Soil survey information should always be verified onsite during the project design phase.

**Disturbance.** The kinds of disturbance that can affect wetland hydrology are nearly infinite. However, some of the most common disturbances that are encountered in relation to regulatory issues are drainage ditches and subsurface drain lines, land clearing or other removal of vegetation, land grading or leveling, upstream dams, levees, irrigation, channelization, downcutting by streams, fill material and increased flow from urban runoff. More information on how to monitor hydrology on disturbed sites is described in relation to wetland types.

**Size of Wetland.** The size of the study area and the wetlands in it are also important factors in the number of wells necessary to document the presence and extent or absence of wetland hydrology. Larger wetlands will usually require more wells to verify wetland hydrology throughout the area.

**WETLAND BOUNDARY:** If the purpose of the study is to determine the location of a wetland boundary, data must be collected on both sides of the suspected wetland boundary (U.S. Army Corps of Engineers 2005). The Corps Tech Standard is intended for use on problem, atypical, or otherwise severely altered sites. Therefore, the potential wetland boundary may be difficult or nearly impossible to locate without the use of monitoring wells. In these situations, a line of wells along transects perpendicular to the suspected wetland boundary may need to be installed from areas that are believed to have wetland hydrology to areas that clearly exhibit upland characteristics. In such instances, determining the wetland hydrology boundary will only be as accurate as the distance between wells. In most cases the distance between wells used to identify a wetland hydrology boundary should be 10 ft (3m) or less.

**ADDITIONAL WELLS AT GREATER DEPTHS:** It can be helpful to include additional wells at greater depths than those specified by the Corps Tech Standard. Wells to 40, 100, or 200 cm are commonly used to provide additional information about the water table. Additional wells are usually installed deep enough to remain in contact with the water table throughout the year. On sites where measurements are taken manually or seasonally, data from a deeper well can alert those taking the measurements that the water table is rising and all of the wells will need to be measured and recorded. Deeper wells should follow similar installation procedures as recommended for the shallow monitoring well in the Corps Tech Standard.

**SITE AND WELL INFORMATION:** Location of each well should be recorded and identified on a site map. Site maps should include a north arrow and landmarks such as roads, buildings, property boundaries, possible hydrologic disturbances such as ditches or levees, and any other information that would help someone who has not been to the site before to find the location of any monitoring wells. If well locations are surveyed, then the location of the benchmark should also be identified on the map. Latitude and longitude or Universal Transverse Mercator (UTM) coordinates as well as a general description of where the well is located (for example, the number of feet from a known property corner or distance from obvious landmarks) should be documented for each well. All wells should be clearly identified with a unique identification record on the well. In most cases simply numbering each well is sufficient. Local regulations may specify well identification or additional information that should be attached to each well. Additional information that should be recorded for each well includes:

- Project name.
- Length of riser above the ground surface.
- Person(s) who installed the well and contact information.

Any deviations in well construction from the Corps Tech Standard must also be documented.

**MAINTENANCE:** Many problems can occur with monitoring wells over the course of a wetland hydrology study, regardless of the duration of the study. Even if automatic data recorders are used, wells should be checked at least every 2 to 3 months to check for problems that might affect data acquisition or reliability (U.S. Army Corps of Engineers 2005).

**Vertical Well Movement.** High shrink-swell clays, such as Vertisols, and freezing and thawing can push a shallow well out of alignment so that the original ground line is several inches above the ground surface.[1] Instruments should be checked at least seasonally and the original riser height above the ground reestablished before collection of water table data.

**Disturbance to Wells.** Precautions should be taken to protect monitoring wells from damage by humans and animals (Sprecher 2000). Damage from humans can be accidental or deliberate (driving over a well that is hidden by vegetation or vandalism). It is important to make wells visible, so that they can be monitored and maintained and not be damaged by accident. At the same time, wells should not be so obvious as to invite vandalism. The same is true for damage by animals. Common precautions are fencing and applying herbicide to herbaceous vegetation around the well to discourage rodents and cattle. In some cases, insecticides may need to be applied to kill ants and wasps. In extreme cases, padlocked metal covers will need to be placed over the wells for protection from vandalism. In all cases, damaged or broken wells will need to be replaced. Depending on the time since the previous reading, the replacement of a well may not affect the monitoring project. However, if the end of the wet or growing season has passed and several weeks of data have been lost or failed to be collected, then an entire year of monitoring may be lost.

