Project Technical Memo 2020

Land Prioritization Mapping for Protecting Drinking Water Quality

INTRODUCTION

Eight drinking water suppliers in the [Potomac River Basin Drinking Water Source Protection Partnership (DWSPP)] collaborated to rank land parcels to protect drinking water quality. Participating utilities included (in order from upstream to downstream) Berkeley County Public Service Water District, Frederick County Division of Water and Sewer Utilities, the Town of Leesburg Department of Utilities, Loudoun Water, Fairfax Water, Washington Suburban Sanitary Commission (WSSC Water), Washington Aqueduct, and DC Water.

The project area encompassed the non-tidal Potomac basin above the DC metro drinking water supply intakes. This memo documents the methods and results, discussion, update needs, and timeline of the prioritization process. In addition to this memo, a project flier and the associated geospatial files are available.

METHODS AND RESULTS

OPPORTUNITY AREAS

The project area included the non-tidal Potomac basin above the DC metro drinking water supply intakes. Within the study area, agricultural and forested lands, as well as riparian areas protected by county ordinance, were considered "opportunity areas" for prioritization. Protected lands like easements and government-owned lands in the study area were excluded from the opportunity areas. **Figure 1** shows the 4.6 million acres of resulting opportunity areas.

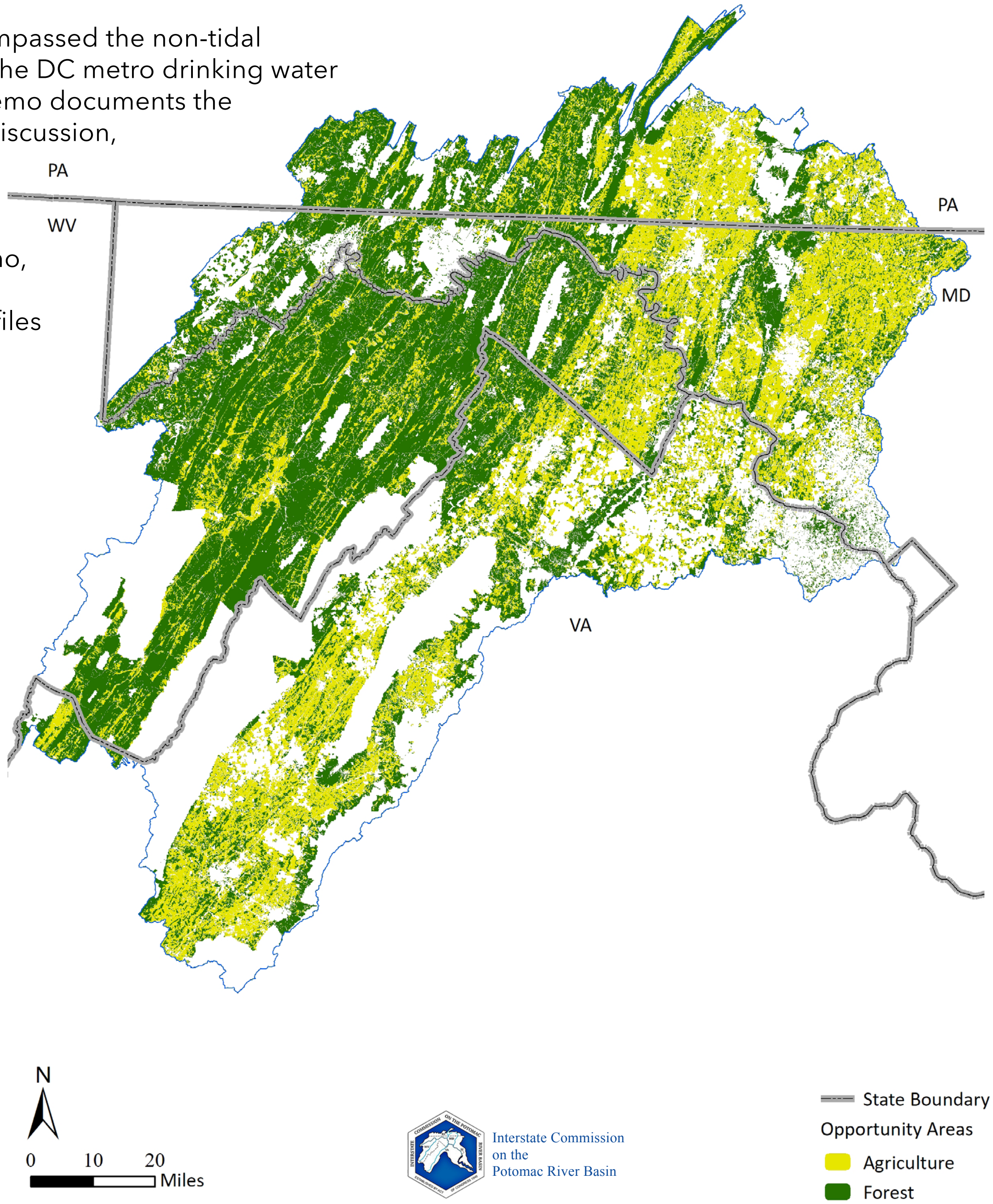


FIGURE 1
Opportunity areas considered in the prioritization effort. Opportunity agricultural areas are shown in yellow, and opportunity forested areas are shown in green.

OBJECTIVE STATEMENT

The stakeholder-developed objective statement for the prioritization scheme was to ***rank parcels to protect drinking water quality and their potential to degrade long-term water quality.*** The prioritization metrics were selected and the methodology was executed in order to achieve this objective.

METRICS

Seven metrics were identified to prioritize parcels according to the objective statement. The metrics and corresponding rationale statements include:

Distance from Waterways

Areas closer to the waterway are more likely to impact downstream drinking water quality.

Distance from Surface Water Intake Weighted by 24-Hour Travel Time

Areas closer to intake locations throughout the basin are more likely to impact drinking water quality. In addition, areas closer to the DC metro utilities may potentially impact larger populations in a shorter amount of time.

Distance from Urban Areas

Areas closer to urban areas are more likely to be impacted by urban land use activities like winter salt applications and are at greater risk of spills at road-stream crossings.

Karst Transmissivity

Areas with higher transmissivity are higher priority as they convey contaminants more readily.

Future Land Use (Year 2025)

Protecting lands expected to be forested or agricultural in 2025 are given priority to minimize the impacts of future urbanization.

Preserving Existing High-Quality Streams

Areas close to high-quality streams are given priority to protect these resources.

Buffer Regulations

Riparian areas in counties without stream buffer regulations are prioritized as there is not an existing regulatory effort for protection, leaving them more vulnerable to activities that may impact downstream drinking water quality.

Spatial data sets were obtained for each metric (Table 1), and GIS mapping was conducted to develop priority maps for each metric. The methods for developing the metric layers from each of these data sources and the resulting metric maps are presented in the subsections below.

All metrics were normalized on a scale of 0 to 100, with a value of 100 indicating highest priority for conservation. Normalizing the values prevents any one metric from being given more or less weight because of the magnitude of the raw values. All normalizations were done in ArcGIS using the Geomorphometry & Gradient Metrics tool (Evans et al., 2014).

