Designing for Success: Long-term Trends of Constructed Freshwater Wetlands in Hillsborough County, Florida

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Abstract

Mitigation wetlands are ideal for studying long-term success of constructed systems because they address many of the well-known short-comings of ecosystem restoration. Unlike many non-mitigation projects, constructed mitigation wetlands have clearly defined goals, success criteria, and mandatory maintenance and monitoring periods to help ensure a desired stable state. This research examines how design variables such as wetland type, size, location, and planted vegetation community affect wetland structure and function following mitigation release.

Since 1987, over 1,200 compensatory freshwater wetlands have been permitted and constructed under the supervision of the Hillsborough County Environmental Protection Commission (EPC). From this database, a total of sixty-three (N=65) forested and non-forested freshwater wetlands were surveyed to determine if constructed wetlands continue on their intended design trajectories through time or degrade to undesired conditions. Vegetation community structure, tree growth rates, uniform mitigation assessment method (UMAM) scores, wetland rapid assessment protocol (WRAP) scores, functional wetland area, and landscape development intensity (LDI) were assessed for both the project design and current state.

Results indicate that long-term success of constructed wetlands is affected by design factors such as size, quality of design, and wetland age. Total wetland area for the surveyed sites has decreased compared to their intended design. Using the data gathered from the design files and field surveys, it is possible to model optimal WRAP scores from controllable design variables for both forested and non-forested systems. Results from this study may provide invaluable insight into wetland design and long-term successional trends of freshwater wetlands in urbanized watersheds.

Site Selection

Created Wetland Database

- Mitigation data for created freshwater wetlands were collected from an existing EPC database
- General information for 1,166 freshwater projects were extracted from the database.
- Wetlands were assigned to two groups, forested and non-forested, based on their FLUCCS descriptions
- "Site Type", which describes the cause of the mitigation project was used to filter out confounding projects.
- Site types phosphate, mitigation bank, exempt impact, wetland preservation, and wetland enhancement were removed to remove the potential influence of large-scale phosphate reclamation and mitigation banking projects, as well as projects that did not involve physical wetland construction.
- The resulting database contained only permittee-responsible, wetland creation projects.

