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A Primer on Inland Wetlands Creation and Restoration for Design Professionals

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> Loss rates of wetlands around the world and the subsequent recognition of wetland values have stimulated restoration and creation of these systems. Policies such as "no net loss" of wetlands in the United States have made wetland creation and restoration a veritable industry.
>
> --Mitsch and Gosselink, *Wetlands* (2007)

The practice of the art and science of wetland creation and restoration is a new phenomenon. Note that I use the words "art" and "science" purposely, because successful wetland creation requires a certain amount of aesthetic sensibility, as well as a knowledgeable application of science.

The creation of wetlands was given little respect in the design field until the mid-1980s. When landowners were required to "restore" areas they had illegally filled, many simply dug a depression beside existing wetlands and planted seed. When developers were required to replicate wetlands lost in a large project, they often replaced a forested swamp with a cattail marsh.

Federal and state regulations often require mitigation to occur when wetlands are impacted, but have provided minimal technical guidance regarding replication methodology. In addition, some states have issued replication directions that are so vague that they effectively allow shrub swamp wetlands to be replaced with odd pockets of soft rush and loosestrife. This pattern of inept and careless replacement is well documented in the Brown and Veneman report, *Compensatory Wetland Mitigation in Massachusetts* (Sept 1998). Bad science, careless construction, basic misunderstandings and inadequate supervision have all contributed to the long history of these failures across the United States.

The wetland regulatory and private consultant community was slow to acknowledge these failures, but mounting evidence, both specific and anecdotal, have made it impossible to ignore. Increasingly, like-kind wetlands are being required.

In short, recognition of the biochemical, biological and habitat values of different types of wetlands are now part of regulation. Forested wetland swamps are recognized as vastly different from monocultural wetland meadows. Professionals now understand that many marsh "restorations" five years after planting became, at best, shrub-scrub depressions. Taken cumulatively, these "junk" replications were finally recognized by the regulatory community as, simply, continued wetland losses. The bar has been raised in the 21st century on how successful restoration is measured.

PRIMARY CONSIDERATIONS

Creating a wetland seems easy enough. Yet what should be obvious is often overlooked or ignored by designers. Sherlock Holmes in *The Hound of the Baskervilles* writes,

> The World is full of obvious things, which nobody by any chance ever observes.

Given this gentle warning by literature's most famous detective, what are the primary considerations for successful wetland creation?

- Hydrology.
- Soils.
- Vegetation.
- Type of wetland, and
- Siting

These are the physical requirements that drive the creation and restoration of a wetland. As we will see, existing wetlands are defined by only three of these elements: hydrology, soils and vegetation. The other two elements are essentially regulatory considerations, and all five requirements come into play when creating or restoring wetlands.

In wetland creation, the single component most frequently overlooked is hydrology. *There is no more important element in wetland design.* Designs that ignore the influence of ground water and surface water on an area usually fail. Such a mistake leads to one of two extremes: unintentional drowning of a new wetland, or water deprivation leading to a similar loss of all water-dependent plants.

Regardless, the successful *long-term* combination of hydrology, soil and vegetation make a thriving wetland. Note the use of the phrase, "long-term." Here's an example:

If a wetland design has correct hydrology, yet has insufficient depths of soil or improper plant types, a reviewer who returned two years after construction and observed plant die-off would probably conclude that the restoration had "failed." But, if the hydrology were calculated correctly (and opportunistic invasive plants like cattails and *phragmite* had not taken over), a reviewer might come back a *decade* later and find that same area to be a thriving wetland–one that had come back on its own. Hydrology, then, is always the key to successful wetland creation. Soils and plants are ancillary, although proper choices strongly influence the eventual result.

Designers should always remember that natural wetlands tend to have microtopography—fallen trees and other woody material, rock outcrops, pools of standing water and even small islands of uplands. Consequently, wetland creations should not be neat, rectangular areas. As Donald Hammer notes in *Creating Freshwater Wetlands*,

> Any sizable wetlands often include portions that are clearly dry land and clearly deep water… Boundaries are imprecise and may seem to vary with seasons and different years.

Before wetlands can be created or restored successfully, a basic understanding of both the regulatory and physical parameters is required. To give you that foundation, a quick review of the origin of wetland protection, wetland definitions, wetland functions and values, wetland types and wetland field identification follow.

Figure 1. Wetlands are messy. Created wetlands should be as well.

REVIEW OF THE ORIGIN OF WETLAND PROTECTION

In the first two courses, you learned that scientists have agreed on universally accepted definitions for various wetland communities. Within the U.S., wetlands are now routinely protected by local, state and/or federal legislation. The federal 1977 Clean Water Act (CWA) has driven all wetland legislation.

The federal regulations were created because of the growing realization that wetlands provide numerous values for humans, including flood mitigation, water supply and the prevention of pollution. Wetlands also provide numerous functions and values for wildlife.

In 1987 in response to the 1977 CWA, the U.S. Army Corps of Engineers issued the *Corps of Engineers Wetlands Delineation Manual*. The *Manual* (available on the web in PDF format at *www.wes.army.mil/el/wetlands/wlpubs.html*) instantly became the most comprehensive definition of wetlands published. The *Manual* changed the public's "common sense," get-your-feet-wet definition that had led to constant disagreements over what constituted a wetland. Today the *Manual* continues to have broad influence, and remains the primary federal guide to wetland delineation nationwide. In addition, many states, towns and cities have instituted wetland rules, regulations and by-laws. These protect wetlands and define allowable impacts, as well as required mitigation.

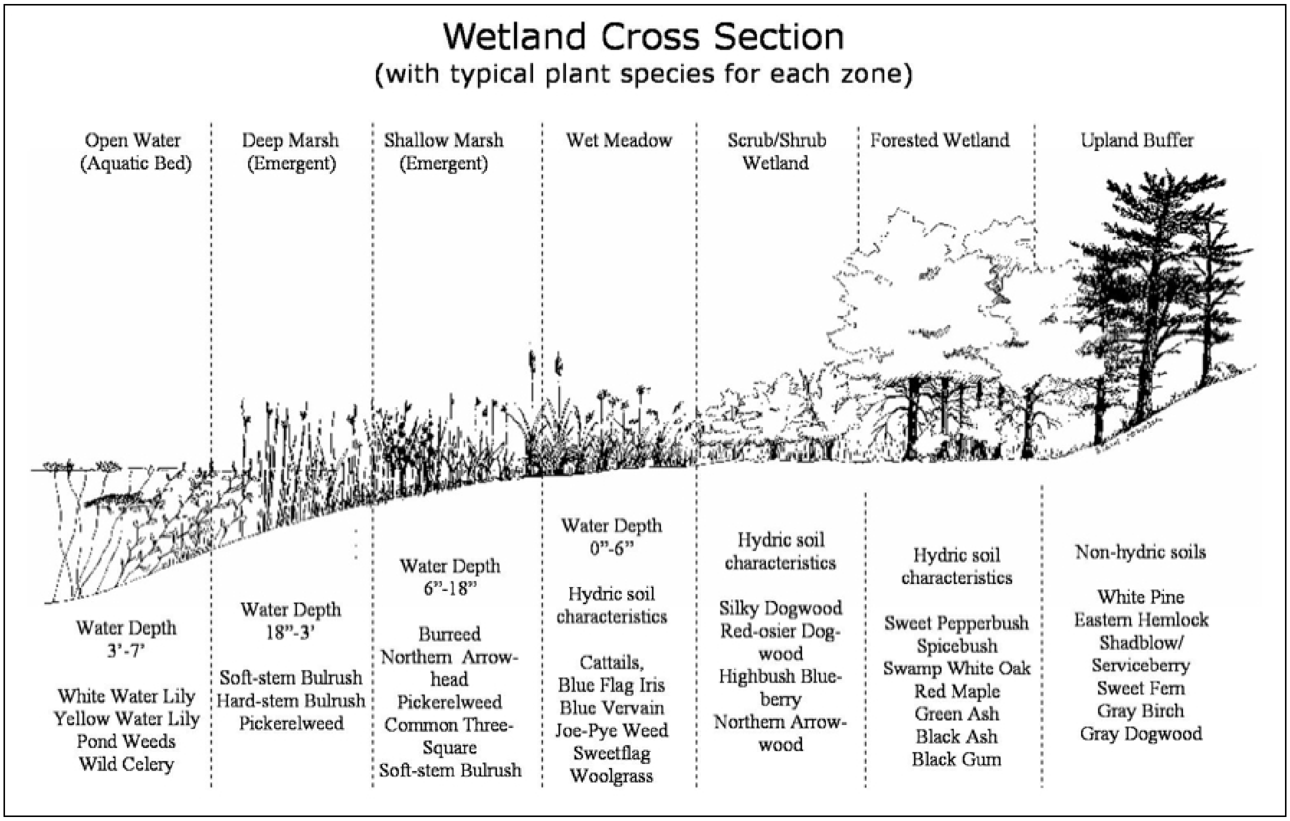

Figure 2. Classic wetland cross-section, courtesy New England Wetland Plants, Inc. (Amherst, Mass.).

