Virginia Water Resources Research Center
Annual Technical Report
FY 2009

Introduction

The Virginia Water Resources Research Center (VWRRC) was established at Virginia Tech in 1965 as a federally authorized program. In 1982, the Virginia General Assembly authorized the VWRRC as a state agency under the Code of Virginia (§23-135.7:8).

Mission

The VWRRC provides research and educational opportunities to future water scientists; promotes research on practical solutions to water resources problems; and facilitates timely transfer of water science information to policy- and decision-makers and the general public.

Mission Elements

Research

Assisting university researchers in securing research support funds from public and private sources.

Assisting university researchers in initiating and executing water resources research.

Education

Advancing educational opportunities for students in water-resources fields by helping university researchers provide undergraduate and graduate research experiences in water resources.

Outreach

Maintaining and making available via the VWRRC website a publication series that synthesizes and reports on water resources science, engineering, and policy.

Securing academic advisors to work in an advisory capacity with public and private sectors as requested.

Initiating and participating in the development and execution of conferences and symposia on Virginia, regional, and national water issues.

Program Administration

Administrative oversight is provided by the Dean of the College of Natural Resources. A Statewide Advisory Board appointed by the Governor advises the VWRRC director on state water research and information priorities. Because of its multiple legislative authorities and administrative responsibilities, the VWRRC has a number of reporting responsibilities. In addition to the annual reporting requirements to the USGS and the National Institutes for Water Resources (NIWR), it presents an annual report to the Virginia Tech administration. Five-year reports and reviews are presented to the USGS and the State Council on Higher Education for Virginia (SCHEV).

National Affiliations

The VWRRC is affiliated with NIWR and the University Council on Water Resources (UCOWR).

Programs of the VWRRC

Programs are structured to meet strategic goals of the VWRRC and are consistent with the VWRRC mission as authorized by the U.S. Congress through the Water Resources Research Act of 1984, (Public Law 98-242)and Code of Virginia (§23-135.7:8). Programs in research and education are available to students and faculty at all Virginia colleges and universities. Outreach and collaborative programs include information transfer to policy/decision makers and citizens, and collaborative partnerships with state agencies and other water interest groups.

1)Research Programs

(a) The VWRRC's statewide competitive grants program provides research funds to find practical solutions to water problems in Virginia and the region. The grant period begins July 1 and ends June 30 of the following year. The review criteria include 1) technical merit of the proposed project, 2) relevance to Virginia and the region, 3) relevance to contemporary water issues, and 4) ability to provide research opportunities for graduate and undergraduate students. A priority listing of water research needs for this competitive grants program is updated annually in consultation with the VWRRC State Advisory Board. These grants are designed to initiate research efforts with a high potential for expanded funding from additional sources.

(b) The VWRRC applies for external grants and conducts in-house research.

(c) The VWRRC facilitates research team building and interdisciplinary, multi-institute collaborative research.

(d) The VWRRC facilitates research opportunities to other university faculty and external contractors through a partnership with federal agencies that provides targeted funding from the USGS.

2) Educational Programs

(a) The VWRRC provides research opportunities to undergraduate students and assistantships to graduate students who participate in sponsored research. Also, numerous graduate and undergraduate students are supported through the VWRRC's competitive grants program in Virginia Tech academic departments, and at Virginia's other colleges and universities.

(b) In 1999, the VWRRC established the William R. Walker Graduate Research Fellowship to honor the many contributions of Dr. William R. Walker, the VWRRC's first director. The $2,500 award is intended for individuals preparing for a professional career in water resources and is provided to a new graduate student each year. Details of the program can be found on the VWRRC website: http://www.vwrrc.vt.edu/walker_fellowship.html

(c) The VWRRC coordinates the interdisciplinary Watershed Management Undergraduate Minor and a Watershed Management Graduate Certificate Program in collaboration with five colleges and ten departments at Virginia Tech.

(d) The VWRRC supports the Virginia Tech Chapter of the American Water Resources Association.

3) Outreach and Collaborative Programs

(a) The VWRRC provides administrative support for the Virginia Water Monitoring Council.

(b) The VWRRC publishes research reports, symposia proceedings and citizen education booklets. It provides funding for the publication of outreach efforts.

(c) The VWRRC publishes a quarterly newsletter, Virginia Water Central. It features scientific and educational articles, legislative information, and water news of interest. The newsletter is available to the public at http://www.vwrrc.vt.edu/watercentral.html and electronic copies are provided via email to more than 650 people.

(d) The VWRRC sponsors or co-sponsors symposia, workshops, and seminars.

(e) The VWRRC facilitates peer reviews for state programs when requested.

(f) The VWRRC website (http://www.vwrrc.vt.edu/) serves as a repository of the Center's publications,houses an academic expert database, provides updated news and information relevant to water resources, and manages website links for several collaborative partners including the Virginia Water Monitoring Council, the Virginia Department of Conservation and Recreation Stormwater BMP Clearinghouse, and the Clinch Powell Clean Rivers Initiative.

(g) The VWRRC maintains Twitter and Facebook sites to facilitate information exchange related to water resources and news at the VWRRC.

Research Program Introduction

Research Program

The research program of the VWRRC is supported through its Virginia state appropriation, external funding, and overhead generated by external funding. The USGS 104B federal funds are not allocated to support research, but are used to support the outreach and information dissemination programs of the VWRRC. During FY2009, the VWRRC funded one research project through its state-supported competitive grant program. For the USGS reporting period, funding for six facilitated grants passed through USGS to the VWRRC and were managed by the VWRRC. Basic information and resulting products are described in the following section.

Grant No. 06HQGR0189 Microtopography Effects on Vegetative and Biogeochemical Patterns in Created Wetlands: A Comparative Study to Provide Guidance for Wetland Creation and Restoration

Basic Information

Title:	Grant No. 06HQGR0189 Microtopography Effects on Vegetative and Biogeochemical Patterns in Created Wetlands: A Comparative Study to Provide Guidance for Wetland Creation and Restoration
Project Number:	2006VA105G
Start Date:	9/1/2006
End Date:	5/30/2009
Funding Source:	104G
Congressional District:	11
Research Category:	Biological Sciences
Focus Category:	Wetlands, Ecology, Hydrogeochemistry
Descriptors:	
Principal Investigators:	Changwoo Ahn, Gregory B. Noe

Publications

1. None
2. Moser, K. F. 2007. Characterization of microtopography and its influence on vegetation patterns and soil nutrients in created wetlands, M.S thesis. George Mason University.
3. Moser, K. F., C. Ahn, G. B. Noe. 2007. Characterization of microtopography and its influence on vegetation patterns in created wetlands. Wetlands 27: 1081-1097.
4. Moser, K. F., C. Ahn, G. B. Noe. 2009. The influence of microtopography on soil nutrients in created mitigation wetlands. Restoration Ecology (in press) online published.
5. Bhattarai, S, C. Ahn. 2008. Induced microtopography and its effects on the first year vegetation development in a mitigation wetland newly created in the piedmont region of Virginia, USA. Annual American Ecological Engineering Meeting Beyond Wetlands:Engineering the landscape, Virginia Tech, Blacksburg, Virginia.
6. Bhattarai, S, C. Ahn. 2008. Vegetation development patterns in wetland mitigation banks newly created in the piedmont region of Virginia, USA.. Society of Wetland Scientist 29th Annual Meeting, Capitalizing on Wetlands, International Conference, Washington, DC, USA.
7. Ahn, C., S. Bhattarai, R.M. Peralta, and K. L. Wolf. 2008. Functional assessment of compensatory wetland mitigation banks with varying design in the piedmont region of Virginia. Society of Wetland Scientist 29th Annual Meeting, Capitalizing on Wetlands, International Conference, Washington, DC, USA.

Final report for USGS –NIWR Project

Project title:
Microtopography effects on vegetative and biogeochemical patterns in created wetlands: a comparative study to provide guidance for wetland creation and restoration (2006-2008)

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** The final report consists of two manuscripts, one for vegetation patterns and the other for soil nutrients pattern as influenced by induced microtopography in created wetlands.*

1. CHARACTERIZATION OF MICROTOPOGRAPHY AND ITS INFLUENCE ON VEGETATION PATTERNS IN CREATED WETLANDS

INTRODUCTION

Microtopography, loosely defined as topographic variability on the scale of individual plants (Huenneke and Sharitz 1986, Titus 1990, Bledsoe and Shear 2000), describes soil surface variation within an elevation range from roughly one centimeter to as much as one meter, encompassing both vertical relief and surface roughness. Microtopography is included in the broader notion of topographic heterogeneity, which includes patterns of elevation at many spatial scales formed by geologic, hydrologic, physical, and biological processes (Larkin et al. 2006). Microtopography can influence wetland hydrology, physicochemistry, and habitat variability, and it is thus important in determining vegetation patterns and, ultimately, ecosystem function. Consequently, the manipulation of microtopography to promote plant community and ecosystem development has implications for wetland creation and restoration.

Created wetlands often show little evidence of ecosystem development comparable to that of their natural counterparts, and many wetlands created to mitigate wetland losses fail to meet basic success criteria within the time frame legally mandated for monitoring (National Research Council 2001, Spieles 2005). Although the legal framework may be insufficient to ensure that mitigation wetlands perform equivalent function to the wetlands they replace, identifying wetland creation methods that enhance ecosystem development might increase the probability of mitigation success, both legal and functional, thus increasing the likelihood that lost wetland ecosystem services will, in fact, be replaced. In the construction of mitigation wetlands, grading is ordinarily performed to assure surface variation within a centimeter or two of the site plan elevation, so the microtopographic variability more typical of natural settings is reduced (Stolt et al. 2000). Although not legally mandated, microtopography is sometimes adopted as a performance/monitoring criterion in compensatory mitigation since it is understood to promote floral and faunal diversity (Norfolk District Army Corps of Engineers and Virginia Department of Environmental Quality 2004). Thus microtopography is sometimes intentionally induced after wetland creation or restoration

by a variety of techniques including bucket-mounding, hand-mounding, tire-rutting, and disking (or disk-harrowing).

Microtopographic relief affects the proximate hydrologic conditions experienced by an individual seed or plant (Pollock et al. 1998, Bledsoe and Shear 2000), but it may also affect wetland hydrology more broadly. Under conditions of standing water, microtopographic features may cause increased flow resistance (Harvey et al. 2003). The implication that increased microtopography enhances water retention in a wetland is supported by field experiments in which disked wetland restoration plots had higher water retention and higher water table levels than non-disked plots, whether for above or belowground water table conditions (Tweedy et al. 2001). Thus, roughing the surface (as by disking) may help in restoring wetland hydrology to agricultural lands, and it has been proposed as a way to reduce the amount of seeding needed (Bledsoe and Shear 2000).

Topographic heterogeneity on the scale of a few centimeters in relief has been shown to promote species richness and abundance in experimental wetland mesocosms (Vivian-Smith 1997). Surface variation on a similar scale also promoted differential germination of species in prepared-bed and pot experiments (Harper et al. 1965). Studies of woody seedling distributions support the importance of microtopography in determining wetland plant species distribution, with preferential establishment of species and growth forms (tree, shrub, vine) dependent on microtopographic setting (Collins et al. 1982, Huenneke and Sharitz 1986, Titus 1990). Furthermore, sedimentation has been linked to reductions in plant species richness through the loss of microtopographic features associated with *Carex* tussocks (Werner and Zedler 2002). Generally stated, processes explaining the effects of microtopography on wetland plant community structure may include: 1) water retention; 2) microsite variations in extent and frequency of inundation due to elevation; 3) propagule dispersal; 4) microsite variations in habitat (e.g., soil physicochemical properties, temperature, light penetration); 5) protection from erosion/deposition; and 6) increased surface area and exposure of soil to the atmosphere.

Because ecological phenomena may only be apparent at certain scales, it is important to recognize the significance of experimental scale; the notion of "micro"-topography itself demands that scale be considered. A proper investigation takes into account the *extent* (overall area of study) and *grain* of the study (i.e., *resolution*, the unit size of individual study plots), attempting to ensure that experimental results are not skewed by these scale-determining factors (Wiens 1989, Reed et al. 1993, Stohlgren et al. 1997). Only a few examples of multiscale microtopography studies have been published (Pollock et al. 1998, Morzaria-Luna et al. 2004), and these suggest that while there is greater variability at smaller scales, microtopographic effects are evident and consistent across scales from 0.1 m^2 to 1000 m^2.

Most ecological studies have categorized microtopography qualitatively with descriptors such as mound/pit or hummock/hollow/flat (Huenneke and Sharitz 1986, Paratley and Fahey 1986, Titus 1990, Bruland and Richardson 2005). Microtopography is difficult to measure and quantify, however, as it encompasses and combines elements of surface relief and surface roughness. Relief is the vertical extent of a topographic profile, whereas roughness is the extent of topographic variability (as opposed to smoothness), although the term roughness is also commonly used to refer to the combination of relief and roughness. Although relief can be measured and its variance quantified (Allmaras et al. 1966), it is an incomplete descriptor. Agricultural tillage

studies have approached the quantification of topography formally, often in the context of erosion or depression storage, and typically at the clod or crumb scale (Romkens and Wang 1986, 1987, Potter and Zobeck 1990, Potter et al. 1990, Saleh 1993, Hansen et al. 1999, Kamphorst et al. 2000).

This study examined the effects of artificially induced microtopography on hydrologic conditions and vegetation patterns in non-tidal freshwater mitigation wetlands, with the goal of informing wetland creation practices. Several index measures were employed to quantify microtopography and separate out components of roughness and relief. A natural wetland was examined as a comparison to address how microtopography differs between created and natural wetlands. Our research hypotheses were: 1) that created and natural wetlands differ quantitatively in terms of microtopography, and that disked wetlands have greater microtopography than non-disked; 2) that increased microtopography is associated with a higher water table, and consequently with more hydrophytic vegetation; and 3) that increased microtopography is associated with greater species richness, diversity, and cover of vegetation, in both created and natural wetlands. Since disking is a method which can be used to rapidly and widely induce microtopography, the comparison of disked to non-disked created wetlands was of particular interest. Due to increased microtopography, disked wetlands were expected to have greater species richness, diversity, and plant cover, and a higher water table, than non-disked wetlands.

METHODS

Site Details

Field research was carried out at created and natural wetlands in Virginia, USA (mean annual precipitation 1085 mm, mean annual temperature min 7.0°C / max 19.3°C). Created wetlands were North Fork and Cedar Run mitigation banks in Prince William County; natural wetlands were at Huntley Meadows Park in Fairfax County (Figure 2). Within each wetland, sites were randomly selected, although for created wetlands where marked survey locations had been previously established, a survey marker was randomly selected and the study site established 3 m north of the marker.

The created wetlands were located in the Piedmont physiogeographic province, generally characterized by rolling terrain underlain by igneous and metamorphic rock, whereas the natural wetlands were in the Coastal Plain province, comparatively flat and underlain by unconsolidated sediment. North Fork Mitigation Wetland is a 125-acre wetland complex created on land formerly used as cattle pasture, graded in 1999-2000, and hydroseeded in fall 2000 and spring 2001. Study sites were located in the "Main Pod," surrounding an open water area fed by the North Fork of Broad Run, with vegetation in its fifth growing season (sites A, B, C, and D). Cedar Run Mitigation Bank is a 610-acre multiple-wetland complex developed on land formerly used for agriculture. Study sites E and F were located in Cedar Run 1, a 67-acre wetland created/graded in 2004, while sites G and H were in a portion of a smaller adjacent mitigation wetland which was graded in 2004; sites E, F, G, and H were hydroseeded in fall 2004, and were thus in their first growing season. While the mitigation projects at North Fork and Cedar Run sites E and F were disked prior to seeding to provide a more heterogeneous soil surface, the mitigation project at sites G and H was not. Owing to incomplete availability

of data, direct comparison of the seed mixes actually used in the created wetlands was not possible. However, these wetlands were seeded with commercially available wetland plant seed mixes appropriate for the region and the intended hydrology (e.g., wetland meadow as opposed to obligate wetland). From the information available, these seed mixes would have included ~20 plant species, mostly within the genera *Carex* (Cyperaceae), *Juncus* (Juncaceae), and *Scirpus* (Cyperaceae). The 1425-acre Huntley Meadows Park prominently featured beaver-engineered wetlands, some of which were in existence before the park was established in 1975. Here, study sites J and L were in mature (> 30 years old) wetland, while sites I and K were in wetland adjacent to a more recently established (~10 years old) beaver pond.

Field data were collected throughout the growing season, between May and December. Each site was examined using a set of tangentially conjoined circular transects (hereafter referred to collectively as a *multiscale transect*), with field measurements and samples taken at regular intervals along the circular paths (Figure 3). The circular transect approach designed for this study was intended to be directionally unbiased; any confounding directional effects of disking orientation, wind, direction of hydrologic flows, orientation of incident sunlight, etc, were minimized. This approach covers a more limited spatial extent than do linear transects, and so reflect more localized conditions. Multiple scales were adopted to aid in identifying any scale-dependent effects; transects were laid out as 0.5 m-, 1 m-, 2 m-, and 4 m-diameter circles using crosslinked polyethylene tube hoops.

Microtopography

Field measurement of microtopography consisted of elevation measurements taken using conventional surveying equipment (Sokkia SET4110 total station). At the beginning of the study (between 23 June and 15 July), and prior to other measurements, elevations were measured at 10 cm intervals along the 0.5 m-, 1 m-, and 2 m-diameter transects (a total of 108 measurements) at each site and at 20 cm intervals along the 4 m-diameter transect (62 measurements per site) at half the sites in each wetland. Conditions for surveying were generally dry (with soil yielding minimally underfoot), although care was taken not to alter the existing microtopography during elevation measurement; likewise, throughout the study, field work was conducted as much as possible to minimize disturbance of microtopography in the vicinity of the multiscale transects. Coordinate data were recorded to the nearest millimeter, although at the distances used, the total station has nominal sub-millimeter precision for elevation (Sokkia Co. 1997). Measurement intervals were chosen as appropriate to the overall scale of interest (plant-scale), the equipment used (survey rod base diameter of ~6 cm), and the transect sizes.

Microtopography was quantified using three index measures. For a two-dimensional path, such as a cross-sectional elevation profile, the ratio of the over-surface distance to the corresponding straight-line path is referred to as "tortuosity" (Kamphorst et al. 2000), and it can either be calculated from elevation data (Werner and Zedler 2002) or measured directly (Saleh 1993, Merrill 1998). This unitless measure is a simple indicator of microtopography, sensitive to changes in both roughness and relief (Figure 1), but incapable of distinguishing a low-relief high-roughness surface (upper-right in Figure 1) from a high-relief low-roughness one (lower left in Figure 1). Although it appears to perform well for measuring the change in soil surface roughness due to rainfall

(Bertuzzi et al. 1990), tortuosity is not regarded as a good predictor for depression storage of runoff (Kamphorst et al. 2000). Tortuosity (T) was calculated using elevation data and the known transect lengths. Point-to-point distances were summed for each transect, then divided by the corresponding planar transect distance (Kamphorst et al. 2000). The method used was analogous to that of Werner and Zedler (2002), although the measurement intervals were finer (10-20 cm versus ~1 m) and transects were shorter and circular.

A geostatistical approach using a combination of limiting slope (LS) and limiting elevation difference (LD) was proposed by Linden and Van Doren (1986) to physically characterize soil surfaces. LS and LD are indices derived from the variogram of change in elevation versus the horizontal interval of measurement (lag distance). The LD index (in elevation units, cm in this study) represents the limit of elevation change approached for large intervals, thus expressing relief. It is somewhat comparable to the random roughness index of Allmaras et al. (1966) and can be used to estimate maximum depression storage (Bertuzzi et al. 1990, Kamphorst et al. 2000). The LS index (a unitless metric) represents the rate of change in elevation as the interval between measurements approaches zero, pertaining to microrelief at small sampling intervals (i.e., roughness); in tillage studies it has been correlated with tortuosity and fractal indices (Bertuzzi et al. 1990). LS and LD were adopted to distinguish roughness from relief. LS and LD were determined by mean absolute-elevation-difference analysis of the first-order variogram after correcting for slope (Linden and Van Doren 1986), treating change in elevation as a function of the distance between two points. Slope correction for elevation data was achieved by nonlinear (wave form) regression, with appropriate periodicity (i.e., 2π times the transect radius). The mean absolute elevation difference (ΔZ_h) is defined as

$$\Delta Z_h = \sum_{i=1}^{n} \left| Z_i - Z_{i+h} \right| / n$$

where:
Z_i is the slope-corrected elevation of a given point;
Z_{i+h} is the slope-corrected elevation of a point h intervals from Z_i; and
n is the number of pairs of points used in the calculation.

Linear regression was used to relate ΔZ_h to the lag distance X_h, the horizontal distance between a pair of points h intervals apart, fitting the equation

$$\Delta Z_h = 1/\left[\left(b\left(1/X_h\right)\right) + a\right]$$

and treating $1/\Delta Z_h$ as a function of $1/X_h$. LS and LD were calculated from the fitted-line parameters a and b (LS = $1/b$ and LD = $1/a$). This approach is equivalent to using Lineweaver-Burk (or double-reciprocal) plots to solve for Michaelis-Menten enzyme kinetics constants.

T, LS, and LD indices were calculated for each circular transect. For the LS and LD indices, lag intervals were considered for every point on the circular transect, with intervals continuing past the starting point on the transect as the last points on the transect were reached. Because the lag distances were chord distances, approaching as a limit the transect diameter, those used for regression differed for each scale: for the 0.5 m-

diameter transects, three lag distances (10 cm, 20 cm, 30 cm as measured along the transect circle) were used for analysis; for 1 m-diameter transects, five (10-50 cm) lag distances were analyzed; for 2 m-diameter transects, ten (10-100 cm) lag distances were analyzed; and for 4 m-diameter transects, ten (20-200 cm) lag distances were analyzed. Since microtopography might vary within a circular transect, "proximal" values for T, LS, and LD indices were also calculated for each transect point based on near-neighbor points and used to express localized microtopography. These indices were proximal tortuosity (pT), proximal limiting slope (pLS), and proximal limiting elevation difference (pLD); they differ from their full-transect counterparts (T, LS, and LD) in that they are based on a small subset of points, with smaller lag intervals represented by more observations, whereas the full- transect indices were based on a larger set of elevation points with equal counts of elevation differences for each lag interval. Near-neighbor points were treated as those within 0.5 m of the point of interest, except for the case of 4 m transects, where, due to the 20 cm spacing between points, near-neighbor points were treated as within 0.6 m. In determining proximal indices, two guiding principles were applied: first, the points included should not account for more than half the data points in a circular transect; second, lag distances used should not exceed those used for transect-level indices. Consequently, the following lag distances were used: 0.5 m transects: 10-30 cm (measured along the transect circle); 1 m transects: 10-50 cm; 2 m transects: 10-60 cm; and 4 m transects: 20-60 cm. Index calculations were carried out using the mathematics application Maple version 10 (Maplesoft Inc. 2005).

Hydrology

Because installing wells/piezometers would have disrupted the surrounding microtopography, water table depth was estimated using 2.4 mm-gauge (3/32") steel welding rods (Bridgham et al. 1991). Rods were driven either to refusal or to a depth of approximately 80 cm and spaced at 80 cm intervals (total 28 measurements per multiscale transect; Figure 3). Rods were left in place for a minimum of 4 weeks, then removed and exchanged for new ones. A total of four deployments were performed beginning in June, with the final collections taking place in December. However, because sampling dates were staggered among study wetlands, there were a total of 12 sampling dates. Upon extraction, the below-surface depth beyond which no oxidation was apparent was recorded and interpreted as water table depth.

Vegetation

Macrophyte species composition and cover were sampled using 0.2 m^2 circular plots located at 160 cm intervals along each circular transect (Figure 3). Vegetation data were collected from 23 to 26 August 2005. Species were field-identified (Newcomb 1977, Brown 1979, Tiner et al. 1988) and percent cover visually estimated, with a minimum cover percentage of 1 percent. Visual estimates of less than 15% cover were reported in increments of 1%, while those of 15% or more were reported in 5% increments. Cover was also estimated for non-plant surface features, such as large rocks or logs. Due to multiple herbaceous canopy layers, the sum of species cover estimates could exceed 100%, even when visual estimate of total cover was less than 100%. Species were assigned a wetland indicator category (Reed et al. 1988, Pepin 2000).

Taxon counts for each vegetation plot, including unidentified taxa, were used to determine species richness (S) per plot, and, for multiscale transects, species richness per m^2. For the latter, taxon-sampling curves were used to derive S for n = 5 survey plots using EstimateS (Colwell 2005), based on the mean for 50 randomized runs without replacement. To characterize plant diversity, we used the Shannon diversity index (H'), which takes into account both the number of species and their relative abundances, without making assumptions about underlying distributions (Hayek and Buzas 1997, Jørgensen et al. 2005). For this study, H' was determined based on percent cover, rather than by count of individuals, similar to a method used to evaluate plant community diversity (Mitsch et al. 2005). Natural log Shannon diversity values were calculated for each sample plot and for each multiscale transect using EstimateS (Colwell 2005).

Vegetation plots were assigned a wetland prevalence index (P.I.) value according to the weighted average of indicator ranks, excluding unidentified and non-listed species (Wentworth et al. 1988). Under this classification, each wetland indicator category was assigned a rank value as follows: OBL (obligate wetland) = 1, FACW (facultative wetland) = 2, FAC (facultative) = 3, FACU (facultative upland) = 4, UPL (upland) = 5, with no adjustment for +/- designations. Rank values were weighted according to the associated percent cover, and the weighted ranks were averaged to reach an indicator rank for the sample area, with lower index values corresponding to prevalence of more hydrophytic vegetation. The prevalence index was calculated as:

$$\text{P.I.} = \frac{\sum A_i W_i}{\sum A_i}$$

where:
A_i = abundance of species i;
W_i = wetland indicator category for species i; and
i = individual species.

Statistical Analysis

Two separate parametric analyses were conducted to compare sites based on creation method (disked, non-disked, natural). First, to address how microtopography differed and to examine issues of scale, full-transect indices (LS, LD, T) were examined. Second, to address how disking relates to vegetation patterns and hydrology, proximal indices (pLS, pLD, pT) were considered in connection with vegetation parameters and steel rod oxidation measurements, using a nested design to partition out variance attributable to site. Two-way multivariate analysis of variance (MANOVA) was used to examine LS, LD, and T for differences attributable to creation method and transect scale (0.5 m, 1 m, 2 m, 4 m) for the combined dependent variable, followed by post-hoc Dunnett's T3 pairwise comparisons. A nested-design two-factor MANOVA (site nested within creation method) was used on the vegetation survey plot data to examine differences among creation methods as to the combined dependent variable of pLS, pLD, pT, H', S, P.I., percent cover, and steel rod oxidation depth, followed by post-hoc Dunnett's T3 pairwise comparisons. MANOVA analyses were conducted using Type IV sum-of-squares and an alpha level of 0.05 (due to unequal sample sizes, Pillai's Trace was adopted as a more robust alternative to Wilks' Λ), and performed using SPSS (SPSS Inc. 2004). A nested (site nested within creation method) two-factor nonparametric

analysis of similarity (ANOSIM) was carried out for species assemblage data ($\alpha = 0.05$). Decomposition of the Bray-Curtis similarity used for ANOSIM was used to characterize within-site similarity and between-site dissimilarity, as well as to express the contributions of individual species to similarity/dissimilarity. ANOSIM and related routines were performed using PRIMER (PRIMER-E Ltd. 2006).

To better conform to the assumptions of MANOVA, appropriate transformations (Osborne 2002) were applied for tortuosity (T and pT, base 10 log), limiting elevation difference (LD and pLD, natural log), and wetland prevalence index (natural log). Multivariate outliers were identified by Mahalanobis distance, using the Chi-square critical value ($p < 0.001$, with df = number of dependent variables) as the criterion for exclusion of outliers from analysis. For ANOSIM of vegetation abundance data, square-root transformation was applied to the data matrix prior to Bray-Curtis ordination in order to downweight the influence of highly abundant species (Clarke and Warwick 2001, Clarke and Gorley 2006). For transformed variables, mean values reported in figures and tables are reported in original untransformed units. While the relationship between microtopographic indices and vegetation/hydrologic variables was conjectured to be monotonic (but not necessarily linear), and because the study design is observational, correlations were examined using non-parametric Spearman rank correlation coefficients ($\alpha = 0.05$) using untransformed variables, without excluding outliers.

RESULTS

Microtopography

Visual inspection of transect elevation profiles suggested empirically that disked, non-disked, and natural sites were microtopographically distinct (Figure 4), with more pronounced vertical relief evident in disked and natural wetlands than in non-disked wetlands. Circular transect microtopographic index values ranged from 0.06 to 1.7 for LS (excluding two negative values likely causing the two Mahalanobis outliers), from 0.4 to 12.4 cm for LD, and from 1.001 to 1.043 for T (Table 1). The combined dependent variable of LS, LD, and T indices differed among creation methods (Pillai's Trace = 0.460, $F_{6,54} = 2.69$, $p = 0.024$), while there were no significant differences for scale (Pillai's Trace = 0.254, $F_{9,84} = 0.86$, $p = 0.56$). Differences existed for LD ($F_{2,28} = 7.62$, $p = 0.002$) and T ($F_{2,28} = 3.47$, $p = 0.045$) indices, but not for LS ($F_{2,28} = 0.83$, $p = 0.45$). LD was significantly higher for disked ($p = 0.002$) and natural ($p = 0.026$) wetlands than for non-disked wetlands (disked [$\bar{x} = 3.4$] ≈ natural [$\bar{x} = 2.5$] > non-disked [$\bar{x} = 1.2$]). T was also higher for disked than for non-disked wetlands ($p < 0.001$), although neither differed significantly from natural wetlands (disked [$\bar{x} = 1.014$] > non-disked [$\bar{x} = 1.002$]; natural [$\bar{x} = 1.012$]). Excluding the one Mahalanobis outlier ($n = 97$), the plot-level combined dependent variable also differed among creation methods (Pillai's Trace = 0.924, $F_{16,158} = 8.48$, $p < 0.001$) (Figure 5), but only pLD differed significantly ($F_{2,85} = 3.88$, $p = 0.024$). Mean pLD was higher for disked than for either non-disked ($p = 0.018$) or natural wetlands ($p = 0.012$), while the latter two did not differ (disked [$\bar{x} = 3.5$] > non-disked [$\bar{x} = 2.1$] ≈ natural [$\bar{x} = 1.8$]).

Hydrology

The record of water table depths during the study period indicated that all the study sites met the legal assessment criteria for wetland hydrology (Federal Interagency Committee for Wetland Delineation 1989). Notwithstanding the drought period, the overall pattern of water table depth readings supported the notion that the study sites were hydrologically comparable, even though the created wetlands were perched, whereas the natural sites were groundwater-connected. Growing-season water table depths ranged from zero to > 69 cm, with a notable drop in depth coinciding with a period without precipitation in September (Figure 5a and b). Over the entire study period, site mean water table depths ranged from 3.4 to 29.2 cm below the surface (Table 1). However, the first two weeks of September were abnormally dry (drought severity D0), followed by three weeks of moderate drought (drought severity D1), which ended with heavy rains on 7 October (National Drought Mitigation Center 2005). Because the steel rod method is less reliable when the water table drops significantly (Bridgham et al. 1991), and since the steel rod data collection dates differed for each wetland, the steel rod oxidation depths used for analysis encompassed only those measurements taken between 19 August and 8 September, reflecting the water table for the pre-drought period (and peak growth). During this time, the mean daily precipitation for the antecedent 30 day period was comparable among study wetlands, averaging ~0.2 cm per day (Figure 5a). Steel rod oxidation depth differed by creation method ($F_{2,85} = 6.32$, $p = 0.003$), but the difference was significant only between disked and natural wetlands ($p = 0.047$, disked [$\bar{x} = 15.6$] < natural [$\bar{x} = 20.4$]; non-disked [$\bar{x} = 25.4$]). For steel rod observations across all sites ($n = 248$), no correlation was evident between rod oxidation depth and pLS ($r_{Sp} = -0.032$, $p = 0.61$), pLD ($r_{Sp} = 0.014$, $p = 0.83$), or pT ($r_{Sp} = 0.019$, $p = 0.76$). Nonetheless, the steel rod oxidation depth did correlate weakly, but positively with elevation (relative to the corresponding multiscale transect mean, $r_{Sp} = 0.16$, $p = 0.014$), validating the expectation that microtopographic high points lie higher in relation to the water table, and are thus drier.

Vegetation

Field identification of macrophytes resulted in a total count of 72 taxa, with 5 identified to genus and 60 identified to species. Accounting for a small proportion of cover were seven taxa that could not be field-identified, either because they were seedlings or because they lacked distinguishing morphologic characteristics. Twenty-seven species had average abundances exceeding 2 percent cover for at least one study location (Table 2). Although the disked sites appeared to have greater vegetation cover than non-disked sites, and although total percent cover differed by creation method ($F_{2,85} = 9.74$, $p < 0.001$), the difference between disked and non-disked sites was not significant ($p = 0.051$), although disked and natural sites differed ($p = 0.016$, disked [$\bar{x} = 125$] > natural [$\bar{x} = 103$]; non-disked [$\bar{x} = 84$]). Geographically, species richness (S) was highest for Cedar Run (42 species total, 30 for disked and 19 for non-disked sites), followed by North Fork (31 species) and Huntley Meadows (26 species). S ranged from 8 to 22.2 species among multiscale transects (Table 1). Considering survey plots across all sites ($n = 106$), S correlated with both pT ($r_{Sp} = 0.208$, $p = 0.032$) and pLD ($r_{Sp} = 0.235$, $p = 0.015$). Within Cedar Run ($n = 34$), the correlations were stronger, although again the correlation for pLD ($r_{Sp} = 0.533$, $p = 0.001$) was stronger than that for pT ($r_{Sp} = 0.424$, $p = 0.013$). Plot-level species richness differed by creation method ($F_{2,85} = 23.89$,

$p < 0.001$) and was higher for disked plots than for non-disked ($p = 0.009$) and natural ($p < 0.001$) plots (disked [$\bar{x} = 7.9$] > natural [$\bar{x} = 5.0$] ≈ non-disked [$\bar{x} = 4.8$]).

Plot-level Shannon diversity index (H') values ranged from zero to 2.13, while transect-level values ranged from zero to 2.56. Because the Shannon index increases with sampling effort (Hayek and Buzas 1997), transect-level values could not be compared across different scales. At the sample plot level, H' differed by creation method ($F_{2,85} = 19.01$, $p < 0.001$), with significant differences among all methods (disked [$\bar{x} = 1.38$] > natural [$\bar{x} = 0.96$] > non-disked [$\bar{x} = 0.72$]). Across all survey plots (n = 106), H' was significantly correlated with both pLD ($r_{Sp} = 0.32$, $p = 0.001$) and pT ($r_{Sp} = 0.31$, $p = 0.001$), although not with pLS ($r_{Sp} = -0.064$, $p = 0.51$). These general correlations were not observed consistently. While they were evident for Cedar Run for both pLD ($r_{Sp} = 0.57$, $p < 0.001$) and pT ($r_{Sp} = 0.45$, $p = 0.007$), they were not for North Fork (pLD $r_{Sp} = -0.15$, $p = 0.38$; pT $r_{Sp} = 0.10$, $p = 0.55$). Considering disked and non-disked created wetland survey plots as a pooled group (n = 70), H' was positively correlated with both pLD ($r_{Sp} = 0.27$, $p = 0.022$) and pT ($r_{Sp} = 0.30$, $p = 0.013$). At the natural wetland survey plots (n = 36), H' correlated with pT ($r_{Sp} = 0.33$, $p = 0.047$), but not pLD ($r_{Sp} = 0.28$, $p = 0.098$).

Although water table depth could affect S and H', particularly where conditions are relatively constant (e.g., inundation), and although it should largely determine the wetland prevalence index (P.I.), the steel rod oxidation depth was not correlated with S ($p = 0.68$), H' ($p = 0.87$), or P.I. ($p = 0.23$). The wetland prevalence index ranged from 1.0 to 4.0 (Table 1), although most were below 2.5, thus within the wetland vegetation range. An exception was site H at Cedar Run, where the vegetation was markedly different from that observed at other sites, with prevalence of non-hydrophytic vegetation (P.I. = 3.6, or FACU) and low percent cover ($\bar{x} = 44\%$). Prevalence indices differed by creation method ($F_{2,85} = 24.92$, $p < 0.001$), where disked and natural wetland plots had significantly lower P.I. values (i.e., prevalence of more hydrophytic vegetation) than non-disked wetland plots (disked [$\bar{x} = 1.4$] ≈ natural [$\bar{x} = 1.4$] < non-disked [$\bar{x} = 2.6$]). Even though hydrology should largely determine the prevalence of hydrophytes, the steel rod oxidation depth difference between disked and non-disked plots ($p = 0.099$, mean difference of 9.8 cm) appeared insufficient to explain the large difference in P.I. (a full indicator category, OBL versus FACW/FAC). The equivalence of P.I. between disked and natural wetlands suggested that their differing steel rod oxidation depths ($p = 0.047$, mean difference of 3.8 cm) did not affect the prevalence of hydrophytes.

Creation methods differed in community composition (Global R = 0.715, $p = 0.002$), while significant assemblage differences were also attributable to site (Global R = 0.634, $p = 0.001$). Pairwise comparisons showed that disked and natural wetlands differed (R = 0.921, $p = 0.005$), but that disked and non-disked wetlands did not (R = 0.396, $p = 0.11$). Although the test for difference between non-disked and natural wetlands was not significant (R = 0.786, $p = 0.067$), it likely reflects the small number of non-disked replicates. Clarke and Gorley (2006) emphasize that the R statistic is more important for interpretation than is the p-value when the number of replicates is small; the large R statistic here suggests significant differences between non-disked and natural sites.

Decomposition of Bray-Curtis similarity showed that the within-site similarity between samples was generally higher (i.e., greater homogeneity) for sites with less

microtopography (Table 1). There were marked contrasts in within-site similarity between disked sites (E and F) and non-disked sites (G and H) at Cedar Run, and between beaver pond sites (I and K) and mature wetland sites (J and L) at Huntley Meadows. Decomposition of similarity percentages by species suggested that four common species were important contributors to within-site similarity (Table 3), as well as to difference between sites: barnyardgrass (*Echinochloa crus-galli* (L.) Beauv.), blunt spikerush (*Eleocharis obtusa* (Willd.) Schult.), rice cutgrass (*Leersia oryzoides* (L.) Sw.), and marsh seedbox (*Ludwigia palustris* (L.) Ell.). *Echinochloa crus-galli*, an annual graminoid often found in association with *E. obtusa* and *L. palustris* (Pepin 2000), was abundant at Cedar Run, and was the overwhelming component of cover observed in the non-disked wetland (and at site G).

DISCUSSION

Microtopography in Created and Natural Wetlands

The range of values obtained for T (Table 1) fell within a range overlapping that obtained by Werner and Zedler (2002) for *Phalaris*- and *Typha*-dominated wetlands (1.00 to 1.02), but considerably lower than those for *Carex*-dominated wetlands (1.06 to 1.16) (although the methods used in this study differed, particularly in terms of the interval of measurement). For created wetlands, the microtopography of disked sites differed from that of non-disked sites in terms of both tortuosity and relief, confirming our hypothesis that disked microtopography is greater than non-disked. The distinction was particularly apparent for relief; whereas disked sites had LD greater than 3 cm, non-disked sites had LD of 2 cm or less. Disked LD exceeded the relief of heterogeneous experimental treatments (Vivian-Smith 1997), while non-disked LD approached the condition of homogeneous treatments in that study. Disked relief is thus sufficient to affect the frequency and spatial variation of flooding (Pollock et al. 1998, Bledsoe and Shear 2000).

Although disked and non-disked microtopography clearly differed, created and natural microtopography did not, in contrast to our hypothesis that created and natural wetlands would differ quantitatively. While natural LD was similar to disked LD and larger than non-disked LD, natural pLD was similar to non-disked pLD and less than disked pLD, suggesting that natural microtopographic relief encompasses the range of relief found in both disked and non-disked created wetlands. Although this finding contrasts with that of Stolt et al. (2000), at the comparatively small scale of this investigation, the distinction between created and natural microtopography may be subtle. At our study's scale, disked relief was comparable to the high end of the relief found in natural wetlands, while non-disked relief fell at the low end.

Wetland microtopography has typically been examined at resolutions (or grain sizes) on the order of meters or square meters and/or spatial extents greater than 10 m or 100 m^2 (Pollock et al. 1998, Bledsoe and Shear 2000, Stolt et al. 2000, Werner and Zedler 2002, Bruland and Richardson 2005). The present study examines wetland microtopography at grain sizes of 10-20 cm (or 0.2 m^2 for vegetation plots) and spatial extent 4 m or less (~12.5 m^2), extents comparable to those of Morzaria-Luna et al. (2004), with the smaller transects comparable in extent to the experiment of Vivian-Smith (1997). At our study's resolution, wetland microtopography differed minimally between extents of 0.5 m to 4 m, a result echoing that of Morzaria-Luna et al. (2004).

This finding validates the use of the proximal indices pT and pLD, since these indices were calculated based on near-neighbor elevations. It also suggests that mesocosm-scale experiments in microtopography might be extrapolated at least as far as the 4 m transect spatial extent. At finer grain sizes (e.g., seed-scale as opposed to plant-scale), this may not necessarily be the case. Moreover, at larger spatial extents, broader-scale patterns in microtopography (such as hummock/hollow) may be more important.

Measures of Microtopography

Although LD and LS were adopted to quantify relief and roughness separately, LD proved more useful than LS. The LS and pLS indices failed to distinguish the study sites (Table 1, Figure 6c). Some of the regressions had negative slopes, resulting in negative (uninterpretable) LS values, implying a non-zero mean absolute elevation difference (ΔZ) as the lag distance approaches zero. In Lineweaver-Burk linear regression, however, such a result can occur when the smallest-interval ΔZ value exceeds those of larger intervals. While this provides qualitative information (i.e., microtopographic roughness more apparent at small intervals than at larger ones), it suggests caution in interpreting LS as a physical parameter, supporting the contention that LS only describes variogram slope, not surface slope (Kamphorst et al. 2000). Several differences in method may explain why LS and pLS results appeared less robust than those of Linden and Van Doren (1986). First, elevation data were collected along circular transects, rather than in oriented grids; second, the smallest interval used was 10 cm, as opposed to 5 cm. For the larger transects, the largest lag intervals exceeded those used in the original method. Moreover, the proximal indices were derived from a small number of elevation measurements. Whereas the original study reported that most regressions had close fits to the Lineweaver-Burk plots ($R^2 > 0.90$), in our study only half the regressions used to calculate LS and LD had comparable fit, and about a third had rather poor fit ($R^2 < 0.50$).

LD appeared to perform reasonably well as a measure of relief, with values appropriate to the respective elevation profiles (Figure 4); pLD values were clustered about their respective transect-level LD index values and produced few univariate outliers. LD and pLD were thus useful in characterizing microtopography, although they were computationally intensive. A simpler measure of relief, such as random roughness (Allmaras et al. 1966) might be more appropriate for future studies. Quantification of relief is essential, however; consideration of tortuosity alone would suggest that disked sites C and D were similar to non-disked sites G and H (Figure 6a), whereas these sites differed in relief, measured as pLD (Figure 6b).

Hydrology

The correlation between relative elevation and steel rod oxidation depth suggests that relief should affect proximate hydrologic conditions, but the weakness of the correlation may reflect steel rod oxidation depth variability. Indeed, steel rod depth standard deviations more than doubled those of elevation. However, the inferred variability in water table depth may reflect redoximorphic conditions independent of water table depth (e.g., soil texture, compaction, or organic/microbial content). As used in this study, the steel rod oxidation method had drawbacks, particularly for fine-scale measurement and comparison.

The lack of correlation between steel rod oxidation depth and any of the index measures of microtopography contrasts to the findings of Tweedy et al. (2001) relating higher water table to microtopography, as well as with our corresponding hypothesis. During the growing season, increased water retention may have been offset by increased evapotranspiration, thus masking microtopographic effects. Alternatively, steel rod oxidation may have been too coarse an approach to establish a meaningful correlation with water table depth, which might only vary on the order of 10 cm due to microtopography (Tweedy et al. 2001). Indeed, while the steel rod oxidation depth differed significantly among creation methods, the mean depths were within a 10 cm range. Moreover, since the steel rod analysis only covers a relatively brief period in late summer, it can not reflect seasonal aspects of the hydrology.

Microrelief appeared to increase water retention by storing water in small depressions. Rarely was standing water observed in the low-relief non-disked sites; when present, it was of less than 2 cm depth (Moser, personal observation). In contrast, standing water of several centimeters depth was frequently observed at disked and natural sites, suggesting that microrelief can affect hydroperiod, increasing inundation stress on plants and germinating seeds. The prevalence of hydrophytic vegetation may thus depend more on ephemeral inundation by perched pools than on water table depth.

Vegetation

The observed association between microtopography and both species richness and Shannon diversity in created wetlands confirms the notion that inducing microtopographic heterogeneity in created wetlands promotes diversity (Vivian-Smith 1997, Bruland and Richardson 2005, Larkin et al. 2006). Furthermore, this association mirrored the patterns observed in natural wetlands in our study and in others, (Huenneke and Sharitz 1986, Titus 1990, Werner and Zedler 2002), supporting our hypothesis that increased microtopography is associated with greater species richness and diversity.

Physiogeographic setting, as well as seed source, may explain some of the differences between created and natural wetland assemblages. The higher-elevation clay loams of the Piedmont likely support a vegetation community different from that supported by the lower, sandier soils of the Coastal Plain. Moreover, the even and abundant supply of seed provided for wetland creation contrasts with the spatially variable, population-dependent seed source and distribution in natural wetlands, possibly explaining the richness and diversity in the created wetlands. Spatial variability was more evident at Huntley Meadows, where numerous additional species were observed in the vicinity, whereas the created wetlands lacked such broader-scale diversity. Furthermore, since the created wetlands were in comparatively early successional stages, their plant communities may include species that will not persist in the long term.

A species-area relationship has been suggested as potentially explaining increased species richness with increased microtopography in tussock sedge meadows (Werner and Zedler 2002, Peach and Zedler 2006). In our study, vegetation effects (e.g., tussock effects) were not confounded with microtopographic effects (the Cedar Run sites had no pre-existing biogenic microtopography). Since tortuosity is the 2-dimensional analogue of surface area, the correlation between species richness and pT may support a species-area relationship. However, surface area may only reflect habitat heterogeneity, rather than being an influence itself (Brose 2001). As a measure of relief, the pLD index should

more closely reflect habitat heterogeneity than does pT, whether considered in terms of hydrology (Pollock et al. 1998, Bledsoe and Shear 2000) or other factors, such as light penetration (Peach and Zedler 2006). At Cedar Run, the strength of correlation with pLD better supports the hypothesis that species richness is promoted by habitat heterogeneity than by a richness-area relationship.

