Modeling and Mapping in Support of the Regional Conservational Strategy Framework

Theresa Burcsu
Tommy Albo
Joe Bernert
Jennifer Dimiceli
Jimmy Kagan
Matt Noone

Institute for Natural Resources
Portland State University

Contents

List of Figures

List of Tables

1

1 Introduction

Prior to November 2010, when The Intertwine Alliance launched the Regional Conservation Strategy (RCS) and Biodiversity Guide (RBG) efforts for the Portland-Vancouver metropolitan region, conservation priorities in the metropolitan region were identified at a broad regional scale that generally excluded urban areas (e.g., state conservation strategies and Willamette Synthesis); were regional but based solely on expert opinion (e.g., Natural Features); and consisted of localized priorities that abruptly ended at jurisdiction boundaries. The goal of the RCS was to fill in the gaps between broad and local scales of information related to conservation priorities. RCS members envisioned a data-driven approach that could add a regional perspective to local efforts and facilitate cross-scale cooperation toward protecting remaining valuable habitat in the Portland-Vancouver metropolitan region. Also, RCS members expected that the product would complement rather than replace local knowledge, by validating what we know and expanding to areas we know less well.

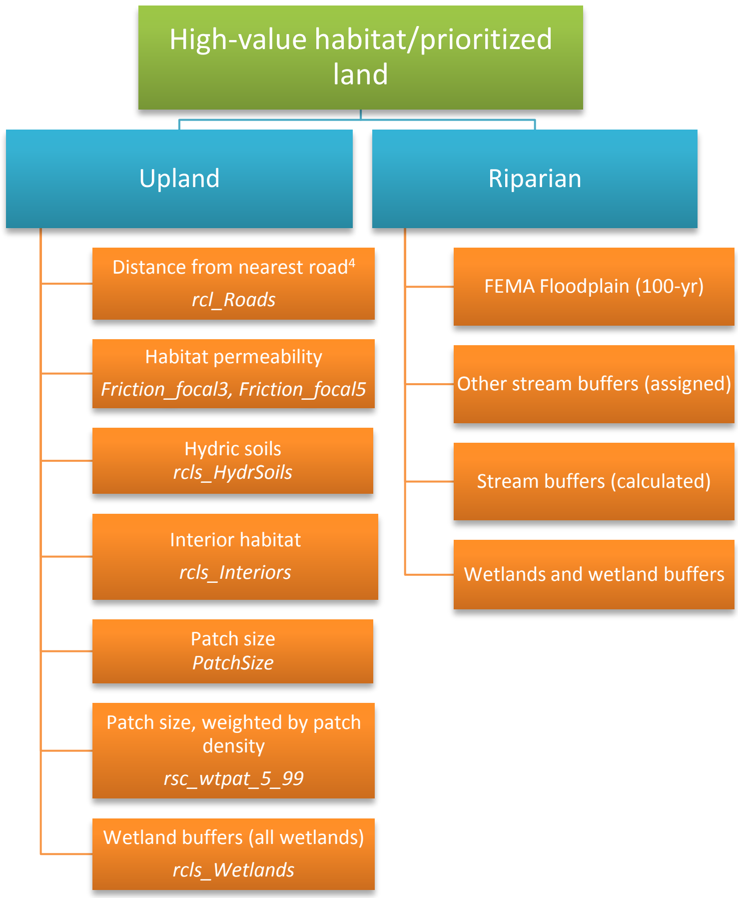
In June 2011, INR completed an initial proof-of-concept product describing high value conservation areas in the Portland-Vancouver region. The product demonstrated a methodology that enabled stakeholder involvement while also being data-driven. In September 2012, we completed a second version of this product that is reported on in this document. While the product is considered complete at this time, it is expected and hoped that the models and data will be updated and improved upon into the future as more and better information becomes available so that the product functions as a "living work" rather than a one-time snapshot in time. Several key products resulted from the project: the High Value Habitat data describing high value terrestrial habitat within the metropolitan region, the Riparian Habitat data describing high value habitat adjacent to streams and rivers, and the high spatial resolution land cover data set describing land cover at a 5 m spatial resolution.

Among the data used, the Portland-Vancouver metropolitan conservation area mapping project makes use of multiple data sets including high (5 m) spatial resolution imagery, improving on past efforts that were mapped at 30 m spatial resolution and nationally available data. The 5 m spatial resolution allows users to distinguish individual features on the landscape, such as individual tree canopies. Because urban landscapes are widely diverse in terms of the vegetation types and types of surfaces (e.g., sidewalks, rooftops, plants, etc.), and many materials may be located in small areas, high resolution spatial data is essential to understanding and cataloging urban areas. The nationally available data allows the products to use spatially consistent data across the whole metropolitan region. Local data sets were used to supplement region-wide data sets.

2 Approach and Data

To map high value conservation areas in the Portland-Vancouver metropolitan area, we employed a basic overlay method in which raster data sets representing important variables for conservation were assigned ranking values based on attributes such as distance from features (e.g., roads), total area, or combinations of attributes. To address the primary focus for the project, we mapped upland[1] and riparian[2] habitats, however, stream channels[3] were also ranked in the process using hydrographic data and may be used as a stand-alone product. Figure 1 illustrates the structure of the upland and riparian metrics.

Figure 1. Data sets were overlaid to create the High-value Habitat Model to differentiate among habitats in the Upland and Riparian metrics. Under the Upland column, the data set names are italicized.



2.1 Base data

Land cover

The Intertwine High Resolution Land Cover data set (IHRLC) was developed in support of the Intertwine's Regional Conservation Strategy effort to catalogue natural resources in the Portland-Vancouver metropolitan region. The land cover data set used for this project is the result of several stages of image classification and post-processing procedures. The first stage land cover data set was a combination of 4 m and 30 m spatial resolution derived classification data with 30 m data filling in areas

[1] The Upland and Riparian metrics replace the WALK metric described in the proof-of-concept product (Burcsu et al. 2011).
[2] The riparian metric replaces portions of the SWIM metric described in the proof-of-concept product (Burcsu et al. 2011).
[3] Stream channel ranking replaces portions of the SWIM metric described in the proof-of-concept product (Burcsu et al. 2011).

where 4 m data was unavailable. The high spatial resolution (4 m) portions of the classification map were developed using data from six LiDAR flights acquired from 2002-2009 and Normalized Difference Vegetation Index (NDVI) derived from National Agriculture Imaging Program (NAIP) imagery. We aggregated both the LiDAR and NAIP datasets from their native spatial resolutions, 1 m and 0.5 m, respectively to 4 m.

We used Landsat 5 Thematic Mapper bands 1-5 and 7 to complete the 30 m moderate resolution classification using a random forest classification technique. Normalized Difference Vegetation Index (NDVI), Normalized Difference Moisture Index (NDMI), and Tasseled Cap Wetness (TCW) spectral indices in combination with a digital elevation model (DEM), slope image, and atmospherically corrected and converted top of atmosphere (ToA) served as input layers to the random forest classifier. Overall accuracy of the 30 m data set was 86%.

To produce the first generation 4 m spatial resolution data set, we combined the high and moderate resolution classified data. Land covers within the urban growth boundary (UGB) classified as agriculture were reclassified as residential land cover in a post-processing step. This data set was then aggregated to a 5 m spatial resolution.

The second generation 5 m spatial resolution data set was created by applying rule-based post-processing techniques to the first generation data set. Rules were used to distinguish between land cover such as agriculture and low-stature vegetation that were not well separated in the classification process. Rules were based on location relative the urban growth boundary (UGB) and elevation (600 feet above sea level; Table 1). The resulting classification contained 33 classes.

The second generation data classes were also aggregated to yield two coarser levels, “level 1” and “level 0” classification schemes. The level 1 classification was not used for analyses, but is useful for display purposes. This classification resulted in 15 classes. Level 0 was created and used for regional statistics as well as cartographic purposes; it contained 6 generalized classes.

Table 1. Land cover classification levels.

Land cover (level 2):

- Developed originally by INR using LiDAR vegetation heights, National Agriculture Imagery Program imagery (NAIP; http://www.fsa.usda.gov/FSA/apfoapp?area=home&subject=prog&topic=nai), and Landsat ETM imagery
- Augmented by Metro to more fully distinguish between land covers/land uses such as agriculture and low-stature vegetation
- Primary data set used for analysis
- Consists of 33 classes (Table 2)

Land cover (level 1):

- Level 1 categories were created by grouping level 2 land cover data set categories/classes
- Consists of 15 classes (Table 3)
- Used for display purposes.
- Not used for analysis purposes

Land cover (level 0):

- Level 2 land cover data set categories/classes were grouped to form the level 3 classification
- Consists of 6 classes (Table 3)
- Created and used for regional statistics as well as cartographic purposes

Digital elevation model

- 10 m spatial resolution
- Highest spatial resolution elevation data that covered the entire area

Table 2. Level 2 land cover class codes, class names, and long descriptions that include criteria for determining the class. Levels 1 and 0 were derived from this classification.

Level 2	Class Name, level 2	Class Description, level 2
1	Water	Open water
2	Paved, built small	Most paved areas
3	Buildings (burned in), built medium	Buildings burned in From Metro's building layer and Clark County's building layer. Taller buildings (> 30 ft.) and other structures (e.g., bridges); includes some edge portions of the canopies of tall shrubs and short trees (sometimes very dark shadows from steep embankments/cliffs)
4	Buildings (detected), built tall	Shorter buildings and other structures (e.g., bridges), semi trucks and rail cars; includes some edge portions of the canopies of tall shrubs and short trees (sometimes very dark shadows from steep embankments/cliffs)
5	Herbaceous, low, inside UGB	Sparse and/or very short vegetation (0 - 2 ft.; e.g., lawn); includes some water with emergent or submersed vegetation, vegetation canopy overhanging water surfaces, or shadows cast on water surfaces; may also include ball fields, mowed areas, golf courses, etc.)
6	Herbaceous, medium, inside UGB	Fairly sparse and/or short vegetation (2 - 5 ft.; e.g., crops, pastures, lawn, Phalaris); may include ball fields, mowed areas, golf courses, etc.
22	Reclassified to herbaceous, low, from developed	Bare ground/pervious surface with sparse vegetation; manual corrections made via heads-up digitizing; these pixels were originally classified as developed.
27	Herbaceous, low, outside UGB	OUTSIDE UGB, > 600 ft. elevation - Sparse and/or very short vegetation (0 - 2 ft.; e.g., lawn); includes some water with emergent or submersed vegetation, or with overhanging vegetation canopy or shadow being cast on water surface
28	Herbaceous, medium, outside UGB	OUTSIDE UGB, > 600 ft. elevation - Fairly sparse and/or short vegetation (2 - 5 ft.; e.g., crops, pastures, lawn, Phalaris)
7	Herbaceous, high, inside UGB	Herbaceous (5 - 13 ft.; e.g., low shrubs, tall crops, medium-sized shrubs, medium-sized tree regeneration); may include ball fields, mowed areas, and golf courses
29	Herbaceous, high, outside UGB	OUTSIDE UGB, > 600 ft. elevation - Fairly sparse and/or short vegetation (5 - 13 ft.; e.g., crops, pastures, lawn, Phalaris)
8	Conifers, small	Conifer woody crops, tall shrubs, small trees, largely tree regeneration (13 - 30 ft.)
13	Hardwood, small	Woody crops, tall shrubs, small trees (e.g., willow, ash), large tree regeneration (13 - 30 ft.)
9	Conifers, medium	Conifers 30 - 70 ft. tall; includes some broadleaved trees with shaded canopies, adjacent to water, or with bright, sparsely vegetated backgrounds (e.g., in urban environments)
10	Conifers, medium - tall	Conifers 70 - 120 ft. tall
14	Hardwood, medium	Broadleaved trees 30 - 70 ft. tall (e.g., ash); includes some conifers with brightly illuminated canopies
15	Hardwood, medium-	Broadleaved trees 70 - 120 ft. tall (e.g., red alder)

Level 2	Class Name, level 2	Class Description, level 2
	tall	
16	Hardwood, tall	Broadleaved trees > 120 ft. tall (e.g., big leaf maple, cottonwood)
11	Conifers, tall	Conifers 120 -200 ft. tall
12	Conifers, very tall	Conifers > 200 ft. tall, old growth
55	Mixed forest	Mixed forest from low resolution (non-LiDAR) areas
56	Conifer	Conifers from low resolution (non-LiDAR) areas
57	Hardwood	Hardwoods from low resolution (non-LiDAR) areas
17	Clear cuts, oldest	Some cuts detected from 2000 or even earlier, most likely is representative of herbaceous or even shrub by now.
18	Clear cuts, 2006-2008	Clear cut between 2006 and 2008, most likely is representative of herbaceous or bare ground.
19	Partial cuts, 2006-2008	Less than 50% volume removal, most representative of mature conifer forest >= 70 ft.
20	Clear cuts, 2008-2010	Clear cut between 2008 and 2010, representative of bare ground.
21	Partial cuts, 2008-2010	Less than 50% volume removal, most representative of mature conifer forest >=70 ft.
41	Digitized clear cuts	OUTSIDE UGB, > 600 ft elevation, patches > 4 acres; manually identified areas of herbaceous classes larger than 4 acres that resembled clear cuts
26	Agriculture, reclassified (inside UGB)	Manually digitized agriculture within the UGB, < 600 ft. elevation, patches > 4 acres
36	Agriculture, digitized (outside UGB)	OUTSIDE UGB, < 600 ft elevation, patches < 2 acres; manually identified
40	Agriculture, digitized (outside UGB)	OUTSIDE UGB, > 600 ft elevation, patches > 4 acres; manually identified areas of herbaceous classes larger than 4 acres that resembled agriculture
61	Undeveloped areas; sandbars	Formerly paved pixels (class ID = 2) near rivers; manually reclassified; class composed mostly of sand bars

Table 3. Crosswalk of land cover levels in the classification scheme.

