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TECHNICAL MEMORANDUM

Date: June 30, 2021

To: Kimberly Swan, Clackamas River Water Providers

From: Jennifer Schmidt, Herrera Environmental Consultants

Subject: GIS Forestry Activities Risk Analysis Results

INTRODUCTION

The Clackamas River is a source of drinking water for more than 300,000 people in Clackamas County and is an important resource for helping to meet future water demand in the region. The Clackamas River Water Providers (CRWP) represents five municipal surface water intakes on the Clackamas River: City of Estacada, Clackamas River Water, North Clackamas County Water Commission, South Fork Water Board, and City of Lake Oswego. Herrera Environmental Consultants (Herrera) was hired in 2011 to complete a series of geographic information system (GIS) analyses to help identify potential pathways for pollutant export to the Clackamas River from seven high-risk activity categories (Clackamas River Water Providers 2010):

- Septic Systems
- Agricultural Activities
- Forestry Activities
- Vulnerable Soils
- Urban Development
- Point-Source Pollutants
- Hazardous Materials

The goal of these GIS analyses was to map risk factors known to have a strong negative correlation with drinking water quality in the Clackamas River watershed. Mapped risk "hot spots" for each category provide a spatial context for both the geography and intensity of risk by activity that can be used by the CRWP to help prioritize mitigation efforts. In 2021, Herrera was hired to update these analyses to map changes that have may have occurred in the locations of risk "hot spots" in the watershed over the last decade based on new or updated GIS data. This memorandum focuses specifically on the results of the updated 2021 GIS Forestry Activities Risk Analysis.

POTENTIAL THREATS FROM FORESTRY ACTIVITIES

The Clackamas River Water Providers (CRWP) have identified stormwater runoff from forestry activities as being one of the most significant sources of risk to drinking water quality in the Clackamas River watershed. The primary threats to source water from forestry activities include (U.S. EPA 1993):

1. Non-point source pollution from sediments, nutrients, forest chemicals, organic debris (residual logs, slash, litter) and oxygen-depleting organic soil matter from timber harvesting, mechanical equipment operation, prescribed burning, regeneration methods, and road construction and use.

2. Increased stream and waterbody temperature as a result of vegetation removal through timber harvesting or herbicide use in riparian areas.

3. Increased streamflow as a result of vegetation removal, resulting in channel scour, eroding streambanks, increased sedimentation, and increased peak flows. The amount of streamflow increase "is related to total area harvested, topography, soil type, and harvesting practices" (Likens et al., 1970; Eschner and Larmoyeux, 1963; Blackburn et al., 1982).

Approximately 90% of the Clackamas River watershed is comprised of forest and shrubland (WPN 2005). The majority of this area (roughly 70%) is in the upper watershed within the Mt. Hood National Forest and is managed by the U.S. Forest Service (USFS); the area in between the national forest and the lower watershed also includes parcels of land owned by private timber companies and the Bureau of Land Management (BLM) (Clackamas River Water Providers 2010). Forested watersheds, like the Clackamas, produce better water quality than any other surface water source; however, forestry activities that are not properly managed can have significant adverse impacts on downstream water quality (Morgenstern 2006).

GIS FORESTRY ACTIVITIES RISK ANALYSIS

Herrera performed a GIS analysis mapping the extent and intensity of forestry activities in the Clackamas River watershed to help predict the potential risk of stormwater runoff from these activities to source water quality. This methodology involved gathering, ranking, and overlaying the following datasets in GIS:

- Forestry activities on federal, state and private forest land over a several year time period, including 1) fertilizer and herbicide use; 2) clearcutting; 3) pre-commercial and commercial thinning; 3) burning; 4) road construction; 5) site preparation; and 6) other harvest activities

- Proximity of forestry activities to riparian stream buffers and surface water
- Soils that are highly sensitive to erosion and landslide areas

The following sections provide more detailed information on this risk analysis, including analysis objectives, methods for how each of the risk datasets were generated, and data sources used and limitations.

Analysis Objectives

The primary objectives of the GIS forestry activities risk analysis were to:

- Identify and characterize forest land in the Clackamas River watershed.
- Use information from the Forest Activity Computerized Tracking System (FACTS) maintained by USFS and the Forest Activity Electronic Reporting and Notification System (FERNS) maintained by Oregon Department of Forestry (ODF) to map the distribution of forest practice activities related to growing and harvesting timber in the watershed.
- Identify and map vulnerable soils, floodplains, and landslide areas that could contribute to water quality impacts from forestry activities.
- Rank, weight, and overlay each dataset and risk factor to produce a map of potential risk to source water quality for each major category of forestry activities in the Clackamas River watershed.
- Identify areas in federal and state-owned forests with a high probability of a severe fire, if a fire were to occur.

The output of this effort is a set of maps showing potential low-to-high risk "hot spots" from forestry activities, including potential risk from: 1) fertilizers and herbicides; 2) burning activities; 3) site preparation activities; and 4) clear cutting and thinning activities. Maps were also produced showing high-severity fire probability.

Data Sources and Limitations

The primary GIS datasets required to assess the risk to source water quality from forestry activities in the Clackamas River watershed are the extent and intensity of forest practices extracted from the FACTS and FERNS databases and vulnerable soils and landslide areas. The following sections describe these datasets in more detail, including any major data limitations that are important to keep in mind when interpreting the GIS forestry activities risk analysis results. Documentation on all datasets used in the analyses can be found in Table 1. Herrera converted all GIS datasets used in the forestry activities risk analysis to the Oregon State Plane North HARN 83 map projection, with both the vertical and horizontal datum measured in feet.

Table 1. GIS datasets used to help assess the risk from forestry activities to source water quality in the Clackamas River watershed.

Dataset Description	Source	Date
Aerial photography	United States Department of Agriculture (USDA) National Agriculture Imagery Program (NAIP)	2019
Clackamas River watershed boundary	Oregon Metro Regional Land Information System (RLIS)	March 2021
Streams and waterbodies	Oregon Metro RLIS	March 2021
Forest Service Activity Tracking System (FACTS) notifications	U.S. Forest Service (USFS) and Oregon Department of Forestry (ODF)	1992 – 2020
High Soil Erosion Potential Areas	Oregon Department of Environmental Quality (DEQ)	2021
Landslides	Oregon Department of Geology and Mineral Industries (DOGAMI)	2021
National Land Cover Dataset (NLCD)	United States Geological Survey (USGS) Multi-Resolution Land Characteristics Consortium (MRLC)	2016
Public land ownership	Bureau of Land Management (BLM)	2021
Tax lot boundaries	RLIS	2021
Northwest Forest Plan Riparian Reserve Areas	USFS	1994
Predicted Future High-Severity Fire Mapping	USFS Rocky Mountain Research Institute	2020

Forestry Service Activity Tracking System (FACTS) Database

FACTS is a database used by all levels of the Forest Service to track information about forest practice activities occurring on forest land related to growing and harvesting timber. Herrera obtained FACTS activity data from two sources for the Clackamas River watershed: 1) Mt. Hood National Forest from USFS; and 2) private and state forest land from the Oregon Department of Forestry (ODF). The ODF version of the FACTS database is FERNS.