## HYDROGEOMORPHIC WETLAND CLASSES:

**Riverine.** Riverine wetlands are described by Brinson (1993) as wetlands that occur in floodplains and riparian corridors in association with stream channels. Dominant water sources are overbank flow from the channel or subsurface hydraulic connections between the stream channel and wetlands. Additional sources may be interflow, overland flow from adjacent uplands, tributary inflow, and precipitation. When overbank flow occurs, surface flows down the floodplain may dominate hydrodynamics. Riverine wetlands lose surface water via the return of floodwater to the

---

[1] Personal Communication. (2004). Wesley Miller, Natural Resources Conservation, Victoria, TX.

channel after flooding and through surface flow to the channel during rainfall events. They lose subsurface water by discharge to the channel, movement to deeper groundwater (for losing streams), and evaporation. It is common for a floodplain to have complex ridge-swale topography. In some cases all surfaces may have wetland hydrology, while at other sites, only the swales will have wetland hydrology. To identify wetland hydrology, wells may need to be located across all topographic surfaces of interest within the floodplain. Electromagnetic Induction (EMI) can be a useful tool in locating zones of discharge and recharge (Doolittle, Noble, and Leinard 2000).

Some of the impacts to riverine systems that may prompt hydrology monitoring are channel downcutting by the stream, upstream dams, levees, or channelization. Downcutting by a stream is usually the result of an increase in the amount of water in the stream channel. Downcutting can lower the water table in the floodplain adjacent to the channel in the same way that a drainage ditch can affect the water table (Figure 1). Wetlands farther from the channel may be affected very little or not at all, depending on the water source, extent of downcutting, and substrate material (Weins and Roberts 2003). In designing a riverine hydrology study, it is important that wells be placed in relationship to the area within the floodplain where a permit is being requested, because the entire floodplain may not need to be monitored.

Figure 1. Downcutting by the stream channel can reduce flooding and lower the water table on the former adjacent floodplain

Stream channelization is another activity that can greatly impact wetlands within the floodplain (Figure 2). Wetlands that were adjacent to the channel and flooded on a regular basis may no longer receive floodwater because of the new channel location. This condition can also occur with natural meander cutoff or channel movement. This process can also create new wetlands.

Figure 2. Aerial photograph showing channelized streams

Dams are often constructed to reduce the amount or frequency of flooding downstream. Even though flooding may have been reduced, the soils may still be saturated long enough to maintain wetland hydrology. Well risers should be long enough to extend above expected floodwaters and be protected from damage due to debris carried by floodwater. Stream gauges or staff gauges are better instruments to measure floodwater than water table wells.

Levees protect the land behind the levee from flooding; however, these areas may still be saturated or inundated from precipitation, groundwater discharge, or local runoff. In some cases the levee can act as a dam and increase the depth and duration of inundation or saturation by preventing the surface flow to the river. Wetlands protected from overbank flooding from a river may now function as a flat or depressional wetland system and any wetland monitoring design should take into consideration that the timing and duration of hydrology will most likely reflect the local rainfall pattern rather than flood stages in the adjacent river.

Other wetland types such as depressions or flats can occur within the floodplain. These types of wetlands will be addressed separately.

**Flats.** Flats are common on extensive relic lake bottoms, or large floodplain terraces where the main source of water is precipitation. They receive virtually no groundwater discharge, which distinguishes them from depressions and slopes. Dominant hydrodynamics are vertical fluctuations. Flats lose water by evapotranspiration, overland flow, and seepage to underlying groundwater. They are distinguished from flat upland areas by their poor vertical drainage due to slowly permeable soil layers, slow lateral drainage, and low hydraulic gradients. They typically occur in relatively humid climates (Brinson 1993). Soil drainage by ditching or subsurface drainage tile is a common impact in flats wetlands. The effect of these impacts is often over-estimated. Wells should be placed in a transect perpendicular to the drainage ditch to a distance that the water table will be intercepted if possible (Figure 3). Using soil information and interpretations from Natural Resources Conservation Service (NRCS) Drainage Guides, estimates of impact based on the Ellipse or van Schilfgaarde Equations (NRCS 1997) can provide guidance as to where monitoring wells need to be located to verify wetland hydrology in a flat landscape.

