Miistakis Institute

Connecting the Dots:

A Guide to Using Ecological Connectivity Modeling in Municipal Planning

Guy Greenaway

Prepared for the Calgary Regional Partnership

November 2016

Innovative research. Engaged communities. Healthy landscapes.

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Introduction

Every municipal planning department in the Calgary region has faced the challenge of addressing *ecological connectivity*, and it is a challenge that is not easily met. It can start from a variety of directions – open house feedback, a councilor request, a regional planning requirement, etc. It can carry many labels: wildlife corridors, linkage zones, structural and functional connectivity.

However, two things are common to all of these cases. First, it is always based on the notion that species need to move to stay healthy and viable. Second, what a municipal planner can or should do about this is not clear. Everything from jurisdictional questions to the complexity of the science to proponent concerns can cloud the issue. For many planners it comes down to: "I know it's an issue – what do I do about it?"

Ecological Connectivity

'Connectivity' is a well-used term in municipalities, with several different meanings (transportation connectivity, human connectivity, etc.)

In this document, *connectivity* will always refer to ***ecological connectivity*** – the state or effort of connecting the pieces of ecological systems.

The goal of this guide, and its companion technical guide[1], is to clear some of the cloudiness. The technical guide (*Pulling the Levers*) outlines how the science can be used to give municipalities map-based illustrations of ecological connectivity. This guide (*Connecting the Dots*), outlines how planners can acquire and use that information to address planning questions, working in partnership with their GIS colleagues and local biologists.

Should You Be Reading This Guide?

Are you in the right place? If you answer 'true' to the following questions, this guide is targeted at you:

1. You ARE trying to figure out how to deal with ecological connectivity, (wildlife movement, corridors, etc.) in your municipality
2. You are NOT a biologist

[1] See *Pulling the Levers: A Guide to Modeling and Mapping Ecological Connectivity*, available from the Calgary Regional Partnership.

3. You are NOT a GIS technician
4. You are NOT a data modeller
5. You ARE involved in municipal planning (i.e., you are a planner, councilor, or other staff member involved in the creation of development or conservation plans for your municipality)

The Companion Technical Guide

If you answered 'false' to number 3 above (i.e., you ARE a GIS technician), then you should read the companion technical guide: *Pulling the Levers: A Guide to Modeling and Mapping Ecological Connectivity*.

That guide provides a technical, but user-friendly, description of the process for modelling and mapping ecological connectivity. It is written for a municipality's GIS technical staff or consultants, but does not require that they are a data modeller. The technical guide is based on the use of CircuitScape (www.circuitscape.org), a robust, commonly-used, free and open-source program for modeling ecological connectivity.

What's in this Guide

This guide – the 'planning guide' – has four main sections:

<u>Connectivity and Modelling</u>

The Connectivity and Modeling section gives an overview of what ecological connectivity is, why it is important to municipalities, and how it relates to planning in general terms. It also describes the modeling process in common terms, explaining the basic function of the connectivity model, but in way that relates it to the planning process.

<u>Planning and Connectivity</u>

The core of this guide is the Planning and Connectivity section. This section starts by laying out the planning questions that need to be *answered* in order to start *asking* the modeling questions: what decision will this support, what scale, connectivity for what, connectivity to where, what's helping/hindering, and what do you as a planner ultimately need.

Potential Planning Applications

Essentially a follow up to Planning and Connectivity, this part describes several sample planning applications – circumstances where you might use ecological connectivity information, and what form that might take.

Planner’s Connectivity Worksheet

If you paid attention to the ‘Planning and Connectivity’ section, this section will look familiar! The *Planner’s Connectivity Worksheet* takes the planning questions identified in the first part of Planning and Connectivity, and converts them to a ‘worksheet’ format. The completed worksheet can frame for the planner what ecological connectivity planning dilemma is actually being addressed, as well as guide the conversation between planners and the GIS technical staff regarding what modeling is needed.

Connectivity and Modeling

For planners, ‘ecological connectivity’ usually comes to their desks either as a policy imperative or as an after-the-fact map … along with an expectation to magically translate those into concrete, implementable plans.

That translation can happen, but it requires key information from two realms that planners don’t normally have expertise in: **biology/ecology** and **data modelling**.

The goal of this section is not to make you fluent in these languages, just to give you enough to get by as a tourist. With a basic understanding of what connectivity is and of how modelling works, planners can be better positioned to plan for connectivity.

Understanding ecological connectivity

What ‘ecological connectivity’ means

In the simplest terms, ecological connectivity is the ability for animals, plants and water to get from A to B. Their health, and that of the systems they inhabit, depends on it. Young animals can disperse to new habitats, genes can flow between communities keeping them resilient to disease, animals can get from summer ranges to winter ranges, flowing water can recharge ponds, evolving plants can find new habitats as the climate changes. Etc.

Connectivity can be a make or break part of a species' survival or the ability of an ecological function (like water cycling) to actually function. The challenge is that the needs of species can vary dramatically, and there is rarely a clear threshold for 'disconnectedness'

So while it may be clear at a high level *what connectivity is*, the question on your desk is what do you need to know about ecological connectivity as a planner? In practical terms, that would include two things:

- A sense of why connectivity is important to ecological conservation in your community, and;
- The different types of connectivity you will need to plan for.

