Residential Density and Outdoor Efficiency Impact on Denver Water Demand: An Exploratory Scenario Analysis

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Agenda

- Background
- Denver Model
- Current Estimates
- Key Concepts of Scenarios and Scenario Analysis
- Scenario Analysis Results
  - Density Scenarios
  - Efficiency Scenarios
- Strategic Insights

Key Questions

- What absolute impact does increasing residential density have on total demand?
- What are the characteristics of increasing residential density in regards to change in total demand?
- What absolute impact might increasing the efficiency of outdoor water use have on total demand?
- What are the characteristics of increasing the efficiency of outdoor water use in regards to density and total demand?

Approach

- Used Denver Water data and model to estimate water demand by building type.
- Used exploratory scenario analysis to examine relationships between increasing density and outdoor efficiency with total demand.

Qualifications
Glossary
Assumptions

Qualifications

- Based on Denver Water data, may not be directly applicable to other places.
- Not a predictive analysis, large amounts of variance and uncertainty!
- Systems of development and water use are very complex, made many assumptions about how systems function to simplify analysis.
- Other systems such as economics and community values were NOT considered.
- Only looking at new housing, not existing.
- More to come ….

Glossary

- Pervious Area: The square feet (or acres) on a parcel that are NOT impervious (building, street, driveway, etc). The assumption is that plants (grass, trees, shrubs, etc.) could be grown in this area.
- Gallons Per SqFt Pervious: A unit of measure for how many gallons of water will be used on one square foot of pervious area for one year.
- Building Type: This is a type of development pattern that is somewhat homogenous in terms of density, pervious area, and gallons per SqFt Pervious.
- Household & Unit: These terms are used interchangeably in this analysis, a household is a group of people living in a housing unit (house, apartment, etc.). Every household has a unit of some building type they live in and every building type unit has a household.
- More to come …..

Assumptions

- Current Building Type characteristics are both building specific and household specific.
  - Gallons Per SqFt outdoor water use and SqFt of Pervious Area are building specific.
  - Indoor GPCD and Persons per Household are household specific.
  - Building characteristics stay with building type.
  - Household characteristics stay with household.
- There are no trends of changing household size, indoor GPCD, nor density of building type.
- Scenario Analysis is based only on new households.
- More to come ….

Basic Denver Model

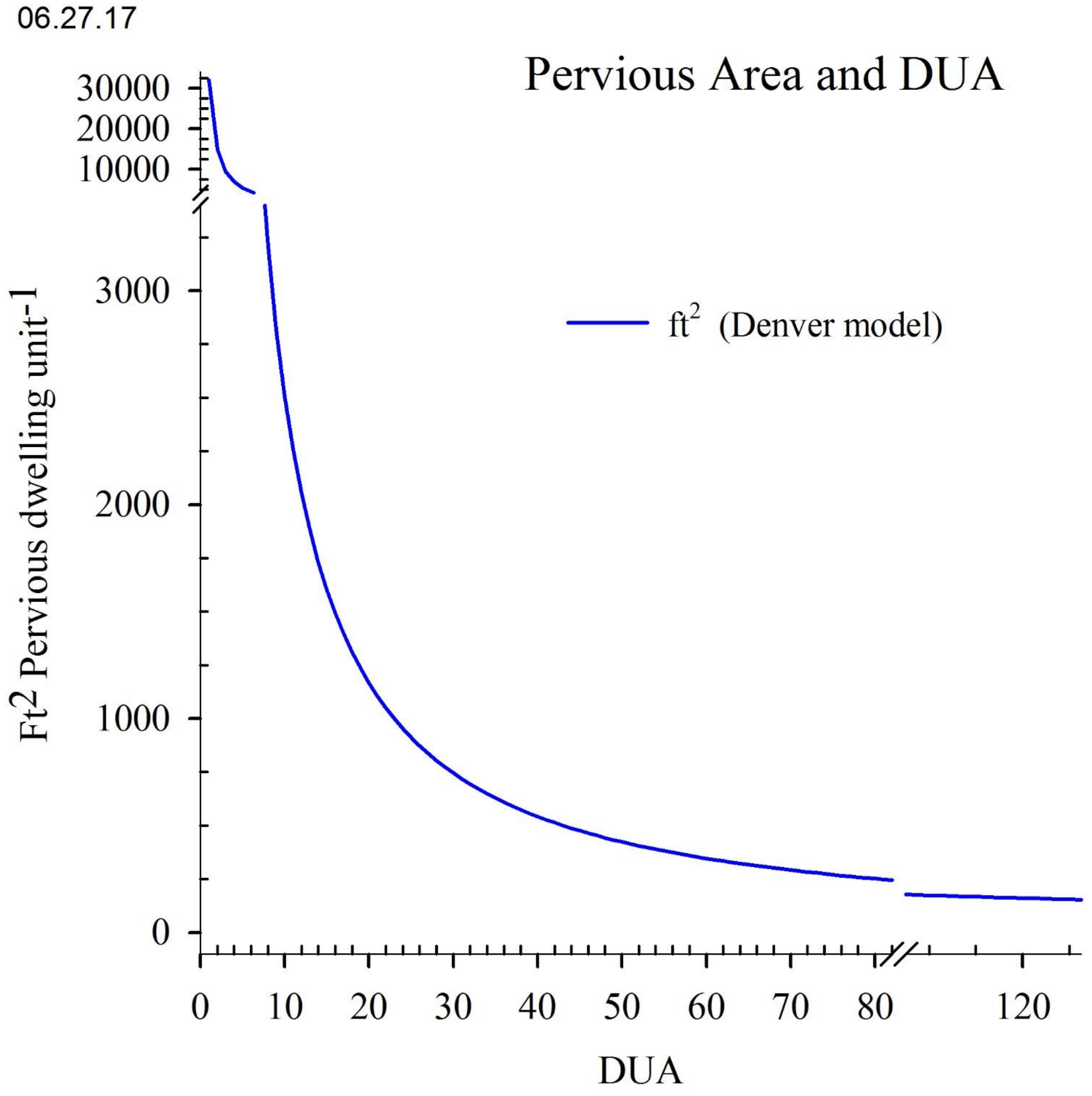
- Based on Building Types/Households

Building Type	Code	Median Dwelling Units Per Acre	Persons Per Household	Indoor GPCD	Pervious SqFt per Unit	Median Gallons Per SqFt Pervious Area
Large Single Family	LSF	2.8	2.5	63.5	8,837	11.9
Typical Single Family	TSF	5.1	2.5	50.9	4,492	8.2
Small Single Family	SSF	8.6	2.4	52.0	2,299	12.5
Small Multifamily	SMF	16.0	2.4	52.6	1,047	13.1
3-Story Walkup	WMF	24.3	2.3	59.8	641	27.2
Mid-Range Multifamily	MMF	71.8	2.1	69.3	160	31.9
High Density Multifamily	HMF	115.2	2.0	60.2	88	57.1

