4-2012

Prioritizing Habitat Restoration Goals in the Tampa Bay Watershed

Mark C. Rains
Univeristy of South Florida, mrains@usf.edu

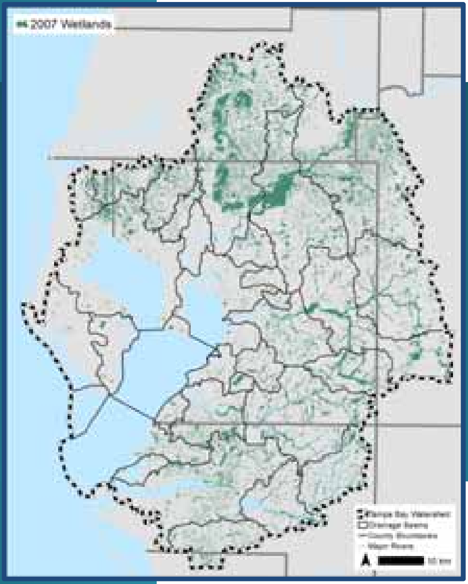
Shawn Landry
University of South Florida, landry@usf.edu

Valerie Seidel
The Balmoral Group

Thomas L. Crisman
University of South Florida

Scholar Commons Citation

Rains, Mark C.; Landry, Shawn; Seidel, Valerie; and Crisman, Thomas L., "Prioritizing Habitat Restoration Goals in the Tampa Bay Watershed" (2012). *School of Geosciences Faculty and Staff Publications*. 1229.
https://digitalcommons.usf.edu/geo_facpub/1229

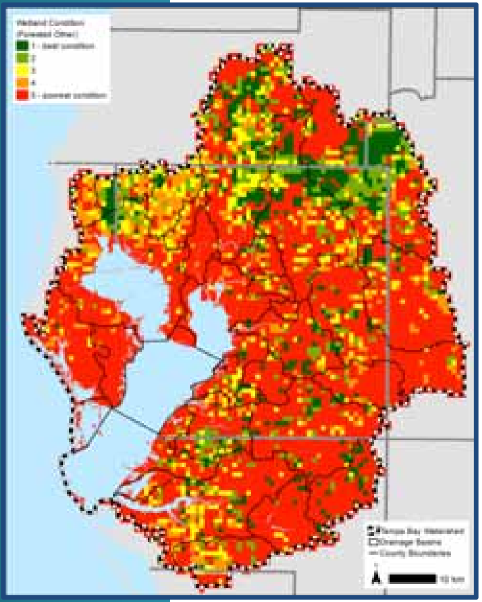


Prioritizing Habitat Restoration Goals in the Tampa Bay Watershed

Submitted to
Tampa Bay Estuary Program

By

Mark Rains, University of South Florida
Shawn Landry, University of South Florida
Valerie Seidel, The Balmoral Group
Thomas Crisman, University of South Florida



April 2012

Table of Contents

Tables and Figures iii
  List of Figures iii
  List of Tables iv
Introduction 1
Physiography 3
  Geographic Extent and Hydrophysiography 3
  Climate 4
  Geology 4
  Land Cover 5
  Types of Freshwater Wetlands 5
Methods 11
  Data Acquisition 11
  Mapping 11
    Creation of historical wetland inventory 11
    Creation of current wetland inventory 15
  Classification 15
  Change Analysis 17
    Change analysis of the individual wetland polygons 17
    Aggregate summary of changes 18
  Conditional Assessment 18
  Economic Analysis 21
  Screening Tools 23
    Wetland Loss 25
    Wetland Loss by Type 25
    Wetland Area 26
    Wetland Condition 26
    Wetland Condition by Type 29
    Wetland Hydrological Connectivity 30
    Wetland Mitigation Opportunity / Planned Development Impact 30
Results and Discussion 31
  Geographic Extent of Wetlands, 1950 and 2007 31
  Wetland Change, 1950-2007 35
  Screening Tools 41
    Wetland Loss 43
    Wetland Loss by Type 44
    Wetland Area 50
    Wetland Condition 51

    Wetland Condition by Type 52
    Wetland Hydrologic Connectivity 58
    Wetland Mitigation Opportunity / Planned Development Impact 59
Conclusions 60
Acknowledgements 62
References 63
Appendix A: FLUCCS to LDI crosswalk used for conditional assessment 66
Appendix B: Overview of Screening Criteria Usage 68

Tables and Figures

List of Figures

Figure 1. Map of the Tampa Bay Watershed Study Area. 3

Figure 2. Diagram of Geology. Geologic setting, especially as regards the surface-water and ground-water interactions between wetlands and the surficial and Floridan aquifers. Reprinted with permission from (Haag and Lee, 2010). 6

Figure 3. Headwater riverine wetland in the northern Tampa Bay Watershed. 8

Figure 4. Lacustrine wetlands fringing a small lake in the eastern Tampa Bay Watershed. 9

Figure 5. Depressional wetland in the northern Tampa Bay Watershed. 10

Figure 6. Availability of historical wetlands data and georeferenced historic aerial imagery 12

Figure 7. Ungeoreferenced historic imagery lacking well-defined control point features. 13

Figure 8. Regression of the LDI score v the UMAM landscape support score. 20

Figure 9. Regression of the LDI score v the UMAM final score. 21

Figure 10. Map showing 1 km Screening Grid. 24

Figure 11. Map of LDI values within wetlands. Higher LDI values imply more impacted wetlands. 27

Figure 12. LDI values overlaid by 1 km screening grid. Higher LDI values imply more impacted wetlands. 28

Figure 13. Illustration of binning technique of mean LDI distribution. Higher LDI values imply more impacted wetlands. 29

Figure 14. Geographic Extent of Wetlands, 1950. 32

Figure 15. Geographic Extent of Wetlands, 2007. 34

Figure 16. Wetland Change, 1950-2007. 36

Figure 17. Wetland loss by drainage basin, 1950-2007. Categories are defined by quartile groups. 39

Figure 18. Screening Tool: Loss of All Wetlands. 43

Figure 19. Screening Tool: Loss of Forested Riverine Wetlands. 44

Figure 20. Screening Tool: Loss of Non-Forested Riverine Wetlands. 45

Figure 21. Screening Tool: Loss of Forested Lacustrine Wetlands. 46

Figure 22. Screening Tool: Loss of Non-Forested Lacustrine Wetlands. 47

Figure 23. Screening Tool: Loss of Forested Other Wetlands. 48

Figure 24. Screening Tool: Loss of Non-Forested Other Wetlands. 49

Figure 25. Screening Tool: Wetland Area. 50

Figure 26. Screening Tool: Condition of All Wetlands. 51

Figure 27. Screening Tool: Condition of Forested Riverine Wetlands. 52

Figure 28. Screening Tool: Condition of Non-Forested Riverine Wetlands. 53

Figure 29. Screening Tool: Condition of Forested Lacustrine Wetlands. 54

Figure 30. Screening Tool: Condition of Non-Forested Lacustrine Wetlands. 55

Figure 31. Screening Tool: Condition of Forested Other Wetlands. 56

Figure 32. Screening Tool: Condition of Non-Forested Other Wetlands. 57

Figure 33. Screening Tool: Connectivity of All Wetlands. 58
Figure 34. Screening tool: Planned Development Impact (LDI). 59
Figure 35. Target areas selected following screening criteria example. 69

List of Tables

Table 1. Land use-land cover in the Tampa Bay Watershed as based upon the 1000-Level of the Florida Land Use, Cover and Forms Classification System (Florida Department of Transportation, 1999). 5
Table 2. Six wetland classification types. 16
Table 3. Crosswalk between FLUCCS, NWI and structural classification of forested/non-forested. 17
Table 4. Wetland surface area in 1950 summarized by type. 31
Table 5. Wetland surface area in 2007 summarized by type. 33
Table 6. Wetland Change, 1950-2007: Total area and percent change. 35
Table 7. Type of change at the scale of individual wetlands. 37
Table 8. Wetland Change, 1950-2007: Total area and percent change by drainage basin. 40
Table 9. Summary statistics of raw grid data used to develop screening criteria. 41
Table 10. Raw data cutoff values used for each 1-5 wetland criteria score. Bin 1 indicates the values used for criteria score 1, Bin 5 indicates the cutoff used for criteria score 5. 42
Table 11. FLUCCS to LDI Crosswalk. 66

Introduction

Florida has a greater abundance of wetlands in terms of both total area and percentage of total land area than any other state in the 48 conterminous states (Hefner and Brown, 1984; Fretwell et al., 1996). However, nearly half of Florida's wetlands have been lost, with wetlands covering ~20 million ac or ~48% of the total land area in 1845 reduced to ~11 million ac or ~27% of the total land area by 1996 (Dahl, 2005). Historically, most wetland losses in Florida were to agriculture, as land was drained to be brought into agricultural production. In more recent years, however, the vast majority of wetland losses in Florida have been to urban development, which accounted for ~72% of wetland losses between 1985 and 1996 and ~61% of wetland losses between 1998 to 2004 (Dahl, 2005; Dahl, 2006). Recently, trends have changed nationally, with wetland area increasing in the conterminous states by an average of ~32,000 ac annually between 1998 and 2004 (Dahl, 2006). The net wetland gains are largely attributable to wetlands created, enhanced, or restored through regulatory and non-regulatory programs. However, many of these wetland gains have been made through structural and functional replacements, with many different types of natural wetlands having been replaced by created open-water ponds in urban settings, with an overall loss of some kinds of wetland functions (Dahl, 2006).

The Tampa Bay Estuary Program (TBEP) has applied considerable research and collective wisdom to develop the idea of "restoring the balance" of freshwater wetlands and habitat in the Tampa Bay watershed. The Tampa Bay Estuary Program Habitat Master Plan Update (PBS&J, 2010), building upon a previously published document entitled Setting Priorities for Tampa Bay Habitat Protection and Restoration: Restoring the Balance (Lewis Environmental Services, Inc., 1996) set forth specific goals. Goals included both shifting future efforts to restoration and protection of habitats in ratios that were historically present, and pursuing a unique federal-state-local-private partnership to provide the framework for the development of a coordinated approach to linking regulatory, resource management, and habitat restoration programs in the Tampa Bay watershed. This project was intended to provide the technical tools to assist in these related efforts. As outlined in the report, the project team was especially interested in structural versus functional criteria, and hydrologic connectivity.

This final report summarizes the ecological, hydrological, econometric and GIS analyses conducted during the project. The project achieved four specific objectives: (1) GIS analysis and mapping of historical changes to freshwater wetland habitats from 1950 to current conditions, (2) Change analysis to identify changes in extent, structure, function and quality of wetland habitats, (3) Conditional assessment to assess the state and condition of existing wetlands, and (4) Development of screening tools for use by local stakeholders in prioritizing restoration, mitigation, and preservation targets. Econometric modeling incorporating expectations of future land use patterns and relative values was incorporated to assess economic viability of various locations. An expected long-term outcome of the project will be for local stakeholders to identify the most desirable areas for future restoration to achieve habitat restoration and protection goals. Existing and planned compensatory mitigation will be included in this analysis, going forward.

Numerical results are presented throughout the report, providing quantifiable findings at the watershed and drainage basin scale. Overall, four broad project findings are significant. First, all types of wetlands have been impacted, but impacts vary widely from basis to basin and from County to County; no overall pattern or trend represents the watershed or a specific County. Secondly, given an objective of achieving habitat ratio goals, the relative scarcity of existing specific wetland function or condition at the drainage basin, County, or other sub-watershed scale must be viewed in historical context of the other wetland functions and conditions within the basin, and their vulnerability given economic pressures for land use change. The Screening Tool provided as a project deliverable allows for such consideration. Thirdly, conditional assessment showed that existing wetlands are distributed throughout the Tampa Bay Watershed, but are particularly concentrated near urban, suburban, and mining land use-land covers. Finally, the priorities of local stakeholders, which include regulators, policymakers, and local planners, are compatible with the screening tools provided, but incompatible with prescriptive targets for restoration, preservation or mitigation. Achievement of the project goals will occur only through commitments by stakeholders to utilize creativity and flexibility in adopting watershed-level principles to transactional activities.

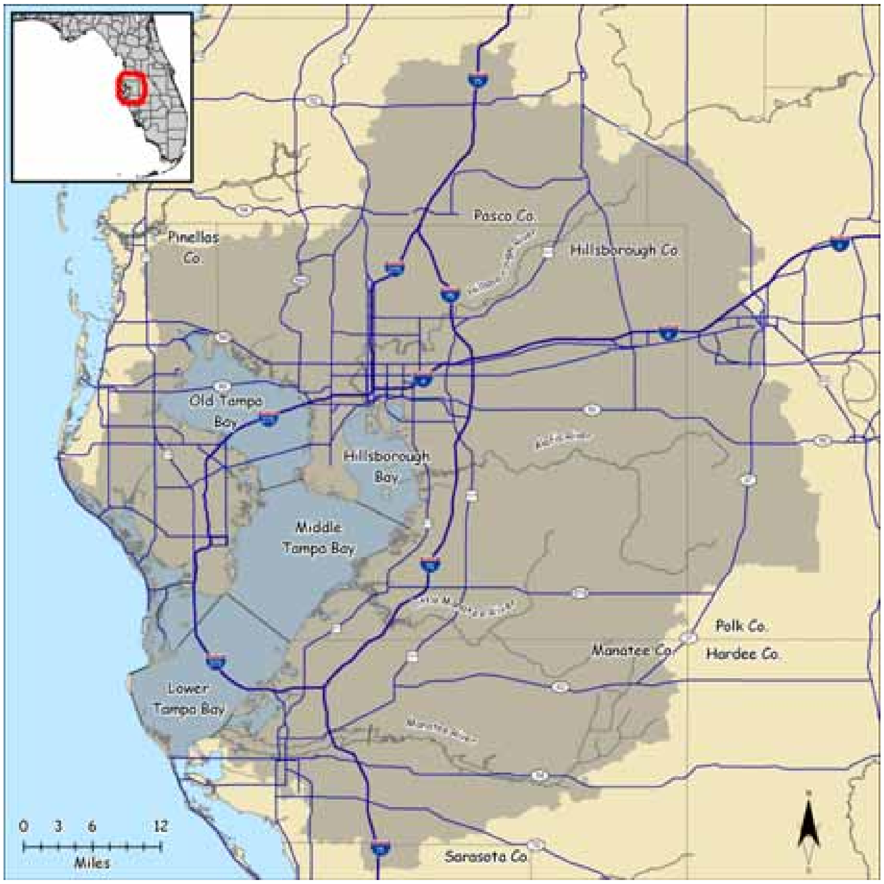
Physiography

The Tampa Bay Watershed contains an extensive and diverse physical landscape, ranging from dense forested wetlands to open, barren lands. Other physiographic factors, such as climate and elevation, can have direct impacts on wetland physiological function and structure. This section examines the geographic and physical attributes of the Tampa Bay Watershed.

Geographic Extent and Hydrophysiography

The Tampa Bay Watershed is the 6,853 km2 terrestrial-estuarine watershed that drains to Tampa Bay on the Gulf of Mexico (Figure 1). It encompasses portions of six counties: Pinellas, Pasco, Hillsborough, Polk, Manatee, and Sarasota. Numerous rivers and artificial drainageways drain the Tampa Bay Watershed, with the Hillsborough River, Alafia River, Little Manatee River, and Manatee River being among the most prominent.

Figure 1. Map of the Tampa Bay Watershed Study Area.



Climate

The climate in the Tampa Bay Watershed is subtropical and humid (Southeast Regional Climate Center data for TAMPA WSCMO ARPT, FLORIDA 088788 for the period of 1933-2010). The mean annual temperature is 22.6 °C, ranging from a minimum monthly mean of 15.9 °C in January to a maximum monthly mean of 28.1 °C in August. The mean annual precipitation is 1203 mm, but intra-annual variability can be large, with annual totals ranging from a minimum of 680 mm in 1956 to a maximum of 1932 mm in 1959. Approximately 60% of the precipitation occurs during a four-month wet season from June-September, primarily during intense, localized thunderstorms, as well as occasional tropical storms and hurricanes. The remaining approximately 40% of the precipitation occurs during an eight-month dry season from October-May, primarily during winter frontal storms.

Geology

The Tampa Bay Watershed is underlain by a thick sequence of carbonate rocks covered by unconsolidated surficial sediments (Miller, 1997). The principal hydrogeologic units are, in descending order, the surficial aquifer, the intermediate confining unit, and the Upper Floridan aquifer (Figure 2).

The top of the surficial aquifer is contiguous with the land surface, and is comprised of complexly interbedded fine and coarse clastic sediments deposited during the Holocene (Sinclair, 1974; Miller, 1997). The thickness of the surficial aquifer varies, ranging from nearly absent in regional and local topographic lows, such as lowland river beds, to many tens of m in thickness in regional topographic highs, such as along the ridges. Water in the surficial aquifer is under unconfined, water-table conditions, and is contiguous with surface water in wetlands and streams.

The intermediate confining unit discontinuously overlies the Upper Floridan aquifer. This semiconfining layer consists primarily of undifferentiated deposits of the Hawthorn Group, a clay-rich sequence deposited during the Miocene, but also includes some post-Hawthorne group siliclastics from re-worked Hawthorne Group deposits and carbonate mud formed as residuum of the limestone in the Tampa Member of the Arcadia Formation (Sinclair, 1974; Knochenmus, 2006). The thickness of the intermediate confining unit varies, ranging from approximately 10 m in thickness in the south-east Tampa Bay Watershed to being absent in the north-west Tampa Bay Watershed (SWFWMD, 1996). Where the intermediate confining unit is present, it perches water in the surficial aquifer and confines water in the Upper Floridan aquifer, though vertical leakance can be high and water can flow up or down between the aquifers, depending upon the local hydraulic gradient (Stewart, 1968; Knochenmus, 2006).

The Upper Floridan aquifer underlies all of Florida and parts of South Carolina, Georgia, Alabama, and Mississippi (Miller, 1997). The Upper Floridan aquifer consists of multiple layers of continuous limestone and dolomite, ranging in age from Eocene to Miocene. Locally, the aquifer includes, in descending order, the Tampa Member of the Arcadia Formation, the Suwannee Limestone, the Ocala Limestone, and the

Avon Park Formation. The Upper Floridan aquifer is semiconfined throughout most of the Tampa Bay Watershed, being confined where the intermediate confining unit is present and unconfined where the intermediate confining unit is absent. Where the intermediate confining unit is absent, the surficial and Upper Floridan aquifers merge from a hydrogeologic standpoint and the Upper Floridan aquifer is said to outcrop at the surface. The Upper Floridan aquifer is an important water source for most residents in the Tampa Bay Watershed.

Land Cover

The total terrestrial area of the Tampa Bay Watershed is 5,908 km^2. The predominant land uses-land covers are urban development and agriculture, though wetlands, upland forests, rangeland, and water all total more than 200 km^2 each (Table 1; Figure 1). Though land uses-land covers are mixed throughout the watershed, urban development is particularly prominent in the lower watershed, while other land uses-land covers, especially agriculture, are particularly prominent in the headwaters.

Table 1. Land use-land cover in the Tampa Bay Watershed as based upon the 1000-Level of the Florida Land Use, Cover and Forms Classification System (Florida Department of Transportation, 1999).

Land Use-Land Cover	Total Area (km^2)	Percent Area (%)
URBAN AND BUILT-UP	2544	43%
AGRICULTURE	1324	22%
WETLANDS	903	15%
UPLAND FORESTS	458	8%
RANGELAND	253	4%
WATER	248	4%
TRANSPORTATION, COMMUNICATION AND UTILITIES	165	3%
BARREN LAND	13	<1%
SUM	**5908**	**100%**

Types of Freshwater Wetlands

In west-central Florida, freshwater wetlands are numerous, often small, and often surface-water isolated, at least during the dry season (Haag and Lee, 2010). This is particularly true in the northern Tampa Bay Watershed, where the surficial aquifer is irregularly pitted with karst depressions, which form due to irregular weathering of the underlying limestone, and are illustrated by localized sinkholes, some of which form small lakes or closed-basin depressional wetlands (Tihansky, 1999) (Figure 2). As is the case in all wetlands, hydrology is the primary control on the structure and function of wetlands in west-central Florida.

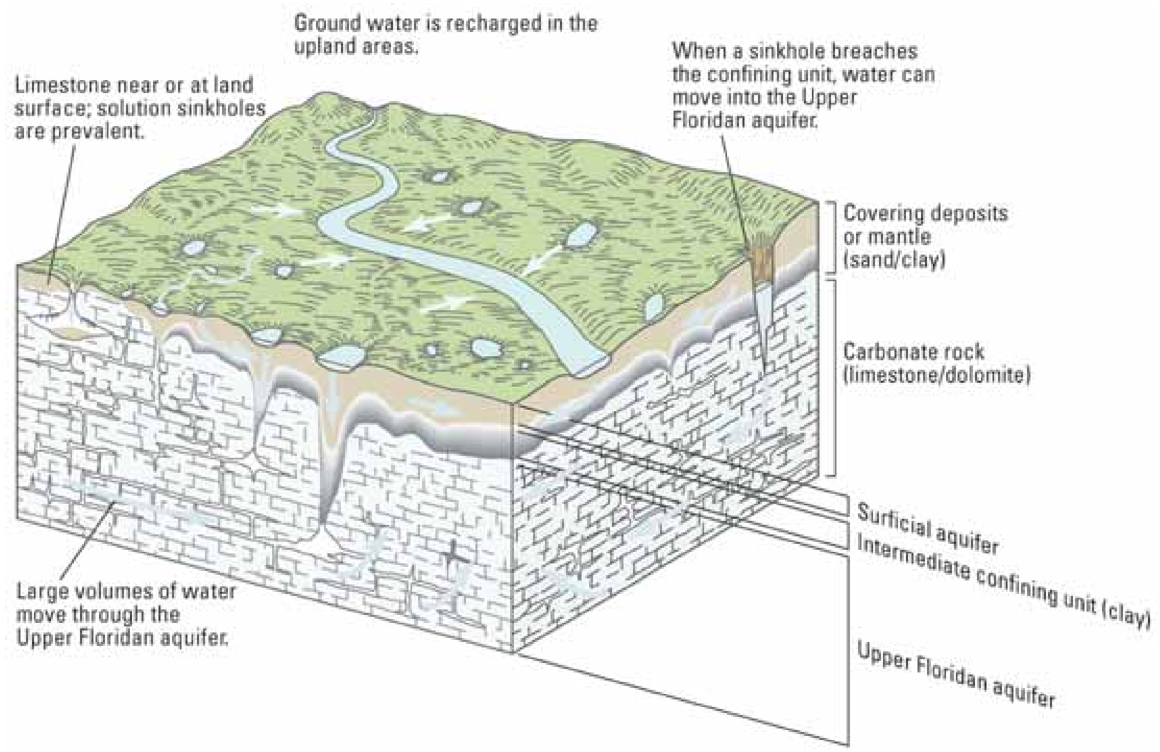


Figure 2. Diagram of Geology. Geologic setting, especially as regards the surface-water and ground-water interactions between wetlands and the surficial and Floridan aquifers. Reprinted with permission from (Haag and Lee, 2010).

Water levels in freshwater wetlands in west-central Florida are controlled by complex interactions between climate, geology, and water use. Where the intermediate confining unit is present and intact, wetland water levels are largely controlled by water levels in the surficial aquifer (Lee et al., 2009; Nilsson et al., In Review), which in turn are largely controlled by seasonal variations in precipitation and evapotranspiration. However, even under these conditions, some wetland water can be lost to groundwater recharge to the Upper Floridan aquifer (Lee et al., 2009). Where the intermediate confining unit is absent or perforated, such as where the Upper Floridan aquifer outcrops in the northern Tampa Bay Watershed, wetland water levels may be largely controlled by hydraulic heads in the Upper Floridan aquifer (Sinclair, 1974; Sinclair, 1977; SWFWMD, 1996), which in turn can be largely controlled by groundwater pumping, at least in close proximity to the wellfields. Therefore, the location of a given wetland relative to the intermediate confining unit is an important characteristic, and can determine whether wetland water levels are largely under local or regional control.

Geologic conditions being equal, water levels in freshwater wetlands in west-central Florida do not vary greatly. Wetland depressions tend to be shallow and surrounding land surfaces are typically relatively level, so water levels do not typically get deep, even during times of intense and long-duration precipitation (Haag et al., 2005; Lee et al., 2009; Nilsson et al., In Review). Furthermore, water levels in the surficial aquifer are typically near the land surface, so water levels do not typically draw down to great depths (Sinclair, 1974). Therefore, the overall possible range of variation in water levels is relatively small and does not always differ greatly between different wetland types (Nilsson et al., In Review).

More precise definitions are often needed to bound different types of wetlands and water bodies for the purposes of inventory, evaluation, and management. Cowardin et al. (1979) provides one such classification system, the Classification of Wetlands and Deepwater Habitats of the United States (Cowardin classification system). The Cowardin classification system is a hierarchical classification system, in which different types of wetlands are classified under one of five primary categories: marine systems, estuarine systems, riverine systems, lacustrine systems, and palustrine systems.

The Cowardin classification system is based upon structural features that can be readily observed from remote-sensing data, which allows the Cowardin classification system to satisfy the primary goal of providing the basis for tracking changes in the geographic extent of the nation's wetlands over time through the US Fish and Wildlife Services' (FWS) National Wetland Inventory. The emphasis on readily observable structural features also causes the Cowardin classification system to aggregate many wetlands and water bodies that are structurally similar but functionally distinct (i.e., wetlands and water bodies that look the same but function differently). This created the need for a separate but equal classification system based upon functional characteristics.

Brinson (1993) provides one such classification system, the hydrogeomorphic approach to wetland classification (HGM classification system). The HGM classification system is based on three characteristics related to how wetlands function: landscape position, water source, and hydrodynamics. The emphasis on functional characteristics allows the HGM classification system to satisfy the primary goal of aggregating wetlands that perform similar functions. The HGM classification system is an approach and not a strict, specifically defined, hierarchical classification system. Following up on Brinson (1993), Smith et al. (1995) suggested that wetlands can be divided into seven primary classes: estuarine, mineral-soil-flat, organic-soil-flat, slope, depressional, riverine, and lacustrine wetlands.