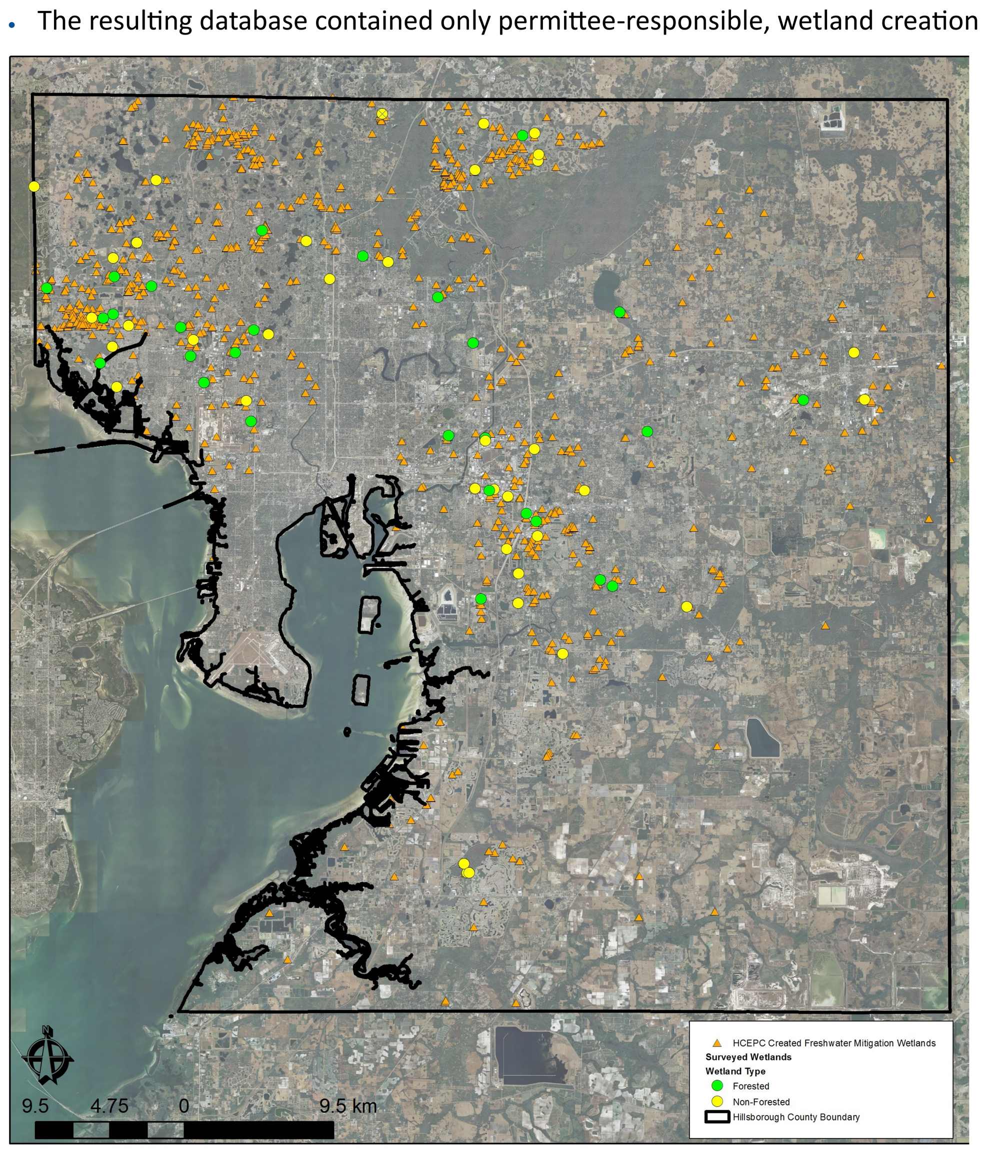


Figure 1. Distribution of HCEPC created freshwater mitigation wetlands and surveyed sites

Surveyed Sites

- Age was calculated by determining the amount of time since the wetland was released from mitigation
- Sites less than 5 years since release were excluded from the study in an attempt both to remove the influence of maintenance and to ensure that all sites had ample opportunity for the vegetation community to coalesce.
- A stratified, random sample was taken to ensure equal selection of both forested and non -forested sites across the entire age spectrum (5-10; 10-15; 15-20; 20+).
- Ten randomly selected forested and non-forested sites in each age class were selected for field sampling, resulting in total of 80 freshwater wetlands.
- Each site's mitigation file was inspected for completeness and lack of issues. If a file was deemed "incomplete, a random alternative was selected.
- The field survey period ran from 1 April to 31 October 2014, during the "wet" or "growing" season, to facilitate plant identification and assessing hydrology.
- Many projects consisted of several distinct wetlands instead of one contiguous system. In such cases, one wetland was randomly selected as a representative for the study.

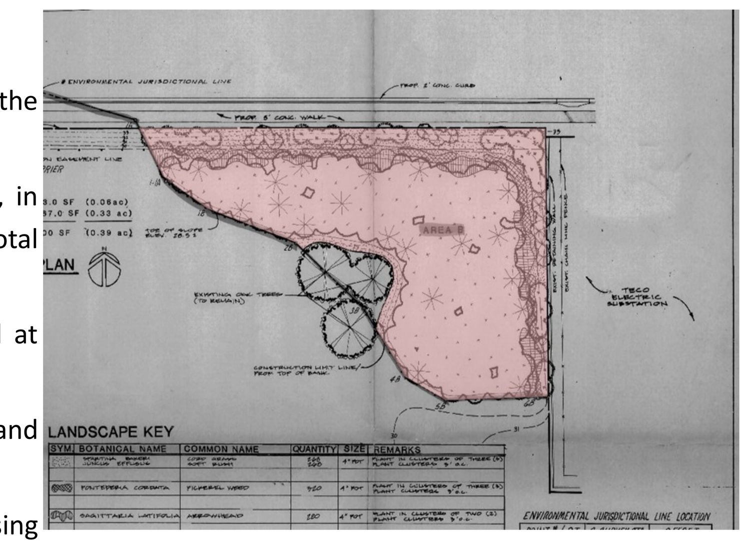
Table 1. Years Since Release for Surveyed Sites