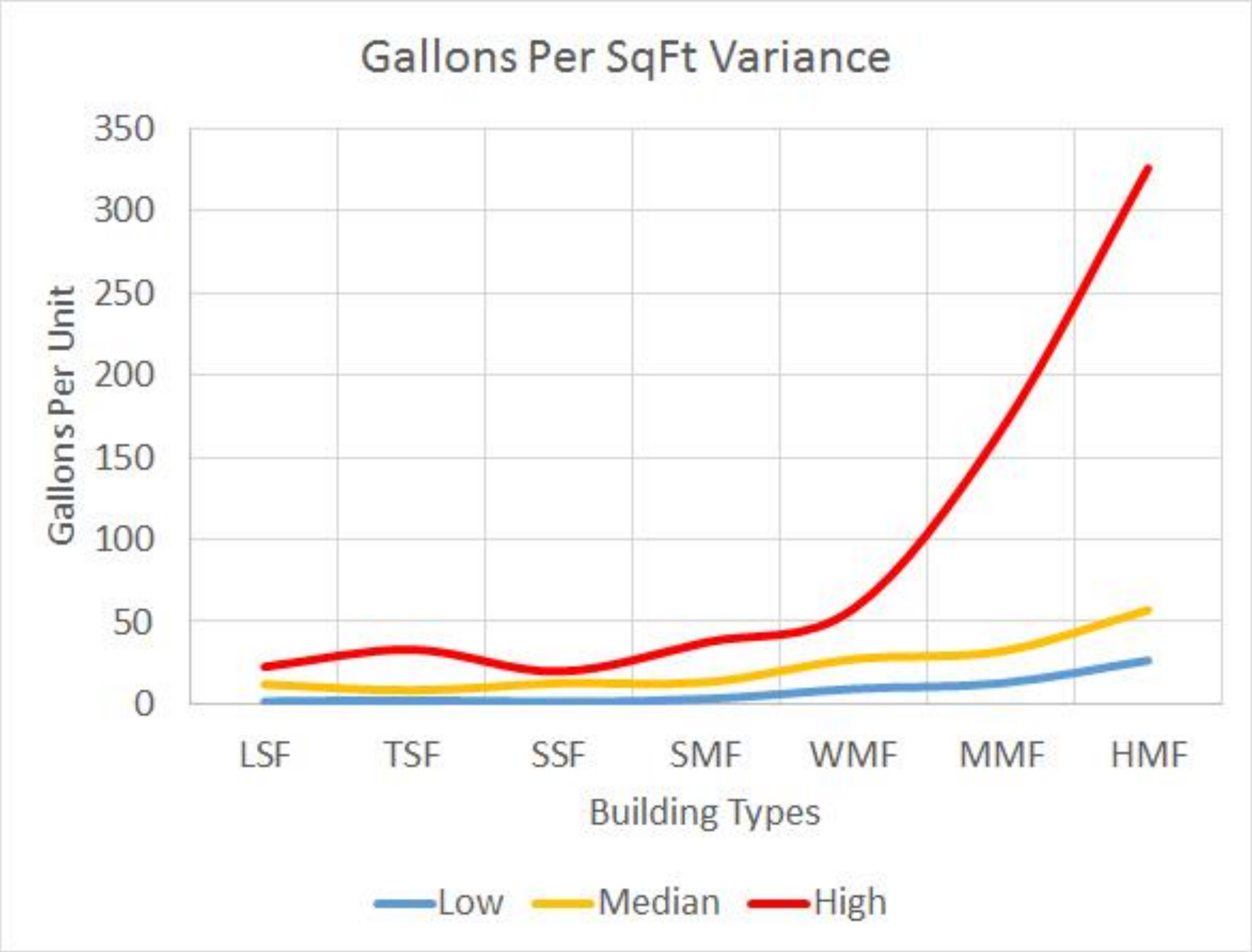
Basic Denver Model

- Indoor Gallons Per Capita Per Day
- People Per Household
- Number of Units - Households
- Pervious Surface Area Per Unit
- Gallons Per Pervious Surface Area
- Indoor Demand =
  (People Per Household * Number of Households) * Indoor GPCD * 365 days
- Outdoor Demand =
  (Pervious Area* Gallons per Pervious Area) * Number of Units

