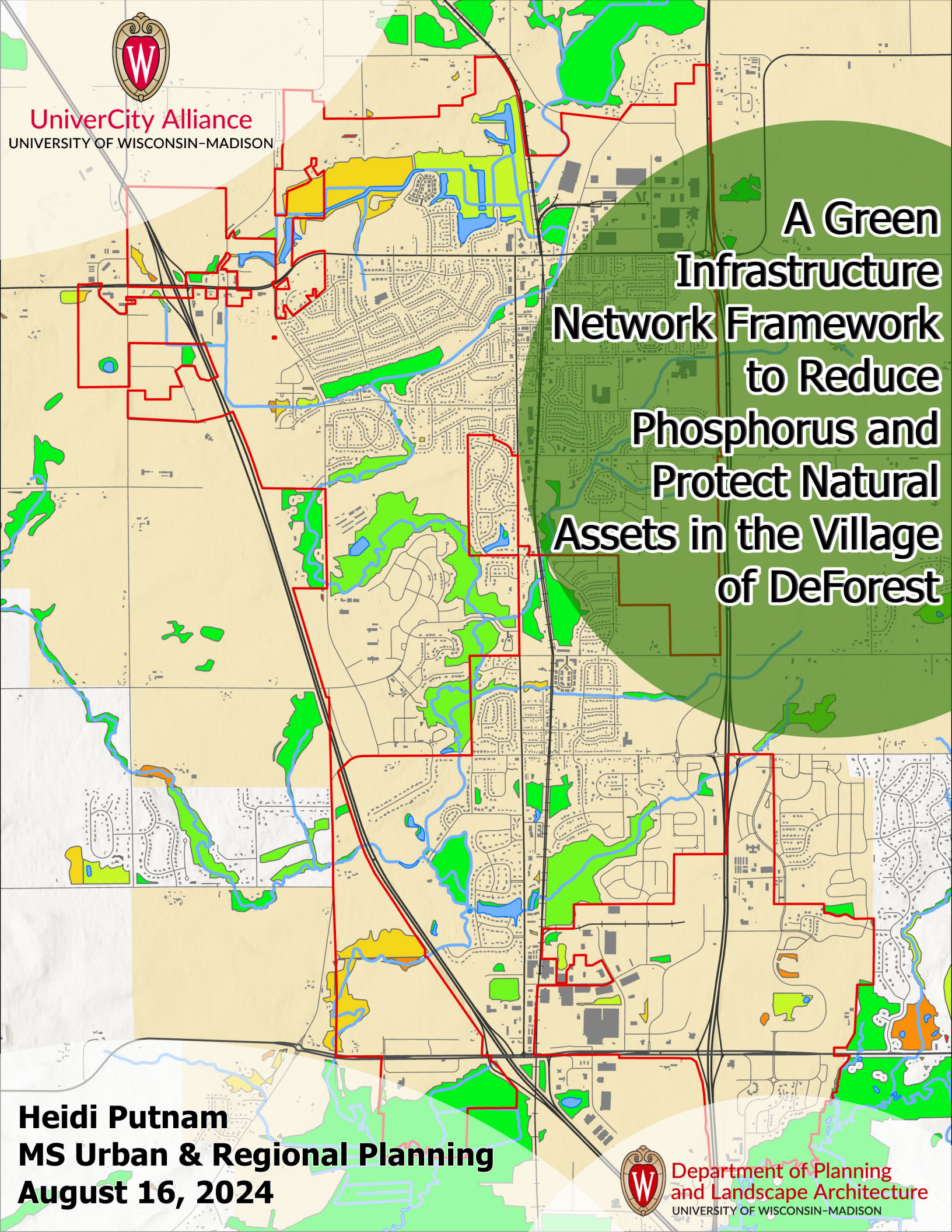

UniverCity Alliance
UNIVERSITY OF WISCONSIN-MADISON
A Green Infrastructure Network Framework to Reduce Phosphorus and Protect Natural Assets in the Village of DeForest
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August 16, 2024
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Executive Summary

The Village of DeForest in northeastern Dane County, Wisconsin is experiencing rapid growth but endeavors to protect their natural assets and reduce phosphorus entering the Yahara River that flows through the center of the community. Green infrastructure (GI) leveraging existing natural features is a cost-effective way to reduce phosphorus entering waterways. Geographic Information Systems (GIS) via ArcGIS Pro was deployed for spatial analyses following a modified GI framework methodology from the Environmental Systems Research Inc. (ESRI) and the Green Infrastructure Center (GIC) leveraging phosphorus export coefficients based on land use from the Wisconsin Department of Natural Resources (WDNR) Pollutant Load Ratio Estimation Tool (PRESTO). Existing land protection designations from the Village, Capital Area Regional Planning Commission (CARPC), and other lands from the Protected Areas Database of the United States (PAD-US) properties were overlaid with natural features and phosphorus coefficients to identify key land areas for the Village to concentrate their protection efforts.

Introduction

Communities worldwide are experiencing increased effects of climate change and urbanization putting pressures on the natural environment. Interdisciplinary frameworks have been created to identify threats and opportunities related to these effects to support a more sustainable future which focuses on patterns and fragmentation of land cover and use. A few statewide models using Geographic Information Systems (GIS) exist which inventory and analyze these phenomena such as the Florida Greenways Commission and the Maryland GreenPrint Program. ESRI and GIC created a coarse-scale nationwide model. Their model hinges on landscape connectivity with a focus on climate adaptation, leveraging existing GI to propose solutions. GI is made up of natural assets across the landscape such as forests, waterways, and parks that "form a natural system of interconnected ecological processes that protect our native species and provide human beings with [benefits] such as clean water, clean air, healthy lifestyles, and significant economic benefits" (Firehock and Walker 2019, 2). These natural assets can be preexisting or created as part of a GI plan to connect naturally occurring features. The GI approach is an integrative process including decision makers and community members to identify shared goals and prioritize areas for preservation or protection. More specifically:

> The science of [GI] provides a framework for sustainable growth and conservation, including such factors as:
>
> - Protection of the Environment – GI protects the health and diversity of wildlife and maintains natural systems that deliver critical, live-sustaining services.
> - Contributing to a Thriving Economy – GI benefits property values, lowers health care costs, boost tourism, and helps communities make smarter investments in grey infrastructure.
> - An Enhanced Quality of Life – GI ensures people can connect with nature, have access to clean air and water, and live happier, healthier lives. (Firehock and Walker 2019, 2)

Communities on the local scale have also replicated the process with finer scale data to provide additional information within their jurisdiction which is what this project aims to do for the Village of DeForest. Conflicts along boundary edges of natural and developed areas occur when the pressure of development may infringe on these natural spaces.

Community background

The Village of DeForest is an actively growing community of about 11,000 residents on the northeast side of Madison in Dane County, Wisconsin (United States Census Bureau 2022). Along with a 60% increase in population forecasted from 2010 to 2050 in the greater Village area (Greater Madison MPO 2017) nonresidential development for distribution, warehousing, and manufacturing is increasing due to the proximity to major transportation networks (Village of DeForest 2023).

> *"DeForest is part of the greater Madison area, yet a place apart, offering village charm, quiet and walkable neighborhoods, top schools, abundant parks and trails, soothing natural resources featuring the Upper Yahara River, and attractive opportunities for business growth driven by exceptional transportation access and a supportive community."*
> *- DeForest Comprehensive Plan Vision Statement (Village of DeForest 2023)*

In their comprehensive plan vision statement, the Village identified the strong natural assets and business growth potential as guiding features they wish to plan for. As part of this commitment, the Village is a member of the Madison Area Municipal Stormwater Partnership (MAMSWaP) which is a municipal stormwater permit with 21 co-permittees within Dane County who collectively reduce adverse impacts to water quality from urban stormwater runoff. The Village has set aside many lands for conservation and public recreational opportunities within nature, many of which are along the Yahara River. The Village is located very near to the headwaters of the Yahara River as shown in Figure 1 which has prompted a strong commitment to natural area stewardship by the Village and its community members.

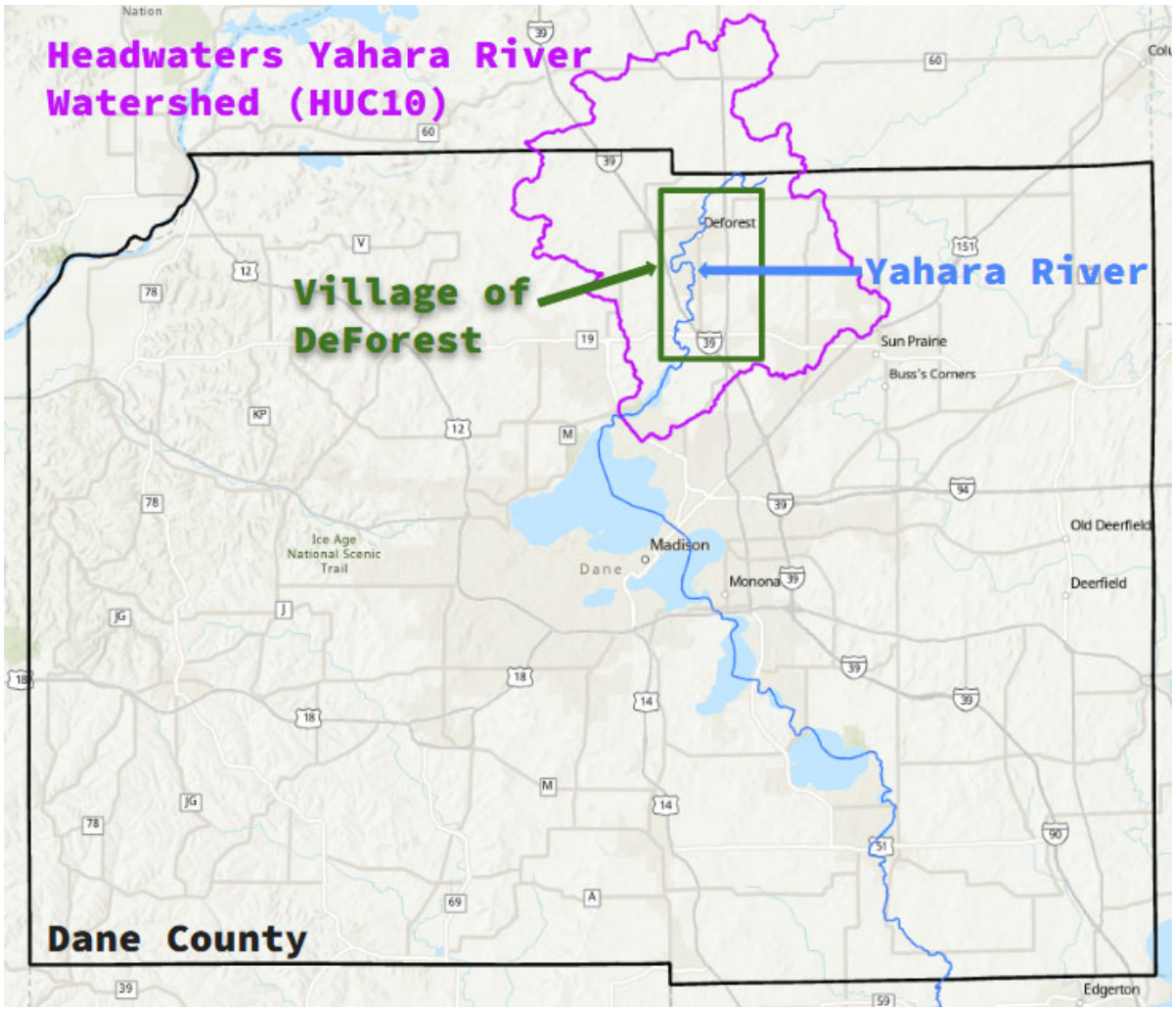


Figure 1: Village of DeForest, Yahara River, and watershed location map.

Following the CARPC guidance on Environmental Corridors, the Village has over 300 acres of land under corridor designation, preserving a buffer along nearly all the Yahara River within Village boundaries. In efforts to expand the buffer, other means such as easements with private landowners have been utilized for either streambank restoration projects or recreational trail development. Their efforts are starting to pay off as in the spring of 2024 parts of the Upper Yahara River were reclassified to a Class II trout stream. There has generally been strong community support for river restoration projects, however, there has also been a push for placing development near natural areas within the Village.

Project Premise

The conundrum of balancing development and natural area preservation led the Village to explore opportunities for support in identifying solutions. As part of that effort, they have partnered with the UniverCity Alliance whose mission is "to improve the quality and visibility of UW-Madison's education, research, and service contribution to the high-road development of local communities that reflects the values of equity, democracy, and sustainability" (UniverCity Alliance n.d.). This partnership ultimately will address six topical areas over a few years, one of which is "preservation of natural resources in coordination with development" under which my project falls.

In project scoping conversations with DeForest Village Administrator, Bill Chang, and Director of Public Works, Judd Blau, it was evident that as land stewards who solicit input from residents, they are having a hard time figuring out how to selectively preserve natural areas while supporting the rapid development of the region in a way that makes everyone at the table happy. A common pushback they receive from residents is on supporting dense growth as residents prefer single family detached homes over denser apartment or condo development. Given that natural area preservation typically requires large land areas, the Village staff are keen on creating a framework to best classify lands for varied levels of protection that still allows for a variety of development. The Village staff understand their role as stewards of the watershed knowing that the decisions they make have downstream effects on other communities and are committed to streambank repair and other projects to improve the watershed.

Overall, the Village staff feel that many residents consider the Village to have numerous "natural assets and jewels" that should be protected, most notably the Yahara River and the adjacent wetlands. There has also been interest in having recreational opportunities within these natural areas as well as for flood mitigation and resiliency efforts and to leverage public-private partnerships such as the Friends of the Yahara group to make these projects happen. Moving forward, the Village feels that most future development is anticipated in the farmland areas to the west as annexations occur. As this happens, the Village desires to strive for co-habitation of land uses and wants holistic approaches to solutions to create a balance between natural communities and human interaction with these spaces.

As part of flood mitigation and resiliency efforts, reducing adverse impacts to the Yahara River is a main goal of the community. Within that, phosphorus is the primary nutrient of concern and a determining factor in how much money the Village owes to the MAMSWaP for their share of the nutrient load. Groups within the partnership can reduce their monetary obligation to the partnership by increasing the amount of phosphorus they are able to capture. The Village has started to identify, quantify and evaluate existing natural assets which has led to leaf pickups and an extensive streambank restoration effort. Part of this project looks at the relationship between land use, land cover, and phosphorus levels to continue this prioritization process for phosphorus reduction.

Study Area Selection

While the primary focus of the project is to look at lands under jurisdiction for the Village, natural features do not follow these administrative boundaries. Therefore, I had to look outside of the Village boundaries to consider an appropriate scale for analysis. A watershed scale approach was most appropriate as evaluation of stormwater flow and accumulation of phosphorus are important for river preservation. When considering watershed scales, there are a few options. To categorize watersheds, the US Geological Survey (USGS) has created a hierarchical land area classification system which delineates where water drains to based on drainage divides at different scales as seen in Figure 2. Within this system, hydrological unit codes (HUC) are used to give each land area a unique identifier. To capture the headwaters area of the Yahara River and all jurisdictional lands of the Village, the HUC-10 size watershed was selected for most analysis.

