Wild Planner User’s Manual



Craighead Institute

Bozeman Montana

# Credits and Use Constraints

## Author:

Brent L. Brock, Landscape Ecologist  
Craighead Institute  
201 S Wallace Ave, STE B2D  
Bozeman, MT 59715  
(406) 585-8705  
info@craigheadresearch.org

## Use Constraints:

This is a beta release of Wild Planner which is still being tested and frequent revisions are expected. It was developed for ArcGIS 9.3 but updated to run in ArcGIS10 although testing for the newer version has been limited. No warranty is implied regarding the use of this software. Wildplanner may be freely download, used, copied, and distributed without express permission of the author for NON-COMMERCIAL purposes only provided the author is acknowledged in all materials produced using these tools. The suggested citation is:

Brock, B.L. 2011. Wild Planner: wildlife tools for land use planning. Craighead Institute. Bozeman, MT, USA.

# Introduction

Wild Planner is a collection of GIS-based tools designed to support land use decision making for wildlife conservation. The toolbox includes tools to assist conservationists, land use planners, developers, and other interested parties with designing landscapes that provide secure living habitat and/or allow movement habitat connectivity for wildlife.

Wild Planner is based on the precautionary principle. It identifies and eliminates areas suspected of compromising wildlife and their habitats and evaluates remaining areas for their potential to support desirable wildlife.

Wild Planner is not intended to replace consultation with wildlife professionals or on-site evaluations. Any conservation or development plans based on results from Wild Planner should be followed up with consultation with local professional wildlife authorities and on-site verification before implementing plans.

# Getting Started

## Installing and Accessing the Toolbox

Wild Planner is an ArcGIS toolbox file with associated Python scripts, layer files, and help documents. Also included in the package is a tutorial that includes an ArcMap document and sample data.

To install Wild Planner simply copy the entire contents of the distribution disc to a local or network drive making sure to copy the entire directory structure. If Wild Planner is obtained as a zip file, unzip the file to the desired folder and the proper directory structure will be created. The tutorial folder can be moved to a different location without affecting toolbox function, or deleted if the tutorial is no longer needed.

Once the toolbox is copied to the desired location, it can be accessed by opening ArcMap and making the ArcToolbox window is open. Right-click on the ArcToolbox icon at the top of the ArcToolbox window and select ‘Add Toolbox’. Navigate to the folder containing Wild Planner and select the ‘Wild Planner.tbx’ file. The Wild Planner toolbox will appear in the toolbox window and is ready to use.

Circuitscape is required for some movement habitat analyses. Circuitscape is a free, open-source program which borrows algorithms from electronic circuit theory to predict patterns of movement, gene flow, and genetic differentiation among plant and animal populations in heterogeneous landscapes (Circuitscape.org) and can be downloaded at: <http://circuitscape.org>. The 64-bit version recommended. If Circuitscape is not installed in the default location, WildPlanner will search the local C: drive and automatically update itself with the new location. If Circuitscape is installed on a different drive, WildPlanner must be updated by opening the file Scripts\local\_params.py in a text editor, and editing the following line to the correct location for the Circuitscape executable file:

cs\_path = u'c:\\Program Files\\Circuitscape\\cs\_run.exe'` *IMPORTANT: Do Not delete the u in front of the quoted path string.*

## Navigating in Wild Planner

Wild Planner is arranged into three toolsets named according to their intended purpose. Within each toolset are the tools. Double-clicking a tool accesses the dialogue box for each tool. When a tool dialogue is opened, a window appears in the help panel in the right-hand side of the dialogue window with a brief description of the tool. Clicking on any of the dialogue inputs changes the help panel contents to describe the input parameter that was clicked. Clicking the ‘Tool Help’ button accesses the help file for the tool.

# Background and Rationale

Rural development impacts wildlife and their habitats in multiple ways. The most direct impact is destruction of habitat within the footprint of infrastructure (e.g. houses and roads), or by blocking access to otherwise suitable habitat by building fences or other structures that impede wildlife movement. However, indirect impacts to wildlife are often more significant than direct loss of habitat due to construction. Wildlife species, and even individuals within species, react in different ways to human presence. Many animals avoid areas of high human activity resulting in an effective loss of habitat. Other animals may be attracted to human dwellings by succulent landscaping vegetation, the smell of food, or structures that provide shelter or nesting sites. Some individuals may discover that human developments provide a safe haven (e.g. from hunting) and seek refuge within these protection zones. When wildlife are attracted to human dwellings, property damage and concerns for human safety often follow while management (e.g. controlled hunting ) becomes difficult or impossible. Other wildlife species (both native and non-native) are well-adapted to living among humans and are attracted to developed areas where they increase in abundance, usually displacing many original native species in the area. Another, rather complex, outcome of human development is the creation of “population sinks”. A population sink is an area where a species finds apparently suitable habitat but animals die at a higher rate than they can reproduce. Therefore, the species’ continued presence in the habitat depends on a surplus of individuals being produced somewhere else and periodically immigrating into the sink habitat. Humans and their domestic pets may chronically disturb resident wildlife, directly prey on them or introduce diseases or toxins such that wildlife mortality rates increase and/or reproductive rates decrease resulting in a potential population source becoming a sink.

The response of wildlife to roads is equally complex. Roads form a major barrier to movement and source of mortality and disturbance for many species. Roads also allow humans to gain access to areas that would otherwise remain relatively undisturbed. Chronic disturbance and increased mortality as animals encounter humans may cause sensitive species to abandon areas that would otherwise provide high quality habitat if they were roadless. However, not all roads influence wildlife equally. Traffic volume and road surface often influence animal responses to roads. Unpaved roads with little traffic may actually become preferred travel routes for some animals while heavily trafficked, paved, four-lane highways may create nearly impenetrable barriers to movement and likely death for individuals that do attempt to cross.

