A method for spatially simulating oil and gas footprint to test for effects of proposed developments on caribou movement

Eric Neilson, Haitao Li, Tyler Muhly, Rob Serrouya, Charlene Nielsen

University of Alberta
GIS Day
November 13, 2012

Alberta Biodiversity Monitoring Institute
Alberta Innovates Technology Futures

Outline

1. Introduction
2. Well pad simulation
3. Linear features simulation
4. Caribou movement modeling
5. Conclusions

Oil and Gas Developments

- Well pads
- Linear features
  - Seismic lines
  - Roads
  - Pipelines
- Processing facilities


Photo: International Boreal Conservation Campaign


Photo: Edward Burtynsky


Photo: Cenovus

Fragmentation

Caribou Movement

- Roads can be barriers to caribou movement[1]
- Caribou avoid roads, well pads and seismic lines[2]
- Decreased permeability and spacing between developments may impede caribou movement
- Need to test for the effects of proposed oil and gas developments on caribou movement


Photo: Cooperative Group

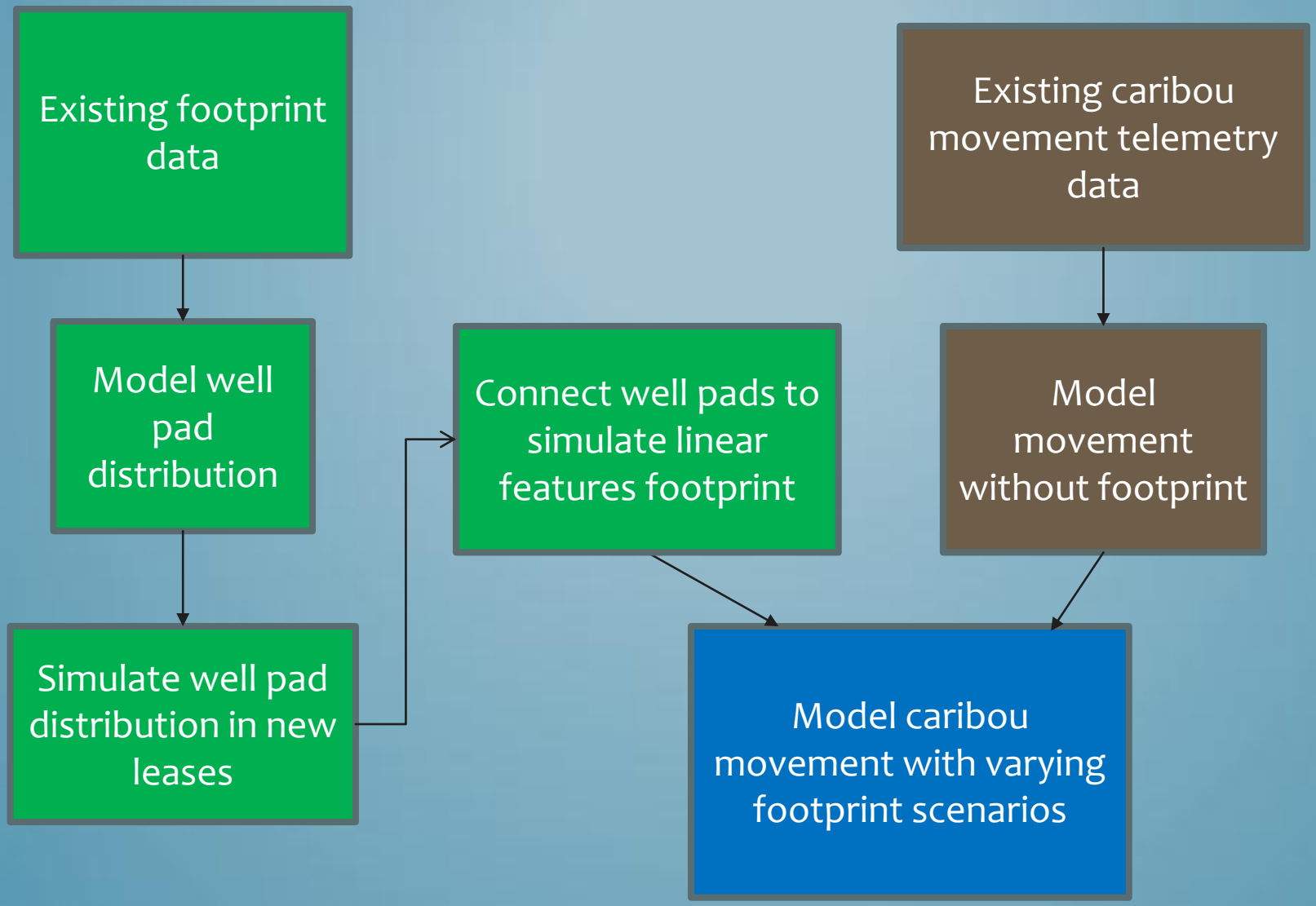
Study Objectives

- Simulate future oil and gas linear, well pad and central facility footprint from existing proposed data

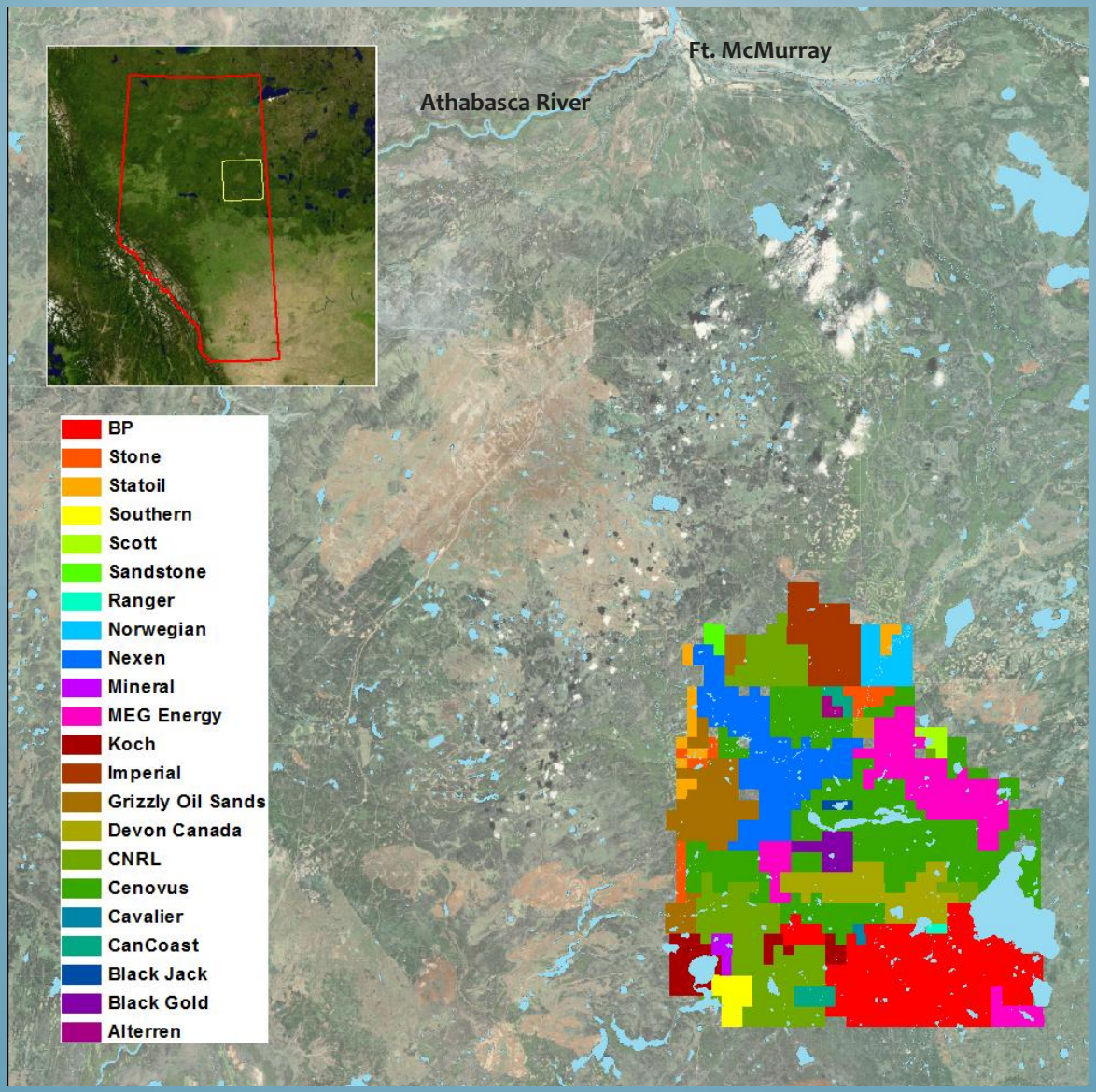
- Test the effect of various footprint characteristics on caribou home range size and movement step length
  - Permeability
  - Spacing
  - Contiguous habitat (protected areas)