Why connectivity is important

The key to why connectivity is important for ecosystem health lies in the 'system' part of ecosystem. A system works only to the extent that it's internal connections and relationships do. For that reason, understanding and maintaining landscape connectivity has become a key ecological conservation strategy in the face of unprecedented land use intensification.

Despite often being characterized in a linear way, connectivity refers to the numerous connections across the system. 'Habitat fragmentation' is simply the degree to which those numerous interconnections are lost or stressed. Think of stretching a knit sweater; what once appeared as a solid surface now shows spaces, and underscores the importance of the strands that connect it. Now imagine cutting the strands and see what happens to the sweater. The more you stretch (stress) the sweater, the more fraying happens.

The main concern about habitat fragmentation is it can separate species from important resources; animals can't find mates, plants can't migrate to climate-suitable conditions, young can't find new territory, birds can't find winter habitat. This has a range of implications at multiple levels. The most concerning is when fragmentation leads to genetic isolation within or between populations, meaning connectivity is lost to the point where animals are no longer able to exchange genes, and become isolated from each other. At that point they become more susceptible to disease in the short term and lose genetic resilience in the long term.

Ripple benefits

Within a municipal landscape, the local government has perhaps the biggest influence on how stretched the sweater gets, and how many strands get cut. For that reason alone municipalities are increasingly playing a role in protecting biodiversity generally and connectivity specifically. However, planning for connectivity also has several positive associated ripples or ‘co-benefits’, including:

- Managing for ecological connectivity increases connectivity for humans. When we create a physically connected system, we create a physically connected community including parks and greenways that span and connect neighbourhoods.

- Connected landscapes provide other ecosystem services on which we rely, such as sense of place, pollinator habitat, green spaces, aquifer re-charge, and oxygen production.

- Promoting ecological connectivity helps landscapes be more resilient in the face of a changing climate by allowing for species to adapt, carbon to be sequestered, heat island effect mitigation, and accommodation of flood events.

- When we plan for connectivity around transportation routes, we can reduce human-wildlife conflict, decreasing traffic accidents, property damage, injury, and loss of life.

‘Species-specific’ vs ‘Non-species-specific’ connectivity

The study of ecological connectivity is broad and can quickly get complex, especially when asking the question, “Connectivity for what?” However, one basic separation is fundamental to all pieces of the connectivity puzzle, from ecological theory to data modelling to planning for connectivity.

Usually referred to as ‘*functional vs. structural*’ connectivity or ‘*species vs. non-species-specific*’ connectivity, this dichotomy splits based on whether you are looking at maintaining connectivity for a specific species, or whether you are trying maintain connectivity for as many species and functions as possible.

Functional connectivity (Species-specific connectivity)

The ‘species-specific’ (*functional connectivity*) approach to modelling connectivity looks at the ease with which individuals of a certain species can move through the landscape based on what they need and how they respond to what they encounter. This could also be a group of similar species (e.g., all amphibians, all carnivores, etc.).

The modelling is then based on empirical data specific to that species (GPS locations, behaviour studies and/or genetic information), or expert opinion. Connectivity needs for different species may vary dramatically – a frog’s-eye view of connectivity is very different from a deer’s!

> **Functional connectivity**
> *(Species-specific connectivity)*
>
> You have a specific species (or group of species) in mind, and you are focused on the connectivity it needs.
>
> **Structural connectivity**
> *(Non-species-specific connectivity)*
>
> You are trying to maintain the ecological connectedness that a natural landscape provides, without thinking about specific species.

Structural connectivity (Non-species-specific connectivity)

The ‘non-species-specific’ (*structural connectivity*) approach is a ‘connected-landscape’ approach (a.k.a. multi-species approach, species generalist approach). The focus is on the naturalness of the landscape, where intactness (less human disturbance) is used as a proxy for the potential of species to move through the landscape. It does not consider the behavioural response of specific species to the landscape. This may be desirable if species-specific information is lacking and habitat loss and fragmentation are a major concern.

The assumption here is that a more intact landscape (less human disturbance) is better for animal movement than a highly fragmented landscape, and that most species are more likely to move through areas with less human disturbance.

Understanding the modeling

It is important for planners to understand the modelling process, but not necessary for them to become technical experts. The GIS or modelling colleagues you work with will be making specific requests for information – understanding how that information will be used is critical to being able to provide quality information … and get quality outputs.

Recall that this guide is a companion to *Pulling the Levers: A Guide to Modeling and Mapping Ecological Connectivity*, so this document assumes the person asking you for information is using the generic modelling approach described in that resource.

Modelling connectivity

Resistance

Nature is extremely adaptable. Redundant pathways in an ecological system create choices, and animals, plants and water are very good at executing their Plan B … to a point.

Not all paths are the same, and some of those alternate choices take much more energy, limiting how much and how long a given species can keep finding workable Plan Bs. The degree to which human development makes it harder for those species to connect with the resources they need is called 'friction' or 'resistance.' Think of it as the difference between running, running in water, and running in molasses – same task, just harder to do in different environments.

In ecological connectivity terms, 'resistance' is increased by having to cross roads, climb fences, take circuitous routes, avoid humans, etc. Natural features can create resistance, too – rivers, cliffs, and dense vegetation can require energy to get around, too.

The 'Resistance surface'

In connectivity modelling, the landscape is viewed as a mosaic of elements that provide a range of habitat 'suitability'. Connectivity is then measured by how easy or difficult it is for a species to move through that landscape to access 'resource patches' (a.k.a. reserves, cores, core habitat, habitat patches, etc.).