REVIEW OF WETLAND DEFINITIONS

The Corps *Manual* defines wetlands as:

> "Those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs and similar areas."

Tiner's *Field Guide to Nontidal Wetland Identification* (1988), another widely referenced text, states:

> "Wetlands lie along the natural soil wetness continuum between the better drained, rarely flooded uplands and the permanently flooded deep waters of lakes, rivers and coastal embayments."

Scientists today characterize all wetlands as having three common components: *hydrology*, *hydric soils and hydric vegetation*. (As emphasized throughout this course, the most important of these components is *hydrology.)*

Also key is the definition of wetland creation and restoration. Mitsch and Gosselink write,

> Wetland restoration involves returning a wetland to its original or previous wetland state, whereas wetland creation involves conversion of uplands or shallow open-water systems to vegetated wetlands… Generally, wetland restoration and creation first involve establishment or reestablishment of appropriate natural hydrologic conditions, followed by establishment of appropriate vegetation communities.

REVIEW OF WETLAND FUNCTIONS & VALUES

The *functions* or impact of wetlands on the environment include biochemical changes from the anaerobic conditions presented and morphological plant adaptation due to constant saturation.

From a human perspective we now recognize that the *values* of wetlands are numerous. Wetlands values include

- Mitigation of flooding.
- Habitat for animals.
- Protection for water supplies. (Hydric vegetation filters hydrocarbons, heavy metals and other pollutants through a complex process called vegetative uptake).
- Mitigation of storm damage.
- Recharge of groundwater, and
- Protection of fisheries and shellfish habitat.

Further, wetlands offer other, more diffuse values. Wetlands provide sanctuary for rare or endangered species, corridors for animal migration and educational and aesthetic opportunities.

Some of these *values* may have to be provided as a regulatory requirement in any given created wetland. If the values are not specifically addressed by regulation, many are implied as an underlying reason for the creation or restoration itself.

REVIEW OF WETLAND TYPES

Federal definitions of wetland types include marshes, bogs, swamps "and similar areas." Wetlands associated with lakes, rivers and freshwater marshes account for 90% of the nation's wetlands. Inland wetlands are further categorized as:

Rivers & Streams

Most inland wetlands lie along or beside rivers, creeks and streams. Associated wetlands often form a rich, bordering ecosystem. (See Figures 3, 6 and 10.)

Common technical terms that may be used by wetland experts or regulators, and therefore are frequently encountered by design professionals when working with riverine-based wetland creation are:

- Bordering lands subject to flooding, and
- Bordering vegetated wetlands

Figure 3. Restored wetlands bordering a stream.

Bogs

Bogs are primarily found in formerly glaciated portions of North America. Concentrated in the Northeast, north central states and Canada, bogs are underlain with a deep substrate of peat and often lack mineral soils. Constant saturation from high ground water, large open areas of water, knolls of evergreen trees and transitional lands often dominated by low shrubs characterize bogs.

Lakes and Ponds

Known as lacustrine systems, lakes and ponds vary in size from “kettle holes” to vast bodies of water such as the Great Lakes. The often shallow waters besides lakes and ponds harbor diverse communities of hydrophilic vegetation and water-dependent animals such as turtles, salamanders and freshwater shellfish. Water deeper than six feet in lakes and ponds is not considered to be a wetland.

Swamps and River Flood Plains

These areas are often the least understood wetlands. Commonly dry in summer, they may hold eight feet of moving water for short periods during winter and spring floods. Although in late summer they often appear to be uplands, they have ground water within a foot or so of the surface. Since they may appear to be “high and dry,” the majority of alterations and losses have occurred in these wetlands. In their natural condition, hardwood trees, evergreens and wetland shrubs, typically dominate swamps and flood plains. Wooded swamps are also referred to as forested swamps. (See Figure 2.)

Wet Meadows and Marshes

Marshes (see Figures 2 and 4) are characterized by wetland shrubs and by soft-stemmed herbaceous plants such as reed and cattails. Seasonal fluctuations in water are typical, with levels varying from six inches to six feet. These systems are frequently called emergent wetlands.

Design Note: You must have a thorough understanding of what type of wetland is to be created. As we have seen, early "restorations" of forested wetlands often ended up "replicated" as cattail marshes.

Figure 4. Shallow marsh restoration.

WETLAND FIELD IDENTIFICATION

Wetland creation most frequently occurs beside existing wetlands. Isolated wetlands are far less protected, may have difficult hydrological considerations, offer less wildlife habitat and tend to be difficult to protect for development considerations. Because replicated wetlands are often sited adjacent to wetlands, existing wetlands must be accurately identified by type.

A wetland scientist or wetland expert almost always makes this determination. Let's briefly review their techniques.

Remember that scientists characterize all inland wetlands by three common components: *hydrology*, *hydric soils* and *hydric vegetation*. Regulatory identification of these components generally follows the methods mandated in the 1987 Corps *Manual*.

Before beginning a wetland analysis, design professionals may check public and governmental sources for resource mapping. Often these sources will provide established data about waterways, watersheds, known wetlands, flood plains, soils and topography. Some available sources are:

- **GIS Maps** Many local communities, particularly in urban and metropolitan areas, have GIS mapping that indicates wetland resources. State mapping is available in increasing numbers of states.

- **Soils Maps** The state offices of the federal Natural Resource Conservation Service (NRCS), formerly the Soil Conservation Service (SCS), will often have detailed soil mapping available--these maps identify areas of muck as well as other soils that are considered hydric. Often, hydric soil lists are available for specific counties or states.

- **USGS Maps** In addition, United States Geologic Survey (USGS) quadrangle maps show large wetland areas, particularly rivers, streams, ponds, lakes and broad marshes. A user should examine 1:24/25,000 and 1:100,000 scale topographic maps for wetland indicator symbols (see Figure 5). Often, topographic features will indicate potential wetland areas, even when not shown as wetlands on specific quad sheets. (See *www.usgs.gov/*)

- **Aerial Photographs** Aerial photographs are often available through both public and private sources. In more heavily populated parts of the country, private aerial companies often fly the entirety of cities and counties. As with the NWI mapping, indications of wetland areas must be field verified.

- **Local Topographic Maps** Many communities have recent community-wide topographic mapping available for public use. Unlike USGS quadrangle maps, these tend to be larger scale, often one to two foot contours, and provide more accurate, and updated information. They can be a useful tool to anticipate likely wetland locations that might border rivers, streams, flood plains and marshes.

