2023 PNW Quantitative Wildfire Risk Assessment Methods

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Suggested Citation:

McEvoy, Andy; Dunn, Christopher; Rickert, Ian. 2023 PNW Quantitative Wildfire Risk Assessment Methods (2023). [Unpublished Manuscript].

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1 Introduction to the 2023 QWRA

1.1 Purpose of Assessment

Risk management is foundational to decision-making under uncertainty and continues to be used across a specturm of industries, including natural resource management. While risk management is often referred to as a mindset, in practice it typically follows the process depicted in Figure 1. As the pace of change in the fire environment increases, faster decisions must be made even when faced with uncertainty. Decision support tools that address critical stages of the risk management process are increasingly needed to support the wildfire challenges impacting environments and communities globally.

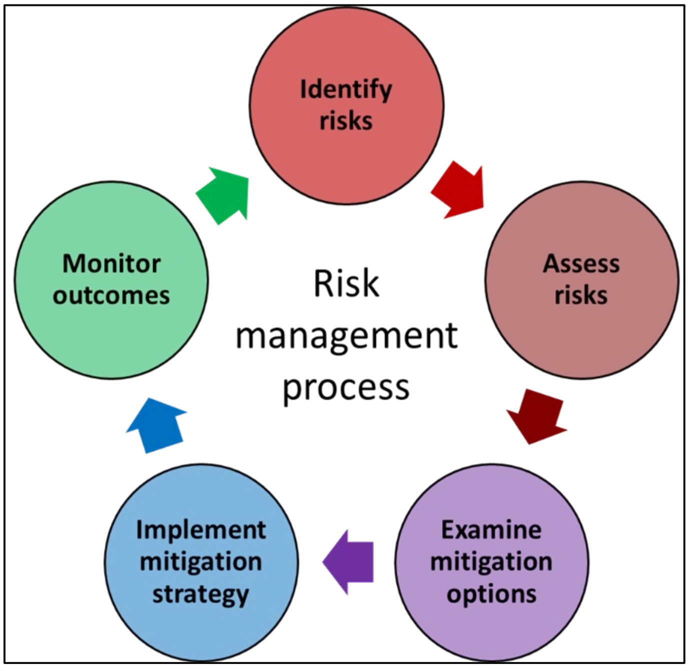

Figure 1. The risk management process

Today we find that risk management is transitioning towards a strategic discussion, blending risk manager's and strategist's expertise. Strategy is about making choices with uncertainty, and one cannot make the right strategic decision without understanding risk. A good strategy relies on the diagnosis of the problem, developing guiding policies, and then a set of coherent actions. As you can see, the components of a good strategy are aligned with the first three steps of the risk management process.

The purpose of the Pacific Northwest Quantitative Wildfire Risk Assessment (PNW QWRA) is to provide objective, science-based risk analytics that can be used to support strategic risk management across Oregon and Washington. Analytics produced as part of the PNW QWRA support community wildfire protection planning, fuels planning, active fire response and myriad other land management needs at regional and sub-regional scales. The PNW QWRA does the following:

1. Updates Oregon and Washington's all-lands wildfire risk assessment to represent current conditions and scientific advances,
2. Fulfills an important step in the risk management process,

3. Provides information symmetry across agencies to support strategic planning and implementation across all-lands,
4. Supports the efficient allocation of finite resources to areas and resources most at risk,
5. Expands the number and distribution of values exposed to wildfire,
6. Helps align land management agencies towards common goals of protecting societal values, and
7. Inform and educate practitioners and the public about wildfire risk.

1.2 2023 Update Process

In 2018, project partners released a PNW QWRA (hereafter PNW QWRA 2018; Gilbertson-Day et al., 2018) which evaluated and represented risk based on the landscape and best available science at that time. Beginning in winter of 2022, project partners began the process of updating PNW QWRA 2018 to evaluate risk on a more contemporary landscape, accounting for changes on the landscape that have occurred since the release of PNW QWRA 2018. The updated risk assessment is hereafter referred to as PNW QWRA 2023. The purpose of the update has been to:

1. Assess wildfire risk on the current landscape that accounts for changes in fuel from wildfires, land management activities, etc.
2. Utilize updated risk assessment tools, technology and data.
3. Consider and incorporate feedback that has been offered since the release of the previous assessment.

The PNW QWRA update process was facilitated and managed by Oregon State University in close collaboration with a leadership team that included representatives from the U.S.D.A. Forest Service, Bureau of Land Management, Washington Department of Natural Resources and Oregon Department of Forestry. Over the course of the year and half long update process, a wide range of partners and stakeholders were engaged.

The PNW QWRA update process was initiated in February of 2022 when work began on updated wildfire hazard modeling. Pyrologix LLC was contracted to conduct the modeling and secondary analyses and produce an array of wildfire hazard analytics for Oregon and Washington, including those that are required for calculating risk in a QWRA framework. Pyrologix and PNW QWRA partners hosted a three-day fuels calibration workshop in February 2022 during which fire and fuel specialists from across Oregon and Washington participated by reviewing available fuel data and recommending changes to it based on their knowledge and experience. Between February 2022 and December 2022, when the hazard modeling was complete, Pyrologix shared multiple different drafts of the hazard modeling landscape and draft hazard results for review. Fire and fuel specialists reviewed draft data and offered feedback.

In November of 2022, PNW QWRA partners, led by OSU, began the process of identifying and characterizing highly-valued resources and assets (HVRAs) for which risk would be assessed in PNW QWRA 2023. Highly-valued Resources and Assets are the values (e.g. timber, infrastructure, habitat, etc.) for which risk is evaluated in the assessment. Selecting HVRAs for the PNW QWRA 2023 began with an ArcGIS storymap illustrating a proposed set of HVRAs based on the PNW QWRA 2018 and feedback from stakeholders. The storymap included descriptions of the data that might be used, and a survey soliciting feedbacks on the proposed HVRAs and suggestions for additional or different HVRAs. We shared the storymap and survey with more than 100 partners and stakeholders.

Based on feedback collected from the survey, OSU formed working groups of relevant subject matter experts to lead development of nine HVRAs. Between December of 2022 and March 1, 2023, the working groups developed strategies for how each HVRA would be characterized, organized the data required, and created draft maps for each HVRA and its constituent sub-HVRAs. More than 30 project partners and subject matter experts reviewed the final list of HVRAs and mapping methods during a hybrid workshop on March 1-3, 2023. Following completion of all HVRA datasets, a group of six individuals representing state and federal agency leadership in Oregon and Washington deliberated on and agreed to a relative importance schema for the PNW QWRA 2023 during a virtual meeting on May 31, 2023.

Oregon State University produced and released preliminary results on June 30, 2023. Project partners and HVRA working group members were given an opportunity to review the preliminary results and offer feedback, including suggested changes. During the course of review, project partners recommend substantial changes to the Ecological Integrity HVRA. The relevant working groups reconvened and responded to the feedback. Using the updated HVRA data, OSU produced and released final PNW QWRA 2023 data to partners in October 2023.

1.3 Using This Report

This report is intended to provide readers with sufficient background, methods and guidance so that they can interpret and apply PNW QWRA 2023 data layers to their specific decision-making context. To that end, the report is divided into the following sections:

- **Section 2, Quantitative Wildfire Risk Assessment Framework**. This section offers an overview of quantitative risk assessment process, generally. This section defines terminology, data layers, and processes which are essential understanding and using the PNW QWRA 2023 outputs.
- **Section 3, Wildfire Hazard Modeling for the Pacific Northwest Quantitative Wildfire Risk Assessment 2023**. This section provides detailed methods regarding the development of wildfire simulation inputs, calibration of wildfire models and a description of burn probability and fire intensity data layers produced for the PNW QWRA 2023.
- **Section 4, Effects Analysis for the Pacific Northwest Quantitative Wildfire Risk Assessment 2023**. This section provides detailed methods regarding HVRA characterization, as well as specific methods describing how we mapped the extent, characterized the susceptibility and assigned relative importance for each sub-HVRA.
- **Section 5, Integrated Risk Results**. This section includes maps for the integrated risk results across all HVRAs as well as HVRA-level maps.
- **Section 6, Suggested Uses and Best Practices**. This section provides readers with guidance on how to choose appropriate QWRA data layers for their project, considerations when symbolizing and classifying QWRA data, and strategies for applying PNW QWRA data to smaller geographies.
- **Appendix A, Summary of PNW QWRA 2023 Sub-HVRAs.** This is a reference summary which includes naming conventions and a brief description of each sub-HVRA.

- **Appendix B, PNW QWRA 2023 Data Description.** This is a summary of the various spatial data layers that are available for download.
- **Appendix C, Additional Hazard Products Available for the Pacific Northwest.** In addition to the hazard data used in development of the PNW QWRA 2023, Pyrologix also produced a large suite of additional hazard information and risk analytics which will be made available upon request. This section is a summary of those additional hazard products.

2 Quantitative Wildfire Risk Assessment Framework

This section provides a summary of the QWRA framework and is intended to help general audiences understand the terminology, methods and outputs common across QWRAs. Specific details about development of the PNW QWRA are in Sections three through seven.

Risk can generally be described as an estimate of the likelihood and consequence of uncertain future events (Yoe, 2016). Wildfire risk is quantified as the spatially coincident estimates of fire likelihood (burn probability), fire intensity (e.g., flame length) and the impacts (susceptibility) of highly-valued resources or assets for which risk is being evaluated (Scott et al., 2013; Figure 2). A quantitative wildfire risk assessment evaluates risk in two parts:

1. Hazard assessment
2. Effects analysis

An in-depth description of the QWRA framework and applications is available in Scott et al. (2013). Here we provide a summary of the framework and general methodology.

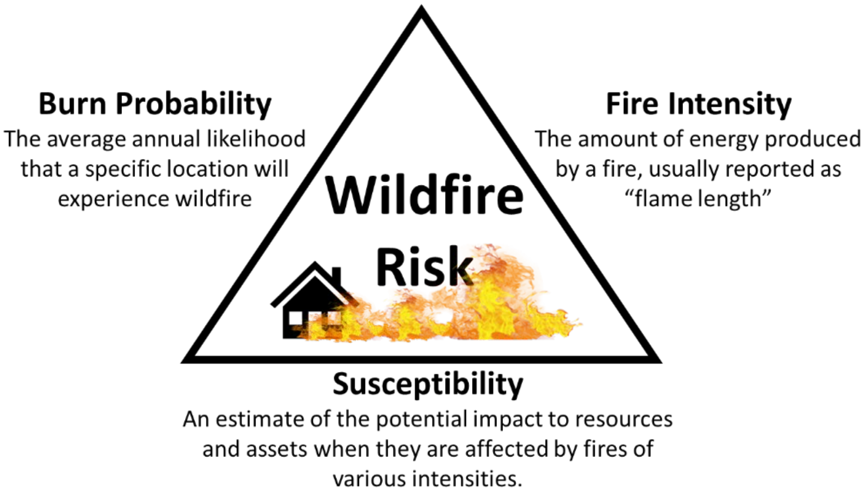

Figure 2. The wildfire risk triangle illustrates the three components that define wildfire risk.

2.1 Hazard Assessment

A hazard is a process, phenomenon, or activity with the potential to cause social, economic, or environmental degradation, including injury or death (UNODRR, 2022). Sometimes wildfire hazard is expressed as the condition of wildland fuel, but this ignores other contributing factors (i.e., weather and topography), and discounts the importance of the likelihood of experiencing a wildfire. Under the QWRA framework, wildfire hazard is comprised of both burn probability and fire intensity.

2.1.1 Burn Probability

Wildfire likelihood (burn probability) is an estimate of the average annual likelihood that a wildfire will occur at any given location. Burn probability is simulated using a model that integrates information about the physical landscape, historical fire occurrence, and historical weather observations. We simulate 10,000 or more plausible fire season scenarios across sub-regions of Oregon and Washington, each driven by a random draw of recent fire weather observations and the physical landscape (Finney et al., 2011). The number of times a point on the landscape is encountered by fire, divided by the number of simulated fire seasons, provides the estimate of average annual likelihood of fire, or burn probability. These burn probability values reflect long-term annual averages and should not be thought of as seasonal forecasts.

2.1.2 Wildfire Intensity

Wildfire intensity is a measure of how much energy is produced at the flaming front of a wildfire (Byram, 1959). Intensity is often measured in terms of flame length for ease of relating to and representing this component of wildfire hazard. Higher flame lengths represent more intense fires. The terms fire intensity and fire severity are often used interchangeably, but, in fact, they are not the same (Keeley, 2009). Fire severity refers to a measure of fire impacts on the resource or asset that has been affected. Common metrics of fire severity include tree mortality, loss of biomass or impacts to soil. Increasing fire intensity often leads to increasing fire severity, but the terms are not interchangeable. We use response functions to crosswalk fire intensity into a measure of severity, which is discussed later in this document.

Similar to burn probability, fire intensity is often quantified from simulation models that integrate information about the physical landscape and historical weather observations, making estimates across a large number of plausible scenarios. Modeled fire intensity level (FIL) outputs are usually binned into six classes:

- **FIL 1**: 0 to 2 ft. flame lengths
- **FIL 2**: 2 to 4 ft. flame lengths
- **FIL 3**: 4 to 6 ft. flame lengths
- **FIL 4**: 6 to 8 ft. flame lengths
- **FIL 5**: 8 to 12 ft. flame lengths
- **FIL 6**: greater than 12 ft. flame lengths

The FIL data layers each quantify the conditional probability that flame lengths will be within the defined range of each class. For example, at a given location FIL 1 might be 0.83, indicating that 83% of the time the location experiences a fire the flame lengths will be less than two feet high. At that same location, FIL 6 might be 0.04, indicating that 4% of the time that location experiences a fire, flame lengths exceed 12 feet. Fire hazard models simulate fires under a wide range of plausible weather conditions across the full length of fire season (e.g., June – October), so any given location will have a distribution of potential fire intensities occurring in multiple FIL classes resulting from variation in fire weather. The FIL values across all six classes will sum to one at any given location.

2.2 Effects Analysis

The effects analysis in the QWRA process addresses the consequences of wildfire to a suite of values exposed to wildfire. Estimating wildfire consequences requires that we: (1) identify highly-valued resources and assets (HVRAs) for which risk will be assessed; (2) characterize and quantify the susceptibility of each HVRA to wildfire; and (3) determine the importance of each HVRA relative to all the other HVRAs. These three steps require subject matter experts from a broad distribution of disciplines. Once complete, we can combine spatial characterizations of HVRAs with the hazard data to calculate risk.

2.2.1 Identifying HVRAs

Highly-valued resources and assets vary from one assessment to the next based on the purpose of the assessment, but generally include infrastructure, natural resources and ecosystem services on which managers base their decisions regarding the allocation of finite resources. The list of HVRAs included in a QWRA should also be specific enough to support a clear mitigation and prioritization schema. Including too many values can result in ineffective prioritization by comparing HVRAs that drive fire and land management decisions (e.g., risk to municipal water sources) to values that do not necessarily drive fire or land management decisions (e.g., risk to deer browse). When selecting HVRAs, it is also important to consider the quality of available data to map and characterize their condition. For this and other reasons, selecting HVRAs is usually a collaborative process.

Highly valued resources and assets are typically classified into sub-HVRAs based on similar characteristics. Often, sub-HVRA designations reflect management priorities and may influence the effects analysis and their relative importance (described below).

2.2.2 Quantifying Susceptibility

Highly-valued resources and assets or sub-HVRAs may have a unique response to fire which, when combined with fire hazard estimates, determines risk values. Within the QWRA framework, the effect of fire on each HVRA or sub-HVRA (susceptibility) is a function of fire intensity. Importantly, fire effects may be beneficial or adverse and, accordingly, the resulting risk may include positive or negative outcomes.

To capture varied fire effects for each HVRA or sub-HVRA at each of the six fire intensity levels, a response function is used (Table 1). Response functions are numeric values ranging from -100 to 100 indicating the magnitude of percent value change for the HVRA at each fire intensity level (FIL). Negative numbers indicate an adverse effect while positive numbers indicate a beneficial effect. To refine estimates of susceptibility, a sub-HVRA may be further characterized by covariates which do not influence relative importance but do influence how the sub-HVRA responds to fire. Covariates are not required. In the example in Table 1, the sub-HVRAs (i.e. species and habitat priority) influence both response functions and relative importance, whereas the covariates (i.e. resilience and resistance scores) only influence response functions.

Fire effects are expressed in terms of percent value change so that risk can be integrated across diverse HVRAs that are not readily comparable through typical financial market estimates. In many cases, scientific information on the susceptibility of all HVRAs to the distribution of simulated fire intensity is not available, requiring subject matter experts (i.e., resource specialists) to capture general trends in how these values respond to increasing fire intensity. Response functions are generally assigned in a collaborative workshop setting with subject matter experts as well as fire and fuels specialists.

2.2.3 Relative Importance

The QWRA framework allows for risk to multiple spatially coincident HVRAs to be integrated in a single value at any given location. From a prioritization standpoint, however, it is necessary that the integrated risk value reflect social values and fire management objectives. To help ensure that is the case, relative importance (RI) values are assigned to each HVRA, quantifying the priority status of each HVRA relative to the other HVRAs. The specific RI schema ought to reflect the priorities and values of the entire planning landscape. Given that QWRAs are decision-support tools for decision makers, it is important that leadership across the collaborative partners are present and contributing to this schema.

Relative importance is assigned in two steps. The first step is to assign RI values to each HVRA (Table 2). Relative importance values reflect mission, policy, and existing strategies which guide or constrain how agencies respond to wildfire risk. In the example in Table 2, Drinking Water is 60% as important as People and Property. The overall share of relative importance is calculated by dividing the relative importance value by the total amount of relative importance and is provided as a means to more easily compare how relative importance is distributed.

Table 1. Example of response function framework for several wildlife species. The sub-HVRA classes represent species and relative habitat priority. In the case of greater sage-grouse, a covariate further explains how the sub-HVRAs respond to fire.

			Fire Intensity Level (flame length)					
Sub-HVRA	**Share of HVRA RI**	**Covariate**	**FIL 1**	**FIL 2**	**FIL 3**	**FIL 4**	**FIL 5**	**FIL 6**
(Habitat Importance)		*(Resilience and resistance score)*	*0 - 2'*	*2 - 4'*	*4 - 6'*	*6 - 8`*	*8 - 12'*	*>12'*
Species #1, *Priority Habitat*	55%	--	20	50	-10	-60	-80	-100
Species #1, *General Habitat*	15%	--	40	20	-10	-60	-80	-100
Species #2, *Priority Habitat*	24%	High RR	30	10	0	-30	-50	-90
		Moderate RR	-10	-20	-30	-60	-100	-100
		Low RR	-10	-30	-70	-100	-100	-100
Species #2, *General Habitat*	6%	High RR	30	10	0	-30	-50	-90
		Moderate RR	-10	-20	-30	-60	-100	-100
		Low RR	-10	-30	-70	-100	-100	-100

For any HVRA where sub-HVRAs have been defined, the second step is to allocate the HVRA-level RI from step one across its constituent sub-HVRAs. Sub-HVRA level RI can be divided equally across the sub-HVRAs, or may be divided in a way that reflects management (e.g. structure density, conservation status, etc.).

Table 2. Example of how relative importance is allocated across hypothetical HVRAs.

HVRA	Relative Importance	Overall Share of Importance
Infrastructure	60	19%
Timber	40	12%
Vegetation Condition	30	9%
Drinking Water	60	19%
People and Property	100	31%
Wildlife Habitat	31	10%
Total RI	**321**	**100%**

When calculating risk, relative importance for each sub-HVRA is normalized by the relative extent of that sub-HVRA and represented as the relative importance per pixel (RIPP; Equation 1). Normalizing by relative extent is designed to ensure that risk to HVRAs with limited spatial extents (e.g. infrastructure) is not underrepresented despite its importance to fire management compared to the risk to HVRAs with broad spatial extents (e.g. ecological integrity; Scott et al., 2013).

2.2.4 Calculating Risk

Risk is estimated within the QWRA framework by combining wildfire hazard with HVRA susceptibility (Scott et al., 2013). Risk is calculated for each pixel separately based on the fire hazard data for that pixel and based on which sub-HVRAs or HVRAs are present. Given that the susceptibility of HVRAs is expressed in terms of value change, risk outputs are expressed as net value change (NVC). At each pixel, NVC can be calculated for a single sub-HVRA, or integrated across all sub-HVRAs/HVRAs present.

There are two ways of calculating NVC: conditional net value change (cNVC) and expected net value change (eNVC). As illustrated in Equation 1, cNVC is first calculated as the risk to a specific sub-HVRA:

$$cNVC_j = \sum_{i}^{n} FLP_i * RF_{ij} * RIPP_j \qquad \text{Eq. (1)}$$

Where,

$cNVC_j$ = conditional net value change for sub-HVRA j
j = specific sub-HVRA
i = fire intensity level class (i.e. FIL 1 through FIL 6)
n = total number of FIL classes (i.e. 6)
FLP_i = flame length probability for FIL class i
RF_i = response function for sub-HVRA j at FIL i
$RIPP_j$ = relative importance per pixel for sub-HVRA j

Then, cNVC for any specific HVRA is the sum of all constituent sub-HVRA cNVC:

$$cNVC_k = \sum_{j}^{m} cNVC_j \qquad \text{Eq. (2)}$$

Where,
$cNVC_k$ = conditional net value change for HVRA k
j = specific sub-HVRA within HVRA class k
m = total number of sub-HVRAs within HVRA class k

Further, cNVC can further be integrated across all or a subset of HVRAs follows in Equation 3:

$$cNVC = \sum_{k}^{r} cNVC_k \qquad \text{Eq. (3)}$$

Where,
$cNVC$ = conditional net value change for all HVRAs or a specific subset of HVRAs
k = specific HVRA class
r = total number of HVRAs across which cNVC is being integrated

Expected net value change is similarly calculated at the pixel level and can be calculated for a single sub-HVRA or HVRA, or integrated across any combination of HVRAs. To calculate eNVC, cNVC is multiplied by burn probability:

$$eNVC = cNVC * BP \qquad \text{Eq. (4)}$$

Where,
$eNVC$ = expected net value change
$cNVC$= conditional net value change
BP= burn probability

QWRAs produce a suite of decision support tools, or data layers, available to support a decision maker as is, or in conjunction with further analyses. By creating multiple data layers, QWRAs provide a lot of flexibility in how one characterizes wildfire risk to address a question or concern by end users. Integrated eNVC is the most commonly used risk characterization metric, but how one chooses to characterize risk (i.e. conditional or expected, integrated or non-integrated) depends on the intended planning process or specific question at hand. For example, fire responders use conditional risk outputs in strategic decision making or pre-planning response strategies since the wildfire is present or assumed present for their decision making. These estimates are also helpful for understanding where values are concentrated despite their burn probability. Alternatively, eNVC supports the efficient allocation of finite resources for risk reduction activities aimed at maximizing risk reduction by strategically targeting areas with greatest likelihood of negative outcomes in any given year. Integrated risk outputs are essential for creating cohesive, cross-boundary understandings of risk, while non-integrated risk products might be easier to comprehend or target a specific resource of interest when financial resources are directed that way.

3 Wildfire Hazard Modeling for the Pacific Northwest Quantitative Wildfire Risk Assessment (2023)

3.1 Fuelscape Development

To model wildfire hazard for the PNW QWRA 2023, Pyrologix LLC developed a modeling landscape (fuelscape) that represents the best approximation of the spatial arrangement and characteristics of fuel for fire season 2022. The fuelscape consists of geospatial raster datasets representing surface fuel model (FBFM40), canopy cover (CC), canopy height (CH), canopy bulk density (CBD), canopy base height (CBH), and topography characteristics (i.e. slope, aspect, elevation). LANDFIRE (LANDFIRE, 2022))data provided the foundation for characterizing the fuelscape, but Pyrologix and PNW QWRA partners compiled spatial disturbance records to make the fuelscape as contemporary as possible, engaged over 50 subject matter experts to refine the fuelscape based on their knowledge and created custom fuel models to improve representation of hazard in agricultural and developed areas.

The LANDFIRE program assigns FBFMs and canopy characteristics using two primary input layers: Existing Vegetation Type (EVT) and Map Zone (MZ). One challenge inherent with large analysis areas, such as the Pacific Northwest region, are seamlines that result from different rulesets for the same EVT across MZs. To reconcile across MZ boundaries, rules were filtered by Pyrologix LLC to allow only one ruleset per EVT for the entire fuelscape. When several MZs had different rules for a specific EVT, Pyrologix LLC determined which MZ had the greatest share of a given EVT and that ruleset was applied across the landscape.

The LANDFIRE fuel data provided the basis for the fuelscape, but was subsequently edited based on expert opinion and local knowledge. Pyrologix LLC hosted a fuel calibration workshop February 1-3rd, 2022 which included 36 wildland fire professionals from across the PNW representing the USDA Forest Service, Department of Interior agencies, Oregon Department of Forestry, Washington Department of Natural Resources, The Nature Conservancy, Oregon State University, and other partners. During the workshop, participants reviewed and edited LANDFIRE fuel data and mapping rulesets to reflect local experience and expectations with the goal of producing more accurate simulated fire behavior results.

To represent as contemporary a fuelscape as possible, Pyrologix LLC incorporated spatial disturbance data representing wildfires and fuel treatments that occurred up through the end of 2021 and modified LANDFIRE FBFM40 data to reflect post-disturbance conditions. Disturbance modifications took into consideration the type of disturbance, the severity, and the time since the disturbance occurred. Fuel treatment records were available from the Forest Activity Tracking System (FACTS) for the USDA Forest Service and the National Fire Plan Operations and Reporting System (NFPORS) for Department of Interior. Washington Department of Natural Resources and Oregon Division of Forestry also provided historical fuel treatment data.

The PNW QWRA 2023 included two new fire behavior fuel models that were designed to estimate fire spread in agricultural and developed areas (Figure 3). In the PNW QWRA 2018, most agricultural and developed areas were characterized as non-burnable because, at the time, there was not adequate way to represent fire spread in those areas during simulations. As a result, many agricultural and developed areas had no risk information in the PNW QWRA 2018.

Pyrologix LLC used two custom fuel models for the PNW QWRA 2023 The Burnable Ag fuel model allowed fires to spread into identified agricultural pixels. However, to be more reflective of observed outcomes, fires were not allowed to ignite in agricultural pixels. Fire spread in dryland agriculture types was represented with a GR2 FBFM, and GR1 in other agricultural types. Similarly, the Burnable Urban fuel model allowed fires to transmit into developed areas under extreme fire weather conditions. The distance which a simulated fire transmitted into a developed area was a function of the fire weather severity.

The final fuelscape adjustment was an effort to account for the mitigating effects of irrigation on fire spread. OSU identified all pixels estimated to have been irrigated in at least three of the last five years from the most recent IrrMapper data available (2017 - 2021; Figure 3; Ketchum et al., 2020). IrrMapper classifies land cover annually, including irrigated agriculture, using machine learning to evaluate geospatial data and satellite imagery across the West. The selected IrrMapper data served as a mask to modify underlying fire hazard data. In pixels identified as irrigated in three out of the last five years, we set the burn probability to 0.0001, assuming that it is very unlikely for persistently irrigated pixels to burn. Similarly, we set the probability of FIL1 to 0.75 and FIL2 to 0.25 while FIL3 through FIL6 were set to zero. The assumption regarding fire intensity was that in the unlikely event that a fire were to transmit into persistently irrigated land, the fuel moisture would likely be high and therefore fire intensities would be low.

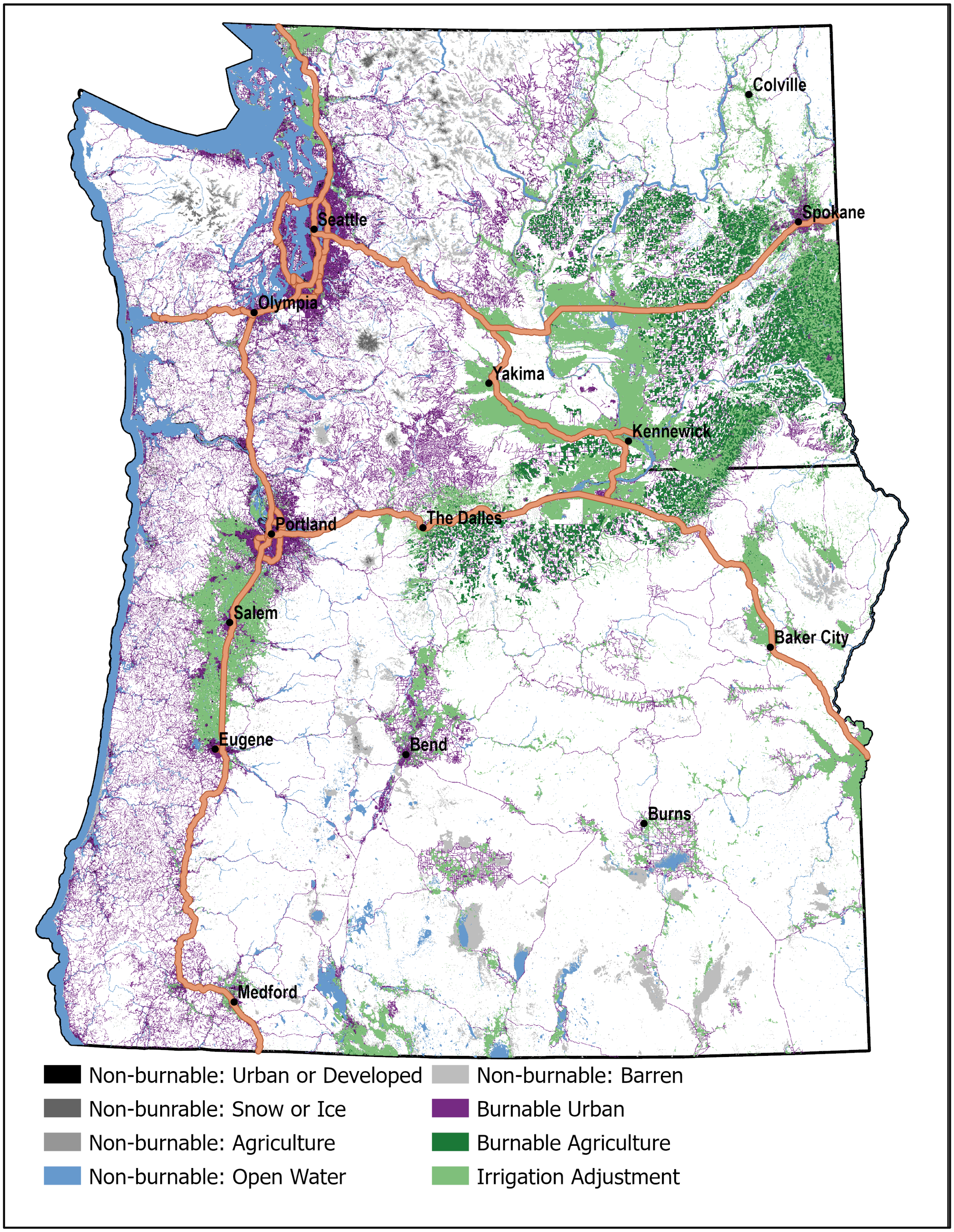

Figure 3. Non-burnable and custom fuel models, and fuelscape adjustments used in wildfire hazard modeling for PNW QWRA 2023. Custom fuel models include burnable agriculture and burnable urban. The irrigation adjustment includes pixels identified as irrigated in at least three of the last five years (Ketchum et al., 2020) and where we adjusted hazard outputs to reflect mitigating effect of irrigation. All raster data is drawn with pyramids to make viewing easier; the actual extent of these fuel models and adjustments is less than shown here.

3.2 Wildfire Hazard Modeling

3.2.1 Burn Probability

Pyrologix LLC estimated burn probability using the large-fire simulator, FSim (Finney et al., 2011). FSim is a Monte Carlo model which simulates a full range of plausible fires and fire seasons based on the variability in factors that influence fire occurrence including, ignition location, seasonality, and fire weather conditions. Fire occurrence probability in FSim is a function of a logistic regression between documented historic large fire ignitions in the study area and the daily Energy Release Component (ERC) at the time of ignition (Cohen and Deeming, 1985). For each day of a simulated fire season, FSim draws from plausible weather scenarios and simulates an ignition if the ERC exceeds the 80th percentile of historic ERC values (Riley et al., 2013). When an ignition is simulated, FSim generates a spatial fire perimeter by computing daily fire spread based on weather and available fuels while estimating the effect of suppression. FSim operates on a daily time step each season and is usually run for at least 10,000 seasons. Burn probability is calculated by adding up the number of instances that a pixel was intersected by simulated fire and dividing the sum by the total number of simulated seasons. Accordingly, burn probability from FSim is an estimate of average annual wildfire likelihood at each pixel.

For the PNW QWRA 2023, Pyrologix LLC calibrated FSim to historic fire occurrence and observed fire weather characteristics and simulated 10,000 fire seasons for each of 23 Fire Occurrence Areas (FOAs, Figure 4). For each FOA, FSim was calibrated to a distribution of fire size and annual number of large fires using spatial fire records from the Fire Occurrence Database (FOD; Short, 2022) which includes fires 1992 – 2020, and records from state and federal agencies for fires that occurred in 2021. For each FOA, the logistic regression between large fire occurrence and ERC was calculated using daily weather records (2007 – 2021) sampled from a representative remote automated weather stations (RAWS) within each FOA. In FOAs 423 and 404, the Labor Day 2020 fires were excluded from the calibration statistics in order to prevent overpredicting the size and likelihood of large wildfires that would lead to overpredictions of rare events. Extensive research on these wildfires has shown the casual wind event to be anomalous. Initial modeling was done at 120-meter pixels and then downscaled to account for unburnable portions of the landscape detected at 30 meters.

The PNW QWRA 2023 burn probability raster was produced by merging the burn probability raster from each FOA (Figure 5).

