

# Connectivity Training Report

---

*Connectivity Training for EBRD Project (September 2015)*

## Table of Contents

Introduction .....	2
Objective of Trainings.....	2
Location of Training.....	3
Attendees .....	3
Curriculum/Skills Taught .....	3
Lecture 1 – Connectivity Modeling Principles and Methods. Brad McRae, Senior Landscape Ecologist with The Nature Conservancy .....	3
Lecture 2 - Traffic Considerations For Wildlife Passage. Pat McGowen, Research engineer at the Western Transportation Institute .....	4
Lecture 3 – East Gobi Connectivity Modeling Update. Mike Heiner, Conservation Scientist at The Nature Conservancy .....	4
Lab practicum – Brad McRae, Senior Landscape Ecologist with The Nature Conservancy .....	4
Class Evaluations .....	5
Course Materials .....	5
Photos from Technical Training.....	5
Appendix A – Names of Training Attendees.....	6
Appendix B – Feedback from technical training attendees.....	8
Appendix C – Lab exercises (Mongolian version available in USB drive download above).....	10
Appendix D – Example Training Certificate .....	21

## Introduction

This training was part of a larger effort of building capacity within MEGD to support landscape-level conservation in the southern Gobi Desert and was funded by the European Bank for Reconstruction and Development (EBRD) Shareholders Special Funds. In this larger project, TNC is assisting MEGD and other stakeholders in the identification, review, assessment, implementation, and monitoring of mitigation and other conservation measures. Four main tasks were identified within this project: 1) conduct an analysis of habitat connectivity of Asiatic Wild Ass (*Equus hemionus*, or khulan) in the eastern Gobi Desert region; 2) create the mitigation design tool (MDT); 3) assess alternatives and logistical constraints of regional traffic; and 4) provide training for a) performing habitat connectivity analyses, b) using MDT, and c) assessing regional soil conditions in the mineralized zones of the Gobi Desert.

fa

This report focuses on task 4a, *training on habitat connectivity analysis*, which we provided on September 8 and 9, 2015. In the original scope of work for the EBRD grant, a general GIS/Connectivity training was proposed. At the inception meeting, Ministry officials requested that we instead provide two different types of training. The first would be a more conceptual training for MEGD managers to understand the capacity and general application of Circuitscape, a connectivity analysis software package created by Brad McRae of The Nature Conservancy. The second training would be a more technical training on the software for graduate-level GIS experts in the ministry. Thus, we provided a manager's workshop on Sept 8 and a more technical one-day classroom training on September 9.

Four distinct groups of people attended the trainings: managers from MEGD, government employees from federal and local agencies responsible for implementation of offset regulations, private mining companies, and non-profit environmental organizations (see Attendees section of this report).

## Objective of Trainings

Our primary objective was to build capacity within Mongolia for connectivity conservation planning. The main focus was connectivity modeling, and we aimed for attendees to come away from the trainings understanding the most commonly applied connectivity modeling techniques (circuit theory and least-cost corridor models). We wanted attendees to also understand why connectivity is important, the limitations of connectivity models, and the critical steps in data development, parameterization, and validation of the models. For the technical training, we also wanted attendees to develop a working knowledge of connectivity modeling software.

Because the greatest threat to connectivity comes from transportation infrastructure, we also wanted to emphasize what is known about road and railroad impacts on wildlife, and how to mitigate these impacts.

A final objective was to present a progress report for our khulan connectivity modeling project in the east Gobi, and to solicit feedback from attendees on this work. This had the added benefit of illustrating the modeling concepts and steps with a local case study.

## Location of Training

Manager's workshop: MGED conference room

One-day trainings: National University of Mongolia, GIS Lab – Dr. Bolorchuluun

## Attendees

For the connectivity trainings, we hosted 47 representatives from MEGT, the United Nations Develop Programme, the Mongolian Academy of Sciences, Oyu Tolgoi, The Nature Conservancy, Wildlife Conservation Society, the National University of Mongolia, seven provincial governments, Altai Tavan Bogd National Park, the Mongolian Bird Conservation Center, the SPAN project, the Wild Sheep Center, and the Agency of Land Affairs, Geodesy and Cartography (See Appendix A for a full list for each day).

## Curriculum/Skills Taught

Brad McRae (TNC) presented on connectivity modeling concepts and methods at the manager's meeting and the technical training. He also led a half-day GIS lab practicum for the technical training. In addition, we presented two lectures to each audience on connectivity issues that are central to current planning challenges in Mongolia. Pat McGowen (Western Transportation Institute) presented on effects of transportation infrastructure on wildlife, data on traffic in Mongolia, and strategies for mitigating road impacts. Mike Heiner (TNC) presented preliminary results of a case study applying Circuitscape to khulan connectivity modeling in the Gobi desert.

We gave similar presentations for both managers and technical staff, but tailored them for each audience, giving more technical detail when presenting to the technical staff.

### **Lecture 1 – Connectivity Modeling Principles and Methods. Brad McRae, Senior Landscape Ecologist with The Nature Conservancy**

This lecture focused on the concepts and tools behind connectivity modeling for conservation planning. It was divided into four parts. Part I focused on what connectivity is and why its conservation is important. Part II focused on common connectivity modeling methods, including least-cost corridors, Circuitscape, and new methods to identify restoration opportunities. Part III focused on critical steps in connectivity modeling. This is particularly important because practitioners often assume that using tools like Circuitscape constitute the main tasks of connectivity modeling. To the contrary, collecting data on movement behavior, mapping landscape features that affect movement, mapping features that need to be connected, parameterizing models, and validating models are the most critical and difficult steps. If we could emphasize any one point, it would be that students should never treat connectivity models as a 'black box.' They must understand how the models work, their limitations, and how changing input data or parameters will affect the results they get. The lecture ended with a list of additional resources for attendees.

Dr. McRae's powerpoint presentation is available here:

[https://dl.dropboxusercontent.com/u/1340127/Mongolia/Connectivity\\_Training\\_Mongolia.n.pptx](https://dl.dropboxusercontent.com/u/1340127/Mongolia/Connectivity_Training_Mongolia.n.pptx)

## **Lecture 2 - Traffic Considerations For Wildlife Passage. Pat McGowen, Research engineer at the Western Transportation Institute**

This lecture focused on road and rail impacts on wildlife, and how they can be studied and mitigated. Dr. McGowen presented an overview of the ways in which transportation infrastructure impacts wildlife, from the simple loss of habitat to mortality and fragmentation of populations. He presented data on vehicle and rail traffic obtained from the Ministry of Transportation and Oyu Tolgoi Mine, and provided many observations from his field time in the Gobi Desert. He discussed monitoring techniques, and the need for public education. He then discussed several potential strategies to mitigate the effects of transportation infrastructure on wildlife populations.