This report and the associated GIS geodatabase very generally follow the terminology proposed by Smith et al. (1995), retaining distinct categories for riverine and lacustrine wetlands but aggregating flat, slope, and depressional wetlands into a single category for simplicity. Estuarine wetlands were omitted, as they were not a focus of this study. The physical properties and characteristic functions of the wetland classes are more specifically described below.

Riverine wetlands occur on floodplains and riparian corridors in association with river channels (Figure 3). Dominant water sources are variable and depend upon specific local hydrologic conditions, and can include any combination of precipitation, channelized surface-water flow down the river channel, overbank and/or ground-water flow from the river channel, or ground-water discharge from the underlying aquifer. Perennial flows in the associated river channels are not requisite. Dominant outflows also are variable and depend upon specific local hydrologic conditions, and can include any combination of evapotranspiration, channelized surface-water flow down the river channel, overland and/or ground-water flow to the river channel, or ground-water recharge to the underlying aquifer. Hydrodynamics are dominated by downgradient, unidirectional flow, though lateral exchanges between the river channel and the riverine wetlands are common during floods. In the headwaters, riverine wetlands often intergrade with flat, depressional, and/or slope wetlands as the bed and bank of the channels disappear.

Figure 3. Headwater riverine wetland in the northern Tampa Bay Watershed.

Lacustrine wetlands occur on the margins of large open water bodies (Figure 4). Dominant water sources are variable, and can include any combination of precipitation, overland or channelized flow, or ground-water discharge. Dominant outflows also are variable, and can include any combination of evapotranspiration, overland or channelized flow, or ground-water recharge. Hydrodynamics are variable, with some depressional wetlands having lateral flow toward or away from the depression, depending upon local hydrologic conditions, and other depressional wetlands having lateral flow through the depression. Regardless, the predominant, readily observable hydrodynamics are vertical surface-water fluctuations, with surface-water stages rising when inflows exceed outflows and surface-water stages falling when outflows exceed inflows.

Figure 4. Lacustrine wetlands fringing a small lake in the eastern Tampa Bay Watershed.

Flat wetlands are located in level to nearly level landscapes, such as the expansive coastal plains located throughout peninsular Florida. Dominant water sources are precipitation. Outflows are vertical by evapotranspiration to the atmosphere and/or ground-water recharge to the water table. Hydrodynamics, to the extent that they occur, are characterized by vertical fluctuations, with water levels rising in response to precipitation and falling in response to evapotranspiration and/or ground-water recharge. The primary characteristic of flat wetlands is poor drainage. Precipitation falls, and cannot infiltrate very deeply due to the presence of a shallow water table and cannot runoff rapidly due to the low gradients and/or low-permeability surficial deposits. Therefore, precipitation accumulates at or near the surface, forming expansive, quiescent, flat wetlands. Extensive flat wetlands can occur by themselves, or can occur in close relation to other classes of wetlands. For example, depressional wetlands can be embedded within flat wetlands, and slope wetlands can form at the fringes of flat wetlands where higher gradients and/or higher-permeability surficial deposits occur.

Slope wetlands occur on gently to steeply sloping landscapes. Dominant water sources are variable, and can include any combination of precipitation, overland flow, shallow ground-water flow, and ground-water discharge to the land surface. Dominant outflows also are variable, and can include any combination of evapotranspiration, overland flow, and ground-water recharge. Channelized flow does not typically occur, though poorly defined swales and sloughs can occur locally. Hydrodynamics are dominated by downgradient, unidirectional flow. Slope wetlands can occur by themselves, but commonly occur in headwater settings, with channelized flows on the edges of slope wetlands forming the headwaters of downgradient riverine systems, as described below.

Depressional wetlands occur in topographic lows with closed-elevation contours (Figure 5). Depressional wetlands may have any combination of surface-water inlets and outlets or may be surface-water isolated. Dominant water sources are variable, and can include any combination of precipitation, overland or channelized flow, or ground-water discharge. Dominant outflows also are variable, and can include any combination of evapotranspiration, overland or channelized flow, or ground-water recharge. Hydrodynamics are variable, with some depressional wetlands having lateral flow toward or away from the depression, depending upon local hydrologic conditions, and other depressional wetlands having lateral flow through the depression. Regardless, the predominant, readily observable hydrodynamics are vertical surface-water fluctuations, with surface-water stages rising when inflows exceed outflows and surface-water stages falling when outflows exceed inflows. Depressional wetlands can occur by themselves, or can occur in close relation to other classes of wetlands. For example, depressional wetlands can be embedded within flat wetlands.

Figure 5. Depressional wetland in the northern Tampa Bay Watershed.

Methods

The first project objective included GIS analysis and mapping of historical changes to freshwater wetland habitats from 1950 to current conditions. This section sets forth the mapping methods applied to accomplish this objective.

Data Acquisition

Data acquisition included obtaining GIS raster and vector layers from multiple agencies and data providers. The contributors and data obtained included historical National Wetlands Inventory (NWI) data and drainage basin delineations from the US Geological Survey (USGS) and current (2007) and historical (1950) land use data from the Southwest Florida Water Management District (SWFWMD). Historic aerial photography, a key element in determining and verifying preexisting wetlands were provided by the University of Florida, the Florida Fish and Wildlife Research Institute and from multiple counties within the Tampa Bay estuary. Additional supporting data was also received from the Florida Geographic Data Library (FGDL), SWFWMD (e.g., shoreline and county boundaries), and TBEP (e.g., program boundaries).

The data acquisition phase also included preparing the data validation and change analysis plan for review and concurrence by the TBEP advisory committee (including crosswalk generation), generating wetland/habitat change maps and data to support later tasks and presentation materials and drafting a plan to prioritize efforts allocated to reviews of aerials, oblique imagery and field visits.

Mapping

Creation of historical wetland inventory

The historic baseline determined for this project was the early 1950s. This time period was chosen because it not only serves as a desirable snapshot of the natural wetlands condition for the area but because it also has a large amount of existing spatial datasets that depict these areas. This time period has also been used by TBEP and partners as the benchmark for estuarine habitats. Although Stetler et al. (2005) used historic soil survey data to provide estimates of wetland loss in Hillsborough County since the early 1900's, these estimates are unavailable for other areas of the watershed. While some wetlands were already lost (e.g., Pinellas County and Tampa) this period precedes the majority of development within the watershed (Cicchetti and Greening, 2011).

Two of the datasets which were used to recreate the representation of wetlands during this era are the 1950s National Wetlands Inventory habitat data (USGS, 1982) and the 1950 SWFWMD land use/land cover data (LULC) (SWFWMD, 2002a). These two existing datasets, combined, cover approximately 50 percent of the estuary (**Figure 6**) so a major portion of the GIS work involved in this project was to recreate the historic wetlands coverage for the missing portions of the estuary.

The creation of the historic wetlands inventory for these gaps was carried out in two phases:

1. Obtain historical aerial imagery from the 1950s for the missing areas, with an emphasis on finding imagery that has already been georeferenced.
2. Delineate wetland features using photointerpretation methods.

To conserve time and money, imagery that was already georeferenced, or defined in physical space, was preferred over imagery lacking a spatial reference. **Figure 6** shows the areas for which georeferenced imagery from the early 1950s was able to be obtained. Georeferenced imagery was available for approximately 50 percent of the area which needed to be recreated for the historical wetlands coverage.

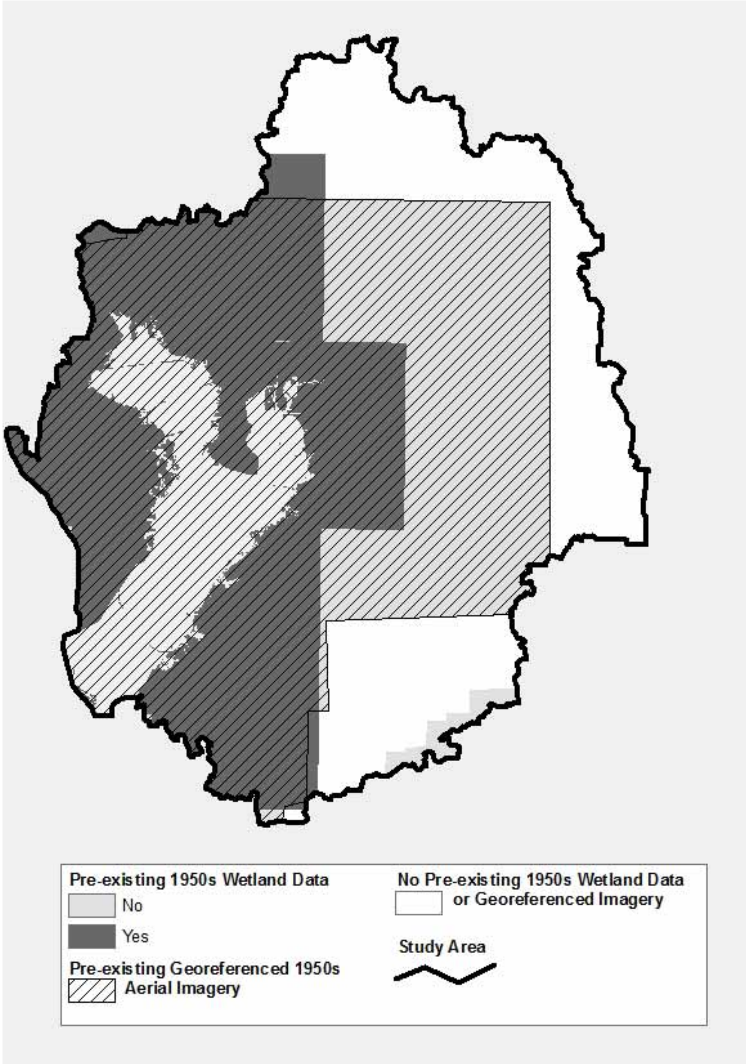


Figure 6. Availability of historical wetlands data and georeferenced historic aerial imagery

For the remaining areas for which georeferenced imagery could not be obtained, unreferenced images were requested from the University of Florida Map and Digital Imagery Library (http://www.uflib.ufl.edu/maps/Aerials/MAPNEWAERIAL.HTML). The methods used for georeferencing the historic aerial imagery followed the methodologies used by members of the project team for a project in which they georeferenced historic 1938 imagery for Hillsborough County (Hammond, 2005; Brooks et al., 2008).

The ArcMap georeferencing toolset was used to help spatially define these raw historic images. Supplemental raster datasets that were used for reference to help determine real-world feature coordinates include SWFWMD 2007 one-foot resolution true-color aerial imagery (SWFWMD, 2007a) and 1970 one-meter, monochromatic digital orthophotos (SWFWMD, 2003). Ancillary vector datasets, including roads and the National Hydrography Dataset, were also used for spatial reference when necessary. Each image was imported into ArcMap and registered against the other raster datasets. A minimum of six control points were created for each image, one distributed among each of the four corners, and the others being more centrally located. Given the time period for which the imagery represents, and the rural nature of the area at the time, locating well-defined control points in some of the imagery was quite difficult. In fact, in some of the images, the wetlands themselves were the only notable features (see Figure 7). Despite this limitation, all attempts were made to accurately reference the imagery and keep the accuracy within commonly accepted thresholds. In this case, the threshold was a Root Mean Square error of five meters or less, a value that is consistent with that used for similar historic georeferencing projects (Brooks et al., 2008).

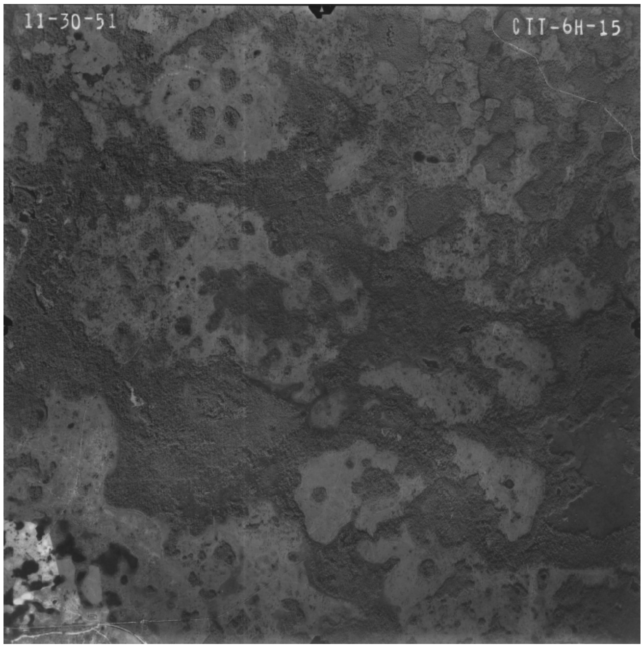


Figure 7. Ungeoreferenced historic imagery lacking well-defined control point features.

After the control points were added, a polynomial transformation method was applied to the raster to warp the image and determine the correct map coordinate for each raster cell. Given the relatively low variance in topography of the area, and the lack of abundant control features present on the historic imagery (which would be needed for higher order transformations), it was determined that a first order, or affine, transformation would provide a level of accuracy sufficient enough for the scope of this project. This transformation method allows raster datasets to be shifted, scaled and rotated, but not bent or curved like higher order transformations (ESRI, 2009). Once the quality control measures were met and USF staff was satisfied with the results of the georeferencing, the results for each raster were updated along with the image in a Mr. Sid (.sdw) world file.

Once completed, this set of georeferenced imagery was then used to photo-interpret historic wetland boundaries. The methodology selected by USF for this process was the same one used by SWFWMD for the creation of the historic 1950 land use/land cover being used in this study. In this process, land use/land cover delineations from a recent SWFWMD land use/land cover dataset were modified to conform to the boundaries recorded on historical imagery. Advantages of using this methodology include guaranteed edge-matching for unchanged portions of wetland polygons and the time savings generated by not having to digitize an entire wetland boundary, as adjustments were only made when necessary to replicate its 1950s extent. Another advantage of using this method is that wetland classifications already existed within the FLUCCS values for this data. While it was not automatically assumed that classifications remained constant over time, these classifications did provide a logical basis from which the true type was derived.

The SWFMWD 1990 land use/land cover (SWFWMD, 2002b) was the source layer for this process. A tabular query was performed on the layer to select and extract all features with a first-level FLUCCS value of either 5 or 6. These features were exported into a new personal geodatabase. This new feature class was then overlaid onto the 1950s historical imagery in ESRI's ArcMap. USF staff worked systematically through each image making changes to the existing linework and attributes when necessary, as defined by the feature boundary on the aerial photography. New features were created where appropriate to represent wetlands that have been completely exhausted over time (i.e., not present in the 1990 data). These were digitized at a scale of 1:5,000, using automated vertice generation every 20 meters. After a wetland feature was created, the wetland structure and wetland function were determined (if possible) and recorded in the appropriate attribute columns.

Quality control and review of the digitized wetlands were conducted weekly by GIS staff at The Balmoral Group. During each review, a random sample of newly digitized features were selected and reviewed to determine feature accuracy. An average accuracy rate of 90% was achieved for the entire digitizing effort. During this review process it was discovered that a handful of the features digitized were actually open water features and not true wetlands. A systematic method to locate and delete these features was developed in which centroids were created from the lake features of the 2007 LULC datasets. These points were spatially joined to any features they intersected within the historic wetlands layer. The area for the lake and the corresponding wetland feature were compared, and those features where the difference of the two was within +/- 50% of one another were targeted for manual inspection. All features meeting the above criteria were exported out and reviewed by Environmental Management staff of the Hillsborough County Environmental Protection Commission (EPC). Features interpreted to be open water by EPC were subsequently removed from the dataset.

Upon the completion of the delineation of historic wetland boundaries, these features were then appended to the dataset derived from the existing features contained within the 1950s NWI dataset and the 1950 SWFWMD land use/land cover wetlands. A specific attribute column was maintained to record from which process each feature was captured.

Creation of current wetland inventory

The most recent SWFWMD land use/land cover (LULC) data was used to create the current wetland inventory (SWFWMD, 2007b). The LULC data was first clipped to the extent of the Tampa Bay watershed. Next, queries were performed against the tabular data to select out all features where the first level FLUCCS code was either 5 (Water) or 6 (Wetlands). These features were then exported out to a new feature class and used as the most accurate representation of current day wetland delineations.

It was determined that polygon features from the original 2007 LULC that were recorded as "extractive" lands should also be reviewed for inclusion in this final wetlands layer. Mosaic, Inc. provided shapefiles representing existing and planned wetlands created in the post-mining landscape within southeast Hillsborough county and southwest Polk county. EPC staff familiar with the mining and reclamation process as well as many of the lands in question reviewed the data provided by Mosaic to ascertain which post-reclamation wetlands were created and functioning as wetlands as reflected in the 2007 aerial coverage provided by SWFWMD. These wetlands were then categorized as forested or nonforested, and as riverine, lacustrine (i.e., lakes 20 acres or greater) or as 'other'. Categorizations were based on the condition of the wetland as of 2007, but where information was available regarding the final design (i.e., target community), this information was included as well.

EPC staff then reviewed the extractive lands to ascertain if there were any additional wetlands that were not impacted by mining activity and should be included in the study. These wetlands were identified by comparison of historic and current aerial imagery, review of the USDA Soil Survey (via GIS layer), and by personal knowledge of some sites by staff. The boundaries were digitized at a scale sufficient to clearly identify the boundary (but no greater than 1:5000) and the polygons categorized as above. These features were then appended to the final 2007 wetlands dataset by USF Staff.

Classification

A step crucial to the success of this project was the determination of the distinct wetland types from both time periods and developing a classification system based on broad wetland categories that were congruous to both, and suitable for future change analysis. This was done by first assigning hydrologic association (i.e., lacustrine, riverine, other) based on National Hydrography Dataset flowpaths and waterbodies (USGS, 2008), and then by crosswalking, or generalizing and categorizing existing data classifications to aggregate categories of structure (i.e., forested and non-forested) to ensure equivalency of elements. The resulting six freshwater wetland categories are outlined in Table 2.

Table 2. Six wetland classification types.

	Structure	**Hydrologic Association**
1	Forested	Riverine
2	Forested	Lacustrine
3	Forested	Other
4	Non-Forested	Riverine
5	Non-Forested	Lacustrine
6	Non-Forested	Other

The USGS National Hydrography Dataset (USGS, 2008) was used to determine wetland hydrologic association. Flowline features from the National Hydrography Database (NHD) were buffered to a distance of 100 meters (to correspond to U.S. Army Corps of Engineers standards. Wetlands within 100 meters of flowlines were classified as riverine. Because of the incomplete status of the NHD dataset, an iterative process was then used to classify remaining wetlands as riverine if they fell within 100 meters of the previously classified riverine wetlands. Remaining unclassified wetlands were then classified as lacustrine if they fell within or touched the boundaries of a lake/pond (NHD FTYPE=390) from the NHD waterbody feature data layer that was greater than 20 acres in size. Once again, an iterative process was used to then assign unclassified wetlands as lacustrine if they fell within 30 meters of the previously classified lacustrine wetlands. Finally, all unclassified wetlands were given the hydrologic association classification of other.

Assignment of hydrologic association for 1950s wetlands used a modified version of the NHD dataset that included an adjustment related to the flowpaths associated with ditching efforts. Current NHD data, as the only data source available within the scope and budget, does not perfectly represent 1950s conditions. Ditches and canals that have been created in the watershed since 1950 were included in the NHD data, but the use of these flowpaths would result in an inaccurate classification of 1950s wetlands. To address this, the NHD ditch/canal flowlines ("FType" = 336) were visually inspected against 1950s aerials. Viewing at a scale of 1:24000 in a grid cell of 5km x 5km, the operator determined whether or not to include/exclude the ditches within that grid for classification of 1950 wetland riverine status. Ditches were included if 50% or more of the ditches could be seen on the 1950s aerial. This resulted in a new NHD layer that was used to more accurately assign wetland hydrologic association to the 1950s wetlands.

Following the assignment of hydrologic association, detailed crosswalks were created to convert the historic National Wetlands Inventory (NWI) wetland classifications and the historic and current FLUCCS codes to the appropriate forest structure assignment: forested or non-forested. Table 3 provides a list of all FLUCCS and NWI codes and the structural classification to which wetlands were assigned.

Table 3. Crosswalk between FLUCCS, NWI and structural classification of forested/non-forested.

Structural Classification	FLUCCS Codes	NWI Codes
Forested	6100, 6110, 6130, 6150, 6160, 6200, 6210, 6230, 6240, 6300	P2FO, PF03, PFO1, PFO2, PFO3, PFO6, PSS1, PSS3, PSS5, PSS6
Non-Forested	6400, 6410, 6430, 6440, 6450, 6500	L1AB, L2EM, PAB2, PAB4, PAB5, PAB6, PAB7, PELC, PEM1, PEM3, PEM5, PEM6, PEMF, PEMS, PFLA, PFLC, PFLF, PLFL, R2AB

Wetland classification was conducted for 1950 data, and QC of wetland classification was conducted for both 1950 and 2007 data. Adjustments to classification were made for several items based on review of classification. First, tidal wetlands were removed from both datasets, as defined in Setting Priorities for Tampa Bay Habitat Protection and Restoration: Restoring the Balance (Lewis Environmental Services, Inc., 1996) and reiterated in the Tampa Bay Estuary Program Habitat Master Plan Update (PBS&J, 2010). For 1950s data, tidal wetlands were removed from the dataset as follows: as defined by the NWI as "E=Estuarine" and "M=Marine" and those recorded in the LULC data with FLUCCS 6120 (mangrove), 6420 (saltwater marsh) and 6600 (salt barrens). For the 2007 wetland dataset, polygons were removed based on these same three FLUCCS values.

Change Analysis

The wetland change analysis was used to describe the structural changes to wetland boundaries and transformations in classification types between 1950s and 2007 within each drainage sub-basin in the Tampa Bay Watershed. This analysis was conducted as two distinct procedures: analysis of change to individual wetland boundaries, and aggregate summary of changes within the watershed.

Change analysis of the individual wetland polygons

This method involved using geospatial processes to compare "from-to" changes between 1950s wetlands and 2007 wetlands. For example, wet prairies may have changed to hardwood forested wetlands; or wetlands may have changed to non-wetlands. This process was carried out by performing a spatial union between the final 1950 historical wetland inventory and the 2007 current wetland inventory. The resulting change dataset shows where changes to individual wetland polygons occurred. Increases and decreases in area of wetland polygons were then summarized for each drainage basin in the watershed.

Aggregate summary of changes

Due to the lower spatial accuracy and precision of the historic data, a direct one-to-one comparison of polygons may not meet accuracy requirements in all areas of the watershed. As a second dataset, we compared total area of each wetland category within each drainage basin and then compared the aggregate change. A determination was made to utilize the 32 drainage basins utilized in other TBEP projects for analysis.

At the scale of a drainage basin, the spatial inaccuracies and differences in precision were less problematic. The aggregate change analysis was used to validate the change analysis of individual wetlands and provide the minimum data required by the project to determine the amount of change within each drainage basin.

The change analysis determined that processing of digitized files included polygons below the minimum mapping unit of 0.5 acres both in 1950 and 2007 datasets. This skewed the minimum, maximum and average wetland size in each wetland classification category. To ensure consistency in all layers, wetland features with a total area less than 0.5 acres were selected out from both datasets and subsequently deleted.

Change Analysis was run with the final wetlands maps and Wetlands Gains/Losses were calculated at the watershed and drainage basin level. Changes were classified as Hydrological, Structural, or both, as well as to size in acreage by patch. Maps were generated reflecting the change analysis results.

Conditional Assessment

Another objective of the project was to assess existing conditions of remaining freshwater wetlands, including habitat quality and sustainability indicators. This was intended to be a conditional assessment, i.e., an assessment of the overall condition, or integrity, of the wetlands; this was not intended to be a functional assessment, i.e., an assessment of the functional capacity of the wetlands. The two are related in that wetlands in good condition tend to have high functional capacity. However, the two differ in important ways. In general, a conditional assessment only assesses the overall condition of a wetland, while a functional assessment first specifies the functions a particular type of wetland performs, then assesses the relative degree to which those functions are performed by that wetland (Fennessy et al., 2004; Fennessy et al., 2007). A conditional assessment was selected for this analysis for two reasons: (1) a conditional assessment score can best be used to rapidly screen between wetlands that can best benefit from preservation (e.g., those in good condition) and those that best can benefit from restoration (e.g., those in poor condition) and (2) a conditional assessment most easily serves the needs of the regulatory community charged with implementing federal, state, and local rules and regulations (Fennessey et al., 2004; Fennessy et al., 2007).

Several approaches were considered for the conditional assessment. The US Environmental Protection Agency (EPA) obligates state, local, and tribal resource and regulatory agencies use assessment methods to report on the condition of waters of the US, including wetlands, under their jurisdiction (EPA, 2002). Therefore, multiple approaches exist, many of which have been thoroughly reviewed (e.g., Fennessy et al., 2004; Fennessy et al., 2007). The bulk of the assessment tools developed to date are local in scale, being driven by the need to provide information for use in case-by-case, decision-making efforts. However, more recent efforts have focused on the development of assessment tools applicable at coarser scales, being driven in part by the desire to provide information for use in regional or national reporting and planning efforts (Brooks et al., 2004; Brown and Vivas, 2005; Reiss et al., 2010; Weller et al., 2007; Whigham et al., 2007; EPA, 2010).

Of the recent efforts focused on assessments at these coarser scales, the Landscape Development Index (LDI) has been calibrated and validated in Florida (Brown and Vivas, 2005; Reiss et al., 2010). The LDI is used as the conditional assessment tool for the purposes of this report. The LDI is based upon the idea that the condition of a landscape unit—a wetland, for example—is a function of the condition of the area immediately contributing to that landscape unit—a watershed, for example. The condition of the area immediately contributing to that landscape unit is taken as a function of the land use-land cover, specifically the amount of non-renewable energy required to create and sustain a given land use-land cover, with lower amounts of non-renewable energy necessary to create and sustain natural and range land uses-land covers and higher amounts of non-renewable energy necessary to create and sustain urban and industrial land uses-land covers. Therefore, low LDI values correspond to low-intensity land uses (e.g., freshwater marsh), while high LDI values correspond to high-intensity land uses (e.g., high-density residential).