TABLE 1
Spatial Data Sources for Each Prioritization Metric

METRIC	DATA SOURCE
Distance from Waterways	USGS, 2015. https://www.usgs.gov/core-science-systems/ngp/national-hydrography
Distance from Surface Water Intakes	Environmental Protection Agency's Safe Drinking Water Information System (EPA SDWIS) data set
Distance from Urban Areas	2016 urban places shapefile (tl_2016_places.shp), https://www.census.gov/cgi-bin/geo/shapefiles/index.php?year=2016&layergroup=Places
Karst Transmissivity	Weary and Doctor, 2014. https://pubs.er.usgs.gov/publication/ofr20141156
Future Land Use (2025)	Chesapeake Bay Program, forecasted for Phase 6 Bay Model, https://gis.chesapeakebay.net/ags/rest/services/LandUseDataViewer/Watershed/MapServer/13
Preserving Existing High-Quality Streams	EPA, 2015. https://www.epa.gov/waterdata/waters-geospatial-data-downloads#ATTAINSProgramData
Buffer Regulations	Review of county regulations

Distance from waterway

The distance from National Hydrography Dataset (NHD) waterways metric was calculated using the Euclidean Distance tool in ArcGIS Spatial Analyst. Areas closer to waterways received a higher ranking as events in these areas are more likely to affect downstream drinking water quality. **Figure 2** shows the distance from waterway metric with higher-priority areas shown in purple and lower-priority areas shown in green.

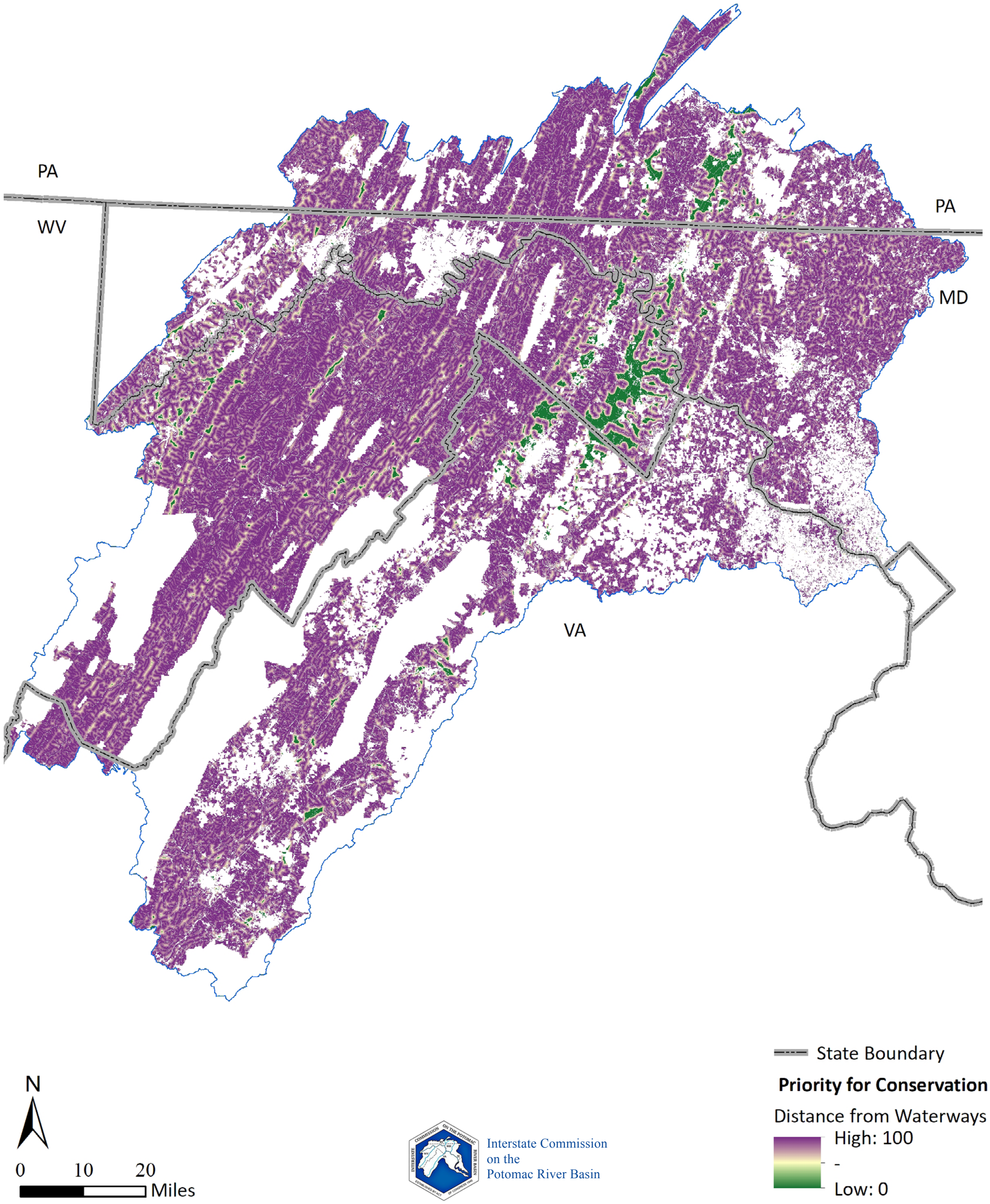


FIGURE 2
Distance from waterway metric. Higher-priority grid cells are shown in purple. Lower-priority grid cells are shown in green.

Distance from surface water intakes

The metric for distance from surface water intakes was weighted by the average 24-hour travel time **(Figure 3)**. Areas closer to surface water intakes with shorter travel times received higher prioritization values.

To develop this metric, the drainage area around each surface water intake was delineated and distance buffers were created around each intake within their respective drainage areas. Areas closer to intakes received a higher ranking because these areas likely have a larger impact on drinking water quality than areas further away.

Next, travel time zones to downstream water utilities were created. The results of the federal ICWater spill model were used to digitize 6-, 12-, and 24-hour travel zones. All other travel zone bands covering the opportunity areas were based on the average 24-hour travel time, which covers about 11 miles. The travel zone bands were normalized from 0 to 100 with areas closer to the DC metro water utilities receiving higher priority rankings because they have the potential to affect a larger population in a shorter time. The two raster grids were then combined using equal weights and the cell values were normalized.