Wetland Type	N	Mean	SE Mean	Minimum	Median	Maximum
Forested	28	15.463	0.92	7.189	16.274	23.653
Non-Forested	37	16.016	0.866	6.45	15.956	23.467
All Sites	65	15.778	0.629	6.45	15.956	23.653

Table 2. Designed Area of Surveyed Sites

Wetland Type	N	Sum	Mean	SE Mean	Minimum	Median	Maximum
Forested	28	29.516	1.054	0.249	0.013	0.542	5.795
Non-Forested	37	45.296	1.224	0.227	0.056	0.914	7.47
All Sites	65	74.812	1.151	0.167	0.013	0.804	7.47

Wetland Designs



- Baseline data for each created wetland was established using planting plans from either the 100% design plans or record drawings.
- In some cases, data from the site inspection reports modified the species or numbers, in which case, the adjusted numbers were used so the final plant counts reflected to total number of installed plants prior to release.
- This approach provides the most comprehensive list of species and quantities installed at each wetland prior to wetland release.
- From the planting data, Shannon-Weiner Diversity Index (H_{design}), Evenness (H'_{design}), and Simpson's Index of Diversity (Ds_{design}) were determined.
- Using data from the mitigation file and historical imagery, each wetland was evaluated using the Uniform Mitigation Assessment Methodology (UMAM) (Chapter 62-345 F.A.C) and Wetland Rapid Assessment Protocol (WRAP) (Miller and Gunsalus 1997).
- Scores were tabulated using current UMAM and WRAP guidelines (FDEP) based upon the conditions at the time of release.
- It was assumed that the site would have met minimal mitigation requirements (i.e. greater than 85% desirable species in good health, fewer than 10% nuisance/exotics, etc.) and that the designed hydrology was appropriate.

Landscape Development Intensity (LDI)

From the mitigation files, sample and alternative site design plans were digitized and georeferenced into ERSI ArcGIS 10.3.1. From either digitized final plans or record drawings, wetland boundaries converted into polygon shapefiles.

Using methodology created by Brown and Vivas (2005), the Landscape Development Index (LDI) for each created wetland was determined for each year of available data since built. The following formula was used to calculate LDI within a 100-meter buffer around each wetland:

$$LDI_{wetland} = \sum \%LU_i * LDI_i$$

where $LDI_{wetland}$ = LDI score for the created wetland; LU_i = percent of the total area of influence in land use i; LDI_i = landscape development intensity coefficient for land use i. If the wetland was released during a year that land use land cover (LULC) data were not available (i.e. 1987-1989, 1991-1994, 1996-1998, 2000-2003), the dataset for the year closest following release was used as the first year. For example, if a site was released in 1988, the LDI value for its first year would be derived from the 1990 dataset ($LDI_{initial}$).