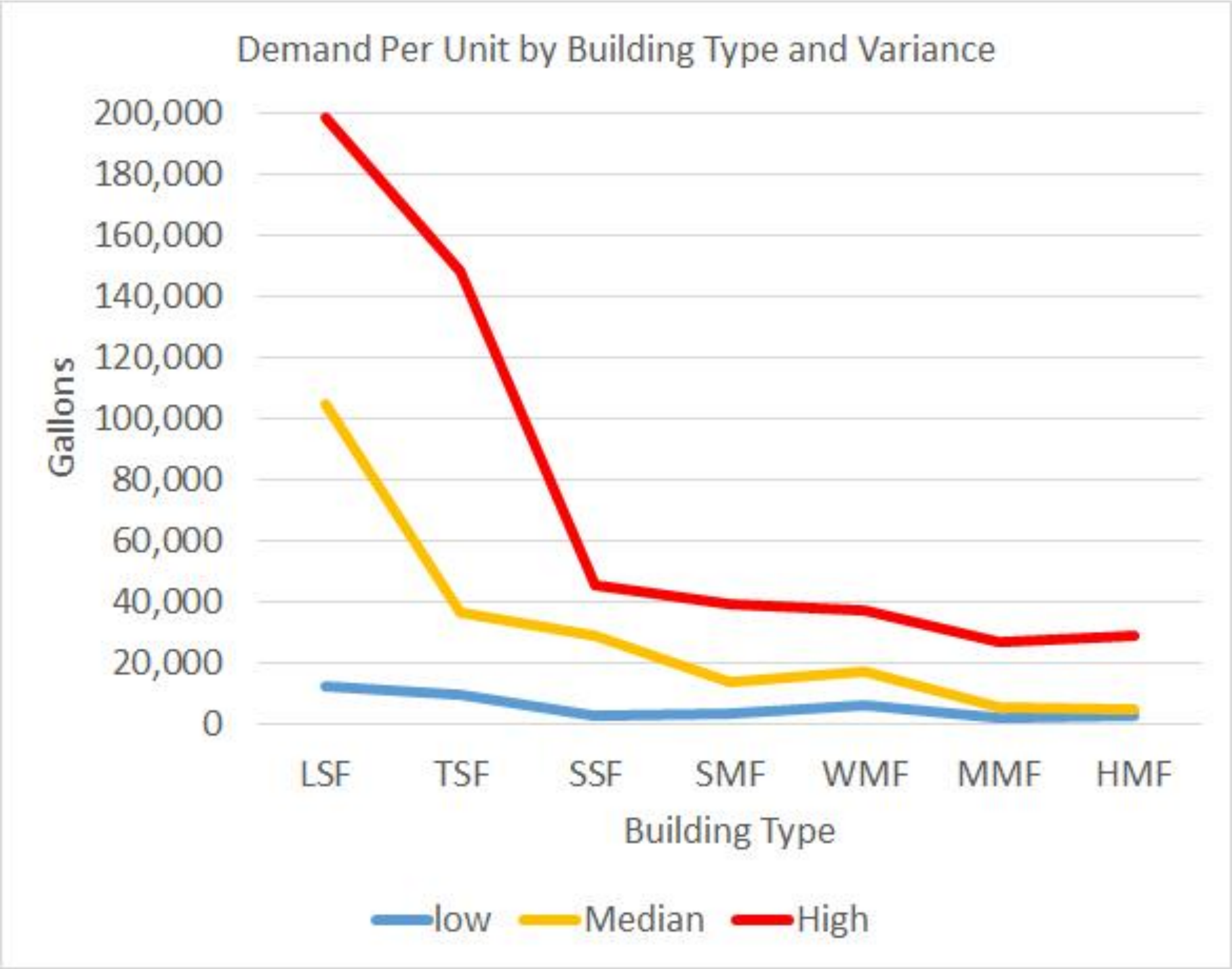
Pervious Area



Efficiency – Gallons Per SqFt Pervious



Outdoor Demand

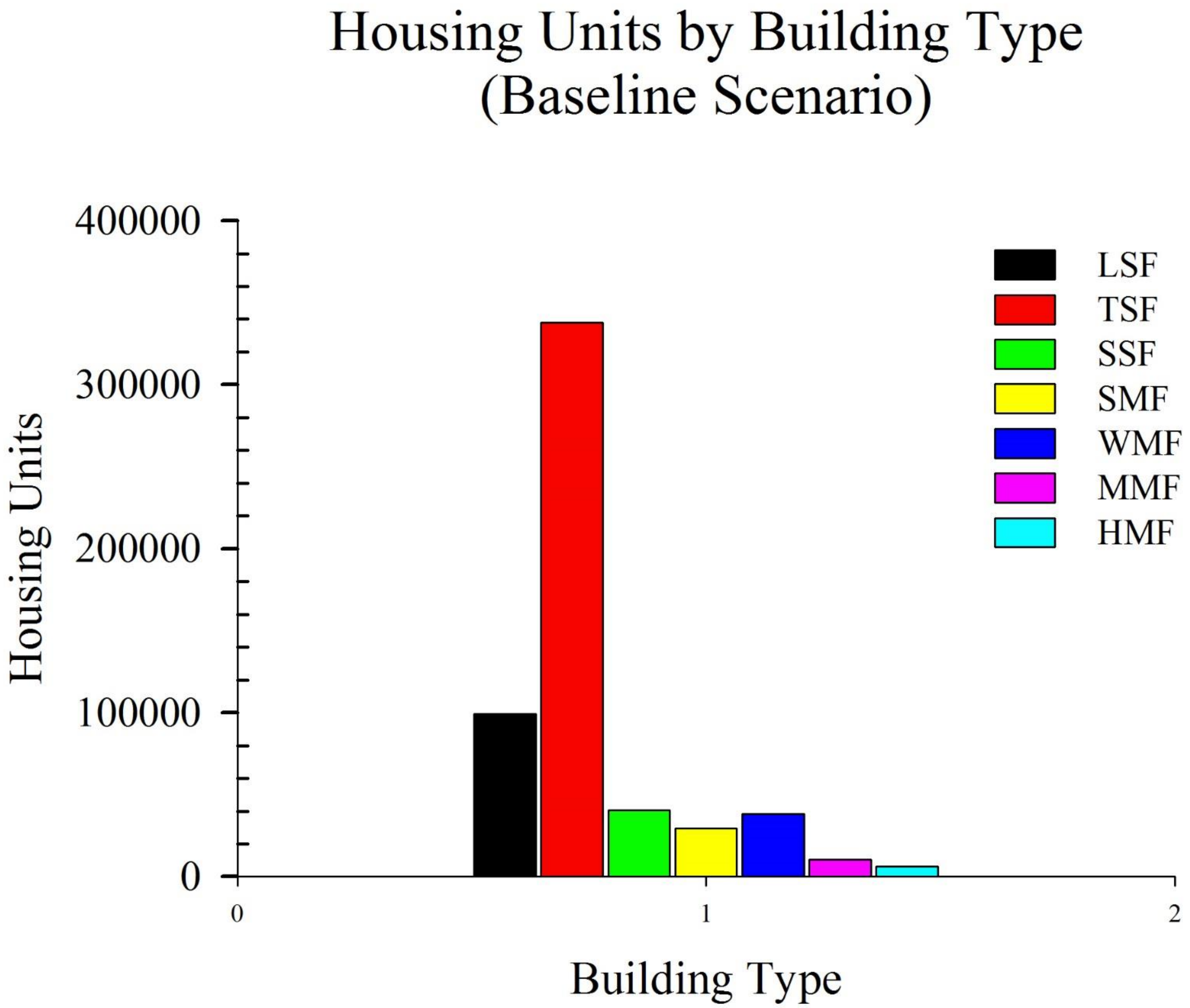


Current Conditions

- Assessment at a Regional Level
  - Number of total households
  - Estimate of Households for each Denver building type.
- Region Estimate of Building Types
- Region Demand By Building Type

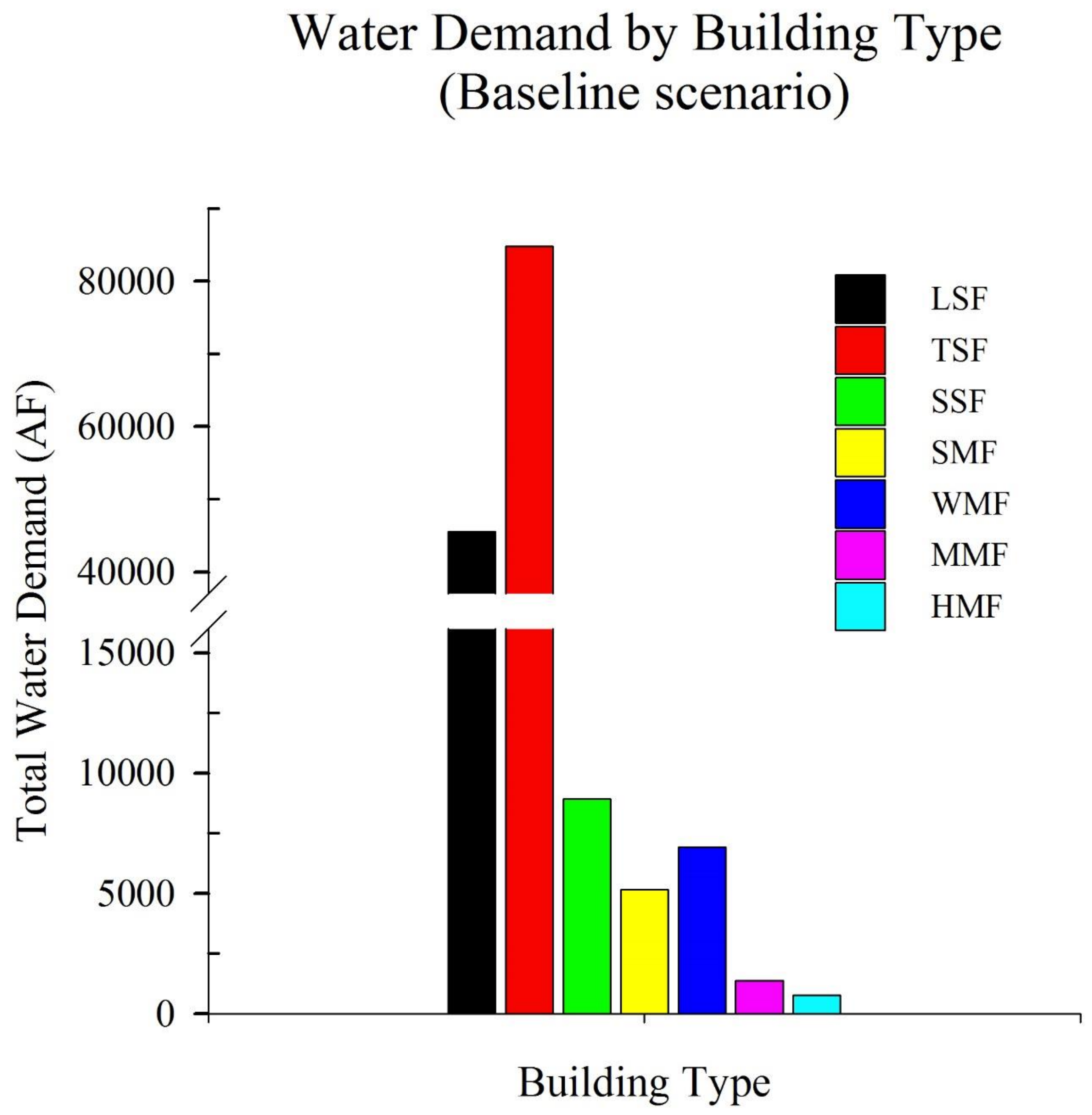
Estimate of 2015 Building Types

- Based on method to classify existing parcels and buildings to Denver types.
- With assistance from DRCOG
- Did not classify 30% of housing units.



