Flood inundation analysis of the Wabash River near New Harmony, Indiana.

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CE 513, GIS in Water Resources

Winter 2021

13 March 2021

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Introduction

Being 810 kilometers long the Wabash River is one of the major tributaries of the Ohio River. The Wabash River begins in western Ohio and Flows through Indiana, then along the Indiana and Illinois border. The Wabash River watershed is approximately 86000 square kilometers and drains water from most of Indiana and parts of Illinois, including major tributaries such as the Little Wabash, White, and Patoka Rivers. During the spring and winter months Indiana and Illinois experience a large amount of precipitation which causes flooding throughout the states and leads to flooding within the Wabash River floodplain. A healthy floodplain can act as a natural erosion control, improve water quality, exchange nutrients between terrestrial and aquatic communities, store nutrients which causes floodplains to be productive habitats, and contain unique habitats such as oxbow lakes. Flooding can greatly impact communities along the river and can influence ecosystems within the flood plain. For example, oxbow lakes that reconnect to the river experience changes in community structure, physiochemical parameters, and heavy metal concentrations.

Problem Statement

There were many purposes of this study the first purpose was to determine the extent of flooding at each flood stage. The second purpose of this study was to determine at what flood stage select lentic oxbow lakes reconnect to the main river channel. The third purpose was to develop maps showing at risk areas within the Wabash River watershed and at risk homes in New Harmony, Indiana at each flood stage. The last purpose of this study was to determine what land uses are most affected at each flood stage.

Site description

New Harmony, IN is a small rural town in southwest Indiana that is located near the Wabash River. New Harmony is located approximately 61 km upstream from the Wabash River's confluence with the Ohio River. The flood stages of the Wabash River near New Harmony are action stage (10 ft), flood stage (15 ft), moderate flood stage (20 ft), and major flood stage (23 ft). The three lentic oxbow lakes; Pitcher, Great House, and Ribeyre, that are of interest for this project are all located south of New Harmony, IN. These lakes that reconnect to the Wabash River during floods, although they do not all connect at the same flood heights. This study was focused on a 61 km stretch of the Wabash river that starts north of New Harmony, IN and ends south of Great House lake (Fig. 1).

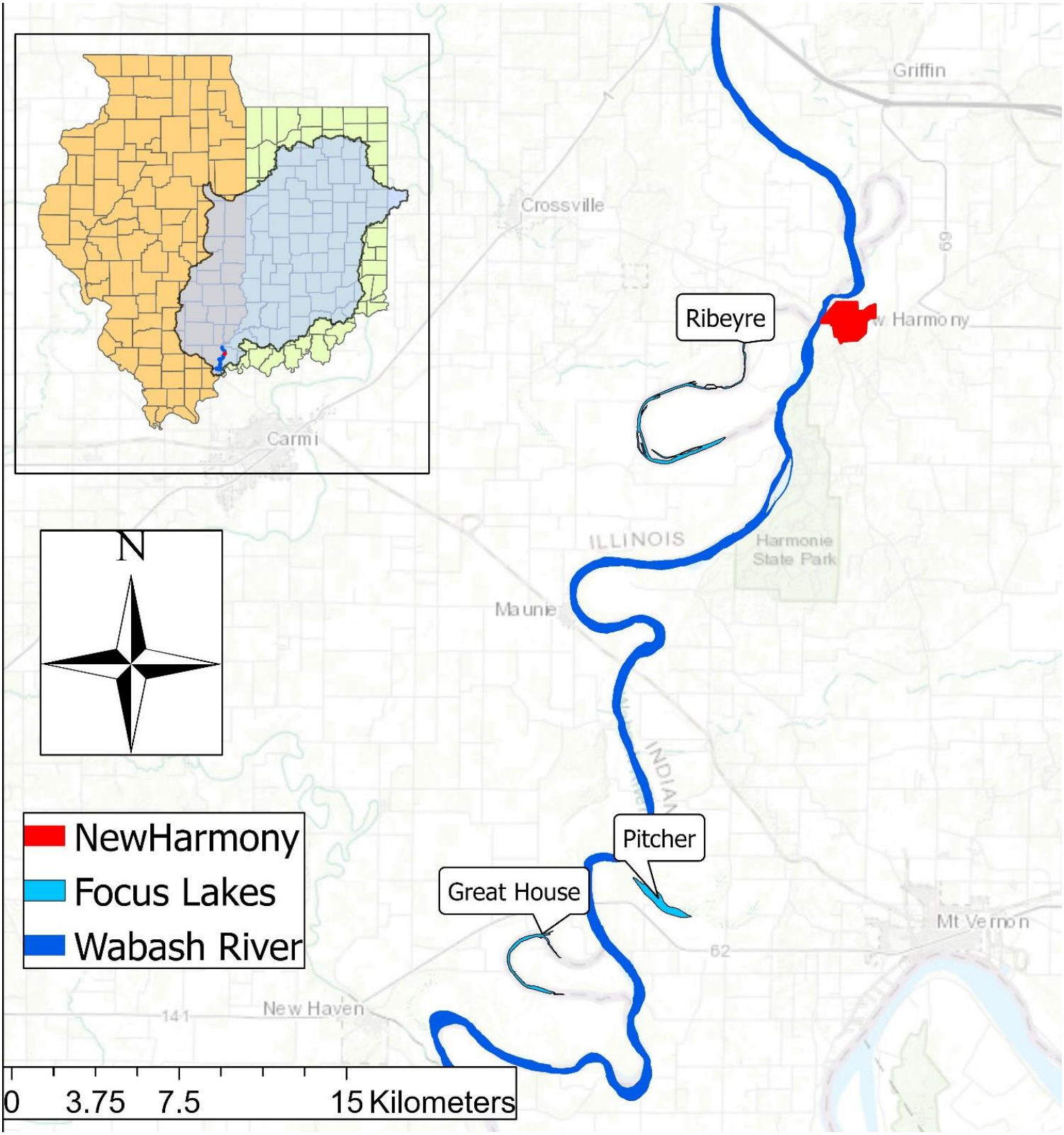

Figure 1: Map showing the location of the focus stretch of the Wabash River, focus lentic oxbow lakes, and New Harmony, IN. Including an inset map showing the study area within the Wabash River watershed, Indiana, and Illinois.

