

Appendix A.10

Habitat connectivity for Beaver (*Castor canadensis*) in the Columbia Plateau Ecoregion

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Introduction

The *Washington Connected Landscapes Project: Statewide Analysis* (WHCWG 2010) modeled connectivity for 16 focal species within Washington. This analysis incorporated data layers such as land cover/land use, elevation, slope, housing density, and roads at a 100-meter scale of resolution. Because of the generality of the layers and the relatively coarse scale of the statewide analysis, the approach was refined for a connectivity assessment of the Columbia Plateau Ecoregion, a part of the state with an extensive human footprint and many species that are declining in both distribution and abundance.



*Beaver, photo by
Ginger Holser*

The arid Columbia Plateau Ecoregion of eastern Washington is predominantly comprised of shrubsteppe vegetation. A vitally important feature within this landscape is water in the form of streams, rivers, wetlands, and lakes. The trees, shrubs, and grasses that thrive in the moist soils bordering these wet areas are collectively referred to as riparian vegetation. Riparian habitats form “oases” in the dry Columbia Plateau landscape and play a key role in providing resources for a diverse array of fish and wildlife species. The beaver (*Castor canadensis*) is inextricably linked to these habitats.

This report describes components of beaver biology that are relevant to an ecoregional analysis of habitat connectivity. We used additional data layers, better defined habitat variables, and a finer scale of resolution to examine connectivity issues for 11 focal species, including beaver. We intend this ecoregional scale analysis of habitat connectivity for the beaver to inform conservation and management of this species, and other similar species, on the Columbia Plateau.

Justification for Selection

The beaver was chosen as a focal species because it was considered to be a good representative of riparian and wetland habitats. Beaver demonstrate considerable adaptability and can thrive in rivers and streams in a mountainous forested setting, as well as rivers and streams that run through the dry shrubsteppe environment. The common habitat feature that beaver need is water, and the vegetation closely associated with water that provides their food supply. Additionally, it

was felt that adequate research existed on the beaver to have an understanding of their movement capability, behavior, and dispersal distances.

Beaver are often referred to as a “keystone species” and are considered “ecosystem engineers” (see review by Baker & Hill 2003). A keystone species is one that plays a critical role in maintaining the structure of an ecological community and whose impact on the community is greater than would be expected based on its relative abundance or total biomass (Paine 1969; Mills et al. 1993). Physical ecosystem engineers, “directly or indirectly control the availability of resources to other organisms by causing state changes in biotic or abiotic materials” (Jones et al. 1997). Beaver dam building, canal building, and foraging activities can dramatically affect ecosystem structure and function by altering both physical (stream morphology, hydrology, and chemistry) and biological attributes (Naiman et al. 1988; Wright et al. 2002; Rosell et al. 2005; Cunningham et al. 2006; Anderson & Rosemond 2010; Fuller & Peckarsky 2011; Cramer 2012). For example, dam building increases the bed elevation of a stream channel and elevates the water table locally, traps sediment and organic material, creates wetlands, and modifies the structure and dynamics of the riparian zone (Naiman et al. 1988). The spatial and temporal dynamics of beaver activities can broadly benefit other riparian dependant wildlife increasing species richness at the landscape scale (Wright et al. 2002; see Baker & Hill 2003). The impact of beavers and their role as ecosystem engineers may be amplified in semi-arid regions (McKinstry et al. 2001; Cooke & Zack 2008). For instance, streams that seasonally run dry may become perennial under the influence of beaver and beaver dam complexes (Buckley et al. 2011).

Prolonged absence of beaver from an area can reduce the quality or suitability of a riparian zone for species that depend on these areas for some aspect of their life history. This absence may have long-term impacts as riparian habitats are recognized as potential travel corridors for wildlife, facilitating dispersal and gene flow among populations, and allowing potential range shifts of species in a changing climate (Knutson & Naef 1997).

Approximately 85% of Washington’s wildlife species use riparian habitat associated with rivers and streams at some point in their life history. Additionally, 57% of neotropical migrants reported in the state are supported by riparian habitat (Knutson & Naef 1997). More than 90% of original riparian habitat along the Columbia River has been lost to hydro-energy development and agriculture. Additionally, the vegetation in many riparian areas in eastern Washington has been altered and suppressed by decades of overgrazing (Knutson & Naef 1997). Increasingly, beaver are receiving recognition as a beneficial species useful for restoring degraded riparian habitat, and establishing a natural disturbance regime in stream and riparian ecosystems (McKinstry et al. 2001; Pollock et al. 2007; Beechie et al. 2008; Demmer & Beschta 2008; Cramer 2012). For example, Beechie et al. 2008 concluded that the recovery time to reconnect incised channels to their historical floodplain for the Walla Walla and Tucannon River basins ranges from 60 to 275 years; beaver activities may decrease these recovery times by 17–33%.

Beaver scored Excellent for four of the five criteria used to evaluate focal species for the Columbia Plateau Ecoregion. Beavers were considered sensitive to threats from development, roads and traffic, and people/domestic animals. Threats to beaver are evident in developed settings and in locations where people have placed their homes, outbuildings, or other infrastructure in close proximity to rivers and streams. Instead of the biological carrying capacity of the landscape, it is often the social carrying capacity, i.e., people’s tolerance of beaver that

influences where beavers can exist or persist. Conflicts with beaver occur when beaver dam building and foraging activities flood or damage property (Jonker et al. 2006; Baker & Hill 2003). In many cases “nuisance” beaver are removed regardless of whether the threat to property is real or perceived. In agricultural areas where irrigation ditches or canals deliver water to crops, or where streams border agricultural fields, dam building is generally not tolerated. If beaver activity interferes with irrigation, or crops are flooded or threatened by water, beaver and their dams are typically removed.

The beaver has no listing status as a state or federal Threatened, Endangered, Candidate or Sensitive species. NatureServe (2012) ranks beaver G5 indicating that populations are considered globally secure. Beaver are not a hunted species in Washington State but are classed as a fur bearer and can be legally trapped statewide. The market and price for beaver pelts varies and a strong fur market results in increased trapping effort. Game harvest reports for the Washington Department of Fish and Wildlife (<http://wdfw.wa.gov/hunting/harvest>) indicate that the annual statewide trapping harvest of beaver averaged 1536 individuals (range 642–2626) between 2000 and 2009. In addition to fur trapping, beaver are also frequently removed from an area when their feeding behavior or dam building activities conflict with landowner needs or preferences. Although beaver have no listing status in Washington State, riparian habitat is considered a Priority habitat (Knutson & Naef 1997).

Distribution

“The North American beaver occurs from coast to coast and ranges from Alaska, Hudson Bay, and northern Labrador in the North to the U.S.–Mexico border, Gulf Coast, and Florida state line in the South” (Müller-Schwarze & Sun 2003). Beaver populations have been established outside of North America including Argentina and Finland (Baker & Hill 2003; Hyvönen & Nummi 2008). The historical population of beaver in North America prior to European settlement is estimated at more than 60 million individuals. Demand for beaver fur during the 1700s and 1800s resulted in indiscriminate and extensive trapping of beaver. Consequently, by 1900 they were largely extirpated across much of their range. Implementation of harvest regulations, and successful reintroduction of beaver to former range, eventually led to recovery of populations. However, beginning in the 1780s the lower 48 states lost an estimated 53% of their original wetlands, “on average, the lower 48 states have lost over 60 acres of wetlands for every hour between the 1780s and the 1980s” (Dahl 1990). Many of these wetlands likely supported populations of beaver (Naiman et al. 1988). The current distribution of beaver reflects both natural re-colonization and reintroduction efforts. In 1988 beaver were estimated to number between 6 and 12 million individuals in the US (Naiman et al. 1988).

