WSRF Grant
Progress Update

Prepared by: 10.10.10, a project of Colorado Nonprofit Development Center (CNDC)
Date: June 30, 2021
PO Number: POGG1, PDAA,202100002519

PROJECT OVERVIEW

10.10.10, a project of the Colorado Nonprofit Development Center, harnesses the power of systems thinking, research, and entrepreneurship to address "wicked problems"--those problems in systems theory that resist definitive formulation and are difficult to solve due to incomplete, contradictory, and changing requirements. WSRF funding will help support research activities and stakeholder engagement connected to our 2021 program on Water and Climate. The Water and Climate virtual program will transpire over four weeks and will involve participation from 15-20 entrepreneurs, a range of stakeholders within the broader Colorado water community, and 35-50 other talented professionals.

WSRF funds would fund the exploration of specific challenges relevant to water in the region and will be applied to our research efforts. Our research process is wholly unique and proven to facilitate innovative solutions to wicked problems. We actively engage "validators"--individuals and stakeholders with deep subject matter expertise--from a variety of sectors to produce systems maps and research briefs that in turn create nuanced and comprehensive views of an issue and accelerate collaborative learning and insight. The three phases of our research process-- stakeholder (aka, "validator") engagement, systems mapping, and the production of research resources--will be devoted to METRO ROUNDTABLE identified priority issues concerning water and climate along the front range, specifically in the areas of conservation and reuse, implementation of IP&Ps, and--via the very nature of the program and research process--education out outreach.

PROJECT OBJECTIVES

The project's ultimate goal is to facilitate the creation of products, services, and businesses that address water and climate challenges while simultaneously reframing the problem through system maps and innovative research, thereby providing opportunities for public education and outreach. Overall, the research and stakeholder engagement process connected to our Water and Climate program will:

- facilitate a unique and collaborative learning process for stakeholders,
- unite subject matter experts and highly experienced entrepreneurs to produce new ways of understanding and thinking about the complex systems of water and climate, ● provide funders with the information, perspective, and partnerships to lead their fields in conversations related to water and climate, and
- Inspire communities to better understand and tackle wicked problems connected to climate and water.

TASKS

Task 1 - Validator Engagement

Description:

- Who is involved: 10.10.10 research team, funding partners, and a range of other stakeholders (or referred to as "validators") from government, the nonprofit sector, and private industry
- Purpose: Cultivate a multi-faceted source of expertise to inform a robust understanding of wicked problems (WP) related to water and climate
- Timeframe: 6-8 weeks
- Value for METRO ROUNDTABLE: Builds a joint understanding of the WP, why it persists, and the roles each stakeholder plays, in turn producing a shared level of accountability and heightened collaboration

- Validator Engagement is a key component of the research process & a way of developing a source of expertise to help inform exploration of wicked problems and is a precursor to systems mapping. Validator engagement is a 6-8 week process wherein 10.10.10/CNDC works with the project funders to identify and engage a range of stakeholders in the area of water and climate. The convening of these stakeholders—("validators') –helps flesh out a bigger picture of the wicked problem and helps those involved "appreciate how they not only support but also often unwittingly undermine system performance, thereby empowering them to think and act more effectively" (David Stroh, Systems Thinking for Social Change). CNDC will work closely with the METRO ROUNDTABLE, to engage in the steps related to validator engagement as outlined below.

Method/Procedure:

1. Identify the key individuals and organizations that affect and are affected by the issue. These may be thought leaders, government or community representatives, for profit and nonprofit organizations, researchers, community members, and anyone with a vested interest in solving the problem or preventing it from being solved.
2. Convene validators and facilitate the creation of a focusing question. Reach out to validators and cultivate buy-in, & convene validators in small groups and begin the work of understanding the wicked problem.
3. Conduct systems interviews. With the focusing question in mind, conduct systems interviews with all validators. These interviews serve as the groundwork for the systems mapping process and provide an opportunity to explore the problem in depth.

Grantee Deliverable:

- Validator (aka stakeholder) list
- Raw data from group meetings and interviews
- Narrowed list of wicked problems for additional exploration

CWCB Deliverable:

- Validator (stakeholder) list with names, roles, and contact information
- Narrowed list of wicked problems (in line with Metro Roundtable priorities) for further exploration
- A presentation to brief Metro Roundtable on the findings from the raw data

Progress Update: Recruiting subject matter experts was truly one of the joys of the program and the grant funding experience. The virtual nature of the program allowed for recruitment of SMEs from across the nation and representing a range of experience and expertise in each of our 4 water and climate categories. In total, 30 validators served as SMEs for the program. Validators participated in Ask Me Anything (AMA) sessions and fielded questions from participating entrepreneurs.

Validator onboarding was conducted as asynchronous orientations and was a smooth process.

Finally, our SME recruitment also included recruitment of four problem advocates who shared their stories of dedication to each of our water and climate categories during the Big Reveal kickoff event. Obstacles emerged in recruiting these advocates, particularly as each is highly devoted to current water issues in the U.S. and in many parts of the country, including Texas and the South, ongoing water crises meant juggling schedules and shifting problems advocates. In the end, the Big Reveal was a tremendous success as the X Genesis team pulled together to accommodate our problem advocates.

Task 2 - Systems Mapping

Description:

- Based on the first-hand experience and boots-on-the-ground feedback from the validators, and in combination with extended secondary research, CNDC will map the challenges, constraints, causal relationships, and feedback loops of the most pressing problems related to water and climate. CNDC will use systems maps to reveal how a wicked problem is grounded in two things: interconnectedness and dynamism. Systems maps will allow CNDC to see how various components of a problem are tied to one another, to observe the often rapid change of a system, and to note the full patterns contributing to a wicked problem.
  - Who is involved: 10.10.10 research team, in conjunction with METRO ROUNDTABLE and validators
  - Purpose: Move from a focus on components of a problem to a full view of the issue, thereby revealing knowledge gaps, intervention points, and insights that would otherwise go undetected
  - Timeframe: 4 weeks
  - Value for METRO ROUNDTABLE: New ways of seeing, creation or enhancement of a learning culture, comprehensive view of the systems connected to water and climate along the front range, identification of intervention points and other insights

Method/Procedure:

- Preliminary systems analysis. The 10.10.10 first creates a preliminary systems analysis.
- Presentation of all systems maps to METRO ROUNDTABLE and validators for further discussion and refinement. This stage is an opportunity to gain any additional feedback and allows validators to respond to the tools CNDC will have created. It is also the stage at which validators explore interventions.

Grantee Deliverables:

- Initial and final systems maps
- Feedback collected from validators

CWCB Deliverables:

- Presentation of systems maps and how to use them to inspire innovation and identify opportunities for intervention and collaboration
- All systems maps and accompanying resources cobranded with Metro Roundtable/CWCB

Progress Update: The Director of Research created four system maps representing the following areas within water challenges and climate change:

1. Deteriorating Water Infrastructure
2. Water Scarcity and Supply
3. Water Quality and Safety

4. Extreme Climate Events (and their connection to water issues)

Various stakeholders participated in the data collection process used to construct the maps (see previous deliverable: List of Stakeholders).

In addition to maps, the Director of Research created data visualizations to further enhance the accessibility of water and climate issues to various audiences, including laypeople and the broader public. Those visualizations include timelines of significant events in the history of each of the four topic areas, contributing factors, and relevant agents and players. The creation of these additional research and communication assets arose out of a desire to more easily translate the complexities of the addressed water and climate wicked problems.

<u>Task 3 - Create Research Resources</u>

Description:

- CNDC will create research briefs outlining wicked problems in detail, yet with an engaging narrative style to ensure the resources are accessible to a range of users. These resources are valuable supplements to existing research and help identify points of leverage for future projects and plans. Like the systems maps, research briefs are co-branded with 10.10.10/X Genesis and our funders, and funders can distribute and utilize these resources to enhance their leadership positions in their fields as well as increase understanding of an issue. These resources would be the product of funding from METRO ROUNDTABLE and made available to METRO ROUNDTABLE for future use.
    - Who is involved: 10.10.10 research team
    - Purpose: Ensure all research efforts and resulting resources are accessible to a range of users
    - Timeframe: 4-6 weeks
    - Value for METRO ROUNDTABLE: Engaging and accessible series of resources for METRO ROUNDTABLE distribution to increase education around issues related to water and climate, and to serve the METRO ROUNDTABLE priority area of education and outreach

Method/Procedure:

- Write research briefs. All research briefs include the following components:
    - Discussion of the factors contributing to the wicked problem
    - Overview of the history and trends of the wicked problem
    - Identification of the populations and agents relevant to the wicked problem
    - Exploration of existing approaches and workarounds to the wicked problem
- Digital design of research briefs. CNDC will work with a graphics designer to enhance the overall look and navigability of our resources.

Grantee Deliverable:

- Series of engaging research briefs, in electronic, interactive form, designed to fully explore the wicked problems associated with water and climate

CWCB Deliverable:

- <u>Series of engaging research briefs, in electronic, interactive form, designed to fully explore the wicked problems associated with water and climate as identified by validators</u>
- <u>All resources cobranded with Metro Roundtable/CWCB</u>
- <u>Presentation to Metro Roundtable offering an overview of all research briefs</u>

Progress Update: As outlined above, the Director of Research outlined the following categories for exploration relevant to water and climate: Deteriorating Water Infrastructure, Water Scarcity and Supply, Water Quality and Safety, Extreme Climate Events (and their connection to water issues). These categories were born from the entrepreneur problem identification and solution design process. The application of this process allows X Genesis to make a unique contribution to ongoing discussions about water and climate, even to the expertise represented by the Metro Roundtable and the CWCB. Rather than a lit review or traditional summation of issues, framing the water research in the lens of entrepreneurial discovery provides a fresh viewpoint and focus on topics such as market opportunity and resource distribution, history and trends, and current approaches and workarounds. All of the above is delineated in the research briefs (roughly 25 pages each) addressing the four categories.

An issue to note: the matter of printing such extensive materials became a topic of ongoing discussion emerging from a desire to make materials as accessible as possible and a competing desire to align with sustainable environmental practices (such as avoiding printing in favor of digital distribution). In the end, COVID made this decision easy as people were not gathering to receive materials. All of our research assets are therefore available digitally.

Task 4 - Grant Management

Description:

- CNDC will manage subcontractors, invoicing, logistics and distributions and provide written reports to CWCB.
    - Who is involved: 10.10.10 research team
    - Timeframe: Throughout project

Method/Procedure:

- Ensure subcontractors are working on & completing Tasks 1-3. Provide logistical support as well as managing distributions for Tasks 1-3. Write complete progress and a final report for CWCB.

Grantee Deliverable:

- Invoicing, reporting, and providing logistical support throughout the project

CWCB Deliverable:

- Final reports and six month progress reports

Progress Update: 10.10.10 and CNDC worked together to manage this project. All contractors have completed all tasks and submitted final deliverables. All invoices and reports have been sent to CNDC for final processing.

Additional Assets:

Prospective CEO Videos & Training Sessions
Training Videos & Meetings - All Participants
Program Overview, Content, and Tools