Data

The data used in this experiment was collected from maps.indiana.edu, geospatial data gateway, NHD website, and ArcGIS Pro Living Atlas. Data layers used in this analysis include state county layers, building footprints, populated areas, waterbodies, NHD flowlines, land cover, HUC 8 watersheds, and a DEM (Table 1). All layers were vector data set except for the land cover and DEM datasets which were raster datasets with a 30m x 30m resolution. All data layers were projected to NAD 1983 UTM Zone 16N projection.

Table 1: Datasets used in this analysis. Including description of data, data type, data source, data projection, and resolution of each layer.

Data Set	Description	Vector or Raster	Source	Map Projection	Resolution
Indiana County Layers	Contains Indiana County boundaries	Vector	maps.indiana.edu	NAD 1983 UTM Zone 16N	N/A
Indiana Building Footprints	Contains boundaries of all building footprints within Indiana	Vector	maps.indiana.edu	NAD 1983 UTM Zone 16N	N/A
Indiana Places Populated Areas	Contains boundaries of all municipal areas within Indiana		maps.indiana.edu	NAD 1983 UTM Zone 16N	N/A
Indiana Waterbodies Rivers	Contians Indiana River boundaries	Vector	maps.indiana.edu	NAD 1983 UTM Zone 16N	N/A
Indiana Land Cover	Contains land use data and information in Indiana	Raster	Geospatial Data Gateway	NAD 1983 UTM Zone 16N	30m x 30m
Indiana HUC 8 Watersheds	Contains boundaries of all HUC 8 watersheds within Indiana	Vector	Geospatial Data Gateway	NAD 1983 UTM Zone 16N	N/A
Wabash River watershed NHD Flowline	Contains Wabash River Watershed Flowlines	Vector	NHD Website	NAD 1983 UTM Zone 16N	N/A
Illinois Land Cover	Contains land use data and information in Illinois	Raster	Geospatial Data Gateway	NAD 1983 UTM Zone 16N	30m x 30m
Illinois HUC 8 Watersheds	Contains boundaries of all HUC 8 watersheds within Illinois	Vector	Geospatial Data Gateway	NAD 1983 UTM Zone 16N	N/A
DEM	Contains data about elevational changes within an area	Raster	Living Atlas	NAD 1983 UTM Zone 16N	30m x 30m

GIS Analysis Methods

Reference layer creation methods (Fig. 2)

After all analysis data layers were added to the map a focus counties layer was created using Posey county in Indiana and White and Gallatin counties in Illinois. The counties layer was used to clip the IN waterbodies layer, DEM layer, and land cover layers. The IN waterbodies layer was then used to clip the NHD flowline layer. The HUC 8 watershed layers from each state were used to create a Wabash River watershed layer. The IN populated areas layer was used to create a New Harmony layer. The IN building footprints layer was used to create a New Harmony buildings layer. The focus lakes layer was created using create a new feature class then edit tools were used to create lake outlines using world imagery.

Flood stage layer creation methods (Fig. 3)

The flow distance tool was used to create a height above drainage layer using a stream raster, DEM raster, and flow direction raster. Raster calculator was then used to create raster layers of each flood stage. Extract by attribute tool was then used to create layers with only flooded areas. Raster to polygon tool was then used to create vector layers of each flood stage. The polygon that represented flooded areas was then selected and export features was used to create polygon layers of flooded areas at each flood stage.

Affected land use layer creation methods (Fig. 4)

The extract by mask tool was used to create land use layers at each flood stage, using the flood polygon layers.

Affected building layer creation methods (Fig. 5)

The select by location tool was used to select building footprints that intersected each flood stage. The affected buildings at each stage were then used to create affected building layers using the export features tool.

Figure 2: Methods used to create all reference layers. Methods used to create the focus area NHD flowline, focus area Wabash river, focus counties, focus DEM, focus oxbow lakes, Wabash River watershed, focus land use, New Harmony, and New Harmony buildings footprints layers are shown in dark orange, dark blue, red, gold, light blue, green, light orange, black, and purple respectively.

