Estimates of Current and Future Impervious Area and Forest Lands Vulnerable to Urban Conversion

For Watershed Based Land Use Planning

Thurston County

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thurston regional planning council

GUIDING GROWTH – HEALTHY WATERSHEDS

Translating Science into Local Policy

Cover photos: Clockwise from upper left. Culvert on 4th Avenue in Olympia during high tide and storm event; Indian Creek near Martin Way during storm event; downtown parking lot and storm drain; stormwater accumulation on rural road in Thurston County (French Road, Butler Cove).

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I. EXECUTIVE SUMMARY

Estimates of current and future impervious area are an important predictor of basin health. Since 2007 the Thurston Regional Planning Council (TRPC) has incorporated a future impervious area module into the adopted Population and Employment Forecast land use model. In 2013 a module was added to the model to generate estimates of forest lands vulnerable to urban development.

The ability to forecast future impervious area and loss of forest lands gives policy makers and staff an important tool for protecting watershed, basin, and stream health.

Estimates were updated in 2013 to reflect an updated regional Population and Employment Forecast.

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II. INTRODUCTION

Thurston County has many features that make it an incredible place to live. We have lakes, rivers, streams, and the sparkling Puget Sound. Together with the friendliness and livability of our local communities, it's no wonder that more than 250,000 people call Thurston County home. Based on our latest forecast, the population is expected to soar to nearly 370,000 by 2030, making Thurston County one of the fastest growing counties in Washington State.

Yet there are downsides to the rapid population growth in Thurston County. Growth in the wrong parts of the county can damage the health of our local watersheds. Damaged watersheds harm lakes, rivers, streams and ultimately Puget Sound, resulting in waterways that are unhealthy or even unusable for both people and wildlife.

We have the tools to predict where growth is likely to occur, and the effect it may have on our streams, lakes and marine waters. This report documents the methodology used to estimate current and future impervious area, and to generate estimates of forest lands vulnerable to urban conversion in Thurston County. It is an important step in protecting our watersheds.

This builds on work by TRPC and supported by the Stormwater Utilities of Lacey, Olympia, Tumwater, and Thurston County during the 2000s to:

1) Develop a land cover layer for Thurston County from satellite imagery
2) Develop relationships between land cover and impervious surfaces, and calibrate the data in a hydrologic model (HSPF) and,
3) Build a future impervious surface module into the Regional Population and Employment Forecast

The update of this data set is part of a larger project called: *Guiding Growth – Healthy Watersheds: Translating Science to Local Policy*, which aims to accommodate future population growth while conserving our healthy watersheds and ultimately Puget Sound.

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III. BACKGROUND

A. Impervious Area, Forest Cover and Stream Health

Numerous studies have shown that as impervious cover increases and forest cover decreases, stream quality decreases. Impervious surfaces are hard surfaces that stop water from infiltrating into the soil. They include things like rooftops, parking lots, roads, and even compacted lawns. Imperviousness decreases the ability of the ground to absorb water and recharge the aquifer (Figure 1). The increased volume and velocity of stormwater associated with impervious area erodes streambanks, causing flooding, habitat loss and degradation habitat, and fills the streambeds with sediment. Water flowing over concrete and lawns picks up contaminants such as nutrients from fertilizer, oil and grease from roads, pesticides, pet waste, and other pollutants from residential and commercial areas. These contaminants can have a negative effect on the biotic communities living in the aquatic ecosystem and also reduce the safety of water for drinking, swimming, and fishing.

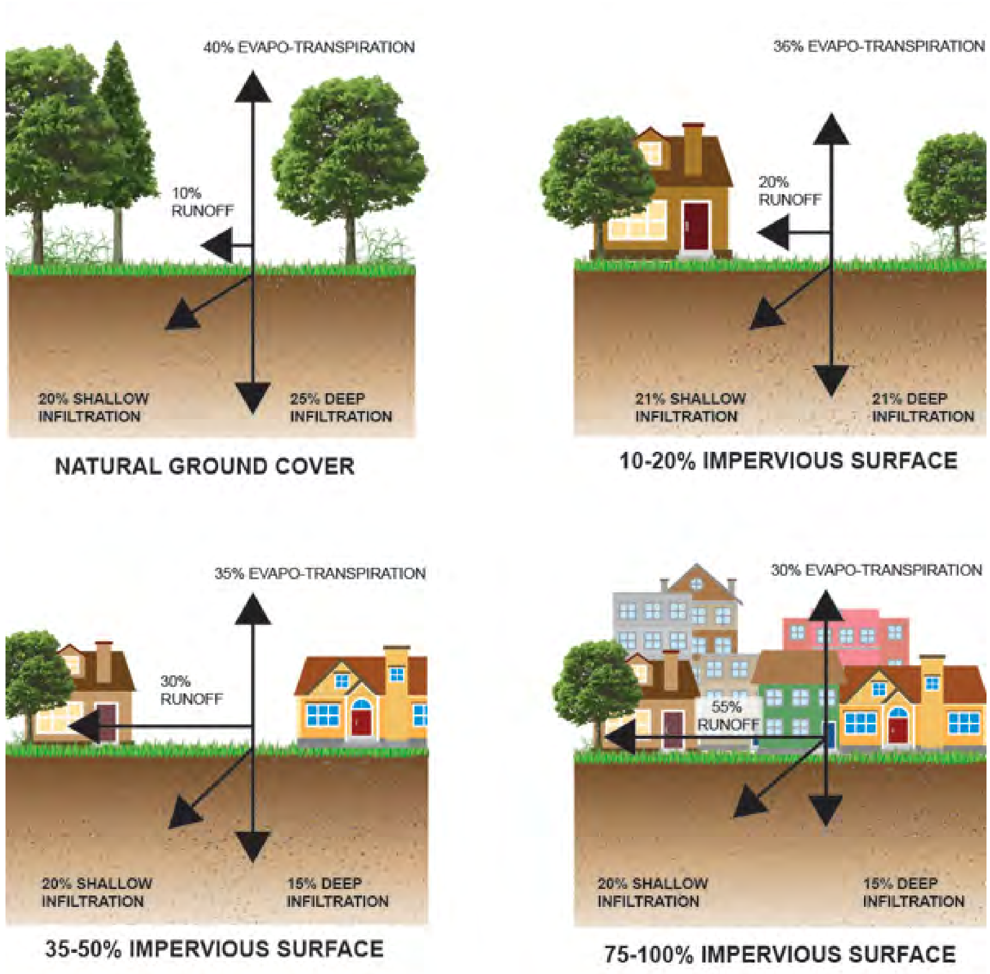
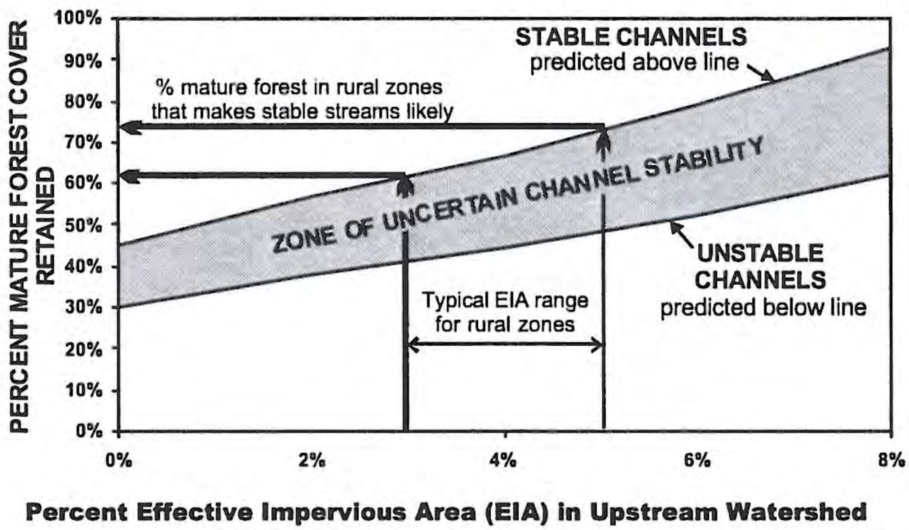


FIGURE 1: WATER CYCLE CHANGES ASSOCIATED WITH URBANIZATION.
SOURCE: (GUIDANCE SPECIFYING MANAGEMENT MEASURES FOR SOURCES OF NONPOINT SOURCE POLLUTION IN COASTAL WATERS, 1993) AS SHOWN IN (ARNOLD, 1996).

Figure 2 shows the conceptual relationship between channel stability, impervious surfaces, and forest cover for rural Puget Sound lowland streams. The basis for this generalization is the empirical data showing a direct correlation between forest cover, impervious area, and stream conditions from a large number of studies (Booth et al., 2002).

These studies indicate that it is important to maintain a forest cover of more than 60 percent, even where effective impervious area is fairly low (in the 2 to 6 percent range). As impervious area increases, the stabilizing effect of forest cover becomes increasingly important. There is no particular impervious threshold where degradation in stream integrity begins to occur — rather the relationship is a continuum.

FIGURE 2: CONCEPTUAL RELATIONSHIP BETWEEN CHANNEL STABILITY, IMPERVIOUS SURFACES, AND



FOREST COVER FOR RURAL PUGET SOUND LOWLAND STREAMS.
SOURCE: BOOTH ET AL., 2002.

B. *Using Future Impervious Area and Forest Cover as a Tool to Predict Watershed Health*

Estimates of future impervious area and forest cover loss can be used by a community to anticipate stream basin degradation, and take steps to prevent it before it occurs. The steps could involve guiding growth away from sensitive areas, minimizing the amount of new impervious surfaces using engineering techniques, or planning for the capture and treatment of stormwater runoff from new impervious surfaces.

To assist in these planning efforts, TRPC first provided estimates of future impervious area for the Stormwater Utilities of Lacey, Olympia, Tumwater, and Thurston County in 2007 (TRPC, 2007). This work linked the regionally adopted population and employment forecast, and stakeholder-reviewed land use inventory (buildable lands) to estimates of future impervious area.

Impervious surfaces are any surfaces that are impermeable for water – such as roads, rooftops, sidewalks, and parking lots. In order to measure this directly, TRPC generated a satellite-derived land cover data layer with three urban classes: high intensity, moderate intensity, and low intensity (TRPC, 2001). This data layer was compared to more traditional ways of estimating impervious area through using land use classes, and found to be at least as reliable, if not more, at estimating total impervious area (TRPC, 2003). Another advantage of the satellite-derived land cover layer was that for the first time, impervious surface for all of Thurston County could be measured at once.

This initial Thurston County mapping project (TRPC, 2001), provided essential data for planners in the region. This was followed by an effort to link land cover to total and effective impervious area, and integrate results into the Hydrologic Simulation Program – FORTRAN (HSPF) Model (TRPC, 2003). A simulation in Woodland Basin confirmed that this new way of measuring impervious area provided a useful data layer to support hydrologic modeling efforts in Thurston County.

In 2007, after the most recent Regional Population and Employment Forecast was adopted, a future impervious surface module was added to the regional model (TRPC, 2007). For the first time, the culmination of adopted land use plans could be evaluated for the effect on stream basin health.

In 2010 funding was received to continue this work, and further implement watershed-based land use planning in Thurston County. This provided the opportunity to update all data layers to reflect changes in buildable lands, land use, zoning, and population and employment projections.

In 2013 a module to identify forest lands vulnerable to urbanization was developed within the framework of the Population and Employment Forecast model. This provided another data tool for decision making.

The updated estimates will be used to evaluate the risk of stream basin degradation due to expected increases in urbanization for the basins in Water Resource Inventory Areas (WRIAs) 13 and 14, and help prioritize efforts in watershed-based land use planning.

IV. IMPERVIOUS AREA FORECASTS

A. *Base Year Estimates of Total Impervious Area*

In the early 2000s the Federal Government (Multi-Resolution Land Characterization (MRLC) 2001 began to develop a National Land Cover database (Homer et al., 2004; Yang, 2003). This was an effort of a consortium of Federal agencies – including USGS, EPA, NOAA, and USFS. One of the products of this effort was an impervious surface data layer, mapping impervious area to one percent thresholds (each mapping unit was assigned an impervious area percentage that ranged from zero to 100). This was accomplished by relating a land cover classification (using combined spring, summer, and fall data) to one-meter digital orthophotography. This enhances the coarser-scale Landsat satellite data derived land cover (30 meter resolution) to a much more useful product in urban areas. The result was a new way of measuring impervious area that was uniform throughout the United States. An updated data set based on similar methodology was released for 2006 (NOAA Coastal Change Analysis Program (C-CAP)). The Washington State Department of Ecology makes these data available on their website (WA Department of Ecology, 2011). The updated data set calibrates well with previous estimates from 2000 (TRPC, 2001), with only a 0.8 percent difference county-wide, despite differences in source data and methodology.

A comparison of both data sets is shown in Table 1. The largest difference between the two estimates is in the Skookumchuck watershed, likely due to the reforestation of the Centralia Coal Mine. Watershed and basin boundaries are shown on Map 1 and Map 2. Basin boundaries are modified from the Thurston County geodata GIS layer in Watershed Resource Inventory Areas 13 and 14 to reflect basins used in the *Guiding Growth – Healthy Watersheds* project.

TABLE 1: COMPARISON OF ESTIMATES OF TOTAL IMPERVIOUS AREA FOR THURSTON COUNTY WATERSHEDS – TRPC 2000 AND NOAA 2006.

