Section 6 (Texas Traditional) Report Review

Attachment to letter dated AUG 0 8 2008

TPWD signature date on report Submitted electronically on 7/8/2008

Project Title: Range-wide modeling of golden-cheeked warbler habitat

Final or Interim Report? Final

Grant #: E-72

Reviewer Station: Austin ESFO

Lead station was contacted and concurs with the following comments:
☐ Yes ☐ No ☒ Not applicable (reviewer is from lead station)

Interim Report (check one):

☐ is acceptable as is

☐ is acceptable as is, but comments below need to be addressed in the next report

☐ needs revision (see comments below)

Final Report (check one):

☒ is acceptable as is

☐ is acceptable, but needs minor revision (see comments below)

☐ needs major revision (see comments below)

Comments:

FINAL REPORT

As Required by

THE ENDANGERED SPECIES PROGRAM

TEXAS

Grant No. TX E-72-R

Endangered and Threatened Species Conservation

Range-wide Modeling of Golden-cheeked Warbler Habitat

Prepared by:

David Diamond

Carter Smith
Executive Director

Mike Berger
Division Director, Wildlife

31 January 2008

FINAL REPORT

STATE: Texas **GRANT NUMBER:** TX E-72-R

GRANT TITLE: Endangered and Threatened Species Conservation

REPORTING PERIOD: 8/01/05 to 1/31/08

PROJECT TITLE: Range-wide Modeling of Golden-cheeked Warbler Habitat

OBJECTIVE(S):

To create a new GIS data layer at 30-meter (900 square meter) pixel resolution in which each pixel is given a value for Golden-cheeked Warbler (GCWA) habitat quality throughout the range using a transparent decision-rule methodology that is adjustable based on relevant new information.

Segment Objectives:

Task 1. Collect and format data,

Task 2. Research literature on GCWA habitat,

Task 3. Extract aspects of habitat quality that can be modeled using land cover, digital elevation models, and other available data,

Task 4. Write decision rules to assign habitat quality to each 30-meter pixel.

Significant Deviation:

None.

Summary Of Progress:

Please see enclosed CD containing Final Report in .pdf format and all relevant GIS files.

Location: The offices of Dr. David Diamond at the University of Missouri, Columbia, MO; and considered all counties within the nesting range of the GCWA.

Cost: Final costs not available at the time of this report.

Prepared by: Craig Farquhar **Date:** 31 January 2008

Approved by: _____ **Date:** 31 Jan 08
C. Craig Farquhar

PROJECT FINAL REPORT

Range-wide Modeling of Golden-cheeked Warbler Habitat

December 15, 2007

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Several workers have provided estimates of Golden-cheeked Warbler (GCW; *Dendroica chrysoparia*) nesting habitat using remote sensing results (McKinney 1995, Diamond and True 1999, 2002). Workers have also suggested local and landscape scale variables that impact habitat quality (Pulich 1976, Ladd 1985, Wahl et al. 1990, Beardmore 1994, Engels 1995, Coldren 1998, Horne and Anders 2000, DeBoer and Diamond 2007, Peak 2007, Fuller et al., *in press*). Our objective was to model GCW habitat quality throughout the range by (1) identifying variables most important to GCW habitat quality, (2) identifying which of those important variables can be assessed using available GIS data, and (3) using GIS methods to model habitat quality.

Approach

We used an expert steering committee approach to facilitate habitat quality modeling. The Steering Committee was involved in the following:

(1) an initial email-screening of potential important habitat variables that influence GCW habitat quality,

(2) a meeting to discuss and select variables for modeling (February 8, 2006),

(3) interim email communications and a WebEx meeting (May 25, 2006),

(4) a second meeting at which important variables were again addressed and initial examples of habitat quality models were reviewed, but not in an interactive way (October 13, 2006),

(5) a final meeting at which draft models were presented and reviewed in an interactive way using GIS software and suggestions for improvement were made (June 26, 2007), and

(6) emails and communications after the June 26 meeting, during which time a new habitat modeling software was applied and a short manuscript comparing different modeling techniques was drafted (Fuller et al. *in press*).

Appendix A lists the initial invitees and contains agendas and notes from the meetings.

Variables Important to GCW Habitat Quality

Studies that link habitat variables to GCW demographic parameters are best for assessing habitat quality, but few of these have been conducted or are planned (van Horne 1983, Vickery et al. 1992, Peak 2007). Therefore, studies that link presence or absence of GCWs to habitat variables have been relied upon (e.g. Wahl et al 1990, Magness et al. 2006, DeBoer and Diamond 2007). The Steering Committee reviewed the literature and relied on their own expertise to develop a list of variables (Tables 1 and 2) likely to influence GCW habitat, and ranked these variables for importance at the initial Steering Committee meeting.

Table 1. Data form for local scale variables evaluated for their influence on GCW habitat quality. Numbers were assigned by each worker.

	Influence on
Stand Characteristic	**Habitat (1-5)[1]**
percent Ashe juniper canopy cover	
age of Ashe juniper	
percent deciduous canopy cover	
total canopy cover	
canopy height	
variance of canopy height in stand	
land cover diversity within patch	

species composition (specific)	
percent slope	
solar insolation	
slope aspect	
land position (high or low)	
soil depth and type	
ecological land type (range site)	
[1]1=highly positive; 2=positive; 3=neutral; 4=negative; 5=highly negative	

Table 2. Landscape scale variables evaluated for their influence on GCW habitat quality.

Landscape Variable	**Influence on Habitat (1-5)[1]**
patch size	
patch shape	
distance to edge	
distance to urban land cover	
distance to roads	
distance to water	
land cover context (100 m circle)	
land cover context (500 m circle)	
landform context (100 m circle)	

landform context (500 m circle)	
distance to "large" patch <100 m	
distance to "large" patch >500 m	
distance to protected land	
precipitation	
[1]1=highly positive; 2=positive; 3=neutral; 4=negative; 5=highly negative	

The Steering Committee selected a subset of these variables that were most important (see Appendix A). Local scale variables such as the species composition of stands and canopy height and density could not be addressed with available data.

Development of GCW Habitat Quality Models

The Steering Committee selected variables for possible incorporation into GCW habitat quality models (see Appendix A for notes on these variables derived from the committee meetings). Following is a discussion of each variable.

Suitable vegetation was identified as the most important factor that defines GCW habitat. Habitat has to have some threshold level of Ashe juniper mixed with deciduous trees. Available remotely sensed data only distinguishes evergreen, mixed, and deciduous forest/woodland, but few pixels are identified as 'mixed' within the breeding range of the warbler. GCWs do not occupy deciduous forest/woodland unless it is within a short distance of mixed or evergreen Ashe juniper forest/woodland, so remote sensing data was manipulated using GIS software to remove deciduous forest that is too far (more than 100 m) from evergreen forest. The USGS also used a new algorithm to estimate percent canopy cover for each pixel in their most recent National Land Cover Dataset (NLCD; see http://erg.usgs.gov/isb/pubs/factsheets/fs10800.html; Homer et al. 2004). Beyond that, no relevant, uniform data are available range-wide at the time this report is being written. However, the Texas Department of Transportation has commissioned a private consultant to develop a data layer on suitable vegetation from air photos. Those data should be evaluated as they become available.

Patch size was suggested as the second most important variable, although the Steering Committee did point out that the species is found in linear patches that are not large. Based on evaluation of the land cover dataset produced for this report, more than 70% of all GCW habitat is found in patches over 250 hectares.

Distance to a large patch was discussed as important, although the Steering Committee pointed out that dispersal distance is not known, so the importance of distance to large patch may be difficult to quantify. Patch shape index (e.g. larger patches with less edge) was an important variable in landscape scale models developed by DeBoer and Diamond (2007).

Solar insolation is a measure of how much sun strikes a spot, and thus integrates slope percent and slope exposure. The Steering Committee felt that wet slopes may support taller, denser forests and thus might represent better habitat for GCWs versus dry slopes, which may support less dense, shorter, more Ashe juniper-dominated woodlands. Most forested areas are so topographically complex that use of this variable appears unwarranted. Often, the distance across canyons in forested landscapes is less than 100 m, and solar insolation values vary from extremely low (wet) to extremely high (dry). Thus, an individual nesting pair of GCWs might easily range across wet slopes, dry slopes, bottoms, and ridges. A related variable, **ecological site type,** was also found to vary across short distances.

Precipitation and related variables such as **evapotranspiration** were suggested as factors that might be used to segment the range of the warbler at larger scale. In this regard, it was suggested that threshold values could be selected and rules written such that areas with lower precipitation and higher evapotransportation could be designated as lower quality, whereas wetter areas could be designated as higher quality. We gathered data from reporting weather stations and interpolated a precipitation surface, and also gathered data from PRISM, a digital compilation of environmental data. The wide spacing of reporting weather stations, and the scale of variation in the distribution of vegetation and site types versus precipitation patterns, makes the use of these data seem dubious. We elected not to include them in our models.

Likewise, we evaluated the use of **geology** data from the Geological Atlas of Texas to stratify GCW habitat and assign different quality to different types of surfaces. Based on an evaluation of known GCW locations and vegetation against the geology, we elected not to use this in our range-wide models, although it may prove useful in any given local area (see results of the WebEx meeting, Appendix A).

Landscape context, calculated as the amount of forest surrounding a given pixel, was suggested as a variable that integrates edge density, patch size, and distance among patches. The fact that >70% of all habitat occurs in patches larger than 250 ha, and that landscape context does integrate a number of important variables, made this variable most useful. Also, a study by Magness, et al. (2006) also used landscape context to define GCW habitat quality.

GCW Habitat Quality Models

We initially grouped forest into habitat patch size classes (not presented here) and this approach may prove useful for further analyses. We developed thirteen models and investigated their utility for defining GCW habitat quality. These models addressed

landscape context, patch size, edge, urban edge, and solar insolation (slope and aspect) in different ways. We addressed the concept of 'appropriate vegetation' by ensuring that all areas identified as habitat were mainly evergreen forest/woodland (most mixed evergreen-deciduous vegetation falls within the evergreen class in remotely sensed classifications of this region), or mixed or deciduous forest/woodland within 100 m of evergreen. Also, all models masked out non-forest (except Model L, which was done by Loomis Austin, see below) as well as deciduous and mixed forest/woodland greater than 100 m from evergreen forest, as not habitat.

Results of the original nine models (Table 3) were presented to the Steering Committee on July 26, 2007. The group selected several areas that were well-known to participants and visually evaluated the models, including the known location of GCW presence/absence from DeBoer and Diamond (2007). Based on these evaluations, coupled with earlier analyses described above and in Appendix A, we made the following decisions:

1. Precipitation and geology are too coarse in resolution to prove useful for modeling GCW habitat quality at finer resolutions.

2. SSURGO soils (digital county soils surveys) are not uniformly delineated from county to county, and so cannot be used range-wide, but may be useful for a given smaller region (a county or two).

3. Data on solar insolation, which integrates slope percent and slope aspect, is not useful because much GCW habitat is in landscapes where nesting territories might easily circumscribe narrow canyons (wet and dry slopes), bottoms, and ridges.

4. Models that are based on landscape context, using a neighborhood analysis, were appealing because they integrate patch size, fragmentation, and edge density indirectly, and these variables were thought by the Committee to be important in defining GCW habitat quality.

5. The Steering Committee could not definitively describe the influence of urban edge versus other types of edge. That is, the extent to which urban edge may be more deleterious to habitat quality versus other types of edge could not be convincingly quantified with available data on reproductive success. At the GCW symposium on June 27, Jennifer Reidy's results seemed to show that urban land cover was not more deleterious than other edges, whereas a study by Cindy Sperry suggested the opposite.

6. We initially used a 1 square km neighborhood (a circle with radius 564 m) to define forested landscapes, but also had test results using other neighborhood sizes. The Steering Committee felt that a smaller neighborhood size was more appropriate.

7. Loomis Austin had completed a Golden-cheeked Warbler habitat quality model using a neighborhood analysis of canopy density from the most recent NLCD (contact Loomis Austin for details). This analysis was appealing in that it used a 7-pixel square

Table 3. Golden-cheeked Warbler Habitat Quality Model Definitions

Model	Model Definition	Ranking Rules	Primary Factors Addressed
1	% forest within a 1 sq km neighborhood	rank 0 (worst, 0 to 20% forest), 1 (20% to 40% forest), 2 (40% – 60%%), 3 (60% to 80%), 4 (best, 80% to 100% forest)	landscape context (indirectly addresses patch size and edge density)
2	model 1 and distance from edge	similar to model 1 but distance to edge added to rank (plus 1 - less than 50m from an edge, plus 2 - 50 to 100m, plus 3 - 100 to 200 m, plus 4 - >200m)	landscape context, edge addressed explicitly in several categories
3	model 2 and distance from urban	similar to model 2 but % urban in a 1 sq km neighborhood added to the final rank ranked plus 0 (worst, 80% - 100% urban), plus 1 (60% to 80%), plus 2 (40% - 60%), plus 3 (20% - 40%), plus 4 (best, 0 to 20% urban)	landscape context, edge density, and urban all addressed
4	model 3 and solar insolation	similar to model 3 but solar insolation added to the rank, plus 1 (worst, driest 10% of slopes), plus 2 (10 - 50% solar insolation values), plus 3 (50 - 90%), plus 4 (best, wettest 10% of slopes)	landscape context, edge density, urban, and slope exposure and percent all addressed
5	forest within 1 km of a forest patch >=5 ha	no ranking of quality	landscape context and patch size
6	forest within 1 km of a forest patch >=250 ha	no ranking of quality	landscape context and patch size
7	% forest within a 1 sq km neighborhood, adjusted for edge, weighted by % forest	model 1 times 2, minus 1 if <50 m from an edge	landscape context weighted and adjusted for edge

8	% forest in a 1 sq km neighborhood, edge, urban, and solar insolation	model 1 minus 1 if <50m from an edge, minus 1 if >25%urban in the neighborhood, plus 1 if on one of the 10% of the wettest slopes, minus 1 if on one of the 10% if the driest slopes	landscape context, urban, edge, and slope percent and exposure all addressed
9	% forest in circle with 1 sq km neighborhood, adjusted for edge (not weighted)	model 1 minus 1 if <50 m from an edge	landscape context and edge addressed directly
A	model 1 re-done using a smaller neighborhood (circle of radius 200 m)	rank 0 (worst, 0 to 20% forest) to 4 (best, 80% to 100% forest)	landscape context (indirectly addresses patch size and edge density)
B	evergreen forest within 200 m of >=250 ha patches of landscapes >20% forested (from Model A)	no ranking of quality	landscape context and patch size
C	model 9 re-done using a smaller neighborhood (circle of radius 200 m)	model A minus 1 if <50 m from an edge	landscape context and edge
D	model C with percent canopy cover considered	model C minus 1 if canopy cover from NLCD was < 30% and plus 1 if canopy cover was >80%	landscape context, edge, and canopy cover
L	average percent canopy cover in a neighborhood of 7, 30 m square pixel, with rank reduced for areas of low canopy that are not near areas of at least 50% canopy	1 (low - average neighborhood canopy cover 30 - 50% and within 90m of high or medium quality habitat), 2 (medium - average neighborhood canopy cover 50 - 70%), 3 (high - average neighborhood canopy cover 70 - 100%)	landscape context and average canopy cover

neighborhood (about 10.9 acres, roughly equivalent to the size of a larger GCW territory) and was based primarily on the average canopy closure within the neighborhood.

Hence, we decided based on the meeting to do four new models (Figures 1-4, Appendix B), and examine the model provided by Loomis Austin (Figure 5), for final presentation. The four completed models were as follows: (1) Model A, a landscape context model using a smaller neighborhood, (2) Model B, a patch size-based model using the results from Model A (using >=20% forest in the neighborhood as the basis for identification of patches), (3) Model C, a landscape context model using the smaller neighborhood adjusted for edge, and (4) Model D, which used results from Model C modified considering canopy closure directly. Again, we also decided to evaluate the model provided by Loomis Austin (Model L) alongside other models (Table 4).

Table 4. Comparison of model results (Model L was completed by Loomis Austin)

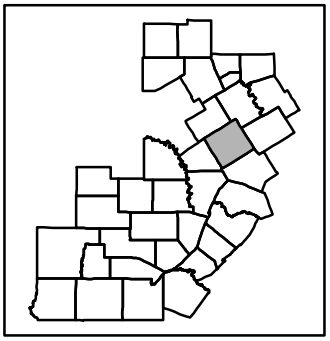
Mod	Model Concept	Total Area	Rank 1	Rank 2	Rank 3	Rank 4	Rank 5
A	percent forest/woodland within a circle of radius 200 m	1,999,534	224,236	374,178	529,080	872,040	N/A
B	evergreen forest within 200 m of >=250 ha patches of landscapes with >20% forest from Model A	1,580,393	N/A	N/A	N/A	N/A	N/A
C	percent forest/woodland within a circle of radius 200 m adjusted for edge	1,771,883	305,044	340,750	370,921	755,168	N/A
D	model C with reduction for low canopy cover and addition for high canopy cover	1,721,949	286,059	301,477	326,176	522,530	285,707
L	average canopy cover in a 7, 30 m pixel neighborhood with adjustments for proximity to heavy canopy	1,679,513	645,961	651,285	382,268	N/A	N/A

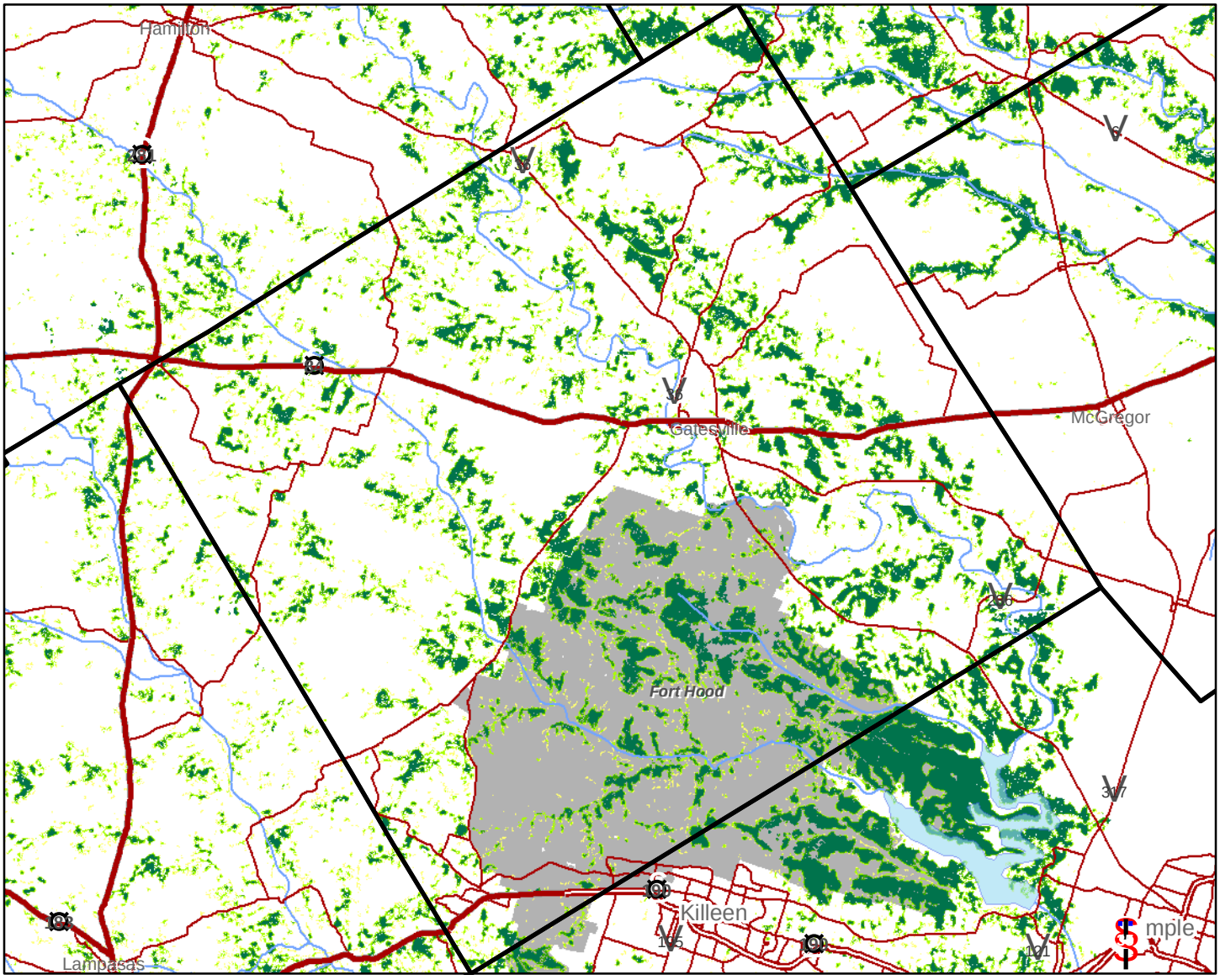
Figure 1. GCW Model A

CORYELL COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3
- 4 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

1:469,397

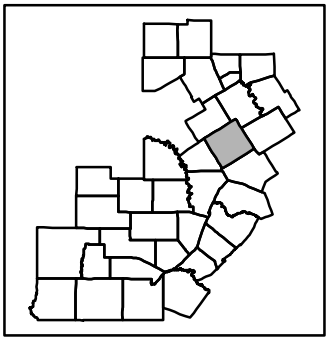
0 4 8 16 Miles

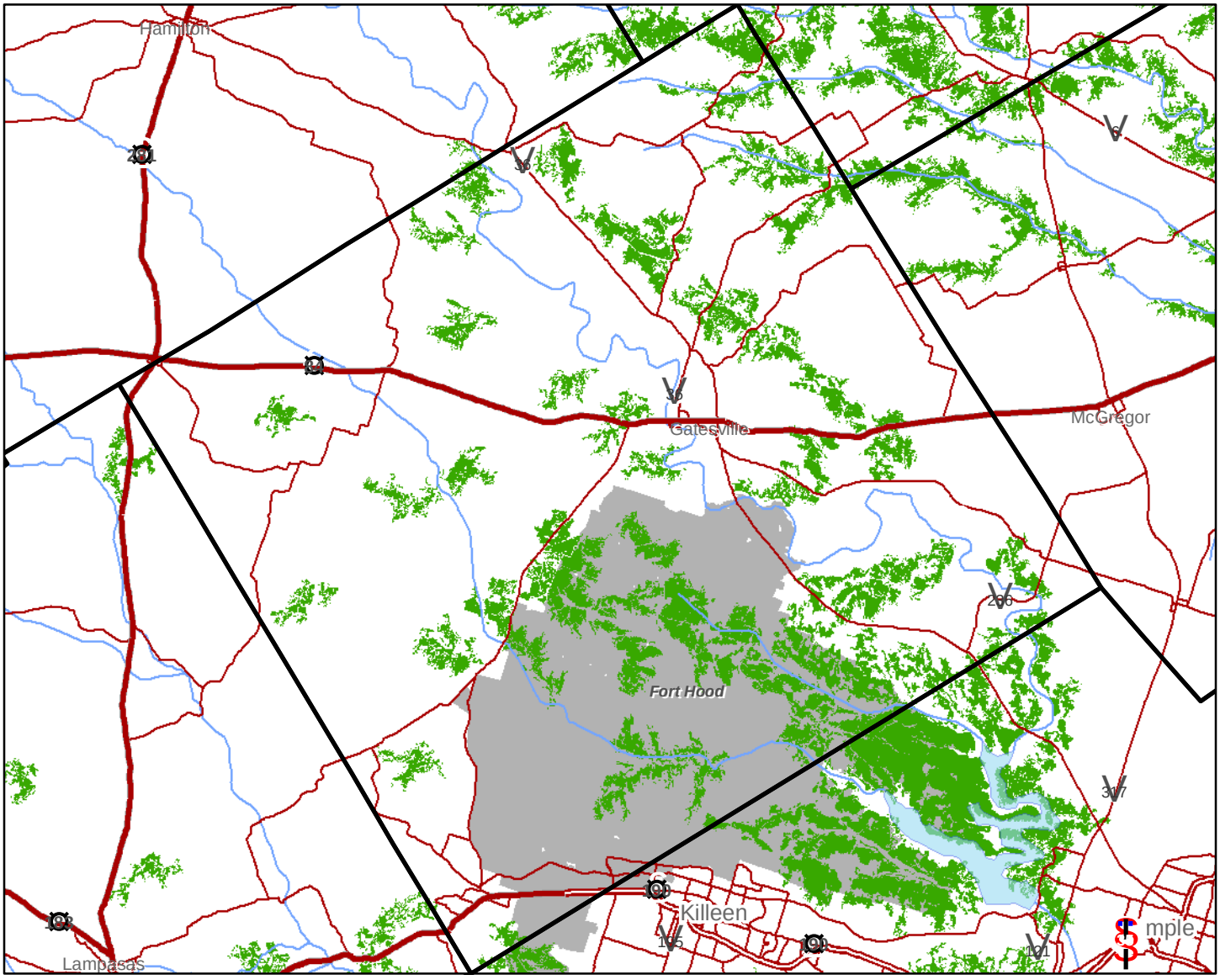
0 5 10 20 Kilometers

Figure 2. GCW Model B

CORYELL
COUNTY

Habitat





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

1:469,397

0 4 8 16 Miles

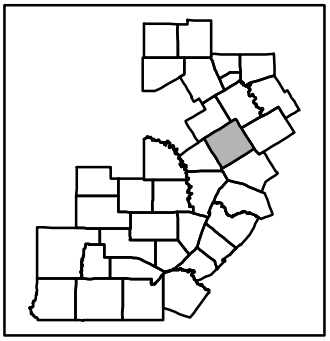
0 5 10 20 Kilometers

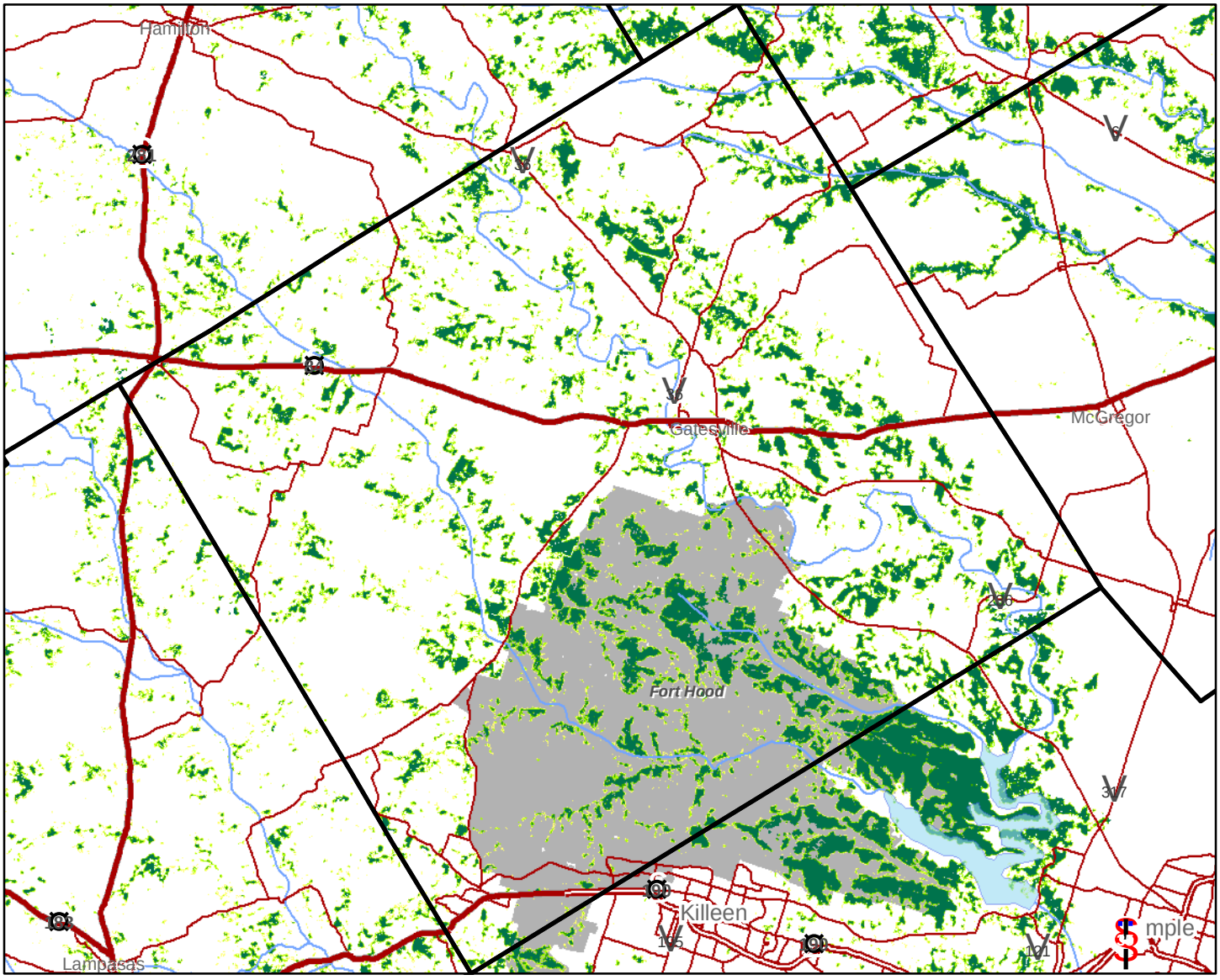
Figure 3. GCW Model C

CORYELL COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3
- 4 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

1:469,397

0 4 8 16 Miles

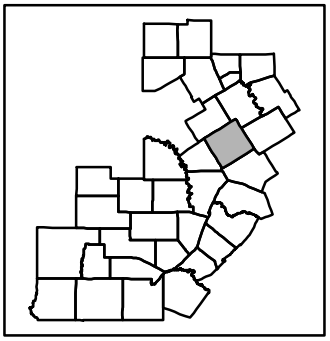
0 5 10 20 Kilometers

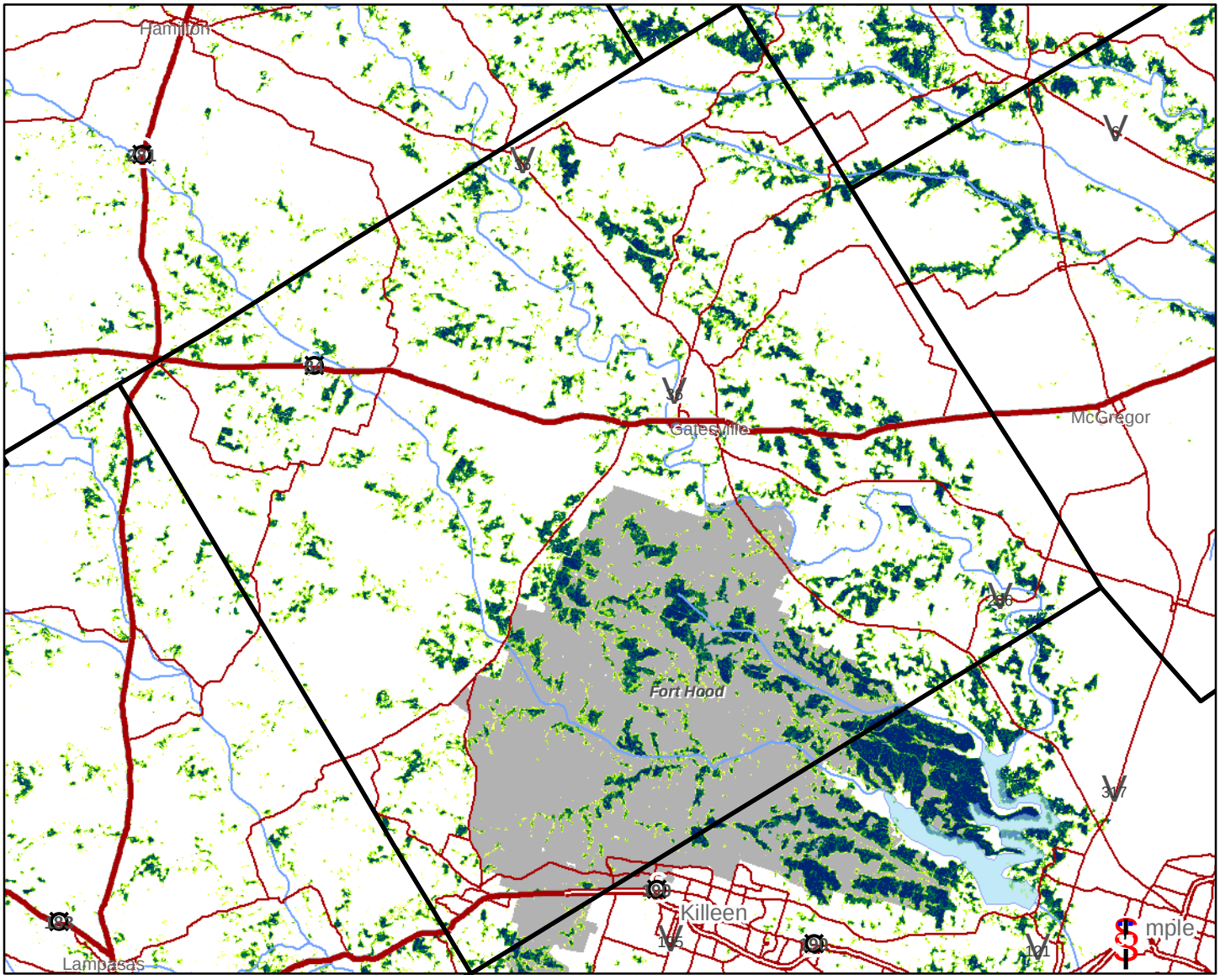
Figure 4. GCW Model D

CORYELL COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3
- 4
- 5 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

1:468,682

0 3.75 7.5 15 Miles

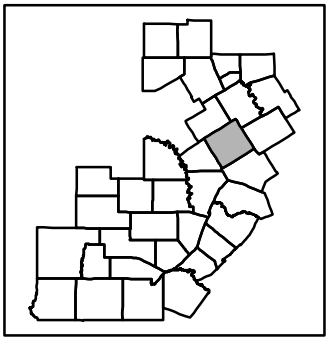
0 5 10 20 Kilometers

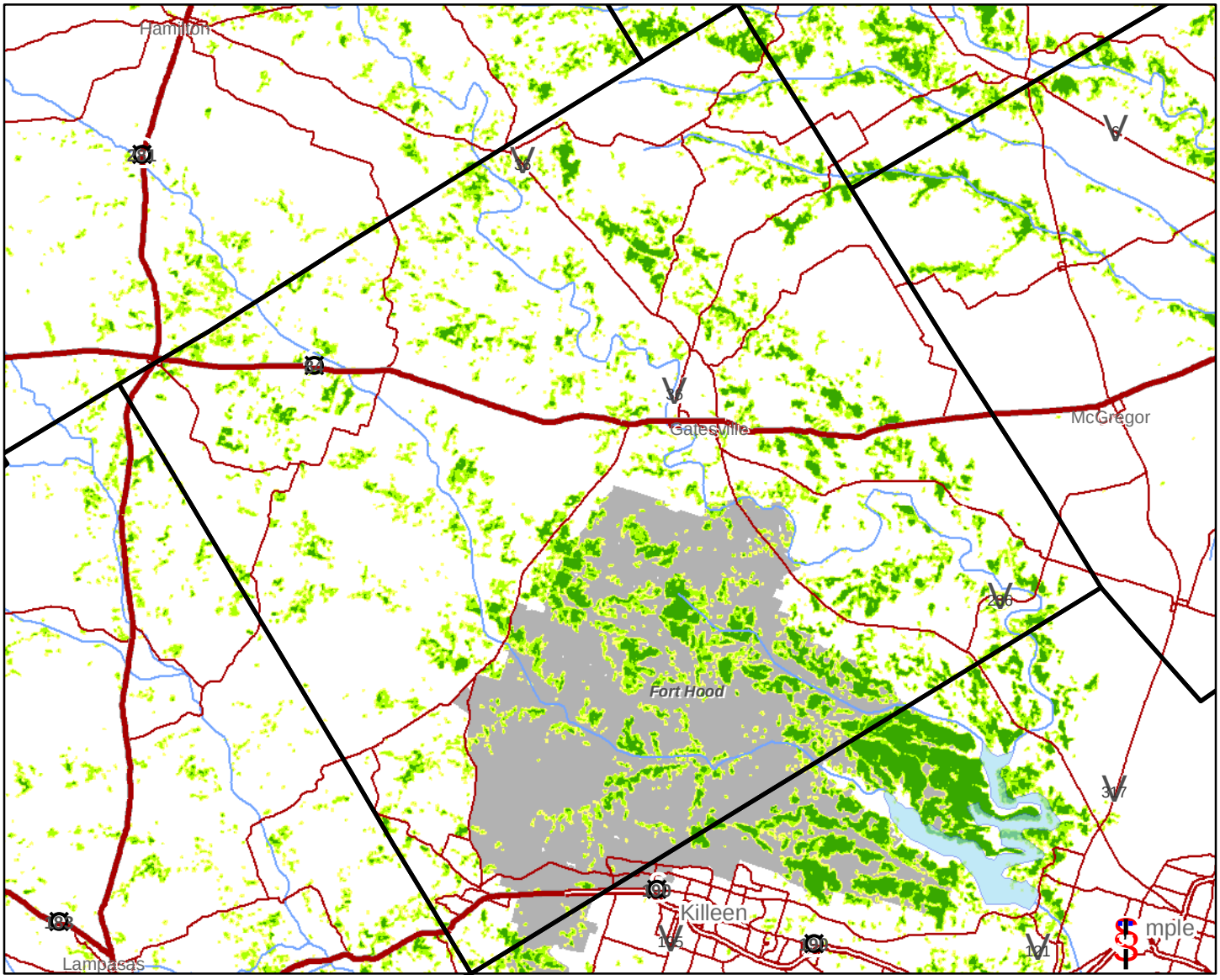
Figure 5. GCW Model L

CORYELL COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

1:469,397

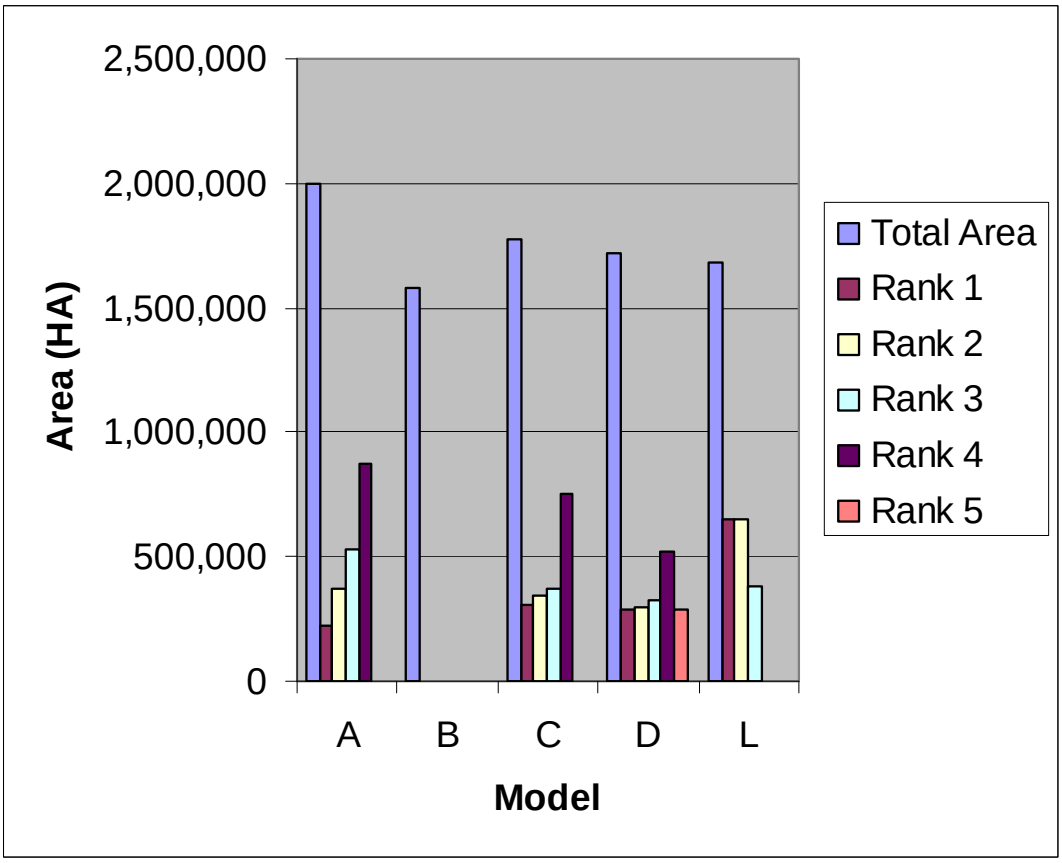
0 4 8 16 Miles

0 5 10 20 Kilometers

Distinguishing Among Models

The difference between Model B, which was the most conservative approach (e.g. only forest within 250 hectare patches of 'partially forested landscapes' or within 200 m of a 250 hectare patch), and Model A, the most liberal 'landscape context' approach, was 419,141 hectares, or 20.9% (Figure 6). Model A only considers landscape context, and even though this integrates patch size and edge density to some extent, it does not consider edge directly. Careful studies have shown that edge does influence reproductive success (hence habitat quality) for GCWs (see Peak 2007, Reidy 2007). Model B does not provide habitat quality rankings at all, and is quite conservative in that only large patches and forest near large patches are considered GCW habitat. We believe that the former is too liberal and the latter is too conservative.

Figure 6. Differences of Total Area among Models



The difference between the most conservative and the most liberal of the three remaining models (C, D, and L) was 92,370 hectares, or 5.2%. Model C considers landscape context and thus patch size and edge density indirectly and also considers edge directly, whereas Model D considers those variables and adjusts quality for canopy density. Model L considers landscape context and canopy density, and reduces quality rank for areas with low cover that are not close to areas of higher cover, but it does not consider edge directly (contact Loomis Austin for detailed methodology).

We believe that these three models all provide a reasonable representation of the total amount of breeding habitat for GCWs. However, important spatial variation in the distribution of habitat exists between Models A – D versus Model L, partly because different base input data and different versions of the range of GCWs were used. The input for Model L came from canopy closure data provided by the USGS, whereas Models A – D used data on forest land cover we developed ourselves. Model L tends to identify less area on the west, northwest, and far northern part of the range as habitat, and the eastern and northeastern boundary of the range of the GCW were different versus the ones we used. Therefore, the FWS should consult Loomis Austin for questions regarding details of Model L. Model C places more habitat within the highest quality rank, whereas Model D places the most habitat within the second highest rank, and Model L places about equal amounts in the first and second rank, and less within the highest rank. Model L identifies only three levels of habitat quality whereas Model C identified four, and Model D, five.

Habitat quality ranks can be interpreted as follows.

Model C

-1 to 0 – not habitat

1 – potential low quality habitat when bordering higher ranked habitat; not habitat when not bordering higher ranked habitat

2 – potential low quality habitat when bordering higher ranked habitat; probably not habitat when not bordering higher ranked habitat

3 – potential moderate quality habitat when bordering habitat ranked 4; potential low quality habitat when not bordering habitat ranked 4

4 – potential moderate to high quality habitat

Model D
Ranks range from -2 to 5. Same interpretation as Model C, except habitat ranked as 5 is dense forest and may have a higher likelihood of being high quality habitat, although not for certain (see discussion below).

Model L (contact Loomis Austin for details)

1 - potential low quality habitat
2 – potential medium quality habitat
3 – potential high quality habitat

Note that average canopy cover within a neighborhood is used to score habitat quality for Model L, whereas canopy cover is overlain directly with neighborhood analyses for

Model D. Since Model L is a 'spatial average,' it accounts for variation in canopy cover within the neighborhood, whereas Model D does not. In other words, the highest scoring areas for Model D have the highest canopy cover, whereas the highest scoring areas for Model L have the highest **average** canopy cover within the neighborhood. Since GCWs have nesting territories that spread across a given area that may include both higher and lower percent canopy cover, Model L has some appeal. Basically, Model L attempts to account for both landscape context and canopy cover at the same time, whereas Model D (and C) account for landscape context first, then edge, then (for Model D) canopy cover.

Defining Habitat Quality - Habitat quality can only be defined based on differences in nest productivity or reproductive success. However, no range-wide studies of reproductive success exist, and indeed local studies are spotty (Keddy-Hector 1993, 1995, Fink 1996, Coldren 1998, Maas-Burleigh 1998, Peak 2007, Reidy 2007). In our view, the most convincing, quantitative evidence from these studies link measures of edge to reproductive success (e.g. nests close to habitat edges experience reduced reproductive success). Other emergent variables such as fragmentation (less is better) and patch size (larger is better) have been suggested as important. Local stand variables such as canopy cover, species-specific canopy cover, canopy height, the variance of canopy height, species composition, slope aspect and percent, stand age, and the overall variability within a breeding territory have also all been suggested as important factors in defining habitat quality.

Evaluation of Models - Lacking data on reproductive success, we evaluated presence/absence data from DeBoer and Diamond (2007) in an attempt to select the best habitat quality model (Table 5). We overlaid the location of GCW sampling points with model results. The percent of GCWs present in Model L's highest class rose to 48%, the highest for any model, whereas the percent absent in the middle class rose to 86%, about the same as for the second highest ranked class for other models. Likewise, no GCWs were found outside of what was considered habitat by Model L, whereas GCWs were found outside of what was considered habitat (1 to 3 samples) for all other models. These samples were not forested but were very near forest (<30 m). Because the presence/absence data involved listening from a point location, the GCWs detected at these spots might well have been within nearby forest. This demonstrates a problem with the presence/absence data gathering as much as a problem with any of the models. Model L did not 'miss' these sample points because the average canopy within the neighborhood was at least 30%, even though the actual spot might not have been forested. This may or may not be good in terms of the model's overall accuracy. Unfortunately, very few samples (6 for the bottom two classes in Models C and D, 6 in the bottom class for Model L, and 0 from the bottom two classes of Model A) from DeBoer and Diamond (2007) actually fall within the lower ranked habitat classes for any of the models.

Table 5. Presence/Absence Data for 5 Models

Model A

Rank	Presence	% Presence	Absence	% Absence	Total
0	2	33.33%	4	66.67%	6
1	0		0		0
2	0		0		0
3	3	15.00%	17	85.00%	20
4	60	40.82%	87	59.18%	147
Total	65		108		173

Model B

Rank	Presence	% Presence	Absence	% Absence	Total
0	3	17.65%	14	82.35%	17
1	62	39.74%	94	60.26%	156
Total	65		108		173

Model C

Rank	Presence	% Presence	Absence	% Absence	Total
< 1	2	33.33%	4	66.67%	6
1	0		0		0
2	1	14.29%	6	85.71%	7
3	2	13.33%	13	86.67%	15
4	60	41.38%	85	58.62%	145
Total	65		108		173

Model D

Rank	Presence	% Presence	Absence	% Absence	Total
<1	1	16.67%	5	83.33%	6
1	0		2	100.00%	2
2	2	33.33%	4	66.67%	6
3	1	12.50%	7	87.50%	8
4	22	34.38%	42	65.63%	64
5	39	44.83%	48	55.17%	87
Total	65		108		173

Loomis

Rank	Presence	% Presence	Absence	% Absence	Total
0	0	0.00%	8	100.00%	8
1	2	25.00%	6	75.00%	8
2	5	13.89%	31	86.11%	36
3	58	47.93%	63	52.07%	121
Total	65		108		173

The data summarized above are too few to allow definitive conclusions even in terms of presence/absence, even though the study used a spatially stratified random design to the extent practical (the only known range wide study to do so, which is why it was used here). The apparent differences among models might not be real, and again, at any rate, presence/absence data are not sufficient to define habitat quality in terms of differences in reproductive success.

Lacking sufficient data, the selection of a preferred model from among Models C, D, and L must be left to best professional judgment. We feel that Model C should be selected if the desire is to (1) identify slightly more habitat area, and therefore miss less actual GCW habitat, and (2) identify more habitat as top quality and relatively less as low quality. Model L should be selected if the desire is to (1) be more conservative in terms of defining habitat (e.g. fewer hectares) and (2) be more conservative in defining top quality habitat (fewer of the hectares of habitat are identified as top quality). Model D is intermediate between Models C and L in terms of total habitat area identified, but identifies the least amount of habitat as top quality.

Habitat quality in terms of nest success is influenced by proximity to edge, at least at Ft. Hood and near Austin (Peak 2007, Reidy 2007). Model L and Model D indirectly assume that the variables evaluated and methods employed effectively integrate factors that influence habitat quality well enough that a relatively small area can be identified as top quality (382,268 hectares and 285,707 hectares, respectively). Model C indirectly assumes that not enough is known to effectively discern habitat quality beyond what can be modeled using landscape context and edge directly, so much of the habitat (755,168 hectares, or almost twice as much versus Model L and more than twice as much as Model D) is ranked at highest quality.

Selection of a Preferred Model - We prefer Model C. First, the basic land cover input data on which the analyses for Models A – D were based used tried and true remote sensing image classification techniques. The input data for Model L used a sub-pixel percent canopy algorithm that has yet to be widely vetted.

Model C also identifies more total area and might therefore be less likely to exclude GCW habitat, incorporates edge directly as a factor in habitat quality, and assumes that the largest faction of habitat is within the highest ranked quality class. This tends to recognize that most of the habitat is indeed in large patches away from patch edges, and that habitat quality may vary within the forest interior for reasons (e.g stand canopy closure, stand height, stand age, stand species composition, slope percent, slope exposure, variability within the stand, interactions among these variables) and in ways we do not understand. The primary argument in favor of Model L and Model D is that they do indeed incorporate canopy closure directly in the model, and habitat quality is thought to influence reproductive success, although we do not feel that the influence of canopy closure, independent of other variables, has been shown as convincingly as the influence of edge. FWS staff must make the final judgment in terms of which model to use,

possibly via re-constitution of the original project Steering Committee (see Appendix A) or the GCW Recovery Team. All models are close in terms of the overall result. Additional spatially explicit presence/absence data may exist, and if so these data could be plotted against model results to provide additional information to distinguish among the habitat quality models. One caution, though: presence/absence data, regardless of the quantity, can never substitute for data on reproductive success in terms of defining habitat quality.

Delivery products

1. This report in hard copy and electronic copy
2. GIS files of model results for Models A, B, C, D, and L

We will also be available for further consultation, clarification, and limited analyses as needed for a minimum of 12 months.

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Appendix A – Steering Committee Meeting Notes

Initial GCW Steering Committee Invitees:

Clay Bales, Texas Forest Service
Clayton Blodgett, MoRAP, University of Missouri
John Cornelius, Ft. Hood
Timery DeBoer, Graduate Student
Lee Elliott, TNC
Craig Farquhar, TPWD
Jeff Hatfield, UGSS
Clif Ladd, Loomis Austin
Charlotte Reemts, TNC, Ft. Hood
Chuck Sexton, USFWS
Rebecca Peak, TNC
Paul Sunby, SWCA
Diane True, MoRAP, University of Missouri
Matt Wagner, TPWD
Butch Weckerly, Texas State University
Christina Williams, USFWS
David Wolfe, Environmental Defense

Added for the second meeting (October 13, 2006):

Amanda Aurora, Loomis Austin
Paul Sunby, SWCA

Added for the third meeting (July 26, 2007):

Tevon Fuller, University of Texas
Sahotra Sarkar, University of Texas

Feb 8, 2006 Meeting Attendees (Becky Peak also provided significant input for this meeting, and Timery DeBoer and Jeff Hatfield attended via phone)

Name	Affiliation
Butch Weckey	Texas State University
Charlotte Reemts	TNC, Ft. Hood
Christina Williams	USFWS
Chuck Sexton	USFWS
Clay Bales	Texas Forest Service
Clif Ladd	Loomis Austin
Craig Farquhar	TPWD
David Diamond	MoRAP, Univ. Missouri
David Wolfe	Environment Defense
Lee Elliott	The Nature Conservancy
Matt Wagner	TPWD

October 13, 2006 Meeting Attendees

Name	Affiliation
Becky Peak	TNC, Ft. Hood
Butch Weckey	Texas State University
Charlotte Reemts	TNC, Ft. Hood
Christina Williams	FWS
Chuck Sexton	Balcones Canyonlands NWR
Clay Bales	Texas Forest Service
Clayton Blodgett	MoRAP, Univ of Missouri
Clif Ladd	Loomis Austin
Craig Farquhar	TX Parks and Wildlife Dept
David Diamond	MoRAP, Univ of Missouri
David Wolfe	Environmental Defense
Diane True	MoRAP, Univ of Missouri
Jeff Hatfield	USGS
John Cornelius	Ft. Hood
Lee Elliott	TNC, San Antonio
Paul Sunby	SWCA, Inc.
Timery DeBoer	Currently Ph.D. Student

June 26, 2007 Meeting Attendees: list not available

February 8, 2006 meeting at TPWD and June 26, 2007 meeting at USFWS: Agendas Presented via PowerPoint

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Golden-cheeked Warbler Habitat Modeling Meeting

GOAL: Review Draft Habitat Quality Model(s) and Define Future Directions

DATE: **October 13, 2006**

TIME: 9:00 A.M. – 1:00 P.M.

PLACE: Texas Parks & Wildlife Dept, Fountain Park Plaza, 3000 IH-35 S, Suite 100, Austin – we will meet in the building across the parking lot, as we did before

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9:00 Introductions (Diamond)

9:15 Progress to date: summary of last meeting, land cover mapping, development of habitat quality model, recent ground verification - PowerPoint (Diamond and Blodgett)

10:00 Discussion: How adequate is the approach? The draft model(s)? How can the models be improved? Be verified? (Group)

10:30 Break

11:00 Continue discussion

11:30 Summarize: What needs to be done, what can be done, and by whom? Utility of the model: What are the caveats? What are the appropriate uses the group would recommend for this habitat quality model? Plans for future input from the group (WebEx meetings? Further review?).

12:00 Group lunch – location to be decided at the meeting; we may order in or eat out

GCW WebEx meeting
May 25

Diane and I met with Lee Elliott and Bill Carr for about 1.5 hours today via WebEx. The goals were:

1. Test the effectiveness of WebEx as a way to show data and gain input
2. Show the landform models and see if those look reasonable
3. View some GCW locations against the landcover, landforms, and geology
4. Look at geology as an influence in terms of GCW habitat quality – specifically, look at the Glen Rose as possibly being lower quality GCW habitat in general

Results

1. We had initial trouble with WebEx but fixed it in about 20 minutes
2. Landform models look good, except we cannot separate low flats from higher flats. We talked about soil depth, parent material, or elevation differences (e.g. just setting a cut-off elevation for low versus high flats). The latter isn't going to work for many landscapes, because we have tried it. The former might work if the SSURGO soils data contain the right information. In this regard, we decided that it really doesn't matter that much for GCW habitat quality mapping anyway. I am thinking that it is not worth the time to try to correct this problem, because there is no reasonably easy way to do it … all are time-consuming.
3. Landform appears to be the main factor in terms of the location of habitat and habitat quality. We cannot use the geology layer for modeling GCW habitat.

Other Notes and Action Items:

1. Precipitation might be important but we don't see how it can be used in any reasonable way given the data available.
2. We need to identify the patches where Timery did NOT find GCWs and try to determine why they were not found in those patches – this will provide clues to habitat quality mapping.
3. We still need to determine how we will treat slope and distance to urban, etc. in terms of habitat quality. It appears that in the landscapes we viewed the slope exposure will not be a factor that can be used. The percent slope might be important but that is highly questionable.
4. The distance to edge was also discussed – we were not sure if that is really a factor in determining habitat quality after viewing the data. Patch size seems an overwhelmingly important and integrating variable.
5. We did not look at the SSURGO soils – specifically, we should look at the utility of using the Redlands type soils as a modifier of habitat quality.

The next task is to complete 2-3 habitat quality models for viewing by a larger group via a WebEx meeting. To do this, we would like to complete our new landcover data layer – that is critically important – that is a minimum of two weeks and possibly as much as two months away.

Most Important Variables Selected during the Feb. 8 Meeting, with notes from subsequent meetings

Variable	Comment
suitable vegetation	must have certain canopy cover, height, and percent juniper/deciduous; we need to get better vegetation data as a priority; Lee suggests to identify suitable habitat by modeling (forest and solar insolation, precipitation, and ecological site type) forest first, then overlaying other variables related to patch size and context .... Craig suggests that we look at Timery's data in the NW (the patches that were not occupied) and see if the composition or other variables were different in that region
patch size	this was considered most important earlier; shape might also be important but Chuck suggested that linear was not bad sometimes; MARCH 8 Up-date - Becky suggests that distance from edge is more important that other factors in determining nest success; she does not hazard a guess on thresholds regarding patch size
distance to large patch	Becky makes point that we don't know dispersal distance so hard to determine from metapopulation standpoint
solar insolation	slope and aspect are important according to some but need to check with Becky who did not find this important on Ft. Hood; further input from Becky notes she found no differences in nest success based on slope and thinks the "slopes are better" idea appears to be an unfounded myth, related possibly to the fact that flats are mainly cleared and slopes are mainly forested on private lands; MARCH 8 NOTE FROM DIAMOND: Ft Hood has a lot of the 'wetter' massive, cracking limestone habitat on uplands, so the idea that slope is important could be a false impression based on a limited sample; Dean Keddy-Hector felt the same way as Becky, and he did also band and closely observe birds in a population farther to the South; this is an issue we need to deal with ... Should we include slope as a factor in habitat quality at all? Timery also noted later that she agrees with Chuck ... the idea that slope is not important at Ft. Hood does not mean that it is not important at all, and in fact I get the feeling that most people think it is important insofar as it influences forest type
landscape context	especially regarding urban land cover; may not be needed if we consider distance to urban; might substitute land cover context for all the distance to the edge values; 100m too small or a neighborhood…maybe 250m … Chuck is looking at Tom's dissertation; Charlotte and Lee made a point here and need to please elaborate ... I believe that they were saying that land cover context may serve as a surrogate for patch size, distance to a large patch, edge, urban, and many other variables

distance to edge	need more input from Becky here - type of edge may be important as well (e.g. urban, crop, grassland); Becky has just now (March 8) been looking at hard data on nest success related to distance form edge, and indicated that distance from edge seems to be a good predictor of nest success - probably the best she has measured
Precipitation	if evapotranspiration is available digitally then that would be a much better variable; Lee might have these data…temperature might also help modify this; MARCH 8 update: Diamond has found that there are no easily accessible data on evapotranspiration; he is looking at the original weather station data to see what can be gleaned ... probably the best that can be done is to look at creating a new interpolated precipitation data layer from the original data
ecological site type	especially when modeling vegetation for new classification and currently for modeling differences on flats; Clay will help with the soils here; March 8 up-date - Diamond now has all of the SSURGO soils data and there seems to be some promise in using these to help identify 'appropriate' vegetation
ADDITIONAL MARCH 8 UP-DATES	we have not been able to get the new, 10m DEMs for the study are yet, but are told that they are 'on the way' .. The soils are in-house and do look promising; we have extracted floodplains using the soils and will work on the 'redlands' … I might call Clay soon to talk about other EcoClass Types we can pull out as supporting different vegetation; we do also have all of the weather data that are available and we are going to try to interpolate a precipitation surface that is better that the one available from PRISM; algorithms are available for calculation of evapotranspiration, but we do not have enough data to support those algorithms from enough reporting weather stations to be able to create a surface across the study area; the new National Land Cover Dataset is not yet out ... our current plan from here now is to await DEMs and NLCD, and work on the weather data and the soils data ... we also need to draft a habitat quality algorithm
ADDITIONAL SEPTEMBER 12 UP-DATES	we had to draft new land cover for the range of the GCW - the circa 1992 coverage from NLCD was too old to live with; this 'coarse and quick' version for the 36 counties will work, and is better than what we had; we used the DEMs to calculate solar insolation and land position; we used SSURGO soils to identify floodplains; we developed a new precipitation model but it was not useful - not enough data points; the geology data proved not useful; we have not gotten with Clay on the use of the soils yet; we are just now ready to develop the habitat quality model and hope to have those done within 3 weeks; we have a field trip to do some ground verification planned for Oct 8 - 12 and will meet with the committee on Oct 13; we had a WebEx meeting with Bill Carr and Lee Elliott to check methods and look at some things we have done

Appendix B

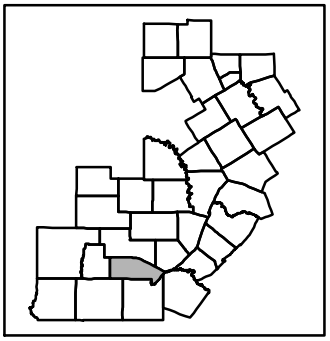
Maps of Models A, B, C, D, and L

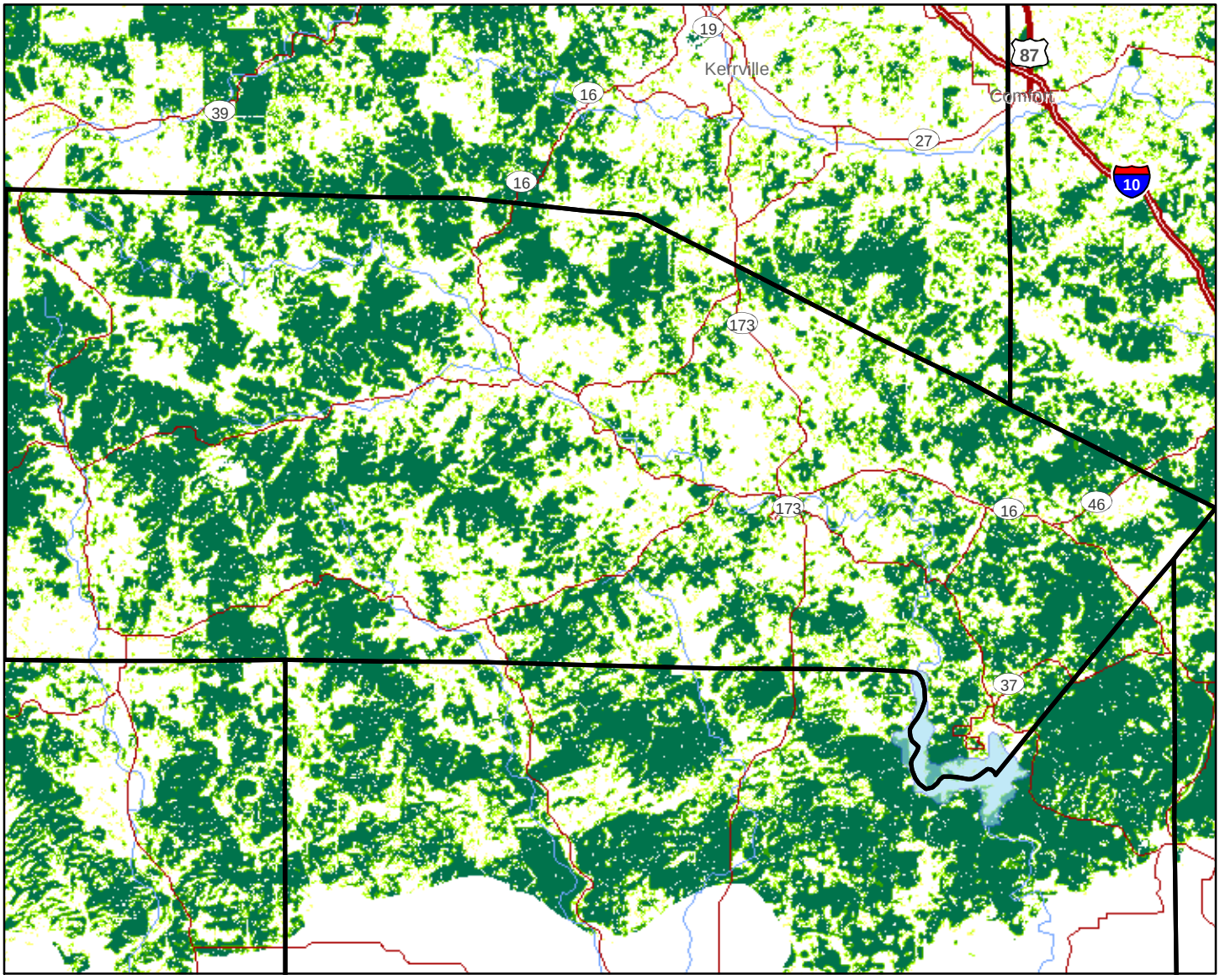
Figure 1. GCW Model A

BANDERA COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3
- 4 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N
W
E
S

1:420,333

0 3.5 7 14 Miles

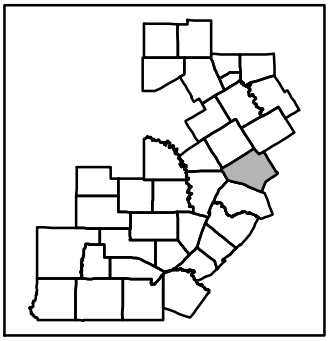
0 4.5 9 18 Kilometers

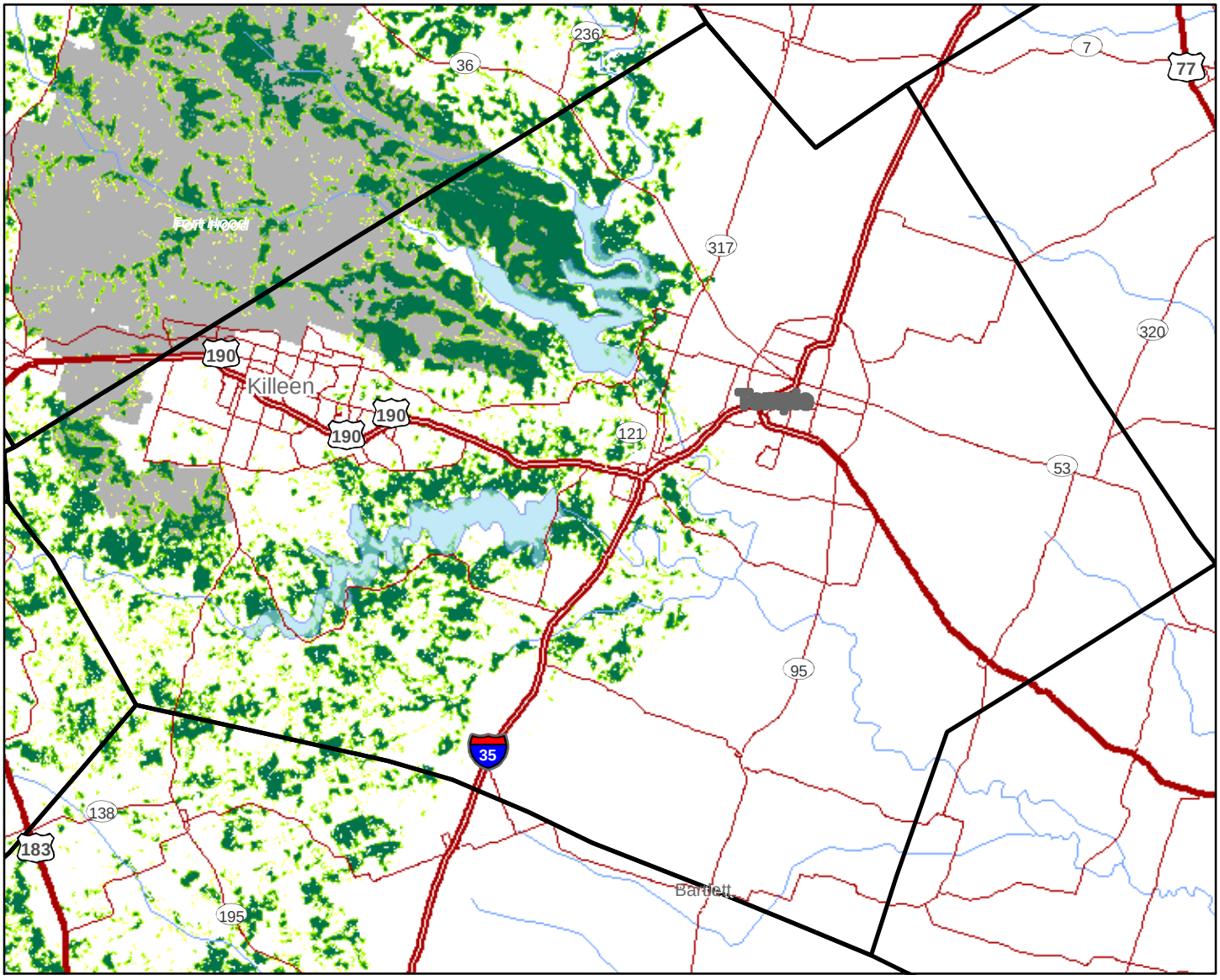
Figure 1. GCW Model A

BELL
COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3
- 4 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N
W
E
S

1:426,603

0 3.5 7 14 Miles

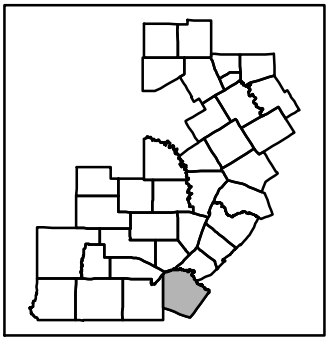
0 4.5 9 18 Kilometers

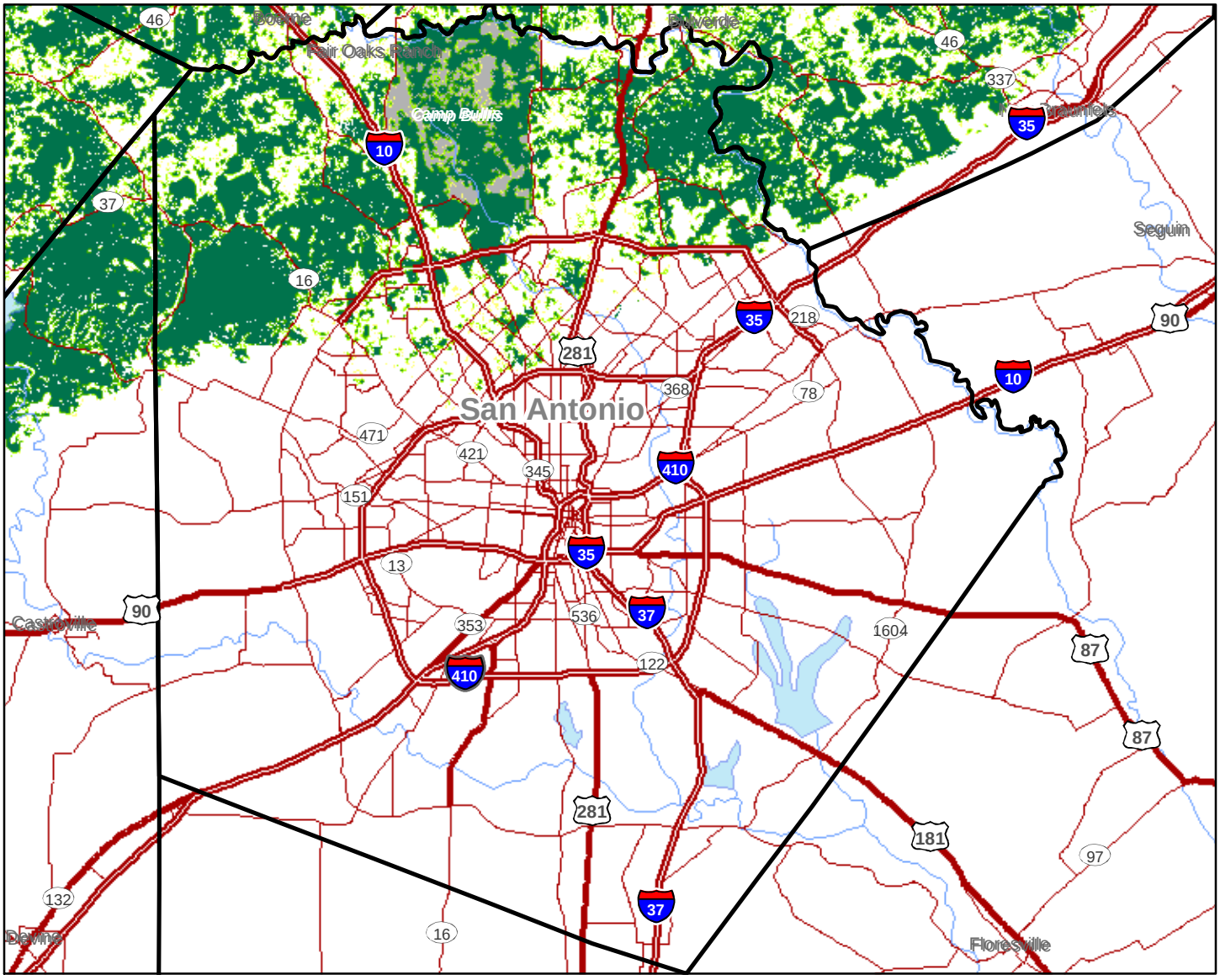
Figure 1. GCW Model A

BEXAR COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3
- 4 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N W E S

1:467,865

0 3.75 7.5 15 Miles

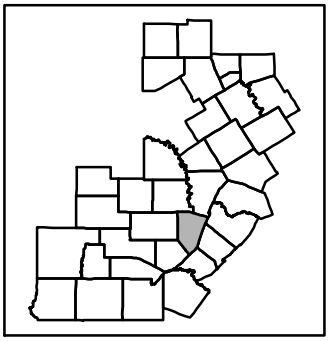
0 5 10 20 Kilometers

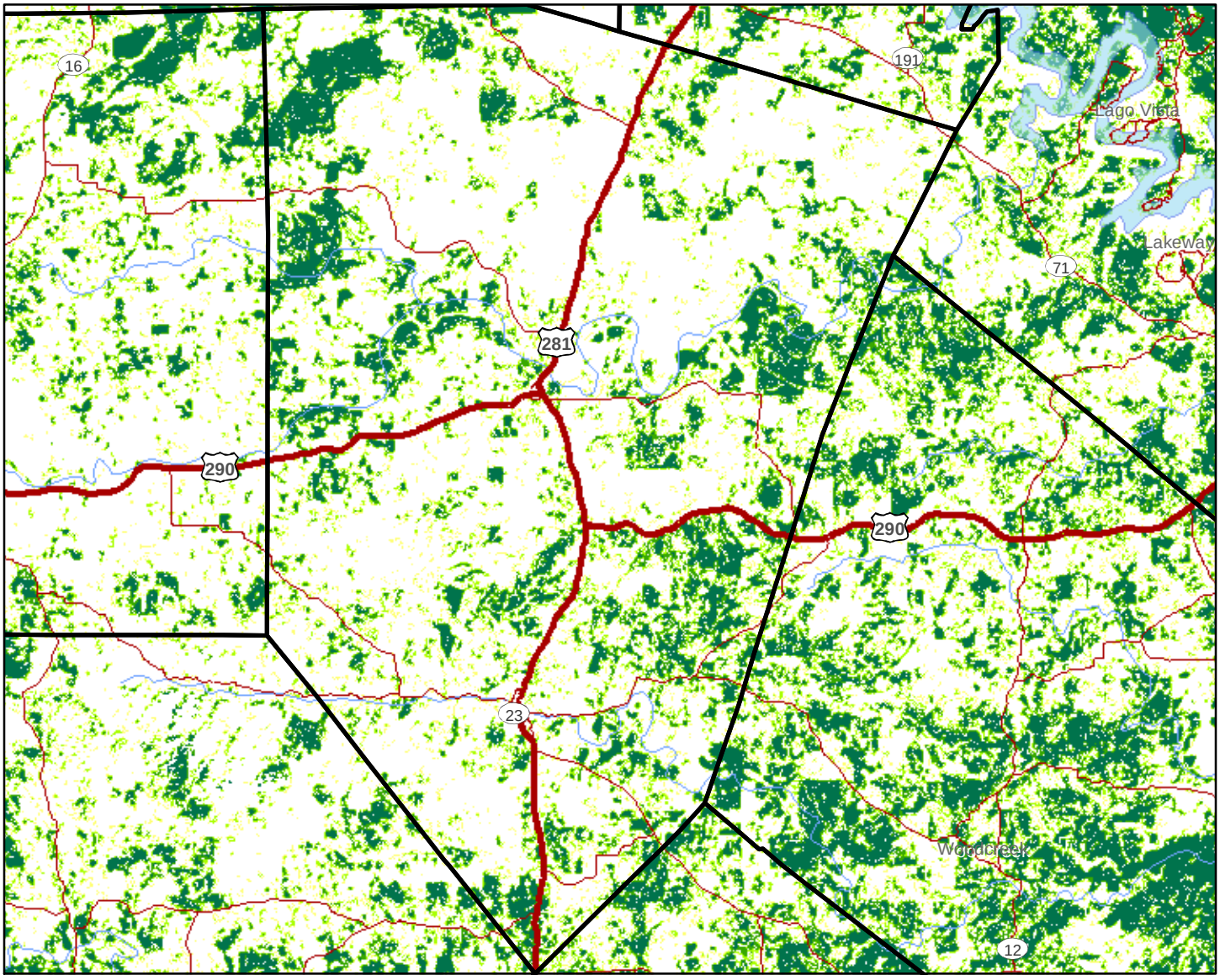
Figure 1. GCW Model A

BLANCO COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3
- 4 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N W E S

1:408,826

0 3.5 7 14 Miles

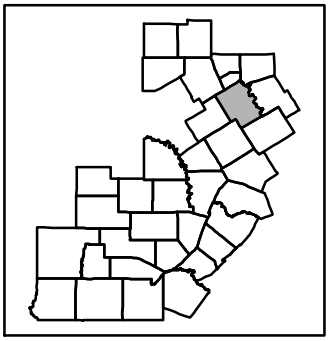
0 4.5 9 18 Kilometers

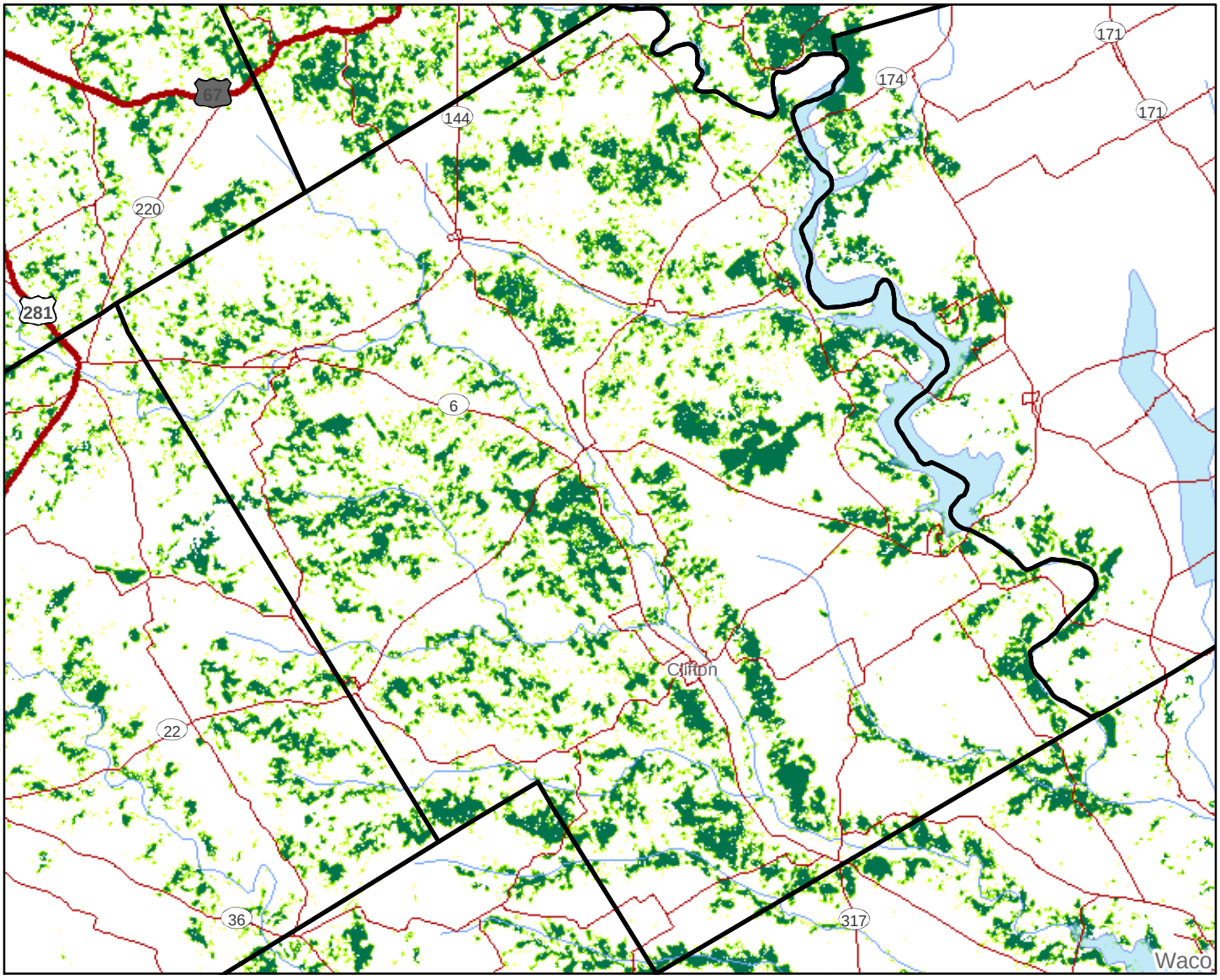
Figure 1. GCW Model A

BOSQUE
COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3
- 4 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N
W
E
S

1:450,274

0 3.75 7.5 15 Miles

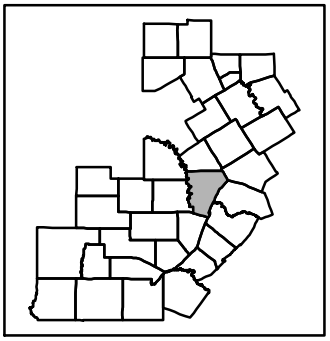
0 5 10 20 Kilometers

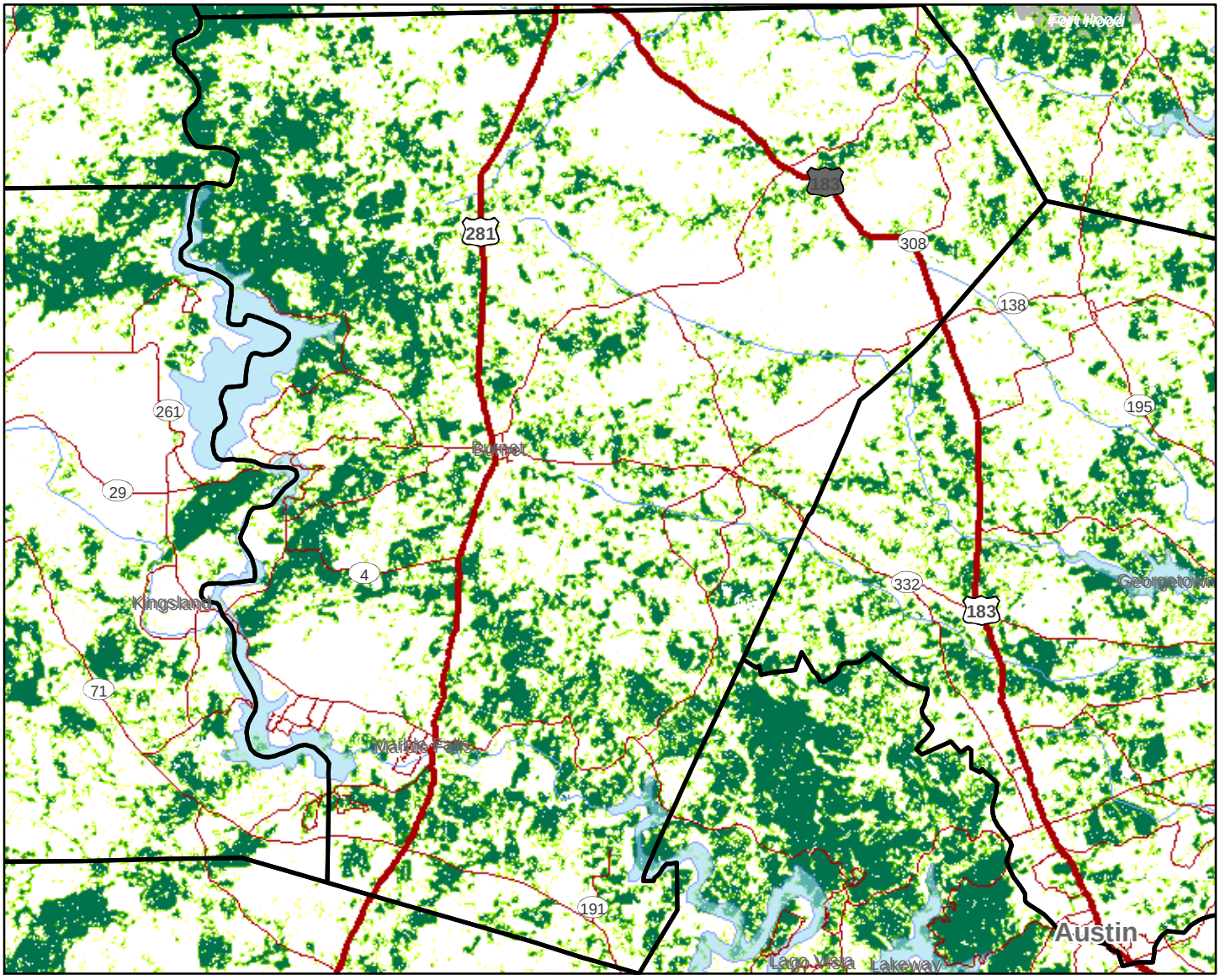
Figure 1. GCW Model A

BURNET
COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3
- 4 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

1:443,072

0 3.75 7.5 15 Miles

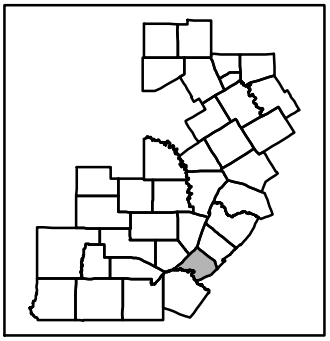
0 5 10 20 Kilometers

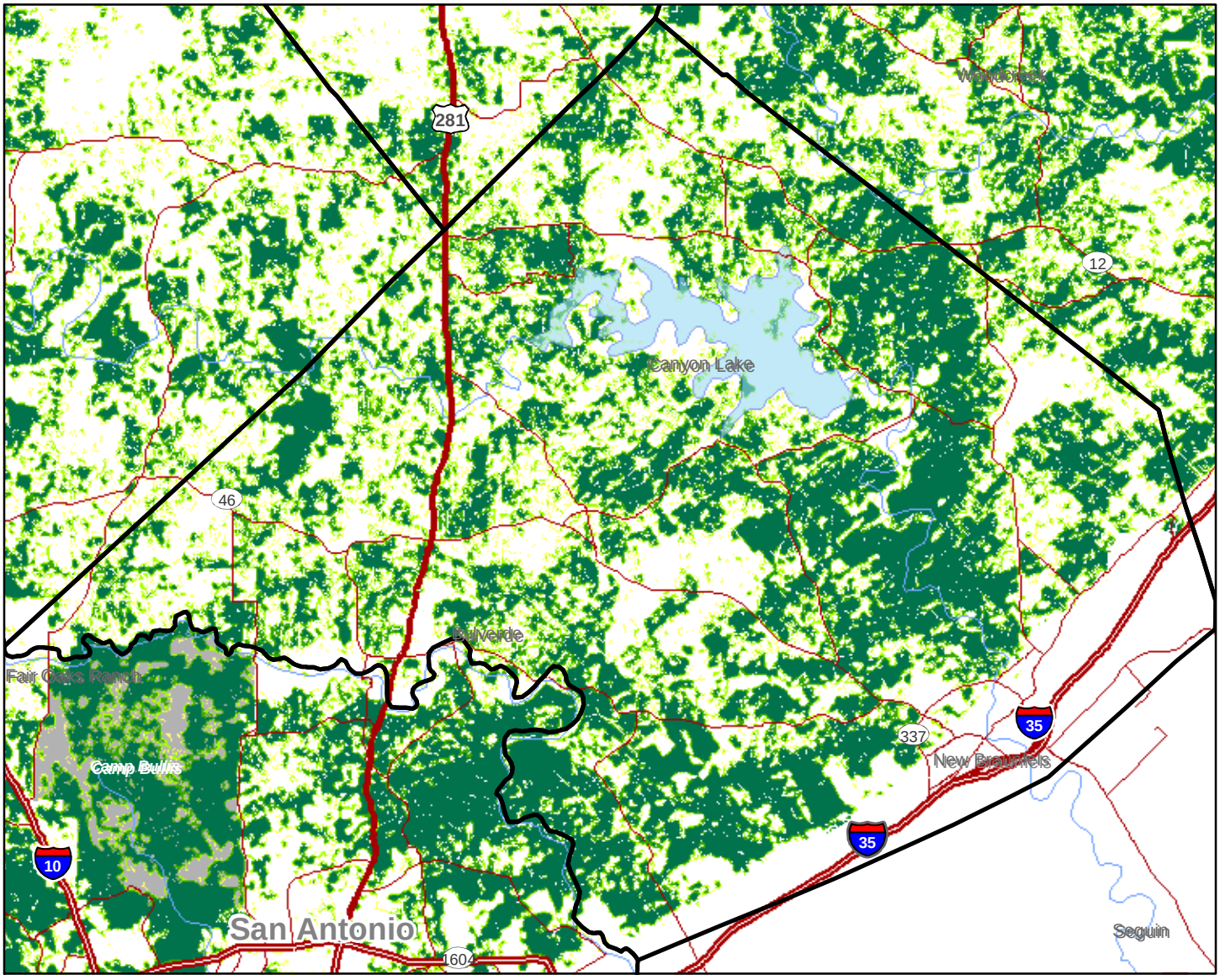
Figure 1. GCW Model A

COMAL
COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3
- 4 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N
W E
S

1:328,003

0 2.5 5 10 Miles

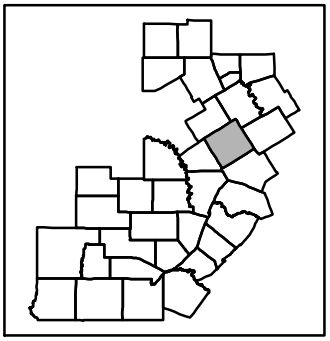
0 3.75 7.5 15 Kilometers

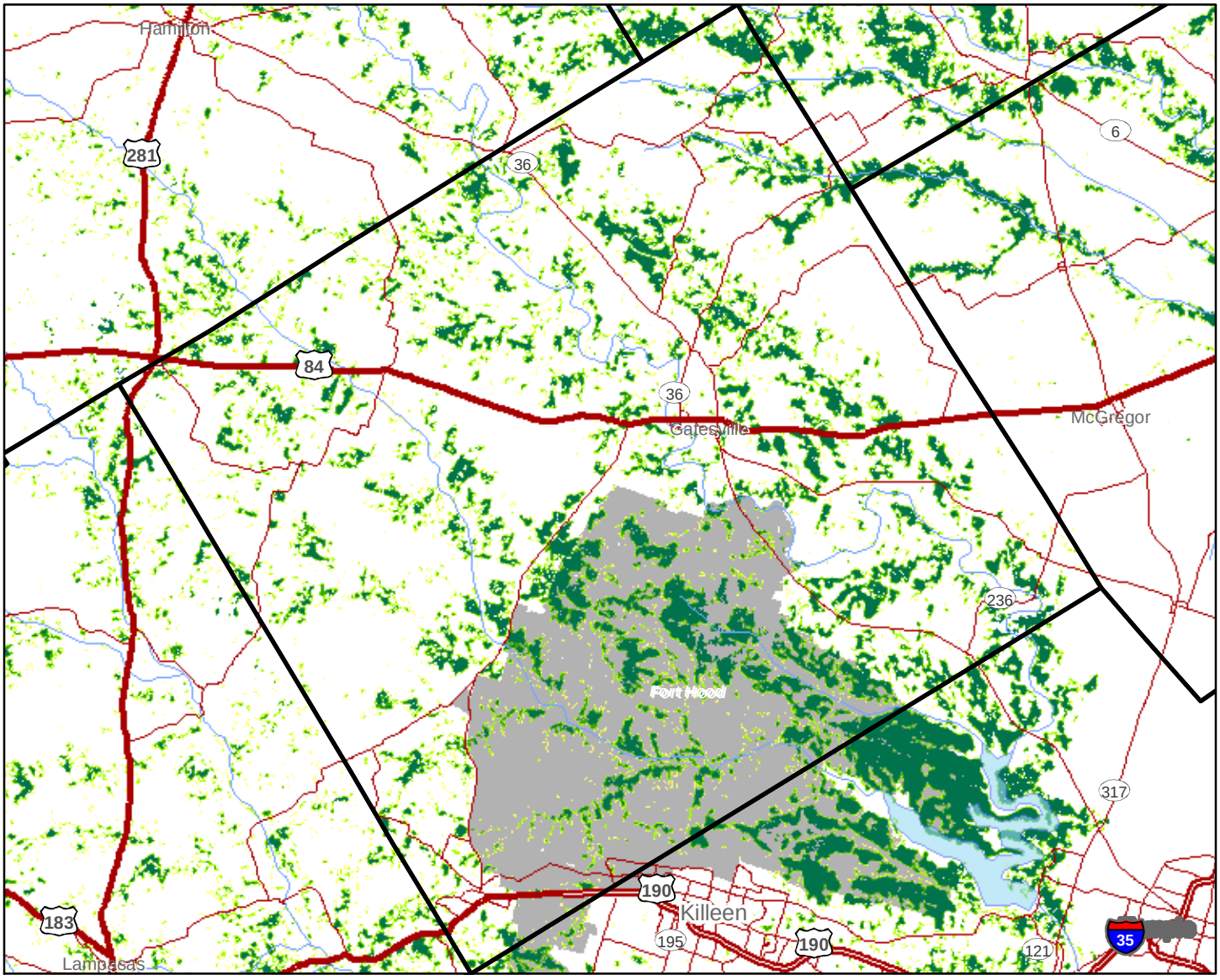
Figure 1. GCW Model A

CORYELL COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3
- 4 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N W E S

1:469,250

0 3.5 7 14 Miles

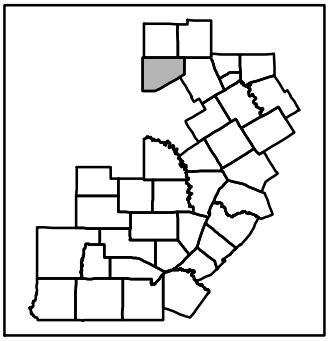
0 5 10 20 Kilometers

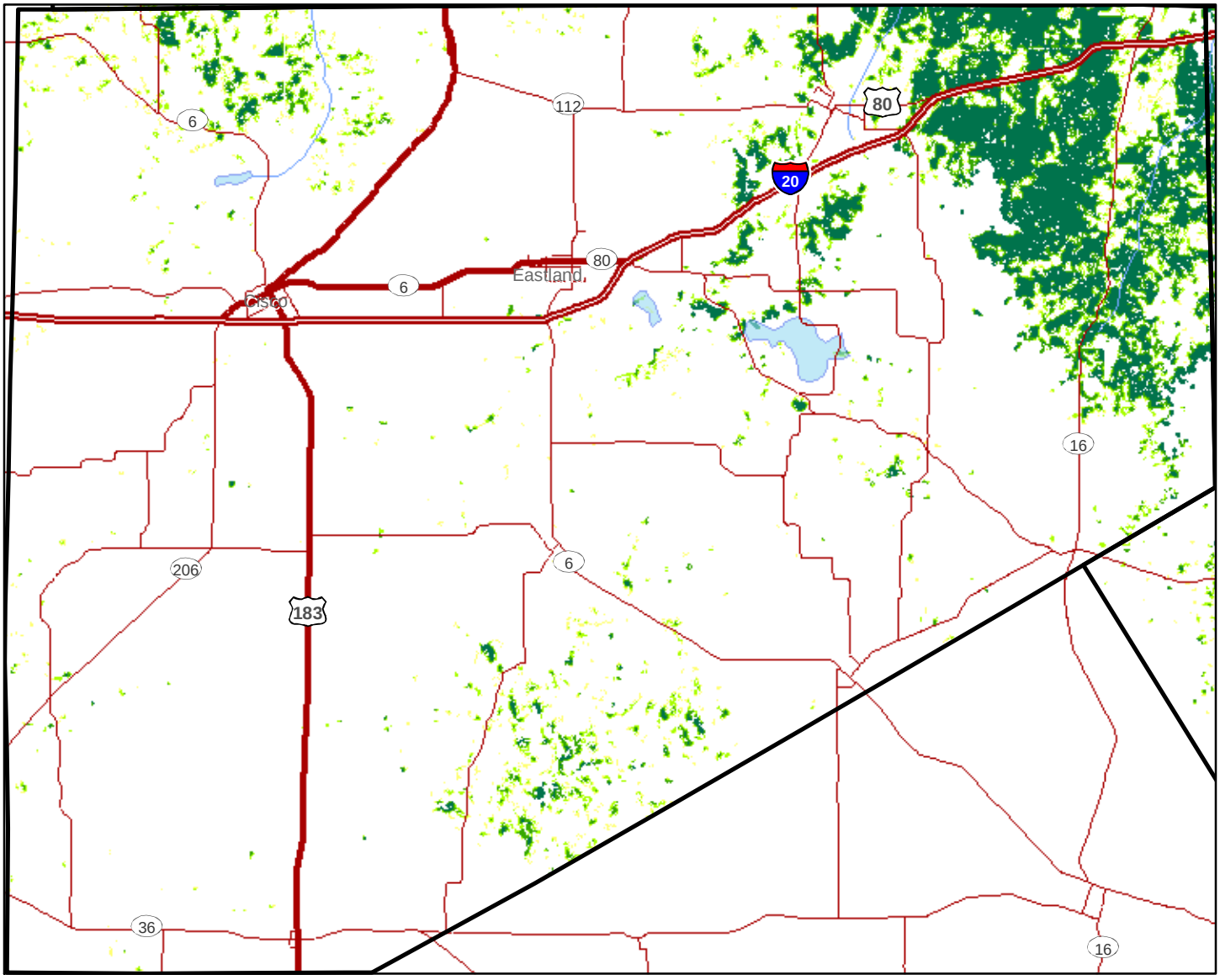
Figure 1. GCW Model A

EASTLAND
COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3
- 4 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N
W
E
S

1:319,430

0 2.5 5 10 Miles

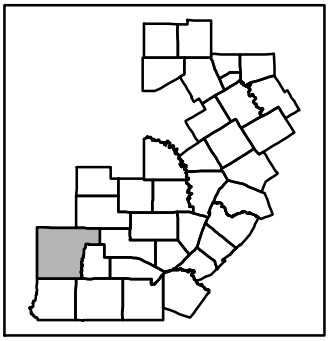
0 3.5 7 14 Kilometers

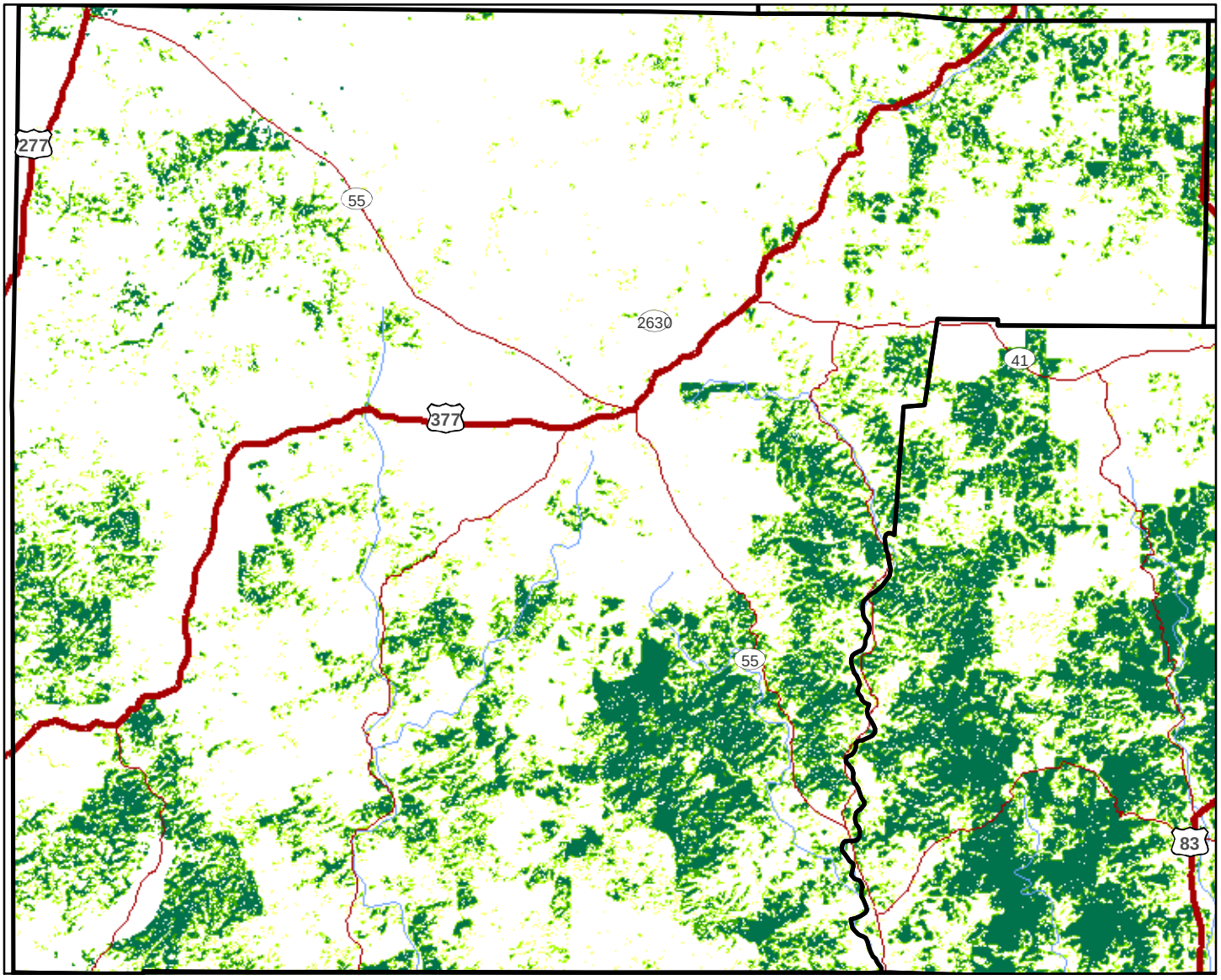
Figure 1. GCW Model A

EDWARDS
COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3
- 4 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N
W E
S

