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Pavement Treatment Practices and Dynamic Albedo Change of Urban Pavement Network in California

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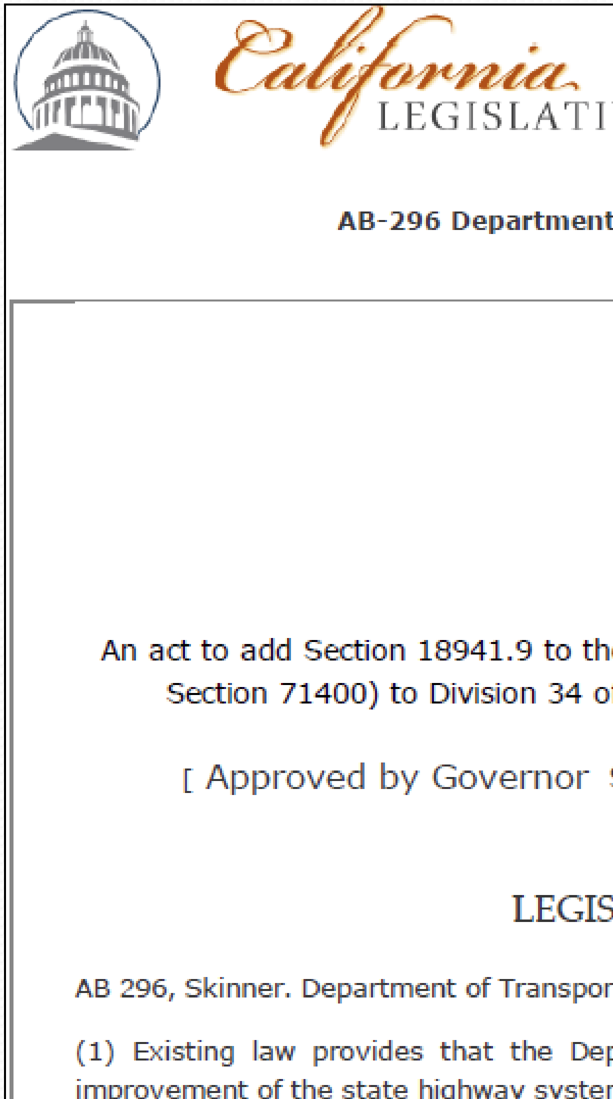
Outline

- Project Background & Objective
- Methodology
  - Pavement Management Practice Survey
  - Field Measurement of Albedo
  - Dynamic Albedo Change Modeling for Urban Pavement Network
- Results
  - Local Government Pavement Management Practice
  - Albedo of Pavement Materials
  - Dynamic Albedo Change of Urban Pavement Network
- Conclusions & Recommendations