- **Hypotheses**
  - Decreased permeability = restricted movements
  - Increased spacing = less restricted movements
  - Protected area = less restricted movement

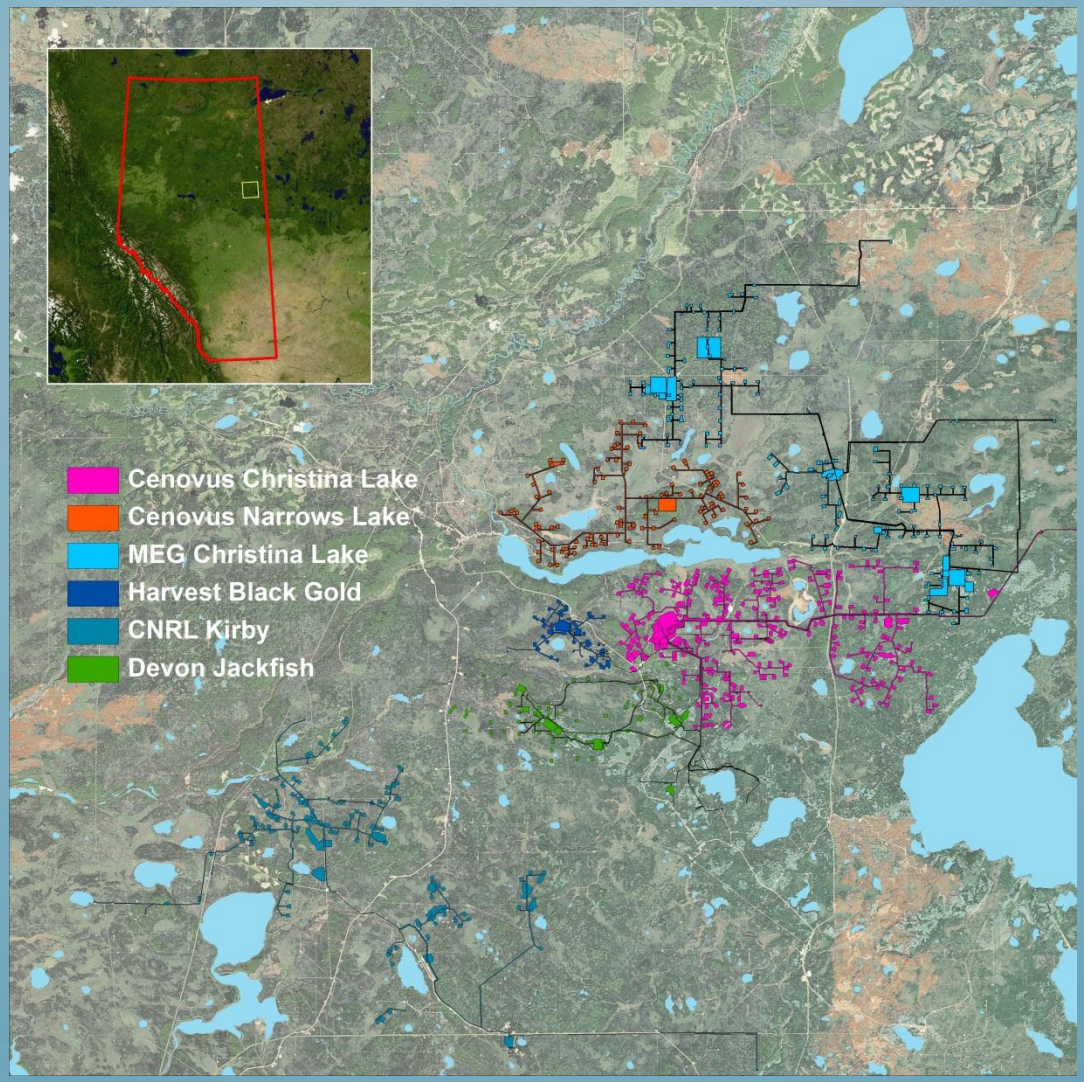
Simulation Approach



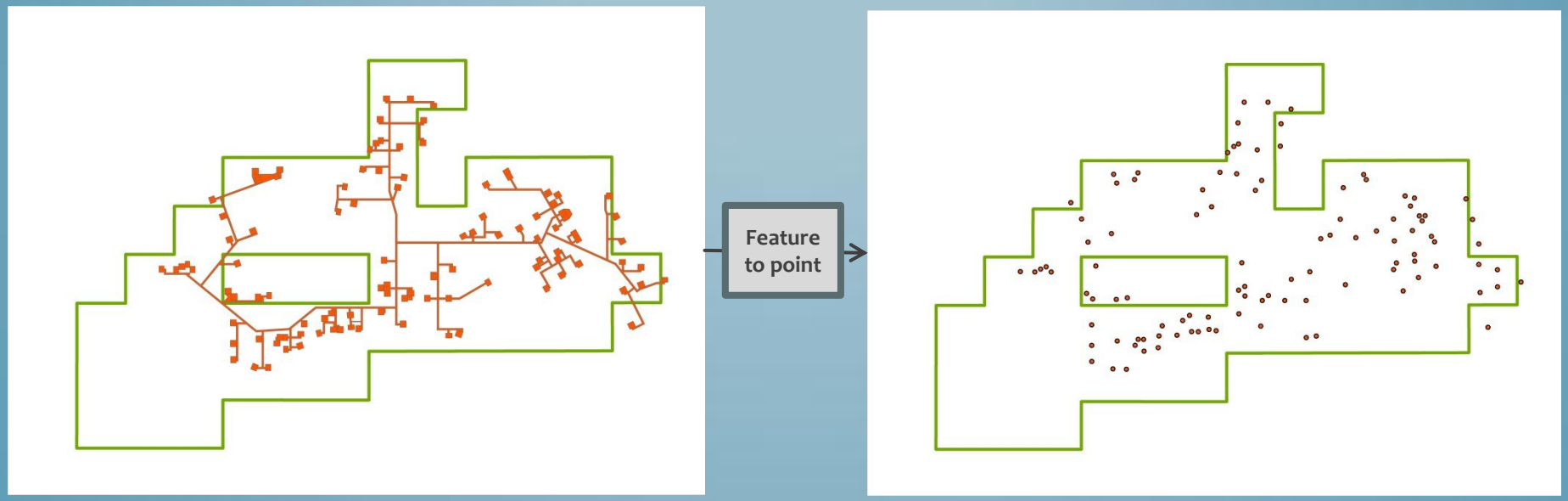
Oil and Gas Developments Leases



Proposed Oil and Gas Developments

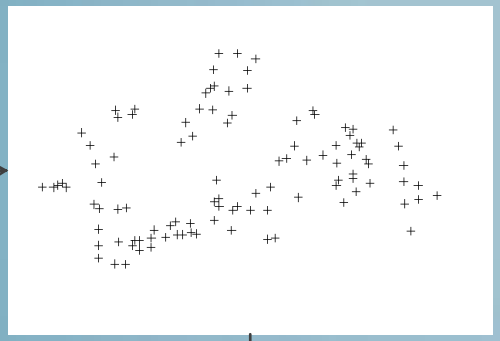


Cenovus Narrows Lake Proposed Development Footprint

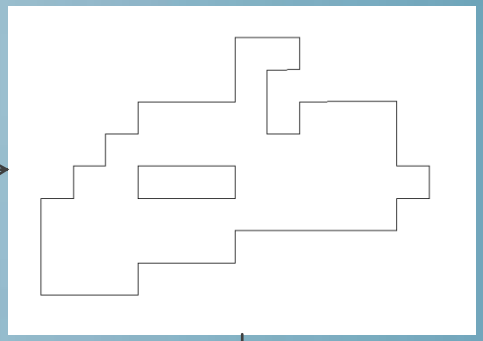


Spatial Data in R
Packages: maptools, sp, rgdal

