Ecography

E6077
Roever, C. L., Boyce, M. S. and Stenhouse, G. B. 2010. Grizzly bear movements relative to roads: application of step selection functions. – Ecography 33: 1113-1122.

# Supplementary material

# Modelling human use of roads to create an index of traffic volume

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## Purpose

In the foothills of Alberta, roads are used by a variety of industrial and recreational users. Roads are typically constructed for resource extraction, such as timber harvesting or oil and gas extraction, but later are open for use by other groups. As a result, both the type of traffic and traffic volume varies both spatially and temporally. Qualifying these traffic patterns is critical to understanding grizzly bear use and/or avoidance of roads. Unfortunately, traffic data is not available for most roads within the study area; therefore, we developed a method to model human use based on first principles (e.g. roads close to town centers have more traffic than roads far from town centers) to classify roads into low and high traffic volume.

## Methods

A roads layer was obtained from the Foothills Research Inst. in cooperation with West Fraser, a timber company. The layer contained all known roads in the study area as of 2003. Starting in 1999, dates of construction were verified for all roads in the study area using Landsat TM imagery (30 m resolution), taken in September of every year (1999–2003). Roads were dated with the year that they first appeared on the Landsat image, and those in existence before 1999 were classified as "pre 1999." Roads that were not visible due to image resolution were dated using surrounding anthropogenic features, such as new cut blocks or well sites. These data then were used to create yearly road maps. Landsat images were also used to verify the timing and location of timber harvesting between 1999–2003 and to identify the location of new well sites.

In order to estimate the least-cost paths for travel throughout the area, we created an estimate of travel speed for each road segment. Because roads were too numerous to individually identify vehicular travel speed, we used road surface type as a relative index: 110, 90, 80, 65, 50 km $h^{-1}$ for divided highway, paved road, primary gravel road, secondary gravel road, and dirt (non-maintained) roads, respectively. Road surface type was obtained from the original road classification.

We estimated forestry traffic by linking active harvest sites in a given year to the mill servicing that region (Hinton or Edson). The year of harvest was obtained from forestry records and Landsat images (FMF; Hinton, Alberta). Because Landsat images were acquired on a yearly basis, we assumed that industrial traffic occurred throughout the Jan–Dec period. Each forestry harvest unit (cutblock) was represented as a point placed within the harvest polygon. Network analysis (Environmental Systems Research Inst., Redlands, CA) was used to identify least-cost paths from the cutblock to the respective mill site. A value of 1 was assigned to each road segment for each cutblock point accessed by that segment, resulting in road segments with values ranging from 0 to 174. Separate analyses were conducted for the Hinton and Edson mill sites and were then merged to create one index for that given year. These values were then subjectively assigned to classes of traffic intensity: 0 = no traffic, 1–5 = low-moderate traffic, >5 = high traffic (Fig. S1). Discrepancies in known traffic routes were corrected by hand.

Road use by the oil and gas industry was modelled the same as for the forest industry, except, due to the large number of different companies operating throughout the area, the nearest population center was used as the destination site. Active well sites were also represented as points, and each was assigned to Hinton or Edson based on spatial location. As above, we assumed a least-cost path from the well site to the nearest population center and assigned a value of 1 to each road segment for each well site access by it (values ranged from 0 to 665). Road segments were subjectively assigned to traffic volume classes as follows: 0 = no traffic, 1–10 = low–moderate traffic, and >10 = high traffic (Fig. S2).

Recreational use of roads was modelled as a function of human behavior and distribution across the landscape (Apps et al. 2004). Creating separate models for each town (Hinton, Edson, Robb, and Cadomin), we calculated how long it would take to travel from the town center to any point along the road network. Merrill et al. (1999) found that human use of roads decays exponentially as travel time increased, so we applied a decay exponent of –1.45 to our travel times. The values were scaled from 0 to 1, with 1 representing highest use at the town center. These values where then multiplied by the population size of the given town (Hinton = 9405, Edson = 7815, Robb = 183, Cadomin = 64) to estimate the relative road use. Values were then summed across the four population centers. Overall, large town centers tended to overestimate use along secondary roads, particularly when nearing town centers. While we expect this to be the case in the towns themselves, we suspected that this effect would drop off rapidly outside of towns. As a result, we applied a correction factor that retained overall trends but suppressed values on secondary roads. Specifically, values were multiplied by 1, 0.75, 0.50, and 0.25 for paved, primary gravel, secondary gravel, and dirt roads, respectively. A quantile algorithm was used to separate road segments into low, moderate, and high use categories (Fig. S3).