Reflective/Cool Pavement Motivations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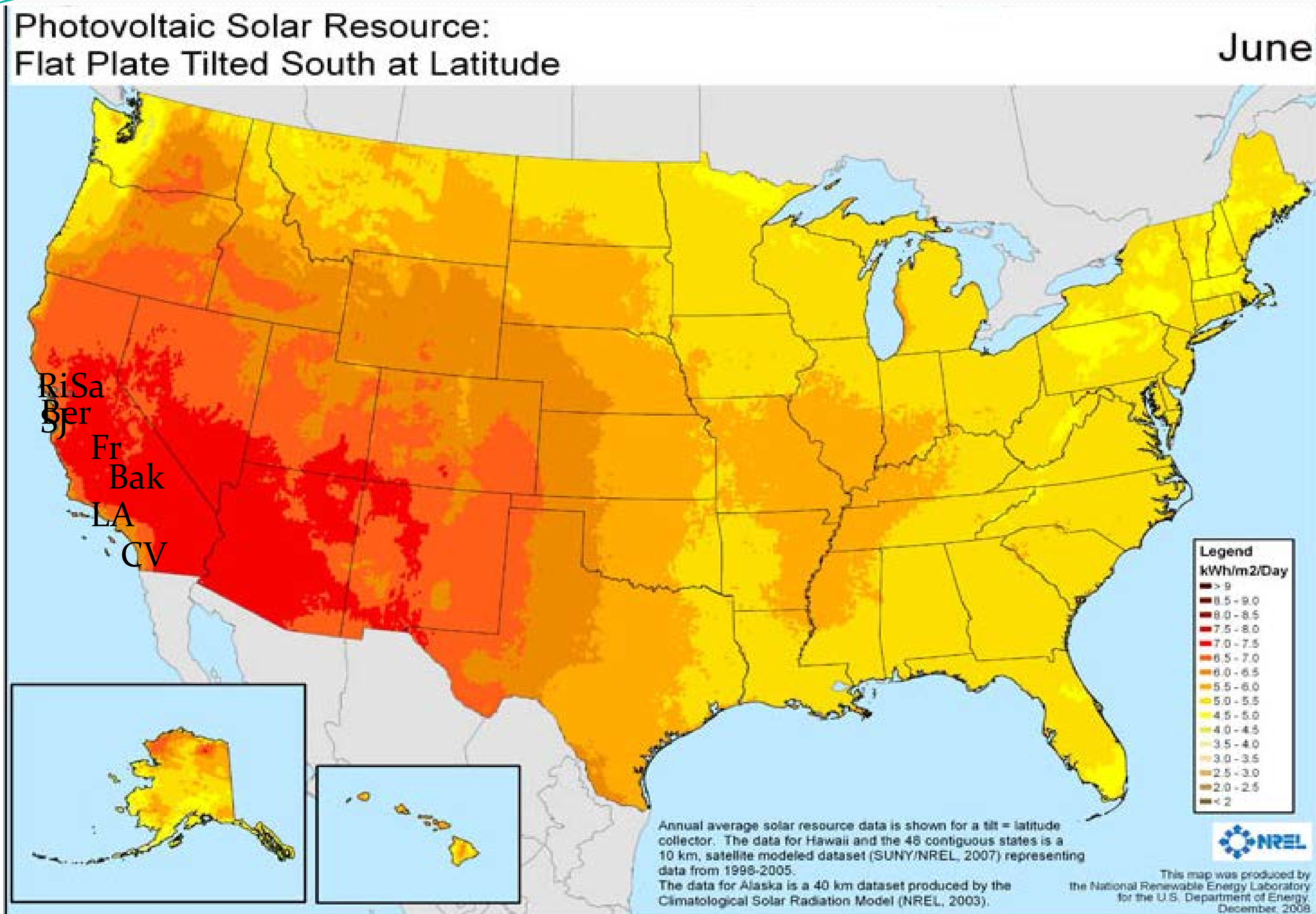
- This paper addresses: how much the urban pavement network albedo can be realistically changed through maintenance over time
- Other work by LBNL, UCPRC and USC addressing lifecycle impacts the change can bring
- Both are open questions for modeling
- Included in Urban Heat Island Life Cycle Assessment analyses currently being completed

Background and Objective

- Background:
  - Climate simulation (WRF) models cannot time-step albedo over simulation analysis period
  - Many climate modelers assume steady state increases of 0.1 to 0.2 for entire network
- Objective: Develop model and tool for estimating
  - Average city-wide albedo for 50 year analysis period
  - To be used in Climate Modeling tool (WRF)
  - Considering local government pavement management practice and available albedo data

Pavement Management Survey



Pavement Management Survey

- Questions:
  - Size of pavement network
  - Portion of the network that in a typical year gets any kind of treatment
    - Example: "treat 7.5 lane-miles per year, or treat 5 percent of network per year"
  - Approximate breakdown of treatments used
    - Example: Slurry seal, 70 percent of network or 200 lane-miles per year
    - Other treatments identified: Asphalt resurfacing, chip seals, sand seals, cape seals, reconstruction (asphalt, FDR, CIR, other)

Field Measurement of Albedo

- Methods:
  - ASTM E1918 (pyranometer), or
  - Modified ASTM E1918 (dual-pyranometer, UCPRC)
- Data Sources
  - Lawrence Berkeley National Laboratory (LBNL)
  - Federal Highway Administration (FHWA) contractors
  - University of California Pavement Research Center (UCPRC) projects

