Exposure of human communities to wildfire in the Pacific Northwest

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Purpose and background

At the request of the United States Forest Service Pacific Northwest Regional Office, Pyrologix[1] assessed the exposure to wildfire of housing units within named human communities across the Pacific Northwest Region (Oregon and Washington). The purpose of the assessment was to identify the communities most threatened by wildfire. The fifty most-threatened communities in each state were identified.

These results have several applications. A home buyer can use these results for comparing the relative wildfire exposure of homes in different communities; homeowners can gauge their wildfire exposure compared to their peers in neighboring communities. Governments and other organizations can potentially use the results to prioritize communities for home-loss mitigation efforts, allocate mitigation funding, inform building codes, and guide residential development. Finally, land owners and land management agencies can use the exposure-source results to identify locations within their ownerships that produce damaging wildfires.

What is exposure to wildfire?

In the broadest sense, wildfire exposure encompasses the likelihood of wildfire burning a given location on the landscape, and the potential intensity of a wildfire if one were to occur. For this assessment we focus only on wildfire likelihood because the effect of fire intensity on home loss rate is not well studied, and because the inclusion of intensity for this and similar assessments did not influence the conclusions. Wildfire likelihood is measured by annual burn probability, a measure generated by comprehensive simulation of wildfire occurrence and spread (see section below on Wildfire hazard simulations).

What is a human community?

We defined a human community as the population (housing units) within a community core as defined by the Populated Place Areas dataset produced by the United States Census Bureau plus the population within a 45-minute drive of the boundary of the community core[2].

Housing unit data

The West Wide Wildfire Risk Assessment (Sanborn Map Company 2013) produced a spatial dataset called Where People Live (WPL). The WPL layer, which was generated by processing LANDSCAN and U.S. Census data, represents the estimated density of housing units across the 17 western states. We converted those housing-unit density values to housing-unit counts. Summing the housing-unit count

[1] Pyrologix is a Montana-based wildfire threat assessment research firm (www.pyrologix.com).
[2] The drive-time analysis was conceived and conducted by Dr. Alan Ager and his staff at the Rocky Mountain Research Station, USDA Forest Service.

values for all locations in a named community provides an estimate of the total number of housing units in the community.

For this assessment, housing units were considered *directly* exposed to wildfire if they were located on burnable land cover[3]. Housing units were considered *indirectly* exposed to wildfire if they were located on nonburnable land cover (other than open water) but within 150 m of burnable land cover. Only directly or indirectly exposed housing units are summarized in this report. Nonexposed housing units (those within an urban core, for example) are not included.

Wildfire hazard simulations

This assessment relies on wildfire behavior simulations produced using a comprehensive wildfire occurrence, growth and behavior simulation system called FSim (Finney and others 2011). The FSim modeling for Oregon was conducted for the Pacific Northwest Region Quantitative Wildfire Risk Assessment (QWRA), which was completed in 2018 (Gilbertson-Day and others 2018). The FSim model works by simulating 10,000 or more "iterations" to produce spatial data representing annual burn probability—the annual likelihood that a wildfire will reach a given point on the landscape. Each iteration is a possible realization of a complete calendar year. The FSim burn probability results show considerable variation in wildfire likelihood across the states (Figure 1).

In addition, FSim records the start location and final perimeter for each of its simulated wildfires, enabling us to attribute housing-unit exposure to the origin location, which we use in an assessment of the source of exposure of housing units to wildfire.

Housing-unit exposure to wildfire

Mean burn probability

We calculated the mean burn probability where the housing units are located within each community. This measure represents the mean likelihood that a housing unit in a community will experience a wildfire in one year. The higher this value, the more likely it is that an individual housing unit will experience a wildfire. Mean burn probability is not a cumulative measure for a community, so it does not necessarily increase as the number of housing units increases. Instead, this measure is sensitive to the general location of a community within the burn probability map (Figure 1) and the specific locations of housing units with each community.

