Ecological Approach to Infrastructure Development:
Wetlands Mapping and Change Detection

Final Report for FY2012
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FIGURES

Tables

The East-West Gateway Council of Governments serves an eight county region, five in Missouri and three in Illinois. The mission of the organization is to help the region "offer its residents an unexcelled quality of life." In FY2010, the Missouri Resource Assessment Partnership produced a regional ecological significance datalayer to help facilitated planning efforts. In FY2011, MoRAP provided a project-level ecological significance data layer (**Figure 1**). Regional significance was defined based on attributes attached to patches of natural and semi-natural vegetation, whereas project-level significance was more focused on the importance of individual communities. Both data layers relied on a new current vegetation map, and on both biological and landscape context criteria.

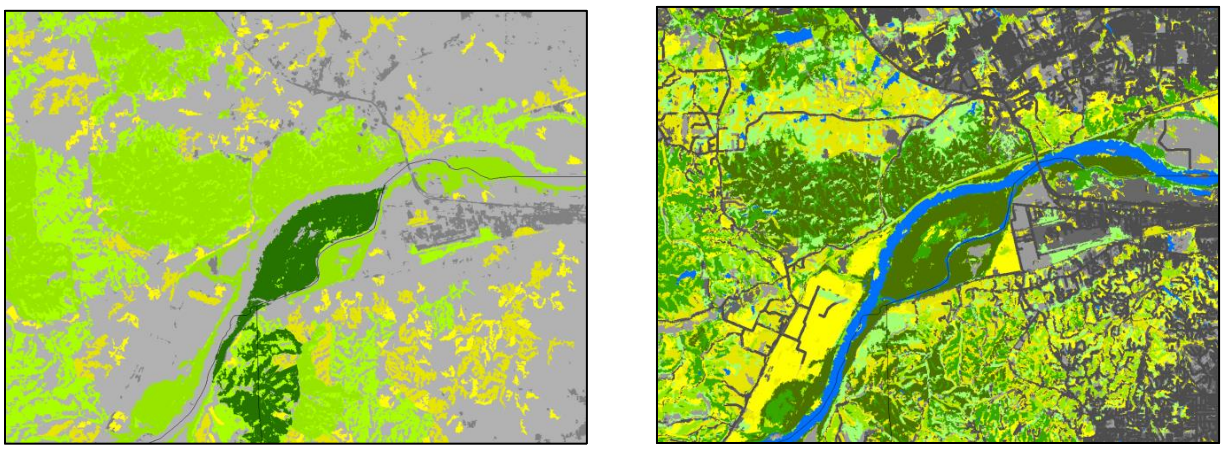

Figure 1. Regional ecological significance (left) and project-level significance (right). Ranking criteria were applied to semi-natural patches for the former, and focused on community-level importance for the latter.

In addition, MoRAP produced wetland mitigation and restoration significance data layers in FY2011 (**Figure 2**). These were based mainly on patch size and landscape context for mitigation significance, which was only applied to extant natural and semi-natural vegetation. Restoration potential was assigned to cropland and barren land on bottomland soils, and was based mainly on landscape context.

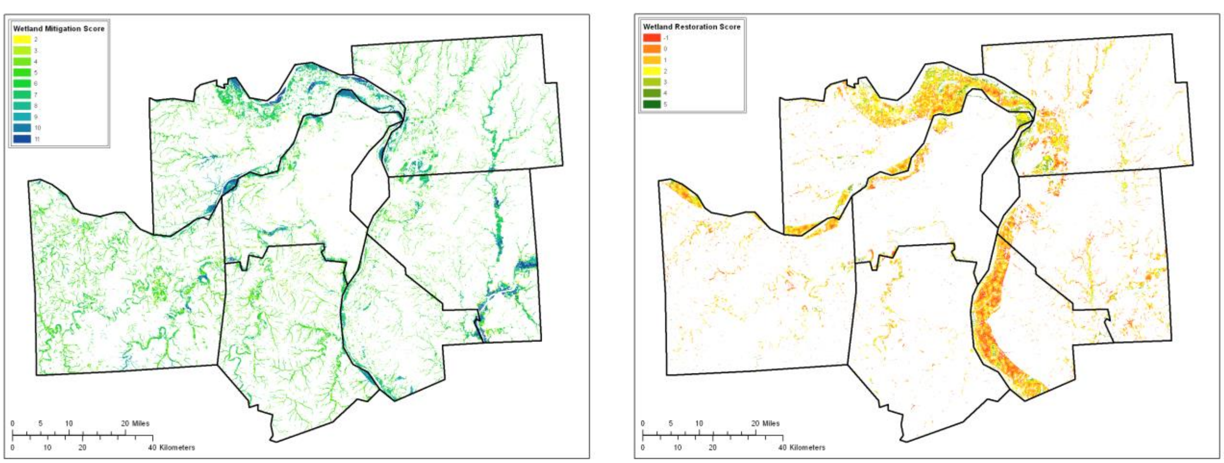

Figure 2. Wetland mitigation (left) and restoration (right) ranks for the East-West Gateway region. Both data layers suffered from lack of information on water regime.

Wetlands were mapped based on modeling which used extant natural and semi-natural vegetation and bottomland soils information, which resulted in some known over-mapping of wetlands on relatively dry bottomland soils. No information on water regime was available, which limited importance ranking for both mitigation and restoration.

All results were explained and presented by MoRAP (David Diamond and Diane True) and East-West Gateway (Jennifer Reiman, Mary Grace Lewandowski) staff to a variety of users during the St. Louis Earth Day Symposium, April 5 & 6 at the Missouri Botanical Gardens. Two presentations focused on generation of the information, whereas two more focused on practical applications of the information for planning. A flash drive containing copies of reports and GIS data was handed out to meeting participants.

Our goals for FY2011 were to build on the work already accomplished to create a revised and improved wetland mitigation and restoration data layer for the Missouri and parts of the Mississippi River floodplain using LiDAR data (**Figure 3**). The focus on wetlands of big river floodplains was warranted because wetlands are subject to regulation, and because many agencies with means and need to mitigate activities, or oversee mitigation, are involved on the floodplains (e.g. the Army Corps of Engineers, Environmental Protection Agency, U.S. Fish and Wildlife Service, Natural Resources Conservation Service, and Missouri Departments of Transportation, Conservation, and Natural Resources). In addition, because change related to urban expansion is rapid in some portions of the East-West Gateway region, we also created a change detection data layer that focused on identification of new clearing for development.