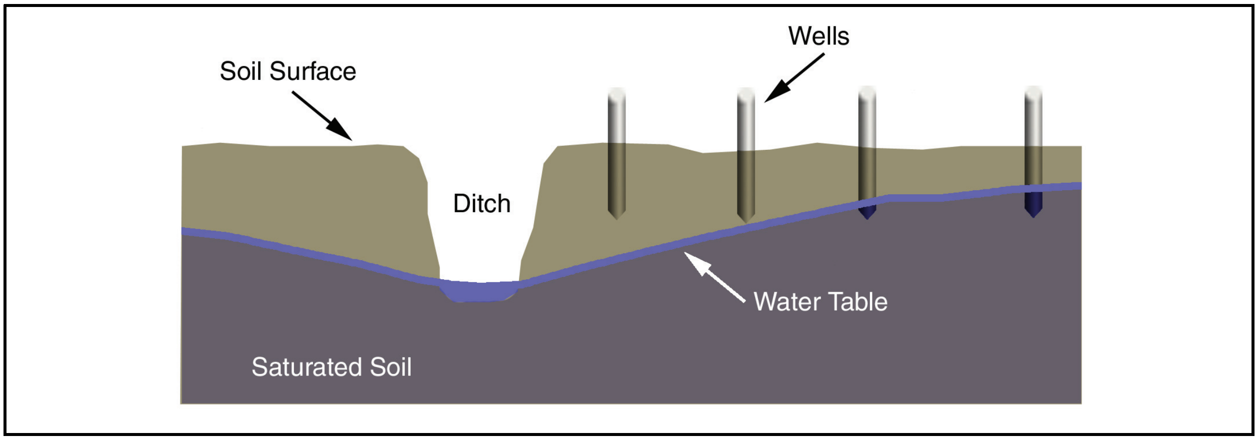


Figure 3. Diagram of water table well installation to determine wetland hydrology associated with drainage ditch

Placement of fill material to raise an area above the water table is a common impact in all wetland types, but is especially prevalent in flats wetlands. The success of the fill in raising the site above the water table may not be evident without hydrologic monitoring. If the fill material is placed on a site that is typically inundated, the filled area may still be saturated at or near the surface and have wetland hydrology. If wetland hydrology is suspected in filled areas, then a series of wells should be installed across the filled area and adjacent areas that have not been filled.

Tree plantations can effectively lower a water table; however, the water table usually rebounds after the trees are removed (Sun, Riekerk, and Kornhak 2000; Bliss and Comerford 2002). Municipal well fields can also have a significant impact on wetland hydrology. The municipal well may be offsite so the relationship to a particular area may be difficult to determine. Areas impacted by municipal well fields or tree plantations may need extensive monitoring over the entire area to determine the extent of hydrologic impact.

**Slopes.** Slope wetlands are found in association with the discharge of groundwater to the land surface or on sites with saturated overflow with no channel formation. They normally occur on slightly to steeply sloping land. The predominant source of water is groundwater or interflow discharging at the land surface. Precipitation is often a secondary contributing source of water. Hydrodynamics are dominated by downslope unidirectional water flow. Slope wetlands can occur in nearly flat landscapes if groundwater discharge is a dominant source to the wetland surface. Slope wetlands lose water primarily by saturated subsurface flows, and by evapotranspiration. Many slope wetlands have a discharge area and a recharge area. The water table may not be at the same level in these two areas (Brinson 1993). Depending on the purpose of the project, monitoring hydrology in slope wetlands may require two or more wells in the zone of discharge and recharge (Figures 4 and 5).