Estimates of Water Demand By Building Type

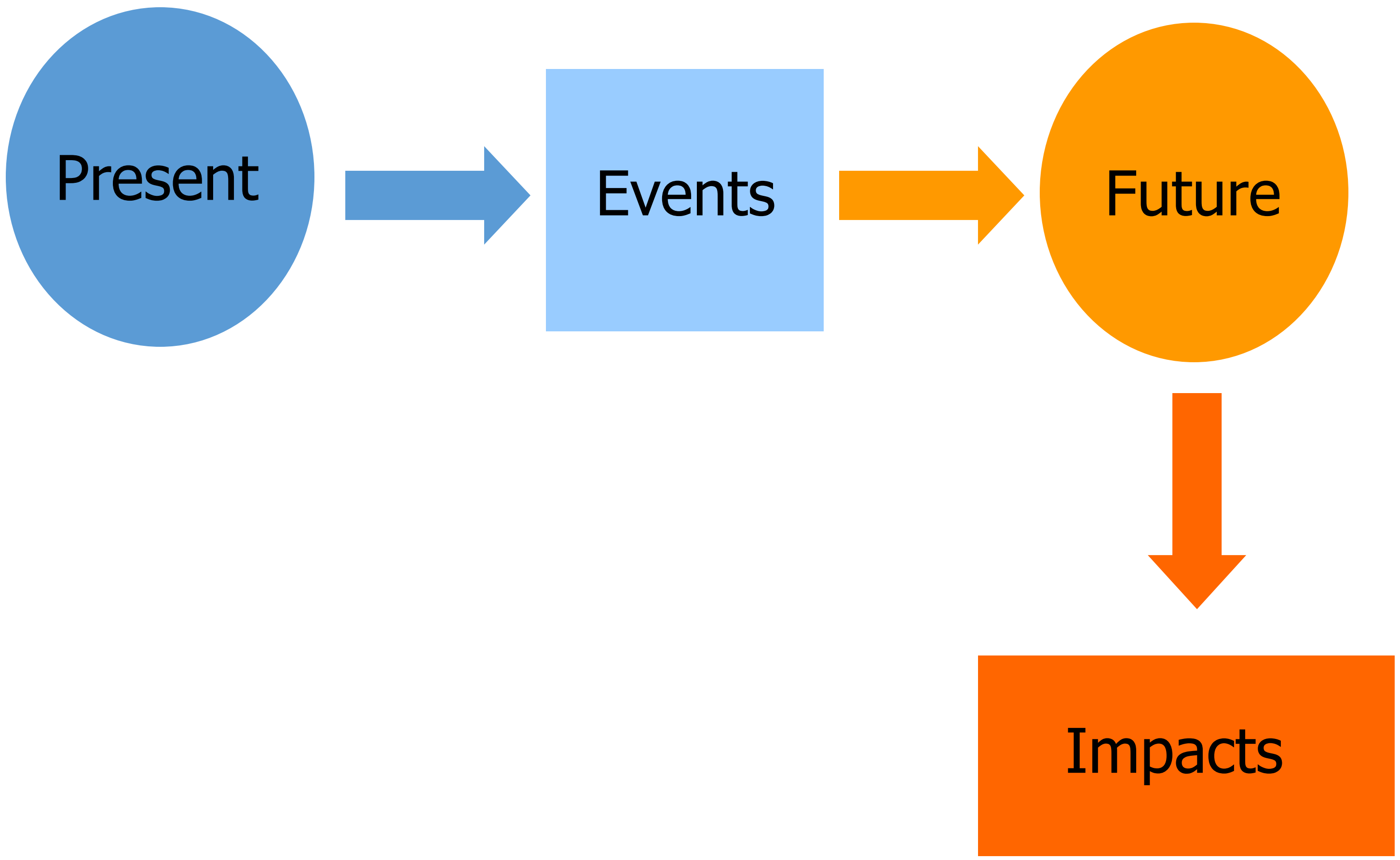
Median Gallons Per SqFt Pervious Area



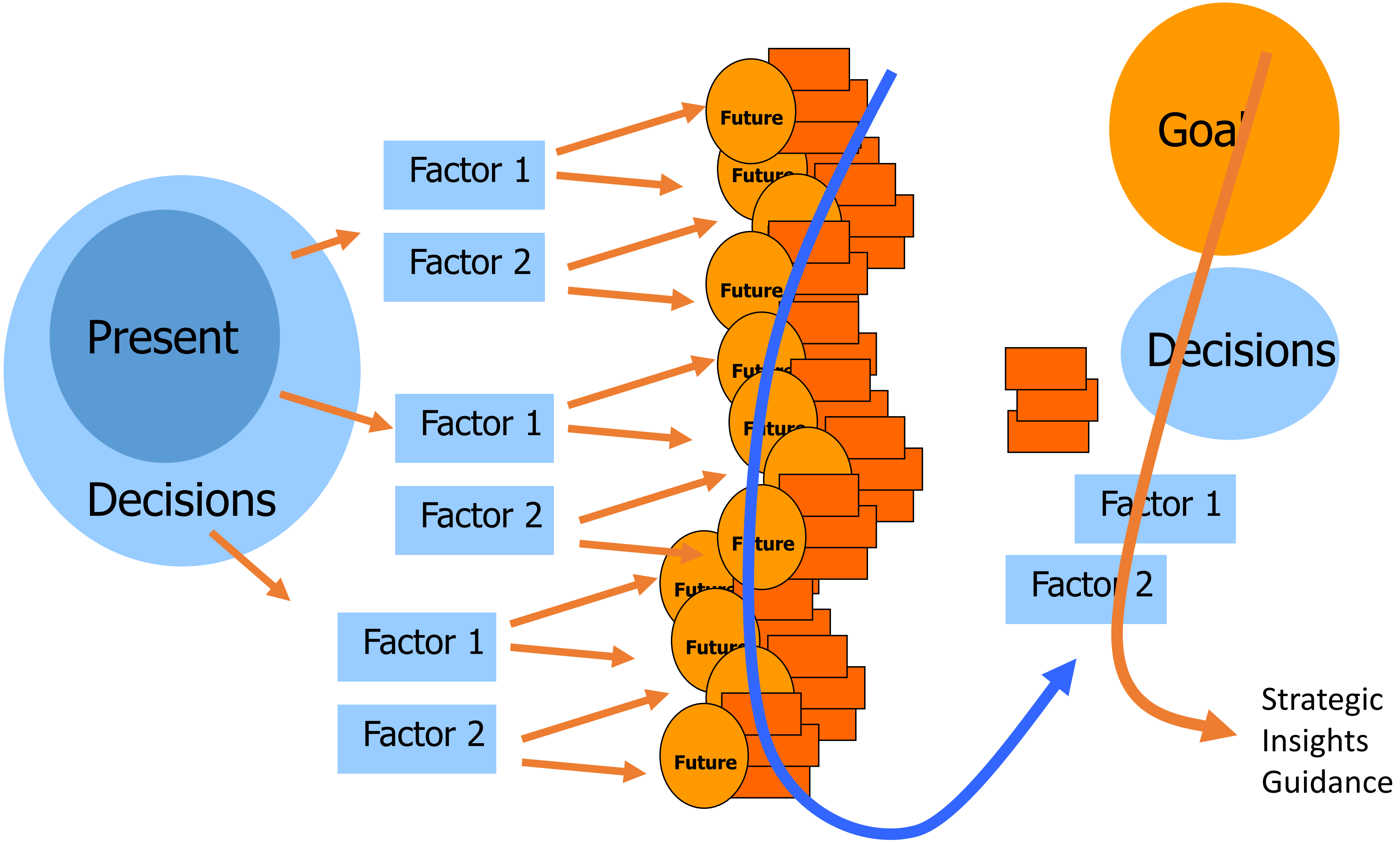
Scenario Analysis

- What is it?
- Scenarios
  - Increasing Density
  - Increasing Efficiency

Futures Analysis - Scenario



Advanced Scenario Analysis



DCDC’s – Denver Water Model

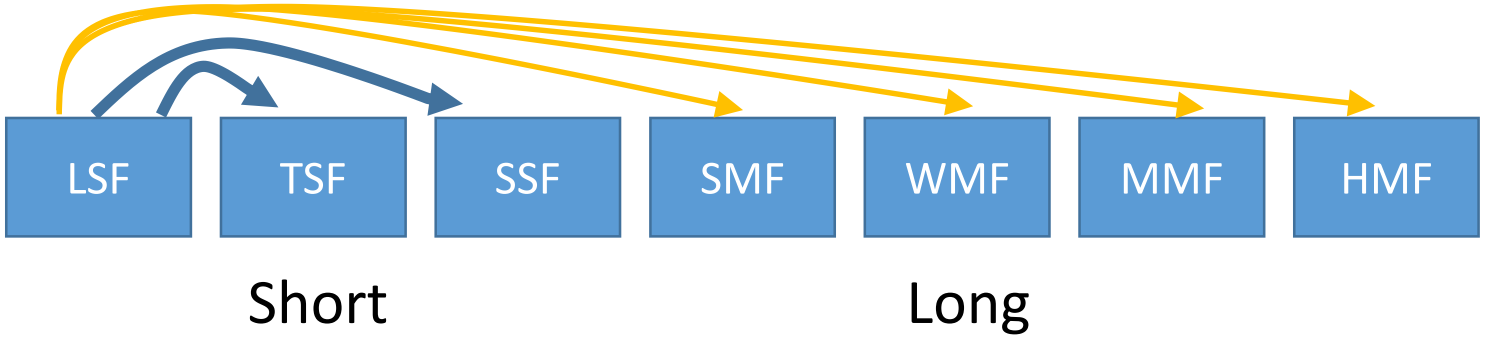
- Based on Denver Water’s model and data.
  - They did most of the hard work.
- Agent based model.
  - **Agent:** a group of households that have common characteristics and behave in the same way.
  - Unique agents make decisions and take actions,
    - Such as choosing a building type and consuming water
  - **Base Scenario:** No change in density or efficiency.
    - Agents have same building type, same persons per household, same indoor GPCD, thus seven agents.
  - **Assumption:** new units are distributed among building types as they are under current estimates.
- One time step, to the future.
  - Using DRCOG 2040 TAZ estimates
    - 1,383,233 new people.
    - 562,069 new units
- Qualification:
  - Analysis results are independent of number of new people and households and the time line.

