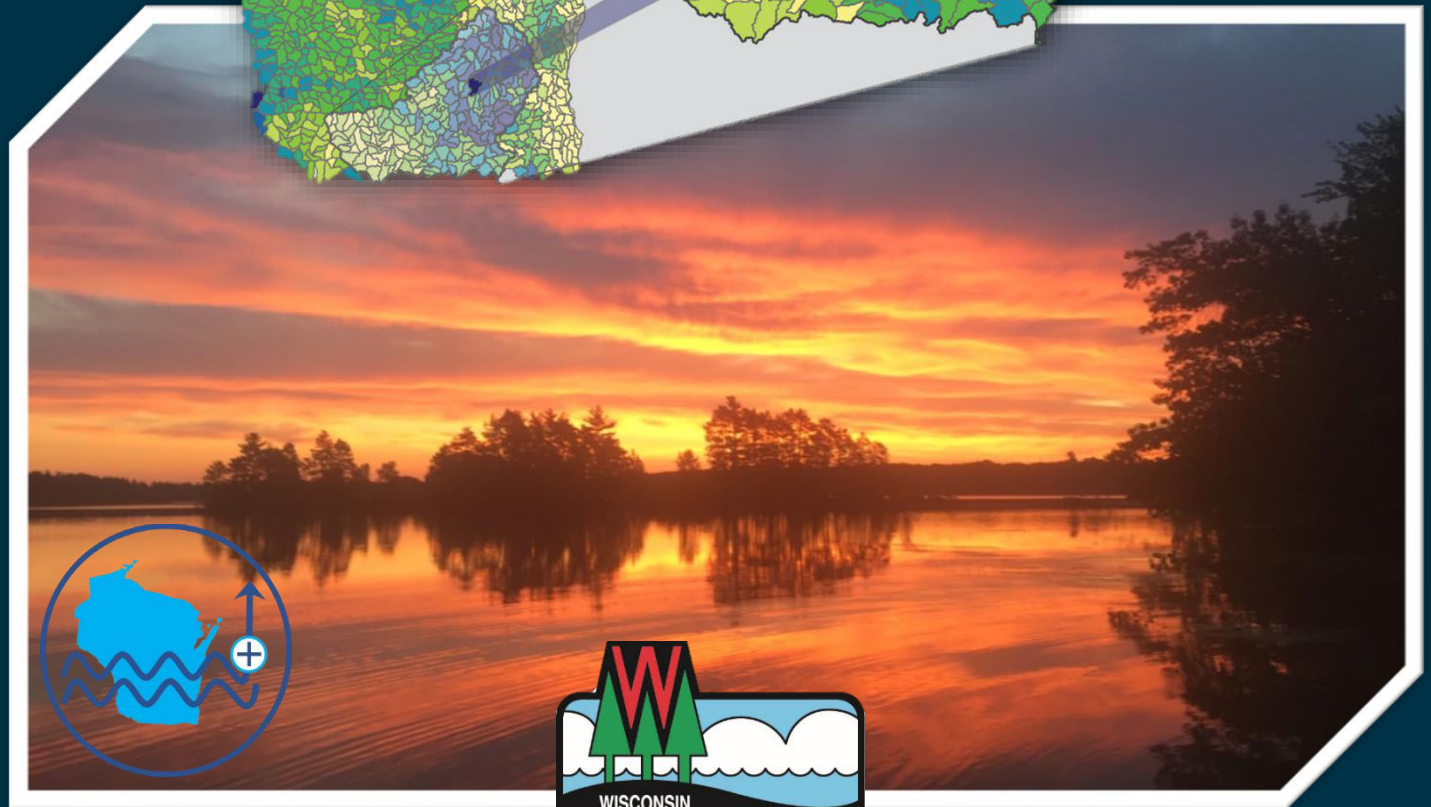# Modeling and Identification of Watersheds (Healthy Watersheds) and Water Bodies (High-Quality Waters) for Water Resources Protection Purposes in Wisconsin

WISCONSIN DEPT. OF NATURAL RESOURCES

APRIL 2022

WISCONSIN DEPARTMENT OF NATURAL RESOURCES
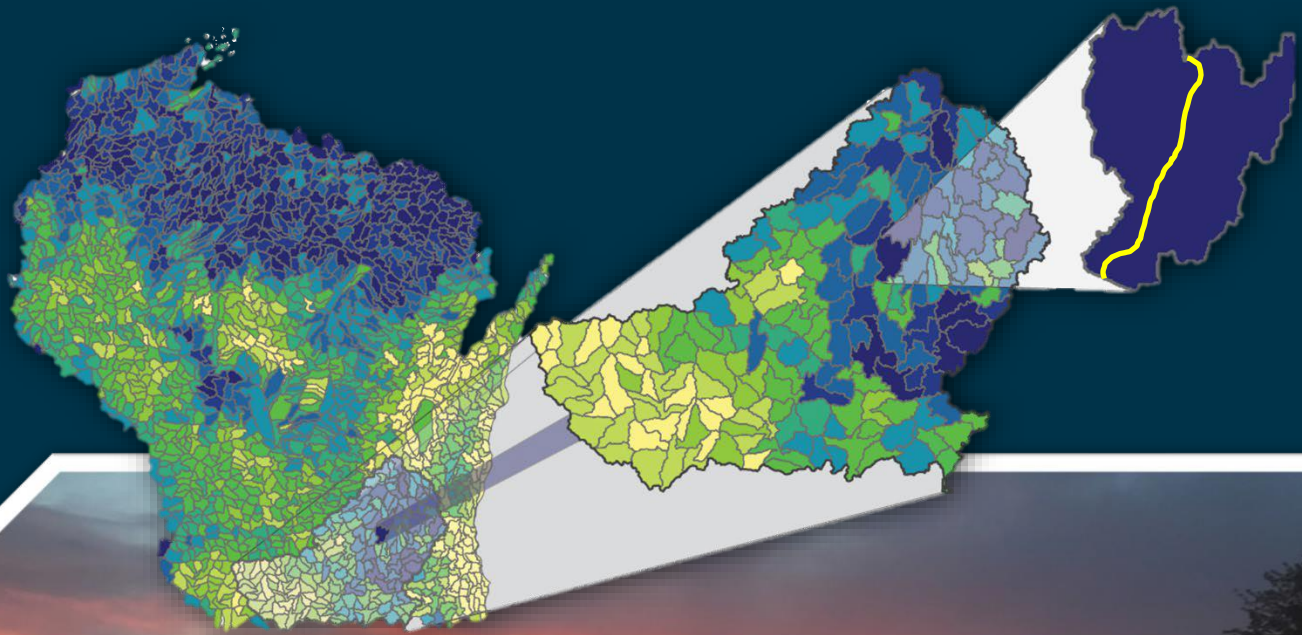
Citation:

Technical Report:

Modeling and Identification of Watersheds (Healthy Watersheds) and Water Bodies (High-Quality Waters) for Water Resources Protection Purposes in Wisconsin

Water Resources Program
Water Quality Bureau
Wisconsin Department of Natural Resources
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<u>Forward</u>

This technical report is a companion report to other Healthy Watersheds, High-Quality Waters documents such as the Kickoff Strategy (i.e. WDNR 2021a) and Action Plan (*in concurrent preparation*) and is not intended to be a stand-alone document. Thus, additional information about this effort and its overall context should be obtained there.

<u>Introduction</u>

Our objective was to identify the healthiest (i.e. those of highest remaining ecological integrity) watersheds and waterbodies in Wisconsin using the best known and available scientifically defensible datasets and processes to enable water resources protection activities at both watershed and waterbody scales across the state.

Before engaging in further modeling or identification approaches, we *a priori* defined both healthy watersheds and High-Quality waters to guide and focus our efforts. We defined healthy watersheds (HW) using US EPA's Definition (US EPA 2012):

"*A healthy watershed is one in which **natural land cover** supports:*

1) *dynamic **hydrologic** and **geomorphologic** processes within their natural range of variation,*
2) ***habitat** of sufficient size and connectivity to support native aquatic and riparian species, and*
3) *physical and chemical **water quality** conditions able to support healthy **biological communities**.*"

Within this definition are 6 primary focal areas (bolded within definition above; also Figure 1).
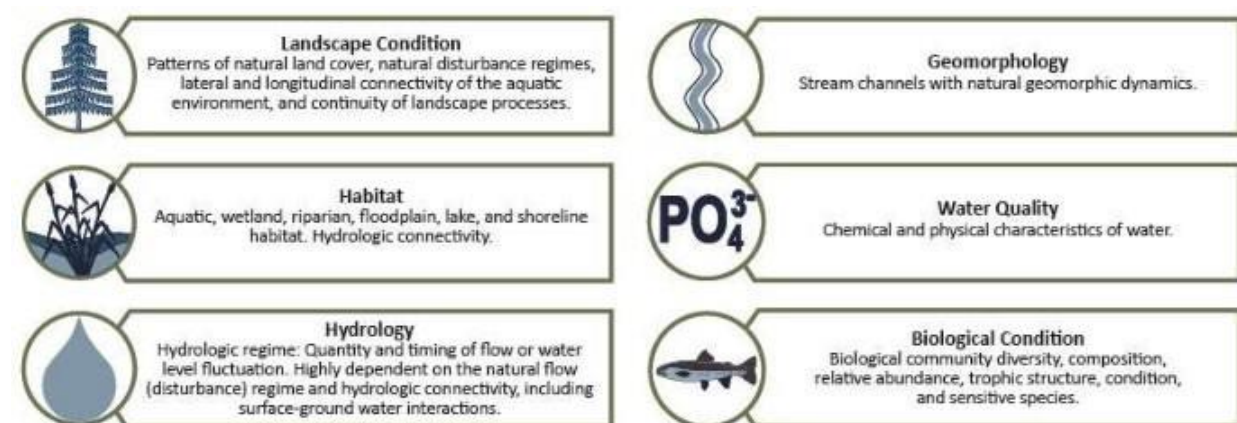

Figure 1. Focal areas/components of healthy watersheds assessments (from US EPA 2012).

We defined High-Quality waters (HQW) as:

"Lakes, streams and rivers which meet at least two of the following attributes:

- *Unique or rare resource*
- *Attainment of state water quality standards*
- *"Good" or "Excellent" biotic integrity*

  OR

wetlands which meet one or more of those attributes, or are in least disturbed/reference condition."

<u>Methods</u>

Review of Existing Conservation Tools

A number of existing conservation planning tools for Wisconsin and beyond were reviewed but ultimately were not selected for inclusion in identification of HW or HQW due to a number of concerns (A non-exhaustive list of those reviewed are in Appendix 1). These concerns included:

1) <u>Age of information</u>- some tools relied on datasets that were upwards of 10-15 years old at the time of review or were created nearly a decade ago
2) <u>Availability-</u> some tools relied on models, data, and methods that were not readily accessible, or personnel that were responsible for creation of the tools or aspects of the tools were no longer available (e.g. retirements, employment changes, mortality) to clarify or provide information
3) <u>Flexibility-</u> similar to availability, tools which likely could not be readily updated with current data or customized to include only portions of certain tools
4) <u>Quality of information (defensibility)-</u> the extent to which tools were created based on data vs. best professional judgement
5) <u>Scope/Coverage-</u> some tools only were designed for specific areas or regions of the state (i.e. not statewide or multi-region within the state) or generated results at scales which have or were likely not to gain adaptation/traction by the agency or other interested partners

Given the difficulties and limitations discovered during the review of the existing conservation planning tools, it was determined that no single tool or combination of tools even with adaptations would fulfill the objective. Thus, alternative tools, datasets, and processes were sought.

US EPA Recovery Potential Screening Tool

The US Environmental Protection Agency (USEPA) developed the Recovery Potential Screening (RPS) Tool for application within the context of "protecting the best of what's left" and identifying areas for restoration (recovery) in watersheds identified as having impaired waters such as TMDL areas (USEPA 2021a). The RPS tool overall addressed many of the types of limitations that were concerns for other conservation planning tools.

1) <u>Age of information</u>- The RPS relies on the Watershed Index Online (WSIO; USEPA 2021b), which is regularly refreshed as updated datasets become available.
2) <u>Availability-</u> the tool is publicly available from USEPA and has dedicated staff and contractor (Cadmus Group) support.
3) <u>Flexibility-</u> The tool allows for customization and selection of pertinent variables from WSIO, including separate indices for estimation of ecological, stressor, and social (capacity) factors. Additionally, custom state-specific variables can be added when available and desired.
4) <u>Quality of information (defensibility)-</u> the RPS tool includes the most updated data at the most resolute scale available.
5) <u>Scope/Coverage-</u> The tool is able to model at multiple scales of interest (e.g. statewide, major basins and sub-basins, ecoregion) based on user selection with the HUC 12 as the basic unit of the model.

As aforementioned, the RPS includes multiple indices to account for ecological, stressor and social factors. We used the RPS Ecological Index to model and identify the current healthiest watersheds in the state to enable protection prioritization. More specifically, we reviewed and customized US EPA's Preliminary Healthy Watersheds Assessment (PHWA; US EPA 2017) and its sub-indices to achieve this objective. All HUC12 watersheds which had >50% area within state borders were included in the analysis. More details about the PHWA and the adaptations/customizations are included in the *Ecological Index* section to follow.

Ecological Index

We customized US EPA's Preliminary Healthy Watersheds Assessment- Watershed Health Index (PHWA-WHI) and its sub-indices to generate the Ecological Index within the RPS tool. We chose to use the PHWA-WHI as a base modeling approach because its sub-indices account for the 6 primary focus areas within US EPA's definition of a Healthy Watershed. Additionally, the PHWA-WHI uses multiple scales within its metrics, and the effects of altered land use/land cover within both the 1) watershed and 2) buffer/riparian/nearshore area on aquatic habitat and condition (physical, chemical and biological) have been well-documented in Wisconsin and Minnesota (Wang et al. 1997; Wang et al. 2001; Jennings et al. 1999; Weigel et al. 2000; Radomski and Goeman 2001; Jennings et al. 2003; Diebel et al. 2009; Cross and Jacobson 2013; Hlina et al. 2015; Marti and Bernthal 2019; Radomski 2019; Marti, Homer and Jarosz 2020). Thus, the use of metrics covering multiple scales within the PHWA-WHI and its sub-indices are well supported. The PHWA-WHI sub-indices also closely align with categories used as part of previous modeling efforts to identify HW in Wisconsin (USEPA 2014).