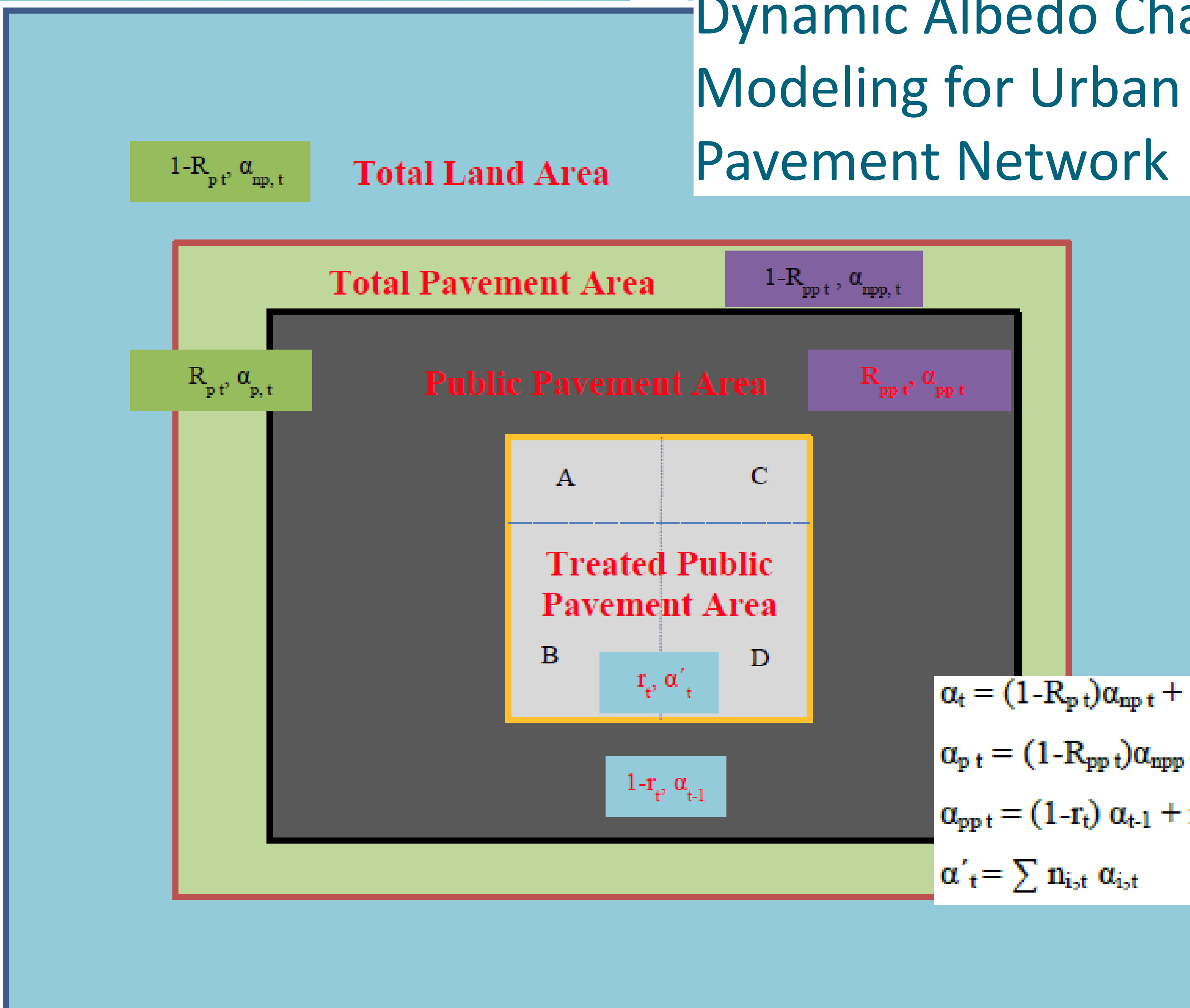
Albedometer with dual-pyranometer

Field Measurement of Albedo

- Materials for which data gathered or measured
  - Asphalt Concrete or Overlay
  - Asphalt Concrete or Overlay with Reflective Coating
  - Chip Seal
  - Slurry Seal
  - Cape Seal
  - Fog Seal
  - Sand Seal
  - Portland Cement Concrete
  - Conventional Interlocking Concrete Pavement
  - Permeable Asphalt Pavement
  - Permeable Concrete Pavement
  - Permeable Interlocking Concrete Pavement
  - Gravel
  - Soil
  - Grass
- Many have limited time history (aging) data

