Climate Change and Population Growth Impacts on Stormwater Management Needs

EPA Puget Sound Watershed Management Assistance Program FY2009

Jeff Burkey
King County
Department of Natural Resources and Parks
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Email: jeff.burkey@kingcounty.gov

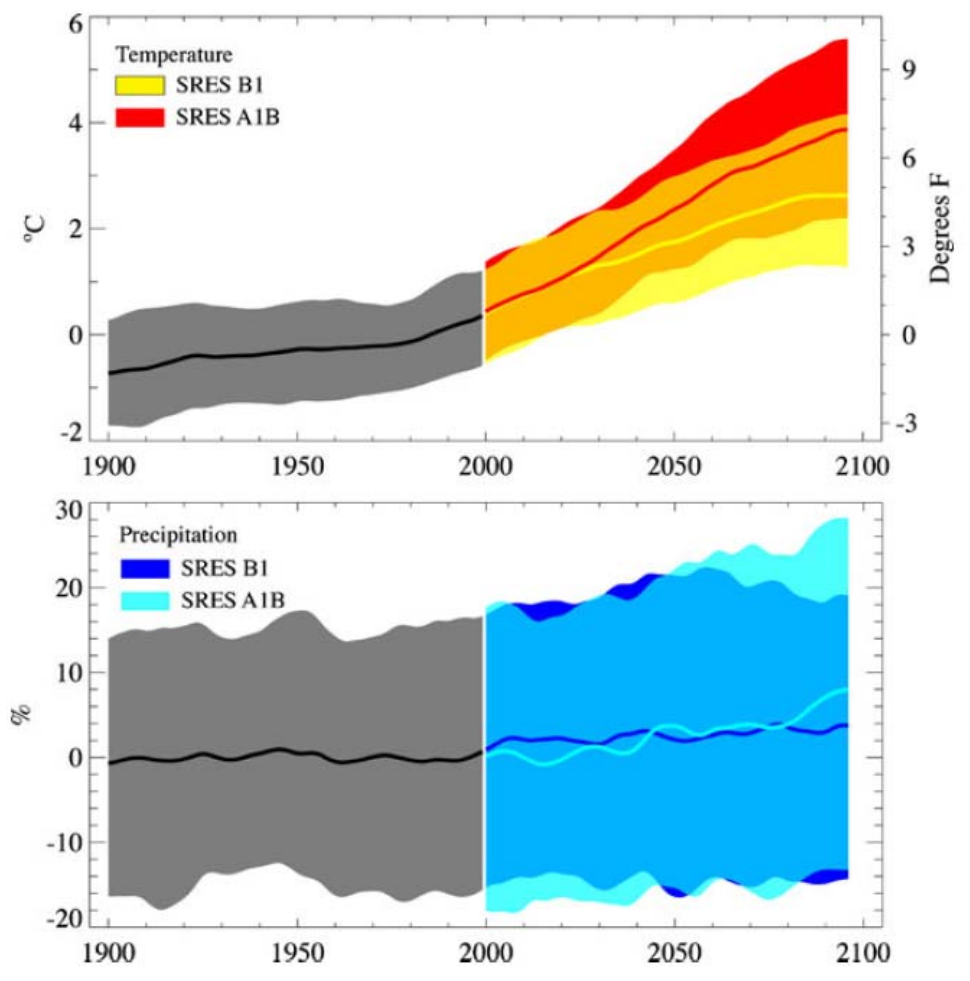
What

- Leverage previous climate change studies as much as possible
- Characterize conditions as *locally* as possible
- Project changes in future land use
- Quantify possible impacts on stormwater infrastructure and streams

Why

- Inform stormwater agencies of what might be coming as a consequence of projected changes in local rainfall