Mt. Hood National Forest FACTS Database

Herrera obtained data extracted from the USFS FACTS database in GIS format from USFS GIS staff at Mt. Hood National Forest GIS representing nearly 3,000 forestry activities in the national forest portion of the watershed for more than 50 categories with planned fiscal years from 1979 to 2020. Information provided for each forestry activity area included the number of affected acres, planned and accomplished activity dates, site slope and elevation, and equipment used. This dataset is summary in nature only and does not provide detailed activity information for sites, such as pounds of fertilizer applied.

Private and State Forest Land FERNS Database

Oregon State law OAR 629-605-0140 requires a written notice be submitted to the State Forester a minimum of 15 days before any of the following operations take place on forest land:

1) harvesting of forest trees; 2) application of chemicals; 3) pre-commercial thinning; 4) clearing of forestland to non-forest used; 5) construction, reconstruction, and improvement of roads; and 6) site preparation for reforestation involving clearing or use of heavy machinery. The ODF FERNS database contains summary information on all notifications of operations for private forest land in the Clackamas River watershed, including names and addresses of the listed operator, landowner, and timber owner; declared size of each operation unit and types of activities; legal description for the location of each unit; and special conditions that may exist (https://ferns.odf.oregon.gov/E-Notification/).

Herrera downloaded FACTS databases for state and private forest land for 2007 to 2021 from the ODF website. This dataset included the locations of approximately 230 forestry activities in 12 categories on state and private forest land in the Clackamas River watershed. There are two important limitations to keep in mind when interpreting risk analysis results based on data extracted from the ODF FACTS databases. First, the legal descriptions provided for activity areas are based on township-section-range data and are referenced to the quarter-quarter quad level. This means that the mapped locations are approximate as compared to the information obtained from USFS. In some cases, township-section-range data in the Clackamas River watershed is irregularly shaped; for these areas, it was not possible to refine the activity area to beyond the entire township-section-range. Second, the information in the ODF FERNS databases is summary in nature only and does not contain all data available on the paper notification of operation forms regarding activity information such as chemical application rates.

Vulnerable Soils and Floodplains

Higher sediment loads from soil erosion due to log removal, site preparation, and other forestry activities can have a major impact on water quality downstream of forested areas (McNulty et. al. 1995). Soil erosion resulting from road construction and road use in particular is the primary source of non-point source pollution from forested land, "contributing up to 90% of the total sediment from forestry operations" (EPA 2012). In addition, soils that have experienced past erosion are more likely to erode again in the future (Wall et. al. 2003).

Herrera obtained a GIS dataset of soils with high soil erosion potential for use in the forestry activities risk analysis from the Oregon Department of Environmental Quality (DEQ). This dataset is based on analysis of slope, erodibility K-Factor, and sediment yield potential from multiple sources of GIS soils data in the Clackamas River watershed.

Landslide Areas

Landslides are a dominant erosion process on steep, forested slopes in western Oregon (OBF 2001). Landslides generate large quantities of sediment, posing a significant risk to water quality as the sediment moves downhill and into rivers and streams. Herrera mapped landslide areas in the Clackamas River watershed using the Statewide Landslide Information Database for Oregon (SLIDO-2) from DOGAMI which is a database of landslides and landslide related features

compiled from more than 300 published and unpublished geologic hazard studies. Approximately 2,500 landslide deposits and landslide-related features and 620 historic landslide point locations were mapped by DOGAMI in the Clackamas River watershed.

Methodology

This section describes the GIS methods used by Herrera to identify and characterize forest land in the Clackamas River watershed; map the locations of forestry activities in Mt. Hood National Forest and state and private forest land; identify and map vulnerable soils and landslides; and rank, weight, and overlay the datasets based on their impact to source water quality.

Identifying and Characterizing Forest Land

The first step in assessing potential risk to source water quality from forestry activities in the Clackamas River watershed was to identify and characterize all public and private forest land), including: 1) Mt. Hood National Forest; 2) forest land owned by the Bureau of Land Management (BLM); and 3) private forest land. To accomplish this, Herrera first obtained GIS data showing the extent of the Mt. Hood National Forest and areas owned by BLM and overlaid this data with the Clackamas River watershed boundary. Next, Herrera used tax parcel data and aerial photography to identify forest parcel owned by private timber companies. Finally, 2006 NLCD land cover data was used to characterize other areas of forested land in the watershed.

A summary of acreages of forest land by type is provided in Table 2; it is important to keep in mind that due to the methods and data sources used for estimating land owned by private timber companies and other forested areas in the watershed, acreages in these categories are approximate. The spatial distribution of forest land in the watershed is shown in Figure 1.

Table 2. Categories of forest land in the Clackamas River watershed

Category	Area	Percent of Watershed
Mt. Hood National Forest	419,367	69.5%
Other Public Forest Areas	13,350	2.2%
Privately-Owned Forest	29,032	4.8%
Other Forest Areas	41,253	6.8%

Mapping Forestry Activities

After Herrera identified and characterized forest land in the Clackamas River watershed, the next step was to use data extracted from the USFS and ODF FACTS databases to map areas of forestry management activities in the watershed over time. FACTS data obtained from the USFS was provided in a GIS compatible format and was overlaid with the watershed boundary.

After mapping the extent of forestry activities based on both the USFS and ODF FACTS and FERNS databases, Herrera determined that based on differences in activity classifications, activity polygon resolution, and years of data analyzed, it was most appropriate to analyze enough risk categories from each dataset separately rather than for the watershed as a whole. This process is described in more detail in the next section.

Calculating Aggregate Forestry Activities Risk on State and Private Land

After Herrera mapped the extent of forestry activities based on data extracted from the USFS FACTS database for Mt. Hood National Forest, the next step completed was to calculate potential aggregate risk from each category of forestry activities to downstream water quality. Potential aggregate risk for each activity polygon category was based on 1) highly erodible soils; 2) landslide presence; 3) ratio of the effected activity area to the total watershed area; and 4) proximity to the stream channel centerline. This analysis was completed using the following methodology.