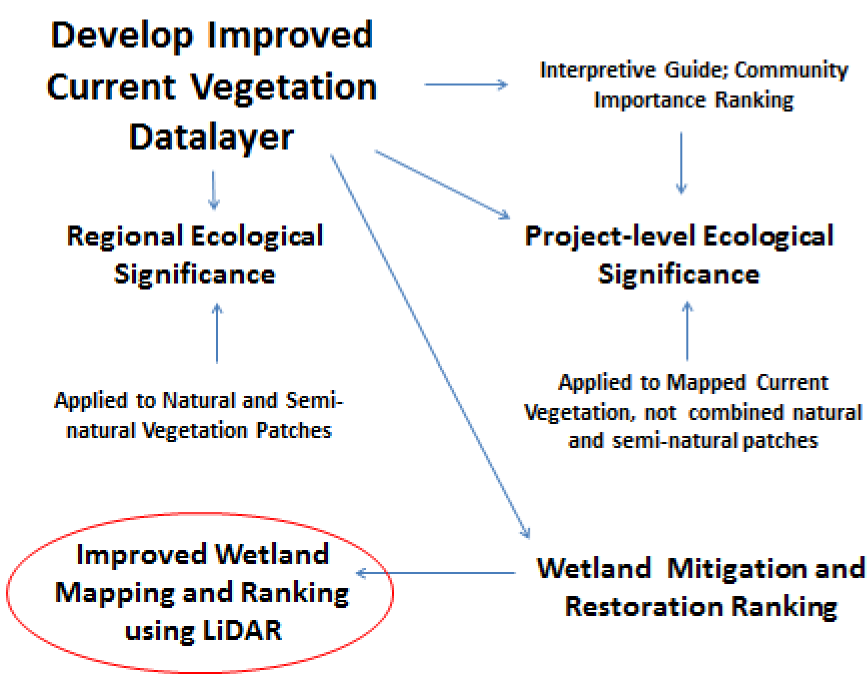

Figure 3. Relationships among products already produced and work accomplished this year using new LiDAR information for wetland mapping (red oval).

Improving Wetland Mitigation and Restoration Information

We defined wetland mitigation areas as extant vegetation with qualifying water regimes, and wetland restoration areas as cropland and barren land. The definition of these terms varies among users.

Generation of Digital Elevation Models (DEMs) and Vegetation Height

Light detection and ranging (LiDAR) data were used to improve wetland mapping for the Missouri River and upper Mississippi River floodplain within the study area (**Figure 4**). Files were acquired from Washington University (http://maps.wustl.edu/mo_lidar_data/). Data files in LAS format totaled 160 GB, and each county was delivered in multiple tiles. Metadata and referencing systems were not available for many of the county data sets, so considerable effort was needed simply to organize and locate data that circumscribed the big river floodplains. LAStools software was initially used to manipulate data (http://www.cs.unc.edu/~isenburg/lastools/).

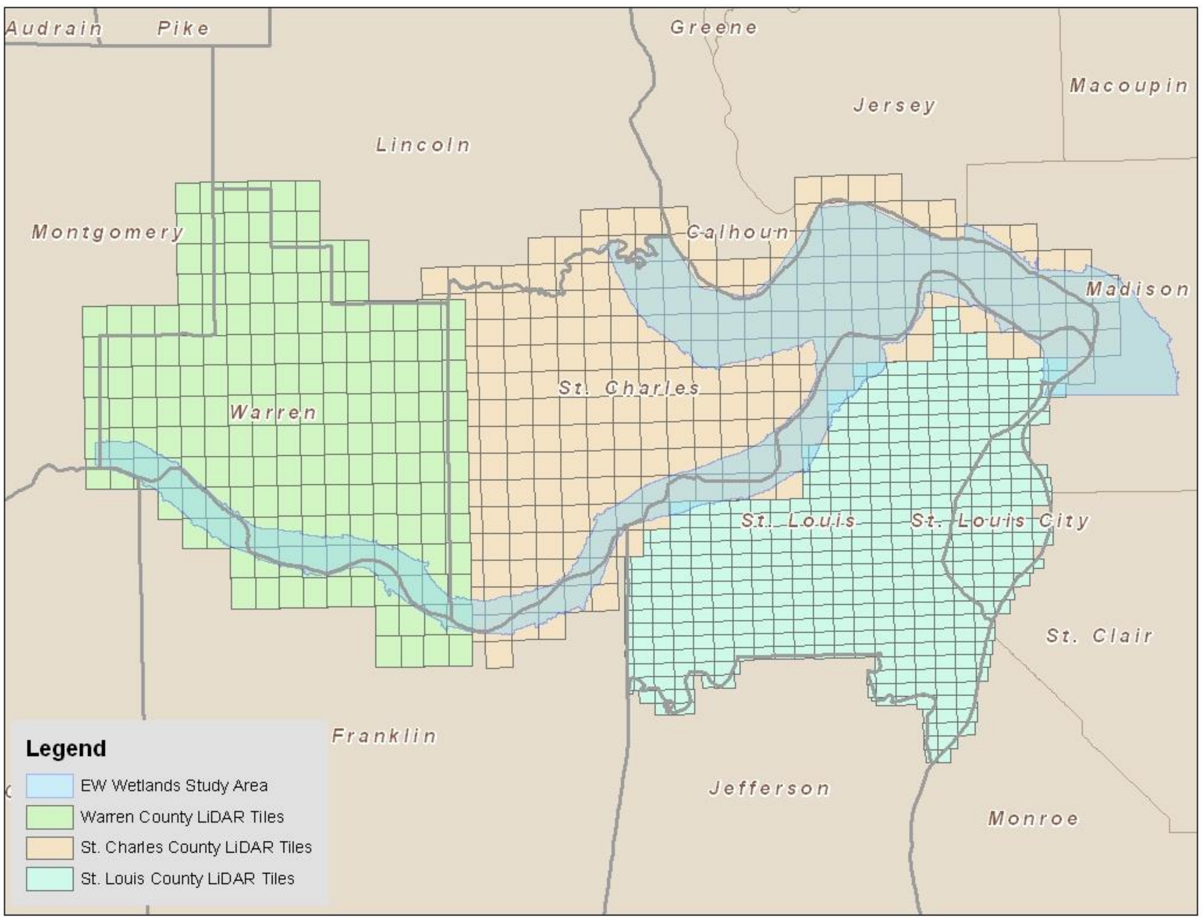

Figure 4. Light detection and ranging (LiDAR) data were acquired by county in multiple tiles and used to improve wetland mapping for big river floodplains within the East-West Gateway region.

Our goal was to extract digital terrain models (DTMs – the ground surface) and digital surface models (DSMs – the top of the highest objects, including vegetation tops) in order to create both digital elevation models (DEMs) and vegetation height models (DSM – DTM). We evaluated several software options and settled on Quick Terrain Modeler (QT Modeler, http://www.appliedimagery.com/) to accomplish this task. We created results based on a 5 m grid cell size, which resulted in reasonable file sizes and processing times, given that the initial total file size was 160 GB. Differences in elevation less than 20 cm were captured by all county data sets. Thus, the DEMs created using these new data were greatly improved over those available from earlier air photo interpretation (**Figure 5**). Visualizations of the results of these analyses are revealing and useful to managers (**Figure 6**).