Beaver occur in the Columbia Plateau Ecoregion in aquatic habitats with perennial water flow, a moderate gradient, and access to riparian vegetation. Areas that are not suitable for colonization can function as travel corridors for beavers to access suitable locations. When compared to other areas of the state the Columbia Plateau has relatively little core habitat for beaver (<http://wdw.wa.gov/conservation/gap/gapdata>). Within our project area and buffer approximately 3% of the land cover is classed as either riparian, herbaceous wetland, introduced riparian or wetlands vegetation, or water.

Beavers live in family units (colonies) of four to eight individuals and defend a common territory of connected pools. Family units typically consist of the breeding pair of adults and their offspring from the current and previous years (Jenkins & Busher 1979; Sun et al. 2000). The distribution of beaver colonies is somewhat discontinuous or patchy and may be influenced by both extrinsic (e.g., habitat alteration and trapping) and intrinsic factors (e.g., territorial behavior). Colony densities reported in the literature range from near zero to 4.6/km² (Baker & Hill 2003). In a study of an unexploited beaver population in southern Illinois the colony density was 3.3/km² (Bloomquist & Nielsen 2010). In this Illinois study, the habitat consisted of broad, non-linear wetlands. Colony dispersion patterns may be influenced by the history of beaver removal through trapping or relocation of nuisance individuals. Re-colonization or re-occupancy and eventual establishment of beaver colonies may not happen rapidly and uniformly. For example in Wyoming, beaver are still absent from 24% of first- to fifth-order streams where they were believed to be once abundant (McKinstry et al. 2001).

Habitat changes may account for observed distribution patterns of beaver. Historically, many streams in the Columbia Plateau were characterized by narrow, deep, and gently meandering channels lined with riparian vegetation (Victor 1935; Pollock et al. 2007). Today many of these streams are incised and contain little or no riparian vegetation or beaver dams (Pollock et al. 2007). Stream reaches that have become deeply incised over time lose beaver dams during high water events. These high flows are confined within these deep narrow channels. The stream energy cannot dissipate on a floodplain and beaver dams wash out. Deeply incised stream reaches are less able to support riparian vegetation because the water table is lower than the rooting depth of the plants, and the steep stream banks may prevent beaver from accessing vegetation on the perched floodplain. Additionally, floodplains in the Columbia Plateau have been drained or altered by drainage ditches, subsurface drain tiles, tree and shrub removal, and straightening of the natural watercourse. Many former streams are now drainage ditches where vegetation has been removed and tillage occurs to the water edge (Stinson & Schroeder 2010). Such land use practices reduce available habitat for beaver.

Habitat Associations

Independent of the type of vegetation present on the landscape, the proximity of that vegetation to water is the overriding issue for beaver. For example, a stand of aspen (*Populus* spp.) trees near a ridgetop would not be considered good beaver habitat. That same stand of aspen trees bordering a low-gradient stream in a valley bottom would be considered excellent beaver habitat. In the Columbia Plateau beaver are not found in areas that lack water.

General

Beaver exhibit surprising plasticity in the types of water bodies and vegetation where they can live. This plasticity has allowed beaver to occupy a wide range of mesic habitats including tundra, boreal forest, peatlands, riparian habitat in hot and cold deserts, hardwood forests, bottomlands, and marshes (Baker & Hill 2003). Beaver can successfully occupy streams bordered predominately by grasses and cattails in prairie regions on the great plains of North America. In contrast, a black cottonwood (*P. balsamifera trichocarpa*) gallery forest with an understory of coyote willow (*Salix exigua*), red-osier dogwood (*Cornus stolonifera*), and wild rose (*Rosa* spp.) growing on the floodplain of a large river can support beaver.

In a boreal forest ecosystem Barnes and Mallik (1997) found the most significant habitat determinants for the location of beaver dams were upstream watershed area and streamside vegetation structure. Beier and Barrett (1987) modeled factors important for habitat use by beaver in the Truckee River Basin in Oregon. Stream gradient, depth, and width were the most important factors while variables reflecting food abundance were less important. Beaver use-sites in the Oregon Coast Range were characterized by wide valley floors, narrow low-gradient streams, high grass/sedge cover, and low red alder (*Abus rubra*) and shrub cover (Suzuki & McComb 1998).

Beaver construct lodges using sticks, branches, and mud. They will also build and use bank burrows. Both types of structures have underwater entrances. The lodge and the bank burrow offer protection from predators and cold winter conditions, provide a location to feed, and a place to give birth to young. Dams are constructed to impound water thereby increasing water depth which allows for an underwater entrance to the lodge or bank burrow. The deeper water created by dams also allows beaver to sink branches and cache food in the pond for later use. When the temperature extremes in winter freeze the surface of the water and conditions for overland travel are unfavorable, the branches and limbs in the deeper water in the vicinity of the burrow or lodge are accessible for consumption (Müller-Schwarze & Sun 2003).

Vegetation near the stream is utilized for food and dam building. Beaver are considered central place foragers. They work out from the water's edge to collect food and construction materials and bring them back to a central place such as their lodge. Foraging distances up to 200 m from water have been observed (Müller-Schwarze & Schulte 1999).

Winter

Because of the harsh conditions presented by freezing temperatures and waters in the northern parts of their range, it is important that food be accessible in winter. Beaver will create a food cache during the growing season by sinking tree limbs and branches into the bottom of ponds they create with their dams. During winter they survive, sometimes under ice, living off these stores of food as well as eating aquatic vegetation such as pond lilies (*Nymphaea* and *Nuphar* spp.; Baker & Hill 2003; Milligan & Humphries 2010).

Agriculture

Agriculture, particularly irrigated agriculture, is a widespread and economically significant land-use in the Columbia Plateau. In many locations areas that were historically floodplains have been converted to agriculture. It is not unusual in agricultural areas to see streams that have been straightened and realigned along the margins of fields. This is a legacy of practices to configure channels to facilitate farming where a meandering stream that bisected a field was an obstacle to efficient farming and access. Streams in an agricultural setting often lack riparian vegetation or are minimally bordered by riparian vegetation. In some areas of the Columbia Plateau the introduction of irrigated land-use practices has created habitat for beaver. However, the potential for conflict with people is high in these areas. Beaver activity that interferes with delivery of water for irrigation or cause flooding of water onto fields and crops generally results in the removal of the dams and the beaver.

Sensitivity to Roads and Traffic

Beaver do not appear to avoid roads or be particularly sensitive to traffic noise. Beaver dams and signs of their activity, such as chewed or fallen trees, are often visible from and occur along roads. Roads bisect or often parallel streams and floodplains. The fill material and armoring that comprise a road represents lost floodplain, stream, riparian, and wetland habitat for beaver. Mortality from vehicle collisions associated with road traffic may be reduced by bridges and culverts since beaver can remain in a stream and pass through a road prism without having to cross the running surface. However, if dam building activities obstruct or plug culverts, or small bridges, and they have to travel across the road to move downstream, beaver are at risk of being hit by a vehicle. In addition to habitat loss and mortality there is the potential for conflict if beaver activities threaten or damage a road (Curtis & Jensen 2004). In these cases the dam building material is removed by highway maintenance crews and the beaver are often removed as well.

Sensitivity to Development

In towns and cities with streams running through them, a beaver establishing a dam, dropping trees, and impounding streams will almost always result in the removal of the beaver. As mentioned earlier, there is a social carrying capacity for beaver in a developed setting and it is likely that these areas are a population sink. It is common practice in dealing with beaver that are viewed as causing problems to either lethally remove them with traps, or capture them live and transport them to a wildlife area or to the forest zone and release them into streams at a new location. Monitoring of radio-marked beaver suggests that relocated individuals are often subject to predation (McKinstry & Anderson 2002). Without the benefit of a lodge, beaver may be vulnerable to predation by coyote (*Canis latrans*), bear (*Ursus* sp.), and mountain lion (*Puma concolor*).