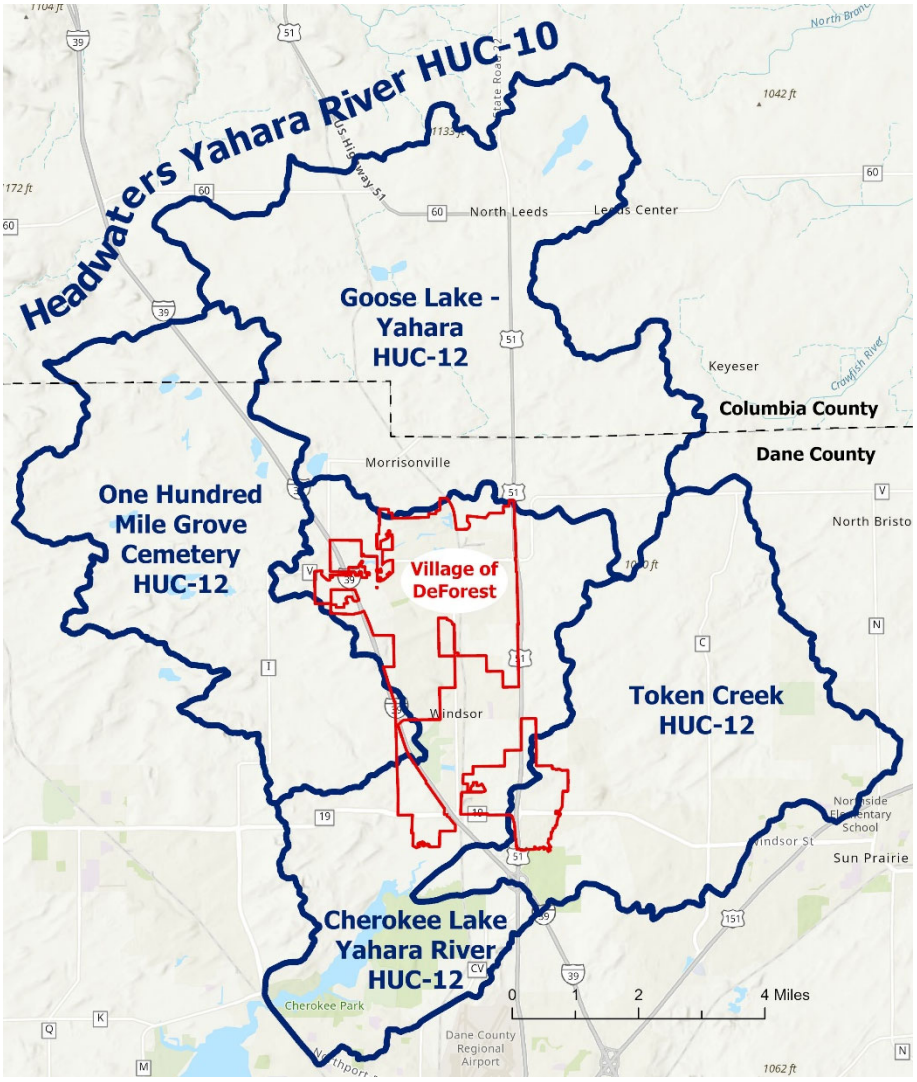


Figure 2: Watershed map for the Village of DeForest and Yahara River headwaters region

The WDNR has a Healthy Watersheds, High Quality Waters program which ranks watersheds and waterbodies based on protection priorities set by the WDNR. This ranking is done at the sub-watershed (HUC-12) scale which is typically the smallest unit used for management purposes. Nearly all the Village lands are located within the Cherokee Lake – Yahara River HUC-12 but some of the land is contained within parts of the other three HUC-12's housed within the Headwaters Yahara River HUC10. One of the other HUC-12's just outside of the Village boundaries, the One Hundred Mile Grove Cemetery HUC-12, is ranked 18th in the top 30% of healthiest watersheds in the HUC-6 Rock Basin (WDNR n.d.). While the Village does not currently have lands within this HUC-12, the lands to the west that are currently part of the Town of Vienna will eventually be annexed by the Village are part of this HUC-12. In addition, the other main waterbody flowing through the southern portion of the Village is Token Creek. Part of this land area is contained within the Token Creek HUC12 which is also where some of the largest existing protected lands are located.

Existing Regulatory Frameworks

When researching the existing environmental protection designations that are present with the Village, I found that the Village, Dane County, and CARPC have slightly different definitions as well as multiple designations that are hard to distinguish between. As of mid-summer 2024, CARPC was working with the County to create updated definitions and criteria within the newest Dane County Parks and Open Space Plan update which was being drafted at the time of writing. These definitions at the time of writing had gotten feedback from County staff but draft definition updates for Resource Protection Corridor, Natural Resource Area, and Natural Resource Area Boundaries had not been shared by CARPC to the County yet and were therefore unable to be shared for use in this project. Instead, I focused on the three new definitions available. Full definitions and supporting clarification are in Appendix A. Consultants for the Village and existing Village ordinances follow the existing 2024 definitions pre-CARPC/County updates. If the draft definitions are accepted, the key points for GI planning considerations which are assumed for this project are included in Table 1 and the key implications from these three definitions are:

- *Regulatory Protections:* Environmental Corridors are the most protected, with specific regulations under the Dane County Water Quality Plan that enforce their preservation. Protection Areas have potential for similar protections but only become fully regulated upon inclusion in an urban service area. Stewardship Areas, by contrast, lack formal legal protections and rely on voluntary efforts for preservation.
- *Designation Purpose:* Environmental Corridors are specifically designated to protect vital environmental features in and near urban areas. Protection Areas are anticipatory designations that identify land that might be protected in the future. Stewardship Areas highlight valuable lands that should be preserved but do not yet meet the criteria for regulatory protection.
- *Inclusion in GI Planning:* Environmental Corridors must be included in urban service area planning processes and are often preserved as open space. Protection Areas are considered during urban service area expansion but do not affect land use until they are designated as Environmental Corridors. Stewardship Areas are suggested for preservation but are not required to be included in planning decisions.

Table 1: CARPC definitions summary pertaining to consideration of legal protections for various land elements in relation to GI needs.

CARPC Designation	Definition Considerations
Environmental Corridors	• Contiguous systems of open space and natural areas designated to protect water resources and other critical environmental features within or near urban areas • Legally protected resources through the Dane County Water Quality Plan and other county and state regulations • Only apply within urban service areas
Protection Areas	• All lands outside of the urban service area that would qualify for Environmental Corridor designation if they were included in an urban service area • Have less regulatory protection than Environmental Corridors (most elements have no legal protection) • Some features like floodplains and wetlands are still regulated under county zoning laws and state regulations offering partial legal protection
Stewardship Areas	• Lands that provide a significant environmental benefit • No formal legal protection even when within an urban service area • Hinges on volunteer stewardship by landowners and local governments to protect • During urban service area amendments, they are considered for inclusion in the Environmental Corridors, but it's not required • Public ownership, dedication, or conservation easements are methods of protection for these lands

Green Infrastructure as a Solution

When scoping the project with Village staff, it was clear that the community has already been incorporating GI into some of their current projects such as with a large Yahara River Habitat and Streambank Restoration Project. The focus of this project (and the goal of future projects) is to safeguard biodiversity and create a sustainable and harmonious space where nature and community coexist. To cultivate this relationship, engagement with residents is key to increased awareness and interest in these issues. During this project to kickstart this process, a project open house, invasive species removal workday, Arbor Day tree planting, and tabling with a rainfall simulator at the farmers market and outdoor movie night were done during the spring and summer of 2024. The Village plans to continue engagement activities like this in the future. Conversations around Village-owned tree nurseries, diversifying street trees for climate resilience and stormwater management, restoration projects related to the Yahara River, increasing Low Impact Development strategies like geotextile grid parking lots, land swaps with developers to protect key natural features, and connection of the existing preserved lands were brought up leading to my select to recommend a GI network analysis to guide future planning.

Site Suitability Analysis

The Green Infrastructure Center Inc. outlined a six-step process to create GI plans (Firehock and Walker 2019, ch. 3) which are to:

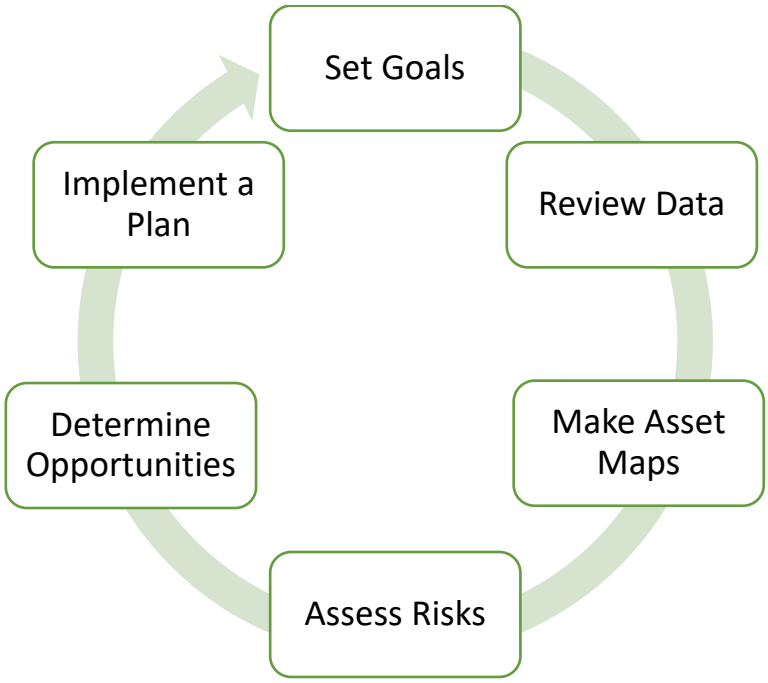


Figure 3: Green Infrastructure Center six-step GI planning process

For this project, I focused on steps 1 ,2, 3, and 5. In setting goals, I had conversations with Village staff about their current hopes and dreams for the future related to natural resource preservation and created two goals to guide prioritization for GI as shown in Figure 4.

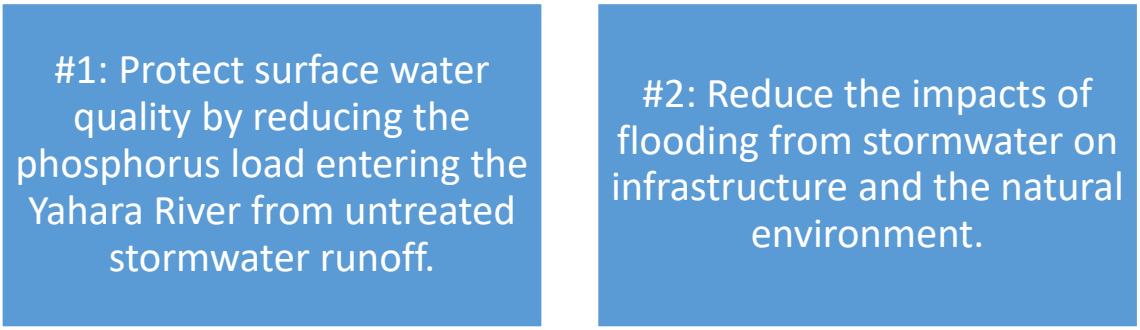


Figure 4: Project GI goals for natural resource preservation

After conducting an informal literature review of existing research methodologies to augment the workflow outlined by the Green Infrastructure Center text, I compiled a list of relevant data files and met with the GIS consultant for the Village. They shared with me the non-public data layers I requested and remaining information I obtained from online open data primarily from Dane County, CARPC, WDNR, and USGS. All data used and information for access are included

within Appendix E. These data became inputs into the suitability analysis workflow outlined in this report and specifics on geoprocessing tools and workflow can be found in the Appendix.

In landscape-scale analysis for GI, habitat fragmentation is a key issue and evaluating the ecological integrity of an area for its ability to maintain natural processes that sustain the species it supports is typically utilized. For example, the ESRI National GI database has an Intact Habitat Cores layer which requires a minimum core size of 100 acres which is set due to size needs to many interior-dwelling birds in the eastern US and therefore may not be most appropriate across the US (Firehock and Walker 2019, 31). However, the large land expanses of contiguous habitat required such as the size suggested in the national dataset are not feasible within the Village boundaries and adjacent lands. Given that the main goals of the Village are tied to physically reducing stormwater runoff and addition of phosphorus into the Yahara River, I was less concerned about the ecological integrity for species habitat, especially since different species have very different requirements of core area size and composition which makes it difficult to select any one land area criteria to be effective across the board. The focus for this project is more so on the undeveloped lands within the Village and how they can best plan for their future uses before getting developed to reduce impacts on the Yahara River and so is focused on the connectivity of corridors as the larger habitat core areas are found outside of the Village boundaries but primarily downstream towards the Cherokee Marsh and associated protected areas. Luckily, another important piece within a GI network is having stepping stones of smaller habitat patches dispersed across a landscape that can allow populations to move across an ecosystem to reach a larger core where they may maintain a more stable population. These stepping stone areas within the Village are what this project is focused on supporting. Only lands within the DeForest Village Limits and Extraterritorial Jurisdiction (ETJ) Boundaries were included for certain analysis as there are consistent zoning categories for future land use within these regions.

Data Scale Considerations

When selecting an appropriate resolution for raster data, the GI framework (Firehock and Walker 2019) identifies a calculation when applied to this project, could mean the following resolution sizes as shown in Table 2.

Table 2: Data resolution calculations

**scale factor x 0.0005 = resolution in meters* (pg 42, Firehock)

Mapping Unit	**Mapping Scale (Scale Factor)**	**Resolution from Calculation (m)**
HUC-10 Watershed	1:125,000	62.5
HUC-12 Subwatershed	1:70,000	35
Village Boundary	1:45,000	22.5

Therefore, beyond the Village Boundary scale, the 30m resolution data is appropriate. The data used for analysis is only available at certain scales and resolutions. Most notably, for the digital elevation model, there was 1 meter x 1 meter data available for Dane County but only 30-meter x 30-meter for Columbia County. Therefore, any analysis done at the HUC-10 scale had to use the

30-meter resolution which is considerably coarser and best used for landscape scale projects whereas the 1-meter resolution is best for identifying specific opportunity areas within the Village for preservation consideration. While following the GI workflow outlined by Firehock and Walker (2019) calls for quite a large habitat core size and edge size, these sizes were unrealistic for the study area and most of the literature supporting certain sizes or distances was related to specific species conservation measures while this project is focused on the water quality primarily and general biodiversity as a secondary metric.

Existing Asset Mapping

To identify areas for protection, understanding existing assets first was key. Developed lands and natural habitat areas were identified before overlaying these to create GI core areas that were ranked for use within the GI site placement identification process. Detailed geoprocessing workflows and details are included in Appendix F.

Developed Land Areas

Land uses or covers that are fragmenting features on the landscape such as intensively managed natural habitats (like pasturelands) as well as built infrastructure were included within this designation. These areas were buffered by 30 meters which is the distance representing the abiotic transition zone from the edge to interior core of a habitat (Firehock and Walker 2019, 134). The buffer is important to "protect core habitat from development features that contribute to fragmentation of habitat" (Firehock and Walker 2019, 134). After buffering, these areas were combined into one layer as shown in Figure 5.