Level 0	Class Name, level 0	Level 1	Class Name, level 1	Level 2	Class Name, level 2
1	Water	1	Open water	1	Water
2	Developed	2	Paved	2	Paved, built small
2	Developed	2	Paved	3	Buildings (burned in), built medium
2	Developed	4	Buildings	4	Buildings (detected), built tall
3	Low vegetation	5	Herbaceous I - Low sparse veg (0 - 2 ft.)	5	Herbaceous, low, inside UGB
3	Low vegetation	5	Herbaceous I - Low sparse veg (0 - 2 ft.)	6	Herbaceous, medium, inside UGB
3	Low vegetation	5	Herbaceous I - Low sparse veg (0 - 2 ft.)	22	Reclassified to herbaceous, low, from developed
3	Low vegetation	5	Herbaceous I - Low sparse veg (0 - 2 ft.)	27	Herbaceous, low, outside UGB
3	Low vegetation	5	Herbaceous I - Low sparse veg (0 - 2 ft.)	28	Herbaceous, medium, outside UGB
3	Low vegetation	7	Herbaceous II - Low vegetation (2 - 7 ft.)	7	Herbaceous, high, inside UGB
3	Low vegetation	7	Herbaceous II - Low vegetation (2 - 7 ft.)	29	Herbaceous, high, outside UGB
4	Tree cover	13	Large shrub/small trees (7 - 30 ft.)	8	Conifers, small
4	Tree cover	13	Large shrub/small trees (7 - 30 ft.)	13	Hardwood, small
4	Tree cover	9	Conifers (30-120 ft.)	9	Conifers, medium
4	Tree cover	9	Conifers (30-120 ft.)	10	Conifers, medium - tall
4	Tree cover	14	Broadleaf (over 30 ft.)	14	Hardwood, medium
4	Tree cover	14	Broadleaf (over 30 ft.)	15	Hardwood, medium-tall

Level 0	Class Name, level 0	Level 1	Class Name, level 1	Level 2	Class Name, level 2
4	Tree cover	14	Broadleaf (over 30 ft.)	16	Hardwood, tall
4	Tree cover	11	Conifers (over 120 ft.)	11	Conifers, tall
4	Tree cover	11	Conifers (over 120 ft.)	12	Conifers, very tall
4	Tree cover	55	Mixed forest from low resolution (non-LiDAR) areas	55	Mixed forest
4	Tree cover	56	Conifers from low resolution (non-LiDAR) areas	56	Conifer
4	Tree cover	57	Hardwoods forest from low resolution (non-LiDAR) areas	57	Hardwood
4	Tree cover	17	Clear cuts	17	Clear cuts, oldest
4	Tree cover	17	Clear cuts	18	Clear cuts, 2006-2008
4	Tree cover	17	Clear cuts	19	Partial cuts, 2006-2008
4	Tree cover	17	Clear cuts	20	Clear cuts, 2008-2010
4	Tree cover	17	Clear cuts	21	Partial cuts, 2008-2010
4	Tree cover	17	Clear cuts	41	Digitized clear cuts
5	Agriculture	26	Agriculture	26	Agriculture, reclassified (inside UGB)
5	Agriculture	26	Agriculture	36	Agriculture, digitized (outside UGB)
5	Agriculture	26	Agriculture	40	Agriculture, digitized (outside UGB)
6	Sand bars	61	Sand bars	61	Undeveloped areas; sandbars

Accuracy Assessment of Land Cover Data

We completed a heads-up accuracy assessment of the second generation land cover data set. To assess land cover accuracy a set of points were created through geographically stratified, random methods. NAIP imagery was used to assess whether the conditions on the ground matched the land cover class. Overall accuracy was 94.3%. See Appendix B for more details.

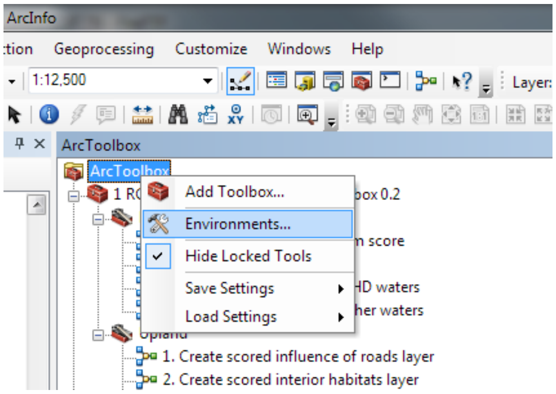
2.2 Metrics

Metrics were derived from base data using a variety of processes including distance analyses and grouping to create gradations of conservation values within spatial data sets (Figure 1). The derived data sets are referred to as “prioritization layers” in this document.

General Procedures

Tools were developed to facilitate model updates, data additions, and understanding of the processes used. The tools produced numerous outputs. The output location is generally the default scratch workspace set at the Toolbox level (Figure 2).

Figure 2. Setting the ArcToolbox workspace environments.



To produce the prioritization layers for the Upland metric, set the default current and scratch workspaces to the same path, run through the tools in the RCS Mapping Toolbox sequentially until you have created the full suite of prioritization layers. The tools in the Upland Toolset are easily run by double-clicking on them, entering in the requested parameters and clicking OK, just like other ArcGIS tools. However, there is one exception that requires the user to open a script in IDLE and run it from IDLE or other Python interface. Most tools in the Riparian Toolset are composed of tools that are complex and therefore require the user to open them in Model Builder to build prioritization layers.

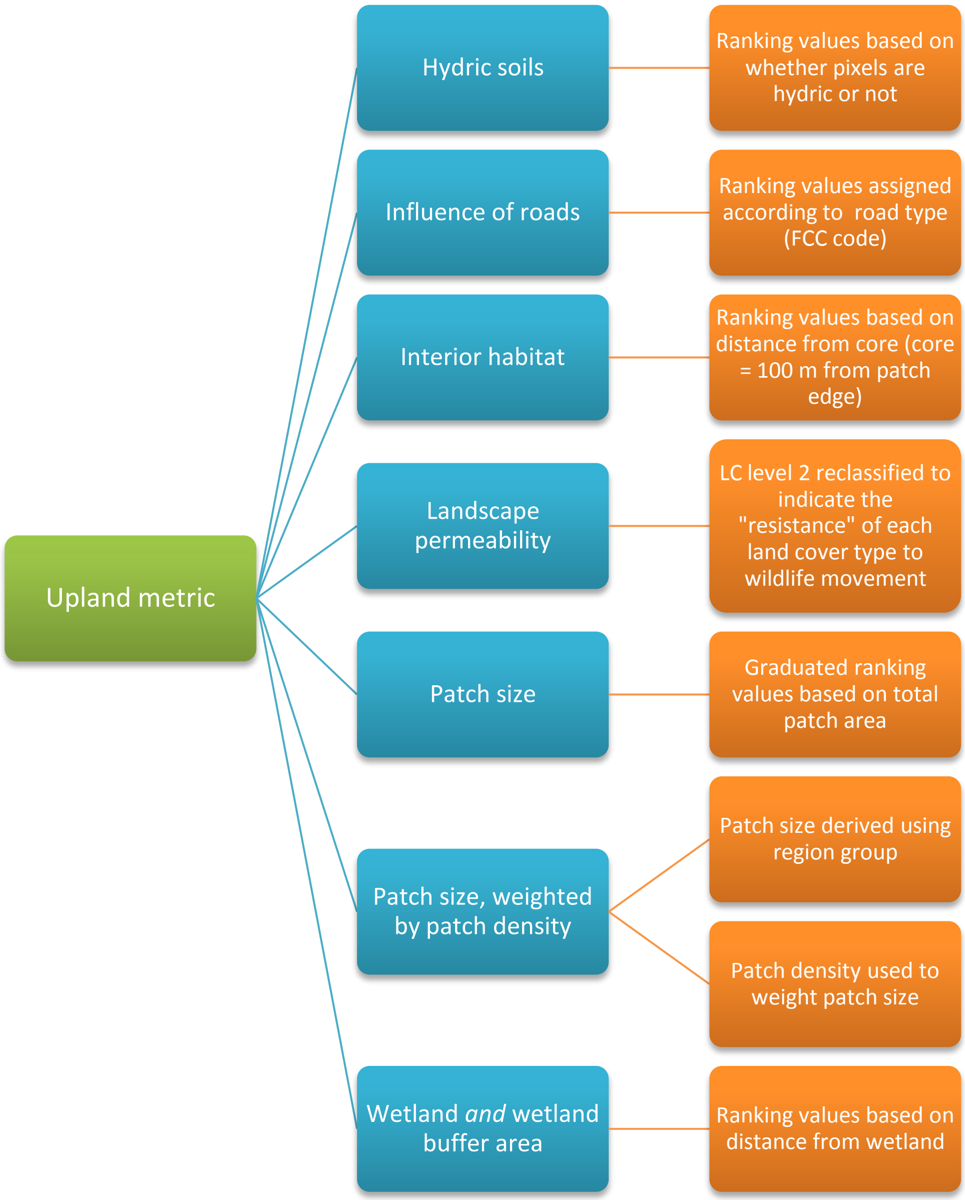
Upland Habitat Metric

The Upland metric (Figure 3) was developed using multiple raster prioritization layers. To develop the prioritization layers we:

1. Assigned conservation values based on each layer's specific attributes
2. Assigned weighting factors
3. Overlaid and multiplied according to their weighting factors in ArcGIS 10 (ESRI 1999-2010)

[4] Distance from nearest road replaces "Ground Condition" described in in the proof-of-concept product (Burcsu et al. 2011).

Figure 3. Descriptive names of the prioritization layers to the Upland metric and short descriptions of the ranking mechanisms.



Influence of Roads

Tool name: 1. Create scored influence of roads layer

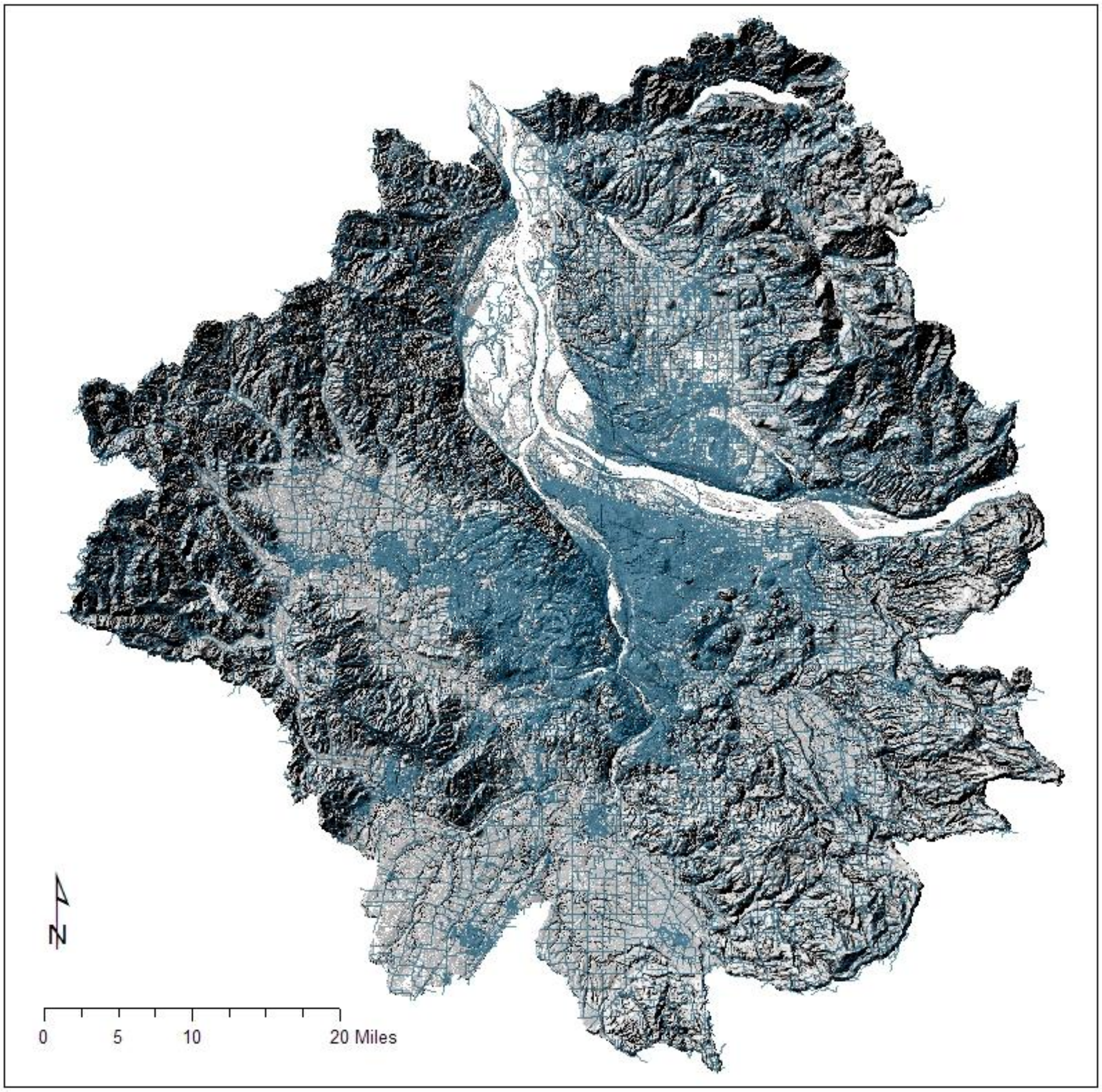
Roads are known to influence wildlife, acting as a barrier to movement in many cases and a perturbation source in others as a result of noise and movement of vehicles (Coffin 2007). Behavior may be modified by species; for example birds such as the European blackbird and Great tit have been found to alter the frequencies over which they sing to avoid masking by traffic noise. Roads also affect the physical landscape by interrupting hydrologic, sediment, and debris transport patterns and processes, and contribute to air and water pollution.

To assign ranks to roads, we assigned influence based on the road types and uses using TIGER Feature Classification Codes (FCC; http://www.census.gov/geo/www/tiger/appendxe.asc) provided in the ESRI 2010 roads data.

Table 4. Ranking values assigned to road types in the study area.

FCC	Description	ROADCLASS	RENDERCL	RendrBuff	RankingValue
A40	Local, neighborhood, and rural road	4	4	10	4
A41	Local, neighborhood, and rural road	4	4	10	4
A43	Local, neighborhood, and rural road	4	4	10	4
A45	Local, neighborhood, and rural road	4	4	10	4
A48	Local, neighborhood, and rural road	4	4	10	4
A50	Vehicular trail (unpaved)	4	4	10	4
A51	Vehicular trail (unpaved)	4	4	10	4
A61	Cul-de-sac	5	4	10	4
A30	State and county highways	3	3	15	6
A31	State and county highways	3	3	15	6
A33	State and county highways	3	3	15	6
A35	State and county highways	3	3	15	6
A37	State and county highways	3	3	15	6
A38	State and county highways	3	3	15	6
A60	Road with characteristic unspecified, major category used alone when the minor category could not be determined	6	5	15	6
A62	Traffic circle	7	5	15	6
A63	Access ramp	6	5	15	6
A64	Service drive	5	5	15	6
A20	U.S. and state highway	2	2	20	8
A21	U.S. and state highway	2	2	20	8
A25	U.S. and state highway	2	2	20	8
A26	U.S. and state highway	2	2	20	8
A15	Primary highway with limited access or interstate	1	1	25	9
A16	Primary highway with limited access or interstate	1	1	25	9
A17	Primary highway with limited access or interstate	1	1	25	9

Figure 4. Ranked roads within the study area.