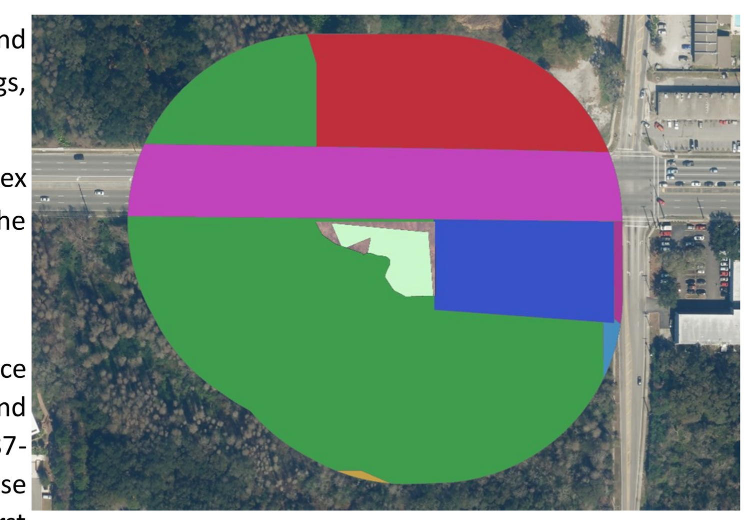


Figure 2. Example of LDI assessment of a created freshwater wetland

Field Surveys

Field surveys were conducted at a total of 65 sites during the wet season of 2014. Numerous biological assessments were conducted to determine the current status of the created wetlands.

Sampled Parameter	Methodology
Vegetation—Groundcover	Randomly selected transects with randomly placed 1 m transect every 5 m
Vegetation—Canopy	10 m belt transect. Height and DHB recorded for all woody species.
Wetland Edge	Extent of wetland area surveyed with a Trimble Geo7x
Wetland Value	UMAM and WRAP scores completed for wetland
Wetland Hydrology	Surveyed elevations for top of bank, deep zone, normal pool, SHW, and in-

Table 3. Field Sampling Methodology

Results

LDI

From 1990 to 2011, mean annual LDI scores for created freshwater wetlands within Hillsborough County (N = 120) increased by 0.53 , or 12% (Table 11). The mean LDI score of non-forested systems was greater than forested systems for every year of the study