First, each category of forestry activities was extracted separately from the ODF FERNSs database. Then each risk variable was analyzed by forestry activity polygon: soil erosion and landslide data were intersected with each polygon to calculate total coverage; the area of each forestry activity polygon was divided by the total watershed to calculate the ratio of affected polygon area; and proximity to forest riparian stream buffers was calculated.

Next, the attributes for each individual resulting dataset were assigned a ranking scheme on a scale of 1 to 5, with a value of 1 indicating a low risk to source water quality from a category of forestry activities and a value of 5 indicating a high risk. The ranking scheme for each dataset was determined using two primary methods. The first method ranked each dataset based on presence or absence. For example, highly erodible soils that overlap with mapped forestry activity areas were assigned a value of 5; areas that did not overlap were assigned a value of 0.

Table 3 shows the detailed ranking scheme applied to each dataset in the risk analyses; the same ranking scheme was applied to all seven forestry activity risk analyses completed on state and private land. No weighting was applied to the datasets used in this risk analysis.

Table 3. Categories of forest land in the Clackamas River watershed		
Dataset	**Ranking Factor**	**Ranking Criteria**
Landslide presence	Yes	5
High soil erosion potential	Yes	5
Ratio of affected activity area to total watershed size	< 0.00005	1
	--	--
	0.0005 to 0.0002	3
	--	--
	> 0.0002	5
Proximity to surface water	< 150 feet	5
	150 to 300 feet	4
	300 to 500 feet	3
	500 to 1,000 feet	2
	> 1,000 feet	1

The results of the analyses showing aggregate risk from each category of forestry activities in state and private forest land to source water quality in the Clackamas River watershed are shown in Figures 2A through 2G. A brief discussion on interpreting the risk trends shown in these figures is included in the Results and Recommendations section

Severe High-Probability Wildfire on Public Lands

Wildfire hazard potential (WHP) is an index that depicts the relative potential for wildfire that would be difficult for suppression resources to contain, based on wildfire simulation modeling. This dataset produced by the USDA Forest Service, Fire Modeling Institute in 2018 shows WHP at a spatial resolution of 270 meters across the entire conterminous United States, classified into five WHP classes of very low, low, moderate, high, and very high. Areas mapped with higher WHP values represent fuels with a higher probability of experiencing torching, crowning, and other forms of extreme fire behavior under conducive weather conditions, based primarily on 2012 landscape conditions. This WHP dataset is based on outputs of wildfire simulation modeling, available in a map service of Probabilistic Wildfire Risk components.

Herrera used this dataset to map wildfire probability in the Mt. Hood National Forest. The results of this analysis are shown in Figure 3.

RESULTS AND RECOMMENDATIONS

Herrera mapped the locations of more than 2,000 forestry activities in Mt. Hood National Forest, and approximately 230 forestry activities in public and private forest land in the Clackamas River watershed in 9 general categories: 1) thinning; 2) clear-cutting; 3) herbicide use; 4) site preparation; 5) fertilization; 6) other harvest activities; 7) road construction; 8) fertilizer use; and

9) burning activities. Herbicide application and road construction activities were specific to state and private forest land; fertilizer use and burning activities were specific to Mt. Hood National Forest. The most prevalent forestry activities in the Mt. Hood National Forest based on number of records listed in the USFS FACTS database are: 1) commercial thinning (Thinning risk analysis category); 2) salvage cuts (Other Harvest category); and Reforestation Needs and Certification (Other Activities category). The most prevalent forestry activities for other forest areas in the Clackamas River watershed are 1) partial cutting (Other Harvest risk analysis category); 2) clear cutting; and 3) road reconstruction. It is important to keep in mind that this is based on prevalence of activities, and not total acres of affected area.

As shown in Figures 2 and 3, the overall risk analysis categories that appear to have the most significant numbers of "hot spots" in the Mt. Hood National Forest are thinning activities, fertilizer applications, and burning activities; for state and private forest land, they are road construction activities and clear-cutting. However, the risk analysis results for each forestry activity category are intended to assess geographic risk by category and are not intended to compare risk between groups of activities. This is due to the fact that the water quality impacts between activity categories may not be directly comparable. For example, the water quality impacts from fertilizer application are primarily from nitrogen and phosphorous runoff, while the primary impact from road construction is sedimentation. For this reason, Herrera did not produce maps of cumulative risk for all forestry activities in the Clackamas River watershed. Results of the risk analyses by activity category are shown in Figures 2A through 2G. The most appropriate method for interpreting these results is to look at overall geographic trends rather than activity-level results due to the potential for data anomalies.

This analysis effort was primarily intended to provide a baseline overview of forestry activities in the Clackamas River watershed on public and private forest land, and therefore mapped a very large number of forestry activities in several broad categories. Herrera recommends that this analysis be repeated in three to five years after the CRWP has completed pollutant load modeling or further water quality monitoring work, and that the GIS analysis focus on the subset of forestry activities and geographic "hot spots" that indicated as having the most significant impacts on source water quality.