		Total Impervious Area		
Watershed	**Total Acres**	**TRPC 2000**	**NOAA 2006**	**Difference**
Black River	80,040	3.5%	2.5%	1.0%
Budd Inlet/Deschutes River	103,490	9.0%	8.3%	-0.7%
Chehalis River	47,080	4.8%	3.2%	-1.6%
Eld Inlet	23,790	3.6%	4.1%	0.5%
Henderson Inlet	29,450	15.3%	15.3%	0.0%
Nisqually River	90,770	4.8%	4.1%	-0.7%
Skookumchuck River	55,860	2.6%	0.8%	-1.8%
Totten Inlet	20,420	1.9%	1.8%	-0.1%
West Capitol Forest	19,440	0.7%	0.2%	-0.5%
Total	***470,350***	**5.5%**	**4.7%**	**-0.8%**

B. Accuracy Assessment

The TRPC land cover has an overall accuracy assessment of 94 percent (TRPC, 2001). No automated accuracy was performed during or at the end of the NOAA C-CAP impervious layer production process. Quality Control was carried out by cross-examination 2006 updated impervious layer with the Landsat TM imagery. Errors of overevaluation, underevaluation and errors of omission and commission were corrected through GIS modeling and hand edits (NOAA (C-CAP) metadata, 2009).

C. Residential Impervious Surface Ratios for Thurston County

Relationships between residential units (urban and rural) and total impervious area (TIA) were updated by comparing fully built lots in Thurston County against the 2006 impervious surface GIS data layer. Three sets of comparisons were drawn from available data (Figure 3):

- Residential lots. These are residential units – single-family and duplexes on individual platted lots. This is reflective of net density.
- Apartments/condominiums. These are residential units in multifamily buildings, on lots that may include parking lots, stormwater facilities, and communal landscaping. Density was adjusted to reflect net density – to be comparable with other data sets.
- Subdivision. Subdivision boundaries reflect a gross density, and include open space tracts, storm water facilities, and local roads. Densities were adjusted to net density to be comparable to other data sets.

This information was used to build impervious area ratios by density classes for Thurston County (Table 2). The difference between net and gross density is shown in Figure 4.

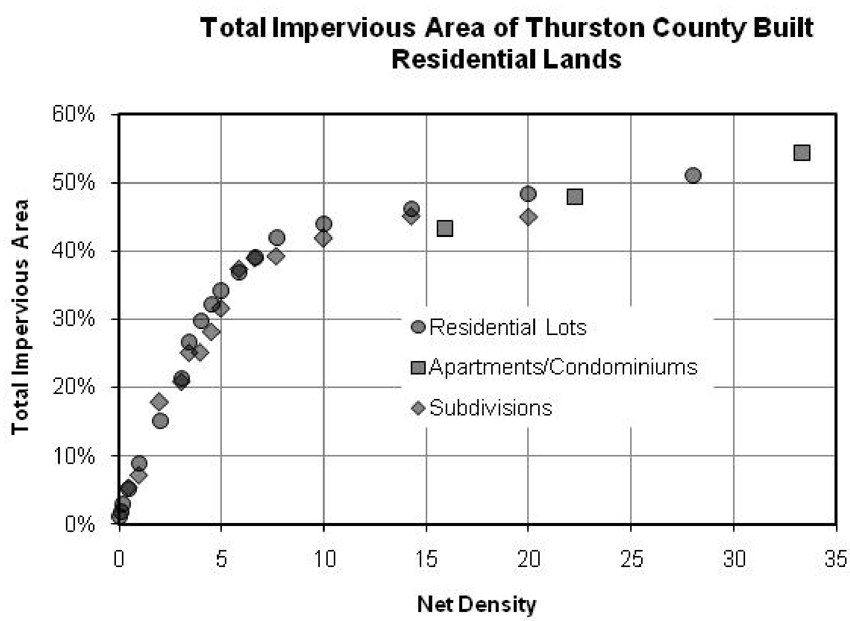


FIGURE 3: TOTAL IMPERVIOUS AREA – THURSTON COUNTY FULLY-BUILT RESIDENTIAL LOTS.

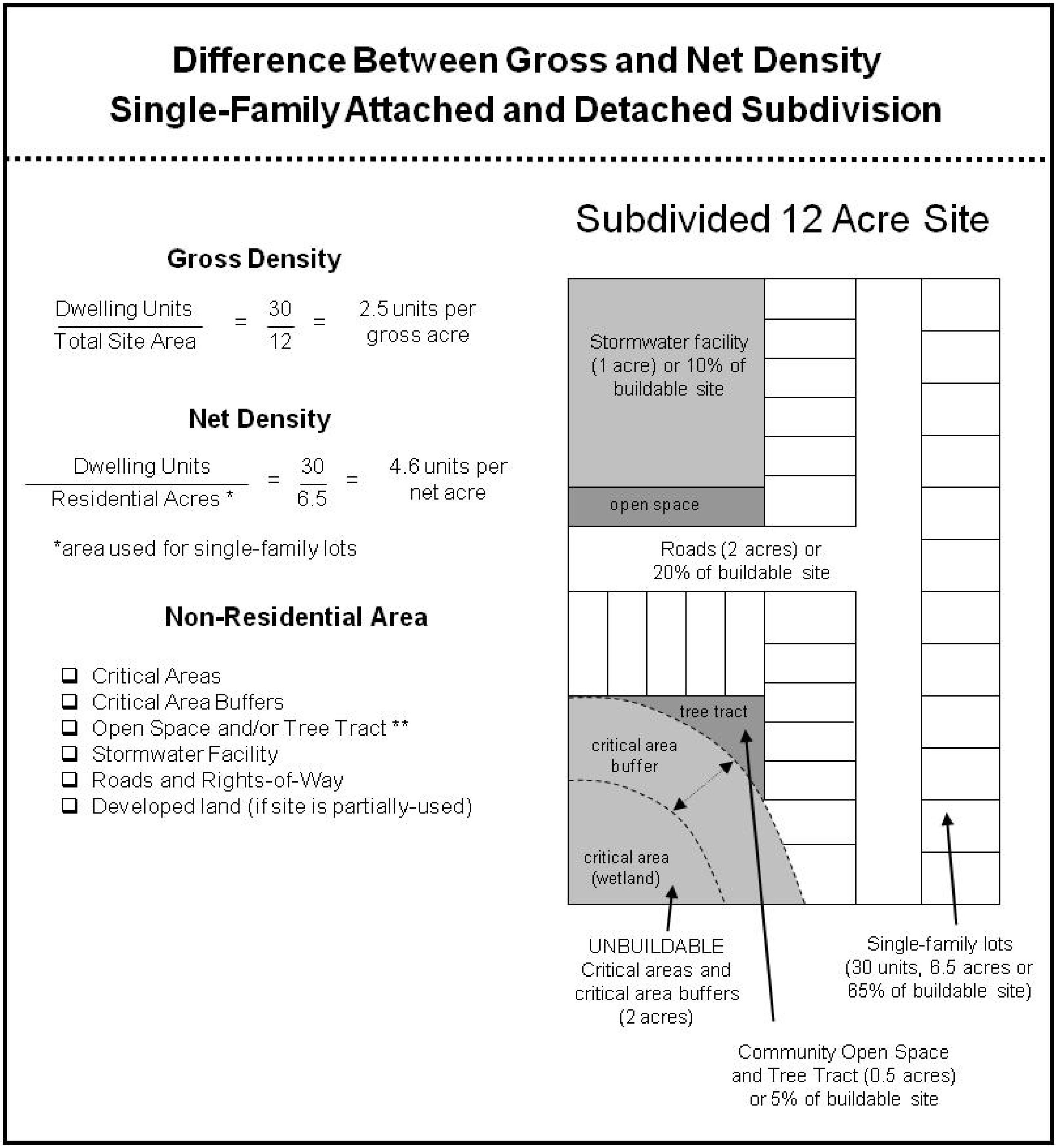


FIGURE 4: NET VERSUS GROSS DENSITY FOR A TYPICAL SINGLE-FAMILY SUBDIVISION.

TABLE 2: ESTIMATES OF PERCENT TIA COVER BASED ON NET AND GROSS DENSITY RANGES.

Net Density Percentages Applied to Platted Undeveloped Lots				Gross Density Percentages Applied to Lots with Subdivision Potential	
Lot size Range (Net acres)	Average Lot Size (Net acres)	Net Density (du/net acre)	Percent TIA Net Acres	Gross Density (du/gross acre)	Percent TIA Gross Acres
< 0.05	0.03	30.00	51%	21.67	49%
0.07 - 0.05	0.05	20.00	48%	13.00	45%
0.10-0.07	0.07	14.29	46%	9.29	43%
0.13-0.10	0.1	10.00	44%	6.50	39%
0.15-0.13	0.13	7.69	41%	5.00	34%
0.17-0.15	0.15	6.67	40%	4.33	31%
0.20 - 0.17	0.17	5.88	36%	3.82	28%
0.22 - 0.20	0.2	5.00	35%	3.25	25%
0.25 - 0.22	0.22	4.55	32%	2.95	23%
0.29 - 0.25	0.25	4.00	30%	2.60	21%
0.325 - 0.29	0.29	3.45	28%	2.24	19%
0.50 - 0.325	0.325	3.08	23%	2.00	17%
1.00 - 0.50	0.5	2.00	14%	1.30	12%
2.00 - 1.00	1	1.00	9%	0.65	6%
5.00 - 2.00	2	0.50	4%	0.33	3%
10.00 - 5.00	5	0.20	3%	0.13	1%
20.00 - 10.00	10	0.10	2%	0.07	1%
>20.00	20	0.05	1%	0.03	0%

D. Non-Residential Impervious Surface Ratios for Thurston County

Estimates for commercial, industrial, and institutional lots were derived in a similar fashion, by measuring actual impervious area for fully-built lots (Table 3). Due to the differences between urban and rural lots – ratios were broken into three categories:

- cities, reflecting urban to suburban conditions;
- unincorporated growth area, which reflect suburban conditions, and
- rural.

TABLE 3: ESTIMATES OF PERCENT TIA FOR NON-RESIDENTIAL LANDS.

	Percent Total Impervious Area		
Category	**Cities**	**Unincorporated Growth Areas**	**Rural**
Agriculture	10%	13%	2%
Forestry	2%	1%	0%
Mining	31%	33%	4%
Commercial	44%	39%	10%
Church	32%	25%	6%
School	37%	30%	20%
Industrial	65%	54%	5%
Parks, Open Space	11%	11%	1%
Rights-of-Way	39%	29%	12%

E. Comparison with Previous Studies

A wide range of impervious surface coefficients have been reported in other studies across the United States. The values generated for this study fall within the range of other studies (Table 4).

TABLE 4: IMPERVIOUS SURFACE PERCENTAGES FROM VARIOUS STUDIES.

Land Use Category	Joe Brascher, 2002 (Local)	Pierce County	USDA, 1986	Bannerman, 2001	Capiella and Brown, 2001 (Chesapeake Bay)	ESA Adolfson, 2007 (Birch Bay)	Yancey, 2008 (Sacramento & Santa Cruz)
Residential							
>8 units/acre	60	50	65	64	41 to 44		63
4 to < 8 units/acre	50	>35		49	33	40	51
3 to <4 units/acre	40	25 to 35	38	41	28	42	
3 units/acre			30			38	45
1 to <3 units/acre	20	16 to 25	25		21		
1 unit/acre			20		14		
< 1 unit/acre	10	<12	12		11	19-22	
Commercial	90	85	85	83 to 96	72	41-49	69-86
Industrial	60	84	72	69	53	27- 66	81-91
Schools	40 to 90 [1]	30		39	34		
Churches	40 to 90 [1]	50					
Open Urban Lands		5			9	13	2

Notes: [1] Values lowered to account for partially-developed parcels.

F. *Estimates of Future Impervious – 2035 and Buildout*

Forecasts of population and employment provide key information on where land conversion from vegetation to impervious surfaces is likely to occur. Estimates of future impervious area were developed for two time horizons:

- 2035 – a 20 year planning horizon commonly used under the Growth Management Act, and
- Buildout – an analysis of Thurston County and City land use when local comprehensive and zoning plans are fully implemented (Table 5).

Estimates were derived using the following assumptions:

- Impervious surface in 2010 will not be reduced in the future
- Fully built lots will not increase in impervious area over time.
- Vacant lots and the vacant portions of partially-developed lots will increase in impervious area, proportionate to planned zoning density.
- Timing of development of residential lands is based on the adopted population forecast.
- Timing of development of commercial, industrial, and institutional lands is based on the broad assumption of fifty percent by 2035.
- Future density is determined based on the Buildable Lands Assumptions (TRPC, 2007b). Impervious area for buildable land was calculated based on the values shown in Table 2 and Table 3.
- Zoning reflects that in place in 2012 – including adjustments to the urban growth area and a rezone in Tumwater.

All other information on development trends and land supply assumptions can be found in the Buildable Lands Report Assumptions Document (TRPC, 2012).

TABLE 5: STEPS FOR CONDUCTING A BUILDOUT ANALYSIS.

1	Assess Current Development Patterns
2	Identify Buildable Lands (as per adopted regulations)
3	Assess Future Development Patterns (location and density)
4	Evaluate changes to impervious cover

Table 6 shows estimates of total dwelling units from 1994 to a Buildout Analysis. Please note that the Buildout Analysis includes reductions for schools, parks, and other types of activity in residential areas. Map 3 through Map 5 and Table 7 show TIA for 1991, 2010 and at Buildout.