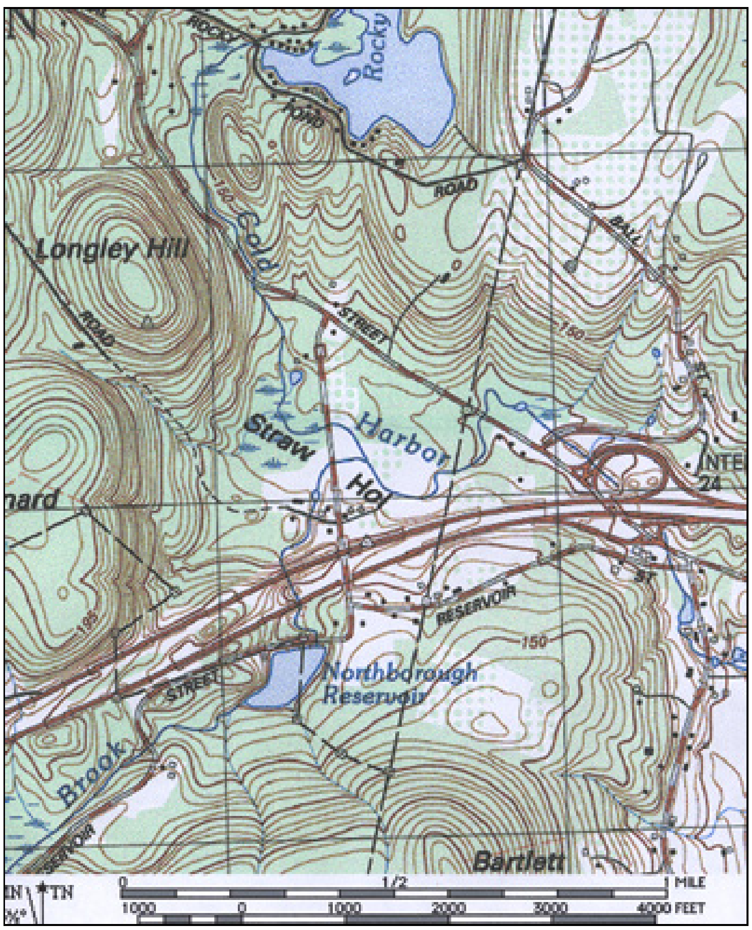

Figure 5. USGS quadrangle map. Note the wetland indicator symbols (in blue) beside the brook.

- **FEMA Floodplain Maps** Nationwide floodplain maps are available from the Federal Emergency Management Agency (FEMA). Developed for the federal flood insurance rate program, these maps indicate either general or detailed 100-year or 500-year flood prone areas, typically as Zones A or AE. Wetlands are commonly found within or beside these zones, particularly where they border rivers and streams.

- **Corps of Engineers Regional Offices** Regional or district offices for the Corps are another potential source for data, particularly if recent nearby developments have had to apply for a Corps Clean Water Act permit (also known as a 404 permit). Frequently, the regional office will have a contact person in the wetland section that will share in-house data, including wetland locations.

- **Local Wetland Conservation Agencies or Commissions** Depending on local bylaws or state regulations, your community may have an agency to protect wetlands and permit certain developments in or around them. Contacting resource specialists at these offices may reveal that nearby or even adjoining lands have been mapped recently. Timely use of this resource can save you headaches later.

- **Other Sources** Local and regional planning boards or agencies are another possible source for wetland resource mapping.

FIELD INVESTIGATION

Once research for a given area or site has been conducted, a detailed on-ground evaluation of potential wetland areas occurs. An *initial* field investigation does not have to be conducted by a professional wetland scientist. Designers with a basic understanding of wetland indicators and the scientific criteria used in delineation are often competent to make these initial determinations.

Confirmation that wetlands exist on a site is relatively simple, and can be made without detailed analysis or calculations. Abrupt changes in plant communities and topographic slope may be strong indicators of a wetland edge. Hydrologic indicators such as wrack lines, stained leaves and areas of standing water are useful. Preliminary investigation of soils, particularly within the first 20 inches of the surface, is often required in more complex wetland communities. Many of these field techniques are discussed in other courses by this author.

Hydrology

As you will read repeatedly in this course, *hydrology* is the key to successful creation of wetlands. Review Figure 2 as an example of how groundwater elevations change the type of vegetation on a given site. *Wetland hydrology* is the movement of water within and through a wetland. Hydrologic features include frequency and duration of inundation, timing, depth of saturation, ground water fluctuation and the movement of surface water.

Wetlands hydroperiod is a term characterizing the condition of saturation in a wetland, and is a function of flood duration and frequency. A wetland's net hydroperiod can be represented by an equation, where volume is based on factors including precipitation, surface inflow, groundwater inflow, evapotranspiration, water outflow and change in volume. Permitting authorities sometimes require a *hydroperiod* calculation, particularly when replication or creation of new wetlands is unusually difficult or problematic. (Such equations can become quite complicated. See course bibliography for Mitsch and Gosselink's *Wetlands*, pages 118-123, for an example.)

Water in a wetland is always characterized as being ground water, surface water (such as sheet flow from storm flooding), or a combination of both. Either one or both of these physical conditions may lead to saturated soil conditions. Surface water in a wetland area sometimes comes from flooding from adjacent water bodies, such as during periodic overtopping of streams or rivers following intense storm precipitation or spring snow melt.

Figure 6. Stream contributes to the groundwater in adjacent uplands.

Ground water is a far more common source for surface inundation. Some wetland areas are fully saturated year round. Others are subject to extensive ground water fluctuation. Because ground water in many soils can vary vertically over a year's period by 12 feet or more, wetland areas that are typically flooded in the spring may appear completely dry several months later.

Ground water may also appear on a surface due to capillary action, a process that draws moisture up through the porous voids in soil. Wetland conditions typically occur on sites where ground water is within 20-inches of the surface for a long enough duration of time to create *anaerobic* (oxygen-depleted) conditions; anaerobic conditions are essential for the creation of wetlands.

Anaerobic conditions produce plant communities that differ from plant species in communities that grow in upland (or aerobic) conditions. The wetland plants that are typical of saturated conditions all have adapted in some manner to survive periods of inundation. These plants are commonly referred to as hydrophilic plants, or as hydrophytes, and are used in created wetlands.

Last, hydrology, through its creation of anaerobic conditions, in turn creates an identifiable component of a wetland—*hydric* soils. These soils are categorized predominately by color and texture. Soil colors are commonly gleyed (having neutral gray to blue colors), or may be dark chocolate browns to almost black. Their textures may be gritty when mineral soils, or slippery or fibrous when organic. In wetland creation such soils can be imported, created or formed in place over time.

Hydrology Field Indicators
Evidence of hydrology is a strong indicator of a potential wetland community. Although not always visible—as noted above, surface inundation may occur infrequently—these indicators are often surprisingly obvious. Indicators of hydrology are

- Actual surface flooding or inundation.
- Water marks or ice scars on tree trunks.
- *Drift or wrack lines.* (These are usually branches, reeds and other debris that are caught in shrubs or trees at periods of flooding. Such debris may be found in late summer as much as six to eight feet above the apparent stream channel, and are an indication of the extent of high flow.)
- Sediment deposits.
- Surface drainage patterns, or distinct channels, or scouring.
- Water-stained leaves.
- Depth to free water in an observation hole of less than 12 inches. (Free water or weeping within 12-inches of the surface is a good indicator of wetland conditions).
- Depth to saturated soil in an observation hole of less than 20 inches.
- Sulfide odor from an opened observation hole. (A “rotten egg” smell is an indicator of hydrogen sulfide, which almost always indicates the presence of organic hydric soil.)

Not all indications of scouring or evidence of sheet flow denote a wetland. Scouring may simply denote an unusual and infrequent flood. Some stream systems may overtop their banks only during a 25-year or greater flood; at such times, the adjoining upland may show water marks and drift lines.

Wetland Vegetation
Wetlands are created in areas that are periodically flooded or saturated, and grow in response to the subsequent anaerobic soil conditions. Wetland plant communities are unique in that they consist of plants that have adapted to varying periods of flooding. This is known as morphological or physiological adaptation.