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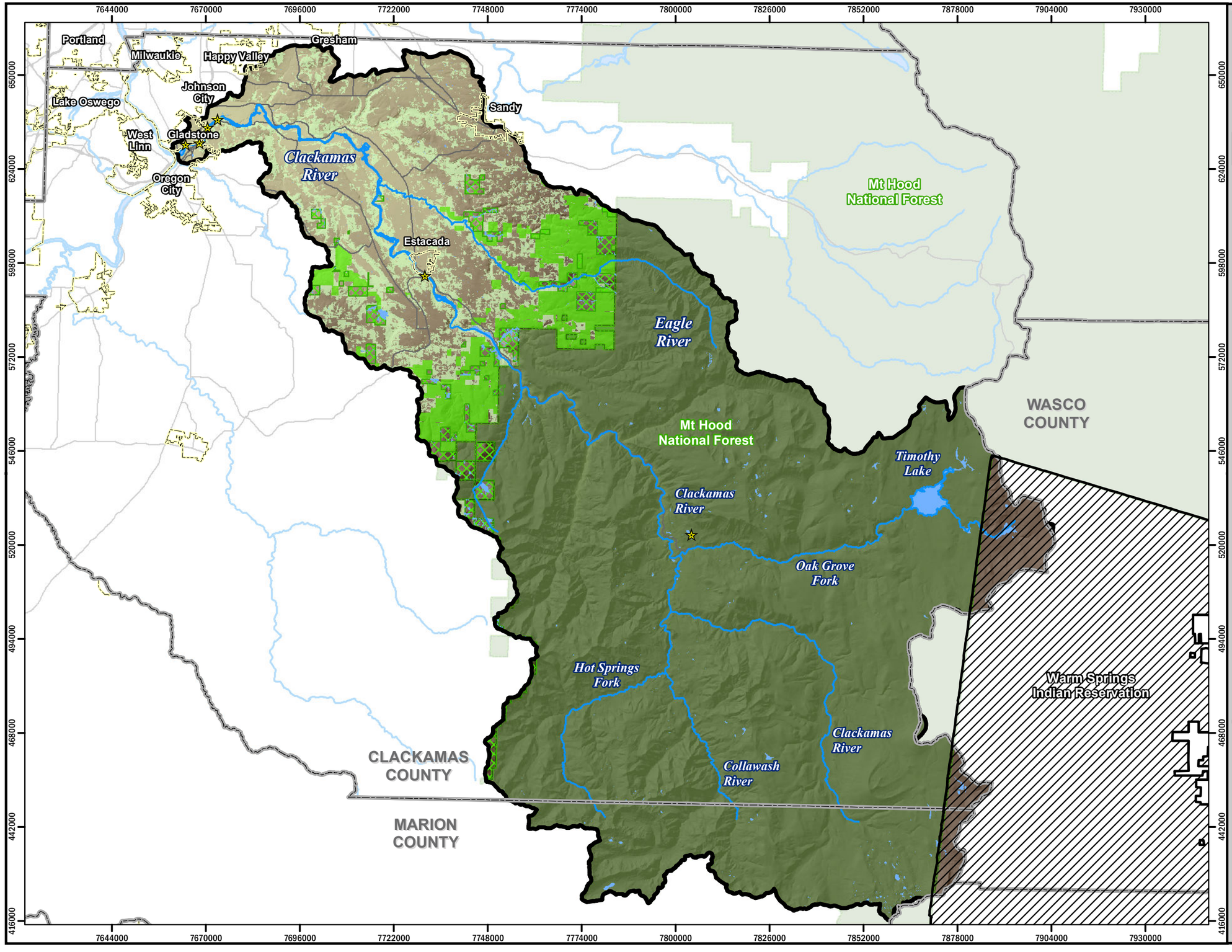
FIGURES

Figure 1.
National Forest, BLM, and private timber land and other forested areas in the Clackamas River watershed.



Legend

- National Forest boundary
- BLM land
- Private timber land
- Other forested areas
- Surface water intake
- County boundary
- City limits
- Clackamas River Watershed boundary
- Warm Springs Indian Reservation

N

0 13,000 26,000 52,000

feet

Clackamas River Water Providers
Working together to protect and conserve our drinking water.

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Coordinates: Oregon State Plane North
HARN NAD83 (feet)

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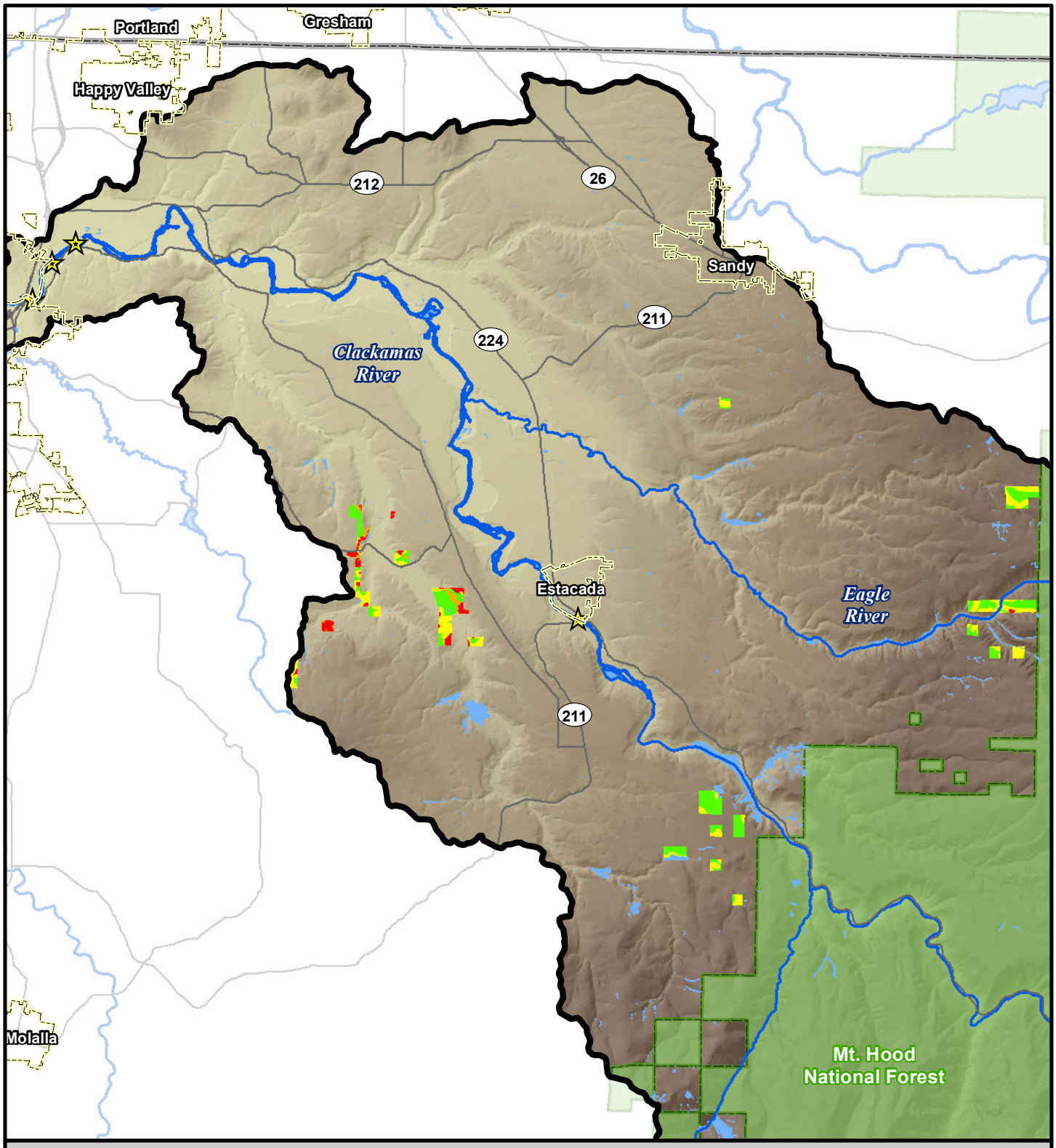

Legend

Potential risk
- Low
- Moderate
- High
- Very High
- Surface water intake

- National Forest boundary
- City limits
- Warm Springs Indian Reservation
- County boundary
- Clackamas River Watershed boundary

Figure 2B. Potential risk from road construction to source water quality in the Clackamas River watershed based on GIS predictive modeling.

