The Effects of Climate Change on Low Impact Development Facilities

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The following presentation was given by Doug Beyerlein at the International LID Symposium held at St. Paul, Minnesota, August 2013.

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Clear Creek Solutions' Hydrology Expertise

Clear Creek Solutions, Inc., provides complete range of hydrologic and stormwater modeling services.

- Clear Creek specializes in continuous simulation hydrologic modeling based on HSPF and SWMM.

- We have 30+ years of experience modeling complex hydrologic and stormwater problems.

- We create stormwater facility sizing software for state and local NPDES MS4 permit holders.

- We teach continuous simulation hydrologic modeling workshops.

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Location Modeled

- City of Everett, WA
- 30 miles north of Seattle
- Annual average rainfall = 38 inches

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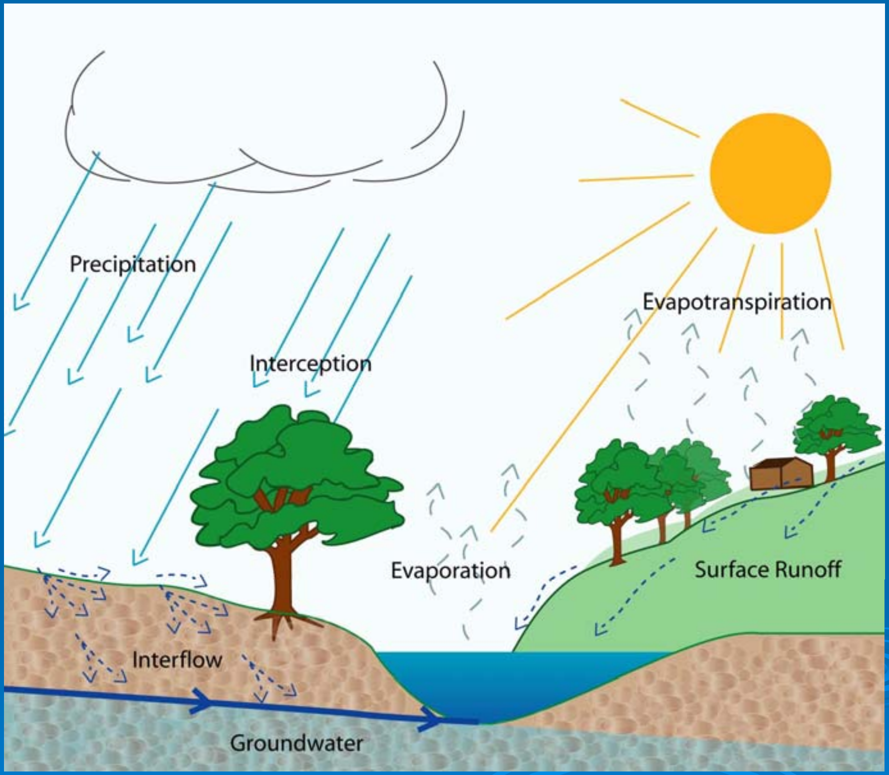
Stormwater LID Modeling

- HSPF continuous simulation hydrology in WWHM.
- Multiple-year hourly historic rainfall used to generate multiple-year hourly runoff data.
- Stormwater runoff = surface runoff + interflow.



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LID facilities modeled

- Bioretention
- Permeable Pavement
- Green Roofs

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How LID Works

- Uses long-term on-site infiltration and evapotranspiration to reduce stormwater runoff.

- What happens between storm events is often more important than what happens during storm events.

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How Climate Change Works

- Changes rainfall patterns (increases or decreases rainfall volume and/or intensity).
- Increases air temperature (increases potential evapotranspiration or PET).

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How Climate Change Works

- Increased rainfall increases stormwater runoff.

- Increased PET decreases stormwater runoff.

- How are LID facilities impacted?

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How Climate Change Works

LID facilities impacts can be calculated in terms of change in:

- runoff annual volume (inches/year)
- peak flows (cfs/acre)

For this work the Q2 (2-year) peak flow was used for calculations.

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Bioretention

- Collect, store, and filter stormwater runoff in a vegetated depression.
- Examples
  - Commercial landscaping, neighborhood drainage

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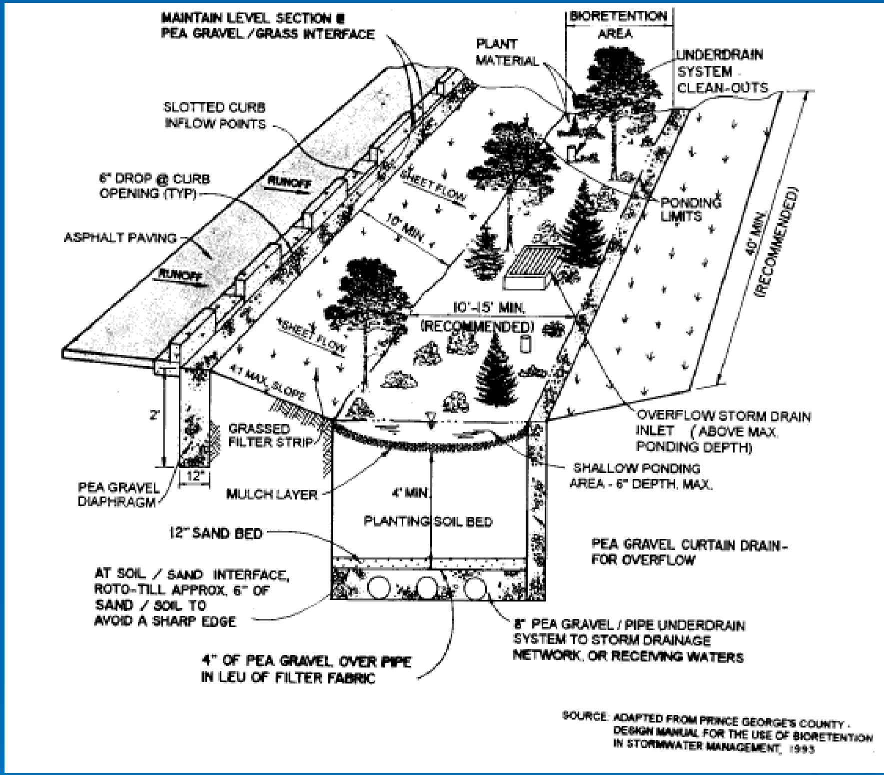
Bioretention

- Reduce total runoff volume by:
  - Increasing evapotranspiration



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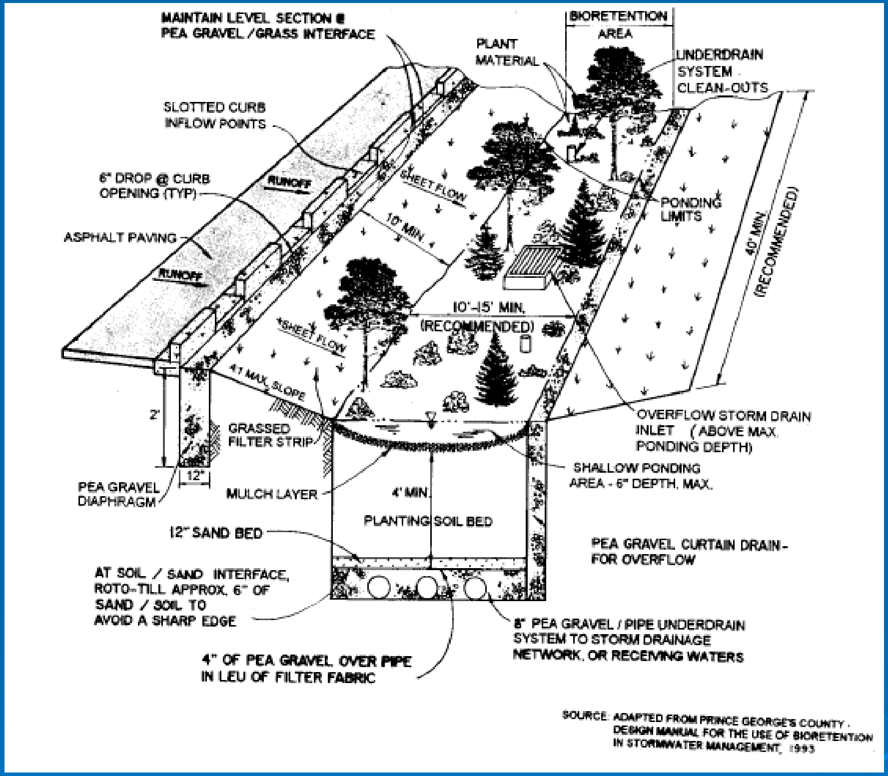
Bioretention

- Reduce Q2 peak flows by:
  - Slowing runoff through soil filtration prior to discharge through underdrain.