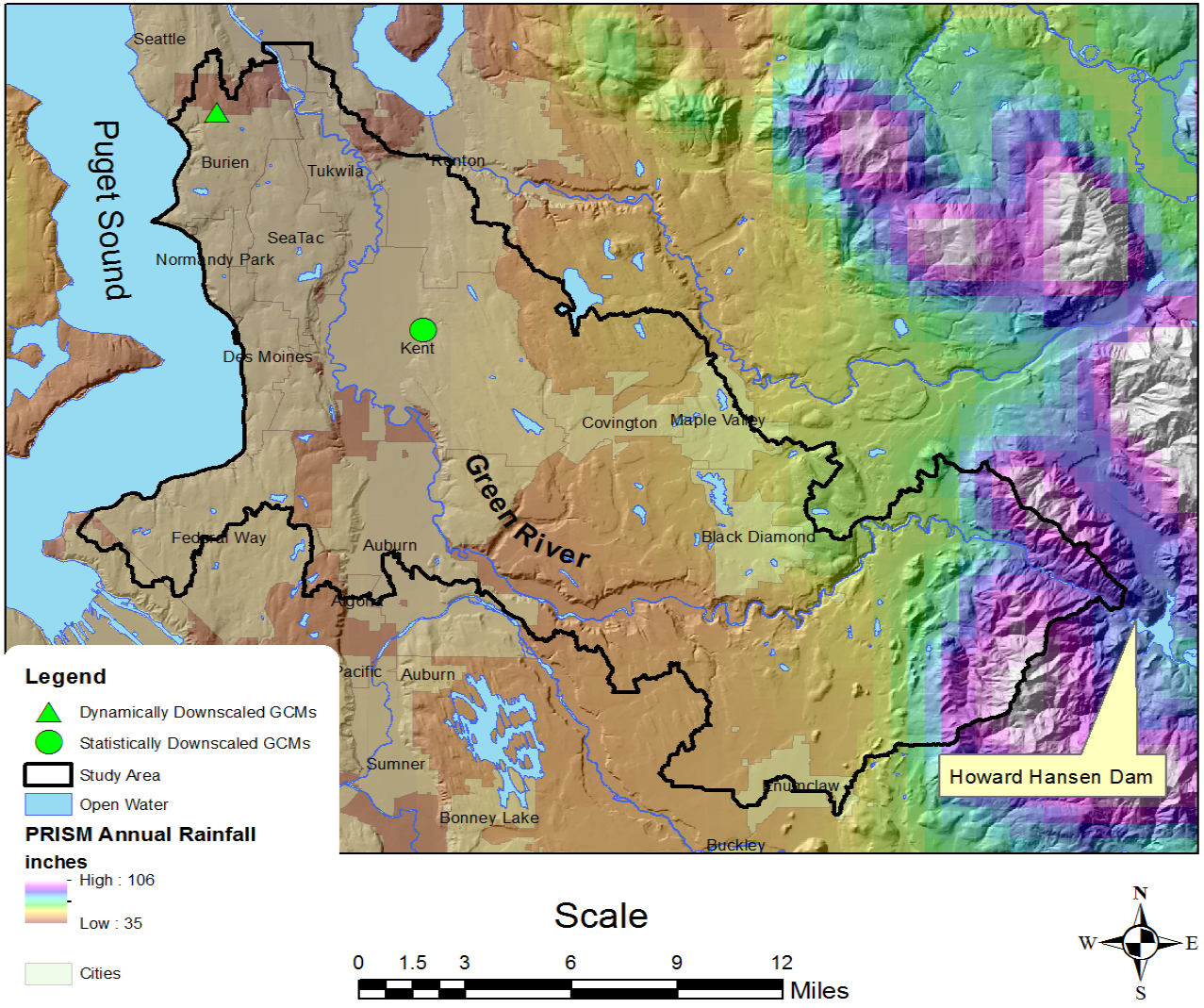
Climate Modeling



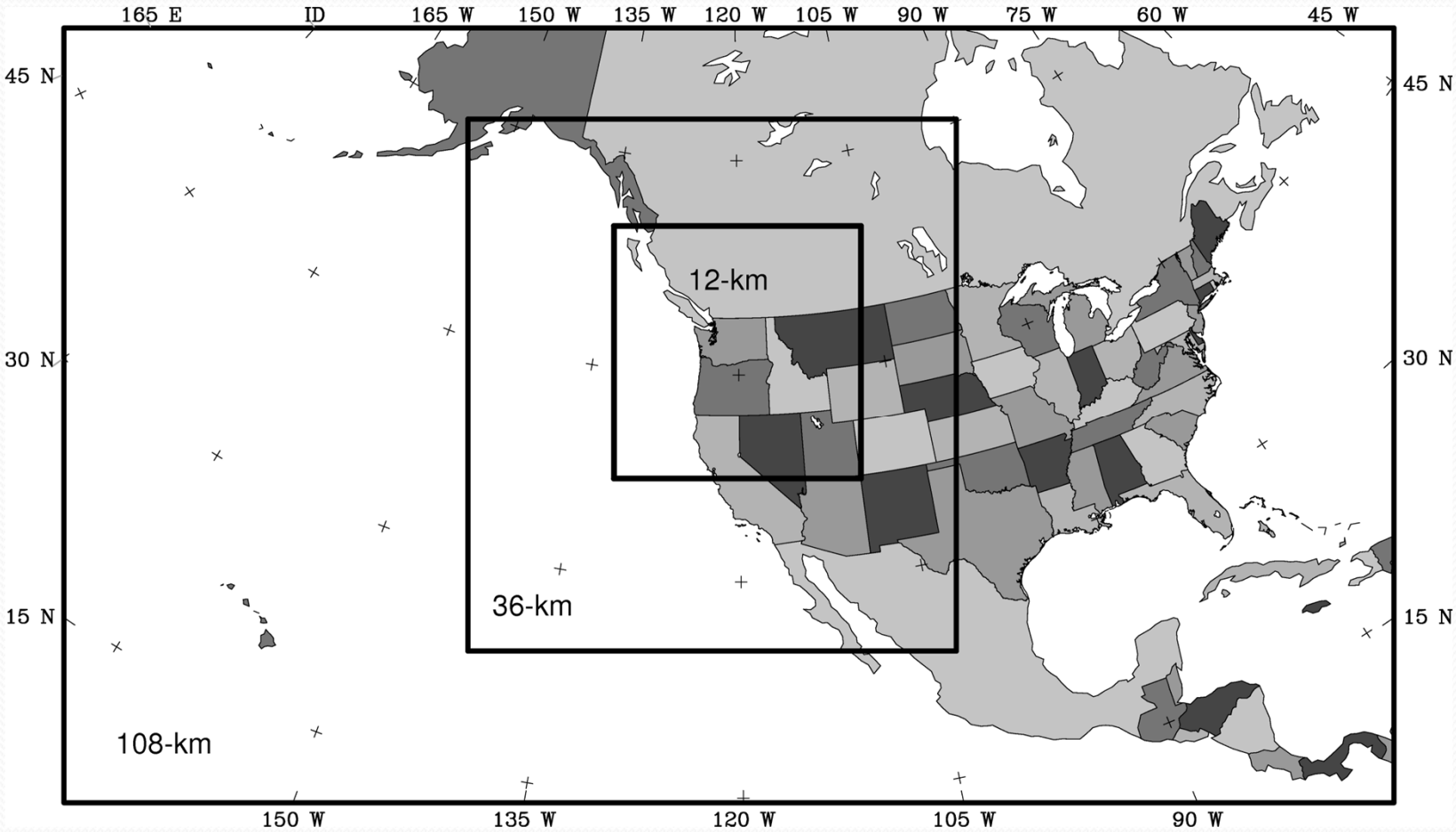
Source: Mote and Salathe 2010

- GCM's
  - consistent for temperature modeling
  - consistent for snow pack and water supply
  - Variable for rainfall

Study Area


Seattle
Puget Sound
Burien
Tukwila
Renton
SeaTac
Normandy Park
Des Moines
Kent
Covington
Maple Valley
Green River
Federal Way
Auburn
Black Diamond
Auburn
Sumner
Bonney Lake
Buckley
Howard Hansen Dam
Legend
Dynamically Downscaled GCMs
Statistically Downscaled GCMs
Study Area
Open Water
PRISM Annual Rainfall
inches
High : 106
Low : 35
Cities
Scale
0 1.5 3 6 9 12
Miles
N
W
E
S

Global Climate Modeling Downscaling



Source: CIG

Method of Analyses

Compare using Relative Percent Difference

$$RPD = \frac{(Future\ -Historical)}{Historical} * 100$$

1. Rainfall patterns using annual maximum daily rainfall (all modeling scenarios)
2. Stormwater ponds using detention volumes
3. Flashiness using High Pulse Counts

Annual Maximum Daily Rainfall

- 20 GCMs (Statistical)
  - +14% avg
  - -7% to +56%
  - Storm sizes generally increase
- 2 GCMs (Dynamic)
  - Small storms get smaller, big storms get bigger (A1B)
  - A2, all storms get bigger (+18% avg)

	Dynamic		Statistical		
Statistic	ECHAM5 | A1B	CCSM3 | A2	A1B Avg	A1B Min	A1B Max
Mean	4%	18%	11%	-1%	29%
100%	6%	53%	24%	-8%	68%
99%	7%	48%	20%	-9%	51%
95%	10%	29%	14%	-7%	56%
90%	-6%	20%	12%	-5%	63%
75%	8%	11%	3%	-10%	19%
50%	8%	17%	13%	3%	22%
25%	2%	12%	18%	6%	32%
10%	-9%	22%	19%	7%	41%
5%	-17%	25%	12%	-2%	24%
1%	-14%	40%	5%	-16%	19%
0%	-10%	46%	4%	-21%	19%

Context for Statistically Significant Changes in Rainfall (Statistical)