Dr. McGowen also gave a similar presentation at the August UNEP-Convention on Migratory Species (CMS) Workshop in Ulaanbaatar. His powerpoint presentation available here: <https://dl.dropboxusercontent.com/u/1340127/Mongolia/McGowen%20Traffic%20Considerations%20v2.pptx>

## **Lecture 3 – East Gobi Connectivity Modeling Update. Mike Heiner, Conservation Scientist at The Nature Conservancy**

Mike Heiner presented preliminary results from the khulan connectivity modeling project in the eastern Gobi Desert. His presentation served three purposes: to provide an update on the khulan project, to give a case study reinforcing the principles and methods from McRae's lecture, and to provide an opportunity to receive feedback from training participants. His presentation consisted of an overview of MEDG contract and products of connectivity modeling project, a brief repeat of the role of modeling and movement data in a connectivity conservation study, and the case study. The latter included study design, model inputs and source data, habitat patch and resistance modeling, preliminary results, next steps, and final work plan and timeline.

Heiner gave a similar presentation at the CMS workshop, but with more of an overview of modeling methods. His powerpoint from the training is available here: <https://dl.dropboxusercontent.com/u/1340127/Mongolia/Heiner%20connectivity%20modeling%20update%20MON%20ENG%2020150907%20150dpi.pptx>

## **Lab practicum – Brad McRae, Senior Landscape Ecologist with The Nature Conservancy**

Following the three lectures described above, Dr. McRae led a series of GIS exercises applying least-cost corridor and circuit models to connectivity conservation. The lab covered the use of Linkage Mapper and Circuitscape connectivity analysis software packages. Participants learned to create maps showing networks of core habitats or protected areas; to connect these areas using least-cost corridors, Circuitscape, and a hybrid of the two models; to identify which core areas and corridors are most important to keeping the overall network connected; and to identify pinch points or bottlenecks in corridors where small additional losses of habitat could sever connectivity (see lab materials in Appendix C and on the link in the Course Materials section below).

## Class Evaluations

We received very positive feedback on the training. All respondents said the training was easy to understand, important, and that this type of training needed to continue. We also received valuable feedback on how to improve trainings in the future (see Appendix B for results from written evaluations).

## Course Materials

All students received a USB drive with published connectivity papers, GIS tools, data, exercises and a presentation. Presentations and exercises were provided in both English and Mongolian. Providing lab exercises and data allowed students to share all information with others and to perform the exercises again at later dates. The main directory on the USB drive had the presentation, plus two sub-directories entitled Connectivity\_Readings and LM\_Lab. Connectivity\_Readings had selected academic papers, reports, and user guides organized into eight topic areas. It also included links to internet resources and software. The LM\_Lab directory included all materials and data used for the afternoon lab exercises (lab instructions included in Appendix C at the end of this document).

The contents of the USB drives (including connectivity modeling lecture, exercises, and academic papers described above) can be downloaded here:

[https://dl.dropboxusercontent.com/u/1340127/Mongolia/Connectivity\\_Training.zip](https://dl.dropboxusercontent.com/u/1340127/Mongolia/Connectivity_Training.zip)

## Photos from Technical Training



## Appendix A – Names of Training Attendees

- *Connectivity analysis lectures for managers of MEGDT (8th of September, 2015)*

No	Name	Position	Organization	Tel	E mail
1.	Tsogtsaikhan.P	Director of environmental assesment and audition department	MEGDT	99075559	<a href="mailto:tsojopurev@gmail.com">tsojopurev@gmail.com</a>
2.	Temuulen.D	Officer	MEGDT	99057170	<a href="mailto:temulengees@yahoo.com">temulengees@yahoo.com</a>
3.	Oyunbileg.Kh	Officer	MEGDT	99224979	<a href="mailto:oyunbileg@mne.gov.mn">oyunbileg@mne.gov.mn</a>
4.	Bayartsetseg.S	Chief officer	MEGDT	95952848	<a href="mailto:bayaraabayars@yahoo.com">bayaraabayars@yahoo.com</a>
5.	Nandin-Erdene.Kh	Officer	MEGDT	88116250	
6.	Gunbileg.L	Officer	MEGDT	99952966	<a href="mailto:idaswet@yahoo.com">idaswet@yahoo.com</a>
7.	Bayarkhuu.S	Chief officer	MEGDT	99049896	<a href="mailto:bayarkhuu@mne.gov.mn">bayarkhuu@mne.gov.mn</a>
8.	Jargalsikhan.L	Chief officer	MEGDT	88057170	<a href="mailto:mongoliamgo@gmail.com">mongoliamgo@gmail.com</a>
9.	Erdenebayasgalan.G	Chief officer	MEGDT	88101010	<a href="mailto:erdenebayasgalan.ganj@yahoo.de">erdenebayasgalan.ganj@yahoo.de</a>
10.	Batjargal.Ts	Officer	MEGDT	91195490	<a href="mailto:tsbatjargal@yahoo.com">tsbatjargal@yahoo.com</a>
11.	Chimeg.J	Programme Analyst	UNDP	327585-127	<a href="mailto:chimeg.junai@undp.org">chimeg.junai@undp.org</a>
12.	Munkhzul.Ts	Officer	Academy of Science, Biological institute	99868116, 86061276	<a href="mailto:tsmunkhzul@yahoo.com">tsmunkhzul@yahoo.com</a>
13.	Otgontugs.M	GIS officer	MEGDT	99190844	<a href="mailto:otgontugs_ngic@yahoo.com">otgontugs_ngic@yahoo.com</a>

- *Connectivity analysis (Circuitscape and Linkage Mapper) training (9th of September, 2015)*