Albedometer with dual-pyranometer

Dynamic Albedo Change Modeling for Urban Pavement Network



$$\alpha_t = (1\text{-}R_{p\,t})\alpha_{np\,t} + R_{p\,t}\,\alpha_{p\,t}$$

$$\alpha_{p\,t} = (1\text{-}R_{pp\,t})\alpha_{npp\,t} + R_{pp\,t}\,\alpha_{pp\,t}$$

$$\alpha_{pp\,t} = (1\text{-}r_t)\,\alpha_{t\text{-}1} + r_t\,\alpha'_t$$

$$\alpha'_t = \sum n_{i,t}\,\alpha_{i,t}$$

Local Government Pavement Management Practice

City	Portion of Each Treatment Used in Total Network Treated					
	A. Slurry Seal	B. Sand Seal	C. Chip Seal	D. Cape Seal	E. Asphalt Overlay	F. Reconstruction (AC, RAC, FDR, CIR)
City of Bakersfield	-	75%	-	-	13%	12%
City of Berkeley	31%	-	-	-	41%	28%
City of Chula Vista	28.3%	-	46.4%	0.5%	21.8%	3%
City of Fresno [a]	-	-	-	-	100%	-
City of Los Angeles	60.7%	-	-		35.4%	3.9%
City of Richmond	47.1%	-	0.7%	0.5%	45.9%	5.9%
City of Sacramento	82.4%	-	-	-	17.6%	-
City of San Jose	80%	-	-	-	20%	-
Average	***41.2%***	***9.4%***	***5.9%***	***0.1%***	***36.8%***	***6.6%***

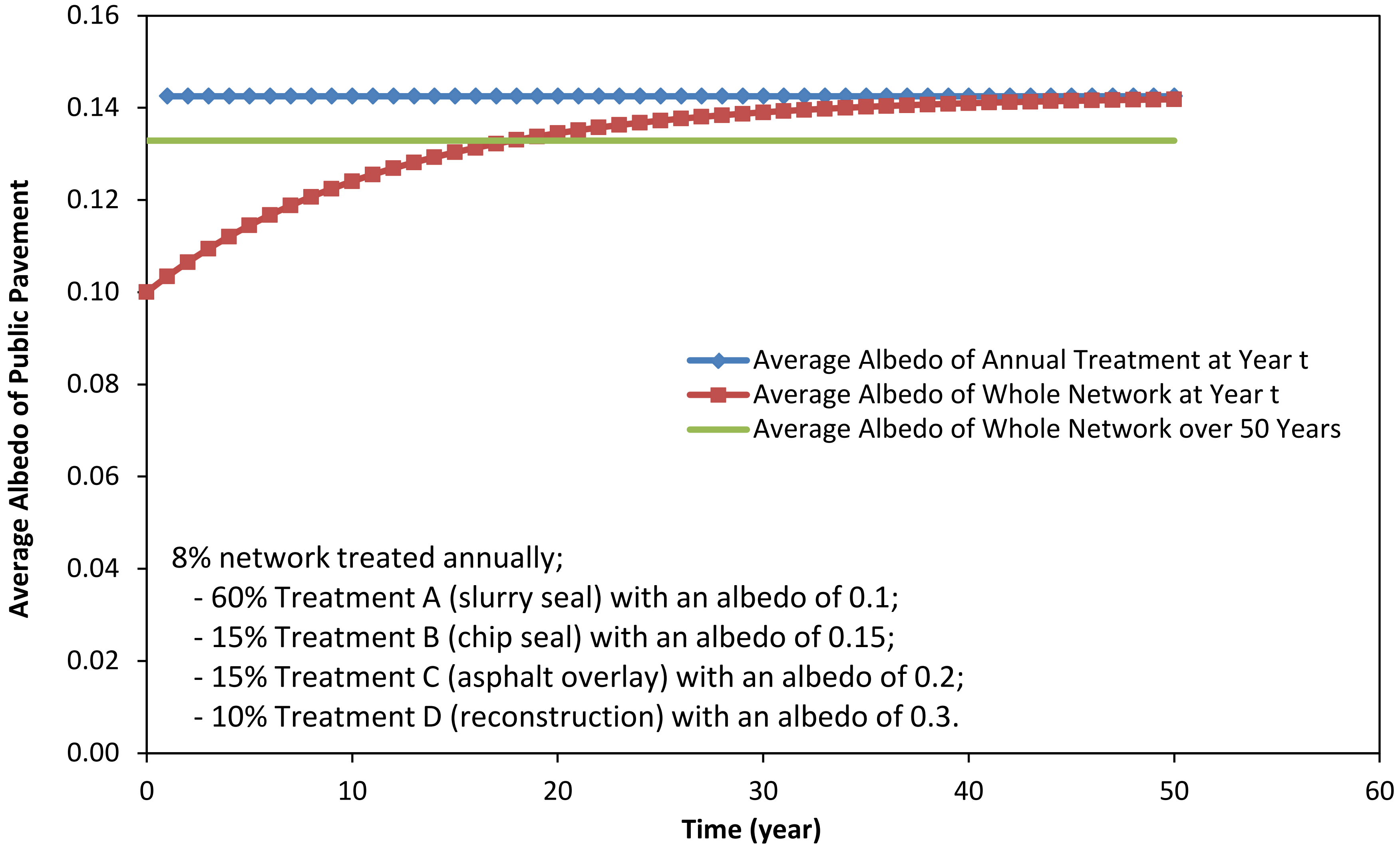
[a] 40 centerline miles asphalt overlay up to 2009, then 20 cen

