Chapter 10. Network Centrality, Pinch-Points, and Barriers and Restoration Opportunities for Western Rattlesnake (*Crotalus oreganus*)

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This chapter is an addendum to the *Washington Connected Landscapes Project: Analysis of the Columbia Plateau Ecoregion* (2012). It includes supplemental connectivity maps for Western rattlesnake (*Crotalus oreganus*) that can be used to help prioritize and implement conservation actions. We have also included the linkage network (Fig. 10.1) and cost-weighted distance surface (Fig. 10.2) previously modeled for Western rattlesnake (See Appendix A.9, WHCWG 2012, available from http://waconnected.org).

Western rattlesnake, photo by James Rosindell

Addendum Connectivity Maps

The supplemental connectivity products developed for Western rattlesnake include maps of (1) linkage network centrality (Fig. 10.3), (2) linkage pinch-points (Fig. 10.4), and (3) barriers and restoration opportunities (Fig. 10.5). There are numerous potential applications of these maps for informing connectivity conservation. We highlight examples on the landscape where conservation efforts for connectivity may be needed (Figs. 10.6–10.11).

Conservation of Connectivity for Western Rattlesnake

- The central backbone of Western rattlesnake connectivity is the river corridors of the Columbia and Snake rivers. However, there are important habitat concentration areas (HCAs) and linkages extending off these main riverine corridors that are important for connecting populations associated with coulees and creeks.
- The network of rattlesnake connectivity is most constrained in a north–south direction in the center of the Columbia Plateau and so this area is the most important for maintaining natural areas for connectivity.
- Many unconstrained linkages are also long linkages, so the presence of intermediate dens should be investigated in these areas to assess the role of these wide linkages in assuring connectivity.
- Many of the fine-scale barriers to rattlesnake connectivity are roads, so limiting the number of new roads is likely to be the most effective method for maintaining connected populations.
- There is not a lot of redundancy in the network; if the highly central HCAs and linkages along the Columbia River were seriously disrupted, rattlesnake connectivity would be highly disrupted and would likely result in isolated populations.