The four species accounting for most of the assemblage similarities are generalists common in wetland plant communities in Virginia and highly tolerant of disturbance (Virginia FQAI Advisory Committee 2004). The distribution and abundance of these generalists within a site's plant community was important in distinguishing among assemblages. These assemblages varied less where microtopography was limited. It thus appears that increased microtopography reduces the importance of generalists and fosters the establishment of non-generalists, as would be expected through niche differentiation. It should also increase the evenness of species distribution, suggested in part by the correlations between H' and both pT and pLD. The higher within-site assemblage similarity for non-disked sites further supports the notion that decreased microtopography is associated with species dominance (Werner and Zedler 2002, Larkin et al. 2006).

CONCLUSIONS

As a practical consequence of engineering practices, created wetland ecosystems are relatively uniform at the outset, in contrast to natural wetland conditions. An area of concern for mitigation is the extent to which this uniformity may lead to the predominance of few species, diminishing ecosystem functions. Our study showed that disking clearly enhanced microtopography in created wetlands and the increased microtopography was associated with greater species richness, diversity, and percent cover, as well as with the prevalence of hydrophytic vegetation. However, it may represent topographic uniformity when considered at the full extent of a created wetland. Disked microtopography was thus qualitatively different from that induced by excavation (hummock/hollow or mound/pit), which provides greater magnitude of relief but is typically applied over a proportionally smaller area. Disking affects vegetation throughout a wetland, whereas hummocks/hollow creation yields localized benefits (e.g., pools of standing water, patches of vegetation) which may be more relevant to wetland fauna.

Disking appears to prevent the dominance of generalist species, some of which may be undesirable species in mitigation wetlands. Where generalist species were associated with the loss of microtopographic features and biodiversity, even the short-term plant community effects of disking, apparent in this study for Cedar Run, might help guarantee longer-term plant species richness and diversity. In terms of mitigation performance criteria (i.e. legal success), the disked sites clearly had the better prospects. The non-disked site H failed the basic performance criterion of prevalence of hydrophytic vegetation. Disking is therefore recommended as a relatively low-cost method of inducing microtopographic variation that could assist ecosystem development in created mitigation wetlands.

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Table 1. Tortuosity (T), limiting slope (LS), and limiting elevation difference (LD, cm) for each transect scale; mean water table depth (WTD ± SE, cm), mean percent cover (%Cover ± SE), mean wetland prevalence index (P.I. ± SE) and corresponding category, species richness (S_{obs}) as estimated from taxon-sampling curves for n = 5 samples (1 m^2), 50 randomized runs; mean Shannon diversity index (H' ± SE); percent within-site similarity as determined from decomposition of average within-group Bray-Curtis similarity. For LS index, "neg" indicates negative/uninterpretable values.

		North Fork (disked)				Cedar Run (disked)		Cedar Run (non-disked)		Huntley Meadows (natural)			
	Scale	A	B	C	D	E	F	G	H	I	J	K	L
T	0.5m	1.011	1.016	1.005	1.001	1.023	1.012	1.002	1.001	1.043	1.003	1.001	1.035
	1m	1.020	1.026	1.010	1.002	1.013	1.021	1.004	1.002	1.005	1.006	1.001	1.012
	2m	1.013	1.030	1.005	1.004	1.020	1.017	1.008	1.002	1.018	1.006	1.004	1.015
	4m	1.015	1.012	--	--	1.011	--	1.004	--	1.023	1.004	--	--
LS	0.5m	0.259	0.351	0.086	0.168	0.180	1.707	0.928	0.083	neg	0.086	neg	0.321
	1m	0.227	0.249	0.328	0.062	0.152	0.260	0.156	0.117	0.104	0.209	0.084	0.254
	2m	0.209	0.524	0.088	0.070	0.248	0.203	0.247	0.074	0.234	0.109	0.132	0.188
	4m	0.471	0.725	--	--	0.220	--	0.173	--	0.352	0.145	--	--
LD	0.5m	2.0	2.2	4.7	0.5	12.4	1.5	0.6	0.5	1.8	2.1	0.4	4.3
	1m	4.6	5.4	1.7	1.9	6.0	4.9	1.2	0.8	3.2	1.5	0.9	2.0
	2m	2.8	3.4	3.7	4.2	4.0	5.0	1.6	1.6	3.2	2.4	1.3	3.3
	4m	3.6	3.2	--	--	5.1	--	2.1	--	4.4	2.1	--	--
WTD		19.2±1.1	18.9±1.1	3.4±0.5	12.9±1.3	18.9±1.2	21.6±2.0	20.0±1.7	27.5±4.3	16.8±1.4	29.2±2.5	11.4±2.0	18.1±1.9
%Cover		129 ± 9	90 ± 14	114 ± 11	166 ± 12	132 ± 8	128 ±12	109 ± 4	44 ± 8	120 ± 4	87 ± 6	107 ± 4	101 ± 8
P.I.		1.4±0.1	1.7±0.1	1.3±0.2	1.3±0.1	1.7±0.1	1.4±0.1	2.0±0.1	3.6±0.2	2.0±0.1	1.1±0.1	1.4±0.2	1.6±0.1
		OBL	FACW	OBL	OBL	FACW	OBL	FACW	FACU	FACW	OBL	OBL	FACW
S_{obs}		11.2	19.5	18	19.2	22.2	16	14.4	10	9.3	13.3	8	14
H'		1.01±0.08	1.54±0.10	1.48±0.21	1.52±0.11	1.68±0.10	1.21±0.08	0.59±0.10	1.06±0.14	0.90±0.08	1.11±0.12	0.65±0.15	1.03±0.17
%Similarity		53	35	41	50	39	52	68	60	58	47	63	35

Table 2. Percent cover and wetland indicator category (Reed 1988) for common species (> 2% average cover at any location). Percent cover totals may exceed 100% due to multiple layers of cover. Mean ± one SE.

SPECIES	Indicator[1]	North Fork (disked)	Cedar Run (disked)	Cedar Run (non-disked)	Huntley Meadows (natural)
Alisma plantago-aquatica L.	OBL	1 ± 1	5 ± 3	0	0
Ambrosia artemisiifolia L.	FACU	0	0	4 ± 2	0
Bidens cernua L.	OBL	7 ± 3	1 ± 1	0	0
Carex frankii Kunth	OBL	10 ± 4	0	0	0
Carex lurida Wahlenb.	OBL	1 ± 1	0	0	4 ± 1.7
Carex vulpinoidea Michx.	OBL	6 ± 3	0	0	0
Carex sp.	--	0	3 ± 1	1 ± 0	0.1 ± 0.04
Cyperus strigosus L.	FACW	0	11 ± 3	0	0
Diodia virginiana L.	FACW	0	4 ± 1	0.1 ± 0.1	0
Echinochloa crus-galli (L.) Beauv.	FACW–[2]	22 ± 4	19 ± 7	61 ± 10	3 ± 1.9
Eleocharis obtusa (Willd.) Schult.	OBL	28 ± 5	29 ± 7	6 ± 3	1 ± 0.8
Juncus effusus L.	FACW+	3 ± 1	2 ± 1	0	6 ± 2.8
Juncus tenuis Willd.	FAC–	9 ± 3	10 ± 3	0	0
Leersia oryzoides (L.) Sw.	OBL	1 ± 0	17 ± 6	0	30 ± 5.0
Lindernia dubia (L.) Pennell	OBL	0	3 ± 1	0.3 ± 0.1	0.1 ± 0.1
Ludwigia alternifolia L.	FACW+	6 ± 3	2 ± 1	0	0
Ludwigia palustris (L.) Ell.	OBL	18 ± 4	12 ± 6	1 ± 0	1 ± 0.5
Microstegium vimineum (Trin.) A. Camus	FAC	0	0	0	24 ± 5.5
Panicum virgatum L.	FAC	0.3 ± 0.3	4 ± 2	6 ± 4	0
Polygonum hydropiper L.	OBL	4 ± 2	3 ± 2	0.1 ± 0.1	0
Polygonum punctatum Ell.	OBL	0.2 ± 0.1	1 ± 1	0	5 ± 2.3
Polygonum sagittatum L.	OBL	0.1 ± 0.1	0	0	4 ± 1.8
Saururus cernuus L.	OBL	0	0	0	12 ± 4.0
Scirpus atrovirens Willd.	OBL	2 ± 2	0	0	0
Scirpus cyperinus (L.) Kunth	FACW+	0	0	0	4 ± 2.9
Setaria glauca (L.) Beauv.	FAC	0	5 ± 2	0	0
Setaria viridis (L.) Beauv.	NL	0	0	6 ± 4	0

[1]OBL = obligate wetland; FACW = facultative wetland; FAC = facultative; FACU = facultative upland; NL = not listed. +/– indicates more/less frequently found in wetlands for a given indicator category.
[2]Indicator category reflects corrected status (Pepin 2000) for *E. crus-galli*.

Table 3. Percent contribution to within-site similarity (from ANOSIM) for the four major contributors to similarity: barnyardgrass (*E. crus-galli*), blunt spikerush (*E. obtusa*), rice cutgrass (*L. oryzoides*), and marsh seedbox (*L. palustris*). Also given are overall mean percent and percentages for created and natural wetlands.

		E. crus-galli	*E. obtusa*	*L. oryzoides*	*L. palustris*
Created wetlands	A	42	36	<1	15
	B	16	2	2	22
	C	7	26	2	30
	D	12	29	<1	14
	E	2	8	7	11
	F	18	51	11	5
	G	75	13	0	2
	H	0	0	0	0
Natural wetlands	I	0	0	33	0
	J	1	1	20	13
	K	0	0	75	0
	L	19	0	8	2
Overall mean %		16.0	13.8	13.1	9.4
Created mean %		21.5	20.6	2.7	12.4
Natural mean %		4.9	0.4	34.0	3.6

LIST OF FIGURES

Figure 1. Basic illustration of the distinction between roughness and relief, represented as hypothetical surface cross-sectional profiles. As roughness increases, so do the index measures tortuosity (T) and limiting slope (LS). As relief increases so do tortuosity and limiting elevation difference (LD).

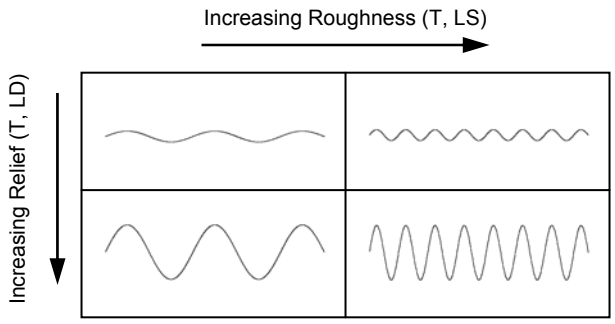
Figure 2. Study location map. Airport weather stations from which precipitation data were collected are also indicated: Reagan Washington National (DCA) and Dulles International (IAD).

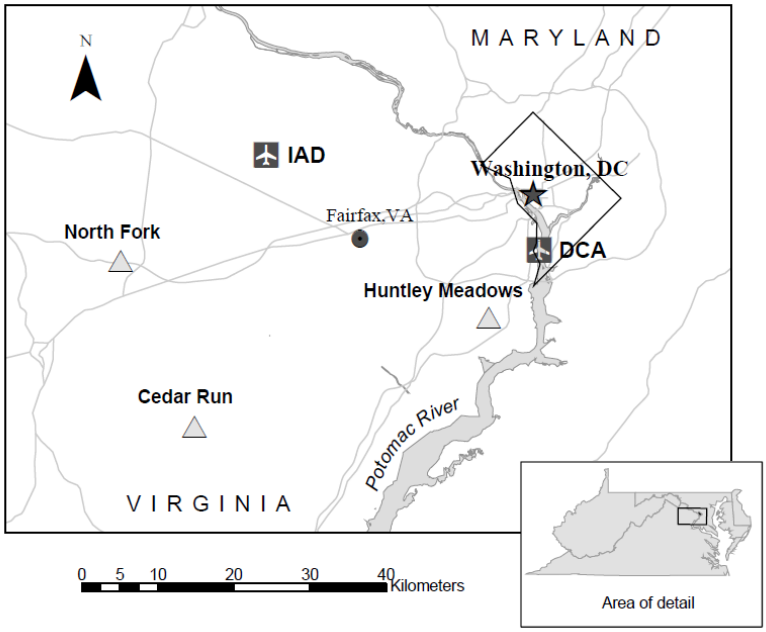
Figure 3. Multiscale circular transects. Elevation data points are at 10 cm intervals (20 cm intervals for the 4 m diameter transects). Steel rod rust depth measurements are at 80 cm intervals. Vegetation plots (0.2 m^2) are at 160 cm intervals.

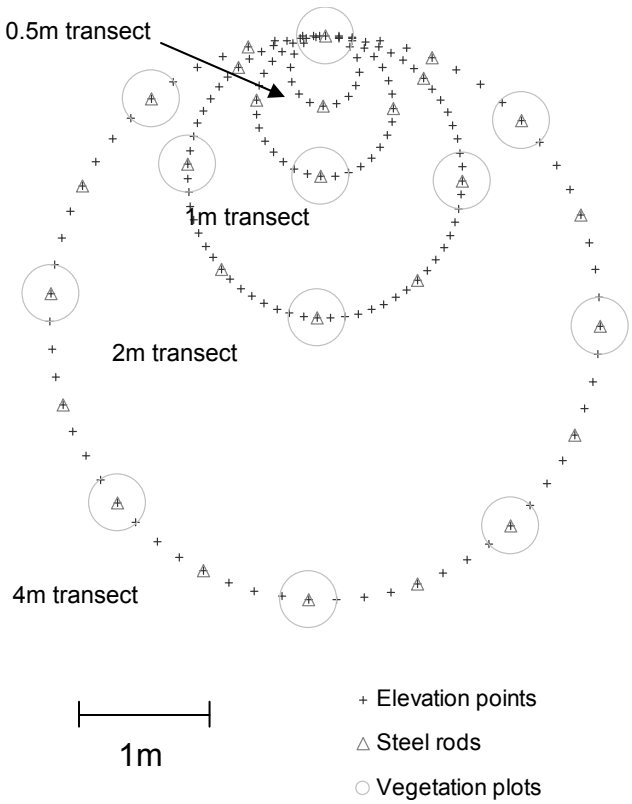
Figure 4. Representative transect elevation profiles for a) disked site F, Cedar Run; b) non-disked site G, Cedar Run; and c) natural site I, Huntley Meadows. Limiting elevation difference (LD) indicated by dashed line. Data and index values for LS, LD, and T are from 2 m-diameter circular transects of overall length 6.2 m.

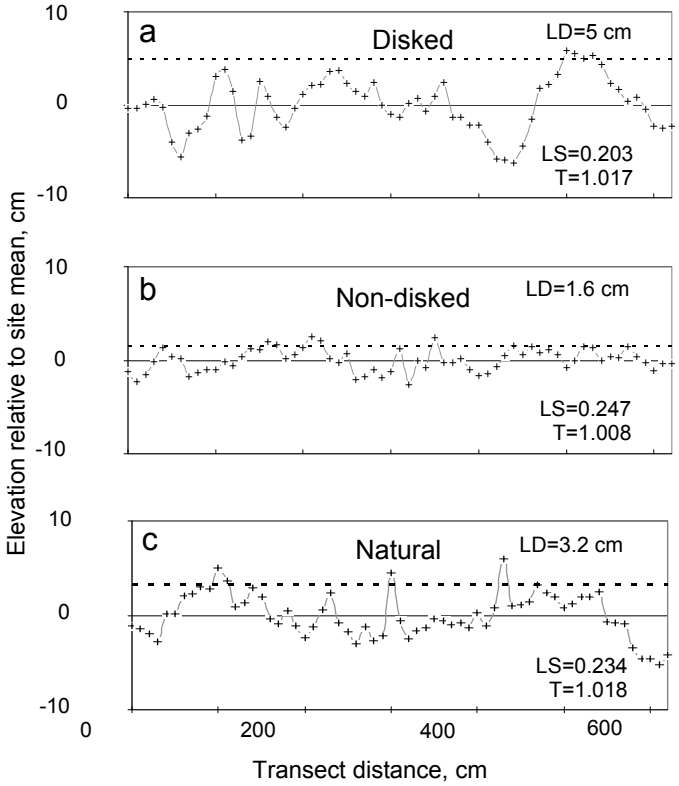
Figure 5. a) Daily precipitation, averaged from airport weather station data, Reagan Washington National and Dulles International airports, July to December 2005. Mean daily precipitation for the preceding 30 days is indicated by dashed line. Period of drought shown, with drought severity index: D0 = abnormally dry, D1 = moderate drought. b) Water table depth (± 1 SE) as measured by steel rod rust depth by date of collection, 2005. Readings reflect the previous month's approximate water table depth. North Fork, sites A-D; Cedar Run, sites E-H; Huntley Meadows, sites I-L.

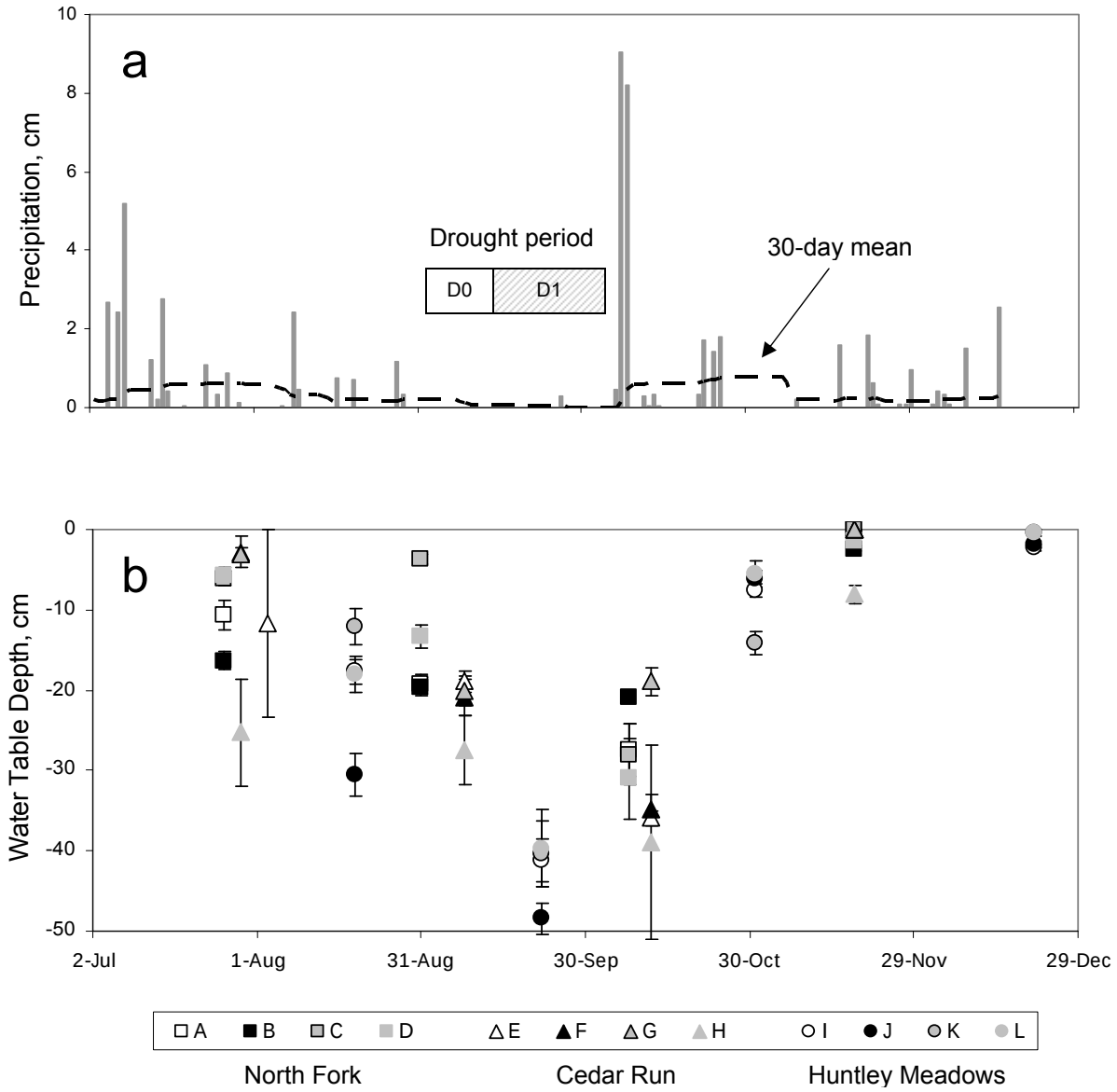
Figure 6. Proximal microtopographic index values, as determined for each transect point, by site, excluding 36 Mahalanobis outliers (n = 1674). a) Proximal tortuosity (pT); b) proximal limiting elevation difference (pLD); c) proximal limiting slope (pLS). Mean ± one SE.

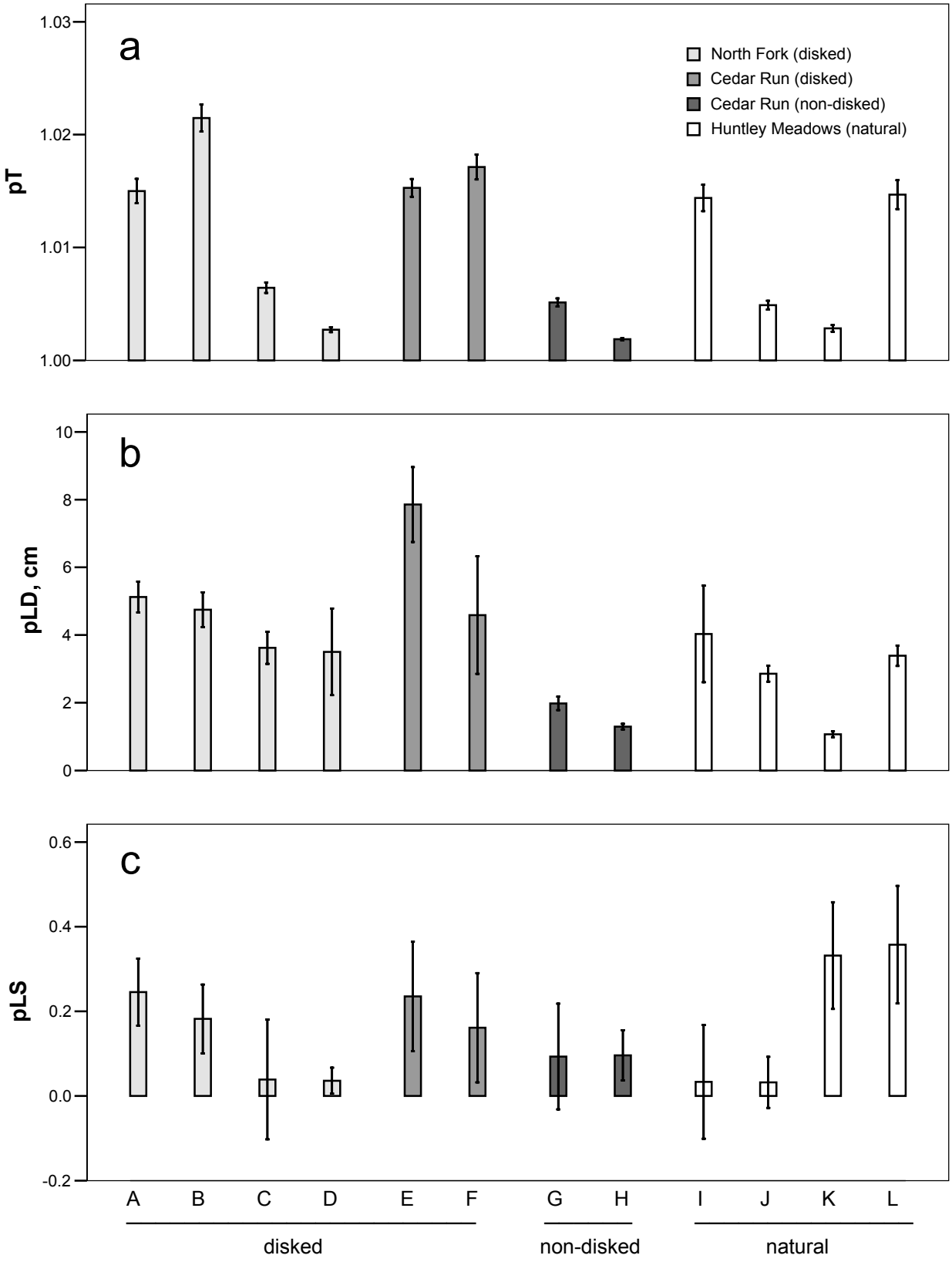

Increasing Roughness (T, LS)
Increasing Relief (T, LD)


N
MARYLAND
IAD
Washington, DC
Fairfax,VA
North Fork
DCA
Huntley Meadows
Cedar Run
Potomac River
VIRGINIA
0 5 10 20 30 40 Kilometers
Area of detail


0.5m transect
1m transect
2m transect
4m transect
1m
Elevation points
Steel rods
Vegetation plots


a
Disked
LD=5 cm
LS=0.203
T=1.017
b
Non-disked
LD=1.6 cm
LS=0.247
T=1.008
c
Natural
LD=3.2 cm
LS=0.234
T=1.018
10
0
-10
0
200
400
600
Elevation relative to site mean, cm
Transect distance, cm


a
Precipitation, cm
10
8
6
4
2
0
Drought period
D0
D1
30-day mean
b
Water Table Depth, cm
0
-10
-20
-30
-40
-50
2-Jul
1-Aug
31-Aug
30-Sep
30-Oct
29-Nov
29-Dec
A
B
C
D
E
F
G
H
I
J
K
L
North Fork
Cedar Run
Huntley Meadows


a
North Fork (disked)
Cedar Run (disked)
Cedar Run (non-disked)
Huntley Meadows (natural)
pT
1.03
1.02
1.01
1.00
b
pLD, cm
10
8
6
4
2
0
c
pLS
0.6
0.4
0.2
0.0
-0.2
A
B
C
D
E
F
G
H
I
J
K
L
disked
non-disked
natural

2. THE INFLUENCE OF MICROTOPOGRAPHY ON SOIL NUTRIENTS IN CREATED MITIGATION WETLANDS

Introduction

Plant-scale topographic variability, or microtopography, may influence wetland hydrology and physicochemistry, thus affecting the balance of plant nutrients in soil. Wetland plants vary in nutrient demands (McJannet et al. 1995; Güsewell & Koerselman 2002) and in adaptations to flooded soil conditions (Kozlowski 1984). Plants also differ in morphology and in their ability to exploit nutrients (Crick & Grime 1987; Hinsinger 2001). Individual species-level responses to soil conditions may determine community composition, richness, and diversity (Bedford et al. 1999; Güsewell et al. 2005), ultimately determining ecosystem functions.

The use of heavy machinery for grading during wetland creation tends to reduce the microtopographic variability commonly found in natural settings (Stolt et al. 2000). Created wetlands also tend to lack the spatial variability of nutrients and biogeochemical processes found in natural wetlands (Bruland et al. 2006). In spite of these characteristic failings, created wetlands are increasingly used to mitigate the loss of natural wetlands. An area of concern for mitigation is the extent to which uniformity of physicochemical conditions may lead to the predominance of few species, thus to a paucity of ecosystem functions (Hooper et al. 2002). In theory, greater variability in localized (plant-scale) nutrient or hydrologic/redoximorphic conditions should support greater plant diversity generally (Tilman 1997; Larkin et al. 2006), greater diversity of functional vegetation types and associated biota (Boutin & Keddy 1993; Grime et al. 1997), and greater ecosystem stability to disturbance (Chapin et al. 1997). Induced microtopography during the restoration or creation of wetlands may enhance such variability and benefit ecosystem development.

Substantial chemical heterogeneity exists at small (1.5 cm interval) vertical scales in wetland soils (Hunt et al. 1997), indicating that even small-scale variations in relief may meaningfully affect soil nutrients. Gradients of increasing moisture, substrate pH and exchangeable Ca and Mg, and decreasing inorganic N and total P, have been shown associated with a microtopographic gradient from higher to lower elevations (Karlin & Bliss 1984; Stoeckel & Miller-Goodman 2001; Bruland & Richardson 2005). Vertical relief may also affect the flux of nutrients with Mn, Fe, and P complexed to Fe accumulating above the water table in microhigh soils, a net upward translocation (Fiedler et al. 2004).

The relationship between microtopography and nutrient distribution is commonly explained in terms of hydrologic/redoximorphic regimes. For instance, in wetland soils, iron plays an important role in phosphorus adsorption, retention, and release (Patrick & Khalid 1974; Baldwin & Mitchell 2000; Aldous et al. 2005); aluminum can likewise affect P availability (Richardson 1985; Axt & Walbridge 1999; Darke & Walbridge 2000). While availability of aluminum-bound phosphate is unaffected by redox status, iron-bound phosphate becomes soluble and available under anaerobic conditions. Consequently, the redox status of Fe in flooded soils may determine P availability (Aldous et al. 2005). Microtopographic elevation affects the frequency, duration, and spatial variability of flooding (Pollock et al. 1998; Fiedler et al. 2004), so it may affect redox conditions and availability of redox-sensitive nutrients. Microtopography may also enhance water retention and soil moisture through increased depression storage (Kamphorst et al. 2000). Thus, roughing the surface (as by disking, the use of tractor-drawn offset disk or disk-harrower) may help establish wetland hydrology, in addition to

promoting redoximorphic variability. Field experiments show higher water retention and water table levels for disked than for non-disked wetland restoration plots (Tweedy et al. 2001).

Within the time frame legally mandated for monitoring at mitigation sites, created wetlands show little evidence of ecosystem development comparable to that of natural wetlands, and many fail to meet basic success criteria (National Research Council 2001; Spieles 2005). Our hope is that wetland creation methods might be refined to enhance wetland ecosystem development and functional diversity, increasing the probability that lost wetland ecosystem services are actually replaced, as well as legally mitigated. This study examines the effects of artificially-induced microtopography on soil nutrients in non-tidal freshwater mitigation wetlands, supplementing a study that suggests disking quantitatively enhances created wetland microtopography and plant diversity (Moser et al. 2007). We investigate major limiting nutrients (N, P, K) and macronutrients (Ca, Mg), as well as micronutrients/trace elements involved in toxicity and P availability (Fe, Mn, Al). Broadly stated, our questions are: 1) How do created and natural wetlands differ in terms of soil nutrients/elements? 2) How do disked and non-disked created wetlands differ in terms of these nutrients/elements? and 3) How does microtopography relate to the distribution/abundance of soil nutrients?

Methods

Site Details

Field research was carried out in summer 2005 at 12 study sites in created and natural non-tidal freshwater wetlands in Virginia, USA. Created wetlands were North Fork (38°49.4' N, 77°40.2' W) and Cedar Run (38°37.6' N, 77°33.6' W) mitigation banks in Prince William County; natural wetlands were at Huntley Meadows Park (38°45.0' N, 77°06.8' W) in Fairfax County. While all study wetlands are located within 30 km of Fairfax, Virginia, the created wetlands are located in the Piedmont physiogeographic province, generally characterized by rolling terrain underlain by igneous and metamorphic rock, whereas the natural wetlands were in the Coastal Plain, comparatively flat and underlain by unconsolidated sediment. Although portions of the created wetlands were intended to mitigate the loss of palustrine forested wetlands, all planted trees were small saplings at the time of the study, and these wetlands could best be characterized as palustrine emergent, comparable to the natural wetlands.

North Fork is a 125-acre wetland/upland complex created in 1999-2000 on land formerly used as cattle pasture. Soils are generally silt loams and silty clay loams over Newark Supergroup basalt and sandstone/siltstone formations of the Culpeper Basin. Four study sites were located in a 51-acre wetland area surrounding open water, with vegetation in its fifth growing season following disked wetland creation. Cedar Run is a large multiple-wetland complex developed on land formerly used for agriculture. Soils are primarily silt loams over Newark Supergroup interbedded sandstone/siltstone/shale. Two study sites were located in a 67-acre wetland complex created and disked in 2004-5, while two sites were in a smaller adjacent wetland that was re-graded without disking and seeded in late 2004. All Cedar Run sites were thus in their first growing season. The 1425-acre Huntley Meadows Park prominently features beaver-engineered wetlands in an urbanized watershed. Soils are derived from gravel, sand, silt, and clay of the Shirley Formation, Pleistocene Epoch deposits of the Potomac River. Two study sites were in a mature (>30 years old) emergent wetland, while two were in an emergent wetland adjacent to a more recently established (~10 years old) beaver pond.

Microtopography

Each of the 12 study sites was examined using a single set of tangentially-conjoined circular transects, with field measurements and samples taken at regular intervals along the circular paths (Figure 1). The circular transect is an approach designed to be directionally-unbiased; any confounding directional effects of disking orientation, wind, direction of hydrologic flows, orientation of incident sunlight, etc, are thus minimized. Transects were laid out as 0.5 m-, 1 m-, and 4 m-diameter circles using polyethylene tubing hoops. Within each wetland, sites were randomly selected, although for created wetlands where marked survey locations had been previously established, a survey marker was randomly selected and the study site established 3 m to the north.

Each soil sampling location was associated with three microtopographic parameters determined from fine-scale survey of transect elevations (10-20cm interval, see Figure 1). These were the indices tortuosity (Kamphorst et al. 2000) and limiting elevation difference (Linden & Van Doren 1986), and elevation relative to the mean multiscale transect elevation. Whereas tortuosity is an overall measure of roughness akin to surface area, limiting elevation difference reflects the degree of topographic relief. Index measures were calculated for each soil sampling location based on transect data for near-neighbor data points (points within 30-60cm, depending on the transect scale) using a methodology developed for evaluating wetland microtopography (Moser et al. 2007). Subsets of the data from that study, these indices characterize the immediate surrounding microtopography, and are referred to as proximal tortuosity (pT) and proximal limiting elevation difference (pLD).

Soil sampling and analysis

Soil samples were collected at 80cm intervals along 0.5 m-, 1 m-, and 4 m-diameter transects (Figure 1, 162 samples total) between 26 July and 2 August 2005, at peak vegetation growth. A soil probe/auger (1.8 cm inner diameter) was used to collect the top 10 cm of soil, excluding surface litter. Samples were stored in polyethylene bags and transported on ice, then stored in the lab at -15°C pending analysis. Samples were thawed and homogenized by hand, with roots, recognizable plant material, and coarse gravel removed. Sub-samples were oven-dried at 105°C for 48 hours and used to determine moisture content for each sample (calculated as [wet weight – dry weight]/dry weight, expressed as a percentage). Dried sub-samples were passed through a 2 mm sieve and ground with a mortar and pestle before analysis for total C and N (percent dry weight) using a Perkin-Elmer 2400 Series II CHNS/O Analyzer (Perkin-Elmer Corporation, Norwalk, CT, USA). KCl extraction (Mulvaney 1996) was performed on field-moist samples to quantify available inorganic nitrogen (NO_3–N and NH_4-N, expressed as µg N/g dry weight), with 40 mL of 1M KCl added to 4 g dry-weight-equivalent soil, the mixture shaken at room temperature for 60 minutes on a reciprocating shaker table and allowed to settle for 30 minutes, and the supernatant passed through a 1.2 µm glass-fiber filter, followed by colorimetric analysis using an Astoria-Pacific segmented flow analyzer (Astoria-Pacific International, Clackamas, OR, USA). Mehlich-3 extraction (Mehlich 1984) was performed for field-moist samples to quantify available Al, Fe, P, Ca, Mg, Mn, and K, with 20 mL of Mehlich-3 extractant added to 2 g dry-weight equivalent of soil, the mixture shaken at room temperature for 5 minutes on a reciprocating shaker table and allowed to settle for 1 minute, then passed through a 0.45 µm polyethersulfone filter. 1:10 (v:v) dilutions were analyzed by inductively-coupled plasma optical emission spectroscopy (ICP-OES) using a Perkin-Elmer Optima 4300 DV analyzer (Perkin-Elmer Corporation, Norwalk, CT, USA), and also analyzed for inorganic P by colorimetry using a Technicon II Autoanalyzer (Bran+Luebbe GmbH, Norderstedt, Germany). Because P

availability depends to a great extent on both Al and Fe, the molar ratio [P/(Al+Fe)] for Mehlich-3 extraction was used as a measure to predict P saturation (Kleinman & Sharpley 2002; Sims et al. 2002). Soil inorganic N:P (designated iN:iP) ratios [(NO_3-N + NH_4-N)/ortho-P], pertaining to the forms of N and P most available to plants, were also used to determine N or P limitation (Wassen et al. 1995; Koerselman & Meuleman 1996; Bedford et al. 1999). N limitation was inferred for iN:iP < 14, P-limitation for iN:iP > 16, and co-limitation for ratios in between.

Statistical analysis

Because the hydrogeomorphic settings differed among study localities, our analysis treats soil moisture as a covariate reflecting differences in both soil pore space attributable to soil composition and proximity to the water table (i.e., concentrations of mobile/water-soluble nutrients were expected to reflect water volume). Moreover, our analysis also stresses comparison of group variances, a necessity because topographic variability may influence nutrient distribution irrespective of nutrient abundance (i.e., group means). Our data conformed poorly to the implicit assumptions of multivariate analysis of variance and covariance (MANOVA/MANCOVA), so univariate analysis of covariance (ANCOVA) was carried out separately for each nutrient variable. Where the covariate was not significant (α=0.05), or the assumption of homogeneity of regression slopes could not be met, univariate analysis of variance (ANOVA) was performed. Data were categorized into four wetland groups for ANOVA/ANCOVA: 1) disked, North Fork (n=52), 2) disked Cedar Run (n=26), 3) non-disked Cedar Run (n=28), and 4) natural, Huntley Meadows (n=52). ANOVA/ANCOVA analyses were nested two-factor analyses (site nested within wetland group) using Type III sums-of-squares and an alpha level of 0.05. Post-hoc Dunnett's T3 pairwise comparisons were performed for ANOVA; since this test is not appropriate for ANCOVA, Bonferroni adjustment was applied for ANCOVA pairwise comparisons. Comparisons of means for microtopographic index measures have previously been reported for the parent data set (Moser et al. 2007), so microtopographic index parameters were not compared here. The Levene test of equality of variance (commonly used to test the ANOVA/ANCOVA equality of variance assumption) was used as a more robust alternative to Bartlett's two-sample test for comparing group variances (α=0.05); Bonferroni adjustment was applied for pairwise comparisons. Correlations among microtopographic indices and nutrient variables for each soil sample location were examined using non-parametric Spearman rank correlation coefficients, using untransformed variables. ANOVA/ANCOVA and Spearman correlation analyses were performed using SPSS (SPSS Inc. 2004). Correlation-based Principal Components Analysis (PCA, conducted using normalized variables) was also performed to reduce the number of nutrient variables to a small number of factors, using PRIMER (PRIMER-E Ltd. 2006). To better conform to the assumptions of ANOVA/ANCOVA and PCA, natural log transformations were applied for Ca, Mg, Mn, and NO_3-N. For log-transformed variables, reported values are converted back to original units.

Results

The microtopographic data supported the notion that though the microtopography of disked created wetlands is generally comparable to that of the natural wetlands at the extent and resolution examined, disked sites have more pronounced microtopography than do non-disked created wetland sites. Proximal limiting elevation difference (pLD) index means clearly distinguished disked and non-disked created wetland microtopography, with minimal relief

evident in non-disked sites (Table 1); proximal tortuosity (pT) likewise showed non-disked sites to be comparatively low in microtopography (Table 1). While pLD and pT means for the natural sites were intermediate, their overall ranges encompassed the corresponding ranges of both disked and non-disked sites.

Soil moisture content, with an overall range between 12 and 44 percent (Table 1), correlated positively, but weakly, with the pLD index but not with the pT index or relative elevation (Table 2). Soil moisture differed significantly among wetlands ($F_{3,8.2} = 8.77$, $p = 0.006$, Figure 2), and it correlated significantly with most parameters (Table 2). Soil moisture was weakly/positively correlated with extractable Ca, Al, Fe, total P, ortho-P, NO_3-N, and NH_4-N, and weakly/negatively with Mn. Despite numerous correlations (r_{Sp}), moisture was a significant covariate only within created wetlands for total C, total N, and extractable Ca, and among all sites for total P and ortho-P (Table 3). For C, N, and Ca, the Huntley Meadows (natural) sites were excluded from ANCOVA in order to satisfy the assumption of homogeneity of regression slopes, enabling ANCOVA adjustment for means comparison among created wetlands. Moisture was not a significant covariate for K, Fe, or Mn, while the assumption of homogeneity of regression slopes could not be met for Mg, Al, and NH_4–N (for NH_4-N, the homogeneity assumption could be met within created wetlands, but moisture was nonetheless not a significant covariate). Thus, group means were selectively ANCOVA-adjusted (Table 3).

As measured, soil total C and N were lower for created (C range 0.3-4.0%, mean 1.2%; N range 0.01-0.26%, mean 0.11%) than for natural wetlands (C range 0.7-7.7%, mean 2.5%; N range 0.06-0.39%, mean 0.19%). Adjusted for the covariate moisture, however, no significant mean difference was evident either for total C ($F_{2,8.7} = 1.96$, $p = 0.20$, Figure 2) or for total N ($F_{2,6.9} = 2.64$, $p = 0.14$, Figure 2). NO_3-N concentrations ranged from zero to 11.7 µg N/g ($\bar{x}$ = 2.2 µg N/g), while NH_4-N concentrations ranged from 0.1 to 35 µg N/g ($\bar{x}$ = 8.4 µg N/g). Average NO_3-N concentrations differed among the study wetlands ($F_{3,9.0} = 6.22$, $p = 0.014$, Figure 2); concentrations were higher for North Fork than for Huntley Meadows. NO_3-N concentrations were lowest at Cedar Run, and there was no apparent difference between the disked and non-disked sites there. Average NH_4-N concentrations also differed ($F_{3,9.1} = 12.75$, $p = 0.001$, Figure 2), with higher concentrations for disked Cedar Run and Huntley Meadows than for North Fork and non-disked Cedar Run (the lowest).

Mehlich-3 extractable total P and orthophosphate-P had similar ranges (0-46 µg/g) and were highly correlated (Table 2), with linear regression slope approximating equality ([orthophosphate-P] = 0.998 * [total P] – 0.810; $R^2 = 0.917$); any extraction of organic P (non-molybdate-reactive P) was apparently minimal, and the two methods are thus essentially equivalent as used here. However, since ICP-OES resolution was limited at low P concentrations, the orthophosphate-P determinations are presumed more reliable; these alone were used for Principal Components Analysis. Mean extractable orthophosphate-P differed among the study wetlands ($F_{3,9.4} = 8.59$, $p = 0.005$, Figure 2). Similarly, mean extractable total P differed among the study wetlands ($F_{3,9.4} = 8.14$, $p = 0.006$, Huntley Meadows [$\bar{x}$ = 15.1 ug P/g] > disked Cedar Run [$\bar{x}$ = 8.6] ≈ non-disked Cedar Run [$\bar{x}$ = 6.1] ≈ North Fork [$\bar{x}$ = 2.1], with disked Cedar Run > North Fork).

Based on the Mehlich-3 [P/(Al+Fe)] molar ratios determined for this study, all sites fell within the "below optimum" category for P availability (Beegle et al. 1998; Sims et al. 2002). Ratios at North Fork and non-disked Cedar Run were especially low ($\bar{x}$ = 0.004 and $\bar{x}$ = 0.005, respectively), while those at disked Cedar Run ($\bar{x}$ = 0.023) compared to those for Huntley Meadows ($\bar{x}$ = 0.024). The iN:iP means suggested N limitation for disked Cedar Run and

Huntley Meadows ($\bar{x}$ = 2.5 and $\bar{x}$ = 1.2, respectively) and P limitation for North Fork and non-disked Cedar Run ($\bar{x}$ = 21.1 and $\bar{x}$ = 26.7, respectively); the distributions were severely skewed, however, and iN:iP medians were below 2, except for North Fork (*Mdn* = 11.4), where 34% of the iN:iP values (15/44) were higher than 16, evenly distributed among sites.

The ranges of Mehlich-3 extractable macronutrient concentrations were 29-3800 µg Ca/g, 10-427 µg Mg/g), and 0.1-32 µg K/g. Mean concentrations differed among wetland types for Ca ($F_{2,6.4}$ = 14.02, p = 0.005, Figure 2) and Mg ($F_{3,8.1}$ = 11.44, p = 0.003, Figure 2), but not for K ($F_{3,8.4}$ = 0.577, p = 0.65, Figure 2). Concentrations of Mg were significantly lower in the disked compared to non-disked Cedar Run sites (Figure 2). Micronutrient concentrations ranged from 26 to 487 µg Fe/g and from 8 to 247 µg Mn/g. Mean Fe concentrations were higher for natural than for created wetlands, and also higher for disked than non-disked created wetlands ($F_{3,8.6}$ = 7.16, p = 0.010, Figure 2); mean Mn concentrations were higher for created than for natural wetlands, but similarly higher for disked than for non-disked created wetlands ($F_{3,8.7}$ = 19.11, p < 0.001, Figure 2). No significant mean difference among sites was apparent for Mehlich-3-extractable Al, which ranged from 80-770 µg/g.

The Levene test indicated inequality of variance for all but three of the measured soil parameters (Table 4); consequently, the p-values of the ANOVA/ANCOVA comparisons (α=0.05) should be understood as somewhat non-conservative (ANOVA/ANCOVA is fairly robust to violations of the homogeneity of variance assumption, however, and p-values were generally well below α). Neither created (disked/non-disked) nor natural wetlands had consistently higher or lower variance, but non-disked variances were consistently the lowest (Table 4).

Numerous significant intercorrelations were apparent among the soil nutrient parameters (Table 2). Strong correlations existed between C and N, extractable total P and orthophosphate-P, and extractable Fe and P (both total P and orthophosphate-P). Correlations with microtopographic parameters were very weak, and only evident for K, Mn, Al, and soil moisture. Extractable K and Al were lower, and Mn greater, with increasing proximal tortuosity.

Principal Components Analysis of the nutrient data identified three components with eigenvalues > 1 (4.6, 2.3, and 1.5), the first two of which accounted for 63% of the nutrient variability. Explaining 41% of the variability, PCA component 1 had highest factor loadings for orthophosphate-P (0.396), NH_4-N (0.339), and Fe (0.383), and a high negative loading for Ca (-0.358). Component 2 accounted for 21% of the nutrient variability, with highest component loadings for Mg (0.469) and NO_3-N (0.397), but also a fairly high loading for Ca (0.339). While the first component axis clearly separates the created from the natural wetlands, with higher component scores for the latter, the second component axis mainly distinguishes the two created wetland locations, with higher component scores for North Fork sites than for Cedar Run sites (Figure 3).

The first PCA factor suggests a gradient from the more mineral soils found in the Piedmont to more organic and comparatively nutrient-rich soil of the Coastal Plain (Figure 3, note also that the two Huntley Meadows wetland groups have similar spreads, but the older wetland is shifted right). Interpretation of the second component is less clear, especially because the Huntley Meadows sites span the range of component scores, but the created wetlands are clearly separated along the second axis by extractable soil cation concentrations. On either component axis a broader range is evident for the natural (Huntley Meadows) sites than for any of the created wetlands, and soil total C and N seems to increase along both axes. Though the

third component axis accounted for 13% of the nutrient variability, this component axis (not shown) did not strongly differentiate the comparison groups.

