HERRERA

TECHNICAL MEMORANDUM

Date: June 30, 2021

To: Kimberly Swan, Clackamas River Water Providers

From: Jennifer Schmidt, Herrera Environmental Consultants

Subject: GIS Urban Development 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. In 2010, the CRWP developed a Drinking Water Protection Plan that outlined a series of strategies and programs to address potential threats to source water quality in the Clackamas River watershed. Herrera Environmental Consultants (Herrera) was hired to complete a series of geographic information system (GIS) analyses to help to identify potential pathways for pollutant export from the Clackamas River Watershed. The following major high-risk activity categories were identified in the Drinking Water Protection Plan (Clackamas River Water Providers 2010):

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

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 will 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. This memorandum focuses specifically on the methods and results of the GIS Urban Development Risk Assessment portion of the Drinking Water Protection Plan.

Potential Threats from Urban Development

The Clackamas River Water Providers (CRWP) have identified unpermitted urban stormwater runoff to the Clackamas River from impervious surfaces such as building roof tops, driveways, sidewalks, parking lots, and highways as being one of the most significant threats to source water quality in the Clackamas River watershed (CRWP 2010). The primary threats to source water quality from expanding impervious cover resulting from urbanization are:

1. Increased stormwater runoff quantities, due to impervious surfaces being nearly 100 percent hydrologically active (Novotony and Chesters 1981). Increased runoff quantity causes decreased water quality via elevated export of solids and nutrients from bank erosion.

2. Decreased water quality from pollutant washoff from impervious surfaces to receiving waters. This runoff contains numerous pollutants that can impact human and aquatic health, including sediment, nutrients, metals, hydrocarbons, bacteria and pathogens, organic carbons, and pesticides (CWP 2003).

3. Increased stream temperatures resulting both from lost streambank vegetation during urban development and warmer stormwater runoff temperatures during summer months from hot asphalt and concrete (Michaud 1994).

According to the *Clackamas Basin Summary Watershed Overview* report prepared for the Clackamas Basin Council in 2005, developed areas of the Clackamas River watershed account for approximately 2% of the total watershed area, and are primarily concentrated within the urban growth boundaries of the cities of Sandy, Estacada, and the metropolitan area (WPN 2005). Vacant and partially developed land within the UGBs are the areas most likely to see future development and thus pose the greatest threat geographically to future source water quality.

GIS Urban Development Risk Analysis

Herrera performed a GIS urban build-out analysis to predict the extent and intensity of development on vacant and partially developed land in urbanizing areas at maximum build-out capacity. The purpose of a build-out analysis is to show what land is available for development, how much development can occur and at what densities, and what consequences may result when complete build-out of available land occurs according to Clackamas County zoning ordinances (Zirkle 2003). The results of the GIS build-out analysis for the Clackamas River watershed will allow the CRWP to focus monitoring and mitigation efforts on the areas predicted to have the highest-intensity future urban development.

To calculate the overall potential risk to source water quality from future urban development within UGBs in the Clackamas River watershed, Herrera ranked and overlayed five spatial datasets used in or generated from the build-out analysis in GIS:

- Vacant and partially-developed land
- Significant future development constraints that would make developing a parcel very difficult or impossible
- Zoning designations
- Number of potential new lots per vacant or partially-developed parcel at maximum build-out capacity
- Percent change in future impervious cover at maximum build-out capacity

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

Analysis Objectives

The primary objectives of the GIS urban development build-out risk analysis were to:

- Identify vacant or partially developed land within UGBs in the Clackamas River watershed with no significant future development constraints.
- Overlay zoning designations with developable land and determine the minimum and maximum lot sizes for each zone based on local ordinances and available literature.
- Calculate the number of potential new lots by zoning designation that could be developed on each vacant or partially developed parcel in the future at full build-out capacity.
- Estimate the percentage increase in impervious surface that would be generated from each vacant or partially-developed lot being developed to full capacity.
- Rank, weight, and overlay each urban development build-out dataset to produce a map of cumulative predicted risk to source water quality from future urbanization at the parcel level.

Data Sources and Limitations

The primary GIS datasets required to complete an GIS build-out analysis are tax parcel boundaries, UGBs, vacant and partially developed lands, development constraints like steep slopes and wetlands, zoning designations and ordinances, and existing percent impervious coverage. The following sections describe these major datasets in more detail, including any major data limitations that are important to keep in mind when interpreting the GIS urban development 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 urban development risk analysis to the Oregon State Plane North HARN 83 map projection, with both the vertical and horizontal datum measured in feet.

Tax Parcel Boundaries

Herrera used tax parcel boundaries with current land use designations help identify vacant and partially developed tax parcels within UGBs in the Clackamas River watershed as well as to help identify areas unlikely to be developed in the future, such as parks and protected open space. Tax parcel boundaries were obtained from the Oregon Metro Regional Land Information System (RLIS). RLIS provides an updated parcel boundary dataset in coordination with Clackamas County on a quarterly basis containing detailed information on parcel land use, building square footage, vacancy status, and other attributes helpful for predicting future build-out capacity.

Urban Growth Boundaries (UGBs) and Urban and Rural Reserves

UGBs for the City of Sandy, the City of Estacada, and the portion of the Portland metropolitan area within the Clackamas River watershed were used as the build-out analysis study boundary. UGBs in the Clackamas River watershed control urban expansion onto farms and forest lands and encourage efficient use of land within the boundary by controlling where urban development can occur (Metro 2012). In addition, Oregon Metro and Clackamas, Multnomah and Washington counties led a regional effort in 2010 and 2011 to identify areas outside of the existing UGBs that would be most suitable for urban growth over the next 50 years (Metro 2012b). Herrera incorporated these urban reserve boundaries into the build-out analysis study boundary.

Vacant and Developed Land

Oregon Metro maintains datasets of vacant and developed land covering the entire Portland metropolitan area and the City of Sandy UGB and the majority of the City of Estacada UGB. These vacant and developed land datasets are updated each fall by the Metro Data Resource Center using a rule-based examination of aerial photography that reflects land status on the date that the photos were taken. These datasets were last updated based on aerial photography flown in 2019, and do not capture any new development that has occurred since then.

Herrera used the Oregon Metro vacant and developed land datasets to develop a preliminary land use classification of each tax parcel in the study boundary as developed, partially developed, or vacant.