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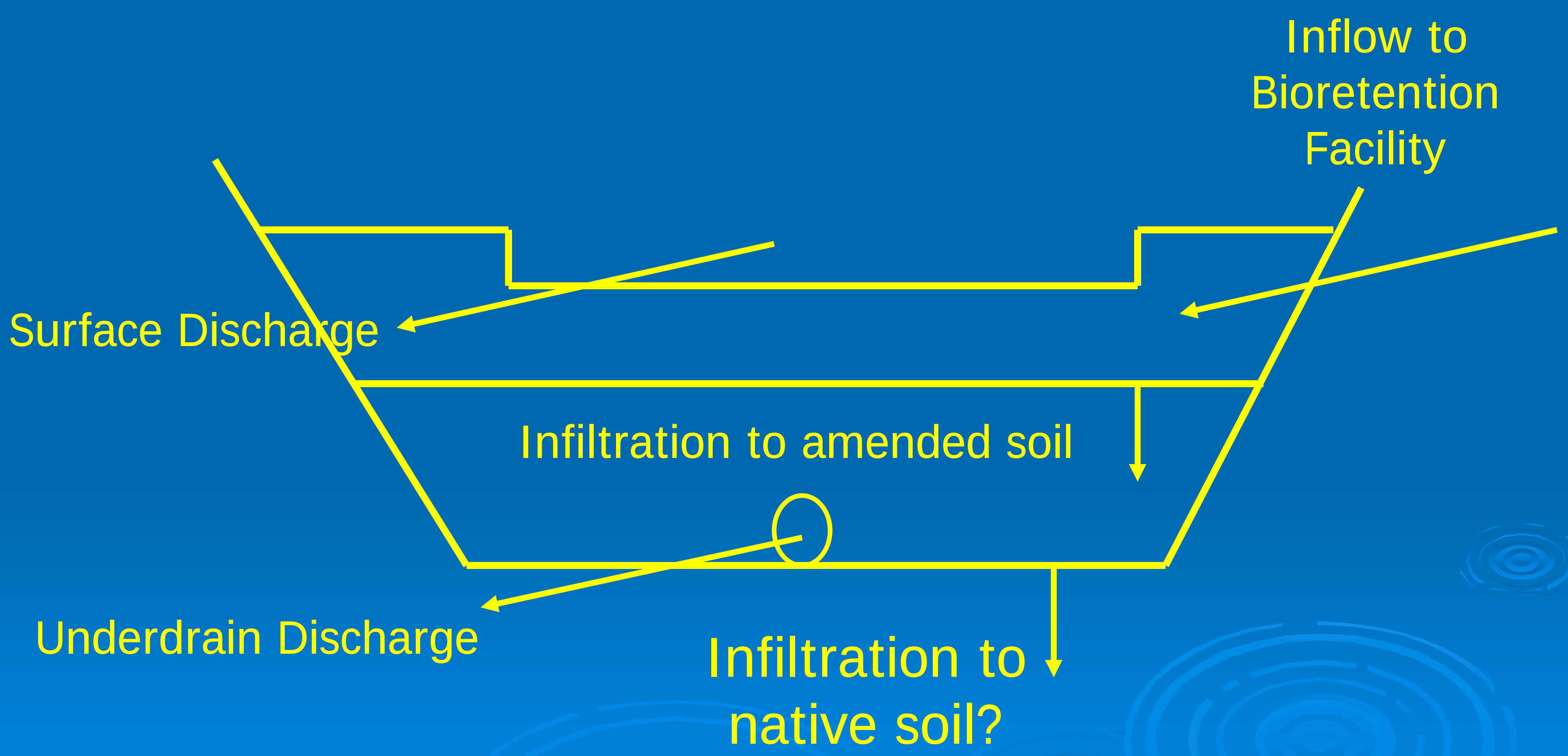
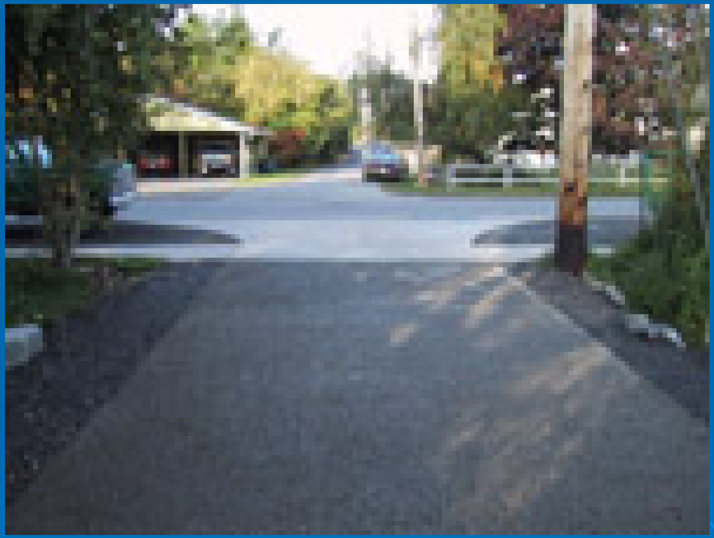
Bioretention Flow Paths



Permeable Pavement

- Infiltrate permeable pavement runoff to the underlying gravel subgrade storage.

- Examples
  - Parking lots
  - Driveways
  - Sidewalks



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Permeable Pavement

- Reduce runoff volume by:
  - No reduction if there is no infiltration to native soils.

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Permeable Pavement

- Reduce Q2 peak flows by:
  - Slowing runoff through storage in gravel subgrade prior to discharge through underdrain.

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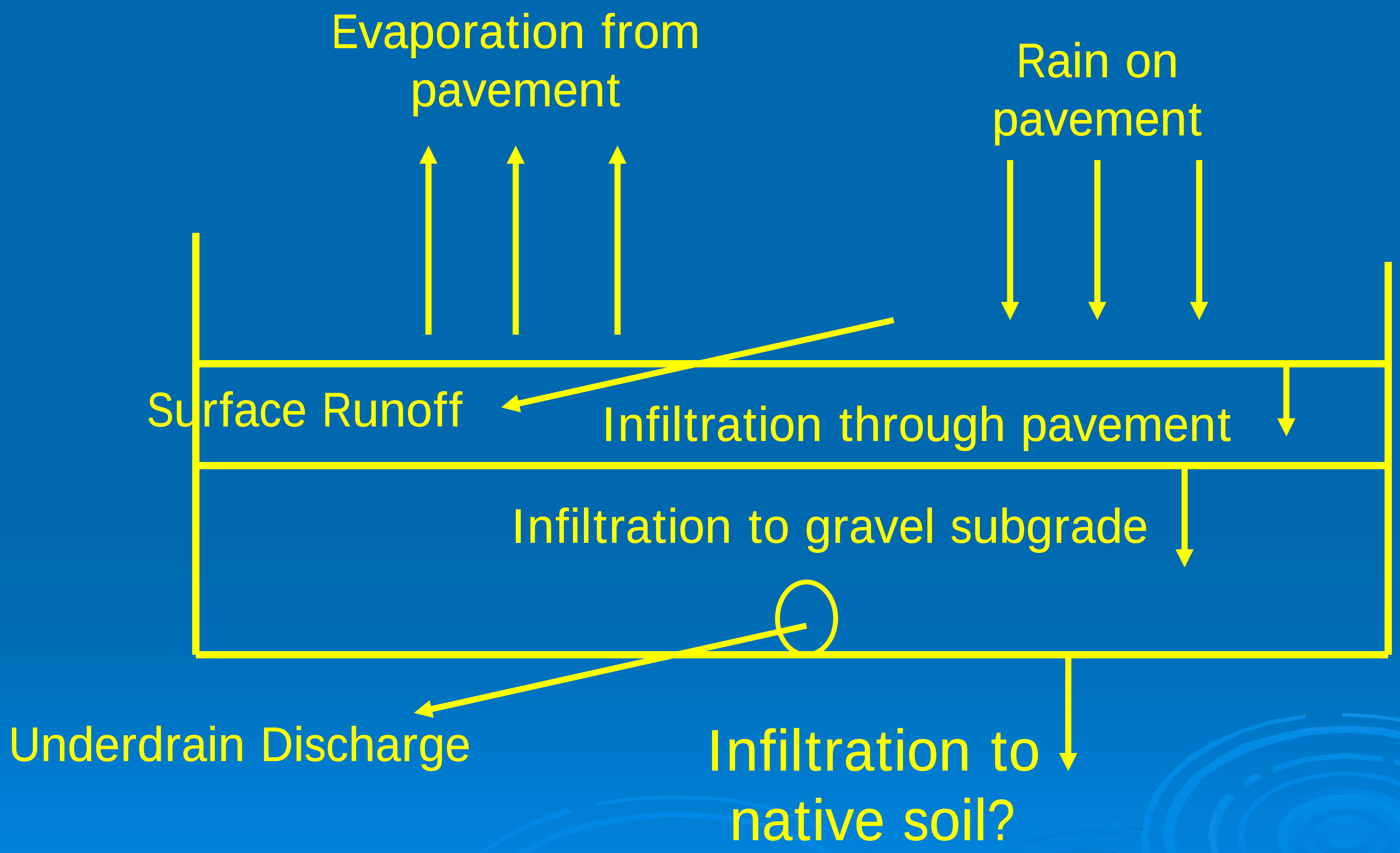
Permeable Pavement Flow Paths