Discussion

Created wetlands are commonly located on former agricultural lands, and thus tend to have mineral soils which gradually accumulate organic matter with age; the relatively low ranges of soil total C and N in this study were fairly typical for created wetlands (Stolt et al. 2000; Anderson et al. 2005). Natural wetlands feature comparatively organic soils, suggested in this study by greater soil C and N, and to some extent by greater soil moisture, reflecting lower bulk density and increased pore space. Created wetland soil moisture, C, and N also increased with both disking and age. Higher P and Fe in natural wetlands may reflect the presence of humic-Fe-P complexes, characteristic of more organic soil.

The contrast between the more recently-flooded mineral/clay soils of the created wetlands and the comparatively more developed organic sandy soils of the natural wetlands may explain the negative correlations between mineral cation elements (Ca, Mn) and C, N, and P. Chemical properties of the weathering rock substrate may be a source of site differences as well; North Fork, for instance, is geologically associated with extrusive basalt, so higher Ca and Mg should be expected. Greater groundwater connectivity and soil permeability also distinguishes the natural from the created wetland study sites. Thus, soil samples collected during a low-water season at a site with greater groundwater recession might be expected to have diminished quantities of soluble nutrients, as was observed for Ca, Mg, and Mn at Huntley Meadows. Current and prior land use may also be a factor; the agricultural/pastoral rural setting of the created wetland sites may promote nutrient depletion, while Huntley Meadows' urbanized setting may contribute nutrients to the wetland.

Due to cultivation and chemical soil amendments, agricultural lands tend to lack nutrient heterogeneity. The low microtopographic relief ordinarily imparted by wetland creation practices further imposes uniformity of soil conditions. Such conditions were apparent from low variances in nutrient concentrations and comparatively low microtopographic index values for non-disked sites, but not for the (disked) created wetlands generally. The PCA ordination suggests that two of the created wetlands (North Fork, all of which was disked, and non-disked Cedar Run) had less nutrient variability than natural wetlands, evident from the relative spread of points for each study location along the first two component axes. The variability within the disked Cedar Run wetland, however, was more comparable to that of the natural wetland.

Significant inequalities of variance were observed for inorganic N, orthophosphate-P, and K, nutrients that are critical for plant growth. While it is difficult to make a fair comparison between the created and natural wetlands based on gravimetric determinations of nutrient concentrations (Wheeler et al. 1992; Bridgham et al. 1998), it is worth noting that the variances of disked wetlands compared favorably with those of the natural wetlands. Non-disked wetlands had comparatively low variance, supporting the contention that nutrients are spatially homogeneous in microtopographically homogeneous created wetlands (Bruland et al. 2006).

The contrast between disked and non-disked created wetlands at Cedar Run is striking, given their shared setting and conditions. Although of the same age, disked sites had higher moisture content than non-disked, possibly attributable to increased storage in soil voids or to increased depression storage. The microrelief induced by disking also appears to enhance availability of certain nutrients, as well as nutrient variability. The disked Cedar Run sites had

higher Mehlich-3 extractable Fe and Mn, and much (7x) higher NH_4-N than the non-disked sites, even though total soil N was comparable. The latter may indicate increased prevalence of nitrogen mineralization relative to nitrification, as might be expected when anaerobic conditions predominate due to greater soil moisture, or it might indicate better nutrient retention. However, it could be a consequence of soil inversion and consequent exposure of previously unavailable organic N substrate to microbial activity, particularly since disking was recent, within a year (Silgram & Shepherd 1999; Calderon & Jackson 2002).

The range of Mehlich-3 extractable P was somewhat lower than values reported for other created freshwater wetlands (Anderson et al. 2005). Available P was low or very low for created wetlands, and low to medium for natural wetlands (Tisdale 1993; Sims et al. 2002). North Fork, in particular, had very low P concentrations (moisture-adjusted $\bar{x}$ = 0.6 μg ortho-P/g) and iN:iP ratios suggesting P limitation. In this study, the iN:iP and [P/(Al+Fe)] ratios reflect soil conditions at peak growth, when a great extent of P cycling within the system might be expected to be in living plant material, as opposed to in the soil. However, low P availability and/or P limitation at this time could affect the growth of late-season developing plants (Boeye et al. 1999).

The intercorrelations among total C and N, P and Fe (and to a lesser extent Al) suggested the importance of humic-metal complexes with adsorbed P, potential sources of P for plant uptake. This result accords with other studies associating extractable Al and Fe with soil organic content (Axt & Walbridge 1999; Darke & Walbridge 2000). Since Fe appears to play a role in P availability, the significant differences in group variances for Fe take on greater importance than the somewhat less definitive differences in Al group variances. Although orthophosphate-P did not differ between disked and non-disked created wetlands, mean differences in Fe may be important both because P limitation was implicated and because P availability influences plant community composition (Güsewell & Koerselman 2002).

Differences in NH_4-N are also important, as this form of N is readily available to plants, and N is commonly limiting (or co-limiting) in freshwater wetlands (Bedford et al. 1999). At very low nutrient levels, vegetation diversity is likely to decline (Tilman 1997; Güsewell et al. 2005), so to the extent that disking enhances retention and variability of nutrients, it is likely to promote diversity as well as productivity during early ecosystem development; moreover, nutrient heterogeneity may also reduce competitive exclusion (Tilman 1997). The concomitant plant and functional diversity may enhance ecosystem stability and resilience (Tilman 1996; Loreau 200).

Explanatory mechanisms were not strongly evident from the study data. The correlation between moisture content and pLD confirmed our expectations based on the utility of limiting elevation difference in predicting depression storage (Kamphorst et al. 2000); it also comports well with the empirical observation that sites with greater microtopographic relief were often associated with the presence and persistence of standing water. If Fe concentrations are attributable to the microtopographic effects of disking, the results are consistent with net upward translocation of Fe and P from reducing to oxidizing soil layers (Fiedler et al. 2004). However, relative elevation correlated with neither Fe nor P, in contradiction. It has been suggested that upward transport of Fe and P is limited to recycling within the top 30 cm of soil (Hunt et al. 1997). As such, the effect of soil inversion by disking would not be expected to increase Fe or P. A possible explanation is that more pronounced flooding in the disked soils leads to development of poorly crystalline hydroxides of iron that are more easily extracted and enhanced release of phosphate to solution (Patrick & Khalid 1974; Gambrell & Patrick 1978); indeed, some evidence

suggests Fe is less crystalline in microlows than in microhighs (Darke & Walbridge 2000). Alternatively, disked microtopography may simply prevent leaching of Fe to soil layers below the root zone and runoff-induced loss.

Conclusions

Though disking clearly provides microtopographic variability not otherwise evident in created wetlands, it does so at a specific scale, with vertical relief on the order of that shown to promote floristic diversity in controlled experiments (Vivian-Smith 1997). Measured as tortuosity or as limiting elevation difference, this effect was apparent at all the spatial extents (i.e., transect scales) in the companion study (Moser et al. 2007). Consequently, though disking promotes microtopographic heterogeneity evident at small spatial extents, it nonetheless represents topographic uniformity when considered at the full spatial extent of a created wetland. Disking-induced microtopography is thus qualitatively different from excavated hummocks/hollows, which provide greater topographic relief in distinct locations. Because disking covers a wide area, its effects apply broadly, whereas hummock/hollow topography yields localized benefits (e.g., pools, patches of vegetation).

A number of soil characteristics associated with disked microtopography are beneficial in wetland mitigation. Increased soil moisture with increasing microrelief suggests that microtopography enhances wetland hydrology, a legal and functional mitigation success criterion, and resulting anaerobic conditions may increase the prevalence of wetland plants. Increased variability of soil nutrients and hydrologic conditions are expected to promote plant diversity by catering to a wider spectrum of plant capabilities and demands. In terms of functional replacement of lost wetlands, the enhanced soil development and nutrient variability should promote a greater complexity of processes and interactions than might be supported by more typical wetland creation methods. As a relatively low-cost method to establish microtopography in mitigation wetlands, disking is recommended, though it should not preclude other methods of inducing microtopography.

Implications for Practice

- In contrast to natural wetlands they are intended to replace, created mitigation wetlands are often characterized by uniformity of soil conditions, including hydrology, nutrients, and microtopography.
- Created wetlands may be disked to establish microtopographic variability, affecting the distribution of nutrients as well as the frequency and duration of flooding, creating heterogeneous soil conditions comparable to those in natural wetlands
- Disking also appears to increase retention of soil nutrients and moisture, enhancing accumulation of organic material and promoting the development of organic soils from the mineral soils typically used to create mitigation wetlands.
- Disking-induced microtopography may help ensure that created mitigation wetlands adequately replace lost wetland functions, as well as meet criteria for legal mitigation success.

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Table 1: Proximal microtopographic indices for tortuosity (pT), limiting elevation difference (pLD), and soil moisture content. Mean ± 1 SE.

	pT	pLD (cm)	Moisture %
North Fork (disked)	1.013 ± .002	5.0 ± .8	26.5 ± .5
Cedar Run (disked)	1.012 ± .001	6.1 ± .9	22.8 ± .8
Cedar Run (non-disked)	1.003 ± <.001	1.6 ± .2	16.8 ± .7
Huntley Meadows (natural)	1.011 ± .003	4.3 ± .7	32.4 ± .5

Table 2: Spearman rank correlations among measured soil/microtopographic parameters. Boldface indicates correlation is significant at the 0.01 level; underlining indicates correlation is significant at the 0.05 level.

	pT	pLD	Elev	% Moist	C	N	NO3	NH4	P	oP	K	Ca	Mg	Fe	Mn
pLD	**.616**														
Elev	-.018	-.058													
% Moist	.083	**.221**	-.012												
% C	-.027	.100	.040	**.836**											
% N	-.042	.076	.047	**.841**	**.974**										
NO3-N	-.058	-.015	-.008	**.411**	**.466**	**.524**									
NH4-N	.048	.102	-.128	**.444**	**.474**	**.426**	-.027								
P	-.109	.041	-.067	**.365**	**.385**	**.314**	-.176	**.711**							
oP	-.082	.027	-.091	**.355**	**.398**	**.336**	-.220	**.757**	**.901**						
K	**-.214**	-.122	**-.214**	.041	.174	.160	**.207**	**.252**	**.370**	**.324**					
Ca	.150	.044	.023	**-.286**	**-.244**	-.181	**.354**	**-.514**	**-.606**	**-.615**	.078				
Mg	.045	.007	.027	-.035	-.030	.054	**.489**	**-.545**	**-.595**	**-.632**	.075	**.877**			
Fe	-.003	.115	-.086	**.448**	**.513**	**.429**	-.085	**.692**	**.759**	**.763**	**.389**	**-.429**	**-.418**		
Mn	**.224**	.141	.057	**-.284**	**-.262**	**-.215**	.165	**-.312**	**-.477**	**-.436**	-.034	**.838**	**.658**	**-.329**	
Al	**-.214**	-.073	-.025	**.204**	**.333**	**.306**	.129	**.259**	**.542**	**.429**	**.636**	-.033	.076	**.552**	-.040

Table 3: Analysis of covariance (ANCOVA) adjustment of means for moisture content. Unadjusted and adjusted means; *p*-value for significance of covariate. na = not adjusted.

	North Fork (disked)		Cedar Run (disked)		Cedar Run (non-disked)		Huntley Meadows (natural)		
	Unadj	*Adj*	*Unadj*	*Adj*	*Unadj*	*Adj*	*Unadj*	*Adj*	*p*
C %	1.59	1.31	1.00	1.06	0.67	1.27	2.60	na	< .001
N %	0.14	0.12	0.09	0.09	0.07	0.11	0.20	na	< .001
P, µg/g	2.2	2.1	7.5	8.6	3.0	6.1	17.0	15.0	.009
ortho-P, µg/g	0.7	0.6	7.2	8.4	1.7	5.0	16.3	14.3	.011
Ca, µg/g	846	944	344	337	464	369	101	na	.004

Table 4: Summary of multiple comparison groupings for equality of variance (α=0.05, Bonferroni-adjusted). Groups sharing the same letter within a row are statistically indistinguishable (A=highest variance, D=lowest). Overall test for total N was significant (α =0.05), but multiple comparisons were not. # indicates exclusion of sites from ANCOVA and associated Levene's test.

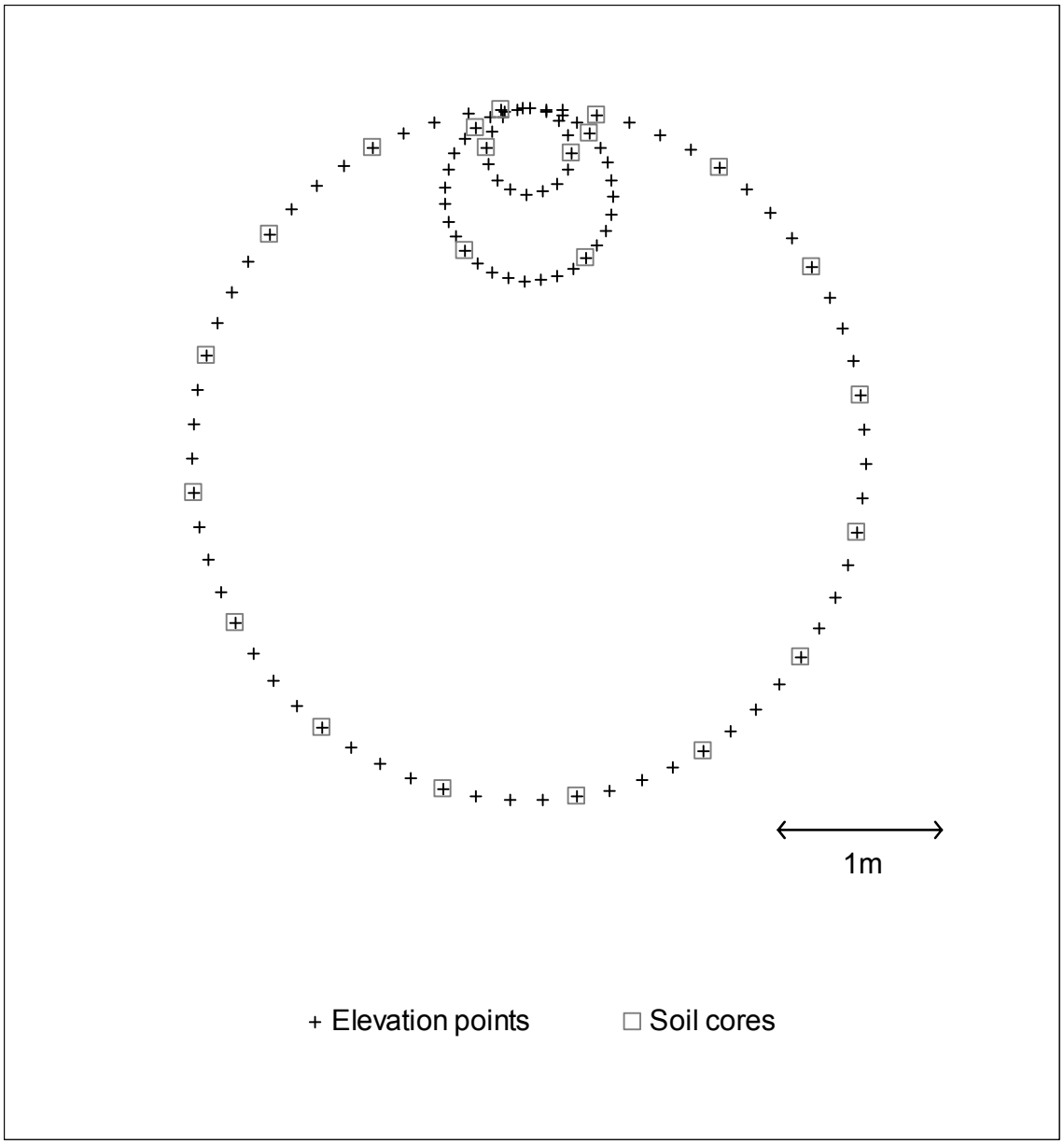
	Levene's test for equality of variance				North Fork	Cedar Run	Cedar Run	Huntley Meadows
	df1	*df2*	*F*	*p*	(disked)	(disked)	(non-disked)	(natural)
Moisture	11	150	5.63	< .001	B	B	C	A
Total C #	7	97	1.91	.077	–	–	–	#
Total N #	7	97	2.62	.016	–	–	–	#
NO_3-N	11	147	9.70	< .001	A	C	C	B
NH_4-N	11	147	13.87	< .001	C	A	D	B
Total P (ICP)	11	149	4.09	< .001	C	A	BC	AB
o-P (colorimetry)	11	149	7.16	< .001	B	A	B	A
K	11	149	2.61	.005	A	A	AB	B
Ca #	7	98	1.16	.33	–	–	–	#
Mg	11	149	2.40	.009	A	AB	AB	B
Mn	11	149	0.61	.82	–	–	–	–
Fe	11	149	4.56	< .001	B	A	C	AB
Al	11	149	2.85	.002	B	AB	B	A

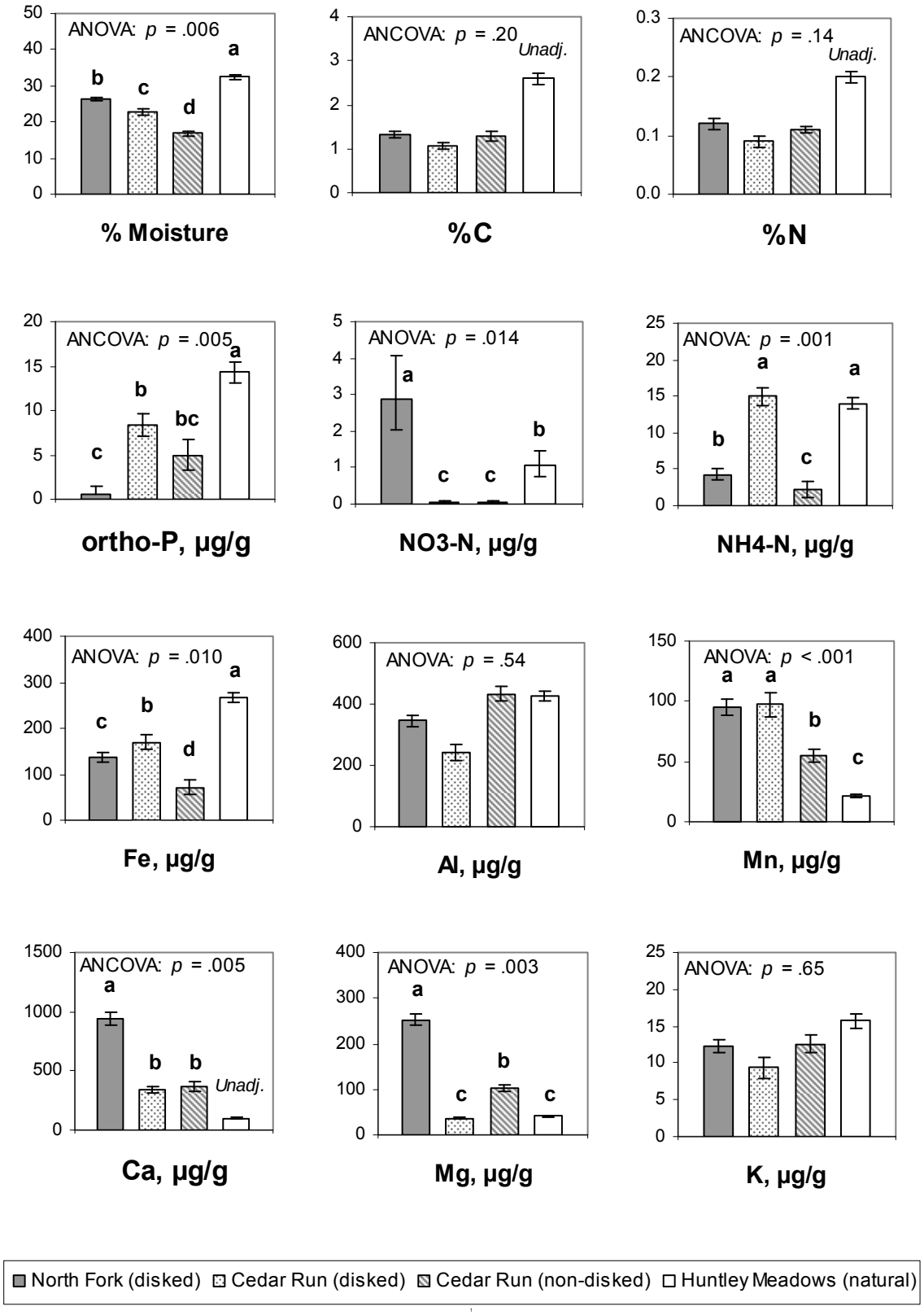
LIST OF FIGURES

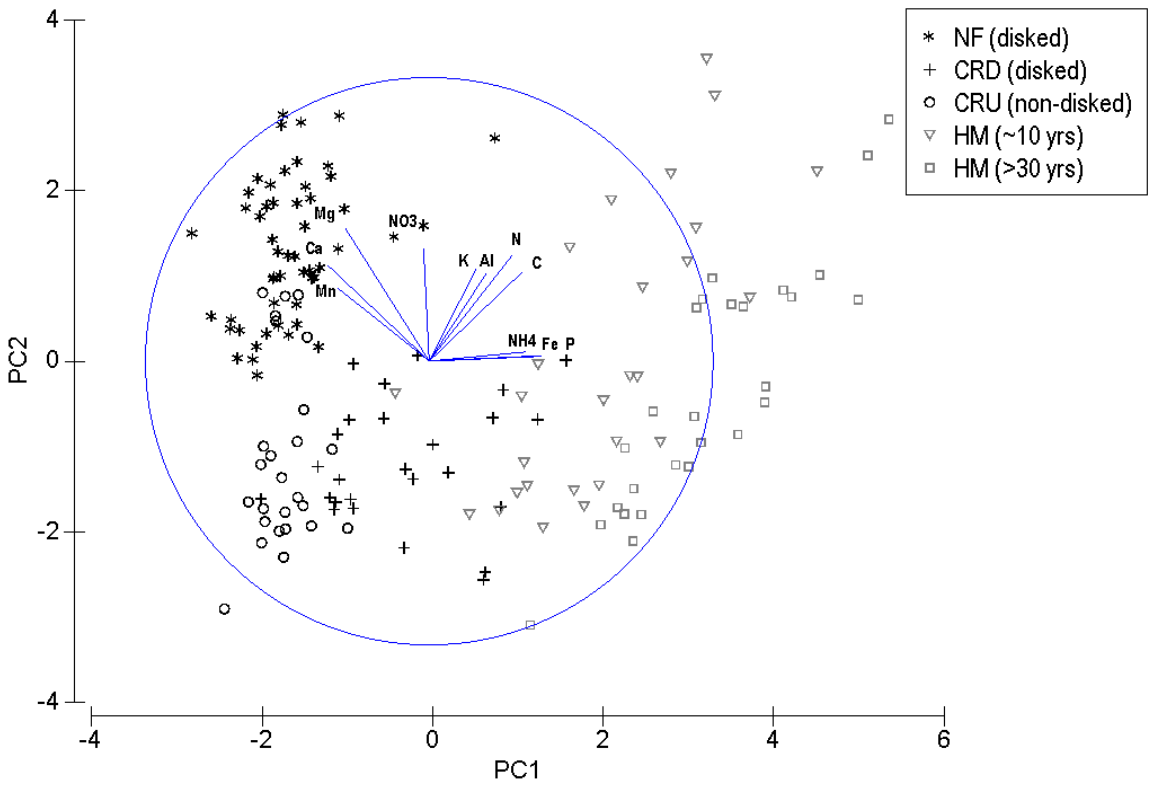
Figure 1: Multiscale circular transects. Microtopographic elevation data point intervals are 10 cm for 0.5 m- and 1 m transects, 20 cm for the 4 m transects. Soil sampling locations are at 80 cm intervals.

Figure 2: Comparison of group mean values (modified population mean) for nutrient parameters. Log-transformed variables Ca, Mg, Mn, and NO_3-N are reported in original units. Means provided for C%, N%, Ca, P, and ortho-P are moisture-adjusted, except where otherwise indicated. Error bars: ±1 SE.

Figure 3: Principal components Analysis (PCA) ordination of normalized nutrient data, first two component axes.


1m
+ Elevation points
Soil cores


ANOVA: p = .006
% Moisture
ANCOVA: p = .20
Unadj.
%C
ANCOVA: p = .14
Unadj.
%N
ANCOVA: p = .005
ortho-P, µg/g
ANOVA: p = .014
NO3-N, µg/g
ANOVA: p = .001
NH4-N, µg/g
ANOVA: p = .010
Fe, µg/g
ANOVA: p = .54
Al, µg/g
ANOVA: p < .001
Mn, µg/g
ANCOVA: p = .005
Unadj.
Ca, µg/g
ANOVA: p = .003
Mg, µg/g
ANOVA: p = .65
K, µg/g
North Fork (disked)
Cedar Run (disked)
Cedar Run (non-disked)
Huntley Meadows (natural)


NF (disked)
CRD (disked)
CRU (non-disked)
HM (~10 yrs)
HM (>30 yrs)
Mg
Ca
Mn
NO3
K
Al
N
C
NH4
Fe
P
PC2
PC1
4
2
0
-2
-4
-4
-2
0
2
4
6

Grant No. 06HQGR0153 Modernizing U.S. Army Corps of Engineers Policies and Programs: Phase II

Basic Information

Title:	Grant No. 06HQGR0153 Modernizing U.S. Army Corps of Engineers Policies and Programs: Phase II
Project Number:	2006VA116S
Start Date:	4/1/2006
End Date:	12/31/2009
Funding Source:	Supplemental
Congressional District:	9
Research Category:	Social Sciences
Focus Category:	Management and Planning, Law, Institutions, and Policy, None
Descriptors:	
Principal Investigators:	Stephen H. Schoenholtz

Publications

1. None
2. None
3. None
4. None

Award No. 06HQGR0153
Modernizing U.S. Army Corps of Engineers Policies and Programs: Phase II

Interim documents prepared, but not yet available:

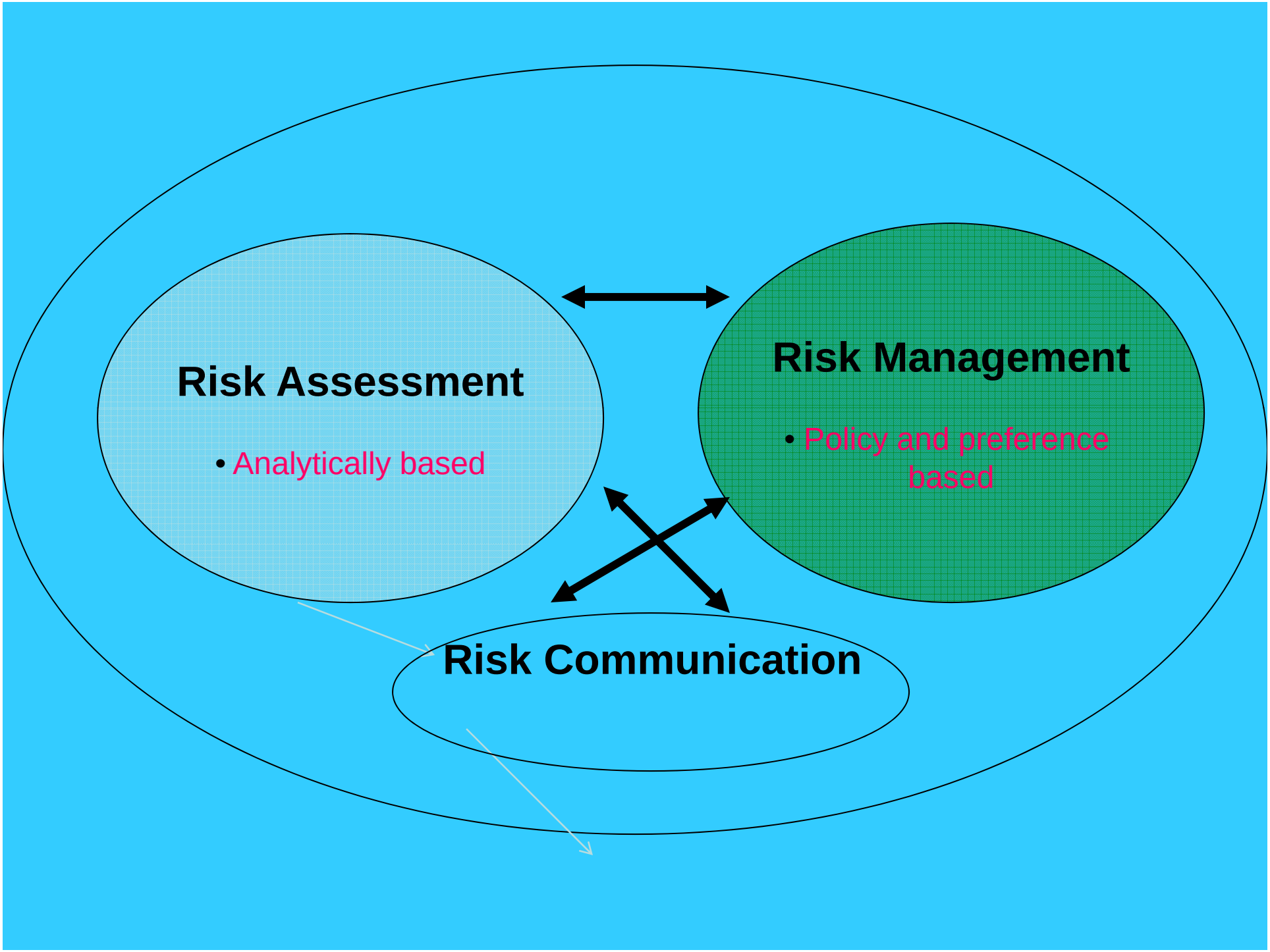
1. ***The Federal Role: A 60-Year Retrospective***
   Working draft by Douglas Woolley and Leonard Shabman
   Chapter 12 on Lessons from the Hurricane Protection Decision Chronology report

2. ***The Purpose and Goal for CADRe***
   Working draft by Leonard Shabman and Kurt Stephenson
   Chapter 2 in forthcoming IWR Maass-White Series publication

3. ***Executing CADRe: Integration of Models with Negotiation Processes***
   Working draft by Kurt Stephenson and Leonard Shabman
   Chapter 3 in forthcoming IWR Maass-White Series publication

4. ***Bringing CADRe to Contemporary Water Policy – Some Challenges***
   Working draft by Kurt Stephenson and Leonard Shabman
   Chapter 10 in forthcoming IWR Maass-White Series publication

National Levee Policy, Tolerable Risk, and the Responsibility of the Professional Engineer


Risk Assessment
• Analytically based
Risk Management
• Policy and preference based
Risk Communication

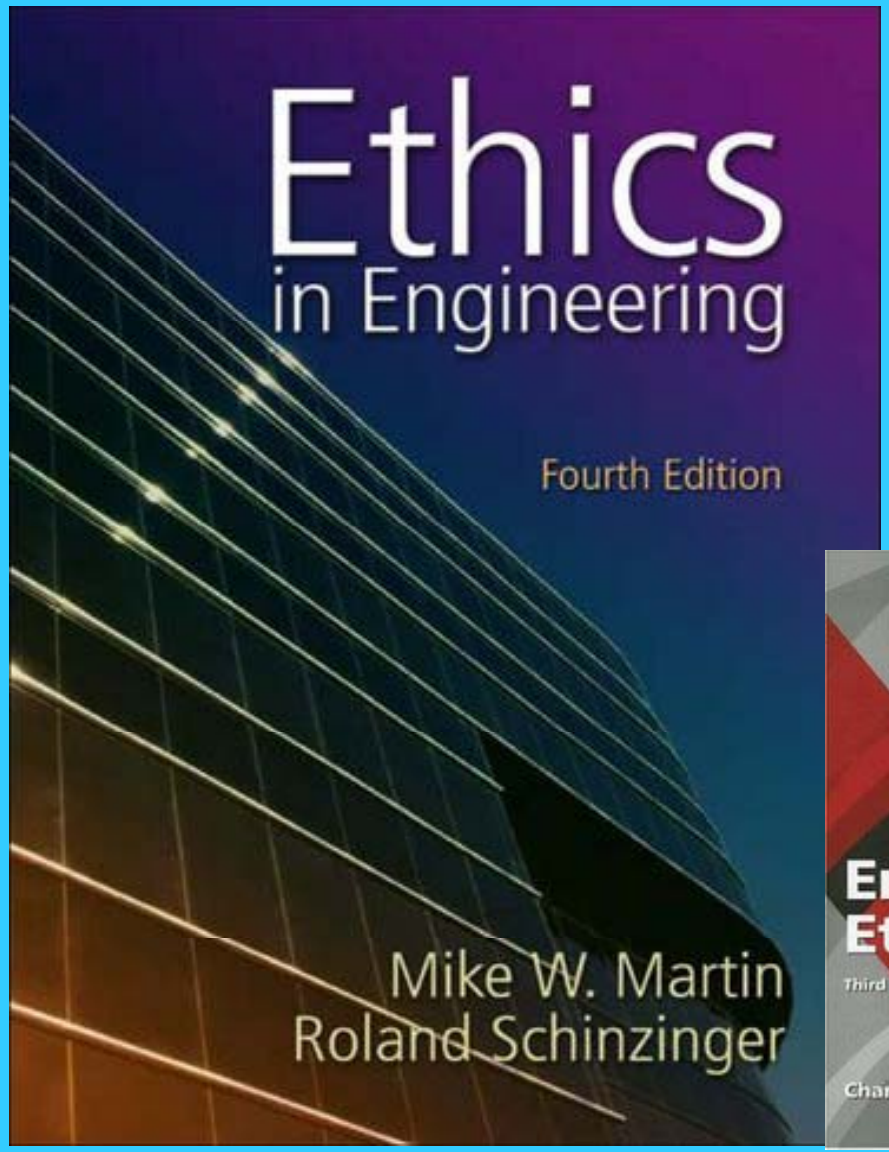
For every risk mitigation action there is a question, “Do risk reductions achieved justify the cost of reducing the risk?”

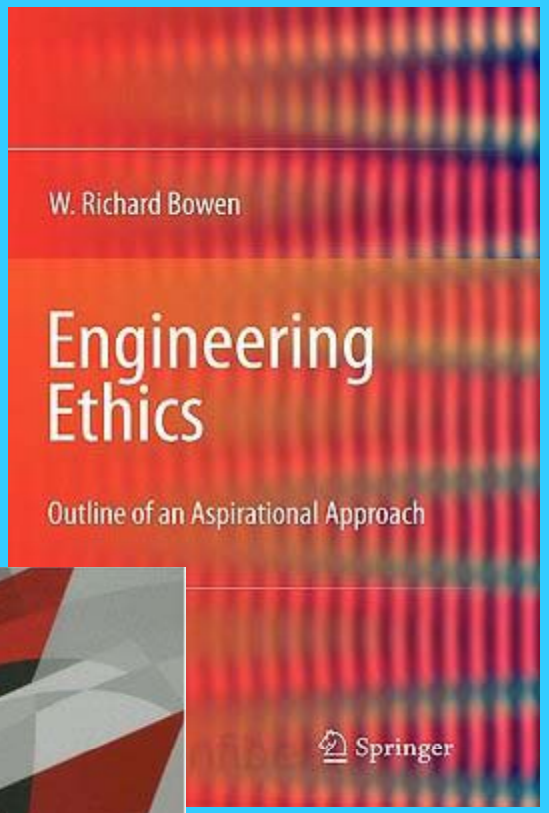
- Financial Outlays (all who pay get a say)
- Economic Costs
- Environmental Consequences of alternative designs
- Adverse Social and Cultural effects of alternative designs

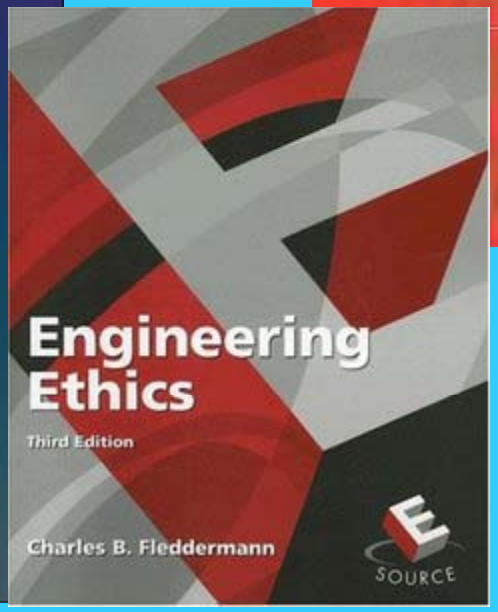
"Ever since the President indicated that risk should be a factor in evaluating water resources projects, the academic community and others have become strong advocates of satisfying the requirement by using statistical and probability theory to quantify the risk...

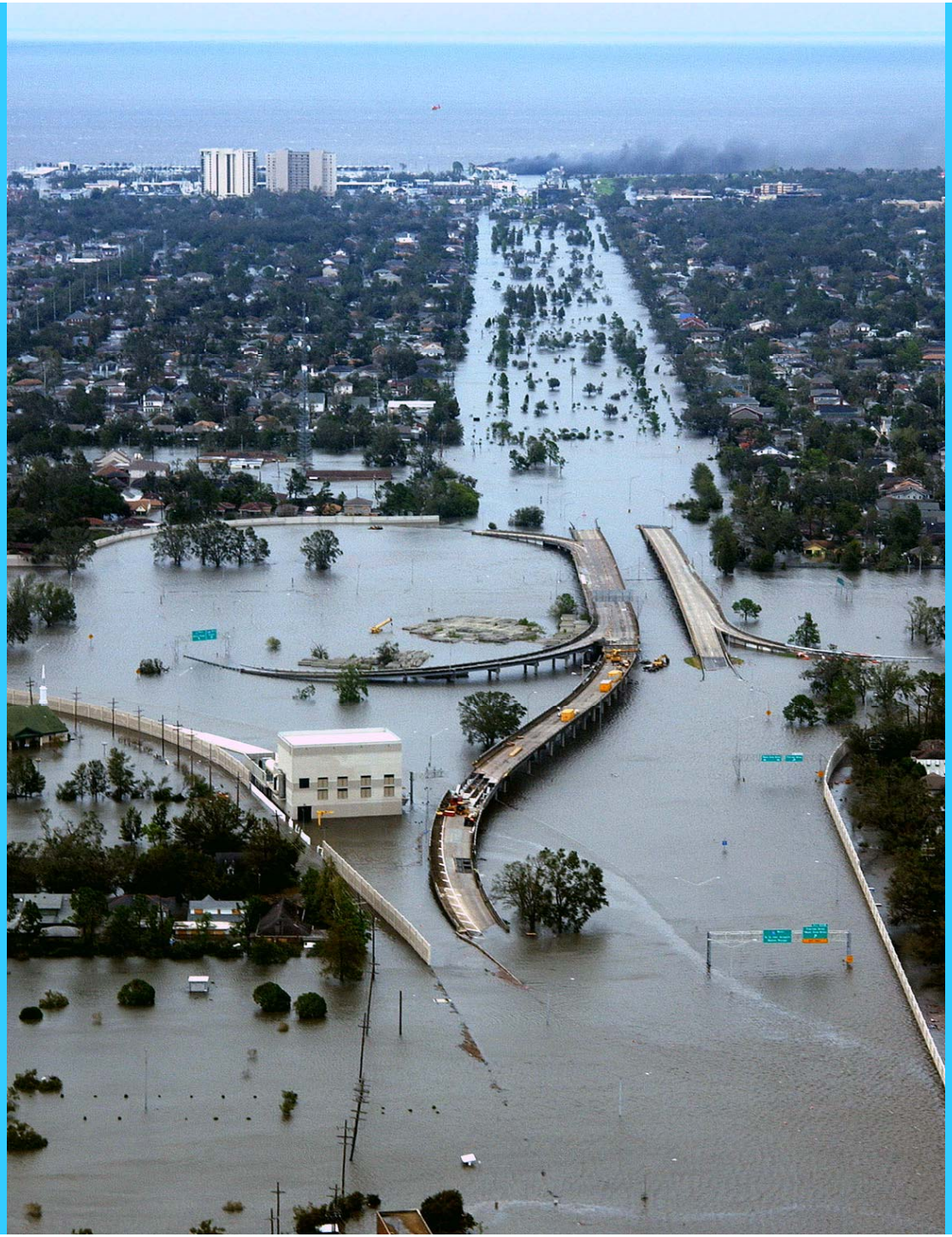
'Although some of the onslaught has been dampened, the forces advocating the use of risk analysis are inexorably growing. To counteract this, I believe we must become better acquainted with the subject and must attempt to influence the approach as much as possible."

(October 1980)


Ethics
in Engineering
Fourth Edition
Mike W. Martin
Roland Schinzinger


W. Richard Bowen
Engineering
Ethics
Outline of an Aspirational Approach
Springer


Engineering
Ethics
Third Edition
Charles B. Fleddermann
SOURCE



- http://www.youtube.com/watch?v=1nAxu8oaZmc&feature=player_embedded

Hold the Corps Accountable!

Levees.org

for the New Orleans Flood.

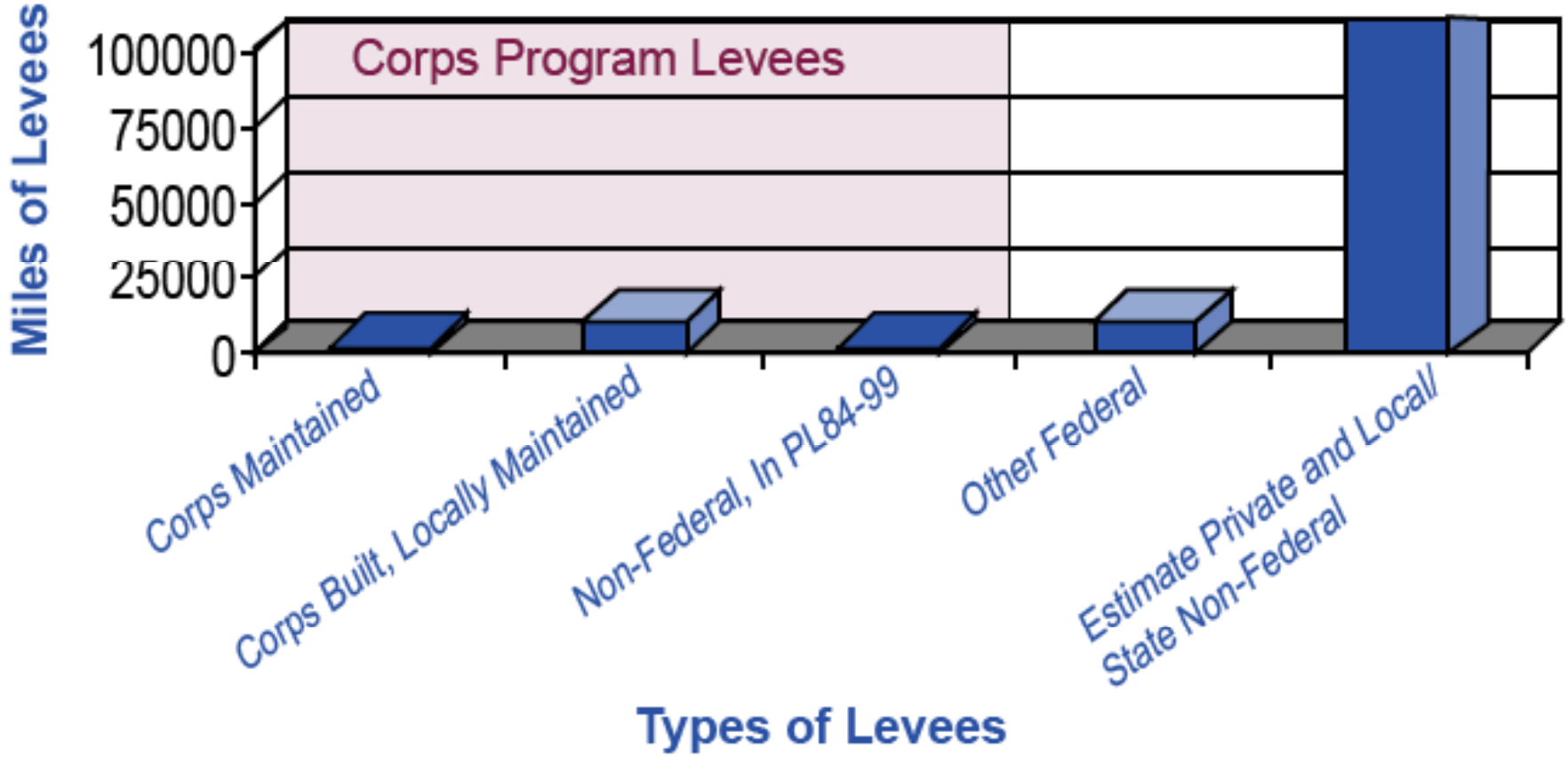
Post Katrina Fallout

National Committee on Levee Safety

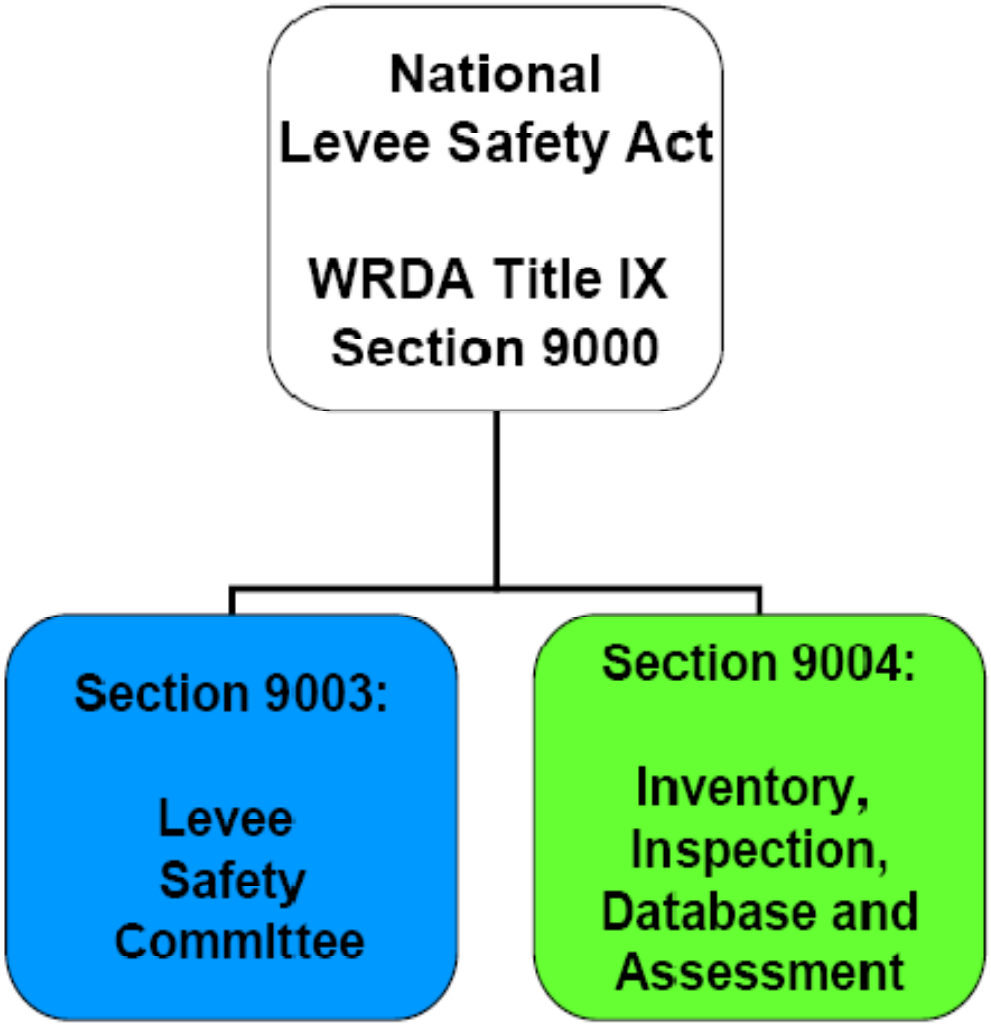
Captured by
Caley '09

Figure 6: United States Levees at a Glance

- *Average Age of Levees in Corps Programs = 50 Years*
- *Population in Leveed areas: Estimated to be Tens of Millions*
- *Some of the Major Urban Centers with Levees: New Orleans, Sacramento, Dallas-Fort Worth, St. Louis, Quad Cities, Louisville, Portland, Washington DC, Kansas City, Tulsa, Little Rock*



National Levee Safety Act



- **Complements Existing Activities & Authorities**
- **Two Major Components:**
  - Recommendations
  - Safety Data Collection
- **"One Time" Nature**
- **Levees Include:**

  Hurricane, Storm & Flood Structures:
  - Earthen embankments
  - Floodwalls
  - Structures along canals

“Put right practices in place to be sure Katrina does not happen again”

Google: Woolley Shabman IWR

The New York Times

July 11, 2007

Engineers Faulted on Hurricane System

By JOHN SCHWARTZ

Asked to explain its failure to protect New Orleans from flooding, the Army Corps of Engineers produced an answer yesterday: Bit by bit over some 50 years, the corps made a series of decisions based largely on dollars, politics and scheduling that inadvertently left the city's hurricane protection system substantially weaker than it should have been.

