TECHNICAL MEMORANDUM

Date: June 30, 2021

To: Kimberly Swan, Clackamas River Water Providers

From: Jennifer Schmidt, Herrera Environmental Consultants

Subject: GIS Agricultural 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 Agricultural Activities Risk Analysis.

POTENTIAL THREATS FROM HAZARDOUS MATERIALS SPILLS

The Clackamas River Water Providers (CRWP) has identified stormwater runoff from agricultural practices as being a significant of risk to drinking water quality in the Clackamas River watershed. The primary threats to source water from agricultural activities include (Clackamas River Water Providers 2010):

1. Non-point source pollution from sediments, nutrients, pathogens, oxygen-depleting organics, pesticides, metals and salts from irrigation and non-irrigated crop areas, plant nurseries, animal grazing areas, boarding stables, farm machinery repair shops, and chemical mixing/storing/handling areas.

2. Increased runoff of nitrates, bacteria, pharmaceuticals, and soil from Confined Animal Feed Operations (CAFOs) where large numbers of animals are confined in one location.

According to the 2000 EPA *National Water Quality Inventory,* agricultural nonpoint source pollution is "the leading source of water quality impacts on surveyed rivers and lakes, the second largest source of impairments to wetlands, and a major contributor to contamination of surveyed estuaries and ground water" (U.S. EPA 2005). Drinking water sources degraded by agricultural non-point source pollutants 1) increase water treatment costs; 2) increase the production of disinfection byproducts due to an overall increase in bacteria and organic carbon; and 2) pose a significant risk to public health (Morgenstern 2006).

GIS Agricultural Activities Risk Analysis

Herrera performed a GIS analysis mapping the extent and intensity of agricultural activities in the Clackamas River watershed to help predict the overall potential risk of stormwater runoff from these activities to source water quality. This methodology involved gathering/generating, ranking, and overlaying five agricultural practice datasets and related information in GIS:

- Recommended fertilizer and pesticide application rates by crop type for agricultural fields and nurseries
- Confined Animal Feed Operation (CAFOs) and other animal activities and impacts
- Proximity of agricultural activities to surface water
- Vulnerable soils and irrigated land

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 agricultural activities risk analysis were to:

1. Identify agricultural fields and nurseries and evaluate their potential impacts to surface water quality based on recommended guidelines for pesticide and fertilizer application rates for each crop type in the watershed.

2. Map the locations of CAFOs and other animal activities and impacts such as concentrated grazing areas, boarding stables, and kennels.

3. Identify and map vulnerable soils, floodplains, and irrigated lands that could contribute to agricultural source water quality impacts.

4. Rank, weight, and overlay the agricultural activities datasets to produce maps of cumulative predicted risk to source water quality from agricultural practices in the Clackamas River watershed.

Data Sources and Limitations

The primary GIS datasets required to assess agricultural activities risk to source water quality are agricultural field locations and crop types, nurseries, and greenhouses, recommended pesticide and fertilizer application rates by crop type, CAFOs and other animal activities and impacts, fish hatcheries, and irrigated land and vulnerable soils. 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 agricultural 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 agricultural 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
Cropland Data Layers (CDL)	USDA National Agricultural Statistics Service (NASS)	2018 – 2020
Confined Animal Feed Operations (CAFOs)	Oregon Department of Agriculture (ODA) and Oregon Department of Environmental Quality (DEQ)	2021
Potential Contaminant Sources	Oregon DEQ	2018
Water rights agricultural irrigation uses	Oregon Water Resources Department (WRD)	May 2021
Highly Erodible Lands	Oregon DEQ	May 2021
Pesticide and fertilizer application rates by crop type	Oregon State University (OSU) Extension Service	Various

Zoning designations	RLIS	March 2021
Nursery licenses	ODA	March 2021

Crop Types

Herrera used CropScape Cropland Data Layer (CDL) grids created by the U.S. Department of Agriculture (USDA) National Agricultural Statistics Service (NASS) to identify agricultural fields and crop types in the Clackamas River watershed from 2009 to 2011. The NASS CDL is a crop-specific land cover dataset that is updated annually using several different sources of satellite imagery and remote sensing software to classify agricultural land into specific crop categories. The statistical classification accuracy of CDL datasets for dominant agricultural crop categories in the continental U.S. generally ranges from 85% to 95%; the CDL datasets obtained for the Clackamas River watershed had a classification accuracy of 81% in 2018, 82% in 2019, and 87% in 2020.

It is important to keep in mind when interpreting the agricultural risk analysis results generated from CDL data that the pixel resolution of the grids is fairly coarse (30 meters), and crop type classifications have not been field verified.

Pesticide and Fertilizer Application Rates

Herrera used crop-specific fertilizer guides and pest and weed management handbooks developed by the Oregon State University (OSU) Extension Service to determine recommended fertilizer and pesticide application ranges to apply to each mapped crop type in the Clackamas River watershed. Rather than indicating specific amounts of fertilizers and pesticides that were actually applied on the ground, these guidelines were used to estimate the average amount of fertilizers and chemicals that could possibly be applied to each field by crop type if 1) recommended application guidelines are followed and 2) all acreages are treated with each fertilizer or pesticide.

Actual applied fertilizer and pesticide rates at the individual field level are dependent on many different factors and may vary significantly from the application rates used in this analysis. Fertilizer application guidelines in particular are based in part on the results of site-specific soil testing, which was not possible to take into account in this analysis.

CAFOs and Other Animal Activities

The Oregon Department of Agriculture (ODA) and Oregon Department of Environmental Quality (DEQ) issue permits for small, medium, and large CAFOs in Oregon to “protect the quality of groundwater and surface waters of Oregon by preventing animal waste from discharging into waters of the state” (ODA and DEQ 2009). Herrera obtained the locations of three permitted CAFOs in the Clackamas River watershed from Oregon DEQ, as well as ten non-permitted locations. This data is current as of May 2021.

An additional source of CAFO and other animal activity locations came from four source water assessments completed by Oregon DEQ and the Oregon Department of Human Services (DHS) with assistance from the Clackamas Basin Watershed Council in 2002-03. The purpose of these assessments was to identify surface water areas that supply public drinking water, identify sensitive areas, and potential contaminant sources that could adversely impact that source of water (Clackamas River Water Providers 2010). Over 1,200 potential contaminant sources (PCS) were identified in the Clackamas River Source Water Assessments and mapped in a GIS dataset, including approximately 200 animal-related activities in the Clackamas River watershed indicated as being of moderate to high risk to source water quality. This included additional unpermitted CAFOs, concentrated animal grazing areas, boarding stables, large kennels, and horse camps. Herrera extracted these animal-related activity locations from the overall PCS dataset for inclusion in the risk analysis.