Green Roofs

- Store, evaporate, and transpire roof runoff to the atmosphere.

- Examples
  - Commercial buildings
  - Public buildings

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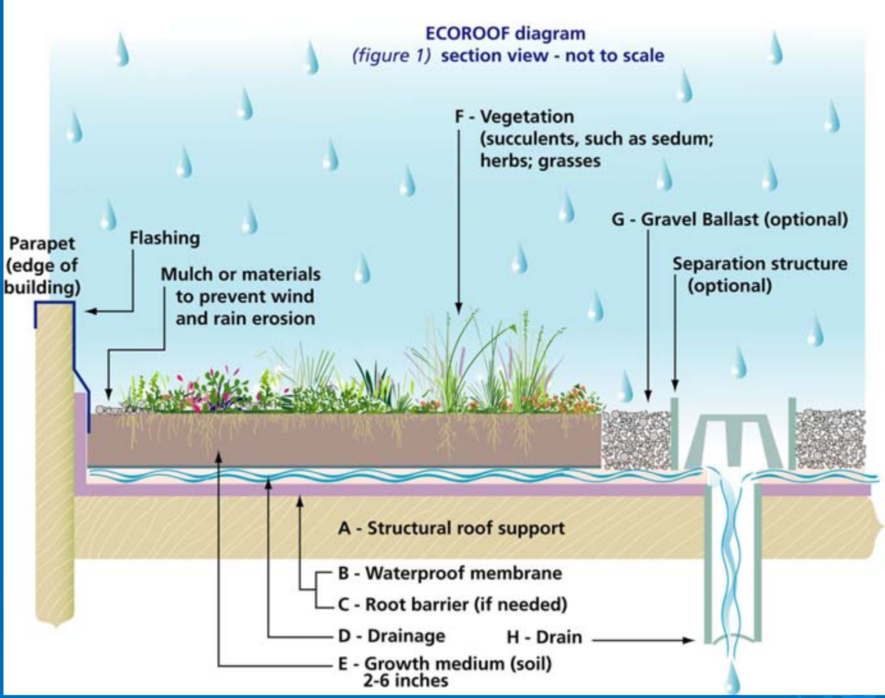
Green Roofs

- Reduce runoff volume by:
  - Evapotranspiration



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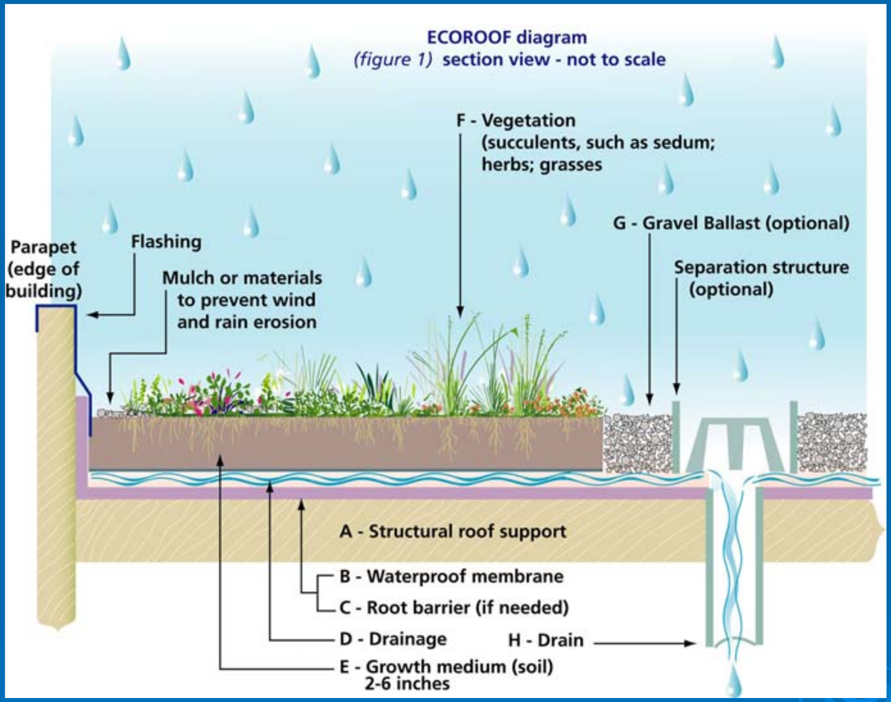
Green Roofs

- Reduce Q2 peak flows by:
  - Slowing runoff through soil filtration prior to discharge through roof drain.



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Modeling Assumption

- Assumed for the purposes of the LID modeling that bioretention and permeable pavement facilities do not include infiltration to native soils (all discharge through underdrain).

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Model Scenarios

- Modeled a range of precipitation annual total volume changes from a decrease in rainfall by 20% to an increase of 20% using historic 1948-1997 Everett NWS hourly rainfall data.

- Modeled a range of air temperature increases from zero to 4 ^{o}C (0 to 20% increase in PET).

Model Scenarios

- Modeled Everett climate change based on University of Washington Center for Science Climate Impact Group’s middle scenario for the Pacific Northwest: ECHAM5 SRES A2.

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Model Scenarios

ECHAM5 SRES A2 predicts between the years 2000 and 2100:

- Winter precipitation increase of 9%.
- Summer precipitation increase of 18%.
- Air temperature increase of 4 ^{o}C (using Hamon eq this equals PET increase of 20%).

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Big Question

Question:

- How will these changes in rainfall and air temperature affect stormwater runoff and the effectiveness of LID facilities?

Answer:

- Less runoff: LID effectiveness increases.
- More runoff: LID effectiveness decreases.

How much???