Community-wide housing-unit exposure

We first generated raster data representing the expected annual number of housing units exposed to wildfire (the product of housing-unit count and burn probability). We then summed those results within each community; a community with more housing units can therefore have a greater community-wide exposure. The resulting sum represents the estimated mean annual number of housing units expected to experience a wildfire. The top 50 Washington communities by this measure are listed in Table 1; the top 50 Oregon communities are listed in Table 2.

[3]Burnable and nonburnable land cover is characterized by the LANDFIRE 2014 FBFM40 data layer (www.landfire.org), with minor calibration edits informed by local expert knowledge. Burnable land cover includes land covered by grasses, forbs, shrubs, tree litter, understory trees, or logging slash. Nonburnable land cover includes urban areas, irrigated agricultural land, permanent snow or ice, bare ground, and open water.

A community can be ranked as highly exposed due a combination of high likelihood or high population. To illustrate those contributing factors, we plotted mean burn probability against total housing unit count for the 50 communities with the greatest cumulative exposure (Figure 2 and Figure 3). Both axes are plotted on a common-log scale. The plot is divided into a 4-by-3 grid, which is convenient for interpreting the results with the communities plotted in the lower right-hand corner having the greatest likelihood of burning, but relatively few exposed housing units, while communities in the top left square have the greatest number of housing units and relatively low burn probability. The communities plotted in the middle, far-right squares have some of the highest burn probabilities and a moderate number of housing units exposed. These communities could be further evaluated for wildfire mitigation opportunities to reduce exposure near the homes.

Landscape-wide sources of housing-unit exposure

We assessed the relative potential for different parts of the landscape to produce wildfires that expose housing units. That damage potential is a function of spatial variation in fire occurrence and fire growth potential (which is simulated by FSim), in conjunction with spatial variation in housing-unit count. To do this we summed the number of housing units within each simulated fire perimeter, then attributed the start location of each fire with that number. We then created a smoothed surface that represents the relative annual number of housing units exposed by fires originating across the landscape (Figure 4). Even though a small number of large fires account for the vast majority of wildfire area burned (Strauss and others 1989) it appears that wildfires originating near populated areas are responsible for the vast majority of the housing-unit exposure. The areas of higher exposure-source tend to fall near where communities exist.

Discussion

Spatial inequality in housing-unit exposure to wildfire

We show results for the 50 most-exposed communities in both Washington and Oregon, but we assessed exposure to all 1,005 named communities across the two states. In Washington, the 50 communities most exposed to wildfire comprise only 12% of the 2,196,244 housing units located on or near burnable land cover in the state. However, those same communities represent roughly 70% of the cumulative housing-unit exposure. In Oregon, the 50 most-exposed communities comprise only 19% of the 1,196,187 housing units located on or near burnable land cover, but 80% of the cumulative housing-unit exposure. Across both states combined, the 100 most-exposed communities comprise 15% of the housing units located on burnable land cover but 76% of the cumulative housing-unit exposure.

These results illustrate an unequal distribution of wildfire exposure among human communities—most of the wildfire exposure occurs in a relatively small number of communities. The unequal distribution suggests that focusing mitigation efforts on the most-exposed communities is likely to result in the greatest benefit.

Ownership at source locations of housing-unit exposure

In contrast with other “risk transmission” analyses, we did not focus on the effects of fires originating on any particular land ownership (e.g., USFS land) on housing-unit exposure. Instead, we identified locations with greater potential for reaching housing units using a purely spatial approach. When USFS land ownership is overlaid on this map, it is evident that USFS land is not the dominant contributor to overall housing-unit exposure in the Pacific Northwest. Fires with potential to affect housing units tend

to start near housing units, and the land surrounding housing units is generally not in USFS ownership. Exceptions exist, however. Fires originating on some portions of USFS land ownership, especially east of the Cascade Mountains in Washington, can indeed reach significant numbers of housing units.

More information

The full list of communities in Washington and Oregon and their exposure to wildfire in is available here as a Microsoft Excel workbook.

Additional detailed spatial information about wildfire hazard and risk to homes in Oregon can be found at the Oregon Wildfire Risk Explorer.