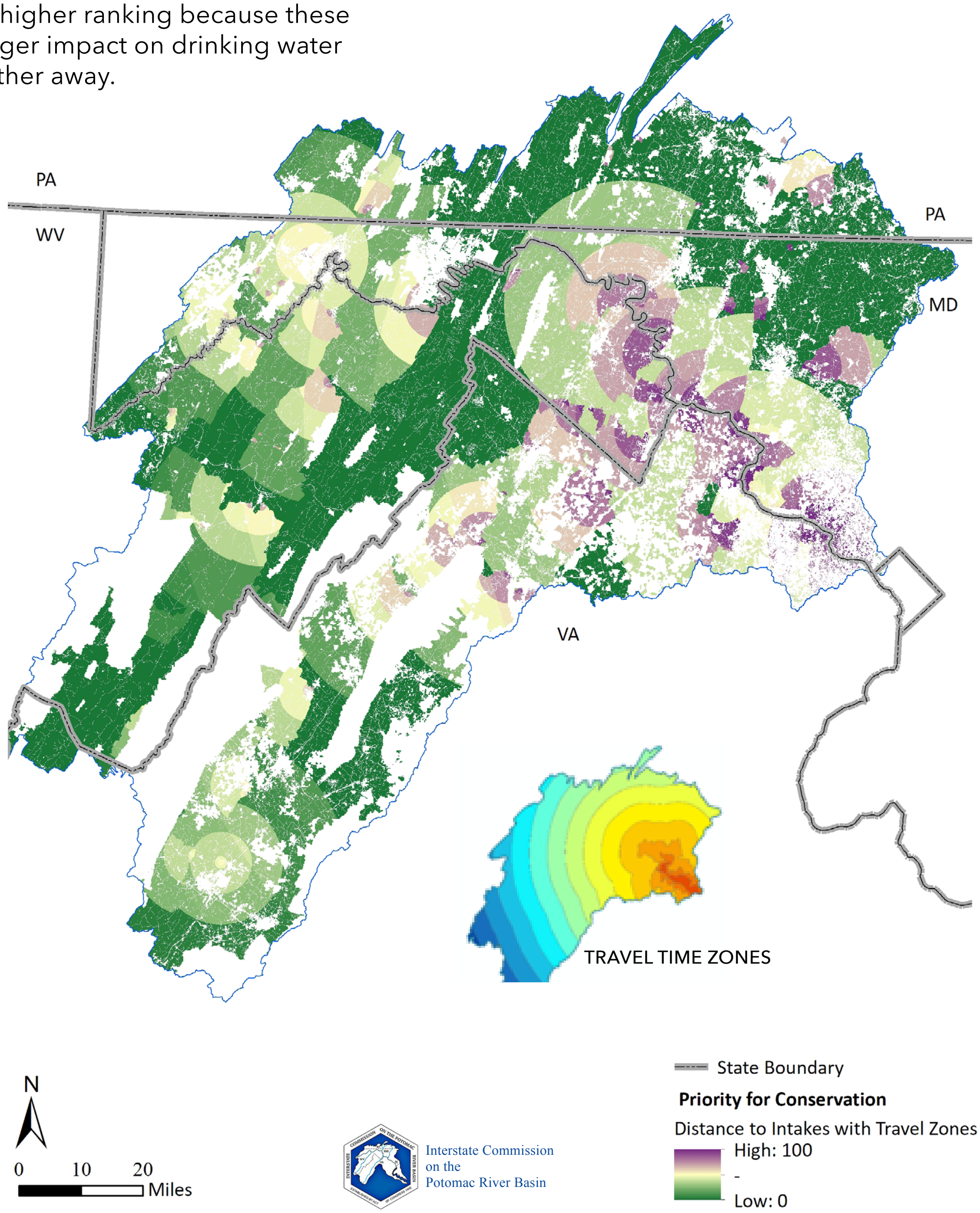


FIGURE 3
Distance from surface water intake metric. Higher-priority grid cells are shown in purple. Lower-priority grid cells are shown in green.

Distance from urban areas

The distance from urban areas metric was calculated using the Euclidean Distance tool in ArcGIS Spatial Analyst. Areas closer to urban centers received a higher-priority ranking because these are more likely to be adversely impacted by activities such as salt applications during winter month or spills of contaminants at road-stream crossings. **Figure 4** shows the distance from urban areas metric.

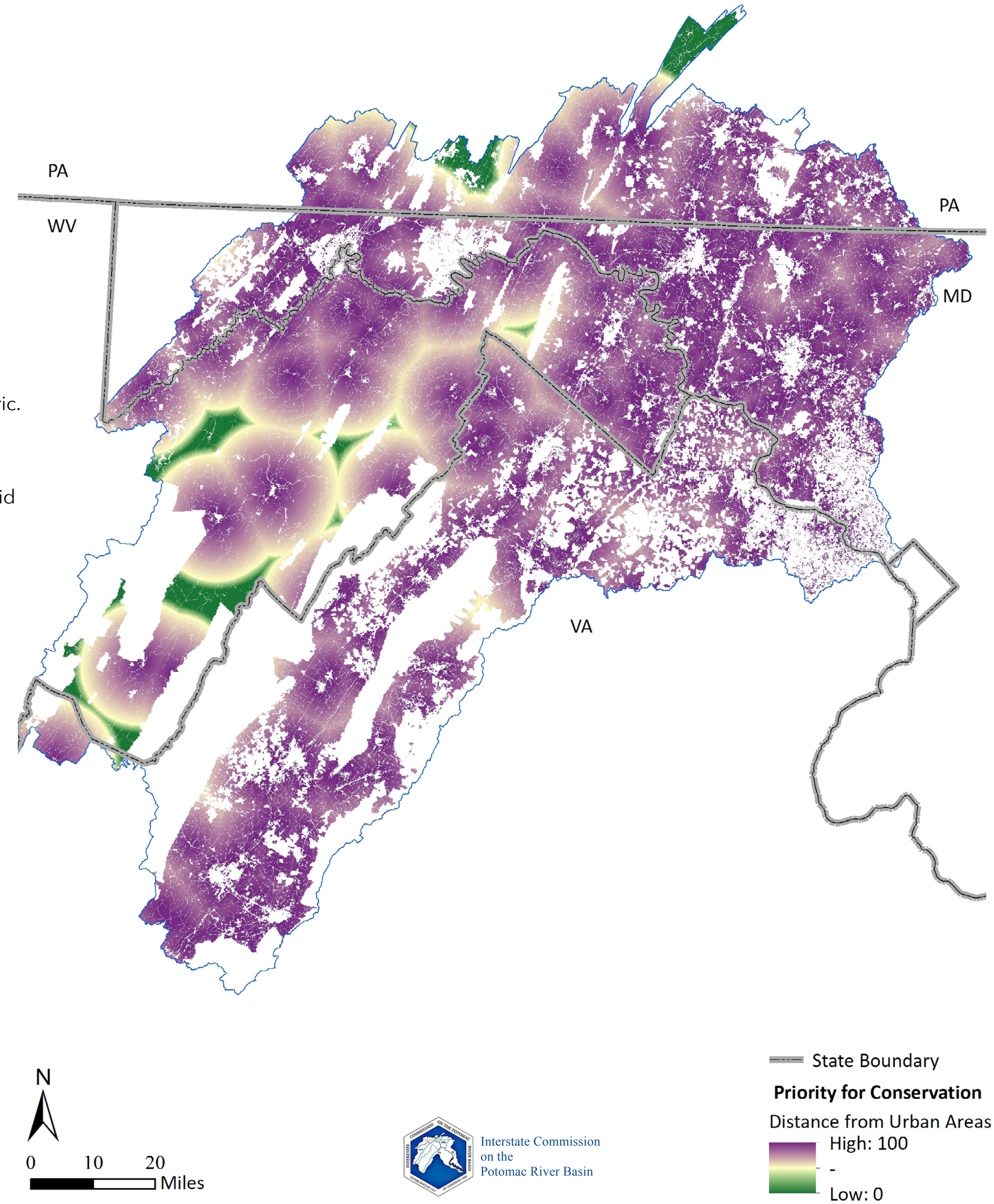


FIGURE 4
Distance from urban areas metric. Higher-priority grid cells are shown in purple. Lower-priority grid cells are shown in green.