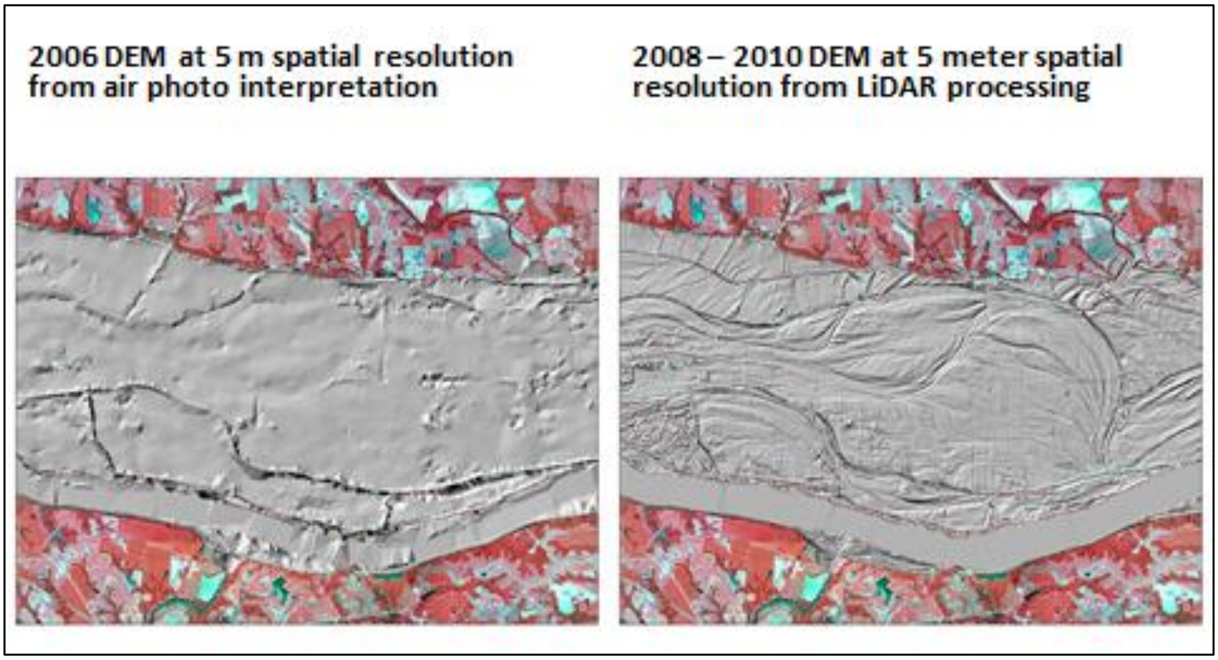

Figure 5. Digital elevation models (DEMs) generated from air photo interpretation(left) versus LiDAR processing (right). Elevation differences of less than 20 cm were reliably captured using LiDAR.

In order to identify homogenous areas as defined by vegetation canopy height (or ground surface elevation where vegetation was lacking), eCognition software (http://www.ecognition.com) was used to analyze LiDAR data at 5 m resolution and produce image objects (homogeneous polygons) based on that data. This set of polygons was then attributed with ancillary information needed to classify the polygons relative to potential wetland conditions.

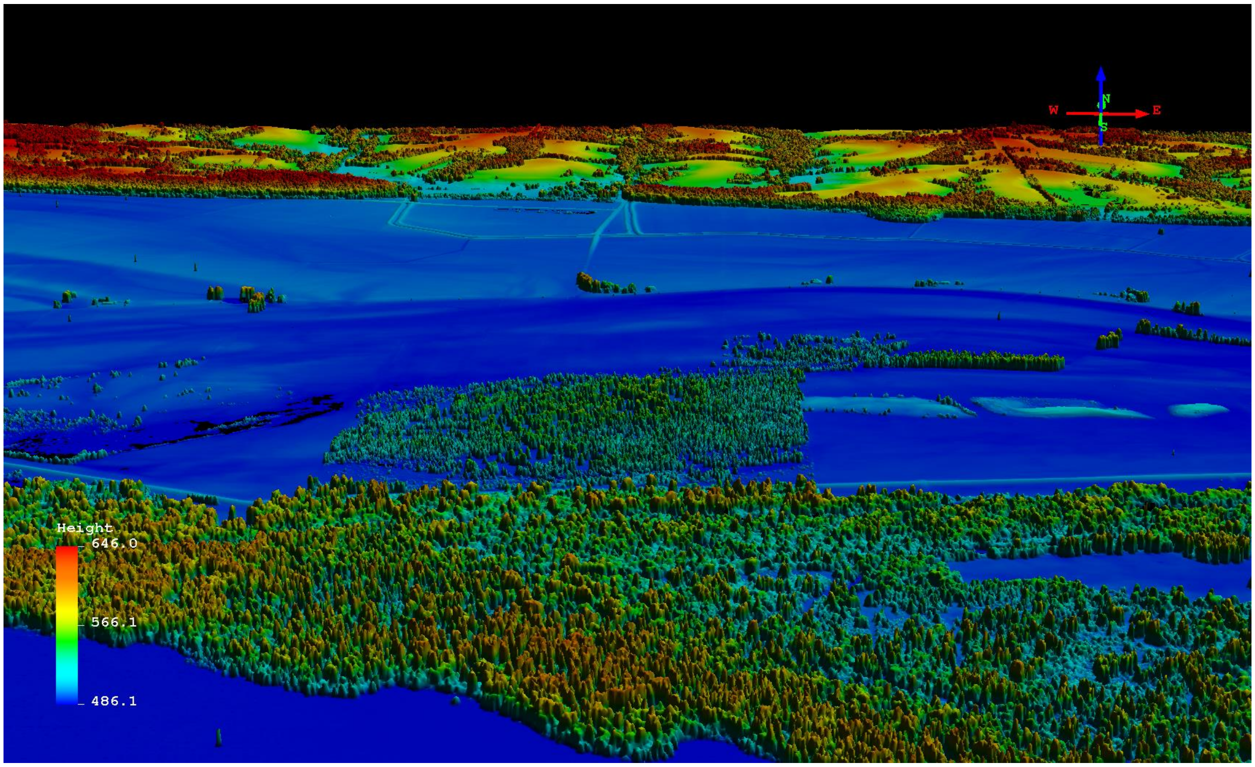

Figure 6. Vegetation height visualization for a section of the Missouri River floodplain. Relative height is indicated by a color scale from red (tall) to blue (short).