Scenario Analysis

- Scenarios
    - Increasing Density
    - Increasing Efficiency

Scenarios: Increasing Density – Key Concepts

- Household movement:
  - Households can move their housing choice from a unit of one building type to a unit of a higher density building type.
  - The household takes its persons (household size) and its indoor water use behavior (indoor GPCD) with it to the new building type.
  - Building type characteristics, such as DUA, Pervious area, and water use per pervious area, stay with the building type unit.
- Movement depth:

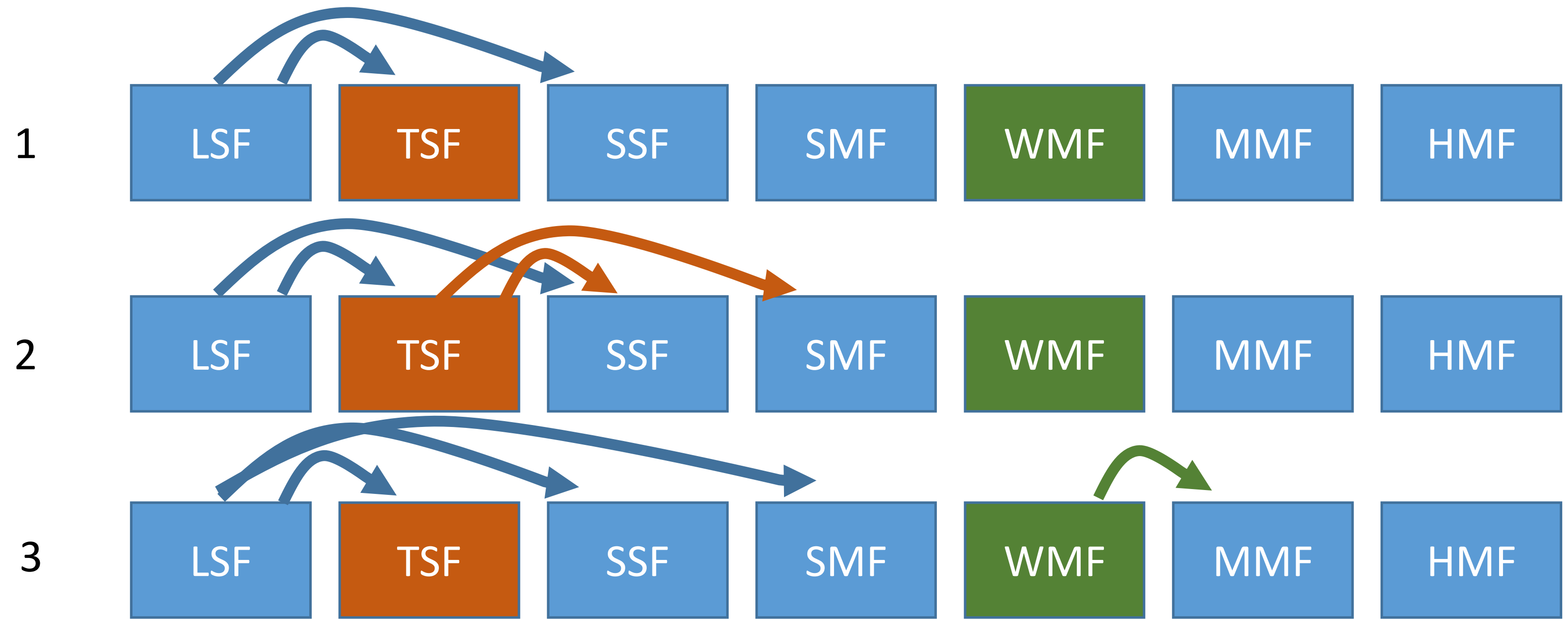


Scenarios: Increasing Density – Key Concepts

- Household Movement Assumptions
  - In a scenario when household movement occurs, building types can not be skipped, movements are cumulative.
    - For example, Movement can occur from LSF to TSF and LSF to SSF, but not just from LSF to SSF.

Scenarios: Increasing Density – Key Concepts

- Scenario Construction
  - A scenario consists of different patterns of movement of households form one building type to another.
    - For example.



Scenarios: Increasing Density – Key Concepts

- Scenario Construction Assumption
  - Households do not move to a less dense building type.
- Scenario Construction
  - No movement is a scenario option
  - Multiple scenarios each representing different combinations of household movements
  - Number of new households moving is a scenario option.
    - 10%, 20%, .. 50%
    - Each adds 5,040 scenarios
    - **Assumption:** When moved to multiple building types, the households are equally distributed to each. 20% of total households moved to 5 building types, each gets 4% .

Building Type	Possible Movements	No Movement	Possible Scenarios
LSF	6	1	7
TSF	5	1	6
SSF	4	1	5
SMF	3	1	4
WMF	2	1	3
MMF	1	1	2
HMF	0	1	1
Total Scenarios			5,040

Scenarios: Increasing Density – Key Concepts

- Household Movement Increases Density
  - As new households chose to live in a denser building type, the average density of the community increases.
  - The more households and the higher the density of building types, the higher the average density increases.
- Increased Density Reduces Per Unit Outdoor Water Demand
  - Generally increases in average community density result in declines in outdoor demand
  - But, decreasing per unit outdoor demand is not uniform across all building types. For example, going from Small Multifamily to Walk-up Multifamily increases demand.

Scenarios: Increasing Density – Key Concepts

- **Assumption:** Indoor use of water is more a function of culture and household structure (i.e., children and age) than of the physical features of low or high density housing.
- **Glossary**
  - **Average DUA:** This is the weighted average across all building types of the communities ratio of Dwelling Units Per Acre.
  - **Percent Savings:** The percent of decline in water demand (total or outdoor) from a base scenario that has no movement of households.