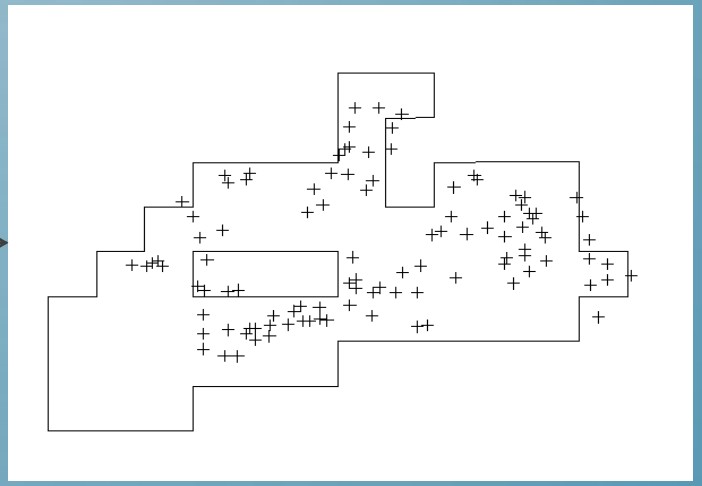
Read in point shape file (readOGR)



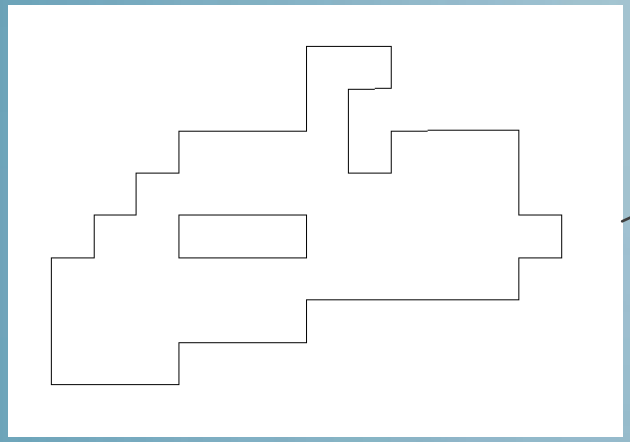
Read in border shape file (readOGR)



Transform projection
(spTransform(NL_shape,CRS("+proj=utm +zone=12 +ellps=GRS80 +units=m +no_defs"))
Spatialreference.org

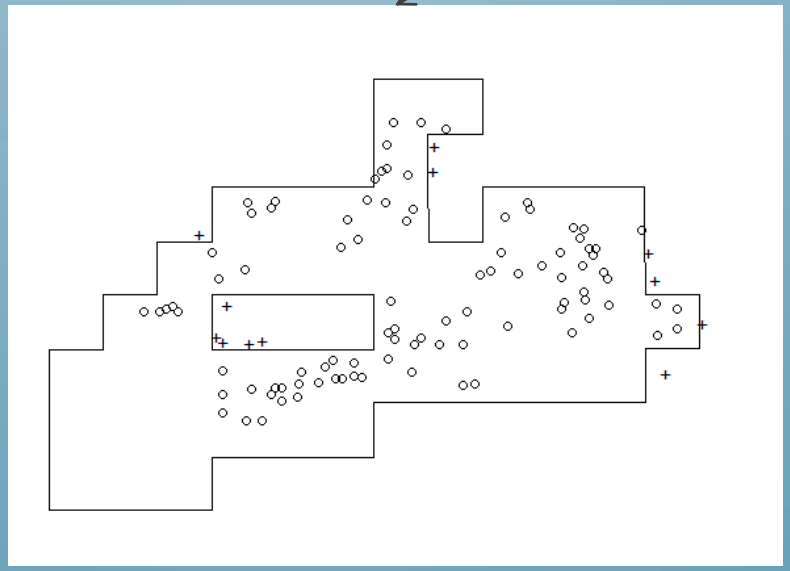


Point Pattern Objects
Package: spatstat



Create owin
NLWIN<-as.owin(NL_shape)

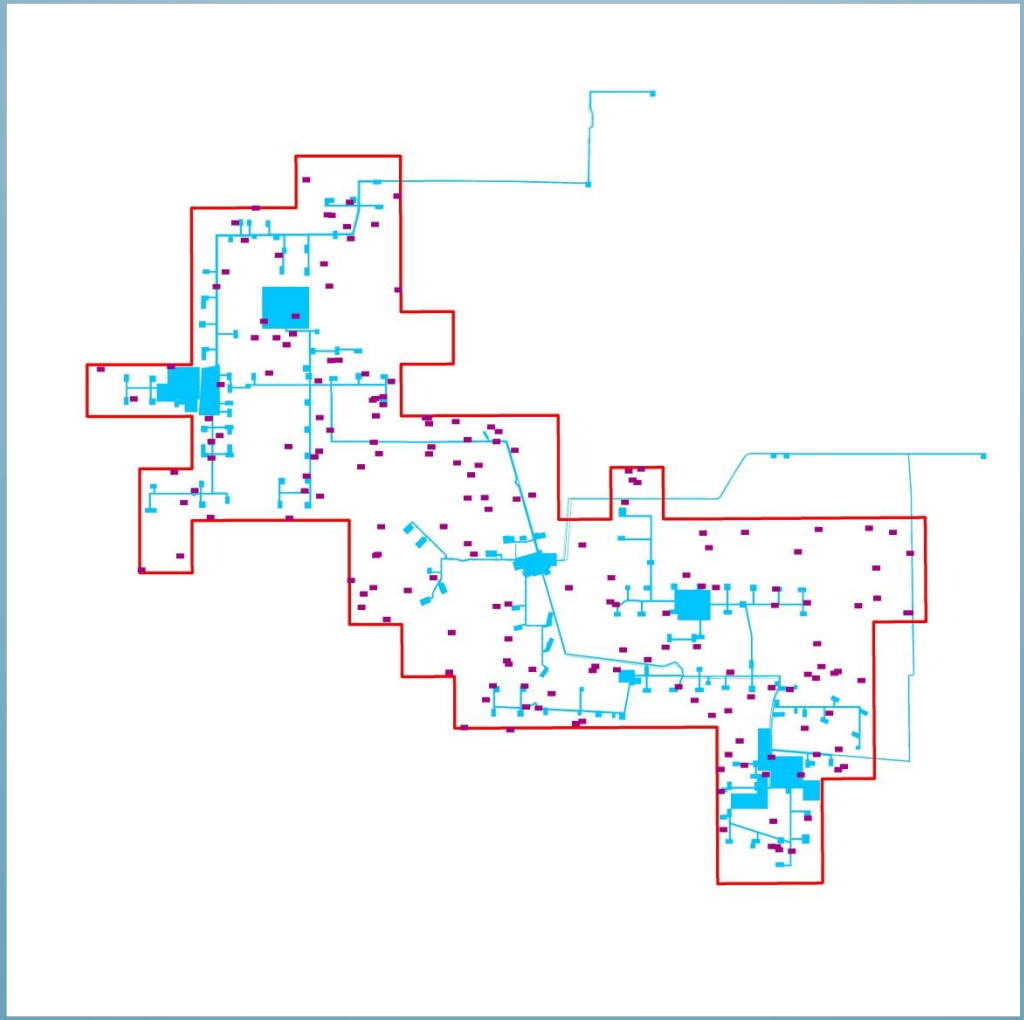
Create ppp object for use with spatstat
NLppp<-ppp(NL_pads$POINT_X,
NL_pads$POINT_Y, window=NLWIN)