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Model Land Conditions

1. Forest A = Forest vegetation, NRCS A soil (high infiltration).
2. Lawn A = Lawn vegetation, NRCS A soil (high infiltration).
3. Forest C = Forest vegetation, NRCS C soil (low infiltration).
4. Lawn C = Lawn vegetation, NRCS C soil (low infiltration).
5. Impervious
6. Green Roof
7. Permeable Pavement
8. Bioretention

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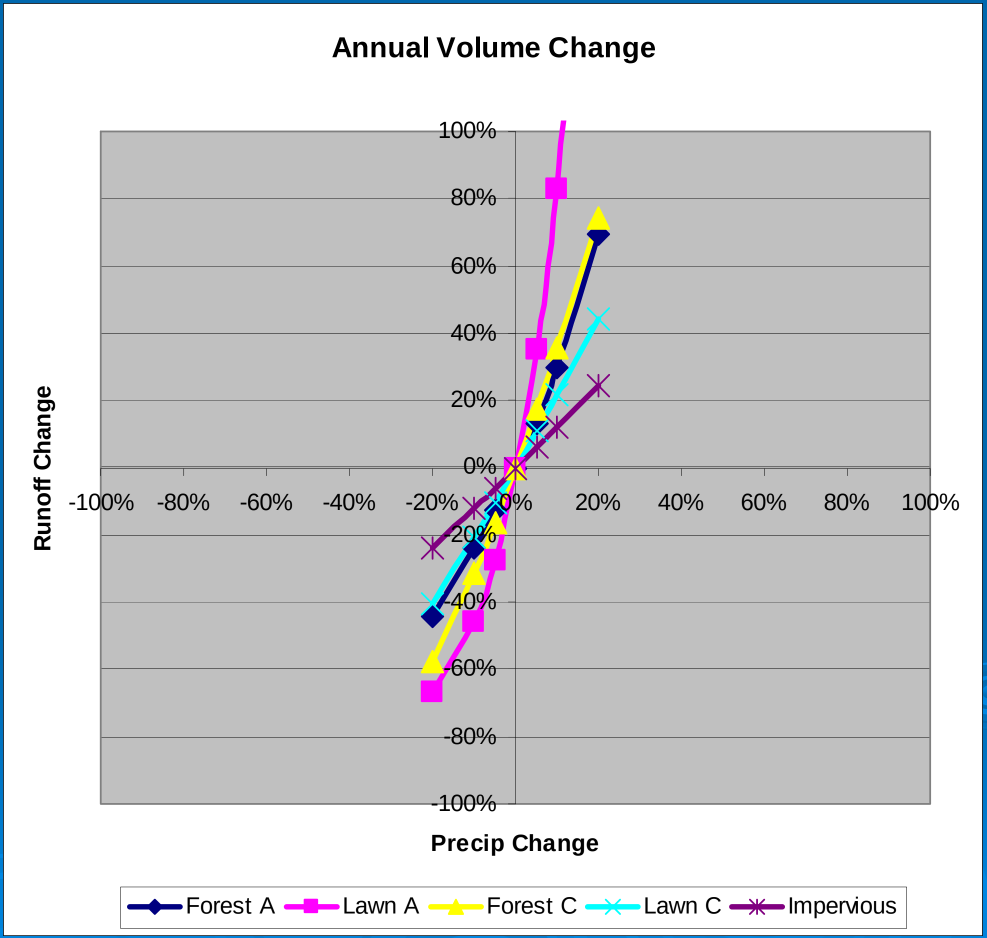
Runoff Volume Results from Rainfall

1. Pervious runoff volume increases faster than precipitation (for example: 10% precip increase produces a 83% Lawn A soil runoff increase).

2. Impervious runoff volume increases at the same rate as precipitation.



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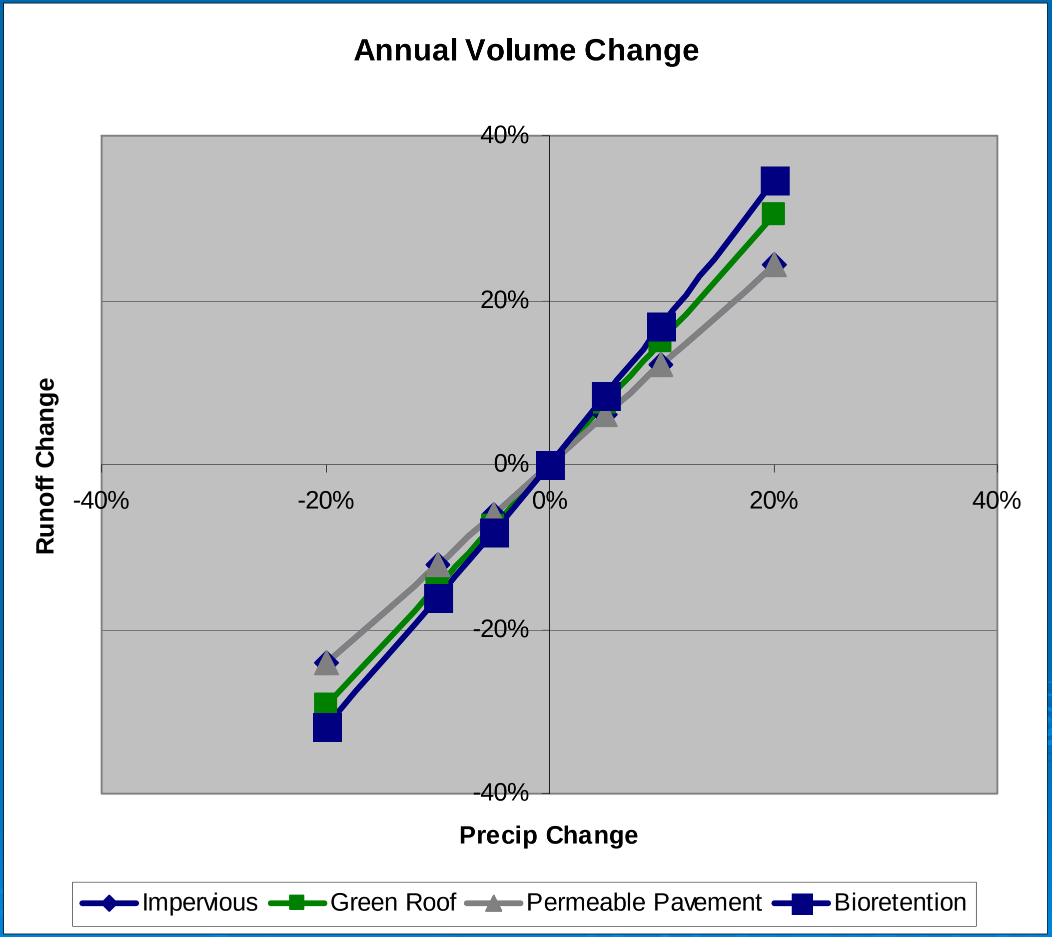
Runoff Volume Results from Rainfall

3. Green roofs and bioretention runoff volumes change more than impervious runoff volume.

4. Permeable pavement runoff volume changes at the same rate as impervious runoff volume.



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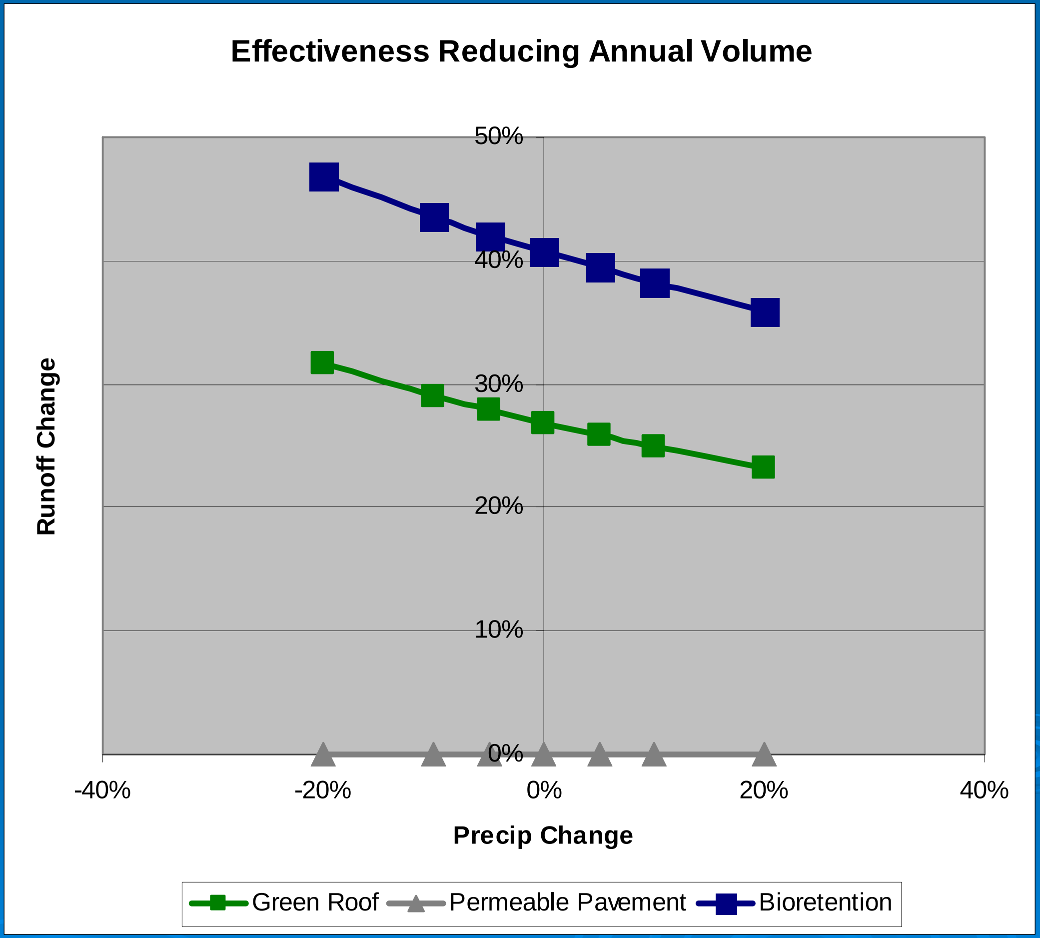
Runoff Volume Results from Rainfall