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Feet

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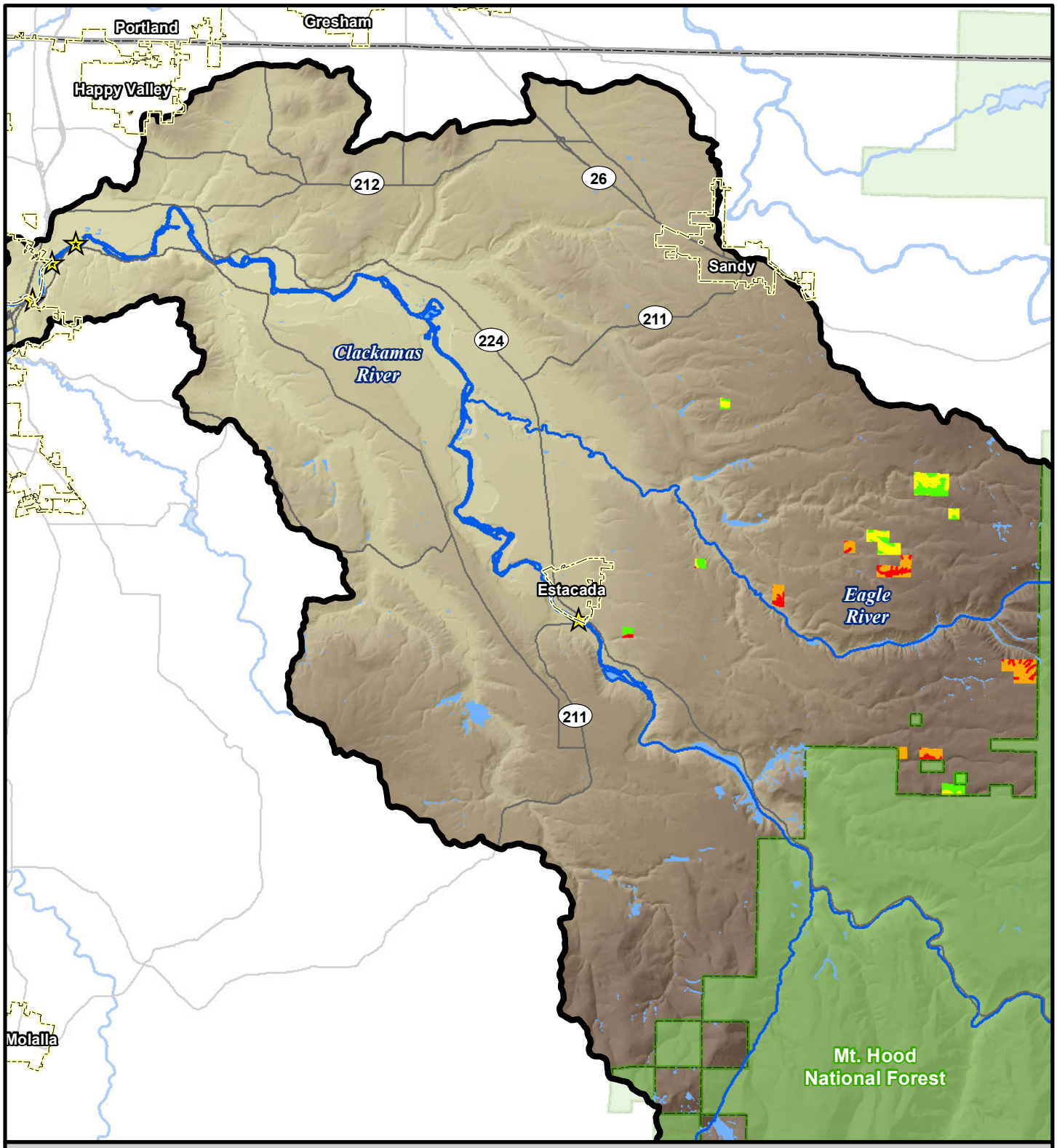

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Potential risk

- Low
- Moderate
- High
- Very High
- Surface water intake
- National Forest boundary
- City limits
- Warm Springs Indian Reservation
- County boundary
- Clackamas River Watershed boundary

Figure 2C. Potential risk from site preparation activities to source water quality in the Clackamas River watershed based on GIS predictive modeling.