No	Name	Position	Organization	Tel	E mail
1	Erdenebayasgalan.G	Chief officer	MEGDT	88101010	<a href="mailto:erdenebayasgalan.ganj@yahoo.de">erdenebayasgalan.ganj@yahoo.de</a>
2	Otgontugs.M	GIS officer	MEGDT	99190844	<a href="mailto:otgontugs_ngic@yahoo.com">otgontugs_ngic@yahoo.com</a>
3	Sanjmyatav.D	Officer	Oyu Tolgoi LLC	99014170	<a href="mailto:sanjmyatavD@ot.mn">sanjmyatavD@ot.mn</a>
4	Bolorchuluun.Ch	GIS lecturer	MNU	89143579	<a href="mailto:bolorchuluun@gmail.com">bolorchuluun@gmail.com</a>
5	Tsogtsaikhan.B	GIS officer	TNC	88965060	<a href="mailto:tbattsengel@tnc.org">tbattsengel@tnc.org</a>
6	Naranzul.B	Project officer	TNC	99124670	<a href="mailto:naranzul.bazarsukh@tnc.org">naranzul.bazarsukh@tnc.org</a>
7	Binderya.O	Project officer	TNC	99044979	<a href="mailto:binderya.oyunbaatar@tnc.org">binderya.oyunbaatar@tnc.org</a>
8	Purevbaatar.G	GIS officer	TNC	89500302	<a href="mailto:puuu.jeece@yahoo.com">puuu.jeece@yahoo.com</a>
9	Batdorj.B	Officer	TNC	97185888	<a href="mailto:batdorj72@yahoo.com">batdorj72@yahoo.com</a>
10	Orgilmaa.B	Officer for underground resource and reclamation	Umnugobi province	99074877	<a href="mailto:orgio_78@yahoo.com">orgio_78@yahoo.com</a>
11	Sugirsuren.E	Officer	Umnugobi province	86985628	
12	Soyolmaa.T	Ranger of Tsogttsetsii soum	Umnugobi province	88555000	<a href="mailto:tsoyoloo@yahoo.com">tsoyoloo@yahoo.com</a>
13	Oyungerel.N	Officer	Dornogobi province	99043225	<a href="mailto:Gerel_64@yahoo.com">Gerel_64@yahoo.com</a>
14	Nyamkhuu.Sh	Officer	Sukhbaatar province	96899366	<a href="mailto:sh_nyamhuu@yahoo.com">sh_nyamhuu@yahoo.com</a>
15	Tsetsegdelger.U	Officer	Sukhbaatar province	93019387	<a href="mailto:deegii_0610@yahoo.com">deegii_0610@yahoo.com</a>
16	Bilguunzaya.B	Officer	Dornod province	99571467	<a href="mailto:batboldbilguunzaya@gmail.com">batboldbilguunzaya@gmail.com</a>
17	Munkhnaran.E	Officer	Dornod province	89130300	<a href="mailto:monkhnaran_e@yahoo.com">monkhnaran_e@yahoo.com</a>
18	Munkh-Erdene.G	Officer for underground resource and NP areas	Khentii province	96480704	<a href="mailto:muugii_best@yahoo.com">muugii_best@yahoo.com</a>
19	Bilegsaikhan.Ts	Officer for cadastre and geodesy	Khentii province	91992817, 98992817	<a href="mailto:bilegee_0628@yahoo.com">bilegee_0628@yahoo.com</a>
20	Nansalmaa.A	Officer for wildlife movement	Khovd province	99439314	<a href="mailto:nansaa_ok21@yahoo.com">nansaa_ok21@yahoo.com</a>
21	Lkhamkhuu.B	Head of environment	Khovd province	99008303	<a href="mailto:oidovarihuu@yahoo.com">oidovarihuu@yahoo.com</a>

		and department	tourism		
22	Davkharbayar.D	Ranger	Mongol Altai NP	95423957	<a href="mailto:ddavharbayar@yahoo.com">ddavharbayar@yahoo.com</a>
23	Gankhuyag.P	Director/ researcher	bird Mongolian Bird Conservation Center	88077576	<a href="mailto:pgankhuyag@gmail.com">pgankhuyag@gmail.com</a>
24	Buuveibaatar	Biologist	WCS	99792424	<a href="mailto:buuveibaatar@wcs.org">buuveibaatar@wcs.org</a>
25	Tungalag	Project officer	SPAN project		
26	Munkhbaatar.D	Biologist	Wild Sheep Center	88476580	
27	Gantig	Officer of cadastral department	ALAGC		

## Appendix B – Feedback from technical training attendees

### Feedback Summary

Training name: Connectivity analysis lab/ Circuitscape and Linkage Mapper/

Participants: 13 people on 8th Sep -27 people on 9th Sep

People who gave feedback: 17

1. Was the training slides understandable?

Easy to understand - 16

Hard to understand - 0

Not sure - 0

Comments:

- I learned well how to plan wildlife corridors efficiently /Researcher of Mongolian Bird Conservation Center/
- It was difficult to create a basic study to identify habitat /Officer from Sukhbaatar province/
- Translation, lecturer, other logistics, training methods and outgoings were good /Officer from Mongol Altai Range NP/
- GIS knowledge is important to understand the slides /Researcher from Argali NGO/
- It was understandable to select the best corridor between habitats / local expert from Dornod province(TNC)/

2. How important were the laboratory exercises and lectures for you?

Important - 17

Not important - 0

Not sure -0

3. Do we need to continue this type of training?

Yes - 17

No - 0

4. Can you give us recommendations if we organize this kind of training next time?

- Training time was short. It would be better if it were 4 days.
- It would be better if it were based on the real example.
- a. Need to explain more detailed about software steps; b. If possible, need to provide distance training for other local experts using videos.
- Time was too short; a. Extend the time; b. Need to use local data as basic data; c. Need to teach how to download raster data.
- Need to learn calculation of results and processing works of data from the beginning.
- Time was short.
- Next training needs to involve other experts such as governors of soums, development policymakers, land managers and other specialists from NGOs.
- Need to consider the translations.
- Basic data must be reasonable.

- Need more practice
- Need to extend practice time work with software.
- Need to repeat this training.
- This training was very useful for environmental officers and national protected areas experts.

#### Other comments about the training

- Further, need to organize this type of training. It was very comfortable that training organized at the GIS laboratory with sufficient computers.
- The training was useful and understandable.

## Appendix C – Lab exercises (Mongolian version available in USB drive download above)

### Lab: Mapping Corridors, Pinchpoints, and Restoration Opportunities using Linkage Mapper and Circuitscape

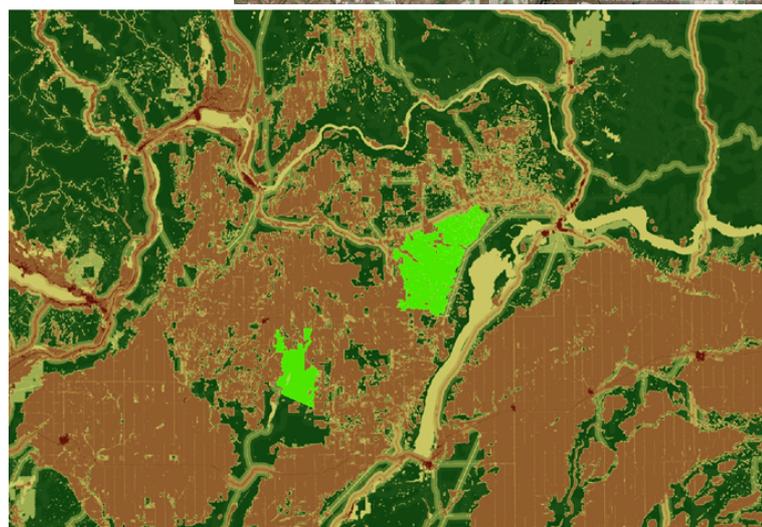
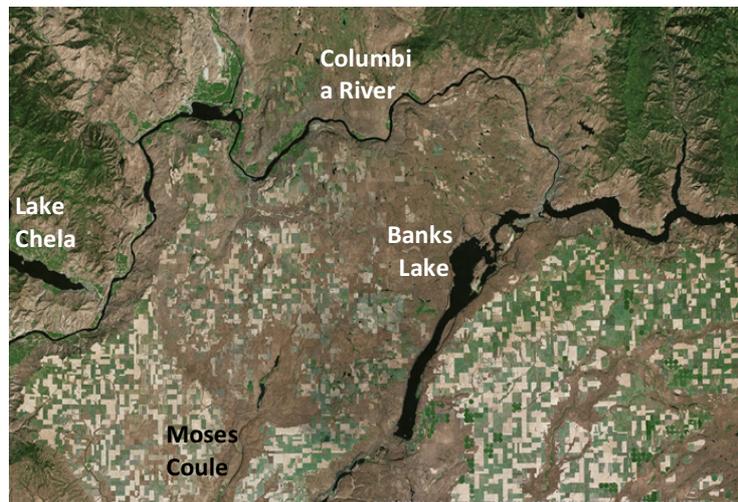
Brad McRae

