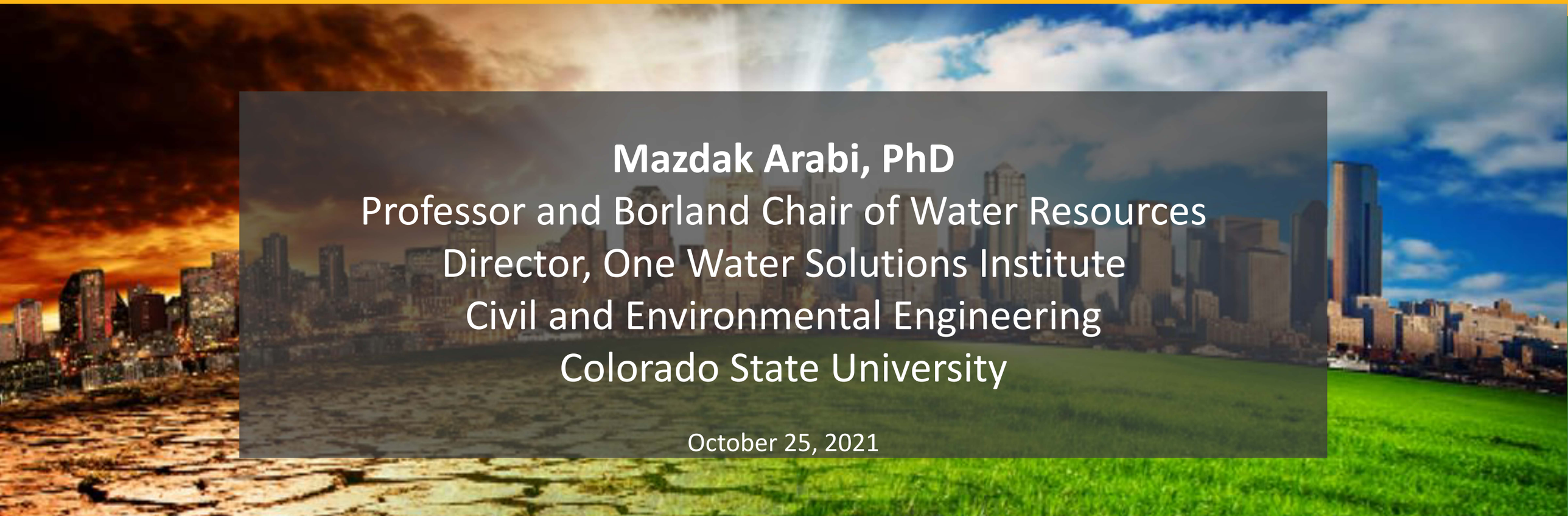
ONE WATER SUSTAINABILITY

GRAD 592 LECTURE



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Director, One Water Solutions Institute
Civil and Environmental Engineering
Colorado State University

October 25, 2021

WATER – THE WORLD'S MOST VITAL RESOURCE

Water defines our places

Vitality Water services are essential to meet the needs of growing population and economies.

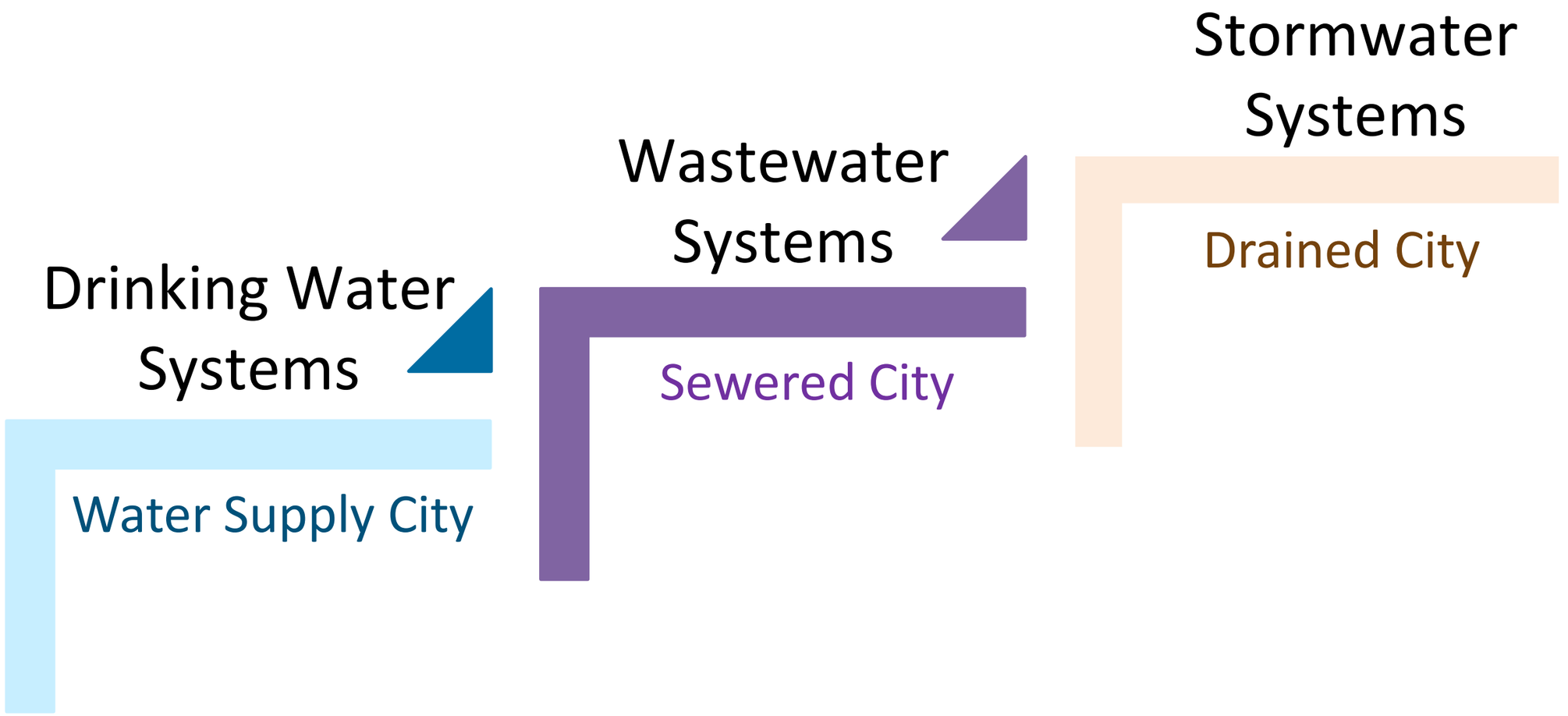
Identity Water bodies are central to the identity of our cities and communities.

Activity Access to water bodies provide recreational opportunities and contribute to the welling and health of our communities.

Health Water sustains the natural capital of our cites, supports ecosystems and food supplies.

Landscape Water features create desirable landscape features.

WATER INFRASTRUCTURE SYSTEMS



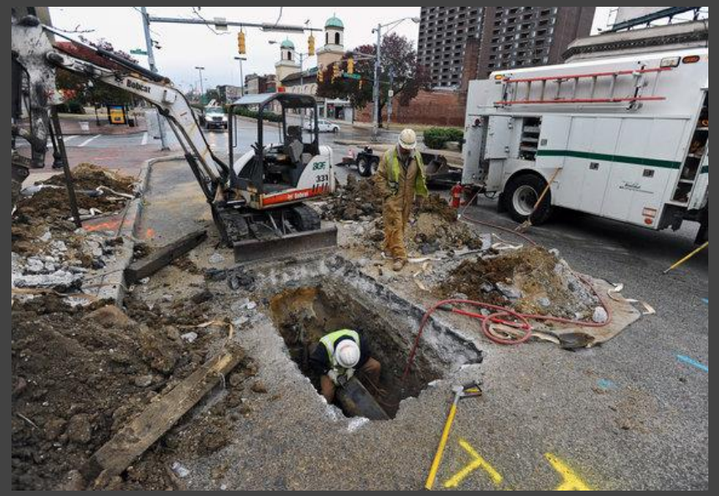
THE GROWING WATER CRISES

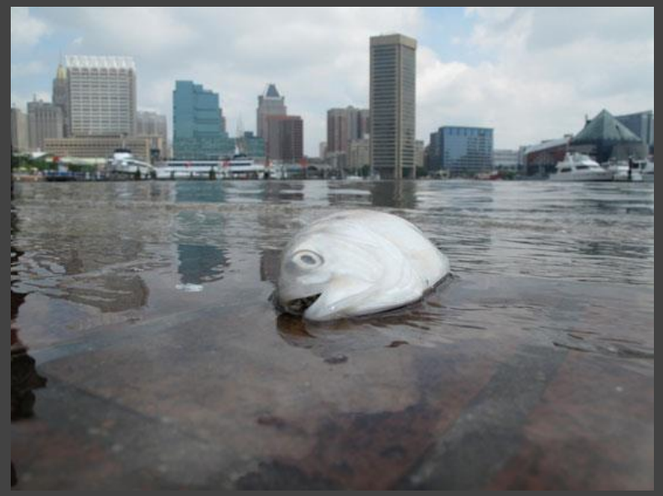
Urbanization is both an opportunity for growth and a threat to natural ecosystems and community livability.

Resources are limited, we demand more services from our aging infrastructure.

An uncertain future underlines the planning of our cities.