Wetland Classification and Mapping

Cowardin's Classification of Wetlands and Deep Water Habitats of the United States (http://www.npwrc.usgs.gov/resource/wetlands/classwet/index.htm), together with a water regime modifier applied at the Class level, serves as a standard for regulatory agencies across the country. Important variables captured in this system include the source of water, vegetation class and subclass type (height and life form), and substrate. We used his system to classify extant wetlands for the big river floodplains analyzed (**Figure 4**). The following general process was used for classification and mapping (**Figure 7**):

1. Identify wetland system based on source of water.
2. Identify wetland class type based on vegetation height, and subclass based on life form (evergreen versus deciduous).
3. Create an index to water regime (a modifier applied at the class level) based on landform (sinks) and soil drainage class.
4. Execute mapping based on attribution of these variables (system, water regime, vegetation class and subclass) to image objects generated from LiDAR information.

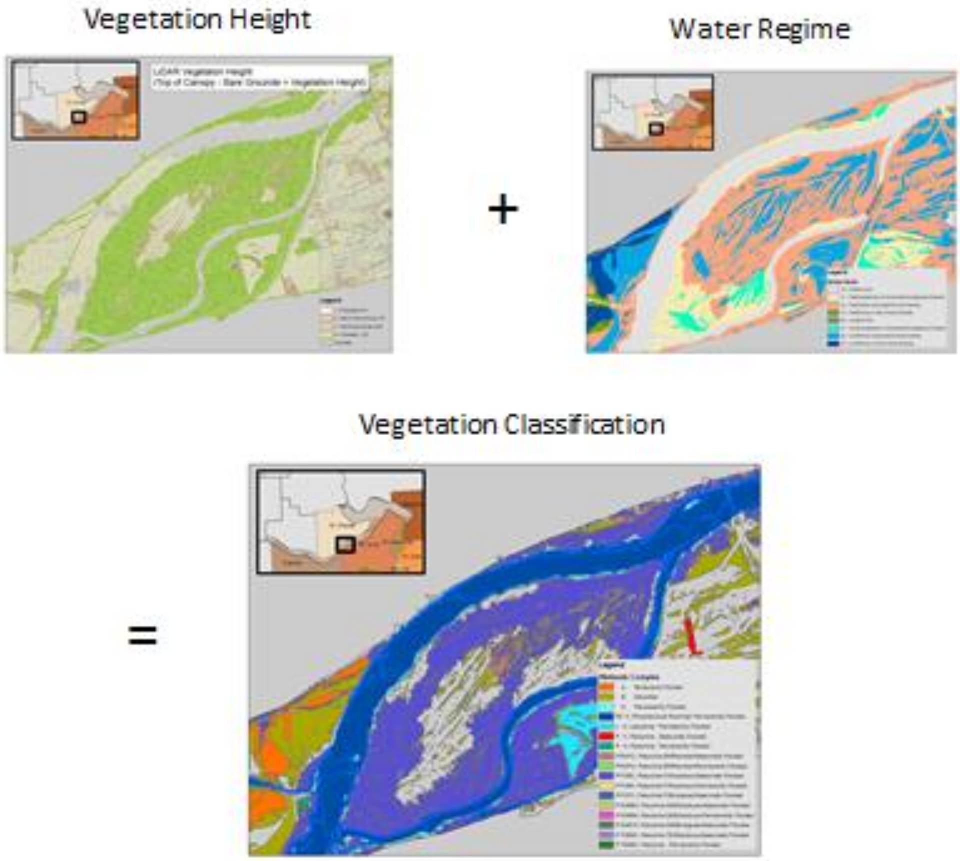

Figure 7. General process used to map wetlands. LiDAR data were used to extract vegetation height and sinks, and digital county soil data were used to identify impermeable soils. Image objects generated from LiDAR served as the basic spatial unit for mapping.

Water regime was defined based both on relative elevation, from which sinks were identified, and soil drainage class. Results were designed to provide an index to Cowardin's water regime definitions (**Table 1**). About 28.8% of the big river floodplains within the study area were uplands, and 71.2% was wetland. Seasonally flooded areas accounted for 16.4% of the study area, whereas relatively drier temporarily flooded and saturated areas made up 37.8% of the area. The temporarily flooded and saturated classes were liberally defined in order to circumscribe all areas that may support a water regime where wetlands could form. Thus, we are likely to have over-represented rather than under-represent the extent of wetlands on the big river floodplains.

Table 1. Distribution of water regimes within the study area. Definitions for saturated and temporarily water regimes were liberal.

Water Regime	Cowardin Code	Area (Hectares)	% of Study Area
Upland	U	28084.7	28.81%
Permanently Flooded	H	16968.2	17.41%
Saturated	B	27345.0	28.05%
Seasonally Flooded	C	16023.1	16.44%
Temporarily Flooded	A	9065.4	9.30%

A total of 22,159 hectares, or 22.7% of the study area, is currently vegetated, extant wetland. An additional 3,775 hectares (3.9%) is extant upland vegetation. Cropland accounts for 51,075 hectares, or 52.4% of the study area, and water (e.g. mainly the Missouri River) covers 14,042 hectares, or 14.4%.

All vegetated wetlands within the study area are within the Palustrine system, and less than 0.1% of the study area is within either the evergreen forest or evergreen shrub/scrub subclass, combined. Almost 60% of extant wetlands are deciduous forest and more than 33% are emergent vegetation less than 1 m tall (**Table 2**). Less than 10% of the wetlands are short (1 m to 3 m) or tall (3 m to 6 m) shrub/scrub vegetation. Most wetlands occurred in the seasonally flooded water regime (82.5%), followed by saturated (12.4%), temporarily flooded (3.6%), and permanently flooded (1.9%).

Table 2. Area of wetland types within the study area using a classification that mimics Cowardin. All wetlands were in the Palustrine system. Emergent, Scrub/Shrub (sub-divided by height), and Forested refer to Class.

Wetland Type and Water Regime	Area (Hectares)	% of Complexes
Emergent (EM; marsh <1 m)		
Permanently Flooded "H"	397.63	1.79%
Seasonally Flooded "C"	4,803.20	21.68%
Temporarily Flooded "A"	498.30	2.25%
Saturated "B"	1,637.12	7.39%
Subtotal	**7,336.25**	33.11%
Short Shrub/Scrub (SSS; 1 to <3 m)		
Permanently Flooded "H"	9.32	0.04%
Seasonally Flooded "C"	510.40	2.30%
Temporarily Flooded "A"	51.28	0.23%
Saturated "B"	127.27	0.57%
Subtotal	**698.27**	3.15%
Tall Shrub/Scrub (TSS: 3 m to <6 m)		
Permanently Flooded "H"	9.44	0.04%
Seasonally Flooded "C"	947.80	4.28%
Temporarily Flooded "A"	51.41	0.23%
Saturated "B"	186.11	0.84%
Subtotal	**1,194.76**	5.39%
Forested (FO; >6 m)		
Permanently Flooded "H"	12.15	0.05%
Seasonally Flooded "C"	12,015.40	54.22%
Temporarily Flooded "A"	185.66	0.84%
Saturated "B"	716.63	3.23%
Subtotal	**12,929.83**	58.35%
Grand Total (All Wetlands)	**22,159.11**	

Wetland Mitigation and Restoration Ranking

We used algorithms that considered size, diversity, and landscape context to assign ranks for mitigation and restoration importance. The basic concepts and process was as follows:

1. Only extant wetlands were ranked for mitigation importance, and only cropland or barren land was ranked for restoration importance.
2. Wetland complexes were defined based on patches formed by aggregation of all wetlands and all non-wetland vegetation touching existing wetlands (**Error! Reference source not found.**). Thus, uplands adjacent to wetlands were included in patches.
3. Mitigation ranks were based on wetland complex size, diversity, and landscape context (distance to public lands or urban lands).
4. Restoration ranks were based on water regime (essentially, a 'do-ability' index for restoring wetlands) and landscape context (distance to extant wetlands, public lands, urban lands, and water).