Karst transmissivity

Karst regions with a potential of higher transmissivity received a higher-priority ranking for conservation. Karst regions develop over certain types of soluble rock like limestone, sandstone, dolomite, and shale (Weary and Doctor, 2014). These rock formations have varying degrees of transmissivity that determine how much water can flow through a formation.

Generalized transmissivity values were developed for this study based on ranges from Swain et al. (2004) **(Table 2)**. Areas with a higher potential of transmissivity received a higher priority for conservation because they may deliver pollutants more readily to ground and/or surface waters **(Figure 5)**.

TABLE 2
Summary of Karst Characteristics in the Study Area Based on Data from Swain et al. (2004)

Karst Type	Area (%)	Transmissivity	Mean	Rank
Limestone	52%	700 - 7,000	3850	51
Dolomite	33%	2,000 - 13,000	7500	100
Shale	5%	130 - 1,300	715	10
Sandstone	5%	20 - 400	210	3

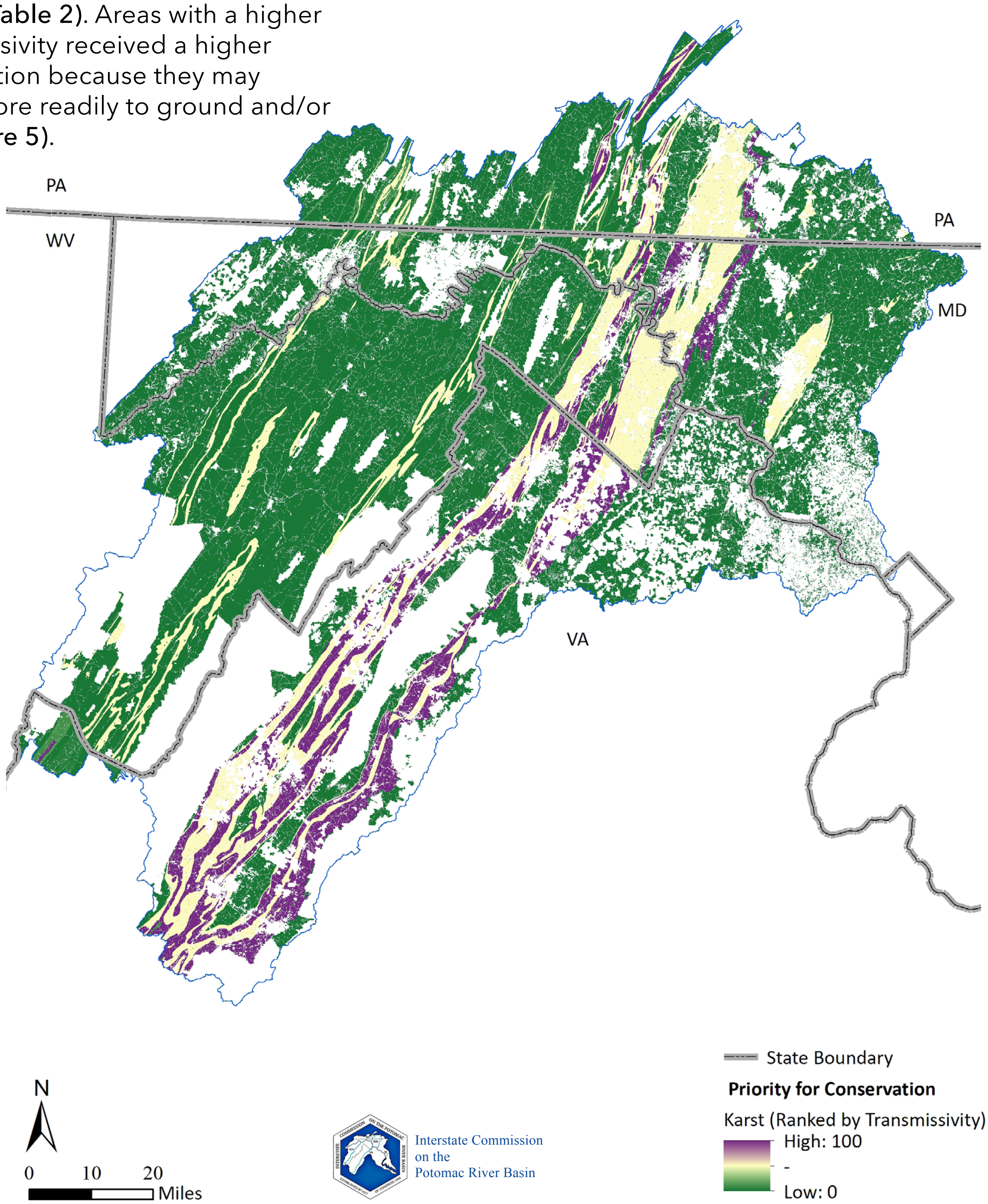


FIGURE 5
Karst transmissivity metric. Higher-priority grid cells are shown in purple. Lower-priority grid cells are shown in green.

Future land use

This metric is based on the 2025 land use scenario the Chesapeake Bay Program forecasted for their phase 6 watershed model (Chesapeake Bay Program Office, 2018). The land uses were categorized into four uses, including forest, agricultural land, urban areas, and a category for all remaining land uses. Lands expected to be forested or agricultural in 2025 were given higher priorities for protection to account for the potential impact of future land development. **Figure 6** shows the future land use metric.