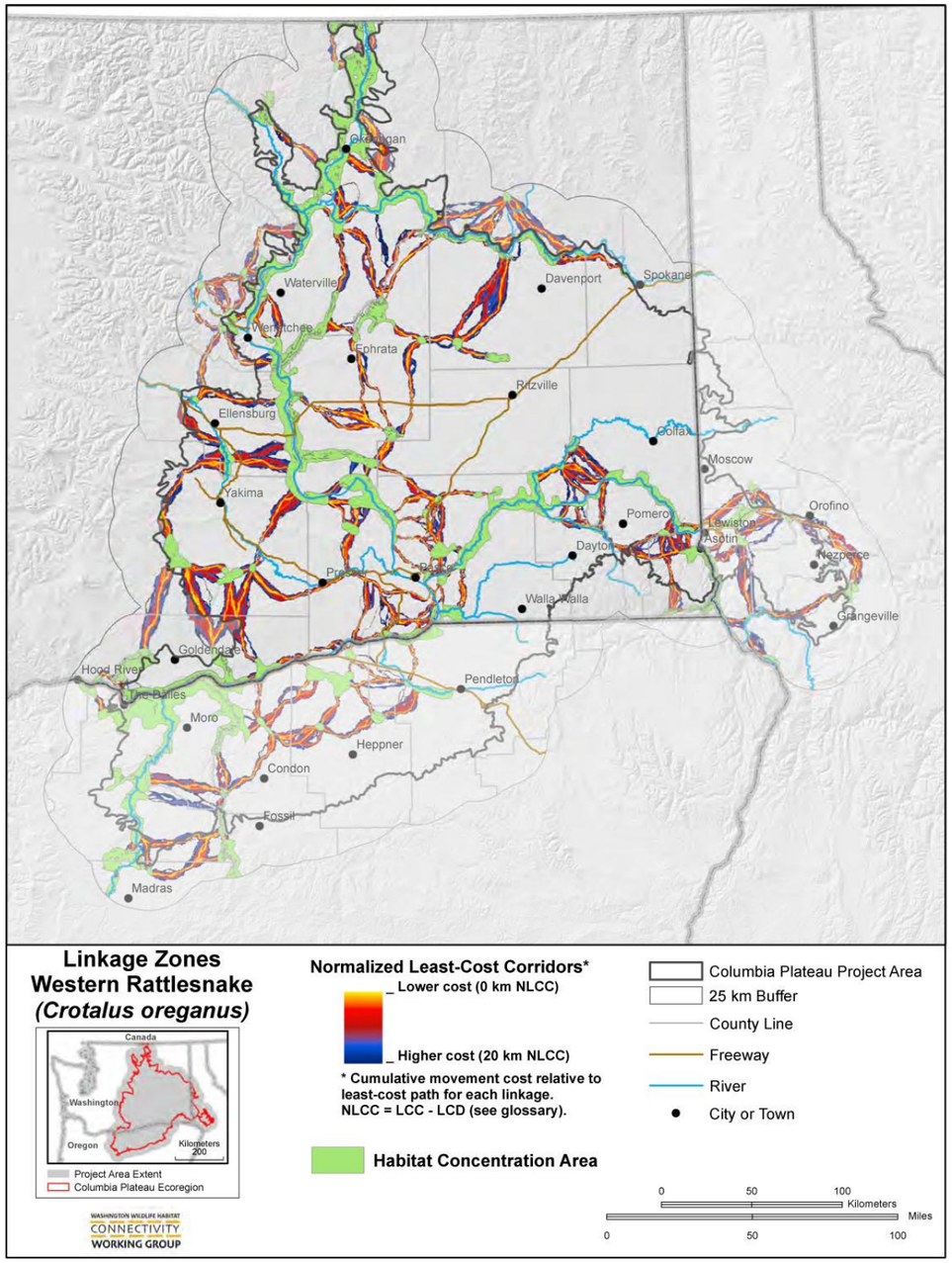

Figure 10.1. Linkage network modeled for Western rattlesnake in the Columbia Plateau Ecoregion (Appendix A.9, WHCWG 2012). Green polygons represent habitat concentration areas (HCAs) for Western rattlesnake. Linkages between HCAs are shown in bright colors; the least-cost pathways are highlighted yellow.