WATER CHALLENGES





Aging and inadequate water infrastructure

Affordability of water services

Fragmentation of water systems and institutions

Water quality

Flooding

Climate change and extreme events

Public participation

EVOLUTION OF URBAN WATER SYSTEMS

Drinking Water Systems

Water Supply City

Wastewater Systems

Sewered City

Stormwater Systems

Drained City

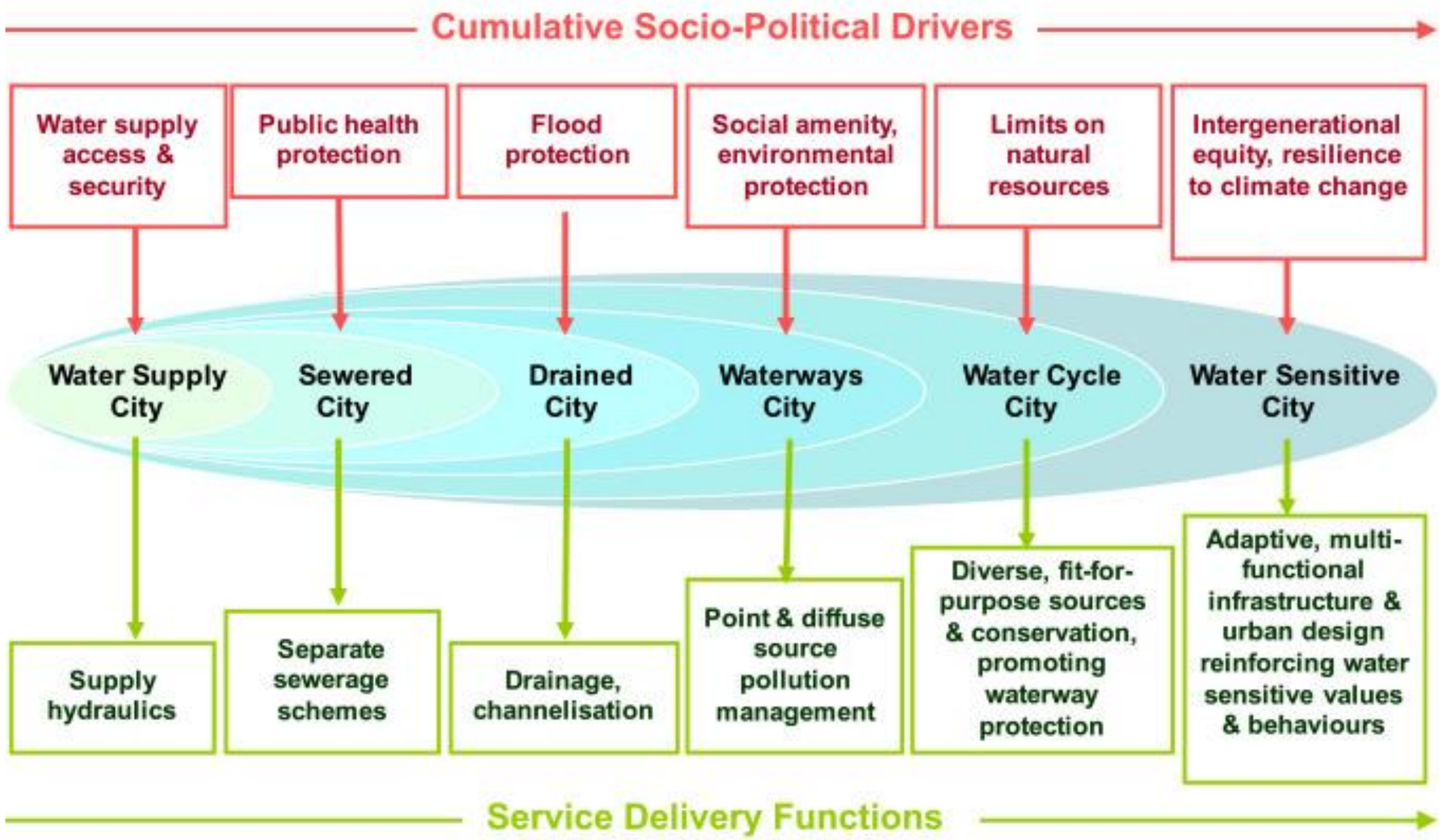
Integrated Systems

Water Sensitive City

Transition from fragmented management of water sectors to an integrated approach

Rain/Stormwater
Groundwater
Wastewater
Recycled Water
Drinking Water

URBAN WATER MANAGEMENT IN CITIES



Brown et al., 2009, Water Sci. Technol., Urban water management in cities: historical, current and future regimes 59 (5): 847-855.

ONE WATER TRANSITIONS

Integrated Management

Resource Management

Resilience Management

US Water Alliance One Water Roadmap:

- A mindset that all water has value
- A focus on achieving multiple benefits
- A systems approach
- Watershed-scale thinking
- Partnerships
- Inclusion and engagement

Image courtesy of Denver Regional Council of Governments (DRCOG)

SERVICE PROVISION → RESOURCE MANAGEMENT

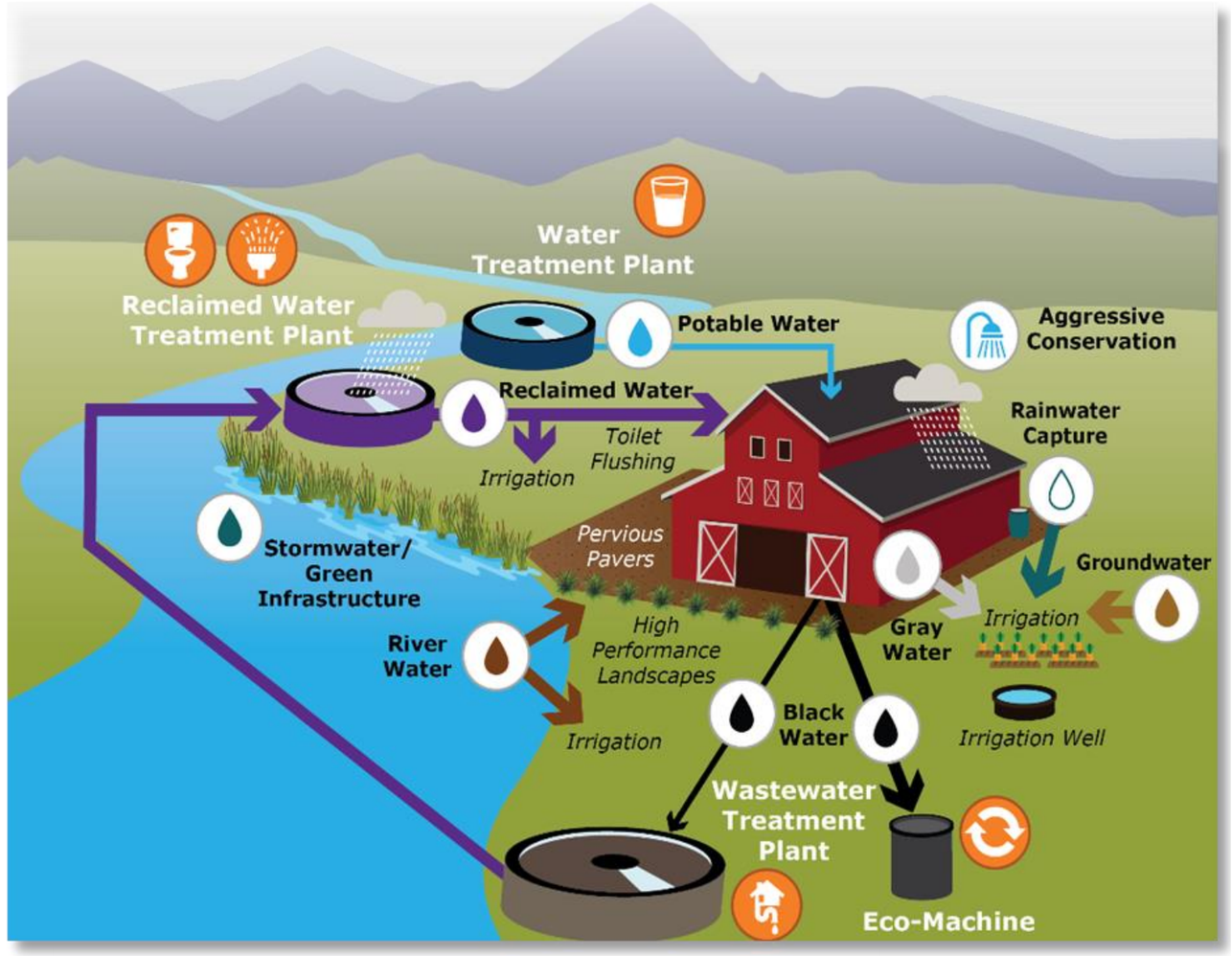
Image courtesy of Wenk Associates

ONE WATER SOLUTIONS

Building- to Municipal- Scale Regenerative and Resilient Systems

- Water Conservation/End-Use Efficiency
- Resource Recovery & Recycling Systems
- “Fit-for-Purpose” Water Sources
- Nature-Based/Green Infrastructure (GI) Systems
- Sustainable Drainage Systems/ Greenways
- Hybrid Centralized-Decentralized Systems