[b] use multiplier 2.2 to convert centerline miles to lane miles.

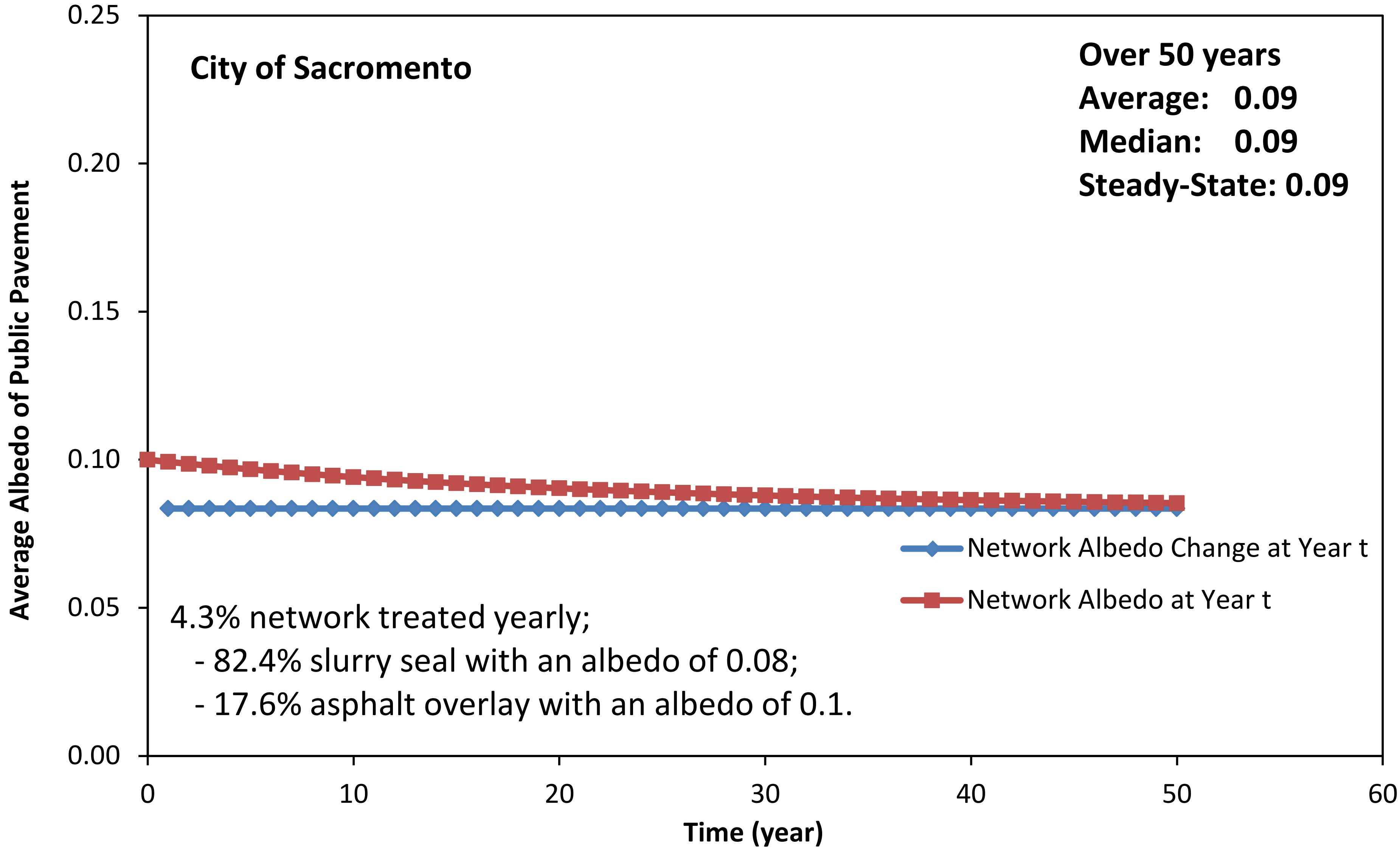
Material Type	Albedo (Typical)	
	Range	Avg.
Asphalt Concrete or Overlay	0.05 - 0.15	0.1
Asphalt Concrete or Overlay with Reflective Coating	0.2 - 0.3	0.2
Chip Seal	0.1 - 0.24	0.15
Slurry Seal	0.07 – 0.1	0.08
Cape Seal	0.05 – 0.15	0.06
Fog Seal	0.04 – 0.07	0.06
Sand Seal	0.07 – 0.1	0.08
Portland Cement Concrete	0.15 - 0.35	0.25
Conventional Interlocking Concrete Pavement	0.25 – 0.3	0.26
Permeable Asphalt Pavement	0.08 – 0.12	0.1
Permeable Concrete Pavement	0.18 – 0.28	0.25
Permeable Interlocking Concrete Pavement	0.25 – 0.3	0.26
Gravel	0.12 – 0.22	0.18
Soil	0.21 – 0.23	0.22
Grass	0.18 – 0.20	0.19