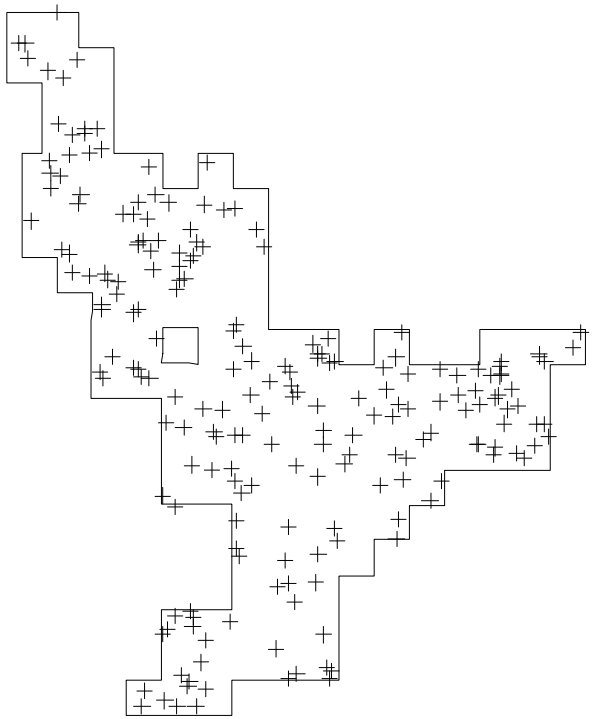
Well Pad Distribution Simulation

- Describe the distribution of points within the lease boundary
- Nearest Neighbour Test
  - K test in spatstat
  - Kest(NLppp)
  - poisson distribution
- Spatial Logistic Regression Model
  - available space divided into pixels
  - presence or absence of points in each pixel
  - useful for poisson spatial distributions
  - NLm<-slrm(NLppp~1)
- Simulate points in remaining leases
  - Lease<-as.owin(lease)
  - sim<-simulate(NLm,window=lease, nsim=100)

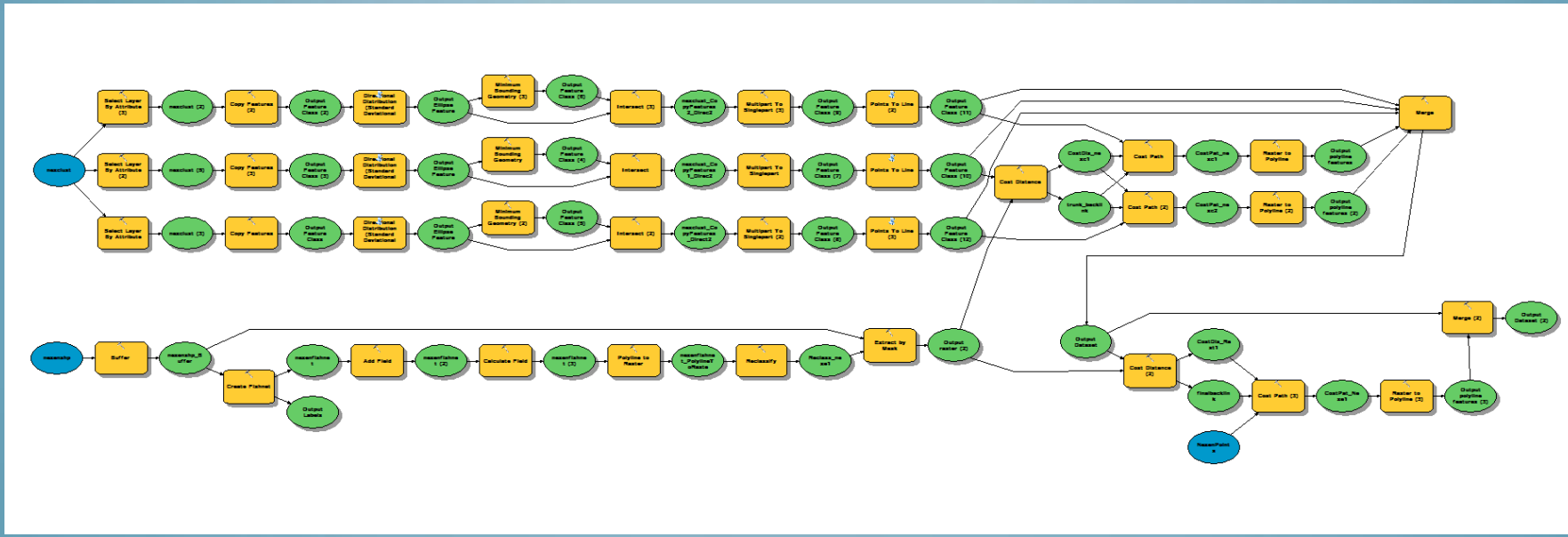
Well Pad Simulation Results
MEG Energy



Well Pad Simulation Results
Nexen Lease



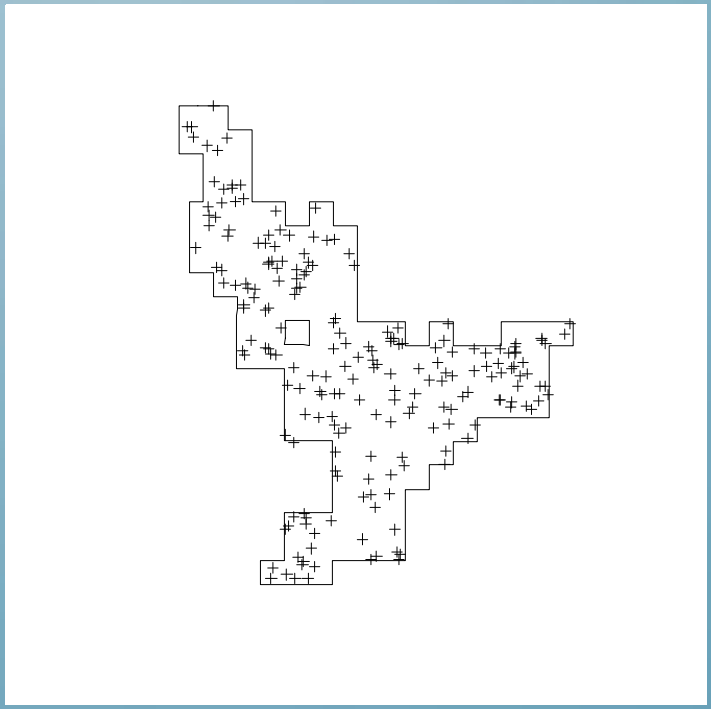
Linear Feature Simulation
Model Building