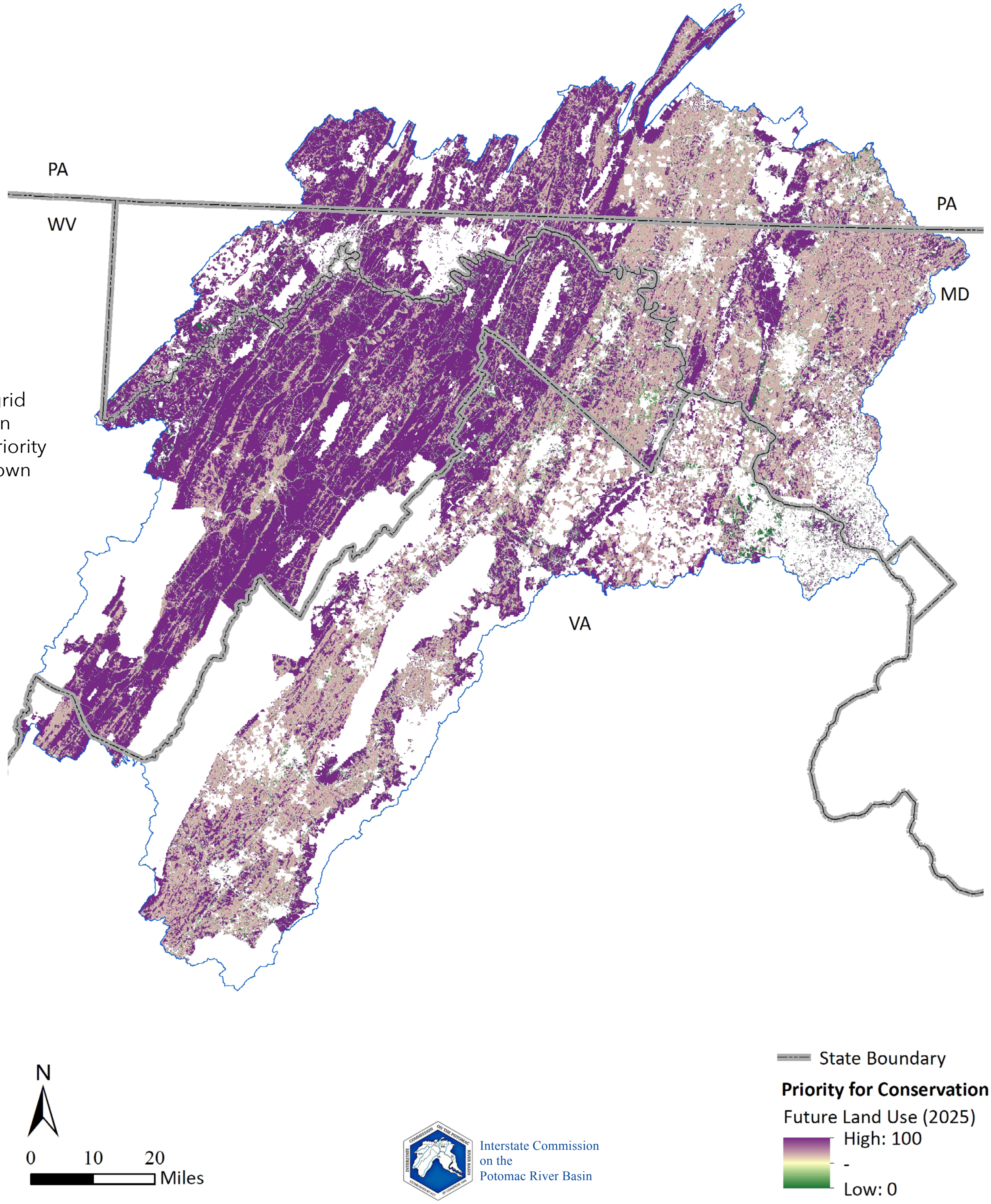


FIGURE 6
Future land use metric. Higher-priority grid cells are shown in purple. Lower-priority grid cells are shown in green.

Preserving existing high-quality streams

The distance to high-quality streams was calculated using the Euclidean Distance tool in ArcGIS Spatial Analyst. Areas closer to high-quality streams received higher-priority ratings to provide protection for this valuable resource. The metric, shown in **Figure 7**, is based on EPA's 2015 Assessment, Total Maximum Daily Load (TMDL) Tracking and Implementation System (ATTAINS).

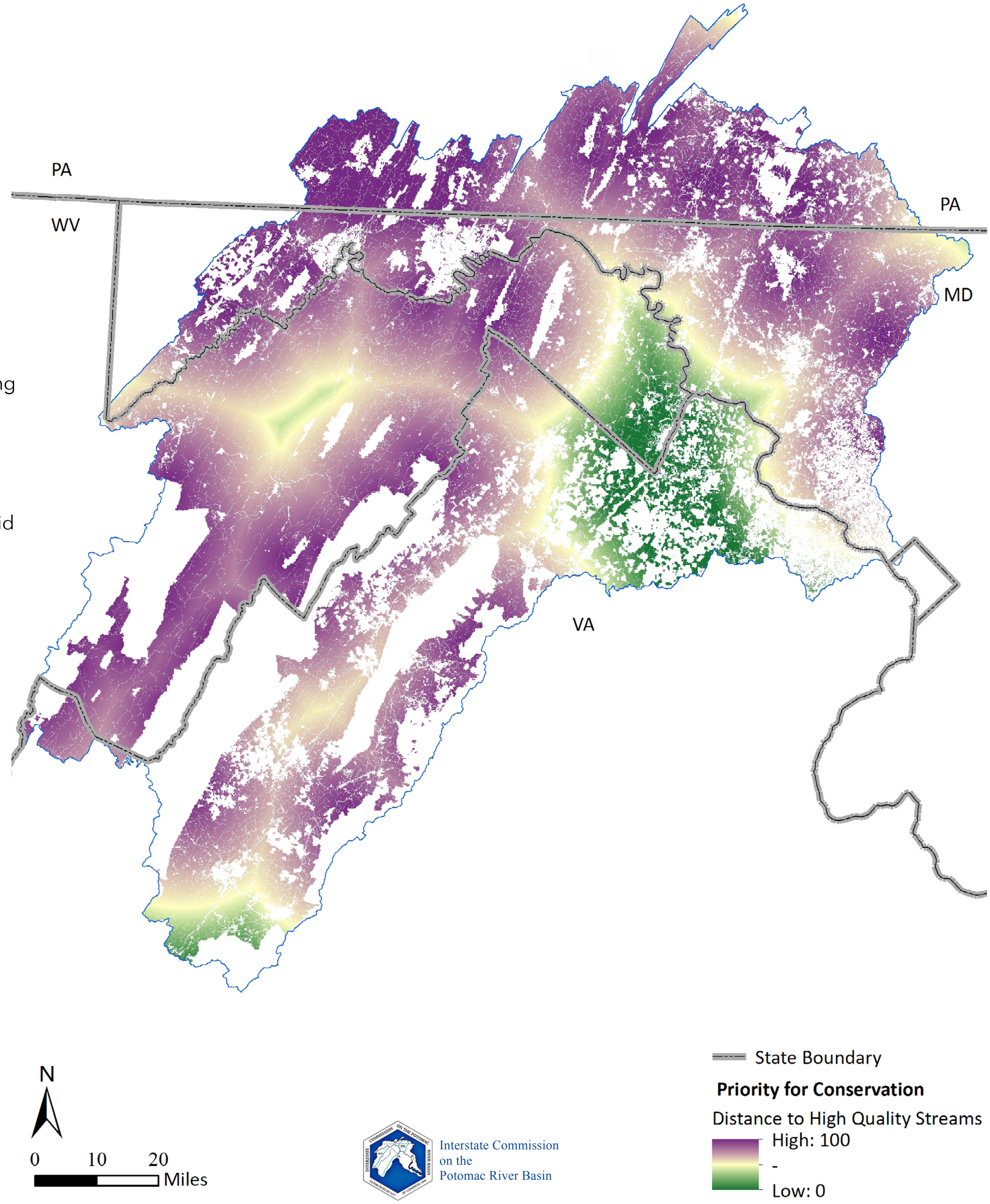
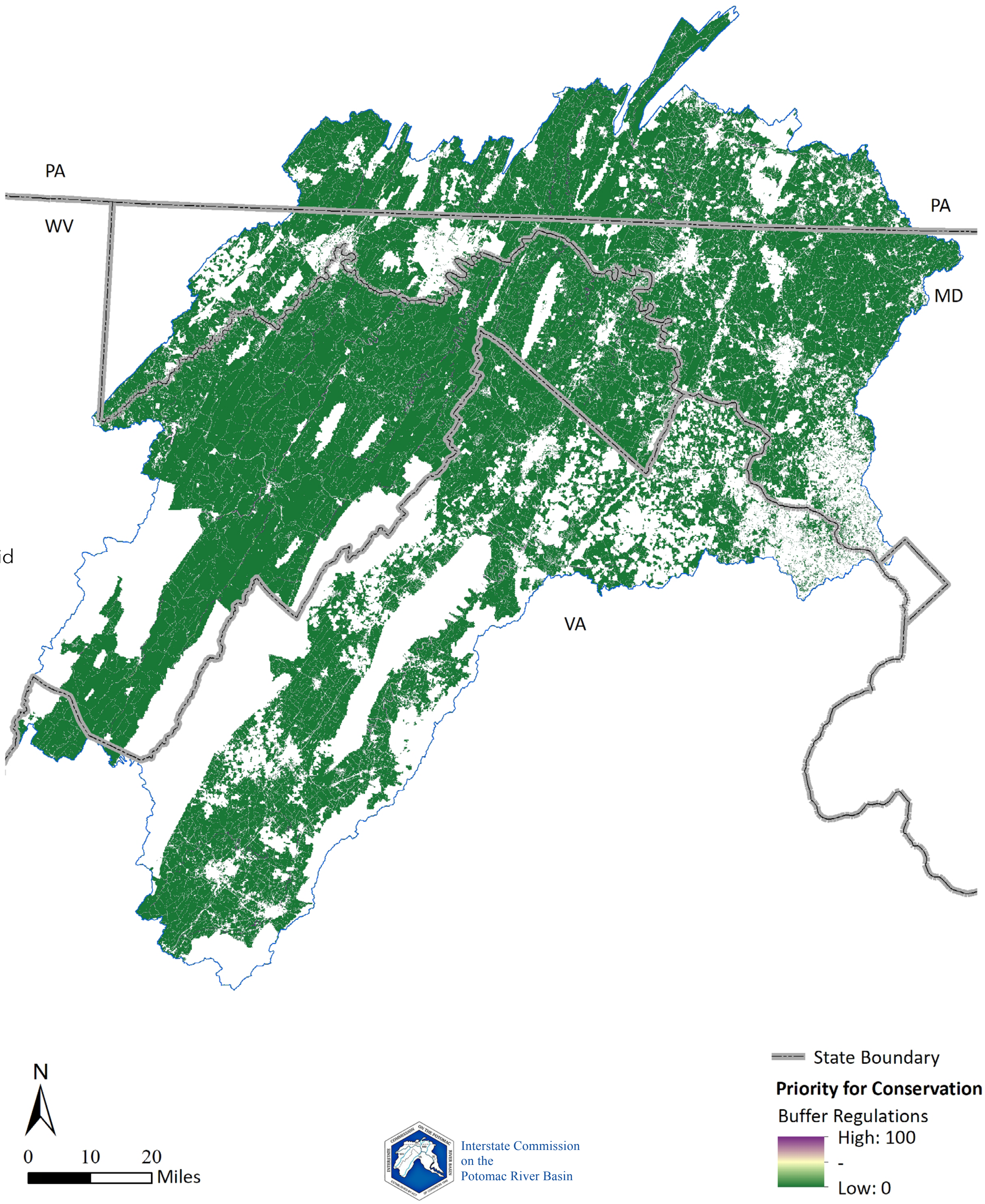