A common approach is to develop a *resistance surface* based on land cover (forest, open water, pavement, etc.) and human features (roads, buildings, etc.) on the landscape. This represents the modelling surface (i.e., the land in the study area) as the degree to which the landscape facilities or impedes movement of a given *species* between identified resource *patches*.

To create a resistance surface, the landscape is divided up into cells (grid squares) where each cell is given a score which represents the ease of movement. Usually these scores are determined using research specific to a species' habitat preferences, food needs, and sensitivity to human features. This information can be obtained from empirical research studies that provide information on species habitat preferences or behaviours, or through expert opinion[2].

For example, each point could be given a score between 0.0 and 1.0. Those scores could also be 'relative,' meaning the best connectivity possible is a 1.0 and the worst possible is 0.0 – everything in between is relative to those end points.

Resource 'Patches'

A key feature of connectivity modelling is the identification of resource *patches*. These are the habitat areas or water bodies or other elements in the ecosystem that need to be connected to each other so that species can access the diversity of *resources* they need to thrive (seasonal habitat, space for offspring, genetic diversity, etc.).

Identifying habitat *patches* can be highly subjective and species specific, and challenging if the supporting data is hard to come by. For that reason some connectivity modeling at regional scales uses a sort of 'patch-free' approach to modeling. In this case *patches* are replaced with a series of points around the study area, and the model assesses the quality of all the points in between in terms of their *resistance* – areas with low resistance are considered higher quality habitat. This approach was used, for example, by the City of Calgary in their landscape connectivity modeling.

Another variation in connectivity modelling is to designate resource *patches* based on those areas managed for conservation, such as protected areas, natural areas, or open space. In this case, connectivity modeling determines how species move between those protected areas.

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[2] Obtaining location specific data for wildlife species appropriate for your study area is often costly, and in many cases represents a key data gap. Given the immense loss of natural habitat and frequent lack of species-specific information to base connectivity modeling on, researchers have begun focusing modeling on *intactness* (level of human disturbance) of the landscape to determine how connected the landscape remains.

Measuring the 'Connectivity'

Once you have

- The **study area**, or the extent of land you want to assess; and
- The '**patches** 'or the places that you want to connect; and
- A picture of the '**resistance'** for your species at any point on that grid…

… you can begin modelling connectivity.

The model can be configured in a number of ways, but they all amount to seeing how the 'flow' between different pairs of patches looks (slick? sticky?). Based on the user's guidance, the model then layers together all those bilateral relationships between patches, and assesses that at every point on the grid, telling you how conducive to connectivity each of those points is. Standing back, this paints a picture of where species are more or less likely to want to move through, allowing planners to identify priorities for ecological connectivity conservation and mitigation.

Interpreting the maps

Your GIS colleagues can generate the resultant maps in any way, shape or colour you want. The difference between getting pretty pictures and getting usable information comes down to how you intend to interpret the map for your purposes. And the way the maps are interpreted comes down to how you ask for the information to be presented. Here are some important points for planners to keep in mind:

- The **title** of the map matters! "Connectivity in the Town of Somewhere" does not tell people what is actually portrayed by the map. Is this priority hot spots? Is this for a specific species? Is this for water? Is this connecting parks or something else? Make sure the title reflects that.

- **Colours** are attractive, but they manipulate you. Hot colours (the reds) can make people think something is amiss, while cool colours (the blues) can make people think things are okay. Green on conservation maps is presumed to be good, blue is water, grey is ecologically poor. Make sure your colours mean something, and that that is clear on the map.

- Is there a **threshold**? And if so, is it clear to the map's viewers? For example, if your map is supposed to show priority areas for planning because they have a certain level of connectivity, is that clear?

- If you are modelling the connections between specific patches, make sure those **patches** are clearly identified on the map, and identified as *patches*.

- Maps and model outputs have a **shelf-life**. Land uses, species populations, management goals all change over time, so maps will need to be re-made, models re-run in order to provide information usable in a current planning context.

Now we can model anything … right?

Well, maybe not quite.

Regardless of how clear you are on the ecological question and the modelling need, you are limited by data. The more complex the questions, the more robust the data needs are. If you have mountains of applicable resistance layer input data, very accurate landcover/use data, traffic volume data, canopy cover data, etc., etc., you can address some very complex questions.

However, it is possible to answer simpler questions with simpler data, so the key is to match the complexity of the question to the hardiness of the available data.

Planning and Connectivity

Successful interaction between planners who are seeking to maintain ecological connectivity in the community and the people who have (or can create) the information to support that effort really comes down to a series of key questions that a planner must ask and secure answers for.

Framing these questions creates a basis for communicating with other departments and functions within the municipality, as well as with external stakeholders, such as landowners, developers, and biologists.

What decision will this support?

The first step is to establish a clear statement of what you need as a planner. It is not enough to say, "we want better connectivity." Your need for information is couched in a decision of some sort. There are two key ways to frame that decision: 'is this conservation or mitigation?' and 'what plans/policies are being informed?'.

Conservation or mitigation?

Simply put, 'conservation' means the connectivity of the landscape is in place, and you are trying to maintain it, while 'mitigation' means connectivity is already (or about to be) disrupted and you are trying to minimize the effect. While conceptually they mean the same thing – helping animals, plants and water move through the system – functionally they are quite different, and therefore so are the approaches you might employ.