TABLE 6: DWELLING UNIT ESTIMATES AND FORECAST FOR THURSTON COUNTY BASINS, 1994-BUILDOUT.

Watershed / Basin	Total Dwelling Units				1994-2010		2010-Buildout	
	1994	2010	2035	Buildout	Num.	%	Num.	%
Black River								
Allen Creek	450	630	690	750	180	40%	120	19%
Beaver Creek	470	770	1,080	1,410	300	64%	640	83%
Black River	1,710	2,650	3,180	4,130	940	55%	1,480	56%
Bloom Ditch	220	390	500	610	170	77%	220	56%
Dempsey Creek	570	720	920	1,080	150	26%	360	50%
Mima Creek	20	40	50	90	20	100%	50	125%
Salmon Creek	960	1,160	2,550	2,890	200	21%	1,730	149%
Waddell Creek	120	190	200	220	70	58%	30	16%
Total	**4,500**	**6,540**	**9,190**	**11,170**	**2,040**	**45%**	**4,630**	**71%**
Budd Inlet/Deschutes River								
Black Lake	1,350	1,720	3,910	4,720	370	27%	3,000	174%
Capitol Lake	2,150	2,390	2,820	2,870	240	11%	480	20%
Chambers	6,910	12,830	17,210	18,260	5,920	86%	5,430	42%
Deschutes River (Mainstem Lower)	5,030	6,160	9,330	10,080	1,130	22%	3,920	64%
Deschutes River (Mainstem Middle)	1,190	1,990	2,940	3,780	800	67%	1,790	90%
Deschutes River (Mainstem Upper)	30	80	90	110	50	167%	30	38%
East Bay	720	820	850	910	100	14%	90	11%
Ellis Creek	240	310	400	430	70	29%	120	39%
Indian/Moxlie Creeks (Indian)	2,090	2,410	3,130	3,300	320	15%	890	37%
Indian/Moxlie Creeks (Moxlie)	4,950	5,700	7,610	7,990	750	15%	2,290	40%
Lake Lawrence	450	760	860	920	310	69%	160	21%
McIntosh Lake	70	140	160	190	70	100%	50	36%
Mission Creek	1,260	1,530	1,920	2,010	270	21%	480	31%
Offut Lake	240	320	390	440	80	33%	120	38%
Percival Creek	4,700	7,110	11,350	12,230	2,410	51%	5,120	72%
Reichel Lake	10	20	40	60	10	100%	40	200%
Schneider Creek (West Bay)	1,090	1,200	1,830	1,960	110	10%	760	63%
Spurgeon Creek	270	540	820	890	270	100%	350	65%
West Bay	2,650	2,830	3,940	4,200	180	7%	1,370	48%
Total	**35,400**	**48,860**	**69,590**	**75,360**	**13,460**	**38%**	**26,500**	**54%**

TABLE 6: DWELLING UNIT ESTIMATES AND FORECAST FOR THURSTON COUNTY BASINS, 1994-BUILDOUT (CONTINUED).

Watershed / Basin	Total Dwelling Units				1994-2010		2010-Buildout	
	1994	2010	2035	Buildout	Num.	%	Num.	%
Chehalis River								
East Fork Independence	20	20	70	150	-	0%	130	650%
Lincoln Creek	30	40	90	180	10	33%	140	350%
Michigan	40	70	130	260	30	75%	190	271%
Prairie Creek	910	1,380	1,920	2,640	470	52%	1,260	91%
Scatter Creek	2,140	3,850	5,320	6,500	1,710	80%	2,650	69%
Total	**3,140**	**5,360**	**7,520**	**9,720**	**2,220**	**71%**	**4,360**	**81%**
Eld Inlet								
Eld Inlet (East)	890	1,350	2,410	2,690	460	52%	1,340	99%
Eld Inlet (West)	820	1,130	1,300	1,540	310	38%	410	36%
Green Cove Creek	740	1,560	1,940	2,030	820	111%	470	30%
McLane Creek	330	470	610	750	140	42%	280	60%
Perry Creek	110	150	170	200	40	36%	50	33%
Squaxin Passage	390	480	510	530	90	23%	50	10%
Total	**3,270**	**5,140**	**6,940**	**7,720**	**1,870**	**57%**	**2,580**	**50%**
Henderson Inlet								
Dana Passage	300	400	450	550	100	33%	150	38%
Henderson Inlet (East)	420	660	760	850	240	57%	190	29%
Henderson Inlet (West)	350	420	490	560	70	20%	140	33%
Woodard Creek	3,190	4,430	6,390	6,860	1,240	39%	2,430	55%
Woodland Creek	12,550	15,400	23,910	25,950	2,850	23%	10,550	69%
Total	**16,800**	**21,310**	**32,000**	**34,770**	**4,510**	**27%**	**13,460**	**63%**
Nisqually River								
Alder Lake	-	-	-	-	-	0%	-	0%
Bald Hill Lake	-	-	-	-	-	0%	-	0%
Clear Lake	180	790	990	1,000	610	339%	210	27%
Elbow Lake	10	30	60	80	20	200%	50	167%
McAllister Creek	4,830	7,580	10,900	12,600	2,750	57%	5,020	66%
Nisqually	1,750	2,640	3,490	4,200	890	51%	1,560	59%
Nisqually Reach	930	2,650	4,120	4,360	1,720	185%	1,710	65%
Thompson Creek	800	1,730	7,210	9,950	930	116%	8,220	475%
Yelm Creek	1,610	3,090	5,060	5,890	1,480	92%	2,800	91%
Total	**10,100**	**18,490**	**31,820**	**38,070**	**8,390**	**83%**	**19,580**	**106%**

TABLE 6: DWELLING UNIT ESTIMATES AND FORECAST FOR THURSTON COUNTY BASINS, 1994-BUILDOUT (CONTINUED).

Watershed	Total Dwelling Units				1994-2010		2010-Buildout	
Basin	1994	2010	2035	Buildout	Num.	%	Num.	%
Skookumchuck River								
Bloody Run	-	-	-	-	-	0%	-	0%
Frost Prairie	10	10	20	50	-	0%	40	400%
Hanaford Creek	-	10	30	50	10	0%	40	400%
Johnson Creek	20	30	40	50	10	50%	20	67%
O'Conner	50	70	90	120	20	40%	50	71%
Salmon Creek (Sk)	-	-	-	-	-	0%	-	0%
Skookumchuck	480	660	1,010	1,350	180	38%	690	105%
Thompson Creek (Sk)	40	60	80	120	20	50%	60	100%
Zenkner	30	60	90	160	30	100%	100	167%
Total	**630**	**890**	**1,360**	**1,890**	**260**	**41%**	**1,000**	**112%**
Totten Inlet								
Burns/Pierre	70	90	100	130	20	29%	40	44%
Kennedy Creek	440	530	590	690	90	20%	160	30%
Schneider Creek (Totten)	170	240	300	420	70	41%	180	75%
Totten Inlet (East)	460	730	800	980	270	59%	250	34%
Total	**1,140**	**1,590**	**1,790**	**2,220**	**450**	**39%**	**630**	**40%**
West Capitol Forest								
Fall Creek	-	-	-	-	-	0%	-	0%
Lost Valley	-	-	-	-	-	0%	-	0%
Monroe Creek	-	-	-	-	-	0%	-	0%
Porter Creek	10	10	10	20	-	0%	10	100%
Sherman Creek	-	-	-	-	-	0%	-	0%
Total	**10**	**10**	**10**	**20**	**-**	**0%**	**10**	**100%**
Total Thurston County	**74,990**	**108,180**	**160,230**	**180,950**	**33,190**	**44%**	**72,770**	**67%**

TABLE 7: ESTIMATES OF CURRENT AND FUTURE TOTAL IMPERVIOUS AREA.

Watershed / Basin	Total Acres	Total Impervious Area 1991	2010	2035	Buildout	Increase* 1991-2010	2010-Buildout
Black River							
Allen Creek	3,420	2.7%	3.9%	4.2%	4.5%	1.2%	0.6%
Beaver Creek	12,800	1.4%	2.3%	2.7%	3.1%	0.9%	0.8%
Black River	25,320	1.4%	2.5%	2.7%	3.1%	1.1%	0.6%
Bloom Ditch	5,010	1.2%	2.2%	2.6%	3.0%	1.0%	0.8%
Dempsey Creek	6,400	0.8%	1.8%	2.2%	2.6%	1.0%	0.8%
Mima Creek	7,940	0.1%	0.4%	0.4%	0.5%	0.3%	0.1%
Salmon Creek	7,950	5.7%	9.1%	13.0%	16.4%	3.4%	7.3%
Waddell Creek	11,200	0.3%	0.5%	0.5%	0.5%	0.2%	0.0%
Total	***80,040***	**1.5%**	**2.6%**	**3.2%**	**3.8%**	**1.1%**	**1.2%**
Budd Inlet/Deschutes River							
Black Lake	4,390	5.1%	8.3%	13.0%	14.7%	3.2%	6.5%
Capitol Lake	1,220	24.6%	28.1%	29.2%	29.5%	3.6%	1.3%
Chambers	8,480	10.2%	19.9%	22.5%	23.4%	9.7%	3.5%
Deschutes River (Mainstem Lower)	11,210	10.6%	15.1%	17.7%	19.1%	4.4%	4.0%
Deschutes River (Mainstem Middle)	23,180	0.9%	2.0%	2.5%	3.0%	1.1%	1.0%
Deschutes River (Mainstem Upper)	22,440	0.1%	0.9%	0.9%	0.9%	0.7%	0.0%
East Bay	2,480	3.6%	6.1%	6.2%	6.6%	2.5%	0.5%
Ellis Creek	940	4.5%	7.5%	8.3%	8.5%	3.0%	1.0%
Indian/Moxlie Creeks (Indian)	1,490	24.5%	28.6%	31.7%	32.7%	4.1%	4.1%
Indian/Moxlie Creeks (Moxlie)	2,510	34.4%	40.2%	42.9%	43.7%	5.9%	3.5%
Lake Lawrence	2,330	1.6%	5.0%	5.5%	5.9%	3.4%	0.8%
McIntosh Lake	1,620	0.8%	2.2%	2.4%	2.7%	1.4%	0.5%
Mission Creek	730	21.2%	24.5%	27.8%	28.6%	3.3%	4.0%
Offut Lake	1,790	1.4%	2.9%	3.3%	3.7%	1.5%	0.8%
Percival Creek	5,660	19.5%	25.5%	30.2%	31.7%	6.1%	6.2%
Reichel Lake	4,470	0.7%	1.5%	1.5%	1.6%	0.8%	0.1%
Schneider Creek (West Bay)	670	17.0%	21.7%	27.6%	28.7%	4.7%	7.0%
Spurgeon Creek	6,050	0.7%	1.6%	2.0%	2.2%	1.0%	0.5%
West Bay	1,820	14.8%	18.4%	20.8%	22.0%	3.6%	3.5%
Total	***103,490***	**5.8%**	**8.6%**	**9.9%**	**10.5%**	**2.8%**	**2.0%**

TABLE 7: ESTIMATES OF CURRENT AND FUTURE TOTAL IMPERVIOUS AREA (CONTINUED)

Watershed		Total Impervious Area				Increase*	
Basin	Total Acres	1991	2010	2035	Buildout	1991-2010	2010-Buildout
Chehalis River							
East Fork Independence	1,550	0.1%	0.5%	0.9%	1.7%	0.4%	1.2%
Lincoln Creek	1,860	0.0%	0.3%	0.8%	1.5%	0.3%	1.2%
Michigan	2,630	0.2%	0.6%	1.0%	1.6%	0.4%	1.0%
Prairie Creek	13,530	3.2%	4.5%	5.3%	6.2%	1.3%	1.7%
Scatter Creek	27,510	2.1%	3.5%	4.2%	4.7%	1.4%	1.2%
Total	***47,080***	**2.2%**	**3.4%**	**4.1%**	**4.7%**	**1.2%**	**1.4%**
Eld Inlet							
Eld Inlet (East)	3,820	4.1%	7.2%	8.9%	9.7%	3.1%	2.5%
Eld Inlet (West)	6,070	2.4%	4.2%	4.7%	5.2%	1.9%	1.0%
Green Cove Creek	2,220	4.5%	12.2%	13.8%	14.1%	7.7%	1.8%
McLane Creek	7,090	0.5%	1.1%	1.3%	1.6%	0.5%	0.5%
Perry Creek	4,120	1.2%	1.9%	2.0%	2.1%	0.7%	0.2%
Squaxin Passage	480	5.5%	10.5%	10.9%	11.5%	5.0%	1.0%
Total	***23,790***	**2.2%**	**4.2%**	**4.9%**	**5.3%**	**2.1%**	**1.0%**
Henderson Inlet							
Dana Passage	1,490	1.8%	4.1%	4.6%	5.4%	2.3%	1.3%
Henderson Inlet (East)	3,280	1.9%	4.6%	5.0%	5.4%	2.7%	0.8%
Henderson Inlet (West)	3,090	1.2%	2.6%	3.0%	3.3%	1.4%	0.7%
Woodard Creek	5,310	9.1%	14.6%	16.6%	17.4%	5.5%	2.8%
Woodland Creek	16,280	14.4%	22.1%	26.9%	29.1%	7.8%	7.0%
Total	***29,450***	**10.0%**	**15.9%**	**19.0%**	**20.5%**	**5.8%**	**4.6%**
Nisqually River							
Alder Lake	4,870	0.0%	0.3%	0.3%	0.3%	0.3%	0.0%
Bald Hill Lake	800	0.0%	0.5%	0.5%	0.5%	0.5%	0.0%
Clear Lake	1,470	0.8%	2.9%	3.9%	4.0%	2.2%	1.1%
Elbow Lake	1,160	0.3%	1.4%	1.6%	1.8%	1.0%	0.4%
McAllister Creek	20,020	4.1%	7.5%	8.8%	9.5%	3.3%	2.0%
Nisqually	31,500	1.0%	2.1%	2.4%	2.7%	1.1%	0.6%
Nisqually Reach	5,250	2.2%	11.1%	13.3%	13.7%	8.8%	2.7%
Thompson Creek	10,630	1.5%	3.6%	9.1%	11.5%	2.0%	7.9%
Yelm Creek	15,080	2.4%	4.7%	6.3%	7.6%	2.3%	2.9%
Total	***90,770***	**2.0%**	**4.3%**	**5.8%**	**6.5%**	**2.3%**	**2.2%**