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

Dataset Description	Source	Date	Online Metadata
Aerial photography	U.S. Department of Agriculture National Agriculture Imagery Program (NAIP)	2019	http://libweb.uoregon.edu/map/orephoto/imagery.html
City limits	Oregon Department of Transportation (ODOT)	2021	http://www.oregon.gov/DAS/EISPD/GEO/alphalist.shtml
	Oregon Metro Regional Land Information System (RLIS)	May 2021	http://rlismetadata.oregonmetro.gov/index.cfm?startpage=main.cfm?db_type=rlislite
Clackamas River watershed boundary	Oregon Metro RLIS	May 2021	http://rlismetadata.oregonmetro.gov/index.cfm?startpage=main.cfm?db_type=rlislite
Designated urban and rural reserve areas	Oregon Metro RLIS	June 2021	http://rlismetadata.oregonmetro.gov/index.cfm?startpage=main.cfm?db_type=rlislite
National Land Cover Dataset (NLCD) percent developed imperviousness	United States Geological Survey (USGS) Multi-Resolution Land Characteristics Consortium (MRLC)	June 2016	http://www.mrlc.gov/nlcd2016.php
Open space acquisitions	Oregon Metro RLIS	May 2011	http://rlismetadata.oregonmetro.gov/index.cfm?startpage=main.cfm?db_type=rlislite
Parks and greenspaces	Oregon Metro RLIS	May 2011	http://rlismetadata.oregonmetro.gov/index.cfm?startpage=main.cfm?db_type=rlislite
Steep slopes	Oregon Metro RLIS	May 2011	http://rlismetadata.oregonmetro.gov/index.cfm?startpage=main.cfm?db_type=rlislite
Streams and waterbodies	Oregon Metro RLIS	June 2011	http://rlismetadata.oregonmetro.gov/index.cfm?startpage=main.cfm?db_type=rlislite
Taxlot boundaries	Oregon Metro RLIS	May 2011	http://rlismetadata.oregonmetro.gov/index.cfm?startpage=main.cfm?db_type=rlislite
Title 3 Stream and Floodplain Protection areas	Oregon Metro RLIS	June 2011	http://rlismetadata.oregonmetro.gov/index.cfm?startpage=main.cfm?db_type=rlislite
Title 13 Habitat Conservation Resource Inventory areas	Oregon Metro RLIS	June 2011	http://rlismetadata.oregonmetro.gov/index.cfm?startpage=main.cfm?db_type=rlislite
Urban growth boundaries (UGBs)	Oregon Department of Land and Conservation Development (DLCD)	2021	http://www.oregon.gov/DAS/EISPD/GEO/docs/metadata/UGB_2010.shp.xml
	Oregon Metro RLIS	2021	http://rlismetadata.oregonmetro.gov/index.cfm?startpage=main.cfm?db_type=rlislite
Zoning designations	Oregon Metro RLIS	2021	http://rlismetadata.oregonmetro.gov/index.cfm?startpage=main.cfm?db_type=rlislite

Future Development Constraints

Herrera used the following GIS datasets to identify protected land and potential development constraints on tax parcels categorized as vacant or partially developed:

- ***Steep Slopes:*** Steep slopes constrain development due to the need for expensive regrading or special construction techniques to resolve stability issues, which can significantly drive up the overall cost of development. Slopes included in the build-out analysis have a grade of 25% or steeper.

- ***Parks and Open Space Acquisitions:*** Parks and open space acquisitions are considered protected areas unavailable for future development (Bolen 2002).

- ***Title 13 Resource Inventory Land:*** The Oregon Metro Title 13 Resource Inventory lands dataset combines regionally significant riparian and upland wildlife habitat, habitats of concern, and associated impacts areas into one comprehensive dataset. These areas are protected and are unlikely to be used for future development.

- ***Title 3 Land:*** The Oregon Metro Title 3 lands dataset includes protected stream and floodplain areas, including wetlands and wetland buffers, riparian areas, and FEMA floodplains. These areas are protected and are unlikely to be used for future development.

The steep slopes, parks, and open space acquisition datasets obtained from Oregon Metro RLIS cover the entire study boundary. The Title 13 Resource Inventory Land and Title 3 Land datasets do not cover the City of Estacada UGB; therefore, development constraints in the City of Estacada UGB are based on steep slopes and parks and open space acquisitions only.

Zoning Designations and Ordinances

Herrera used zoning designations from Oregon Metro RLIS to help determine future build-out capacity for each parcel within the study boundary. The zoning dataset is based on input from 24 cities and three counties in the Portland metropolitan region and contains both local jurisdiction zoning designations as well as broader categories for the entire Metro Region. 44 regional categories are included in the zoning dataset; 37 of these are present in the study boundary.

Detailed information about lot size requirements for each zoning category was obtained by reviewing local jurisdiction zoning ordinances, including Clackamas County, City of Sandy, City of Estacada, City of Oregon City, City of Happy Valley, and others. Because more than 500 local zoning designations were consolidated into the 44 regional categories summarized in the zoning dataset, it was not possible to find specific zoning ordinance information for every designation. In these cases, Herrera used best judgement based on literature values and GIS analysis of average lot sizes of developed land by zoning designation to estimate approximate required lot sizes within the study boundary.

Percent Imperviousness

The 2016 National Land Cover Dataset (NLCD) percent developed imperviousness dataset was obtained for the study boundary. This raster dataset consists of 30-meter grid cells with a value of 0 to 100 indicating the approximate percent impervious cover. Herrera used this dataset to help estimate future change in impervious cover under full build-out capacity conditions within the study boundary.

Methodology

This section describes the GIS methods Herrera used to identify vacant or partially developed lands within the study boundary with no significant future development constraints; overlay zoning designations on developable land and calculate the number of potential new lots based on zoning ordinances; calculate linear distance to nearest tributary; estimate the percentage increase in impervious surfaces at full build-out capacity; and rank, weight, and overlay the datasets based on their impact to source water quality.

Identifying Vacant or Partially Developed Lands

The first step of the build-out capacity analysis was to classify tax parcels within the study boundary into three categories: vacant, partially developed, or fully developed. Herrera first identified fully vacant tax parcels using tax parcel land use designations. Fully vacant taxlots are defined by Oregon Metro as having no structure, appreciable improvements, or identifiable land use based on an interpretation of aerial photography (Bolen 2002). Of the 21,745 taxlots in the study boundary, 2,617 were classified as fully vacant, totaling approximately 2,735 acres. This acreage is based solely on land vacancy and does not consider protected land or development constraints.

Next, Herrera overlaid the developed and vacant land use datasets from Oregon Metro with the remaining tax parcel boundaries to identify the total percentage of vacant land available on each tax parcel for potential future development. Taxlots with less than ½ acre of contiguous vacant land were classified as developed, and taxlots with ½ acre or greater available were classified as partially developed. The “half-acre” rule was adopted by Oregon Metro RLIS as a practical adequate size threshold for ensuring that land was suitable for supporting future urban development (Bolen 2002).