1:486,990

0 3.75 7.5 15 Miles

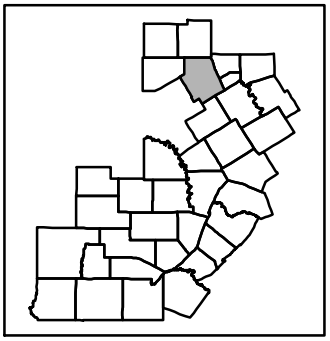
0 5 10 20 Kilometers

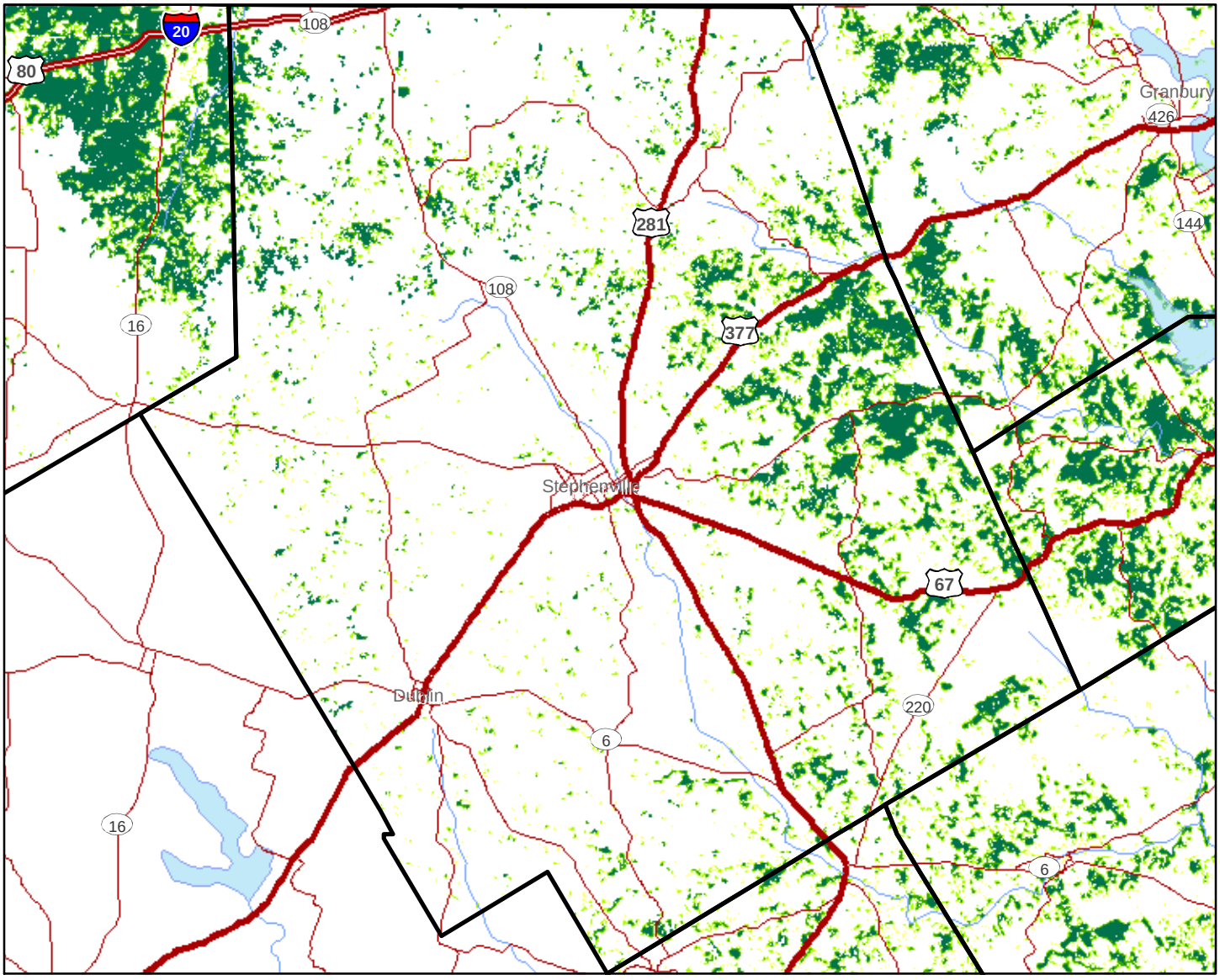
Figure 1. GCW Model A

ERATH
COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3
- 4 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N
W E
S

1:436,311

0 3.5 7 14 Miles

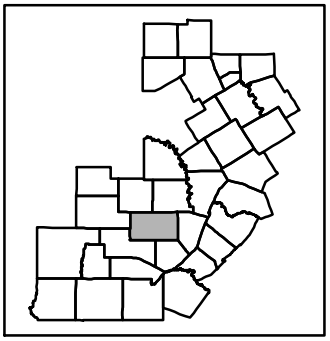
0 4.5 9 18 Kilometers

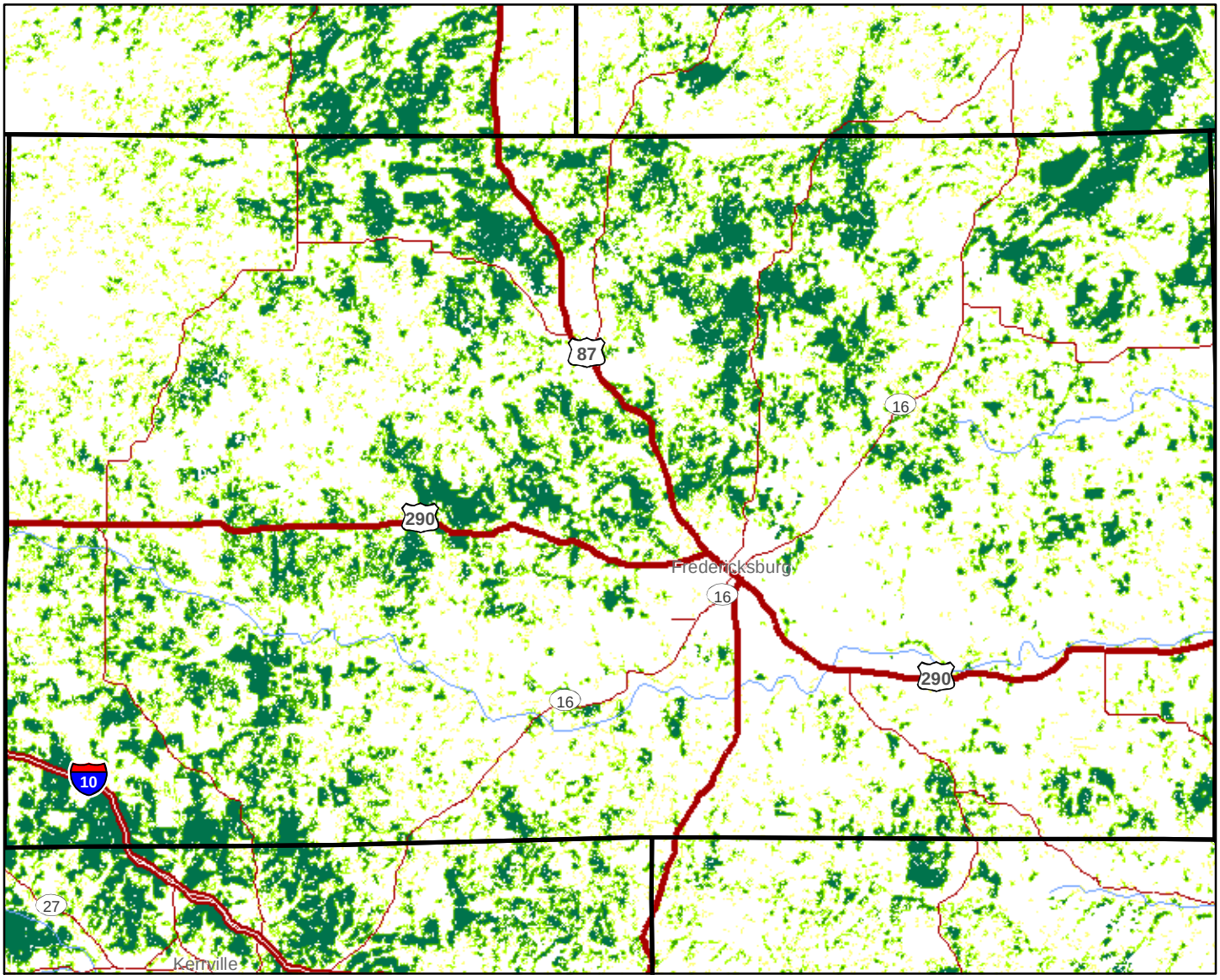
Figure 1. GCW Model A

GILLESPIE COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3
- 4 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N W E S

1:360,868

0 3 6 12 Miles

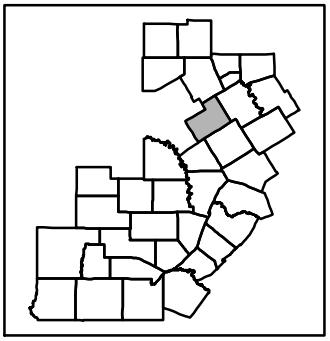
0 3.75 7.5 15 Kilometers

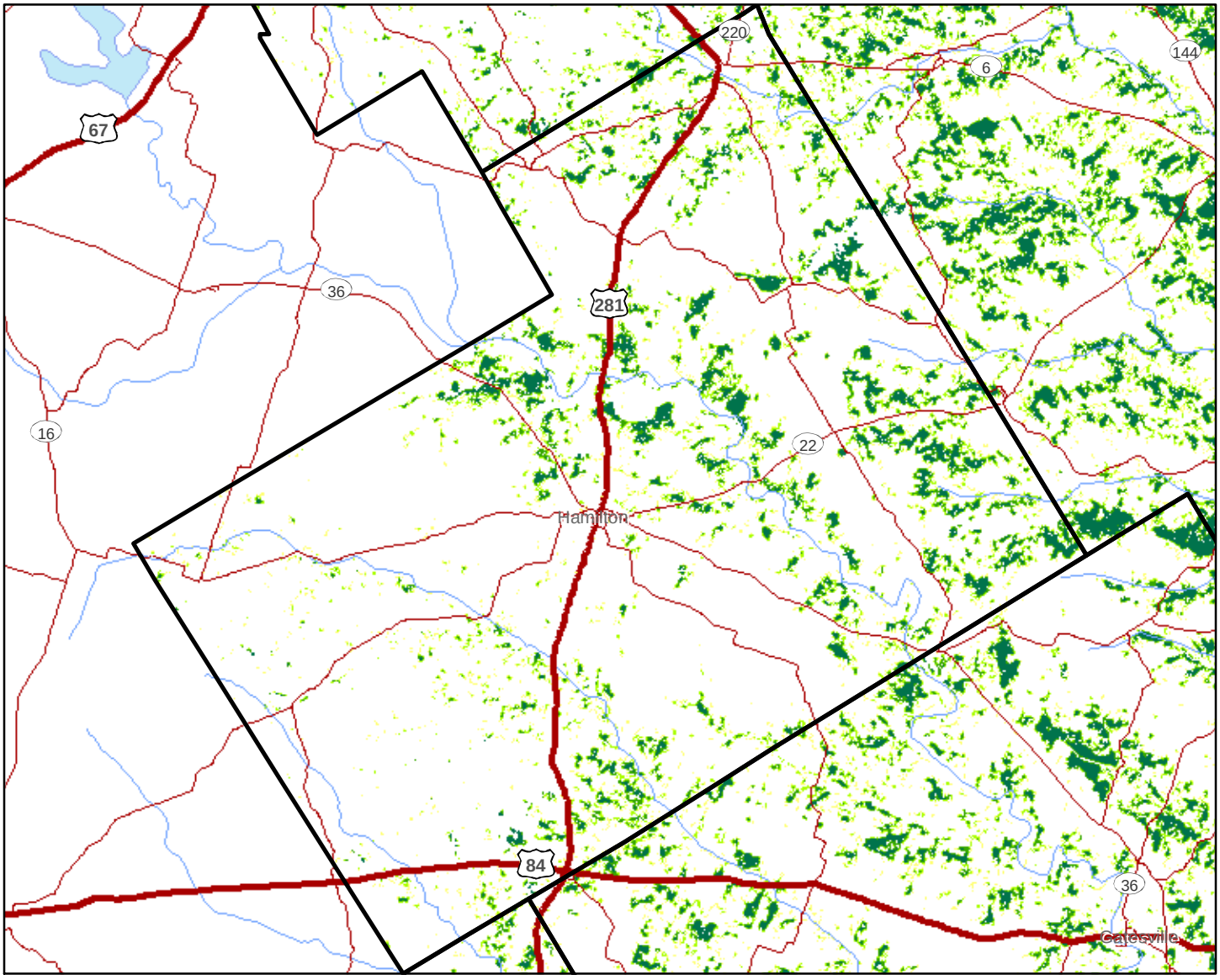
Figure 1. GCW Model A

HAMILTON COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3
- 4 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N W E S

1:440,225

0 3.75 7.5 15 Miles

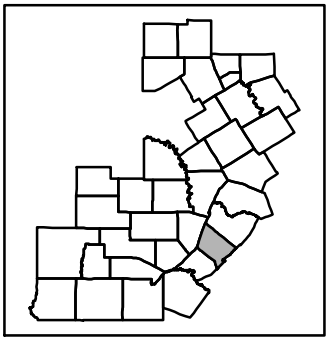
0 4.5 9 18 Kilometers

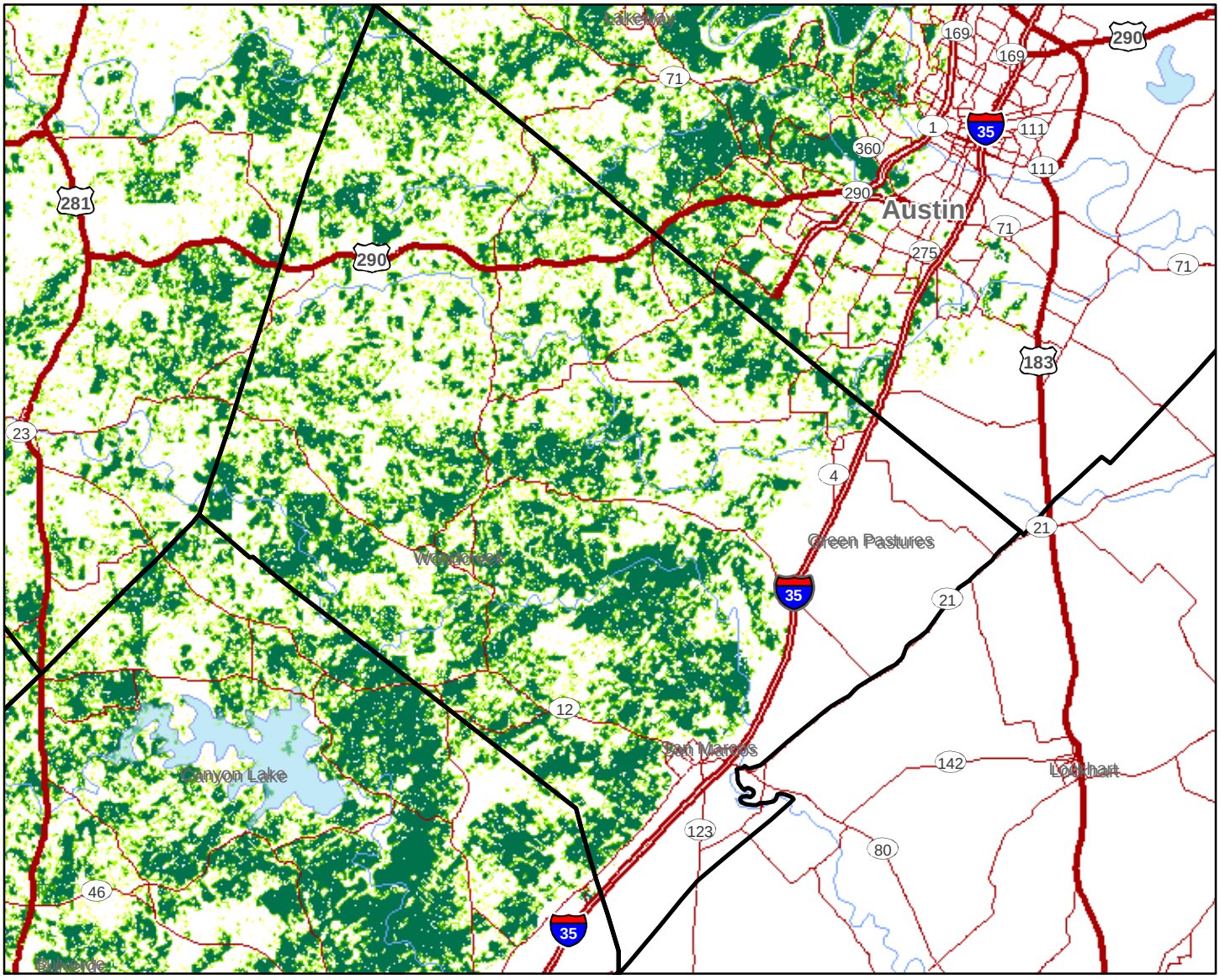
Figure 1. GCW Model A

HAYS
COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3
- 4 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N
W
E
S

1:438,757

0 3.75 7.5 15 Miles

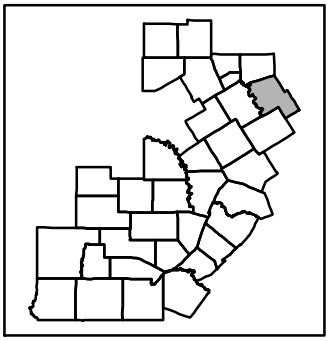
0 4.5 9 18 Kilometers

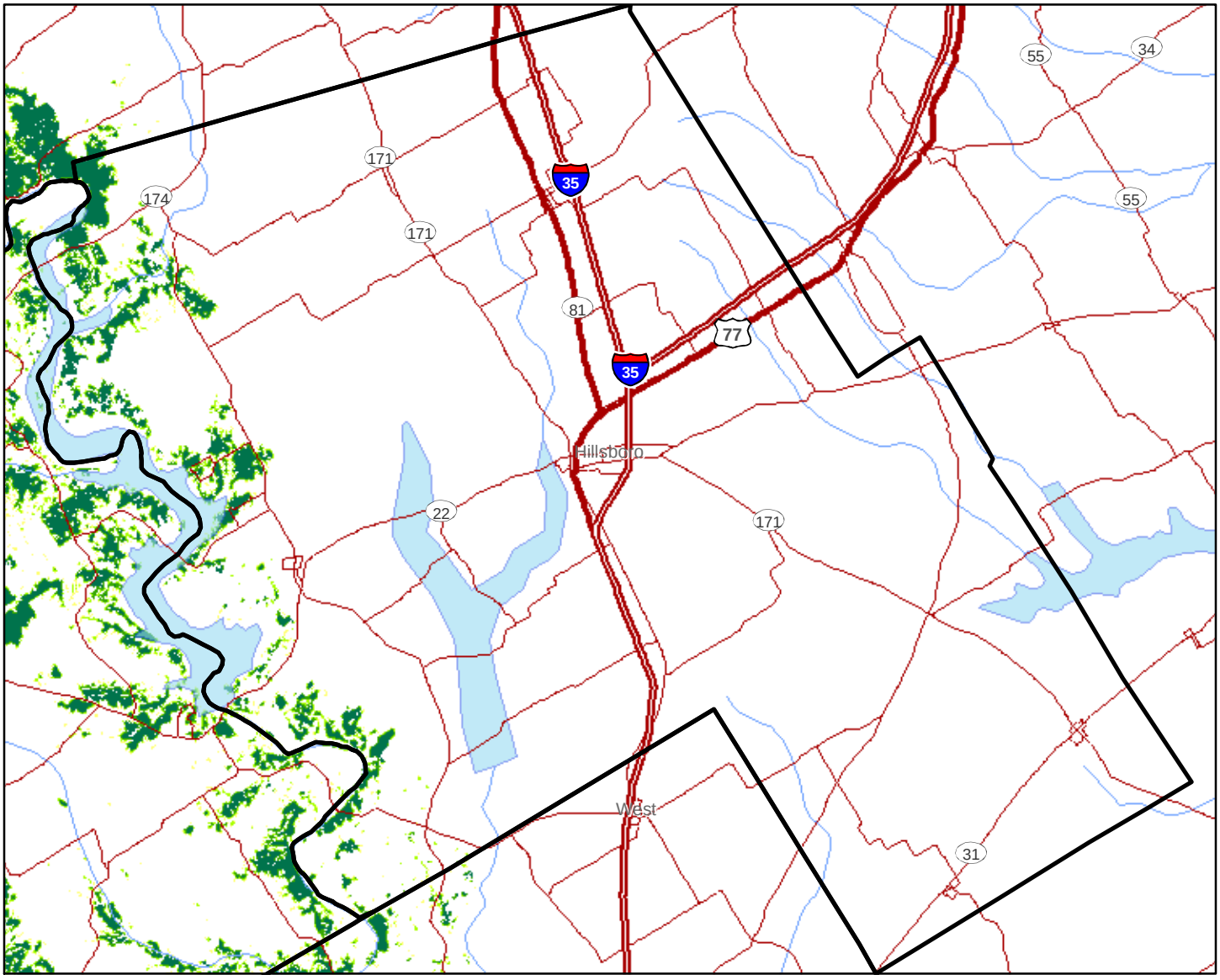
Figure 1. GCW Model A

HILL
COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3
- 4 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

1:405,536

0 3.5 7 14 Miles

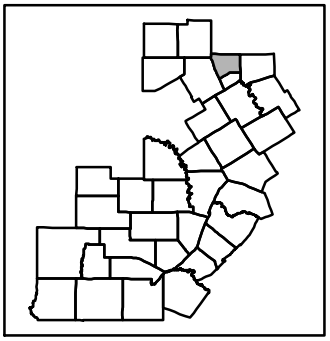
0 4 8 16 Kilometers

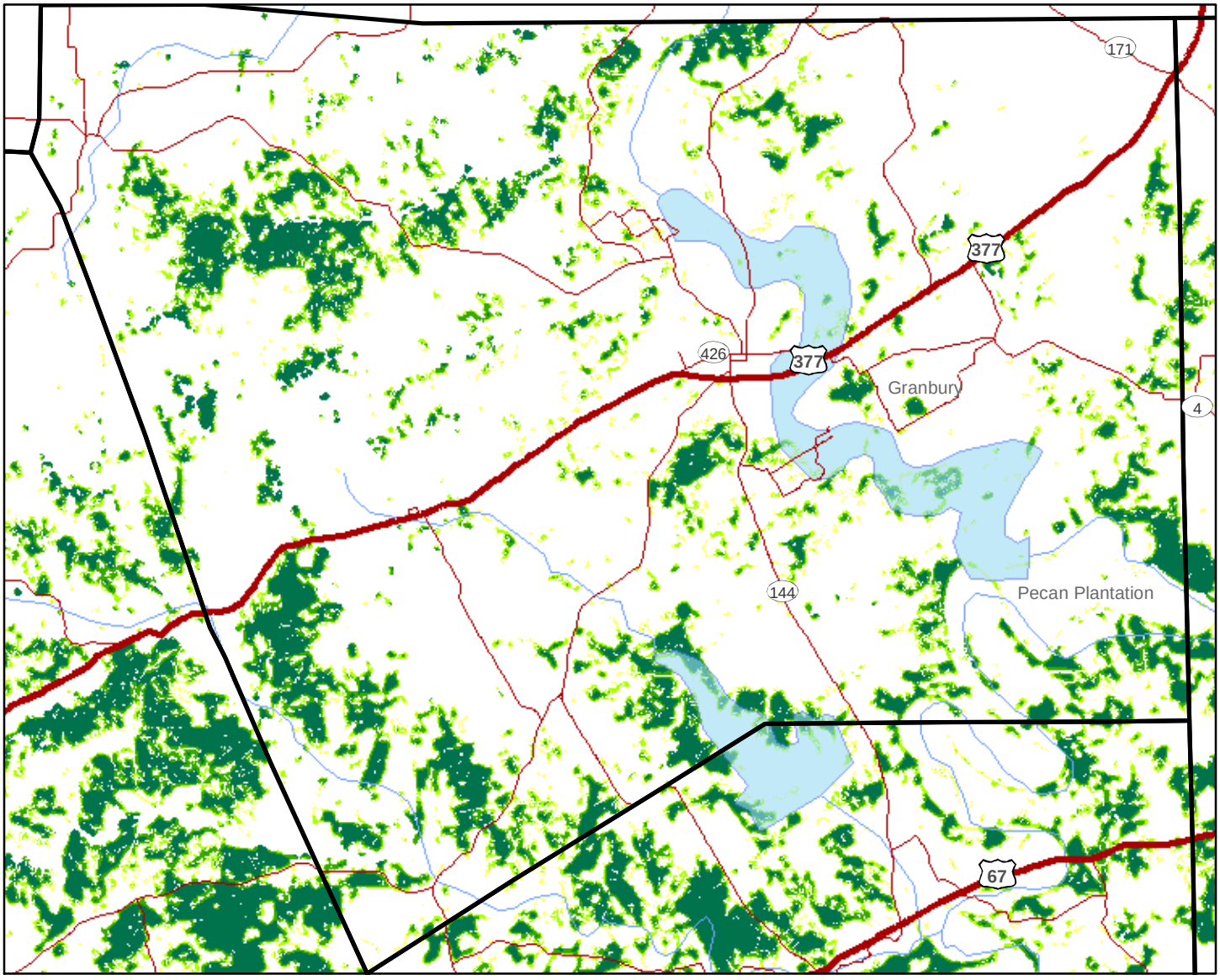
Figure 1. GCW Model A

HOOD
COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3
- 4 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N
W
E
S

1:236,188

0 2 4 8 Miles

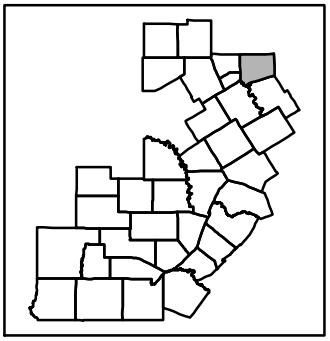
0 2.5 5 10 Kilometers

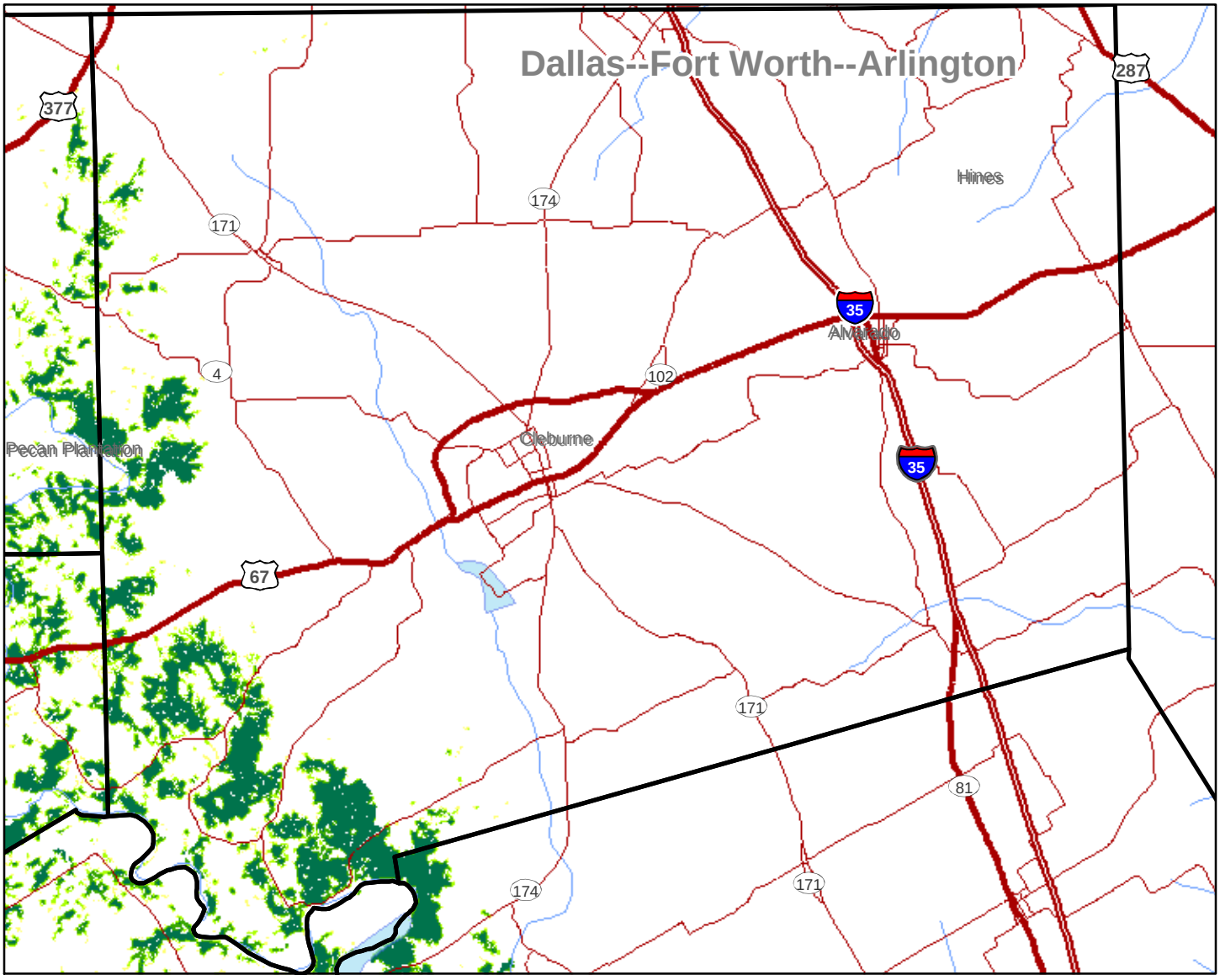
Figure 1. GCW Model A

JOHNSON COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3
- 4 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N W E S

1:307,857

0 2.5 5 10 Miles

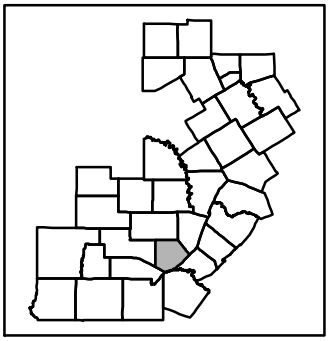
0 3.5 7 14 Kilometers

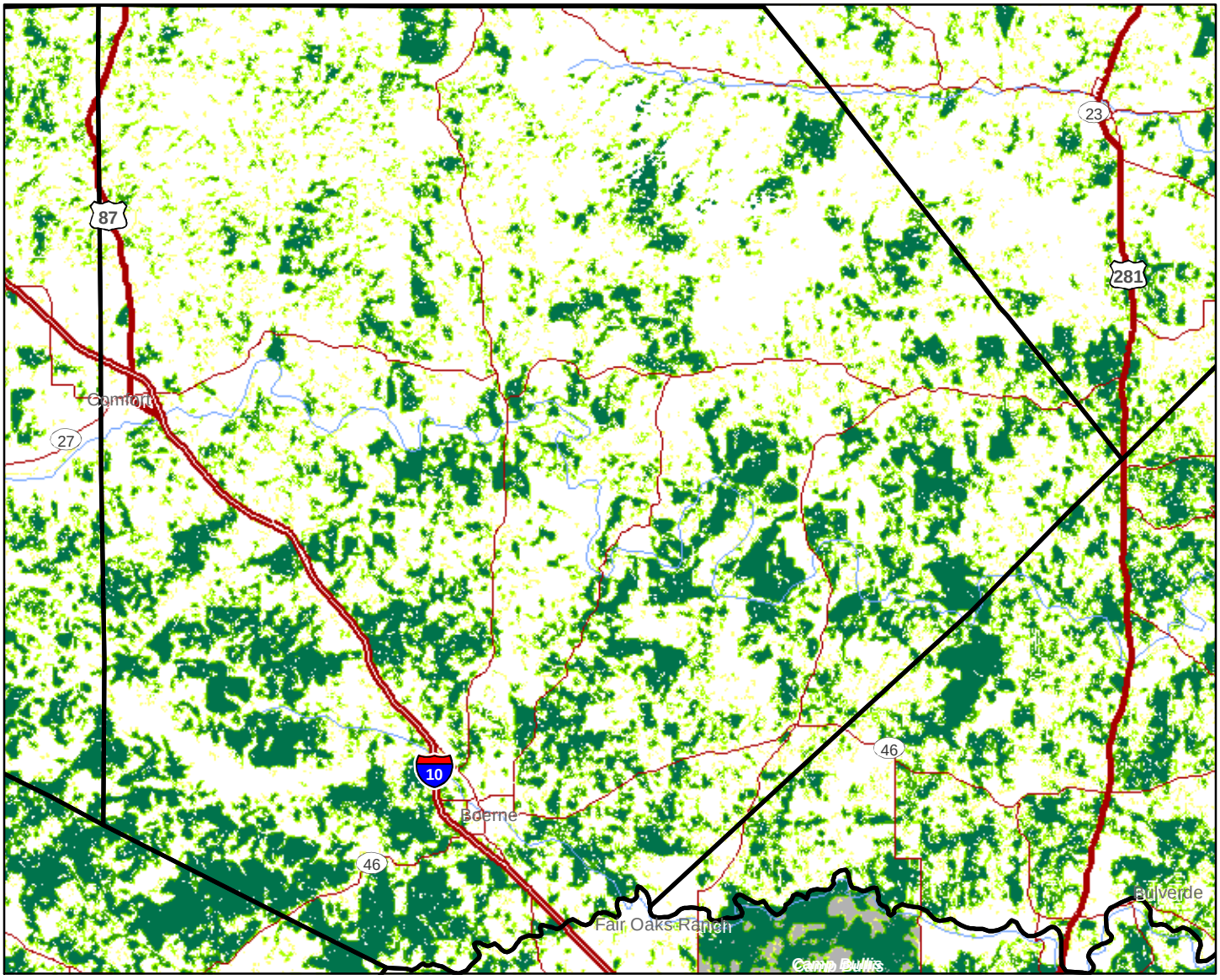
Figure 1. GCW Model A

KENDALL
COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3
- 4 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N
W E
S

1:305,681

0 2.5 5 10 Miles

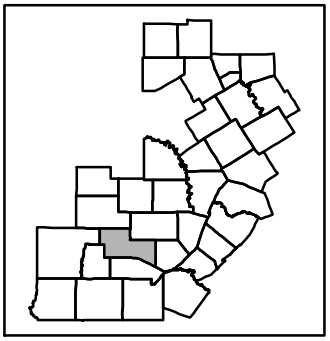
0 3.5 7 14 Kilometers

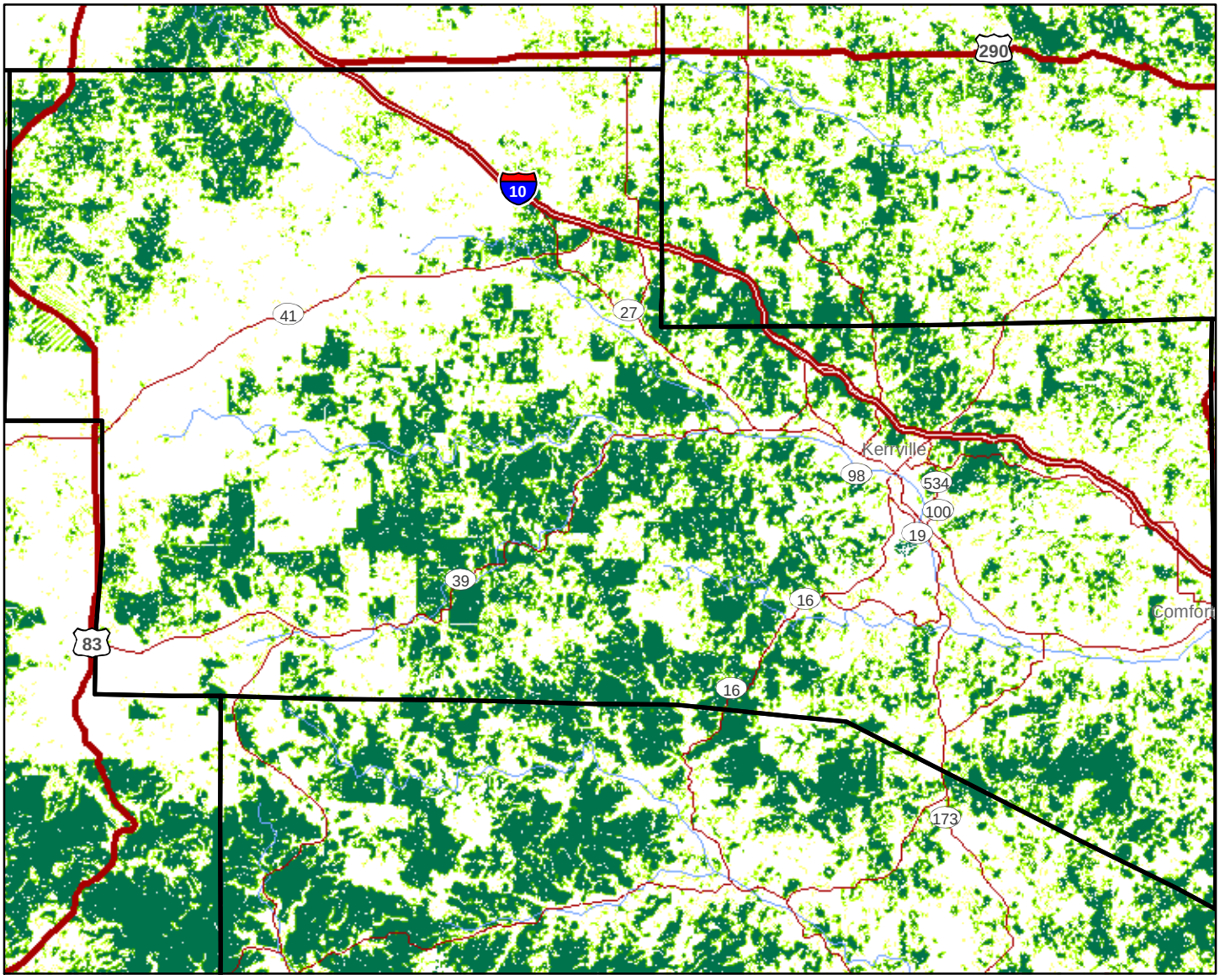
Figure 1. GCW Model A

KERR
COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3
- 4 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N
W E
S

1:424,453

0 3.5 7 14 Miles

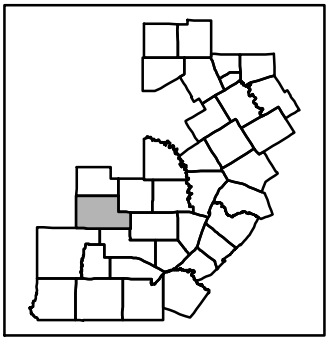
0 5 10 20 Kilometers

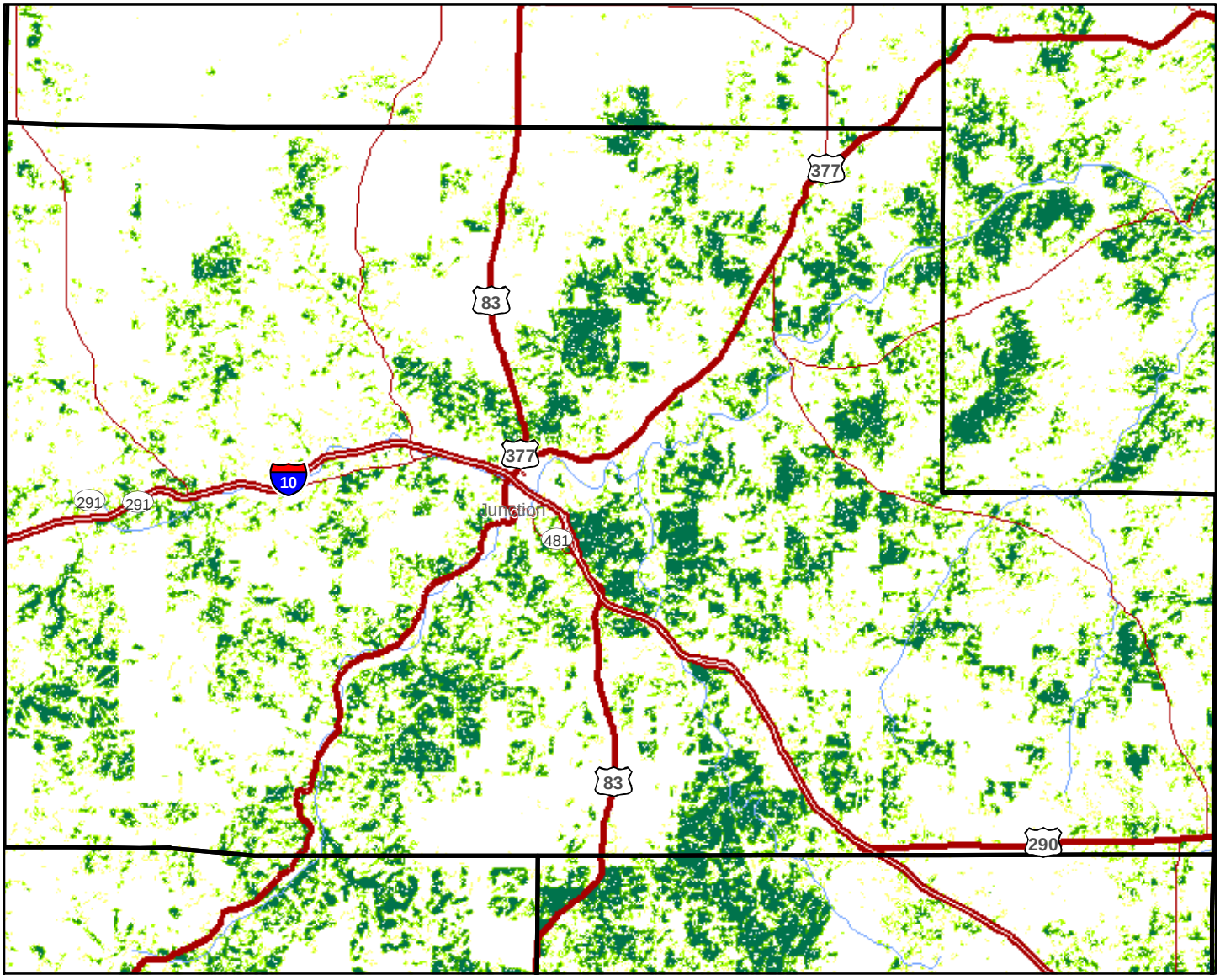
Figure 1. GCW Model A

KIMBLE
COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3
- 4 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N
W
E
S

1:410,168

0 3.5 7 14 Miles

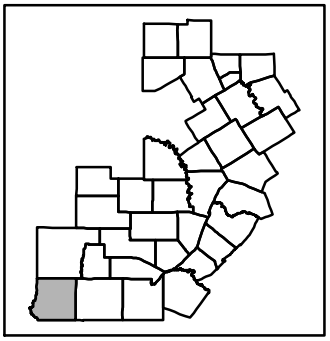
0 5 10 20 Kilometers

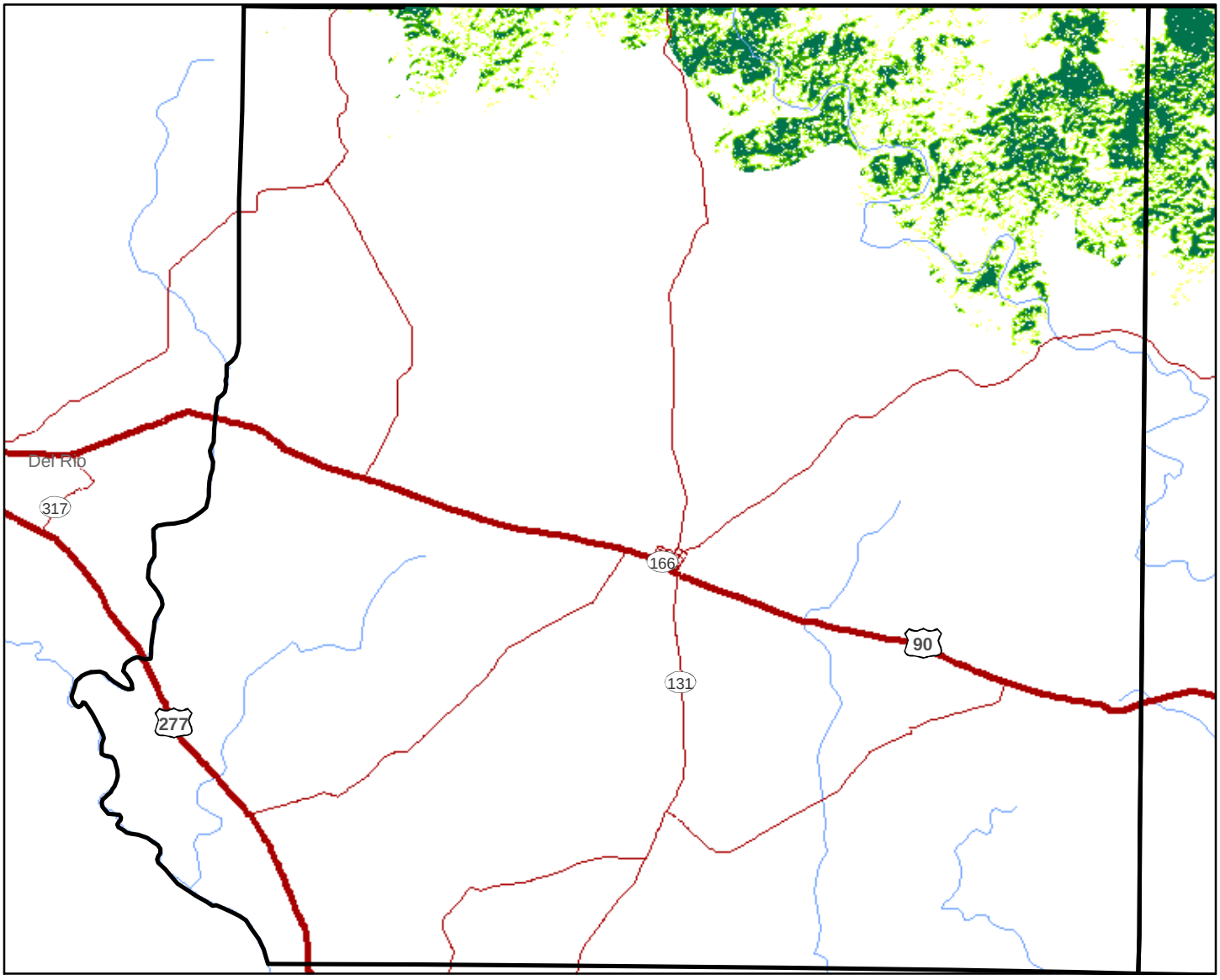
Figure 1. GCW Model A

KINNEY COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3
- 4 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N
W
E
S

1:396,413

0 3.5 7 14 Miles

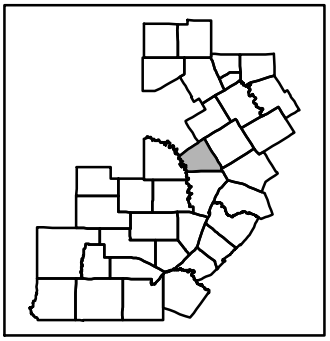
0 5 10 20 Kilometers

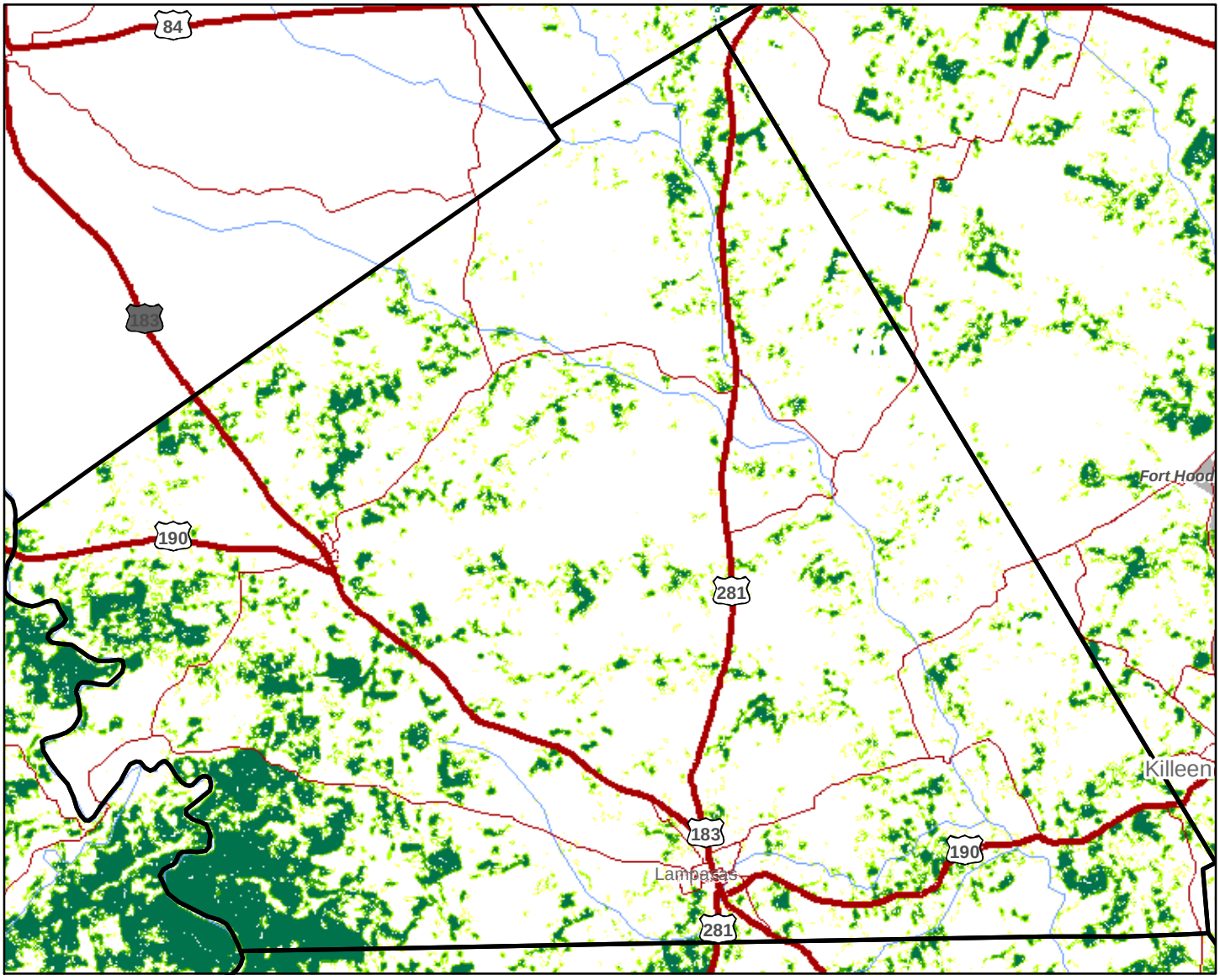
Figure 1. GCW Model A

LAMPASAS COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3
- 4 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N W E S

1:330,663

0 3 6 12 Miles

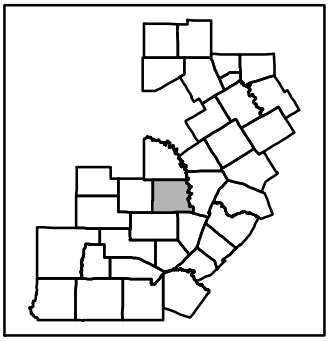
0 4 8 16 Kilometers

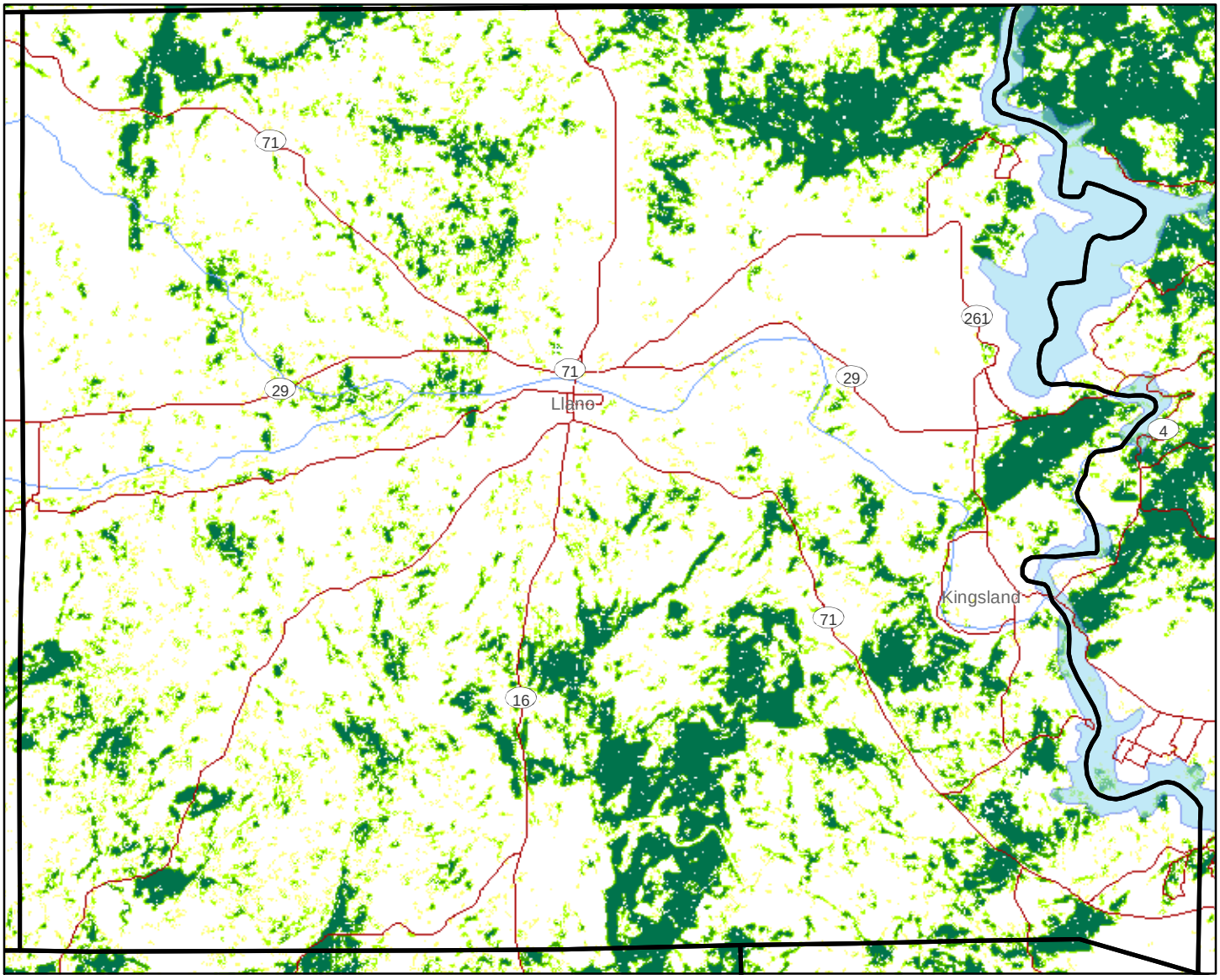
Figure 1. GCW Model A

LLANO
COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3
- 4 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N
W
E
S

1:318,007

0 3 6 12 Miles

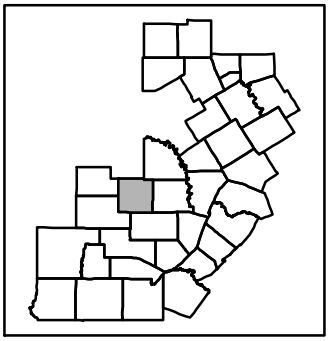
0 3.75 7.5 15 Kilometers

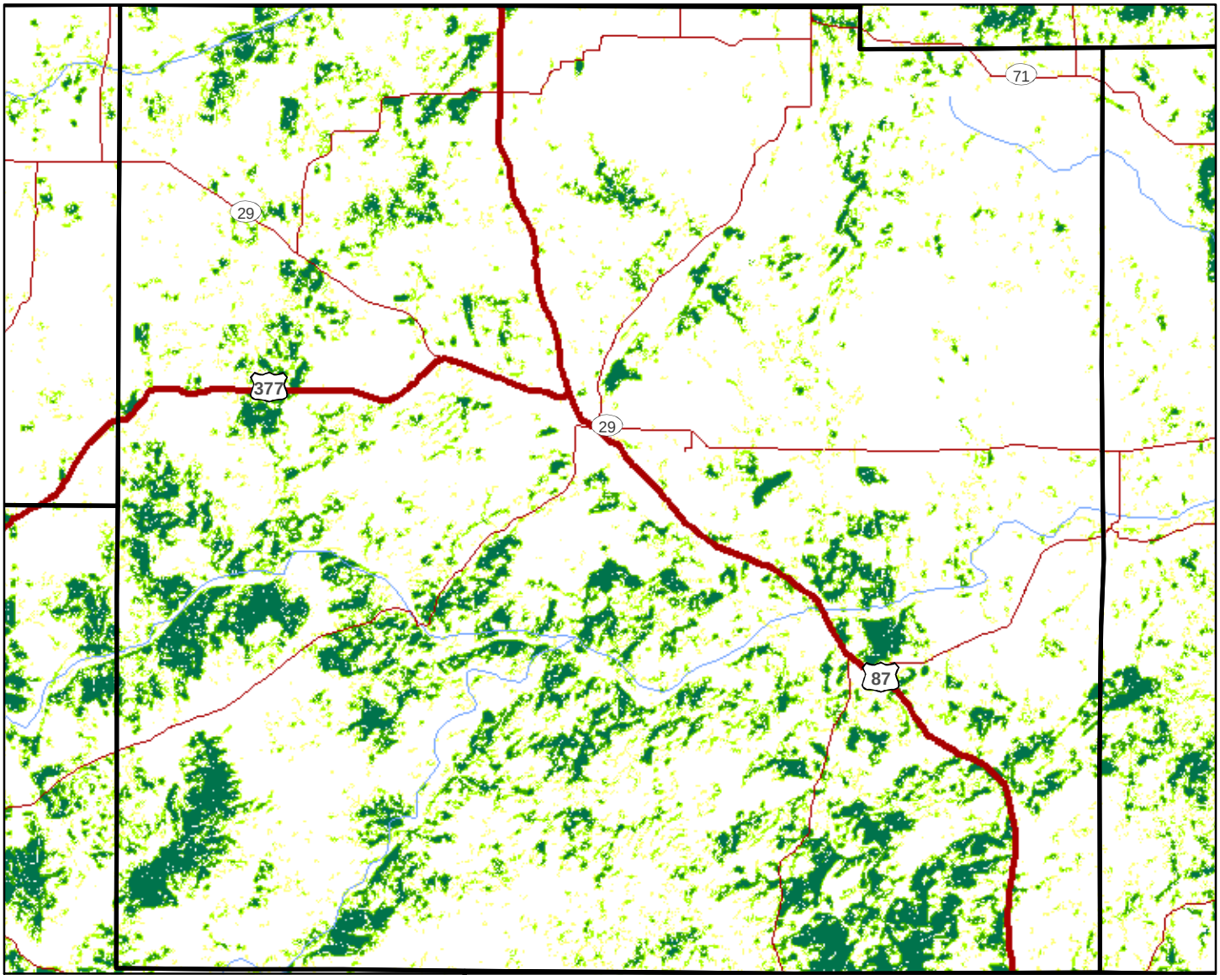
Figure 1. GCW Model A

MASON
COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3
- 4 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N
W E
S

1:322,650

0 3 6 12 Miles

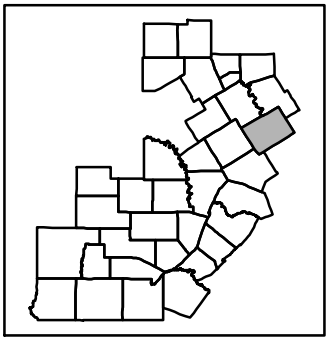
0 3.75 7.5 15 Kilometers

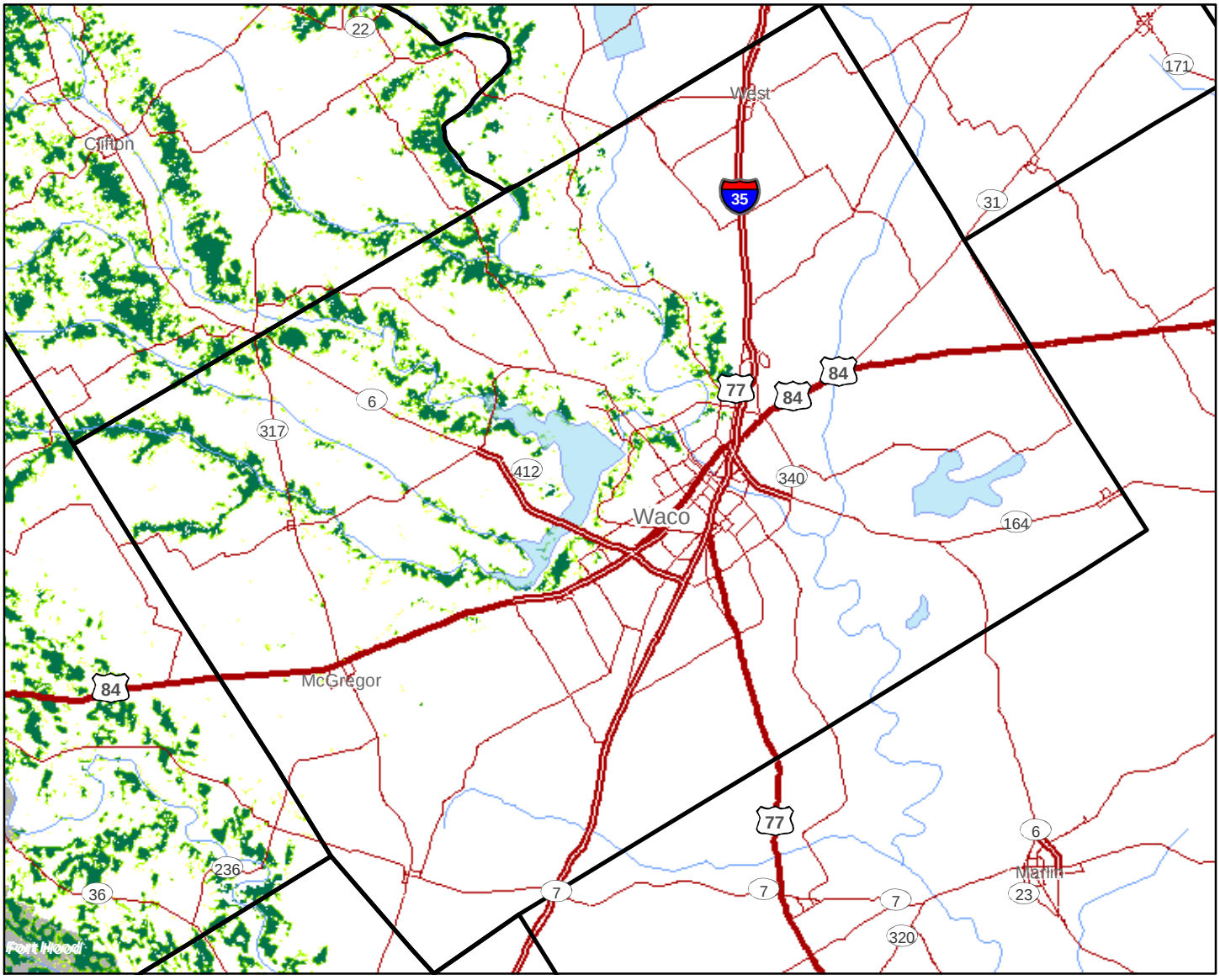
Figure 1. GCW Model A

MCLENNAN COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3
- 4 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N W E S

1:454,790

0 4 8 16 Miles

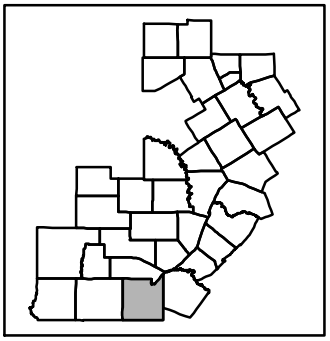
0 5 10 20 Kilometers

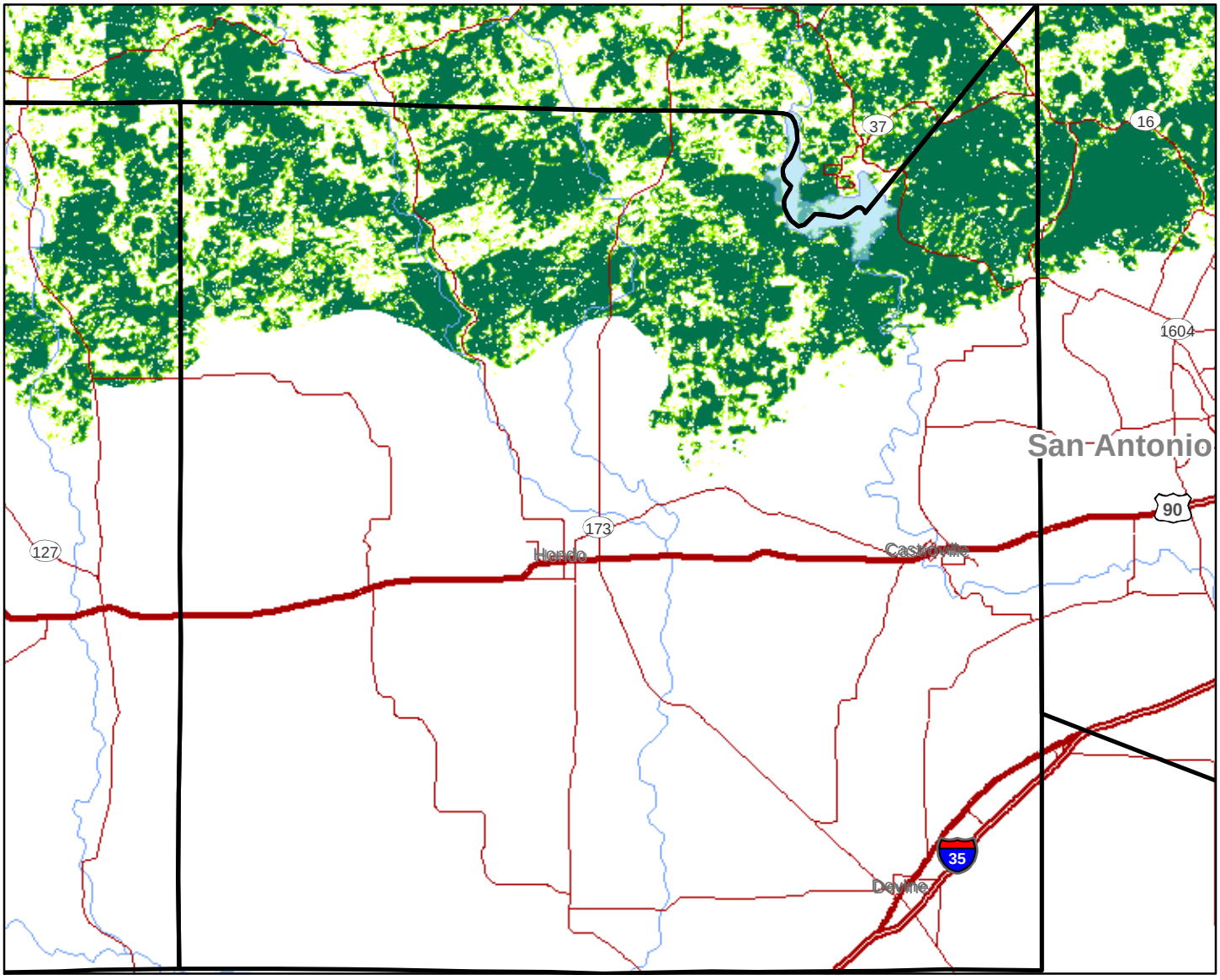
Figure 1. GCW Model A

MEDINA
COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3
- 4 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N
W E
S

1:436,612

0 3.75 7.5 15 Miles

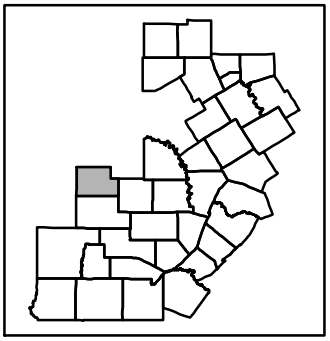
0 5 10 20 Kilometers

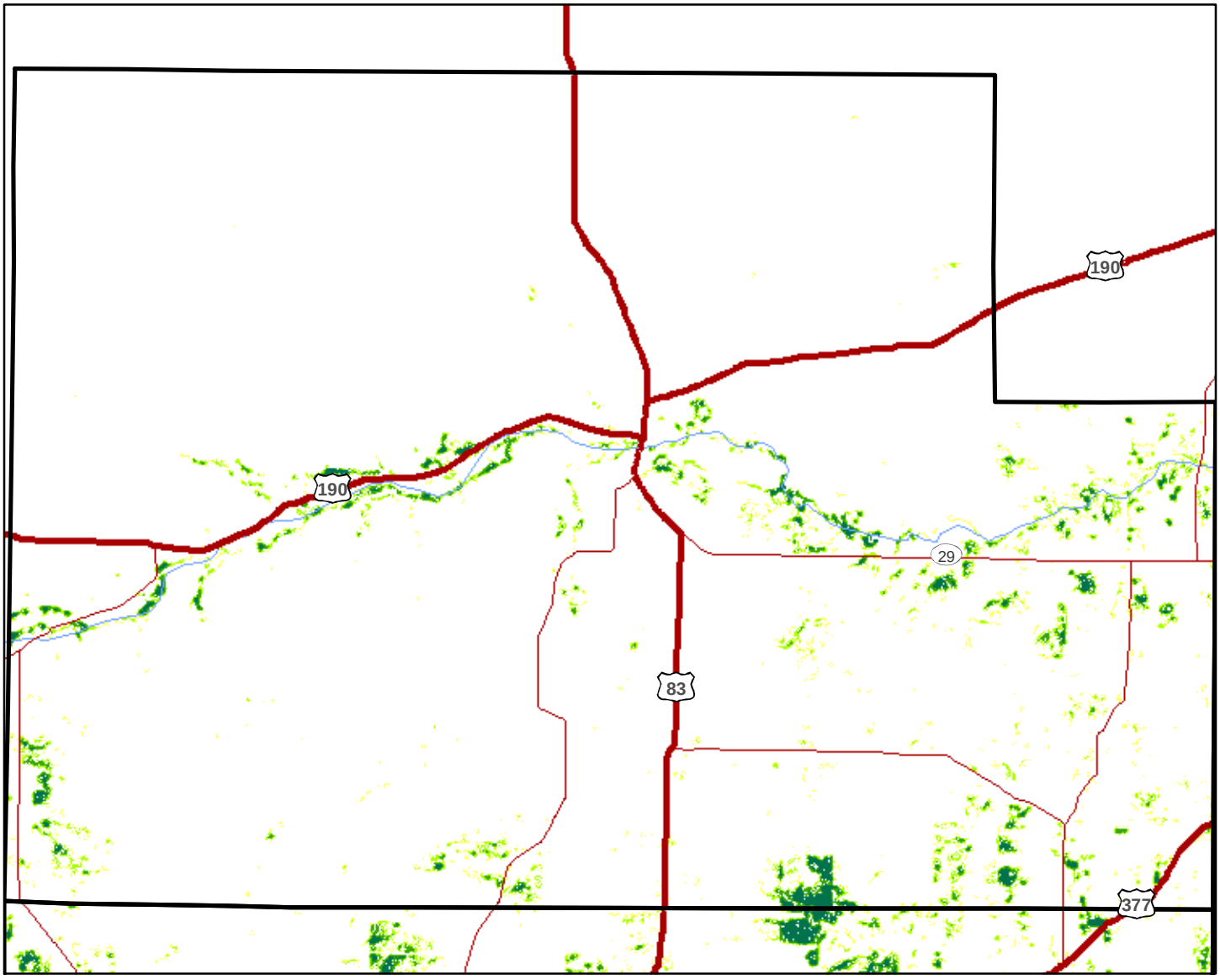
Figure 1. GCW Model A

MENARD COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3
- 4 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N W E S

1:318,185

0 2.5 5 10 Miles

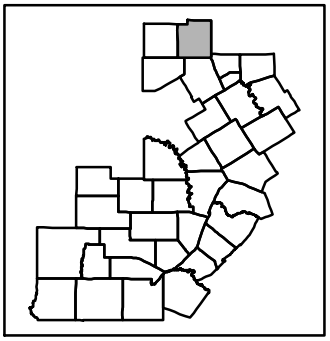
0 3.75 7.5 15 Kilometers

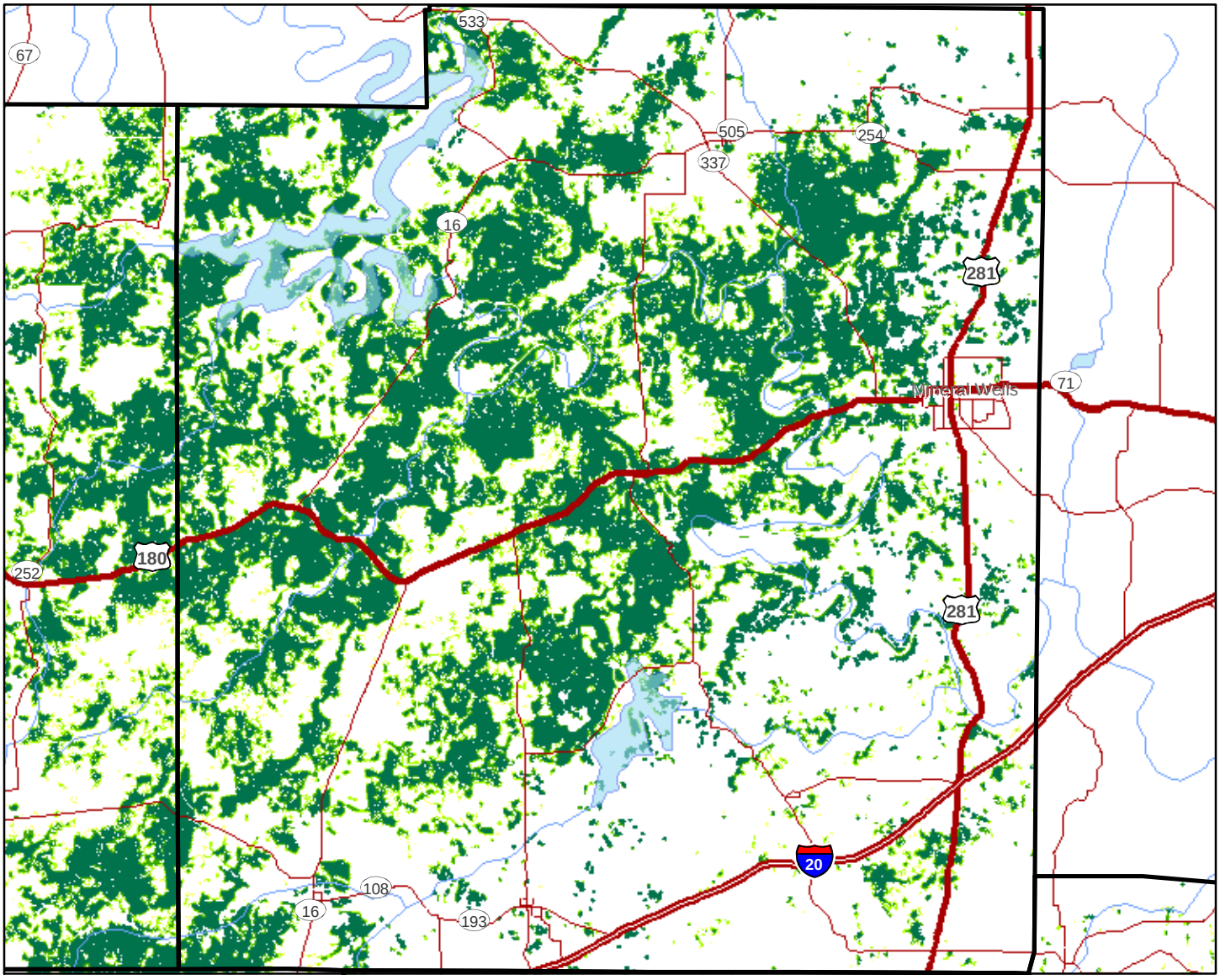
Figure 1. GCW Model A

PALO PINTO COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3
- 4 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N
W E
S

1:357,880

0 3 6 12 Miles

0 4 8 16 Kilometers

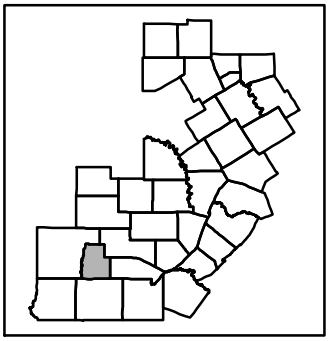
Figure 1. GCW Model A

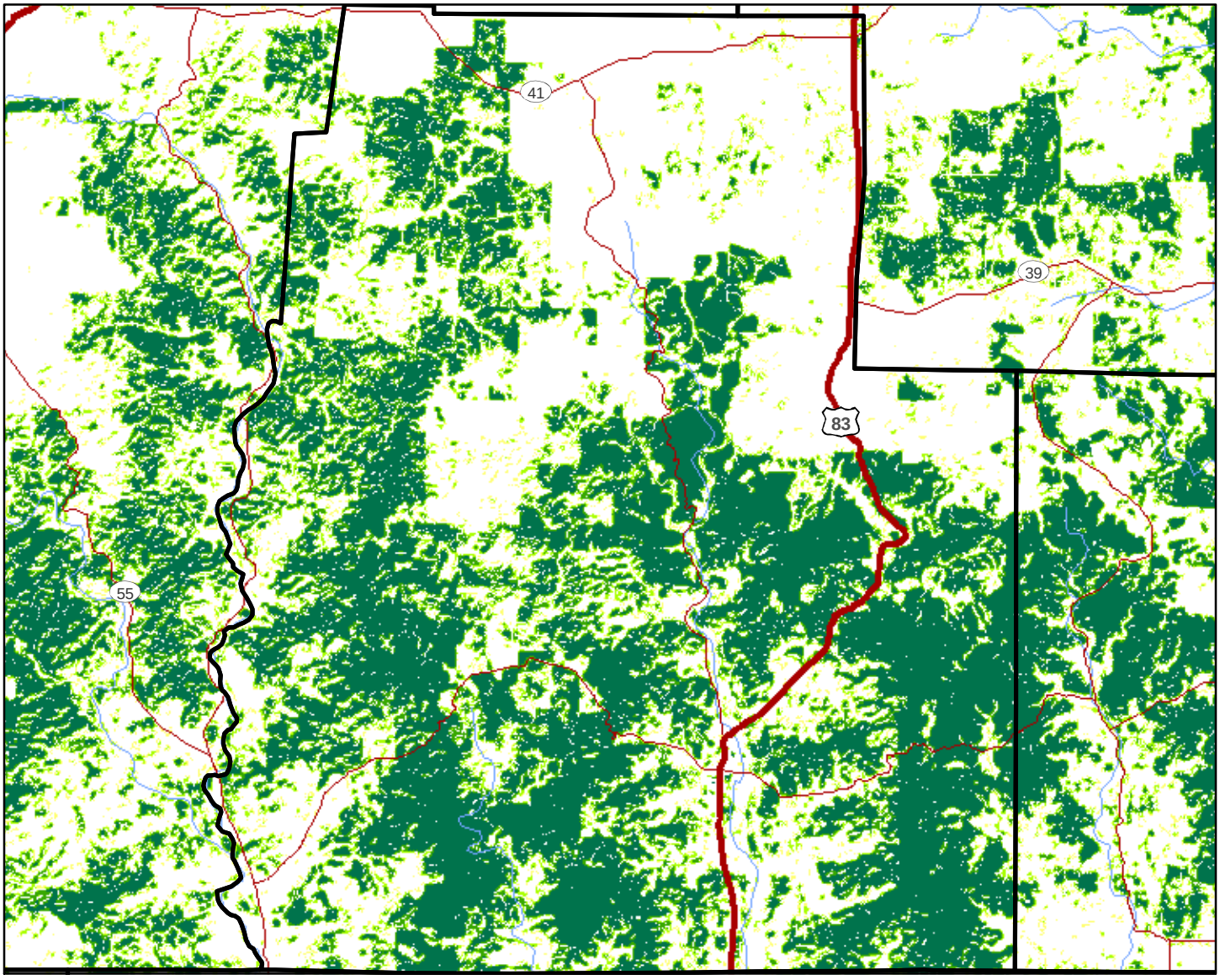
REAL

COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3
- 4 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N W E S

1:329,759

0 2.5 5 10 Miles

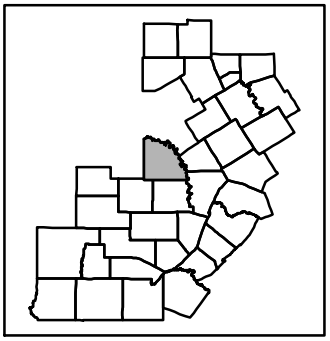
0 3.75 7.5 15 Kilometers

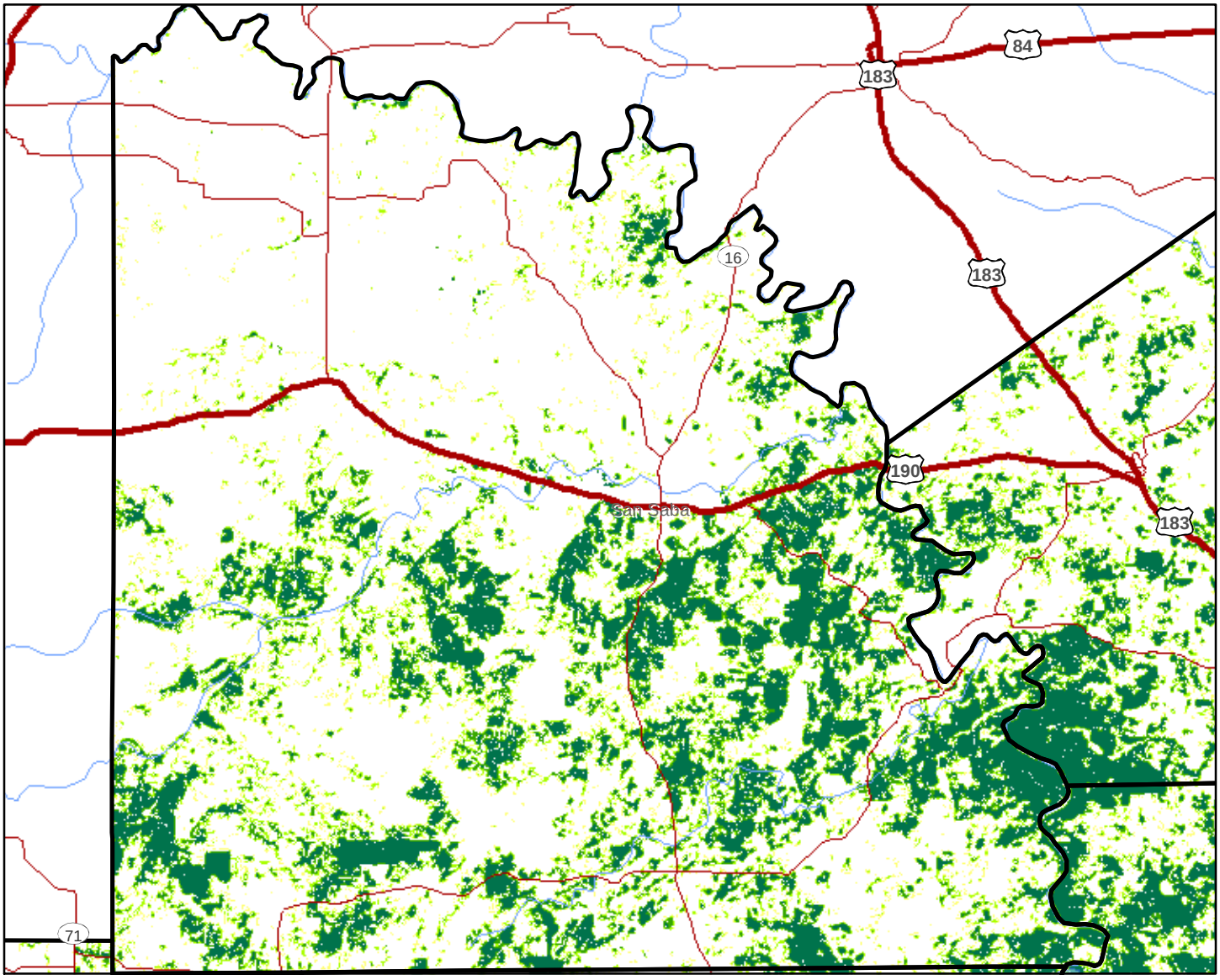
Figure 1. GCW Model A

SAN SABA COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3
- 4 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N W E S

1:414,376

0 3 6 12 Miles

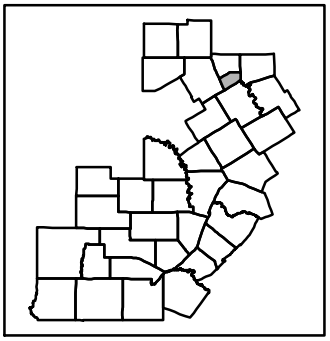
0 4.5 9 18 Kilometers

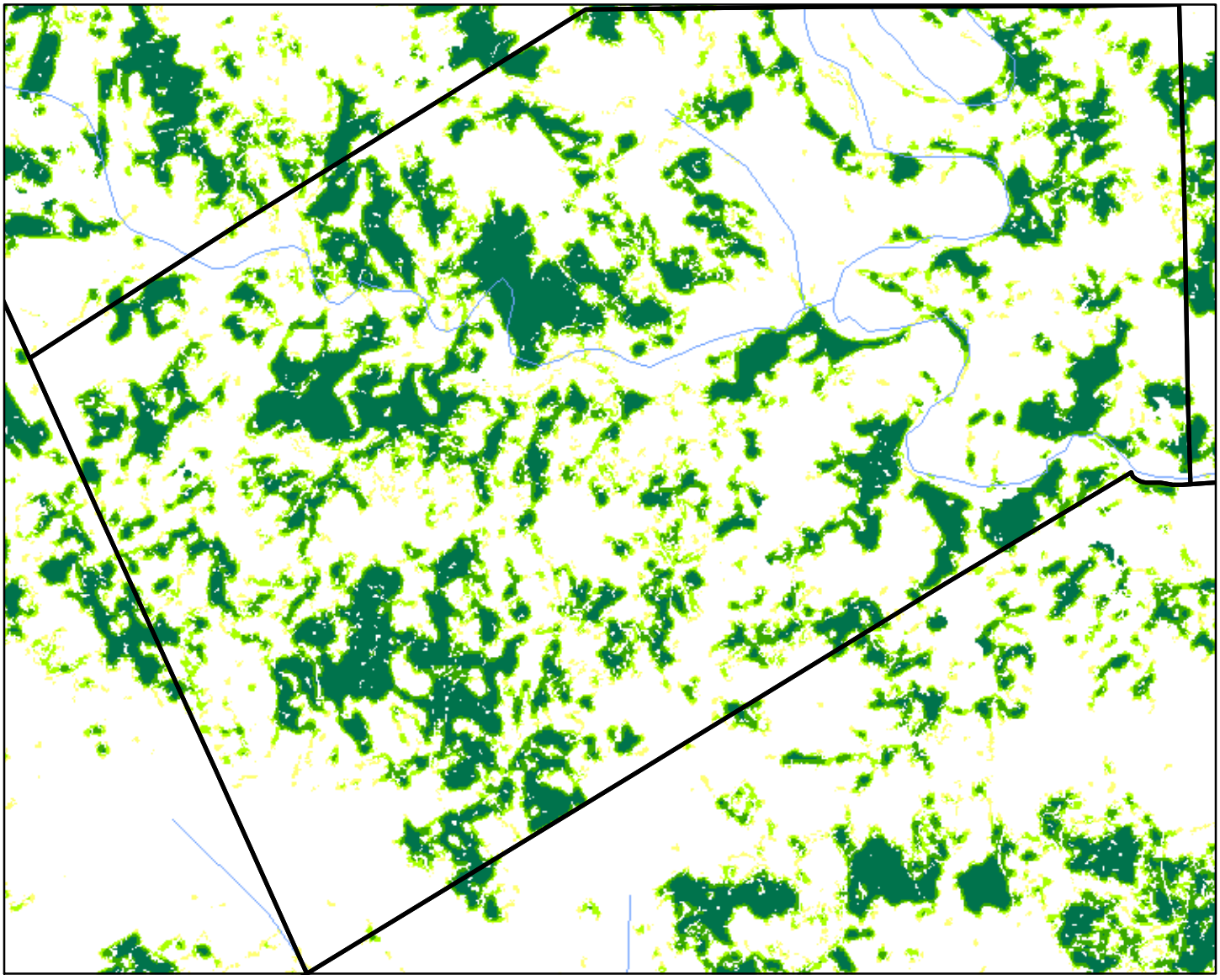
Figure 1. GCW Model A

SOMERVELL COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3
- 4 High Quality





1:168,949

Legend

- County
- Stream

0 1.25 2.5 5 Miles

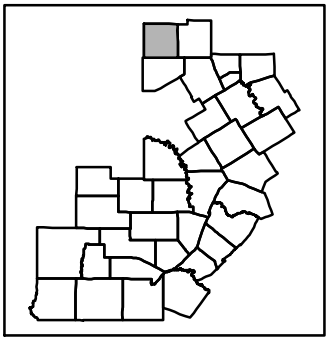
0 2 4 8 Kilometers

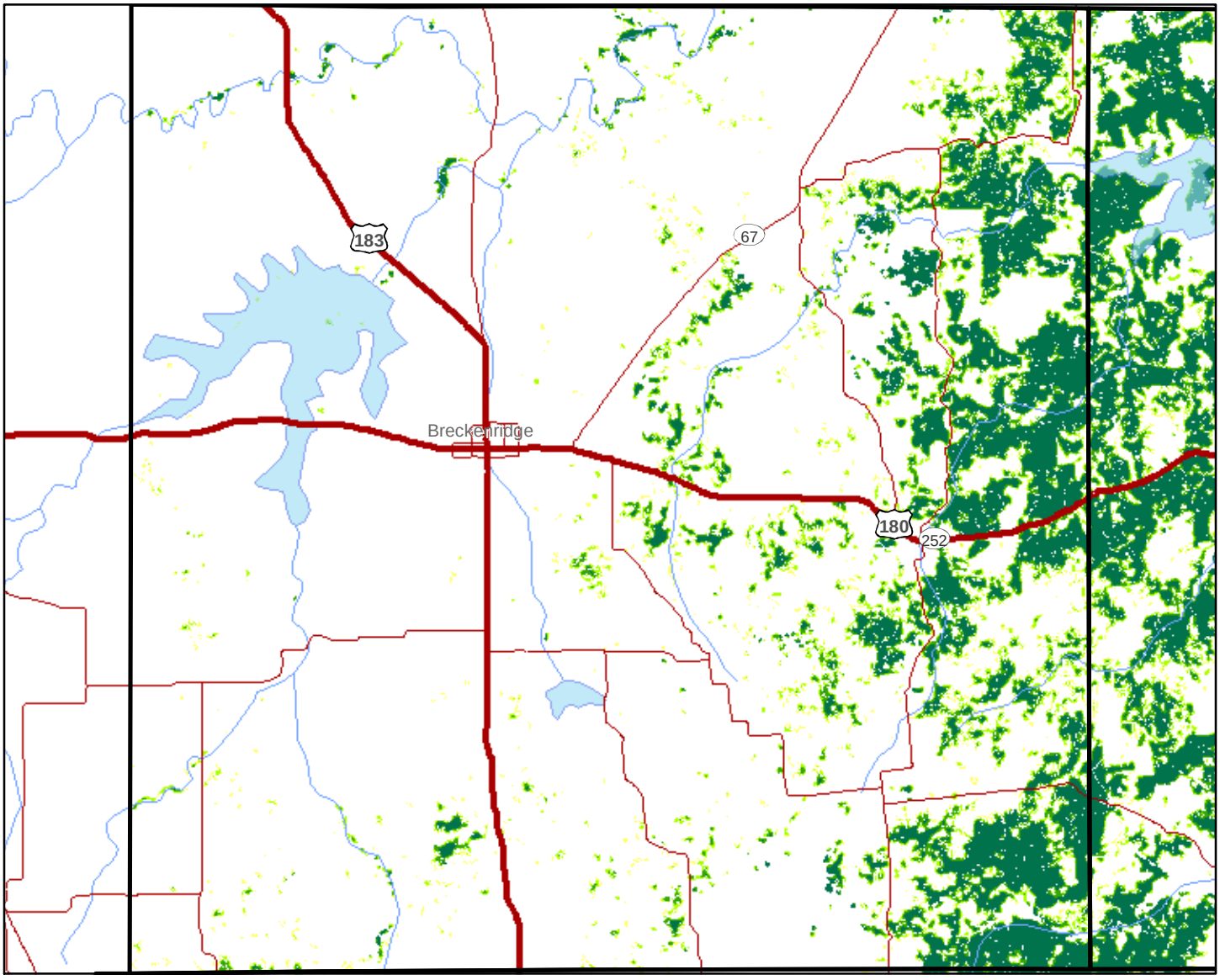
Figure 1. GCW Model A

STEPHENS COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3
- 4 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N
W
E
S

1:321,941

0 2.5 5 10 Miles

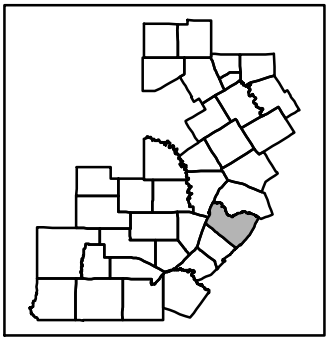
0 3.75 7.5 15 Kilometers

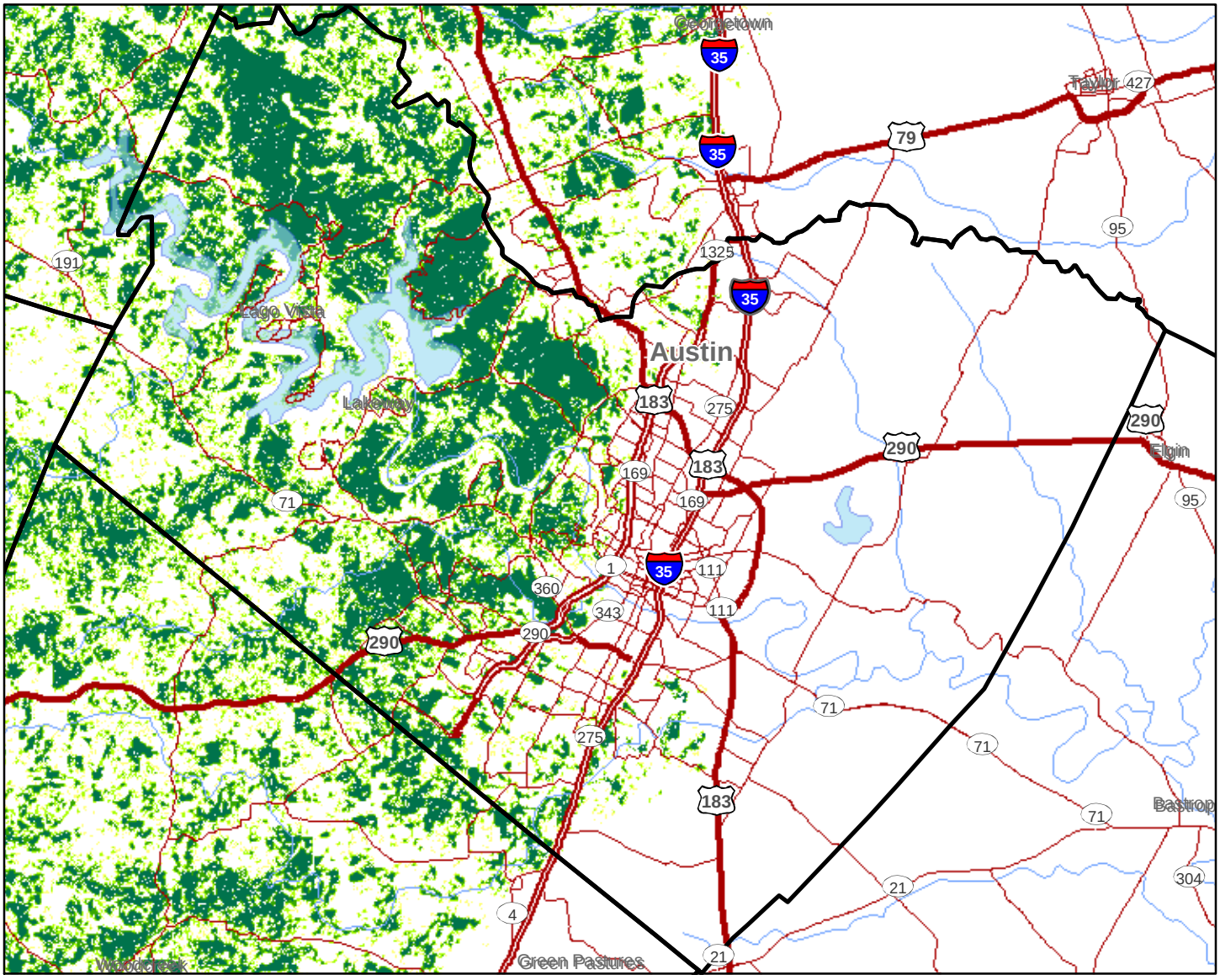
Figure 1. GCW Model A

TRAVIS
COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3
- 4 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

1:440,119

0 3.5 7 14 Miles

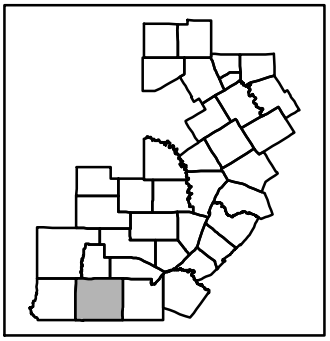
0 5 10 20 Kilometers

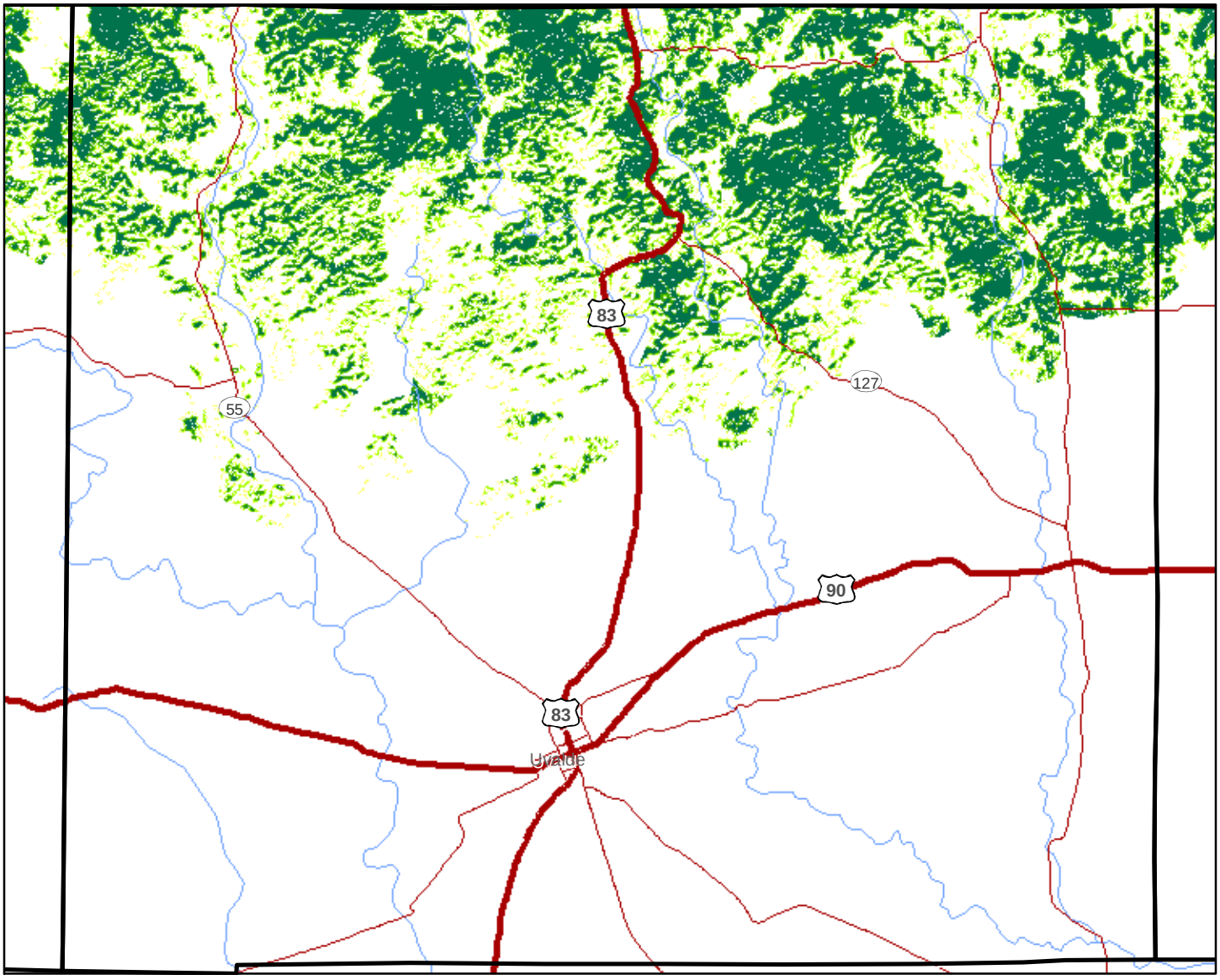
Figure 1. GCW Model A

UVALDE
COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3
- 4 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N
W E
S