Nurseries and Greenhouses

Nurseries and greenhouses are not included as a specific crop land cover category in the NASS CDL dataset. Herrera obtained the locations of nurseries, greenhouses, and Christmas tree grower licenses in the Clackamas River watershed directly from ODA.

Vulnerable Soils and Irrigated Land

The most prevalent source of agricultural water pollution is eroded soil and the pollutants attached to soil particles that are washed off of fields and into nearby water bodies (U.S. EPA 2005). Oregon DEQ provided Herrera with a Highly Erodible Land (HEL) Class 1 dataset for Clackamas County that represents highly erodible soils to use in the agricultural activities risk analysis. The criteria used to determine soil erodibility is based on slope and K Factor, which is a calculated value representing both the susceptibility of soil to erosion and the rate of runoff. An HEL class of 1 represents highly erodible soils related to bare lands once crops have been harvested.

The Oregon DEQ/WRD statewide water right agricultural irrigation areas data was also used to help identify potential source water quality impacts from irrigated land in the Clackamas River watershed. Inefficient or excessive irrigation can cause erosion, increase sedimentation, and transport nutrients, pesticides, and heavy metals to water bodies (U.S. EPA 2005).

Methodology

This section describes the GIS methods used by Herrera to identify agricultural fields, nurseries, and greenhouses and apply crop-specific pesticide and fertilizer application rates; map the locations of CAFOs and other animal activities and impacts; identify and map vulnerable soils and irrigated lands; and rank, weight, and overlay the datasets based on their impact to source water quality.

Identifying Agricultural Fields and Nurseries and Greenhouses

The first step in assessing the overall risk to source water quality from agricultural activities in the Clackamas River watershed was to identify and map areas of agricultural production by crop type. To accomplish this, Herrera obtained CropScape CDL data and mapped the distribution of 47 different crop categories in the Clackamas River watershed. Next nursery and greenhouse locations were overlaid with each year of CropScape CDL data to produce comprehensive coverages of agricultural crop production in the Clackamas River watershed between 2018 and 2020.

Detailed crop type acreages by year can be found in Table 2. This data is sorted by highest percent crop cover in 2020, which is the most recent CDL data available. Detailed crop type distribution maps can be viewed online through the CropScape website at: http://nassgeodata.gmu.edu/CropScape.

Table 2. Crop cover acreages for 2018, 2019, and 2020 in the Clackamas River watershed based on USDA NASS CropScape CDL data.

Crop Type	2018	%	2019	%	2020	%
Pasture and Hay	32,195	84.1	36,720	86.5	32,579	79.3
Nurseries or Greenhouses	3,640	9.5	3,640	8.7	3,640	8.9
Cranberries	1,463	3.8	877	2.1	1,515	3.7
Other Hays	383	1	266	0.63	703	1.7
Seed and Sod Grass	245	0.64	61	0.15	679	1.7
Christmas Trees	124	0.33	172	0.41	307	0.8
Blueberries	76	0.20	10	0.02	322	0.8
Corn	28	0.07	46	0.11	17	0.04
Spring Wheat	23	0.06	23	0.05	58	0.14
Other Tree Nuts (Hazelnuts)	15	0.04	171	0.41	219	0.53
Winter Wheat	14	0.04	32	0.08	176	0.43
Cherry Orchard	13	0.04	3	0.01	80	0.19
Alfalfa	11	0.03	7	0.02	4	0.01
Other Crops	10	0.03	54	0.13	261	0.64

Clover and Wildflowers	9	0.02	21	0.05	177	0.43
Oats	8	0.02	4	0.01	31	0.08
Radish	3	0.01	0	0	0	0
Dry Beans	2	0.01	31	0.07	129	0.31
Grapes	2	0.01	15	0.04	49	0.12
Sweet Corn	2	0	19	0.04	19	0.05
Prunes	1	0	0.2	0	0	0
Onions	1	0	0	0	3	0.01
Turnips	0.5	0	0	0	4	0.01
Cabbage	0.4	0	23	0.06	0	0
Walnuts	0.4	0	0.5	0	13	0.03
Strawberries	0.2	0	6	0.01	15	0.04
Vetch	0.2	0	1	0	0	0
Rye	0.2	0	0	0	0	0
Apples	0.2	0	0	0	0.5	0
Hops	0.1	0	14	0.03	20	0.05
Barley	0.1	0	0	0	1	0
Pasture and Grass	0	0	60	0.14	17	0.04
Squash	0	0	59	0.14	3	0.01
Cauliflower	0	0	15	0.04	8	0.02
Peppers	0	0	11	0.03	9	0.02
Beets	0	0	8	0.02	3	0.01
Peas	0	0	5	0.01	13	0.03
Canola	0	0	2	0	0.2	0
Herbs	0	0	1	0	5	0.01
Mint	0	0	0.8	0	5	0.01

Potatoes	0	0	0.7	0	2	0
Misc. Fruits and Vegetables	0	0	0.7	0	0	0
Triticale	0	0	0.7	0	0.7	0
Broccoli	0	0	0.4	0	0	0
Greens	0	0	0.2	0	1	0
Pecans	0	0	0	0	2	0.01
Garlic	0	0	0	0	1	0
Plums	0	0	0	0	1	0
Total	**38,271**	**100**	**41,932**	**100**	**41,095**	**100**

Based on this data, the top crop items by acreage in the Clackamas River watershed between 2018 and 2020 were: 1) pastures and hay; 2) nurseries and greenhouses; 4) seed and sod grass; 5) blueberries; and 6) Christmas trees.

Applying Crop-Specific Fertilizer and Pesticide Application Rates

After Herrera mapped crop type distributions in the Clackamas River watershed between 2018 and 2020, the next step was to determine crop-specific fertilizer and pesticide application rates to apply to each field or nursery. To accomplish this, Herrera completed a review of fertilizer guides by crop type prepared by the OSU Extension to determine the recommended amounts of nitrogen and phosphorous to apply to each field. Phosphorous and nitrogen runoff from manure and synthetic fertilizers can have significant impacts on water quality and human health; phosphorous is "often the primary concern in freshwaters (lakes and streams), while nitrogen is the main concern for coastal water (bays and oceans) and drinking water supplies" (Rutgers 2011). When manure is spread on fields as a fertilizer, it can also introduce some of the more toxic substances present in livestock excretions to source water, including pharmaceuticals and bacteria (Campagnolo et. al. 2002).

Recommended nitrogen and phosphorous application rates were frequently presented as a range that was dependent on several factors, including site-specific soil test results, previous crop cover, and crop stage. To determine the most appropriate application rate to apply from this range to each crop type, Herrera went through the following steps:

1. The minimum and maximum recommended application rates for nitrogen and phosphorous, regardless of site-specific soil test results, were determined for each crop type from individual fertilizer guides.