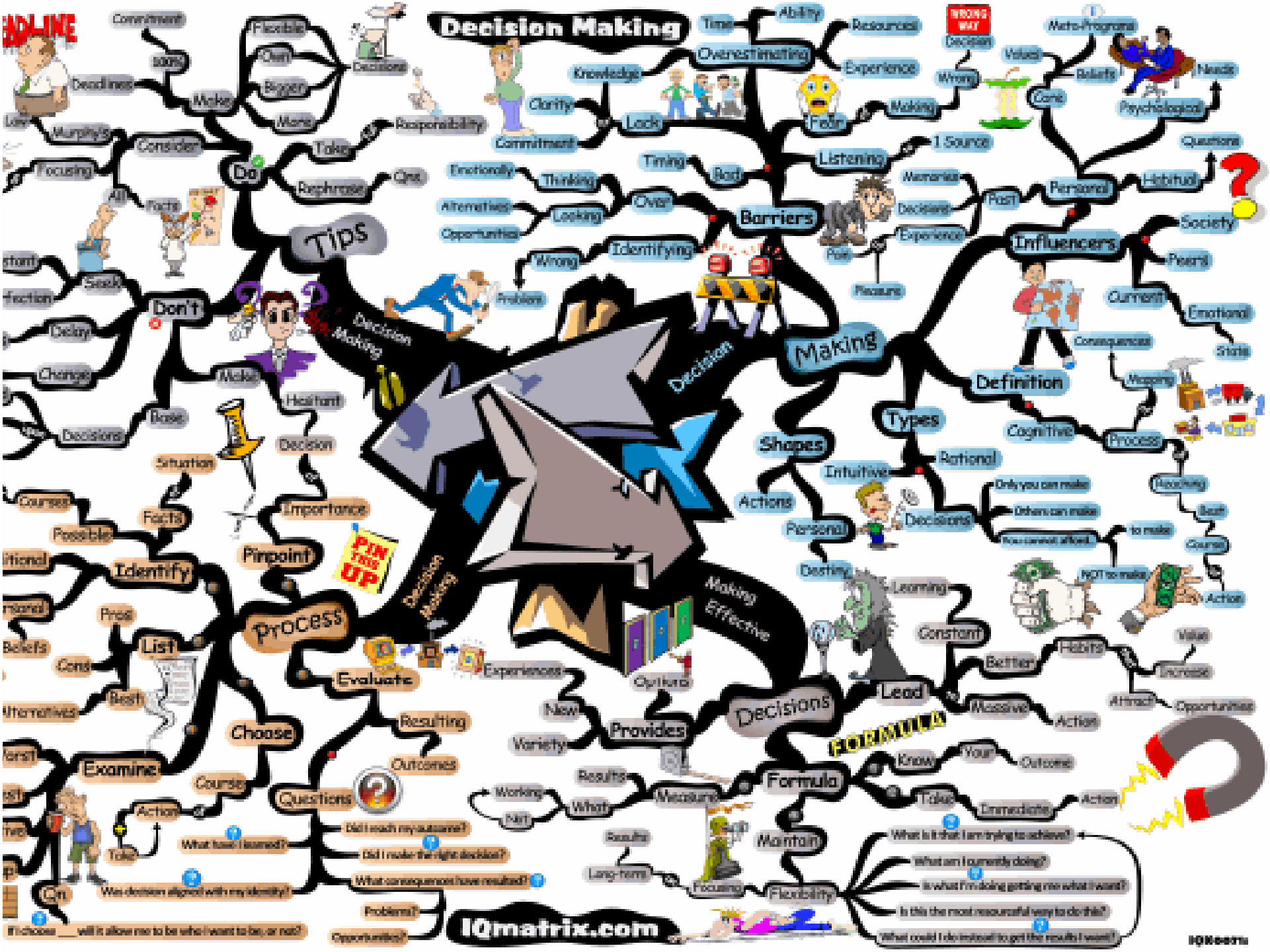
Understanding the History

“ Presentism is a mode of historical analysis in which present-day ideas and perspectives are anachronistically introduced into depictions or interpretations of the past. Most modern historians seek to avoid presentism in their work because they believe it creates a distorted understanding of their subject matter.”

Gordon Wood, The Purpose of the Past: Reflections on the Uses of History 2008

Decisions

- **Selection of the Design Storm in 1962**
  - **The Standard Project Hurricane (SPH) –Wind speed and CPI**
  - **Stillwater Surge**
  - **Structure Elevations**
- **The Treatment of New Information**
  - **Betsy (wind fields) and early PAC**
  - **Camille (PMH change)**
  - **1979 NWS Report (central pressure)**
  - **Computer Modeling (storm surge)**
  - **Benchmark Elevations**
  - **Parallel or Frontage Protection**
  - **Storm water Drainage**
  - **Authorization**
  - **Cost redistribution**
- **Congress Directs Parallel Protection**
- **Canal Walls**
  - **The Choice of I-Walls**
  - **New Design Criteria and Design Variations Over Time**


Decision Making
Tips
Don't
Identify
Pinpoint
Process
List
Choose
Examine
Evaluate
Questions
Barriers
Influencers
Making
Definition
Types
Shapes
Decisions
Lead
Formula
Provides
Maintain
Listening
Overestimating
Lack
Commitment
Thinking
Looking
Identifying
Problem
Decision Making
Decision
Making Effective
Decision Making
Did I reach my outcome?
Did I make the right decision?
What consequences have resulted?
Problems?
Opportunities?
What have I learned?
Was decision aligned with my identity?
If I choose ___ will it allow me to be who I want to be, or not?
What is it that I am trying to achieve?
What am I currently doing?
Is what I'm doing getting me what I want?
Is this the most resourceful way to do this?
What could I do instead to get the results I want?
IQmatrix.com

“While the Corps is not responsible for levees we did not build or for lack of funding for recommendations we made that were not funded, we do have accountability for our own design shortcomings and we should have done more to inspect and reassess the condition of the levees and communicate risk to the people of New Orleans.”

General Carl Strock, August 24, 2006 News conference transcripts

What do I think is the big lesson?

Have we learned the lesson?

"We as a society*, with input and guidance from engineers and scientists*, must determine the target for risk, how much we are willing to spend to achieve the target, and what the most effective use of our resources is in managing the risk we face"

ASCE external review panel, September 3 2008

What do we do now?

“Tolerable Risk Begins with the end in mind. …. “

“How do we balance the desire to reduce risk with the availability of resources? “

National Committee on Levee Safety, 2009

Consider the reliability of the data, the chances of exceedence of design floods, the consequences of exceedence and the potential for catastrophe. Judgment and the acceptability of risk are important elements in the process of arriving at the appropriate level of protection. *(Department of the Army, 12 December, 1975.)*

Engineering is a science that has as its purpose satisfying the wants and needs of people. In accomplishing this objective, the aim of the engineer should be to attain maximum results in the most economical manner. This cost optimization should provide the basis for selecting a project level of protection or evaluating alternative designs once project functional adequacy and safety are assured. In other words, only after design criteria have been achieved (minimum level of protection) can cost optimization be applied. (EM 1110-2-1611, sec. 14-1

When risk analysis was first proposed there was resistance among agency professionals

- Fear for Organizational and Professional Reputation
- Ethical Imperative

Operating simultaneously with the desire for advancement of professional reputation is the motivation to maintain a high level of public respect and stature for the employee's organization. Preservation and advancement of the organization's stature, while not a formally stated organizational objective, is generally a fundamental operational objective (Shabman and Cox, 1998).

“Trust seemed to be the biggest item on the agenda at the October 22 public meeting hosted by the U.S. Army Corps of Engineers in New Orleans.”

ENR, 10/24/2008

“ That engineers have moral and legal obligations beyond those of the ordinary citizen is well accepted. This is because trained engineers can perceive and evaluate hazardous conditions that ordinary persons are not aware of. This is especially true for man-made hazards, because engineers are often involved in making them ... In more basic ethical terms, the moral obligation of the engineer arises from the general philosophy that it is part of a natural relationship between human beings to warn and protect one another from hazards as far as they can be known. Because of his knowledge, therefore, an engineer has a higher moral obligation than one who is not knowledgeable in the field.” Adcock – 1978

http://www.cnn.com/video/data/2.0/video/us/2009/11/19/sot.la.canal.ruling.katrina.wgno.html

The Katrina Experience -- New interest in Risk Communication and Management

Assessment

Communication

Management

“As Low As Reasonably Practical”

The ALARP consideration states that risks lower than the tolerable risk limit are tolerable only if further risk reduction is impracticable or if the cost is grossly
disproportional to the risk reduction.

Determining that ALARP is satisfied is a matter of judgment.

NCLS, p. 37

... In more basic ethical terms, the moral obligation of the engineer arises from the general philosophy that it is part of a natural relationship between human beings to warn and protect one another from hazards as far as they can be known. Because of his knowledge, therefore, an engineer has a higher moral obligation than one who is not knowledgeable in the field."

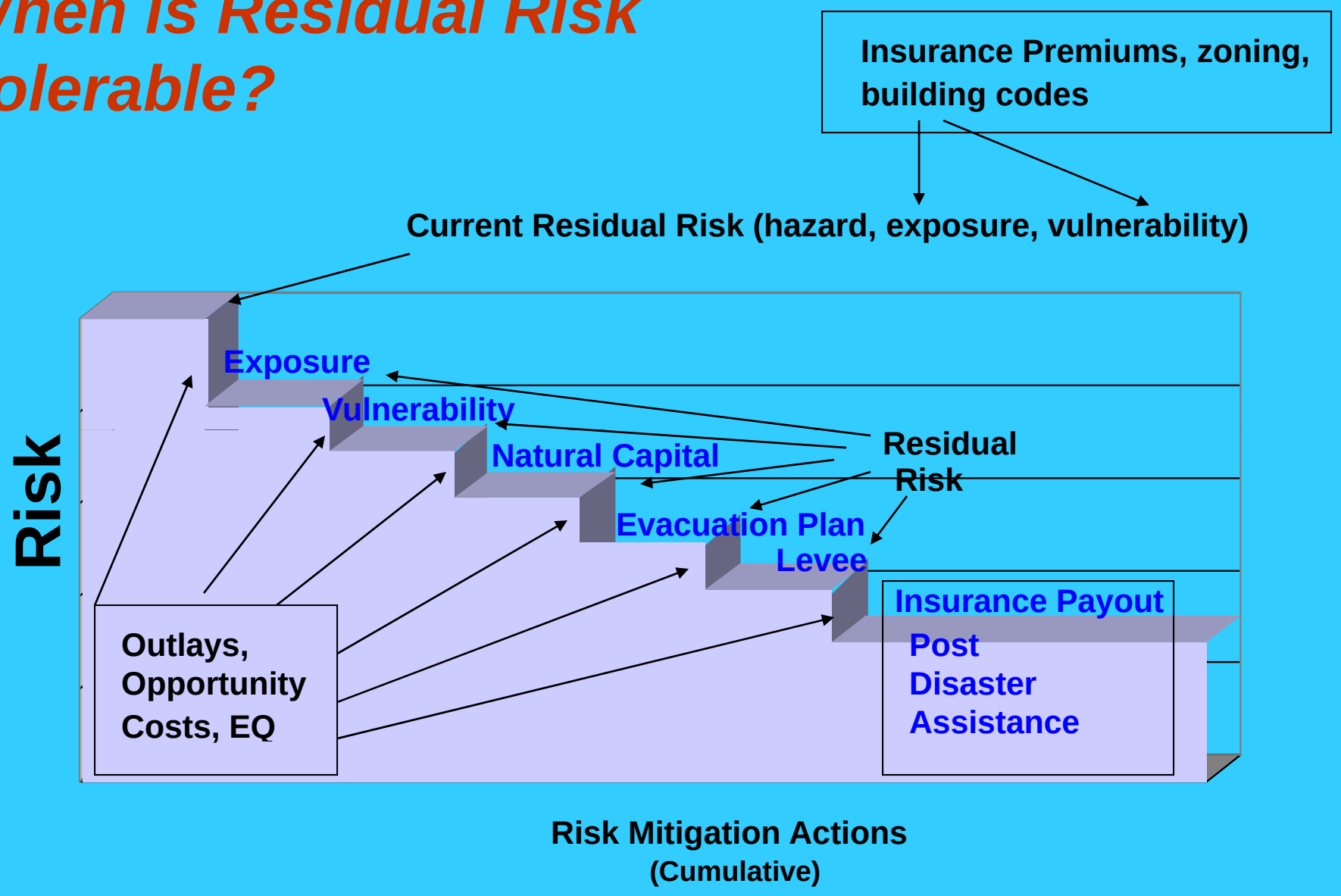
"moral relationships between engineers and the public should be of the informed-consent variety enjoyed by some physicians and their patients. In this moral model, engineers would acknowledge to their customers that they do not know everything. They would give the public their best estimate of the benefits of their projects (and alternative projects) and the dangers. And, if the public agreed, and the engineers performed honorably and without malpractice, even if they failed, the public would not hold them at fault."

"…expertise places them in a unique position to monitor projects, to identify risks, and to provide clients and the public with the information needed to make *<u>reasonable</u>*** decisions." (***emphasis added***)**

Martin and Schinzinger Ethics in Engineering, 2000

Why “we” need informed consent for a National Levees Policy ?

When is Residual Risk Tolerable?



"We" decide tolerable risk

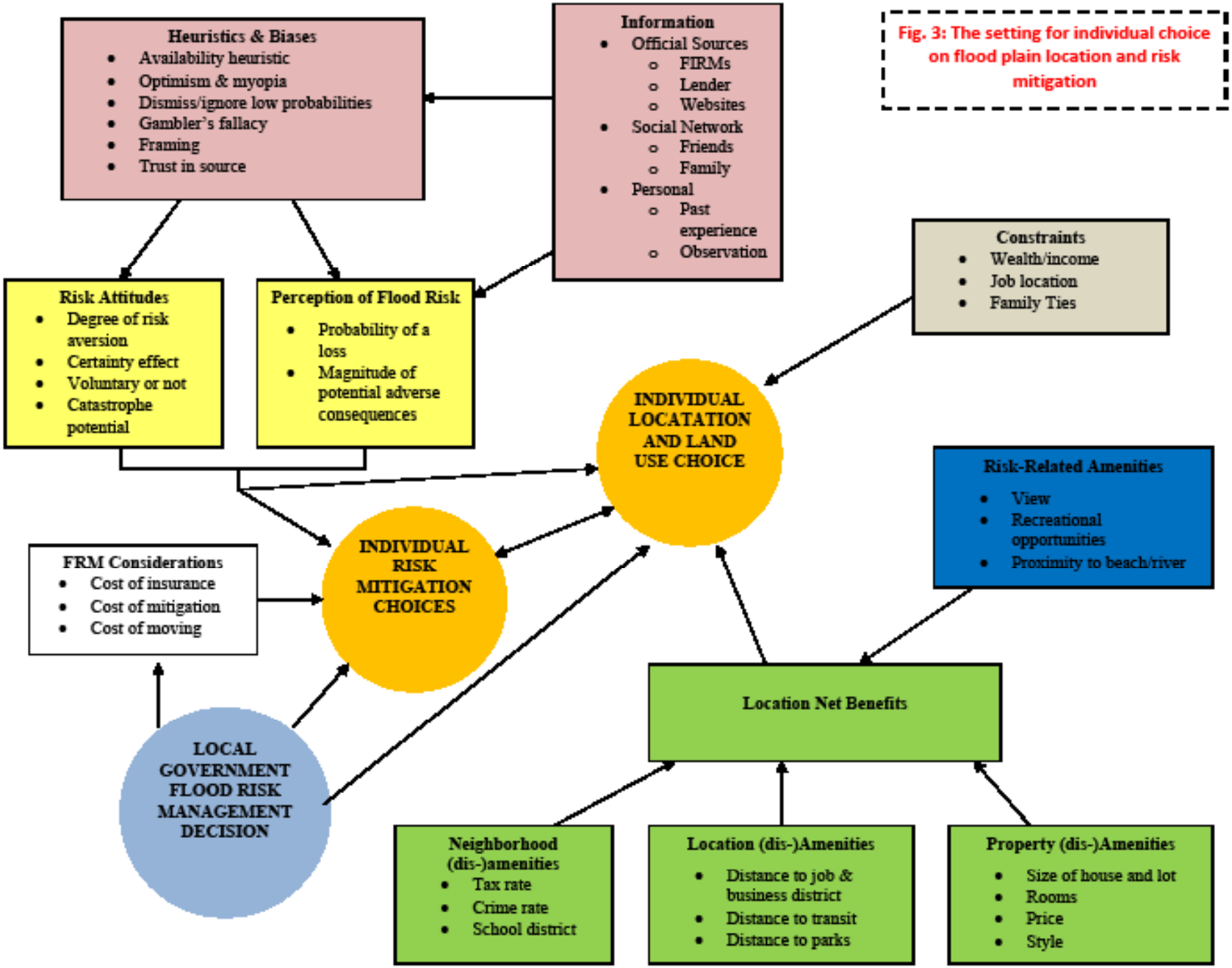
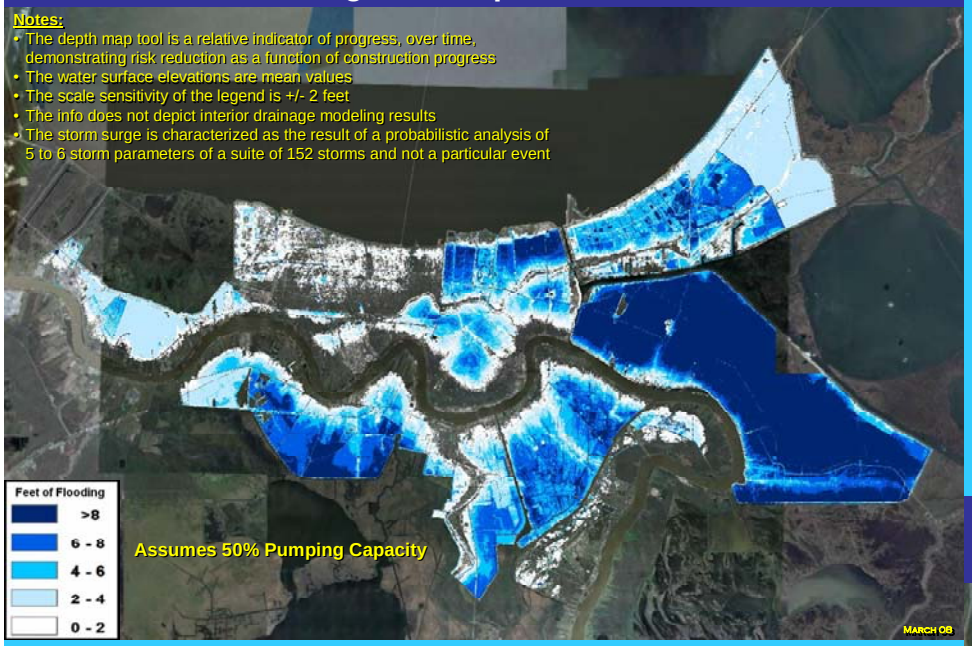
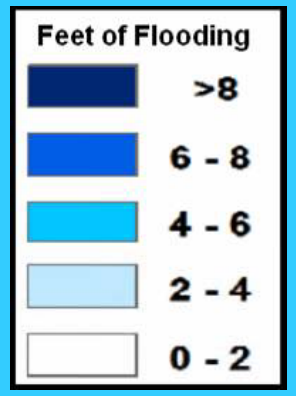


Fig. 3: The setting for individual choice on flood plain location and risk mitigation

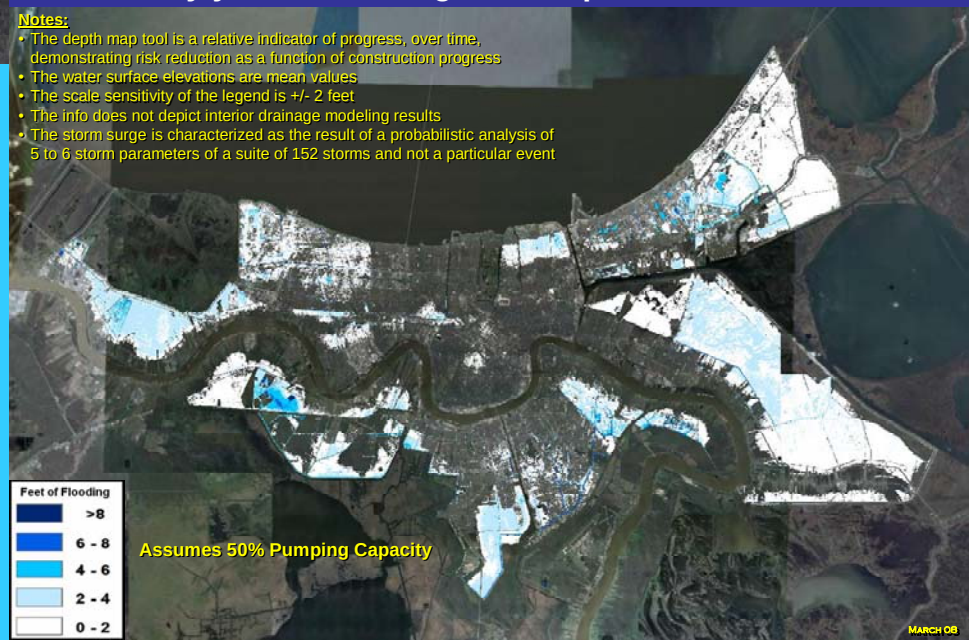
TFH Change in 1% Flood Depth Maps 2011

Before Katrina, you had a 1% chance every year of flooding this deep from Hurricanes

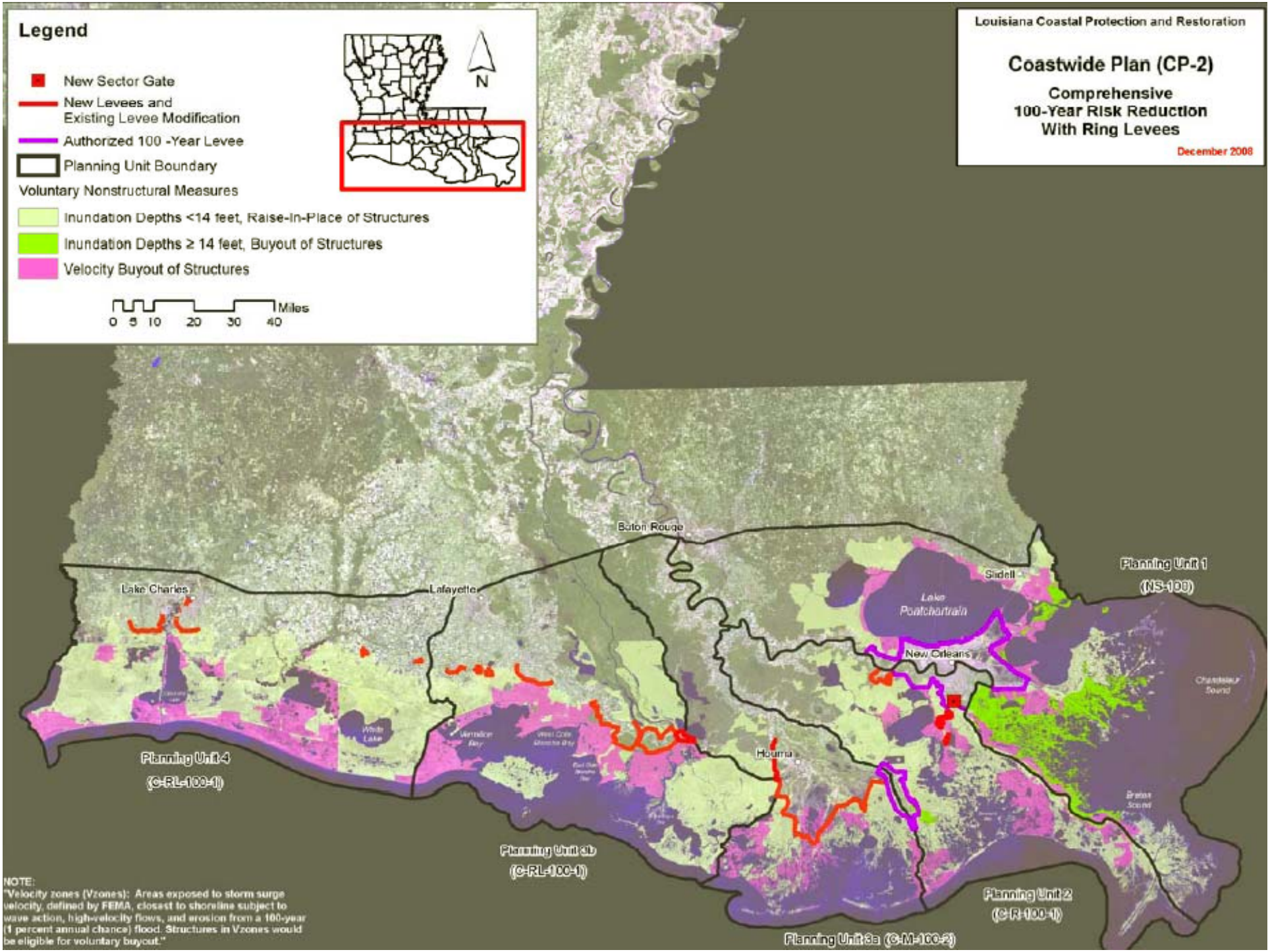


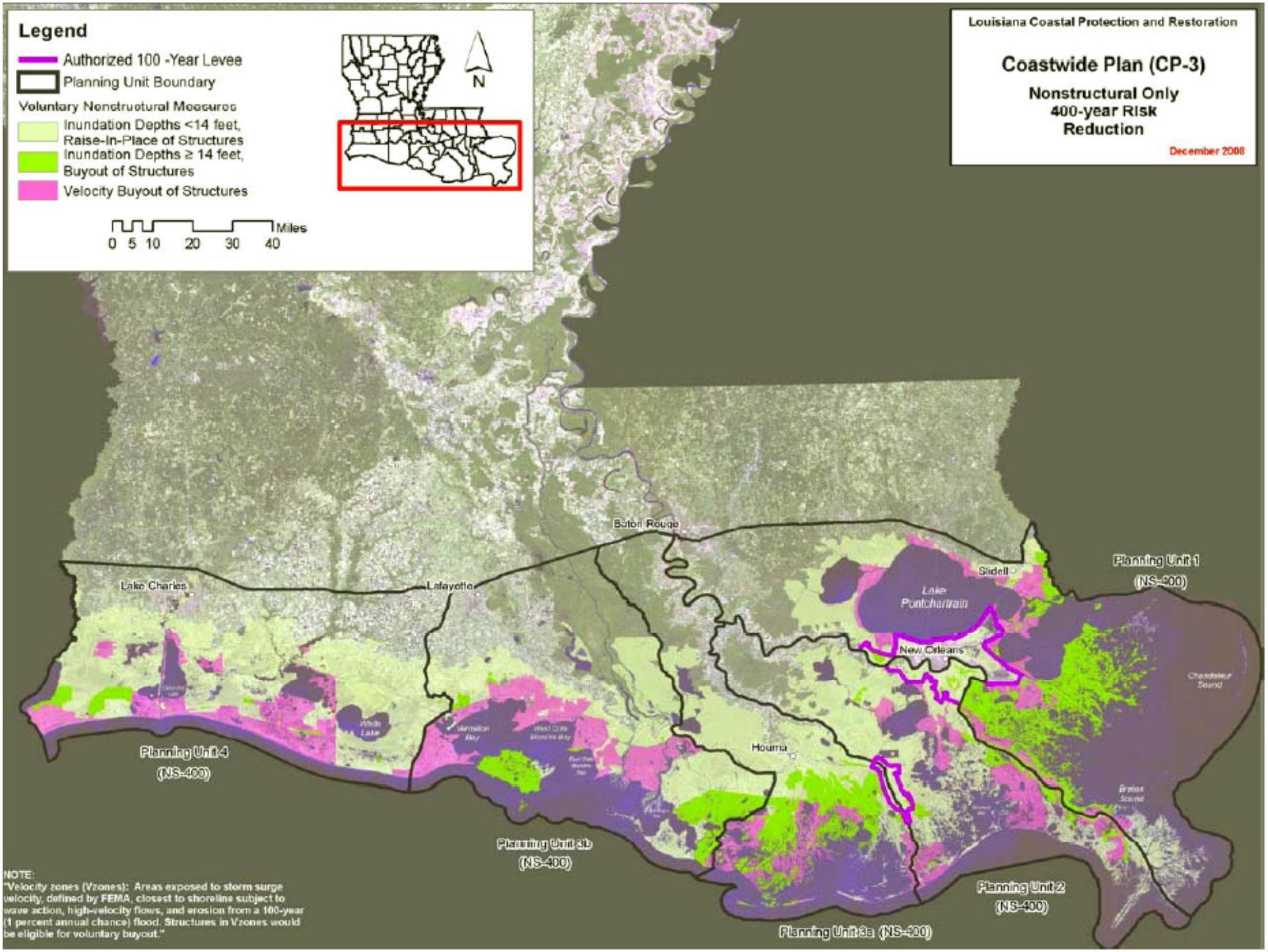


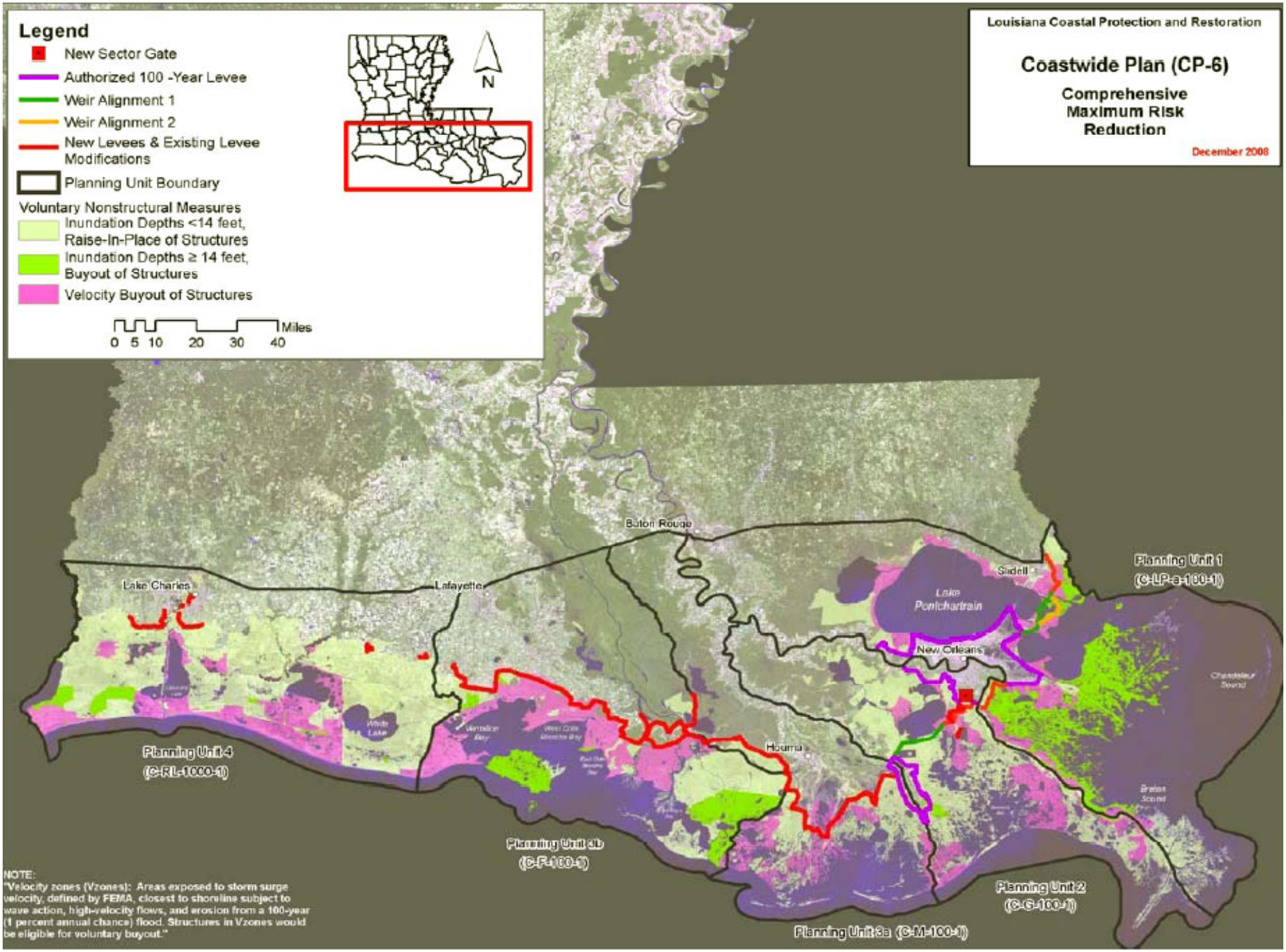
With the 100-year level of protection, you have a 1% chance every year of flooding this deep from Hurricanes



Public and political understanding the highly uncertain world of engineering design, of choices on performance and reliability vs. cost are not enough.


Legend
New Sector Gate
New Levees and Existing Levee Modification
Authorized 100 -Year Levee
Planning Unit Boundary
Voluntary Nonstructural Measures
Inundation Depths <14 feet, Raise-In-Place of Structures
Inundation Depths ≥ 14 feet, Buyout of Structures
Velocity Buyout of Structures
0 5 10 20 30 40 Miles
N
Louisiana Coastal Protection and Restoration
Coastwide Plan (CP-2)
Comprehensive
100-Year Risk Reduction
With Ring Levees
December 2008
Baton Rouge
Lake Charles
Lafayette
Sidell
Lake Pontchartrain
New Orleans
Houma
Planning Unit 1
(NS-100)
Planning Unit 4
(C-RL-100-1)
Planning Unit 3b
(C-RL-100-1)
Planning Unit 2
(C-R-100-1)
Planning Unit 3a (C-M-100-2)
NOTE:
"Velocity zones (Vzones): Areas exposed to storm surge velocity, defined by FEMA, closest to shoreline subject to wave action, high-velocity flows, and erosion from a 100-year (1 percent annual chance) flood. Structures in Vzones would be eligible for voluntary buyout."


Legend
Authorized 100 -Year Levee
Planning Unit Boundary
Voluntary Nonstructural Measures
Inundation Depths <14 feet, Raise-In-Place of Structures
Inundation Depths ≥ 14 feet, Buyout of Structures
Velocity Buyout of Structures
0 5 10 20 30 40 Miles
N
Louisiana Coastal Protection and Restoration
Coastwide Plan (CP-3)
Nonstructural Only
400-year Risk
Reduction
December 2008
Baton Rouge
Lake Charles
Lafayette
Slidell
Lake Pontchartrain
New Orleans
Houma
Planning Unit 1 (NS-400)
Planning Unit 4 (NS-400)
Planning Unit 3b (NS-400)
Planning Unit 2 (NS-400)
Planning Unit 3a (NS-400)
NOTE:
"Velocity zones (Vzones): Areas exposed to storm surge velocity, defined by FEMA, closest to shoreline subject to wave action, high-velocity flows, and erosion from a 100-year (1 percent annual chance) flood. Structures in Vzones would be eligible for voluntary buyout."


Legend
New Sector Gate
Authorized 100 -Year Levee
Weir Alignment 1
Weir Alignment 2
New Levees & Existing Levee Modifications
Planning Unit Boundary
Voluntary Nonstructural Measures
Inundation Depths <14 feet, Raise-In-Place of Structures
Inundation Depths ≥ 14 feet, Buyout of Structures
Velocity Buyout of Structures
0 5 10 20 30 40 Miles
N
Louisiana Coastal Protection and Restoration
Coastwide Plan (CP-6)
Comprehensive Maximum Risk Reduction
December 2008
Baton Rouge
Lake Charles
Lafayette
Slidell
Lake Pontchartrain
New Orleans
Houma
Planning Unit 1 (C-LP-a-100-1)
Planning Unit 4 (C-RL-1000-1)
Planning Unit 3b (C-F-100-1)
Planning Unit 2 (C-G-100-1)
Planning Unit 3a (C-M-100-1)
NOTE:
"Velocity zones (Vzones): Areas exposed to storm surge velocity, defined by FEMA, closest to shoreline subject to wave action, high-velocity flows, and erosion from a 100-year (1 percent annual chance) flood. Structures in Vzones would be eligible for voluntary buyout."

"... all designs for use are arbitrary. The designer <u>or his client</u> has to choose in what degree and where there shall be failure. Thus the shape of all things is the product of arbitrary choice. If you vary the terms of your compromise - say more speed, more heat, less safety, more discomfort, lower first cost - then you vary the shape of the thing designed. It is quite impossible for any design to be 'the logical outcome of the requirements' simply because, the requirements being in conflict, their logical outcome is an impossibility.“

David Pye, as quoted by Henry Petroski in his book "To Engineer is Human,“, 25 years ago!

USGS Grant No. 08HQGR0004 A Weight of Evidence Screening Value Approach to Nutrient Criteria Development for Wadeable Streams

Basic Information

Title:	USGS Grant No. 08HQGR0004 A Weight of Evidence Screening Value Approach to Nutrient Criteria Development for Wadeable Streams
Project Number:	2007VA123S
Start Date:	1/1/2008
End Date:	8/31/2009
Funding Source:	Supplemental
Congressional District:	09
Research Category:	Water Quality
Focus Category:	Water Quality, Surface Water, Methods
Descriptors:	
Principal Investigators:	Tamim Younos

Publications

1. None
2. None

Final Report

A Weight of Evidence Screening Value Approach to Nutrient Criteria Development for Wadeable Streams

Interagency Agreement Number DW-14-94426101-0

Submitted by
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Virginia Water Resources Research Center
Virginia Tech

August 15, 2009

Executive Summary

The objective of this project was to conduct a trial run of a weight of evidence nutrient-criteria screening value approach for wadeable freshwater streams. The proposed approach employs N and P screening values (nutrient-concentration thresholds below which monitoring sites are determined to be unimpaired by nutrients) and critical values (nutrient-concentration thresholds above which sites are considered impaired by nutrients). Streams with nutrient concentrations that do not allow assessment using the screening or critical values would be visually assessed. If the visual assessment is inconclusive, a benthic-macroinvertebrate assessment is employed to assess the stream.

In spring 2008 the Virginia Department of Environmental Quality (DEQ) initiated a pilot project involving stream sampling of benthic macroinvertebrate communities along with algae, chlorophyll and water samples at 29 selected sites. Additional sampling at 33 other sites occurred during the fall of 2008. The DEQ transferred data to the Academic Advisory Committee (AAC) for analysis.

Program results did not suggest screening values. In addition, the critical values suggested by the program results would be sufficient to assess only a very small number of monitoring sites because they are at the extreme upper end of the distribution of nutrient concentrations that occur in Virginia streams. Using a visual procedure, DEQ regional biologists were able to identify a subset of sites as impaired by nutrients, but they could not apply the visual-assessment method to prove that a stream was not impaired by nutrients.

An exploratory analysis was conducted in an attempt to develop an alternative procedure for identifying screening and critical values. In developing this procedure, it was recognized that the trade-offs embodied by the screening-value approach and sought to limit assessment errors to 10% or less. The “reference conditions” used by DEQ for other analyses was applied (including the development of the Stream Condition Index) to derive screening values. The 2001-2006 probabilistic-monitoring data were used for the exploratory analysis, and its results are considered for illustrative purposes only. The results of the analysis indicate that the technique employed shows promise as a potential mechanism for deriving screening values. However, as with the pilot program, the critical values suggested would be sufficient to assess only a very small number of sites because they are at the extreme upper end of the distribution of nutrient concentrations found in Virginia streams.

The analyses described above utilized data from nutrient concentrations measured from single-point-in-time water samples to characterize each monitoring site’s nutrient status. The Virginia DEQ, however, is expected to assess water-quality nutrient data collected over extended periods of time. A third analysis, therefore, was conducted for the purpose of exploring the stability in time of TN and TP concentrations in Virginia streams. The results indicate that sites with high concentrations of nutrients had more variability with regard to nutrient concentrations than did sites with low concentrations of nutrients.

I. Introduction

Under the Clean Water Act, criteria are components of water quality standards. The U.S. Code of Federal Regulations (CFR) defines criteria as "elements of State water quality standards, expressed as constituent concentrations, levels, or narrative statements, representing a quality of water that supports a particular use. When criteria are met, water quality will generally protect the designated use" [40 CFR 131.3(b)]. The U.S. Environmental Protection Agency (EPA) requires that all states develop criteria to protect waters from impairment by nutrient enrichment using scientifically defensible approaches that consider the effects of nutrients on designated use within the stream segment being assessed (localized effects) and on receiving water bodies located further downstream (downstream-loading effects) (U.S. EPA 2000).

When present in surface water bodies at elevated concentrations, nutrients (nitrogen and phosphorus) are water pollutants. Excess nutrients cause negative effects in surface water bodies nationwide. Recent EPA reports to Congress have listed nutrients as prominent pollutants impairing freshwater rivers and streams nationwide (Table 1).

Table 1. Prevalence of nutrient impairments in assessed rivers and streams as documented by U.S. Environmental Protection Agency National Water Quality Inventory (U.S. EPA 2009).

Year	Stream Miles Assessed	Stream Miles Affected by Nutrient Impairment	Nutrient Impaired Streams (% of assessed)
1998	842,246	84,071	10.0%
2000	699,946	52,870	7.6%
2002	695,540	52,228	7.5%
2004	563,955	38,632	6.9%

This report documents activities being conducted by the Water Quality Academic Advisory Committee (AAC) to Virginia Department of Environmental Quality (DEQ) in collaboration with Virginia DEQ for the purpose of developing nutrient criteria for wadeable, freshwater rivers and streams in the Mountain and Piedmont regions of Virginia. The Mountain region of Virginia is within the following Level III Ecoregions: Central Appalachians, Ridge and Valley, and Blue Ridge. The Piedmont region of Virginia is within the following Level III Ecoregions: Northern Piedmont and Piedmont.

Background: Virginia's Nutrient Criteria Development Process

In Virginia, all state waters are designated to support aquatic life. Virginia water quality standards define the aquatic-life designated use as "the propagation and growth of a balanced, indigenous population of aquatic life" (Virginia DEQ 2007). In accord with EPA guidance, Virginia has developed a biological-monitoring procedure to assess the suitability of freshwater rivers and streams for the aquatic-life use. Like many other state agencies, Virginia DEQ employs benthic macroinvertebrates in determining the support of the aquatic-life use (Tetra Tech, Inc. 2003; Virginia DEQ 2006).

The Virginia DEQ has requested advice from the AAC to aid in the development of nutrient criteria for freshwater rivers and streams. The AAC is recommending that nutrient criteria for freshwater wadeable streams be defined using a unique approach, termed as the "screening value approach" (AAC 2006). This approach employs a series of monitoring procedures to determine whether the amount of nutrients in a water body allows it to support the aquatic-life use (Figure 1).

