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Using Measured Hydrology and Vegetation Performance from a Reference Natural Area to Design Wetland Restoration Plant Communities in the Soil Saturation Zone: West Chicago Prairie Nature Preserve, DuPage County, IL

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ABSTRACT

The protection of West Chicago Prairie State Nature Preserve has served as an important reference area for the measurement of wetland hydrology and vegetation systems relations. Measured shallow surface and subsurface hydrology data were not readily available regionally for use in the design of wetland restorations. This lack of data has contributed to designs in midwestern prairie landscapes favoring emergent and aquatic wetland types rather than the historically prevalent sedge meadows and wet prairie ecosystem types. In the absence of data, regulatory guidance has not been sufficient to understand the water depths and durations to meet hydrology criteria for wetland types that may experience shallow, short-duration, spring-growing season inundation, then quickly dry down but remain saturated during most of the growing season. Many zone-of-saturation wetland restorations have failed as a result. The purpose of this paper is to provide hydrology depth/duration data correlated with wetland ecosystem types from a reference area nature preserve to help guide future restoration designs.

This paper evaluates shallow ground-water well data for six years, from wells distributed along replicated parallel transects, located to integrate vegetation community mapping that includes upland bur oak savannas, through increasingly lower elevations along each transect that sequentially encountered mesic prairie, wet mesic prairie, wet prairie, sedge meadow, and emergent and aquatic wetlands. The study was conducted in the West Chicago Prairie, a dedicated Illinois Nature Preserve. The water depth was measured weekly at shallow water wells that provided the correlation between vegetation and water depth and duration.

The Army Corps of Engineers regulatory criteria for what constitutes successful wetland mitigation requires wetland restorations to have water levels within 30.5 cm of the ground surface for 12.5% of the growing season (or 23 consecutive days) in all wetland ecosystem types. We found that only emergent and aquatic communities in one of the highest quality natural areas in Chicago region—West Chicago Prairie, would meet this criterion. Sedge meadows and wet prairie only achieved this criterion for 4-7 days annually. This criterion favors deeper water and perpetually inundated wetland types over once prevalent sedge meadow and wet prairie ecosystems that seasonally dried down. Hydrologic criteria currently in use for determining successful wetland restoration are not applicable to higher elevation wetlands in the soil saturation zone. These systems cannot be restored using the current standard, as even these ecosystems in West Chicago Prairie Nature Preserve do not meet the U. S. Army Corps of Engineers (USACE) hydrology criterion.

Alignment of performance criteria with measured reference natural area vegetation and hydrology relationships from the West Chicago Prairie Nature Preserve, can be used to refine wetland mitigation designs and performance standards for the Chicago region. The same type of data and analysis would be required for the refinement of criteria in other regions of the USA and perhaps elsewhere.

Key Words: wetland hydrology, depth-duration criteria, wetland restoration requirements

INTRODUCTION

A dearth of good reference area field data has contributed to uncertainty in ecological restoration, environmental policy, and regulatory oversight of wetlands. Regulatory definitions for wetlands (Table 1) do not adequately guide the design of restorations, nor do they provide regulatory agency flexibility in the review and determination of wetland restoration success. The uncertainty has become most apparent where the proposed restoration include sedge meadows and wet prairies, which may be inundated for a short period each spring and then dry down to a saturated condition. Often, regulatory guidance has required that wetland water levels exceed what has been believed to be the hydrology necessary to restore these wetlands types. However, without data from reference areas, there has been no recourse to create an alternative design and defensible performance criteria. As such, existing criteria favor the restoration of deeper, perennially inundated, emergent wetlands.

Lacking good reference data, many hectares of restored wetlands that were intended to be shallow zone-of-saturation systems, have been constructed to deep and have become cattail monocultures (Apfelbaum 1983, Lampa and Wilhelm unpublished) or are dominated by common reed grass (*Phragmties australis*). Insufficient hydrologic data also has resulted in attempts to restore sedge meadows and wet prairies, without reference natural area data, resulting in many now dominated by invasive reed canary grass (*Phalaris arundinacea*).

This paper provides one reference area dataset to better inform the design of wetland restorations in the prairie ecoregion of the midwestern United States. The criterion of the USACE requires wetland mitigation restorations to have water levels within 30.5 cm of the ground surface for 12.5%, or

23 consecutive days of the growing season. This hydrology performance is required by the USACE for wetland restoration mitigation projects, across all wetland types, to determine if they meet the hydrology criterion and definitions (Table 1). Hydrology, a predominance by hydrophytic vegetation, and hydric soils, all typically must also be present.