TABLE 7: ESTIMATES OF CURRENT AND FUTURE TOTAL IMPERVIOUS AREA (CONTINUED)

Watershed		Total Impervious Area				Increase*	
Basin	Total Acres	1991	2010	2035	Buildout	1991-2010	2010-Buildout
Skookumchuck River							
Bloody Run	2,190	0.0%	0.3%	0.3%	0.3%	0.3%	0.0%
Frost Prairie	1,840	0.1%	0.2%	0.4%	0.7%	0.1%	0.5%
Hanaford Creek	6,060	0.6%	1.0%	1.1%	1.2%	0.4%	0.2%
Johnson Creek	6,930	0.1%	0.5%	0.6%	0.6%	0.4%	0.0%
O'Conner	2,190	0.3%	0.7%	0.9%	1.2%	0.4%	0.5%
Salmon Creek (Sk)	2,830	0.0%	0.4%	0.4%	0.4%	0.4%	0.0%
Skookumchuck	9,470	1.2%	2.0%	2.4%	2.9%	0.8%	0.9%
Thompson Creek (Sk)	21,360	0.1%	0.5%	0.5%	0.6%	0.4%	0.1%
Zenkner	3,000	0.1%	0.2%	0.5%	1.0%	0.2%	0.7%
Total	***55,860***	**0.3%**	**0.8%**	**0.9%**	**1.1%**	**0.4%**	**0.3%**
Totten Inlet							
Burns/Pierre	370	1.4%	2.5%	3.0%	3.9%	1.1%	1.3%
Kennedy Creek	11,650	0.9%	1.5%	1.6%	1.7%	0.6%	0.2%
Schneider Creek (Totten)	5,360	1.1%	1.8%	2.1%	2.5%	0.8%	0.6%
Totten Inlet (East)	3,040	1.8%	3.0%	3.4%	4.2%	1.3%	1.1%
Total	***20,420***	**1.1%**	**1.8%**	**2.0%**	**2.3%**	**0.7%**	**0.5%**
West Capitol Forest							
Fall Creek	1,440	0.0%	0.1%	0.1%	0.1%	0.0%	0.0%
Lost Valley	1,140	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Monroe Creek	1,070	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Porter Creek	9,600	0.2%	0.5%	0.5%	0.5%	0.2%	0.0%
Sherman Creek	6,180	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Total	***19,440***	**0.1%**	**0.2%**	**0.2%**	**0.2%**	**0.1%**	**0.0%**
Total Thurston County	***470,350***	**3.0%**	**4.9%**	**5.9%**	**6.5%**	**1.9%**	**1.6%**

Note: *Increase measured as TIA % in Year 2 minus TIA % in Year 1.

G. *Effective Impervious Area*

Estimates of effective impervious area (EIA) are generally assumed to have a stronger correlation with stream hydrologic conditions over total impervious area. Generalized EIA estimates were produced as part of this study, and are available for basin-level modeling.

Several studies have compared TIA to EIA at various levels of TIA. Relationships published in Roy and Schuster, 2009, and Sutherland, 1995, were graphed against those used in previous estimates by TRPC (TRPC, 2007). The relationships used by TRPC and based on local studies, were found to be fairly similar to other studies (Figure 5).

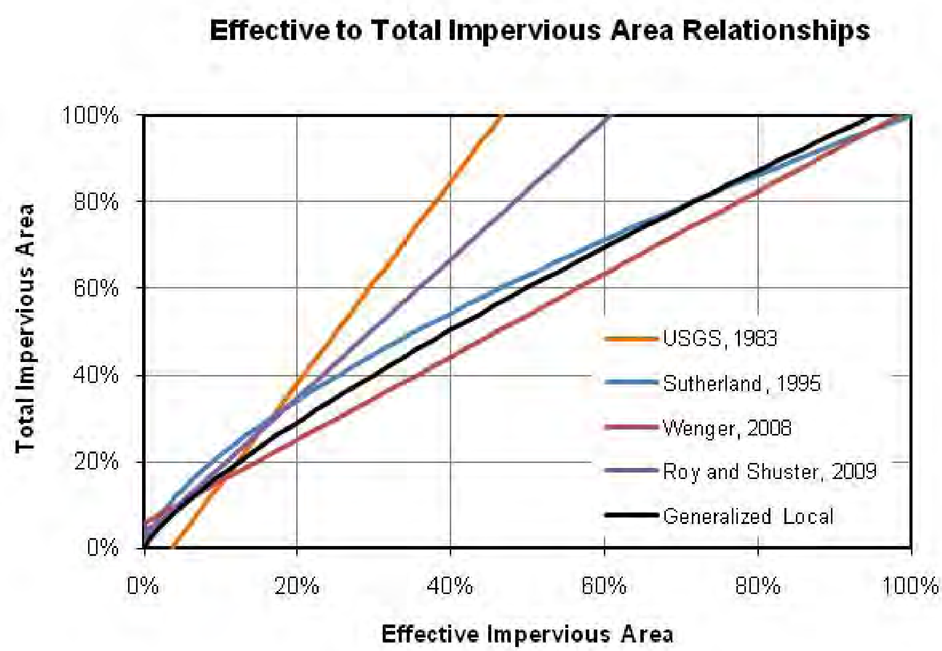


FIGURE 5: EFFECTIVE TO TOTAL IMPERVIOUS AREA RELATIONSHIPS. GENERALIZED LOCAL WAS USED IN THIS STUDY.

TABLE 8: ESTIMATES OF CURRENT AND FUTURE EFFECTIVE IMPERVIOUS AREA

Watershed		Total Impervious Area		Effective Impervious Area		Increase 2010-Buildout *	
Basin	Total Acres	2010	Buildout	2010	Buildout	TIA	EIA
Black River							
Allen Creek	3,420	3.9%	4.5%	2.6%	2.8%	0.6%	0.2%
Beaver Creek	12,800	2.3%	3.1%	1.5%	1.8%	0.8%	0.3%
Black River	25,320	2.5%	3.1%	1.6%	1.9%	0.6%	0.2%
Bloom Ditch	5,010	2.2%	3.0%	1.5%	1.7%	0.8%	0.3%
Dempsey Creek	6,400	1.8%	2.6%	1.1%	1.3%	0.8%	0.3%
Mima Creek	7,940	0.4%	0.5%	0.2%	0.3%	0.1%	0.0%
Salmon Creek	7,950	9.1%	16.4%	6.6%	12.2%	7.3%	5.6%
Waddell Creek	11,200	0.5%	0.5%	0.3%	0.3%	0.0%	0.0%
Total	***80,040***	**2.6%**	**3.8%**	**1.8%**	**2.5%**	**1.2%**	**0.7%**
Budd Inlet/Deschutes River							
Black Lake	4,390	8.3%	14.7%	5.8%	10.5%	6.5%	4.7%
Capitol Lake	1,220	28.1%	29.5%	22.4%	23.4%	1.3%	1.0%
Chambers	8,480	19.9%	23.4%	15.2%	17.7%	3.5%	2.5%
Deschutes River (Mainstem Lower)	11,210	15.1%	19.1%	11.6%	14.4%	4.0%	2.8%
Deschutes River (Mainstem Middle)	23,180	2.0%	3.0%	1.3%	1.8%	1.0%	0.4%
Deschutes River (Mainstem Upper)	22,440	0.9%	0.9%	0.5%	0.5%	0.0%	0.0%
East Bay	2,480	6.1%	6.6%	4.0%	4.2%	0.5%	0.2%
Ellis Creek	940	7.5%	8.5%	4.9%	5.5%	1.0%	0.6%
Indian/Moxlie Creeks (Indian)	1,490	28.6%	32.7%	22.0%	24.9%	4.1%	2.9%
Indian/Moxlie Creeks (Moxlie)	2,510	40.2%	43.7%	32.9%	35.7%	3.5%	2.8%
Lake Lawrence	2,330	5.0%	5.9%	3.2%	3.6%	0.8%	0.3%
McIntosh Lake	1,620	2.2%	2.7%	1.3%	1.5%	0.5%	0.2%
Mission Creek	730	24.5%	28.6%	18.3%	21.2%	4.0%	2.9%
Offut Lake	1,790	2.9%	3.7%	1.9%	2.1%	0.8%	0.3%
Percival Creek	5,660	25.5%	31.7%	20.6%	25.1%	6.2%	4.4%
Reichel Lake	4,470	1.5%	1.6%	1.0%	1.0%	0.1%	0.0%
Schneider Creek (West Bay)	670	21.7%	28.7%	15.8%	20.8%	7.0%	5.0%
Spurgeon Creek	6,050	1.6%	2.2%	1.0%	1.3%	0.5%	0.2%
West Bay	1,820	18.4%	22.0%	13.9%	16.2%	3.5%	2.3%
Total	***103,490***	**8.6%**	**10.5%**	**6.5%**	**7.8%**	**2.0%**	**1.3%**

TABLE 8: ESTIMATES OF CURRENT AND FUTURE EFFECTIVE IMPERVIOUS AREA (CONTINUED)

Watershed		Total Impervious Area		Effective Impervious Area		Increase 2010-Buildout *	
Basin	Total Acres	2010	Buildout	2010	Buildout	TIA	EIA
Chehalis River							
East Fork Independence	1,550	0.5%	1.7%	0.3%	0.7%	1.2%	0.4%
Lincoln Creek	1,860	0.3%	1.5%	0.2%	0.6%	1.2%	0.4%
Michigan	2,630	0.6%	1.6%	0.3%	0.7%	1.0%	0.3%
Prairie Creek	13,530	4.5%	6.2%	3.3%	4.4%	1.7%	1.1%
Scatter Creek	27,510	3.5%	4.7%	2.4%	3.1%	1.2%	0.7%
Total	***47,080***	**3.4%**	**4.7%**	**2.4%**	**3.1%**	**1.4%**	**0.8%**
Eld Inlet							
Eld Inlet (East)	3,820	7.2%	9.7%	5.0%	6.7%	2.5%	1.7%
Eld Inlet (West)	6,070	4.2%	5.2%	2.9%	3.2%	1.0%	0.4%
Green Cove Creek	2,220	12.2%	14.1%	8.8%	9.8%	1.8%	1.1%
McLane Creek	7,090	1.1%	1.6%	0.6%	0.8%	0.5%	0.2%
Perry Creek	4,120	1.9%	2.1%	1.3%	1.3%	0.2%	0.1%
Squaxin Passage	480	10.5%	11.5%	7.1%	7.6%	1.0%	0.5%
Total	***23,790***	**4.2%**	**5.3%**	**2.9%**	**3.4%**	**1.0%**	**0.6%**
Henderson Inlet							
Dana Passage	1,490	4.1%	5.4%	2.5%	3.1%	1.3%	0.5%
Henderson Inlet (East)	3,280	4.6%	5.4%	2.9%	3.2%	0.8%	0.3%
Henderson Inlet (West)	3,090	2.6%	3.3%	1.6%	1.9%	0.7%	0.3%
Woodard Creek	5,310	14.6%	17.4%	11.0%	12.9%	2.8%	1.9%
Woodland Creek	16,280	22.1%	29.1%	17.4%	22.6%	7.0%	5.2%
Total	***29,450***	**15.9%**	**20.5%**	**12.2%**	**15.5%**	**4.6%**	**3.3%**
Nisqually River							
Alder Lake	4,870	0.3%	0.3%	0.2%	0.2%	0.0%	0.0%
Bald Hill Lake	800	0.5%	0.5%	0.3%	0.3%	0.0%	0.0%
Clear Lake	1,470	2.9%	4.0%	1.9%	2.6%	1.1%	0.7%
Elbow Lake	1,160	1.4%	1.8%	0.8%	1.0%	0.4%	0.2%
McAllister Creek	20,020	7.5%	9.5%	5.5%	6.9%	2.0%	1.4%
Nisqually	31,500	2.1%	2.7%	1.4%	1.6%	0.6%	0.2%
Nisqually Reach	5,250	11.1%	13.7%	8.2%	9.8%	2.7%	1.6%
Thompson Creek	10,630	3.6%	11.5%	2.5%	8.5%	7.9%	6.0%
Yelm Creek	15,080	4.7%	7.6%	3.3%	5.2%	2.9%	1.9%
Total	***90,770***	**4.3%**	**6.5%**	**3.1%**	**4.6%**	**2.2%**	**1.5%**

TABLE 8: ESTIMATES OF CURRENT AND FUTURE EFFECTIVE IMPERVIOUS AREA (CONTINUED).