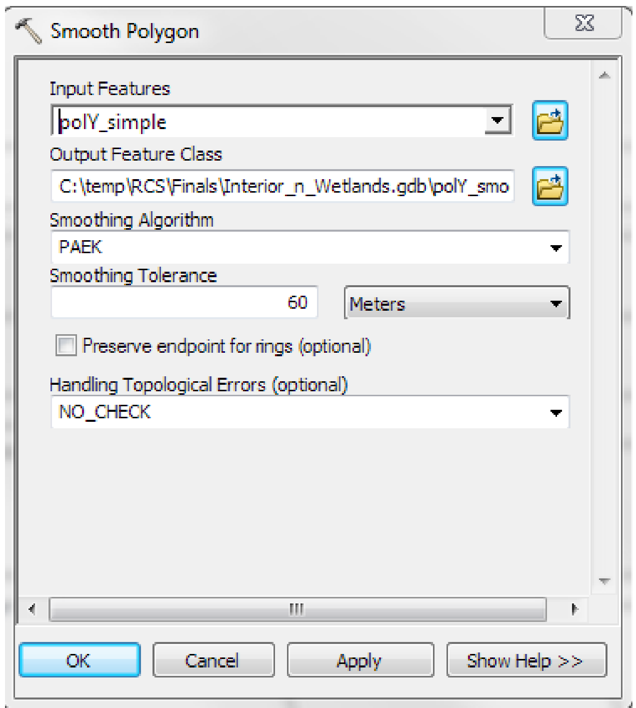
Interior Habitat

Tool name: 2. Create scored interior habitats layer

A layer describing interior habitat or natural habitat "cores" was created to represent the benefits of habitat located far from edges. The method reclassified the land cover data (level 2) so that classes representing land cover types dominated by trees (conifers, large shrubs, tree regeneration areas, woody crops, etc), clear cuts, and sand bars were grouped into "natural" habitat types (Table 5); all other classes were considered "built" or nonhabitat. Patches under 5000 m^2 (1.24 acres) were removed. Development of this layer (Figure 6) was accomplished by:

1) Reclassifying the land cover data layer to represent only habitat and non-habitat land cover types.
2) Removing speckling (isolated single pixel regions of either class) in a multiple step process.
3) Creating visually acceptable interior regions in vector data format using the Smooth Polygon tool (Figure 5).

Figure 5. Settings used to smooth the interior polygons



4) Selecting polygons that met our minimum size criteria (greater than 0.5 ha or 1.24 acres)
5) Re-rasterizing the polygons
6) Calculating the Euclidean distance from each habitat patch interior
7) Classifying the distances to reflect a simplified gradient of ranking values (Table 6)

Table 5. Table used to identify habitat and non-habitat land covers.

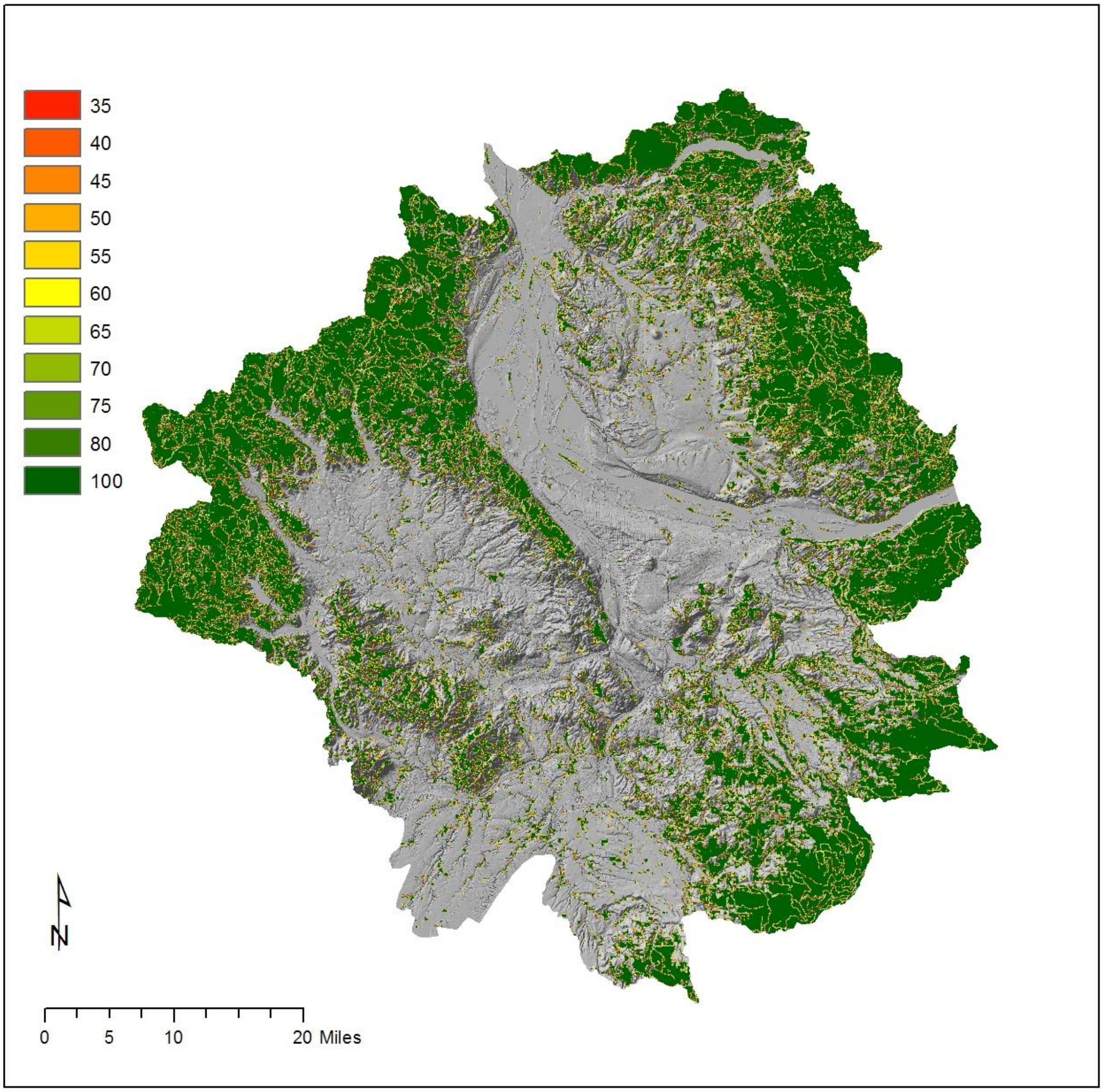
Level 2 land cover code	Landcover description	Habitat type
0	Unclassified	not habitat
1	Water	not habitat
2	Paved, built small	not habitat
3	Buildings (burned in), built medium	not habitat
4	Buildings (detected), built tall	not habitat
5	Herbaceous, low, inside UGB	not habitat
6	Herbaceous, medium, inside UGB	not habitat
7	Herbaceous, high, inside UGB	not habitat
8	Conifers, small	habitat

Level 2 land cover code	Landcover description	Habitat type
9	Conifers, medium	habitat
10	Conifers, medium - tall	habitat
11	Conifers, tall	habitat
12	Conifers, very tall	habitat
13	Hardwood, small	habitat
14	Hardwood, medium	habitat
15	Hardwood, medium-tall	habitat
16	Hardwood, tall	habitat
17	Clear cuts, oldest	habitat
18	Clear cuts, 2006-2008	habitat
19	Partial cuts, 2006-2008	habitat
20	Clear cuts, 2008-2010	habitat
21	Partial cuts, 2008-2010	habitat
22	Reclassified to herbaceous, low, from developed	not habitat
26	Agriculture, reclassified (inside UGB)	not habitat
27	Herbaceous, low, outside UGB	not habitat
28	Herbaceous, medium, outside UGB	not habitat
29	Herbaceous, high, outside UGB	not habitat
36	Agriculture, digitized (outside UGB)	not habitat
40	Agriculture, digitized (outside UGB)	not habitat
41	Digitized clear cuts	habitat
55	Mixed forest	habitat
56	Conifer	habitat
57	Hardwood	habitat
61	Undeveloped areas; sandbars	habitat

Table 6. Valuation table used for ranking interior habitat areas. Descriptions were created to provide users with enough information to visualize the ranking value gradient and its meaning rather than define each value explicitly.

Distance (m)	Ranking Value	Description
0	100	Interior
> 0 - 3	90	Functions very much like interior
3 - 7	80	
7 - 12	75	
12 - 17	70	
17 - 22	65	
22 - 28	60	
28 - 33	55	
33 - 38	50	Habitat quality depleted by approximately 50% relative to the habitat core due to edge effects
38 - 43	45	
43 - 48	40	
48 - 53	35	Nearly completely dominated by edge conditions
53 - 95	0	Dominated by edge conditions, equivalent to matrix

Figure 6. Habitat interior areas for the study area.



Hydric Soils

Tool name: 3. Create scored hydric soil layer

To develop the hydric soils prioritization layer (Figure 7) (Soil Survey Staff; http://soils.usda.gov/survey/geography/ssurgo/description.html, http://www.mass.gov/mgis/ssurgodb.pdf) prioritization layer we:

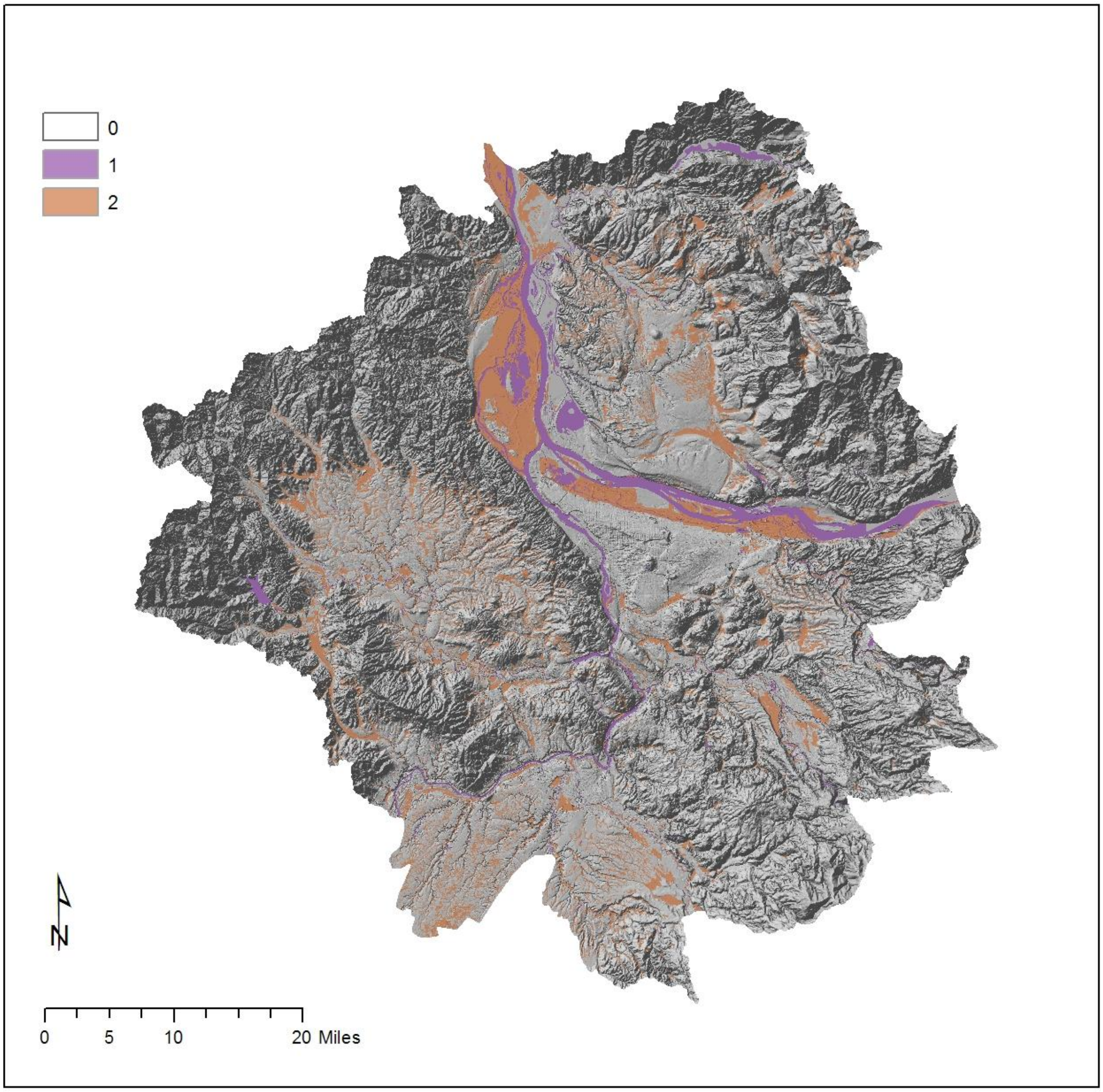
1) Converted soil unit classes to ranking values based on the "hydric soil rating" values[4]
2) Converted the original data from vector to raster data format
3) Reclassified the rasterized data using Table 7

Table 7. Reclassification table used to rank values in the hydric soils layer.

Hydric Rating	RCSGrid	ScoringValue
Yes	4	2
Unranked	3	1
No	0	0
NoData	NoData	0

[4] The hydric rating values are contained in the "hydric rating" field in the SSURGO attribute database. This field indicates if a soil unit is considered hydric or not. If it is rated as hydric, specific criteria are provide in the Component Hydric Criteria table provided in a SSURGO download package (soildatamart.nrcs.usda.gov/documents/SSURGO Metadata - Table Column Descriptions Report.pdf)

Figure 7. Hydric soils extracted for the study area.