Mapping Protected Land and Development Constraints

After classifying the taxlots as vacant, partially developed, or fully developed, the next step was to identify protected land and other potential development constraints that could make build-out of vacant land difficult or impossible. Vacant land (both fully vacant taxlots and vacant portions of partially developed lots) was overlaid with parks, open space acquisitions, steep slopes greater than 25%, Title 13 Resource Inventory land, and Title 3 land within the study boundary. These areas were classified as having significant constraints. For the purposes of this analysis, all significantly constrained land was considered to be equally impactful to development potential.

Herrera subtracted vacant land with significant constraints from vacant and partially developed parcels to calculate the remaining area feasible for future buildout. Partially developed taxlots with less than ½ acre remaining for development were classified as developed, and fully vacant lots with less than ½ acre remaining were classified as having significant constraints. After eliminating protected land and areas with significant development constraints from the total vacant land in the study boundary, 17,537 of the 21,745 taxlots in were classified as developed (7,554 acres); 1,288 were classified as partially developed with at least ½ acre available for future build-out (7,788 acres); 1,708 were classified as vacant (1,765 acre); and 4,045 lots were classified as significantly constrained (2,707 acres).

Figure 1 shows the taxlots within the study boundary in these four categories.

Calculating Vacant Land Build-Out Capacity

The next step after identifying vacant lots with no significant development constraints available for future build-out was to calculate the number of new lots that could be constructed if 100% of the land was developed to full capacity based on zoning regulations. First, Herrera overlaid zoning data with vacant land (both fully vacant taxlots and vacant portions of partially developed lots) to assign a zoning designation to each area. Next Herrera reviewed available zoning ordinances and development guidelines from local jurisdictions to determine lot size requirements for each zoning designation. In some cases, zoning ordinances were not available or did not clearly indicate lot size requirements; for these designations, Herrera calculated an average required lot size based on existing developed taxlots within the same zoning designation instead. For most zoning designations, one lot size value was used for this analysis; however, where minimum and maximum lot size values were both indicated, the number of potential new lots was calculated using both values to estimate the range of potential new lots that could be constructed at full build-out capacity depending on the lot sizes constructed.

After the required minimum and maximum lot sizes for each zoning designation had been determined, Herrera divided the available vacant land on each taxlot by the required lot size for its zoning designation to determine the number of potential new lots that could be constructed at full build-out capacity within the study boundary. In addition to the required lot size, 15% of additional required area was added to all taxlots to account for utility easements, property

Table 2. GIS datasets used to help assess the risk from urban development to source water quality in the Clackamas River watershed.

Zoning Abbreviation	Zoning Description	Number of Fully Vacant Taxlots	Number of Partially Developed Taxlots	Minimum Required Lot Size	Maximum Required Lot Size	Number of New Lots (Min. Req. Lot Size)	Number of New Lots (Max. Req. Lot Size)
CC	Central Commercial	2	0	0.25 acres	0.5 acres	6	4
CG	General Commercial	22	15	1 acre	5 acres	121	49
CN	Neighborhood Commercial	2	1	5,000 s.f.	10,000 s.f.	27	14
FUD	Future Urban Development	13	145	10 units/acre	10 units/acre	465	465
IC	Industrial Campus - Campus/Industrial/Business Park	11	10	6 acres	6 acres	24	16
IH	Heavy Industrial	15	17	4.5 acres	4.5 acres	20	20
IL	Light Industrial	59	48	2.5 acres	2.5 acres	135	135
MFR1[1]	Multi-Family	2	4	15 units/acre	15 units/acre	12	12
MFR2 [1]	Multi-Family	12	10	20 units/acre	20 units/acre	63	63
MFR3[1]	Multi-family	4	0	25 unites/acre	25 units/acre	4	4
MFR4 [1]	Multi-family	0	1	30 units/acre	30 units/acre	1	1
MUR1[2]	Mixed Use Commercial & Residential – FAR Max of 0.3	5	6	0.25 acres	0.25 acres	127	127
MUR4[2]	Mixed Use Commercial & Residential – FAR Max of 1.2	1	2	4 acres	4 acres	2	2
MUR5[2]	Mixed Use Commercial & Residential – FAR Max of 1.5	6	32	4 acres	4 acres	32	32
MUR6[2]	Mixed Use Commercial & Residential – FAR Max of 1.75	1	0	4 acres	4 acres	1	1
MUR7[2]	Mixed Use Commercial & Residential – FAR Max of 2	5	1	4 acres	4 acres	5	5
MUR8[2]	Mixed Use Commercial & Residential – FAR Max of 3	0	1	4 acres	4 acres	0	0
MUR10[2]	Mixed Use Commercial & Residential – FAR Max of 12.5	2	1	3 acres	3 acres	1	1

Table 2 (continued). GIS datasets used to help assess the risk from urban development to source water quality in the Clackamas River watershed.

Zoning Abbreviation	Zoning Description	Number of Fully Vacant Taxlots	Number of Partially Developed Taxlots	Minimum Required Lot Size	Maximum Required Lot Size	Number of New Lots (Min. Req. Lot Size)	Number of New Lots (Max. Req. Lot Size)
RC	Rural Commerial	2	2	0.5 acres	0.5 acres	6	6
RI	Rural Industrial	31	11	2.5 acres	2.5 acres	7	7
RRFU	Rural Residential or Future Urban	188	721	10 acres	1 dwelling/lot	219	217
SFR1	Single Family Residential	0	3	35,000 s.f.	35,000 s.f.	3	3
SFR2	Single Family Residential	10	12	15,000 s.f.	1 acre	205	73
SFR3	Single Family Residential	9	33	10,000 s.f.	15,0000 s.f.	320	215
SFR4	Single Family Residential	9	7	9,000 s.f.	9,000 s.f.	282	282
SFR5	Single Family Residential	7	5	7,000 s.f.	7,000 s.f.	93	93
SFR6	Single Family Residential	25	25	6,000 s.f.	6,000 s.f.	836	836
SFR7	Single Family Residential	32	12	5,000 s.f.	5,000 s.f.	1,441	1,441
SFR8	Single Family Residential	11	8	4,500 s.f.	4,500 s.f.	522	522
SFR9	Single Family Residential	1	0	4,000 s.f.	4,000 s.f.	7	7
SFR10	Single Family Residential	0	2	3,500 s.f.	3,500 s.f.	12	12
SFR14	Single Family Residential	7	5	2,500 s.f.	2,500 s.f.	1,061	1,061
SFR15	Single Family Residential	0	9	2,300 s.f.	2,300 s.f.	291	291
TOTAL		**494**	**1149**			**6,351**	**6,017**

[1]The minimum and maximum number of new lots for multi-family residential designations reflects the number of acres available for potential development. The number of new units is number of available acreage times the units per acre designation.

setbacks, and other development requirement. The results of the build-out analysis using both minimum and maximum lot size guidelines are shown in Figures 2A and 2B. Detailed information on lot size requirements and total number of new lots by zoning designation at full build-out capacity are included in Table 2.