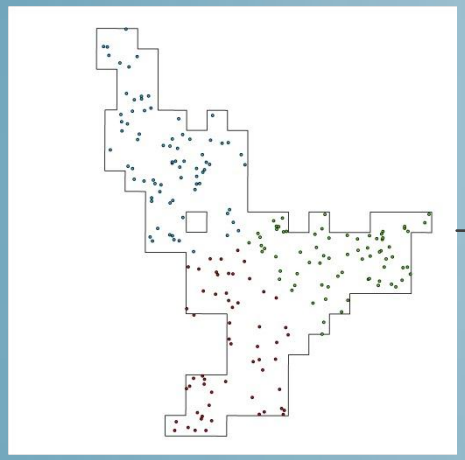
Linear Feature Simulation
Package: cluster

- Package: cluster
  - Partitioning around medoids
  - Clusters data into *k* clusters
  - wellcluster<- pam(sim,3)

- Import simulated points with clusters into ArcGIS

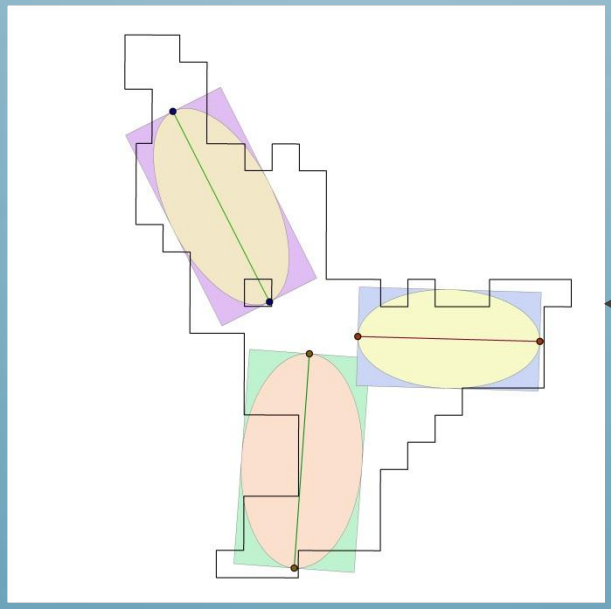


Linear Feature Simulation
Part 1. Trunk Roads

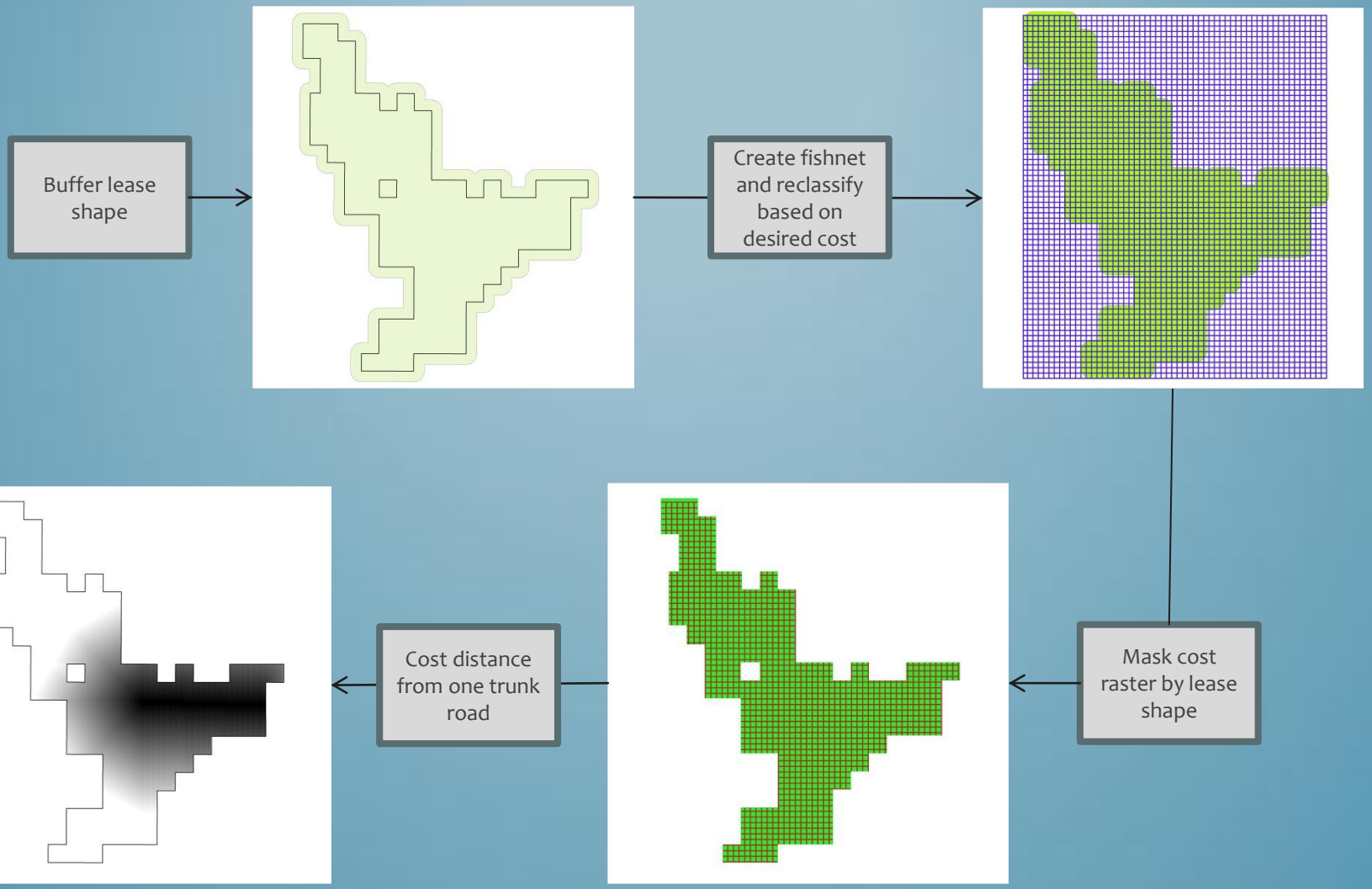


Determine one standard deviational ellipse around each cluster

Intersect with minimum bounding geometry and connect points with line



Linear Feature Simulation
Part 2. Cost Distance

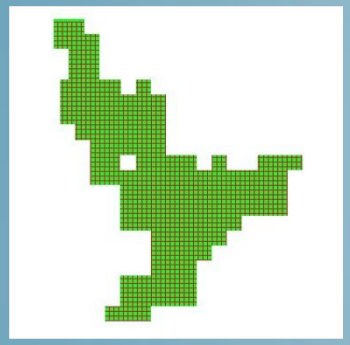


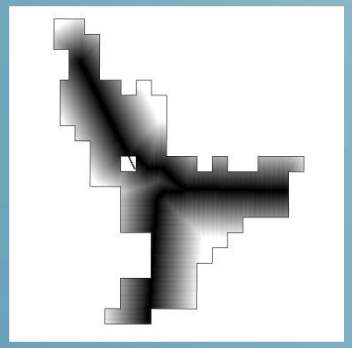
Linear Feature Simulation
Part 3. Cost Path

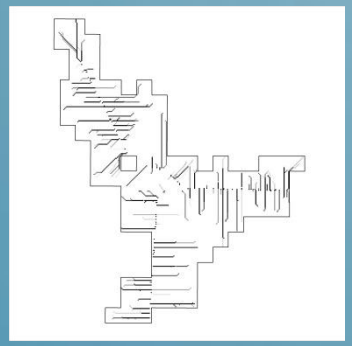
Cost Path: remaining trunk roads as destination