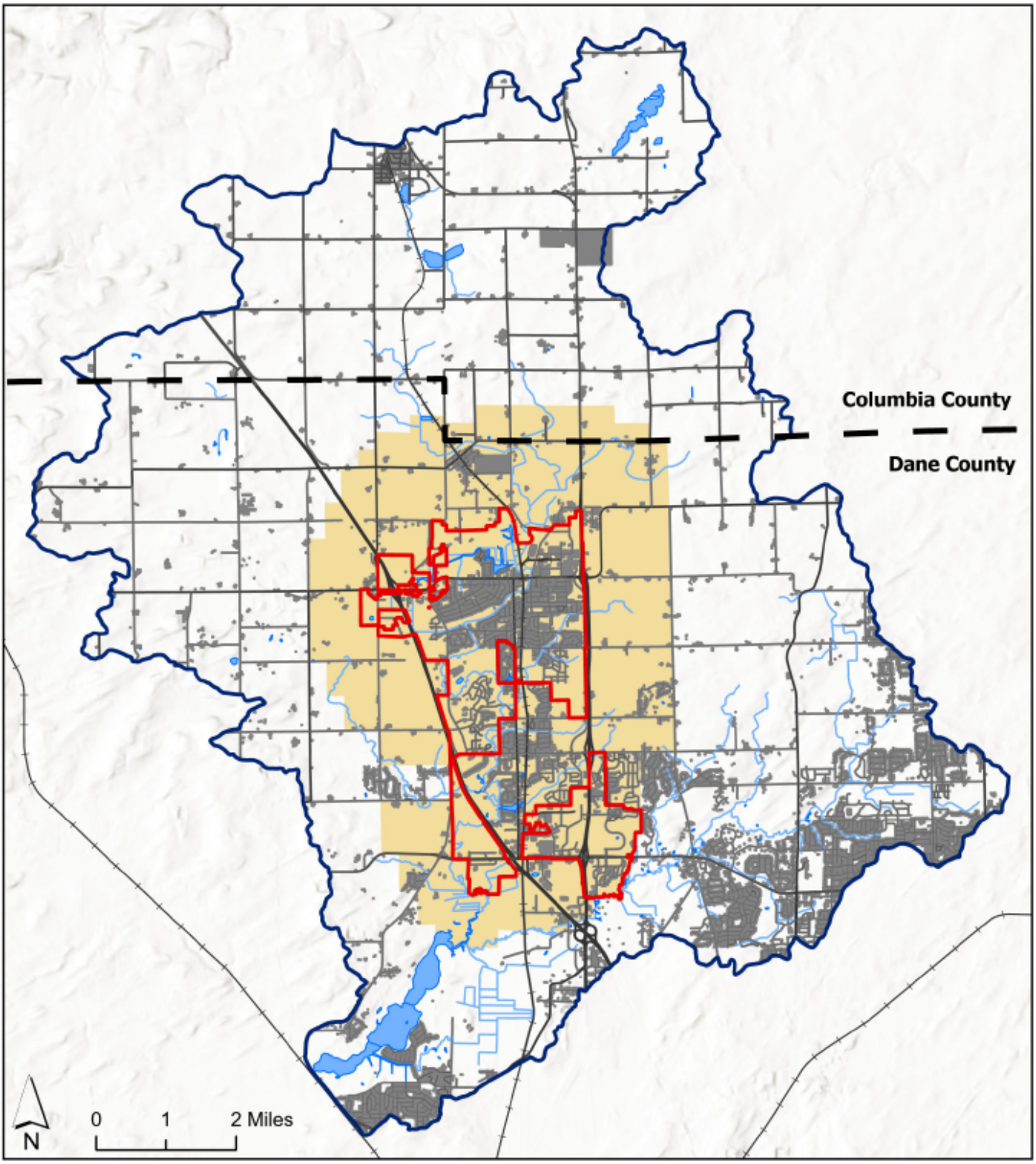


Figure 5: Developed Lands Area

Natural Habitat Areas

Natural land covers not intensively managed by humans were included. The WDNR Wiscland 2.0 landcover data set was used to select the natural landcovers. Wiscland 2.0 has four levels of categorization with level one having seven basic classes up to level four having 42 classes. The accuracy assessment documentation within the user guide as well as the phosphorus export coefficient table for the Pollutant Load Ratio Estimation Tool (PRESTO) discussed later in this report. Generally, the more class divisions, the less accurate the data based on method ground truthing. However, level one only had seven classes, which were not enough to separate agricultural uses which are important in this region. I chose to go with Level two data to provide enough data layer options for the analysis related to phosphorus coefficients but keep a higher level of accuracy. Level two data has an overall accuracy of 86% with most of the issues being with classifying shrubland (53% accuracy which is the same as level one) and distinguishing mixed forestlands (also at 53% accuracy) which are presumably labeled as deciduous or coniferous forests which does not matter for this analysis (WDNR 2016, 73). The WDNR Wisconsin Wetland Inventory mapped wetlands layer was unioned with the natural land covers from Wiscland 2.0 and dissolved to result in more accurate wetland information to complete the natural habitat areas layer as shown in Figure 6.

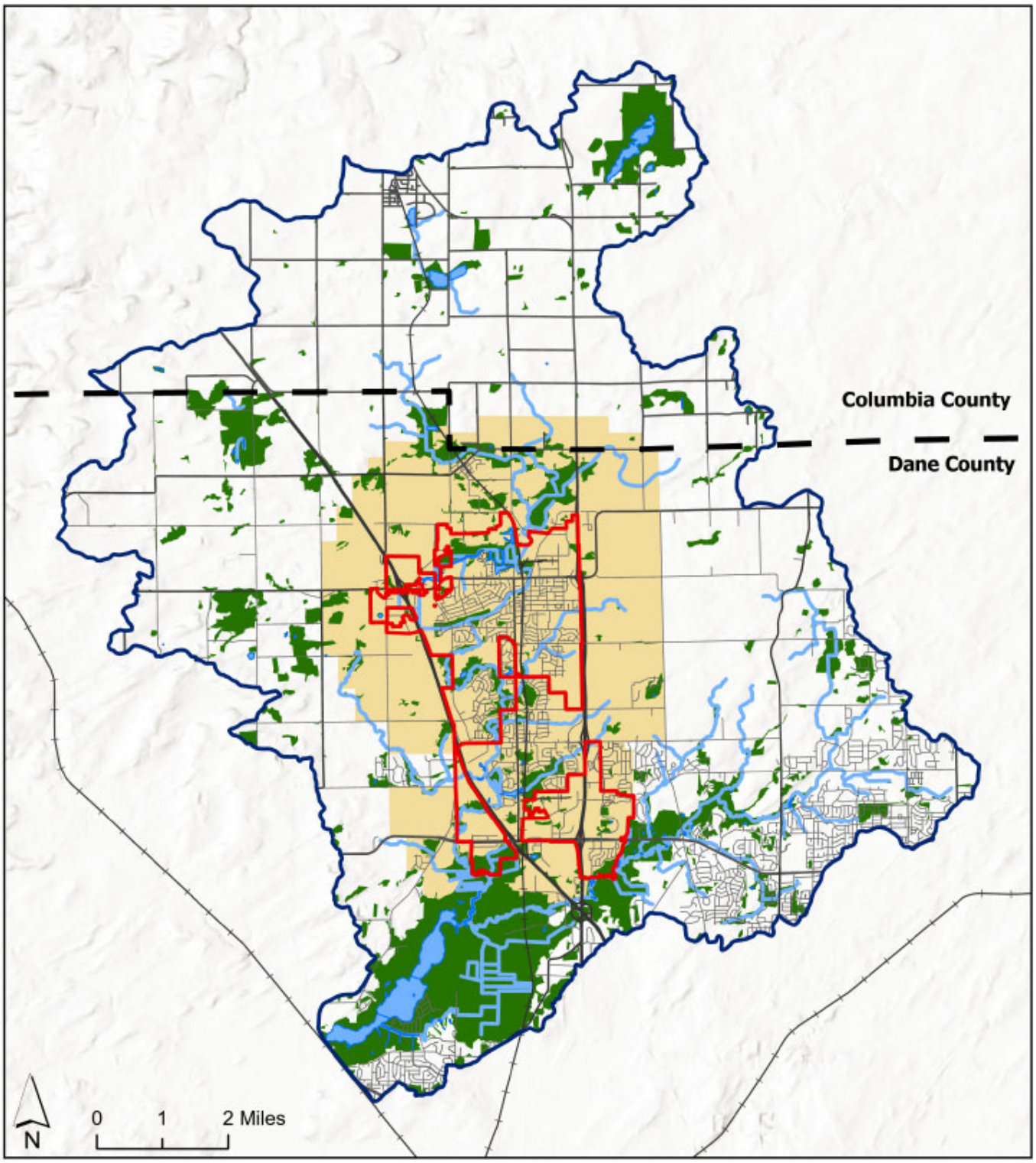


Figure 6: Natural Habitat Area

Green Infrastructure Core Areas

Defining habitat core and edge size is project specific and most research identifying these are for specific species. The 100 acres for core habitat used in the Firehock and Walker (2019, 14) methodology for primarily statewide analysis was from research done in the eastern United States. Other literature shows that "Buffer zone width should be based on the desired ecological functions, landscape context, and external pressures" (Forest Service 2007, 53). Wisconsin does not publicly release sensitive habitat and species information, especially in geographic form, which would also make it hard to plan for threatened and endangered species. General biodiversity, especially as it relates to pollinators, was identified as important by the Village staff. Overall, regardless of core habitat or edge size, literature supports having more connectivity results in higher biodiversity preservation. To create the core areas, the developed land area layer was placed on top of the natural habitat areas layer to remove the areas that intersect. The resulting revised natural habitat areas layer can then be categorized to identify core and fragmented lands. Once the polygons were categorized across the HUC-10, their counts were summarized as shown in Table 3 and then just cores intersecting and within the Village ETJ boundary were considered as these are the lands the project community would most easily be able to influence management decisions within. All core areas within the HUC-10 are shown in Figure 7.

Table 3: Green infrastructure core areas categorized prior to consideration of protected lands status.

Core Category	**Count of Polygons within HUC-10**	**Count of Polygons Within and Intersecting the Village Extraterritorial Jurisdiction Boundary**
Tiny Fragment <1 acre	390	110
Small Fragment ≥1 to <5 acres	199	67
Medium Fragment ≥5 to <10 acres	68	18
Large Fragment ≥10 to <25 acres	54	17
Tiny Core ≥25 to <50 acres	24	15
Small Core ≥50 to <100 acres	12	3
Medium Core ≥100 to <200 acres	5	2
Large Core ≥200 to <500 acres	6	3
Extra Large Core ≥500 acres	3	2
Total Polygons	**761**	**237**

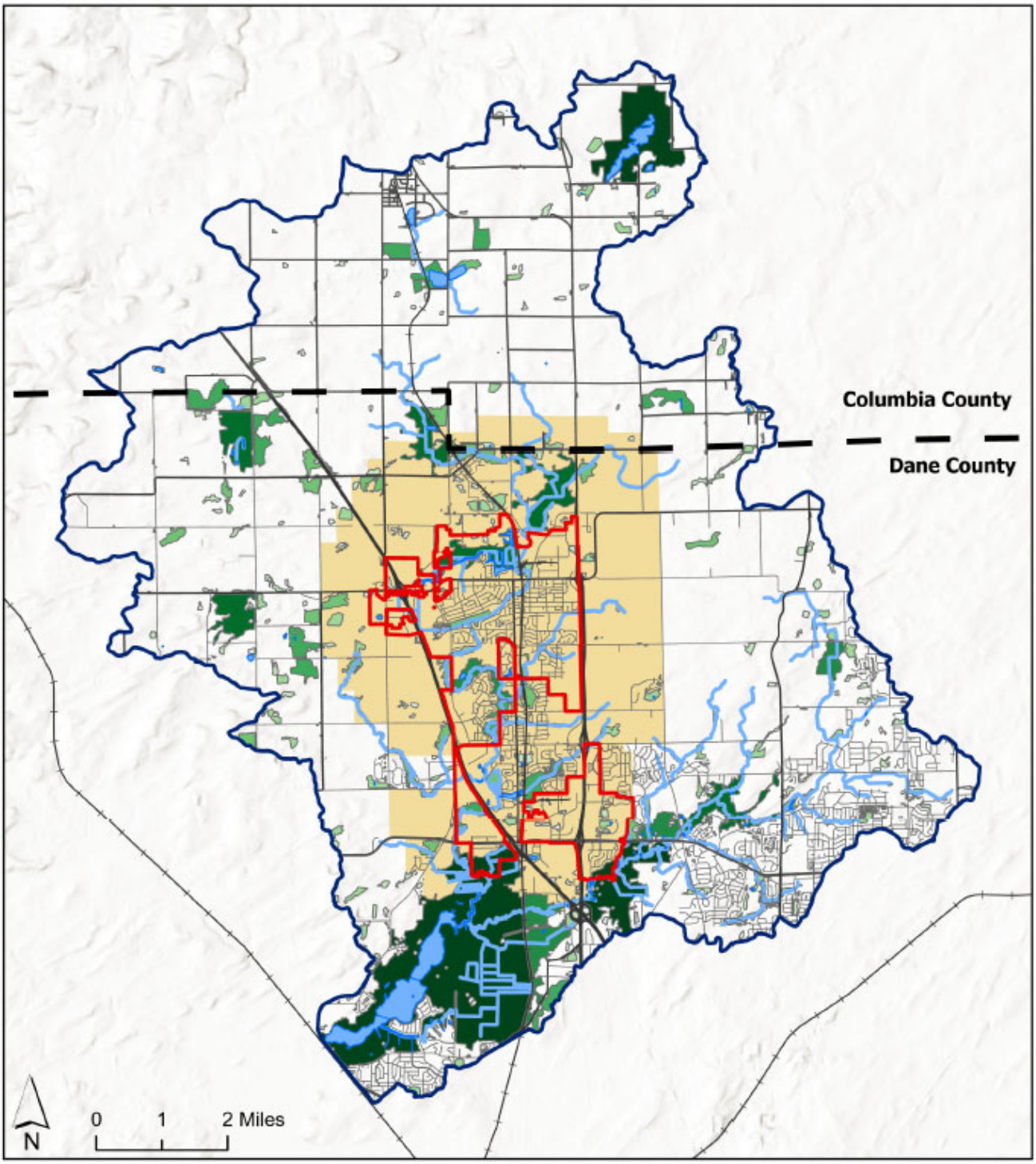


Figure 7: Green Infrastructure Core Areas

Village of DeForest Boundary
HUC-10 Watershed Boundary
Extraterritorial Jurisdiction (DeForest)
Roads
Current & Future Rail
Lakes
Rivers

Core Areas (in Acres)

- Extra Large Core (≥500 acres)
- Large Core (≥200 to <500)
- Medium Core (≥100 to <200)
- Small Core (≥50 to <100)
- Tiny Core (≥25 to <50)
- Large Fragment (≥10 to <25)
- Medium Fragment (≥5 to <10)
- Small Fragment (≥1 to <5)
- Tiny Fragment (<1)

Water Resources Attributes

To assist in the ranking process later, select water resources were overlaid with the core's locations (Firehock 2013, Appendix A). Mapped wetlands, waterbodies, and hydrologic flowlines were spatially joined to the HUC10 cores layer so that the length or area of water features within each core could be calculated. This information is contained within the attribute tables of the data layers to be shared with the Village and their consultant for use in further analysis.

Phosphorus Nutrient Loading

To estimate nonpoint source phosphorus loading within the watershed to help prioritize GI placement, three models used with the WDNR PRESTO were considered. A discussion of the selection process is described in Appendix B. Ultimately, a land cover specific export coefficient model was used but was modified to fit a finer scale of data needed for the project. PRESTO uses the National Land Cover Dataset (NLCD) as the default, so I paired the most logical land cover categories with the WNDR Wiscland 2.0 level 2 land cover dataset to assign coefficient values as shown in Table 6 of Appendix B. A summary of land cover and annual phosphorus loading is below in Table 4 and a map of land cover within the HUC-10 is shown in Figure 8 and a more detailed view of land cover within the Village boundary is in Figure 9.

Table 4: Phosphorus loading summary by land cover type

	Wiscland 2 Level 2 Description	**Most Likely Annual Phosphorus Loads in lb/mi2**
Highest Loading	Developed, High Intensity	856
	Crop Rotation	571
	Developed, Low Intensity	286
	Forage Grassland (hay/pasture)	171
	Idle Grassland (cool and warm season grasses)	97
	Lowland Scrub/Shrub	74
	Broad-Leaved Deciduous Forest	54
	Coniferous Forest	54
	Barren	0
	Forested Wetland	0
	Emergent Wet Meadow	0
	Floating Aquatic Herbaceous Vegetation	0
Lowest Loading	Open Water	0

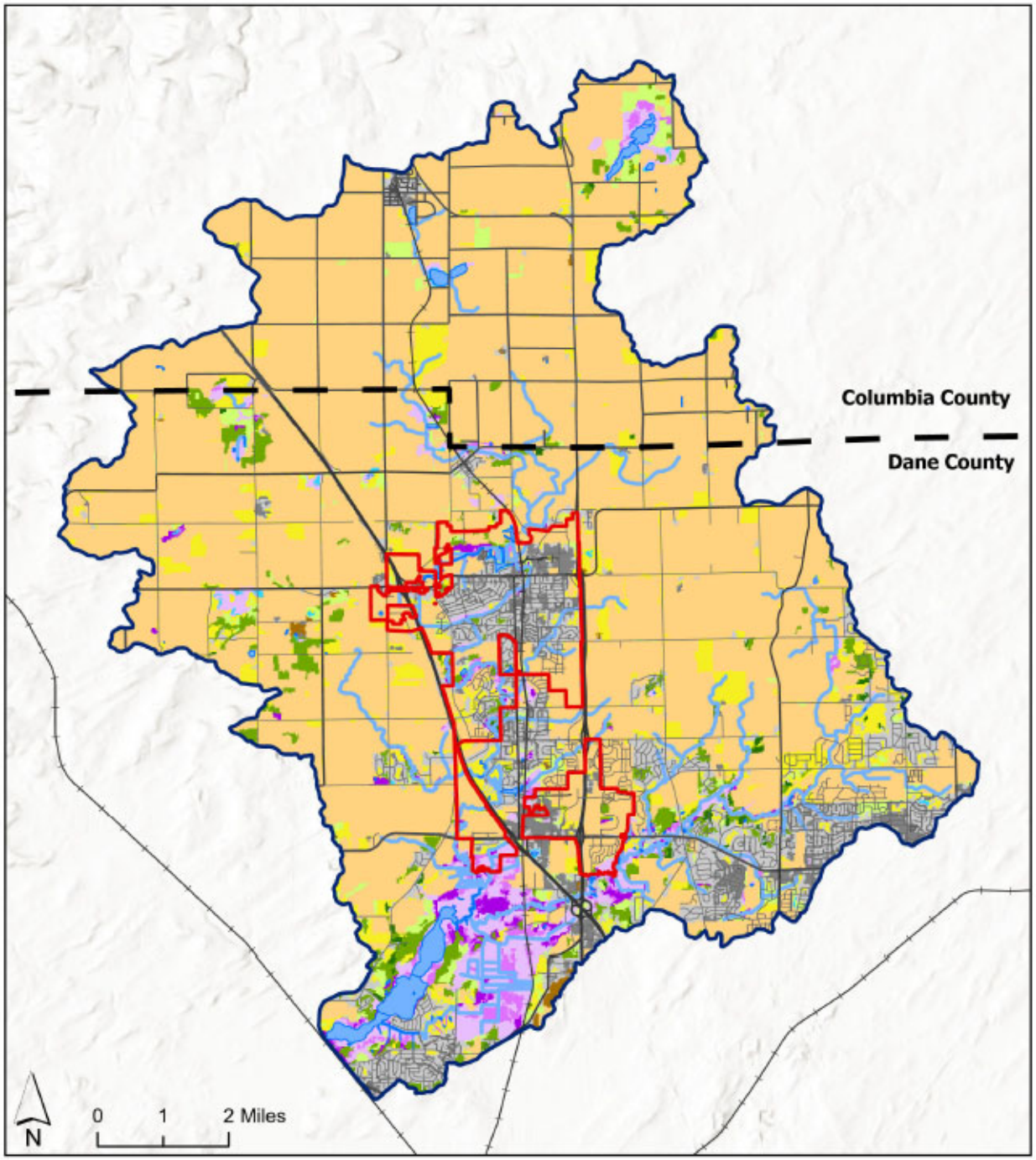


Figure 8: Wiscland 2 Land Cover for Phosphorus Contributions

Village of DeForest Boundary
HUC-10 Watershed Boundary
Extraterritorial Jurisdiction (DeForest)
Roads
Current & Future Rail
Lakes
Rivers