1:396,913

0 3 6 12 Miles

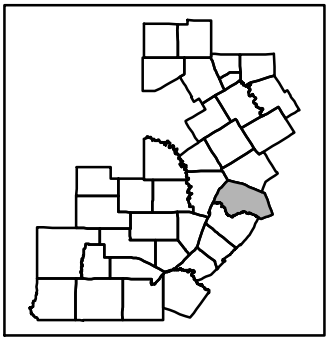
0 4.5 9 18 Kilometers

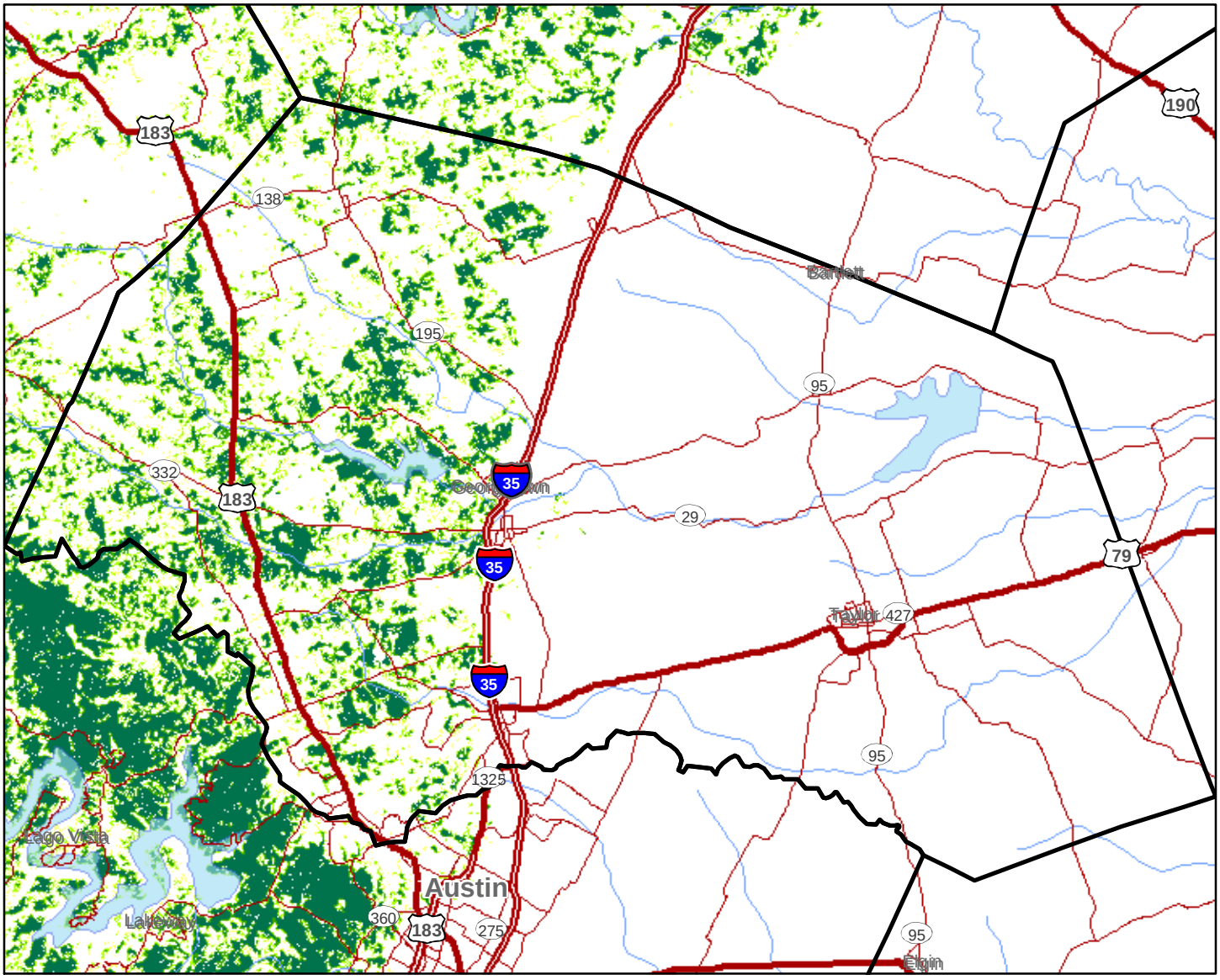
Figure 1. GCW Model A

WILLIAMSON COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3
- 4 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