Recently, the United States Forest Service (USFS) and Washington Department of Fish and Wildlife (WDFW) have partnered with other groups to initiate programs to relocate entire family groups instead of individual beaver (<http://www.rco.wa.gov/prism/ProjectSnapshot>; <http://www.pacificbio.org/initiatives/beaver>). This technique involves capturing family groups over a period of several days. The beaver are held during this time in an unused fish hatchery raceway and fed freshly cut aspen, cottonwood, and willow branches. The raceway is partially filled with water and a cinder block and plywood “lodge” is provided. When all the beaver have been captured, the whole group is transported to a new location where a rudimentary dam and lodge have been previously constructed. The branches that the beaver have been feeding on, as well as fresh branches, are piled by the lodge and at the water’s edge. The beaver are placed in the lodge and the entrance is kept closed till evening. Their departure from the lodge is volitional. Because beaver are crepuscular and nocturnal they are introduced to the new location in the evening when they are thought to be less vulnerable to predation.

Sensitivity to Energy Development

WIND ENERGY DEVELOPMENT

Wind energy facilities are generally sited on ridge tops and not in valley bottoms where streams are located. Unless roads are constructed across streams or trenching for underground installation of electrical cables cross streams, few conflicts are anticipated outside of the normal impacts associated with construction and maintenance.

TRANSMISSION LINES

Similar to wind energy development, few conflicts with beaver are inherent with transmission line corridors. Conflicts may occur if transmission lines cross rivers, streams, and wetlands and beaver activity floods the footings of a transmission tower and threatens the structural integrity of the tower. In these cases beaver are removed. Periodically, trees are topped or removed within transmission corridors to address concerns with repair, maintenance, access, and the potential for electricity to arc from lines to trees that have grown too close to the lines. This can degrade or remove habitat for beaver. Trees in riparian zones that have the potential to fall on wooden power poles and/or the lines they support are removed or topped.

Sensitivity to Climate Change

For sagebrush habitats global climate-change models predict more variable and severe weather events, higher temperatures, drier summer soil conditions, and wetter winter seasons (Miller et al. 2011). In the Pacific Northwest greater seasonal and inter-annual variation in precipitation is expected with wetter fall/winter seasons and drier summers (Cramer 2012). Beaver dams spread water out across a floodplain during spring runoff and impound water year-round. Actions that may help minimize the impacts of drought on wetland function and water availability. For instance, beaver activity tends to make streams and floodplains more moisture retentive which benefits riparian vegetation. Beaver activities have been suggested as potentially mitigating the effect of increasing climatic temperatures for some amphibian species (Popescu & Gibbs 2009). Hood and Bayley (2008) examined climatic variables and how beaver presence affected the area of open water in a mixed-wood boreal region of Canada. Between 1948 and 2002, during both wet and dry years, the presence of beaver was associated with a 9-fold increase in open water area suggesting that beaver can dramatically influence the creation and maintenance of wetlands even during drought years.

Dispersal

We used natural dispersal movements (Table A.10.1) not movements of individuals following translocation in our model as beaver often move considerable distances after release to a new location. Translocations place beaver in an unfamiliar setting and they may be exploring the habitat or seeking familiar territory or members of their home colony.

Table A.10.1. Dispersal distances of North American beaver (table reproduced from Müller-Schwarze & Sun 2003).

Geographical Regions	Dispersal Distance	
	Mean	Maximum
New York	A: Males—3.5 km (2.2) Females—10.2 km (6.3)	A: 31.7 km (19.7; a female)
Idaho	A: 8.5 km (5.3) Males—8.3 km (5.2) Females—10.9 km (6.8)	A: 18.1 km (11.3; a male)
Minnesota	A: 17.1 km (10.7) S: 29.9 km (18.7)	A: 49.6 km (31) S: 81.6 km (51)

Note: A, by air (straight line); S, along stream. Values in miles are given in parentheses.

Conceptual Basis for Columbia Plateau Model Development

Overview

Perennial streams with a low gradient, rivers, lakes, ponds, wetlands, and reservoirs were considered to be features that offered little resistance for beaver movement (Table A.10.2). We had no information as to whether major hydroelectric dams were barriers to movement, impediments that could be negotiated, or not an issue for beaver. It was difficult to generalize an effect of hydroelectric dams since design, and site terrain are variable across our project area. Beaver exist in waterways above and below dams and there is anecdotal evidence of individuals traversing atypical habitats, e.g., the elementary school parking lot in the city of Bridgeport immediately below Chief Joseph Dam (L. Robb, personal communication). It is possible that beavers incur a movement cost when negotiating large hydroelectric dams. However, because of lack of information regarding the effect of dams on beaver movement we did not consider these features in our model although we acknowledge that they may have an effect.

The proximity of vegetation to water was the primary consideration when assessing habitat value of land-cover classes; habitat value decreases with increasing distance from water. Beaver can and do venture overland but this behavior appears to be to access sources of food or feeding areas and these areas are strongly associated with water. “Beaver are awkward and slow on land, exposing themselves to predators such as wolves, bears and coyotes. Hence, beavers minimize their time on land and stay close to water” (Müller-Schwarze & Sun 2003). Steep or inhospitable landscape features such as cliffs, talus, dune, and high-gradient stream reaches were considered poor beaver habitat. Land cover/ land use classes assigned high resistance included Dunes, Scabland, and the Cliffs Rocks Barren category. Elevation and housing density were considered to have minimal impact on movement and habitat value for beaver except when elevation was greater than 2500 m and housing density was less than 10 acres/dwelling unit. Slope was considered to influence beaver movement capability and habitat value when it exceeded 20 degrees. Energy development was not considered to impede movement capability for beaver.

Irrigation infrastructure included lined canals, unlined ditches, modified streams, and natural streams that serve to deliver water to fields and crops. A confounding element with irrigation is seasonality as irrigation does not necessarily occur year-round. Additionally, watering livestock from irrigation infrastructure can occur outside of the growing season. Some irrigation infrastructure is associated with streams and is in floodplain areas and involves natural, semi-natural, or entirely man-made water conveyance features. Other irrigation systems are not associated with or in proximity to stream features. For the purposes of this study, irrigation features are considered collectively and were assigned low resistance as beaver can select these areas to move through and as pathways for dispersal. However, these areas may not be good habitat for a beaver to colonize and thus were assigned a relatively low habitat value (0.5).

Table A.10.2. Landscape features and resistance values used to model habitat connectivity for beaver.