2. In most cases, the average value from this range was used as the estimated fertilizer application rate for each crop type used in the GIS risk analysis. Some fertilizer guides provided more detailed information on common application rates for Western Oregon that varied from the average; in these cases, the more detailed application rates were used.

3. After the average nitrogen and phosphorous application rates were determined, Herrera joined these values to the CDL crop type grids for 2018, 2019, and 2020. The recommended nitrogen and phosphorous application rates for each CDL grid were then added together and dividied by three to produce average nitrogen and phosphorous application rates for each pixel between 2018 and 2020. The purpose of this step was to attempt to account for potential crop rotation in the watershed over time.

After average fertilizer application rates were estimated for each crop type, the next step was to identify recommended pesticide application rates. More than two hundred different herbicide and insecticides were listed for managing weeds and insects in the Clackamas River watershed based on the OSU Extension Service herbicide and insecticide handbooks. To help narrow the focus of the risk analysis efforts to the pesticides that have historically been most impactful to source water quality, Herrera reviewed 119 water quality sample results collected in the Clackamas River watershed between 2000 and 2005 to identify pesticides that 1) were detected in at least 20% of samples or 2) were detected at levels that exceeded aquatic-life benchmarks. In total, 17 pesticide compounds met one or both of these criteria; average recommended application rates were obtained for eleven herbicides and six insecticides, with the most frequent detection rates being: 3,4-Dichlorophenyl isocyanate, a degradate of diuron (100%); glyphosate (71%); simazine (52%); atrazine (47%); napropamide (44%); and diuron (44%) (Carpenter et. al. 2005).

The same steps followed for determining average recommended application rates for fertilizers by crop type were also used to determine application rates for pesticides. It is important to keep in mind when interpreting the pesticide and fertilizer application rates data that this information does not indicate the amount of pesticides and fertilizers physically applied on the ground. Instead, this data is intended to help compare the relative amount of fertilizers and pesticides recommended for application by crop type.

Map CAFOs and Other Animal Activities

After Herrera mapped crop distribution and estimated average recommended fertilizer and pesticide application rates for each crop type between 2009 and 2011, the next step was to map the extent and intensity of CAFOs and other animal activities in the Clackamas River watershed. The locations of three permitted CAFOs and approximately 200 other animal-related activities were mapped using the Oregon PCS dataset, including grazing areas, boarding stables, large kennels, and horse camps. Each PCS location includes a low-to-high risk ranking based on its potential impact to source water quality. Because the PCS data was mapped at the state level, the locations are approximate.

Mapped CAFOs and other animal activity locations by risk category are shown in Figure 3.

Calculating Linear Distance to Nearest Tributary

Herrera used stream centerline data to calculate the linear distance from agricultural activities in the Clackamas River watershed to the nearest tributary to the Clackamas River. This calculation was based on surface drainage only and does not consider existing agricultural ditches or other stormwater conveyance systems.

Mapping Vulnerable Soils

Sediment is the largest contaminant of surface water in the U.S. by weight and volume (Koltun et. al. 1997). Disturbing soil through tillage and cultivation and leaving it without vegetative cover can increase the rate of soil erosion (USDA 2006). Herrera mapped HEL Class 1 soils data obtained from Oregon DEQ representing areas of highly erodible soils with rapid runoff potential in the Clackamas River watershed. This data was then overlaid with mapped agricultural activities and irrigated land to identify areas of highly erodible soils where agricultural production is concentrated.

Calculating Aggregate Agricultural Activities Risk

After Herrera mapped crop distribution and nurseries and greenhouses locations; estimated crop-specific fertilizer and pesticide application rates to apply to each field or nursery; mapped CAFOs, other animal activities, and fish hatcheries; calculated proximity of agriculture activities to Clackamas River tributaries; and mapped vulnerable soils and irrigated land, the next step completed was to rank and overlay the datasets together to determine aggregate risk from agricultural activities to source water quality in the Clackamas River watershed. Herrera produced two separate maps showing risk from agricultural activities in the watershed: 1) aggregate risk from fertilizers; and 2) aggregate risk from pesticides. Low-to-high risk rankings were included in the Oregon PCS data for fish hatcheries and CAFOs and other animal activities and Herrera did not analyze potential risk from these locations any further; these results are shown in Figure 3. Both the fertilizer and pesticide risk analyses incorporated HEL Class 1 soil data, irrigated land, and proximity to surface water as contributing factors to aggregate risk. These risk datasets were generated using the following methodology.

First, the attributes for each individual dataset were assigned a ranking scheme on a scale of 1 to 5, with a value of 1 indicating a low risk from agricultural activities to source water quality and a value of 5 indicating high risk. The ranking scheme for each dataset was determined by computing a histogram of the data distribution in GIS and then using statistical breaks in the data to assign relative risk rankings. For example, recommended application rates of the herbicide 2,4-D ranged from 0.48 to 3 pounds per acre depending on weed type and crops being treated, with statistical breaks in the data histogram occurring at 0.85, 1, and 1.5 pounds. This information was used to determine the 2,4-D risk factors used in the aggregate pesticide risk analysis.

Tables 3 and 4 show the detailed ranking factors applied to each dataset used in the fertilizer and pesticide aggregate risk analyses. All datasets contributing to the aggregate risk datasets were weighted equally in these analyses. After the ranking factors were applied, the final step was to convert each dataset to a raster grid with 10-meter pixels and overlay the grids together to calculate a cumulative risk value for each pixel. These results were then mapped into low, moderate, and high risk categories. The results of the analyses showing aggregate risk from fertilizers and pesticides to source water quality in the Clackamas River watershed are shown in Figures 4A and 4B.

Table 3. Ranking, ranking criteria, and weighting factors applied to each GIS dataset to determine the risk from fertilizers to source water quality in the Clackamas River watershed.

Dataset	Ranking Factor	Ranking Criteria
HEL Class 1 Soil Designation	Yes	5
Irrigated Land	Yes	5
Proximity to Surface Water	0 to 150 feet	5
	150 to 300 feet	4
	300 to 500 feet	3
	500 to 1,000 feet	2
	> 1,000 feet	1
Fertilizers: Average Annual Recommended Application Rate of Nitrogen	None	1
	< 25 lbs	2
	25 to 75 lbs	3
	75 to 150 lbs	4
	> 150 lbs	5
Fertilizers: Average Annual Recommended Application Rate of Phosphorous	None	1
	< 25 lbs	2
	25 to 50 lbs	3
	50 to 75 lbs	4
	> 75 lbs	5

Table 4. Ranking, ranking criteria, and weighting factors applied to each GIS dataset to determine the risk from pesticides to source water quality in the Clackamas River watershed.