1:452,765

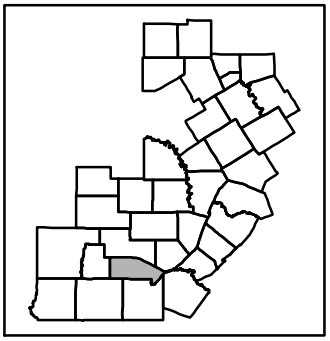
0 3.5 7 14 Miles

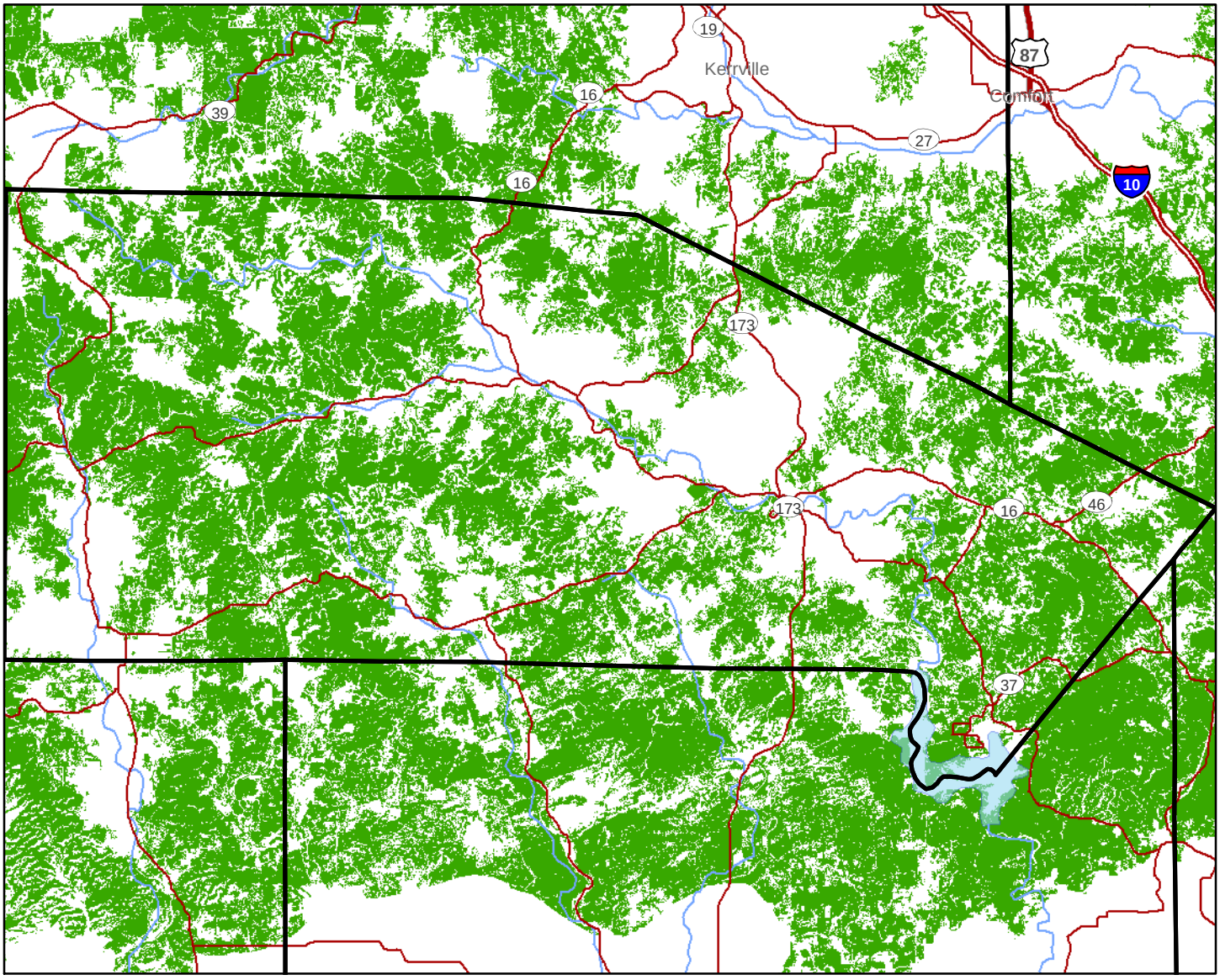
0 5 10 20 Kilometers

Figure 2. GCW Model B

BANDERA
COUNTY

Habitat





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

1:420,333

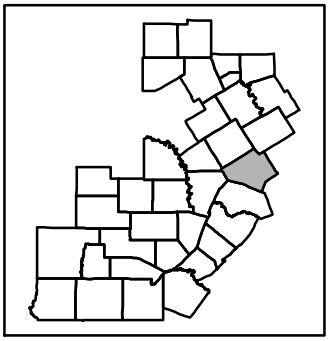
0 3.5 7 14 Miles

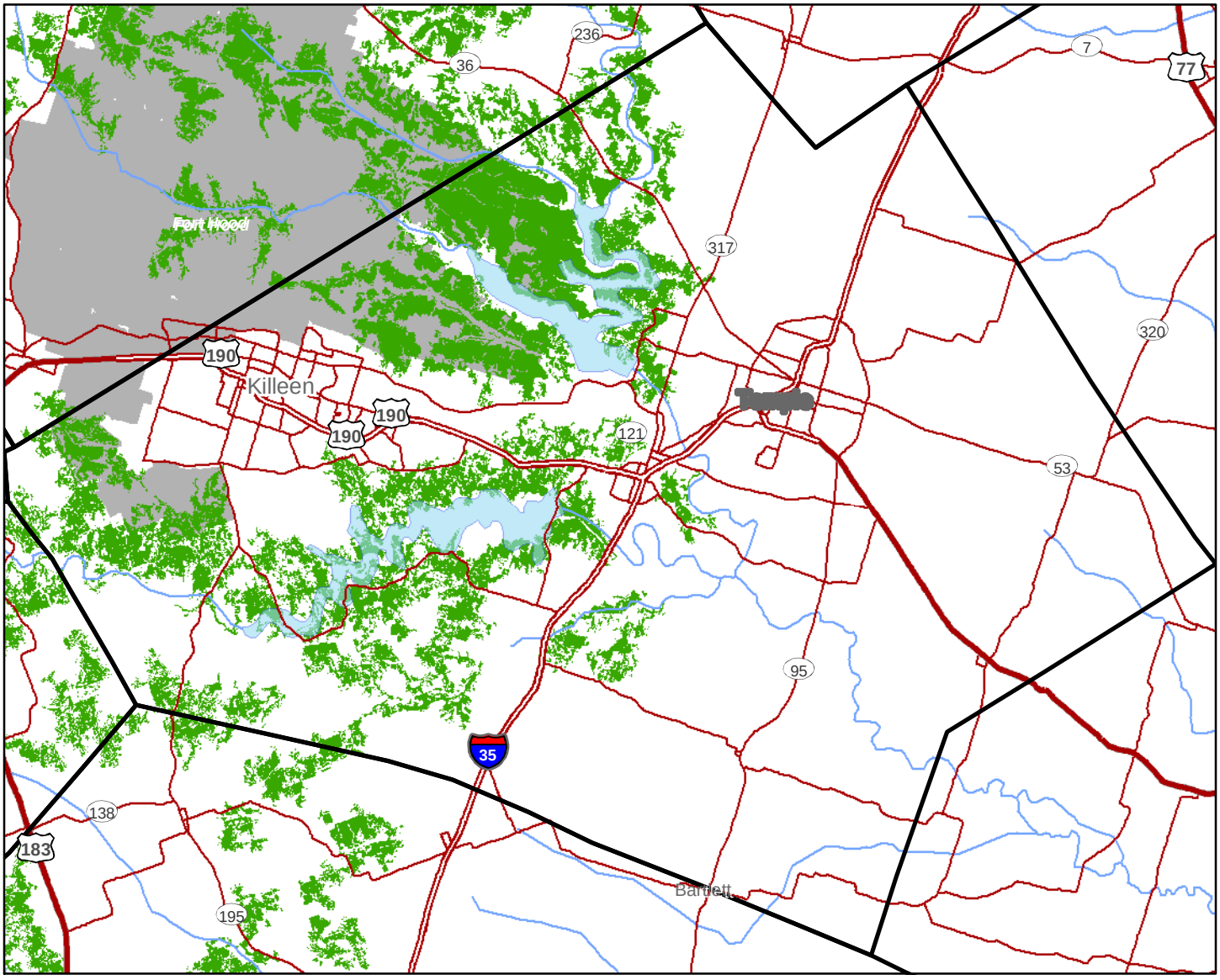
0 4.5 9 18 Kilometers

Figure 2. GCW Model B

BELL
COUNTY

Habitat





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

1:426,603

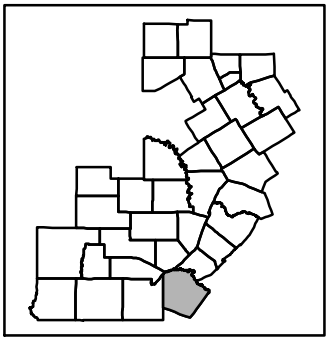
0 3.5 7 14 Miles

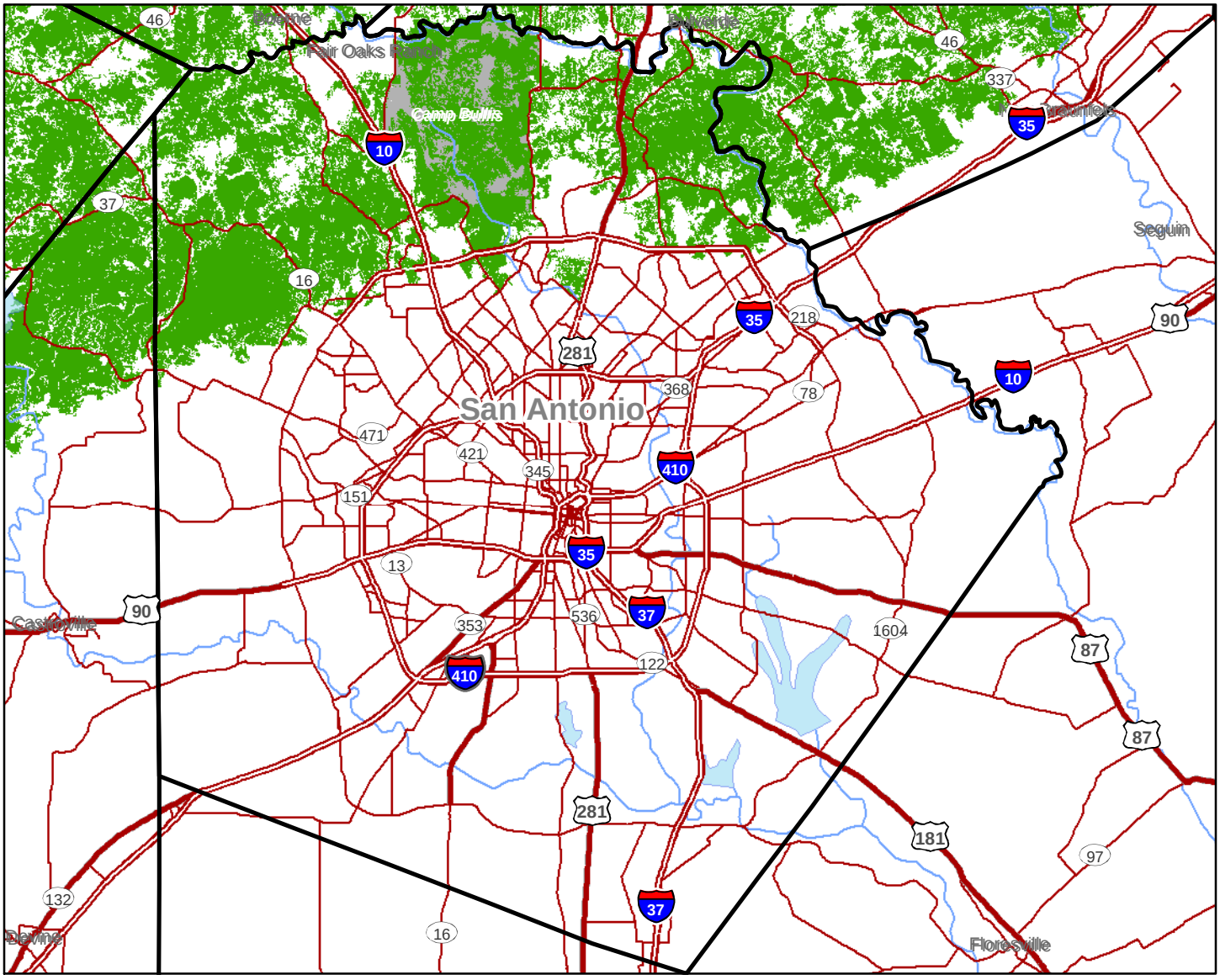
0 4.5 9 18 Kilometers

Figure 2. GCW Model B

BEXAR
COUNTY

Habitat





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

1:467,865

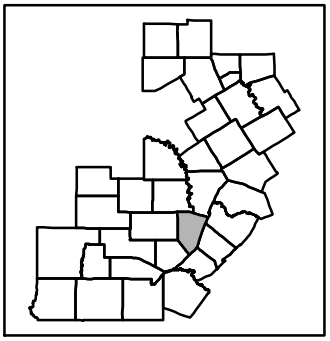
0 3.75 7.5 15 Miles

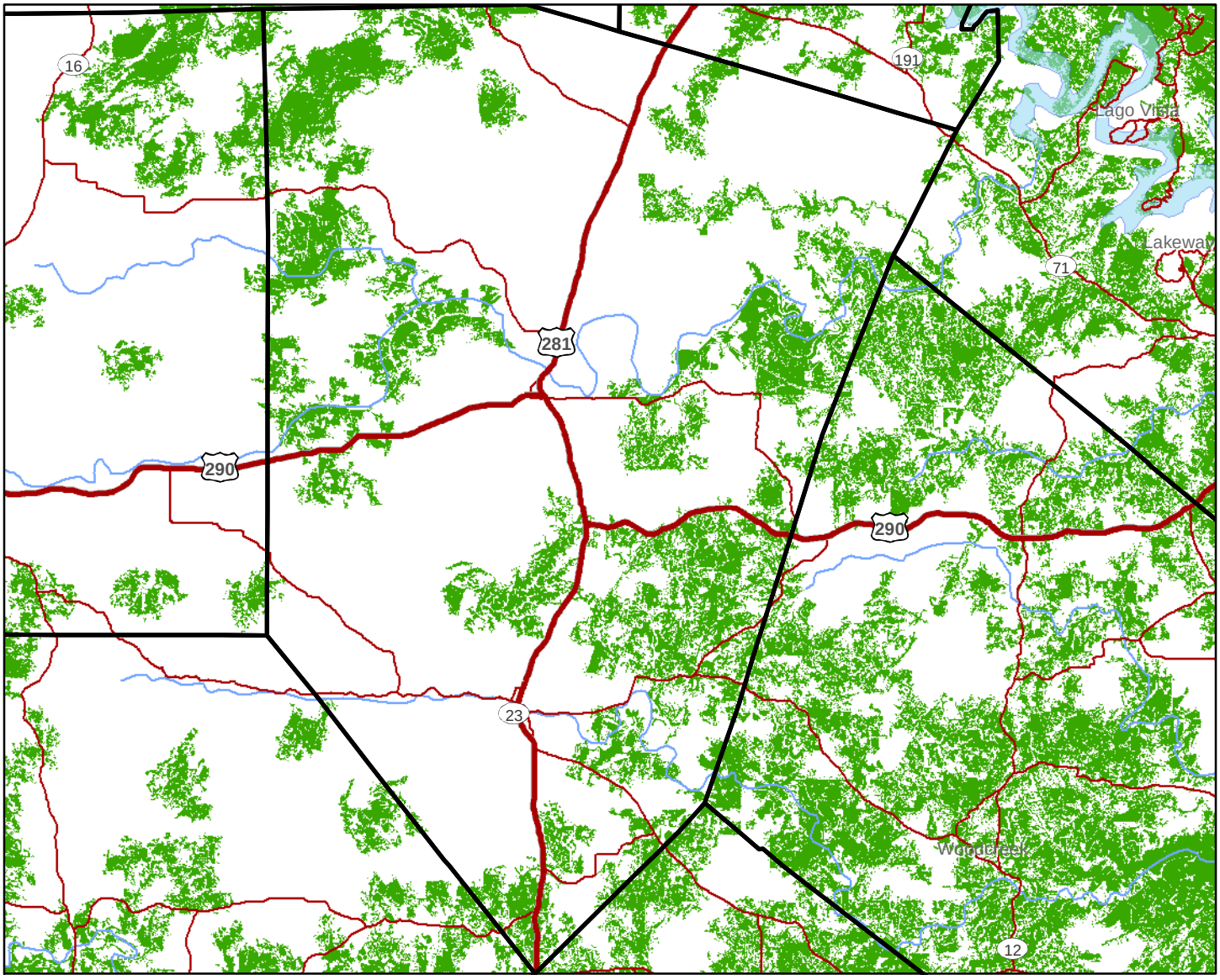
0 5 10 20 Kilometers

Figure 2. GCW Model B

BLANCO COUNTY

Habitat





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N
W
E
S

1:408,826

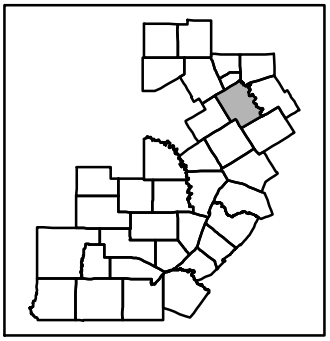
0 3.5 7 14 Miles

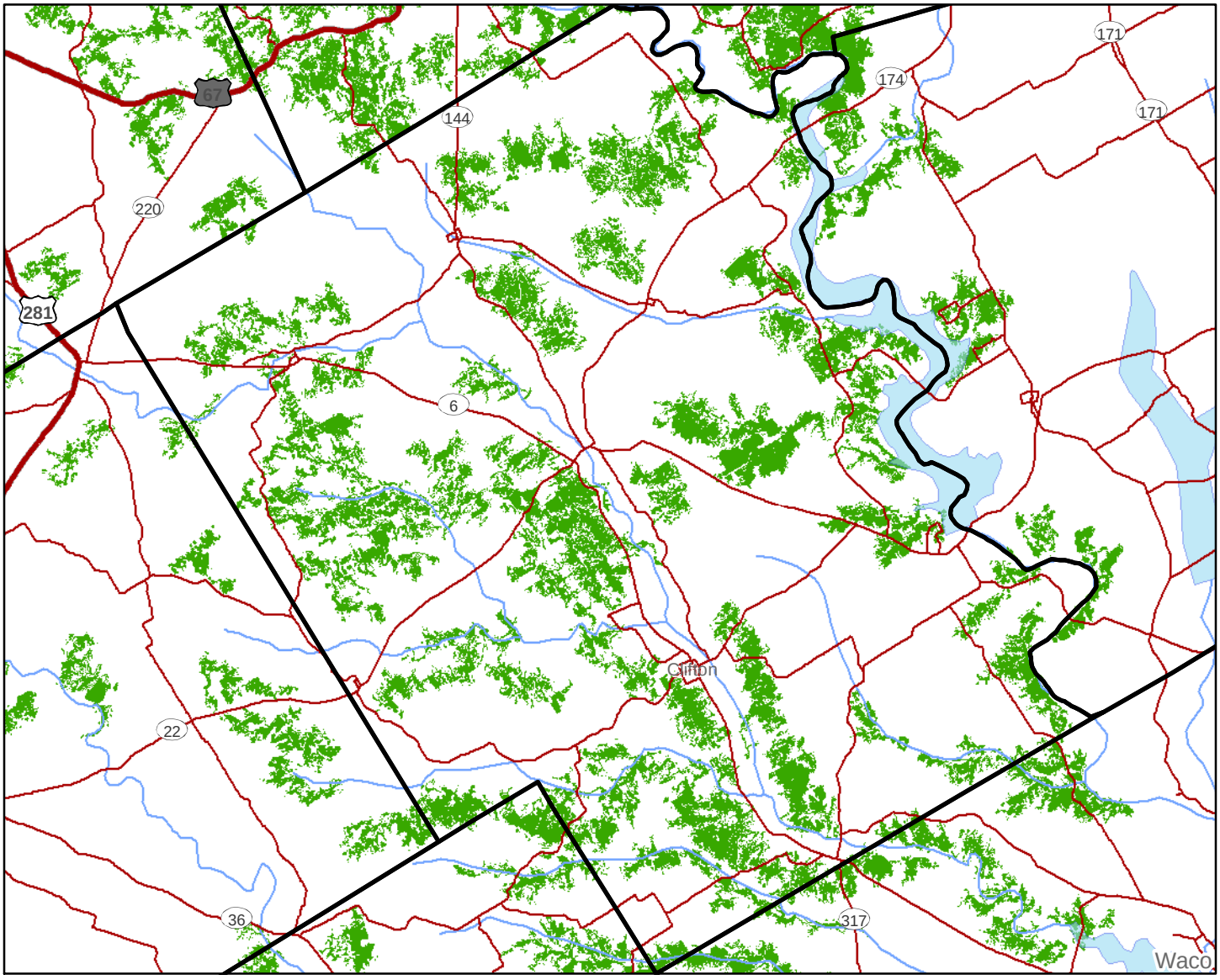
0 4.5 9 18 Kilometers

Figure 2. GCW Model B

BOSQUE
COUNTY

Habitat





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N
W
E
S

1:450,274

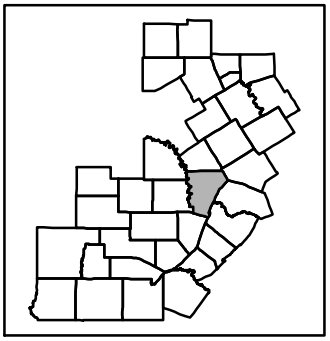
0 3.75 7.5 15 Miles

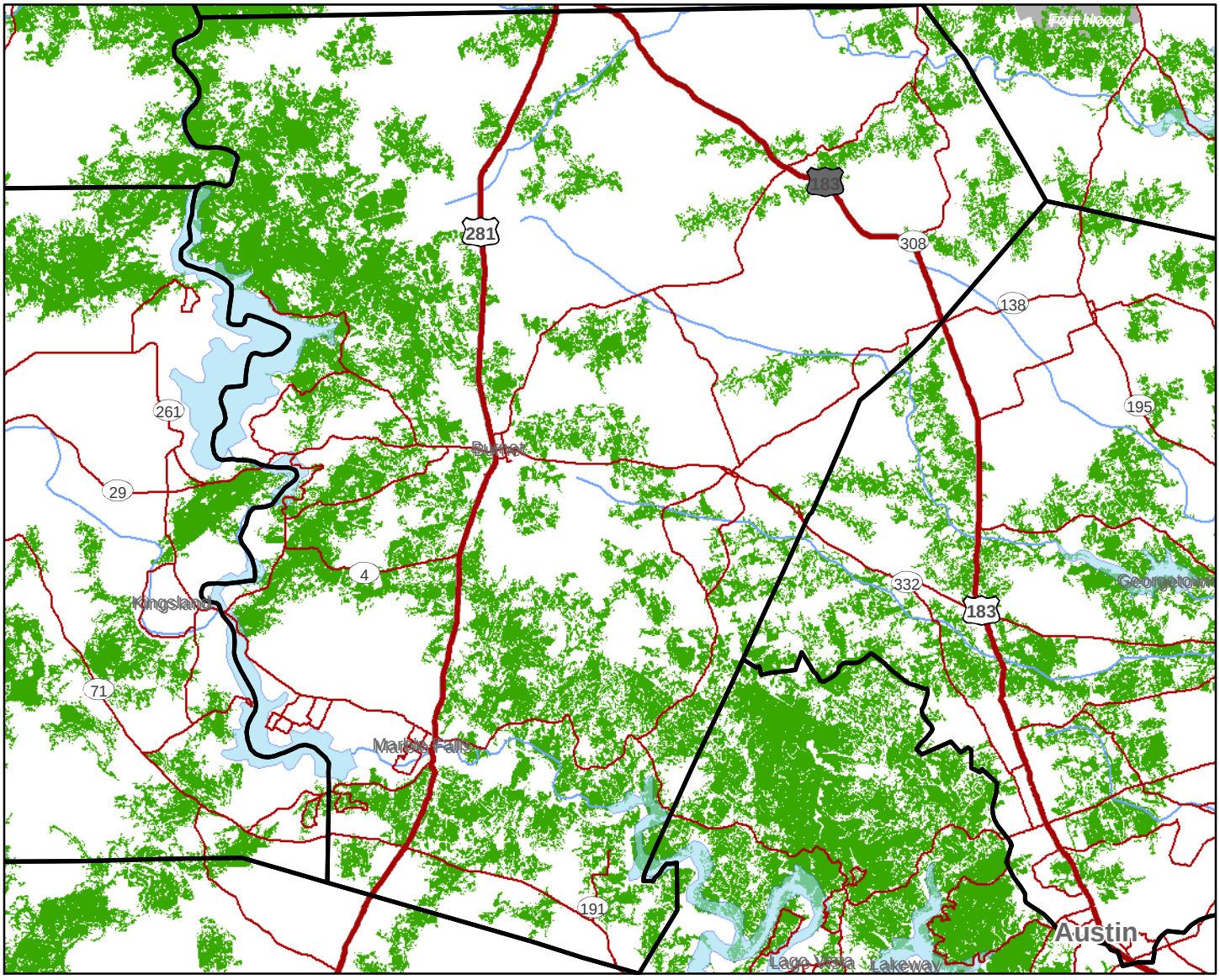
0 5 10 20 Kilometers

Figure 2. GCW Model B

BURNET
COUNTY

Habitat





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

1:443,072

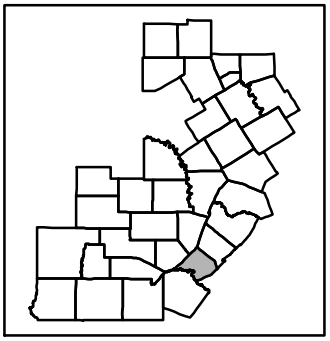
0 3.75 7.5 15 Miles

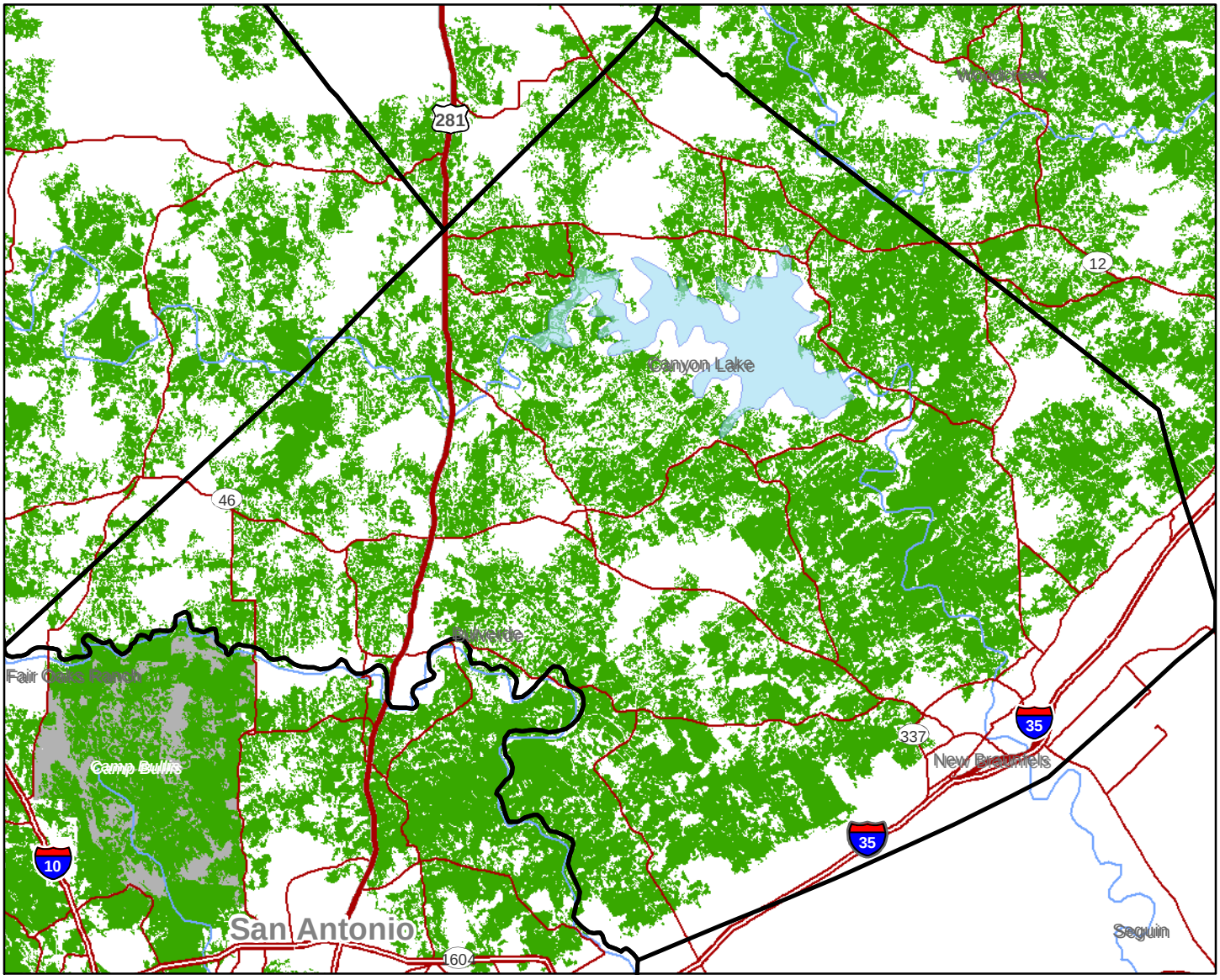
0 5 10 20 Kilometers

Figure 2. GCW Model B

COMAL
COUNTY

Habitat





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N
W
E
S

1:328,003

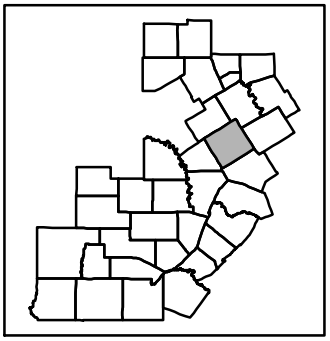
0 2.5 5 10 Miles

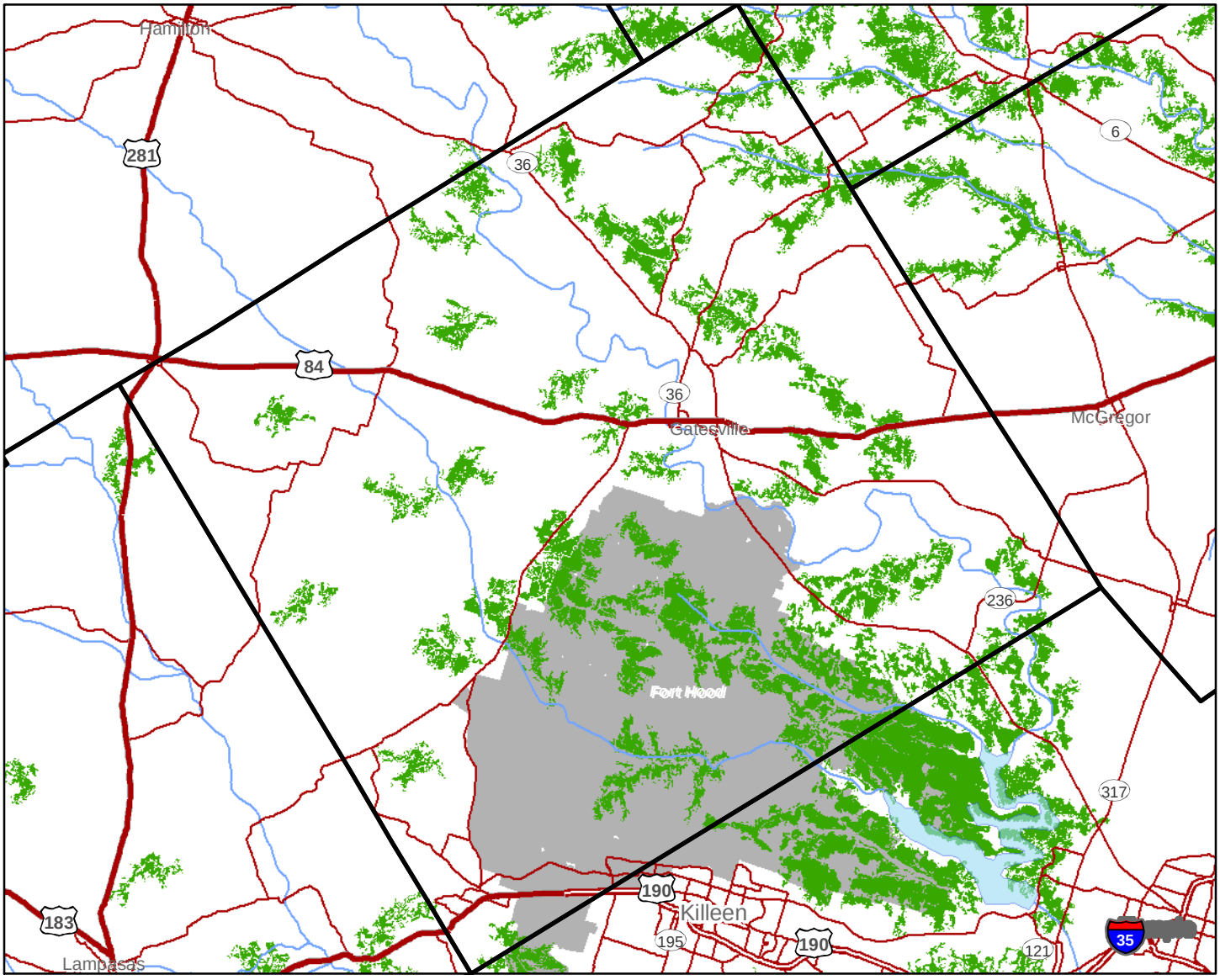
0 3.75 7.5 15 Kilometers

Figure 2. GCW Model B

CORYELL
COUNTY

Habitat





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

1:469,250

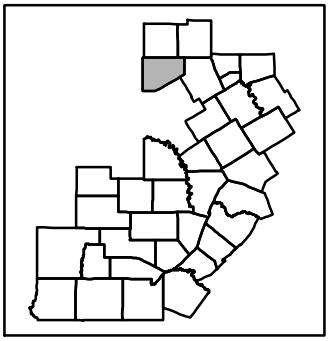
0 3.5 7 14 Miles

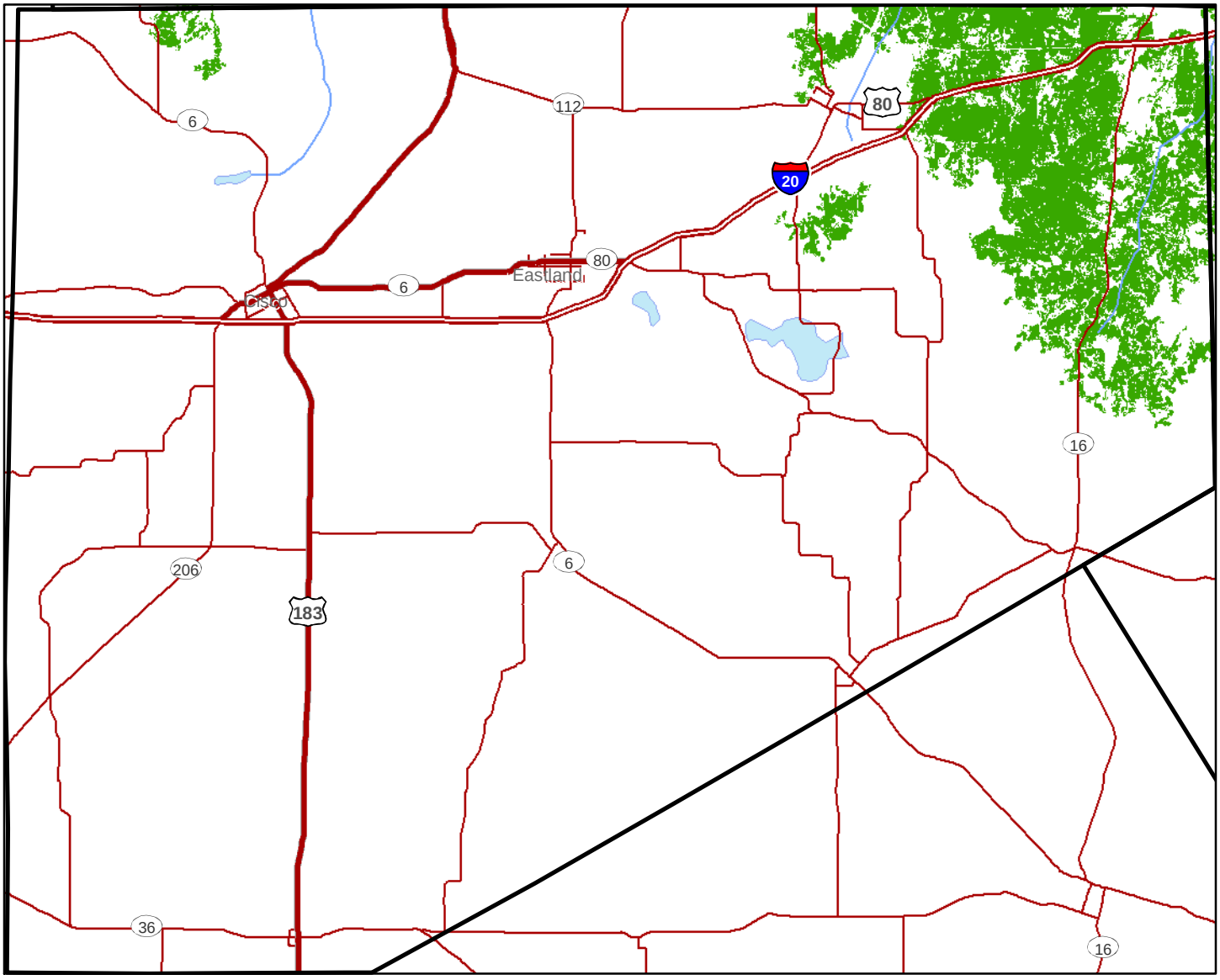
0 5 10 20 Kilometers

Figure 2. GCW Model B

EASTLAND
COUNTY

Habitat





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N
W
E
S

1:319,430

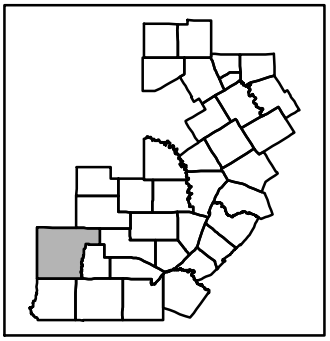
0 2.5 5 10 Miles

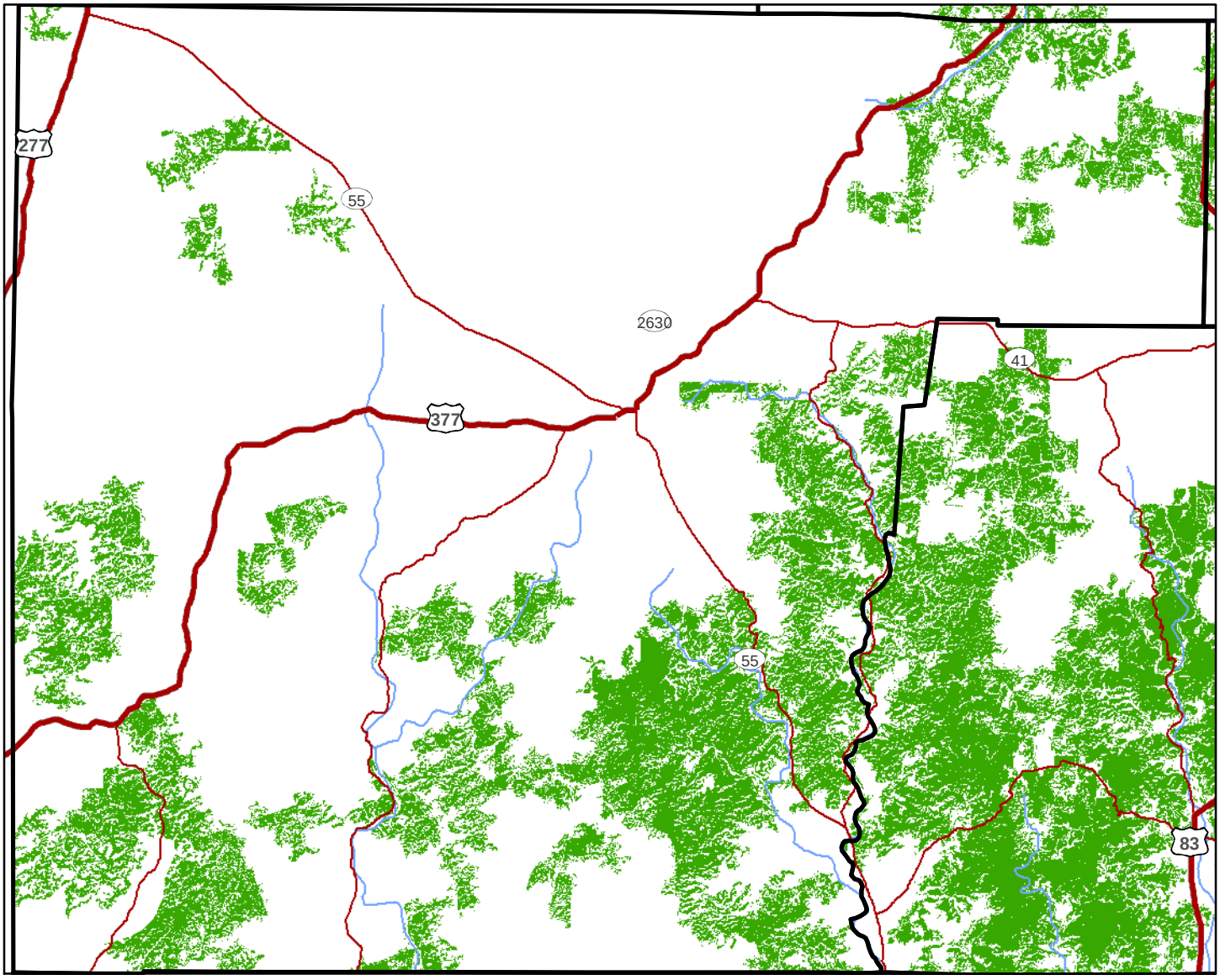
0 3.5 7 14 Kilometers

Figure 2. GCW Model B

EDWARDS
COUNTY

Habitat





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N
W
E
S

1:486,990

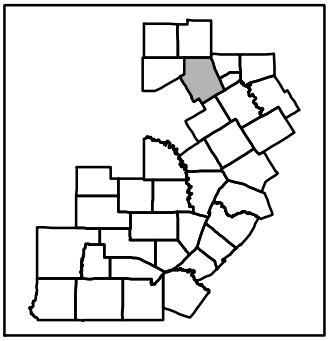
0 3.75 7.5 15 Miles

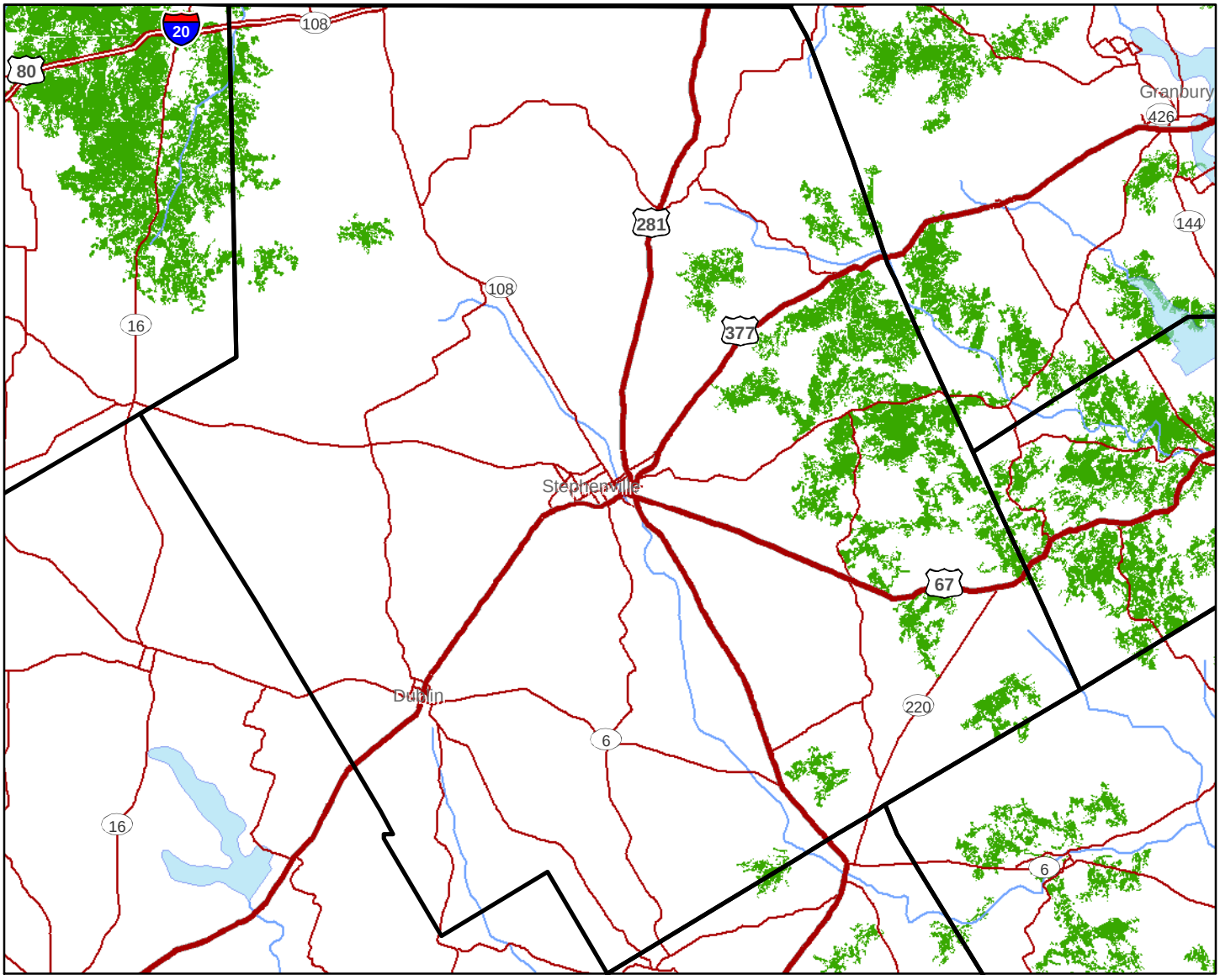
0 5 10 20 Kilometers

Figure 2. GCW Model B

ERATH
COUNTY

Habitat





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N
W
E
S

1:436,311

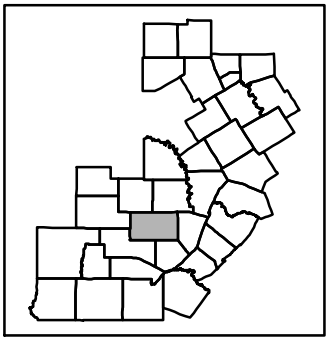
0 3.5 7 14 Miles

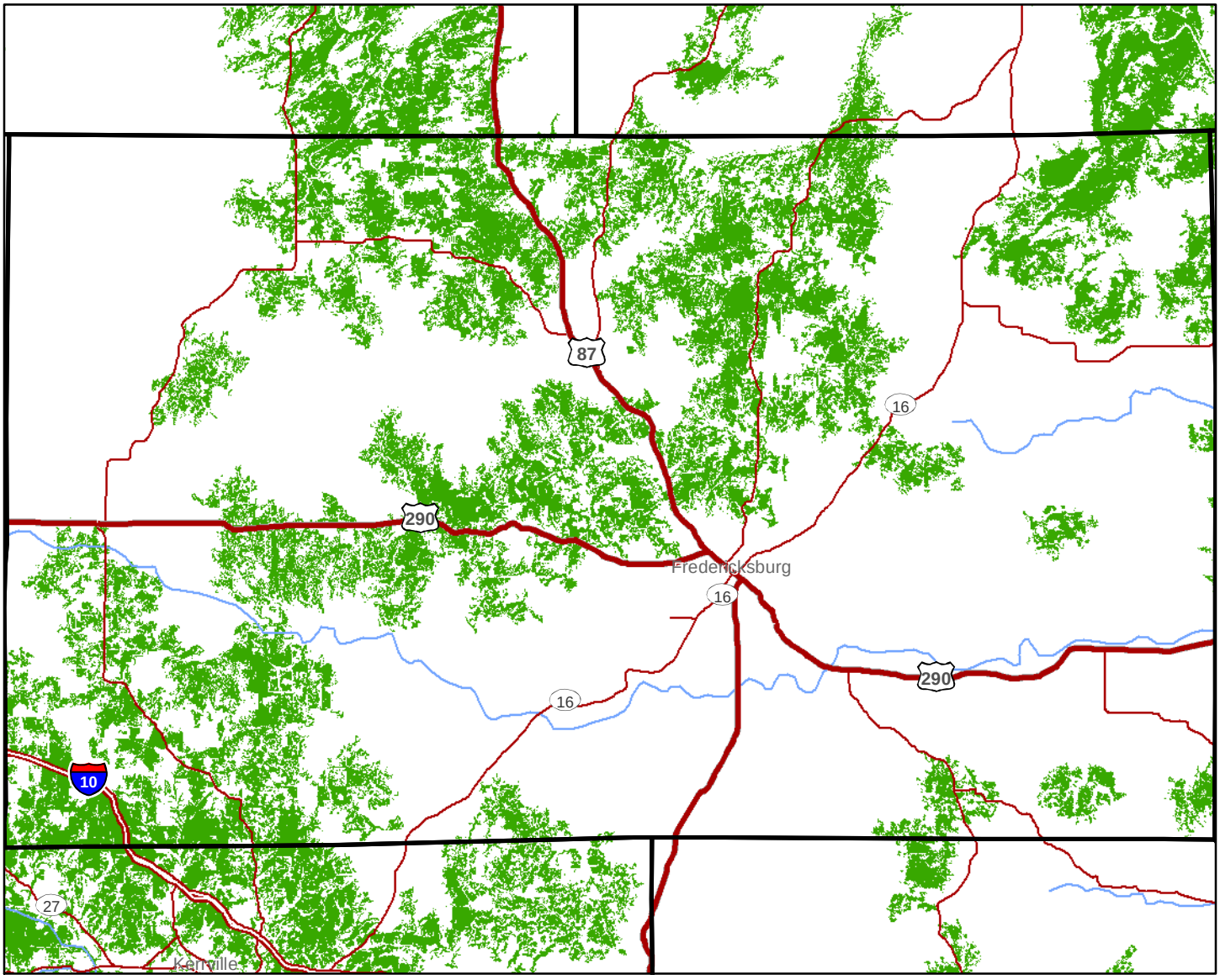
0 4.5 9 18 Kilometers

Figure 2. GCW Model B

GILLESPIE
COUNTY

Habitat





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N
W
E
S

1:360,868

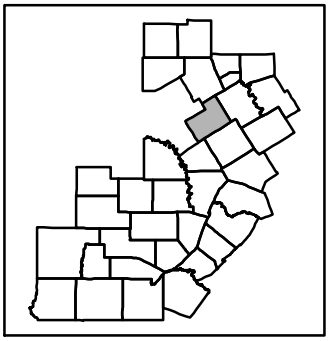
0 3 6 12 Miles

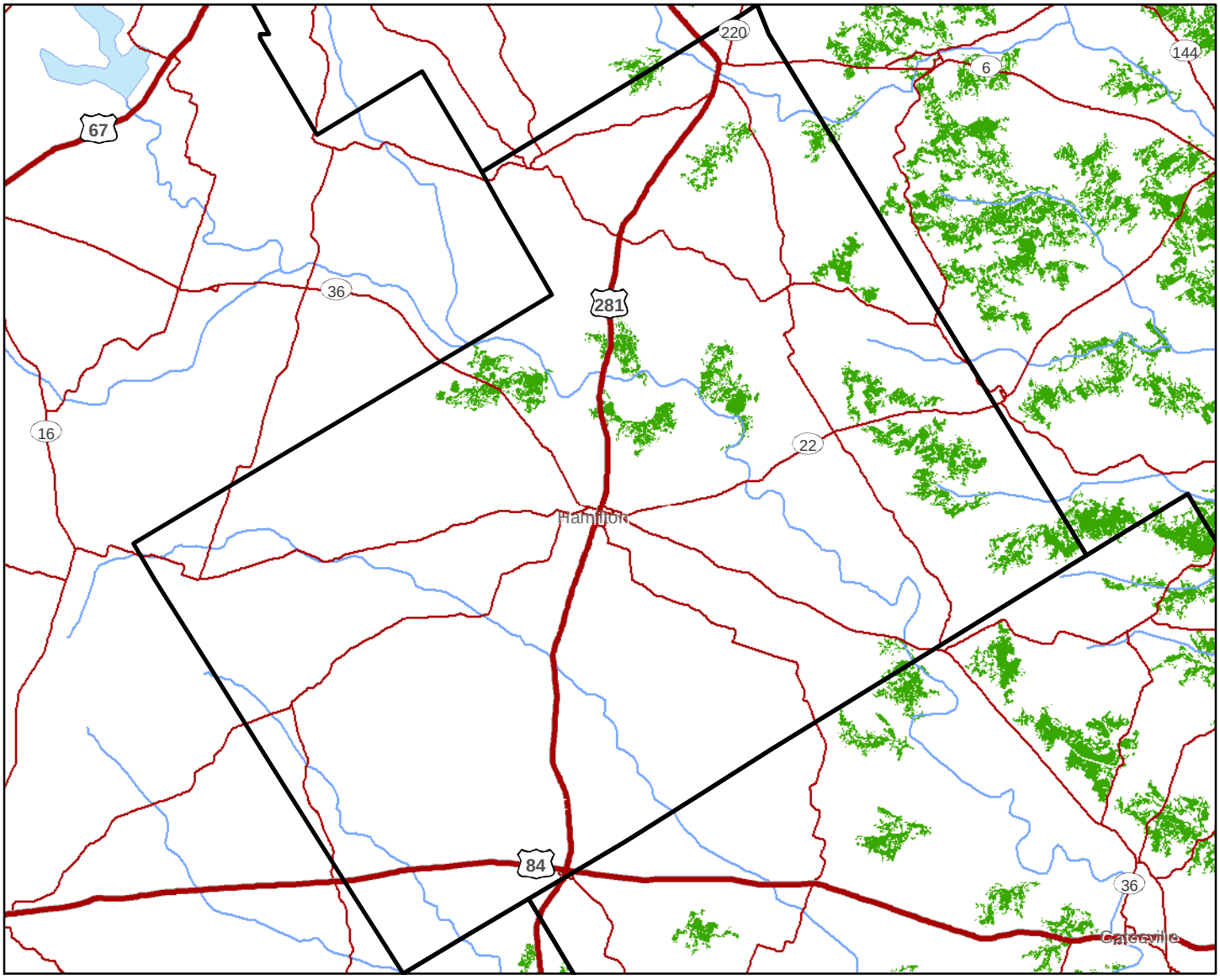
0 3.75 7.5 15 Kilometers

Figure 2. GCW Model B

HAMILTON
COUNTY

Habitat





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N
W E
S

1:440,225

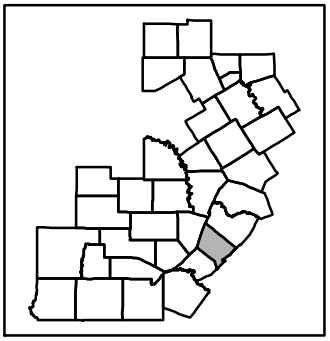
0 3.75 7.5 15 Miles

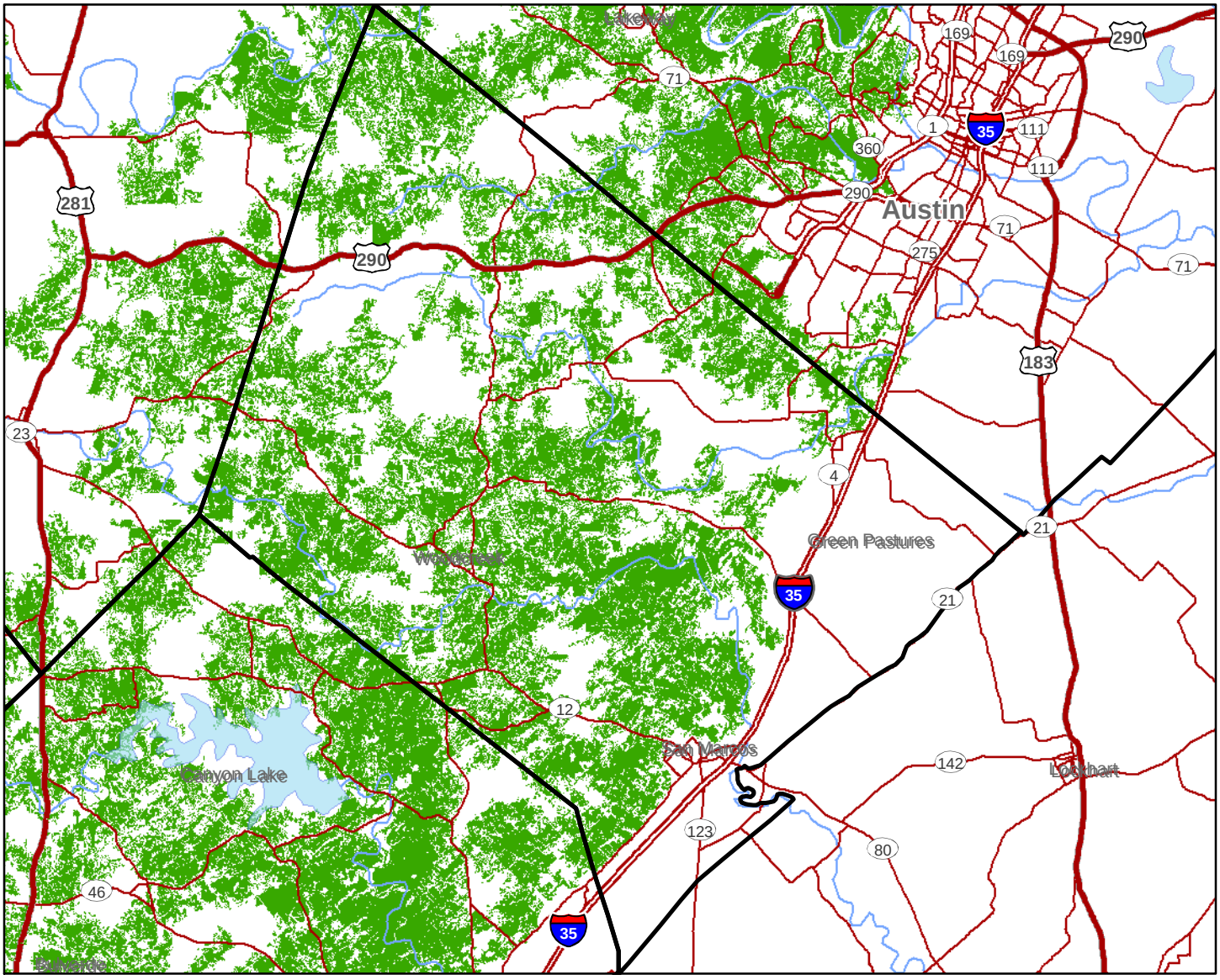
0 4.5 9 18 Kilometers

Figure 2. GCW Model B

HAYS
COUNTY

Habitat





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N
W E
S

1:438,757

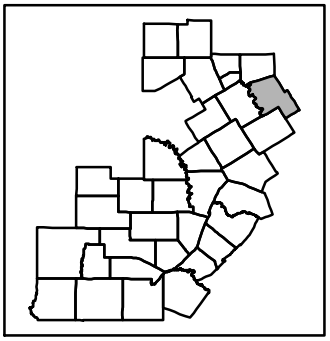
0 3.75 7.5 15 Miles

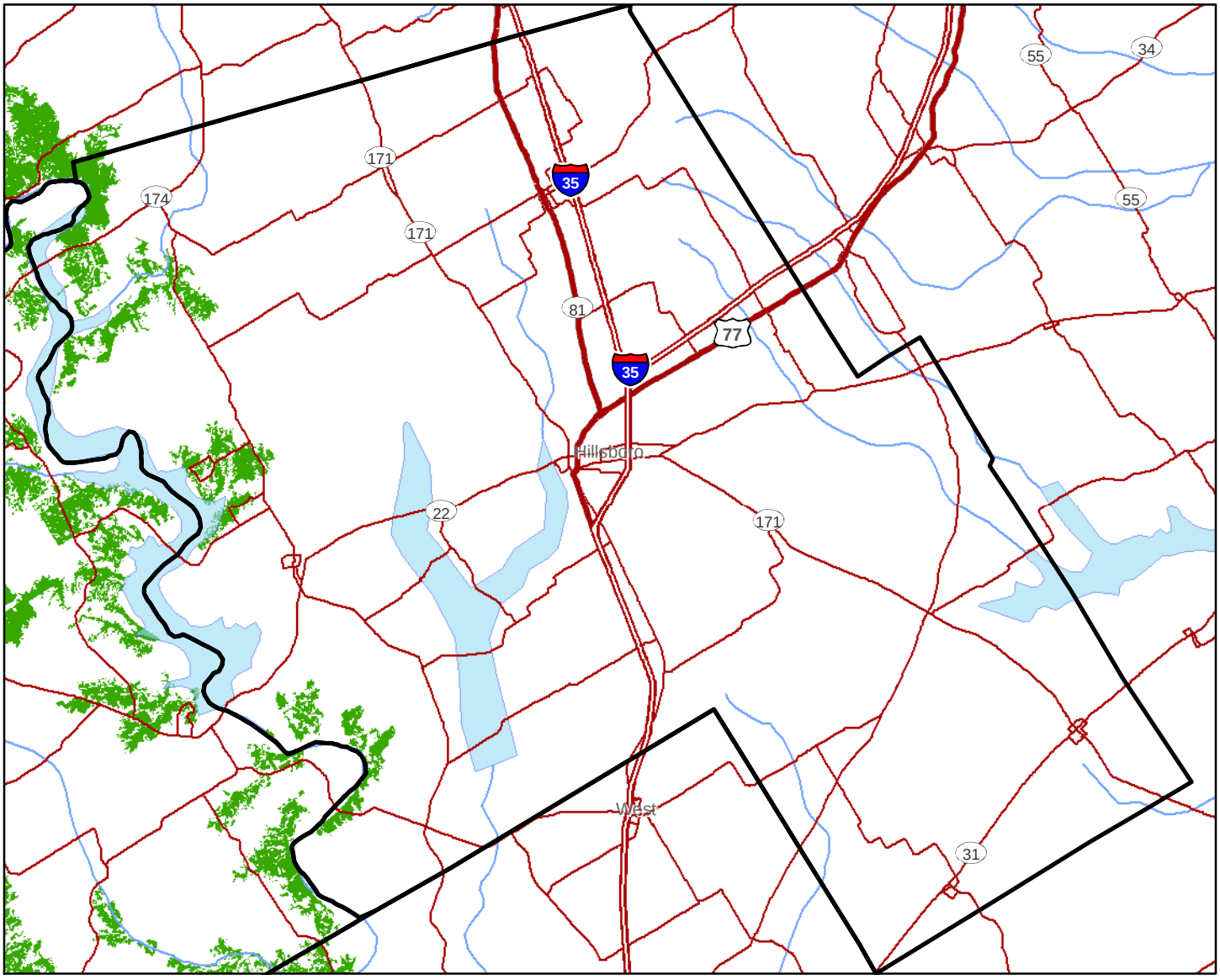
0 4.5 9 18 Kilometers

Figure 2. GCW Model B

HILL
COUNTY

Habitat





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N
W
E
S

1:405,536

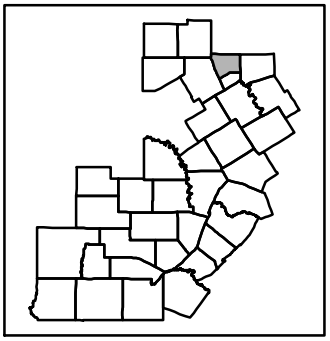
0 3.5 7 14 Miles

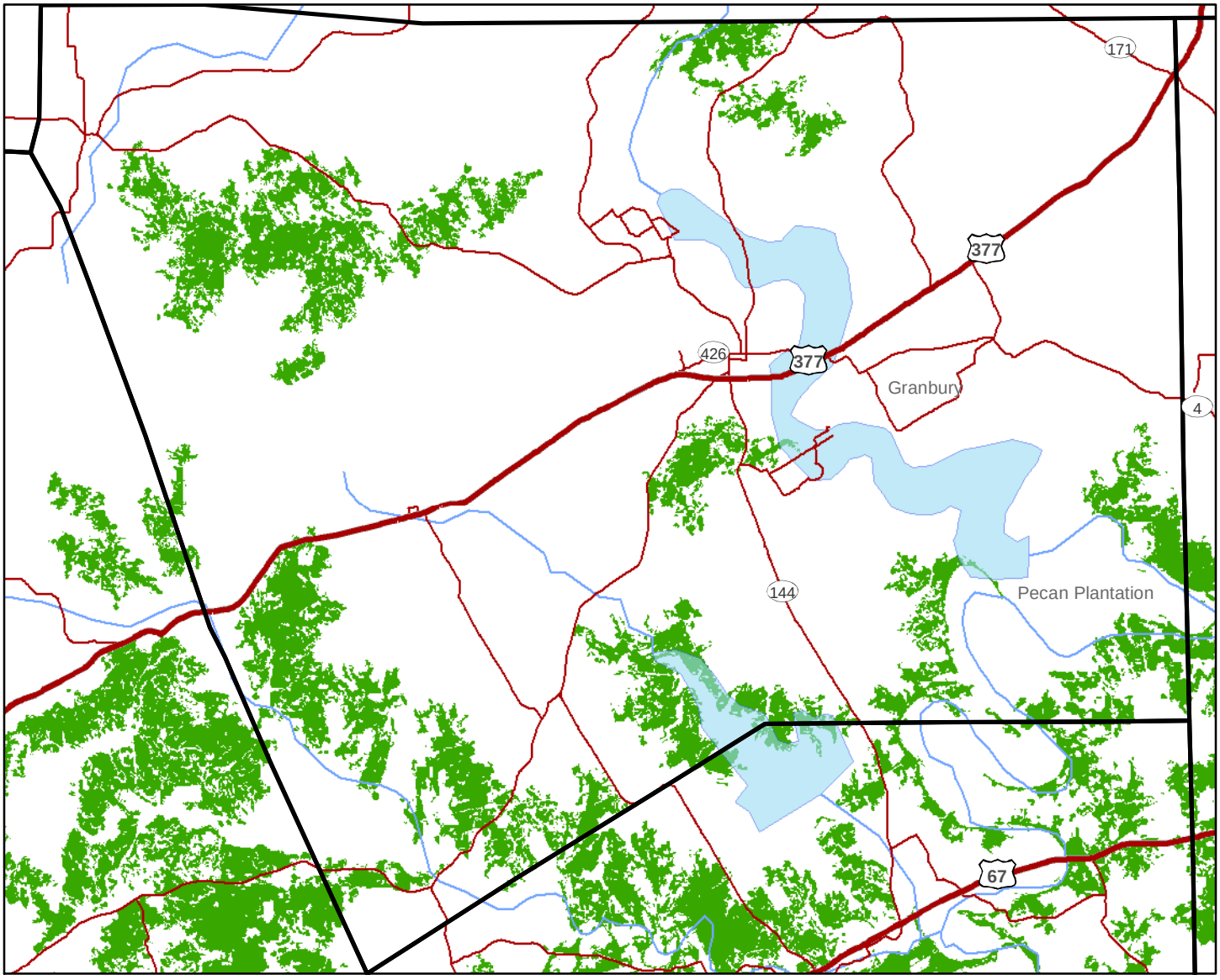
0 4 8 16 Kilometers

Figure 2. GCW Model B

HOOD
COUNTY

Habitat





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N
W
E
S

1:236,188

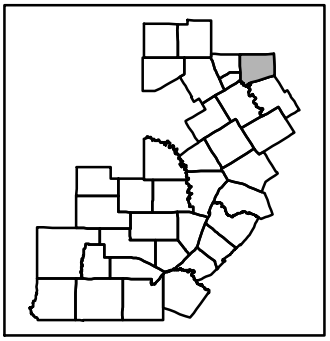
0 2 4 8 Miles

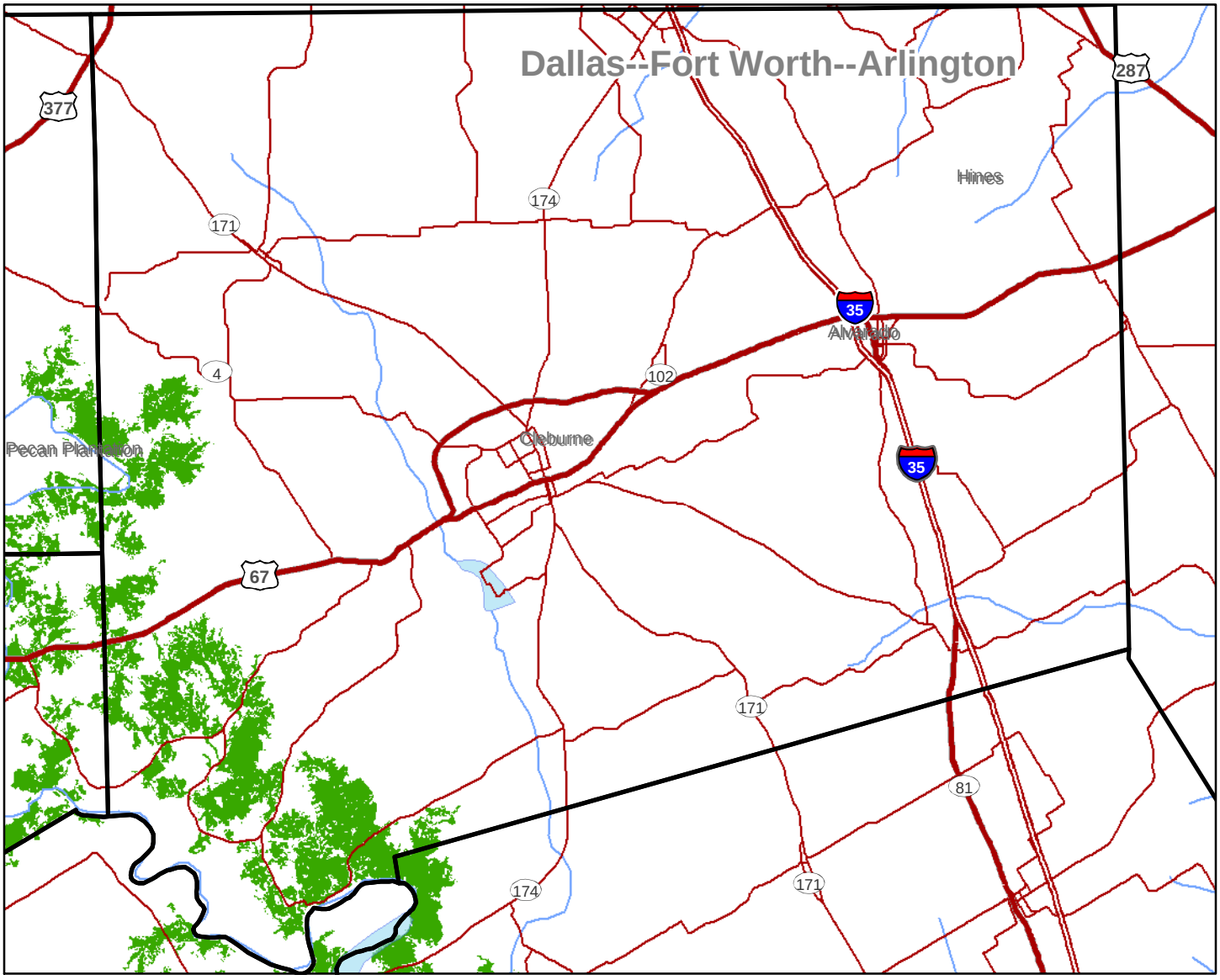
0 2.5 5 10 Kilometers

Figure 2. GCW Model B

JOHNSON
COUNTY

Habitat





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N
W
E
S

1:307,857

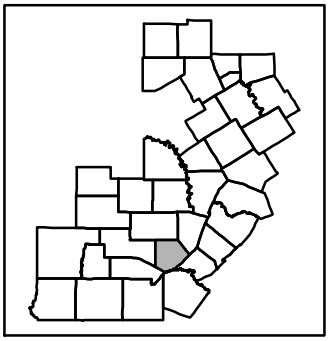
0 2.5 5 10 Miles

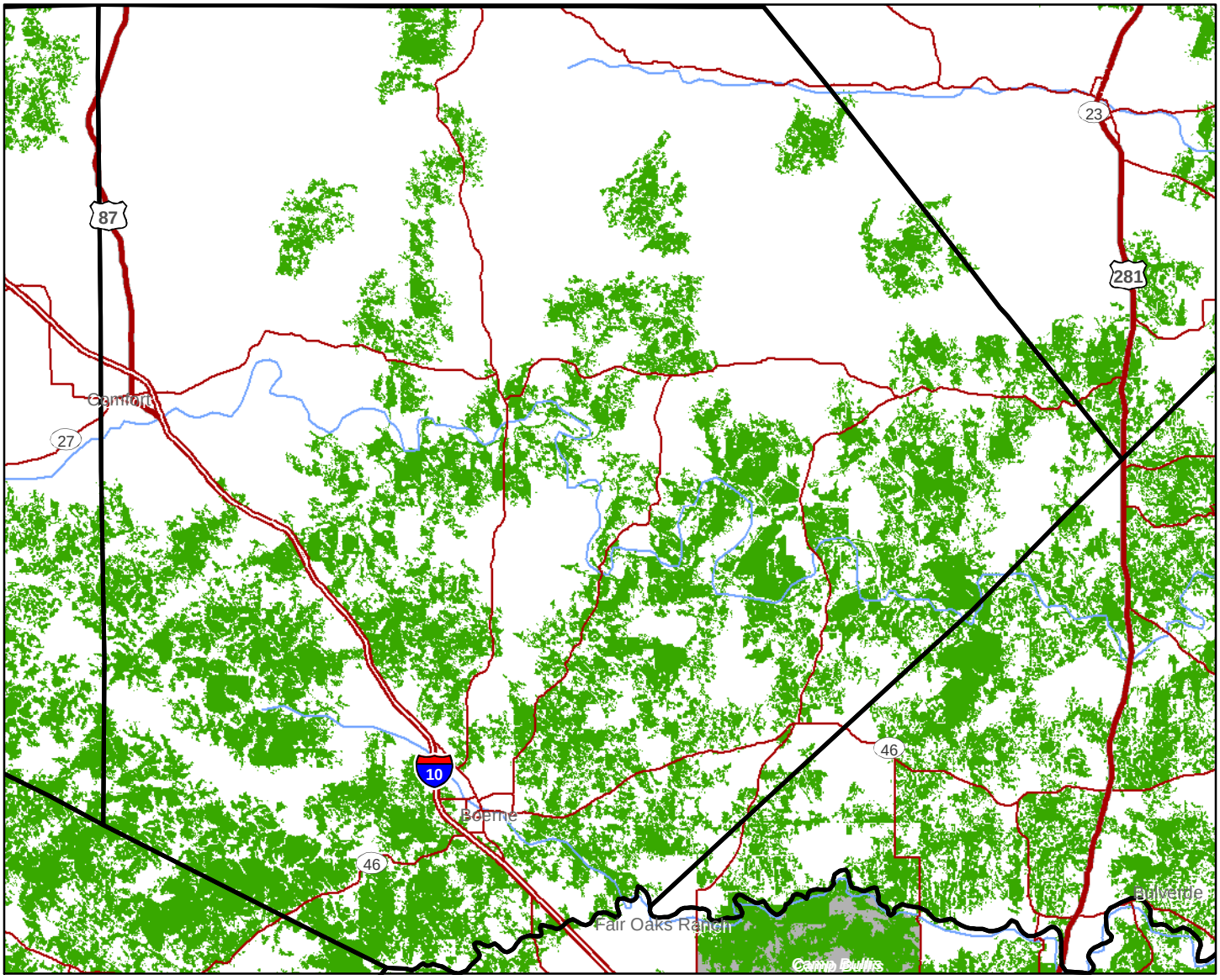
0 3.5 7 14 Kilometers

Figure 2. GCW Model B

KENDALL
COUNTY

Habitat





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N
W E
S

1:305,681

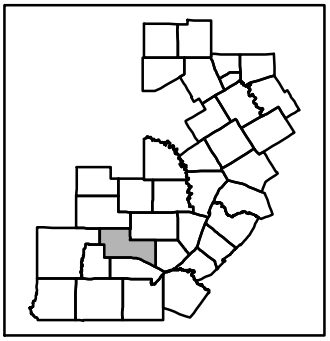
0 2.5 5 10 Miles

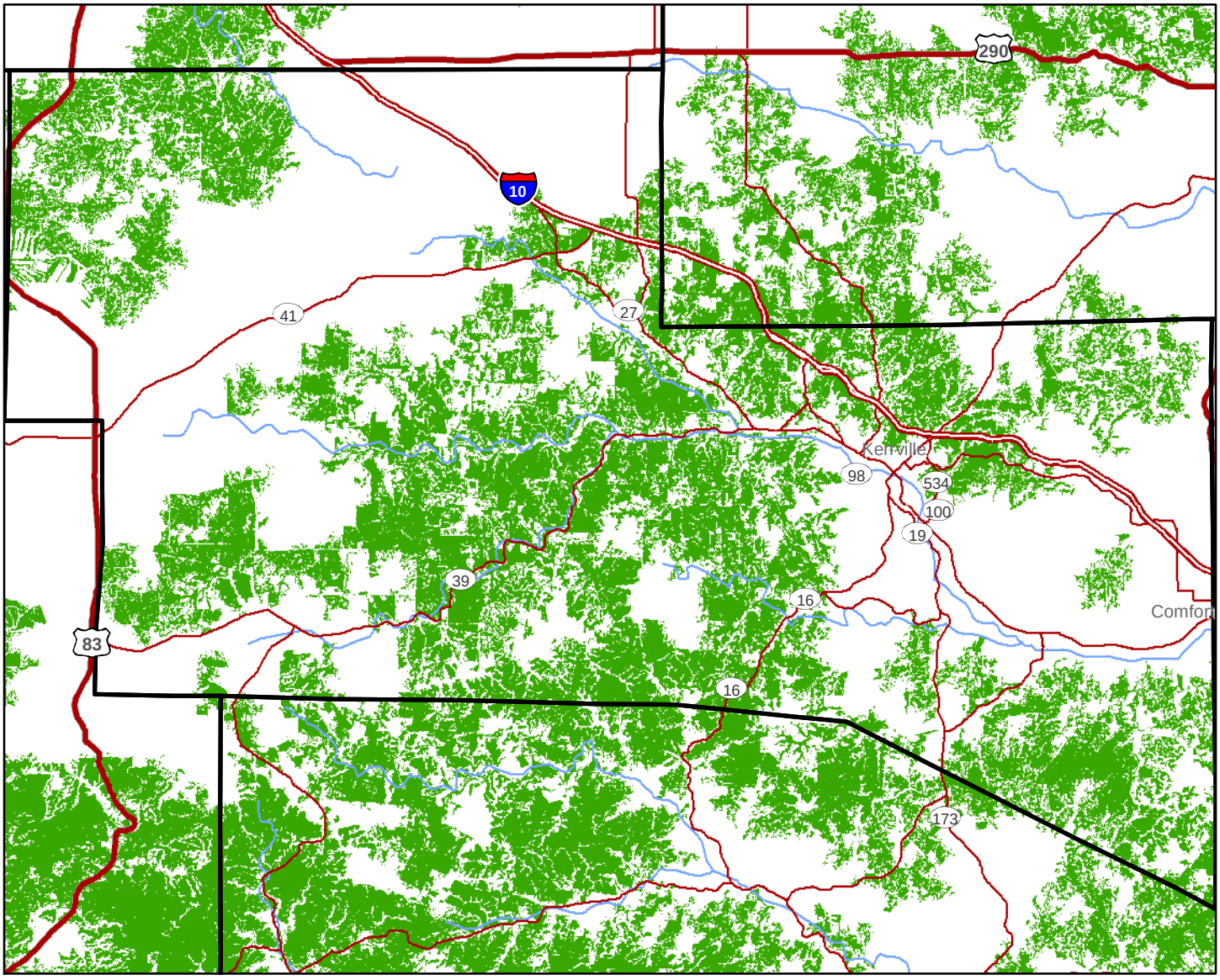
0 3.5 7 14 Kilometers

Figure 2. GCW Model B

KERR
COUNTY

Habitat





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N
W E
S

1:424,453

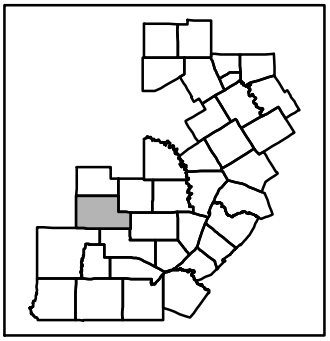
0 3.5 7 14 Miles

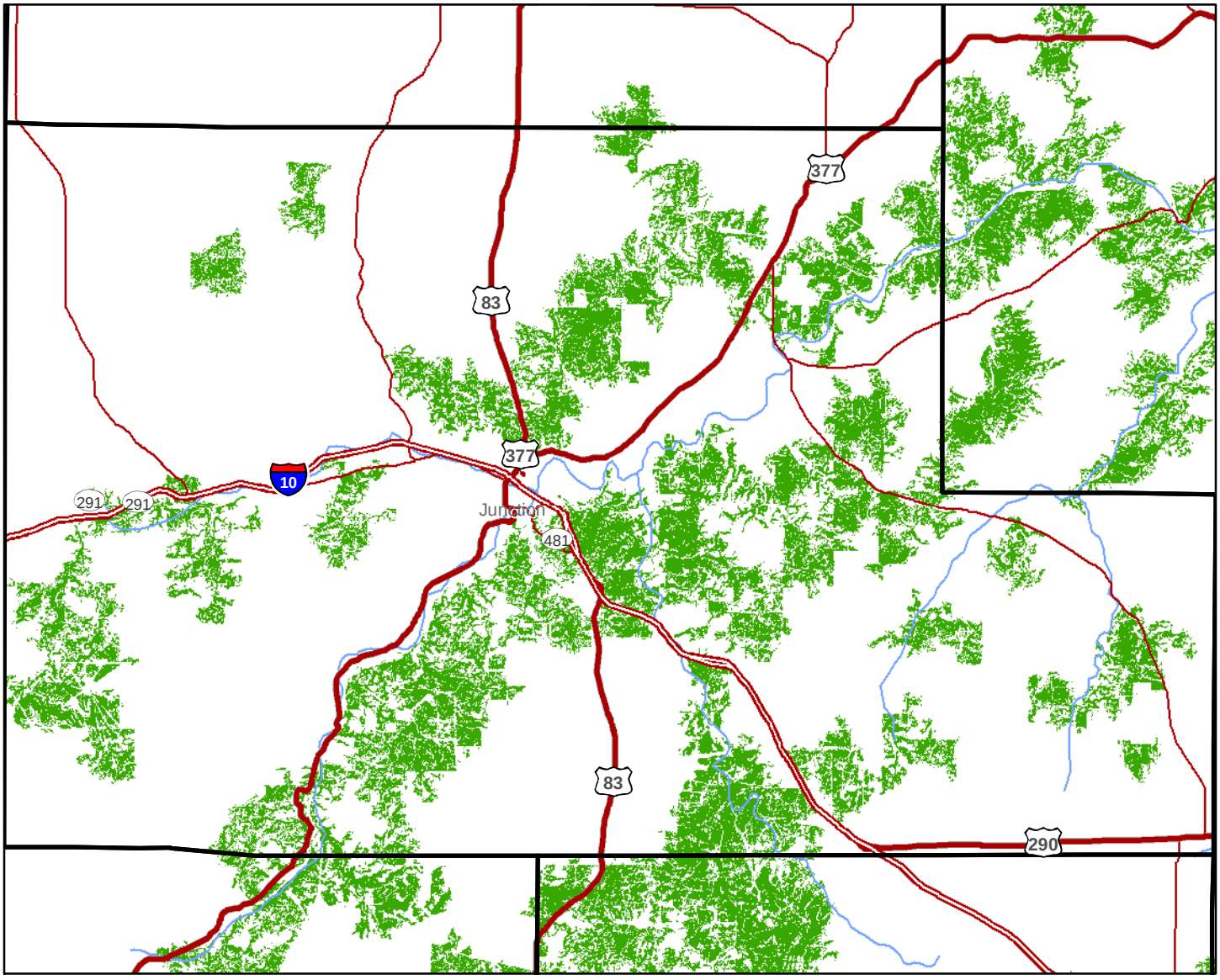
0 5 10 20 Kilometers

Figure 2. GCW Model B

KIMBLE
COUNTY

Habitat





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N
W
E
S

1:410,168

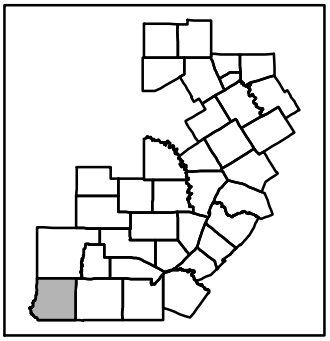
0 3.5 7 14 Miles

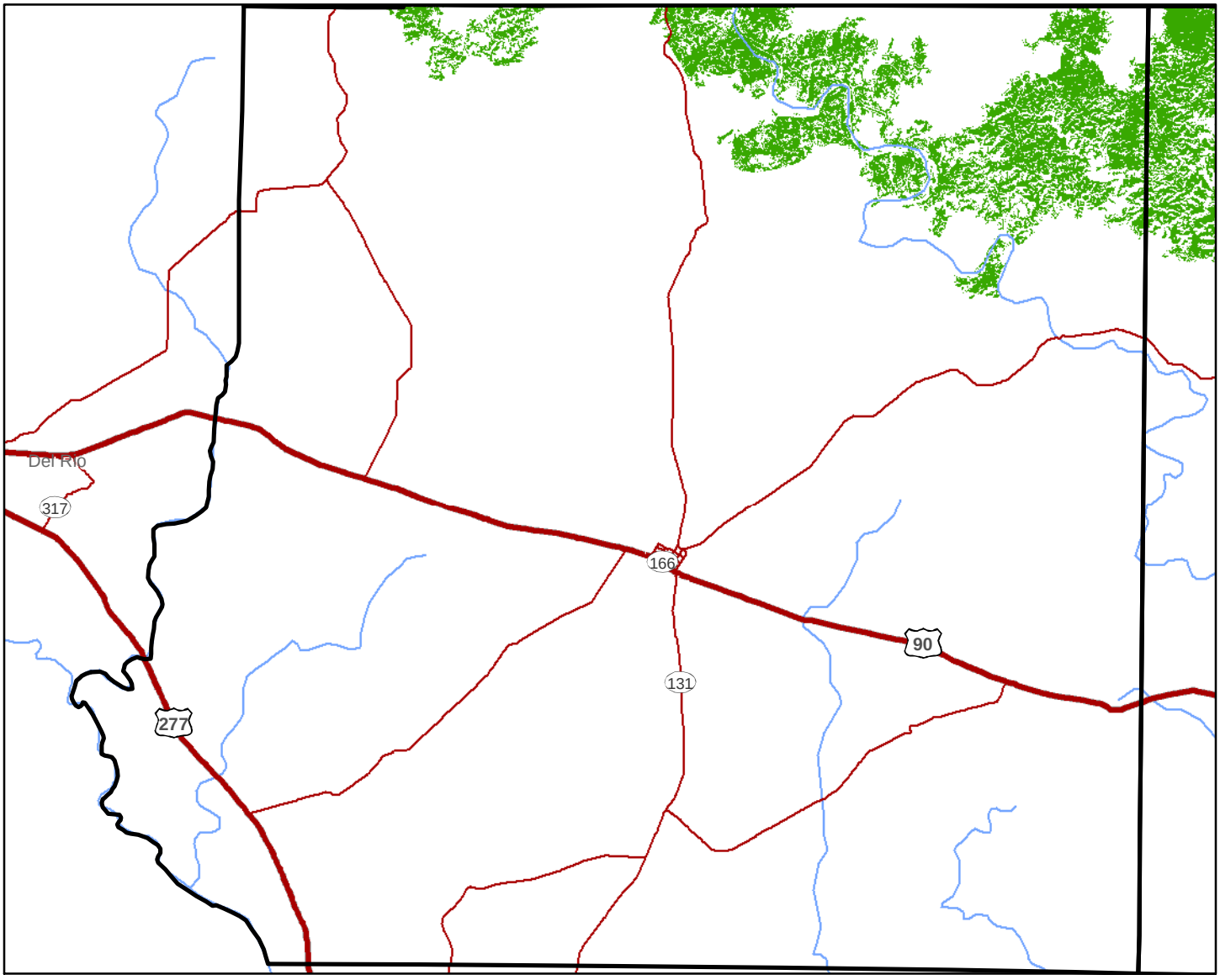
0 5 10 20 Kilometers

Figure 2. GCW Model B

KINNEY
COUNTY

Habitat





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N
W
E
S

1:396,413

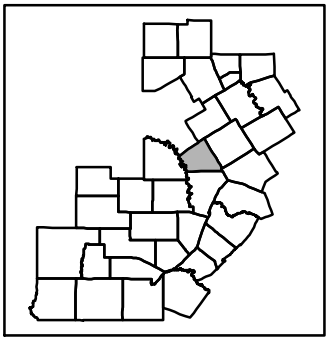
0 3.5 7 14 Miles

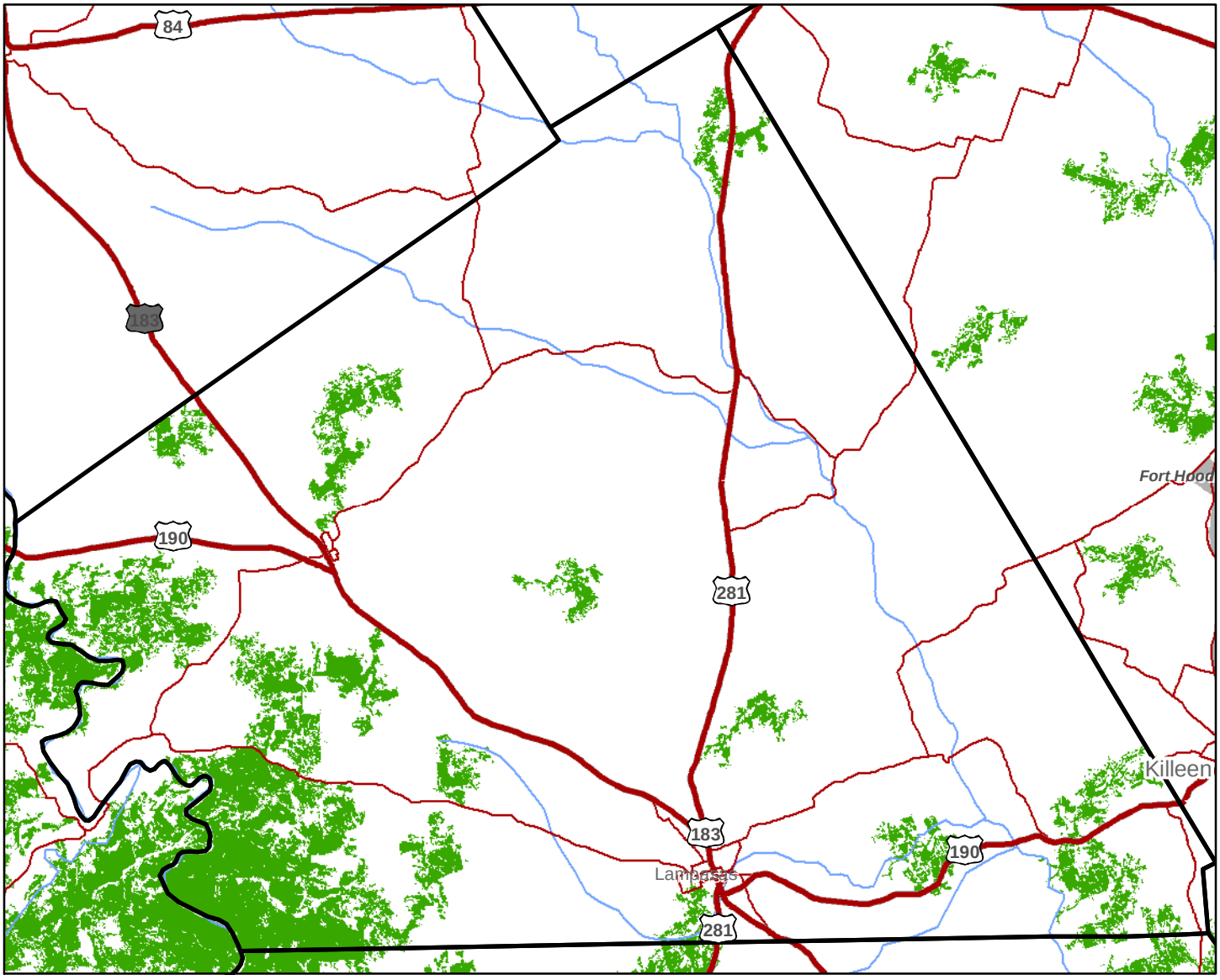
0 5 10 20 Kilometers

Figure 2. GCW Model B

LAMPASAS
COUNTY

Habitat





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N
W
E
S

1:330,663

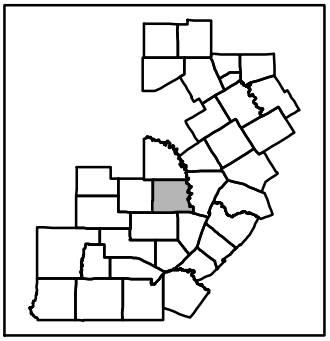
0 3 6 12 Miles

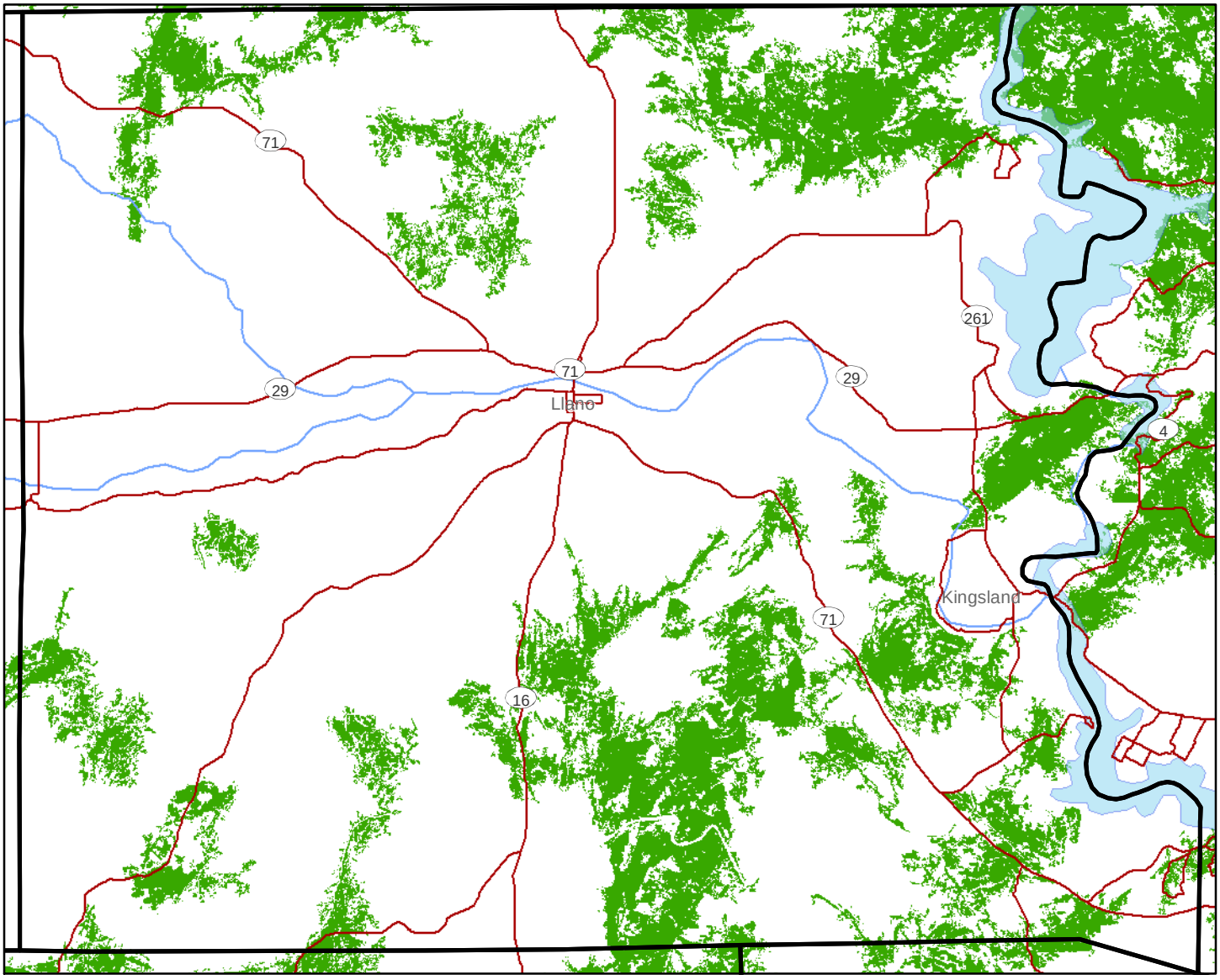
0 4 8 16 Kilometers

Figure 2. GCW Model B

LLANO
COUNTY

Habitat





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N
W
E
S

1:318,007

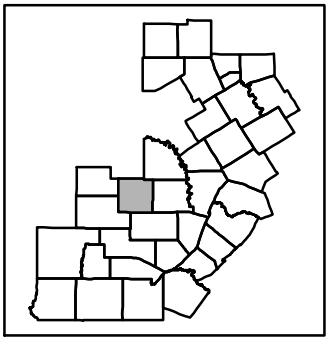
0 3 6 12 Miles

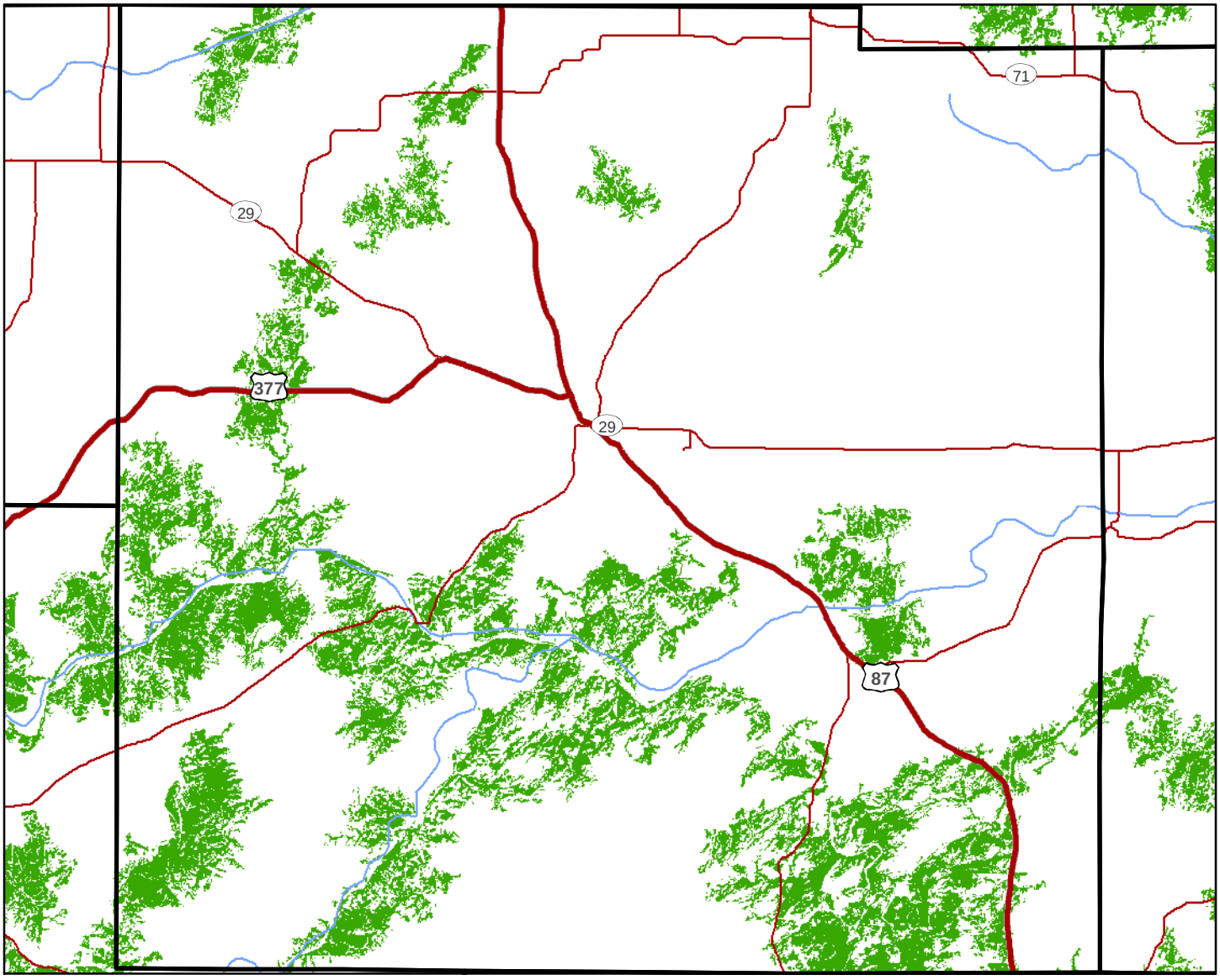
0 3.75 7.5 15 Kilometers

Figure 2. GCW Model B

MASON
COUNTY

Habitat





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N
W
E
S

1:322,650

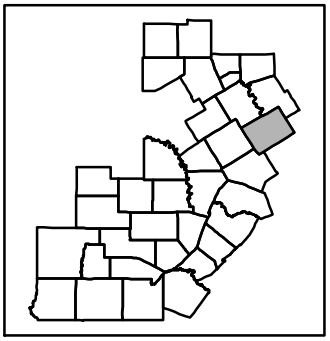
0 3 6 12 Miles

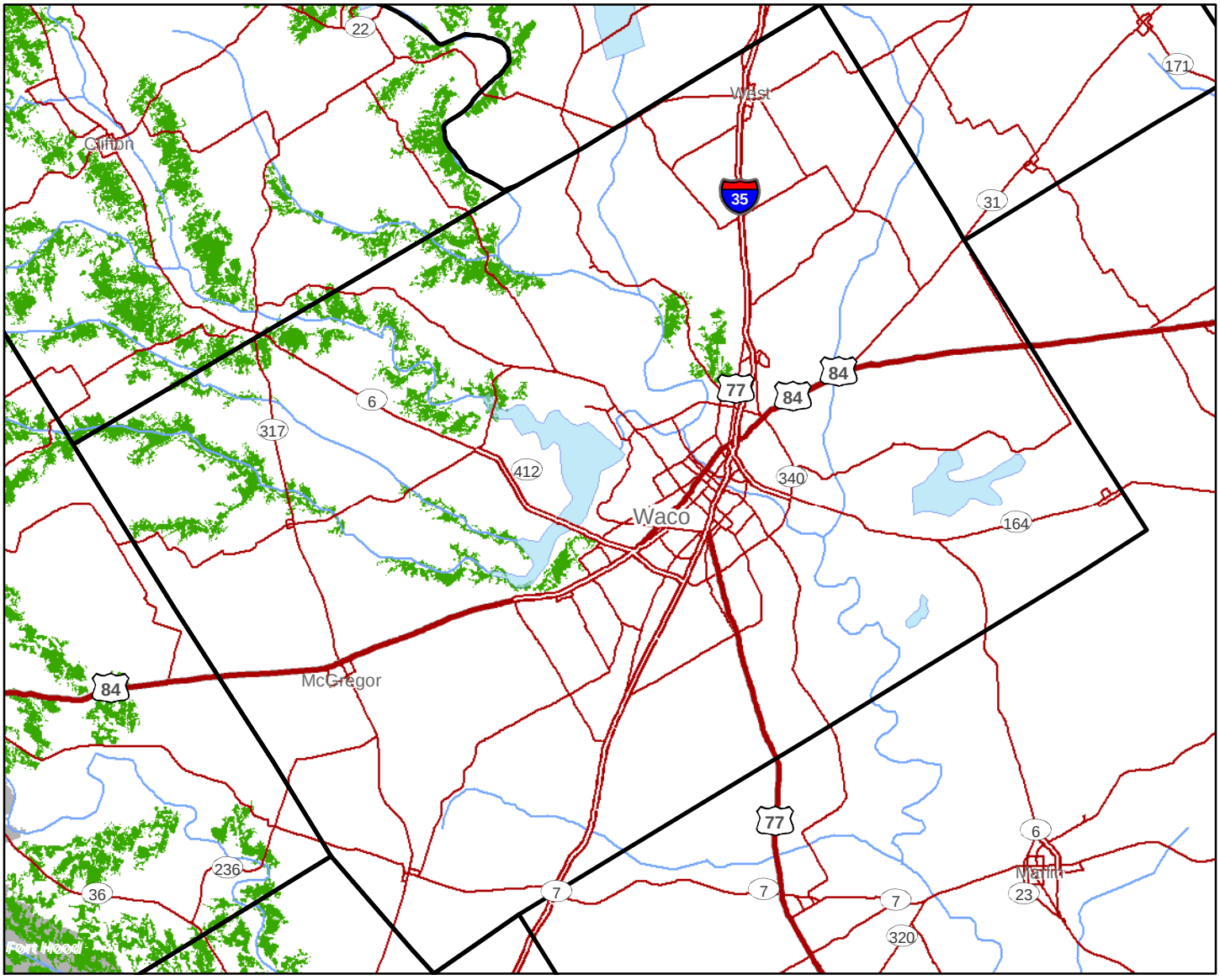
0 3.75 7.5 15 Kilometers

Figure 2. GCW Model B

MCLENNAN COUNTY

Habitat





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N W E S

1:454,790

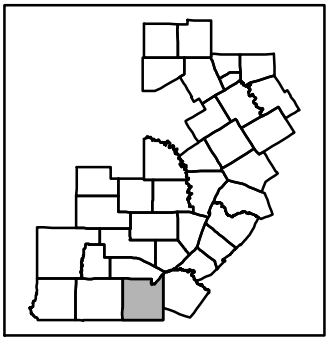
0 4 8 16 Miles

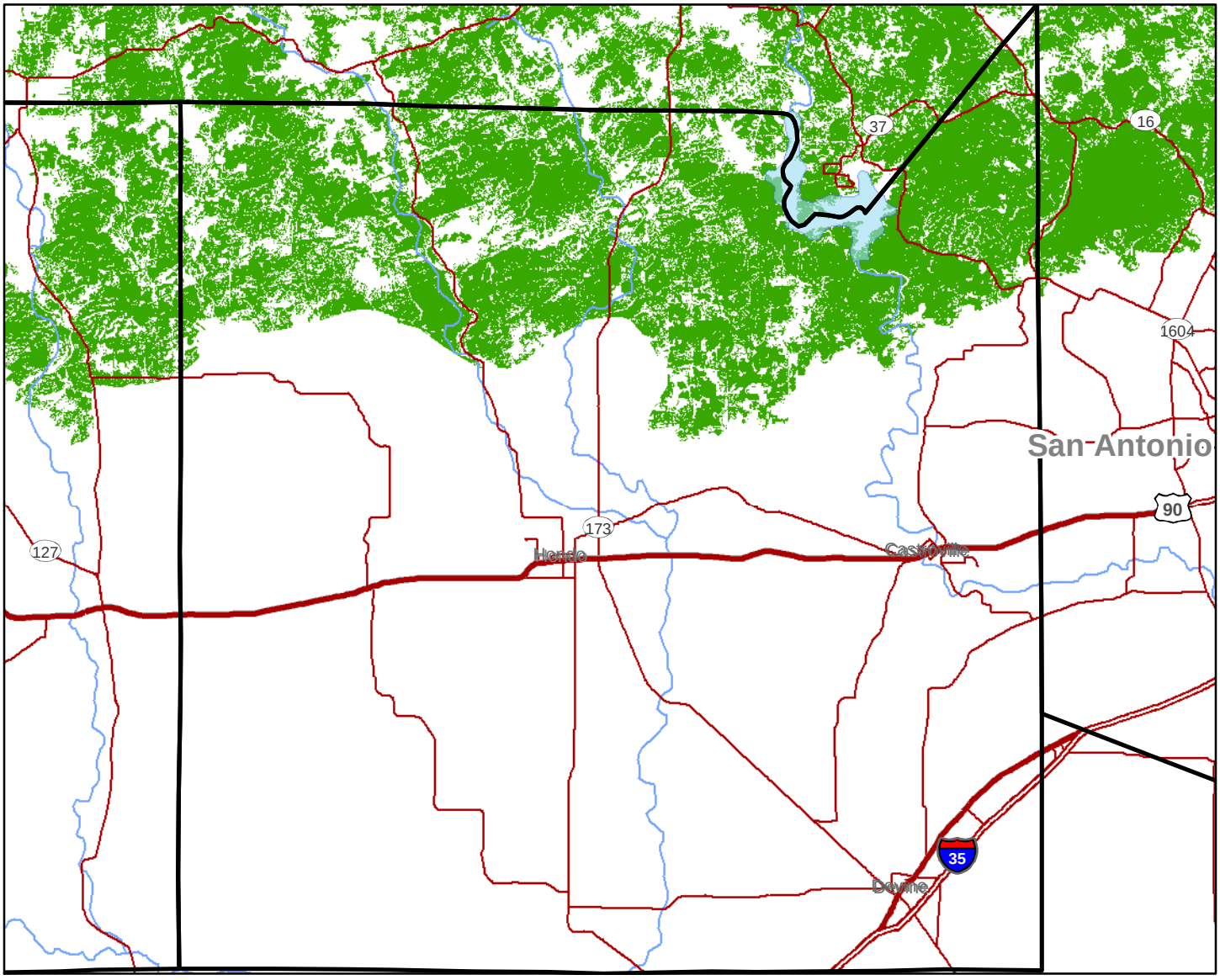
0 5 10 20 Kilometers

Figure 2. GCW Model B

MEDINA
COUNTY

Habitat





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N
W
E
S

1:436,612

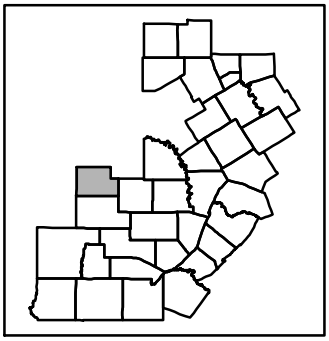
0 3.75 7.5 15 Miles

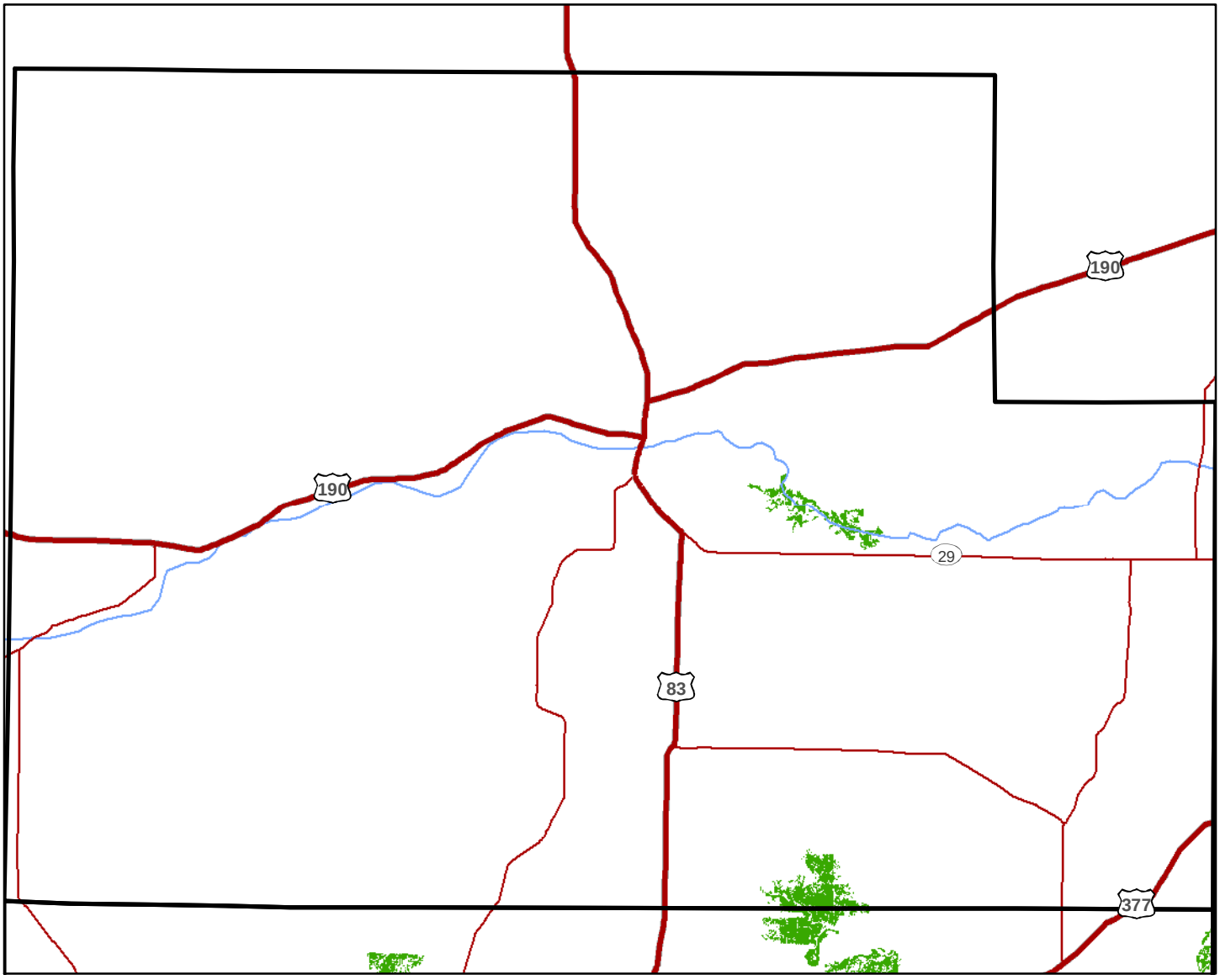
0 5 10 20 Kilometers

Figure 2. GCW Model B

MENARD
COUNTY

Habitat





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N
W
E
S

1:318,185

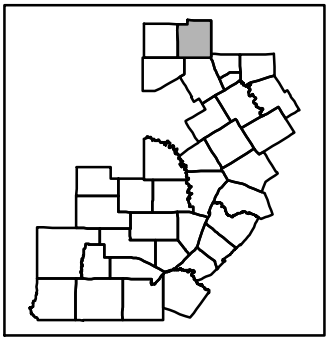
0 2.5 5 10 Miles

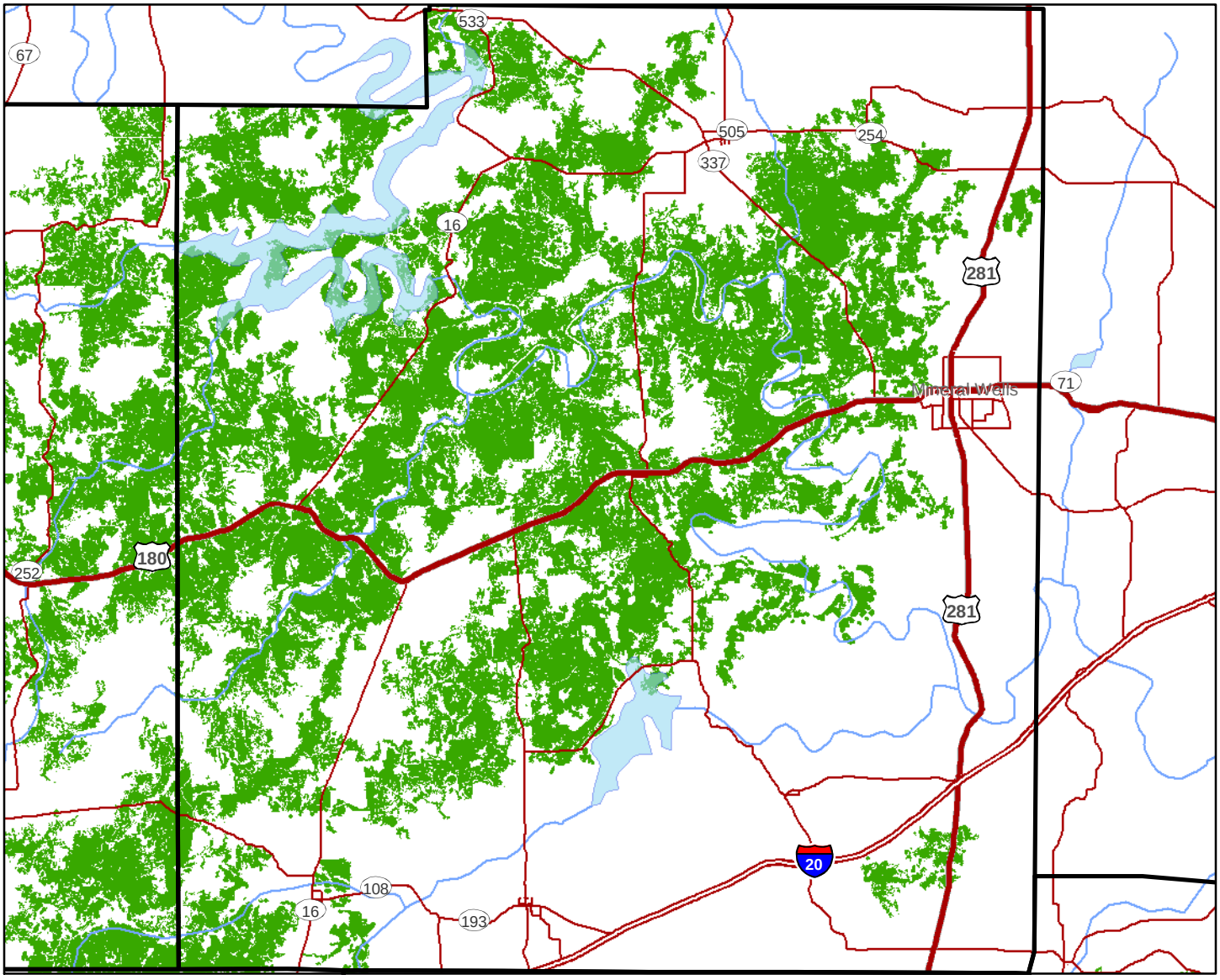
0 3.75 7.5 15 Kilometers

Figure 2. GCW Model B

PALO PINTO COUNTY

Habitat





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N W E S

1:357,880

0 3 6 12 Miles

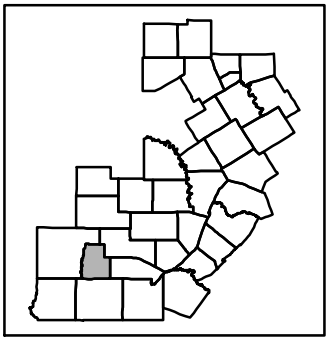
0 4 8 16 Kilometers

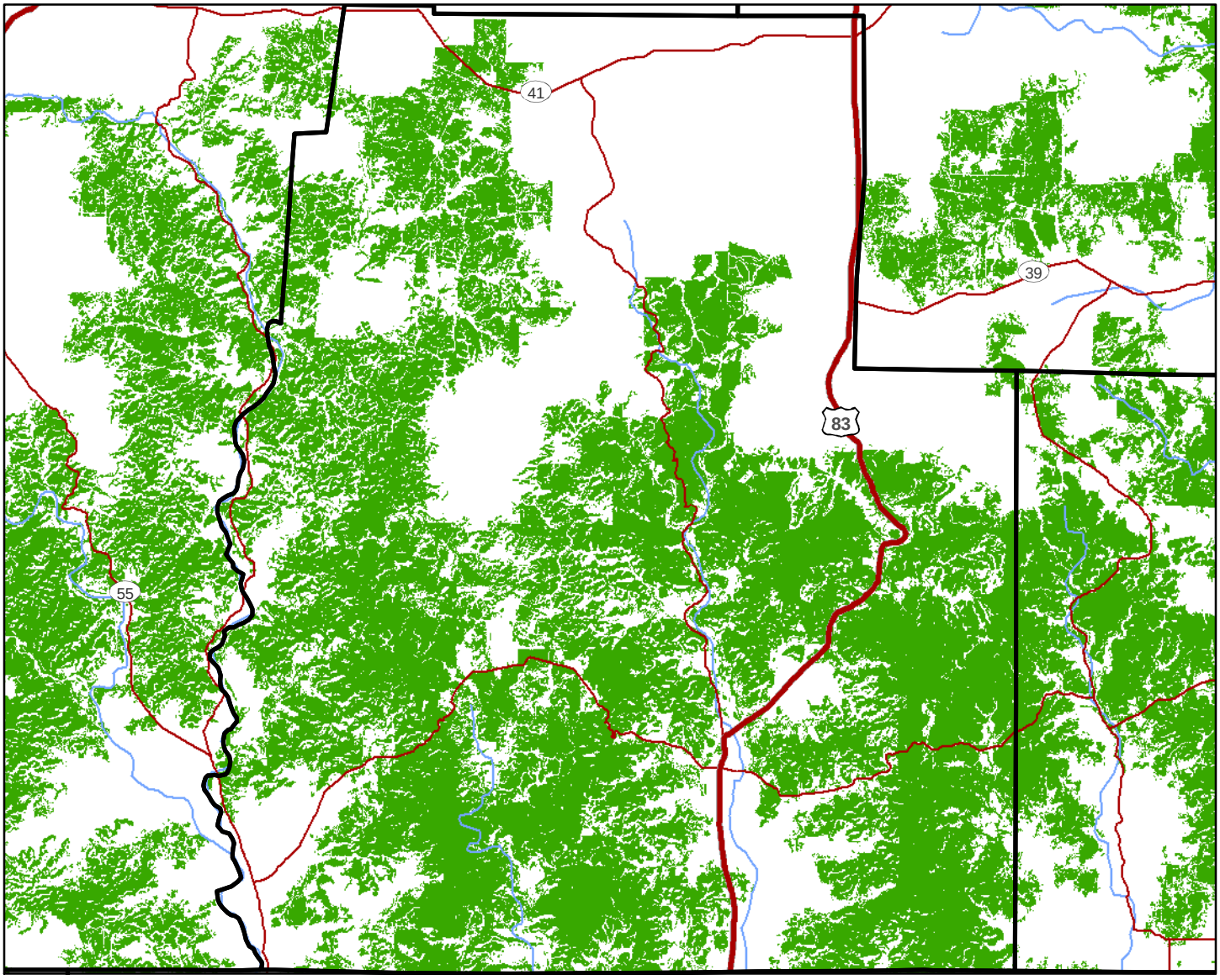
Figure 2. GCW Model B

REAL

COUNTY

Habitat





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N W E S

1:329,759

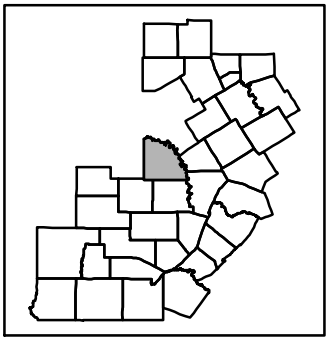
0 2.5 5 10 Miles

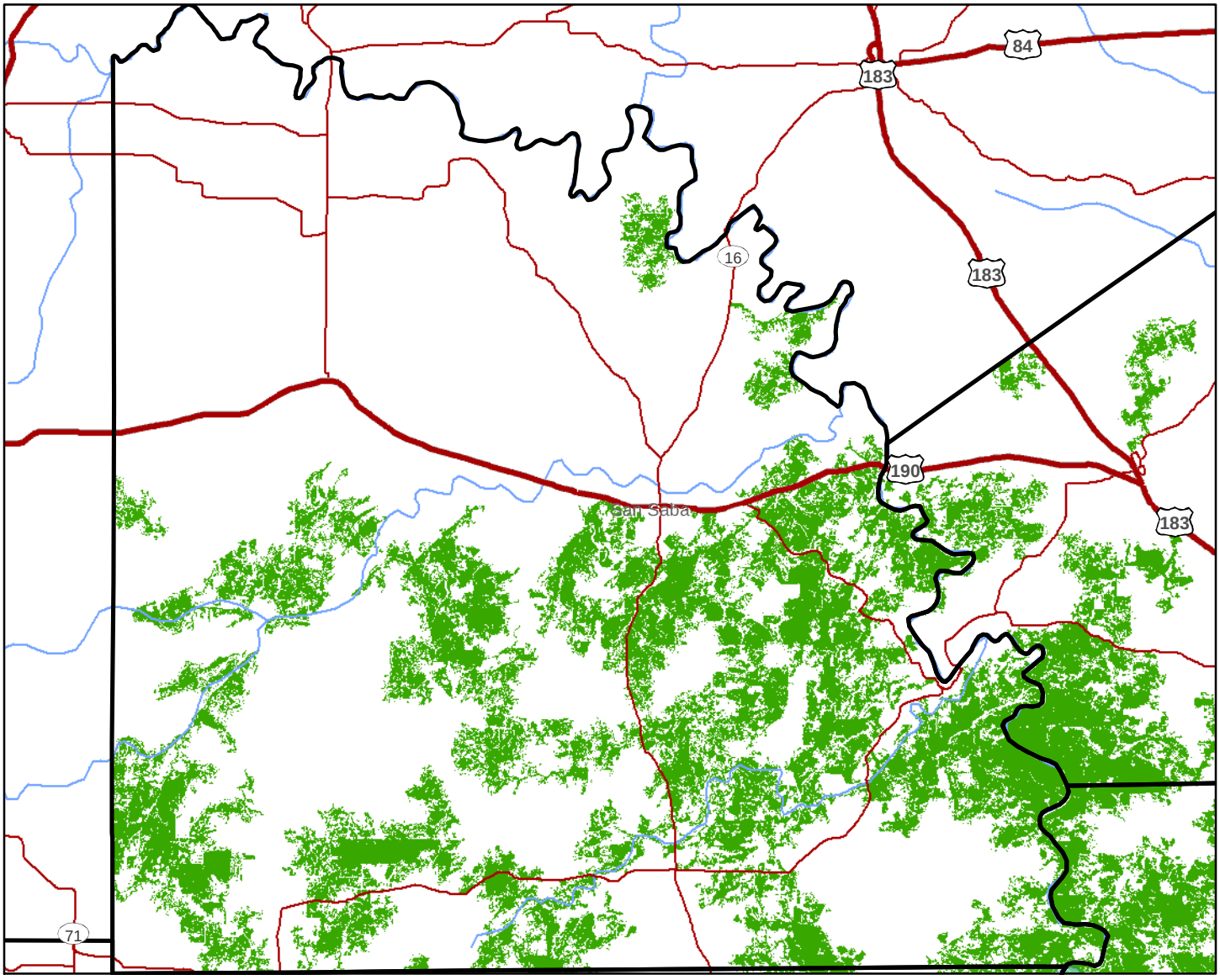
0 3.75 7.5 15 Kilometers

Figure 2. GCW Model B

SAN SABA COUNTY

Habitat





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

1:414,376

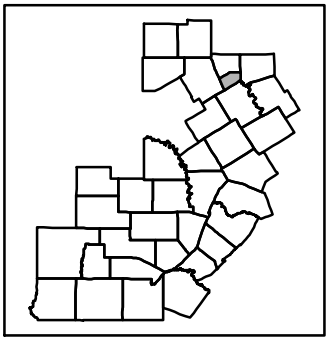
0 3 6 12 Miles

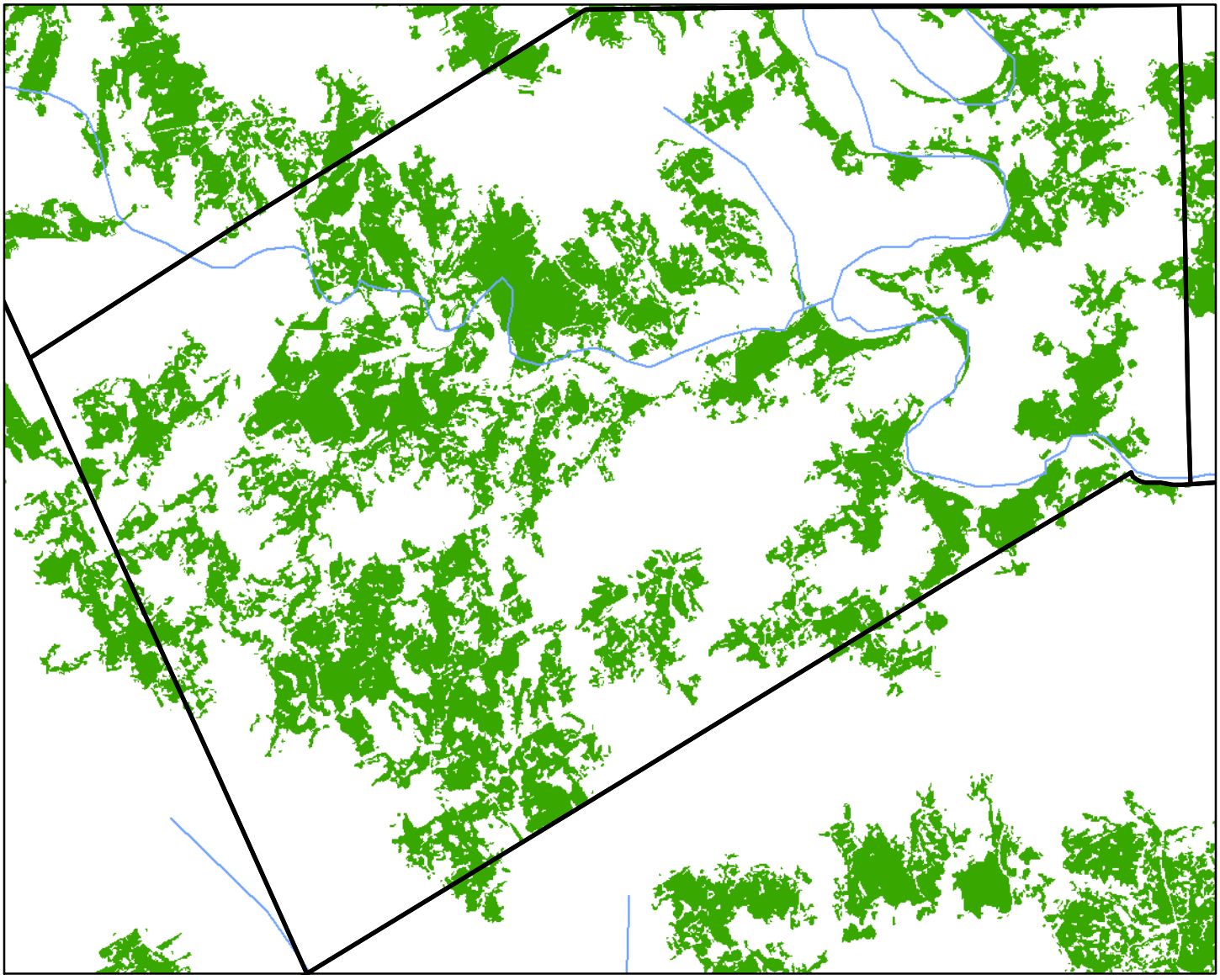
0 4.5 9 18 Kilometers

Figure 2. GCW Model B

SOMERVELL
COUNTY

Habitat





N
W E
S

1:168,949

Legend

County

Stream

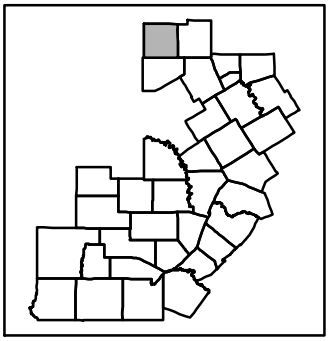
0 1.25 2.5 5 Miles

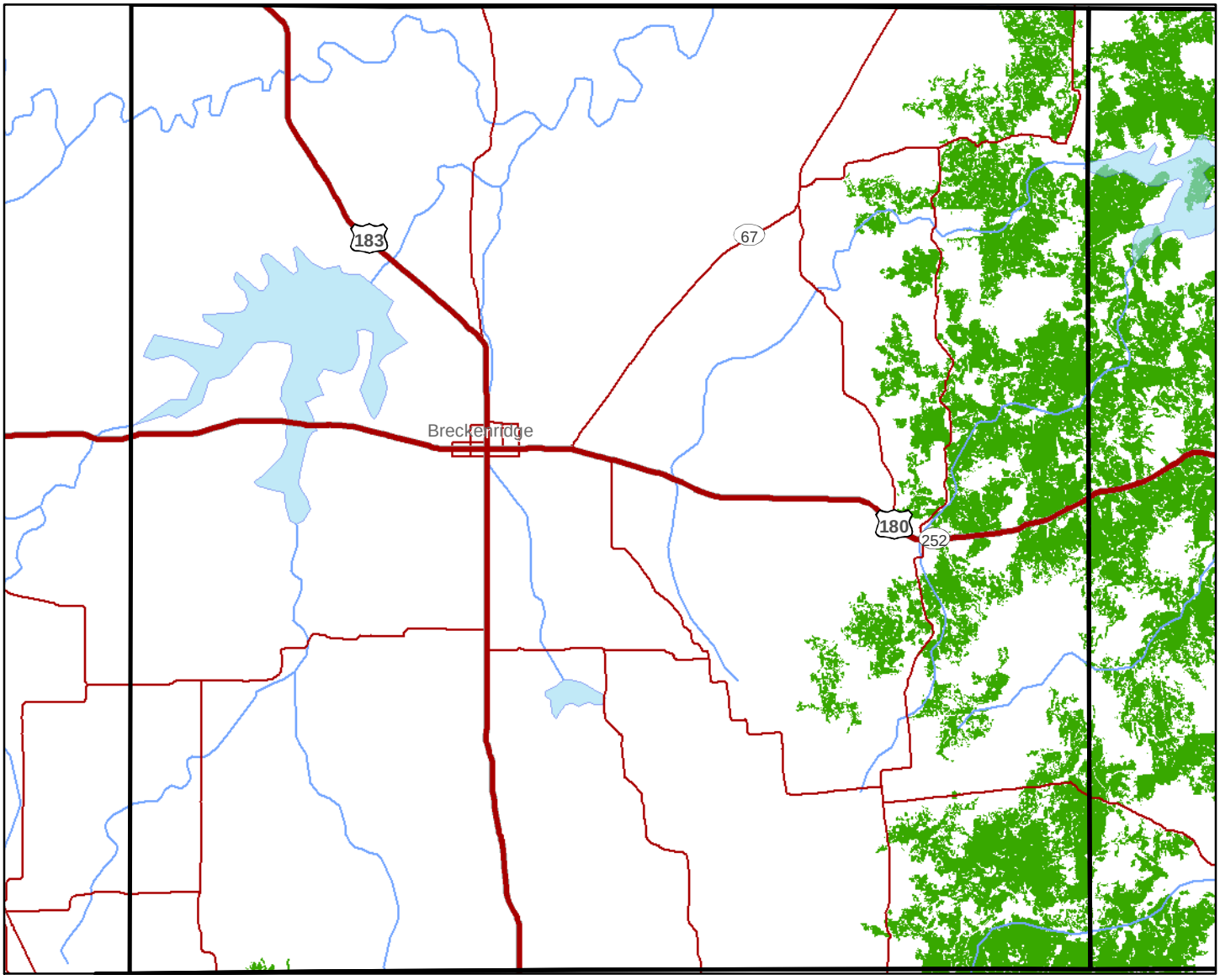
0 2 4 8 Kilometers

Figure 2. GCW Model B

STEPHENS
COUNTY

Habitat





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N
W
E
S

1:321,941

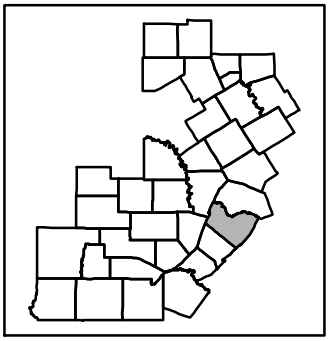
0 2.5 5 10 Miles

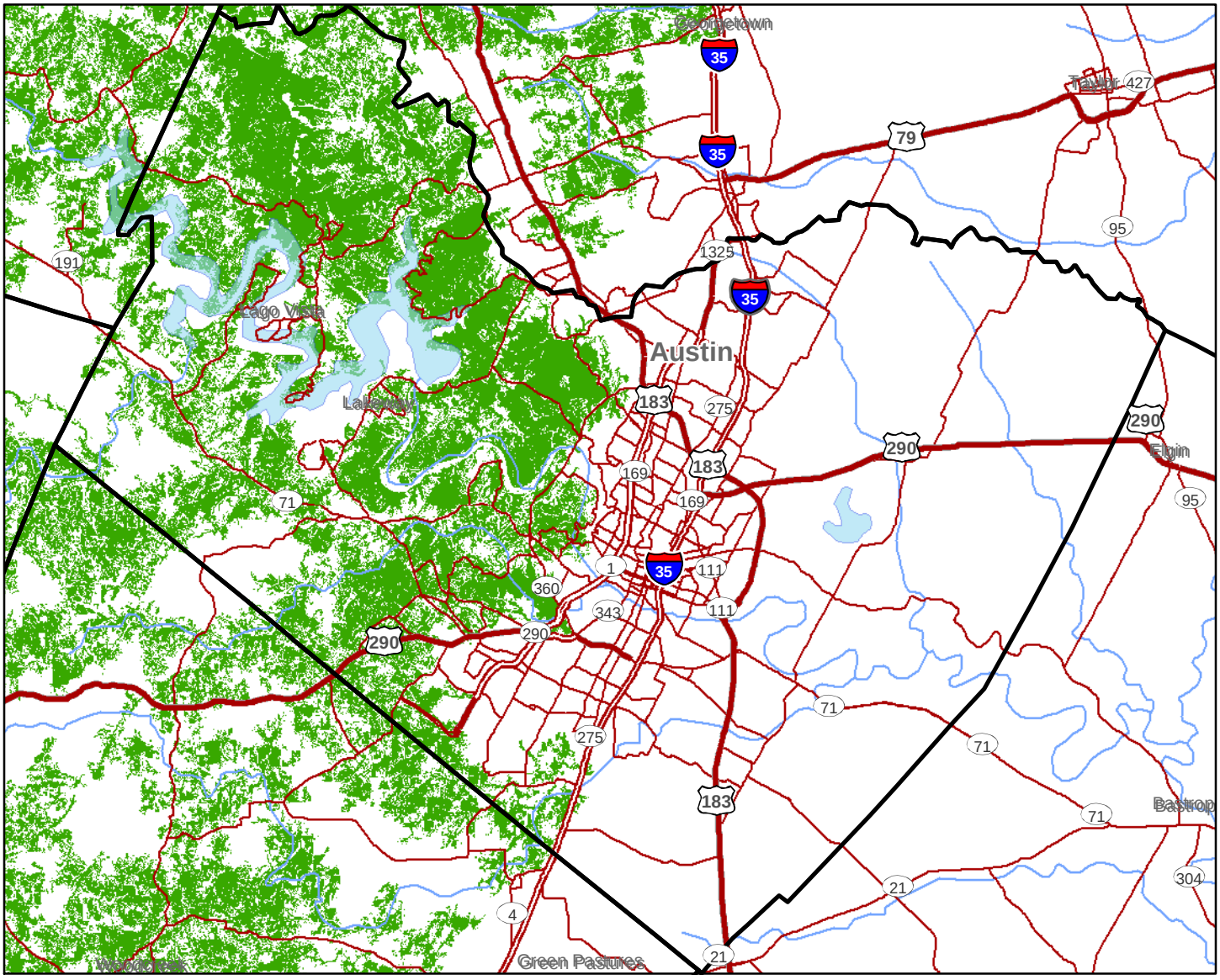
0 3.75 7.5 15 Kilometers

Figure 2. GCW Model B

TRAVIS
COUNTY

Habitat





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N
W
E
S

1:440,119

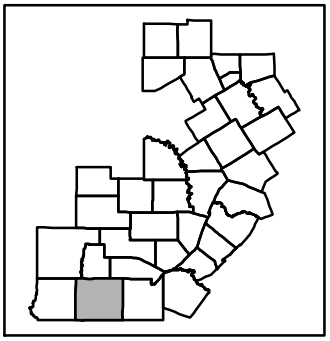
0 3.5 7 14 Miles

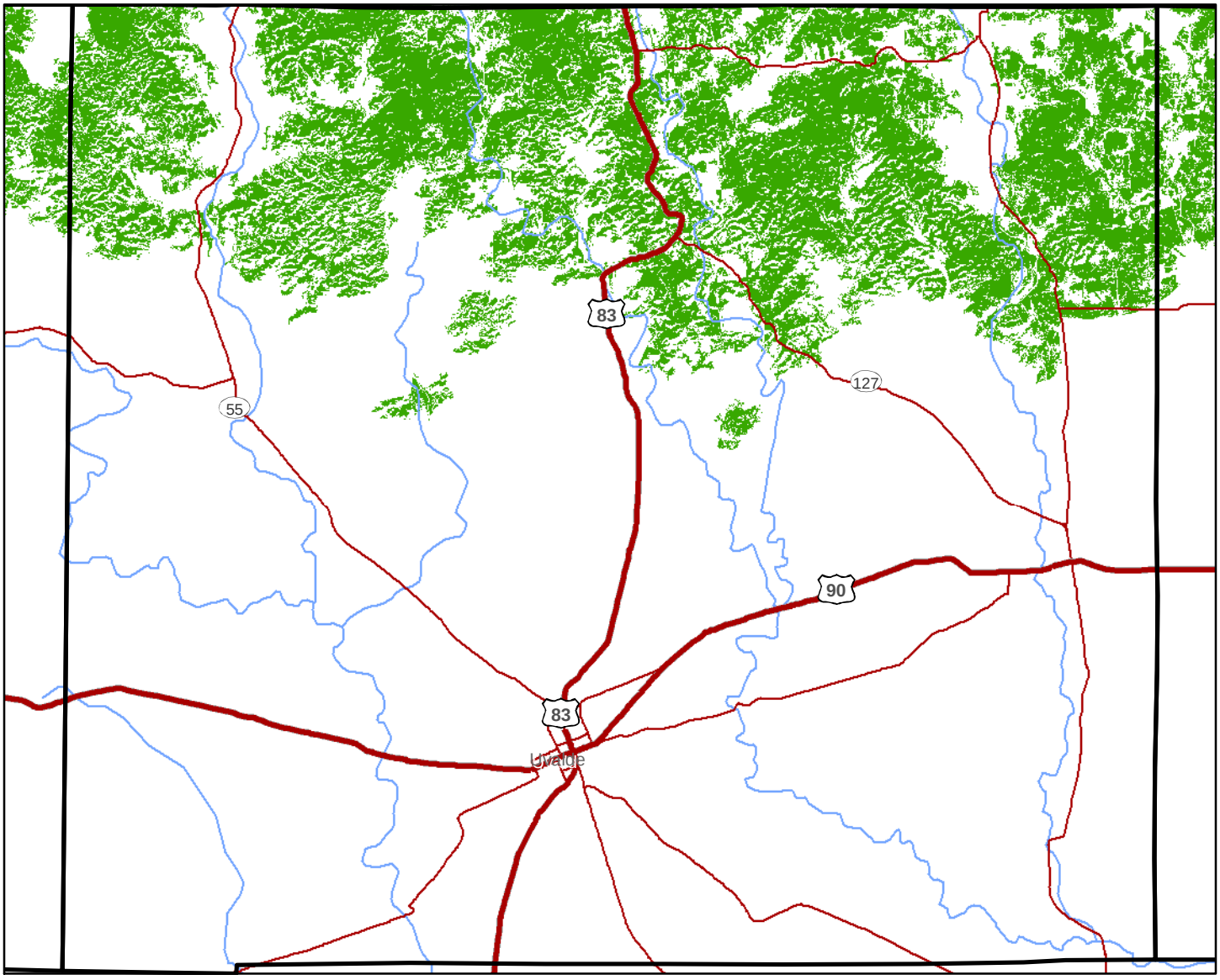
0 5 10 20 Kilometers

Figure 2. GCW Model B

UVALDE
COUNTY

Habitat





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N
W
E
S

1:396,913

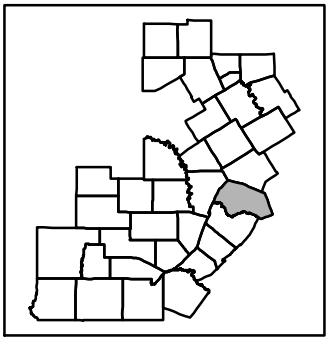
0 3 6 12 Miles

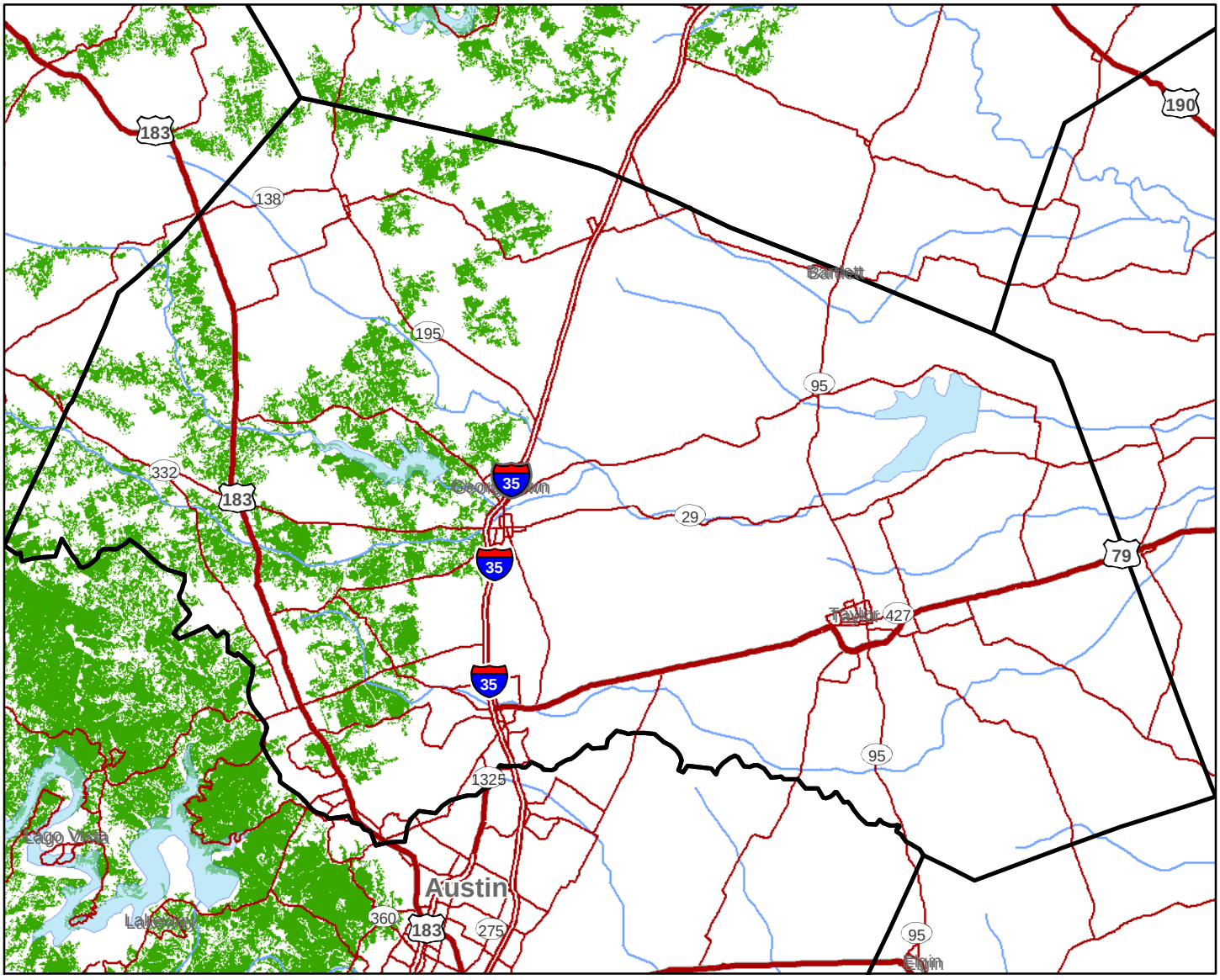
0 4.5 9 18 Kilometers

Figure 2. GCW Model B

WILLIAMSON COUNTY

Habitat





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

1:452,765

0 3.5 7 14 Miles

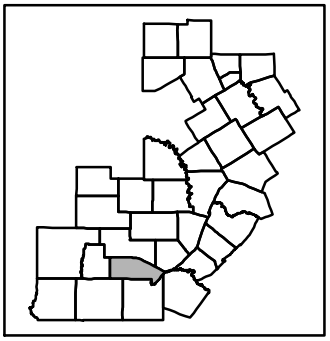
0 5 10 20 Kilometers

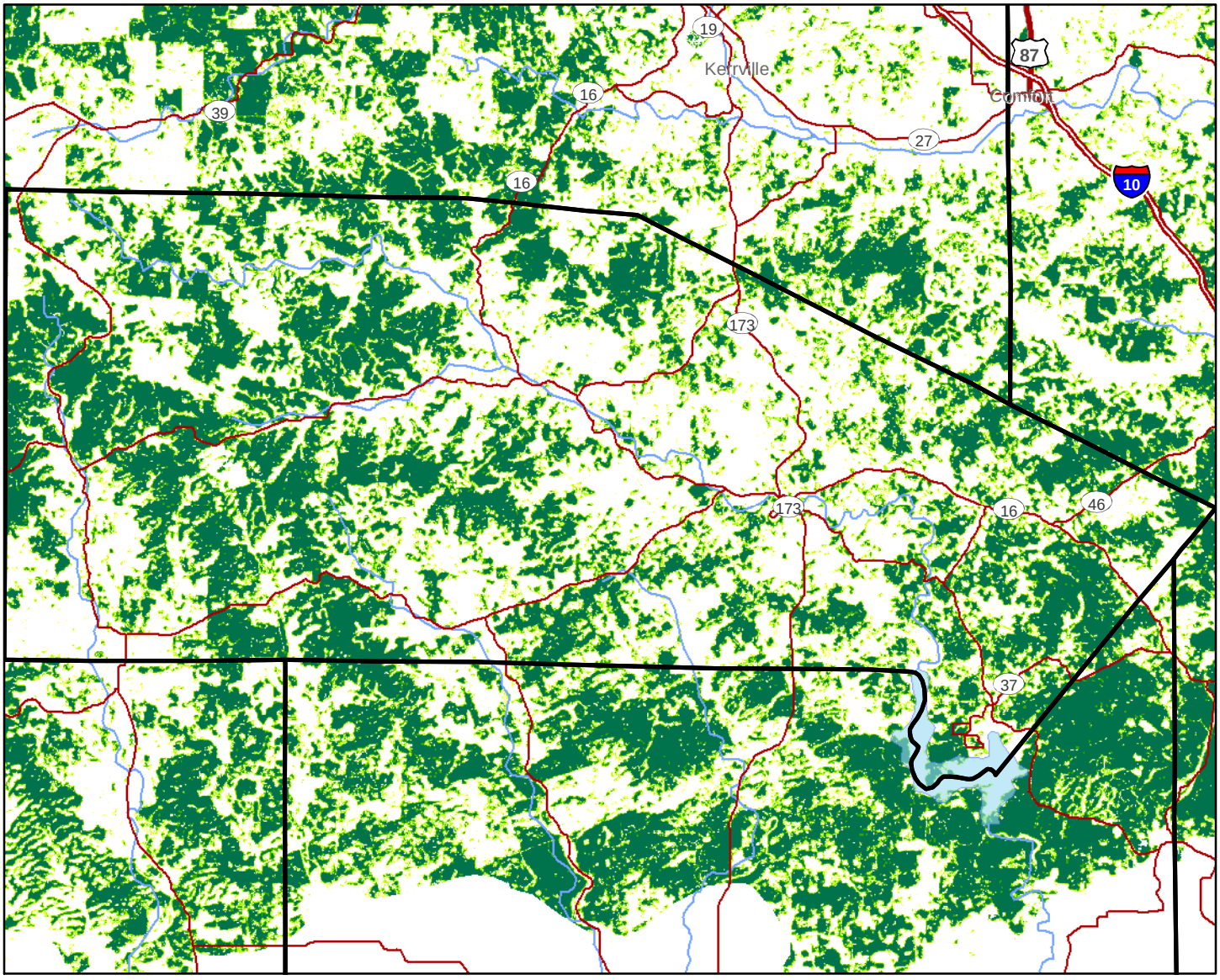
Figure 3. GCW Model C

BANDERA COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3
- 4 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N
W E
S

1:420,333

0 3.5 7 14 Miles

0 4.5 9 18 Kilometers

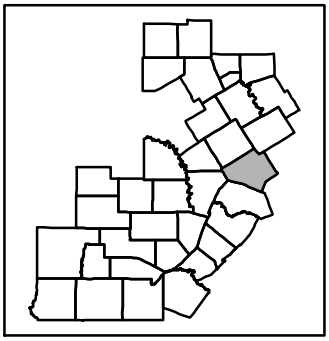
Figure 3. GCW Model C

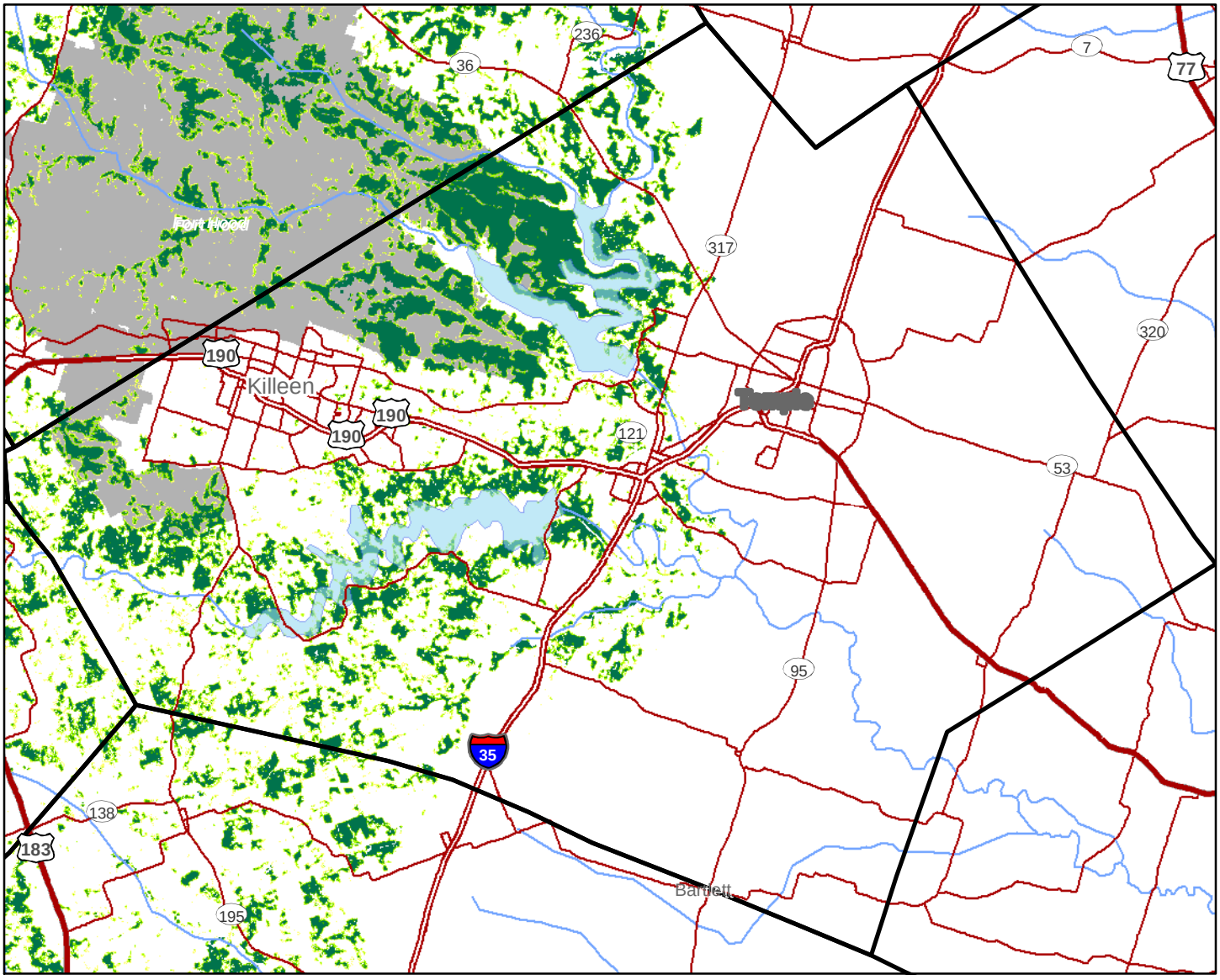
BELL

COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3
- 4 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N
W
E
S

1:426,603

0 3.5 7 14 Miles

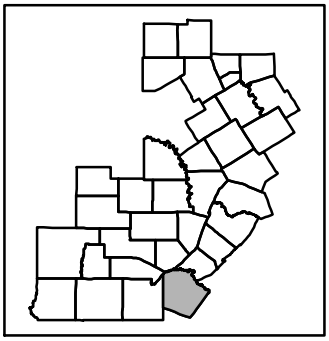
0 4.5 9 18 Kilometers

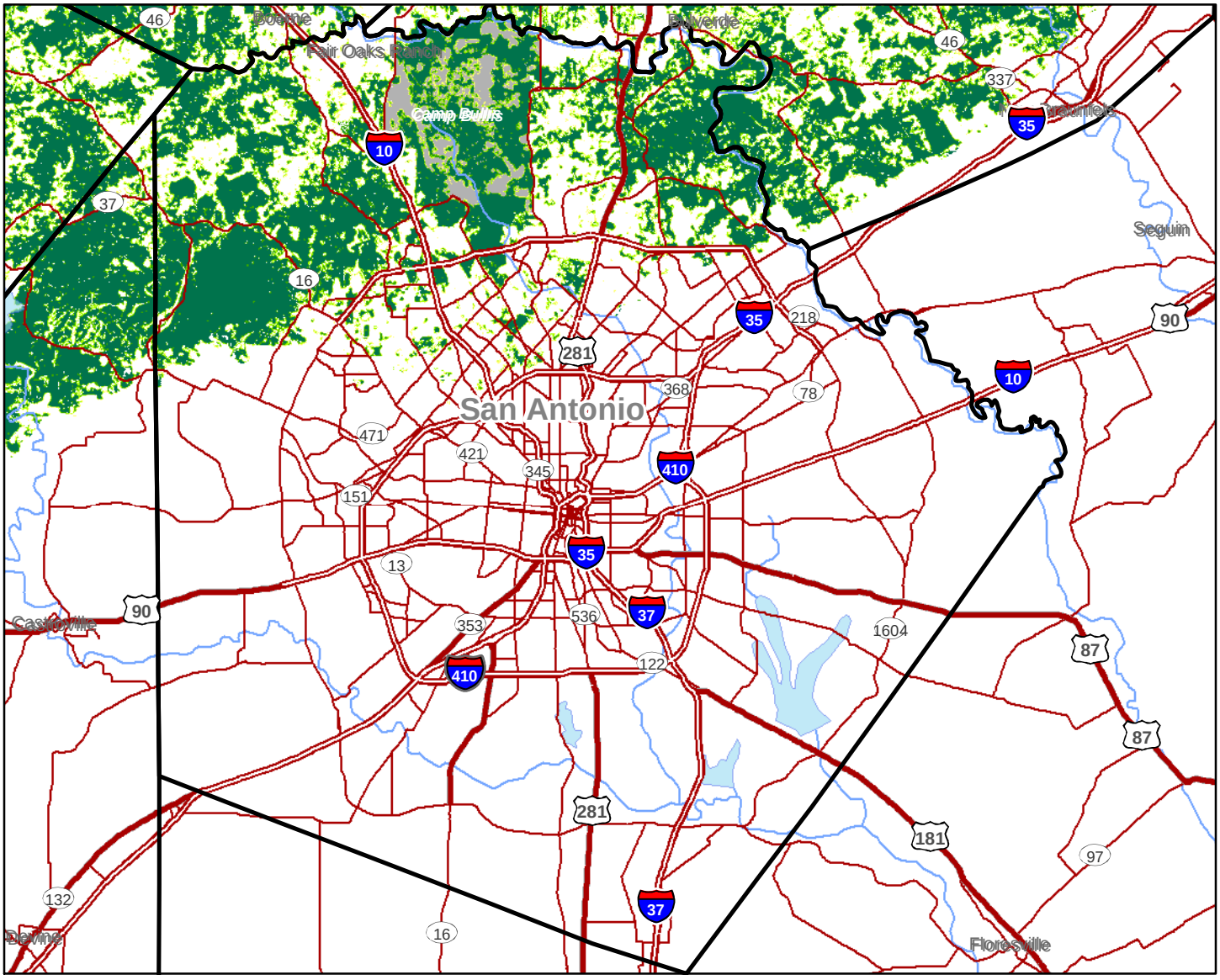
Figure 3. GCW Model C

BEXAR
COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3
- 4 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

1:467,865

0 3.75 7.5 15 Miles

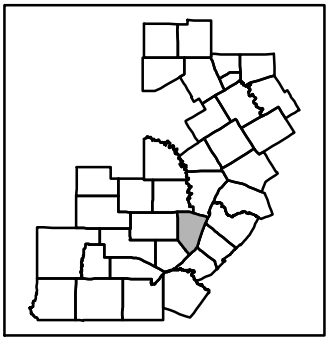
0 5 10 20 Kilometers

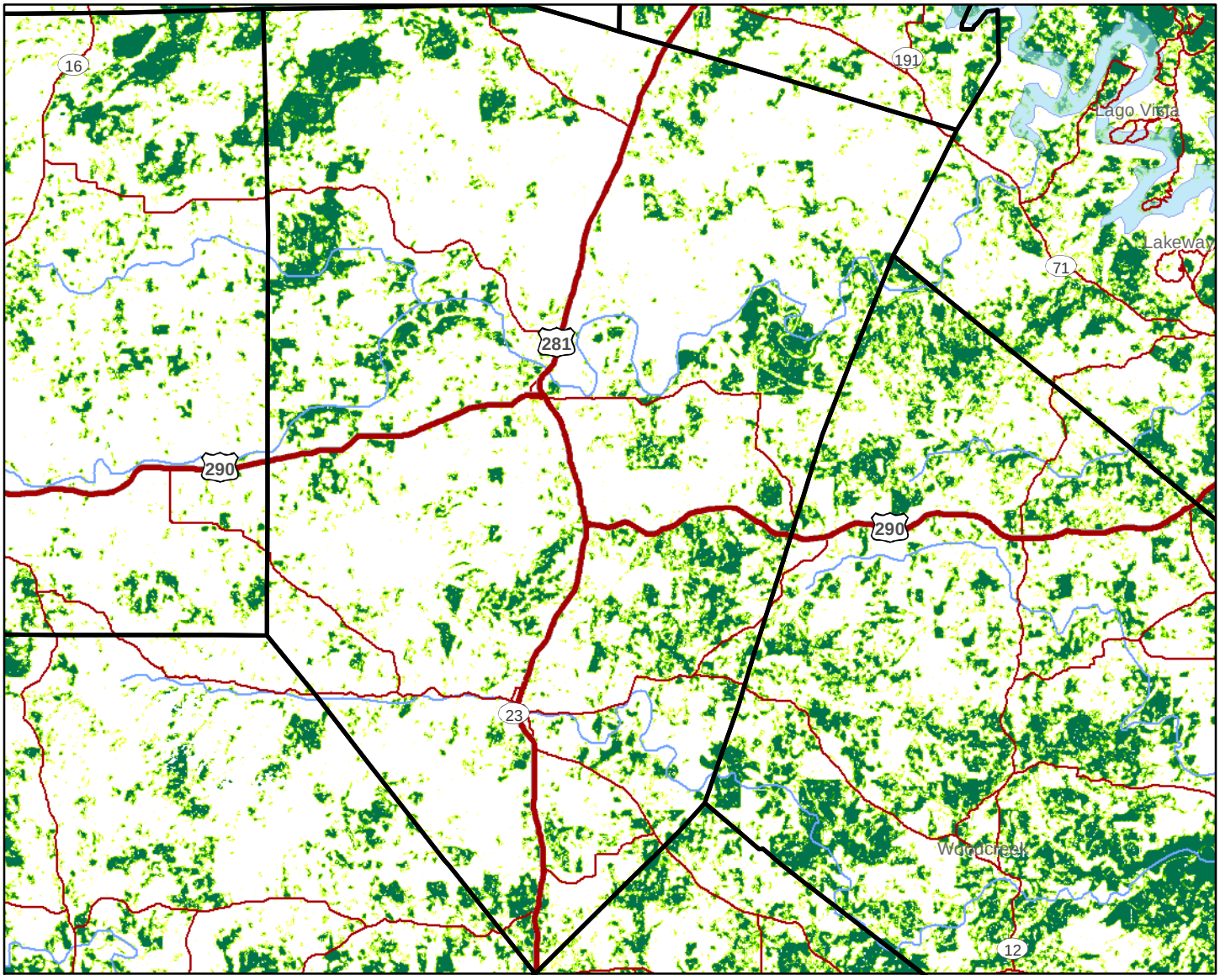
Figure 3. GCW Model C

BLANCO COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3
- 4 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N
W E
S

1:408,826

0 3.5 7 14 Miles

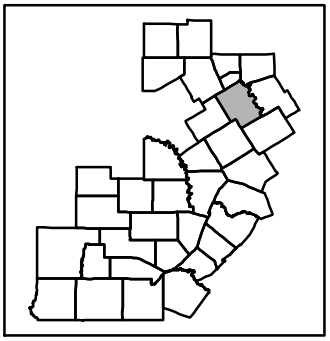
0 4.5 9 18 Kilometers

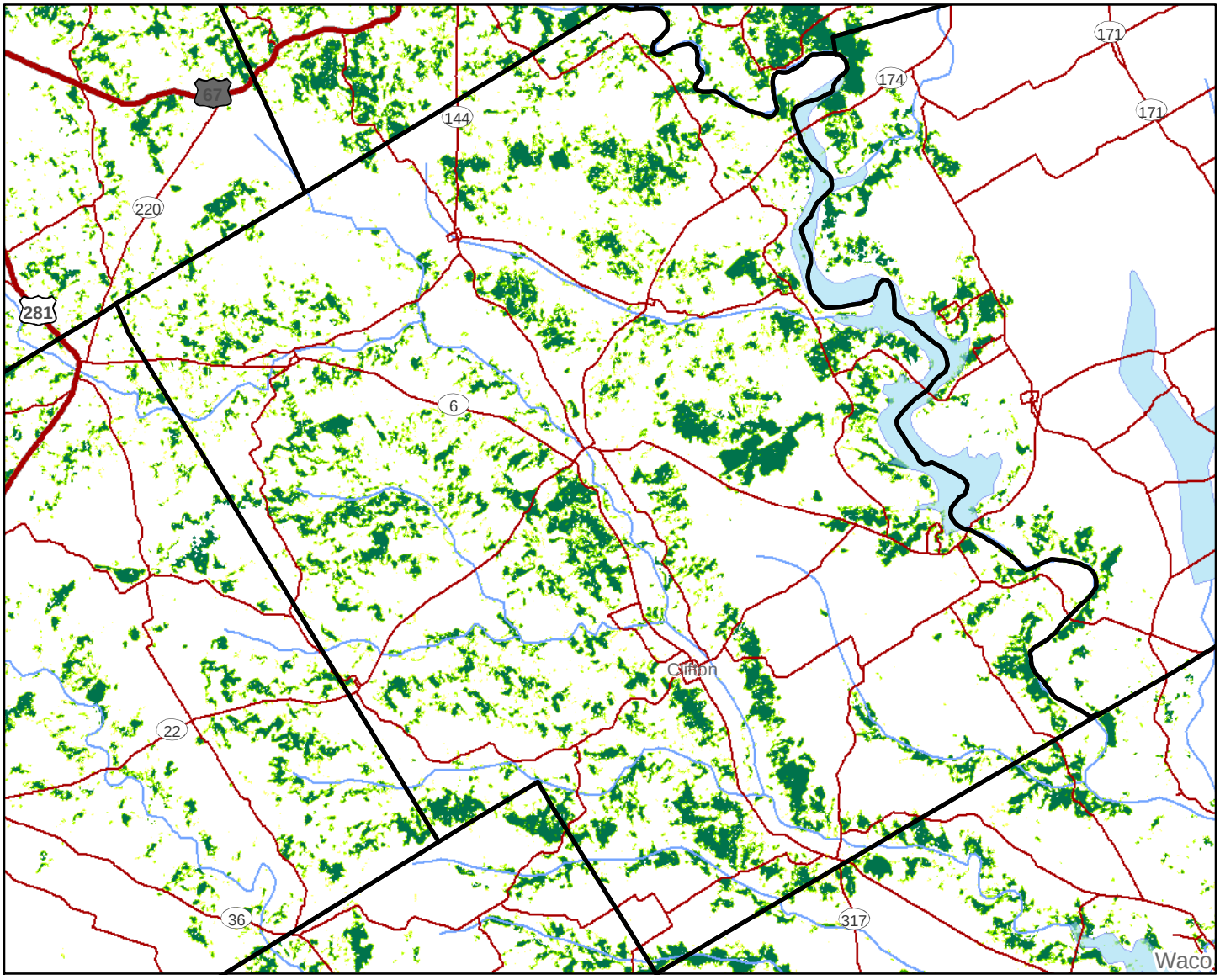
Figure 3. GCW Model C

BOSQUE
COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3
- 4 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N
W
E
S

1:450,274

0 3.75 7.5 15 Miles

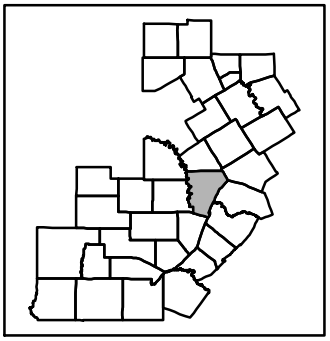
0 5 10 20 Kilometers

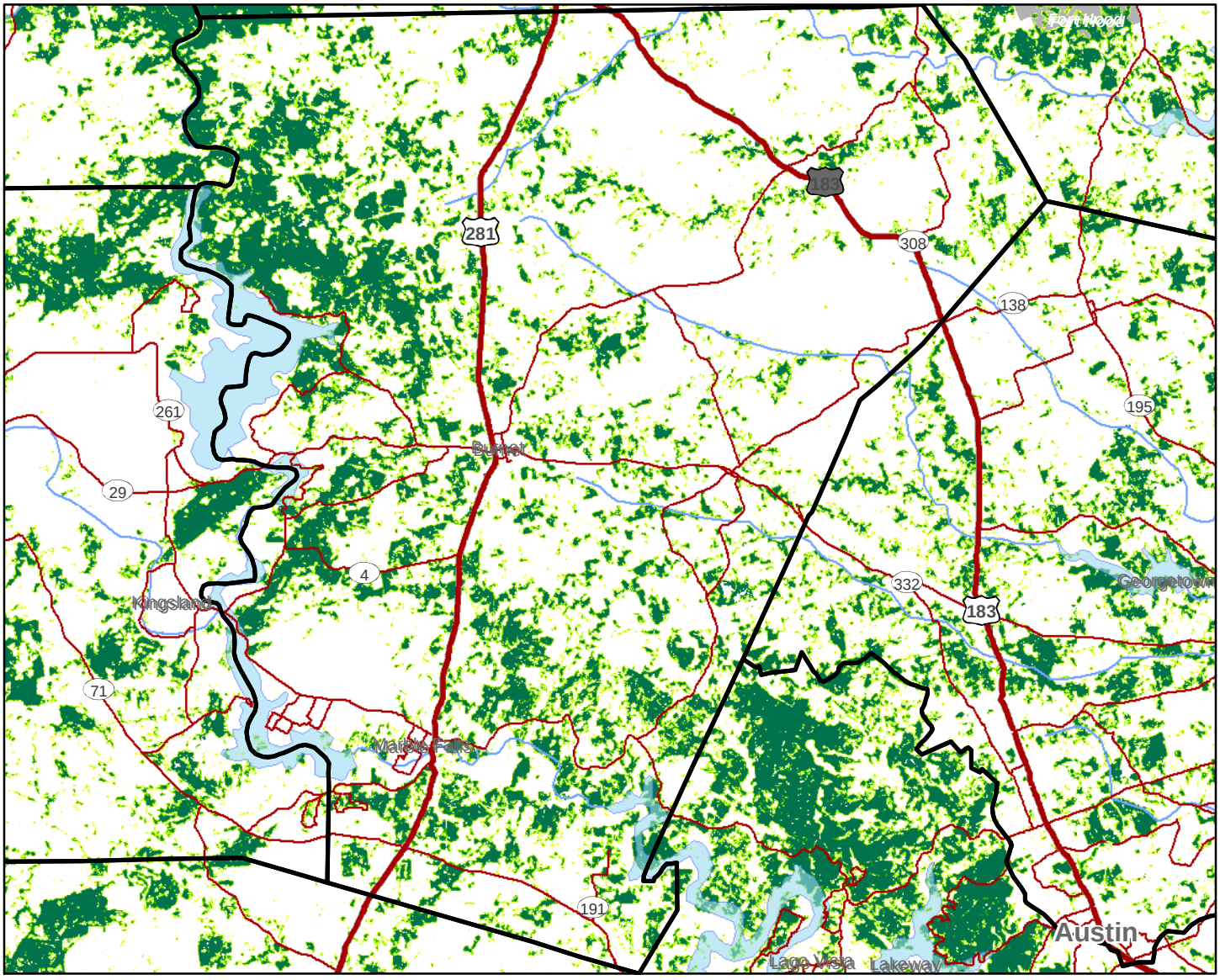
Figure 3. GCW Model C

BURNET COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3
- 4 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

1:443,072

0 3.75 7.5 15 Miles

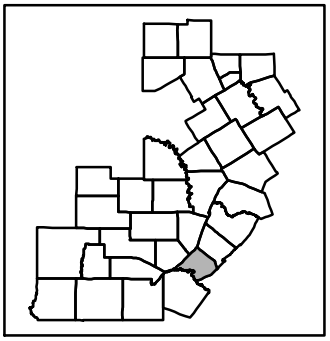
0 5 10 20 Kilometers

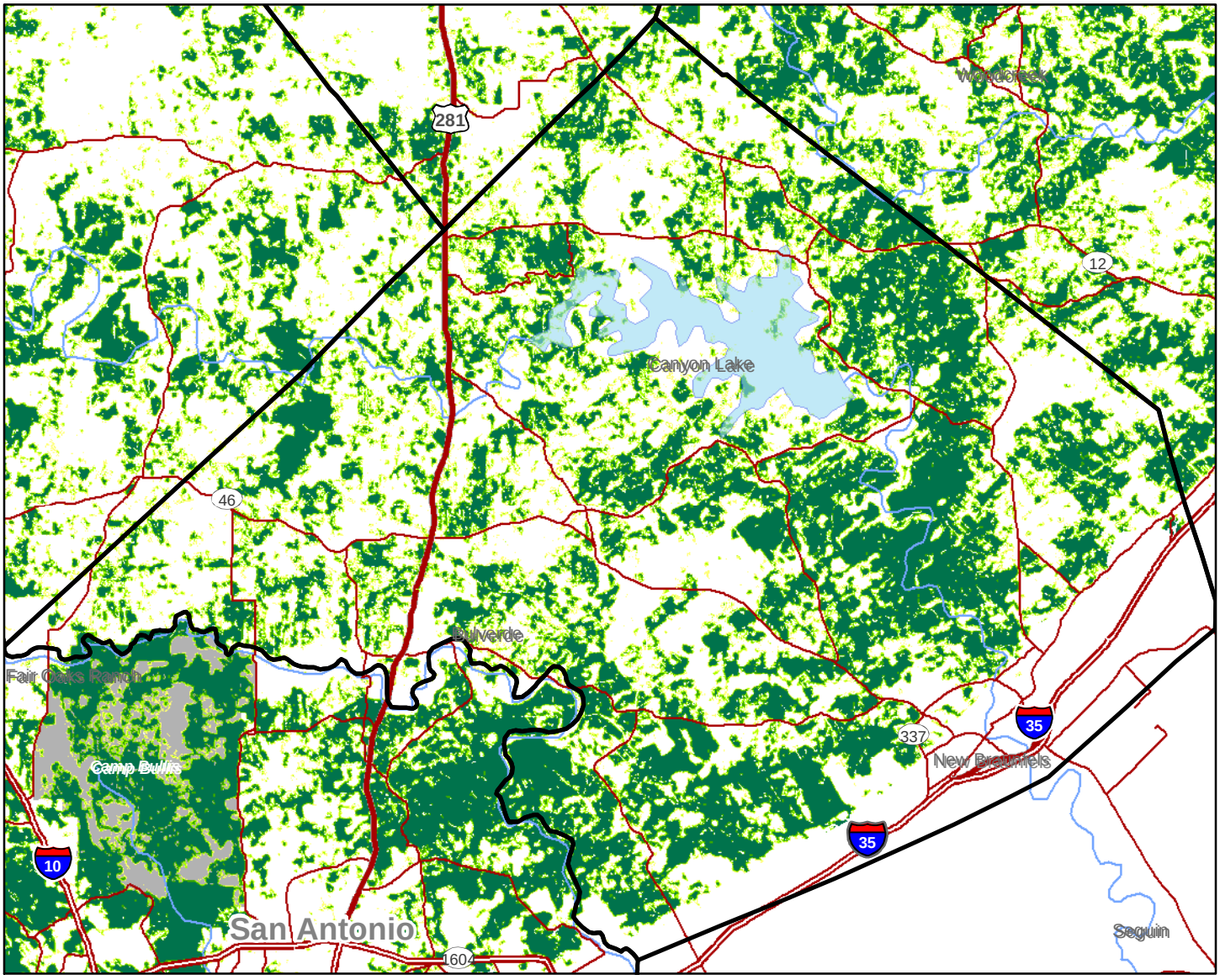
Figure 3. GCW Model C

COMAL
COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3
- 4 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N
W E
S

1:328,003

0 2.5 5 10 Miles

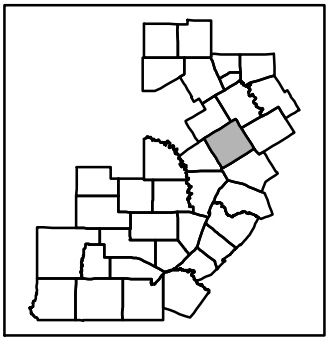
0 3.75 7.5 15 Kilometers

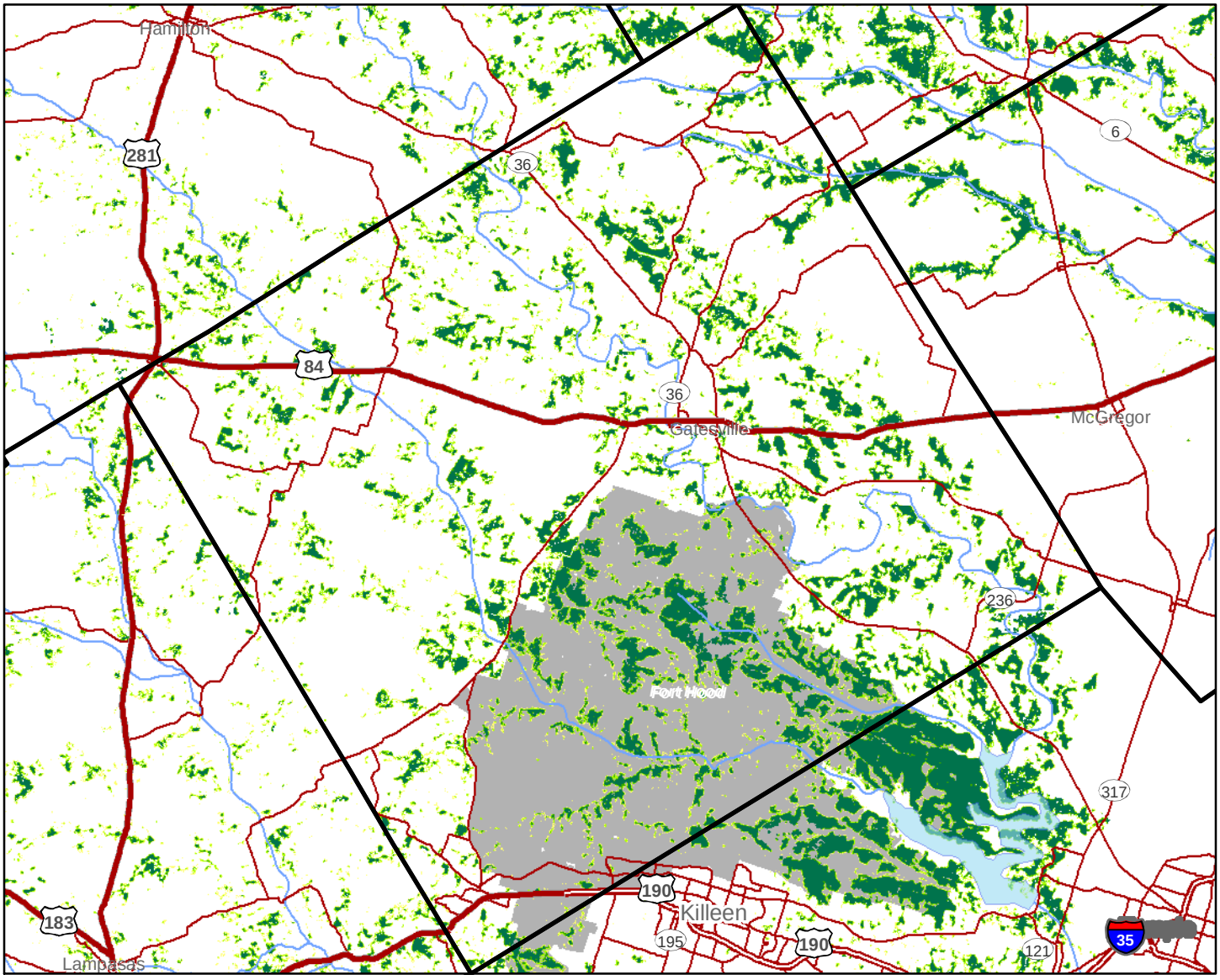
Figure 3. GCW Model C

CORYELL COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3
- 4 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N W E S

1:469,250

0 3.5 7 14 Miles

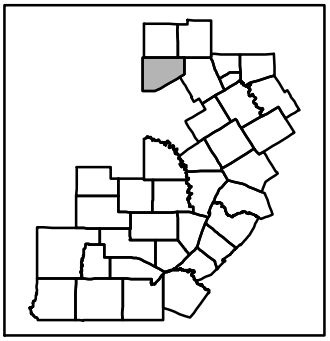
0 5 10 20 Kilometers

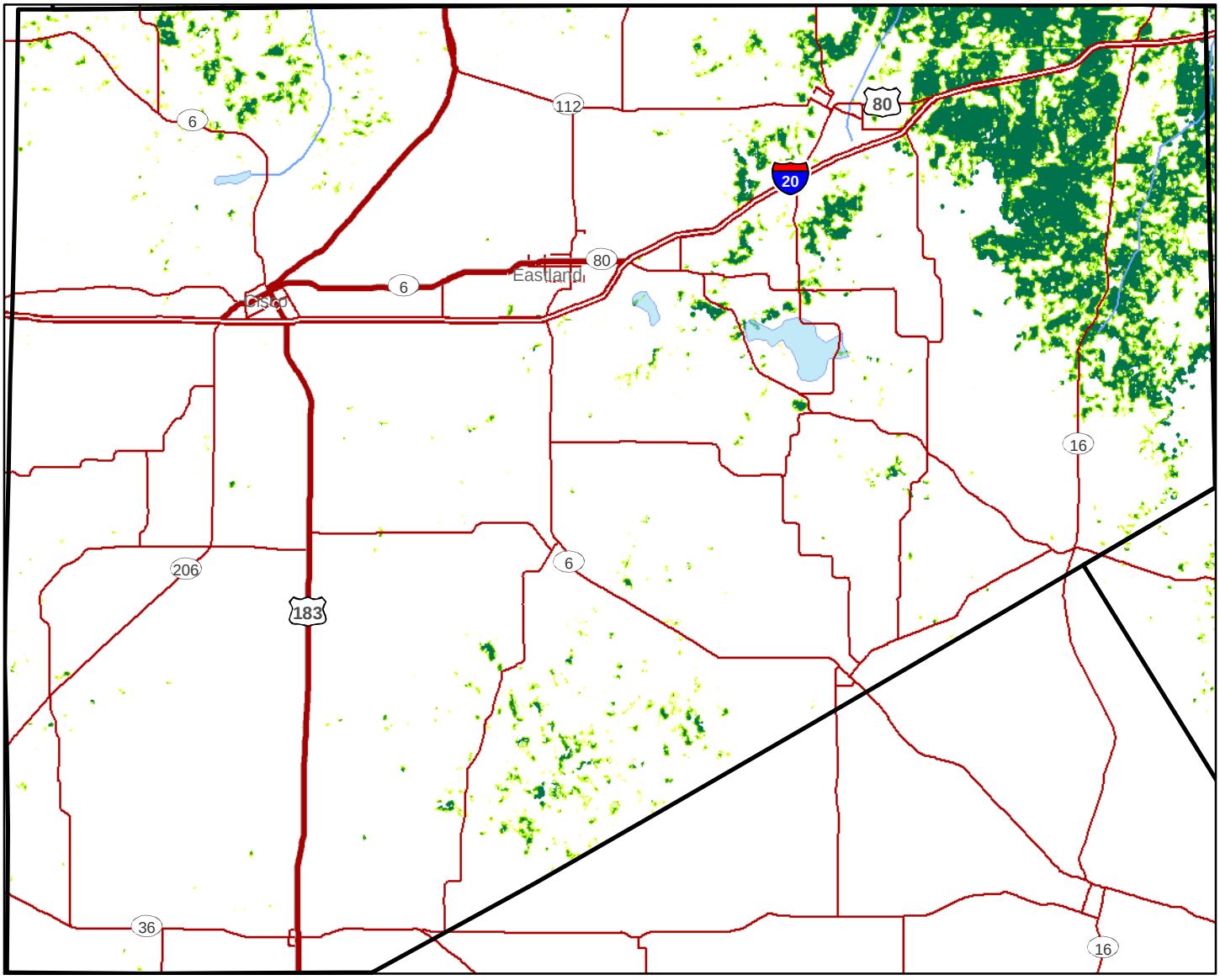
Figure 3. GCW Model C

EASTLAND
COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3
- 4 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N
W
E
S

1:319,430

0 2.5 5 10 Miles

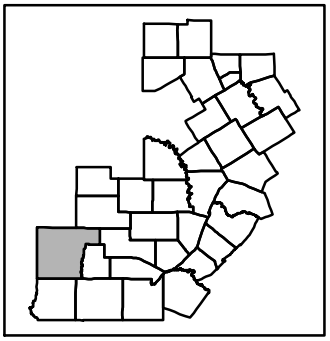
0 3.5 7 14 Kilometers

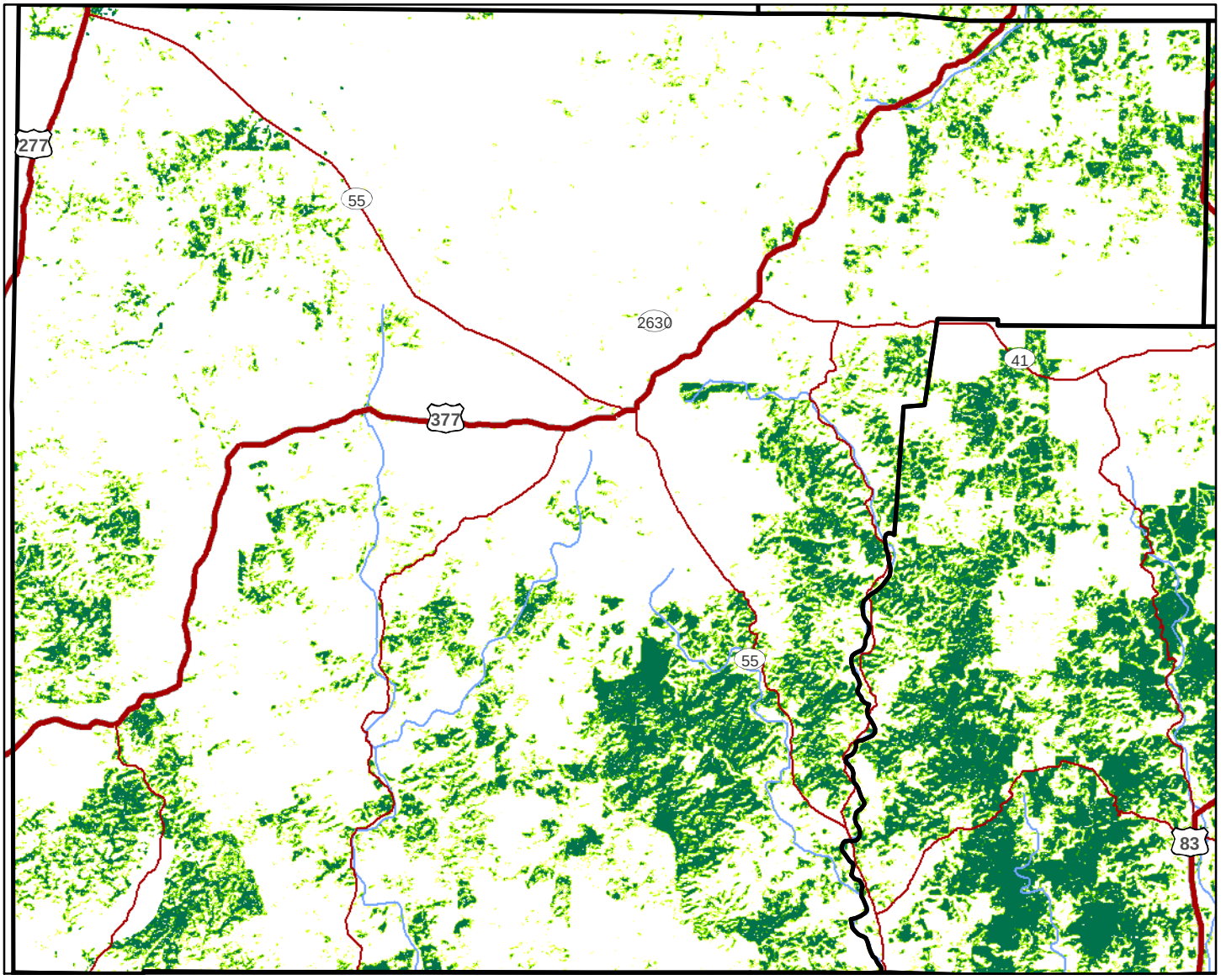
Figure 3. GCW Model C

EDWARDS
COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3
- 4 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N
W E
S

1:486,990

0 3.75 7.5 15 Miles

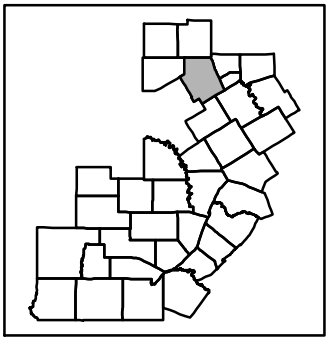
0 5 10 20 Kilometers

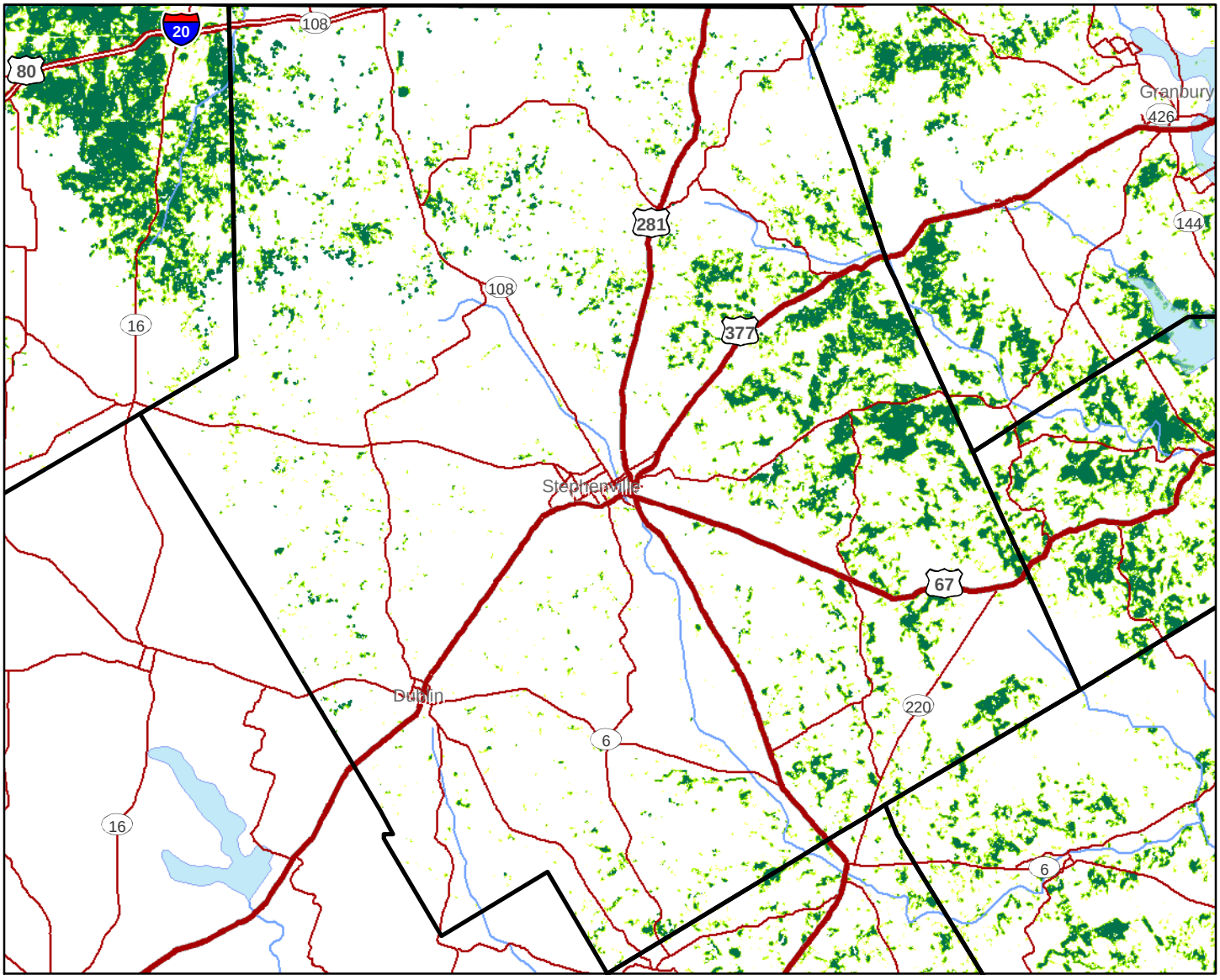
Figure 3. GCW Model C

ERATH
COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3
- 4 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N
W
E
S

1:436,311

0 3.5 7 14 Miles

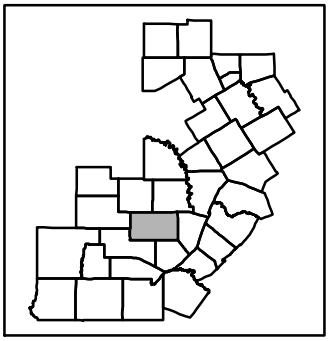
0 4.5 9 18 Kilometers

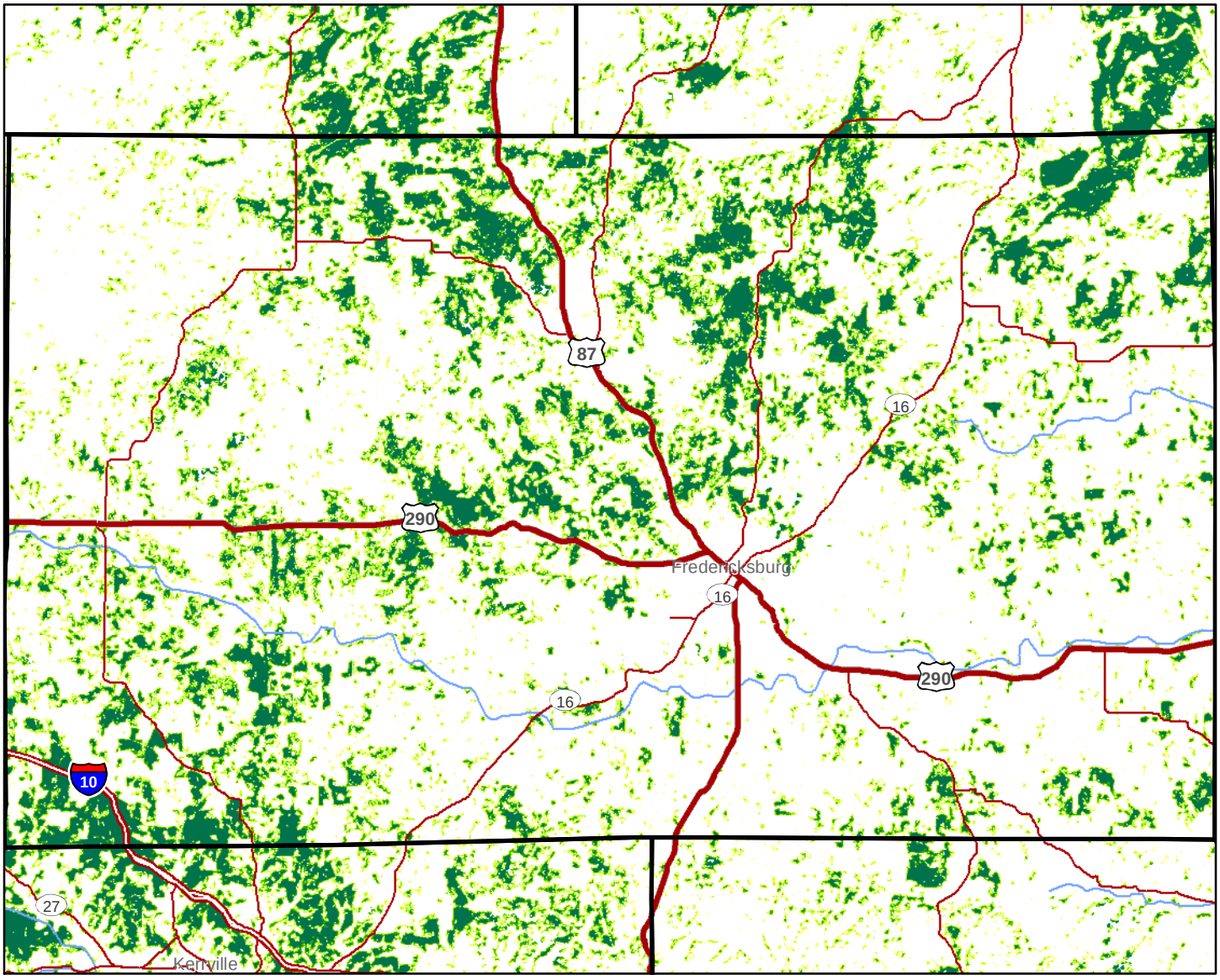
Figure 3. GCW Model C

GILLESPIE COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3
- 4 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N W E S

1:360,868

0 3 6 12 Miles

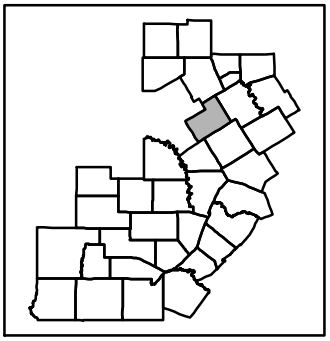
0 3.75 7.5 15 Kilometers

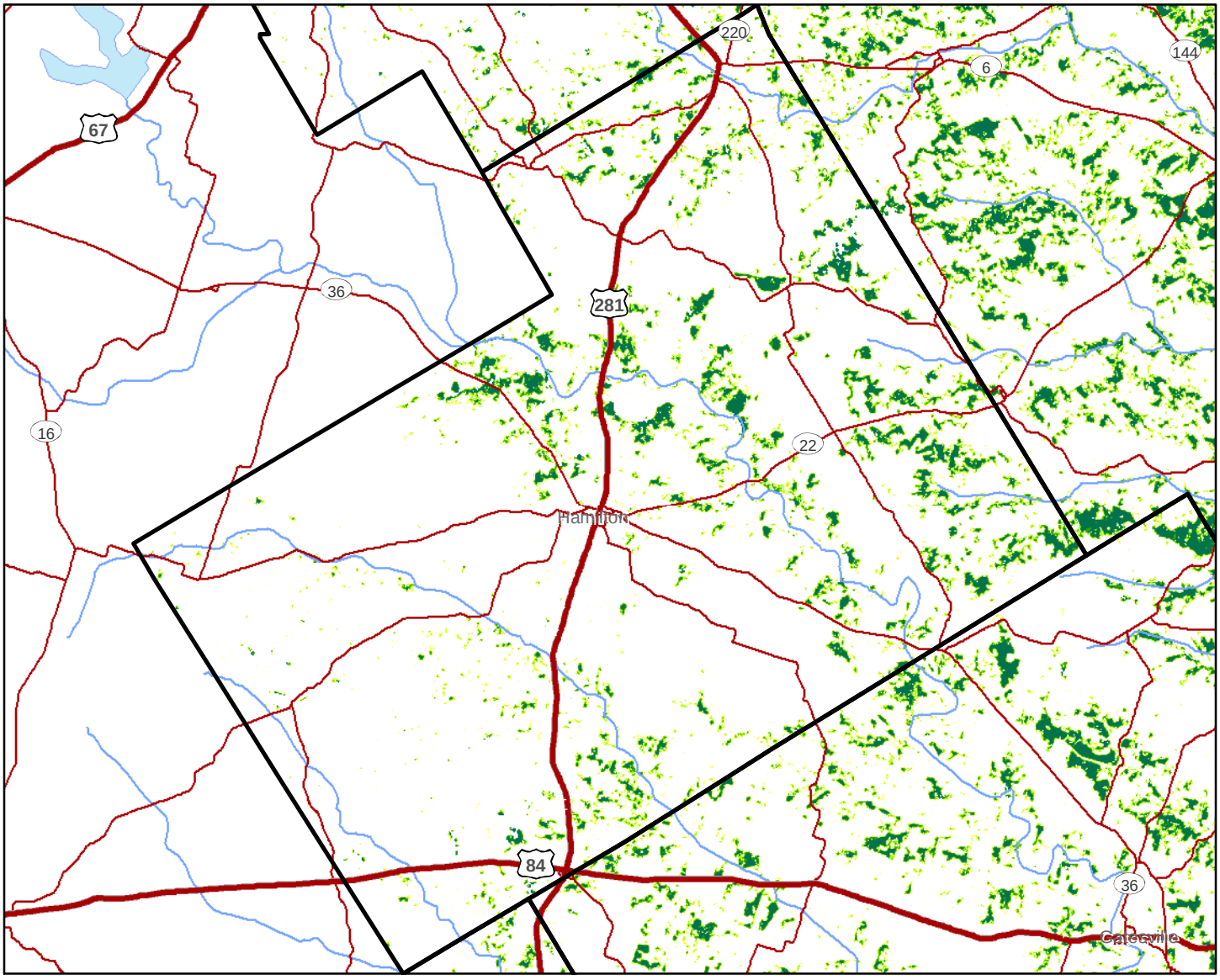
Figure 3. GCW Model C

HAMILTON
COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3
- 4 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