Regardless of how wildlife responds to human development, the result is a zone of influence around developments where wildlife habitat, species communities, and behaviors are altered. As described above, the response is not always negative, and a positive response is not always good. The sizes of these zones of influence depend on a variety of factors such as type of habitat surrounding the development, sensitivity of the wildlife species present, and behavior and land stewardship of the residence. Zones of influence often extend beyond property lines and spill over to affect neighboring properties as well. The cumulative pattern of these zones influences landscape level habitat use and movement patterns for many species. In extreme cases, overlapping zones of influence can create barriers that impede regional movement of migrating or dispersing species.

The Wild Planner toolbox is based on the precautionary principle that acknowledges species specific responses to a particular development cannot be precisely predicted. But by considering general sensitivities of species to human disturbance and habitat needs, areas unlikely to be harmed by development can be identified and evaluated according to their ability to provide for wildlife needs. By controlling the pattern of the cumulative zone of influence on the landscape, planners and developers can design for future growth that maintains sufficient blocks of undisturbed habitat and movement corridors to allow the opportunity for wildlife to flourish. The intent is to provide a bridge that translates scientific information about species needs into a result that is useable and understandable by planners, developers, and other interested groups.

Ideally, rural development would be neutral with respect to wildlife. The goal should be to create developments that meld as seamlessly as possible with the surrounding landscape to allow residents to enjoy wildlife as they naturally live and move through the area without creating attractive havens that increase property damage complaints, raise issues of human safety, or upset the natural balance of species living in the area. This ideal is difficult to achieve, but at a minimum requires careful consideration for density and placement of structures on the landscape, and a commitment to follow best stewardship practices among a majority of residence. Wild Planner provides a first step toward assisting planners and developers with addressing density and placement issues.

# Using Wild Planner

Wild Planner is relatively straightforward and easy to use. By understanding a few simple concepts and assembling the necessary data, users should be able to begin using the toolbox quickly.

## Important Concepts

Most of the Wild Planner tools use simple models to map the location of habitat outside the influence zone of development and compare results with user-supplied information about species requirements. The following concepts are important for using the toolbox appropriately:

Influence Distance: The distance from a development feature where wildlife habitat use or behavior is altered from what would occur if the feature did not exist. As noted earlier, the actual response by wildlife is often difficult to predict. Likewise, the impact of the cumulative disturbance zones on species populations is difficult to predict although numerous studies have shown that as development densities increase, either the total number of native species decreases, or naturally occurring human-sensitive species are replaced by human-tolerant species that have become familiar and ubiquitous in suburbanized areas throughout the U.S. The most prudent assumption based on current science is to assume that a full assemblage of naturally occurring species can only be maintained by providing a sufficient amount of undisturbed habitat.

**Important** – a zone of influence does not mean that a species will be excluded from the area. It simply indicates an area where the ability of desirable species to live and reproduce in, or move through an area is likely to be decreased; or that a species might begin using the area in an undesirable fashion. Therefore, a species may persist within a zone of influence and may even increase in abundance but within the zone there is ***potential*** that the species’ abundance or behavior has been altered from the natural and desirable state.

Habitat Type: The Wild Planner tools address two broad categories of habitat types:

Core Habitat – blocks of habitat that can be loosely described as “Living Habitat”. This is habitat needed for animals to obtain food, find shelter from the elements or predators, reproduce, etc. Habitat cores may be used continuously, seasonally, or intermittently over a period of years but they are important for maintaining the species in a region over long time periods (decades to centuries or longer). The size requirement for a “core” depends on the species and management objectives. It is up to the user to determine the appropriate criteria. Cores can be defined at a variety of scales. Examples include: a patch that provides forage or security within an individual’s home range; the size needed for an individual to live throughout the year (home range); an area of seasonal use (e.g. winter range); or an area large enough to maintain a sustainable population.

Movement Habitat – areas that allow animals to move between discrete habitat patches is collectively known as “movement habitat”. Specific areas of movement are often called “corridors” or “linkages”. The latter term is often preferred to avoid the assumption that movement follows a relatively straight and narrow path like a hallway corridor. Although such movements do occur in some species, movement is more often less predictable, may wander to avoid obstacles or take advantage of food or security patches, and does not always follow the same pathway to a destination. Therefore, good movement habitat typically provides multiple possible pathways to complete a connection. Movement habitat may, or may not, differ significantly from a species’ preferred habitat in terms of vegetation, topography and other features. Some species are strictly tied to rather specific habitats and movement habitat may consist of ribbons or “stepping stone” patches of habitat that allow animals to move from one patch of preferred habitat to another without actually having to leave their preferred habitat for more than brief periods. Other species may move widely across areas that are markedly different from areas where they are typically found, but predicted how different areas can be before they no longer function as movement habitat is difficult. As with habitat cores, movement habitat can be defined at multiple scales with different frequencies of use. For example, movement habitat may be areas that connect discrete patches of suitable habitat that collectively comprises an individual’s home range. In this case, the frequency of movement may be weekly, daily, or even several times a day. Or movement habitat may connect areas of seasonal use such as between summer and winter range. In this case, the frequency of use may be only once or twice a year. Or finally, movement habitat may allow individuals to disperse to distant habitat patches. Such movements may be extremely rare with many years passing between events. But despite the rarity of occurrence, such movements may be critical for maintaining genetic diversity needed for the long term survival of the species, or to facilitate recovery into habitats where the species has been extirpated.