Updated August 30, 2015

Please send suggestions for improvements to me at [bmcr@tnc.org](mailto:bmcr@tnc.org)

For this lab, you will be using the Linkage Mapper Toolkit to map corridors connecting core areas (large patches of semi-natural vegetation) in eastern Washington, USA. This lab uses three Linkage Mapper modules: **Linkage Mapper** (to map corridors), **Pinchpoint Mapper** (to map constrictions or ‘bottlenecks’ in corridors by calling **Circuitscape**), and **Barrier Mapper** (to map important barriers and restoration opportunities). User guides for these tools are included in the Linkage Mapper download.

Here’s the study area:



Top panels: 80 km by 120 km study area in eastern Washington, USA. Bottom panel: Resistance map used to model corridors across the Columbia Plateau Ecoregion by the Washington Wildlife Habitat Connectivity Working Group. Resistance values range from 1

*(dark green) to 1000 (red). Low resistance areas include native grassland and shrub-steppe. High resistance areas include roads, developed areas, and agriculture. Core areas to be connected are shown in bright green.*

The bright green core areas were identified by the Washington Wildlife Habitat Connectivity Working Group as having high 'landscape integrity.' They represent contiguous areas with low levels of human modification like roads, agriculture, and power lines. They are home to several species of conservation concern, like Greater Sage-Grouse, and connecting them is a conservation priority for state and federal agencies.

### **1) View the study area and base data**

First, you will need to download and unzip the lab data if you haven't already. Download the lab data from <http://www.circuitscape.org/linkagemapper>. Unzip it and place it in a shallow directory with no spaces or special characters (something like C:\LM\_LAB). If Circuitscape isn't installed on your computer, you will need to download and install it from <http://www.circuitscape.org/downloads>.

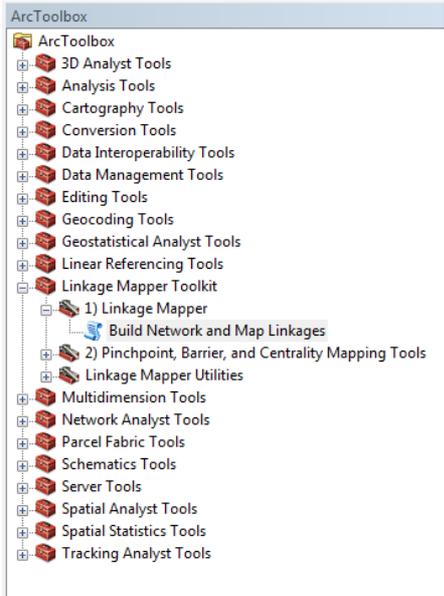
Open *LM\_Lab\_2Cores.mxd* in ArcMap. In ArcMap, make sure the Linkage Mapper Toolkit is installed. Click Geoprocessing >> ArcToolbox. If Linkage Mapper isn't in the list, right-click on ArcToolbox and click 'Add Toolbox.' Browse to *LM\_Lab\LinkageMapper1\_0\_9\toolbox* and add 'Linkage Mapper Arc10.tbx.'

Take some time to look at the aerial imagery, core areas, and resistance surface. The resistance surface was created by combining features from many base layers such as roads, utilities, and land cover, and assigning appropriate resistances to each feature. The core areas were created using a similar procedure, as well as a set of rules to delineate contiguous polygons. Tools in the [Gnarly Landscape Utilities](#) toolkit can facilitate resistance and core area layer creation.

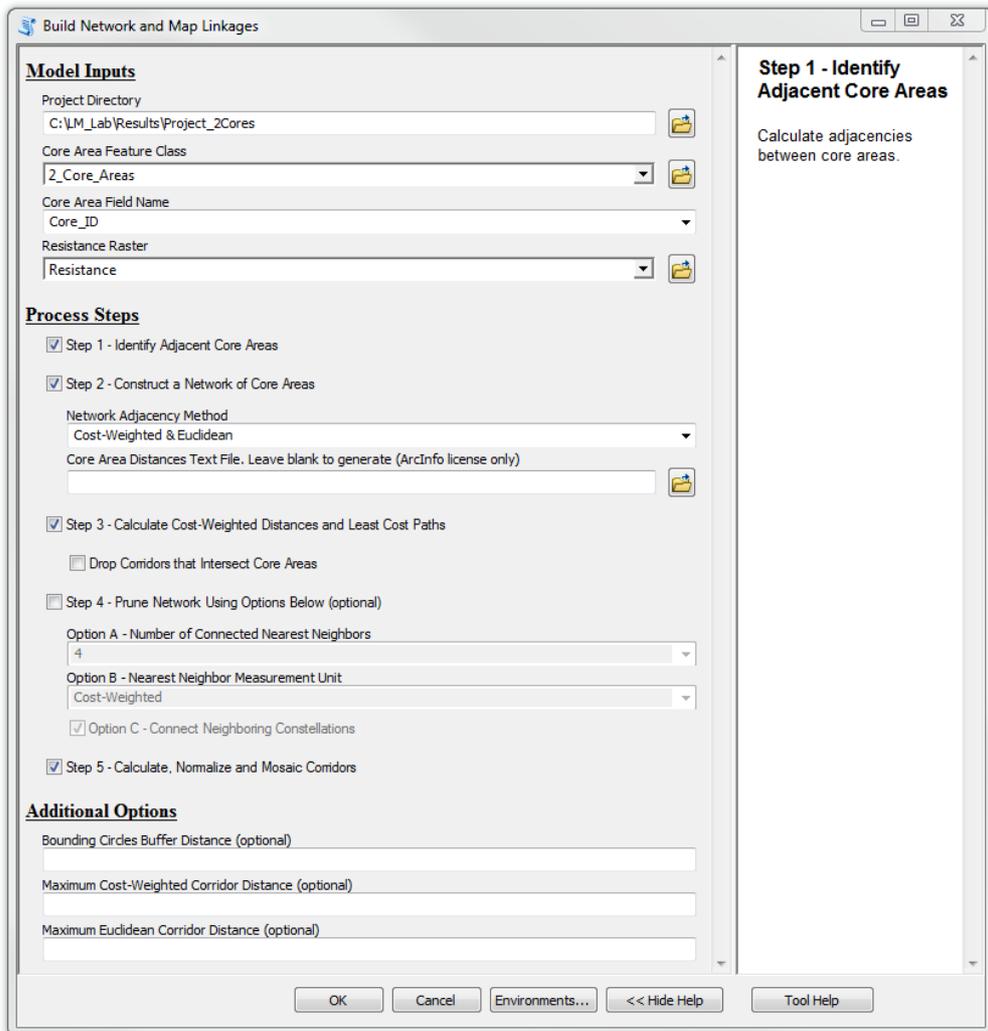
Based on the resistances (lower is better), where do you think the most important areas for movement between the two core areas might be?