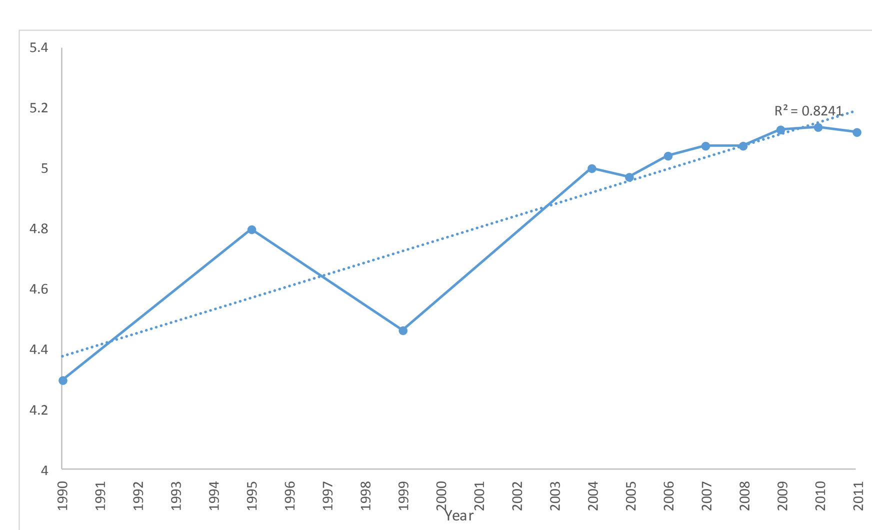


Figure 3. Mean LDI scores of surveyed sites over time

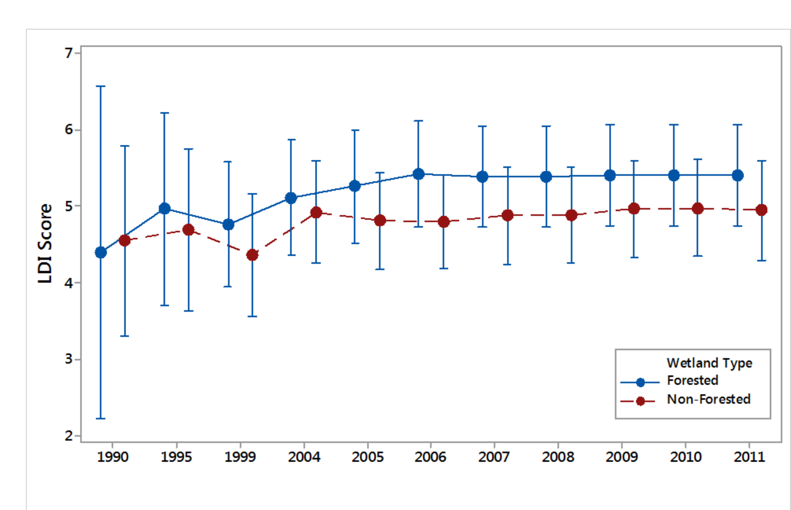


Figure 4. Mean LDI scores of surveyed sites by wetland type over time

Wetland Edge

Non-forested wetlands displayed a greater degree of loss over the course of the study compared to forested sites. Total wetland area decreased by 13.34 acres from the time of construction to the time of survey (18% reduction).

Table 4. Change in wetland area

Wetland Type	Design Area	Survey Area	Difference
Forested	29.52	25.64	-3.88
Non-Forested	45.30	35.84	-9.46
All Sites	74.81	61.47	-13.34

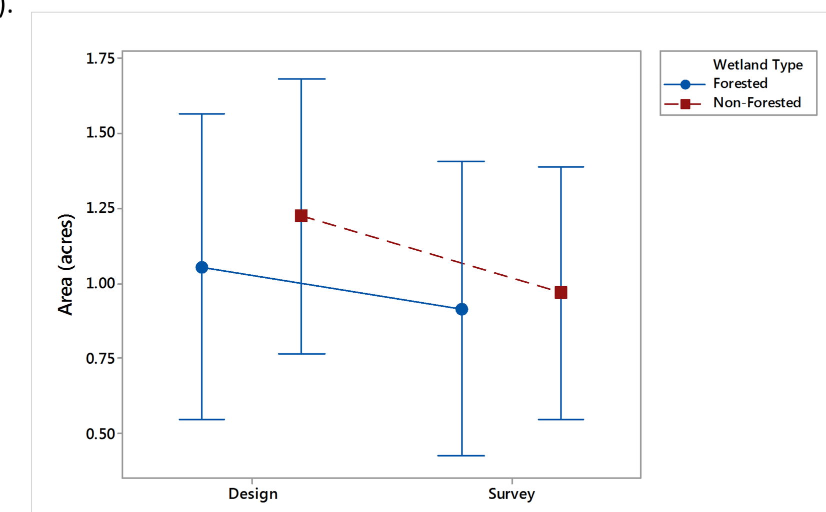


Figure 5. Mean decrease in wetland area by wetland type

Wetland Value

Based upon the results of a Pearson's Correlation Matrix, WRAP scores were chosen as the best representative of wetland value and we used for all modelling.

Table 4. Correlation matrix of biological assessment methodologies

	$UMAM_{survey}$	LDI_{2011}	$H_{groundcover}$	$Ds_{groundcover}$	H_{canopy}	Ds_{canopy}
LDI_{2011}	-0.39 0.00					
$H_{groundcover}$	0.17 0.18	-0.08 0.52				
$Ds_{groundcover}$	0.09 0.48	-0.03 0.80	0.90 0.00			
H_{canopy}	0.20 0.18	0.00 0.99	-0.20 0.20	-0.17 0.29		
Ds_{canopy}	0.12 0.42	-0.03 0.87	-0.27 0.09	-0.23 0.14	0.89 0.00	
$WRAP_{survey}$	0.68 0.00	-0.62 0.00	0.06 0.63	-0.04 0.79	0.19 0.21	0.18 0.24