References

Gilbertson-Day, Julie; Scott, Joe; Vogler, Kevin; Brough, April. 2018. Pacific Northwest Quantitative Wildfire Risk Assessment: Methods and Results. Final report. Available: http://pyrologix.com/ftp/Public/Reports/PNRA_QuantitativeWildfireRiskReport_08_27_18.pdf

Sanborn Map Company. 2013. West wide wildfire risk assessment: FINAL REPORT. Available: http://www.odf.state.or.us/gis/data/Fire/West_Wide_Assessment/WWA_FinalReport.pdf

Strauss, David; Bednar, Larry; Mees, Romain. 1989. Do one percent of forest fires cause ninety-nine percent of the damage? Forest Science 35(2): 319–328.

Suggested citation

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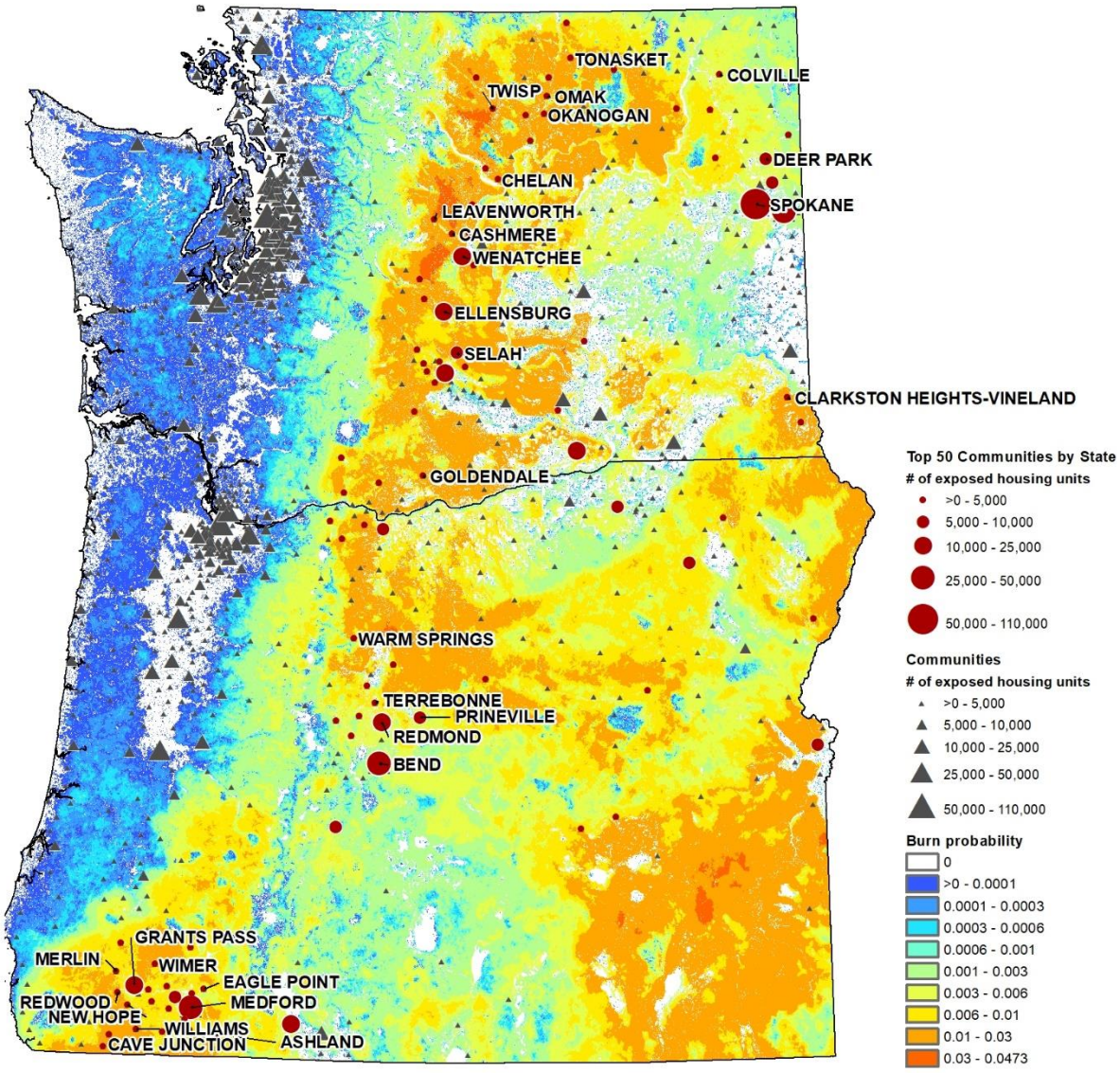