Habitat Preference: areas where a species is most likely to be found, where they feel most secure, and where their chance of survival is greatest is their “preferred habitat”. Wild Planner estimates movement habitat quality on the assumption that areas that are similar to preferred habitat and free from human disturbance make the best movement habitat. Wild Planner broadly defines habitat preference. Three categories are currently supported: Forest-Shrub for species that prefer to be in or near woody concealment cover, Grassland-Open for species that avoid dense woody cover, and Wetland-Marsh for species that avoid venturing far from water.

Focal Species: most of the tools in Wild Planner depend on wildlife requirements as inputs. These data are most often available in published studies on individual species, or other taxonomic groups (e.g. grassland birds). It is not necessary or desirable to attempt to analyze every species to be conserved through the planning process. By choosing a few key species to represent the needs of all species in an area, a robust plan can usually be developed by focusing analysis on a half dozen or fewer species. To be effective, the most demanding or sensitive species should be chosen for each element of conservation. For example, if living habitat for grassland species is important, then choose the grassland species in the area with the largest core area requirements. If forest habitat connectivity is important, then choose the forest species most sensitive to human disturbance to analyze. Even if the most demanding species is expected to use an area only very rarely, by designing for that possibility, the planner has accounted for the uncertainty of other species requirements by designing a landscape that will accommodate all species.

Roads and Movement Habitat: Users will notice that roads are not included as inputs in movement habitat analyses. This may seem counter intuitive since roads represent

## Data Requirements

Wild Planner combines maps of a landscape with information about wildlife needs to produce data and visualizations to help users understand potential changes in patterns of usable habitat due to development. An attempt has been made to minimize data requirements for using the tools while allowing flexibility for applying the tools to a variety of projects and locations. Each tool will require a subset of the following data:

### Input Layer Descriptions:

Constraint Layer (Buildable Area): a GIS polygon layer representing areas where future development is possible. This layer should be developed according to the constraints associated with a particular area. These constraints may include:

* Regulatory constraints such as zoning regulations, wetlands protection laws, etc.
* Deed Restrictions such as sell or transfer of development rights through easements or other instruments.
* Physical constraints such as steep slopes, unstable soils, etc.
* Ownership constraints – public land that can’t be developed.
* Other constraints

Analysis Area: the area of interest to be analyzed. Depending on the tool, this can be either a polygon layer or an extent. If the input is a layer, analyses are confined to areas inside polygons. Choosing the correct analysis area is important for achieving satisfactory results. The best analysis area depends on the characteristics of the area being studied and the objectives of the analyses. Following are some general guidelines to consider:

FOCUS ANALYSES ON IMPORTANT AREAS – Wild Planner is designed for use within a multi-scale planning framework. Broad-scale analyses can identify regionally important areas core and/or movement habitat and Wild Planner can help set conservation priorities within those areas. This is particularly useful for analyzing movement habitat so local conservation actions contribute to regional habitat connectivity.

Restrict Analyses to Potential Habitat – when analyzing habitat patches, analysis layers should exclude areas that are unsuitable for use by the species of interest. Users should consider requirements for long term persistence of the target species. Maps based on habitat occupancy over a relatively short period may not include areas that are crucial for surviving relatively rare events such as extreme winters when animals need to travel farther than normal to escape deep snows and find sufficient forage. Habitat models and species distribution maps are two commonly available sources for developing habitat analysis layers.

When analyzing movement habitat, the analysis extent should include all areas of potential movement habitat between source/destination habitat patches. The extent does not have to include entire source/destination patches as long as it includes the appropriate patch boundaries. For example, if the objective is to analyze movement habitat between two national forests, the analysis extent only needs to include areas of the forests that border potential movement areas.

Include a Landscape Level View – The analysis area should be large enough to provide a landscape view of habitat patches and linkage zones. Analysis should never be confined to the boundaries of a proposed development because that is not informative about how the development might impact the size, shape, and access to surrounding habitat. At a minimum, the analysis area should include all patches of potential living habitat that intersect a proposed development boundary and the nearest potential living habitat patches beyond intersecting patches in all directions. Typically the analyses are calculated for an area of several square miles to give the user a broad perspective. The user can then zoom in to the area of interest for a closer look.

Keep the Analysis Area Manageable – Most of the Wild Planner tools can analyze large areas quickly, making it practical to process entire counties with a single analysis. However, the movement evaluation tools use some computer-intensive raster processing that can take a long time to complete at high resolution and large areas. At the default resolution of 30 meters, these tools can typically process ten square miles on most GIS-capable computers in less than an hour. For larger areas, the user should be prepared for significantly longer processing times or consider increasing the analysis cell size.

Influence Distance: See the ‘Important Concepts’ section for definition and discussion. Ideally these values are gleaned from published studies. Table 1 contains selected values with references. Unfortunately disturbance studies are rarely available for the same species, habitat, and geographic area as the area of interest so values must be adapted using a combination of published studies for other areas and often surrogate species, and local expertise to adjust those values to local condition.

Tip: Consider analyzing areas with two or more influence distances to account for uncertainties in predicting responses to human disturbances. The longest influence distance can represent the “ideal” situation where confidence is highest that wildlife use and movement outside influence zones will be minimally affected by human activities. Analysis at shorter distances can be used to estimate “sub-optimal” areas where animals may be influenced by human activities but not so severely as to negate all wildlife use. Alternatively, shorter influence distance might reflect benefits gained from improved stewardship by human residence to minimize human disturbance in the area.