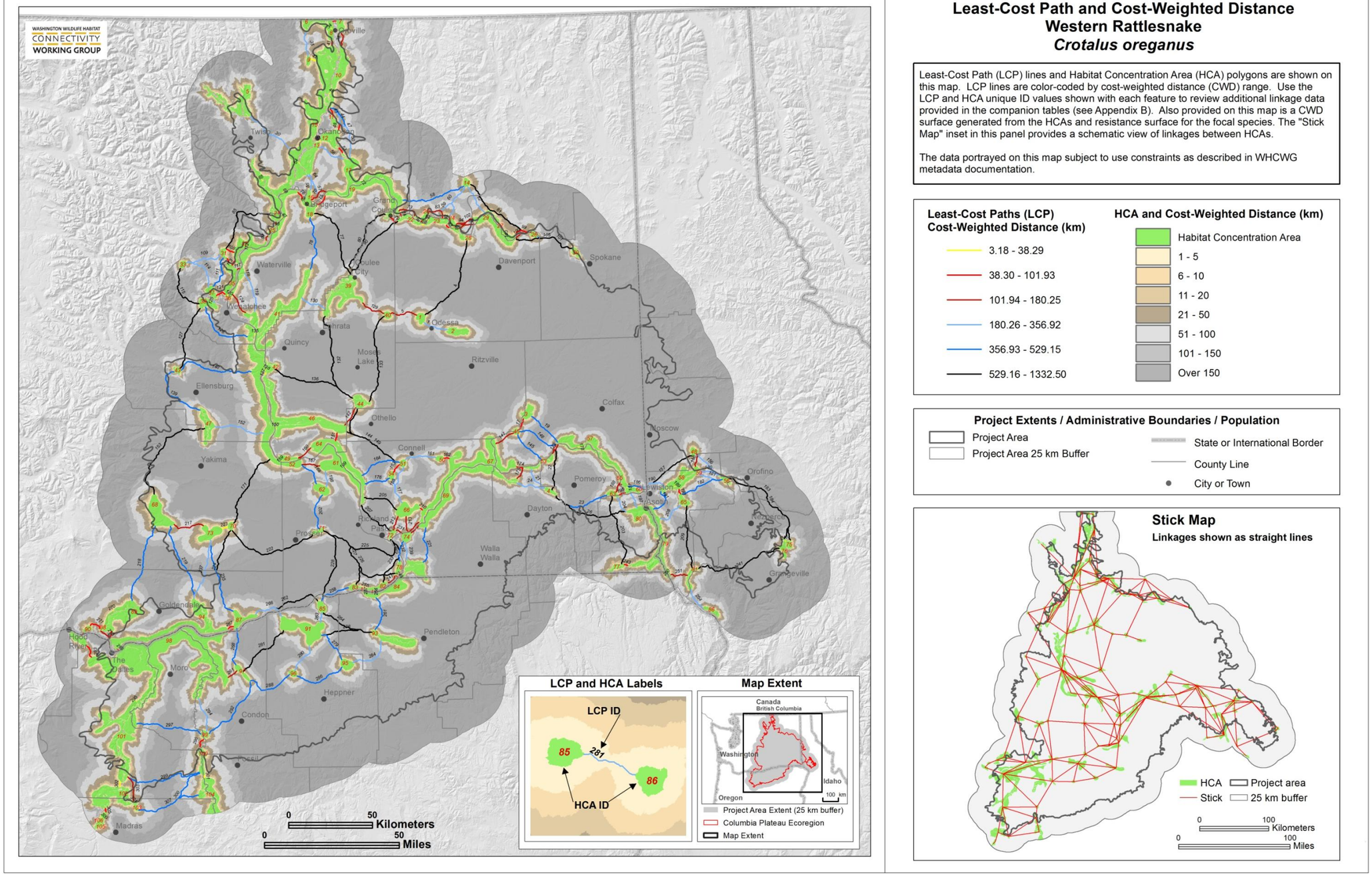

Figure 10.2. The cost-weighted distance map with numbered habitat concentration areas (HCAs) and least-cost paths for Western rattlesnake in the Columbia Plateau Ecoregion (Appendix A.9, WHCWG 2012).

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Figure 10.3. Linkage Network Centrality for Western Rattlesnake (*Crotalus oreganus*).

WHAT IS CENTRALITY?

Centrality is a measure of how important a habitat area or linkage is for keeping the overall connectivity network connected. For our analyses, we calculated current flow centrality using the Linkage Mapper Toolbox (see more at http://www.circuitscape.org /linkagemapper).

WHY IS CENTRALITY IMPORTANT?

The connectivity network is comprised of habitat concentration areas (HCAs) and linkages for movement of wildlife between them. Linkages or HCAs with high centrality are expected to be the "gatekeepers" for connectivity. For example, if a linkage with high centrality is severed, a wildlife species may risk having its population separated into sub-populations.

HOW IS CENTRALITY DEPICTED ON THE MAP?

- Centrality results are depicted based on four quartiles (four equal parts). However, the top quartile includes areas shown in yellow (the top 10% of this quartile), and red (the remaining 90%).
- Linkages and HCAs shown in orange also have relatively high network centrality, while those colored blue and green tend to be on the periphery of the network.

TYPES OF QUESTIONS AND DECISIONS THIS MAP HELPS INFORM

- Where are important areas on the landscape for maintaining connectedness?
- Where should further disturbance to connectivity be avoided?
- Which HCAs might be important for species recovery efforts (e.g., sites for translocations and augmentations of populations)?

Notes: This map depicts modeled HCAs and linkages (see more at http://waconnected.org). While we've used the best available data layers, field review is necessary to ensure the HCAs and linkages are viable. We included areas in Oregon and Idaho to help understand transboundary connectivity; however, our products may be less accurate in these adjoining areas.

Habitat Concentration Area (HCA) Centrality*

- Highest
- Very High
- High
- Medium
- Low
- Not Connected

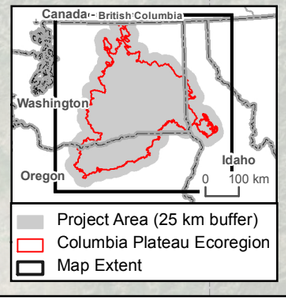
*Habitat Concentration Area (HCA) polygon labels on the map indicate HCA ID number.

Least-Cost Path (LCP) Centrality

- Highest
- Very High
- High
- Medium
- Low

Boundaries and Population Centers

- Columbia Plateau Project Area
- Columbia Plateau Project Area 25 km Buffer
- State or Provincial Border
- Freeway
- Major Highway
- City or Town
- Important Site



The data portrayed on this map are subject to use constraints as described in WHCWG metadata documentation.