5. Green roofs and bioretention effectiveness in reducing runoff volume decreases with increasing rainfall.

6. Permeable pavement is not effective in reducing runoff volume if infiltration to the native soil is not included.



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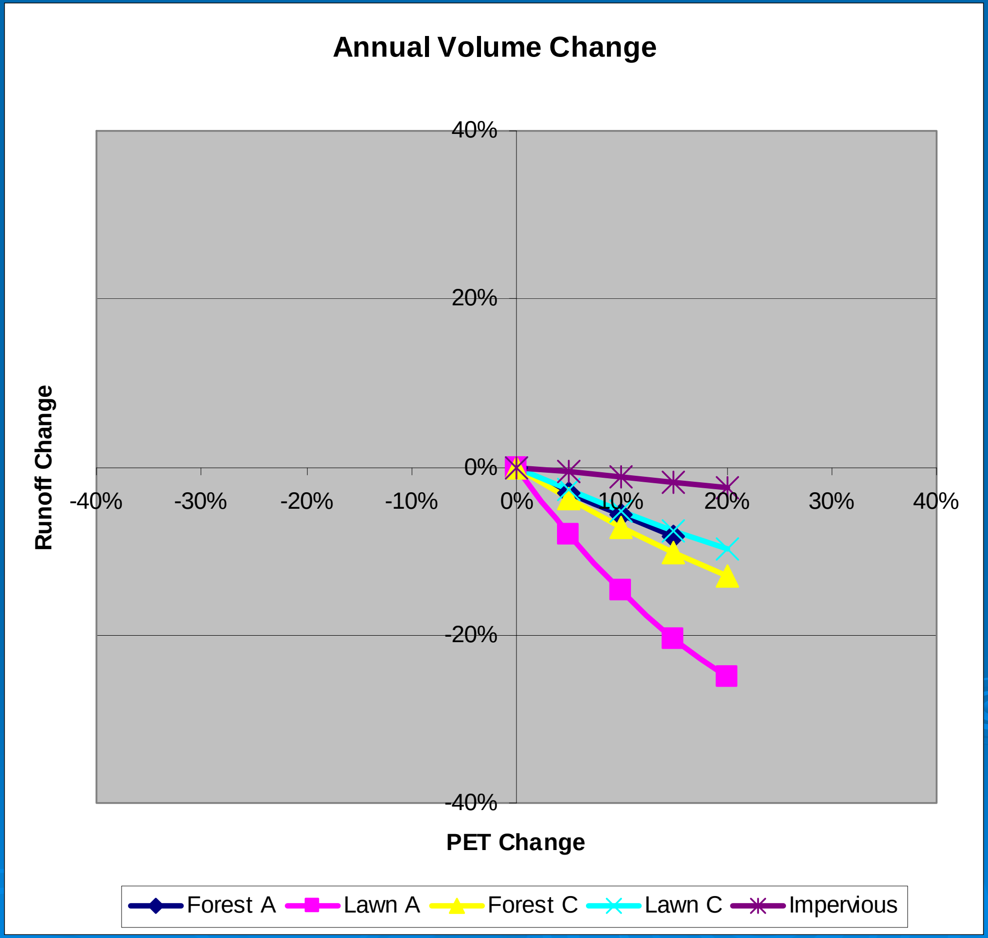
Runoff Volume Results from Temperature

1. Pervious runoff volume decreases with increased PET; size of change less than for rainfall.

2. Impervious runoff volume changes very little with increased PET.



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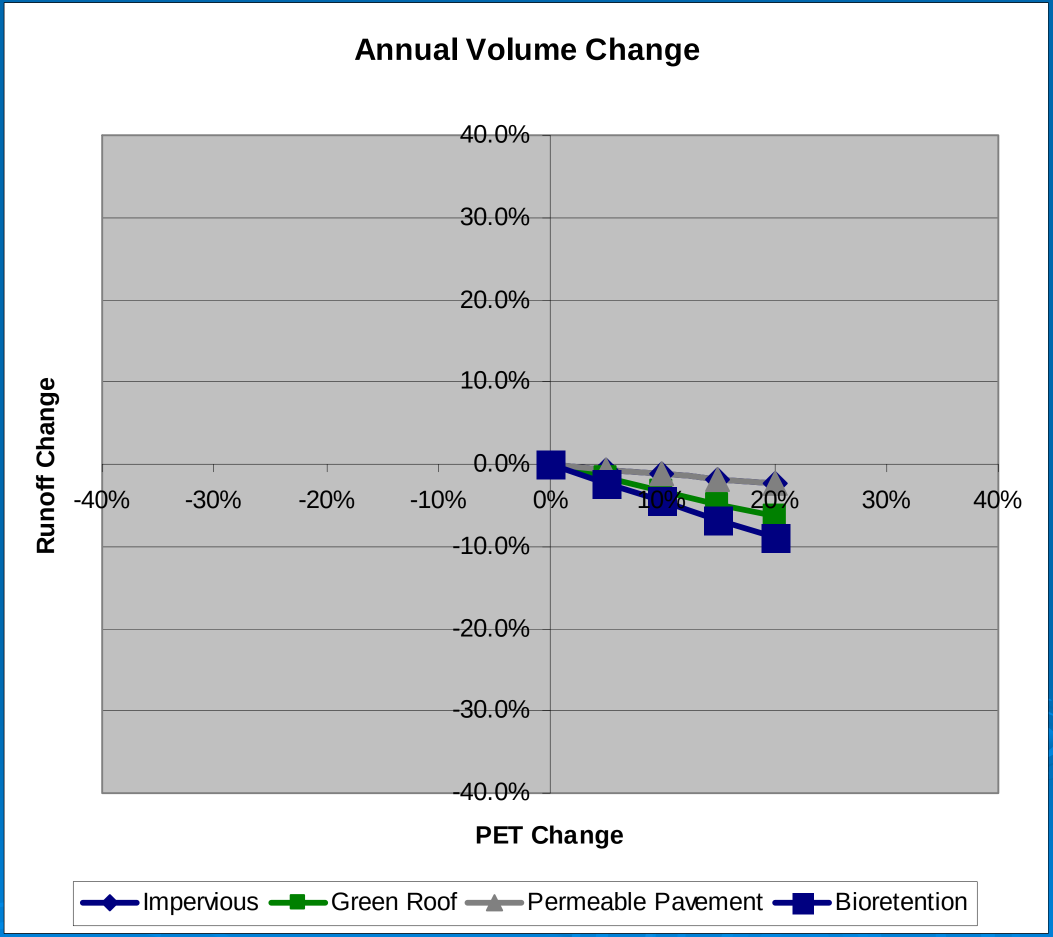
Runoff Volume Results from Temperature