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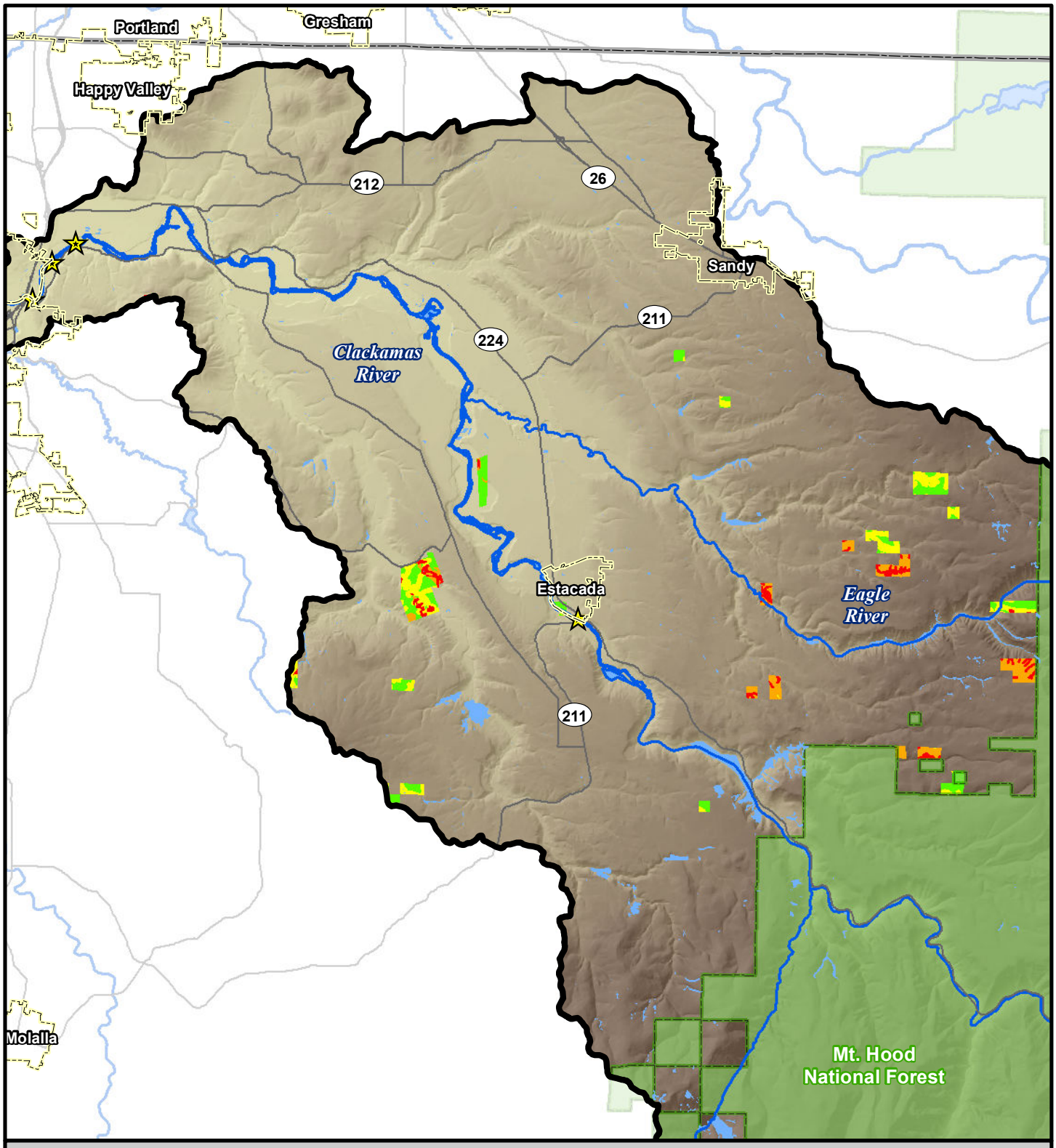

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Potential risk

- Low
- Moderate
- High
- Very High
- Surface water intake
- National Forest boundary
- City limits
- Warm Springs Indian Reservation
- County boundary
- Clackamas River Watershed boundary

Figure 2D. Potential risk from clear cutting activities to source water quality in the Clackamas River watershed based on GIS predictive modeling.

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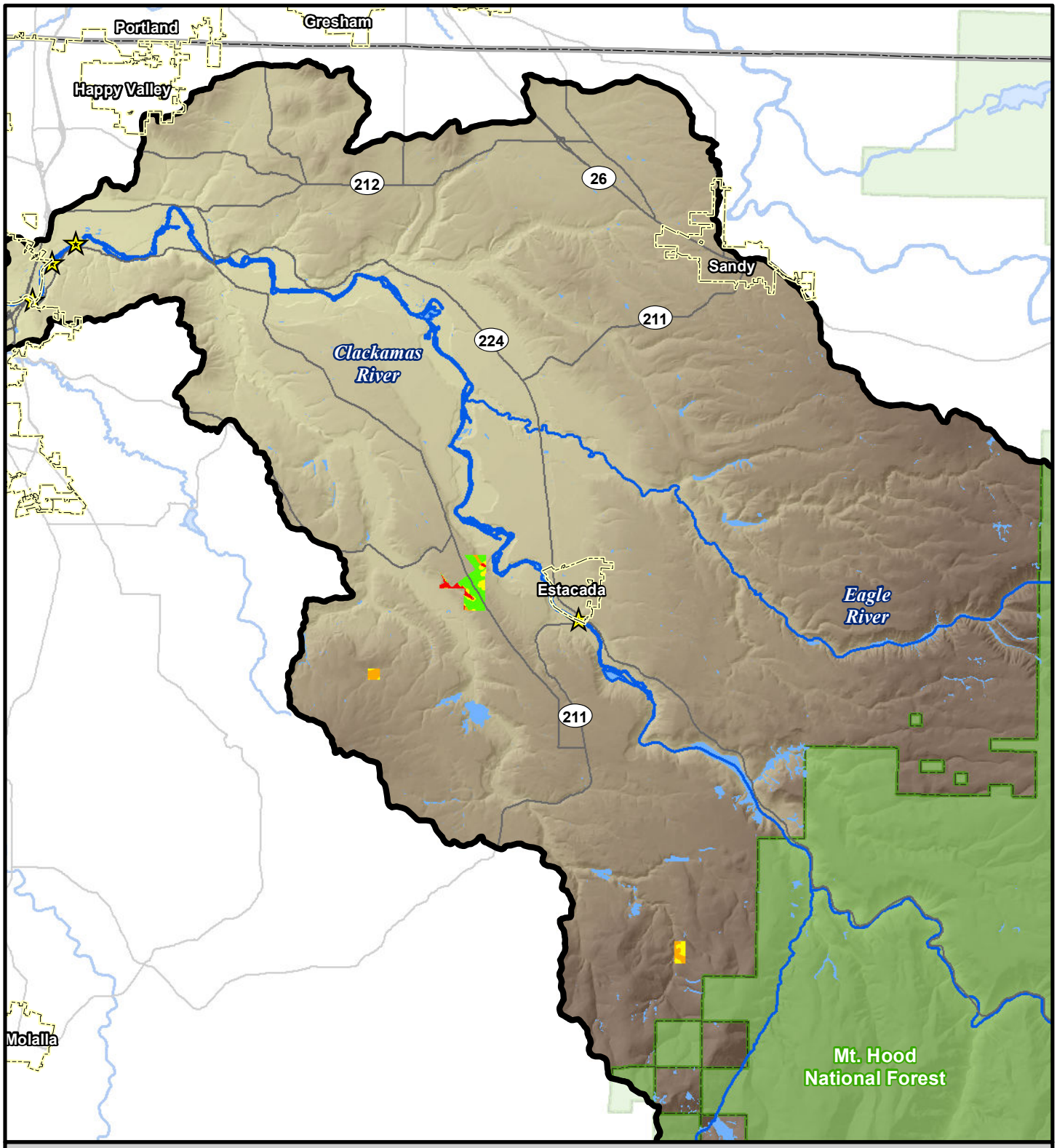

Legend

Potential risk

- Low
- Moderate
- High
- Very High
- Surface water intake
- National Forest boundary
- City limits
- Warm Springs Indian Reservation
- County boundary
- Clackamas River Watershed boundary

Figure 2E. Potential risk from thinning activities to source water quality in the Clackamas River watershed based on GIS predictive modeling.