Calculating Linear Distance to Nearest Tributary

Next Herrera calculated the linear distance for each vacant or partially developed taxlot centerpoint to the nearest tributary to the Clackamas River. This calculation was based on surface drainage only and does not consider any existing stormwater conveyance systems.

Estimating Future Change in Impervious Cover at Full Build-Out Capacity

After the number of potential new lots in the study boundary at full build-out capacity had been calculated, the next step in assessing cumulative risk of urban development to source water quality was to estimate the percent change in future impervious cover resulting from 100% development. To accomplish this, Herrera first grouped the zoning designations within the study area into several general categories, and then used the NLCD 2016 percent impervious cover dataset to calculate average existing percent impervious cover of developed land in each zoning category within the study boundary. Average estimated percent impervious cover rounded to the nearest 5% for each zoning category is shown in Table 3.

Table 3. Average estimated percent impervious cover for developed land by zoning category.

Zoning Category	Zoning Designations	Average % Impervious Cover
Commercial or Mixed-Use Commercial and Residential	CC; CG; CN; MUR1; MUR4; MUR5; MUR6; MUR7; MUR8, MUR10	85
Heavy Industrial	IH	90
Light Industrial	IL	80
Single-Family Residential District: ≤ 1/8-acre lot size	SFR7; SFR8; SFR9; SFR10; SFR14; SFR15	65
Single-Family Residential District: > 1/8 and ≤ ¼ acre lot size	SFR3; SFR4; SFR5; SFR6	40
Single-Family Residential District: > 1/3 and ≤ ½ acre lot size	SFR2	20
Single-Family Residential District: > ½ and ≤ 1 acre lot size	SFR1	20
Rural Residential	RRFU	15
Future Urban Development	FUD	25
Rural Commercial or Industrial	RC; RI; IC	40
Multi-Family Residential	MFR1; MFR2; MFR3; MFR4	65

The existing percent impervious cover estimated were then applied to each vacant taxlot by zoning category to estimate future percent impervious cover at 100% development. Finally, the estimate of percent impervious cover for vacant land in the future was overlaid with existing percent impervious cover to calculate approximate percent change in impervious cover at full build-out capacity within the study boundary. The results of this analysis are shown in Figure 3.

For residential land use, percent change in impervious cover is not the only metric that is useful for estimating cumulative basin-wide environmental impacts. An analysis completed by EPA on the impacts of higher density development on water quality determined that for the same amount of development, more densely developed lots produce less runoff and require less impervious cover per house than low-density development at all lot sizes due to a more efficient use of land (EPA 2006). To account for this in the cumulative risk build-out analysis, Herrera extracted residential land use and grouped it into risk categories based on residential density based on the number of units per acre. The detailed risk ranking applied to residential density is shown in Table 4, and the rankings are shown in Figure 4.

Assessing Cumulative Urban Development Risk

After Herrera identified vacant land with no significant development constraints, estimated the number of new lots that could be built on this land based on zoning designations, calculated the linear distance from vacant land to the nearest Clackamas River tributary, and estimated percent change in future impervious cover at full build-out capacity, the final step was to rank and overlay the datasets together to determine aggregate risk from urban development to source water quality in the Clackamas River watershed. This analysis was completed 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 urban development posing a low risk to source water quality 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 relatively based on an analysis of the distribution of its attributes. For example, proximity to the nearest tributary was analyzed by calculating the linear distance of the centerpoint of vacant land to the closest tributary to the Clackamas River. This generated values ranging from a few feet to more than a mile, and the data were ranked by analyzing the natural statistical breaks in this data range. This method is essentially comparing each vacant taxlot to other vacant land in the study boundary and ranking the distances accordingly. The second method involved assigning scientifically meaningful rankings to dataset attributes based on literature reviews of best available science. Table 4 shows the detailed ranking scheme applied to each dataset.

The next step was to determine whether any of the datasets in the urban development risk analysis should be weighted as posing a more significant risk to source water quality than the others. For example, two vacant taxlots may both have been estimated to have capacity for 6

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

Dataset	Ranking Factor	Ranking Criteria	Dataset Weight
Number of Potential New Lots at Full Build-Out Capacity	1	1	1
	2 to 5	2	
	6 to 10	3	
	11 to 25	4	
	> 25	5	
Residential % impervious/unit/acre	Multi-Family Residential (max = 4.3%)	1	3
	Single-Family Residential: ≤ 1/8 acre lot size (max = 8.1%)	2	
	Single-Family Residential: > 1/8 and ≤ ¼ acre lot size (max = 10%)	3	
	Single-Family Residential: > 1/3 and ≤ ½ acre lot size (max = 10%)	3	
	Rural Residential (max = 15%)	4	
	Single-Family Residential: > ½ and ≤ 1 acre lot size (max = 20%)	5	
Estimated Future Percent Increase of Impervious Cover	0 to 10%	1	2
	10 to 25%	2	
	25 to 50%	3	
	50 to 75%	4	
	> 75%	5	
Linear Distance to Nearest Tributary	0 to 100 feet	5	0.5
	100 to 500 feet	4	
	500 to 1000 feet	3	
	1000 to 2500 feet	2	
	> 2500 feet	1	

new lots at full build-out capacity. However, one lot may be zoned as heavy industrial with potential for up to 90% future impervious cover, and the other may be zoned as rural commercial with potential for up to 40% future impervious cover. For this reason, future percent impervious cover was weighted more heavily than number of potential new lots. Weighting factors applied to each dataset are also shown in Table 4.

After a ranking scheme and weighting factor had been applied, the final step was to convert each dataset to a raster grid with 10-meter pixels, overlay the grids together to calculate a cumulative risk value for each pixel, and map the data into low, moderate, and high risk categories. The results of this analysis showing cumulative risk from urban development to source water quality in the Clackamas River watershed are shown in Figure 5.

Results and Recommendations

Of the 21,745 taxlots in urban growth boundaries and urban reserve areas in the Clackamas River watershed, approximately 20,537 were ranked as posing a very low or low risk to source water quality from urban development (14,930 acres), 415 were ranked as moderate risk (1,200 acres), 515 were ranked as high risk (2,421 acres), and 278 were ranked as very high risk (1,216 acres). These rankings are average risk estimates at the taxlot level and do not take into account development distribution within an individual lot. The most appropriate method for analyzing the risk analysis output is to focus on overall geographic risk trends rather than parcel-level results due to the potential for data anomalies. It is important to keep in mind that the build-out capacity and percent change in impervious cover values are estimated forecasts only and are not appropriate for parcel-level decision-making.