In addition to overall recreational use, campsites were located and modelled the same as well sites using the closest population center as the destination. Because of the configuration of the study area, we assumed campers originated from Hwy 16, which makes

up the northern border of the study area and services both Hinton and Edson. Using the Network analyst we created least-cost paths from each campsite to the population centers, assigning 1 to every road segment for each campsite accessed by it (ranging from 0 to 34). Values were summed across the two population centers to create an index of camper travel. These values were subjectively assigned to traffic volume classes as follows: 0 = no traffic, 1–5 = low–moderate, >5 = high (Fig. S4).

Lastly, we merged all user-group classifications (forestry, oil and gas, recreation, and campsites) into a single road use index representing low and high traffic volume. If any of the four use levels were high, the final model was classified as "high volume". Roads were only classified as "low volume" if forestry was none, oil and gas was none or low/moderate, recreation was low, and there was no traffic from campsites (Fig. S5). All other combinations of moderate volume were classified as "high volume". Separate indices were created for each year to reflect the changing use by the industrial sector and to account for new road development. Thus, the final product accounted for road use by all major sectors of the population. Ultimately, we believe this method is a more accurate means to model changing road use patterns over a large area and is superior to traditional classifications based on road size or surface type.

## References


Apps, C. D. et al. 2004. Estimating grizzly bear distribution and abundance relative to habitat and human influence. – J. Wildl. Manage. 68: 138–152.

Merrill, T. et al. 1999. Defining landscapes suitable for restoration of grizzly bears (*Ursus arctos*) in Idaho. – Biol. Conserv. 87: 231–248.


