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# A Wetland Restoration Spatial Decision Support System for the Mississippi Gulf Coast

Jeff P. Lin and Barbara A. Kleiss

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**Abstract:** The Engineer Research and Development Center, Environmental Laboratory, has created a Wetlands Restoration Spatial Decision Support System (SDSS) based on Geographic Information System (GIS) tools. SDSS will be used to identify and prioritize potential wetland restoration areas along the Mississippi Gulf Coast as part of the non-structural solutions planned for that area following Hurricane Katrina. Advantages of the SDSS approach include relatively rapid identification and assessment of a large number of restoration sites across a wide area. Potential sites can also be evaluated and restored in a watershed or landscape context, maximizing the benefits of wetland restoration.

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# Preface

This report was prepared by Jeff P. Lin and Dr. Barbara A. Kleiss, both of the Environmental Laboratory (EL), Wetlands and Coastal Ecology Branch (ECEB), U.S. Army Engineer Research and Development Center (ERDC). The authors would like the thank Darrell Evans and Scott Bourne, both of EL, for additional review of this report.

This report was completed under funding from the U.S. Army Engineer District, Mobile. This work took place under the general supervision of Dr. Morris Mauney, Jr., Chief, ECEB; Dr. David J. Tazik, Chief, Ecosystem Evaluation and Engineering Division, EL; and Dr. Beth Fleming, Director, EL.

COL Richard B. Jenkins was Commander and Executive Director of ERDC. Dr. James R. Houston was Director.

# 1 Introduction

In response to major damages on the coast of Mississippi as a result of Hurricane Katrina, Congress has directed the U.S. Army Corps of Engineers to conduct an analysis and design for comprehensive modifications and improvements in the Mississippi Coast area for the purposes of hurricane damage reduction, prevention of saltwater intrusion, preservation of fish and wildlife, prevention of erosion, and other related water resources purposes. One proposed improvement is the large-scale restoration of coastal wetlands, which would address both storm protection and fish and wildlife preservation issues. Wetlands primarily reduce storm damage in two ways: 1) by providing an offshore buffer, which diminishes wave energy, storm surge, and coastal erosion prior to the water hitting the shoreline; and 2) by providing storm water storage areas and buffers in the headwater areas of tidal creeks. Additionally, wetlands provide valuable habitat for a variety of fish and wildlife species.

The Engineer Research and Development Center's Environmental Laboratory was tasked to create a Wetland Restoration Spatial Decision Support System (SDSS) based on Geographic Information System (GIS) tools that could be used to identify and prioritize potential wetland restoration areas along the Mississippi Gulf Coast as part of the non-structural solutions planning in that area. There are several benefits in using an SDSS and GIS-based approach to wetland restoration. This approach allows for the relatively rapid identification and assessment of a large number of restoration sites across a wide area. Also, potential sites can be evaluated and restored in a watershed or landscape context. Using this approach can help to maximize the benefits of wetland restoration.

# 2 Description of the SDSS

## General overview

The SDSS has two general components or steps: 1) the identification of potential wetland restoration areas, and 2) evaluation of these identified areas. The purpose of the first step is to obtain from the entire study area (Mississippi coastal counties) sites that meet the basic objectives of the study or plan. In this case, the objective is private property buyouts in hurricane-damaged areas, in lieu of rebuilding. Therefore, one screening mechanism was to eliminate from consideration areas that were not damaged by the hurricane. After the initial screening is complete, the identified sites are then evaluated and scored based on their suitability to be restored into wetland, and their potential to provide quality wildlife habitat and storm and flooding protection. This evaluation can then be used to rate, prioritize, and select sites for restoration.

## Identification and evaluation of potential restoration areas

Both the identification and evaluation of sites consists of combining multiple GIS layers that are originally in, or have been converted to, a raster (cell-based) format. The spatial extent of all layers used is the three coastal Mississippi counties: Harrison, Hancock, and Jackson. The following sections will list each layer that was used, along with the following information:

***Source:*** Where the data layer originally came from, and the date of collection, if known.

***Description***: The type of information that is contained in the layer.

***Purpose***: Justification of inclusion in the SDSS.

***Processing***: Any GIS processing of the original layer so that it could be incorporated into the SDSS. Because the highest native resolution of any of the layers used is 10 m by 10 m, the final processing step for all layers is conversion to a raster of this resolution.

***Limitations***: Any significant factors, including processing methods, which could potentially affect the accuracy of the layer.

### Identification of potential restoration areas

Potential restoration areas were selected by combining three different spatial layers: 1) storm-damaged areas, 2) FEMA 100-year floodplain, and 3) non-natural land cover. The SDSS identified blocks are intended to be used as a guide as to the general location of restorable areas. However, because of the spatial resolution (30 m) of the land cover file, it should be noted that the exact boundaries of each potential restoration block in the SDSS may not be precise. The boundaries of an actual restoration area may differ slightly, or may only encompass a portion of the SDSS identified block.

1. Storm-damaged areas

   ***Source:*** FEMA, residential substantial damage estimate (RSDE) (date unknown) and post-storm imagery derived estimation of damage (IDD) map (9/5/05).

   ***Description***: This is a combination of two separate data layers. The IDD layer (a polygon layer) was an image-derived storm damage assessment that was generated within a week after Hurricane Katrina. The second layer (a point layer) is the RSDE map, which consists of locations of individual residences and an estimate as to the amount of damage sustained.

   ***Purpose***: Areas damaged by the hurricane are potential buyout areas that may be suitable for wetland restoration as part of the non-structural solutions plan.

   ***Processing***: The IDD shapefile was converted to a raster. The RSDE point shapefile was also converted to a raster, with each individual point corresponding to a 100-m by 100-m cell. This raster was then mosaicked with the image-derived raster in order to create the final damaged areas raster.

   ***Limitations***: The damaged areas as presented in the layer may be incomplete.

2. FEMA 100-year floodplain map

   ***Source:*** FEMA (date unknown, although pre-Katrina)

   ***Description***: This layer consists of areas that are within the FEMA 100-year floodplain, including areas susceptible to storm surge.

   ***Purpose***: Areas within the 100-year floodplain are more susceptible to future flood and storm damage, and thus can be potential buyout areas that can then be restored to wetland as part of the non-structural solutions plan.

   ***Processing***: The FEMA 100-year floodplain shapefile was converted to a raster.

   ***Limitations***: None.

3. Non-natural land cover

   ***Source***: Derived from Mississippi Department of Marine Resources (MDMR) land cover data (2001)

   ***Description***: This layer consists of urban (vegetated and non-vegetated), agricultural, and deforested land.

   ***Purpose***: Areas that are already in a "natural" land cover do not need to be restored; therefore, only non-natural areas were targeted.

   ***Processing***: The original 30-m by 30-m land cover raster was reclassified into natural/non-natural. The following MDMR land cover categories were classified as "non-natural": high and medium density urban, cropland/pasture/grassland, upland sand/barren, wet sand/barren, wet cutover land, and upland cutover land.

   ***Limitations***: Land cover may have changed since 2001, and the layer does not capture changes in land use that are less than 30 m by 30 m.

### Creating the "Potential Restoration Areas" layer

Any 10-m by 10-m cell in the three Mississippi coastal counties that fell within the areas covered by all three of these layers was considered to be part of a potential restoration area. Any contiguous group of cells were considered to be a single restoration "block." The final layer of potential restoration sites was then created by selecting all blocks that were ≥ 1 acre. In total, 1,086 sites totaling 7,892 acres were identified and evaluated. Figure 1 is an overview of the locations of these restoration blocks in the coastal counties.