Input data are land use-land cover data which, in this case, were readily available FLUCCS data. All FLUCCS polygons were assigned a non-renewable energy index value using a crosswalk developed from Reiss et al. (2010), and then rasterized to a 10 m X 10 m grid. Appendix A provides the full FLUCCS to LDI crosswalk used in the assessment. The LDI was then calculated two different ways: on a grid-cell basis for illustrative purposes and on a wetland basis for validation purposes. For illustrative purposes, the LDI was calculated for each grid cell by calculating the average LDI score for the 100 m buffer surrounding the grid cell, and the raster was then clipped to the wetland boundaries to illustrate condition for each wetland on a grid cell basis. For validation purposes, the LDI was calculated for each wetland by calculating the average LDI score for the 100 m buffer surrounding the wetland. For rivers, the wetland was defined as the 200 m reach upstream of any given point.

The LDI has been validated and shown to correlate with numerous conditional assessment and water quality metrics (Brown and Vivas, 2005; Reiss and Brown, 2007; Reiss et al. 2010). For this project, further validation was performed by comparing scores from the LDI and the Uniform Mitigation Assessment Method (UMAM) at 37 locations throughout the Tampa Bay Watershed, with UMAM scoring performed by EPC staff scientists. UMAM was selected as the basis for validation because Section 373.414(18), Florida Statutes, directs state agencies, in cooperation with federal, tribal, and local agencies, to use a uniform, state-wide method to determine the amount of mitigation required for regulatory permits. UMAM was developed in response to this statute (Chapter 62-345, F.A.C.). The quantitative portion of the UMAM assessment involves scoring the wetland for three indicators: location and landscape support (LL), water environment (WE), and community structure (CS). The final score for the wetland is then calculated as the sum of the scores for each indicator divided by 30, which yields a number between 0.0-1.0, with a 0.0 corresponding to a wetland in poor condition and a 1.0 corresponding to a wetland in good condition. The validation showed that the LDI was strongly correlated with the UMAM, especially with the LL and final scores (Figure 8 and Figure 9).

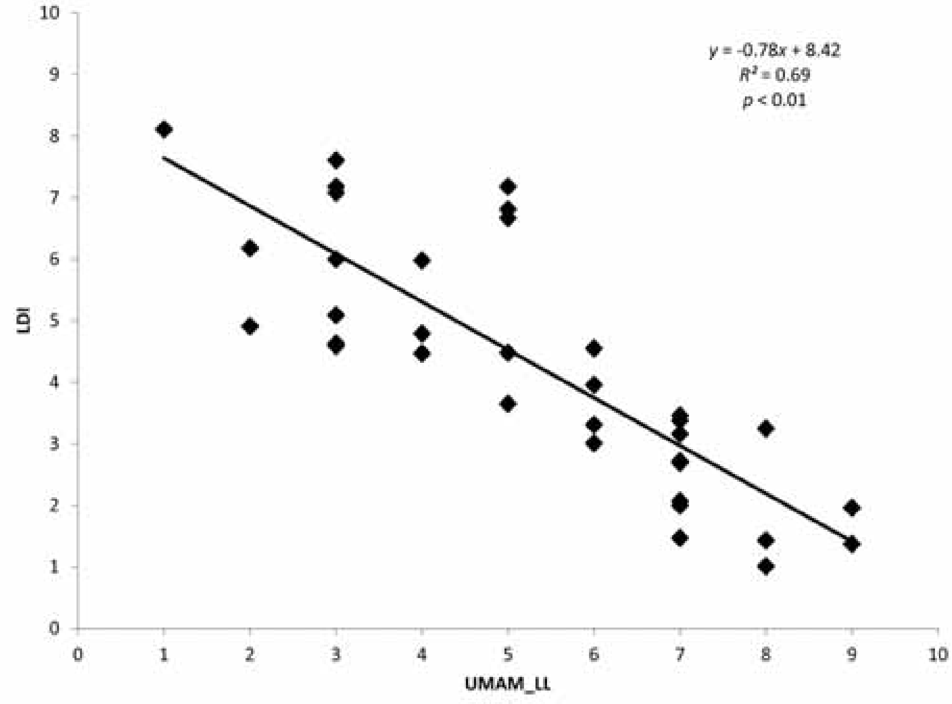


Figure 8. Regression of the LDI score v the UMAM landscape support score.

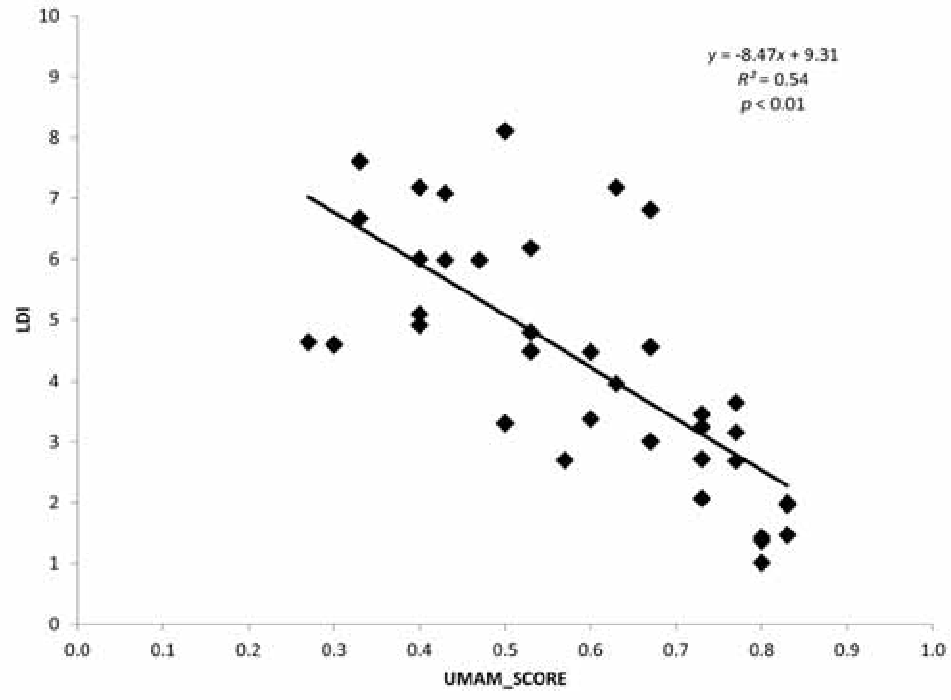


Figure 9. Regression of the LDI score v the UMAM final score.

Economic Analysis

The economic team worked closely with the GIS and wetland hydrology team to project future impacts to freshwater wetlands based on sound economic principles. For example, notwithstanding the need for habitat quality or connectivity, wetlands in areas with highest future land values are most likely to be lost, while mitigation banks are most likely to be located on land with the lowest land values (Milon, 2009). Research has found that, despite the varying functions or levels of ecosystem services provided by different mitigation banks in an area, the sole determinant of value tends to be underlying land value and its alternative (e.g., commercial/developed) uses (Milon, 2009). Investors in mitigation banks, therefore, have a market-based incentive to locate their wetland banking efforts on the “cheapest” land, regardless of whether it has high quality habitat or the potential for a highly functional wetland system. This is valuable information, since the issues of incentives and financial mechanisms to achieve watershed-specific performance will be driven by economics, not ecology. As a result, analysis of expected impacts, and of opportunities to influence those impacts, can begin with relatively simple fundamentals: expected future land use conditions.

Future economic development is uncertain, just as future wetland condition is uncertain. However, the intentions of municipal planning agencies are known and reflected in the Comprehensive Plans as changes to land uses. In Florida, each County files a Comprehensive Plan to outline its intended growth management plans, as well as how schools, roadways and infrastructure will be managed to support planned development. GIS files of the Comprehensive Plans (hereafter, “Comp Plans”) were used to obtain future land use maps for each County and municipality in the study area. Land use types were slightly different for each local government, and were converted to like categories for comparison across the watershed, based as closely as possible to FLUCCS coding for consistency.

Comp plans change over time, and in the economic downturn experienced during the study period, dramatic changes in expectations of future development were occurring. As such, two scenarios were envisioned to facilitate discussion of prioritization processes: (1) a slow recovery, high gas/oil price scenario, and (2) a rapid recovery, low gas/oil price scenario. In the former, maps of monthly commuting costs were overlaid with current (existing) land use maps to identify areas where development and redevelopment were likely to occur with the most urgency; recognizing that commuting costs were likely to shift development closer to employment centers. In the latter, currently undeveloped areas with medium to high density future development were identified as prime candidates for conversion to residential development. In both cases, areas with current land use more than two levels of density below future land use were identified as priority areas for vulnerability to economic pressure for land use change. By overlaying these identified areas with the conditional assessment developed during the Mapping and Classification steps, it is possible to model various restoration, mitigation and preservation scenarios.

The wetland change analysis, conditional assessment and proximity to bay are all factors that could be used in setting priorities. The economic element enlightens the urgency in some cases. For example, a small area of forested riverine wetland may be a tiny portion of a drainage basin’s overall wetland composition, but represent the vast majority of that type of wetland within the basin, and be situated directly in the path of land highly vulnerable to land use change under either scenario. If this type of wetland previously comprised a majority of the basin’s wetland composition, important baseline requirements for restoring the hydrologic balance in the basin may hinge on the particular patch. Having this kind of information available to environmental planners as they assess mitigation requests can help, over time, to achieve the watershed goals. Without this information, planners are missing vital data.

Preliminary economic analysis approaches were demonstrated and discussed with the Technical Advisory Committee and with local planners, policymakers and environmental staff. Specific change analysis results for a representative drainage basin were provided to show the implications for restoration, vs. mitigation or preservation. Identification of the criteria most important to the stakeholders was discussed. The following parameters were suggested:

- Linkages to other public lands
- Linkages to water bodies
- Linkages to areas providing a high level of environmental services (based on EPA data)
- Linkage with watershed plans
- Potentially non-restorable due to restoration impediments, e.g., land use, soils

A goal of the planning workshops was preliminary discussion of target-setting processes. Individual land use decisions accumulate over time, and each land use change transaction can contribute to the overall objective of restoring habitat ratios. Long-term, targets are most likely to be achieved if documented processes allow local planners and environmental staff to incorporate project objectives into their transactional work on a daily basis. Discussions focused on how the change analysis information might be used to assess historical wetland composition, and how this might translate into local targets at the drainage basin level, and at political jurisdictional levels.

Existing policies for local governments were found to be largely compatible with the general conceptual plan of achieving targets. Policymakers felt targets could be achieved through documentation within Comprehensive Plan updates, or through reference to this TBEP Final report as a watershed plan. At the same time, there were varied reactions to the target-setting process discussions. In some areas, policymakers felt that no wetland loss was acceptable, even if a small, poorly functioning wetland patch was the only remaining wetland in an area. In other areas, policymakers felt that drainage-basin level targets created unfair competitive disadvantages for less developed municipalities. In these cases, targets below the watershed level were considered undesirable for economic development reasons.

Screening Tools

Screening criteria maps and data layers were developed to assist with the selection of wetlands for consideration as restoration targets. The screening criteria were purposefully designed to be flexible since the selection of individual sites is the responsibility of appropriate governmental agencies. Screening metrics were developed and maintained as separate map layers in order to allow an individual agency to choose and rank only those criteria that meet institutional mandates. The relative importance of each criteria is likely a temporal moving target that must be adjusted periodically to account for urban expansion patterns and availability of appropriate wetlands that can be managed to achieve the maximum level of watershed services and functions.

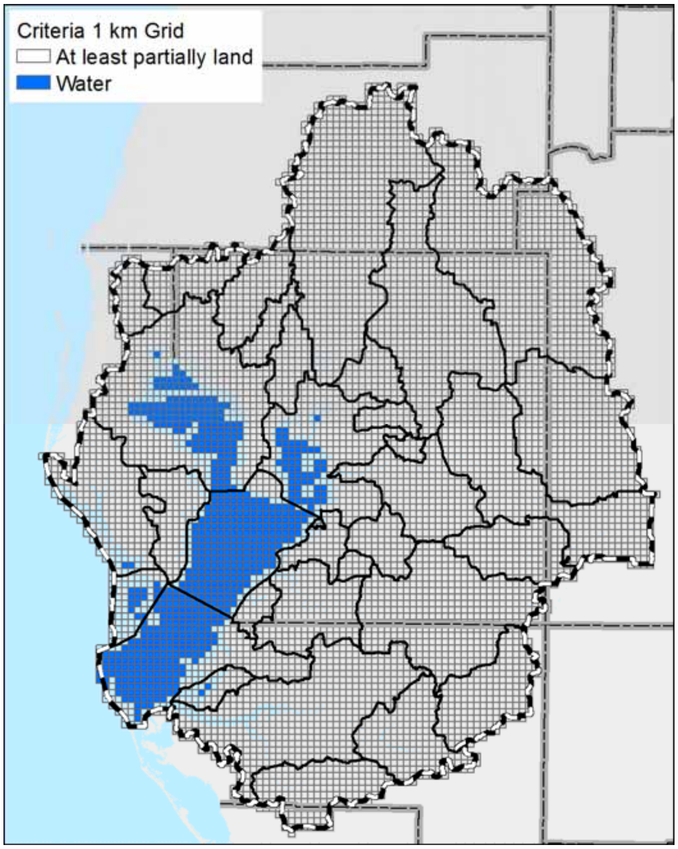


Figure 10. Map showing 1 km Screening Grid.

The screening tool was calculated using a 1 km grid for the Tampa Bay Watershed (Figure 10). Each grid cell was given a “priority” ranking for each of the criteria stated below. The meaning of the priority value generally remain the same for each criteria: one indicates the “best” condition and higher values indicate progressively “poorer” conditions. The ArcGIS 10 “Fishnet” tool was used to create a 1 km polygon grid for the extent of the Tampa Bay Watershed (referred to below as “screening grid”). All screening criteria were calculated separately and added as individual value fields to the screening grid. Grid cells located entirely within Tampa Bay, as defined by the SWFWMD map layer of detailed coastlines (SWFWMD County Boundaries), were labeled as water and assigned null values for each screening criteria.

The following sections describe each of the screening criteria. The descriptions briefly describe the reason why the criteria are recommended, the methods used to develop each criteria as a screening grid, and the meaning of the rankings defined within each criteria. Although most methods are briefly described, the Wetland Condition section contains a detailed step by step process description and is meant to illustrate the detailed steps used to create all criteria maps.

Wetland Loss

Special attention should be paid, not only to those sites whose restoration could have the greatest impact to reverse overall wetland loss within the watershed, but also to areas that have undergone the greatest loss of wetlands historically. For example, future development scenarios could be considered in order to predict where replacement of lost wetlands would have the greatest positive benefit into the future for watershed management.

The 1km screening grid cells were categorized according to the relative extent of area-weighted wetland loss on a scale of 1-5. The 1950-2007 Wetland Change map layer was used to define wetland loss. A value of 1 (i.e., "best") was assigned to all grid cells where there has been no net change in wetlands or where there has been a gain in wetlands. Grid cells where wetlands were not found in both 1950 and 2007 were assigned a null value. All grid cells where wetland change was negative were ranked on a scale of 2-5 according to their quantile distribution of all grid cell values within the watershed. Grid cells with the least wetland loss (i.e., lowest quantile) were given a value of 2 to indicate that these areas were worse than areas of no change, but better than areas of greater change.

Wetland Loss by Type

It is sometimes important to consider where the loss of specific types of wetlands had occurred. Whereas the criteria for total wetland loss would conceal areas where wetlands had undergone change in classification type (e.g., from a forested to a non-forested wetland), wetland loss by type would show these areas. Following the same methods described in the preceding section, wetland loss was also calculated separately for each of the six wetland classification types.

Area-weighted wetland loss on a scale of 1-5 was calculated for each of the six types of wetlands in the 1950-2007 Wetland Change map layer, based on the change in area of the 1950 wetlands. The example of forested riverine wetlands will be used here to illustrate the method. Consider wetlands listed as forested riverine wetlands in 1950. A value of 1 was assigned to all grid cells where there was no loss in forested riverine wetlands or where there was a gain in forested riverine wetlands. Grid cells where forested riverine wetlands were not found in both 1950 and 2007 were assigned a null value. Grid cells where forested riverine wetland change was negative (i.e., loss) were ranked on a scale of 2-5 according to their quantile distribution of all grid cell values within the watershed. The same process was repeated for each of the six wetland types. It is important to note that a change from one classification type (e.g., forested riverine) to another classification (e.g., non-forested riverine), such as what would occur as a result of deforestation, would be listed as a loss of the individual wetland for that classification type and result in a worse criteria score.

Wetland Area

The distribution of remaining wetland area is an important consideration by itself and in conjunction with other screening criteria (e.g., combined with wetland condition). The proportion of each 1 km grid cell covered by 2007 wetlands is provided as the wetland area criteria.

In order to determine the total area of wetlands within each grid cell, the 1 km grid cell GIS layer first was used to divide (i.e., ArcGIS 10 Identify tool) wetland polygons from the 2007 Wetlands data layer. The identify tool split the wetland polygons along grid cell boundaries, and then all wetland polygons within a single grid cell were labeled with the unique identifier of that cell. The resulting data table was used to calculate total surface area (in km^2) of all wetland within each grid cell, and then divided by 1 km^2 to determine the proportion of each grid cell occupied by wetlands of any type. A value of 1-5 is assigned to each grid cell based on the quartile distribution of wetland area in all grids. Grids in the upper 20% of wetland area (i.e., the "best") are assigned a value of 1, while grids with the least, lowest 20% of wetland area are assigned a value of 5.

Wetland Condition

While conservation of wetland structure should be a goal, maximization of wetland functions and services should be the ultimate goal of any management or restoration effort. Elevation of function and process in the decision process recognizes the reality of wetlands within urbanizing landscapes, namely that multiple wetland types (structures) can perform the same vital functions and processes considered critical for landscape and downstream management.

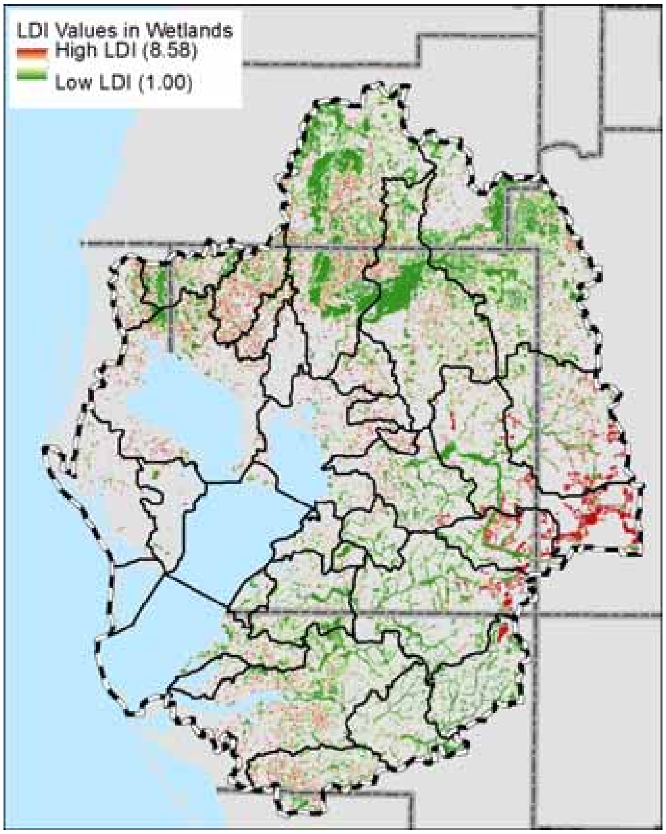


Figure 11. Map of LDI values within wetlands. Higher LDI values imply more impacted wetlands.

Conditional assessment, using the Landscape Development Intensity index (LDI) was used as a proxy for wetland function; low LDI indicates a minimally impacted wetland, while high LDI indicates a highly impacted wetland. Refer to the Condition Assessment methods section for a full description of all wetland condition methods. Using the ArcGIS 10 raster clipping tool, boundaries of existing 2007 wetlands were used to extract LDI values in the 10 meter raster grid that were located within wetlands. Figure 11 shows a map of LDI values, generated from the conditional assessment phase of the project. Note the difficulty in interpreting the map for the purpose of prioritization at the watershed scale. Our approach to developing a watershed scale screening criteria was to generalize the LDI values at the scale of the 1 km screening grid.

Several steps were necessary to convert LDI information at the wetland scale into screening criteria at the watershed scale. The first step in this process was to calculate the mean LDI values within each of the 1 km screen grid cells. Using the ArcGIS 10 Spatial Analyst Statistics Table tool, mean LDI values within wetlands were then calculated for each 1km grid cell. The screen grid (Figure 10) was used to define the zones (i.e., one zone was a grid cell) and the Wetland Condition LDI map layer was used as the input to calculate mean LDI value per zone.

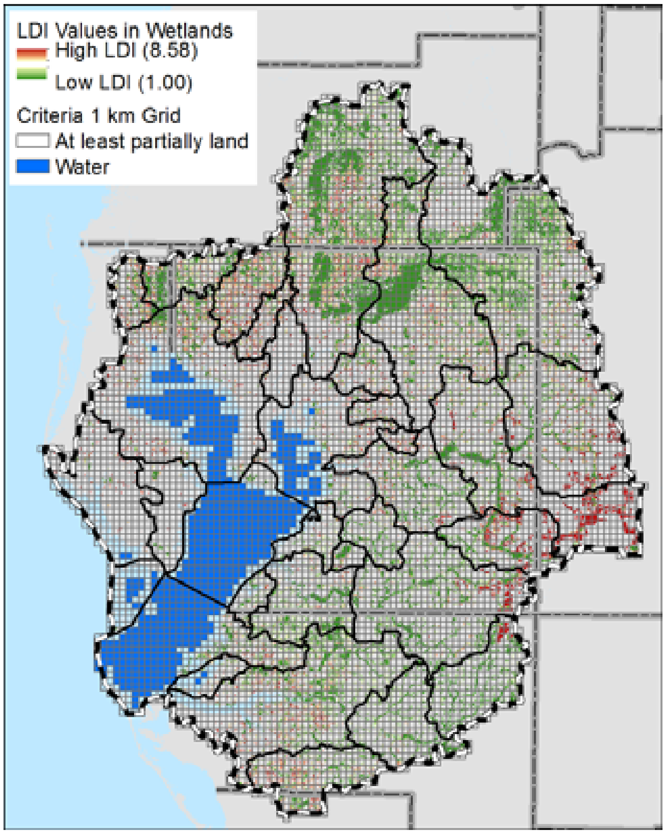
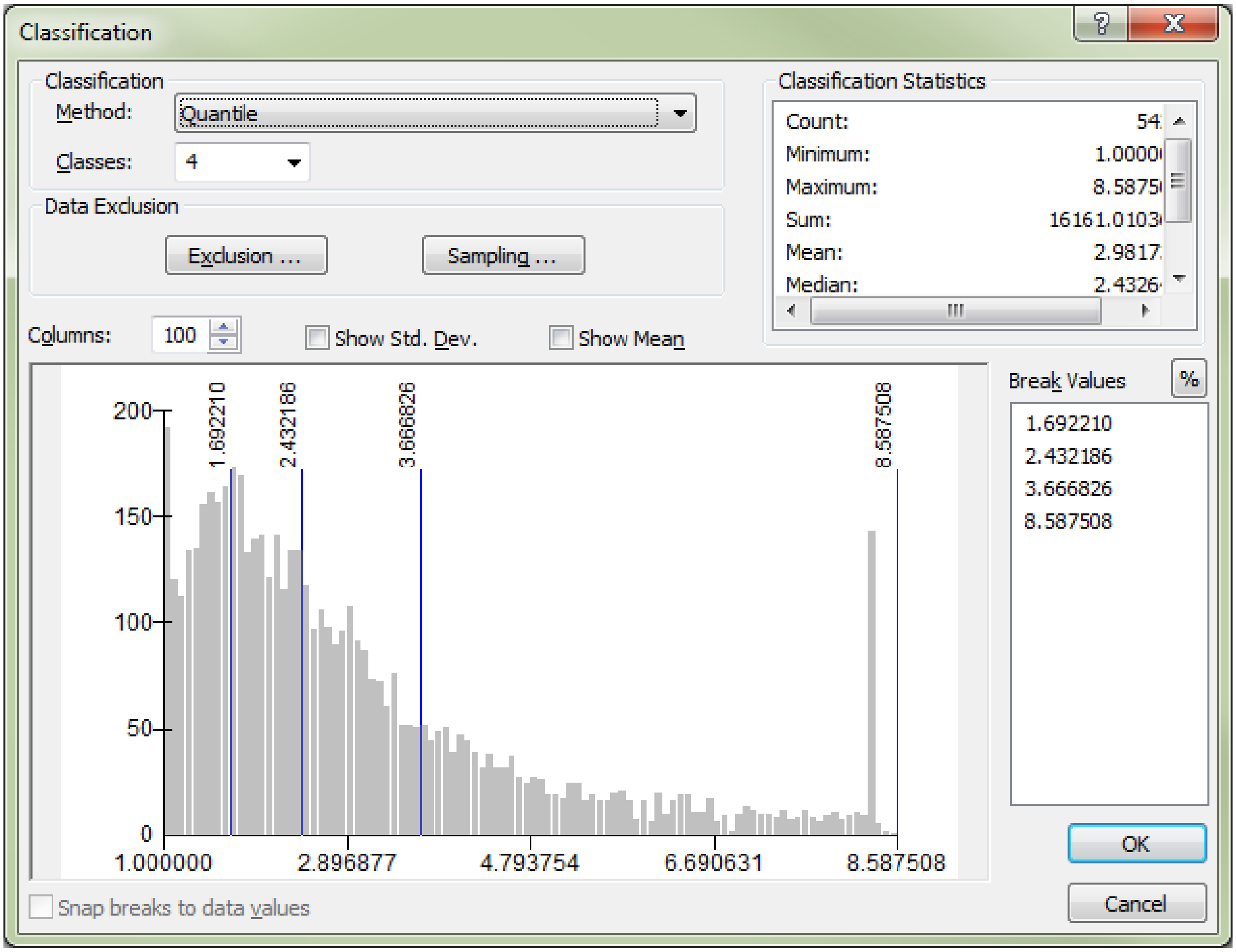


Figure 12. LDI values overlaid by 1 km screening grid. Higher LDI values imply more impacted wetlands.