Planning for connectivity "conservation" might involve using knowledge of important connectivity zones and associated patches in any of the following cases:

- Prioritizing the securement undeveloped open spaces for municipal parks and natural areas.
- Supporting identification high-value biodiversity areas to inform municipality-wide biodiversity conservation plans.
- Highlighting areas of importance for both wildlife and human/community connectivity.
- Comparing different scenarios for development to see which maintains the greatest amount of land important for connectivity
- Aligning with connectivity outcomes identified in provincial regional plans

- Supporting conservation-oriented planning tools such as Transfer of Development Credits.
- Identifying areas within the municipality that may be of interest for private land conservation efforts (i.e., coordinating with local land trusts)

Planning for "mitigation" might involve using knowledge of important connectivity zones and associated patches in any of the following cases:

- Planning for transportation corridors to allow for animal, water, or plant movement.
- Retrofitting transportation corridors to allow for water, plant or animal movement.
- Comparing different scenarios for housing or infrastructure development to see which has the least impact on connectivity
- Creating development guidelines that minimize the impact on wildlife movement.
- Identifying areas where humans and wildlife are most likely to come into conflict to prioritize education or active mitigation efforts.
- Prioritizing 'connectivity' areas with the greatest potential benefit arising from mitigative efforts.
- Identifying ecological restoration zones where establishment or re-establishment of connectivity will aid species movement.

Clearly communicating this "conservation vs. mitigation" context helps everyone involved understand what information is needed, and what options might come into play.

What plans or policies are you informing?

The ability to promote ecological connectivity within a municipality exists at many different planning/policy levels – accordingly, the specific information needs are different in each case. Identifying the plan or policy within which you are trying to promote ecological connectivity is perhaps the most direct way of stating what the actual decision you are trying to affect is.

- *Intermunicipal Development Plan / Regional Plan* – You may be seeking to align with connectivity needs outside your municipality as represented by Intermunicipal Development Plans or provincially-mandated regional plans.
- *Municipal Development Plan* – You may be seeking to establish a 'culture of connectivity' with broad assertions of the value of connectivity and the municipality-wide approaches that should be taken.

- *Land Use Bylaw* – You many be seeking to information general development regulations, or practices within specific land use districts.
- *Sustainability Plans* – You may be seeking to establish practice guidelines that would inform both connectivity conservation and mitigation efforts in all municipal functions.
- *Policies / bylaws* – You may be seeking to have a specific policy on promoting ecological connectivity, or a bylaw directed requiring certain types of mitigative actions.
- *Drainage plan* – You may be seeking to contribute to a master drainage plan, identifying needs/opportunities for important hydrological connectivity.
- *Design guidelines* – You may be seeking to establish practice guidelines for use in all greenfield developments to promote connectivity.
- *Parks plan* – You may be seeking to inform park management plans, or inform park and open space securement efforts.
- *Area Structure Plan* – You may be seeking to establish development parameters for an area with reference to specific wildlife movement needs.
- *Outline plans* – You may be seeking to have developers explicitly outline protected connectivity zones within a plan for lot locations.

Who are the stakeholders?

Once you have articulated this, it should become clear who the internal and external stakeholders are. Internally, do you need to communicate with parks, drainage, transportation, council, etc.? Externally, is it individual landowners, biologists, land developers, the Province, etc.?

When in the planning process should connectivity be addressed?

A critical question to consider will be *when* in the planning process you need to consider ecological connectivity. This informs the kind of questions you need to ask, and the kinds of information you need as support.

There are two basic ways to look at this.

First, you can view this through your actual planning cycle. Do you need information at the 'concept' level (Municipal Development Plan, Transportation Master Plan), at the 'plan development' level (ASP, ARP, outline plan), or at the 'operations' level (management plan, operation guidelines).

Second, you can view this on the 'conservation – mitigation' continuum. Is your plan aimed at supporting maintenance of the features that enable connectivity (e.g., parks plan, conservation plan)? Or does your plan need to identify and prioritize restoration or mitigation of impacts on connectivity (e.g., transportation plan, riparian strategy)?

What scale are you considering?

The connectivity information you need depends heavily on the geographic scale you are considering. For the GIS person using a model like CircuitScape, the answer to this question will tell them what to use as the 'study area.'

There are a number of ways you can represent the scale:

- *Relative to the municipality* – Is the scale the region around the municipality, the whole municipality or a specific part of the municipality?
- *Planning scale* – Is the scale based on an Intermunicipal Development Plan, Municipal Development Plan, Area Structure Plan, outline plan or other type of plan with a specified extent?
- *Species* range – Is the scale based on the range of a particular species (or collection of species)?

Remember that your chosen scale may have data limitations. For example, you may want a species-specific assessment for an ASP, but local biologists may tell you that data does not exist. This may simply mean you need to switch to a landscape-connectivity approach.

'Structural connectivity' models (those that don't focus on specific species) may be most appropriate at a regional or larger scale. For modellers and GIS technicians, you will need to be clear as to what you mean by 'regional'. In some applications, the City of Calgary may be a *region*; in others, a rural municipality may be; and in yet others, the entire Calgary Regional Partnership area may be the focal region.

Connectivity for what?

One of the most important questions to answer is what specifically you are trying to maintain connectivity for. This is also one of the most challenging questions to answer as a planner, not being a biologist, ecologist or hydrologist!

You do ultimately need to consult these experts, but in order to use their answers it is important to know that the ‘connectivity for what’ question has essentially three possible responses: a specific species (or group), multiple species, or water.