Figure 1. Annual burn probability across the states of Washington and Oregon and exposed human communities in each state. The 50 most-exposed communities in each state are mapped in dark red. The most-exposed communities tend to be in areas with the highest annual burn probabilities based on the FSim modeling results.

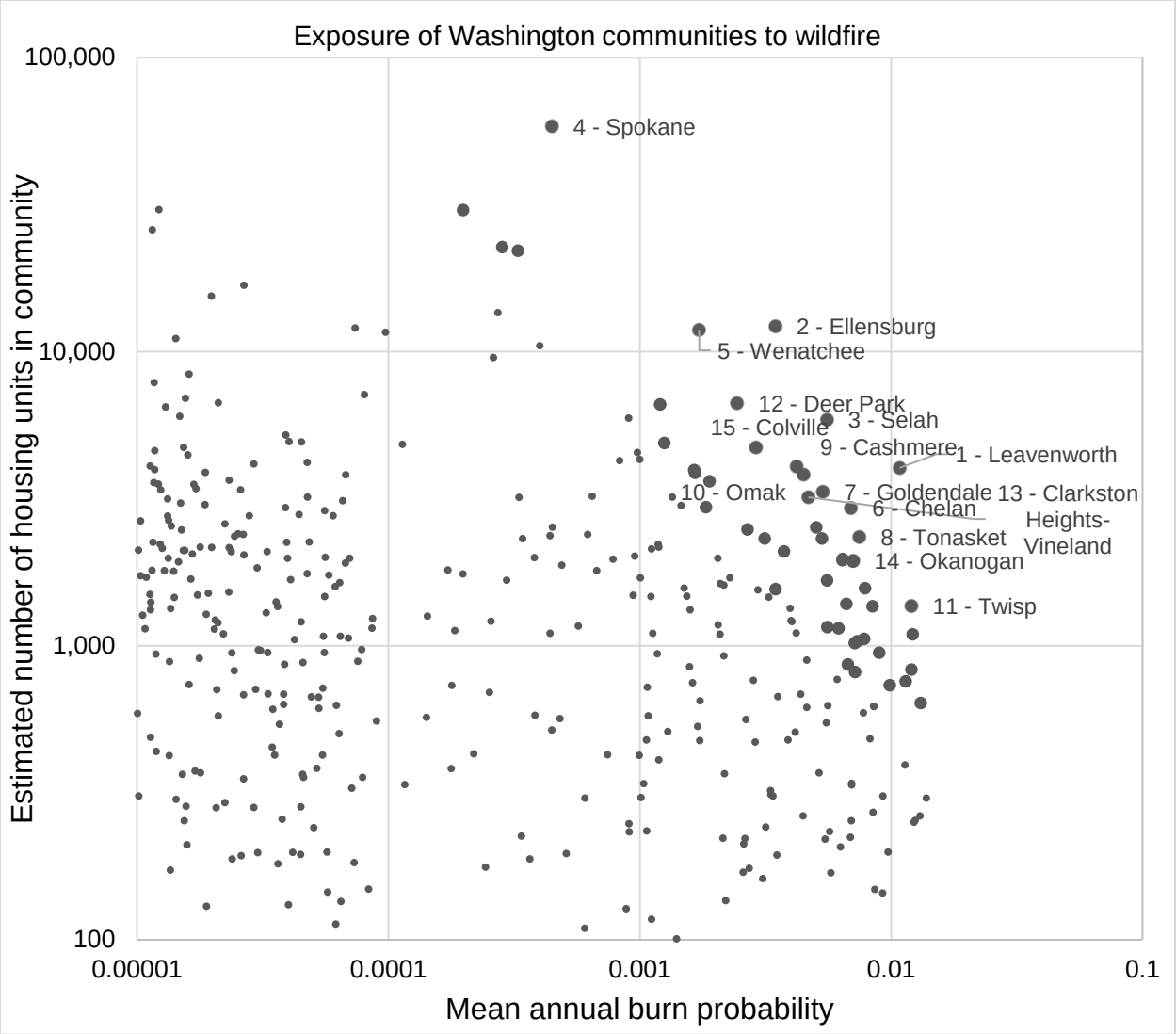

Figure 2. Exposure of Washington communities to wildfire. The 50 most-exposed communities (by cumulative annual housing-unit exposure) are shown as larger gray dots. The top 15 are labeled with the rank and community name. See Table 1 for the names of the remaining top-50 communities. Smaller gray dots represent communities not among the 50 most exposed. Only the 382 communities with a mean burn probability greater than 0.0001 (1 in 10,000) are shown; 245 communities with a lower mean burn probability are not shown. Axes are shown on a common-log scale (base 10).