Original PHWA-WHI sub-indices and corresponding variables included the following (further descriptions and acronyms included within USEPA 2021b and USEPA 2017):

- Landscape Condition
  - % Natural Land Cover (Ws)
  - % Natural Land Cover (HAZ)
  - Population Density (Ws)

- o Population Density (Rz)
- o Mining Density in Watershed
- Hydrology
  - o % Agriculture on Hydric Soil (Ws)
  - o Dam Storage Ratio (Ws)
  - o % Forest Remaining (Ws)
  - o % Wetlands Remaining (Ws)
  - o % Impervious Cover (Ws)
  - o Road Stream Crossing Density (Ws)
- Geomorphology
  - o Dam Density (Ws)
  - o % Ditch Drainage (Ws)
  - o Road Density (Rz)
  - o %High-Intensity Land Cover (RZ)
- Habitat
  - o NFHP Habitat Condition Index Local Watershed
- Water Quality
  - o Mean probability of Good Biological Condition (Ws)
  - o Biological Condition at Watershed Outlet
- Biological Condition
  - o Difference between % Assessed HUC12 Stream length Supporting vs. Impaired
  - o Difference between % Assessed HUC12 Waterbody area Supporting vs. Impaired

Of the original variables, Mining Density within the Landscape Condition sub-index was the only variable not retained for analysis given limited occurrence and distribution across the state.

In addition, we took advantage of the flexibility of the PHWA-WHI to include a number of variables representing the most up-to-date advances in aquatic resource condition and functional modeling available in Wisconsin. These included the following:

- Wetlands by Design: A Watershed Approach- WDNR and The Nature Conservancy (TNC) partnered to create Wetlands by Design (WbD) and an associated decision support system (Wetlands and Watersheds Explorer) to guide and enable prioritization of voluntary and regulatory wetland and watershed conservation across Wisconsin. WbD used extensive GIS analyses to estimate ecosystem service provision of remaining wetlands on the landscape based on the landscape position of each wetland (more information is available at wetlandsbydesign.org). After consultation with TNC, we obtained statewide coverage of HUC-12 scale estimates of wetlands providing "high" and "very high" estimated levels of ecosystem service provision for 5 separate ecosystem services. We incorporated each ecosystem service as follows into PHWA-WHI sub-indices:
  - o Hydrology
    - ▪ WbD Surface Water Supply
  - o Geomorphology

- WbD Flood Abatement
  - o Water Quality
    - WbD Sediment Retention
    - WbD Nutrient Transformation

  - o Biological Condition
    - WbD Fish and Aquatic Habitat

- Modeled "Good" and "Excellent" Condition Stream Macroinvertebrate Hilsenhoff Biotic Index- Percent predicted good and excellent HBI scores indexed to HUC12. Department and USGS staff developed statistical models to estimate the current physical, chemical, and biological conditions of all inter-confluence wadeable stream segments (n= 110,000) in Wisconsin. Sampling data from 5,000 stream sites from across the state and numerous landscape variables for each of these sample sites' watershed were used to train the models to estimate the current conditions of the tens of thousands of inter-confluence stream segments in the state that lack monitoring data. Data from approximately 1000 sampled stream sites not used in the models development were used to evaluate the bias, precision, and accuracy of the physical, chemical, and biological predictive models developed. A complete description of the models can be found in the department report: *Development of Ecological Expectations for Wisconsin Streams* EGAD# 3200-2016-4 (Miller et al. 2017a). We included this information within the Biological Condition sub-index.

Customization of PHWA-WHI and Score Normalization Process

EPA and CADMUS provided customized R code that was used for their Preliminary Healthy Watersheds Assessment, and this script was edited to include more specific data for Wisconsin. To complete the Ecological Index, the input metrics were modified within the script utilizing the following techniques/process:

1. Metrics of interest were extracted from EPA's RPS database and Wisconsin DNR data layers after deliberation as to why and how they related to identifying healthy watersheds. After metrics were selected and related to Wisconsin's HUC12's, they initially went through a windsorizing process to remove any large outliers in the datasets and bring the outlier data down to the 1st and 99th percentiles of the data range.
2. The windsorized metrics were then normalized to a range of zero to one to create congruency in the ranges of the different metrics. Since some metrics are percent-based and others are created through different area calculations, normalizing helps provide equal value between metrics.
3. The normalized metrics were analyzed individually as whether higher values meant healthier or less healthy status. For example, a high value in the population density metric would relate to poorer health status. If the high end of a metric range was associated with poor health, then the values for that metric were inverted within the zero to one range so all metrics' values would accurately reflect good or poor health.

4. The metrics were then placed within their respective sub-indices relating to the six key focal areas of healthy watersheds: landscape condition, hydrology, geomorphology, habitat, water quality and biological condition.
5. The final six sub-index scores were averaged together to calculate the final Ecological Index score for each HUC12. This score will be used as a standalone product and also within the Recovery Potential Screening tool.

Initial Healthy Watersheds Modeling QA/QC and Adjustments

After the initial results for HW were completed, Statewide and HUC 6 scale maps were sent to WDNR Water Quality Biologists across the state for review in late January 2021. The opportunity for review was intended for experienced regional staff to generally assess whether initial HW modeling results matched their relative broad in-field observations of watershed health, as well as identify potential factors not captured within the model that might explain any deviations. Staff were asked to identify broader scale trends and factors (if possible) that would point towards potential systemic modeling effects that were not capturing reality on the ground. A number of trends were identified and are synopsized within the major observations below:

- Staff Observation 1: *Watersheds in the Central Sands and Driftless areas of the state*- Staff from WDNR's Office of Great Waters and local biologists in the Water Quality Program noted that a large number of watersheds in both the Central Sands and Driftless Areas were scoring higher than anticipated despite known water quality issues related to nitrogen and other issues in these areas. Additionally, biologists in the Central Sands noted that extensive ditching, drainage and water level management due to agriculture (i.e. row, root, and bed crops) did not seem to be adequately accounted for in the model despite multiple dam and ditch related indicators within various sub-indices. Staff also noted large flooded areas and water level manipulation of existing and former wetlands in this area that likely were not accounted for in the model. Additionally, they noted WbD metric scores for these watersheds seemed particularly high in some instances.
- Staff Observation 2: *Watersheds in Lake Superior Basin*- Staff from WDNR's Office of Great Waters and local biologists in the Water Quality Program noted that watersheds with known field conditions representing minimal to low anthropogenic disturbance were scoring more poorly than they would have expected at a statewide scale. In particular, they noted WbD metric scores for these watersheds seemed particularly low in some instances.
- Staff Observation 3: *WbD Fish and Aquatic Habitat included in the Biological Condition Sub-index*- Staff pointed out that this metric was more closely related to the Habitat Sub-Index based on the description provided in WbD documentation.
- Staff Observation 4: *"Non-Contributing" watersheds scoring far above or below observed field conditions*- Watersheds consisting almost entirely of islands (e.g.

Apostle Islands) and watersheds considered to be "non-contributing" hydrologically to adjacent watersheds (n=18) scored either much higher or lower than would be expected based on field conditions and land cover. A list of these watersheds is provided in Table 1.

To account for these observed patterns, we combed through modeling results to identify factors which may have led to the broader systemic patterns above which could be adjusted to increase accuracy. Additionally, where adjustment of existing factors within subindices did not appear to be an option, we searched for additional datasets within WSIO and within state (with statewide coverage) to add if justified. Added variables were prepared as noted in the previous section for incorporation into the model sub-indices. A number of changes were made to the initial model:

- Model Change 1: *A new metric called % Watershed with Agriculture on Nitrogen Sensitive Soils (WI NRCS 590) was added to the Landscape Condition sub-index*. After consultation with EPA and Cadmus Group, it was determined that no metrics within existing sub-indices or WSIO would adequately capture biologist concerns related to nitrogen. Thus, a new indicator was created by intersecting the 2019 USDA Cropland Data Layer with the WI NRCS 590 Standard Soils that were previously determined as susceptible to groundwater N leaching and relativizing that to a HUC12 scale (see DATCP 2021 for resources related to WI NRCS 590 Standard). These changes were intended to partially address concerns within Staff Observation 1.
- Model Change 2: *Individual WbD metrics were adjusted in their weight to 0.25 within their respective sub-indices*. WbD scores as well as the WbD Viewer (Wetlands and Watersheds Explorer) were reviewed in both the Lake Superior Basin as well as the Central Sands Region given Staff Observations 1 and 2. In the Lake Superior basin, a number of watersheds received very low scores for some WbD variables despite having little to no known wetland loss or modification and had large acreage of apparent riparian and/or headwater wetlands. In the Central Sands, it was discovered that bed crop agricultural operations (i.e. cranberry operations) were considered as wetlands within WbD and tended to score high or very high functionally on the WbD viewer despite being heavily hydrologically modified and anthropogenically altered. Thus, we down weighted these metrics to account for these discrepancies rather than removing the metric altogether because they still include the best available wetland functional information at hand.
- Model Change 3: *WbD Fish and Aquatic Habitat was moved to the Habitat Condition Sub-Index to satisfy Staff Observation 3*.

Table 1. A list of HUC12 watersheds in Wisconsin identified as "non-contributing" or comprised mostly of islands. Bolded values indicate > 75% watershed natural land cover.

"Non-Contributing" and Island-Dominated Watersheds in Wisconsin

HUC12	HUC12 Name	HUC6	HUC6 Name	% Natural Land Cover (WS)
040103011001	Apostle Islands	040103	Southwestern Lake Superior	**97.87%**
040103020601	Flynn Lake	040103	Southwestern Lake Superior	**97.30%**
040301020101	Mink River-Frontal Lake Michigan	040301	Northwestern Lake Michigan	68.79%
040302020203	Hardwood Lake	040302	Fox	**94.03%**
040302021802	Lake Emily	040302	Fox	18.06%
040302021805	Wolf Lake	040302	Fox	48.10%
070300010101	Shunenberg Creek	070300	St. Croix	**97.07%**
070300020104	Non-Contributing-Upper Namekagon River	070300	St. Croix	**97.41%**
070300020404	Birch Island Lake	070300	St. Croix	70.76%
070300050604	McKeith Lake	070300	St. Croix	43.13%
070300050805	South Fish Lake	070300	St. Croix	25.54%
070300050808	Squaw Lake	070300	St. Croix	31.62%
070300051102	Twin Lakes	070300	St. Croix	6.80%
070300051204	Town of Troy	070300	St. Croix	26.68%
070700021101	Lawrence Lake	070700	Wisconsin	**97.57%**
070700030501	Lake Huron	070700	Wisconsin	22.57%
070700031801	Strongs Prairie	070700	Wisconsin	54.95%
071200060401	North Lake	071200	Upper Illinois	19.00%

After incorporation of the above model changes, WDNR staff who provided feedback and additional staff met with the modeling team in Early April 2021 to review the changes (with revised and updated maps) and approved the changes. These draft results were also shared with partners and the public during an 8-meeting series of HWHQW virtual discussion groups held via Zoom from April-June 2021. No comments/suggestions were received regarding revision or improvement of the metrics or draft maps of watershed health at statewide or HUC6 scales during these meetings or through other communications.

Concurrent with these public meetings, the modeling team explored options for correcting the island/non-contributing watershed observation, as the above model changes did not resolve these discrepancies. In particular, the Water Quality Sub-Index and its variables of the PHWA-WHI were determined to be where consistent over- or under-ranking was occurring, resulting in the following model change:

- Model Change 4: *Island and "Non-Contributing" watersheds Water Quality Subindex adjustment factor-* The Water Quality Sub-Index for the watersheds listed in Table 1 was manually adjusted by adding an additional adjustment factor within the Sub-Index as follows (*sensu* Cross and Jacobson 2013; Radomski 2019):
    - All watersheds with % Natural Land Cover (WS) in the Landscape Condition Sub-Index >75 %, Adjustment Factor Score = "1"
    - All watersheds with % Natural Land Cover (WS) in the Landscape Condition Sub-Index <75 %, Adjustment Factor Score = "0"

After completing PHWA-WHI variable customization and model changes, we conducted correlation matrix analyses using R to investigate potential metric redundancy within each sub-index (R Core Team 2019). Normalized metric scores were used for these analyses as previously described. Overall, very few metrics were strongly correlated ($r > 0.7$) within any given sub-index with the following exceptions (Table 2):

- Landscape Condition
    - Natural Land Cover (Ws) and Natural Land Cover (HAZ) [+]
    - Population Density (Ws) and Population Density (Rz) [+]
- Water Quality
    - WbD Sediment Retention and WbD Nutrient Transformation [+]
- Biological Condition
    - Mean probability of Good Biological Condition (Ws) and Biological Condition at Watershed Outlet [+]

Given that there were only minimal potential correlative redundancies in the data (8% [4 of 51] of possible within-index paired correlations), all original variables were maintained.