Botanists have classified all known plants in North American by genealogy and organized them into different groups. Plants have common names, but scientists do not consider these reliable as plant names may change from region to region, and even from town to town. In response to this, scientists have identified plants by a single scientific name, consistent worldwide—always indicated in italics. For instance, a red maple has the scientific name, *Acer rubrum,* whether found in the United States or in Canada, and an American larch, the scientific name*, Larix latifolia*.

Figure 7. A mix of Obligate & FACW plants.

Scientists also categorize plants by their propensity to live in uplands or wetlands. This classification is based on the frequency or percentage of time that each plant is found in a wetland versus upland community. In the late 1980s, the Fish & Wildlife Service (FWS) published the *National List of Plant Species That Occur in Wetlands* (see bibliography at the end of this course). Any successful wetland creation will be partly based on implementing the FWS classification system.

The publication lists all major plants found in a given state by both common and scientific name. Each plant is assigned an "indicator" category that indicates the likelihood that the plant will be found in a wetland. For instance, in New Hampshire, Massachusetts and Rhode Island, a red maple (*Acer rubrum*) is classified as *facultative* (FAC), indicating that it is equally likely to occur in uplands and wetlands.

Plant species that almost always grow in inundated wetland conditions during the growing season are classified as *obligate wetland* (OBL) species—see Figure 7. Upland plants (that is, plants rarely found in wetlands) are classified as *facultative upland* (FACU). Plants that are between these two extremes have other classifications.

FWS indicator categories for nationally identified plants are:

Obligate wetland	OBL	>99% frequency in wetlands
Facultative wetland	FACW	67-99% frequency
Facultative	FAC	equally likely wet or upland
Facultative upland	UPL	<01% frequency in wetlands

Plant guides are widely available and are strongly recommended for field investigations. These guides are also helpful seasonally when, depending on the region of the country, leaves may not be out and herbaceous plants may have died back, leaving only dried stem material. Plant field identification is also particularly difficult under snow cover, and may only be possible using buds and stems, and analysis of soils.

Several recommended guides follow. Others are available.

- *Common Marsh, Underwater and Floating-leaved Plants of the United States and Canada,* Neil Hotchkiss. 1972. Dover Publications.
- *Field Guide to Nontidal Wetland Identification,* Ralph W. Tiner Jr. 1988. Maryland Department of Natural Resources and USFWS.
- *Freshwater Wetlands,* Dennis Magee. 1981. University of Massachusetts Press.
- *Plants in Wetlands,* Charles B. Redington. 1994. Kendall Hunt Publishing.
- *Wetlands, Audubon Society Nature Guides,* William Niering. 1987. Alfred A. Knopf.
- *Winter Botany: An Identification Guide to Native Trees and Shrubs,* William Trelease. 1931. Dover Press.

Hydric Soils

Hydric soils are produced under anaerobic conditions, which are the result of saturation, flooding or ponding over a sufficient period (usually two weeks or more). The hydrology section described how saturated or inundated conditions produce anaerobic soil conditions. This so-called “diagnostic” condition leads to changes in soil chemistry and coloration, and can take place in as little as a year’s time depending on the type of soil and the length of growing season.

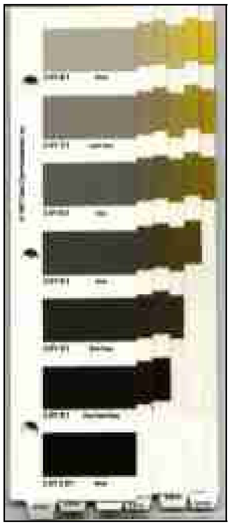

Figure 8. Color book used to determine soil chromas.

Hydric soils are partially described by what is called a specific *Munsell* color (Kollmorgen Corporation 1975), and further defined within that system by hue, value and chroma. A 1991 publication, *Hydric Soils of the United States*, categorizes the two major soil groups—organic and mineral soils—by their field indicators.

Munsell colors (see Figure 8) are used to provide critical information on the degree of soil wetness and inundation, and serve to standardize color description. Soils are sampled using a circular observation hole that has a 12-inch or greater radius. The sampled soil is removed from the hole. The sample itself then creates what is referred to as the *soil profile*. The profile is examined and broken down by the analyst into *horizons*.

Horizons are layers of soil, parallel to the surface, having distinct characteristics produced by soil forming processes. The top layer is called the O and/or A horizon; the subsurface layer is the B-horizon; and further layers below are the C and R-horizon. These layers are briefly described below.

Soil Horizons & Layers

O-Horizon This layer, commonly called "duff" or the "litter layer," is dominated by organic material in varying states of decomposition.

A-Horizon A mineral horizon formed at the surface or just below the O-layer, commonly referred to as "topsoil."

B-Horizon Horizon formed below an A or O-layer, and commonly called "subsoil." Considered hydric with a soil chroma of 1 or less.

C-Horizon The layer little affected by processes of weathering and that lacks the properties of an O, A or B-layer.

ASSESSING WETLAND TYPES & COMMUNITIES

As we have seen, more and more authorities are mandating the re-creation of existing wetland communities, or the creation of like-kind wetlands. Differentiating one type of existing community from another is therefore critical. Doing so is often relatively easy.

Most wetland communities can be determined by vegetation and surface hydrology. A simple site walk through an area may be used to conduct an assessment. Remember that the Corps *Manual* describes wetlands as

- Rivers & Streams.
- Bogs.
- Lakes and Ponds.
- Swamps and River Flood Plains, and
- Wet Meadows and Marshes.

Determining the type of wetland almost always occurs during preliminary field investigations. Few of these types are difficult to identify for even a non-expert. Rivers and streams, lakes and ponds—all of us immediately recognize these. (Also, review Figure 2.)

Swamps are usually wooded, as are river flood plains. There are exceptions of course. Most river flood plains were wooded before settlement in the 17th and 18th century, but were clear-cut at that time. Wet meadows and marshes may be more difficult to distinguish, but are usually characterized by shrub-scrub vegetation and/or wide grasslands. (Again, see Figure 2.)

Figure 9. River flood plain just before being cleared for a highway. This area will require wetland creation to recreate existing conditions. (See section in course on creating forested wetlands.)

REVIEW SUMMARY

This has been an essential review of wetland basics. If you understand wetland definitions, types and the driving principles of *hydrology*, *soils* and *vegetation* that characterize a wetland, wetland creation itself becomes relatively simple.

The principles that apply to natural wetlands apply to created ones. Successful wetland creation requires the same three components. In short,

- Success is dependant on the application of these components.
- If these components are applied knowledgeably and with care, a created wetland thrives.

In many ways we are fortunate today: Designers have access to the required science and understanding, which earlier professionals lacked. Assuring that restored or replicated wetlands succeed is no longer a mystery, and no longer hit-and-miss.

CREATING AND RESTORING WETLANDS

Site Selection

Creating a successful wetland is predicated on choosing an appropriate site. Doing so is usually determined by evaluating site topography and other physical data. Appropriate sites can be upland areas or previously filled wetland areas. Acceptable sites may also include degraded landscapes such as old gravel pits where creating a wetland may increase ecological values. Unacceptable sites may be areas with shallow ledge or bedrock, areas with highly compact soils, areas with insufficient hydrology, or land adjacent to a previously developed area (like a road or parking lot) that would directly affect the wetland value and functions.

Relevant data often includes

- Land ownership.
- Geology.
- Hydrology.
- Underlying soils.
- Proximity to other wetlands and water bodies.
- Existing over story trees (for shading) and
- Applicable regulatory requirements.

Once a site is selected, the designer should conduct a detailed study of hydrology, soils and vegetation.

Figure 10. Buffer zone restoration beside a stream, courtesy of the Penn. Conservation Reserve Enhancement Program (CP).

Hydrology

General

Nothing is more important than hydrology for wetland development. As Hammer emphasizes in *Creating Freshwater Wetlands*,

> The long-term success of any wetlands restoration or creation project is, to a very large extent, dependant upon restoring, establishing, or developing and managing the appropriate hydrology.