Classification Level 2 Land Covers

- Barren
- Developed (High Intensity)
- Developed (Low Intensity)
- Crop Rotation
- Open Water
- Forage Grassland (Hay/Pasture)
- Idle Grassland (Cool & Warm Season Grasses)
- Coniferous Forest
- Broad-Leaved Deciduous Forest
- Floating Aquatic Herbaceous Vegetation
- Emergent/Wet Meadow
- Lowland Scrub/Shrub
- Forested Wetland

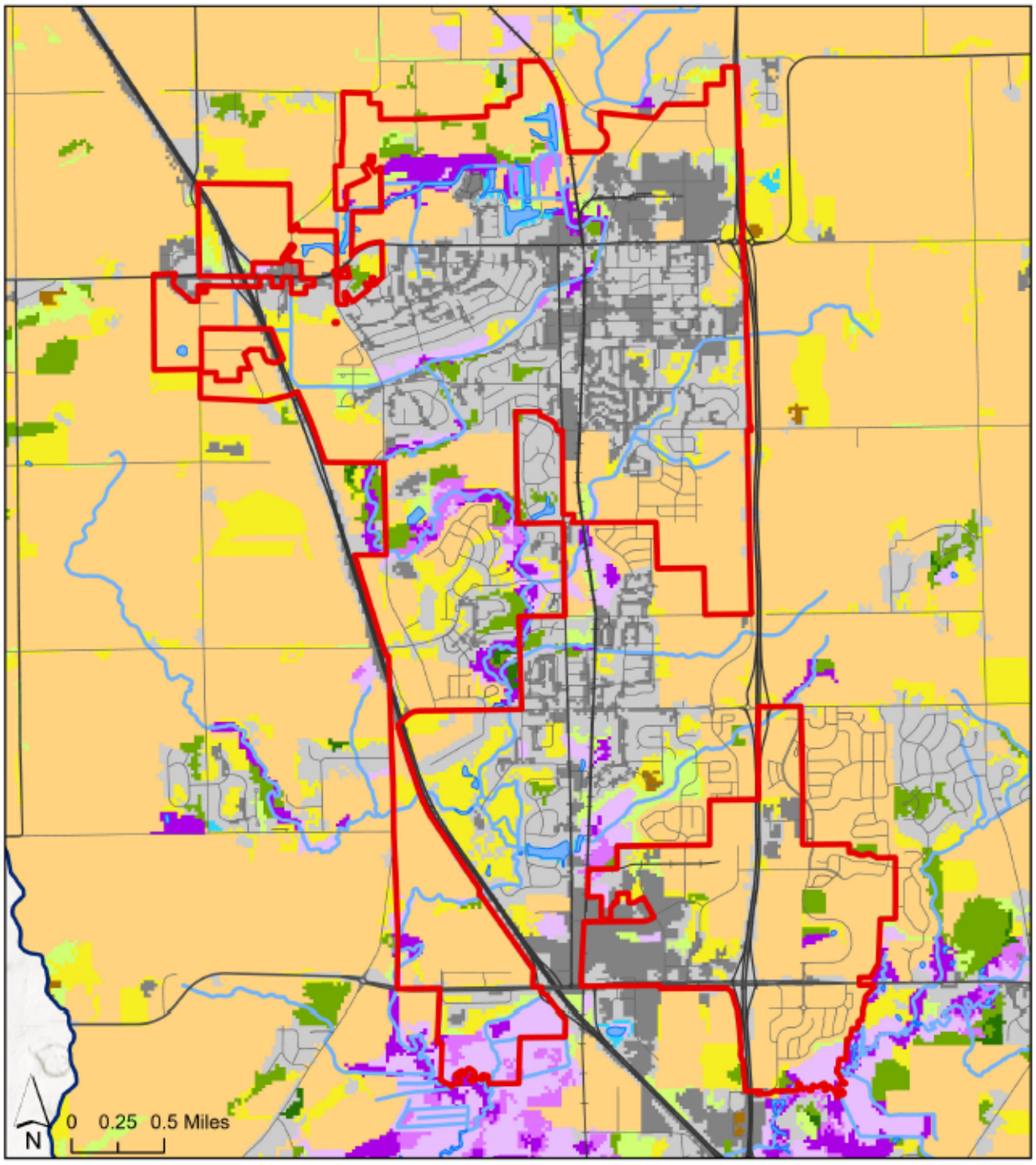


Figure 9: Wiscland 2 Land Cover for Phosphorus Contributions (Village of DeForest)

Village of DeForest Boundary
HUC-10 Watershed Boundary
Extraterritorial Jurisdiction (DeForest)
Roads
Current & Future Rail
Lakes
Rivers

Classification Level 2 Land Covers

- Barren
- Developed (High Intensity)
- Developed (Low Intensity)
- Crop Rotation
- Open Water
- Forage Grassland (Hay/Pasture)
- Idle Grassland (Cool & Warm Season Grasses)
- Coniferous Forest
- Broad-Leaved Deciduous Forest
- Floating Aquatic Herbaceous Vegetation
- Emergent/Wet Meadow
- Lowland Scrub/Shrub
- Forested Wetland

Green Infrastructure Placement

To determine opportunities, existing assets and phosphorus nutrient loading were considered to identify potential locations for GI or other protections. First, lands that are already under a form of protection were identified so that the non-protected lands could be focused on for the purposes of this project. Given that CARPC designations are only within Dane County, the portion of the HUC10 that is within Columbia County will only have the PAD-US properties and not also additional layers of land designations like in Dane County. Given that this is focused on the Village of DeForest this was acceptable to me.

There are no WDNR Conservation Opportunity Areas within the watershed which highlight significant features and habitats for species of greatest conservation need so other data had to be consulted. PAD-US is the official national inventory of "protected areas dedicated to the preservation of biological diversity and to other natural, recreation and cultural uses, manage for these purposes through legal or other effective means" (USGS n.d.). This database compiles local, state, federal, and non-profit organization lists of properties. Within this database, the GAP status provides US Fish and Wildlife Service ratings for secured lands which are summarized in Table 5. Within the Village boundary all PAD-US lands are Village parklands with no GAP status reported. Outside of the current Village boundary but within the ETJ there are also state and private easement lands that are GAP-2 status. PAD-US lands can be combined with the CARPC designated lands and C1 zoned conservancy lands within the Village to comprise a protected lands layer. A Summary of this overlay and percentage calculation is shown in Figure 10.

Table 5: GAP status definitions (Crist et al 1998)

GAP Status	**Definition**
GAP 1: Permanently Secured for Nature and Natural Processes	"An area having permanent protection from conversion of natural land cover and a mandated management plan in operation to maintain a natural state within which disturbance events (of natural type, frequency, intensity, and legacy) are allowed to proceed without interference or are mimicked through management."
GAP 2: Permanently Secured for Nature with Management	"An area having permanent protection from conversion of natural land cover and a mandated management plan in operation to maintain a primarily natural state, but which may receive uses or management practices that degrade the quality of existing natural communities, including suppression of natural disturbance."
GAP 3: Permanently Secured for Multiple Uses including extraction and recreation	"An area having permanent protection from conversion of natural land cover for most of the area, but subject to extractive uses of either a broad, low-intensity type (e.g., logging) or localized intense type (e.g., mining). It also confers protection to federally listed endangered and threatened species throughout the area."

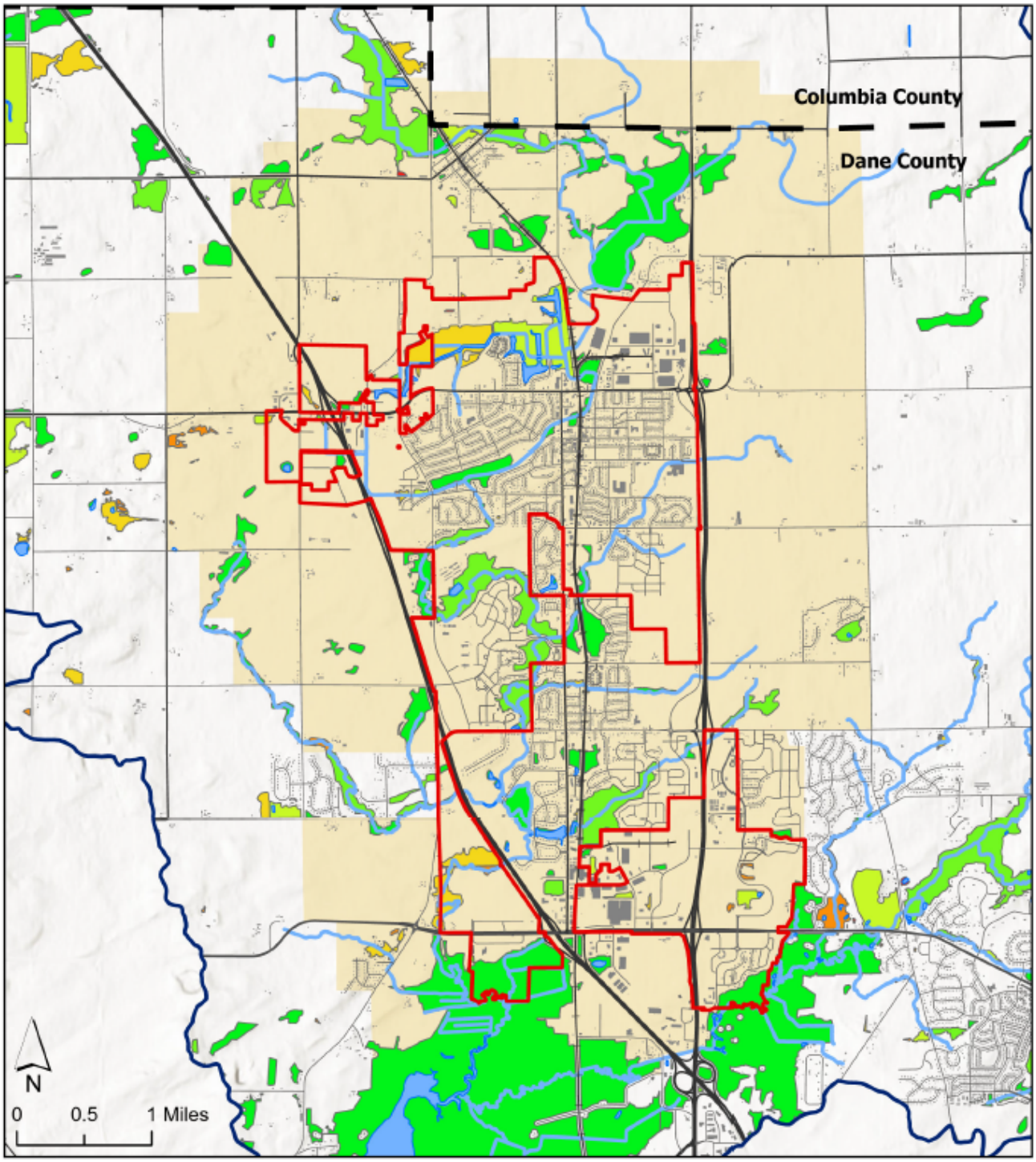


Figure 10: Percentage protection for core areas

Village of DeForest Boundary
HUC-10 Watershed Boundary
Extraterritorial Jurisdiction (DeForest)
Roads
Buildings
Current & Future Rail
Lakes
Rivers

Percent Protected Land

- Not Protected <1%
- Barely Protected ≥1 to <25%
- Partially Protected ≥25 to <50%
- Mostly Protected ≥50 to <75%
- Nearly Fully Protected ≥75 to <95%
- Fully Protected ≥95%

Green Infrastructure Network Prioritization & Closing Thoughts

After overlaying core areas with protected lands areas, the Yahara River Restoration work and existing parks and conservancy lands along the river within the Village are doing a good job at protecting core natural resources. At the fringes where expansion and development are or will soon occur is where efforts should be prioritized as shown by priority zones one through four in Figures 11, 12, 13, 14, and 15. Most priority zones are within the extraterritorial jurisdiction area or close to the current municipality extent. Zone specific recommendations are in Table 6 below. Moving forward, Village staff can use these recommendations as a basis for future planning discussions and to start a community dialogue around GI planning and natural asset protection. Traditionally, a process like this should include community engagement throughout. This report can be used as a framework to move forward. Additional tools, resources, analysis ideas, and community engagement contacts are included in Appendix C. This process will be most useful when planning for new development on the fringe of the Village and consideration should be given during ETJ and Urban Service Area amendment discussions to prioritize environmental corridor buffer placement around waterways.

Some other solutions for which conversations with Village staff started but had not yet been fleshed out at the time of writing was expanding the conservancy portion of the Village zoning to separate out multiple types of conservation lands rather than the single C-1 zoning that currently exists. This would allow the Village to place what they currently consider to be “natural areas” and any future environmental corridor lands as something separate from more developed park properties. This could also be a way to identify lands for stormwater or flooding reduction specific uses. We also started briefly to discuss the potential for looking into potentially restorable wetlands (as well as the similarly named “actually restorable wetlands” that the Rock River Coalition identified) as areas to focus on hydrological restoration to restore the natural systems before or as development occurs west of the current Village boundary within what is now the ETJ.

In addition, WinSLAMM modeling should be completed for the community (possibly as part of their MS4 permit requirements) to more accurately estimate phosphorus loading into the Yahara and evaluate the accuracy of their current Yahara WINS contribution. Once this model has been built, it can be updated annually with all new developments or storm sewer expansions to ensure accurate assessment of loading. Increased partnerships with groups such as the Friends of the Yahara River Headwaters and the Rock River Coalition to increase surface water quality monitoring, especially for total phosphorus, will be important to ensure accuracy in the WinSLAMM model. This model shows the loading without best management practices (BMP’s) in place and then reductions in loading based on additions of BMP’s.

Table 6: Natural asset protection priority zone recommendations

**References to Tax Increment Districts (TID's) are those listed in the Village Comprehensive Plan*

Priority Zone	Recommendations
1	• Consider the environmental impact of proposed development within TID #9 located in the westernmost extent of this priority zone to ensure placement of lighter uses in closer proximity to the river and leave a buffer along it. • On the east end of this priority zone, work with potential business park clients to fund a tree nursery on the west end towards the riverbank for the Village and keep business park infrastructure in upland areas as close to the existing roads as possible. • Acquire lands as they become available from the single private landowner who owns most of the property in this river stretch. This area is one of the largest contiguous primarily natural parcels within the Village remaining and would be a key addition to ensuring a river buffer for the long term.
2	Currently most of this land is in agricultural production. As the community expands westward, consider creating a buffer along the tributary stream to reduce impacts downstream to the Yahara. There are potentially restorable wetlands in this area that could be investigated as part of a larger stream restoration corridor before plotting out development placement.
3	Review stormwater runoff within TID #8 carefully to ensure it is not heading towards the river. The area between the river and the TID would be a good spot for permanent conservation to connect to the Cherokee Marsh properties just downstream.
4	Consider the environmental impact of proposed development within TID #7 located on the east end of this priority zone to ensure placement of lighter uses in closer proximity to the river and leave a buffer along it. If future residential expansion is proposed, encourage further setbacks from Token Creek and vegetative buffers.