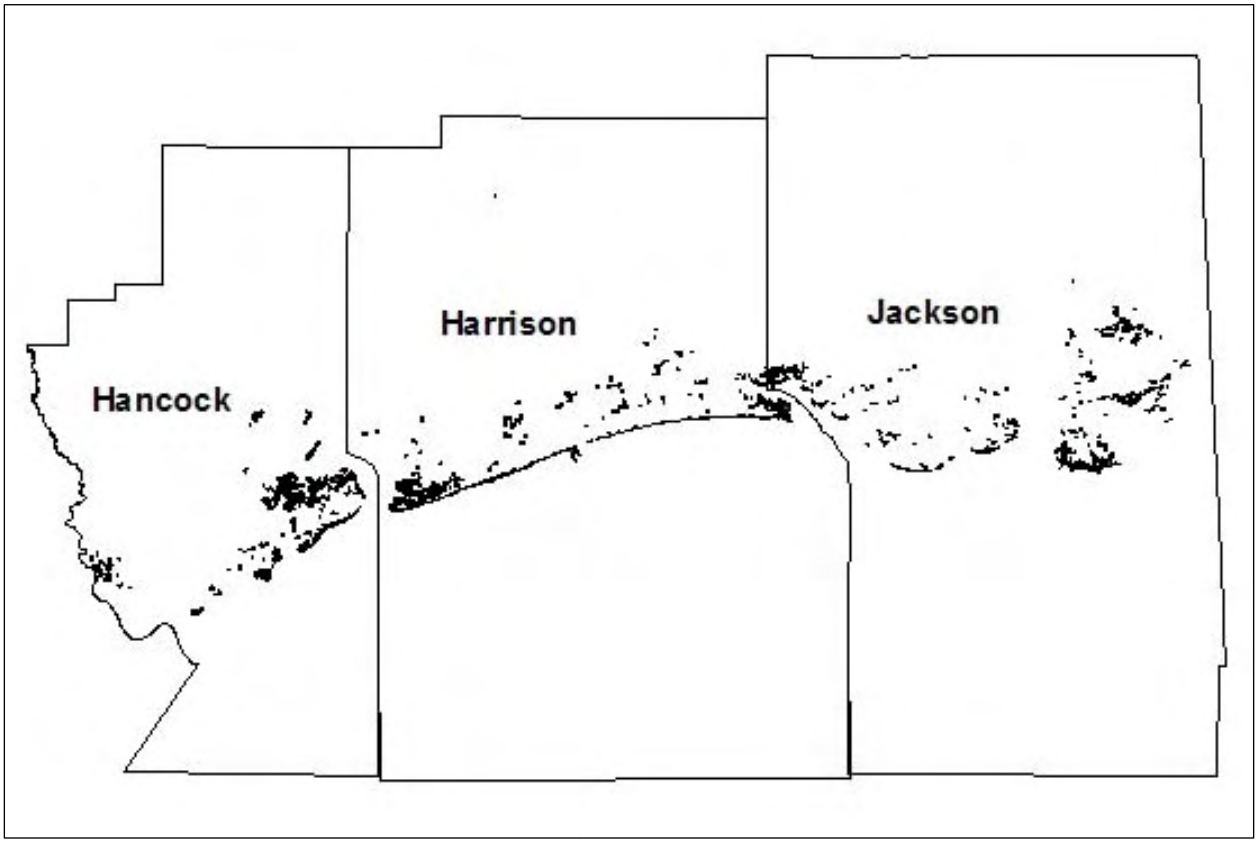


Figure 1. Location of SDSS identified restoration blocks in the three Mississippi coastal counties.

### Variables used for the evaluation of Potential Restoration Areas

GIS layers used to evaluate the potential restoration areas were divided into four categories/functions: Wetland Restorability, Storm Surge/Flood Protection, Habitat, and Other Layers.

*Wetland restorability*

These variables measure the suitability of an area to be a functioning and sustainable wetland. The variables address the three factors that define a jurisdictional wetland: hydrology, hydric soils, and wetland vegetation (Environmental Laboratory 1987).

1. Wetness index

   ***Source***: Derived from National Elevation Data (NED) 10-m Digital Elevation Map (DEM).

   ***Description/Purpose***: A wetness index layer can be used as an indicator of a site's hydrologic suitability for sustaining a wetland (Russell et al. 1997, O'Neill et al. 1997, White and Fennessy 2005). The wetness index is a relative measure of the potential for saturation (wetness) in an area as compared to its surrounding landscape (Phillips 1990). The index (W) is calculated as $W = \ln(\alpha/(T \tan ß))$, where $\alpha$ = pslope drainage area, ß = surface slope in degrees, and T = soil transmissivity. Sites with large drainage areas and low slopes will have a higher wetness relative to sites with smaller drainages or higher slopes.

   ***Processing***: The original DEM was processed using the ArcGIS Spatial Analyst "Fill" Tool, which removes small data imperfections in the raster. The Spatial Analyst "Flow Direction," "Flow Accumulation," and "Slope" tools were run on the "filled" DEM in order to generate the variables that were input into the wetness index equation. Soil transmissivity was removed from the equation as those data were not readily available for the entire coast. The final equation used in this analysis was $W = \ln(\alpha/(\tan ß + 0.0001))$. The constant (0.0001) was added to avoid generating undefined terms that would be caused if tanß = 0.

   ***Limitations***: Any inaccuracies in the original DEM will lead to inaccuracies in the calculated wetness index.

2. Hydric soils

   ***Source***: Soil Survey Geographic (SSURGO) database.

   ***Description***: The layer consists of areas mapped as having hydric soils, based on county hydric soils list.

***Purpose***: The presence of hydric soils is a good indicator that an area was formerly a wetland. Since it can take several years for hydric soils to develop naturally, it is preferable to restore a site where these soils already exist.

***Processing***: Polygons that contained soils listed on the county hydric soils list were selected from the original data layer. These polygons were then converted into a raster. Areas with hydric soils were assigned a value of "1," all other areas were assigned a value of "0."

***Limitations***: The soil maps include a class of soil which is essentially a "spoil/fill" category, and is considered non-hydric. Hydric soils may exist underneath the spoil/fill; however, this fact will not be reflected in the hydric soil map.

3. Distance to seed source

***Source***: Derived from Mississippi Department of Marine Resources (MDMR) land cover data, 2001

***Description***: This layer depicts the closest distance (in meters) of every cell to an area that might be a potential seed source for a restored wetland.

***Purpose***: Depending on its proximity to the restoration area, a seed source has the potential to naturally regenerate the vegetation at a site (Middleton 1999). The appropriate seed source may be a forested or herbaceous area, based on the type of wetland being restored. For instance, in bottomland hardwood systems, restoration areas that are near existing mature forest tend to have much higher species diversity than areas that are far away from existing mature stands (Allen 1990). Similarly, Reinartz and Warne (1993) found that for herbaceous depressional wetlands, diversity and number of native wetland plant species increased significantly as distance to the nearest seed source decreased.

***Processing***: The Spatial Analyst "Euclidian Distance" Tool was used to determine the closest distance to cells (in meters) classified as either bottomland hardwood, swamp, wet pine forest/savanna, tidal marsh,

or non-tidal marsh in the MDMR 2001 land cover layer, using an output cell size of 10 m by 10 m.

***Limitations***: Land uses may have changed since 2001. Also, all possible wetland land use types were considered to be possible seed sources, although depending on the type of wetland being restored, this may not actually be the case.

*Storm surge/flood protection*

The following variables were used to measure the suitability of a potential restoration site for mitigating storm and flood damage in other areas.

1. Storm surge category

***Source***: Based on ERDC Coastal and Hydraulics Lab model

***Description***: This layer depicts the predicted landward extent of the storm surge resulting from category 1-5 hurricanes.

***Purpose***: Wetlands can act as a buffer to help minimize the impact in areas that are susceptible to damage and flooding from hurricane storm surges.

***Processing***: A 10-m by 10-m cell raster, which covered all three coastal counties and contained category 1-5 storm surges, was created from individual storm surge shapefiles. Each cell was assigned a value of 1 to 5, based on the minimum category hurricane required for a storm surge to reach that area. For example, areas susceptible to category 3, 4, and 5 hurricane surges were assigned a value of 3.

***Limitations***: The accuracy of this layer is based on the accuracy of the model used to generate the storm surge extent, and any inputs into that model.

2. Depressions

***Source***: Derived from National Elevation Data (NED) 10-m Digital Elevation Map (DEM).

***Description***: This layer depicts areas in the landscape that can be classified as topographic depressions. Depressions are defined as areas at a lower elevation than all other immediately surrounding areas.

***Purpose***: Depressional wetlands can store water from storms and flooding, thus preventing water from reaching and damaging more upland areas.

***Processing***: This layer was generated using the following steps:

- The Spatial Analyst "Fill" Tool was used on the original 10-m DEM.
- Values from the original DEM were subtracted from the values in the filled DEM.
- All values > 0 were considered part of a sink, and reclassified as value 1. All other areas retained a value of 0.

***Limitations***: The accuracy of this layer is dependent on the quality of the original DEM.

3. Stream buffer

***Source***: Derived from High Resolution National Hydrography Data (NHD).

***Description***: This layer depicts areas within the landscape that are within a given buffer distance from a stream, with the buffer distance being dependent on the stream order.

***Purpose***: Wetlands that buffer streams can help to mitigate flooding in upland areas by storing floodwater and reducing peak flows downstream (Ogawa and Male 1983). A layer depicting < 5-year flood frequencies would be better for the purpose of this function; however, since this layer is unavailable for the area, the “stream buffer” layer is being used as a proxy.