Table 2. Correlation matrix results of WDNR customized USEPA Preliminary Healthy Watersheds Assessment- Watershed Health Index metrics with normalized data. Bolded results indicate within sub-index correlations where r > 0.7. Shaded areas denote all results which are within-index, but not within a given sub-index. Variables denoted hereafter from USEPA 2021b, USEPA 2017, or state-specific customized variables (denoted *) defined within the Methods section. Landscape Condition Sub-Index Metrics include: LC1 = % Natural Land Cover (WS), LC2 = % Natural Land Cover (HAZ), LC3 = Population Density (WS), LC4 = Population Density (RZ), LC5* = % Watershed with Agriculture on Nitrogen-Sensitive Soils. Hydrology Sub-Index metrics include: HY1 = % Agriculture on Hydric Soils (WS), HY2 = Dam Storage Ratio (WS), HY3 = % Forest Remaining (WS), HY4 = % Wetlands Remaining (WS), HY5 = % Impervious Cover (WS), HY6* = WbD Wetland Surface Water Supply, and HY7 = Road Stream Crossing Density (WS). Geomorphology Sub-Index metrics include: G1 = Dam Density (WS), G2 = % Ditch Drainage (WS), G3 = Road Density (RZ), G4 = % High-Intensity Land Cover (WS), and G5* = WbD Wetland Flood Abatement. Habitat Sub-Index Variables include HB1 = NFHP Habitat Condition Index Local Watershed Score and HB2* = WbD Wetland Fish and Aquatic Habitat. Biological Condition Sub-Index metrics include: BC1 = Mean Probability of Good Biological Condition (WS), BC2 = Biological Condition at Watershed Outlet, and BC3* = % Good/Excellent Hilsenhoff Biotic Index Score in Watershed. Water Quality Sub-Index metrics include: WQ1 = Non-Impaired Stream Length by Assessed Stream Length, WQ2 = Non-Impaired Waterbody Area by Assessed Waterbody Area, WQ3* = WbD Wetland Sediment Retention, and WQ4* = WbD Wetland Nutrient Transformation.

		Landscape Condition					Hydrology							Geomorphology					Habitat		Biological Condition			Water Quality			
	LC1	LC2	LC3	LC4	LC5	HY1	HY2	HY3	HY4	HY5	HY6	HY7	G1	G2	G3	G4	G5	HB1	HB2	BC1	BC2	BC3	WQ1	WQ2	WQ3	WQ4
LC1	1																									
LC2	**0.88**	1																								
LC3	0.34	0.25	1																							
LC4	0.37	0.28	**0.93**	1																						
LC5	0.45	0.47	-0.12	-0.1	1																					
HY1	0.53	0.36	0.06	0.08	0.25	1																				
HY2	-0.06	-0.08	0.06	0.09	-0.11	-0.06	1																			
HY3	0.93	0.79	0.33	0.36	0.38	0.57	-0.07	1																		
HY4	0.28	0.23	-0.01	0.01	0.23	0.33	-0.1	0.23	1																	
HY5	0.39	0.3	0.96	0.91	-0.09	0.1	0.04	0.38	0.05	1																
HY6	0.35	0.53	0.14	0.16	0.21	-0.12	0	0.26	0.03	0.17	1															
HY7	0.45	0.57	0.23	0.25	0.21	0.12	-0.1	0.43	0.18	0.29	0.34	1														
G1	-0.1	-0.12	0.12	0.14	-0.1	-0.1	0.47	-0.09	-0.13	0.09	-0.02	-0.15	1													
G2	0.35	0.18	0.09	0.11	0.05	0.43	-0.06	0.4	0.18	0.12	-0.09	0.09	-0.09	1												
G3	0.32	0.46	0.51	0.56	0.11	-0.09	0.07	0.28	0.01	0.54	0.43	0.63	0.11	-0.08	1											
G4	0.74	0.56	0.12	0.15	0.35	0.78	-0.12	0.75	0.31	0.18	0.01	0.3	-0.17	0.56	0.03	1										
G5	0.44	0.63	0.16	0.18	0.28	-0.02	-0.02	0.35	0.09	0.19	0.93	0.39	-0.03	-0.05	0.47	0.1	1									
HB1	0.83	0.73	0.46	0.47	0.26	0.53	-0.05	0.79	0.25	0.51	0.33	0.42	-0.08	0.3	0.35	0.62	0.4	1								
HB2	0.43	0.63	0.15	0.18	0.27	-0.05	-0.02	0.33	0.09	0.19	0.92	0.39	-0.03	-0.05	0.47	0.09	0.98	0.39	1							
BC1	0.66	0.66	0.15	0.17	0.45	0.31	-0.07	0.6	0.28	0.17	0.24	0.49	-0.17	0.15	0.27	0.49	0.3	0.48	0.3	1						
BC2	0.66	0.67	0.2	0.23	0.4	0.28	-0.07	0.62	0.24	0.22	0.34	0.49	-0.16	0.13	0.35	0.46	0.39	0.49	0.38	**0.89**	1					
BC3	0.42	0.15	0.32	0.33	-0.06	0.59	0.02	0.47	0.18	0.35	-0.2	0.05	-0.04	0.47	-0.04	0.58	-0.15	0.45	-0.18	0.21	0.2	1				
WQ1	0.19	0.18	0.12	0.12	0.09	0.07	0.1	0.15	-0.02	0.11	0.08	0.12	0.02	0.06	0.07	0.05	0.05	0.19	0.04	0.17	0.12	0.05	1			
WQ2	0.49	0.41	0.26	0.25	0.2	0.32	-0.09	0.48	0.11	0.29	0.09	0.25	-0.08	0.21	0.16	0.41	0.14	0.42	0.13	0.33	0.32	0.34	0.12	1		
WQ3	0.55	0.73	0.18	0.21	0.34	0.12	-0.02	0.47	0.09	0.2	0.75	0.41	-0.03	0.03	0.46	0.23	0.9	0.47	0.9	0.37	0.44	-0.04	0.06	0.23	1	
WQ4	0.49	0.68	0.17	0.2	0.3	0.02	-0.02	0.39	0.08	0.2	0.9	0.4	-0.02	-0.03	0.48	0.14	0.98	0.44	0.98	0.33	0.41	-0.13	0.06	0.17	**0.95**	1

High-Quality Waters Identification

While the RPS has many advantages for modeling the health and protection potential of watersheds, it is not intended to model the health of individual lakes, rivers, streams, and wetlands. Thus, an alternative process was needed to identify HQW. We considered our definition of HW and reviewed existing available internal classification schemes and data to create data-driven requirements for a given water to be considered a HQW. To be considered a HQW, a water body had to meet at least two of the three criteria areas below:

- Criteria Area 1: Unique and Rare Natural Communities
    - State Natural Areas (waters within and adjacent)
    - Trout Streams and/ or springs
    - Outstanding and Exceptional Resource Waters
    - Wild Rice Waters (GLIFWC/WDNR 2019 List)
    - Waters in ecologically significant coastal wetlands along Lakes Michigan and Superior as identified in the Coastal Wetlands of Wisconsin
    - Federal or state waters designated as wild or scenic rivers
    - 2-Story fishery lakes with at least one non-stocked native coldwater species
- Criteria Area 2: Water Quality Standards
    - Attaining uses and currently described as "healthy" (Category 2a and 2b Waters)
- Criteria Area 3: Biotic Integrity
    - Good and/or Excellent macroinvertebrate IBI or fish IBI scores if a stream or river
    - A rank of "attaining" or "Good" using the Macrophyte Assessment of Condition for Lakes (Mikulyuk et al. 2017)

Wetlands are not currently monitored for Clean Water Act assessment purposes in Wisconsin because numeric water quality criteria have not been established. Therefore, meeting water quality standards was not an option for wetlands, which we anticipated would extremely limit the number of wetlands able to make the HQW list if meeting 2 criteria areas was the threshold for inclusion. Thus, we decided that wetlands needed to only meet one of the following criteria areas for HQW inclusion:

- Criteria Area 1: Unique and Rare Natural Communities
    - Wetland communities ranked as vulnerable, imperiled, or critically imperiled within Global or Statewide rankings on the WDNR Natural Heritage Inventory Working List (G1, G2, or G3 with any Srank OR S1 and S2 with any Grank; WDNR 2021b)
- Criteria Area 3: Biotic Integrity
    - Reference Quality Wetlands (O'Connor and Doyle 2017)
    - Wetlands with Overall Disturbance or Plant Community Condition Scores of "1" or "2" as a proxy for "Good" or "Excellent" Condition Floristic Quality (Hlina et al. 2015; Marti and Bernthal 2019)

Criteria areas were verified by compiling datasets from multiple DNR databases (SWIMS, NHI Inventory, etc.) into Microsoft Excel and using the PivotTable function to gain a count for number of criteria area that were met.

Adapting the Recovery Potential Screening Tool as Protection Potential Screening Tool for Wisconsin

Stressor and Social Indices, which are also included within the RPS, were not explicitly included within the calculations for determination of the healthiest watersheds (though some variables inferentially account for the absence of stressors within some variables in the Ecological Index). However, based on feedback from the 8 virtual discussion groups held with public and the partners from April to June 2021, the vast majority of participants supported investigating not only watershed health, but also potential watershed stressors and management opportunities, when considering where watershed and waterbody protection efforts should be implemented. Thus, the modeling team worked in collaboration with US EPA, Cadmus, and others to customize the RPS Stressor and Social Indices to reflect 1) trend-based stressors/vulnerabilities (hurdles to long-term watershed protection), and 2) protection opportunities (existing known social or institutional assets, priority areas, and leverage for watershed protection), respectively.

The Vulnerability Index includes the following standard variables included within the RPS Tool:

- % Waters Near ≥ 5% Impervious Cover (WS)
- % Human Use Change, 2001-2016 (HCZ)
- % Developed Cover Change, 2010-2050 (WS)
- % Urban Cover Change, 2001-2016 (WS)
- % Agriculture Cover Change, 2001-2016 (WS)

Additionally, a number of customized vulnerability metrics were developed and included:

- Number of WDNR Wetland and Waterway Permits, 2015-2020 (WS)- the modeling team requested and acquired all Individual Permits, General Permits, and Exemption requests submitted to WDNR with an approved decision in the following categories: Dams, Shoreland Alterations, Stream Crossings, Watershed Alterations within 500 feet, and Wetland Alterations. These particular categories were determined to have the greatest potential for negative adverse effects on water resources based on an internal staff survey conducted in cooperation between the WDNR Water Quality and Watershed Bureaus (Kyle McLaughlin WDNR, Personal Communication). Each permit (n = ~11,500) was then geolocated based on permit data provided where possible and a sum count of all permitted activities was calculated for each HUC12.
- Average Projected Change of Summer Air Temperature 2061-2090 - the modeling team worked in collaboration with USEPA and Cadmus Group to develop this metric. Water temperature (and by proxy changes to air temperature due to climate change) is a key variable in the development of Harmful Algal Blooms (HABs), overall warmer water temperatures, oxythermal stress, and disruption of stratification in lentic ecosystems in Wisconsin and beyond (e.g. Paerl et al. 2016; Magee and Wu 2017; Magee, McIntyre, and Wu

2018). Given overall insufficient data at a statewide scale to model predicted changes in surface water temperature across aquatic ecosystems (i.e. lakes, rivers, streams and wetlands) as a whole, summer air temperature change was deemed as a suitable proxy that would be most likely to elucidate potential temperature-related changes across ecosystem types (Madeline Magee and Katie Hein, WDNR, Personal Communication). (Note: This variable was custom at the time of metric creation but now is standard within the RPS tool and WSIO.)

- % Projected Change in Spring Runoff Volume 2061-2095 (WS)- the modeling team worked in collaboration with USEPA and Cadmus Group to develop this metric. In particular, spring runoff (as a function of more extreme precipitation events; e.g. Gyawali, Greb and Block 2015) was selected as a variable of interest given that the highest observed non-point nutrient and sediment loads to waterbodies in Wisconsin generally occur in the spring (Good et al. 2019; Waller et al. 2021). This period coincides with non-growing season (or early growing season) conditions which limit plant uptake of nutrients and also lower opportunity for plants to physically intercept runoff. Additionally, high spring flows from increased runoff may also result in mass erosion events of streambanks and channels (WICCI 2011). (Note: This variable was custom at the time of metric creation but now is standard within the RPS tool and WSIO.)

- Cumulative Loss of Wetland Ecosystem Services (WS)- Similar to previous WbD metrics incorporated into the Ecological Index, WDNR worked with TNC to obtain estimates of the current cumulative loss of wetland ecosystem services due to wetland loss at a HUC12 scale. WbD used extensive GIS analyses to also estimate lost ecosystem service provision of wetlands filled or removed from the landscape based on the landscape position of each prior wetland (more information is available at wetlandsbydesign.org). After consultation with TNC, we obtained statewide coverage of HUC-12 scale estimates of wetlands formerly providing "high" and "very high" estimated levels of ecosystem service provision for 5 separate ecosystem services used in Ecological Index Sub-Indices. We then calculated cumulative wetland ecosystem service loss at the watershed scale.

The Protection Opportunities Index includes the following standard variable included within the RPS tool:

- Freshwater Fishing Demand (WS)

Additionally, a number of customized opportunity metrics were developed including the following:

- Stream and River Length Classified as a WDNR Conservation Opportunity Area- Streams and Rivers classified as Conservation Opportunity areas in the 2015-2025 Wisconsin Wildlife Action Plan (WWAP; WDNR 2015) were obtained from the WDNR Natural Heritage Conservation Program. We weighted this variable to a 0.5 point weight given that two Conservation Opportunity Area variables were used in this index.