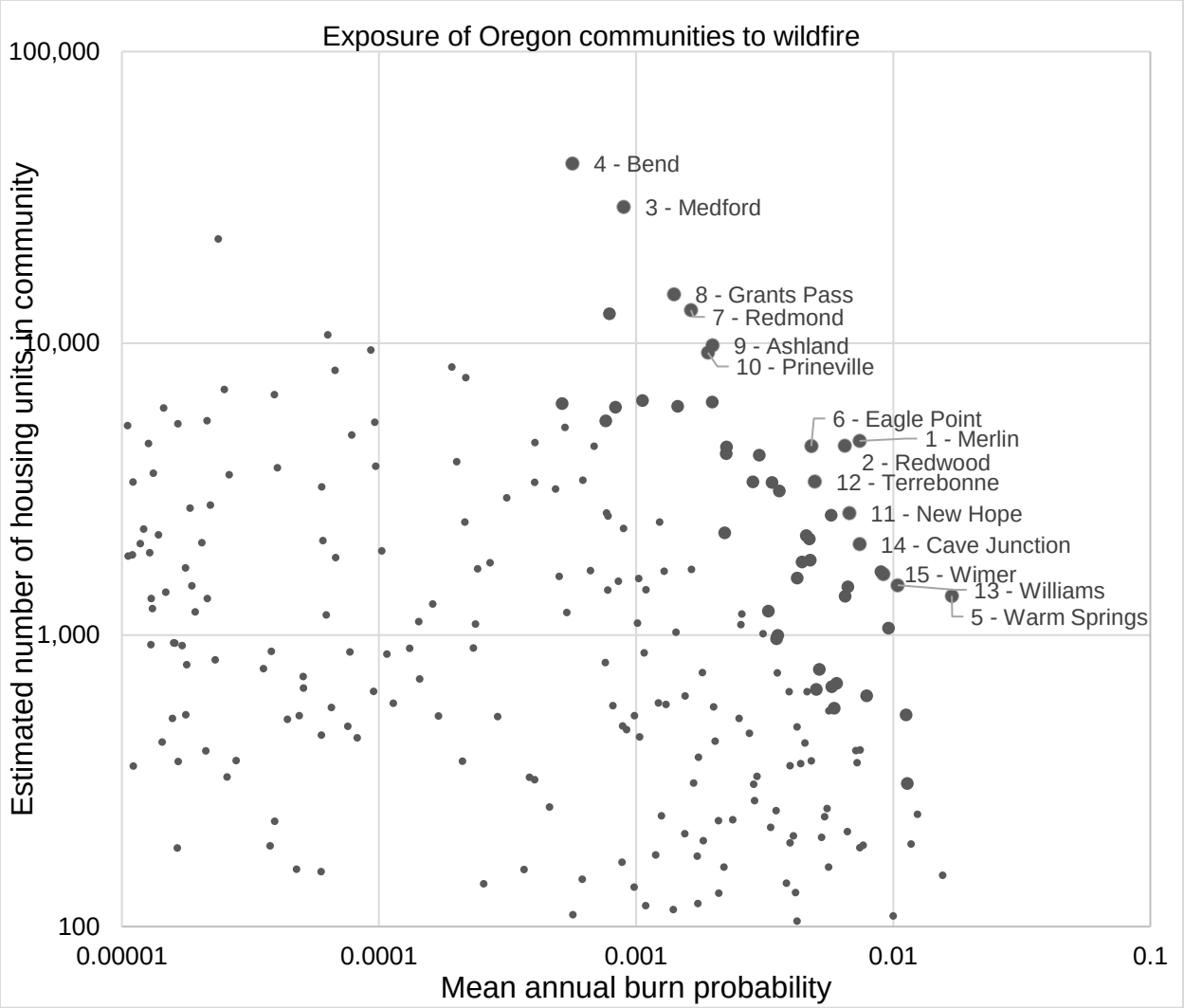

Figure 3. Exposure of Oregon communities to wildfire. The 50 most-exposed communities (by cumulative annual housing-unit exposure) are shown as larger gray dots. The top 15 are labeled with the rank and community name. See Table 2 for the names of the remaining top-50 communities. Smaller gray dots represent communities not among the 50 most exposed. Only the 244 communities with a mean burn probability greater than 0.0001 (1 in 10,000) are shown; 133 communities with a lower mean burn probability are not shown. Axes are shown on a common-log scale (base 10).

Table 1. The 50 communities in Washington with greatest cumulative housing-unit exposure to wildfire. The "mean of exposed housing units" rank indicates the mean (typical) burn probability of housing units within each community.

Community Exposure Ranking	Community Name	Total number of housing units exposed to wildfire	Estimated mean annual number of housing units visited by wildfire	Mean annual burn probability	Burn probability rank
1	Leavenworth	4,025	43.5	0.0108	11
2	Ellensburg	12,204	42.3	0.0035	76
3	Selah	5,873	32.6	0.0056	52
4	Spokane	58,409	26.2	0.0004	165
5	Wenatchee	11,864	20.4	0.0017	112
6	Chelan	2,938	20.3	0.0069	37
7	Goldendale	3,341	17.9	0.0053	55
8	Tonasket	2,343	17.5	0.0075	28
9	Cashmere	3,822	17.1	0.0045	62