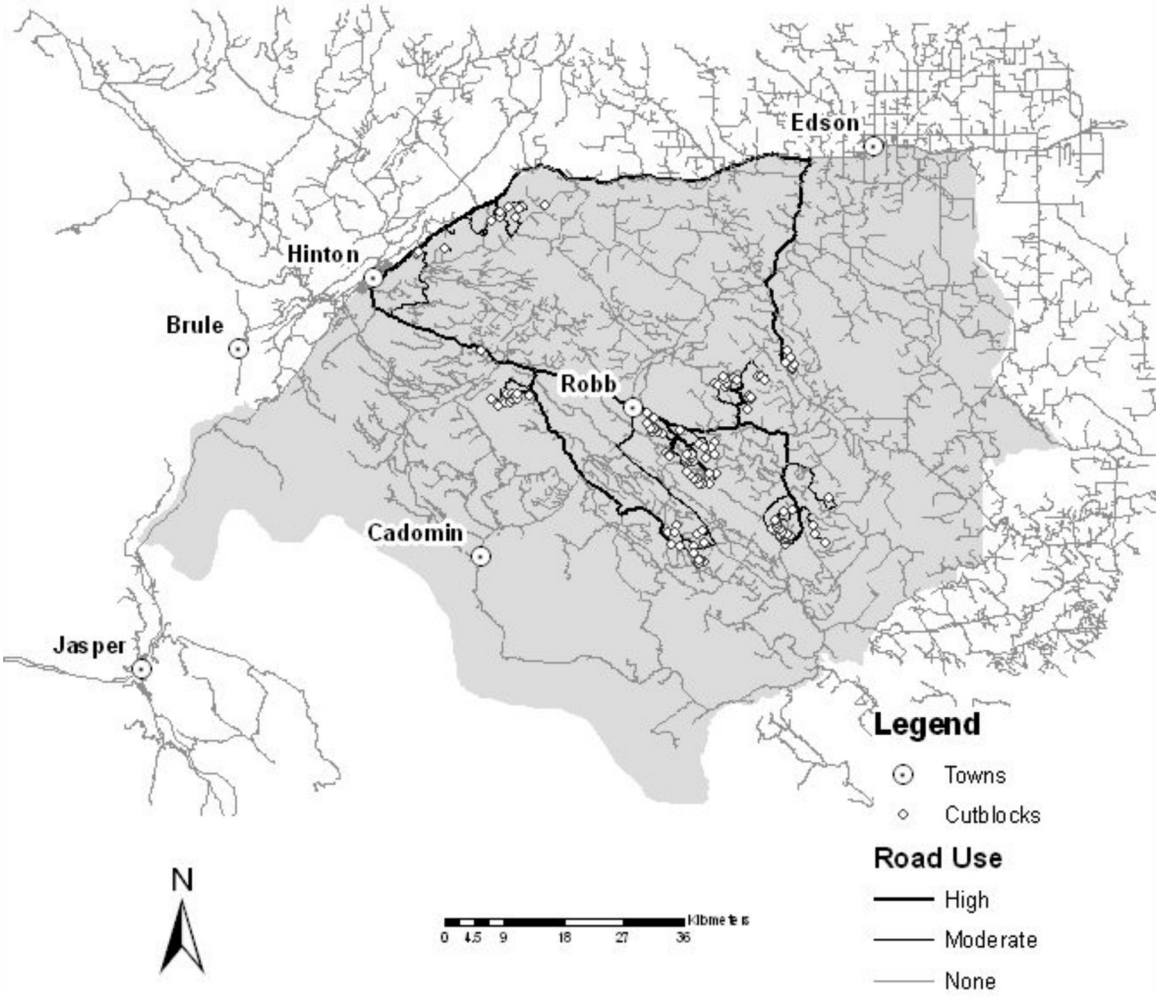


Figure S1. Modelled road usage by forestry industries in 2002 based on least-cost paths from active cutblocks to the processing plants in the towns of Hinton and Edson.