Minimum Patch Size: See the section on ‘Core Habitat’ under ‘Important Concepts’ for definition and discussion. The same sources, limitations, and suggestions apply as for influence distance.

Roads: This is a line layer indicating the location of roads likely to influence wildlife. Several tools require an existing roads layer to evaluate the influence of road networks on wildlife habitat, or to create simulations of potential development. The layer may represent either existing structures or structure locations for hypothetical development. Not all roads impose a strong influence on wildlife so the choice of roads layer should consider the traffic volume of roads used, the sensitivity of the species of interest, and perhaps pavement type. For most analyses, roads servicing residential areas are an appropriate cutoff for selection. Small “two track”s (e.g. ranch service roads) or lightly traveled remote roads (e.g. Forest Service roads) would not be included depending on the sensitivity of the target species. If hypothetical developments are being analyzed, the roads layer should include both hypothetical new roads to be added, as well as all existing structures within the analysis area. ‘Generate Roads can be used to generate hypothetical roads and merge them with existing roads if desired.

Structures: This is a point layer indicating the location of structures likely to influence wildlife. The layer may represent either existing structures or structure locations for hypothetical development. Some states and many counties can provide these layers of existing structures. If they are unavailable, the layer will have to be generated. One option is to digitize points from digital images. All commercial and residential buildings expected to have significant human activity (even if only seasonally) should be included. If hypothetical developments are being analyzed, the structure layer should include both hypothetical new structures to be added, as well as all existing structures within the analysis area.

Tip: When analyzing hypothetical development scenarios for impacts on habitat patches, it is important include both potential structures and roads.

Elevation Raster: A digital elevation model (DEM). DEMs are available for the entire globe. For DEMs within the United States, the National Elevation Dataset (NED) available online from the U.S. Geological Survey is usually the best choice. For tools that perform viewshed analysis, use the highest resolution DEM available but see ‘Analysis Area’ for impacts on processing time. For all other tools, a 30m DEM will generally provide good results and 90m may also be acceptable. For those tools, the DEM resolution affects the precision of simulated roads which may not need to be very precise depending on the application.

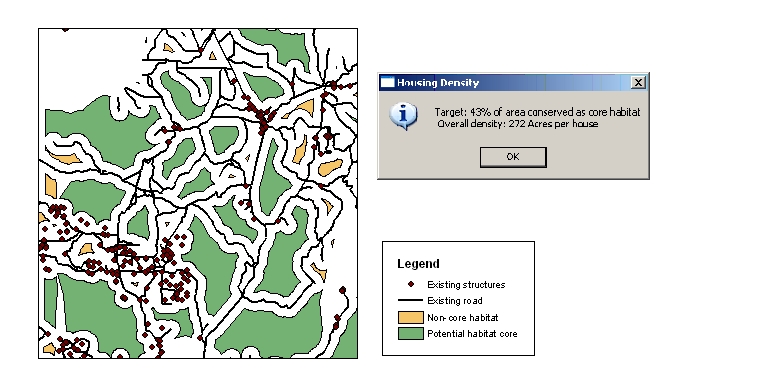
Other Data Inputs: These are described in the tool descriptions and context sensitive help associated with each tool.

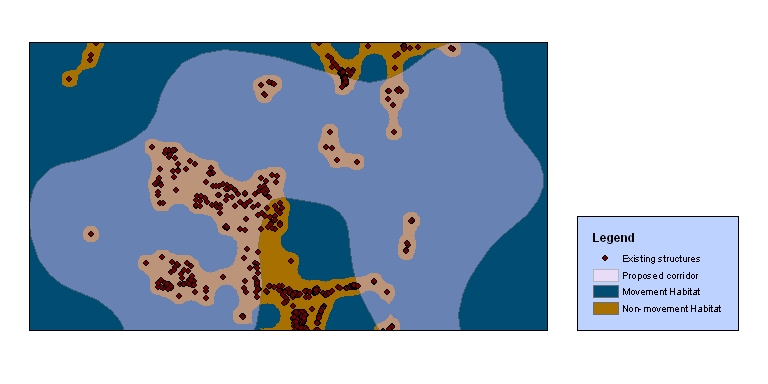
## Description of Tools and How They Work

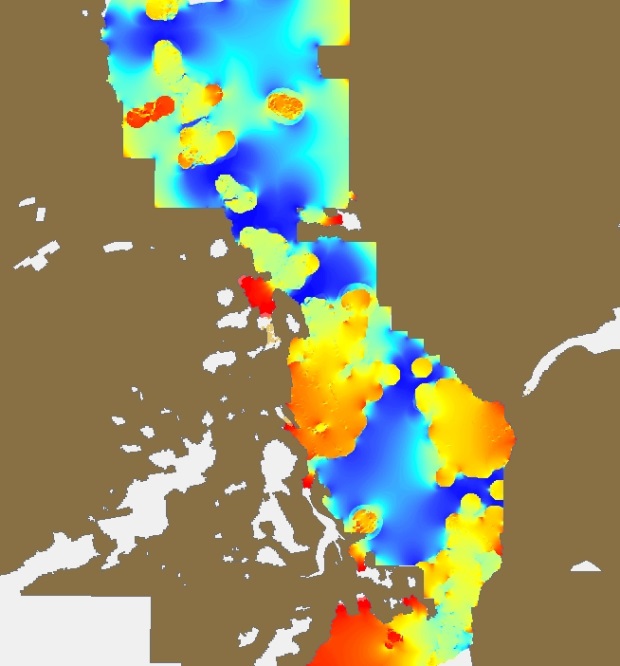
Following are overviews of WildPlanner tools with details about how the work. Additional help for using the tools and specific inputs are included in sidebar and help documentation accessible by opening tools in ArcGIS.