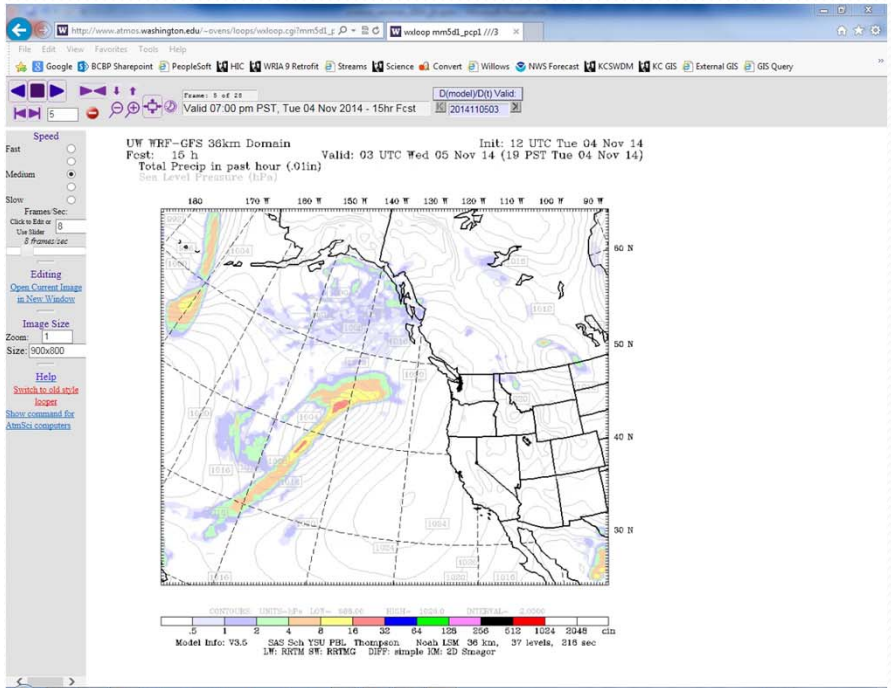
2020 - 2050

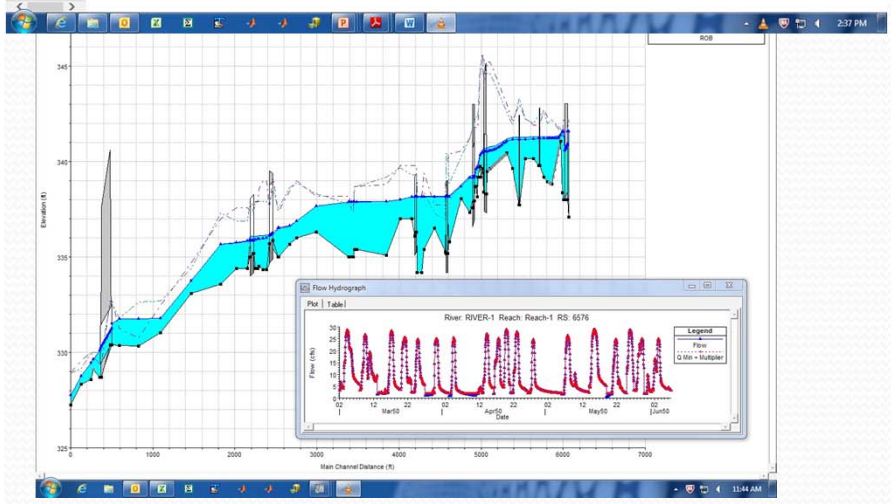
GCM	Wilcoxon Rank Sum (*p*)	Kolmogorov-Smirnov (*p*)	Mann-Kendall		Sen's Slope (inches/yr.)
			tau	*p*	
BCCR	0.267	0.200	0.31	**0.019**	0.0205
CGMCM 3.1 T47	**0.031**	**0.026**	0.40	**0.002**	0.0503
CGMCM 3.1 T63	0.228	0.200	0.25	0.054	0.0198
CCSM3	0.130	0.200	0.08	0.568	0.0080
CNRM_CM3	0.133	0.200	0.06	0.669	0.0049
CSIRO_3_5	0.412	0.342	0.20	0.134	0.0132
ECHAM5	0.191	0.200	0.15	0.254	0.0104
ECHO_G	0.501	0.342	0.03	0.830	0.0016
FGOALS_0_G	0.912	0.760	0.06	0.643	0.0029
GFDL_CM2_0	0.420	0.537	0.22	0.087	0.0177
GFDL_CM2_1	0.412	0.760	0.31	**0.017**	0.0234
GISS_AOM	0.196	0.109	-0.09	0.521	-0.0065
GISS_ER	0.178	0.200	0.01	0.943	0.0011
HADCM	0.095	0.055	-0.04	0.748	-0.0031
HADGEM1	0.348	0.342	0.03	0.803	0.0035
INMCM3_0	**0.035**	**0.005**	0.03	0.830	0.0027
IPSL_CM4	0.154	0.200	-0.06	0.669	-0.0051
MIROC_3.2	0.107	0.200	0.05	0.695	0.0048
MIROC_3.2_HI	0.064	0.109	0.18	0.164	0.0171
PCM1	0.412	0.537	0.13	0.335	0.0103

2001 - 2098

GCM	Wilcoxon Rank Sum (p)	Kolmogorov-Smirnov (p)	Mann-Kendall		Sen's Slope (inches/yr)
			tau	*p*	
BCCR	**0.025**	0.122	0.10	0.156	0.002
CGMCM 3.1 T47	**0.000**	**0.000**	0.12	0.086	0.003
CGMCM 3.1 T63	**0.000**	**0.001**	0.10	0.166	0.002
CCSM3	**0.029**	**0.042**	0.00	0.993	0.000
CNRM_CM3	**0.023**	0.077	0.24	**0.000**	0.006
CSIRO_3_5	**0.034**	0.129	0.21	**0.002**	0.005
ECHAM5	0.057	0.103	0.18	**0.008**	0.005
ECHO_G	**0.027**	0.135	0.18	**0.007**	0.004
FGOALS_0_G	0.430	0.398	0.01	0.922	0.000
GFDL_CM2_0	**0.034**	0.145	0.15	**0.033**	0.004
GFDL_CM2_1	0.192	0.322	-0.01	0.906	0.000
GISS_AOM	**0.002**	**0.005**	0.11	0.104	0.002
GISS_ER	**0.010**	**0.026**	0.14	0.053	0.004
HADCM	**0.013**	**0.017**	0.11	0.104	0.002
HADGEM1	**0.043**	0.170	0.09	0.215	0.002
INMCM3_0	**0.000**	**0.000**	0.12	0.080	0.003
IPSL_CM4	**0.000**	**0.002**	0.22	**0.002**	0.006
MIROC_3.2	**0.000**	**0.000**	0.14	**0.041**	0.004
MIROC_3.2_HI	**0.001**	**0.002**	0.25	**0.000**	0.005
PCM1	**0.029**	0.161	0.06	0.394	0.001