Inadequate hydrology is often a result of inadequate evaluation of the wetland site before construction, particularly when sites depending on ground water are not excavated deeply enough to provide groundwater contact at appropriate seasons. Problems can also result when a site is over-excavated to depths below the water table.

In short, design professionals must understand the hydrology of the replication site. To do so successfully, a water budget of input/outputs must be determined. (This is an calculation we will discuss a little later in the course.) Note that it is common to create unrestricted hydraulic connections *between* the created wetland and water sources such as adjoining streams, ponds or floodplains.

Figure 11. Illegal fill in a wetland meadow. The owner was required to remove it and restore the wetland. Silt fencing has been installed to protect existing wetlands from further impacts.

Desirable Hydrologic Information

The expected annual seasonal depth, duration, and timing of both inundation and saturation must be established for the existing wetland and for each of the proposed vegetation types in the created area. Data sources should be gathered from the immediate area and may include hydrological records that provide evidence of periods of continuous flooding from 7 to 21 days during the growing season. Possible sources, listed in order of increasing importance, are

- USGS stream gauging stations.
- US Army Corps of Engineers data from major water bodies.
- State and local flood data, or NRCS flood information.
- Direct observation of inundation, ponding or saturation.
- Mean annual high water or bankfull indicators on streams/rivers, or their equivalent in isolated wetlands.
- Evidence of soil saturation from hydrology, including free water in a soil test hole, wells, saturated soil or oxidized rhizospheres.

Note that the most accurate means of determining hydrology is from actual testing, typically using a soil test hole or monitoring wells. Because ground water levels are critical, designers should begin data collection activities as far in advance of the project as possible.

In more complex replication sites, monitoring wells or piezometers may be necessary to collect groundwater data. Such devices are simply open pipes set in the ground. A piezometer (see Figure 12) is a small diameter water well used to measure the hydraulic head of groundwater in aquifers. It may be a standpipe or tube. Regardless, it measures the pressure of a fluid at a specific location in a column. Piezometers can be read periodically in the field, or can be setup with data loggers, which transmit, or record measurements at predetermined intervals.

Figure 12. Stainless steel piezometer, courtesy of Fish & Wildlife Service.

Typically, a monitoring well is sufficient to investigate a smaller replication area when a free water surface is within the top foot or two of the soil. Piezometers are appropriate when investigating larger replication areas to characterize water flows into and out of a wetland or differences in water pressure of soil horizons. Monitoring must be conducted during normal high groundwater periods and during non-drought years. Monitoring during periods of extreme precipitation results in unsuitable data.

In the event that groundwater determination is complex enough to require monitoring, it should be conducted twice monthly, and ideally between March and November, when groundwater is highest. From this cumulative data design professionals can then calculate a surface hydrologic budget based on

- Watershed characteristics (slope, soil permeability, area) and
- Precipitation data (usually through a 25-year storm).

These parameters, in combination with seasonal groundwater elevations, allow designers to know the total annual water budget, as well as maximum seasonal high groundwater levels.

Groundwater-monitoring wells may be used for wetlands greater than a quarter acre or at proposed sites lacking adjacent wetlands that can be used to observe hydrology. (We assume that surface water elevations of adjacent wetlands approximate groundwater elevations.) Groundwater monitoring wells or piezometers are usually overkill at smaller sites, unless the topography of the wetland site is complex.

Anticipated Hydroperiod

There are multiple scientific definitions of hydroperiod. For the purposes of wetland design, *hydroperiod* is the time during which a wetland is covered to within 12-inches of the surface by water. Designers should base their wetland plans on the following data:

- The anticipated seasonal depth, duration and timing or frequency of both inundation and saturation for each proposed wetland type (such as forested, shrub or emergent).
- Water tolerance characteristics of the proposed plantings.
- The input and output of water—commonly known as the water budget—to ensure that inputs equal or exceed outputs. Otherwise, the site may not support a wetland system.

Wetland areas should not depend on precipitation and storm runoff only, but should also make contact seasonally with groundwater. So-called "perched" wetlands may be established without these latter inputs, but monitoring wells or piezometers are normally required to demonstrate that runoff and precipitation inputs exceed infiltration rates during the growing season. (Perched wetlands occur where an impervious layer lies *above* the water table. Surface runoff infiltrates the soils above the impervious layer creating a "perched water table" that can produce wetland conditions. Saturation is therefore from storm runoff rather than groundwater contact.)

Figure 13. Large-scale wetland restoration bordering a river, courtesy of USDA.

Land Subject to Flooding

If wetland creation is proposed within lands subject to flooding (particularly annual floods), designers should ensure that spring floods do not negatively impact the area. Inundation for extended periods, scouring and deposition can all heavily impact a new wetland. (See Figure 13 for an example of an area subject to extensive spring flooding.)

Soils

General
As noted, hydric soils provide substrate for wetland plants. Hydric soil also acts as a matrix to treat groundwater and support vegetation that slows floodwaters. Appropriate hydrology maintains soils in a hydric condition. Soils are of secondary importance to hydrology in wetland creation, but are a critical component.

Soil Translocation
Soil *translocation* is the technical term used for moving hydric soil from one location on a site to another. Such an option works only when new wetlands are created to compensate for wetlands being filled on a site. In such cases, existing wetland soils from the area to be impacted may be set aside for use in the new area.

If additional soils are needed, then soil from off-site is used. (See “Soil Amendments” below.) Soil taken from areas where invasive species are present should always be avoided. Seed stock, tubers or active roots from invasives can be transferred too easily, creating unanticipated regulatory problems in future growing seasons.

Soil Amendments
If soils are brought from off-site, design professionals should specify the composition of the additional material, as well as the techniques used to prepare it. Translocated soils, when manufactured, should specify the amount of organics, sands and silts. Some compost may be used in created wetlands. Regardless, soil composition will ideally be similar to the wetland soils found in nearby existing wetlands. Commercial and academic labs can determine existing and proposed soil composition at little cost.

Figure 14. Wetland meadow/pond restoration, courtesy Morris Arboretum (Philadelphia, Penn.).

Specifications for Soil Preparation

Rototilling or similar techniques are typically used to ensure appropriate soil compaction. Compaction should be similar to adjacent wetland soils, presuming the new wetland will have similar plants.

A common reason for failure of some wetlands is that only a few inches of A or O-horizon materials are placed over a remaining C-horizon. Although some C-horizons are sandy and may work well as subsoil, C-horizons may not provide a suitable rooting medium for plants to thrive. Wetland sites that are constructed on compacted C-horizons with a thin layer of A or O placed on top are at risk of failing. Hence, loosening the soils through some mechanical means is useful.

Figure 15. Soil in an upland area is being tested for future wetland restoration potential.

The goal for soils at any restoration should be to approximate soil profiles at the nearest undisturbed existing wetland. A surface horizon is created that is similar to the A or O-horizon at the nearby wetland site. At a minimum, the new soil should contain 9 to12 inches of A or O-material. Beneath this should be a B-horizon (the subsoil) that is similar to the depth and texture of the B-horizon at the nearby wetland site. The consistency of the wetland B-horizon should be relatively loose, and the texture should be that of a loamy sand to silt loam. Within these ranges, the consistency and texture should approximate the conditions at the nearby wetlands.

Natural wetlands are messy. To supplement organic material, coarse woody debris (that is, branches and even logs) may be scattered across the new wetland. Such a technique adds structure, microclimate, protection for herbaceous vegetation and a long-term source of organic material. Such a technique also creates immediate wildlife habitat.

Soil pH is another parameter to consider monitoring. Similar pH is often an important factor for successful plant propagation. Use a pH meter in the proposed new wetland area and adjacent wetlands. Soil or plant professionals should evaluate the results, because some pH differences may be acceptable, depending on site conditions and proposed vegetation. Additionally, some differences in pH may be acceptable. For instance, soil with a pH of 7.4 may be compatible with soil having a pH of 6.8, or even 7.7—someone familiar with variations in soil pH and with plant tolerances can make such a determination. The take-home point is that soils should not be too acidic or too alkaline for a given suite of plants.