In the mid-1980s, during the review of the very first wetland mitigation projects in the Chicago region, the USACE, U.S. Environmental Protection Agency (USEPA), U.S. Fish and Wildlife Services (USFWS), and those doing wetland mitigation, recognized a gap in how reference natural area wetlands could improve restoration criteria. This paper provides a dataset to address this gap.

Table 1. Regulatory definitions of wetland and hydrology criterion used by federal agencies.

Definition	Agency
"Those areas that are inundated or saturated by surface or groundwater 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."	US Army Corps of Engineers and US EPA
"Wetlands are defined as areas that have a predominance of hydric soils and 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 hydrophytic vegetation typically adapted to life in saturated soil conditions. . . "	USDA, NRCS
"Wetlands are transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water. For the purposes of this classification wetlands must have one or more of the following three attributes: (1) at least periodically, the land supports predominantly hydrophytes, (2) the substrate is predominantly undrained hydric soil, and (3) the substrate is nonsoil and is saturated with water or covered by shallow water at some time during the growing season of each year."	US Fish and Wildlife Service
Hydrology Criterion - water levels must be present within 12 inches (30.48 cm) of the ground surface for 12.5 % of a growing season, or 23 consecutive days.	US Army Corps of Engineers, Chicago District

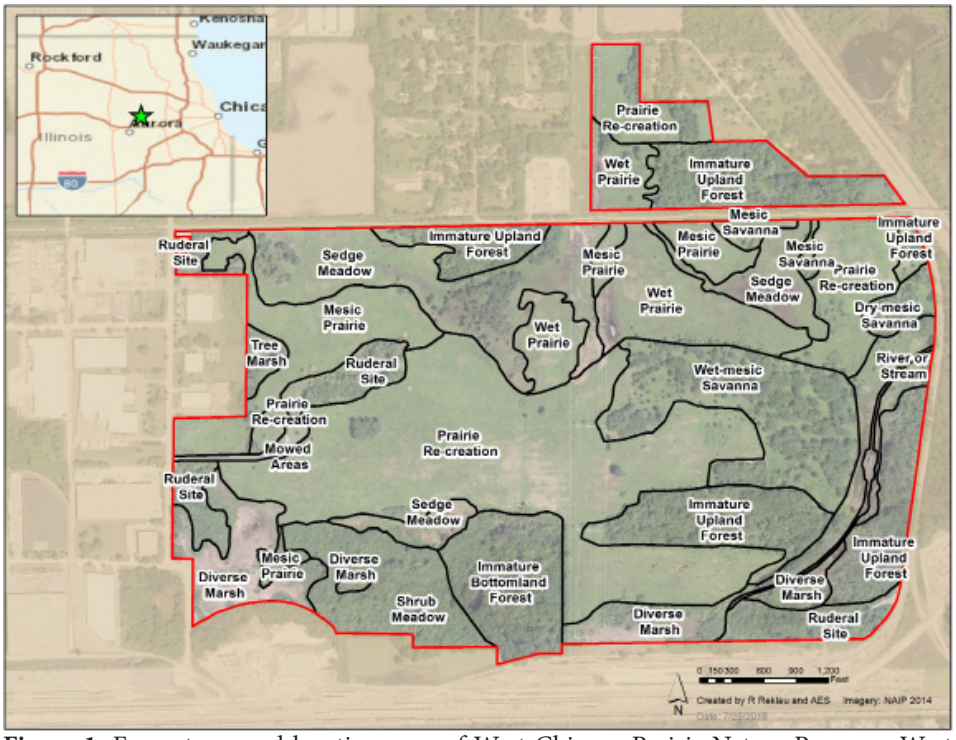

Figure 1. Ecosystems and location map of West Chicago Prairie Nature Preserve, West Chicago, DuPage County, IL.

STUDY AREA

The West Chicago Prairie Nature Preserve is a diverse remnant of the once vast prairie ecosystem located on the outwash plain of the West Chicago moraine. The prairie constitutes a part of the headwaters of Kress Creek, a tributary to the West Branch of the DuPage River, and contains a variety of plant communities including pond, marsh, sedge meadow, wet prairie, mesic prairie, and savanna (Figure 1). More than 550 native plants have been identified on the 121.9 ha comprising the preserve. The topography of the prairie varies by 4.5m from east to west (Figure 2).

