

# **APPENDIX: WATER AND STORM WATER MANAGEMENT**

# Imperviousness Statistics for Denver

- Buildings Make Up 30% of Impervious Surfaces in Denver
  - Remaining 70% are roads, driveways, parking lots, and sidewalks
- Approximately 40% of Surfaces in Denver are Impervious (Includes DIA)
- Amount of Impervious Surfaces in Denver are Projected to Increase by 30% - 40% by 2040 (CU Boulder, unpublished data)

# Summary of Studies – Impacts on Runoff

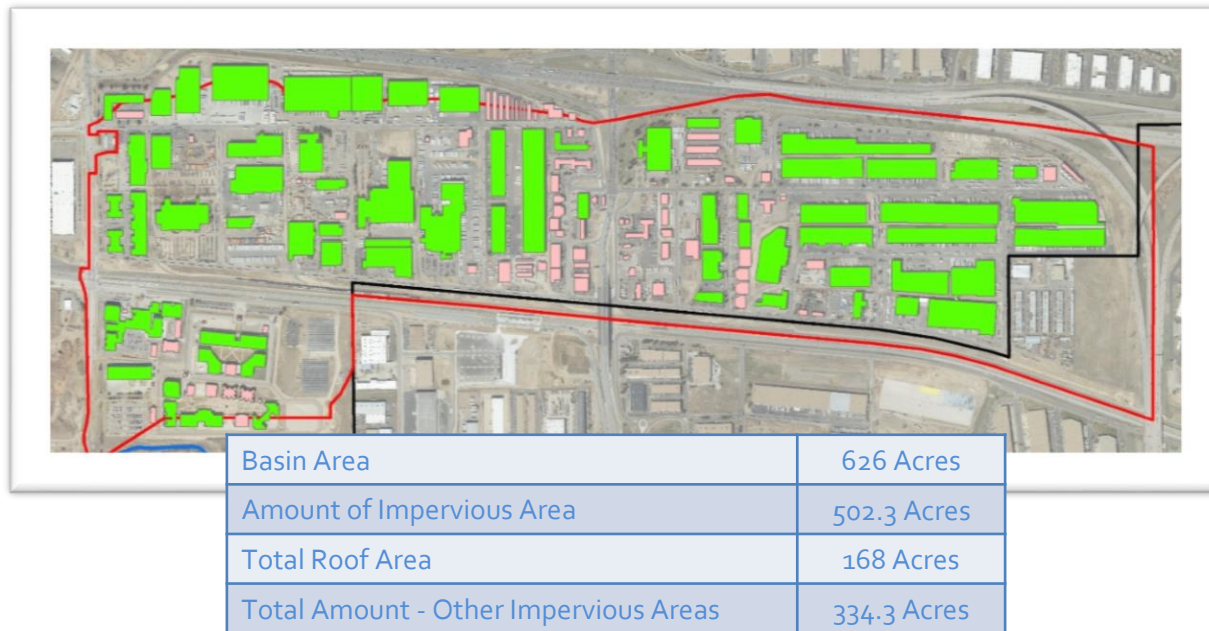
| Authors                                | Location            | Peak Flow Reduction            | Average Annual Reduction in Runoff | Comments                                                                                                  |
|----------------------------------------|---------------------|--------------------------------|------------------------------------|-----------------------------------------------------------------------------------------------------------|
| Moran, et. al. (2004)                  | Goldsboro, NC       | 78.00%                         | 62.00%                             | Extensive roof                                                                                            |
|                                        | Kinston, NC         | 87.00%                         | 63.00%                             | Extensive roof                                                                                            |
| MacMillan (2004)                       | Toronto, ON         | 85.00%, 82.00%, 68.00%, 46.00% | 54.90%                             | System includes storage tank, peak flow reduction depended on storm size and decreased with larger storms |
| Portland Environmental Services (2013) | Portland, OR        | 96.00%                         | 50.00%                             |                                                                                                           |
|                                        | Portland, OR        | 83.00%                         | -5.00%                             | Site required irrigation                                                                                  |
|                                        | Portland, OR        | 88.00%                         | 70.00%                             |                                                                                                           |
| Speak, et. al. (2013)                  | Manchester, UK      | N/A                            | 65.70%                             | Intensive roof                                                                                            |
| EPA (2009)                             | University Park, PA | N/A                            | >50%                               | Extensive roof, almost 100% retained in summer, <20% retained in winter                                   |
| Glass (2007)                           | Washington, DC      | N/A                            | 74.00%                             |                                                                                                           |
| Murillo, et. al. (2016)                | Bogota, Columbia    | N/A                            | 73.00%                             | Studied 15 extensive roofs                                                                                |
| EPA (2014)                             | New York, NY        | N/A                            | 37.00%-66.00%                      | Studied four extensive roof, percent retention decreases as storm size decreases                          |
| USGS (2010)                            | Ipswich, MA         | N/A                            | >50.00%                            |                                                                                                           |