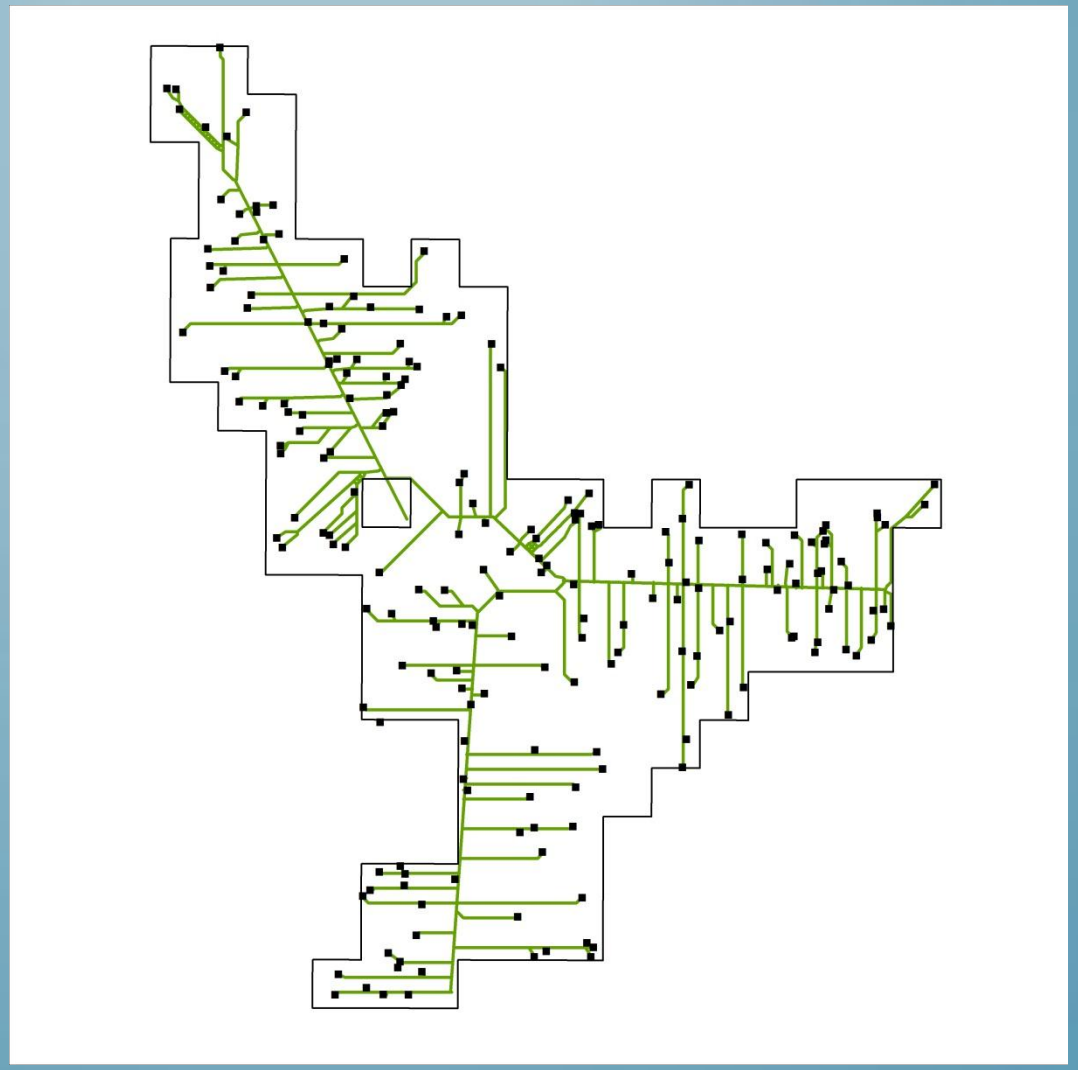
Raster to polyline, merge

Linear Feature Simulation
Part 3. Cost Path









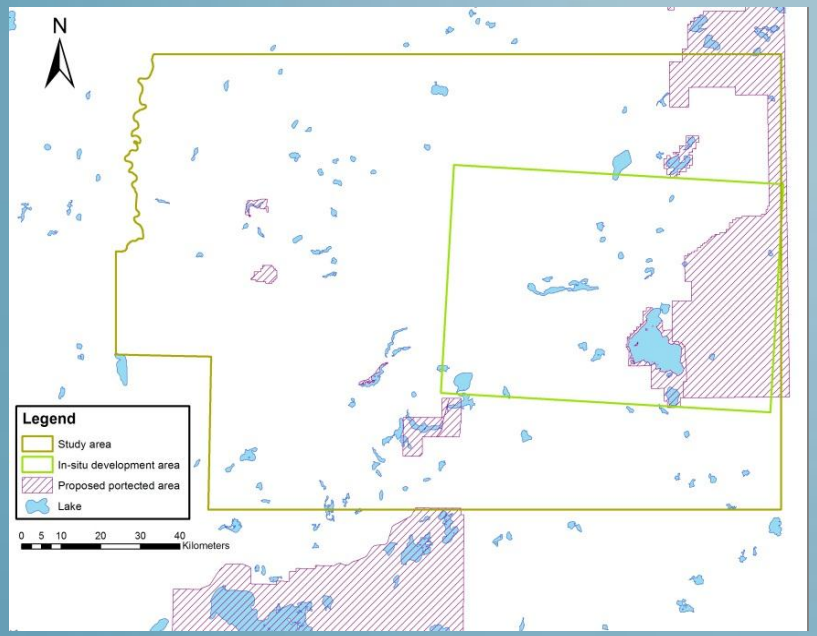
Caribou Movement Model
Methods

- Used 2-hour interval telemetry data from 20 collared caribou in boreal Alberta to create a step selection function (SSF) containing:
  - Turning angle distribution (angle between points)
  - Step length distribution (straight-line distance between points)
  - Habitat selection model
    - Logistic regression model comparing land cover along step to habitat along a sample of random steps

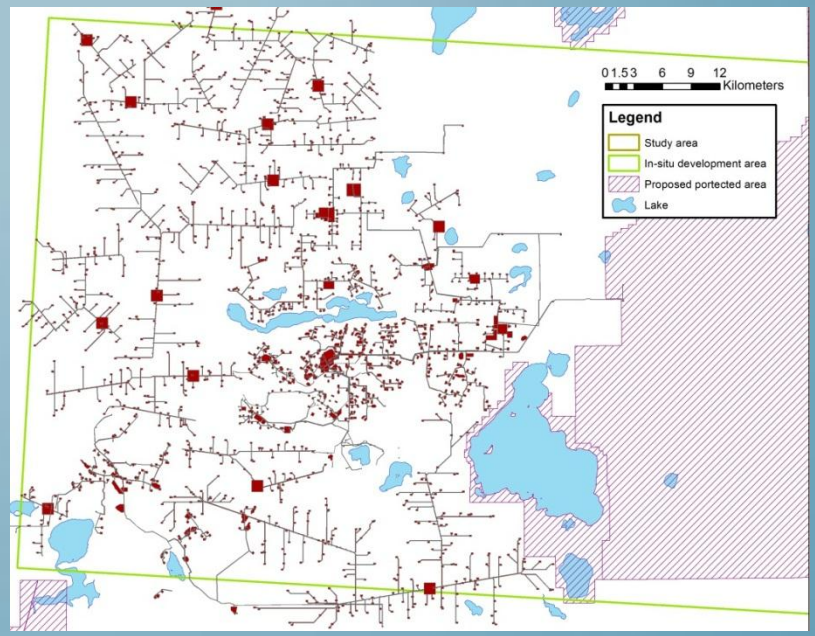
- Various simulated footprint scenarios included as new covariate in SSF to test for effect on minimum convex polygon (MCP) home range and step length