CWCB PRESENTATION

January 27, 2021

WATER & CLIMATE

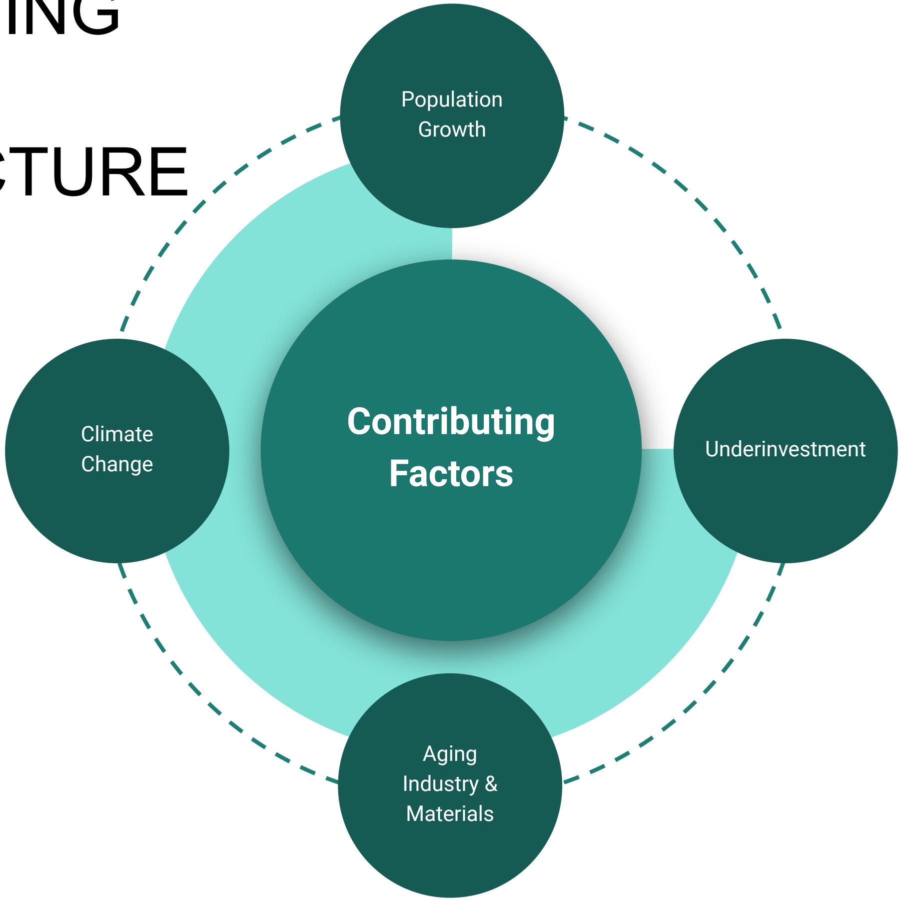
DETERIORATING INFRASTRUCTURE

SUPPLY & SCARCITY

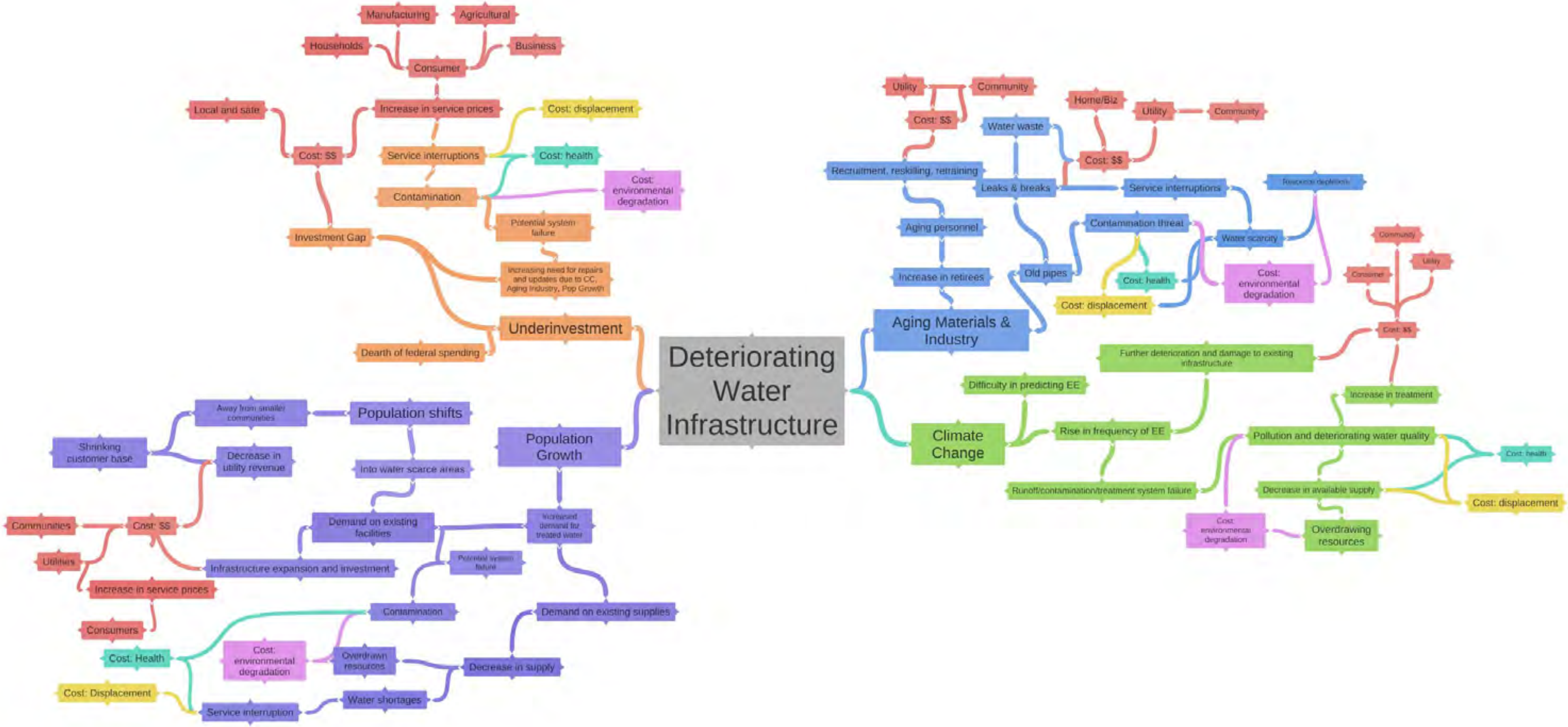
QUALITY & SAFETY

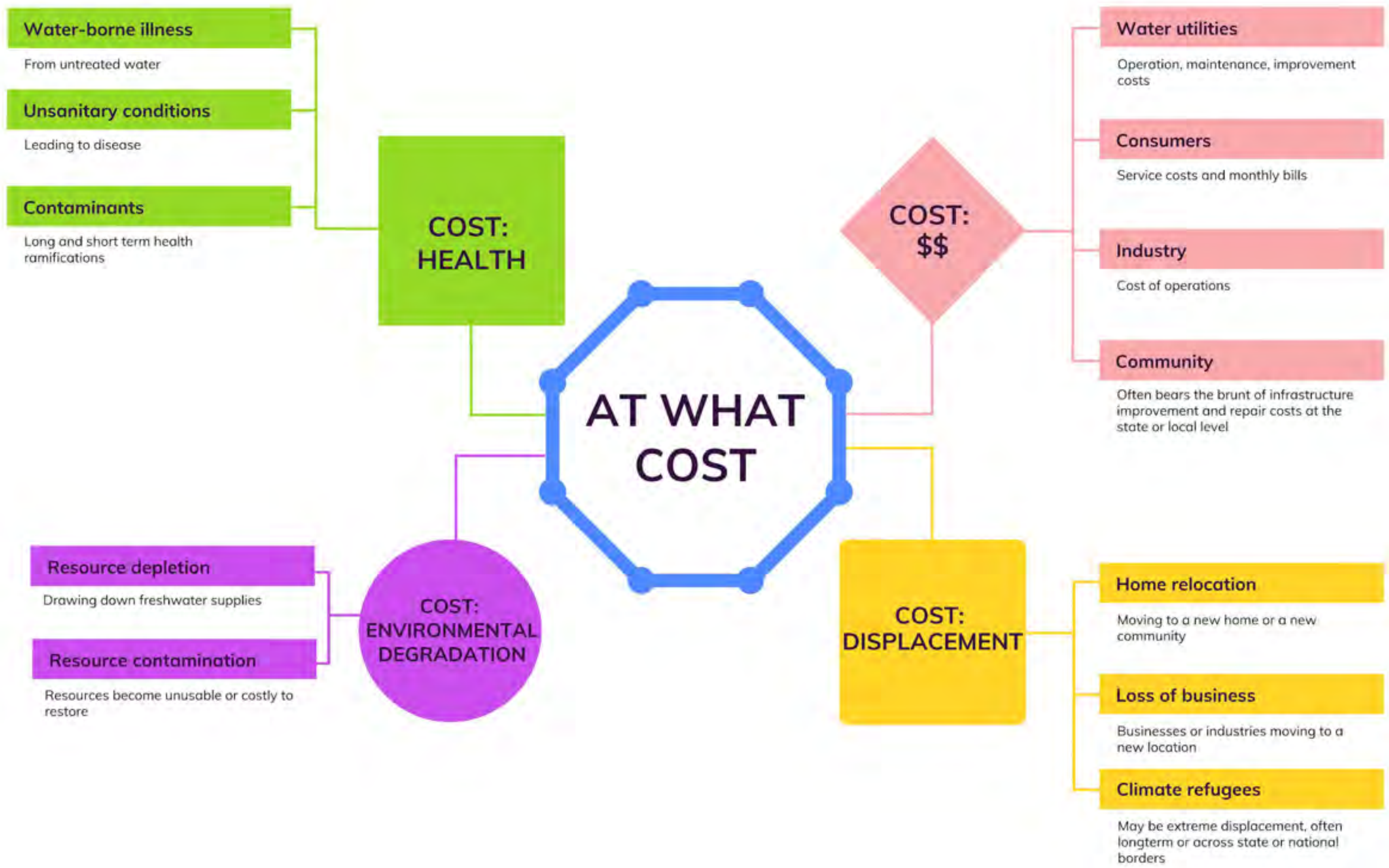
EXTREME EVENTS

DETERIORATING WATER INFRASTRUCTURE



CONTRIBUTING FACTORS




AT WHAT COST
COST: HEALTH
Water-borne illness
From untreated water
Unsanitary conditions
Leading to disease
Contaminants
Long and short term health ramifications
COST: $$
Water utilities
Operation, maintenance, improvement costs
Consumers
Service costs and monthly bills
Industry
Cost of operations
Community
Often bears the brunt of infrastructure improvement and repair costs at the state or local level
COST: ENVIRONMENTAL DEGRADATION
Resource depletion
Drawing down freshwater supplies
Resource contamination
Resources become unusable or costly to restore
COST: DISPLACEMENT
Home relocation
Moving to a new home or a new community
Loss of business
Businesses or industries moving to a new location
Climate refugees
May be extreme displacement, often longterm or across state or national borders

HISTORY

1800S

DEVELOPMENT

As towns and cities grew in population the need for infrastructure also grew.

Late 1800s - early 1900s

SAFETY AND HEALTH

Concerns over health and disease at the tail of the Industrial Revolution led to a corresponding hygiene movement that prompted creation of sanitation and water treatment methods.

Mid 1900s

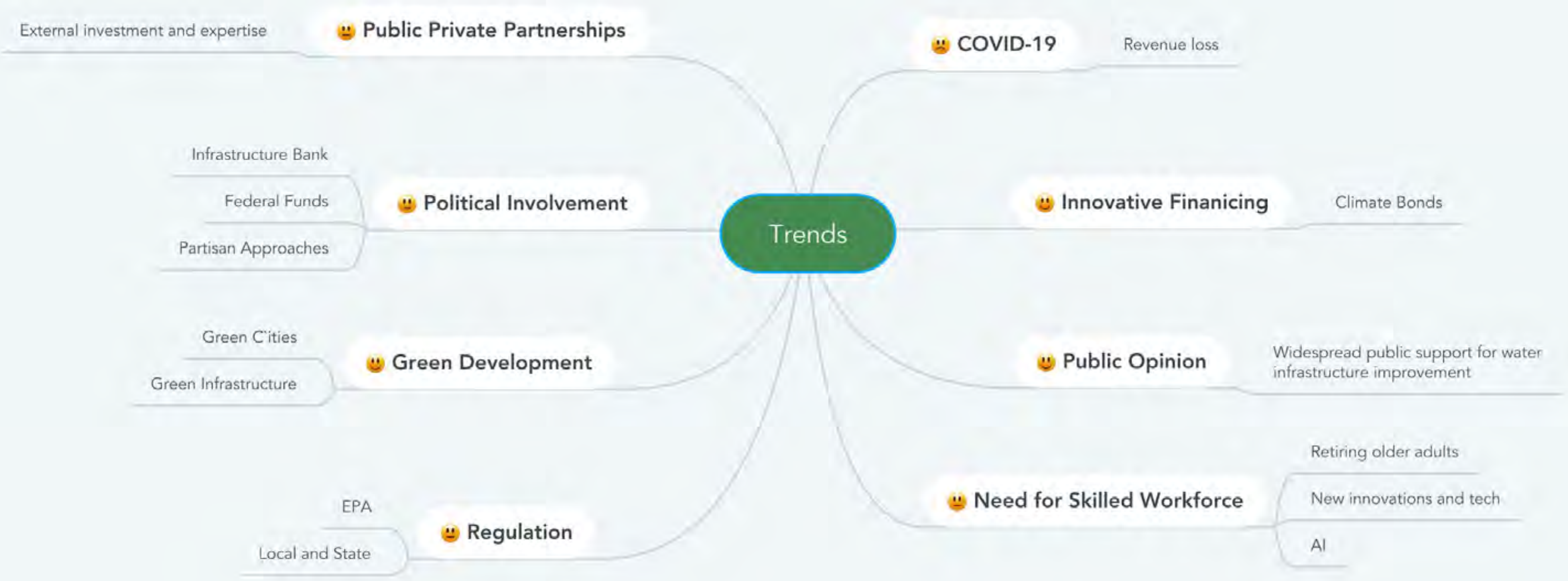
REGULATION

Environmental concerns prompted legislation regulating wastewater disposal and drinking water quality.

21st Century

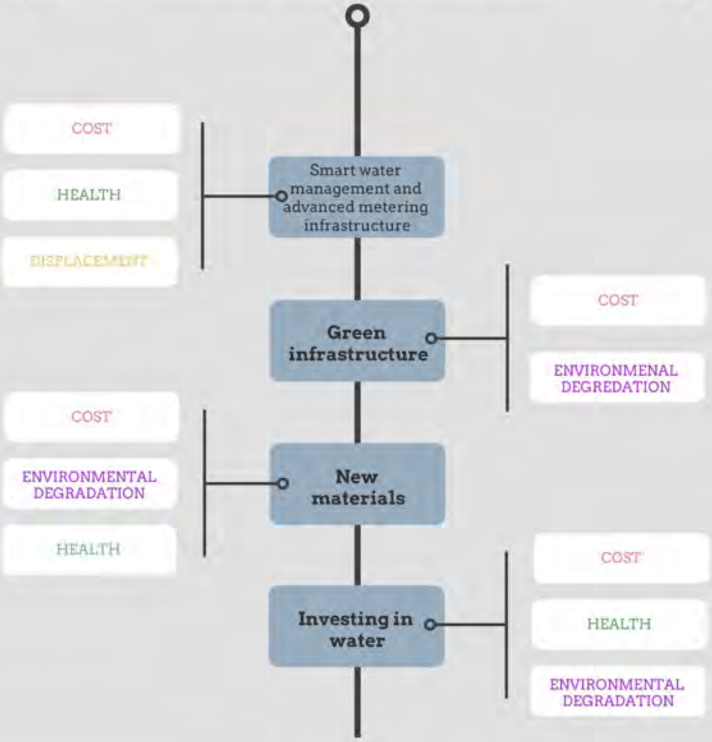
DISREPAIR

Decades of underinvestment and in places century old materials culminate in an industry with pressing needs. In 2017, the ASCE bestows a grade of D+ on the state of infrastructure in America, with drinking water and wastewater each receiving a D+.

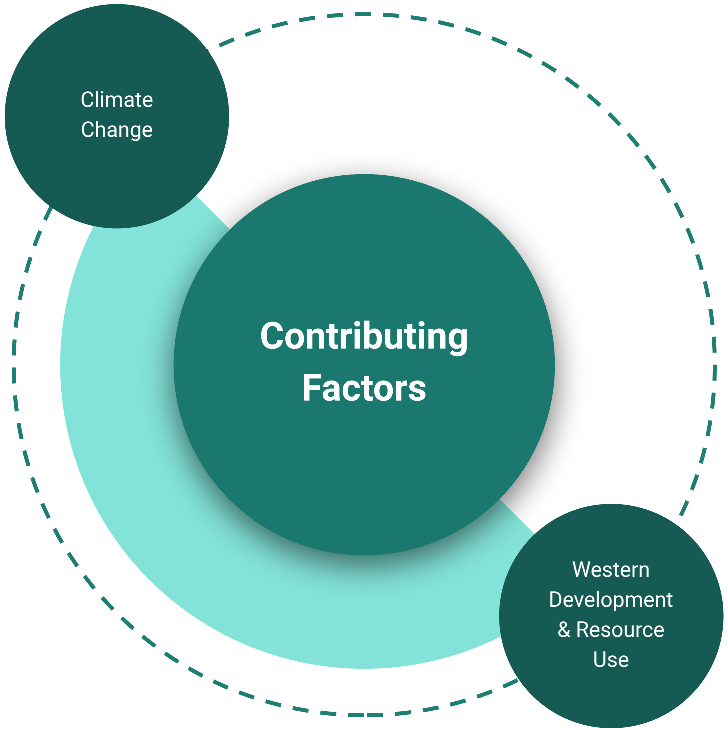

Trends
Public Private Partnerships
External investment and expertise
Political Involvement
Infrastructure Bank
Federal Funds
Partisan Approaches
Green Development
Green C`ities
Green Infrastructure
Regulation
EPA
Local and State
COVID-19
Revenue loss
Innovative Financing
Climate Bonds
Public Opinion
Widespread public support for water infrastructure improvement
Need for Skilled Workforce
Retiring older adults
New innovations and tech
AI


AGENTS
REGULATORY BODIES
EPA
FDA
WATER UTILITIES
Denver Water
AWWA
INDUSTRY
Recreation
Agriculture
Energy
INVESTORS
Water Asset Management
Climate Change Bond Funds
ASSOCIATIONS
ASCE
AWWA
COMMUNITIES
Local Gov and Governing Bodies
Rural Municipalities
Cities
CONSUMERS
Indian Tribes
Urban Centers
Rural Communities
INNOVATORS
Entrepreneurs
Thought Leaders
Activists

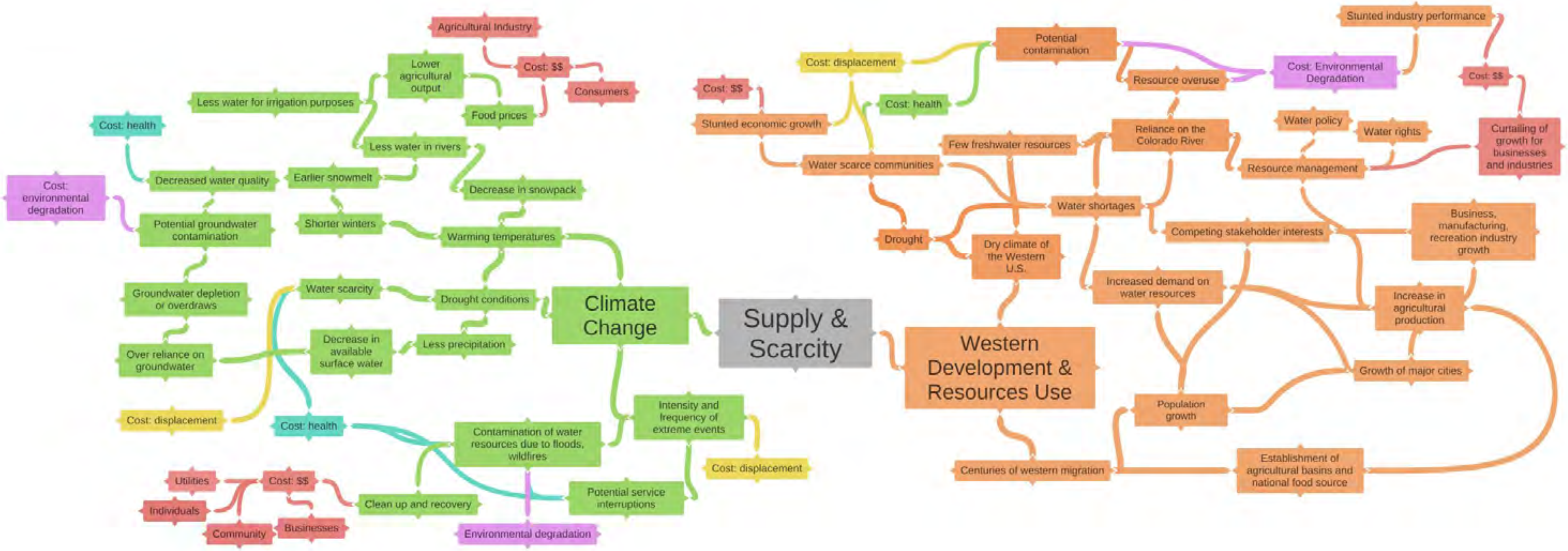
APPROACHES


Smart water management and advanced metering infrastructure
COST
HEALTH
DISPLACEMENT
Green infrastructure
COST
ENVIRONMENAL DEGREDATION
New materials
COST
ENVIRONMENTAL DEGRADATION
HEALTH
Investing in water
COST
HEALTH
ENVIRONMENTAL DEGRADATION

SUPPLY & SCARCITY



SUPPLY & SCARCITY



HISTORY

1800s

Developing the West

What began with mining booms eventually scaled up to extended migration and settlement of the West. Water was scarce and “first in, first in right” water rights were established.