FIGURE 7
Preserving existing high-quality streams metric. Higher-priority grid cells are shown in purple. Lower-priority grid cells are shown in green.

Buffer regulations

The buffer regulation metric contains opportunity areas in counties without stream buffer regulations. The metric, shown in **Figure 8**, is expressed as the percent of unprotected riparian areas. Riparian areas without buffer regulations received a higher priority because they are more vulnerable to events that may impact downstream drinking water quality.

FIGURE 8
Buffer regulation metric. Higher-priority grid cells are shown in purple. Lower-priority grid cells are shown in green.



Correlation

Since the final prioritization should only include unique metrics, the correlation between metrics was calculated. Including correlated metrics would effectively double count the characteristics being described.

Table 3 shows the correlation between all normalized metrics. With one exception, the correlation values are quite low. The distance to intakes metric displayed a higher degree of correlation with both the urban areas and high-quality stream metrics. These values indicate that at least 60 percent of the variability in that metric is not explained by the other metrics, and it was therefore included in the final prioritization scheme. As a result, all seven of the metrics were included in cumulative maps.

TABLE 3
Metric Correlation Table

METRIC	WATERWAY	INTAKES	URBAN AREA	KARST	HIGH-QUALITY STREAMS	BUFFER REGULATIONS	FUTURE LAND USE	OPPORTUNITY AREA
Distance from Waterways	1	-0.08	-0.06	-0.19	0.1	0.04	0.03	-0.01
Distance from Surface Water Intakes		1	0.32	0.07	-0.39	-0.003	-0.1	-0.1
Distance from Urban Areas			1	0.2	-0.22	0.004	-0.24	-0.1
Karst Transmissivity				1	-0.14	-0.005	-0.2	-0.02
Preserving Existing High-Quality Streams					1	0.01	0.16	0.06
Buffer Regulations						1	-0.03	-0.02
Future Land Use (2025)							1	0.12
Percent Opportunity Area in Parcel								1

Cumulative Mapping

The product of this effort is a cumulative prioritization map at the parcel scale. This final map was derived by summing raster layers for all metrics. Each metric received equal weight during the summing process except for the karst transmissivity layer. Karst transmissivity received 50 percent weight compared to the other metrics due to its dominance at equal weight. The final parcel-scale cumulative map also includes an additional metric for percent of opportunity area within the parcel. This additional metric is important to help identify parcels with larger amounts of opportunity area. The final prioritized opportunity parcels are shown in **Figure 9**.[1]