Stormwater Pond Volumes

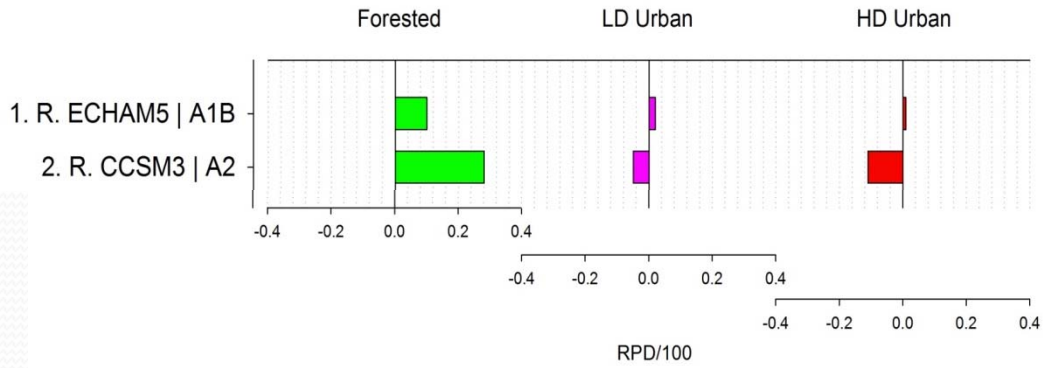




- Hypothetical Catchment with Low Density Residential Land Use Distribution
- Designed to Level 2 Flow Control Targets
- Modeling Scenario (ECHAM5 |A1B)
  - <1% increase
- Modeling Scenario (CCSM3 | A2)
  - +11% increase

Flashiness High Pulse Counts

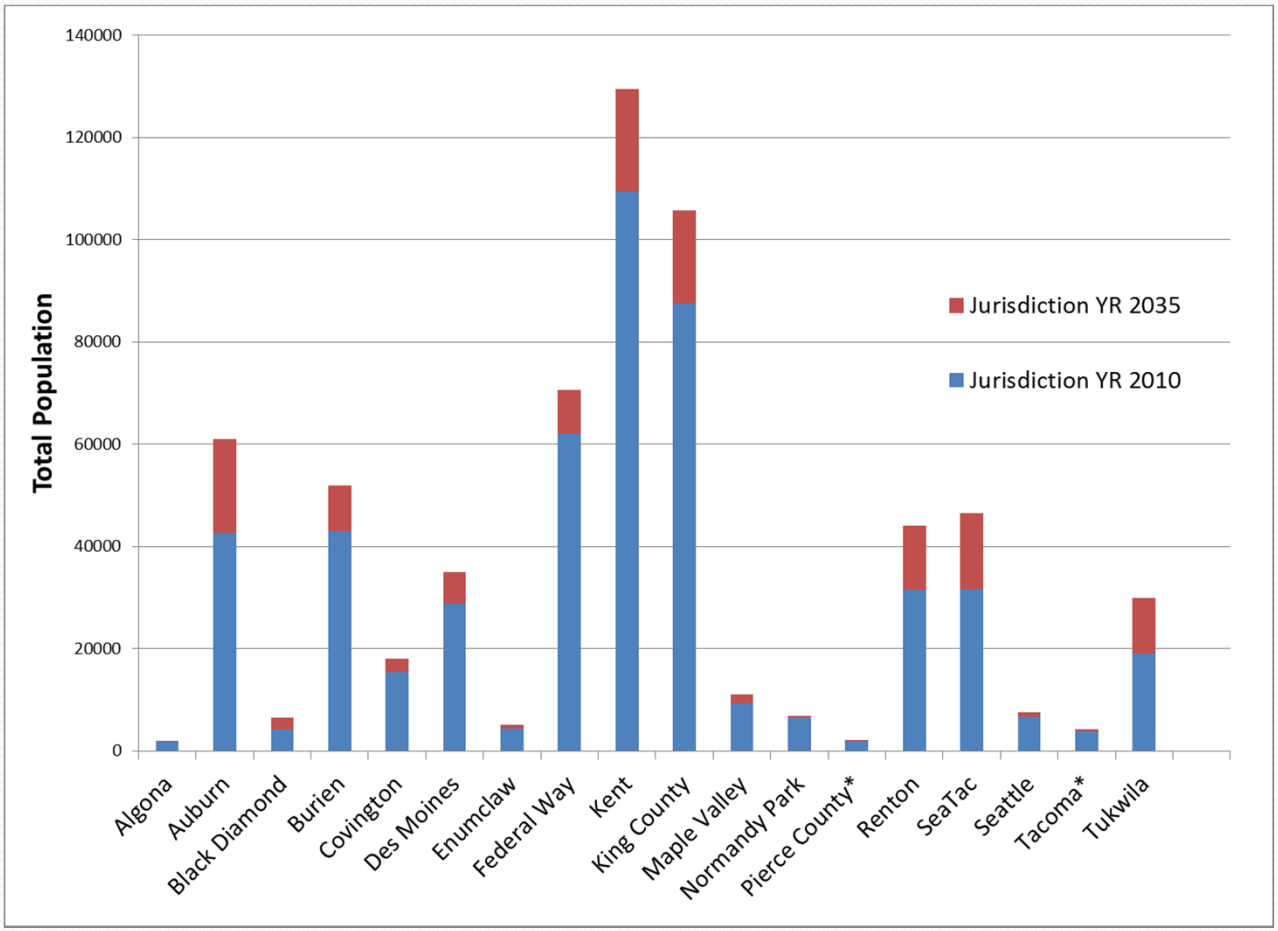
- Forested HPCs increase
- Developed landscapes may see little or no increase in frequency, just bigger storms



GCM and GHG Emission Scenario	Land Use Land Cover	Wilcoxon Rank Sum (p)	Kolmogorov -Smirnov (p)	*Welch's t-test (p)***
ECHAM | A1B	Forest	0.557	0.342	--
	LD Urban	0.682	0.342	--
	HD Urban	0.911	> 0.999	--
CCSM3|A2	Forest	**0.02**	0.200	**0.017**
	LD Urban	0.749	0.537	--
	HD Urban	**0.011**	0.055	--

**missing p-values indicate one or both of the HPC time series were not normally distributed using Quantile-quantile plot test for a valid parametric 2-sample *t*-test.
Note: highlighted cells in red indicate p-values ≤ 0.05.