Watershed		Total Impervious Area		Effective Impervious Area		Increase 2010-Buildout *	
Basin	Total Acres	2010	Buildout	2010	Buildout	TIA	EIA
Skookumchuck River							
Bloody Run	2,190	0.3%	0.3%	0.1%	0.1%	0.0%	0.0%
Frost Prairie	1,840	0.2%	0.7%	0.1%	0.3%	0.5%	0.2%
Hanaford Creek	6,060	1.0%	1.2%	0.7%	0.8%	0.2%	0.1%
Johnson Creek	6,930	0.5%	0.6%	0.3%	0.3%	0.0%	0.0%
O'Conner	2,190	0.7%	1.2%	0.4%	0.6%	0.5%	0.2%
Salmon Creek (Sk)	2,830	0.4%	0.4%	0.2%	0.2%	0.0%	0.0%
Skookumchuck	9,470	2.0%	2.9%	1.3%	1.7%	0.9%	0.4%
Thompson Creek (Sk)	21,360	0.5%	0.6%	0.3%	0.3%	0.1%	0.0%
Zenkner	3,000	0.2%	1.0%	0.1%	0.4%	0.7%	0.3%
Total	***55,860***	**0.8%**	**1.1%**	**0.5%**	**0.6%**	**0.3%**	**0.1%**
Totten Inlet							
Burns/Pierre	370	2.5%	3.9%	1.6%	2.1%	1.3%	0.5%
Kennedy Creek	11,650	1.5%	1.7%	1.0%	1.1%	0.2%	0.1%
Schneider Creek (Totten)	5,360	1.8%	2.5%	1.3%	1.5%	0.6%	0.3%
Totten Inlet (East)	3,040	3.0%	4.2%	1.9%	2.4%	1.1%	0.4%
Total	***20,420***	**1.8%**	**2.3%**	**1.2%**	**1.4%**	**0.5%**	**0.2%**
West Capitol Forest							
Fall Creek	1,440	0.1%	0.1%	0.0%	0.0%	0.0%	0.0%
Lost Valley	1,140	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Monroe Creek	1,070	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Porter Creek	9,600	0.5%	0.5%	0.3%	0.3%	0.0%	0.0%
Sherman Creek	6,180	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Total	***19,440***	**0.2%**	**0.2%**	**0.2%**	**0.2%**	**0.0%**	**0.0%**
Total Thurston County	***470,350***	**4.9%**	**6.5%**	**3.6%**	**4.6%**	**1.6%**	**1.0%**

Note: *Increase measured as TIA % in Year 2 minus TIA % in Year 1.

V. FOREST CANOPY COVER AND FOREST LANDS VULNERABLE TO URBANIZATION

A. Historic Estimates of Forest Canopy Cover

The Multi-Resolution Land Characterization (MRLC) 2001 program also developed estimates of forest canopy cover as part of the National Land Cover database. Estimates are provided for the years:

- 1991
- 1996
- 2001
- 2006

These estimates provide snapshots in time of forest canopy. Overall, Thurston County has increased forest canopy between 1991 and 2006, with the lowest period in 2001 (Table 9.) Much of the fluctuation can be attributed to the forest harvest cycle and the reforestation of the Centralia Coal Mine (in Skookumchuck River Watershed).

TABLE 9: ESTIMATES OF FOREST CANOPY IN THURSTON COUNTY, 1991 TO 2006.

Watershed / Basin	Total Acres	Forest Canopy 1991	1996	2001	2006
Black River					
Allen Creek	3,420	39.6%	35.3%	32.9%	41.1%
Beaver Creek	12,800	53.3%	48.5%	47.4%	55.9%
Black River	25,320	39.7%	34.3%	34.0%	46.1%
Bloom Ditch	5,010	50.5%	45.5%	43.7%	54.7%
Dempsey Creek	6,400	65.6%	64.0%	62.4%	75.2%
Mima Creek	7,940	66.3%	69.0%	71.8%	75.6%
Salmon Creek	7,950	40.9%	35.3%	33.2%	44.1%
Waddell Creek	11,200	81.4%	79.2%	80.1%	80.2%
Total	***80,040***	**53.2%**	**49.5%**	**49.1%**	**57.8%**
Budd Inlet/Deschutes River					
Black Lake	11,210	36.3%	34.3%	33.4%	41.8%
Capitol Lake	1,220	19.1%	19.1%	19.1%	28.6%
Chambers	8,480	29.1%	26.6%	26.4%	32.3%
Deschutes River (Mainstem Lower)	11,210	36.3%	34.3%	33.4%	41.8%
Deschutes River (Mainstem Middle)	23,180	52.3%	47.4%	46.8%	52.9%
Deschutes River (Mainstem Upper)	22,440	77.7%	75.8%	71.5%	71.2%
East Bay	2,480	60.4%	55.0%	54.0%	62.1%
Ellis Creek	940	54.8%	54.2%	53.4%	65.3%
Indian/Moxlie Creeks (Indian)	1,490	22.5%	22.0%	22.3%	37.4%
Indian/Moxlie Creeks (Moxlie)	2,510	17.9%	17.4%	17.3%	27.2%
Lake Lawrence	2,330	43.2%	40.3%	38.9%	44.6%
McIntosh Lake	1,620	56.5%	64.2%	71.0%	80.6%
Mission Creek	730	30.7%	30.7%	30.7%	44.7%
Offut Lake	1,790	55.0%	54.9%	58.2%	61.2%
Percival Creek	5,660	37.5%	36.7%	34.2%	45.7%
Reichel Lake	4,470	70.0%	65.5%	61.7%	62.3%
Schneider Creek (West Bay)	670	37.0%	37.0%	37.0%	55.6%
Spurgeon Creek	6,050	68.9%	66.1%	64.9%	69.4%
West Bay	1,820	46.4%	45.8%	45.4%	57.3%
Total	***103,490***	**52.6%**	**50.0%**	**48.4%**	**54.2%**

TABLE 9: ESTIMATES OF FOREST CANOPY IN THURSTON COUNTY, 1991 TO 2006.

Watershed / Basin	Total Acres	Forest Canopy 1991	1996	2001	2006
Chehalis River					
East Fork Independence	1,550	71.8%	68.0%	65.5%	65.7%
Lincoln Creek	1,860	70.5%	58.6%	62.8%	61.2%
Michigan	2,630	58.4%	54.8%	58.4%	68.5%
Prairie Creek	13,530	36.9%	34.5%	35.8%	40.9%
Scatter Creek	27,510	39.3%	36.0%	34.9%	40.3%
Total	***47,080***	**42.0%**	**38.5%**	**38.6%**	**43.7%**
Eld Inlet					
Eld Inlet (East)	3,820	71.4%	69.4%	68.7%	77.0%
Eld Inlet (West)	6,070	68.8%	64.2%	63.9%	70.0%
Green Cove Creek	2,220	60.9%	58.8%	55.9%	66.4%
McLane Creek	7,090	70.9%	65.9%	63.3%	72.7%
Perry Creek	4,120	76.9%	75.3%	71.6%	80.3%
Squaxin Passage	480	60.4%	56.3%	56.0%	68.4%
Total	***23,790***	**70.3%**	**66.8%**	**64.9%**	**73.4%**
Henderson Inlet					
Dana Passage	1,490	72.6%	69.7%	69.8%	78.6%
Henderson Inlet (East)	3,280	66.7%	64.3%	61.0%	67.8%
Henderson Inlet (West)	3,090	61.4%	59.0%	58.8%	66.6%
Woodard Creek	5,310	40.4%	36.1%	35.5%	45.9%
Woodland Creek	16,280	35.1%	33.3%	32.5%	40.1%
Total	***29,450***	**44.3%**	**41.8%**	**40.9%**	**49.0%**
Nisqually River					
Alder Lake	4,870	54.6%	62.7%	63.5%	68.9%
Bald Hill Lake	800	75.4%	69.9%	69.9%	75.9%
Clear Lake	1,470	83.3%	79.2%	75.1%	59.0%
Elbow Lake	1,160	78.0%	74.3%	70.2%	70.0%
McAllister Creek	20,020	54.0%	51.8%	50.3%	53.0%
Nisqually	31,500	63.0%	59.5%	56.6%	63.4%
Nisqually Reach	5,250	66.8%	62.4%	60.8%	66.0%
Thompson Creek	10,630	49.6%	47.7%	47.6%	56.1%
Yelm Creek	15,080	38.5%	33.2%	31.1%	36.4%
Total	***90,770***	**55.8%**	**53.0%**	**51.1%**	**56.3%**

TABLE 9: ESTIMATES OF FOREST CANOPY IN THURSTON COUNTY, 1991 TO 2006.

Watershed Basin	Total Acres	Forest Canopy 1991	1996	2001	2006
Skookumchuck River					
Bloody Run	2,190	85.8%	85.4%	76.8%	82.4%
Frost Prairie	1,840	58.3%	66.3%	71.4%	72.6%
Hanaford Creek	6,060	26.4%	22.3%	37.3%	42.7%
Johnson Creek	6,930	70.0%	69.3%	66.9%	75.4%
O'Conner	2,190	57.2%	55.1%	57.0%	64.0%
Salmon Creek (Sk)	2,830	79.7%	82.1%	85.1%	93.3%
Skookumchuck	9,470	43.8%	41.5%	40.9%	47.2%
Thompson Creek (Sk)	21,360	65.4%	54.1%	50.9%	61.9%
Zenkner	3,000	55.6%	53.7%	49.6%	50.5%
Total	***55,860***	**58.5%**	**53.5%**	**53.3%**	**61.2%**
Totten Inlet					
Burns/Pierre	370	72.6%	72.4%	73.0%	69.9%
Kennedy Creek	11,650	77.8%	73.8%	70.2%	68.0%
Schneider Creek (Totten)	5,360	72.0%	66.2%	66.3%	70.5%
Totten Inlet (East)	3,040	74.1%	73.4%	73.3%	79.7%
Total	***20,420***	**75.6%**	**71.7%**	**69.7%**	**70.4%**
West Capitol Forest					
Fall Creek	1,440	86.4%	84.3%	81.1%	89.5%
Lost Valley	1,140	85.1%	78.9%	73.6%	80.4%
Monroe Creek	1,070	90.1%	89.7%	71.3%	75.0%
Porter Creek	9,600	79.9%	77.8%	79.1%	80.3%
Sherman Creek	6,180	79.9%	79.8%	75.9%	80.2%
Total	***19,440***	**81.2%**	**79.6%**	**77.5%**	**80.6%**
Total Thurston County	***470,350***	**55.5%**	**52.3%**	**51.1%**	**57.4%**

B. Estimates of Forest Lands Vulnerable to Urban Conversion

Forest Lands are our working forest lands. They include:

- Public Forests such as Capitol Forest.
- Private Forest Lands enrolled in the Open Space Forest Tax Program. This program provides landowners the option of having their land valued at "current use" rather than "highest and best use." As a result, their taxes are lowered if their properties are accepted into the program. This program is an incentive for conservation, but is not designed to protect farmlands in perpetuity.

Forest lands should not be confused with forest canopy cover. Forest land is an ownership and use designation, while forest cover is usually a direct measure (through air photos or satellite date) of tree canopy.

Private forest lands are vulnerable to conversion to urban uses. A TRPC (TRPC, 2002) indicated that approximately 18,600 acres of forested lands were converted to urban uses between 1985 and 2000, a rate of approximately 1,200 acre per year.

Table 10 shows an estimate of Forest Lands in Thurston County. The private forest lands in the Cities and unincorporated Urban Growth Area (UGA) are more vulnerable to development pressures than the forest lands in the rural areas. Table 11 provides estimates of the percent of forest lands vulnerable to urban conversion, by basin in Thurston County.

TABLE 10: FOREST LAND INVENTORY FOR THURSTON COUNTY.

2010 Forest Land Inventory	Cities	UGA	Rural	Total
Total Forest Lands (acres)	**370**	**480**	**188,040**	**188,890**
Public Forest Lands	30	30	63,760	63,820
Private Forest Lands	340	450	124,280	125,070
Unlikely to convert to residential uses	*160*	-	*79,760*	*79,930*
Vulnerable to residential or commercial development	*170*	*450*	*44,520*	*45,140*

TABLE 11: ESTIMATES OF FOREST LANDS VULNERABLE TO URBAN CONVERSION, THURSTON COUNTY.