Acknowledgements

EPC—Dawn Hart, Larry Sellers, Bill Vorstadt, Lisa Henningsen, Chris Cooley, Pete Owens, Dave Karlen, Scott Emery, Sterlin Woodard

USGS -Kim Haag

SWFWMD—Kristen Kaufman, Stephanie Powers, Leigh Vershowske

EPA—This presentation was developed under Assistant Agreement No. CD - 95488011-1 awarded by the U.S. Environmental Protection Agency. It has not been formally reviewed by EPA. The views expressed are solely those of (name of recipient) and EPA does not endorse any products or commercial services mentioned.

IAN Symbology -Courtesy of the Integration and Application Network, University of Maryland Center for Environmental Science (ian.umces.edu/symbols/).

WRAP Assessments

Surveyed sites' WRAP scores decreased by an average of 0.09 for All Sites, 0.09 for forested sites, and 0.08 for non-forested sites (Table 38 page 56). Water Quality Input and $Treatment_{\Delta}$ scores displayed a mean increase for All Sites and Forested Sites, while all other categories for the wetland types decreased.

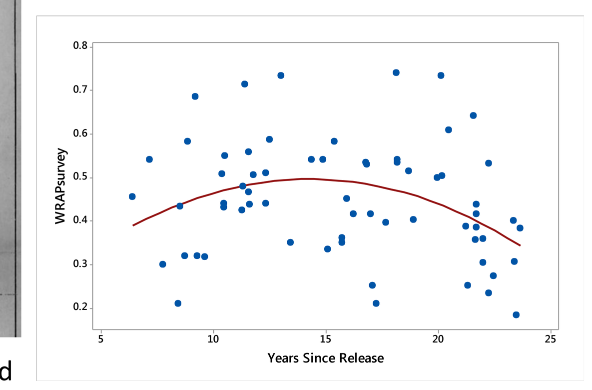


Figure 6. Regression analysis of $WRAP_{survey}$ versus Time

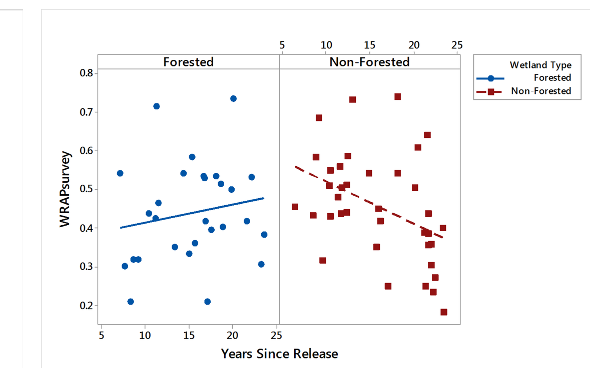


Figure 7. Regression analysis of $WRAP_{survey}$ versus Time by wetland type

WRAP Optimization

Using the results from a multiple regression analysis of the effects of design variables on $WRAP_{survey}$ scores, an optimization model was created to target a maximized WRAP score. Design area, time, and $WRAP_{design}$ were used to model a predicted WRAP score.