Dataset	Ranking Factor	Ranking Criteria
HEL Class 1 Soil Designation	Yes	5
Irrigated Land	Yes	5
Proximity to Surface Water	0 to 150 feet	5
	150 to 300 feet	4
	300 to 500 feet	3
	500 to 1,000 feet	2
	> 1,000 feet	1
Herbicides: Average Recommend Application Rates of 2,4-D (ai/acre)	0	1
	< 0.85 lbs	2
	0.85 to 1 lbs	3
	1 to 1.5 lbs	4
	> 1.5 lbs	5
Herbicides: Average Recommend Application Rates of Atrazine (ai/acre)	0	1
	< 0.85 lbs	2
	0.85 to 1 lbs	3
	1 to 1.5 lbs	4
	> 1.5 lbs	5
Herbicides: Average Recommend Application Rates of Dichlobenil (ai/acre)	0	1
	< 1 lbs	2
	1 to 1.5 lbs	3
	1.5 to 2.5 lbs	4
	> 2.5 lbs	5
Herbicides: Average Recommend Application Rates of Dimethenamid-P (ai/acre)	0	1
	< 0.25 lbs	2
	0.25 to 0.5 lbs	3
	0.5 to 0.75 lbs	4
	> 0.75 lbs	5
Herbicides: Average Recommend Application Rates of Diuron (ai/acre)	0	1
	< 0.25 lbs	2
	0.25 to 0.75 lbs	3
	0.75 to 1.25 lbs	4
	> 1.25 lbs	5

Results and Recommendations

Based on the results of this analysis, the top crops grown by acreage in the Clackamas River watershed between 2018 and 2021 were: 1) pastures and hay; 2) nurseries and greenhouses; 3) seed and sod grass; 4) blueberries; and 5) Christmas trees. Of these crops, the highest average rates of herbicides recommended for use are for nurseries and greenhouses, Christmas trees, and blueberries; for insecticides, nurseries and greenhouses, and Christmas trees; for nitrogen, pastures and hay, and seed and sod grass; and for phosphorous, Christmas trees and pastures and hay. It is important to keep in mind when interpreting the pesticide and fertilizer application rates data that this information does not indicate the amount of pesticides and fertilizers physically applied on the ground. Instead, this data is intended to help compare the relative amount of average fertilizers and pesticides recommended for application by crop type.

As indicated in Figure 4A there are several regions with high potential aggregate risk to source water quality from fertilizer use in the Clackamas River watershed based on the GIS predictive modeling, including: 1) northwest of the City of Sandy, near the HWY 212/26 junction and 2) south of Clackamas River Road near the surface water intakes. The largest high potential aggregate risk "hot spot" from pesticide uses as indicated in Figure 4B is the area northwest of the City of Sandy, primarily due to the concentration of nurseries and greenhouses located in this area. The most appropriate method for analyzing the risk analyses output maps is to focus on overall geographic risk trends rather than field-level results due to the many assumptions applied to the risk analyses input data and the coarse resolution of the CDL crop type data. It is important to keep in mind that the agricultural activities risk estimates are predicted values only and do not necessarily reflect agricultural practices on the ground. If a modeling effort is developed in the future to help to quanitfy pollutant loading from various sources, the GIS crop type and application rates data will serve as valuable model input.

Herrera recommends that this GIS analysis be repeated every three to five years to account for changes in crop cover and the potential decommissioning of pesticides by U.S. EPA. An exact timeline for repeating this analysis should be determined based on the availability of updated pesticide detection data from water quality sampling in the watershed.