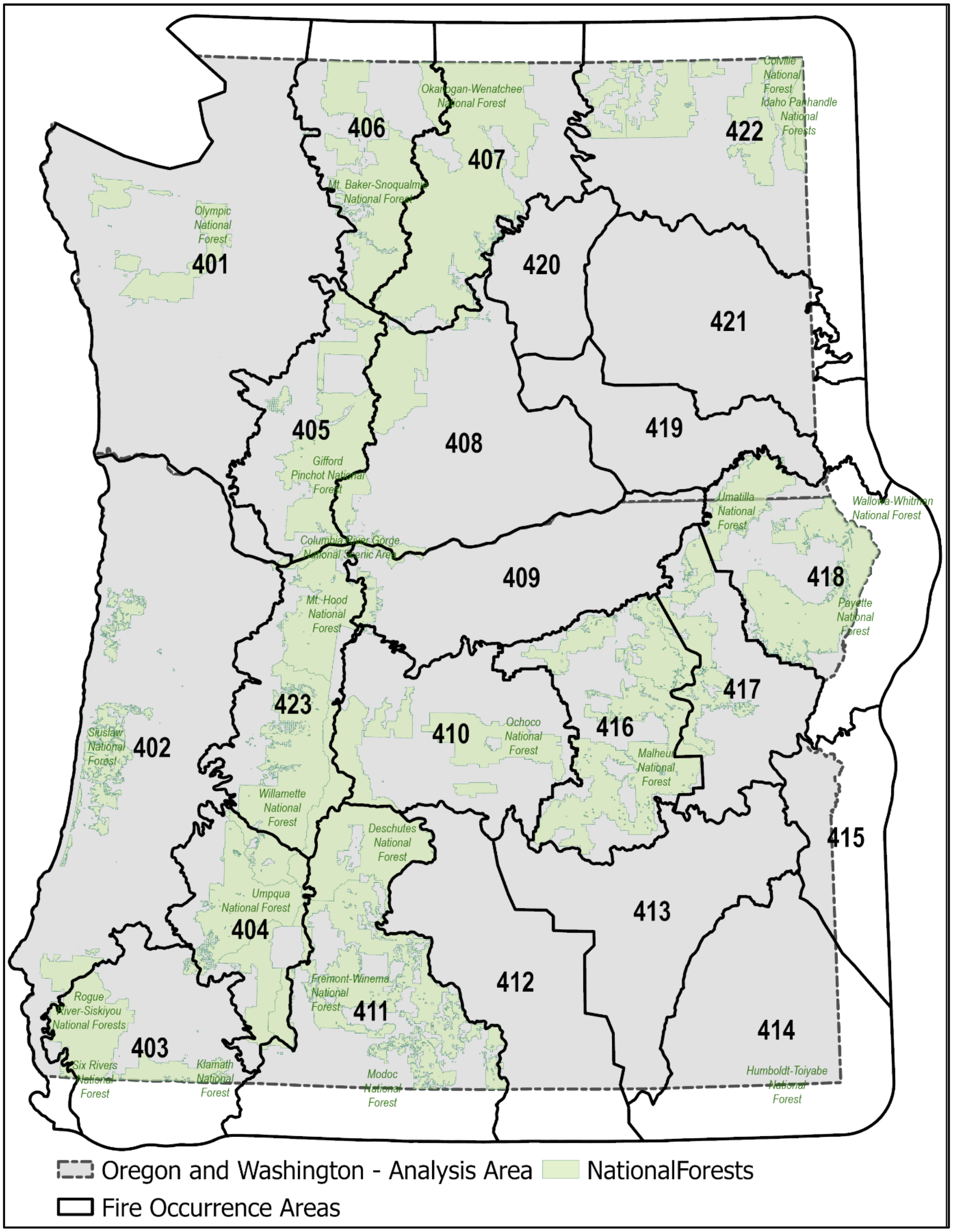

Figure 4. The 23 Fire Occurrence Areas (FOAs) used to calibrate wildfire hazard models and run simulations. Fire Occurrence Areas extend beyond the analysis area (i.e. Oregon and Washington) to allow for fires that ignite outside the analysis area but transmit into it.

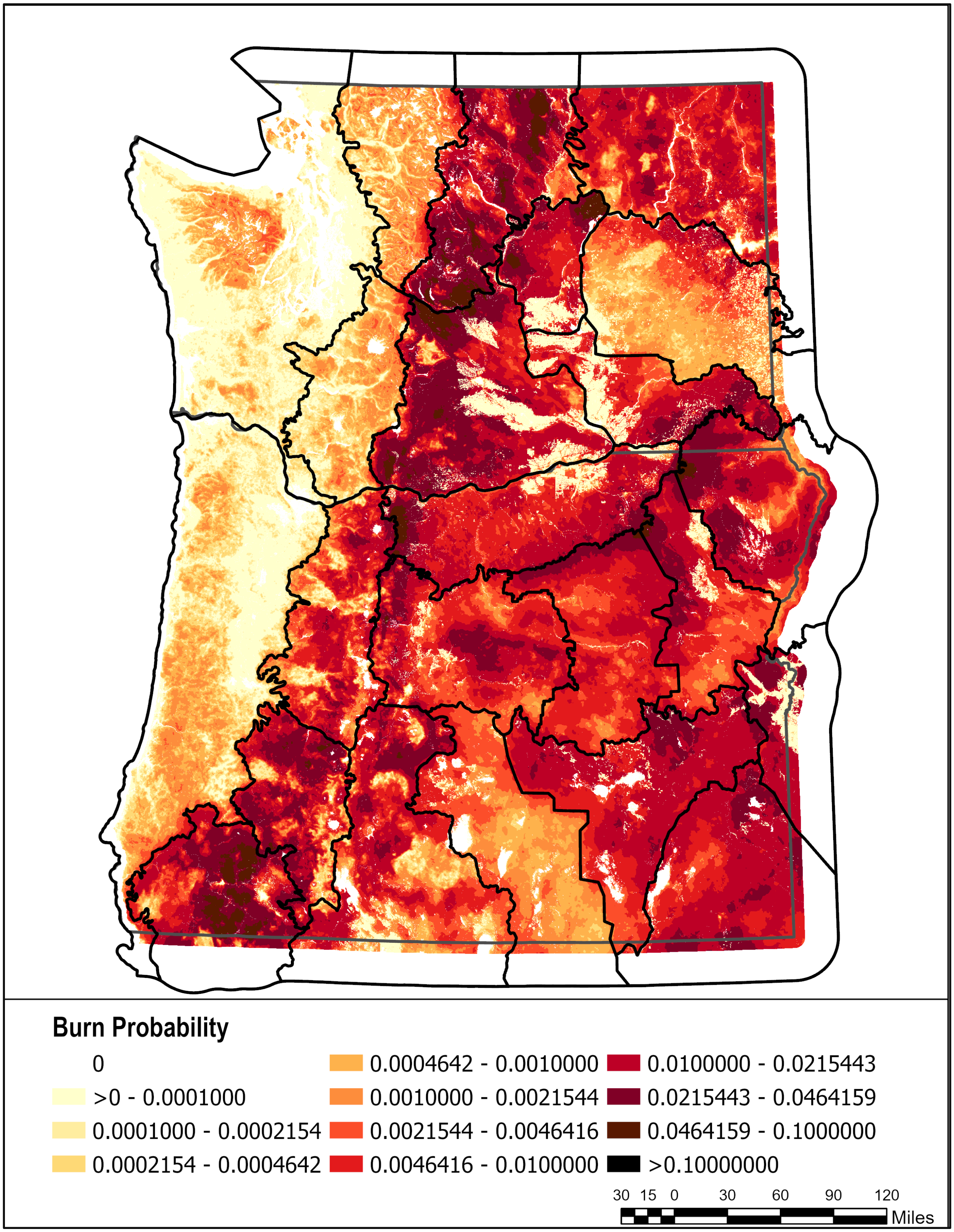

Figure 5. Burn probability across the analysis area, including changes to agricultural lands informed by IrrMapper data.

3.2.2 Wildfire Intensity

Pyrologix LLC generated spatial estimates of wildfire intensity using WildEST (Scott, 2020). WildEST is a deterministic wildfire modeling tool that uses a command-line version of FlamMap (Finney, 2006) to simulate 216 deterministic scenarios based on combinations of wind speed, wind direction and fuel moisture content. The 216 scenarios were weighted according to Weather Type Probabilities (WTPs), where more weight was assigned to scenarios associated with higher spread conditions. Pyrologix LLC used 4-Km gridded weather data to develop the 216 scenarios. WildEST simulations were performed at 30-meter resolution.

WildEST produced spatially explicit flame length probabilities for each of the six fire intensity levels (FIL) required for fire effects analysis in the QWRA framework (Figures 6 - 11). Fire intensity level rasters represent the probability of a fire occurring within the specified flame length range based on heading and non-heading fire types simulated in WildEST.

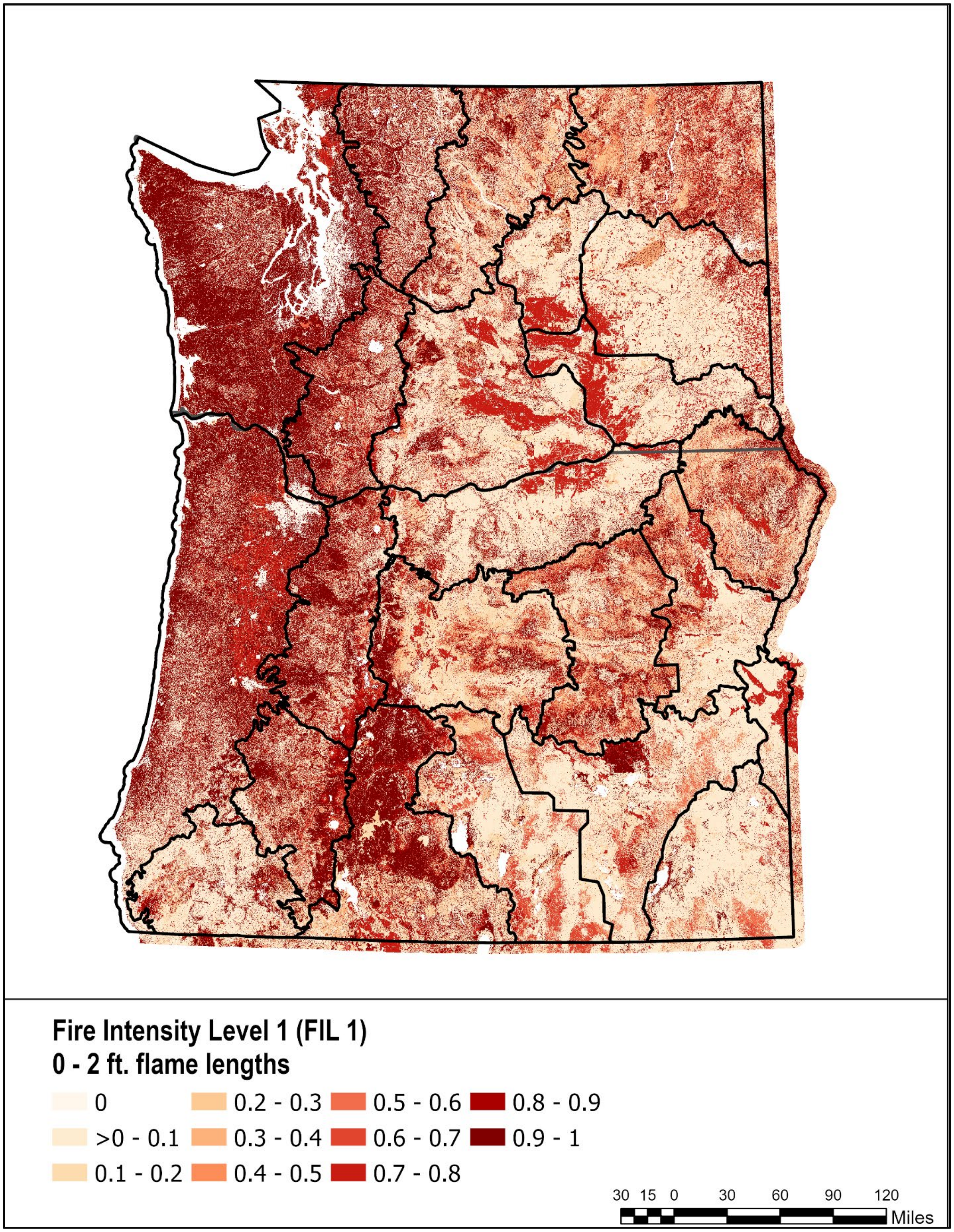

Figure 6. The conditional probability of Fire Intensity Level 1 (FIL 1) flame lengths, 0 – 2 ft. Fire Occurrence Areas are clipped to the Oregon and Washington boundary.

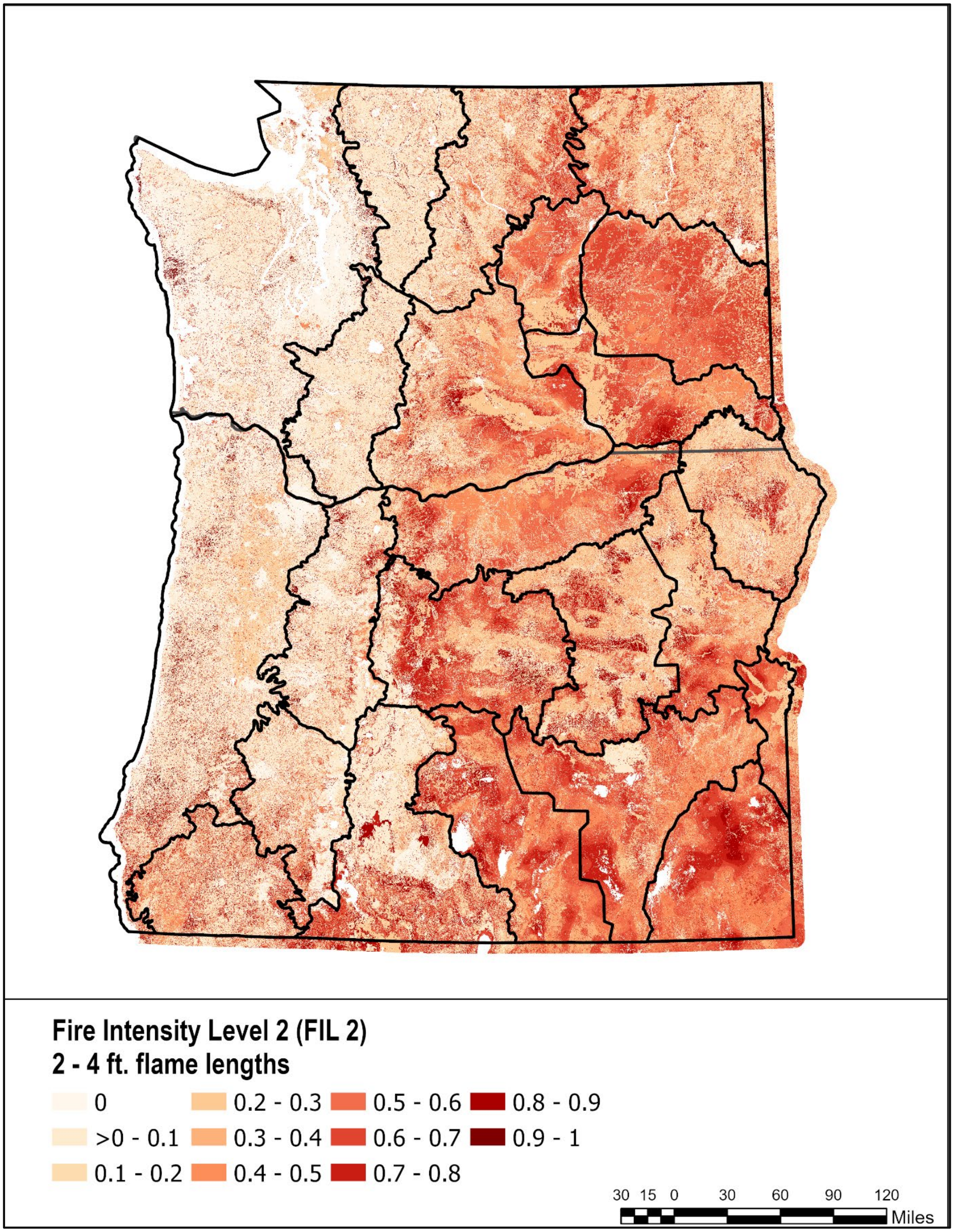

Figure 7. The conditional probability of Fire Intensity Level 2 (FIL 2) flame lengths, 2 - 4 ft. Fire Occurrence Areas are clipped to the Oregon and Washington boundary.

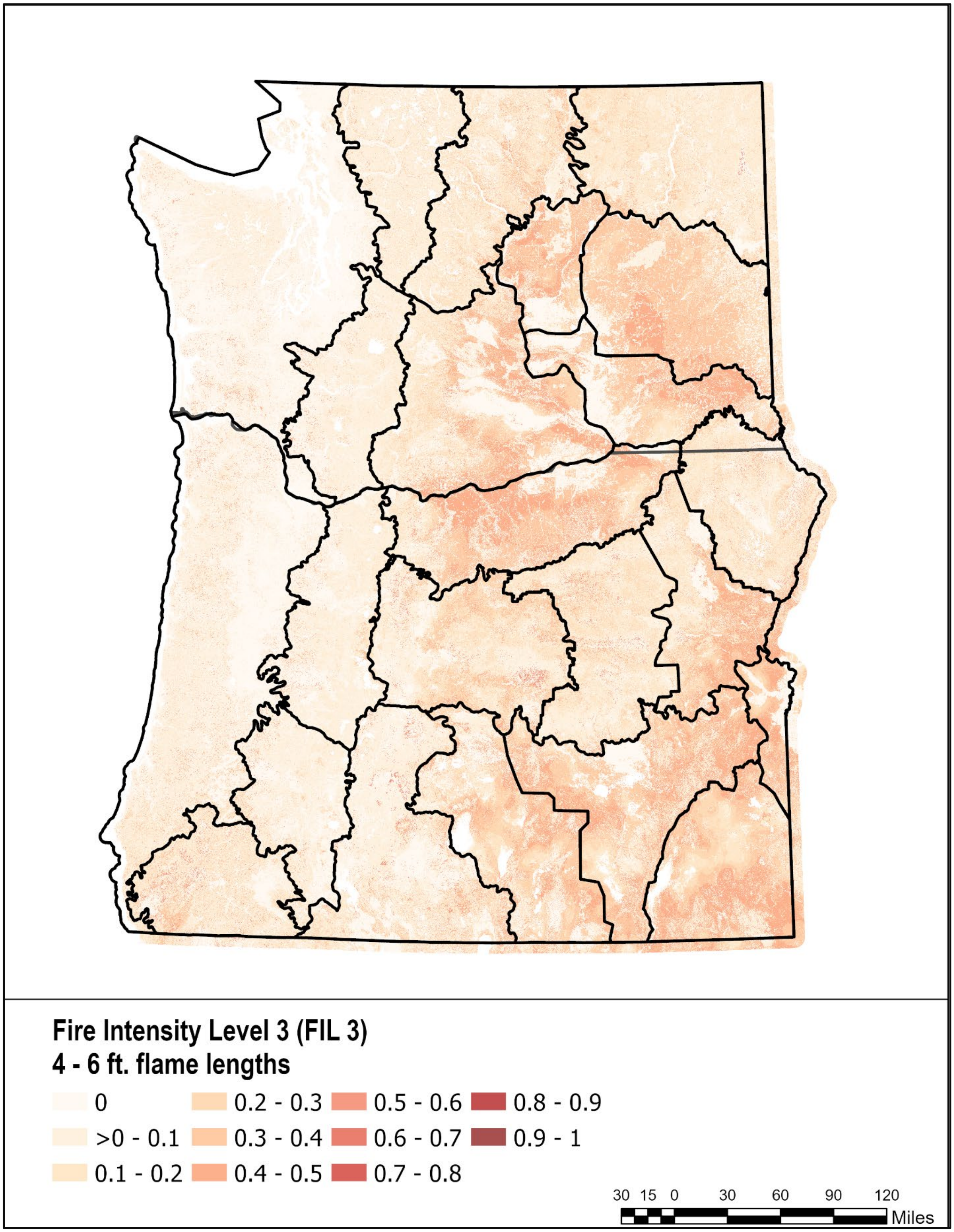

Figure 8. The conditional probability of Fire Intensity Level 3 (FIL 3) flame lengths, 4 - 6 ft. Fire Occurrence Areas are clipped to the Oregon and Washington boundary.

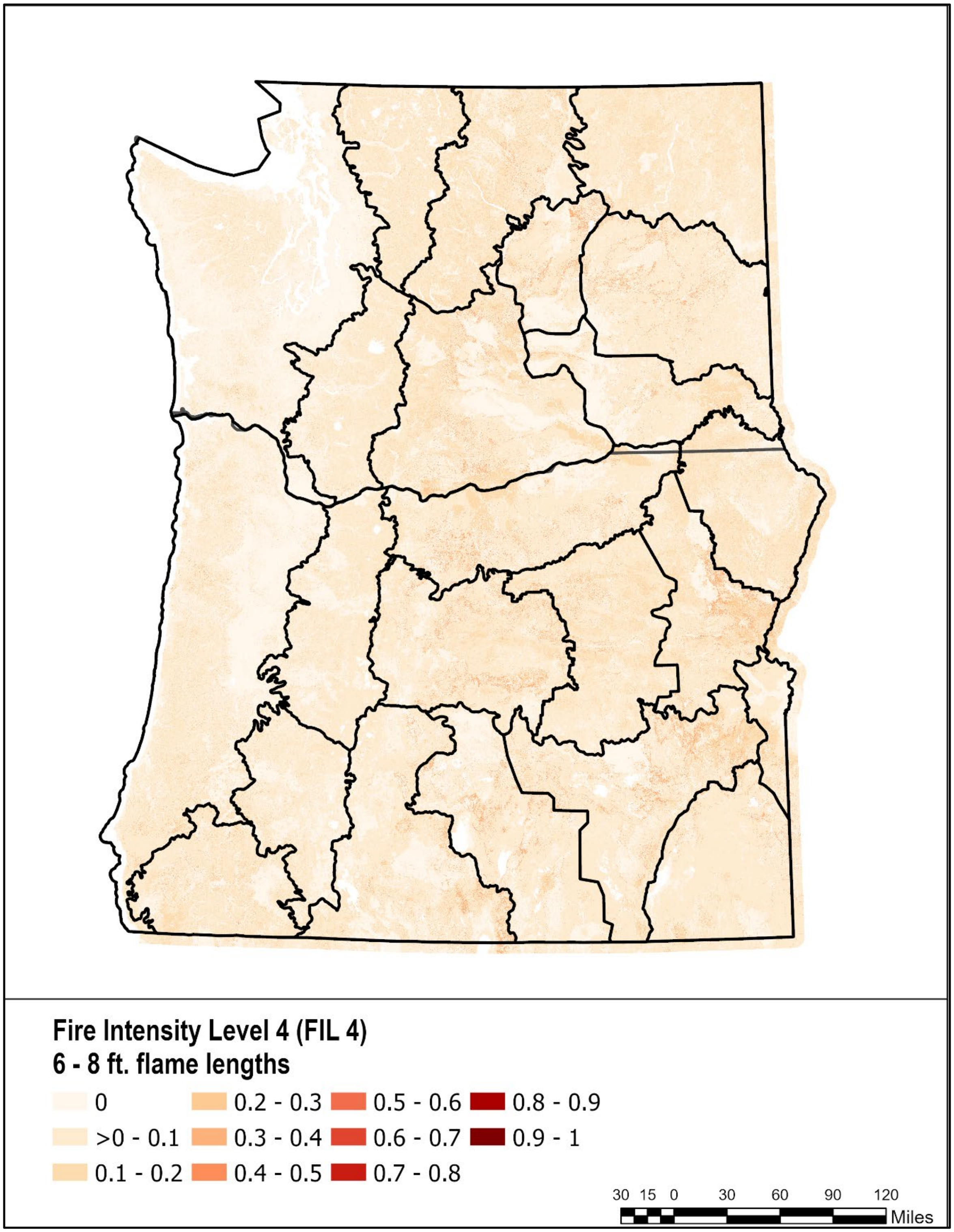

Figure 9. The conditional probability of Fire Intensity Level 4 (FIL 4) flame lengths, 6 - 8 ft. Fire Occurrence Areas are clipped to the Oregon and Washington boundary.

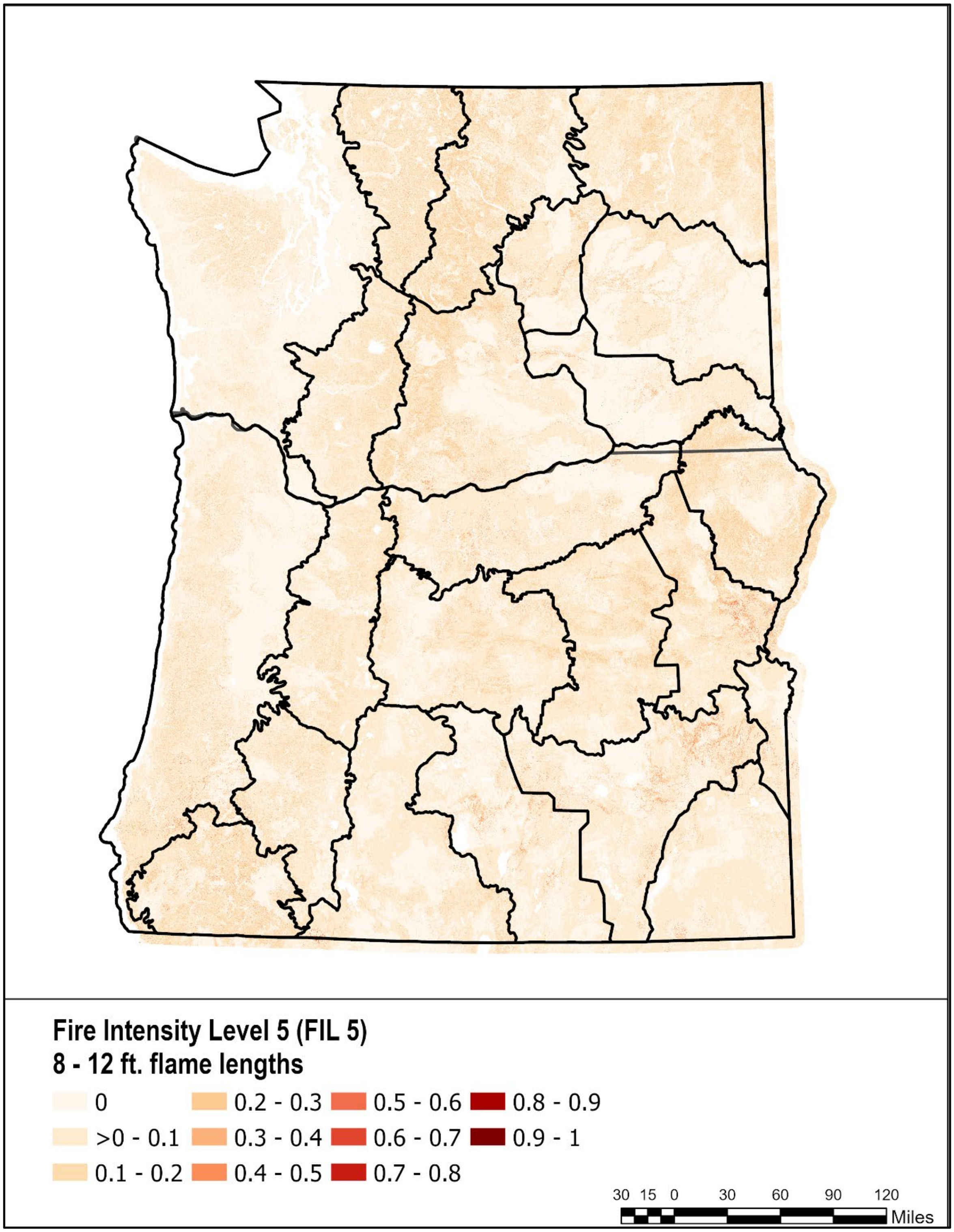

Figure 10. The conditional probability of Fire Intensity Level 5 (FIL 5) flame lengths, 8 - 12 ft. Fire Occurrence Areas are clipped to the Oregon and Washington boundary.

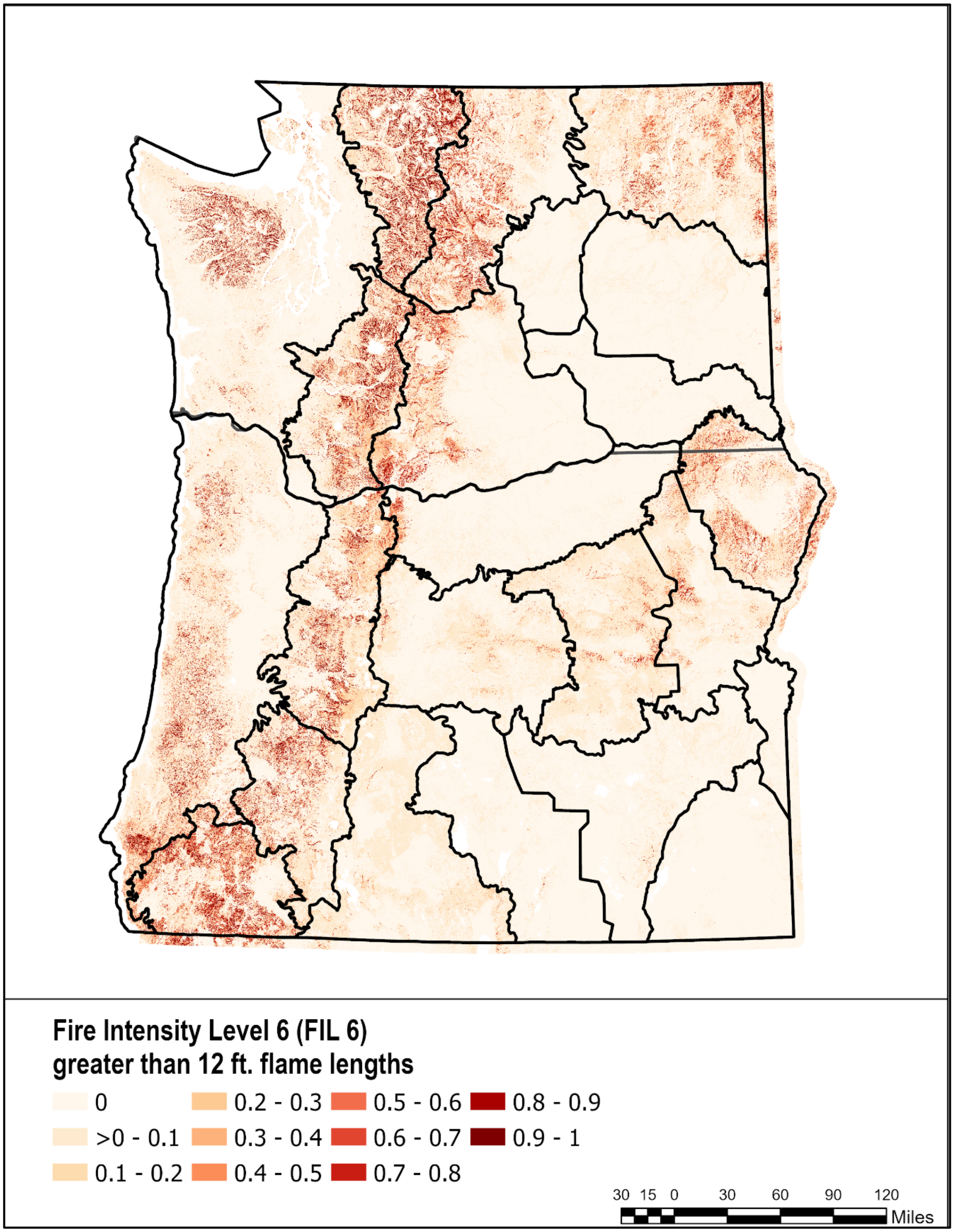

Figure 11. The conditional probability of Fire Intensity Level 6 (FIL 6) flame lengths, greater than 12 ft. Fire Occurrence Areas are clipped to the Oregon and Washington boundary.

4 Effects Analysis for the Pacific Northwest Quantitative Wildfire Risk Assessment (2023)

4.1 Identifying HVRAs for the PNW QWRA 2023

PNW QWRA partners updated the PNW QWRA 2018 HVRAs based on best available science and feedback from PNW QWRA stakeholders. In November 2022, we distributed a digital survey to over 100 stakeholders requesting their feedback on which HVRAs to include in the assessment and how best to represent them. Most of the feedback we received focused on improving the characterization of existing HVRAs, although we did add a few new HVRAs to better represent values across Oregon and Washington.

Table 3. Summary table of HVRAs included in the 2023 QWRA and how they compare to HVRAs in the previous assessment.

HVRA	Included in 2018?	Description of changes
People and Property	Yes	PNW QWRA 2018 used data estimating the distribution of residential structures. We updated to a building footprints data layer that includes residential and non-residential structures.
Infrastructure	Yes	Datasets updated. Some energy production and storage sites were added to list of sub-HVRAs not accounted for in the building footprints dataset. Historical structures, sawmills, and recreation sites are omitted as they are captured in the building footprints dataset.
Drinking Water	Yes	We updated the process for assessing watersheds directly contributing to drinking water. The extent of watersheds changes and reduced significantly across the Columbia Plateau in Washington.
Timber	Yes	We updated the timber volume (i.e., size class) data layers to the most recent estimates. We added private non-industrial ownership as a sub-HVRA.
Agriculture	No	We added this value to the PNW QWRA, accounting for annual and perennial crops.
Ecological Integrity	Yes	We updated the datasets for forest vegetation, but otherwise assessed this value in much the same way. We added new rangeland sub-HVRAs and estimated the effect of wildfire on post-fire annual grass invasion and juniper encroachment.
Wildlife Habitat	Yes	Similar methods with updated datasets. Refined extent and characterization of northern spotted owl. Removed Lahontan cutthroat trout.
Recreation	No	Similar methods but taken out from under the Infrastructure HVRA and placed in its own HVRA.

More than 30 project partners and subject matter experts reviewed the final list of HVRAs and mapping methods for mapping during a three-day workshop March 1-3, 2023. Participants included research scientists, fire and fuels planners, ecologists, wildlife biologists, and resource specialists from across Oregon and Washington. We maintained all HVRAs from the previous risk assessment and added two new HVRAs (Table 3). However, we did adopt updated data layers and methodology for characterizing individual HVRAs that significantly improved their estimates.

During a workshop March 1-3, 2023, relevant subject matter experts from around the PNW, including wildfire fire professionals, assigned response functions to each sub-HVRA. For HVRAs or sub-HVRAs carried over from PNW QWRA 2018, the pre-existing response functions served as a starting point, but, in some cases, changed in the updated QWRA in this update based on new science or gained knowledge. In the case of HVRAs and sub-HVRAs new to the PNW QWRA 2023, we asked working groups of subject matter experts to develop draft response functions which were then reviewed, and when necessary adjusted, by a larger audience during the response function workshop previously mentioned above.