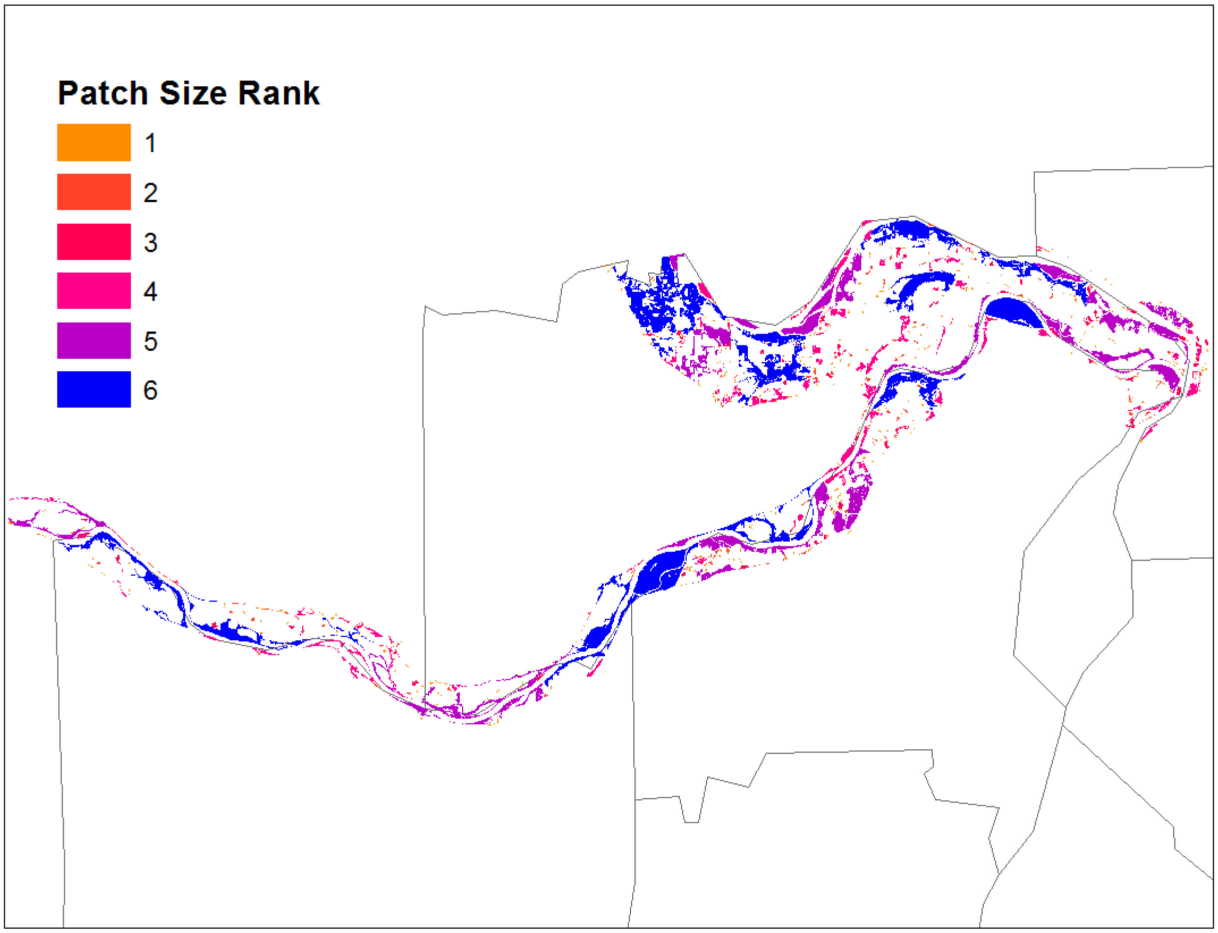

Figure 8. Patch size rank for wetland complexes within the study area. Patches were formed from wetlands and all upland vegetation touching wetlands. Ranks were from 1 to 6, with breaks at 5 hectares, 10 hectares, 25 hectares, 100 hectares, and 500 hectares.

The ranking algorithm for wetland mitigation was (**Error! Reference source not found.**, **Error! Reference source not found.**):
Wetland Mitigation Importance Rank = Patch Size(1.5) + Wetland Diversity + Distance to Public Lands + Distance to Urban Lands*

Where:
Patch size was ranked 1 to 6 with breaks as follows:
<5 hectares = 1
>=5 – 10 hectares = 2
>=10 – 25 hectares = 3
>=25 – 100 hectares = 4
>=100 – 500 hectares = 5
>=500 hectares = 6

Patch Diversity: number of different wetland and upland types within the patch, ranked from 1 to 5 based on natural breaks
Distance to Public Land: ranked 1 to 3 with breaks at 1 m, 50 m, 100 m, and 150 m
Distance to Urban: ranked (-1) if within 100 m of urban and (-2) within 50 m