***Processing***: Before the appropriate buffers could be generated, stream orders first had to be assigned to the various reaches in the NHD layer. Calculating stream order was a multi-step process. Initially a visual inspection of the stream layer was made to locate any errors in the data set. Stream segments that were disconnected from the network were evaluated to determine if they needed to be connected to the system or left as is. A series of Arc Macro Language (AML) scripts were used to do the calculation. This required that the shapefiles be converted to coverages. Once the conversions were made, the stream layers were displayed in ArcEdit and all streams not connected to the system or that did not have a name assigned in a GNIS name attribute were removed from the coverage and put in a new coverage to be used later. Next, an AML called *flipperp* was used to assign stream order attributes Jorder and Strahler to the coverage to the remaining arcs. During the running of the flipper AML, a Jorder value was calculated for each stream segment. Once this was complete, the layer was ready for a Strahler value to be calculated. To accomplish this task, the Shreve AML was used. To complete this portion of the process, the layer was brought back into ArcEdit and the arcs that were removed were returned to the coverage and a Strahler value of 0 was assigned to those arcs. The file was then converted back to a shapefile.

The fist step in generating the stream buffers was to separate the streams shapefile based on the calculated stream order value found in the Strahler attribute. This resulted in six new shapefiles. These individual layers were then buffered. Buffer distances were assigned based on Strahler stream order. The buffer values used were as follows (distance is from either side of the stream center):

| Stream Order | Distance (m) |
|---|---|
| 0 | 10 |
| 1 | 20 |
| 2 | 40 |
| 3 | 70 |
| 4 | 100 |
| 5 | 150 |

Once all the buffers were generated, the layers were merged back to create a single stream buffer shapefile. This shapefile was then converted to a raster file, and cells falling within the designated stream

buffer were assigned a value of 1. All other cells were assigned a value of 0.

***Limitations***: There are likely to be some inaccuracies in the calculated stream orders due to the input layer and particular methodology used. Also, the specific buffer distances being used are relative in nature and their actual validity is unknown. Finally, buffer distances were calculated from the stream centerline (the original stream layer only depicts the centerline); therefore the width of the stream is not factored into the buffer distance.

*Habitat*

These variables measure the suitability of the wetland to provide quality habitat for a variety of wildlife species.

1. Distance to roads

   ***Source***: Derived from National Atlas and BTS roads data

   ***Description***: This layer depicts the closest distance, in meters, of each cell to the nearest road.

   ***Purpose***: Roads can limit movements and be a potential source of disturbance and hazard to certain animals (Roe et al. 2006, Herrmann et al. 2005), which could make the restored wetland less than optimal for wildlife habitat.

   ***Processing***: The Spatial Analyst "Euclidian Distance" tool was used to create a 10-m by 10-m cell size raster depicting the closest distance (in meters) from each cell on the landscape to a road.

   ***Limitations***: The variable does not distinguish between different types of roads, some of which may have more impact on wildlife than others.

2. Distance to protected areas

   ***Source***: Derived from national forests, wildlife management, and state and federal parks layers, which were obtained from the Mississippi

Automated Resource Information System (MARIS) website, and a coastal preserves layer, obtained from MDMR.

***Description***: This layer shows the closest distance, in meters, of each cell to the nearest protected area. Protected areas are defined as national forests, wildlife management areas, state parks, and coastal preserves.

***Purpose***: Protected areas can include such things as wildlife refuges, conservation areas, special management areas, and state and federal parks. Restoring wetlands close to these protected areas can create larger contiguous patches of habitat or add connections and travel corridors between patches that are beneficial for the movement of wildlife (Semlitsch and Bodie 2003).

***Processing***: A single protected areas shapefile was created by merging four separate layers: national forests, wildlife management areas, state parks, and coastal preserves. The Spatial Analyst "Euclidian Distance" tool was used to create a 10-m by 10-m cell size raster depicting the closest distance (in meters) of each area on the landscape to a protected area.

***Limitations***: The protected areas layer does not include any privately owned conservation lands.

3. Distance to open water

***Source***: Derived from MDMR 2001 land cover.

***Description***: This layer shows the closest distance, in meters, of every cell to the nearest cell classified as "surface water" in the MDMR land cover layer. Open water includes rivers, lakes, ponds, and coastal waters.

***Purpose***: Permanent open water that is proximate to the wetland can serve as an additional habitat or foraging resource for resident and transient wildlife.

***Processing***: The Spatial Analyst "Euclidian Distance" tool was used to create a 10-m by 10-m cell size raster depicting the closest distance (in

meters) from each cell on to the closest cell classified as “surface water.”

***Limitations***: None.

4. Block size

***Source***: Derived from “Potential Restoration Areas” layer (see page 5 of report).

***Description***: This layer depicts the area, in acres, of each contiguous block identified as a potential restoration area.

***Purpose***: For many species, having a few large contiguous patches of suitable habitat is preferable to numerous small, unconnected or isolated patches (Wigley and Roberts 1997, Pearlstine et al. 1997). Therefore, it is desirable to select areas that allow for a large contiguous wetland to be restored.

***Processing***: The area (in acres) of each polygon in the Potential Restoration Areas shapefile layer was calculated through the attribute table in ArcMap. The shapefile was then converted to a 10-m by 10-m cell raster, using the calculated area as the cell value.

***Limitations***: The block size calculation does not include wetlands that are adjacent to the potential restoration area. Restoring an area that is already adjacent to an existing wetland would create a contiguous wetland block that is larger than just the area of the restoration site.

5. Core area ratio

***Source***: Derived from “Potential Restoration Areas” layer (see page 5 of report).

***Description***: This layer shows the core area ratio for each potential restoration block. The ratio is the core area (the area within a block beyond some specified edge distance or buffer width, in this case, 100 m) divided by the total area of the entire block.

***Purpose***: Having a high core area ratio increases the amount of habitat interior space, thereby increasing species diversity in the interior (Ohman and Eriksson 1998).

***Processing***: The core area ratio layer was generated using an ArcGIS ModelBuilder model that was created specifically for this purpose.

***Limitations***: The core area ratio calculation does not include wetlands that are adjacent to the potential restoration area. Restoring an area that is already adjacent to an existing wetland would create a contiguous wetland block that could potentially have a core area ratio that is different than the core area ratio of the restoration site alone.

*Other layers*

These variables are factors that do not relate to the three functions above, but could still affect the suitability of a site to be a wetland restoration area.

1. MDMR restoration areas

   ***Source***: MDMR.

   ***Description***: This layer depicts areas targeted for potential restoration by MDMR.

   ***Purpose***: Having potential Corps restoration areas that overlap with potential state restoration areas offers collaborative opportunities among agencies.

   ***Processing***: The original shapefile was converted into a raster.

   ***Limitations***: No obvious limitations.

2. Storm damage level

   ***Source***: Storm-damaged areas layer (see page 3 of report).

   ***Description***: This layer rates damage to all cells in the “storm damage area” as moderate, extensive, or catastrophic.

***Purpose***: Areas that are extensively or catastrophically damaged may potentially offer a better opportunity for buy-outs than areas that experienced only moderate damage.

***Processing***: The IDD map was already classified into the three damage categories. The RSDE map was classified based on the total percent damage: 0-33 percent was classified as moderate, 34-66 percent was classified as extensive, and 67-100 percent was classified as catastrophic. Cells with moderate damage were assigned a value of 6, extensive damage a value of 3, and catastrophic damage a value of 1.

***Limitations***: The layer may not include all areas that were damaged by the storm. Also, damage level estimates may not be relevant in areas that have begun or completed rebuilding.

3. MDMR proposed coastal preserves

***Source***: MDMR.

***Description***: This layer depicts areas that MDMR has considered for acquisition as coastal preserve.

***Purpose***: Having potential Corps restoration areas that overlap with potential state coastal preserve areas offers collaborative opportunities among agencies.

***Processing***: The original shapefile was converted into a 10-m by 10-m cell raster.

***Limitations***: No obvious limitations.

### Scaling and weighting of variables

Table 1 depicts the scaling/scoring of the variables used in the SDSS, grouped by function. For the variables in the Habitat function (with the exception of "Core Area Ratio"), as well as the "Distance to Seed Source" variable in the Restorability function, the grouping of the raw values was based on those used in the O'Hara et al. (2000) SDSS for the Yazoo Backwater area in Mississippi. Grouping of the "Wetness Index" raw values was based on evenly dividing the range of wetness index values calculated for every 10-m by 10-m cell in the three coastal counties.