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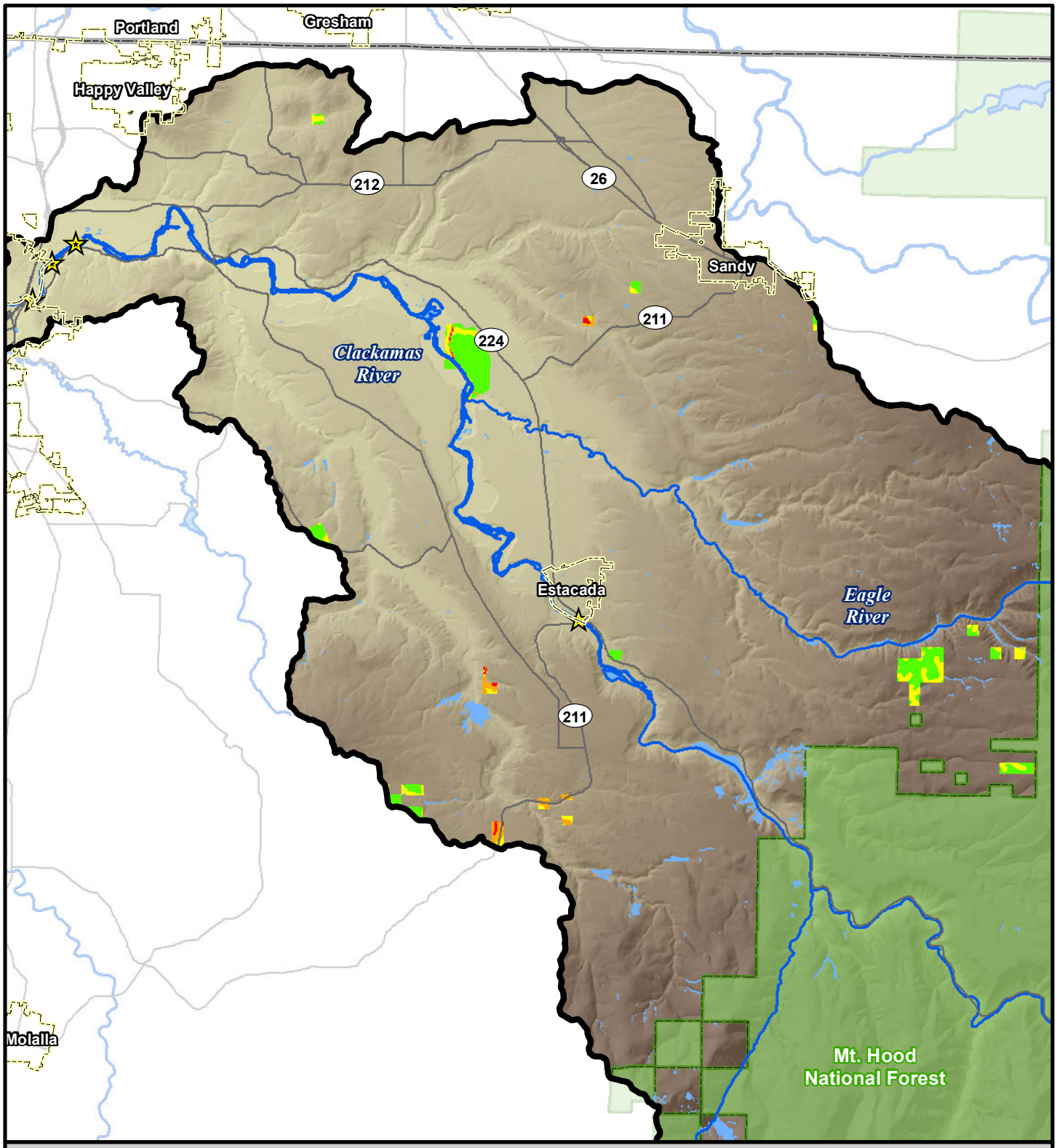

Legend

Potential risk

- Low
- Moderate
- High
- Very High
- Surface water intake
- National Forest boundary
- City limits
- Warm Springs Indian Reservation
- County boundary
- Clackamas River Watershed boundary

Figure 2F. Potential risk from other harvest activities to source water quality in the Clackamas River watershed based on GIS predictive modeling.

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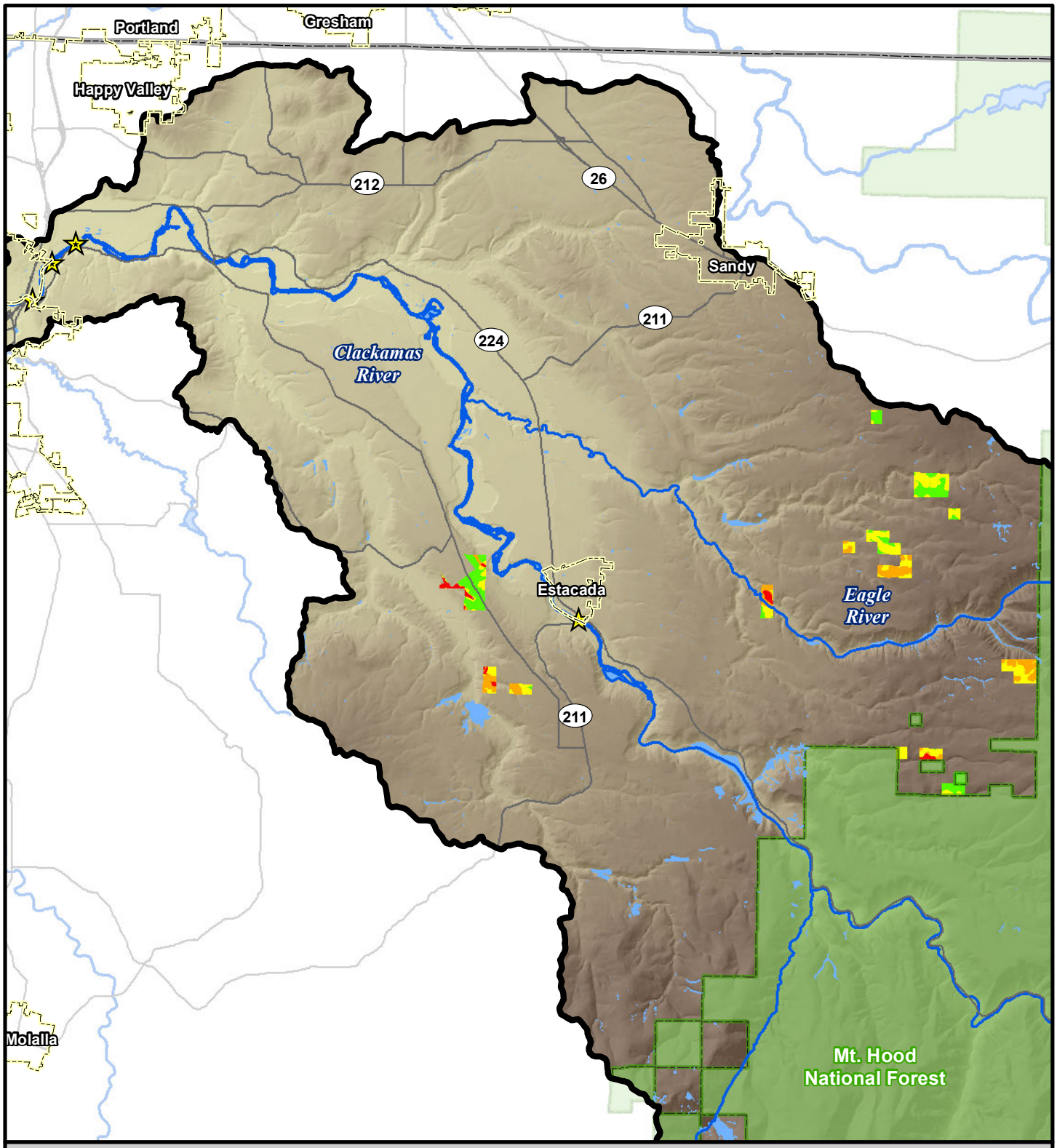