Landscape Permeability

Tool names:

5a. Calculate scored landscape permeability (friction) layer (single output) – allows the user to specify a smoothing window size, among other parameters

5b. Calculate scored landscape permeability (friction) layer (two outputs) – reproduces the friction layers created by INR analyst using two hard-coded smoothing window sizes

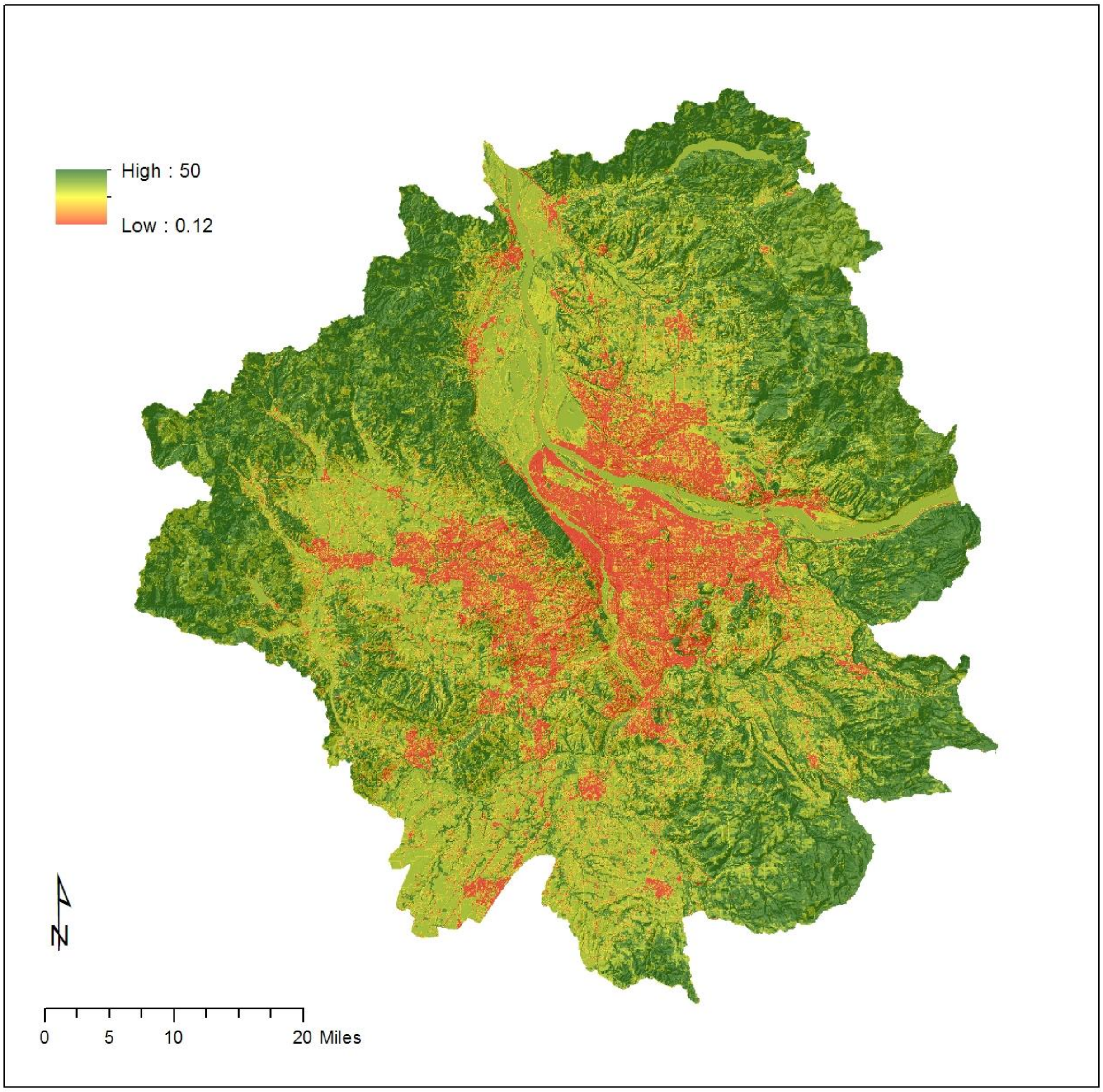
Land cover types vary in their capacity to support wildlife for foraging, reproducing, and movement. We attempted to capture this variability through the permeability layer (Figure 8). The layer was developed through the:

1) Assignment of resistance values to land cover types
2) Inversion of the resistance values to indicate permeability (Table 8)
3) Smoothing of resulting layer

Table 8. Permeability values assigned to land cover types. Permeability values are considered the inverse of resistances so that high values are considered better than low values.

Level 2 land cover code	Description	Permeability ranking value
0	na	0
1	Water	20
2	Paved, built small	11
3	Buildings (burned in), built medium	10
4	Buildings (detected), built tall	10
5	Herbaceous, low, inside UGB	30
6	Herbaceous, medium, inside UGB	31
7	Herbaceous, high, inside UGB	32
8	Conifers, small	44
9	Conifers, medium	47
10	Conifers, medium - tall	48
11	Conifers, tall	49
12	Conifers, very tall	49
13	Hardwood, small	46
14	Hardwood, medium	46
15	Hardwood, medium-tall	47
16	Hardwood, tall	48
17	Clear cuts, oldest	38
18	Clear cuts, 2006-2008	37
19	Partial cuts, 2006-2008	36
20	Clear cuts, 2008-2010	36
21	Partial cuts, 2008-2010	36
22	Reclassified to herbaceous, low, from developed	10
26	Agriculture, reclassified (inside UGB)	35
27	Herbaceous, low, outside UGB	32
28	Herbaceous, medium, outside UGB	33
29	Herbaceous, high, outside UGB	33
36	Agriculture, digitized (outside UGB)	35
40	Agriculture, digitized (outside UGB)	36
41	Digitized clear cuts	35
55	Mixed forest	46
56	Conifer	46
57	Hardwood	46
61	Undeveloped areas; sandbars	42

Figure 8. The permeability prioritization layer was derived from the land cover types.



Patch Size and Patch Density Weighted Patch Size

Tool name: 4. Create patches scored by size layer

Script name: 6. Calculate weighted patch size layer (run in Python interface)

Patch size is an important indicator of habitat quality as greater area is often negatively correlated with edge effects and positively correlated with increased habitat quality.

To capture the influence of patch size we developed two layers:

1) a simple layer of patch area in which patch areas were grouped and ranked (Table 9, Figure 9), and
2) a patch area layer that was weighted by the patch density in 5 km neighborhoods so that small patches in more urbanized environments were among the higher ranked patches in this prioritization layer (Figure 10)

$$Weighted\ Patch\ Size = \ln(PA * PD^2) \qquad \text{Equation 1.}$$

where *PA* is the patch area and *PD* is the neighborhood patch density. Patches in the largest 1% (i.e., the largest patches in the RCS area) were weighted equally regardless of patch density in this layer.

Table 9. Patch size categories used in the models.

Patch size (pixel count)	Scoring Value	Description
1 - 1	0	No value
1 - 404	0	No value
404 - 1212	1	Low value
1212 - 3236	8	Somewhat valuable
3236 - 16040	12	Moderately valuable
16040 - 40400	15	Good value
40400 - 1329586	18	Best value

To create the patch size layer:

1) Double-click on the “4. Create patches scored by size layer” tool.
2) Enter the appropriate data.
3) Set the current and scratch environments.

To create the patch density weighted patch size layer:

1) Right-click on the “6. Calculate weighted patch size layer (run in Python interface)” tool.
2) Choose the Edit menu option. An IDLE or other Python shell will open.
3) Alter the variables to point to your data in the script.
4) Save the script.
5) Run the script.

Or if the script has been parameterized to run as a GUI:

1) Double-click on the “6. Calculate weighted patch size layer” tool.
2) Enter the appropriate data.
3) Set the current and scratch environments.

Figure 9. Patch size category prioritization layer for the study area.

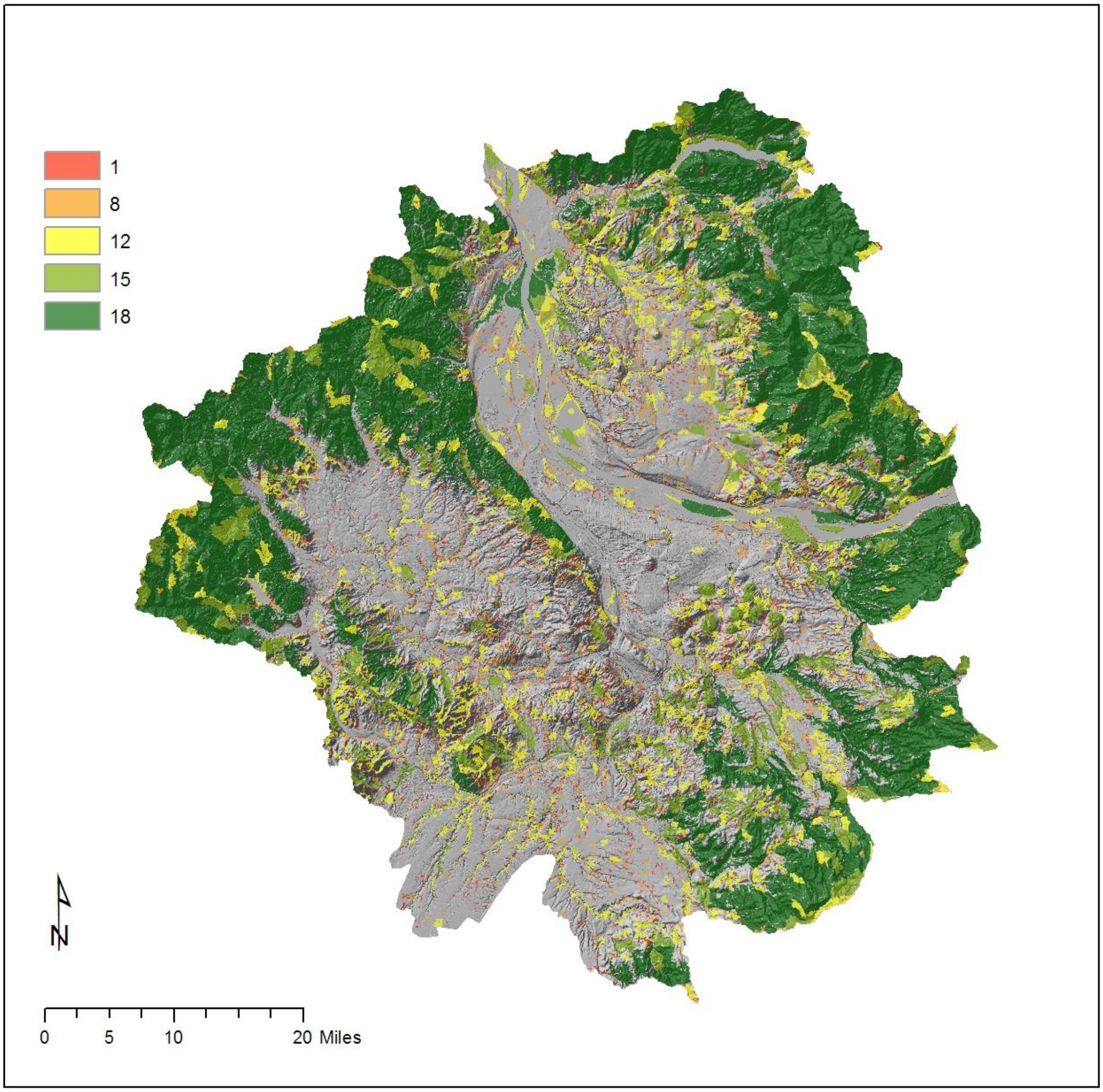
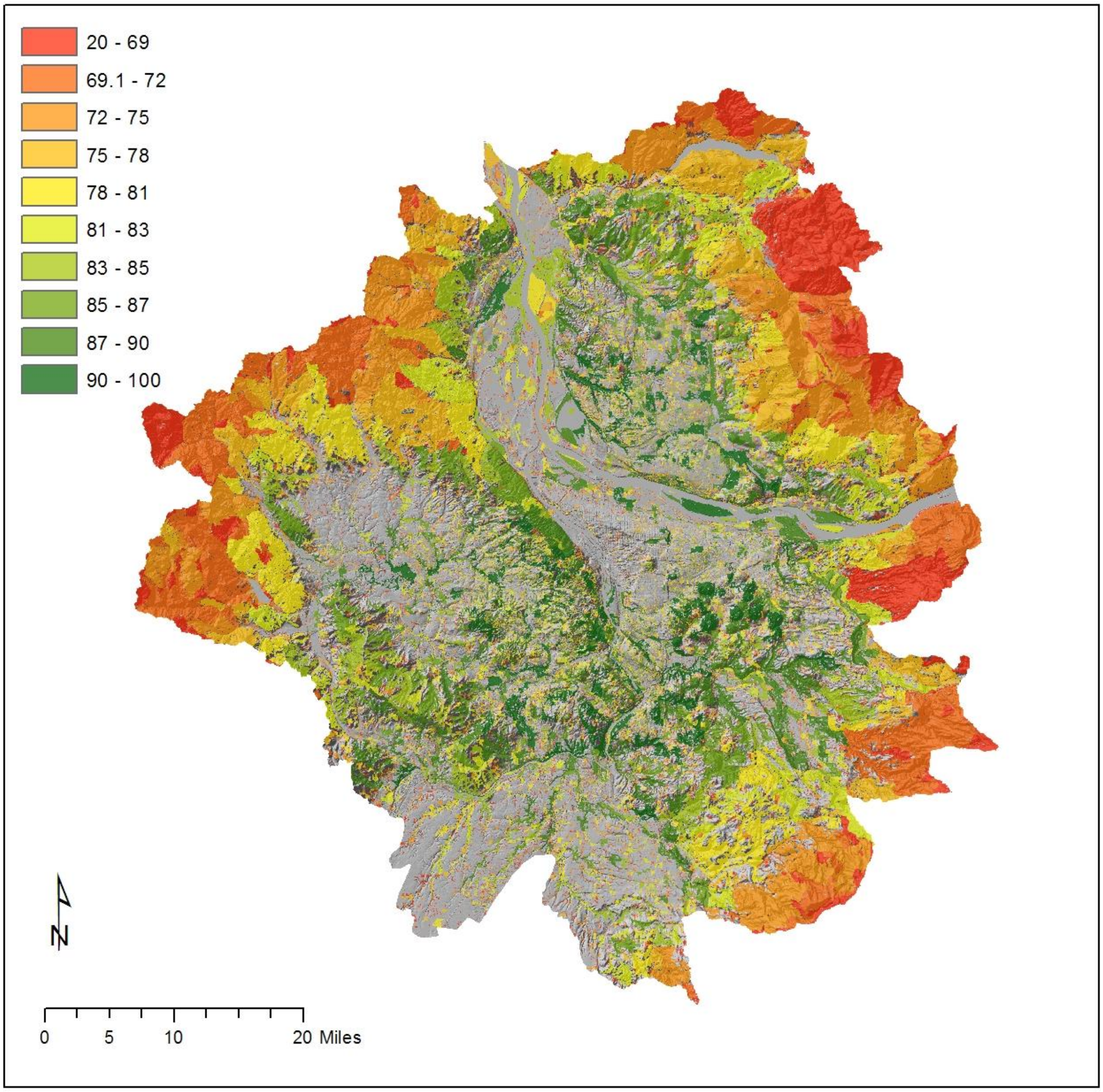


Figure 10. Patch density weighted patch size data input.



Wetlands and Wetland Buffers

Tool name: 7. Create scored wetlands layer

Wetlands are important landscape features highly valued for biodiversity conservation and the ecosystem services they provide. The work presented in this document emphasizes a conservation perspective and so wetlands and the land surrounding them were considered important. As with the roads influence layer, a distance function was used to identify the gradient between a wetland edge and neighboring land covers and land uses. We created distance classes and ranked the classes in terms of their importance for wetland function. The rankings for the distance classes provide a place where later implementations of the work can be modified using better data or alternative expert opinions.