Early 1900s

Selling the West

The railroads and CA State Agricultural Society embarked on a campaign promising an agricultural paradise for those willing to move West. Those who heeded the call were met with a far different set of circumstances, including water scarcity.

Mid 1900s

Public Work Projects

It became clear water supplies in the West could not keep pace with demand. The federal government intervened with a series of water development projects to enhance water infrastructure in the West.

1960s on

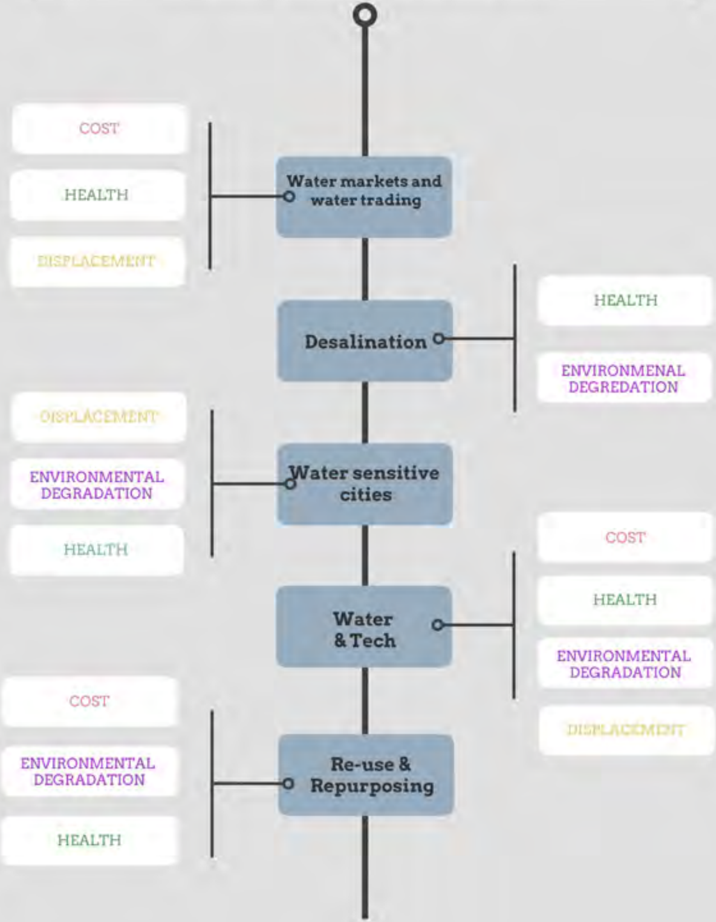
The Environmental Movement

Development sometimes collided with environmental concerns and the growing environmental movement called for legislation to project water resources. The movement and its resulting policies created a better understanding of the need to protect the health of the water cycle and water ecosystems.

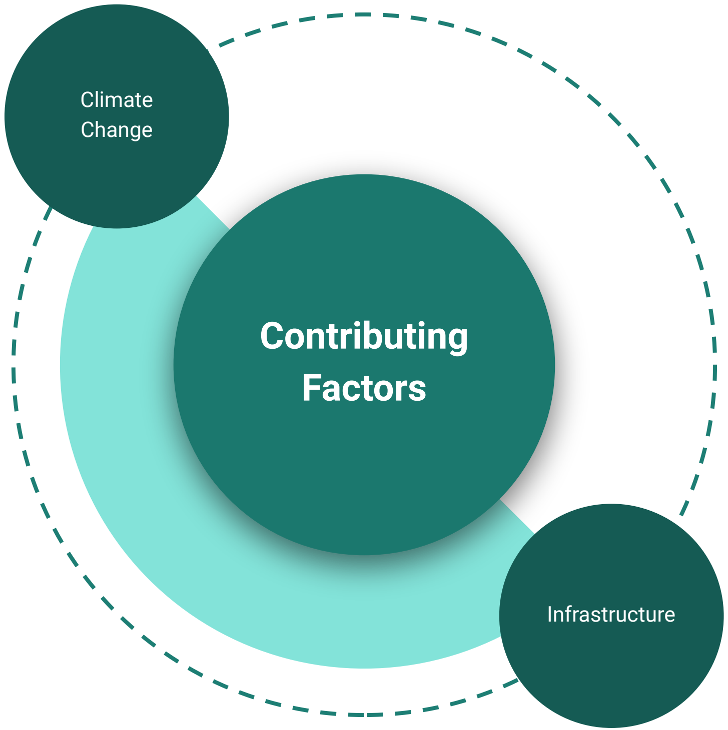
Trends
Population shifts in the West
Growing populations in water stressed areas
Pressure on water resources
Water Use
Driest states are biggest users
Conservation Practices
Municipal utility consolidation
Absorption of smaller utilities
Meeting demand for high volume services
Collaborative Agreements
Replacing water conflict with water collaboration
Colorado River Cooperative Agreement
Frequency and Intensity of Extreme Events
More frequent and severe droughts
Extended wildfire season
Flood threats
Tribal Water Rights
Tribal Rights have been and continue to be ignored
Ongoing infrastructure and water needs


AGENTS
WATER RIGHTS SECTOR
Attorneys
Land Management
WATER UTILITIES
Denver Water
AWWA
WATER MANAGING BODIES
Bureau of Reclamation
Regional Water Boards
Transboundary River Basin Management Authorities
COMMUNITIES
Local Gov and Governing Bodies
Rural Municipalities
Cities
INNOVATORS
Entrepreneurs
Thought Leaders
Activists
CONSUMERS
Indian Tribes
Urban Centers
Rural Communities
PRIVATE COMPANIES
Nestlé Waters
Danone
INDUSTRY
Recreation
Agriculture
Energy

APPROACHES


COST
HEALTH
DISPLACEMENT
Water markets and water trading
HEALTH
ENVIRONMENAL DEGREDATION
Desalination
DISPLACEMENT
ENVIRONMENTAL DEGRADATION
HEALTH
Water sensitive cities
COST
HEALTH
ENVIRONMENTAL DEGRADATION
DISPLACEMENT
Water & Tech
COST
ENVIRONMENTAL DEGRADATION
HEALTH
Re-use & Repurposing

QUALITY & SAFETY



QUALITY & SAFETY

HISTORY

19th century

Increasing Urbanization

Increasing urbanization in the 19th century and the rising population of the working poor in condensed urban neighborhoods in part ushered in the era of sanitation.

Early 1900s

Water Treatment

Water treatment processes such as chlorination are introduced to ensure safe water and prevent disease.

Mid 1900s

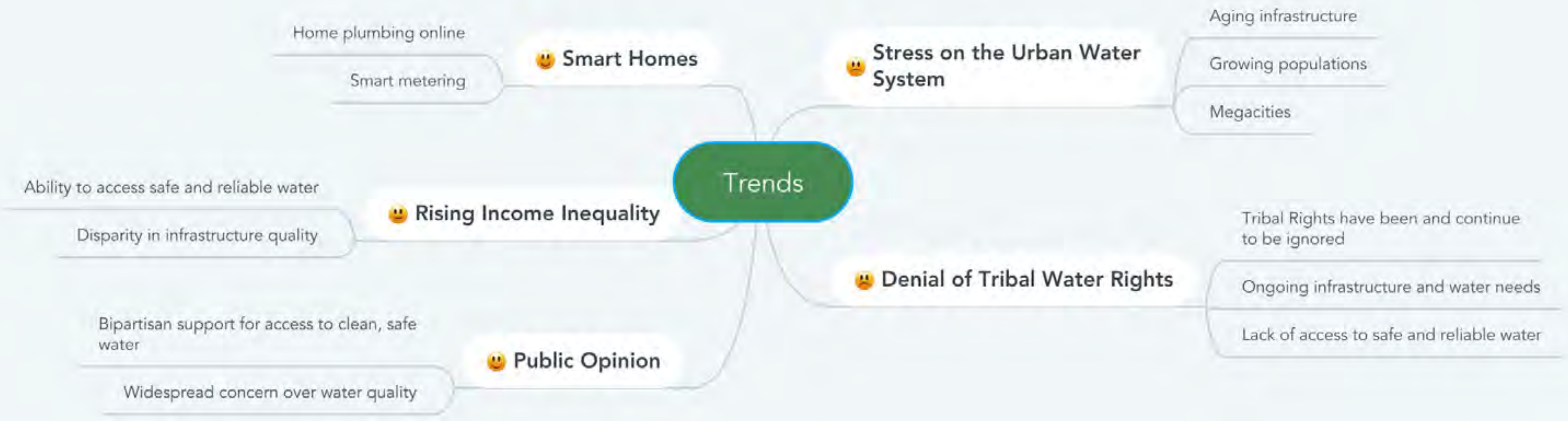
Reckoning with Waste

The Industrial Revolution supercharged the American economy. It also supercharged levels of industrial waste in lakes and rivers as factories dumped waste directly into water supply sources.

1960s and 1970s

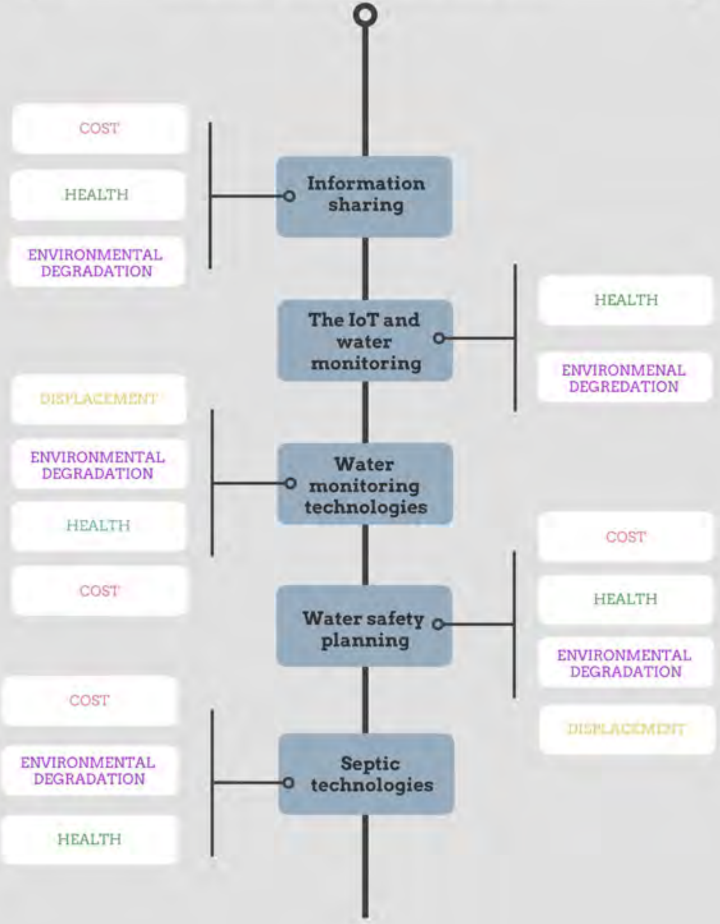
Environmental Policy

Pollution was eventually met with policy and regulation, including the formation of the EPA and the Clean Water Act.


Trends
Smart Homes
Home plumbing online
Smart metering
Rising Income Inequality
Ability to access safe and reliable water
Disparity in infrastructure quality
Public Opinion
Bipartisan support for access to clean, safe water
Widespread concern over water quality
Stress on the Urban Water System
Aging infrastructure
Growing populations
Megacities
Denial of Tribal Water Rights
Tribal Rights have been and continue to be ignored
Ongoing infrastructure and water needs
Lack of access to safe and reliable water

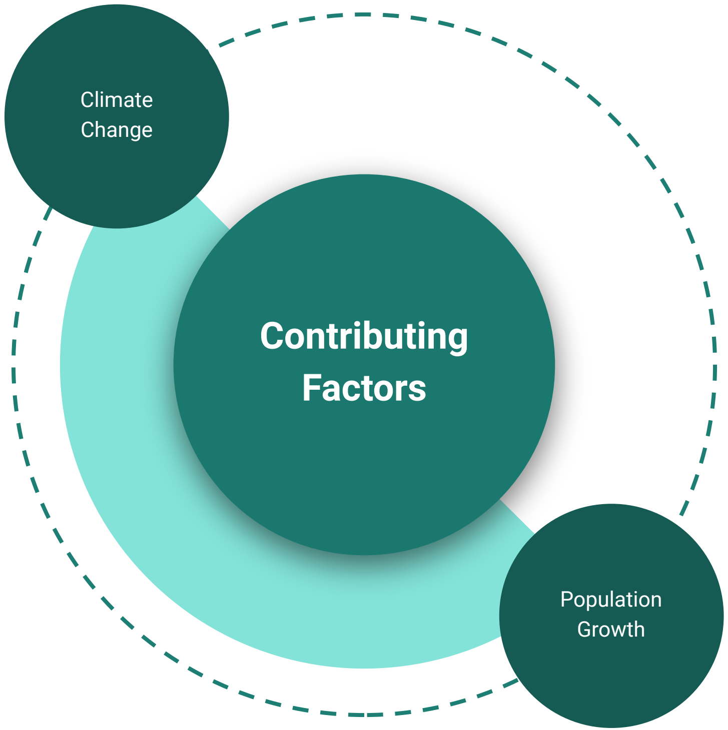

AGENTS
HOUSEHOLDS
Those with private wells and septic
Those without plumbing
WATER UTILITIES
Denver Water
AWWA
REGULATORY AGENCIES
EPA
CDC
US Fish and Wildlife Service
ENVIRONMENTAL & ADVOCAY GROUPS
Environmental Defense Fund
Colorado Water Trust
Water Education Colorado
INNOVATORS
Entrepreneurs
Thought Leaders
Activists
INDUSTRY SECTORS
Food and Beverage
Hospitality
Tourism and Recreation
PRIVATE COMPANIES
Nestlé Waters
Danone
INDUSTRY
Suncor
Thor Industries

APPROACHES

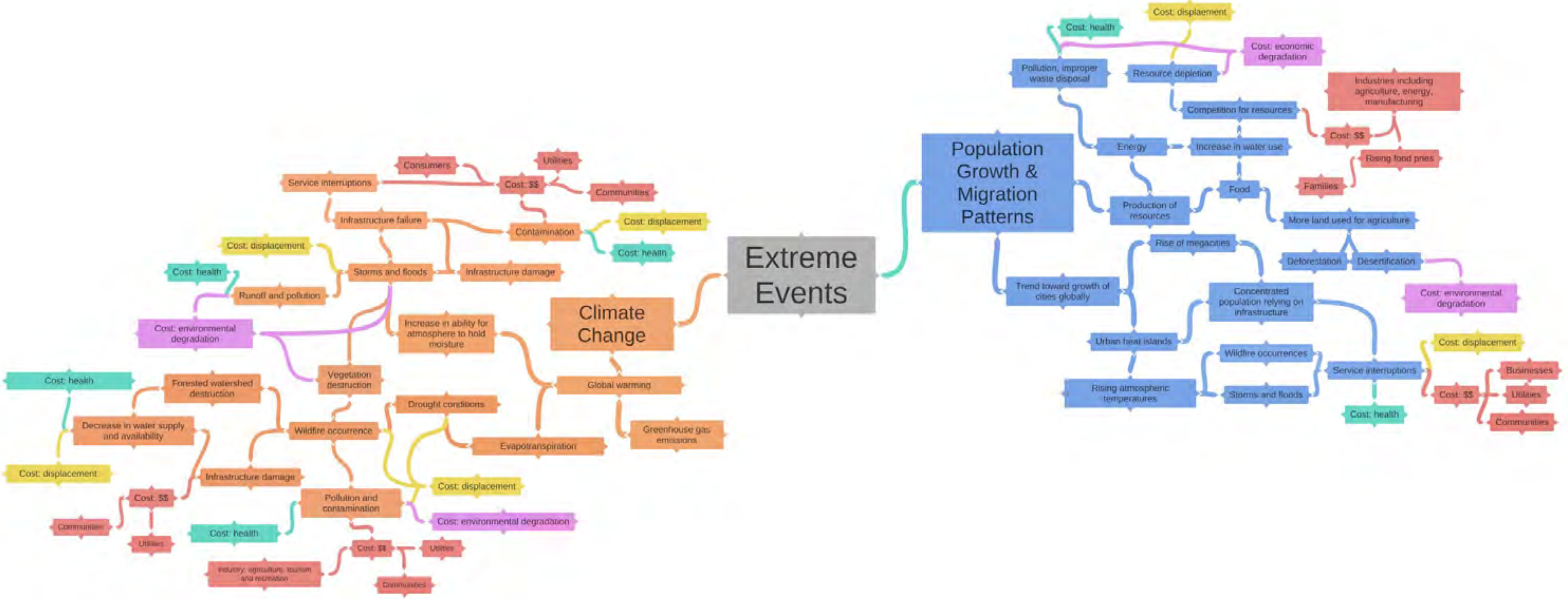


Information sharing
COST
HEALTH
ENVIRONMENTAL DEGRADATION
The IoT and water monitoring
HEALTH
ENVIRONMENAL DEGREDATION
Water monitoring technologies
DISPLACEMENT
ENVIRONMENTAL DEGRADATION
HEALTH
COST
Water safety planning
COST
HEALTH
ENVIRONMENTAL DEGRADATION
DISPLACEMENT
Septic technologies
COST
ENVIRONMENTAL DEGRADATION
HEALTH

EXTREME EVENTS



EXTREME EVENTS



HISTORY

1930s

Human Influence on Weather

The Dust Bowl of the 1930s is an example of human influence over extreme weather events. Caused in part by changes in land policy and agricultural practices.