10	Omak	4,065	17.1	0.0042	65
11	Twisp	1,364	16.4	0.0121	7
12	Deer Park	6,684	16.3	0.0024	96
13	Clarkston Heights-Vineland	3,198	15.0	0.0047	59
14	Okanogan	1,947	13.8	0.0071	32
15	Colville	4,720	13.7	0.0029	87
16	Cle Elum	1,936	13.7	0.0071	33
17	Winthrop	1,095	13.3	0.0122	6
18	Sunnyslope	2,528	12.7	0.0050	58
19	Brewster	1,973	12.6	0.0064	41
20	Kittitas	1,952	12.5	0.0064	42
21	Entiat	1,570	12.3	0.0079	25
22	Ahtanum	2,318	12.3	0.0053	56
23	Summitview	1,361	11.5	0.0084	23
24	Malott	830	10.0	0.0120	8
25	Manson	1,670	9.3	0.0056	51
26	Springdale	1,388	9.2	0.0066	40
27	Thorp	757	8.6	0.0114	9
28	Asotin	947	8.5	0.0089	18
29	Riverside	638	8.4	0.0131	2
30	Republic	1,057	8.3	0.0078	26
31	Mead	6,614	8.0	0.0012	126
32	South Wenatchee	2,090	7.8	0.0037	73
33	White Swan	1,035	7.6	0.0073	29
34	Inchelium	1,022	7.3	0.0072	31
35	Oroville	2,317	7.3	0.0031	84
36	Klickitat	734	7.2	0.0099	13
37	Yakima	22,047	7.2	0.0003	176
38	Naches	1,147	7.1	0.0062	44
39	Ephrata	3,623	6.9	0.0019	108
40	White Salmon	2,487	6.7	0.0027	91
41	Othello	3,961	6.5	0.0016	115
42	Addy	1,157	6.5	0.0056	50
43	Kennewick	22,660	6.4	0.0003	178
44	Newport	3,871	6.4	0.0017	114
45	West Richland	4,889	6.1	0.0013	125
46	Spokane Valley	30,340	6.0	0.0002	186
47	Trout Lake	814	5.9	0.0072	30
48	Cowiche	864	5.8	0.0067	39
49	Terrace Heights	2,960	5.4	0.0018	109
50	Gleed	1,557	5.4	0.0035	77