- % Watershed Area Classified as a WDNR Terrestrial and/or Lake Conservation Opportunity Area- Terrestrial Areas and Lakes classified as Conservation Opportunity areas in the 2015-2025 Wisconsin Wildlife Action Plan (WWAP; WDNR 2015) were obtained from the WDNR Natural Heritage Conservation Program. We weighted this variable to a 0.5 point weight given that two Conservation Opportunity Area variables were used in this index.
- WDNR Fisheries Management Program Brook Trout Environmental Resilience Reserve Area (WDNR 2019)- Watersheds which have been identified as brook trout reserves as part of the WDNR 2020-2029 Inland Trout Management Plan Core Strategy, Action 2.1.B.2. (WDNR 2019). Data were obtained from the WDNR Fisheries Management Bureau. This variable is scored binary (1 = watershed included in reserve area, 0 = watershed not included in reserve area) rather than continuous.
- Number of Lake, River, and Watershed Organizations (WS)- This metric is a sum count of all known water resources (lake, river, stream, wetland) or watershed related organizations, districts, coalitions, etc. within a given watershed. A list of WBICs (Water Body Identification Codes) was provided by University of Wisconsin- Madison Extension Lakes program (E. Olson, Personal Communication) and a list of river and stream organizations provided by the River Alliance of Wisconsin (A. Werner, Personal Communication).
- Protection Designated Watershed within an Existing Approved TMDL Area- Wisconsin currently has 35 approved TMDL areas, each having watersheds targeted for restoration purposes in order to restore impaired waterbodies. However, there are also watersheds considered not impaired within TMDL areas referred to as "protection" watersheds, where maintaining the current state of an unimpaired waterbody or segment is also part of the strategy. While the vast majority of funding, time and effort historically have been spent completing work in restoration watersheds within TMDL areas, there also may be opportunities for using funding in protection oriented watersheds within TMDL areas to protect unimpaired water resources (even though these resources may not be considered High-Quality Waters). This variable is scored trinary (1 = watershed is a protection priority in TMDL area, 0 = watershed is a restoration priority in TMDL area, N/A = watershed not in TMDL area) rather than continuous.
- Abundance of Forestry in Watershed (SFAP 2020) – Abundance scores were developed within each ecological landscape by means of the national priority framework. Scores were developed through calculations of: forests remaining, protected forests, certified forests, and total carbon. This data was provided by Joseph Klang and Andrew Stoltman as part of the State Forestry Action Plan, and the ecological landscape abundance scores were given an area-weighted average within each HUC12 to give each watershed their respective abundance score. Higher scores equate to higher priority. We weighted this variable to a 0.5 point weight given that two forestry variables were used in this index.

- Rarity of Forestry in Watershed (SFAP 2020) – Rarity scores were developed within each ecological landscape by means of the national priority framework. Scores were developed through calculations of: forest health risk, conservation opportunity areas, and state rank and natural communities. The data was provided by Joseph Klang and Andrew Stoltman as part of the State Forestry Action Plan, and the ecological landscape rarity scores were given an area-weighted average within each HUC12 to give each watershed their respective rarity score. We weighted this variable to a 0.5 point weight given that two forestry variables were used in this index.

Data for the previous metrics were prepared in the same manner as those used for the Ecological index, unless specified otherwise above. Additionally, correlation matrices were completed using R to investigate potential within-index metric redundancy (R Core Team 2019). Normalized metric scores were used for these analyses as previously described. Overall, very few metrics were strongly correlated ($r > 0.7$) within either index with the following exception (Tables 3 and 4):

- Vulnerability Index- % Urban Cover Change, 2001-2016 (WS) and % Agricultural Cover Change, 2001-2016 (WS) were inversely correlated.

Given that there was only this single potential correlative redundancy in the data, all original variables were maintained.

Table 3. Correlation matrix results of WDNR Healthy Watersheds, High-Quality Waters customized USEPA Recovery Potential Screening Tool Stressor Index metrics with normalized data for calculation of a Watershed Vulnerability Index. Bolded results indicate within-index correlations where r > 0.7. Variables denoted hereafter from USEPA 2021b, USEPA 2017, or state-specific customized variables (denoted with *) defined within the Methods section of this report. Vulnerability Index metrics include: ST1 = % Waters near ≥ 5% Impervious Cover (WS), ST2 = % Human Use Change U-Index 1 2001-2016 (HCZ), ST3 = % Developed Cover Change 2010-2050 (WS), ST4 = % Urban Change 2001-2016 (WS), ST5 = % Agricultural Change 2001-2016 (WS), ST6* = Number of WDNR Wetland and Waterway Permits 2015-2020 (WS), ST7* = Average Projected Change Summer Air Temperature 2061-2095 (WS), ST8* = % Projected Change in Spring Runoff Volume 2061-2095 (WS), ST9* = WbD Cumulative Loss of Wetland Ecosystem Services (WS).

				Watershed Vulnerability Index					
	ST1	ST2	ST3	ST4	ST5	ST6	ST7	ST8	ST9
ST1	1								
ST2	0.33	1							
ST3	0.2	0.19	1						
ST4	0.61	0.47	0.34	1					
ST5	-0.56	-0.19	-0.3	**-0.94**	1				
ST6	0.47	0.23	0.08	0.5	-0.47	1			
ST7	-0.38	-0.13	-0.23	-0.38	0.35	-0.28	1		
ST8	-0.39	-0.15	-0.12	-0.24	0.24	-0.15	0.37	1	
ST9	0	0.18	0.09	0.08	-0.03	0.08	-0.15	-0.14	1

Table 4. Correlation matrix results of WDNR Healthy Watersheds, High-Quality Waters customized USEPA Recovery Potential Screening Tool Social Index metrics with normalized data for calculation of a Watershed Protection Opportunities Index. Bolded results indicate within-index correlations where r > 0.7. Variables denoted hereafter from USEPA 2021b, USEPA 2017, or state-specific customized variables (denoted with *) defined within the Methods section of this report. Protection Opportunity Index metrics include: SO1 = Freshwater Fishing Demand (WS), SO2* = Stream and River Length Classified as a WDNR Conservation Opportunity Area, SO3* = % Watershed Area Classified as a WDNR Terrestrial and/or Lake Conservation Opportunity Area, SO4* = WDNR Fisheries Management Program Brook Trout Environmental Resilience Reserve Area (WDNR 2019), SO5* = Number of Lake, River, and Watershed Organizations (WS), and SO6* = Protection Designated Watershed within an Existing Approved TMDL Area.

			Watershed Protection Opportunities Index			
	SO1	SO2	SO3	SO4	SO5	SO6
SO1	1					
SO2	0.06	1				
SO3	-0.1	0.17	1			
SO4	-0.11	0.01	0.06	1		
SO5	0.17	0	0.1	-0.02	1	
SO6	-0.11	0.02	0.05	0.04	0.08	1

Results

Maps and a list (Appx. 2) displaying ecological index scores for HW have been generated at both statewide (Figure 2) and HUC6 scales (Figs. 3 – 15). Overall, the vast majority of the top 30% of healthiest modeled watersheds at a statewide scale are located within the northern 1/3 of the state (Figure 2). However, there are a number of HUC12 watersheds throughout the southern 2/3 of the state which also were modeled as being healthy— particularly near eastern Jackson County and southwestern Clark County—as well as a number of watersheds directly adjacent to the Mississippi River. In general, the healthiest modeled watersheds within individual HUC6's occur near headwaters watersheds (e.g. Figs. 6, 7, 8, 13). However, some HUC6s had many of their healthiest modeled watersheds occurring near the major waterbody associated with the HUC (e.g. Figs. 10 and 12 with Mississippi River) while others did not follow any sort of upstream-downstream or geographic pattern (e.g. Figs. 14 and 15).

For the immediate future, we have included a final list of HQW for review in Appendix 3. This list includes **2,853 HQW** (1,769 lakes, rivers, streams, and reservoirs and 1,084 wetlands) across Wisconsin. Rather than try to further summarize these data given the sheer number of identified HQW, we intend to display HW and HQW through alternative means such as an interactive map on the WDNR Surface Water Data Viewer or by other reasonable means. Lists of HQW for each HUC12 (or an equivalent) may also be available as the viewer is developed.

Given that HW and HQW identification were the objective of this report, we have not included vulnerability and opportunity results within the main body of the report. However, for those interested in reviewing the results of those indices, we also intend to include these within the previously mentioned viewer, etc. time and resources allow.

Discussion

Future potential applications of results are discussed further within the Kickoff Strategy (i.e. WDNR 2021a) and Action Plan (*in concurrent preparation*). Thus, the remainder of this discussion will focus on further technical and methodological improvements that may be undertaken in the future for identification of HW, HQW, and prioritization efforts.

Dependent upon timelines and planned intervals for implementation/evaluation of the Action Plan (e.g. 5 or 10 years), future modeling efforts using the Wisconsin Modified PHWA-WHI, RPS Tool and updated datasets (as they become available through internal and external sources) may be used to evaluate changes in overall watershed ecological health scores over time so long as equivalent updated data are used within each subindex. Additionally, more variables may also be added as technology, analyses, and data availability/quality advance if they add additional insight to particular sub-indices. For example, a major hurdle incorporating

wetland-relevant variables within our analyses occurred given that wetlands within national and local datasets are often treated as a land use or land cover type variable (rather than using other land use or land cover variables/analyses to assess which of these may affect the condition or function of wetlands as water resources themselves). As an example, variables we used within the geomorphology sub-index that assessed road density or high-intensity human land uses in riparian zones included wetland areas (where present) as part of the riparian zone cover rather than assessing road density or high-intensity land uses adjacent to wetlands and the other aquatic ecosystems present. Another example occurs within the % Waters Near ≥ 5% Impervious Cover (WS) variable we used within the RPS Stressor Index, where "waters" include only "traditional" surface waters (i.e. lakes, rivers, streams, and reservoirs)—thus not accounting for potential effects of extensive impervious cover (near wetlands) on wetlands. Thus, the potential full effects of altered land cover and land use on watersheds and specifically wetlands as aquatic ecosystems in and of themselves do not appear to be holistically captured within existing datasets or sources—meaning that our analyses (and the many analyses of others) likely vastly under-account for implications on all aquatic resources.

Despite identifying nearly 3,000 HQW, we anticipate that many more HQW likely exist across the state that were not captured in our analyses due to lack of data. This is especially anticipated for wetlands given wetlands are not currently monitored for Clean Water Act assessment purposes in Wisconsin because numeric water quality criteria have not been established. Additionally, researchers and other independent entities (e.g. universities, private consultants, sovereign tribal nations) may have data that are currently unavailable to WDNR. Thus, future internal and external efforts may focus on capturing HQW through increased data sharing or through collaboratively monitoring waters which do not have any/enough existing data to objectively evaluate whether they meet HQW criteria.

While Ecological, Vulnerability and Protection Opportunity Indices were modeled individually, the use of all three indices as intended within the RPS also can generate a Protection Potential Index—similar to how other states have used the RPS for identifying recovery (restoration) potential. This PPI may constitute a way to prioritize those healthiest watersheds with the greatest potential for protection success in areas with the least modeled vulnerability and greatest known opportunities—especially when considered in combination with local knowledge and other conservation planning tools (e.g. those in Appendix 1 and beyond). Based on feedback from 8 virtual discussion groups held with public and the partners from April to June 2021, the vast majority of participants supported first identifying the healthiest (e.g. top scoring 30%) watersheds at statewide and other scales (e.g. HUC6 or USEPA Omernik Ecoregion), and then applying the PPI as described previous to guide decision making. This may be an approach used by WDNR or others such as counties, conservation groups, lake and river organizations, land trusts, or other interested parties to help with ranking and prioritization of efforts.