Watershed Basin	Total Acres	Forest Canopy 2006	Forest Lands Vulnerable to Urban Conversion 2010 to 2035	Forest Lands Vulnerable to Urban Conversion Buildout
Black River				
Allen Creek	3,420	41.1%	9.7%	18.8%
Beaver Creek	12,800	55.9%	12.2%	23.9%
Black River	25,320	46.1%	5.4%	17.9%
Bloom Ditch	5,010	54.7%	12.3%	22.6%
Dempsey Creek	6,400	75.2%	7.9%	15.7%
Mima Creek	7,940	75.6%	0.2%	0.6%
Salmon Creek	7,950	44.1%	3.4%	6.6%
Waddell Creek	11,200	80.2%	0.1%	0.2%
Total	***80,040***	**57.8%**	**5.8%**	**13.7%**
Budd Inlet/Deschutes River				
Black Lake	11,210	41.8%	8.7%	12.6%
Capitol Lake	1,220	28.6%	0.0%	0.0%
Chambers	8,480	32.3%	1.3%	2.0%
Deschutes River (Mainstem Lower)	11,210	41.8%	8.7%	12.6%
Deschutes River (Mainstem Middle)	23,180	52.9%	5.8%	13.7%
Deschutes River (Mainstem Upper)	22,440	71.2%	0.1%	0.3%
East Bay	2,480	62.1%	0.5%	2.0%
Ellis Creek	940	65.3%	0.0%	0.0%
Indian/Moxlie Creeks (Indian)	1,490	37.4%	0.0%	0.0%
Indian/Moxlie Creeks (Moxlie)	2,510	27.2%	0.0%	0.0%
Lake Lawrence	2,330	44.6%	2.8%	5.6%
McIntosh Lake	1,620	80.6%	2.0%	4.5%
Mission Creek	730	44.7%	0.0%	0.0%
Offut Lake	1,790	61.2%	23.1%	42.7%
Percival Creek	5,660	45.7%	2.8%	6.4%
Reichel Lake	4,470	62.3%	1.4%	3.0%
Schneider Creek (West Bay)	670	55.6%	0.0%	0.0%
Spurgeon Creek	6,050	69.4%	1.4%	1.8%
West Bay	1,820	57.3%	1.2%	7.5%
Total	***103,490***	**54.2%**	**3.3%**	**6.6%**

TABLE 11: ESTIMATES OF FOREST LANDS VULNERABLE TO URBAN CONVERSION, THURSTON COUNTY.

Watershed Basin	Total Acres	Forest Canopy 2006	Forest Lands Vulnerable to Urban Conversion 2010 to 2035	Forest Lands Vulnerable to Urban Conversion Buildout
Chehalis River				
East Fork Independence	1,550	65.7%	29.3%	78.8%
Lincoln Creek	1,860	61.2%	17.1%	46.4%
Michigan	2,630	68.5%	17.1%	46.2%
Prairie Creek	13,530	40.9%	5.8%	14.1%
Scatter Creek	27,510	40.3%	9.0%	23.5%
Total	***47,080***	**43.7%**	**9.5%**	**24.8%**
Eld Inlet				
Eld Inlet (East)	3,820	77.0%	2.1%	3.6%
Eld Inlet (West)	6,070	70.0%	7.3%	17.8%
Green Cove Creek	2,220	66.4%	0.2%	0.4%
McLane Creek	7,090	72.7%	6.6%	13.0%
Perry Creek	4,120	80.3%	2.3%	4.7%
Squaxin Passage	480	68.4%	0.8%	2.0%
Total	***23,790***	**73.4%**	**4.6%**	**9.9%**
Henderson Inlet				
Dana Passage	1,490	78.6%	1.1%	4.2%
Henderson Inlet (East)	3,280	67.8%	5.4%	10.6%
Henderson Inlet (West)	3,090	66.6%	6.0%	12.2%
Woodard Creek	5,310	45.9%	0.4%	0.9%
Woodland Creek	16,280	40.1%	1.0%	2.2%
Total	***29,450***	**49.0%**	**1.9%**	**4.0%**
Nisqually River				
Alder Lake	4,870	68.9%	0.0%	0.0%
Bald Hill Lake	800	75.9%	0.0%	0.0%
Clear Lake	1,470	59.0%	0.0%	0.0%
Elbow Lake	1,160	70.0%	3.7%	7.0%
McAllister Creek	20,020	53.0%	2.2%	5.8%
Nisqually	31,500	63.4%	5.1%	10.3%
Nisqually Reach	5,250	66.0%	1.5%	2.9%
Thompson Creek	10,630	56.1%	1.3%	3.5%
Yelm Creek	15,080	36.4%	5.3%	12.6%
Total	***90,770***	**56.3%**	**3.4%**	**7.6%**

TABLE 11: ESTIMATES OF FOREST LANDS VULNERABLE TO URBAN CONVERSION, THURSTON COUNTY.

Watershed Basin	Total Acres	Forest Canopy 2006	Forest Lands Vulnerable to Urban Conversion	
			2010 to 2035	Buildout
Skookumchuck River				
Bloody Run	2,190	82.4%	0.0%	0.0%
Frost Prairie	1,840	72.6%	8.0%	20.1%
Hanaford Creek	6,060	42.7%	2.5%	6.4%
Johnson Creek	6,930	75.4%	0.0%	0.0%
O'Conner	2,190	64.0%	5.1%	12.8%
Salmon Creek (Sk)	2,830	93.3%	0.0%	0.0%
Skookumchuck	9,470	47.2%	8.2%	20.2%
Thompson Creek (Sk)	21,360	61.9%	0.3%	0.7%
Zenkner	3,000	50.5%	11.8%	29.5%
Total	***55,860***	**61.2%**	**2.9%**	**7.1%**
Totten Inlet				
Burns/Pierre	370	69.9%	0.0%	0.0%
Kennedy Creek	11,650	68.0%	0.2%	0.5%
Schneider Creek (Totten)	5,360	70.5%	3.9%	11.2%
Totten Inlet (East)	3,040	79.7%	3.9%	13.5%
Total	***20,420***	**70.4%**	**1.7%**	**5.2%**
West Capitol Forest				
Fall Creek	1,440	89.5%	0.0%	0.0%
Lost Valley	1,140	80.4%	0.0%	0.0%
Monroe Creek	1,070	75.0%	0.0%	0.0%
Porter Creek	9,600	80.3%	0.0%	0.0%
Sherman Creek	6,180	80.2%	0.0%	0.0%
Total	***19,440***	**80.6%**	**0.0%**	**0.0%**
Total Thurston County	***470,350***	**57.4%**	**4.1%**	**9.6%**

VI. POLICY IMPLICATIONS AND CONCLUSIONS

Land use plans developed under the Growth Management Act (GMA) show where future growth can be accommodated. For each area of the County, land use designations indicate what type of growth may occur, and in what form. For residential growth, densities, or the number of dwelling units per acre, are designated under these plans.

Thurston County is expected to grow by approximately 150,000 people in the next 25 years. Accommodating these people will require will require roughly 70,000 housing units. How these housing units are accommodated can make a tremendous difference on the amount of new imperious area in the County.

Numerous studies have shown that limiting basin-wide total impervious area to under 10 percent is essential to maintaining high stream basin biologic integrity.

It is counter-intuitive, but compact growth – or growth at higher densities, is friendlier to the environment than sprawl or even some categories of rural growth. Table 12 shows that accommodating dwelling units at urban densities – above 4 units per acre - produces significantly less total impervious area than the same amount of dwelling constructed at lower densities – or below 1 unit per acre. Typical neighborhood densities are as follows:

- Five acre lots are typical in rural Thurston County.
- One acre lots were common in the 1970s, but now are considered urban sprawl. They are found in older suburban neighborhoods.
- Four units per acre is typical of new suburban subdivisions in Thurston County.
- Eight dwellings per acre is typical of traditional urban neighborhoods such as those on the Eastside and Westside of Olympia, with a mixture of single-family, duplexes, and town homes.
- Thirty dwelling units per acre are typical condominiums or townhouse type apartments.
- One hundred units per acre is typically urban apartments or condos with limited parking, such as the Boardwalk apartments in downtown Olympia.

TABLE 12: DENSITY AND TOTAL IMPERVIOUS AREA. LOCAL CONDITIONS.

Net Density	Acres of Land	Percent Total Impervious Surface (TIA)	Acres of Total Impervious Surface
1 du/5 acres	350,000	3%	10,500
1 du/acre	70,000	9%	6,300
4 du/acre	17,500	30%	5,250
8 du/acre	8,400	42%	3,530
30 du/acre	2,300	51%	1,170
100 du/acre	700	55%	385

Both the population forecast and estimates of buildout – or the culmination of adopted land use plans – are based on zoning and development regulations that are in place today. Local Comprehensive Plans are due to be updated by 2014 under the Growth Management Act. As the community examines issues related to growth and planning, the ability to forecast future impervious area conditions based on alternatives to the current plans is an important tool for policy makers and staff.

VII. LIST OF MAPS

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VIII. REFERENCES

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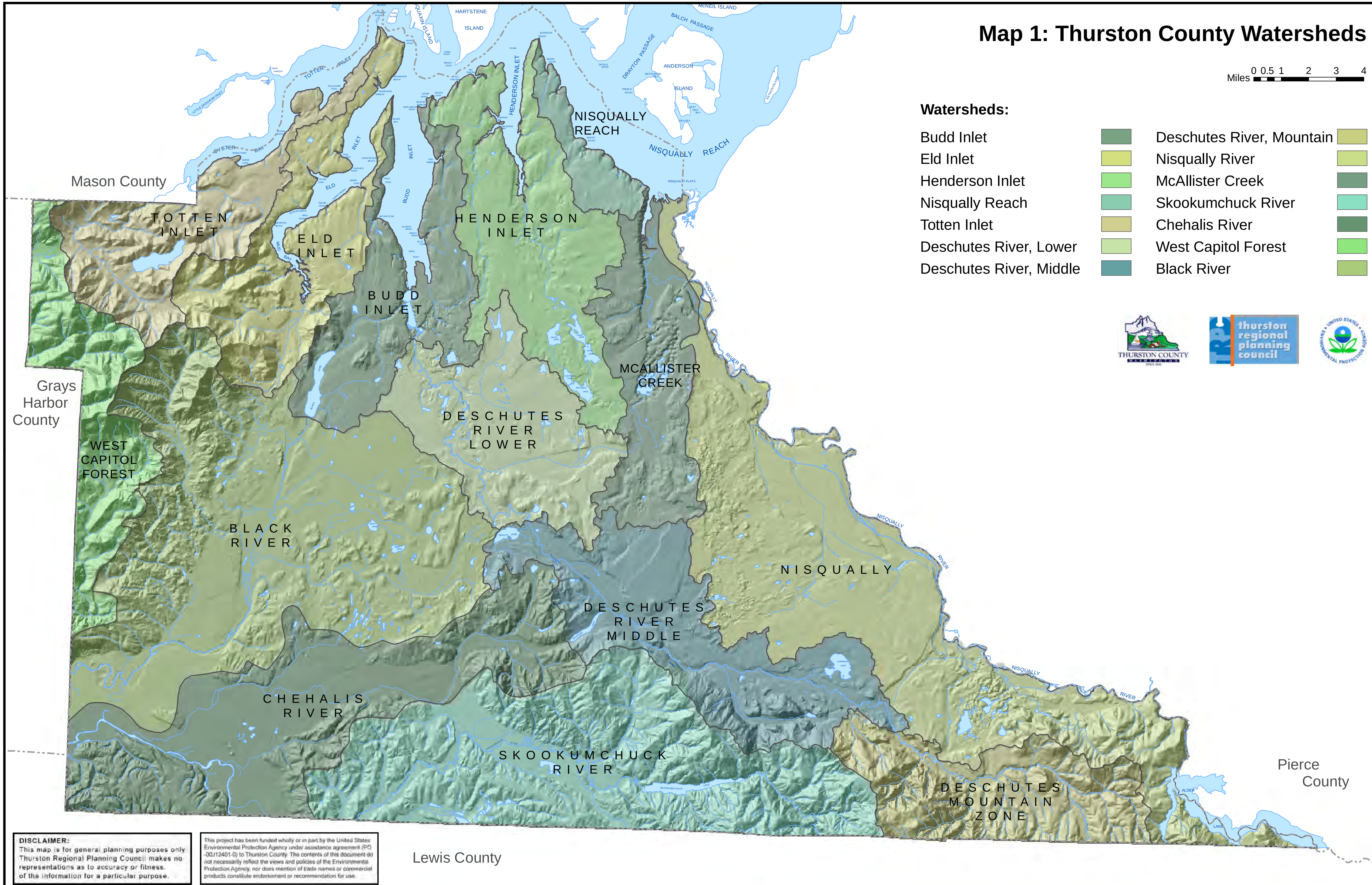