Integration Land Use and Water Planning and Management

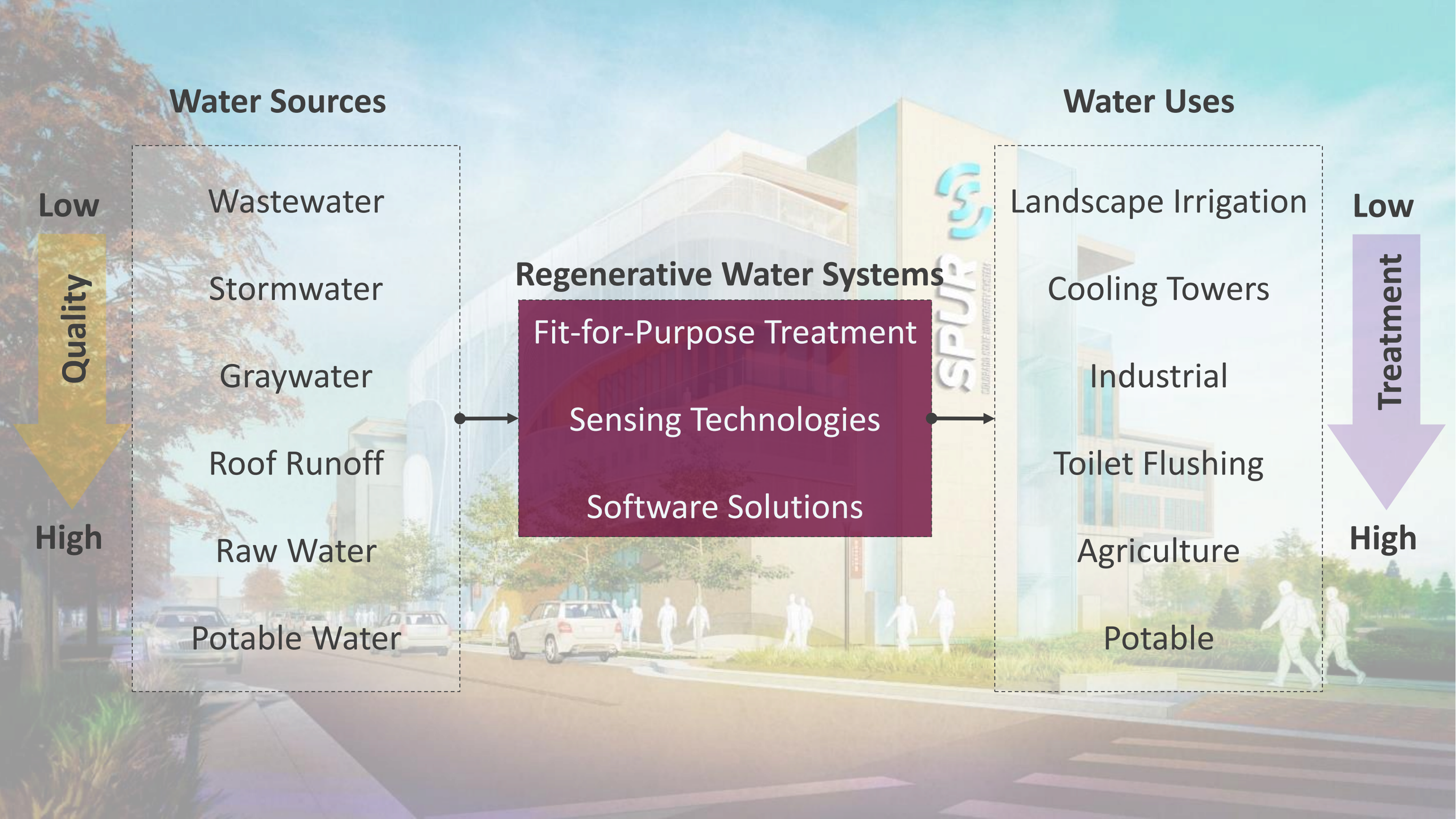


Potable Water
Graywater
River Water
Reclaimed
Rainwater
Groundwater
Black Water
Stormwater
End-use-efficiency

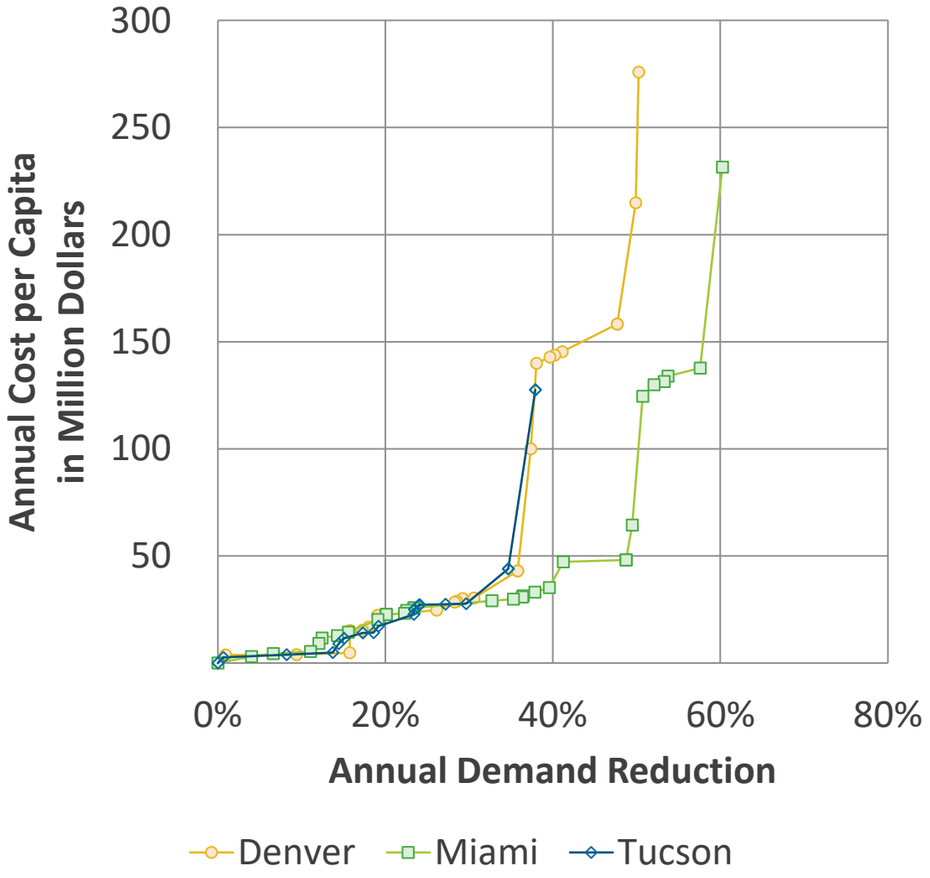
THE RATIONALE FOR RESOURCE RECOVERY (USWA)

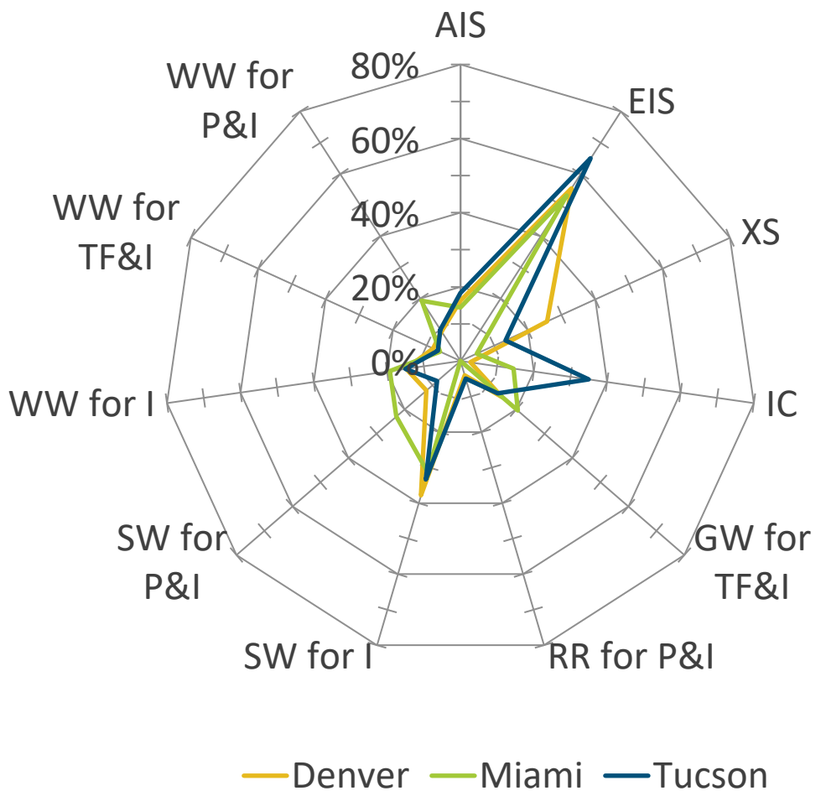
The Battery, NYC
NYC-DEP launched the On-site Water Reuse Grant Pilot Program in November 2016 to provide commercial, mixed-use, and multi-family residential property owners with incentives to install water reuse systems (rainwater, black water, or gray water)

- Reduce the demand on potable water
- Reduce our reliance on fossil fuels
- Reduce the carbon footprint of our water/wastewater treatment facilities
- Produce economically viable, yet environmentally sustainable fertilizer products (nutrients)
- Reduce reliance upon environmentally destructive chemicals and heavy metals
- Enhance stormwater management
- Improve security of our food and water resources


Water Sources
Low
Quality
High
Wastewater
Stormwater
Graywater
Roof Runoff
Raw Water
Potable Water
Regenerative Water Systems
Fit-for-Purpose Treatment
Sensing Technologies
Software Solutions
Water Uses
Landscape Irrigation
Cooling Towers
Industrial
Toilet Flushing
Agriculture
Potable
Low
Treatment
High