Finally, a reminder that our efforts, particularly in modeling of HW, constitute a starting point for prioritizing protection of HW and HQW. Our HW modeling efforts were based on a high-level screening tool that used the best information available (i.e. accuracy, spatial resolution, statewide scale). Thus, it is encouraged that local knowledge and experience also should be a factor when deciding where to prioritize and place local priority HW efforts.
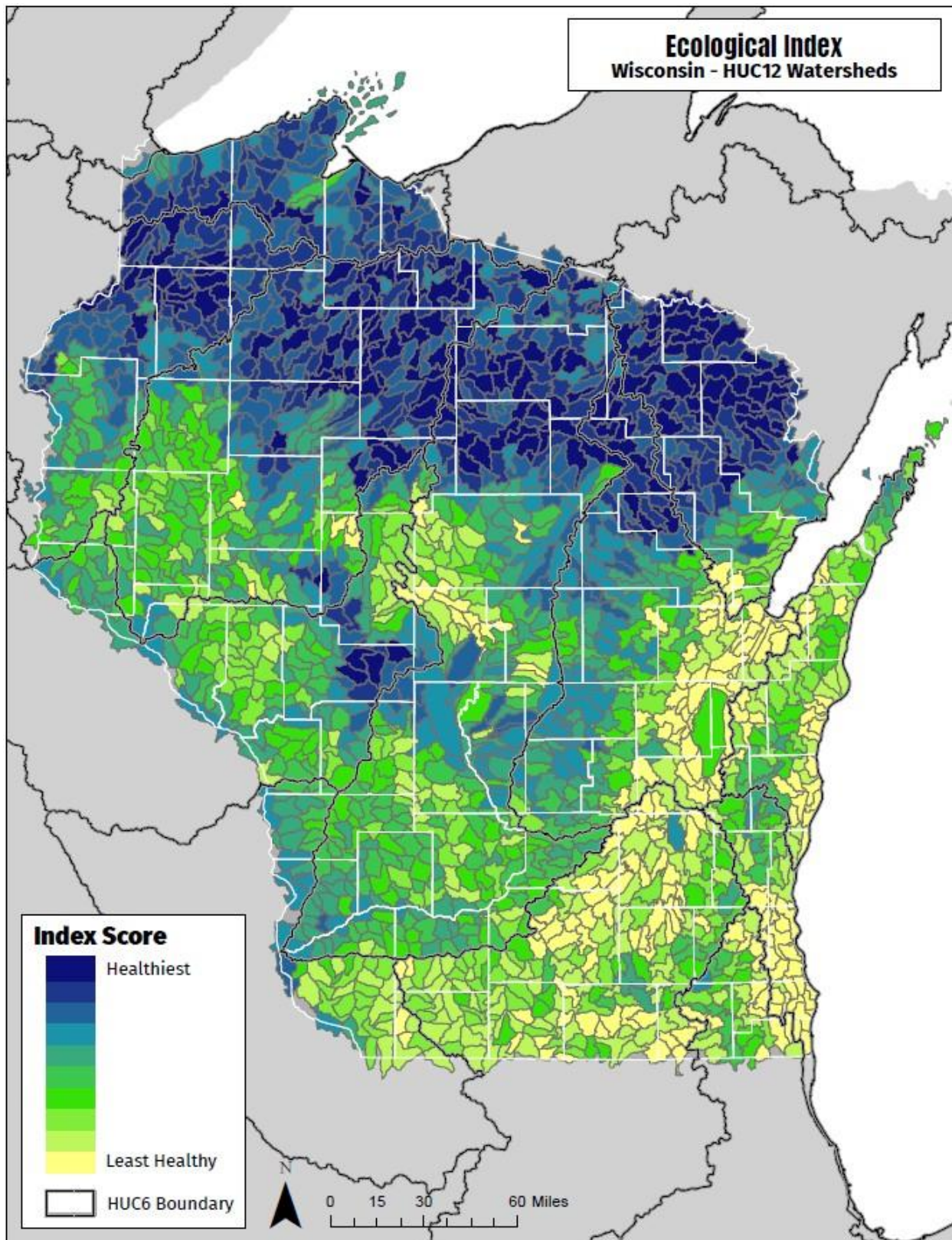
Figure 2. Results of a Wisconsin modified US EPA Preliminary Healthy Watersheds Assessment- Watershed Health Index (PHWA-WHI) reflecting watershed Ecological Health. Individual HUC12 results reflect ranking vs. all other HUC12s statewide. County boundaries are outlined in white.
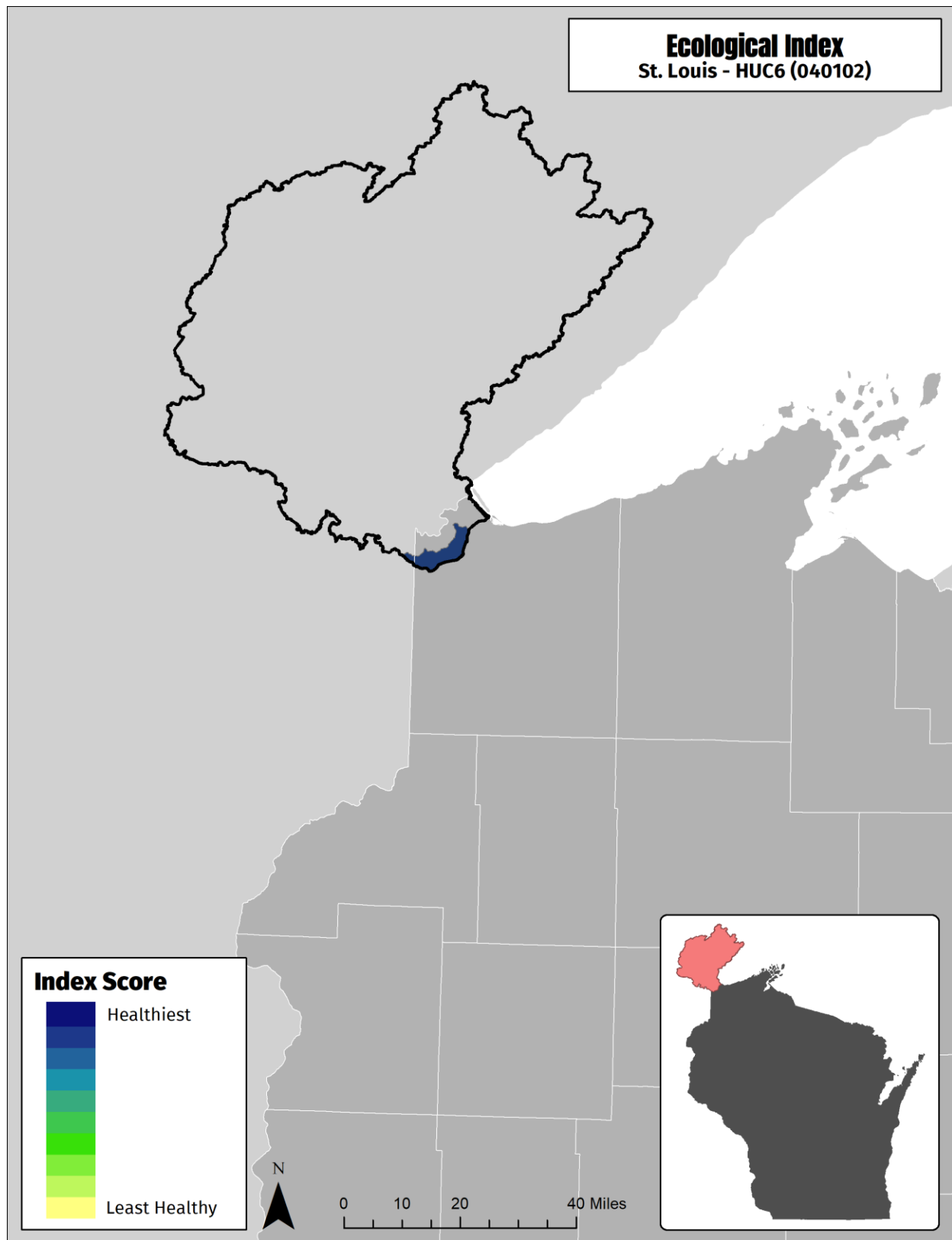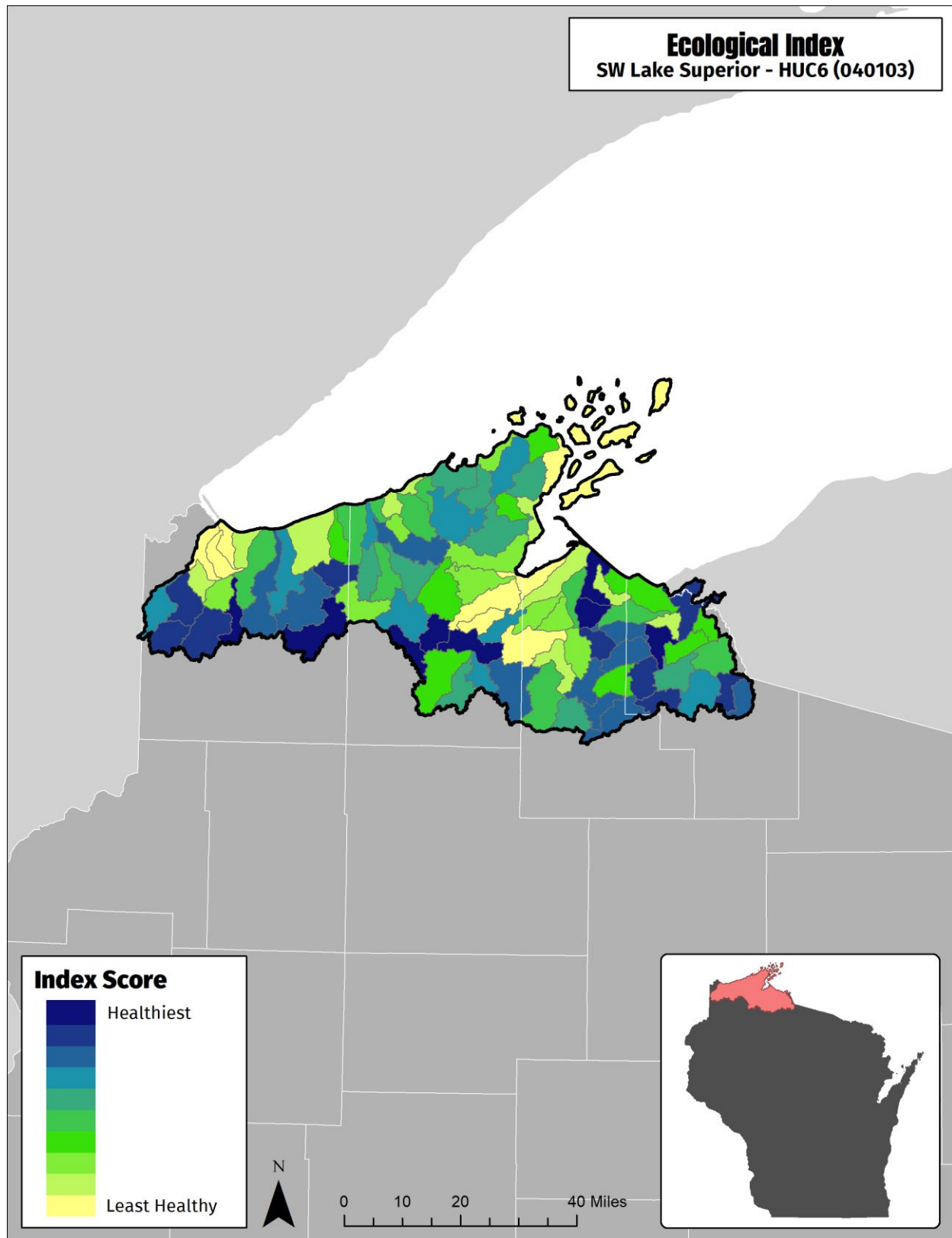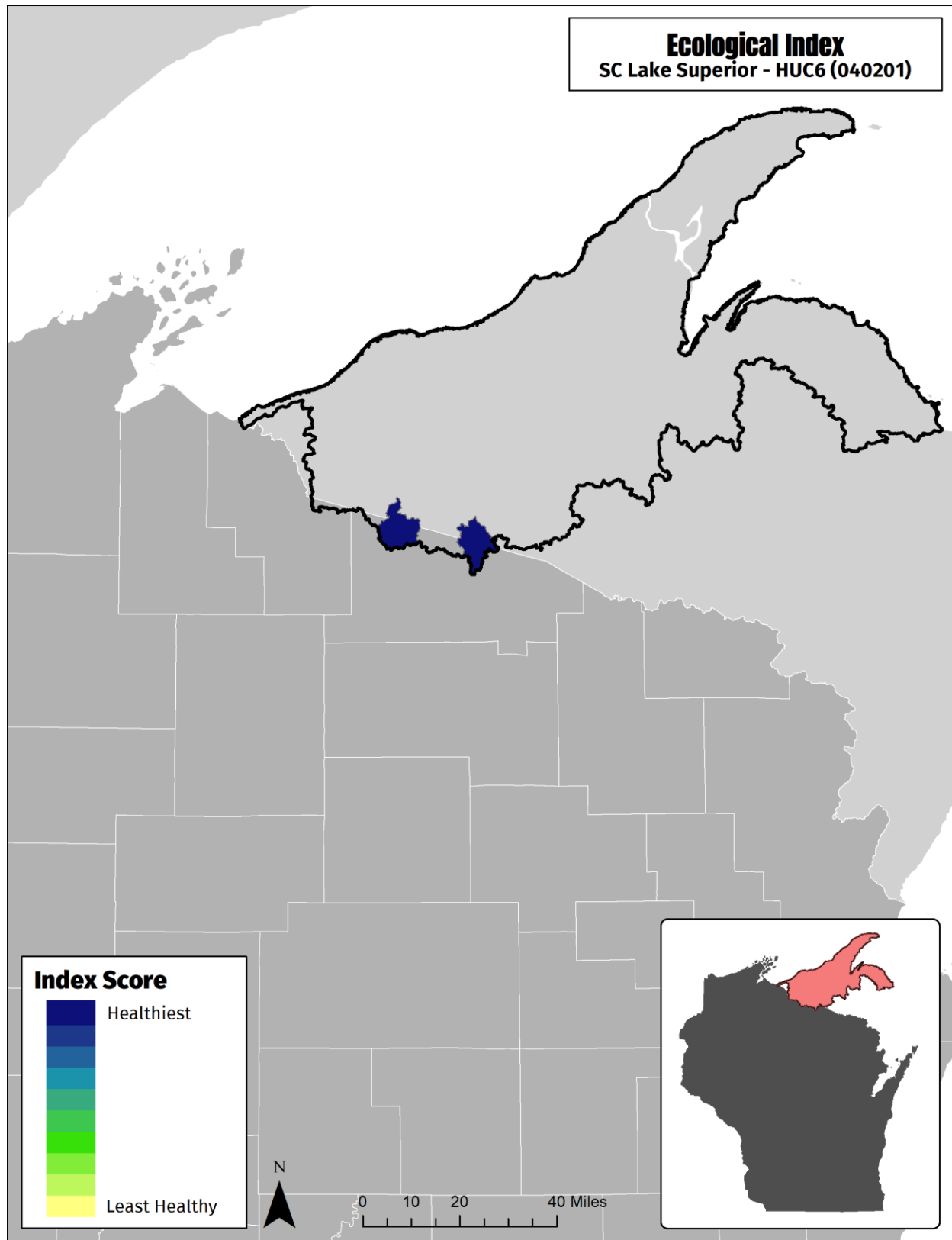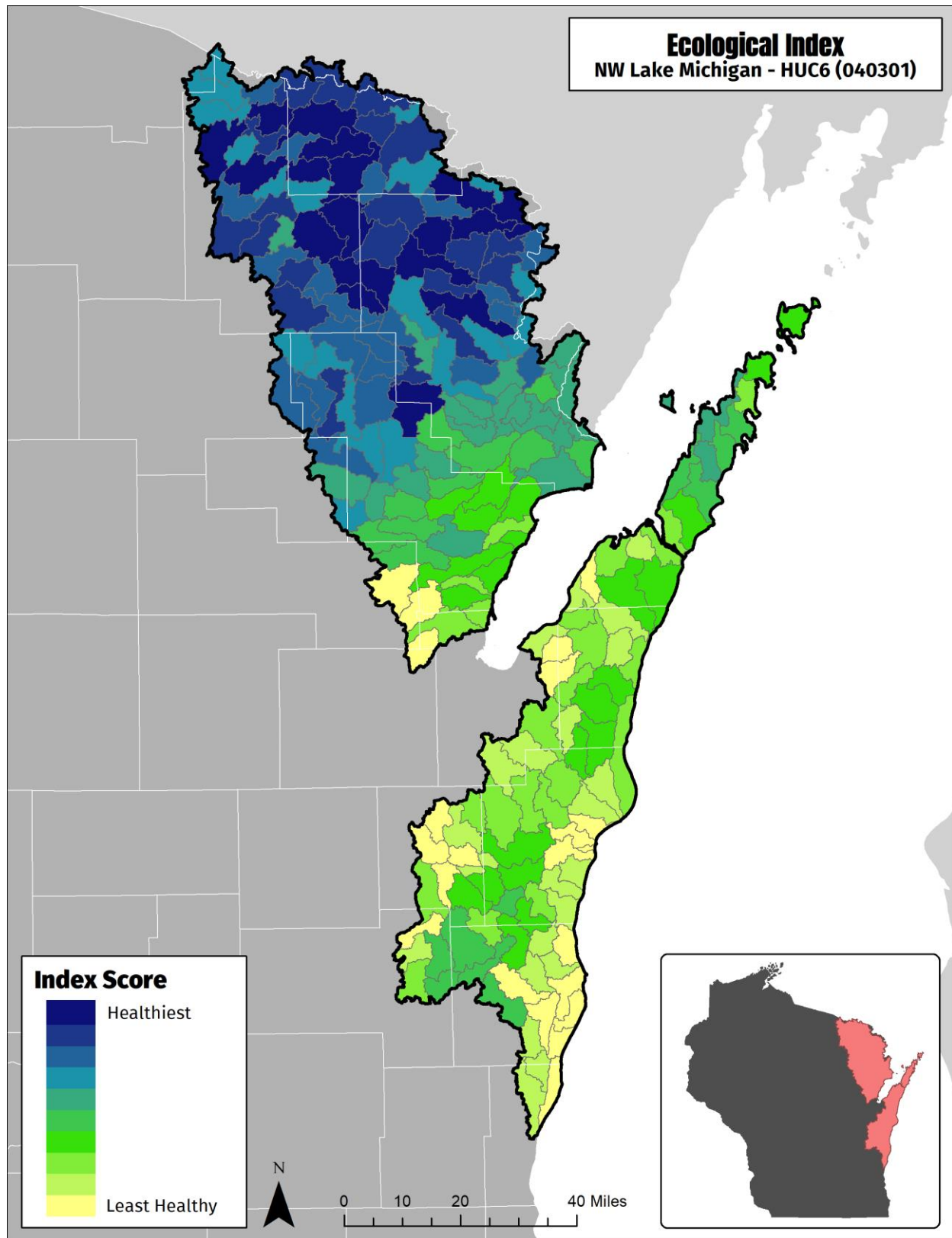