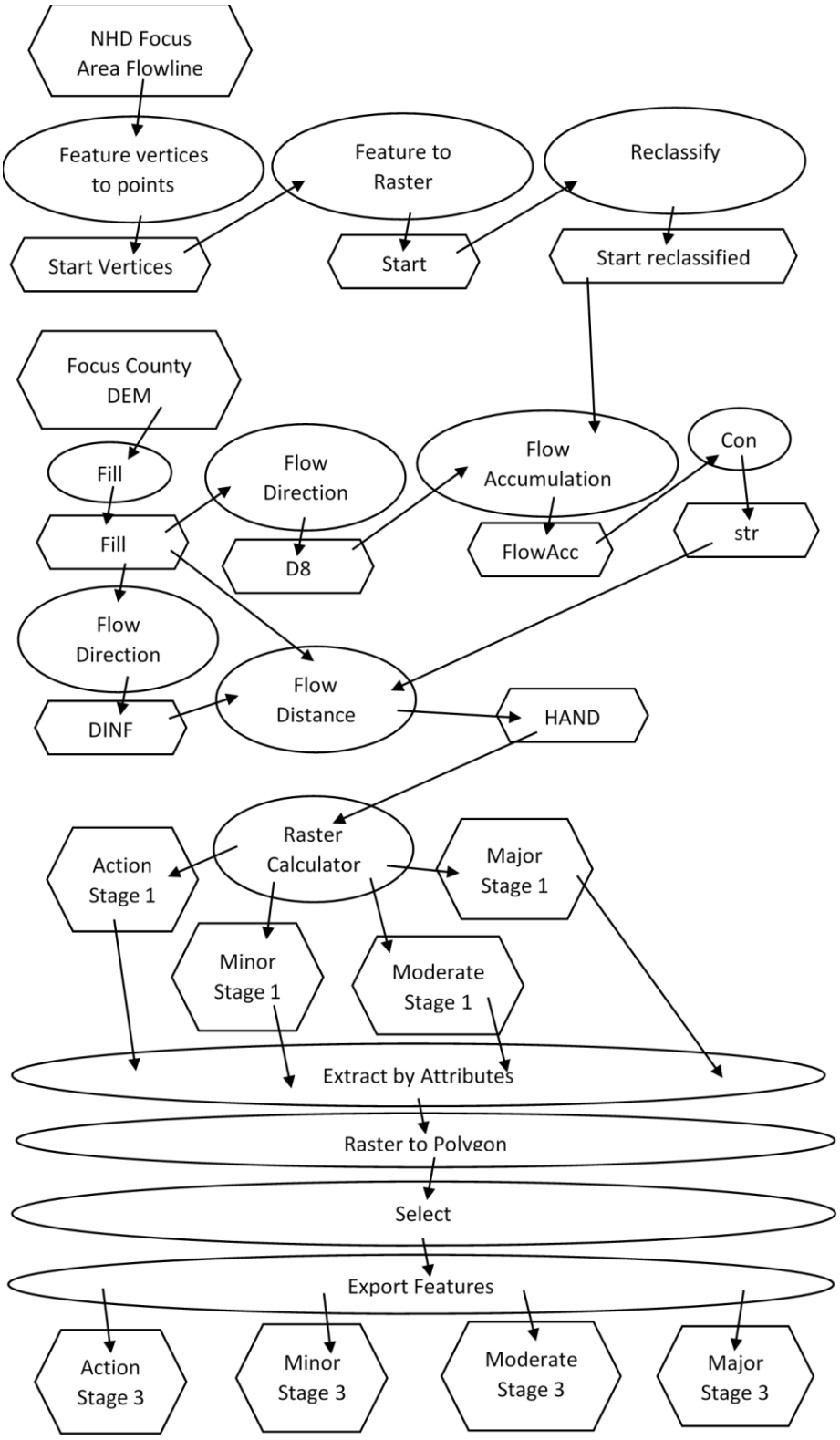

Figure 3: Methods used to create polygon layers of each flood stage.

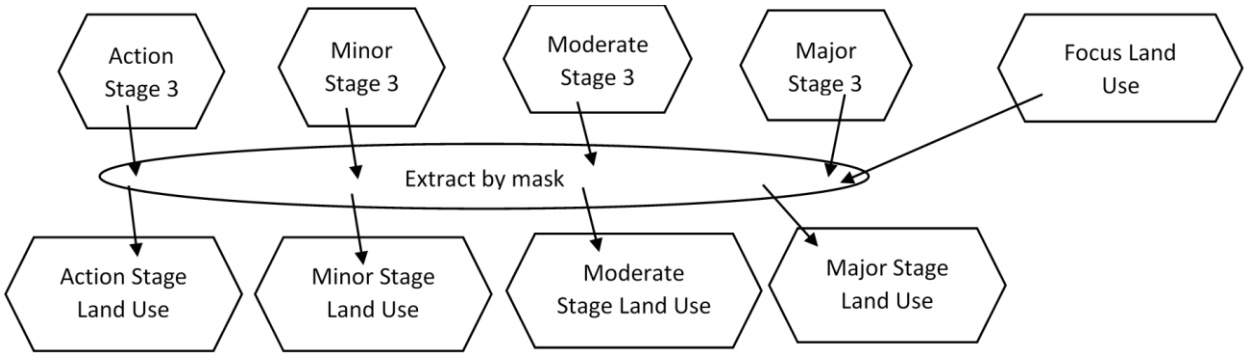

Figure 4: Methods used to create affected land use layers at each flood stage.

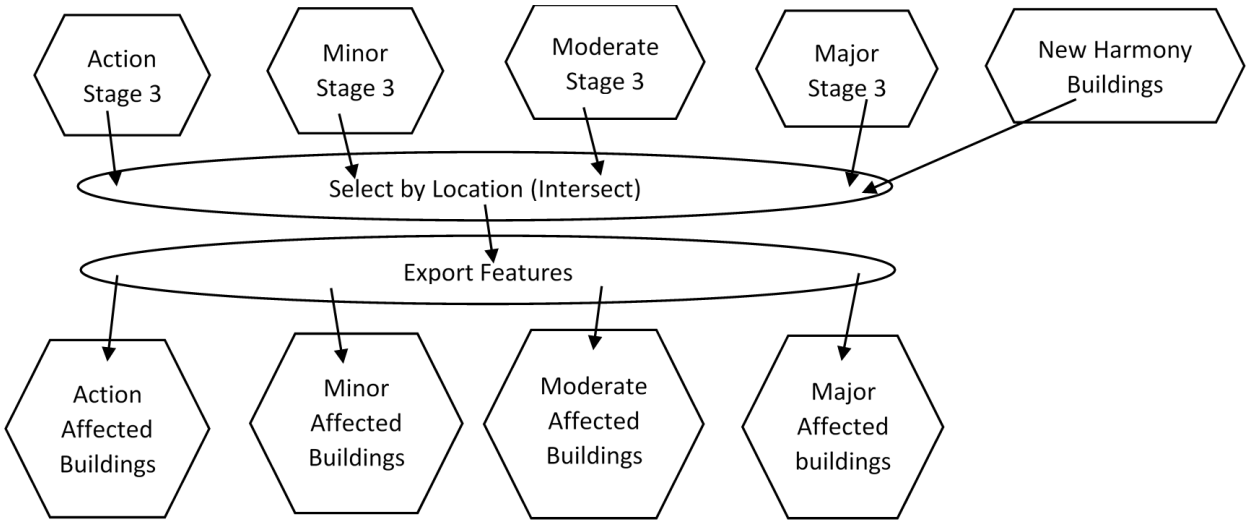

Figure 5: Methods used to determine which buildings are affected at each flood stage.