As indicated in Figure 5 the regions with the highest risk from urban development at full build-out capacity are north of Highway 212 just outside of the City of Happy Valley, within the City of Happy Valley, particularly in the northern portion of the watershed, and in the Cities of Sandy and Estacada. The majority of these high-risk areas are zoned as single-family residential. To reduce this risk, stringent stream buffer requirements should be required in these areas in connection with future watershed planning efforts. Additional stormwater management efforts should also be implemented in these areas as they begin to build-out. In particular, low impact development practices should be required where feasible to reduce stormwater runoff quantities and pollutant loads. Finally, to guide the CRWP's broader management efforts in the watershed, data from this analysis should be considered as potential input for future modeling efforts to quantify the overall risk of water quality impairment from urban development relative to other pathways (e.g., septic systems, agricultural areas).

Herrera recommends that this analysis be repeated every five years to account for changes in zoning designations, expansions of urban growth boundaries and urban reserve areas, and to recalculate capacity estimates and distributions. The following adjustments could also be made when the analysis is repeated to help refine the results:

1. More detailed build-out calculations could be completed for high-risk development areas. This could include looking at more specific zoning ordinance information such as utility designations, property setbacks, and other development guidelines that were not feasible to include within the scope of this analysis

2. All protected land and development constraints were weighted equally in this analysis and were assumed to make vacant land too constrained to support future development. A refinement that could be made to this analysis in the future is to rank development constraints differently based on mitigation difficulty. This may

highlight additional land that is available for development that was not included in this analysis.

3. Changes in future impervious cover from roadway development was not included in this analysis. Incorporating roadway data, both for existing and future conditions, would be a valuable addition to the urban development risk results.

4. No stormwater conveyance information was including in this analysis. Including this information in a future risk assessment, along with stormwater treatment infrastructure and known structural stormwater Best Management Practices (BMPs) that are being used to help manage stormwater runoff, would be a very helpful way to refine areas of highest concern in urbanizing areas of the Clackamas River watershed.

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FIGURES

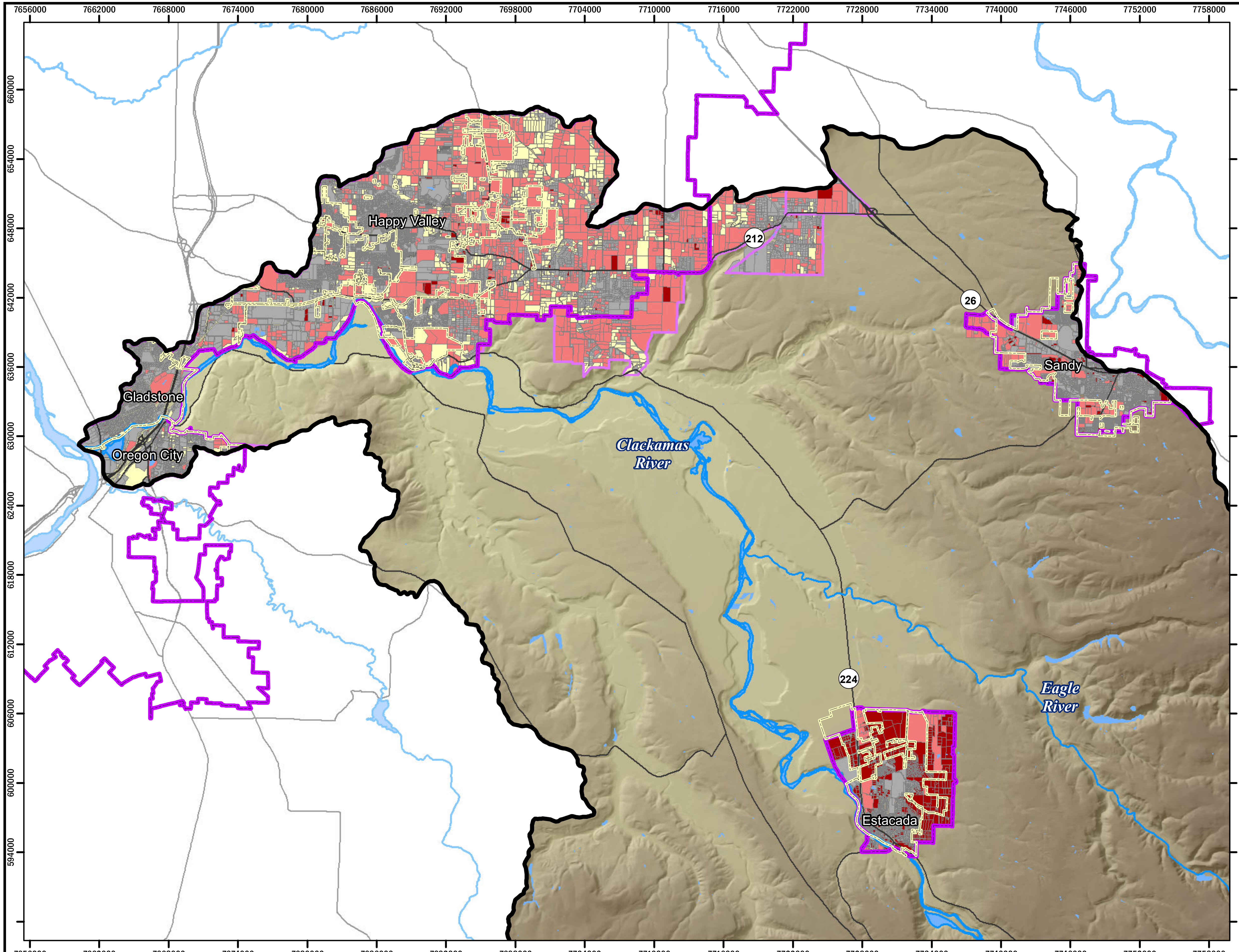

Figure 1.
Development status of tax parcels within urban growth boundaries and urban reserves in the Clackamas River watershed based on GIS predictive modeling.