At the time of settlement (1830s), approximately 60% of DuPage County (51,822 ha) was covered by various wetlands communities. The flat topography and clay-rich glacial till soils contributed to the common presence of sedge meadows, wet prairies with marshes, bottomland forests, and flatwoods commonly found bordering rivers. Only about 5% of the original wetland acreage is extant. Deep rich soils with sedge meadows and wet prairies were quickly converted to agricultural lands after Indo-European settlement (Apfelbaum 1983).

Historic accounts from the earliest trappers and hunters found large tracts of the prairie that were waterlogged for most of the year:

> "This morning I walked a league further into the meadow, having my feet almost always in the water; afterwards I met with a kind of pool or marsh which had a communication with several others of different sizes, but the largest not above a hundred paces in circuit."(Southern Cook County, Illinois, History of Dupage County in Lampa, undated report 1985-1990.)

The surveyors reported in 1841 that much of the land that now constitutes the DuPage County Forest Preserve was wet land. About 500 meters west of the study area, the surveyors (General Land Office, Original Land Survey 1841 - summarized in Lampa, undated report 1985-1990).

> "Land all prairies except marsh with a few scattering bur oaks around it;" and to the north, "Land all prairie and marsh."

The study area is located at the east end of

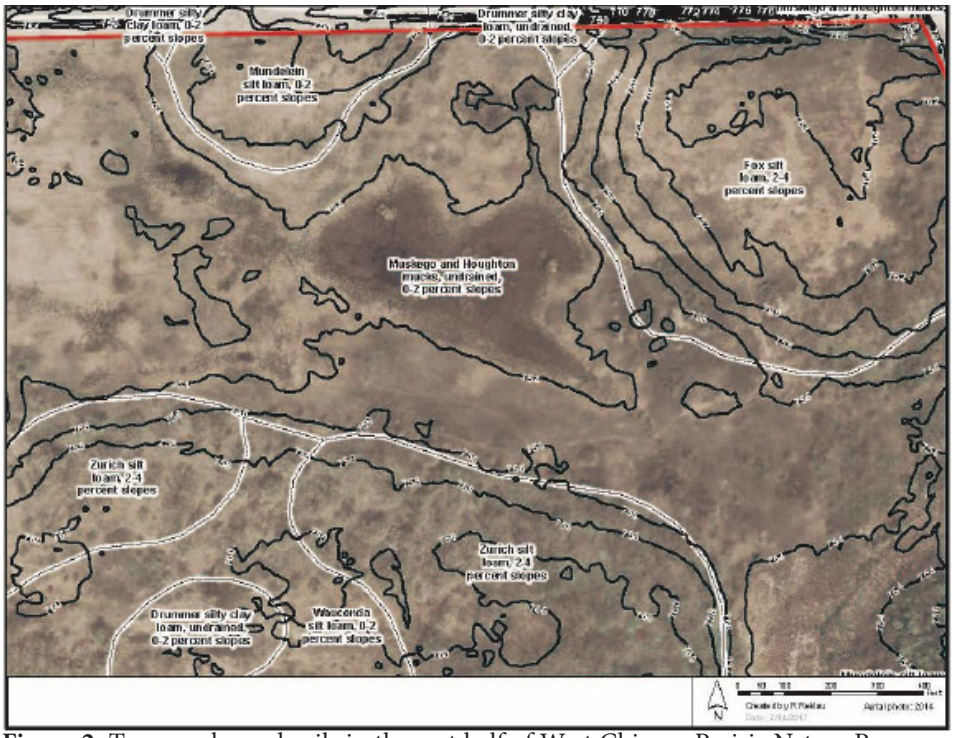

Figure 2. Topography and soils in the east half of West Chicago Prairie Nature Preserve, West Chicago, DuPage County, IL.

the preserve. Botanical surveys by Lampa (Undated Report, 1985-1990), and Kobal (1996), as a part of a larger project, found this segment of the preserve to be very diverse, with over 230 native plant species. Muskego and Houghton muck soils underlie the wetland plant community types, while upland mesic prairie and savanna vegetation grow in Wauconda and Zurich silt loams with Fox and Drummer silt loam soil inclusions. These soils overlie Cahokia Alluvium Formations of bedded sand and gravel with embedded lenses of clay. The uplands are situated on the Wadsworth Till Member of the Wedron Formation, a clay to silty clay till. Lampa (undated report 1985-1990) summarized that both the surface and subsurface water movements are generally east to west.