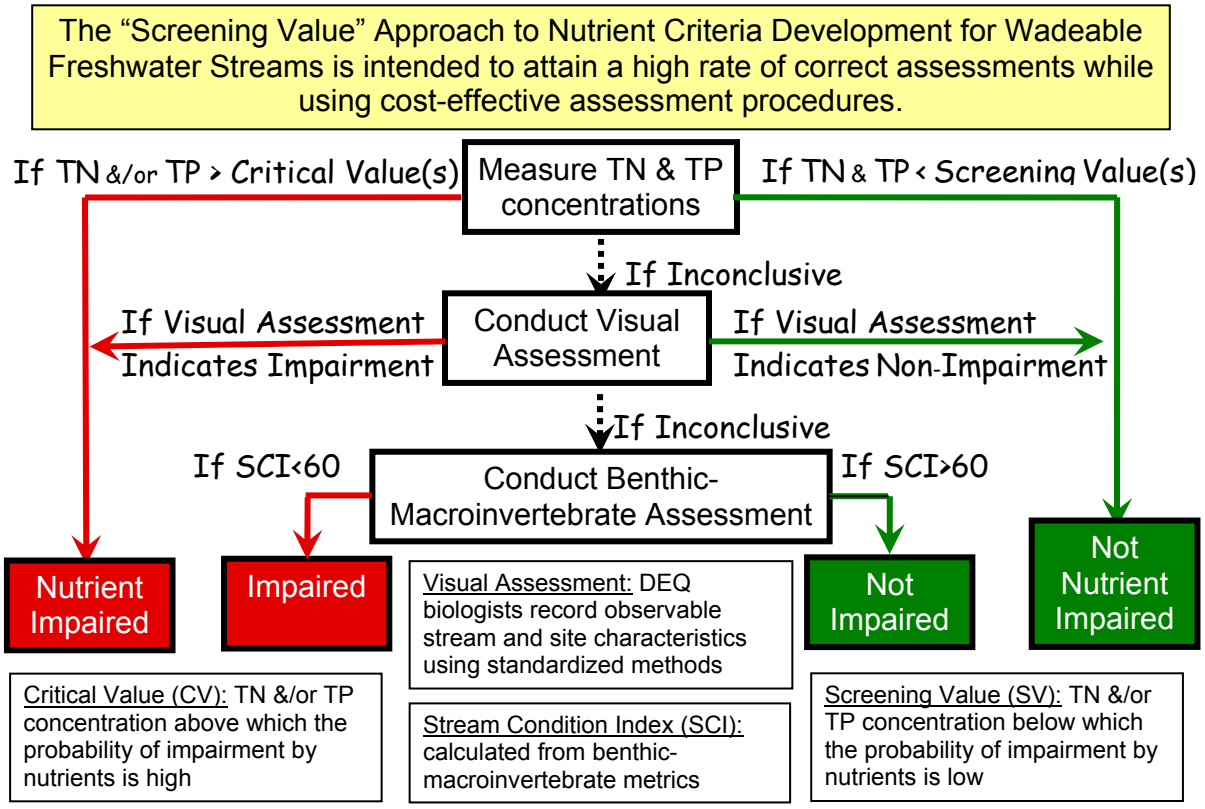


Figure 1. A proposed screening-value approach for developing nutrient criteria in Virginia's freshwater-wadeable streams. TN = total nitrogen; TP = total phosphorus

The first stage of the screening-value approach to water-quality assessment for nutrient effects, as recommended by the AAC (2006), would employ two sets of thresholds for nitrogen (N) and phosphorus (P):

- Screening Value(s): Streams with nutrient concentrations below the screening value(s) are assessed as "not impaired by nutrients."
- Critical Value(s): Streams with nutrient concentrations above the critical value(s) are assessed as "impaired."

Streams that cannot be assessed using the screening or critical values would be visually assessed.

- Visual Assessment: Nutrient impairments occur due to the effects of algal and plant growth stimulated by the nutrients. A visual procedure to assess the stream for impairment by nutrients would rely on the presence or absence of visible macrophytes and algae. As proposed by the AAC, the visual assessment can have three possible outcomes: impaired by nutrients, not impaired by nutrients, or inconclusive.

If a stream's nutrient concentrations do not allow assessment using the screening or critical values, and if the visual assessment is inconclusive, a benthic-macroinvertebrate assessment would be employed to assess the stream.

- Benthic-Macroinvertebrate Assessments: Virginia DEQ uses the assessment of the benthic-macroinvertebrate community to determine that the stream meets the aquatic-life use.

A screening-value approach is recommended as an alternative to traditional fixed-threshold criteria because nutrient effects on aquatic systems differ from the effects of traditional stressors. Whereas traditional stressors tend to exert toxic influences at the organism level, nutrient overenrichment effects are systemic (i.e., nutrients, themselves, are not generally toxic, but overenrichment of nutrients affects the stream system, such as by depleting oxygen levels, and thus causes detrimental impacts on organisms). Furthermore, unlike traditional toxic stressors, nutrients are required in surface waters to support aquatic life. Nutrients are considered a stressor in surface waters only when present in excessive amounts. Thus, variations among physical characteristics of river-and-stream systems affect those systems' responses to nutrient enrichment. As a result, biotic responses to nutrient enrichment at specific concentration levels are highly variable among river and stream systems.

The screening-value approach is applied with the intention of limiting assessment errors despite the inherent variability of aquatic systems' responses to nutrients. The screening-value approach has a secondary goal of achieving efficiency in the DEQ resource expenditures necessary to meet the goals of the Clean Water Act.

The AAC has been consistent in recommending that DEQ develop nutrient criteria to limit assessment errors in recognition of the costs that result from incorrect assessments (Figure 2). When streams are assessed as impaired, a TMDL study is required. Thus, when non-impaired streams are incorrectly assessed as impaired (false-positive assessment, Type I error), the resulting costs of the TMDL study utilizes resources for enforcing the Clean Water Act that could otherwise be applied elsewhere for water-quality protection. False-positive assessments can also affect investment decisions by regulated point sources discharging into that stream

segment. When impaired streams are not assessed as impaired (Type II error, false negative), costs are borne by the public in the form of lost environmental services that result from failure of that water body to support its designated uses.

		Actual Condition	
		Impaired	Not Impaired
Assessment Outcome:	Impaired	Correct Assessment (true positive)	Incorrect Assessment (false positive, type I error)
	Not Impaired	Incorrect Assessment, (false negative, type II error)	Correct Assessment (true negative)

Figure 2. Type I and Type II errors. The screening-value approach is being developed with the intention of limiting both Type I and Type II assessment errors.

Application of the screening-value approach requires consideration of trade-offs, given the inherent variability of streams' responses to nutrient concentrations and the resulting uncertainty of assessment decisions based on fixed thresholds for nutrients.

When applied together, the critical and screening values define a range of nutrient concentrations (termed the "inconclusive-nutrient-concentration range") for which additional monitoring and assessment resources must be expended for assessment (Figure 3). A conservative approach to establishing these assessment thresholds – setting the critical value at a relatively high concentration and setting the screening value at a relatively low concentration – would result in a high rate of correct assessments. Having a broad distribution of nutrient concentrations within the inconclusive-nutrient -concentration range, however, would increase the monitoring expenditures of DEQ. Given resource limitations that constrain Virginia DEQ (a taxpayer-supported public agency that operates its water-quality protection programs on funds allocated by the state legislature), an expansion of resource expenditures for water-monitoring and assessment would likely require that the agency's other environmental protection services be reduced. The additional resource expenditures required for a visual assessment of streams that occur within the inconclusive-nutrient-concentration range would be relatively modest, but a visual assessment is expected to be adequate for only a fraction of streams in the inconclusive-nutrient-concentration range. For the remaining streams a benthic-macroinvertebrate assessment would be required. Each benthic-macroinvertebrate assessment requires on the order of one day's investment of time by regional biologists for sampling and analysis. This level of resource expenditure is considered significant given that DEQ employs a limited number of regional biologists and that these personnel have a range of responsibilities in addition to whatever duties may result from the implementation of nutrient criteria.

The approach described above for defining critical and screening values is conservative. The implementation of a less conservative approach, one with a narrow range of inconclusive

concentrations, could be expected to reduce the agency's monitoring expenses. The cost savings for monitoring, however, would be accompanied by an increase in the error rate of screening- and critical-value assessments. Thus, the screening-value approach embodies essential trade-offs between public benefits, which require error limitation, and water-monitoring resource expenditures.

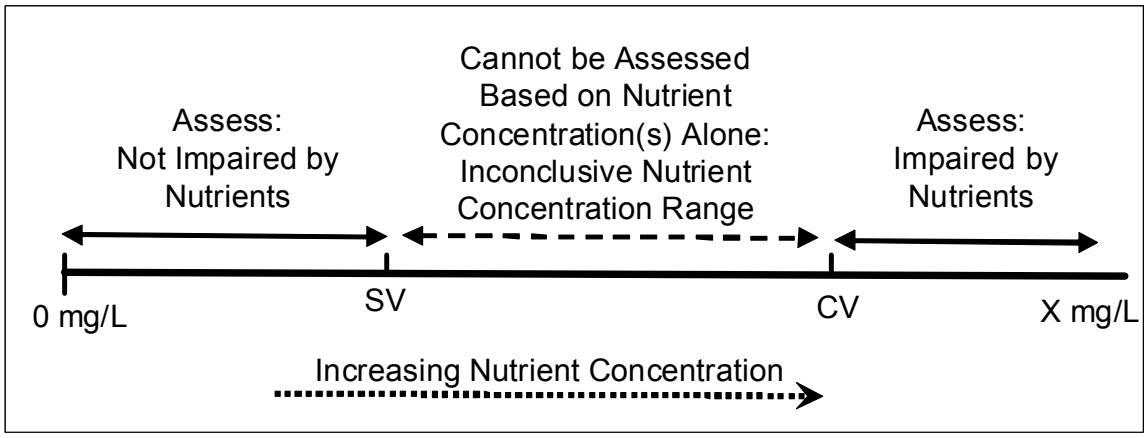


Figure 3. Graphic representation of nutrient-concentration ranges defined by the screening-value approach to nutrient criteria, as recommended by the AAC. SV = screening value; CV = critical value.

II. Pilot-Program Description and Results

Working within the context described above, the Virginia DEQ and the AAC conducted a trial run of a screening-value approach for nutrient criteria in wadeable, freshwater streams between March 2007 and June 2009. This study took place in Virginia's Mountain and Piedmont regions (located within EPA's Aggregate Nutrient Ecoregions XI and IX, respectively). In the text that follows, we refer to the activity as the "pilot program."

Project Goals

The goals of the pilot program were to:

a. Develop a visual-assessment procedure.
b. Propose visual-assessment levels that may trigger impairment or non-impairment designations (see Figure 1), and determine the levels of uncertainty that would be associated with such designations.
c. Propose total-nitrogen (TN) and total-phosphorus (TP) values that can serve as screening values and as critical values (see Figure 1), and determine the levels of uncertainty that would be associated with such designations.
d. Determine the ability of the screening-value approach (Figure 1) to successfully discriminate impaired from non-impaired sites using screening- and critical-values that result with reasonable resource expenditures by DEQ.
e. Determine the resource requirements of full-scale implementation by DEQ.

Methods

The pilot program was conducted over a time period extending from mid-2007 through mid-2009, and included site selection, development of the visual-assessment procedure, sampling, and data analysis (Figure 4).

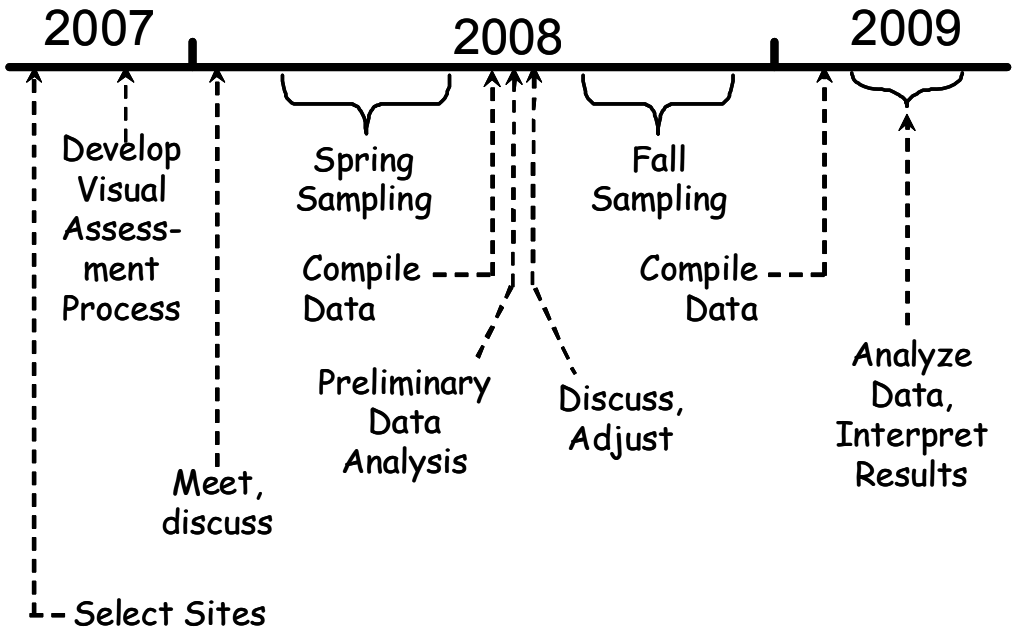


Figure 4. Pilot-program timeline for major activities.

Site Selection

Sites included in the pilot program were selected using the following method:

1. All ambient water-quality monitoring sites within Virginia's Mountain and Piedmont regions meeting either of the following two conditions were identified.
   a.) For sites that have been in operation continuously during the previous 12 months, 5 or more TN and 5 or more TP concentrations recorded during the previous 12 months.
   b.) For sites that have been in operation continuously only since January 2007, 3 or more TN and 3 or more TP concentrations recorded since January 2007.
2. Median TN and TP values were calculated from monitoring observations collected during the prior 12 months for each station. Using these median values, each monitoring station was placed in a TN category and a TP category (Table 2).
3. DEQ biologists in the Mountain and Piedmont regions were asked to select up to 12 monitoring stations (approximately 6 sites for sampling in the fall and 6 sites for sampling in the spring) for inclusion in the pilot program by applying the following criteria:

a) Site is represented by recent water-quality data so it can be placed reliably within a nutrient category.
b) Site is wadeable and suitable for benthic-macroinvertebrate sampling.
c) Site is not known to be subject to major influence by non-nutrient stressors (urban runoff, toxics, sediments, point source discharges, etc.).
d) Site is from the list of stations prepared by DEQ's water-monitoring data coordinator, Mr. Roger Stewart.
   i. At least one station within each of the 6 N-concentration categories and at least one station within each of the 6 P-concentration categories are to be represented. (Note: because each station is placed in both an N-concentration category and a P-concentration category, this condition can be met with fewer than 12 sites).
   ii. To the extent possible:
      -- For the lowest N-concentration category: assure that relatively low, medium, and high P concentrations are represented; and
      -- For the lowest P-concentration category: assure that relatively low, medium, and high N concentrations are represented.
e) Sites are not clustered geographically or fluvially, and thus are distributed throughout the entire region.

Table 2. Nutrient-concentration categories used for selection of water-monitoring stations for the pilot program.

Total Nitrogen (mg/L), median	**TN Category**	**Total Phosphorus (mg/L), median**	**TP Category**
<0.5	1	<0.02	1
0.5 - <1.0	2	0.02 - <0.04	2
1.0 - <1.5	3	0.04 - <0.06	3
1.5 - <2.0	4	0.06 - <0.10	4
2.0 - <3.0	5	0.1 - <0.20	5
>=3.0	6	>=0.2	6

Development of a Visual-Assessment Procedure

DEQ's biologists, its water quality standards staff, and AAC member Dr. Len Smock collaborated to develop a visual-assessment procedure that can be implemented within the nutrient criteria framework (see Figure 1). The developed visual-assessment field forms are attached to this report as Appendix A (used during Spring 2008) and Appendix B (used during Fall 2008). Site attributes relevant to the potential nutrient effects, such as amount of shading (full shade, partial shade, full sun), estimated surface stream velocity (slow, moderate, fast), stream substrate (sand, gravel, cobble), stream depth and width were included on the field survey forms. The visual-assessment procedure also included a qualitative assessment by the regional biologist regarding whether or not the site is impaired by nutrients.

The visual-assessment procedure was designed to produce numeric results that are both reproducible and independent of the individual who is applying the method. Visual-assessment

components included factors such as an estimated percentage of the visible stream bottom covered with algae or macrophytes, estimated percentage of some number of rocks removed randomly from the stream bottom that are covered with algae, and the type and amount of algae present. The biologists were asked to rate each site by nature and type of algae present. Algal types that were rated included combinations of color (bright green, dark green, brown, and black) and form (film, thin mat, thick mat, short filamentous, and tall filamentous). The types listed above are for the fall rating; a similar but less inclusive set of algal color and form combinations was used for the spring rating. Biologists were asked to rate each site for presence of algal color/form combinations using a scale of 1-10%, 10-40%, 40-70%, and 70-100% coverage categories. We used these ratings to construct the Algal Index for each site by summing the algal color/form combinations that biologists described as being present, weighting each by visually estimated stream bottom coverage on a scale of 1 – 3 – 6 – 10 for the 4 categories; this constructed measure was called the "Algal Index 13610" or "Algal Index" for short.

Development of the Quality Assurance Project Plan (QAPP)

In collaboration with the AAC, DEQ developed a QAPP, which was submitted to EPA in association with the USEPA Region 3 grant application.

Initiation of Pilot-Program Activities

The initial schedule called for DEQ biologists to begin sampling in Fall 2007. However, administrative procedures associated with the EPA grant application had not yet been completed by that date so the initial sampling was delayed until Spring 2008. Excessively wet weather in some parts of the state, combined with the study design, which required sampling during baseflow and avoidance of sampling during time periods following scouring rains, interfered with the spring sampling. As a result, some of the sites scheduled for spring sampling were not sampled.

Trial Application Round I: Spring 2008

DEQ biologists conducted a visual assessment, a benthic-macroinvertebrate assessment, and a habitat assessment at approximately half of the sites selected for study implementation in Spring 2008. All sampling was conducted according to established DEQ protocols as detailed in DEQ Standard Operating Procedures (SOP) manuals and the QAPP prepared in association with this project. Sampling was conducted during baseflow conditions so as to be consistent with DEQ probabilistic-monitoring protocols and to assure lack of algal scouring effects. In addition, sampling took place 14 or more days after the last rain event judged by regional biologists to have caused an algal scouring effect. Benthic-macroinvertebrate sampling results were transformed to a Stream Condition Index score using DEQ standard procedures (Tetra Tech, Inc. 2003).

In-situ water-quality measures were recorded for each sampling site:

- Temperature – In-Situ, YSI or Hydro-Lab multi-probe meter (calibrated with NIST thermometer in lab).

- pH – In-Situ, YSI or Hydro-Lab multi-probe meters (calibrated and post-confirmed checked each field day, using commercially available standards)
- Dissolved oxygen – In-Situ, YSI or Hydro-Lab meter (pre-calibrated and post-confirmed each field day, using (100% RH) air standard)
- Conductivity – In-Situ, YSI or Hydro-Lab meter (calibrated and post-confirmed each field day, using commercially available standards).

In addition to these field measures, water samples were taken as point samples using standard DEQ protocols. Nutrient variables analyzed include nitrate-N (NO_3-N), nitrite-N (NO_2-N), total kjeldahl N (TKN), TN, and TP; all are expressed as mg/L as N or P. Other variables measured included suspended solids (Storet 530 – non-filterable residue) and total residue (Storet 500).

Benthic algae (periphyton) were sampled to estimate periphytic biomass. Algal biomass was scraped from 3 randomly selected rocks, and the scraped area was estimated via a tracing. The biomass samples were processed to determine chlorophyll-a (Chl-a) and ash-free dry mass (AFDM) by the Virginia Division of Consolidated Laboratory Services (DCLS) following Standard Methods (APHA 1992) for algal-biomass estimates.

Mid-Course Program Review

Data from the spring 2008 sampling was assembled and made available to the AAC and to interested parties within DEQ for analysis during the summer of 2008. First-round results were discussed with biologists on a conference call. As a result of this call, several program adjustments were made. The visual-assessment field form was modified (see Appendix B), and several regional biologists decided to move the initially selected sampling stations as needed to better achieve study goals.

Trial Application Round II: Fall 2008

The trial application protocol, as described above for Spring 2008, was repeated in the fall at the remaining sites, with minor modifications as per the mid-course program review.

Data Analysis and Interpretation: Early 2009

Data were analyzed using JMP statistical software (SAS Institute, Cary NC), using a variety of statistical procedures including one-way analysis of variance (ANOVA) and linear regression. Most variables were not normally distributed, the primary exception being Stream Condition Index (SCI). When a log transformation was able to transform a non-normally distributed variable to a normal or near-normal distribution, the log-transformed variable was used in data analysis. Otherwise, statistical analysis was performed using non-parametric procedures applied to the ranks.

Preliminary data analysis was completed in March, 2009. Results were presented and discussed at a meeting of the AAC with Virginia DEQ staff in Charlottesville on March 18, 2009.

Results: Study Process

Selection of Sites

The goal of the site selection process (described in the Methods section) was to assure that high nutrient concentrations and variable N and P concentration ranges were represented. Past studies had revealed that TN and TP concentrations in Virginia freshwater streams are correlated, and that the distributions of these nutrient concentrations are skewed.

Table 3 shows the distribution of 69 sites among nutrient categories as initially selected (upper table). However, when sampled, some sites had concentrations that differed from the expected concentration. The distribution of the 62 sites actually sampled is provided in Table 3 (lower table). The location of each monitoring site in the pilot program, the DEQ regional office conducting the monitoring, and the season in which monitoring occurred are represented in Figure 5.

Table 3. Distribution of stations among TN and TP categories as initially selected (upper table) and as actually measured during the pilot program (lower table).

			TP						
			1	**2**	**3**	**4**	**5**	**6**	**All**
		(mg/L)	<0.02	0.02 - <0.04	0.04 - <0.06	0.06 - <0.10	0.1 - <0.20	>=0.2	
TN	**1**	<0.5	6	8	4	1	2	-	21
	2	0.5 - <1.0	1	4	4	4	3	-	16
	3	1.0 - <1.5	2	2	3	2	-	-	9
	4	1.5 - <2.0	-	2	2	1	3	1	9
	5	2.0 - <3.0	1	2	1	2	2	1	9
	6	>=3.0	-	-	1	3	-	1	5
	All		10	18	15	13	10	3	69

			TP						
			1	**2**	**3**	**4**	**5**	**6**	**All**
		(mg/L)	<0.02	0.02 - <0.04	0.04 - <0.06	0.06 - <0.10	0.1 - <0.20	>=0.2	
TN	**1**	<0.5	5	12	4	1	2	-	24
	2	0.5 - <1.0	-	7	4	2	2	-	15
	3	1.0 - <1.5	-	1	3	3	1	-	8
	4	1.5 - <2.0	-	1	3		1	1	6
	5	2.0 - <3.0	-	-	1	1	-	2	4
	6	>=3.0	-	2	-	-	-	3	5
	All		5	23	15	7	6	6	62

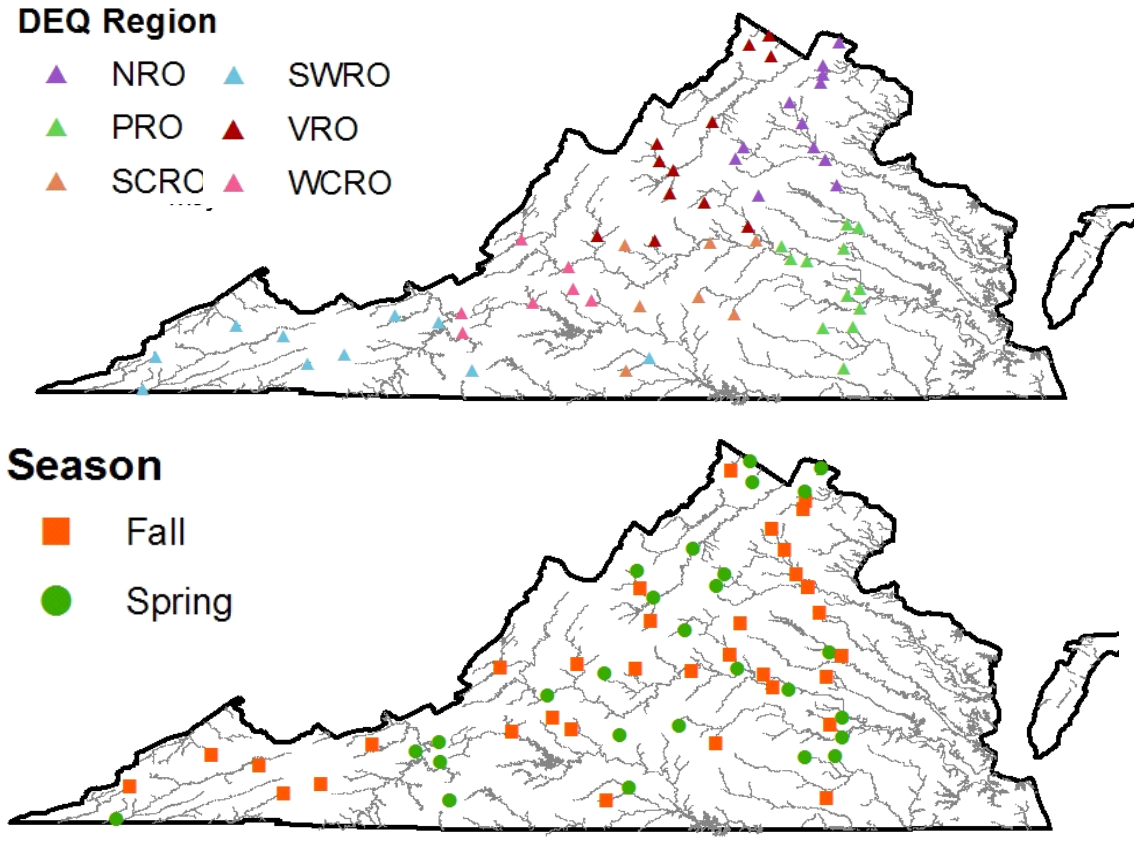


Figure 5. The 62 sites monitored and sampled by DEQ biologists during the pilot-program activity, by DEQ region and by season. NRO = Northern Regional Office; PRO = Piedmont Regional Office; SCRO = South Central Regional Office; SWRO = South West Regional Office; VRO = Valley Regional Office; and WCRO = West Central Regional Office.

Sampling

Data from 29 sites were obtained in the spring, and data from 33 sites were obtained in the fall. Benthic-macroinvertebrate assessments were replicated at one site sampled in spring and three sites sampled in fall. Impairment status (i.e., whether or not SCI < 60) for replicate samples did not differ from the primary sample, so only primary sample results are used in the following analysis. Minor adjustments were made in the visual-assessment form after the spring sampling, as several new assessment procedures were added in response to the spring experience. Sites were selected for inclusion in the study based on previously measured TN and TP concentrations, with the intention of ensuring sufficient representation of high-nutrient streams to allow characterization of the high-nutrient effects that are of primary interest in this study. Basic data from streams included in the study are described in Table 4.

Table 4. Summary statistics for the 62 water-monitoring sites sampled and characterized through the pilot program.[a]

Parameter	SCI<60[b]	SCI>60	All
Number of Observations	36	26	62
TN (median, mg/L)	0.85*	0.47	0.61
NO_3-N (median, mg/L)	0.54*	0.10	0.25
TKN (median, mg/L)	0.4	0.4	0.4
TP (median, mg/L)	0.045	0.03	0.04
Benthic Algae: Ash-free dry mass (AFDM, median, mg/m^2)	20.8	16.6	17.6
Benthic Algae: Chlorophyll-a (Chl-a, median, mg/m^2).	56.8	27.0	39.5
SCI (mean)	47.5	68.3	57.3

[a] For replicated sites, only the first replication was used to calculate summary statistics.
[b] SCI = 60 is the impairment threshold. When SCI<60, DEQ considers the site to be impaired for the aquatic-life use.
* = significantly different (P < 0.05, one way ANOVA using ranks) vs. SCI > 60 sites. Other water-quality and benthic-algae measures are not significantly different.

Results: Data Analysis

Biochemical Relationships

In general, the biochemical relationships occurred as expected: high-nutrient concentrations, high algae/plant densities, and low SCI scores were all correlated. However, those relationships, although often statistically significant and sometimes highly significant, did not provide a basis for development of predictive models. High variance and low coefficients of determination, R^2, prevented the development of models with the potential for precise application.

Generally speaking, relationships with benthic algae and SCI are stronger for N than for P and are stronger for TN than for either of the two major TN components (TKN, NO_3-N). Influences of TN, NO_3-N, and TKN concentrations on the Stream Condition Index (SCI) are all negative and statistically significant ($P < 0.05$). Of the three major nitrogen measures, TN exhibits the strongest relationship ($P = 0.0002$; see Figure 6), but NO_3-N exhibited a stronger relationship ($P = 0.0031$) than did TKN ($P = 0.03$). The relationship of measured TP values with SCI was not statistically significant. Both measures of benthic algae (AFDM and Chl-a) appeared to influence SCI, with higher benthic-algae levels associated with lower SCI scores, but the relationships were weak (Figure 7).

Benthic-algae biomass increased with measured nutrient concentrations. Generally speaking, these relationships were stronger for TN than for TP, and stronger for Chl-a than for AFDM (Figure 8). Only the TN relationships were statistically significant. Of the two major nitrogen components: NO_3-N exhibited stronger relationships with benthic-algal biomass, especially Chl-a, than did TKN.

Generally speaking, nitrogen exhibited the expected biochemical relationships (i.e., positive relationship with benthic-algal biomass, negative relationship with SCI) more strongly than did TP. This is as expected given that the majority of P in most Virginia streams is generally

considered to originate from non-point sources and that the streams were sampled under baseflow conditions. Non-point-source P tends to be associated with sediments, the movement of which tends to vary closely with streamflow. Thus, the sampling conditions were not conducive to detection of sediment-associated P movement. TN tended to exhibit stronger biochemical relationships than either NO_3-N or TKN but not consistently. The NO_3-N data exhibited consistently stronger biochemical relationships than did TKN, which supports our interpretation of streamflow conditions as a factor that influenced results. Because NO_3 occurs only in water-soluble forms, it is easily transported through groundwater systems to the stream under baseflow conditions. In contrast, some TKN components occur as solid-phase forms whose movement tends to be more flow dependent.

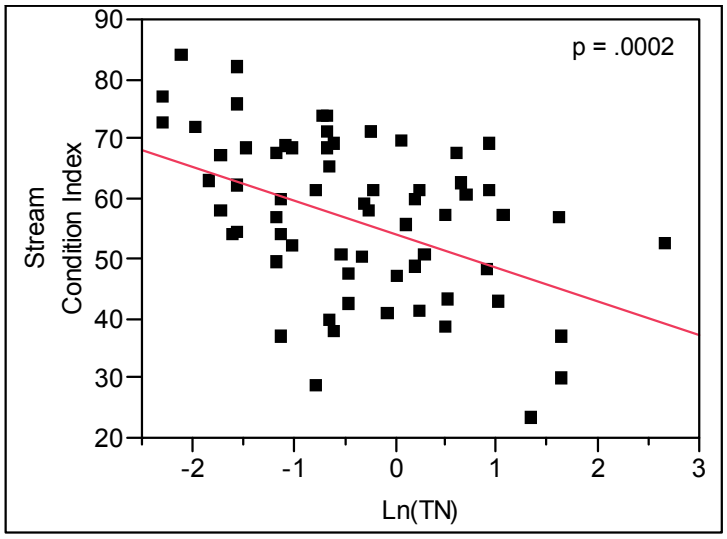


Figure 6. Linear regression of Log-transformed TN (mg/L) vs. Stream Condition Index (SCI) (R^2 = 0.21). The relationship was highly significant (p = 0.0002).

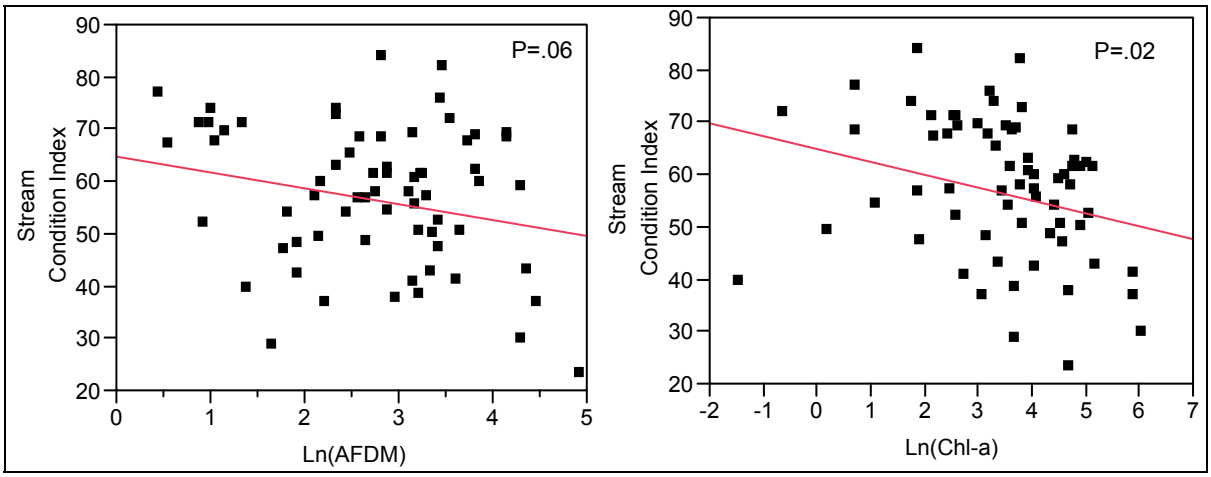


Figure 7. Linear regression of two measures of benthic-algae biomass – ash-free dry mass (AFDM, g/m^2) and Chlorophyll-a (Chl-a, mg/m^2), both log-transformed – against SCI. The R^2 is 0.06 for the Ln(AFDM) relationship (left), and 0.08 for Ln (Chl-a) (right).

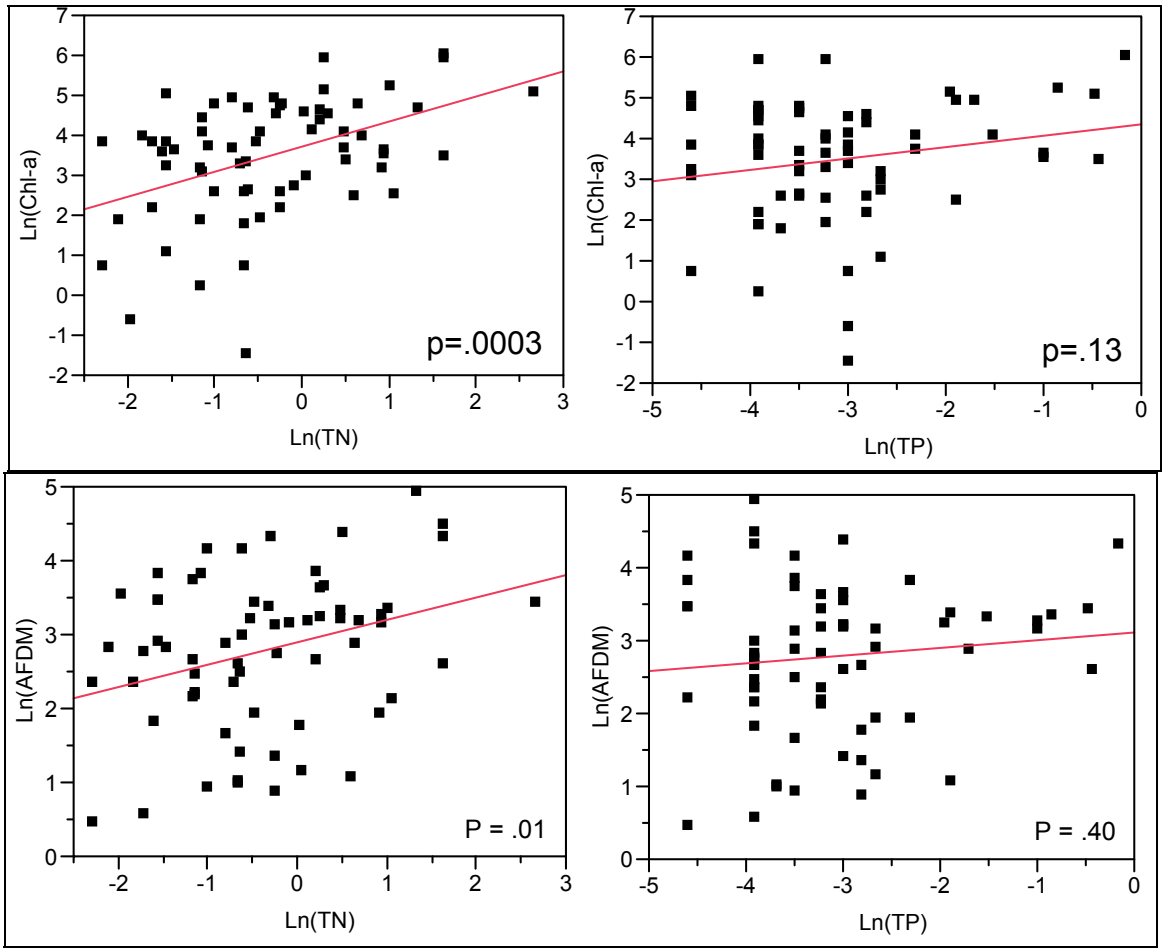


Figure 8. Linear regressions of Log-transformed TN (mg/L) and TP (mg/L) against benthic-algae biomass, expressed as Chlorophyll-a (Chl-a, mg/m^2), log-transformed (above); and ash dry mass (AFDM, g/m^2), log-transformed (below). R^2 values for these relationships are 0.19 (upper left), 0.04 (upper right), 0.11 (lower left), and 0.01 (lower right).

Visual Assessments

The visual-assessment procedure required biologists to rate sites for the probability of impairment by *nutrients* during both spring and fall, and to rate sites for a probability of impairment due to *any cause* during fall only.

Sites identified by biologists as having a high probability of being nutrient impaired based on the visual assessment usually were impaired for aquatic life according to the SCI score (SCI < 60) (Of 7 sites rated as high probability for nutrient impairment based on the visual assessment, 6 had SCI < 60) (Table 5). The visual assessments were not as successful at the other end of the spectrum. A number of the sites identified as having a low probability of nutrient impairment based on the visual assessment were identified as impaired according to the SCI (15 sites listed as impaired according to the SCI were among the 31 sites rated as low probability of nutrient impairment based on the visual assessment). Nutrient effects were visually evident at one site rated as non-impaired based on the SCI score. This site had 40-70% of the stream

bottom covered by algae (predominantly tall filamentous algae) and plants and thus given a high probability of being impaired according to the visual assessment.

Table 5. Impairment status of sites monitored in 2008 as part of the pilot program compared to the rating categories assigned by DEQ biologists.

	Impairment Probability Rating			
Spring: Nutrient Stressors Only	**Low**	**Medium**	**High**	**Total**
Not Impaired (SCI > 60)	8	4	0	12
Impaired (SCI < 60)	8	6	3	17
Fall: Nutrient Stressors Only				
Not Impaired (SCI > 60)	8	5	1	14
Impaired (SCI < 60)	7	9	3	19

One reason for the difficulty in defining sites as "non-impaired for nutrients" based on a visual assessment in comparison to the SCI score is that, most possibly, non-nutrient stressors were also acting at a number of sites. Comments cited by the biologists on the data forms indicated that sediments were by far the most common non-nutrient stressor. The non-nutrient factors may have influenced the SCI score but not the visual assessment, which was based on the visual presence of plants and algae.

The biologists' visual assessments of algae presence tended to agree with in-stream measurements but with high variance. AFDM corresponded more closely with biologists' visual assessments of stream-bottom coverage by algae (P = 0.005; Figure 9 left) than did Chl-a (not significant). The Algal Index exhibited a negative relationship with Stream Condition Index, but the relationship was weak (P = 0.09; Figure 9 right).

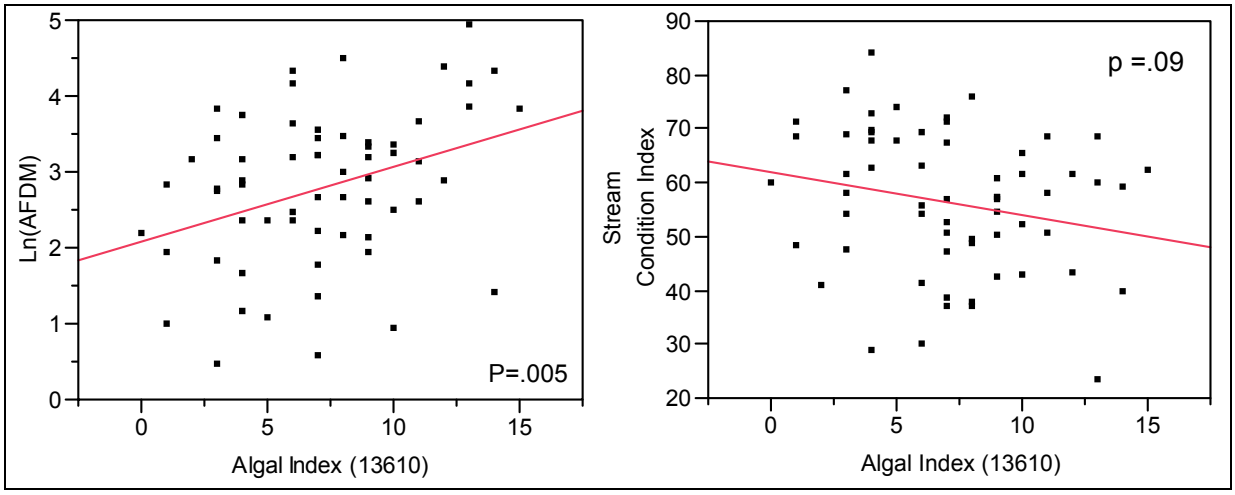


Figure 9. Relationship of Algal Index to log-transformed AFDM (g/m^2) (left) and Stream Condition Index (right). R^2 values for these relationships are 0.12 (left) and 0.05 (right).

In the fall only, regional biologists visually rated each stream for total stream bottom coverage by algae and vascular plants. The biologists' best professional judgment (BPJ) of whether or not the stream was impaired by nutrients was strongly influenced by their perceptions of algae and vascular plant presence (Table 6). The biologists' ratings of 70-100% coverage corresponded with higher levels of algal biomass (Figure 10), measured both as Chl-a and AFDM, although these results were not statistically significant. However, the visual measurement of total stream bottom coverage is meant to include both plants and algae, whereas AFDM and Chl-a are measures of benthic algae only. This difference in what is being measured adds a confounding element to this analysis. Thus, it is not surprising that the biologists' estimates did not correspond more closely with the AFDM and Chl-a values.

Table 6. Relationship of regional biologists' best professional judgment of nutrient impairment by visually estimated stream bottom coverage by plants and algae.

Stream Bottom Coverage	**Best Professional Judgment Nutrient Impairment Probability Rating**			
	Low	**Medium**	**High**	**Total**
A: 0 – 10%	3	0	0	3
B: 10 – 40%	5	1	0	6
C: 40 – 70%	2	5	1	8
D: 70 – 100%	4	8	3	15
Total	14	14	4	32

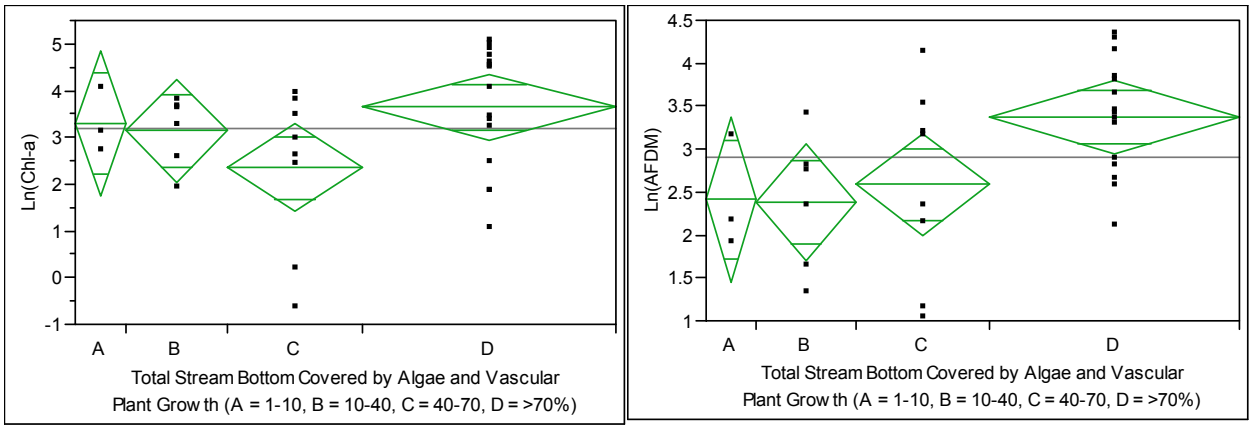


Figure 10. Correspondence of biologists' ratings of stream bottom coverage by plants and algae with measured benthic-algae levels. These results were not statistically significant.

The total stream bottom coverage visually assessed (in Fall 2008 only) by estimating algae and vascular plant growth showed no statistically significant relationship with SCI and did not confirm the expected trends. Of the 4 stream-bottom coverage categories (<10%, 10-40%, 40-70%, and >70%), the <10% category showed the highest proportion of SCI-determined

impairments (3 of 3). The 40-70% category showed the lowest proportion of SCI-determined stream impairments (2 of 8) (Figure 11). Eleven (11) of the 15 streams with >70% stream bottom coverage were considered impaired (SCI<60), but the two highest SCI's among fall-sampled streams were also within this (>70%) visual-assessment category.

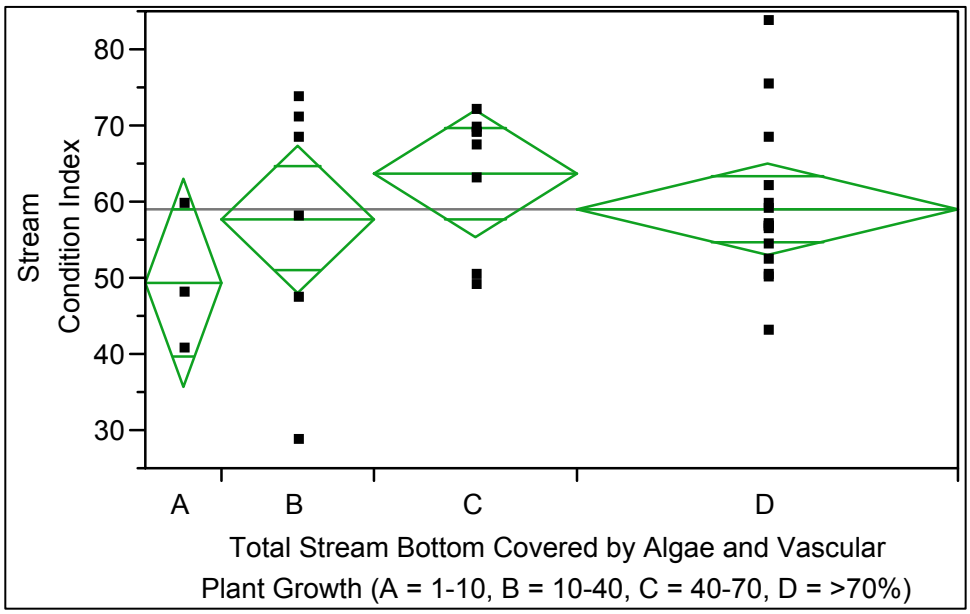


Figure 11. Relationship of Stream Condition Index to biologists' visual ratings of total stream bottom coverage by algae and plants.

Potential Critical Values and Screening Values

"Critical values" and "screening values" are defined in the study plan as in-stream concentrations that allow the stream to be assessed for nutrient impairment. Critical values can be relatively high concentrations that allow sites to be identified as "nutrient impaired," while screening values are relatively low concentrations that allow sites to be identified as "not nutrient impaired." Screening values were not evident from this data set, possibly because the data set does not allow discrimination of nutrient from non-nutrient impairment. High-end critical values (i.e., values above which all sites had SCI<60) were evident (Table 7).

Table 7. Potential critical values suggested by the results of the pilot program.