Legend

Parcel coverage designation

- Partially developed lot
- Vacant lot
- Developed lot
- Significant development constraint
- Clackamas River Watershed boundary
- City limits
- Urban growth boundary
- Urban reserve boundary

N

0 4,000 8,000 16,000
feet

Clackamas River Water Providers
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HERRERA

Coordinates: Oregon State Plane North
HARN NAD83 (feet)

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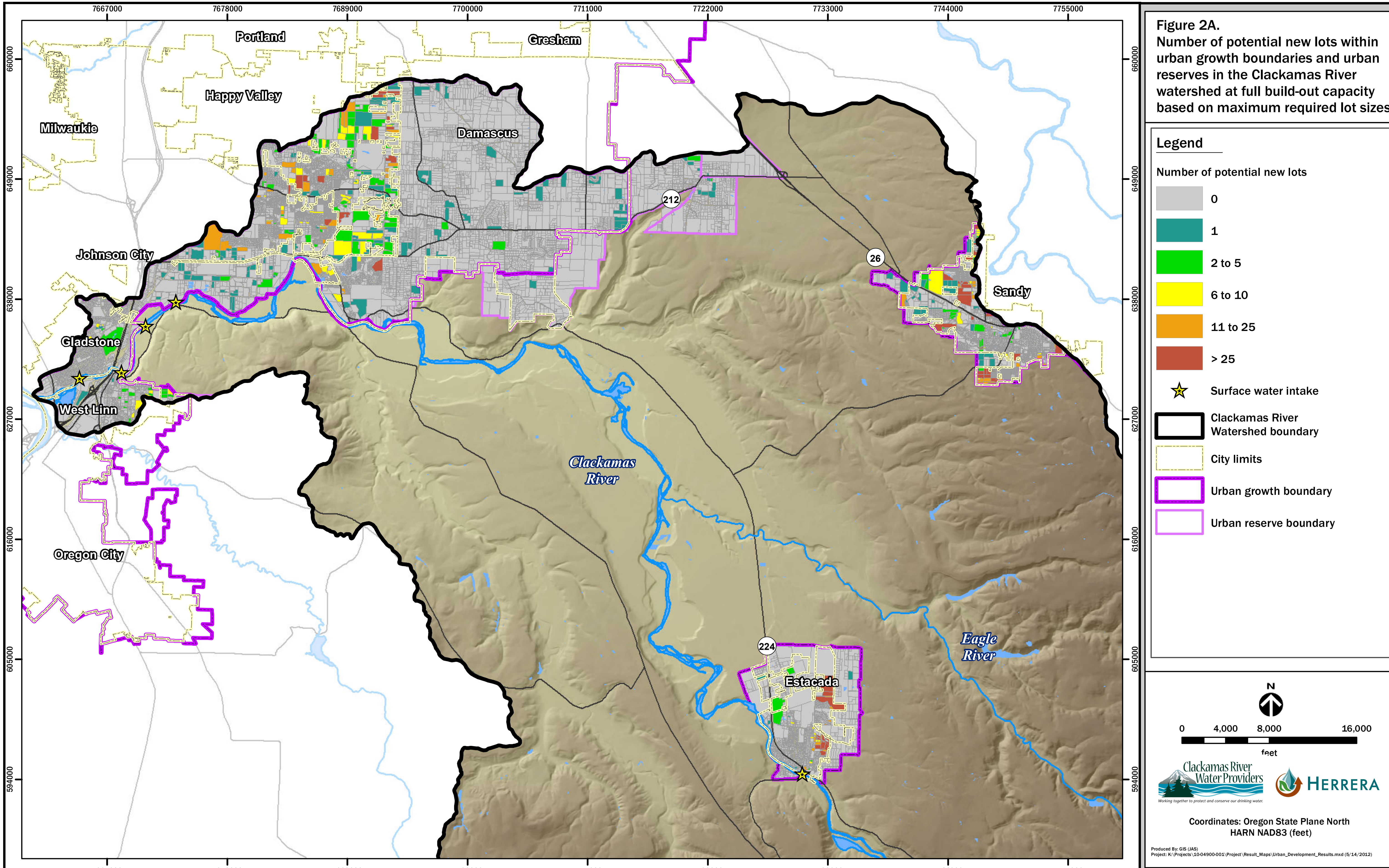

Figure 2A.
Number of potential new lots within urban growth boundaries and urban reserves in the Clackamas River watershed at full build-out capacity based on maximum required lot sizes.

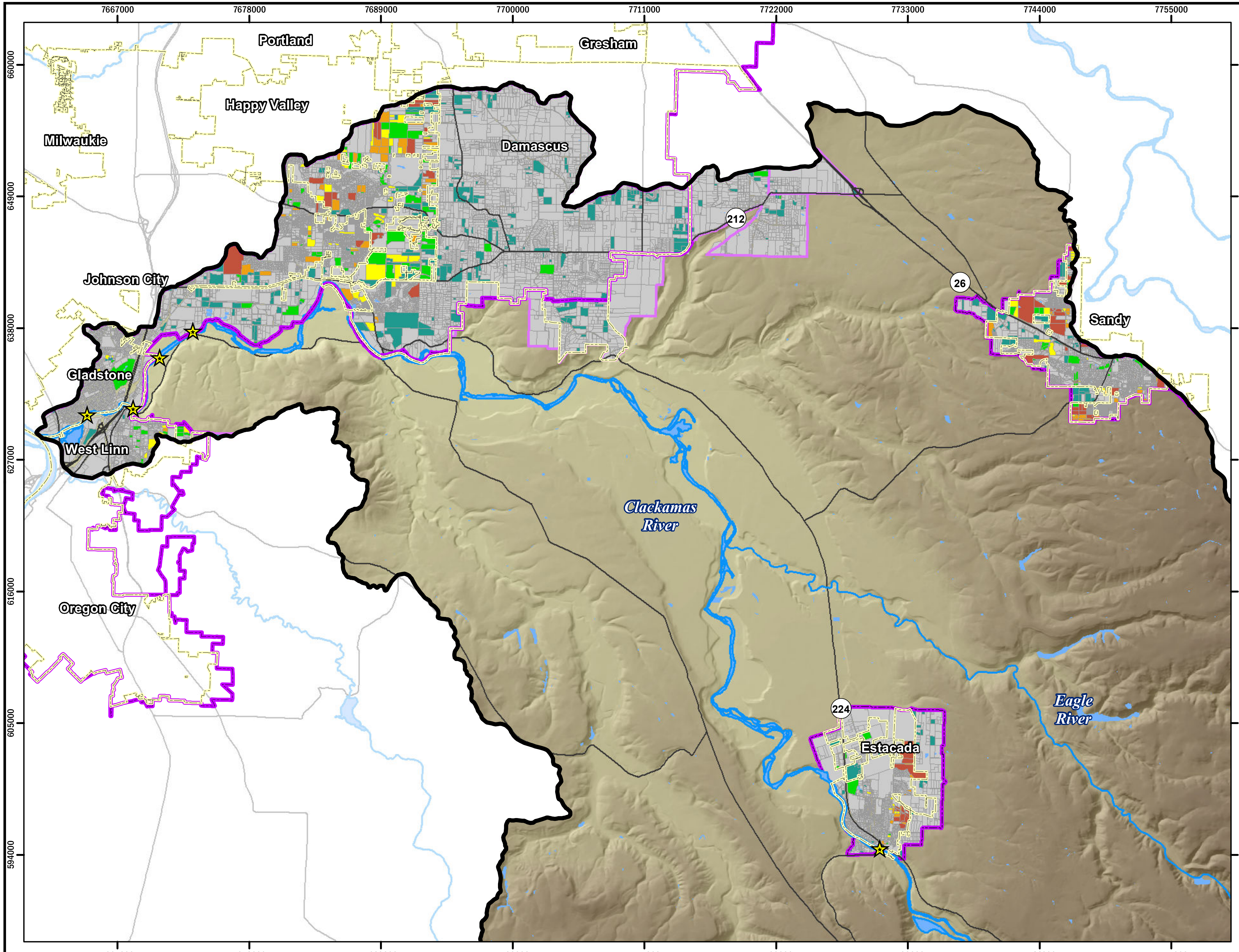

Figure 2B.
Number of potential new lots within urban growth boundaries and urban reserves in the Clackamas River watershed at full build-out capacity based on minimum required lot sizes.