February 7, 2011

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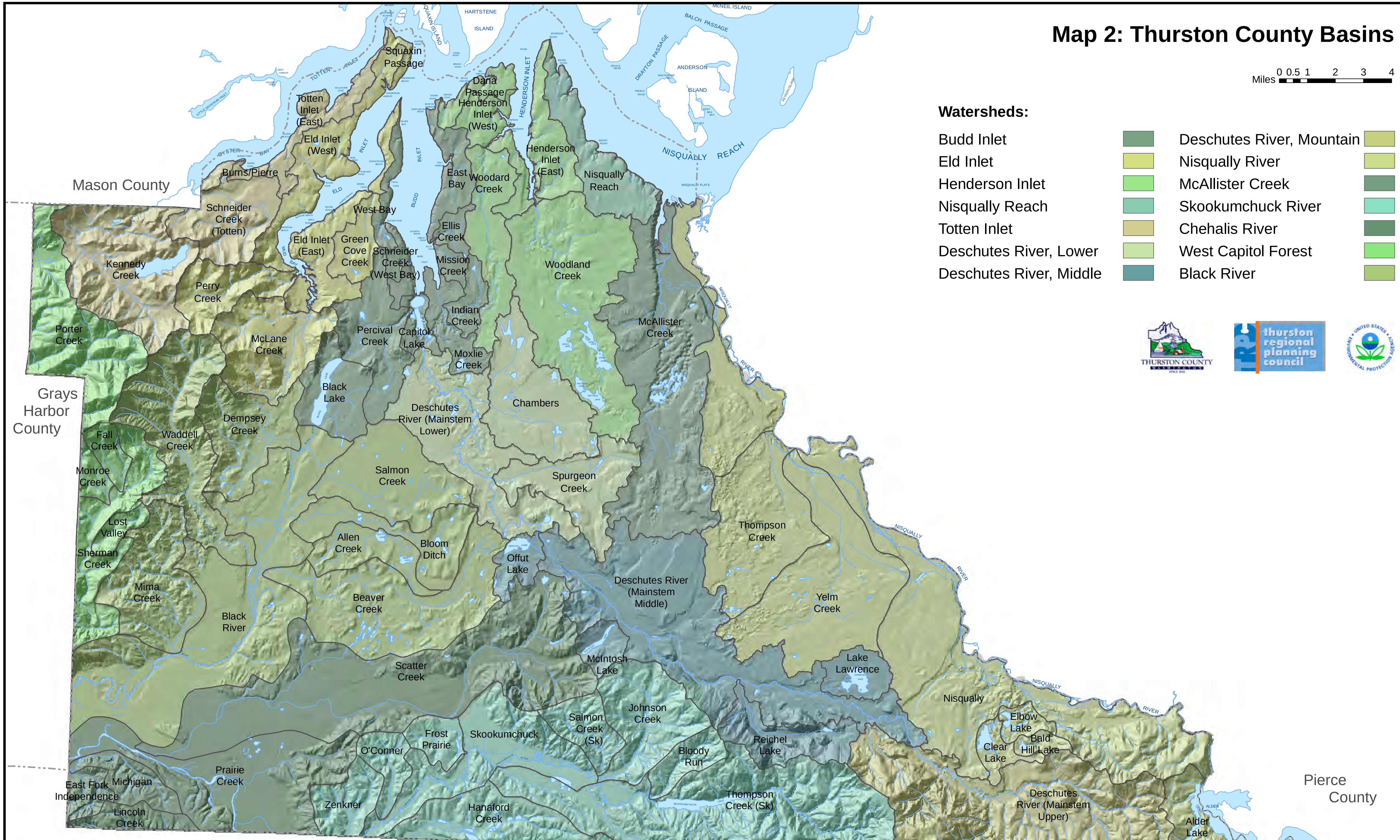
Map 2: Thurston County Basins



DISCLAIMER:
This map is for general planning purposes only Thurston Regional Planning Council makes no representations as to accuracy or fitness of the information for a particular purpose.

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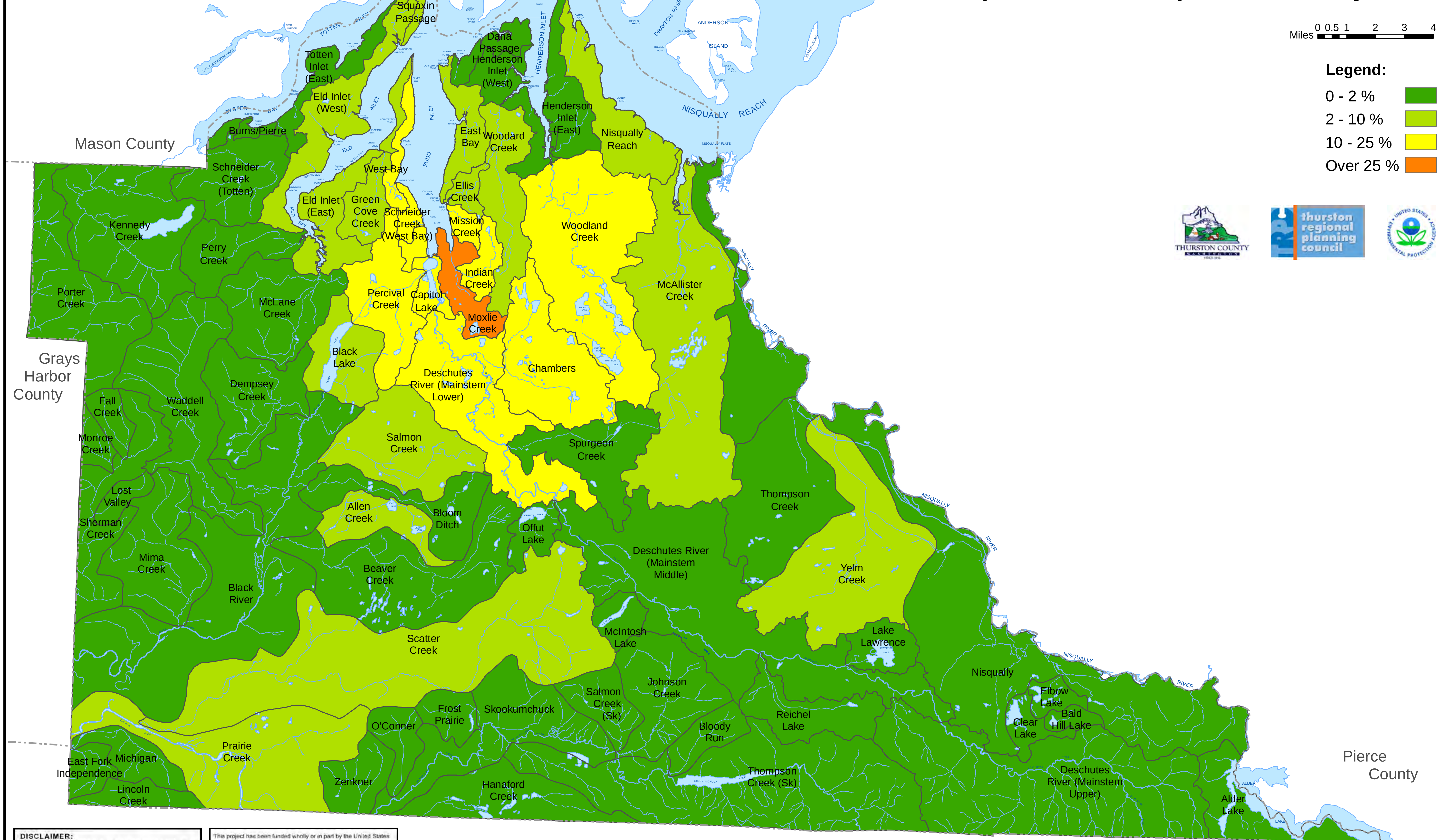
Map 3: 1991 Total Impervious Area by Basin



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February 7, 2011

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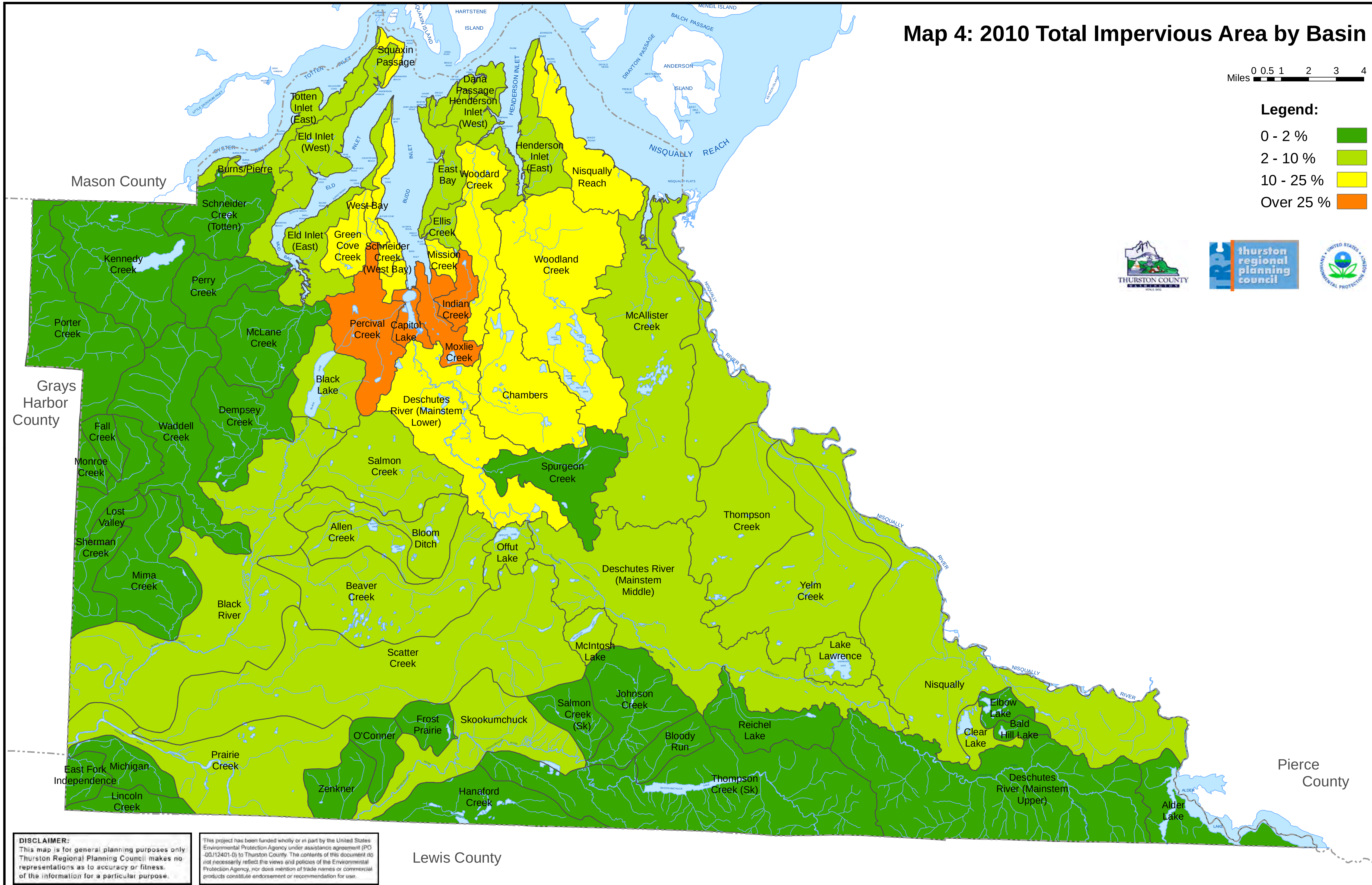
Map 4: 2010 Total Impervious Area by Basin
Miles 0 0.5 1 2 3 4
Legend:
0 - 2 %
2 - 10 %
10 - 25 %
Over 25 %
thurston regional planning council
THURSTON COUNTY
Mason County
Grays Harbor County
Pierce County
Lewis County
NISQUALLY REACH
HENDERSON INLET
Squaxin Passage
Totten Inlet (East)
Eld Inlet (West)
Burns/Pierre
Dana Passage
Henderson Inlet (West)
Henderson Inlet (East)
Nisqually Reach
East Bay
Woodard Creek
West Bay
Schneider Creek (Totten)
Ellis Creek
Eld Inlet (East)
Green Cove Creek
Schneider Creek (West Bay)
Mission Creek
Woodland Creek
Kennedy Creek
Perry Creek
Indian Creek
McAllister Creek
Porter Creek
McLane Creek
Percival Creek
Capitol Lake
Moxlie Creek
Black Lake
Chambers
Deschutes River (Mainstem Lower)
Dempsey Creek
Fall Creek
Waddell Creek
Salmon Creek
Spurgeon Creek
Monroe Creek
Thompson Creek
Lost Valley
Allen Creek
Bloom Ditch
Sherman Creek
Offut Lake
Deschutes River (Mainstem Middle)
Mima Creek
Beaver Creek
Yelm Creek
Black River
McIntosh Lake
Lake Lawrence
Scatter Creek
Nisqually
Salmon Creek (Sk)
Johnson Creek
Elbow Lake
Frost Prairie
Skookumchuck
Bald Hill Lake
O'Conner
Reichel Lake
Clear Lake
Bloody Run
Prairie Creek
East Fork Independence
Michigan
Thompson Creek (Sk)
Deschutes River (Mainstem Upper)
Zenkner
Hanaford Creek
Lincoln Creek
Alder Lake
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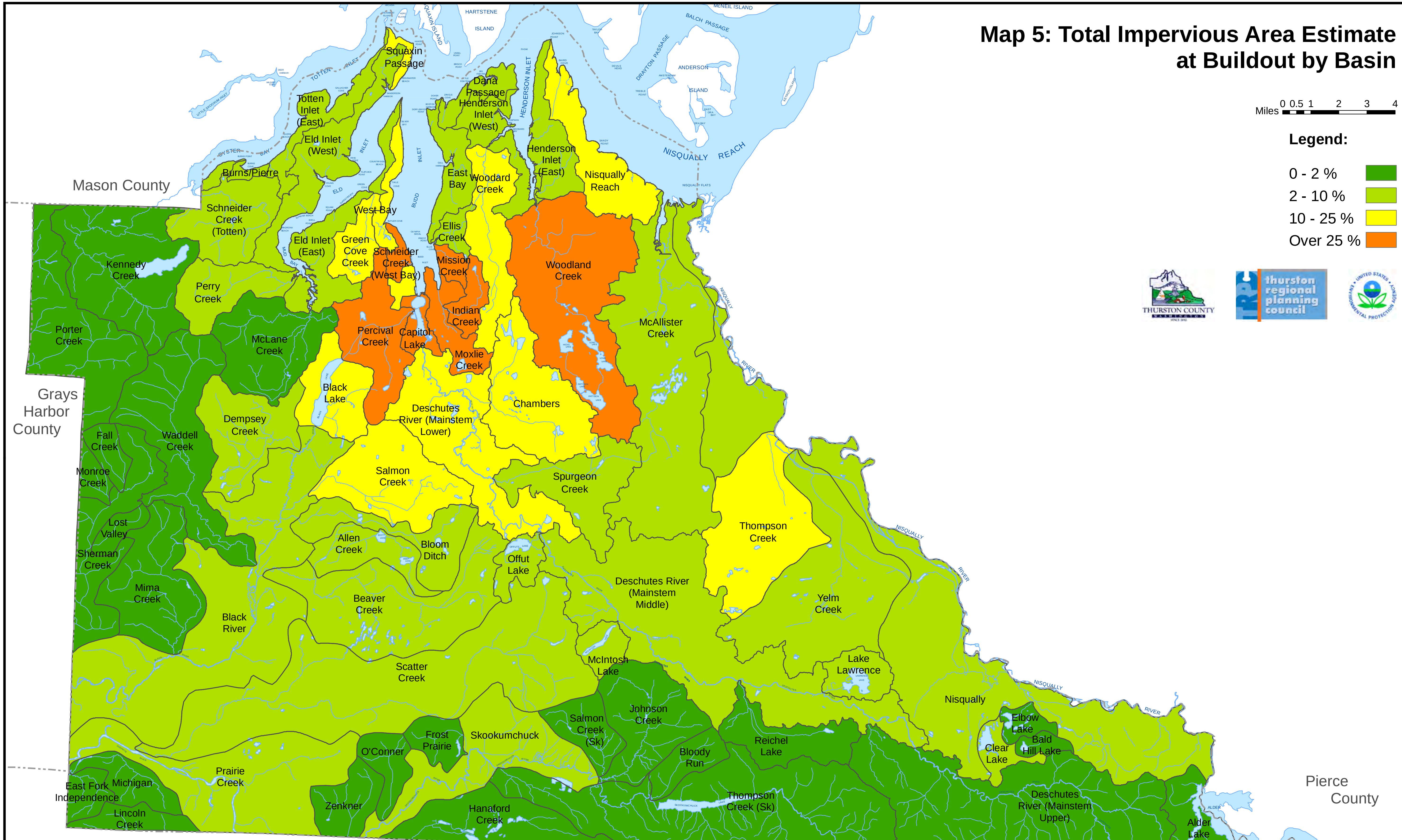
Map 5: Total Impervious Area Estimate at Buildout by Basin