FIT-FOR-PURPOSE USE OF ALTERNATIVE WATER RESOURCES



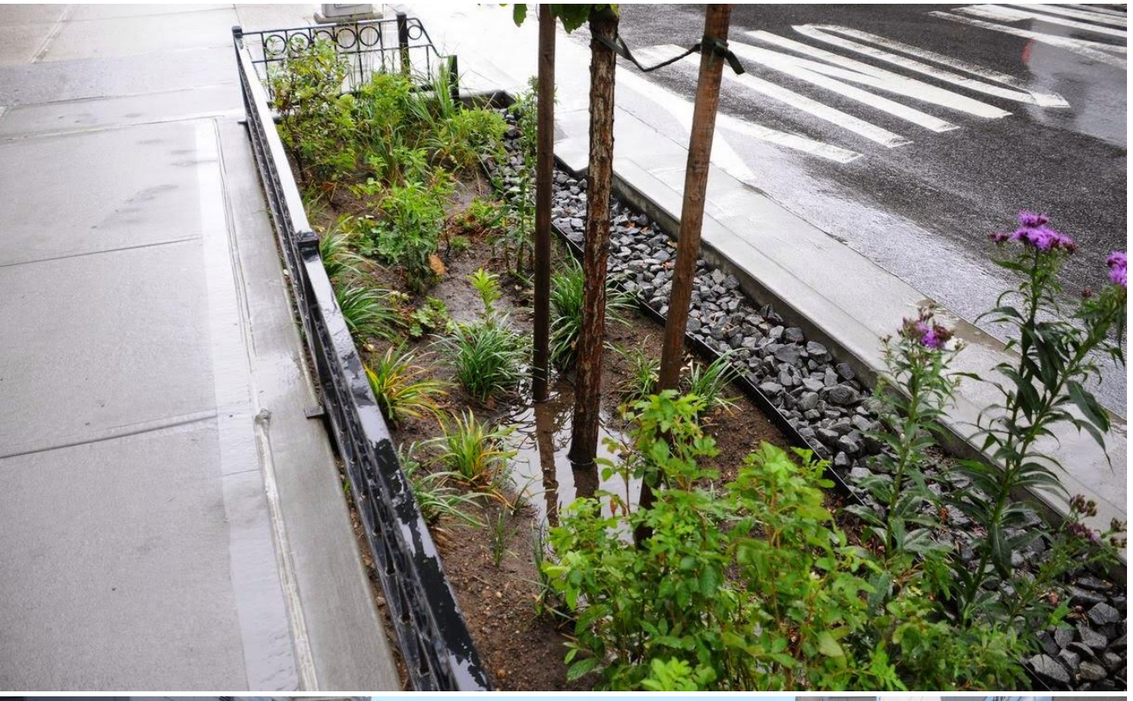


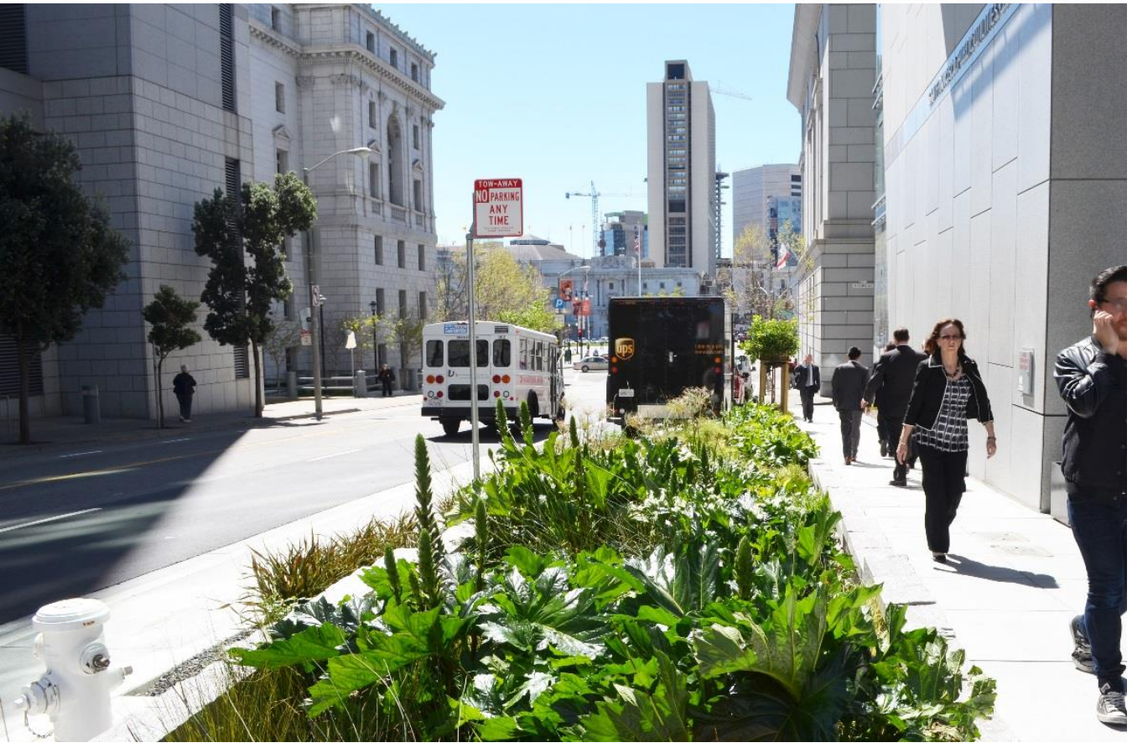
Source: Neale, M., S. Sharvelle, M. Arabi, A. Dozier, and C. Goemans, 2021, Assessing tradeoffs of strategies for urban water conservation and fit for purpose water, Journal of Hydrology, 8,100059.

Sources:
WW: Wastewater
SW: Stormwater
GW: Graywater
RR: Roof Runoff

Uses:
P: Potable
I: Irrigation
TF: Toilet Flushing

End-Use Efficiency Systems:
IC: Indoor Conservation
EIS: Efficient Irrigation
AIS: Advanced Irrigation
XS: Xeriscaping



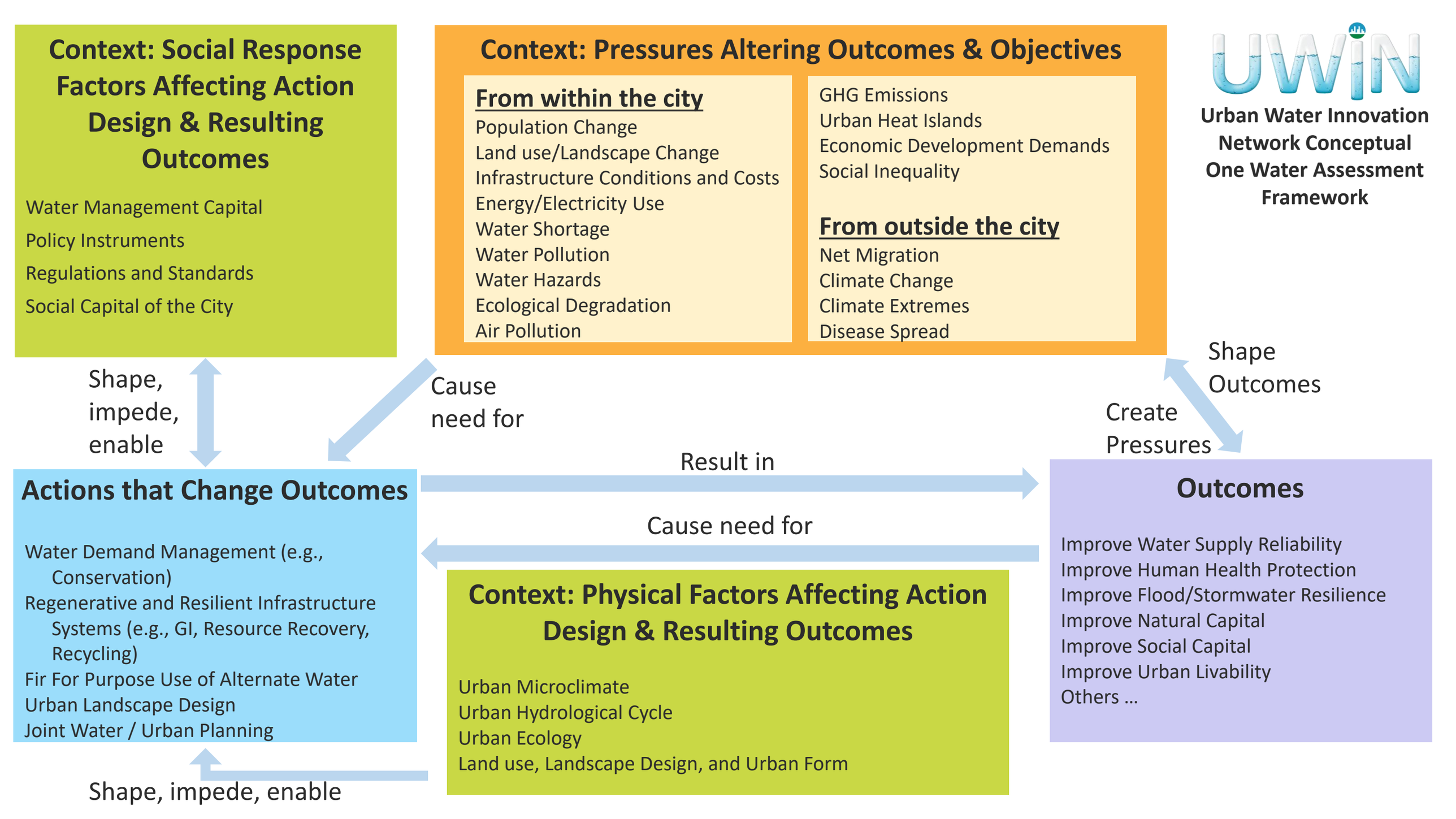


THE RATIONALE FOR GREEN INFRASTRUCTURE (USWA)

- Improve the health and livability of our communities;
- Expand employment opportunities;
- Reduce municipal expenses; and
- Improve the safety and security of our water resources.

SUSTAINABLE ASSESSMENT FRAMEWORKS & RATING SYSTEMS

- Smart City Index
- Sustainable City Index
- City Blueprint
- ENVISION
- Effective Utility Management
- Water Sensitive Cities Index
- *One Water Cities Rating System*


Context: Social Response Factors Affecting Action Design & Resulting Outcomes
Water Management Capital
Policy Instruments
Regulations and Standards
Social Capital of the City
Context: Pressures Altering Outcomes & Objectives
From within the city
Population Change
Land use/Landscape Change
Infrastructure Conditions and Costs
Energy/Electricity Use
Water Shortage
Water Pollution
Water Hazards
Ecological Degradation
Air Pollution
GHG Emissions
Urban Heat Islands
Economic Development Demands
Social Inequality
From outside the city
Net Migration
Climate Change
Climate Extremes
Disease Spread
UWIN
Urban Water Innovation Network Conceptual One Water Assessment Framework
Shape, impede, enable
Cause need for
Shape Outcomes
Create Pressures
Result in
Actions that Change Outcomes
Water Demand Management (e.g., Conservation)
Regenerative and Resilient Infrastructure Systems (e.g., GI, Resource Recovery, Recycling)
Fir For Purpose Use of Alternate Water
Urban Landscape Design
Joint Water / Urban Planning
Cause need for
Outcomes
Improve Water Supply Reliability
Improve Human Health Protection
Improve Flood/Stormwater Resilience
Improve Natural Capital
Improve Social Capital
Improve Urban Livability
Others …
Context: Physical Factors Affecting Action Design & Resulting Outcomes
Urban Microclimate
Urban Hydrological Cycle
Urban Ecology
Land use, Landscape Design, and Urban Form
Shape, impede, enable