<i>Spatial data layers and included factors</i>	<i>Resistance value</i>	<i>Habitat value</i>
Landcover/Landuse		
Grassland_Basin	5	0.3
Grassland_Mountain	5	0.3
Shrubsteppe	5	0.3
Dunes	165	0.1
Shrubland_Basin	5	0.3
Shrubland_Mountain	5	0.3
Scabland	165	0.1
Introduced upland vegetation_Annual grassland	5	0.1
Cliffs_Rocks_Barren	165	0.1
Meadow	5	0.3
Herbaceous wetland	0	1.0
Riparian	0	1.0
Introduced riparian and wetland vegetation	0	1.0
Water	0	1.0
Aspen	5	0.7
Woodland	5	0.5
Forest	5	0.5
Disturbed	5	0.2
Cultivated cropland from RegapNLCD	5	0.3
Pasture Hay from CDL	5	0.3
Non-irrigated cropland from CDL	5	0.3
Irrigated cropland from CDL	5	0.4
Highly structured agriculture from CDL	5	0.3
Irrigated/Not Irrigated/Cultivated Crop Ag Buffer 0 – 250m from native habitat	5	0.3
Irrigated/Not Irrigated/Cultivated Crop Ag Buffer 250 – 500m from native habitat	5	0.3
Pasture Hay Ag Buffer 0 – 250m from native habitat	5	0.3
Pasture Hay Ag Buffer 250 – 500m from native habitat	5	0.3
Elevation (meters)		
0 – 250m	0	1.0
250 – 500m	0	1.0
500 – 750m	0	1.0
750 – 1000m	0	1.0
1000 – 1250m	0	1.0
1250 – 1500m	0	1.0
1500 – 2000m	0	1.0
2000 – 2500m	0	1.0
2500 – 3300m	165	0.1
Slope (degrees)		
Gentle slope Less than or equal 20 deg	0	1.0
Moderate slope Greater than 20 less than equal to 40 deg	82	0.2
Steep slope Greater than 40 deg	165	0.1
Landform		
Drainage	0	1.0
U-shaped valley	0	1.0
Plain (or surface water)	0	1.0
Midslope	0	0.2
Ridge or mountain top	165	0.0
Housing Density Census 2000		
Greater than 80 ac per dwelling unit	0	1.0
Greater than 40 and less than or equal 80 ac per dwelling unit	0	1.0
Greater than 20 and less than or equal 40 ac per dwelling unit	0	1.0
Greater than 10 and less than or equal 20 ac per dwelling unit	0	1.0
Less than or equal 10 ac per dwelling unit	9	0.6

<i>Spatial data layers and included factors</i>	<i>Resistance value</i>	<i>Habitat value</i>
Roads		
Freeway Centerline	9	0.3
Freeway Inner buffer 0 – 500m	0	1.0
Freeway Outer buffer 500 – 1000m	0	1.0
Major Highway Centerline	5	0.3
Major Highway Inner buffer 0 – 500m	0	1.0
Major Highway Outer buffer 500 – 1000m	0	1.0
Secondary Highway Centerline	5	0.4
Secondary Highway Inner buffer 0 – 500m	0	1.0
Secondary Highway Outer buffer 500 – 1000m	0	1.0
Local Roads Centerline	5	0.4
Local Roads Inner buffer 0 – 500m	0	1.0
Local Roads Outer buffer 500 – 1000m	0	1.0
Transmission Lines		
Less Than 230KV One Line Centerline	0	0.4
Less Than 230KV One Line Inner buffer 0– 500m	0	1.0
Less Than 230KV One Line Outer buffer 500 – 1000m	0	1.0
Less Than 230KV Two or More Lines Centerline	0	0.4
Less Than 230KV Two or More Lines Inner buffer 0 – 500m	0	1.0
Less Than 230KV Two or More Lines Outer buffer 500 – 1000m	0	1.0
Greater Than or Equal 230KV One Line Centerline	0	0.4
Greater Than or Equal 230KV One Line Inner buffer 0 – 500m	0	1.0
Greater Than or Equal 230KV One Line Outer buffer 500 – 1000m	0	1.0
Greater Than or Equal 230KV Two Lines Centerline	0	0.4
Greater Than or Equal 230KV Two Lines Inner buffer 0 – 500m	0	1.0
Greater Than or Equal 230KV Two Lines Outer buffer 500 – 1000m	0	1.0
Wind Turbine		
Wind turbine point buffer 45m radius	0	0.5
Buffer zone beyond point buffer 0 – 500m	0	1.0
Buffer zone beyond point buffer 500 – 1000m	0	1.0
Irrigation Infrastructure	0	
Irrigation canals	2	0.5

Movement Distance

Dispersal distances (straight line) reported in the literature show considerable variability (Table A.10.1) but typically average less than 20 km. Movements reported for beaver translocated to new locations indicate that they are physically capable of moving considerably further. For example, Hibbard (1958) recorded a translocated adult beaver in South Dakota moving 148 stream miles (67 straight line miles) from the release site (238 and 108 km respectively). This beaver was released in May and was trapped in December of the same year, “In order to reach this spot by water, the beaver would have had to navigate three drainages, the Red River and the two tributaries mentioned above...” (Hibbard 1958). Because we were interested in connectivity opportunities for beaver across the Columbia Plateau Ecoregion we wanted to be inclusive when selecting a movement distance for the model. Therefore, we used 60 km as the maximum Euclidean distance between habitat concentration areas (HCAs) for which to model habitat linkages. This value exceeded maximum “natural” dispersal distances (Table A.10.1) but still fell within the range of movement capability of beaver.

Habitat Concentration Areas

The distribution of beaver throughout the study area has not been well surveyed, so we relied on modeling beaver habitat to identify habitat concentration areas (HCAs). We defined beaver habitat according to the parameters in Table A.10.2. Input layers included land cover, elevation, slope, landform, housing density, all road types, railroads, transmission lines, wind turbines, and irrigation infrastructure. In addition, small low-gradient perennial streams are a primary aquatic habitat for beaver but were not adequately reflected in the above data layers. We therefore assigned cells in the beaver habitat model a value of 1.0 if they coincided with perennial streams defined by the National Hydrography Dataset (NHD; see Appendix D), had a slope between zero and six degrees (Suzuki & McComb 1998), and were otherwise ideal habitat in all layers aside from land cover. Similarly, we altered cells meeting the same criteria in the beaver resistance model to have a value of zero.

We modeled beaver HCAs based on a threshold minimum average habitat value of 0.25 within a 4000 m radius moving window. This identified portions of the landscape where suitable aquatic habitat comprised at least 25% of the home range. We then converted the beaver habitat model (modified by inclusion of low-gradient perennial streams) into a binary model based on a threshold of 0.75, and expanded the binary model outwards 4000 m in cost-weighted distance to merge the aquatic habitat cells together if they were within a home range movement distance. Finally, we eliminated cells from the merged patches if the patch area was less than 25 km². Patches that met all of these criteria served as the beaver HCAs.

Resistance and Habitat Values for Landscape Features

We assigned resistance and/or habitat values to parameters associated with the following GIS data layers (Table A.10.2) to model habitat connectivity for beaver.

- 1) Land cover/Land use
- 2) Elevation
- 3) Slope
- 4) Landform
- 5) Housing Density
- 6) Roads
- 7) Transmission Lines
- 8) Wind Turbine
- 9) Irrigation Infrastructure

Modeling Results

Resistance Modeling

The resistance surface for beaver in the Columbia Plateau (Fig. A.10.1) shows a landscape that is largely resistant to movement except for areas in close proximity to water and wetlands. Noticeable areas of low resistance include rivers and lakes (e.g., the Columbia, Snake, and Palouse rivers, Banks Lake, and Potholes Reservoir). Stretches of the larger rivers are bounded

by high resistance habitat, e.g., the Columbia River north of Wenatchee, the Okanogan River, and the Snake River. Tributaries and small streams also have low resistance to movement for beaver in the Columbia Plateau but these features are more difficult to discern. For example, the area near Turnbull National Wildlife refuge has many small patches of low resistance habitat across the landscape. A similar, but less pronounced, pattern of low resistance habitat is seen below Rock Lake in Whitman County and in the northern portion of the Methow Valley in Okanogan County. The Backbone (see Fig. 3.16 Chapter 3), the eastern portion of the Columbia Plateau from Spokane southwest to Walla Walla, and much of the buffer area are of relatively high resistance to movement. Parts of the Columbia Plateau from Ephrata to Pasco, the area from Yakima to Prosser, and the area near Ellensburg are of relatively low resistance to movement primarily because of irrigation associated with agriculture.