Figure 10.4. Linkage Pinch-Points for Western Rattlesnake (*Crotalus oreganus*).

WHAT ARE PINCH-POINTS?

Pinch-points are "bottlenecks" where wildlife movement is funneled within linkages. Pinch-point modeling methods are based on electrical circuit theory. Locations where current is very strong are constrictions within linkages and represent areas most vulnerable to being severed (see more at http://www.circuitscape.org /linkagemapper). Pinch-points can be the result of both natural and human-made landscape features.

WHY ARE PINCH-POINTS IMPORTANT?

Pinch-points are a conservation priority as they are locations where loss of a small area could disproportionately compromise connectivity due to a lack of alternative movement routes. Loss of these areas may sever migration routes, or impact other critical movement needs.

HOW ARE PINCH-POINTS DEPICTED ON THE MAP?

- Habitat concentration areas (HCAs) are indicated in green, while the linkages are depicted in a yellow to blue color ramp.
- Reds and yellows indicate moderate to highly constrained areas for movement within linkages.
- Blue areas are not necessarily "better" areas of the linkages but rather places where resistance is similar across broad swaths of the landscape.

TYPES OF QUESTIONS AND DECISIONS THIS MAP HELPS INFORM

- Where along linkages is potential movement highly or moderately constrained?
- Are there areas where alternative movement routes may not be available?

To determine the relative importance of pinch-points in different linkages, users should consider the pinch-point map in conjunction with other measures, such as centrality.

Notes: This map depicts modeled HCAs and linkages (see more at http://waconnected.org). While we've used the best available data layers, field review is necessary to ensure the HCAs and linkages are viable. We included areas in Oregon and Idaho to help understand transboundary connectivity; however, our products may be less accurate in these adjoining areas.

Linkage Pinch-Points

Current Flow

Highly Constrained

Unconstrained

Habitat Concentration Area (HCA)*

Least-Cost Path (LCP)

*Habitat Concentration Area (HCA) polygon labels on the map indicate HCA ID number.

Boundaries and Population Centers

Columbia Plateau Project Area

Columbia Plateau Project Area 25 km Buffer

State or Provincial Border

Freeway

Major Highway

City or Town

Important Site

Project Area (25 km buffer)

Columbia Plateau Ecoregion

Map Extent

0 50 Kilometers

0 50 Miles

The data portrayed on this map are subject to use constraints as described in WHCWG metadata documentation.

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Figure 10.5. Barriers and Restoration Opportunities for Western Rattlesnake (*Crotalus oreganus*).

WHAT ARE BARRIERS?

Barriers are areas where landscape features impede wildlife movement between habitat concentration areas (HCAs). Least-cost modeling methods (see more at http://www.circuitscape.org/linkagemapper) identify and rank barriers by their impact and quantify the extent to which restoration may improve connectivity. Barriers may be partial or complete, and they may be natural (e.g., rivers, cliffs) or human-made (e.g., urban areas, highways, some types of agriculture). Not all barriers are restorable.

HOW ARE BARRIERS AND RESTORATION OPPORTUNITIES DEPICTED?

- The Barrier Impact/Restoration Improvement Score reflects the percent reduction in corridor resistance per hectare restored. The scores are shown as three equal proportions, indicated in the colors of yellow, red, and blue.
- Barriers highlighted yellow or red are places that, if restored or enhanced, may yield the greatest improvement in potential movement between HCAs.
- Areas highlighted blue may yield moderate improvement in potential movement if restored.
- Barriers identified outside linkage pathways have the potential to produce new, alternative corridors for movement between HCAs if restored.

TYPES OF QUESTIONS AND DECISIONS THIS MAP HELPS INFORM

- Where in a linkage will restoration efforts have the greatest effect on connectivity?
- Where can alternate linkage pathways be created through restoration of key areas or removal of key barriers?

Since **all types** of barriers to movement are identified on this map users must further evaluate the feasibility of each restoration opportunity.

Notes: This map depicts modeled HCAs and linkages (see more at http://waconnected.org). While we've used the best available data layers, field review is necessary to ensure the HCAs and linkages are viable. We included areas in Oregon and Idaho to help understand transboundary connectivity; however, our products may be less accurate in these adjoining areas.