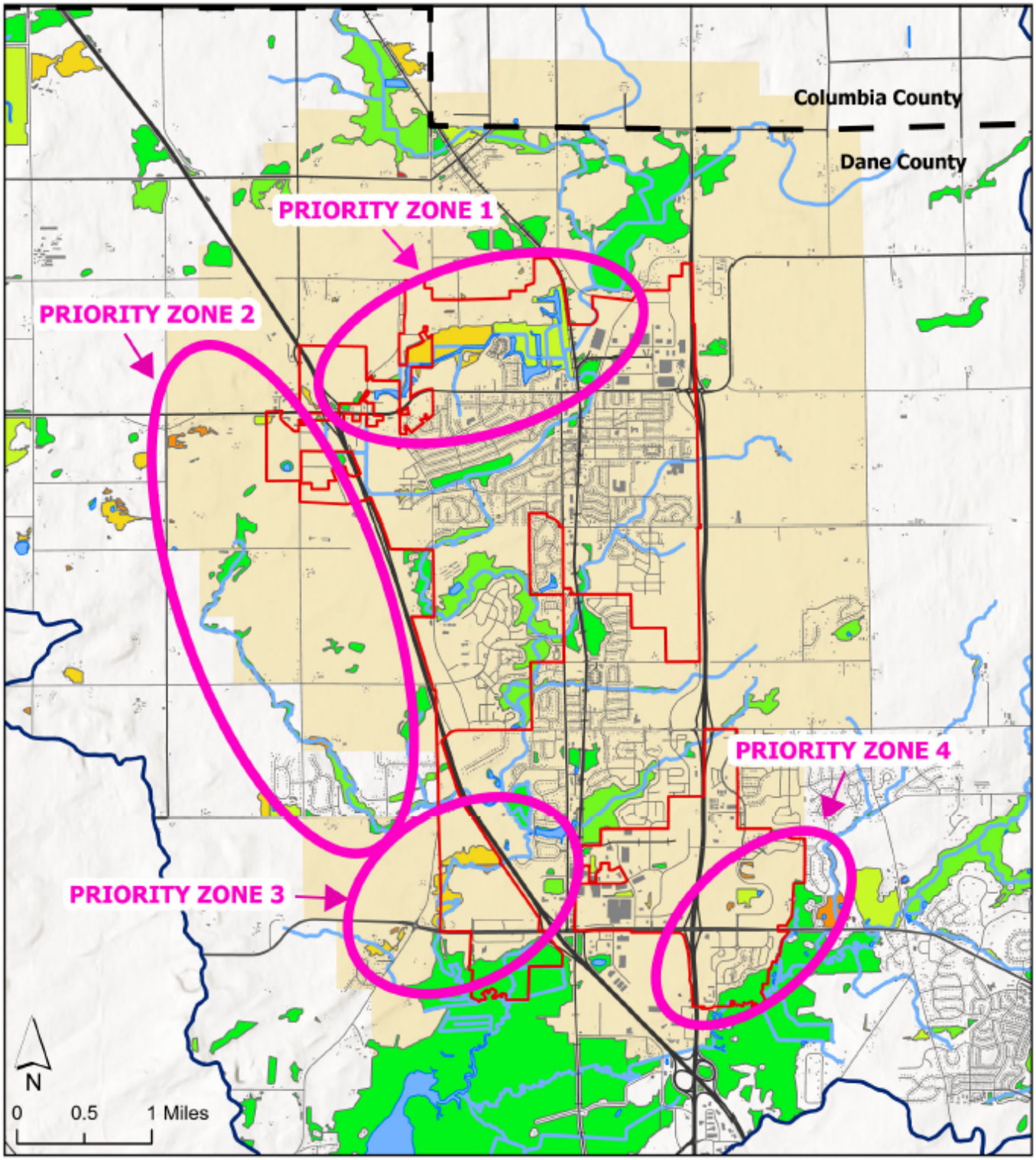


Figure 11: Core Protection Priority

Village of DeForest Boundary
HUC-10 Watershed Boundary
Extraterritorial Jurisdiction (DeForest)
Roads
Buildings
Current & Future Rail
Lakes
Rivers

Percent Protected Land

Under <75% Protected
Nearly Fully Protected ≥75 to <95%
Fully Protected ≥95%
Natural Asset Protection Priority Zones

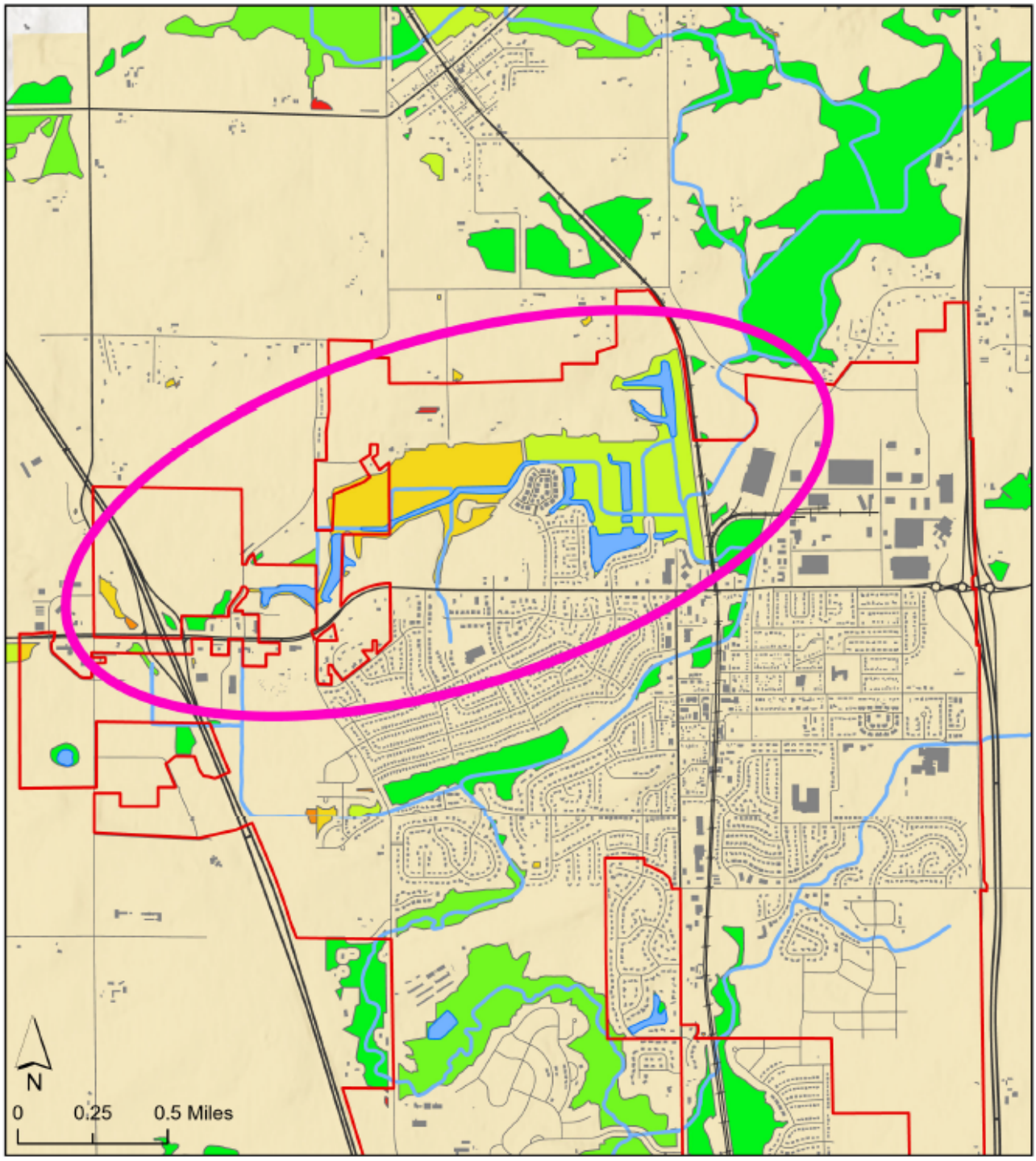


Figure 12: Natural Asset Protection Priority Zone 1

Natural Asset Protection Priority Zone

Village of DeForest Boundary

HUC-10 Watershed Boundary

Extraterritorial Jurisdiction (DeForest)

Roads

Buildings

Current & Future Rail

Lakes

Rivers

Percent Protected Land

- Not Protected <1%
- Barely Protected ≥1 to <25%
- Partially Protected ≥25 to <50%
- Mostly Protected ≥50 to <75%
- Nearly Fully Protected ≥75 to <95%
- Fully Protected ≥95%

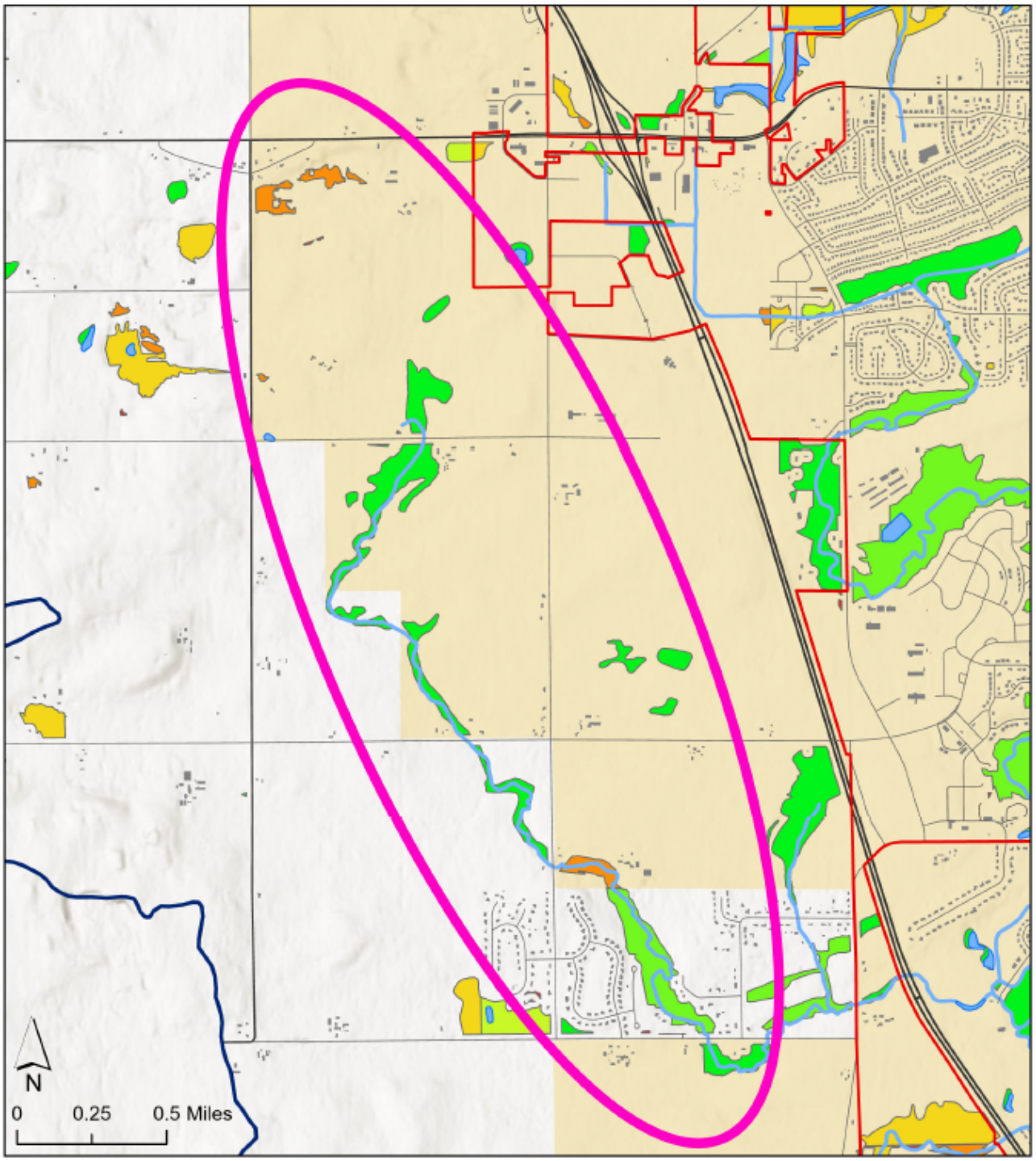


Figure 13: Natural Asset Protection Priority Zone 2

Natural Asset Protection Priority Zone

Village of DeForest Boundary

HUC-10 Watershed Boundary

Extraterritorial Jurisdiction (DeForest)

Roads

Buildings

Current & Future Rail

Lakes

Rivers

Percent Protected Land

- Not Protected <1%
- Barely Protected ≥1 to <25%
- Partially Protected ≥25 to <50%
- Mostly Protected ≥50 to <75%
- Nearly Fully Protected ≥75 to <95%
- Fully Protected ≥95%

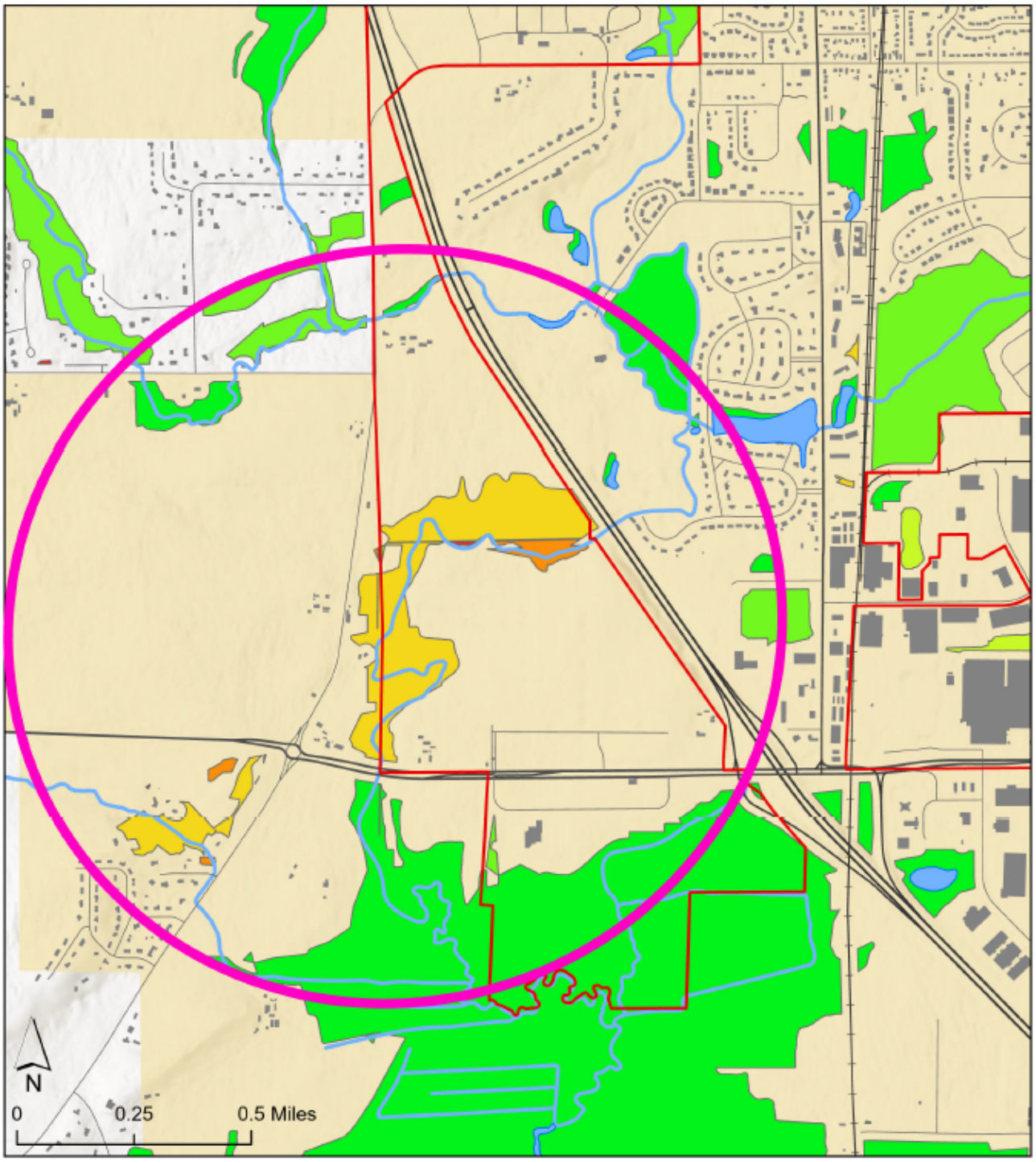


Figure 14: Natural Asset Protection Priority Zone 3

Natural Asset Protection Priority Zone

Village of DeForest Boundary

HUC-10 Watershed Boundary

Extraterritorial Jurisdiction (DeForest)