1:440,225

0 3.75 7.5 15 Miles

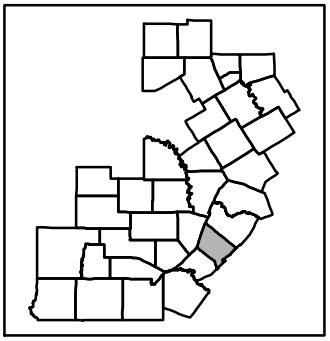
0 4.5 9 18 Kilometers

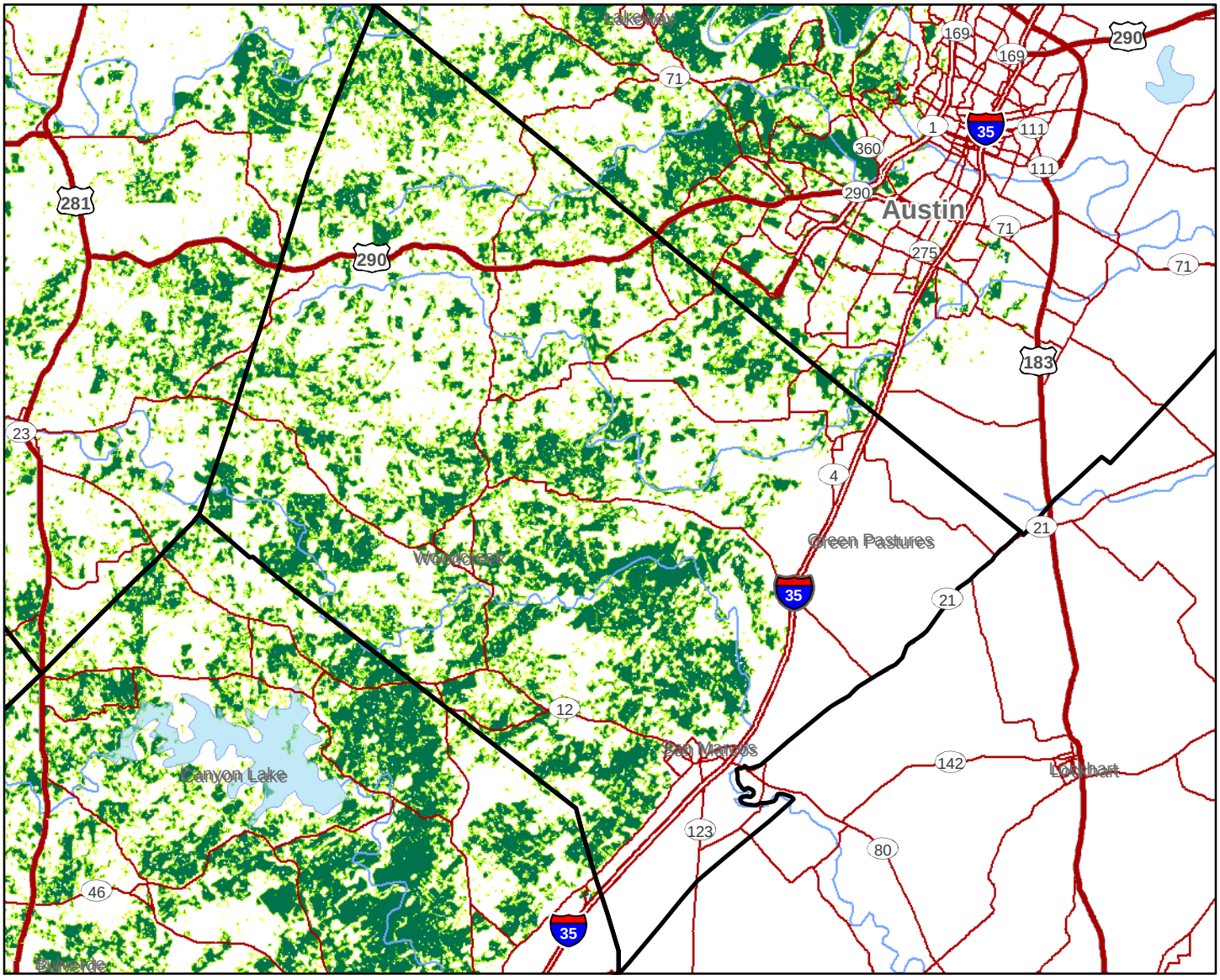
Figure 3. GCW Model C

HAYS
COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3
- 4 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N
W E
S

1:438,757

0 3.75 7.5 15 Miles

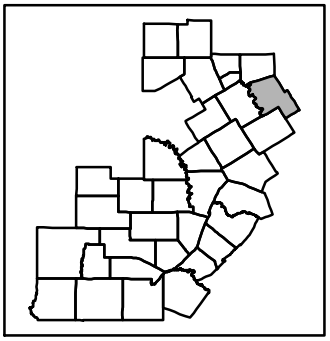
0 4.5 9 18 Kilometers

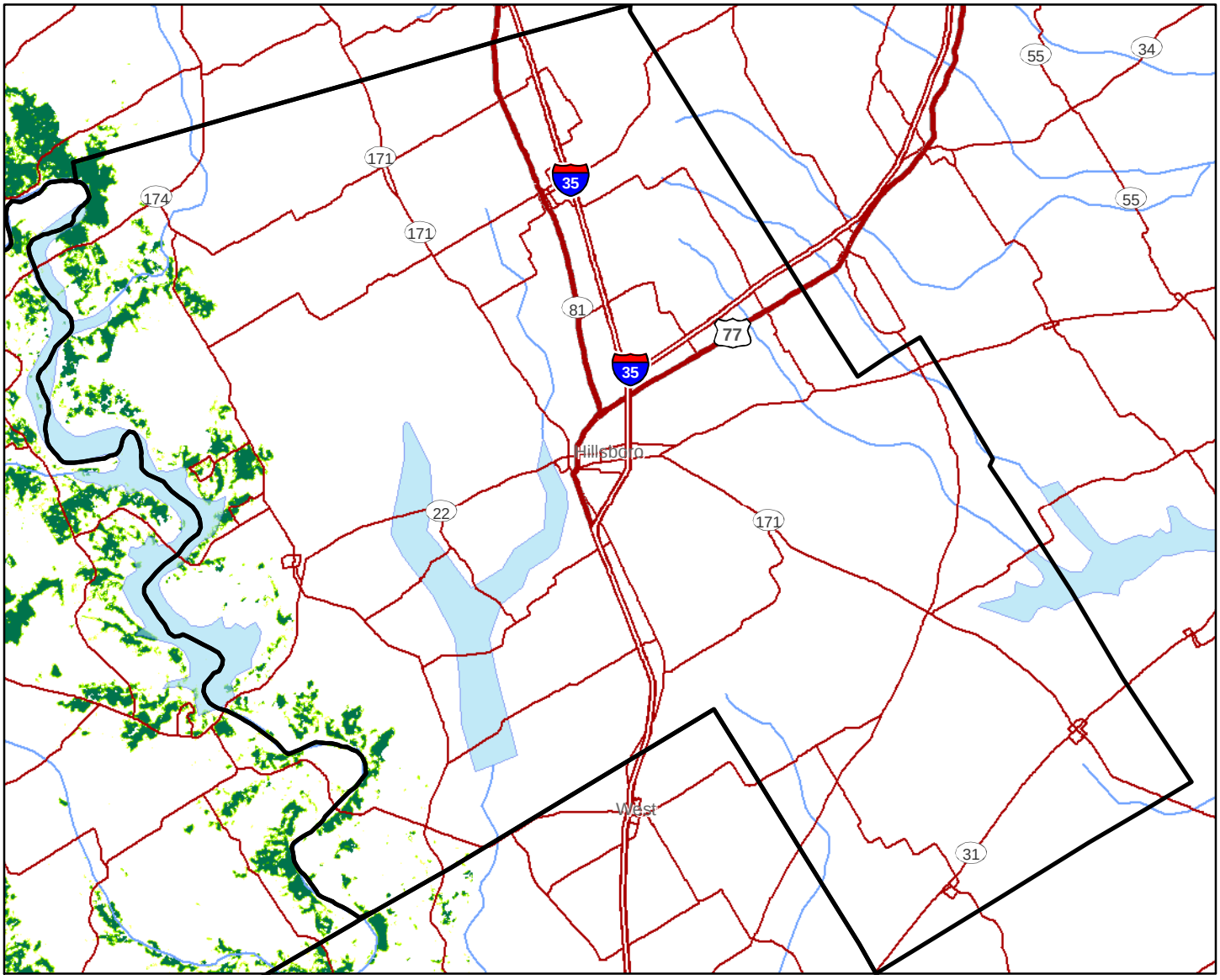
Figure 3. GCW Model C

HILL
COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3
- 4 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N
W
E
S

1:405,536

0 3.5 7 14 Miles

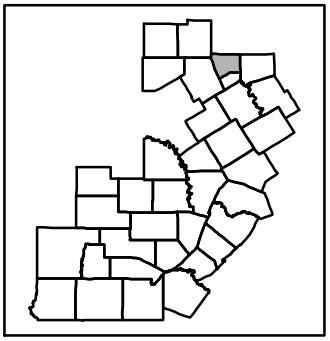
0 4 8 16 Kilometers

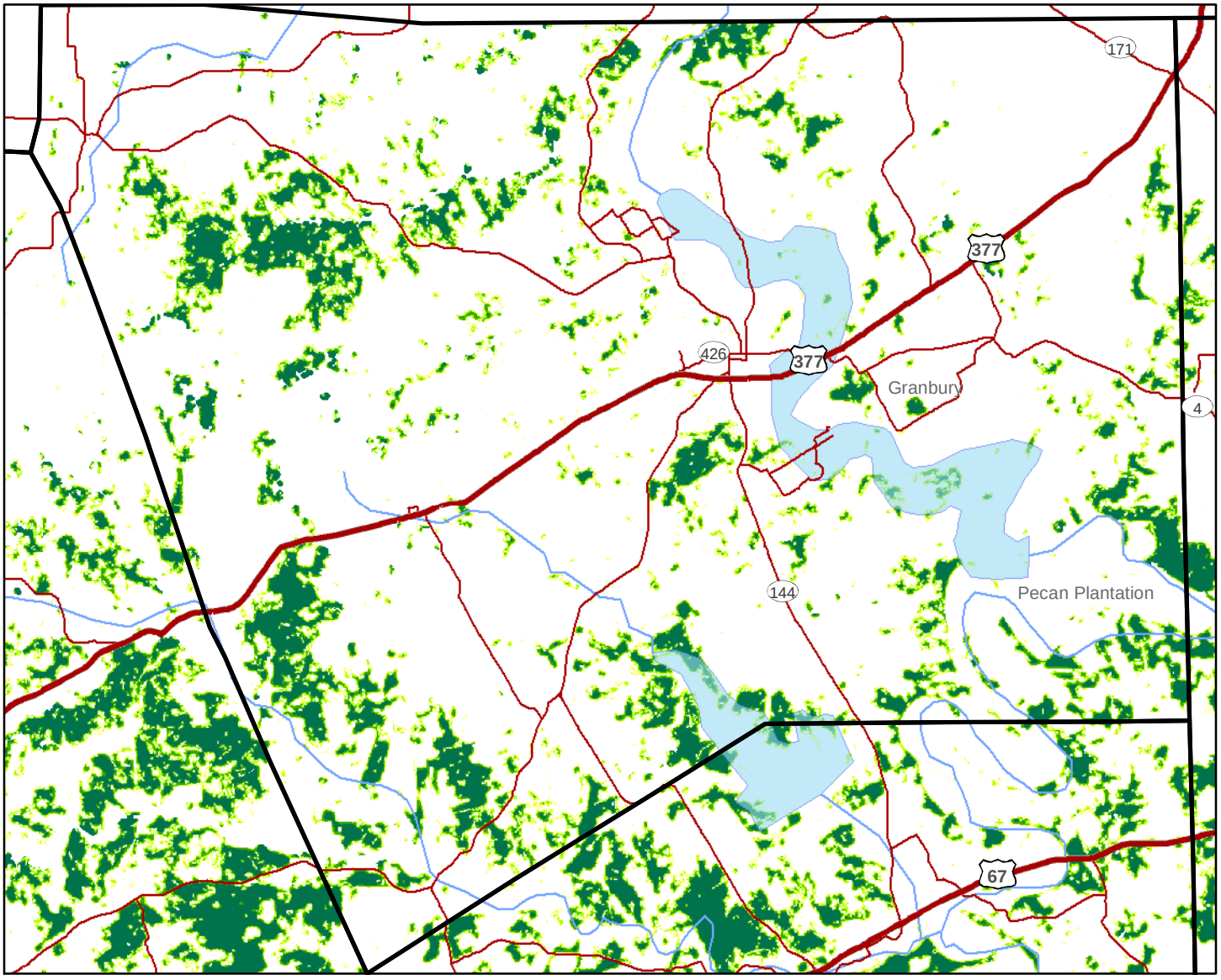
Figure 3. GCW Model C

HOOD
COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3
- 4 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N
W
E
S

1:236,188

0 2 4 8 Miles

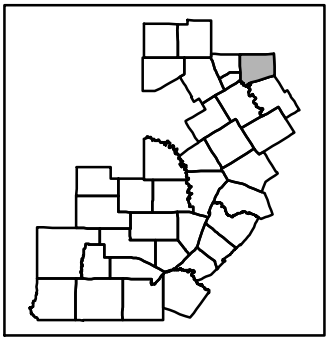
0 2.5 5 10 Kilometers

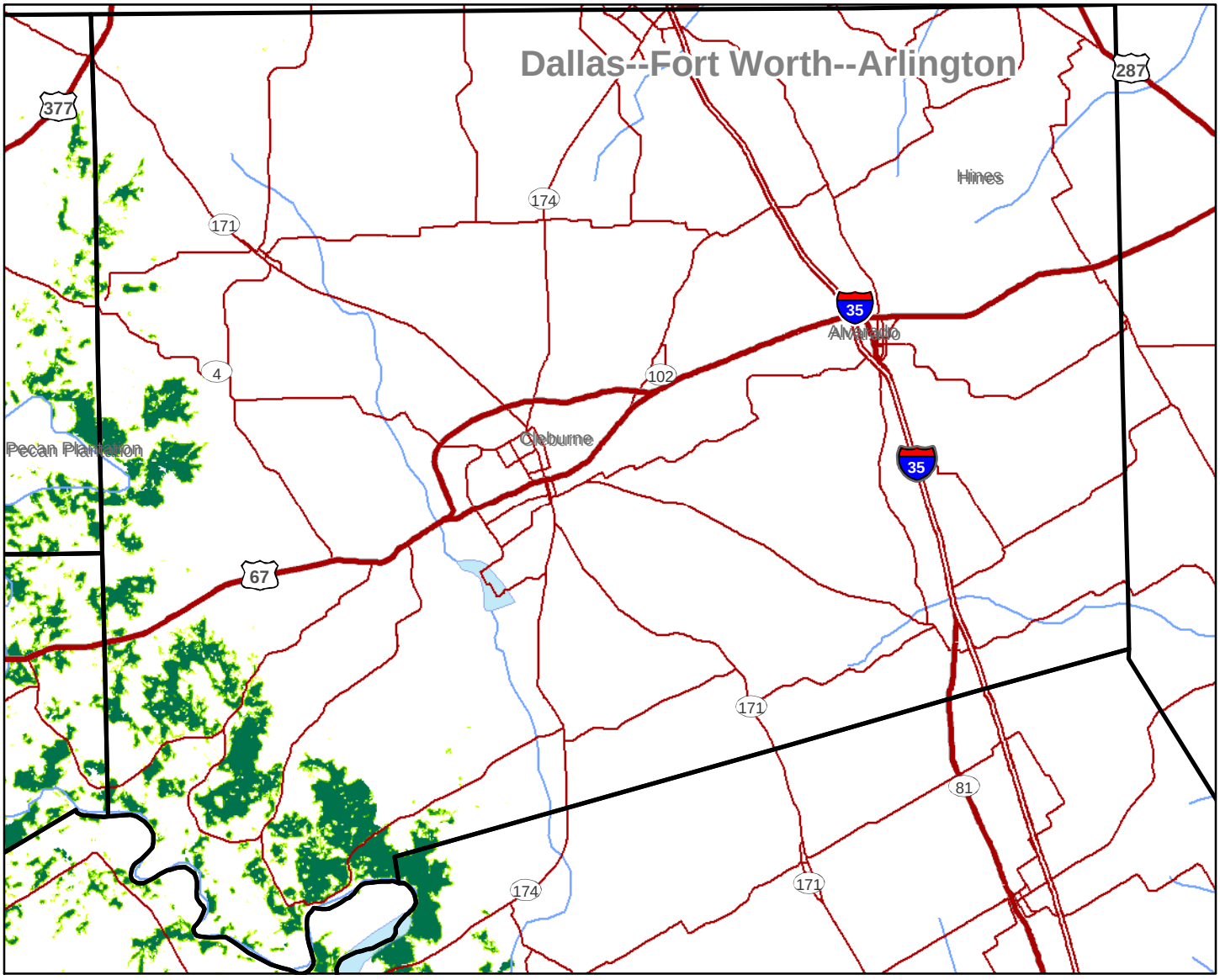
Figure 3. GCW Model C

JOHNSON COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3
- 4 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N W E S

1:307,857

0 2.5 5 10 Miles

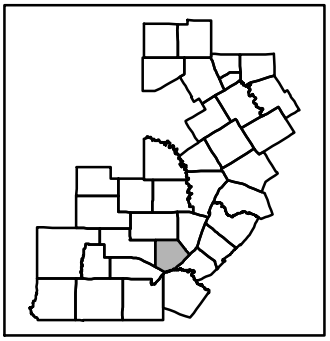
0 3.5 7 14 Kilometers

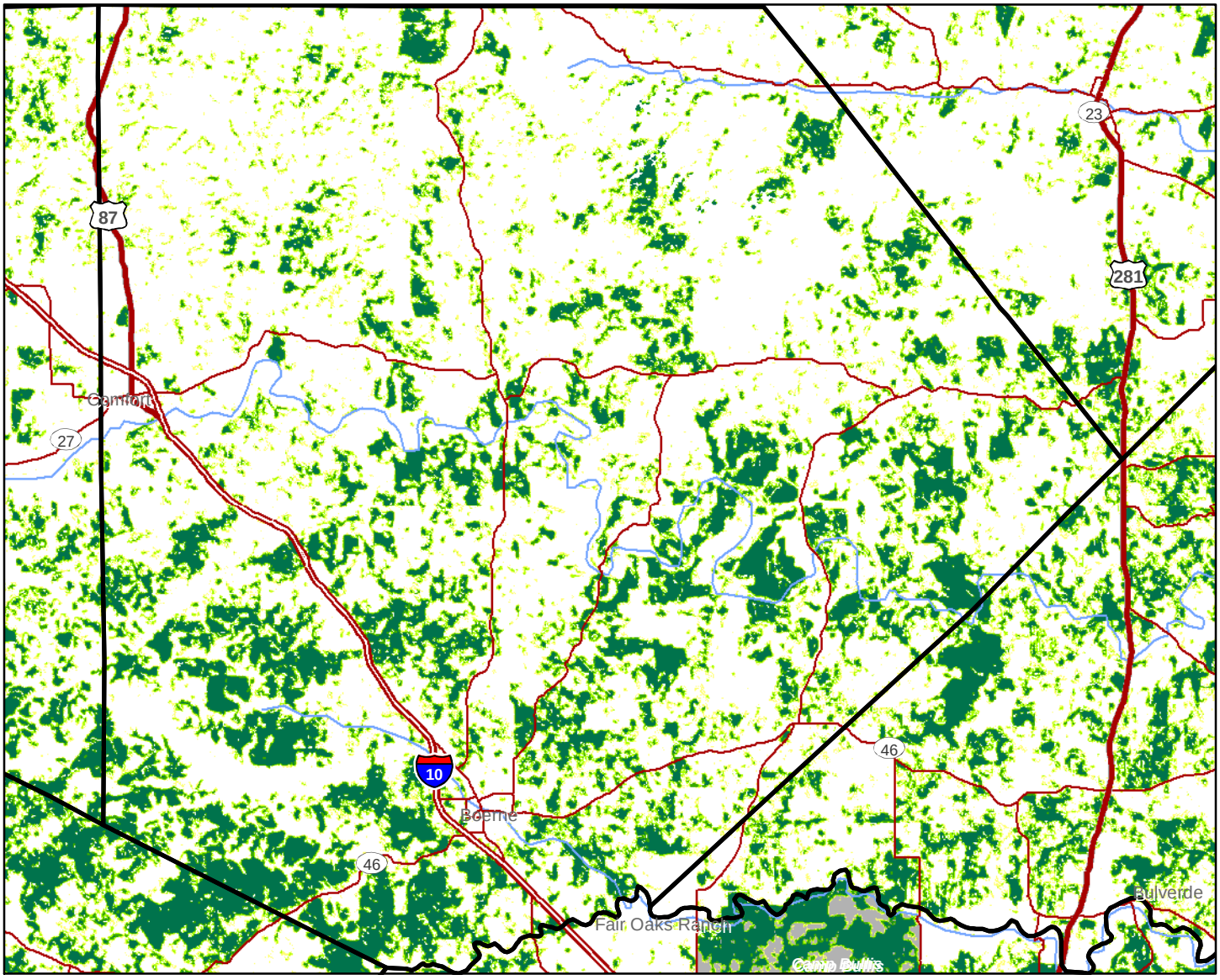
Figure 3. GCW Model C

KENDALL
COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3
- 4 High Quality





Legend

- County
- Lake
- Limited Access Highway
- Military Installation
- Highway
- Major Road
- Stream

N
W E
S

1:305,681

0 2.5 5 10 Miles

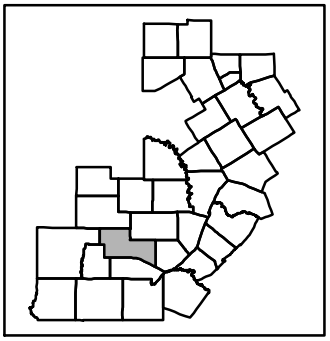
0 3.5 7 14 Kilometers

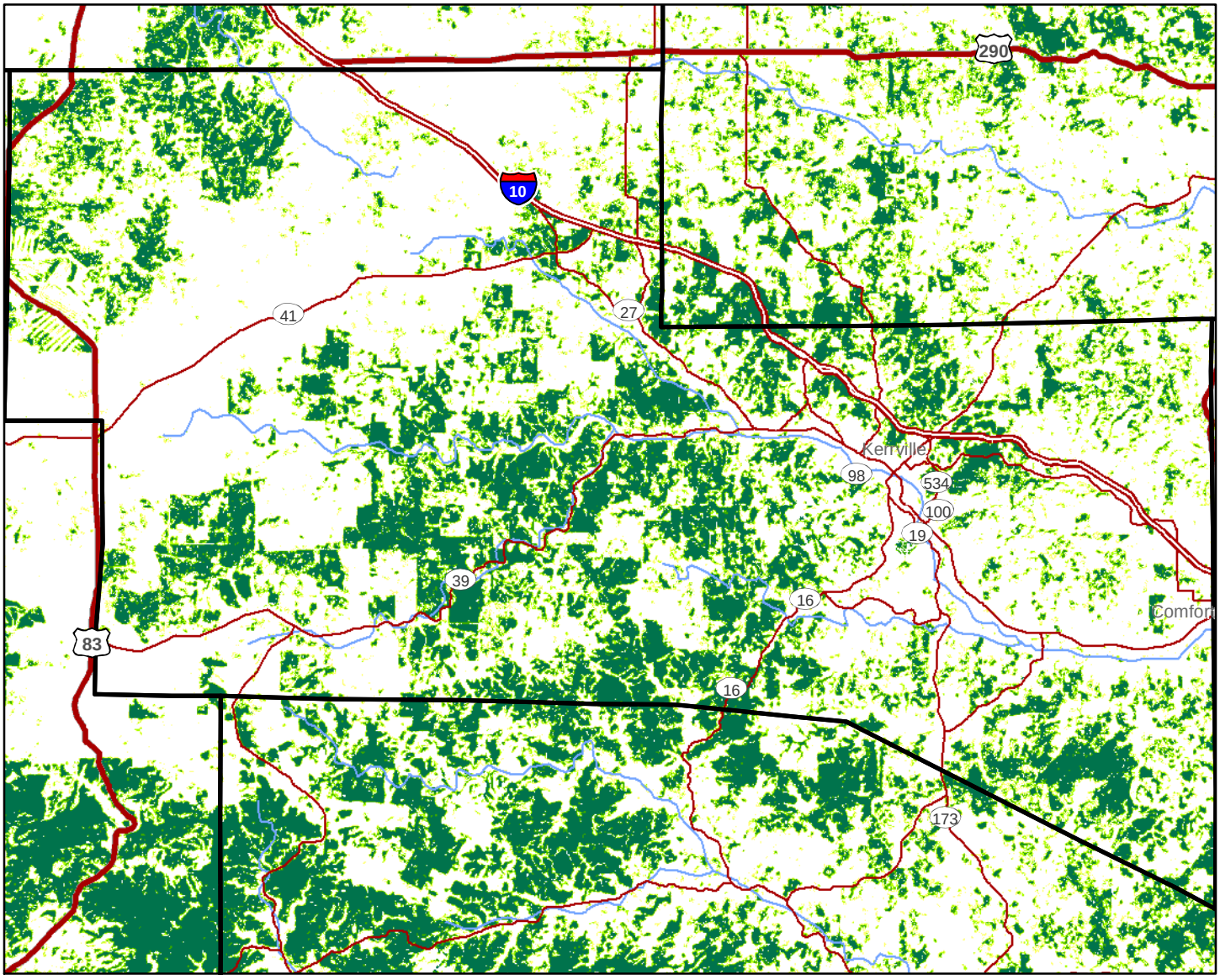
Figure 3. GCW Model C

KERR
COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3
- 4 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

1:424,453

0 3.5 7 14 Miles

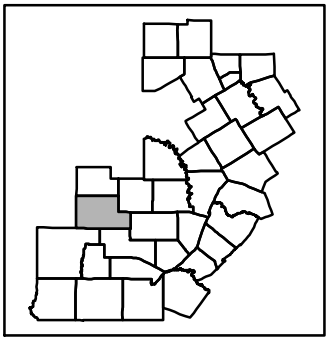
0 5 10 20 Kilometers

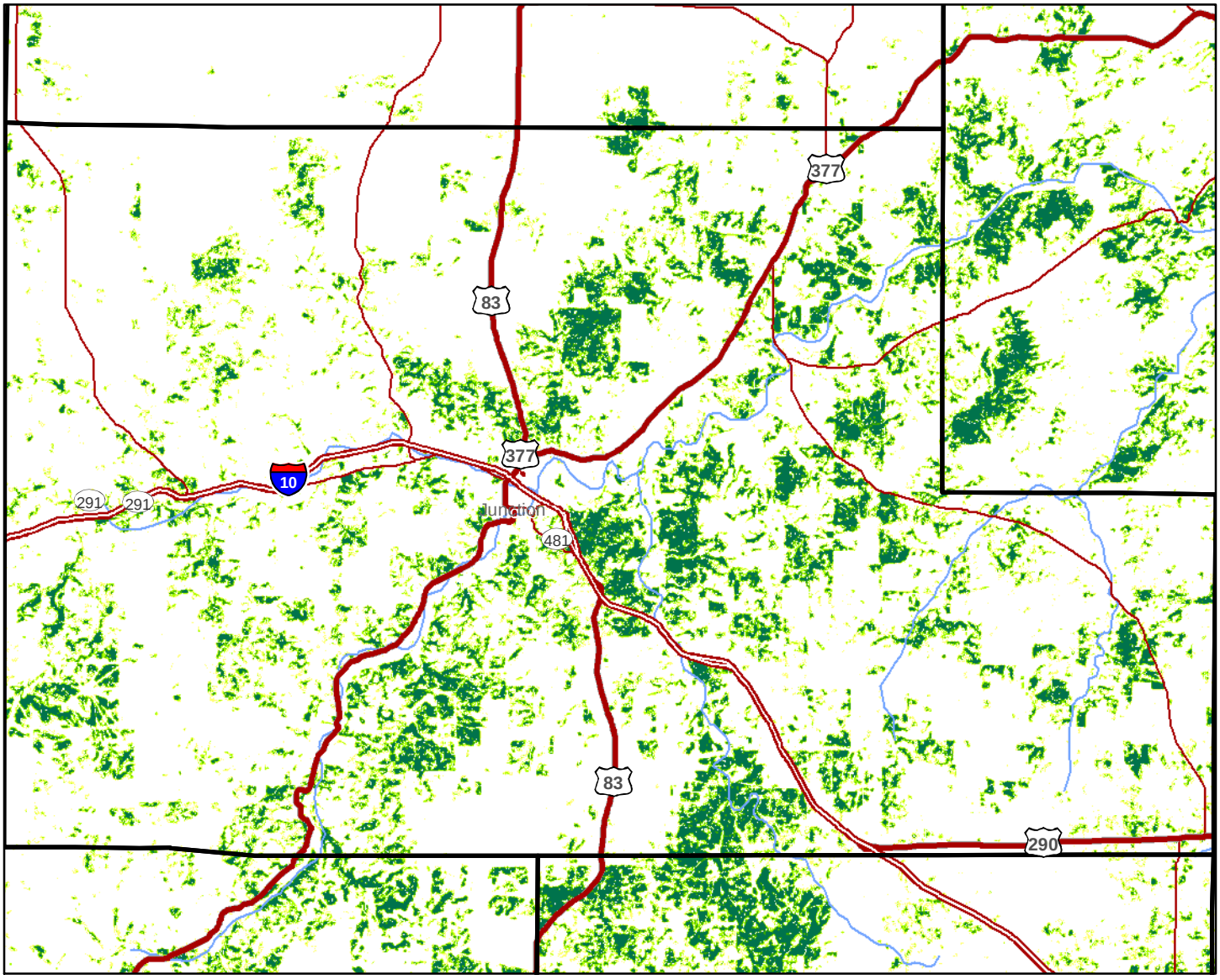
Figure 3. GCW Model C

KIMBLE
COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3
- 4 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N
W
E
S

1:410,168

0 3.5 7 14 Miles

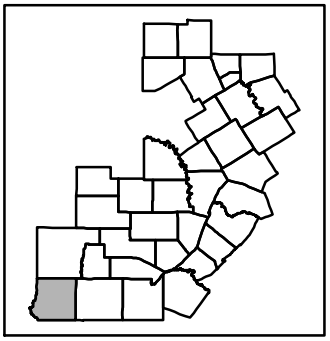
0 5 10 20 Kilometers

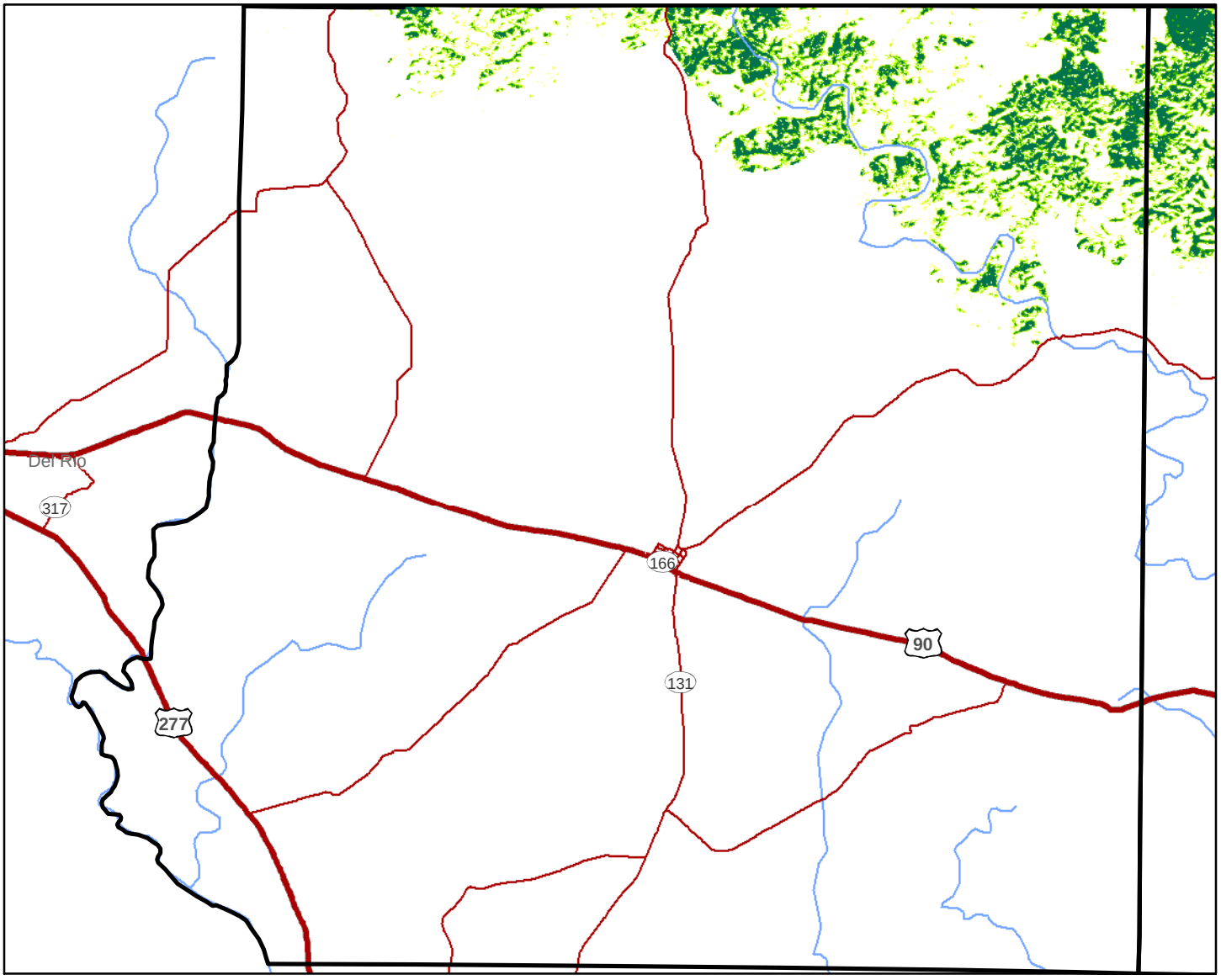
Figure 3. GCW Model C

KINNEY
COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3
- 4 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N
W
E
S

1:396,413

0 3.5 7 14 Miles

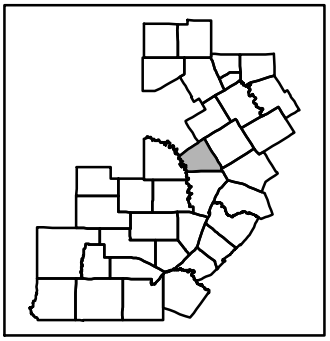
0 5 10 20 Kilometers

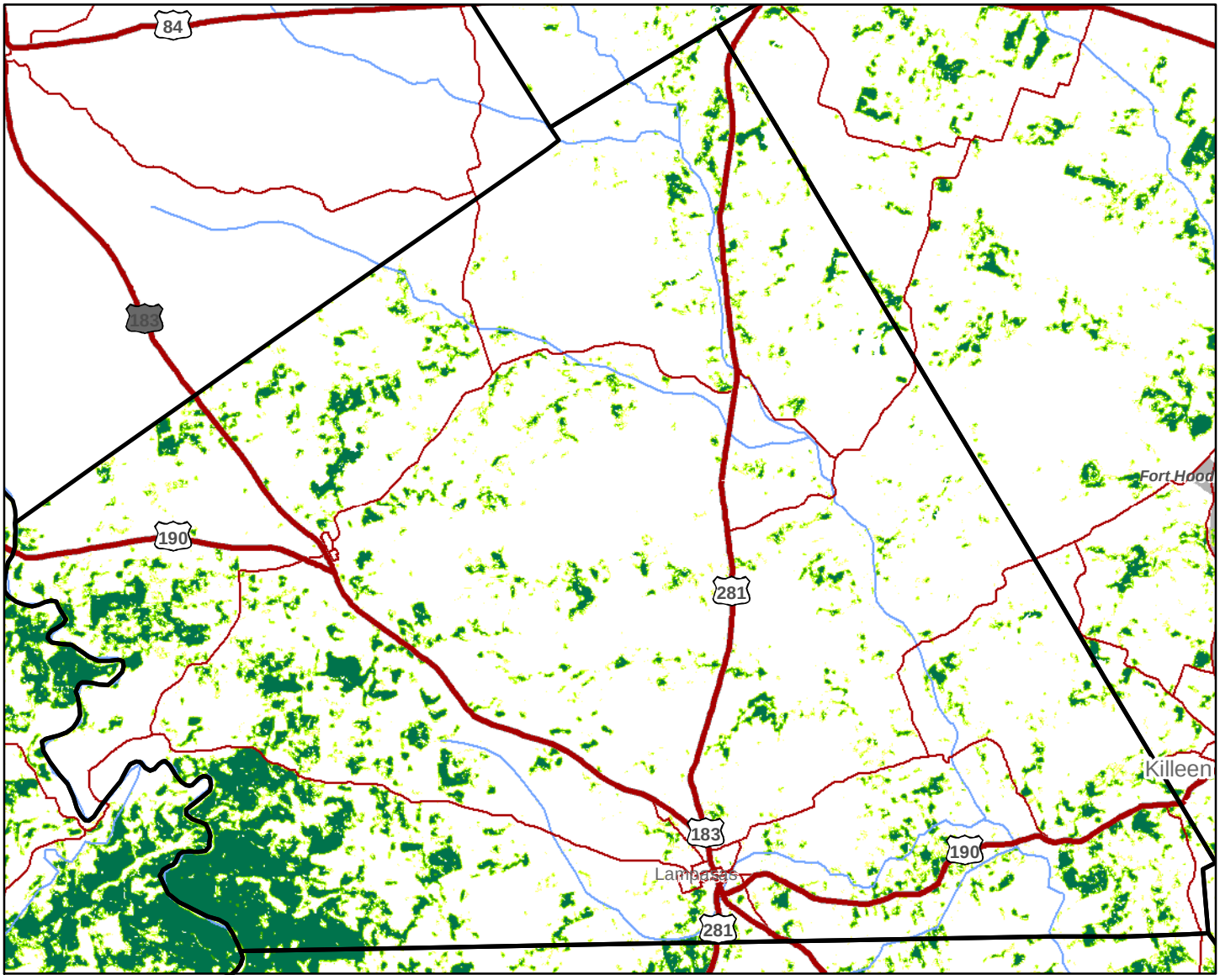
Figure 3. GCW Model C

LAMPASAS COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3
- 4 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N W E S

1:330,663

0 3 6 12 Miles

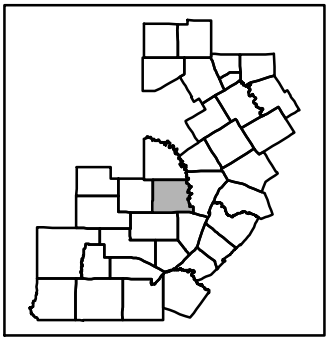
0 4 8 16 Kilometers

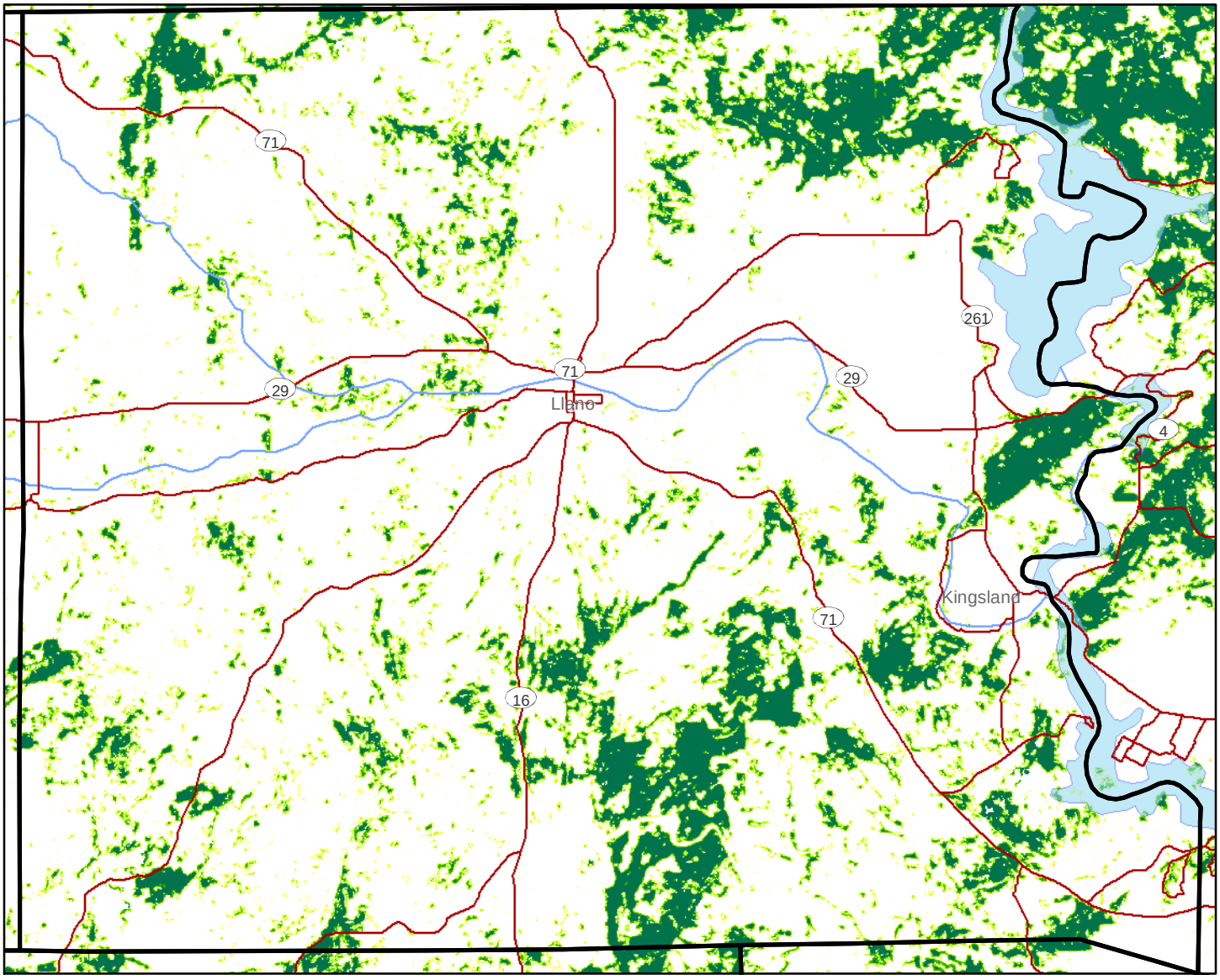
Figure 3. GCW Model C

LLANO
COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3
- 4 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N
W
E
S

1:318,007

0 3 6 12 Miles

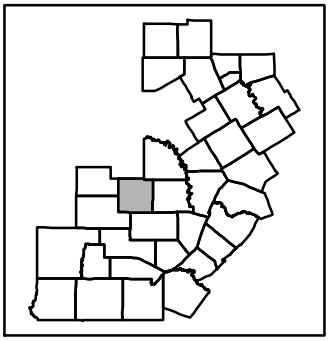
0 3.75 7.5 15 Kilometers

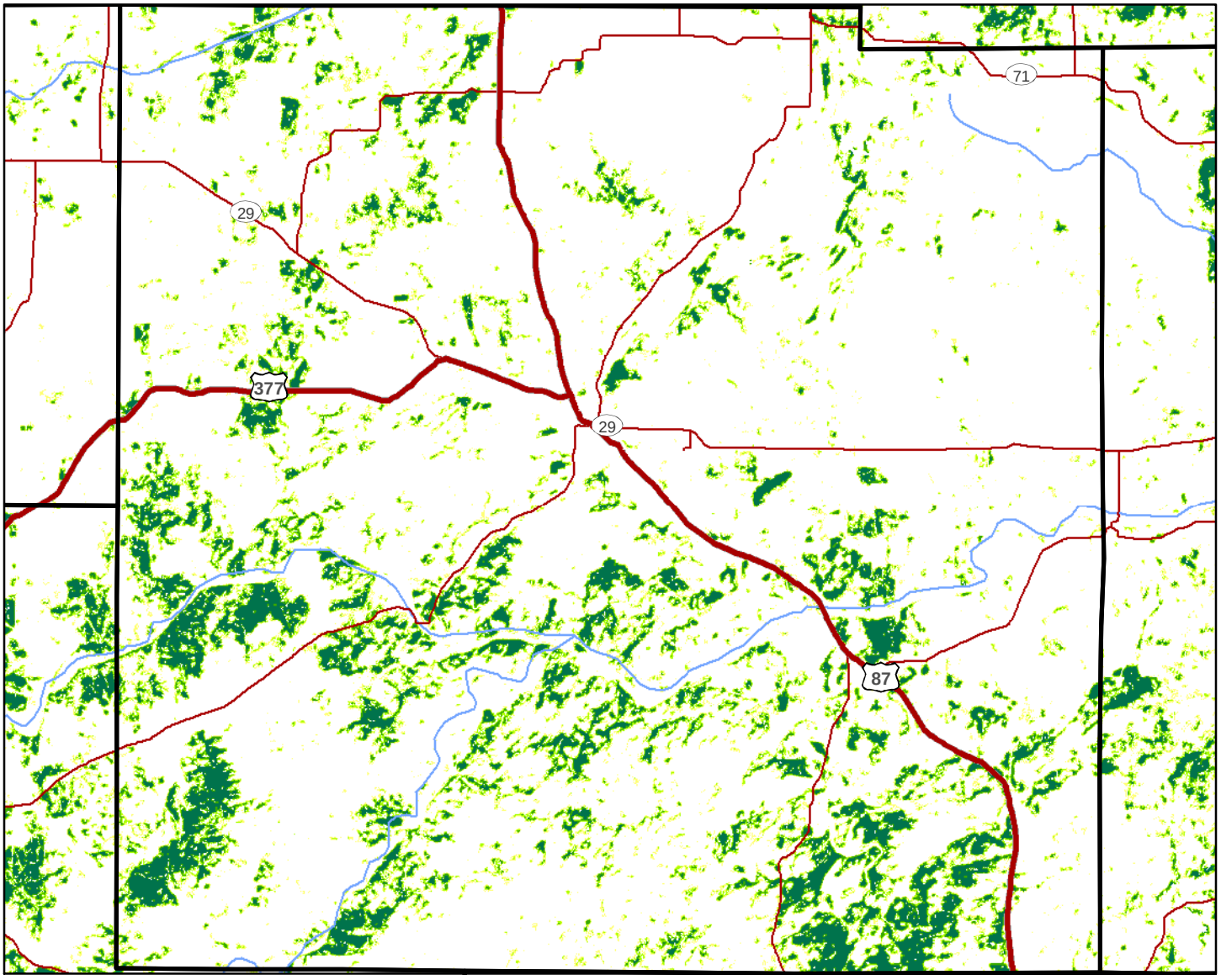
Figure 3. GCW Model C

MASON
COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3
- 4 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N
W E
S

1:322,650

0 3 6 12 Miles

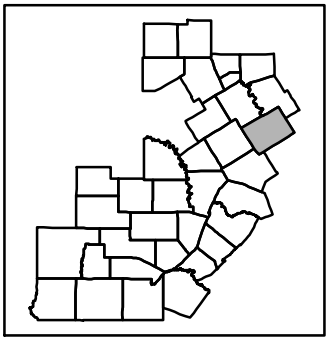
0 3.75 7.5 15 Kilometers

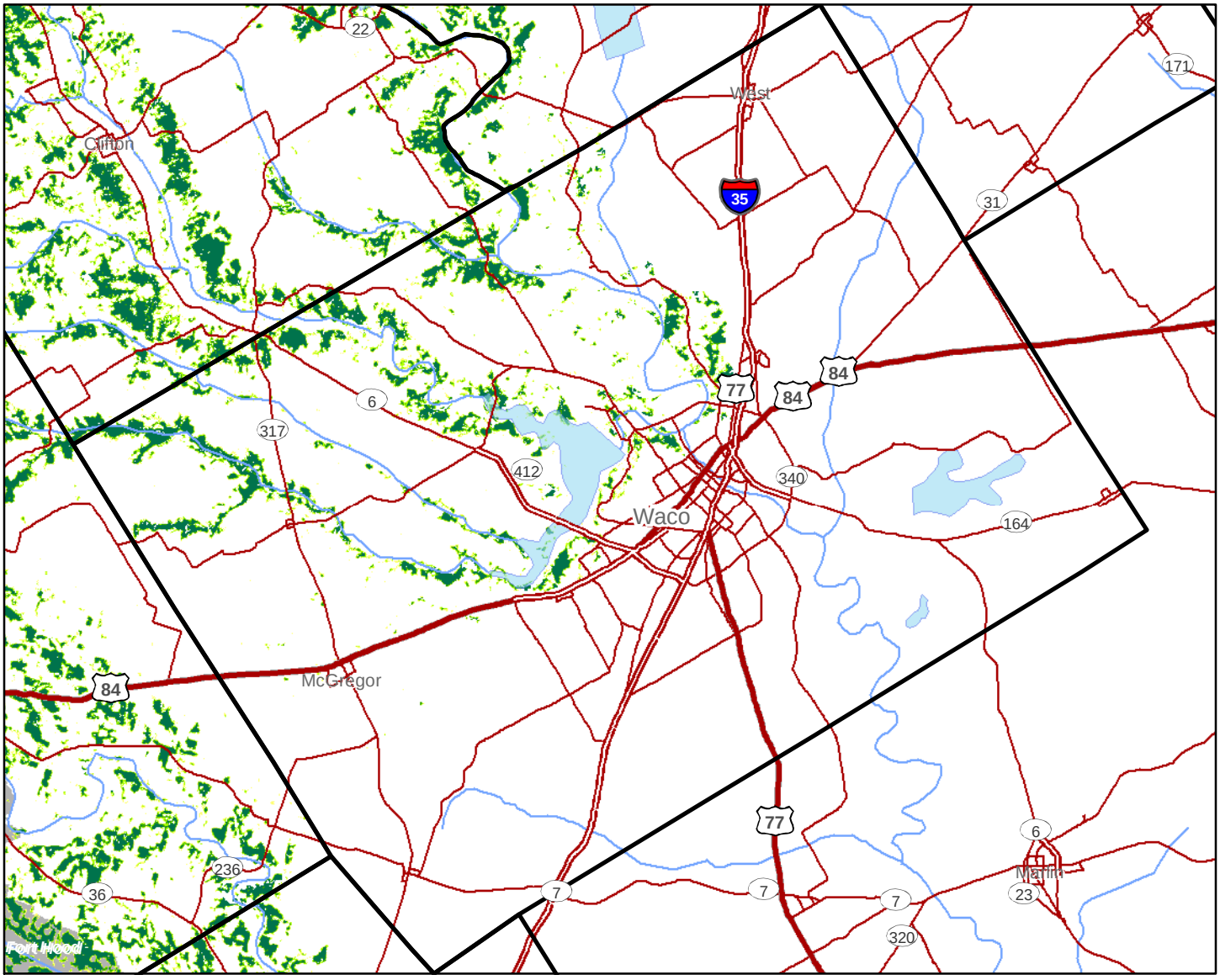
Figure 3. GCW Model C

MCLENNAN COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3
- 4 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N W E S

1:454,790

0 4 8 16 Miles

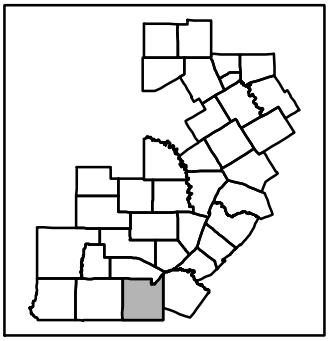
0 5 10 20 Kilometers

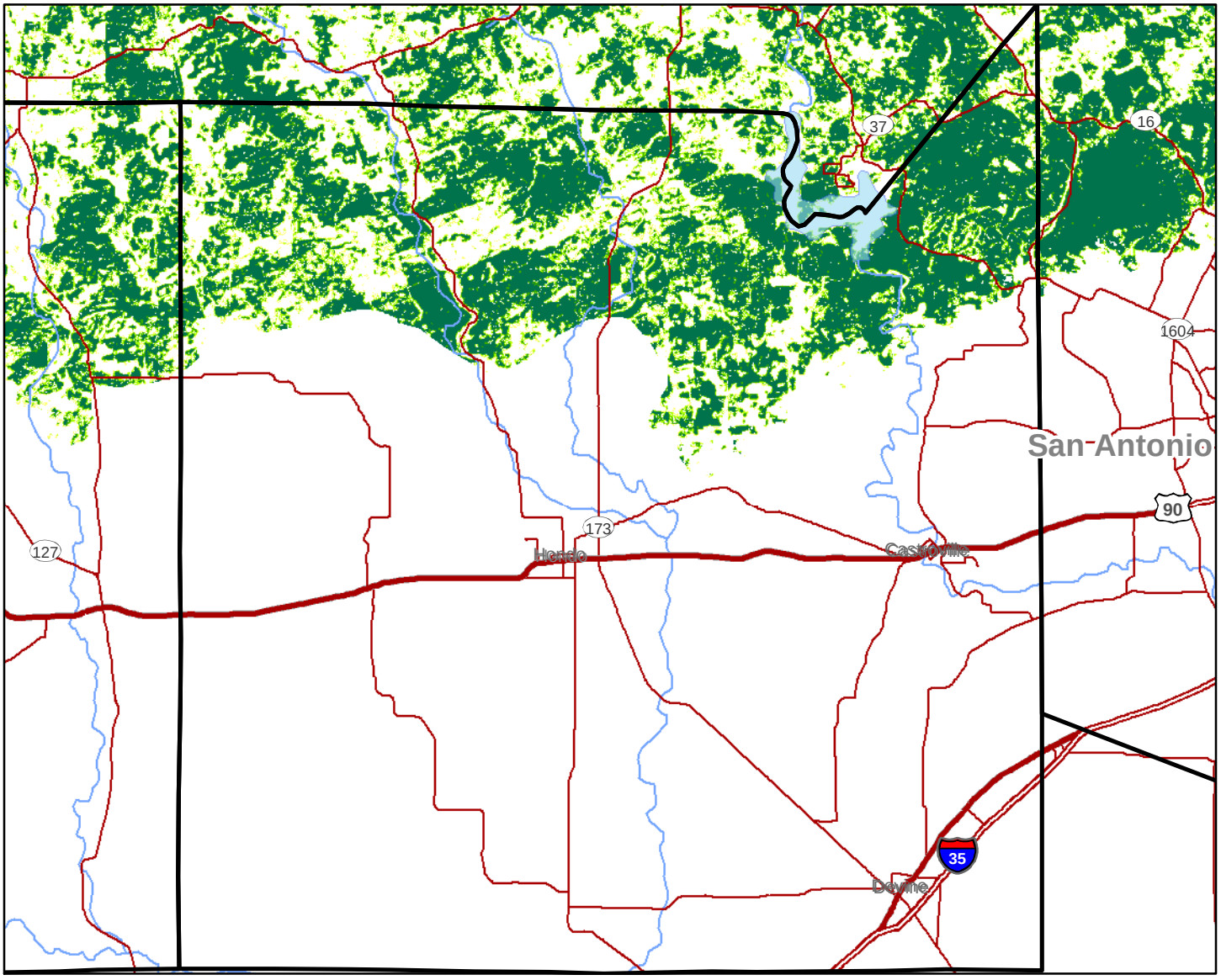
Figure 3. GCW Model C

MEDINA
COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3
- 4 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N
W
E
S

1:436,612

0 3.75 7.5 15 Miles

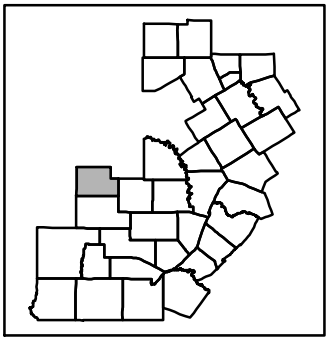
0 5 10 20 Kilometers

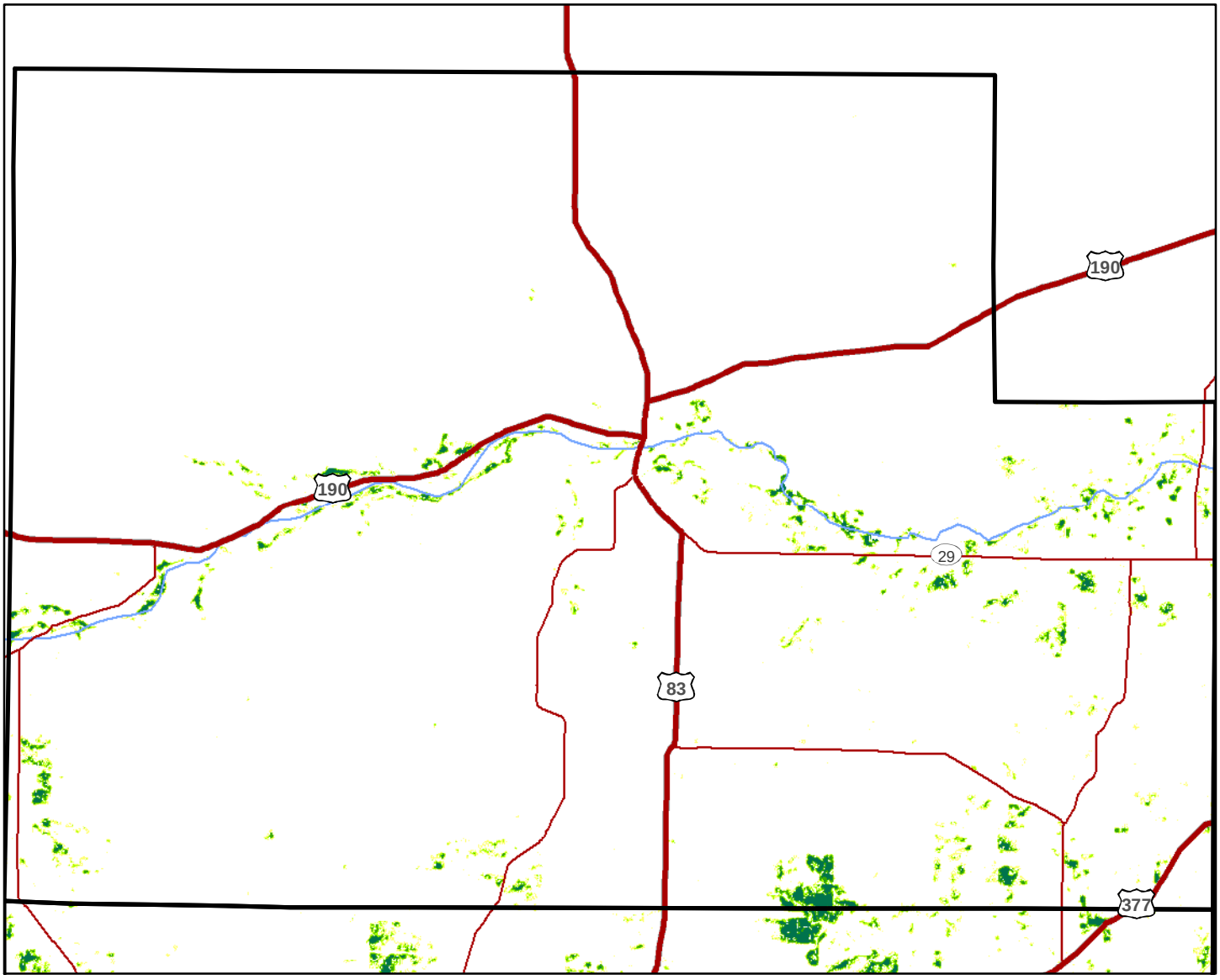
Figure 3. GCW Model C

MENARD
COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3
- 4 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N
W
E
S

1:318,185

0 2.5 5 10 Miles

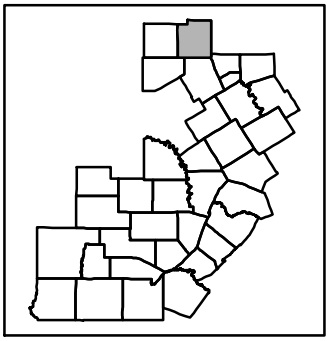
0 3.75 7.5 15 Kilometers

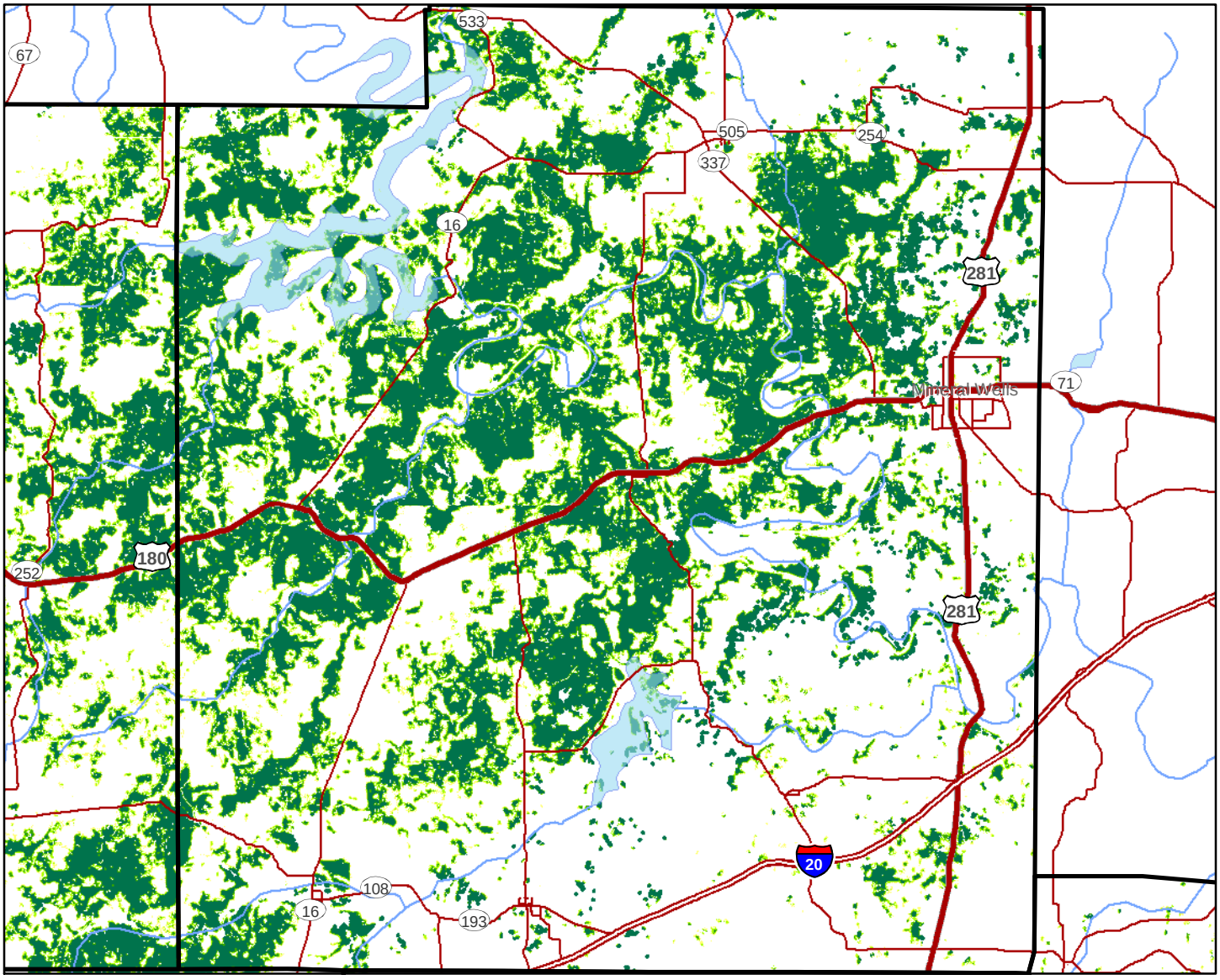
Figure 3. GCW Model C

PALO PINTO COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3
- 4 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N W E S

1:357,880

0 3 6 12 Miles

0 4 8 16 Kilometers

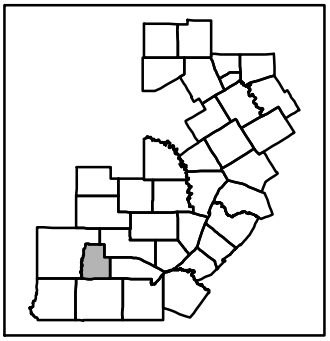
Figure 3. GCW Model C

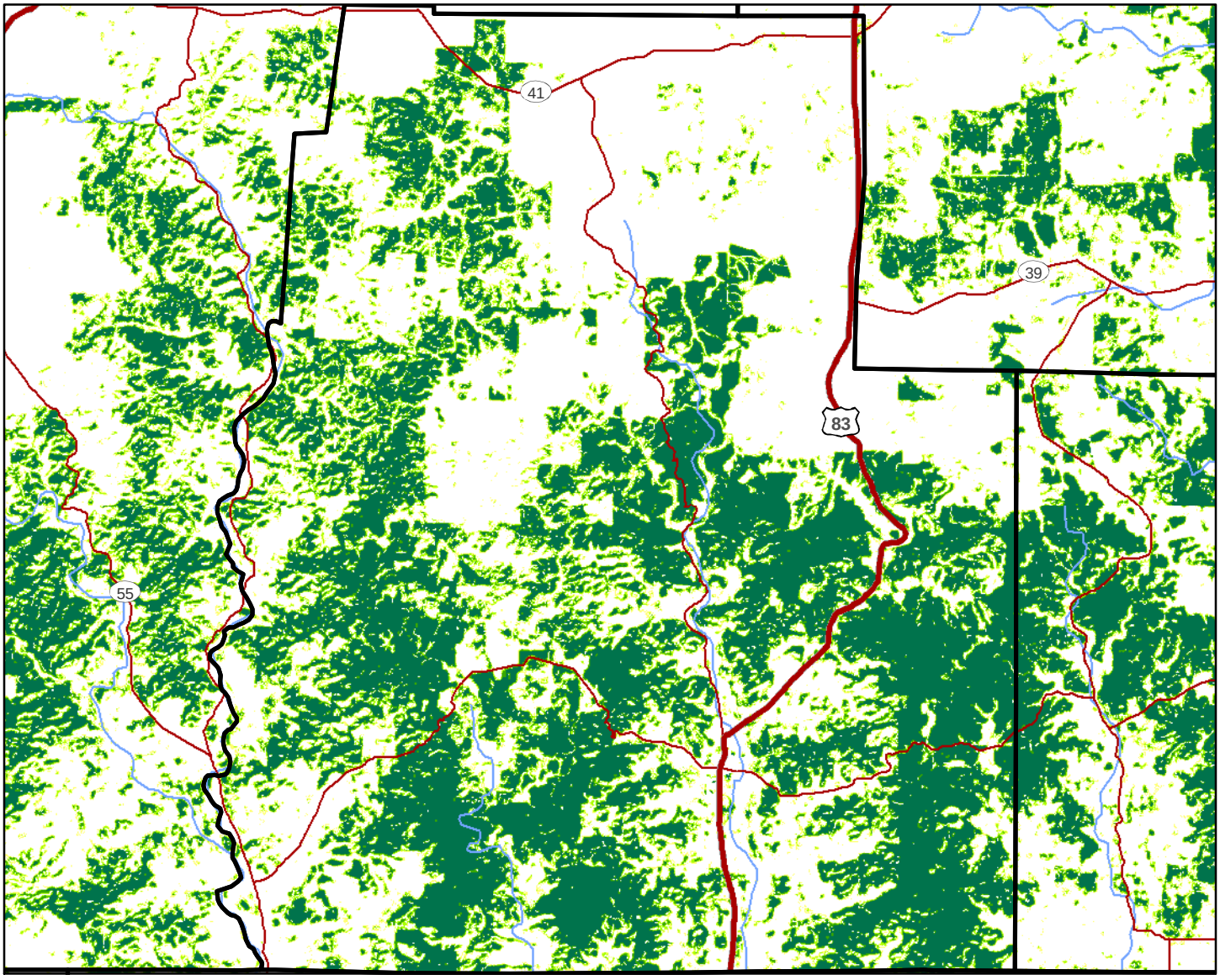
REAL

COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3
- 4 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N W E S

1:329,759

0 2.5 5 10 Miles

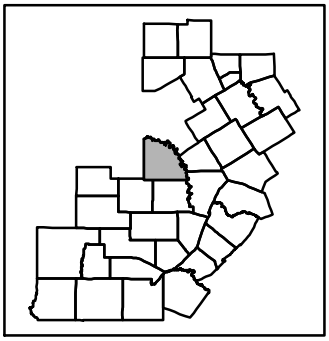
0 3.75 7.5 15 Kilometers

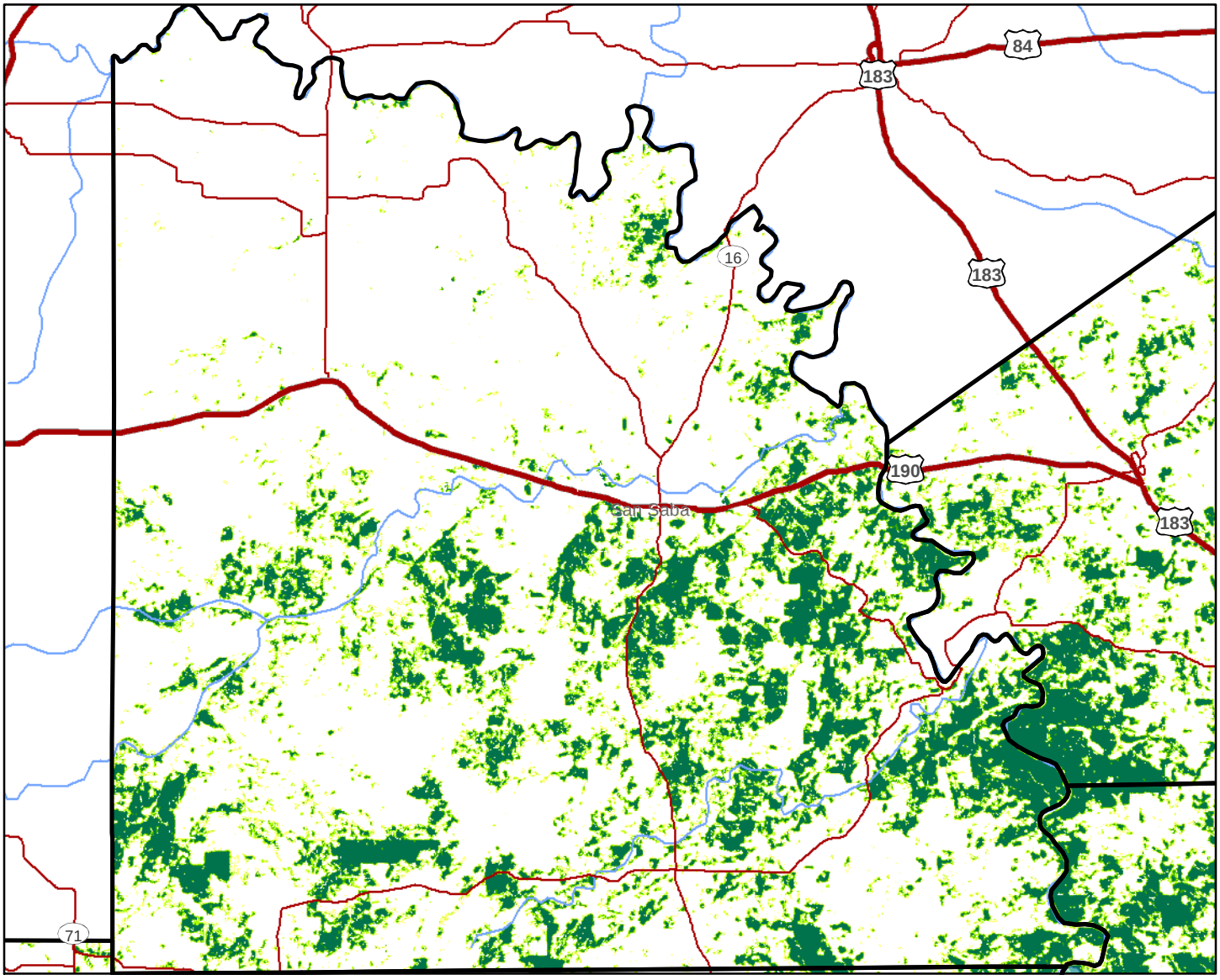
Figure 3. GCW Model C

SAN SABA COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3
- 4 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N W E S

1:414,376

0 3 6 12 Miles

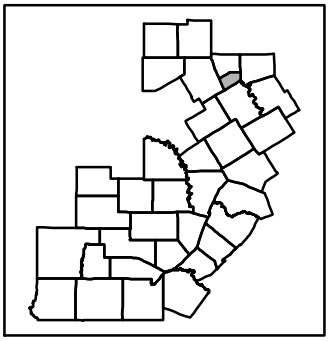
0 4.5 9 18 Kilometers

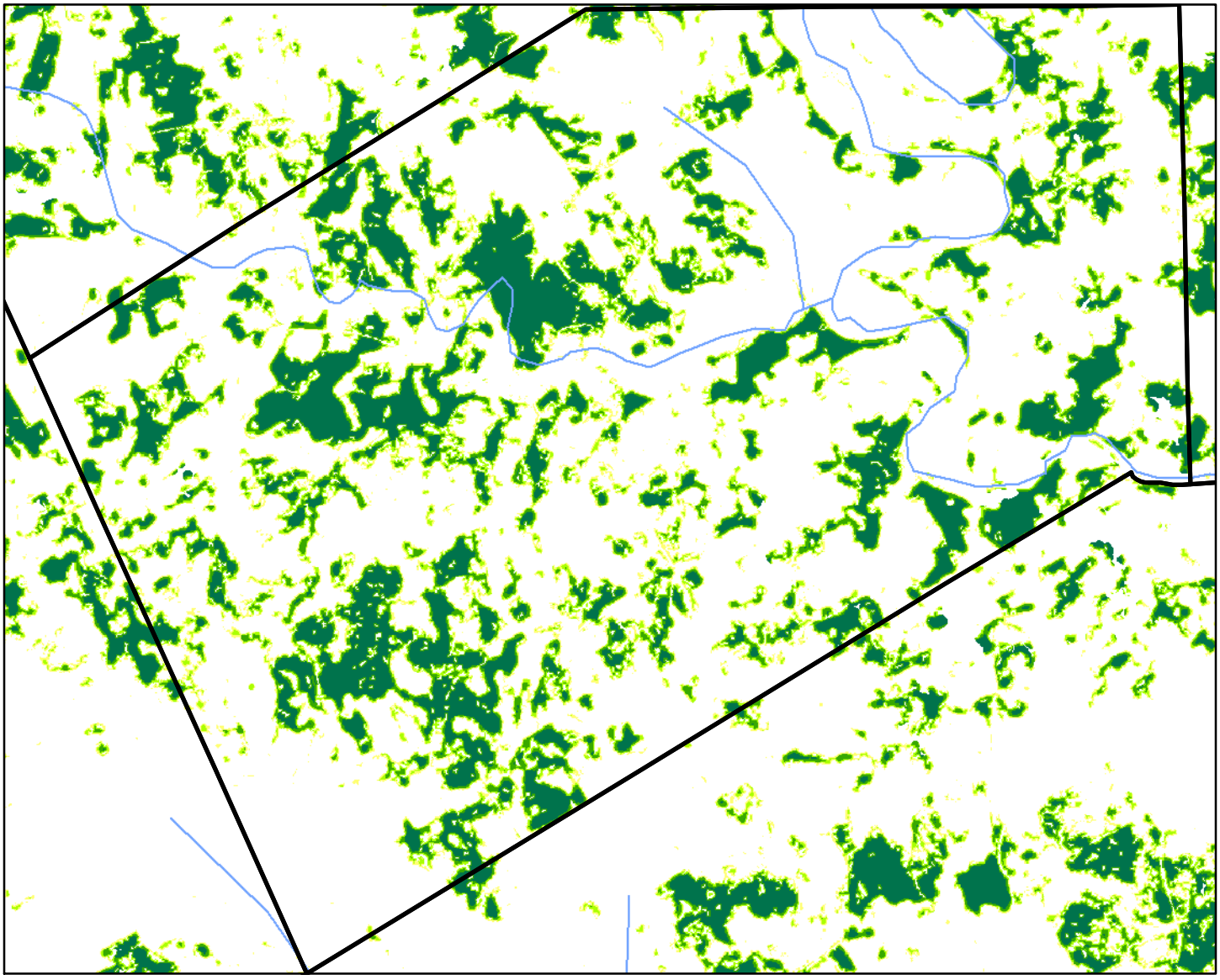
Figure 3. GCW Model C

SOMERVELL COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3
- 4 High Quality





1:168,949

Legend

- County
- Stream

0 1.25 2.5 5 Miles

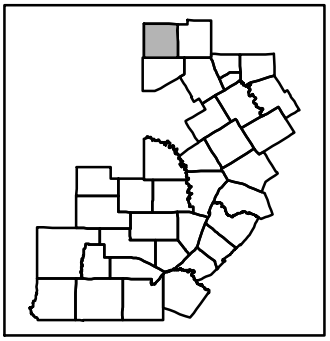
0 2 4 8 Kilometers

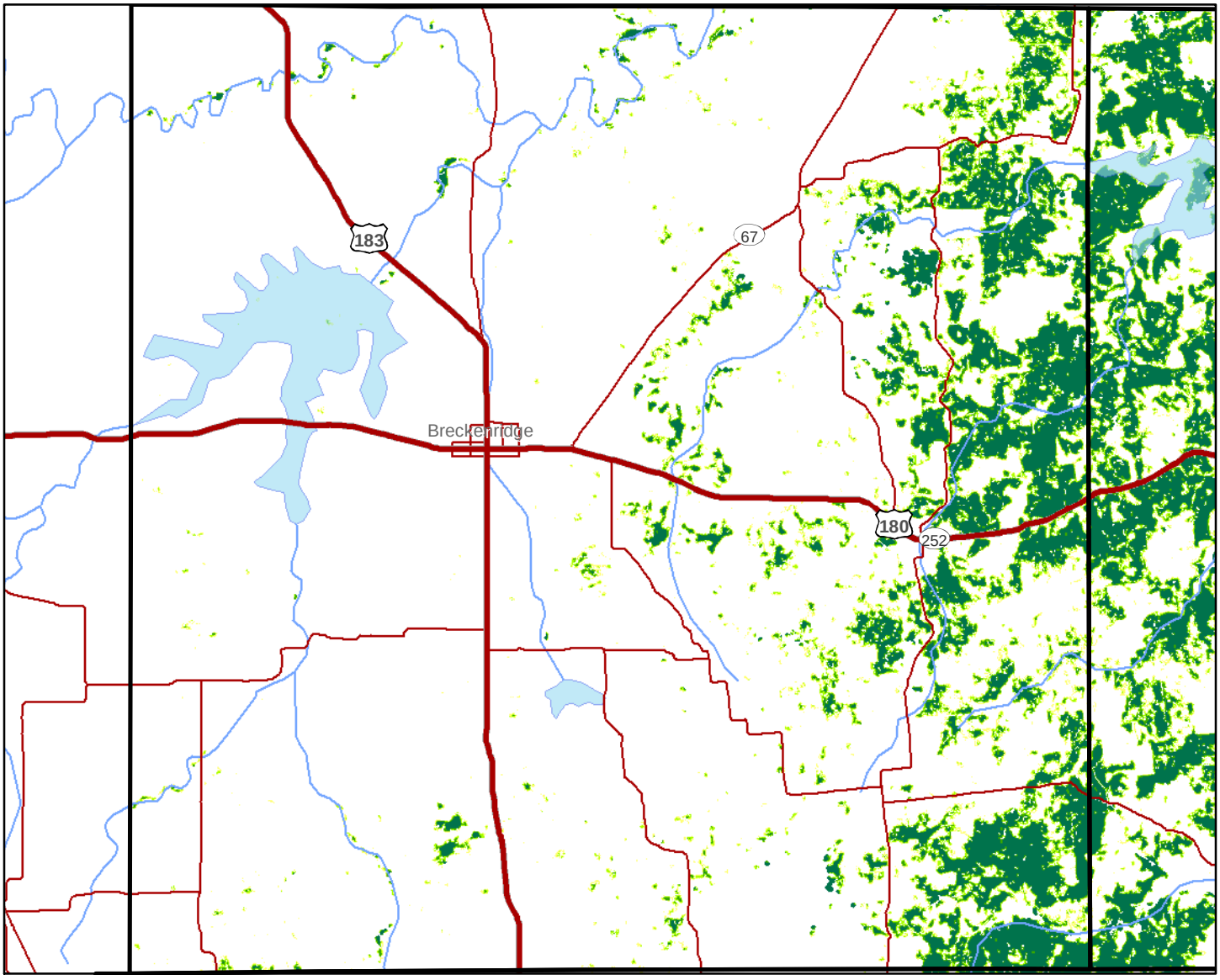
Figure 3. GCW Model C

STEPHENS
COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3
- 4 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N
W E
S

1:321,941

0 2.5 5 10 Miles

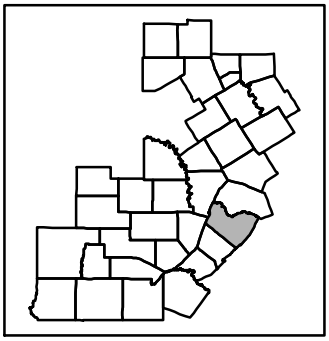
0 3.75 7.5 15 Kilometers

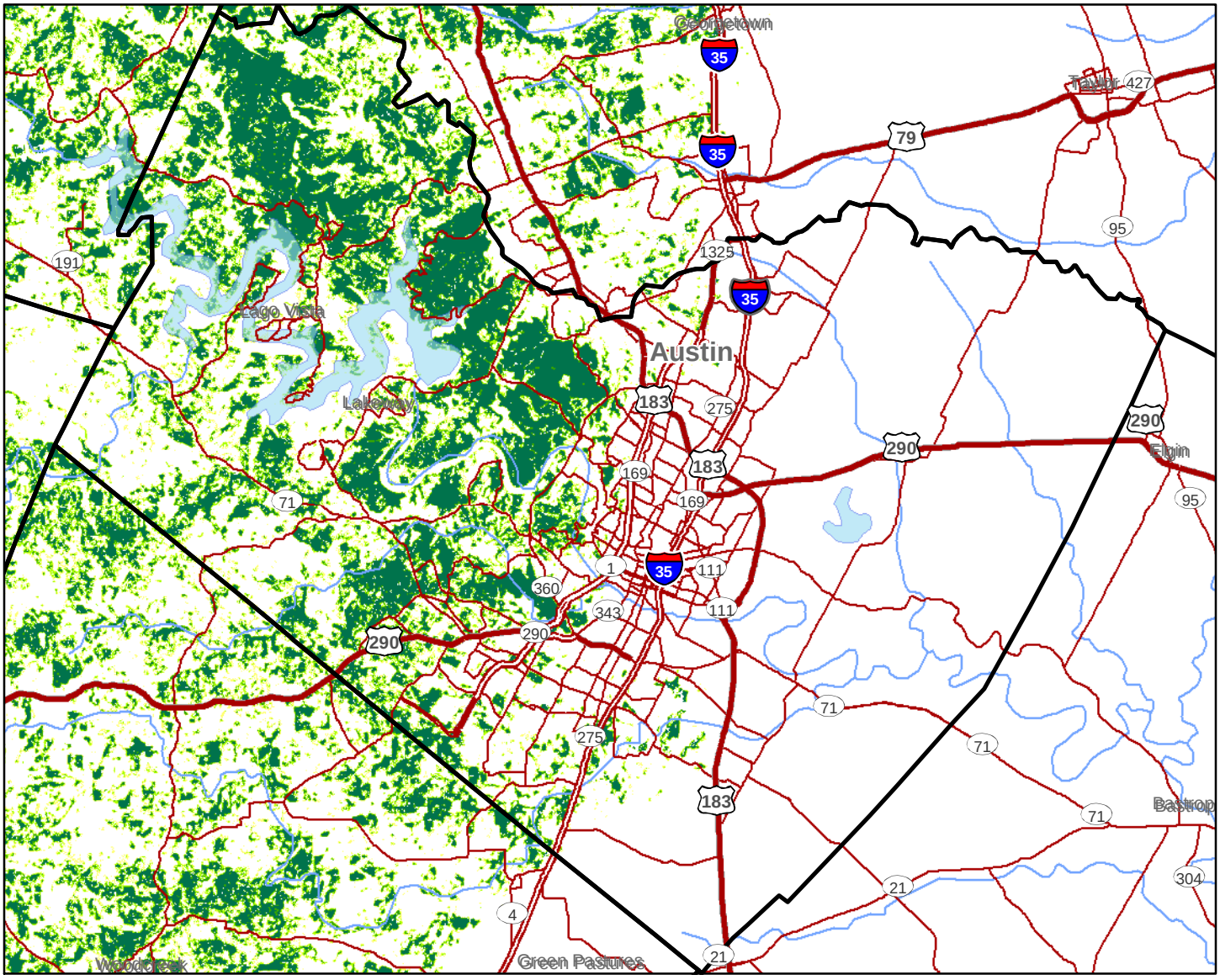
Figure 3. GCW Model C

TRAVIS
COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3
- 4 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

1:440,119

0 3.5 7 14 Miles

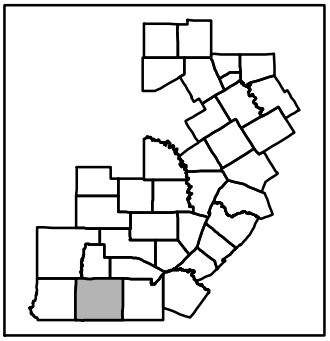
0 5 10 20 Kilometers

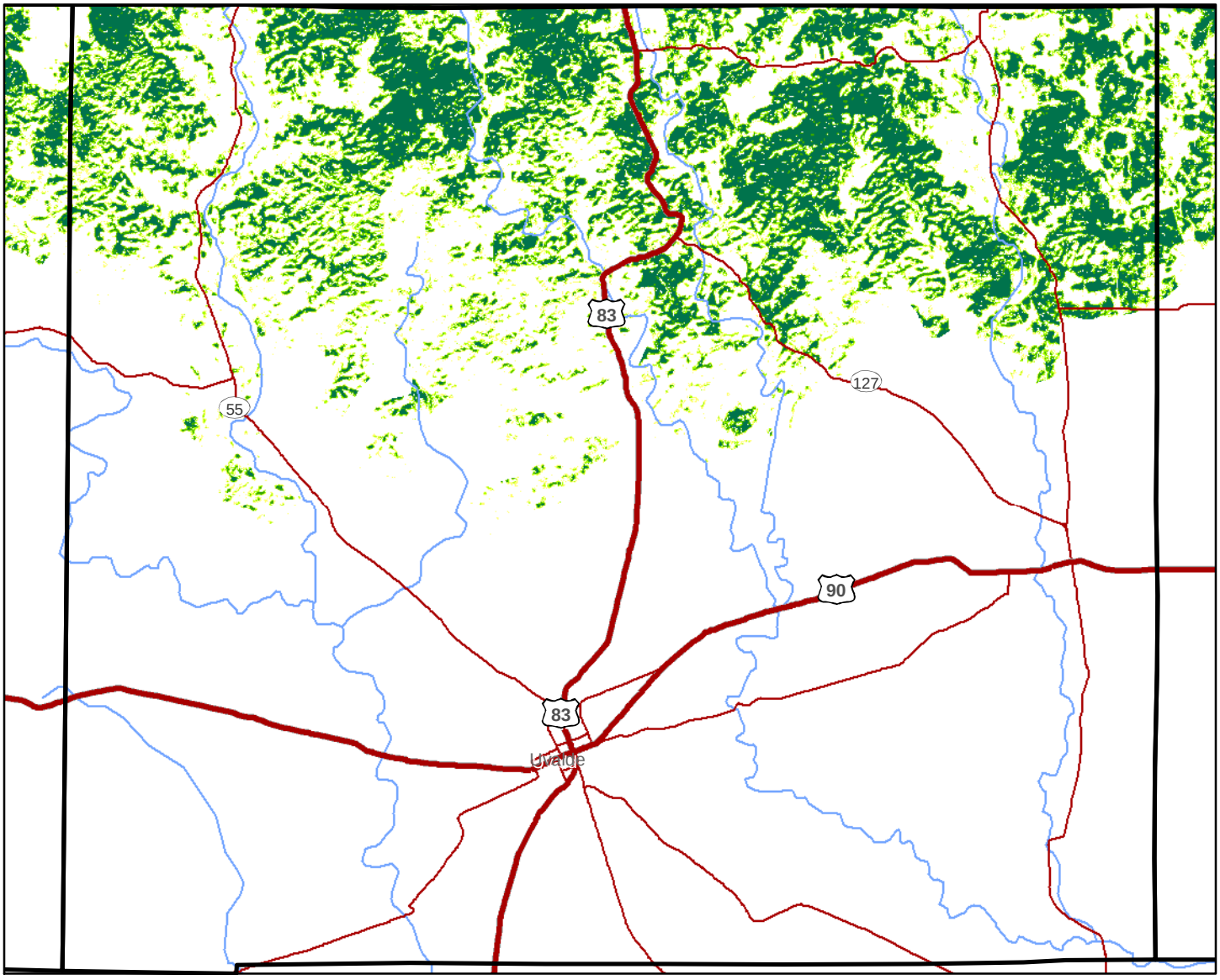
Figure 3. GCW Model C

UVALDE
COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3
- 4 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N
W E
S

1:396,913

0 3 6 12 Miles

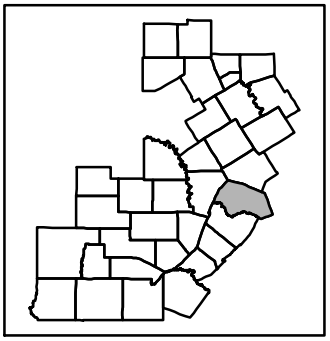
0 4.5 9 18 Kilometers

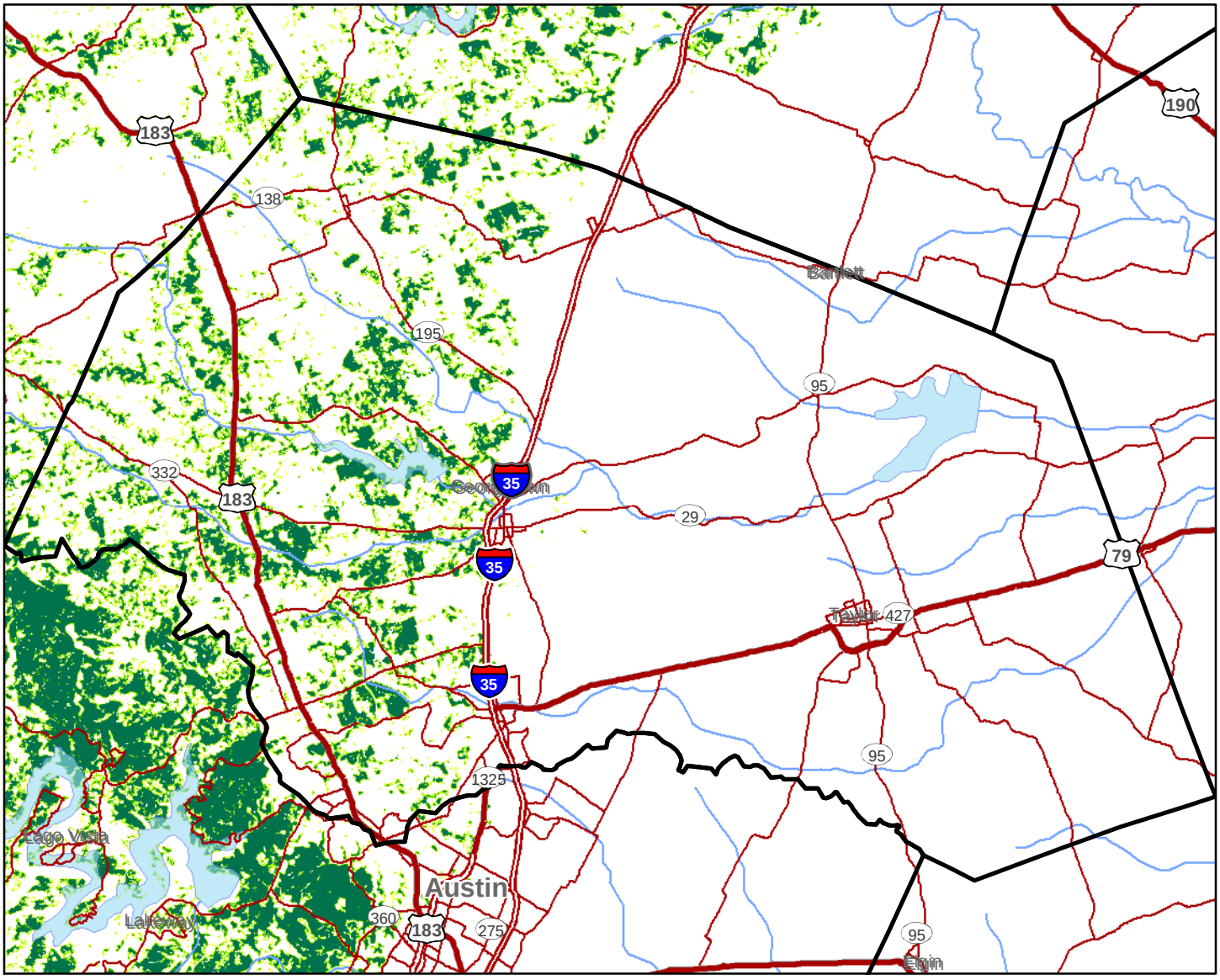
Figure 3. GCW Model C

WILLIAMSON COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3
- 4 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

1:452,765

0 3.5 7 14 Miles

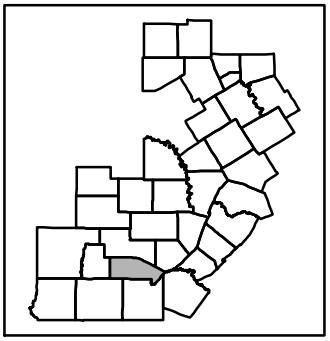
0 5 10 20 Kilometers

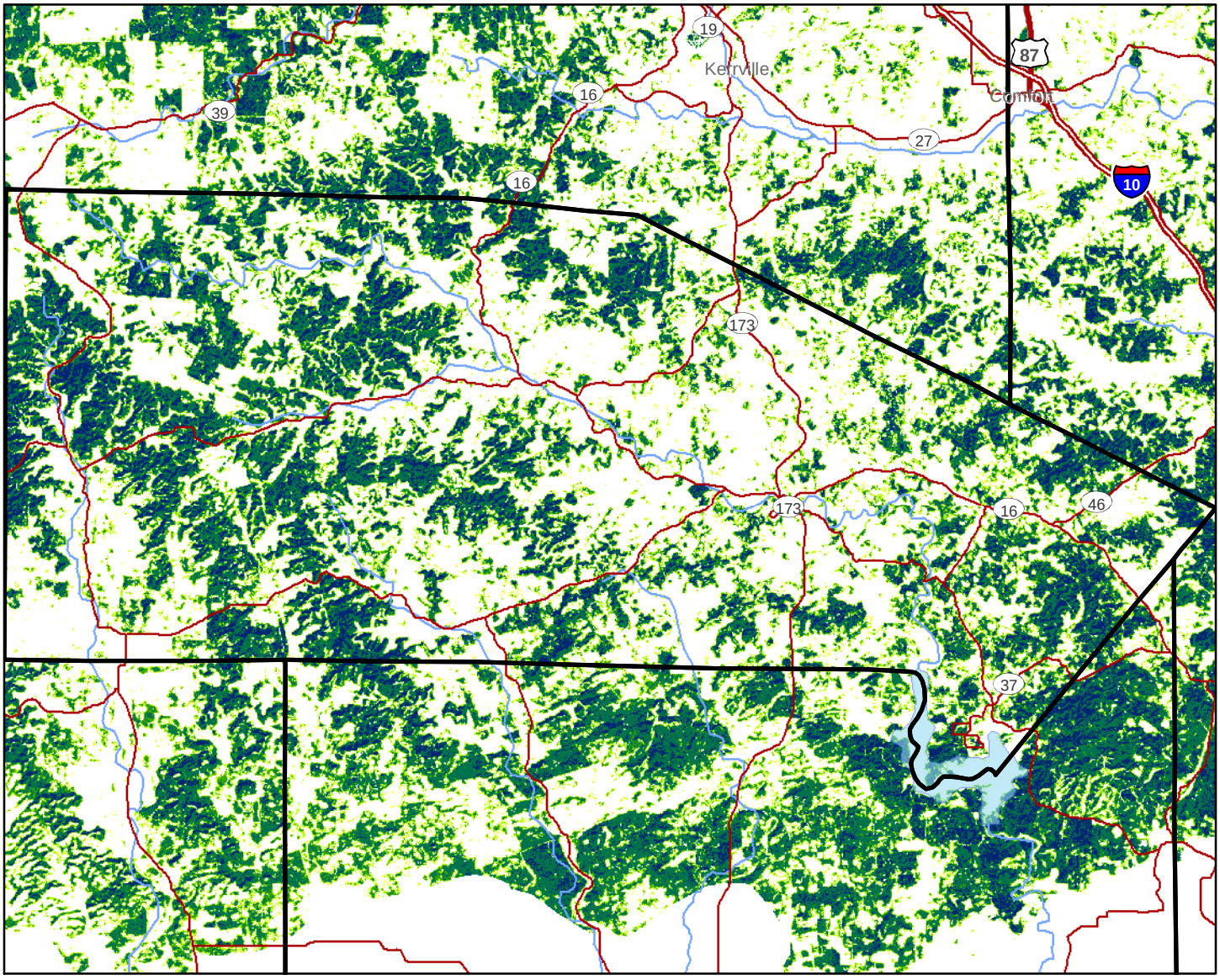
Figure 4. GCW Model D

BANDERA COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3
- 4
- 5 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N
W
E
S

1:420,333

0 3.5 7 14 Miles

0 4.5 9 18 Kilometers

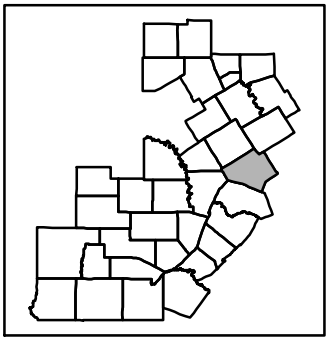
Figure 4. GCW Model D

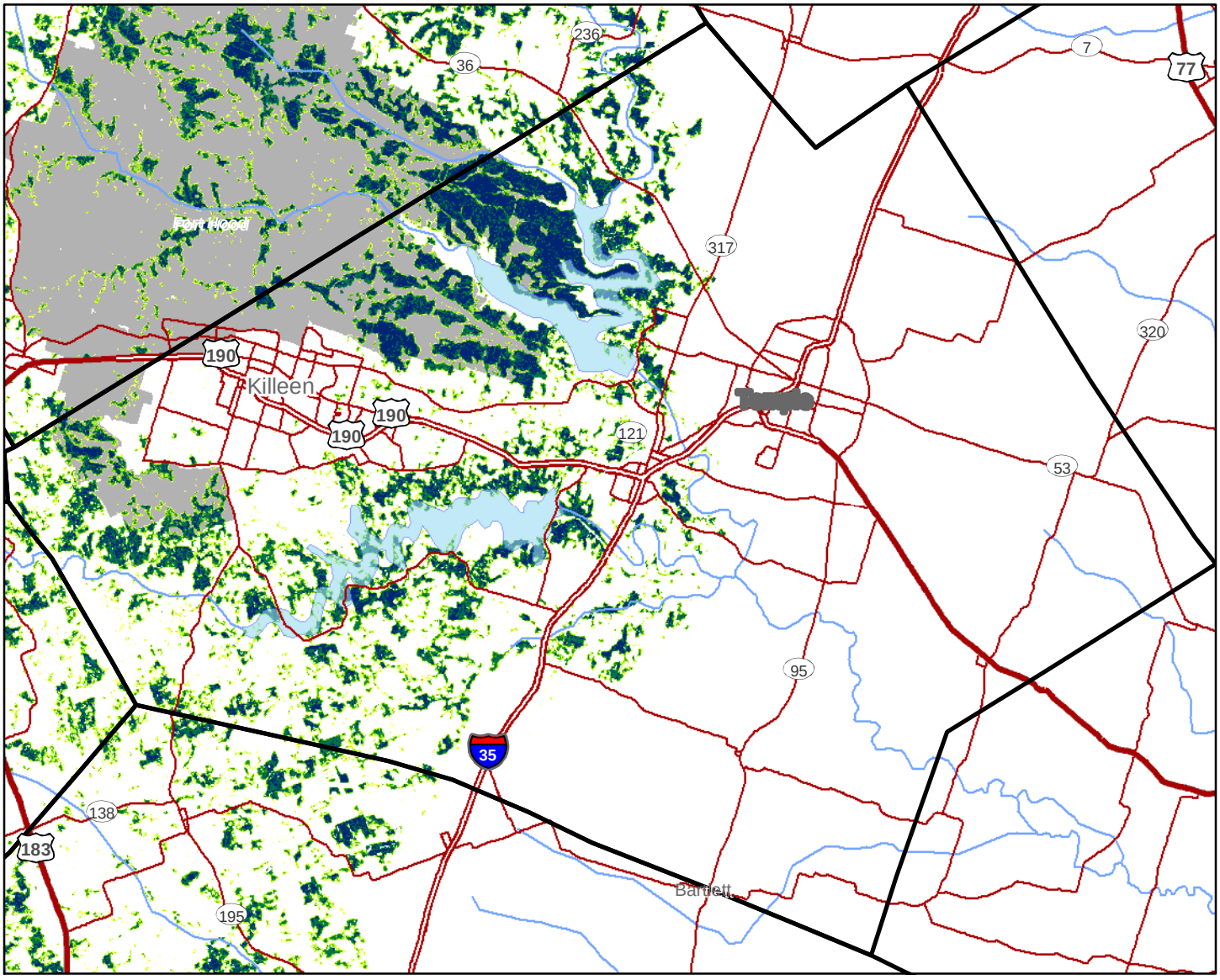
BELL

COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3
- 4
- 5 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