1980s-2019

More--and more extreme--extreme events

More frequent and intense extreme events also means a rise in cost. The annual average of billion dollar events from 1980-2019 is 6.6. As of October 7, 2020, the number of billion dollar extreme events in the U.S. was 16.

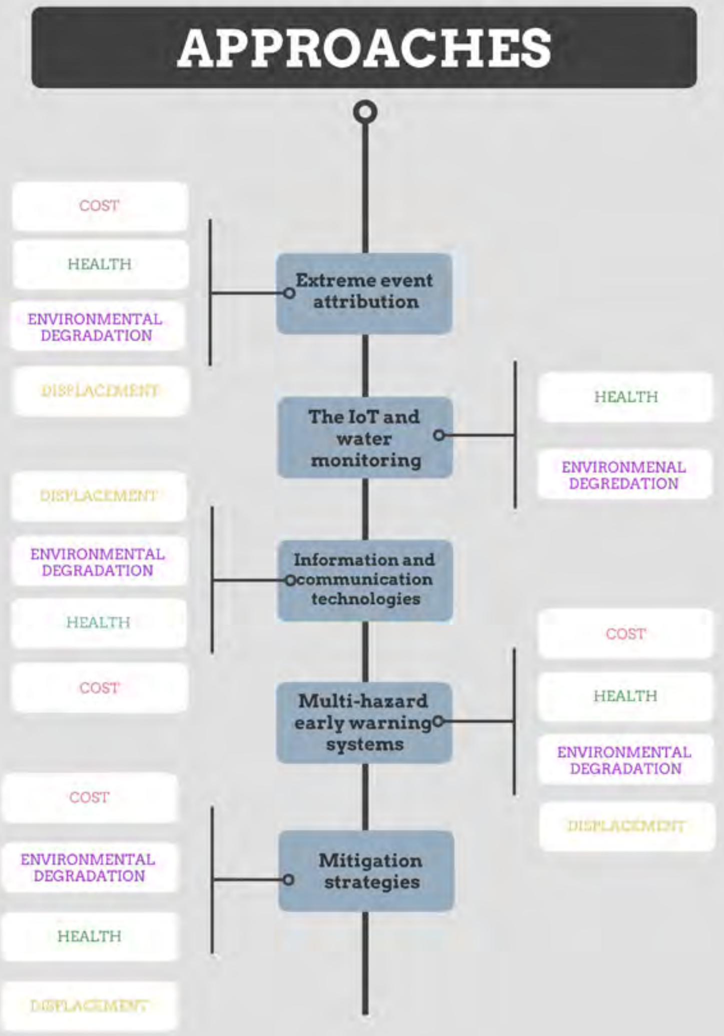
2020

Another Record-Setting Wildfire Season

In 2020, there were 52,113 wildfires that burned 8,889,297 acres in 2020, roughly 2.3 million more acres burned than the 10-year average and almost double the acreage burned in the 2019 season.


Trends
Worsening Wildfires
More frequent fires
More intense fires
Greater damage and cost
Extreme Heat
Intensity, frequency, and duration of heat waves on the rise
Urban heat islands
Contamination of water supplies
Increased demand for water
Megadroughts
Prolonged and intense drought
Environmental and economic impact
Strategic Approaches to Wildfires
Future fire mitigation
Collaborative approach
Federal oversight
Wildfire Budgeting
Changes to how funds are applied to wildfire mitigation and prevention
Establishment of reserve fund


Local and state level
National level
ELECTED OFFICIALS
Recreation
Agriculture
Energy
INDUSTRY
WATER UTILITIES
Denver Water
AWWA
AGENTS
COMMUNITIES
Individual Households and Local Neighborhoods
Rural Municipalities
Cities
FEMA
GOVERNMENT AGENCIES
EPA
Federal natural resource agencies
INNOVATORS
Entrepreneurs
Thought Leaders
Activists


APPROACHES
Extreme event attribution
COST
HEALTH
ENVIRONMENTAL DEGRADATION
DISPLACEMENT
The IoT and water monitoring
HEALTH
ENVIRONMENAL DEGREDATION
Information and communication technologies
DISPLACEMENT
ENVIRONMENTAL DEGRADATION
HEALTH
COST
Multi-hazard early warning systems
COST
HEALTH
ENVIRONMENTAL DEGRADATION
DISPLACEMENT
Mitigation strategies
COST
ENVIRONMENTAL DEGRADATION
HEALTH
DISPLACEMENT

Email	First name	Last name	Linkedin URL	Please include a short bio (limit 250 words)	In what program topic areas are you comfortable offering your expertise? (Check all that apply)	How would you generally identify yourself or your organization? (Check all that apply)
kim@elementalexcelerator.com	Kim	Baker	https://www.linked	As the Director of Water Innovation, Kim works directly with Elemental Excelerator's water portfolio companies and partners. With over a decade of experience in launching and growing technology and organizational platforms rooted in sustainable impact, she helps Elemental's portfolio companies co-design and implement successful projects, as well as scale their solutions. In addition to guiding portfolio companies, Kim works alongside municipalities, corporates, and investors in the water sector, expanding Elemental's work in the sector through collaboration with multi-dimensional stakeholders and fundraising and acquisition opportunities for Elemental's portfolio companies. Kim launched and led a fast-growing drinking water product line for a growth-stage company that was acquired by UGSI Solutions. She co-founded a venture in industrial wastewater treatment, completing multiple capital raises and winning awards on behalf of the company. Before becoming an entrepreneur, Kim was a consultant on a variety of public-sector projects including the expansion of citywide Green Business Programs, energy transmission projects in San Francisco, and early adoption of California's Greenhouse Gas reporting initiative. Kim's formal education includes an MBA in Sustainable Management and a BS in Environmental Engineering.	Water Scarcity and Supply, Water Quality and Safety, Deteriorating Infrastructure	Technology Experts: Water and Climate related AI, Data, Hardware, Software, Other
cesar.morales@cereseng.com	Cesar	Morales	http://linkedin.com	Cesar is a former Naval officer whose professional career has been a diverse and dynamic path, from being a defense analyst for Department of Defense, to managing the development of cutting edge technology while working in the research and development field, and now a co-founder of a flood risk analytics start up, Ceres Engineering. Prior to moving to starting Ceres Engineering, Cesar and his wife embarked on a seminal road trip, driving from Washington DC, down the PanAmerican Highway through Central and South American, down to Patagonia, Argentina. The people and places encountered during this trip has helped shape Cesar's views and motivations in applying innovative data driven technologies to the climate based risks emerging today.	Extreme Events	Technology Experts: Water and Climate related AI, Data, Hardware, Software
will@waterfoundry.com	William	Sarni	https://www.linked	Will is an internationally recognized thought leader on water strategy and innovation. He was ranked as;A Key Player Pressuring Businesses to Care About Water and one of the Top 15 Interviews In Smart Water Magazine 2019. He has been a water strategy advisor to multinationals, water technology companies, investors and NGO's for his entire career. Will works with multinationals on water strategies, technology innovation and market entry strategies. His work with technology companies is as a strategy advisor and investor. Will has written numerous books and articles and presents on;the value of water, innovations, the circular economy, and the energy-water-food nexus. He is currently working on "Digital Water: New Technologies for a More Resilient, Secure and Equitable Water Future" (Routledge, 2021). He is a Board Member of;Flowater, Silver Bullet and Project WET;Chairman of the Scientific Advisory Board for the WAITRO Global Water Innovation Summit;on the Editorial Board of the Journal of Water Security and a Technical Advisor for the Climate Bonds Initiative. He was an Advisor to the 2020 X-PRIZE, led the 2016 X-PRIZE Safe Drinking Water Team and on the Scientific Program Committee for Stockholm World Water Week from 2013 - 2019.	Water Quality and Safety, Water Scarcity and Supply, Deteriorating Infrastructure	Industry Experts:large corporations, utilities, etc., Technology Experts: Water and Climate related AI, Data, Hardware, Software, Environmentalists
karin.wadsack@nrel.gov	Karin	Wadsack	https://www.linked	Karin Wadsack is a program manager for the National Renewable Energy Laboratory, where she leads multiple tribal renewable energy projects and performs applied analysis for energy system decarbonization and resilience projects around the world. She has over a decade of experience working with tribes across the United States on energy analysis, policy, and project development. Her background includes experience in international development, business management, and more than 20 years developing and executing projects. Education: Karin holds a PhD in Engineering Sustainable Systems, a certificate in Applied Statistics, master's degrees in Environmental Science & Policy and Journalism, and a bachelor's degree in Government. Her dissertation research focused on the implications for air quality regulation of power system modeling of high-renewables-and-storage scenarios considering the reduced-hydroelectric effects of climate change in the American Southwest.	Extreme Events, Water Scarcity and Supply	Scientists
kristinleighcampbell@gmail.com	Kristin	Campbell	https://www.linked	Kristin Leigh Campbell is an Environmental and Climate Justice Research and Policy Consultant for the National Associate for the Advancement of Colored People (NAACP). Prior to joining this role with the NAACP, Kristin served as the Science and Policy Analyst for the Institute for Governance and Sustainable development, focusing on incorporating scientific research on short-lived climate pollutants and near-term climate change impacts into policies centered around fast-action mitigation. She has served as an Expert Reviewer for numerous Intergovernmental Panel on Climate Change (IPCC) reports, including the three special reports—the 1.5 C of warming, the ocean and cryosphere, and the land-use reports—as well as the first drafts of all three Working Groups of the upcoming Sixth Assessment Report. Kristin has a Juris Doctor and Masters of Environmental Law and Policy from Vermont Law School, a Master of Arts in Climate and Society from Columbia University, and Bachelor of Science in Meteorology from Florida State University.	Extreme Events	Scientists, Environmentalists, Legal Experts: policy makers, lawyers, human rights advocates
brian.glazebrook@gmail.com	Brian	Glazebrook	https://www.linked	Brian began his career as an environmental consultant in Washington, DC, working with companies and organizations around the world on a wide range of sustainability issues. The work focused heavily on climate change and sustainable product design, and included developing GHG offset projects for the Chicago Climate Exchange, designing a tool for the World Bank to help them evaluate the sustainability of their investments, and partnering with NIST to develop life cycle environmental data for their BEES green building design tool. In 2006, he left consulting and joined Cisco to create a program to manage the environmental performance of its $10B supply chain. One of the first programs of its kind, it has won awards and praise from outside groups. He then moved to NetApp to lead the company's corporate sustainability activities, where he worked across functions to quantify and reduce the company's energy footprint, implement a water management plan to address the California drought and revamped the company's global e-waste program, reducing waste and saving the company $500k annually. Most recently, he was at Nutanix, a cloud software company, where he designed a first-of-its-kind supply chain security management program, launched the company's first Business Continuity program and led a hackathon team to develop an energy/carbon tracking application that could be integrated into the company's software platform. Brian has a Master's in Environmental Science and a Master's in Public Affairs from Indiana University and lives in Half Moon Bay, California with his family and a very energetic German Shorthaired Pointer.	Extreme Events, Water Scarcity and Supply, Deteriorating Infrastructure	Environmentalists, Technology Experts: Water and Climate related AI, Data, Hardware, Software, Industry Experts:large corporations, utilities, etc.
pgrevatt@waterrf.org	Peter	Grevatt	https://www.linked	As CEO of The Water Research Foundation (WRF), Peter Grevatt, Ph.D. directs the world's leading water research cooperative. WRF oversees research and promotes innovation across all aspects of the water sector—in pursuit of ensuring the highest water quality and improving water services to communities across the globe. With approximately 1,200 subscriber members in the U.S. and abroad, the Foundation has over $130 million of contracted research and innovation activities currently underway. Dr. Grevatt has dedicated over 30 years to the implementation of public health and environmental protection programs, including significant national leadership experience in the water sector. He previously served as Director of EPA's Office of Ground Water and Drinking Water (OGWDW) where he was responsible for ensuring the safety of the nation's drinking water supply. Dr. Grevatt also served as Senior Advisor to EPA's Administrator for Children's Environmental Health and has held leadership roles in EPA's water quality and national hazardous waste cleanup programs. Dr. Grevatt is a graduate of New York University Medical Center with M.S. and Ph.D. degrees in Basic Medical Sciences. He earned his bachelor's degree in Biology from Earlham College in Richmond, Indiana.	Extreme Events, Deteriorating Infrastructure, Water Scarcity and Supply, Water Quality and Safety	Scientists, Environmentalists, Conservationists, Technology Experts: Water and Climate related AI, Data, Hardware, Software, Industry Experts:large corporations, utilities, etc.
ariel.miara@nrel.gov	Ariel	Miara	https://www.linked	Ariel Miara is a leading energy, water, and environment research analyst at the National Renewable Energy Laboratory. As an energy-water nexus expert, Ariel leads research on a range of topics related to the interactions between energy systems, water resources, the environment, and policy. His modeling and analysis work includes integrating water resources and energy models to evaluate water risk, weather, and climate impacts on electricity generation infrastructure. His cutting-edge energy-water nexus work includes researching energy requirements for water infrastructure and innovative synergies between energy and water systems to maximize productivity and efficiency, under current and future conditions. As part of the National Alliance for Water Innovation team, he leads the model development of the WaterTAP3 techno-economic model that evaluates the cost and performance of water treatment systems. Ariel completed his PhD in Civil Engineering, with a focus on water resources and environmental engineering, at The City College of New York.	Water Scarcity and Supply, Extreme Events	Scientists, Technology Experts: Water and Climate related AI, Data, Hardware, Software, Other
lewynli@gmail.com	Lewyn	Li	https://www.linked	My passion lies in using science and technology to tackle urgent and important problems in health and the environment. I am a self-driven, focused and result-oriented bioinformatics scientist/computational biologist who is an accomplished leader of technical and scientific teams. With >14 years of experience in pharmaceutical and diagnostic Product Research and Development, I have expertise in digital droplet PCR (ddPCR) and next-generation sequence (NGS) analysis. My area of specialty is cancer and infectious disease genomics and epigenomics, spanning machine learning, biomarker identification, multivariate regression, survival analysis, and protein structural and dynamics modeling. As a recent example, my team and I were responsible for the data analyses and algorithm behind Bio-Rad's SARS-CoV-2 ddPCR kits, which received Emergency Use Authorization from the US FDA in May 2020. (https://www.bio-rad.com/en-us/product/sars-cov-2-droplet-digital-pcr-ddpcr-kit?ID=Q9KNF4RT8IG9).	Water Quality and Safety	Scientists, Technology Experts: Water and Climate related AI, Data, Hardware, Software
mike@aqaix.com	michel	gardner	https://www.linked	Mike has a degree in resource economics from UC Berkeley, and has had a long career as an entrepreneur and managing engineering and Big Data groups at companies such as eBay, Apigee, and BNY Mellon (one of the largest global banks). Mike has been involved in digitization of industries as diverse as retail, fashion, Telco, and others. In 2017 Mike founded Aqaix, an Impact startup, to try to help bring more funding to water infrastructure projects of all types. The Aqaix Software platform automates the processes of financing for resilience infrastructure, and enables new finance instruments such as green bonds, environmental credits, and social impact bonds.	Deteriorating Infrastructure, Water Scarcity and Supply, Water Quality and Safety	Scientists, Economists, Environmentalists, Technology Experts: Water and Climate related AI, Data, Hardware, Software, Industry Experts:large corporations, utilities, etc.
jessica.brody@denverwater.org	Jessica	Brody	n/a	Jessica Brody joined Denver Water as General Counsel in August 2018. Previously, she served as the lead environmental attorney for the City and County of Denver (2013 – 2016) and then as an Assistant Director (2016 – 2018) in the Denver City Attorney's Office. A 2003 graduate of The Yale Law School, Jessica started her career as an environmental attorney at Arnold & Porter LLP, an international law firm. Jessica has always had a passion for public service. She was a member of the AmeriCorps program inaugural class and was selected as a Harry S. Truman Scholar in 1998. In her spare time, she serves as President of the board of a Denver public charter school. She is also a member of the Colorado Bar Association Environmental Law Section Advisory Council.	Deteriorating Infrastructure, Water Scarcity and Supply, Water Quality and Safety	Legal Experts: policy makers, lawyers, human rights advocates
lauren.schmeisser@gmail.com	Lauren	Schmeisser	https://www.linked	Lauren Schmeisser is an engineer and scientist with comprehensive expertise in environmental challenges. Lauren has formal education in water, earth, and atmospheric sciences, with an emphasis on climate change. She solves complex systemic problems with a spectrum of tools and techniques ranging from data analysis to field work to models. She is well versed in environmental datasets, including satellite, reanalysis, and in-situ data, and primarily programs in Python in order to investigate science questions using these datasets. Lauren knows her way around the global climate model databases and is passionate about analyzing model output to learn more about what a potential future climate will look like here on earth. Applied projects with intersection between climate science, engineering, and business are of particular interest to her. Lauren holds a PhD in Atmospheric Science from the University of Washington;a MSc in Earth Sciences from the Universiteit van Amsterdam, and a BS/MS in Environmental Engineering from the University of Colorado Boulder. She is currently a postdoctoral researcher at the Cooperative Institute for Research in Environmental Sciences at the University of Colorado and NOAA in Boulder. When not working on science, Lauren enjoys teaching yoga, hiking, and cooking new recipes!	Extreme Events	Scientists
sam.stein@state.co.us	Sam	Stein	https://www.linked	Sam Stein (he/him) is a Program Manager in the Water Supply Planning department at the Colorado Water Conservation Board. He is also the CWCB's liaison to the Basin Roundtables where he engages local regional stakeholders to further and inform the Colorado Water Plan. Prior to joining the CWCB, Sam served as a Demand Planner for Denver Water where he modeled long-term municipal water demands by considering both a changing climate and changing population. Sam holds a bachelor's degree in Economics from Goucher College, and a master's degree in Natural Resource and Environmental Economics from Colorado State University.	Water Scarcity and Supply, Extreme Events	Economists, Environmentalists, Conservationists, Industry Experts:large corporations, utilities, etc.
grizz@ixpower.com	John R (Grizz)	Deal	https://www.linked	John R. (Grizz) Deal • Executive Chairman & CEO • IX Power Clean Water, Inc. John R. (Grizz) Deal has nearly thirty years of experience in technology commercialization, tech-based startups, fast-growing ventures, and product development. Grizz was CEO and a co-founder of Hyperion Power Generation, a Los Alamos National Laboratory (LANL) spinout developing a Small Modular Reactor (SMR). He has also served as the chief marketing officer for Space Imaging and was the founder and CEO of LizardTech, one of the more successful LANL spinouts. Additionally, Grizz has served as Entrepreneur in Residence for the U.S. Department of Energy (DOE) National Nuclear Security Administration (NNSA) at Technology Ventures Corporation and as Visiting entrepreneur at Los Alamos National Laboratory. Grizz founded seven firms based on U.S. DOE technologies and holds graduate and undergraduate science degrees in geography from Texas A&M University. Grizz is on the Board of the Riga Innovation Centre (RIC) in Latvia, the former Product Development Sensei for GVA Launch Gurus in Russia and Kazakhstan, a former adjunct faculty member at the Moscow School of Management Skolkovo, a member of the Texas A&M University College of Geosciences Advisory Council, a Mentor at the University of Northern Colorado BizHub Collaborative, and a Steering Committee member of the JeffCo Energy Action Project.	Water Quality and Safety, Water Scarcity and Supply	Scientists, Economists, Environmentalists, Conservationists, Technology Experts: Water and Climate related AI, Data, Hardware, Software
salzman@ucsb.edu	Jim	Salzman	https://law.ucla.edu	James Salzman holds joint appointments at the UCLA School of Law and at the UCSB School of the Environment. In thirteen books and more than 100 articles and book chapters, his broad-ranging scholarship has addressed topics spanning drinking water, policy instrument design, and creating markets for ecosystem services. A national expert on drinking water, he formerly served on EPA's drinking water advisory council. Author of Drinking Water: A History, he is a frequent media commenter on water issues.	Water Scarcity and Supply, Water Quality and Safety	Legal Experts: policy makers, lawyers, human rights advocates
erothste@grg-ltd.com	Eric	Rothstein	https://www.linked	Eric has over 30 years of experience in water, wastewater, and stormwater utility financial and strategic planning. His recent projects include supporting the City of Atlanta Watershed Management Department's capital financing program, and as co-author of the report: "Developing a New Framework for Household Affordability and Financial Capability Assessment in the Water Sector". Previously, Eric served on the Michigan Governor's Flint Water Advisory Task Force, and as program manager for establishment of the Great Lakes Water Authority. For the Detroit Water and Sewerage Department, he chaired the Blue Ribbon Panel on Affordability and led initial implementation of its impervious area based drainage fee. He was Jefferson County, AL's rate consultant and municipal advisor for litigation related to the County's bankruptcy and issuance of $1.7 billion in sewer warrants. Eric prepared the City of Atlanta's Financial Capability-Based Schedule Extension Report. For several permittees (Atlanta, Akron, EBMUD, Honolulu, Guam, NEORSD, ST. Louis), Eric provided strategic and financial consulting and negotiation support services on financial capability assessment and low-income affordability issues. Eric is a member of the USEPA Environmental Finance Advisory Board, an MSRB registered Municipal Advisor, and a contributing author of the WEF Financing and Charges for Wastewater Systems and AWWA Principles of Water Rates, Fees and Related Charges Manual of Practices. Education MA, Economics, University of California-Davis;AB, Economics & History, Ripon College, Ripon WI	Deteriorating Infrastructure, Water Scarcity and Supply	Economists, Industry Experts:large corporations, utilities, etc., Legal Experts: policy makers, lawyers, human rights advocates
javier.marti@divirod.com	Javier	Marti	https://www.linked	Javier is an entrepreneur with strong international experience in anything from satellites to state of the art instrumentation for big data, ground based, distributed operations. Since 2016 he is the CEO of divirod addressing water risk problems.	Water Scarcity and Supply, Extreme Events	Technology Experts: Water and Climate related AI, Data, Hardware, Software, Scientists, Environmentalists, Conservationists
joshua.sperling@nrel.gov	Josh	Sperling	https://www.linked	Josh Sperling is an Urban Futures and Energy-X Nexus Engineer, working at the nexus of rapidly changing urban environments, water, energy, and complex decision systems. He is a former Fulbright Scholar, holds a PhD from the interdisciplinary Sustainable Urban Infrastructure program at UC-Denver, and co-leads thrusts focused on smart cities, infrastructure and urban-decision sciences. In NSF, DOE, to State Dept-funded consortiums, he is focused on a future of integrated systems and services transformations for improving quality of life, infrastructure, and with emphasis on addressing priority goals of diverse stakeholders. He joined NREL's New Concepts Incubator, Joint Institute for Strategic Energy Analysis, Urban Science, International, and National Alliance for Water Innovation teams in 2015. He also co-leads multi-disciplinary, cross-sector initiatives for DOE/NREL;strategic and global partnerships (including with universities);and supports early-career mentoring at NREL and beyond.	Extreme Events, Deteriorating Infrastructure, Water Scarcity and Supply	Scientists, Economists, Environmentalists, Technology Experts: Water and Climate related AI, Data, Hardware, Software, Other