4.2 Relative Importance in the PNW QWRA 2023

Leadership representatives from the Oregon Department of Forestry, Washington Department of Natural Resources, U.S. Forest Service, and the Bureau of Land Management assigned relative importance to each of the eight HVRAs during a meeting on May 31, 2023 (Table 4, Figure 12). Following the assignment of HVRA RI, we allocated each HVRA's RI across its constituent sub-HVRAs. sub-HVRA relative importance was determined based on expert judgement and by referring to policy or management documents. In Section 4.3 we report the overall share of each HVRA's RI allocated to each sub-HVRA. Importantly, the share of RI assigned to each sub-HVRA reflects both the relative importance placed on the sub-HVRA and the spatial extent of the sub-HVRA.

Table 4. Relative importance for HVRAs in the PNW QWRA 2023. Relative importance was assigned by QWRA project partner leaders. The share of relative importance was calculated by dividing a relative importance value by the total amount of importance (i.e. 284).

HVRA	Relative Importance	Share of Relative Importance
People and Property	100	35%
Drinking Water	50	18%
Infrastructure	45	16%
Timber	35	12%
Wildlife Habitat	20	7%
Ecological Integrity	30	11%
Agriculture	3	1%
Recreation	1	0.40%
Total	**284**	**100%**

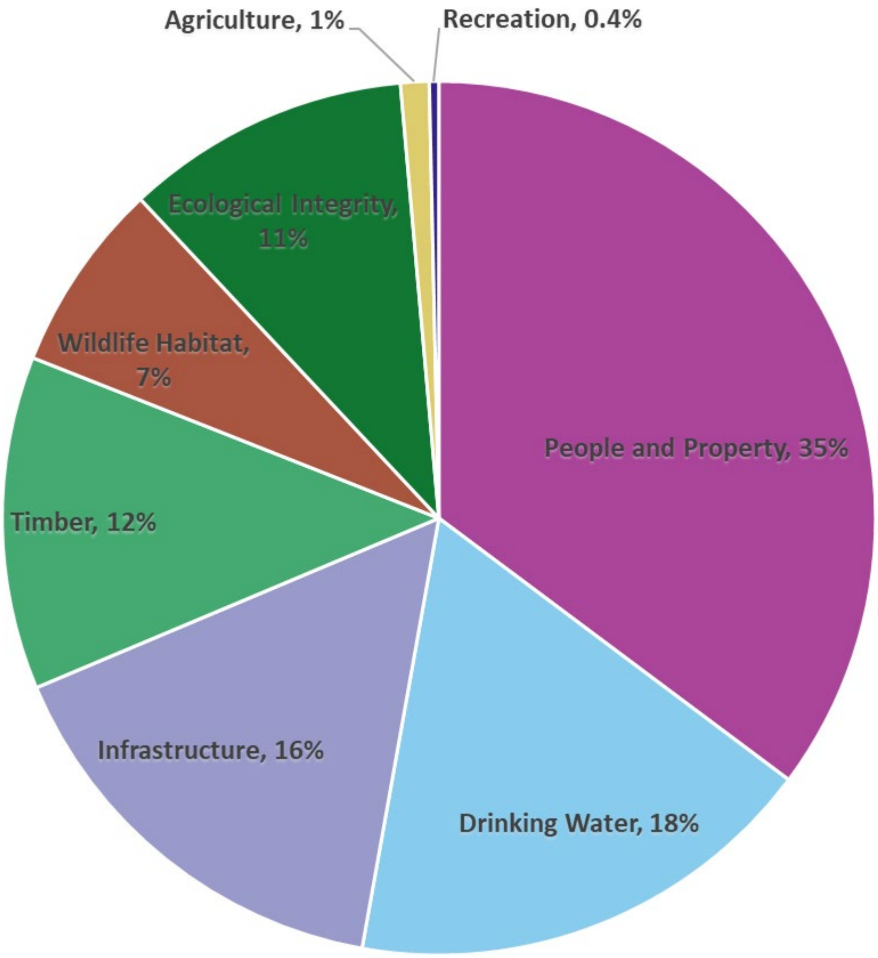

Figure 12. Overall relative importance among HVRAs in PNW QWRA 2023.

4.3 HVRA Summaries

The following sub-sections describe the detailed methods we used to define and map each sub-HVRA, to characterize susceptibility, and to assign relative importance.

4.3.1 People and Property

4.3.1.1 Intent

The People and Property HVRA assesses wildfire risk to residential and non-residential structures and associated property infrastructure.

4.3.1.2 Summary of changes

For this update, we expanded the People and Property HVRA to include non-residential structures and associated property infrastructure. This change is, in part, a result of using building footprint datasets to identify structure locations, as well as the need to account for risk to non-residential structure that in some cases is more important to community resilience than homes (e.g., hospitals, schools). As a result of the changes, the extent of the People and Property HVRA expanded by 1.2 million acres compared to the extent in the PNW QWRA 2018.

4.3.1.3 Methods

We determined the People and Property HVRA extent using a combination of structure location spatial datasets. Microsoft Building Footprints (MBF) served as the foundational dataset-level source of structure location data (Microsoft, 2018), but was updated with local data. The MBF data maps the footprint of individual buildings using a machine learning algorithm applied to aerial imagery. This dataset creates polygons of building footprints that are subsequently converted to points for estimating the number or density of structures.

In Oregon and Washington, we used refined structure point location data which was based on MBF, but amended with additional information from regional, county and local planning sources. In Oregon, the Statewide Building Footprint of Oregon (SBFO) data produced by the Oregon Department of Geology and Mineral Industries (Williams, 2021) used regional, county and local planning data to review and amend MBF data. The SBFO process deleted 18,961 false positive structure locations from the original MBF data, but added 39,188 structures which had previously been unrepresented in the MBF data. In Washington, the Department of Natural Resources similarly modified the MBF data using statewide parcel information to add missing structures and remove false positives. The Washington structure location data is unpublished. To determine structure densities in adjacent states (i.e. California, Nevada, Idaho) to extend out our modeling region beyond the borders of Oregon and Washington (address edge effects), we relied on MBF point locations from each state.

We further classified this HVRA into sub-HVRAs based on the estimated structure density. We calculated density using the kernel density function in ArcPro v3.0 using a 744-foot search radius (approx. 40 acres) and selecting expected structure counts for the output. The kernel density approach concentrates the value on and adjacent to known structure locations, but also assigns some structure density to the surrounding 40-acre area to account for smaller outbuildings potentially missed, additional property amenities, and other property-level improvements or adjacent vegetation that have direct values to the occupants of the primary structures. We then assigned seven density-based sub-HVRAs to account for variation in value from the structures outwards using the following schema:

1. **Very Low Density**: > 0 structures per acre - 1 structure per 40 acres
2. **Low Density**: 1 structure per 40 acres - 1 structure per 20 acres
3. **Moderately Low Density**: 1 structure per 20 acres - 1 structure per 10 acres
4. **Moderate Density**: 1 structure per 10 acres - 1 structure per 5 acres
5. **Moderately-High Density**: 1 structure per 5 acres - 1 structure per 2 acres
6. **High Density**: 1 structure per 2 acres - 3 structures per acre
7. **Very High Density**: > 3 structures per acre

Concurrently, the susceptibility of people and property was stratified by structure density (Table 5). We assumed susceptibility at any given fire intensity level was consistent across the sub-HVRAs until moderately-high structure densities when the response becomes more negative at lower fire intensity levels. The responses are designed to reflect operational limitations in higher density environments as well as the increased potential for structure to structure transmission.

Thirty-five percent of the overall relative importance was allocated to the People and Property HVRA. Within the HVRA, relative importance was allocated proportional to the average number of structures per pixel across the sub-HVRAs. The most importance was allocated to the Very High Density sub-HVRA and the least to the Very Low Density sub-HVRA.

Table 5. Response functions for sub-HVRAs in the People and Property HVRA. Share of HVRA RI is the amount of the HVRA's relative importance assigned to each sub-HVRA.

		Fire Intensity Level (flame length)					
		FIL 1	**FIL 2**	**FIL 3**	**FIL 4**	**FIL 5**	**FIL 6**
Sub-HVRA	Share of HVRA RI	*0 - 2'*	*2 - 4'*	*4 - 6'*	*6 - 8`*	*8 - 12'*	*>12'*
Very low density; > 0 structures - 1 structure per 40 acres	< 1%	-10	-20	-40	-80	-100	-100
Low density; 1 structure per 40 - 1 structure per 20 acres	1%	-10	-20	-40	-80	-100	-100
Moderately low density; 1 structure per 20 - 1 structure per 10 acres	3%	-10	-20	-40	-80	-100	-100
Moderate density; 1 structure per 10 - 1 structure per 5 acres	7%	-10	-20	-40	-80	-100	-100
Moderately high density; 1 structure per 5 - 1 structure per 2 acres	14%	-10	-30	-50	-80	-100	-100
High density; 1 structure per 2 - 3 structures per acre	47%	-20	-40	-60	-80	-100	-100
Very high density; > 3 structures per acre	28%	-30	-50	-70	-100	-100	-100

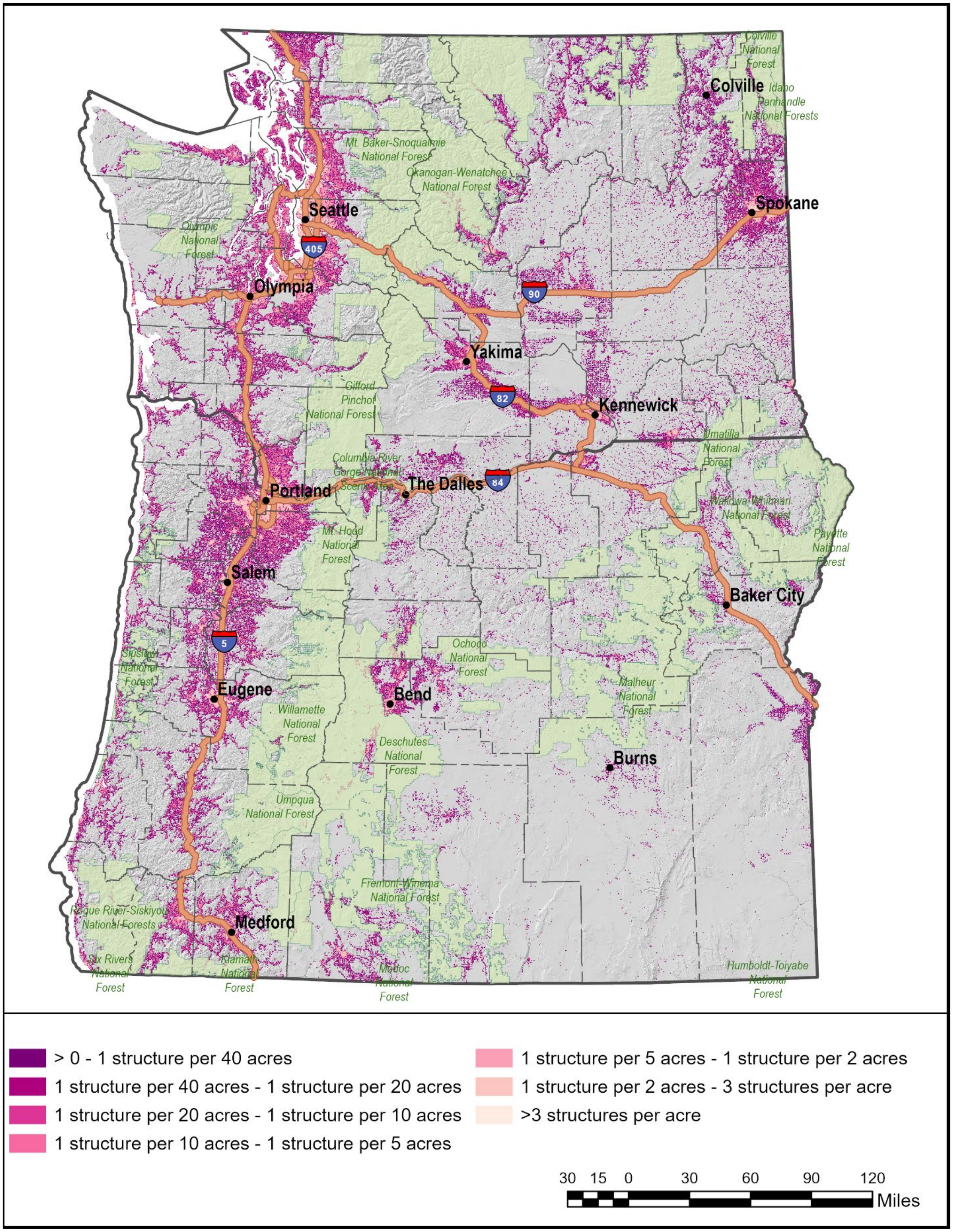

Figure 13. Extent of each sub-HVRA in the People and Property HVRA.

4.3.2 Ecological Integrity

4.3.2.1 Intent

Overall, the Ecological Integrity HVRA is intended to capture the quality and condition of ecosystems and how they respond to wildfires. In the PNW QWRA 2018, this HVRA was called Vegetation Condition.

4.3.2.2 Ecological Integrity, Forested Ecosystems

Summary of changes

We made two notable changes to the ecological integrity data layer within forested ecosystems. First, we excluded the Ecological Integrity HVRA from some privately-owned forested lands based on zoning codes and presumed land management objectives. In total, approximately 5 million forested acres were excluded from the HVRA, largely in western Oregon and Washington or in populated centers throughout the rest of the region.

Secondly, we adjusted response functions in mid- and late-seral forests to account for the relative time required to reestablish them once lost. Generally, we assigned more negative response to transitions from mid- or late-seral structure to early seral structure. In PNW QWRA 2018, response to fire was based only on the relative abundance of the post-fire seral class with respect to historic ranges of variation. The change was first premised on the declining extent of old-growth forests in Oregon and Washington and the amount of time and uncertainty involved in ever re-establishing them once lost. Subsequently, we reasoned that mid-seral structure also takes more time to recover than early-seral structure, and mid-seral structure is essential along the pathway to recovering late-seral structure which is departed from its historical range of variation.

Methods

The Forested Ecological Integrity process evaluated existing structural conditions and assesses whether wildfire moves forest structure towards or away from desired restoration targets. The framework and methods are described in detail in Laughlin et al. (2023), DeMeo et al. (2018), and Haugo et al. (2015).

To begin, we mapped the extent of the HVRA using forest structure data (LEMMA, 2017). However, we constrained the extent further to exclude certain privately-owned and developed landscapes. While ecological integrity is certainly a goal for many private landowners, we assumed that relatively few of them have the capacity or risk tolerance to advance ecological integrity through effects of wildfire. To that end, forested Ecological Integrity was not mapped in the following areas:

- *Within urban growth boundaries and the wildland urban interface (WUI)*. Washington Dept. of Natural Resource and Oregon Dept. of Forestry provided statewide WUI maps. Washington State Dept. of Ecology and Oregon Dept. of Land Conservation and Development provided statewide urban growth boundary datasets.

- *Within tax lots zoned as residential, commercial or industrial.* In Oregon, we referred to the most contemporary statewide zoning spatial data (Oregon Department of Land Conservation and Development, 2023)and zoning code classifications (Oregon Department of Land Conservation and Development, 2014). We mapped forested Ecological Integrity on lands classified as Parks and Open Space, Open Space or Conservation, Federal Forest, Federal Range, Indian Reservation, Tribal Trust, Forest, Prime Forest 80, Secondary Forest 80, Mixed Farm Forest 80 and Mixed Farm Forest 160. Additionally, spatial planning data is not available for all Oregon counties, and, in the absence of zoning data, we elected to map forested Ecological Integrity on all lands. Forested Ecological Integrity was excluded from all other zoning codes.

In Washington, we used spatial land use classification data from the Washington State Forestland Database (Rodgers et al., 2019) and zoning code descriptions (Washington State Legislature, 2023). We mapped forested Ecological Integrity on lands classified as Parks, Designated Forestland, and all Undeveloped Land and Water Areas. Forested Ecological Integrity was excluded from all other zoning codes.

- *Within tax lots managed as private industrial timberland.* We used spatial timberland ownership classifications (Atterbury Consultants Inc., 2023) and excluded lands manage by Real Estate Investment Trusts, Timber Management Investment Organizations, and Industrial Private Forestland Owners.

- *Where forests overlap with the People and Property HVRA.* We excluded forested Ecological Integrity as a mapped HVRA on forested pixels that were also mapped within the extent of the People and Property HVRA.

Within the modified extent, we characterized forest structure (s-class) using canopy cover and tree size thresholds (LEMMA, 2023). The five sub-HVRAs that comprise the forested Ecological Integrity HVRA represent these five s-classes:

1. A: Early seral
2. B: Mid-seral, closed canopy
3. C: Mid-seral, open canopy
4. D: Late-seral, open canopy
5. E: Late-seral, closed canopy

We then calculated the current abundance of each S-Class for individual biophysical settings (BpS; as delineated in Haugo et al. 2015) within ecologically meaningful landscape analysis units (LAUs). LAUs were generally defined by HUC 10 or HUC 8 watersheds. For each S-class within a BpS-LAU combination, we compared the contemporary abundance of the s-class to its historical range of variation (HRV) to estimate if it is currently in excess, deficit, or within HRV (similar) for the LAU.

We estimated fire effects to successional pathways using the s-class transition matrix (Table 7). We also estimated fire effects across fire regime groups (FRG) to account for fire-adaptative traits. We applied the FRG associated with a BpS (Haugo et al., 2015).

Lastly, we defined response functions based on current s-class and its departure status. Most pixels were represented by a standard five-box BpS (Table 8). However, some BpS were associated with non-conventional state and transition models that required tailored response frameworks (Tables 9 – Table 11).

Eleven percent of the overall relative importance was allocated to the Ecological Integrity HVRA (Table 4). Within the HVRA, 50% of the importance was allocated to forested sub-HVRAs and 50% to non-forested sub-HVRAs (Table 6). Each of the five forested sub-HVRAs was assigned 10% of the within HVRA importance.

Table 6.Relative importance for all Ecological Integrity sub-HVRAs. Share of HVRA RI is the amount of the HVRA's relative importance assigned to each sub-HVRA.

Sub-HVRA	**Share of HVRA RI**
Good and Intermediate Condition Grasslands	12%
Poor Condition Grasslands	2%
Good and Intermediate Condition Shrublands	15%
Poor Condition Shrublands	2%
Encroaching Juniper, >20% cover, Poor Condition	2%
Encroaching Juniper, >20% cover, Good/Intermediate Condition	5%
Encroaching Juniper, 5 - <20% cover, Poor Condition	2%
Encroaching Juniper, 5 - <20% cover, Good/Intermediate Condition	10%
Forests, Early Seral	10%
Forests, Mid-Seral Closed Canopy	10%
Forests, Mid-Seral Open Canopy	10%
Forests, Late-Seral Open Canopy	10%
Forests, Late-Seral Closed Canopy	10%

Table 7. S-class transition matrix for forested Ecological Integrity HVRAs.

	Fire Intensity Level (flame length)					
	FIL 1	**FIL 2**	**FIL 3**	**FIL 4**	**FIL 5**	**FIL 6**
	0 - 2'	*2 - 4'*	*4 - 6'*	*6 - 8`*	*8 - 12'*	*>12'*
Beginning s-class	**Transition to s-class**					
Fire Regime Group I, Standard 5-box model						
Early Seral (A)	A	A	A	A	A	A
Mid-Seral Closed (B)	B	B	C	C	A	A
Mid-Seral Open (C)	C	C	C	C	A	A
Late-Seral Open (D)	D	D	D	D	A	A
Late-Seral Closed (E)	E	E	D	D	A	A
Fire Regime Group III, Standard 5-box model						
Early Seral (A)	A	A	A	A	A	A
Mid-Seral Closed (B)	B	B	C	A	A	A
Mid-Seral Open (C)	C	C	C	C	A	A
Late-Seral Open (D)	D	D	D	D	A	A
Late-Seral Closed (E)	E	E	D	D	A	A
Fire Regime Group III, Non-standard 3-box model						
Early Seral (A)	A	A	A	A	A	A
Late Closed (B)	B	B	C	C	A	A
Late Open (C)	C	C	C	C	A	A
Fire Regime Group IV & V, Standard 5-box model						

Early Seral (A)	A	A	A	A	A	A
Mid-Seral Closed (B)	B	C	A	A	A	A
Mid-Seral Open (C)	C	C	A	A	A	A
Late-Seral Open (D)	D	D	D	A	A	A
Late-Seral Closed (E)	E	D	D	A	A	A
Fire Regime Group IV, Non-standard 5-box model						
Early Seral (A)	A	A	A	A	A	A
Mid-Seral Closed (B)	A	A	A	A	A	A
Mid-Seral Open (C)	C	A	A	A	A	A
Late-Seral Open (D)	D	A	A	A	A	A
Late-Seral Closed (E)	E	D	A	A	A	A
Fire Regime Group V, Non-standard 5-box model						
Early Seral (A)	A	A	A	A	A	A
Mid-Seral Closed (B)	D	A	A	A	A	A
Mid-Seral Open (C)	D	A	A	A	A	A
Late-Seral Open (D)	D	A	A	A	A	A
Late-Seral Closed (E)	E	D	A	A	A	A

Table 8. Response functions for standard five-box models in the forested Ecological Integrity HVRA.

Standard Five- Box Model			TO														
			A - Early			B - Mid Closed			C - Mid Open			D - Late Open			E - Late Closed		
			Deficit	Similar	Surplus	Deficit	Similar	Surplus	Deficit	Similar	Surplus	Deficit	Similar	Surplus	Deficit	Similar	Surplus
FROM	Early	Deficit	30	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
		Similar	NA	0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
		Surplus	NA	NA	-25	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Mid-Closed	Deficit	0	-50	-100	45	NA	NA	30	15	0	NA	NA	NA	NA	NA	NA
		Similar	20	-10	-50	NA	30	NA	45	50	40	NA	NA	NA	NA	NA	NA
		Surplus	30	10	-30	NA	NA	15	55	50	40	NA	NA	NA	NA	NA	NA
	Mid- Open	Deficit	0	-50	-100	NA	NA	NA	50	NA	NA	NA	NA	NA	NA	NA	NA
		Similar	5	-50	-90	NA	NA	NA	NA	40	NA	NA	NA	NA	NA	NA	NA
		Surplus	25	0	-50	NA	NA	NA	NA	NA	30	NA	NA	NA	NA	NA	NA
	Late-Open	Deficit	*-100*	-100	-100	NA	NA	NA	NA	NA	NA	60	NA	NA	NA	NA	NA
		Similar	*-90*	*-95*	-100	NA	NA	NA	NA	NA	NA	NA	60	NA	NA	NA	NA
		Surplus	*-80*	*-90*	*-100*	NA	NA	NA	NA	NA	NA	NA	NA	50	NA	NA	NA
	Late-Closed	Deficit	*-100*	-100	-100	NA	NA	NA	NA	NA	NA	*30*	10	5	60	NA	NA
		Similar	*-90*	*-95*	-100	NA	NA	NA	NA	NA	NA	45	*45*	15	NA	60	NA
		Surplus	*-80*	*-90*	*-100*	NA	NA	NA	NA	NA	NA	60	60	*60*	NA	NA	50

Table 9. Response functions for non-standard five-box models in fire regime IV in the forested Ecological Integrity HVRA.

Non-Standard Five-Box Model FRG IV			TO														
			Early Open (A)			Early Closed (B)			Mid Closed (C)			Mid Open (D)			Late Closed (E)		
			Deficit	Similar	Surplus	Deficit	Similar	Surplus	Deficit	Similar	Surplus	Deficit	Similar	Surplus	Deficit	Similar	Surplus
FROM	Early Open (A)	Deficit	30	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
		Similar	NA	0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
		Surplus	NA	NA	-25	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Early Closed (B)	Deficit	30	15	0	30	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
		Similar	45	50	40	NA	0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
		Surplus	55	50	40	NA	NA	-25	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Mid Closed (C)	Deficit	0	-50	-100	NA	NA	NA	40	NA	NA	NA	NA	NA	NA	NA	NA
		Similar	20	-10	-50	NA	NA	NA	NA	30	NA	NA	NA	NA	NA	NA	NA
		Surplus	30	10	-30	NA	NA	NA	NA	NA	15	NA	NA	NA	NA	NA	NA
	Mid Open (D)	Deficit	0	-50	-100	NA	NA	NA	NA	NA	NA	50	NA	NA	NA	NA	NA
		Similar	5	-50	-90	NA	NA	NA	NA	NA	NA	NA	40	NA	NA	NA	NA
		Surplus	25	0	-50	NA	NA	NA	NA	NA	NA	NA	NA	30	NA	NA	NA
	Late Closed (E)	Deficit	*-100*	-100	-100	NA	NA	NA	NA	NA	NA	30	10	5	60	NA	NA
		Similar	*-90*	*-95*	-100	NA	NA	NA	NA	NA	NA	45	45	15	NA	60	NA
		Surplus	*-80*	*-90*	*-100*	NA	NA	NA	NA	NA	NA	60	60	60	NA	NA	50

Table 10. Response functions for non-standard five-box models in fire regime V in the forested Ecological Integrity HVRA.

Non-Standard Five-Box Model FRG V			**TO**														
			A - Early			B - Mid1 Closed			C - Mid2 Closed			D - Mid Open			E - Late Closed		
			Deficit	Similar	Surplus	Deficit	Similar	Surplus	Deficit	Similar	Surplus	Deficit	Similar	Surplus	Deficit	Similar	Surplus
FROM	Early (A)	Deficit	30	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
		Similar	NA	0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
		Surplus	NA	NA	-25	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Mid1 Closed (B)	Deficit	0	-50	-100	NA	NA	NA	NA	NA	NA	30	15	0	NA	NA	NA
		Similar	20	-10	-50	NA	NA	NA	NA	NA	NA	45	50	40	NA	NA	NA
		Surplus	30	10	-30	NA	NA	NA	NA	NA	NA	55	50	40	NA	NA	NA
	Mid2 Closed (C)	Deficit	0	-50	-100	NA	NA	NA	NA	NA	NA	30	15	0	NA	NA	NA
		Similar	20	-10	-50	NA	NA	NA	NA	NA	NA	45	50	40	NA	NA	NA
		Surplus	30	10	-30	NA	NA	NA	NA	NA	NA	55	50	40	NA	NA	NA
	Mid Open (D)	Deficit	0	-50	-100	NA	NA	NA	NA	NA	NA	50	NA	NA	NA	NA	NA
		Similar	5	-50	-90	NA	NA	NA	NA	NA	NA	NA	40	NA	NA	NA	NA
		Surplus	25	0	-50	NA	NA	NA	NA	NA	NA	NA	NA	30	NA	NA	NA
	Late Closed (E)	Deficit	*-100*	-100	-100	NA	NA	NA	NA	NA	NA	30	10	5	60	NA	NA
		Similar	*-90*	*-95*	-100	NA	NA	NA	NA	NA	NA	45	45	15	NA	60	NA
		Surplus	*-80*	*-90*	*-100*	NA	NA	NA	NA	NA	NA	60	60	60	NA	NA	50

Table 11. Response functions for non-standard three-box models in the forested Ecological Integrity HVRA.

Three Box Model			TO								
			Early (A)			Late Closed (B)			Late Open (C)		
			Deficit	Similar	Surplus	Deficit	Similar	Surplus	Deficit	Similar	Surplus
FROM	Early (A)	Deficit	30	NA	NA	NA	NA	NA	NA	NA	NA
		Similar	NA	0	NA	NA	NA	NA	NA	NA	NA
		Surplus	NA	NA	-25	NA	NA	NA	NA	NA	NA
	Late-Closed (B)	Deficit	*-100*	-100	-100	45	NA	NA	30	15	0
		Similar	*-90*	*-95*	-100	NA	30	NA	45	50	40
		Surplus	*-80*	*-90*	*-100*	NA	NA	15	55	50	40
	Late-Open (C)	Deficit	*-100*	-100	-100	NA	NA	NA	60	NA	NA
		Similar	*-90*	*-95*	-100	NA	NA	NA	NA	60	NA
		Surplus	*-80*	*-90*	*-100*	NA	NA	NA	NA	NA	50

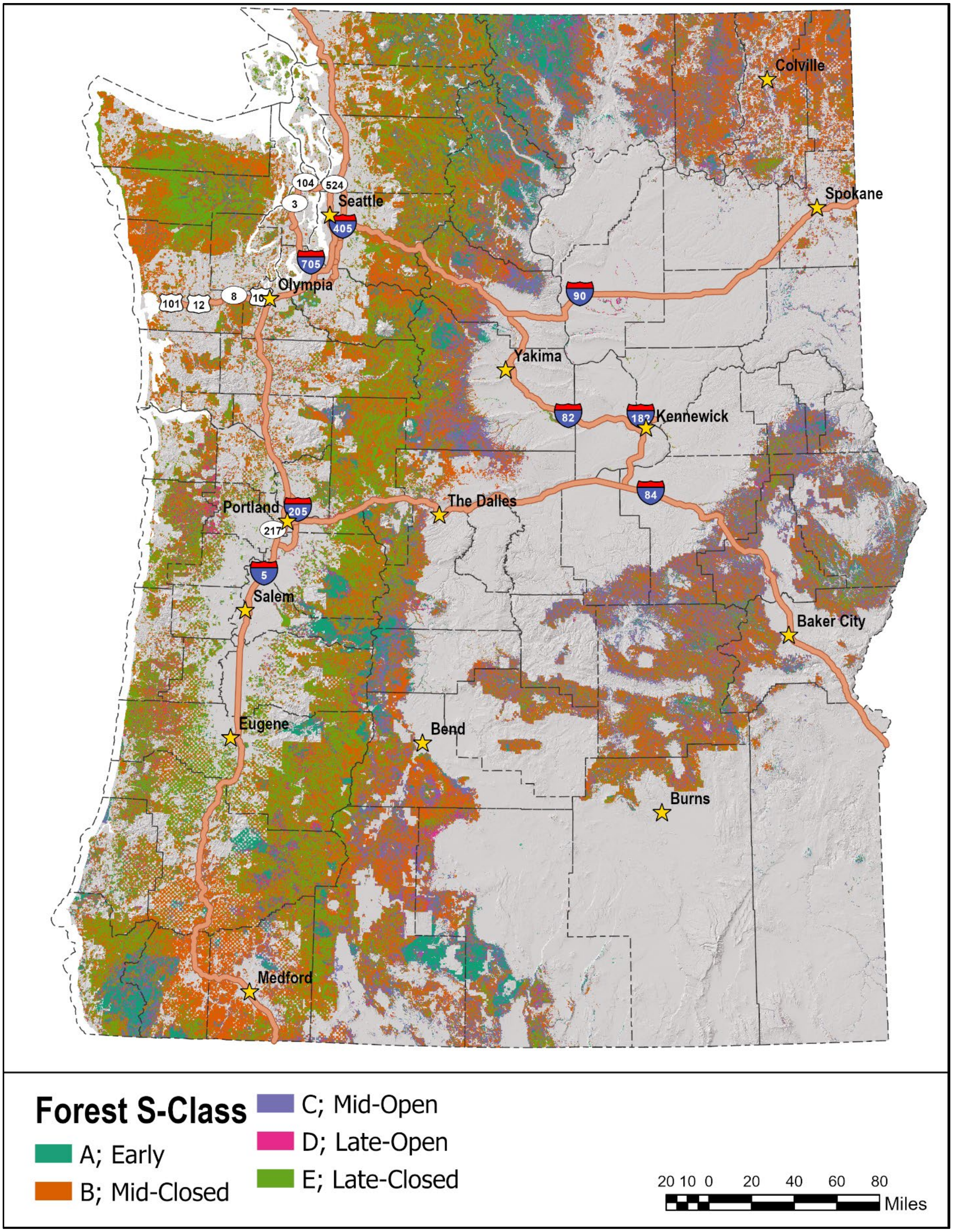

Figure 14. Extent of forested sub-HVRAs in the Ecological Integrity HVRA.

4.3.2.3 Ecological Integrity, Rangeland Ecosystems

Intent

Overall, the Ecological Integrity HVRA is intended to capture the quality and condition of ecosystems and how they respond to wildfires. Our intent within rangeland ecosystems was to assess the likely effect of wildfire on overall condition as measured by threat-based ecostates, with a particular emphasis on post-fire invasion by non-native plant species (i.e., invasive annual grasses).

Summary of changes compared to previous QWRA

Non-forested ecosystems were previously excluded from the Ecological Integrity HVRA in PNW QWRA 2018.

Methods

Assessing wildfire risk to rangeland Ecological Integrity required that we classify existing vegetation into sub-HVRAs based on factors that influence vegetation susceptibility to wildfire. To do so, we used the concepts of threat-based land management (Johnson et al., 2019), as captured in threat-based ecostate maps (Creutzburg, 2022) to characterize existing rangeland condition. The resulting ecostates were classified based on the dominant vegetation (i.e. - shrub, grass, trees) and the relative proportion of percent cover of perennial forbs & grasses to annual forbs & grasses using data from the Rangeland Analysis Platform (U.S. Department of Agriculture, Agricultural Research Service, 2022). The spatial extent of rangeland sub-HVRAs was defined using data from the National Land Cover Database (NLCD; Rigge et al., 2020). The ecostates resulted in our eight rangeland sub-HVRAs:

- **Class A: Good and Intermediate Condition Shrubland** – areas with more than 10% shrubs and the proportion of perennials is greater than annuals in the herbaceous layer
- **Class B: Good and Intermediate Condition Grasslands** – areas with less than 10% shrubs and the proportion of perennials is greater than annuals in the herbaceous layer
- **Class C: Poor Condition Shrubland** – areas with more than 10% shrubs and the proportion of annuals is greater than perennials in the herbaceous layer
- **Class D: Poor Condition Grassland** – areas with less than 10% shrubs and the proportion of annuals is greater than perennials in the herbaceous layer
- **Juniper: early to mid-encroachment, Good and Intermediate Condition Understory** – tree cover (assumed to be encroaching juniper) is 5% - 20% canopy cover and the proportion of perennials is greater than annuals in the herbaceous layer.
- **Juniper: early to mid-encroachment, Poor Condition Understory** – tree cover (assumed to be encroaching juniper) is 5% - 20% canopy cover and the proportion of annuals is greater than perennials in the herbaceous layer.
- **Juniper: late encroachment, Good and Intermediate Condition Understory** – tree cover (assumed to be encroaching juniper) is more than 20% canopy cover and the proportion of perennials is greater than annuals in the herbaceous layer.
- **Juniper: late encroachment, Poor Understory** – tree cover (assumed to be encroaching juniper) is more than 20% canopy cover and the proportion of annuals is greater than perennials in the herbaceous layer.