1:426,603

0 3.5 7 14 Miles

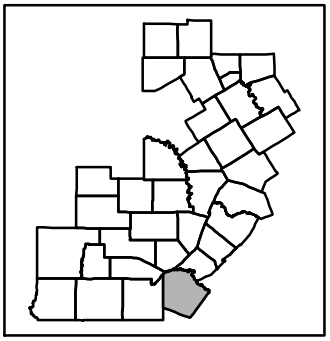
0 4.5 9 18 Kilometers

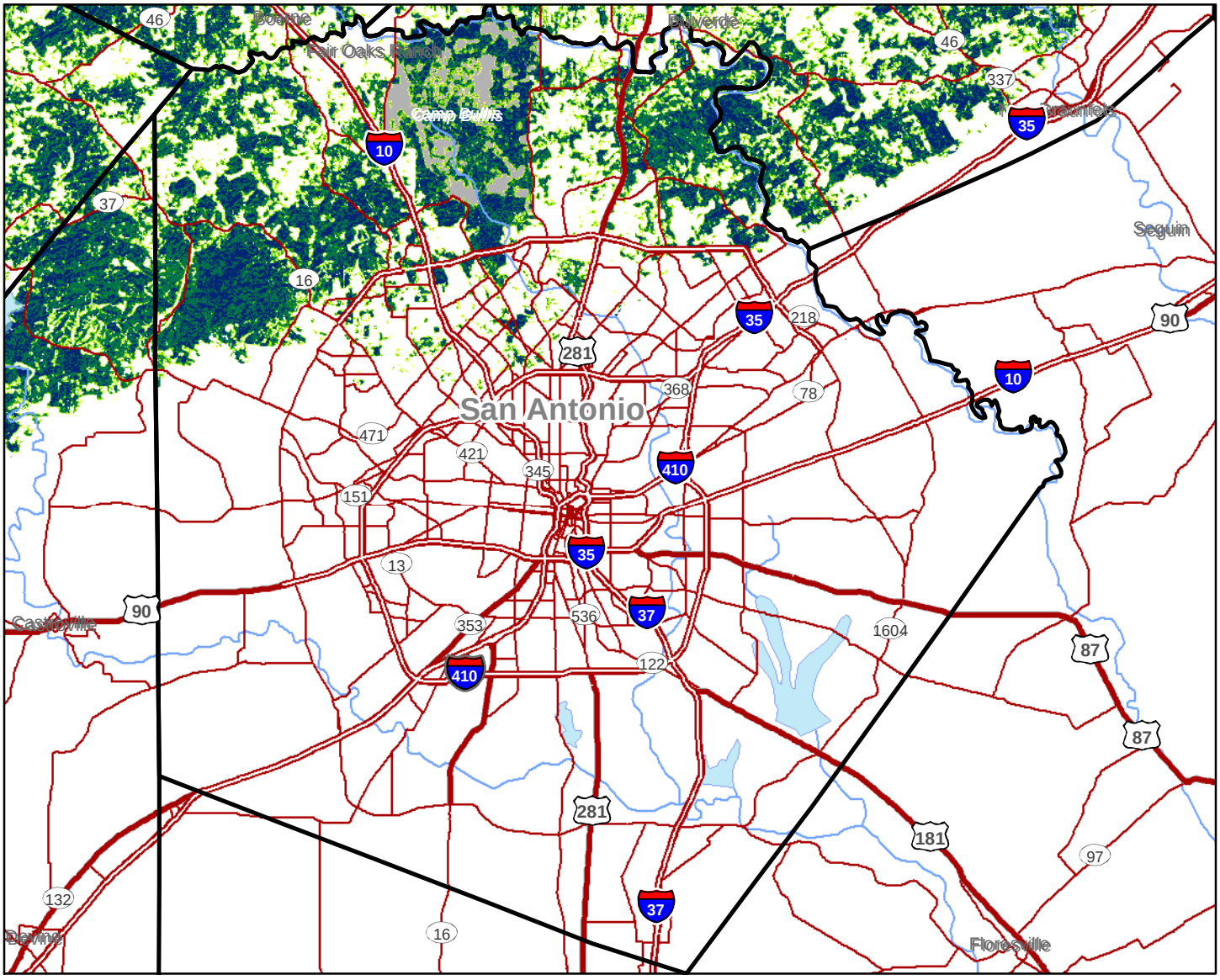
Figure 4. GCW Model D

BEXAR COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3
- 4
- 5 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N W E S

1:467,865

0 3.75 7.5 15 Miles

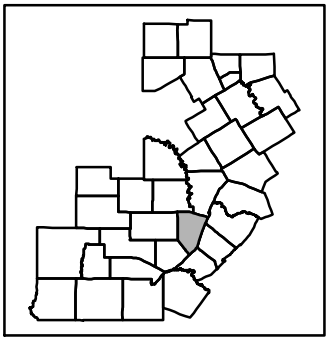
0 5 10 20 Kilometers

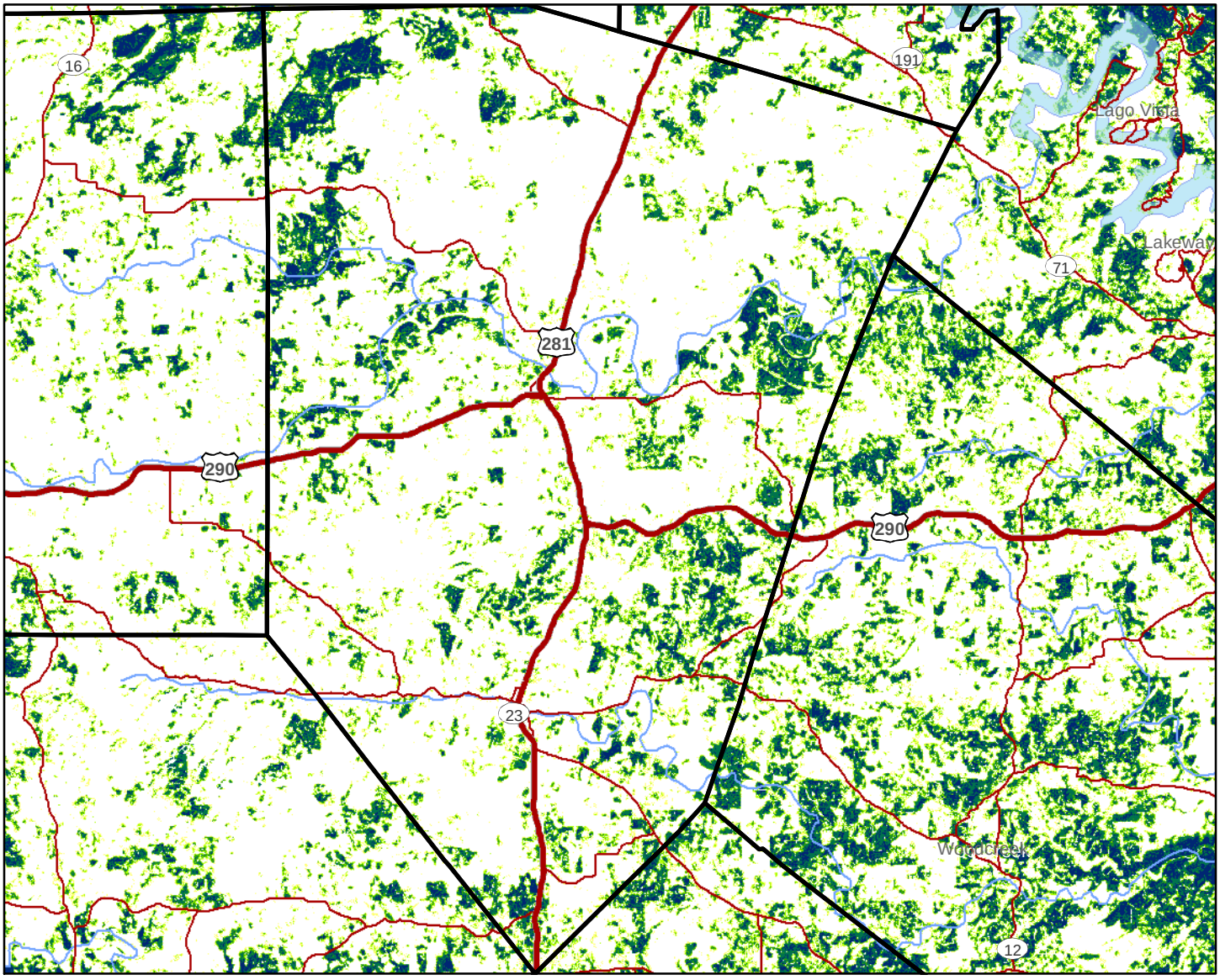
Figure 4. GCW Model D

BLANCO COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3
- 4
- 5 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N
W
E
S

1:408,826

0 3.5 7 14 Miles

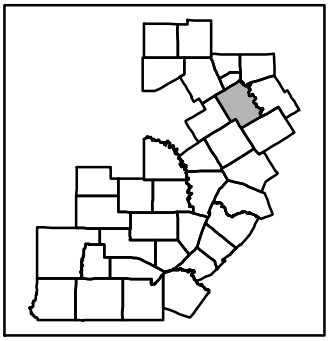
0 4.5 9 18 Kilometers

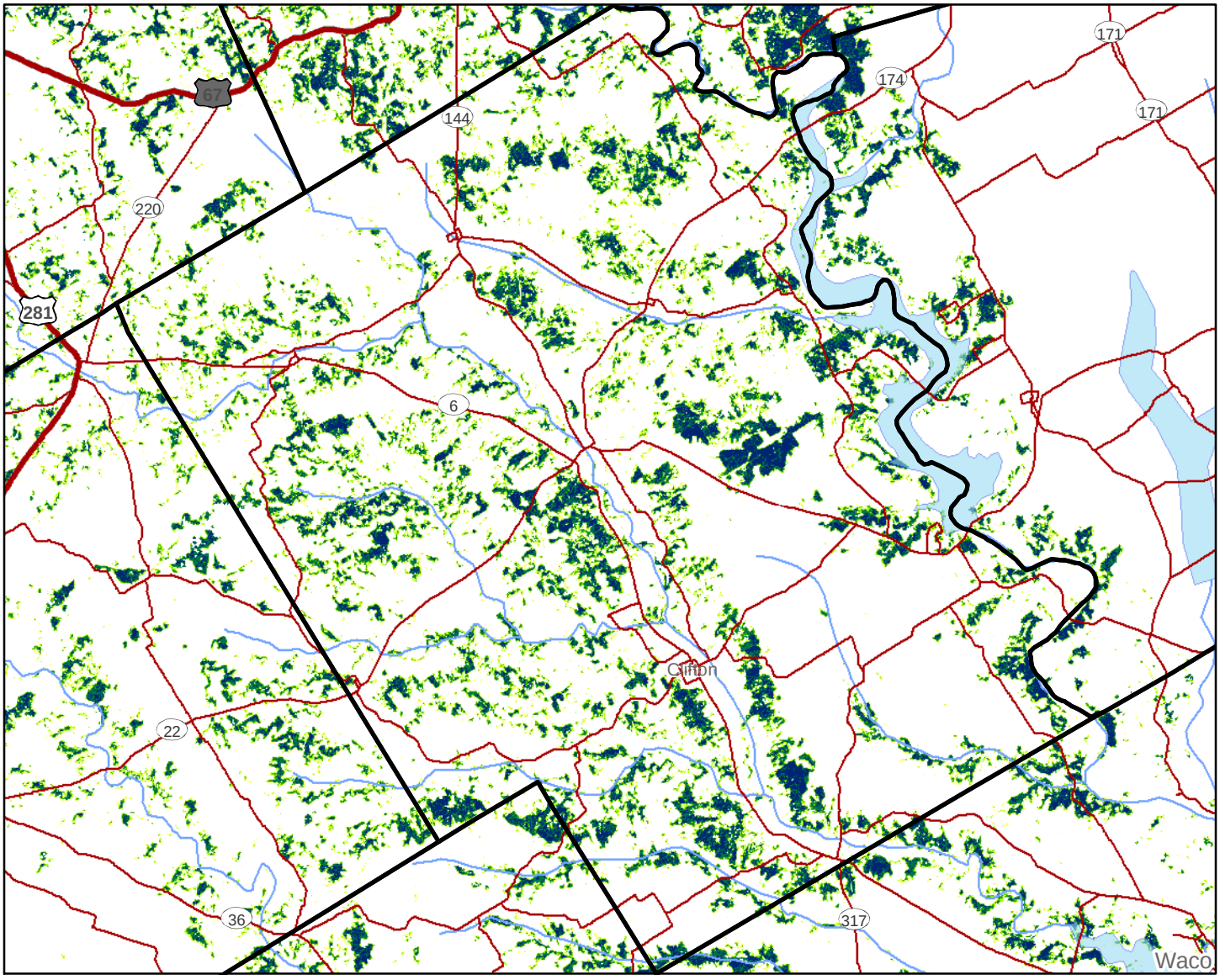
Figure 4. GCW Model D

BOSQUE
COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3
- 4
- 5 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N
W E
S

1:450,274

0 3.75 7.5 15 Miles

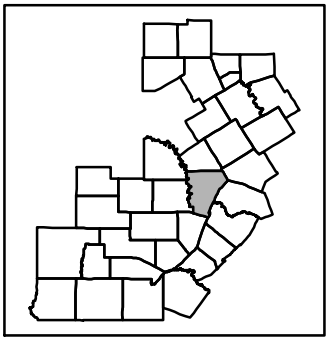
0 5 10 20 Kilometers

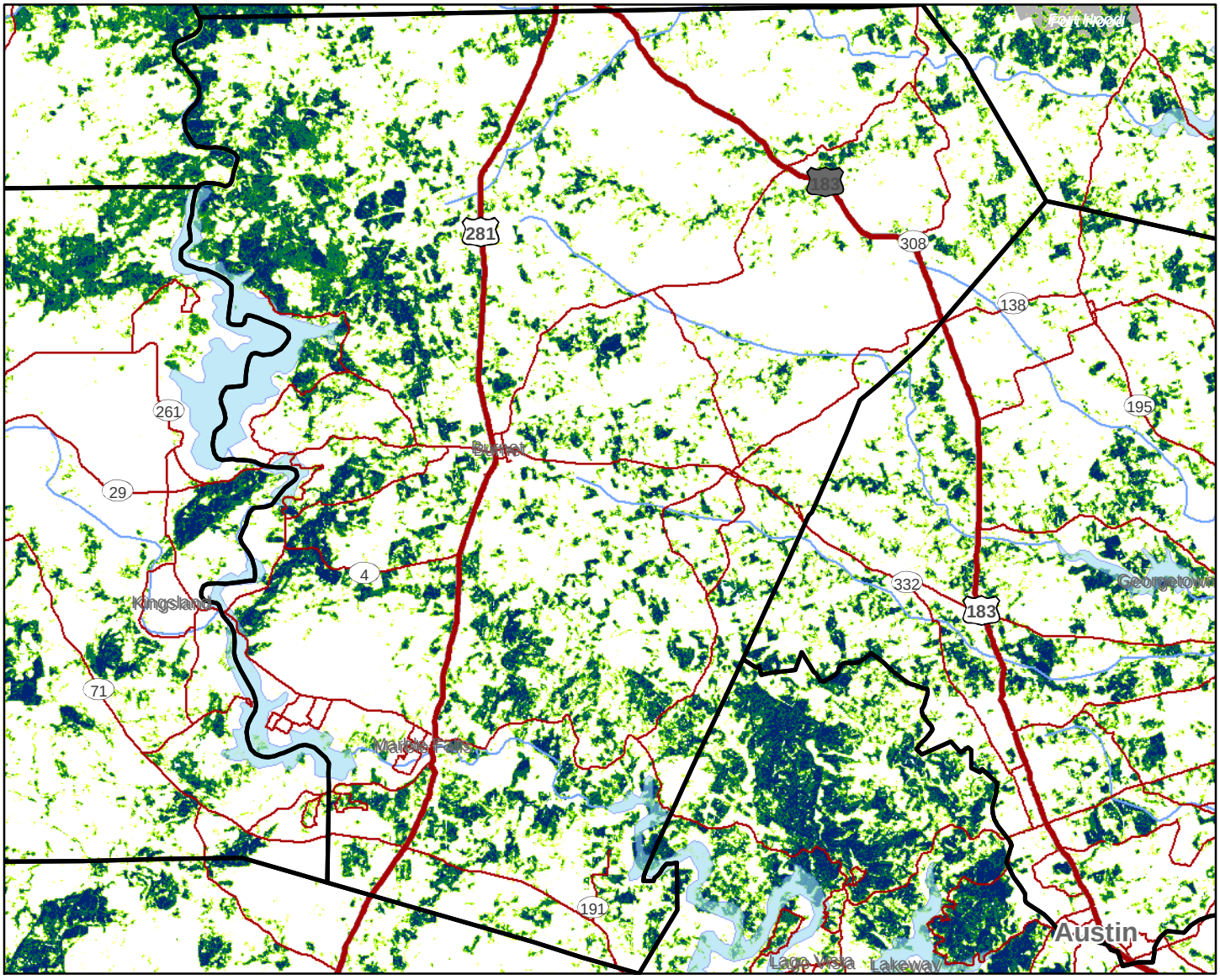
Figure 4. GCW Model D

BURNET COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3
- 4
- 5 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N W E S

1:443,072

0 3.75 7.5 15 Miles

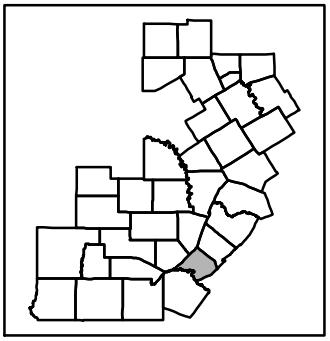
0 5 10 20 Kilometers

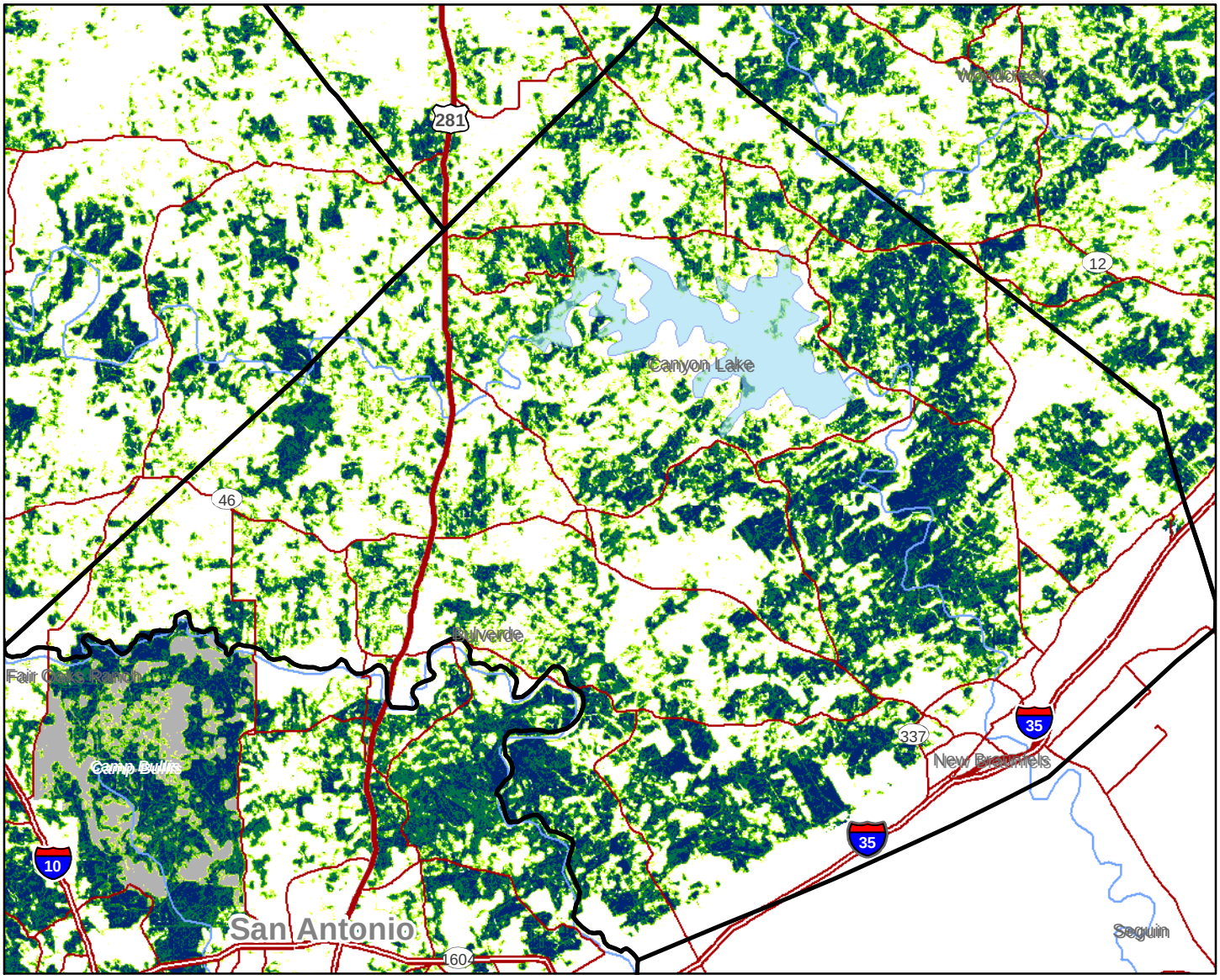
Figure 4. GCW Model D

COMAL
COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3
- 4
- 5 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N
W E
S

1:328,003

0 2.5 5 10 Miles

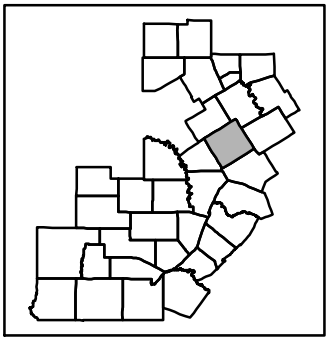
0 3.75 7.5 15 Kilometers

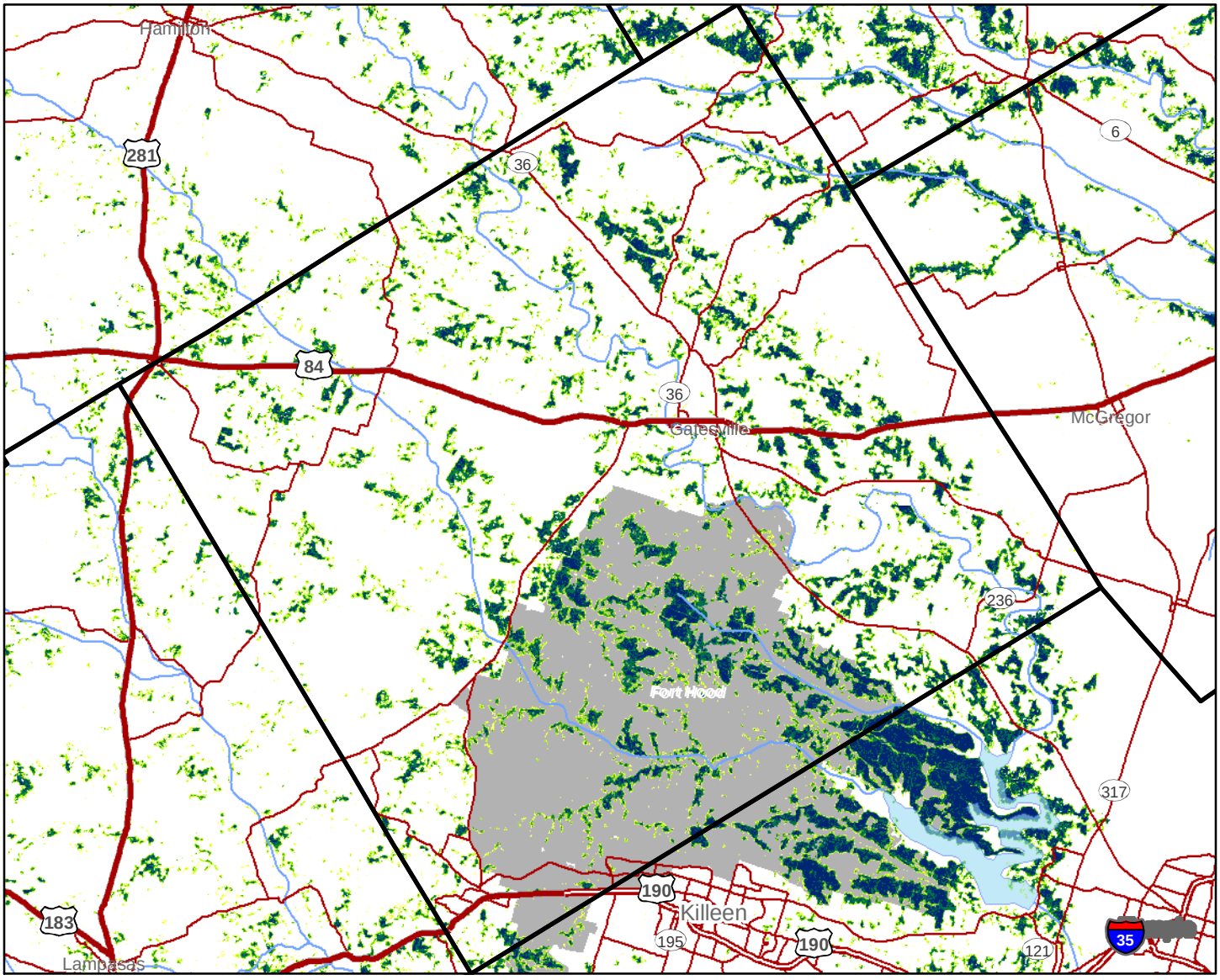
Figure 4. GCW Model D

CORYELL COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3
- 4
- 5 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N W E S

1:469,250

0 3.5 7 14 Miles

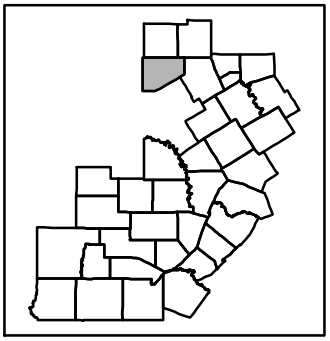
0 5 10 20 Kilometers

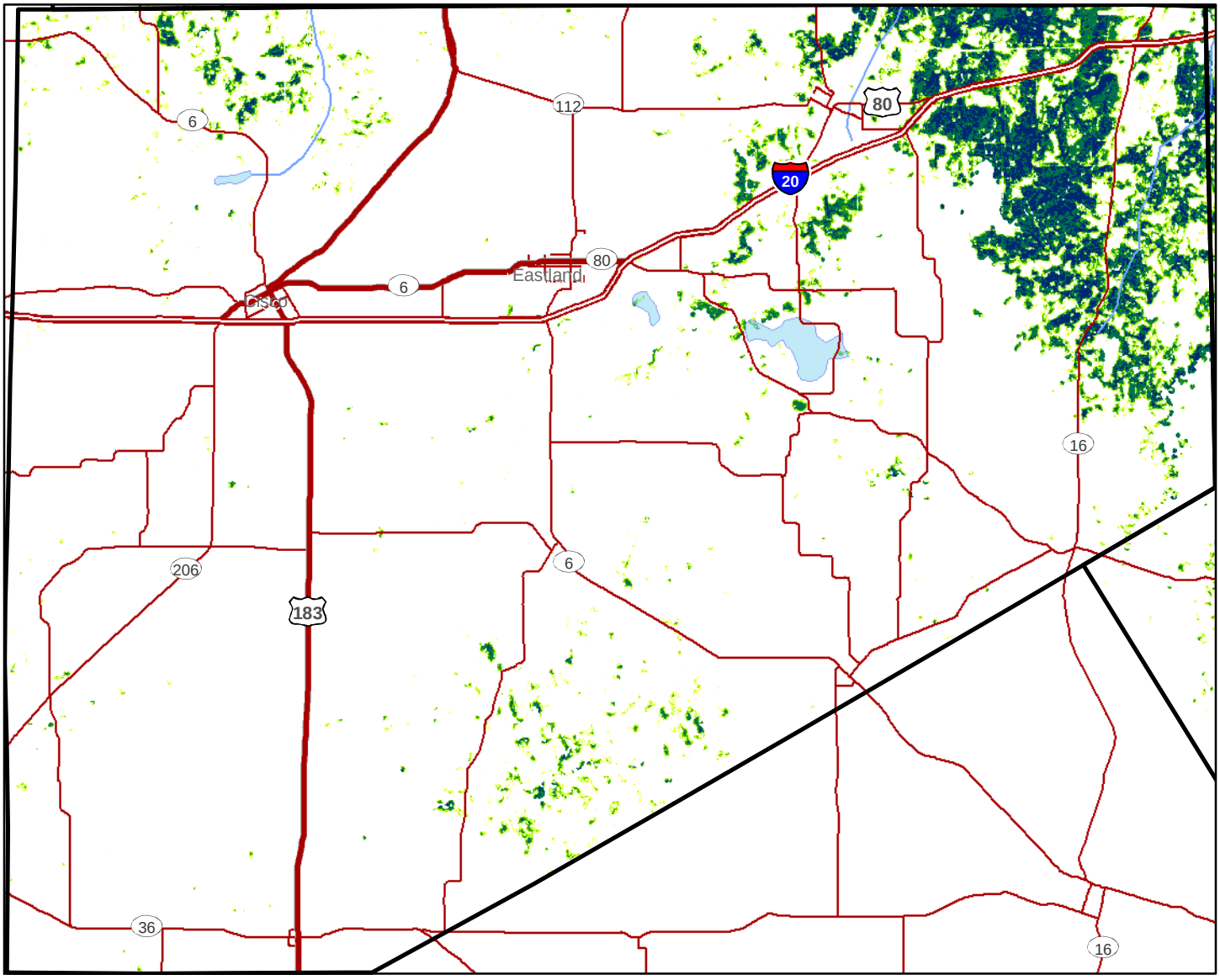
Figure 4. GCW Model D

EASTLAND
COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3
- 4
- 5 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N
W
E
S

1:319,430

0 2.5 5 10 Miles

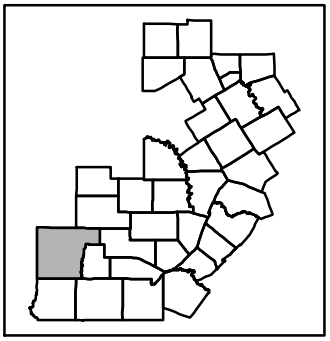
0 3.5 7 14 Kilometers

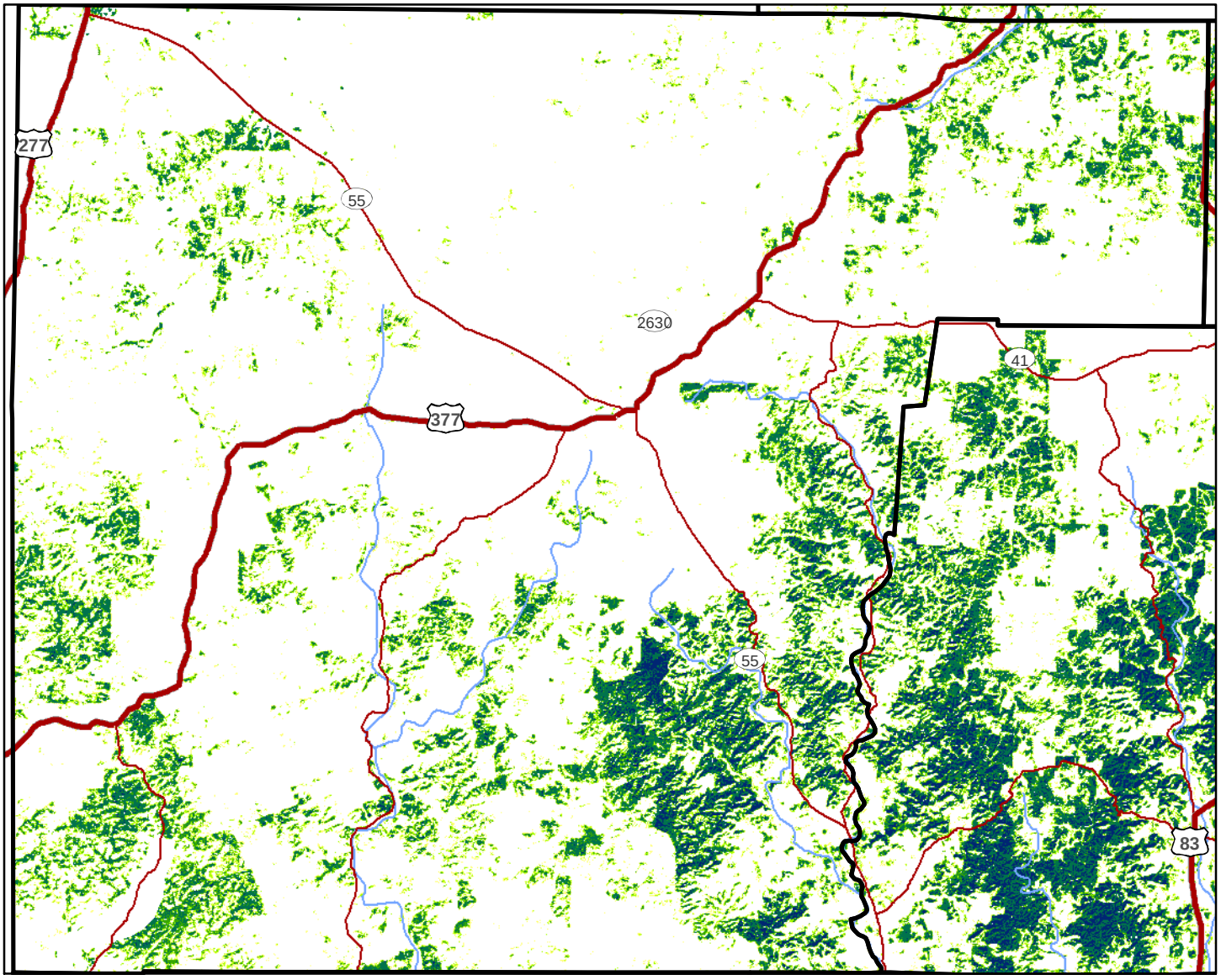
Figure 4. GCW Model D

EDWARDS
COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3
- 4
- 5 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N
W E
S

1:486,990

0 3.75 7.5 15 Miles

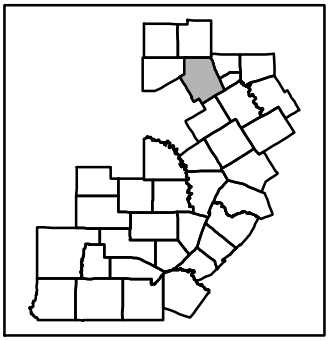
0 5 10 20 Kilometers

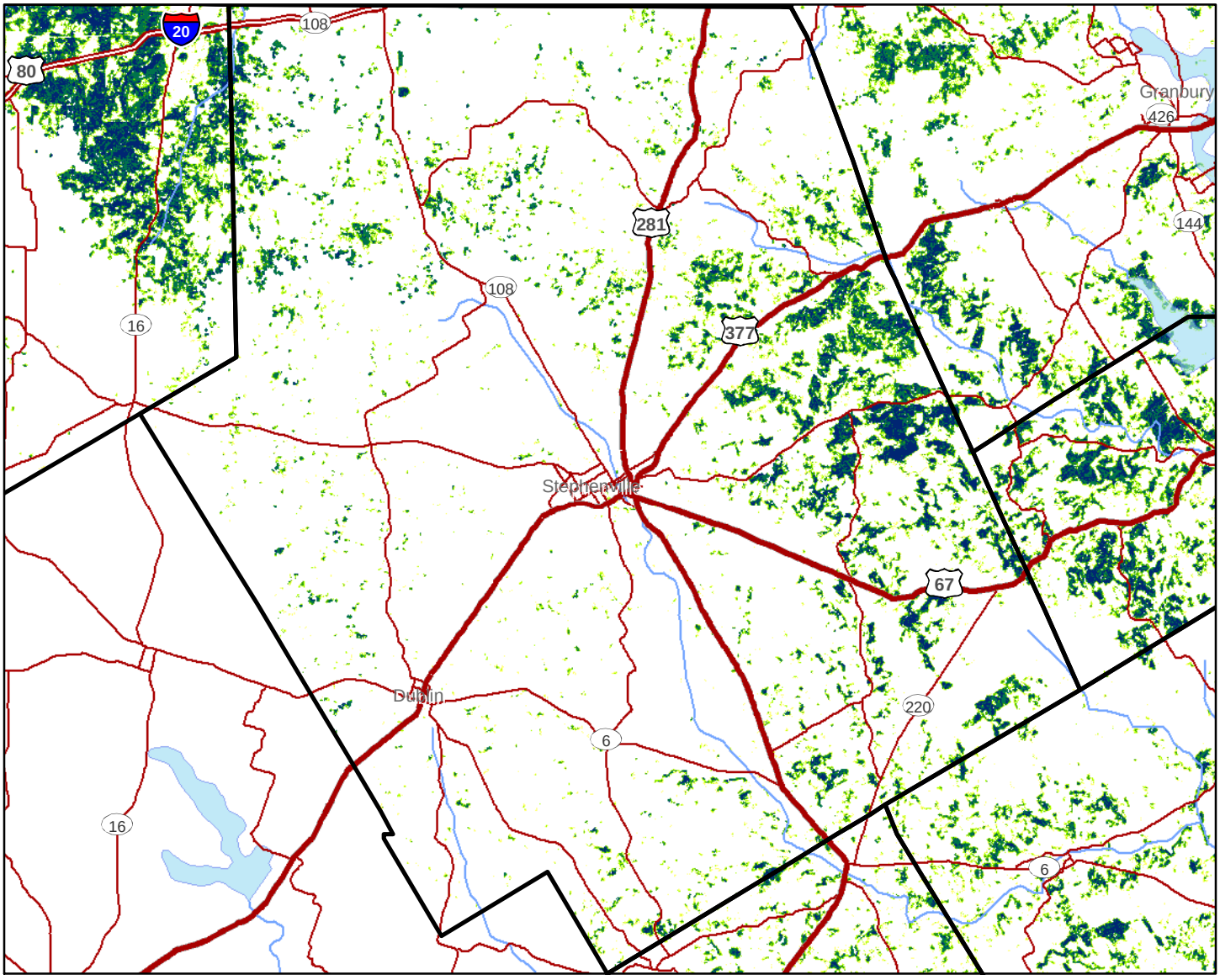
Figure 4. GCW Model D

ERATH
COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3
- 4
- 5 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N
W E
S

1:436,311

0 3.5 7 14 Miles

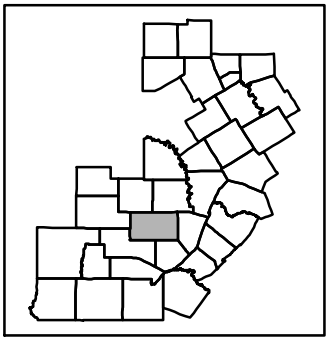
0 4.5 9 18 Kilometers

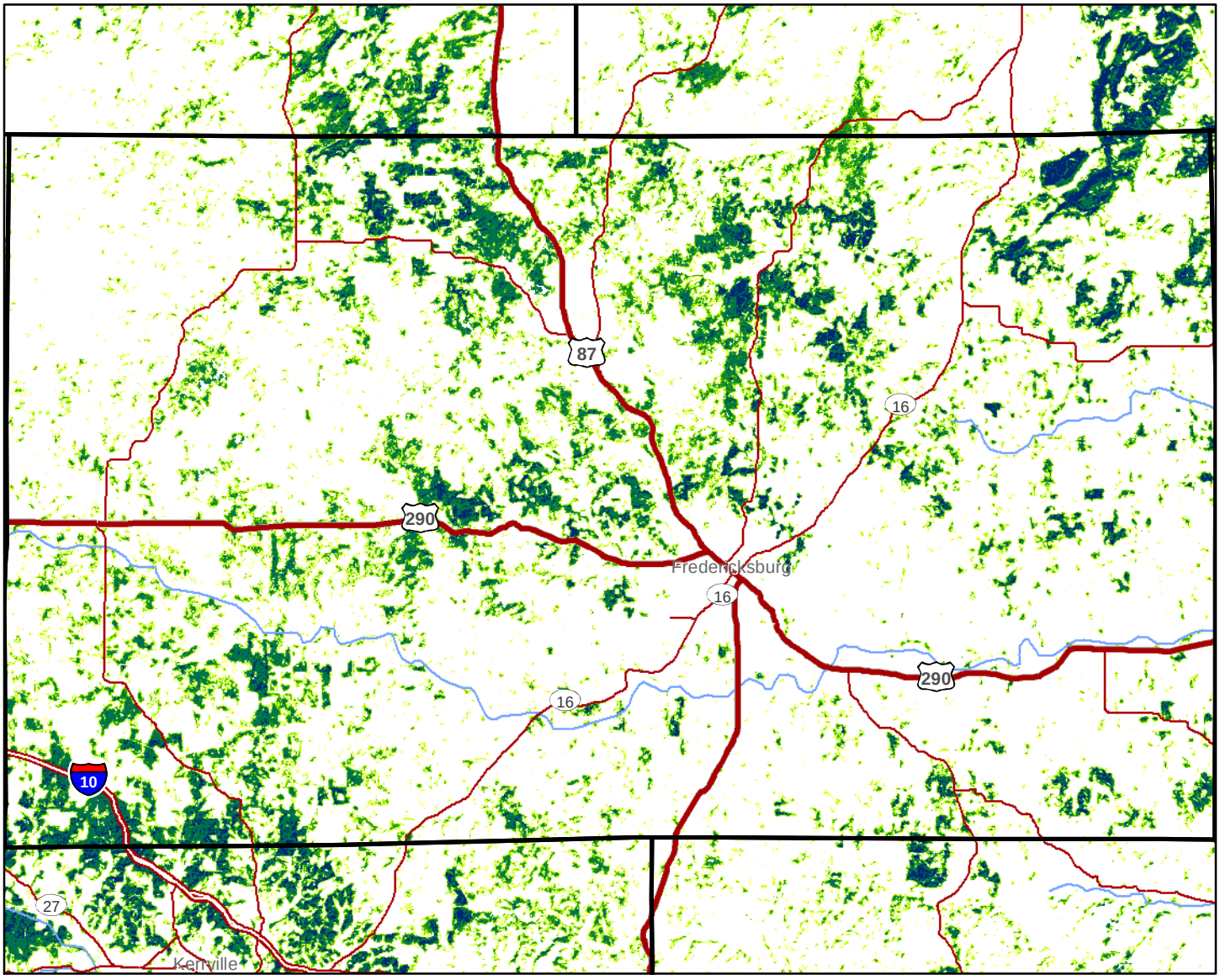
Figure 4. GCW Model D

GILLESPIE COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3
- 4
- 5 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N
W E
S

1:360,868

0 3 6 12 Miles

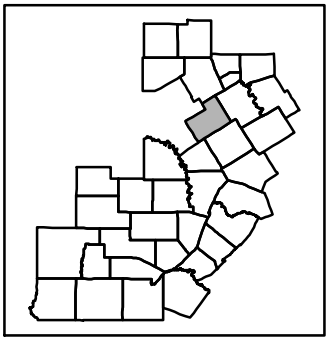
0 3.75 7.5 15 Kilometers

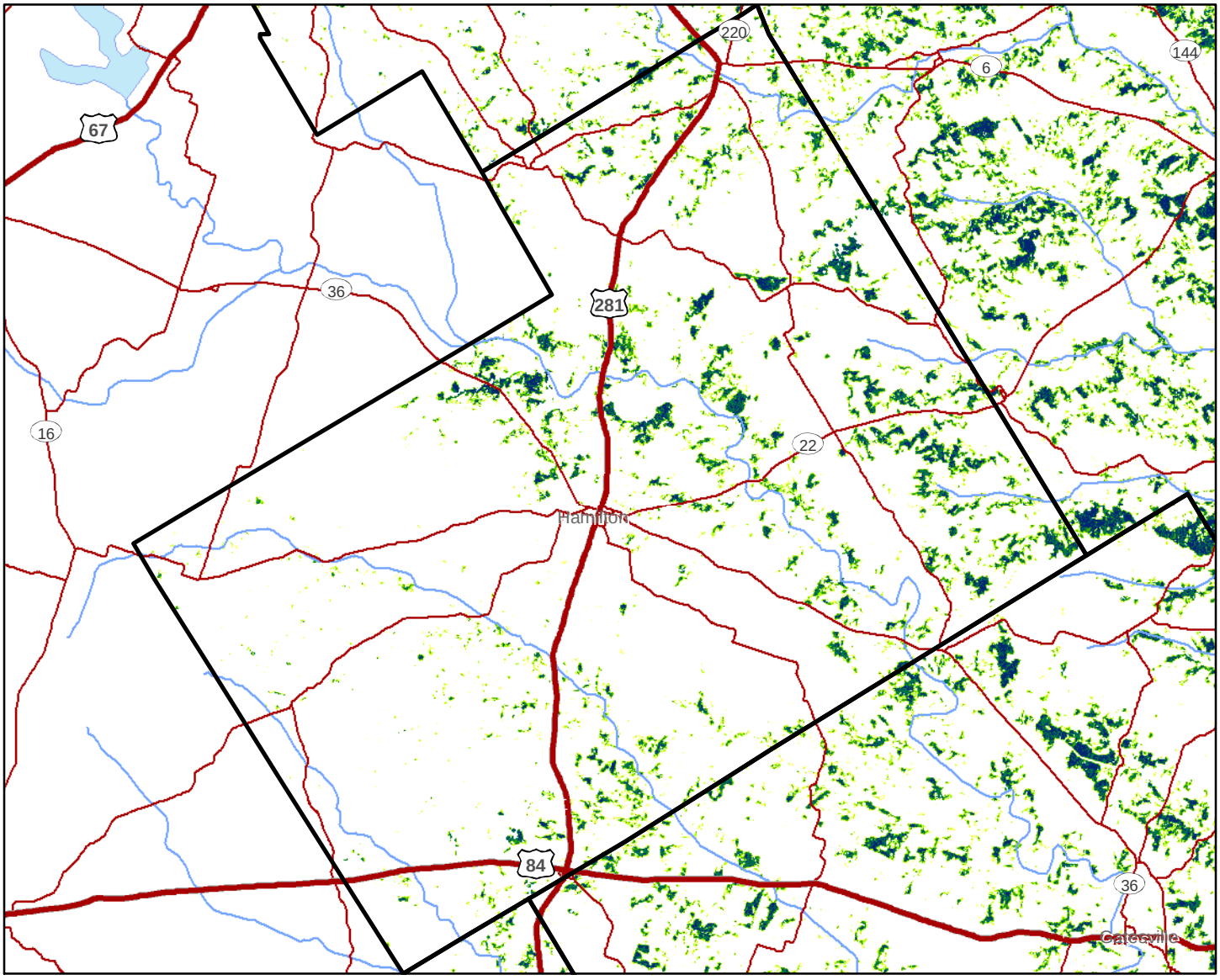
Figure 4. GCW Model D

HAMILTON
COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3
- 4
- 5 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N
W E
S

1:440,225

0 3.75 7.5 15 Miles

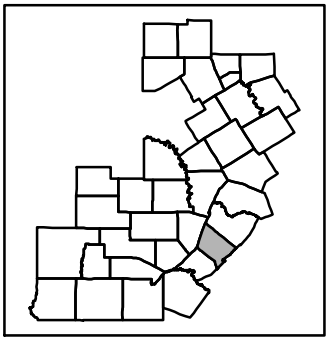
0 4.5 9 18 Kilometers

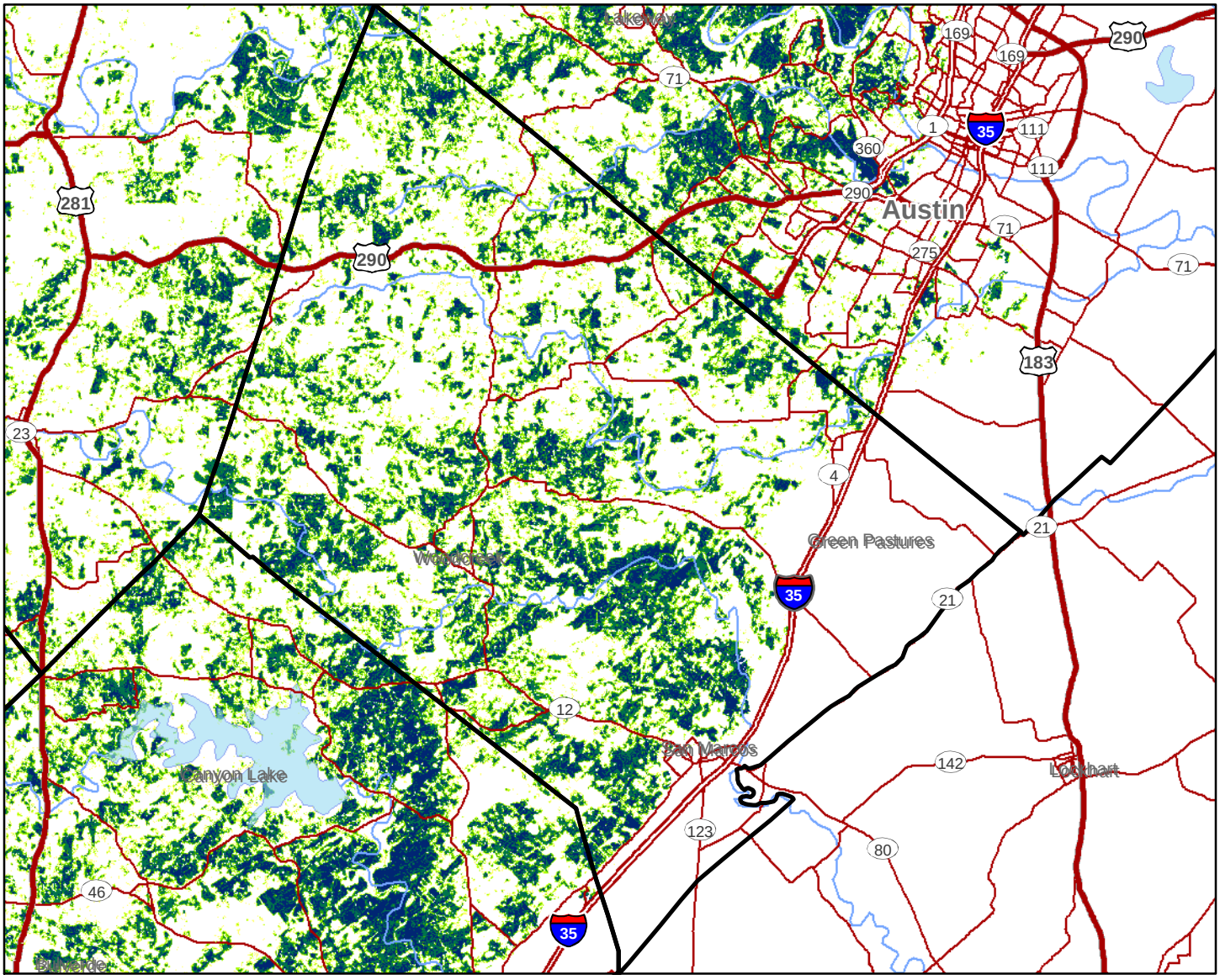
Figure 4. GCW Model D

HAYS
COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3
- 4
- 5 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N
W E
S

1:438,757

0 3.75 7.5 15 Miles

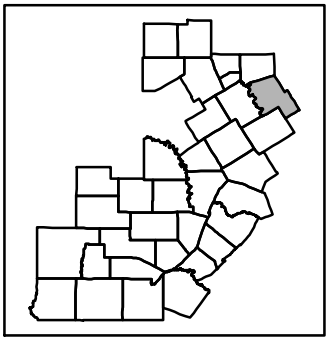
0 4.5 9 18 Kilometers

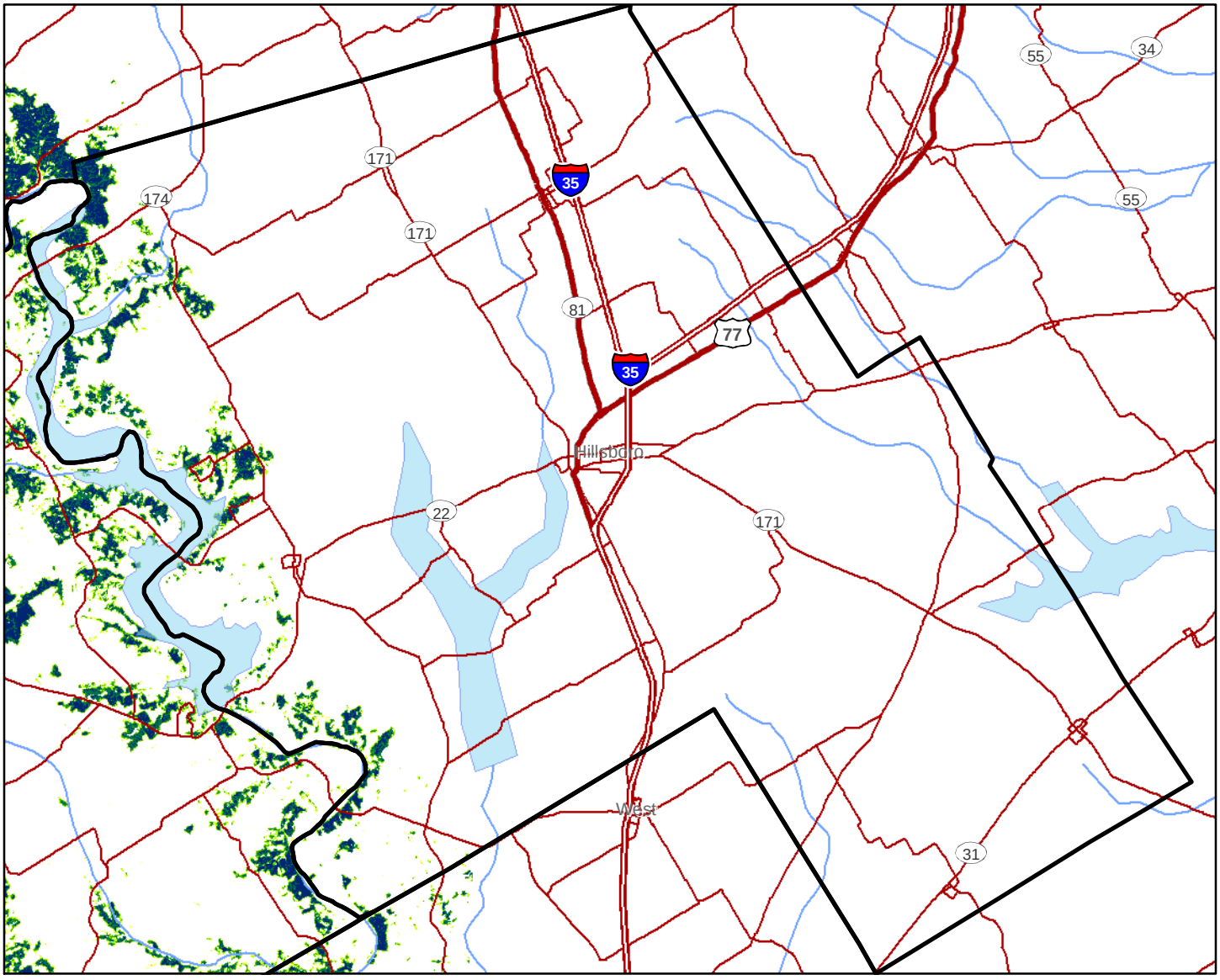
Figure 4. GCW Model D

HILL
COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3
- 4
- 5 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N
W
E
S

1:405,536

0 3.5 7 14 Miles

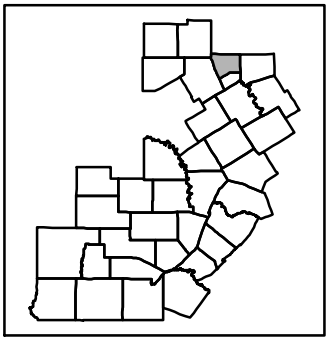
0 4 8 16 Kilometers

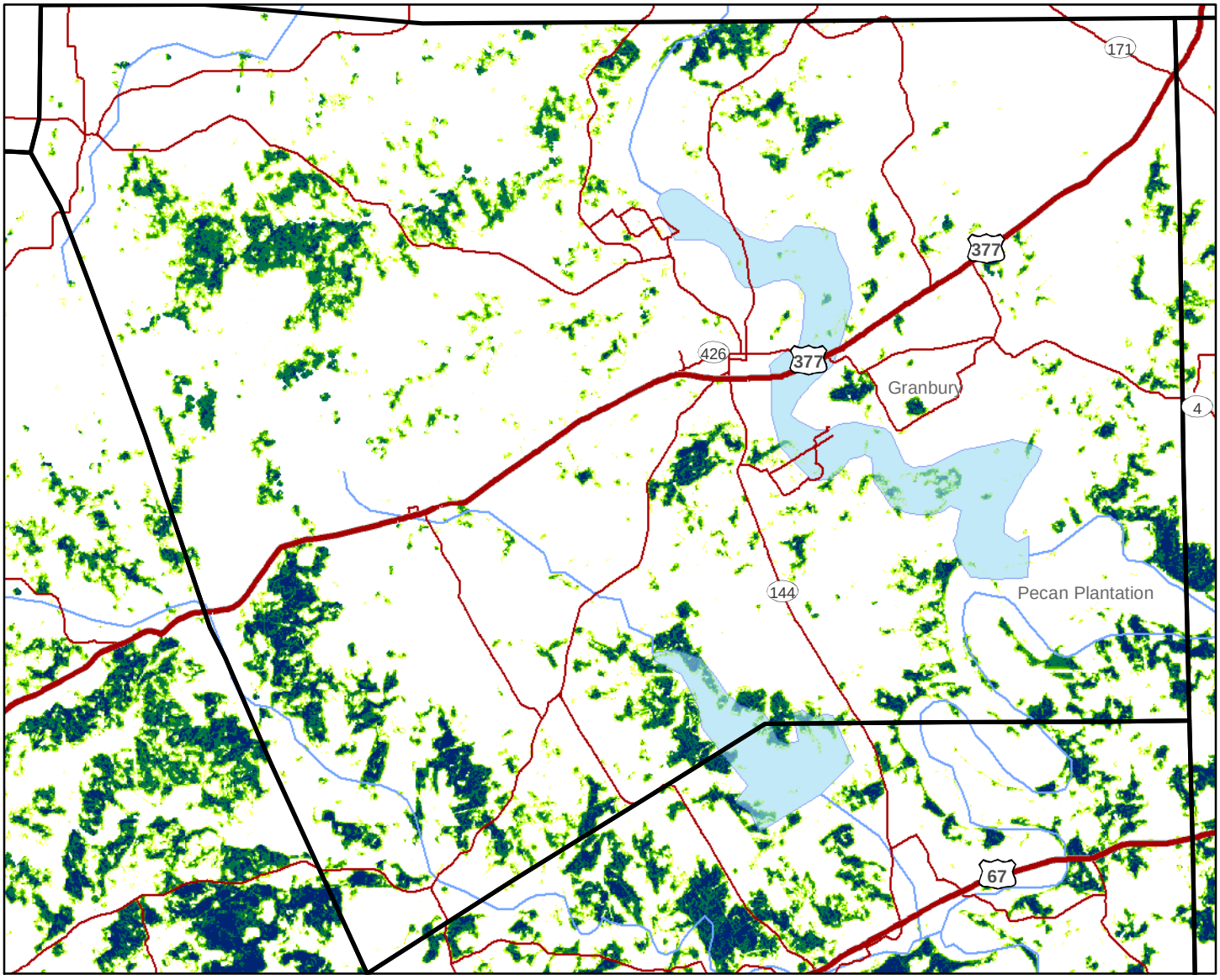
Figure 4. GCW Model D

HOOD
COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3
- 4
- 5 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N
W
E
S

1:236,188

0 2 4 8 Miles

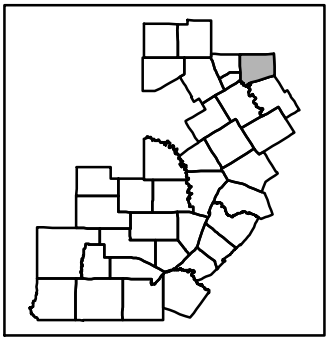
0 2.5 5 10 Kilometers

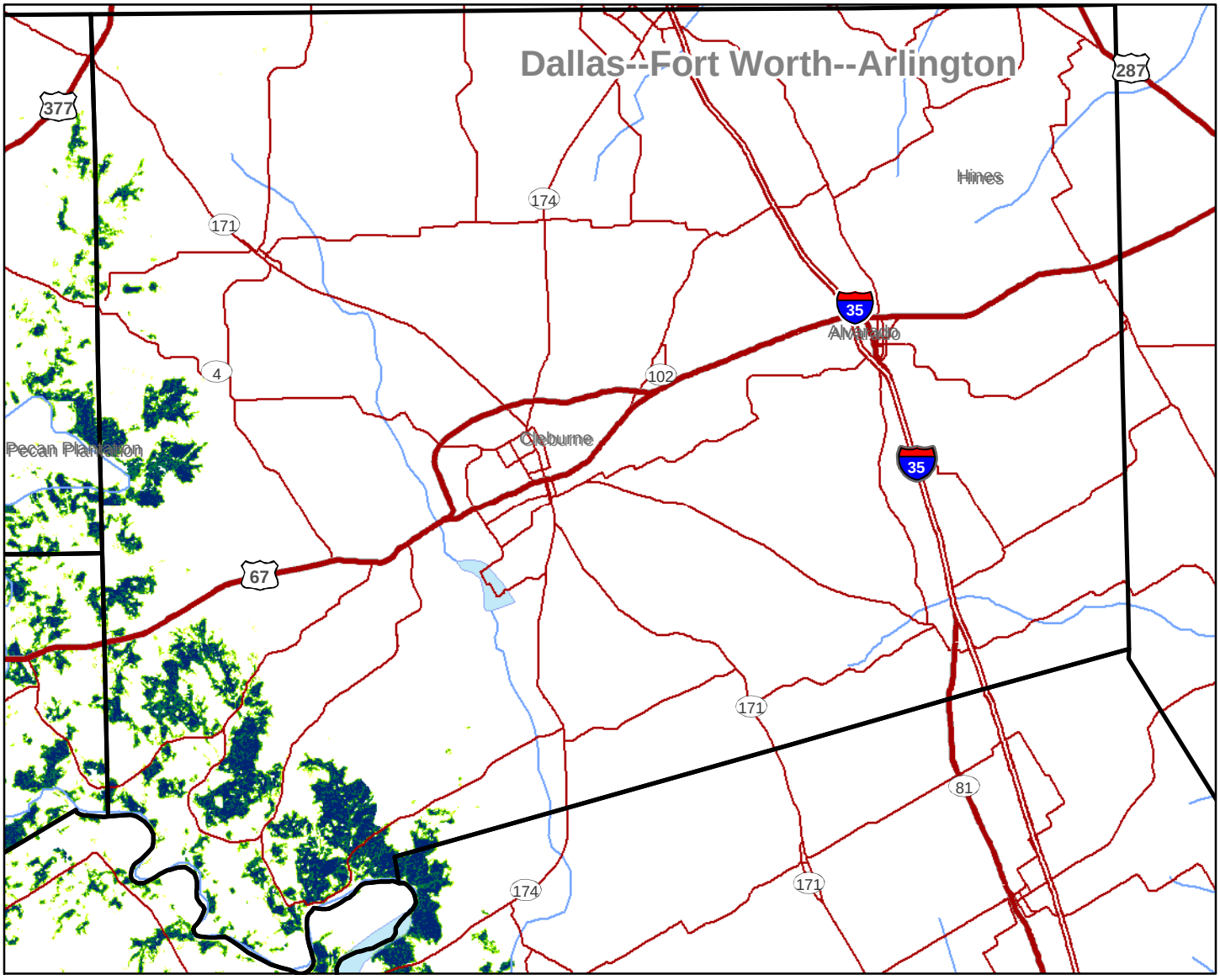
Figure 4. GCW Model D

JOHNSON COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3
- 4
- 5 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N W E S

1:307,857

0 2.5 5 10 Miles

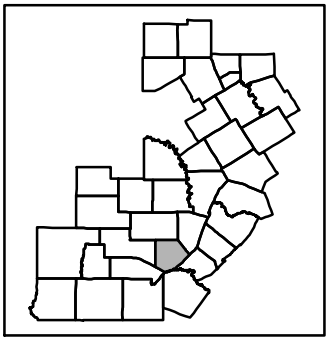
0 3.5 7 14 Kilometers

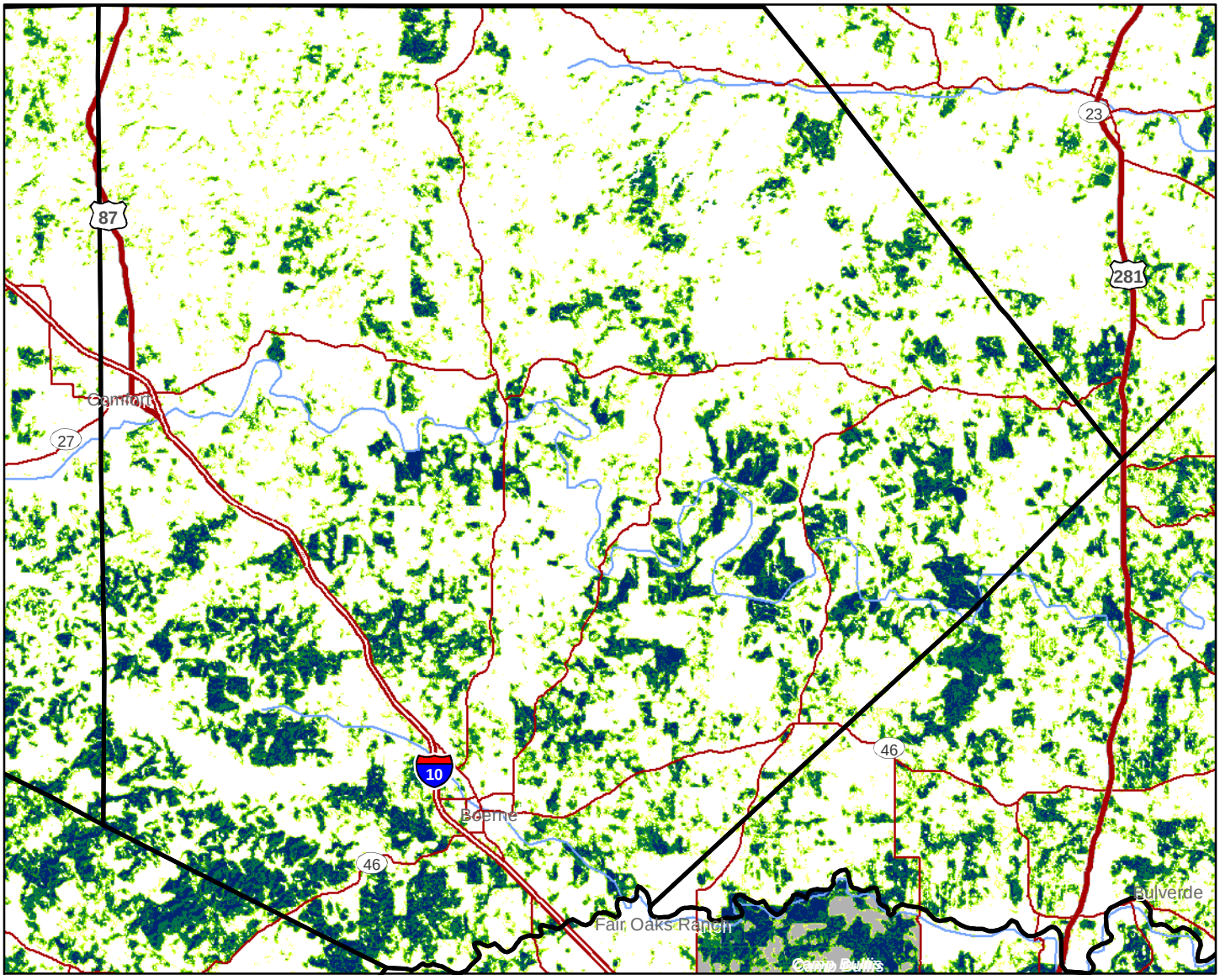
Figure 4. GCW Model D

KENDALL COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3
- 4
- 5 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

1:305,681

0 2.5 5 10 Miles

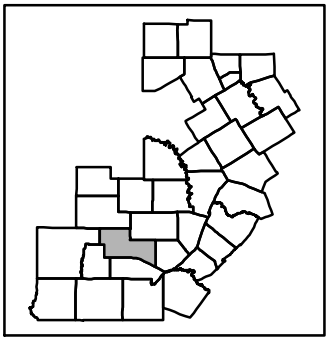
0 3.5 7 14 Kilometers

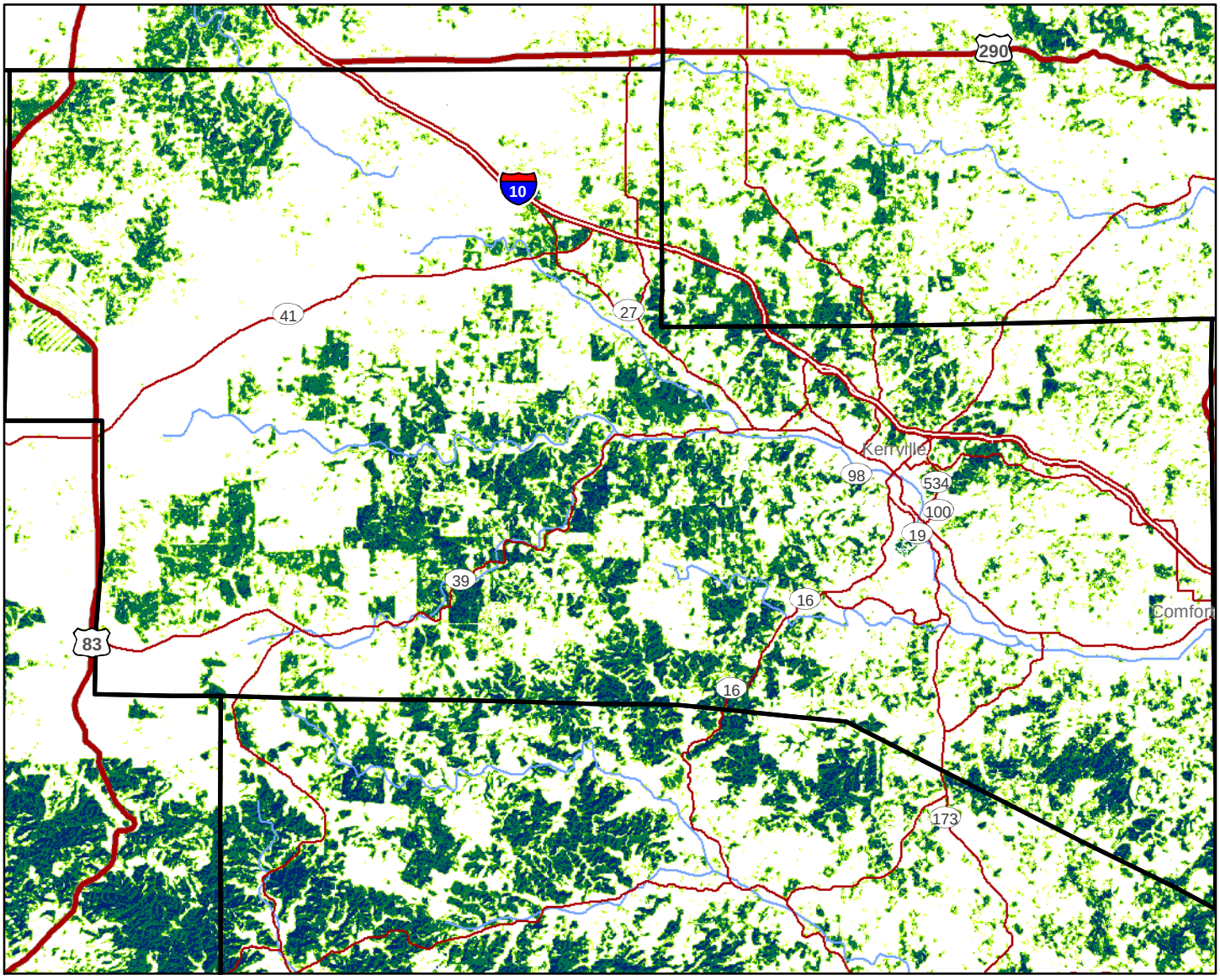
Figure 4. GCW Model D

KERR
COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3
- 4
- 5 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

1:424,453

0 3.5 7 14 Miles

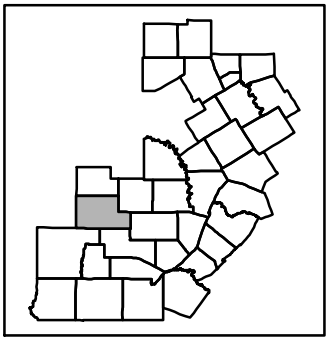
0 5 10 20 Kilometers

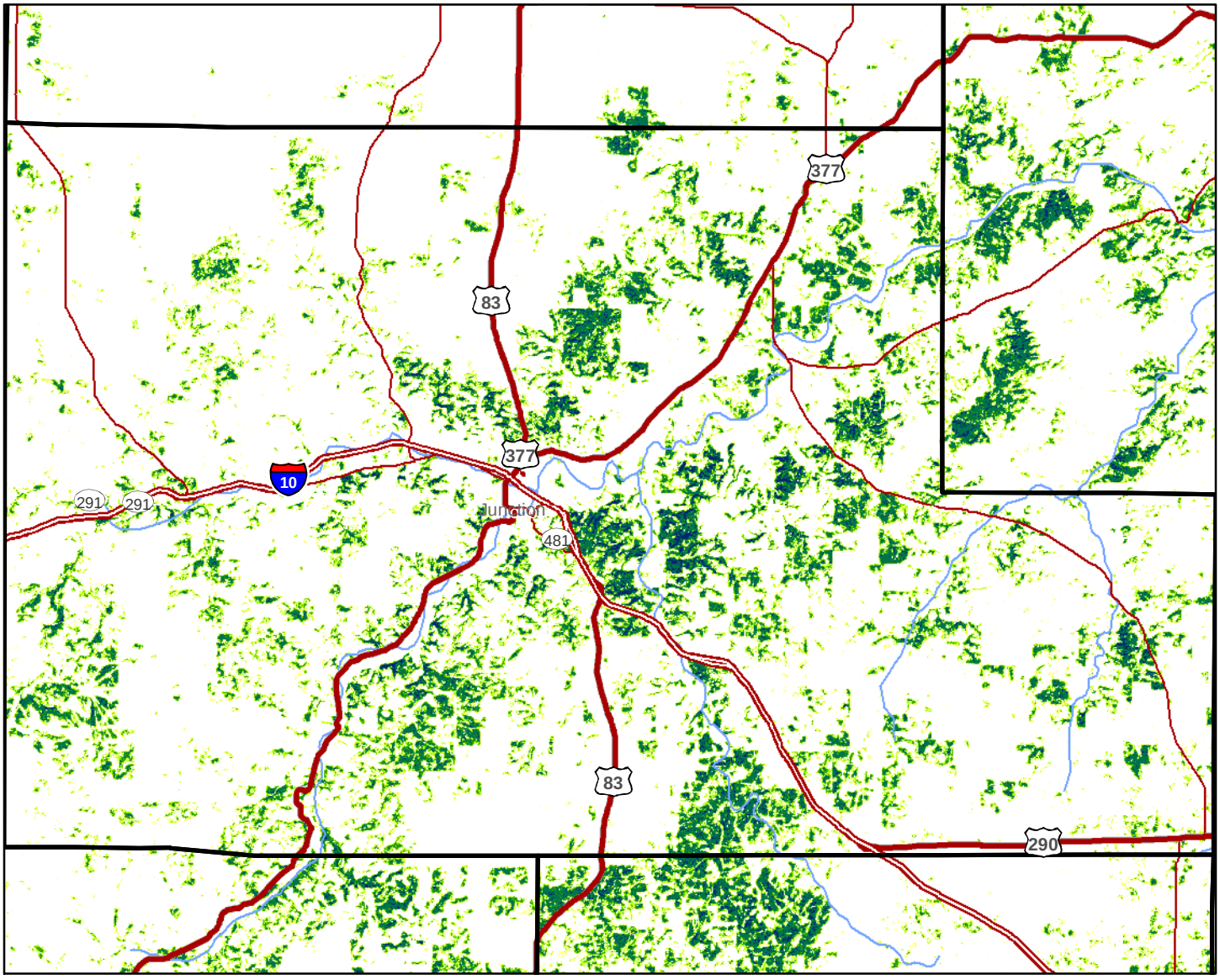
Figure 4. GCW Model D

KIMBLE
COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3
- 4
- 5 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

1:410,168

0 3.5 7 14 Miles

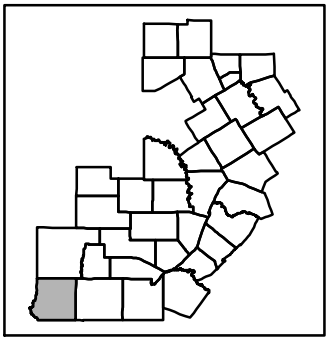
0 5 10 20 Kilometers

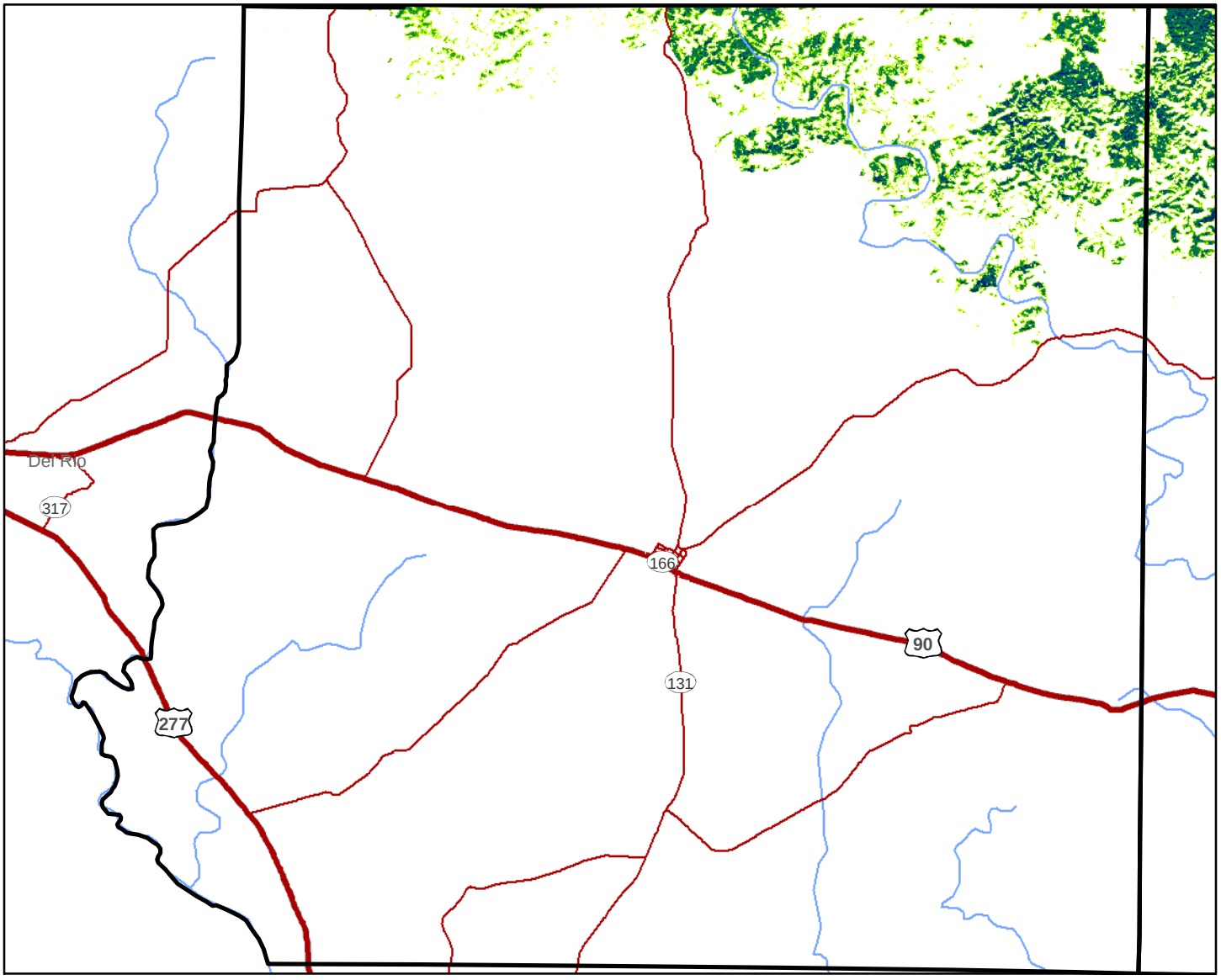
Figure 4. GCW Model D

KINNEY
COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3
- 4
- 5 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N
W E
S

1:396,413

0 3.5 7 14 Miles

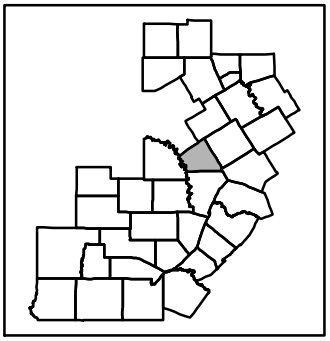
0 5 10 20 Kilometers

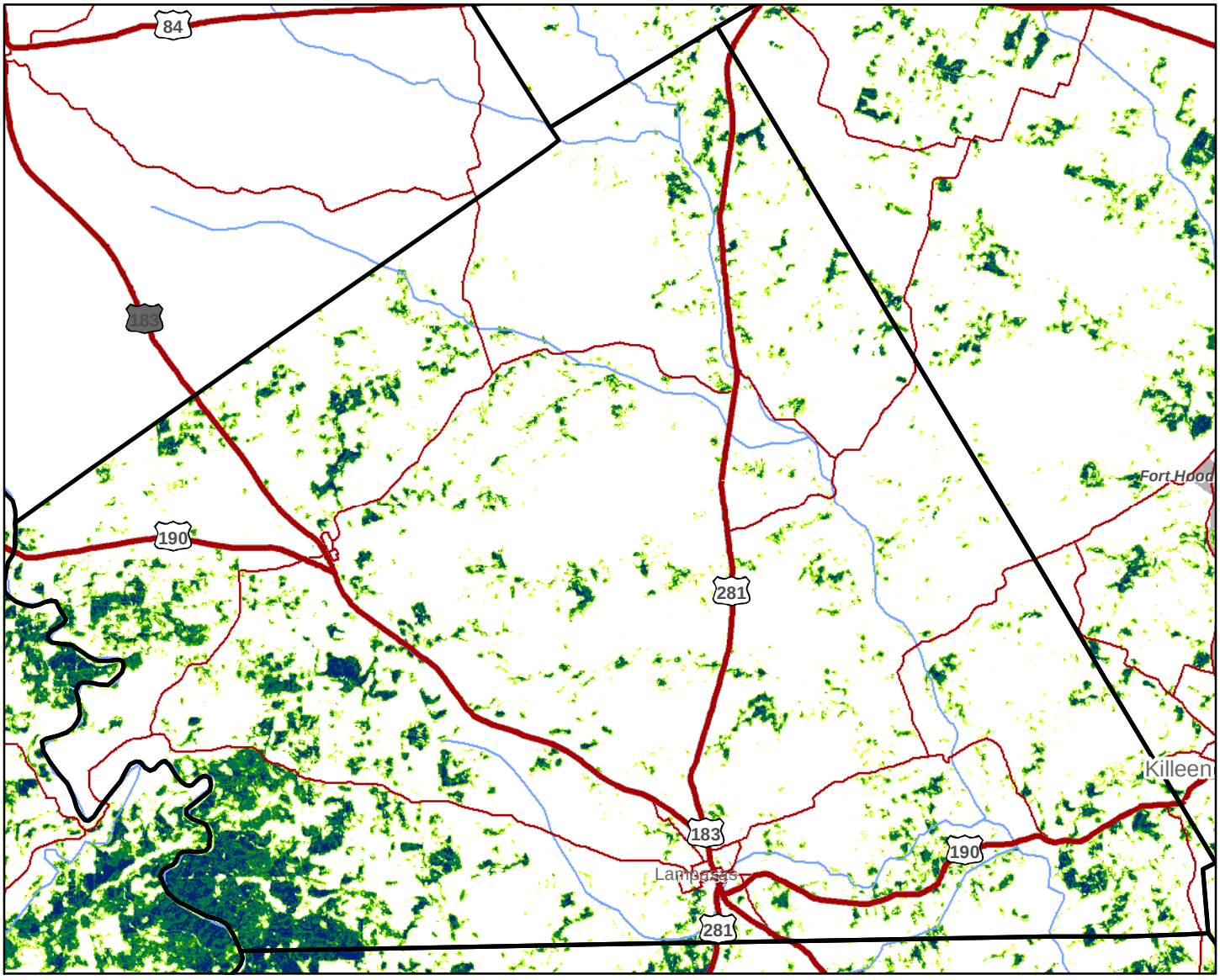
Figure 4. GCW Model D

LAMPASAS COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3
- 4
- 5 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N W E S

1:330,663

0 3 6 12 Miles

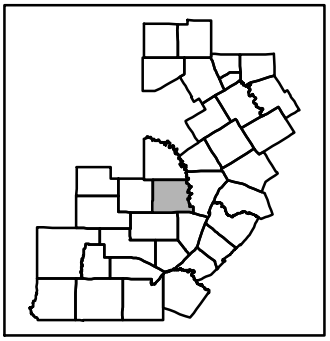
0 4 8 16 Kilometers

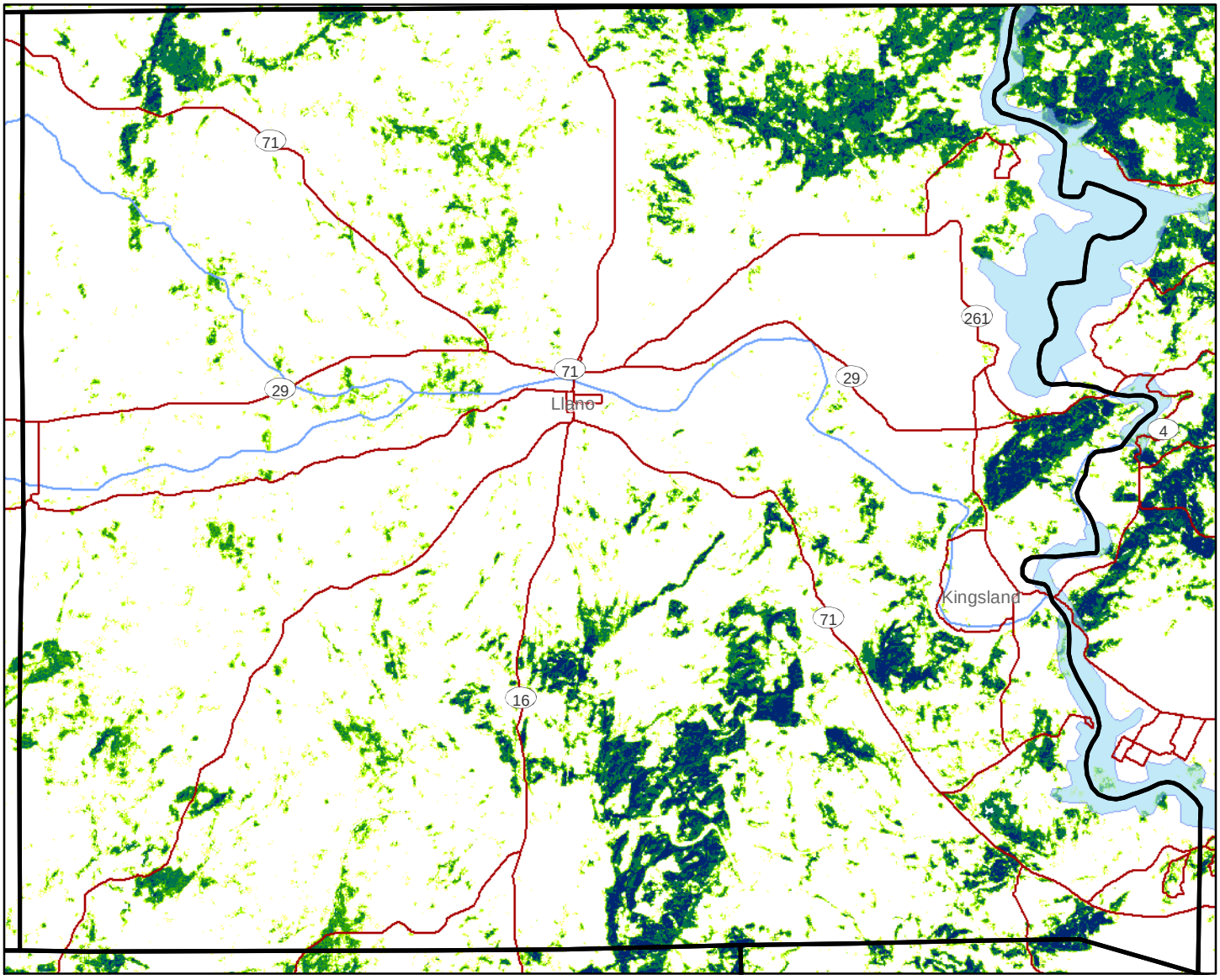
Figure 4. GCW Model D

LLANO
COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3
- 4
- 5 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N
W
E
S

1:318,007

0 3 6 12 Miles

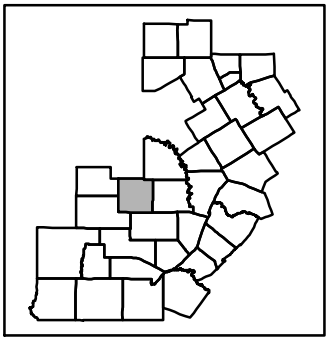
0 3.75 7.5 15 Kilometers

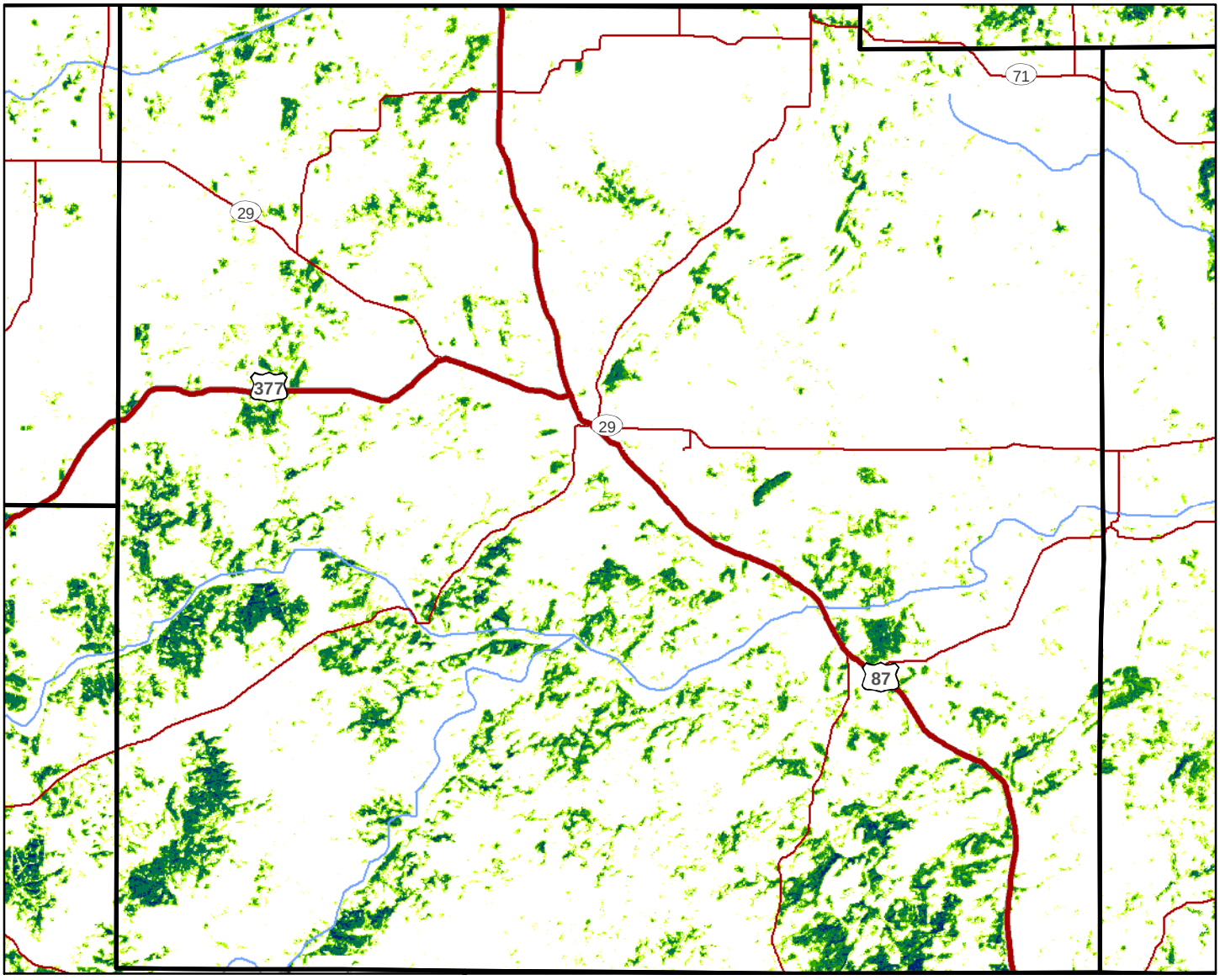
Figure 4. GCW Model D

MASON
COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3
- 4
- 5 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N
W E
S

1:322,650

0 3 6 12 Miles

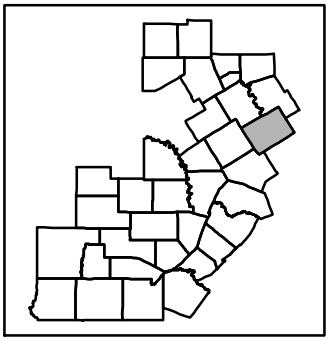
0 3.75 7.5 15 Kilometers

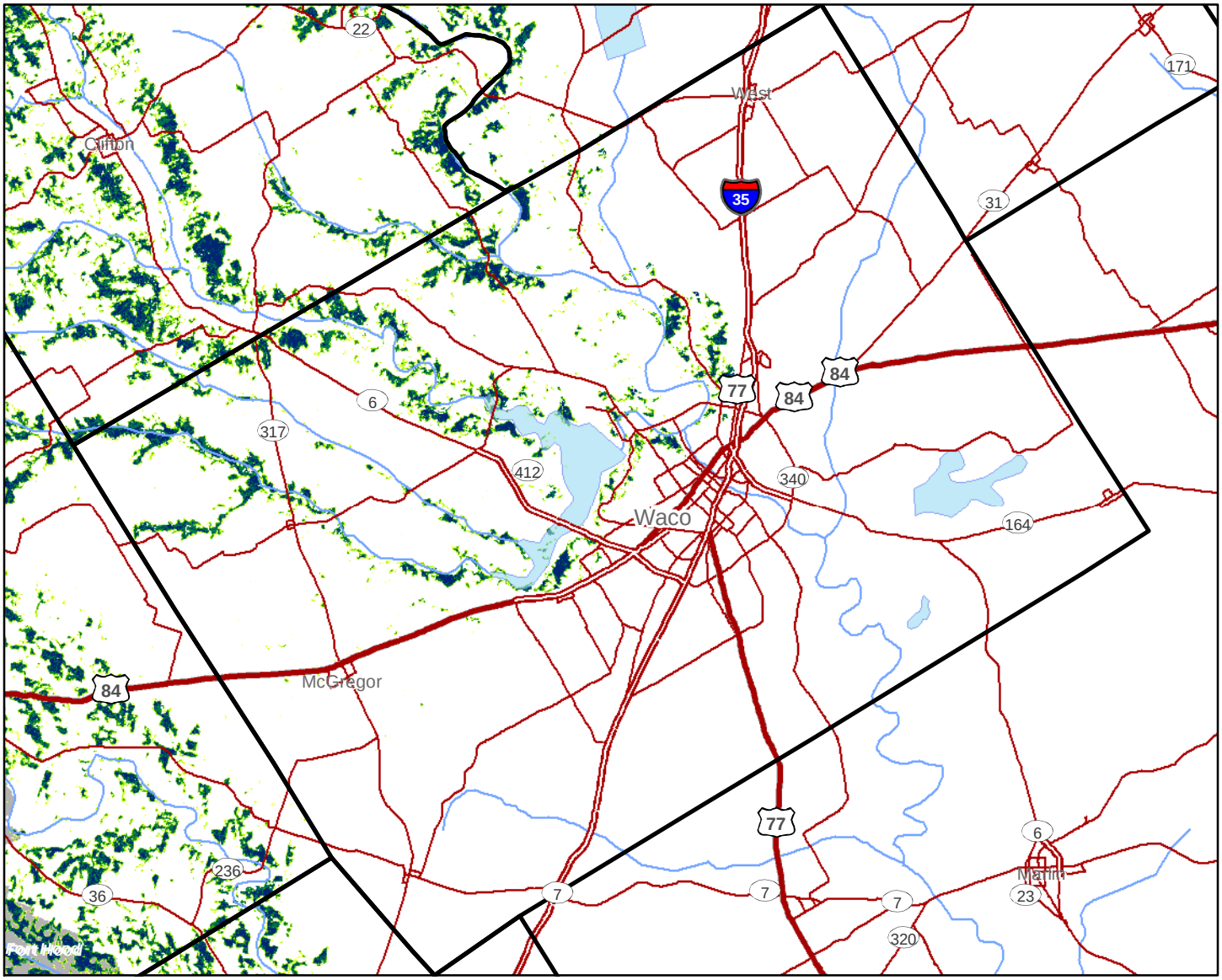
Figure 4. GCW Model D

MCLENNAN
COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3
- 4
- 5 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N
W
E
S

1:454,790

0 4 8 16 Miles

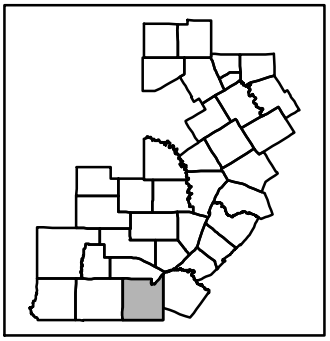
0 5 10 20 Kilometers

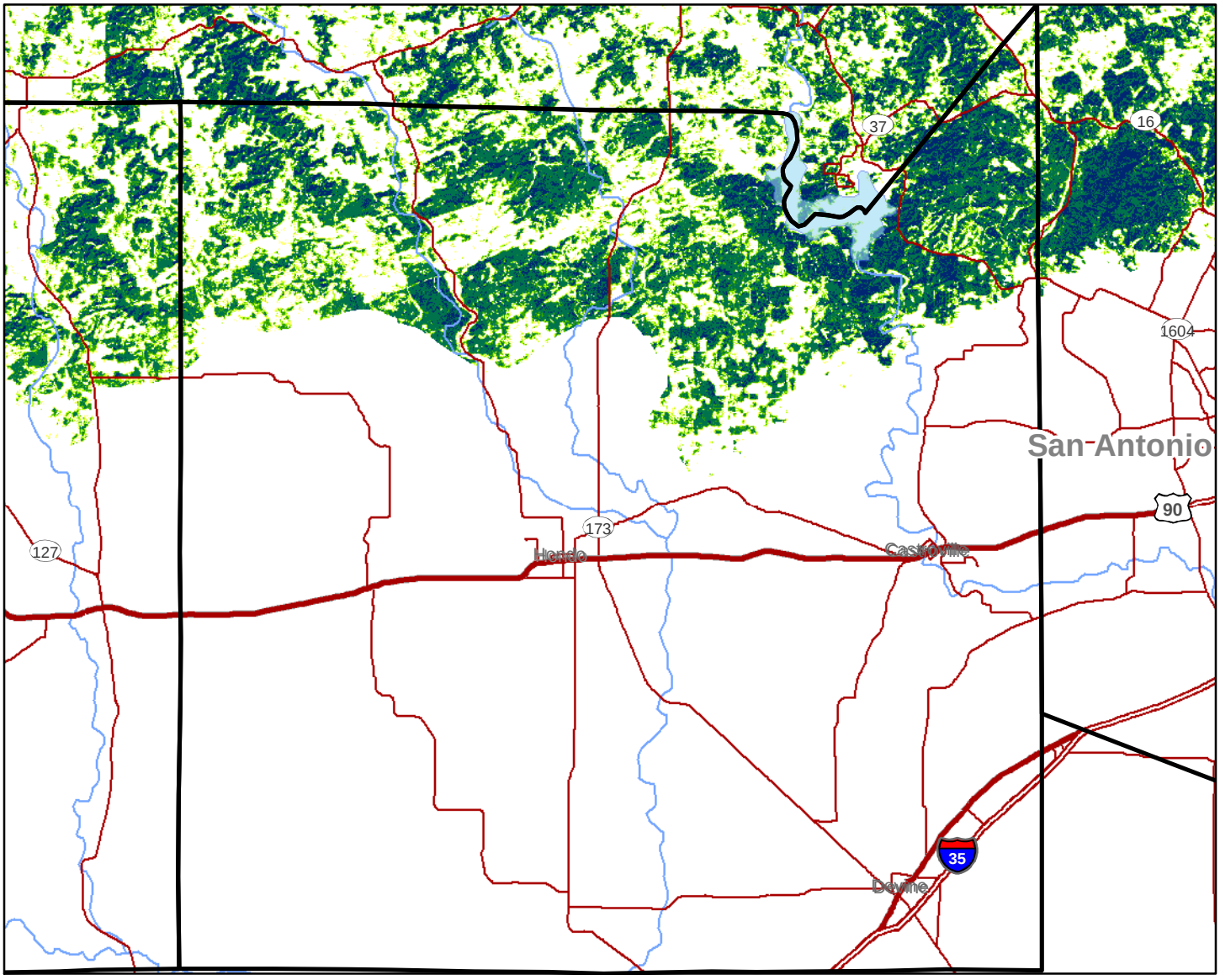
Figure 4. GCW Model D

MEDINA
COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3
- 4
- 5 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N
W E
S