Results

Extent of flooding at each flood stage

The size of the Wabash River within the focus area was 19.4 km^2. The extent of the Wabash River during the action stage was 41.9 km^2. The extent during the minor stage was 155.2 km^2. The extent during the moderate stage was 255.8 km^2. The extent during the major stage was 320.8 km^2 (Fig. 6)(Fig. 7).

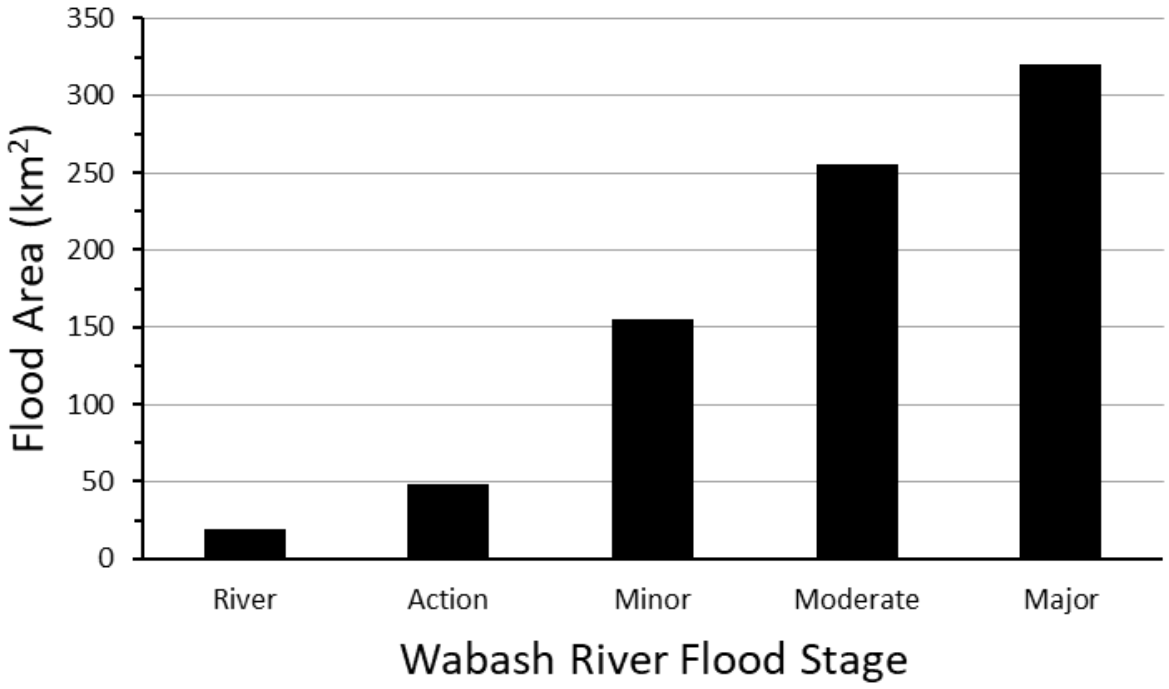

Figure 6: Bar graph that shows the change in the size of the Wabash river at each flood stage.