We used resilience and resistance (R&R) classes as a covariate to help explain the response to fire in conjunctions with the ecostate (Table 12). Resilience and resistance data characterize ecosystem resilience to disturbance and resistance to annual invasive grasses based on abiotic characteristics (Chambers et al., 2017). First, we used the most up to date soil survey data and expert-derived rulesets to classify rangeland ecosystems across Oregon and Washington in one of three R&R classes (Maestas et al., 2016; U.S. Department of Agriculture, Natural Resources Conservation Service, 2023a, 2023b). Next, we replaced some of the original R&R data in eastern Oregon with an updated version of R&R which corrected some known errors in the original STATSGO2 and SSURGO soil data (NRCS West Technology Support Center, 2020).

Across grassland and shrubland ecostates, fire was generally assumed to have negative consequences except at low intensity in some areas with High R&R (Table 12). Negative consequences represent the loss of perennial vegetation as well as increased opportunities for non-native annual vegetation to colonize post-fire areas. Good and intermediate condition ecostates were deemed to have more value at risk, and therefore greater loss compared to poor condition ecostates. In addition, ecostates with High R&R were assumed to be less susceptible than those with Low R&R.

For the encroaching juniper sub-HVRAs, we balanced the benefits of fire-induced juniper mortality with the potential for post-fire invasion by non-native annual grasses with the response functions (Table 12). When fires were high intensity (i.e. FIL 5 and FIL 6), we assumed they would be more likely to kill perennial vegetation and create opportunities for non-native grasses to germinate quickly and invade. That is reflected in all sub-HVRAs as either moderated benefits or significantly enhanced adverse consequences. The early-mid encroachment condition was assumed to have more value at risk of loss.

Eleven percent of the overall relative importance was allocated to the Ecological Integrity HVRA (Table 4). Within the HVRA, 50% of the importance was allocated to forested sub-HVRAs and 50% to rangeland sub-HVRAs (Table 6). Relative importance among the non-forested sub-HVRAs was allocated according to conservation value. The greatest value, and therefore the largest share of relative importance, was placed on good and intermediate condition ecostates.

Table 12. Response functions for sub-HVRAs in the non-forested Ecological Integrity HVRA.

Sub-HVRA	**Covariates** *(Resistance & Resilience Class)*	**Fire Intensity Level (flame length)**					
		FIL 1	**FIL 2**	**FIL 3**	**FIL 4**	**FIL 5**	**FIL 6**
		0 - 2'	*2 - 4'*	*4 - 6'*	*6 - 8`*	*8 - 12'*	*>12'*
Good & Intermediate Condition Shrubland *(perennial cover > annual cover)*	High	20	0	0	-50	-60	-60
	Moderate	0	0	-20	-50	-60	-60
	Low	-60	-60	-70	-70	-80	-80
Good & Intermediate Condition Grassland *(perennial cover > annual cover)*	High	20	10	0	0	0	0
	Moderate	10	10	-10	-20	-20	-20
	Low	-40	-40	-40	-40	-40	-40
Poor Condition Shrubland *(annual cover > perennial cover)*	High	-20	-20	-30	-30	-40	-40
	Moderate	-60	-60	-70	-70	-80	-80
	Low	-80	-80	-90	-90	-100	-100
Poor Condition Grassland *(annual cover > perennial cover)*	High	-20	-20	-20	-20	-20	-20
	Moderate	-30	-30	-30	-30	-30	-30
	Low	-40	-40	-40	-40	-40	-40
Juniper, early-mid encroachment, Good & Intermediate Condition Understory *(5-20% tree cover; perennial cover > annual cover)*	High	30	30	40	40	30	30
	Moderate	20	20	30	30	20	20
	Low	10	10	20	20	10	10
Juniper, early-mid encroachment, Poor Condition Understory *(5-20% tree cover; perennial cover < annual cover)*	High	-10	-10	-10	-20	-60	-90
	Moderate	-20	-20	-20	-30	-70	-100
	Low	-30	-30	-30	-40	-80	-100
Juniper, late encroachment, Good & Intermediate Condition Understory *(>20% tree cover; perennial cover > annual cover)*	High	10	10	20	20	10	10
	Moderate	0	0	10	10	0	0
	Low	-10	-10	0	0	-10	-10
Juniper, late encroachment, Poor Condition Understory *(>20% tree cover; perennial cover < annual cover)*	High	-20	-20	-20	-30	-70	-100
	Moderate	-30	-30	-30	-40	-80	-100
	Low	-40	-40	-40	-50	-90	-100

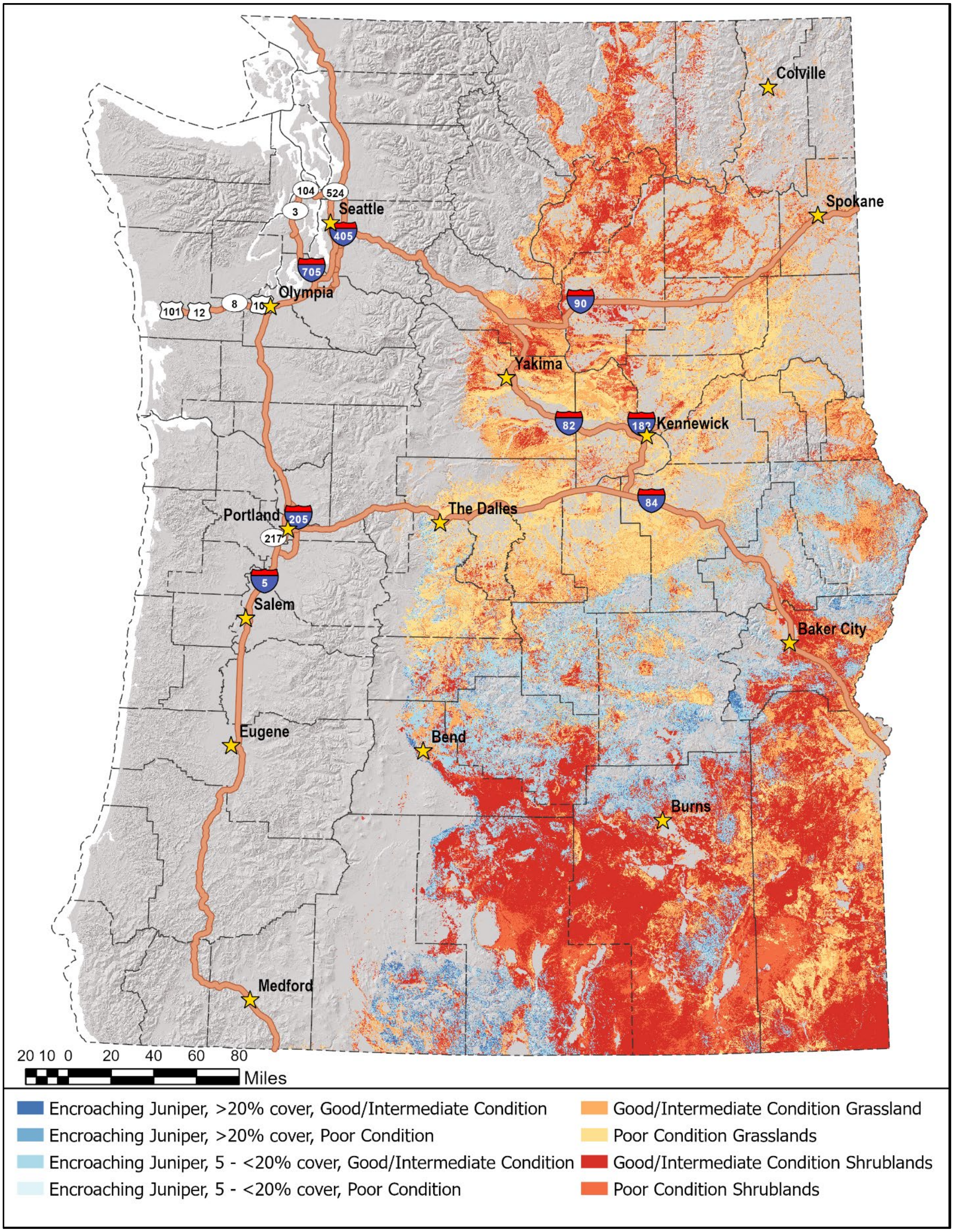

Figure 15. Extent of rangeland sub-HVRAs in the Ecological Integrity HVRA.

4.3.3 Drinking Water

4.3.3.1 Intent

The Drinking Water HVRA is intended to evaluate the risk of post-wildfire sediment delivery to drinking water sources. In the 2018 QWRA this was called the Watershed HVRA. The name change is intended to help communicate the intent.

4.3.3.2 Summary of changes compared to previous QWRA

In response to feedback from QWRA stakeholders, we constrained the extent of this HVRA in central and eastern Washington when compared to the PNW QWRA 2018. The extent of the Watersheds HVRA in the PNW QWRA 2018 included nearly all of central and eastern Washington, reflecting the fact that there are a number of communities who draw their water from the Columbia River. In consultation with the Washington Dept. of Health's Source Water Protection Program intakes and associated source water areas that draw water directly from the Columbia River were omitted from the PNW QWRA 2023.

Response to fire is, in part, based on distance to water body. In the PNW QWRA 2018, the response to fire was based only on the erosion potential. In the PNW QWRA 2023, the response to fire is a function of erosion potential but also a function of how close the pixel is to a drinking source water body.

4.3.3.3 Methods

The Drinking Water HVRA extent was mapped using drinking water intake and source water area data provided by the Oregon Health Authority and the Washington Department of Health. Only surface water intakes were considered. In both states, intakes and source water areas that draw directly from the Columbia were omitted. In Oregon, source water areas were re-delineated using unique intake locations so that source water areas were overlapping and thereby reflecting the entire basin that contributes to an intake.

The population served by each intake was divided evenly across all pixels in the associated source water area. The square root of pixel-level population served was the basis for dividing the HVRA into quantiles which served as the sub-HVRAs:

1. Lowest population served
2. Low population served
3. Moderate population served
4. High population served
5. Highest population served

The response to fire is based on post-fire erosion potential as well as the flow distance from any given pixel to the nearest source water body (Table 13). Post-fire erosion potential was assessed for the PNW QWRA 2018 by the Remote Sensing Applications Center. Flow distance from each pixel in a source water area to the nearest source water was calculated using the Flow Distance tool in ArcPro and using streams, rivers, ponds, lakes and reservoirs identified in the National Hydrography dataset (U.S. Geological Survey (USGS), 2023).

Table 13. Response functions for sub-HVRAs in the Drinking Water HVRA. Response to fire was based on two covariates, erosion potential and distance to water whereas the sub-HVRAs were defined based on the population served.

		Fire Intensity Level (flame length)					
Covariate	**Covariate**	**FIL 1**	**FIL 2**	**FIL 3**	**FIL 4**	**FIL 5**	**FIL 6**
Erosion Potential	*Distance to Water*	*0 - 2'*	*2 - 4'*	*4 - 6'*	*6 - 8`*	*8 - 12'*	*>12'*
Slight	0 - 100 meters	0	0	0	-5	-10	-15
	100 - 500 meters	0	0	0	0	-5	-5
	> 500 meters	0	0	0	0	0	0
Moderate	0 - 100 meters	0	0	0	-10	-25	-35
	100 - 500 meters	0	0	0	0	-10	-10
	> 500 meters	0	0	0	0	0	0
High	0 - 100 meters	0	0	0	-30	-40	-50
	100 - 500 meters	0	0	0	-10	-20	-20
	> 500 meters	0	0	0	0	-5	-10
Very High	0 - 100 meters	0	0	-10	-50	-75	-90
	100 - 500 meters	0	0	-5	-20	-30	-40
	> 500 meters	0	0	0	0	-10	-20

Table 14. Relative importance assigned to Drinking Water sub-HVRAs. Share of HVRA RI is the amount of the HVRA's relative importance assigned to each sub-HVRA.

Sub-HVRA	Share of HVRA RI
Lowest Population Served	0.2%
Low Population Served	0.8%
Moderate Population Served	4.3%
High Population Served	4.5%
Highest Population Served	90.2%

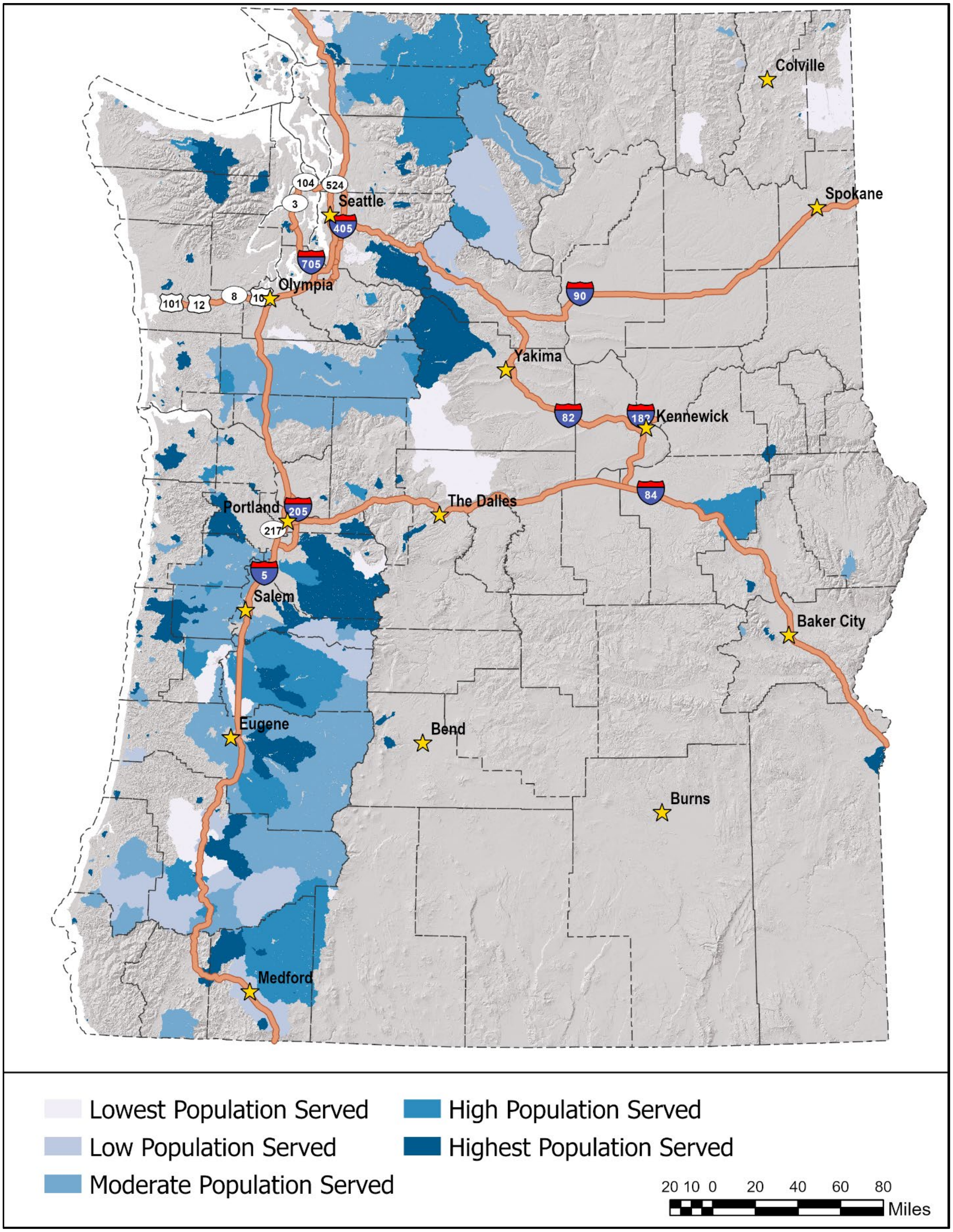

Figure 16. Extent of sub-HVRAs based on per-pixel population served in the Drinking Water HVRA.

4.3.4 Infrastructure

Intent

The Infrastructure HVRA is intended to evaluate wildfire risk to critical infrastructure, namely energy, communication, transportation infrastructure, as well as other essential facilities.

4.3.4.1 Electric Transmission Lines

Summary of changes compared to previous QWRA

The extent of transmission lines in the PNW QWRA 2023 is generally consistent with the PNW QWRA 2018, but we made several changes in how transmission lines were characterized. First, we defined the high voltage transmission lines as those carrying ≥ 100 kV whereas the PNW QWRA 2018 defined them as ≥ 230 kV. This change aligns with industry standards (North American Electric Reliability Corporation, 2018). Secondly, we included vegetation height adjacent to transmission lines as a covariate to further stratify wildfire consequences where taller vegetation poses a greater immediate post-fire hazard and therefore consequence.

Methods

Electric transmission lines were mapped using data from the Homeland infrastructure Foundation-Level Database (HIFLD). High voltage lines were defined as lines with ≥ 100 kV. Low voltage lines were defined as lines with < 100 kV. Lines were converted to 30-meter rasters and expanded by three pixels on each side. We further classified the rasters based on the average adjacent canopy height. Using zonal statistics in ArcPro v3.0 and canopy height(LEMMA, 2023b), we determined the average canopy height within a 60-meter radius. Adjacent canopy height influenced the response to fire, but had no impact on relative importance.

High voltage lines are generally constructed out of steel and therefore relatively resistant to fire effects (Table 15). We also assumed that in most cases, high voltage lines are strung more than 80 feet above the ground. Accordingly, we anticipate low to moderate intensity fire (FIL 1 – FIL4) to have slightly positive to neutral outcomes by reducing fuel loads without adversely impacting transmission infrastructure. Fire effects become increasingly negative as fires exceed FIL5. We assumed low voltage transmission lines were likely constructed out of wood and strung at much lower heights, and therefore more susceptible at all intensities to high voltage lines.

Table 15. Response functions for electric transmission line sub-HVRAs. Share of HVRA RI is the amount of the HVRA's relative importance assigned to each sub-HVRA. In this case, electric transmission lines were assigned about 36% of all the importance within the Infrastructure HVRA.

			Fire Intensity Level (flame length)					
Sub-HVRA	**Share of HVRA RI**	**Covariate**	**FIL 1**	**FIL 2**	**FIL 3**	**FIL 4**	**FIL 5**	**FIL 6**
			0 - 2'	*2 - 4'*	*4 - 6'*	*6 - 8`*	*8 - 12'*	*>12'*
Electric Transmission Lines - Low Voltage	25%	Canopy height >= 80'	-30	-40	-50	-70	-100	-100
		Canopy height 20 - 80'	-20	-30	-40	-60	-90	-100
		Canopy height < 20'	-10	-20	-30	-50	-70	-90
		Non-forested	-5	-5	-5	-10	-10	-20
Electric Transmission Lines - High Voltage	11%	Canopy height >= 80'	0	0	-20	-30	-50	-60
		Canopy height <80'	0	0	-5	-10	-10	-20
		Non-forested	0	0	0	0	0	0

4.3.4.2 Electric Substations

Summary of changes compared to previous QWRA

The extent and characterization of electric sub-stations is the same as in the PNW QWRA 2018.

Methods

Electric substations were mapped using data from the Homeland Infrastructure Foundation-Level Database (HIFLD). This HVRA captures electric power substations primarily associated with facilities and equipment that switch, transform, or regulate electric power at voltages equal to, or greater than, 69 kV. Points were converted to 30-meter rasters and expanded by three pixels on each side to represent the likely spatial extent of these facilities.

Electric substations were assumed to be relatively resistant to fire overall, reflecting the assumptions that they are generally constructed from non-combustible materials and sites are often maintained with minimal vegetation (Table 16). As fire intensity increases, fire effects are more negative to capture potential impact to the infrastructure as well as the likelihood that operations staff might be forced to evacuate and shut down operations.

Table 16. Response functions for the electric substation sub-HVRA. Share of HVRA RI is the amount of the HVRA's relative importance assigned to each sub-HVRA. In this case, electric substations were assigned about 0.25% of all the importance within the Infrastructure HVRA.

		Fire Intensity Level (flame length)					
Sub-HVRA	**Share of HVRA RI**	**FIL 1**	**FIL 2**	**FIL 3**	**FIL 4**	**FIL 5**	**FIL 6**
		0 - 2'	*2 - 4'*	*4 - 6'*	*6 - 8`*	*8 - 12'*	*>12'*
Electric Substations	0.25%	0	0	-10	-20	-30	-40

4.3.4.3 Oil and Gas Wells

Summary of changes compared to previous QWRA

Oil and gas wells were not previously mapped in the PNW QWRA 2018. This is a new sub-HVRA.

Methods

We mapped oil and gas wells using data from the Homeland Infrastructure Foundation-Level Database (HIFLD). The data represents oil and natural gas wells which is a hole drilled in the earth for the purpose of finding or producing crude oil or natural gas; or producing services related to the production of crude oil or natural gas. Points were converted to 30-meter rasters and expanded by three pixels on each side.

Oil and gas wells were assumed to be relatively resistant to fire overall, reflecting assumptions that they are generally constructed from non-combustible materials and sites are often maintained with minimal vegetation. As fire intensity increases, fire effects are more negative to capture potential impact to the infrastructure as well as the likelihood that operations staff might be forced to evacuate and shut down operations.

Table 17. Response functions for the Oil and Gas Wells sub-HVRA. Share of HVRA RI is the amount of the HVRA's relative importance assigned to each sub-HVRA. In this case, Oil and Gas Wells were assigned about 3% of all the importance within the Infrastructure HVRA.

		Fire Intensity Level (flame length)					
Sub-HVRA	**Share of HVRA RI**	**FIL 1**	**FIL 2**	**FIL 3**	**FIL 4**	**FIL 5**	**FIL 6**
		0 - 2'	*2 - 4'*	*4 - 6'*	*6 - 8`*	*8 - 12'*	*>12'*
Oil and Gas Wells	3%	0	0	0	-10	-10	-20

4.3.4.4 Powerplants

Summary of changes compared to previous QWRA

The extent and characterization of powerplants is the same as in the PNW QWRA 2018.

Methods

Powerplants were mapped using data from the Homeland Infrastructure Foundation-Level Database (HIFLD). The dataset represents electric power plants of multiple types including hydroelectric dams, fossil fuel, nuclear, solar, wind geothermal and biomass. We converted point locations to 30-meter raster pixels and expanded them by three pixels on each side to reflect the spatial distribution of built infrastructure.

Powerplants were assumed to be relatively resistant to fire overall, reflecting the assumptions that they are generally constructed from non-combustible materials and sites are often maintained with minimal vegetation. As fire intensity increases, fire effects are more negative reflecting potential impact to the infrastructure as well as the likelihood that operations staff might be forced to evacuate and shut down operations.

Table 18. Response functions for Powerplants sub-HVRA. Share of HVRA RI is the amount of the HVRA's relative importance assigned to each sub-HVRA. In this case, Powerplants were assigned about 0.15% of all the importance within the Infrastructure HVRA.

		Fire Intensity Level (flame length)					
Sub-HVRA	**Share of HVRA RI**	**FIL 1**	**FIL 2**	**FIL 3**	**FIL 4**	**FIL 5**	**FIL 6**
		0 - 2'	*2 - 4'*	*4 - 6'*	*6 - 8`*	*8 - 12'*	*>12'*
Powerplants	0.15%	0	0	0	-10	-20	-30

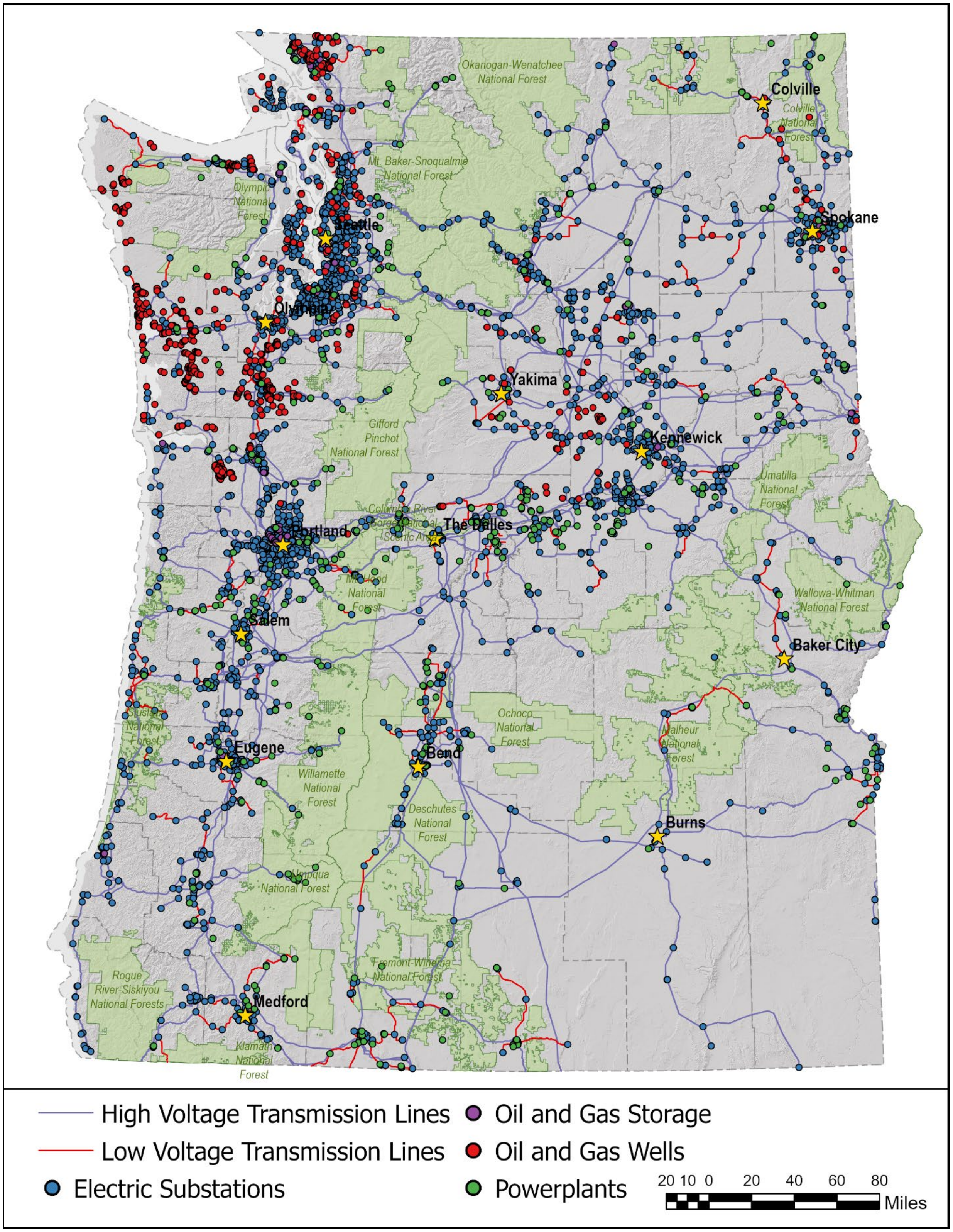

Figure 17. Extent of energy-related sub-HVRAs in the Infrastructure HVRA.

4.3.4.5 Interstates and Highways

Summary of changes compared to previous QWRA

The extent and characterization of interstates and highways is similar to the PNW QWRA 2018. Adjacent canopy cover added as covariate to help explain the response to fire.

Methods

Interstates and highways were mapped using data from the Homeland Infrastructure Foundation-Level Database (HIFLD). Lines were converted to 30-meter rasters and expanded by three pixels on each side. The expanded raster data was then further classified based on the average adjacent canopy height. Using zonal statistics in ArcPro v3.0 and canopy height (LEMMA, 2023b), we determined the average canopy height within a 60-meter radius. Adjacent canopy height influenced the response to fire, but had no impact on relative importance.

Interstates and highways where the adjacent canopy was less than 20 feet high were assumed to be mostly resistant to fires of all intensities. Where the adjacent canopy was greater than 20 feet tall, fire effects become increasingly negative, reflecting the increasing possibility that trees will fall across the road and make it impassable.

Table 19. Response functions for Interstate and State Highway sub-HVRAs. Share of HVRA RI is the amount of the HVRA's relative importance assigned to each sub-HVRA. In this case, Interstates and Highways were cumulatively assigned about 34% of all the importance within the Infrastructure HVRA.

			Fire Intensity Level (flame length)					
Sub-HVRA	**Share of HVRA RI**	**Covariate**	**FIL 1**	**FIL 2**	**FIL 3**	**FIL 4**	**FIL 5**	**FIL 6**
			0 - 2'	*2 - 4'*	*4 - 6'*	*6 - 8`*	*8 - 12'*	*>12'*
Interstates	8%	Canopy height >= 80'	-20	-50	-80	-90	-100	-100
		Canopy height 20 - 80'	-20	-30	-60	-80	-90	-100
		Canopy height < 20'	-20	-20	-20	-20	-20	-20
State Highways	26%	Canopy height >= 80'	-40	-70	-80	-100	-100	-100
		Canopy height 20 - 80'	-40	-50	-70	-90	-100	-100
		Canopy height < 20'	-20	-20	-20	-20	-20	-20

4.3.4.6 Railroads

Summary of changes compared to previous QWRA

The extent and characterization of railroads is similar to the PNW QWRA 2018. Adjacent canopy cover was added as covariate to help explain the response to fire.

Methods

Railroads were mapped using data from the Homeland Infrastructure Foundation-Level Database (HIFLD). Lines were converted to 30-meter rasters and expanded by three pixels on each side. The expanded raster data was then further classified based on the average adjacent canopy height. Using zonal statistics in ArcPro v3.0 and canopy height (LEMMA, 2023b) we determined the average canopy height within a 90-meter radius. Adjacent canopy height influenced the response to fire, but had no impact on relative importance.

Railroad lines where the adjacent canopy was less than 20 feet high were assumed to be mostly resistant to fires of all intensities. Where the adjacent canopy was greater than 20 feet tall, fire effects become increasingly negative, reflecting the increasing possibility that trees will fall across the railroad and make it impassable.

Table 20. Response functions for the Railroad sub-HVRA. Share of HVRA RI is the amount of the HVRA's relative importance assigned to each sub-HVRA. In this case, Railroads were assigned about 14% of all the importance within the Infrastructure HVRA.

			Fire Intensity Level (flame length)					
Sub-HVRA	**Share of HVRA RI**	**Covariate**	**FIL 1**	**FIL 2**	**FIL 3**	**FIL 4**	**FIL 5**	**FIL 6**
			0 - 2'	*2 - 4'*	*4 - 6'*	*6 - 8`*	*8 - 12'*	*>12'*
Railroads	14%	Canopy height >= 80'	-20	-50	-80	-90	-100	-100
		Canopy height 20 - 80'	-20	-30	-60	-80	-90	-100
		Canopy height < 20'	-5	-5	-5	-5	-5	-5

4.3.4.7 Essential Facilities

Summary of changes compared to previous QWRA

Essential facilities were not previously mapped in the PNW QWRA 2018. This is a new sub-HVRA.

Methods

Essential facilities were mapped using data from the Homeland Infrastructure Foundation-Level Database (HIFLD). Essential facilities are meant to represent structures that might be essential to community function during and immediately following a wildfire, including: hospitals, EMS stations, fire stations, colleges and universities, local law enforcement, schools, childcare centers, solid waste facilities, nursing homes, public health departments, urgent care facilities, wastewater treatment sites, EPA emergency response facilities, public transit centers, and state government buildings.

Essential facilities were assumed to be mildly resistant to low intensity fires, but increasingly susceptible as fire intensities increase. The increasingly negative outcomes were meant to convey not only impacts to the infrastructure but also reduced or canceled operations in many cases (e.g. schools) if staff are forced to evacuate.

Table 21. Response functions for Essential Facilities sub-HVRA. Share of HVRA RI is the amount of the HVRA's relative importance assigned to each sub-HVRA. In this case, Essential Facilities were assigned about 13% of all the importance within the Infrastructure HVRA.

		Fire Intensity Level (flame length)					
Sub-HVRA	**Share of HVRA RI**	**FIL 1**	**FIL 2**	**FIL 3**	**FIL 4**	**FIL 5**	**FIL 6**
		0 - 2'	*2 - 4'*	*4 - 6'*	*6 - 8`*	*8 - 12'*	*>12'*
Essential Facilities	13%	-15	-25	-40	-60	-80	-95

4.3.4.8 Communication Sites

Summary of changes compared to previous QWRA

The extent and characterization of Communication Sites is the same as the PNW QWRA.

Methods

Communication sites were mapped using data from the Homeland Infrastructure Foundation-Level Database (HIFLD). Specifically, we included FM transmission towers, AM transmission towers, broadband radio transmitters, cellular towers, microwave service towers, paging transmission towers, land mobile commercial transmission towers, land mobile broadcast towers, antenna structure, TV broadcast contours, TV digital station transmitters, TV analog station transmitters, and TV digital station transmitters. Points were converted to 30-meter rasters and expanded by three pixels on each side.

Communication sites were assumed to be relatively resistant to fire at low intensities (i.e. FIL1 – 3), but increasingly susceptible as fire intensity increases. The decision to characterize communication sites as relatively resistant to fire overall was intended to reflect the assumption that the infrastructure is often made of steel and also that, in many cases, when damaged the infrastructure can be repaired or replaced relatively quickly.

Table 22. Response functions for the Communication Sites sub-HVRA. Share of HVRA RI is the amount of the HVRA's relative importance assigned to each sub-HVRA. In this case, Communication Sites were assigned about 8% of all the importance within the Infrastructure HVRA.