The result of the mean LDI calculations was a range of mean values ranging from 1 to 8.58 (i.e., LDI value), in addition to numerous null (i.e., empty) values for cell locations were wetlands did not exist. In order to convert these values into screening criteria that was comparable with other criteria, the condition of remaining wetlands was categorized on a scale of 1-5, with 1 being the "best" condition and 4 being the “poorest” condition for grid cells with wetlands. Grid cells with no wetlands (i.e., null/empty values) that were not located within the Bay waters were assigned a value of 5 to indicate that areas lacking wetlands were worse than areas with wetlands. Grid cellswith existing wetlands were assigned the category 1-4 according to the quantile distribution of mean LDI values. Grid cells with the lowest, or best, mean LDI value were assigned a value of 1 and grid cells with the worst LDI values were assigned a value of 4. Figure 13 shows the distribution of all valid (i.e., not null) mean LDI values within grid cells of the Tampa Bay Watershed. A quantile binning technique was used in order to establish a rank that included equal numbers of grid cells within each rank. The break value section of the figure illustrates that 25% of the grid cells representing the “best” condition had a mean LDI value of less than or equal to 1.69, while the “poorest” condition (aside from having no wetlands) was represented by grid cells with a mean LDI greater than 3.66. Rankings 1-4 used the break values shown in the Figure 13.



Classification

Classification

Method: Quantile

Classes: 4

Columns: 100

☐ Show Std. Dev.

☐ Show Mean

Classification Statistics

Count: 54

Minimum: 1.0000

Maximum: 8.5875

Sum: 16161.0103

Mean: 2.9817

Median: 2.4326

Break Values

1.692210

2.432186

3.666826

8.587508

☐ Snap breaks to data values

Figure 13. Illustration of binning technique of mean LDI distribution. Higher LDI values imply more impacted wetlands.

The methods described above represent the same basic process used for all screening criteria. In summary: 1) raw data at the wetland scale were summarized for each 1 km grid cell; 2) if necessary, null/empty values were assigned the lowest ranking (or highest, depending on the criteria); 3) summarized values were placed into a quantile distribution (note that other criteria use quartile); and finally 4) remaining ranks were set based on quantile distribution.

Wetland Condition by Type

The condition of specific types of classified wetlands can also be important criteria to consider. Following methods similar to those used for all wetlands, condition of remaining wetlands was also calculated separately for each of the six classified wetland types.

Separate wetland boundary polygon layers were created for each of the six types from the existing 2007 wetlands, such that each layer contained only one type (e.g., forested riverine). Each of the six polygon layers was used to extract LDI values in the 10 meter raster grid that were located within wetlands of that type. Mean LDI values within wetlands of that type were then calculated for each 1km grid cell and ranked according to the quantile distribution specific to that wetland classification type. Six additional screening criteria were thus created, one for each wetland type following the same ranking method used for combined wetlands.

Wetland Hydrological Connectivity

The hydrologic connectivity of remaining wetlands is an important consideration because wetlands with a more direct hydrologic connection to Tampa Bay may have a greater influence on Bay water quality. Existence of riverine wetlands in 2007 was used to develop a binary score to indicate wetland connectivity. Grids with riverine wetlands were scored as 1 and grids without riverine wetlands were scored as 0.

The data table from the wetland area calculations contained a unique identifier for each 1 km grid cell, and records of all wetland polygons located within each cell. The wetland classification type data value was retained and used to determine hydrologic connectivity. Grid cells that contained a riverine polygon were selected and assigned a value of 1 (i.e., riverine wetlands present). All remaining grid cells (i.e., lacking riverine wetland polygons) were then assigned a value of 0, except water grid cells which were assigned a null value.

Wetland Mitigation Opportunity / Planned Development Impact

Planned or future land use acquired from the various planning agencies (see methods) was consolidated into a single polygon map layer. Future land use categories were converted to Landscape Development Intensity (LDI) using the same lookup table that was utilized to convert FLUCCS level 1 land use land cover classifications into LDI. Planned land use derived LDI values were converted from a polygon layer to a raster dataset using the same 15 meter cell size that was used for wetland condition calculations. Using the ArcGIS 10 Spatial Analyst Statistics Table tool, mean planned LDI values were calculated for each 1km grid cell. A value of 1-5 is assigned to each grid cell based on the quartile distribution of mean planned LDI in all grids. Grids in the lowest 20% of planned LDI (i.e., the "best") are assigned a value of 1, while grids with the highest 20% of planned LDI were assigned a value of 5.

Results and Discussion

Geographic Extent of Wetlands, 1950 and 2007

Total surface area of wetlands of all types in the Tampa Bay Watershed in 1950 was 1,271 square kilometers, or 314,170 acres (see Table 4). The majority, 76%, of all wetland area was classified as riverine, while slightly more than 7% was lacustrine and 16% was classified as other wetlands. In 1950, nearly 65% of all wetlands were classified as forested.

Table 4. Wetland surface area in 1950 summarized by type.

Wetland Type	1950 Wetland Area (km^2)	% of All Wetland Types
Riverine Forested	681.1	53.6%
Riverine Non-Forested	284.7	22.4%
Total Riverine Wetlands	**965.8**	**76.0%**
Lacustrine Forested	45.1	3.5%
Lacustrine Non-Forested	50.0	3.9%
Total Lacustrine Wetlands	**95.1**	**7.5%**
Other Forested	97.4	7.7%
Other Non-Forested	113.0	8.9%
Total Other Wetlands	**210.4**	**16.5%**
Total all Forested Wetlands	**823.7**	**64.8%**
Total all Non-Forested Wetlands	**447.7**	**35.2%**
Total Wetlands of All Types	**1,271.4**	**100.0%**

The geographic extent of wetland coverage in 1950 within the Tampa Bay Watershed is shown in Figure 14. Although a detailed description of the geographic extent is beyond the scope of this report, there are a few important points to make regarding this distribution. The map shows that by 1950, wetlands are largely absent within the large urban areas of the City of Tampa and St. Petersburg. The urban core in both of these cities had experienced the bulk of their growth prior to World War II. Determining pre-settlement wetland coverage would require going back in time to the early 1800s. Reconstructing pre-settlement wetland area and distribution may be a valuable exercise for future research.

In 1950, wetlands were abundant within the northern and northeastern areas of the watershed. Large wetland systems were associated with basins around the Hillsborough River in the north and the Alafia River in the east. Smaller riverine wetland systems are evident throughout the eastern and southern areas of the watershed. High densities of smaller wetlands cover large areas of the eastern and northeastern watershed, as well as the south portion of the watershed.

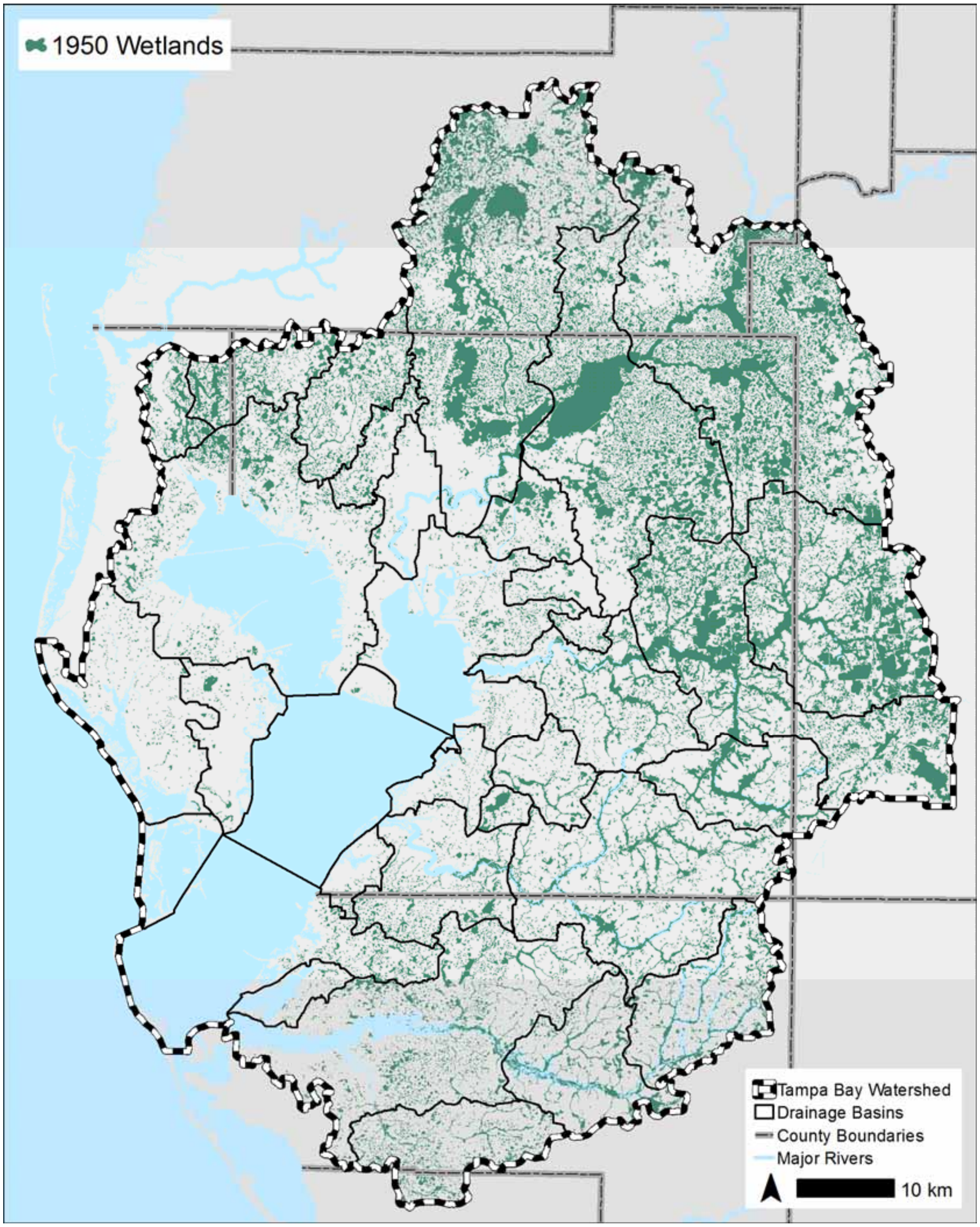


Figure 14. Geographic Extent of Wetlands, 1950.

Total surface area of wetlands of all types in the Tampa Bay Watershed in 2007 was 855 km^2, or 211,325 acres (see Table 5). Slightly over 76% of all wetland area was classified as riverine, while nearly 6% was lacustrine and 18% was classified as other wetlands. In 2007, nearly 70% of all wetlands were classified as forested.

Table 5. Wetland surface area in 2007 summarized by type.

Wetland Type	2007 Wetland Area (km^2)	% of All Wetland Types
Riverine Forested	495.8	58.0%
Riverine Non-Forested	155.1	18.1%
Total Riverine Wetlands	650.9	**76.1%**
Lacustrine Forested	26.3	3.1%
Lacustrine Non-Forested	22.3	2.6%
Total Lacustrine Wetlands	48.6	**5.7%**
Other Forested	77.2	9.0%
Other Non-Forested	78.5	9.2%
Total Other Wetlands	155.7	**18.2%**
Total all Forested Wetlands	599.3	**70.1%**
Total all Non-Forested Wetlands	255.9	**29.9%**
Total Wetlands of All Types	855.2	**100.0%**

The geographic extent of wetland within the Tampa Bay Watershed in 2007 is shown in Figure 15. Existing wetlands classified from 2007 data sources show a distribution comprised of generally much smaller wetland systems than those evident on the 1950 map (Figure 14). Large wetland systems are associated with basins around the Hillsborough River and to a lesser extent around the Alafia River in the east. Smaller riverine wetland systems remain throughout the eastern and southern areas of the watershed. The density of smaller wetlands appears to be fairly evenly distributed throughout northern and southern areas of the watershed.

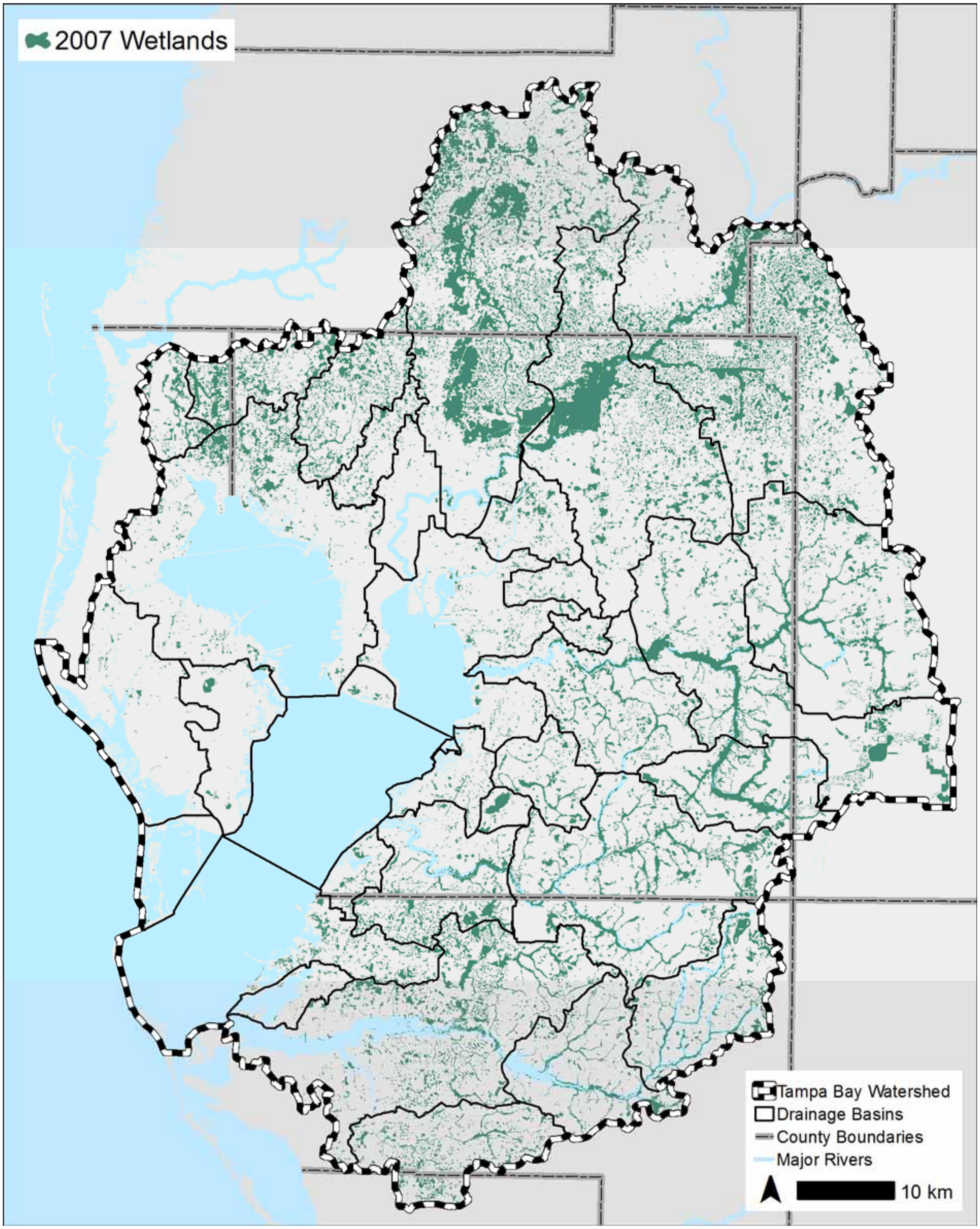


Figure 15. Geographic Extent of Wetlands, 2007.

Wetland Change, 1950-2007

Total freshwater wetland surface area decreased by over 416 km^2 between 1950 and 2007 within the Tampa Bay Watershed (Table 6). The change is a 33% reduction in total wetland area. The largest loss, by far, to surface area occurred to riverine wetlands (314.9 km^2). Lacustrine wetlands exhibited the largest loss as a percentage of surface area that existed in 1950; nearly 50% of the 1950 lacustrine wetland area had been lost by 2007. While loss to total wetland area was slightly greater for forested (224.4 km^2) compared to non-forested (191.8 km^2), the percentage change was actually much larger for non-forested (43% compared to 27% for forested). Within the riverine classification, forested wetland area loss was greater (185.3 km^2) compared to non-forested (129.6 km^2) even though the percentage lost was higher for non-forested. In the lacustrine and other wetland categories, both the area lost and percentage lost were higher for non-forested.

Table 6. Wetland Change, 1950-2007: Total area and percent change.

Wetland Type	1950 Wetland Area (km^2)	2007 Wetland Area (km^2)	Wetland Change 1950 – 2007 km^2 (%)
Riverine Forested	681.1	495.8	-185.3 (-27%)
Riverine Non-Forested	284.7	155.1	-129.6 (-46%)
Total Riverine Wetlands	**965.8**	**650.9**	**-314.9 (-33%)**
Lacustrine Forested	45.1	26.3	-18.8 (-42%)
Lacustrine Non-Forested	50	22.3	-27.7 (-55%)
Total Lacustrine Wetlands	**95.1**	**48.6**	**-46.5 (-49%)**
Other Forested	97.4	77.2	-20.2 (-21%)
Other Non-Forested	113	78.5	-34.5 (-31%)
Total Other Wetlands	**210.4**	**155.7**	**-54.7 (-26%)**
Total all Forested Wetlands	**823.7**	**599.3**	**-224.4 (-27%)**
Total all Non-Forested Wetlands	**447.7**	**255.9**	**-191.8 (-43%)**
Total Wetlands of All Types	**1,271.4**	**855.2**	**-416.2 (-33%)**

In addition to examining wetland area changes at the aggregate of the entire Tampa Bay Watershed, this study also compared changes at the scale of individual wetlands. Figure 16 illustrates the general geographic distribution of four types of change that occurred with individual wetlands 1950-2007. “No change” is indicated when neither the wetland boundaries nor the type of wetland changed. “Wetland gain” occurred in areas of wetland expansion or wetland creation. “Change in type” means that an area remained a wetland, but that the type of wetland (e.g., riverine forested) in 2007 was different than the type of wetland that was present in 1950. Finally, “wetland loss” shows the areas where wetlands were present in 1950 but no longer existed in 2007. The small map in Figure 16 is provided to show major patterns of change. In order to examine large scale local changes, consult the complete spatial database of map layers provided with this report.

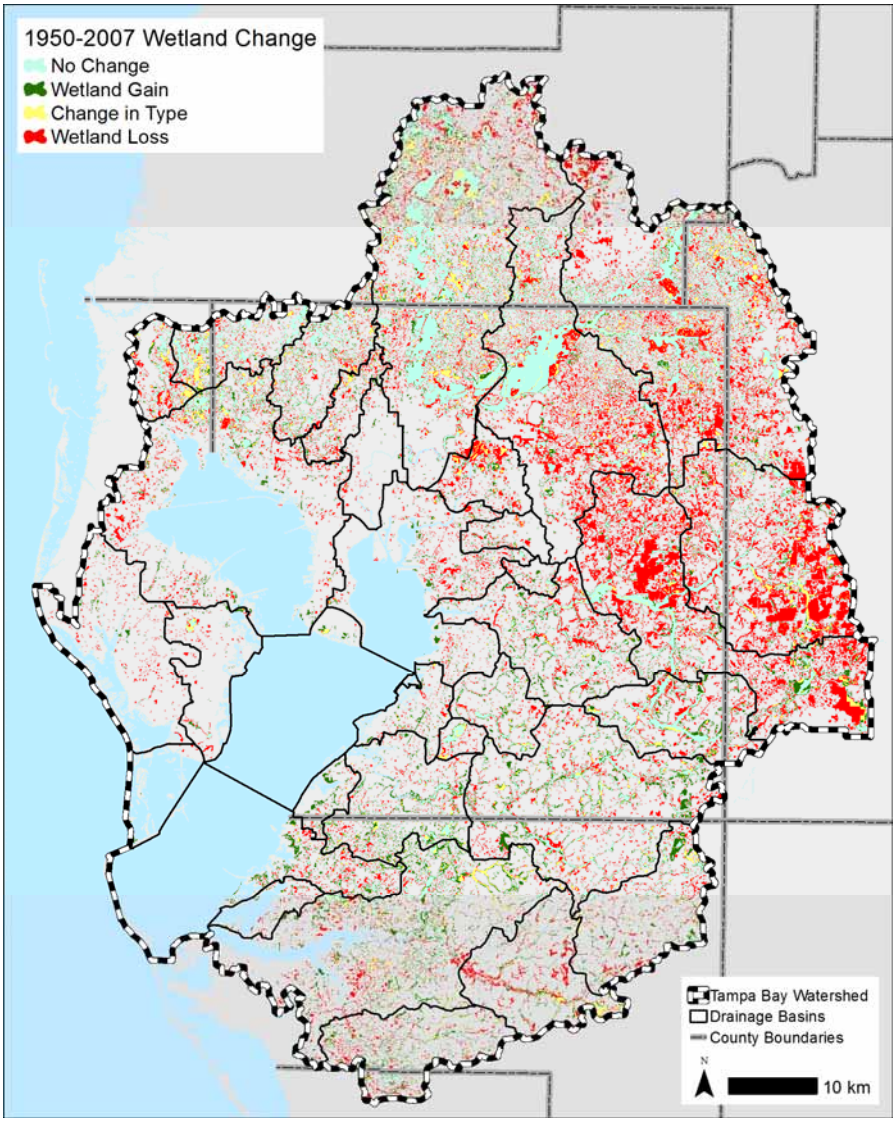


Figure 16. Wetland Change, 1950-2007.

Several patterns of wetland change are evident from the map of wetland area change shown in Figure 16. The eastern portion of the watershed is marked by loss of very large wetland systems and numerous other wetland areas. These areas of the watershed have been impacted by phosphate mining activities, large scale agriculture and suburban expansion. In addition to wetland loss, change in wetland type and some gain is also visible in the eastern areas of the watershed. Mine reclamation activities may be responsible for some of these patterns.

Change in wetland classification type is defined as a change in classified structural or hydrologic connectivity for all or a portion of individual wetlands between 1950 and 2007. Change to type is visible as small patches distributed throughout the watershed. The northernmost drainage basin is dotted with numerous areas where the type of wetland changed. Wetlands in these areas may have undergone a structural change between non-forested and forested. The growth of trees on former agricultural or timber lands is one example. To understand the magnitude of classification type changes within the watershed, Table 7 shows the types of changes that were found when comparing differences between 1950 and 2007 boundaries or individual wetlands. Changes to the structure and hydrological connectivity of wetlands was 15.2% of all changes that occurred at the scale of individual wetlands; a total of 146.5 km^2. Change from non-forested to forested, or vice versa, represent the greatest proportion of all types of change, excluding loss and gain.

Table 7. Type of change at the scale of individual wetlands.

Type of Change	Area (km^2)	% of all Change
Structural Change	73.1	7.5%
Hydrologic Change	58.5	6.0%
Change to both Structure and Hydrology	14.9	1.5%
Total Change in Structure or Hydrology	**146.5**	**15.2%**
Wetland Loss	**622.7**	**63.8%**
Wetland Gain	**206.7**	**21.2%**
Total Individual Wetland Change	**975.9**	**100%**

Gains to the areas of individual wetlands (i.e., wetland gain), shown spatially in Figure 16 and as total area in Table 7, was recorded when the boundaries of an individual wetland were larger in 2007 than in 1950 or when a wetland recorded in 2007 had not been visible in 1950. Green areas of Figure 16 are visible throughout much of the watershed. There are at least several major explanations for these wetland gains. Construction of water management infrastructure can include the creation of retention and detention ponds and associated wetland areas. Construction activities can change the surface hydrology within localized areas, thus turning formerly dry areas into wet areas, and vice versa. Restoration and reclamation activities on mining lands have led to the creation of many wetlands, as evidenced by the large areas of gain in the easternmost portions of the county (see Figure 16).

Photointerpretation error is also a possible explanation for the large total area of wetland gain, as well as other types of change. Classification of 1950 and 2007 wetlands was done using photointerpretation techniques. Although photointerpretation is arguably the best available method for reconstructing historic land cover, differences in results have been shown to be highly dependent on both the interpreter and the quality of the imagery. Small differences in the digitized boundary of a wetland can result in wetland change that is recorded as a gain (or loss). In other cases, the wetland area may not have changed, but a small spatial shift can result in gain that is equal to the loss. The minimum mapping unit of 0.2 hectare (½ acre) can result in small patches of wetland left undetected in one or both of the datasets, and the total impact of the differences at the watershed scale may be somewhat large. Independent validation testing demonstrated a 90.1% accuracy of the digitized 1950s wetlands. According to the SWFWMD, the source of the 2007 land use land cover data used for wetland classification, accuracy testing results are not reported but is likely to be 80-90% (SWFWMD, 2008). Individual wetland change was not the primary focus of this study, and therefore a detailed accuracy testing of individual wetland changes was not attempted. Caution should be exercised when interpreting the results at the scale of the individual wetland shown in Figure 16 and in Table 7.

Aggregate net change at larger geographic extents is a much more valid way of interpreting the change analysis results.

Wetland change aggregated by drainage basin ranged from a net loss of 90.3 km^2 to a net gain of 4.8 km^2 (Table 8). Percent change in wetland area by basin is shown geographically in Figure 17. Total area and percent change is listed in Table 8 and sorted in descending order by the total area of wetland loss. As shown in Figure 17, basins with the largest (top two quartile groups) percentage loss in wetland area between 1950 and 2007 are located in the southeast portion of the watershed associated with the Manatee and Alafia Rivers (especially basins 204-2 and 02300500), coastal areas on the east side of Tampa Bay near Cockroach Bay (basin 206-E) and Bullfrog Creek (basin 206-3E and 2300700), northeast basins associated with the Hillsborough River and Itchepackesassa Creek (basins 02303330 and 02303000), and the coastal areas on the north and west sides of Old Tampa Bay (basin 206-1).