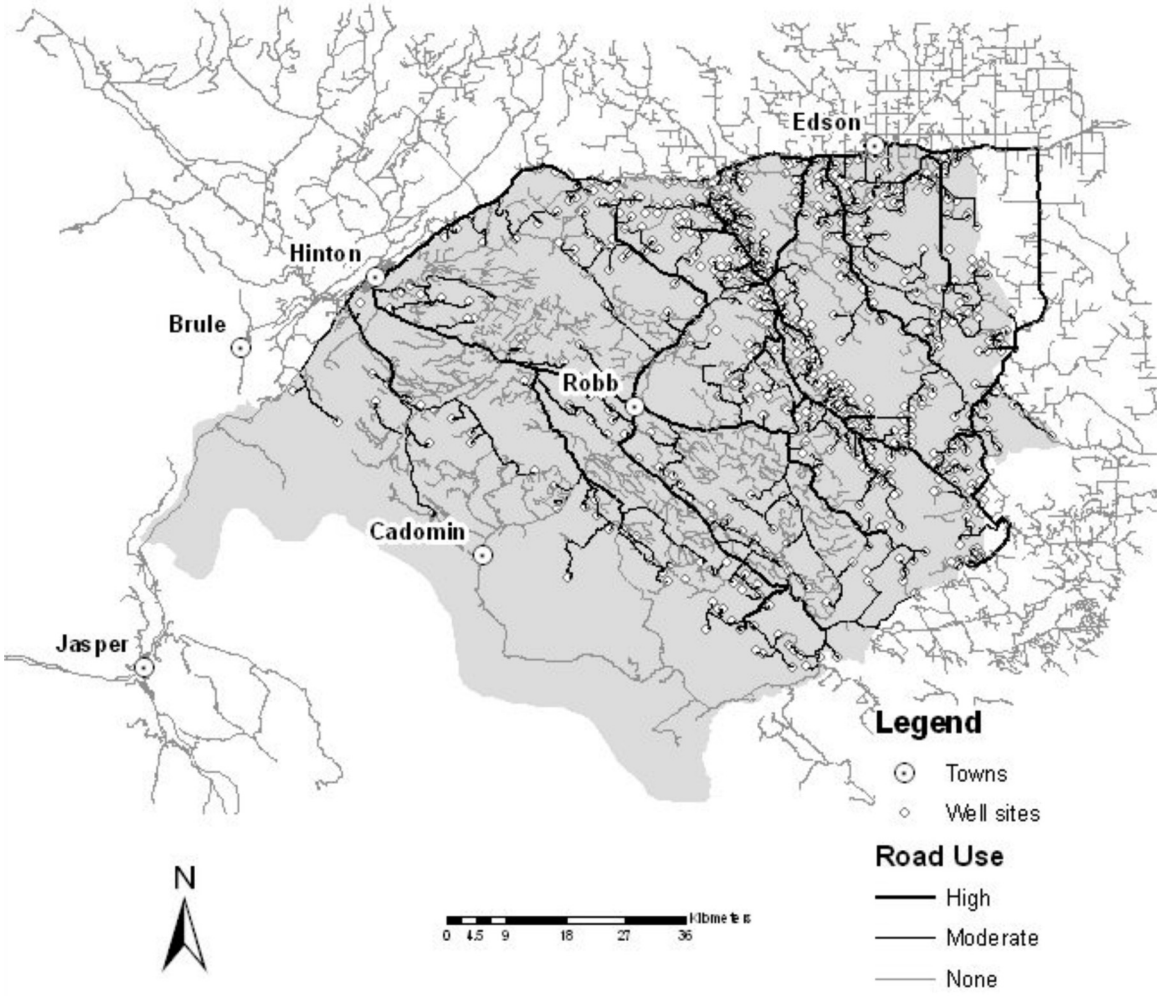


Figure S2. Modelled road usage by the oil and gas industries in 2002 based on least-cost paths from active well sites to the nearest population center (Hinton or Edson).