Table 1. Scaling and scoring of variables used in the SDSS.

| Function | Variable | Raw Value | Scaled Score |
|---|---|---|---|
| Habitat | Core Area Ratio | 0 - 0.07 | 0 |
| | | .07 - .15 | 5 |
| | | > .15 | 10 |
| | Block Size (acres) | 1-10 | 0 |
| | | 10 -320 | 5 |
| | | > 320 | 10 |
| | Distance to Roads (m) | 0 - 50 | 0 |
| | | 50 - 500 | 3 |
| | | > 500 | 5 |
| | Distance to Open Water (m) | 0 - 150 | 5 |
| | | 150 - 1000 | 3 |
| | | > 1000 | 0 |
| | Distance to Protected Areas (m) | 0 - 150 | 5 |
| | | 150 - 300 | 3 |
| | | 300 - 750 | 1 |
| | | > 750 | 0 |
| Restorability | Hydric Soils | 1 | 20 |
| | | 0 | 0 |
| | Wetness Index | -10.6 - 1.44 | 0 |
| | | 1.44 - 13.5 | 5 |
| | | 13.5 - 25.6 | 10 |
| | Distance to Seed Source (m) | 0 - 60 | 10 |
| | | 60 - 120 | 5 |
| | | > 120 | 0 |
| Storm/Flood Protection | Depressions | 1 | 15 |
| | | 0 | 0 |
| | Storm Surge Category | 5 | 1 |
| | | 4 | 3 |
| | | 3 | 5 |
| | | 2 | 8 |
| | | 1 | 10 |
| | Stream Buffer | 1 | 15 |
| | | 0 | 0 |
| Other | MDMR Restoration Sites | 1 | 3 |
| | | 0 | 0 |
| | Damage Level | 1 | 3 |
| | | 3 | 1 |
| | | 6 | 0 |
| | Proposed Coastal Preserves | 1 | 3 |
| | | 0 | 0 |

Grouping of the "Core Area Ratio" raw values was based on evenly dividing the range of core area ratio values calculated for all of the identified potential restoration sites.

The remaining variables were either multi-categorical (storm surge category, damage level), in which case the variable scoring was based on distributing the score range about equidistantly among the categories, or true/false, in which case the "true" condition was assigned a positive value, and the "false" condition was assigned a score of 0. The maximum possible score for each variable was assigned to reflect its relative importance in the function. This weighting was done based on the best professional judgment of the author and in consultation with personnel from the U.S. Fish and Wildlife Service and MDMR. The nature of the SDSS allows for the weighting and scaling of variables to be easily changed in the future, should the current values be disputed.

### Calculating function scores

Scores for the Habitat, Restorability, and Storm/Flood protection functions were calculated for each 10-m by 10-m cell by adding the scores for each variable included in that function, along with the score for variables listed in the "Other" category. For instance, the score for the Storm/Flood protection function for an individual cell would be determined by adding the scores from the Depressions, Storm Surge Category, Stream Buffer, MDMR Restoration Sites, Damage Level, and Proposed Coastal Preserves variables, with a maximum score for the function of 49.

Scores for each function were then calculated for each potential restoration block by averaging the scores for each individual cell within the block (Figure 2).

An "all functions" score was also calculated for each restoration block by averaging the scores for the three functions. In order to weight the functions equally, the scores from the restorability and storm/flood protection functions were multiplied by 0.898, to account for the fact that the maximum score (49) for those two functions was greater than the maximum score for the habitat function (44). Table 2 shows the maximum possible score by function for each site, as well as the actual range of scores calculated for all potential restoration sites.

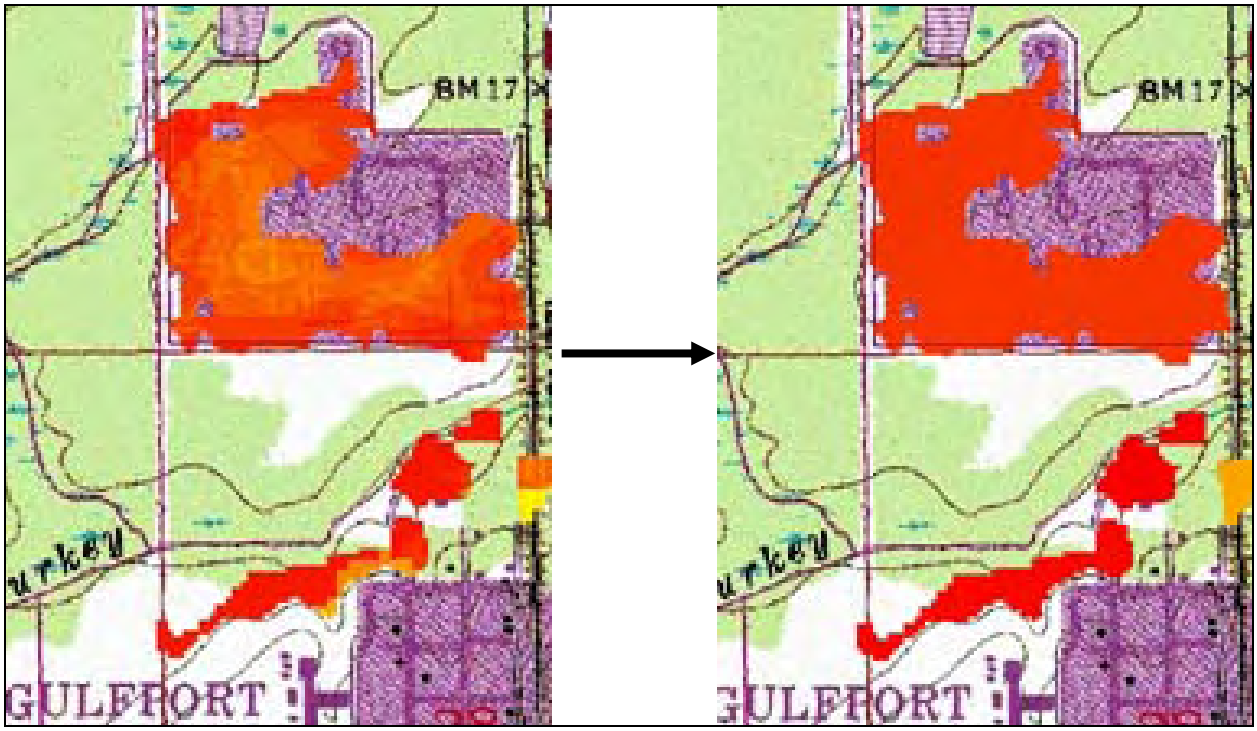


Figure 2. Illustration of averaging of scores for each 10-m by 10-m cell in order to obtain a single score for the restoration block.

Table 2. Maximum possible scores and the actual range of calculated scores for potential restoration sites.

| Function | Maximum Possible Score | Actual Range of Scores |
|---|---|---|
| Habitat | 44 | 1.0 – 32.0 |
| Restorability | 49 | 4.4 – 44.0 |
| Storm/Flood Protection | 49 | 1.0 – 42.0 |
| All Functions | 44 | 5.4 – 29.7 |

Based on their score, each potential restoration site was assigned a value of 1- Low, 2- Medium-Low, 3- Medium, 4- Medium High, or 5- High, for each function. Classification into these values was based on dividing the actual range of scores for each function into five equal-range groups. The exception was the Storm/Flood protection function, where the high score was 42, but only four sites had a score higher than 33. Therefore, the classification for that function was based on dividing the groups based on a maximum score of 33, rather than 42. The classification ranges are shown in Table 3. Table 4 shows the number of sites that fall into each classified category, along with the total acreage of those sites.

Table 3. Classification ranges used to determine classified scores for each function.

| Function | Classified Score | Raw Value Range |
|---|---|---|
| Habitat | 1 | 1.0 - 7.2 |
| | 2 | 7.2 - 13.4 |
| | 3 | 13.4 - 19.6 |
| | 4 | 19.6 – 25.8 |
| | 5 | 25.8 - 32.0 |
| Restorability | 1 | 4.6 - 12.5 |
| | 2 | 12.5 - 20.4 |
| | 3 | 20.4 - 28.2 |
| | 4 | 28.2 - 36.1 |
| | 5 | 36.1 – 44.0 |
| Storm/Flood Protection | 1 | 1.0 – 7.4 |
| | 2 | 7.4 – 13.8 |
| | 3 | 13.8 – 20.2 |
| | 4 | 20.2 – 26.6 |
| | 5 | 26.6 - 42.0 |
| All Functions | 1 | 5.4 – 10.2 |
| | 2 | 10.2 - 15.1 |
| | 3 | 15.1 – 20.0 |
| | 4 | 20.0 – 24.8 |
| | 5 | 24.8 – 29.7 |

Table 4. Number of sites and total acreage of those sites for each classified value score, by function.

| Classified Value | Function | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Habitat | | Restorability | | Storm/Flood Protection | | All Functions | |
| | # of Sites | Total Acres | # of Sites | Total Acres | # of Sites | Total Acres | # of Sites | Total Acres |
| 1 | 101 | 255 | 66 | 396 | 26 | 93 | 48 | 156 |
| 2 | 452 | 1,633 | 248 | 1,596 | 531 | 3,933 | 243 | 1,520 |
| 3 | 314 | 3,608 | 178 | 2,703 | 402 | 3,405 | 556 | 4,702 |
| 4 | 152 | 1,970 | 405 | 2,665 | 78 | 325 | 204 | 1,355 |
| 5 | 67 | 425 | 189 | 532 | 49 | 135 | 35 | 159 |

Maps showing potential restoration sites and their classified/raw scores by function have been provided to the U.S. Army Engineer District, Mobile, as an ArcView GIS shapefile. Appendix A contains images of selected portions of the SDSS map outputs.