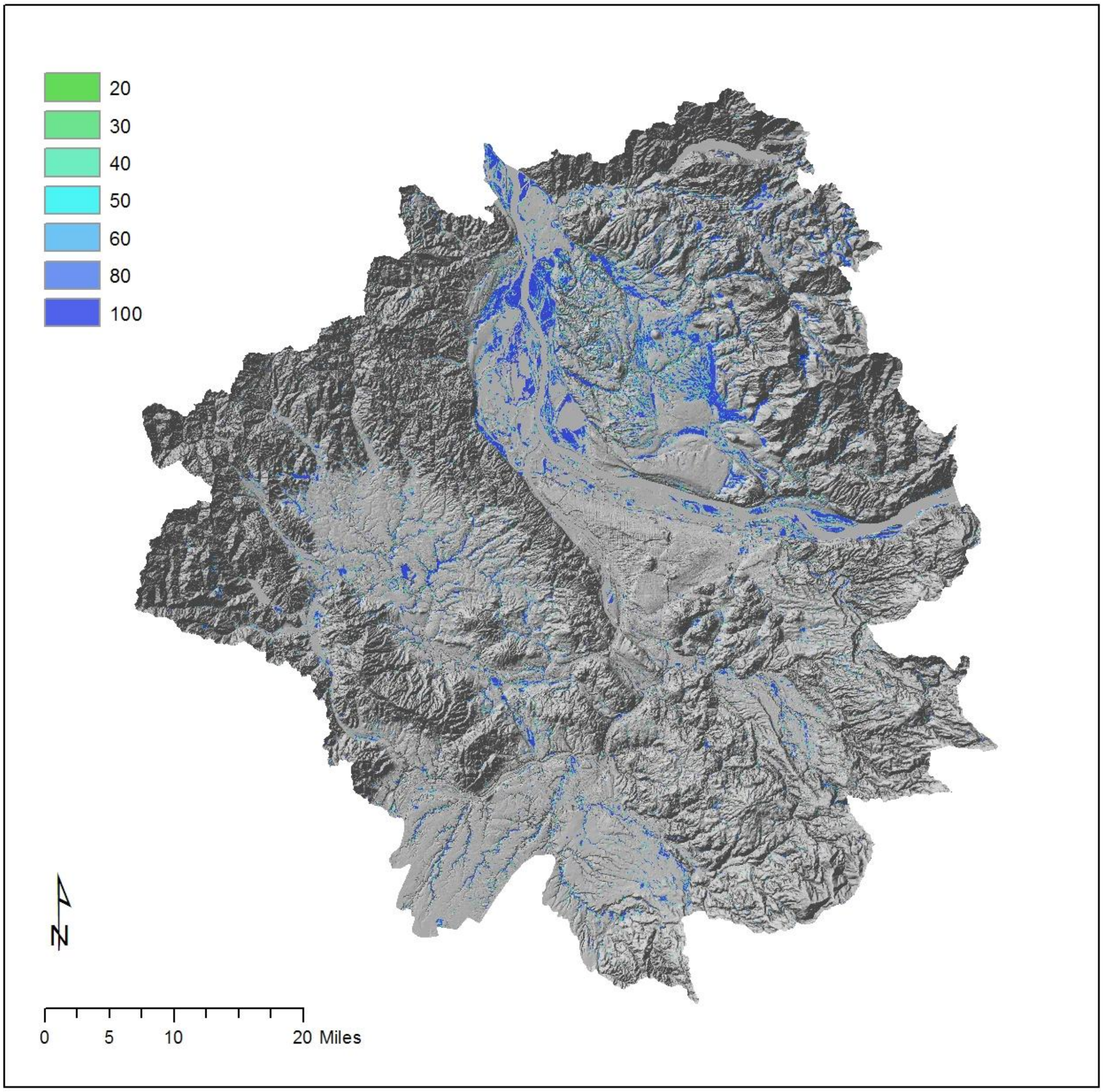
The wetlands prioritization layer was developed by:

1) Calculating the Euclidean distance from wetlands.
2) Assigning graduated ranking values away from wetlands up to 100 m from a wetland boundary (Table 10, Figure 11).

Table 10. Ranking values assigned to wetland buffer areas.

Distance (m)	Value	Description
0 - 1	100	Best value
1 - 6	80	
6 - 11	60	
11 - 16	50	
16 - 21	40	
21 - 26	30	
26 - 31	20	
> 31	0	No value

Figure 11. Wetlands and wetland buffers



Results

Tool name: 8a. Calculate Upland Metric Layer (single output) – this tool allows the user to alter the weights used to create a single output dataset in the user interface.

8b. Calculate Upland Metric Layer (multiple output) – this tool allows the user to alter weights for several output scenarios. To alter the weights, the user must “hard code” the weights in each Raster Calculator process within the tool. Weights and scenarios included as defaults are the weights and scenarios used to calculate outputs by INR.

The Upland metric score products are described in Table 11. Three permeability layers were examined for the final product: one layer was developed using a 3 x 3 focal smoothing filter, another was developed using a 5 x 5 focal smoothing filter, and a third was developed using a path cost distance analysis. The Upland metric ranges from -9 – 100 where 9 is the lowest score and 100 is the highest or best score. Prioritization layers used in the Upland metric results were designed to fit within a 0 -100 scale.

Table 11. Upland metric score products.

	Input layers								
	Alternate permeability layers								
	Friction_focal3	**Friction_focal5**	**rsc_Permeability_int_C**	**Hydric soils Rcls_HydrSoils**	**Patch density weighted patch size rscpat_5_99a**	**Wetlands rcls_wetlands**	**Interior habitat rcls_interiors**	**PatchSize**	**Influence of roads rsmp_rcl_ROADS_b**
Weight	1	1	1	1	0.2	0.07	0.06	1	1
Output layers UPLAND_SOILS_A	x			x	x	x	x	x	
UPLAND_SOILS_B		x		x	x	x	x	x	
UPLAND_SOILS_C			x	x	x	x	x	x	
UPLAND_SOILS_D	x			x	x	x	x	x	x
UPLAND_SOILS_E		x		x	x	x	x	x	X

Riparian Metric

Riparian areas have been strongly influenced by urbanization and development. These habitat types are sensitive because they are strongly dependent on fluctuations in water levels and flooding intensities and prone to erosion in urbanized areas due to increased surface runoff resulting from hydrologic modifications by humans and impervious surfaces, among a suite of other factors. To capture the conservation importance of riparian areas we included four prioritization layers: FEMA 100-year floodplains, National Hydrography Dataset (NHD) stream buffers, other stream buffers, and wetland buffers (Figure 12). The Riparian metric ranges from 0 – 100 where 0 is the lowest score and 100 is the highest or best score. The Riparian metric results were transformed to the 0 – 100 scale using a maximum normalization algorithm.

The general steps for developing the prioritization layers for this metric and the final metric are:

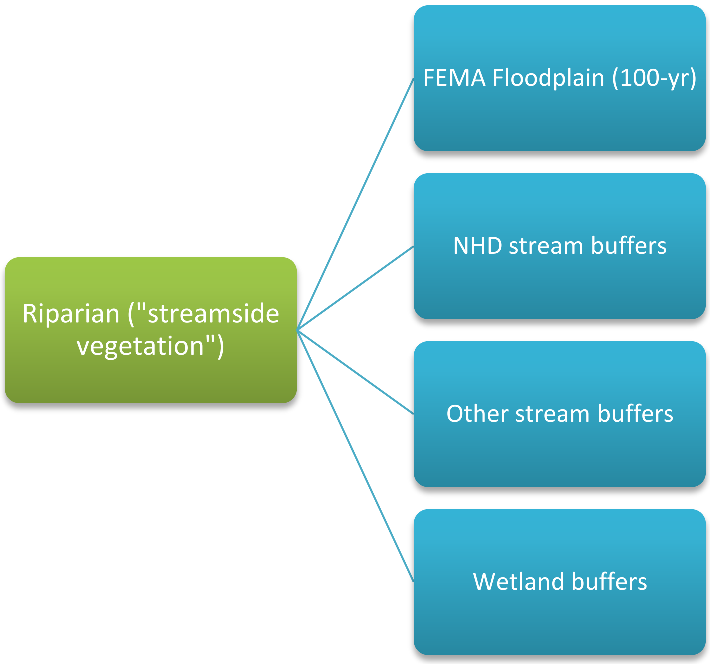
1) Run the model “1. Calculate prioritized stream score” to generate and populate the stream score field called “Srm_pref” for NHD flowlines.
2) Run the model “2. Create Curve layer” to develop a curve number layer representing surface runoff potential as a function of land cover type.

3) Run the model "3a. Create AOI buffers for NHD waters" to identify the riparian areas for NHD prioritization layers and "3b. Create AOI buffers for other waters" to identify the riparian areas for other water feature prioritization layers (e.g., DoGAMI) based on the ranking schema. NHD data riparian areas are determined using the prioritized stream score

   Note: NHD data processing takes just under 27 minutes to run on the full RCS data set.

4) Create layers that represent the combination of curve and cost distance values away from the prioritization layer features as a function of elevation using the model "4a. Create CostCurve layer (single data set)" or "4b. Create CostCurve layers (multiple data sets & scenarios)."
5) Clip the cost-curve raster for each prioritization layer to each data input's area of interest buffer using the tool "5. Clip CostCurve to riparian buffers."
6) Run the model "6. Calculate Riparian Metric (weighted score)" to perform a weighted sum overlay of the four prioritization layers.
7) Review and revise the weighting schemes.

Figure 12. Organization of the Riparian metric.



FEMA 100-year Floodplains

Tool name: 4a. Create CostCurve layer (single data set)/4b. Create CostCurve layers (multipler data sets & scenarios), 5. Clip CostCurve to riparian buffers, and 6. Calculate Riparian Metric (weighted score)

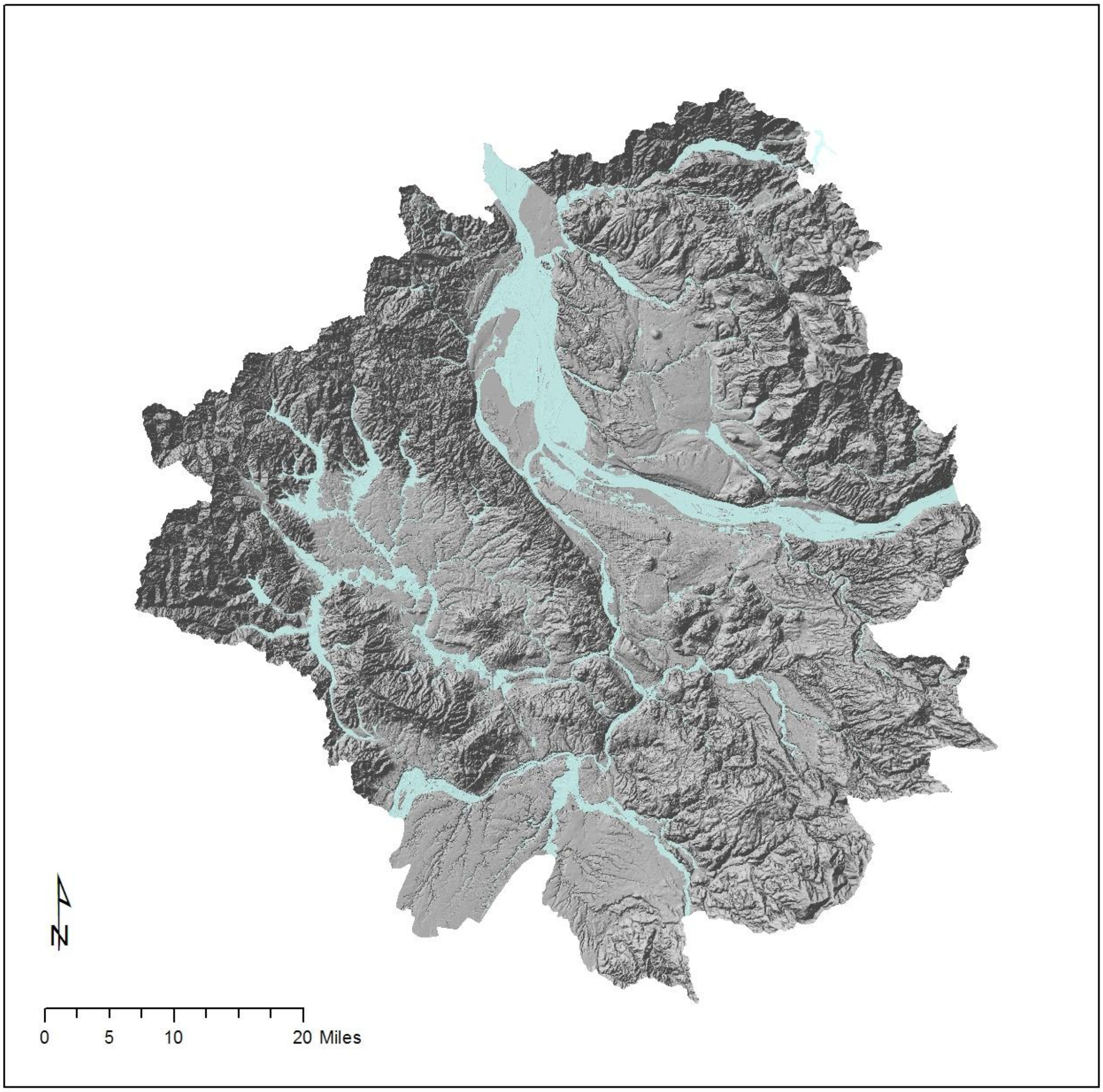
FEMA 100-year floodplains provide information on the presence of riparian habitats. This data set was essentially used in its original form in contrast to the other prioritization layers to the riparian metric. No buffer was created for this layer.

To use this data set:

1) Create layer that represents the combination of curve and cost distance values away from floodplain boundaries as a function of elevation using the model "4a. Create CostCurve layer (single data set)" or "4b. Create CostCurve layers (multipler data sets & scenarios)."
2) Clip the cost-curve raster for floodplains to the floodplain boundary (instead of the floodplain buffer, as was done for the other riparian metric prioritization layers.) [5]

[5] Note: resulting layer provides curve values within floodplain boundaries only.

Figure 13. FEMA 100-year floodplains for the study area.