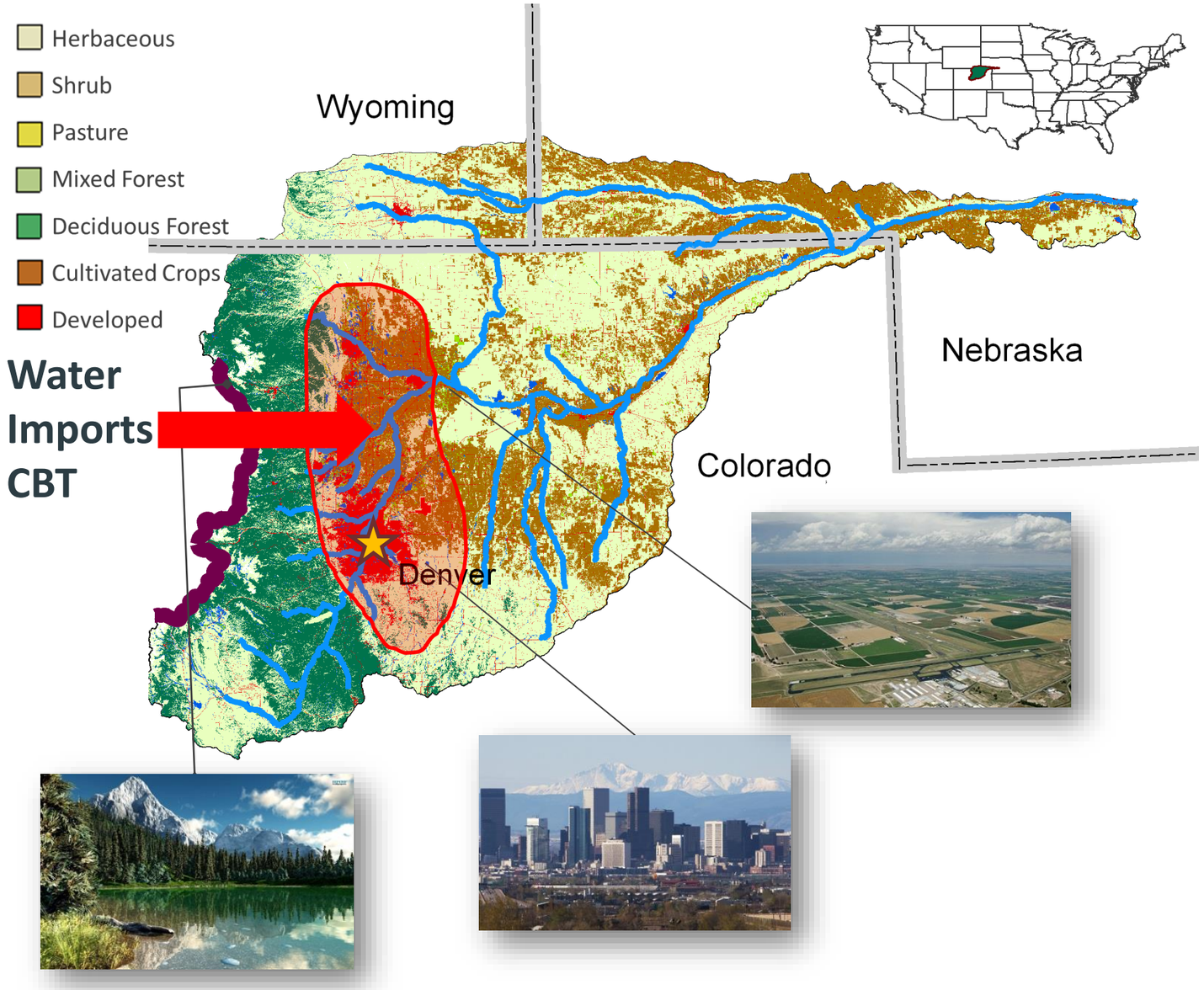
Pathways	Context	Goals and Outcomes						
Build One Water Management Capital	**Identify Driving Forces and Pressures**	**Improve Water Supply Reliability**	**Improve Human Health Protection Services**	**Improve Flood and Stormwater Resilience**	**Improve Natural Capital**	**Improve Social Capital**	**Improve Water Infrastructure Resilience**	**Improve Urban Livability**
Vision	Population Change	Water Supply Infrastructure Enhancement	Drinking Water Quality	Flood Risks / Hazards	Surface Water Quality	Public Education, Literacy, and Awareness	Resource Recovery and Water Recycling	Access to Water / Sanitation Services
Leadership & Long-Term Commitment	Land Use Change and Urban Form	Water Demand Management	Wastewater Effluent Pollution	Flood Standards / Regulations	Groundwater Quality	Public Engagement / Participation	Decentralized and On-Site Water Systems	Affordability of Water/ Sanitation Services
Knowledge, Expertise, and Skills	Economic Development	Local Water Withdrawals / Footprint	Waterborne Illness, Disease, and Deaths	Stormwater Standards / Regulations	Coastal Water Quality	Public Acceptance	Fit-For-Purpose Use of Water	Green Spaces
Cross-Organizational Coordination	Built Infrastructure/ Costs	Watershed Health	Exposure to Extreme Flooding	Land Use and Zoning Ordinances	Biodiversity & Ecological Functioning	Social Environmental Justice	Water Supply Portfolio Diversity	Water Recreation
Aligned Legislation and Regulations	Wastewater Effluent and GHG Emissions	Reclaimed / Alternate Water Resources	Exposure to Extreme Heat / Thermal Comfort	Urban Drainage Systems and Waterways	Air Quality		Green Infrastructure	Employment / Green Jobs
Integrated Financing and Incentives	Energy / Electricity Use	Imported Water Supply	Air Pollution Illness, Disease, and Deaths		Urban Microclimate / Heat Islands		Proper Maintenance	Property Prices
Joined Water/Urban Planning	Climate Change and Extremes	Drought Risks / Hazards					Smart Systems for Monitoring and Control	
Collaboration Networks	Urban Heat Islands							

New generation of urban and agricultural infrastructure systems are needed to enhance the resilience of our communities in a changing world. **System integration** is the Holy Grail of the transition toward resilient and regenerative infrastructure systems.

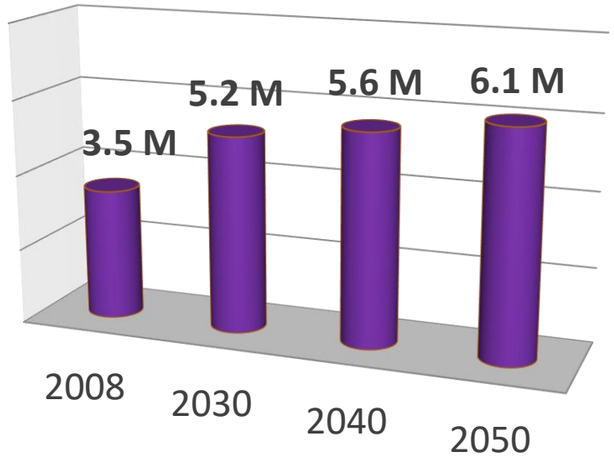
Image curtesy of Wenk Associates

SOUTH PLATTE RIVER BASIN

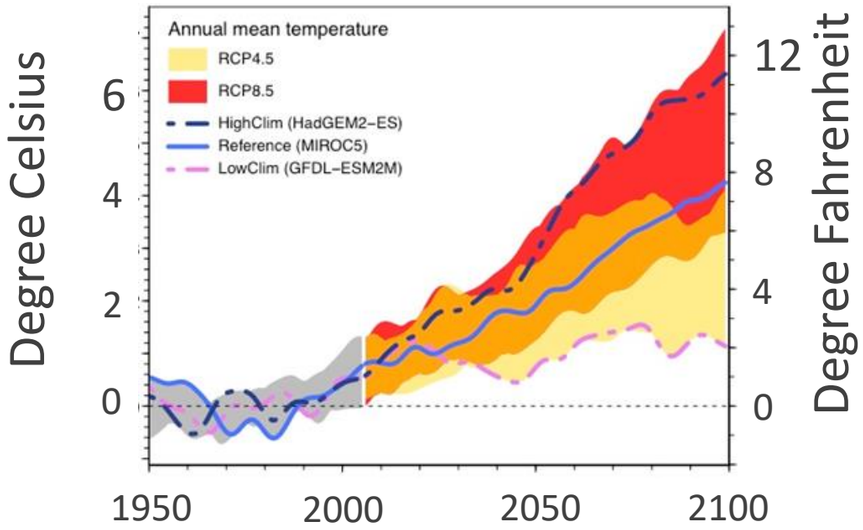
Drainage Area 24,300 sq. miles



Growing Population



Warming Temperatures

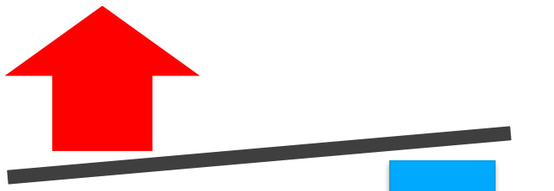


How will growing population and warming climate impact water resources in the West?

What is the future of agriculture in rapidly urbanizing river basins?