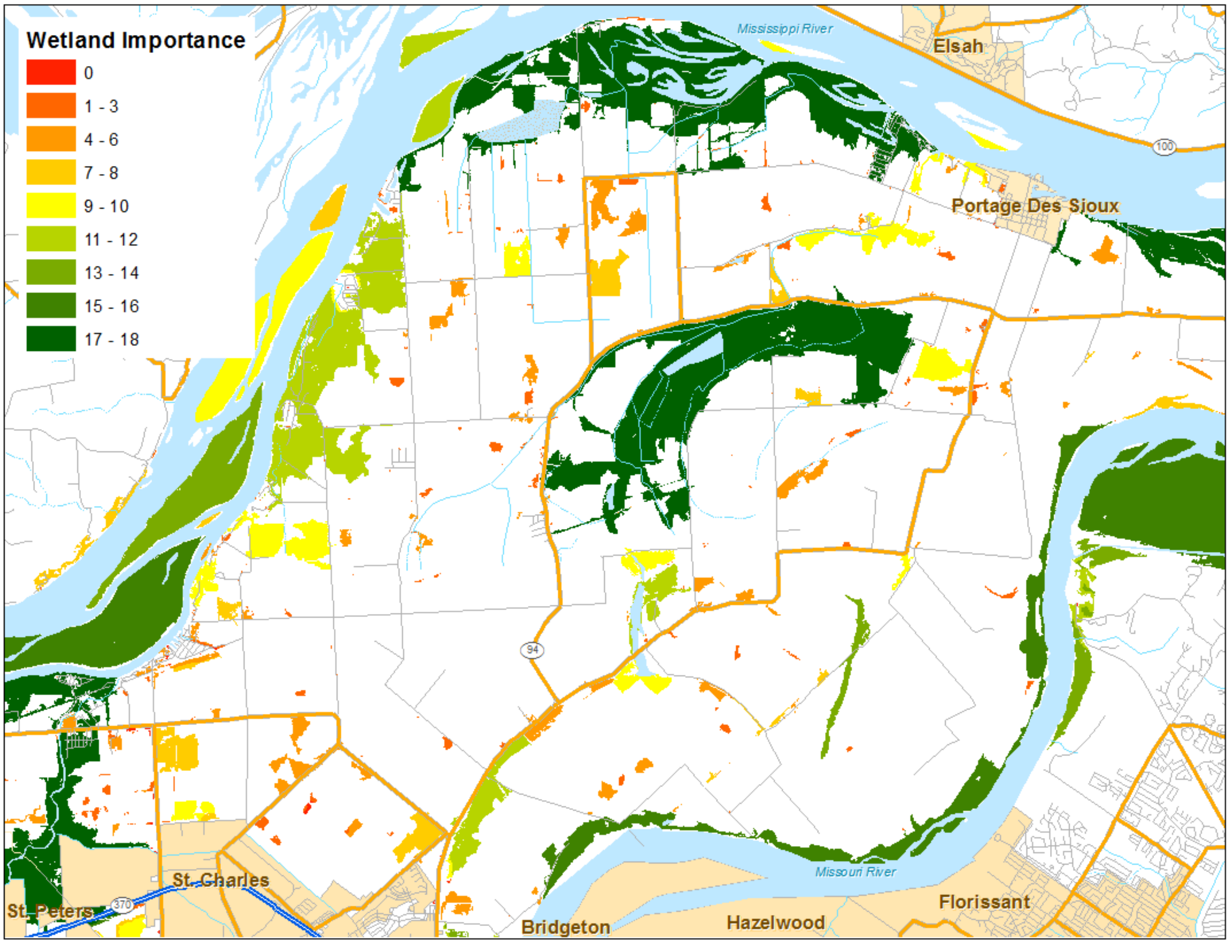

Figure 9. Wetland mitigation importance ranks applied to extant wetland complexes for the area of the confluence of the Missouri and Mississippi Rivers.

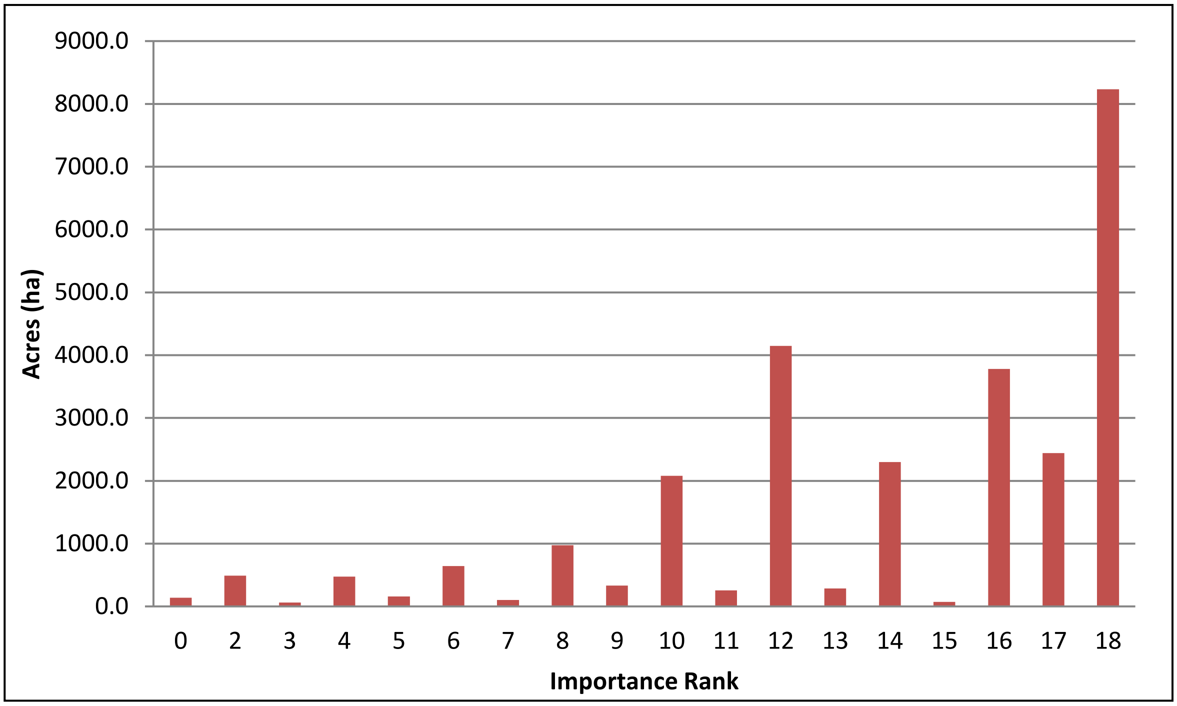

Figure 10. Distribution of wetland mitigation importance ranks applied to extant wetland complexes within the study area. Most extant wetlands are of relatively high importance.

The ranking algorithm for wetland restoration was (**Figure 11**, **Error! Reference source not found.**):

Wetland Restoration Importance Rank = Water Regime + Distance to Public Lands + Distance to Urban Lands + Distance to Water + Distance to Extant Wetlands

Where:
Water Regime: "C" – Seasonally Flooded (score = 6); "A" Temporarily Flooded (score = 4); "D" Saturated (score = 2)
Distance to Public Land: ranked 1 to 3 with breaks at 1 m, 50 m, 100 m, and 150 m
Distance to Water: ranked 1 if within 50 m
Distance to Extant Wetland: ranked 3 if within 50 m, 2 if within 100 m; 1 if within 150 m