Parameter	Critical Value (CV)	# sites > CV*
Benthic-Algae Chl-a	170 mg/m^2	4
Benthic-Algae AFDM	70 g/m^2	5
TN	2.6 mg/L	6
NO_3-N	2.3 mg/L	6
TKN	0.9 mg/L	4
TP	0.4 mg/L	4
TN, TP, NO_3, TKN (WQ)	Combined	10
WQ + Benthic Algae	Combined	13
Best Professional Judgment (BPJ)	High (nutrients only)	7 (6 SCI < 60)
WQ + BPJ	Combined	13
WQ + Benthic Algae + BPJ	Combined	14

* Out of 62 total sites and 36 impaired (SCI<60) sites in pilot program. At 32 sites, SCI<57.5; of the 4 remaining sites ("borderline impaired"), 1 was caught by the AFDM screen but none were caught by the WQ or BPJ screens.

Discussion

Potential applications of pilot-program results to DEQ's overall monitoring program must be considered in light of the characteristics of the sites selected and included in the program: sites were selected to include a higher proportion of high-nutrient sites than occurs generally within the population of monitoring sites in DEQ's program. The relatively high-nutrient levels at the pilot-program sites were a deliberate result of the site-selection process.

Another essential characteristic of the pilot-program data set is that both nutrient and non-nutrient stressors were affecting aquatic resources. Although the study design was intended to isolate nutrient effects by focusing efforts on sites where non-nutrient stressor effects were not evident, this goal was not met despite the best efforts of regional biologists in selecting sites. Sediments were identified as a non-nutrient stressors at 37% of the sites included in the program (Table 8), but 37% should be considered as a lower-bound estimate of the sites where sediments had an effect. Only the field form for the fall visual assessment requested information on non-nutrient stressors. Sedimentation is ubiquitous as a water pollutant in human-inhabited landscapes. Nutrient pollution is often associated with sedimentation, particularly phosphorus because it binds to soil particles.

Table 8. Sites where sediments were cited as a non-nutrient stressor by the regional biologists in comments on the visual-assessment forms.[a]

	Sites where sediments cited as an influential non-nutrient stressor	Total sites	% of total sites where sediments were cited.
Spring	5	29	17%
Fall	17	33	52%
Total	23	62	37%

[a] Non-nutrient stressor effects were addressed specifically by the visual-assessment data form during fall only. In spring, sediment effects were noted as general comments.

The pilot-program results indicate that the visual-assessment procedure has the potential for successful identification of some nutrient-impaired sites. Regional biologists were able to successfully identify some sites that were impaired (according to the SCI score) using the visual assessment process. Of the 62 sites included within the study, regional biologists identified seven has having a high probability of being nutrient impaired using the visual assessment; six of these sites were found to have SCI scores of less than 60, indicating impairment. However, regional biologists were not able to classify all sites identified as impaired according to the SCI score by using the visual assessment; of the 36 sites with SCI scores of less than 60, regional biologists visually identified 16% (six) as nutrient impaired.

The pilot-program results provide no indication that a visual assessment will be an adequate mechanism for assessing monitoring sites as "not impaired by nutrients." Of the 31 sites identified by regional biologists through the visual assessment as having a low probability of being nutrient impaired, 15 were found to have SCI scores of <60, indicating biotic impairment (see Table 5). It may be that the biologists' success in identifying sites not impaired by nutrients was actually greater than these figures indicate, but these results provide no basis for determining whether impaired sites were primarily affected by nutrients or by non-nutrient stressors.

The pilot program proved to be inadequate as a mechanism for identifying screening values or critical values. Possibly because of the widespread presence of non-nutrient stressor effects (including sediments), no potential screening values were evident. Some impaired sites (SCI<60) had relatively low nutrient concentrations. From a scientific standpoint, the most robust critical values would appear to be TN and TP, since allocation of water-quality N among the TKN and oxidized N forms in Virginia is both seasonally and regionally dependent (Zipper and Holtzman, unpublished). At the upper end of the concentration ranges, nutrient thresholds with a potential to serve as a critical variable were evident (2.6 mg/L TN, 0.4 mg/L TP) (Table 7). However, the TN threshold is very high, relative to the distribution of TN concentrations in Virginia streams and thus would provide little benefit if implemented as a critical value (Figure 12). At first glance, the combination of water-quality data with benthic-algae measurements appears to offer potential; however, benthic-algal biomass is not measured routinely at Virginia DEQ ambient-monitoring sites.

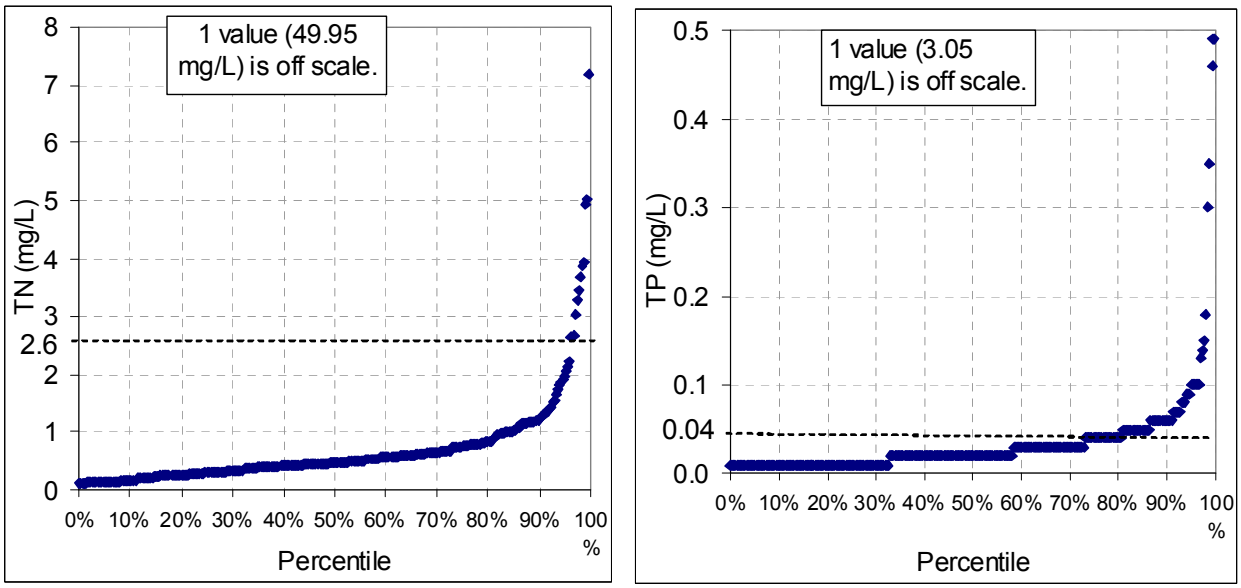


Figure 12. Distributions of TN and TP concentrations at Virginia DEQ probabilistic- monitoring sites in the Mountain and Piedmont regions of Virginia where the freshwater nutrient criteria for rivers and streams that are the focus of this report potentially could be applied. The potential critical values suggested by these results are 2.6 mg/L TN and 0.04 mg/L TP.

Conclusions

Using the visual-assessment procedures, regional biologists were able to successfully identify a subset of sites determined to be impaired (SCI < 60). However, efforts to visually identify non-impaired sites were not as successful; a number of the sites identified in the visual assessment as not impaired by nutrients had SCI scores of less than 60, indicating impairment of the benthic-macroinvertebrate community. Although it is possible that many or most of these non-visually evident, but nonetheless, impaired sites were impaired by non-nutrient stressors, the study design did not allow discrimination of impairment sources. Based on this result, we conclude that identification of nutrient-impaired sites has a potential for successful application within a nutrient-criteria program that incorporates a screening-value approach. However, these results do not support the AAC recommendation that a visual-assessment approach be applied to assess sites as non-impaired by nutrients.

Results of the pilot program do not appear as a useful means for identifying nutrient concentrations that can act as critical and screening values. Possibly because non-nutrient stressor effects were evident at a number of the sites selected for study, no potential screening values were evident from these results. Although potential critical values were evident, those suggested by these results are high, relative to the distribution of nutrient concentrations that occur in Virginia streams, especially for TN. A more useful approach in the development of potential critical and screening values would be to analyze water-monitoring data sets that are more representative of the conditions of freshwater rivers and streams in Virginia's Mountain and Piedmont regions. Such an approach could include the probabilistic-monitoring data and a

subset of the ambient-monitoring program sites for which biological-monitoring data are also available.

The pilot-program activity failed to provide the level of support for the screening-value approach to nutrient-criteria development that was anticipated, but the results provided no evidence to suggest that such a program would not be workable. The visual-assessment procedure offers potential to serve as a valid and valuable component of such a program. However, a more in-depth analysis of monitoring data from Virginia's Mountain and Piedmont regions will be required to define and evaluate potential critical values and screening values. Analysis is also needed to evaluate the effect of nutrient criteria developed from the screening-value approach on Virginia DEQ's monitoring resources.

III. Development and Application of Screening and Critical Values: Exploratory Analysis

The AAC's recommended approach to nutrient-criteria development involves the use of critical values and screening values. Nutrient concentrations greater than the set critical values would be defined as "nutrient impaired," while those concentrations less than the screening values would be defined as "not nutrient impaired." Nutrient concentrations in between the critical values and screening values would be assessed using a visual assessment. If the visual-assessment results are not definitive, a benthic-macroinvertebrate assessment would be conducted (see Figure 1).

As a means of illustrating the screening-value approach, we provide the following example. Critical values and screening values in the example are advanced for the purpose of illustrating a possible method for deriving these values from existing data sets. They are intended to stimulate discussion and, as such, should not be considered as actual, suggested, or likely values.

1. Deriving Illustrative Critical Values using a Variant of Paul and McDonald's Conditional-Probability Approach

Using DEQ probabilistic-monitoring (ProbMon) data (2001-2006) for the Mountain and Piedmont regions of Virginia, TN, TP, NO_3-N, and TKN were plotted using a [$Prob_{SCI<60}$: X>Xo] framework derived from Paul and McDonald (2005). This approach is based on the increasing probability that SCI will be <60 as the nutrient concentration increases. For any given concentration, the probability of impairment at that and higher concentrations is calculated as the ratio of impaired sites to total sites within the range of concentrations extending from the given concentration to the maximum. In the graphics that follow, the probability functions, represented as "Prob SCI<60," are overlaid on plots of SCI vs. TN in Figure 13a and SCI vs. TP in Figure 13b.

Unlike Paul and McDonald, we included only the threshold concentration for $P_{SCI<60}$=100% (i.e., the lowest concentration at which Prob $_{SCI<60}$=100%) in the data points used to draw a probability trend line (not represented in the figure). Our reasoning is that the nutrient concentrations above the 100% threshold should not influence the general form of a probability

function that is intended to represent biological condition. Furthermore, our goal is to derive critical values, not numeric criteria.

Plotting a line through the "Prob SCI<60" data points on the TN and TP charts (and including only the lowest concentration for which $Prob_{SCI<60}$ = 100%) yielded functions that were used to estimate the illustrative critical values (CVs). For this example and for the purpose of discussion, we selected the 90%-probability TN and TP levels as illustrative critical values. The 90%-probability level was selected considering the overall goals of the AAC approach, which seeks to optimize the trade-off between assessment errors and DEQ resource expenditures for conducting benthic-macroinvertebrate assessments. It would also be possible to select CVs at higher or lower probability levels. Table 9 lists the CVs obtained by this method for TN and TP concentrations that indicate a 90% probability of SCI<60.

It would also be possible to derive comparable values for TKN and NO_3-N. We have not done so for two reasons (a) the illustrative CV that results from a trial application of that operation for NO_3-N was greater than the comparable value for TN, and (b) prior investigations revealed that the distribution of TN between TKN and oxidized forms is seasonally and regionally influenced.

The illustrative CVs in Table 9 were applied independently, i.e., if TN or TP exceeded the corresponding CV, the site was defined as "nutrient impaired." Applying the illustrative CVs to the ProbMon data set revealed that 12 of 15 sites (or 80%) with TN concentrations above the critical value (> 1.8 mg/L), assessed as nutrient impaired, were also determined to be impaired according to the SCI score (Table 10). Eight sites were identified as impaired for having TP concentrations above the critical value (> 0.1 mg/L), and all eight sites (100%) were also considered impaired based on the SCI. The combined application of the two CVs yielded an 81% (13 of 16) correct assessment level in comparison to the SCI score. These assessment levels are less than the targeted 90% because the illustrative CV's were derived from trend lines, not the individual data points. If the two illustrative CVs had been applied in combination (i.e., if an impairment assessment were to require that both conditions be satisfied), eight monitoring locations would have been assessed as impaired. This example is provided for discussion purposes, recognizing that a superior test would have been to apply the illustrative CVs to an independent data set.

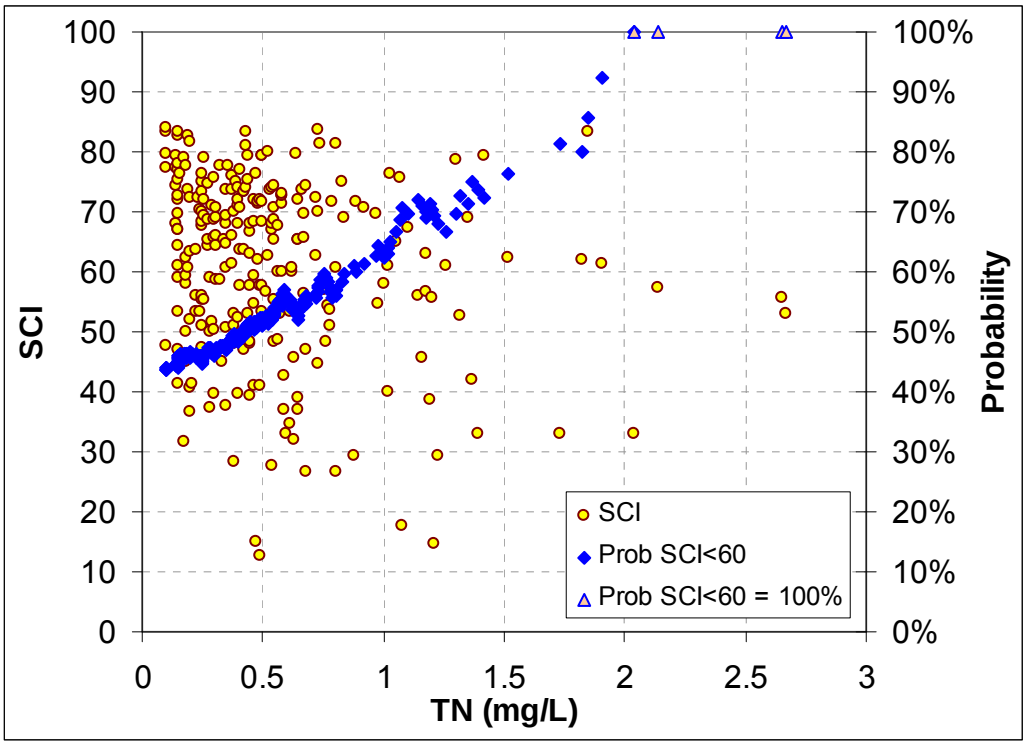


Figure 13a. SCI vs. TN (left axis) and $Prob_{SCI<60}$ for TN (right axis) plots based on DEQ probabilistic monitoring data, Mountain and Piedmont regions only, 2001-2006.

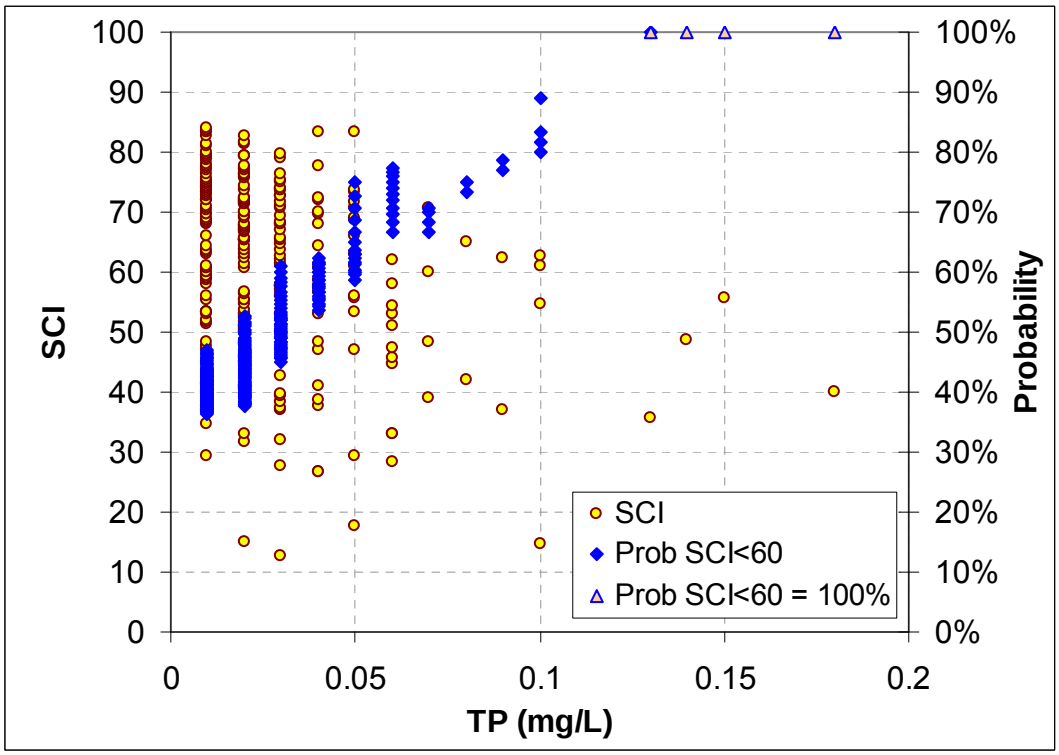


Figure 13b. SCI vs. TP (left axis) and $Prob_{SCI<60}$ for TP (right axis) plots based on DEQ probabilistic-monitoring data, Mountain and Piedmont regions only, 2001-2006.

Table 9. Illustrative critical values (CVs) for TN and TP concentrations. These concentrations are for illustrative purposes only and should not be considered as actual, suggested, or likely critical values. TN and TP CVs would be applied independently, i.e., if either TN or TP exceeds the threshold, the site would be assessed as impaired.

Nutrient variable	**Critical Value: Concentration where $P_{SCI<60} \geq 90\%$**	**Illustrative CV, as Percentile of Probabilistic-monitoring TN Distribution**
TN (mg/L)	1.8	94th
TP (mg/L)	0.1	94th

Table 10. Results of illustrative critical-value application to probabilistic-monitoring data set.

	Assessment is Correct Based on SCI	**Assessment is Incorrect Based on SCI**	**Sites Below CV so Not Assessed**
TN > 1.8	12	3	252
TP > 0.1	8	0	259
Both	13	3	251

2. Derive Illustrative Screening Values from Reference Conditions

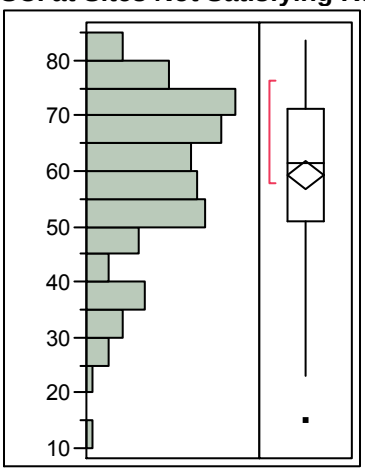
DEQ has used a set of criteria to define reference conditions in various studies. For example, the criteria were used to establish reference conditions in the studies conducted to develop the SCI (Tetra Tech, Inc. 2003), which was approved by EPA. The approach described here uses reference conditions to identify screening values for use in developing nutrient criteria. The following (Table 11) are reference conditions used in the SCI validation study (Virginia DEQ 2006), which were more restrictive than those used by Burton and Gerritsen in the original SCI development.

Table 11. Reference filters applied by DEQ for Mountain and Piedmont regions (Virginia DEQ 2006).

	Mountain	**Piedmont**
% Urban	< 5%	< 5%
Total Nitrogen	< 1.5 mg/L	< 1.5 mg/L
Total Phosphorus	< 0.05 mg/L	< 0.05 mg/L
Specific Conductance	< 250 µS/cm	< 250 µS/cm
Dissolved Oxygen	> 6 mg/L	> 6 mg/L
pH	> 6 and < 9	> 6 and < 9
Channel Alteration	> 11	> 11
Embeddedness	> 11	
Epifaunal Substrate/Cover	> 11	> 11
Riparian Vegetative Zone	> 11	> 11
Total Habitat Score	> 140	> 140

The Virginia DEQ (2006) reference conditions include TN and TP values. We tested the adequacy of those TN and TP reference-condition values as potential screening values by applying the full set of reference-filter conditions to the probabilistic-monitoring data set (2001-2006, Mountain and Piedmont regions only). Results are listed in Figure 14.

SCI at Sites Not Satisfying Reference Filter



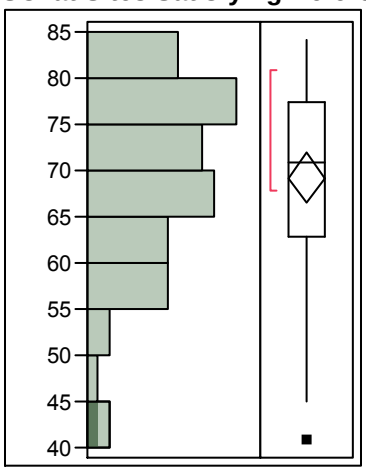
Quantiles

100.0%	maximum	83.640
99.5%		83.640
97.5%		81.328
90.0%		75.836
75.0%	quartile	71.126
50.0%	median	61.279
25.0%	quartile	51.004
10.0%		37.118
2.5%		29.478
0.5%		14.710
0.0%	minimum	14.710

Other Descriptive Stats

Mean	59.355077
N	127

SCI at Sites Satisfying Reference Filter



Quantiles

100.0%	maximum	84.128
99.5%		84.128
97.5%		83.719
90.0%		82.364
75.0%	quartile	77.400
50.0%	median	70.780
25.0%	quartile	62.894
10.0%		55.855
2.5%		43.048
0.5%		40.680
0.0%	minimum	40.680

Other Descriptive Stats

Mean	69.226727
N	61

Figure 14. Results of applying the reference filters (Table 11) to DEQ probabilistic-monitoring data set (2001-2006, Mountain and Piedmont regions only).

The 10th percentile of the SCI distribution at sites satisfying the reference-filter conditions is SCI = 56. If DEQ and the AAC were to decide that screening values (SVs) would be developed with the intent of limiting false negative (Type II) assessment errors to 10 percent or less, the result of this exercise would have been more satisfactory if the 10th percentile for the Reference Sites were SCI=60 or above. However, considering that both non-nutrient and nutrient stressors are likely responsible for the observed SCI<60 impairments at the reference-filter sites, we continued the example.

We applied the highest observed TN and TP concentrations derived from the population of sites that satisfied the reference filter as illustrative screening values. The highest observed TN

value within the reference data set was 0.80 mg/L. This value is well below the 1.49 mg/L reference-filter maximum. The highest observed TP value at the reference-filtered sites was 0.04 mg/L, which is the highest possible concentration than can satisfy the reference filter at the analytical precision of these data Therefore, we describe the screening values in this illustrative example as TN<0.81 mg/L and TP<0.05 mg/L.

Applying these screening values to the probabilistic-monitoring data yields the results in Table 12. These results should be considered while recognizing that both reference and non-reference sites are included within the 267 sites, and that the observed benthic-macroinvertebrate impairments are by both nutrient and non-nutrient stressors.

Table 12. Numbers of sites affected by illustrative screening values (SV). The extent to which impairments (SCI<60) occur when TN and TP are below the screening values cannot be used to determine the adequacy of the screening values because the SCI<60 values can occur due to the effects of non-nutrient stressors.

Illustrative Screening Value	SCI>60	SCI<60	Total	Illustrative SV as Percentile of ProbMon TN/TP Distributions
TN<0.81 mg/L	130	89	219	76th
TP<0.05 mg/L	133	87	220	77th
TN<0.81 mg/L and TP<0.05 mg/L	121	78	199	
Total Sites	150	117	267	

Hypothetical Applications of the AAC Recommended Approach

The illustrative CVs and SVs were applied to the probabilistic-monitoring data set and pilot-program data set. Sites were hypothetically considered "not impaired by nutrients" when the TN concentration was below 0.81 mg/L and the TP concentration was below 0.05 mg/L. Sites were listed as "impaired by nutrients" if either the TN concentration was above 1.8 mg/L or TP concentration was above 0.1 mg/L.

When applied to the probabilistic-monitoring data set, the illustrative CVs and SVs were sufficient to assess 81% of the observations (Table 13). The remaining 19% of observations were not classified. Extending this result to a real-world context and assuming the AAC recommended procedure were in place, this would mean that 19% of the total number of sites would need to be assessed visually by regional biologists. Additionally, a percentage of the visually assessed sites would need to be further evaluated using the benthic-macroinvertebrate community.

Table 13. Results of hypothetical combined application of illustrative critical values (CVs) and screening values (SVs) to ProbMon (2001-2006), Mountain and Piedmont regions.

	Number of sites	**% of total sites**
All sites	267	100%
"Assessed" by SV	199	75%
"Assessed" by CV	16	6%
"Assessed" by either SV or CV	215	81%
Not "Assessed"	52	19%

It is possible to apply the illustrative SVs and CVs to the pilot-program data to generate a second hypothetical example. For this data set, if the status of the site was not determined by the nutrient concentrations, it was evaluated based on the results of the visual assessment. The results were generated assuming a visual assessment that indicated "high probability of nutrient impairment" would result in a designation of "assessed as nutrient impaired." The results of the visual assessment were only used to determine if a site would be considered "impaired by nutrients" (The visual assessment was not used to define a site as "not impaired by nutrients."). All sites in the pilot-program that were not assessed using the SV, CV, or visual assessment would need a benthic-macroinvertebrate assessment. Results of this hypothetical application are summarized in Table 14; station-specific results are reviewed in Appendix C.

Table 14. Outcome of hypothetical application of illustrative CVs and SVs, in combination with regional biologists' visual assessments, to the pilot-program data set.

Outcome	**SCI>60**	**SCI<60**	**Total**
	- - - Number of sites - - -		
All sites	26	36	62
"Assessed" by SV (Not Impaired by Nutrients)	15	13	28
"Assessed" by CV (Impaired by Nutrients)	6	10	16
"Assessed" Visually as Impaired by Nutrients	-	3	3
Not "Assessed"– Benthic-Macroinvertebrate Assessment Needed	5	10	15

In evaluating the results, readers should consider the limitations of the pilot-program data set as a basis for inferring potential results if these procedures were to be applied more generally. Monitoring locations used in the pilot program were characterized by higher nutrient concentrations than those in the probabilistic-monitoring data set (Figure 15). This high-nutrient-level characteristic was by design because the procedure to select stations for the pilot program was intended to assure that high-nutrient locations (of primary interest in nutrient criteria development) were adequately represented. In contrast, the probabilistic-monitoring locations are selected with the intention of representing the population of Virginia streams. Non-parametric comparisons of the pilot-program and probabilistic-monitoring data sets reveal that both nutrient distributions differ significantly ($p<0.01$ for TN, $p<0.0001$ for TP) (Figure 15).

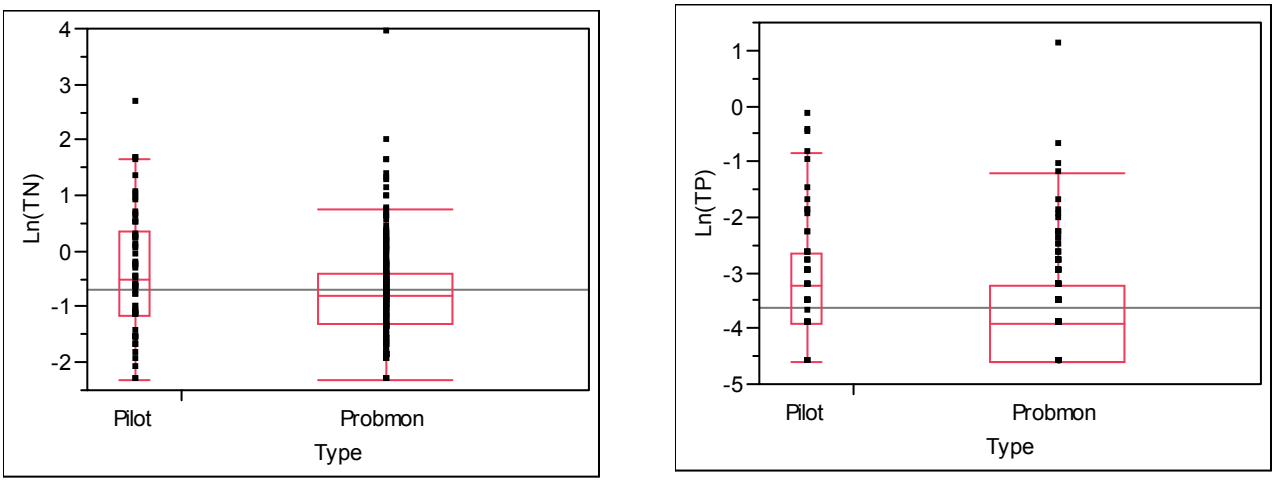


Figure 15. Distributions of Ln-transformed TN (left) and TP (right) concentrations for the pilot-program and probabilistic-monitoring data sets.

IV. Analysis of Nutrient Concentration Stability in Time

An essential question in evaluating how nutrients might be applied by the Virginia DEQ in water-quality assessments concerns the stability in time of measured-nutrient concentrations. Whereas both the pilot-program and probabilistic-monitoring data analyses were conducted using the nutrient concentrations of one water sample per site, Virginia DEQ would be applying nutrient criteria to assess water quality using data containing multiple observations collected over extended periods of time by its ambient water-monitoring program. Thus, it is reasonable to ask how conclusions derived from the pilot-program and probabilistic-monitoring data analyses might be applied within a nutrient-criteria program that is implemented as an assessment of the ambient-monitoring data.

The analysis of the pilot-program data was conducted for the purpose of aiding the process to develop nutrient criteria. Here, we conduct an additional analysis to investigate the effect of using values derived from the pilot program as opposed to values derived from monitoring data collected over prior-time periods. Understanding this relationship is important because monitoring data collected over prior-time periods will likely be used to determine a stream's impairment or non-impairment by nutrients once nutrient criteria are fully developed and implemented.

Methods

The ambient-monitoring database was queried by DEQ's water-monitoring coordinator to extract water-monitoring observations for each of the pilot-program sites over a three-year period extending from 1/1/2006 through 12/31/2008. For each location, the coordinator isolated water-monitoring observations occurring within 183 days, 365 days, and 730 days prior to the sampling period of the pilot program. Median TN and TP were calculated for each of these periods for those locations where >2 observations (i.e., 3 or more) were in the database for the 183-day prior

period, >4 observations were available for the 365-day prior period, and >6 observations were available for the 730-day prior period.

The TN and TP prior-period medians were analyzed for correspondence with observed values obtained from the pilot program. For each prior-period median, the difference from the corresponding pilot-program value was calculated, and the distribution of those differences was tested for equivalence to 0.0 using the non-parametric, Wilcoxon Rank Sum procedure. Ratios of TN and TP pilot-program values to period medians were calculated, and the distribution of those ratios was tested for difference from 1.0 using the Wilcoxon Rank Sum procedure. Log-transformed, prior-period medians were regressed against log-transformed, pilot-program values.

Relationships of prior-period medians to benthic-algae metrics and the SCI were compared to corresponding relationships for the pilot-program observations. Log-transformed TN and TP concentrations – as measured by the pilot program, and prior 183-day, 365-day, and 730-day medians – were regressed against four benthic-algae measures and the SCI. The four algae measures included two algal indices (Algal Index 1234 and Algal Index 13610), benthic chlorophyll-a (Chl-a), and ash-free dry mass (AFDM). The algal indices were constructed for each site by summing the algal color/form combinations that biologists described as being present in the visual analysis procedure, weighting each by visually estimated stream bottom coverage on a scale of 1– 2 – 3 – 4 to construct the "Algal Index 1234," and using a weighting of 1 – 3 – 6 – 10 to construct "Algal Index 13610." Medians were calculated only when the number of prior-period observations exceeded a minimum threshold (> 2 for 183 days, > 4 for 365 days, and > 6 for 730 days) as described above. The monitoring locations included in this analysis were defined separately for TN and TP, and only those locations with sufficient prior-period observations to enable calculation of at least one prior-period median were used.

Critical-value thresholds were derived using the prior-period medians and compared to those derived using the pilot-program observations.

Results

Pilot-Program Results vs. Period Medians

The non-parametric analyses found no pilot-program measured concentrations minus period-median concentrations to be significantly different from zero. Likewise, no ratios of the pilot-program concentrations to the period-median concentrations were significantly different from 1.0. Both measures, however, exhibited substantial variability around measures of central tendency.

As expected, the magnitude of TN and TP differences (pilot-program concentration minus period-median concentration) increased with concentration (Figure 16); larger magnitude differences were mostly positive for both TN and TP. Thus, the highest concentrations observed during the pilot program tended to be unusually high values, suggesting that concentration deviation from the median is primarily on the positive side at such sites. Concentration ratios also increased with pilot-program concentration for both TN and TP, and for all period medians ($p < 0.0001$ for TN; $p < 0.05$ for TP) (Figure 17).

Both measures can be interpreted to indicate that nutrient concentrations in streams with low concentrations tend to remain stable, whereas high-concentration streams exhibit greater variability on both a concentration-magnitude and on a proportionate basis. However, the pilot-program values and all period medians were highly correlated for TN and TP (Figure 18).

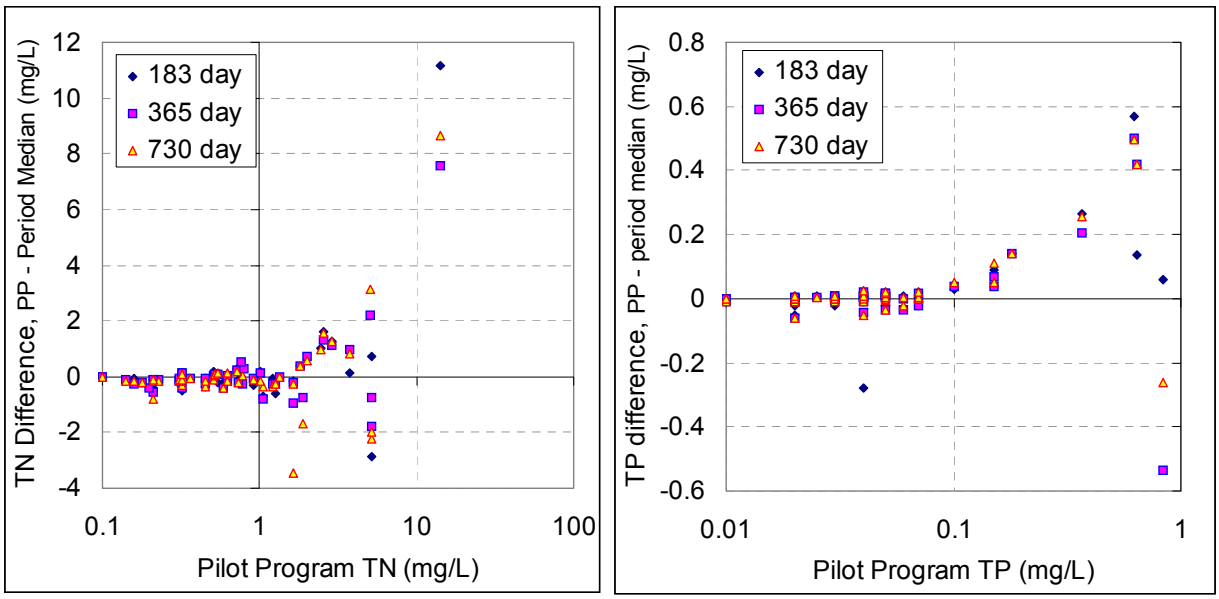


Figure 16. Concentration differences (pilot-program concentrations minus period-median concentration) as a function of pilot-program concentrations.

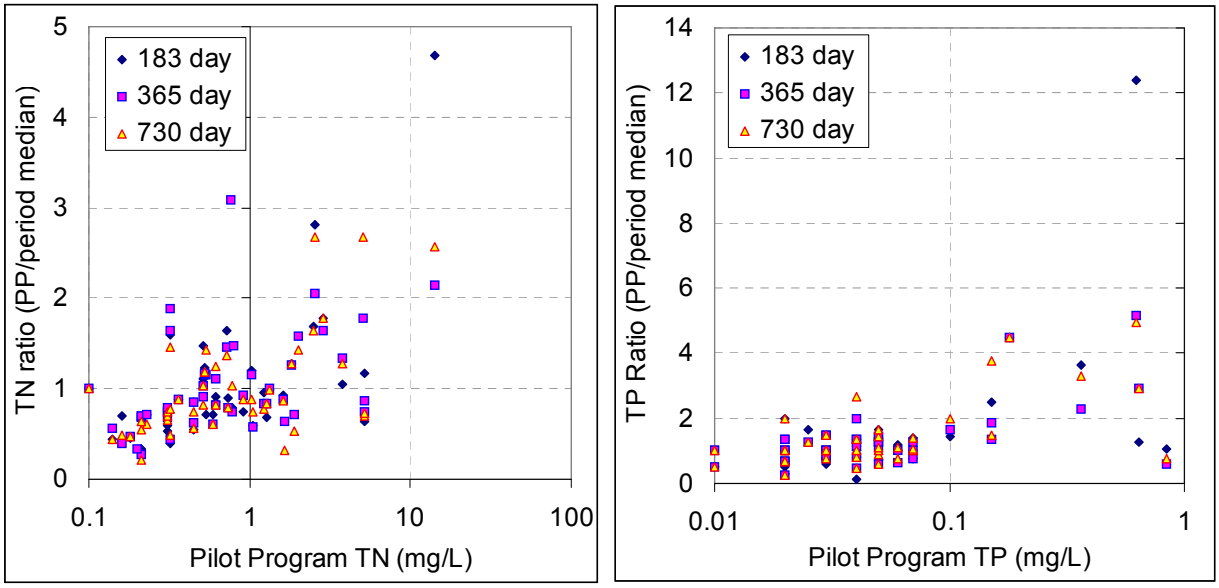


Figure 17. Concentration ratios (pilot-program concentration / period-median concentration) as a function of pilot-program concentration.

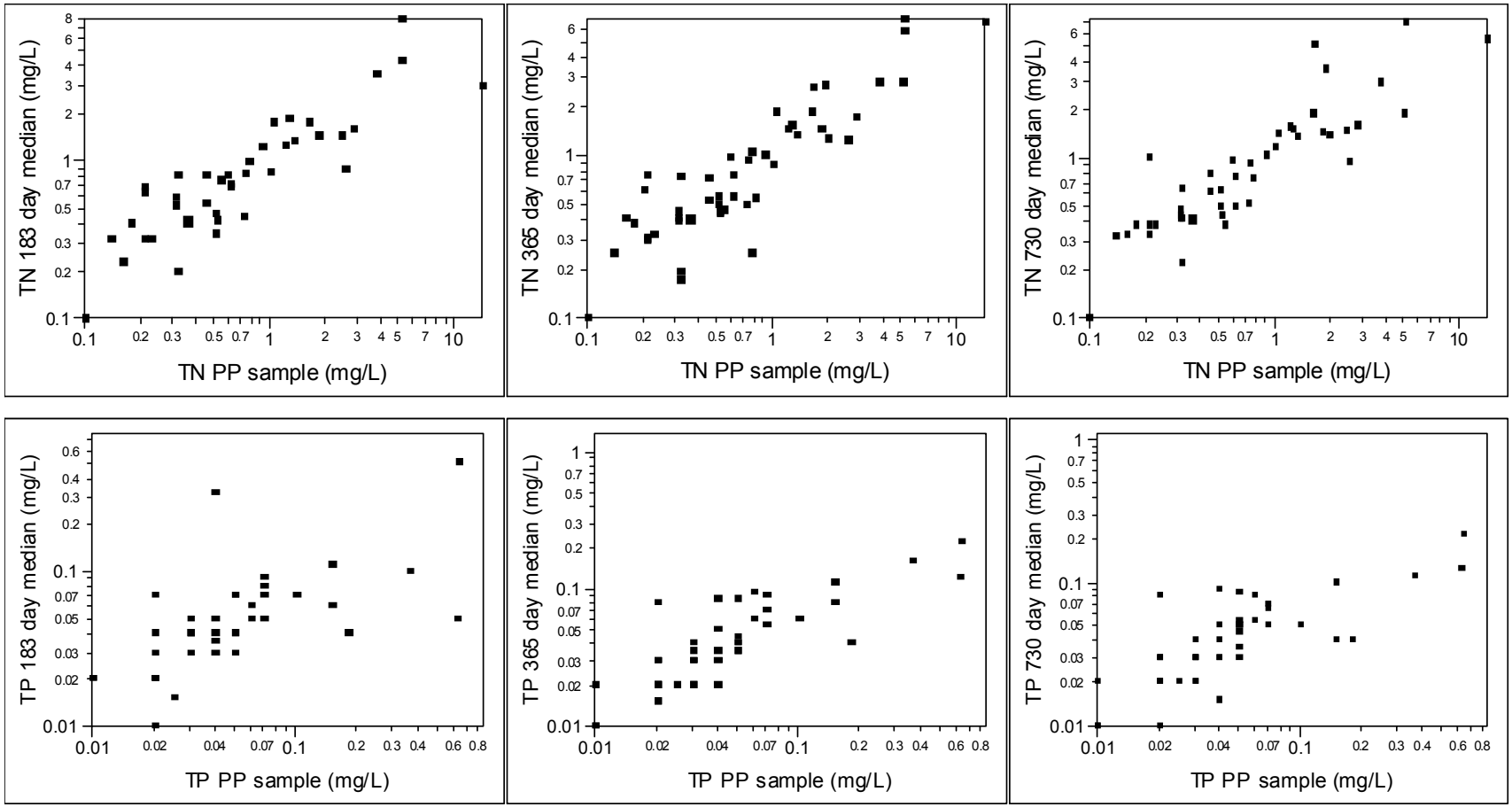


Figure 18. The 183-day, 365-day, and 730-day median TN and TP concentrations as a function of pilot-program (PP) concentrations. All relationships are statistically significant ($p<0.0001$).

Relationships with Benthic- Algae and Benthic- Macroinvertebrate Measures

Results of the comparative analysis of nutrient concentrations against benthic-algae and benthic-macroinvertebrate measures are listed in Table 15. In general, use of the prior-period medians resulted in tighter regressions (higher R^2 values, lower p values) for TN relative to pilot-program values. Longer period medians (e.g., 730-day median) were responsible for the highest R^2 values. The degree of improvement, however, was not sufficient to alter the basic conclusions derived from the pilot-program analysis. For the TP analysis, no systematic change in outcomes was apparent as due to use of the prior-period medians.

Table 15. Results of comparative linear-regression analyses for pilot-program TN and TP concentrations and prior-period median TN and TP concentrations against benthic-algae indices and the Stream Condition Index (SCI). All nutrient concentrations were Ln-transformed.

		Algal Index (1234)	**Algal Index (13610)**	**Ln (Chla)**	**Ln (AFDM)**	**SCI**
TN	n	50	50	50	50	50
Pilot	R^2	0.014	0.015	0.141	0.071	0.144
Program	p	0.66	0.71	0.0072	0.061	0.0066
TN 183	n	40	40	40	40	40
Day	R^2	0.020	0.009	0.157	0.116	0.295
Median	p	0.6523	0.5541	0.011	0.018	0.0003
TN 365	n	49	49	49	49	49
Day	R^2	0.019	0.016	0.171	0.107	0.144
Median	p	0.3335	0.38	0.0032	0.0212	0.0071
TN 730	n	47	47	47	47	47
Day	R^2	0.023	0.023	0.226	0.133	0.210
Median	p	0.031	0.031	0.0007	0.011	0.0012
TP	n	47	47	47	47	47
Pilot	R^2	0.0000	0.005	0.017	0.0002	0.008
Program	p	0.963	0.615	0.394	0.946	0.544
TP 183	n	41	41	41	41	41
Day	R^2	0.033	0.003	0.003	0.0000	0.034
Median	p	0.247	0.733	0.733	0.956	0.247
TP 365	n	45	45	45	45	45
Day	R^2	0.017	0.032	0.012	0.0000	0.018
Median	p	0.399	0.237	0.477	0.998	0.383
TP 730	n	47	47	47	47	47
Day	R^2	0.019	0.043	0.002	0.0000	0.021
Median	p	0.35	0.056	0.797	0.949	0.331

Potential Screening-Value and Critical-Value Thresholds

As with the analysis of the pilot-program data set, the analysis of the prior-period data set offered little in the way of useful thresholds. Potential screening values derived from the prior-period medians are quite low (0.1 mg/L for the three TN prior-period medians, and 0.01 mg/L for the three TP prior-period medians). Potential critical values derived from the prior-period medians tend to be at very high levels relative to the distribution of TN and TP values from the 2001-2006 probabilistic-monitoring locations (Table 16).

Table 16. Comparison of potential critical values[a] (CV) for TN and TP derived from prior-period medians to those derived from the pilot-program observations, and corresponding percentiles within DEQ's probabilistic-monitoring observations (2001-2006, Virginia's Mountain and Piedmont regions).

	CV Concentrations (mg/L)		**ProbMon Percentile**	
	TN	**TP**	**TN**	**TP**
Pilot-program observations	2.6	0.4	96	99
Prior-period medians:				
183-day medians	1.8	0.2	94	98
365-day medians	2.75	0.2	97	98
730-day medians	4	0.12	99	97

[a] Potential critical values are set at approximate midpoint of range between the highest concentration at a non-impaired site and the next-highest concentration.

Conclusions

This analysis should be considered as an initial effort to address questions regarding the operational aspects of applying the screening-value approach within DEQ's water-quality monitoring and assessment framework.

Nutrient concentrations at any given location in a stream are variable in time. The TN and TP concentrations of water samples collected during the pilot program were good estimates, in a statistical sense and on average, of median values for water-monitoring samples collected during 183 days, 365 days, and 730 days prior to the pilot program sampling event (prior-period medians). When comparing the measured concentrations from the pilot program to the concentration medians of the prior-period data, the variability increased in both measured (mg/L) and relative terms at the higher concentrations. Substitution of prior-period-median values for pilot-program-measured values affected results of several analyses, but the differences were minor and inconsequential to the conclusions drawn from the pilot-program data analysis.

One would expect that the additional information in the historical record would provide better results than a single nutrient-concentration measurement obtained during the pilot program. However, questions remain about how the historical data should be analyzed in order to provide an improved result.

Reducing the set of available observations to the median might not be the best way to utilize the historical record. Diminution of the SCI would be caused by a history of high-nutrient concentrations over a period of time, i.e., by an accumulation of high-concentration events over a period of time. If such events were to occur frequently, although less than 50% of the time, they would not be reflected by a median value. Thus, an alternative approach would be to use a mean or a weighted, moving average of the historical record.