james@eklundhanlon.com	James	Eklund	eklundhanlon.com	James is co-founder and CEO of Eklund Hanlon, LLC, a water law and policy firm. As Director of the Colorado Water Conservation Board, James was the architect of Colorado's first strategic water plan and is regularly consulted in implementing what has become the "gold standard" of water plans in the Western US. During his tenure as director, he quickly built a reputation as a leader in negotiation and diplomacy – bringing together multiple stake holders with opposing goals in order to collaboratively craft binding solutions to common problems. James also served as Colorado's Colorado River Commissioner. James had the honor of negotiating and signing the first management plan for the Colorado River that recognizes climate change and will be the foundation for all future management decisions on a river that serves 40 million people, seven of the United States, and the Republic of Mexico. In near record time, he successfully helped craft and shepherd critical Colorado River legislation through the US Congress and testified in the House of Representatives in support of the bill that was ultimately signed into law. Recently, while at the international law firm Squire Patton Boggs, James led firm's global water and climate change practices. He also previously served as legal counsel to the Governor of the state of Colorado and an Assistant Attorney General for Colorado specializing on interstate and international water issues. James also currently teaches graduate environmental classes at the University of Denver and is a frequent presenter on water and climate change issues. His favorite endangered species is the Razorback Sucker (he thinks of himself as sharp but gullible at times).	Water Scarcity and Supply, Extreme Events, Deteriorating Infrastructure	Legal Experts: policy makers, lawyers, human rights advocates, Other, Industry Experts:large corporations, utilities, etc.
kevin.prokop@gmail.com	Kevin	Prokop	https://www.linked	Before a career in business, I was a Mechanical Engineer in a variety of applications. Recently, my experience includes entrepreneurship, sustainability projects with a water focus, impact finance, forest health, and the infrastructure surrounding these problem areas. Looking forward, my interests include becoming more adept and involved with international projects, finance, technology (software), sustainability, and entrepreneurial ventures that have a triple bottom line impact. I hope while on this journey to find new solutions for emerging markets and ways to create positive effects for the stakeholders involved.	Deteriorating Infrastructure, Water Scarcity and Supply, Water Quality and Safety, Extreme Events	Other, Technology Experts: Water and Climate related AI, Data, Hardware, Software, Industry Experts:large corporations, utilities, etc.
dvazpocas@gmail.com	Daniel	Vaz-Pocas	https://www.linked	Daniel has 12 years of experience serving as an innovator and has been bringing new equipment to market for CPG companies for the past 9 years. After graduating from Manhattan College with a Master of Science in Mechanical Engineering, he began his career designing defense systems for government contractors like Lockheed Martin and ITT Exelis. He then moved into the Food & Beverage industry by joining PepsiCo as an Associate Principal Engineer, where he led the development of new vending machine and visi-cooler innovations. He is now a Sr. Manager of Innovation with Nestle Waters USA, leading the end-to-end development of new dispensing equipment and delivery services. Outside of his career, Daniel has always been passionate about the environment and the anthropogenic impact on it. He loves traveling around the world to explore the diversity of our planet, and enjoys experiencing nature everywhere he goes. One of the most inspirational experiences of his lifetime was camping in the Okavango Delta of Bostwana, where he experienced nature in its complete ecological balance, nearly unaltered by humans. This has inspired him to take a more proactive role in driving sustainability efforts forward. He is extremely excited to join X Genesis as a Validator and is looking forward to the program.	Water Quality and Safety	Industry Experts:large corporations, utilities, etc.
rehbrown1@gmail.com	Rachel	Brown	https://www.linked	Rachel Brown is a Senior Policy Advisor in the Native American and International Affairs Office at the Bureau of Reclamation. In her current role, she works primarily on Indian water rights settlements and water resource issues in the western United States, and on projects with foreign countries seeking technical expertise from the Bureau. Prior to joining Reclamation, she worked for the National Park Service in the American Indian Liaison Office. In her position with NPS, she worked on negotiations to create the first Tribal National Park and advised the Park Service on issues relating to cultural and natural resource protection. Prior to joining the Department of the Interior, she worked for the Senate Homeland Security and Governmental Affairs Committee Subcommittee on Disaster Recovery where her portfolio included Gulf Coast recovery following hurricanes Katrina and Rita, and the federal disaster response to the Deepwater Horizon oil spill and the 2010 earthquake in Haiti. She has a spent her career working in the areas of federal policy making and federal appropriations with a focus on water resources development, infrastructure, western water rights, climate change, and disaster response and recovery. Rachel a Presidential Management Fellow (class of 2012), and 2020 Presidential Leadership Scholar.	Deteriorating Infrastructure, Water Scarcity and Supply, Extreme Events	Other, Legal Experts: policy makers, lawyers, human rights advocates
ghale@fullbodysound.com	Griffin	Hale	https://www.linked	Griffin Hale is an Environmental Control and Life Support (ECLSS) Engineer, hardware entrepreneur and outdoor enthusiast. He received his masters degree in aerospace engineering from the University of Colorado with a focus in Bioastronautics and a minor in Biochemistry. He has worked with multiple life support systems and has successfully taken concepts from paper to functional prototypes. He is not afraid to get his hands dirty and enjoys both researching new technology and running experiments in the lab. During his time as a lab manager, he performed a multitude of tasks including: writing procedures, calibrating instruments, performing data analysis and developing sampling techniques. Griffin also helped pioneer a water reclamation system that transformed urine to drinking water. The novel process took in situ salts from urine and transformed them into chlorine species that then oxidized organic waste. Griffin is also the founder of Full Body Sound and has created technology that allows users to feel music and audio. The tech has the potential to increase accessibility as well as create a more immersive experience for everyone. When Griffin is not working, he loves to adventure and is passionate about the outdoors. He and his amazing wife / co-founder Allison can be found skiing, biking or leading raft expeditions down the Grand Canyon.	Water Quality and Safety	Scientists, Technology Experts: Water and Climate related AI, Data, Hardware, Software
jerry@westurb.com	Jerry	Tinianow	https://www.westu	Jerry Tinianow is the proprietor of Western Urban Sustainability Advisors, LLC. WestUrb advises local governments on the creation and improvement of sustainability plans and programs. WestUrb also assists businesses that offer sustainability-related products and services to local governments. WestUrb's work is based on his service as Denver's first Chief Sustainability Officer (2012-19). He worked with all departments in Denver's 13,000-employee city/county government on programs across a wide variety if disciplines, including climate change and water. During his tenure Denver won Platinum-level certification under the U.S. Green Building Council's LEED for Cities and Communities program, one of only five U.S. cities to reach that level. Denver met its ambitious 2020 greenhouse gas reduction goal in 2018, two years ahead of schedule. Denver was put on the "A List" of top-performing climate change programs worldwide by CDP (formerly known as the Climate Disclosure Project). Jerry was the 2018 winner of the Wirth Chair Sustainability Award given by the University of Colorado, based on his role in creating Denver's climate change plan. Prior to his work in Denver, Jerry was a national officer in both the Sierra Club and the National Audubon Society. He also served as the director of the Center for Energy and Environment at the Mid-Ohio Regional Planning Commission. An attorney by training, Jerry was a partner and commercial trial attorney in two large Ohio law firms. Jerry received his undergraduate degree in International Affairs and his law degree from the George Washington University.	Extreme Events, Deteriorating Infrastructure, Water Scarcity and Supply, Water Quality and Safety	Environmentalists, Legal Experts: policy makers, lawyers, human rights advocates
bill.hartman@atargis.com	Bill	Hartman	https://www.linked	The CEO of Atargis Energy Corporation, the first company with the technology to product low-cost, utility-scale electricity from ocean waves. Has been the President/CEO of four other startups in photonics, real-time big data analytics, cancer therapy and semiconductor testing. Retired Navy Captain, USNR. BS US Naval Academy. MBA University of Rochester.	Deteriorating Infrastructure	Scientists, Technology Experts: Water and Climate related AI, Data, Hardware, Software, Industry Experts:large corporations, utilities, etc.
erothste@grg-ltd.com	Eric	Rothstein	https://www.linked	Eric has over 30 years of experience in water, wastewater, and stormwater utility financial and strategic planning. Eric is a member of the USEPA Environmental Finance Advisory Board, an MSRB registered Municipal Advisor, and contributing author of the AWWA and WEF ratemaking Manuals of Practices.		Economists, Industry Experts:large corporations, utilities, etc.
bmartin@awwa.org	Barbara	Martin	https://www.linked	Barbara Martin is Director of Engineering & Technical Services at AWWA. She has worked for global water service providers, including business development for a proprietary process treatment technology. She has a BA in chemistry from Boston University, an MS in geochemistry from Colorado School of Mines, and an MBA from Colorado State University.	Water Scarcity and Supply, Water Quality and Safety, Deteriorating Infrastructure	Scientists, Industry Experts:large corporations, utilities, etc.
james@eklundhanlon.com	James	Eklund	www.linkedin.com	James is co-founder and CEO of Eklund Hanlon, LLC, a water law and policy firm based in Colorado. As Director of the Colorado Water Conservation Board, James was the architect of Colorado's first strategic water plan and is regularly consulted in implementing what has become the "gold standard" of water plans in the Western US. During his tenure as director, he quickly built a reputation as a leader in negotiation and diplomacy – bringing together multiple stake holders with opposing goals in order to collaboratively craft binding solutions to common problems. In 2016, James was appointed by Governor John Hickenlooper to serve as the Colorado River Commissioner for the state of Colorado. James fought fiercely to protect Colorado's rights to water on the river, but also worked collaboratively with downstream states in order to ensure a good outcome for all 40 million people who rely on the Colorado River for their health and well-being. To do this, James negotiated and signed ground-breaking agreements binding the seven basin states, the Republic of Mexico and the US federal government. In near record time, James successfully helped craft and shepherd critical Colorado River legislation through the US Congress and testified in the House of Representatives in support of the bill that was ultimately signed into law by the US President. He, along with other state representatives, later signed the Drought Contingency Plan which ensures the near-term sustainability of the Colorado River. Recently, while at the international law firm Squire Patton Boggs, James led the global water and climate change practices. He also previously served as legal counsel to the Governor of the state of Colorado and an Assistant Attorney General for Colorado specializing on interstate and international water issues. James also currently teaches graduate environmental classes at the University of Denver and is a frequent presenter on water and climate change issues. More at EklundHanlon.com.	Water Scarcity and Supply, Deteriorating Infrastructure	Environmentalists, Conservationists, Industry Experts:large corporations, utilities, etc., Legal Experts: policy makers, lawyers, human rights advocates
info@jbdondolo.org	Lumbie	Mlambo	https://www.linked	Lumbie Mlambo is a mother, wife, graduate from Indiana University South Bend and Texas Woman's University, UNA Women member, a 2019 UN Global Leadership Award Recipient, a Global Goodwill Ambassador, and an active advocate for Clean Water and Empowerment of Women and Youth. She was born in Zimbabwe, but moved to the USA in 1985. She currently resides in Dallas, Texas with her family (2 sons JB and Sam Jr and her husband Sam of 32 years). Lumbie is the President & CEO of JB Dondolo, Inc. (https://.jbdondolo.org), a nonprofit which helps underserved and impoverished communities who struggle with the lack of clean water. Her organization removes barriers of access to clean water, sanitation, and hygiene in underserved and impoverished communities to reduce poverty and promote gender equity.	Water Quality and Safety, Water Scarcity and Supply, Extreme Events	Technology Experts: Water and Climate related AI, Data, Hardware, Software, Conservationists, Environmentalists, Other
jodorfman@gmail.com	Josh	Dorfman	https://www.linked	Josh Dorfman is a mission-driven entrepreneur. He was CEO of The Collider, an innovation center for climate change resilience solutions. He was Managing Director of Asheville Angels, an early-stage angel investment group. He is currently co-founder of Simbly, a modern sustainable furniture startup.	Extreme Events, Deteriorating Infrastructure	Environmentalists, Conservationists, Technology Experts: Water and Climate related AI, Data, Hardware, Software
richardpfisher@gmail.com	Richard	Fisher	https://www.linked	I am an engineer with a diverse 12-year career extending from research (high-temperature solar processes, off-grid sanitation) to spacecraft testing (contamination control and thermal-vaccum testing) to consulting in water resources and water rights. I am a registered Professional Engineer in the State of Colorado.	Deteriorating Infrastructure, Water Scarcity and Supply, Water Quality and Safety	Scientists, Other, Environmentalists
toludebbie@gmail.com	Tolu	Oyewumi	www.linkedin.com	Dr. Tolu Oyewumi's (MD, MPH) rich background spans across various fields;clinical medicine, research (scientifically published), epidemiology, disease prevention, clinical trials, regulatory affairs, innovation, and startup advisory. She leverages her superpower of empathy to solve complex healthcare and social problems.	Water Quality and Safety, Extreme Events, Water Scarcity and Supply	Scientists, Legal Experts: policy makers, lawyers, human rights advocates, Other
jim.ginley23@gmail.com	Jim	Ginley	https://www.linked	I have spent more than 30 years in the water sector as a not-for-profit association professional, utility management and technology consultant. My areas of expertise include strategic planning, organizational assessments, and benchmarking, as well as workshop facilitation and training. I have led or facilitated dozens of sessions/workshops that engaged hundreds of utility sector professionals, including senior executives, appointed and elected officials, top managers and supervisors, and front-line staff. I helped build and launch the AWWA QualServe program and Utility Benchmarking effort, as well as the series of AWWA/ANSI Utility Management Standards. I helped build the nationally known and multi-association sponsored Effective Utility Management (EUM) framework (2007, 2008) and I have been retained by AWWA to build and present the revised version of EUM, which has been delivered across the US since 2017. I also teach a one-day version of the updated EUM framework as a subcontractor to the US EPA. I am a frequent presenter and facilitator at professional conferences such as AWWA, WEFTEC and the Utility Management Conference. I have been published in Journal AWWA, co-authored an AWWA guide book on the AWWA/ANSI Utility Management System Standard (G-400), and authored a chapter in an award-winning water sector anthology, "Damned if We Don't: Ideas for Accelerating Change around Water." I am listed as the author for AWWA's M5 Manual on Utility Management (because I chaired the committee of a dozen people who contributed) and authored a chapter on strategic planning. I am a member of the AWWA Strategic Management Practices Committee, the AWWA Utility Benchmarking Advisory Committee, the WEF Utility Management Committee, and I am the founder and co-chair of the Rocky Mountain Utility Management Committee.	Deteriorating Infrastructure, Water Scarcity and Supply, Water Quality and Safety	Industry Experts:large corporations, utilities, etc.