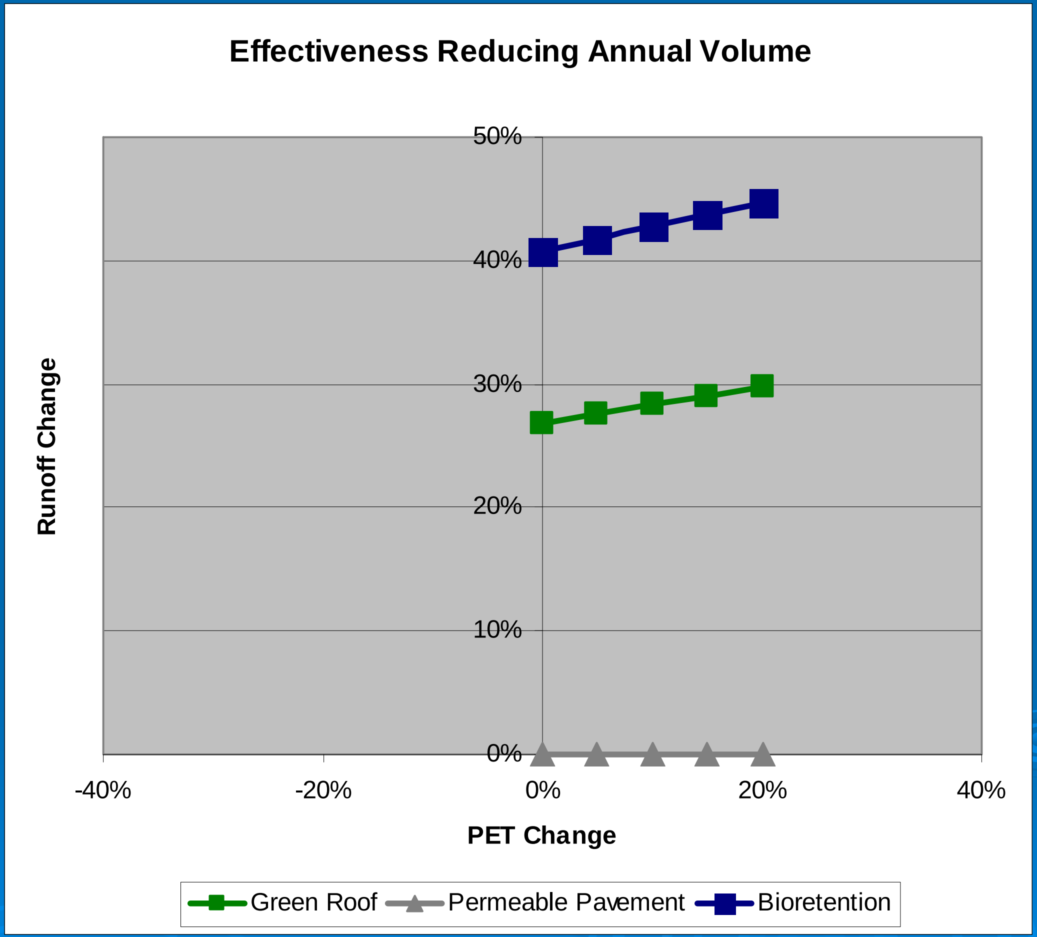
3. Little LID runoff volume change with increased PET.



Runoff Volume Results from Temperature

4. Green roof and bioretention effective-ness in reducing volume increases with increased PET.

5. Permeable pavement is not effective in reducing runoff volume if infiltration to the native soil is not included.



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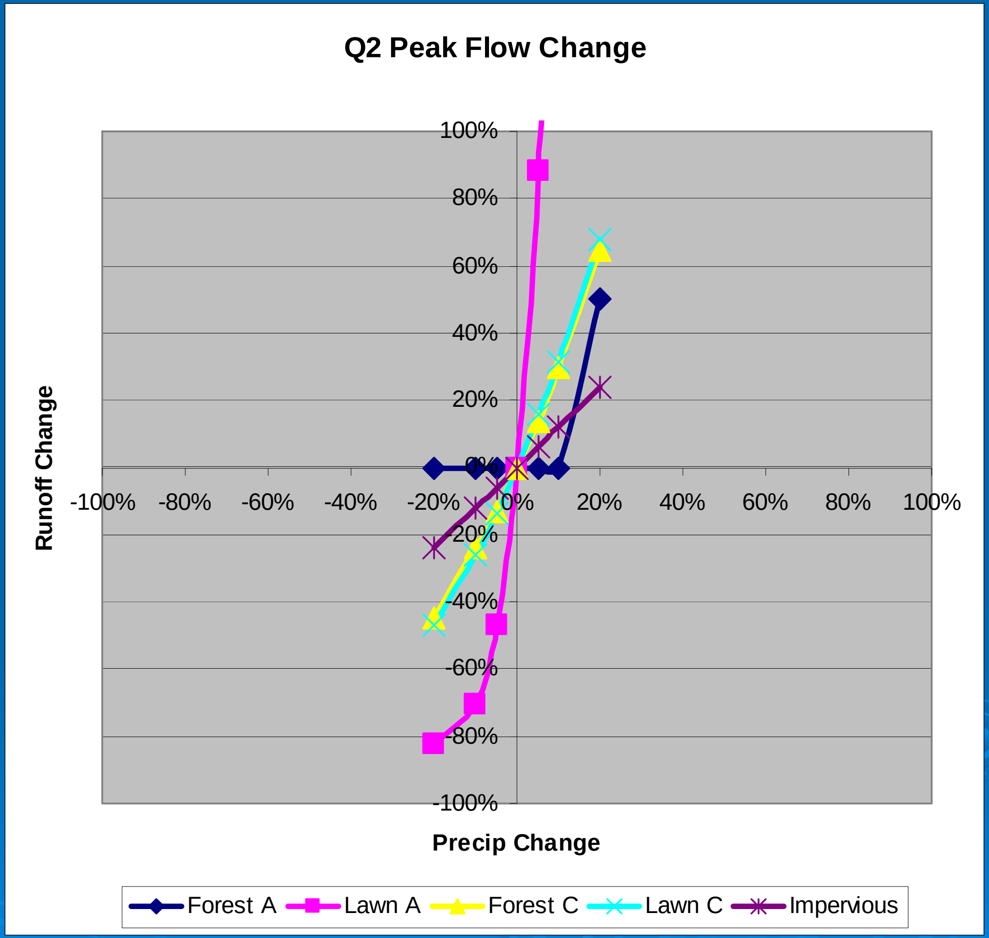
Runoff Peak Flow Results from Rainfall

1. Pervious runoff peak flows increases faster than precipitation (for example: 10% precip increase produces a 235% Lawn A soil runoff peak flow increase).

2. Impervious runoff peak flows increases at the same rate as precipitation.



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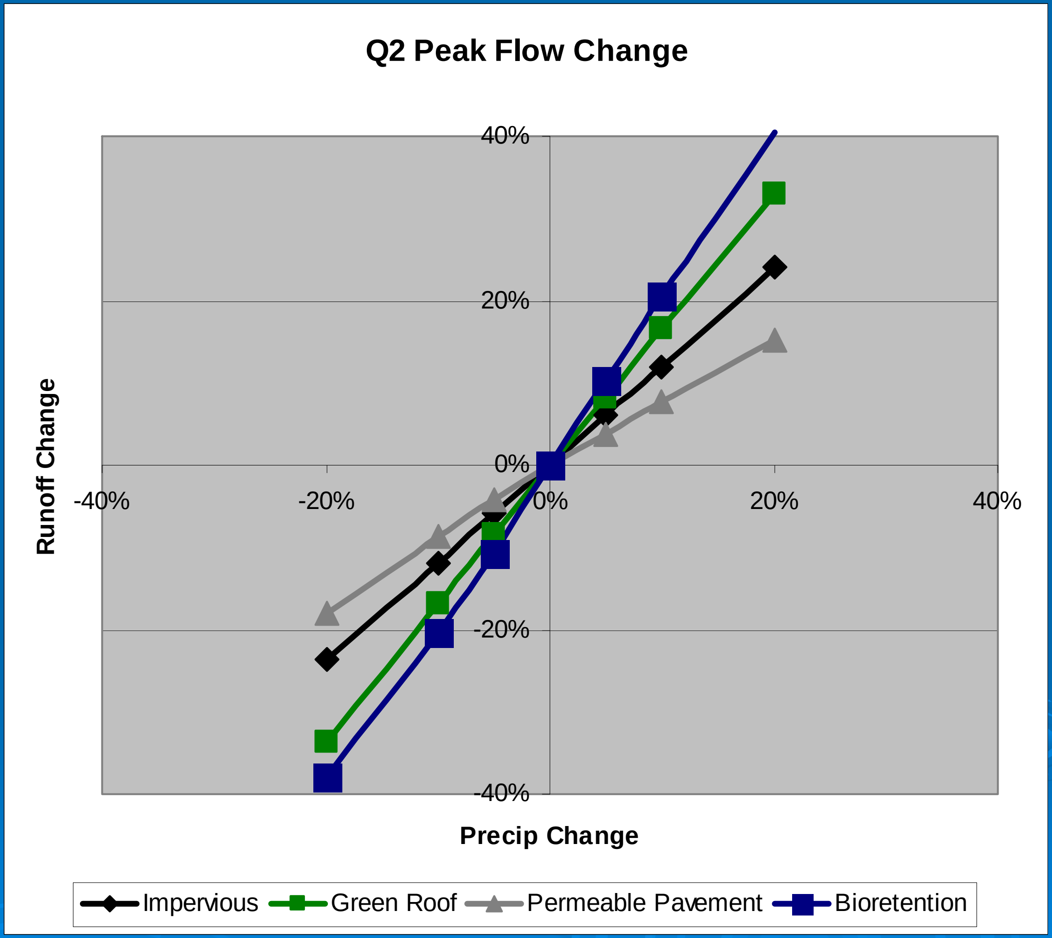
Runoff Peak Flow Results from Rainfall