Wetland soils that have been stockpiled should be used for new wetlands as soon as possible. While stockpiled, soils should be kept moist. Stockpiles are usually tarped. Covering stockpiled materials also minimizes windblown contamination of soils from nearby sources. Last, if soils are transported from one location to another, the transporting vehicles' tires should be washed to prevent exotic or invasive seeds from piggybacking to the new location.

Soil amendments used for the A-horizon should consist of the following

- A mixture of equal volumes of organic and mineral materials.
- Uncontaminated materials that do not include woodchips.
- Organic materials that are completely or partially decomposed.
- Clean leaf compost.
- Mineral materials that are loam, or are loamy sand to silt loam.
- Minimal quantities (< 10%) of gravel or rock.

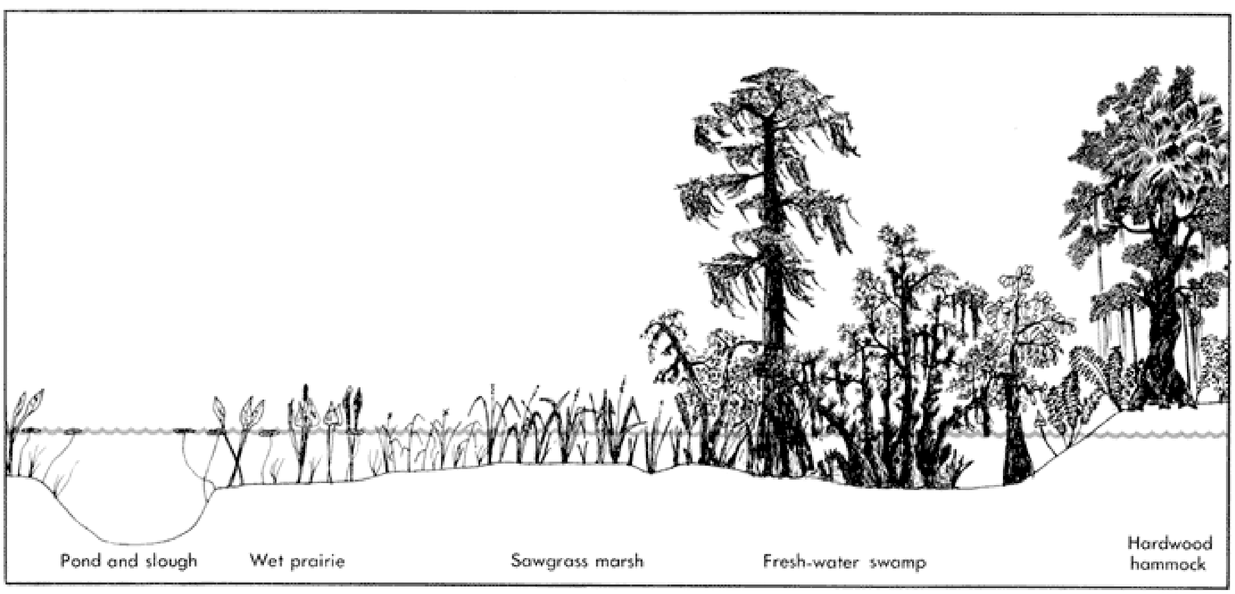

Figure 16. Depending on depth, groundwater levels dramatically alter the types of vegetation in a restoration. (Also see Figure 2.)

Vegetation

General

Typical state wetland restoration regulations require that at least 75% of the surface of the new wetland be reestablished with indigenous wetland plant species within two to three growing seasons. In order to accomplish this, the hydrology and soils conditions must be appropriate for each type of wetland vegetation that is proposed in the replication area.

Planting Requirements

A vegetation plan should provide detailed descriptions of the techniques proposed to establish wetland vegetation, including transplanting appropriate plant materials. A qualified professional with training in wetland science should oversee planting procedures.

As an example, designers frequently see projects through all required permits so that construction can begin. It is not unusual at that point for a designer to lose control as the owner contracts actual construction to an unrelated party, and supervision shifts to those unfamiliar with the nuances of wetland creation.

What frequently happens in the aftermath is that the contractor may, for instance, take a specific plant list to a nursery and ask that these plants be supplied. The design professional will have typically required native, indigenous wetland plants, but the nursery may not be able to supply these specialty species and consequently, substitutes similar plants. These may be (and are commonly) hybrids that have only a distant genetic relationship to the indigenous plants specified.

The contractor will install these plants. Many, if not all, of these species may not tolerate wetland conditions. The result is plant die-off, regulatory rejection and loss of habitat— as well as possible damage to the design professional's reputation. These situations can, and do, become litigious. *Experienced designers often include a condition in their contract requiring them to monitor the project through completion.*

Note that trees and shrubs should be root pruned prior to transplanting**.** Vegetation should be planted within one day of removal from existing wetland or as soon as possible and properly protected (e.g. burlap), watered and handled.

Shrubs are typically planted 8 to10 feet on center, and trees at 10 to 15 feet on center unless a nursery or wetland professional recommends otherwise**.** Shrub and tree densities are used to determine the total number of specimens within a given area. Plantings should occur in a natural manner (i.e. clumping, mini-communities, leaving mud flats, etc.). Remember: Natural wetlands are messy.

Invasive Species

Preventing invasive plants from contaminating a site has already been discussed in general. Foremost, designers should avoid inadvertently specifying an invasive plant. Many states furnish lists of exotic or invasive plants. Such plants vary from state to state, and region to region. A designer should be extremely familiar with the species considered native and indigenous to any given area. Specifying invasive plants is a surprisingly common error.

The following invasive species are frequently considered invasive. Soils from existing wetlands that contain these species—presuming they are considered invasive where a new wetland is being created—should never be used in such areas.

- Purple Loosestrife (*Lythrum salicaria*).
- Phragmites (*Phragmites australis).*
- Buckthorn*, (Rhamnus Frangula alnus).*
- Honeysuckles *(Lonicera spp.).*
- Garlic Mustard *(Alliaria petiolata).*
- Japanese Knotweed (*Polygonum cuspidatum or Fallopia Japonica).*
- Japanese Stilt Grass (Microstegium vimineum).
- Reed Canary Grass (*Phalaris arundinacea*).
- Bittersweet nightshade (*Celastrus Orbiculatus).*
- Black Swallow-wort (*Cynanchum nigrum).*
- Pale Swallow-wort (*Cynanchum rossicum)*.

The U.S. Department of Agriculture (USDA) maintains a national invasive species list. The list is categorized by region and state. See http://www.invasivespeciesinfo.gov/ for this data. Again, some species considered invasive in one region are not in another. Reed Canary Grass (*Phalaris arundinacea*) is one example. It is recommended by the USDA to stabilize open areas, ditches and to reduce erosion in the Midwest, while being considered an invasive in many New England states.

Timing of Plantings
Planting normally occurs at the beginning or end of the growing season. Fall plantings should be done before the first frost. Shrubs and trees, however, may be planted later. These rules-of-thumb vary regionally. Some plant species are ill suited to fall planting and therefore knowledge regarding individual plant tolerances should be determined during design. Information regarding optimal planting seasons may be obtained from local USDA offices.

Wildlife Habitat
Wetland restoration areas provide important food, shelter, migratory and over-wintering areas, as well as breeding areas for many birds, mammals, amphibians and reptiles. Wetland characteristics that provide wildlife habitat include hydrologic regime, plant and soil composition and structure, topography and water chemistry. In areas with endangered species, design professionals may be called upon to describe the wildlife habitat characteristics of the wetlands to be lost to determine its wildlife habitat value. Typically, the more ecologically sensitive an area, the more analysis of habitat values may be required as a component of permitting.

Monitoring & Maintenance of Created or Restored Wetlands

Initial monitoring of any newly created or restored wetland is essential. Plant material almost always dies off by the second growing season. A loss rate of 10-20% is not unusual. Further, plants may be eaten by wildlife. Deer, beavers, muskrats, foraging geese and other animals are all quick to take advantage of fresh, immature shrubs and trees. Some sites have wildlife fencing installed to prevent such losses.