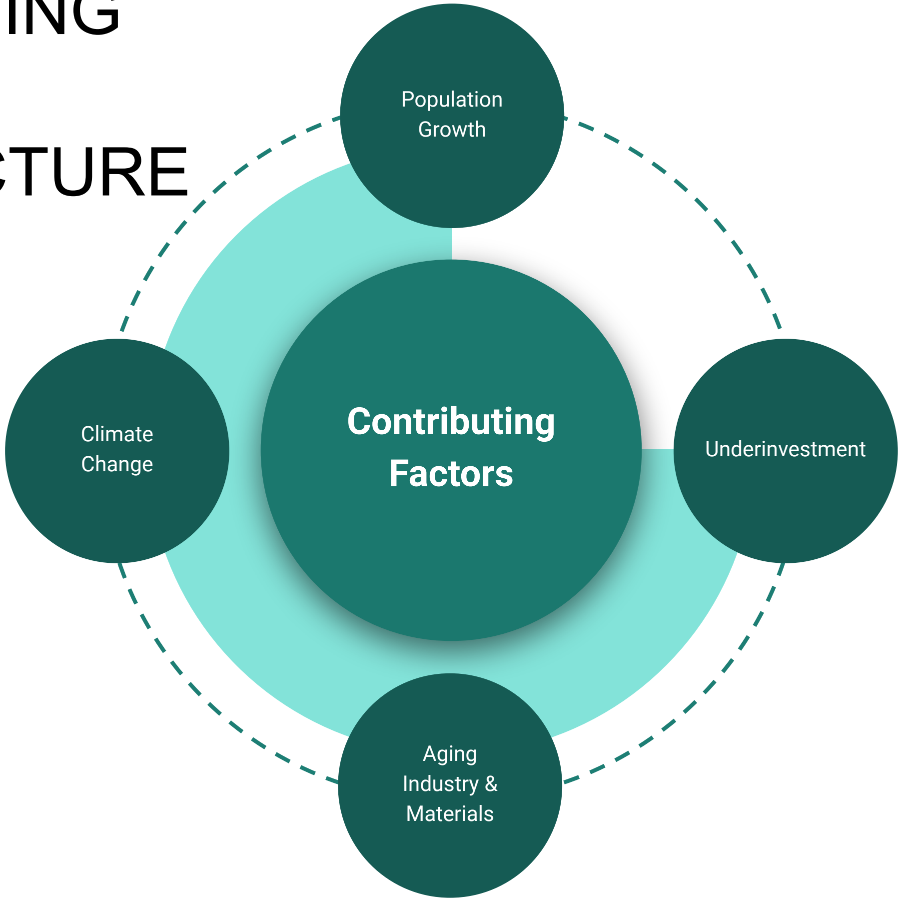
CWCB PRESENTATION

January 27, 2021

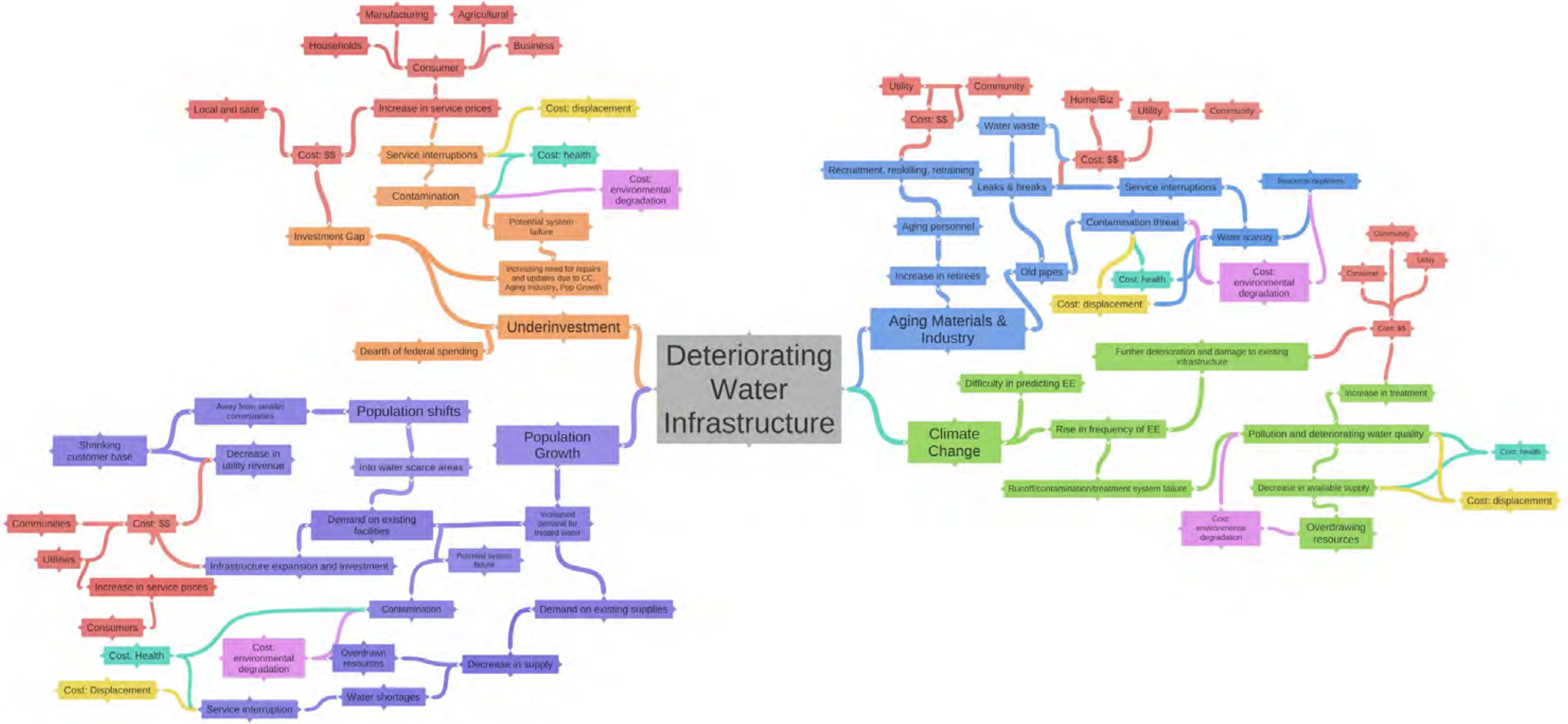
WATER & CLIMATE

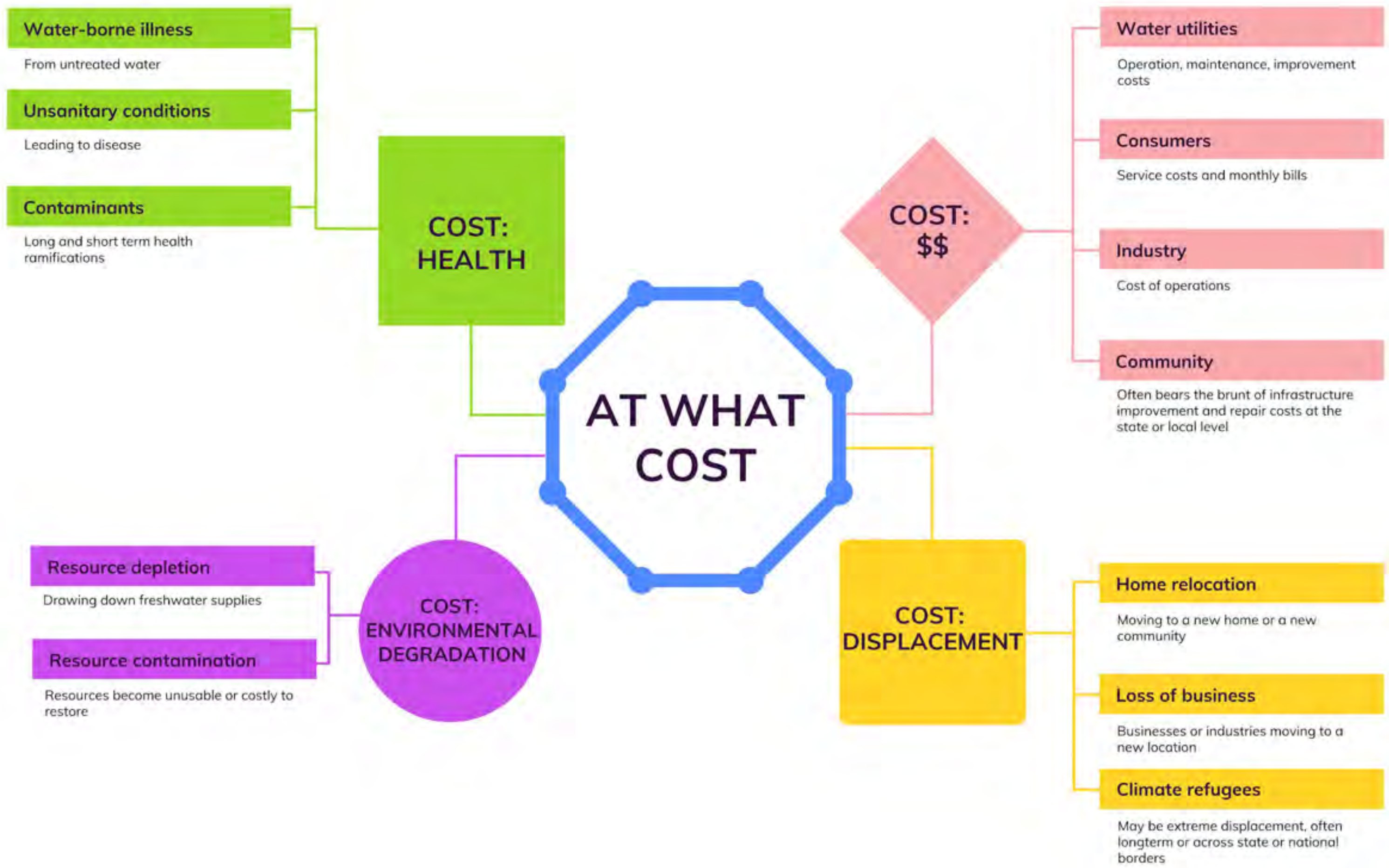
- DETERIORATING INFRASTRUCTURE
- SUPPLY & SCARCITY
- QUALITY & SAFETY
- EXTREME EVENTS