### Landscape Evaluation Toolset:

Landscape Evaluation Tools are designed to assist with evaluating the impacts of existing or potential landscape scenarios on wildlife. The tools can be used to evaluate an existing landscapes ability to provide habitat for a given wildlife target, or to predict the potential impacts of various development scenarios on target wildlife. Tools are provided to evaluate ‘living habitat’, and ‘movement habitat’.

Evaluate Habitat Patches: Measures the percentage of the landscape that qualifies as core habitat and produces a map of core and non-core habitat patches. When calculations are complete, a pop-up window appears with the percentage of area within the analysis layer that qualifies as core habitat. This result is stored in the output shapefile in a field named ‘PRCNT\_AREA’. Core areas are calculated by buffering roads and structures by their respective influence distances and measuring the area of the resulting habitat patches that lie outside these buffers. Areas are compared with the ‘Minimum Habitat Patch’ value specified by the user. An attribute named ‘CORE’ is created and patches large enough to qualify as cores are given a value of ‘1’ while smaller patches are assigned a value of ‘0’. Percent area of core habitat is calculated by summing the areas of all core patches and dividing by the total area of the analysis layer. The output shapefile is added to the map project table of contents.

Evaluate Movement Landscape: Maps areas of the landscape predicted to provide undisturbed areas for animals to move through the landscape. These areas are determined by recoding areas within the influence distance as ‘Avoidance’ areas and areas outside the influence distance as preliminary ‘Movement’ habitat. Next, distances between avoidance areas are measured and movement habitat areas that are restricted to less than the ‘Minimum Linkage Width’ are recoded as avoidance areas because they are too narrow to satisfy requirements for movement habitat. If the ‘Consider Viewshed’ analysis is selected, a viewshed analysis is performed to determine areas that are not visible from structures and vice versa. If no structures can be seen from a location, it is coded as potential movement habitat regardless of proximity to structures or resulting corridor width.

Measure Resistance Landscape: Estimates the ability of a landscape to provide habitat connectivity based on the output of 'Evaluate Movement Landscape' and species preferences by estimating cumulative resistance between source patches. Measure Landscape Resistance calculates a cost (resistance) surface based on compromised linkage areas derived from Evaluate Movement Landscape, structure density, and species habitat preference. Lowest costs are assigned to areas with low structure density, within preferred habitat, and within undisturbed movement habitat. A cumulative current map is calculated using Circuitscape with the pair-wise comparison option. The resulting map shows areas of high current density as dark blue indicating potential bottlenecks for movement. Text files are generated tabulating the total resistance between each source patch pair. Users should consult the Circuitscape and Wild Planner users manuals for more details about interpreting and using results.

**Requirements**: This tool requires Circuitscape installed on the user's computer. The tool will look for Circuitscape in the default installation location (c:\prgoram files\circuitscape). If the executable is not found, the tool will search the entire C: drive of the local computer and, if found, will update the script's program location parameter to speed up future runs of the tool. If Circuitscape is installed on a different drive, you must open the local\_params.py file (located in the Wild Planner 'scripts' folder) in an editor and edit the path to 'cs\_run.exe' being careful to follow the instructions in the file.

NOTE: Best results will be obtained running this tool on a 64 bit operating system with at least 4 Gb of RAM. Tests using this tool on a 32 bit operating system have resulted in frequent crashes due to memory limitations. Users with 32 bit machines should consult the Circuitscape User’s Manual for a suggested work around for memory issues.

**How this Tool Works:** This tool operates on the assumption that areas relatively free from human disturbance and contain a species' preferred security habitat are best for animal movement. Three input layers (structures, linkage layer, and habitat preference) are combined to create a resistance surface and connectivity is estimated between user specified habitat patches. The linkage layer to be evaluated is normally obtained from the ‘Evaluate Movement Landscape’ tool but can be any raster layer with value = 1 representing movement habitat, and value = 0 representing avoidance areas.

*Calculating Resistance* Surface: Structure density is calculated as number of structures per square mile within a circular search area and assigned the following resistance values:

|  |  |
| --- | --- |
| Houses per square mile | Resistance Score |
| 0 4 | 1 |
| 4 8 | 2 |
| 8 16 | 3 |
| 16 32 | 4 |
| 32 64 | 10 |
| 64 128 | 20 |

Assignment of resistance scores for specific land cover types can be viewed by examining the appropriate reclass files located in the ‘Scripts\ReclassTables’ folder in the WildPlanner directory. In general land cover classes are reclassified into resistance values based on habitat preference as follows:

|  |  |
| --- | --- |
| Habitat Rank | Resistance Score |
| Preferred | 0 |
| Marginal | 2 |
| Avoided | 4 |

NOTE: If Habitat Preference is set to ‘NO PREFERENCE’, the ‘Land Cover Layer’ and ‘Land Cover Source’ parameters are ignored. No resistance scores are assigned for land cover types and resistance is calculated based only on structure density and avoidance areas (see below).

Users have the option of specifying a custom cost surface. This provides users with infinite flexibility for modeling the movement landscape. To be consistent with outputs generated from standard land cover options, habitat areas that impose no additional cost (best habitat) should be assigned cell values = 0 and maximum cost value (worst habitat) should be assigned value = 4. But users are free to use values appropriate for their analyses. Costs assigned to structure density range from 1 to 50. Special cases occur when assigning values to cells representing semi-permeable or impermeable barriers. Impermeable barriers should be assigned NoData values and semi-permeable barriers can be assigned any appropriate value that reflects the resistance to movement imposed by the barrier.