# Factors Influencing Green Roof Runoff Retention

- Storm Event Size and Intensity
- Antecedent Precipitation
- Temperature
- Green Roof Configuration
  - Substrate Depth
  - Rooftop Slope
  - Plant Coverage
  - Drainage Configuration
  - Orientation
  - Location of Unvegetated Areas

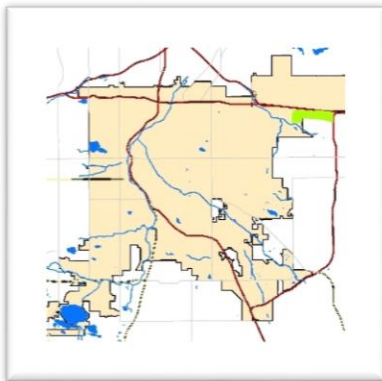
# Water Quality Impact

Green Roofs Do Not Address Primary Sources of Storm Water Pollutants in Receiving Waters



# Green Roofs Initiative Example

|                           | Existing    |
|---------------------------|-------------|
| Basin Area                | 626 Acres   |
| Amount of Impervious Area | 502.3 Acres |
| Percent Imperviousness    | 80.2%       |



|                                    | With Green Roofs |
|------------------------------------|------------------|
| Roof Area , Bldgs. >25,000 sq. ft. | 147.7 Acres      |
| Required Green Roof Area           | 14.8 Acres       |
| Impervious Area with Green Roofs   | 487.5 Acres      |
| Percent Imperviousness             | 77.9%            |

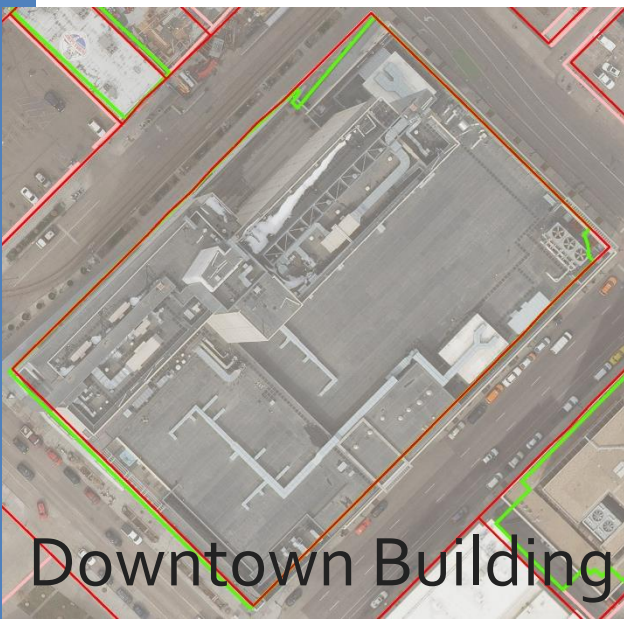
Green roofs result in a 0.7% - 2.3% decrease in basin imperviousness in an industrial area.  
 Green roofs result in a 4.2% - 14.1% decrease in basin imperviousness in urban areas with high density and 60% green roof coverage requirements.  
 Benefits are greater in denser areas with less pervious areas on the ground