Barrier Impact / Restoration Improvement Score

- Highest
- High
- Moderate

HCAs and LCPs

- Habitat Concentration Area (HCA)*
- Least-Cost Path (LCP)

*Habitat Concentration Area (HCA) polygon labels on the map indicate HCA ID number.

Boundaries and Population Centers

- Columbia Plateau Project Area
- Columbia Plateau Project Area 25 km Buffer
- State or Provincial Border
- Freeway
- Major Highway
- City or Town
- Important Site

The data portrayed on this map are subject to use constraints as described in WHCWG metadata documentation.

Example Areas of Interest for Connectivity

Linkage Network Centrality

- The highest areas of centrality follow the major river corridors such as the Columbia and Snake rivers (Fig. 10.6).
- An important exception is the HCA of Highest centrality that extends from the Columbia River up Lower Crab Creek (Fig 10.6).
- The remaining habitat around the Wenatchee area appears to be highly important for connecting the Okanogan region with the rest of the Columbia Plateau; this area is threatened by increasing urban development (Fig 10.6).

Linkage Pinch-Points

- The linkages of high centrality are some of the most constrained linkages, suggesting that disturbances to these river corridors may disrupt connectivity (Fig 10.4).
- Linkages that cross state boundaries in the Columbia Plateau are generally constrained as well (Fig. 10.7).
- Linkages of broad suitability are associated with areas of lower road density and are concentrated on the Yakama Reservation and protected lands (Figs. 10.8, 10.9).
- The broad linkages are often long in length suggesting they may better serve as suitable corridor habitat rather than one-time movement paths (Figs. 10.8, 10.9).

Barriers and Restoration Opportunities

- The greatest opportunities for restoration are across the Hanford area, southeast Washington near the Lewiston/Clarkston area, in the vicinity of the Tri-Cities area, and between the Columbia and Okanogan rivers (Fig 10.5).
- Most narrow barrier restoration opportunities represent major road crossings and may be targets for road mitigation strategies (Figs 10.10, 10.11).
- Restoration activities around the vicinity of HCA 39 (Dry Falls) could be especially beneficial as there are multiple linkages extending from or near this HCA with high restoration potential (Fig. 10.10).
- Given that there are relatively few narrow areas with high habitat restoration potential, the best strategy for Western rattlesnake may be protecting and maintaining current suitable habitat as projects to restore habitat would be need to be quite expansive.