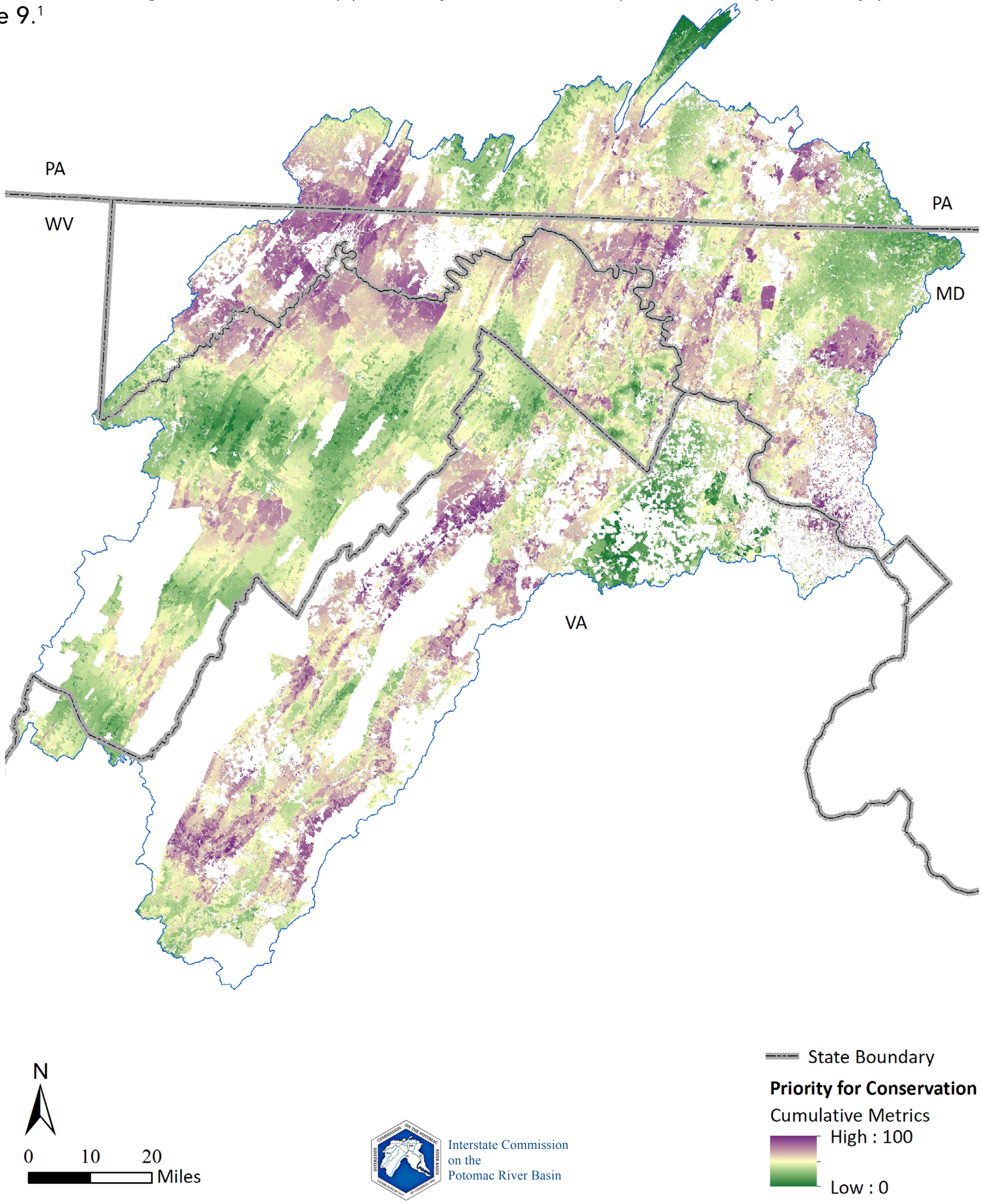


FIGURE 9
Priorities for land conservation from a drinking water source protection perspective at the parcel scale in the Potomac basin. Higher-priority parcels are shown in purple. Lower-priority parcels are shown in green.

1 *Parcel-scale rankings are not available for Somerset County, Pennsylvania because a digital parcel layer was not available at the time of analysis.*

Discussion

A total of 3,737 acres comprising 621 parcels of high-priority land were identified in the study area.[2] **Table 4** shows the distribution of the high-priority lands in the study area jurisdictions. High-priority land makes up 0.05 percent of the study area and 0.08 percent of the opportunity area.

TABLE 4

High-Priority Forested and Agricultural Lands in the Potomac Basin by Jurisdiction

		High-Priority Forest		High-Priority Agriculture		High-Priority TOTAL	
Jurisdiction	# Counties	# Parcels	Acres	# Parcels	Acres	# Parcels*	Acres
Maryland	4	60	213	22	27	61	240
Pennsylvania	3	12	139	41	15	41	154
Virginia	9	443	2,683	258	499	445	3,181
West Virginia	8	73	150	21	11	74	161
TOTAL	24	588	3,185	342	552	621	3,737

**The total number of high-priority parcels may not equal the number of high-priority forest parcels plus the number of high-priority agricultural parcels because some parcels include both high-priority forest and high-priority agriculture.*

Static county maps for participating utilities are provided in **Figure 10** and **Figure 11** for a close-up view of the prioritization scheme. The number of high-priority parcels within 20 miles upstream of the participating utility intakes are also provided below:[3]

- Berkeley County, West Virginia: 65 parcels
- Frederick County, Maryland: 12 parcels
- Town of Leesburg: 12 parcels
- Loudoun Water: 12 parcels
- Fairfax Water: 25 parcels
- WSSC Water: 6 parcels
- Washington Aqueduct: 25 parcels

2 For the purposes of this summary, "high priority" is considered a cumulative value of greater than or equal to 75. However, the cumulative values range from 0-100, and users may want to evaluate their own threshold for action. Users are encouraged to obtain the GIS layers and identify local high-priority areas based on their own threshold of interest.

3 Note that some parcels may appear in the 20 miles upstream of more than one water supplier. DC Water is not included in this list because they are a wholesale customer of Washington Aqueduct.

FIGURE 10

Static county maps for participating utilities in West Virginia and Maryland. Maps show a) Berkeley County, West Virginia; b) Frederick County, Maryland; and c) Montgomery County, Maryland.