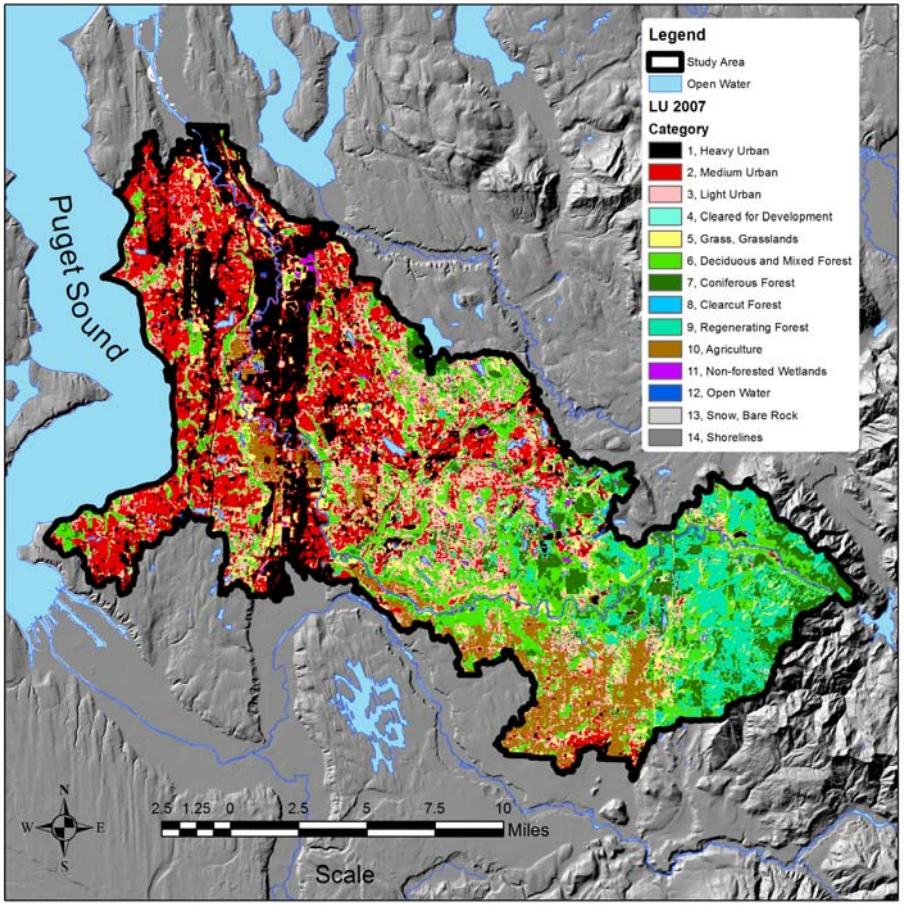
Projected Population Growth by Jurisdiction in 2035



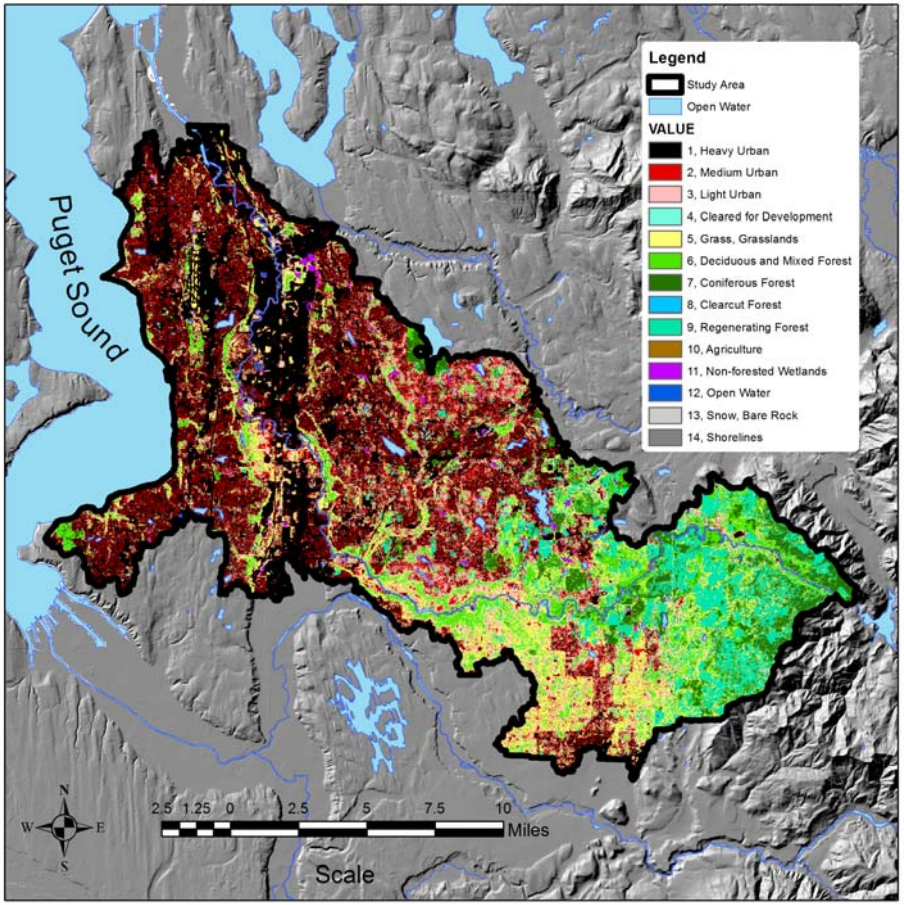
- 510,000 (2010)
- 640,000 (2035)
- 25% increase