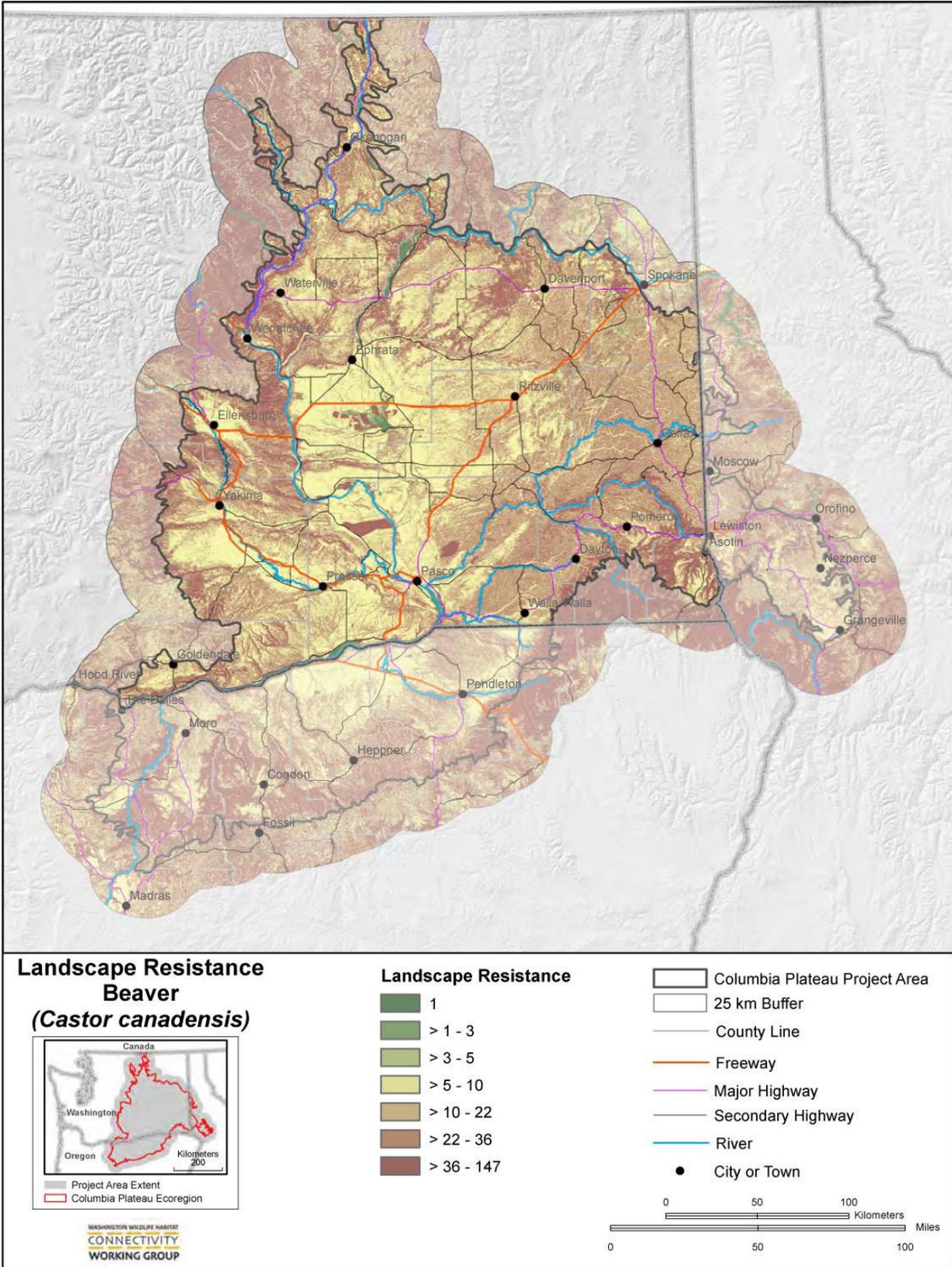


Figure A.10.1. Resistance map for beaver in the Columbia Plateau Ecoregion.

Habitat Modeling and Habitat Concentration Areas

The habitat model we developed for beaver lead to the identification of 73 habitat concentration areas (HCAs) across the Columbia Plateau Ecoregion and buffer (Fig. A.10.2; Fig. A.10.3). Average HCA size is 134 km² (range 25–1394 km²) the median size is 48 km². Habitat concentration areas for beaver are long, narrow areas following rivers and larger landscape areas where aquatic habitats are expected to be abundant. Our model did not identify HCAs in many areas of the Columbia Plateau such as most of the Okanogan and Methow valleys, as well as extensive areas in Lincoln, Adams, Whitman, Asotin, Garfield, and Columbia counties. Additionally, we identified very few HCAs in areas south of the Columbia River bordering Washington and Oregon, as well as in the eastern portion of the ecoregion that extends into Idaho. The HCAs we identified in Oregon and Idaho were primarily located in the study area buffer.

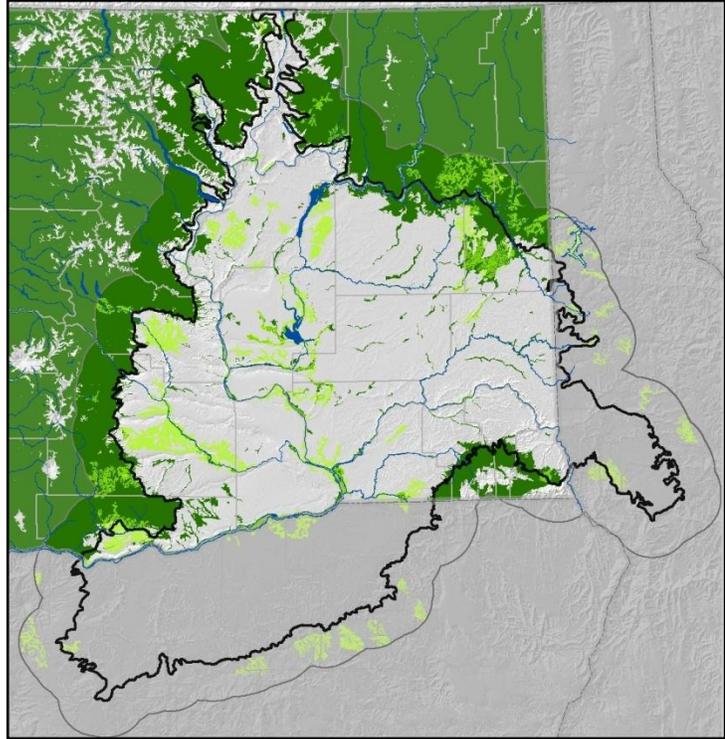


Figure A.10.2. Beaver HCAs (light green) and GAP distribution (dark green) in the Columbia Plateau Ecoregion.

The GAP distribution for Washington identifies most of the buffer area as beaver habitat (Cassidy et al. 1997). Our identification of HCAs modeled relatively little habitat in the buffer except in areas north and east of Spokane and north of Goldendale.

Because of low gradient and the presence of water, the model identified several large HCAs in irrigated agriculture in the western portion of the Columbia Plateau where water is distributed by canals and ditches. Prior to development of irrigation practices and associated infrastructure, many of these areas contained complex stream habitat that supported beaver. The area south of Union Gap to the vicinity of Toppenish is a good example of this alteration of habitat (Figure A.10.2). While unlined irrigation canals, straightened stream segments, and drains are inferior habitat when compared to a natural meandering stream, they can still support beaver. However, the potential for conflict with people is high in these areas and removal of nuisance beaver likely alters the social and demographic structure of local populations.

Habitat value of many areas adjacent to the large rivers in the Columbia Plateau is relatively low (Fig. A.10.3). Beavers are mainly associated with first- to fourth-order streams (Naiman et al. 1988) where stream morphology is often complex, e.g., multi-branched channels and nodes where small streams join. Many higher order rivers in the Columbia Plateau would facilitate movement of beavers to different drainages, but may not be areas of ideal habitat for occupancy.