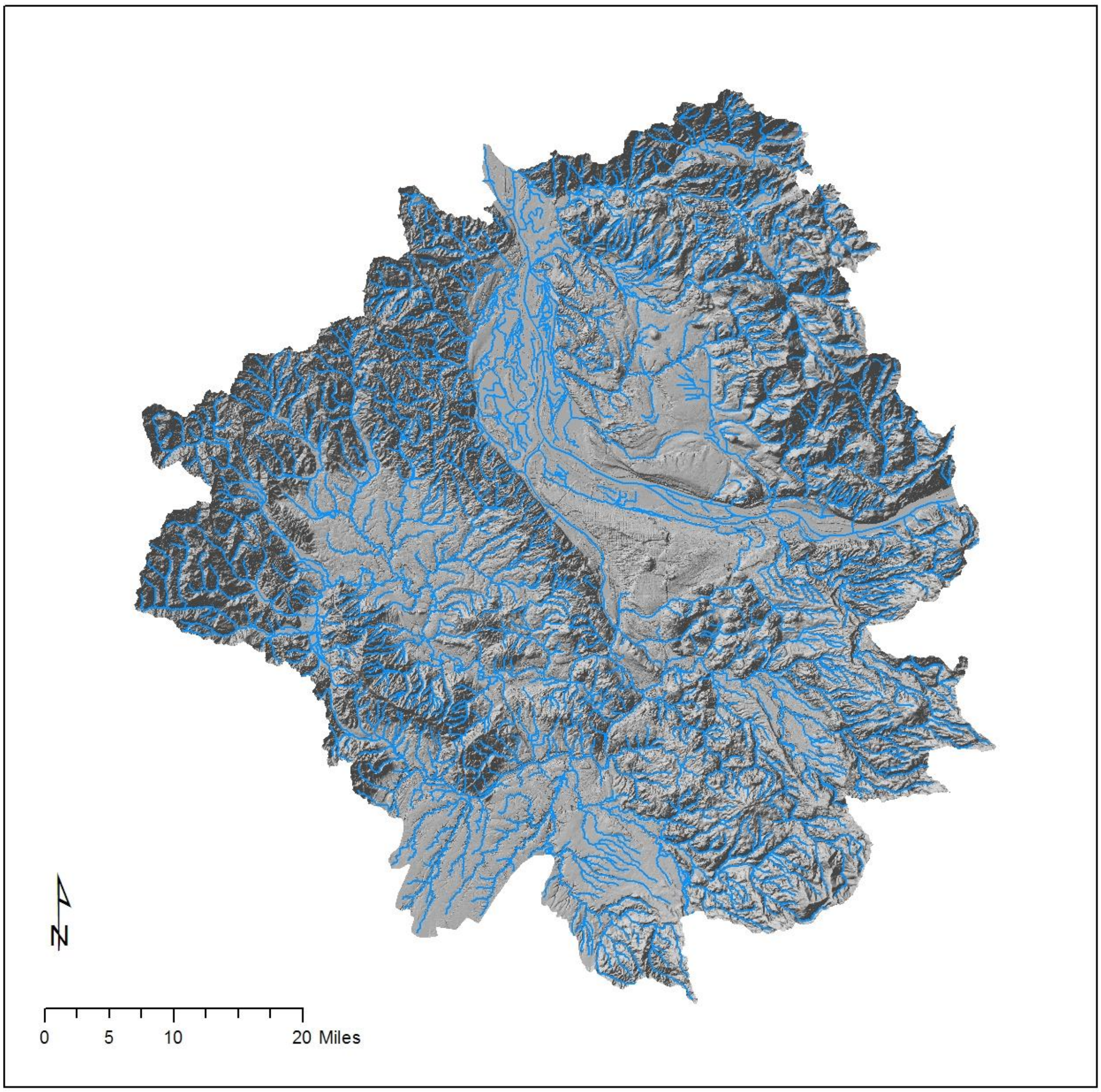
National Hydrography Dataset Stream Buffers

Tool names: 1. Calculate prioritized stream score, , 3a. Create AOI buffers for NHD waters, 4a. Create CostCurve layer (single data set)/4b. Create CostCurve layers (multiple data sets & scenarios), 5. Clip CostCurve to riparian buffers

To create this data set:

1) Run the model “1. Calculate prioritized stream score” to determine stream rankings based on fish species richness, flow velocity, and flow volume.
2) Run the model “3a. Create AOI buffers for NHD waters” to create buffers for the NHD stream layer based on the prioritized stream score determined in step 1.
3) Create layers that represent the combination of curve and cost distance values away from stream sides as a function of elevation using the model “4a. Create CostCurve layer (single data set)/4b. Create CostCurve layers (multipler data sets & scenarios)”
4) Clip the cost-curve raster for NHD streams to the area of interest buffer for NHD created in step 3 using “5. Clip CostCurve to riparian buffers.”

Figure 14. NHD streams prioritized based on fish habitats, fish species richness, stream flow and velocity.



Other Stream Buffers

Tool names: 3b. Create AOI buffers for other waters, 4a. Create CostCurve layer (single data set)/4b. Create CostCurve layers (multipler data sets & scenarios), and 5. Clip CostCurve to riparian buffers

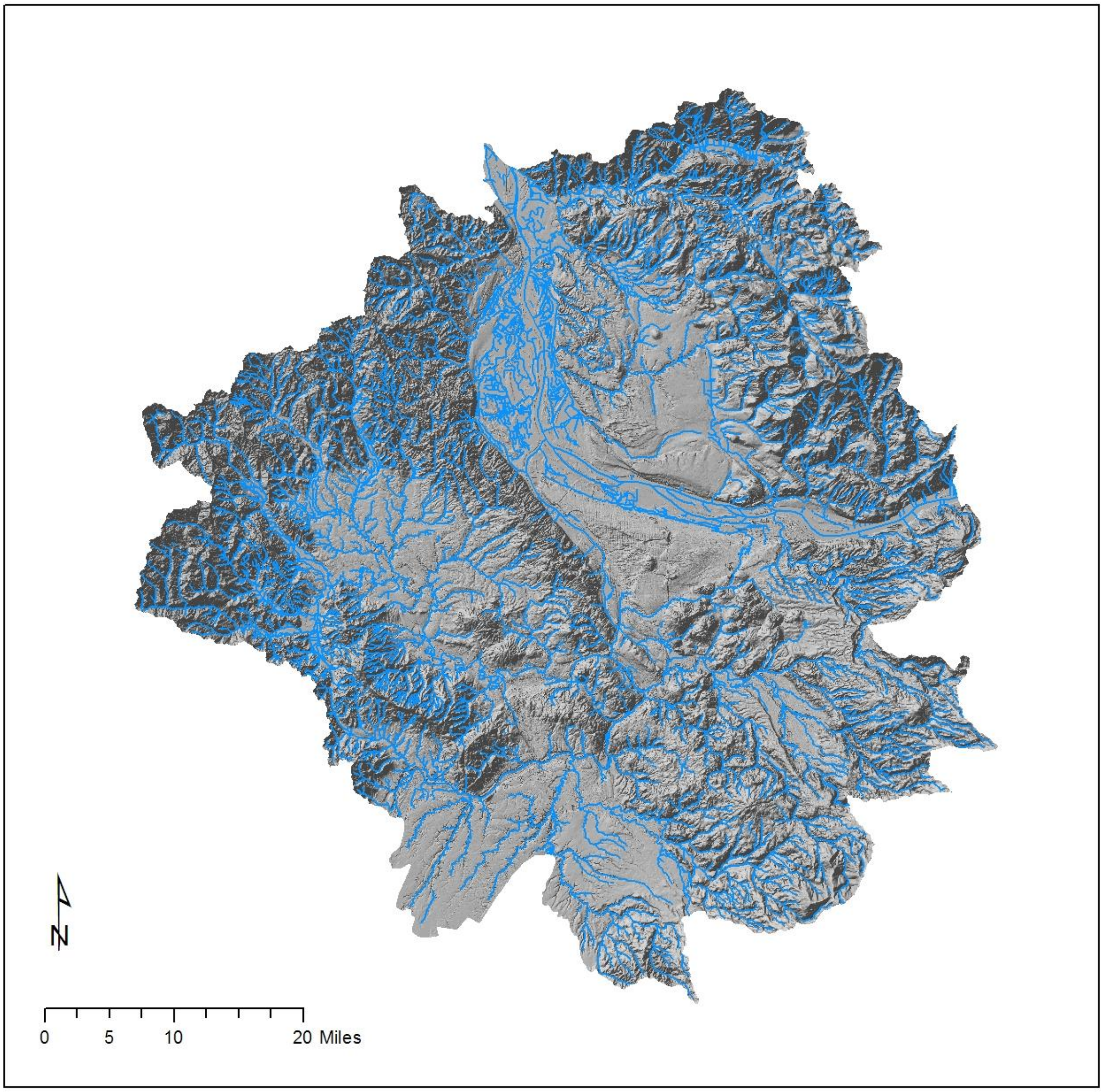
1) Assemble this supplemental stream layer from a variety of sources.
2) Run the model "3b. Create AOI buffers for other waters" to create buffers[6].
3) Create layers that represent the combination of curve and cost distance values away from stream sides as a function of elevation using the model "4a. Create CostCurve layer (single data set)" or "4b. Create CostCurve layers (multipler data sets & scenarios)."
4) Clip the cost-curve raster for other streams to the area of interest buffer created in step 2 using "5. Clip CostCurve to riparian buffers."

Table 12. Buffer distances were based on the stream types.

Stream Type	Buffer Distance (m)
B25 - canal	15
B100 - artificial paths - streams	30
B200 - artificial paths large rivers	30
B75 - artificial paths - no name	30
B150 - perennial streams	50
B150 - perennial streams - no names	50

[6] Note: wetland buffers are created simultaneously with this tool.

Figure 15. Other streams considered for the study area. Department of Geology and Mines (DoGAMI) streams data were the primary source for this layer.



Wetland Buffers

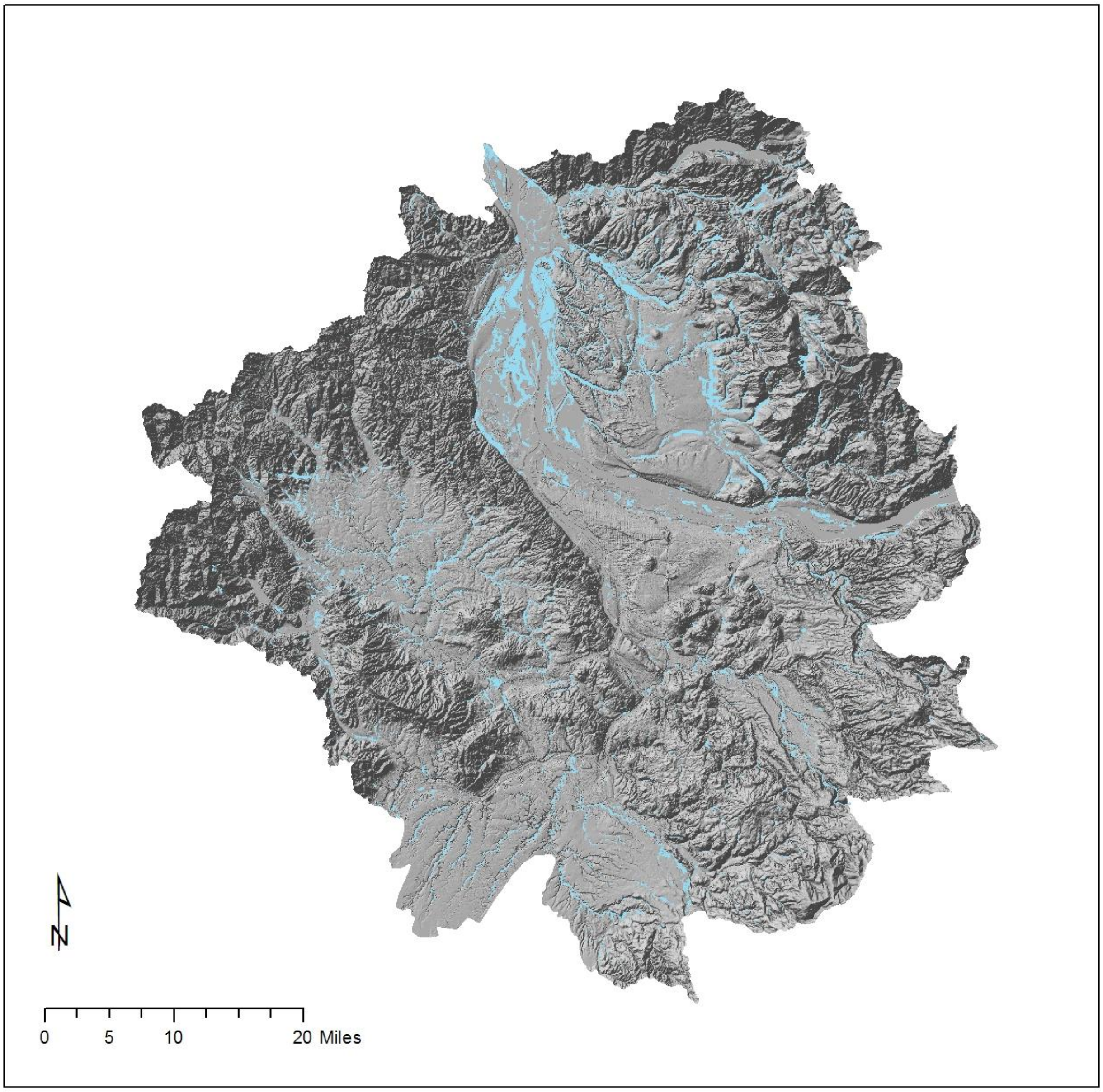
Model names: 3b. Create AOI buffers for other waters, 4a. Create CostCurve layer (single data set)/4b. Create CostCurve layers (multipler data sets & scenarios), and 5. Clip CostCurve to riparian buffers

A subset of the wetlands layer used for the Upland metric (Figure 11) was used as the base data for this step (Figure 16). To develop the wetlands prioritization layer to the Riparian metric, you must:

1) Run the model “3b. Create AOI buffers for other waters” to create buffers based on distance from wetland (Table 10).
2) Create layers that represent the combination of curve and cost distance values away from wetland boundaries as a function of elevation using the model “4a. Create CostCurve layer (single data set)/4b. Create CostCurve layers (multipler data sets & scenarios).”
3) Clip the cost-curve raster for wetlands to the area of interest buffer created in step 1 using “5. Clip CostCurve to riparian buffers.”[7]

[7] Note: the wetlands prioritization layer is created simultaneously with the other stream buffers prioritization layer.

Figure 16. Subset of wetlands used in the Riparian metric. These wetlands were within 200 m of the "other streams" layer.



Results

Tool names: 6. Calculate Riparian Metric (weighted score); Finalize Riparian Model: tools used to mask water pixels and normalize the final data sets from 0 – 100.

Riparian score products are described in Table 13.

Table 13. Riparian score products

Prioritization layer	Description	Weight Scenarios & Identifiers				
		1	2	3	4	5
NHD stream buffers	Buffer distances come from prioritized stream score (Field name: Srm_pref)	0.5	0.45	0.4	0.35	0.175
Other stream buffers	Combination of DoGAMI (2012) streams data and NHD "enhanced" streams, provided by Metro	0.15	0.15	0.2	0.2	0.3
FEMA floodplains, 100 year	100 year floodplains, provided by Metro	0.2	0.25	0.2	0.25	0.4
Wetland buffers 30m, close to streams	Wetlands within 200 m of streams	0.15	0.15	0.2	0.2	0.125

2.3 Combined Metric Results: High-value Habitat (HVH)

Tool name: Weighted Sum in the Spatial Analyst Tools > Overlay toolset[8]

To create the final HVH layer:

1) Double-click the Weighted Sum tool.
2) Change the current and scratch workspaces as desired in the model properties.
3) Enter the desired input and output layer names.
4) Enter the desired weights.
5) Run the model.
6) Normalize model output using the "Min-Max Normalization Tool" if data ranges from negative to positive values or the "Max Normalization Tool" if data values are entirely positive or if you want to retain the true minimum value. For this project, the HVH was normalized using the "Min-Max Normalization Tool."