Land Use Land Cover

Existing 2007

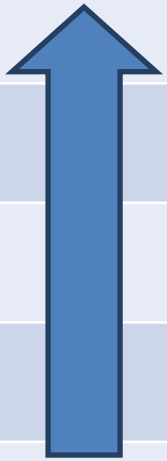


2040 BAU

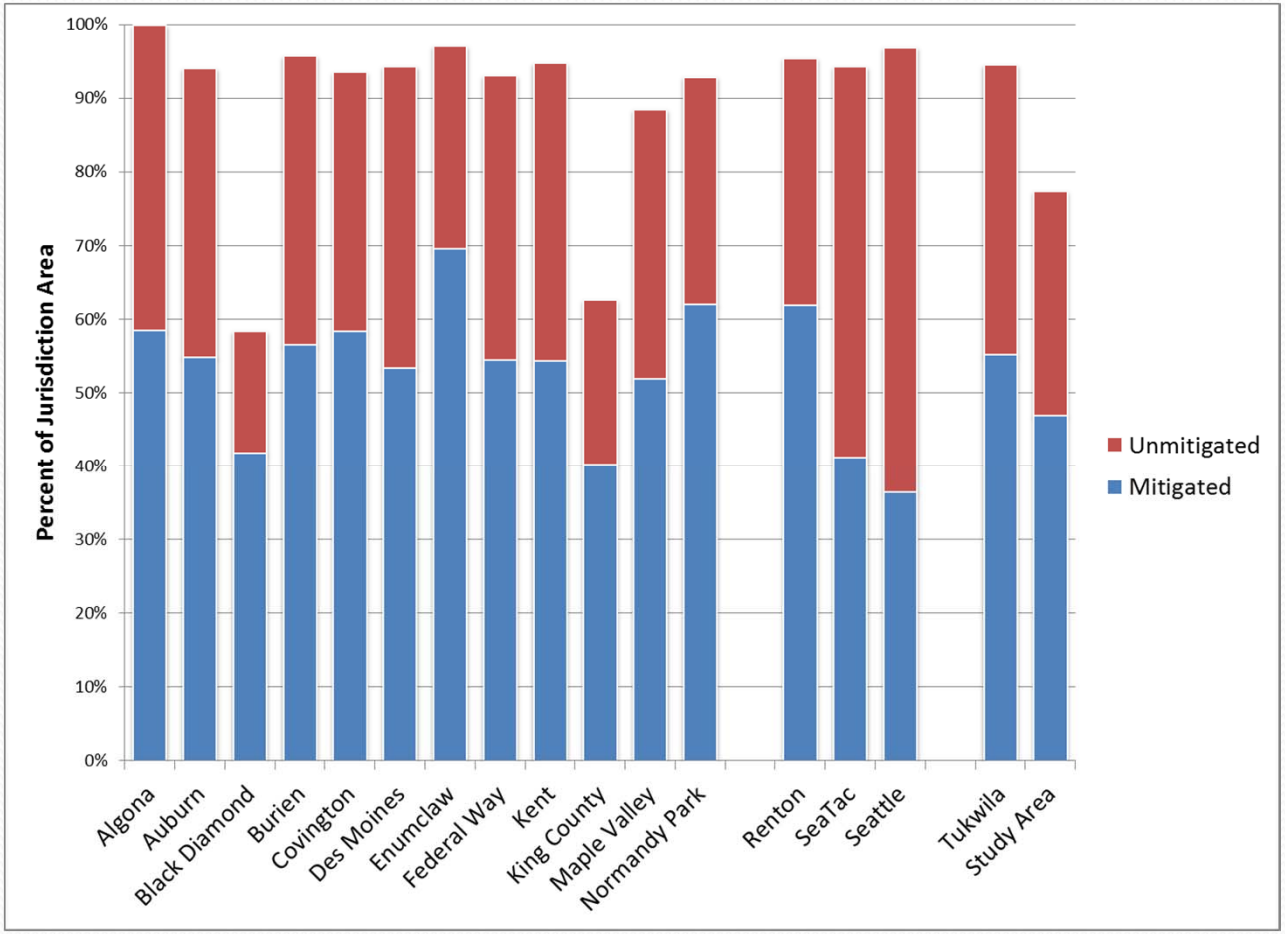


Applying Triggers to Land Use

Category	Level of disturbance
Heavy Urban (> 80% Imp.)	High
Medium Urban (50-80% Imp.)	
Light Urban (20-50% Imp.)	
Grass, grasslands	
Agriculture	
Forest, and all other	Low



Future Development by Jurisdiction



Summary (Land Use)