# 3 Field Validation of SDSS

Sixteen potential wetlands restoration areas across the coast that were identified and scored by the SDSS were visited on January 9 and 10, 2007, to check the validity and applicability of the results. Sabrina Clark and Paul Necaise from U.S. Fish and Wildlife Service alternately accompanied the author on field visits. At each site, photographs were taken, and general observations as to the restorability of the site were noted, including relevant information not included in the SDSS, such as extent of rebuilding and economic class of the area. These field observations were later compared to the scores generated by the SDSS (Table 5).

Table 5. SDSS raw and classified scores (rating) for potential restoration sites visited on the ground. The Site Polygon ID refers to the ID in the "Restoration_Site_Evaluation" shapefile.

| Site Polygon ID | Location | Block Size (acres) | Restor-ability Raw Score | Restor-ability Rating | Habitat Raw Score | Habitat Rating | Flood Protection Raw Score | Flood Protection Rating | All Functions, Raw Score | All Functions, Rating |
|---|---|---|---|---|---|---|---|---|---|---|
| 450 | Biloxi | 468.7 | 21 | Medium | 21 | Med-High | 15 | Medium | 18 | Medium |
| 351 | Biloxi | 14.0 | 30 | Med-High | 18 | Medium | 19 | Medium | 21 | Med-High |
| 224 | Biloxi | 127.0 | 25 | Medium | 15 | Medium | 14 | Medium | 17 | Medium |
| 166 | Biloxi | 118.7 | 22 | Medium | 17 | Medium | 14 | Medium | 17 | Medium |
| 189 | Biloxi | 12.6 | 36 | High | 21 | Med-High | 15 | Medium | 22 | Med-High |
| 194 | Biloxi | 26.7 | 30 | Med-High | 28 | High | 13 | Med-Low | 22 | Med-High |
| 643 | Pascagoula | 221.5 | 21 | Medium | 13 | Medium | 11 | Med-Low | 14 | Med-Low |
| 602 | Pascagoula | 4.9 | 36 | High | 10 | Med-Low | 17 | Medium | 19 | Medium |
| 293 | Gulfport | 50.0 | 34 | Med-High | 13 | Med-Low | 17 | Medium | 19 | Medium |
| 388 | Gulfport | 26.4 | 39 | High | 14 | Medium | 24 | Med-High | 23 | Med-High |
| 691 | Pass Christian | 5.2 | 33 | Med-High | 12 | Med-Low | 13 | Med-Low | 18 | Medium |
| 933 | Pass Christian | 11.4 | 34 | Med-High | 17 | Medium | 12 | Med-Low | 19 | Med-High |
| 903 | Waveland | 2.2 | 35 | Med-High | 7 | Low | 12 | Med-Low | 16 | Medium |
| 966 | Waveland | 47.0 | 32 | Med-High | 12 | Med-Low | 11 | Med-Low | 17 | Medium |
| 1088 | Pearlington | 9.2 | 32 | Med-High | 20 | Med-High | 15 | Medium | 21 | Med-High |
| 1076 | Pearlington | 9.3 | 36 | High | 24 | Med-High | 31 | High | 28 | High |

All the sites visited had a wetland restorability function rating of at least "Medium," and most of them could potentially be restored into wetlands based on what was seen on the ground. For instance, bald cypress trees (a good indicator that the site is "wet") were seen at site 388 (Figure 3), which has a wetland restorability function rating of "High."

Site 643, which includes some residential area and a public beachfront park in the city of Pascagoula (Figure 4) and site 450 (Figure 5), which includes residential and commercial areas (including casinos) in Biloxi had the lowest wetland restorability function raw scores, based on having intermittently mapped hydric soils, a relatively low wetness index, and distance from existing seed sources. These factors were verified in site visits, so the lower wetlands restorability function score is fairly accurate. Both of these sites are relatively large areas, and some portions of them may be more restorable than others. However, taken as a whole, these sites have a much more limited potential for wetland restoration, particularly site 643, which had the lowest overall score of all the sites visited.

Figure 3. Part of site 388, located next to Turkey Creek in Gulfport. The site scores in the "High" range for wetland restorability.

Figure 4. Part of site 643, which includes some residential area and a public beachfront park in the city of Pascagoula. This site had the lowest overall score of the sites visited.

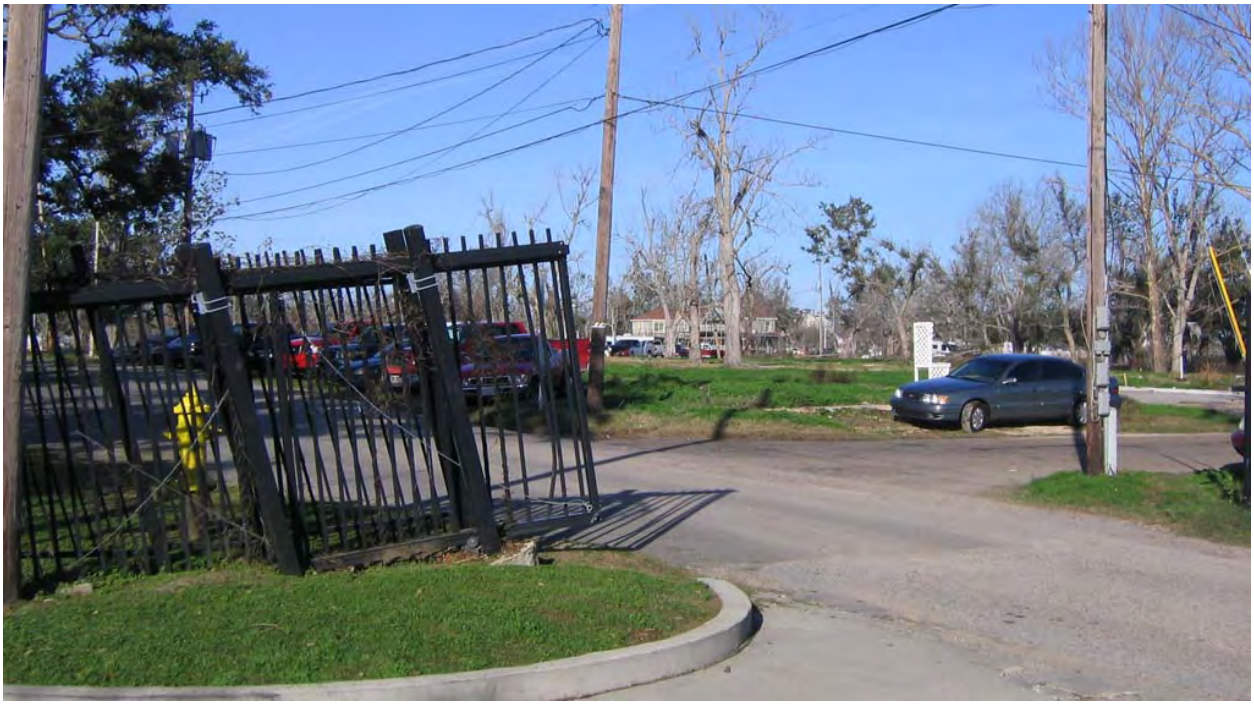

Figure 5. Site 450, located in Biloxi. This is a relatively large restoration block (470 acres), containing residential and commercial areas, including the casinos.

The highest scoring site visited was site 1076, a small residential area adjacent to the Pearl River in Pearlington (Figure 6). This site scored in the "High" category for all functions except Habitat, for which it scored "Medium-High." The desirability of this area as a restoration site was confirmed by the field visit, as the site remains heavily damaged and no reconstruction has occurred.

Figure 6. Part of site 1076, located in Pearlington. The site was the highest scoring of those visited, and appears to be a good area for wetland restoration.

However, some sites that score high in the SDSS will still need to be ruled out of consideration as wetland restoration sites, due to economic and real estate factors that were not considered in the analysis. For example, site 189, which has a "High" score for the restorability function and "Medium-High" scores for the habitat function and "all" functions, contains a new, expensive housing subdivision (Figure 7), making a buyout unlikely.

Figure 7. Part of site 189, located near Point Ascot/Biloxi. The area has high SDSS scores and functionally, it appears to be a good site to restore. However, a buyout may not be economically feasible, as the area contains a new subdivision with what appear to be expensive homes.