Demand

Cities
Farmland
Industry
Environment

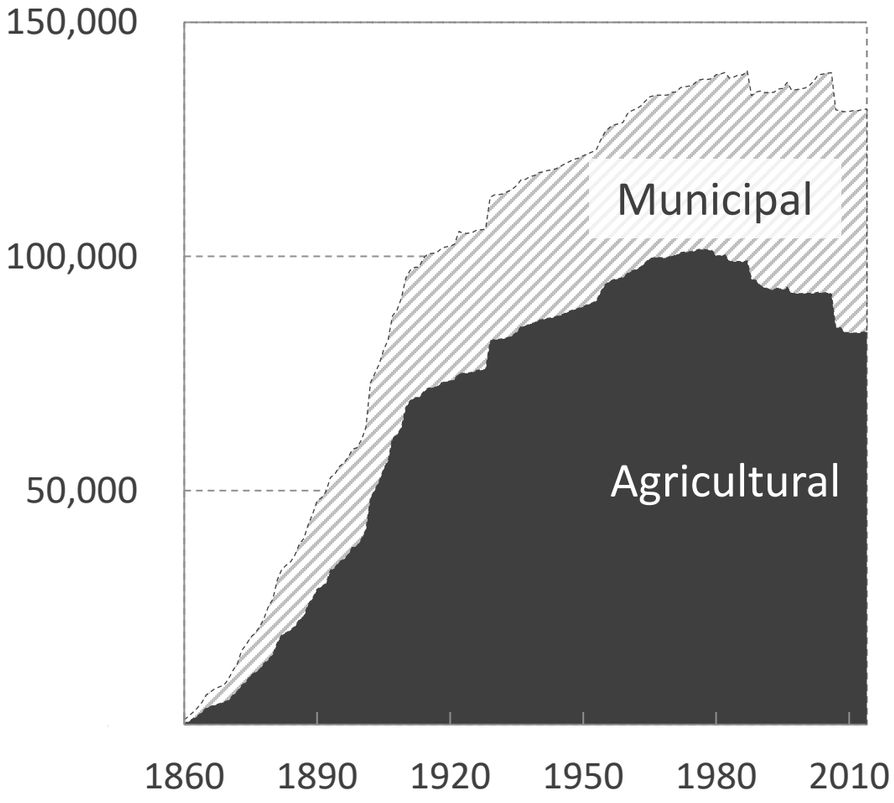


Supply

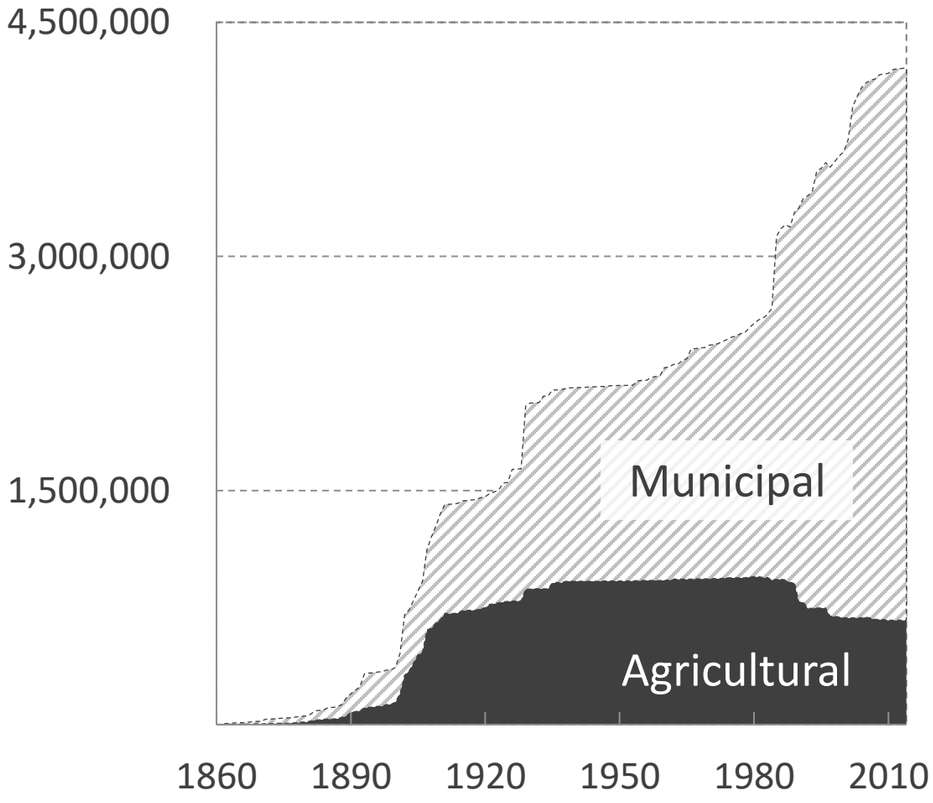
Surface
Groundwater
Storage
Trans-basin

Water Ownership in the South Platte River Basin

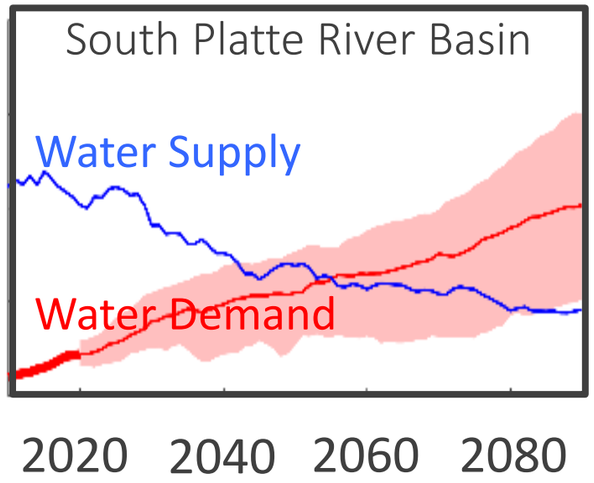
Direct Flow Rights in Cubic Feet per Second

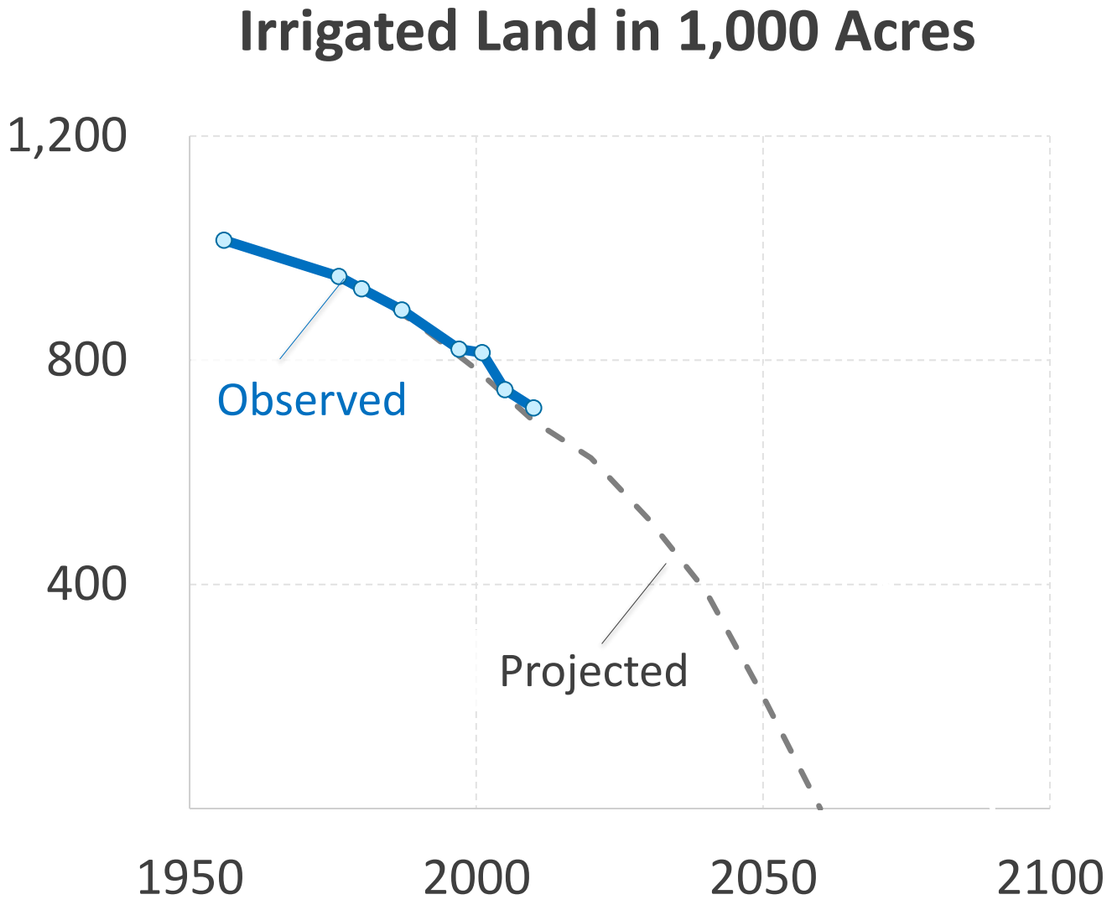


Storage Rights in Acre Feet



Increased competition for water will likely expedite agricultural dry out.





Colorado's Water Plan 2050 Projections:

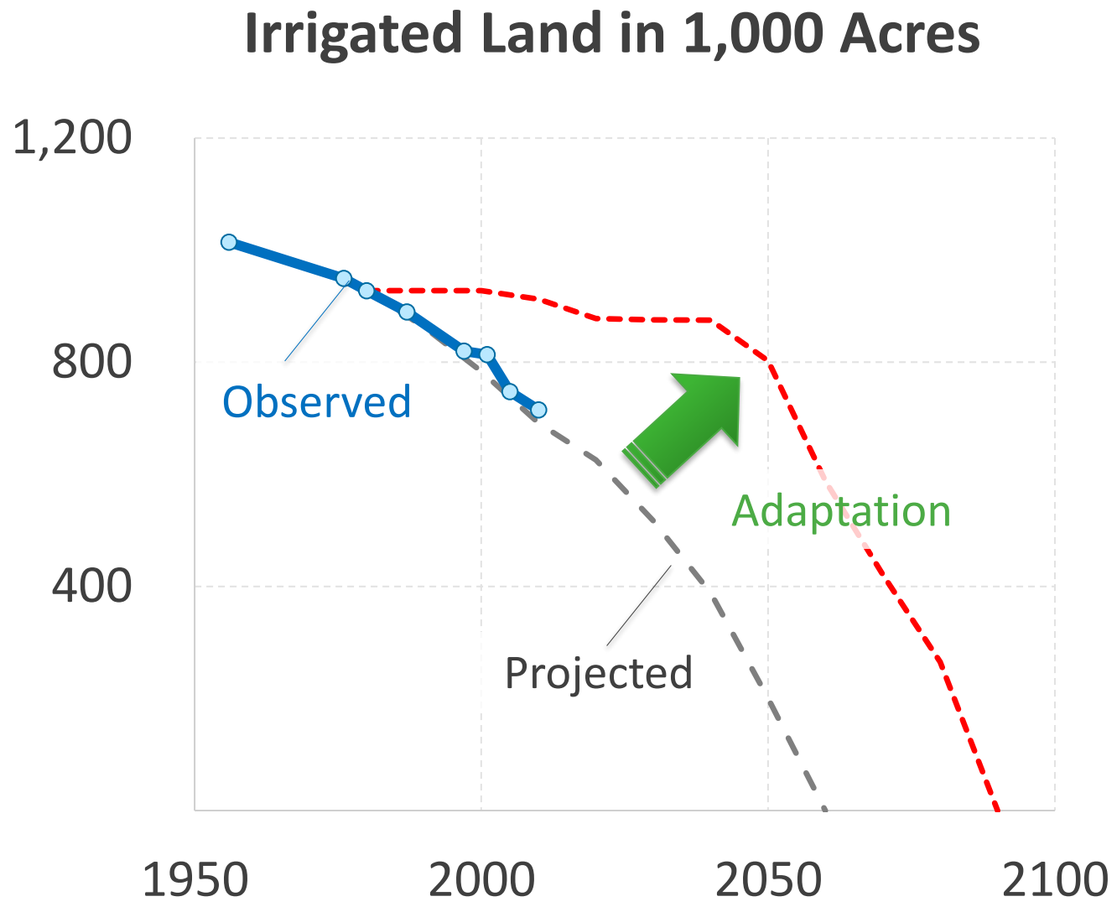
Water Supply Gap: Approx. 700,000 acre-feet

Reduction in Irrigated Agricultural Land: 22% - 32%

Dozier, A., M. Arabi, B. Wostoupal, C. Goemans, Y. Zhang, and K. Paustian, 2017, Water management tradeoffs and targets for the agricultural sector in rapidly urbanizing semi-arid regions, Environmental Research Letters, 12 (2017) 085005.