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FIGURES

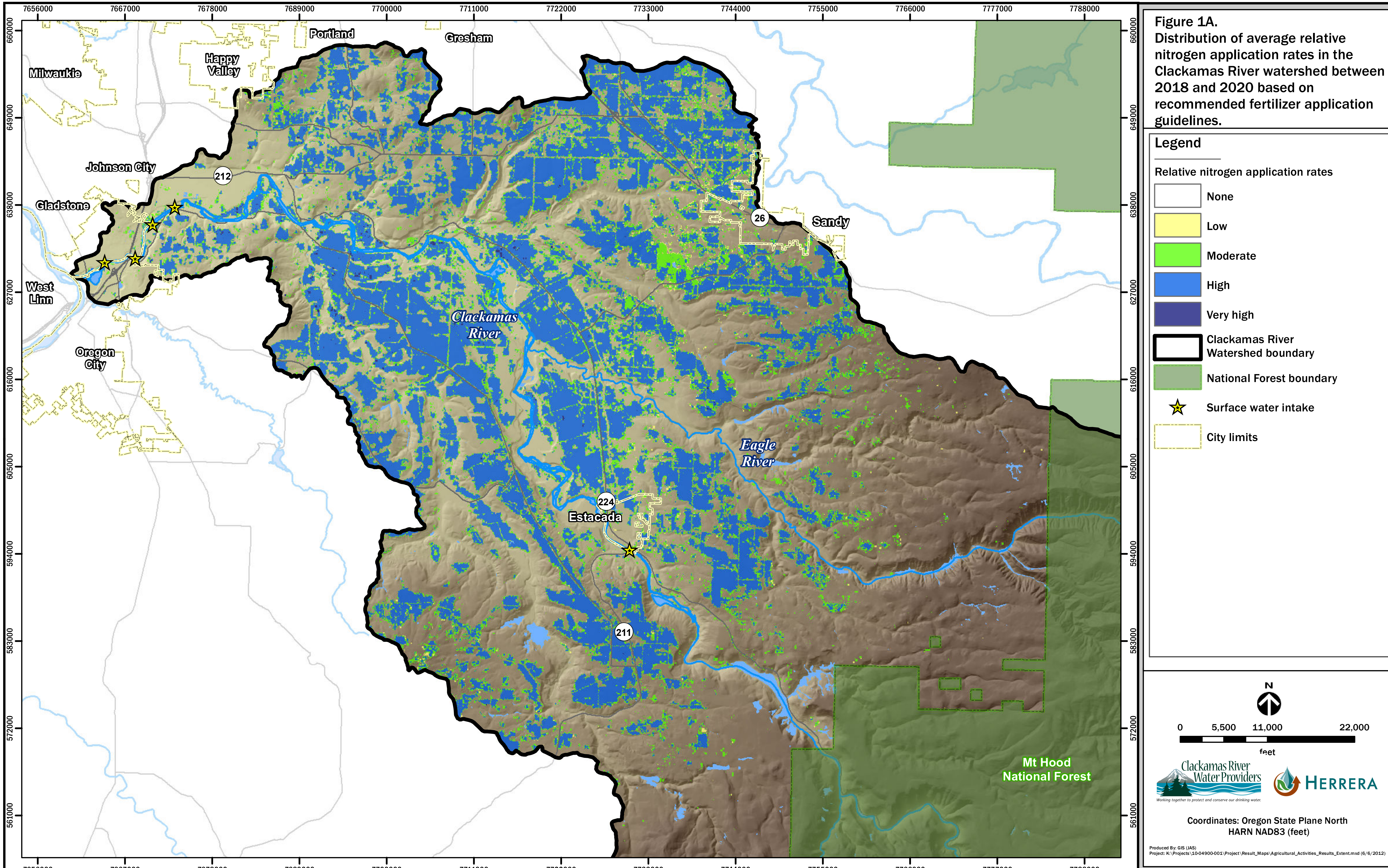
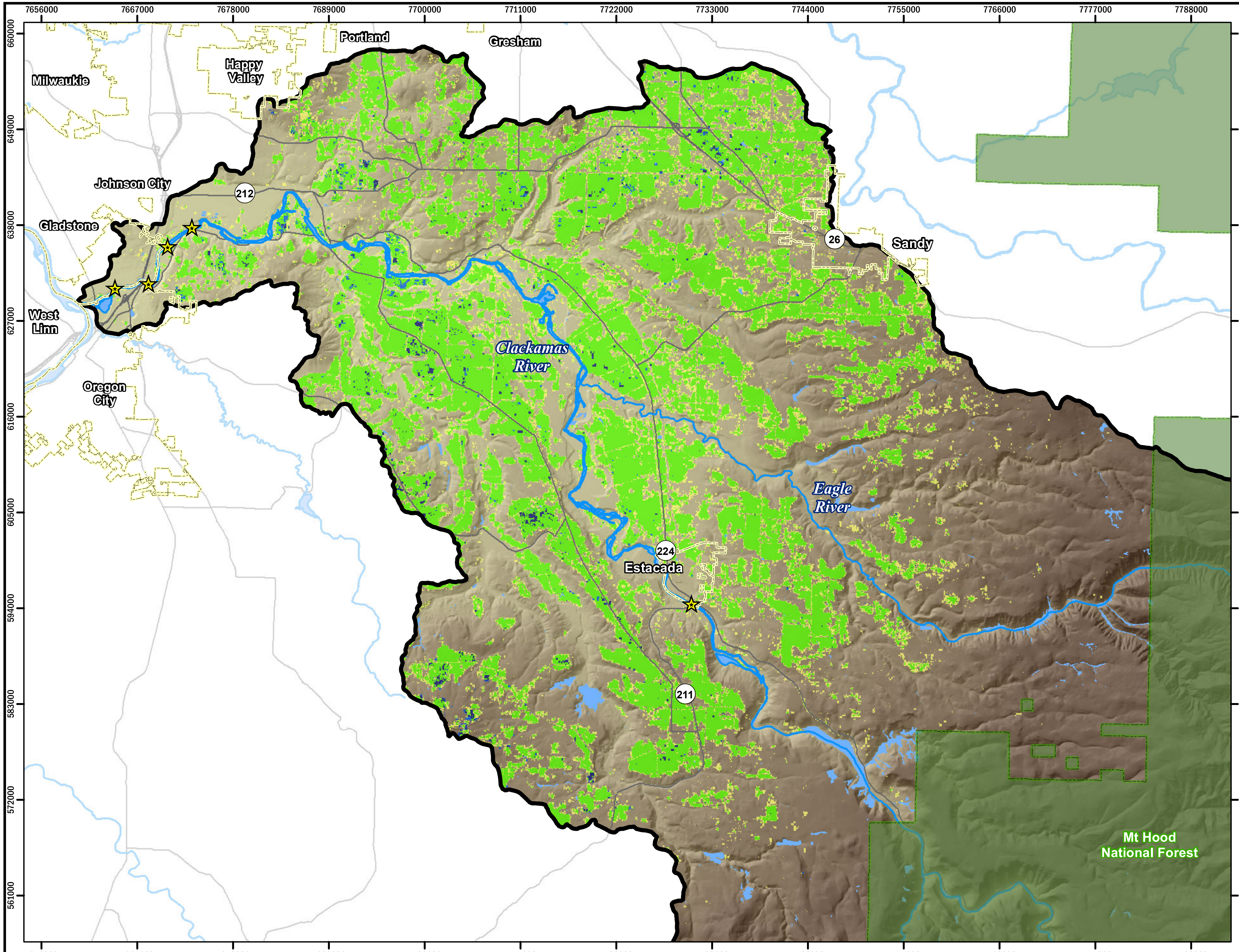


Figure 1A.
Distribution of average relative nitrogen application rates in the Clackamas River watershed between 2018 and 2020 based on recommended fertilizer application guidelines.

Figure 1B.
Distribution of average relative phosphorous application rates in the Clackamas River watershed between 2018 and 2020 based on recommended fertilizer application guidelines.



Legend

Relative phosphorous application rates

- None
- Low
- Moderate
- High
- Very high
- Clackamas River Watershed boundary
- National Forest boundary
- Surface water intake
- City limits