Roads

Buildings

Current & Future Rail

Lakes

Rivers

Percent Protected Land

- Not Protected <1%
- Barely Protected ≥1 to <25%
- Partially Protected ≥25 to <50%
- Mostly Protected ≥50 to <75%
- Nearly Fully Protected ≥75 to <95%
- Fully Protected ≥95%

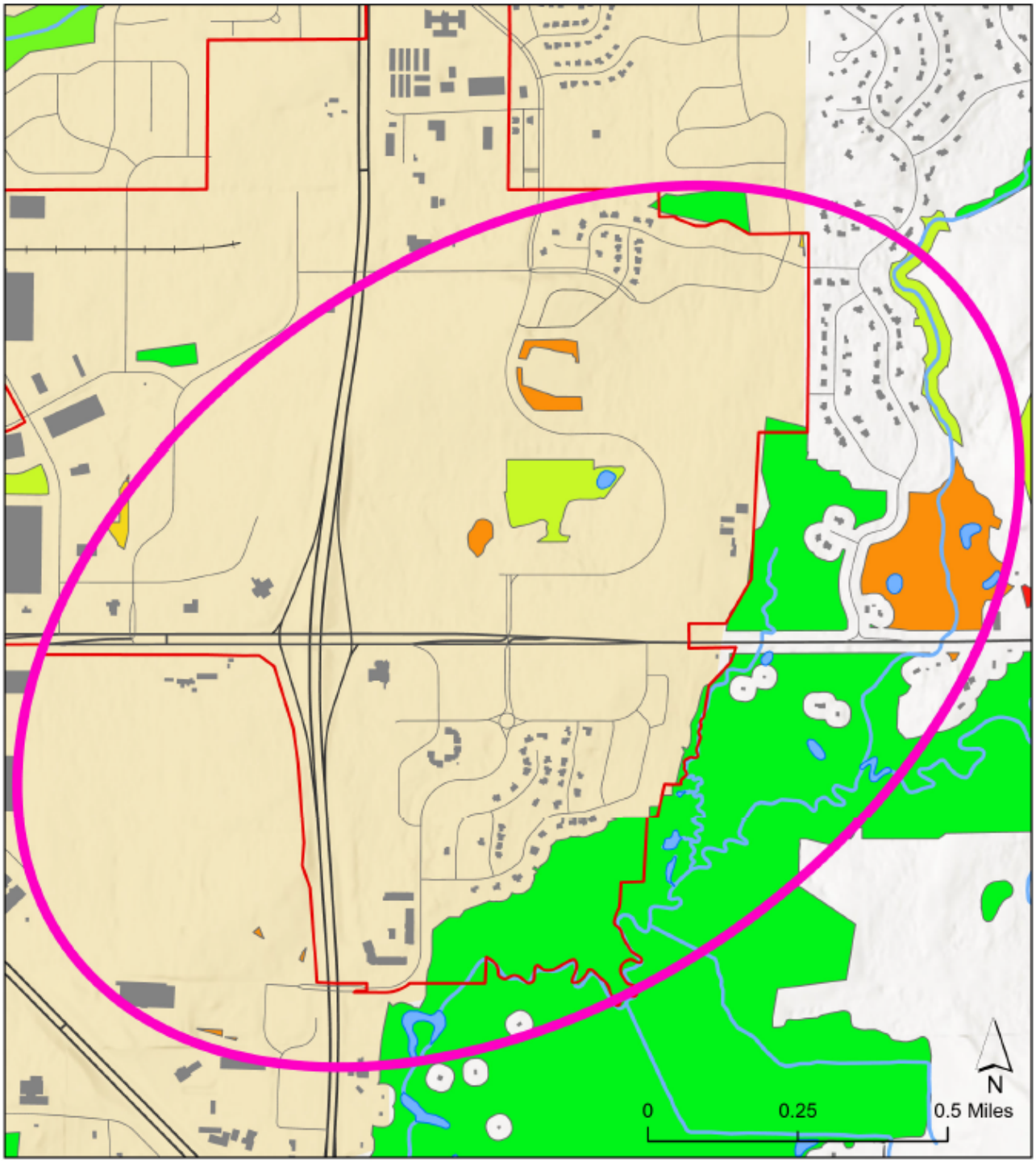


Figure 15: Natural Asset Protection Priority Zone 4

Natural Asset Protection Priority Zone

Village of DeForest Boundary

HUC-10 Watershed Boundary

Extraterritorial Jurisdiction (DeForest)

Roads

Buildings

Current & Future Rail

Lakes

Rivers

Percent Protected Land

- Not Protected <1%
- Barely Protected ≥1 to <25%
- Partially Protected ≥25 to <50%
- Mostly Protected ≥50 to <75%
- Nearly Fully Protected ≥75 to <95%
- Fully Protected ≥95%

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Appendix

A: Key Definitions

Core: intact landscape that is large enough to support a multitude of native species (sometimes used interchangeably with patch). Cores are connected by corridors that provide pathways for species to move across a landscape. (Firehock and Walker 2019, 11)

Corridor: Primarily a linear pathway that connects habitat patches and is wide enough to allow for species to travel safely (Firehock and Walker 2019, 11)

Edge: the transitional boundary of a core, where the vegetation assemblage and structure differ markedly from the interior, such as forest edges. (Firehock and Walker 2019, 31)

Environmental Corridor (CARPC Draft Definition, July 2024)
Environmental corridors are generally contiguous systems of open space and natural areas within lands that are developed for urban use or planned for such development. This designation is part of the Dane County Water Quality Plan and is primarily intended to protect water resources in and near urban areas. The designation is also applied to lands with other regulatory protections (archeological sites and endangered/sensitive habitats) and other lands expected to be open spaces in perpetuity (parks and stormwater management facilities). The following policies and criteria for Environmental Corridor designation are adopted in the Dane County Water Quality Plan. Protected resources that must be included in environmental corridors are:

- Wetlands under WDNR jurisdiction with a 75-foot minimum vegetative buffer
- 1%-annual chance (100-year) floodplains and floodways
- Riparian, wooded steep slopes (where the base of slope is not greater than 75 feet from the ordinary high water mark or top of bank of perennial streams, ponds and lakes). Steep slopes are defined as having 12% gradient and higher in the glaciated portions of the county; 20% gradient and higher for the driftless portion of the county.
- Navigable water bodies based on WDNR determination of navigability (plus minimum 75-foot shoreland buffer)
- Non-navigable waterways based on WDNR determination of navigability (plus minimum 25-foot shoreland buffer on each side of the waterway and a 75-foot minimum total width)
- Public lands, parks, and conservancy areas
- Problem soil areas and unique geologic formations (such as Karst features and known critical recharge areas)
- Archaeological sites
- Endangered/Sensitive habitats, such as savanna
    - I inquired with CARPC about how these are identified as at the time of writing, most sensitive habitats and species information is not publicly available. CARPC staff shared that many of these habitats, especially remnant prairie and oak savanna, coincide with parks and open space areas that are mapped as Environmental Corridors. CARPC reports being in discussion with the WDNR

about the definition of what endangered/sensitive habitats are and what mapping can be publicly shared. As of late July 2024, there has not be any resolution to this discussion. CARPC at the time of writing does show oak savanna habitat on their Protection and Stewardship Areas map which is publicly available online.

- Stormwater facilities

Green Infrastructure Network: an interconnected landscape of prioritized cores and connecting corridors that support the biodiversity of both flora and fauna (Firehock and Walker 2019, 13)

Habitat fragmentation: the breaking up of natural landscapes into smaller and more disconnected pieces which can lead to species loss and decline when damages to one area cannot be overcome by repopulation as organisms migrate to a new habitat(Firehock and Walker 2019, 10)

Patch: Distinct areas of similar types of habitat that differ significantly from adjacent landscapes and are often dependent on delicate climate factors or a specific underlying geology and hydrology (Firehock and Walker 2019, 8). It merely refers to different types of land cover and does not relate to its integrity (Firehock and Walker 2019, 25).

Protection Area (CARPC Draft Definition, July 2024)
*(Confused with DC's "Resource Protection Corridor", CAPRC alternative name suggestions: "Estimated Environmental Corridor"; Critical Resource Area; Sensitive Resource Area)***.**

This is a preliminary estimate of lands that would be required to be designated as Environmental Corridor if and when brought into an urban service area. It is mapped based on limited data and therefore the boundaries should be considered as approximations. Mapping of streams and wetlands (plus required buffers) is refined as better data becomes available, especially at the time of consideration for inclusion in the urban service area. The criteria for inclusion in this designation are the same as for the Environmental Corridor designation (see above). This designation has no regulatory effect prior to consideration for urban service area amendment.

- I followed up with CARPC staff about this definition to ask about if there is guidance for communities on how to plan for these areas when the designation does not have any regulatory effect prior to consideration for urban service area amendments. CAPRC mentioned that some elements that are part of the criteria for Protection Areas are regulated by Dane County zoning and therefore have some level of regulatory protection even when not yet part of an Environmental Corridor. These include floodplains under chapter 17; wetlands and buffers, streams and buffers under Chapter 11; and that slopes have some regulations related to them but was unsure of the particulars without further later review of the zoning code.

Stewardship Area (CARPC Draft Definition, July 2024)
Confused with Knowles-Nelson Stewardship grants and associated easements. CARPC alternative name suggestion: "Voluntary Preservation Area"

These are lands that provide important benefits to the region but do not have legal protection from development or disturbance. Preserving these benefits requires stewardship by landowners and local government, and protection may be achieved through methods such as fee-simple public ownership, dedication to the public, or by conservation easement. These lands are recommended for inclusion in environmental corridors during urban service area amendments, but lands with this designation are not required to be included under the policies and criteria adopted in the Dane County Water Quality Plan. Lands with this designation include:

- Potentially restorable wetlands and hydric soils
- High quality woodlands
- 0.2%-annual chance (500-year) floodplains
- Ice Age Trail corridor
- Natural Resource Area Boundaries [or other name if revised]
- Internally drained areas

B: Phosphorus Export Coefficients by Land Cover Category

The PRESTO script itself was not utilized as it was designed to run on ArcGIS 10, not ArcGIS Pro which could lead to software glitches. In addition, within the PRESTO documentation, the developers found that it was not appropriate for implementation targeting subwatersheds with high phosphorus export that did not also have detailed on the ground monitoring data to verify the phosphorous export. PRESTO also uses a 30x30m DEM scale and only has up to year 2011 outfall phosphorus loads along with the 2006 NLCD. Given the lack of a long-term phosphorus monitoring dataset and coarse scale of the tool at the HUC-12 level needed for this project, the documentation for PRESTO was consulted to select a method to estimate nonpoint source phosphorus loading outside of the tool. PRESTO has options for two different Multiple Regression Models and one option for a land use specific export coefficient. Within the documentation the PRESTO developers assessed the validity of each model and the export coefficient model most closely matched the spatial pattern of the Soil and Water Assessment Tool which the WDNR PRESTO developers considered to be the best information available to compare these methods to at the subwatershed scale. One caveat they noted was that this method tended to overestimate the annual total nonpoint source loads at this scale so this analysis should be taken as a rough estimate sufficient for prioritizing areas for load reduction efforts. The coefficients were assigned to the Wiscland 2.0 level 2 data categories based on which NLCD category they matched with most closely.

Table 7 Notes:

Modified as shown from the PRESTO user manual (WNDR 2013, 7) to align with Wiscland 2.0 Level 2 categories

**Wiscland 2.0 Level 2 only has Developed Low and High Intensity (no medium intensity). The PRESTO P load values for NLCD Developed Low Intensity were used instead of the Developed Low Intensity based on the PRESTO Source descriptions of WiLMS using rural residential (>1 acre) for Developed Low Intensity and medium urban density (1/4 acre) for Developed Medium Intensity. The ¼ acre size more closely aligns with the density of developed areas within the non-urban core of the ETJ area of the Village.*

***Average of PRESTO NLCD Deciduous Forest and Grassland/Herbaceous Values (PRESTO documentation)*

<u>Note:</u> NLCD 21 – Developed (Open Space), 22 – Developed (Low Intensity), and 43 – Mixed Forest did not have comparable categories within Wiscland 2.0 Level 2 and were not used to assign coefficients.

Table 7: Phosphorus export coefficients by land cover category

				Annual Phosphorus (P) Loads in lb/mi2			
NLDC ID	**NLCD Description**	**Wiscland 2.0 Level 2 ID**	**Wiscland 2.0 Description**	**P - Low**	**P – Most Likely**	**P - High**	**PRESTO Sources for P Loads**
11	Open Water	5000	Open Water	0	0	0	NA
		6100	Floating Aquatic Herbaceous Vegetation				
23	Developed, Medium Intensity	1200	Developed, Low Intensity*	171	286	457	WiLMS: Medium Density Urban (1/4 ac)
24	Developed, High Intensity	1100	Developed, High Intensity	571	856	1142	WiLMS: High Density Urban (1/8 ac)
31	Barren Land	7000	Barren	0	0	0	NA
41	Deciduous Forest	4200	Broad-Leaved Deciduous Forest	29	54	103	WiLMS: Forest
42	Evergreen Forest	4100	Coniferous Forest	29	54	103	WiLMS: Forest
52	Shrub/Scrub	6300	Lowland Scrub/Shrub	43**	74**	123**	MPCA, 2004: Shrubland/Transitional
71	Grassland/Herbaceous	3200	Idle Grassland (Cool & Warm Seasonal Grasses)	57	97	143	MPCA, 2004: Grassland/Herbaceous
81	Pasture/Hay	3100	Forage Grassland (Hay/Pasture)	57	171	286	WiLMS: Pasture/Grass
82	Cultivated Crops	2100	Crop Rotation	286	571	1713	WiLMS: Row Crop AG
90	Woody Wetlands	6400	Forested Wetland	0	0	0	NA
95	Emergent Herbaceous Wetlands	6200	Emergent Wet Meadow	0	0	0	NA

C: Recommended Future Steps

- Increase community engagement into this decision-making process.
    - I asked staff from UW-Extension, the Capital Area Regional Planning Commission, and the Village about best practices for useful community engagement and there has been discussion amongst this group about setting up sessions within the next year at the conclusion of this project. One of the main target groups is to partner with the DeForest High School science courses and/or the Future Farmers of America (FFA) club to get input from the next generation of residents to see what they want the future of their community to look like. In addition, groups such as the Friends of the Yahara River and the Rock River should be involved to incorporate additional scientific data and on the ground knowledge of the river.
- Create an opportunities roadmap for implementation steps of priority areas and associated tasks
    - Consult with green infrastructure and design professionals on the costs to design, construct, and maintain various GI options and identify level of staffing needs by the Village to address ongoing maintenance needs of facilities
- Investigate funding opportunities and alternative financing methods through partnerships such as via public private partnerships
- Consider other land preservation options like partnering with a local land trust such as Groundswell Conservancy
    - They have used Purchase of Development Rights in places like the Town of Dunn to
- Have conversations with adjacent municipality leadership to create connectivity between efforts and possibly partner on cross-border projects to get funding
- Consult with the WNDR and a consulting firm about creating a wetland mitigation bank, possibly in the northern portion of the community
- Use iTree to plan for urban tree management. Some key uses and inputs for this free online service:
    - Rainfall intercept, stormwater runoff avoided, air quality, CO2 sequestration, value of benefits
    - You can do either a full inventory, or enter sample sites (plot samples)
    - Team based mobile applications and also desktop option
    - iTree design option allows you to add trees and forecast ecological services over time (as well as energy efficiency calculations)
    - iTree Eco is the most robust option and you need a fair amount of data input to use (weather and pollution, dieback percent is assumed unless you have other information to add in, genus species must be together in iTree)
    - It is a good way to model tree cycling (basically super large trees aren't always providing the best/most benefits as they may be providing the most benefit while growing, not once they have reached maturity – so a blend is best)

        - adding in a 2:1:2:1 tree planting succession plan with a fast growing tree interspersed amongst the larger trees (is a larger level of investment and upkeep but one of the most effective methods for maximizing benefits)
- Create an ESRI Experience Builder interactive webpage that contains all the analysis layers which would allow people to do their own analysis prioritizing different items
- WINSLAMM should be used to more accurately calculate phosphorus nutrient loading in the community with the assistance of consultant engineers
- The draft definitions of Environmental Corridors, Protection Areas, and Stewardship Areas were allowed to be shared for use in this project but those reviewing this work should check with the updated Parks and Open Space Plan and/or CARPC staff to see if definitions have been finalized to update this workflow for implementation later.
- Further consultation with water quality experts should be done to incorporate a more accurate and southern-Wisconsin based scientific justification for these area size determinations.