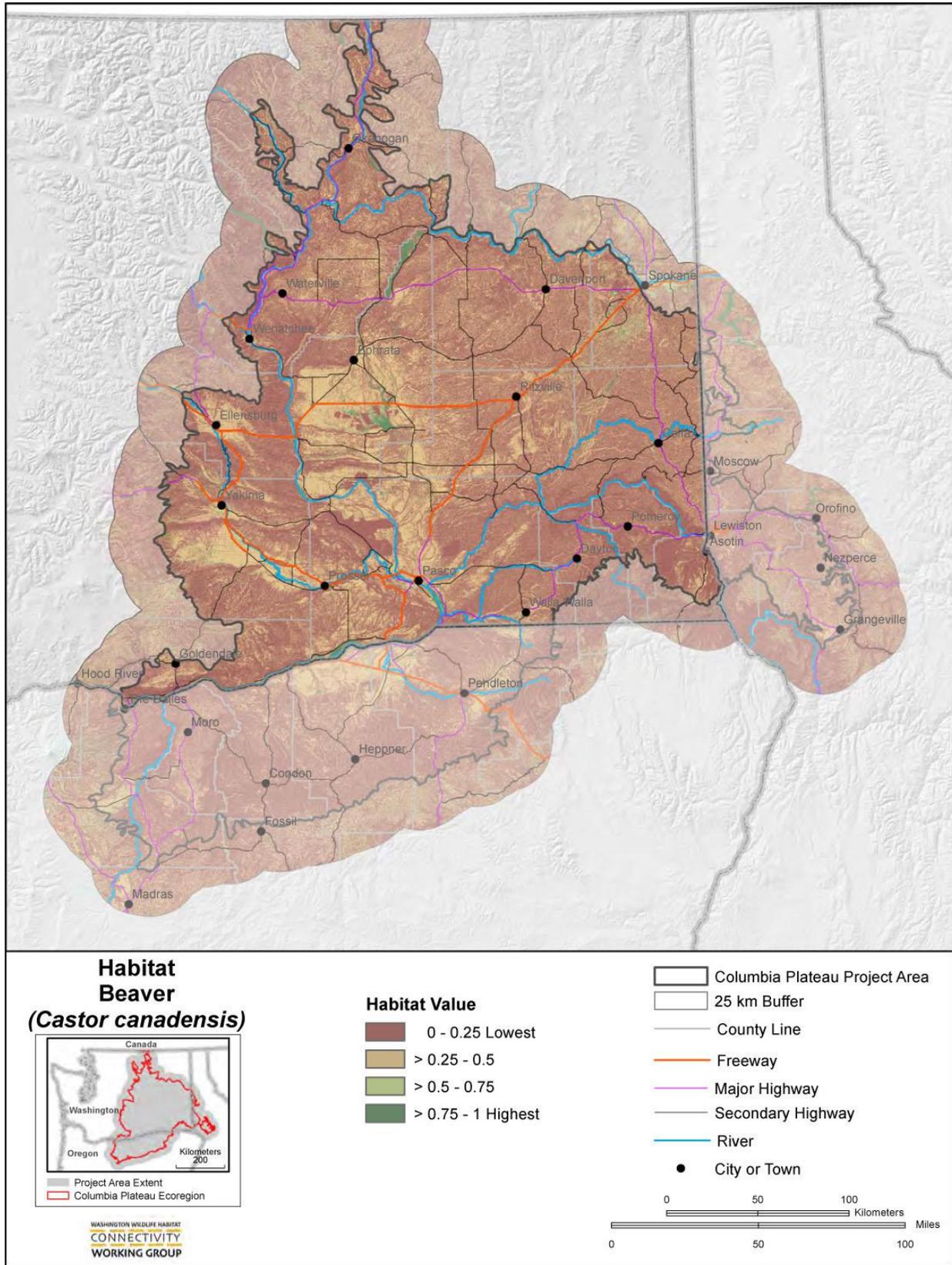


Figure A.10.3. Habitat map for beaver in the Columbia Plateau Ecoregion.

Cost-Weighted Distance Modeling

The cost-weighted distance map for beaver demonstrates that water courses are good pathways for beaver movement and increased distance from water increases movement cost (Fig. A.10.4; Fig. A.10.5). The greatest impediments to movement by beaver appear to be natural features such as topography and distance from water, rather than man-made features such as roads. For instance, steep terrain, cliff, and dune areas accumulate cost-weighted distance rapidly. Although some HCAs are relatively close in terms of Euclidean distance they are often separated by land cover features of high resistance. This is in part a reflection of the topography associated with the headwaters of a drainage system. Outside of feeding activity, beaver appear reluctant to travel overland between different drainages. They instead travel by water course to where the drainages meet.

River systems in the Columbia Plateau tend to flow around the ecoregion such that broad east–west movements by beaver are hindered by a large area of high resistance habitat in the central part of the ecoregion. Many HCAs we identified are peripherally located in the ecoregion or are in the buffer and appear to be extensions of potentially occupied habitats outside the ecoregion. For example the HCAs near the Turnbull National Wildlife Refuge (HCAs 21, 33, and 34) have good potential for movement to HCAs located in the buffer area immediately to the north but movement to other HCAs in the Columbia Plateau is limited to following the Columbia River west along the northern boundary of the ecoregion. The cluster of HCAs north of Grand Coulee (HCAs 4, 5, 6, and 7) is somewhat isolated and surrounded by areas of high resistance. The HCAs in the northern part of the Okanogan Valley (HCAs 1 and 2) appear isolated from other HCAs in the ecoregion by high resistance, as is HCA 3 in the Methow Valley. Along the western boundary of the ecoregion and buffer the locations of identified HCAs suggest that movement of beaver into and out of the Columbia Plateau may follow particular drainages including the area near Lake Chelan (HCA 14), the area west of Ellensburg (HCAs 35 and 40), and the area north of Goldendale (HCAs 57 and 59). There appears to be little potential for movement of beaver between HCAs in Washington and Oregon.

The movement potential between HCAs is often constrained by areas of high resistance, e.g., HCAs 29 to 38, 62 to 52, 51 to 52, 53 to 56, and 30 to 36. The higher elevation shrubsteppe habitat east of Ellensburg and Yakima creates a band of high resistance between HCAs 41 and 51 and those identified near Moses Lake and Othello. Potential for movement from the HCA cluster near Moses Lake and Othello to neighboring HCAs 41 and 51 is restricted by high resistance between Prosser and Richland. Similarly, movement is constrained between HCAs 61 and 62 near Walla Walla and HCA 52 near Pasco.