DETERIORATING WATER INFRASTRUCTURE



CONTRIBUTING FACTORS





AT WHAT COST
COST: HEALTH
Water-borne illness
From untreated water
Unsanitary conditions
Leading to disease
Contaminants
Long and short term health ramifications
COST: $$
Water utilities
Operation, maintenance, improvement costs
Consumers
Service costs and monthly bills
Industry
Cost of operations
Community
Often bears the brunt of infrastructure improvement and repair costs at the state or local level
COST: ENVIRONMENTAL DEGRADATION
Resource depletion
Drawing down freshwater supplies
Resource contamination
Resources become unusable or costly to restore
COST: DISPLACEMENT
Home relocation
Moving to a new home or a new community
Loss of business
Businesses or industries moving to a new location
Climate refugees
May be extreme displacement, often longterm or across state or national borders

HISTORY

1800S

DEVELOPMENT

As towns and cities grew in population the need for infrastructure also grew.

Late 1800s - early 1900s

SAFETY AND HEALTH

Concerns over health and disease at the tail of the Industrial Revolution led to a corresponding hygiene movement that prompted creation of sanitation and water treatment methods.

Mid 1900s

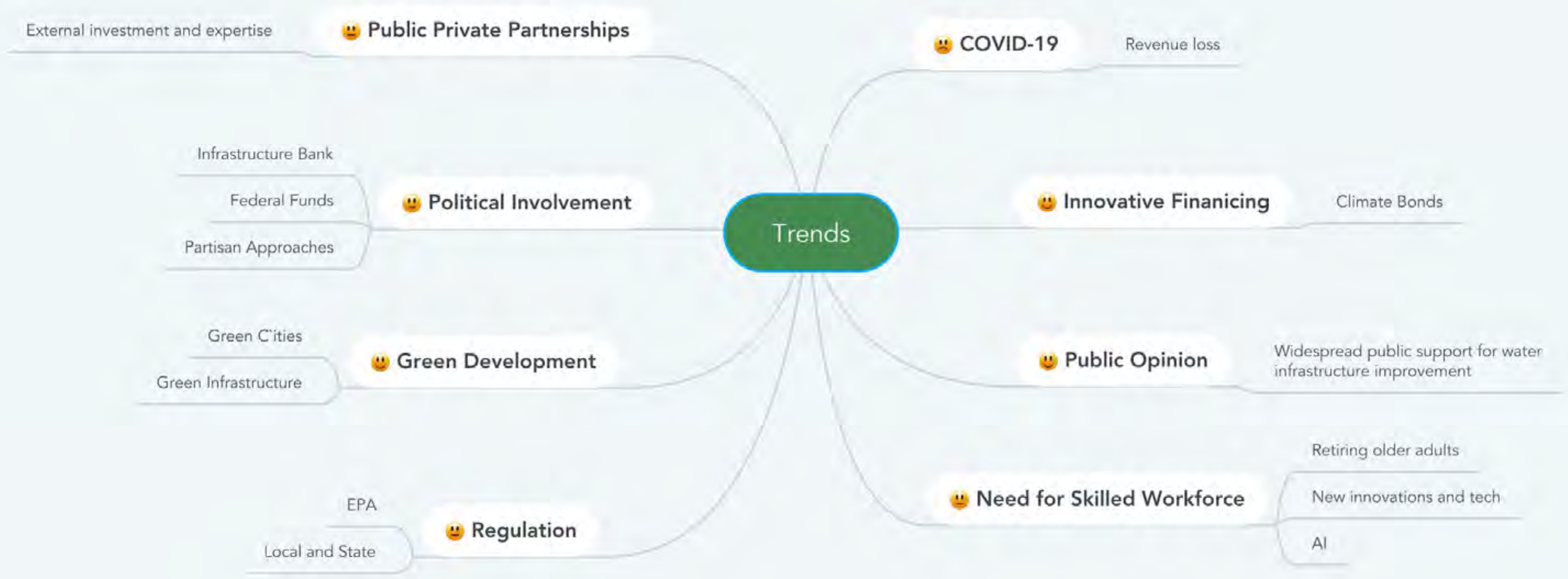
REGULATION

Environmental concerns prompted legislation regulating wastewater disposal and drinking water quality.

21st Century

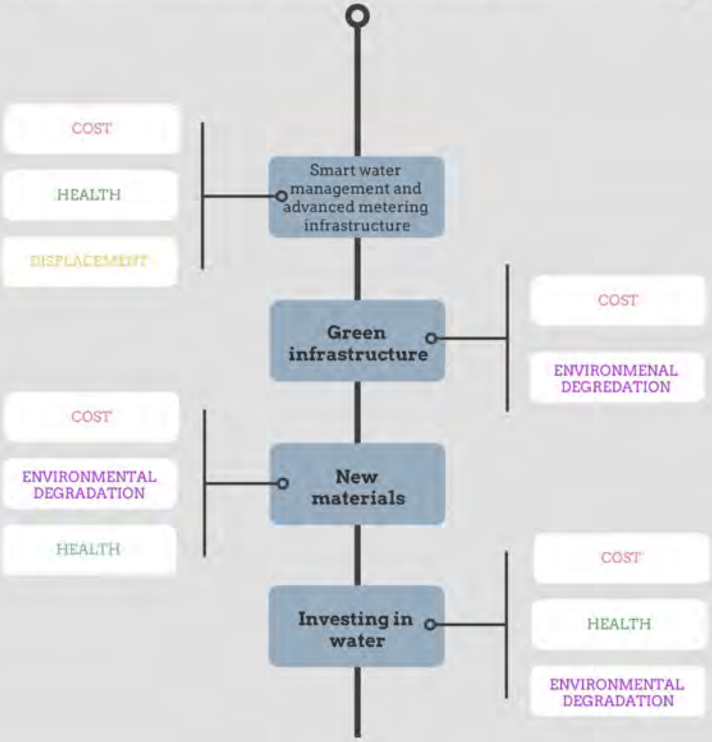
DISREPAIR

Decades of underinvestment and in places century old materials culminate in an industry with pressing needs. In 2017, the ASCE bestows a grade of D+ on the state of infrastructure in America, with drinking water and wastewater each receiving a D+.

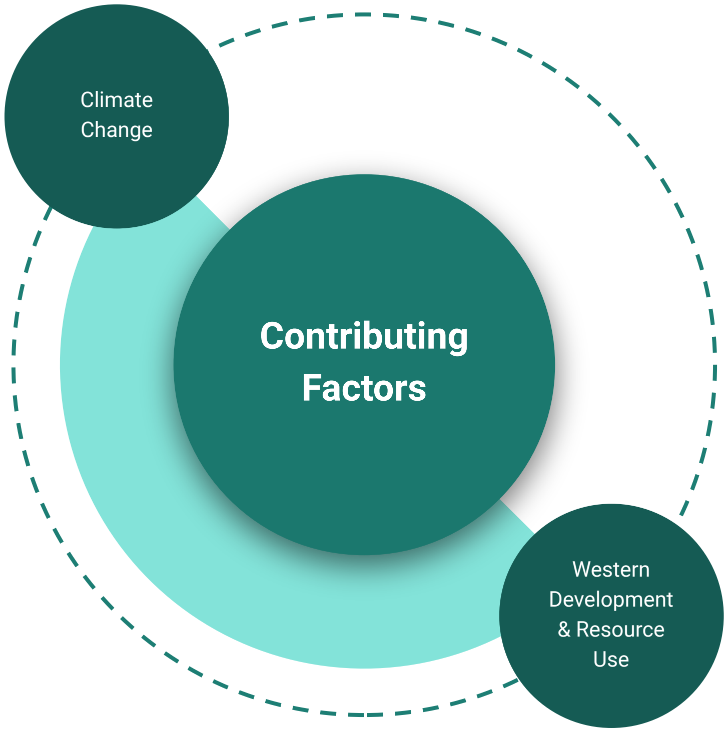

Trends
Public Private Partnerships
External investment and expertise
Political Involvement
Infrastructure Bank
Federal Funds
Partisan Approaches
Green Development
Green C'ities
Green Infrastructure
Regulation
EPA
Local and State
COVID-19
Revenue loss
Innovative Financing
Climate Bonds
Public Opinion
Widespread public support for water infrastructure improvement
Need for Skilled Workforce
Retiring older adults
New innovations and tech
AI


AGENTS
REGULATORY BODIES
EPA
FDA
WATER UTILITIES
Denver Water
AWWA
INDUSTRY
Recreation
Agriculture
Energy
INVESTORS
Water Asset Management
Climate Change Bond Funds
ASSOCIATIONS
ASCE
AWWA
COMMUNITIES
Local Gov and Governing Bodies
Rural Municipalities
Cities
CONSUMERS
Indian Tribes
Urban Centers
Rural Communities
INNOVATORS
Entrepreneurs
Thought Leaders
Activists

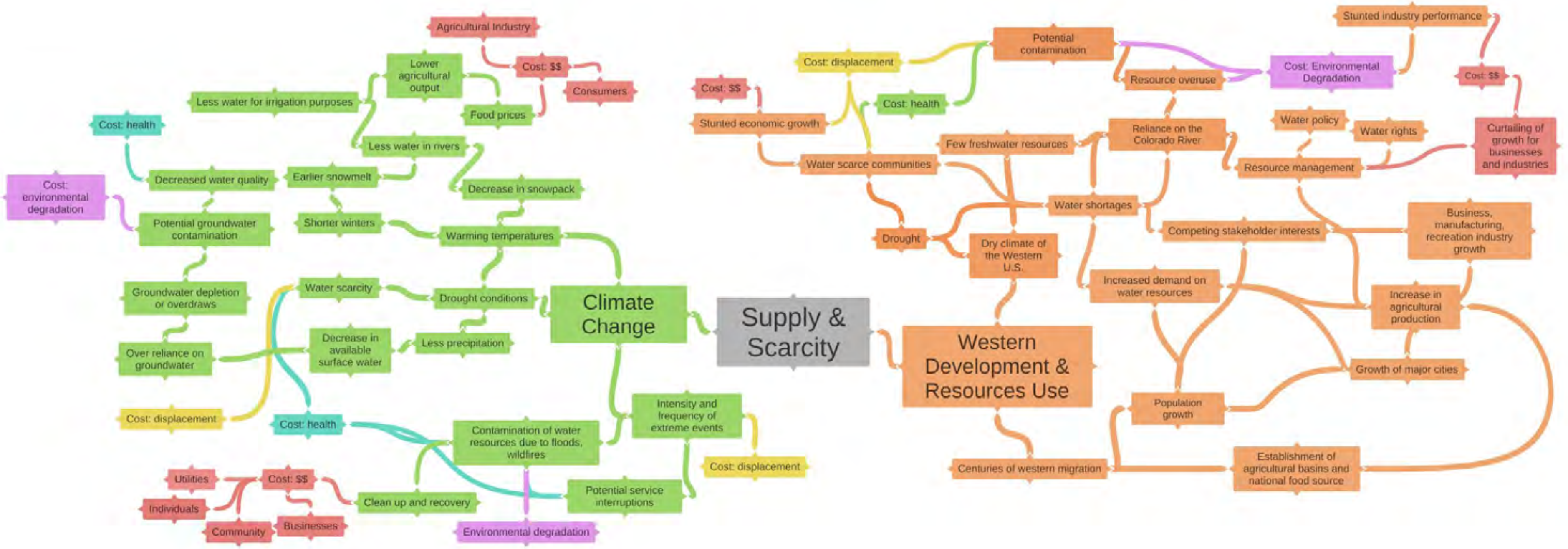
APPROACHES


Smart water management and advanced metering infrastructure
COST
HEALTH
DISPLACEMENT
Green infrastructure
COST
ENVIRONMENAL DEGREDATION
New materials
COST
ENVIRONMENTAL DEGRADATION
HEALTH
Investing in water
COST
HEALTH
ENVIRONMENTAL DEGRADATION

SUPPLY
&
SCARCITY



SUPPLY & SCARCITY



HISTORY

1800s

Developing the West

What began with mining booms eventually scaled up to extended migration and settlement of the West. Water was scarce and “first in, first in right” water rights were established.

Early 1900s

Selling the West

The railroads and CA State Agricultural Society embarked on a campaign promising an agricultural paradise for those willing to move West. Those who heeded the call were met with a far different set of circumstances, including water scarcity.

Mid 1900s

Public Work Projects

It became clear water supplies in the West could not keep pace with demand. The federal government intervened with a series of water development projects to enhance water infrastructure in the West.

1960s on

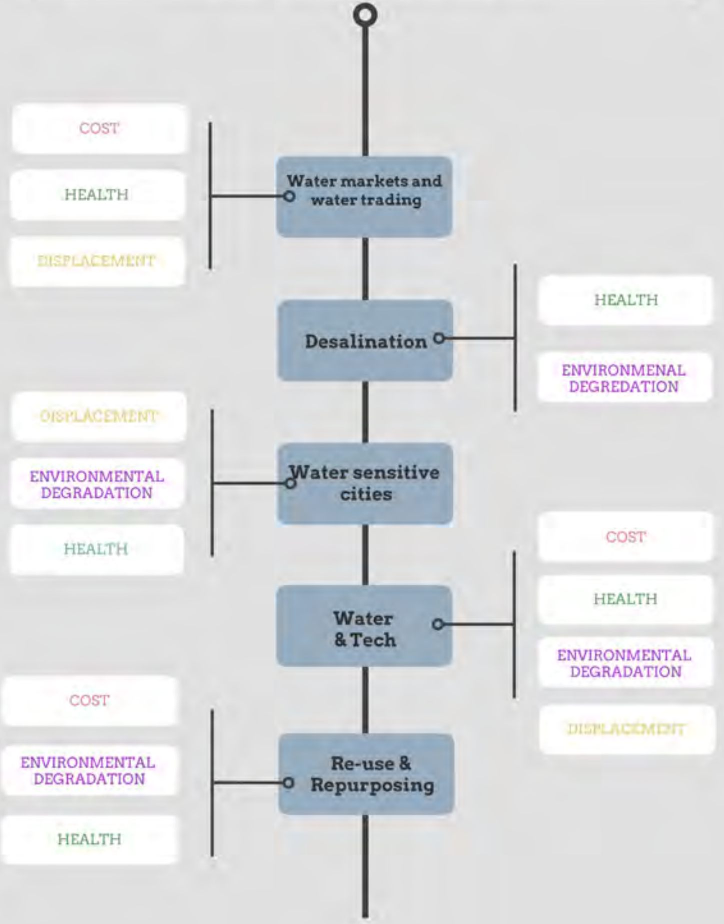
The Environmental Movement

Development sometimes collided with environmental concerns and the growing environmental movement called for legislation to project water resources. The movement and its resulting policies created a better understanding of the need to protect the health of the water cycle and water ecosystems.