Table 2. The 50 communities in Oregon with greatest cumulative housing-unit exposure to wildfire. The "mean of exposed housing units" rank indicates the mean (typical) burn probability of housing units within each community.

Community Exposure Ranking	Community Name	Total number of housing units exposed to wildfire	Estimated mean annual number of housing units visited by wildfire	Mean annual burn probability	Burn probability rank
1	Merlin	4,628	34.2	0.0074	21
2	Redwood	4,451	28.9	0.0065	29
3	Medford	29,340	26.3	0.0009	128
4	Bend	41,321	23.4	0.0006	145
5	Warm Springs	1,362	23.0	0.0169	1
6	Eagle Point	4,443	21.3	0.0048	45
7	Redmond	13,005	21.3	0.0016	103
8	Grants Pass	14,718	20.6	0.0014	108
9	Ashland	9,853	19.5	0.0020	90
10	Prineville	9,285	17.7	0.0019	92
11	New Hope	2,616	17.7	0.0067	25
12	Terrebonne	3,353	16.6	0.0050	43
13	Williams	1,481	15.4	0.0104	9
14	Cave Junction	2,049	15.2	0.0074	20
15	Wimer	1,617	14.8	0.0091	13
16	Gold Hill	2,576	14.8	0.0057	35
17	Chenoweth	1,650	14.8	0.0090	15
18	Talent	4,138	12.5	0.0030	71
19	Central Point	6,282	12.4	0.0020	91
20	Sisters	3,336	11.3	0.0034	67
21	Tumalo	3,119	11.2	0.0036	62
22	Selma	1,055	10.1	0.0096	12
23	Jacksonville	2,132	10.1	0.0047	47
24	Rogue River	2,189	10.1	0.0046	49
25	Klamath Falls	12,620	9.9	0.0008	134
26	Madras	4,408	9.9	0.0022	82
27	Ruch	1,463	9.7	0.0067	26
28	Phoenix	3,346	9.5	0.0028	75
29	White City	4,186	9.4	0.0022	83
30	Ontario	6,086	8.8	0.0015	106
31	Glendale	1,356	8.8	0.0065	28
32	Shady Cove	1,804	8.6	0.0048	46
33	Burns	1,778	7.9	0.0044	51
34	La Pine	6,357	6.7	0.0011	120
35	Eagle Crest	1,565	6.6	0.0042	53
36	Takilma	532	6.0	0.0112	8
37	The Dalles	6,032	5.0	0.0008	132
38	Odell	2,239	5.0	0.0022	84
39	Halfway	619	4.9	0.0079	16
40	La Grande	5,426	4.1	0.0008	138
41	Foots Creek	683	4.1	0.0060	31
42	Culver	1,207	3.9	0.0033	69
43	Trail	763	3.9	0.0052	41
44	Mount Hood	664	3.8	0.0058	34
45	Elgin	997	3.5	0.0036	63
46	Mitchell	310	3.5	0.0114	7
47	Hines	970	3.4	0.0035	65
48	Butte Falls	560	3.3	0.0059	33
49	Prairie City	650	3.3	0.0050	21
50	Pendleton	6,215	3.2	0.0005	29