V. Summary and Future Plans

Several additional activities are planned for fiscal year 2010 (July 2009-June 2010). These activities include an analysis of the 2001-2008 probabilistic-monitoring data using a more rigorous application of the exploratory data analysis procedure. The planned analysis, which uses an extended data set that includes a larger number of monitoring sites with benthic-algae measurements, is considered desirable and necessary to derive more robust results.

Also during FY2010, the AAC will continue to explore mechanisms for deriving critical values. Downstream-loading issues will be considered in this activity, given the fact that all of the coastal waters that receive Virginia's surface-water streams (Chesapeake Bay, Pamlico Sound, Gulf of Mexico) suffer from nutrient overenrichment. Furthermore, the distribution of nutrient concentrations in Virginia streams is upwardly skewed (see Figure 12), suggesting that a small number of Virginia's surface water streams with excessively high-nutrient concentrations are responsible for a disproportionate share of the nutrients carried by surface waters into the coastal water bodies.

An additional activity planned for FY2010 is an analysis of DEQ's ambient-monitoring data to determine how a screening-value approach would be expected to affect DEQ resource allocations. This analysis would consider regional biologists' time as a critical resource that must be applied to implement a screening-value approach successfully.

Also during FY2010, regional biologists have stated an intent to continue developing the visual-assessment procedure that was employed on a trial and developmental basis during the pilot-program activity. The AAC is willing to continue working with the DEQ's biological-monitoring staff in this activity, as per DEQ and staff preferences.

VI. Acknowledgements

Roger Stewart, Jason Hill, and David Whitehurst of Virginia DEQ prepared data sets used in these analyses. DEQ's regional biologists assisted in developing and conducting the pilot program, especially with the visual-assessment component. David Whitehurst, Alex Barron, and Amy Genung provided oversight and coordination of AAC activities.

Financial support for this activity was provided by Virginia DEQ, U.S. EPA Region 3, and U.S. Geological Survey (USGS). The project described in this document was supported by Grant/Cooperative Agreement Number 08HQGR0004 from the USGS; the funding originated from U.S. EPA Region 3. John Schefter and Kimberly Dove of the USGS facilitated the interagency transfer of funding.

VII. Disclaimer

The contents of this document are solely the responsibility of the authors and do not necessarily represent the official views of the U.S. EPA Region 3, USGS, Virginia DEQ, or Virginia Water Resources Research Center at Virginia Tech.

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Appendix A: Nutrient Criteria Visual Assessment Field Form (Spring)

Station ID: Field Crew:

Stream Name: Ecoregion:

DEQ Region: **TP Category**

Location: **TN Category**

DATE _____ Start Time _____ Finish Time _____

LATITUDE (Decimal degrees) _____ LONGITUDE (Decimal degrees) _____

Stream Physicochemical Measurements

TEMPERATURE:_____ºC CONDUCTIVITY:_____µS/cm

DISSOLVED OXYGEN:_____mg/L pH: _____

Benthic Macroinvertebrate Collection

Method used (circle one) **Single habitat** **Multi-habitat**

Riffle quality (circle one) **Good** **Marginal** **Poor** **None**

Habitats sampled	**Riffle**	**Snags**	**Banks**	**Vegetation**
# jabs	____	____	____	_____

Algae Community

Algae community growth (% of stream bottom) **Categories; 1-10; 10-40; 40-70; >70**

Type of growth	bright green	dark green	brown	black	other
Film					
Thin mat					
Thick mat					
Filamentous					

Vascular Plant Growth

Vascular plant growth (% of stream bottom) **Categories; 1-10; 10-40; 40-70; >70**

Submerged macrophytes	
Emergent macrophytes	
Other	

Observations

Stream substrate type **Categories; 1-10; 10-40; 40-70; >70**

sand	**gravel**	**cobble**	**bedrock**	**mud**
_____	_____	_____	_____	_____

Estimated average stream width (Meters): _____

Estimated average stream depth (Meters): _____

Stream shading: (circle one) **Categories; 1-10; 10-40; 40-70; >70**

Stream flow (circle one) **Low** **Normal** **Above Normal**

Estimated stream velocity (Meters/sec): _____

Days since last potentially scouring rain: _____

Photo documentation taken? **YES / NO**

BPJ based on observations of algae and macrophyte biomass; probability of impairment to macroinvertebrate community (circle one)

Low **Medium** **High**

Provide a brief explanation for rating: _____

_____

Watershed features

Land Use

(Indicate the predominant surrounding land use with a "1". . If applicable, indicate a secondary land use with a "2".)

___ Forest ___Commercial

___Field/Pasture ___Industrial

___Agricultural ___ Residential

___Livestock ___ Other _____

Local Watershed Pollution (circle one)

No evidence Some potential sources

Obvious sources

Local Watershed Erosion (circle one)

None Moderate

Low Heavy

Appendix B: Nutrient Criteria Visual Assessment Field Form (Fall)

Station ID: Field Crew:

Stream Name: Ecoregion:

DEQ Region: **TP Category**

Location: **TN Category**

DATE _____ Start Time _____ Finish Time _____

LATITUDE (Decimal degrees) _____ LONGITUDE (Decimal degrees) _____

Stream Physicochemical Measurements

TEMPERATURE:_____ºC CONDUCTIVITY:_____µS/cm

DISSOLVED OXYGEN:_____mg/L pH: _____

Benthic Macroinvertebrate Collection

Method used (circle one) **Single habitat** **Multi-habitat**

Riffle quality (circle one) **Good** **Marginal** **Poor** **None**

Habitats sampled	**Riffle**	**Snags**	**Banks**	**Vegetation**
# jabs	____	____	____	_____

Algae Community and Vascular Plant Growth

Algae community growth (% of stream bottom) **Categories; 1-10; 10-40; 40-70; >70**

Type of growth	bright green	dark green	brown	black	other
Film					
Thin mat					
Thick mat					
Short Filamentous					
Tall Filamentous					

Vascular plant growth (% of stream bottom) **Categories; 1-10; 10-40; 40-70; >70**

Submerged macrophytes	
Emergent macrophytes	
Mosses	
Other	

Total stream button coverage by algae and vascular plant growth _____
(Categories; 1-10; 10-40; 40-70; >70)

Observations

Stream substrate type **sand** **gravel** **cobble** **bedrock** **mud**

Categories; 1-10; 10-40; 40-70; >70 _____ _____ _____ _____ _____

Estimated average stream width (Meters): _____

Estimated average stream depth (Meters): _____

Stream shading: (circle one) **full shade** **partial shade** **full sun**

Stream flow (circle one) **Low** **Normal** **Above Normal**

Estimated stream velocity (Meters/sec): _____

Days since last potentially scouring rain: _____

Photo documentation taken? **YES / NO**

BPJ based on observations of algae and macrophyte biomass; probability of impairment to macroinvertebrate community by nutrients (circle one)

Low **Medium** **High**

Provide a brief explanation for rating: _____

_____

BPJ based on observations of algae and macrophyte biomass; probability of impairment to macroinvertebrate community by non-nutrient stressor (circle one)

Low **Medium** **High** **Stressor(s):**_____

Provide a brief explanation for rating: _____

_____

Watershed features

Land Use: (Indicate the predominant surrounding land use with a "1". If applicable, indicate a secondary land use with a "2".)

___ Forest ___Field/Pasture ___Agricultural ___Livestock

___Commercial ___Industrial ___ Residential ___ Other _____

Local Watershed Pollution (circle one)

No evidence **Some potential sources** **Obvious sources**

Local Watershed Erosion (circle one)

None **Moderate** **Low** **Heavy**

Appendix C. Pilot Program Data

Hypothetical application to sites in the pilot program for illustrative screening and critical values within AAC recommended approach.

StationID	Sea-son	TN (mg/L)	TP (mg/L)	BPJ: Prob Nutrient Impair-ment	BPJ: Prob Non-Nutrient Impair-ment	CV: TN>1.8	CV: TP>0.1	SV: TN<0.81 & TP<0.05	BPJ	Outcome	Stream Con-dition Index
6BPLU002.15	Spr	1.27	0.04	MEDIUM	-	-	-	-	-	BenMac Assess	40.94
2-PCT002.46	Spr	0.62	0.10	MEDIUM	-	-	-	-	-	BenMac Assess	42.12
1ANOG005.69	Spr	1.02	0.06	MEDIUM	-	-	-	-	-	BenMac Assess	46.81
1BSSF053.09	Spr	1.22	0.06	LOW	-	-	-	-	-	BenMac Assess	48.28
4ATKR000.69	Fal	1.34	0.05	MEDIUM	MEDIUM	-	-	-	-	BenMac Assess	50.34
6CMFH055.88	Fal	0.59	0.05	MEDIUM	MEDIUM	-	-	-	-	BenMac Assess	50.35
4ASEE003.16	Fal	0.21	0.07	MEDIUM	LOW	-	-	-	-	BenMac Assess	54.37
2-CNE000.96	Spr	1.11	0.05	LOW	-	-	-	-	-	BenMac Assess	55.31
6BIDN000.69	Fal	1.22	0.03	MEDIUM	LOW	-	-	-	-	BenMac Assess	59.81
5AGRV000.08	Spr	0.51	0.05	LOW	-	-	-	-	-	BenMac Assess	68.20
2-NOR000.20	Spr	0.34	0.10	LOW	-	-	-	-	-	BenMac Assess	68.62
3-MTN000.59	Fal	1.05	0.07	MEDIUM	MEDIUM	-	-	-	-	BenMac Assess	69.51
3-RAP006.53 (S1)	Fal	0.78	0.06	LOW	MEDIUM	-	-	-	-	BenMac Assess	70.99
2-HAT000.14	Fal	0.14	0.05	LOW	MEDIUM	-	-	-	-	BenMac Assess	71.86
1ASYL000.02	Spr	3.77	0.02	MEDIUM	-	imp	-	-	-	Impaired	23.01
1AOPE036.13	Spr	5.13	0.84	LOW	-	imp	Imp	-	-	Impaired	29.78
1BMDD005.81	Spr	5.13	0.02	MEDIUM	-	imp	-	-	-	Impaired	36.66
9-STE007.29	Spr	1.63	0.05	HIGH	-	-	-	-	Imp	Impaired	38.18
5ABTR002.80	Spr	0.52	0.05	HIGH	-	-	-	-	Imp	Impaired	39.41
2-CHK079.23	Fal	0.92	0.07	LOW	HIGH	-	-	-	Imp	Impaired	40.62

4AMEY016.00	Spr	2.76	0.43	HIGH	-	imp	Imp	-	Imp	Impaired	42.66
1BCKS001.03	Fal	1.66	0.05	HIGH	HIGH	-	-	-	Imp	Impaired	42.98
3-THM001.40	Fal	2.48	0.07	LOW	MEDIUM	imp	-	-	-	Impaired	47.94
2-JKS018.68	Fal	0.72	0.15	HIGH	LOW	-	Imp	-	Imp	Impaired	50.13
3-GRT001.70	Fal	14.2	0.62	HIGH	LOW	imp	Imp	-	Imp	Impaired	52.43
4ALOR008.64	Fal	5.04	0.64	MEDIUM	MEDIUM	imp	Imp	-	-	Impaired	56.52
1BSTH019.52	Fal	1.62	0.22	LOW	LOW	-	Imp	-	-	Impaired	56.78
2-SOL001.00	Fal	2.86	0.04	LOW	MEDIUM	imp	-	-	-	Impaired	57.11
6BPOW179.20	Fal	0.74	0.02	MEDIUM	HIGH	-	-	NotNI	Imp	Impaired	59.03
9-DEN000.03	Spr	1.99	0.04	MEDIUM	-	imp	-	-	-	Impaired	60.44
1BSTH002.14	Spr	1.28	0.14	MEDIUM	-	-	Imp	-	-	Impaired	61.15
2-APP012.79	Spr	0.45	0.18	MEDIUM	-	-	Imp	-	-	Impaired	61.29
9-MLC005.44	Spr	1.91	0.03	LOW	-	imp	-	-	-	Impaired	62.34
6CMFH033.40	Fal	1.83	0.15	LOW	LOW	imp	Imp	-	-	Impaired	67.39
2-RVN015.97 (S1)*	Fal	2.54	0.37	HIGH	MEDIUM	imp	Imp	-	Imp	Impaired	69.06
1ALIV012.12	Fal	0.45	0.03	LOW	LOW	-	-	NotNI	-	Not Nut Imp	28.56
6ASAT000.26	Spr	0.32	0.01	LOW	-	-	-	NotNI	-	Not Nut Imp	36.70
2-IVC010.20	Spr	0.54	0.02	LOW	-	-	-	NotNI	-	Not Nut Imp	37.37
2-MTC001.24	Fal	0.62	0.04	LOW	MEDIUM	-	-	NotNI	-	Not Nut Imp	47.17
2-LIH005.28	Fal	0.31	0.02	MEDIUM	MEDIUM	-	-	NotNI	-	Not Nut Imp	49.07
8-LTL009.54	Spr	0.36	0.03	LOW	-	-	-	NotNI	-	Not Nut Imp	52.02
3-RAP077.28	Spr	0.32	0.02	LOW	-	-	-	NotNI	-	Not Nut Imp	53.66
9-LTL001.22	Spr	0.20	0.02	LOW	-	-	-	NotNI	-	Not Nut Imp	54.01
2-LIA000.50	Fal	0.31	0.02	MEDIUM	MEDIUM	-	-	NotNI	-	Not Nut Imp	56.40
6BWAL005.97	Spr	0.77	0.03	MEDIUM	-	-	-	NotNI	-	Not Nut Imp	57.56
6AIND000.52	Fal	0.18	0.02	MEDIUM	MEDIUM	-	-	NotNI	-	Not Nut Imp	57.88
8-SAR097.82	Fal	0.32	0.04	LOW	NO	-	-	NotNI	-	Not Nut Imp	59.81
1ACAX004.57	Spr	0.80	0.02	LOW	-	-	-	NotNI	-	Not Nut Imp	61.39
2-MIS000.04	Fal	0.21	0.01	LOW	MEDIUM	-	-	NotNI	-	Not Nut Imp	62.16
9-NBS000.70	Fal	0.16	0.02	MEDIUM	LOW	-	-	NotNI	-	Not Nut Imp	62.93

2-FIN000.81	Spr	0.52	0.03	MEDIUM	-	-	-	NotNI	-	Not Nut Imp	65.18
3-ROB023.06	Spr	0.18	0.02	LOW	-	-	-	NotNI	-	Not Nut Imp	66.98
4ASNA015.30	Fal	0.31	0.03	LOW	-	-	-	NotNI	-	Not Nut Imp	67.42
1AHOC006.23	Fal	0.36	0.01	MEDIUM	MEDIUM	-	-	NotNI	-	Not Nut Imp	68.21
1AGOO022.44	Fal	0.23	0.04	LOW	LOW	-	-	NotNI	-	Not Nut Imp	68.38
5ATRE038.07	Fal	0.54	0.03	MEDIUM	MEDIUM	-	-	NotNI	-	Not Nut Imp	68.91
6CSFH097.42 (S1)	Spr	0.52	0.03	LOW	-	-	-	NotNI	-	Not Nut Imp	71.04
2-JES000.80	Spr	0.10	0.02	LOW	-	-	-	NotNI	-	Not Nut Imp	72.61
8-POR008.97	Fal	0.49	0.04	LOW	LOW	-	-	NotNI	-	Not Nut Imp	73.77
8-NAR005.42 (S1)	Fal	0.21	0.01	MEDIUM	LOW	-	-	NotNI	-	Not Nut Imp	75.48
2-BNF003.52	Spr	0.10	0.01	LOW	-	-	-	NotNI	-	Not Nut Imp	76.91
2-RKI003.40	Fal	0.12	0.02	LOW	LOW	-	-	NotNI	-	Not Nut Imp	83.64

* SCI for 2-RVN015.97 (S2) was 61.22.

Grant No. 08HQGR0002 U.S. Army Corps of Engineers Initiatives, Policies and Programs - Regulatory Improvement Initiatives

Basic Information

Title:	Grant No. 08HQGR0002 U.S. Army Corps of Engineers Initiatives, Policies and Programs - Regulatory Improvement Initiatives
Project Number:	2007VA124S
Start Date:	10/5/2007
End Date:	3/30/2009
Funding Source:	Supplemental
Congressional District:	09
Research Category:	Social Sciences
Focus Category:	Management and Planning, Law, Institutions, and Policy, None
Descriptors:	
Principal Investigators:	Stephen H. Schoenholtz

Publications

1. None
2. None
3. None

Wrap up for previously reported (June 2009) documents on Shared Vision Planning.

Shared Vision Planning Steps

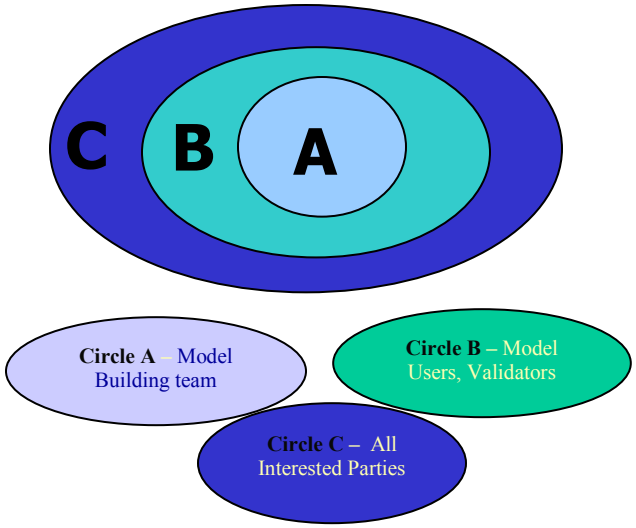
Shared Vision Planning uses traditional Corps planning principles but modifies them to include earlier and more intensive collaboration with a wide variety of stakeholders

- *Build a team* and identify problems *with stakeholders, decision-makers and experts.*
- Develop objectives & metrics for evaluation *that may differ from national objectives and metrics*
- Describe the status quo using *a collaboratively built model*
- *Collaboratively* formulate alternatives using the model
- *Collaboratively* evaluate alternatives and identify tradeoffs using the model
- Develop *team recommendations*
- *Implement and institutionalize* the team's recommended plan
- *Exercise and update* the plan

Model Characteristics Support Collaborative Planning

Integrated—All stakeholder interests and their interactions are in one place
User Friendly—capable of being used by multiple stakeholders and decision makers
Understandable/Transparent—assumptions, inputs, relationships, & output
Relevant to the interests and values of stakeholders and decision makers
Adaptable/Flexible to changing condition & evolving processes

Structured Collaboration



Shared Vision Planning uses a "Circles of Influence" approach to structure collaboration.

Is This Just Theory?

No, its not just theory— Collaborative Modeling in general has been gaining popularity across government agencies, within the private sector and within NGOs.
Shared Vision Planning traces its roots to water supply planning for the Washington DC region in the mid '70s. It was formalized in the early '90s in the
National Drought Study and applied in various cases including:

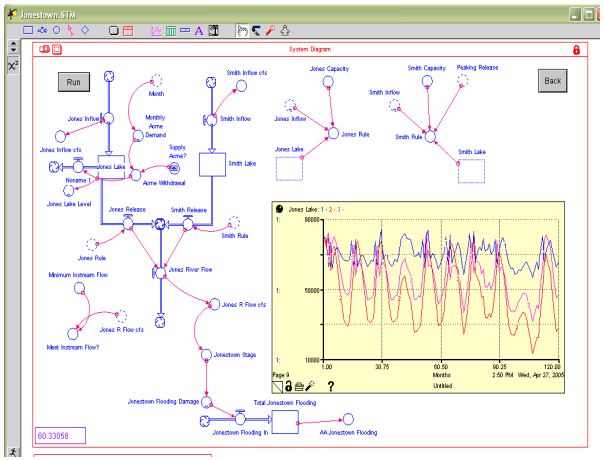
- Five Pilot Studies in the National Drought Study (USACE)
- ACT-ACF (USACE)
- Rappahannock River (USACE, Virginia Tech)
- Mississippi Headwaters Reservoir Operations Plan Evaluation (USACE)
- Lake Ontario Saint Lawrence River Study (USACE, Intl Joint Commission)

How it Works with 404 Permitting

SVP as a collaborative process can aid in permit reviews by opening the reviews earlier to a greater number of vested stakeholders. SVP thereby assists in identifying and assessing the importance of all issues early in the process. Stakeholders agree upfront on important issues, and collaboratively go through the technical analysis for issue assessment. In this way, the model(s) used for assessing impacts has been developed by stakeholders themselves, is transparent in both development and operation, and directly addresses the concerns of stakeholders.

When to Use SVP in the 404 Permit Process

- Incorporated into the pre-application process for issue identification and improved stakeholder involvement
- During Scoping
- After DEIS problem identification
- Wherever, after reviewing your permit process, it seems appropriate.



Why Use SVP?

- Improve predictability with respect to issue identification and reaction to impacts from the Corps and from Federal Agencies
- Improve issue resolution
- Reduce controversy during the review process and at the presentation of the permit decision
- Increase the reliability of answers to resource questions.
- Reduce the chances for supplemental DEIS by identifying and addressing issues upfront.
- Improve early issue identification
- Support or rebuke findings of no significance (FONSI).
- Develop a project constituency.
- Improve trust among stakeholders.
- Improve information sharing.

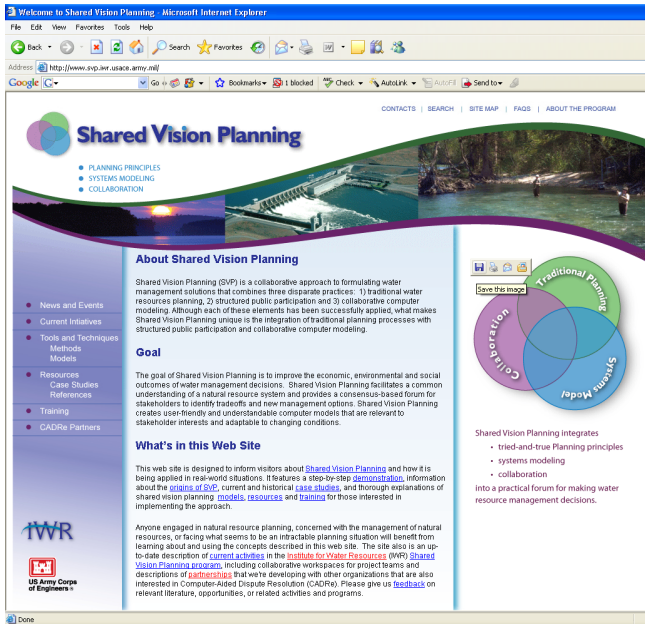
Current Case Studies

- Cache la Poudre, CO
- Willamette, OR
- James River, VA
- Upper Great Lakes, US & Canada
- Connecticut River, New England

Want More Info?

- Description of Cache la Poudre pilot on SVP for 404 water supply permit.
- White Paper " Shared Vision Planning Applied to Regulatory Decisions"
- Video & workshop summary on SVP in 404 & Water Supply
- Visualization Primer and Tutorials
- Case Studies, Background, References, links

www.SharedVisionPlanning.us



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US Army Corps of Engineers

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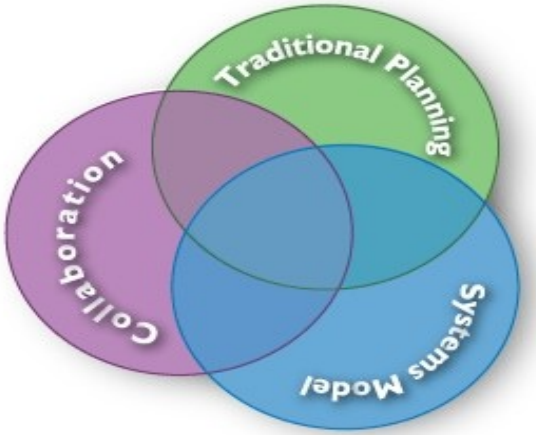
Shared Vision Planning



Shared Vision Planning integrates

- tried-and-true Planning principles
- systems modeling
- collaboration

into a practical forum for making water resource management decisions.

www.SharedVisionPlanning.us

Award No. 08HQGR0153 Studies of U.S. Army Corps of Engineers Policies and Programs, Phase II - Part 2

Basic Information

Title:	Award No. 08HQGR0153 Studies of U.S. Army Corps of Engineers Policies and Programs, Phase II - Part 2
Project Number:	2008VA132S
Start Date:	9/9/2008
End Date:	12/31/2010
Funding Source:	Supplemental
Congressional District:	09
Research Category:	Social Sciences
Focus Category:	Management and Planning, Law, Institutions, and Policy, None
Descriptors:	
Principal Investigators:	Stephen H. Schoenholtz

Publication

1. None

No report available at this time.

Award No. G09AP00149 Modernizing U.S. Army Corps of Engineers Planning and Regulatory Policies and Programs, Phase III

Basic Information

Title:	Award No. G09AP00149 Modernizing U.S. Army Corps of Engineers Planning and Regulatory Policies and Programs, Phase III
Project Number:	2009VA133S
Start Date:	8/1/2009
End Date:	3/31/2011
Funding Source:	Supplemental
Congressional District:	
Research Category:	Not Applicable
Focus Category:	None, None, None
Descriptors:	
Principal Investigators:	Stephen H. Schoenholtz, Stephen H. Schoenholtz

Publication

1. None

Award No. G09AP00149
Modernizing U.S. Army Corps of Engineers Planning and Regulatory Policies and Programs: Phase III

Interim document prepared, but not yet available:

Flood Insurance for Risk Communication: Reclaiming Original Intent
Working draft by Leonard Shabman

Grant No. G09AP00111 U.S. Army Corps of Engineers Regulatory Initiatives

Basic Information

Title:	Grant No. G09AP00111 U.S. Army Corps of Engineers Regulatory Initiatives
Project Number:	2009VA141S
Start Date:	6/1/2009
End Date:	12/31/2010
Funding Source:	Supplemental
Congressional District:	
Research Category:	Social Sciences
Focus Category:	Law, Institutions, and Policy, Management and Planning, None
Descriptors:	Water supply, permitting, regulation
Principal Investigators:	

Publications

There are no publications.

Comments of the Independent Peer-Review Team for the Draft Eastern Mountains and Piedmont Regional Supplement to the 1987 Corps of Engineers Wetland Delineation Manual, and Responses by the Corps of Engineers and the Eastern Mountains and Piedmont Working Group

Comments and recommendations developed by the peer-review team are given in Columns A through E of each spreadsheet page (click the tabs below). Responses developed by the US Army Engineer Research and Development Center (ERDC) and the Eastern Mountains and Piedmont Working Group are given in Column F.

Members of the Independent Peer-Review Team were:

Joanne M. Barry, Chair, contractor, U.S. Army Engineer Institute for Water Resources, Alexandria, VA
John H. Brooks III, Resource International, Ltd., Ashland, VA
Thomas P. Colson, North Carolina State University, Raleigh, NC
Christopher Huysman, Strategic Natural Resources Group, Inc., Sparta, NC
Melissa McCanna, Dewberry & Davis LLC, Fairfax, VA
Richard P. Reaves, CH2M Hill, Atlanta, GA
Kevin Seaford, Timmons Group, Richmond, VA
Michael G. Wood, The Catena Group, Hillsborough, NC

The Corps of Engineers thanks all reviewers for their helpful and well-reasoned comments.

Chapter 1

Initials	Ch	Pg	Par	Comment	Response
Chris Huysman - CH	Abstract			Put definition of wetlands under 1987 manual into intro para 3 - either by reference or explicitly	The Corps/EPA definition of wetlands is presented in the 1987 Corps of Engineers Wetlands Delineation Manual (i.e., the Manual) and does not need to be repeated in the supplement. That definition has not changed.
McCanna - MM	Contents			Add a list of figures and tables to table of contents	This will be done by ERDC editors before publication.
Team	Preface			Add peer review panel to preface: John Brooks, Thomas Colson, Chris Huysman, Melissa McCanna, Richard Reaves, Kevin Seaford, Michael Wood.	We will make the recommended change.
Team	Preface			Recommendation to reader to completely fill out data sheet.	This suggestion seems premature for the Preface.
MM	Intro	1	1	Use consistent citing for 404 and Section 10 within document, I.e. the first time it is used cite the acts in their entirety and then in parenthesis put how you will refer to them in the rest of the document. There are currently inconsistencies.	The relevant sections of U.S. Code are cited in the first paragraph for both the Clean Water Act and Rivers and Harbors Act. Subsequent wording uses the names of the Acts or the relevant sections, which are also stated in paragraph one. This seems clear.
CH	Intro	1	2	Last line in para - add Clean Water Act to statement about jurisdiction	Again, the exact meanings of "Section 404" and "Section 10" are given in paragraph one. The suggested change seems redundant and unnecessary.
MM		2		Will National Advisory Committee exist forever? If not should that citation for comments be included.	The National Advisory Team will continue in its role after the initial versions of the supplements have been published. The Team will receive and act on future proposals for changes to the supplements.
	Throughout Manual		General	Define terms the first time they are used regardless of their inclusion in the glossary. Consider including definition of terms that are defined in the 87 Manual and those definitions that are no longer valid.	In most cases, we have attempted to define technical terms as they are used, especially if those terms were not used in the Manual. However, we did not wish to duplicate the Manual's full glossary in each regional supplement. As implied in the comment, many of the 1987 Manual's definitions are no longer used. They will be updated when the Manual is revised and republished.
MW	1	4	1	Last line, change "northeastern areas" to "northeastern portions"	We will make the recommended change.
John Brooks - JB	1	4	map	Map is very general. It does not accurately display the coastal plain vs. piedmont around Richmond, Virginia, as I-95 is typically used as a line of demarcation. The pixel split for Richmond extends into the coastal plain. It is not. Move the pixel for Richmond.	The map is intended to be a general depiction of the region. In reality, climatic, physiographic, and ecological boundaries are not so abrupt. As explained in text, the region boundary in the vicinity of Richmond is actually the Fall Line, which is a zone of change and not a line. For all practical purposes, Richmond lies on the Fall Line. We will tweak the location of the point on the map, but users should read the text before deciding which supplement to use.
Kevin Seaford - KS	1			Suggest obtaining downloadable GIS data for regions, and NWI layers	GIS layers for the supplement regions are available upon request from ERDC. However, region boundaries are derived from USDA Land Resource Regions (LRR) and Major Land Resource Areas (MLRA). GIS layers are available at http://soils.usda.gov/survey/geography/mlra/index.html. NWI boundaries are simply state lines.
CH	1	4	sect 1	Also suggest other references, such as the USDA NRCS soils manual for the delineation of Piedmont vs. Mountain vs. Coastal Plain. Hydric soil indicators should be used to delineate the subregions and included on the map	We do not know what is meant by the "USDA NRCS soils manual." In effect, the subregions do coincide with differences in hydric soil indicators, because they are based on USDA LRRs, which are also used to regionalize hydric soil indicators.
MW	1	5	para 2	First line, remove "in the region"	We do not agree. The statement deals with this region and would be incorrect for other regions.
MW	1	5	para 3	Remove "in the Eastern Mountains and Piedmont Region"	We do not agree. The statement deals with this region and would be incorrect for other regions. Furthermore, these introductory paragraphs are similar in structure and content across all 10 regional supplements and allow users the opportunity to compare the characteristics of adjacent regions. From a national perspective, we think this wording provides added clarity. The only disadvantage is a little redundancy.
MW	1	5	last para	Line 12 - change "the Appalachians, northern hardwood forests are present, characterized...." to the Appalachians are northern hardwood forests, characterized...."	We will revise the sentence.
MM/MW/Richard Reaves - RR	1	5	general	Include more information on soil orders similar to the Coastal Regional Manual. Recommend referencing it in Intro and adding more information on soils in the Hydric Soil indicator section.	We will make the recommended change, although we generally try to avoid details of soil taxonomy in regional supplements because they are not needed to perform wetland delineations.
JB	1	5	last para	Remove "eastern hemlock". It is no longer in the region	We do not understand the comment. Tsuga canadensis is found throughout the eastern portion of the region.

Initials	Ch	Pg	Par	Comment	Response
RR	1	6	2	First portion of the sentence “subregion receives 37 to 45 in (940 to 1,145 mm)” is misleading --- Richmond, Virginia has an average yearly rainfall of 46+ inches	The statement is a general one for all of MLRA 136 and the source is cited. Some locations in the subregion may differ, particularly a borderline location like Richmond.
CH/JW	1	6	general	This section deals with broad types and distributions and one does not pick up the differences within these types from the broad definition. In that it is the introduction, perhaps that is acceptable but the section needs to be more consistent, either more general throughout or more specific.	We will consider specific recommendations for changes.
MM	1	6	general	Is HGM the reference for the other Regional Manuals? If not, why reference it in this one? The manuals should be consistent and this group finds the reference confusing.	Basic terminology from the HGM wetland classification (i.e., depression, slope, flat, fringe, etc.) is used in all regional supplements even if the original reference is not cited.
TC	1	6	2	"Southern Piedmont (MLRA 136 of LRR P)" This section does not discuss the extreme variability and unusual hydrologic conditions found in the Triassic Basin. Text should include statement about unusual hydrologic conditions that influence hydroperiods.	We have cited the source of our information and it does not include any special features of the Triassic Basin. We would appreciate any additional relevant information or references.
TC	1	6	para - sentence 1/"Types and Distribut	"Wetlands occupy a small proportion of the landscape within the Eastern Mountains and Piedmont Region (Dahl 1991, Bales and Newcomb 1996, Darst and Light 1996, Haag and Taylor 1996) but are widespread in distribution." This statement is wrong. Wetlands can be very large, prevalent, and exist in great numbers in the Eastern Mountains and Piedmont and in many areas, occupy a substantial part of the landscape. Suggest not using this citation.	We based this general statement on published literature and experience in the region. It is intended as an overview and may not reflect every local area. We have cited a few examples of exceptions. Compared with the adjacent coastal plain, for example, wetlands are not very large or abundant in the region.
Team	1	6	and Distribution of	Move the types and distribution of wetlands into the section on physical and biological characteristics of the region that begins on page 4. In this way you incorporate the types and distributions into each section and clarify the soil issues	For consistency and ease of use, this supplement is organized as all previous regional supplements have been. This is advantageous for any user who works in more than one region.
MW	1	6	5	Change "are forested today" to "is forested today" - tense issue	The sentence has two subjects, "55 percent" and "25 percent," which suggests that "are" is appropriate. The ERDC editors will make the final decision.
TC	1	7	1 - continued from prev pg	line 2 to 4 "...but most wetlands in the region are relatively small and may not even appear on large-scale data bases, such as National Wetlands Inventory maps orcounty soil surveys (Roberts et al. 2003).". This statement is also misleading. There are many large-scale wetland complexes in the region. In addition, other data sources should be cited here, most notably, SEGAP. Add "sparse" to description	The statement in the supplement acknowledges that notable concentrations of wetlands exist in some areas, but many wetlands in the region are small and scattered. We think this is useful information for new wetland delineators who may put too much reliance on mapping data. However, we will modify the wording to avoid the impression that all wetlands are small or isolated. It is not the intent of this section to list sources of land-cover data.
MW	1	7	4	Change "distinctive zones" to "distinct zones"	We will make the recommended change.
MW	1	7	5	with respect to "greenbriers" consider listing name as "greenbriers, (Smilax sp)"	We will make the recommended change.
TC	1	8	3	"Slope wetlands occur throughout the Eastern Mountains and Piedmont Region and are common in most areas. " This paragraph is confusing. The geomorphic position of slope wetlands is given as at the base of hills, broad level valleys, yet...."Slope wetlands often occur above the headwaters of streams but, in some areas, wetland conditions may continue down-gradient for considerable distances along shallow drainageways in otherwise upland landscapes.". The average reader will be confused as the "picture" they interpret of a slope wetland. Give clearer examples and landscape positions.	Slope wetlands by the HGM definition are maintained by shallow groundwater that flows laterally down gradient. Slope wetlands are common on hillslopes and in riparian headwaters not affected directly by the stream. We will reword the description.
TC	1	8	3	Second sentence, "...small areas at the bases of slopes where groundwater discharge occurs throughout the year often are called “perennial seeps...". Perennial seeps can occur well upslope of the base of a slope, particularly in the Eastern Blue Ridge Foothills. Text should encompass all the likely landscapes were a perennial seep may occur.	We will make the recommended change.
CH	1	8	3	Last sentence, remove the word "bog". It is unclear.	Bogs are maintained mainly by precipitation. The point here is that the local use of the term "bog" does not describe the true origin of these slope wetlands. The section assumes some familiarity with wetland terminology.
MW	1	9	4	2nd line - remove " that falls onto the site"	We will make the recommended change.
MW	1	9	5	1st line - remove "within the region"	We do not agree. The statement deals with this region and would be incorrect for other regions.
Team	1	general	general	Remove reference to HGM. It is confusing	Basic terminology from the HGM wetland classification (i.e., depression, slope, flat, fringe, etc.) is used in all regional supplements even if the original reference is not cited.

Initials	Ch	Pg	Par	Comment	Response
Team	1	general	general	When using common names for plants, be clear. Use USDA Plant Website (http://plants.usda.gov/) for consistency of the use of common names and the correlation to Latin names (i.e. genus species).	We try to be consistent in the use of common names and generally use the common name suggested by the USDA Plants database; we will re-check all common names. We use the latest Latin names specified by the USDA Plants database, giving synomyns that were used in the 1988 wetland plant lists, where appropriate.
JB	1	general	general	Common names make sense for a Regional Manual but be clear, consistent and use citation in preliminary usage.	See the previous response.
CH	1	general	general	Be more specific in terms of what is included in the sections in the introduction - Remember that it is an introduction.	We do not understand the comment.
Team	1	general	general	Primary and secondary indicator distinctions are cloudy. Can we clarify distinction between?	See Chapter 4 on wetland hydrology indicators.
TC	1	9	1st full	3rd sentence "...floristically complex...". This choice of words will confuse entry-level readers. Should read "...diverse in vegetative strata..." or words and phrases that are used elsewhere in the manual to describe vegetation communities.	We will make the recommended change.
	1	9	3	Flat wetlands occur in Virginia, and are called a “Slash” defined as a high flat wet area. This should be added to this paragraph.	We will make the recommended change.
?	1	9	last para	White oak and white ash are FACU species according to the USDA plant list and the sentence that includes them does not accurately state this as it refers to them collectively as “Facultative”. Bittenut Hickory is FACU as well as FAC depending on the region. This sentence should be revised to reflect this. Otherwise this sentence is confusing and not accurate.Includng Fac U species (I.e. white oak) in the list of faculative species is confusing. If it is a list of fac species, include only fac - no facu or facw	The paragraph used "facultative" in the common sense and not with regard to wetland indicator status. We will reword it.
TC	1	10	1	"North Carolina, for example, has no natural lakes outside of the coastal plain, but over 100 reservoirs exist in the Piedmont and Blue Ridge Provinces (Bales and Newcomb 1996). Many reservoirs are very large, with hundreds of miles of shoreline, and contain numerous fringe wetlands, especially in shallow embayments....Fringe wetlandcommunities may vary substantially over time given water-level variations in lakes and reservoirs due to rainfall patterns, changing management goals, demands for hydropower production, and other factors." No mention of beaver ponds is given, which constitute a major portion of the wetlands found in the region. Another paragraph should address the types of habitats formed by beaver ponds, fluctuating water levels, and potential (or lack of) transition to upland habitat when drained for "...changing management goals...".	We will mention beaver ponds as another place where fringe wetlands exist.
CH	1	6 to 10		Remove the section entitled "Types and Distributions of Wetlands". or make it more general, or incorporate it into the section entitled "Physical and Biological Characteristics of the Region". Elaborate on the nuances in the hydrophytic vegetation or soils section of the supplement.	For consistency and ease of information retrieval, this supplement is similar in organization and content to the previous nine regional supplements.
MW	1	general		Overall, these two parts (Intro and Ch 1) are well-written and easy to read. However, none of the citations that suggest size and number of wetlands refer to work that studied the extent of wetlands using federal jurisdictional rules in the strict context of the '87 manual or "significant nexus" rules. This manual is meant to assist the reader in determining the jurisdictional boundary of a wetland using a strict standard and a high-degree of application of scientific and regulatory knowledge. The text of this manual should adopt a more neutral tone when suggesting how many, what size, and where wetlands will be found.	This supplement addresses all wetlands, without regard to their jurisdictional status. Statements about wetland abundance and distribution come from the National Wetlands Inventory (NWI) and other general sources, and are not intended to reflect regulatory policy.
MW	1	general		Throughout the introduction, check consistency - currently incosistent in capitalizing Piedmont and Coastal Plain (consistency issue applies to entire manual)	We will capitalize these words except when they refer in general to a geologic piedmont or coastal plain.

				Chapter 2	
Initials	**Ch**	**Pg**	**Par**	**Comment**	**Response**
KS	2	general	general	Why is "Indicator 4: Morphological Adaptations" included in this supplement and not the coastal plain supplement?	Each regional working group selects the indicators that are appropriate to the region. Therefore, lists of indicators vary by region. The Coastal Plain group determined that plant morphological adaptations were too widespread across the landscape, particularly in Florida, to be reliable weltand indicators.
Team	2	11	2	Remove reference to history of developmental FL - Keep first two and last sentences.	To help orient new users, regional working groups nationwide have chosen to include a brief summary of the origin and development of the regional flora in the introduction to Chapter 2. For consistency, we prefer to keep these few sentences although they are not critical to wetland identification.
RR	2	11	general	Recommend adding in a list of current regional taxonomic sources that are ore up-to-date, along with listing the older ones that are still in substantial use to supplement the list in the 87 manual which is dated and not region specific. As a starting point: Plant Life of Kentucky: An illustrated Guide to the Vascular Flora. 2005. Ronald L. Jones. The University Press of Kentucky; The Plants of Pennsylvania: An Illustrated Manual, Second Edition. 2007. Ann F. Rhodes and Timothy A. Block. Unniversity of Pennsylvania Press; Steyermark's Flora of Missouri. Volume 1, Revised Edition. 1999. G. Yatskievych. The Missouri Department of Conservation in cooperation with the Missouri Botanical Garden; Steyermark's Flora of Missouri. Volume 2, Revised Edition. 2006. G. Yatskievych. Missouri Botanical Garden Press in cooperation with the . The Missouri Department of Conservation; Vol 3 will be out in a few years and is partially available online; Flora of the Carolinas, Virginia, and Georgia, and Surrounding Areas, Working Draft of April 8, 2009. Alan S. Weakley. UNC Herbarium, North Carolina Botani	We appreciate the great list of references. However, it is not the purpose of the supplement to list the many floras and guidebooks that cover the region.
TC	2	11	1	Reorganize the paragraph to start with the third sentence, "Hydrophytic vegetative decisions are based on ...." and finish with the first sentence, "The 87 Corps Manual defines...."	The paragraph sets the stage for the Clean Water Act concept of hydrophytic vegetation by presenting, first, a definition and, second, the role of indicators. Again, this presentation is consistent with other regional supplements.
MW	2	11	1	First line, delete the word "present"	We disagree. The 1987 Manual's concept of hydrophytic vegetation centers on the presence and abundance of particular plant species, rather than more subtle effects of inundation or saturation on plants. Plant species presence or occurrence is important.
MW	2	11	2	Third line, delete "existing"	We will make the recommended change.
MW	2	11	3	Last 2 lines should read “occurrence of **non-native** “weedy” species in the flora.” The last line should read “Estimates of the percentage of non-native species range from 22 percent to 37 percent.”	We will make the recommended change.
MW	2	11	4	2nd line, delete "in the region"	We will make the recommended change.
MW	2	12	1	3rd sentence, delete "primarily"	We disagree. Many wetlands are dominated by FACU species, that is, one or more dominant species are FACU. This is not a problem to wetland identification if they are outnumbered by other dominants that are OBL, FACW, or FAC. But some problematic wetland types are dominated "primarily" by FACU species.
TC	2	12	1	Begin first full paragraph wtih "The Corps Manual defines hydrophytic vegetation as the community of macrophytes that occurs in areas where inundation or soil saturation is either permanent or of sufficient frequency and duration to exert a controlling influence on the plant species present." Then continue.	We disagree. For emphasis, we presented the definition as the first sentence in the Introduction to the chapter. At this point in the section, we are getting down into details of hydrophytic vegetation decisions.
JB	2	12	2	4th sentence needs clarification. Suggest rewriting to "Where FACU species dominate an area with hydrophytic soils and positive indicators of wetland hydrology, the investigator must document other hydrophytic vegetation indicators, such as morphological adaptations to living under prolonged conditions of soil inundation or saturation."	The suggested revision focuses on only one alternative, the use of the "morphological adaptations" indicator. Other alternatives include the prevalence index and various approaches for problematic hydrophytic vegetation discussed in Chapter 5. The sentence in question was only intended to alert the reader that other indicators and procedures exist beyond the well-known dominance test. However, the reader must read further for the details. We cannot explain all the options in this introductory paragraph.