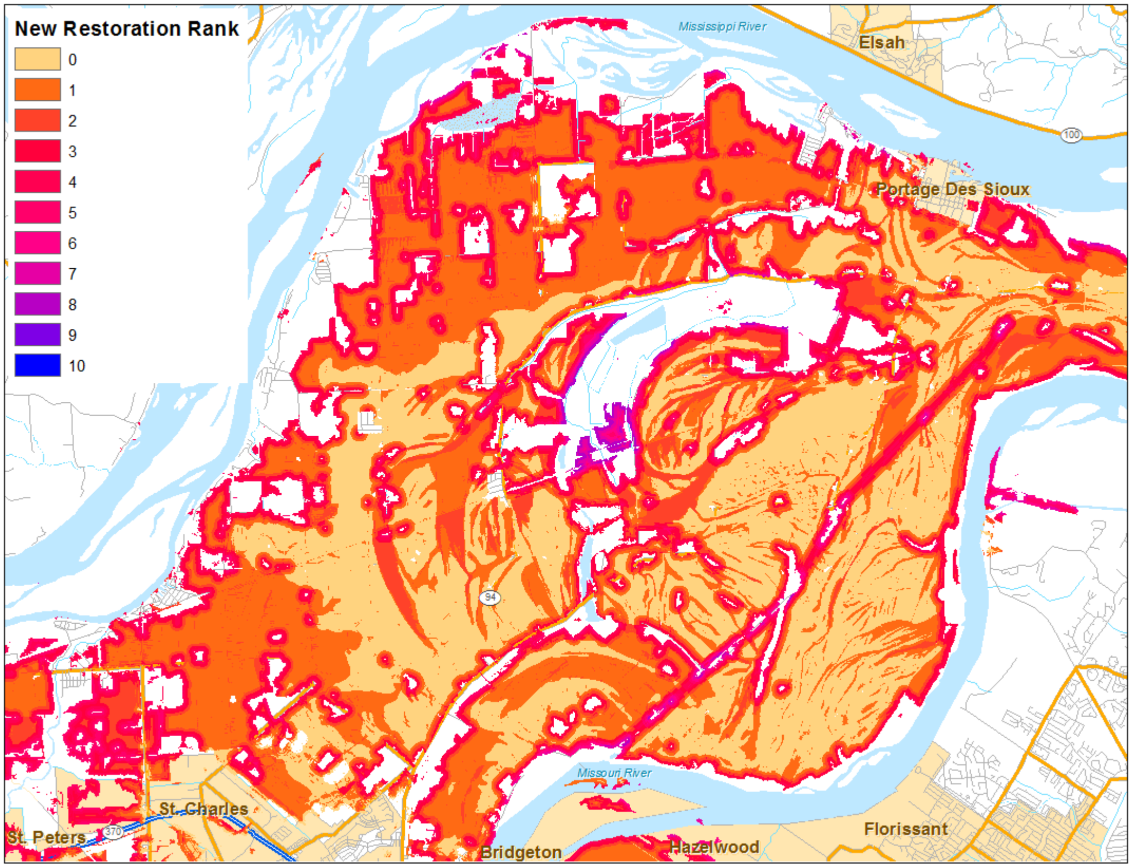

Figure 11. Wetland restoration importance ranks applied to cropland and barren land for the area of the confluence of the Missouri and Mississippi Rivers.

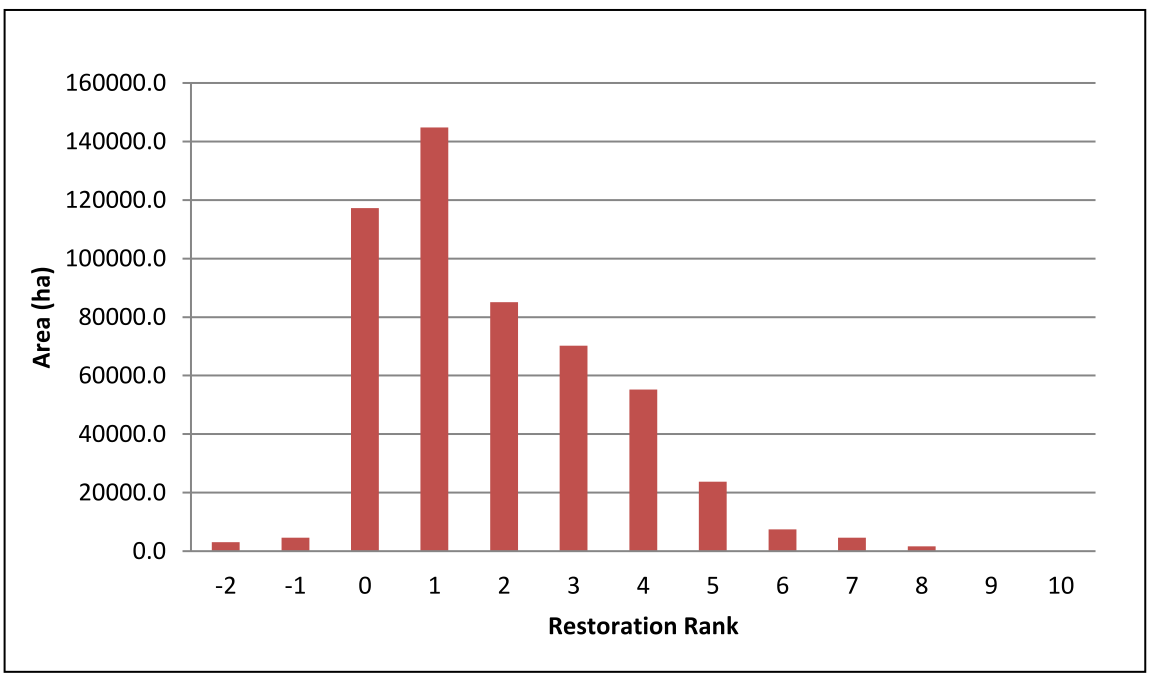

Figure 12. Distribution of wetland restoration importance ranks applied to areas that are currently cropland or barren land within the study area.

Land Cover Change Detection

Urban development has occurred apace in some regions within the East-West Gateway study area, so we analyzed change in the region (**Figure 13**). We compared 2008 Landsat imagery to 2010 imagery using three dates (spring, summer, fall) for each year.

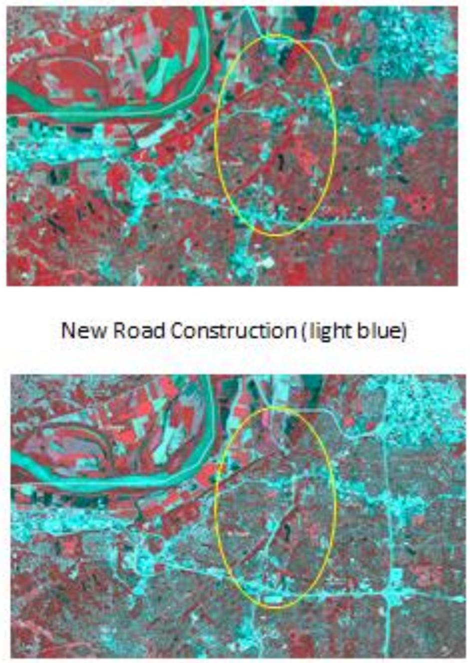

Figure 13. New urban development (light blue) such as road construction has occurred within the East-West Gateway region.