As a reference natural area, West Chicago Prairie Preserve is a largely undisturbed natural area where we sought to understand wetland hydrology, vegetation ecology, and inform the design of wetland restorations to approximate the structure and function of natural systems, framed with the following research questions:

1. What are the water-level dynamics in reference natural area ecosystem types?
2. Is there a pattern to the number of days during the growing season when wetland waterlevels as defined by the 1987 wetland delineation manual are measured within 30.5 cm of the ground surface elevation?
3. Do water-level dynamics predict wetland community types, including wet prairies, wet-mesic prairies, sedge meadows, and emergent wetlands?

METHODS

Previous Vegetation Studies

During complete growing seasons in 1987 and 1996, detailed vegetation community mapping, and plant species cover and frequency were measured and mapped using randomly placed transects superimposed over a 50 x 50 m grid in a portion of the preserve. The grid encompassed approximately 152.4 m east to west by 182.9 m, encompassing ~2.8 ha. The transects bisected the vegetation zones, and followed the topographic gradient from the most elevated areas with oak savanna vegetation that transitioned to mesic, and wet mesic prairies at lower topographic positions. Below this elevation were various wetland types - wet prairies, sedge meadows, emergent, and aquatic ecosystems. This gradient was intentionally traversed to document the relationships of vegetation and water-level dynamics across these ecosystems (Lampa, undated report); Kobel (1996). Elevations ranged from 235.0 m to 236.0 m above mean sea level (USGS 1:24,000 series topographic mapping and Total Station GPS survey) from the lowest aquatic wetland vegetation type to highest relief oak savanna sampling location along all previous study transects. An overall elevational slope of <4% was measured along each of the study transects. The wet-prairie, sedge meadow, emergent, and aquatic zones occupied grades of 0% - 2%. These physical conditions generally supported a prevalence by hydrophytic wetland vegetation at elevations 1m above the average annual spring high water level. The plant communities in this wetland were well-defined by distinct vegetation breaks, demarcated by dominant plant species. The uniform grades have contributed to consistent vegetation zonation in the wetland.

Vegetation data were collected by DuPage County Forest Preserve natural resources (and Applied Ecological Services staff (Lampa, Undated Report, 1985-1990), and was continued by Kobal (1996). Lampa installed regular and systematic vegetation sampling one square meter circular quadrats every 4.6 m along six parallel transects spaced 130.5 m apart (Figure 3). Vegetation was sampled annually during June,1987 -1995. The quadrats were centered over a flagged GPS survey point and every plant species with cover in quadrat was assigned a Braun-Blanquet cover (Mueller-Dombois and Ellenberg 1987) value ranging from 1 to 5 using the following cover classes:

1. consisting of one-few stems in only 1 quadrant of the quadrat, 1% to 10% coverage.
2. occupying 1-3 quadrants and numbering several stems, 11% to 25% coverage.
3. occupying 2-4 quadrants with notable density or cover in each quadrant, 26% to 75%coverage.
4. occupying 3-4 quadrants with regular

Figure 3. Water well and vegetation sampling locations in the east half of West Chicago Prairie, West Chicago Prairie Nature Preserve, West Chicago, DuPage County, IL. Georeferenced sampling point locations are available from the authors, if anyone wants to duplicate findings.

Figure 4. Study transects and ecosystem types in the east half of West Chicago Prairie-Nature Preserve, West Chicago, DuPage County, IL. Transects A and Z were randomly chosen for installation of the water wells used in this study.

density throughout, 76% to 90% coverage.

5. restricted to those species dominating all 4 quadrants, 91% to 100% coverage.

A total of 286 vegetation samples points were geo-referenced using GPS and elevations were surveyed from a nearby USGS benchmark and datum. Relativized plant cover and frequency from these sample quadrats was used to compute Relative Importance Values (R.I.V.), as the sum of relative cover and frequency, expressed as a percent, for each recorded plant species. The plant species composition and importance values were used to classify the plant community into the primary types present - oak savanna, mesic prairie, wet prairie, sedge meadow, emergent and aquatic systems.

As the water wells for the hydrology investigation were placed, the previous vegetation classification mapping was used to preliminarily document the vegetation community classification at each water well. Then, vegetation sampling was repeated using the same method to confirm the classified vegetation for measuring water levels at randomly placed water wells.