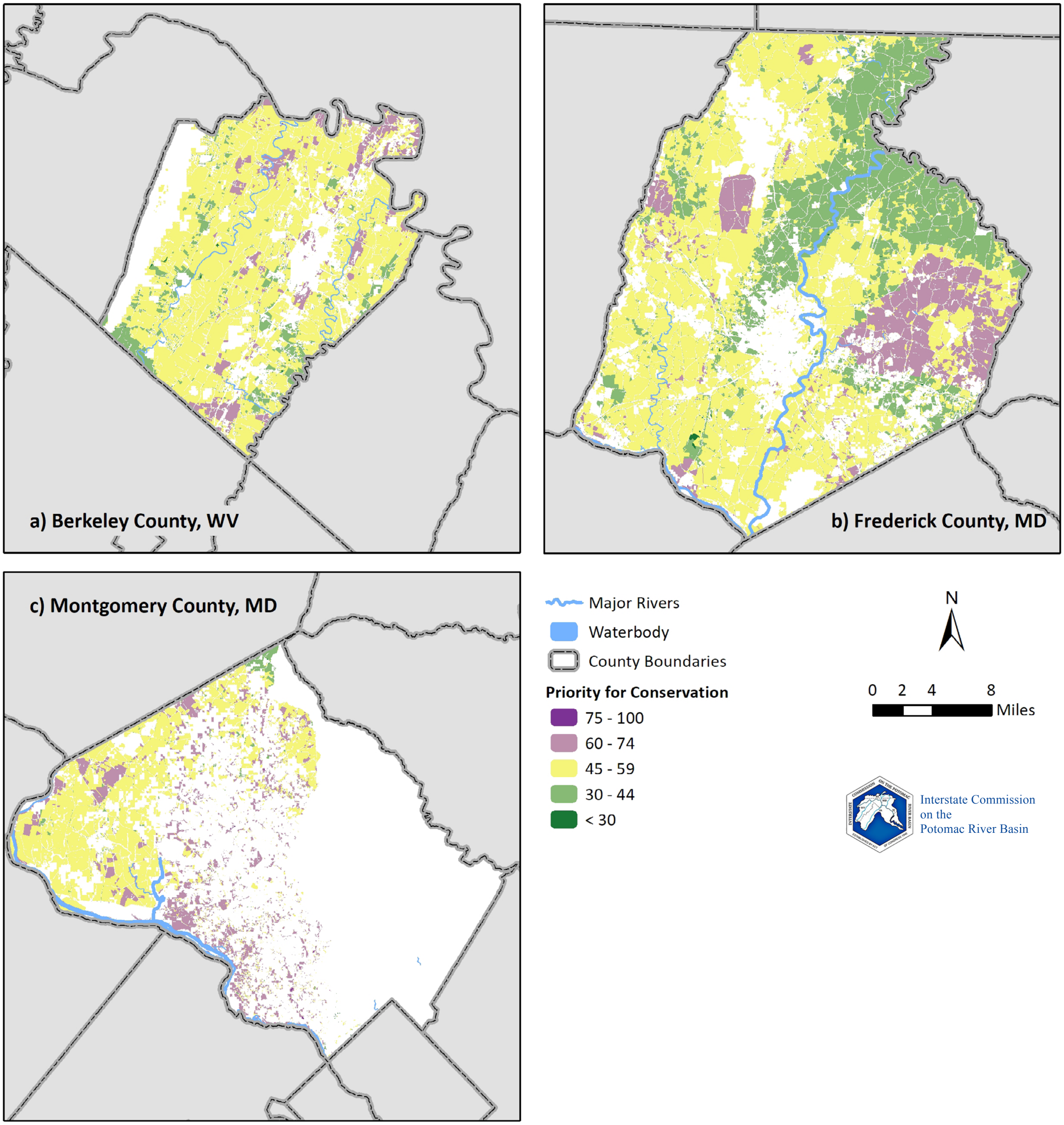
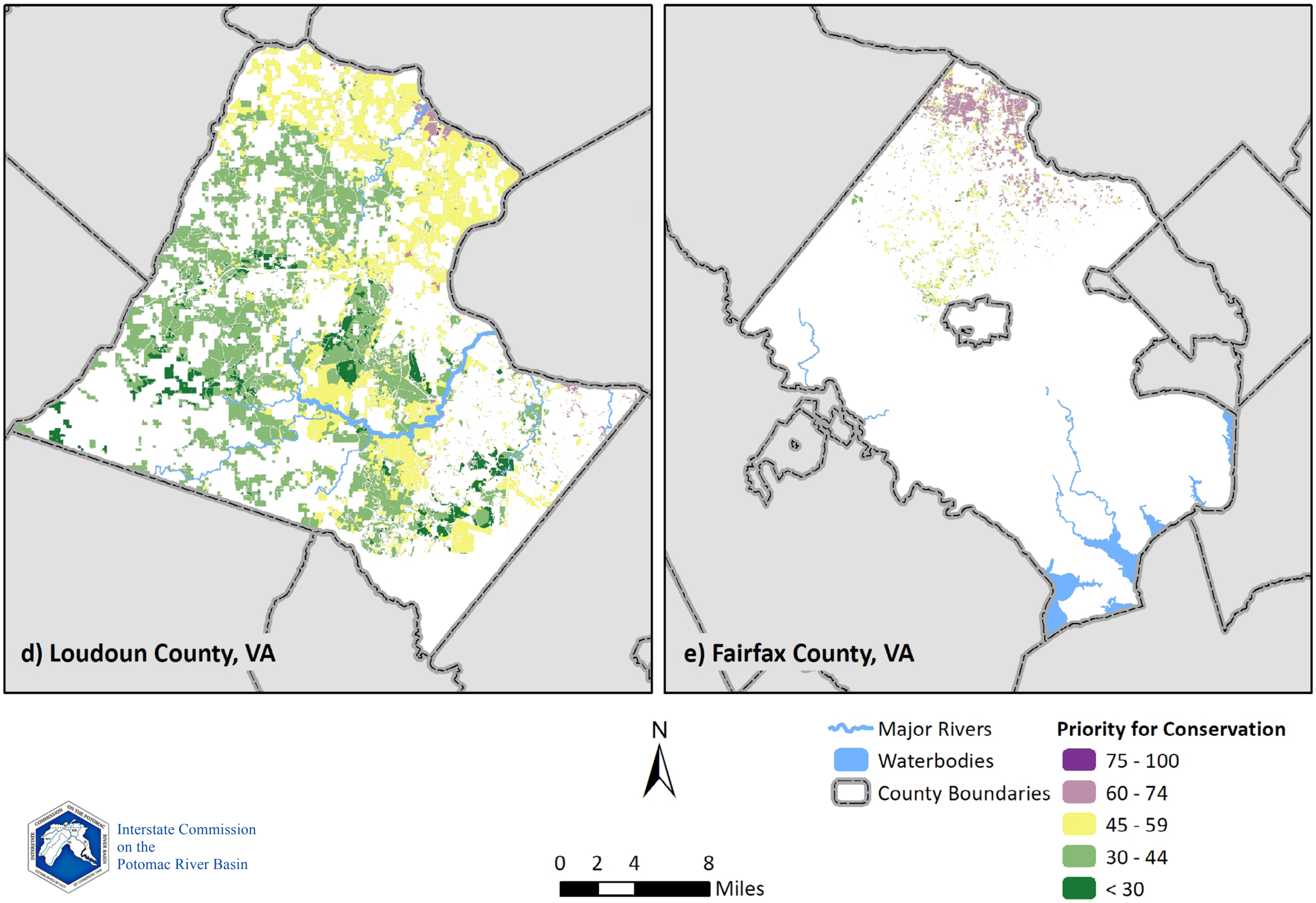


FIGURE 11

Static county maps for participating utilities in Virginia. Maps show d) Loudoun County, Virginia and e) Fairfax County, Virginia.



Update Needs and Timeline

The data sets used to develop the prioritization represent a snapshot in time and, therefore, will only remain current for a limited amount of time. For example, future land use projections are regularly updated by the Chesapeake Bay Program and county buffer regulations may change periodically. In addition, drinking water supplier priorities change over time and, as such, a prioritization that takes into consideration changes in threats, treatment capabilities, and current challenges is important. Further, advances in prioritization tools and techniques will likely become available over time and can be incorporated during an update process.

Given these update needs and resources, it is expected that an update may be warranted every five years, making the first update in the year 2025. However, the need should be re-evaluated at that time.

To Learn More

Products of this study, including the geospatial files, this technical memo and a project flier are available. Visit the ICPRB website or contact us for more information.

Acknowledgments

Stakeholder engagement in the development of the land prioritization scheme was essential to ensuring that the final products reflect source water protection priorities of the participating water suppliers and are readily available for implementation by land conservation groups as well as Potomac basin jurisdictions. ICPRB staff would like to thank all those that have contributed to this effort.

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Washington Aqueduct
Washington Suburban Sanitary Commission (WSSC Water)

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