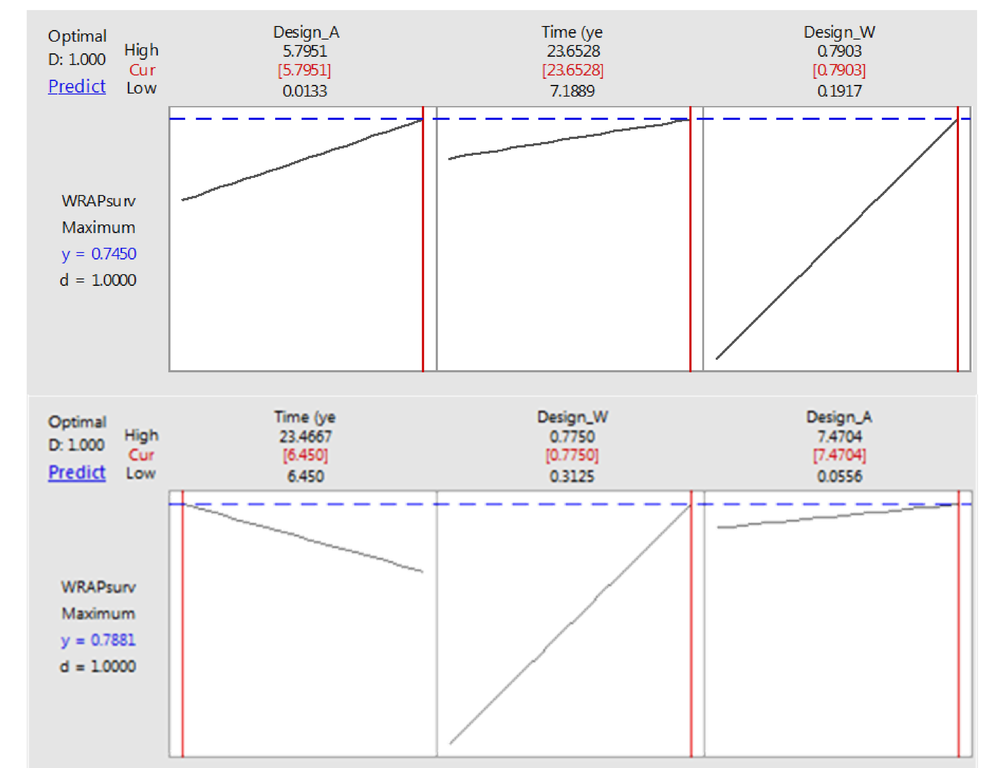


Figure 8. Optimization models for forested (top) and non-forested (bottom) wetlands

For forested systems, maximizing the design area, time until survey, and $WRAP_{design}$ score, yielded the greatest $WRAP_{survey}$ score of 0.75; with the model variables accounting for 63% of the model variation.

Non-forested systems were similar for WRAP and area, but displayed the highest $WRAP_{survey}$ scores with less time until survey (79% of the model variation was accounted for by the variables).

Discussion

- Supporting location, whether it be measured within a WRAP, UMAM, or LDI assessment, is a large contributor to the design and eventual value of a wetland. Regression analyses of wetland designs identified location as the dominate contributor to the variability of the score. This means if all the controllable factors are optimized, location is going to dictate the value of the design.
- When developing the optimized regression model, the importance of design become very apparent. Both wetland models use the maximum values for time and $WRAP_{design}$, but changes in $WRAP_{design}$ have the greatest impact on $WRAP_{survey}$.
- With regards to the chronosequence utilized by this research, the relationship between non-forested freshwater wetland value and time is of particular concern. Non-forested $WRAP_{corrected}$ scores display a negative correlation with time. This finding is exacerbated by the fact that non-forested freshwater sites have been lost at a greater proportion within Hillsborough County over time.
- Perhaps the most surprising finding of this study is the total loss of wetland area. If the 18% loss from the surveyed sites remains constant across the entire parent population, current estimates of mitigated wetland area for Hillsborough County and the Tampa Bay watershed could be greatly exaggerated. There is also a possibility that the conditions set forth by "no net loss" are not being met.

Conclusions

This study has illuminated the discrepancy between intended and actual wetland value and area for a subsample of created freshwater wetlands. Despite many of the surveyed biodiversity indicators being relatively similar between forested and non-forested wetlands, analyses show that over time non-forested systems steadily degrade from the design state while forested systems slowly improve. Optimization models indicate that the quality of design has great ramifications on the outcome of a created wetland, however location, which is often uncontrollable, may be the single most important factor. Every effort was taken to ensure the sample group of freshwater wetlands was random and representative of the parent population. Additional research would strengthen the models and provide greater insight to the relationships between design and surveyed wetland value.

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