- *Not available.*

Example Simulation of Dynamic Albedo Change for 50 year period



Example for current practices: Sacramento



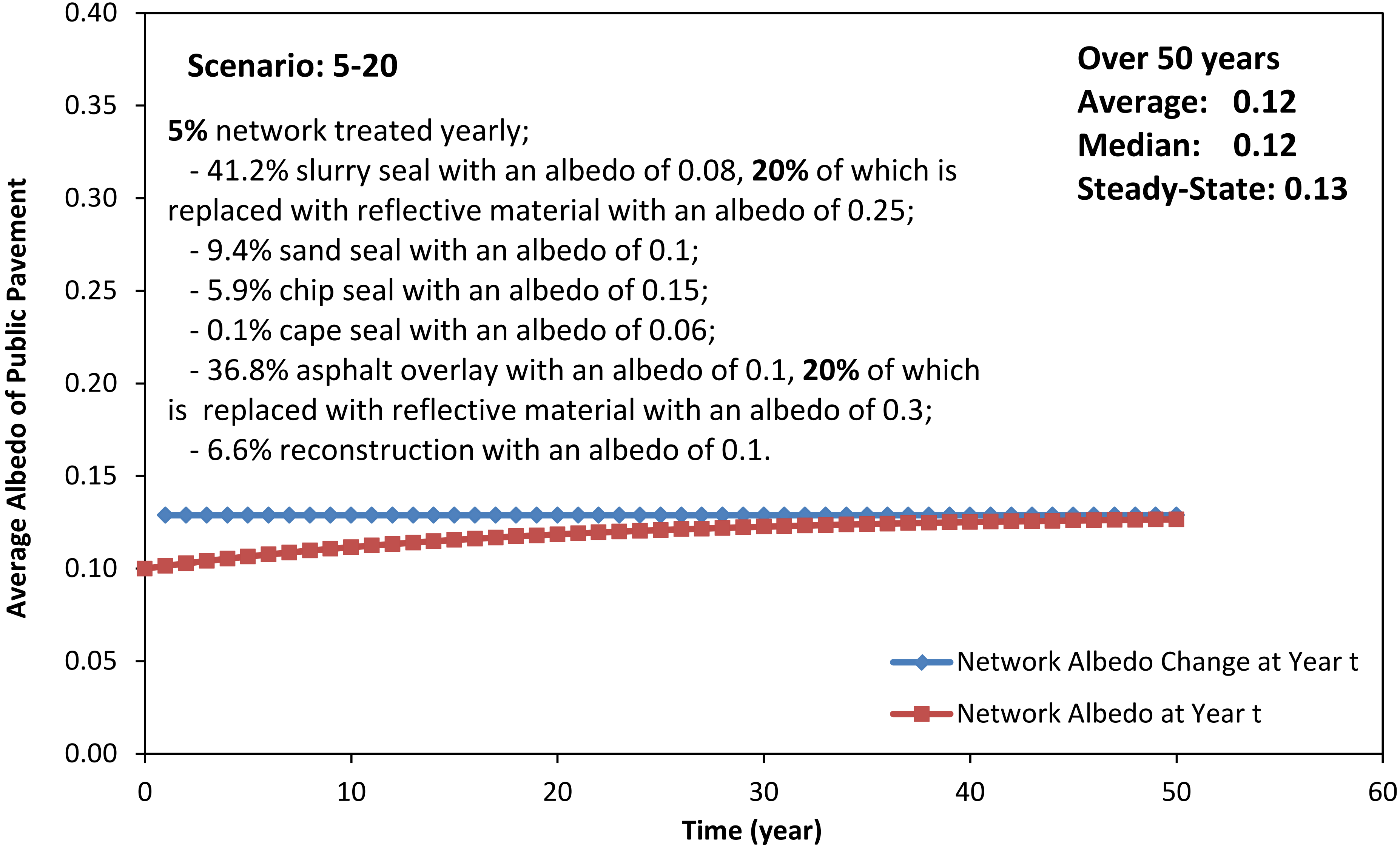
Steady State Albedos with Current Practice