- Population is projected to increase ~25% by 2035
- Development in the study area is projected to increase from 65% to 77%
- 47% (1.5%/yr) of the future development will be mitigated during the course of time assuming current regulations
- 30% (1%/yr) of the future development will still need to be mitigated
- Converting to Urban High, 24% mitigated (0.8%/yr), 53% unmitigated (1.75%/yr)

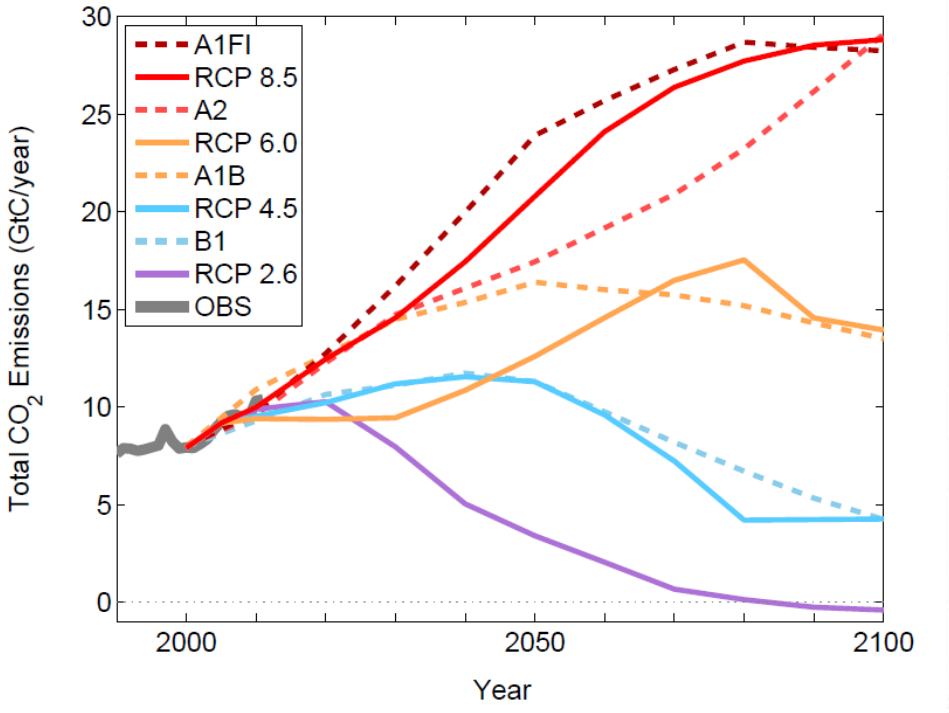
Summary (Climate)

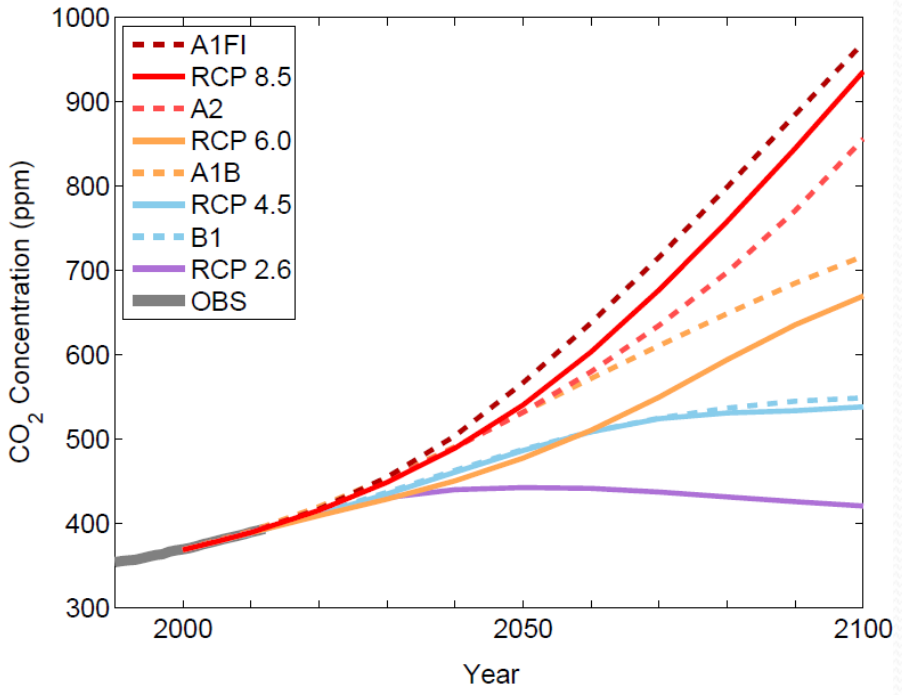
- Storm volumes generally increase, but are wide ranging -/+
- A single balanced climate scenario (ECHAM5 | A1B) marginally increases stormwater pond size (< +1%)
- A pessimistic emission scenario (A2) coupled with a GCM producing larger than ensemble average storms (CCSM3) increases stormwater pond volumes +11% (**LD Residential**)
- Stream flashiness increases for forested conditions
- Landscapes that are already flashy may not see an increase in frequency of flashiness, *maybe* just magnitude.

Questions?

Next Steps: Updated GHG Emission Scenarios (AR5) available for a more comprehensive assessment.

★ Fingers Crossed on getting ECY Grant Award! ★





Source: CIG 2013