D: Village Staff Site Specific Thoughts for the Future

Omitted from public version as conversations are ever evolving and to keep residents information private. A full copy of my notes from these conversations have been provided to Village staff and evaluators within the Department.

E: Data Sources

Data used within this analysis:

Data	Source	Notes
Wisconsin Wetlands Inventory	WI DNR https://data-wi-dnr.opendata.arcgis.com/datasets/200c06fc04074ef7ae24c0b74737b187/about	
Environmental Corridor Boundary	Capitol Area Regional Planning Commission https://data-carpc.opendata.arcgis.com/datasets/43ee630f8cba40b39aa24ea3d2eb5e0d_0/explore	
Parcels	Columbia County https://www.sco.wisc.edu/parcels/data/ Dane County https://dcimapapps.countyofdane.com/arcgissrv/rest/services/DaneCountyBase/MapServer/12	
Waterways 24K Hydro Full Geodatabase (Rivers, Lakes, Tributaries)	WI DNR https://data-wi-dnr.opendata.arcgis.com/datasets/cb1c7f75d14f42ee819a46894fd2e771/about	
Land Cover	WI DNR - Wiscland 2 (2016) https://data-wi-dnr.opendata.arcgis.com/documents/d7f5d33b182044c187c776e47d72ce84/explore *(please note this link sparks a download right when you open it)*	Used instead of NLCD national coverage as there is slightly higher accuracy levels of the state data per the documentation
Watershed Boundary (HUC12 scale)	WI DNR https://data-wi-dnr.opendata.arcgis.com/datasets/478fe58cd72e419cab24eff04ecfb839_5/explore	
Parks (includes Natural Resource Areas and Forest Lands)	Dane County https://dcimapapps.countyofdane.com/arcgissrv/rest/services/Parks/MapServer/1	
Environmental Protection Areas (Stewardship and Protection Areas Combined)	Capitol Area Regional Planning Commission https://data-carpc.opendata.arcgis.com/	
Village of DeForest Boundary (Municipal Boundaries)	Dane County https://dcimapapps.countyofdane.com/arcgissrv/rest/services/DaneCountyBase/MapServer/19	
Phosphorus export coefficients to estimate phosphorus loading	PRESTO tool from WI DNR (https://dnr.wisconsin.gov/topic/SurfaceWater/PRESTO.html) & 2016 Massachusetts Small MS4 Permit Pollutant Loading Export Rates Analysis Methodology (https://www.mass.gov/doc/land-use-land-cover-guidance-updated-2016/download)	*not a data layer, but instead workflow guidance with a table of numbers that have coefficients by land cover category and workflow diagram for calculating these values
Roads	Dane County https://dcimapapps.countyofdane.com/arcgissrv/rest/services/Roads/MapServer/7	

	Columbia County https://geodata.wisc.edu/catalog/ADE1EDD6-42EB-4A52-AB30-64BF2D10A02C	
Railroads	Statewide (WDNR) https://dnrmaps.wi.gov/arcgis/rest/services/DW_Map_Cached/EN_Basic_Basemap_WTM_Ext/MapServer/6 Dane County https://dcimapapps.countyofdane.com/arcgissrv/rest/services/Roads/MapServer/3	
Airport Reference Points	WI DOT https://data-wisdot.opendata.arcgis.com/datasets/d5adcd8fe0714b5e996badd24196540a_0/explore?location=43.226669%2C-89.278786%2C10.94	
Hydrologic Units	Dane County https://dcimapapps.countyofdane.com/arcgissrv/rest/services/WaterResources/MapServer/12	Watershed boundaries of features in Depression and Surface Drainage Network layers. All runoff volume estimates are for a 2-year, 24-hour rainfall (2.84 inches) for Dane County. Attributes include runoff curve number and runoff delivery.
Public Lands	Dane County https://dcimapapps.countyofdane.com/arcgissrv/rest/services/Parcels/MapServer/10	
Building Footprints	GitHub Download for State Specific Data taken from the ESRI Microsoft Data https://github.com/microsoft/USBuildingFootprints?tab=readme-ov-file ESRI Microsoft Building Footprints https://hub.arcgis.com/datasets/esri::microsoft-building-footprints-features/about Server Path: https://services.arcgis.com/P3ePLMYs2RVChkJx/arcgis/rest/services/MSBFP2/FeatureServer/0	ESRI built a machine deep learning algorithm to extract these from imagery
PAD-US 4.0 (Protected Areas Database of the United States)	USGS https://www.sciencebase.gov/catalog/item/652d4f80d34e44db0e2ee45c These lands and other data can be viewed through the TNC Resilient Land Mapping Tool online interactive map as well to see other information. The PAD info is within the conservation > secured lands overlay portion of this map viewer.	Preferred Citation: U.S. Geological Survey (USGS) Gap Analysis Project (GAP), 2024, Protected Areas Database of the United States (PAD-US) 4.0: U.S. Geological Survey data release, https://doi.org/10.5066/P96WBCHS.

Data found but not used within this analysis but could be useful for future work:

Data	Source	Notes
Wisconsin Potentially Restorable Wetlands	WI DNR https://data-wi-dnr.opendata.arcgis.com/datasets/04ee9425804d4bf2b5b3e304c42a4cc7/about	
Digital Elevation Model (2017)	USGS https://geodata.wisc.edu/catalog/9077d957-3b31-46e0-aabe-385fa1cd4fe2	To create a slope and accumulation layer using ArcHydro tools
Future Land Use	**Village of DeForest Consultant*	Used instead of current land use since the application will be for future development and natural asset protection moving forward rather than present day conditions
Tree Canopy Coverage	Capitol Area Regional Planning Commission (2017 LiDAR Derived Canopy Cover) https://data-carpc.opendata.arcgis.com/	
Street Tree Inventory	**Village of DeForest Consultant*	
SSURGO Soil Data	USDA NRCS https://websoilsurvey.nrcs.usda.gov/app/WebSoilSurvey.aspx	
Floodplain	FEMA National Flood Hazard Layer https://hazards.fema.gov/arcgis/rest/services/public/NFHL/MapServer	
Contours (1ft)	Dane County https://dcimapapps.countyofdane.com/arcgissrv/rest/services/Contours/MapServer/5	
Steep Slopes (>6%)	Dane County https://dcimapapps.countyofdane.com/arcgissrv/rest/services/Elevation/MapServer/0	
Digital Elevation Model (2ft Tiles)	USGS LiDAR-Derived DEM 2017 https://geodata.wisc.edu/catalog/9077d957-3b31-46e0-aabe-385fa1cd4fe2	
Digital Elevation Model (30m)	USGS National Elevation Dataset 2024 https://apps.nationalmap.gov/downloader/#/	
Public Parks	**Village of DeForest Consultant*	
Surface Drainage Network	Dane County https://dcimapapps.countyofdane.com/arcgissrv/rest/services/WaterResources/MapServer/15	Linear features representing flow paths on the land surface (i.e., not in a storm sewer) of the ACPF HUC12 extent with a minimum drainage area of 10 acres. No flow frequency classification has been made for these features. The surface drainage network is symbolized by unit stream power, which is a measure

		of energy available to transport sediment.
Public Lands	Dane County https://dcimapapps.countyofdane.com/arcgissrv/rest/services/Parcels/MapServer/10	
Building Footprints	GitHub Download for State Specific Data taken from the ESRI Microsoft Data https://github.com/microsoft/USBuildingFootprints?tab=readme-ov-file ESRI Microsoft Building Footprints https://hub.arcgis.com/datasets/esri::microsoft-building-footprints-features/about Server Path: https://services.arcgis.com/P3ePLMYs2RVChkJx/arcgis/rest/services/MSBFP2/FeatureServer/0	ESRI built a machine deep learning algorithm to extract these from imagery
National Conservation Easement Database	Partnership between Ducks Unlimited and The Trust for Public Land https://www.conservationeasement.us/ **To download data, you must create a free account*	Later found that these lands are included within the PAD-US 4.0 Data and therefore did not use this in the end
Healthy Watersheds, High Quality Waters Dataset (lakes and large rivers, streams, wetlands, and watershed health ecological index)	WDNR https://dnr.wisconsin.gov/topic/SurfaceWater/HQW.html **This is the program landing page with links to each dataset that are housed in the DNR Open Data Portal*	

F: GIS Analysis Workflow Details

All analysis was done in ESRI ArcGIS Pro 3.3.1 and used some geoprocessing tools under the Spatial Analyst license. All data outside of a few layers provided by the project communities consultant were open source publicly available data as outlined in the later Data Sources Appendix section. The below details accompany the ModelBuilder layout images for general process information.

Pre-processing was done for all layers to limit the extent of the layer to the HUC-10 (maximum study area extent) and project all data to the same coordinate system. The *NAD 1983 HARN WI CRS Dane (US Feet)* in the *Lambert Conformal Conic* projection (WKID = 8193) was used as all data received from the project community's consultant utilized this projection.

1. **Create the Natural Habitats and Developed Areas layers.**
    - ***a. Natural Habitats:***
        - i. Extract the land covers with minimal human disturbance from the Wiscland 2.0 level 2 data using **Extract by Attributes**
            1. Where *cls_desc_2* (classification description column from the attribute table) is equal to: *Coniferous Forest, Broad-leaved Deciduous Forest, Barren, Emergent/Wet Meadow, Floating Aquatic Herbaceous Vegetation, Forested Wetland, Idle Grassland, Lowland Scrub/Shrub, Open Water,* OR *Shrubland*
        - ii. Then **Extract by Mask** to keep Wiscland data only within the HUC-10 (Study Area largest extent)
            1. Extraction Area = *Inside*
        - iii. Use **Raster to Polygon** to convert the layer to vector for use in combining this area with other vector-based information.
            1. Field = *cls_desc_2*
            2. Check Simplify Polygons
            3. Uncheck Create multipart features
        - iv. Bring in the *Wisconsin Wetlands Inventory* layer (mapped wetlands only, not potentially restorable wetlands) and the *Waterbodies* layer (both previously clipped to HUC-10) as well as the *Hydro Flowlines* layer. Since the flowlines are polylines and not polygons like the other layers being used in the union next, use **Feature to Polygon** to convert the *Hydro Flowlines* to polygons
            1. Check Preserve Attributes
        - v. Then **Union** the *Wiscland Natural Land Cover, Wisconsin Wetlands Inventory, Waterbodies,* and *Hydro Flowlines* (polygon) layers together
            1. Attributes to Join = All Attributes
            2. Uncheck Gaps Allowed
            3. Do not rank the inputs
        - vi. Then **Dissolve** the Union output layer to create a *Natural Habitats* output feature class
            1. Leave Dissolve Fields blank

2. Leave Statistics Fields blank
3. Uncheck Create Multipart Features
4. Uncheck Unsplit Lines

vii. You are left with one contiguous feature class representing all existing natural habitats.

b. Developed Areas:

i. Using the parcels layer and outside information, locate all airports within the study area and merge those parcels together into one *Airports* layer.
   1. The same could be done for golf courses, ski hills, and other intensive land use areas that come up as natural land covers frequently. This was the only extra layer outside of built infrastructure pulled out for this project.

ii. For this project, *Road Centerlines* were combined since there were two counties within the HUC-10 using **Merge**

iii. For railroads, existing mainlines and future rail spurs were combined using **Merge** and clipped to the HUC-10 boundary

iv. Using **Buffer**, each layer *(Road Centerlines, Airport Parcels, Building Footprints,* and *Railroads)* was buffered individually by 30 meters
   1. Accepted default options:
      a. Side Type = Full
      b. Method = Planar
      c. Dissolve Type = No Dissolve

v. Then, the resulting four buffered outputs were combined using **Union** to create one *Developed Areas* layer
   1. Do not rank input layers
   2. Attributes to Join = All Attributes
   3. Check Gaps Allowed

2. Create the Cores layer.

a. **Erase** the *Natural Habitats* (input) by the *Developed Areas* (erasing feature)

b. Then **Dissolve** the output
   i. Leave Dissolve Fields blank
   ii. Leave Statistics Fields blank
   iii. Uncheck create multipart features
      1. Important as this is what will show the remaining intact habitat areas outside of development
   iv. Uncheck split lines

c. Next, if you have justifiable Edge zone distances this is where you could buffer the intact habitat by the negative amount of the edge sone to remove the edge area from the intact cores.
   i. You could then use **Multipart to Single Part** to remove disconnected habitat areas (fragmentation) and remove under 10 acre polygons (these are important at the site scale but the resolution of the data at a 30x30m scale does not appropriately value these small fragments)

ii. Then you'll see that some habitat fragments have no interior acreage so you can remove those fragments by creating a new field in the attribute table and using **Calculate Geometry** in US Arces and then do the same to calculate the perimeter in meters
iii. You can then rank the core areas based on their interior acreage size and then also calculate the perimeter to area ratio using **Field Calculate** which leaves you with final *Habitat Core* data with attributes populated

d. However, since this project is at a smaller scale and is fairly developed (when considering the huge acreage suggested for core sizes being >100 acres on a landscape/national scale), it would not be appropriate to remove all the smaller features entirely. Part of the goal of this project is treating the lands within the Village as stepping stones between the larger cores located outside of the HUC-10. So, this process was modified as follows:
    i. I did not buffer these areas since they mostly will be stepping stone fragments or part of a corridor between cores.
    ii. **Multipart to Singlepart** on the dissolved *Natural Habitats* layer
    iii. I did not remove polygons under 10 acres as the same reason as why I did not buffer. However this will be accounted for later in this process when assigning core types to polygons
    iv. Within ModelBuilder I ran **Calculate Geometry Attributes** on the multipart/singlepart output
        1. Geometry Attributes:
            a. Field = Interior Acreage (this is a new, not existing attribute, it will be created when the tool is ran)
            b. Property = Area
        2. Area Unit = US Survey Acres
        3. Coordinate System = project selected coordinate system
    v. Then, outside of ModelBuilder, within the attribute table of the previously created layer, I did **Add Field** to create a *CoreCategory* column
    vi. Back in ModelBuilder, I did **Calculate Field** and selected my new field under field name.
        1. Then under Expression, I entered *CoreCategory = categorize(!InteriorAcerage!)*
        2. And under the Code Block, I added this Python script:
            a. def categorize(InteriorAcerage):
                if InteriorAcerage < 1:
                  return "Tiny Fragment"
                elif 1 <= InteriorAcerage < 5:
                  return "Small Fragment"
                elif 5 <= InteriorAcerage < 10:
                  return "Medium Fragment"
                elif 10 <= InteriorAcerage < 25:
                  return "Large Fragment"
                elif 25 <= InteriorAcerage < 50:

```
    return "Tiny Core"
elif 50 <= InteriorAcerage < 100:
    return "Small Core"
elif 100 <= InteriorAcerage < 200:
    return "Medium Core"
elif 200 <= InteriorAcerage < 500:
    return "Large Core"
else:
    return "Extra Large Core"
```

vii. This resulted in all polygons being assigned a Core Category based on 9 classes. These were chosen after visually looking at the summarized data for all 761 data points in the attribute table. The category names were not chosen based on the Green Infrastructure Institute and ESRI workflow guidance as theirs simply states that core areas (excluding the edge areas) are ideally at least 100 acres in size. So instead, take the non-edge area excluded classes here with a grain of salt and consider these more hubs within an urban fringe area that has few traditionally labeled cores.