### **2) Map the least-cost corridor between the two core areas**

Use Linkage Mapper to map the least-cost corridor. To do this, open the Linkage Mapper Toolkit and navigate to 'Build Network and Map Linkages' as shown below:



Use the settings below. 'Results\Project\_2Cores' will be your **project directory**, which is where outputs will be written.



**Note: with any of these tools, if you get errors and you are sure you have the settings right, save your work, restart ArcMap, and try again.**

Linkage Mapper will create two corridor files (both located in the project directory under *Results\Project\_2Cores\output\corridors.gdb*) plus a map of cost-weighted distances to the nearest core area (in *cwd.gdb*) and least-cost path lines (in *link\_maps.gdb*). I've put layer files (\*.lyr) for some of these in your project directory to make things easier. These are already symbolized.

Add the following corridor layer file to ArcMap:

***Results\Project\_2Cores\Project\_2Cores\_corridors.lyr***

Note that the corridor raster fills the entire study area. It shows the cost-weighted distance of the best route passing through each cell on the landscape. The map has lower values for routes close to the least-cost path, higher values for routes that are more costly.

***Results check 1: what is the range of values in the corridor raster? (Answers at end of this document.)***

Now add a corridor raster that has been automatically truncated (clipped) to a width of 200 cost-weighted km to show just the best part of the corridor. Also add the layer showing the least-cost path (LCP):

***Results\Project\_2Cores\Project\_2Cores\_corridors\_truncated\_at\_200k.lyr***

***Results\Project\_2Cores\Project\_2Cores\_LCPs.lyr***

Use the information button to click on the LCP layer (*Project\_2Cores\_LCPs*). This will give you statistics on the corridor including:

-CW\_Dist: total cost-weighted distance (in weighted meters) incurred moving along the least-cost path.

-LCP\_Length: total (un-weighted) length of the least-cost path.

It will also provide ratios of these quantities to give you an idea of resistance encountered per unit distance (again, lower is better).

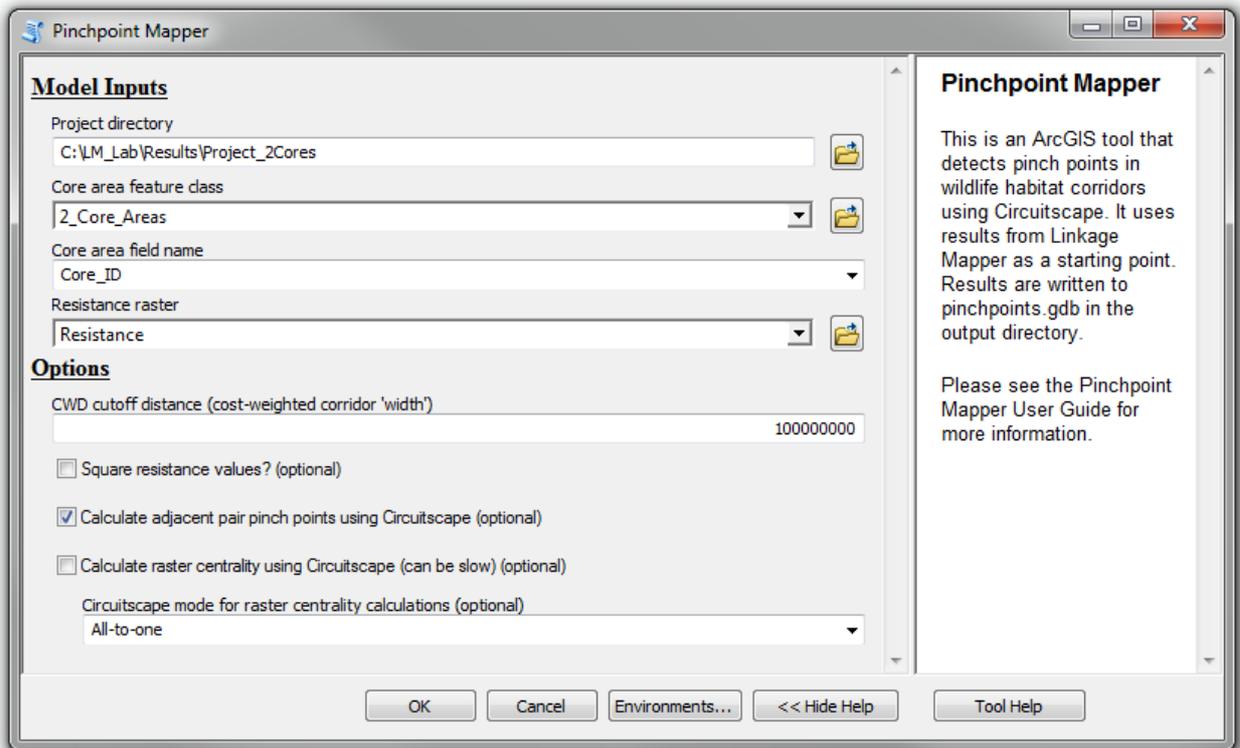
***Results check 2: What is the CW\_Dist value?***

***Results check 3: What is the LCP\_Length value?***

### **3) Run Circuitscape between the core areas**

We could use the **Circuitscape stand-alone program** (which doesn't require ArcGIS) or the **Circuitscape for ArcGIS toolbox** to do this, but for convenience we will just use the Pinchpoint Mapper tool in Linkage Mapper here.

In the Linkage Mapper Toolbox, click on 'Pinchpoint, Barrier, and Centrality Mapping Tools.' **Run Circuitscape** using Pinchpoint Mapper with the following settings (most importantly use **100 million** as your CWD cutoff distance):



This tool will run Circuitscape, injecting electrical current into one core area and letting it flow across the landscape to the other core area. Because the **CWD cutoff distance of 100 million** is higher than the highest cost-weighted distance in the corridor map, Circuitscape will be run across the entire resistance surface (in other words it will not constrain current flow to the least-cost corridor). Current will concentrate in pinch points and potential stepping-stone habitats.

Add ***Project\_2Cores\_current\_adjacentPairs\_100m.lyr*** from your project directory to ArcMap (the actual current raster will be in *Results\Project\_2Cores\output\pinchpoints.gdb*).