1:436,612

0 3.75 7.5 15 Miles

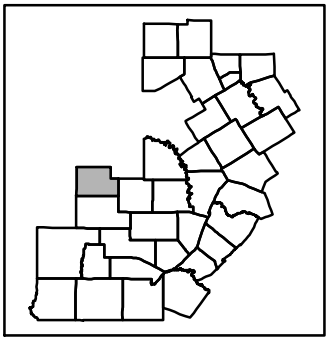
0 5 10 20 Kilometers

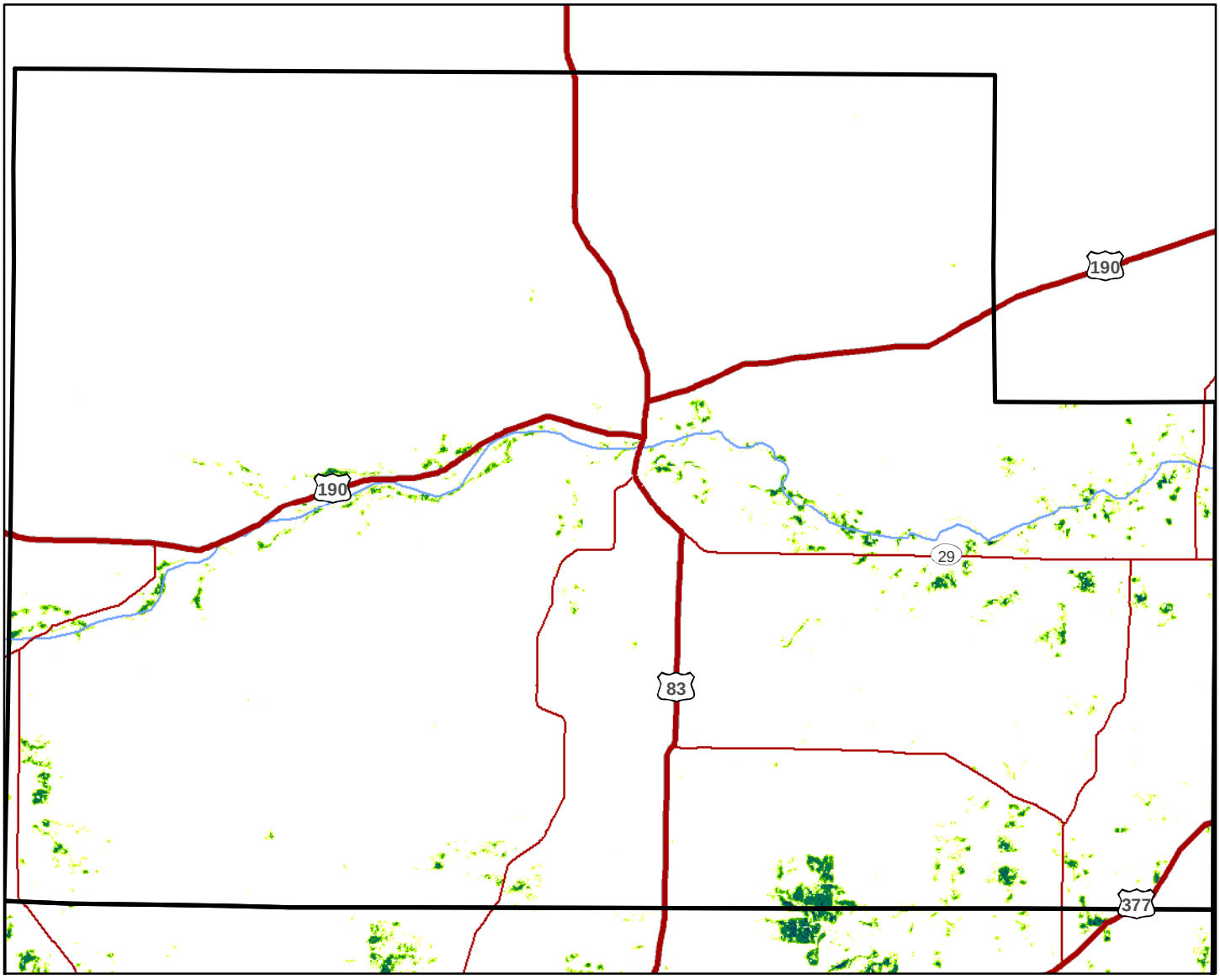
Figure 4. GCW Model D

MENARD
COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3
- 4
- 5 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N
W E
S

1:318,185

0 2.5 5 10 Miles

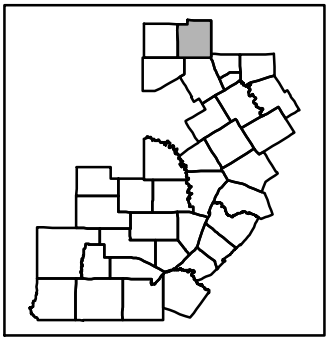
0 3.75 7.5 15 Kilometers

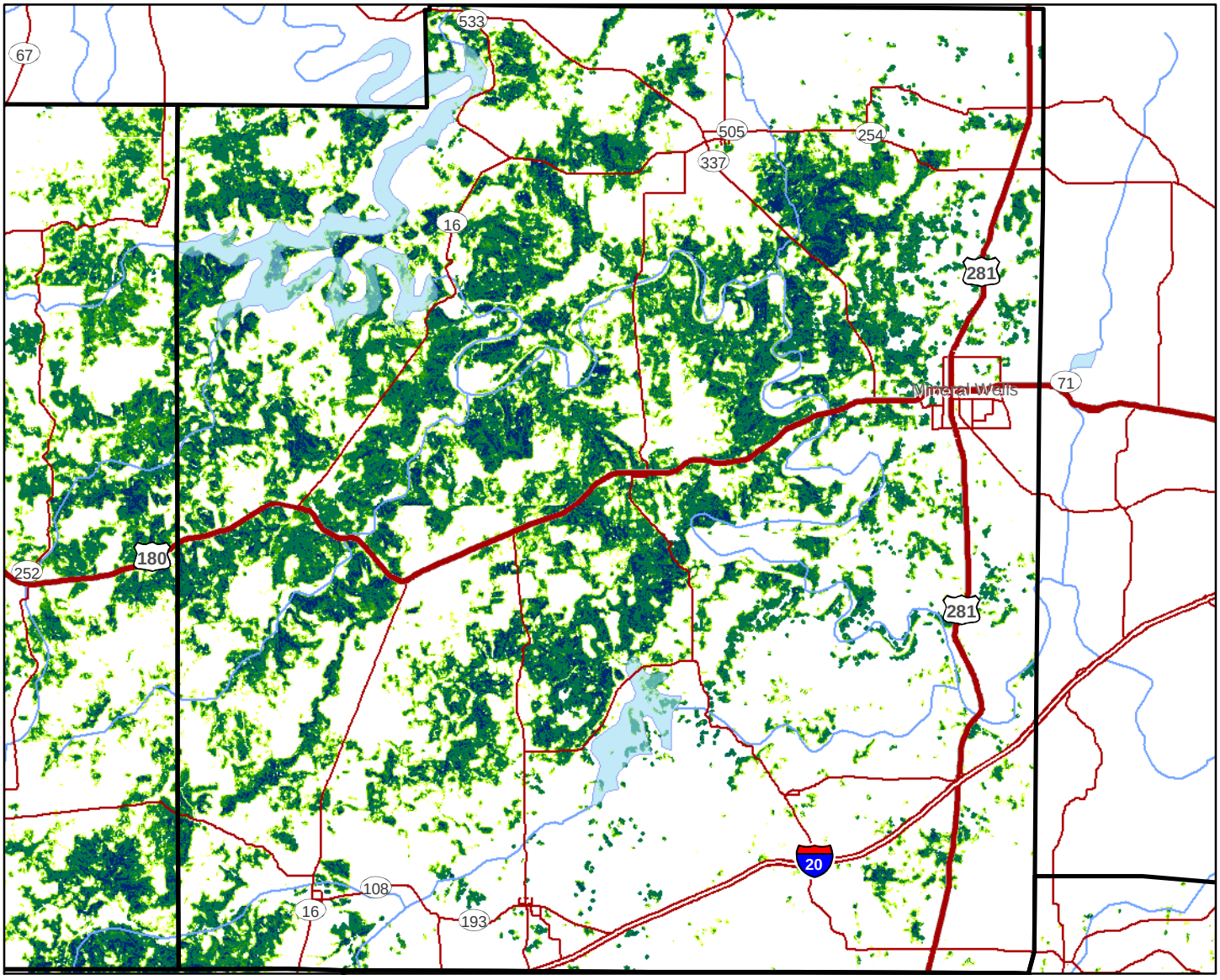
Figure 4. GCW Model D

PALO PINTO COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3
- 4
- 5 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N W E S

1:357,880

0 3 6 12 Miles

0 4 8 16 Kilometers

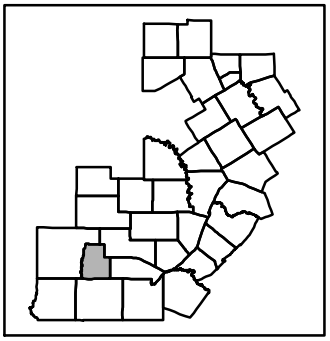
Figure 4. GCW Model D

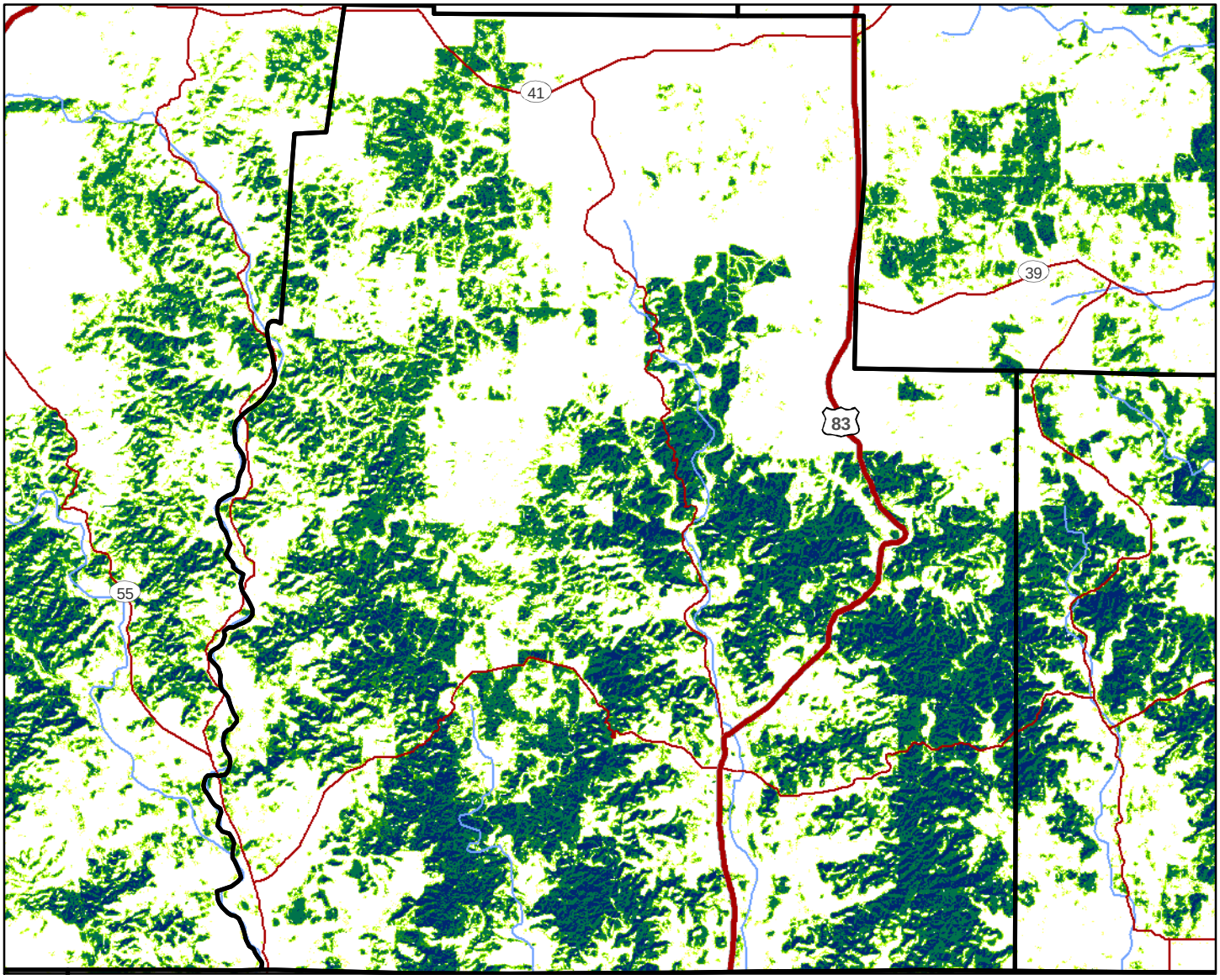
REAL

COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3
- 4
- 5 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N W E S

1:329,759

0 2.5 5 10 Miles

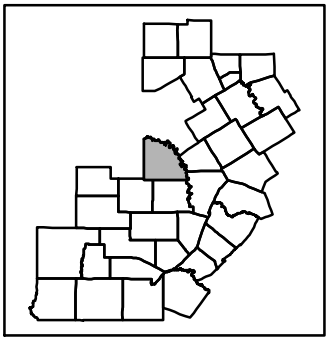
0 3.75 7.5 15 Kilometers

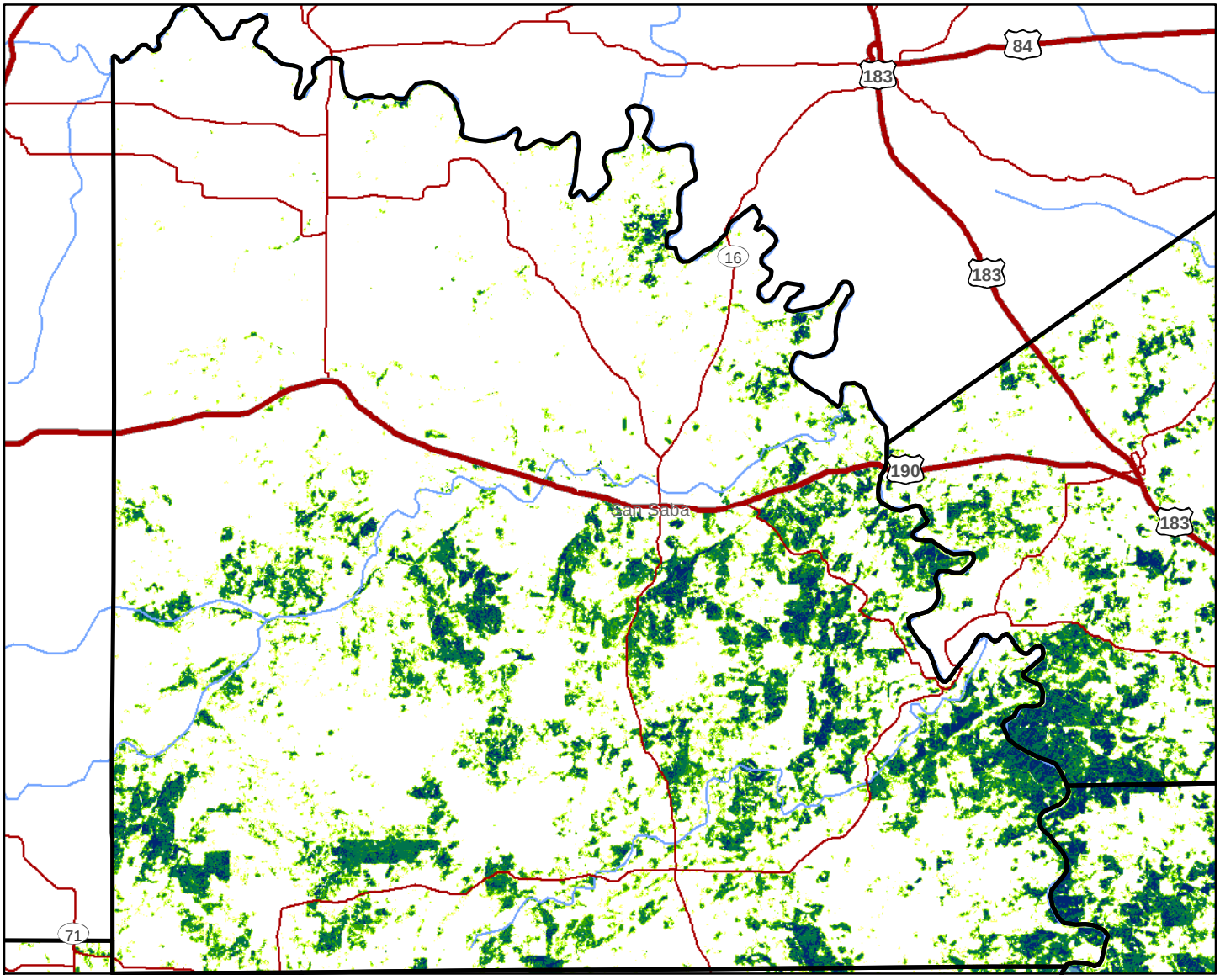
Figure 4. GCW Model D

SAN SABA COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3
- 4
- 5 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N W E S

1:414,376

0 3 6 12 Miles

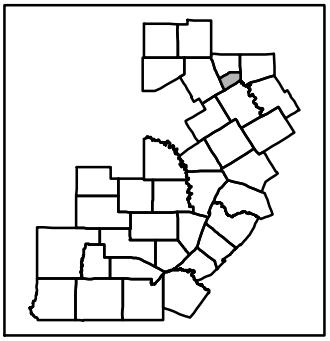
0 4.5 9 18 Kilometers

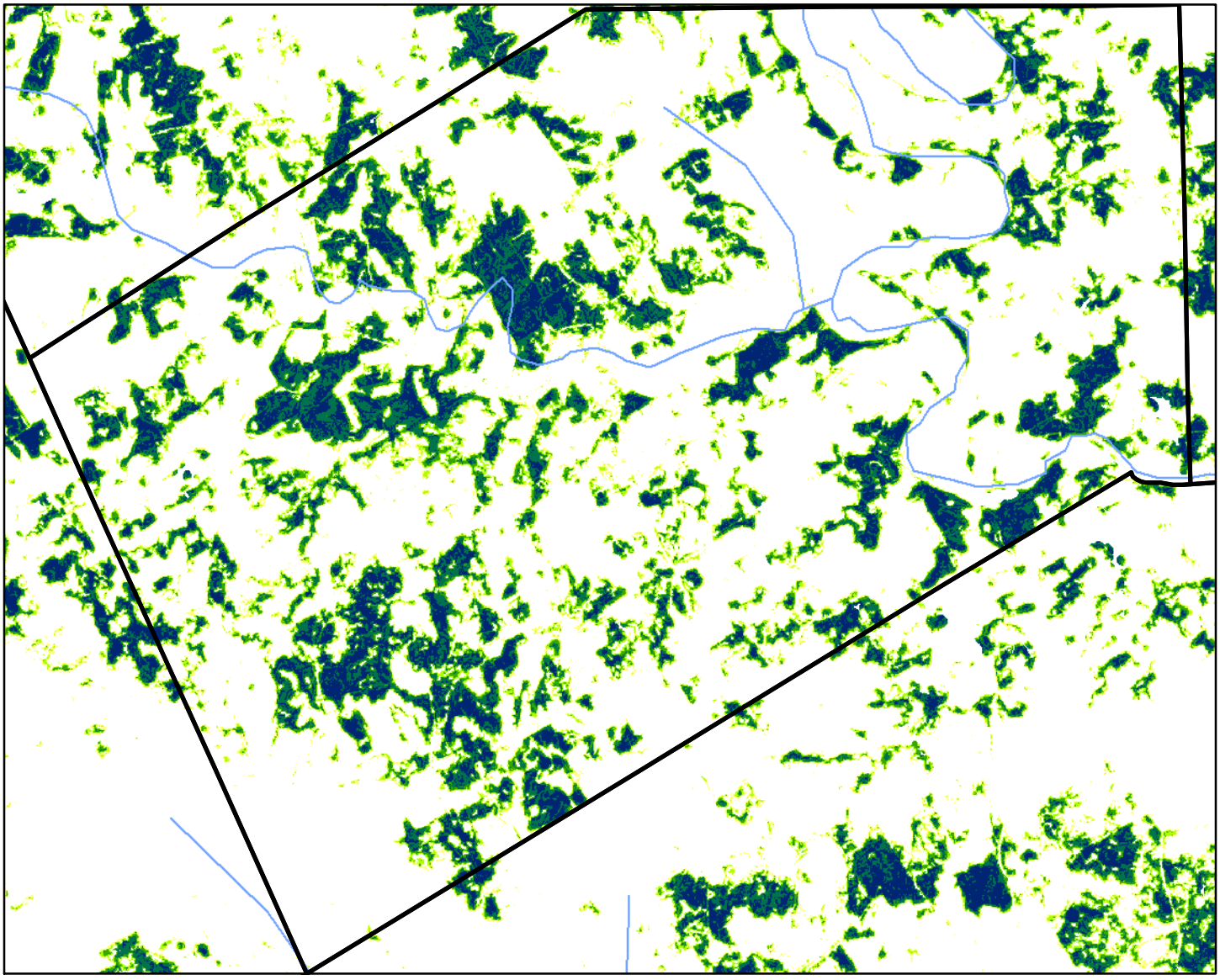
Figure 4. GCW Model D

SOMERVELL COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3
- 4
- 5 High Quality





N
W E
S

1:168,949

Legend

- County
- Stream

0 1.25 2.5 5 Miles

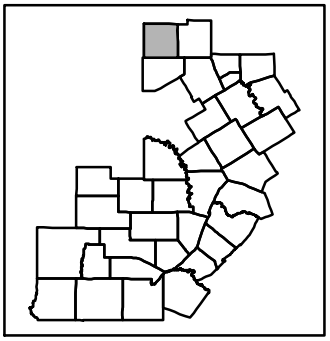
0 2 4 8 Kilometers

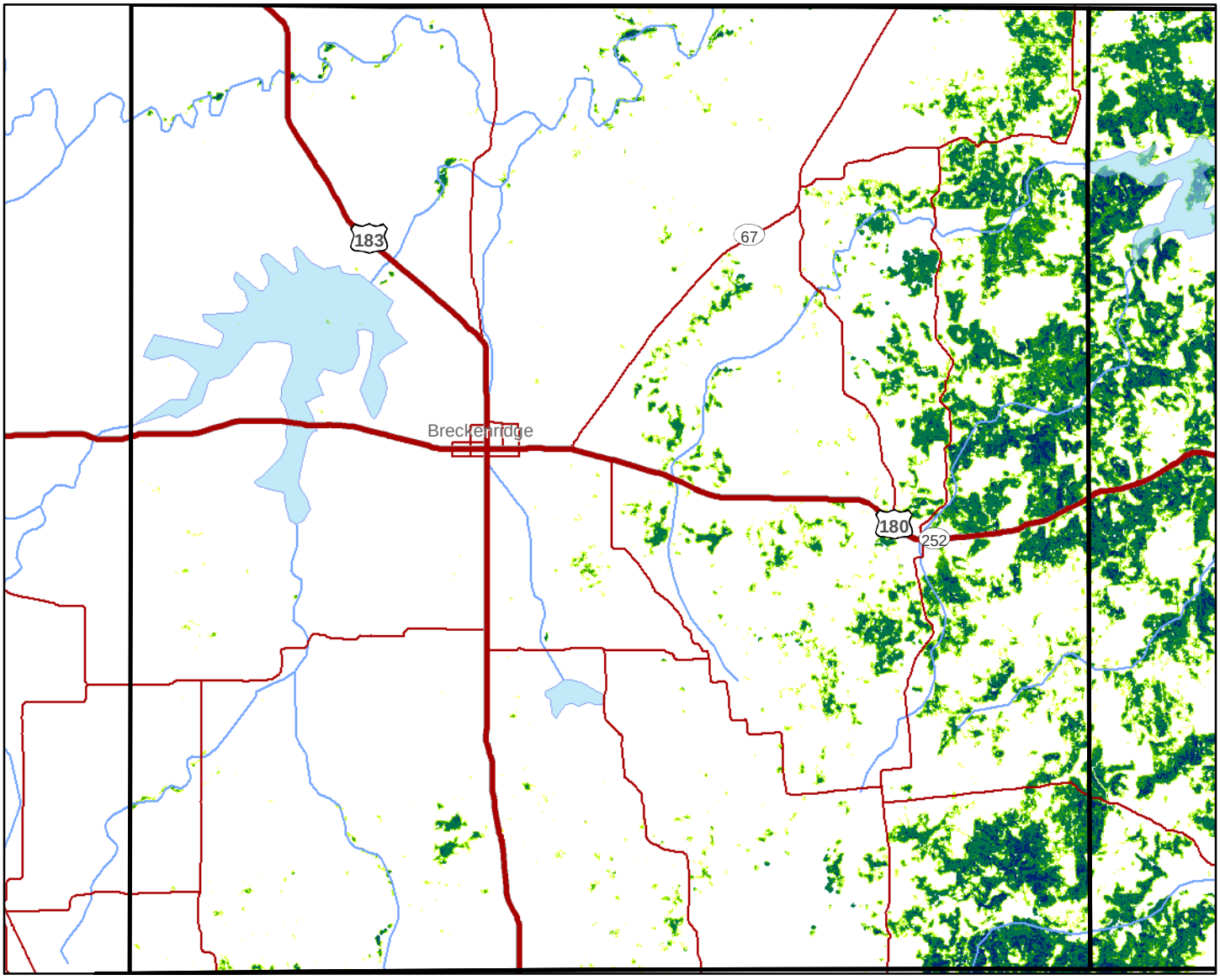
Figure 4. GCW Model D

STEPHENS
COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3
- 4
- 5 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

1:321,941

0 2.5 5 10 Miles

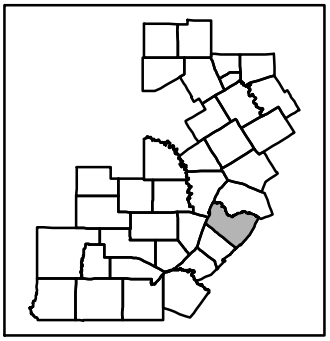
0 3.75 7.5 15 Kilometers

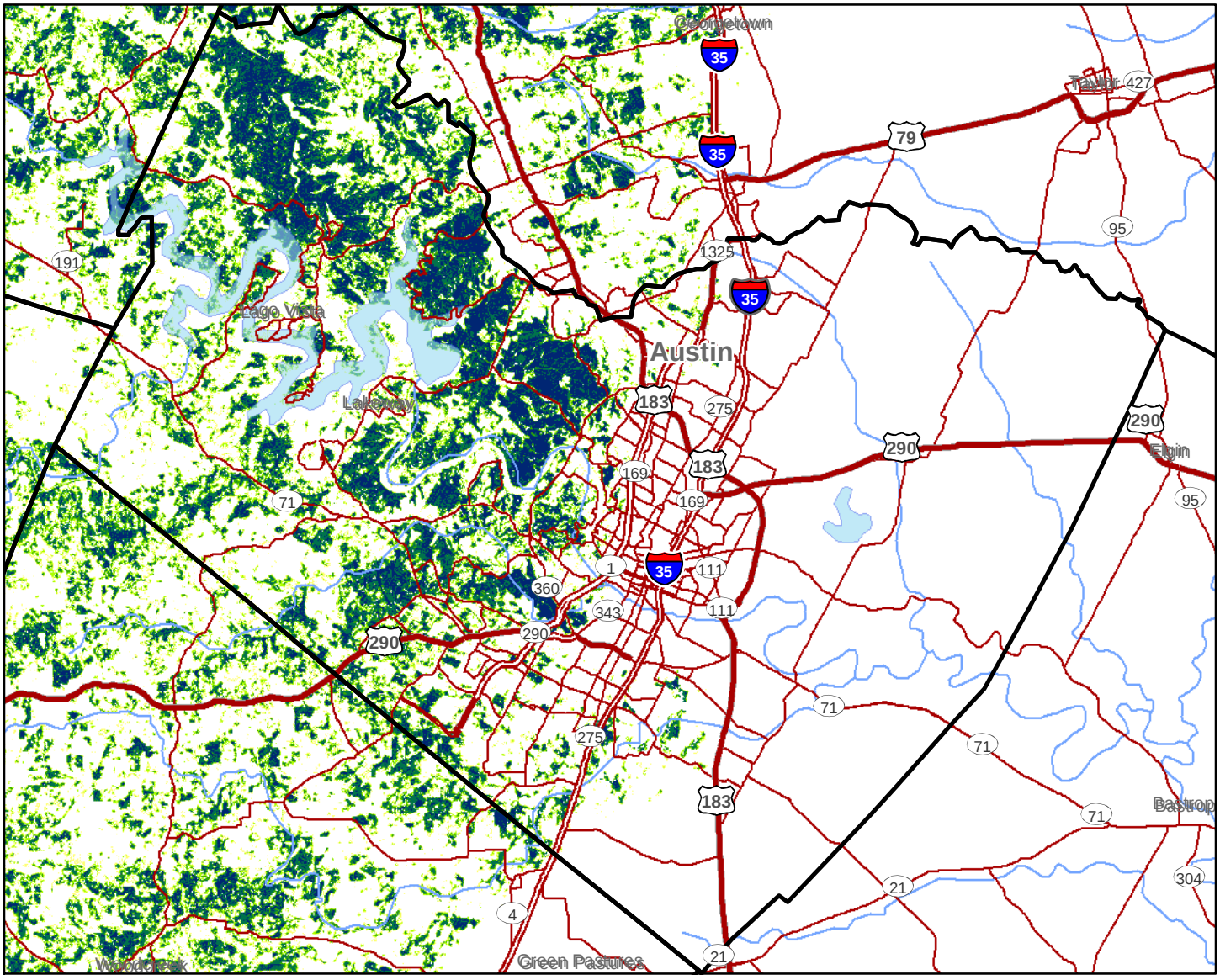
Figure 4. GCW Model D

TRAVIS
COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3
- 4
- 5 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

1:440,119

0 3.5 7 14 Miles

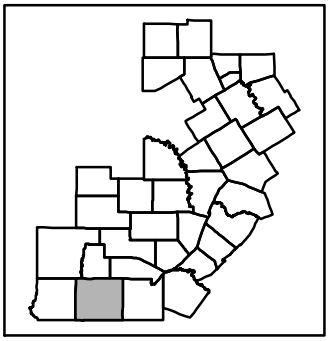
0 5 10 20 Kilometers

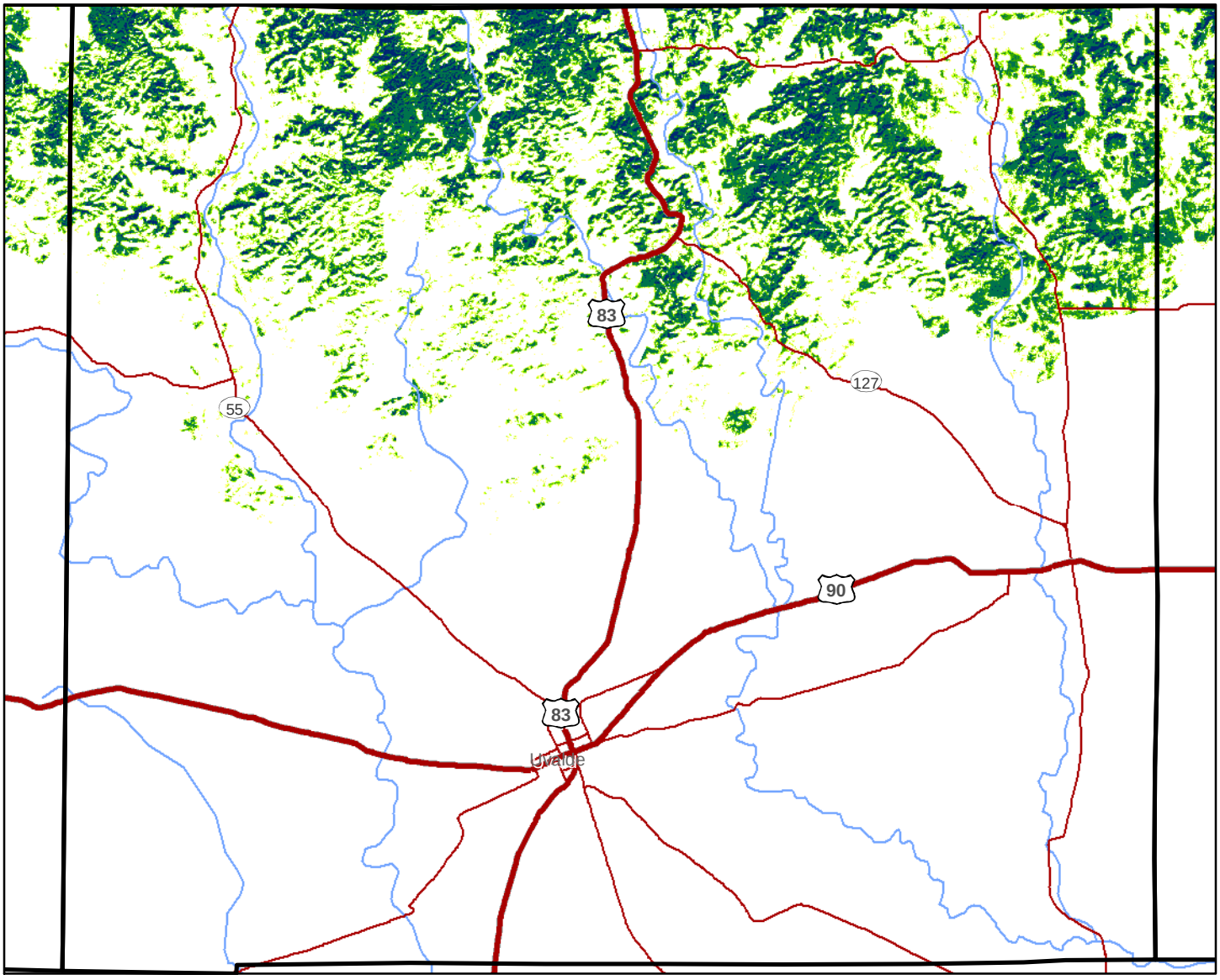
Figure 4. GCW Model D

UVALDE
COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3
- 4
- 5 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N
W E
S

1:396,913

0 3 6 12 Miles

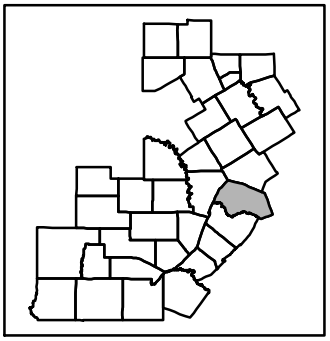
0 4.5 9 18 Kilometers

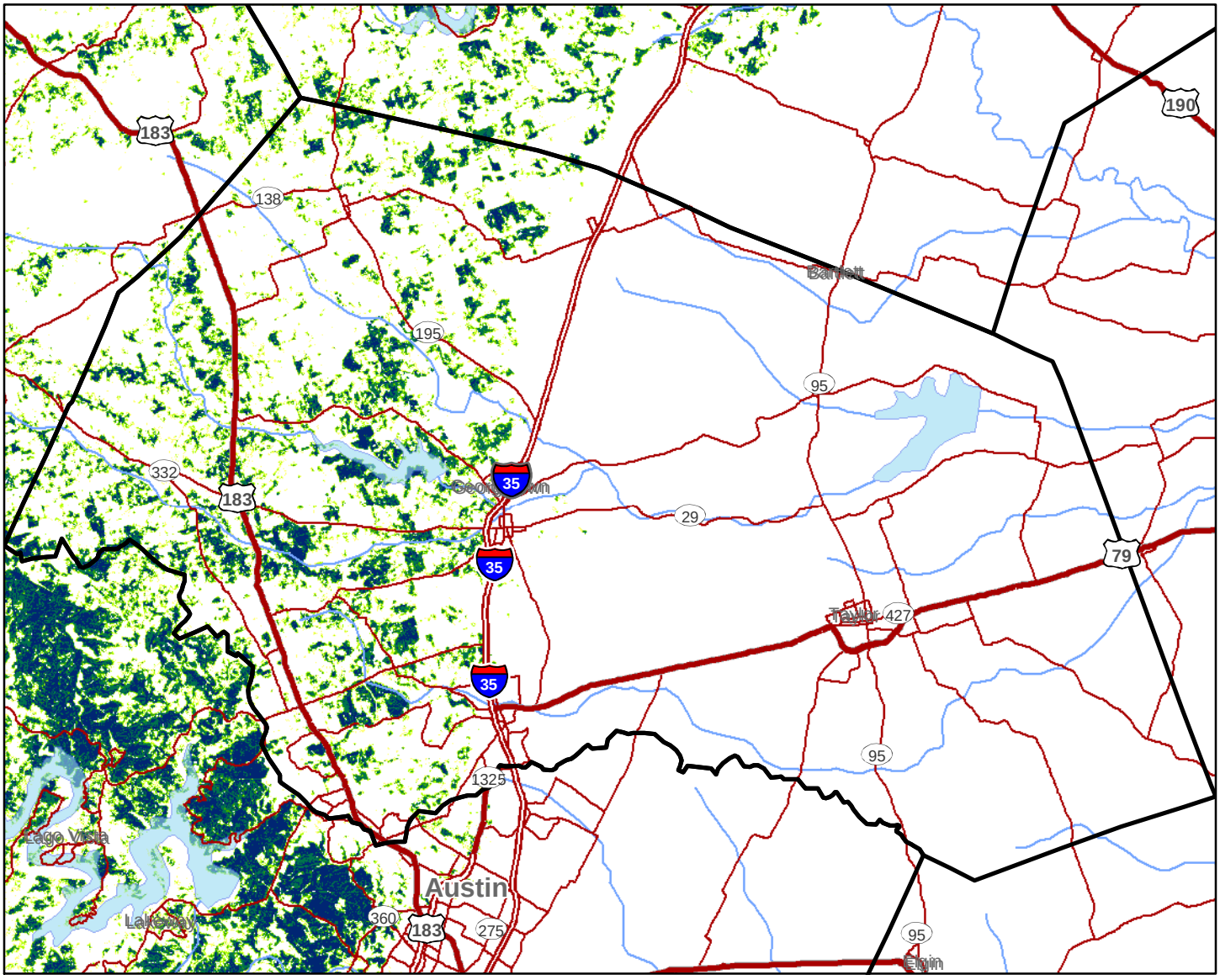
Figure 4. GCW Model D

WILLIAMSON COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3
- 4
- 5 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