		Fire Intensity Level (flame length)					
Sub-HVRA	**Share of HVRA RI**	**FIL 1**	**FIL 2**	**FIL 3**	**FIL 4**	**FIL 5**	**FIL 6**
		0 - 2'	*2 - 4'*	*4 - 6'*	*6 - 8`*	*8 - 12'*	*>12'*
Communication Sites	2%	0	-5	-15	-20	-40	-50

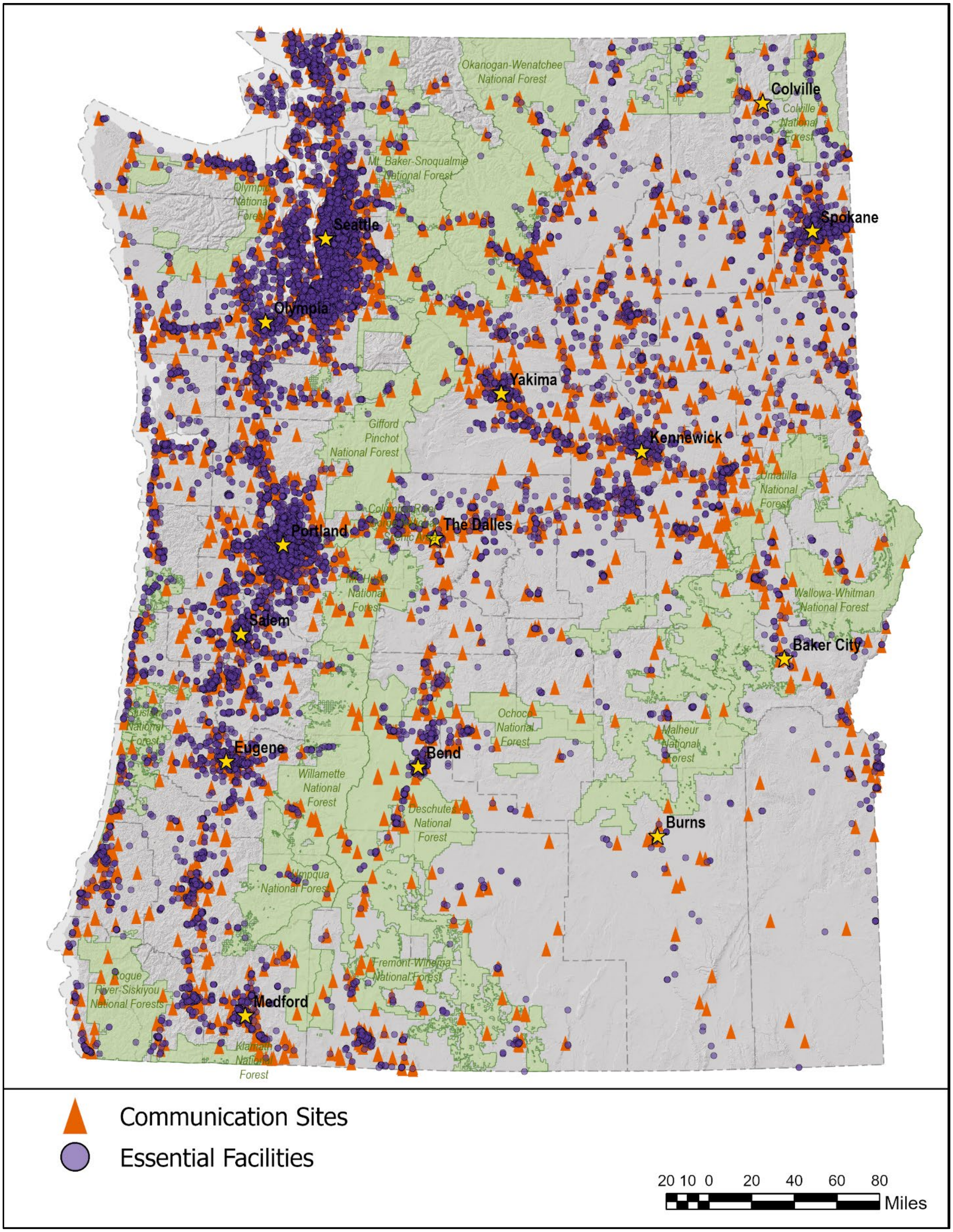

Figure 18. Extent of communication sites and essential facilities.

4.3.5 Timber

Intent

The Timber HVRA is intended to evaluate wildfire risk to commercial timber resources.

General Methods

We grouped sub-HVRAs based on three criteria: land manager, assumed management priority, and timber size class. Land managers included private, state, U.S. Forest Service, Bureau of Land Management and Tribal entities. Methods for mapping the extent of each land manager's timberlands are described in detail in the following sections. We used assumed management priority criteria to distinguish between lands where commercial timber management is the primary objective from those lands where commercial timber management is part of a multiple use strategy. Tribal Active Management, U.S. Forest Service Active Management, BLM Active Management and Private Industrial sub-HVRAs all represent timberlands where commercial timber management is assumed to be the primary management objective. Within all other Timber sub-HVRAs, commercial timber management is presumed to be one of several equally important management objectives. State and federal agencies made these designations on public land, and used available data for tribally-managed lands (Section 4.3.5.3.2 below). We mapped timber size class data using Quadratic Mean Diameter (QMD) from the most recent forest structure data available which approximates forest structure in 2021 (LEMMA, 2023a).

We included fire regime group (FRG), along with timber size class, as a covariate to explain the response to fire. We gave all land managers equal relative importance, but within a land manger type about twice as much importance was placed on active management timberlands compared to timberlands with multiple, equally important management objectives. Additionally, within any sub-HVRA the most relative importance was assigned to the largest size class and the least was assigned to the smallest size class.

4.3.5.1 Private Timberlands

Summary of changes compared to previous QWRA

We included private non-industrial timberlands in this update, which were not included in the last QWRA.

Methods

Industrial ownership was identified using the most recent version of the Atterbury Consultants Forest Ownership data (Atterbury Consultants Inc., 2023), regarded as the most definitive source of this spatial data. Specifically, we selected parcels in Oregon and Washington that were classified as Industrial Forest Private Company (IFPC), Real Estate Investment Trust (REIT) or Timber Investment Management Organizations (TIMO).

We mapped the extent of Private Non-Industrial timber resources using different data and methods in each state. In Oregon, the best available method was to use comprehensive land use rules to identify parcels where active timber management is an allowable land use, and to then further refine the extent based on tree cover. Using statewide planning data, we selected all parcels in Oregon classified as either Farm-Forest, Primary Forest or Secondary Forest (Oregon Department of Land Conservation and Development, 2023), and then further refined the extent by selecting pixels that were greater than 20% tree canopy cover. Private industrial ownerships were excluded using the data previously described.

In Washington, we used the Washington State Forestland Database and selected only parcels identified as small forest landowners (Rodgers et al., 2019) and then further refined the extent by selecting pixels that were greater than 20% tree canopy cover.

Table 23. Response functions for Private Non-Industrial and Private Industrial sub-HVRAs. Share of HVRA RI is the amount of the HVRA's relative importance assigned to each sub-HVRA. In this case, Private Industrial and Private Non-Industrial sub-HVRAs cumulatively were assigned about 44% of all the importance within the Timber HVRA.

			Fire Intensity Level (flame length)					
Sub-HVRA	**Share of HVRA RI**	**Covariate**	**FIL 1**	**FIL 2**	**FIL 3**	**FIL 4**	**FIL 5**	**FIL 6**
			0 - 2'	*2 - 4'*	*4 - 6'*	*6 - 8`*	*8 - 12'*	*>12'*
Private Non-Industrial, QMD < 10"	3%	FRG I	10	-20	-50	-100	-100	-100
Private Non-Industrial, QMD < 10"		FRG III	0	-30	-60	-100	-75	-100
Private Non-Industrial, QMD < 10"		FRG IV/V	-20	-40	-80	-100	-50	-100
Private Non-Industrial, QMD 10" - 20"	5%	FRG I	50	30	0	-30	-100	-100
Private Non-Industrial, QMD 10" - 20"		FRG III	20	0	-40	-80	-80	-100
Private Non-Industrial, QMD 10" - 20"		FRG IV/ V	-20	-40	-60	-80	-80	-100
Private Non-Industrial, QMD > 20"	1%	FRG I	50	30	0	-10	-100	-100
Private Non-Industrial, QMD > 20"		FRG III	30	10	-20	-80	-100	-100
Private Non-Industrial, QMD > 20"		FRG IV/V	-20	-40	-60	-80	-100	-100
Private Industrial, QMD < 10"	13%	FRG I	10	-20	-50	-100	-100	-100
Private Industrial, QMD < 10"		FRG III	0	-30	-60	-30	-75	-100
Private Industrial, QMD < 10"		FRG IV/V	-20	-40	-80	-10	-50	-100
Private Industrial, QMD 10" - 20"	18%	FRG I	50	30	0	-100	-100	-100
Private Industrial, QMD 10" - 20"		FRG III	20	0	-40	-80	-80	-100
Private Industrial, QMD 10" - 20"		FRG IV/ V	-20	-40	-60	-80	-80	-100
Private Industrial, QMD > 20"	4%	FRG I	50	30	0	-100	-100	-100

Private Industrial, QMD > 20"		FRG III	30	10	-20	-80	-100	-100
Private Industrial, QMD > 20"		FRG IV/V	-20	-40	-60	-80	-100	-100

4.3.5.2 Tribal Timberlands

Summary of changes compared to previous QWRA

The extent and characterization of tribal timberlands is similar to PNW QWRA 2018, although updated timber size class data was used.

Methods

Specific spatial data for tribal owned timber resources was not readily available for most tribes. However, during the development of the PNW QWRA 2018, the Colville reservation provided an extent for commercial timber. The Tribal Owned, Active Management sub-HVRA represents the commercial timber resources on the Colville Reservation using the same spatial extent provided in 2018. The extent of the Tribal Owned, Other sub-HVRA includes all forestland on tribally owned and managed lands.

Table 24. Response functions for the two Tribal timberland sub-HVRAs. Share of HVRA RI is the amount of the HVRA's relative importance assigned to each sub-HVRA. In this case, Tribal sub-HVRAs cumulatively were assigned about 9% of all the importance within the Timber HVRA.

			Fire Intensity Level (flame length)					
Sub-HVRA	**Share of HVRA RI**	**Covariate**	**FIL 1**	**FIL 2**	**FIL 3**	**FIL 4**	**FIL 5**	**FIL 6**
			0 - 2'	*2 - 4'*	*4 - 6'*	*6 - 8`*	*8 - 12'*	*>12'*
Tribal Active Management, QMD < 10"	< 1%	FRG I	10	-20	-50	-100	-100	-100
Tribal Active Management, QMD < 10"		FRG III	0	-30	-60	-100	-100	-100
Tribal Active Management, QMD < 10"		FRG IV/V	-20	-40	-80	-100	-100	-100
Tribal Active Management, QMD 10" - 20"	1%	FRG I	50	30	0	-30	-75	-100
Tribal Active Management, QMD 10" - 20"		FRG III	20	0	-40	-80	-80	-100
Tribal Active Management, QMD 10" - 20"		FRG IV/V	-20	-40	-60	-80	-100	-100
Tribal Active Management, QMD > 20"	< 1%	FRG I	50	30	0	-10	-50	-100
Tribal Active Management, QMD > 20"		FRG III	30	10	-20	-80	-80	-100
Tribal Active Management, QMD > 20"		FRG IV/V	-20	-40	-60	-80	-100	-100
Tribal Other Management, QMD < 10"	2%	FRG I	10	-20	-50	-100	-100	-100
Tribal Other Management, QMD < 10"		FRG III	0	-30	-60	-100	-100	-100
Tribal Other Management, QMD < 10"		FRG IV/V	-20	-40	-80	-100	-100	-100
Tribal Other Management, QMD 10" - 20"	4%	FRG I	50	30	0	-30	-75	-100

Tribal Other Management, QMD 10" - 20"		FRG III	20	0	-40	-80	-80	-100
Tribal Other Management, QMD 10" - 20"		FRG IV/V	-20	-40	-60	-80	-100	-100
Tribal Other Management, QMD > 20"	1%	FRG I	50	30	0	-10	-50	-100
Tribal Other Management, QMD > 20"		FRG III	30	10	-20	-80	-80	-100
Tribal Other Management, QMD > 20"		FRG IV/V	-20	-40	-60	-80	-100	-100

4.3.5.3 U.S. Forest Service

Summary of changes compared to previous QWRA

The extent and characterization of timberlands managed by the U.S. Forest Service is similar to the PNW QWRA, although we updated the timber size class data to modernize estimates.

Methods

The extent of the U.S. Forest Service, Active Management sub-HVRA was mapped based on national forest land management plans and by selecting areas where the land classification is “active management” (Ringo et al., 2016). Active management land classifications represent areas where mechanical treatments are allowable to meet wood production targets.

The extent of the U.S. Forest Service, Multiple Objectives sub-HVRA was mapped based on national forest land management plans and by selecting areas where the land classification is described as having “multiple objectives” (Ringo et al., 2016). Multiple objectives land classifications represent areas where mechanical treatments are restricted and can only be implemented if there is no conflict with other forest plan objectives.

Table 25. Response functions for the two U.S. Forest Service timberland sub-HVRAs. Share of HVRA RI is the amount of the HVRA’s relative importance assigned to each sub-HVRA. In this case, USFS-managed sub-HVRAs cumulatively were assigned about 36% of all the importance within the Timber HVRA.

			Fire Intensity Level (flame length)					
Sub-HVRA	**Share of HVRA RI**	**Covariate**	**FIL 1**	**FIL 2**	**FIL 3**	**FIL 4**	**FIL 5**	**FIL 6**
			0 - 2'	*2 - 4'*	*4 - 6'*	*6 - 8`*	*8 - 12'*	*>12'*
U.S. Forest Service Active Management, QMD < 10"	5%	FRG I	10	-20	-50	-100	-100	-100
U.S. Forest Service Active Management, QMD < 10"		FRG III	0	-30	-60	-100	-100	-100
U.S. Forest Service Active Management, QMD < 10"		FRG IV/V	-20	-40	-80	-100	-100	-100
U.S. Forest Service Active Management, QMD 10" - 20"	16%	FRG I	50	30	0	-30	-75	-100
U.S. Forest Service Active Management, QMD 10" - 20"		FRG III	20	0	-40	-80	-80	-100
U.S. Forest Service Active Management, QMD 10" - 20"		FRG IV/ V	-20	-40	-60	-80	-100	-100
U.S. Forest Service Active Management, QMD > 20"	3%	FRG I	50	30	0	-10	-50	-100
U.S. Forest Service Active Management, QMD > 20"		FRG III	30	10	-20	-80	-80	-100
U.S. Forest Service Active Management, QMD > 20"		FRG IV/V	-20	-40	-60	-80	-100	-100
U.S. Forest Service Multiple Use Management, QMD < 10"	2%	FRG I	10	-20	-50	-100	-100	-100
U.S. Forest Service Multiple Use Management, QMD < 10"		FRG III	0	-30	-60	-100	-100	-100

U.S. Forest Service Multiple Use Management, QMD < 10"		FRG IV/V	-20	-40	-80	-100	-100	-100
U.S. Forest Service Multiple Use Management, QMD 10" - 20"	7%	FRG I	50	30	0	-30	-75	-100
U.S. Forest Service Multiple Use Management, QMD 10" - 20"		FRG III	20	0	-40	-80	-80	-100
U.S. Forest Service Multiple Use Management, QMD 10" - 20"		FRG IV/ V	-20	-40	-60	-80	-100	-100
U.S. Forest Service Multiple Use Management, QMD > 20"	3%	FRG I	50	30	0	-10	-50	-100
U.S. Forest Service Multiple Use Management, QMD > 20"		FRG III	30	10	-20	-80	-80	-100
U.S. Forest Service Multiple Use Management, QMD > 20"		FRG IV/V	-20	-40	-60	-80	-100	-100

4.3.5.4 U.S. Bureau of Land Management

Summary of changes compared to previous QWRA

The extent and characterization of timberlands managed by the U.S. Bureau of Land Management is similar to the previous QWRA, although updated timber size class data was used.

Methods

The Bureau of Land Management, Active Management sub-HVRA extent was provided by the Bureau of Land Management and is based on the Resource Management Plan and current Land Use Allocation. Specifically, active management class includes all forested Harvest Land Base, Oregon and California Re-vested Railroad Lands and Coos Bay Wagon Road that are not otherwise designated as Congressionally Reserved or wilderness lands.

The Bureau of Land Management, Other Management sub-HVRA extent was provided by the Bureau of Land Management and is based on the Resource Management Plan and current Land Use Allocation. The Other Management sub-HVRA includes all remaining forest land managed by the Bureau of Land Management which is neither included in the Active Management sub-HVRA nor designated as Congressionally Reserved or wilderness.

Table 26. Response functions for the two BLM timberland sub-HVRAs. Share of HVRA RI is the amount of the HVRA's relative importance assigned to each sub-HVRA. In this case, BLM-managed sub-HVRAs cumulatively were assigned about 10% of all the importance within the Timber HVRA.

			Fire Intensity Level (flame length)					
Sub-HVRA	**Share of HVRA RI**	**Covariate**	**FIL 1**	**FIL 2**	**FIL 3**	**FIL 4**	**FIL 5**	**FIL 6**
			0 - 2'	*2 - 4'*	*4 - 6'*	*6 - 8`*	*8 - 12'*	*>12'*
BLM Active Management, QMD < 10"	1%	FRG I	10	-20	-50	-100	-100	-100
BLM Active Management, QMD < 10"		FRG III	0	-30	-60	-100	-100	-100
BLM Active Management, QMD < 10"		FRG IV/V	-20	-40	-80	-100	-100	-100
BLM Active Management, QMD 10" - 20"	4%	FRG I	50	30	0	-30	-75	-100
BLM Active Management, QMD 10" - 20"		FRG III	20	0	-40	-80	-80	-100
BLM Active Management, QMD 10" - 20"		FRG IV/V	-20	-40	-60	-80	-100	-100
BLM Active Management, QMD > 20"	4%	FRG I	50	30	0	-10	-50	-100
BLM Active Management, QMD > 20"		FRG III	30	10	-20	-80	-80	-100
BLM Active Management, QMD > 20"		FRG IV/V	-20	-40	-60	-80	-100	-100
BLM Other Management, QMD < 10"	< 1%	FRG I	10	-20	-50	-100	-100	-100

BLM Other Management, QMD < 10"		FRG III	0	-30	-60	-100	-100	-100
BLM Other Management, QMD < 10"		FRG IV/V	-20	-40	-80	-100	-100	-100
BLM Other Management, QMD 10" - 20"	< 1%	FRG I	50	30	0	-30	-75	-100
BLM Other Management, QMD 10" - 20"		FRG III	20	0	-40	-80	-80	-100
BLM Other Management, QMD 10" - 20"		FRG IV/V	-20	-40	-60	-80	-100	-100
BLM Other Management, QMD > 20"	< 1%	FRG I	50	30	0	-10	-50	-100
BLM Other Management, QMD > 20"		FRG III	30	10	-20	-80	-80	-100
BLM Other Management, QMD > 20"		FRG IV/V	-20	-40	-60	-80	-100	-100

4.3.5.5 State Owned or Managed Timberlands

Summary of changes compared to previous QWRA

The extent and characterization of timberlands managed by the Oregon Department of Forestry is similar to the previous QWRA, although updated timber size class data was used. In Washington, new data was used to map the extent of timberland managed by the Washington Department of Natural Resources.

Methods

State owned or managed timberland in Oregon included all state forests managed by the Oregon Department of Forestry (Oregon Department of Forestry, 2022). In Washington, data defining state owned or managed timberland was provided directly by Washington Department of Natural Resources. Using the data provided by DNR, we refined the extent based on the deferral status and any operational restrictions. On some parcels, commercial timber activities are deferred; we selected on parcels or portions of parcels where there was no deferral or the deferral is less than ten years. Likewise, we selected forested state managed timberland where there are no or minimal restrictions on mechanical harvest activities.

Table 27. Response functions for the State Owned or Managed sub-HVRA. Share of HVRA RI is the amount of the HVRA's relative importance assigned to each sub-HVRA. In this case, State-managed sub-HVRAs cumulatively were assigned about 4% of all the importance within the Timber HVRA.

			Fire Intensity Level (flame length)					
Sub-HVRA	**Share of HVRA RI**	**Covariate**	**FIL 1**	**FIL 2**	**FIL 3**	**FIL 4**	**FIL 5**	**FIL 6**
			0 - 2'	*2 - 4'*	*4 - 6'*	*6 - 8`*	*8 - 12'*	*>12'*
State Owned/Managed, QMD < 10"	1%	FRG I	10	-20	-50	-100	-100	-100
State Owned/Managed, QMD < 10"		FRG III	0	-30	-60	-100	-100	-100
State Owned/Managed, QMD < 10"		FRG IV/V	-20	-40	-80	-100	-100	-100
State Owned/Managed, QMD 10" - 20"	2%	FRG I	50	30	0	-30	-75	-100
State Owned/Managed, QMD 10" - 20"		FRG III	20	0	-40	-80	-80	-100
State Owned/Managed, QMD 10" - 20"		FRG IV/V	-20	-40	-60	-80	-100	-100
State Owned/Managed, QMD > 20"	1%	FRG I	50	30	0	-10	-50	-100
State Owned/Managed, QMD > 20"		FRG III	30	10	-20	-80	-80	-100
State Owned/Managed, QMD > 20"		FRG IV/V	-20	-40	-60	-80	-100	-100

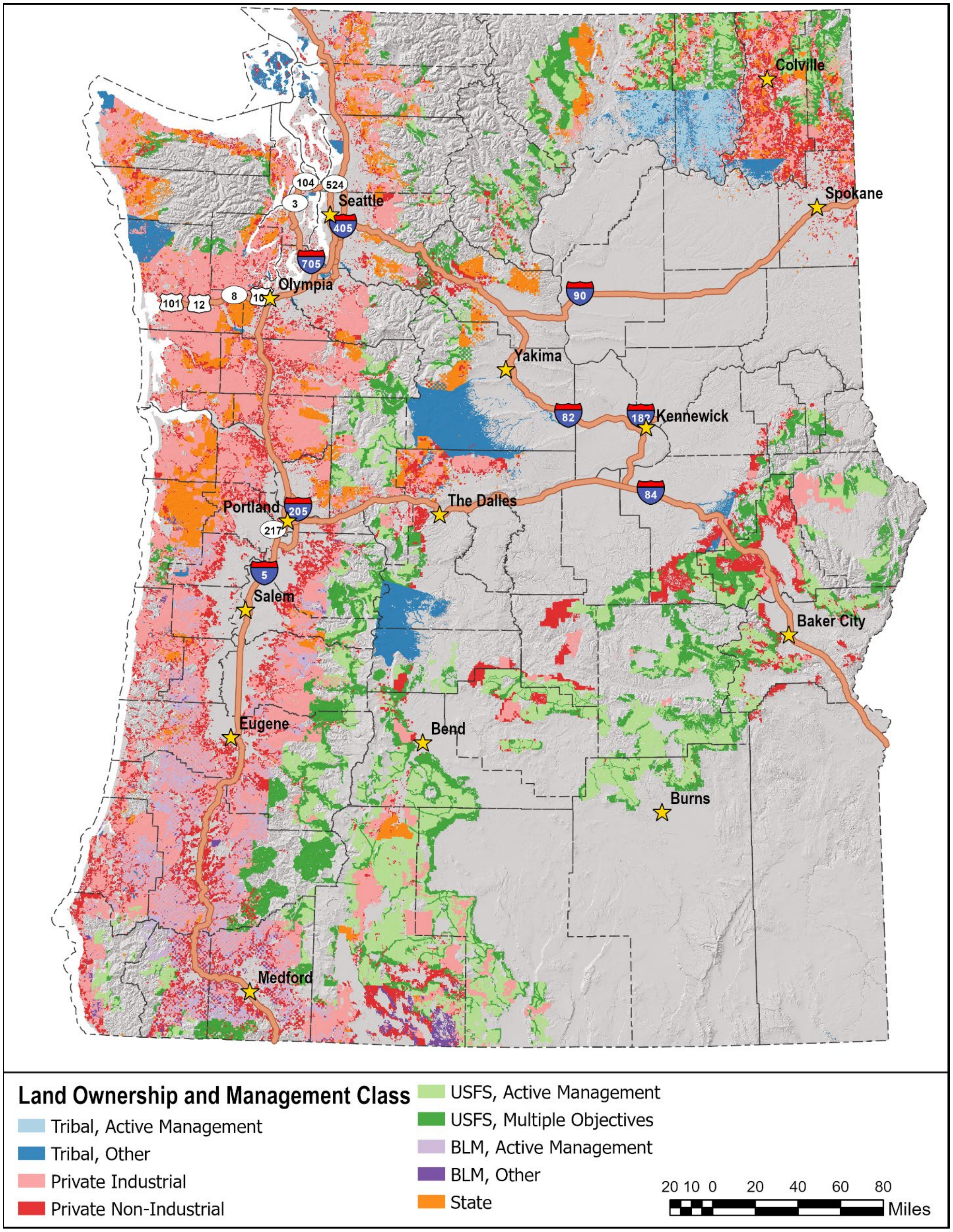

Figure 19. Extent of land management-based sub-HVRAs in the Timber HVRA.

4.3.6 Wildlife Habitat

Intent

The Wildlife HVRA is intended to evaluate wildfire risk to wildlife habitat.

4.3.6.1 Northern Spotted Owl

Summary of changes compared to previous QWRA

In the PNW QWRA 2018 there was a single sub-HVRA for northern spotted owl. In the PNW QWRA 2023, we used updated data, including maps of fire refugia produced by the U.S. Forest Service, to further classify into two sub-HVRAs.

Methods

Northern spotted owl (NSO) habitat extent is based primarily on modeled suitable habitat data developed by the U.S. Forest Service (Davis et al., 2022). Suitable habitat represents areas where the biotic and abiotic characteristics are suitable for nesting, breeding, hunting and dispersal. For the purposes of assigning relative importance, we further classified suitable habitat into two sub-HVRAs based on the likelihood of high severity fire using unpublished data developed by the U.S. Forest Service (Meigs et al., 2020). The data characterizes areas with comparatively low likelihood of high severity fire as "fire refugia." When suitable habitat was co-located within fire refugia it was given a larger share of the relative importance as a way of recognizing habitat with the highest conservation priority. Conversely, habitat outside the refugia has a greater likelihood of being converted to non-suitable habitat by high severity fire and is therefore still important but of lesser conservation value.

Response to fire was similar across the two sub-HVRAs but assumed to be slightly more positive at FIL 2 for the non-refugia sub-HVRA as a way on conveying the benefits of removing understory fuels in areas with comparably higher likelihood of high severity fire.

Table 28. Response functions for the two northern spotted owl sub-HVRAs. Share of HVRA RI is the amount of the HVRA's relative importance assigned to each sub-HVRA. In this case, northern spotted owl sub-HVRAs cumulatively were assigned about 21% of all the importance within the Wildlife Habitat HVRA.

		Fire Intensity Level (flame length)					
Sub-HVRA	**Share of HVRA RI**	**FIL 1**	**FIL 2**	**FIL 3**	**FIL 4**	**FIL 5**	**FIL 6**
		0 - 2'	*2 - 4'*	*4 - 6'*	*6 - 8`*	*8 - 12'*	*>12'*
Northern Spotted Owl, outside refugia	3%	20	50	-10	-60	-80	-100
Northern Spotted Owl, inside refugia	18%	40	20	-10	-60	-80	-100

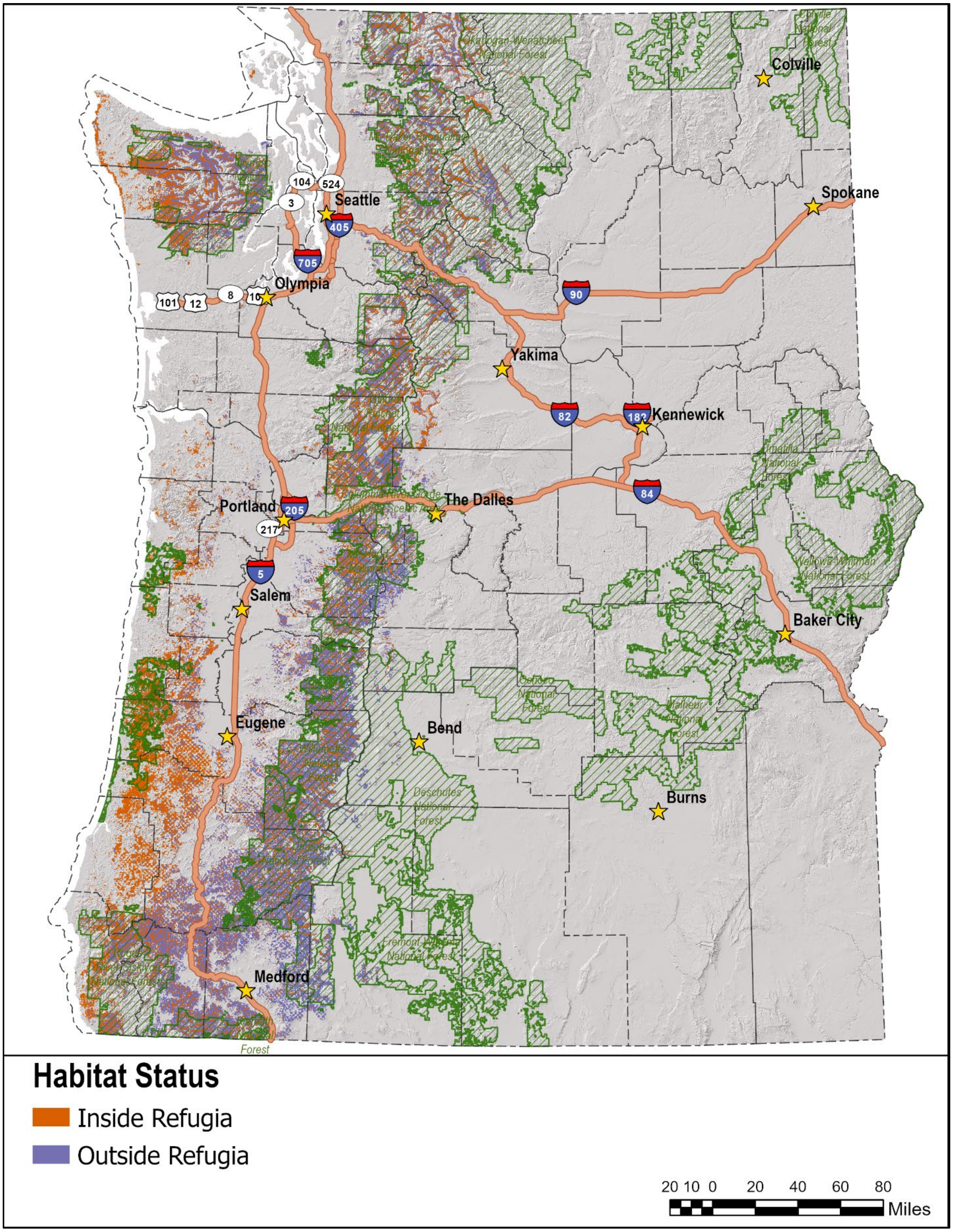

Figure 20. Distribution of the northern spotted owl sub-HVRA in the Wildlife HVRA.

4.3.6.2 Greater Sage-Grouse

Summary of changes compared to previous QWRA

The extent and characterization of greater sage-grouse sub-HVRAs is the same as in the PNW QWRA 2023.

Methods

Greater sage-grouse extent was mapped primarily based on the 2015 Resource Management Plans developed by the U.S. Bureau of Land Management (e.g. U.S. Department of Interior, Bureau of Land Management, 2015). The plans designate greater sage-grouse habitat as focal, priority, and general habitat. Focal areas are particular subsets of the priority habitat which are identified by U.S. Fish and Wildlife as essential strongholds for sage-grouse and of the highest conservation priority. Priority habitat includes areas essential to breeding, late brood-rearing, winter concentration areas, and migration or connectivity corridors. General habitat is of the least conservation priority and includes areas where special management might need to occur in order to sustain greater sage-grouse populations. These habitat management areas defined the sub-HVRAs and influenced allocation of relative importance.

The response to fire was a function of the habitat's resistance to invasive annual plants and resilience to wildfire effects as represented in regional resilience and resistance (R&R) data (NRCS West Technology Support Center, 2020). For all sub-HVRAs and all R&R classes, the impact of fire became increasingly negative as fire intensity increased (Table 29). Habitat with high R&R were assumed to be less susceptible to fires of all intensity levels, and even capable of benefiting from low intensity fire.

Table 29. Response functions for the greater sage-grouse sub-HVRAs. Share of HVRA RI is the amount of the HVRA's relative importance assigned to each sub-HVRA. In this case, greater sage-grouse sub-HVRAs cumulatively were assigned about 28% of all the importance within the Wildlife Habitat HVRA.

			Fire Intensity Level (flame length)					
Sub-HVRA	**Share of HVRA RI**	**Covariate**	**FIL 1**	**FIL 2**	**FIL 3**	**FIL 4**	**FIL 5**	**FIL 6**
			0 - 2'	*2 - 4'*	*4 - 6'*	*6 - 8`*	*8 - 12'*	*>12'*
Greater sage-grouse, focal habitat	17%	High R&R	30	10	0	-30	-50	-90
		Moderate R&R	-10	-20	-30	-60	-100	-100
		Low R&R	-10	-30	-70	-100	-100	-100
Greater sage-grouse, priority habitat	8%	High R&R	30	10	0	-30	-50	-90
		Moderate R&R	-10	-20	-30	-60	-100	-100
		Low R&R	-10	-30	-70	-100	-100	-100
Greater sage-grouse, general habitat	3%	High R&R	30	10	0	-30	-50	-90
		Moderate R&R	0	-10	-30	-60	-100	-100
		Low R&R	-10	-30	-70	-100	-100	-100

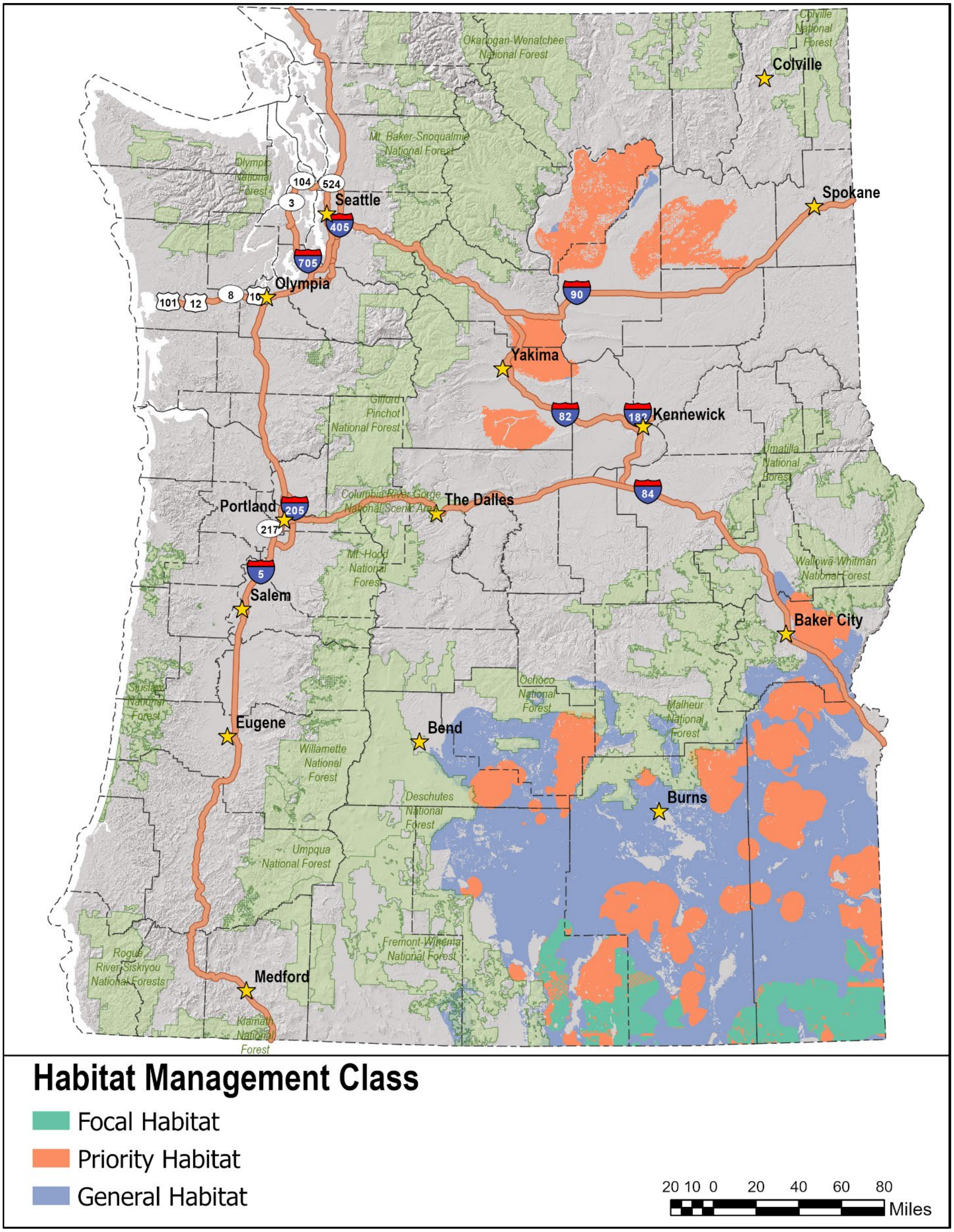

Figure 21.Extent of greater sage-grouse sub-HVRAs in the Wildlife HVRA.