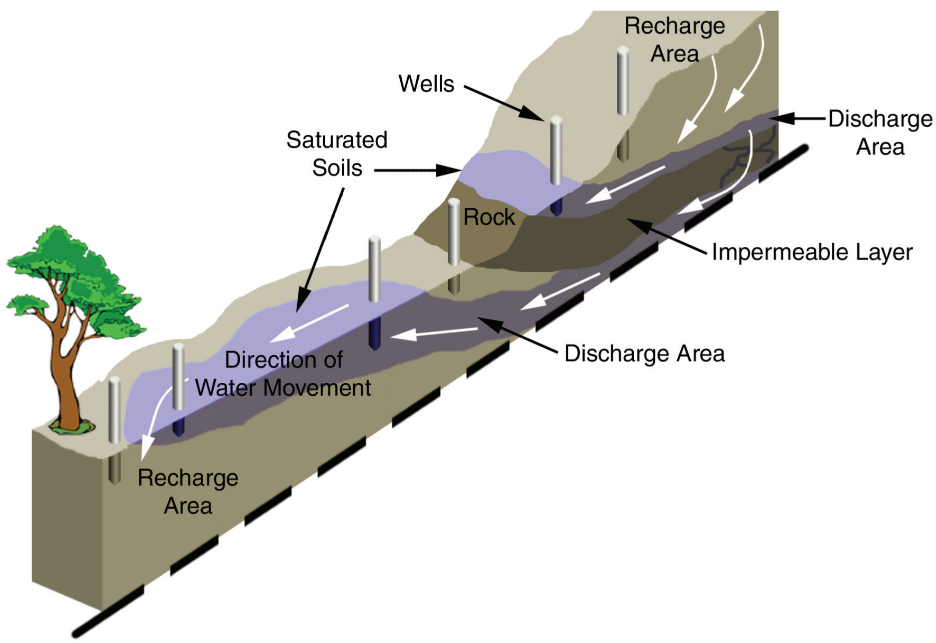


Figure 4. Possible well locations for monitoring recharge and discharge zones in a slope wetland

Common impacts to slope wetlands include the interception and removal of water from recharge areas by drainage ditches or diversions or cover by impervious materials such as pavement and rooftops. These types of impacts can greatly reduce the amount and timing of subsurface water delivery to the discharge area and increase the delivery of surface water to the associated wetland.