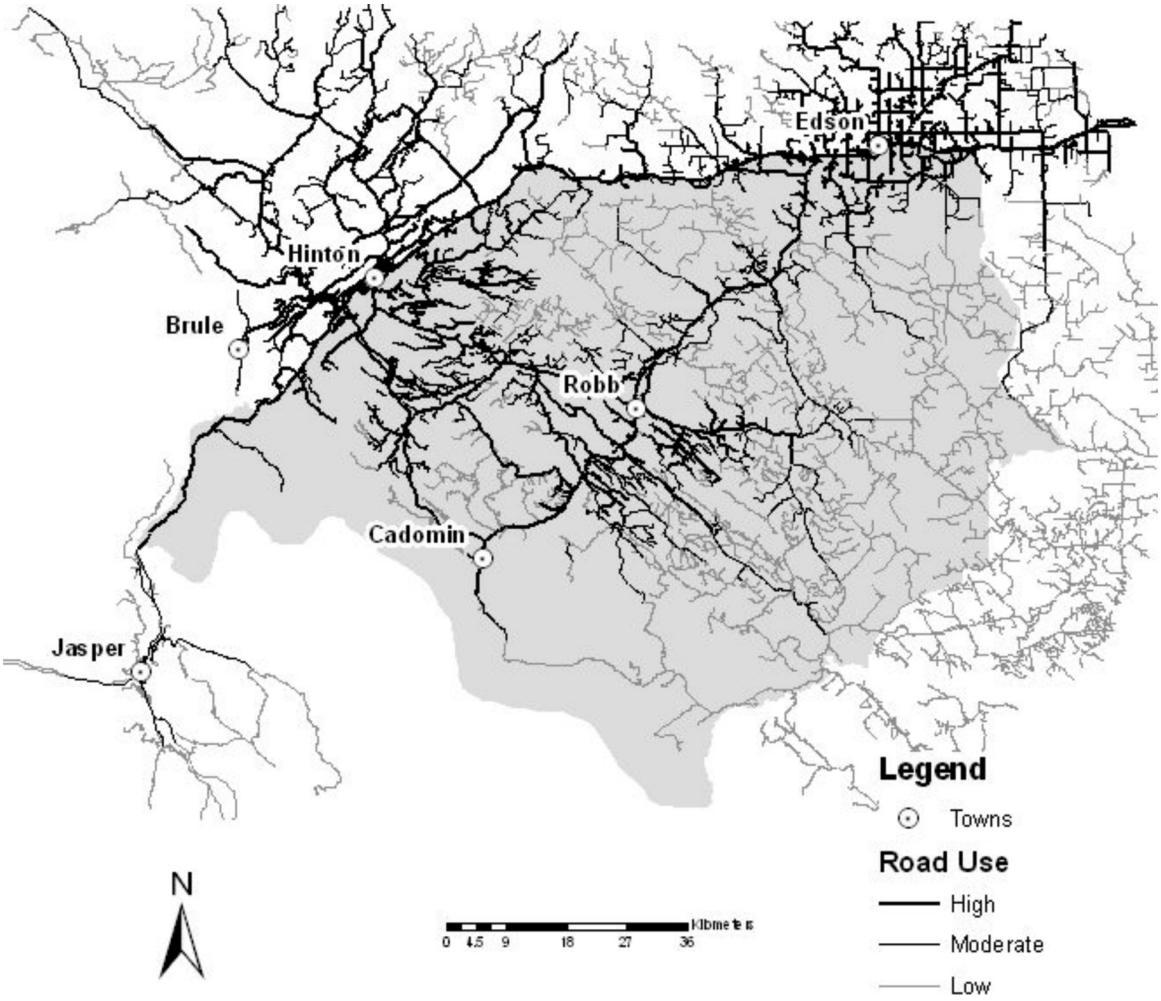


Figure S3. Modelled road usage by recreational users based human demography and behavior. The travel time was calculated for all points along the road network to each population center within the study area (grayed area). A decay exponent of –1.45 was then applied to all travel times. Traffic was scaled based on the population of each town.

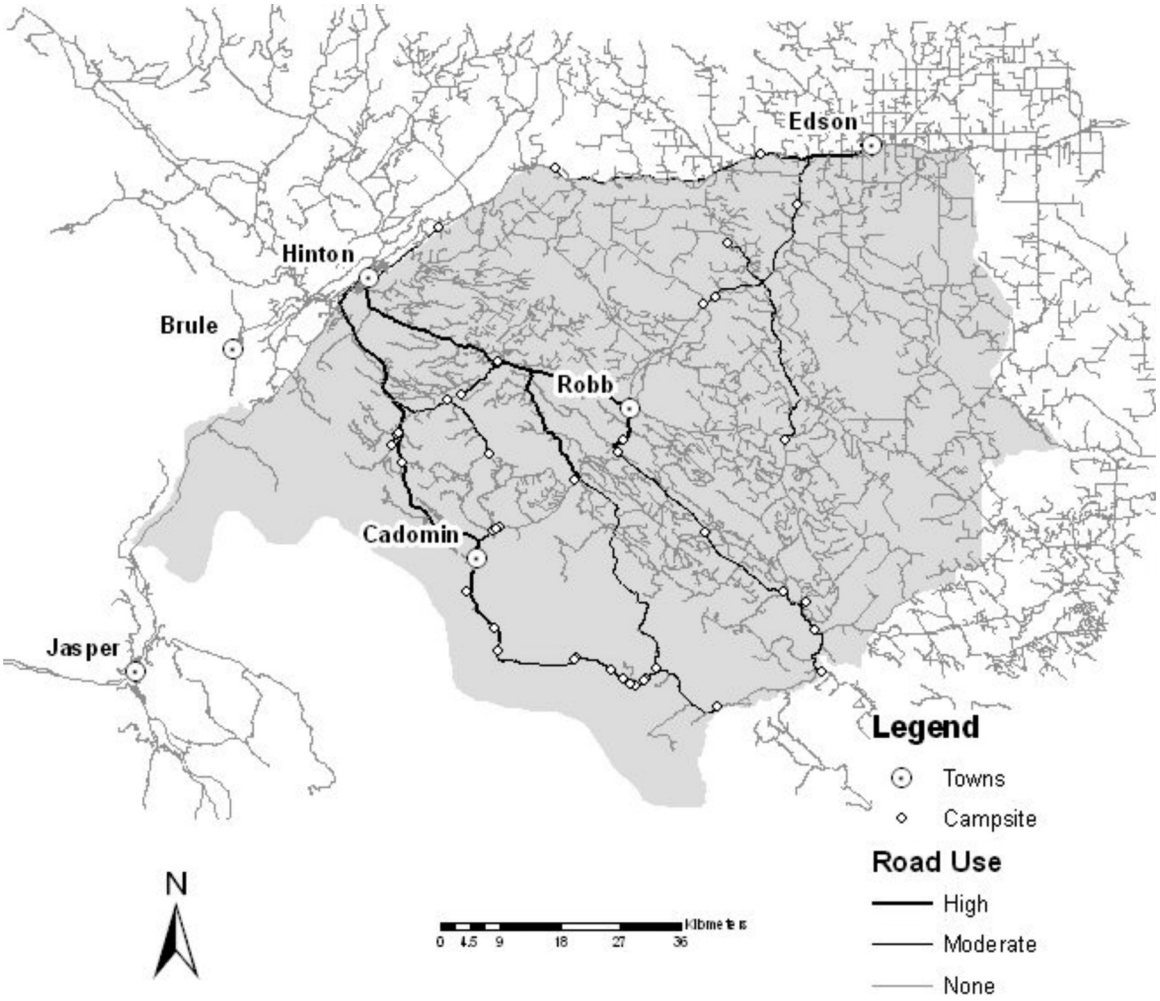


Figure S4. Modelled road usage by campers based on least-cost paths from campsites to the nearest population center.