A specific species or group of species?

Based on existing ecological surveys, public feedback, provincial policy, conflict incidents, etc., it may be possible to identify one species or a group of species for which you want to promote connectivity. In these cases, you may be able to identify specific movement needs, habitat characteristics, regional opportunities, etc. that suit that species.

Your focal ‘species’ may in fact be a group of species, such as deer-like species (ungulates), small mammals, grasses, amphibians, etc.

Your data and information needs may be very specific, and your ability to go this route will vary depending on the availability. In some cases, you may be able to get by with very basic habitat data (what kinds of things does this species need, and do examples of that exist here). In other cases, you may have access to more detailed surveys and/or modelling information (habitat models, habitat preferences, movement/dispersal patterns, feeding/foraging patterns, predator/prey relations, etc.)

Multiple species?

As mentioned above, landscape or habitat fragmentation is known to be a key driver in reducing the viability of numerous species. As such, a connected landscape, with generally natural habitat and as much permeability as possible works against this fragmentation. In this case, the answer to ‘connectivity for what?’ may simply be ‘for as much as possible.’

For this ‘landscape connectivity’ approach, answering the questions ‘connectivity to where’, ‘what’s in the way’, and ‘what is helping’ become the key determinants of what is needed for connectivity in the absence of specific-species information.

Water?

Seeking better connectivity for ‘water’ may be sufficient, but ensuring water can move unimpeded can be considered both in terms of *hydrology* and *habitat*. Answering this question better directs the creation of suitable connectivity data and information for use in planning applications.

In hydrologic terms, the question is whether there is a physical connection between water bodies of various types. This may be underground or on the surface.

In habitat terms, the connectivity of water may be used as a proxy for the connectivity needs of water-loving animals and plants. In some cases, animals may actually be moving and dispersing from one water body to another. In other cases, animals may depend on the refresh and recharge of a water body to maintain the quality of their habitat.

Consult the experts

Be sure to consult on this question with local biologists or hydrologists. They will be your primary source of data, but they will also help you answer the questions like whether it is practical to look at one species versus another, if your system relies more heavily on groundwater or surface water, or if a non-species-specific approach is more appropriate given your needs and resources.

Be aware of data and modelling limitations

You may have a strong sense of the species for which you want to maintain connectivity – but that does not mean the data will support you modeling it in an efficient and effective way.

Generally speaking, there are more data *gaps* than there are *data*! You'll need to make sure the data exist for the species you target. At the other end of the spectrum, if you have copious data, this will increase the complexity, time and cost of the modeling.

Connectivity to where?

Similar to 'connectivity for *what*?', the question of 'connectivity to *where*?' has a strong ecological foundation which may make planners hesitate to weigh in. However, planners seeking to promote ecological connectivity in their community can provide strong direction to both ecologists and modellers as to what is needed.

Recall from above that connectivity – both in an ecological and modeling context – is about connecting what we can call 'patches.' The most fundamental direction needed for answering this *where* question is whether these patches are *known* or *unknown*.

Known ‘patches’?

Municipalities already have, or have ready access to, information about many different types of patches. For example, protected areas, environmentally significant areas, natural areas, etc. span the planning and ecology worlds – they are ecologically-important landscapes explicitly tagged with planning designations.

Similarly, some areas with explicit planning tags may have potential as patches, such as natural water bodies, open space, urban forest, rights of way, permeable areas, constructed water bodies, etc.

With information from local biologists, other more specific patches can be identified or derived. These would include known habitat for specific species, habitat types of high value, landscapes with higher-quality natural features, etc.

Unknown ‘patches’?

In many cases, specific ‘patches’ are not known. Though the need for maintaining connectivity may be evident from documented wildlife, water and/or plant movement in the municipality, detailed analyses of habitat, water flow, dispersal, etc. may not be available or practically achievable.

Fortunately, there is a viable process for cases where patches are not known. Models like CircuitScape allow users to analyze the general ecological ‘flow’ through an area, assessing where it is most porous and where movement would be most hindered, allowing for the identification of the best connectivity zones. In these cases, the ‘patches’ are identified as being around the perimeter, as the primary concern is where the best *flow* is within the landscape.

It is important to note that some biologists argue that to limit consideration of connectivity to only those species we know well may be presuming too much about our knowledge and presuming too little about valuable areas of the landscape.

Consult the experts

Again, be sure to consult on this question with local biologists or hydrologists. They will have more specific knowledge about the ‘known’ patches (perhaps even augmenting or refining the planning designations) and recommendations for using the ‘unknown patches’ approach.

What's in the way? What's helping?

In order to model and analyze ecological connectivity from both an ecological and a planning perspective, it is important to be clear as to what is causing *barriers* to movement, as well as what is *supporting* movement.

What's in the way?

The ease of movement across a landscape for animals, water or plants is dependent, obviously, on what is in the way. It is important to be able to identify those for both proactive conservation planning and reactive mitigation planning.

Some examples of barriers could include roadways, residential developments, industrial compounds, areas with impenetrable fencing, interruptions to stream flow, etc.

Recall from above that in modelling terms the tendency to impeded movement through a landscape is referred to as 'friction'. The concept of friction is important as not all barrier types are the same or have the same impact. In most modelling exercises (like with CircuitScape), the modeller will need not just the identify of the barrier, but its relative impact (e.g., is a line of houses a bigger barrier than a major road?).