Other impacts to new wetlands can be unexpected. Exotic plants may invade a site over the course of a year. Seed stock with invasive species may have been unknowingly mixed in the wetland topsoil. Other common impacts are

- Unexpected flooding from upgradient surface runoff.
- Flooding from downgradient floodplain activity.
- Malicious destruction of plant materials. This occurs as wanton breaking or cutting of vegetation, and sometimes results from dirt bike or other vehicle use of the area.
- Brush fires.
- Prolonged drought or record storms.
- Unusual insect outbreaks.

Regular or periodic monitoring will sometimes minimize such impacts. There are occasions, though, when an inspection simply reveals that all planted areas have been lost. While most authorities require immediate restoration of impacted areas, the scientific community often takes a longer-term approach to such losses.

A multi-decade approach presumes that if the designer properly establishes hydrology, then in time wetland plants, whether installed or not, will populate the created wetland area. This approach might be characterized as the “If you build it, they will come” approach.

Hammer notes in *Creating Freshwater Wetlands*,

> To paraphrase an old adage, the three most important factors in maintaining wetlands are: disturbance, disturbance and disturbance… Whether large scale (glaciation) or small scale (beaver dams), whether long term (tectonic forces) or short term (seasonal flooding), wetlands are absolutely dependant upon some disturbance factor for initial formation *and* for continued existence.

Rarely though do approving authorities take a long-term approach. Designers must deal with a common regulatory assumption that what is built must succeed, and that success must occur within a designated period of no more than five years (and often less). Therefore, designers must monitor their created wetland until there is an official sign-off that the project succeeded.

Narrative Report

Permitting authorities almost always require plans and written reports for wetland approvals. Such applications can be relatively simple—or tremendously complex. Plan complexity will depend on the site, conditions and magnitude of the project. Such reports typically contain the following minimum sections

- Background.
- Technical planting procedures.
- Seed mix consistency.
- Vegetative detail, including types of vegetation, densities and plant sizes, and
- Various conditions, such as seasonal considerations.

A narrative report describing the existing wetland (in general terms) and proposed wetland (more detailed) should include descriptions of water movement and quantity (surface water and groundwater), wetland vegetation (especially species and their relative cover, and interspersion and diversity of various cover types), soils, proximity to other wetlands and underlying geological conditions. The specific type of wetland the designer proposes (e.g., wet meadow, marsh, shrub-scrub or forested) should be included.

A narrative may include all or some of the following data

- Description of how the site(s) meets regulatory criteria.
- An assessment of the functions and values of the existing and proposed wetland areas.
- Compatibility with undesirable neighboring land uses. (For example, replicated wetlands adjacent to parking lots, snow disposal areas, airports or commercial roadways may receive pollutants that affect their ecological functions.)
- Topographic and geologic considerations that may affect construction feasibility if large amounts of fill or bedrock require removal to meet design grades.
- Soil composition, compatibility and depth; soil chemistry analysis.
- Hydrological considerations including: (1) area of contributing watershed; (2) water budget inputs and outputs; (3) elevation of maximum seasonal high groundwater table; (4) location of existing wetlands; and (5) seasonal alterations.
- Analysis of whether the proposed wetland siting impacts valuable *upland* wildlife habitats (such as mature forests) so that inadvertent impacts to upland animal or plant species and vernal pools are avoided. (Designers should always choose the least sensitive and least ecologically valuable location, when possible, for a proposed wetland. This means carefully walking all proposed sites before committing designs to paper.)

WETLAND RESTORATION REPORT

A typical, relatively simple example report follows. This example is intended to show minimum details for a simple restoration.

Also accompanying the report would be a scaled plan, cross-sections, plan details, construction notes and other criteria that the regulatory authorities might require or find beneficial. Some wetland creation or restoration reports may be as long as 75-pages; plans may be multi-sheet. Details are always driven by the size and complexity of the proposed work. In this case, the project is assumed to be uncomplicated.

EXAMPLE REPORT

BACKGROUND

The property now owned by the Smiths recently had areas of wetland meadow near the house. Those wetlands no longer exist. The previous owner filled them to extend the backyard. Regulatory authorities now require the Smiths to restore the wetlands (culpability aside). This report, in conjunction with a drawing by the XYZ firm entitled, "Existing and Proposed Conditions," dated XX/XX/XX (the "Plan"), describes procedures for restoring those wetlands, and specifies plant species to be used.

TECHNICAL PROCEDURES

The following procedures will be followed to effectively restore the described areas:

1. An erosion control barrier, consisting of double-staked haybales, will be installed as indicated on the Plan to prevent erosion into the downgradient areas.

2. In the two areas to be restored, all fill overlying the existing, disturbed soils will be removed. Said fill will either be set aside elsewhere on the site (and haybaled until stabilized) or removed from the property.

3. Material to be removed will be excavated in sections to a depth of between 18 to 24-inches until a depth 8-inches below original grade is achieved.

4. Disturbed upland areas will be seeded with upland grass mix during the growing season. Seed will be planted at a similar density to that which exists in the adjoining undisturbed buffer zone.

5. The restored wetland areas and the seeded upland area will be mulched with hay to assist in the immediate stabilization of the bare soil and then thoroughly watered.

VEGETATION

1. Seed stock needed for the project will be purchased from a nursery specializing in wetland species. The following seed mix should be used:

XXX seed mix from ABC Wetland Seeds (see below for contact information). Some of the species in said mix follow:

TYPE

Common Name	**Scientific name**
Sensitive fern	*Onoclea sensibilis*
Joe Pye Weed	*Eupatorium maculatum*
Swamp Milkweed	*Asclepias incarnata*
Fox sedge	*Carex vulpinoidea*
Lurid sedge	*Carex lurida*

Blue Vervain *Verbena hastata*

2. The proposed restoration area will be loamed with 8-inches of hydric soil. The soil shall be obtained from an adjoining wetland area, as required by permitting authorities. Subsoil shall be tilled prior to placement of the hydric soil.

3. Upon completion of soil placement, restoration will include installing the following shrub plant material:

TYPE **Common Name**	**Scientific name**	**Minimum** **Height**	**Indicator status**
Silky Dogwood	*Cornus amomum*	18" +	FACW
Arrowwood	*Viburnum dentatum*	18" +	FAC
Red Maple	*Acer rubrum*	36" +	FAC
N. Red Oak	*Quercus rubra*	48" +	FACW
Sweet Pepperbush	*Clethra alnifolia*	18" +	FAC+
Cinnamon Fern	*Osmunda cinnamomea*		FACW

All of these species are found in or near the area to be altered and are not exotic to the immediate region. All of the species are also commonly available from regional wetland nurseries.

4. Shrub plant material will be installed in the following density:

DENSITY **Common Name**	**Number**	**Minimum** **Spacing**	**Notes**
Silky dogwood	30	12' o.c.	
Arrowwood	32	same	
Red maple	12	16' o.c.	
N. Red oak	8	same	
Sweet pepperbush	30	6' o.c.	
Cinnamon fern	60	4' o.c.	1 gallon

COMMENTS & CONDITIONS

1. Seed stock from nurseries may be limited. The contractor should carefully plan restoration operations with the nursery prior to beginning work.

2. Upon completion, haybales will be checked and reinstalled if necessary along the perimeter of the new restoration area.

3. The new area will be monitored on a timely basis over the subsequent two growing seasons to assure that at least 75% of the area is covered with healthy vegetation. Monitoring will occur at least monthly through the typical growing season once planting is complete. Monitoring shall

also occur during periods of severe drought, or during and after unusual storms to ensure the continued health of the plants.

4. A photographic record of the site will be made both before and after work is begun. If 75% of the restoration area is not covered with healthy wetland vegetation at the end of two years, additional seed stock must be purchased (see type listed above) and planted, using the same procedures.