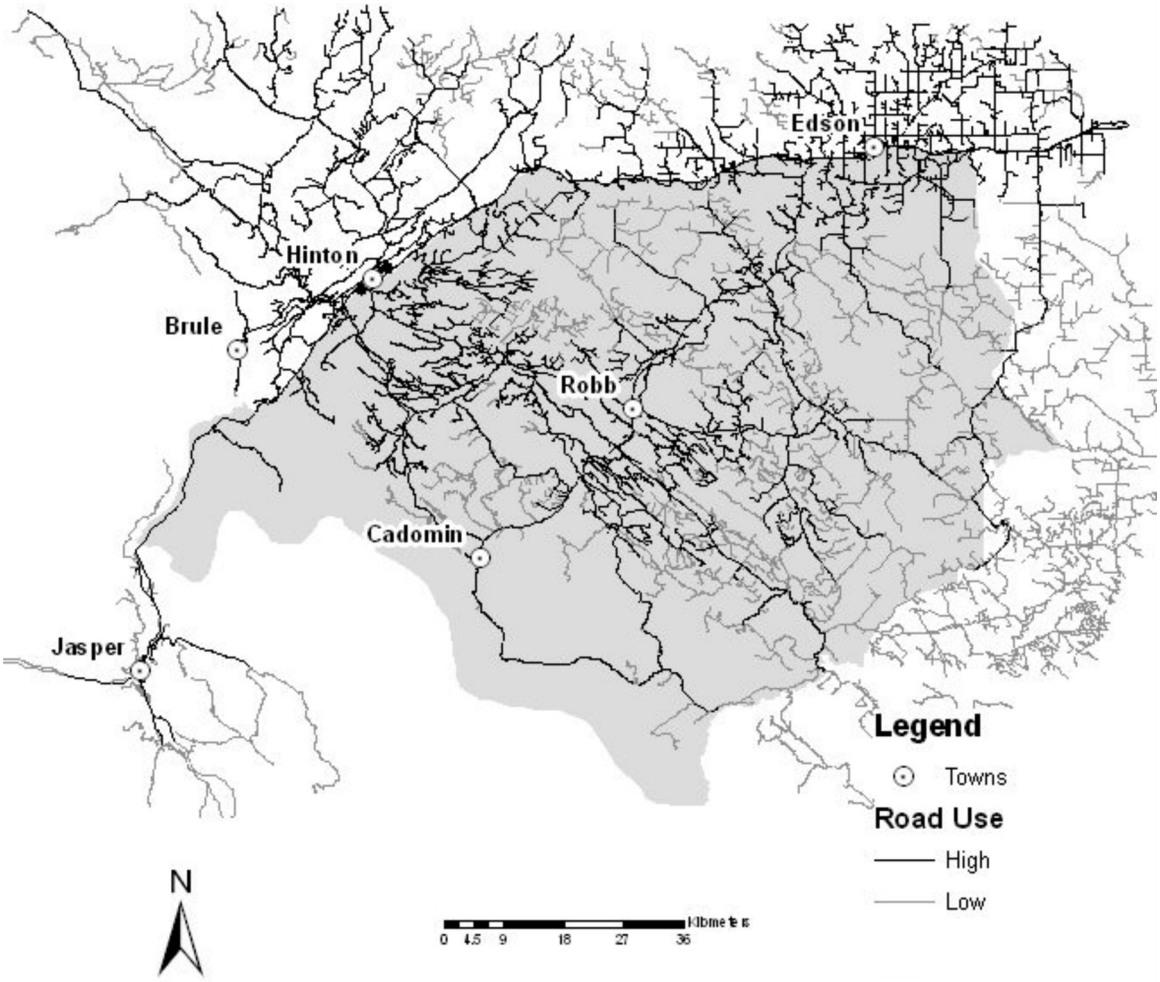


Figure S5. The final road usage model created by combining modelled human use by forestry, oil and gas, recreational users, and campers.