The area where the SDSS appears to be the least robust is in ratings for the storm/flood protection function, where actual performance of this function at some sites may be higher than reflected by the SDSS. This problem is to be expected as it is largely a result of the "stream buffer" variable, which is a replacement for an unavailable "flood frequency" variable/layer, which would have been more accurate for use in this function. The limitations of using the "stream buffer" layer as a proxy are detailed on page 11 of this report. Therefore, buffer widths being used in this analysis may be too narrow in certain areas and underestimate the actual extent of flooding at the site. As seen in Table 4, about half of all the potential wetland restoration sites scored in the "Medium-Low" category for storm/flood protection function, but it is likely that a number of these sites would rate higher given more accurate buffer distances. These caveats aside, the SDSS still seems to be able to accurately distinguish the higher scoring sites in the storm/flood protection function, particularly if they are located immediately adjacent to a stream and/or are located in a depression. For instance, site 734, which is adjacent to the Pearl River, scored a "High" and site 162, which is adjacent to Turkey Creek and located in a topographic depression, scored a "Medium-High" for the storm/flood protection function. Another weakness of the SDSS is in the evaluation of the restorability function for any sites that have historically had hydric soils,

but are mapped as having non-hydric soils (although fortunately there are not a substantial number of sites which would fall into this category). Because they are evaluated as having non-hydric soils, these sites will score low in the wetland restorability function. However, in reality, since hydric soils may actually exist at the site, the restorability of the site will be higher than reflected by the SDSS. For example, the Shoreline Park neighborhood in Bay St. Louis is mapped in the state soil survey in essentially a "spoil/fill" category, which is classified as non-hydric. The site received a restorability class of Medium-Low. However, it is known that historically the Shoreline Park neighborhood contained hydric soils, which could easily be re-established through the removal of the existing fill and spoil. Therefore, the actual wetland restorability potential of the area is higher than the Medium-Low category assigned by the SDSS.

# 4 Conclusions

Overall, the SDSS appears to be working as expected in identifying priority wetland restoration sites, especially in terms of the restorability and habitat functions. The most apparent weakness in the SDSS is in evaluating the Storm/Flood protection function, since the “stream buffer” variable used in this function probably does not adequately cover the true extent of periodic flooding in certain areas. Therefore, some sites may be underrated by the SDSS in terms of this function. The quality of the evaluation would be improved if a <5-year flood frequency map was available as a GIS layer. Another layer that would benefit the SDSS is one showing privately owned conservation lands (easements, etc.), which would then be used to expand the “Protected Areas” layer, used in the Habitat function.

If additional useable GIS layers are made available in the future, or it is decided that certain variables should be weighted or scaled differently, or if different restoration blocks need to be evaluated, the nature of the SDSS is such that these changes can be made fairly easily and new maps can be generated quickly.

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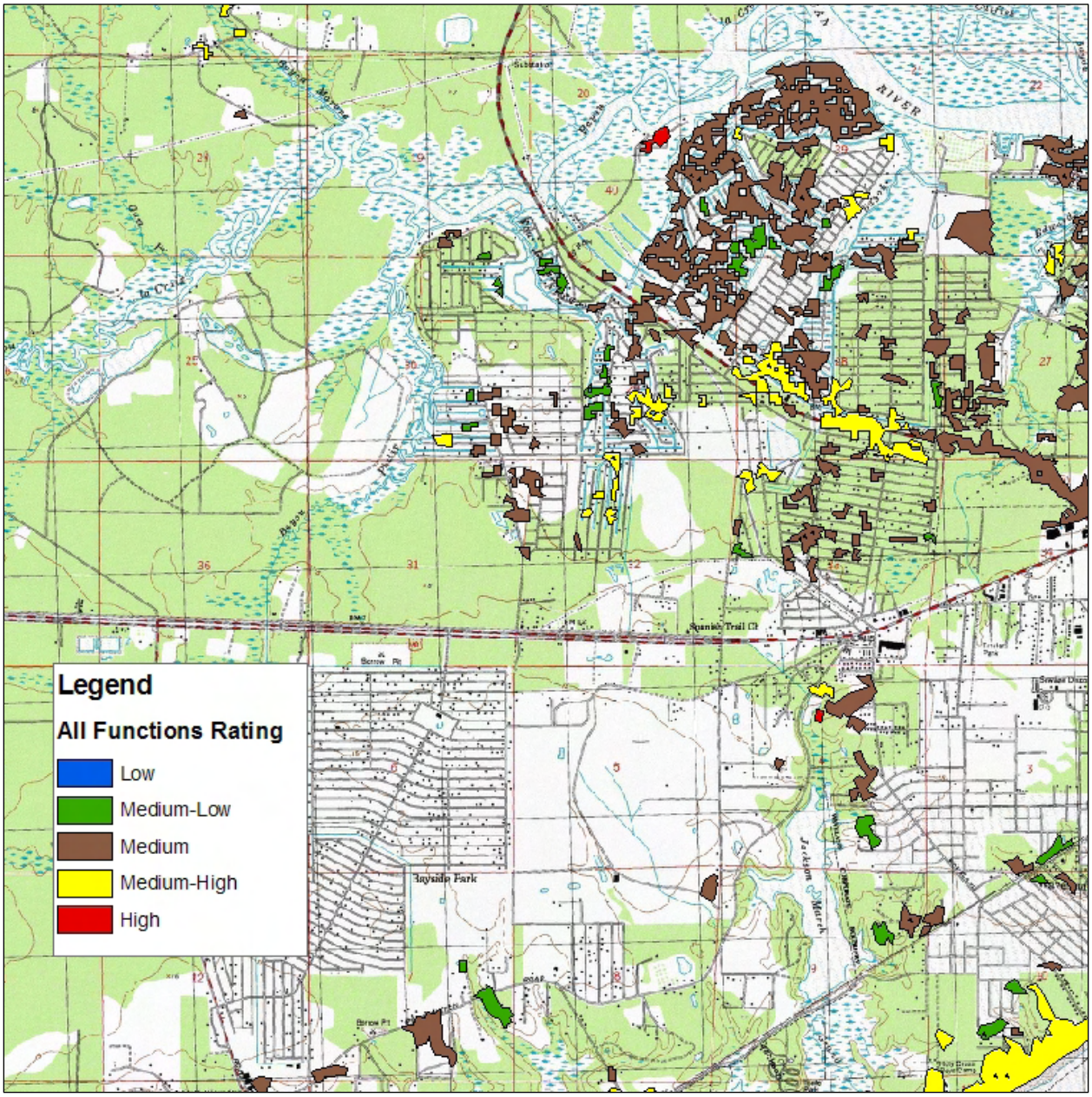
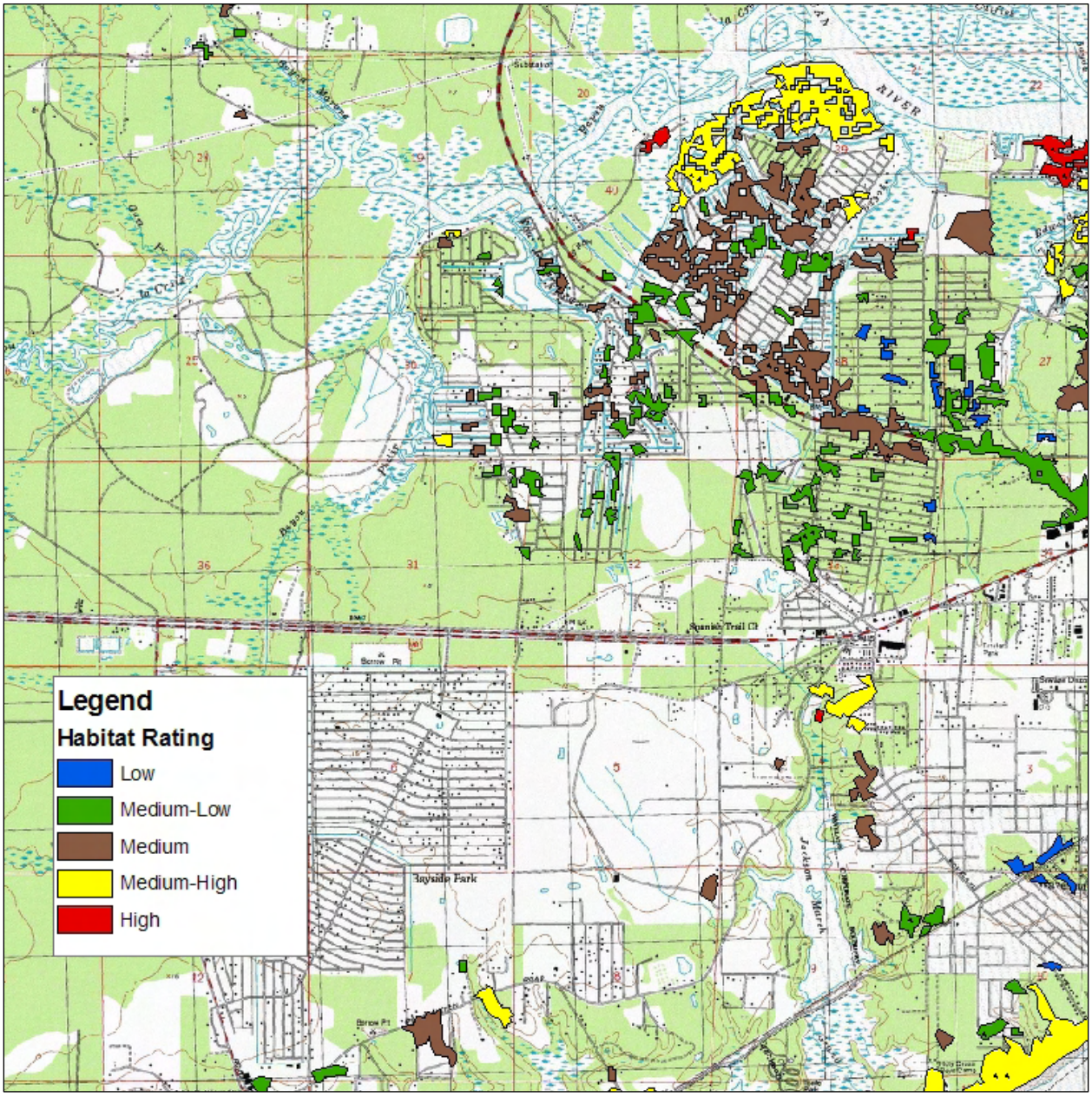
# Appendix A: SDSS Map Outputs