Figure 3. Results of a Wisconsin modified US EPA Preliminary Healthy Watersheds Assessment- Watershed Health Index (PHWA-WHI) reflecting watershed Ecological Health within the HUC6. Individual HUC12 results reflect ranking vs. all HUC12s within the St. Louis River HUC6. County boundaries are outlined in white.
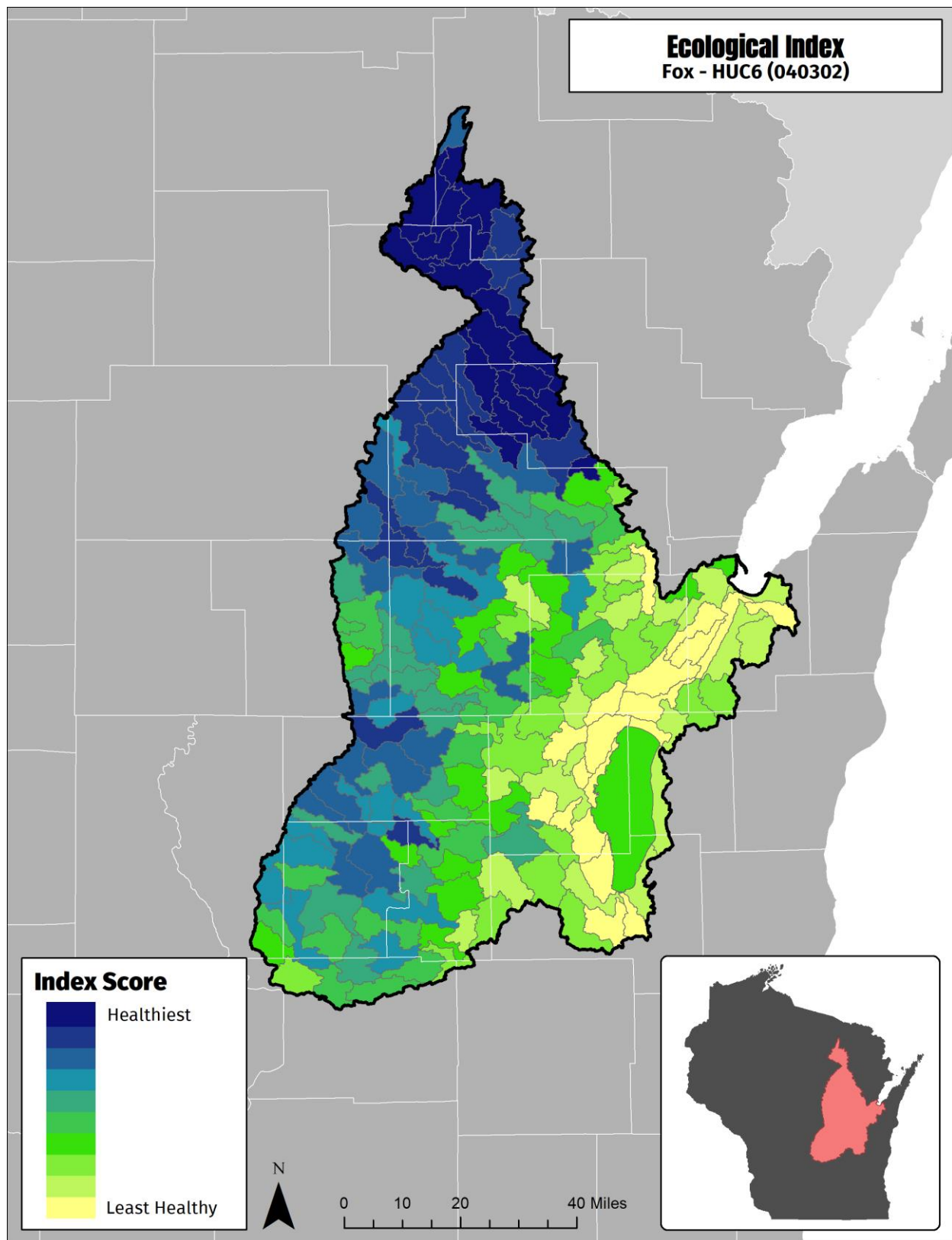
Figure 4. Results of a Wisconsin modified US EPA Preliminary Healthy Watersheds Assessment- Watershed Health Index (PHWA-WHI) reflecting watershed Ecological Health within the Southwestern Lake Superior HUC6. Individual HUC12 results reflect ranking vs. all HUC12s within the HUC6. County boundaries are outlined in white.
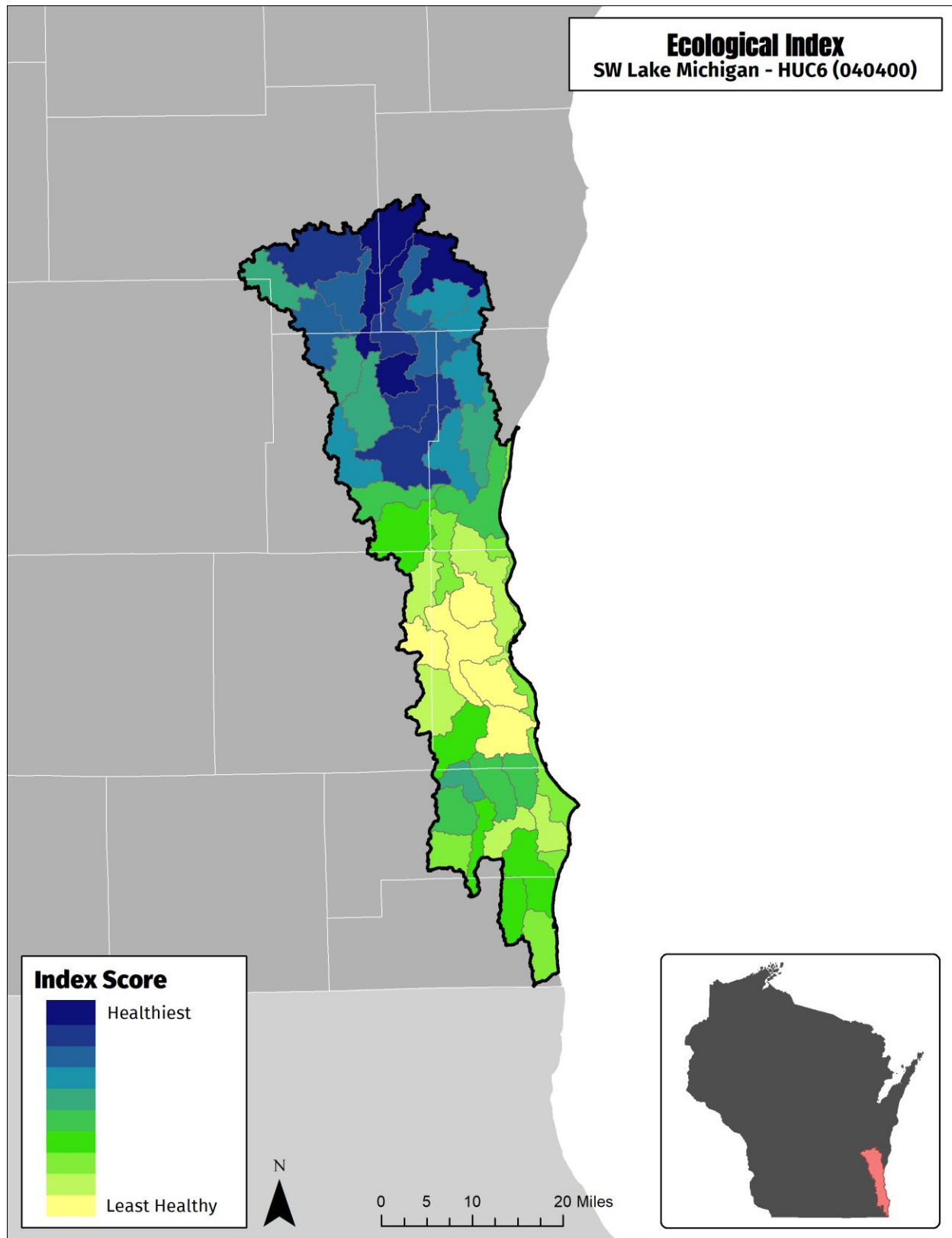
Figure 5. Results of a Wisconsin modified US EPA Preliminary Healthy Watersheds Assessment- Watershed Health Index (PHWA-WHI) reflecting watershed Ecological Health within the Southcentral Lake Superior HUC6. Individual HUC12 results reflect ranking vs. all HUC12s within the HUC6. County boundaries are outlined in white.