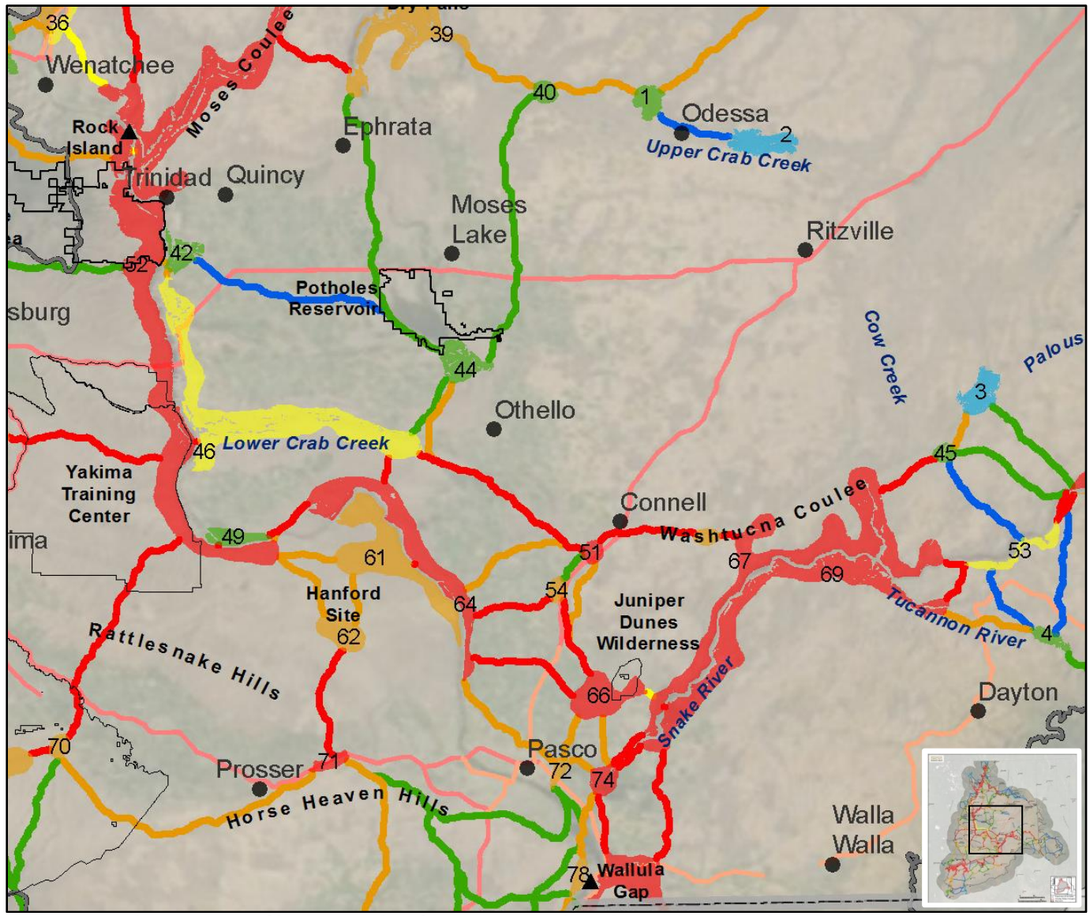

Figure 10.6. The core area of high centrality for Western rattlesnakes in the Columbia Plateau.

- HCAs 46 (Lower Crab Creek) and 53 (Snake River) are the most central HCAs for rattlesnake connectivity. HCA 46 serves as the main link between the Columbia River and the Potholes region and some of the channeled scablands. HCA 53 serves as the core area connected to the remaining remnant populations around the Snake River.
- The linkage to the north (east of Wenatchee) provides one of the most essential connections for the entire Columbia Plateau rattlesnake network, and may be one of the most imperiled due to urban growth.
- The area around the Wallula Gap is the most central HCA and linkage between Washington and Oregon.

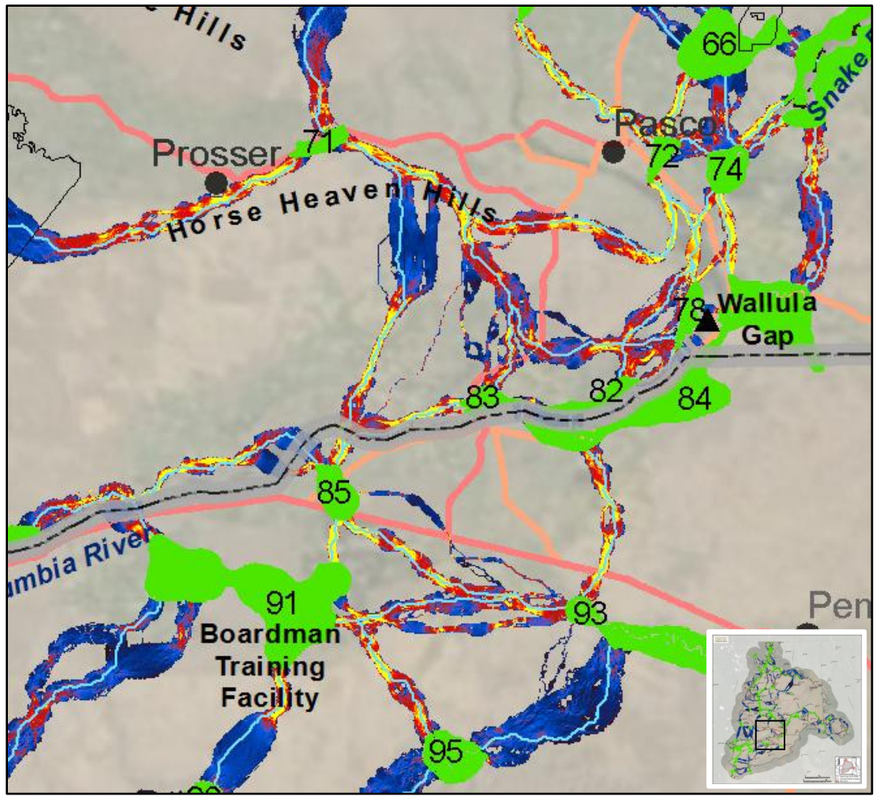

Figure 10.7. Area of high linkage constraint (pinch-points) surrounding the Washington–Oregon border.