An examination of total area of wetland change (i.e., in contrast to percent change) by basin shows a somewhat different result. Table 8 includes two columns to compare the difference between total area versus percentage change: rank order by km^2 change and rank order by % change. Only two of the basins ranked in the top five in terms of percentage change were also in the top five in terms of total area change. Basins associated with the Manatee River (basins 02299950 and 02300500) were near the top rank in terms of both total area lost and total percentage loss. Several basins that lost a substantial surface area of wetlands between 1950 and 2007 are not in the top rank in terms of percentage wetland lost. Basins associated with the Hillsborough River (e.g., 02303330 and 02303000) ranked moderately high in terms of both area and percentage loss. In contrast, Alafia River basins (02301000, 02301500 and 02301300) were not in the upper two quartiles in terms of percentage loss, but were in the highest quartile in terms of total surface area of wetland loss.

Extreme care must be exercised when using wetland change statistics within the environmental management and policy arena. For example, from the perspective of the total magnitude loss of ecosystem services derived from wetlands (e.g., water quality treatment), the total area lost in many basins might be a primary concern. However, when viewed from a habitat change perspective, a greater percentage loss to wetlands may result in substantial change to ecosystem dynamics and associated widespread consequences to ecosystem function. Interpretation of the results of the change analysis therefore depends on the specific goals of the agency.

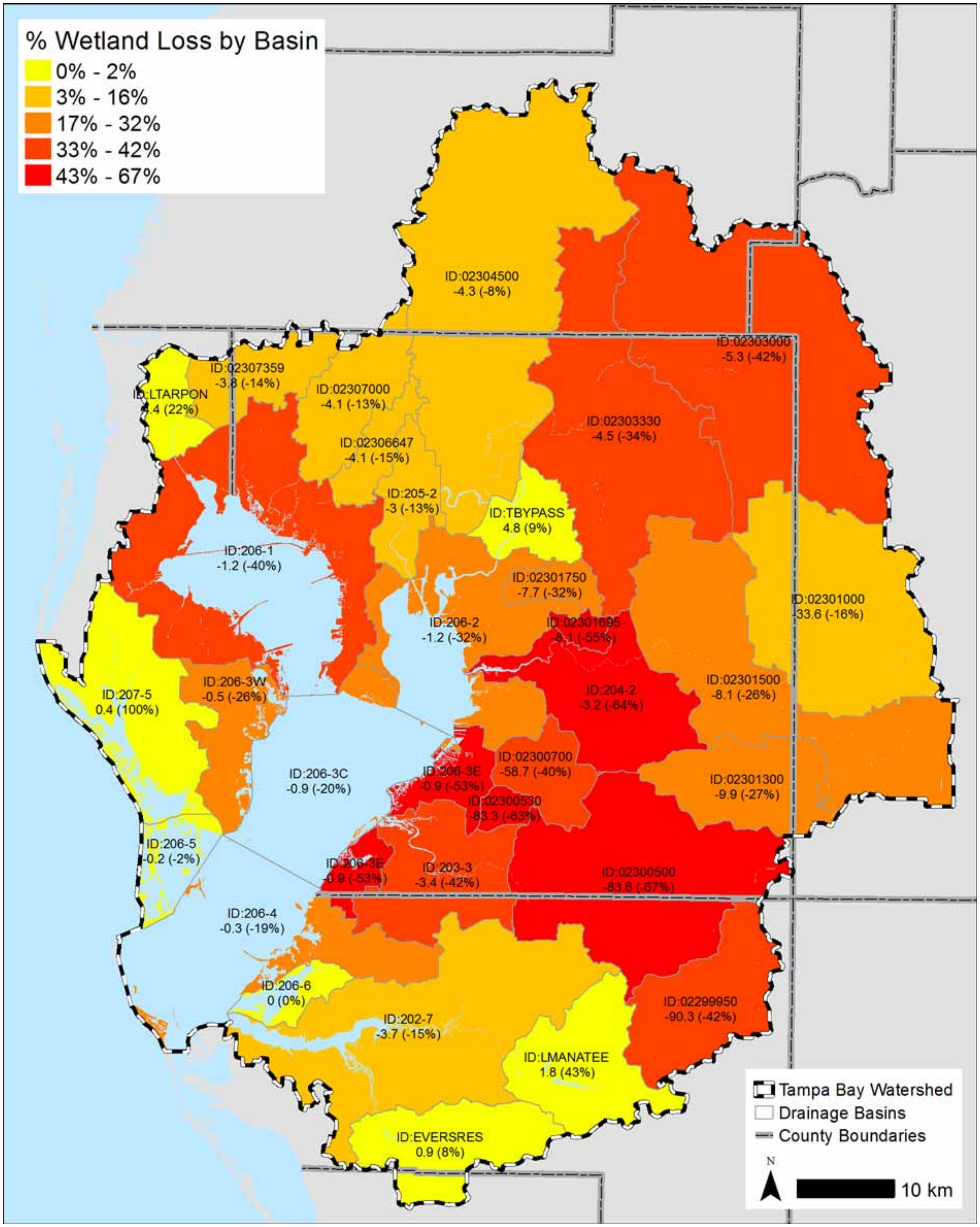


Figure 17. Wetland loss by drainage basin, 1950-2007. Categories are defined by quartile groups.

Table 8. Wetland Change, 1950-2007: Total area and percent change by drainage basin.

Drainage Basin ID	1950 Wetland Area (km^2)	2007 Wetland Area (km^2)	Change 1950 – 2007 km^2 (%)	Rank order by km^2 change	Rank order by % change
02299950	215.5	125.2	-90.3 (-42%)	1	6
02300500	124.9	41.3	-83.6 (-67%)	2	1
02300530	132.4	49.1	-83.3 (-63%)	3	3
02300700	147.4	88.7	-58.7 (-40%)	4	9
02301000	204.7	171.1	-33.6 (-16%)	5	19
02301300	36.5	26.6	-9.9 (-27%)	6	14
02301500	30.6	22.5	-8.1 (-26%)	8	4
02301695	14.7	6.6	-8.1 (-55%)	7	15
02301750	24.2	16.5	-7.7 (-32%)	9	12
02303000	12.6	7.3	-5.3 (-42%)	10	7
02303330	13.1	8.6	-4.5 (-34%)	11	11
02304500	55.8	51.5	-4.3 (-8%)	12	25
02306647	26.6	22.5	-4.1 (-15%)	13	20
02307000	31.1	27	-4.1 (-13%)	14	23
02307359	27.7	23.9	-3.8 (-14%)	15	22
202-7	25.4	21.7	-3.7 (-15%)	16	21
203-3	8.1	4.7	-3.4 (-42%)	17	8
204-2	5	1.8	-3.2 (-64%)	18	2
205-2	23	20	-3 (-13%)	19	24
206-1	3	1.8	-1.2 (-40%)	20	10
206-2	3.8	2.6	-1.2 (-32%)	21	13
206-3C	4.4	3.5	-0.9 (-20%)	23	5
206-3E	1.7	0.8	-0.9 (-53%)	22	17
206-3W	1.9	1.4	-0.5 (-26%)	24	16
206-4	1.6	1.3	-0.3 (-19%)	25	18
206-5	8.2	8	-0.2 (-2%)	26	26
206-6	0.1	0.1	0 (0%)	27	27
207-5	0.4	0.8	0.4 (100%)	28	32
EVERSRES	10.8	11.7	0.9 (8%)	29	28
LMANATEE	4.2	6	1.8 (43%)	30	31
LTARPON	20.4	24.8	4.4 (22%)	31	30
TBYPASS	51.4	56.2	4.8 (9%)	32	29
Total Wetland Area	**1271.4**	**855.4**	**-416 (-33%)**		

Screening Tools

Screening criteria maps and data are summarized in this section of the report. The maps are primarily for illustrative purposes. The reader is encouraged to utilize the screening criteria GIS data layer directly for the purpose of analysis or prioritization. Appendix B provides a demonstration of the use of the Wetland Screening Criteria. The demonstration is meant to serve as an example of how the criteria might be used to address basic prioritization questions.

Table 9 provides a summary of the grid data used to develop the screening criteria. The wetland loss 1-5 scale screening criteria was developed from the “change” data listed in the table. The term change is used here to recognize that the raw data represent both an increase (positive values) and a loss (negative values) of wetlands within each 1 km^2 grid. As shown in the table, 1950-2007 wetland loss of all wetland types averaged 0.07 km^2 within 1 km^2 grid cell, or 7% loss. Each 1 km^2 grid cell contains an average of 0.13 km^2, or 13% wetland coverage by area. Wetland condition of all types within each 1 km^2 grid cell is equal to a 2.98 average LDI value. Future “planned LDI” based on future land use will result in a worsening of wetland condition as indicated by a 5.78 average LDI value. Finally, wetland connectivity screening criteria data indicates that 71% of all 1 km^2 grid cells contain a riverine wetland (of any size).

Table 9. Summary statistics of raw grid data used to develop screening criteria.

Screening Criteria	Units	Mean	Std. Dev	Min	Max
Change (All Types)	change in km2 within 1 km2 grid	-0.07	0.14	-1.00	0.67
Change (Forested Lacustrine)	change in km2 within 1 km2 grid	-0.02	0.08	-0.47	0.69
Change (Forested Other)	change in km2 within 1 km2 grid	-0.01	0.04	-0.36	0.56
Change (Forested Riverine)	change in km2 within 1 km2 grid	-0.04	0.12	-1.00	0.48
Change (Non-Forested Lacustrine)	change in km2 within 1 km2 grid	-0.02	0.08	-0.72	0.51
Change (Non-Forested Other)	change in km2 within 1 km2 grid	-0.01	0.03	-0.24	0.57
Change (Non-Forested Riverine)	change in km2 within 1 km2 grid	-0.03	0.10	-1.00	0.80
Wetland Area Remaining	area remaining within 1 km2 grid	0.13	0.16	0.00	1.00
Condition (All Types)	wetlands LDI within 1 km2 grid	2.98	1.79	1.00	8.59
Condition (Forested Lacustrine)	wetlands LDI within 1 km2 grid	2.94	1.38	1.00	8.32
Condition (Forested Other)	wetlands LDI within 1 km2 grid	3.20	1.58	1.00	8.32
Condition (Forested Riverine)	wetlands LDI within 1 km2 grid	2.35	1.27	1.00	8.32
Condition (Non-Forested Lacustrine)	wetlands LDI within 1 km2 grid	3.63	2.25	1.00	8.32
Condition (Non-Forested Other)	wetlands LDI within 1 km2 grid	3.92	1.98	1.00	8.59
Condition (Non-Forested Riverine)	wetlands LDI within 1 km2 grid	3.07	1.85	1.00	8.42
Planned LDI	future LU LDI within 1 km2 grid	5.78	2.33	1.00	8.66
Wetland Connectivity	presence of rivers (Yes/No)	0.71	0.45	0	1

Table 10 provides the cutoff values used to calculate each 1-5 criteria score. For example, a score of 1 for change/loss of all types of wetlands was assigned to each 1 km^2 grid cell with raw data values greater than or equal to 0. A change/loss score of 1 was assigned for all raw data values less than 0 and greater than or equal to -0.024. Bin values for change criteria and wetland area remaining should be interpreted as follows: score 1 is assigned when values meet the criteria shown in Bin 1; score 2 when values are less than Bin 1 and greater than or equal to Bin 2; score 3 when values < Bin 2 and >=Bin 3; score 4 when values < Bin 3 and >=Bin 4; score 5 when values < Bin 4. Condition and planned LDI score are calculated similarly except that all values for progressive scores are greater than, rather than less than, the preceding score. For example, condition score 2 for all types is assigned for values >=Bin 1 and < Bin 2. Note that wetland connectivity is not shown in the table because it is a binary indicator based on presence (i.e., 1) or absence (i.e., 0) of rivers.

Table 10. Raw data cutoff values used for each 1-5 wetland criteria score. Bin 1 indicates the values used for criteria score 1, Bin 5 indicates the cutoff used for criteria score 5.

Screening Criteria	Bin 1	Bin 2	Bin 3	Bin 4	Bin 5
Change (All Types)	>=0	-0.024	-0.066	-0.150	-1.000
Change (Forested Lacustrine)	>=0	-0.008	-0.024	-0.061	-0.471
Change (Forested Other)	>=0	-0.005	-0.013	-0.029	-0.357
Change (Forested Riverine)	>=0	-0.016	-0.047	-0.123	-0.995
Change (Non-Forested Lacustrine)	>=0	-0.007	-0.022	-0.060	-0.724
Change (Non-Forested Other)	>=0	-0.004	-0.012	-0.026	-0.241
Change (Non-Forested Riverine)	>=0	-0.009	-0.027	-0.067	-1.000
Wetland Area Remaining	>=0.21	0.10	0.03	0.00	0
Condition (All Types)	<1.69	2.43	3.67	8.59	NULL
Condition (Forested Lacustrine)	<1.96	2.78	3.59	8.32	NULL
Condition (Forested Other)	<1.98	2.87	4.21	8.32	NULL
Condition (Forested Riverine)	<1.44	2.00	2.87	8.32	NULL
Condition (Non-Forested Lacustrine)	<1.93	2.88	4.76	8.32	NULL
Condition (Non-Forested Other)	<2.36	3.43	5.24	8.59	NULL
Condition (Non-Forested Riverine)	<1.74	2.51	3.74	8.42	NULL
Planned LDI	<3.83	6.80	7.47	8.33	8.66

Wetland Loss

Screening criteria for loss of all types of wetlands is shown in Figure 18. As shown in the map, the eastern portion of the study area contains the 1 km^2 grid cells with the greatest amount of loss, or poorest condition. Southeastern areas of the study area contain 1 km^2 grid cells with the lowest amount of loss and/or gain, or best condition. Other areas of the study area are highly variable in terms of loss.

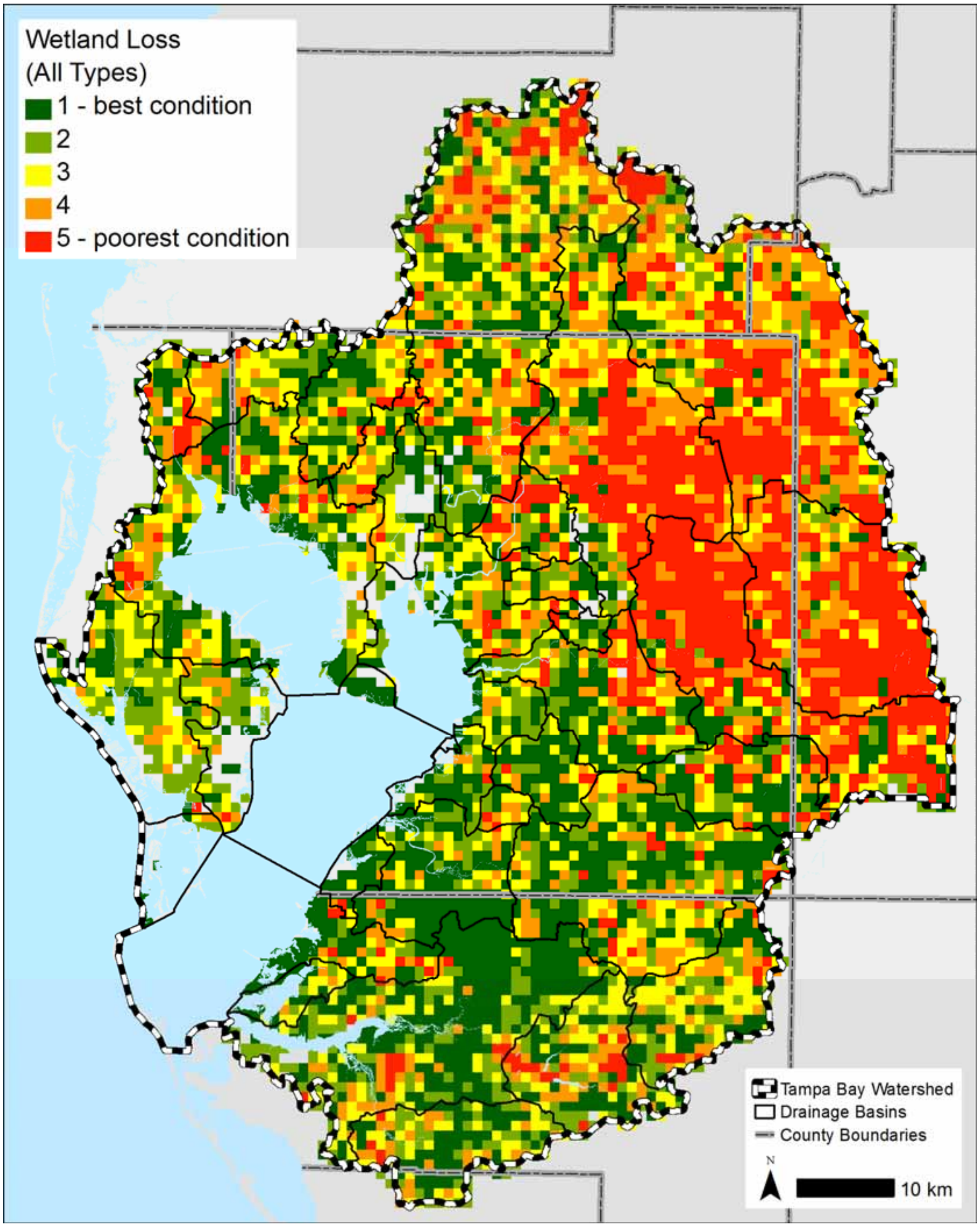


Figure 18. Screening Tool: Loss of All Wetlands.

Wetland Loss by Type

Screening criteria for loss of specific types of wetlands is shown in Figure 19 through Figure 24. The patterns of loss shown within the 1 km^2 grid cells on these maps are highly variable. In general, the eastern and northeastern portion of the study area suffered a large amount of loss of all wetland types. Other patterns vary by type of wetland.

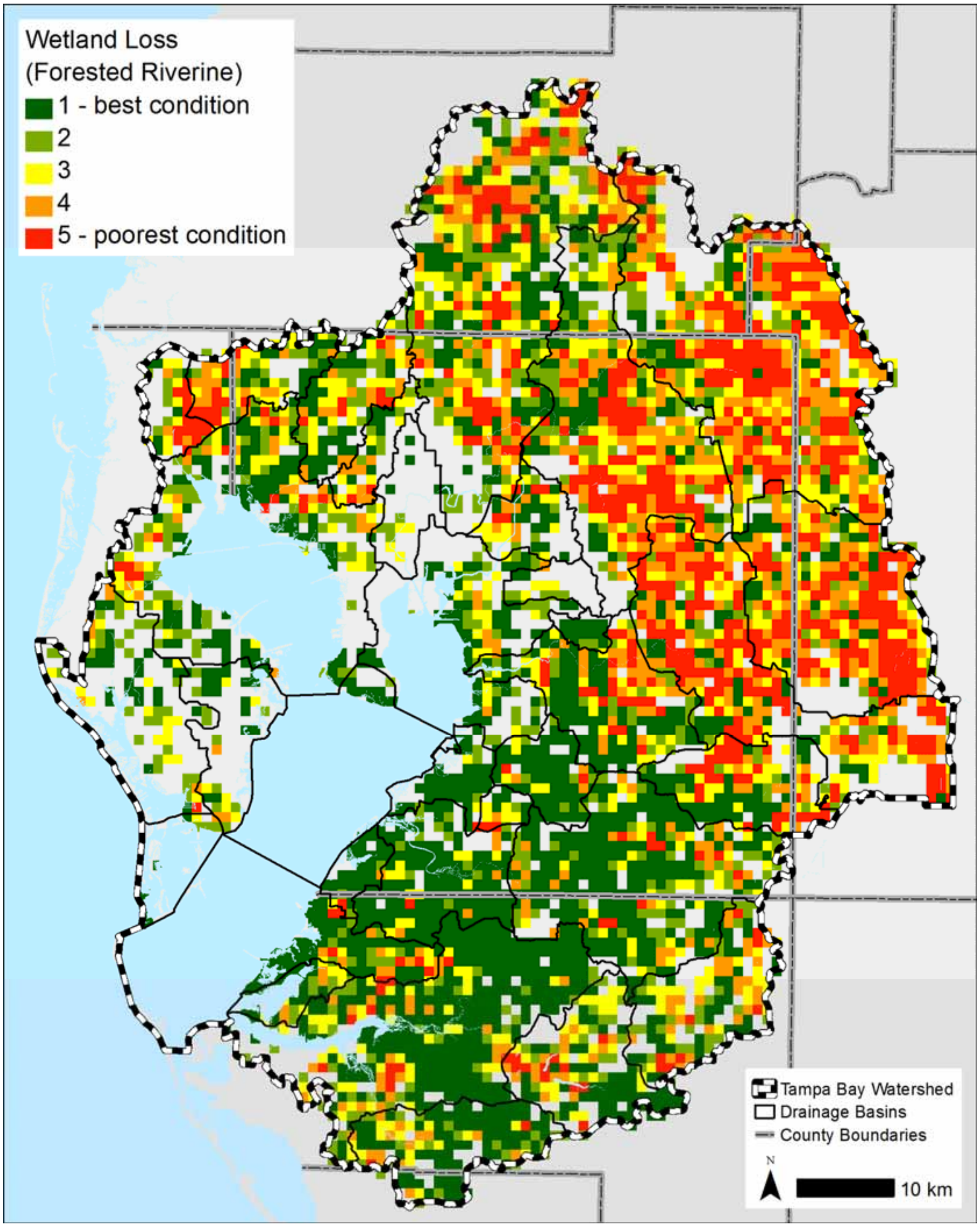


Figure 19. Screening Tool: Loss of Forested Riverine Wetlands.

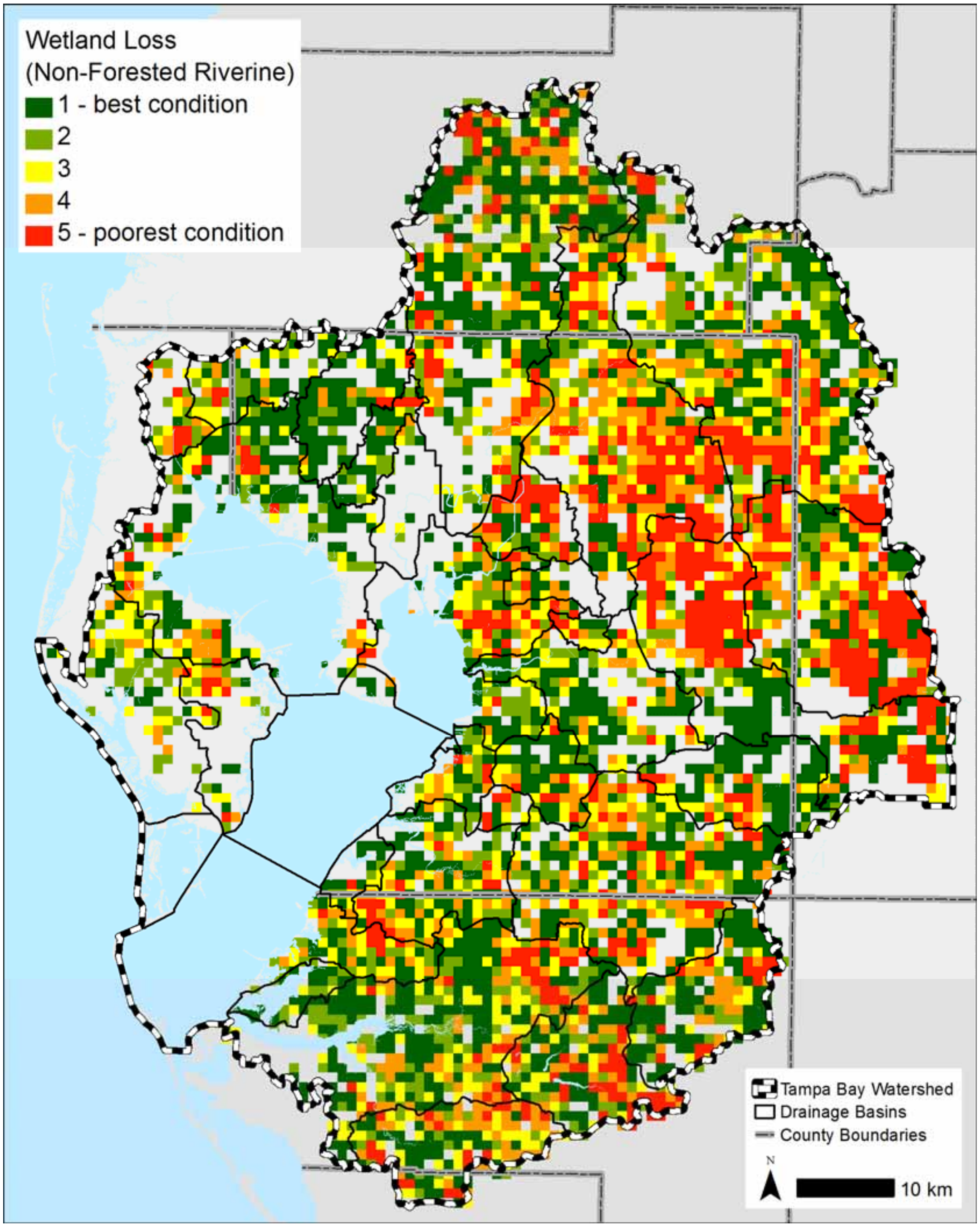


Figure 20. Screening Tool: Loss of Non-Forested Riverine Wetlands.