This current map shows the probability that a random walker leaving one patch and moving until it hits the other patch would pass through each cell. (A random walker has no memory- it wanders through the landscape, preferring to enter cells with low resistance, until it reaches its destination.) Running Circuitscape across the landscape like this shows areas outside of corridors that might add redundancy (alternative routes and stepping stones).

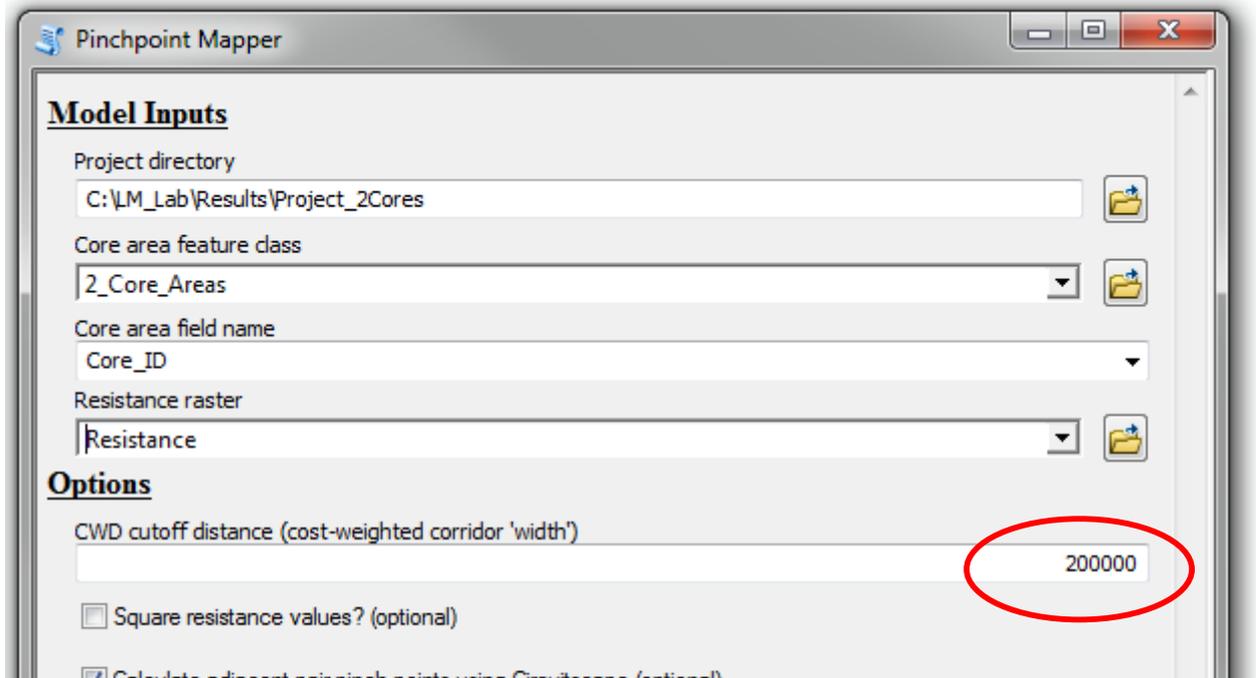
*Results check 4: What is the highest value in the current map?*

*Discussion question: Do any of the highlighted areas seem like they'd be important for conservation? Does this add useful information to the least-cost corridor maps?*

#### 4) Run a hybrid least-cost corridor and Circuitscape analysis

Pinchpoint Mapper was designed to run Circuitscape *within* least-cost corridors to map pinch points. This produces current flow maps that identify and map pinch points (places where corridors are constricted, also called bottlenecks or choke points).

**Map pinch points** within the corridor using Pinchpoint Mapper with the following settings:



This tool will run Circuitscape, injecting current into one core area and letting it flow *through the corridor* to the other core area. **The CWD cutoff distance of 200,000** tells the tool to limit current to a cost-weighted corridor 'width' of 200 cost-weighted km (the same as the truncated corridor you mapped earlier). Current will concentrate in areas where corridors get narrow.

Add **Project\_2Cores\_current\_adjacentPairs\_200k.lyr** from your project directory

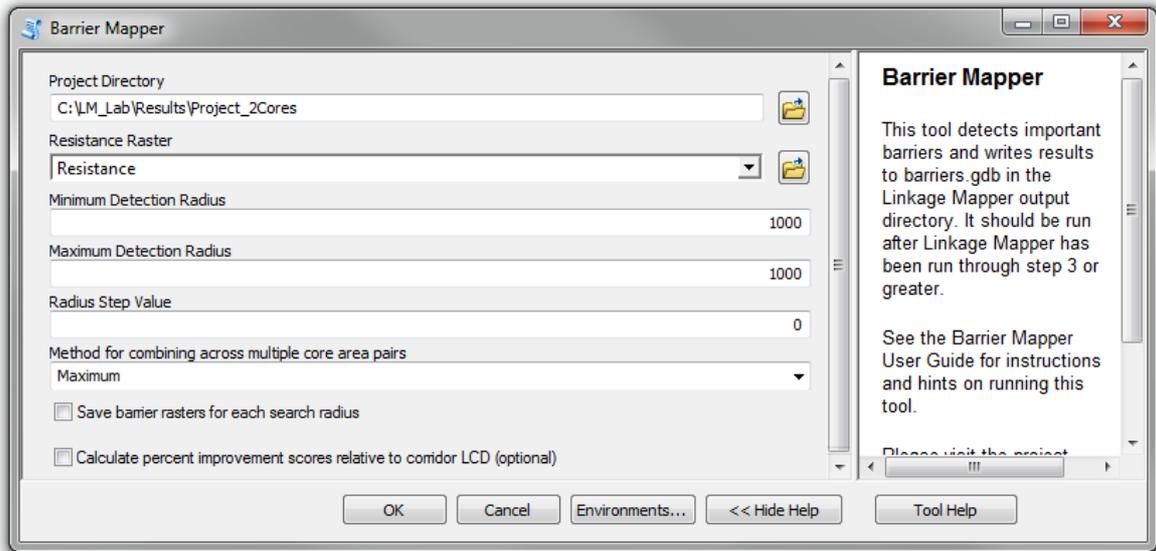
Examine the pinch point map. The higher the value, the more the corridor is constricted (and movement is funneled) at the pinch point.

*Results check 5: What is the highest value in this current map?*

*Discussion question: Does the pinch point map give you any extra information or insight into important areas for connectivity in this landscape?*

## 5) Map important barriers

Here we will use Barrier Mapper tool to map important barriers (some of which might represent restoration opportunities). Run Barrier Mapper using a **barrier detection radius of 1000 m** (detecting effects of barriers up to 2km across):



Add the result from the run to ArcMap:

**Results\Project\_2Cores\Project\_2Cores\_BarrierCircles\_Rad1000.lyr**

*(The actual raster will be in Results\Project\_2Cores\output\barriers.gdb.)*

Higher numbers indicate barriers that have the strongest effect on cost-weighted distances between the core areas. Restoring these would most improve connectivity. Any area that shows up outside of the least-cost path would re-route the path if restored.