Scenarios Increasing Density

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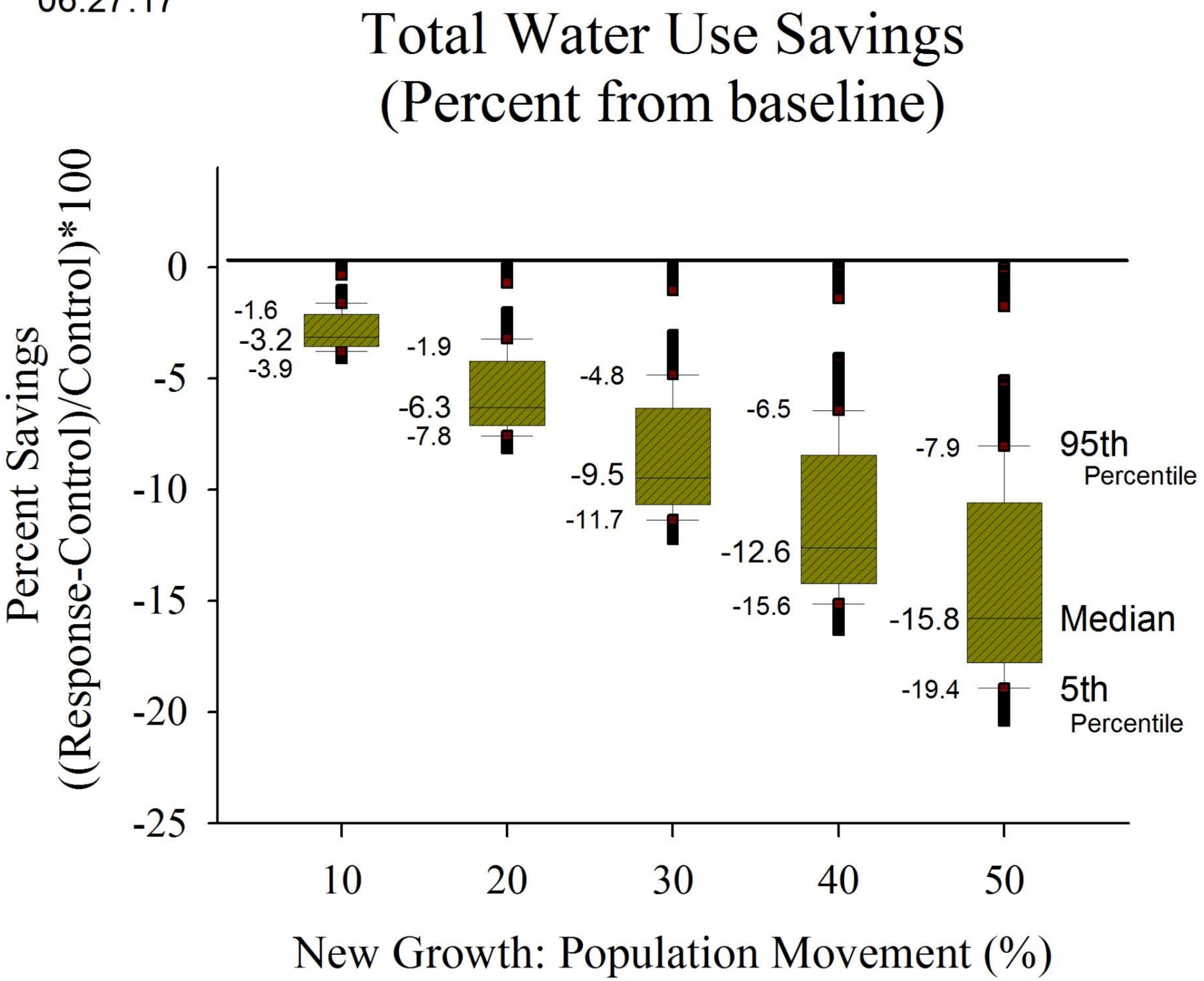

5 levels of % households moving
5,040 Scenarios each
25,200 Total Scenarios

Scenarios: Increasing Density – Key Concepts

- **Resource Costs:** The efforts to influence household choice of building type are considered resource costs. These costs may be **political**, such as the effort to change zoning and building codes, **economic**, such as the subsidy of the higher costs of denser housing, or **social**, such as changes in culture or values.
- **Assumption:** The more household movement and the deeper this movement the higher the Resource Costs.

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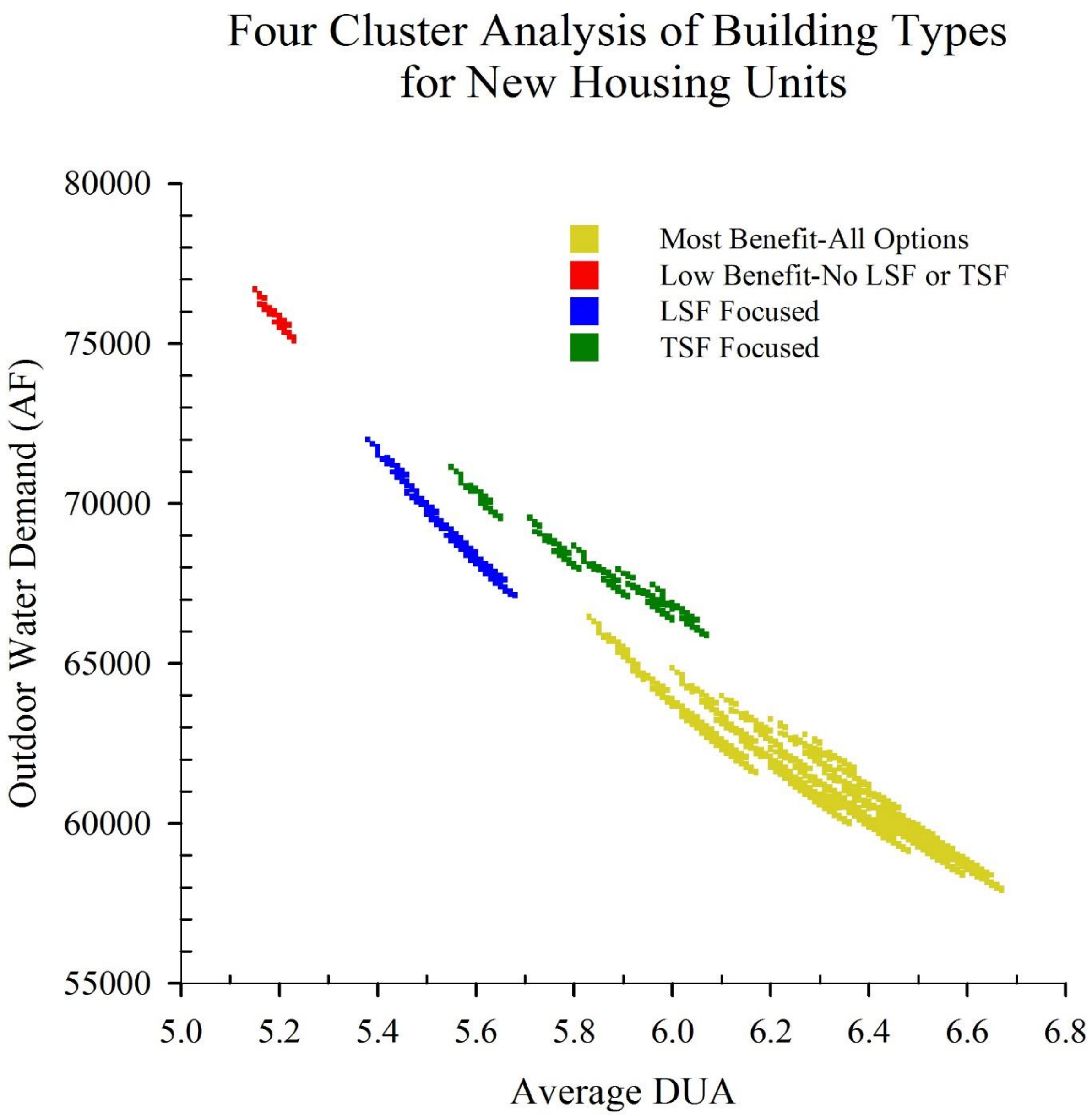
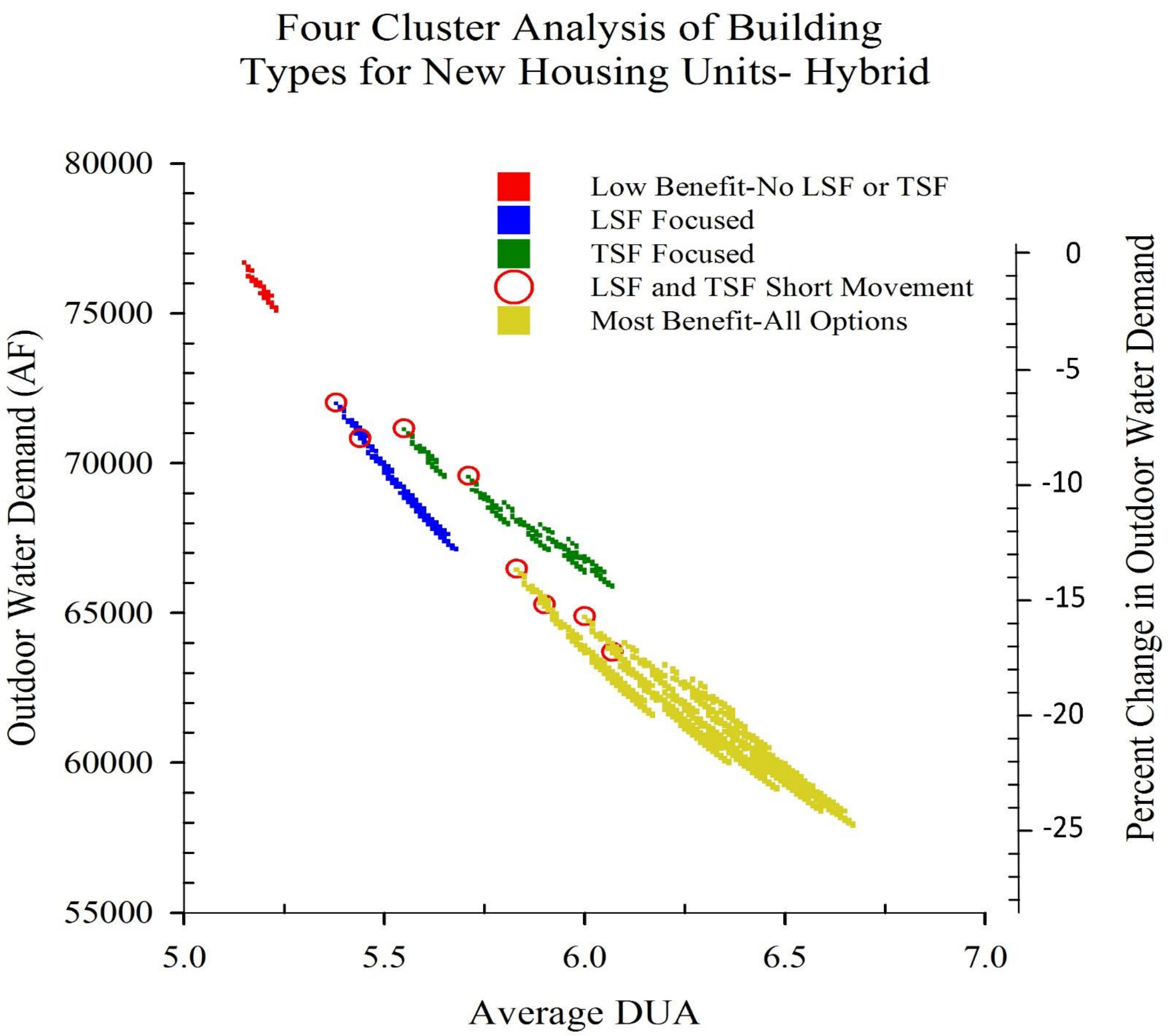
Scenarios Increasing Density