Table 14. Prioritization layers and weights used to calculate the High-value Habitat layer.

Prioritization layer	Description	Weights
Upland_Soils_E	Buffer distances come from Stream Preference Score (SPS)	0.75
Riparian_1_05	combination of DoGAMI (2012) and NHD "enhanced" streams	0.25

3 References Cited

Coffin, A. W. 2007. From roadkill to road ecology: A review of the ecological effects of roads. Journal of Transport Geography 15:396-406.

ESRI. 1999-2010. ArcGIS Desktop 10 Service Pack 4. Redlands, CA.

Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture. Soil Survey Geographic (SSURGO) Database for The Intertwine, Oregon and Washington]. Available online at http://soildatamart.nrcs.usda.gov. Accessed May 8, 2012.

[8] A stand alone tool was not necessary for this step of the analysis.

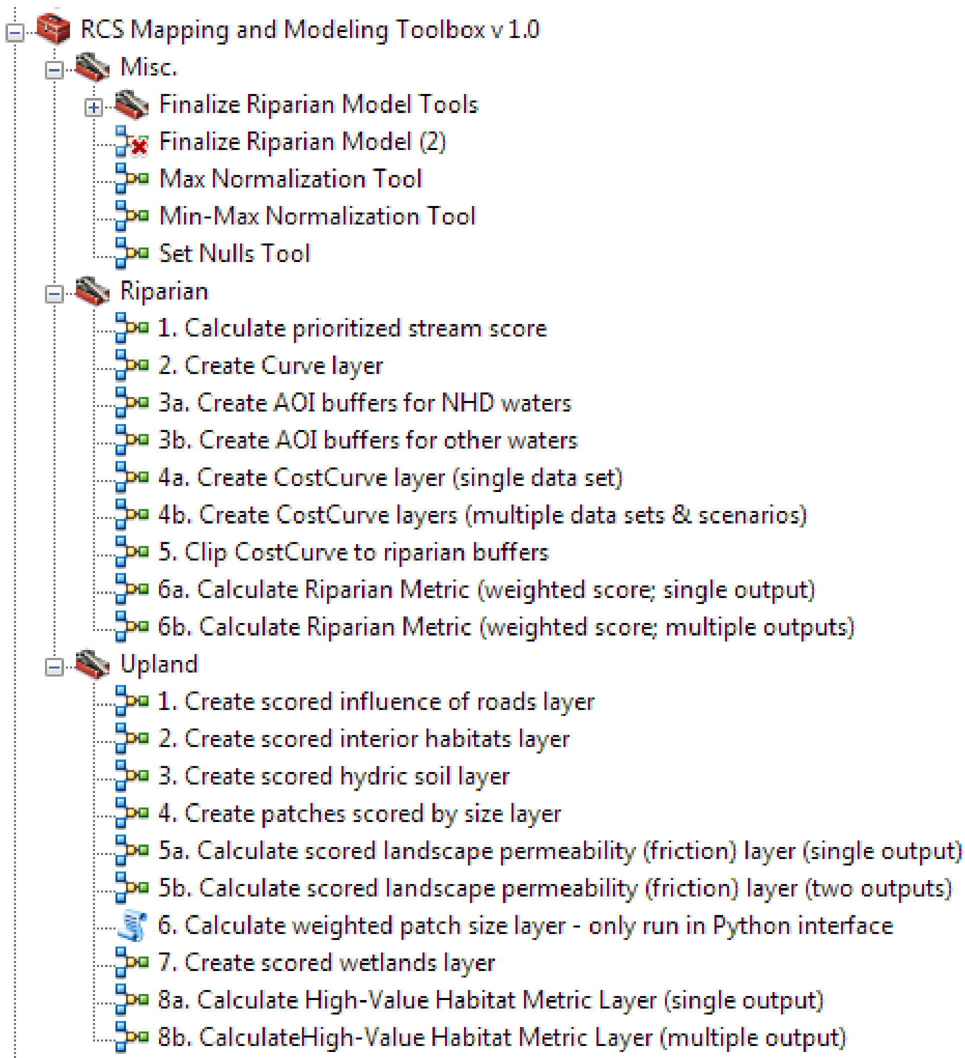
4 Appendices

4.1 Appendix A. Toolboxes

Next actions: update the toolbox diagrams after the toolboxes have been finalized

A single toolbox was developed for this revision of the modeling called the "RCS Mapping and Modeling Toolbox v 1.0." Tool descriptions can be found in the Tool Properties or viewed in ArcCatalog.

Figure 17. The RCS Conservation Area Modeling Toolbox.



4.2 Quick Reference

Table 15. UPLAND (Upland) metric score products.

Output layers	Friction_focal3	Friction_focal5	rsc_Permeability_int_	Rcls_HydrSoils	rscpat_5_99a	rcls_wetlands	rcls_interiors	PatchSize	rsmp_rcl_ROADS_b
	Input layers								
UPLAND_SOILS_A	x			x	x	x	x	x	
UPLAND_SOILS_B		x		x	x	x	x	x	
UPLAND_SOILS_C			x	x	x	x	x	x	
UPLAND_SOILS_D	x			x	x	x	x	x	x
UPLAND_SOILS_E		x		x	x	x	x	x	x

Table 16. Riparian score products

Prioritization layer	Description	Weight Scenarios & Identifiers				
		1	2	3	4	5
NHD stream buffers	Buffer distances come from prioritized stream score (Field name: Srm_pref)	0.5	0.45	0.4	0.35	0.175
Other stream buffers	Combination of DoGAMI (2012) streams data and NHD "enhanced" streams, provided by Metro	0.15	0.15	0.2	0.2	0.3
FEMA floodplains, 100 year	100 year floodplains, provided by Metro	0.2	0.25	0.2	0.25	0.4
Wetland buffers 30m, close to streams	Wetlands within 200 m of streams	0.15	0.15	0.2	0.2	0.125

4.3 Appendix B. Uncertainty and Sensitivity Analysis

Land Cover

Visual assessment of the land cover layer by analysts and clients led Metro to take on the task of revising the layer to separate agriculture from low-stature vegetation and improve resolution of impervious surfaces using ancillary datasets. A two-stage accuracy assessment was carried out on the resulting layer. The first stage was an overall accuracy assessment across the full Regional Conservation Strategy project area. The second stage was a more intensive assessment of urban locations. Analyses of the assessment locations were carried out to yield accuracy measures in four formats (Table 17). The first two analyses were for stage 1 and stage 2 assessments. The third analysis combined the stage 1 and 2 assessment points. Finally, in a fourth analysis, agriculture and short vegetation classes were combined to understand the impact of confusion between those two classes on the combined stage 1 and stage 2 accuracy levels. Overall accuracy (kappa; Eq. 1) was determined from the final analysis to be 93.5%.

Table 17. Accuracy assessment results are presented for the four analyses. (a) is for the stage 1, (b) is for stage 2, (c) contains the combined stage 1 and 2 results, and (d) contains the fourth analysis in which agriculture and short vegetation were combined into a single assessment class.

(a)

Stage 1 Initial Overall Assessment									
	Ground reference								
Mapped class	woody (13-30')	clearcut	trees > 30'	short vegetation	agriculture	water	**Grand Total**	*Total*	*User's AA*
woody (13-30')	100						100	100	1.00
clearcut		99	1				100	99	0.99
trees > 30'	2		93	2			97	93	0.96
short vegetation	2			97		1	100	97	0.97
agriculture			4	1	97		102	97	0.95
Grand Total	**104**	**99**	**98**	**100**	**97**	**1**	**499**		
Total correct	100	99	93	97	97				
Producer's AA	0.96	1.00	0.95	0.97	1.00	0.00		overall AA	0.97

(b)

Stage 2 Urban Intensive Assessment									
	Ground reference								
Mapped class	woody (13-30')	trees > 30'	short vegetation	agriculture	impervious	water	**Grand Total**	*Total*	*User's AA*
woody (13-30')	21	6		4			31	*21*	*0.68*
trees > 30'	3	31	1	3			38	*31*	*0.82*
short vegetation	1		29	3			33	*29*	*0.88*
agriculture	1			28		1	30	*28*	*0.93*
impervious	1	1	6	3	116	3	130	*116*	*0.89*
water	1					129	130	*129*	*0.99*
Grand Total	**28**	**38**	**36**	**41**	**116**	**133**	**392**		
Total correct	21	31	29	28	116	129			
Producer's AA	0.75	0.82	0.81	0.68	1.00	0.97		overall AA	0.90

(c)

Stage 1 and 2 Combined Assessment										
	Ground reference									
Mapped class	woody (13-30')	clearcut	trees > 30'	short vegetation	agriculture	impervious	water	**Grand Total**	*Total*	*User's AA*
woody (13-30')	121		6		4			131	121	0.92
clearcut		99	1					100	99	0.99
trees > 30'	5		124	3	3			135	124	0.92
short vegetation	3			126	3		1	133	126	0.95
agriculture	1		4	1	125		1	132	125	0.95
impervious	1		1	6	3	116	3	130	116	0.89
water	1						129	130	129	0.99
Grand Total	**132**	**99**	**136**	**136**	**138**	**116**	**134**	**891**		
Total correct	121	99	124	126	125	116	129			
Producer's AA	0.92	1.00	0.91	0.93	0.91	1.00	0.96		overall AA	0.943

(d)

Stage 1 and 2 Alternative Scenario									
	Ground reference								
Mapped class	woody (13-30')	clearcut	trees > 30'	short vegetation	impervious	water	**Grand Total**	*Total*	*User's AA*
woody (13-30')	121		6	4			131	121	0.92
clearcut		99	1				100	99	0.99
trees > 30'	5		124	6			135	124	0.92
short vegetation	4		4	255		2	265	255	0.96
impervious	1		1	9	116	3	130	116	0.89
water	1					129	130	129	0.99
Grand Total	**132**	**99**	**136**	**274**	**116**	**134**	**891**		
Total correct	121	99	124	255	116	129			
Producer's AA	0.92	1.00	0.91	0.93	1.00	0.96		overall AA	0.947

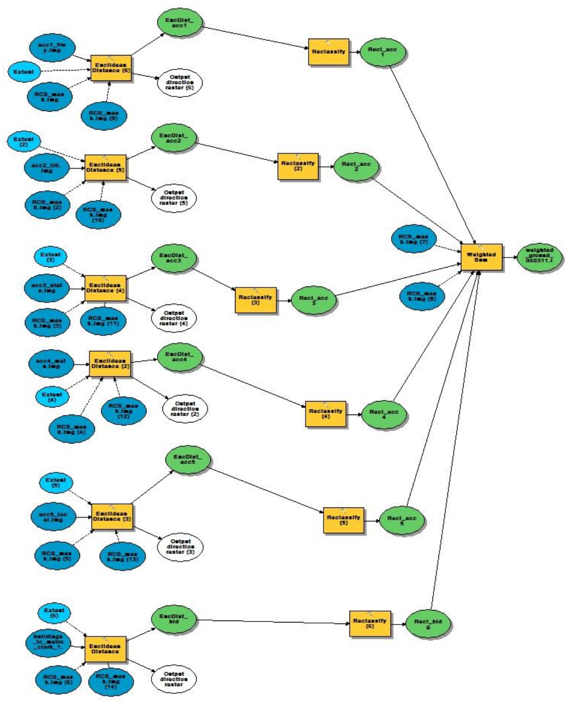
kappa = (Observed Accuracy - Expected Accuracy) / (1 - Expected Accuracy) **Eq. 1**

Influence of roads

For the current RCS effort two additional means for including road influence were explored to find the simplest acceptable solution. In the first method, the influence of roads was identified as the "ground condition" prioritization layer in the original modeling project. Distance to road classes were ranked based on their impact to wildlife. The second technique simplified the process so that roads were buffered with a single distance based on the road type. Each road type had a prioritization ranking value rather than a gradient of ranking values as in the first method. Ranking values were determined by the clients. Qualitative assessments determined that the simpler road influence model would facilitate error assessments and understanding of the project products in the future.

Distance to roads and buildings, gradient method (Method 1 – not used in final product)

Roads were associated with a wide range of disturbances to wildlife including noise, light, and of course, moving vehicles. Dwellings and other buildings also influence wildlife behavior. Most studies have examined rural development effects. For this analysis, the Euclidean distance to five road distinct types and all buildings were developed individually. For each road type, we determined distance classes with heavy input from the client and ranked each distance class in terms of its negative influence on wildlife. For example, large roads were considered to be influential over greater distances than small roads. The six layers were combined using a weighted sum to represent distance to roads or *road influence*.



Distance to roads and buildings, single buffer method (Method 2 – adopted)

In this revision of the models, the road influence layer ranking values ranged from 4 – 9 (Table 18). Ranking values were based on road type and were considered to be a negative benefit (influence) on habitat. The influence of roads layer was subtracted from positivie benefit prioritization layers in the final overlay process.

Table 18. Ranking values assigned to road types in the study area.

FCC	Description	ROADCLASS	RENDERCL	RendrBuff	RankingValue
A40	Local, neighborhood, and rural road	4	4	10	4
A41	Local, neighborhood, and rural road	4	4	10	4
A43	Local, neighborhood, and rural road	4	4	10	4
A45	Local, neighborhood, and rural road	4	4	10	4
A48	Local, neighborhood, and rural road	4	4	10	4
A50	Vehicular trail (unpaved)	4	4	10	4
A51	Vehicular trail (unpaved)	4	4	10	4
A61	Cul-de-sac	5	4	10	4
A30	State and county highways	3	3	15	6
A31	State and county highways	3	3	15	6
A33	State and county highways	3	3	15	6

FCC	Description	ROADCLASS	RENDERCL	RendrBuff	RankingValue
A35	State and county highways	3	3	15	6
A37	State and county highways	3	3	15	6
A38	State and county highways	3	3	15	6
A60	Road with characteristic unspecified, major category used alone when the minor category could not be determined	6	5	15	6
A62	Traffic circle	7	5	15	6
A63	Access ramp	6	5	15	6
A64	Service drive	5	5	15	6
A20	U.S. and state highway	2	2	20	8
A21	U.S. and state highway	2	2	20	8
A25	U.S. and state highway	2	2	20	8
A26	U.S. and state highway	2	2	20	8
A15	Primary highway with limited access or interstate	1	1	25	9
A16	Primary highway with limited access or interstate	1	1	25	9
A17	Primary highway with limited access or interstate	1	1	25	9

Landscape permeability

Landscape permeability represents the ability of wildlife to travel through a land cover type. We attempted to represent landscape permeability using two layers initially: the natural habitat layer and habitat resistance layer to represent the ease with which wildlife could cross land cover types to get to natural habitat patches. The landscape permeability layer was ultimately omitted from the final product analysis due to complexities in the modeling process that were not easily explained to a lay audience, unsatisfactory results in the input data sets, and the need for a simpler solution. Uncertainty analyses and their context are explained below.