# Green Roofs have a Significant Water and Water Quality Benefit

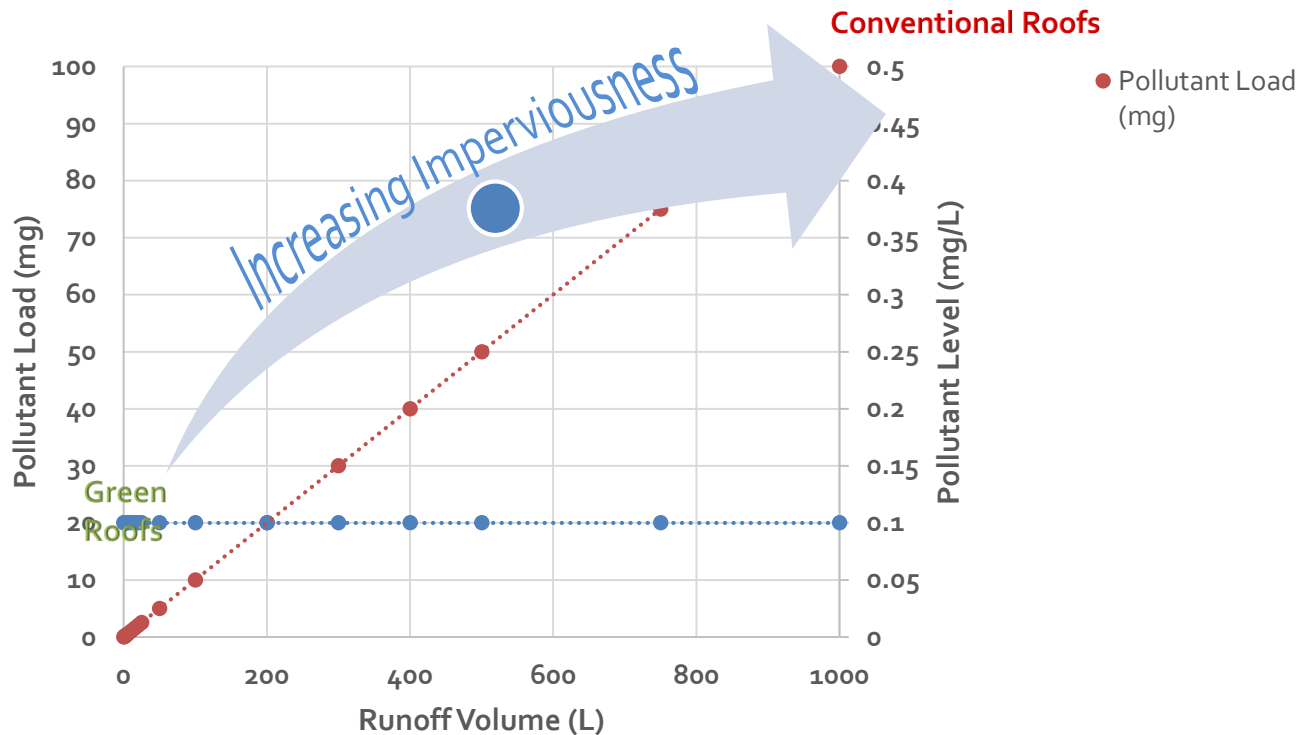
Green roofs result in a **4.2% - 14.1%** decrease in basin imperviousness in urban areas with high density and a 60% green roof coverage requirement.

Green roofs result in a **0.7% - 2.3%** decrease in basin imperviousness in an industrial area with a 10% coverage requirement.

**Benefits are greater in denser areas where imperviousness is higher.**



# Reduced Pollutant Load Benefit





# Examples - Additional Water Quality Provided by Green Roofs

|                                   | Site 1                                                                          | Site 2                                                                                 |
|-----------------------------------|---------------------------------------------------------------------------------|----------------------------------------------------------------------------------------|
| Site Description                  | 3 acre site<br>90% impervious<br>80,000 sq. ft. structure<br>40 hour drain time | 10 acre site<br>80% impervious<br>10 – 30,000 sq. ft. structures<br>40 hour drain time |
| Required Water Quality            | 0.1 acre-ft                                                                     | 0.27 acre-ft                                                                           |
| Required Green Roof Size          | 0.55 acre                                                                       | 1.4 acre                                                                               |
| Extra Water Quality Provided      | 0.015 acre-ft                                                                   | 0.07 acre-ft                                                                           |
| Percent Increase in Water Quality | 15%                                                                             | 25%                                                                                    |

See Chapter 3, Volume 3, UDFCD for methodology to determine water quality requirements.