3. Bioretention peak flows change more than green roofs.

4. Green roof peak flows change more than permeable pavement.



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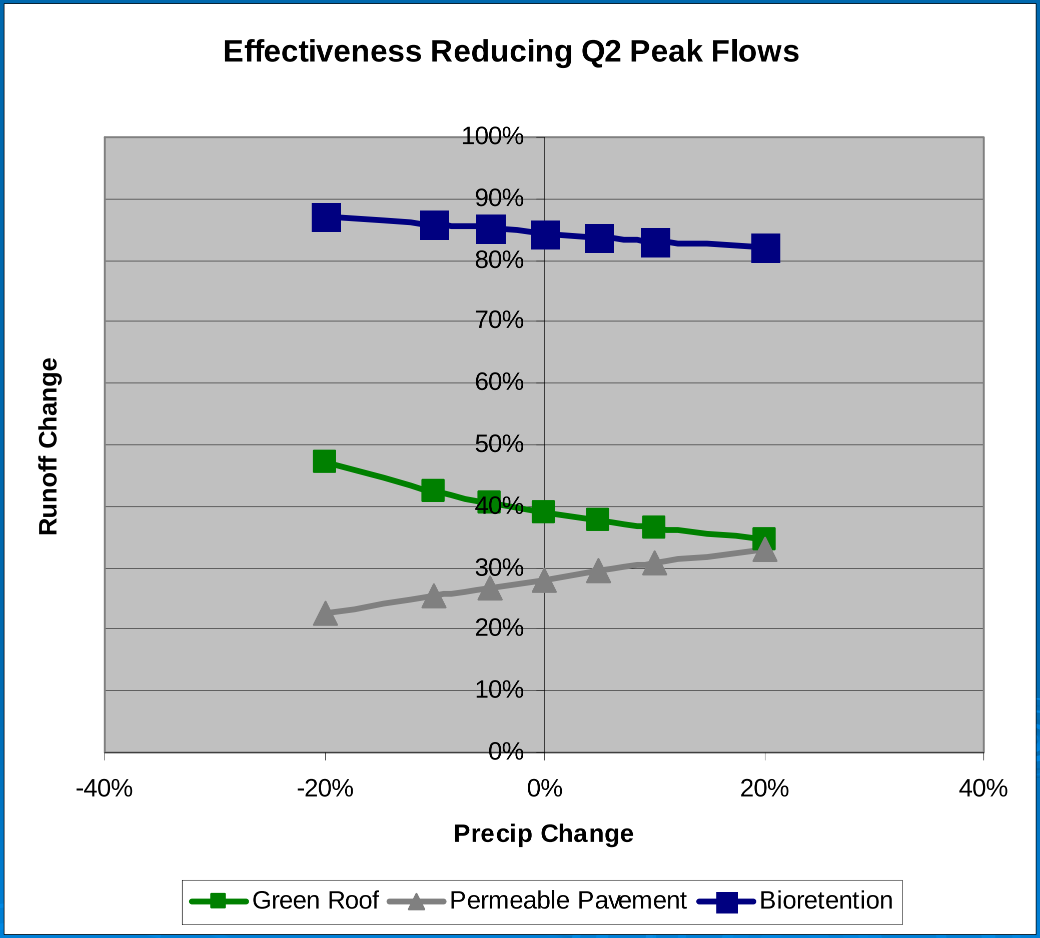
Runoff Peak Flow Results from Rainfall

5. Bioretention and green roof effectiveness in reducing Q2 peak flows decreases with increased rainfall.

6. Permeable pavement effectiveness increases with increased rainfall.



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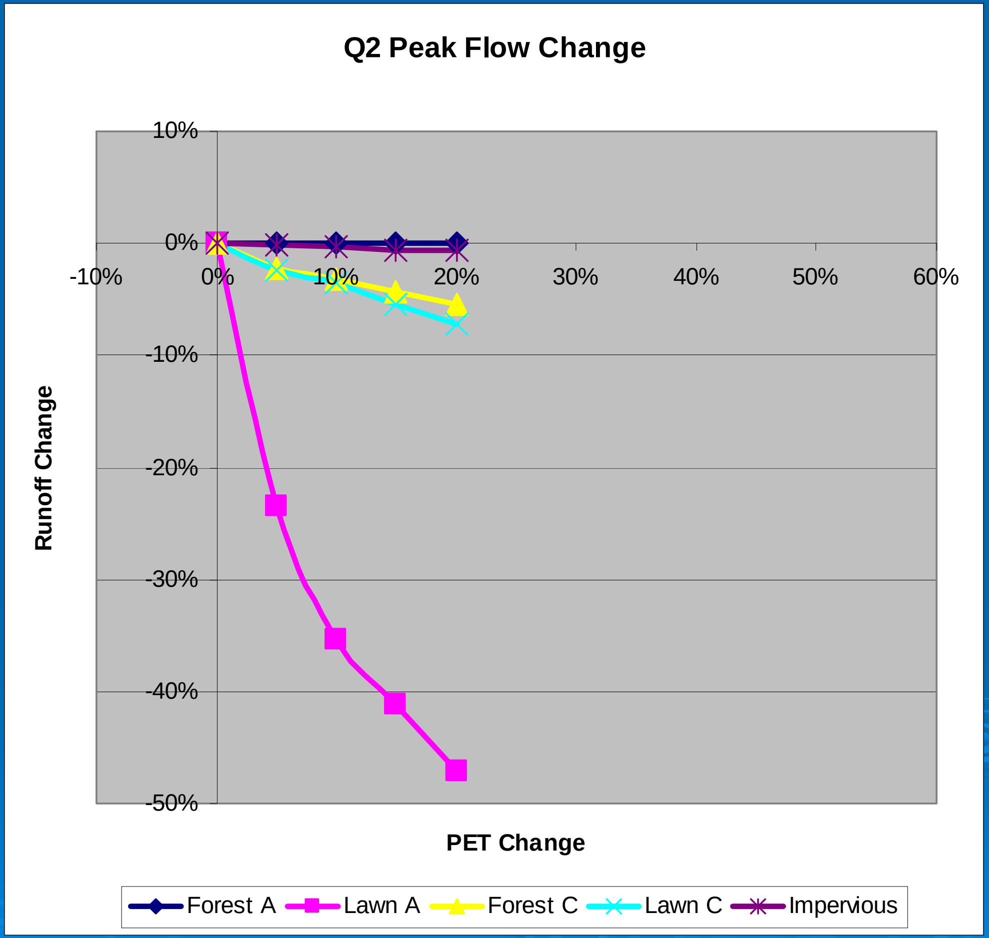
Runoff Peak Flow Results from Temperature