City	Portion of network treated every year	Steady-State Albedo in 50 Years (Initial Albedo = 0.1)
City of Bakersfield	20%	0.1
City of Berkeley	7.4%	0.09
City of Chula Vista	3.9%	0.12
City of Fresno	1.3%	0.1
City of Los Angeles	7.4%	0.09
City of Richmond	5.2%	0.09
City of Sacramento	4.3%	0.09
City of San Jose	5%	0.09
Average	*6.8%*	*0.1*

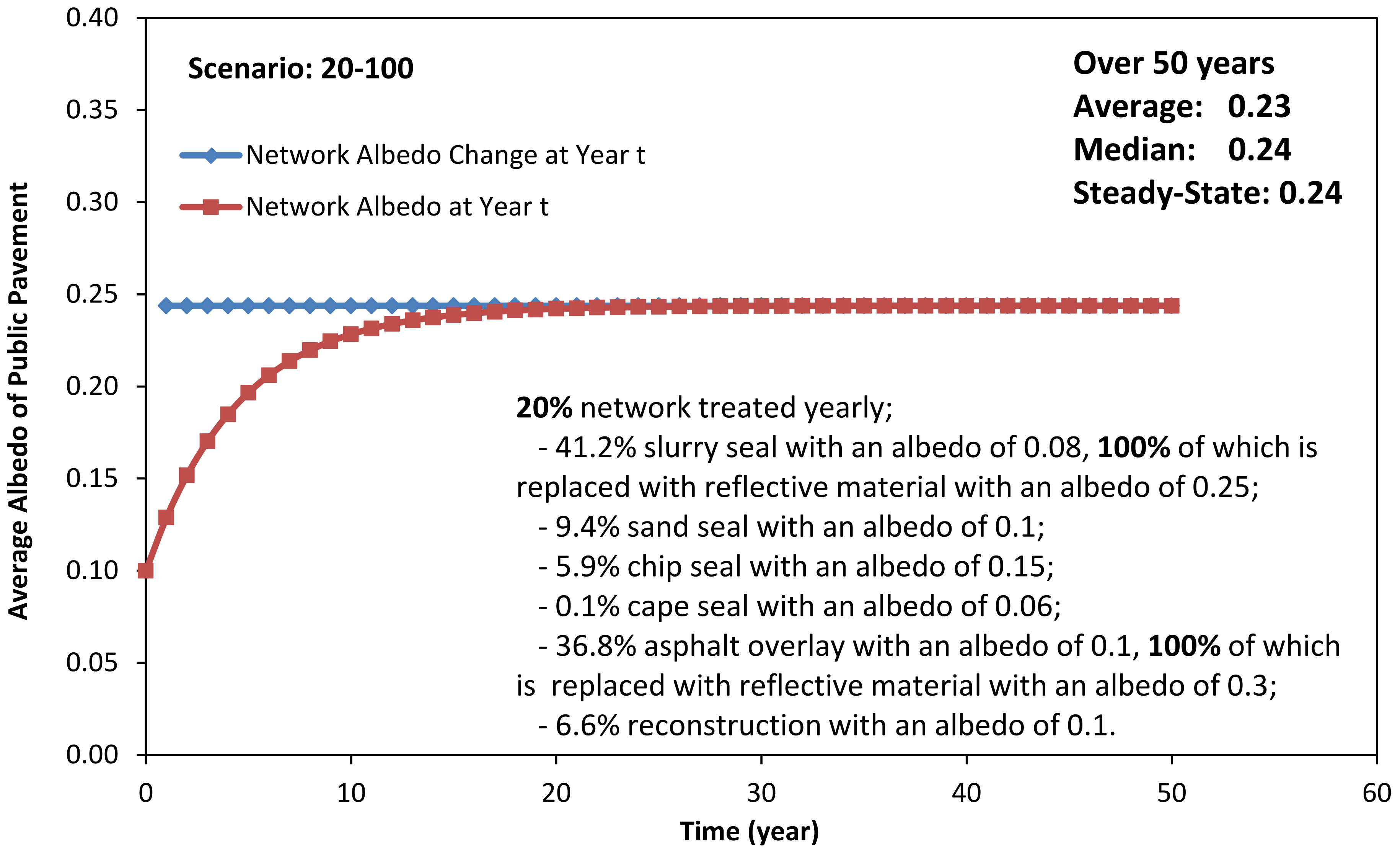
Dynamic Albedo with Cool Pavement Scenario Examples