*Results check 6: What is the highest barrier value?*

*Discussion question: Have a look at the barriers and at the resistance surface under them. Do all of the areas identified as barriers make sense to you?*

## 6) Restore a barrier

Next, we will simulate a restoration in one of the areas identified by Barrier Mapper. Instead of focusing on a barrier *in* the least-cost corridor, we will restore one entirely *outside* the corridor. It's not a particularly strong barrier, but because it doesn't fall on the least-cost path, we know that its restoration would completely re-route the least-cost corridor.

**Add the Restoration Area polygon and corresponding new resistance raster:**

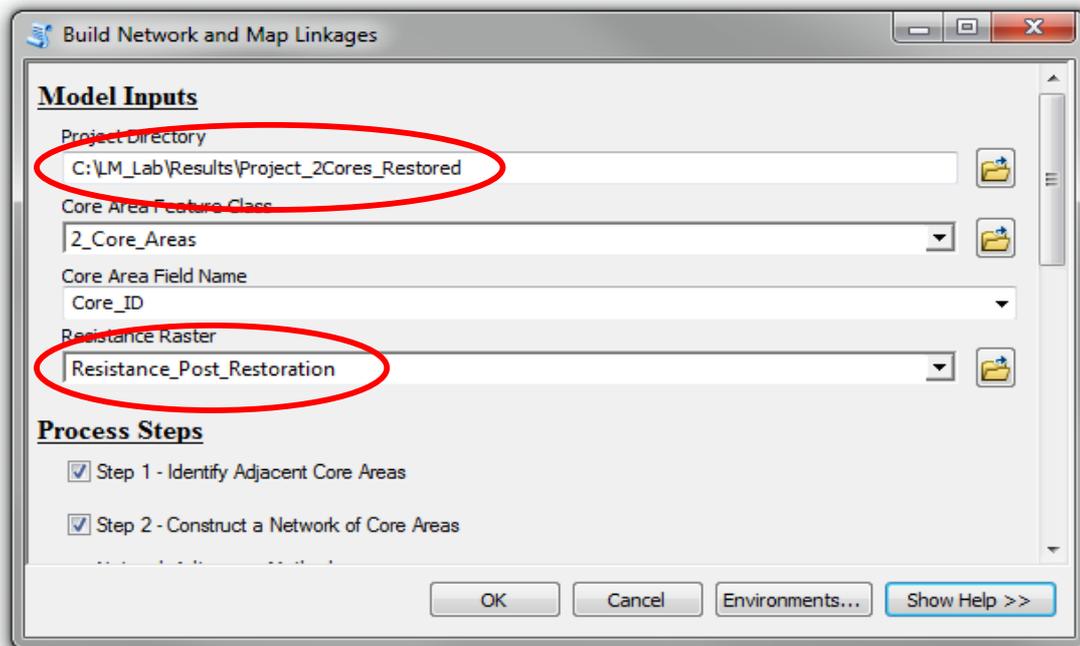
*Input\_Data\Restoration\_Area.lyr*

*Input\_Data\Resistance\_Post\_Restoration.lyr*

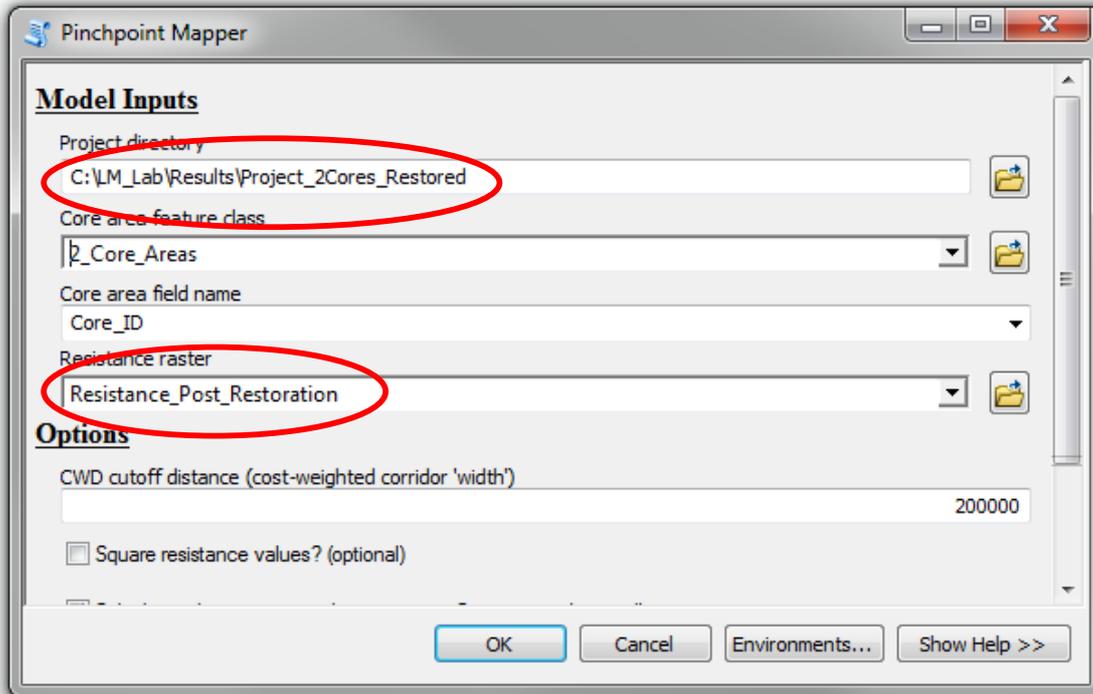
The polygon is a 1km<sup>2</sup> (500 m x 2 km) strip of agricultural land indicated as an important barrier in the analysis above. The resistance layer we will use for the next model run will simulate restoring this area to natural vegetation by lowering its resistance. This would

result in not just an easier least-cost path, but would also add redundancy because in addition to the original corridor, there would be a new, entirely independent least-cost corridor.

**Repeat steps 2-3** using **'Results\Project\_2Cores\_Restored'** as your project directory and **'Resistance\_Post\_Restoration'** as the resistance raster in Linkage Mapper. This raster has the simulated restored area. The resistance in the restoration polygon has been reduced to 1, the same as natural vegetation. Keep all other settings in the tools the same as before.



Now do the same with Pinchpoint Mapper (with a CWD cutoff distance of 200,000):



Add in the corridor, pinch point and LCP layer files from these new runs to your ArcMap project. Layer files will be in the *Results\Project\_2cores\_Restored* directory. Compare the corridors and pinchpoints. Click on the post-restoration LCP polyline to see new corridor statistics.

How do the corridor statistics compare to the old corridor statistics? Visually, how do the corridors compare?