3. Add Water Resources Information to Cores Data

a. Use **Calculate Geometry** on both the *WI Wetlands Inventory* and *Hydro Waterbody* layer and add a new field for AreaAcres and set the property to Area.
   i. Area Unit = US Survey Acres
b. The *Hydro Flowline* layer already has length calculated in the attribute table, so this step is not needed for that layer
c. **Clip** the three water layers *WI Wetlands Inventory*, Hydro Flowlines, and *Hydro Waterbody* to the HUC10 sized Cores layer
d. Do a **Spatial Join** on the *WI Wetlands Inventory Clip* layer
   i. Target Features = *WI Wetlands Inventory Clip* layer
   ii. Join Features = HUC10 sized Cores layer
   iii. Join Operation = Join one to one
   iv. Check keep all target features
   v. Match Option = Within a distance
   vi. Search Radius = 1 US Survey Feet
e. Do a **Spatial Join** on the *Hydro Flowlines Clip* layer
   i. Target Features = *Hydro Flowlines Clip* layer
   ii. Join Features = HUC10 sized Cores layer
   iii. Join Operation = Join one to one
   iv. Check keep all target features
   v. Match Option = Intersect
   vi. Search Radius = leave blank
f. Do a **Spatial Join** on the *Hydro Waterbody Clip* layer
   i. Target Features = *Hydro Waterbody Clip* layer
   ii. Join Features = HUC10 sized Cores layer
   iii. Join Operation = Join one to one

iv. Check keep all target features
v. Match Option = Within a distance
vi. Search Radius = 1 US Survey Feet

4. **Create a Protected Lands Layer**
    a. **Union** together the *CARPC Environmental Corridor, CARPC Stewardship Areas, CARPC Protection Areas, PAD-US Properties,* and *C1 Conservancy Zoning* for The Village of DeForest (parks, conservancy, etc) layers
        i. Do not rank the inputs
        ii. Attributes to Join = all attributes
        iii. Uncheck gaps allowed
    b. **Intersect** the union output with the *HUC10 Cores* layer
        i. Attributes to join = all attributes
    c. Run **Multipart to Singlepart** on the intersected output to create a single layer showing all protected lands combined
    d. Then **Dissolve** the output
        i. Leave Dissolve Fields blank
        ii. Leave Statistics Fields blank
        iii. Uncheck create multipart features
        iv. Uncheck split lines
    e. The final layer results in all protected lands that include Core areas.
    f. To determine how much of core areas are within protective boundaries, add a field to the final *protected areas* layer, "ProtAcre" and calculate geometry in US Survey Acres
    g. Then use **Spatial Join** the *protected areas* layer with the *cores* layer
        i. Target Features = *protected areas* layer
        ii. Join Features = HUC10 sized Cores layer
        iii. Join Operation = Join one to one
        iv. Check keep all target features
        v. Match Option = Within a distance
        vi. Search Radius = -1 US Survey Feet
    h. The "ProtAcre" field can then be utilized to calculate the percentage of a core under protection by creating another field "ProtPerc"
        i. **Calculate Field** = [ProtAcre]/[InteriorAC]*100
        ii. *This step was done outside of ModelBuilder as the program was crashing frequently so it will not appear on the model graphic.
    i. Then to add a rank to these by adding a new field "ProtRank"
        i. <1% = 1 (not protected)
        ii. ≥1 to <25% = 2 (barely protected)
        iii. ≥25 to <50% = 3 (partially protected)
        iv. ≥50 to <75% = 4 (mostly protected)
        v. ≥75 to <95% = 5 (nearly fully protected)
        vi. ≥95 to <105% = 6 (fully protected)
        vii. All other = 0
        viii. To do this, use this Python script:

```
def categorize(ProtPerc):
    if ProtPerc < 1:
        return "1"
    elif 1 <= ProtPerc < 25:
        return "2"
    elif 25 <= ProtPerc < 50:
        return "3"
    elif 50 <= ProtPerc < 75:
        return "4"
    elif 75 <= ProtPerc < 95:
        return "5"
    elif 95 <= ProtPerc < 105:
        return "6"
    else:
        return "0"
```

G: GIS Analysis Workflow ModelBuilder Graphics

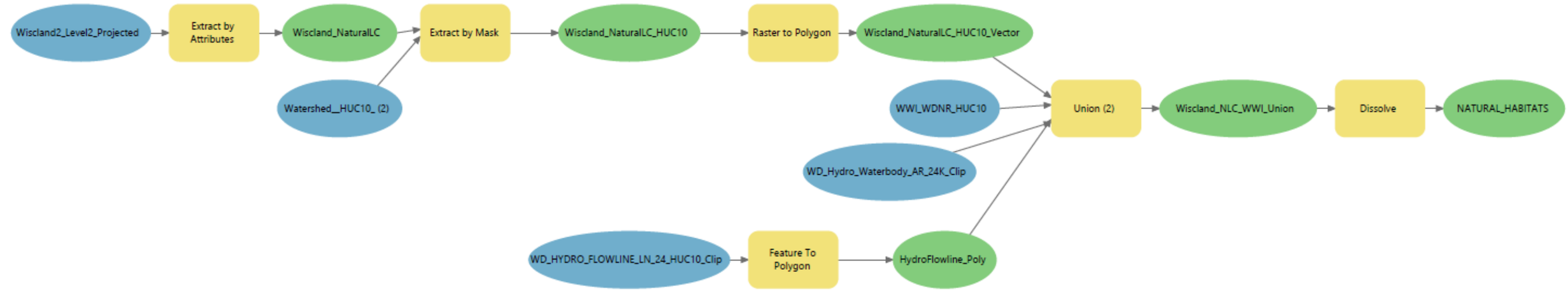


Figure 16: Natural habitats layer ModelBuilder process

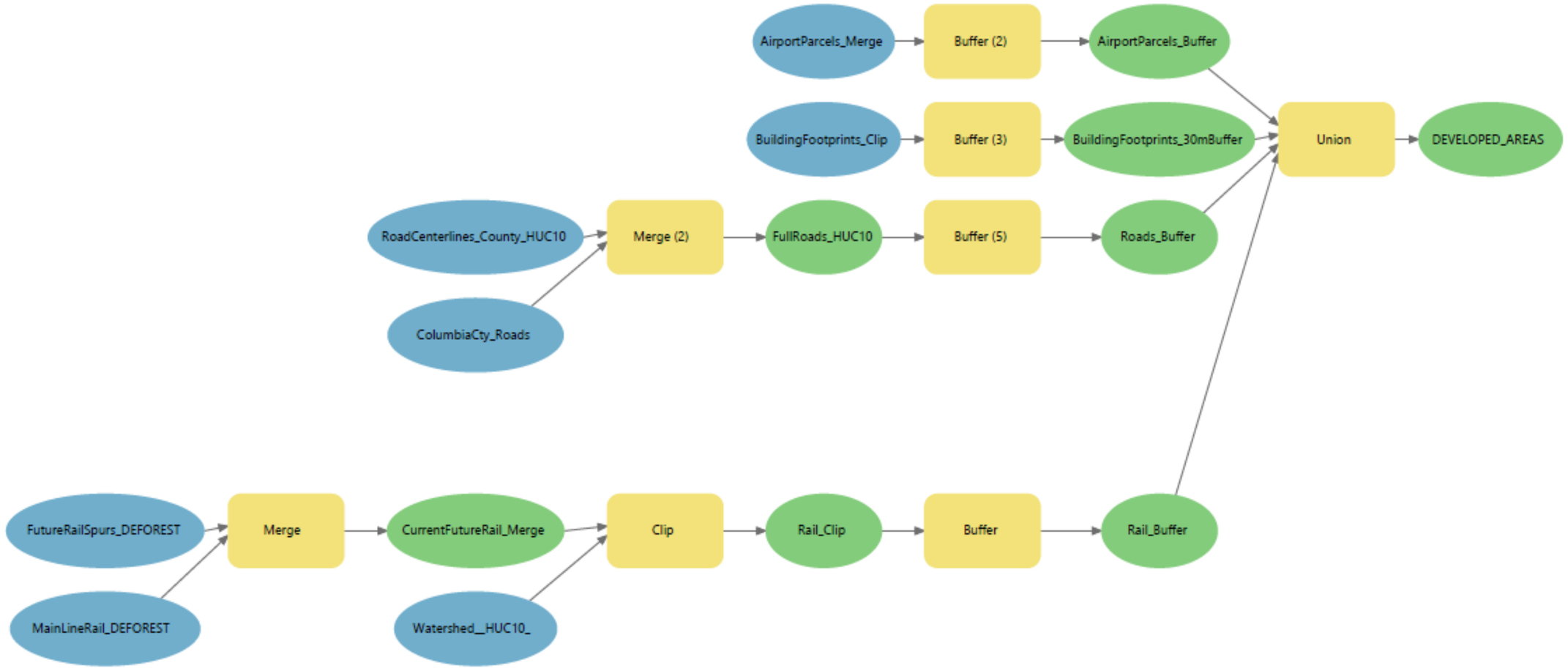


Figure 17: Developed areas layer ModelBuilder process

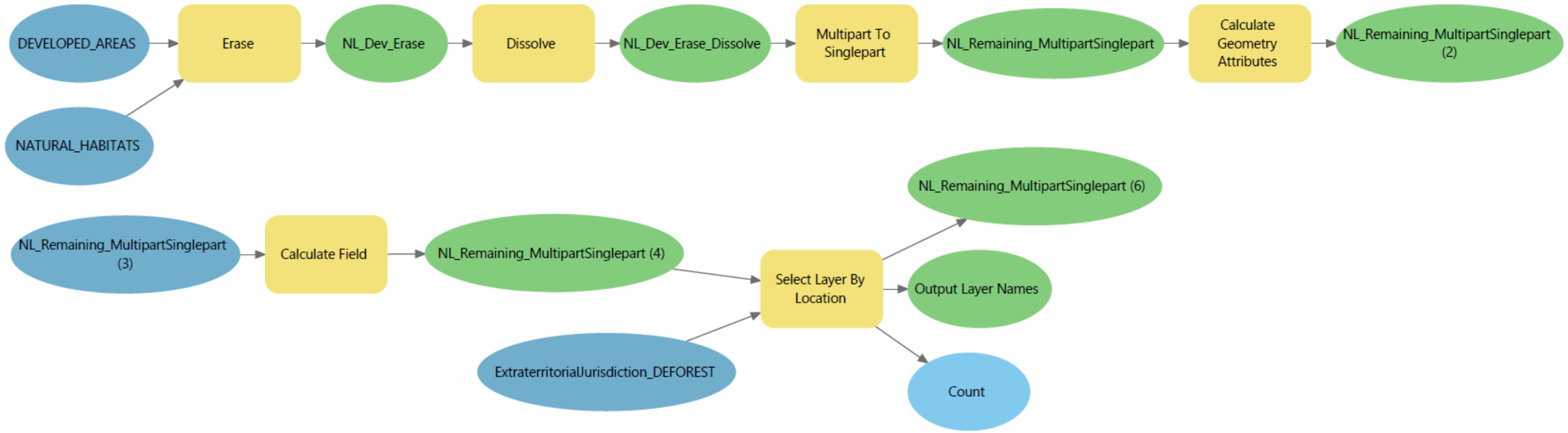


Figure 18: Cores layer ModelBuilder process

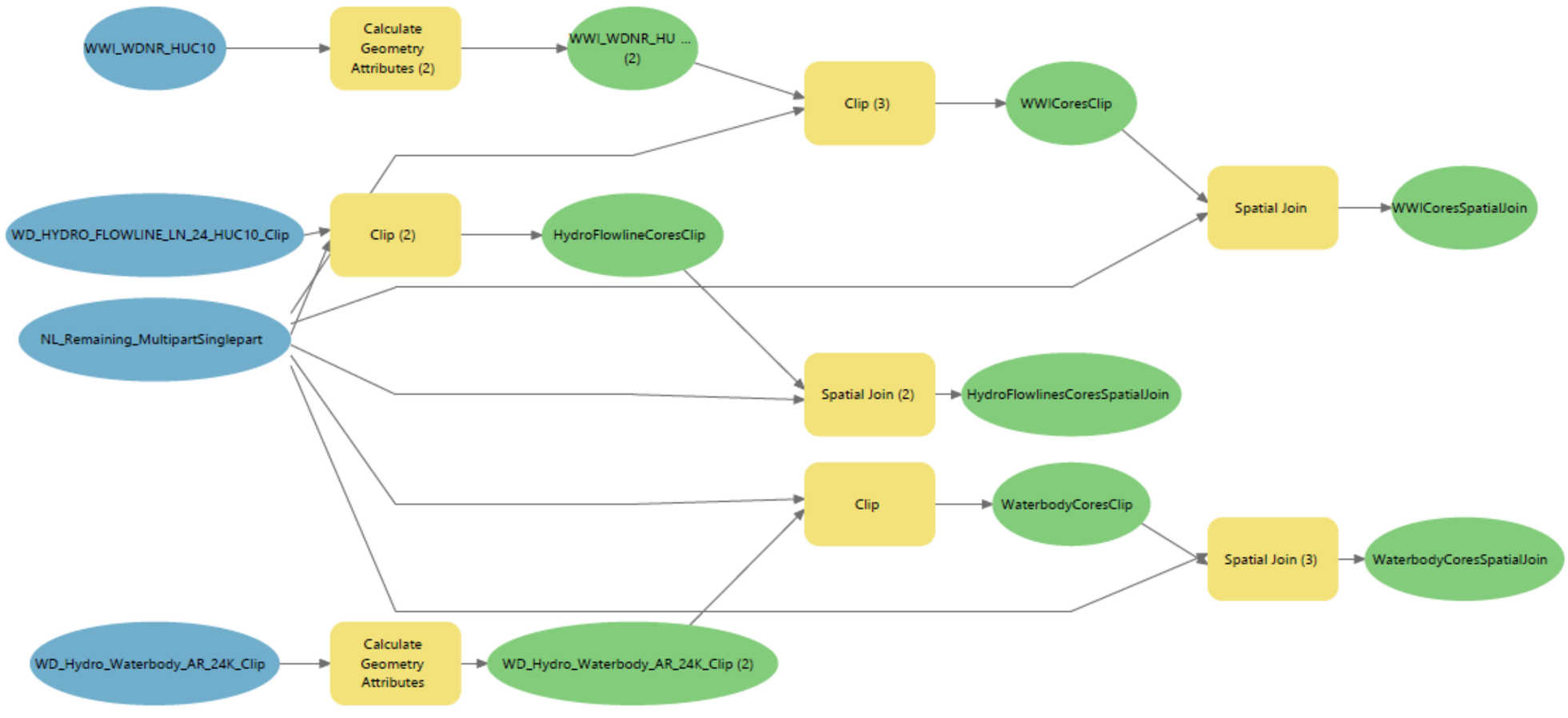


Figure 19: Adding water resources information attributes to the cores layer ModelBuilder process

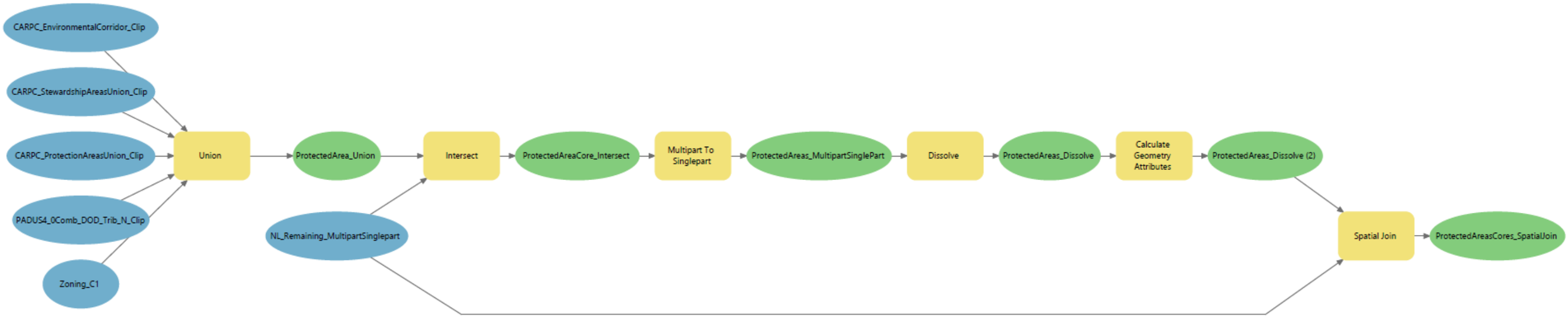


Figure 20: Protected areas of cores layer ModelBuilder process