Keep in mind some barriers may be relatively intuitive, while some are not. For example, water bodies may be barriers for some species while not for others, a slope may be a barrier in some cases but a movement corridor in others, Again, this speaks to the need for consultation with local biologists as to what is a barrier or not in the context of your connectivity planning need, and how they rank relative to each other.

What's helping?

At the same time that some elements of a municipal landscape are hindering connectivity, some elements are facilitating it. For both modelling and planning needs, it is important that these are recognized.

Elements that help may have been constructed specifically as mitigative responses to interrupted connectivity, or they may simply serve that function. For example, when mitigating connectivity barriers, there may be crossing structures over roads, specially-designed culverts, fencing to direct wildlife to better routes, etc. However, wide-span bridges, existing culverts, protected rights-of-way, recreational greenways, stepping stone ponds, etc. may also be promoting flow and movement 'unintentionally.'

Similar to answering 'what's in the way?', it may be important to rank helpful elements in a context-specific way – are some things more helpful in certain circumstances than others? Expert involvement is usually vital here.

What do you ultimately need?

The final question that planners need to ask themselves is what ultimately is needed to support their planning effort to promote connectivity. Having a clear sense of this can streamline the entire modelling and planning process.

This, of course, links back to the decision question, but is more specific to the 'output.' Some examples might include:

- A new policy for connectivity
- A set of criteria / guidelines for best practices
- A map, or a GIS data set to allow for visualization
- A comparison of different scenarios
- A method for prioritizing between multiple valuable options

This can be a fundamental problem when (e.g.) you ask for a map, when really you need a new policy.

Potential Connectivity Planning Applications

There are a few examples scattered through the text thus far, but the key question planners will ask is, "How would I use the connectivity modelling outputs in real-world applications?"

This section is intended to spark the answer to that question.

Your specific application may not be in here, but likely one of these issues/approaches is similar enough that it will catalyze your more-specific thinking on how you could use connectivity modelling to get answers to your planning questions.

Area Structure Plans

An Area Structure Plan (ASP) provides a framework for how a given part of a municipality will be subdivided and developed, including what land uses will be accommodated and where the major transportation routes and public utilities will go.

Although ASPs are generally a response to an expressed desire for subdivision and development, they do provide a 'proactive' opportunity for ecological connectivity planning. For example:

- A 'connected landscape'-based connectivity assessment could be undertaken at the outset to identify areas of intactness, and allow for prioritization of the most important areas for either 'patches' or 'connections'. This could inform decisions to either direct development away from certain areas, or to require relevant landscape design guidelines.

- Depending on the policy and geographic context, the localized 'connected landscape' assessment could link to municipality-wide conservation plans, transportation plans, or to regional or intermunicipal plans with identified ecological connectivity goals.

- Consultation with local biologists may indicate there are specific species in the area, for which the municipality wants to maintain connected habitats for movement and dispersal. In this case, a 'connected landscapes' approach could be augmented by a 'species-specific' analysis of connectivity for those species.

- Because the development of the ASP is conceptual, connectivity scenario planning can be undertaken to choose between options. Several proposed configurations of the housing, land use, road, and utility placement can be subjected to the CircuitScape modelling, allowing planners to choose the configuration that best supports ecological connectivity.

- Developers building within an ASP region will usually be required to undertake environmental assessments in advance of development approvals. The requirement for a connectivity assessment can help provide a clear, shared basis for what that environmental assessment should include. Likewise, in the case where consultation with biologists indicates a potential species-specific concern, the 'species-specific' assessment could be identified as an environmental assessment requirement.

Parks and Open Space Acquisition

Parks, protected area, and open space programs are used to achieve a variety of a municipality's ecological and recreational objectives. The process of identifying and prioritizing areas, especially with limited budgets, can be challenging, as there are a number of factors to consider.

Increasingly, parks departments are working to employ ecological network approaches to guide the acquisition and management of municipal protected areas. Connectivity assessments can be a critical part of this assemblage process. For example:

- Municipality-wide protected lands acquisition programs can be informed by both 'connected-landscape' and 'species-specific' connectivity modelling approaches. Identifying areas important for generally connectivity and intactness can inform the prioritization process. When consultation with local biologists indicates certain species may be of particular concern, or the municipality is within the habitat range of listed species, 'species-specific' assessments can augment general intactness assessments.

- The term Open Space is a double-edged sword, as it can mean everything from a parking lot to wilderness. Many municipalities develop a range of open space types to address this issue, and each type has its own character and objectives. A measure of connectivity can be used to help distinguish those open space types on the more natural end.

- In connectivity modelling terminology, larger parks and open spaces function as 'resource patches' or 'nodes'. An important part of their ecological health is their ability receive and send species wanting to move beyond their borders. Modelling connectivity, using the parks as resource patches, can identify areas that are important to maintain the connections between flagship areas. Those connections can then be subject to distinct development guidelines (different transportation design guidelines, landscape design guidelines, limitations on development, creation of mitigation, etc.).

- Within parks, the placement of recreational and operational infrastructure (trails, maintenance yards, visitor centres) can have a significant impact on connectivity. Connectivity assessments can be done on larger park areas to determine the best place to locate such facilities that will impact connectivity the least. At the planning stage, scenarios can be used to compare different facility layouts. 'Species-specific' assessments can be used to ensure known species of concern are accommodated.