During the previous study, vegetation composition, dominance, and Relative Importance Value by species changed little from 1987 to 1995. Also, the mean cover by species and the number of species per quadrat remained consistent from year to year as reported elsewhere (Lampa, undated report; Kobel 1996). Kobel found a high level of stability shown by the vegetation systems, as previously reported by Lampa (undated report) and concluded that no significant changes in vegetation were measurable in the time between studies.

Hydrology Studies

Ground-water monitoring wells followed the Illinois State Water Survey design and installation procedures (Miner and Simon 1997) and were placed in 12 randomly selected points, at multiple locations in each plant community along two north-south transect lines, (Figure 4). Hydrology was measured 1990-1995 in these water wells that coincided with the vegetation zones identified by the previous vegetation study transects (Figures 3 and 4). Transect zero

endpoints started in the oak savanna ecosystems and wells were placed at random distances within each mapped vegetation zone. Using a random number generator, wells were placed at randomized distances measured along the transects starting where each vegetation zone was encountered, along each of the two transects.

Wells were constructed from 2.54 cm diameter PVC pipes capped at both ends, and inserted to a depth of 1.60 m, with ~0.5 m of free-standing pipe with a friction fit cap, above the ground (substrate) surface. Pipes were perforated with four drilled holes ~30 cm from the base. Wells were measured once weekly, for water depth during each year 1990-1995, starting prior to green-up in very early spring and ending the last week of October, or when freeze-up occurred.

Water well installation was accompanied by substrate mapping, and physical and chemical characterization, and a formal wetland delineation conducted by others (Kelsey Unpublished report, The Morton Arboretum).

RESULTS

Water Depth Range for Vegetation Communities

Average water and soil saturation depths measured above or below the substrate surface are tabulated (Table 2). They ranged from >-75 cm (A "-" sign denotes water was below the ground surface) in oak savannas to -45 to -75 cm in mesic and wet-mesic prairies, while wet prairies had depths ranging from -22 to +45 cm (A "+" sign denotes water level was above the ground surface). Sedge meadows experienced a narrower range and shallower water ranging from +0.01 cm to +22.5 cm and emergent wetlands had water at (0.00 cm depth) or above the substrate surface elevations to +26 cm depth when inundated. Aquatic vegetation communities were inundated with > +27 cm water depths.

Federal Wetland Jurisdictional Hydrology Requirement

To evaluate how the hydrology of each vegetation community performed against the federal wetland hydrology criterion, the

Table 2. Annual ground water monitoring well measured water depths. Zero is the substrate surface elevation; negative (-) is below, and positive (+) represents inundation of water depth above the substrate surface.

Vegetation Community	Water Depth/Saturation level (cm)
Aquatic	>+27
Emergent	+26.00 to 0.00
Sedge meadow	-0.01 to +22.50
Wet prairie	+22.51 to -45.00
Wet/mesic prairie	-45.01 to -75.00
Mesic prairie/oak savanna	>-75

Table 3. Annual totals and mean number of days (+- St. D.) with water well depths meeting the hydrology criterion by vegetation community, West Chicago Prairie Nature Preserve, West Chicago, DuPage County, IL.

Well ID	1990	1991	1992	1993	1994	1995	X	Std Dev.	Vegetation Zone
WC_A-01	0	0	0	0	0	0	0	0	savanna
WC_A-07	0	0	0	0	0	0	0	0	savanna
WC_A-12	354	354	354	354	354	354	354	0	aquatic
WC_A-15	354	354	354	354	354	354	354	0	aquatic
WC_A-19	354	354	354	354	354	354	354	0	aquatic
WC_A-27	0	49	14	14	0	0	13	19	emergent
WC_A-41	7	0	0	7	7	0	4	4	sedge meadow/ wet prairie
WC_A-42	0	0	7	7	0	7	4	4	sedge meadow/ wet prairie
WC_A-43	0	7	7	7	0	7	5	4	sedge meadow/ wet prairie
WC_A-44	0	7	0	7	0	7	4	4	sedge meadow/ wet prairie
WC_A-45	0	7	14	7	0	7	6	5	sedge meadow/ wet prairie
WC_A-46	0	7	0	7	0	14	5	6	sedge meadow/ wet prairie
WC_A-47	0	28	14	14	7	41	17	15	emergent
WC_U-01	41	59	20	55	21	56	42	18	emergent
WC_Z-06	0	14	0	7	7	0	5	6	sedge meadow/ wet prairie
WC_Z-13	0	0	0	0	0	0	0	0	savanna
WC_Z-18	27	45	14	14	0	0	17	17	emergent
WC_Z-22	0	0	0	0	0	0	0	0	savanna
WC_Z-25	0	0	0	0	0	0	0	0	savanna
WC_Z-34	7	7	0	0	0	0	4	4	wet-mesic
WC_Z-36	7	0	0	0	0	0	1	3	wet-mesic