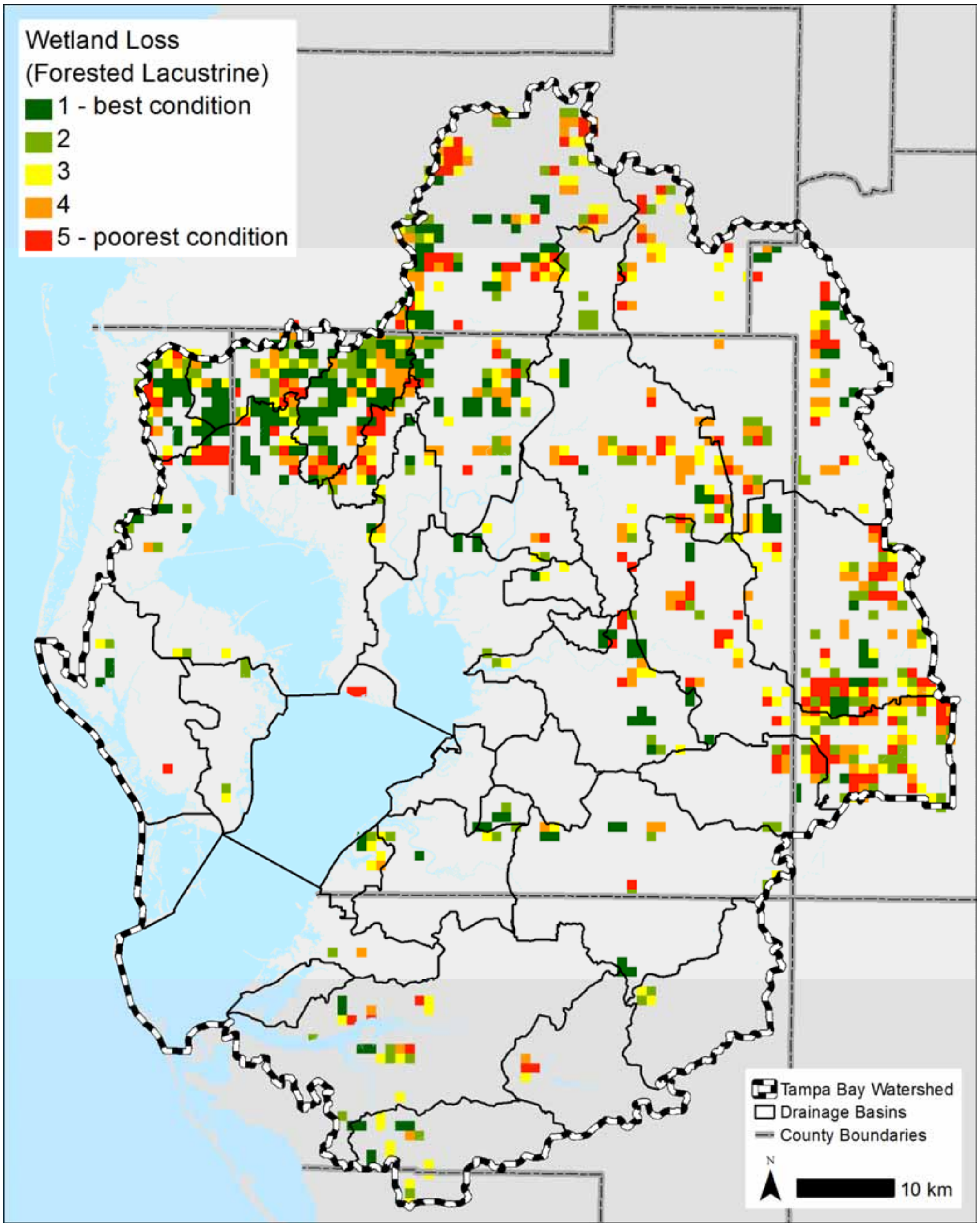


Figure 21. Screening Tool: Loss of Forested Lacustrine Wetlands.

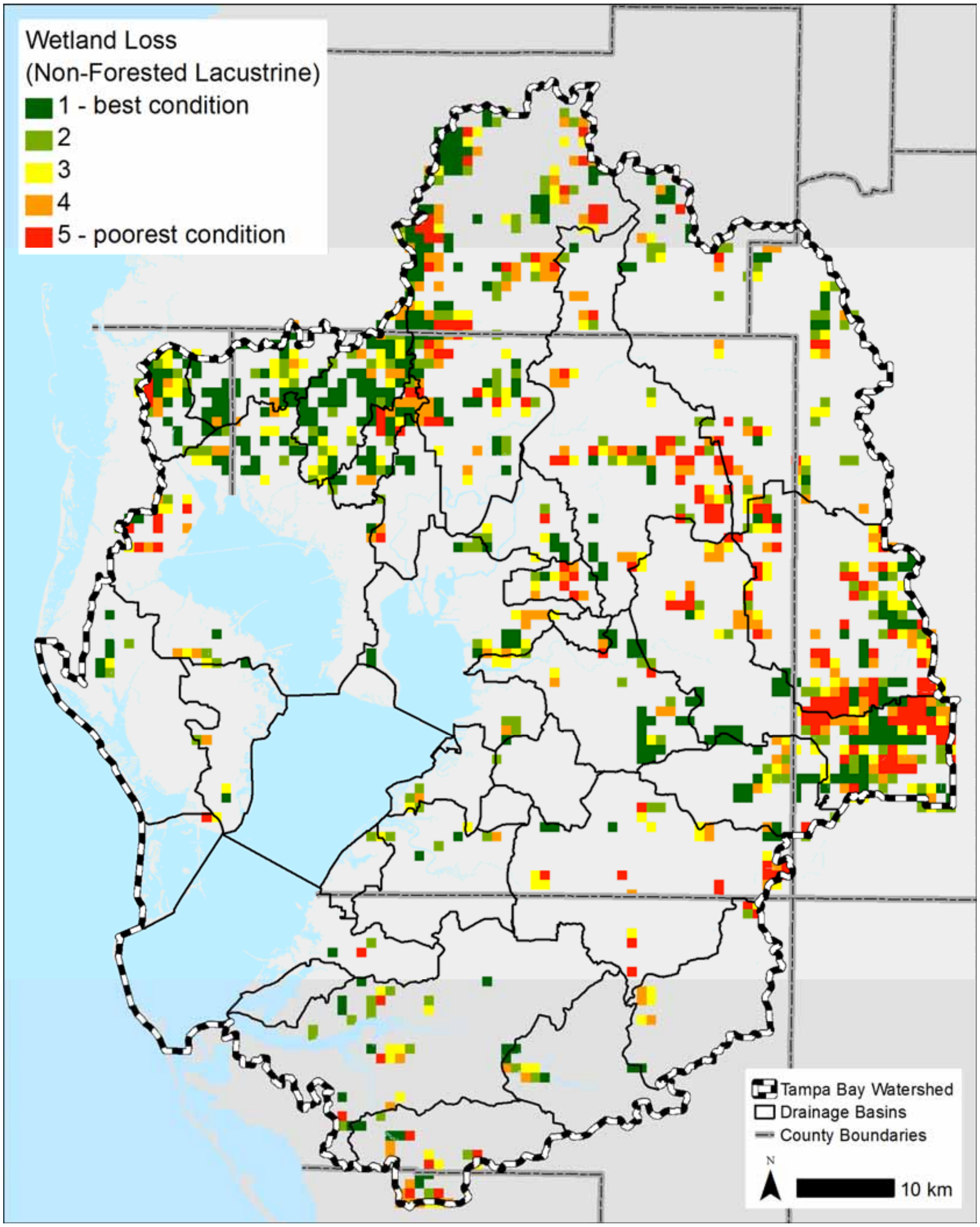


Figure 22. Screening Tool: Loss of Non-Forested Lacustrine Wetlands.

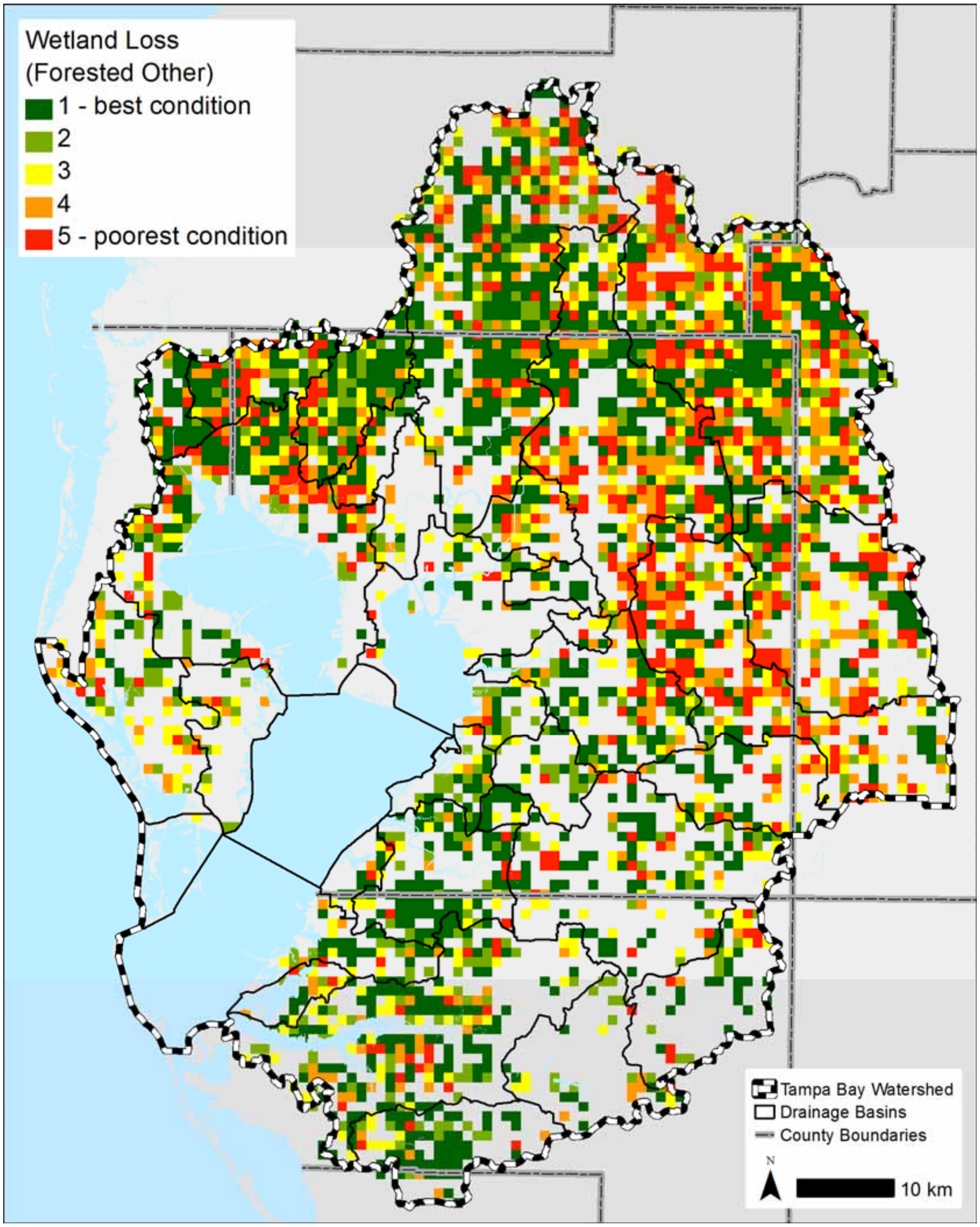


Figure 23. Screening Tool: Loss of Forested Other Wetlands.

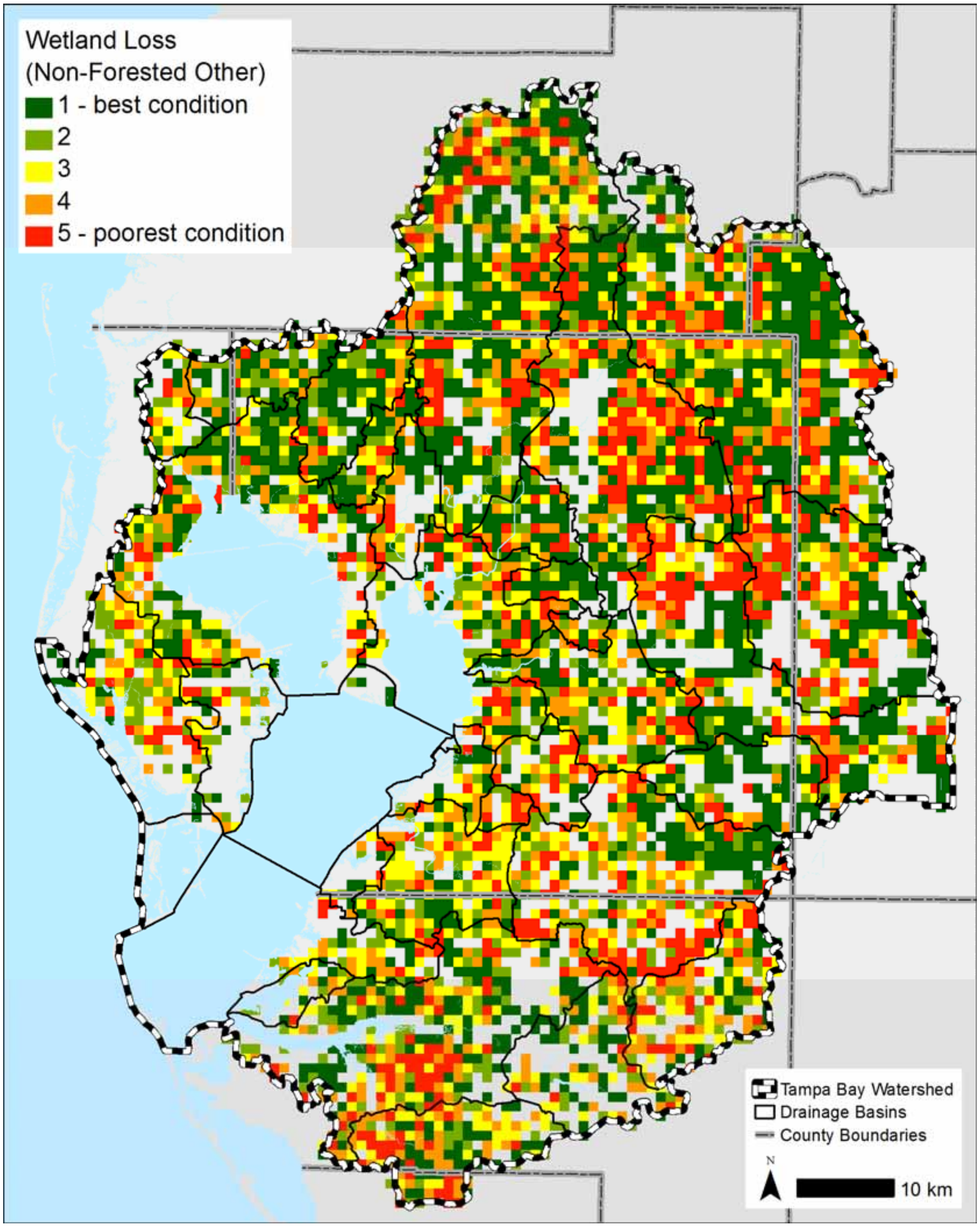


Figure 24. Screening Tool: Loss of Non-Forested Other Wetlands.

Wetland Area

Wetland area remaining screening criteria is shown in Figure 25. As shown on the map, the areas of St. Petersburg and Tampa are in the poorest condition because they have no remaining wetlands within many 1 km^2 grid cells. The best condition, or largest area of wetlands remaining, is in the northeast portion of the study area, near the Hillsborough River.

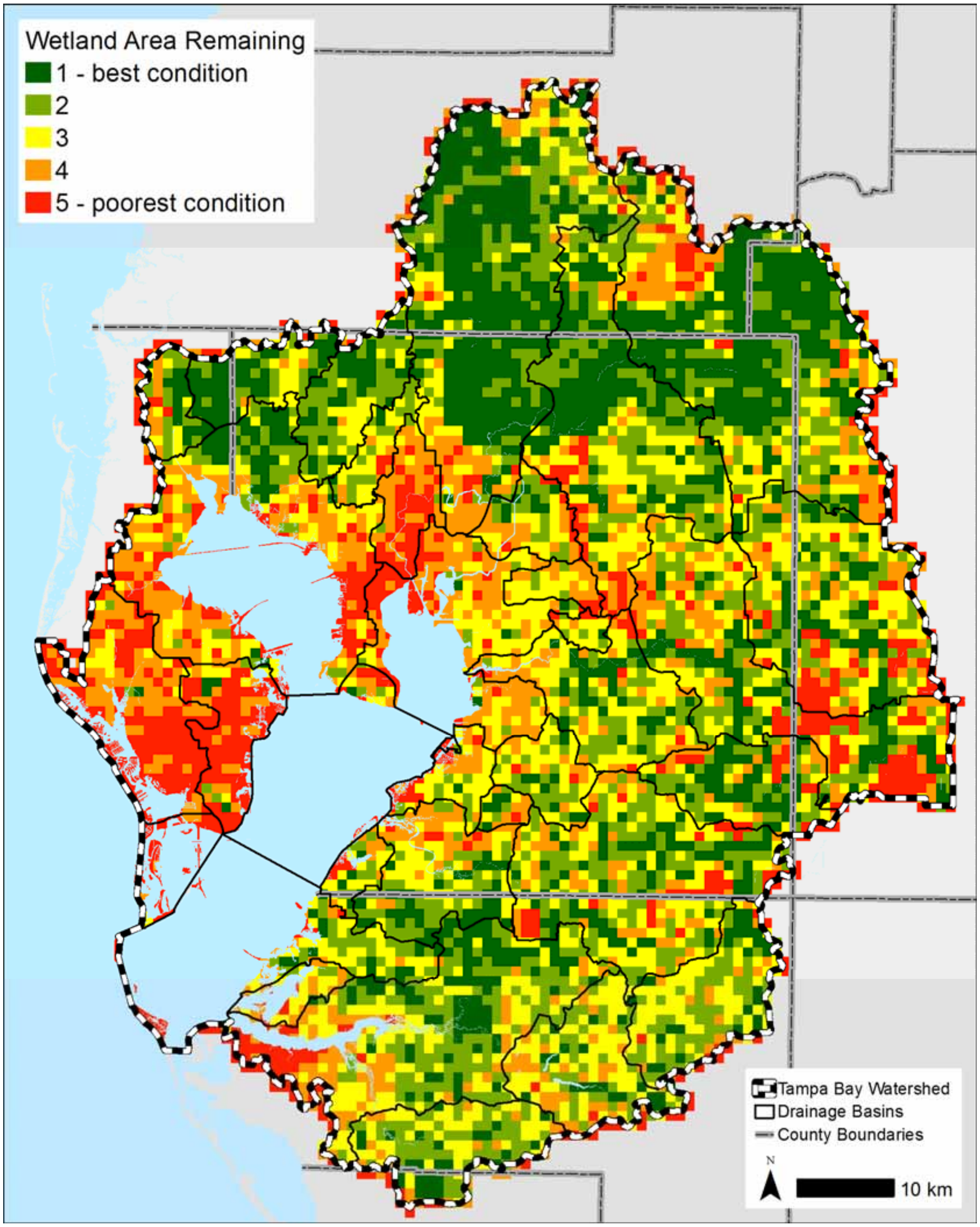


Figure 25. Screening Tool: Wetland Area.

Wetland Condition

Wetland condition for all types of wetlands is shown in Figure 26. Values 1-4 are used to indicate the condition in areas that had wetlands. Areas without wetlands are considered to be the poorest condition and therefore assigned a value of 5. Large areas of wetlands in the best condition are located in the southern, northern and northeastern portions of the study area. Wetland condition is worst in many areas of the urban areas of Tampa and St. Petersburg, as well as in the mined areas in the east.

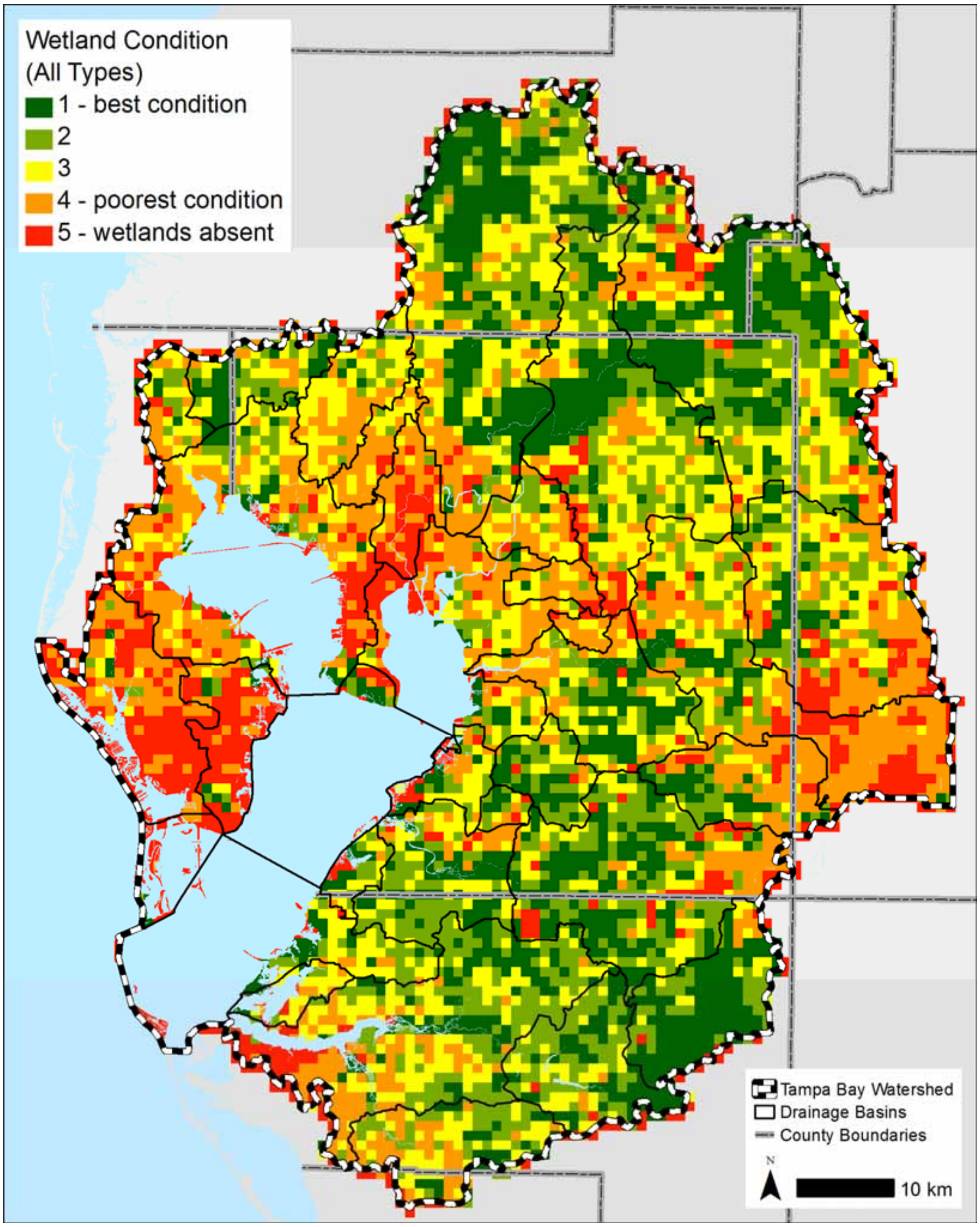


Figure 26. Screening Tool: Condition of All Wetlands.

Wetland Condition by Type

Wetland condition for each individual type of wetlands is shown in Figure 27 through Figure 32. Although the pattern of best and worst condition for each type of wetland is generally similar to the map of all types of wetlands (Figure 26), many 1 km^2 grid cells throughout the study area lack forested riverine wetlands (i.e., 5).

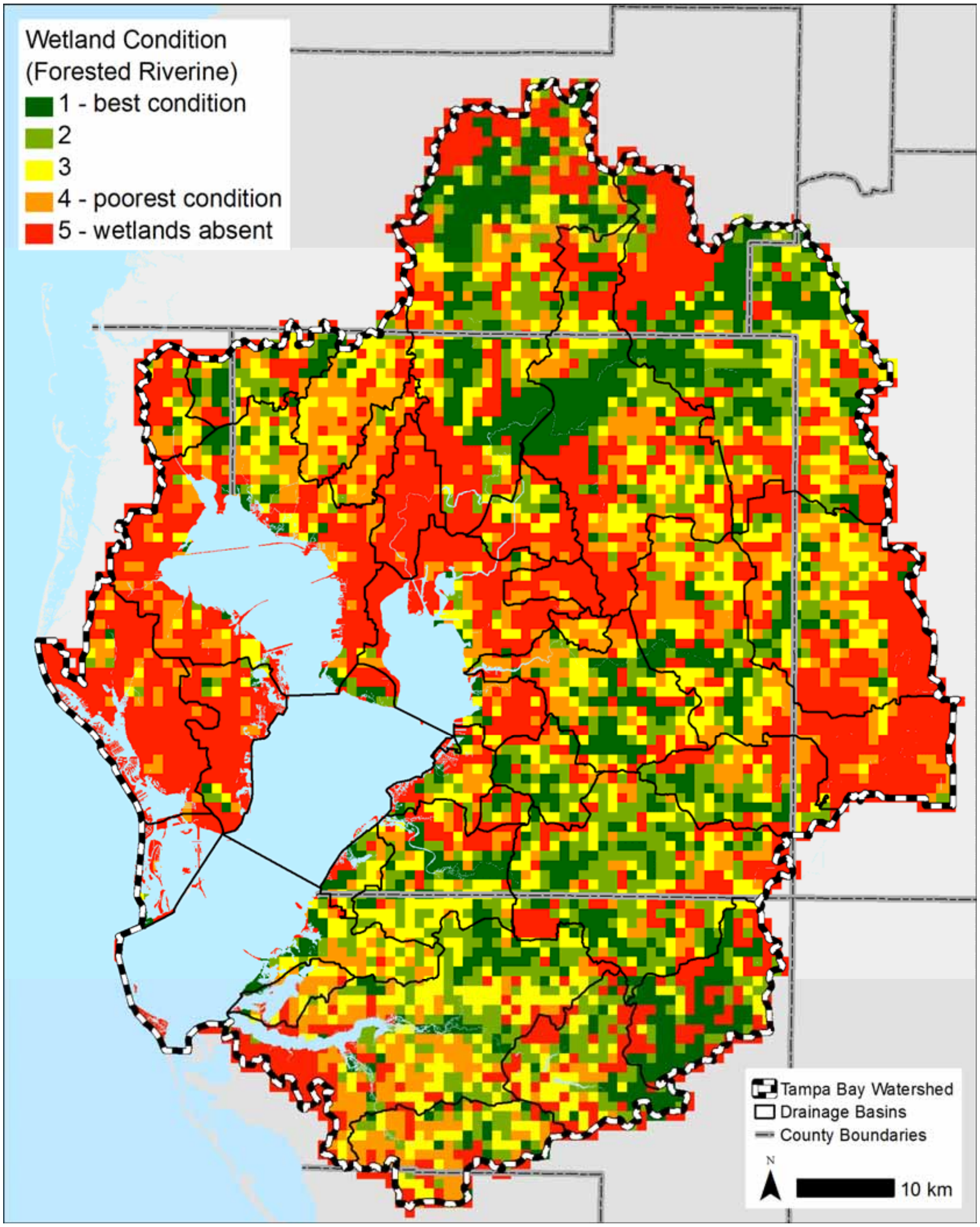


Figure 27. Screening Tool: Condition of Forested Riverine Wetlands.