Legend

Number of potential new lots

- 0
- 1
- 2 to 5
- 6 to 10
- 11 to 25
- > 25
- Surface water intake
- Clackamas River Watershed boundary
- City limits
- Urban growth boundary
- Urban reserve boundary

N

0 4,000 8,000 16,000
feet

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Coordinates: Oregon State Plane North HARN NAD83 (feet)

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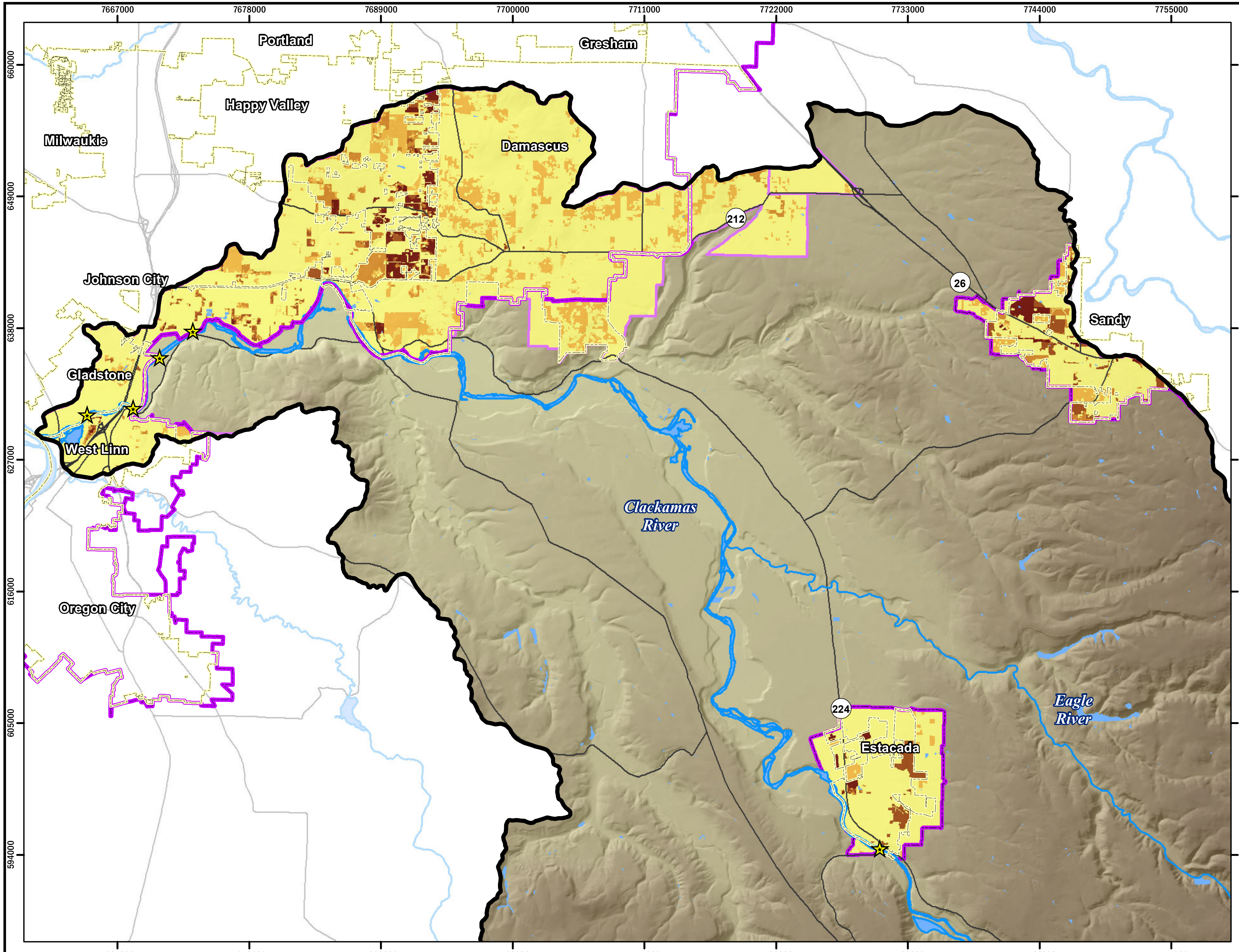

Figure 3.
Estimated percent change in impervious cover in the Clackamas River watershed at full build-out capacity based on minimum required lot sizes.

Coordinates: Oregon State Plane North HARN NAD83 (feet)