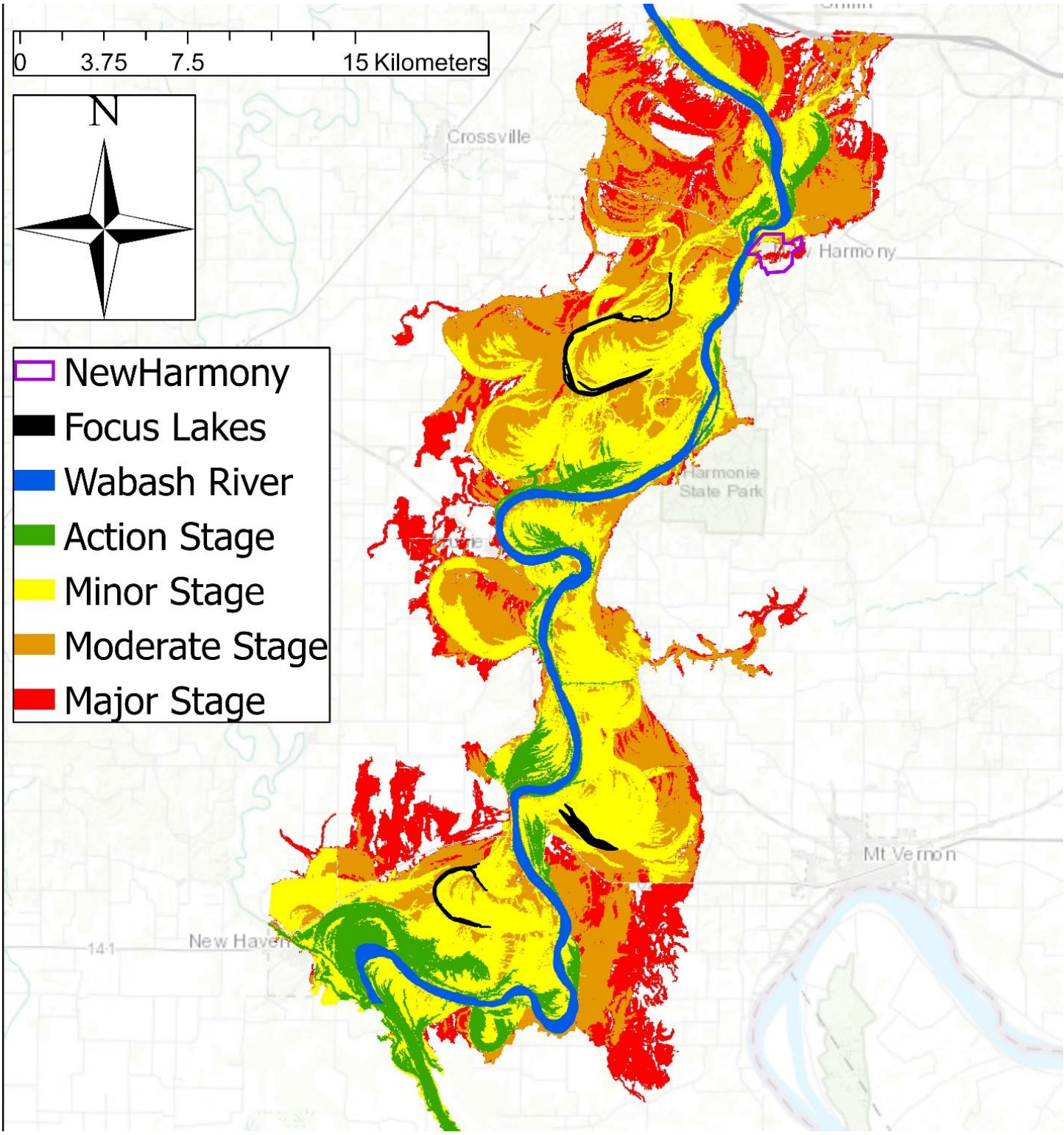

Figure 7: Map representing the extent of the Wabash River within the focus area at each flood stage.

Affected New Harmony buildings at each flood stage

There are 628 building within or near New Harmony, Indiana. During the action stage 0 buildings are affected by the flooding. During the minor stage 4 buildings are affected by flooding. During the moderate stage 13 buildings are affected by flooding. During the major stage 260 buildings are affected by flooding (Fig. 8) (Fig. 9).

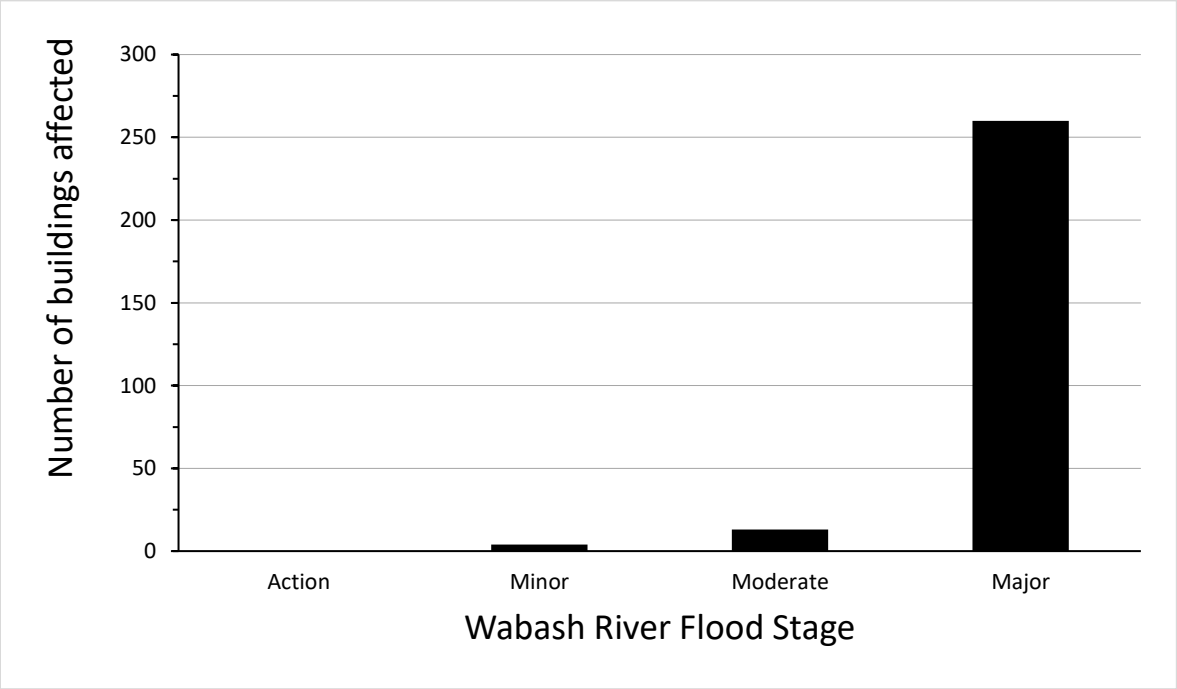

Figure 8: Bar graph showing the number of buildings within New Harmony, IN affected at each flood stage.