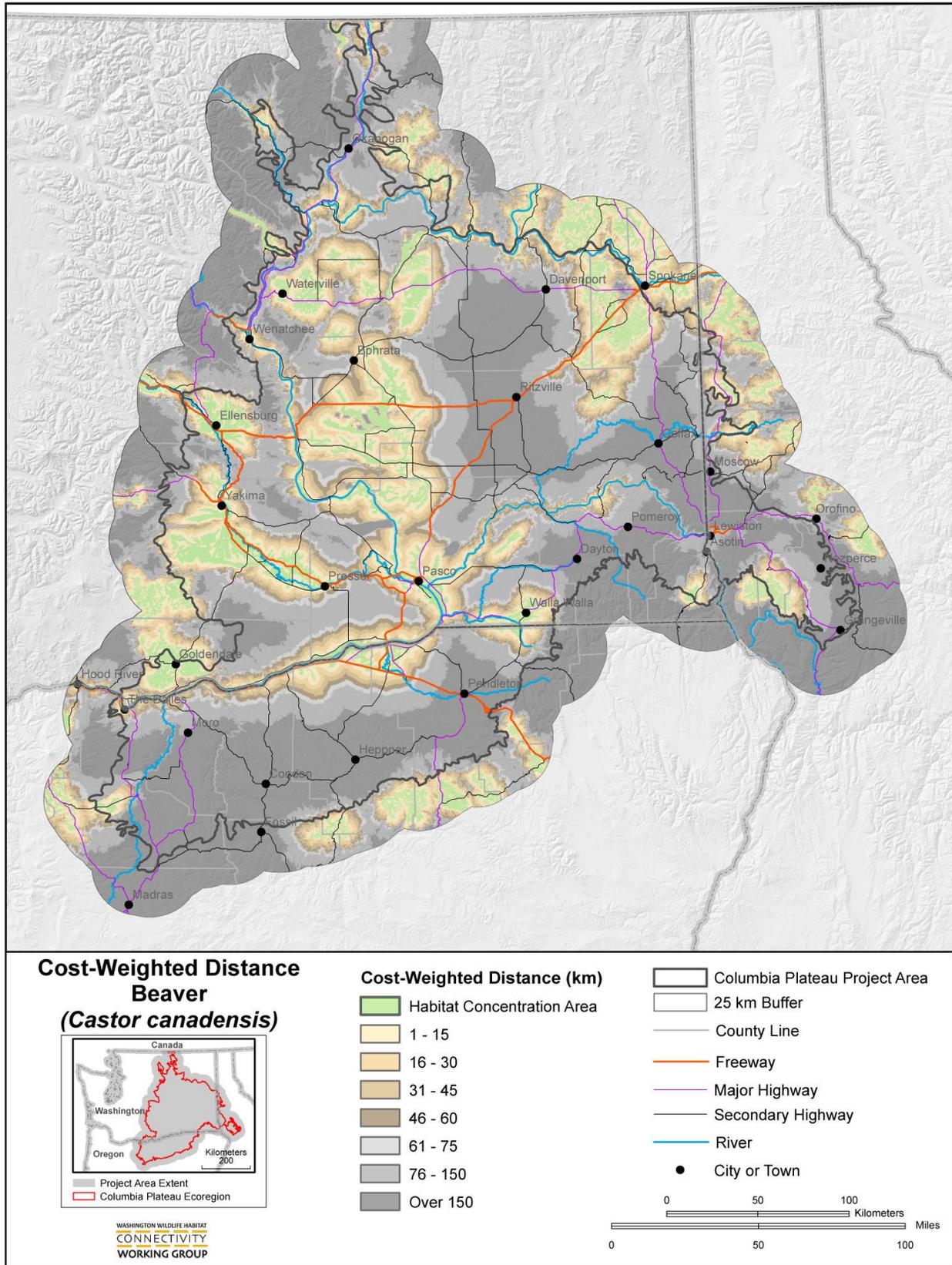


Figure A.10.4. Cost-weighted distance map for beaver in the Columbia Plateau Ecoregion.

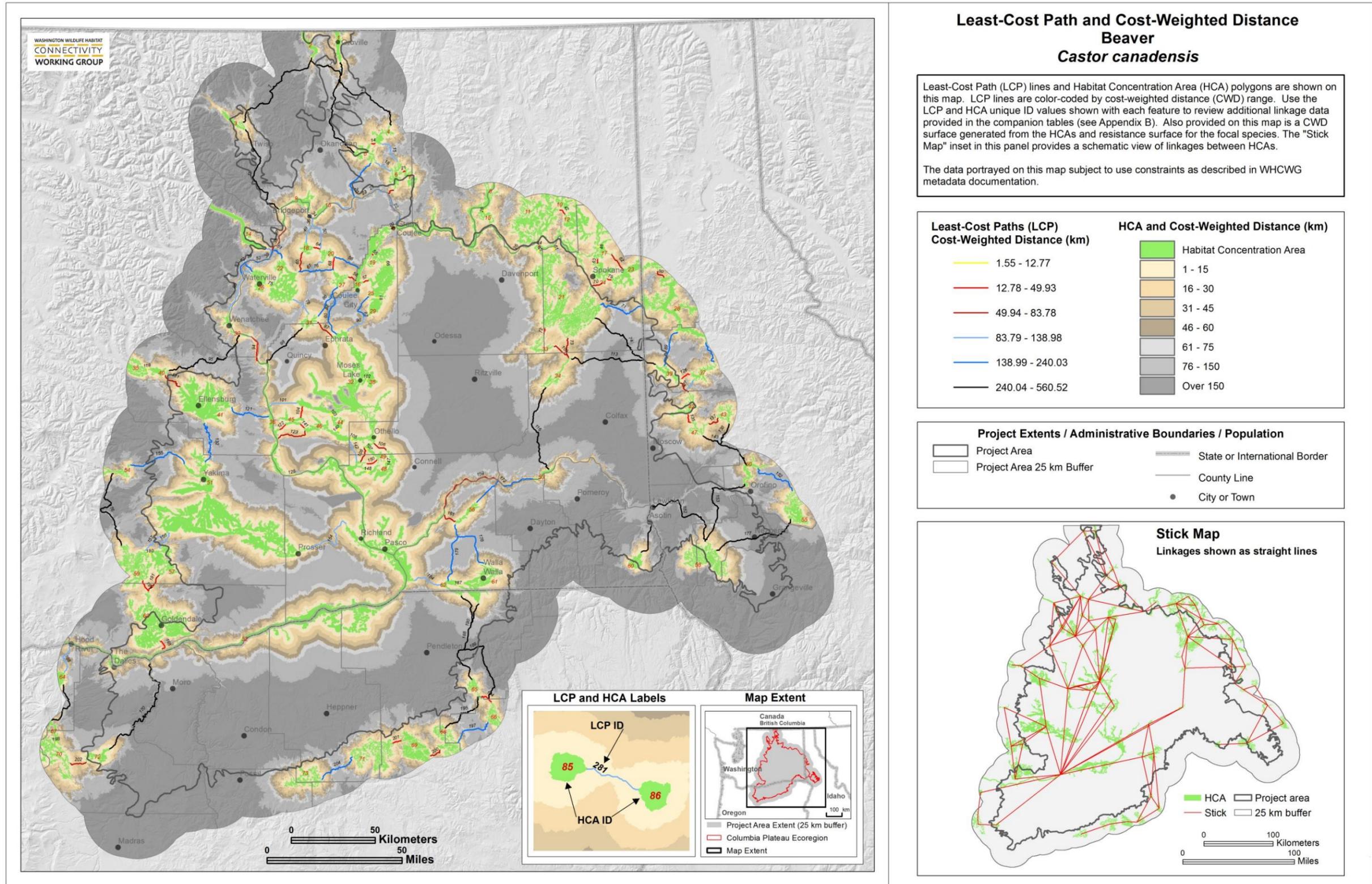


Figure A.10.5. Cost-weighted distance map with numbered HCAs (green polygons labeled with red numerals) and least-cost paths (lines labeled with black numerals) for beaver. Linkage modeling statistics provided in Appendix B.

Linkage Modeling

There were 135 discrete linkages modeled between 73 HCAs that met the criteria of being less than 60 km Euclidean distance (Fig. A.10.6 and Appendix B). All HCAs were linked to at least one other. The average Euclidean distance of modeled linkages was 16 km (SD 16 km, range <1–59 km). The average cost-weighted distance of linkages was 127 km (SD 131 km, range 1–560 km). The high standard deviation for both Euclidean and cost-weighted distance values of linkages indicates that these parameters were quite variable. The cost-weighted distance to Euclidean distance ratio is an indication of linkage quality. Higher ratios mean that the least-cost corridors are longer or have higher resistance. Ratios for beaver averaged 13 (SD 25, range 1–281) but the median ratio was 8 indicating that while some linkages had very high values most did not; six ratios were >30, one of these was 281. The linkage with the highest ratio occurred between HCAs 16 and 19 in the vicinity of Banks Lake and crossed steep terrain.