Table 4. Average (St.D.) and range of number of days annually with water depths measured within 30.5 cm of substrate/ground surface elevations, September 1989 –October 1995, West Chicago Prairie Nature Preserve, West Chicago, DuPage County, IL.

Community	Mean (Std.D.) and range days water within 30.5 cm of ground surface
Aquatic	254 (±0%) 354
Emergent	22.5 (±19) 13-42
Sedge meadow/Wet prairie	4.7 (±4) 4-7
Wet/mesic prairie	1.5 (±4) 1-4
Mesic prairie/oak savanna	0.0 (±0.0) 0

Table 5. Relative importance value of plant strata along study transects, West Chicago Prairie Nature Preserve, West Chicago, DuPage County, IL (Lampa, undated report; Kopal 1996).

Strata	Species Group Summed RIV	% of Total Species
Trees	6.1%	3.6%
Forbs	68.3%	69.1%
Sedges	19.9%	11.3
Grasses	15.0%	7.4%
Shrubs	4.8%	5.2%
Other	2.5%	3.1%

total (Table 3) and average number (Table 4) of days annually when water levels were within 30.5 cm of the substrate surface elevation were summarized. The data show sedge meadow/wet prairie, with a mean of 4.7 days. The emergent zone averaged of 22.5 days annually when the criterion was met. The aquatic zone always met the criterion. Annually, on average the wet-mesic prairie only met the criterion 1.5 days annually, and the mesic prairie and oak savanna never met the criterion.

A total of 230 native species) were recorded in the vegetation quadrats (Table 5). Average plant species richness was greatly different in hydrologic community types (e.g. two species/quadrat in the aquatic, and 26 species /quadrat in wet-mesic prairie vegetation zone).

DISCUSSION

Starting in 1989, staff of DuPage Forest Preserve District and Applied Ecological Services, Inc. (AES), evaluated the success of many wetland restoration (mitigation) projects. A large number of unsuccessful restorations prompted a call to researchers to collect reference natural area data for hydrology and vegetation communities such as provided in this paper. Other challenges were also identified that are not addressed in this paper, including: a) design flaws, b) grading and substrate suitability and compaction issues that challenged wetland plant survival, c) highway de-icing salts, wildlife herbivory, and bio-turbation from invasive fish, and d) and drought or overly wet meteorological conditions, during the restoration establishment years. The focus of this paper was perhaps the most fundamental challenge - misunderstanding of the hydrologic regime requirements, specifically the design depths and durations of water levels in wetlands.

Another regional study followed, that evaluated wetland mitigation project performance success (Lampa and Wilhelm unpublished, study) that documented greater water depths than intended to be present in intended sedge meadow and wet prairie vegetation restoration types. They documented a concurrent shift of emergent plant communities to monocultures of cattails (*Typha*) and reed canary grass (*Phalaris arundinacea*).

Elevated water levels, deeper depths and longer durations of deeper water conditions have also been shown to be associated with the conversion of diverse restored wetlands and native wetland plant communities to monocultures of cattails (Apfelbaum et al 1984; Apfelbaum 1985; Wilcox et al 1985; Wilcox et al. 1987; Motivans and Apfelbaum 1988) including in large watersheds such as Lake Ontario (Wilcox et al. 2008) or Red River of the North, MN (Apfelbaum et al. 2012). Where wetland hydrology was to create continuous saturation, short or no inundation, and no seasonal dry-down, intended wet prairie and sedge meadow restorations have shifted to monotypic stands of reed canary grass (Apfelbaum and Sams 1987).