Figure 6. Results of a Wisconsin modified US EPA Preliminary Healthy Watersheds Assessment- Watershed Health Index (PHWA-WHI) reflecting watershed Ecological Health within the Northwestern Lake Michigan HUC6. Individual HUC12 results reflect ranking vs. all HUC12s within the HUC6. County boundaries are outlined in white.
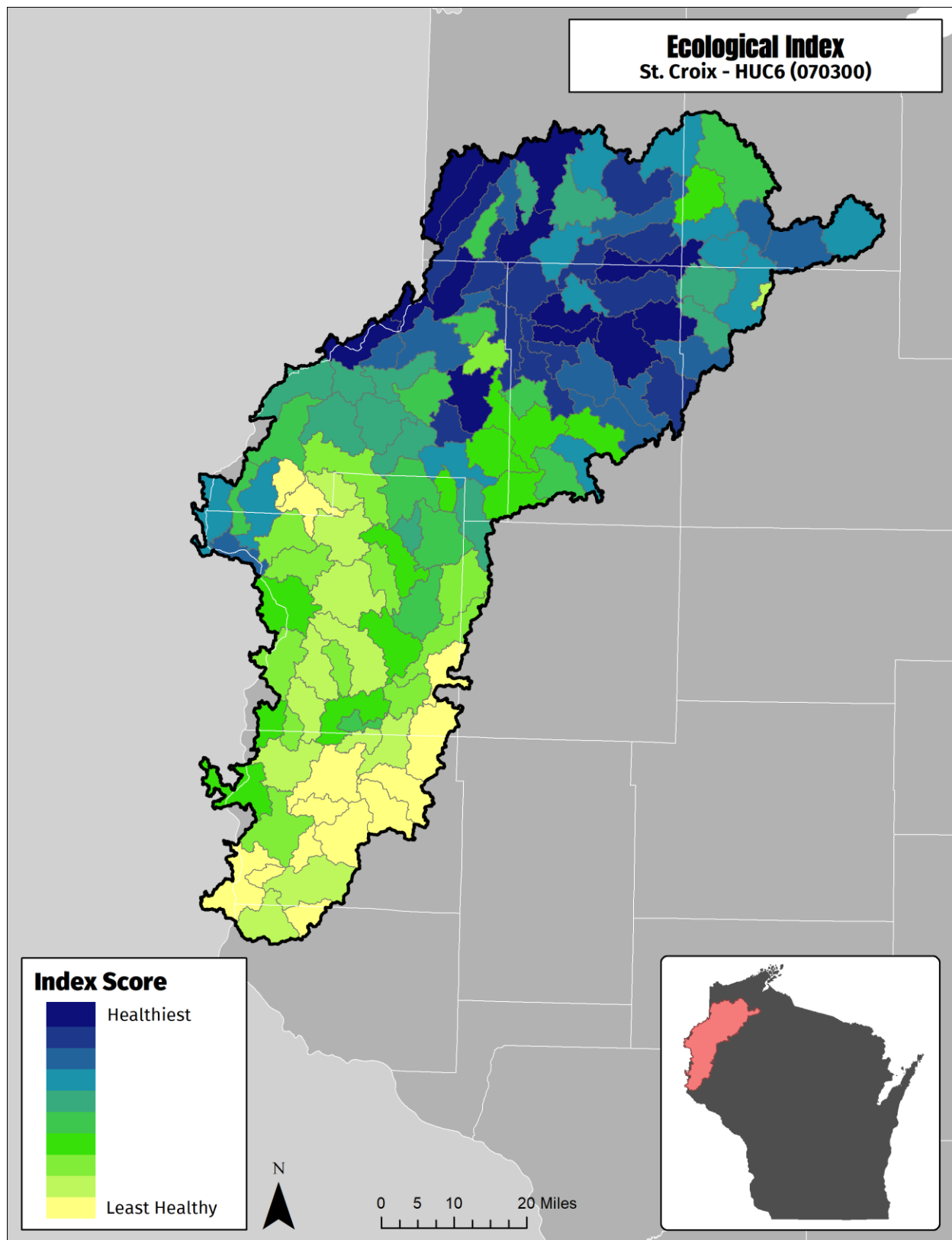
Figure 7. Results of a Wisconsin modified US EPA Preliminary Healthy Watersheds Assessment- Watershed Health Index (PHWA-WHI) reflecting watershed Ecological Health within the Fox-Wolf River HUC6. Individual HUC12 results reflect ranking vs. all HUC12s within the HUC6. County boundaries are outlined in white.