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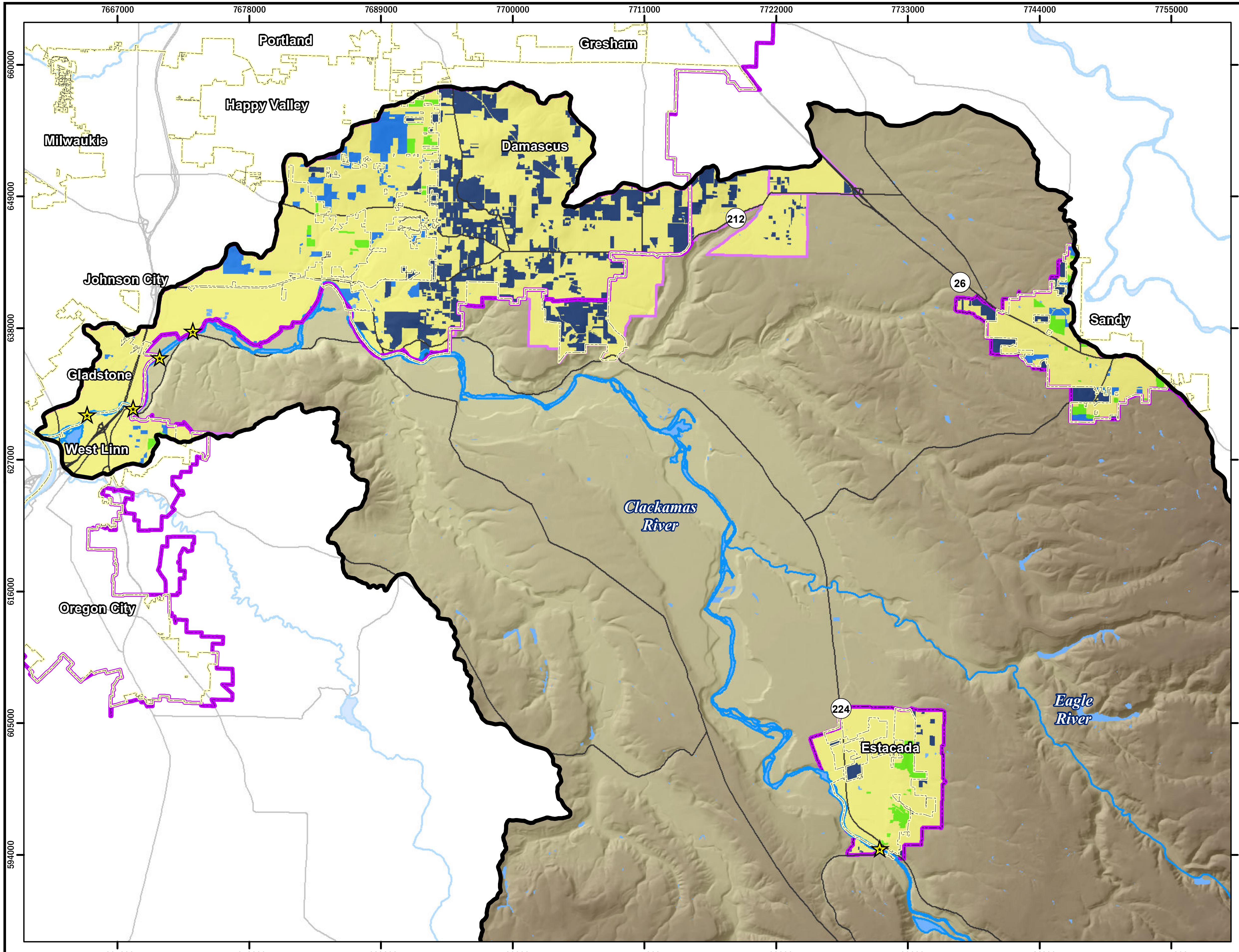

Figure 4.
Risk to source water quality based on zoned residential density in the Clackamas River watershed.

Legend

Residential density risk

- Very Low
- Low
- Moderate
- High
- Surface water intake
- Clackamas River Watershed boundary
- City limits
- Urban growth boundary
- Urban reserve boundary

N

0 4,000 8,000 16,000
feet

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Coordinates: Oregon State Plane North
HARN NAD83 (feet)

Produced By: GIS (JAS)
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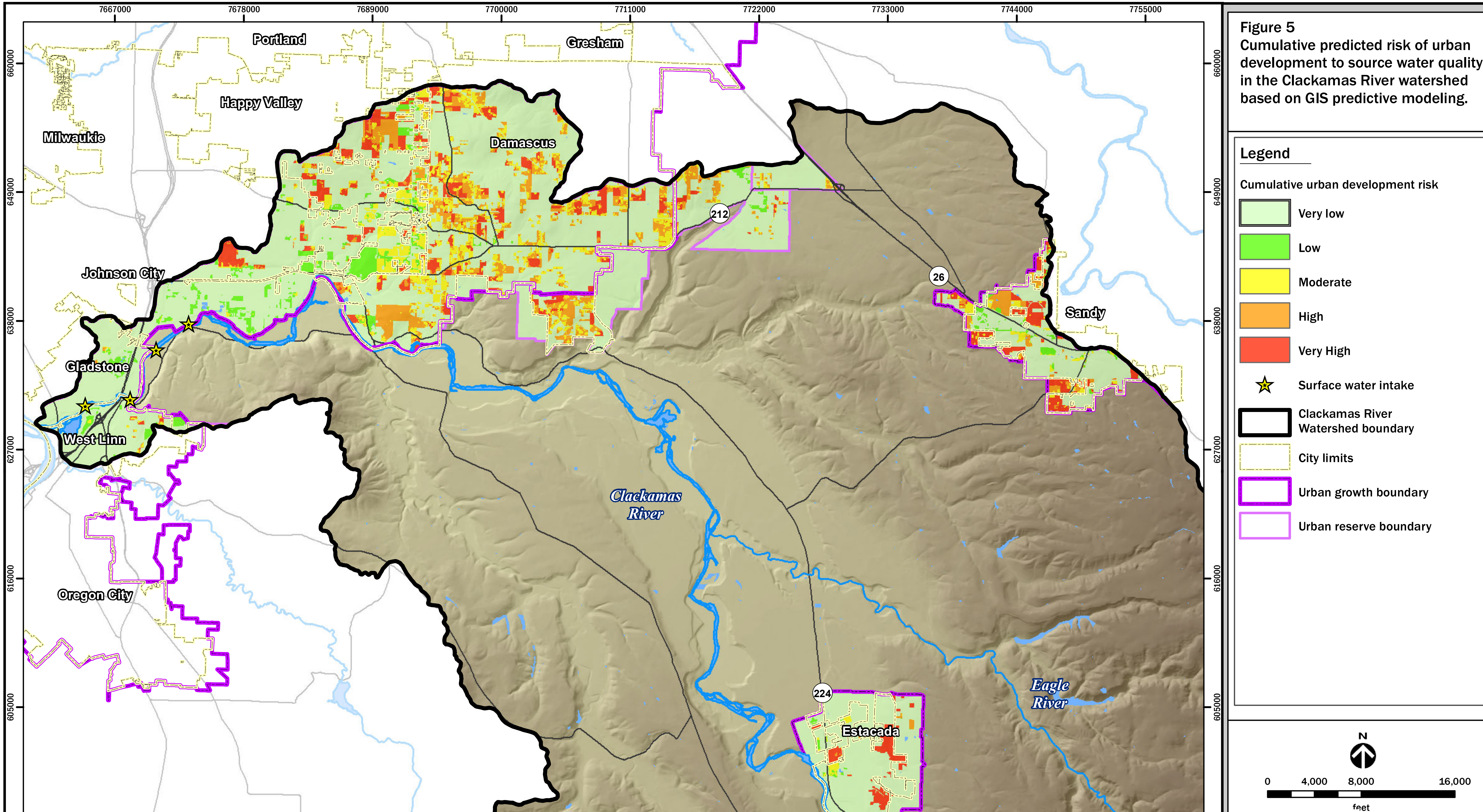
Figure 5
Cumulative predicted risk of urban development to source water quality in the Clackamas River watershed based on GIS predictive modeling.



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