# Water Quality Impact

Green Roofs Do Not Address Primary Sources of Storm Water Pollutants in Receiving Waters

Average Pollutant Level in Run Off from Roofs and Roads

| Metric            | Roof Run Off | Road Run Off |
|-------------------|--------------|--------------|
| pH                | 6.07         | 6.9          |
| TSS (mg/L)        | 47           | 8,500        |
| Zinc (mg/L)       | 0.70         | 1.08         |
| Copper (mg/L)     | 0.42         | 0.09         |
| Lead (mg/L)       | 0.30         | 0.41         |
| Aluminum (mg/L)   | 0.49         | 2.10         |
| Nitrogen (mg/L)   | 0.02         | 1.74         |
| Phosphorus (mg/L) | 0.22         | 0.49         |

rain first flush monitoring  
All conventional roof types included in calculation

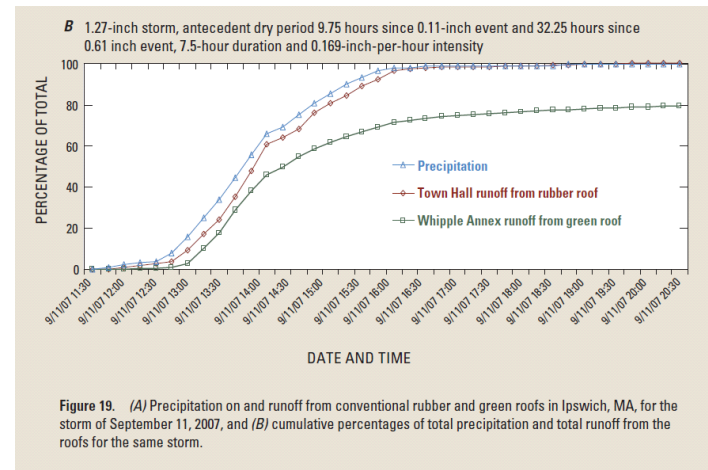
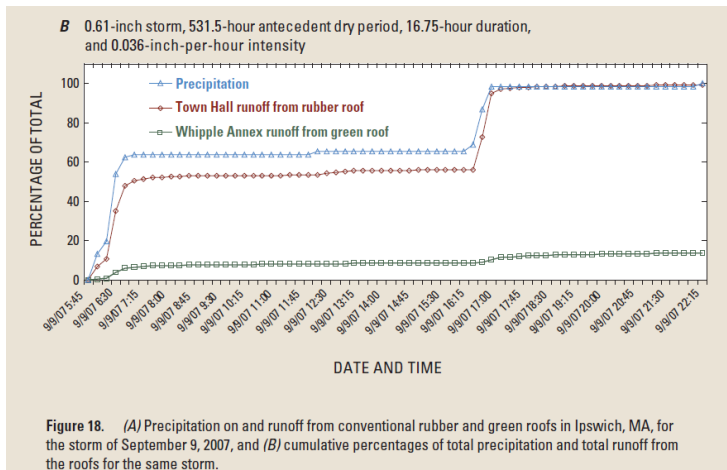


## Factors Influencing Water Quality Results at a Site

- Growing media
  - Amount of organic matter
- Growing media depth / thickness
- Plantings
  - Presence of plants
  - Plant palette
  - Fertilization needs

# Benefits are Conditional

- Water Quality Benefits Vary from Site to Site
- Benefits are all dependent on storm size and time since previous storms
  - Ability to absorb stormwater is decreased if green roof is partially or completely saturated



# Other Issues – Water Resources

- Initiative
  - Conflicts with Colorado water law
- Draft Rules (12/26/17)
  - Conflicts with Colorado water law
  - Does not properly reflect administration of Colorado water law
  - Provides no options for projects without an approved augmentation plan