- Not all scenarios of household movements are the same
- 30% household movement example
- Four clusters of scenarios

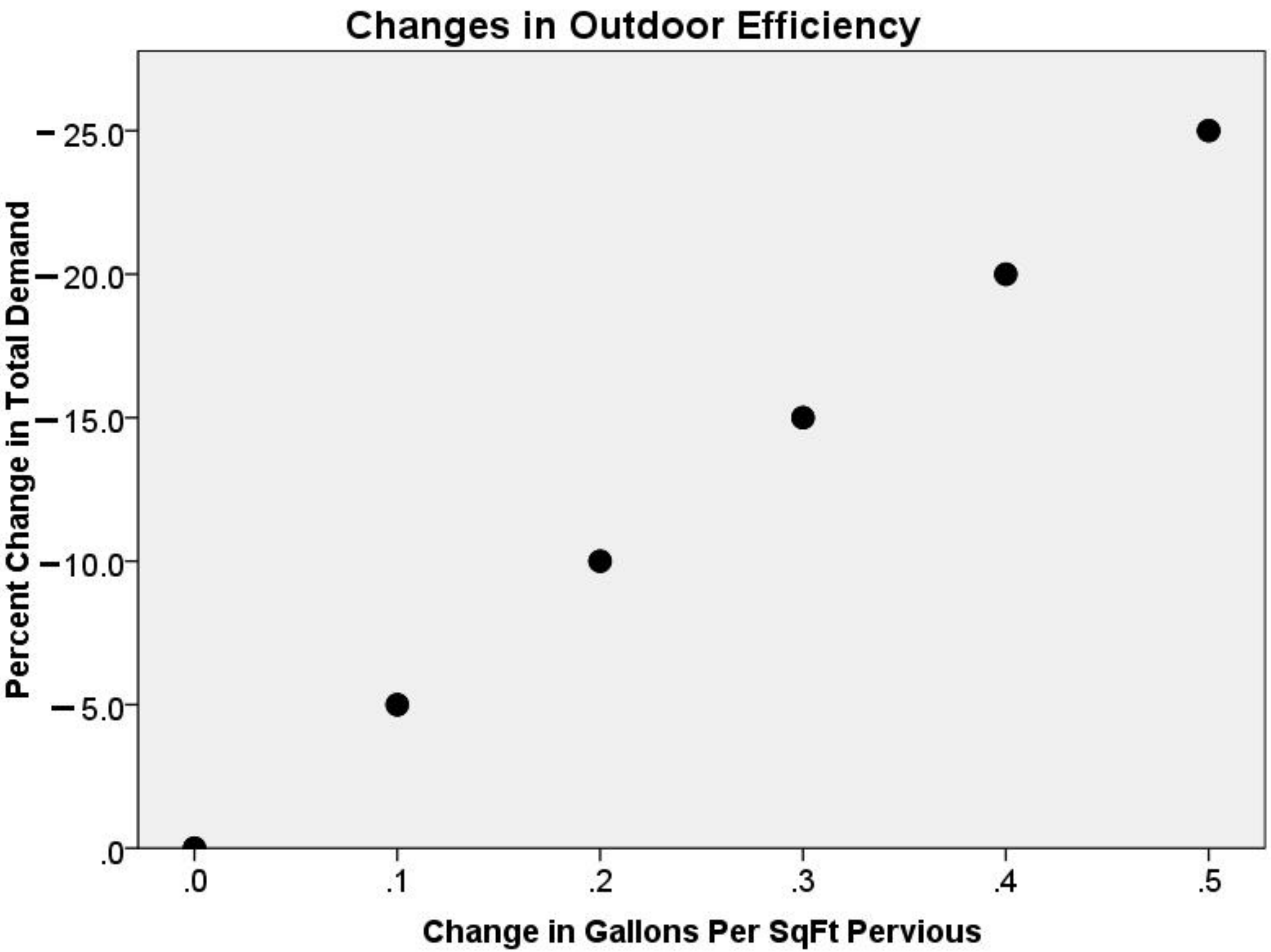


Increasing Density

LSF and TSF short movement scenarios are low resource costs



Increasing Efficiency



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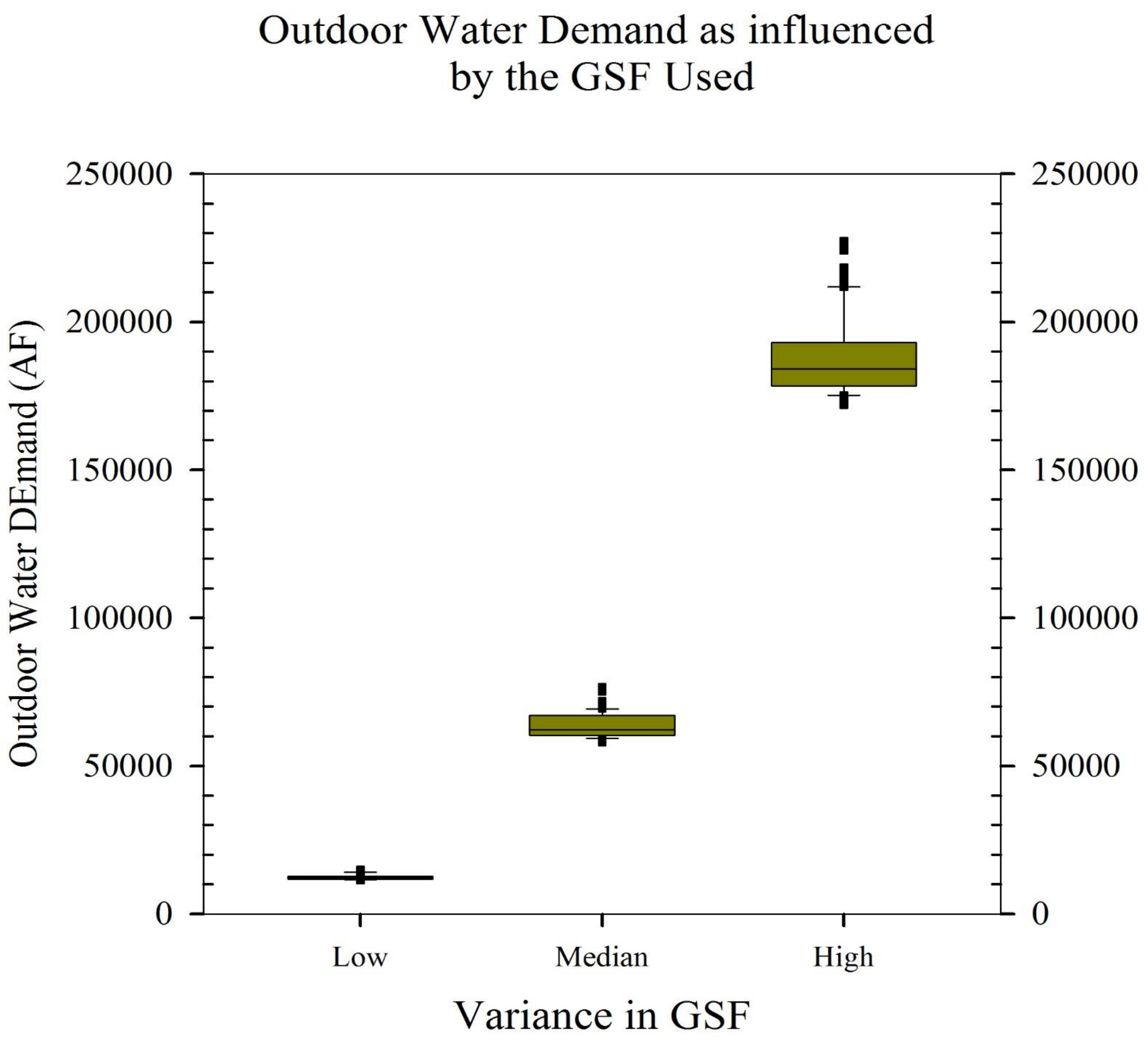
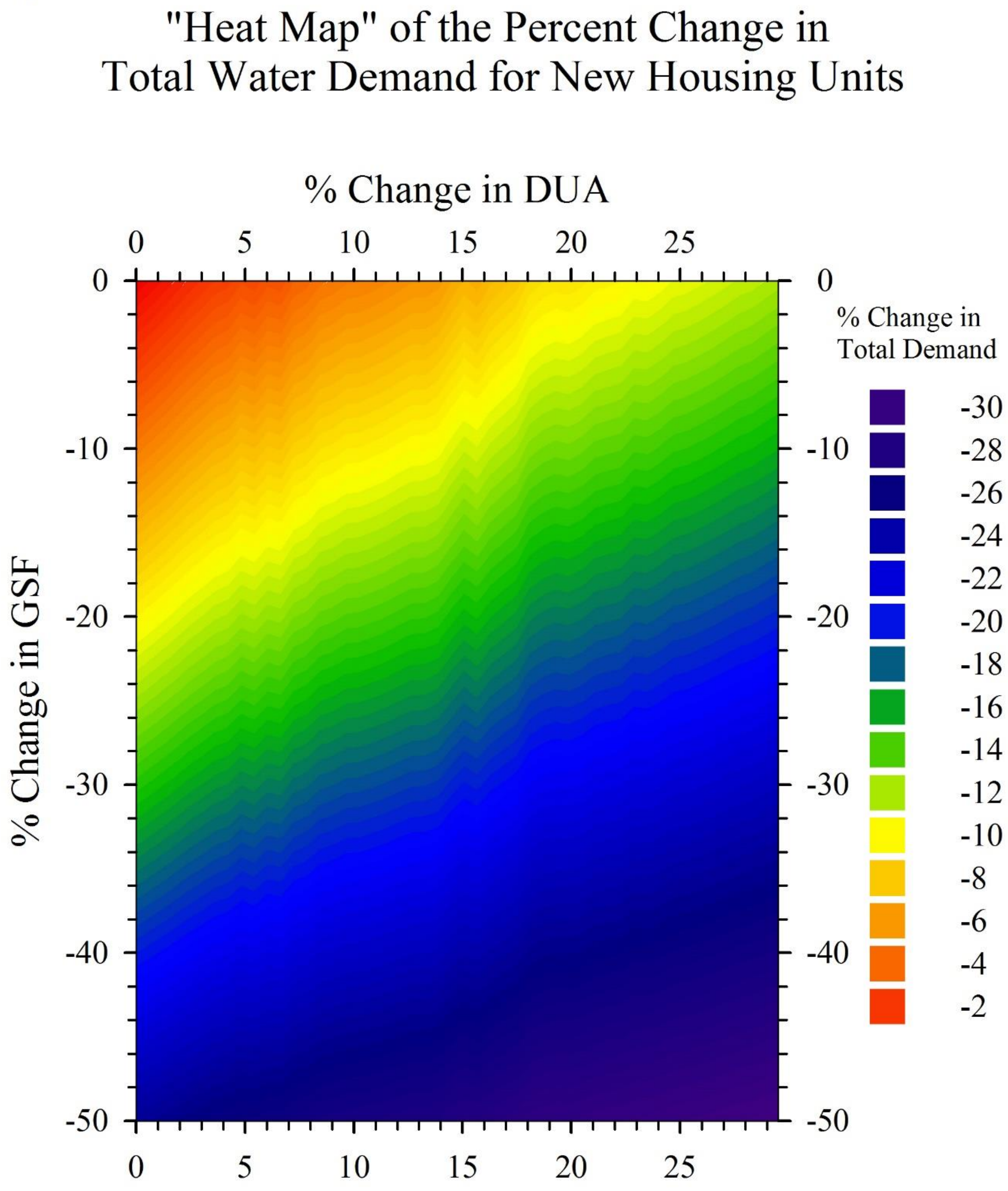
Increasing Efficiency



Scenarios: Density and Efficiency

- Median Gallons Per SqFt Pervious
- 30% Household Movement



Strategic Insights (Key Points)

- Increasing density may decrease demand of new growth in the range of 2% to 12%, with higher resource costs associated with the higher number.
- Lower resource cost increased density scenarios may achieve 3% to 8% reduction for new housing.
- Reducing Demand Per SqFt Pervious Area (DPSFP) may decrease demand of new growth in the range of 5 to 25%, and be as effective, if not more, at reducing demand as increasing density.
- Combining low resource cost density increase with low resource cost reductions of DPSFP may achieve reductions in total demand of new growth by 10 to 12%.

Strategic Insights (Key Points)

- Household movement from the Large Single Family and Traditional Single Family to other building types provides the largest reductions in total water demand of new housing.
- Scenarios that do not include LSF and TSF have little benefit.
- The Walk-up Multifamily building type has a higher per unit outdoor demand than any other multi family building type. Future household growth in this building type could increase demand.
- The medium and high density multifamily building types have a very large variance in gallons per sqft pervious area. If future development occurred in this higher range, this could actually result in increased demand.
- **Qualification:** DCDC resources to conduct this analysis are limited and these insights are based on a preliminary assessment. Further refinement of the model, data, and assessment may reveal other insights or change these insights.

Future Efforts

- May do further analysis
  - Sensitivity of factors
  - Variance of Indoor GPCD
  - Variance of DUA
- Will write at least one academic paper
- May do similar analysis for other major Colorado Basin urban regions

More Information

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