To calculate final resistance, all cells where linkage layer = 0 are assigned a score of 50; remaining cells are assigned values by adding resistance scores for housing density and habitat preference.

*Source Patches:* Users must specify a source patches layer. This patch layer represents the source and destination patches for Circuitscape analysis. A Patch ID field is specified to tell WildPlanner which polygons or regions of the input layer represent unique source patches. This gives users flexibility to specify whether clusters of habitat patches should be treated as one or many sources. WildPlanner will analyze connectivity between each unique patch pair so increasing the number of patches can greatly increase processing time.

*Circuitscape Parameters:* Source patch and resistance layers are converted to ASCII files and passed to Circuitscape for processing. The parameters for Circuitscape are:

* Pairwise: iterate across all pairs in focal node file
* Focal REGIONS: Focal nodes may contain multiple cells
* Habitat data specify per-cell RESISTANCES
* Cell connection scheme: Connect EIGHT neighbors
* Cell connection calculation: Average RESISTANCE
* Output: Current maps and Voltage maps

TIP: For most analyses, these parameters are appropriate. The parameters can be modified by editing the *circuitscape.ini* file in the Scripts folder of WildPlanner. See the *Circuitscape User’s Guide* for details.

*Outputs:* Measure Landscape Resistance adds a cumulative current density layer the table of contents in ArcMap. Areas of high cumulative current density indicate pinch points for movement. A text file is created with resistances for each pair-wise calculation of patches. These files can be used to calculate average landscape resistances for comparing development scenarios (see ‘Compare Resistance Scenarios’). These files are named ‘[base name]\_resistances\_3columns.out’, where [base name] is the path and name specified for base name in the tool. A number of additional outputs are stored in the path and base name specified. Consult the *Circuitscape User’s Guide* for details about these outputs.

Prioritize Linkage Areas: Identifies priority areas for conserving wildlife connectivity. This tool analyzes outputs from ‘Evaluate Movement Landscape’ and ‘Measure Landscape Resistance’ to identify crucial areas to focus conservation efforts. These priorities are based on the following assumptions:

1. Movement pathways that do not cross uncompromised (disturbed) areas are better than those that do.
2. Short movement pathways are better than long ones.

using a three step process:

1. Connected landscape – Extracts areas from the linkage layer that form contiguous connections between two or more source patches. This removes enclaves of uncompromised movement habitat that cannot be accessed without passing through the influence zone of structures.
2. Least-cost path analysis – A series of least-cost paths are calculated to identify specific pathways important for animal movement. Source patches and current density generated by ‘Measure Landscape Resistance’ are used for sources and cost surface respectively. Three least-cost path types are generated:
   1. Primary – Finds the single least-cost path through uncompromised movement habitat between any source patch pair.
   2. Secondary – Finds the least-cost path through connected uncompromised movement habitat for each source patch segment to another source patch. A patch segment is the portion of a source patch that borders connected uncompromised movement habitat. In other words, it finds the best pathways for each area where an animal can move from source habitat to uncompromised movement habitat within the connected landscape.
   3. Restore Path – These are identical to Secondary pathways except the least-cost paths are not restricted to the connected landscape and can cross compromised habitat. This is useful for identifying opportunities where restoration could improve habitat connectivity for the target species.
3. Fuzzy logic and vulnerability analysis – A series of fuzzy memberships are created and overlaid to identify areas that are likely bottlenecks for animal movement, are located along least-cost paths, and whether resulting priority patches are vulnerable to development. Vulnerability is determined by comparing a linkage layer with a build out linkage layer. Areas that change from uncompromised to compromised under the tested scenario are classified as vulnerable.

Discussion of Landscape Evaluation Tool Uses and Limitations: Landscape Evaluation tools provide a powerful method for predicting impacts of proposed development on wildlife earlier in the planning process. This allows developers and reviewing authorities to design and review planned developments using a common framework for evaluating impacts to wildlife. Developers can explore multiple development design options quickly and cheaply to highlight potential issues with wildlife likely to be encountered, and to present local governing authorities with development proposals that adequately address wildlife issues before issues are raised during the review process. These tools therefore offer the potential for proactive, rather than reactive, planning for wildlife.

Landscape Evaluation Tools can be used to prioritize areas for conservation by identifying areas for protection as well as restoration. For example, analyzing current and future build out scenarios for movement habitat and comparing the results with maps of conservation easements and other protect lands, can identify areas crucial for maintaining connectivity to those areas and therefore are crucial for protecting investments in wildlife conservation. Priority areas identified may include areas currently function as core or movement habitat that may be lost to development, or they may be areas that are currently non-functional but could potentially be restored to functionality through restoration.

Landscape Evaluation Tools are intended to provide a bird’s eye view of broad landscapes rather than analyzing parcel or subdivision sized areas. Users should carefully consider the appropriate extent of analysis before using these tools (see Important Concepts). The outputs of these tools are only as accurate as the layers used for input. Habitat maps and models rarely reflect the fine-scale pattern of variation that can be observed from the ground. Results from Landscape Evaluation Tools should be considered as a preliminary “first look” at potential impacts on wildlife and the results should be followed with consultations with local wildlife experts and sight visits to verify results or make adjustments to their findings.

### Policy Tools:

Policy Tools are designed to assist with broad-scale land use policy decisions that would impact wildlife. Specifically, the current version of policy tools in Wild Planner is intended to assist policy makers with determining appropriate development density allowances for maintaining sufficient amounts of wildlife habitat. Future versions will allow other tools such as clustering and setbacks to be incorporated in simulations.