The linkage network for beaver looks generally well-connected in the Columbia Plateau. Areas where linkage quality was good include the HCAs clustered near the vicinity of Moses Lake and Othello, the Turnbull National Wildlife Refuge and HCAs in the buffer area to the north, and in the vicinity of Banks Lake and Moses Coulee. Areas where wet habitats are expected to be more broadly distributed on the landscape demonstrate multiple potential pathways between neighboring HCAs, e.g., the areas near Waterville, Moses Lake, and Othello. The linkage model identified locations along the Columbia River that beaver may use to access HCAs further inland. For example, the linkage between the HCA along the Columbia River and Banks Lake, and the linkage running through Foster Creek near Bridgeport. The linkage network in the eastern part of the Columbia Plateau has an interesting “bottle-neck” where pathways are funneled into the north end of HCA 34. This HCA has linkages extending to the Palouse River.

Linkages that cross the divide between different watersheds may not be suitable for beaver movements. These are locations where surface water is infrequently present and steeper gradients often prevail. For example, HCAs 4 and 5 and HCAs 6 and 7 form two clusters along the ecoregion boundary and buffer area east of Okanogan. The two linkages between these HCAs clusters are 9 km Euclidean distance and 100 km cost-weighted distance and 14 km Euclidean distance and 138 km cost-weighted distance respectively. In the Methow Valley there are two linkages for HCA 3, one extending north the other south. The linkage to the north is constrained and has a cost-weighted distance value of 561 km (56 km Euclidean distance) the linkage extending south is also costly as it is 360 km cost-weighted distance (50 km Euclidean distance).

Linkage pathways in the Okanogan Valley did not follow the Okanogan River to the Columbia River as might be anticipated. Instead, the least-cost pathway from HCA 1 connected to HCA 4 by passing through the buffer and to HCA 5 by following the Okanogan River to Okanogan then moving east to the buffer area. This does not mean that the lower reaches of the Okanogan River are not necessarily important for connectivity of beaver, but rather is a function of the model seeking to connect nearest HCAs.

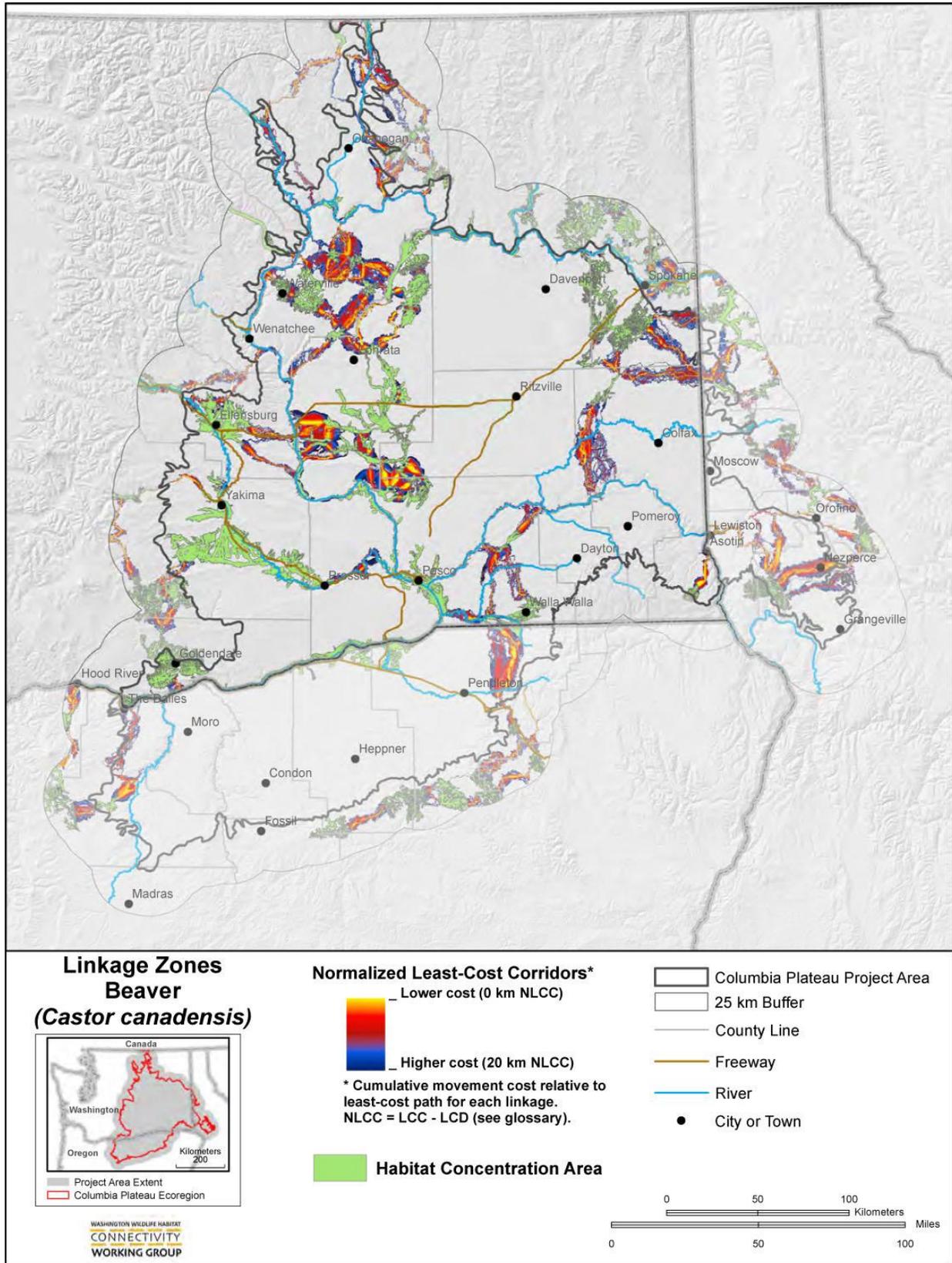


Figure A.10.6. Linkage map for beaver in the Columbia Plateau Ecoregion.

Key Patterns and Insights

Key patterns and insights for our connectivity analysis of beaver in the Columbia Plateau Ecoregion include:

- Some areas modeled as good habitat with low resistance to movement are compromised by land-use practices that negatively impact beaver.
- Social carrying capacity (human tolerance) for beaver is a significant factor in their abundance and distribution.
- Reduction in beaver or the absence of beaver can lead to decreased and degraded riparian habitat.
- The linkage network for beaver appears well-connected within the Columbia Plateau Ecoregion as well as the buffer.
- Broad patterns of connectivity within the Washington portion of the ecoregion include large dispersed areas, and extensive linear paths along major rivers such as the Columbia, Snake, and Yakima rivers.
- The most dense connectivity network areas include: (1) the Grand and Moses Coulee vicinities, (2) the Kittitas Valley (near Ellensburg), and (3) Potholes and nearby areas to the west and southeast.

Considerations and Needs for Future Modeling

Radio-telemetry studies of beaver, especially use of GPS transmitters, would potentially provide a better understanding of movement, habitat use, and landscape resistance. In the past, radio-telemetry studies of beaver have been difficult because of challenges with respect to transmitter attachment but advances have been made in recent years. Due to the considerable variability among locations, we were not able to assign a blanket resistance to hydroelectric dams in our project area. Beaver do occur above and below these dams. Understanding the impact of hydroelectric dams to beavers would further our understanding of beaver movement potential. The role of beaver in semi-arid landscapes needs further research especially given future climate change predictions.

Opportunities for Model Validation

Genetics could be used to evaluate beaver movement through the Columbia Plateau especially between HCAs located in the western and eastern parts of the ecoregion and HCAs in the Methow and Okanogan valleys.

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