N

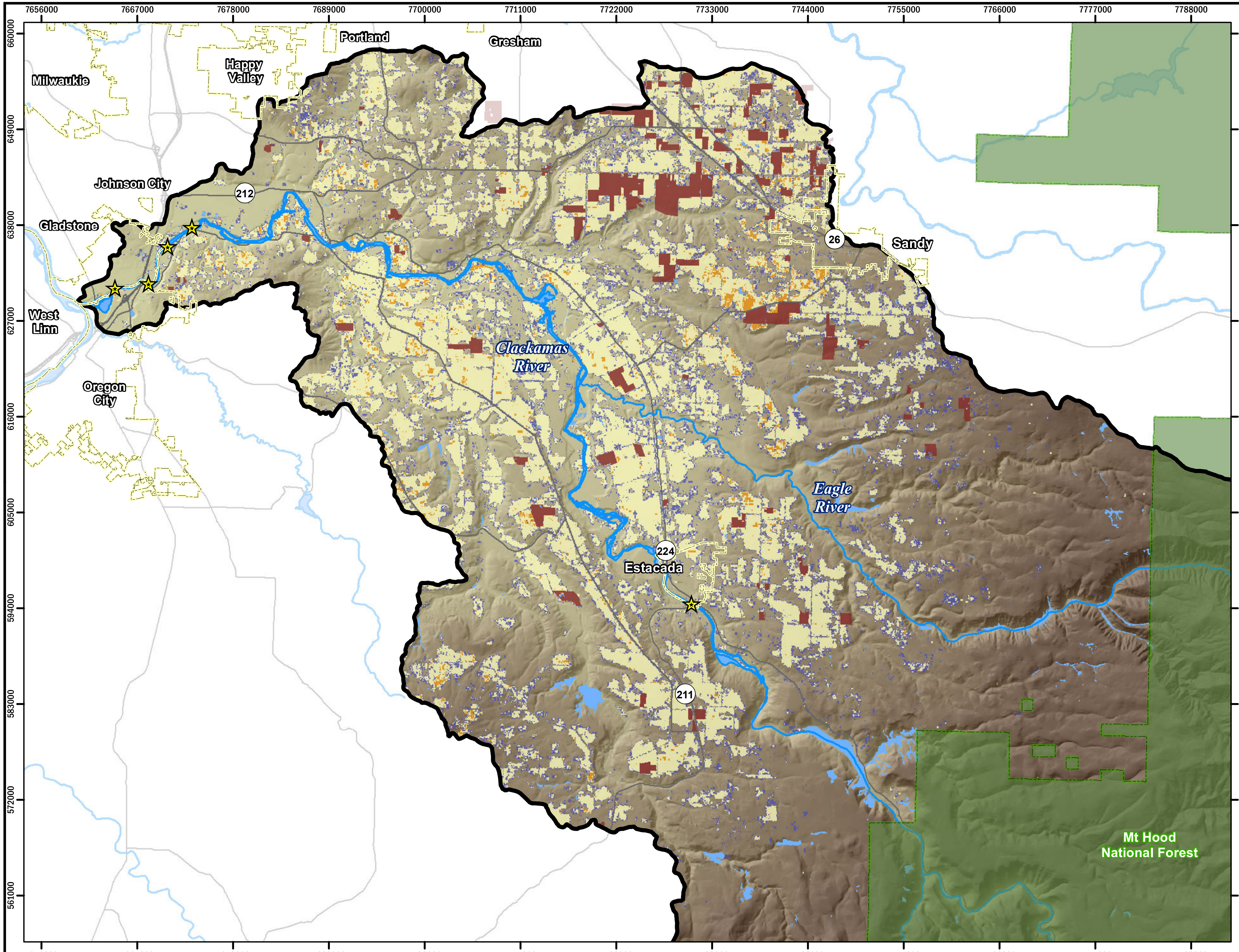
0 5,500 11,000 22,000
feet

Working together to protect and conserve our drinking water.

Coordinates: Oregon State Plane North
HARN NAD83 (feet)

Produced By: GIS (JAS)
Project: K:\Projects\10-04900-001\Project\Result_Maps\Agricultural_Activities_Results_Extent.mxd (6/6/2012)

Figure 2A.
Distribution of average relative herbicide application rates in the Clackamas River watershed between 2018 and 2020 based on recommended pesticide application guidelines.



Legend

Relative herbicide application rates

- None
- Low
- Moderate
- High
- Very High
- Clackamas River Watershed boundary
- National Forest boundary
- Surface water intake
- City limits

N

0 5,500 11,000 22,000
feet

Clackamas River Water Providers
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HERRERA

Coordinates: Oregon State Plane North HARN NAD83 (feet)

Produced By: GIS (JAS)
Project: K:\Projects\10-04900-001\Project\Result_Maps\Agricultural_Activities_Results_Extent.mxd (6/6/2012)

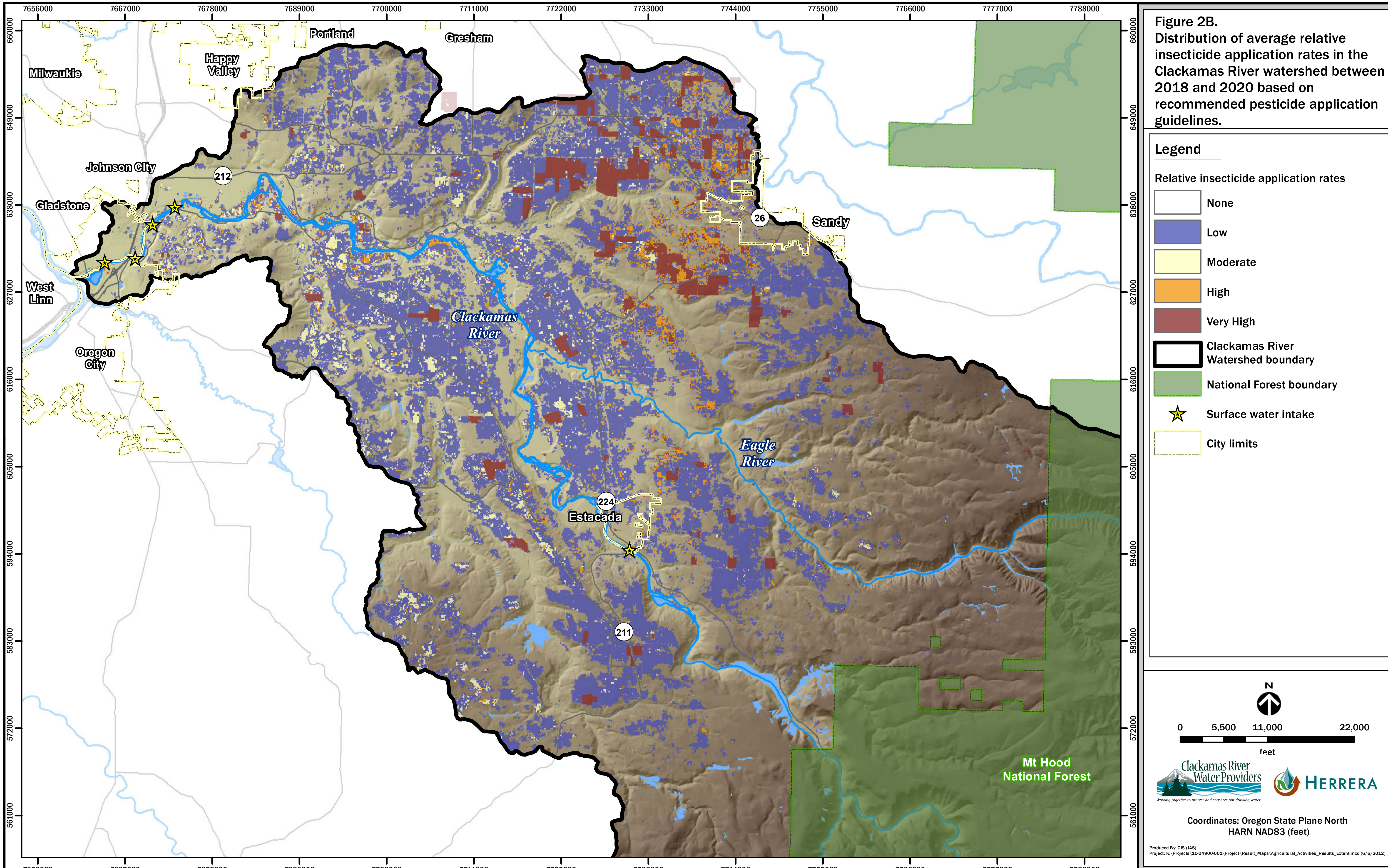

Figure 2B.
Distribution of average relative insecticide application rates in the Clackamas River watershed between 2018 and 2020 based on recommended pesticide application guidelines.