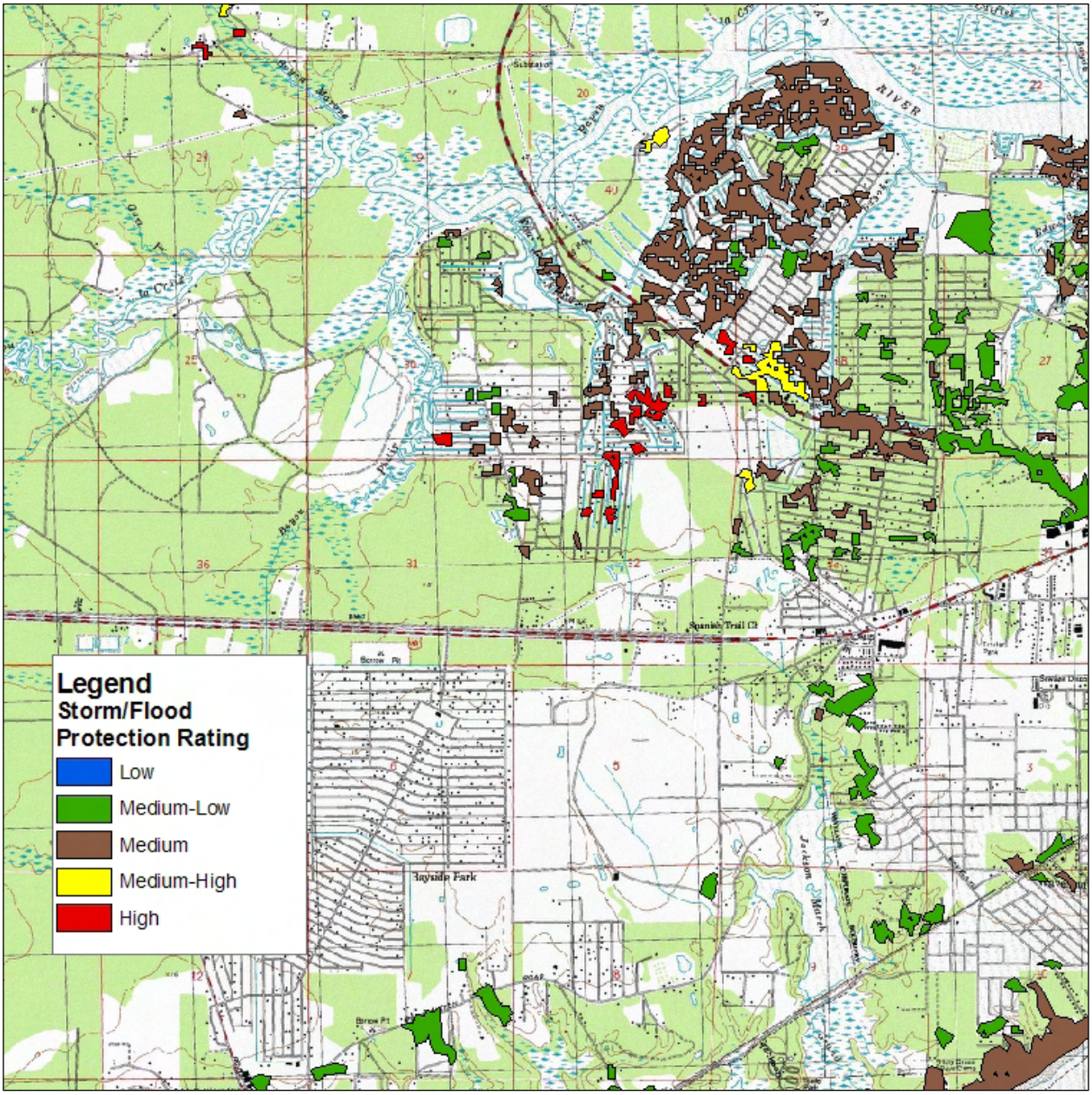
This appendix contains several examples of possible SDSS map outputs for selected areas along the Mississippi Gulf Coast.



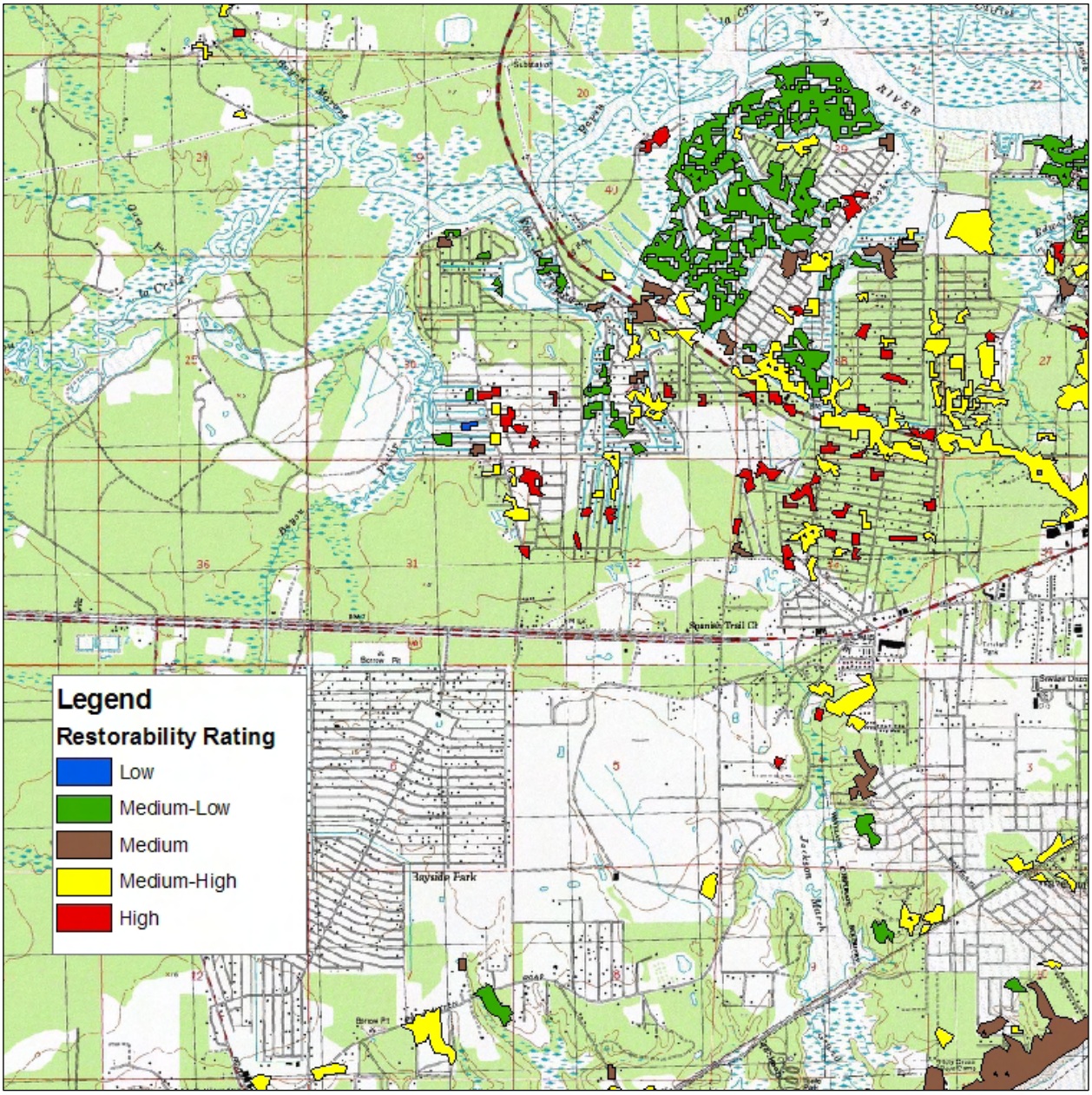

Map 1: "All functions" ratings for potential restoration sites near Waveland/Bay St. Louis.