Adaptation strategies can combat agricultural decline:

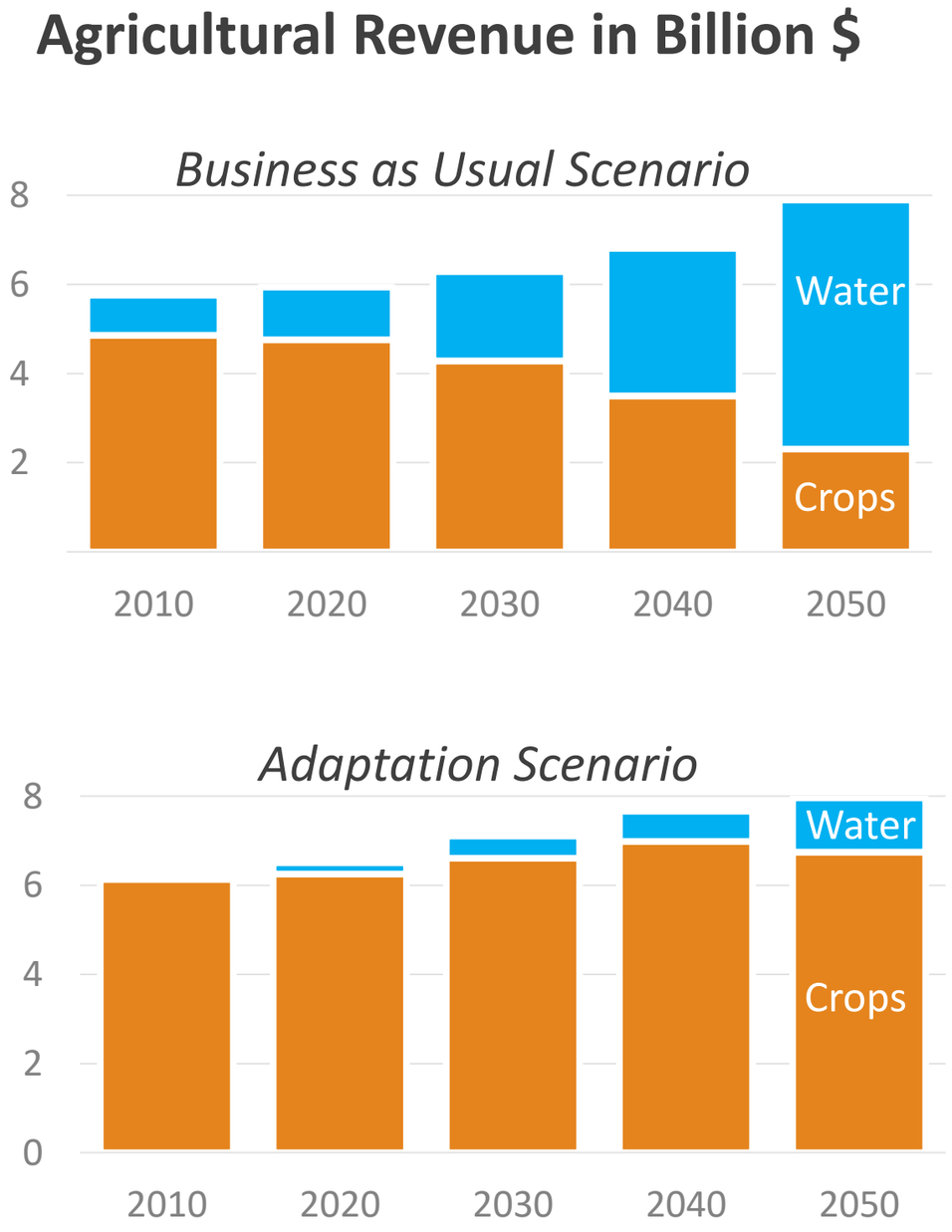
- Urban Demand Reduction
- Alternative Water Sources
- Agricultural Irrigation Technology and Strategies
- Alternative Transfer Methods
- Storage Systems



Dozier, A., M. Arabi, B. Wostoupal, C. Goemans, Y. Zhang, and K. Paustian, 2017, Water management tradeoffs and targets for the agricultural sector in rapidly urbanizing semi-arid regions, Environmental Research Letters, 12 (2017) 085005.

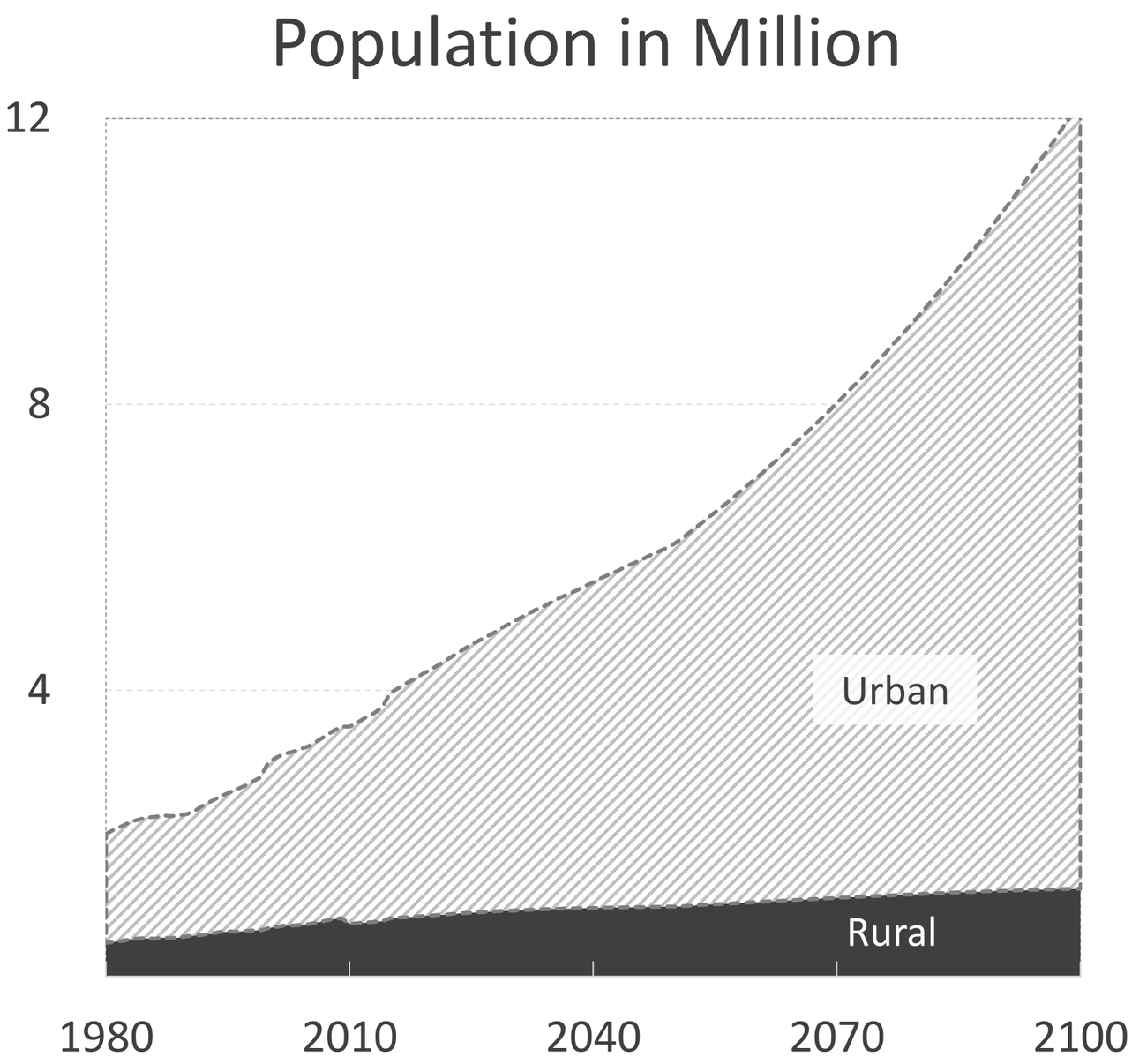
Adaptation strategies – including technological, policy, and financial solutions – must balance tradeoffs among:

- Agricultural revenue
- Rural expenditure
- Water rate
- M&I costs
- Accessibility and equity



A dominant majority of the population will be living in urban areas.

Nearly 40% - 45% of homes in the region by 2050 have not been built yet.