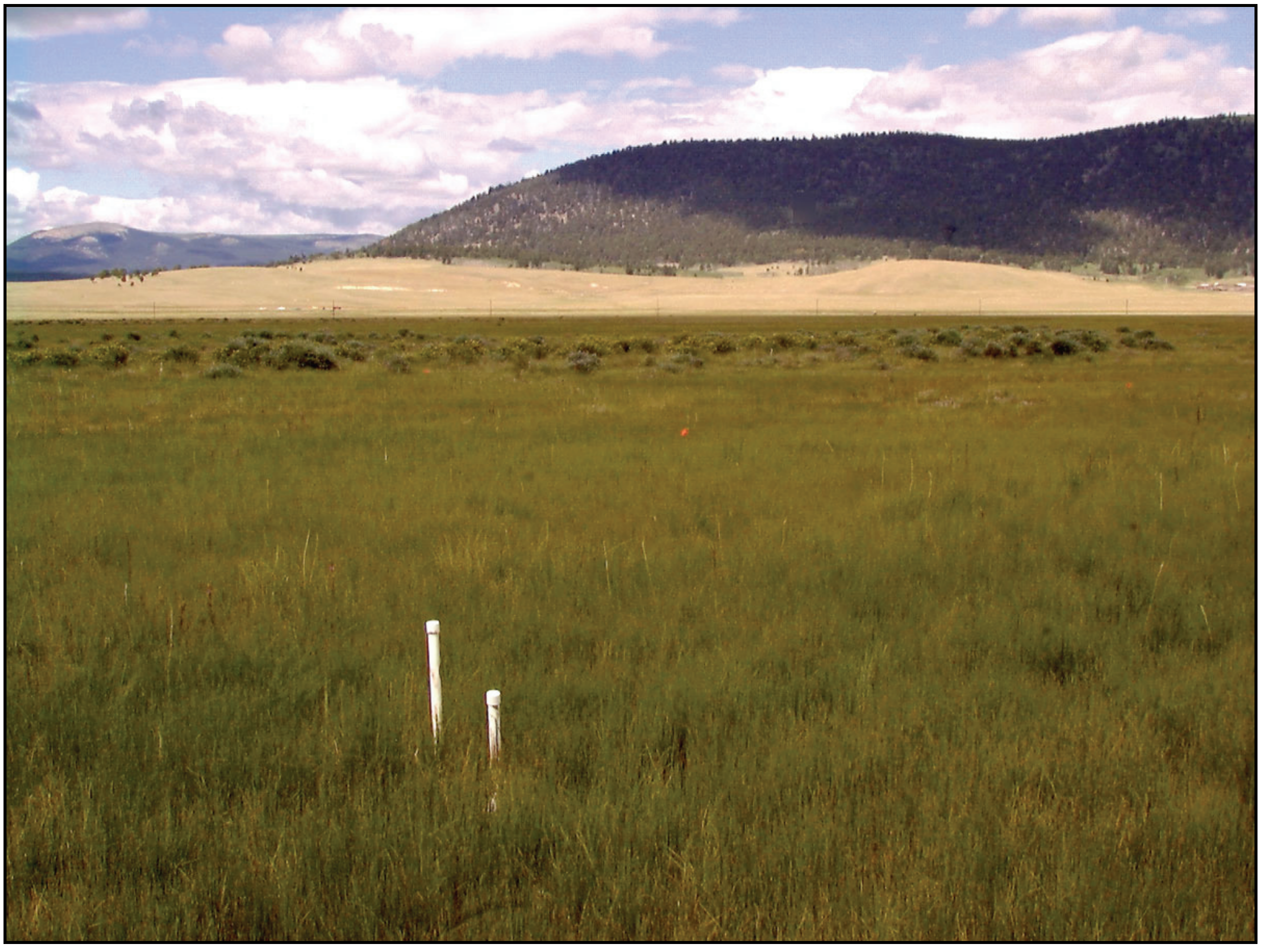

Figure 5. Monitoring wells at the discharge area of a slope wetland

Leakage from irrigation canals can create groundwater discharge wetlands that would be defined as slope wetlands. Hydrologic monitoring of these wetlands would be the same as other slope wetlands; however, the time of year that the site is wet will coincide with the time of year that fields are being irrigated and water is flowing in the canals. This is usually during the driest part of the year when many other wetlands are normally dry.

**Depressions.** Depressional wetlands occur in topographic depressions with closed elevation contours that allow the accumulation of surface water. Depressional wetlands may have any combination of inlets and outlets or lack them completely. However, to retain water, some portion of the depression must be below the elevation of the outlet. Potential water sources are precipitation, overland flow, streams, or groundwater/interflow from adjacent uplands. The predominant direction of flow is from the higher elevations toward the center of the depression. The predominant hydrodynamics are vertical fluctuations that range from diurnal to seasonal (Brinson 1993).

Drainage is a common impact to wetland hydrology in depressional wetlands (Figure 6).

Figure 6. Drainage ditches are a common hydrologic impact to depressional wetlands

Depressional wetlands are sometimes created to mitigate for impacts to other wetlands. Sometimes newly created wetlands lack indicators of hydric soils, and wetland vegetation has not become established. It may be necessary to install water table wells to monitor the success of the establishment of wetland hydrology in newly created wetlands. A series of wells along transects that cross the wetland boundary, repeated at selected locations around the entire perimeter of the wetland, may be necessary to determine the success of establishing wetland hydrology to meet mitigation requirements. It is possible for ditches and drainage tiles to remove surface water, but the soils remain saturated for a sufficient period to maintain wetland hydrology. Wells placed along a topographic gradient should provide the hydrologic information necessary to determine the wetland hydrology boundary (Figures 7 and 8). The distance between wells depends on many factors, such as percent slope and location of wells in relation to impacts or disturbance. The number of transects that are needed around the depression depends on the size of the wetland and location of the impacts.

**Tidal Fringe.** Tidal fringe wetlands occur along coasts and estuaries and are under the influence of sea level. They intergrade landward with riverine wetlands where tidal current diminishes and river flow becomes the dominant water source. Because tidal fringe wetlands frequently flood and water table elevations are controlled mainly by sea surface elevation, tidal fringe wetlands seldom dry for significant periods. Tidal fringe wetlands lose water by tidal exchange, by overland flow to tidal creek channels, and by evapotranspiration. The most common impact to tidal wetlands is filling, either anthropomorphic or natural erosional deposition (Brinson 1993). Often the boundaries are abrupt and distinct and the placement of wells to quantify wetland hydrology is relatively apparent.

Figure 7. Water table monitoring wells near the center and edge of a depressional wetland