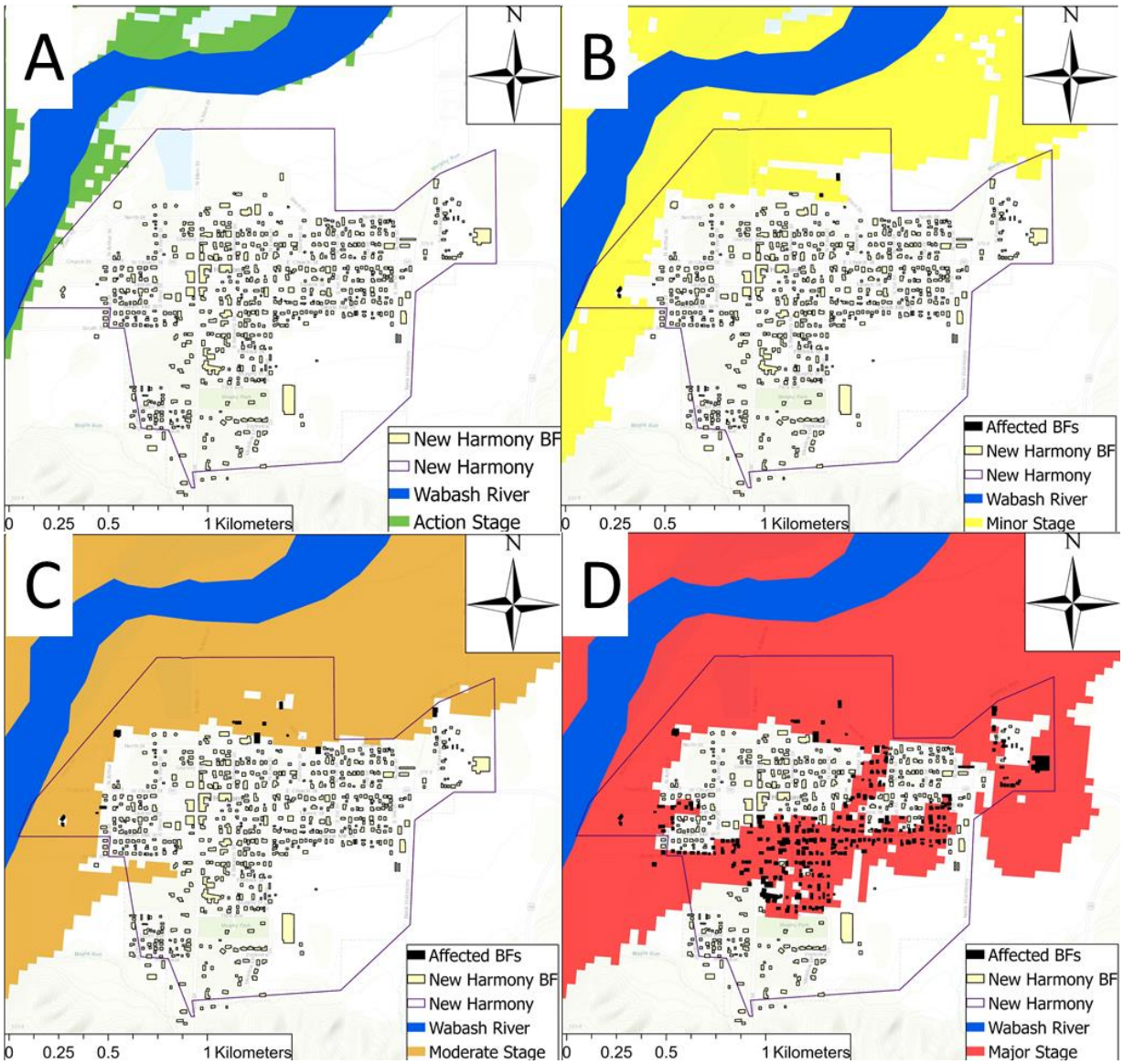

Figure 9: Maps representing the locations of New Harmony, IN buildings affected at each flood stage. Maps A, B, C, and D represent action, minor, moderate, and major flood stages respectively.

Connection of lentic oxbow lakes

All three lentic oxbow lakes reconnected with the main river channel during the minor flood stage (Fig. 10). This is supported by the sudden increase in water land use during the minor stage (Table 2).

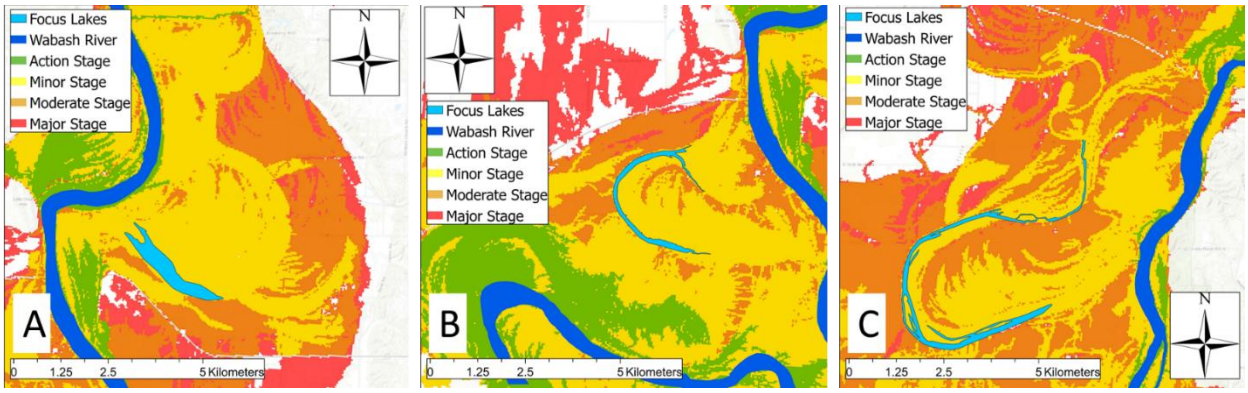

Figure 10: Maps representing the flood that affects areas near each oxbow lake. Maps A, B, and C represent Pitcher, Great House, and Ribeyre respectively.

Affected land use

The most affected land use at each flood stage was agricultural (Table 2) (Fig. 11) (Fig. 12). During action, minor, moderate, and major floods there are 10.5 km^2, 73.9 km^2, 149.2 km^2, and 203.5 km^2 of agricultural land affected, respectively. The second largest land use affected at each flood stage was forest. The third largest land use that is flooded at each stage is wetlands.

Table 2: Square kilometers of each land cover type affected at each flood stage.

Land Use	Action Stage	Minor Stage	Moderate Stage	Major Stage
Barren Land	0.0513	0.0594	0.0837	0.1143
Agriculture	10.5066	73.8567	149.1687	203.5314
Forest	10.296	32.1705	45.6039	50.058
Developed	0.7434	4.3425	10.2195	15.0372
Wetlands	5.0697	18.3357	22.797	23.7195
Water	1.9804	6.9223	8.3722	8.6125