- The presence of the urban footprint of the Tri-Cities has created a network of narrow linkages in which connectivity may be easily disrupted.
- The narrow linkages also suggest a tenuous connection between Washington and Oregon populations.

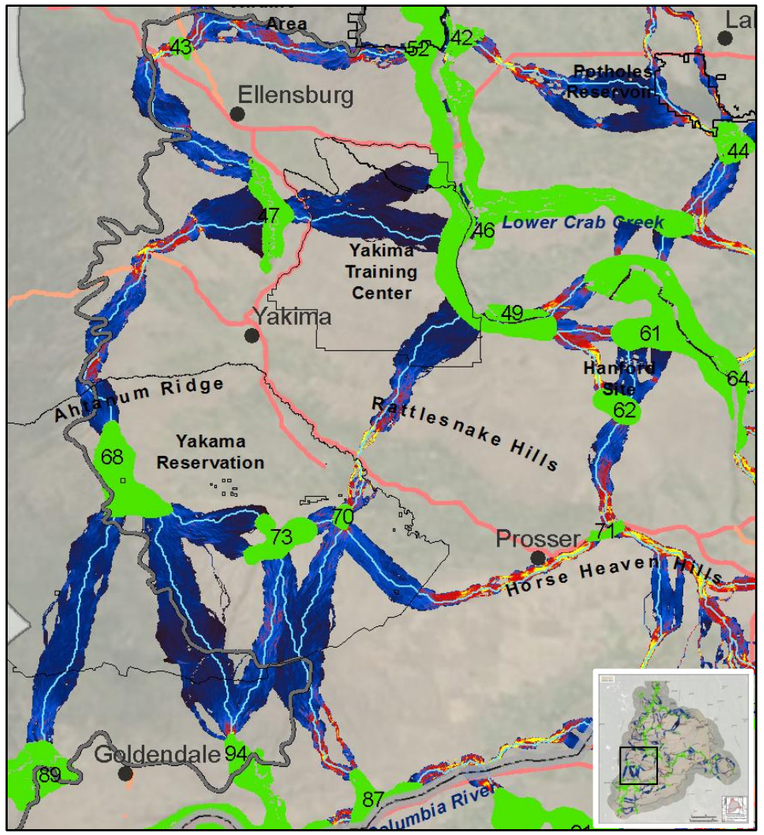

Figure 10.8. A concentration of less-constrained linkages around the southwest Columbia Plateau in Washington.

- This area of high linkage suitability is generally characterized by restricted-use lands such as the Yakima Training Center, Yakama Reservation, Hanford site, and Columbia National Wildlife Refuge.
- Many of these linkages have high suitability but long length, so actual linkage efficacy is uncertain unless denning habitat is available within corridors.
- Some of the HCAs of highest centrality (46, 49, and 52) are joined by less constrained linkages.

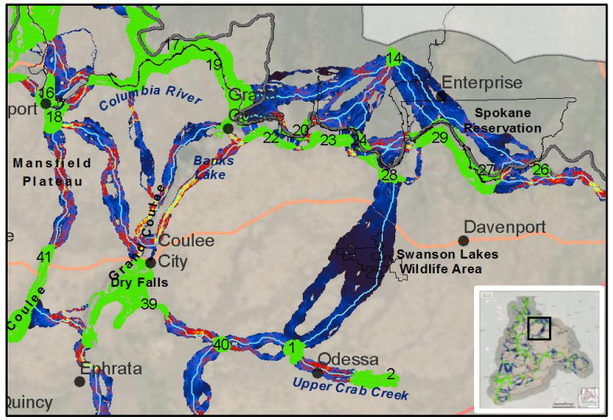

Figure 10.9. Constrained and unconstrained linkages in the northern portion of the Columbia Plateau.

- Swanson Lakes Wildlife Area appears to serve as a key (albeit long) linkage for Western rattlesnakes between the Columbia River and Upper Crab Creek. In contrast, the east side of Banks Lake has a very constrained connection.
- There appear to be many unconstrained linkages between Grand Coulee and Enterprise.