Permeability prioritization layer

Permeability was determined using a cost distance function in which natural habitat patches and habitat resistances (Table 19) were combined. Cost distance in GIS is typically used to identify the distance between spatial features on the landscape as a function of real distance and another spatial variable. In our case, we estimated permeability as the distance between patches weighted by the resistance exerted by each habitat type. Ultimately, this process of determining permeability was scrapped as it resulted in uniformly permeable patches; agriculture and other land covers that are known to be crossable by wildlife were not represented as impermeable; and gaps of non-natural habitat within larger patches of natural habitat were represented as not permeable. Furthermore, the values of resistance were determined by expert opinion and a simpler more transparent solution was desired. Ultimately the permeability layer was replaced with a simple layer of “habitat friction” that represented the ease with which wildlife could cross land cover types. Friction values were linked to the level 2 classification rather than the level 1 classification used with the permeability layer.

Table 19. LUT for level 1 land cover classes to resistance values used to determine the permeability layer.

ClassID	Class Name	Resistance
1	Open water	8
2	Paved	500
4	Buildings	1000
5	Herbaceous I - Low sparse veg (0 - 2 ft.)	7.5
7	Herbaceous II - Low vegetation (2 - 7 ft.)	3.5
9	Conifers (30-120 ft.)	2
11	Conifers (over 120 ft.)	1
13	Large shrub/small trees (7 - 30 ft.)	2.5
14	Broadleaf (over 30 ft.)	2
17	Clear cuts	3
26	Agriculture	5
55	Mixed forest from low resolution (non-LiDAR) areas	2
56	Conifers from low resolution (non-LiDAR) areas	1.5
57	Hardwoods forest from low resolution (non-LiDAR) areas	2
61	Sand bars	2

Natural habitat layer

Natural habitat patches were developed to represent terrestrial upland habitats. The natural habitat layer for permeability was created from the level 2 land cover data set. The land cover data set was reclassified to a binary classification system representing “natural” and “other” habitat types (Table 21). The major waterbodies and roads were removed from the layer, and patches were enumerated using the Region Group function. Patches under 1 acre (162 pixels, 5 x 5 m) in size were omitted to decrease processing time and facilitate a more varied permeability layer in subsequent steps, at the request of the client. Extensive qualitative assessments were made of the natural habitat layer and the steps used to develop it; these are discussed below.

Habitat resistance layer

The habitat resistance information was determined by expert classification of land cover classes. Habitat resistance values ranged from 0 - 1000. Low resistance land covers had low resistance values and represented land cover classes that were considered to be highly permeable or easily crossed by wildlife. Land cover classes that were considered to be difficult to cross or barriers to wildlife movement received high resistance values; roads were assigned the highest resistance values (Table 19). Major waterbodies and roads were masked and removed from the habitat resistance layer as well.

Uncertainty Analysis of Natural Patches Classification

The project was initially designed to produce a single natural patches layer that would be used as a base data set. Ultimately, however, several versions of natural habitat patches were developed and used in the development of different draft and final prioritization layers. One version included wetlands as part of the natural habitat patches, while one included sparse vegetation classes, and the last did not include sparse vegetation as natural habitat (Table 20). All versions used the level 2 land cover layer and all were masked using a roads and major waterbodies layer.

Table 20. Several natural habitat layers were developed depending on the prioritization layer being developed. Differences were attributable to the inclusion or omission of wetlands and sparse vegetation types. Dots identify the classification used for the prioritization layer listed on the left.

Prioritization layer	Classification scheme		
	Wetlands included as natural habitat	*Low, sparse vegetation included as natural habitat (e.g., herbaceous) "alternate"*	*Tall, woody vegetation-focus (e.g., conifers, tall shrubs); low sparse vegetation not included as natural habitat "main"*
Permeability			●
Weighted patch size*	●	●	●
Interior habitat	●		●

* Several natural patches layers were developed for the weighted patch size prioritization layer because it was assessed under all classification schemes.

To conduct the assessment, the land cover layer (level 2 classification) was crosswalked to natural habitat using a look-up table. Two natural habitat formation scenarios were used, "main" analysis and "alternate" analysis. Water classes were classified as natural, wetlands from an ancillary data source were included as natural habitat, and a mask applied to remove roads and major waterbodies. An initial version of the interior habitat prioritization layer was created using the main analysis scenario natural patches data set and included only forest habitat as natural habitat. Visual assessments of over 16 data sets were used to identify the most suitable assignment of land cover classes to the natural habitat class.

We examined the distribution of patch sizes to determine a cut-off for removing the smallest patches. Patch size distribution was heavily skewed to smaller patches. For the uncertainty assessment, we dropped all patches below the 95th percentile (156 – 5 x 5 m pixels) or 1 acre (162 – 5 x 5 m pixels). Ultimately, the results of the alternate classification scheme were favored and used to construct natural habitat patch layers for the patch-density weighted patch size prioritization layer.

Table 21. Level 2 land cover classes were grouped into "natural" and "other" habitat types as part of the uncertainty analysis.

Level 2	Short land cover description	Classification scheme		
		Main classification	*Alternative classification*	*Interior habitat classification*
1	Water	other	other	other
2	Paved, built small	other	other	other
3	Buildings (burned in), built medium	other	other	other
4	Buildings (detected), built tall	other	other	other
5	Herbaceous, low, inside UGB	other	natural	other
6	Herbaceous, medium, inside UGB	other	natural	other
7	Herbaceous, high, inside UGB	other	natural	other
8	Conifers, small	natural	natural	natural
9	Conifers, medium	natural	natural	natural
10	Conifers, medium - tall	natural	natural	natural
11	Conifers, tall	natural	natural	natural
12	Conifers, very tall	natural	natural	natural
13	Hardwood, small	natural	natural	natural
14	Hardwood, medium	natural	natural	natural
15	Hardwood, medium-tall	natural	natural	natural
16	Hardwood, tall	natural	natural	natural

17	Clear cuts, oldest	natural	natural	natural
18	Clear cuts, 2006-2008	natural	natural	natural
19	Partial cuts, 2006-2008	natural	natural	natural
20	Clear cuts, 2008-2010	natural	natural	natural
21	Partial cuts, 2008-2010	natural	natural	natural
22	Reclassified to herbaceous, low, from developed	natural	natural	other
26	Agriculture, reclassified (inside UGB)	other	other	other
27	Herbaceous, low, outside UGB	other	natural	other
28	Herbaceous, medium, outside UGB	other	natural	other
29	Herbaceous, high, outside UGB	other	natural	other
36	Agriculture, digitized (outside UGB)	other	other	other
40	Agriculture, digitized (outside UGB)	other	other	other
41	Digitized clear cuts	natural	natural	natural
55	Mixed forest	natural	natural	natural
56	Conifer	natural	natural	natural
57	Hardwood	natural	natural	natural
61	undeveloped areas	natural	natural	natural

Interior Habitat Areas

Natural habitat cores were created by Tommy Albo. The method used the land cover data (level 2), reclassifying it so that classes representing tree land cover types (conifers, large shrubs, tree regeneration areas, woody crops, etc), clear cuts, and sand bars were grouped into "natural" habitat types (Table 21); all other classes were considered "built" or non-habitat. The binary natural/non-natural data were coarsened to 10 m resolution to merge isolated pixels into nearby groups and then resampled to the 5m resolution for the remainder of processing. Natural habitats were then shrunk by 50 m to yield the interior natural habitat areas. The data were converted to polygons to smooth the interior area boundaries and remove areas smaller than 1 acre. The data were converted back to a raster format and the Euclidean distance from the areas determined, with a 45 m maximum distance. The resulting data set represented distance from interior to edge. The distances were grouped and assigned "goodness" values (Table 22).

Table 22. Draft values assigned to edge depth or distance from edge. The distances represent distances determined from the habitat patch edge and proceeding toward the center of the patch. These distances were used in the uncertainty analyses.

Class	Class Description	Ranking value
x9	>=50 m from edge	100
x8	40-50 m from edge	80
x7	35-40 m from edge	70
x6	30-35 m from edge	60
x5	25-30 m from edge	50
x4	20-25 m from edge	40
x3	20-25 m from edge	30
x2	10-15 m from edge	20
x1	5-10 m from edge	10

Analysis steps:

1. Reclassified land cover classed with desirable habitat attributes (trees, clear cuts and land cover values 8-21 as well as 41-61)
2. Resampled the land cover layer to 10 m with majority assignment
3. Resampled back to 5 m resolution
4. Shrink by 5 cells (50 m) to get interior areas
5. Raster to polygon conversion
6. Smoothed polygons (smoothing tolerance 60 m)
7. Selected polygons over 1 acre in size
8. Polygon to raster conversion
9. Euclidean distance (maximum distance 45 m)
10. Reclassified distance values to yield the gradient from edge to interior habitats

Patch-Density Weighted Patch Size Layer and Prioritization Layer Weighting Scenarios

Patch density calculations

Windows were used to identify the neighborhoods over which patch density was calculated. We completed model runs to understand the effect of using a 1 km versus 5 km moving window size in calculating patch density. The analysis was completed using draft interior, wetlands, ground condition, and habitat resistance layers.

Additionally, to reduce the effects of very large and very small patches on the patch ranking values, we also explored aggregating the smallest and largest patches into the same rank value class. Two size cutoffs were explored: the 1% tail and the 2.5% tail (Table 2). The rank factor that occurred at the cutoff was assigned to all patches above the cutoff for large patches or below for small patches.

Table 2. Distribution of patch sizes after smallest patches removed in Main scenario (a) and alternate scenario (b).

(a)

Percentile	Count	Acres
2.5	161	0.994578
5	165	1.019288
10	177	1.093418
20	203	1.254033
30	241	1.488778
40	291	1.797653
50	364	2.24861
60	488	3.01462
70	715	4.416913
80	1287.4	7.952914
90	3630.1	22.42494
95	10857	67.06912
97.5	35172.78	217.2798

Percentile	Count	Acres
99	115177.1	711.5068
99.9	785970.2	4855.331
99.99	2330692	14397.85
99.999	4920119	30394.04

(b)

Percentile	Count	Acres
2.5	98	0.605395
5	102	0.630105
10	110	0.679525
20	130	0.803075
30	156	0.96369
40	192	1.18608
50	249	1.538198
60	339	2.094173
70	507	3.131993
80	884.6	5.464617
90	2492.3	15.39618
95	7118.15	43.97237
97.5	22434.37	138.5884
99	83225.77	514.1272
99.9	647577.9	4000.413
99.99	1635061	10100.59
99.999	4862859	30040.31

Weighting Scenario Explorations

In addition to examining the influence of window size on the patch density weighted patch size layer, multiple weighting scenarios were explored to understand the effects of prioritization layer weighting on the model results (Table 23 and Table 24).

Table 23. Weighting scenarios used to explore the results of the Upland metric for the initial model drafts.

Prioritization Layer	Weight Scenario			
	1	2	3	4
	Weight 2.0	Weight 2.1	Weight 2.2	Weight 2.3
Patch density weighted patch size	0.2	0.25	0.25	0.25
Interior habitat	0.2	0.3	0.3	0.35
Wetland buffers, all wetlands	0.2	0.15	0.2	0.2
Ground condition-street trees/Influence of roads	0.2	0.15	0.15	0.1

Permeability (cost distance between patches)	0.2	0.15	0.1	0.1

Table 24. Scenarios used to explore prioritization layer weightings in combination with two window sizes for calculating patch density as part of the patch-density weighted patch size layer.

File Geodatabase Code	Run # (7.x)	Weighting Scenario	Patch Size Patch Density Window Size	Patch Density Max Tail	Interior habitat	Wetland buffers	Ground condition	Habitat resistance/friction
A	2	1	5 km	97.5	rcl_cores	wet_iii_reclass	rsc_gr_cond	rcs_permeab
A	3	2	5 km	97.5	rcl_cores	wet_iii_reclass	rsc_gr_cond	rcs_permeab
A	10	3	5 km	97.5	rcl_cores	wet_iii_reclass	rsc_gr_cond	rcs_permeab
A	11	4	5 km	97.5	rcl_cores	wet_iii_reclass	rsc_gr_cond	rcs_permeab
B	4	1	5 km	99	rcl_cores	wet_iii_reclass	rsc_gr_cond	rcs_permeab
B	5	2	5km	99	rcl_cores	wet_iii_reclass	rsc_gr_cond	rcs_permeab
B	13	3	5 km	99	rcl_cores	wet_iii_reclass	rsc_gr_cond	rcs_permeab
B	14	4	5km	99	rcl_cores	wet_iii_reclass	rsc_gr_cond	rcs_permeab
C	6	1	1 km	97.5	rcl_cores	wet_iii_reclass	rsc_gr_cond	rcs_permeab
C	7	2	1 km	97.5	rcl_cores	wet_iii_reclass	rsc_gr_cond	rcs_permeab
C	15	3	1 km	97.5	rcl_cores	wet_iii_reclass	rsc_gr_cond	rcs_permeab
C	16	4	1 km	97.5	rcl_cores	wet_iii_reclass	rsc_gr_cond	rcs_permeab
D	8	1	1 km	99	rcl_cores	wet_iii_reclass	rsc_gr_cond	rcs_permeab
D	9	2	1 km	99	rcl_cores	wet_iii_reclass	rsc_gr_cond	rcs_permeab
D	17	3	1 km	99	rcl_cores	wet_iii_reclass	rsc_gr_cond	rcs_permeab
D	18	4	1 km	99	rcl_cores	wet_iii_reclass	rsc_gr_cond	rcs_permeab

Conclusions

We used a qualitative approach to perform uncertainty analysis for this project to better understand how prioritization layers and weights affected the final model product. The assessment allowed us to refine our methods to better reflect the needs of the clients and users of the final products. Through this process we simplified how most prioritization layers were developed and identified some gaps in the set of prioritization layers. We simplified the development of the influence of roads prioritization layer and used it as a replacement to the ground condition prioritization layer used in the original model contracted by Metro. We also simplified the way that habitat connectivity was represented by replacing the habitat permeability layer developed using a cost distance analysis with the habitat friction layer, a layer that would have been used as an input to the cost distance analysis. We explored several means of developing an interior habitat layer and settled on a method that takes advantage of raster- and vector-based processing to yield an analytically useful and visually appealing interior habitat layer. We also determined that using a larger window size for calculating patch density as part of the calculation of the patch density weighted patch size layer produced a more acceptable prioritization layer. Through these analyses we also added layers to identify existing and potential (hydric soils) wetland habitats.

While it is possible to create highly complex prioritization layers, this capacity should be balanced with the need to explain analysis results to a wide variety of audiences and stakeholders. By simplifying the prioritization layers, it became possible for a wider range audiences to understand the concepts and values input to the model product and therefore have confidence in the results. As modifications are made to the model in the future, we recommend that analysts maintain a balance between analytic power and audience comprehension in order to obtain the most acceptable and accurate model possible.