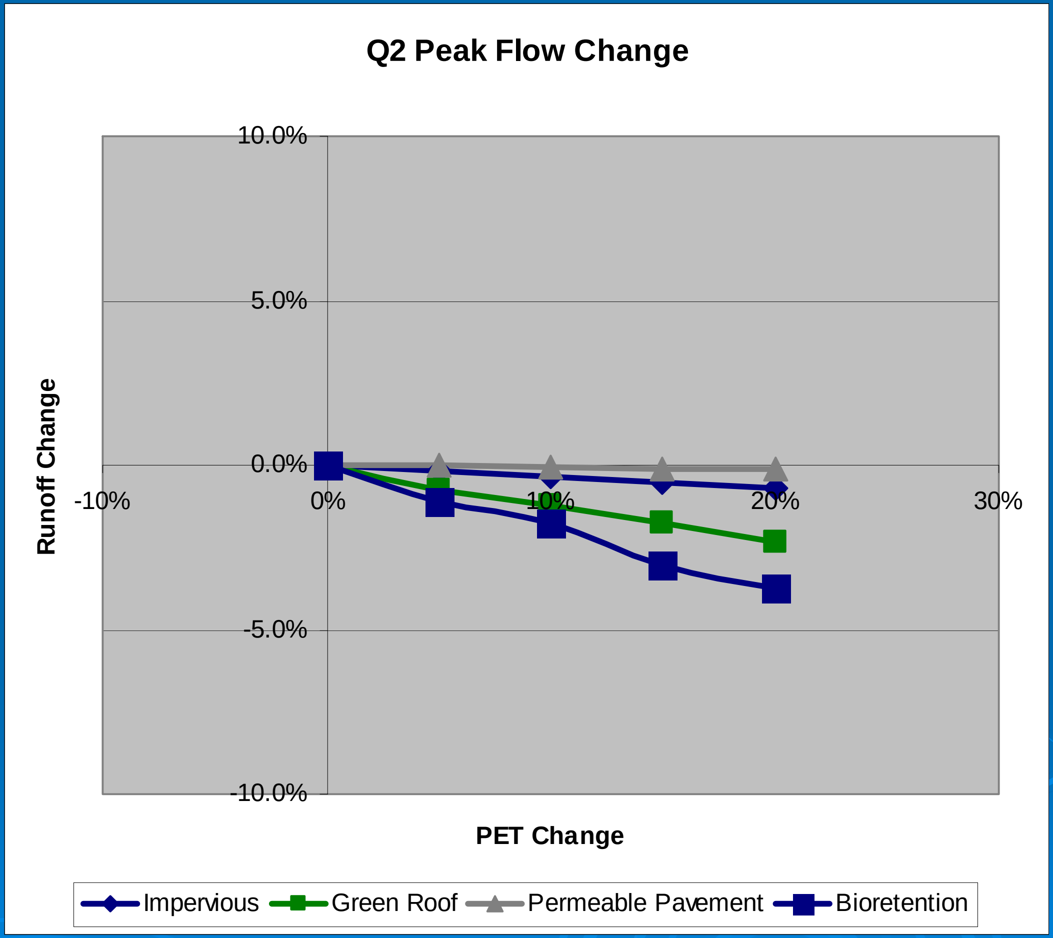
1. Pervious runoff decreases with increased PET; size of change less than for rainfall except for Lawn A.

2. Impervious runoff peak flows change very little with increased PET.



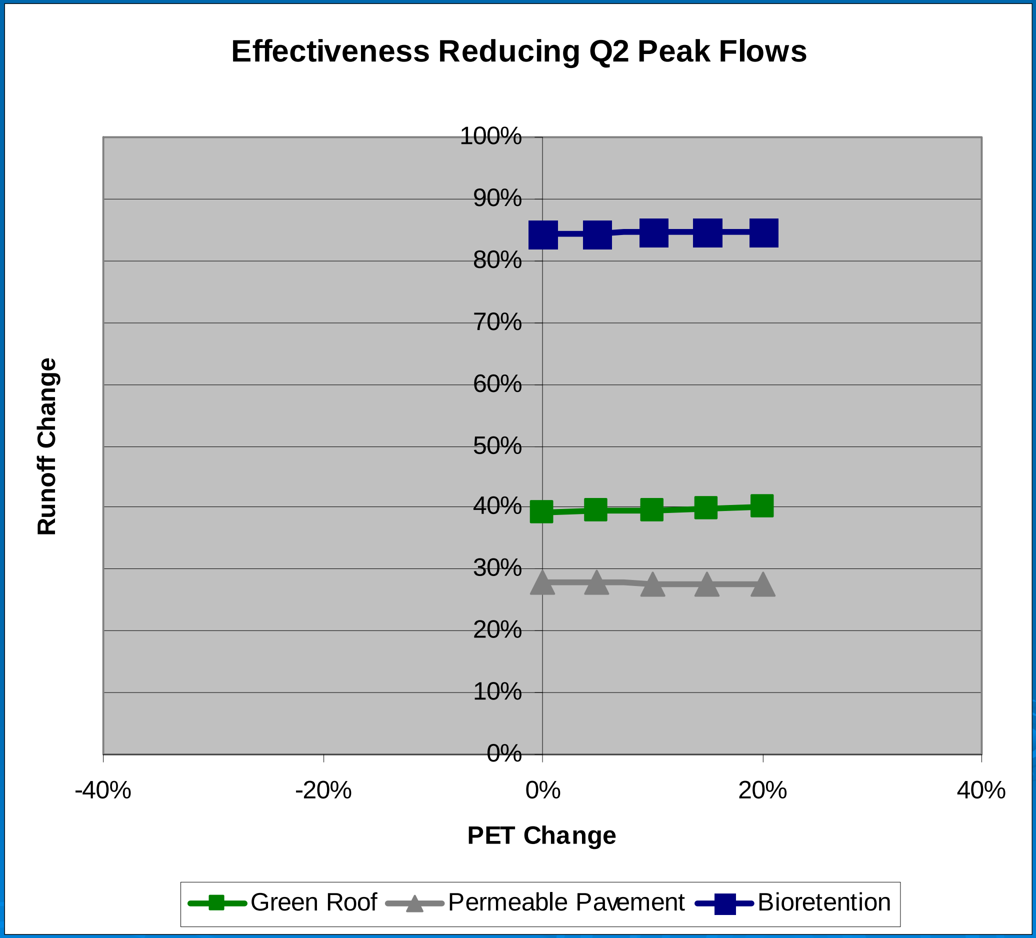
Runoff Peak Flow Results from Temperature

3. Peak flows for all LID decrease by less than 5% with increased PET.



Runoff Peak Flow Results from Temperature

4. Peak flow reduction effectiveness unchanged for all LID with increased PET.



Annual Runoff Volume Reduction from Rainfall

LID	P -20%	P -10%	P -5%	P +5%	P +10%	P +20%
Green Roof	-29%	-15%	-7%	8%	15%	30%
Permeable Pavement	-24%	-12%	-6%	6%	12%	24%
Bioretention	-32%	-16%	-8%	8%	17%	35%

Annual Runoff Volume Reduction from Temperature

LID	T +1 °C	T +2 °C	T +3 °C	T +4 °C
Green Roof	-1.7%	-3.3%	-4.8%	-6.3%
Permeable Pavement	-0.6%	-1.2%	-1.8%	-2.4%
Bioretention	-2.3%	-4.6%	-6.7%	-8.8%

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Q2 Peak Flow Reduction from Rainfall

LID	P -20%	P -10%	P -5%	P +5%	P +10%	P +20%
Green Roof	-34%	-17%	-8%	8%	17%	33%
Permeable Pavement	-18%	-9%	-4%	4%	8%	15%
Bioretention	-38%	-20%	-11%	10%	21%	41%

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Q2 Peak Flow Reduction from Temperature

LID	T +1 ^oC	T +2 ^oC	T +3 ^oC	T +4 ^oC
Green Roof	-0.7%	-1.2%	-1.8%	-2.3%
Permeable Pavement	-0.0%	-0.0%	-0.1%	-0.1%
Bioretention	-1.1%	-1.8%	-3.1%	-3.7%

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Conclusions

- The largest climate change impact to LID facilities will be from changes in precipitation. More precip will mean more runoff into and out of LID facilities.
- Q2 peak flows will change more than annual runoff volumes (except for permeable pavement).

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Conclusions

- Q2 peak flow changes may impact NPDES MS4 discharge permits and the sizing of LID facilities that are based on Q2 values (for example: California and Washington).

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Conclusions

- Increased air temperature (and increased PET) will only slightly decrease runoff volume and peak flows from LID facilities.

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Conclusions

For the City of Everett increased precip and increased PET will result in:

- 12% increase in LID runoff volume by the year 2100;
- 10-20% increase in LID runoff peak flow by the year 2100.
- Larger LID facilities will be needed in the future.

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Acknowledgements

- City of Everett, Washington, funded some of the initial LID modeling; Otak, Inc. was the prime consultant on the City of Everett project.

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Questions?

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