Calculate Target Housing Density: Estimates an appropriate housing density that will meet specific wildlife conservation targets (percent area to conserve). The user specifies the minimum area requirement for core habitat and distances from structures and roads.

The tool uses a Monte Carlo simulation to estimate the maximum structure density that will maintain the desired percentage of the landscape as core habitat patches. When the tool is executed, a seed number of structures is randomly placed within buildable areas of the analysis extent layer. Roads are simulated by generate lines that connect each simulated structure to the existing road network along a path that minimizes both gradient and distance. Structures and roads are buffered by their respective user-specified influence distances and the areas of remaining habitat patches are calculated and compared with the minimum patch size. The areas of all patches ≥ the specified ‘Minimum Habitat Patch’ are summed and this sum is divided by the total area of the analysis extent layer to yield the percent area conserved for that simulation. This result is stored in the ‘Output Table’ and the process is repeated the number of replications specified by the user. After the last replication has completed, the results are averaged and compared against target (‘Percent Area Conserved’) specified in the inputs. If the averaged result is higher than the target, the number of structures for the next iteration is increased, the process is repeated for another iteration. If the averaged result is lower than the target, the number of structures is decreased for the next iteration. Processing stops when the result of an iteration = the target value ± 5%.

When the final solution is reached, a message box displays the density of houses (in acres) that satisfied the target parameters. Outputs include a summary table of all simulation runs, and example shapefiles of cores and houses representing the final simulation that satisfied target parameters. Two density calculations are calculated. Density within the buildable area represents the density allowance that could safely be set to maintain the targeted percentage of the total landscape as high quality habitat. If the analysis extent contains unbuildable areas, then the total housing density will be lower than density within buildable areas. Total housing density represents the actual density that would be achieved if the buildable area were developed to the maximum allowance calculated by the tool.

Calculate Corridor Housing Density: Assists policy makers with determining appropriate development density allowances to provide movement permeability for a targeted wildlife species.

Calculate Corridor Housing Density operates similar to Calculate Target Housing Density. The major differences are that roads are not simulated and instead of calculated habitat patch areas, Calculate Corridor Housing Density calculates the average distances between simulated structures and compares them with the target value of ‘Minimum Corridor Width’ + 2(‘Influence Distance’). As with Calculate Target Housing Density, the tool runs the user-specified number of replications for each iteration of the model. Processing stops when an iteration produces a result within 5% of the target average distance.

When the final solution is reached, a message box displays the density of houses (in acres) that satisfied the target parameters. Outputs include a summary table of all simulation runs, and an example shapefiles of simulated structures representing the final simulation that satisfied target parameters. Two density calculations are calculated. Density within the buildable area represents the density allowance that could safely be set to maintain the targeted percentage of the total landscape as high quality habitat. If the analysis extent contains unbuildable areas, then the total housing density will be lower than density within buildable areas. Total housing density represents the actual density that would be achieved if the buildable area were developed to the maximum allowance calculated by the tool.

Discussion of Policy Tool Uses and Limitations: The current versions of Wild Planner policy tools are limited in purpose and use. The current versions only support random placement of structures within the buildable landscape. This type of simulation assumes prospective density policy is based strictly on density allowances without policies to influence the actual placement of structures. In most cases, careful placement of structures to avoid high quality habitats or to cluster development to reduce the cumulative zone of influence would allow wildlife targets to be met with substantially higher allowable development densities than calculated by these tools. However, density-based zoning and similar policies remain important tools in land use planning which may be implemented independently of other development allowances. Future versions of these policy tools are planned that will incorporate clustering into the analysis but the current tools may be helpful for policy-makers contemplating implementing density allowances as a stand-alone solution to meeting wildlife conservation targets.

Calculate Corridor Housing Density provides a conservative estimate of density to assure sufficient movement permeability across a landscape. Because the structure patterns are random, distances between simulated structures can be assumed to be randomly distributed around the average distance. This means that approximately half of the distances will be ≤ the average while the other half is ≥ the average. In this case, the average is the minimum distance needed to provide a suitable undisturbed space for movement. Therefore, half of the distances between structures will be sufficiently large to allow animal movement. However, this does not mean that half of the landscape will provide sufficient movement habitat for the target species. As an animal moves through a landscape, it must move between multiple structure pairs. Probability suggests that as an animal moves in a straight line, approximately half of the structure pairs it moves between will be sufficiently far apart to allow undisturbed movement, while the other have are close enough together to cause the animal to meander off a straight course. At each course change, the animal encounters a 50% probability of the next structure pair distance providing sufficient space for undisturbed movement and an 87.5% chance that for every three structure pair choices; at least one is sufficiently wide for undisturbed movement. Therefore, there is about a 90% chance that when encountering a disturbance zone, an animal will be able to find undisturbed alternatives to continue travel without having to change course more than 90 degrees from its original direction of travel. This provides a generous estimate of allowable development density that provides a high probability that the target species could successfully navigate across the landscape with minimal disturbance. If placement of houses is controlled, then the location of potential movement paths is more predictable and policies could be developed that maintain movement habitat at much greater development densities than the current tools predict.

### Utilities:

Utilities are a collection of tools to assist with generating simulation layers that can be used as input into other tools in the toolbox.

Generate Roads: Simulates roads for the policy tools but is included as a stand-alone utility to simplify simulating roads for hypothetical developments. The tool connects points representing structures in a build out scenario to the existing road network generating least-cost paths. A cost surface is created by creating contours and calculating slopes from a digital elevation model. If a slope layer is not available, it will be generated from the elevation raster. Cells along contour lines are assigned minimal cost and cells outside contours are assigned costs relatively to their slope with steep slopes receiving the highest cost and shallow slopes the lowest. The resulting least-cost path connects structure points to existing roads based on a combination of the shortest distance and lowest gradient. If the merge with existing roads option is selected, the resulting roads are merged with existing roads and the attribute table is coded indicating whether a road is existing or simulated.