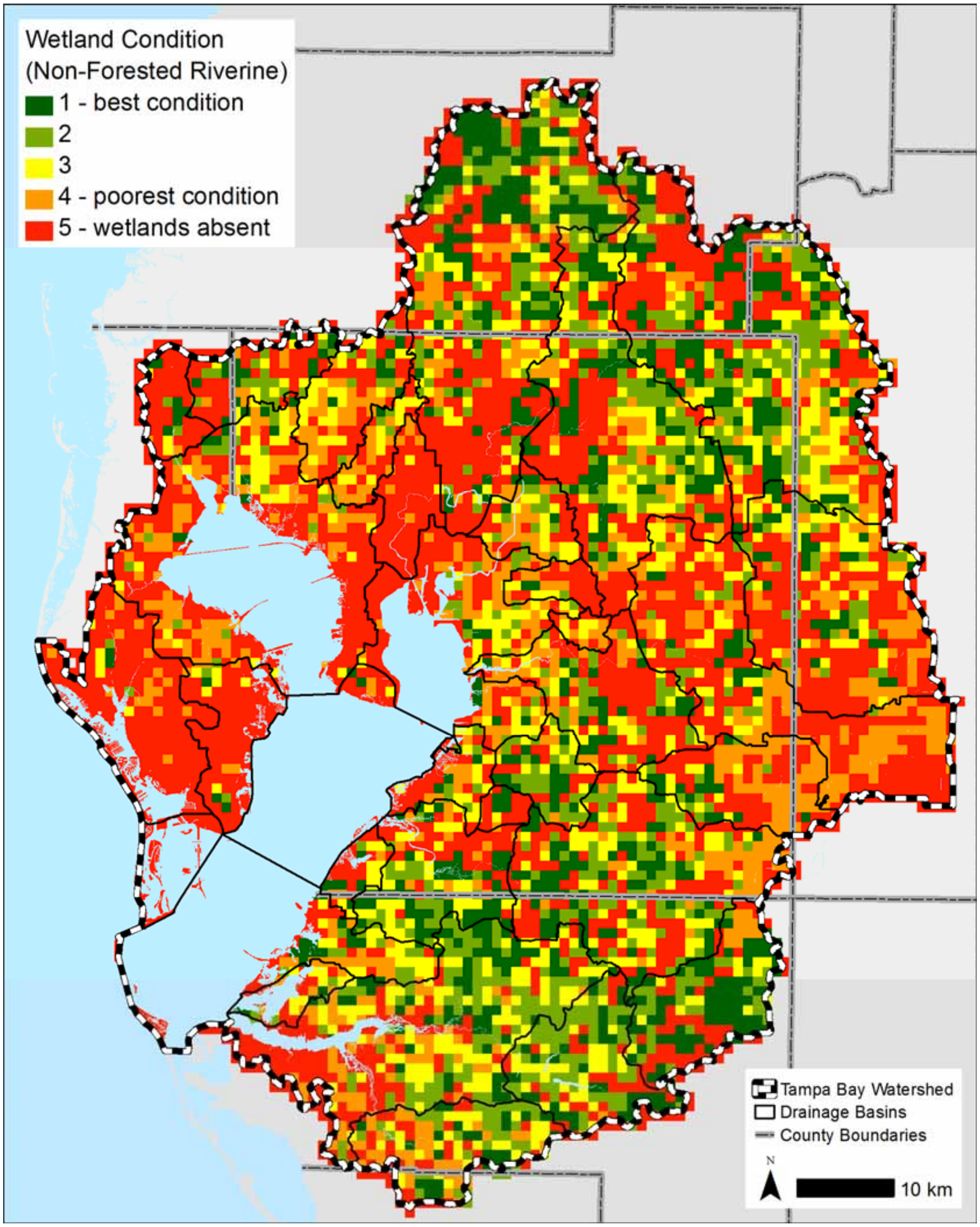


Figure 28. Screening Tool: Condition of Non-Forested Riverine Wetlands.

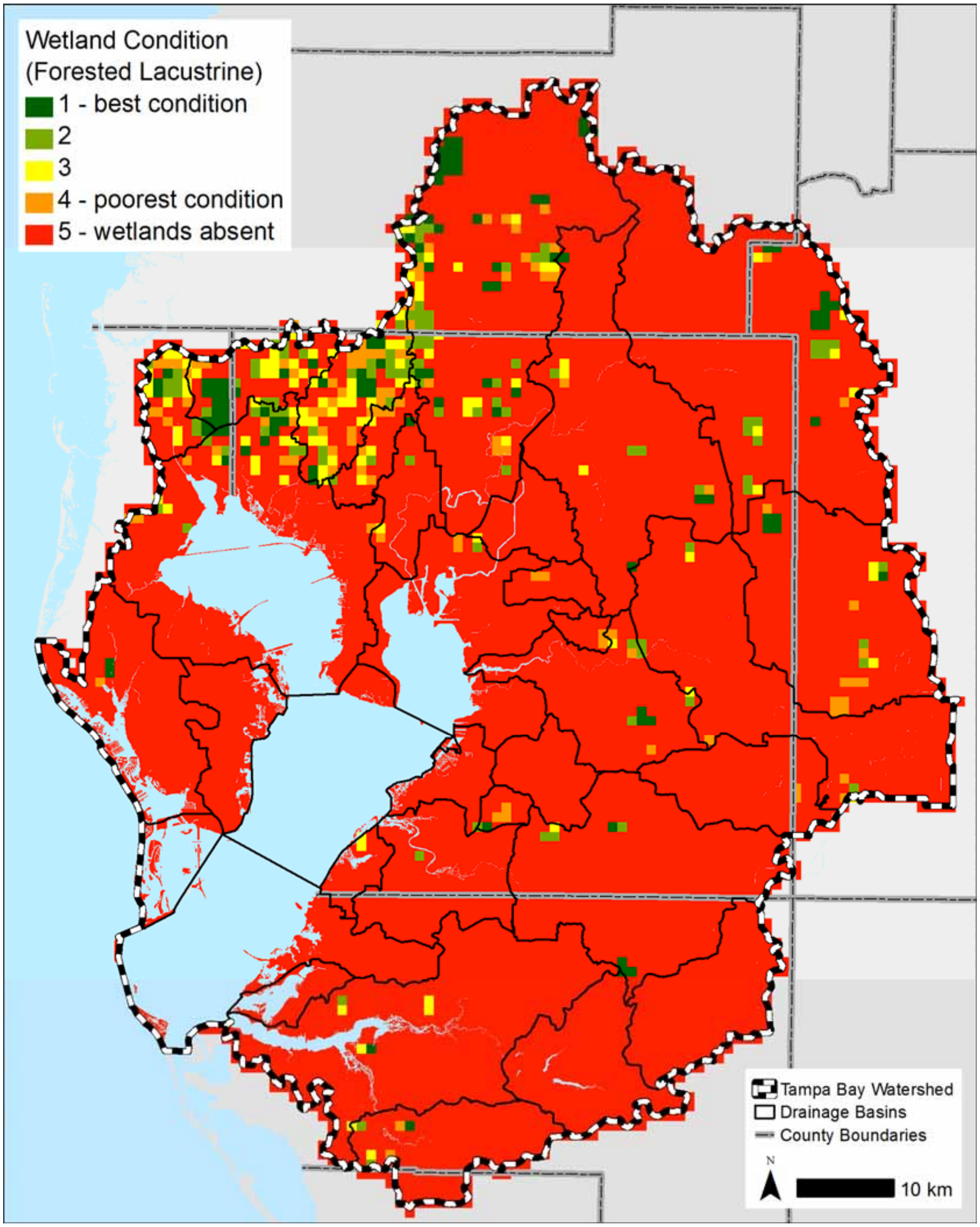


Figure 29. Screening Tool: Condition of Forested Lacustrine Wetlands.

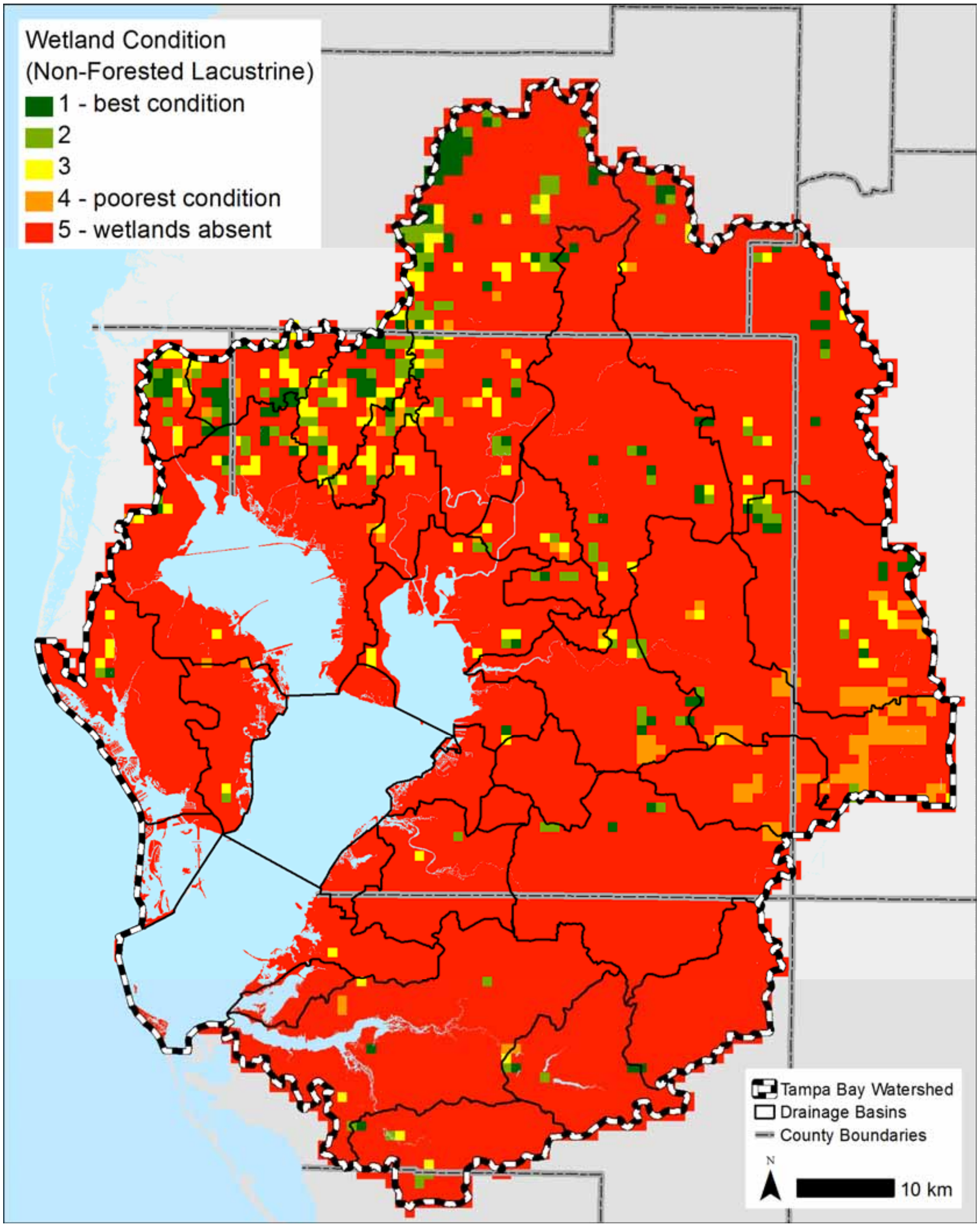


Figure 30. Screening Tool: Condition of Non-Forested Lacustrine Wetlands.

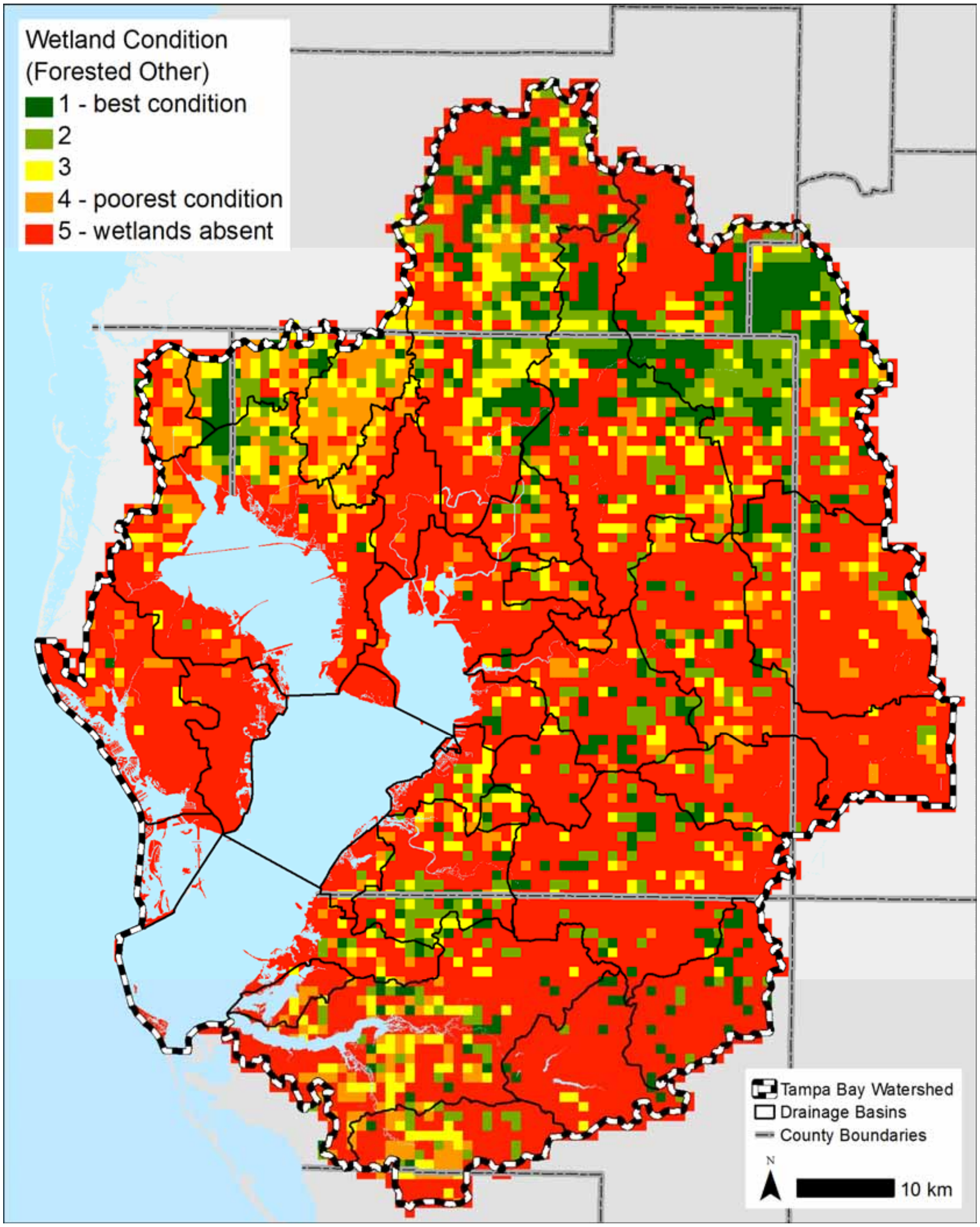


Figure 31. Screening Tool: Condition of Forested Other Wetlands.

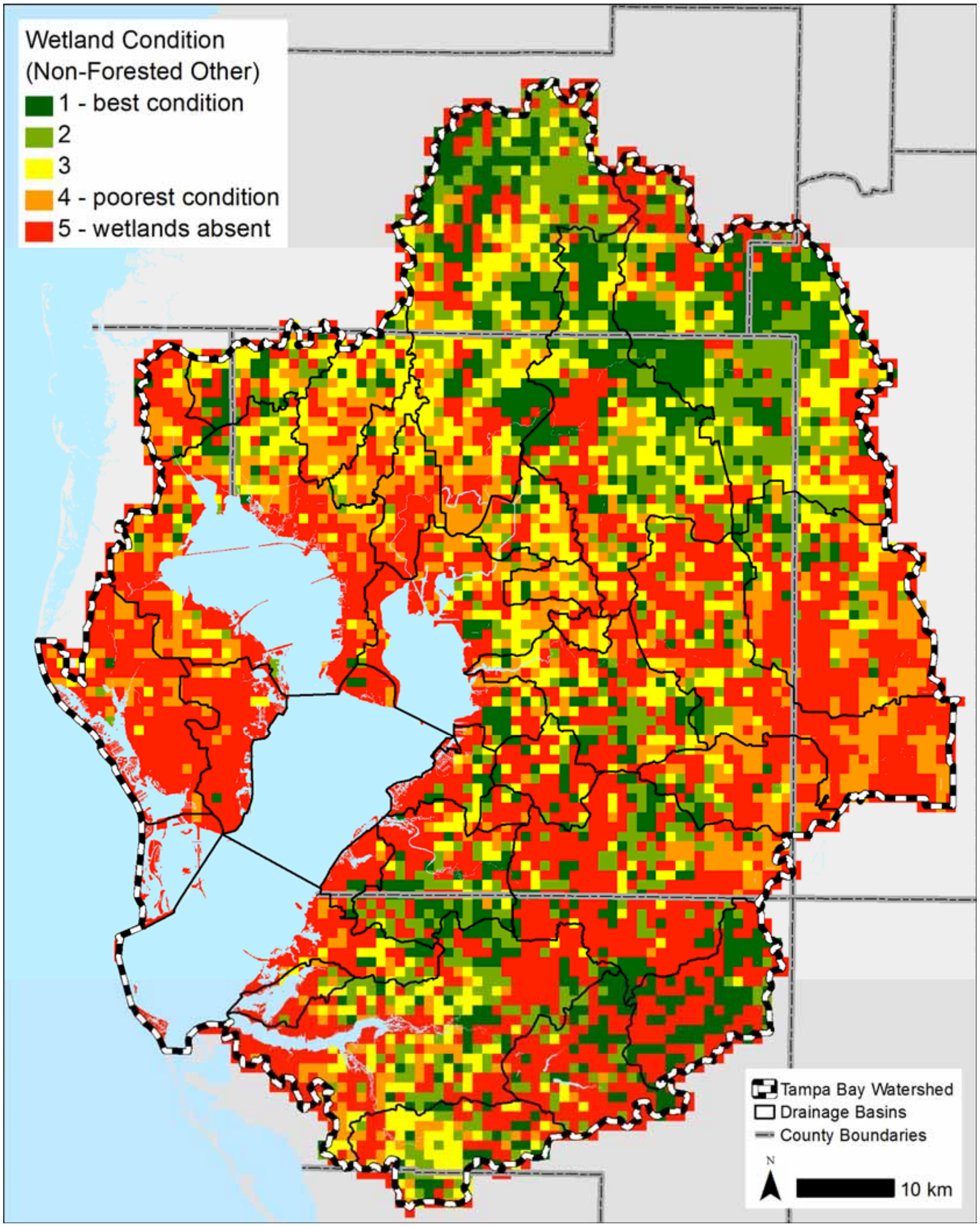


Figure 32. Screening Tool: Condition of Non-Forested Other Wetlands.

Wetland Hydrologic Connectivity

Figure 33 shows the screening criteria for hydrologic connectivity. The map shows 1 km^2 grid cells with riverine wetlands present (i.e., 1) and absent (i.e., 0). As a result of the large networks of creeks, streams and rivers in the study area, many of the grid cells have at least one riverine wetland.

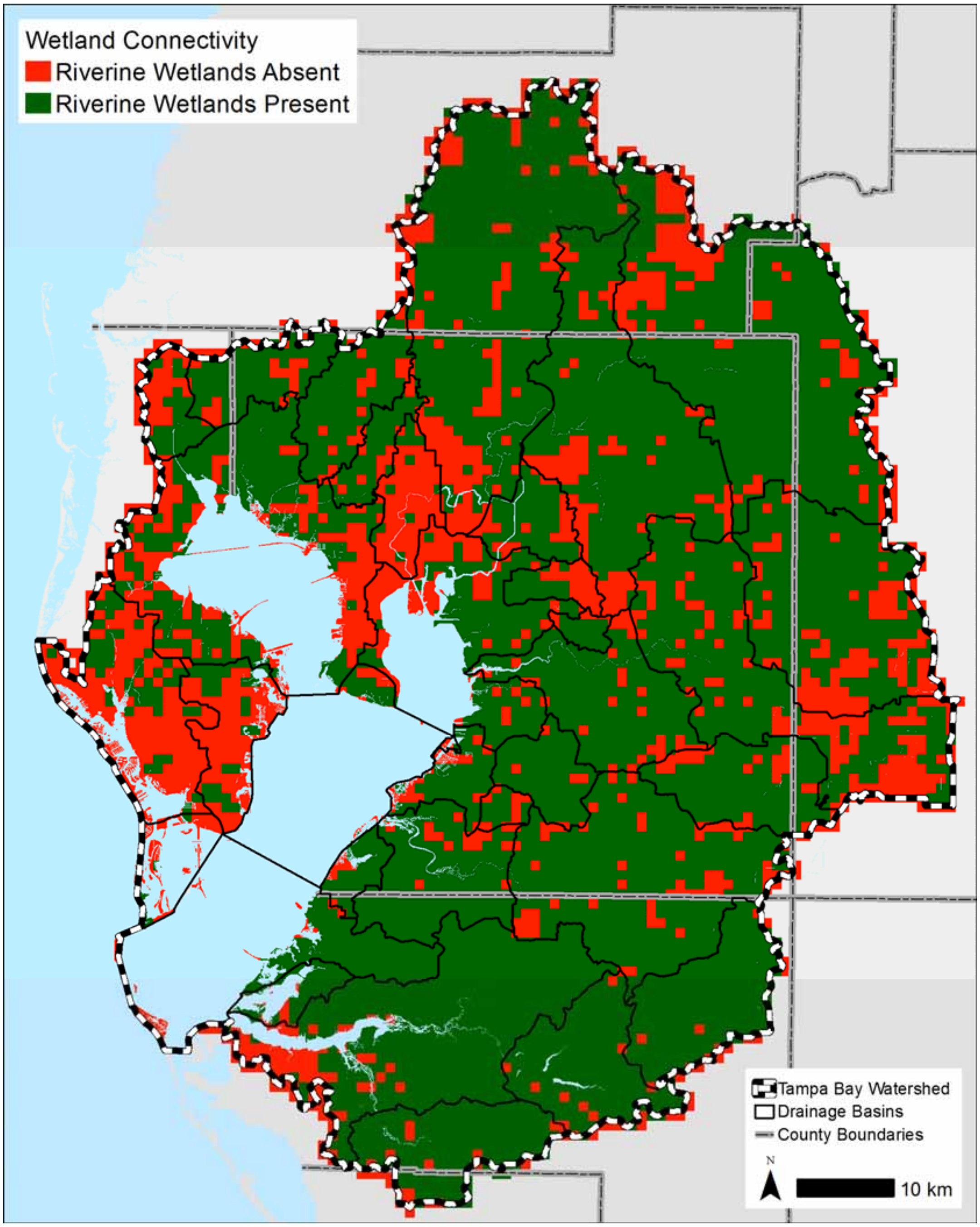


Figure 33. Screening Tool: Connectivity of All Wetlands.

Wetland Mitigation Opportunity / Planned Development Impact

Figure 34 shows the map of best and worst conditions as indicated by the future planned development (i.e., Planned LDI). Because the scores are based on the distribution of LDI values specific to the planned LDI data layer, the best and worst condition may differ greatly from the existing wetland condition maps of Figure 26 through Figure 32.