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Chapter 2 Comments

Initials	Ch	Pg	Par	Comment	Response
Team	2	12	4	This may be done in advance using a CURRENT aerial photograph or topographic map AVAILABLE ON LINE, or by walking over the site." Add words in capital letters.Then add an example of how to do this, e.g, detect change in vegetation community in air photo by comparing like-colored pixels, etc.	We will revise the sentence but prefer not to add the example. It is not the purpose of this supplement to provide guidance on aerial photo interpretation. Other sources of information or expertise should be consulted, if needed.
MW	2	12	2	Hydrophytic vegetation decisions are based on the wetland indicator status (Reed [1988] or current approved list) of species that make up the plant community. Species in the facultative categories (FACW, FAC, and FACU) are recognized as occurring in both wetlands and uplands to varying degrees. Although most wetlands are dominated mainly by species rated OBL,FACW, and FAC, some wetland communities may be dominated primarily by FACU species and cannot be identified by dominant species alone. In those cases, other indicators of hydrophytic vegetation must also be considered, particularly where indicators of hydric soils and wetland hydrology are present. This situation is not necessarily due to inaccurate wetland indicator ratings; rather, it is due to the broad tolerances of certain plant species that allow them to be widely distributed across the moisture gradient. The statement that some wetland communities may be dominated primarily by FACU species appears inconsistent with the 87 Manual.	The 1987 Manual recognizes a number of ways that "FACU-dominated" wetland plant communities can be identified. First, it provided a number of alternative hydrophytic vegetation indicators (i.e., visual observation of plant species growing in areas of prolonged inundation and/or soil saturation, morphological adaptations, technical literature, physiological adaptations, and reproductive adaptations). In addition, Section IV, F (Atypical Situations) discussed natural and human disturbance and Section IV, G described various Problem Area situations. The supplement provides more regional examples, along with suggested approaches for dealing with them, but does not go beyond the original intent of the 1987 Manual.
MW	2	12	4	2nd line, delete "over"	We will make the recommended change.
MW	2	12	last	1st line, change to read "….possible to locate at least one plot in a way….."	We will make the recommended change.
TC	2	13		The definition of relative and absolute and DBH should be in this paragraph/section with an example from the wetlands indicators book to clarify.	Absolute cover is defined in the glossary to the supplement. That definition also contrasts relative cover, but we do not provide a separate definition because we do not recommend or want to emphasize relative cover. Diameter at breast height (DBH) is defined in the glossary of the 1987 Manual. In general, the supplements do not repeat the 1987 Manual's extensive glossary.
TC	2	14	general	For hydrophytic vegetation determinations, the abundance of each species is determined by using areal cover estimates. A better explanation of what "areal" means with examples, is needed here. Those learning the "trade" are not always familiar with the vegetative terminology.	See the definition of absolute cover in the glossary. In addition, we provide five references for vegetation sampling in Table 2. Those references provide more detail than we can dedicate to the topic in this supplement.
RR	2	14/15	general	Add explanation that "any time the sample plot would exceed the size of the wetland, it is necessary to characterize all vegetation in the wetland."	Outside of a few vernal pools and wind throws, this is an unusually small wetland size. However, it seems obvious from the discussion in the supplement that the plot must fit entirely within the wetland, and considering the entire wetland is an option.
	2	15	1	Line 8, replace "parallels the stream" with "parallels the linear feature". While true in most cases, not all linear wetlands are associated with streams.	We disagree. This scenario in the supplement is just an example and seems straightforward. We would rather not risk confusing readers with "linear feature" instead of "stream."
MW	2	15	3	Last line, delete, "in any case,"	We will make the recommended change.
	2	15	4	Change " In this supplement" to "For use of this supplement"	We prefer the shorter construction, and the meaning is the same.
TC	2	15	4	Clarify the statement, "For percent cover estimates, plants do not need to be rooted in the plot as long as they are growing under the same soil and hydrologic conditions" There is the potential to determine "no jurisdiction" based on observation of a ring of FACU around their plot (but not in). Does the canopy need to extend within the plot, but not the roots? If so, what percentage of the canopy? Is dripline used to define this?	All the recent regional supplements give this guidance and the comment makes it unnecessarily complicated. The guidance is a practical approach that does not force people to imagine away certain plants whose canopies overhang the plot but are not rooted there. And it simply doesn't matter to the determination, as long as our purpose is to compile data that link specific soil, vegetation, and hydrology conditions. It only matters if something different is happening (in soil, hydrology, and/or vegetation) immediately beyond the boundaries of the plot. If that were the case, those conditions should be sampled separately. The guidance in the 1987 Manual and the supplement also says that you should be sampling a "representative" location. If you are, then you would not have a ring of FACU species surrounding your plot unless they represented a different "community." In that case, you SHOULD delete their overhanging canopies from the plot. Sampling is based on observable plant canopies and not hidden roots. Any portion of a plant's canopy counts if it is in the plot. We can't plan for all the ways that untrained individuals might err in making wetland determinations.

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Chapter 2 Comments

Initials	Ch	Pg	Par	Comment	Response
KS	2	15	3	Last sentence, the reader is referred to the section on Hydrophytic Vegetation Indicators. This reference needs to include section numbers or a page number for the reader to turn to page 17.	We try to avoid unnecessary internal references to page numbers because these shift in various drafts and require added care in the final published version. In this case, the section heading on Hydrophytic Vegetation Indicators is easy to find and appears in the Table of Contents.
TC	2	16	1	Add the following to the last sentence: "...These sources include not only leaf-ID guides, but twig and bark guides as well. "	This sentence doesn't follow the logic or content of the paragraph. Did you intend to suggest it be inserted somewhere else?
MW	2	16	2	Reorganize the paragraph to add "prelimiinary delineations, made using off site indicator data, are not acceptable for regulatory purposes.	The supplements are technical documents and generally do not address issues of policy or permitting procedures. In general, districts will use the best information available to make decisions within their time constraints.
MW	2	17	2	Maintain consistency with the notation for the plant list, i.e. for scientific / common names and facultative status.	We agree but do not understand how the comment pertains to the specified paragraph.
	2	17	2	Need a provision instructing user to rely on the primary literature for habitat requirements of species that are newly described to science. Primary literature will include the species description and will discuss the habitat(s) in which it occurs. Where available, this is more scientifically defensible than treating as a problem situation.	We agree that primary literature is preferable but would not exclude secondary literature if the information therein is relevant. In these situations, the user must decide on the relevance of the information and build a case. The use of technical literature to evaluate NI, NO, or unlisted plant species is discussed in Chapter 5 because it goes beyond the routine use of indicators to evaluate vegetation.
TC	2	17	general	Remind the reader that there is no requirement to look at secondary vegetative indicators unlike in soils and hydrology parameters.	There are no secondary indicators given in the supplement for either hydrophytic vegetation or hydric soils. A reminder is unnecessary because there are none to use.
JB	2	17-20	general	Include a flow chart to enhance the explanation.	A flowchart seems redundant and unnecessary in the supplement because there are only 4 steps in this procedure and the sequence is clear. A flowchart could be useful in classes as a training aid, but primarily as a graphical replacement for the written procedure rather than in addition.
KS	2	19	general	As with the statement cautioning users about shallow roots, add a statement cautioning users about buttressed trunks and tree diseases (cankers). The Chestnut blight (Cryphonectria parasitica) is a fungus that causes cankers on Quercus coccinea, Quercus rubra, and Quercus stellata in the Appalachian region. It is common for the fungus to cause the base of the trunk and stump to swell in Quercus coccinea. Also, some species have shallow roots that are unrelated to soil hydrology or saturation. It is common for Fagus grandifolia to exhibit shallow and surface roots. I've heard several people describe Fagus grandifolia as having buttressed roots even in very well drained soils. Examples from Tyner would be helpful to illustrate this for the user.	We will add a sentence about chestnut blight.
MW	2	20	3	Maintain consistency by adding absolute in sentence so that it reads, "Calculate the absolute coverage of all species in the stratum (I.e., sum their individual percent absolute cover values……"	We will make the recommended change.
RR	2	21 - 22	User no	Recommend allowing use of prevelance index based on cover of the collective sedge group when it is not possible to speciate. Recommend using a FACW value for wetland sedges and FACU values for non-wetland sedges, as a conservative method. This would avoid the situation where someone randomly picks sedges known from the area to fill out the form and get a number. Based on point that it is nearly impossible to speciate sedges during much of the year (except for a very small handfull of folks) but it is easy to distinguish wetland-associated sedges from upland-associated sedges while in vegetative state.	This is an interesting approach to the problem of identifying sedges. However, one could make this argument for many other taxa. By using the suggested approach, we would lower the bar on vegetation analysis, inviting criticism and challenges. We don't believe this represents sound practice.
MW	2	23	1	End with "in weltands" not "in wetland areas".	We will make the recommended change.
MW	2	24	3	3rd sentence delete "present"	We think the current wording is clearer.
TC/Tean	2	general	general	Overall: Section could use more photos and graphics, especially of examlples of morphological adaptations.	Additional examples of morphological adaptations are given in Appendix C of the 1987 Manual.

				Chapter 3	
Initials	**CH**	**Pg**	**Par**	**Comment**	**Response**
Team	3	25	1	Statement, "In the upper part is too ambiguous. Change to "within top 20" unless the statement is intended to be vague.	No change can be made to the definition of a hydric soil, which was developed by the National Technical Committee for Hydric Soils (NTCHS) and published in the Federal Register. For this definition, the upper part means 6 in. for sandy soils and 12 in. for all other soil textures.
CH	3	25	2	Line 3 -strike sentence - it is confusing	We are not sure what is confusing. This is an important concept in hydric soils and needs to be included. No change is needed.
KS	3	25	General	Provide a better definition for distinct and prominent. For example, on page 62, the last sentence under User Notes, the user is referred to the glossary for a definition. In the glossary, the definitions of both words refer the user to the definition of contrast, which then refers you to the NRCS. Since distinct and prominent are used frequently in the hydric soil indicators, it would be beneficial to provide definitions. In the above example, instead of referring users to the NRCS. direct reader to page 137.	The glossary definition for "contrast" already refers users to Table A1, which is on page 137 of the draft. We prefer to avoid internal references to specific page numbers because these shift in various drafts and require added care in the final publication.
KS	3	25	General	Add a figure that clearly illustrates other landforms (see page 29, paragraph 6 and page 30, figure 6.)	We provided figures to illustrate "toe slope" and "convergent slopes" because the terms are not widely known. The other relevant landforms (e.g., depression, floodplain, etc.) are widely understood and do not require illustrations in the supplement. The supplement is a field manual and is not intended to be a comprehensive treatment of background knowledge in geomorphology or other subjects.
RR	3	25	2	Insert paragraph stating: "The Corps Manual identifies certain situations where hydric soils may be assumed without identifying specific hydric soil indicators. Please refer to page 48, Steps 3 and 4, in the Corps Manual for the discussion of this process."	The proposed sentence is true but not needed in the supplement. This portion of the 1987 Manual is still in effect and has not been superseded by the supplement. Users should continue to follow the steps involved in either the routine or comprehensive methods described in the 1987 Manual.
MM	3	25	4	Last sentence, "Although an indicator….in the transition to an adjacent subregion." remove "in the transition"	It is not the intent of this sentence to allow hydric soil indicators to be applied throughout a subregion or region where they have not been approved. The sentence allows the use of an indicator only in the transition to an adjacent subregion. The width of the transition zone is not specified and is left to the user to justify. No change is needed.
MW	3	26	1	3rd sentence - strike "often" add "may"	We will make the recommended change.
CH	3	26	2	Last sentence, change "organic carbon" to "organic matter"	We do not understand the reason for this change. No change is needed.
CH	3	26	5	Add sentence to add "typically dominated by upland species" just before "folistic surface layers".	The suggested change refers to vegetation and has no relationship to hydric soils or relevance to this section. No change is needed.
MW	3	27	1	Strike "material" add "soils" in first sentence	We do not understand the reason for this suggested change. The paragraph discusses various soil materials, more than one of which may be present in any particular soil. No change is needed.

Chapter 3 Comments

MW	3	27	1	Strike word "material" after word "soil" and change last sentence …"If the material is an organic soil a further division..."	See the previous response.
MM	3	27	2	Stike word "Often" in 2nd sentence and add "may" after "features" put "may have diffuse boundaries…" and add "May" to "have sharp boundaries"	We will revise the text according to emphasis given in the source (Vepraskas 1992).
Team		28	2	Add a figure that clearly illustrates other landforms (see page 29, paragraph 6 and page 30, figure 6.)	We provided figures to illustrate "toe slope" and "convergent slopes" because the terms are not widely known. The other relevant landforms (e.g., depression, floodplain, etc.) are widely understood and do not require illustrations in the supplement. The supplement is a field manual and is not intended to be a comprehensive treatment of background knowledge in geomorphology or other subjects.
	3	29	General	Delete "close" as modifier for proximity. It is redundantunt	We will reword the sentence.
RR	3	29	5	Add question under "hydrology" for "Is a springhead present?" add more examples of "landforms" since data form requires it, or add another figure.	We will add springs to the examples. The working group considered citing or duplicating some standard landform classification from the literature, but could not find one that seemed appropriate. Rather than developing a new classification, we rely on the user to describe the site in his/her own words.
RR	3	29	bullet list	Strike second sentence - not necessary	It is not clear which sentence is indicated. We do not see any unnecessary sentences. No change is needed.
RR	3	31	3	Change sentence to read, "Significant changes in the parent material (I.e. lithologic discontinuities) can affect…"	We prefer the existing wording because changes in parent materials and lithologic discontinuities are not necessarily the same thing.
RR	3	31	last	3rd sentence stirke "they" and add "Mapping Units" if in fact that is what you are talking about - otherwise define "they"	We will make the recommended change.
team	3	32	1	Move last sentece into the paragraph above at the end of soil survey - and add to the end, "and areas mapped as hydric can include non-hydric soils".	Actually, that is what the existing sentence is intended to say. We will try to clarify it.
CH	3	32	2	"Individual strata are dominantly less than1 in. (2.5 cm) thick." This statement seems to be written incorrectly and should be clarified. Was "typically less" intended rather than "dominantly less"?	This sentence is on page 39, not 32. It is correct as written by NTCHS.
RR	3	39	3	Delete sentence beginning "Organic soil material is called…" this has already been discussed and repetition is not needed.	We agree that it is redundant. However, each User Note needs to stand alone because the user may not read the background material, or may need to be reminded. The working group felt that this information should be repeated. No change is needed.
RR	3	41	3	User Notes. There is no mention regarding if this indicator is or is not useful in the wetland/upland bourndary as in the coastal supplement - consistency issue since the user will be looking for guidance on this issue.	The first sentence addresses this issue. No change recommended.
TC	3	38	4	Define "fragmental soil material"	"Fragmental soil material" is defined in the Glossary. No change necessary.
RR	3	41	bullet list	Recommend adding "Approximate" to start of caption to allow for mapping errors. Add this throughout for figure captions.	It is not clear to what "caption" or "mapping" this comment refers.

Chapter 3 Comments

RR	3	65	Figure caption	User Notes: reference to gleyed matrix and gray colors should be moved from F2 (where that referece is first used) to here, where gleyed matrix is first used as an indicator. Future references to gleyed matrix should then be cited to the appendix in all subsequent indictors.	Most indicators that include a gleyed matrix simply cite the Glossary for the definition. Indicator F2 is the exception. We will revise the User Notes for indicator F2, dropping the list of required colors, and simply refer the reader to the better definition of gleyed matrix given in the Glossary and Figure A2.
TC	3	42	A4	User Notes: should "...not be a relict or parent material feature" be here as well. In addition, I see many soils incorrectly classified in areas of historic disturbance, most often in utility easements, and some mention of taking care when historic disturbance is suspected should be used early in this chapter.	This comment does not seem to pertain either to page 42 or indicator A4. Many places have disturbed soils; however, it is not clear what specific problem requires a change to the supplement.
TC	3	44	A12	User Notes: should "Soils with dark gley colors (value less than 4) do not meet the definition of a gleyed matrix..." go here as in the coastal?	The sentence is unnecessary with the definition and figure in the Glossary, and probably should have been deleted from the Coastal Plain supplement as well. No change is needed.
TC	3	47	S4	it would be beneficial to users of this supplement to provide an example that is applicable to the Eastern Mountains and Piedmont Region instead of interdunal swales along the Atlantic Ocean	The only place this example was used was for S7 on page 50. We will either add a relevant example or delete the wording.
KS	3	50	last	Remove the words, "on right".	"On right" refers to the right side of the ruler. The left side is in centimeters. Therefore, "on right" is needed to determine the scale.
KS	3	51	User Notes	The words "to delineate wetlands" should be replaced with "throughout the region".	We meant that the indicator is often useful to determine the wetland boundary. We will reword the statement.
Team	3	58	F6	Recommend adding "Approximate" to start of caption to allow for mapping errors, as stated above.	The MLRA maps are not approximate. They are as defined by the USDA. If you mean that there is actually a transition zone and not a firm line between MLRAs, we agree. This was addressed in the Introduction to Chapter 3.
RR	3	65	Figure Caption	Recommend adding "Approximate" to start of caption to allow for mapping errors, as stated above.	See the previous response.
RR	3	66	Figure Caption	Need clarification on verb tense, "is" or "are". We had some discussion regarding wether the verb refers to plural modifier or singular noun subject as in "none of the indicators is (or are?) Also discussion of whether the word none is singular or plural.	The ERDC editors will check for proper subject/verb agreement.
KS	3	68	1	Recommend adding "Approximate" to start of caption to allow for mapping errors.	The MLRA maps are not approximate. They are as defined by the USDA. If you mean that there is actually a transition zone and not a firm line between MLRAs, we agree. This was addressed in the Introduction to Chapter 3.
RR	3	69	Figure Caption	Recommend adding "Approximate" to start of caption to allow for mapping errors.	We will make the recommended change.

Chapter 4

				Chapter 4	
Initials	**Ch**	**Pg**	**Par**	**Comment**	**Response**
TC	4		General	RE-EMPHASIZE that even if a primary hydrologic indicator is found, the presence (or lack) of secondary indicators MUST ALSO BE NOTED! Caution users of this manual to document ALL indicators.	We will make the recommended change.
MW	4		Throughout Indicators Section	Be consistent. The General Descriptions are not consistent. In some instances, descriptions consist of a sentence fragment (B16) while in others they are full sentences (B4)	We agree that the wording of indicators is not always consistent. However, similar wording has been used in many previous regional supplements. Therefore, we are reluctant to reword some indicators because of the confusion it could cause among users who work in more than one region.
MW	4	71	1	Referenece to Hydrology Table in Manual would be helpful.	We do not understand what is meant by "Hydrology Table in Manual." If you are referring to Table 5 in the 1987 Manual, that table has been superseded by this supplement and is no longer in effect.
Team	4	72	1	Last few sentences cause some concern due to the subsequent definition of Growing Season, for example, in growing zone 7A you can have year round emergence of winter rye. Consider clarifying.	That is one reason why the procedure requires that at least two species in the area show signs of growth. However, from a technical standpoint, if plants are growing, it is hard to argue that you are not in the growing season.
TC	4	72	1	"wetness signatures" should be "soil moisture signatures" or "wet soil signatures"	We don't understand the reason for this suggested wording change.
CH	4	72	1	from "off site" to end of paragraph is confusing	We need a more specific comment or suggestion to consider making a change. In any case, all of these techniques are discussed in more detail in Chapter 5. This section is only intended as an introduction.
	4	71	3	3rd sentence, the phrase, "into account", should go after" climatic conditions" to read more clearly. Final should read, "it is important to take weather and climatic conditions "INTO ACCOUNT" prior to the site visit to minimize….	We will revise the wording.
MW	4	71	4	delete "also" in the first line	We will make the recommended change.
MW	4	72	Growing Season, para 2	Suggest that WETs be used as the primary source for determining a growing season. There are significant problems trying to tie temperatures to the growing season especially in mountain valleys and north facing slopes. A date certain is far better than some observations.	Problems dealing with mountain valleys and various slope aspects are reasons to abandon WETS tables as indicators of the growing season. Weather stations are almost never located in appropriate places to determine the local growing seasons in mountains. Furthermore, WETS tables are based on long-term averages and do not reflect differences in initiation of the growing season from year to year. WETS tables provide an easy date to work with, but that date is almost meaningless for our purposes.

Chapter 4

MW	4	73	1st full	Move, "The determination should not included evergreen species" to the end of the previous paragraph.	The caveat applies to both of the previous paragraphs. For consistency between regional supplements, we prefer to leave the sentence where it is.
MW	4	73	3rd para, #2.	Clarify method for measuring soil temperature. Is inserting thermo into pit to measure soil recommended or required?	The method is straightforward. "Soil temperature can be measured directly in the field by immediately inserting a soil thermometer into the wall of a freshly dug soil pit." As it says in the same paragraph, the measurement is not required and is only recommended if needed to evaluate certain indicators, such as the observation of surface water during early spring when it is not clear whether the growing season has begun.
MW	4	73	1st full	To be consistent, either add example for groups A and D if you believe there is a need to list indicators, since you list indcators for group B and C or cut them entirely	The existing examples or explanations are already adequate.
RR	4	73	1st full para after the numbered list	insert user notes above wetland hydrology saying users should be aware of weather patterns abnormal for the region. Spring ephemeral plants may germinate and bloom after the end of the growing season if conditoins are proper. This should not be construed as an extension of the growing season. Certain unique habitats, such as granitic outcrop dissolution pools, exhibit winter growing seasons.	These specific examples should be adequately captured, or not, by the procedures described here, and there is information in several indicators and in Chapter 5 about evaluating normal weather patterns.
Team	4	75	table	Think about putting color into table to differentiate between secondary and primary - split is between B 4 and B 6 and highlighting will help users.	These indicators are adequately distinguished by the "Primary" and "Secondary" columns in Table 10.
CH	4	75	table	Based on the discussions on page 73-74, suggest that the following indicators be considered secondary indicators: sediment deposits, drift deposits, aerial imagry. Because, the text indicates that "… indicators are intended as one-time observations of site conditions that are sufficient evidence of hydrology..." and then the user notes go on with very well written caution notes. The amount of caveates should be an indicator that these are of secondary value.	This working group and working groups in most other regions do not agree. These indicators require care in interpretation, but if the caveats are considered, all are reliable evidence of a recent episode of inundation. The first two have been used for more than 20 years under the 1987 Manual. And aerial imagery that shows inundation is irrefutable, as long as the normality of rainfall is considered.
CH	4	75	table	Note that surface soil cracks can happen with saturation	The comment is true, but surface cracks are generally associated with inundation. Which group they are listed in does not affect their use as an indicator.
MW	4	76	General Description	Suggest creating sentence fragments in the General Descriptions - I.e. begin with just "Direct Visual…." Same recommendation throughout General Descriptions, use phrases for each. At a minimum be consistent.	We agree that the wording of indicators is not always consistent. However, similar wording has been used in many previous regional supplements. Therefore, we are reluctant to reword some indicators because of the confusion it could cause among users who work in more than one region.

Chapter 4

KS	4	77/78	1	1st sentence on page 77 but also relevant to p 78 - define water table	We will add the sentence to the User Notes for the saturation indicator on page 78. "Water table" is defined in the glossary of the 1987 Manual. These supplements do not repeat the extensive glossary in the Manual.
MW	4	77	General Description	Define, "throughflow" in this context under General Description or give example.	We will define "throughflow" in the Glossary.
KS	4	77 and 99	2	Sentence 2, change end to read, "soil properties".	We will make the recommended change.
RR	4	78	General Description	Line 5, define "episaturated" at first use	"Episaturation" is defined in the Glossary.
TC	4	79	Section B1 B2	Distinctions should be made within different flood events and normal flow in thalweg - Sediment deposits on vegetation within an active stream bed should not be confused with sediment deposits located on vegetation located outside of the top-of-bank	We don't see the reason for making this distinction and prefer not to complicate the indicator. Jurisdictional determinations within the active channel of a stream or river are usually based on the Ordinary High Water Mark and do not depend on presence or absence of wetland indicators.
Team	4	80, 81 and 85	B2, B3, B7	These should be listed as secondary indicators. Additionally, give a better definition of what makes a primary and secondary indicator. The explanation on page 74 last para is not adequate.	See the response to the comment in line 18. We will try to clarify the distinction between primary and secondary indicators.
TC	4	81	Section B3	Include the term "wrack lines" in parentheses after "drift deposits"	The dictionary definition of "wrack" implies that the material is of marine origin. No change is needed.
RR	4	84	General Description	Add description of Iron Sheen to description if it is intended as an indicator, otherwise remove the photo and discussion under user notes.	Actually, the sheen itself was not intended as the indicator, because the presence of surface water (indicator A1) is already sufficient evidence of wetland hydrology. However, previous working groups and peer reviewers requested the added photo and description of sheen. As currently written, one could record both indicators A1 and B5 if iron sheen was observed.
RR	4	85	Photo	Photo is from outside growing season. You need to replace the example with a photo from during growing season which would meet the indicator requirement.	We used the best photo we have available.

Chapter 4

TC	4	87	B13	As mentioned above, think about augmenting the definition of primary and secondary indicators and classifying these indicators - consider a hydroperiod classification and consider a test for reproduceability in terms of primary and secondary.	We have attempted to clarify the distinction between primary and secondary. In general, we rely on vegetation and soils to tell us whether the seasonal timing, frequency, and duration of inundation or saturation have been sufficient over a period of years to produce a wetland. The purpose of wetland hydrology indicators is to provide evidence that the hydrologic regime is still in effect and that vegetation and soils are not relicts of a regime that is no longer operating. Thus, hydrology indicators provide evidence of a recent EPISODE of inundation or soil saturation. Most say little about hydroperiod or other aspects of the hydrologic regime.
Team	4	88	B14	Professional judgment should be exercised to determine that the presence of true aquatic plant remains are not a result of deposition from a high flow event uprooting them from upstream. Emphasis needs to be on checking to see if the plant remains include attachment to root system, etc...	In our experience, this scenario is not common. Furthermore, it would not affect the outcome of a wetland hydrology determination. Whether the detached pieces are counted as aquatic plants (indicator B14) or drift deposits (B3), or both, the result is at least one primary indicator. Furthermore, the list of aquatic plants includes Lemna, which is not rooted at all.
RR	4	88	End of user notes	Add: Caution: There are terrestrial bladderworts and observer should be competent in distinguishing terrestrial from aquatic bladderworts to use this genus as an indicator.	We will make the recommended change.
MW	4	89	Caution and User Notes	Line 1 states, "enough to destroy surface soil structure", this statement assumes that there was once a soil structure that had been altered, which is typically not true. State "enough to prohibit the development of surface soil structure."	We will make the recommended change.
	4	90	User Note	Add: Allelopathic Vegetation (Black Walnut) can be cause of sparse understory vegetation.	We agree that allelopathy and many other factors can cause a sparse understory. However, the indicator is limited to concave positions, and the 3-factor approach involving indicators of hydrophytic vegetation, hydric soil, and wetland hydrology already ensures that areas with indicators of only one and not all three factors will not be mistaken for wetlands. Furthermore, as a secondary indicator, at least one more indicator of wetland hydrology is required. That seems like enough safeguards against errors.
MW	4	91	General Description	Consistency issue again - create a phrase rather than complete sentence and continue to create phrases	We agree that the wording of indicators is not always consistent. However, similar wording has been used in many previous regional supplements. Therefore, we are reluctant to reword some indicators because of the confusion it could cause among users who work in more than one region.

Chapter 4

TC	4	91	B10	User notes - provide clarification on stream vs drainage pattern - may be local rules that should be considered - perhaps use definition of OHW and subsurface soil sorting.	The 1987 Manual and this supplement address wetlands, not streams. Jurisdictional limits in streams are based on the ordinary high water mark, and are beyond the scope of this supplement (see Chapter 1). Drainage patterns do not include stream channels (i.e., bed and bank).
TC	4	92	B16	User notes - provide clarification on stream vs drainage pattern - may be local rules that should be considered - perhaps use definition of OHW and subsurface soil sorting.	See previous response.
RR	4	92	Caution and User Notes	Again description should include definition. Move 2nd Sentence "Trim lines on different trees in the inundated area should indicate the same water-level elevation." to General Discussion	We think this information is appropriate in the User Notes.
MW	4	93	Caution and User Notes	Change 3rd line statement, "often permanently saturated.." to "often saturated for extended periods during the growing season…"	The current statement is true.
MW	4	94, 96, 97, 98	General Description	Again, create phrases in order to be consistent by removing, "presence of" and begin sentence with "A layer…"	We agree that the wording of indicators is not always consistent. However, similar wording has been used in many previous regional supplements. Therefore, we are reluctant to reword some indicators because of the confusion it could cause among users who work in more than one region.
MW	4	99	Caution and User Notes	Line 2, insert "typically" before "indicates a normal…."	The word "indicates" already implies some uncertainty. However, we think the statement is nearly always true.
MW	4	99	Caution and User Notes	Remove texture and add "depending on soil characteristics"	We will make the recommended change.
MW	4	100 and 102	General Description	Again consistency issue - create a phrase rather than complete sentence. On page 102, delete the entire first phrase from "in agricultural… present if"	We agree that the wording of indicators is not always consistent. However, similar wording has been used in many previous regional supplements. Therefore, we are reluctant to reword some indicators because of the confusion it could cause among users who work in more than one region.
RR	4	101	Photo	Replace photo with an example that is clearly from during growing season, which would meet the indicator requirement.	We used the best photo we have available.
MW	4	103	Caution and User Notes	Clarify region - Is the use of the word abundant to describe rainfall - appropriate?	Compared to some other supplement regions (e.g., Arid West, Great Plains), rainfall in the Eastern Mountains and Piedmont is abundant.
RR	4	103	User Notes	Move first two sentences up to start of general description paragraph.	We do not see any advantage to this suggestion. We prefer to keep the General Description short.
RR	4	104	User Notes	Move first sentence up to start of general description paragraph.	We do not see any advantage to this suggestion. We prefer to keep the General Description short.
RR	4	105	User Notes	Move first two sentences up to start of general description paragraph.	We do not see any advantage to this suggestion. We prefer to keep the General Description short.

Chapter 4

Team	4	105	User Notes	Add example of an exclusion to include "bedding or microtopical relief caused by silvaculture practices" at end.	We will make the recommended change.
RR	4	106	User Notes	Move description of method up to general description and eliimnate user notes from this indicator.	We do not see any advantage to this suggestion. We prefer to keep the General Description short.

				Chapter 5, References and Appendices	
Initials	**Ch**	**Pg**	**Par**	**Comment**	**Response**
Team	5	General	1	Need to define: *significantly disturbed* and *problemmatic* , *problem areas* and *atypical* . What is the difference.	Most ecosystems in the country has been disturbed to some extent. However, the guidance given in this chapter is not needed unless the site is disturbed to such an extent that wetland indicators are missing or misleading. That is generally what the supplement means by "significantly disturbed" although it is not defined. Problem areas and atypical situations are defined in the 1987 Manual and in paragraph 1 of chapter 5 of the supplement.
MW	5	107	2	1st line, delete "presented in this chapter"	Meaning is lost if these words are deleted.
MW	5	107	3	2nd line, change "planted to crops" to read, "planted **in** crops", remove "use" after "herbicide	We will make the first recommended change. The words "herbicide use" are needed to convey a "management practice" and maintain the sentence's parallel construction.
MW	5	107	3	Remove desirable from "desirable tree species" - so will read "tree species"	We will make the recommended change.
TC	5	108	2	Vegetation bullet a: add, "or during the growing season immediately after cultivation or harvesting".	We will make the recommended change.
MW	5	109	Hydrology	last line, change "Their" to "The"	We will make the recommended change.
TC	5	109	General	Suggest inclusion of Resource Appendix - under the Hydrology Section. Among the things to list is analysis of Digital Elevation Models to examine drainage and flow patterns, which the Corps DOES use and often makes significant nexus and JD calls based upon for DEM analysis of “on the fence” sites. This manual still assumes that the only technology that exists to aid the delineator is a paper topo map and a trip to the air photo room at the local NRCS office. While Joe Landowner might be limited to that, there are few, if any, consultants and regulators that are NOT using GIS to aid delineations.	We have tried to update the guidance given in the 1987 Manual by mentioning relevant online and electronic data sources whenever possible. However, this supplement does not address "significant nexus" or other policy issues, so we see no need to mention DEMs here.
	5	109	Section 2	Address Logging Activities under problem areas, 2nd sentence - add "ruts caused be logging equipment" reference the RGL (if still used) on significantly naturalized areas to assist user.	We will make the recommended change.
MW	5	110	First item e	Add to the end: "On-site monitoring, for as long a period as possible, should always be used to calibrate the hydrologic models."	Proper application of hydrologic models requires many more assumptions, cautions, and caveats than just the one suggested. Listing and discussing them is beyond the scope of this supplement. We prefer that users consult the cited reference or a hydrologist.
MW	5	110	1	2nd sentence, rewrite to read "… but may lack **any of** the hydrophytic…..Chapter 2 at certain times.	We will make the recommended change.
MW	5	110	Procedure, Items 1 and 2	Item 1. 2nd line. change "likely non-wetland' to "likely a non-wetland" Item 2. Delete second line and change the first line to end as "...concentrate water, such as those listed below."	We prefer to use "non-wetland" as an adjective, rather than a noun. We will make the second recommended change.
MM	5	110	Procedure, Item 2.b.	define "active floodplain" include reminder that this is not necessarily the active floodway. It should be mentioned. that many delineators use the REGULATORY floodplain when the active floodplain is based on the delineators assessment of the upslope extent of overbank flow when standing next to the stream. Include these resources in the Resource appendix to be added for sources of data.	We prefer to leave this determination to the user.
TC	5	110	Procedure	Intro to Problematic Hydrophytic Vegetation - mention GIS resources. SEGAP is a VERY RICH SOURCE for identifying potential reference veg communities.	We will add a reference to SEGAP and other sources of land-cover data to the section on Reference Sites (page 115 of the peer-review draft).
MW	5	111	4.a	Remove "interdunal swales" as they are not a major part of this region	We will make the recommended change.
MW	5	111	4.a.(1)(d)	delete "on the site"; replace "substantially" with "mostly" or identify what "substantial" denotes. Get more definitive on what most or substantial means.	We prefer the original wording. The user must determine whether the unknown and reference sites are sufficiently similar. There are no objective standards to aid this determination.
MW	5	112	4.a(2)(a)	2nd sentence, delete "on the site".	We think the original wording is clearer.
CH	5	112	Vernal Pools	Previously stated on page 2 of the intro that vernal pools were beyond scope of document - now include a whole section - Consistency issue	Page 2 mentions "unvegetated seasonal pools." If they are never vegetated, they are not wetlands by the Corps/EPA definition and, therefore, are not covered in the Manual or this supplement (although they may still be regulated). However, vernal pools that are vegetated at some point in their annual cycles are wetlands.
MW	5	112	4.a.(2) (b)	Throughout the Chapter, replace the word "substantially" with "mostly". Think about clarifying qualitative modsifiers and using them consistently with respect to meaning.	We prefer the original wording. The user must determine whether the unknown and reference sites are sufficiently similar. There are no objective standards to aid this determination.

Initials	Ch	Pg	Par	Comment	Response
MM	5	114	4.f	include user note that not all "sphagnums" are hydrophitic	We agree that not all Sphagnums are wetland plants. However, at this point in the procedure, it has already been confirmed that the site has indicators of hydric soil and wetland hydrology, and is in an appropriate landscape position. It simply lacks a vascular plant community. Under these circumstances, any Sphagnum community should be accepted as hydrophytic.
Team	5	115	1	add to the end of 1st para that FACU plants can be found in wetland and may function as a wetland plant under certain conditions.	The FACU indicator status already acknowledges that these species exist in wetlands up to 33% of their occurrence in nature. No one should be surprised to find FACU plants in wetlands. However, the paragraph under consideration specifically lists eleven FACU plant species in this region that are known to dominate certain wetlands to such an extent that they may fail hydrophytic vegetation indicators. The special procedure for dealing with these situations does not extend to any other FACU species.
Team	5	115	d.	List the FACU plants known to occur in the region and include a table where those plants are known to occur.	According to the Corps of Engineers' National Wetland Plant List (NWPL), there are more than 650 plant species with a FACU indicator status in the Eastern Mountains and Piedmont Region. Information about these species and their distributions can be found at the NWPL (https://rsgis.crrel.usace.army.mil/apex/f?p=703) or at the USDA Plants database (http://plants.usda.gov/). It is beyond the scope of the supplement to provide these lists.
RR	5	115	d.	The technical literature discussion should be included in the main vegetation section (Section 2) rather than in the problem section - with regard to NI, NO, and unlisted species. The FACU-dominated wetland is a problematic wetland situation. The other 3 are problematic plant list issues, not problematic vegetation issues.	We disagree. Technical literature is used to solve a problem with hydrophytic vegetation indicators or with the indicator status of certain plants. Therefore, it is appropriate that this option appears in Chapter 5. Furthermore, this information is found in the same place in all previous regional supplements. It is important to maintain consistency of organization of these supplements for users who work in more than one region.
MW	5	115	c.	Replace "substantially" with "mostly" - see note above	We prefer the original wording. The user must determine whether the unknown and reference sites are sufficiently similar. There are no objective standards to aid this determination.
Team	5	116	2	Fluvial deposits could include indicator F 19 as a reference indicator. 1st sentence - replace "and" with "or"	We will make the second recommended change in wording. However, indicator F19 specifically addresses floodplain wetland soils that are higher than 2 chroma due to high iron content of the fluvial material. This is not the same concept as the "Fluvial Deposits within Floodplains" problem soil situation, which is caused by other factors (insufficient time to develop redox features, low organic content, etc.).
MW	5	116	1	In preamble to the problemmatic soil section give specific definition of when problem hydric soil determinations must be accompanited by certification by certified soil scientist.	It is not the purpose of the Supplements to require certification of wetland practitioners. No change is needed.
MW	5	120	c.2	Combine sentences 2 and 3 to read "…. concentrate water, such as those listed below"	We will make the recommended change.
MW	5	121	c.2	1st sentence, change "color of the soil" to "color of a moist soil"	The suggested change is not needed. If the soil were dry, no color change upon exposure to air would be expected.
MW	5	123	2	3rd sentence, delete "in the region".	We disagree. These examples are found in this region. Other regions may differ.
MW	5	123	procedure 2	combine first 2 sentences to read, "concentrate water, such as those listed below"	We will make the recommended change.
	5	124	b	User Note to consider more than just 2 to 3 months of rainfall, consider if there has been a long term climate change in the previous 12 months.	Longer term rainfall deficits are considered in the following section on droughts. One or the other of these two approaches should be appropriate in most situations.
MW	5	125	e	Add the word "Seven:" in introduction relating to the 7 hydrology tools listed and referenced at NRCS website. First line with read…."The 'Seven Hydrology Tools' (USDA Natural Resources…."	"Hydrology Tools" is the commonly used name for this collection of procedures developed by NRCS. No change is needed.
MW	5	126	6	Change to "Estimate the effectiveness of agricultural drainage systems using NRCS state drainage guides."	We will make the recommended change.
Team	5	127	general	Give an example of when you would start including this sort of analysis, perhaps a break point or flow chart to assist the delineator in knowing when to include the wetland mosaic. In interest of clarity place under procedure a number in the sentence "First identify and flag all ...that are X acres or more.	These decisions should be made by the field investigator and/or Corps District staff based on site conditions and other factors. There is no minimum size for an area that can or should be mapped as wetland or non-wetland, and no objective standards for when to use the mosaic approach. If in doubt about the applicability of this procedure on a specific site, users should consult the Regulatory Branch of the appropriate Corps District.

Initials	Ch	Pg	Par	Comment	Response
JB	5		throughhout	Alpha-alpha-Dipyridyl is called a “dye”. It is not a “dye” as is does not artificially color the soil. It however is a “reagent” used to detect the presence of the ferrous ion, and thus used as an indication of the occurrence of the reduction of iron (ferrous (Fe2+ to ferric Fe3+). Please change all reference of “alpha-alpha-Dipyridyl dye” (as found on pages pages 96 (5x), 109, 117 (2x), and 122 (7x)) to “alpha-alpha-Dipyridyl reagent”.	We will make the recommended change.
MM	References			the following links don't work: Sprecher, S. W., and A. G. Warne. 2000. Accessing and using meteorological data to evaluate wetland hydrology. ERDC/EL TR-WRAP-00-1. Vicksburg, MS: U.S. Army Engineer Research and Development Center. (http://el.erdc.usace.army.mil/elpubs/pdf/wrap00-1/wrap00-1.pdf U.S. Army Corps of Engineers. 2009. National wetland plant list. (https://maps.crrel.usace.army.mil/apex/f?p=393). Visited January 2009. USDA Natural Resources Conservation Service. 2005. National soil survey handbook, part 629, glossary. Washington, DC: U.S. Department of Agriculture. (ftp://ftpfc.sc.egov.usda.gov/NSSC/Soil_Survey_Handbook/629_glossary.pdf (most have additional text that only appears when clicked)	We will verify all links before publication.
MM	References			reference where to find MOU's, RGLS, other important info for delineator	This is beyond the scope of the supplement. The supplement supersedes some existing guidance memos from Corps Headquarters. This will be explained in the Public Notice announcing publication and implementation of the final supplement.
Team	Appendix A			general recommendation about defining terms	We do not understand the comment. Important terms are defined in the Glossary (Appendix A) or in other sources cited there.
				Add a Resource Appendix for users recommending current resources available to aid in delineations.	Many information sources are already cited in the supplement. Other resources useful to delineators (e.g., maps, aerial photos, GIS layers), particularly internet resources, change so frequently that any list given in the supplement would rapidly go obsolete. We rely on wetland delineation trainers to provide up-to-date resources to their students. Previously trained and experienced users can use standard internet search techniques to locate relevant resources.
MM	Data Sheets			Capitalization is inconsistent	We will check for consistency.
Team	Data sheet		veg section	Procedure goes through with indicator 1 2 3 … data form doesn't - nowhere on the data form does it indicate which indicator is referenced - can you include the indicator numbers	We will make the recommended change.
Team	Data sheet			Change title to read, "Hydrophytic Vegetative Indicator Summary"	We disagree with the suggested wording, and it is not clear where this heading is intended to go.
Team	Data sheet		Hydrology	Include a para in chapters 3 and 4 explaining how to use "other". Each sheet has a blank for "Other" but there is no discussion of "Other" in the text. Direct people to comment using professional judgement explaining that notes concerning "other" should be something that influences either of the primary or secondary indicator status and should be elaborated upon on the data sheets.	There are no procedures or guidance for using the "other" category, except in relation to wetland hydrology indicators (see page 74 of the peer-review draft). The presence of the "other" category on the data form is simply to allow the user some flexibility in interpreting field observations that may not fit an indicator. As stated on the data form, the user should provide some justification in the Remarks. No additional requirements are needed. The Corps of Engineers has final authority over the use and interpretation of the supplement, including the acceptability of any "other" observations. If in doubt, consult the appropriate Corps District.
Team	Data sheet		data sheet	Two versions of the form - one for 4 veg strata and one for 5. The one for 4 has been shortened by a page making it more difficult to use. It incentivizes the use of the 5 veg strata form. To keep them consistent, alter the second page on the 4 veg sheet and allow for bigger remarks section.	We will expand the 4-stratum data form to three pages to provide more room for recording observations and to make it parallel with the optional 5-stratum data form.

Information Transfer Program Introduction

The VWRRC supports timely dissemination of science-based information to policy and decision-making bodies and citizens. The VWRRC used its USGS 104B funds to support expert personnel with responsibilities related to the VWRRC's outreach and collaborative programs. In FY 2009, the USGS 104B funds supported:

1. Preparation and electronic publication of the newsletter *Virginia Water Central*.

2. Partial support for organizing the 2009 Mid-Atlantic Regional Water Resources Research Conference.

3. Partial administrative support for the Virginia Water Monitoring Council.

4. Partial support for management of the VWRRC webpage, VWRRC Facebook, VWRRC Twitter, and Virginia Water Radio.

Information Dissemination

Basic Information

Title:	Information Dissemination
Project Number:	2006VA97B
Start Date:	3/1/2006
End Date:	2/28/2010
Funding Source:	104B
Congressional District:	9th
Research Category:	Not Applicable
Focus Category:	None, None, None
Descriptors:	
Principal Investigators:	Stephen H. Schoenholtz, Changwoo Ahn

Publications

1. Parece, T., T. Younos and V. K. Lohani (Editors). NSF REU 2009 Proceedings of Research: Research Opportunities in Interdisciplinary Watershed Sciences and Engineering. VWRRC Special Report SR47-2009. Virginia Water Resources Research Center, Virginia Tech, Blacksburg, Virginia. http://www.vwrrc.vt.edu/special_reports.html
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27. *Virginia Water Central*, June 2009 (No. 49), 45 pp.
28. *Virginia Water Central*, August 2009 No. 50), 46 pp.
29. *Virginia Water Central*, November 2009 (No. 51), 48 pp. plus 15-page news supplement.
30. *Virginia Water Central*, February 2010 (No. 52), 40 pp.

Outreach and Information Transfer Accomplishments

Newsletter
Email distribution to approximately 650 recipients and announcement/availability on VWRRC website.

Special Notifications via VWRRC Listserv

1. Notice about public comment periods, ending August 21, for poultry litter management regulations and new stormwater management regulations (7/29/09).
2. Notice about online water bills inventory from 2010 Virginia General Assembly (2/12/10).

Notifications via Virginia Water Monitoring Council (VWMC) Listserv
Weekly water-related announcements are provided to approximately 450 members of the VWMC. Announcements include information about conferences, workshops, total maximum daily load (TMDL), public meetings in Virginia, job openings, newly published reports, information posted on websites, and other pertinent information.

VWRRC Website (www.vtrrc.vt.edu)
The VWRRC website is updated at least weekly and supports a Water News Grouper page, which is updated daily. The VWRRC website also serves as the portal for three other websites the VWRRC manages:

1. Virginia Water Monitoring Council (http://www.vwrrc.vt.edu/vwmc/default.asp
2. Virginia Department of Conservation and Recreation Stormwater BMP Clearinghouse (http://www.vwrrc.vt.edu/swc/)
3. Clinch-Powell Clean Rivers Initiative (http://www.vwrrc.vt.edu/cpcri/default.asp)

VWRRC is now on *Twitter* at http://twitter.com/VaWaterCenter and ***Facebook*** (http://www.facebook.com/pages/Blacksburg-VA/Virginia-Water-Resources-Research-Center/186479556264?v=wall)

Virginia Water Radio (www.virginiawaterradio.org)
In FY10, the VWRRC began to host a weekly 5-minute radio show featuring summaries of recent water news, upcoming water events, and water-related sounds or music.

2009 Virginia Water Research Conference
(http://www.vwrrc.vt.edu/2009conference.html)
The 2009 Virginia Water Research Conference, *Water Resources in Changing Climates,* was co-sponsored by the VWRRC and the Rice Center for Environmental Sciences at Virginia Commonwealth University (VCU) and held on the campus of VCU October 15-16. The theme of the conference focused on the environmental, political, and economic changes we face as stakeholders, researchers, and managers of water resources. The conference featured approximately seventy oral and poster presentations, including 39 student presentations, and was attended by more than 140 participants. The proceedings of this conference are available at http://www.vwrrc.vt.edu/proceedings.html.

VWRRC/ICTAS Water Seminar Series
The VWRRC established, provided leadership for, and organized a new Water Seminar Series at Virginia Tech in collaboration with the Institute for Critical Technology and Applied Science (ICTAS). See http://www.vwrrc.vt.edu/seminar_archive.html

Four invited speakers participated in the series in spring 2009.

1. Dr. Marc Edwards, Virginia Tech. *Corrosion Control Hits Home: The Profound Implications of Premise Plumbing Corrosion* (March 27, 2009)
2. Dr. Nicolas Zegre, West Virginia University. *In Lieu of the Paired-Catchment Approach: Hydrologic Model Change Detection at the Catchment Scale* (April 6, 200)
3. Dr. Jim Wigington, Western Ecology Division, US EPA. *Prospects for Hydrologic Classification of Landscapes and Watersheds* (April 17, 2009)
4. Dr. K. Ramesh Reddy, University of Florida. *Coupled Biogeochemical Cycles in Wetlands: The Everglades as a Case Example* (April 27, 2009)

International Outreach Activities

1. Co-organized international workshop on *Climate Drivers, Hydrological Regime and Environmental Change*, August 31 – September 3, 2009, Ottawa, Canada.
2. Hosted an exchange PhD water resources student from *Universidad Austral de Chile*, August – October, 2009.

USGS Summer Intern Program

None.

Student Support					
Category	**Section 104 Base Grant**	**Section 104 NCGP Award**	**NIWR-USGS Internship**	**Supplemental Awards**	**Total**
Undergraduate	0	0	1	0	1
Masters	0	0	0	0	0
Ph.D.	0	2	0	0	2
Post-Doc.	0	0	0	0	0
Total	0	2	1	0	3

Notable Awards and Achievements

Publications from Prior Years