5. In addition, the installer must plant only between May 1 through June 15, and September 1 through November 1, unless the area is in a known drought condition; if a drought exists, installation must wait until normal precipitation conditions occur.

—END EXAMPLE REPORT—

RESTORATION PROBLEMS

Forested Wetlands

As noted elsewhere, the restoration or creation of forested wetlands—particularly in a short-term window—remains problematic. Many forested wetlands are populated with trees that are 75 to 200-years old. These trees are the result of a gradual and dynamic natural process that cannot be easily recreated. In addition, the vast majority of wetland science in the last two decades has concentrated on the creation of wetland meadows, shrub swamps and wetlands that border rivers and lacustrine areas.

Mitsch and Gosselink observe,

> There is less experience with forested wetland restoration and creation compared to herbaceous marshes, although these wetlands have been lost at alarming rates, particularly in the southeastern United States. Forested wetland creation and restoration are different from marsh creation and restoration, because forest regeneration takes decades rather than years to complete, and there is more uncertainty about the results.

For design professionals, the creation of forested wetlands when regulations require "like-kind" replacement within a fixed time frame remains a challenge. Replacing biomass with equal biomass is not possible within a narrow window. Replacing 50-foot swamp white oak trees with 12-foot high nursery stock will not, in a 5-year completion window, satisfy a like-kind regulation.

If impacts to existing forested wetlands can be avoided by project redesign, such issues disappear. Avoidance of wetland impacts is always preferable. If avoidance is not possible, designers should coordinate with permitting authorities early in preliminary stages to determine acceptable mitigation. If authorities insist on reforestation, then reasonable time frames must be established.

In addition, long-term maintenance becomes a legitimate concern. Over a wider time frame, planted trees may be subject to gradual die-off and replacement by shrub-scrub vegetation. Design professionals must provide sufficient monitoring to ensure that the intended wetland is actually created over time.

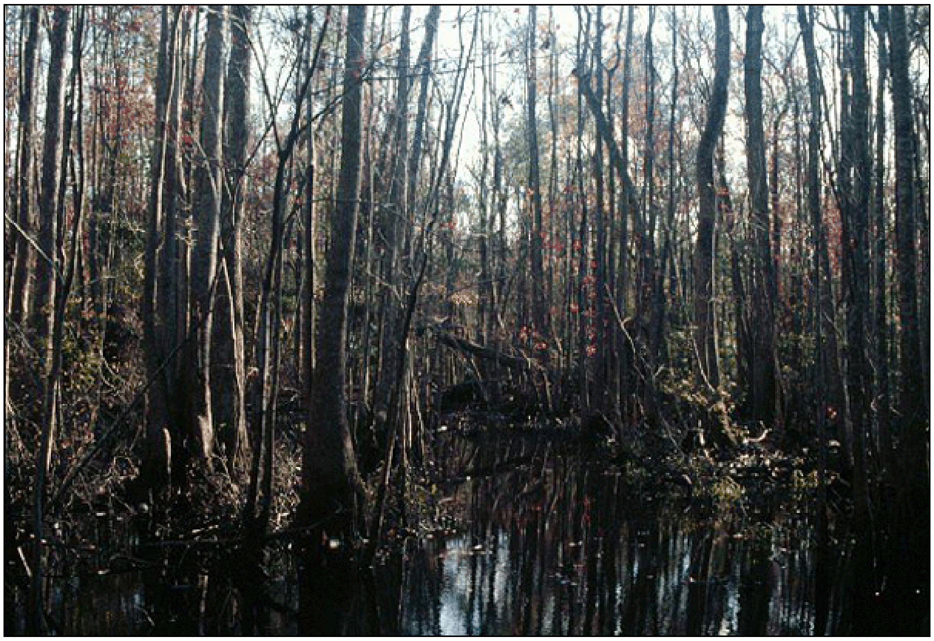

Figure 17. Ancient palustrine forested wetland, courtesy NOAA.

Mosquitoes

Public resistance to restored wetlands is often driven by fear of mosquitoes. Any discussion of creating open water may trigger such concerns, particularly in regions subject to large mosquito populations. Increasing the potential habitat of disease-carrying mosquitoes is a legitimate public concern, even if a given restoration represents but a tiny fraction of already existing mosquito habitat.

The potential for creating mosquito habitat can be monitored during and after construction. Depending on the region of the country, use of mosquito fish (*Gambusia affinis*) and/or shading the water surface are alternative prevention measures, as is the spraying of eggs. But as Hammer notes in *Creating Freshwater Wetlands*,

> If all else fails, proper application of appropriately labeled insecticides may be necessary, but caution is advised. Overzealous insecticide application has stressed emergent vegetation in at least one [wetland] system.

Regardless, design professionals may have to address such concerns during permitting approval.

Obtaining Plant Material

As noted throughout this course, designers should specify native, indigenous plants. These species are not commonly available through commercial nurseries.

Increasingly, specialty wetland nurseries are found which provide regionally compatible wetland plants and herbaceous seed mixes. Many of these specialty nurseries select and handpick their own seeds. Designers should become familiar with these providers. When a project may require large quantities of plant stock, nurseries should be contacted well in advance to ensure that stock is on hand when construction begins.

Summary

The emphasis throughout this course has been on properly estimating and calibrating site hydrology to successfully create or restore wetlands. Soils and vegetation play a role, but that role is secondary to hydrology. If groundwater (usually the predominant source of hydrology) is estimated too low, plants that are dependent on a certain period of saturation are likely to die. Similarly, if there is too much saturation, long periods of anaerobic conditions may cause a similar vegetative failure. The most important fieldwork before construction should be to accurately determine seasonal high groundwater.

A thorough understanding of the three components that define a wetland is also crucial. Those components are hydrology, soils and vegetation. As important as hydrology may be, proper use of hydric soils and wetland plants are particularly necessary for short-term success. Accidental or ignorant use of invasive species can rapidly destroy the most careful restorations. Similarly, improper contact of hydric soils with untilled substrates can prevent healthy root growth.

The course has also emphasized the importance of initial discussions of goals and requirements with regulatory authorities. Pre-planning wetland creation with permit granting authorities is almost always fruitful. Such input may require changes in project design; it is always better to have such feedback before expensive, definitive design takes place.

As we have seen, there are many distinct varieties of inland wetlands, including marshes, bogs, bordering vegetative wetlands and shrub-scrub or emergent swamps. Using the principles emphasized in this course, these wetlands are easily created or restored.

Recreating forested wetlands, on the other hand, is always problematic. A project should attempt to avoid impacting such areas. Be aware of like-kind requirements, and be certain that you can provide restoration or wetland creation that meets regulatory requirements.

In addition, if reports and plans are required, providing the necessary basic data is to your advantage. Working through those requirements early in project planning can help you design a better project. Further, reviewers use checklists, so if data is missing from an application, you have cost yourself time and your client money. Above all, design with the understanding that the underlying components that define a wetland must exist in any successful wetland creation or restoration.

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Web Resources

1987 Corps Manual (PDF file of the entire manual)	www.wes.army.mil/el/wetlands/wlpubs.html
US Corps of Engineers	www.usace.army.mil/
Environmental Protection Agency, Wetlands, Oceans, Watershed	www.epa.gov/owow/
NWI Wetland Inventory Maps	www.nwi.fws.gov/

Hydric Soils of the United States	http://soils.usda.gov/soil_use/hydric/main.htm
Soils of New England	www.nesoil.com/
USGS (General Information)	www. usgs.gov/
Society of Wetland Scientists (excellent source for wetland links, & for wetland regulations in many states)	www.sws.org
Wetland Science Institute (federal venture between USGS, USDA & NRCS: great source for soils data, training materials, plants guides & hydrology tools)	www.pwrc.usgs.gov/wli/wetdel.htm

Credits
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Photograph Fig. 12, courtesy USFWS.
Photograph Fig. 13, courtesy USDA.
Photograph Fig. 14, courtesy Morris Arboretum.
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