Figure 8. Results of a Wisconsin modified US EPA Preliminary Healthy Watersheds Assessment- Watershed Health Index (PHWA-WHI) reflecting watershed Ecological Health within the Southwestern Lake Michigan HUC6. Individual HUC12 results reflect ranking vs. all HUC12s within the HUC6. County boundaries are outlined in white.

Figure 9. Results of a Wisconsin modified US EPA Preliminary Healthy Watersheds Assessment- Watershed Health Index (PHWA-WHI) reflecting watershed Ecological Health within the St. Croix River HUC6. Individual HUC12 results reflect ranking vs. all HUC12s within the HUC6. County boundaries are outlined in white.
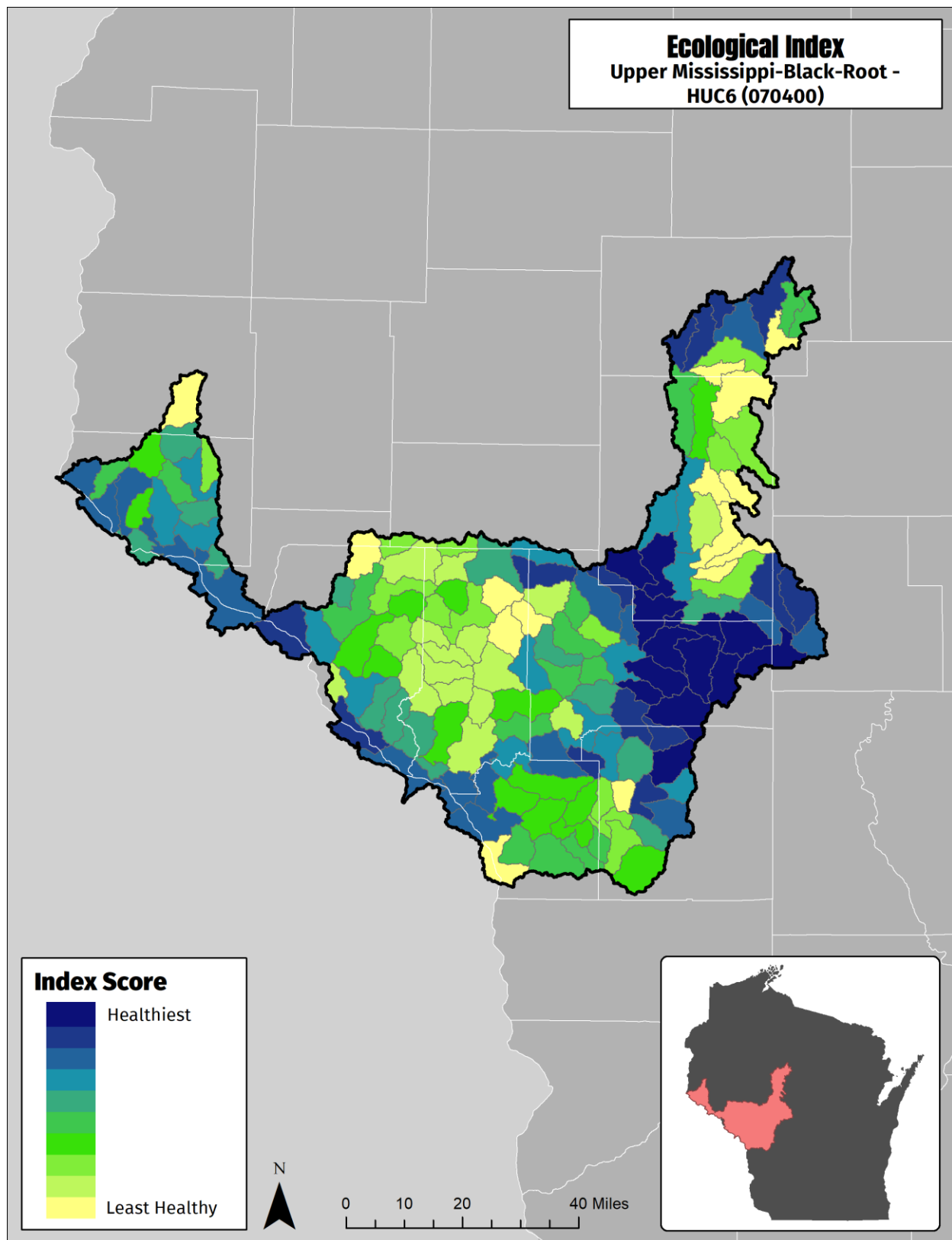
Figure 10. Results of a Wisconsin modified US EPA Preliminary Healthy Watersheds Assessment- Watershed Health Index (PHWA-WHI) reflecting watershed Ecological Health within the Upper Mississippi-Black-Root River HUC6. Individual HUC12 results reflect ranking vs. all HUC12s within the HUC6. County boundaries are outlined in white.
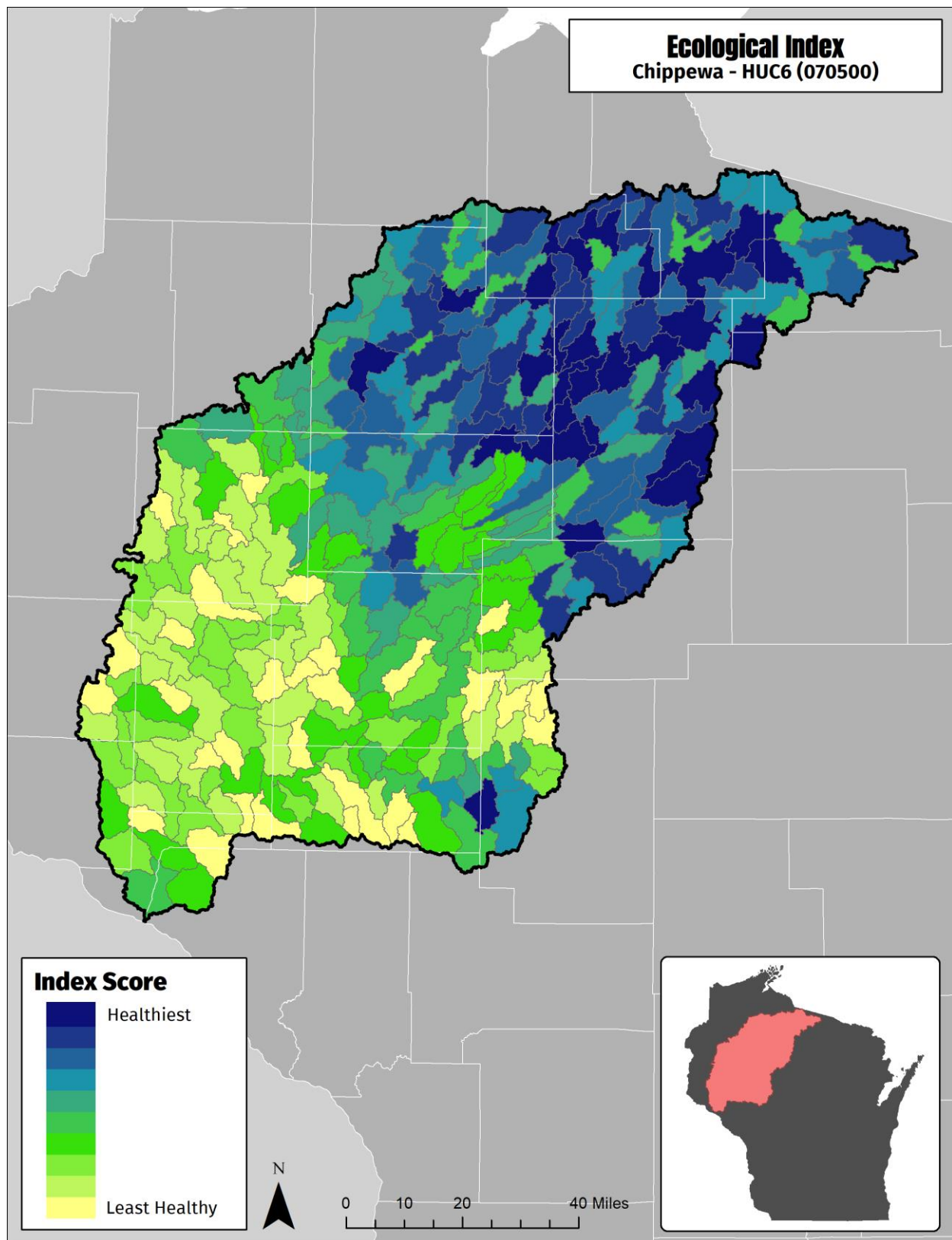
Figure 11. Results of a Wisconsin modified US EPA Preliminary Healthy Watersheds Assessment- Watershed Health Index (PHWA-WHI) reflecting watershed Ecological Health within the Chippewa HUC6. Individual HUC12 results reflect ranking vs. all HUC12s within the HUC6. County boundaries are outlined in white.
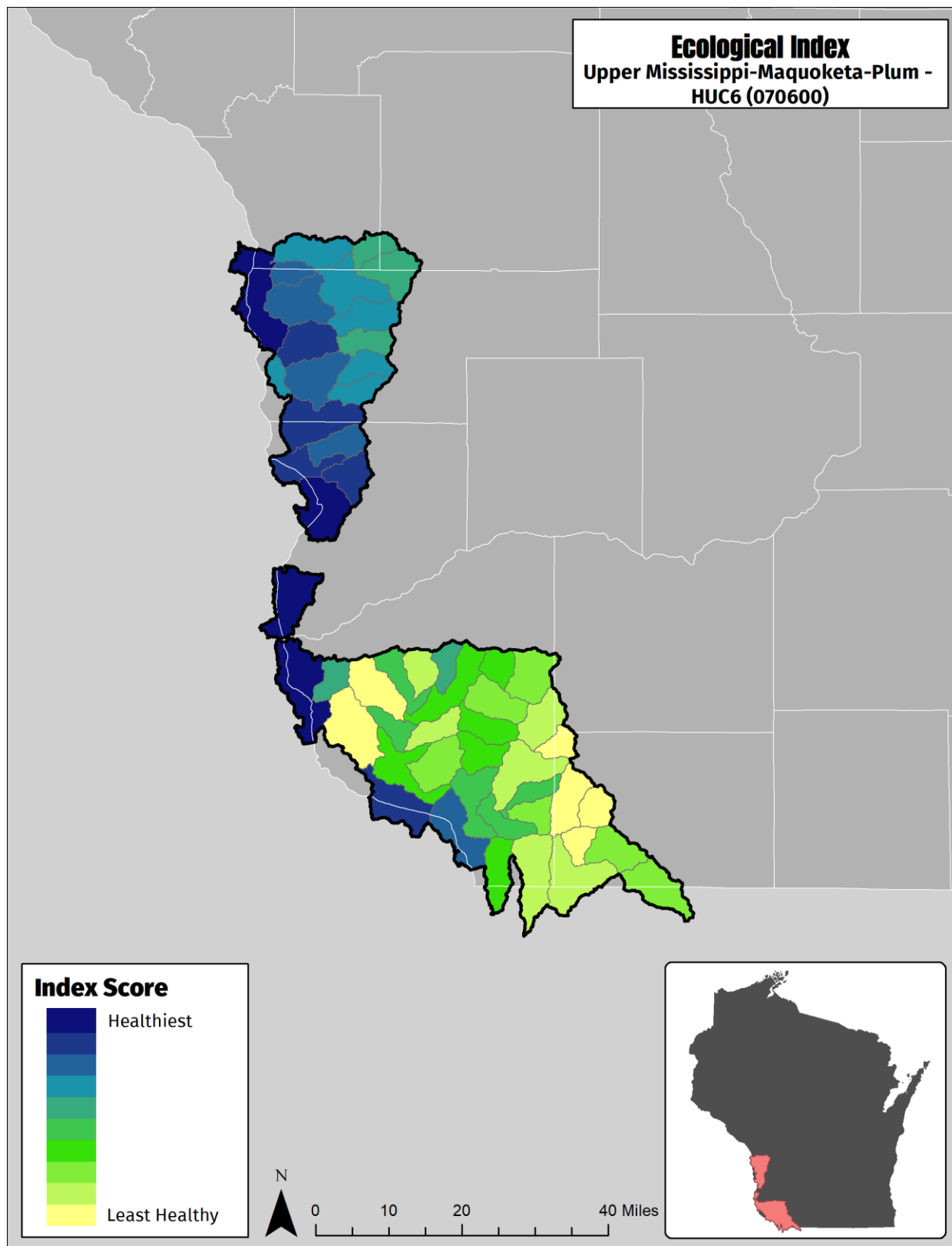
Figure 12. Results of a Wisconsin modified US EPA Preliminary Healthy Watersheds Assessment- Watershed Health Index (PHWA-WHI) reflecting watershed Ecological Health within the Upper Mississippi-Maquoketa-Plum HUC6. Individual HUC12 results reflect ranking vs. all HUC12s within the HUC6. County boundaries are outlined in white.
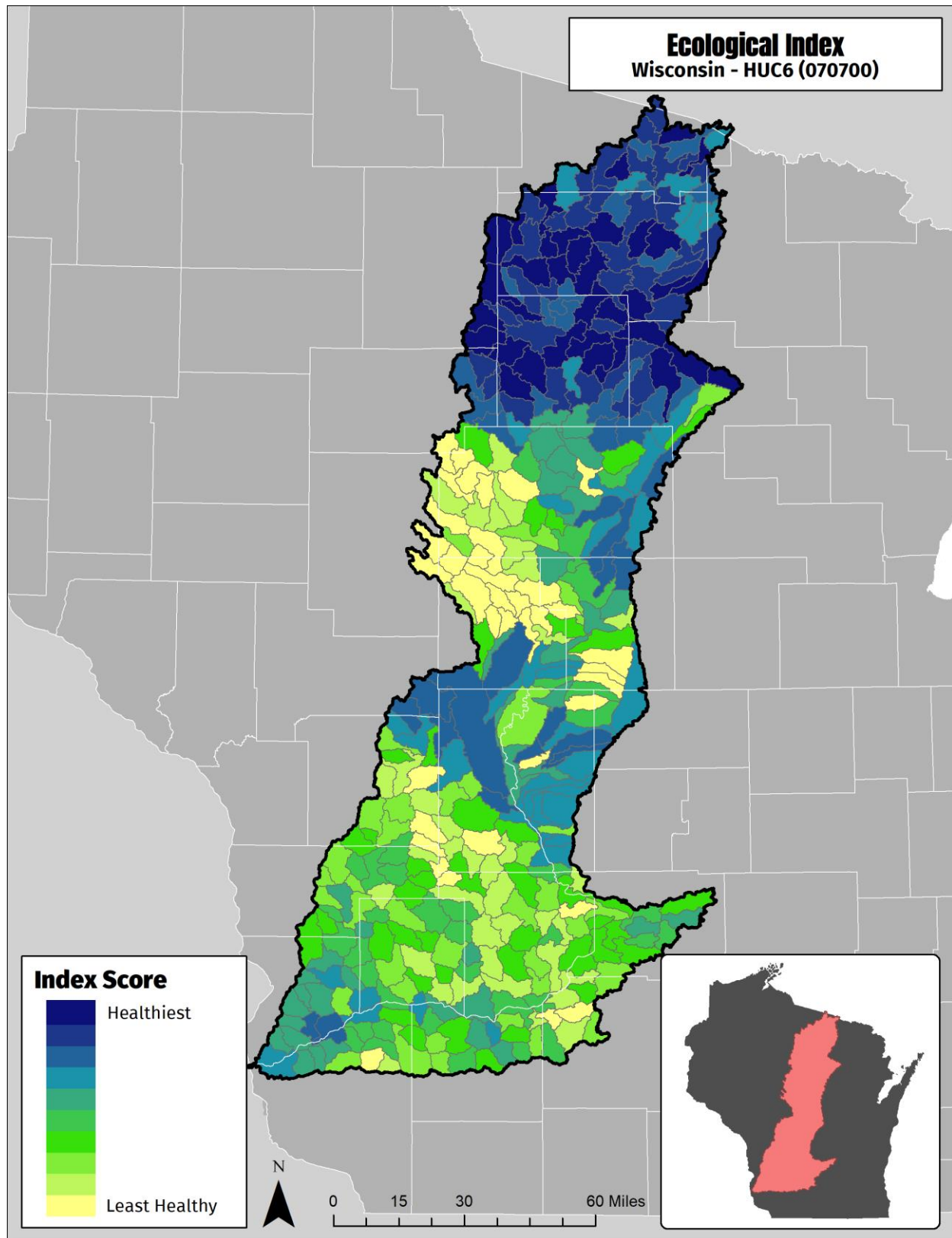
Figure 13. Results of a Wisconsin modified US EPA Preliminary Healthy Watersheds Assessment- Watershed Health Index (PHWA-WHI) reflecting watershed Ecological Health within the Wisconsin River HUC6. Individual HUC12 results reflect ranking vs. all HUC12s within the HUC6. County boundaries are outlined in white.
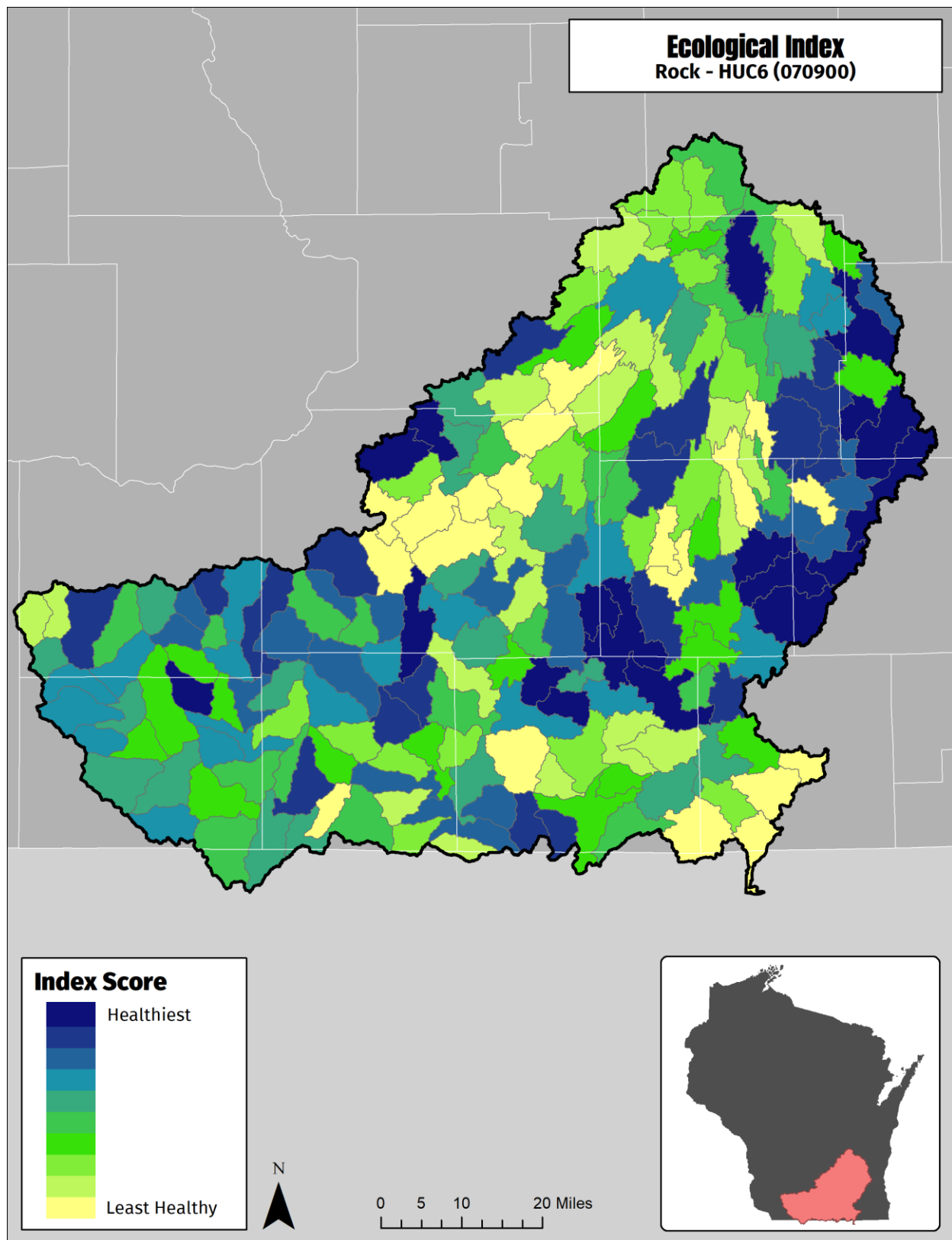
Figure 14. Results of a Wisconsin modified US EPA Preliminary Healthy Watersheds Assessment- Watershed Health Index (PHWA-WHI) reflecting watershed Ecological Health within the Rock River HUC6. Individual HUC12 results reflect ranking vs. all HUC12s within the HUC6. County boundaries are outlined in white.
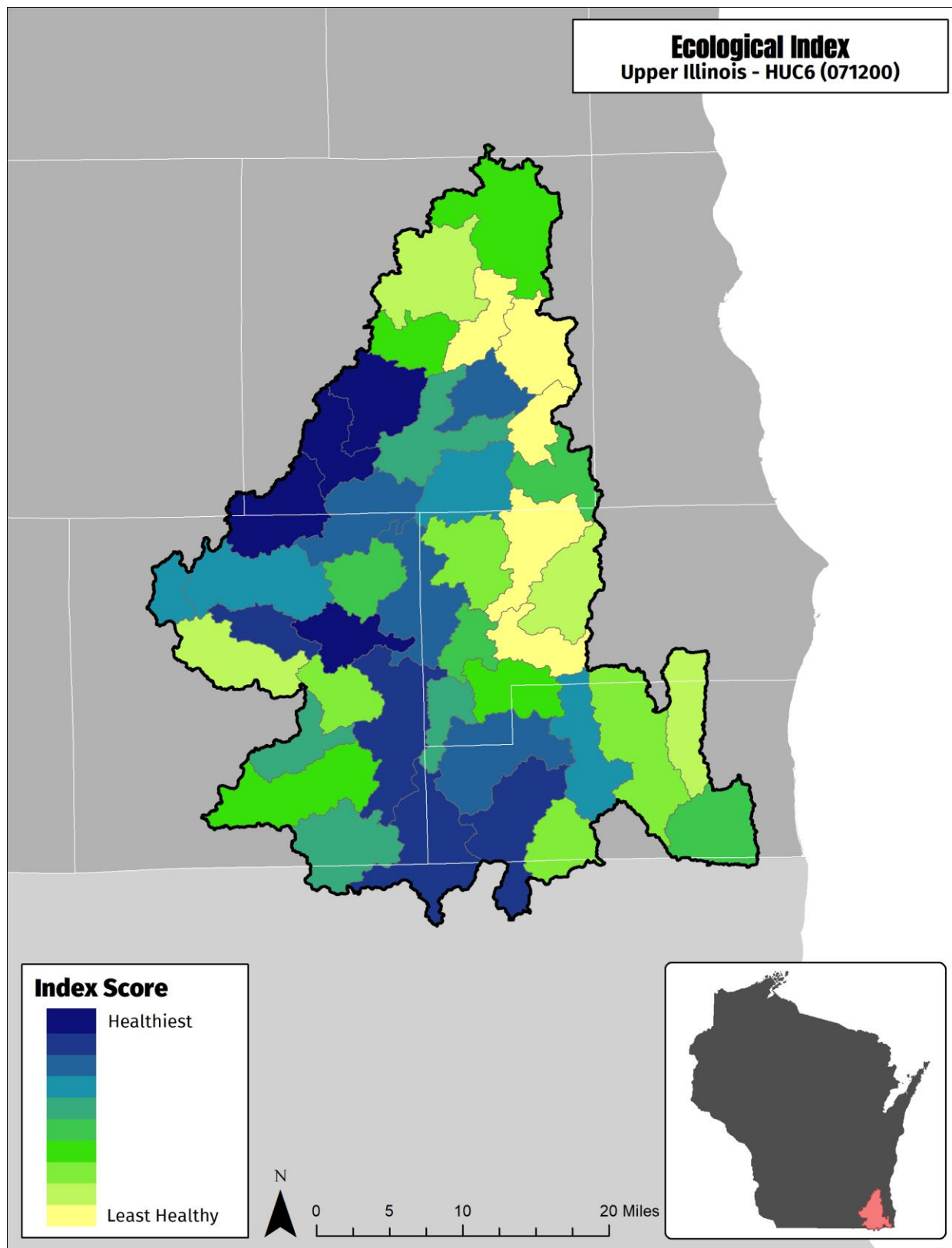
Figure 15. Results of a Wisconsin modified US EPA Preliminary Healthy Watersheds Assessment- Watershed Health Index (PHWA-WHI) reflecting watershed Ecological Health within the Upper Illinois River HUC6. Individual HUC12 results reflect ranking vs. all HUC12s within the HUC6. County boundaries are outlined in white.

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APPENDIX 1: A (non-exhaustive) list of conservation planning tools reviewed as part of the Healthy Watersheds, High-Quality Waters development process.

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APPENDIX 2: Healthy Watersheds modeling results including statewide rank, Ecological Index and Sub-Index, and individual metric scores.

Please see this link for a protected spreadsheet copy of Healthy Watersheds modeling results:

https://widnr.widen.net/s/xmcl89tgpx/wy_ecologicalmetricsscores_rps2021

APPENDIX 3:   Final list of identified High-Quality Waters (HQW) in Wisconsin.

Disclaimer: Please note that while hundreds of wetland areas across the state were identified as HQW, many of these ecosystems lack well-known place names or formal names. Additionally, unlike other aquatic ecosystems (e.g. lakes, rivers, streams, and reservoirs) which have Water Body Identification Codes (WBICs), the vast majority of wetlands lack a numeric system of inventory or categorization. These areas also are not neatly categorized or identified within the WDNR Wisconsin Wetland Inventory either as some wetland areas cross multiple remotely-sensed and interpreted wetland complex polygons. Thus, listing HQW wetlands in a format that is informative at this time is a difficult technical hurdle. For the time being, we have included HQW Wetlands in this list and we will work to incorporate them within a viewer or similar means as described in the Results and Discussion section of this report.

Please see this link for a list of final High-Quality Waters:

https://dnr.wisconsin.gov/sites/default/files/topic/SurfaceWater/HWHQW_HUC6_StatewidePriorities.pdf

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