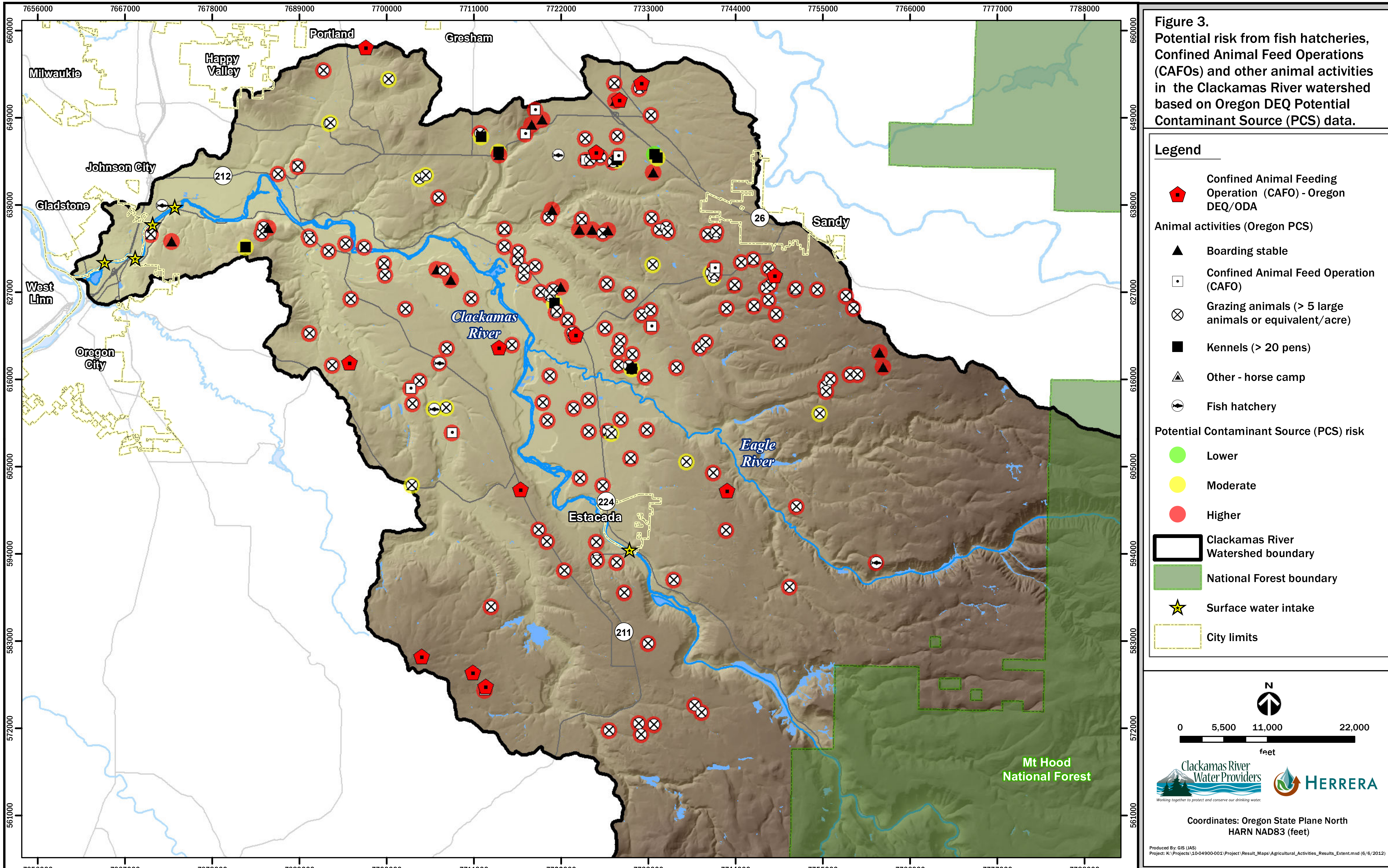

Figure 3.
Potential risk from fish hatcheries, Confined Animal Feed Operations (CAFOs) and other animal activities in the Clackamas River watershed based on Oregon DEQ Potential Contaminant Source (PCS) data.