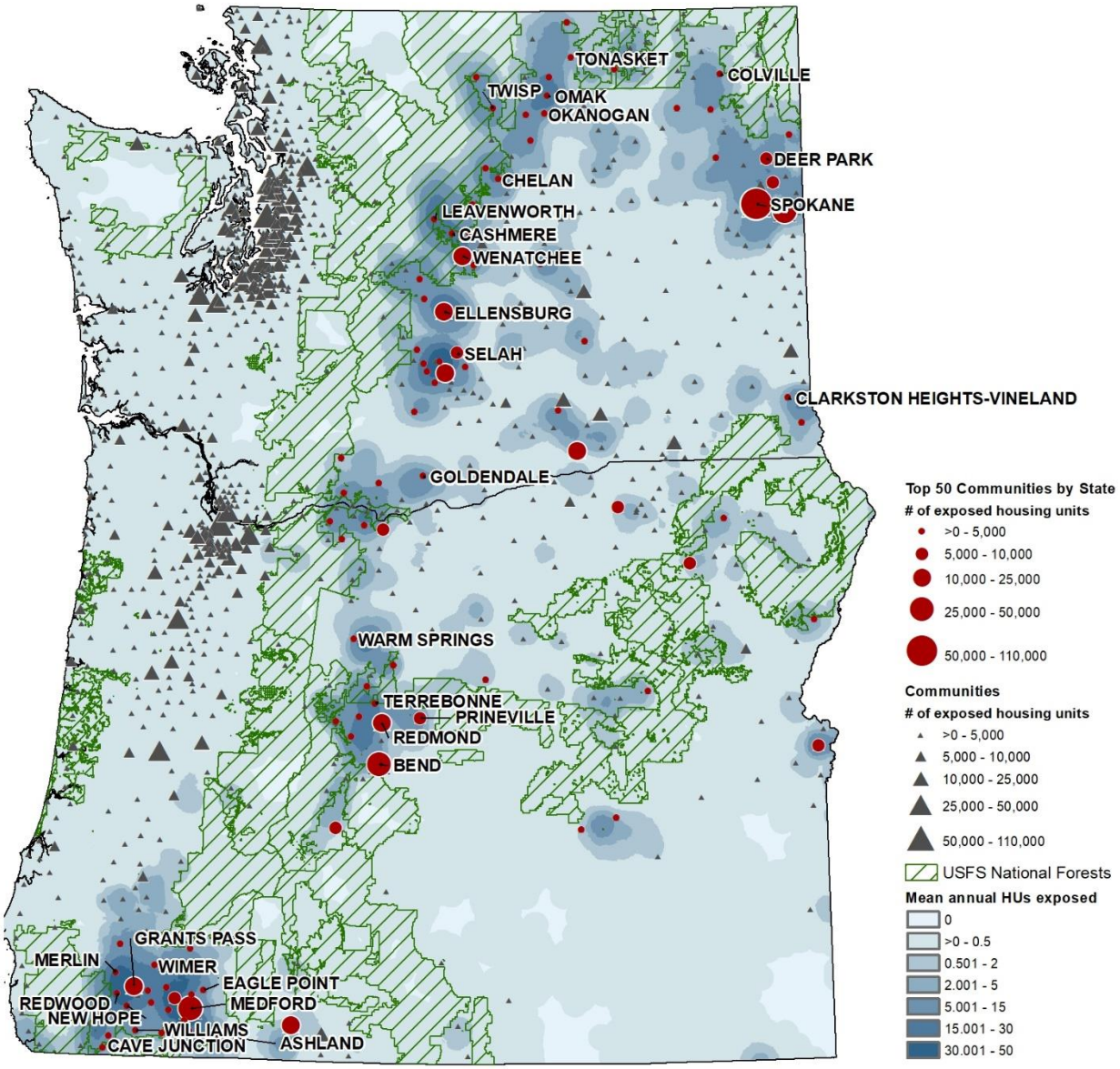

Figure 4. Sources of housing-unit exposure to wildfire across Washington and Oregon and exposed communities across the two states. The fifty most exposed communities in each state are shown in dark red, the remaining communities in gray. Dark blue areas of the map tend to produce greater annual housing-unit exposure.