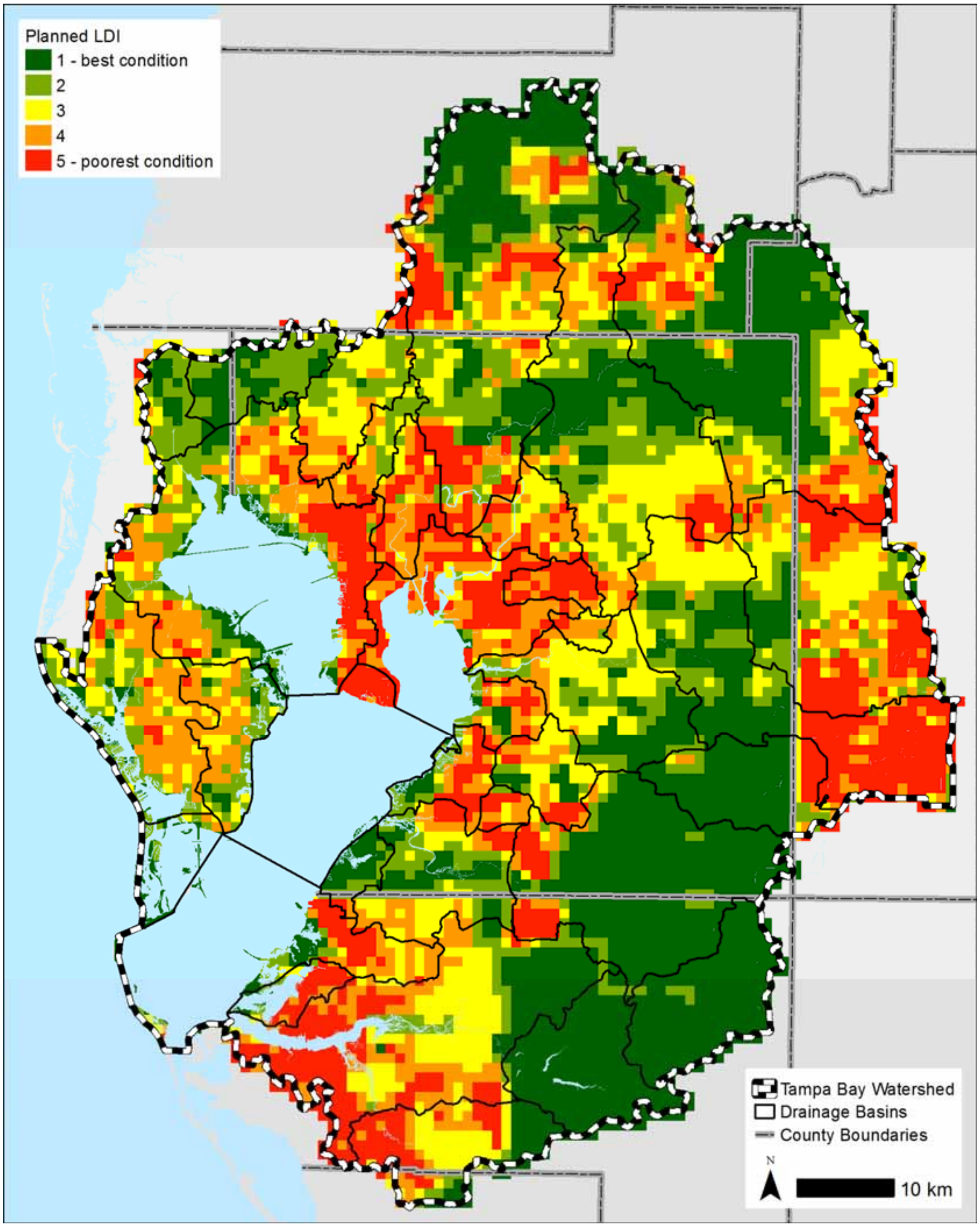


Figure 34. Screening tool: Planned Development Impact (LDI).

Conclusions

The overall objectives of this project were threefold: (1) assess the current status of wetlands within the Tampa Bay Watershed and provide a historical perspective on the losses and gains in wetlands since 1950, (2) establish criteria for addressing which wetlands should be considered for restoration and what the restoration goal should be and (3) suggest tools that management and/or permitting agencies might use to rank wetlands within their jurisdictions for restoration. Such an approach was designed to add complexity, and in a sense uncertainty, progressively to the overall questions leading to increased importance of agencies in the ultimate decision process.

The criteria for wetland loss/gain since 1950 were physical and biological structure, with emphasis on wetland size classes, wetland types, total numbers of systems lost and position within the wateshed. While in line with similar surveys of wetland loss internationally, this strictly structural approach does not provide information on how wetlands have changed in function within the watershed over time. In addition, the role of wetlands created as part of development or mitigation cannot be distinguished from that of "natural" systems in general or such systems that have been hydrologically isolated within the landscape or connected to major development.

Criteria for identifying wetlands to be considered for restoration utilized both structural and functional criteria. Initially, structural elements were considered, including rareness of the wetland type being considered and historical loss of total wetlands by sub-basin within the Tampa Bay watershed. The conditional assessment provided increased complexity to the evaluation, but was an important step toward determining which wetlands were candidates for preservation (e.g., those with low LDI scores) or restoration (e.g., those with moderate to high LDI scores). Similarly, the economic analysis provided increased complexity to the evaluation, but was an important step toward determining locations where preservation or restoration efforts might best be prioritized, given planned development impacts. Connectivity is seen as a secondary criteria that may be of particular interest if one is interested in federal regulatory jurisdiction under the Clean Water Act following the Supreme Court decisions of *SWANCC v US* (2001) and *Rapanos v US* (2006) or in the water quality effects of freshwater wetlands in the Tampa Bay Watershed on Tampa Bay. In this regard, the focus is on hydrological connectivity, because flowing water is a primary mechanism by which mass, energy, and organisms move across landscapes, and because the flow of water is so central to both the federal regulatory context and the water quality in Tampa Bay. To this end, the assessment of hydrologic connectivity was based mainly on surface connectivity with the stream/river network of the watershed, although groundwater connectivity and associated interaction with the stream network was presumed to be related directly to distance from the network as well. Reasoning for this approach was that the closer the wetland to the stream network leading to Tampa Bay, the greater the influence of that wetland ultimately on nutrient loading to the bay. Throughout the analysis, it was recognized that land use was an importance factor determining the watershed function of wetlands, especially related to the extent of impervious surfaces, that had to be considered along with connectivity as a wetland selection criterion.

Selection of the ultimate restoration goal for an individual rests with the agency initiating the process, but it is suggested that, with the exception of extremely rare wetland types, restoration goals should emphasize functional rather than structural criteria. It will be nearly impossible to establish and maintain the structural integrity of a “natural” wetland within a highly urbanized landscape. As hydrology determines the success of both plant and animal species residing in a wetland, linking “protected” wetlands with the urban landscape via storm water runoff can result in hydroperiods and water levels not conducive to characteristic species. In addition, urban development presents an insurmountable physical barrier to biotic exchange with other wetlands and eliminates upland habitats needed for the successful life cycle of many amphibians. If true restoration – i.e., restoration to a pre-development state – is not possible, then mitigation goals should focus on functional criteria, seeking to best restore functional capacity to the Tampa Bay Watershed by carefully taking advantage of the preservation and restoration opportunities that remain available now and will likely remain available in the future. Obvious examples include management of storm water and sequestering of associated nutrients to lessen impacts downstream to Tampa Bay. To this end, the tools provided herein can assist in these decisions, by providing information on what types of wetlands have been lost or impacted in what locations, and what types of opportunities remain now and will likely remain in the not-too-distant future.

A number of criteria were selected from which final decisions for ranking wetlands for restoration can be performed. While a system was proposed to determine the relative importance of individual criteria, it was clearly recognized that only the agency in charge of final selection of wetlands for restoration would be able both to assess and rank the relative importance of individual criteria during the process of wetland evaluation. It must be emphasized that each wetland should be regarded as an individual case; therefore, the criteria and their relative ranking should be applied on a case by case basin.

Acknowledgements

This project was funded through a US Environmental Protection Agency Region IV Regional Wetlands Program Development Grant (Assistance ID # is CD-95415909) by way of the Tampa Bay Estuary Program under the joint project management of Rhonda Evans (US Environmental Protection Agency) and Lindsay Cross and Holly Greening (Tampa Bay Estuary Program). This project could not have been completed without the many participants in four peer-review workshops: Glenn Bailey (Pinellas County), Lisa Baltus (Pinellas County), Diana Bandlow (Florida Department of Environmental Protection), Mark Brown (Southwest Florida Water Management District), Rob Burnes (Pinellas County), Joel Christian (Manatee County), Chris Cooley (Hillsborough County Environmental Protection Commission), Mike Dalsis (Southwest Florida Water Management District), Dick Eckenrod (Tampa Bay Conservancy), Dawn Hart (Hillsborough County Environmental Protection Commission), Brandt Henningsen (Southwest Florida Water Management District), Clark Hull (Southwest Florida Water Management District), Charlie Hunsicker (Manatee County), Amber Jones (Hillsborough County), Charles Kovach (Florida Department of Environmental Protection), Eric Lesnett (Hillsborough County Environmental Protection Commission), Martin Montalvo (Hillsborough County), Alissa Powers (Manatee County), Thomas Ries (Scheda Ecological Associates), Stephen Robinson (Pinellas County), Angela Ryan (US Army Corps of Engineers), Mike Thompson (Hillsborough County Environmental Protection Commission), Laura Thorne (Hillsborough County Environmental Protection Commission), Christina Uranowski (Southwest Florida Water Management District), and Cynthia Wood (US Army Corps of Engineers).

References

Brinson, M.M. 1993. A hydrogeomorphic classification for wetlands, Technical Report WRP-DE-4. US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Brooks, C., M. Wienert, L. Spaete, and R. Dobson. 2008. Georeferencing of scanned historical FSA aerial photographs for extraction of wetlands boundaries and other information for the Michigan NRCS. Michigan Tech Research Institute. Web. Accessed Sept 24, 2009 <http://mtri.org/LinkedDocs/GeoRef_Final.pdf>.

Brooks, R.P., D.H. Wardrop, and J.A. Bishop. 2004. Assessing wetland condition on a watershed basis in the Mid-Atlantic Region using synoptic land-cover maps. Environmental Monitoring and Assessment. 94: 9–22.

Brown, M.T., and M.B. Vivas. 2005. Landscape Development Intensity index. Environmental Monitoring and Assessment 101:289–309.

Cicchetti, G., and H. Greening. 2011. Estuarine biotope mosaics and habitat management goals: An application in Tampa Bay, FL, USA. Estuaries and Coasts 34:1278-1292.

Cowardin, L. M., V. Carter, F. C. Golet, and E.D. LaRoe. 1979. Classification of wetlands and deepwater habitats of the United States. Publication FWS/OBS-79/31. US Department of Interior, Fish and Wildlife Service, Office of Biological Services, Washington, DC.

Dahl, T.E. 2005. Florida's wetlands: An update on status and trends 1985 to 1996. US Department of the Interior, Fish and Wildlife Service, Washington, DC.

Dahl, T.E. 2006. Status and trends of wetlands in the conterminous United States 1998 to 2004. US Department of the Interior, Fish and Wildlife Service, Washington, DC.

ESRI. 2009. Georeferencing a raster dataset, in ArcGIS 9.3 Webhelp. http://webhelp.esri.com/arcgisdesktop/9.3/index.cfm?TopicName=Georeferencing_a_raster_dataset. Accessed 24 September 2009.

Florida Department of Transportation. 1999. Florida Land Use, Cover and Forms Classification System. Florida Department of Transportation, Tallahassee, Florida.

Fennessy, M.S., A.D. Jacobs, and M.E. Kentula. 2007. Review of rapid methods for assessing wetland condition. EPA/620/R-04/009. US Environmental Protection Agency, Washington, DC.

Fennessy, M.S., A.D. Jacobs, and M.E. Kentula. 2007. An evaluation of rapid methods for assessing the ecological condition of wetlands. Wetlands 27:543-560.

Fretwell, J.D., J.S. Williams, and P.J. Redman (eds). 1996. National water summary on wetland resources. US Geological Survey Water-Supply Paper 2425. US Government Printing Office, Washington, DC.

Haag, K.H., and T.M. Lee. 2010. Hydrology and ecology of freshwater wetlands in central Florida—A primer. US Geological Survey Circular 1342. US Government Printing Office, Washington, DC.

Haag, K.H., T.M. Lee, and D.C. Herndon. 2005. Bathymetry and vegetation in isolated marsh and cypress wetlands in the northern Tampa Bay area, 2000-2004. US Geological Survey Scientific Investigations Report 2005-5109. US Government Printing Office, Washington, DC.

Hammond, R.E. 2005. Methodology for georeferencing historical Hillsborough County aerial imagery. Tech. 2005. Print.

Hefner, J.M., and J.D. Brown. 1984. Wetland trends in the southeastern United States. Wetlands 4:1–11.

Knochenmus, L.A. 2006. Regional evaluation of the hydrogeologic framework, hydraulic properties, and chemical characteristics of the intermediate aquifer system underlying southern west-central Florida. US Geological Survey Scientific Investigations Report 2006-5013. US Government Printing Office, Washington, DC.

Lee, T.M., K.H. Haag, P.A. Metz, and L.A. Sacks. 2009. Comparative hydrology, water quality, and ecology of selected natural and augmented freshwater wetlands in west-central Florida. US Geological Survey Professional Paper 1758. US Government Printing Office, Washington, DC.

Lewis Environmental Services, Inc. 1995. Setting Priorities for Tampa Bay Habitat Protection and Restoration: Restoring the Balance. Technical Publication #09-95 of the Tampa Bay National Estuary Program.

Miller, J.A. 1997. The hydrogeology of Florida. Pp. 69-88 in D.S. Jones and R. Randazzo (eds), The Geology of Florida, University Press of Florida, Gainesville, Florida.

Milon, J.W., D. Scrogin, and J. Weishampel. 2009. A consistent framework for valuation of wetland ecosystem services using discrete choice methods. National Center for Environmental Economics, US Environmental Protection Agency, Washington, DC.

Nilsson, K.A., M.C. Rains, D.B. Lewis, and K.E. Trout. In Review. Hydrologic characterization of 56 geographically isolated wetlands in west-central Florida using a probabilistic method. Wetlands Ecology and Management.

PBS&J. 2010. Tampa Bay Estuary Program Habitat Master Plan Update. Technical Report #06-09 of the Tampa Bay Estuary Program.

Reiss, K.C., and M.T. Brown. 2007. Evaluation of Florida palustrine wetlands: Application of USEPA Levels 1, 2, and 3 assessment methods. EcoHealth 4:206-218.

Reiss, K.C., M.T. Brown, and C.R. Lane. 2010. Characteristic community structure of Florida's subtropical wetlands: the Florida wetland condition index for depressional marshes, depressional forested, and flowing water forested wetlands. Wetlands Ecology and Management 18:543-556.

Sinclair, W.C. 1974. Hydrologic characteristics of the surficial aquifer in northwest Hillsborough County, Florida. Florida Bureau of Geology Information Circular 86. Florida Bureau of Geology, Tallahassee, Florida.

Sinclair, W.C. 1977. Experimental study of artificial recharge alternatives in northwest Hillsborough County, Florida. US Geological Survey Water-Resources Investigations 77-13. US Government Printing Office, Washington, DC.

Smith, R.D., A. Ammann, C. Bartoldus, and M.M. Brinson. 1995. An approach for assessing wetland functions using hydrogeomorphic classification, reference wetlands, and functional indices. Technical Report WRP-DE-9. US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Stetler, R., B. Wharton, E. Kelly, G. Morrison, and E. Lesnett. 2005. Freshwater Wetlands: Status and Trends. Proceedings, Tampa Bay Area Scientific Information Symposium, BASIS4: 27-30 October 2003, St. Petersburg, FL., Tampa Bay Estuary Program.

Stewart, J.W. 1968. Hydrologic effects of pumping from the Floridan aquifer in northwest Hillsborough, northeat Pinellas, and southwest Pasco Counties, Florida. US Geological Survey Open-File Report 68-005. US Government Printing Office, Washington, DC.

Southwest Florida Water Management District. 1996. Northern Tampa Bay Water Resources Assessment Project: Vol. 1, Surface-water/ground-water interrelationships. Southwest Florida Water Management District, Brooksville, Florida.

Southwest Florida Water Management District. 2002a. 1950 land use [Computer File, GIS shapefiles]. Obtained from April Davis.

Southwest Florida Water Management District. 2002b. 1990 land use/cover classifications [Computer File, GIS shapefiles]. Retrieved from http://www.swfwmd.state.fl.us/data/gis/layer_library/metadata/lu90.html\

Southwest Florida Water Management District. 2003. 1970's black and white aerial photography [Computer File, GIS raster imagery]. Obtained from April Davis.

Southwest Florida Water Management District. 2007a. 2007 one foot natural color ortho photographs – Central District [Computer File, GIS raster imagery]. Obtained from April Davis

Southwest Florida Water Management District. 2007b. 2005 land use/cover classifications [Computer File, GIS shapefiles]. Retrieved from http://www.swfwmd.state.fl.us/data/gis/layer_library/metadata/lu05.html

Southwest Florida Water Management District. 2008. 2007 land use/cover classifications [Computer File, GIS shapefiles]. Retrieved from http://www.swfwmd.state.fl.us/data/gis/layer_library/metadata/lu07.html

Tihansky, A.B., 1999, Sinkholes, west-central Florida. Pp. 121-140 in D. Galloway, D.R. Jones, and S.E. Ingebritsen (eds.), Land subsidence in the United States: US Geological Survey Circular 1182. US Government Printing Office, Washington, DC.

US Environmental Protection Agency. 2002. Wetland monitoring and assessment: a technical framework. EPA 843-F-02-002(h). US Environmental Protection Agency, Washington, DC.

US Environmental Protection Agency. 2010. National Wetland Condition Assessment. (http://www.epa.gov/wetlands/survey/).

US Geological Survey. 1982. Habitat data for Tampa Bay, Florida, USA, in 1952. [Computer File, GIS coverages]. Retrieved from http://dl.cr.usgs.gov/net_prod_download/public/gom_net_pub_products/metadata/tb_hab52.htm

US Geological Survey. 2008. High resolution national hydrography dataset. [Computer File, GIS shapefiles]. Retrieved from http://nhdgeo.usgs.gov/metadata/nhd_high.htm

Weller, D. E., M. N. Snyder, D. F. Whigham, A. D. Jacobs, and T. E. Jordan. 2007. Landscape indicators of wetland condition in the Nanticoke River Watershed, Maryland and Delaware, USA. Wetlands 27: 498–514.

Whigham, D. F., A. D. Jacobs, D. E. Weller, T. E. Jordan, M. E. Kentula, S. F. Jensen, and D. L. Stevens. 2007. Combining HGM and EMAP procedures to assess wetlands at the watershed scale - status of flats and non-tidal riverine wetlands in the Nanticoke River Watershed, Delaware and Maryland (USA). Wetlands 27: 462–478.

Appendix A: FLUCCS to LDI crosswalk used for conditional assessment

The table below provides the full crosswalk between FLUCCS codes contained within the 2007 SWFWMD LULC dataset and the LDI value assigned as an indicator of wetland condition.

Table 11. FLUCCS to LDI Crosswalk.

FLUCCS	FLUCCS Description	LDI
1100	RESIDENTIAL LOW DENSITY < 2 DWELLING UNITS	6.9
1200	RESIDENTIAL MED DENSITY 2->5 DWELLING UNIT	7.47
1300	RESIDENTIAL HIGH DENSITY	8.66
1400	COMMERCIAL AND SERVICES	8.59
1500	INDUSTRIAL	8.32
1600	EXTRACTIVE	8.32
1650	RECLAIMED LAND	8.32
1700	INSTITUTIONAL	8.07
1800	RECREATIONAL	4.38
1820	GOLF COURSES	6.92
1900	OPEN LAND	1.83
2100	CROPLAND AND PASTURELAND	3.41
2140	ROW CROPS	4.54
2200	TREE CROPS	3.68
2300	FEEDING OPERATIONS	7
2400	NURSERIES AND VINEYARDS	3.68
2500	SPECIALTY FARMS	7
2550	TROPICAL FISH FARMS	7
2600	OTHER OPEN LANDS <RURAL>	2.02
3100	HERBACEOUS	2.02
3200	SHRUB AND BRUSHLAND	2.02
3300	MIXED RANGELAND	2.02
4100	UPLAND CONIFEROUS FOREST	1
4110	PINE FLATWOODS	1
4120	LONGLEAF PINE - XERIC OAK	1
4200	UPLAND HARDWOOD FORESTS - PART 1	1
4340	HARDWOOD CONIFER MIXED	1
4400	TREE PLANTATIONS	1.58
5100	STREAMS AND WATERWAYS	1
5200	LAKES	1
5300	RESERVOIRS	4.38
5400	BAYS AND ESTUARIES	1
5720	GULF OF MEXICO	1
6100	WETLAND HARDWOOD FORESTS	1
6110	BAY SWAMPS	1
6120	MANGROVE SWAMPS	1
6150	STREAM AND LAKE SWAMPS (BOTTOMLAND)	1
6200	WETLAND CONIFEROUS FORESTS	1
6210	CYPRESS	1
6300	WETLAND FORESTED MIXED	1
6400	VEGETATED NON-FORESTED WETLANDS	1

FLUCCS	FLUCCS Description	LDI
6410	FRESHWATER MARSHES	1
6420	SALTWATER MARSHES	1
6430	WET PRAIRIES	1
6440	EMERGENT AQUATIC VEGETATION	1
6520	SHORELINES	1
6530	INTERMITTENT PONDS	1
6600	SALT FLATS	1
6600	SALT FLATS	1
7100	BEACHES OTHER THAN SWIMMING BEACHES	1
7200	SAND OTHER THAN BEACHES	1
7400	DISTURBED LAND	4.375
8100	TRANSPORTATION	8.045
8200	COMMUNICATIONS	8.32
8300	UTILITIES	8.32

Appendix B: Overview of Screening Criteria Usage

This section provides a demonstration of the use of the Wetland Screening Criteria. The demonstration is meant to serve as an example of how the criteria might be used to address basic prioritization questions. The brief instructions outlined here are written for the level of expertise of a user of geographic information systems applications, but the terminology may be specific to the ESRI ArcGIS 10 suite of applications.

Screening Criteria Project Goal: Locate potential areas for wetland restoration efforts in areas of the watershed that lost a lot of wetlands between 1950-2007, and where restoration may make a substantial contribution to wetland-based water quality treatment, but in areas that will be less impacted by future planned development.

The Wetland Screening Criteria dataset (GIS data layer name: Wetland_Screening_Criteria contains 17 separate criteria: Wetland Condition, Wetland Condition by Type of wetland (6 criteria), Wetland Loss, Wetland Loss by Type (6 criteria), Wetland Area, Wetland Hydrological Connectivity, and Wetland Mitigation Opportunity / Planned Development Impact. The GIS data layer is structured as a polygon grid with an attribute table that contains separate columns for each criterion. Record selection (i.e. selecting grid cells) based on attributes is one of the easiest GIS methods to locate potential areas that meet the project goal.

The following steps illustrate this example:

1. In this example, the screening goal might be to find wetlands that are currently in poor condition (i.e. Wetland Condition) where restoration will be beneficial. Using the attribute selection tool of the GIS application, we might select grid cells with wetland condition ranked as 4 or 5 (on a scale of 1=best condition and 5=worst condition).
2. A second goal might be to focus on portions of the watershed that lost a relatively large amount of wetland area, such that providing restored wetlands to the area might make a relatively large improvement to the water quality treatment capacity of the sub-basin. Using the “remove from selection” attribute selection tool of the GIS application, we would select grid cells where wetland loss was not the worst (select wetland loss = 4 or 5). The result after the remove from selection query would be grid cells with wetlands of condition 4 or 5 where the grid cell lost substantial amounts of wetland between 1950-2007.
3. Finally, we want to invest in restoration in areas where the land is not planned for extensive land use densification. Although one might argue with this strategy, the example suggests that we would not want to invest in restoration where future surrounding impacts would negatively impact the wetland. In this case, we wish to only consider grid cells where Planned LDI is the best condition (i.e. a score of 1 or 2). Using the “remove from selection” query, we would select Planned LDI values of worse than 1 or 2 (i.e., greater than 2).

The final result would meet the three goals of our analysis. Figure 35 provides a map of the grid cells remaining after the three-step selection process illustrated by the example. The Target Areas are shown as the selected grid cells that met all three criteria.

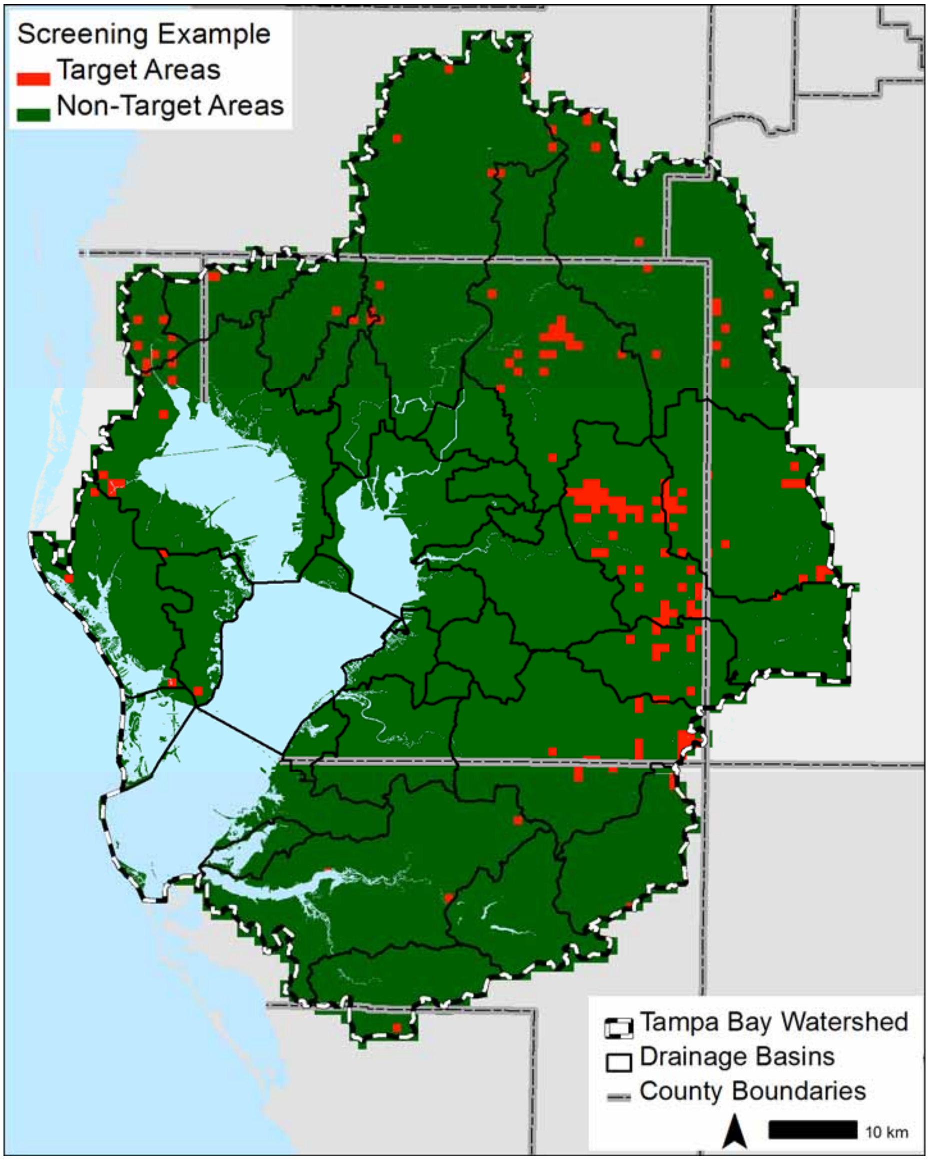


Figure 35. Target areas selected following screening criteria example.