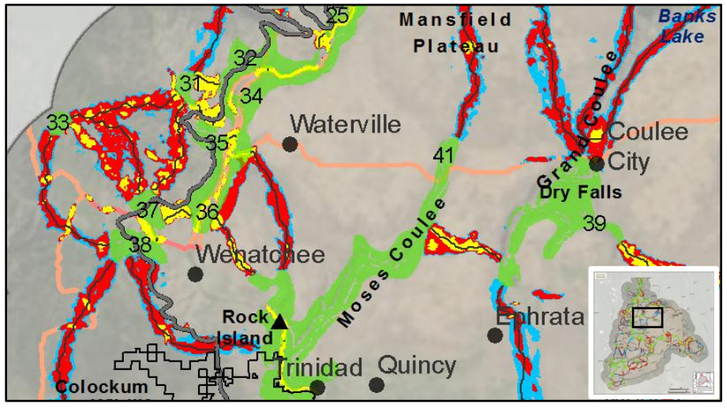

Figure 10.10. Barriers to movement with high restoration potential around the Wenatchee area.

- The linkage just east of the city of Wenatchee is a narrow path with high restoration potential in its central portion.
- There are multiple opportunities for restoration in the "triangle" connecting HCAs 31, 33, and 37 such that new least-cost pathways could be created with strategic restoration.
- Multiple connections to HCA 39 have high restoration potential.
- Roads provide two major barriers to the linkage between HCAs 33 and 38.

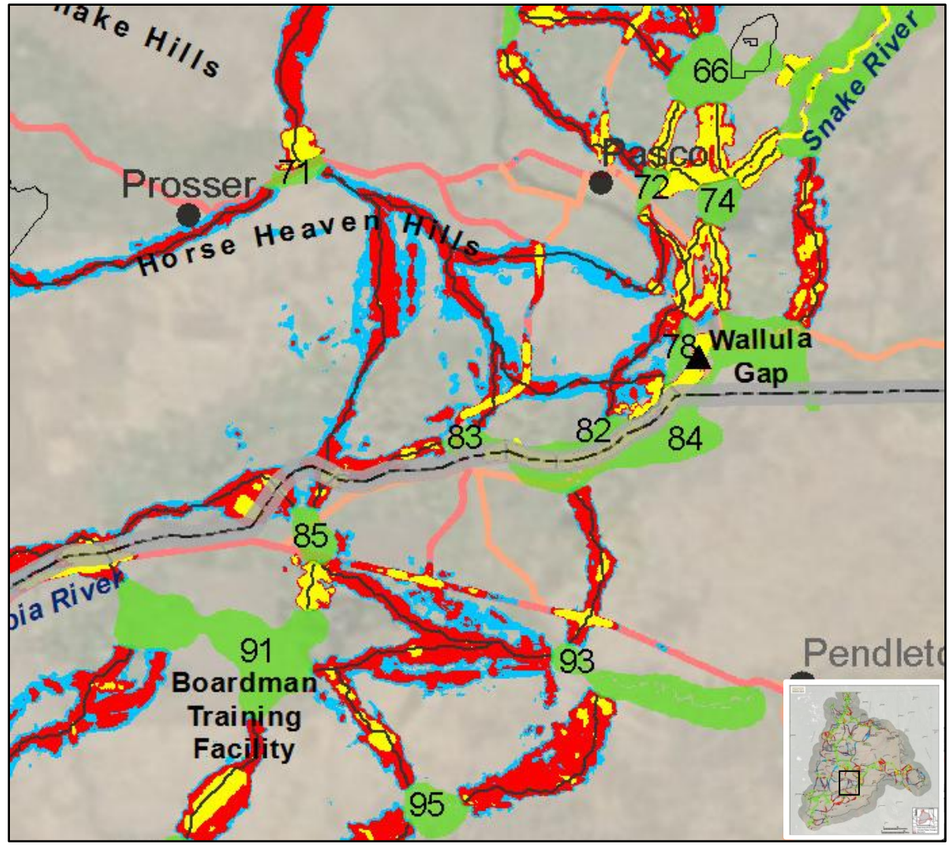

Figure 10.11. Identified barriers around the same region with constrained paths as depicted in Figure 10.7.

- The area south from Pasco to Wallula Gap has multiple barriers that have high restoration potential.
- The linkage from the Snake River to Wallula Gap has fewer major barriers and may be an easier target for restoration.
- Many of the barriers here are also associated with roads, which may be difficult to mitigate, but suggests that the non-roaded landscape should be kept relatively intact to reduce the amount of additional resistance to the road.

Acknowledgements

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