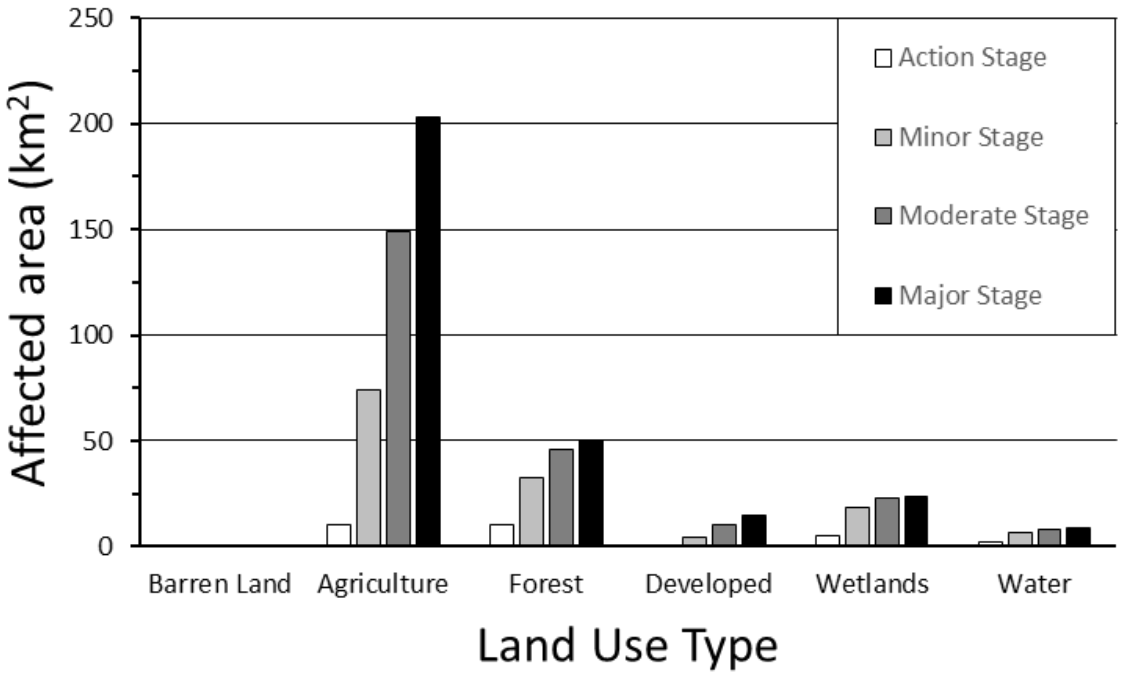

Figure 11: Bar graph showing the amount of each land cover type (km^2) at each flood stage.

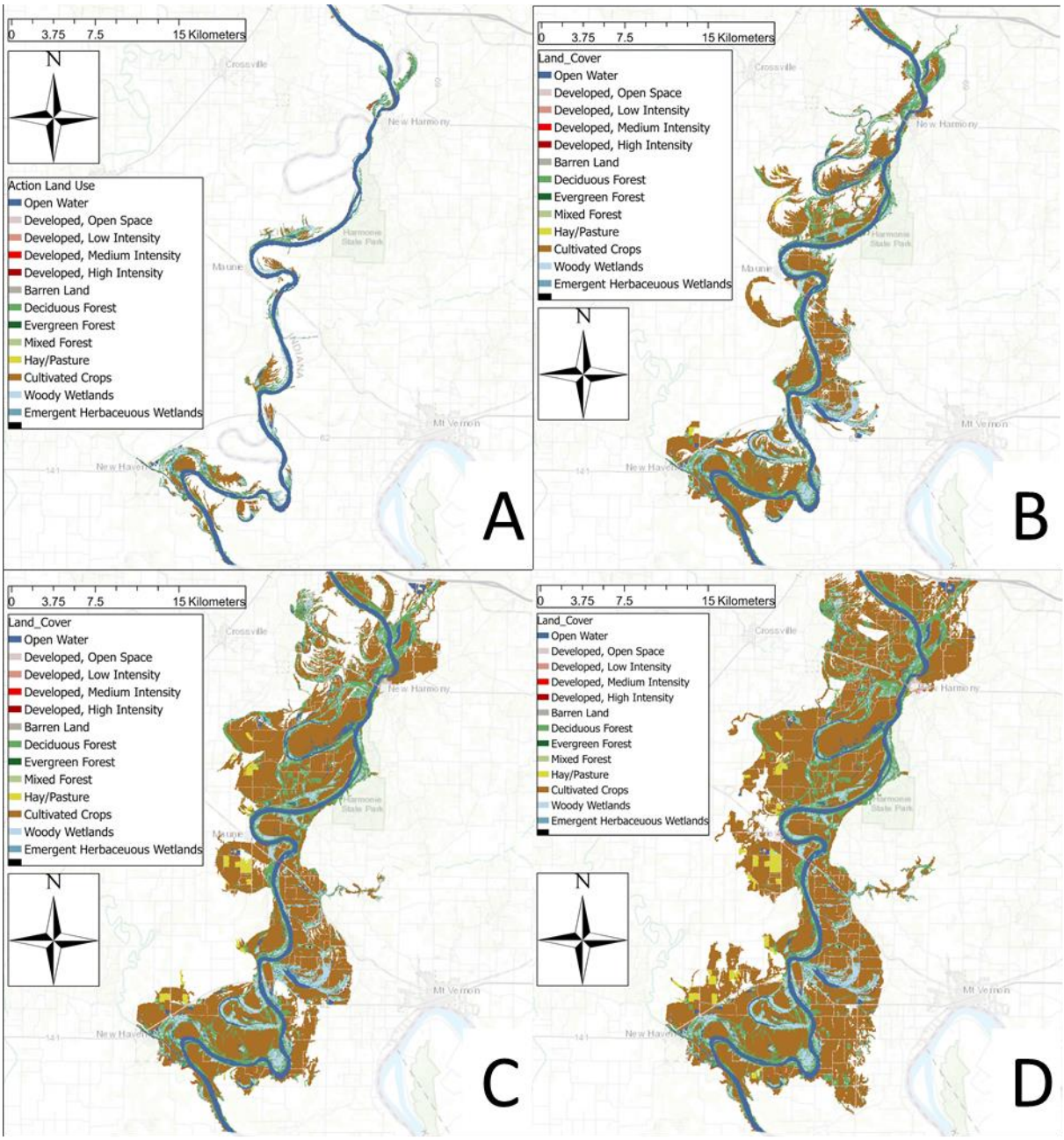

Figure 12: Maps representing the land uses affected at each flood stage. Maps A, B, C, and D represent action stage, minor stage, moderate stage, and major stage respectively.

Conclusions and Limitations

Using satellite images of flooding within the Wabash River and prior Knowledge of the area it was determined that the extent of floods calculated using methods in this study are accurate. The stage at which select lentic oxbow lakes also reconnect to the main river channel is also accurate. It is also believed that the affected land use is accurate because of the large amount of agriculture within the Wabash River floodplain.