- Higher albedo material assumpations
  - Slurry seal is replaced with reflective material with albedo of 0.25
  - Asphalt overlay is replaced with reflective material with albedo of 0.3
- Scenario: x-y:
  - x% network gets treated yearly
  - y% of slurry seal and asphalt overlay are replaced with reflective materials
- Scenarios considered
  - x% portion of network treated each year is 5%, 10%, and 20%
  - y% of higher albedo materials is 20%, 50% and 100%

5% treatment, 20% replacement



20% treatment, 100% replacement



Albedo with Assumed High-Albedo Practice

Scenario [a]	Portion of Network Treated Every Year	Replacement Ratio of Reflective Treatment		Network Albedo for 50 Year Period (Initial Albedo: 0.1)		
		A2. Reflective Slurry Seal	E2. Reflective Asphalt Overlay	Average	Median	Steady-State
1 (5-20)	5%	20%	20%	0.12	0.12	0.13
2 (5-50)	5%	50%	50%	0.15	0.15	0.17
3 (5-100)	5%	100%	100%	0.19	0.21	0.23
4 (10-20)	10%	20%	20%	0.12	0.13	0.13
5 (10-50)	10%	50%	50%	0.16	0.17	0.17
6 (10-100)	10%	100%	100%	0.22	0.23	0.24
7 (20-20)	20%	20%	20%	0.13	0.13	0.13
8 (20-50)	20%	50%	50%	0.17	0.17	0.17
9 (20-100)	20%	100%	100%	0.23	0.24	0.24

Limitations of modeling

- Aging-related pavement albedo changes over the long term were not explicitly considered
- Treatment albedo is assumed to be constant after reaching a fairly steady condition until a new treatment is applied.
- Development of albedo aging models and their inclusion in the dynamic modeling of albedo for the network will be included in the revised model when adequate data are available

Conclusions (1/2)

- Pavement Management Practice
  - Most local governments treat a small portion of their networks in recent years
    - 1.3% to 20% (sand seal only) with an average of 6.8%.
  - A number of different treatments, most of them with low albedos
    - Primarily slurry seals (avg albedo of 0.08) and asphalt overlays (avg albedo of 0.10)
- Sparse field data for albedo
  - Time histories, ranges
  - Local government surfaces
  - Reflective coatings, reflective chip seals, high albedo concrete and other higher albedo alternatives

Conclusions(2/2)

- Pavement Network Albedo Modeling
  - 50 year average albedo increases from assumed initial value of 0.1 up to 0.12 (5/20 scenario) to 0.23 (20/100 scenario)
  - Steady state albedos range from 0.13 to 0.24 for the 5/20 and 20/100 scenarios, respectively
- Of the scenarios analyzed, only those with 100% use of higher reflectivity treatments result in steady state average albedos > 0.2
  - Require 10 to 50 years to reach steady state
  - Steady state average of 0.2 is typical assumption of WRF modelers to date

Recommendations

- Improved albedo data for typical pavement treatments at various ages is needed, especially considering urban local government and private pavement treatments
- The aging-related pavement albedo changes over long term should be explicitly considered when adequate data regarding aging is available
- Realistic pavement management scenarios should be considered in climate modeling so that realistic expectations of the effects of changing albedo and its effects are considered in decision-making

Thanks!
Q&A

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