4.3.6.3 Marbled Murrelet

Summary of changes compared to previous QWRA

The extent and characterization of marbled murrelet is the same as in the previous QWRA.

Methods

The extent of Marbled Murrelet habitat was mapped using critical habitat was obtained from U.S. Fish and Wildlife, Endangered Species Program. The response to fire indicates some benefits of fire at lower intensities, reflecting conditions under which fuel loads might be reduced, thereby diminishing future opportunities for high severity fire without threatening habitat quality. As fire intensity increases however, it is increasingly likely that marbled murrelet habitat would be degraded or destroyed.

Table 30. Response functions for the Marbled Murrelet sub-HVRA. Share of HVRA RI is the amount of the HVRA's relative importance assigned to each sub-HVRA. In this case, marbled Murrelet sub-HVRAs cumulatively were assigned about 21% of all the importance within the Wildlife Habitat HVRA.

		Fire Intensity Level (flame length)					
Sub-HVRA	**Share of HVRA RI**	**FIL 1**	**FIL 2**	**FIL 3**	**FIL 4**	**FIL 5**	**FIL 6**
		0 - 2'	*2 - 4'*	*4 - 6'*	*6 - 8`*	*8 - 12'*	*>12'*
Marbled Murrelet	21%	40	20	-10	-60	-100	-100

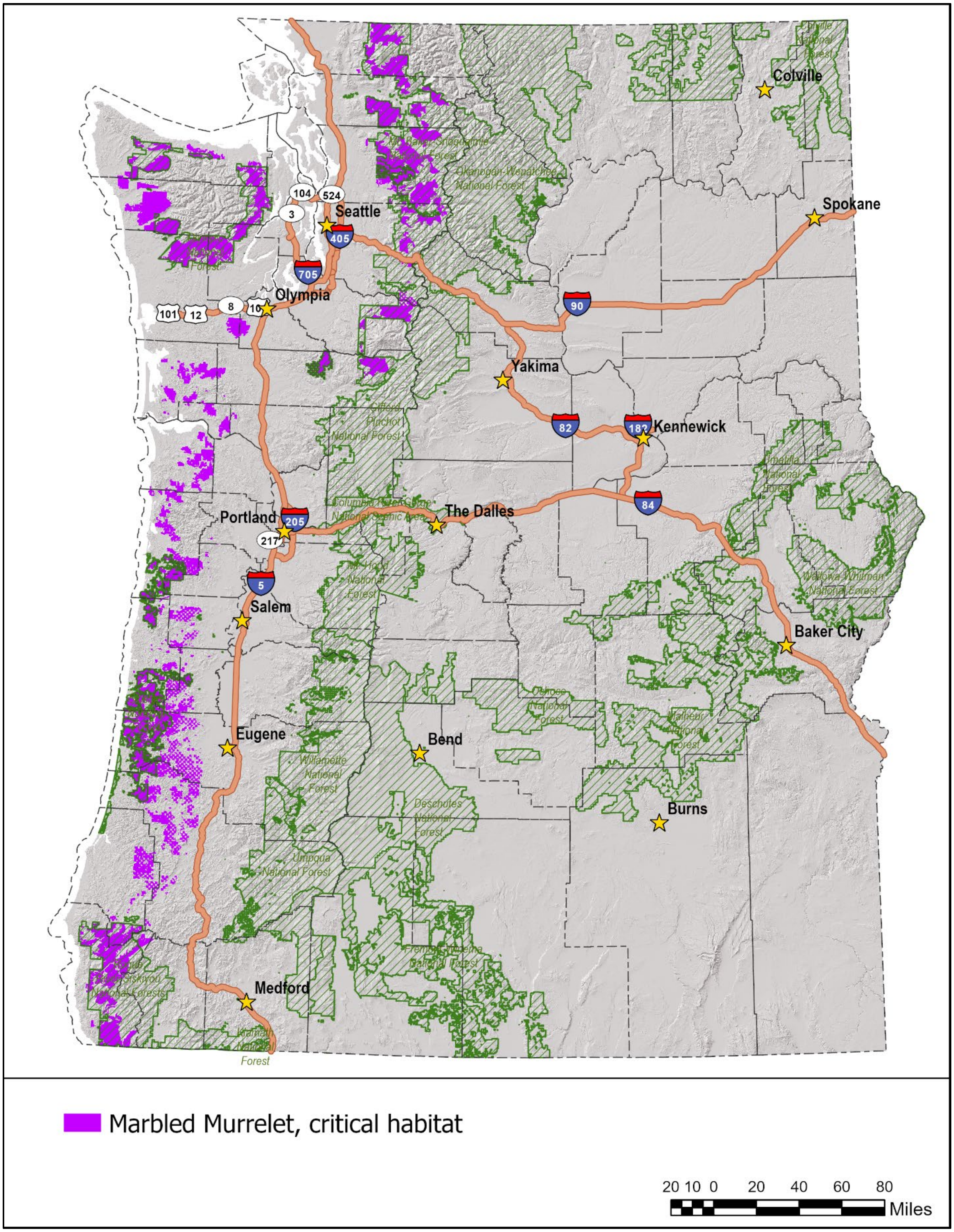

Figure 22. The extent of the marbled murrelet sub-HVRA in the Wildlife HVRA.

4.3.6.4 Aquatic Species

Summary of changes compared to previous QWRA

The extent and characterization of aquatic species sub-HVRAs are similar to the PNW QWRA 2023.

Methods

The extent of the bull trout sub-HVRA was mapped using StreamNet Generalized Fish Distribution layer. Line data was converted to a 30-meter raster and expanded by three pixels on either side to account for the area which might be affected by wildfire and which might impact habitat that includes the riparian area.

We mapped the extent of the steelhead trout sub-HVRA using U.S. Fish and Wildlife Critical Habitat data (NOAA Marine Fisheries Services, 1994). We converted line data to a 30-meter raster and expanded by three pixels on either side to account for the area which might be affected by wildfire and which might impact habitat.

We mapped the extent of the chinook salmon sub-HVRA using U.S. Fish and Wildlife Critical Habitat data (NOAA Marine Fisheries Services, 1994). Line data was converted to a 30-meter raster and expanded by three pixels on either side to account for the area which might be affected by wildfire and which might impact habitat.

The majority of the extent of the Coho salmon sub-HVRA using U.S. Fish and Wildlife Critical Habitat data (NOAA Marine Fisheries Services, 1994). However, the Southern Oregon Northern California Coast (SONCC) Evolutionarily Significant Unit (ESU) was not represented in that layer. To map the SONCC ESU, we compiled spatial population data from multiple sources (Bureau of Land Management; Oregon Department of Fish and Wildlife, 2012) and then clipped streams to the polygons of the SONCC ESU(NOAA Marine Fisheries Services, 2018). Finally, we identified permanent barriers to fish passage and eliminated upstream reaches (Bureau of Land Management). Line data was converted to a 30-meter raster and expanded by three pixels on either side to account for the area which might be affected by wildfire and which might impact habitat.

The response to fire indicates that fire is largely beneficial at low and moderate intensities, but increasingly negative beyond FIL 3 (Table 31).

Table 31. Response functions for the aquatic wildlife sub-HVRAs. Share of HVRA RI is the amount of the HVRA's relative importance assigned to each sub-HVRA. In this case, fish species sub-HVRAs cumulatively were assigned cumulatively about 24% of all the importance within the Wildlife Habitat HVRA.

		Fire Intensity Level (flame length)					
Sub-HVRA	**Share of HVRA RI**	**FIL 1** *0 - 2'*	**FIL 2** *2 - 4'*	**FIL 3** *4 - 6'*	**FIL 4** *6 - 8`*	**FIL 5** *8 - 12'*	**FIL 6** *>12'*
Bull Trout	8%	20	20	10	-10	-20	-50
Steelhead Trout	8%	20	20	10	-10	-20	-50
Coho Salmon	8%	20	20	10	-10	-20	-50
Chinook Salmon	8%	20	20	10	-10	-20	-50

Figure 23.Extent of bull trout sub-HVRA in the Wildlife HVRA.

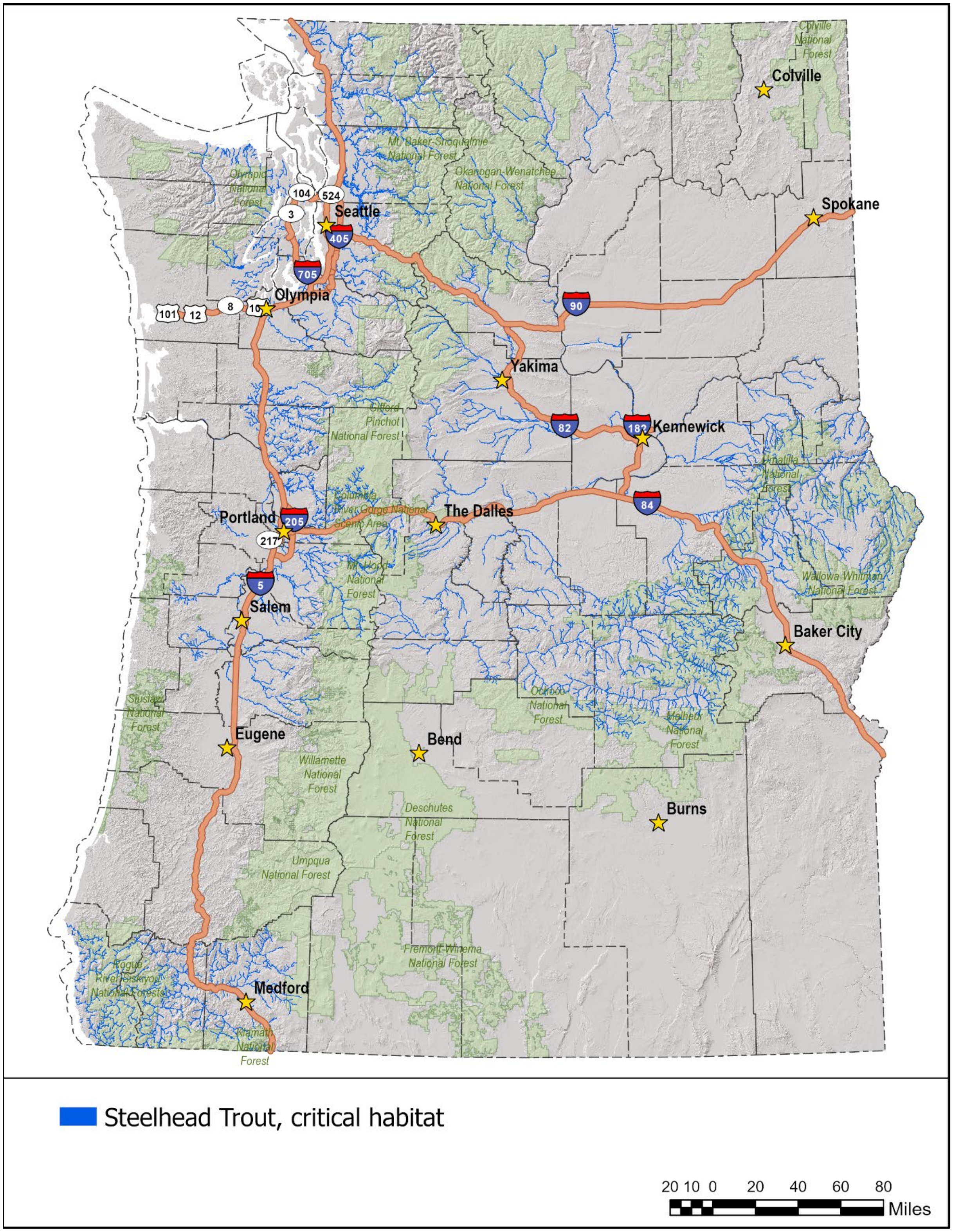

Figure 24 Extent of steelhead trout sub-HVRA in the Wildlife HVRA.

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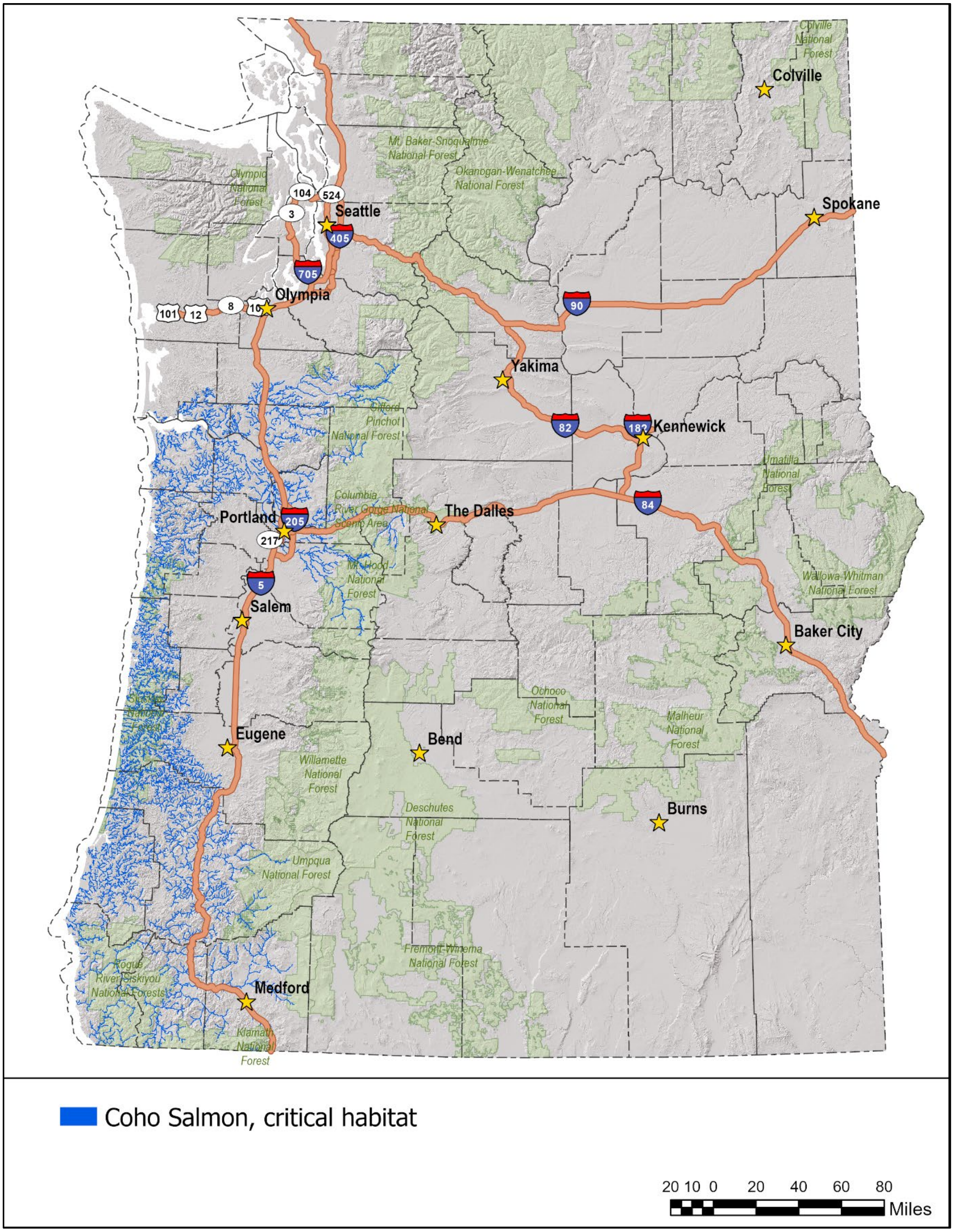

Figure 25. Extent of coho salmon sub-HVRA in the Wildlife HVRA.

Figure 26. Extent of chinook salmon sub-HVRA in the Wildlife HVRA.

4.3.7 Agriculture

4.3.7.1 Intent

The Agriculture HVRA is intended to evaluate wildfire risk to cropland and associated infrastructure.

4.3.7.2 Summary of changes compared to previous QWRA

Agriculture was not mapped as an HVRA in the PNW QWRA.

4.3.7.3 Methods

We mapped the extent of croplands using the last five years of Cropscape data from the U.S. Department of Agriculture (USDA-NASS, 2022). All pixels that were considered cultivated between 2018 and 2022 were included in the HVRA extent and the most common crop type associated with each cultivated pixel was used to classify the sub-HVRA as either perennial or annual.

The response to fire was uniformly adverse across all sub-HVRAs at all intensities (Table 32).

Nine percent of the overall relative importance was allocated to the Agriculture HVRA. Of that, perennials were deemed to be ten times more important than annuals, reflecting the reality that annuals can often be recovered in the following years while perennials may take decades to recover.

Table 32. Response functions for the Agriculture sub-HVRAs. Share of HVRA RI is the amount of the HVRA's relative importance assigned to each sub-HVRA.

		Fire Intensity Level (flame length)					
Sub-HVRA	**Share of HVRA RI**	**FIL 1**	**FIL 2**	**FIL 3**	**FIL 4**	**FIL 5**	**FIL 6**
		0 - 2'	*2 - 4'*	*4 - 6'*	*6 - 8`*	*8 - 12'*	*>12'*
Perennial	17%	-100	-100	-100	-100	-100	-100
Annual	83%	-100	-100	-100	-100	-100	-100

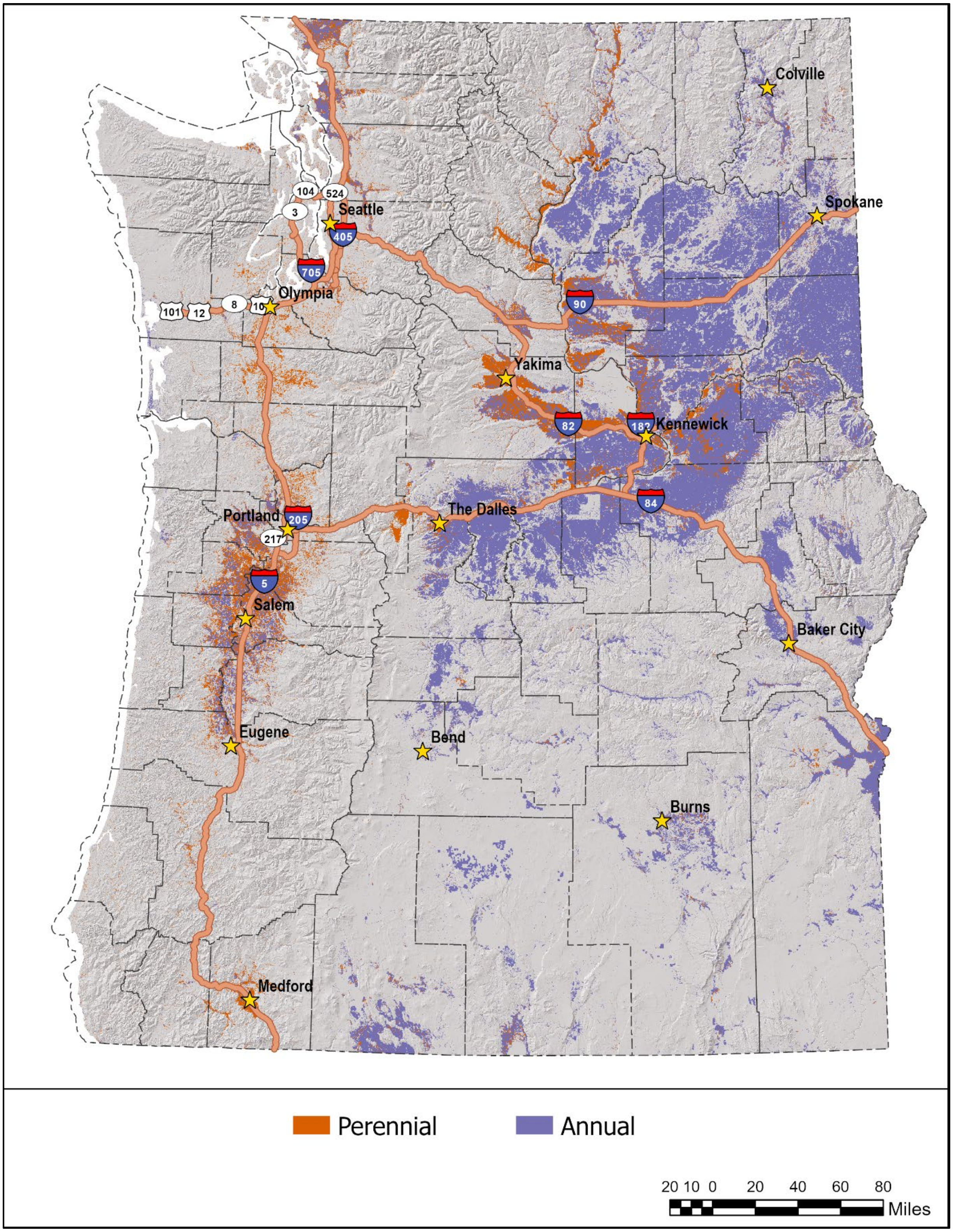

Figure 27. Extent of the Agriculture sub-HVRAs.

4.3.8 Recreation Infrastructure

4.3.8.1 Intent

The Recreation HVRA is intended to evaluate wildfire risk to outdoor recreation infrastructure.

4.3.8.2 Summary of changes compared to previous QWRA

In the PNW QWRA 2018, wildfire risk to recreation infrastructure was captured within the Infrastructure HVRA. In this update, we used the same methods and similar data to map and characterize recreation infrastructure, but created a new Recreation HVRA so that the updated Infrastructure HVRA remains focused on energy, communications, and transportation.

4.3.8.3 Methods

Mapping the extent of recreation infrastructure required a wide range of data sets and methods according to what was available from each landowner or agency.

Non-Federal Recreation Infrastructure in Oregon. We combined multiple spatial datasets from various state agencies. First, we used the Oregon Parkland Dataset which was developed by Oregon State Parks and which maps publicly accessible parks in Oregon (Oregon State Parks, 2019). We filtered the types of parks to include Special Use Park, Nature Park, Regional Park, Regional Sports Park, Destination Park and Community Park. The result was 2,847 parks.

The Oregon Parkland Dataset represents parks as polygons and does not identify specific infrastructure. To estimate the location of recreation infrastructure we intersected the park polygons with known structure locations from the Statewide Building Footprints of Oregon data (Williams, 2021). Any structure mapped in this fashion was assumed to be in the High Development sub-HVRA.

Finally, the Oregon Department of forestry provided a point dataset of recreation infrastructure within State Forests (Oregon Department of Forestry, 2020). Using the Layer_Name attribute, I classified them into appropriate sub-HVRA categories. If the point was attributed as Camping, Visitor Center, Camping, Day-use area, or Day-use area then it was classified as High Development recreation. All other attribute values – e.g. trailhead – were classified as Low Development recreation.

Non-Federal Recreation Infrastructure in Washington. We combined multiple spatial datasets from various state agencies. Washington State Parks and Recreation Commission provided a point dataset of recreation infrastructure locations and descriptions on state lands(Washington State Parks and Recreation, 2018a). Using the Name attribute, we classified all features as either High or Low Development sub-HVRAs. Features described as toilet, pump house, vault, storage, picnic, shed, or shelter were classified as Low Development and everything else as High Development recreation infrastructure.

Next, we used the Washington Major Public Lands polygons to identify likely recreation infrastructure (Washington State Department of Natural Resources, 2017). The Washington Major Public Lands dataset includes ownership parcels for Federal, State, County and City lands within Washington, excluding any lands owned by the Washington Department of Natural Resources. Identifying likely recreation infrastructure required two steps. First, we filtered the dataset so that only parcels described as recreation or park were maintained. Second, we intersected the remaining polygons with Washington's structure point location data. All points were classified as High Development because they represent structures.

Finally, we added developed campgrounds using data from the Washington State Parks and Recreation Commission (Washington State Parks and Recreation, 2018b).

Recreation Infrastructure on Federal land. Federal recreation infrastructure was identified using a national dataset of recreation infrastructure on lands managed by the U.S. Department of the Interior and the U.S. Forest Service (Esri U.S. Federal Datasets, 2021). The dataset includes campgrounds, trailheads, cabins, shelters, picnic areas, headquarters, visitor information centers and ranger stations. We classified all infrastructure as High Development except trailheads.

One percent of the overall relative importance was allocated to the Recreation Infrastructure HVRA. Within this HVRA, significantly more importance was placed on High Development infrastructure compared to Low Development infrastructure.

Table 33. Response functions for the Recreation sub-HVRAs. Share of HVRA RI is the amount of the HVRA's relative importance assigned to each sub-HVRA.

		Fire Intensity Level (flame length)					
Sub-HVRA	**Share of HVRA RI**	**FIL 1** *0 - 2'*	**FIL 2** *2 - 4'*	**FIL 3** *4 - 6'*	**FIL 4** *6 - 8`*	**FIL 5** *8 - 12'*	**FIL 6** *>12'*
High Development	97%	-10	-30	-70	-90	-100	-100
Low Development	3%	-10	-30	-70	-90	-100	-100

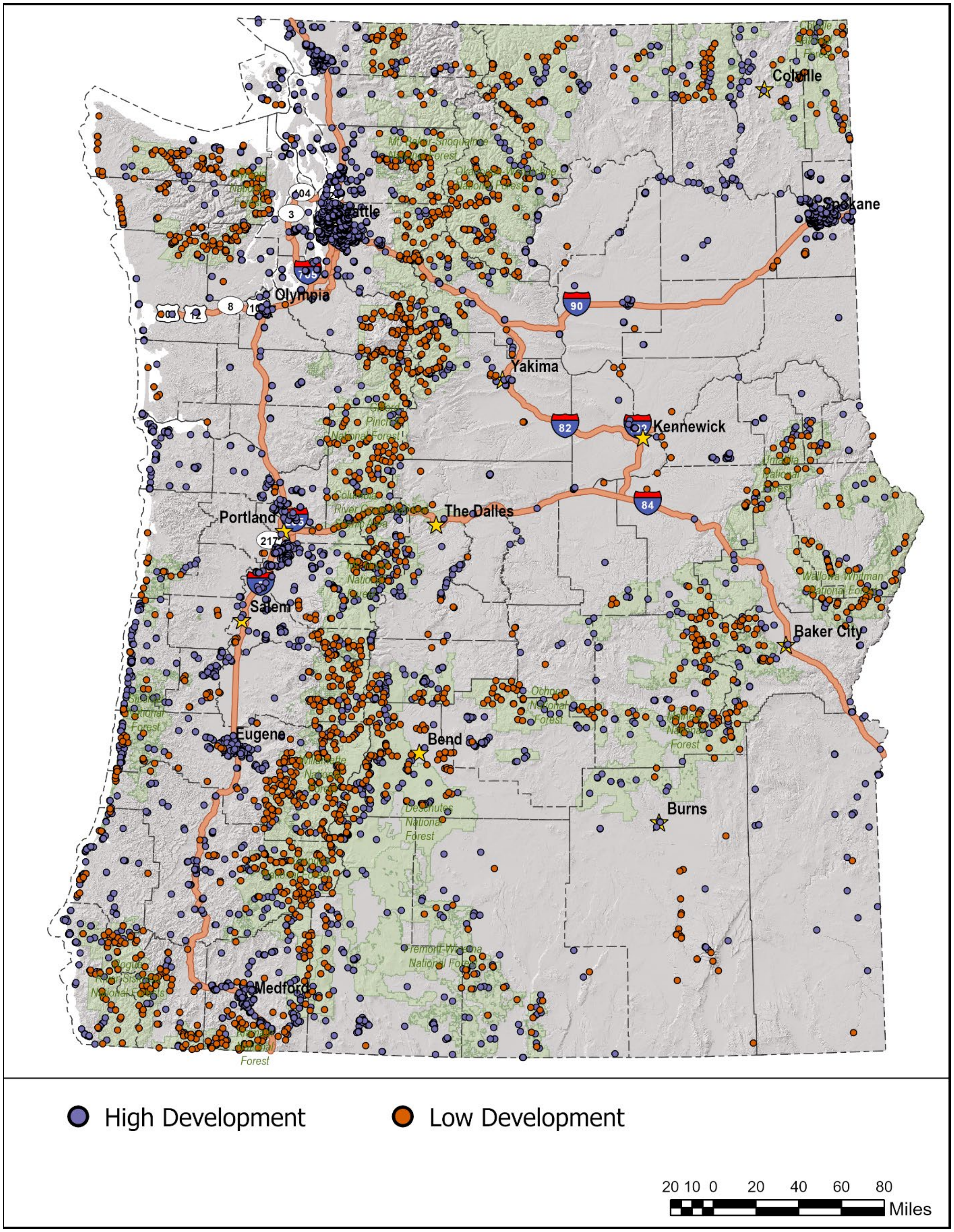

Figure 28. Extent of the Recreation sub-HVRAs.

5 Integrated Risk Results

Integrated risk results (i.e. eNVC and cNVC) are useful ways to look at net risk across multiple HVRAs simultaneously. Users can integrate any combination of HVRAs and sub-HVRAs that might be relevant to their planning objectives. The following figures illustrate the most common integrate risk products which includes integrating HVRAs (Figures 29 and 30), and HVRA-level integrated products which integrate risk across all the sub-HVRAs within an HVRA category (Figures 31 through Figures 38).

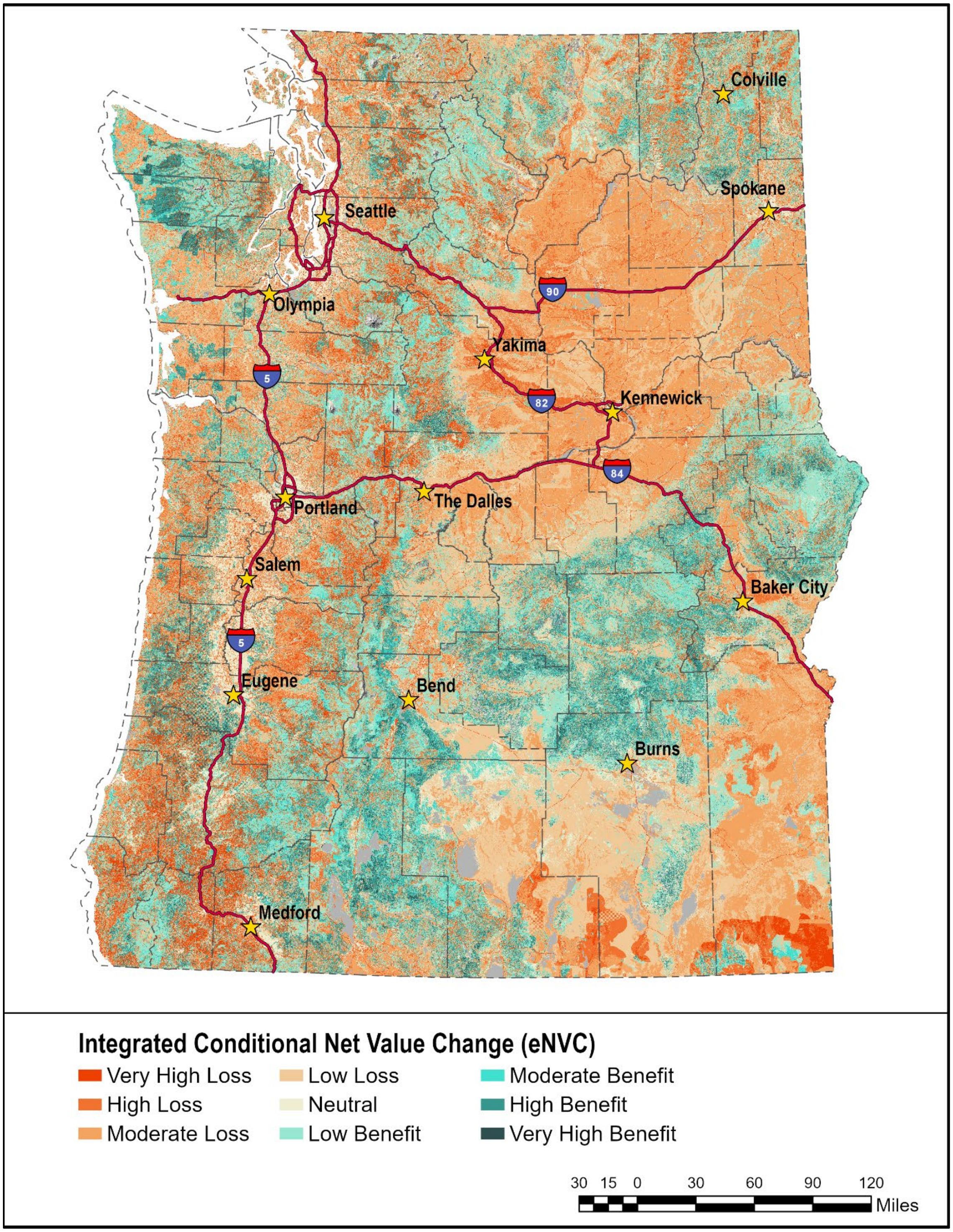

Figure 29. Final expected net value change (eNVC) integrated across all eight HVRAS.