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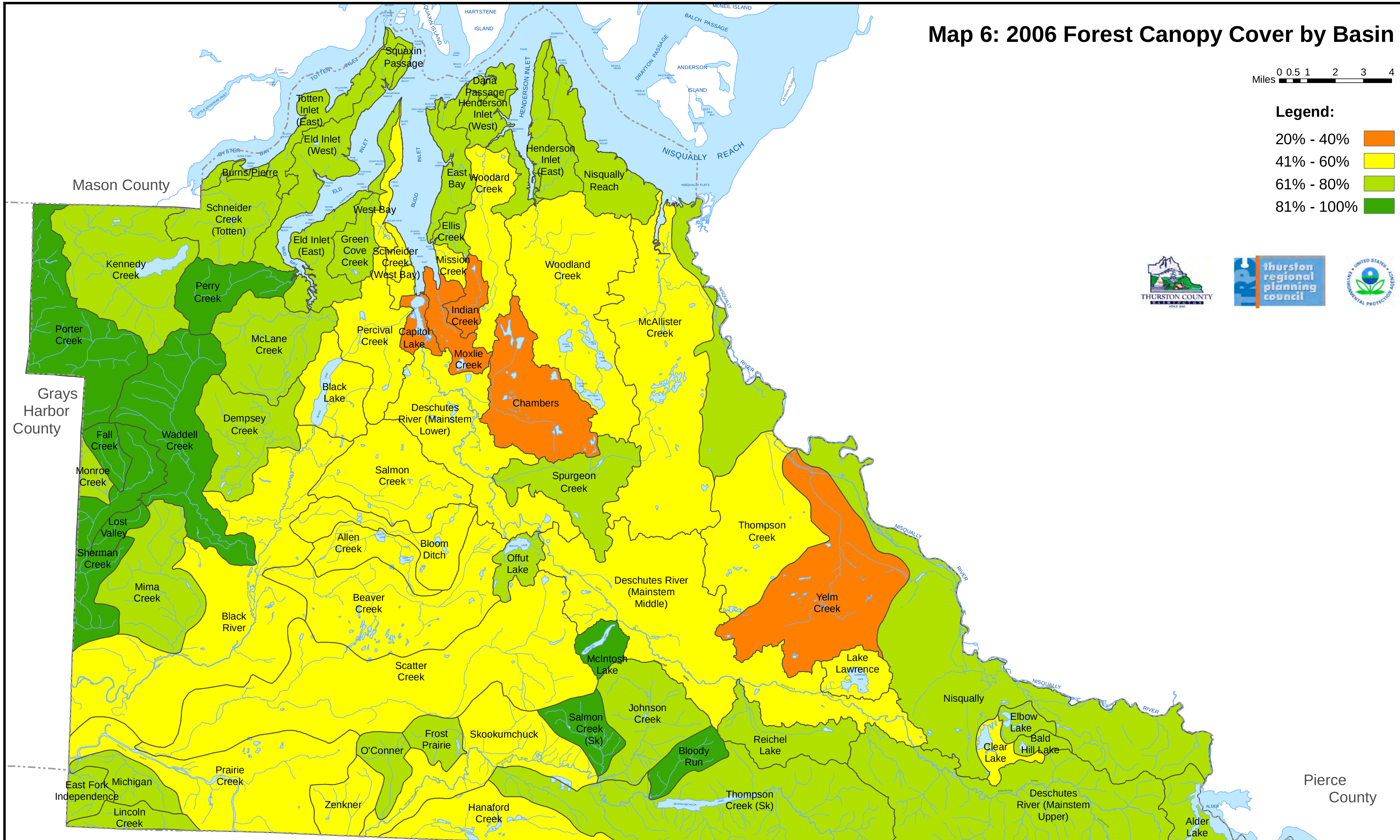
Map 6: 2006 Forest Canopy Cover by Basin



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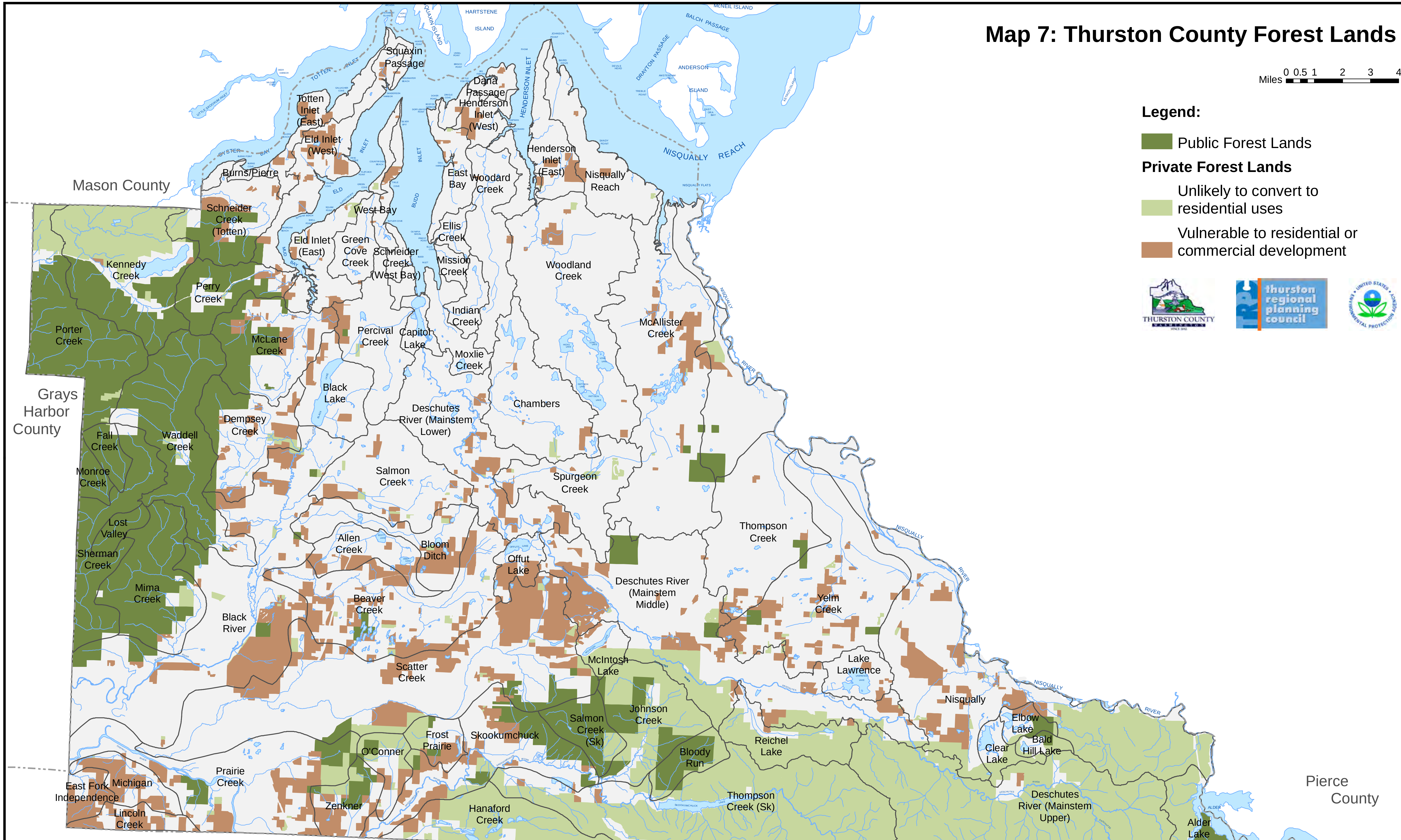
Map 7: Thurston County Forest Lands



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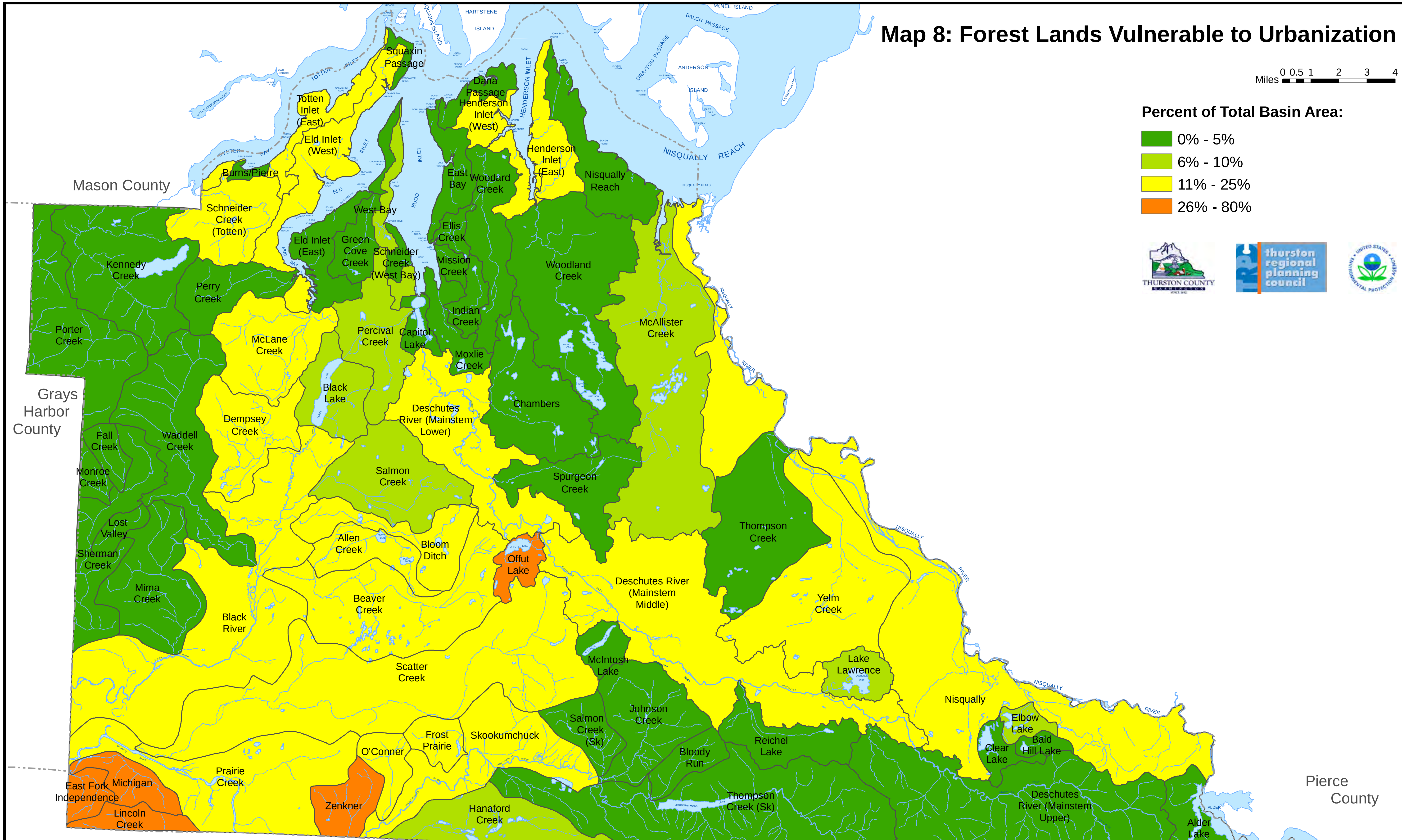
Map 8: Forest Lands Vulnerable to Urbanization



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