The limitations of this study are due to the spatial scale of the data used. The land cover data and DEM used in this analysis had a 30 meter x 30 meter resolution, although the analysis could be more accurate if a smaller resolution was used. This analysis could also be more accurate if flood maps were made for rivers near the Wabash River, for example tributaries such as the Little Wabash River and other major streams such as the Ohio River. If these flood maps were used it would be possible to determine the total area affected during a flood depending on the flood height of each major stream in the area. Another possibility to improve this analysis would be to use bathymetry maps of the stream bed to more accurately determine the depth of the stream.

References

Arras, T. Lab 5 creation of height above nearest drainage.

ESRI. *Flow Distance (Spatial Analyst)-ArcGIS Pro Documentation.*

Fowler, K.K. 2016. Flood- Inundation Maps for the Wabash River at New Harmony, Indiana. *Scientific Investigations Report 2016-5119*, 1-26.

Ghebremariam, M.A. 2017. Urban flood modelling: a GIS based approach in Lomma, Skane region. *INES nr 439*, 1-79.

Manfreda, S., and Samela, C. 2019. A DEM-based Method for a Rapid Estimation of Flood Inundation Depth. Journal of Flood Risk Management, *Journal of Flood Risk Management*, 1-17.

Garousi-Nejad, I., Tarboton, D.G., Aboutalebi, M., and Torres-Rua, A.F. 2019. Terrain Analysis Enhancement to the Height Above Nearest Drainage Flood Inundation Mapping Method. *Water Resources Research*, 55(10): 1983-8009.

Location of New Harmony, Indiana, focus reach of the Wabash River and focus lentic oxbow lakes. Including an inset map showing the location of New Harmony, Indiana and the focus Wabash River reach within the Wabash River Watershed and Indiana and Illinois.

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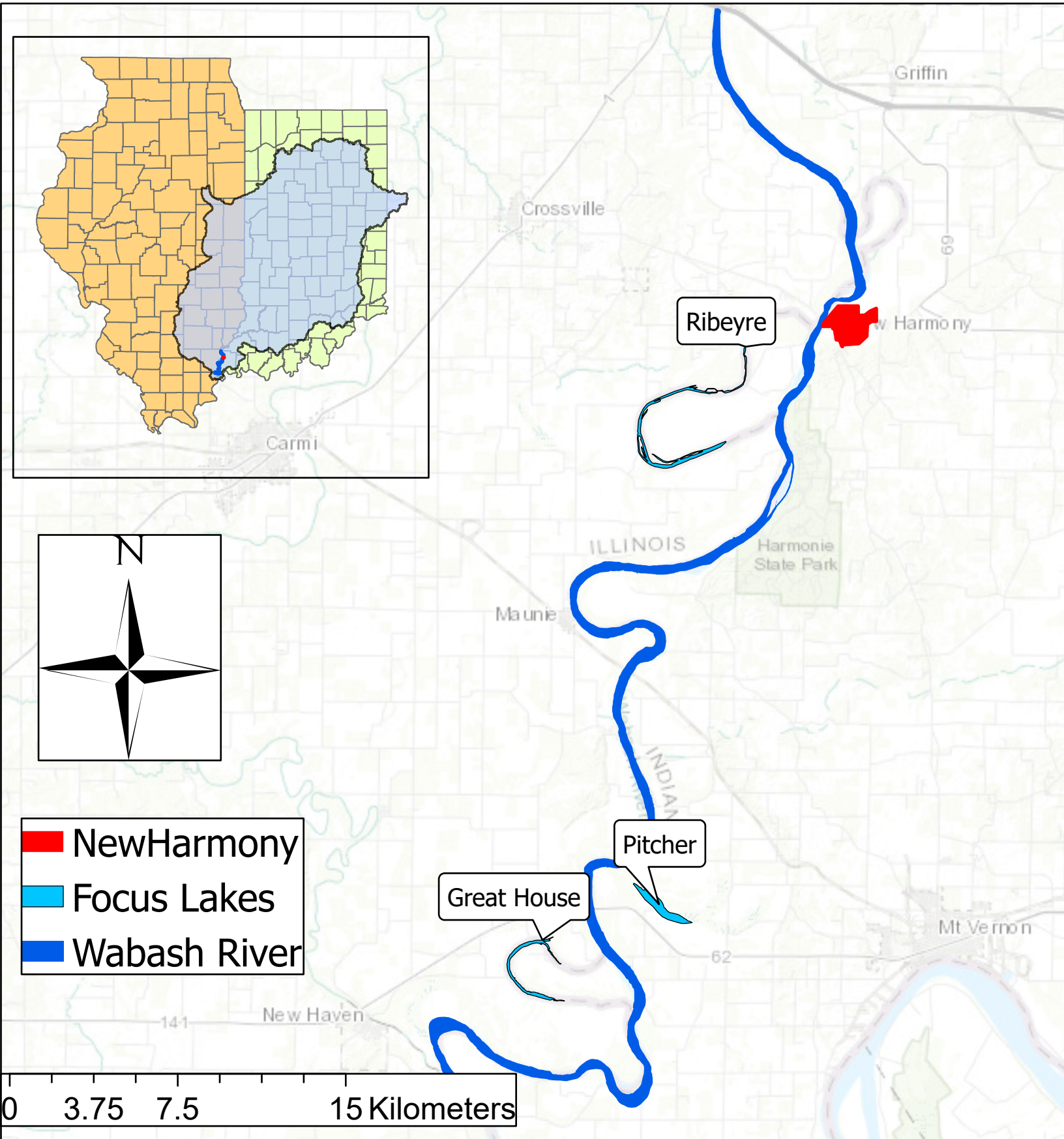

Areas affected by flooding of the Wabash River near New Harmony, Indiana at each flood stage; Action (10 ft), Minor (20 ft), Moderate (15 ft), and Major (23 ft). Including locations of New Harmony, Indiana and focus lentic oxbow lakes.

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