Simulate Buildout: Estimates the development that will exist if all currently buildable parcels are developed. The tool overlays an existing parcel layer, an existing structures layer, and a buildable area layer (see ‘Constraint Layer’ under Data Requirements) to identify parcels which do not contain a developed structure but could be developed without subdivision review under existing regulations. For each of those parcels, a structure is added at the centroid of the buildable portion inside the parcel and a road network is generated using the process described for ‘Generate Roads’. The resulting roads and structures are merged with existing roads and structures and the attribute table is coded indicating whether a road or structure already exists or is simulated.

Discussion of Utility Tool Uses and Limitations: Generate Roads provides only a rough approximation of where roads might be routed on the landscape. The tool obviously does not account for engineering and other factors that would be considered during actual road network design. It is recommended that generated roads be used during the exploratory phase of designing a planned developed to easily evaluate multiple structure placement options for potential impacts on wildlife species of interest. As a preferred plan moves forward, the plan should be re-evaluated using the actual proposed road placements to verify that impacts on wildlife have not significantly changed from preliminary predictions.

Simulating a full build out scenario is a valuable tool for predicting future impacts on wildlife. Review of development proposals commonly evaluate potential impacts of the development within the context of the current build environment, but may fail to consider the amount of potential development that could occur. Full build out represents what an area might look like in the future without any additional subdivision or changes in regulation. Evaluating full build out scenarios allows users to visualize potential changes to wildlife habitat and movement connectivity under the status quo and help users plan appropriately for the future. For example, the results of full build out evaluations can be compared with stated wildlife goals and objectives to determine if they are achievable without changes in policy. For example, full build out evaluations may reveal opportunities to replat undeveloped parcels within important wildlife areas as well as identifying major blocks of habitat that are likely to remain intact. It is recommended that full build out scenarios be routinely included in all landscape evaluation analyses.

**Lessons Learned**

* **Generate roads for existing structures before comparing with other scenario**

**Available Data:** Table 1 is an incomplete example of data available that can be used as a basis for development criteria. Only one of twenty-eight sources cited so far directly report on the influence of specific housing densities on wildlife habitat suitability. However, data regarding minimum habitat requirements, disturbance distances, and corridor widths are more readily available. Appropriate housing densities that satisfy these reported requirements can be estimated using GIS tools developed by CERI. Conversely, existing landscapes or potential development scenarios can be evaluated with respect to their ability to provide adequate wildlife habitat.

**Table 1.** Habitat requirements for selected species gleaned from literature. Habitat area requirements and disturbance distances can be used to estimate suitable housing densities using a GIS-based approach.

| **Overlay ‘Zones’** | Housing density (ha / dwelling) | Housing buffers (m) | Core Area Requirement (ha) | Road density | Road buffers (m) | Stream setbacks | Corridor width\* |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Species Diversity Areas** |  |  |  |  |  | 100m[[1]](#endnote-1), [[2]](#endnote-2) | 200m\* |
| Mountain Lion (ML) | 163 | 100m 3 | 220,000[[3]](#endnote-3) |  | 50-100m3 |  | 1-2 km |
| Grizzly Bear (GB) |  | 100-900m[[4]](#endnote-4),[[5]](#endnote-5),[[6]](#endnote-6),[[7]](#endnote-7),9\* | 2,800[[8]](#endnote-8), 9009 | 6 km/km2,([[9]](#endnote-9)) 1 mi./ mi2 | 100-900m[[10]](#endnote-10),[[11]](#endnote-11),[[12]](#endnote-12),[[13]](#endnote-13),9 |  | 200m |
| Mink (Mi) |  |  |  |  |  | 100[[14]](#endnote-14)200m[[15]](#endnote-15) | 92m[[16]](#endnote-16) |
| Marten (Ma) |  |  |  |  |  | 100m2 | 91m16,200m[[17]](#endnote-17) |
| Fisher (Fi) |  |  |  |  |  | 91m16 | 18216 |
| Red Fox (RF) |  |  |  |  |  | 100m2 | 200m17 |
| Deer (D) |  | 61m[[18]](#endnote-18),82m[[19]](#endnote-19), 100m[[20]](#endnote-20) | 0.81 - 2[[21]](#endnote-21) |  | 61m18,82m19, 100m20 | 100m2 | 200m |
| Elk (E) |  | 750-1200[[22]](#endnote-22)805[[23]](#endnote-23), 100 – 1,00020 | 10122 | 0.75 mi./ mi2 | 80522,100 – 1,00020 | 100m2 |  |
| Reptiles and Amphibians (Amph) |  | 25-30m[[24]](#endnote-24),300m[[25]](#endnote-25) | 5.9[[26]](#endnote-26) |  | 25-30m23,300m24 | 30-275[[27]](#endnote-27) |  |
| Song Birds (SB) |  | 50 - 600[[28]](#endnote-28) | 1 - 8027 |  | 50 - 60027 |  |  |
| Raptors(Rap) |  | 100-1600[[29]](#endnote-29) |  |  |  |  |  |
| Herons and Cranes (H) |  |  |  |  |  | 300-400m(11) |  |
| Rodents (RO) |  | 45 | 1 - 10 |  | 45 |  |  |

\* corridor width estimate is twice the average buffer distance.

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