- Scenarios varied
  Permeability: 0%, 25%, 50%, 100%
  Spacing: Actual leases, 2km spacing between leases, 800m spacing, Combo of 800m and 2km
  Protected area: Portion of study area withheld as protected area

Caribou Movement Model

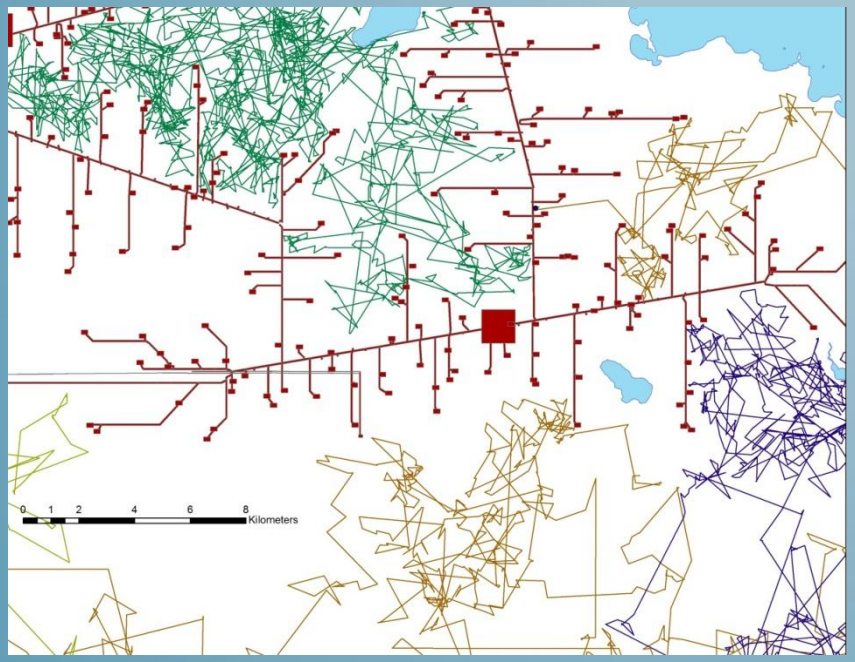


Study Area

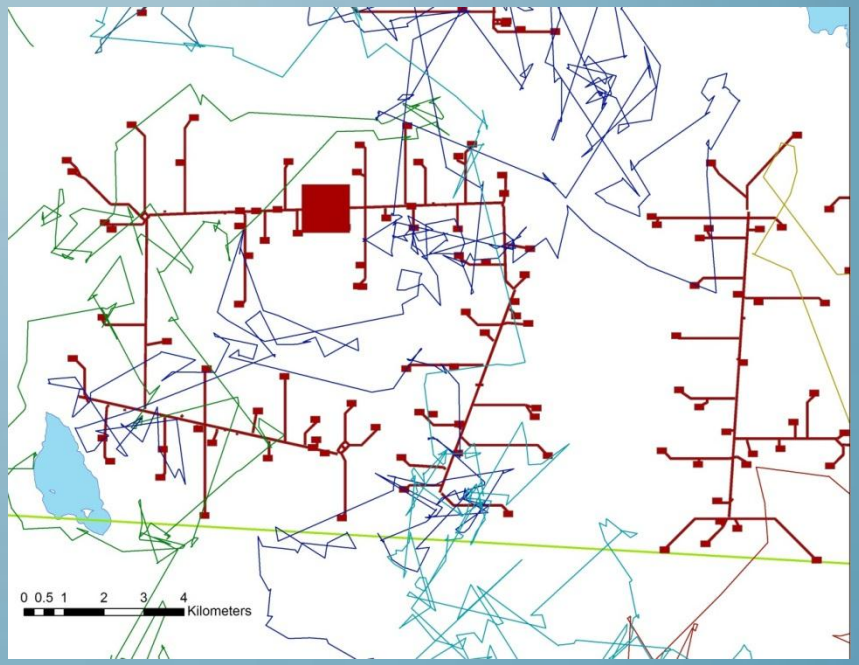


Actual and simulated footprint in development leases

Caribou Movement Model Results

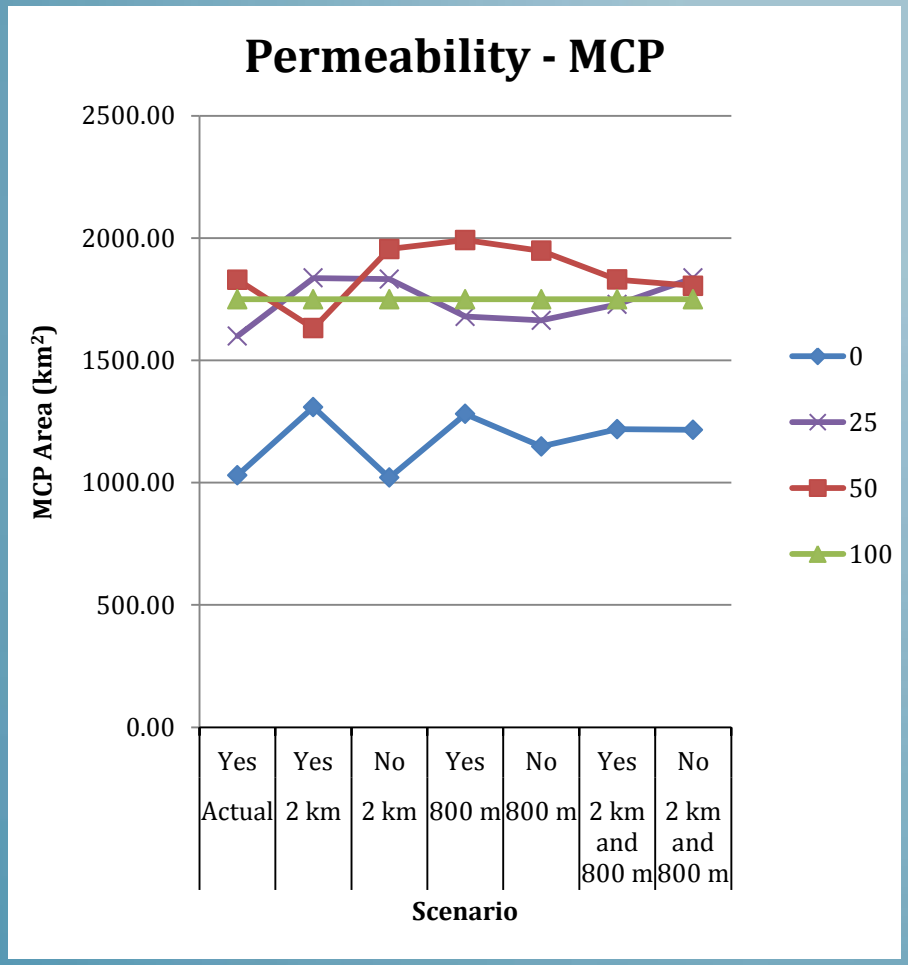


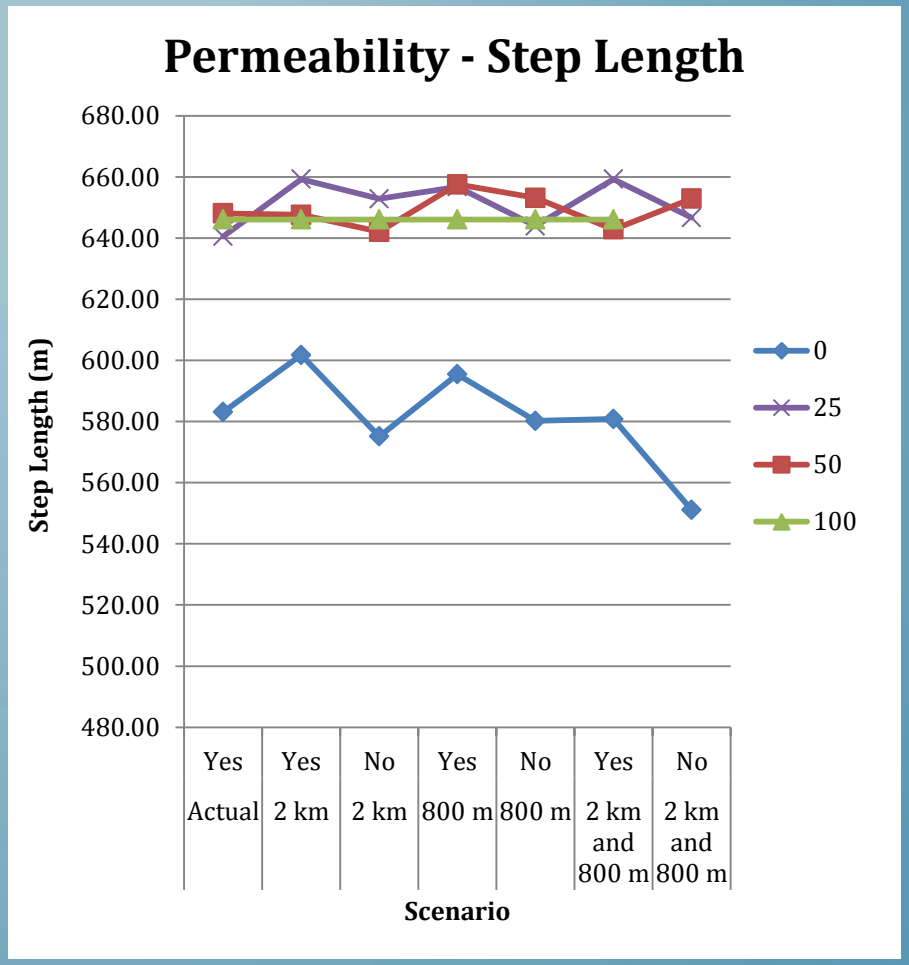
Simulated caribou movement with impermeable footprint



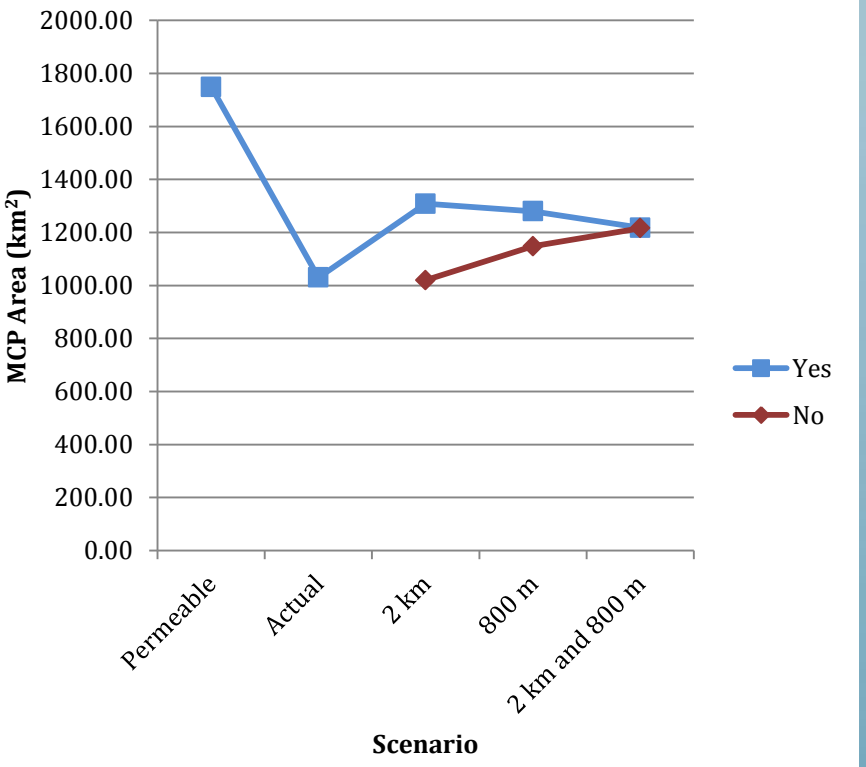
Simulated caribou movement with 25% permeable footprint

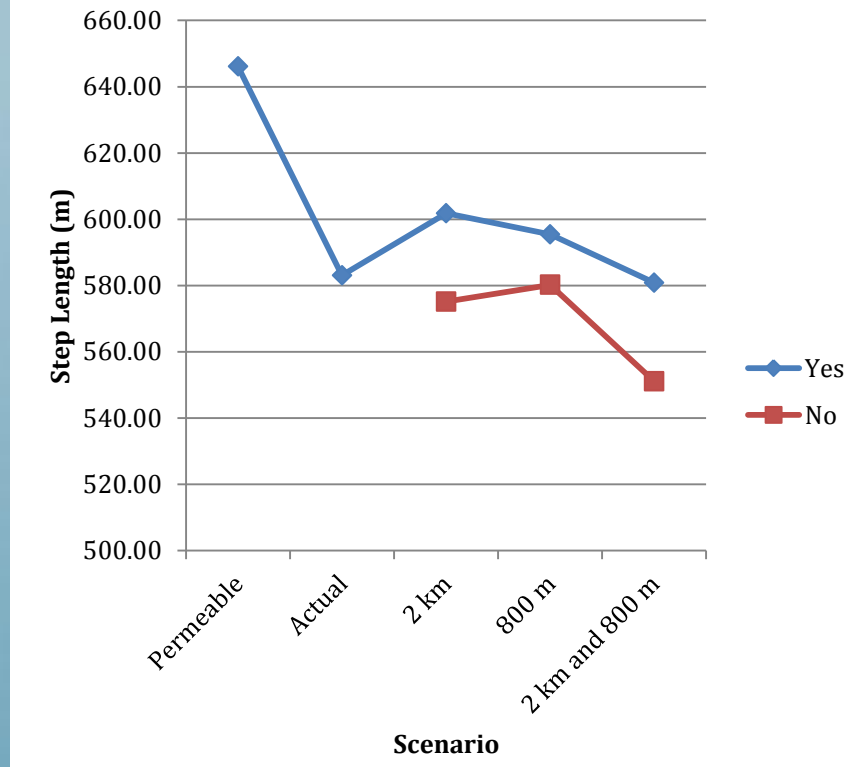
Caribou Movement Model Results





Caribou Movement Model Results





Caribou Movement Model Conclusions

- Some footprint permeability (<25%) needed to allow movement
- If footprint not permeable - some increase in MCP and step length with protected areas
  - set aside large contiguous areas
- Minimum 2km spacing not enough to increase movement

Future Work

- Fit other functions to the spatial linear regression model for new development areas
- Add more environmental variables to cost raster for footprint simulations (hydro, slope, land cover)
- Proceed with more caribou movement simulations to identify amount of permeability that is limiting for caribou movement
- Ground truth actual permeability of footprint with field work

Questions


Photo: Canadian Wildlife Federation

References

1. Dyer, S. J., O'Neill, J. P., Wasel, S. M., & Boutin, S. (2001). Avoidance of industrial development by woodland caribou. *The Journal of wildlife management 65(3): 531-542.*

2. Dyer, S. J., O'Neill, J. P., Wasel, S. M., & Boutin, S. (2002). Quantifying barrier effects of roads and seismic lines on movements of female woodland caribou in northeastern Alberta. *Canadian Journal of Zoology 80(5): 839-845.*