# Water Quality - Outcomes

- Add incentive – green roofs offset for water quality elsewhere on site
- Allow builders to use white roof / onsite water quality combo instead of green roof only – if goal is to reduce heat island effect and improve water quality
- Specify fee in lieu goes to funding regional water quality projects
- Add flexibility to regulations
  - Develop a tool, similar to the water quality scorecard that identifies needs in different areas– water quality / quantity, heat island, etc. - and prioritize for implementation.
- Ability to monitor / identify partners and funding to do monitoring with

# Reduction in Amount of Pollutants Reaching Denver's Streams and Lakes

## Green / Conventional Roof Comparison

- Decreased runoff
  - Some water that falls on green roofs will evaporate, not runoff
- Treatment of Water
  - Runoff from green roofs contains lower levels of metals
  - Solids retained more effectively by green roofs
  - Green roofs may or may not have a benefit for nitrogen and phosphorus
    - Nutrient levels in discharges from green roofs decrease as a function of time

# Reduces Localized Flooding

- Delayed runoff may result in reductions in localized flooding
  - Some of Denver's storm sewers designed to contain the 2 or 5 year storm event
    - Larger storm events result in localized neighborhood flooding
- Delaying runoff it reduces volume of water to be conveyed



# Summary

- Green Roofs
  - Decrease runoff
    - Reduction in imperviousness in one Montbello storm drainage basin
  - Impact varies depending on how recently the previous storm occurred.
- Benefits
  - Reduction in amount of pollutants reaching Denver's streams and lakes
    - Decreased runoff
    - Provides treatment for some pollutants
  - Delayed runoff may reduce localized flooding

# Questions from Last Meeting

- How Do Green Roofs Compare to Other Water Quality BMPs?
  - Bioretention
    - Trees or plants on the ground
    - Trade impervious parking for green space at ground level
  - Pervious Pavement
    - Trade impervious surface for pervious surface at grade
  - Retention
    - Holding tank for stormwater

Limited Information Comparing Relative Effectiveness of Green Roofs to  
Other Practices for Improving Water Quality

More Appropriate to Compare Green Roofs to Other Types of Roofs

# Water Quality Capture Volume

- Water Quality Capture Volume (WQCV) - The volume of runoff that a water quality BMP is designed to capture and treat prior to release to receiving waters
  - Applies to water quality and runoff volume
    - Based on site imperviousness, size of tributary area, and stormwater retention time
    - Treatment targets storm events of up to 0.6 inches precipitation
- Requirements for Stormwater Detention are also Based on the Water Quality Capture Volume

# Green Roof Benefits

- Primary Benefit - Delay of Peak Flows and Runoff Volume Reduction
  - Benefit varies with storm size, duration, and time between storms
  - Benefit depends on green roof construction
- Secondary Benefit - Water Quality Improvement
  - May be helpful in managing volume for water quality storm events
    - Reduced rooftop runoff = reduced volume treated by in-ground BMPs
  - Green roofs are highly effective at managing typical roof-top pollution but don't provide treatment for other surfaces

# Comparison of Two Green Roofs

## Downtown Building – 100% Impervious Site

|                           |             |
|---------------------------|-------------|
| Building Footprint        | 2.4 acres   |
| Lot Size                  | 2.4 acres   |
| % Imperviousness          | 100%        |
|                           |             |
| Required Runoff Retention | 4,450 sq ft |
| Available Space           | 0           |
|                           |             |
| 40% Green Roof Coverage   |             |
| Site Imperviousness       | 61%         |
|                           |             |
| 100% Green Roof Coverage  |             |
| Site Imperviousness       | 1%          |

## Industrial Facility – 67% Impervious

|                           |      |              |
|---------------------------|------|--------------|
| Building Footprint        | Site | 5.75 acres   |
| Other Impervious Surfaces |      | 4.7 acres    |
| Lot Size                  |      | 15.4 acres   |
| % Imperviousness          |      | 67%          |
|                           |      |              |
| Required Runoff Retention |      | 14,825 sq ft |
| Available Space           |      | 5 acres      |
|                           |      |              |
| 10% Green Roof Coverage   |      |              |
| Site Imperviousness       |      | 64%          |
|                           |      |              |
| 100% Green Roof Coverage  |      |              |
| Site Imperviousness       |      | 30%          |