*Results check 7: What is the CW\_Dist value for the new corridor?*

*Results check 8: What is the LCP\_Length value for the new corridor?*

*Discussion question: How much did the corridor map and statistics change following restoration? What does the strong effect of restoring a 1km<sup>2</sup> strip of land say about the sensitivity of corridor maps to errors in base data or resistance estimates?*

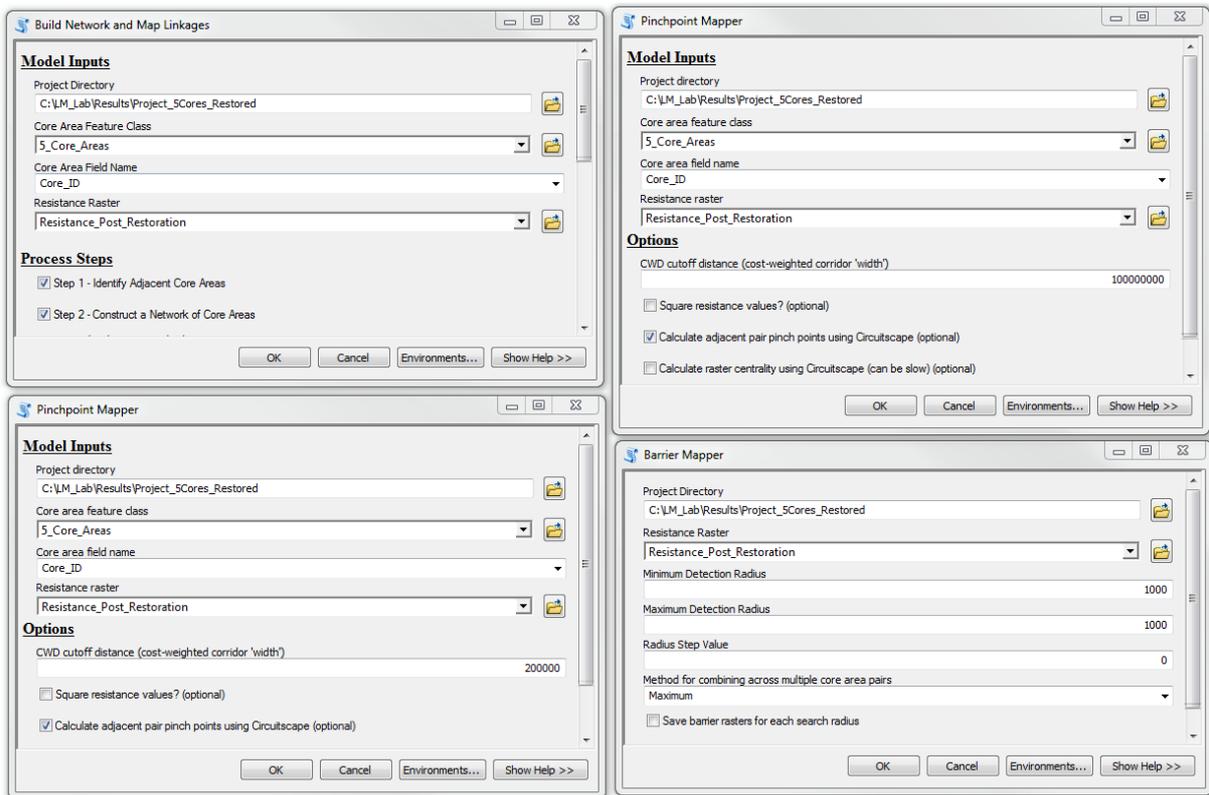
## **PART II: Connectivity among Multiple Core Areas**

For this part, we will repeat the above steps but with multiple sets of core areas to connect. We will use Linkage Mapper to connect adjacent (neighboring) core area pairs only, but it can also be run to map corridors among all pairs of core areas.

### **7) Model corridors, pinch points, and barriers among 5 core areas**

First, open *LM\_Lab\_5Cores.mxd*. This has the restored resistance raster and five core areas to be connected.

Repeat steps 2-5 above using these settings:



Add in all of the layer files from the *Results\Project\_5Cores\_Restored* directory. An additional layer (*Project\_5Cores\_Restored\_Sticks.lyr*) is included to show which core areas were connected based on the settings (recall that only core areas that are adjacent to one another were connected).

*Discussion question: If you were a conservation planner, which maps do you think would be most useful to you?*

*Discussion question: Looking at the aerial imagery, are there barriers that don't look restorable?*

*Discussion question: If you could only protect or restore some of the corridors, how would you prioritize among them? What factors would you consider?*

## 8) Optional data exploration

**Optional:** Display the raw cost-weighted distance map found in the *output/cwd.gdb* directory within any of your project directories. These maps show the cost-weighted distance to the nearest core area. Take some time to look at these and how they relate to

the resistance map (you will probably want to try different color ramps and classification schemes to really get a good feel for them). Think about how resistance accumulates as you move outward from a core area. Can you tell from the maps where the least-cost corridor would be? Or where barriers might be? Does examining these maps give you a better feel for connectivity in the area or not?

**Optional:** Try the Centrality Mapper tool with the 5-core area data. This provides a very simple measure of which core areas and corridors might be most important for keeping the network connected. It assumes that all core areas have equal importance and is sensitive to decisions made earlier in the process, such as whether to only map corridors between adjacent core areas. It updates the LCP layer with a Current Flow Centrality attribute, and also creates a new core area layer with centrality scores in *output\core\_centrality.gdb*.

**Optional:** Experiment with different settings with the 5-core area dataset. Choose whether or not to drop intermediate core areas or whether to connect adjacent or all core areas. **Use a new project directory for each new run of the 'Build Network and Map Linkages' tool.** Try displaying corridors with different width cutoffs (you can take a corridor map and truncate it to any value you wish in Linkage Mapper Toolkit > Utilities > Clip Corridors to Cutoff Width). Try running Pinchpoint Mapper with different cutoffs as well.

**Optional:** Try restoring different areas by editing either of the resistance rasters, and observe the effect on corridor location and quality. **Use a new project directory for each new run of the 'Build Network and Map Linkages' tool.**

**Results check answers. These are provided to help you make sure analyses have been run correctly.**

*Results check 1: what is the range of values in the corridor raster? Cost-weighted distance values for the corridor range from -2 to 12,641,021. (The real minimum value should be zero, but there is some rounding error in the ArcGIS calculations).*

*Results check 2: What is the CW\_Dist value? 1,488,982.75 (1,488 cost-weighted km)*

*Results check 3: What is the LCP\_Length value? 50,285 (50 km)*

*Results check 4 What is the highest value in the current map? 0.178 Amps*

*Results check 5: What is the highest value in this current map? 0.84 Amps*

*Results check 6: What is the highest barrier value? 343*

*Results check 7: What is the CW\_Dist value for the new corridor? 1,348,383 (1,348 cost-weighted km)*

*Results check 8: What is the LCP\_Length value for the new corridor? 28,245 (28 km)*

Appendix D – Example Training Certificate