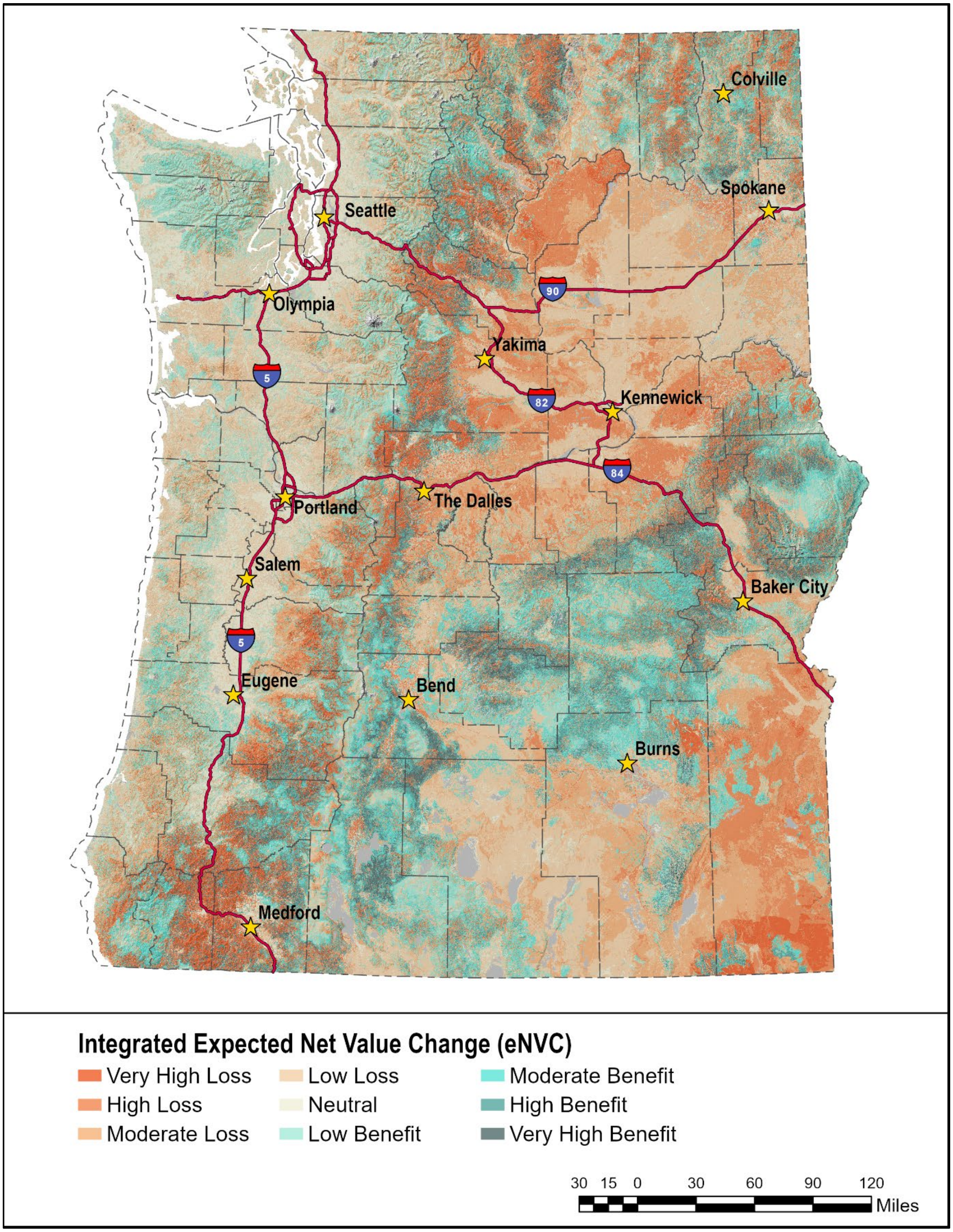

Figure 30. Final conditional net value change (cNVC) integrated across all eight HVRAS.

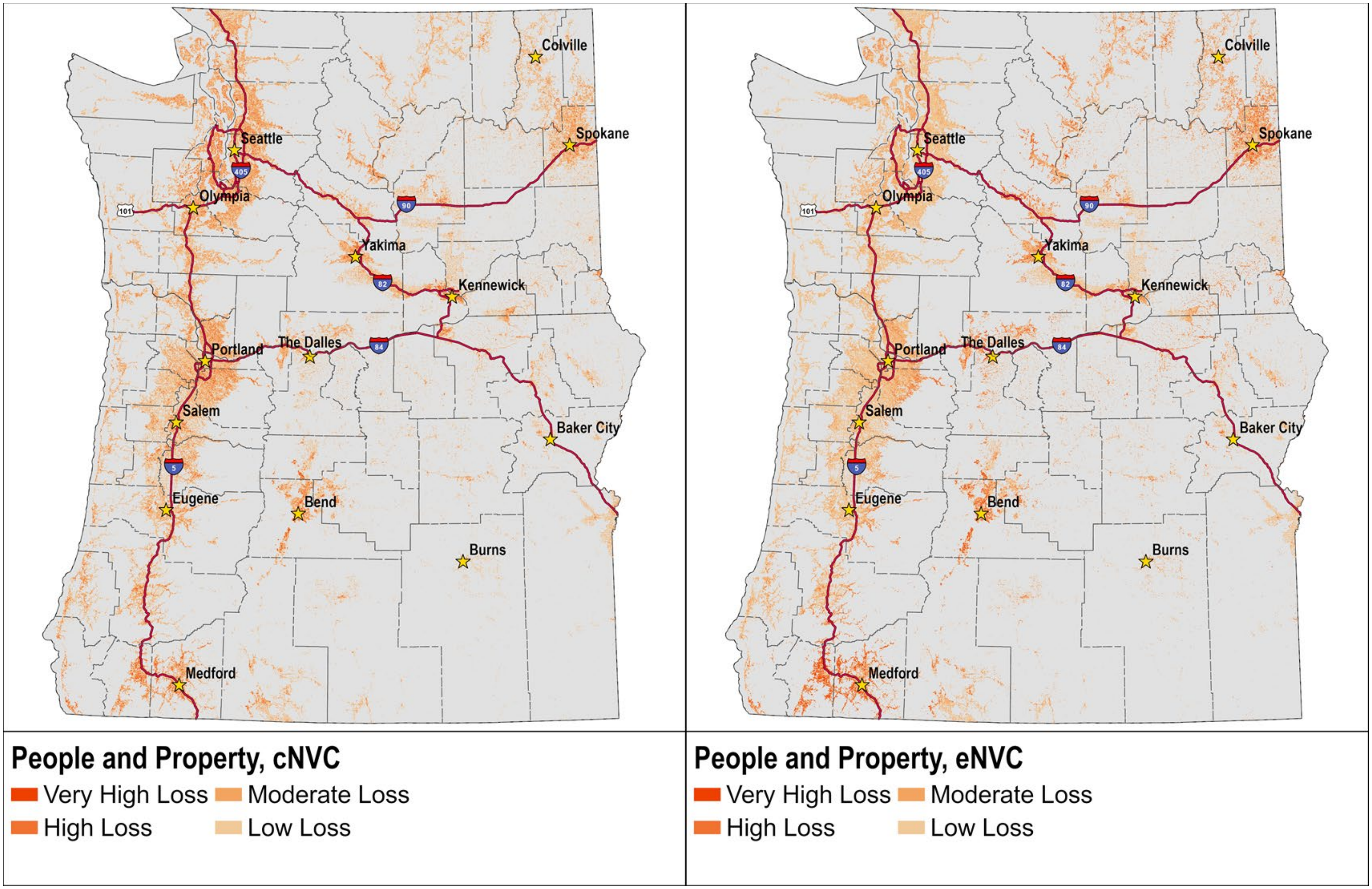

Figure 31. Conditional net value change (cNVC, left) and expected net value change (eNVC, right) for the People and Property HVRA in the PNW QWRA 2023.

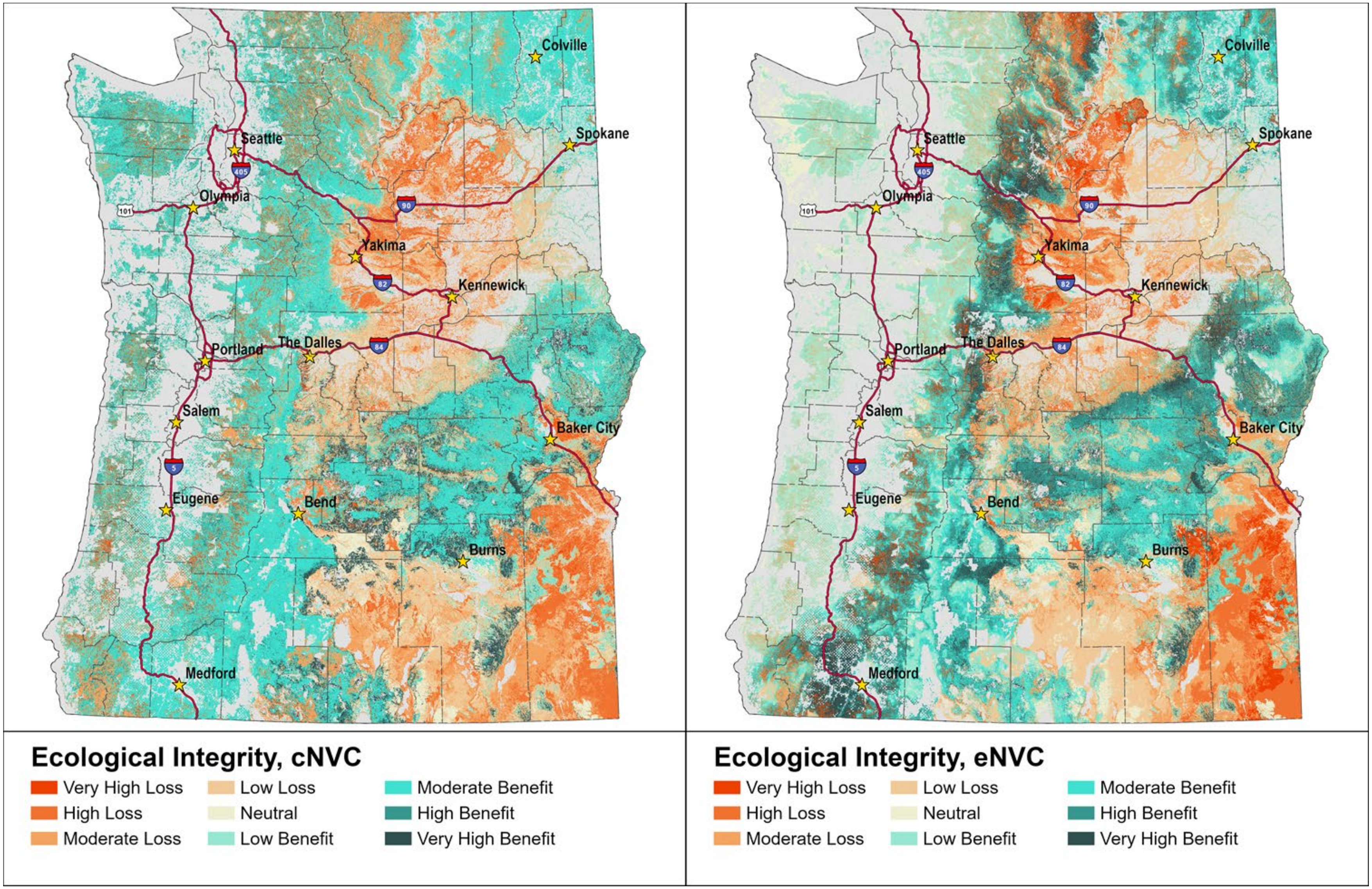

Figure 32. Conditional net value change (cNVC, left) and expected net value change (eNVC, right) for the Ecological Integrity HVRA in the PNW QWRA 2023.

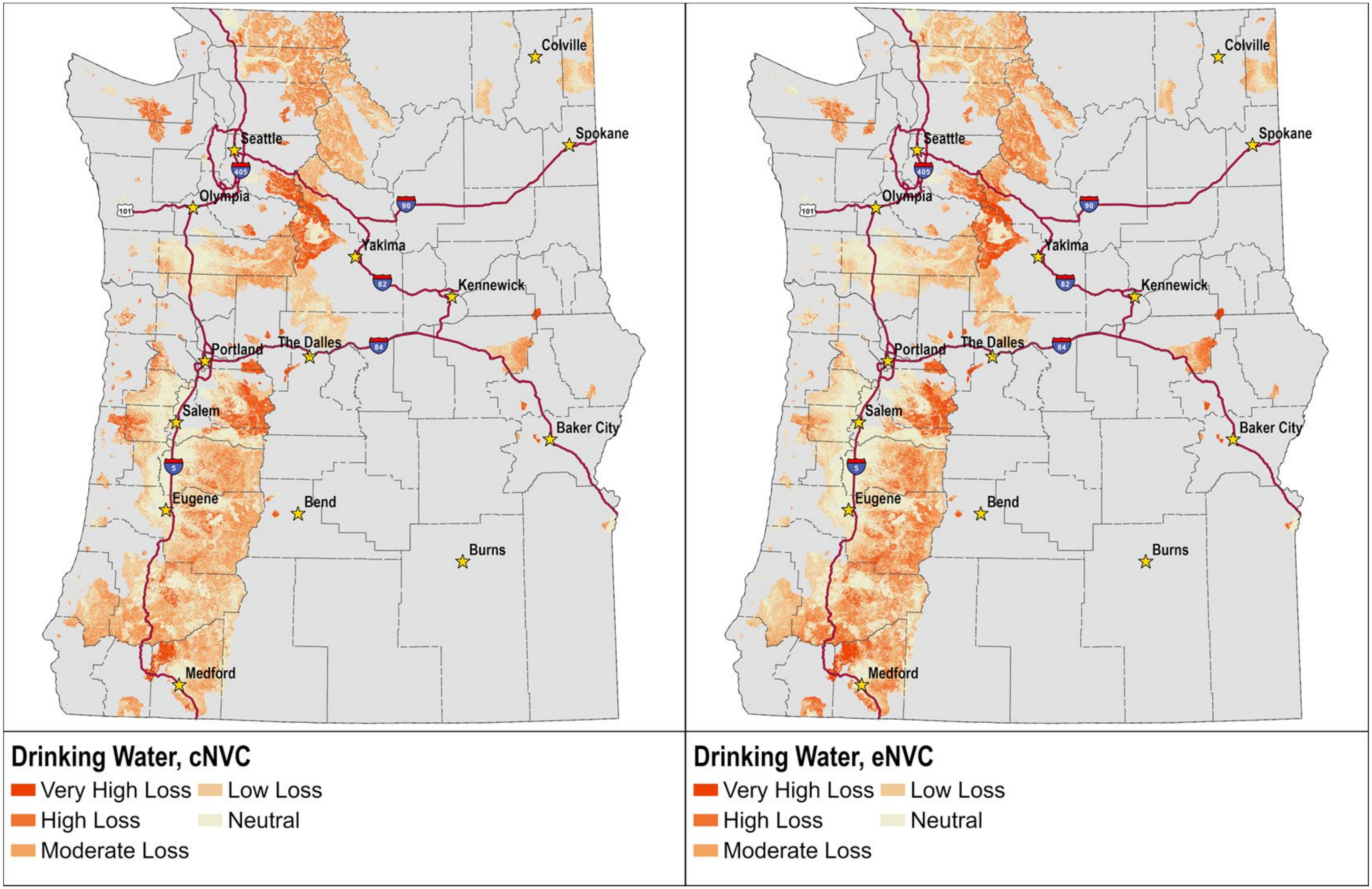

Figure 33. Conditional net value change (cNVC, left) and expected net value change (eNVC, right) for the Drinking Water HVRA in the PNW QWRA 2023.

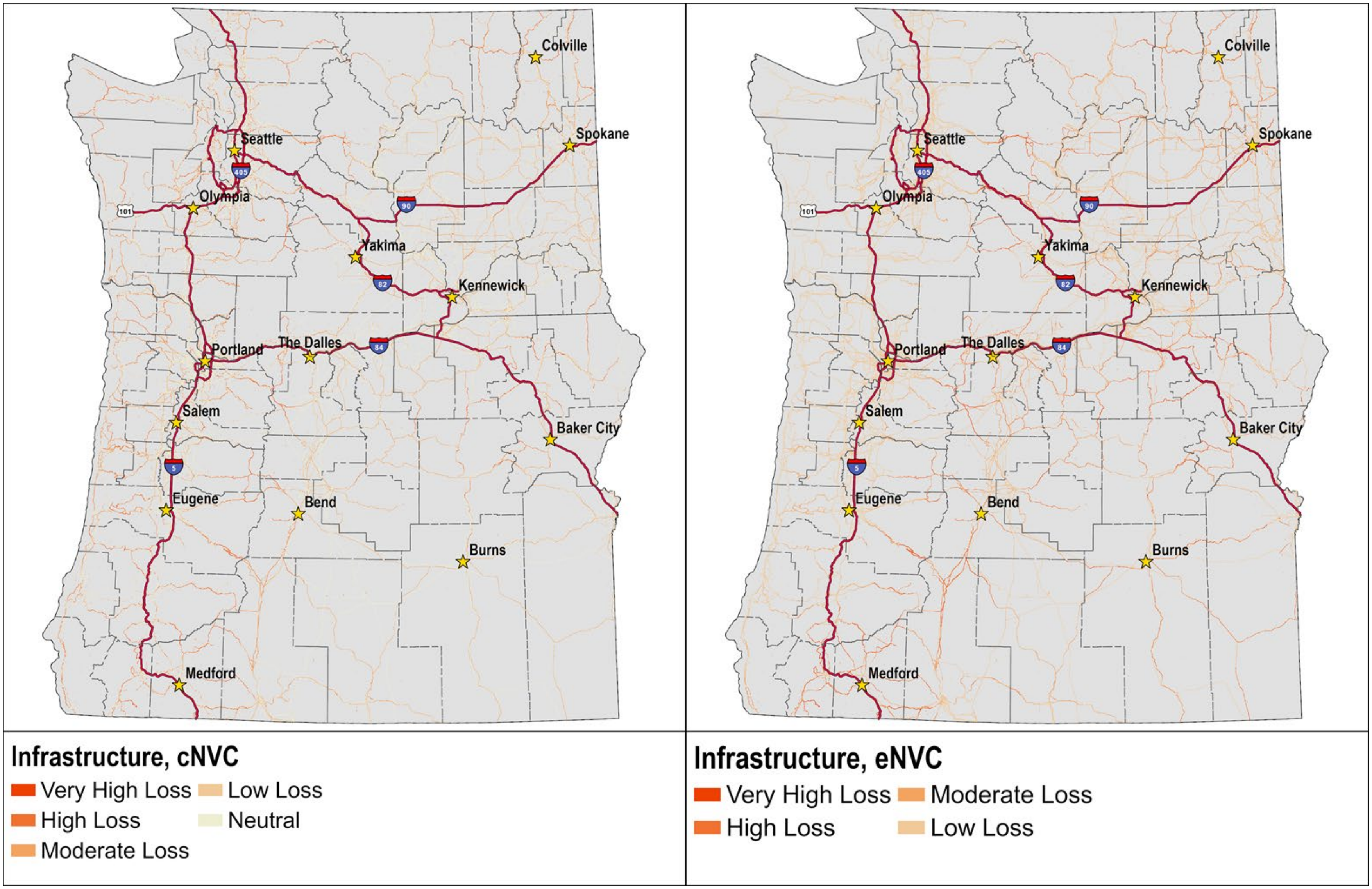

Figure 34. Conditional net value change (cNVC, left) and expected net value change (eNVC, right) for the Infrastructure HVRA in the PNW QWRA 2023.

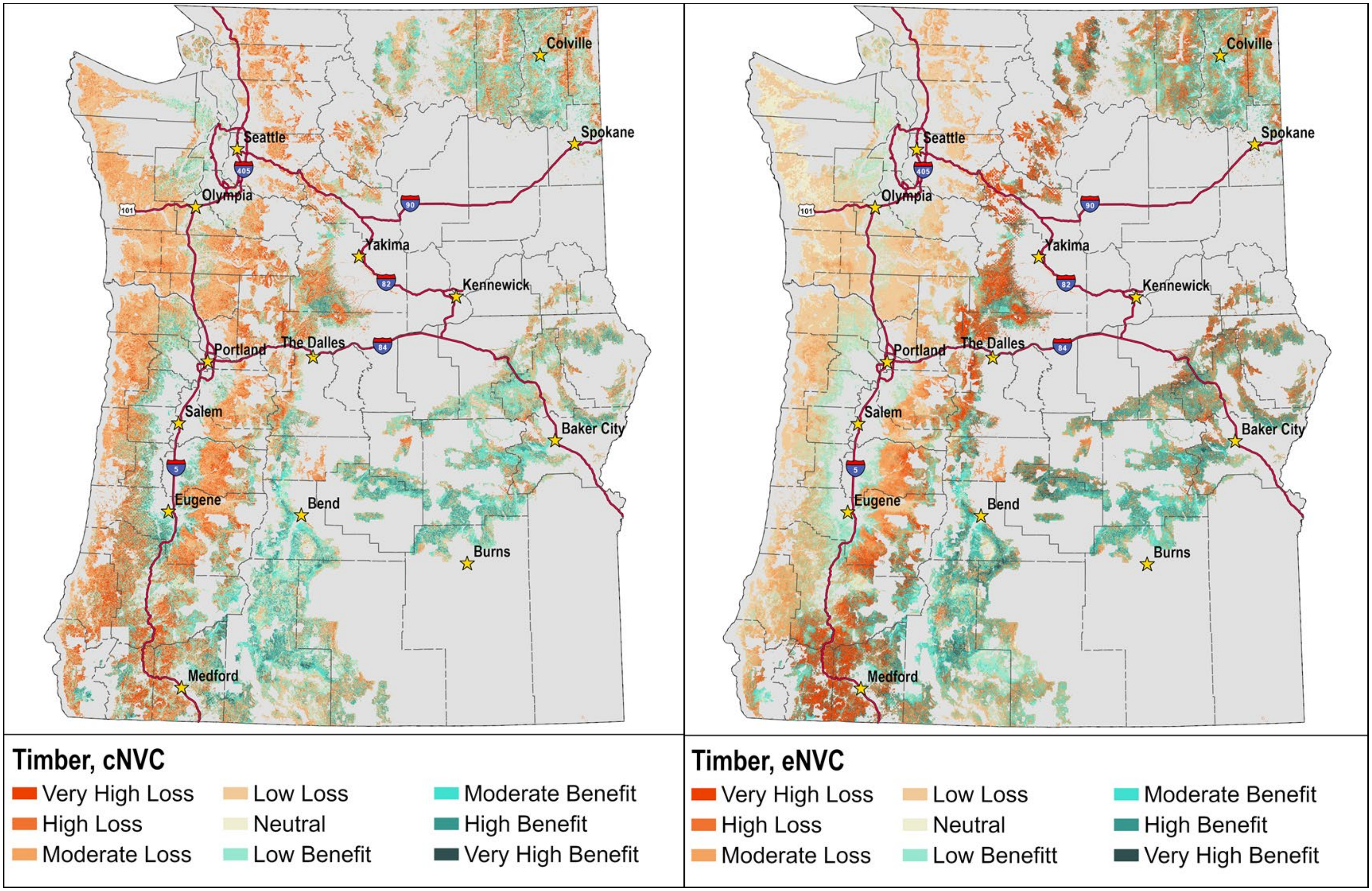

Figure 35. Conditional net value change (cNVC, left) and expected net value change (eNVC, right) for the Timber HVRA in the PNW QWRA 2023.

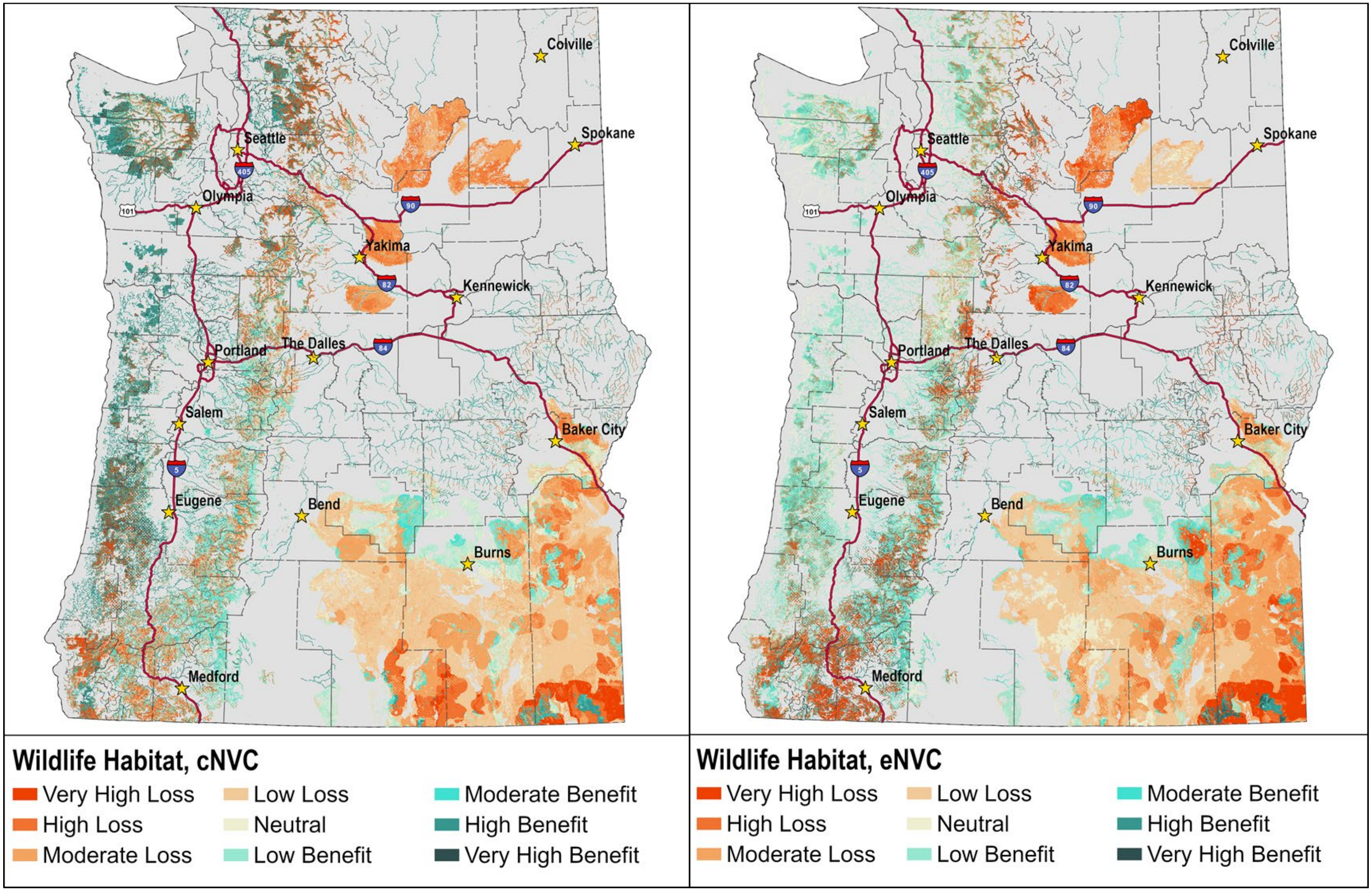

Figure 36. Conditional net value change (cNVC, left) and expected net value change (eNVC, right) for the Wildlife Habitat HVRA in the PNW QWRA 2023.

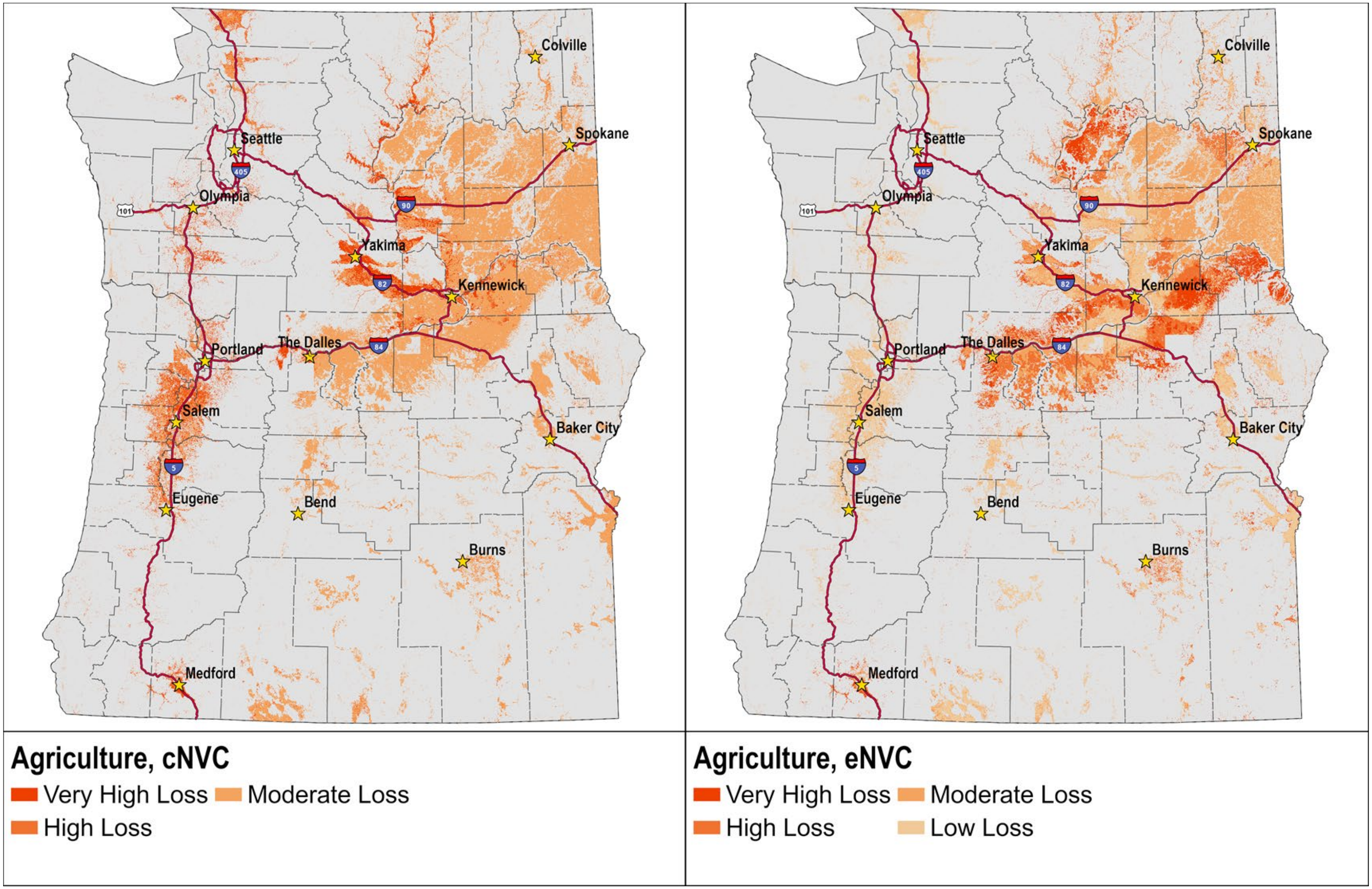

Figure 37. Conditional net value change (cNVC, left) and expected net value change (eNVC, right) for the Agriculture HVRA in the PNW QWRA 2023.

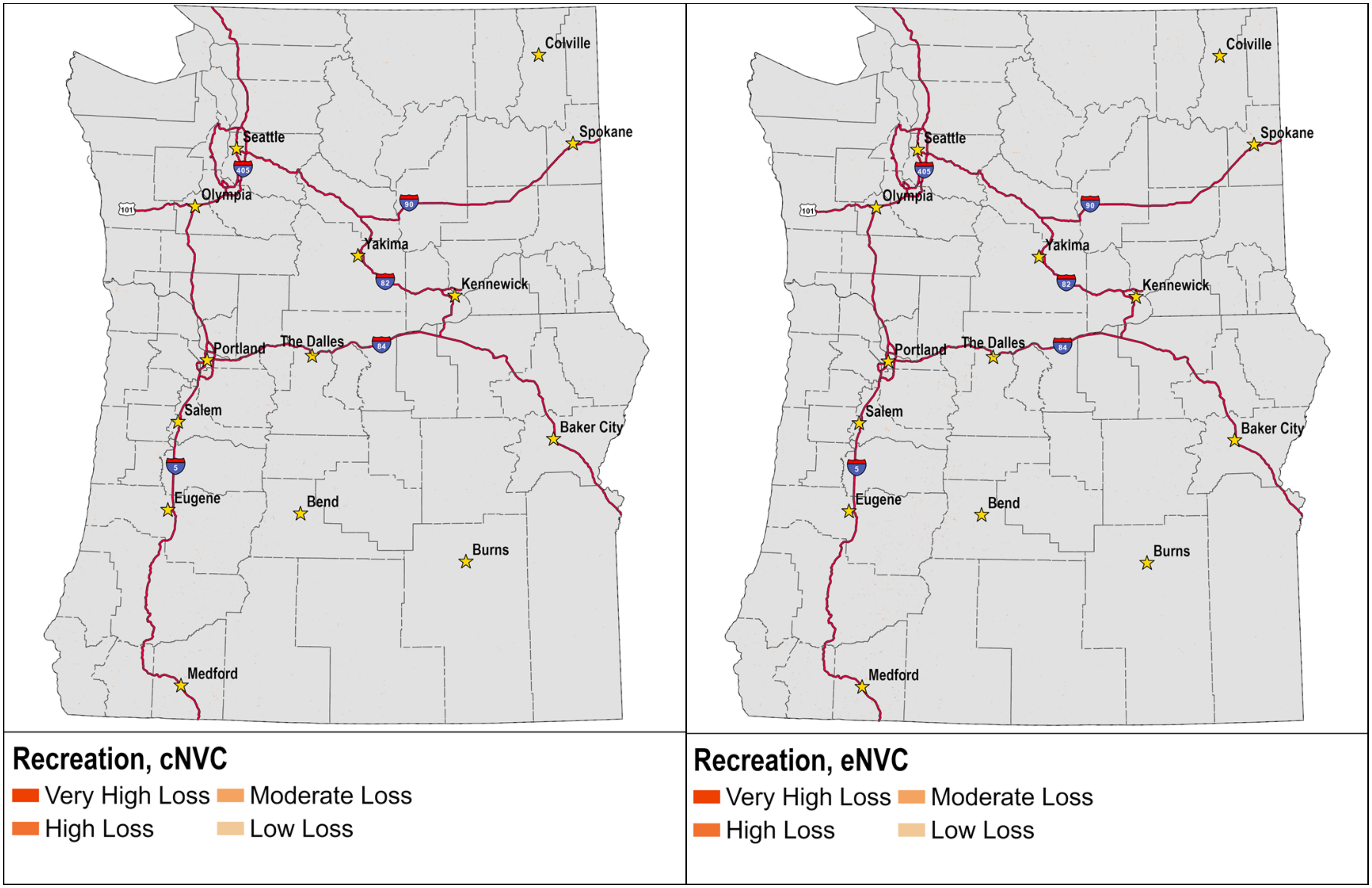

Figure 38. Conditional net value change (cNVC, left) and expected net value change (eNVC, right) for the Recreation HVRA in the PNW QWRA 2023. Note that results are difficult to see because in most cases recreation resources have very small extents.