The general procedure was as follows:

- Acquire spring, summer, and fall imagery for 3 Landsat path/rows for 2008 and 20010 to cover the study area
- Mosaic imagery by season
- Stack imagery by year (18 band stacks, one for 2008 and one for 2010)
- Mask out cropland using existing vegetation cover data to improve results for non-crop areas
- Use Erdas Imagine DeltaCue change detection module to classify each mosaic into 12 classes
- Concatenate the two stacks (144 potential change classes created), and manually identify classes that depict change
- Recode classes as change (1) or not change (0)
- Assign 2008 land cover class to all pixels with a value of 1 to determine which classes had changes in order to calculate statistics and summarize by county

A total of 9,171 hectares of change were detected within the East-West Gateway region, or about 0.78% of the study area. Conversion of urban low intensity to high intensity accounted for 27.8% of the change, whereas change within the grassland (2,376 ha, 25.9%), cropland (1133 ha, 12.3%), and deciduous forest (963 ha, 10.5%) classes were also apparent. Change was not evenly distributed in space. St. Louis and Madison counties had relatively concentrated areas of change, and a total of 1.24% and 1.14% change overall, respectively. Franklin and Jefferson counties had relatively little change, at 0.40% and 0.60%, respectively (**Table 3**).

Table 3. Land cover change by county for the East-West Gateway region.

County	No Change (HA)	Change (HA)	Total County Area (HA)	% of County Changed
Franklin	240632	968	241600	0.40%
Jefferson	168684	1023	169707	0.60%
Madison	185987	2139	188127	1.14%
Monroe	102182	761	102944	0.74%
St. Charles	151404	1170	152574	0.77%
St. Clair	171249	1172	172421	0.68%
St. Louis	134401	1684	136085	1.24%
St. Louis City	18483	171	18654	0.92%
EW Gateway Region	**1173023**	**9088**	**1182111**	**0.77%**

Summary

We used LiDAR data to improve the wetland classification for the Missouri River floodplain and a portion of the Mississippi River floodplain upstream of the confluence with the Missouri (**Figure 14, Figure 15**). The process involved used of LiDAR data to create better digital elevation models, vegetation height information, and image objects for mapping. Wetland classification results were designed to mimic Cowardin's classification scheme (including the water regime modifier), which in turn is used by regulatory agencies. We also improved wetland restoration potential information, mainly by improving the water regime index (e.g. identifying low-lying areas at fine resolution). We defined water regime in a way that is likely to identify too many, rather than too few, areas as "wet." Even given this caveat, we identified less area as wetland versus the earlier version based on coarser information (**Figure 14**). Finally, we provide a change detection data layer from 2008 to 2010 that identifies major land clearing that is on-going in the region. Based on lessons learned and results provided, we hope to move forward to create compatible wetland data for the Mississippi downstream of the confluence with the Missouri. In addition, we hope to look into the possibility of improving conservation outcomes by providing forest height information for selected watersheds next year.

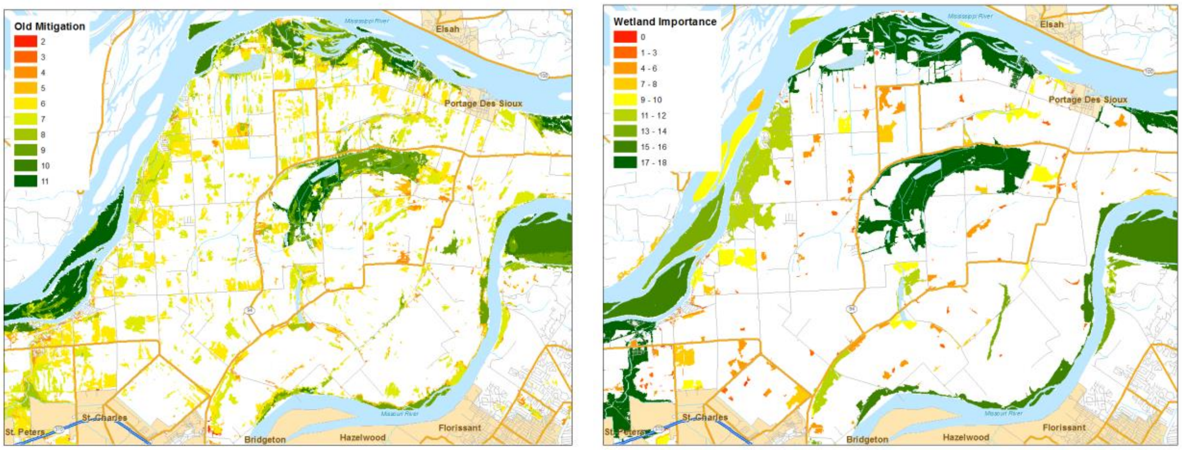

Figure 14. Wetland mitigation importance ranks from older versus improved data on the upstream side of the confluence. Darker greens are more important. Note the 'false positives' for wetlands (yellows on the left image).

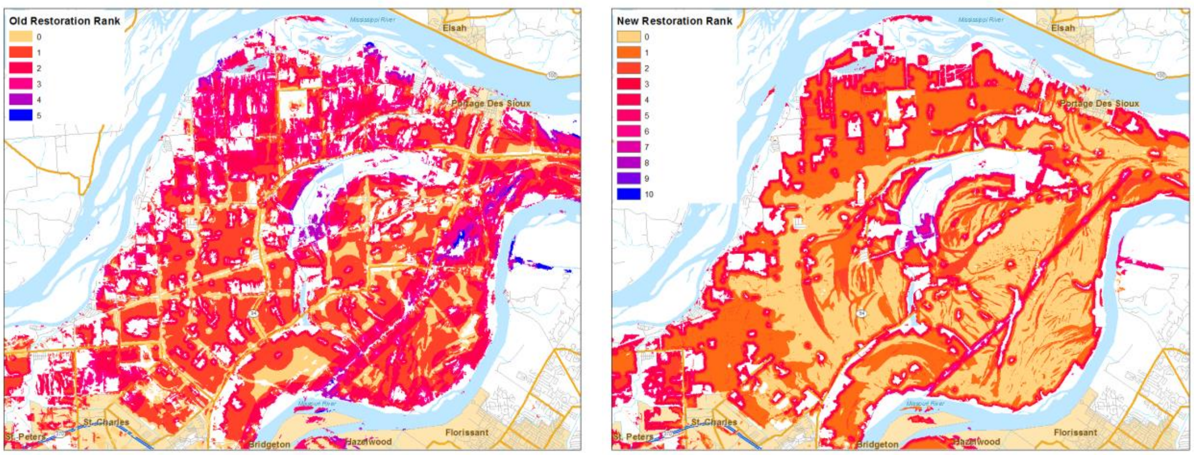

Figure 15. Wetland importance ranks from older versus improved data on the upstream side of the confluence. Darker reds are ranked higher for restoration value. Note the newer data that ranks the location of old channels as more appropriate for restoration.