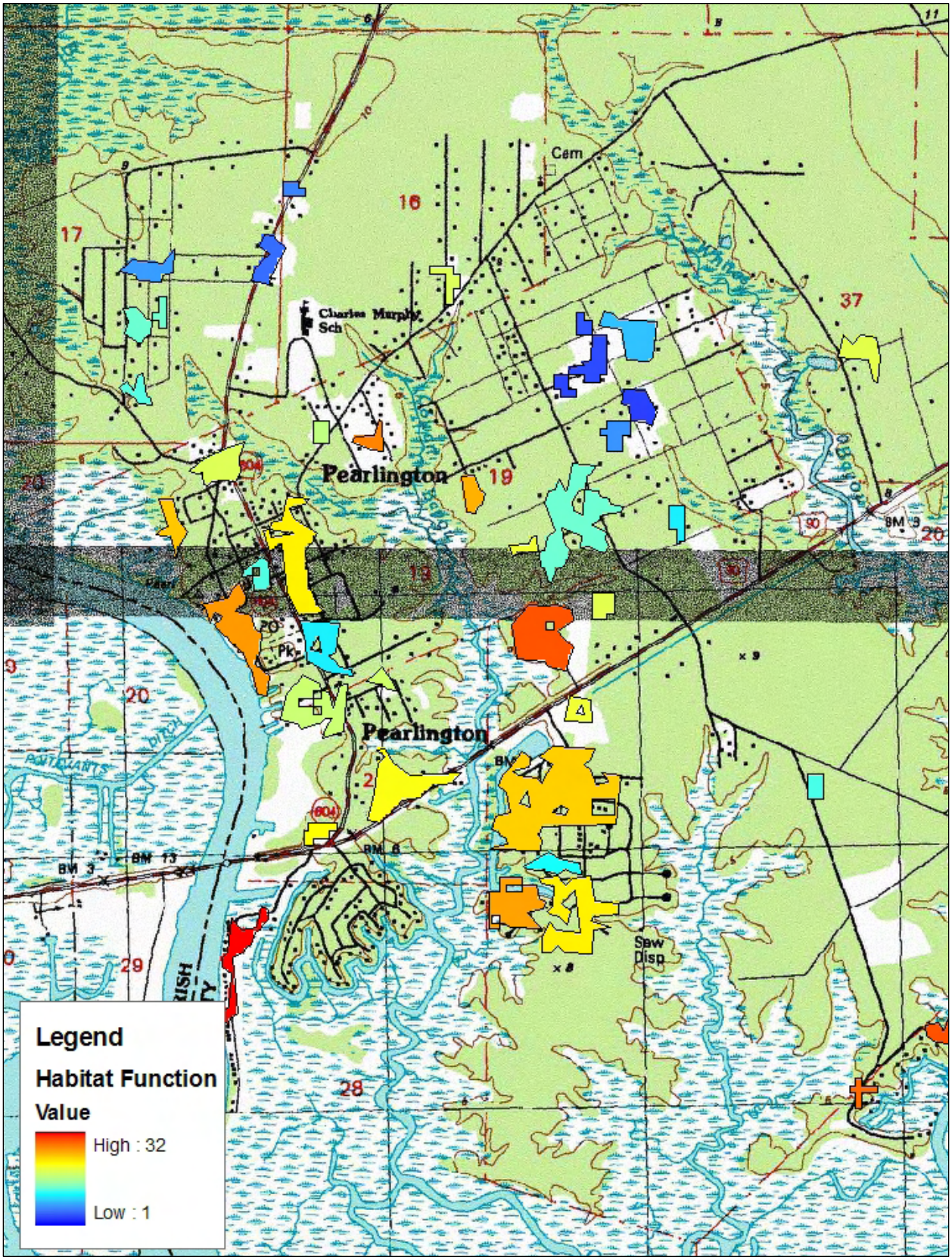

Map 2: Habitat function ratings for potential restoration sites near Waveland/Bay St. Louis.



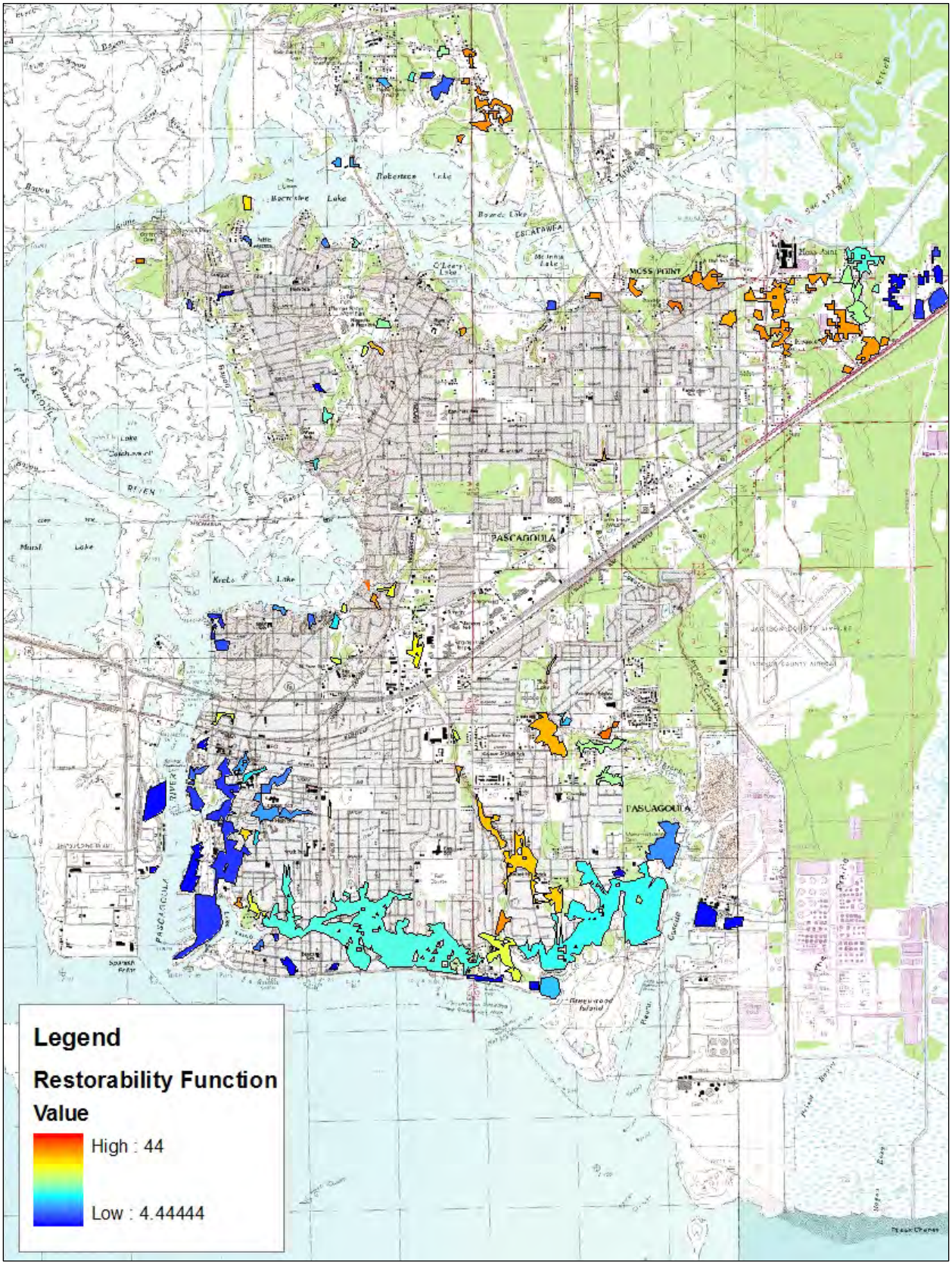

Map 3: Storm/Flood Protection function ratings for potential restoration sites near Waveland/Bay St. Louis.




Map 4: Restorability function ratings for potential restoration sites near Waveland/Bay St. Louis.




Map 5. Habitat function raw values for potential restoration sites in Pearlington.




Map 6. Restorability function raw values for potential restoration sites in Pascagoula.

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The Engineer Research and Development Center, Environmental Laboratory, has created a Wetlands Restoration Spatial Decision Support System (SDSS) based on Geographic Information System (GIS) tools. SDSS will be used to identify and prioritize potential wetland restoration areas along the Mississippi Gulf Coast as part of the non-structural solutions planned for that area following Hurricane Katrina. Advantages of the SDSS approach include relatively rapid identification and assessment of a large number of restoration sites across a wide area. Potential sites can also be evaluated and restored in a watershed or landscape context, maximizing the benefits of wetland restoration.

**15. SUBJECT TERMS**

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Spatial Decision Support System (SDSS)
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