At West Chicago Prairie Preserve, wetland plant species diversity and composition were initially sampled in 1985-1990 Lampa (undated report) and re-assessed by Kobal (1996). This study created data to help understand vegetation distributions spatially correlated hydrology data. In West Chicago Prairie wetlands, the hydrology data document that wet prairie and sedge meadow communities dry down seasonally and substrate saturation is below the 30.5 cm depth required for successful wetland hydrology as defined in the 1987 wetland delineation manual and Chicago regional Inter-Agency Coordination Agreement (ICA) . This dataset also suggests that even in emergent plant communities, dry-down to saturated conditions occurs from time to time.

Meeting Water-level Criteria

Shallow water-well measurements able to measure inundation through saturated conditions are required for assessing wetland hydrology. Wetland substrate saturation, which is recognized as one of the primary indicators of wetland hydrology by USACE, has been defined to guide the process of conducting wetland delineations, but what constitutes saturation for purposes of monitoring wetland restoration performance has not been clearly defined (USACE, 1987 Delineation Manual). In this study, we chose to only measure and report water depths to evaluate what percentage of the growing season met the 30.5 cm hydrology criterion. This criterion was only met in aquatic and emergent plant communities. To illustrate the regulatory challenge, a majority of the West Chicago Prairie wetlands would be delineated as jurisdictional wetlands using the 1987 manual but would not meet the current ICA (USACE, 2008) hydrology criteria that must be met for receiving agency approval that the hydrology of a wetland restoration mitigation project has been successful.

Specifically, in this reference natural area, the saturated zone vegetation communities that are wetland ecosystems meet the delineation criteria (e.g. sedge meadows, wet prairie, and wet mesic prairie communities at West Chicago Prairie) but not the federal hydrology criterion of water levels within 30.5 cm of the substrate surface for 12.5 % of the growing season, or 23 consecutive days. This suggests participating federal regulatory agencies would not consider a restoration of these vegetation community types to be a success. The requirements for meeting the hydrology criterion need to be revised to recognize and encourage the design and restoration of sedge meadow, wet prairie, and wet-mesic prairie vegetation communities.

The importance of reference area data sets may be essential in other regions to refine further the wetland mitigation standards and to also recognize the annual temporal dynamics of the water levels rather than simply the period of time inundation or saturation occurs. For example, in the West Chicago Prairie the water table was measured at or above the ground surface elevation in all vegetation communities, responding to saturated conditions after snow melt and major storm events. However, in the elevated oak savanna and mesic prairie vegetation communities, the water saturation elevation recedes rapidly into early summer, and by late autumn the elevation below ground of the saturation level can be at the surface-water elevation of emergent wetland zones. Seasonally, hydrographs revealed somewhat predictable trajectories that included a seasonal high water or ground saturation level and trend toward low levels did not occur in vegetation communities that are vulnerable to encroachment by invasive species (Apfelbaum 1983; Apfelbaum 1885, 2012.

At West Chicago Prairie, weather and the resulting hydrology measured in some wet-

land plant communities contributed to few if any measurable distributional differences for any plant species. For example, in 1988-1989 northeastern Illinois experienced one of the hottest and driest summers on record. Kobel (1996) compared post drought vegetation data with Lampa's (undated report) original data and found few species to measurable change in cover and frequency during drought.

SUMMARY AND CONCLUSIONS

Existing wetland restoration hydrology criterion, as defined in by the 1987 Federal Wetland Delineation Manual and the regional ICA, need to be revised. The data and analyses appear to justify changing the wetland hydrology criteria necessary to support the restoration of the broader range of wetland vegetation communities, especially "zone of saturation types" that were historically prevalent on the Illinois landscapes. The criteria could also be improved by creating a standard procedure for measuring soil saturation and correlating that with monitoring well water depth and targeted wetland vegetation performance. As with previous changes in the Delineation Manual, regulatory guidance documents have been released by USACE from time to time to refine technical and legal regulatory guidance in the manual. A similar refinement process has used to update the ICA being used in the Chicago by the USACE.

Changes in regulatory decision-making about wetland performance could streamline decision- making by emphasizing vegetation performance criteria for determining success, especially where vegetation targets are achieved in advance of the wetland hydrology being achieved. Also, a regulatory requirement to collect and compare vegetation, and hydrologic monitoring and soil moisture data from representative reference wetland areas could provide additional regional data to inform wetland restoration design, management, and regulatory proceedings.

Regulatory standards for the performance of some types of ecological restorations often are initially created with best professional judgment and not empirical data from reference natural areas. Rectifying the differences between regulatory guidance, performance standards created using best professional judgments, and reference natural area data sets is an important way to adaptively refine the restoration and regulatory process.

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