1:452,765

0 3.5 7 14 Miles

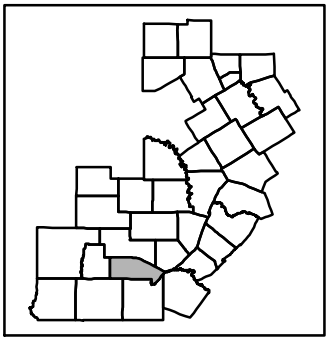
0 5 10 20 Kilometers

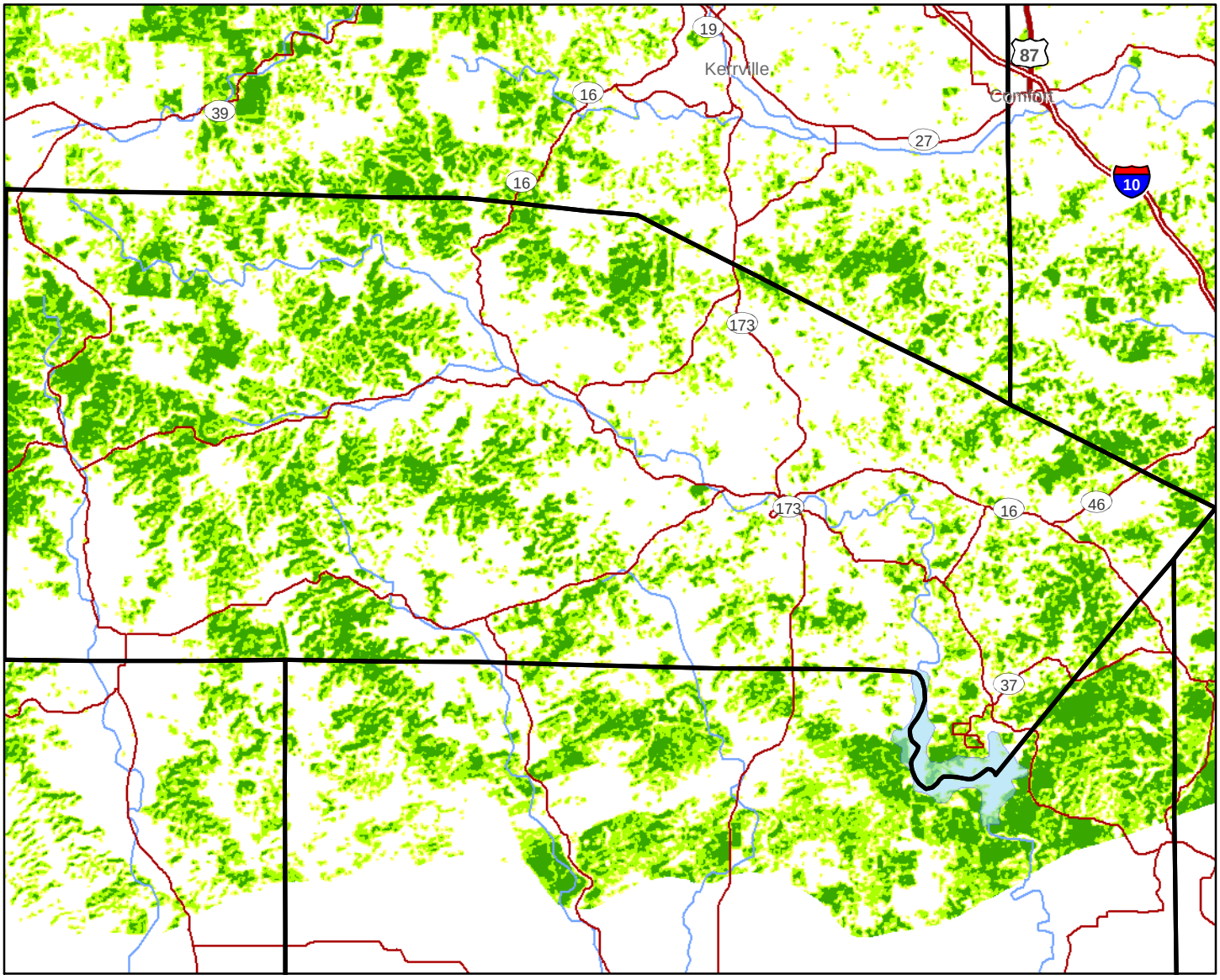
Figure 5. GCW Model L

BANDERA COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N W E S

1:420,333

0 3.5 7 14 Miles

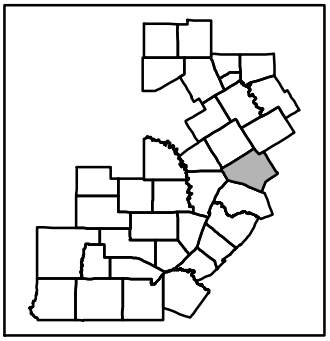
0 4.5 9 18 Kilometers

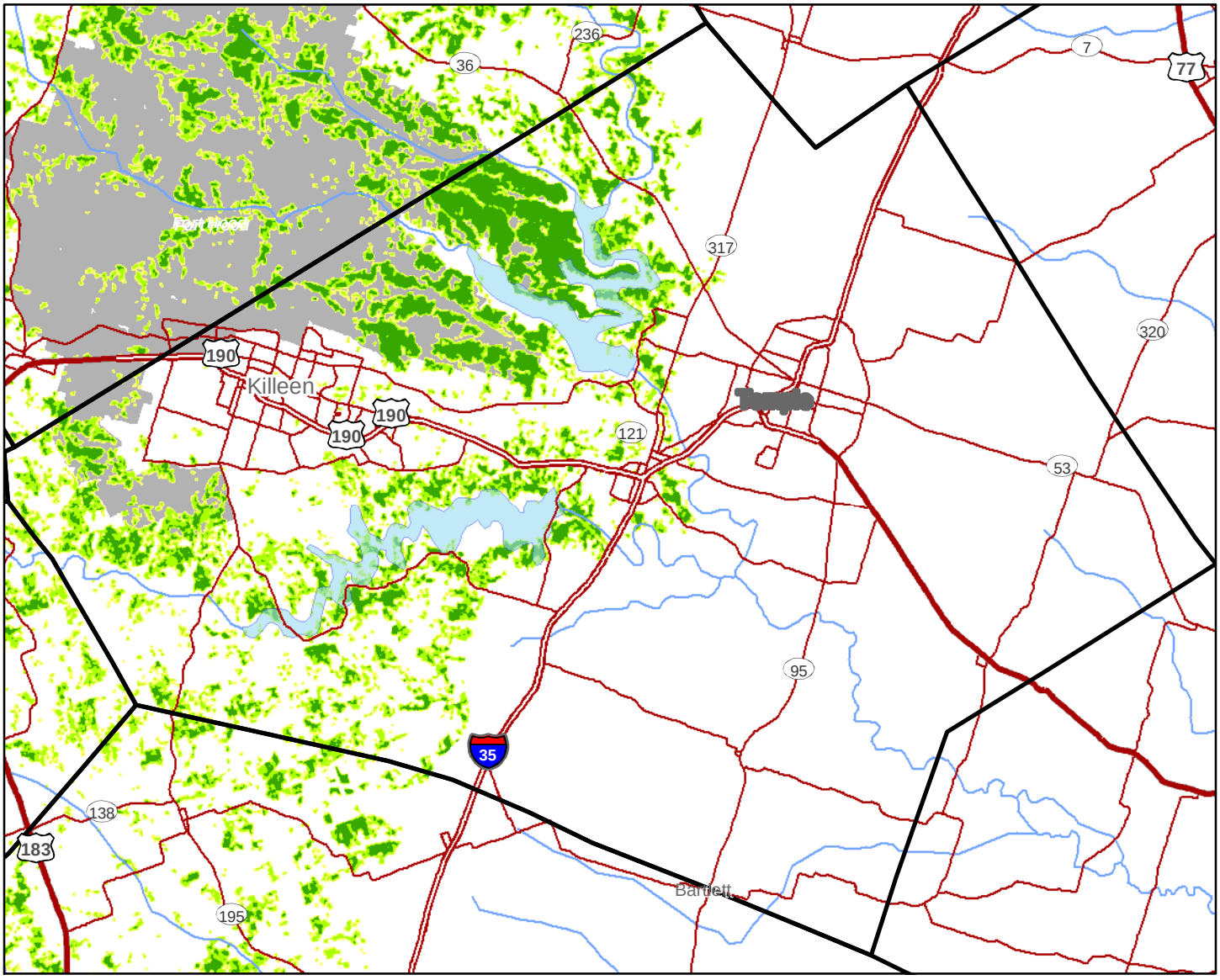
Figure 5. GCW Model L

BELL
COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

1:426,603

0 3.5 7 14 Miles

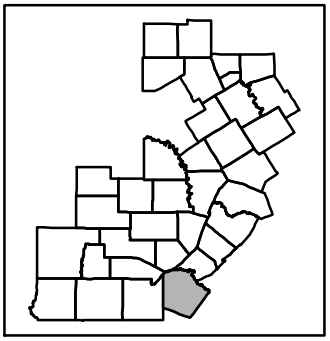
0 4.5 9 18 Kilometers

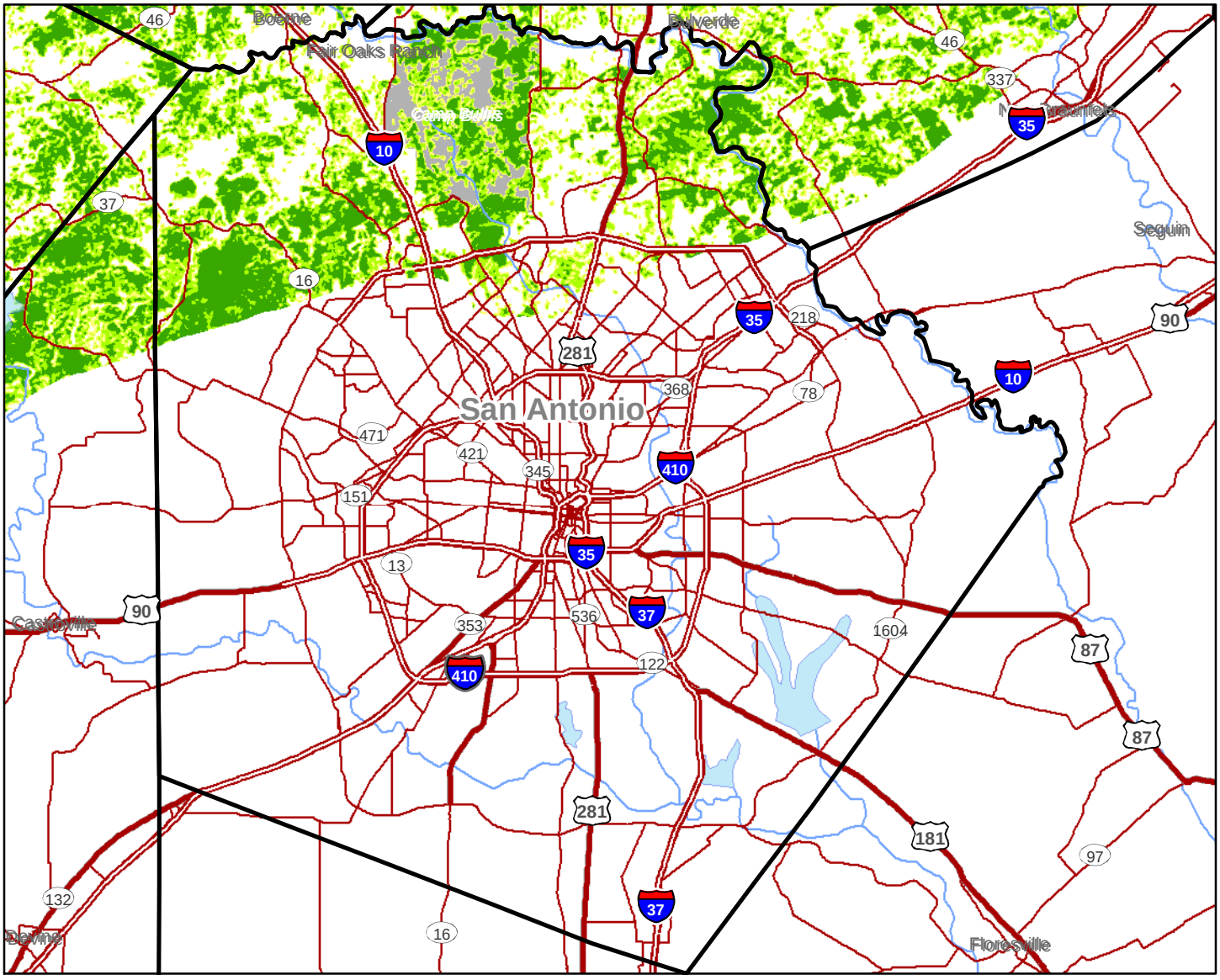
Figure 5. GCW Model L

BEXAR COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

1:467,865

0 3.75 7.5 15 Miles

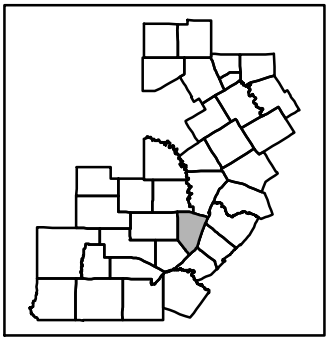
0 5 10 20 Kilometers

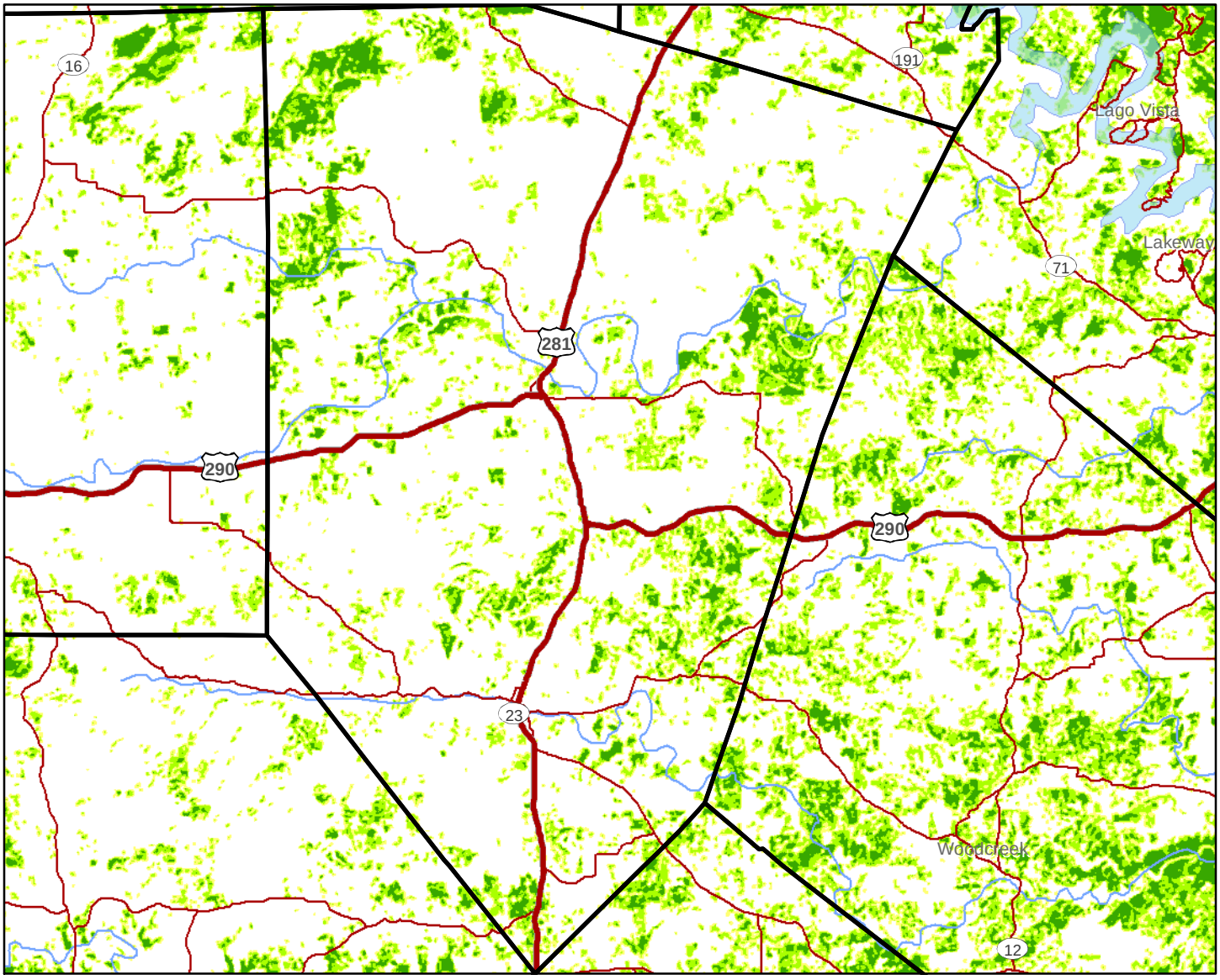
Figure 5. GCW Model L

BLANCO COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N
W
E
S

1:408,826

0 3.5 7 14 Miles

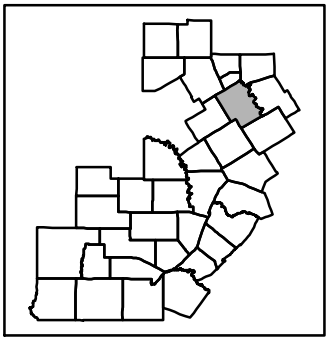
0 4.5 9 18 Kilometers

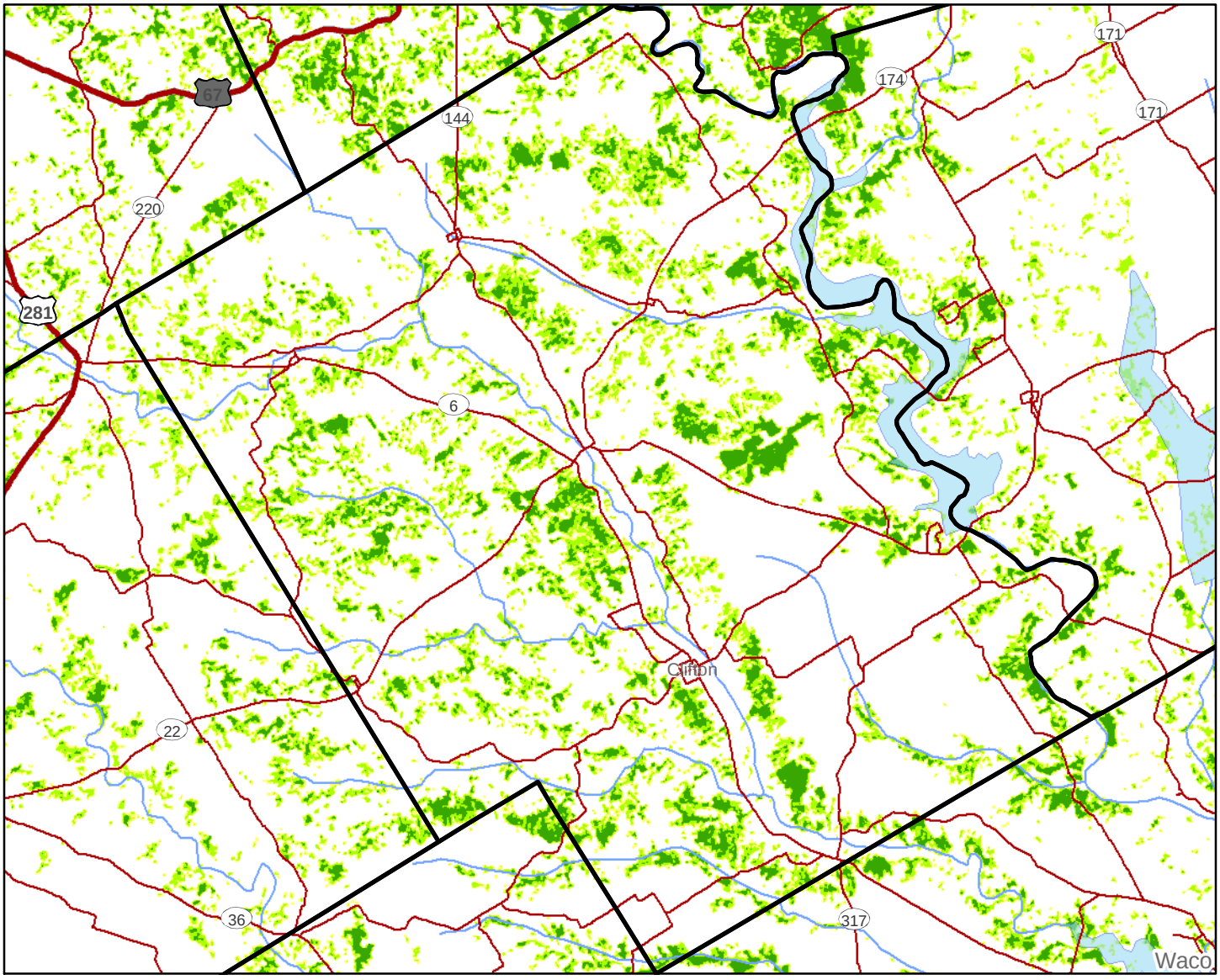
Figure 5. GCW Model L

BOSQUE
COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N
W
E
S

1:450,274

0 3.75 7.5 15 Miles

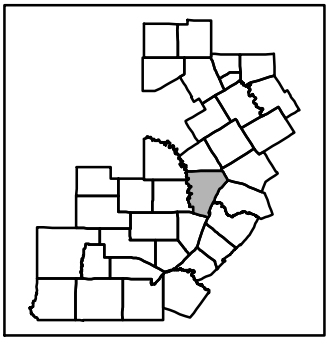
0 5 10 20 Kilometers

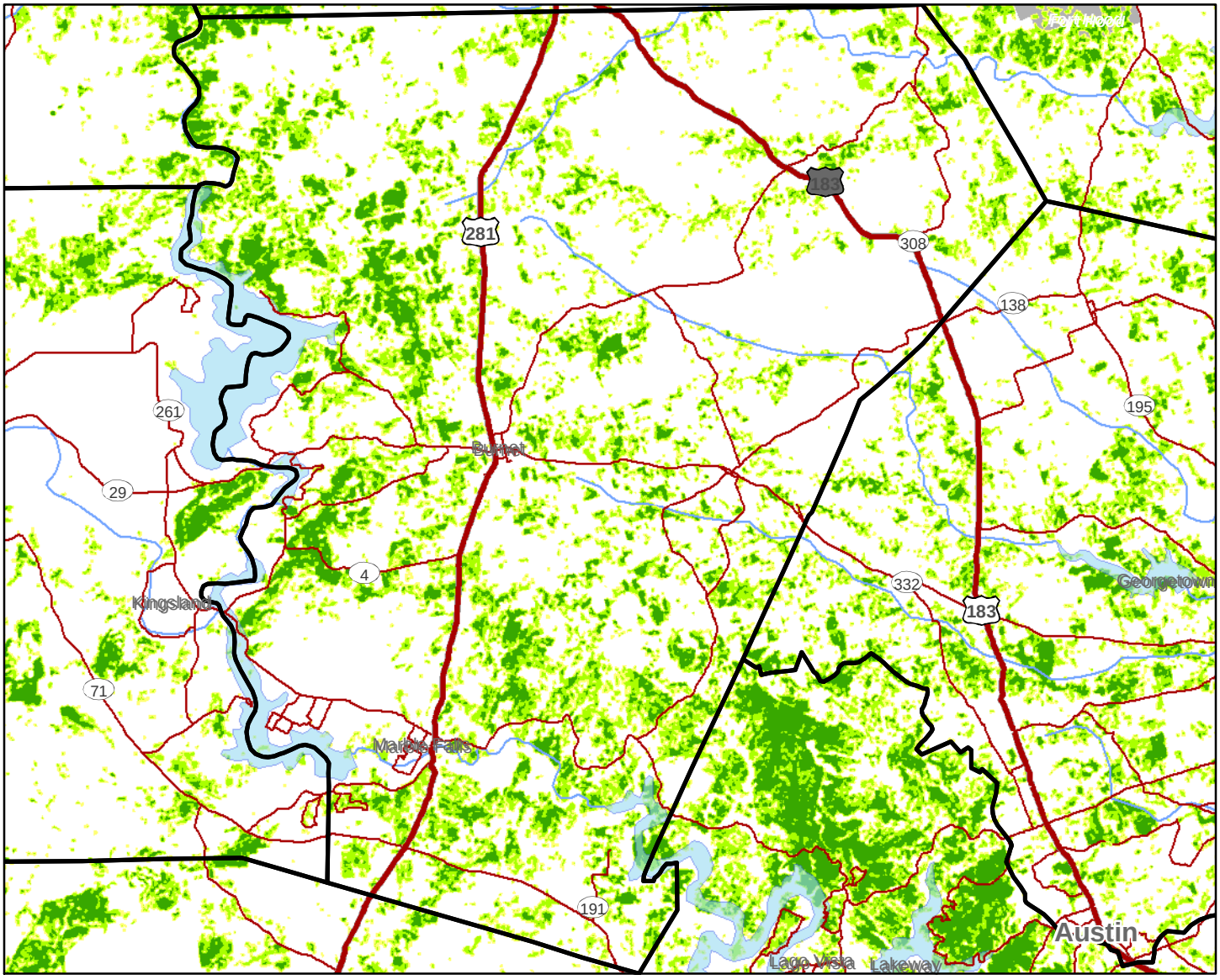
Figure 5. GCW Model L

BURNET
COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

1:443,072

0 3.75 7.5 15 Miles

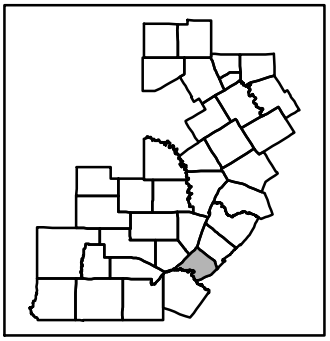
0 5 10 20 Kilometers

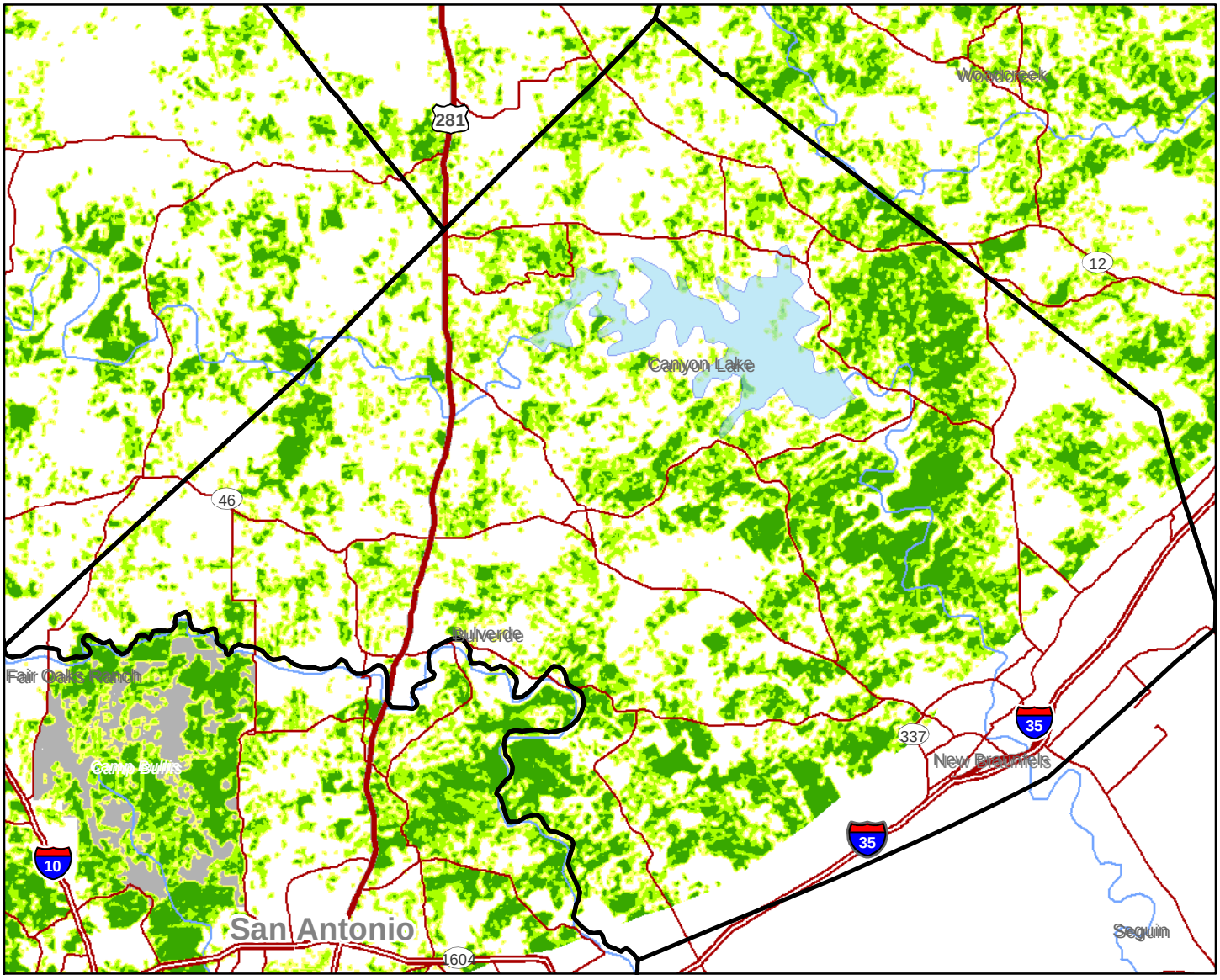
Figure 5. GCW Model L

COMAL
COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N
W E
S

1:328,003

0 2.5 5 10 Miles

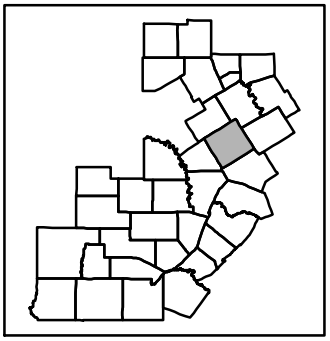
0 3.75 7.5 15 Kilometers

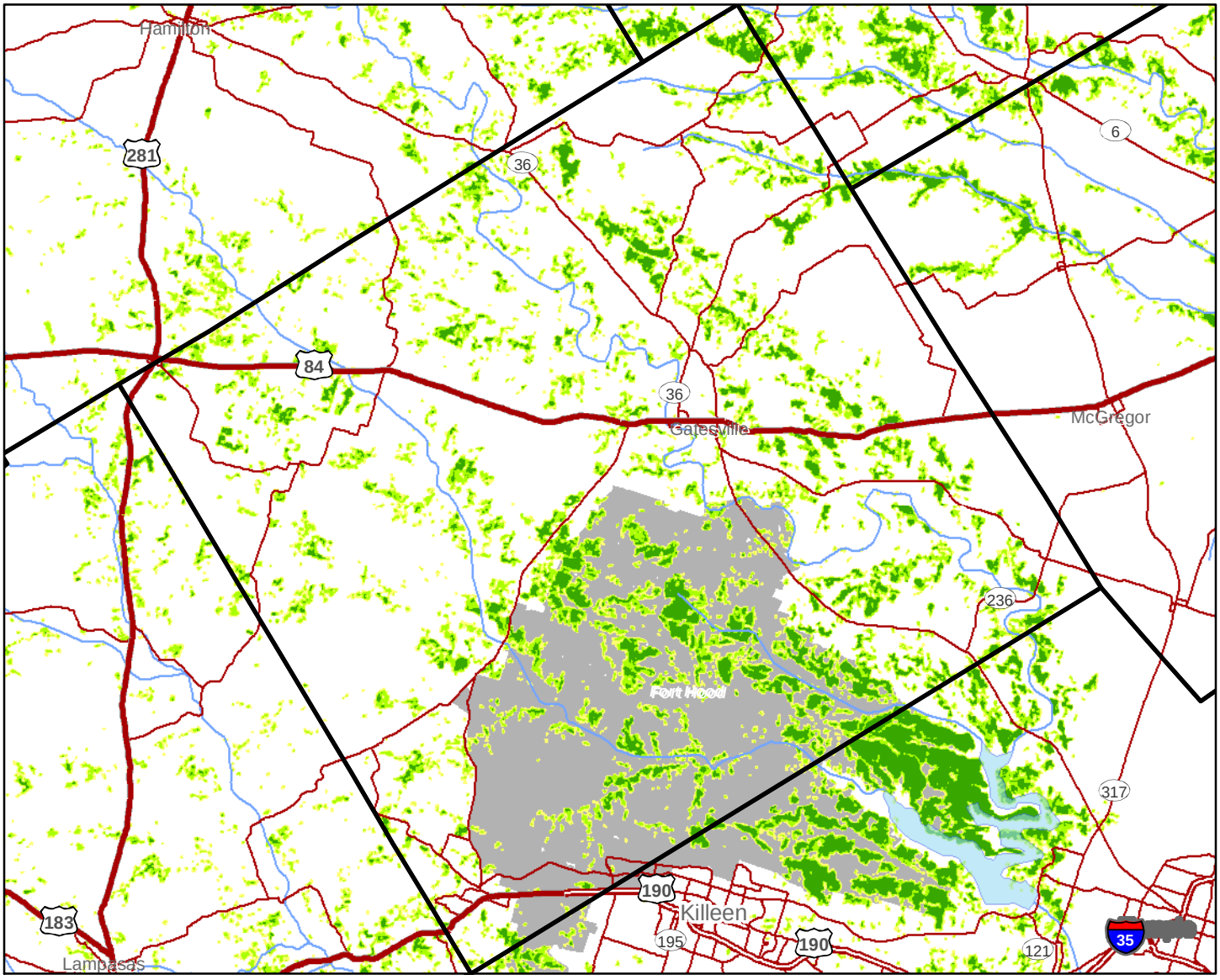
Figure 5. GCW Model L

CORYELL COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N W E S

1:469,250

0 3.5 7 14 Miles

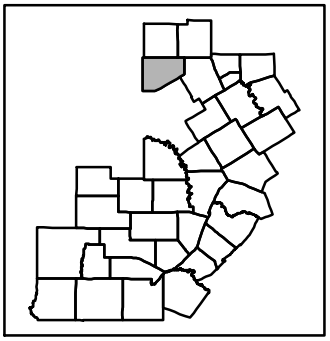
0 5 10 20 Kilometers

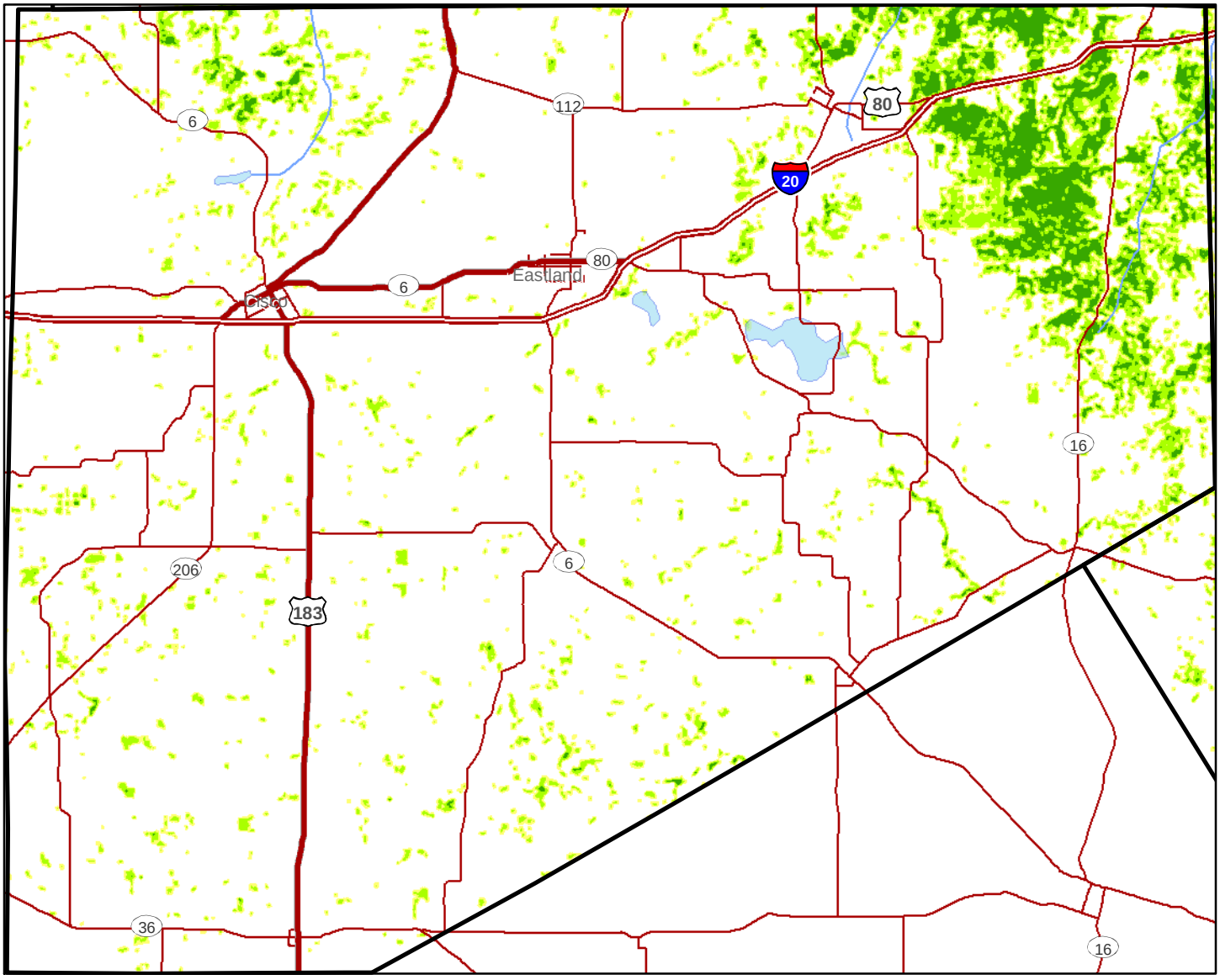
Figure 5. GCW Model L

EASTLAND
COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N
W
E
S

1:319,430

0 2.5 5 10 Miles

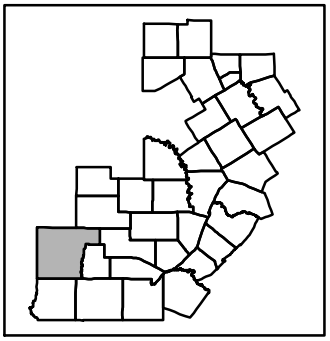
0 3.5 7 14 Kilometers

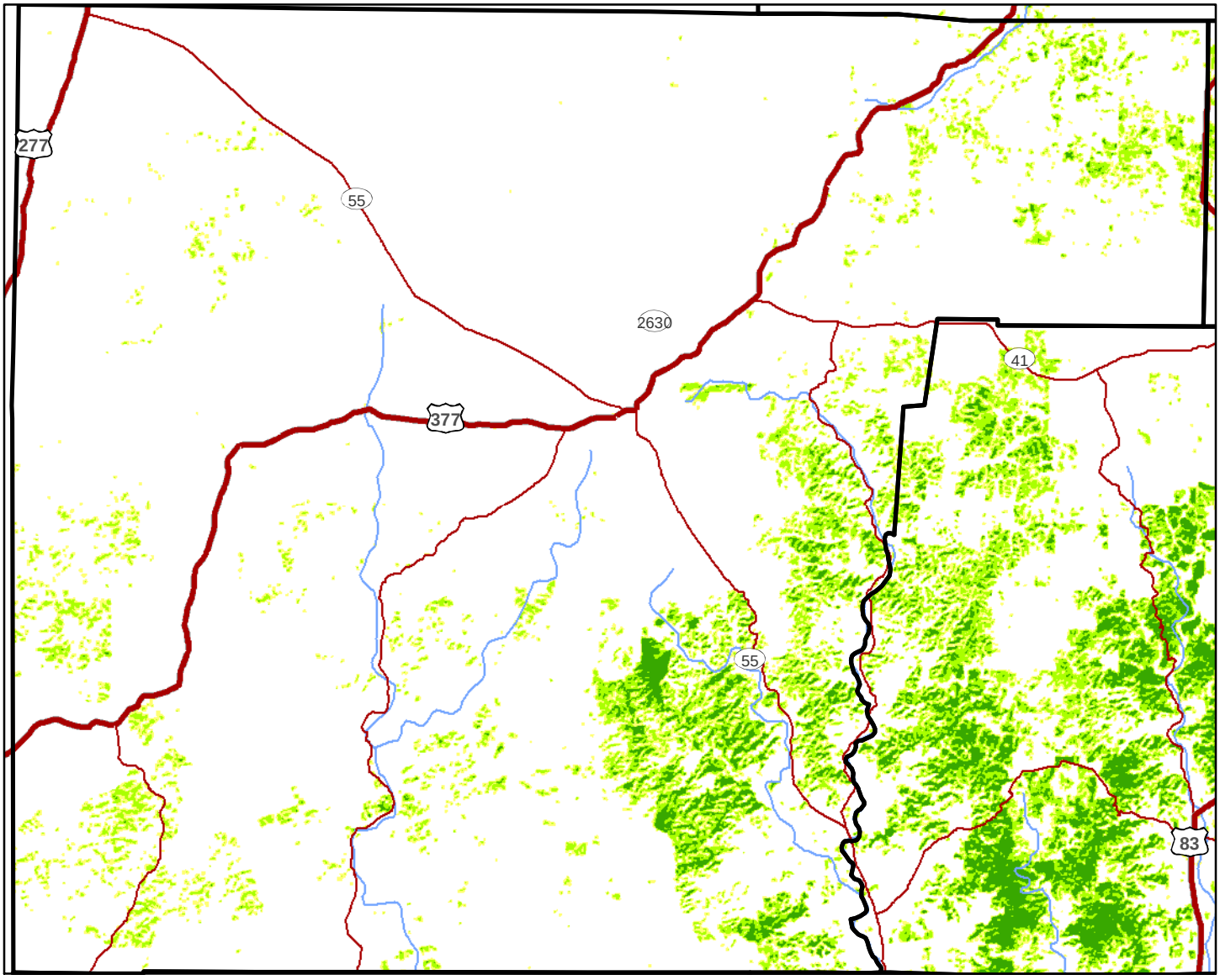
Figure 5. GCW Model L

EDWARDS
COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N
W E
S

1:486,990

0 3.75 7.5 15 Miles

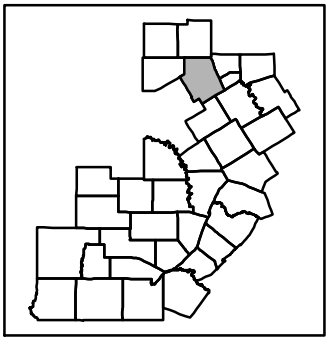
0 5 10 20 Kilometers

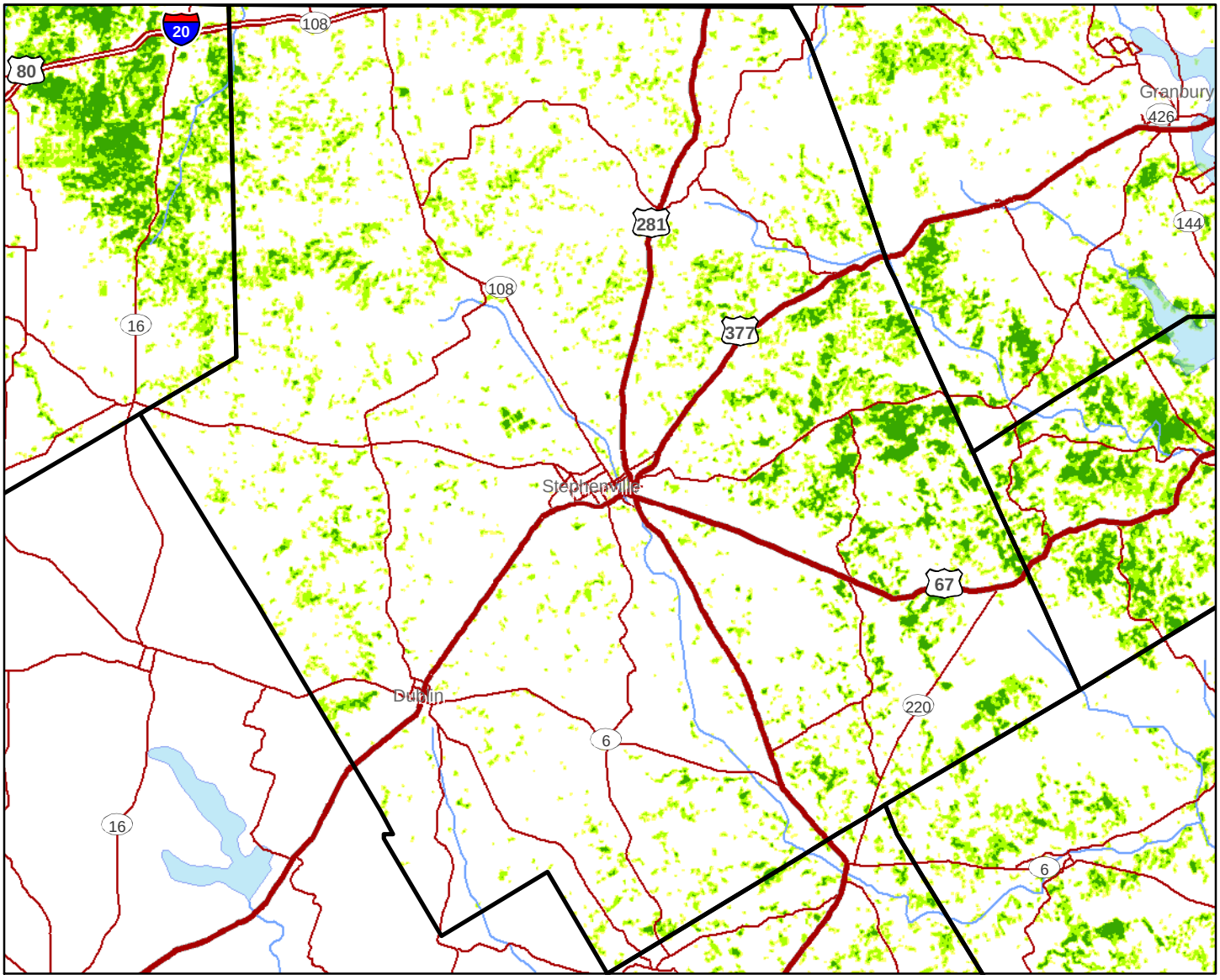
Figure 5. GCW Model L

ERATH
COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N
W
E
S

1:436,311

0 3.5 7 14 Miles

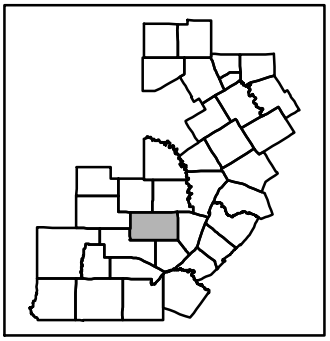
0 4.5 9 18 Kilometers

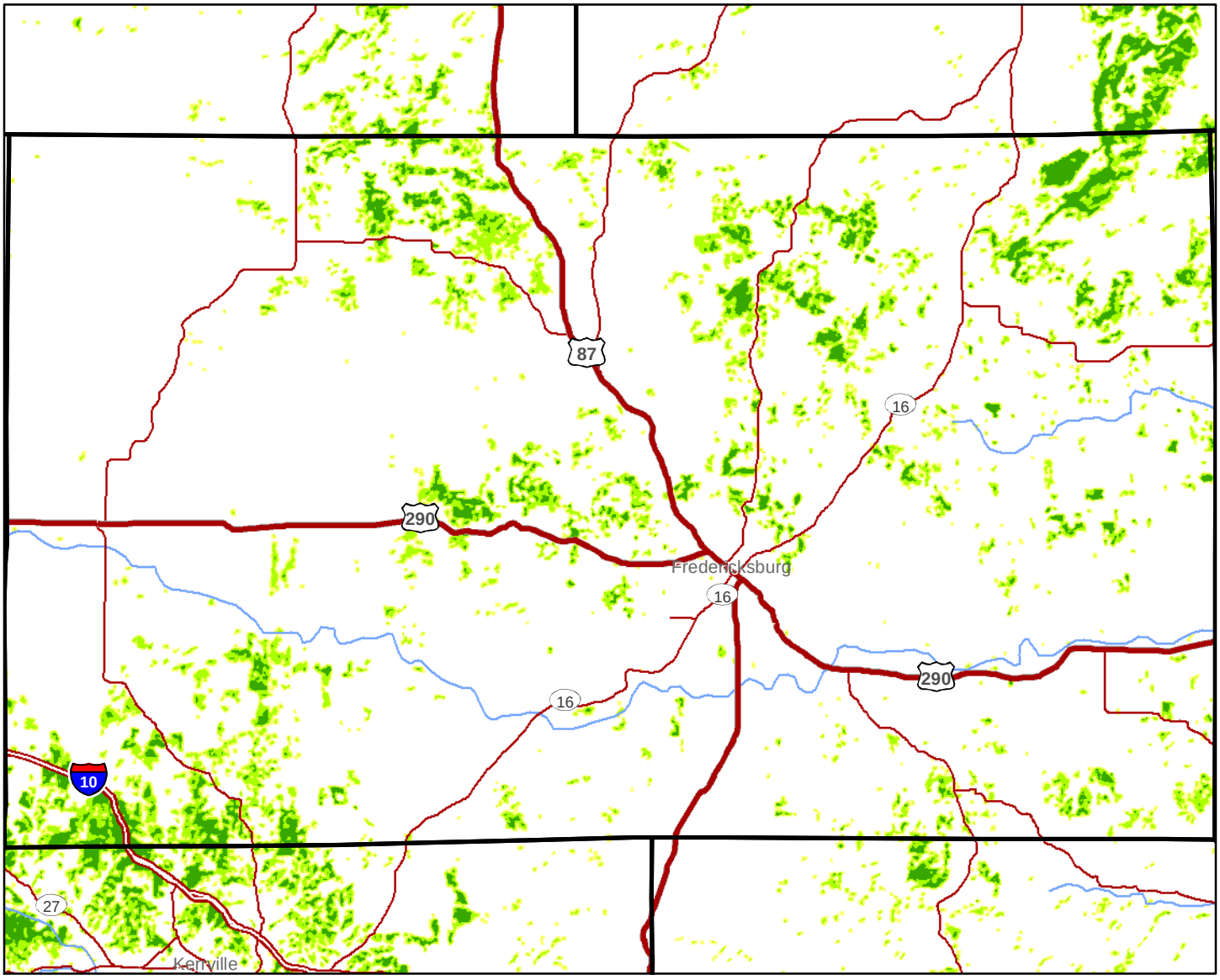
Figure 5. GCW Model L

GILLESPIE COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N
W E
S

1:360,868

0 3 6 12 Miles

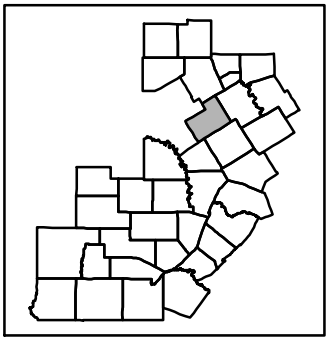
0 3.75 7.5 15 Kilometers

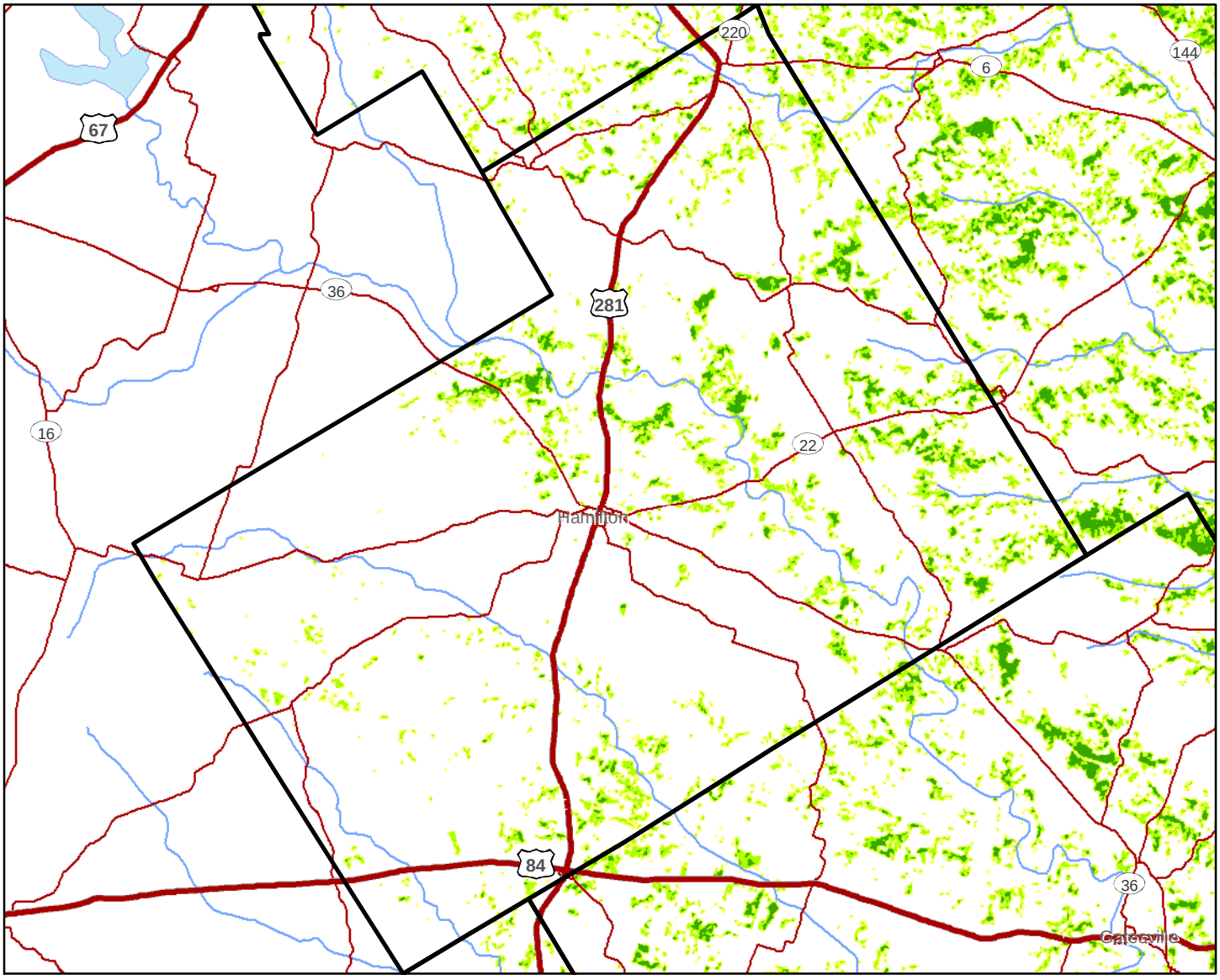
Figure 5. GCW Model L

HAMILTON
COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N
W E
S

1:440,225

0 3.75 7.5 15 Miles

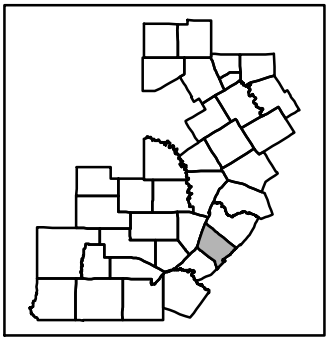
0 4.5 9 18 Kilometers

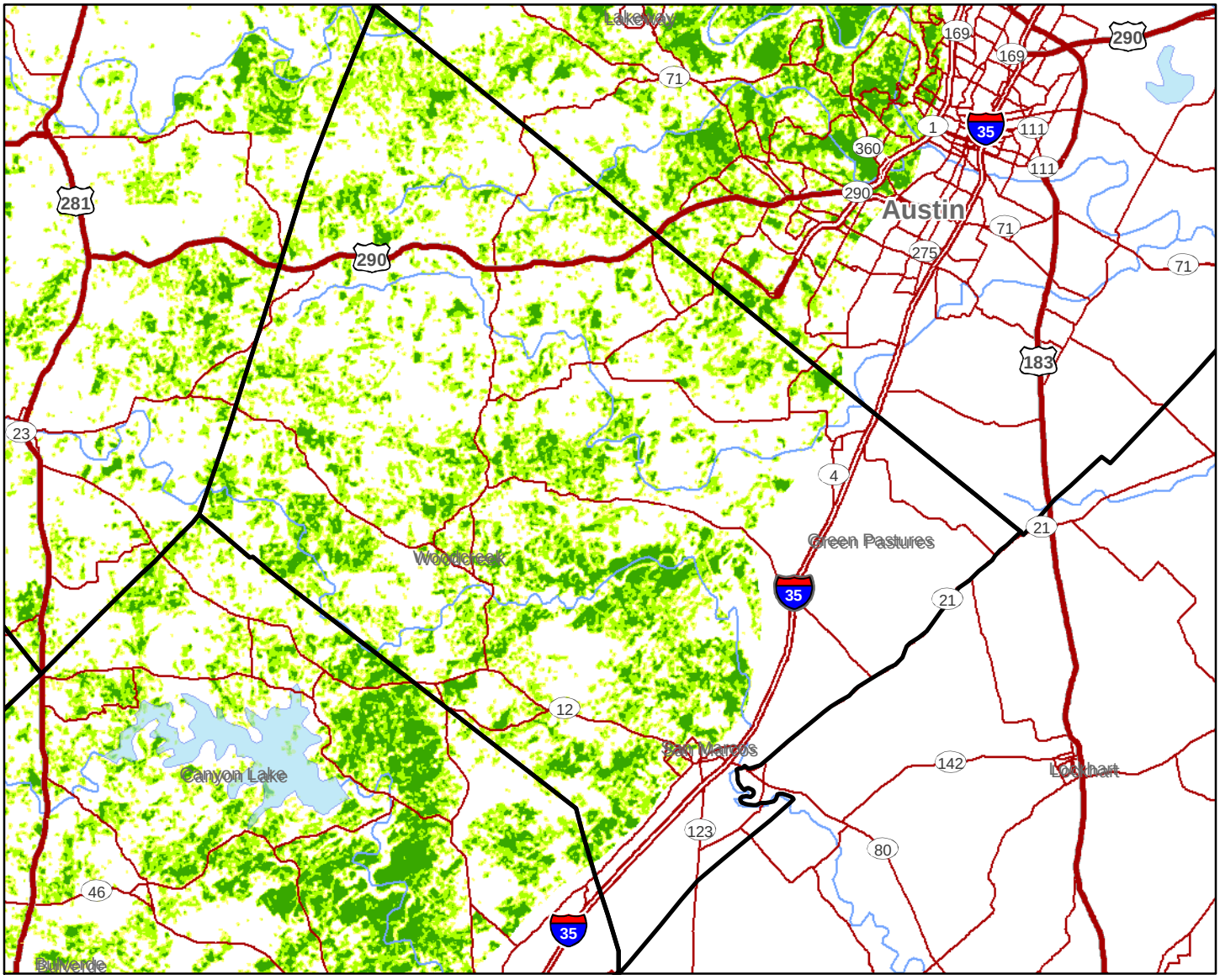
Figure 5. GCW Model L

HAYS
COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N
W E
S

1:438,757

0 3.75 7.5 15 Miles

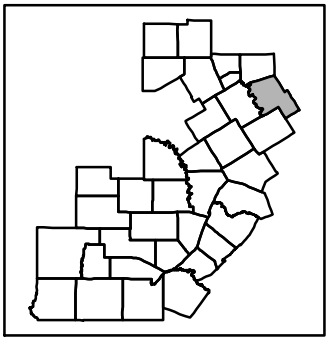
0 4.5 9 18 Kilometers

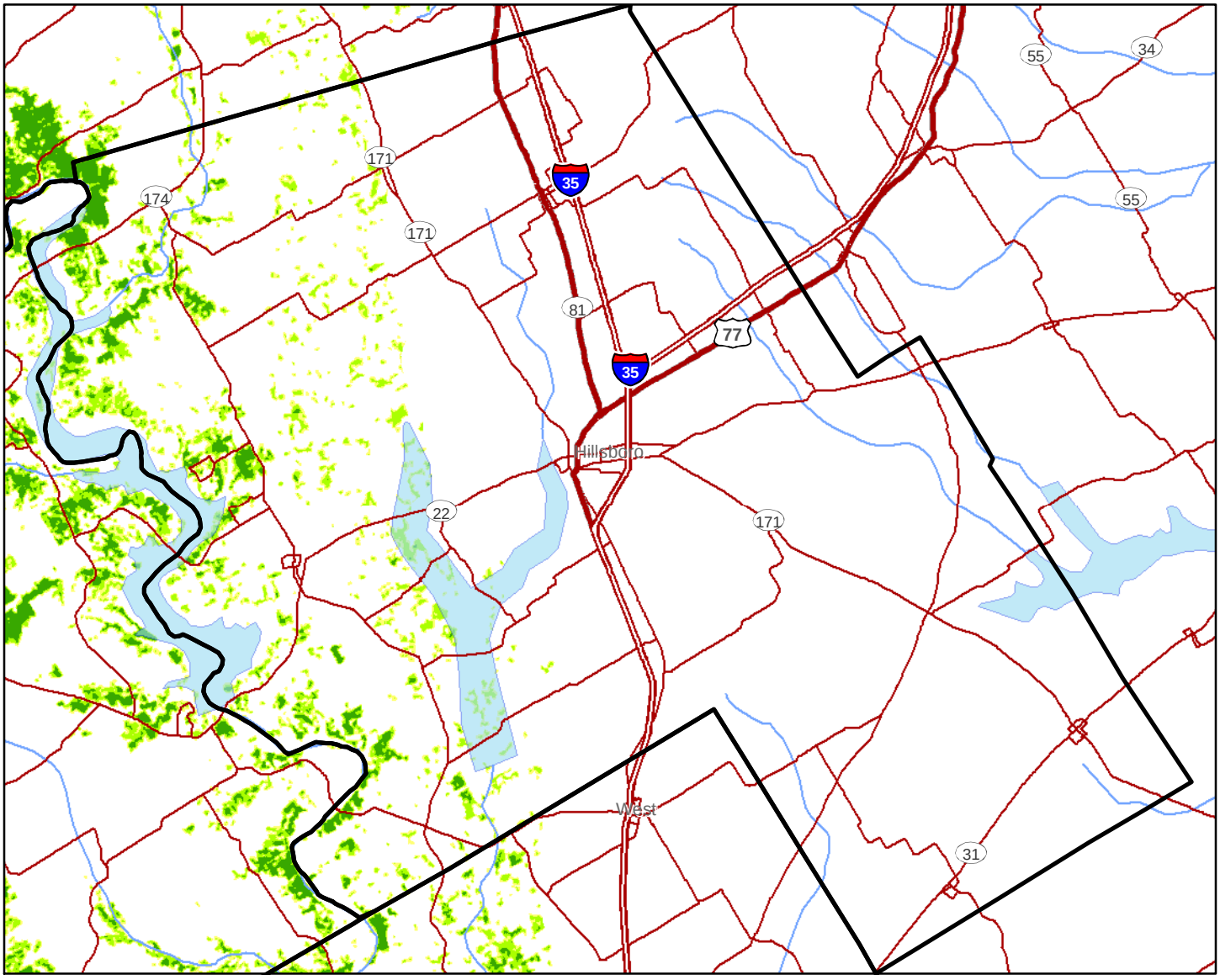
Figure 5. GCW Model L

HILL
COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

1:405,536

0 3.5 7 14 Miles

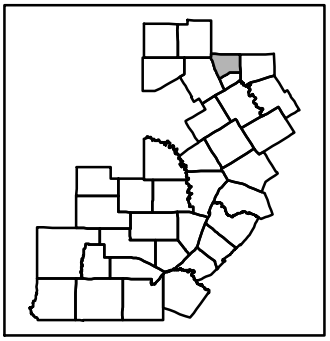
0 4 8 16 Kilometers

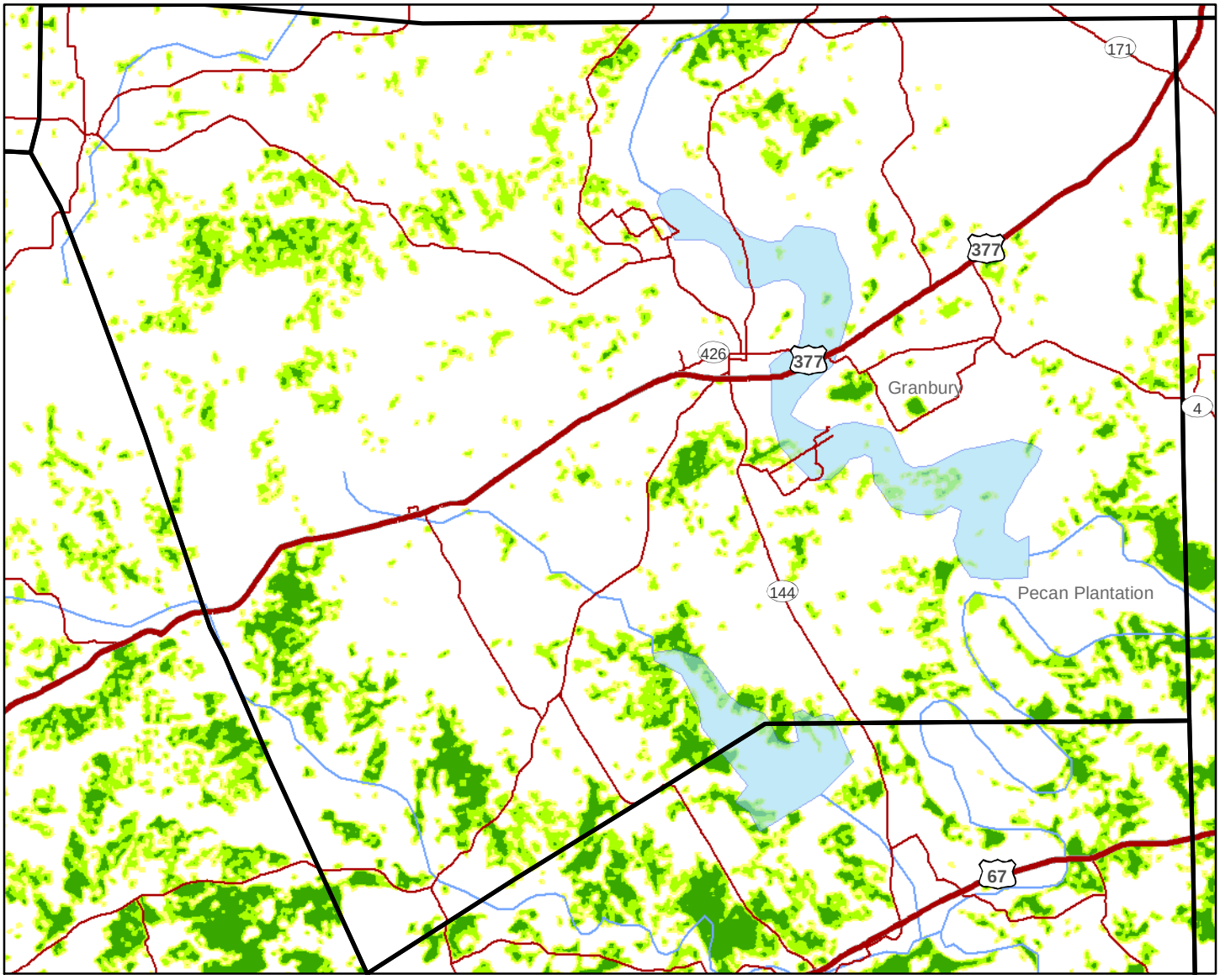
Figure 5. GCW Model L

HOOD
COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N
W
E
S

1:236,188

0 2 4 8 Miles

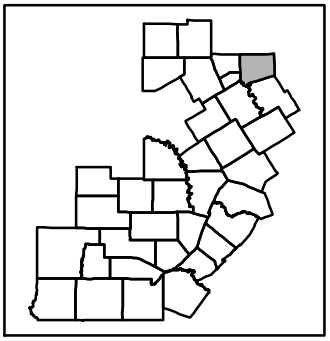
0 2.5 5 10 Kilometers

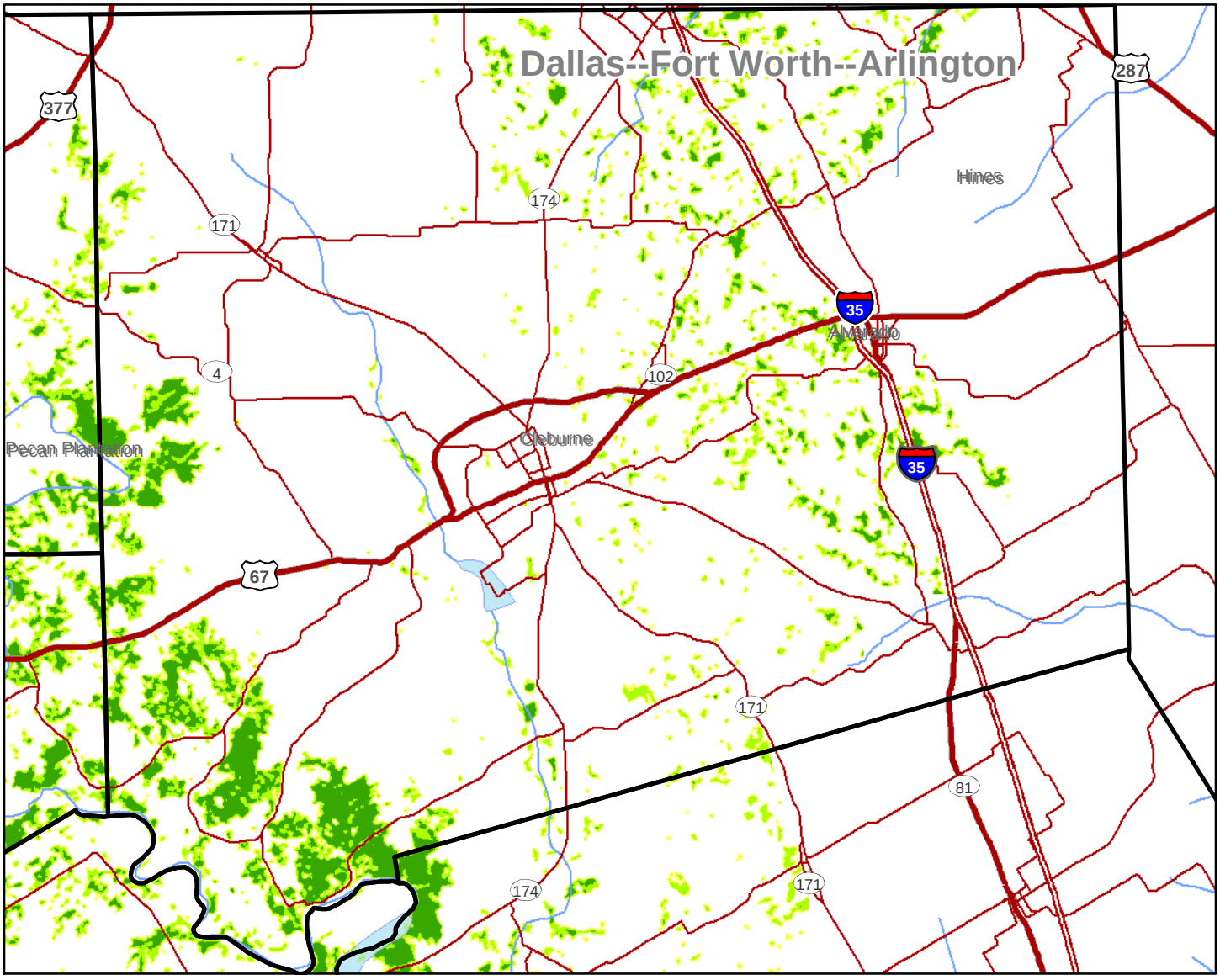
Figure 5. GCW Model L

JOHNSON COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N W E S

1:307,857

0 2.5 5 10 Miles

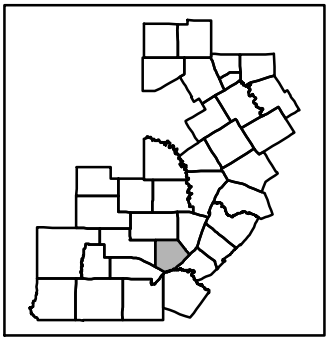
0 3.5 7 14 Kilometers

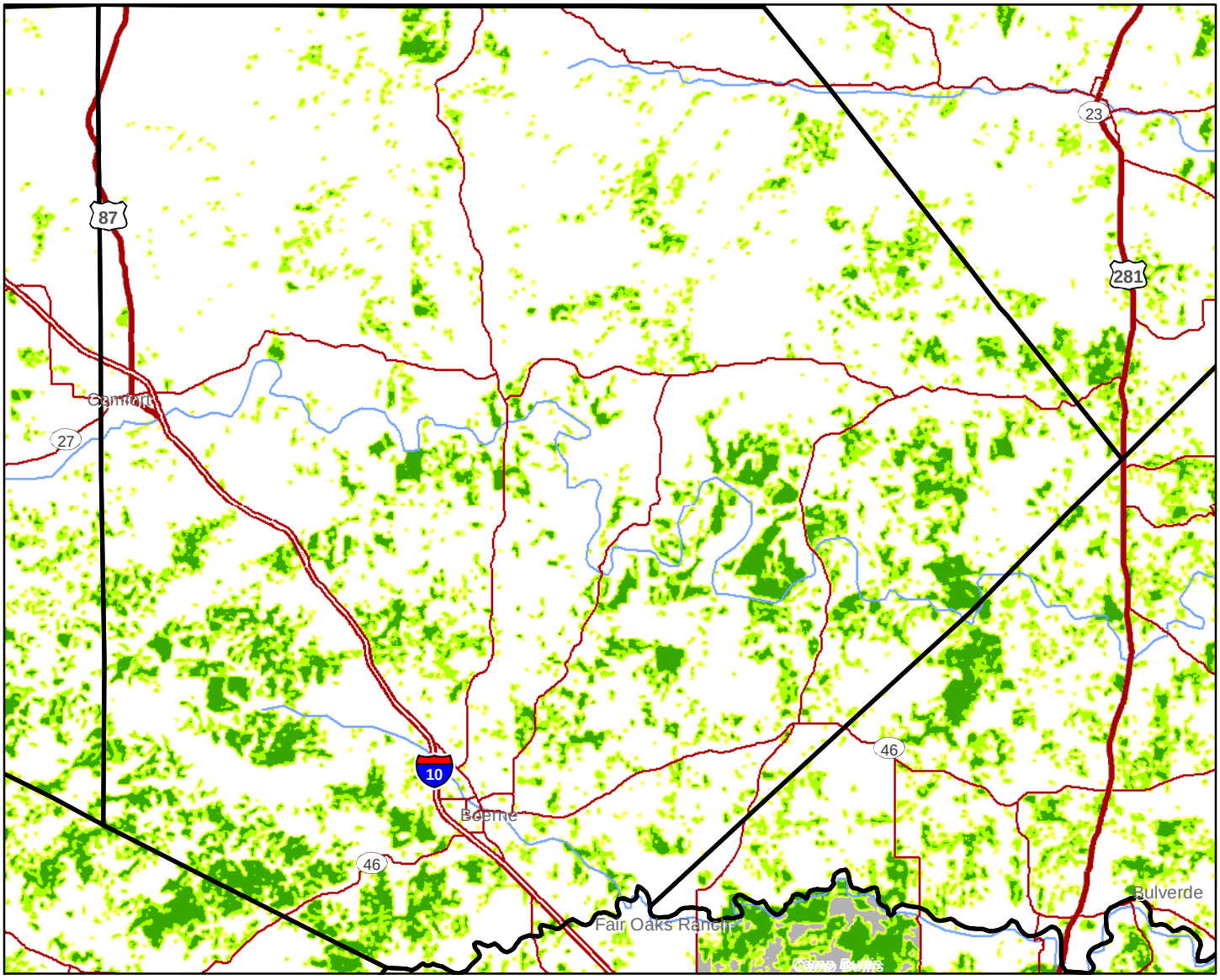
Figure 5. GCW Model L

KENDALL
COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N
W E
S

1:305,681

0 2.5 5 10 Miles

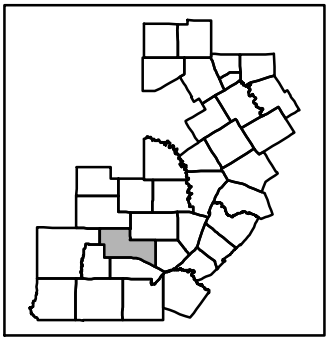
0 3.5 7 14 Kilometers

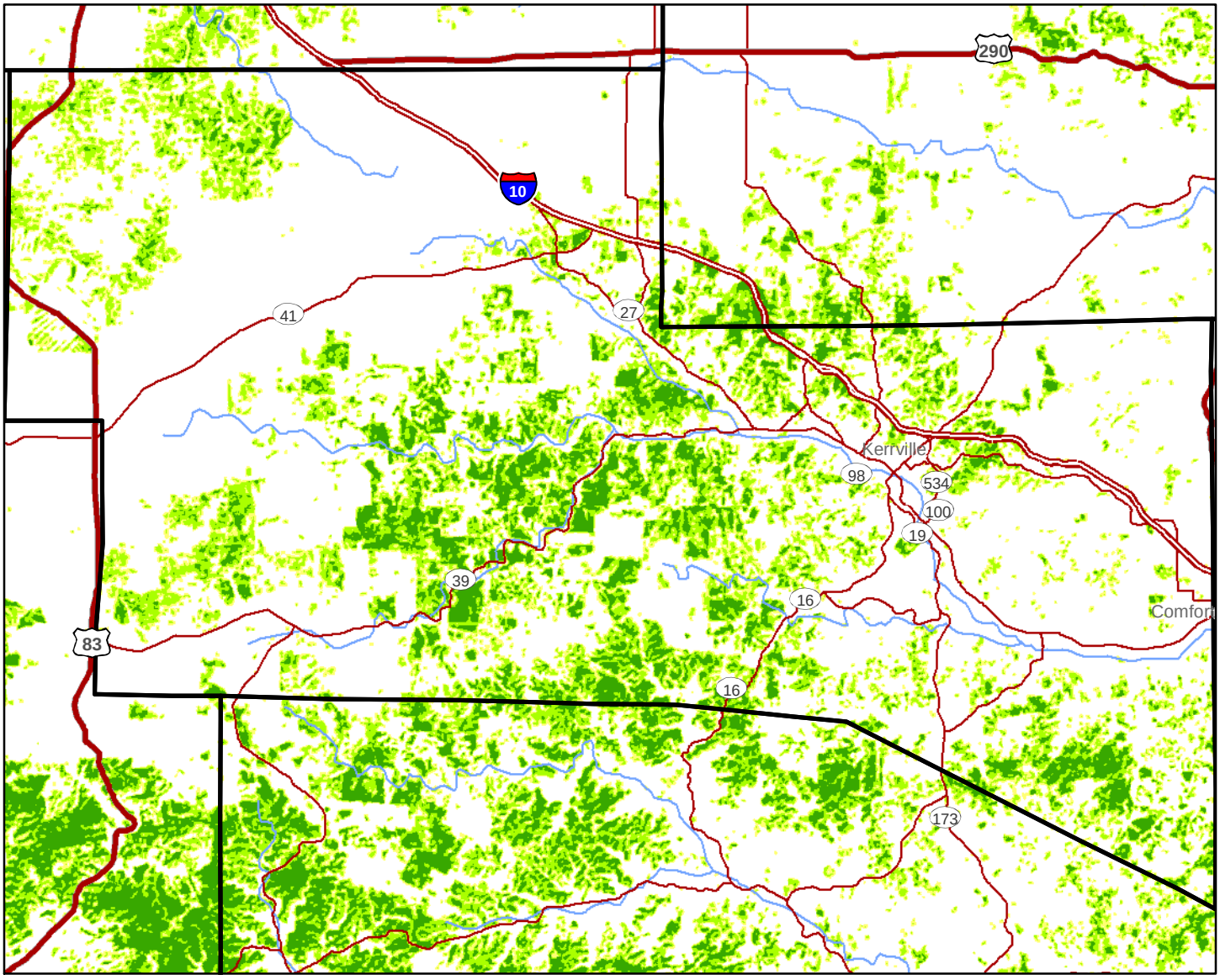
Figure 5. GCW Model L

KERR
COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

1:424,453

0 3.5 7 14 Miles

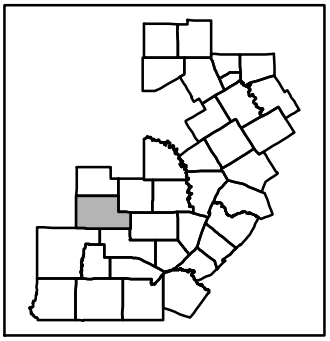
0 5 10 20 Kilometers

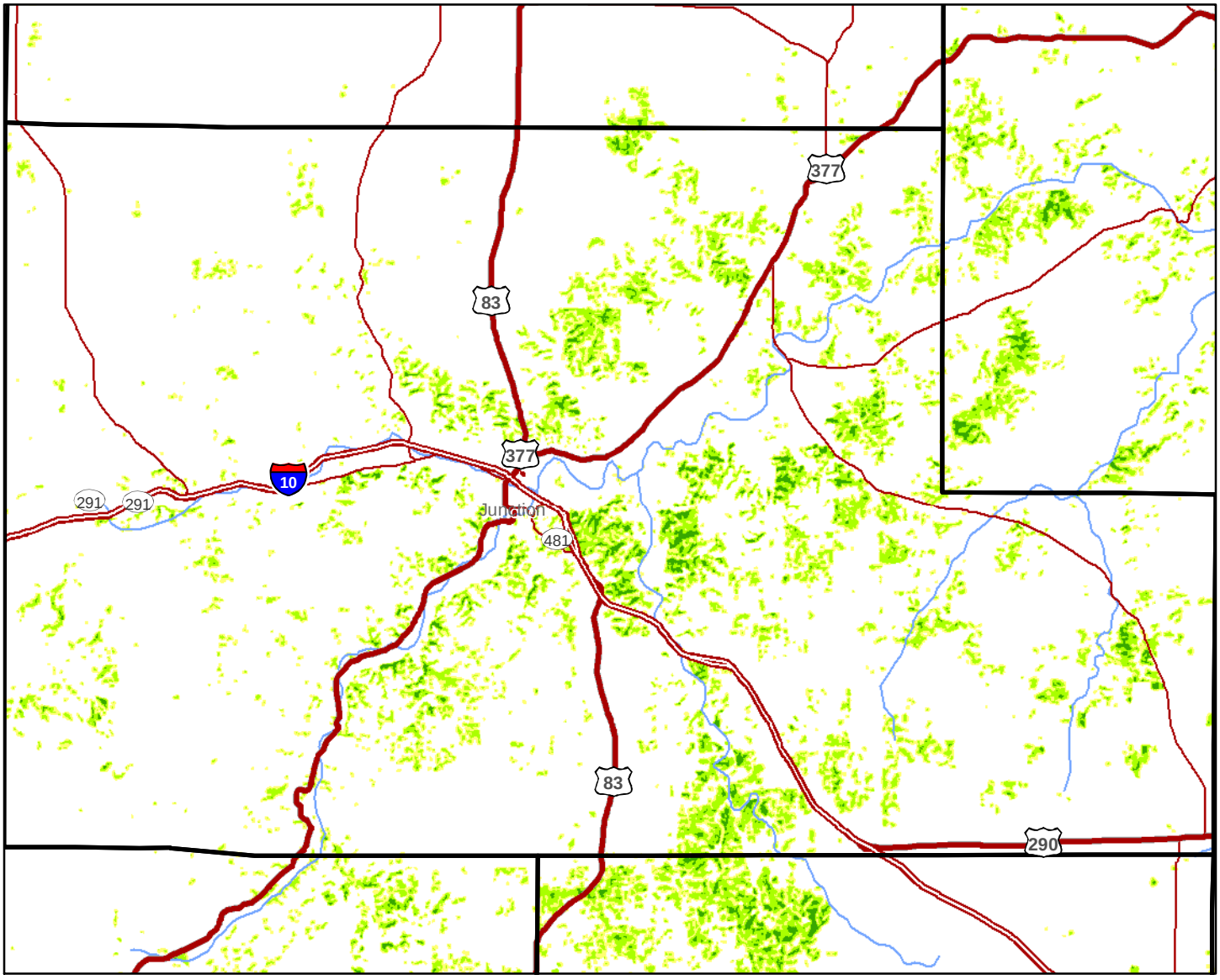
Figure 5. GCW Model L

KIMBLE
COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N
W
E
S

1:410,168

0 3.5 7 14 Miles

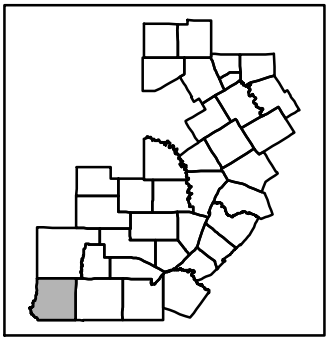
0 5 10 20 Kilometers

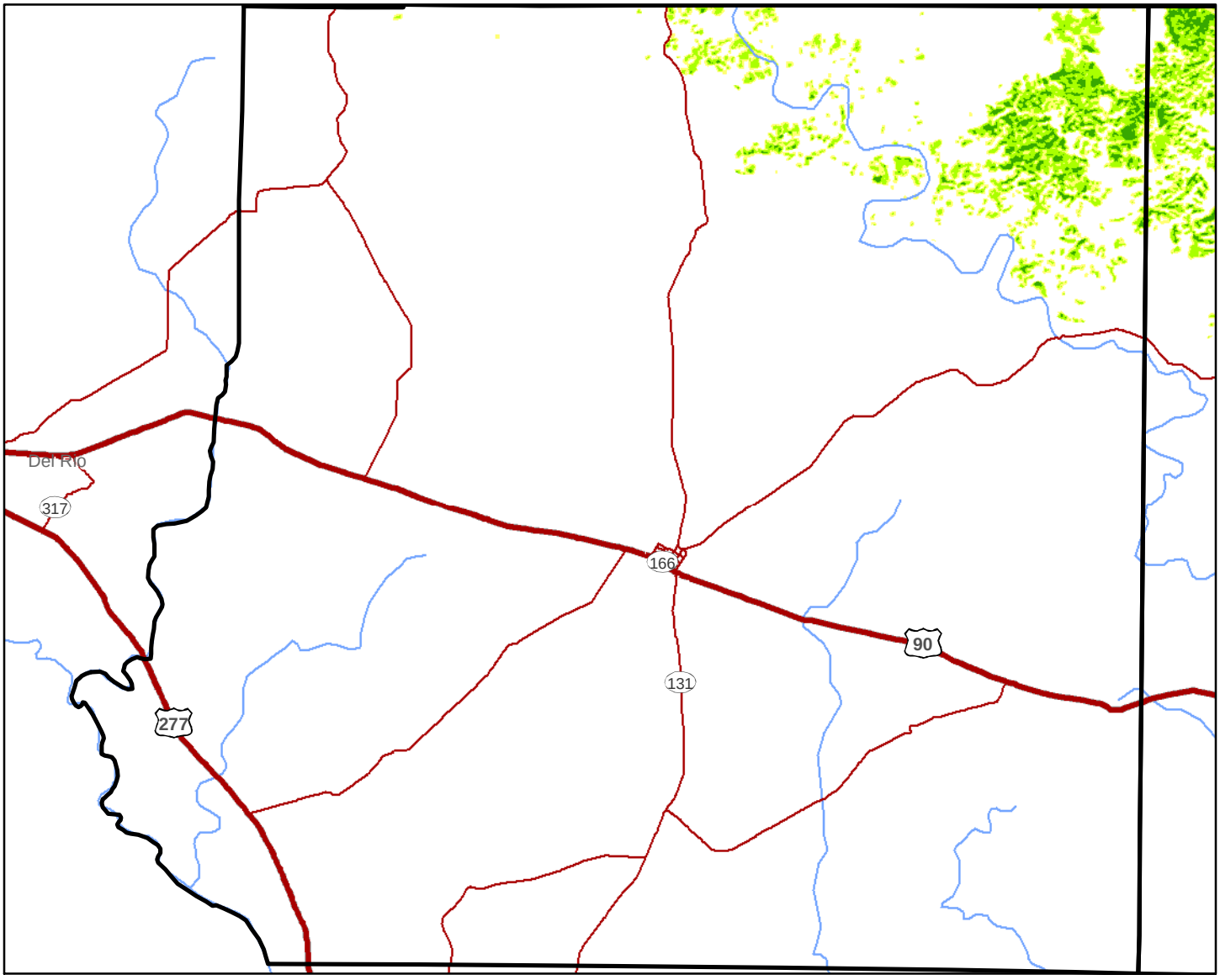
Figure 5. GCW Model L

KINNEY
COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N
W E
S

1:396,413

0 3.5 7 14 Miles

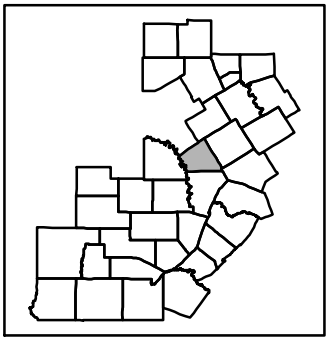
0 5 10 20 Kilometers

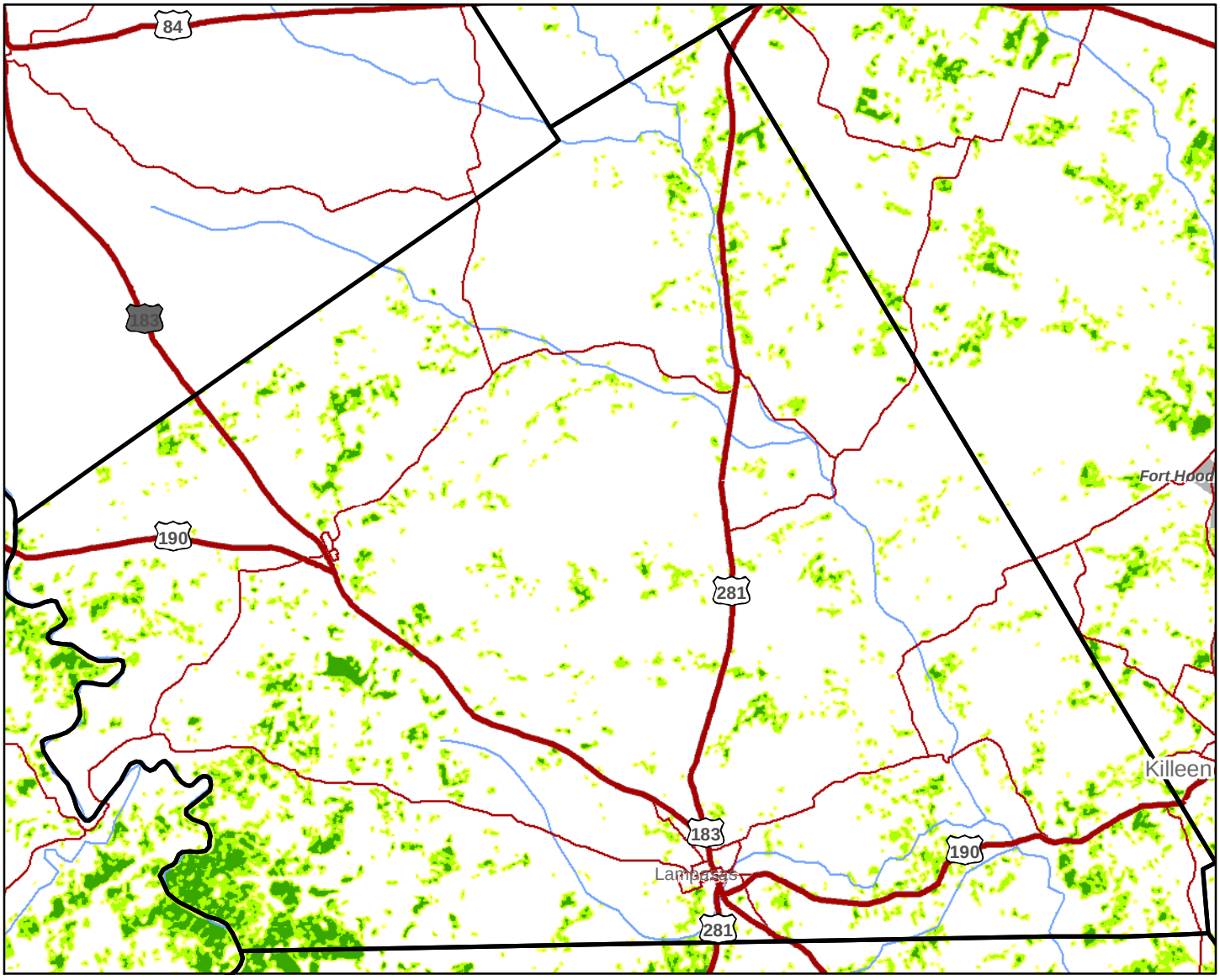
Figure 5. GCW Model L

LAMPASAS
COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N
W
E
S

1:330,663

0 3 6 12 Miles

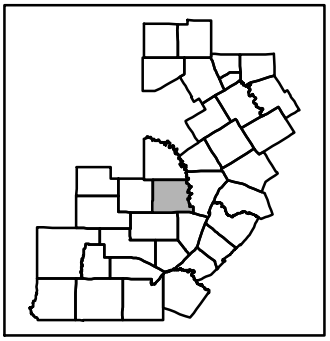
0 4 8 16 Kilometers

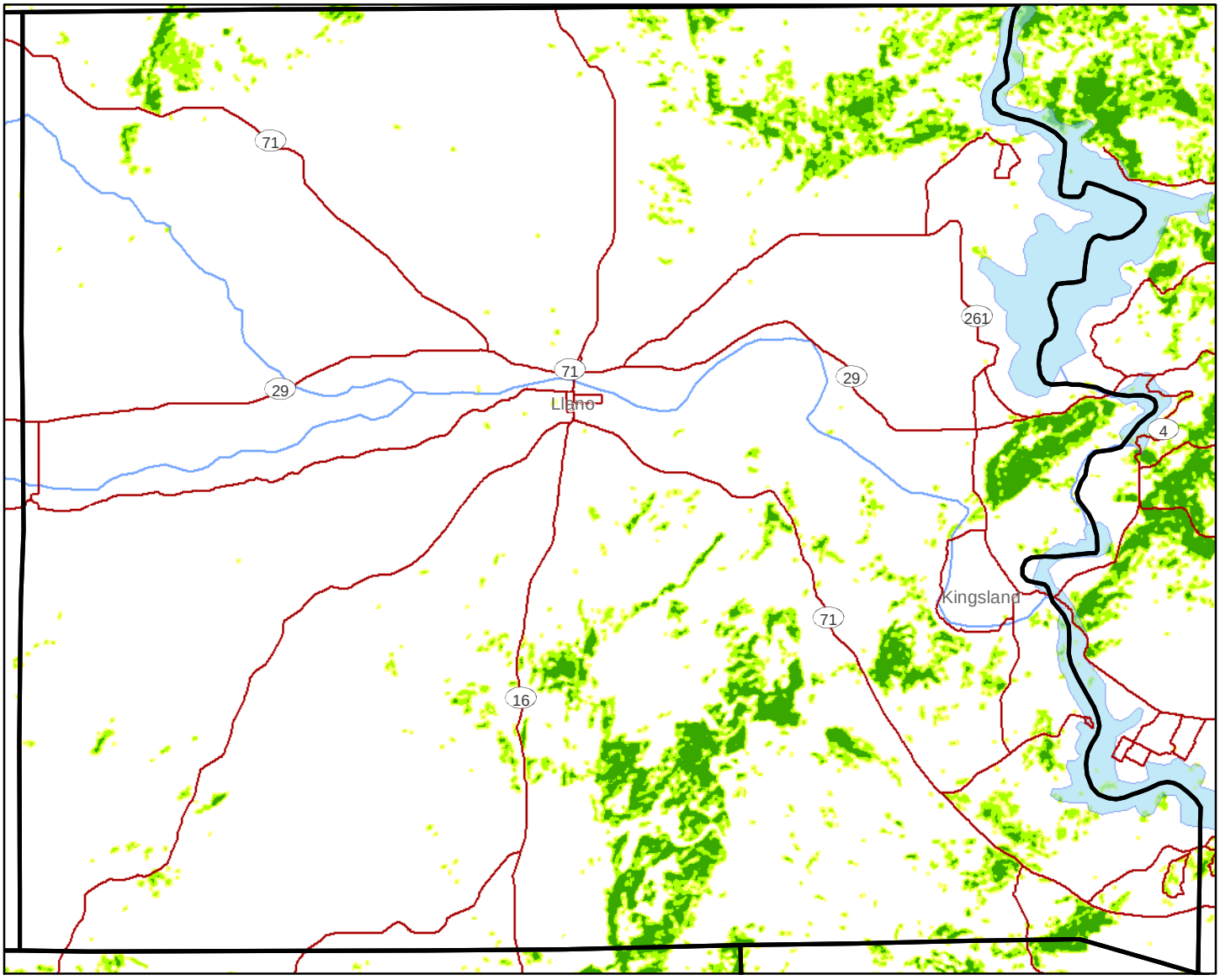
Figure 5. GCW Model L

LLANO
COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N
W E
S

1:318,007

0 3 6 12 Miles

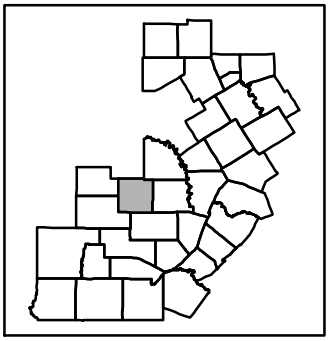
0 3.75 7.5 15 Kilometers

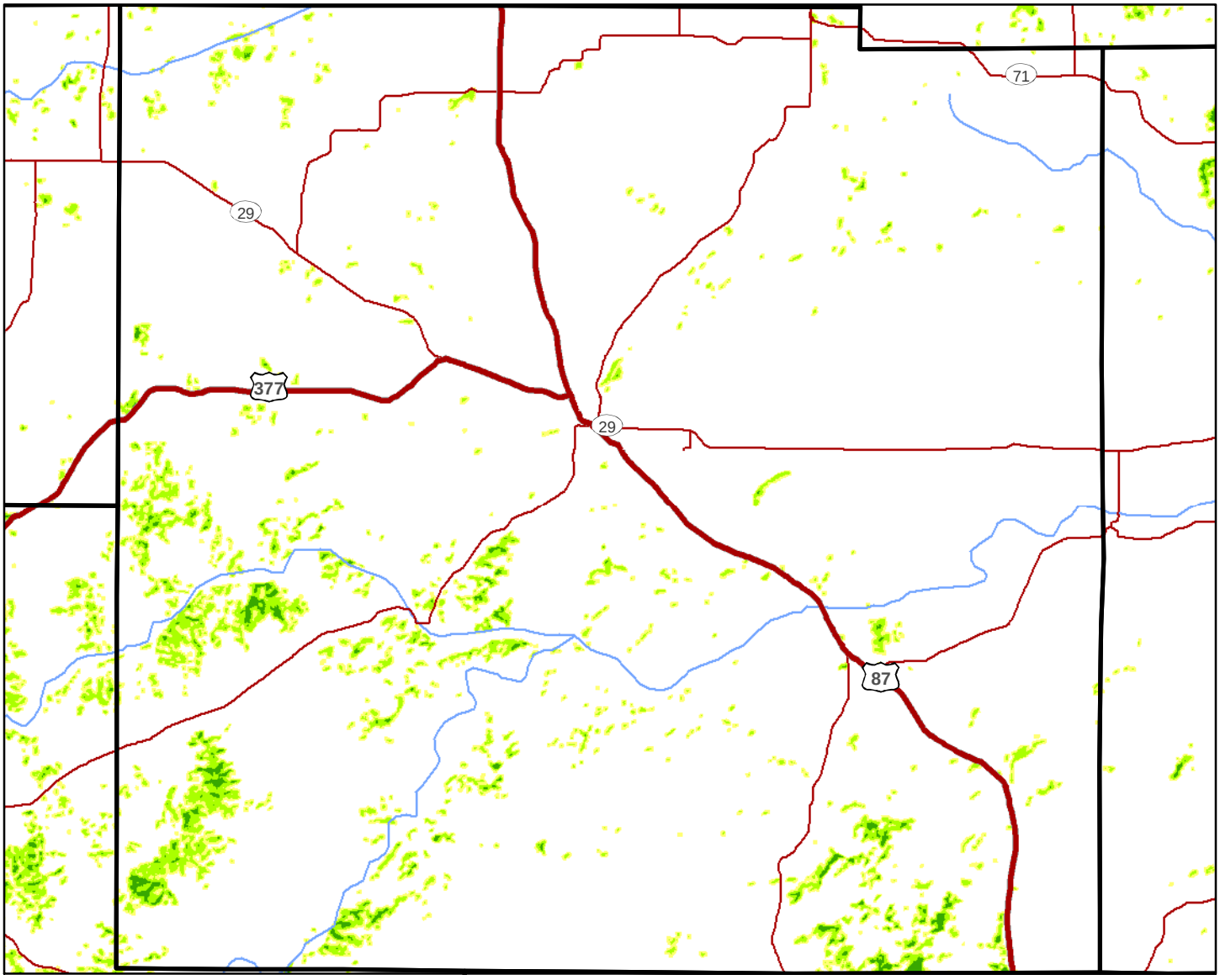
Figure 5. GCW Model L

MASON
COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N
W E
S

1:322,650

0 3 6 12 Miles

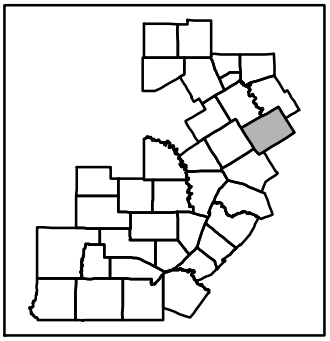
0 3.75 7.5 15 Kilometers

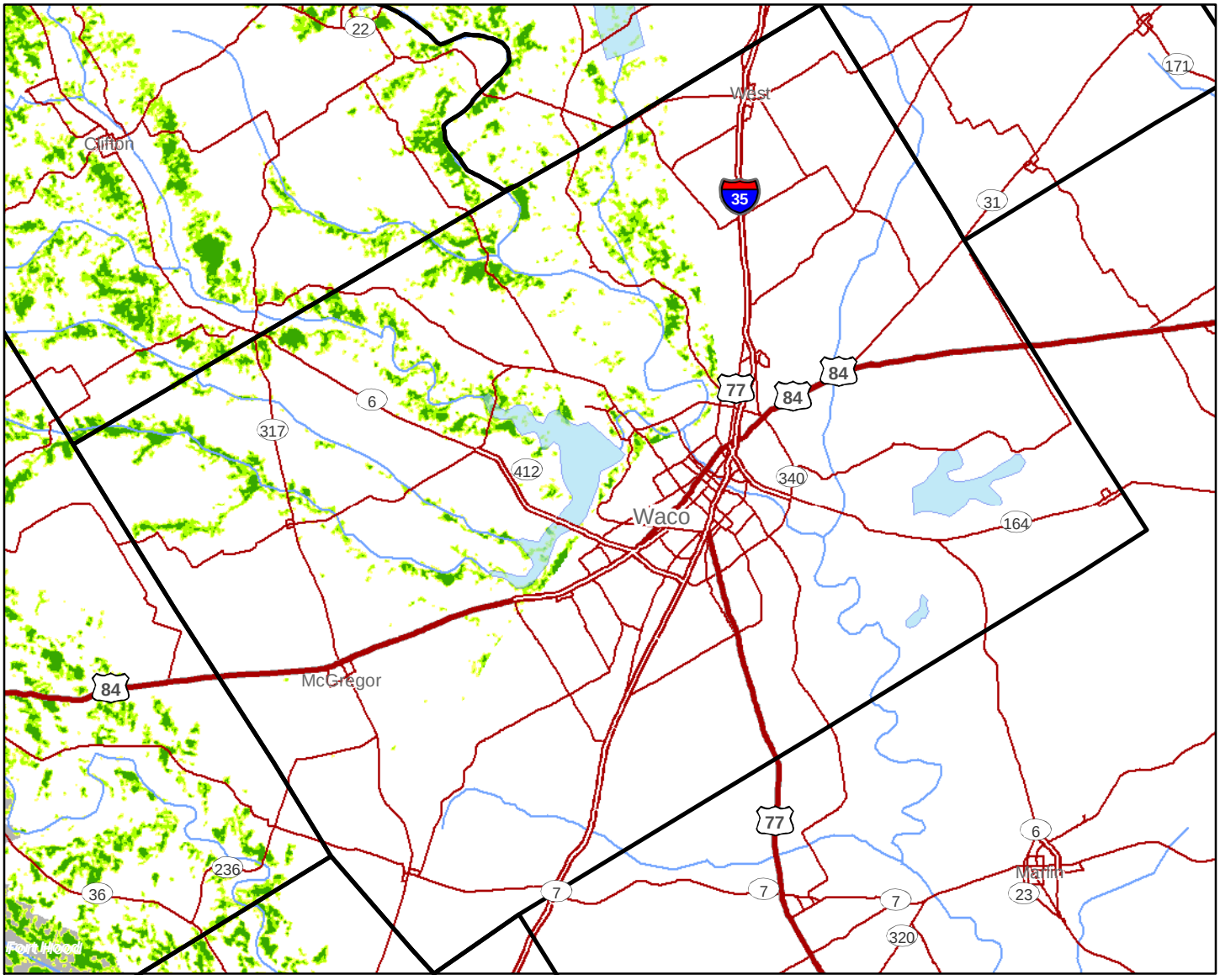
Figure 5. GCW Model L

MCLENNAN COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N W E S

1:454,790

0 4 8 16 Miles

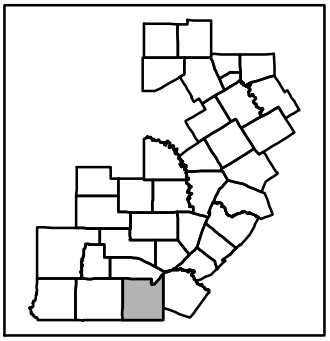
0 5 10 20 Kilometers

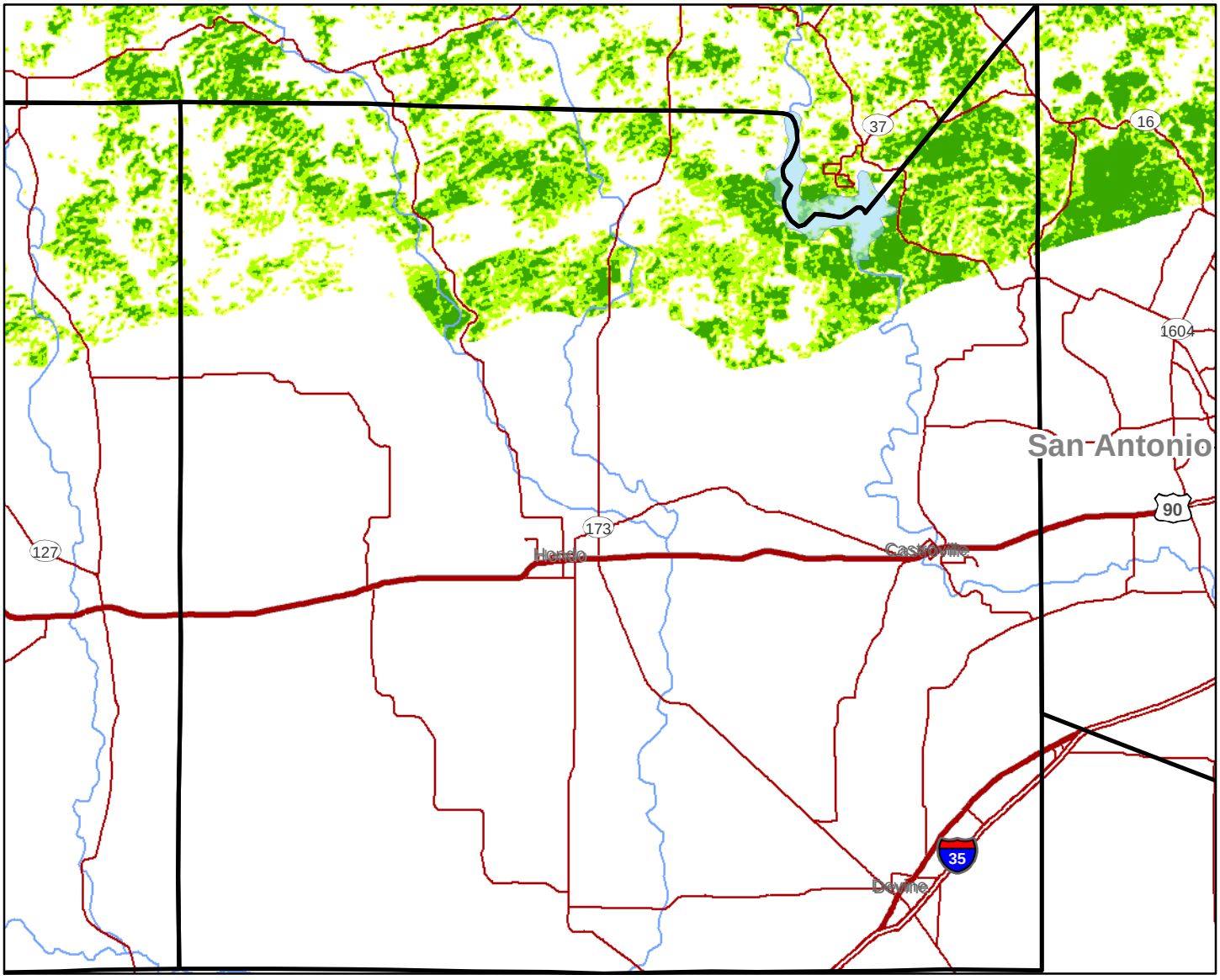
Figure 5. GCW Model L

MEDINA
COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N
W
E
S

1:436,612

0 3.75 7.5 15 Miles

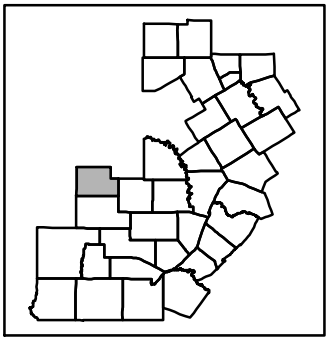
0 5 10 20 Kilometers

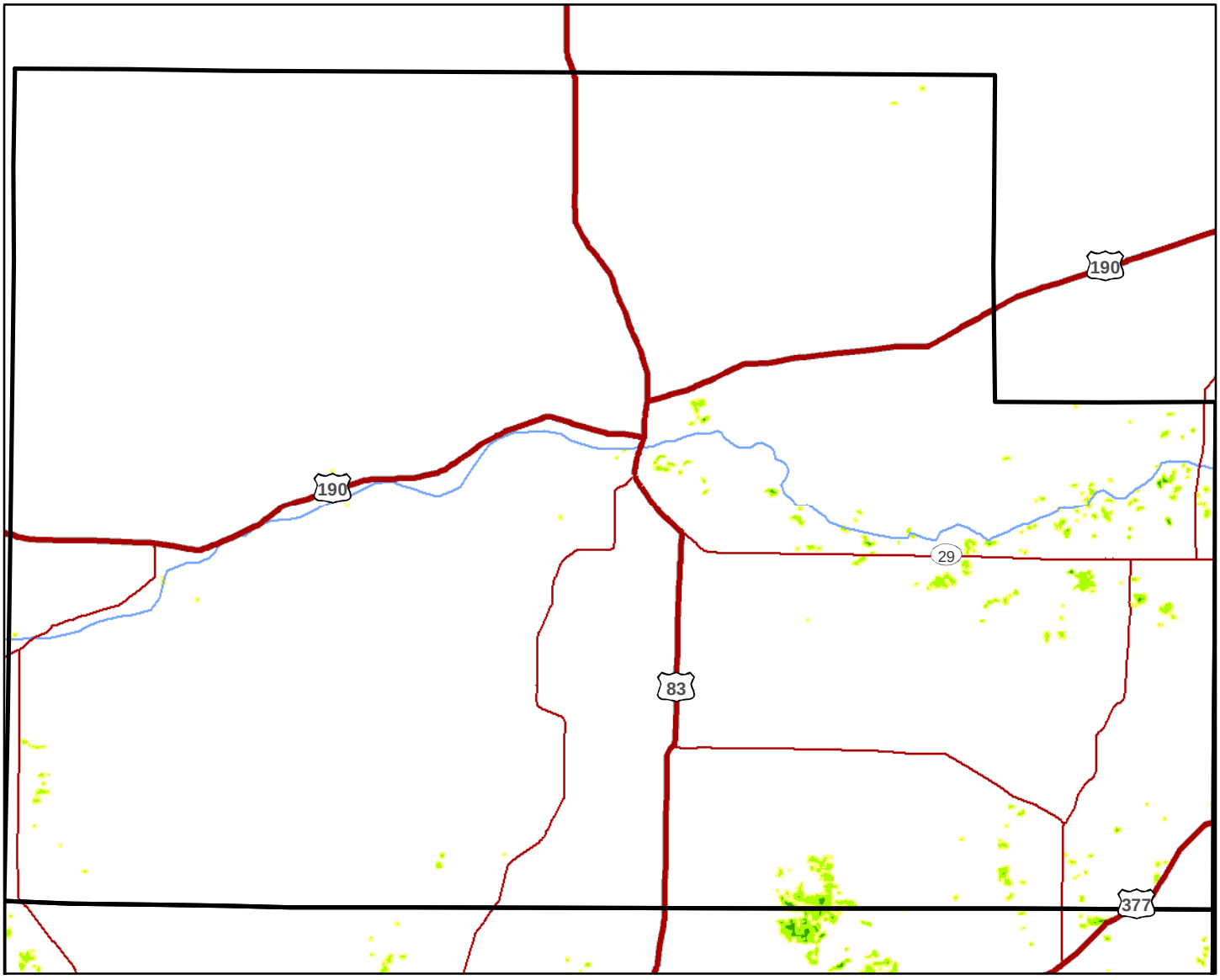
Figure 5. GCW Model L

MENARD
COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N
W E
S

1:318,185

0 2.5 5 10 Miles

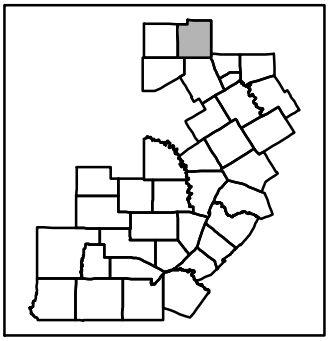
0 3.75 7.5 15 Kilometers

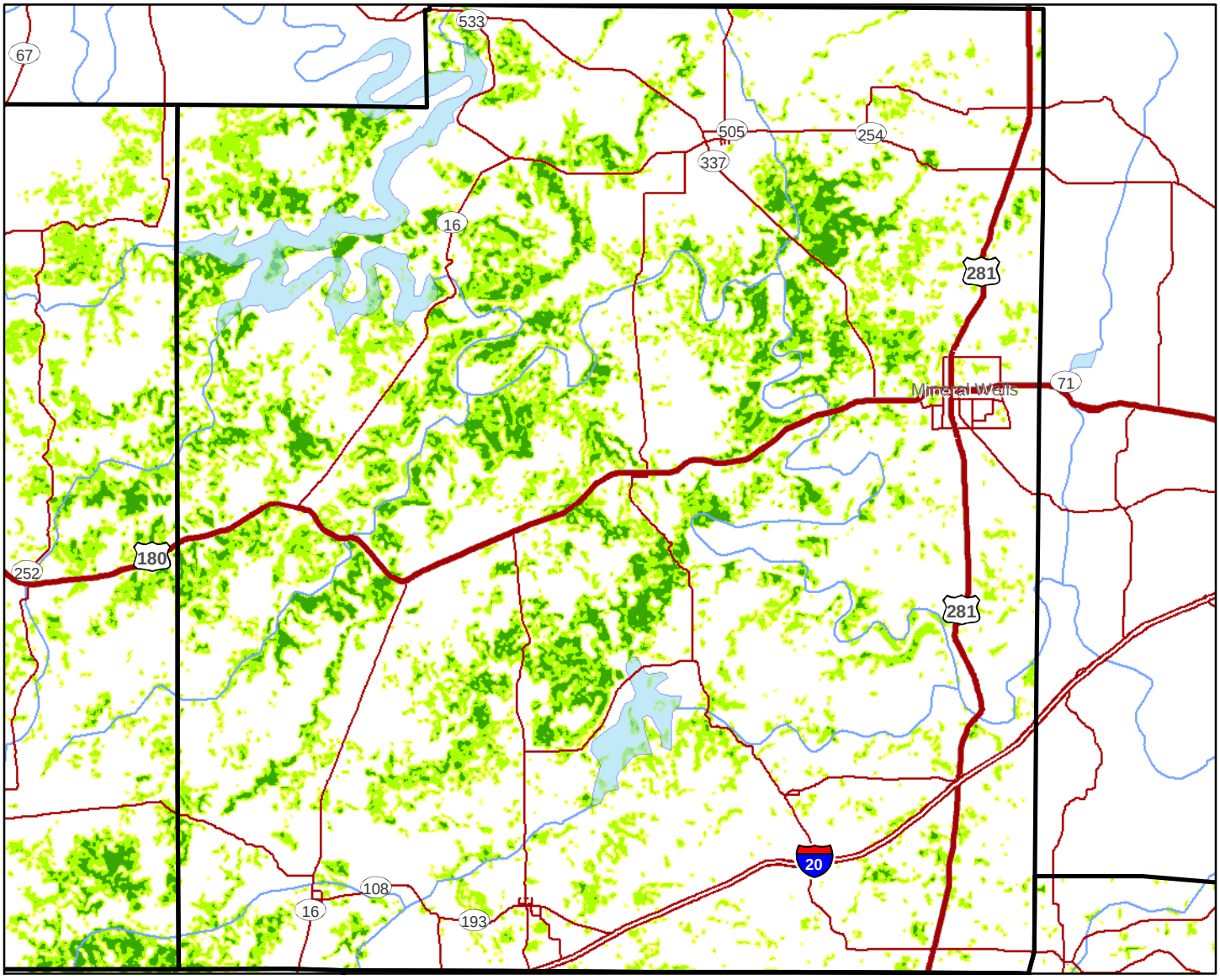
Figure 5. GCW Model L

PALO PINTO COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N W E S

1:357,880

0 3 6 12 Miles

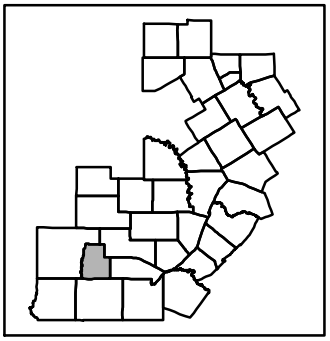
0 4 8 16 Kilometers

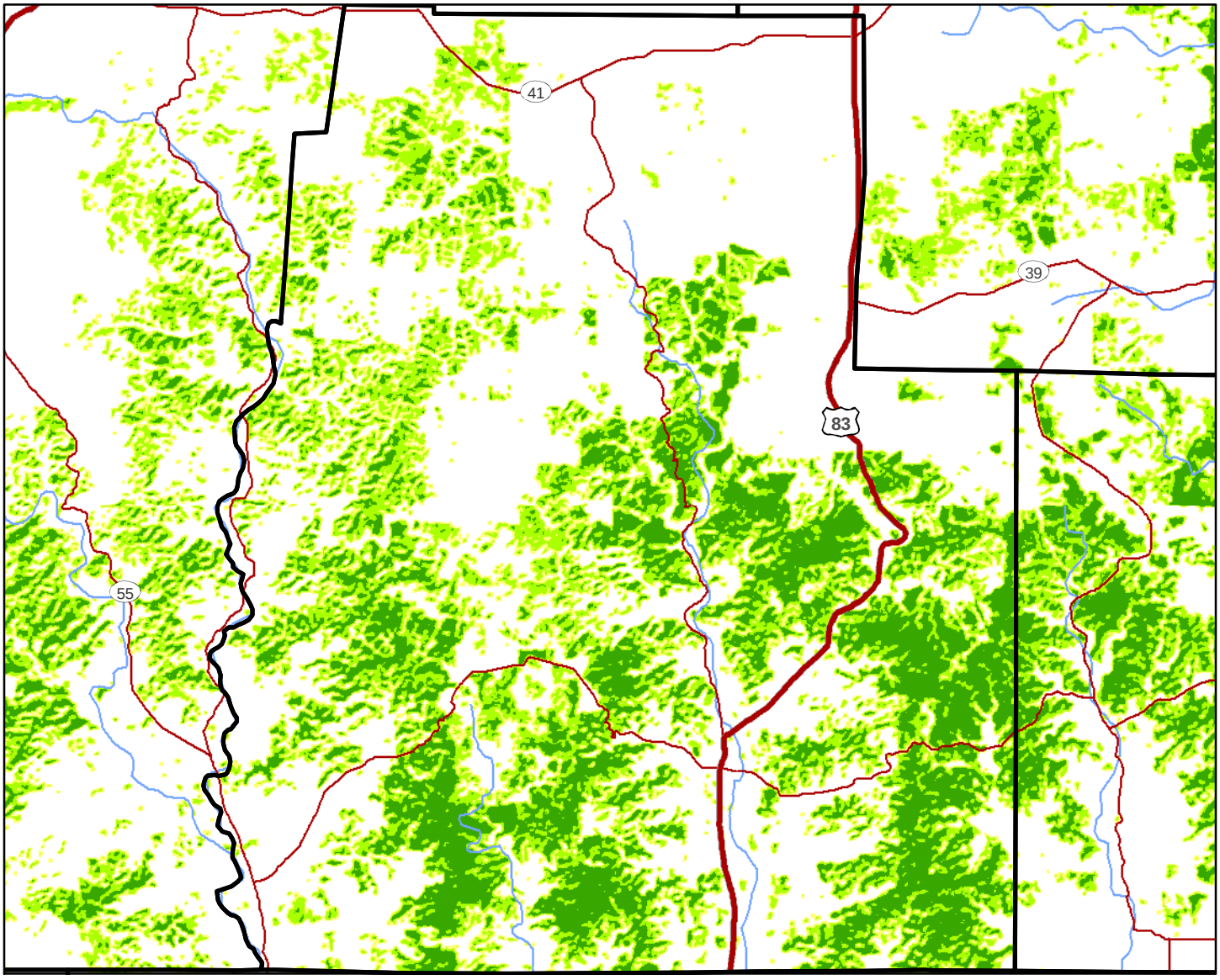
Figure 5. GCW Model L

REAL
COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N
W E
S

1:329,759

0 2.5 5 10 Miles

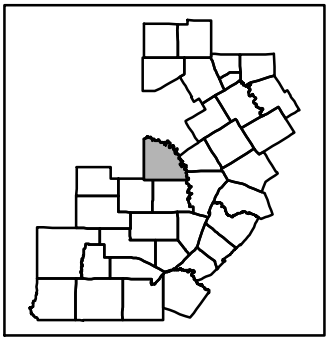
0 3.75 7.5 15 Kilometers

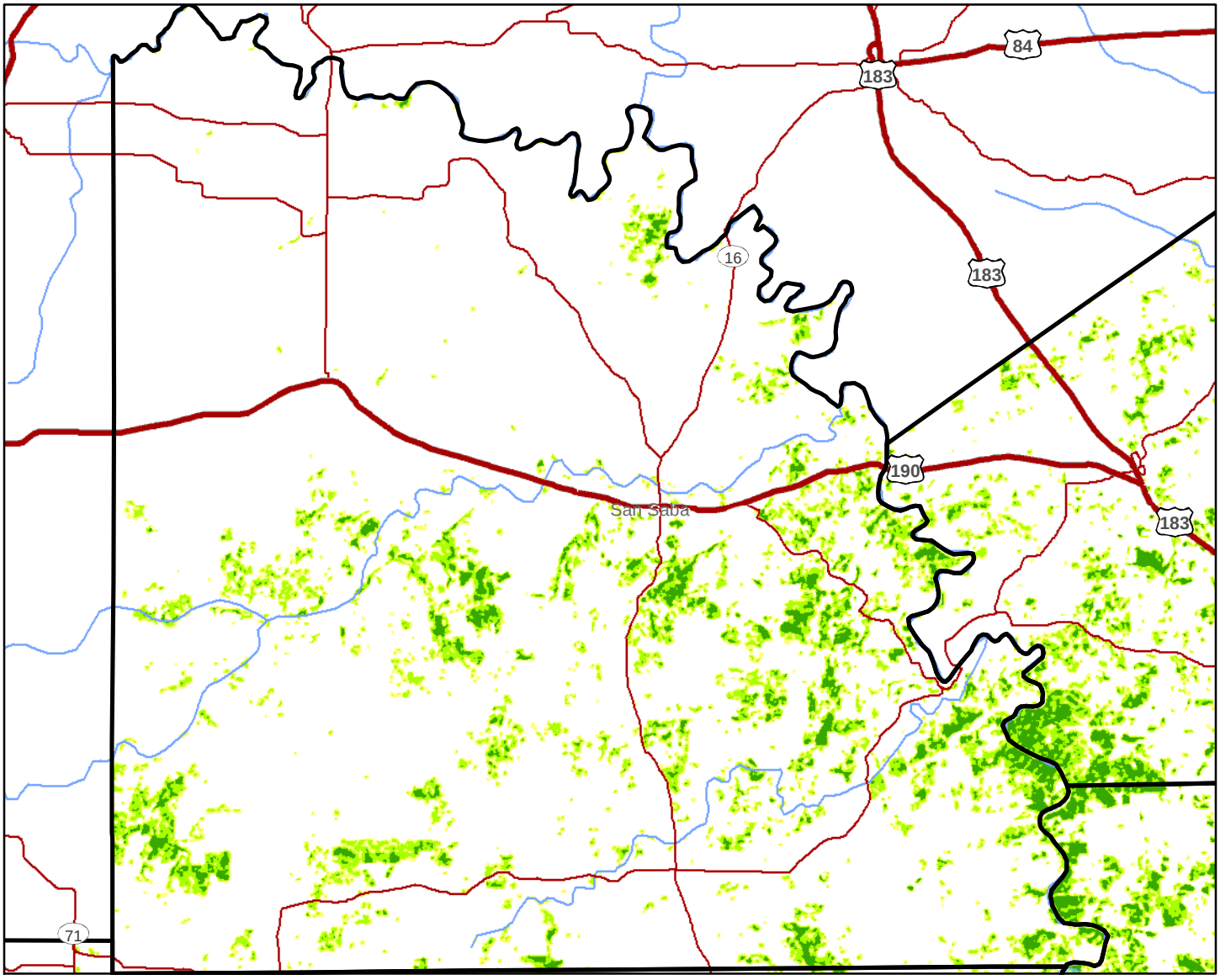
Figure 5. GCW Model L

SAN SABA COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N W E S

1:414,376

0 3 6 12 Miles

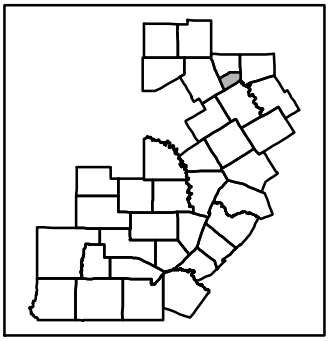
0 4.5 9 18 Kilometers

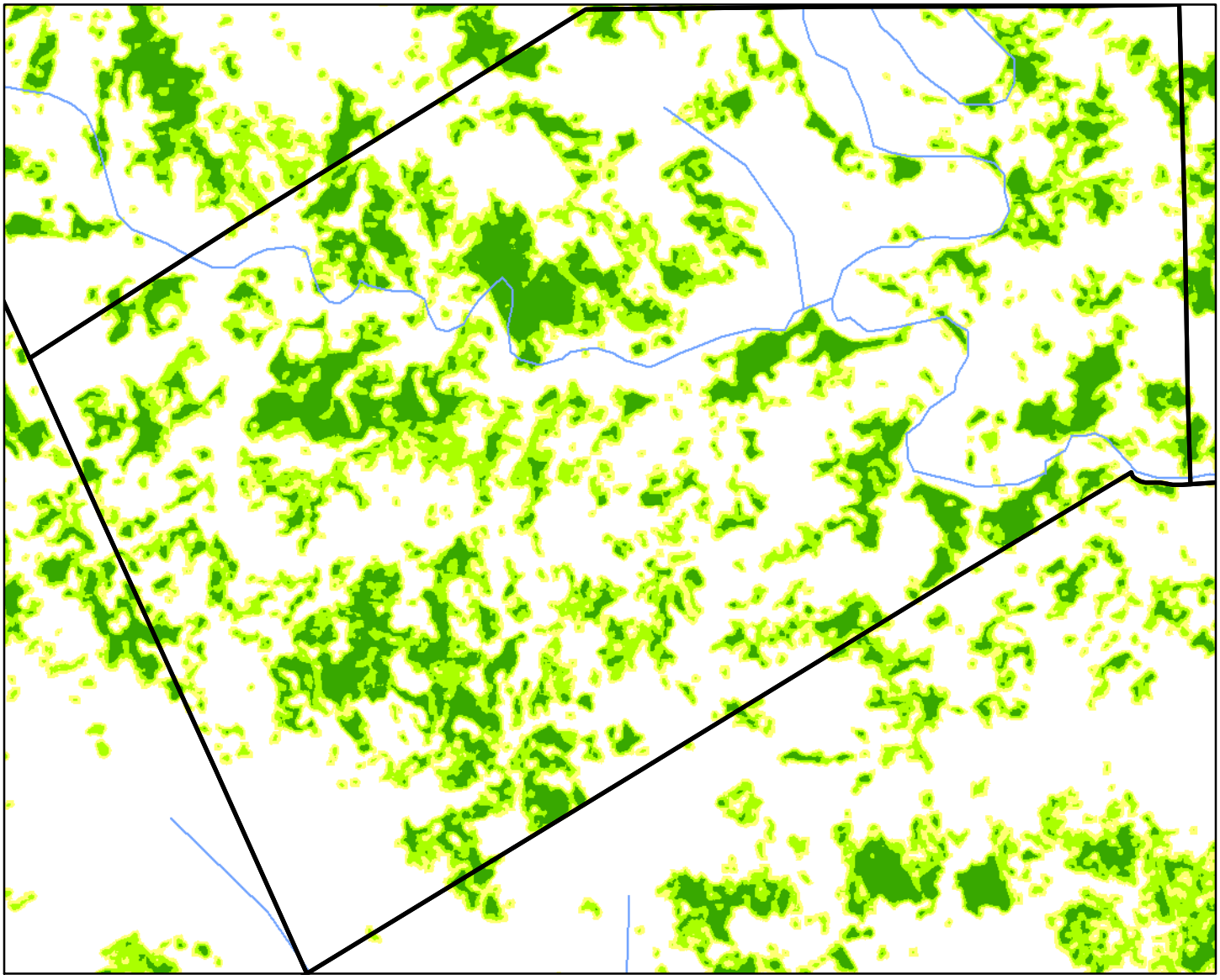
Figure 5. GCW Model L

SOMERVELL COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3 High Quality





1:168,949

Legend

- County
- Stream

0 1.25 2.5 5 Miles

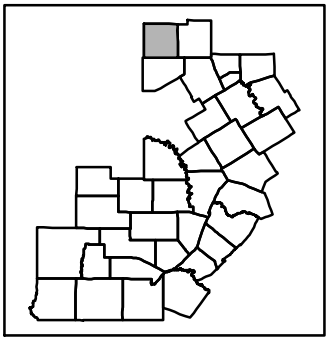
0 2 4 8 Kilometers

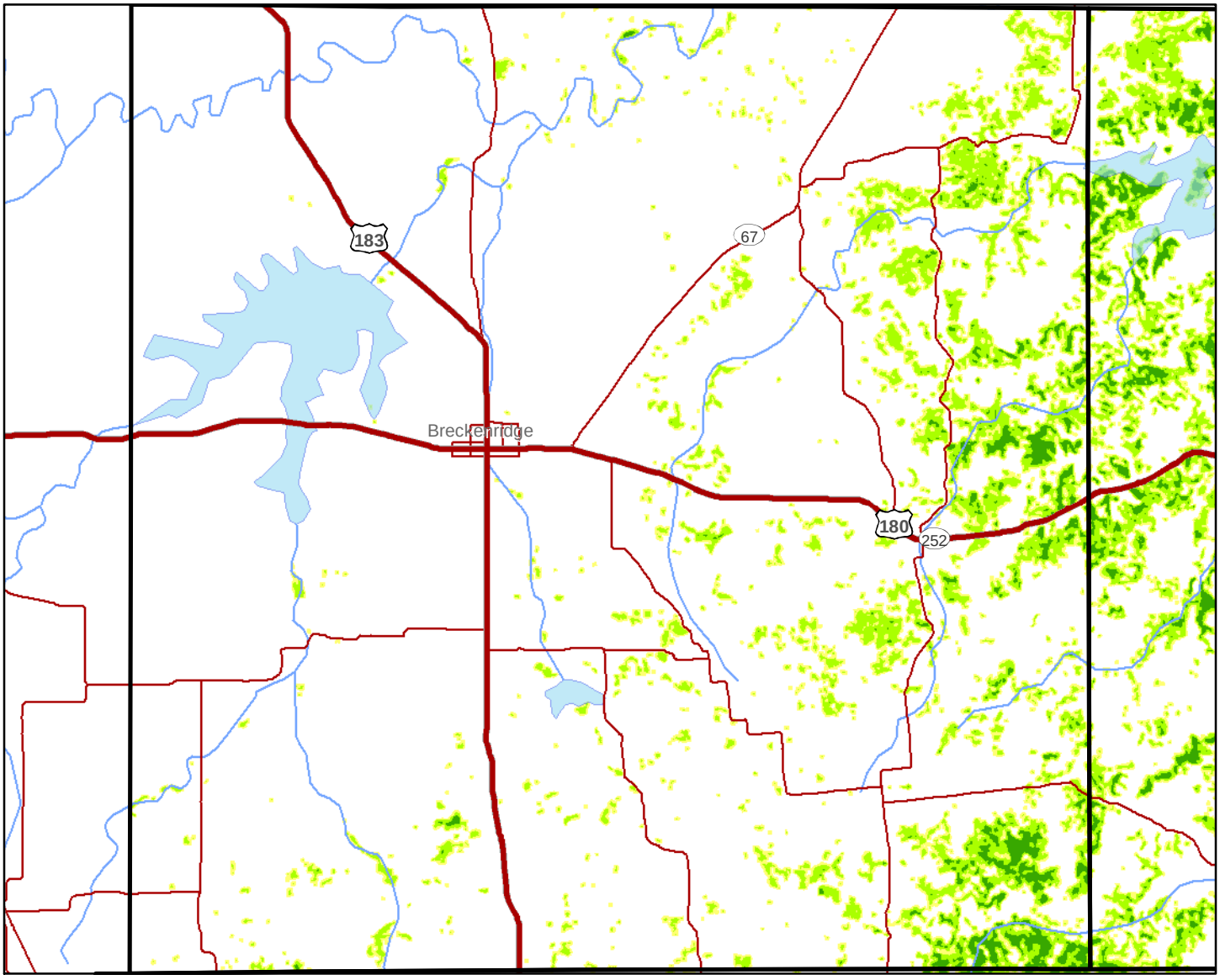
Figure 5. GCW Model L

STEPHENS COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

1:321,941

0 2.5 5 10 Miles

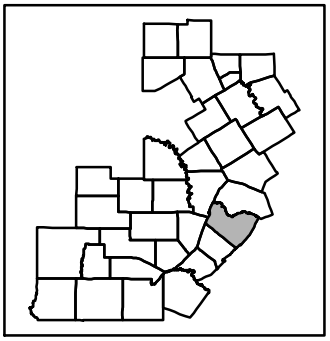
0 3.75 7.5 15 Kilometers

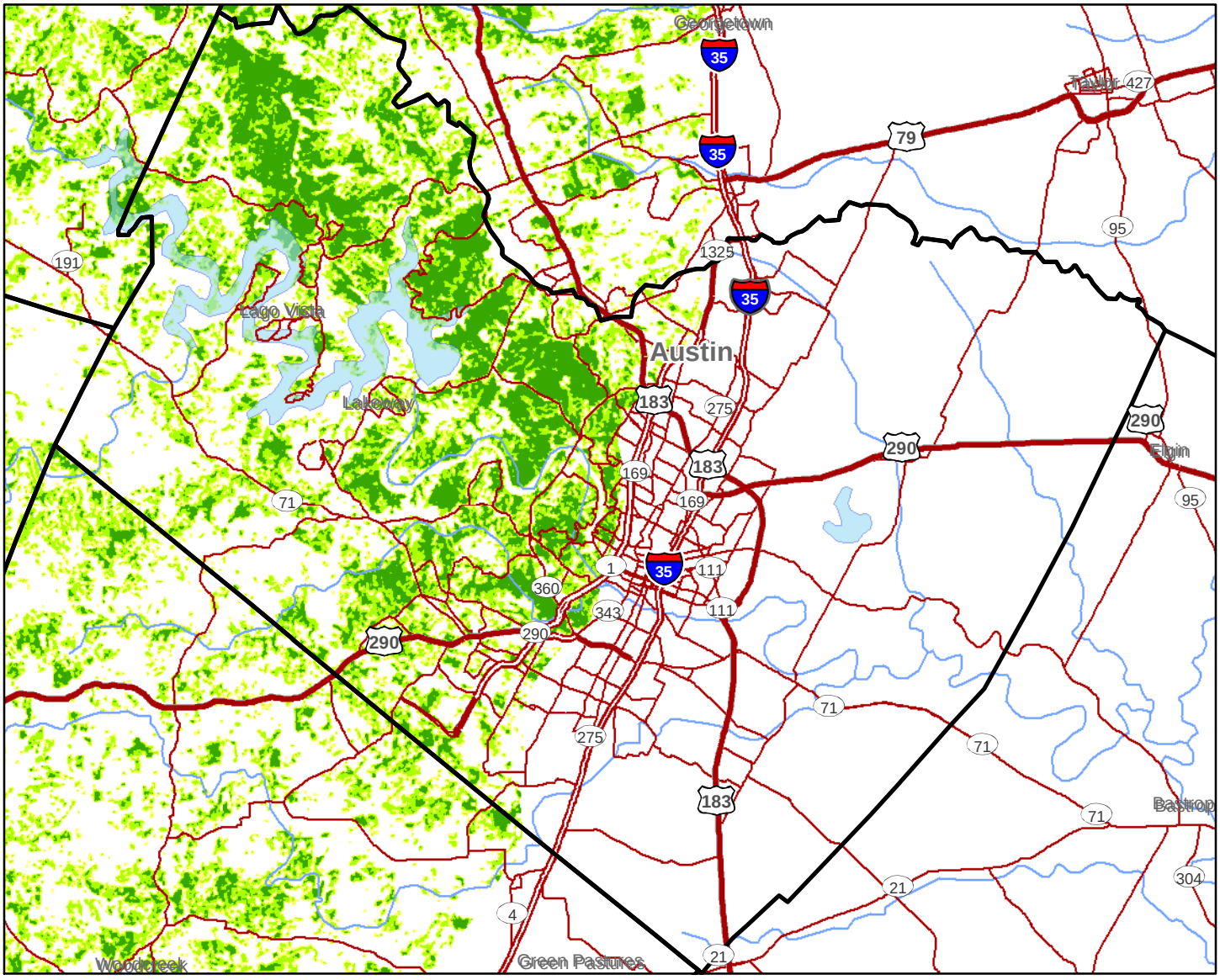
Figure 5. GCW Model L

TRAVIS
COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N
W E
S

1:440,119

0 3.5 7 14 Miles

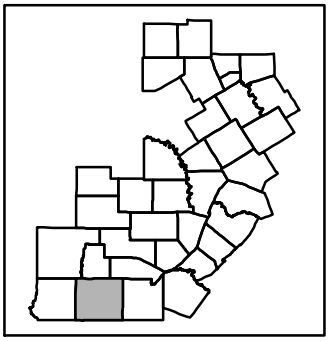
0 5 10 20 Kilometers

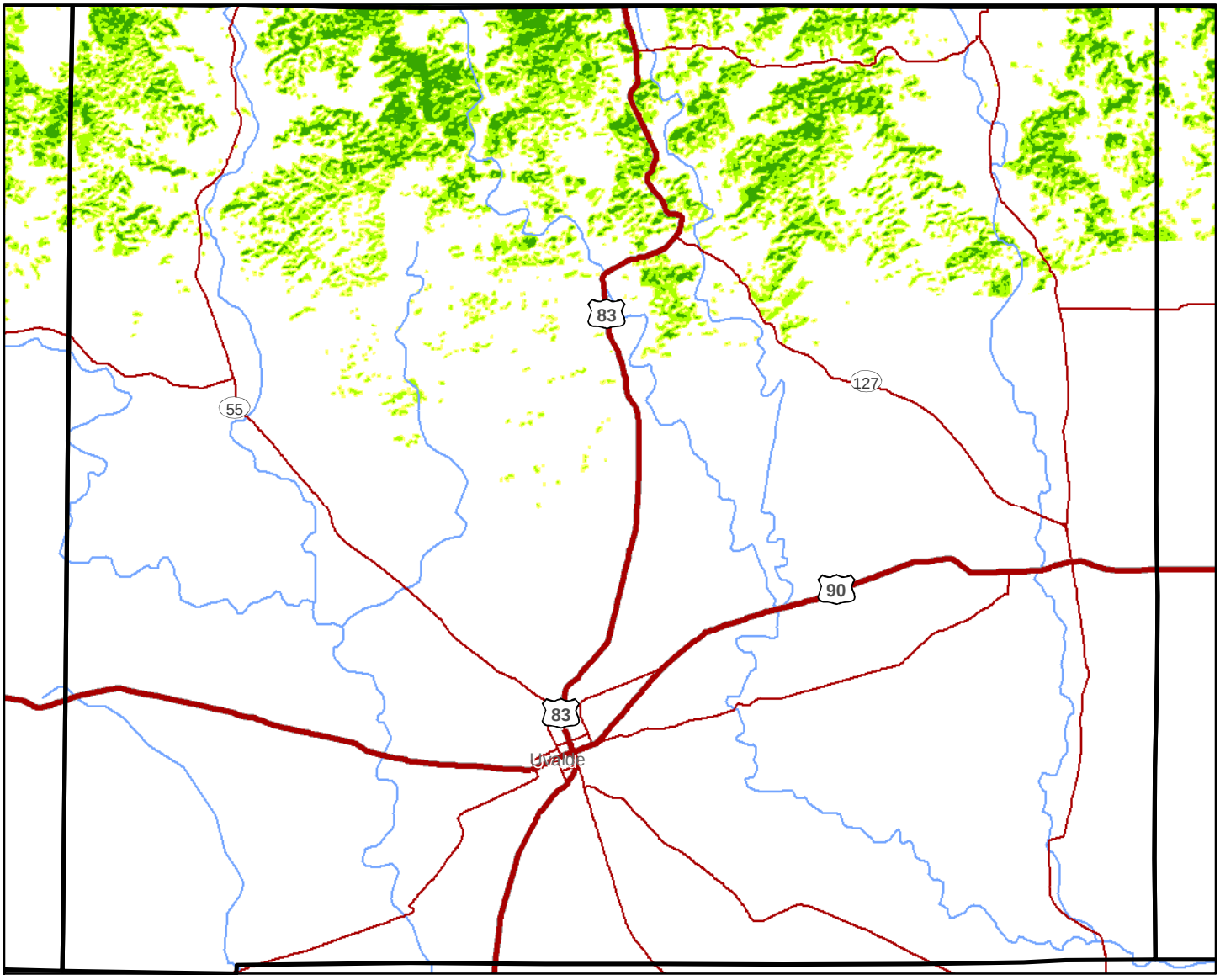
Figure 5. GCW Model L

UVALDE
COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

N
W E
S

1:396,913

0 3 6 12 Miles

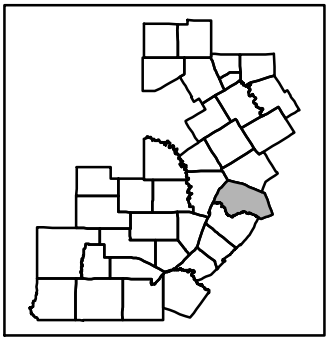
0 4.5 9 18 Kilometers

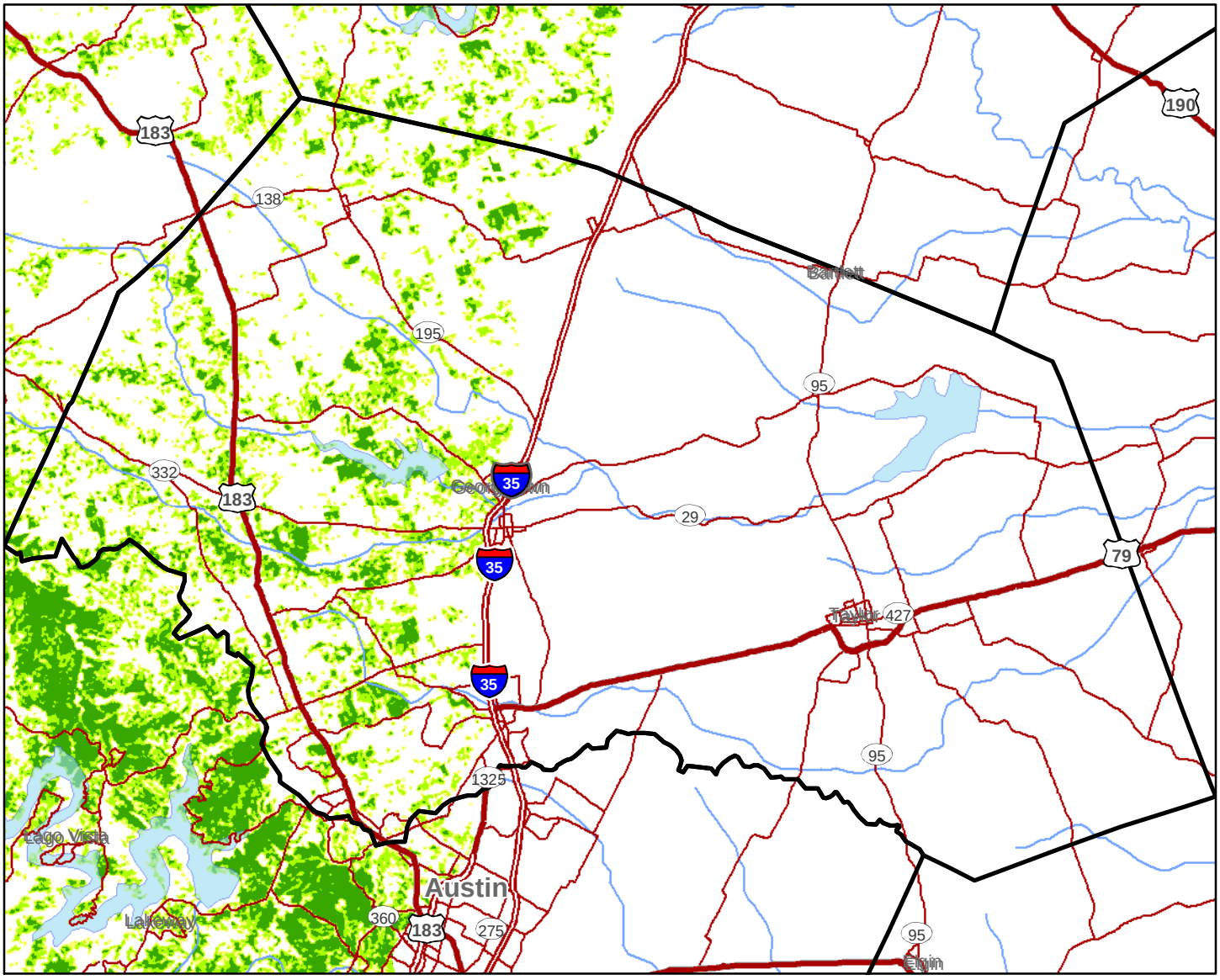
Figure 5. GCW Model L

WILLIAMSON COUNTY

Habitat Quality

- Not Habitat
- 1 Low Quality
- 2
- 3 High Quality





Legend

- County
- Limited Access Highway
- Highway
- Major Road
- Stream
- Lake
- Military Installation

1:452,765

0 3.5 7 14 Miles

0 5 10 20 Kilometers

Golden-cheeked Warbler Habitat Up-date
Final Report
November, 2010

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The Southern Edwards Plateau Habitat Conservation Plan seeks to provide information to obtain a permit from the US Fish and Wildlife Service in compliance with the Endangered Species Act. The Golden-cheeked Warbler (GCW) is one of the species of concern in this regard. Land management practices and development for urban infrastructure result in loss of GCW habitat throughout the range.

Several versions of GCW habitat have been delineated. Most have been modeled based on satellite remote sensing information, while one, completed for TXDOT, was based on human interpretation and delineation from air photos. The remote sensing classifications have generally relied on both the location of woodland and forest, and on the overall amount of woodland and forest within a neighborhood (circular area around a given pixel). The remote sensing based classifications have largely resulted in similar delineations of habitat. Based on input from the Biological Advisory Team (BAT), we focused on a satellite remote sensing model called "new model C live oak as deciduous." A full discussion and evaluation of differences among models is beyond our current scope.

Our goal was to provide information to up-date the "new model C live oak as deciduous" GCW habitat model. Four Thematic Mapper satellite images are needed to cover the study area (Figure 1) Importantly, the new model C live oak as deciduous classification used two time periods of satellite data: most was based on 2005 to 2007, three-date satellite mosaics, but two small areas were filled-in using data from the middle to late 1990's (Figure 2). The fill-ins were needed because at the time new model C live oak as deciduous was completed, no new classified satellite data were available for those two scenes (Table 1). The areas that were filled in with 1990's data are small but the eastern sliver is significant, because it is centered just north and west of San Antonio, where development has occurred apace over the past 15 years.

Table 1. Dates of Thematic Mapper satellite data used for new model C live oak as deciduous Golden-cheeked Warbler habitat model.

Path/Row	Summer/Fall	Winter	Spring
27/39	9/26/2005	2/14/2007	4/4/2007
28/39	9/20/2006	2/8/2006	3/31/2007
27/40	from National Land Cover Dataset: mid to late 1990's		
28/40	from National Land Cover Dataset: mid to late 1990's		

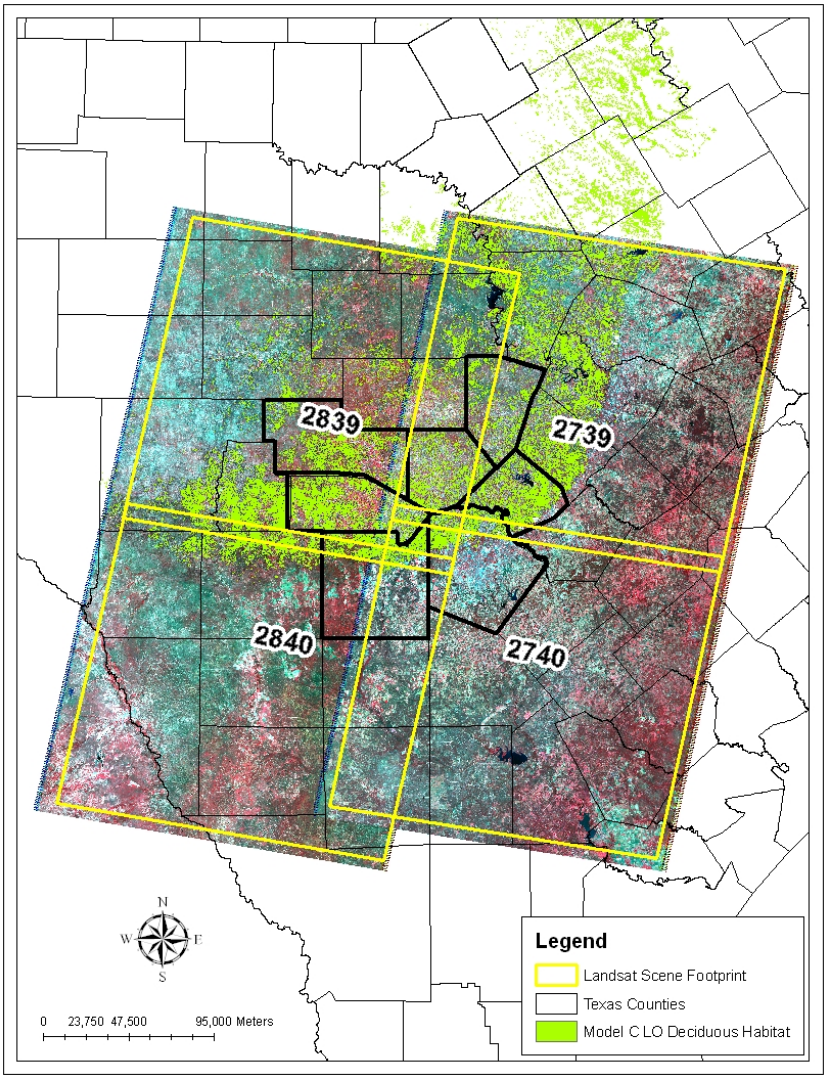

Figure 1. Satellite image footprints for the study area. For the new model C live oak as deciduous Golden-cheeked Warbler habitat model, path/row 27/39 and 28/39 used 2005 to 2007 data, whereas middle to late 1990's data were used for path/row 27/40 and 28/40 (see Figure 2).

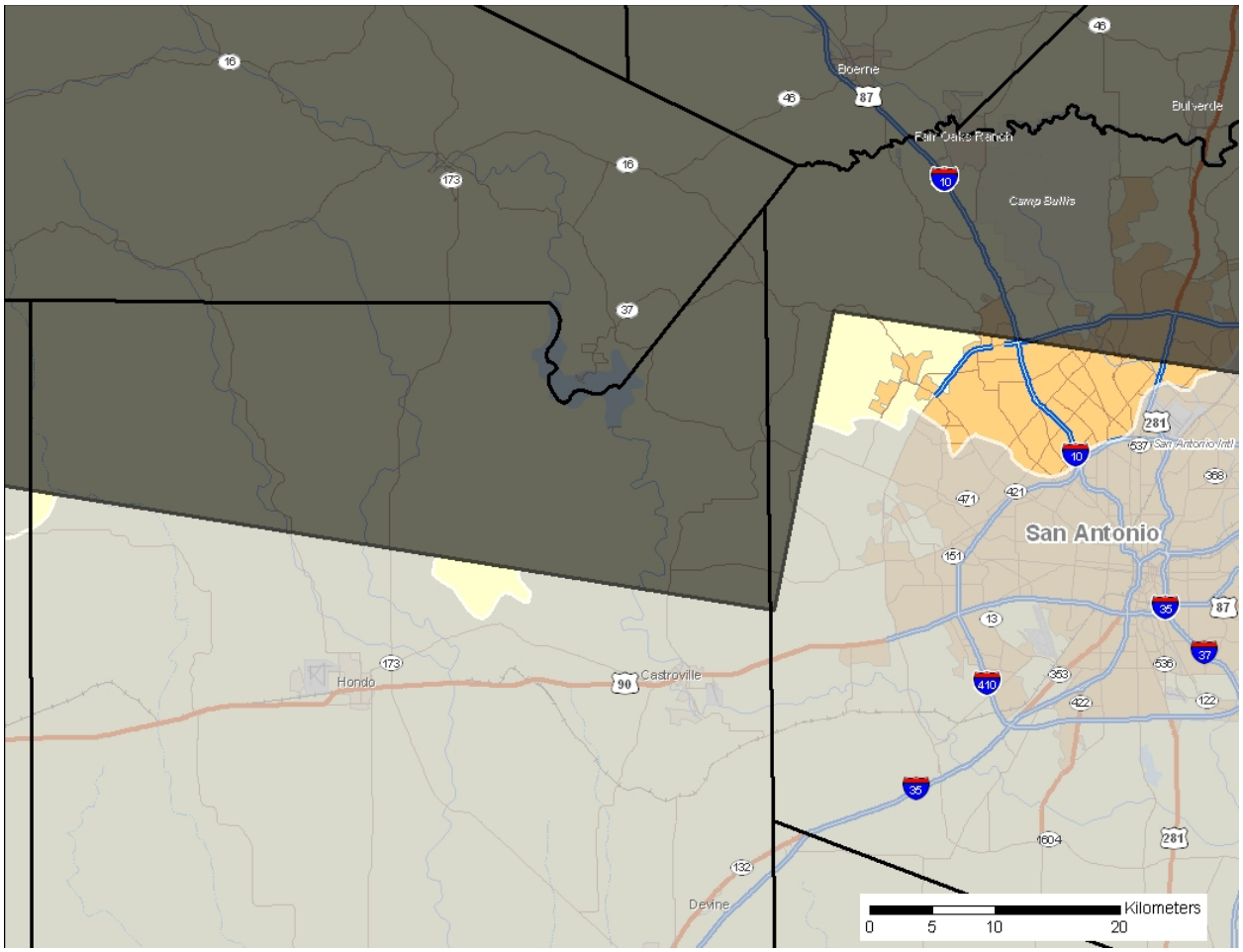

Figure 2. Depiction of area where 2005 to 2007 data were unavailable (un-shaded area), and National Land Cover Dataset (middle to late 1990's) data were used to develop new model C live oak as deciduous. Light yellow areas are within the range of the Golden-cheeked Warbler whereas the other un-shaded areas are outside the range.

Methods

We used ERDAS Imagine software and ArcMAP to perform all analyses. Basic steps included:

1. Create a 2010 Thematic Mapper satellite image mosaic (30 meter resolution) using 2010 data (August 23 for path/row 27/39 and 27/40, and October 1 for 28/39 and 28/40).

2. Classify the 2010 image mosaic into 'forest' and 'non-forest' using the Isodata routine in ERDAS Imagine, including cluster-busting of confused classes.

3. Perform change detection using Delta Cue in ERDAS Imagine using the 2010 mosaic versus a classification from the Texas Parks and Wildlife Department that used 2005 to 2007 data.

4. Overlay "non-forest" and "change" to define forest areas that have been cleared between 2005/ 2007 and 2010.

NOTE: steps #3 and #4 provided a GCW habitat change result for a three- to five-year time for most of the study area, but not for the small slivers on the south side, one of which covers an area immediately north and west of San Antonio (see Figure 1).

5. For the two southern slivers outlined above, we compared the 2010 "non-forest" with the National Land Cover Dataset (NLCD) "forest" classes. Areas that were not forested in 2010 but were in the NLCD represent forest clearing across an approximately 15-year time step, which corresponds with the timing of data used to develop new model C live oak deciduous.

6. Perform accuracy assessment (two workers, independently) on forest change using photo-interpretation of 2010 NAIP imagery. Sample points were selected in a stratified random manner, with 125 points each representing the change and no change classes. In addition, 50 points were selected within 100 meters of main roads per request from representatives of the granting agency.

Results and Discussion

Accuracy for the forest change detection was 92% overall, which is excellent for a product of this type (Table 1). Errors of commission were greater for change (14.4%) than for no change (1.6%). In other words, we may have suggested that some areas have been cleared when they have not, but these might well have been non-forest, and therefore non-habitat, in both 2010 and on the earlier dates. We almost never suggested an area has been cleared when it has not been cleared based on photo interpretation. Satellite imagery acquires data by averaging reflectance over a 900 square meter pixel, but we were able to interpret land cover using a point viewed on 2010 air photos of much higher resolution. A 900 square meter area might well be mainly forest or mainly grassland but may contain smaller amounts of other land cover types, or edges between different types. A photo-interpreter does not know how any given 900 square meter pixel is situated on the landscape (e.g. centered on the edge between forest and grassland, or centered over a very small opening in a forest), so errors invariably arise.

Table 2. Accuracy assessment for Golden-cheeked Warbler habitat change for the Southern Edwards Plateau Habitat Conservation Plan region.

# of Sample Points	Classification Data				
Reference Data	**Class Change**	**Class No Change**	**Row Total**	**Producer's Accuracy**	**Error's of Omission**
Lee & Ron Change	107	2	109	107/109	2/109
Lee & Ron No Change	18	123	141	123/141	18/141
Column total	125	125	250	230/250	20/250
User's Accuracy	107/125	123/125	**230/250**		
Error's of Commission	18/125	2/125	18/250		

Percentages	Classification Data				
Reference Data	**Class Change**	**Class No Change**	**Row Total**	**Producer's Accuracy**	**Error's of Omission**
Lee & Ron Change	42.8%	0.8%	43.6%	98.2%	1.8%
Lee & Ron No Change	7.2%	49.2%	56.4%	87.2%	12.8%
Column total	50.0%	50.0%	100.0%	92.0%	8.0%
User's Accuracy	85.6.2%	98.4%	**92.0%**		
Error's of Commission	14.4%	1.6%	8.0%		

A total of about 9,340 hectares (23,081 acres; 36 square miles) of forest clearing occurred within what was identified as Golden-cheeked Warbler habitat by model C live oak as deciduous between the time it was created and late 2010 (Figure 2; Table 3). This represents 2.4% of the habitat. The mean patch size of cleared areas was 0.37 hectares (0.91 acres), but 53.8% of the cleared area was in patches >1 hectare (2.47 acres), and 33.3% of the cleared area was in patches >4 hectares (9.88 acres). The largest loss of habitat was in Bexar, Bandera, and Kerr Counties, but note that change within parts of Bexar County was across a 15 year time step, rather than a five year time step as for most of the region (see Figure 1).

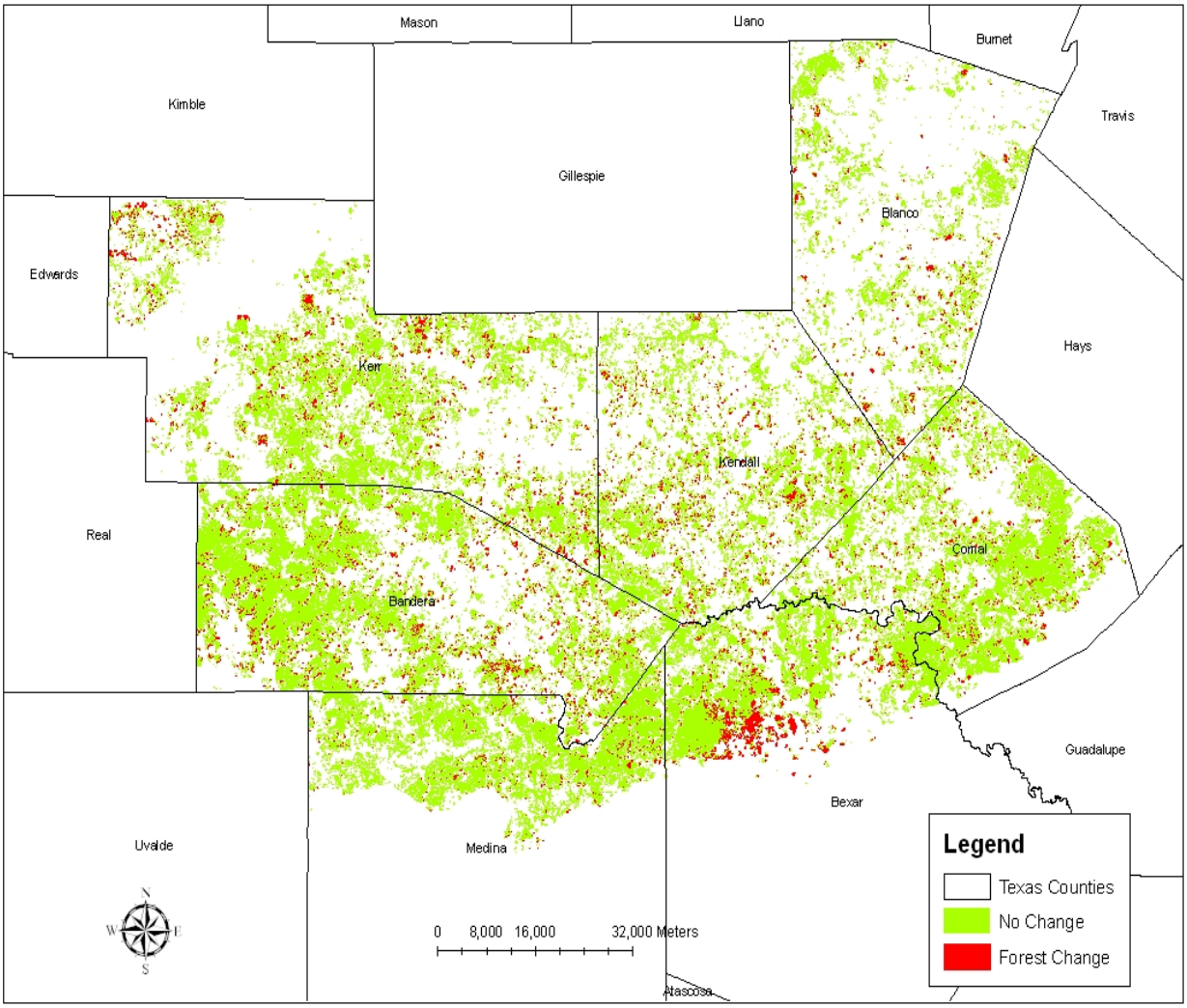

Figure 2. Location of change (forest clearing) within the area identified as Golden-cheeked Warbler Habitat by model C live oak as deciduous. Compare with Figure 1 to note the areas in the south where change was across a 15-year time step instead of a five year time step, especially the area immediately to the west of San Antonio. ***Note that the size of forest change patches are exaggerated for illustrative purposes, or change would scarcely be visible across much of the region.***

Table 3. Change (forest clearing) within Golden-cheeked Warbler habitat from model C live oak as deciduous. Time-step was five years for most of the area, but was about 15 years for a sliver in the south (see Figure 1)

County	Class	Class Area (ha)	% Class Area	# of Patches	Mean Patch Size	Median Patch Size	Patch StandDev
Bandera	No Change	91,893.69	24.2%	3,637.00	25.27	0.27	873.18
	Change	1,913.40	20.5%	6,953.00	0.28	0.09	0.78
Bexar							
	No Change	37,317.60	9.8%	2,095.00	17.81	0.27	266.94
	Change	2,241.09	24.0%	2,752.00	0.81	0.18	5.46
Blanco							
	No Change	29,581.38	7.8%	2,845.00	10.40	0.27	74.15
	Change	555.57	5.9%	1,355.00	0.41	0.09	1.22
Comal							
	No Change	58,706.82	15.5%	2,350.00	24.98	0.36	478.75
	Change	1,109.34	11.9%	3,267.00	0.34	0.09	1.04
Kerr							
	No Change	66,979.44	17.7%	5,244.00	12.77	0.27	170.51
	Change	1,856.43	19.9%	4,643.00	0.40	0.09	1.73
Kendall							
	No Change	46,601.82	12.3%	3,680.00	12.66	0.36	109.91
	Change	1,133.01	12.1%	4,074.00	0.28	0.09	1.18
Medina							
	No Change	48,249.90	12.7%	1,591.00	30.33	0.18	600.46
	Change	531.27	5.7%	1,991.00	0.27	0.09	1.23
Total	No Change	379,330.65	97.6%				
	Change	9,340.11	2.4%				

Final Notes

The original model C live oak as deciduous model was done on a 10-meter resolution, image object based land cover classification provided by Texas Parks and Wildlife Department. We used change in forest land cover at 30 meter resolution provided here to create a revised GCW habitat model at 30 meter resolution using methods developed for model C. This model is not directly comparable with "new model C live oak as deciduous," but does represent yet one more revision of the GCW habitat model – this time using 2010 data. Overall, we do not feel that use of this model will significantly impact planning efforts, and risks adding some confusion, given all of the different models available and the multitude of caveats attached to each.

We are available to modify and improve the delivered products and to provide clarifications and comments as needed. Hopefully, we can host a WebEx meeting for the Biological Advisory Team and partners, which will allow us to field questions, and will allow partners to view results on-screen in multiple locations, and at multiple resolutions. Please do not hesitate to contact us.