Transportation Network Planning and Development

One of the primary functions of a municipality is to provide the transportation system that moves citizens around within the municipality. As such, conservation planning is often forced into a reactive role when the transportation network is being built or expanded.

However, transportation planners are increasingly being called on to create this system with greater consideration for the ecological impacts it can have. In particular, the requirement for attention to the potential effects of roads on wildlife and their movement corridors is appearing in policy documents more often. Connectivity modelling can support this need in at least the following ways:

- A 'connected-landscape' assessment could be undertaken as part of any transportation master plan to identify where ecological connectivity and road systems may be in conflict. In areas where there is apparent conflict, planners can explore re-alignment, localized adjustments (e.g., at the ASP level), mitigations (culverts, crossings).

- The human safety and cost to society implications of wildlife-vehicle collisions can be significant. Roads may bisect wildlife movement corridors, or re-directing animal movements such that they end up on roadways. A connectivity assessment and associated collision and cost study can identify the places where animals and vehicles are most likely to conflict.

- As watercourses are most often wildlife movement ribbons, where roads cross these (i.e., bridges), there can be significant impacts on wildlife use of these routes. However, bridge design that includes efforts such as wider spans, noise barriers, and higher decks can mitigate these issues. Transportation plans that include watercourse crossings (either at the master plan level or the ASP level) could be overlain on connectivity modelling (either 'connected-landscape' or 'species-specific') to determine where these issues are likely to arise, and open the door to proactive mitigation efforts.

- Roadway fencing can be an impediment to wildlife movement, but it can also be used strategically to direct wildlife to cross at areas that are known to be safer. A species-specific connectivity modelling exercise conducted along the planned route of a major roadway can help identify where fencing can be used to satisfy both the need for human safety and for more effective wildlife movement.

Urban Conservation Planning and Management

Wildlife, native plant species, and water do not feel compelled to exist only in places we designate as 'natural areas.' Well beyond the 'natural' areas of a municipality, nature is present and active, creating conflicts as well as opportunities.

Municipal planners can use an awareness of how and where species are moving across the municipal landscape to assist efforts towards urban conservation planning and management in at least the following ways:

- Urban forests, greenways and other planted landscapes have the potential to support ecological connectivity within a municipality, provided they are done in a manner (planting patterns, species selection) that promotes that function. Species-specific or connected-landscape modelling can help identify the places where these linear spaces could play a connectivity role.

- With development offsets and reclamation efforts, local governments are well-positioned to undertake or facilitate restoration of ecologically-important areas within their communities. Connectivity mapping, especially using scenario comparisons, can help identify and prioritize areas where precious restoration resources could best be deployed.
- Because both urban and rural landscapes are teeming with wildlife, citizens and animals are often seeking to occupy the same space, and conflicts can occur. Connectivity mapping for species that are deemed to be 'problems' can help identify where they are likely to go, allowing municipalities to prioritize mitigation or education programs in those areas, or redirect / modify recreation activities to reduce conflict.

Wetland and Hydrological Connectivity Protection

When we think of ecological connectivity, we tend to think of animal movement, but the *hydrological* connectivity (how water moves) within ecological systems is equally important.

Wetlands, in particular, are an important focus of biodiversity conservation. These seemingly-distinct water bodies are part of interconnected wetland complexes, and the ability for water to flow between them is vital to their viability.

Municipalities can employing a connectivity modelling and mapping exercise for hydrologic connectivity in at least the following ways:

- Several municipalities have undertaken to map the wetland resources within their boundaries, but do not have a clear sense of how they are connected, and more importantly how to protect those connections. A 'connected-landscape' connectivity assessment, using existing wetlands as the 'resource patches, can highlight for a municipality where these important connections are.

- Once identified and prioritized, these areas of important hydrologic connections could be subject to acquisition (by either the parks or the drainage departments), environmental reserve, development limitations, landscape design guidelines, or protective measures.

- Prioritizing hydrologic connectivity zones for protection can involve scenario planning (compare different build scenarios to assess relative impact), identification of connectivity zones between provincial-jurisdiction water bodies, or consideration of important connections to and from keystone or priority water bodies.

- Assessments of wetland connectivity from an ecological perspective can be overlain with assessments of drainage from a stormwater movement perspective to identify connections important for both functions.

Policies, practices, guidelines, bylaws

The issue of ecological connectivity (often expressed as 'wildlife corridors') is often raised in summaries of public feedback, or by municipal personnel who see this as part of their role.

Alberta municipalities are starting to respond to the demand for greater attention to wildlife and their needs by developing policies targeted at this conservation issue.

Connectivity modelling can support this effort to create specific policies and practices in at least the following ways:

- Increasingly, municipalities are working to assemble/maintain natural area systems, and developing policies to do so. These policies often require connectivity to be a significant consideration in planning applications and plan amendments. Accompanying such a policy could be reference to connected-landscape or species-specific modelling outputs or prescribed methods.
- Landscape design guidelines, either at a general Land Use Bylaw level or a more specific Area Structure Plan level, can direct developers and builders to use techniques more conducive to supporting wildlife movement. Scenario comparisons can be used to show how different development patterns/practices lead to different connectivity outcomes.
- Municipality-wide conservation plans (sustainability plans, biodiversity plans, urban conservation plans, ecological network plans) often state the need to maintain ecological connectivity, but struggle to articulate what that means. Maps of connectivity zones (species-specific, or connected-landscape based) can highlight where these plans should focus, especially if layered with other conservation or sustainability goals).
- A bylaw could be drafted with the express purpose of promoting ecological connectivity within the municipality. The challenge in doing so is generally

the need to identify what is meant by connectivity. A connected-landscape modelling exercise could be used to anchor such a bylaw, with an attendant requirement for more detailed modelling (or perhaps scenario modelling) in cases where connectivity 'hotspots' are identified.