6 Suggested Uses and Best Practices

6.1 Interpreting Risk Results, Classifying Data and Symbology

Quantitative wildfire risk assessments produce relative risk values for each pixel in the analysis area, reflecting which HVRAs are present, and how those HVRAs would likely respond to fire given the coincident fire hazard characteristics. The risk value is expressed as net value change (NVC), either positive or negative. Expected Net Value Change (eNVC) numbers in particular are usually very small decimals because we multiply susceptibility by burn probability, a small decimal value itself, to calculate eNVC. For some users it may be confusing that very high risk is associated with a value so close to zero, but the magnitude of an NVC number is only meaningful within the context of NVC values from across the rest of the study area because the QWRA framework is an evaluation of *relative* risk.

For prioritization applications, the continuous NVC outputs are usually classified into categories. The classification schemes included with the data are just one way of binning risk values. Importantly, the classification schemes included with the QWRA data are based on the full range of risk values from across Oregon and Washington. Consequently, when clipping QWRA results to a different extent (e.g., county, national forest, watershed, etc.), it is advisable to reclassify the data based on the range of risk values within the new extent.

The classification schemes provided with the data were all based on the same general methodology. First, using the full range of risk values from across the analysis area, we calculated the 5th, 40th, 70th and 90th percentile values of the negative risk values only. Then, we mirrored those percentile values to create class breakpoints for the positive risk values (Table 34).

The provided classification schemes vary based on whether the data represent eNVC or cNVC, and based on whether the data represent integrated risk results (i.e. ieNVC or icNVC) or HVRA-level risk results. For integrated risk results, the percentile breakpoints were calculated using the full range of integrated NVC values. For HVRA-level classification schemes, the percentile breakpoints were calculated using NVC values from that HVRA only.

Table 34. Example of a classification scheme. The negative values in the "high" column are the 5th, 40th, 70th and 90th percentile breakpoint values of all the negative risk values sampled for this example. Note how those breakpoint values (e.g.-0.00074, -0.00019, etc.) are mirrored for the benefit classes.

Risk Value Range		Label
Low	*High*	
-0.73218	-0.00074	Very high loss
-0.00074	-0.00019	High loss
-0.00019	-0.00003	Mod loss
-0.00003	0.00000	Low loss
0.00000	0.00000	Neutral
0.00000	0.00003	Low benefit
0.00003	0.00019	Mod benefit
0.00019	0.00074	High benefit
0.00074	0.73218	Very high benefit

6.2 Integrated vs. Non-Integrated Products

The PNW QWRA generates a wide range of unique representations of risk from which end-users can choose to support their planning needs. When identifying the most appropriate PNW QWRA analytics, one very common consideration is whether to use integrated or non-integrated risk products. The decision depends on what questions you're trying to answer.

Integrated risk products, where risk to multiple HVRAs is combined into a single value, offer a comprehensive representation of risk to the values described in this report. At any location, integrated risk products provide insight into the net effect for all HVRAs present. One advantage to integrated risk products is that they facilitate optimized planning for multiple objectives. When managers want to optimize risk mitigation to several spatially coincident HVRAs, integrated risk analytics make that process simpler than having to compare multiple separate data layers. Another advantage to integrated risk products is that they condense a lot of information into a single data layer which can simplify communication with broad audiences or expedite decision-making during active fire events. One disadvantage to integrated risk products is that, depending on the number of HVRAs included, it can be nearly impossible to tease apart which HVRAs are driving the risk value. Another disadvantage could be that overall relative importance plays a role in integrated risk outputs. In some circumstances, end-users might have significantly different relative importance frameworks than the one used in the QWRA. In that case, end-users need to be thoughtful about whether integrated risk products accurately represent risk for their planning needs, which ultimately depends on how one diagnosis the problem. Putting thought into this stage of a strategy is worth it in the outcome of your effort.

Non-integrated risk products, where risk to each HVRA is represented in a unique data layer, offer comparatively simple representations of risk. Non-integrated risk products facilitate targeted analysis to develop HVRA-specific risk mitigation plans. One advantage of non-integrated risk analytics is that it is much easier to determine what is driving risk at any given location because end-users need only to compare the HVRA data with the fire hazard data to gain insight into fire effects. Likewise, it could be an advantage that relative importance is not a factor in non-integrated risk products. The most obvious disadvantage to using non-integrated risk products is that they do not provide a comprehensive picture of risk and therefore may develop a risk mitigation strategy that only supports one of many values on a landscape This of course can be compounded by personal biases and perspectives, rather than a more collaborative approach.

6.3 Applying QWRA Data to Different Extents

Because the QWRA represents relative risk, all the risk products can be applied to smaller geographies and still meaningfully represent the spatial distribution of risk. When applying QWRA outputs to different geographic extents, consider the following three observations.

First, risk classification schemes might need to be re-designed based on a different range of values. Unless the end-user wants to compare risk values from their local planning landscape to risk across all of Oregon and Washington, risk will need to be reclassified when applying QWRA outputs to a smaller geography. Reclassifying risk values on a smaller planning landscape will illustrate a gradient of risk that is relevant to that particular landscape. Note that depending on the geographic scale and location of the smaller planning landscape, there may not be a significant range in risk values and so end-users might have to be creative with solutions for binning the data.

Second, the relative importance scheme used in the overall QWRA may not be accurate for some planning landscapes or some planning projects. Overall relative importance reflects regional, cross-boundary priorities among the eight HVRAs. In most QWRA applications, the general relative importance hierarchy will likely be similar, but in some cases, it might not be. For instance, in the QWRA, Timber was allocated a larger share of the overall relative importance than Wildlife Habitat, but in some multiple use management areas Wildlife Habitat might be considered more important than Timber. Most users will not be able to re-run the assessment using new relative importance schemes, in which case they are advised to use non-integrated risk products if there is a concern about relative importance.

Third, the spatial data underpinning the QWRA was designed to meet regional planning needs and may not always align with or meet the needs of specific, local planning. When end-users apply the QWRA to locally specific planning needs they may observe mismatches between their own HVRA data and the HVRA data used in the QWRA. Those mismatches could affect how QWRA risk outputs are interpreted.

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8 Appendix A – Summary of PNW QWRA 2023 Sub-HVRAs

Table 35. Summary of each sub-HVRA included in the QWRA. Sub-HVRA short names are included in spatial data file names and may be useful for navigating the spatial data.

HVRA Abbreviation	Sub-HVRA Short Name	Description
PP	PP_VeryLow	Represents residential and non-residential structures where density is > 0 structures - 1 structure per 40 acres
PP	PP_Low	Represents residential and non-residential structures where density is 1 structure per 40 - 1 structure per 20 acres
PP	PP_ModerateLow	Represents residential and non-residential structures where density is 1 structure per 20 - 1 structure per 10 acres
PP	PP_Moderate	Represents residential and non-residential structures where density is 1 structure per 10 - 1 structure per 5 acres
PP	PP_ModerateHigh	Represents residential and non-residential structures where density is 1 structure per 5 - 1 structure per 2 acres
PP	PP_High	Represents residential and non-residential structures where density is 1 structure per 2 - 3 structures per acre
PP	PP_VeryHigh	Represents residential and non-residential structures where density is > 3 structures per acre
INFRA	INFRA_Interstates	Represents interstates across Oregon and Washington
INFRA	INFRA_Highways	Represents highways across Oregon and Washington
INFRA	INFRA_Railroads	Represents railroads across Oregon and Washington
INFRA	INFRA_TransHigh	Represents high vlotage transmission lines where voltage is ≥ 100kV
INFRA	INFRA_TransLow	Represents high vlotage transmission lines where voltage is < 100kV
INFRA	INFRA_Communications	Represents communication sites, including FM transmission towers, AM transmission towers, broadband radio transmitters, cellular towers, microwave service towers, paging transmission towers, land mobile commercial transmission towers, land mobile broadcast towers, antenna structure registrate, TV broadcast contours, TV digital station transmitters, TV analog station transmitters, and TV digital station transmitters

INFRA	INFRA_PowerPlants	Represents electric power plants of multiple types including hydroelectric dams, fossil fuel, nuclear, solar, wind geothermal and biomass
INFRA	INFRA_Substations	Represent electric power substations primarily associated with electric power transmission including facilities and equipment that switch, transform, or regulate electric power at voltages equal to, or greater than, 69 kilovolts
INFRA	INFRA_OilGas	Represents oil and natural gas wells. An oil and natural gas well is a hole drilled in the earth for the purpose of finding or producing crude oil or natural gas; or producing services related to the production of crude or natural gas
INFRA	INFRA_EssentialFacilities	Represent structures that might be essential to community function during and immediately following a wildfire, including: hospitals, EMS stations, fire stations, colleges and universities, local law enforcement, schools, childcare centers, solid waste facilities, nursing homes, public health departments, urgent care facilities, wastewater treatment sites, EPA emergency response facilities, public transit centers, and state government buildings
WH	WH_SpottedOwl_Refugia	Represents areas where the biotic and abiotic characteristics are suitable for nesting, breeding, hunting and dispersal habitat, and are located in fire refugia
WH	WH_SpottedOwl_NonRefugia	Represents areas where the biotic and abiotic characteristics are suitable for nesting, breeding, hunting and dispersal habitat, and are located outside fire refugia
WH	WH_SageGrouse_Focal	Represent focal habitat identified by U.S. Fish and Wildlife as essential strongholds for sage-grouse and of the highest conservation priority
WH	WH_SageGrouse_Priority	Represents priority habitat identified by U.S. Fish and Wildlife and includes areas essential to breeding, late brood-rearing, winter concentration areas, and migration or connectivity corridors
WH	WH_SageGrouse_General	Represents general habitat identified by U.S. Fish and Wildlife and includes areas where special management might need to occur in order to sustain greater sage-grouse populations. It is of the least conservation priority
WH	WH_MarbledMurrelet	Represents habitat mapped as critical habitat by U.S. Fish and Wildlife, Endangered Species Program.
WH	WH_BullTrout	Represents generalized fish distribution in Oregon and Washington
WH	WH_SteelheadTrout	Represents U.S. Fish and Wildlife Critical Habitat designations
WH	WH_CohoSalmon	Represents U.S. Fish and Wildlife Critical Habitat designations

WH	WH_ChinookSalmon	Represents U.S. Fish and Wildlife Critical Habitat designations
TIM	TIM_TribalOther_SizeClass1	Represents tribal-owned forest land other than the Colville Reservation where timber quadratic mean diameter is <10"
TIM	TIM_TribalOther_SizeClass2	Represents tribal-owned forest land other than the Colville Reservation where timber quadratic mean diameter is 10" - 20"
TIM	TIM_TribalOther_SizeClass3	Represents tribal-owned forest land other than the Colville Reservation where timber quadratic mean diameter is > 20"
TIM	TIM_TribalActive_SizeClass1	Represents tribal-owned forest land on the Colville Reservation where timber quadratic mean diameter is <10"
TIM	TIM_TribalActive_SizeClass2	Represents tribal-owned forest land on the Colville Reservation where timber quadratic mean diameter is 10" - 20"
TIM	TIM_TribalActive_SizeClass3	Represents tribal-owned forest land on the Colville Reservation where timber quadratic mean diameter is > 20"
TIM	TIM_PrivateIndustrial_SizeClass1	Represents private industrial forest land where timber quadratic mean diameter is <10"
TIM	TIM_PrivateIndustrial_SizeClass2	Represents private industrial forest land where timber quadratic mean diameter is 10" - 20"
TIM	TIM_PrivateIndustrial_SizeClass3	Represents private industrial forest land where timber quadratic mean diameter is > 20"
TIM	TIM_PrivateNonIndustrial_SizeClass1	Represents private non-industrial forest land where timber quadratic mean diameter is <10"
TIM	TIM_PrivateNonIndustrial_SizeClass2	Represents private non-industrial forest land where timber quadratic mean diameter is 10" - 20"
TIM	TIM_PrivateNonIndustrial_SizeClass3	Represents private non-industrial forest land where timber quadratic mean diameter is > 20"
TIM	TIM_BLMActive_SizeClass1	Represents forest land managed by the U.S. Bureau of Land Management where commercial timber production is the primary management objective including all forested Harvest Land Base, Oregon and California Re-vested Railroad Lands and Coos Bay Wagon Road that are not otherwise designated as Congressionally Reserved or wilderness lands. Quadratic mean diameter is < 10"

TIM	TIM_BLMActive_SizeClass2	Represents forest land managed by the U.S. Bureau of Land Management where commercial timber production is the primary management objective including all forested Harvest Land Base, Oregon and California Re-vested Railroad Lands and Coos Bay Wagon Road that are not otherwise designated as Congressionally Reserved or wilderness lands. Quadratic mean diameter is 10" - 20"
TIM	TIM_BLMActive_SizeClass3	Represents forest land managed by the U.S. Bureau of Land Management where commercial timber production is the primary management objective including all forested Harvest Land Base, Oregon and California Re-vested Railroad Lands and Coos Bay Wagon Road that are not otherwise designated as Congressionally Reserved or wilderness lands. Quadratic mean diameter is > 20"
TIM	TIM_BLMOther_SizeClass1	Represents forest land managed by the U.S. Bureau of Land Management where commercial timber production is a management objective including all remaining forest land managed by the Bureau of Land Management which is neither included in the Active Management sub-HVRA nor designated as Congressionally Reserved or wilderness. Quadratic mean diameter is < 10"
TIM	TIM_BLMOther_SizeClass2	Represents forest land managed by the U.S. Bureau of Land Management where commercial timber production is a management objective including all remaining forest land managed by the Bureau of Land Management which is neither included in the Active Management sub-HVRA nor designated as Congressionally Reserved or wilderness. Quadratic mean diameter is 10" - 20"
TIM	TIM_BLMOther_SizeClass3	Represents forest land managed by the U.S. Bureau of Land Management where commercial timber production is a management objective including all remaining forest land managed by the Bureau of Land Management which is neither included in the Active Management sub-HVRA nor designated as Congressionally Reserved or wilderness. Quadratic mean diameter is > 20"
TIM	TIM_USFSActive_SizeClass1	Represents forested areas within National Forests classified as "active management" where mechanical treatments are allowable to meet wood production targets. Quadratic mean diameter is < 10"
TIM	TIM_USFSActive_SizeClass2	Represents forested areas within National Forests classified as "active management" where mechanical treatments are allowable to meet wood production targets. Quadratic mean diameter is 10" - 20"

TIM	TIM_USFSActive_SizeClass3	Represents forested areas within National Forests classified as "active management" where mechanical treatments are allowable to meet wood production targets. Quadratic mean diameter is > 20"
TIM	TIM_USFSMultipleObjectives_SizeClass1	Represents forested areas within National Forests classified as "active management" where mechanical treatments are restricted and can only be implemented if there is no conflict with other forest plan objectives. Quadratic mean diameter is < 10"
TIM	TIM_USFSMultipleObjectives_SizeClass2	Represents forested areas within National Forests classified as "active management" where mechanical treatments are restricted and can only be implemented if there is no conflict with other forest plan objectives. Quadratic mean diameter is 10" - 20"
TIM	TIM_USFSMultipleObjectives_SizeClass3	Represents forested areas within National Forests classified as "active management" where mechanical treatments are restricted and can only be implemented if there is no conflict with other forest plan objectives. Quadratic mean diameter is > 20"
TIM	TIM_State_SizeClass1	Represents state owned or managed timberland where quadratic mean diameter is < 10"
TIM	TIM_State_SizeClass2	Represents state owned or managed timberland where quadratic mean diameter is 10" - 20"
TIM	TIM_State_SizeClass3	Represents state owned or managed timberland where quadratic mean diameter is > 20"
AG	AG_Annual	Represents areas considered cultivated between 2018 and 2022 and where the most common crop type in that period was an annual crop
AG	AG_Perennial	Represents areas considered cultivated between 2018 and 2022 and where the most common crop type in that period was an perennial crop
REC	REC_LowDeveloped	Represents low development recreation infrastructure on all ownerships in Oregon and Washington including trail heads, toilets, etc.
REC	REC_HighDeveloped	Represents high development recreation infrastructure on all ownerships in Oregon and Washington including ranger stations, developed campsites, interpretive sites, etc.
DW	DW_Lowest	Represents drinking water source provision areas with the lowest per pixel population served
DW	DW_Low	Represents drinking water source provision areas with the low per pixel population served

DW	DW_Moderate	Represents drinking water source provision areas with the moderate per pixel population served
DW	DW_High	Represents drinking water source provision areas with the high per pixel population served
DW	DW_Highest	Represents drinking water source provision areas with the highest per pixel population served
EI	EI_Range_ClassB	Represents good and intermediate condition grasslands where the proportion of perennials is greater than annuals
EI	EI_Range_ClassD	Represents poor condition grasslands where the proportion of annuals is greater than perennials
EI	EI_Range_ClassA	Represents good and intermediate condition shrublands where the proportion of perennials is greater than annuals
EI	EI_Range_ClassC	Represents poor condition shrublands where the proportion of annuals is greater than perennials
EI	EI_Range_JuniperLate_Good	Represents rangelands where encroaching juniper is > 20% of total cover and where the proportion of understory perennials is greater than annuals
EI	EI_Range_JuniperEarly_Good	Represents rangelands where encroaching juniper is 5% - 20% of total cover and where the proportion of understory perennials is greater than annuals
EI	EI_Range_JuniperLate_Poor	Represents rangelands where encroaching juniper is > 20% of total cover and where the proportion of understory annuals is greater than perennials
EI	EI_Range_JuniperEarly_Poor	Represents rangelands where encroaching juniper is 5% - 20% of total cover and where the proportion of understory annuals is greater than perennials
EI	EI_Forests_LateOpen	Represents forests where current s-class is late seral with an open canopy
EI	EI_Forests_Early	Represents forests where current s-class is early seral
EI	EI_Forests_MidOpen	Represents forests where current s-class is mid seral with open canopy
EI	EI_Forests_LateClosed	Represents forests where current s-class is late seral with a closed canopy
EI	EI_Forests_MidClosed	Represents forests where current s-class is mid seral with a closed canopy

9 Appendix B – PNW QWRA 2023 Data Description

9.1 Hazard Data

Wildfire hazard data as formatted and used in the calculation of risk is available in 'FireHazard.gdb.'

Wildfire hazard data includes burn probability and fire intensity raster datasets. All data is represented with 30-meter cell size.

- **BP** – This dataset is the average annual likelihood of wildfire at any given location within the project area. Burn probabilities were modeled by Pyrologix using the large fire simulator FSim. The original modeling was conducted at 120-meter cell size and then resampled to 30-meter cell size. The original BP data was modified as described previously to account for fires plausibly burning on irrigated croplands.
- **FIL** – There are six fire intensity level (FIL) rasters, each representing the probability that when a fire occurs, the flame lengths fall within a specific range. At any single pixel, the six FIL probabilities sum to 100. Fire intensity was modeled by Pyrologix using WildEST and methods described above. All rasters were resampled to a 30-meter cell size. The original FIL datasets were modified as described previously to account for fires plausibly burning on irrigated croplands.
    - **FIL1**- conditional probability that flame lengths are between zero and two feet.
    - **FIL2**- conditional probability that flame lengths are between two and four feet.
    - **FIL3**- conditional probability that flame lengths are between four and six feet.
    - **FIL4**- conditional probability that flame lengths are between six and eight feet.
    - **FIL5**- conditional probability that flame lengths are between eight and 12 feet.
    - **FIL6**- conditional probability that flame lengths are greater than 12 feet.

- **iCFL**- This dataset represents the mean conditional flame length. For each pixel, it was calculated as the sum product of all FIL rasters and the midpoint flame length of each FIL class. For FIL6 we used a midpoint flame length of 100 feet to represent torching trees.

9.2 HVRA Data

Two types of HVRA data are available. The first is descriptive. Descriptive HVRA data represents the extent of each sub-HVRA and includes attribute information about covariates. Descriptive HVRA is intended to provide users with an understanding of how and where HVRAs were mapped. In contrast, the risk calculation HVRA spatial data include a unique raster for each sub-HVRA as formatted for risk calculations. When used in conjunction with the PNW QWRA 2023 excel workbook, risk calculation HVRA data will allow users to re-produce or re-run an alternative risk assessment for landscapes in Oregon and Washington.

- **HVRAs_Descriptive_v2.gdb -** This zipped folder contains a geodatabase of raster files representing all sub-HVRAs used in the development of the 2023 Pacific Northwest Quantitative Wildfire Risk Assessment (QWRA).The data included here were used to map the extent of and characterize sub-HVRAs for all HVRAs in the QWRA.The data layers are not formatted for the actual risk assessment, but rather are formatted and attributed to give viewers the most complete information regarding each HVRA or sub-HVRA, including covariates that were used to determine sub-HVRA response functions. All rasters are 30-m resolution and projected in

NAD_1983_USFS_R6_Albers. For more details on data sources and methods refer to the QWRA Methods Report. All raster names begin with the HVRA code:
  - PP = People and Property
  - INFRA = Infrastructure
  - TIM = Timber
  - DW = Drinking Water
  - AG = Agriculture
  - REC = Recreation Infrastructure
  - EI = Ecological Integrity
  - WILD = Wildlife Habitat

  For HVRAs where constituent sub-HVRAs are not spatially coincident (e.g. People and Property) there may be a single raster which includes detailed spatial data for all sub-HVRA in which case the HVRA code is followed by "_combine". In cases, where sub-HVRAs are spatially coincident (e.g. Wildlife) then sub-HVRAs may be represented in unique rasters in which case the HVRA code will be followed by an abbreviated description of the sub-HVRA - e.g. "WILD_Chinook" is the layer for the Chinook salmon sub-HVRA within the Wildlife HVRA.

- **HVRAs_RiskCalcs_v2.zip -** This zipped folder contains a geodatabase of raster files representing all sub-HVRAs as formatted for calculating risk in the 2023 Pacific Northwest Quantitative Wildfire Risk Assessment (QWRA). Rasters in this geodatabase, as compared to rasters in 'HVRA_Descriptive_v2.zip,' are suitable for re-calculating or re-producing risk results when used in conjunction with 'PNWQWRA_2023_workbook.xlsx'. There is a unique raster for each sub-HVRA. Raster values are a six-digit code where the first two values represent the HVRA, the middle two values indicate which sub-HVRA, and the last two values indicate which covariate if any. Raster values correspond to the look-up table which can be found in 'PNWQWRA_2023_workbook.xlsx' in the worksheet titled "LookUpTable." All rasters are 30-m resolution and projected in NAD_1983_USFS_R6_Albers.

9.3 Risk Results

Risk results are represented in three geodatabases. Raster file names include an HVRA code so that each layer is associated with an HVRA. **PP** = People and Property; **INFRA** = Infrastructure; **TIM** = Timber; **DW** = Drinking Water; **AG** = Agriculture; **REC** = Recreation; **EI** = Ecological Integrity; **WILD** = Wildlife

- **ExpectedNVC.gdb**- includes 84 rasters representing expected net value change (eNVC) to all sub-HVRAs (n = 75), HVRAs (n = 8) and integrated across all HVRAs (n = 1). Expected net value change is a risk-neutral metric which is calculated as the sum-product of burn probability and value change over a range of plausible fire intensities.
  - **weNVC_***: represent eNVC risk for individual sub-HVRAs. The file name includes a brief descriptor of the sub-HVRA.
  - **HVRA_weNVC_***: represent eNVC risk for HVRAs. Each HVRA-level raster is the sum of all constituent sub-HVRA eNVC.
  - **ieNVC**: expected net value change integrated across all HVRAs. This layer is the sum of all HVRA-level eNVC rasters.
- **ConditionalNVC.gdb**- includes 84 rasters representing conditional net value change (cNVC) to all sub-HVRAs (n = 75), HVRAs (n = 8) and integrated across all HVRAs (n = 1). Conditional net value

change is a risk-neutral metric which includes anticipated value of change given the probability of burning at different intensity levels. Notably, cNVC does not account for annual burn probability.

- **wcNVC_***: represent cNVC risk for individual sub-HVRAs. The file name includes a brief descriptor of the sub-HVRA.
- **HVRA_wcNVC_***: represent cNVC risk for HVRAs. Each HVRA-level raster is the sum of all constituent sub-HVRA cNVC.
- **icNVC**: conditional net value change integrated across all HVRAs. This layer is the sum of all HVRA-level cNVC rasters.

10 Appendix C Additional Hazard Products Available for the Pacific Northwest.

The focus of this report is largely on development of the PNW QWRA 2023 which is framed to represent wildfire risk on an existing landscape. In addition to the fire hazard layers which serve as the foundation of the PNW QWRA 2023, Pyrologix produced additional fire hazard analytics including common fire management analytics like suppression difficulty index, wildfire hazard potential and wildfire risk to potential structures. Furthermore, Pyrologix generated these and other hazard-related analytics on a current landscape, a future landscape where existing disturbances have been allowed to re-grow, and a "treated" landscape which represents a hypothetical situation in which all timbered pixels have received some kind of fuel reduction treatment. These additional analytics can be used as standalone products or in concert with the HVRA data described above to model risk and possible changes in risk. All products listed were produced by Pyrologix LLC under contract by the USDA Forest Service. The specific datasets are available upon request. Requests can be directed to:

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10.1 Intent of additional wildfire hazard deliverables

Wildfire risk varies spatially and temporally. To facilitate a better understanding of how risk changes over space and time, its necessary to frame wildfire hazard under specific scenarios. During the spring of 2022 additional calibration workshops were held to create different versions of the PNW landscape and facilitate additional fire hazard modeling. The focus of these workshops was refining the LANDFIRE data and modeling inputs to be applied to a high herbaceous scenario fuelscape, a treated fuelscape, and a 2032 fuelscape. Each has a unique purpose and application. The deliverables associated with each fuelscape are listed below.

Fire managers have known for decades that the largest fires in rangelands typically occur in response to an increase in the "grass crop." When herbaceous loading is below average, we typically see fewer larger fires and lower acreage burned. In contrast, an increase in loading, represented by a different choice in fuel model can set the stage for increased large fire size and/or intensity. The high herbaceous results can be used to demonstrate how the fire environment changes in response in biomass fluctuation. When compared against the fire hazard outputs using the 2022 fuelscape, its possible to objectively contrast the significance of herbaceous loading changes and if desired quantify changes in risk to HVRAs.

The treated landscape reflects all timbered pixels receiving a generalized fuel treatment. Its known that residual fuel composition after a treatment can vary based upon objectives and methods, yet there are advantages to quickly being able to quantify changes in fire hazard resulting from active management. Fuel treatments generally result in a reduced surface fuel loading (captured by a different fuel model), increased canopy base height, reduced canopy bulk density and canopy cover. Alone, this dataset is purely theoretical. However, when paired with others it can be leveraged to show the effects of proactive fuels investments and how they can change the risk profile to a specific HVRA or a suite of HVRAs. Fire hazard outputs using the treated fuelscape are not intended to replace the need for detailed modeling, yet this dataset can be used to quickly determine residual fire hazard or risk to select pixels.

The 2032 fuelscape applies LANDFIRE disturbance rules to grow out the fuels within recently burned areas. Fuel model assignment is reflective of known post-fire regeneration trends, in some cases capturing type conversion (i.e. brush fields replacing what was formerly timber). Additionally, a regression analysis on each FOA was used to determine the trajectory of both large fire occurrence and extent. Calibration targets for FSim reflect the large fire trendline of each FOA, extrapolated to 2032. This results in a marked increase in burn probability in some areas and relatively stable trend in others. The application or disturbance rules and calibration targets factors in changes in successional trajectory on fuel composition and indirectly captures the results of a changing climate. The wildfire hazard deliverables using this landscape are intended for site specific application. Its impossible to know where large fires will occur in the future, but the results can be applied to project future risk in those areas that have seen widespread, recent wildfires.

Table 36. All available, additional hazard data for Oregon and Washington.

Product Category	**Deliverable**	**Fuelscapes**						**Notes**
		2022	**2022 treated**	**2032**	**2022 high herb**	**2032 high herb**	**2022 treated high herb**	
Fuelscape development (30-m resolution)	FBFM	✓	✓	✓	✓	✓	✓	LANDFIRE data was adjusted during multiple workshops and differs from national datasets. Changes were driven by SMEs from throughout PNW. The 6 different landscapes produced are intended for facilitating scenario modeling. The 2022 fuelscape (also known as landscape file or LCP) was used as the basis for current condition wildfire hazard modeling.
	CBH	✓	✓	✓	✓	✓	✓	
	CBD	✓	✓	✓	✓	✓	✓	
	CC	✓	✓	✓	✓	✓	✓	
	CH	✓	✓	✓	✓	✓	✓	
	Slope	✓						
	Aspect	✓						
	Elevation	✓						
FSim modeling	Burn Probability (120m upsampled to 30m)	✓	-	✓	-	-	-	Calibration for current landscape and treated landscape were the same, only the fuels were adjusted. Treated fuelscape uses generalized treatment prescription (fuel model change, increased CBH, slight reduction in CBH, etc). 2032 landscape uses LF disturbance rules to "grow out fuels" and calibration adjusted based regression model for each FOA.
	Ignitions	✓	-	✓	-	-	-	Ignitions for each Fire Occurrence Area (FOA).

	Event Set - perimeters	✓	-	✓	-	-	-	Event set can be used for transmitted-risk analysis. Perimeters are organized by FOA.
	Calibration Files	✓	-	✓	-	-	-	Fsim input files by FOA. Includes ERC stream for each season, FRISK, FDIST, ADJ, FMS files. Only necessary for rerunning Fsim model.

Product Category		**Deliverable**	**Fuelscapes**						**Notes**
			2022	**2022 treated**	**2032**	**2022 high herb**	**2032 high herb**	**2022 treated high herb**	
Fire characteristics modeling with WildEST (30-m resolution)	Flame-front characteristics	Characteristic Flame Length	✓	✓	✓	✓	✓	✓	Weighted-average FL over 216 weather types.
		Characteristic Fireline Intensity	✓	✓	✓	✓	✓	✓	Weighted-average FLI over 216 weather types.
		Characteristic Rate of Spread	✓	✓	✓	✓	✓	✓	Weighted-average ROS over 216 weather types.
		Characteristic Heat per Unit Area	✓	✓	✓	✓	✓	✓	Weighted-average HPA over 216 weather types.
		Fire Intensity Scale	✓	✓	✓	✓	✓	✓	Log-10 of the maximum fireline intensity (kW/m) under any of 216 weather types.
		Fire Type Probabilities	✓	✓	✓	✓	✓	✓	Locations without a forest canopy are only "surface fire". Locations with a forest canopy can be any of the the following: underburn; low-, mid- or high-grade passive crown fire; or active crown fire.
		Operational Control Probabilities	✓	✓	✓	✓	✓	✓	Probability of headfire flame length exceeding 4 feet (limit of manual fire control), 8 feet (mechanical control) and 11 feet (extreme fire behavior). Three separate rasters for each fuelscape.
		Fire Effects Flame Length Probabilities	✓	✓	✓	✓	✓	✓	Probability of flame-front flame length in each of six standard Fire Intensity Levels, after accounting for the effect of non-

									heading spread directions on flame length. Six rasters that sum to 1.0.

Product Category		**Deliverable**	**Fuelscapes**						**Notes**
			2022	**2022 treated**	**2032**	**2022 high herb**	**2032 high herb**	**2022 treated high herb**	
Fire characteristics modeling with WildEST (30-m resolution)	Ember characteristics	Conditional Ember Production Index	✓	✓	✓	✓	✓	✓	A relative index of the potential for a pixel to produce embers if a fire were to occur, a function of fuel, weather and topography.
		Conditional Ember Load Index	✓	✓	✓	✓	✓	✓	A relative index of the potential for a pixel to receive embers from surrounding land if a fire were to occur.
		Conditional sources of ember load to buildings	✓	✓	✓	✓	✓	✓	A relative index of the potential for a pixel to produce embers that land at a location where buildings exist.
		Ember Production Index	✓	✓	✓	✓	✓	✓	A relative index of the annualized potential for a pixel to produce embers after accounting for the pixels burn probability.
		Ember Load Index	✓	✓	✓	✓	✓	✓	A relative index of the annualized potential for a pixel to receive embers after accounting for the burn probability of the surrounding pixels.
		Sources of ember load to buildings	✓	✓	✓	✓	✓	✓	A relative index of the annualized potential for a pixel to produce embers (after accounting for the BP of the surrounding pixels) that land at a location where buildings exist.
	Wildfire	Conditional Risk to Potential Structures	✓	✓	✓	✓	✓	✓	WRC-style measure of conditional risk to buildings

		Risk to Potential Structures	✓	✓	✓	✓	✓	✓	WRC-style measure of annualized risk to buildings
		Damage Potential	✓	✓	✓	✓	✓	✓	Proprietary index of conditional risk to structures—incorporates fire intensity and ember load
		Structure Exposure Score	✓	✓	✓	✓	✓	✓	Proprietary index of annualized risk to structures—incorporates fire intensity, ember load, and burn probability
Composite measures		Wildfire Hazard Potential	✓	✓	✓	✓	✓	✓	Dillon and Menakis model, but generated from the custom fire modeling instead of from the national products.
		Suppression Difficulty Index	✓	✓	✓	✓	✓	✓	The SDI model on the custom fire modeling.