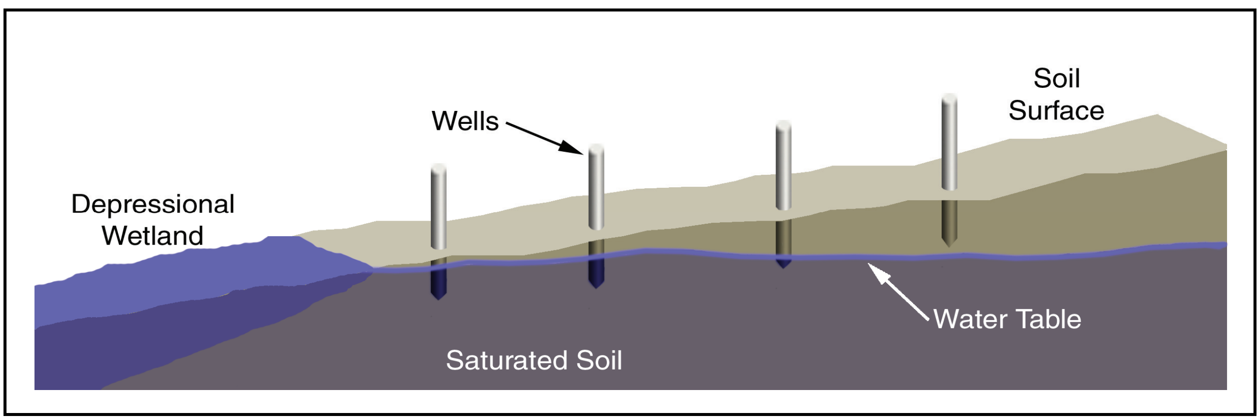


Figure 8. Transect of water table wells along a topographic gradient to determine the wetland hydrology boundary

**Lacustrine Fringe.** Lacustrine fringe wetlands are adjacent to lakes where the water elevation of the lake maintains the water table in the wetland. In some cases, these wetlands consist of a floating mat attached to land. Additional sources of water are precipitation and groundwater discharge, the latter dominating where lacustrine fringe wetlands intergrade with uplands or slope wetlands.

Surface water flow is bidirectional, usually controlled by water-level fluctuations resulting from wind. Lacustrine wetlands lose water by flow returning to the lake after flooding and by evapotranspiration (Brinson 1993). The impacts to lacustrine fringe wetlands are similar to tidal fringe and issues associated with hydrologic monitoring are similar as well.

**WELL REMOVAL:** When any wetland hydrology study is completed, wells and all other items such as fencing should be completely removed. Holes should be filled with natural soil material, whenever possible.

**CONCLUSIONS AND RECOMMENDATIONS:** Any wetland hydrology monitoring project requires planning, documentation, and maintenance. Proper planning includes an understanding of what questions the project is expected to answer and a basic understanding of the type of wetland that is being monitored. Well locations must be recorded and wells identified to ensure that data collected is associated with the proper location on the landscape. If wells are not properly maintained, then data can be lost and an entire project can be nullified. It is always advisable to have any project plan reviewed by others with experience in wetland hydrology monitoring to help identify any obvious shortcoming.

**POINTS OF CONTACT:** For additional information, contact Mr. Chris V. Noble, Environmental Laboratory, U.S. Army Engineer Research and Development Center, Vicksburg, MS (601-634-3482, Chris.V.Noble@erdc.usace.army.mil) or the 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:

> Noble, C. V. (2006). "Water table monitoring project design," *WRAP Technical Notes Collection* (ERDC TN-WRAP-06-2), U.S. Army Engineer Research and Development Center, Vicksburg, MS. http://el.erdc.usace.army.mil/wrap/

## REFERENCES:

Bliss, C. M., and Comerford, N. B. (2002). "Forest harvesting influence on water table dynamics in a Florida flatwoods landscape," *Soil Science Society of America Journal* 66(4), 1344-1349.

Brinson, M. M. (1993). "A hydrogeomorphic classification for wetlands," Technical Report WRP-DE-4, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Doolittle, J., Noble, C., and Leinard, B. (2000). "An electromagnetic induction survey of a riparian area in Southwest Montana," *Soil survey horizons* 41(2), 27-36.

Natural Resources Conservation Service. (1997). "Hydrology tools for wetland determination," Chapter 19, *Engineering field handbook.* D. 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://www.wes.army.mil/el/wrap/pdf/tnwrap00-2.pdf)

Sun, G., Reikerk, H., and Kornhak, L. V. (2000). "Ground-water-table rise after forest harvesting on cypress-pine flatwoods in Florida," *Wetlands* 20(1), 101-112.

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. (http://el.erdc.usace.army.mil/wrap/pdf/tnwrap05-2.pdf)

Weins, K., and Roberts, T. H. (2003). "Effects of headcutting on the bottomland hardwood wetlands adjacent to the Wolf River, Tennessee," ERDC TN-WRP-HS-CP-2.1, U.S. Army Engineer Research and Development Center, Vicksburg, MS. (http://el.erdc.usace.army.mil/elpubs/pdf/hscp2-1.pdf)