- The work of a municipality is increasingly global, with international conventions, partnerships, and commitments more common on issues from trade to conservation. For example, the ICLEI Durban Commitment for Biodiversity, with at least two Alberta signatories, requires reporting on biodiversity conservation. Regular modelling of municipality-wide biodiversity would allow for local governments to report on their efforts to maintain connectivity zones.

Regional Decision Making

Municipal efforts to promote ecological connectivity exist within a broader set of regional initiatives. Other municipalities, the provincial government and its agencies, watershed groups, conservation groups, and others play complementary roles in maintaining and restoring connectivity.

To effectively interface with these partners and their plans on issues of connectivity, municipalities need a clear articulation of what connectivity means to them and which areas within their jurisdiction are important for connectivity.

Connectivity modelling can support this sort of regional connectivity decision making in at least the following ways:

- Because Intermunicipal Development Plans (IDPs) focus explicitly on the interface between municipalities, they are an obvious place for regional connectivity to be considered. The Modernized Municipal Government Act, introduced by the Alberta government in the spring of 2016, directs that Intermunicipal Development Plans (IDPs) must consider environmental matters within the area. Regional scale connectivity maps could be included to identify the areas where more detailed connectivity analysis must be undertaken before development could occur.
- Regional plans created under the Alberta Land Stewardship Act require biodiversity plans with specific reference to connectivity. These plans also require municipalities to align with their outcomes. Ecological connectivity mapping at the municipality level can both report on, and set pragmatic direction for, regional plans

- The Bow River Basin Council's Watershed Management Plan calls for a better understanding of the connectivity of wetlands in the region, as well as of the spatial connectivity of terrestrial and aquatic landscape features. The intent of these efforts is to better inform all management planning in the Basin, including that of municipalities. Regional scale connectivity modelling undertaken by individual municipalities
- Provincial parks and protected areas constitute vital 'patches' for regional ecological connectivity. Yet the routes of connection run through lands for which local municipalities have planning jurisdiction. Connectivity modelling at a regional scale could inform where connectivity zones are most valuable for these regional ecological assets.
- Partnerships between private land conservation organizations (land trusts) and municipalities are appearing throughout the province, as both recognize the importance the other plays in conserving natural heritage in their community's. Local and regional connectivity mapping can be used to help coordinate securement activities of both groups and planning activities of municipalities, ensuring that key 'patches' are understood, and key connectivity zones between them are protected.
- Municipalities are criss-crossed with provincial-jurisdiction roads and rights-of-way, many of which play major roles in facilitating and impeding wildlife movement. As well, municipalities are peppered with provincial-jurisdiction wetlands. Connectivity mapping within municipalities of wildlife movement and hydrological flows can be used as the basis for informed collaborations between municipalities and the Province of Alberta with regard to protecting or restoring ecologically-valuable 'patches' and 'connections'.

Planner's connectivity Worksheet

One the next page is a 'tear-off' worksheet for you to use as you move forward with trying to promote ecologically connectivity in your municipal planning work.

The worksheet is your **planning guide**, but it is also your **communication guide**:

- With your GIS / spatial analysis colleagues, it functions like an order form – this tells them **what you need**.
- With your senior management or council, it functions as your business case – this tells them **why this is feasible.**
- With your biologist / ecologist / hydrologist partners, it functions as a research plan – it tells them **what information you need**.
- With landowners and developers in your community, it functions like their application form – it tells them **what the municipality will require** of them.

For instructions on how to fill the worksheet out, consult the 'Planning and Connectivity' section – it has the same structure and sections, with more detail.

Planner's Connectivity Worksheet

What decision will this support?	• Conservation? (maintaining connectivity) • Mitigation? (restoring connectivity) • Plans / policy level? (MDP, LUB, sustainability plan, dedicated policy or bylaw, drainage plan, transportation plan, design guidelines, parks plan, ASP, outline plan); Where in the planning process is information needed?
What scale are you considering?	• Provincial, regional, intermunicipal? • Whole municipality, part of the municipality?
Connectivity for what?	• Specific species, guild, community? • Water? (groundwater, surface water) • Landscape connectivity? (maintaining general connectedness and maximizing naturalness for the greatest number of species) • Data or modeling limitations?
Connectivity to where?	• Specific 'patches' ?(protected areas, natural open spaces, ecological network nodes, water bodies) • Unknown 'patches'? (green space, undeveloped areas, entire perimeter)
What's in the way, what's helping?	• Potential barriers? (roads, built areas, waterways) • Potential assistance? (mitigation structures, wide-span bridges, culverts, protected corridors, greenways, stepping stone parks/ponds)
What outputs do you need?	• A new policy? • A set of criteria / guidelines? • A map? A GIS data set? • A scenario comparison? • A prioritization?
What input information is required?	• Species-specific habitat data or behaviour information? • 'Patches' data? (location of parks, open space, undeveloped areas, wetlands, etc.) • Ranking information? ('better/worse' for barriers, mitigations, habitats, patches) • Development plans?