Legend

Potential risk

- Low
- Moderate
- High
- Very High
- Surface water intake
- National Forest boundary
- City limits
- Warm Springs Indian Reservation
- County boundary
- Clackamas River Watershed boundary

Figure 2G. Potential risk from other forestry activities to source water quality in the Clackamas River watershed based on GIS predictive modeling.

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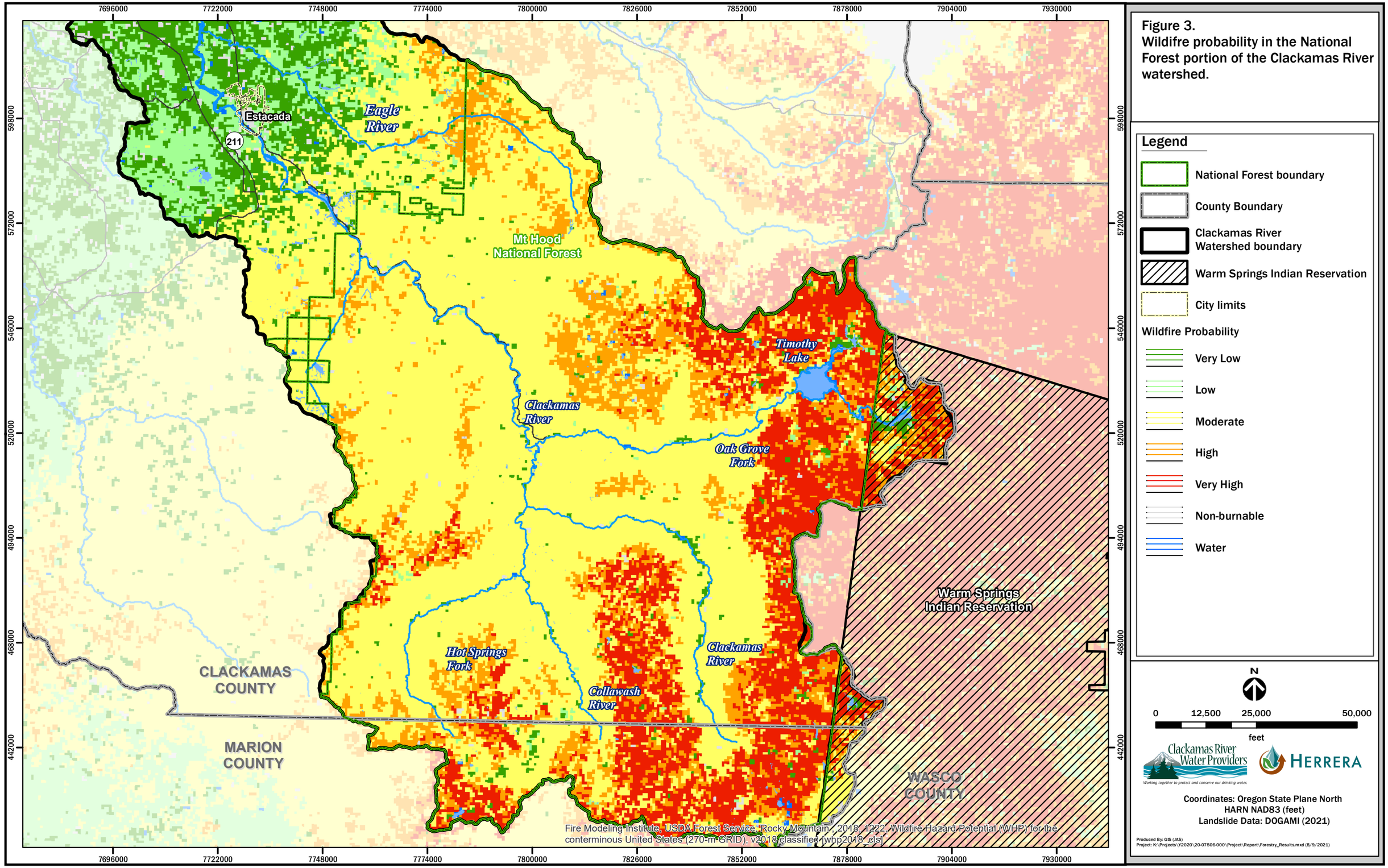
Figure 3.
Wildfire probability in the National Forest portion of the Clackamas River watershed.



Legend

- National Forest boundary
- County Boundary
- Clackamas River Watershed boundary
- Warm Springs Indian Reservation
- City limits

Wildfire Probability

- Very Low
- Low
- Moderate
- High
- Very High
- Non-burnable
- Water

N

0 12,500 25,000 50,000

feet

Clackamas River Water Providers
Working together to protect and conserve our drinking water.

HERRERA

Coordinates: Oregon State Plane North
HARN NAD83 (feet)
Landslide Data: DOGAMI (2021)

Produced By: GIS (JAS)
Project: K:\Projects\Y2020\20-07506-000\Project\Report\Forestry_Results.mxd (8/9/2021)