# Important Points to Take Away

- Water Quality Benefits from Green Roofs are Secondary to Delay of Peak Flows and Reduction in Volume of Runoff
  - Focus should be on delay of peak runoff and volume reduction
  - Water quality should be considered site-wide and integrate green roofs with in-ground BMPs
- Green Roof Stormwater Benefits May Prove Most Useful in Neighborhoods with
  - Higher Building Density
  - Nuisance Flooding
  - Existing, or planned, high imperviousness (60-70%+)

# QUESTIONS?

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# Denver's Stormwater Capture / Treatment Requirements

- §56-111 DRMC:
  - (a) ...each developer of land within the city has a duty to provide on his/her property all reasonably necessary drainage and detention facilities to ensure the adequate drainage and control of ... stormwaters which fall or develop on his/her property or which contribute runoff to his/her property.
  - (b)...each developer/redeveloper of land conducting projects that disturb one (1) or more acres of soil, including projects less than one (1) acre that are part of a larger common plan of development or redevelopment, has the duty to prevent or minimize water quality impacts from the completed project.

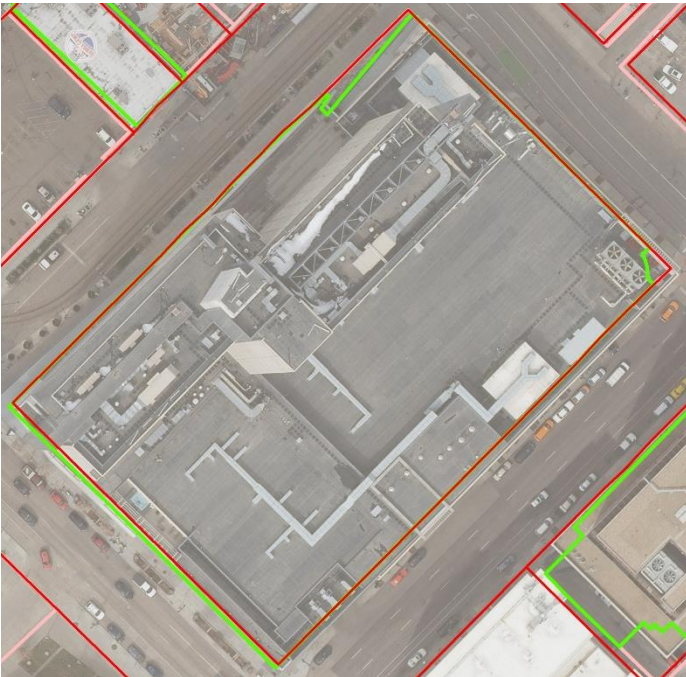


# Perviousness/Imperviousness

- Pervious surfaces allow water soak into the ground, impervious surfaces do not, instead creating runoff.

| Pervious Surfaces     | Impervious Surfaces        |
|-----------------------|----------------------------|
| Grass                 | Roads and Sidewalks        |
| Dirt, Sand, or Gravel | Roofs                      |
|                       | Parking Lots and Driveways |

## Downtown Building



## Industrial Facility



Note: Photos are not at the same scale.

# Other Types of Water Quality BMPs

- Traditional
  - Extended Detention Basin
  - Constructed Wetlands (Pond or Channel)
  - Permeable Pavement
  - Sand Filter
  - Retention Pond
  - Underground Treatment
- Green Infrastructure
  - Bioretention (Rain Gardens or Porous Landscape Detention)
  - Grass Buffer
  - Grass Swale
  - Curb-Side Planters

Source: UDFCD (2012). Criteria Manual, Volume 3, Chapter 6

# Assessment of WQ BMP Effectiveness

Studies conducted by the International Stormwater BMP Database

- Most recent summary report available at:

<http://www.bmpdatabase.org/Docs/03-SW-1COh%20BMP%20Database%202016%20Summary%20Stats.pdf>

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