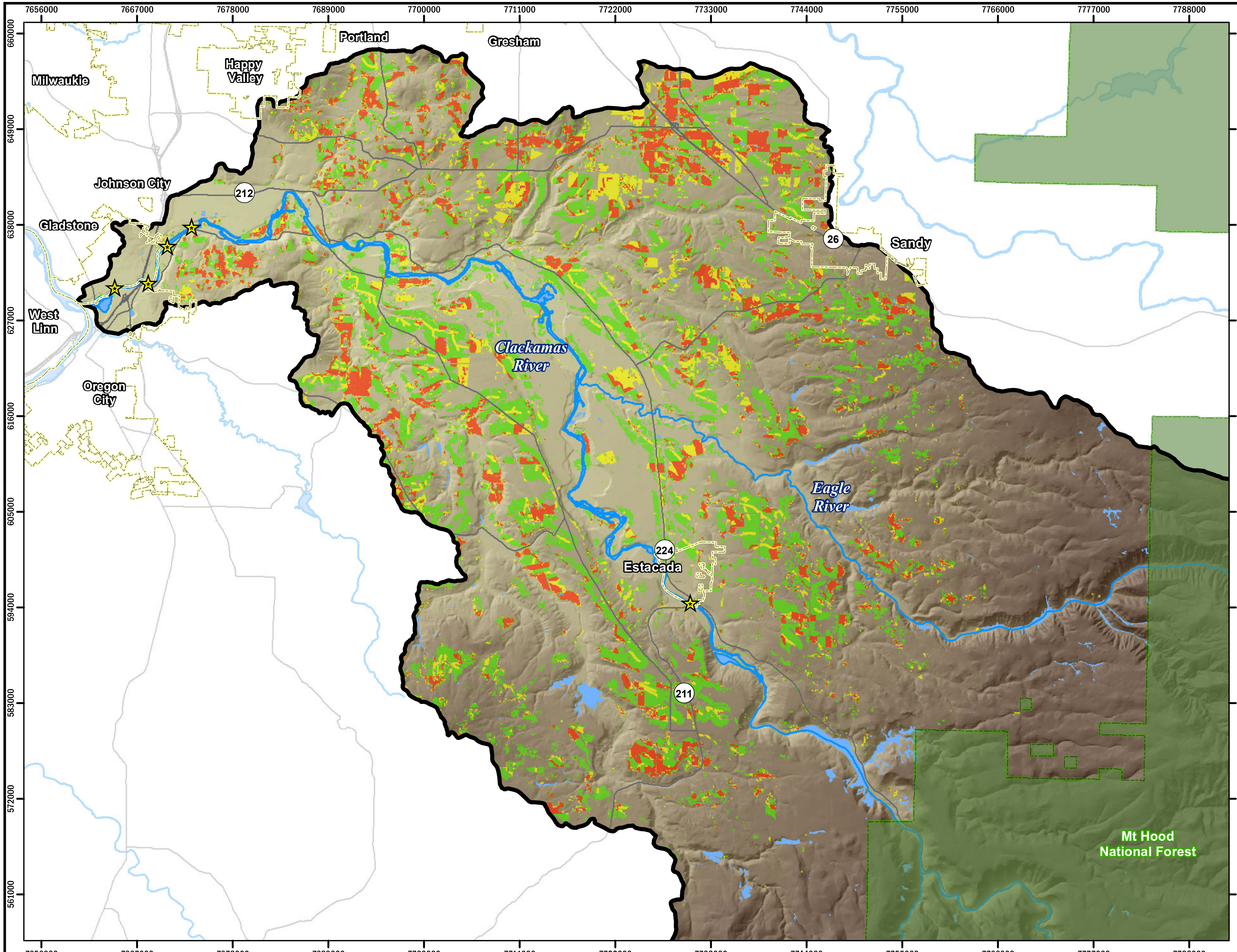

Figure 4A.
Potential cumulative risk from fertilizers to drinking water quality in the Clackamas River watershed based on GIS predictive modeling.

Legend

Cumulative predicted risk
- Very low
- Low
- Moderate
- High
- Surface water intake
- City limits
- Clackamas River Watershed boundary
- National Forest boundary

N

0 5,500 11,000 22,000
feet

Clackamas River Water Providers
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HERRERA

Coordinates: Oregon State Plane North
HARN NAD83 (feet)

Produced By: GIS (JAS)
Project:
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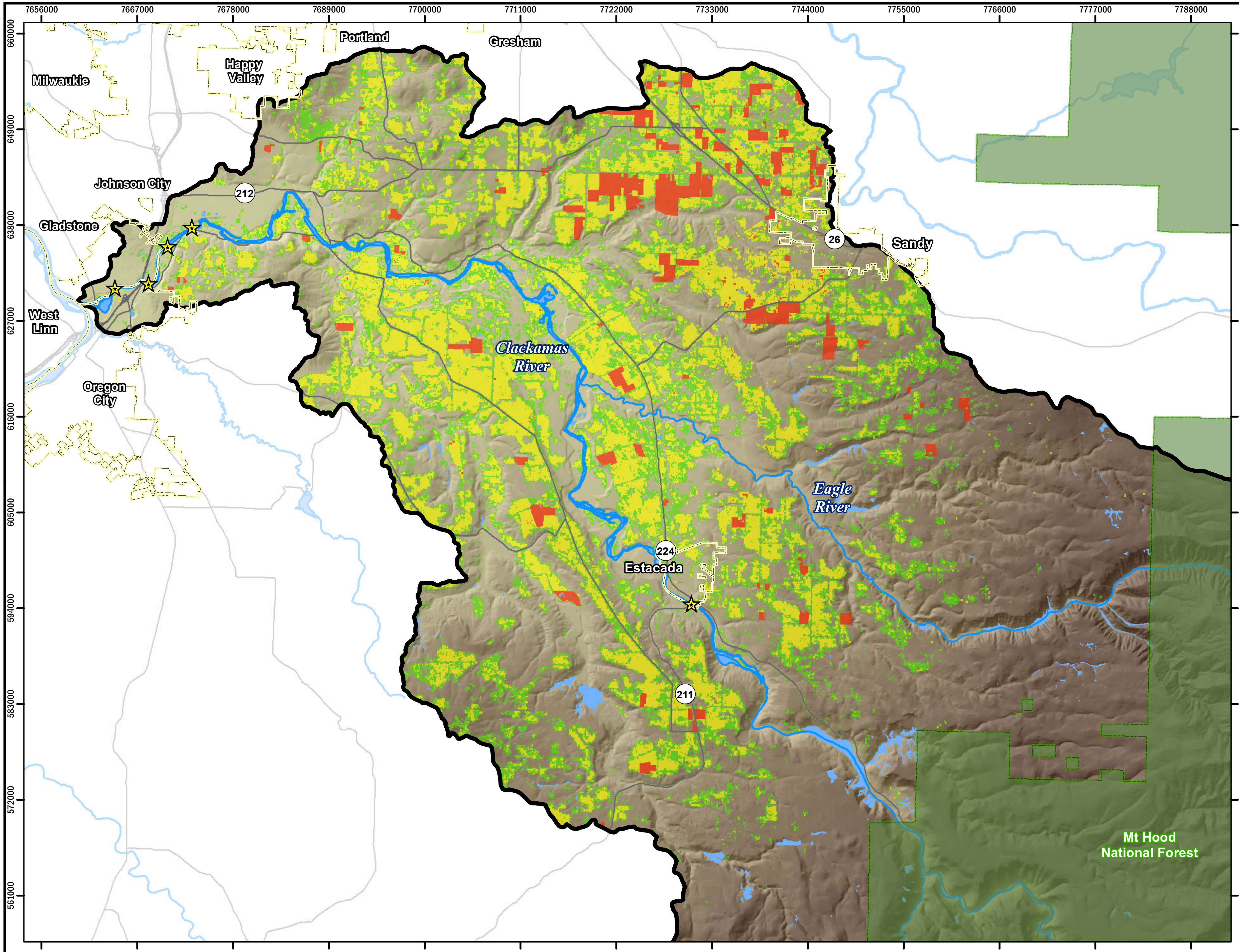
Figure 4B.
Potential cumulative risk from pesticides to drinking water quality in the Clackamas River watershed based on GIS predictive modeling.



Legend

Cumulative predicted risk

- Very low
- Low
- Moderate
- High
- Surface water intake
- City limits
- Clackamas River Watershed boundary
- National Forest boundary

N

0 5,500 11,000 22,000
feet

Clackamas River Water Providers
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HERRERA

Coordinates: Oregon State Plane North
HARN NAD83 (feet)