DENVER ONE WATER PLAN

City and County of Denver

Colorado Water Conservation Board

Denver Water

Metro Wastewater Reclamation District

Mile High Flood District

The Greenway Foundation

ONE WATER PLAN GOALS

GOAL #1
PROMOTE INSTITUTIONAL COLLABORATION

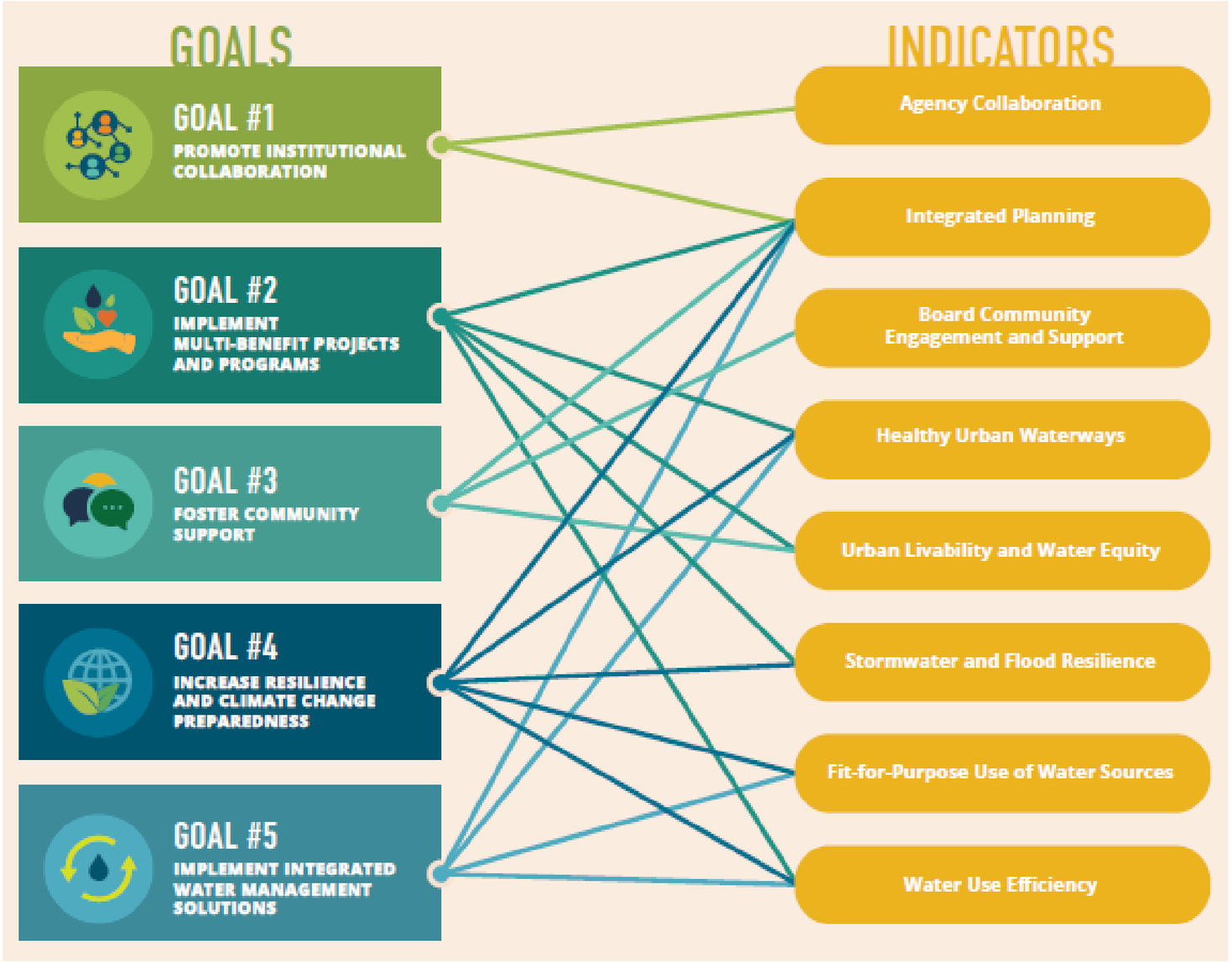
GOAL #2
IMPLEMENT MULTI-BENEFIT PROJECTS AND PROGRAMS

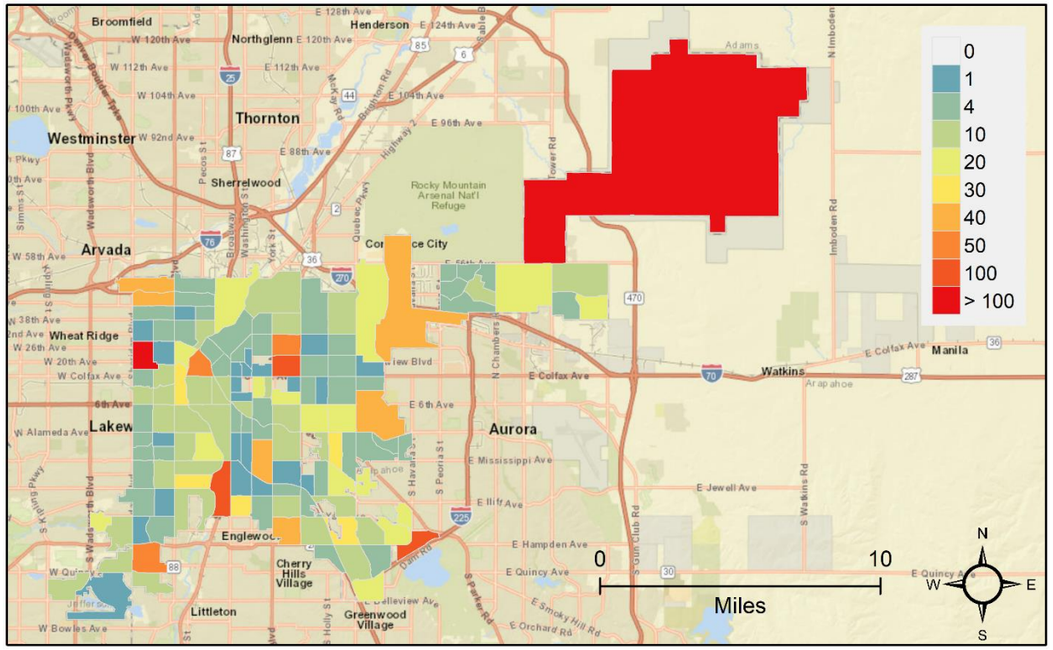
GOAL #3
FOSTER COMMUNITY SUPPORT

GOAL #4
INCREASE RESILIENCE AND CLIMATE CHANGE PREPAREDNESS

GOAL #5
IMPLEMENT INTEGRATED WATER MANAGEMENT SOLUTIONS

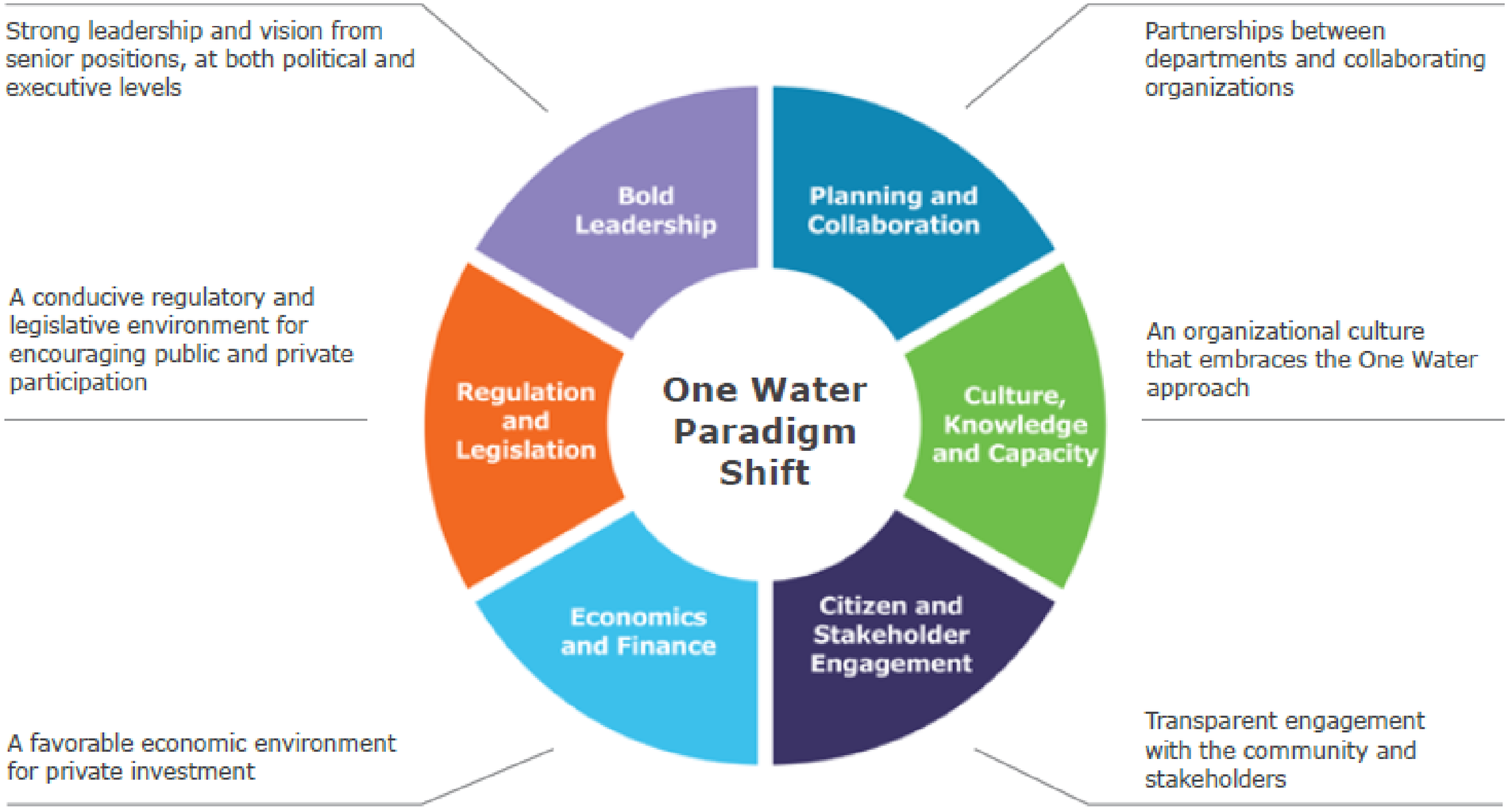
DENVER ONE WATER MONITORING PLAN





Areas of accessible green spaces per 1000 persons in Denver by Census Tracts.

KEY ELEMENTS OF THE ONE WATER APPROACH



Water Research Foundation (WRF)
Blueprint for One Water

Thank you.

- **Mazdak Arabi**

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