Trends
Population shifts in the West
Growing populations in water stressed areas
Pressure on water resources
Water Use
Driest states are biggest users
Conservation Practices
Municipal utility consolidation
Absorption of smaller utilities
Meeting demand for high volume services
Collaborative Agreements
Replacing water conflict with water collaboration
Colorado River Cooperative Agreement
Frequency and Intensity of Extreme Events
More frequent and severe droughts
Extended wildfire season
Flood threats
Tribal Water Rights
Tribal Rights have been and continue to be ignored
Ongoing infrastructure and water needs

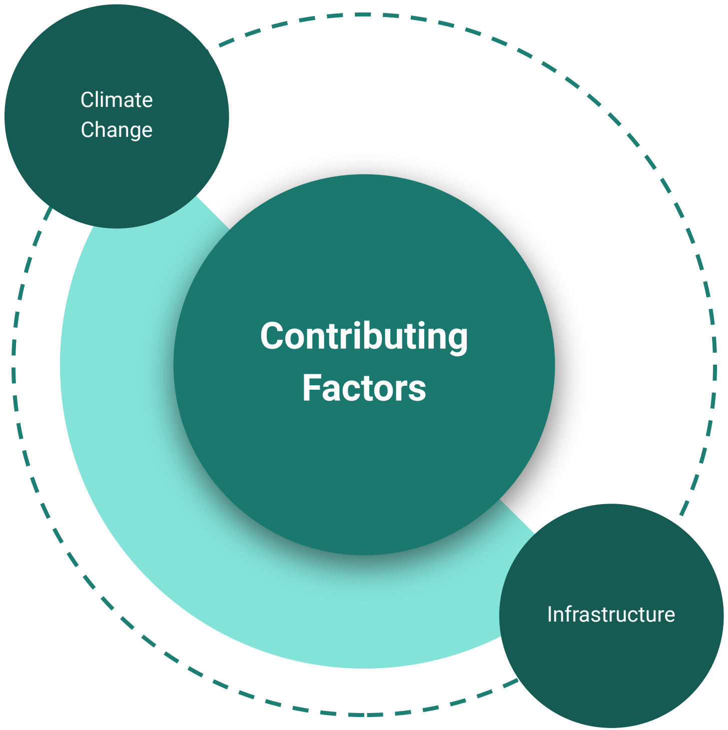

AGENTS
WATER RIGHTS SECTOR
Attorneys
Land Management
WATER UTILITIES
Denver Water
AWWA
WATER MANAGING BODIES
Bureau of Reclamation
Regional Water Boards
Transboundary River Basin Management Authorities
COMMUNITIES
Local Gov and Governing Bodies
Rural Municipalities
Cities
INNOVATORS
Entrepreneurs
Thought Leaders
Activists
CONSUMERS
Indian Tribes
Urban Centers
Rural Communities
PRIVATE COMPANIES
Nestlé Waters
Danone
INDUSTRY
Recreation
Agriculture
Energy

APPROACHES



Water markets and water trading
COST
HEALTH
DISPLACEMENT
Desalination
HEALTH
ENVIRONMENAL DEGREDATION
Water sensitive cities
DISPLACEMENT
ENVIRONMENTAL DEGRADATION
HEALTH
Water & Tech
COST
HEALTH
ENVIRONMENTAL DEGRADATION
DISPLACEMENT
Re-use & Repurposing
COST
ENVIRONMENTAL DEGRADATION
HEALTH

QUALITY & SAFETY



QUALITY & SAFETY

HISTORY

19th century

Increasing Urbanization

Increasing urbanization in the 19th century and the rising population of the working poor in condensed urban neighborhoods in part ushered in the era of sanitation.

Early 1900s

Water Treatment

Water treatment processes such as chlorination are introduced to ensure safe water and prevent disease.

Mid 1900s

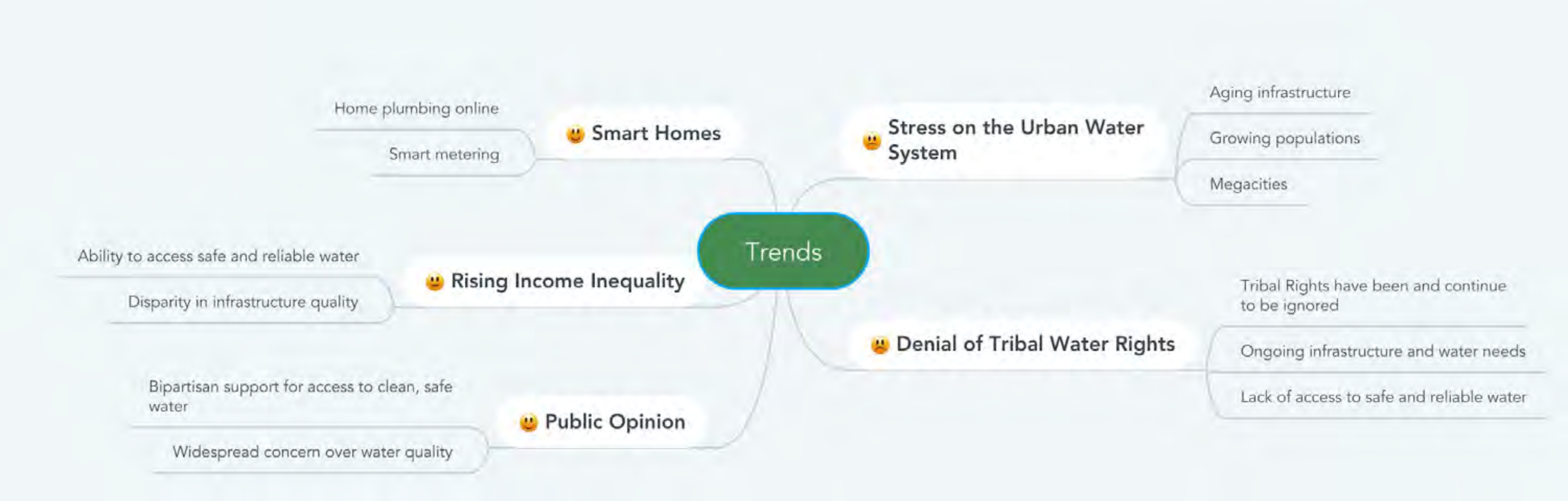
Reckoning with Waste

The Industrial Revolution supercharged the American economy. It also supercharged levels of industrial waste in lakes and rivers as factories dumped waste directly into water supply sources.

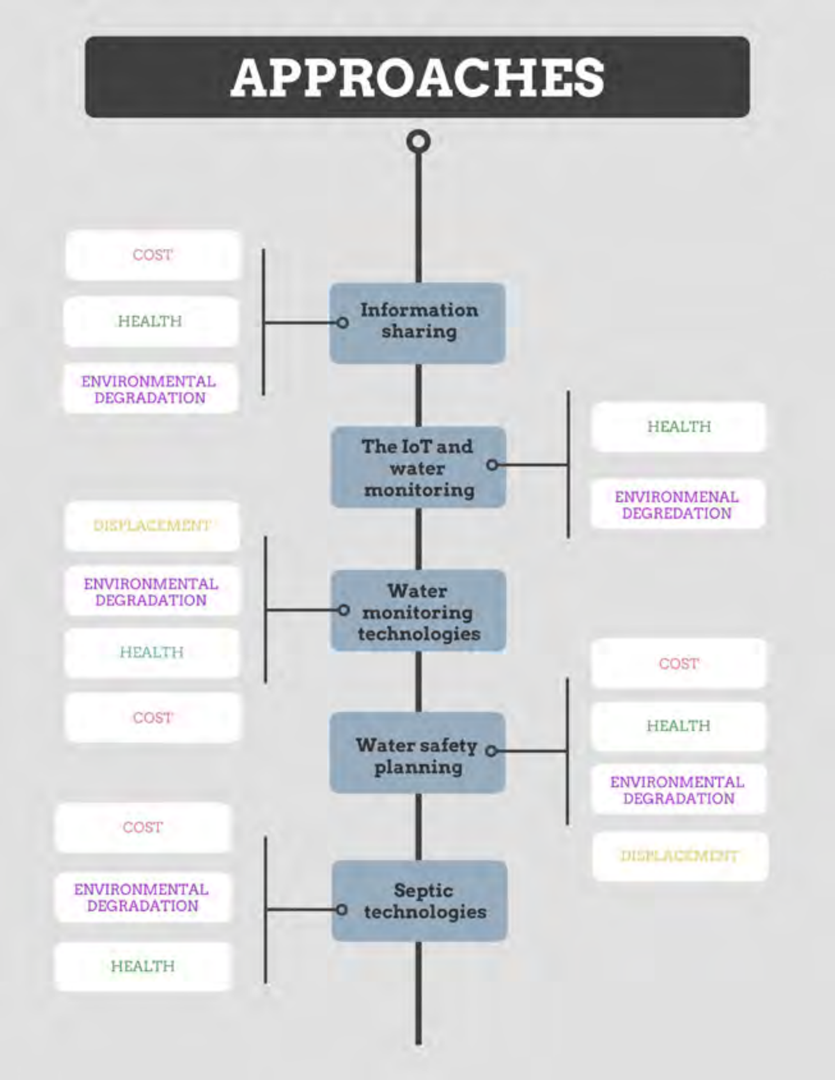
1960s and 1970s

Environmental Policy

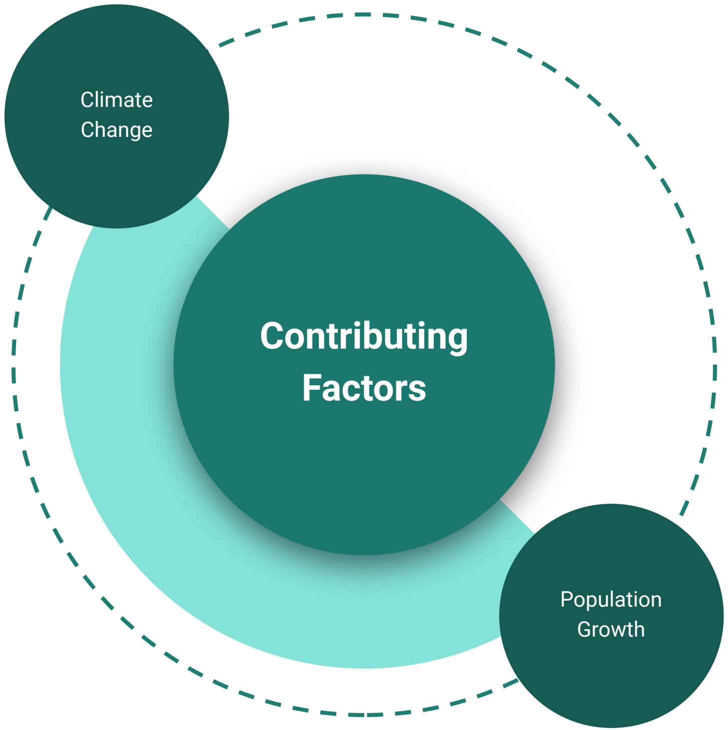
Pollution was eventually met with policy and regulation, including the formation of the EPA and the Clean Water Act.


Trends
Smart Homes
Home plumbing online
Smart metering
Rising Income Inequality
Ability to access safe and reliable water
Disparity in infrastructure quality
Public Opinion
Bipartisan support for access to clean, safe water
Widespread concern over water quality
Stress on the Urban Water System
Aging infrastructure
Growing populations
Megacities
Denial of Tribal Water Rights
Tribal Rights have been and continue to be ignored
Ongoing infrastructure and water needs
Lack of access to safe and reliable water

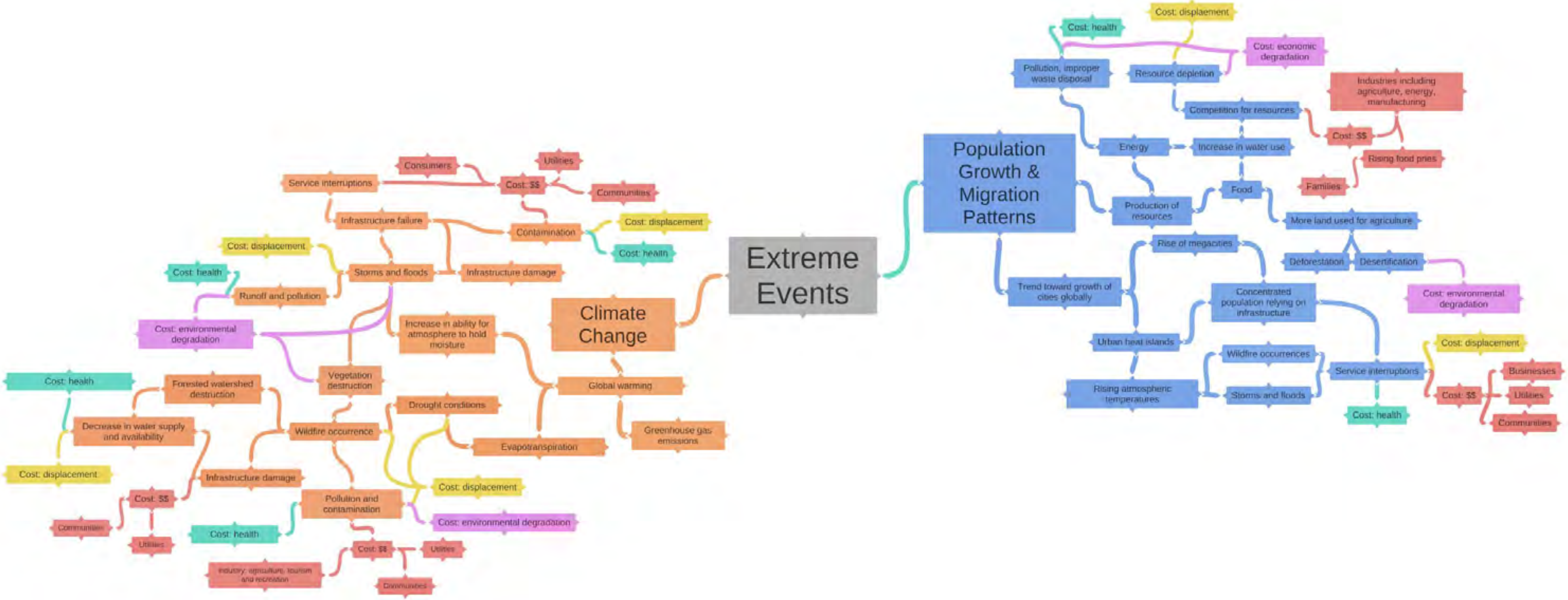

AGENTS
HOUSEHOLDS
Those with private wells and septic
Those without plumbing
WATER UTILITIES
Denver Water
AWWA
REGULATORY AGENCIES
EPA
CDC
US Fish and Wildlife Service
ENVIRONMENTAL & ADVOCAY GROUPS
Environmental Defense Fund
Colorado Water Trust
Water Education Colorado
INNOVATORS
Entrepreneurs
Thought Leaders
Activists
INDUSTRY SECTORS
Food and Beverage
Hospitality
Tourism and Recreation
PRIVATE COMPANIES
Nestlé Waters
Danone
INDUSTRY
Suncor
Thor Industries


APPROACHES
COST
HEALTH
ENVIRONMENTAL DEGRADATION
Information sharing
The IoT and water monitoring
HEALTH
ENVIRONMENAL DEGREDATION
DISPLACEMENT
ENVIRONMENTAL DEGRADATION
HEALTH
COST
Water monitoring technologies
Water safety planning
COST
HEALTH
ENVIRONMENTAL DEGRADATION
DISPLACEMENT
COST
ENVIRONMENTAL DEGRADATION
HEALTH
Septic technologies

EXTREME EVENTS



EXTREME EVENTS



HISTORY

1930s

Human Influence on Weather

The Dust Bowl of the 1930s is an example of human influence over extreme weather events. Caused in part by changes in land policy and agricultural practices.

1980s-2019

More--and more extreme--extreme events

More frequent and intense extreme events also means a rise in cost. The annual average of billion dollar events from 1980-2019 is 6.6. As of October 7, 2020, the number of billion dollar extreme events in the U.S. was 16.

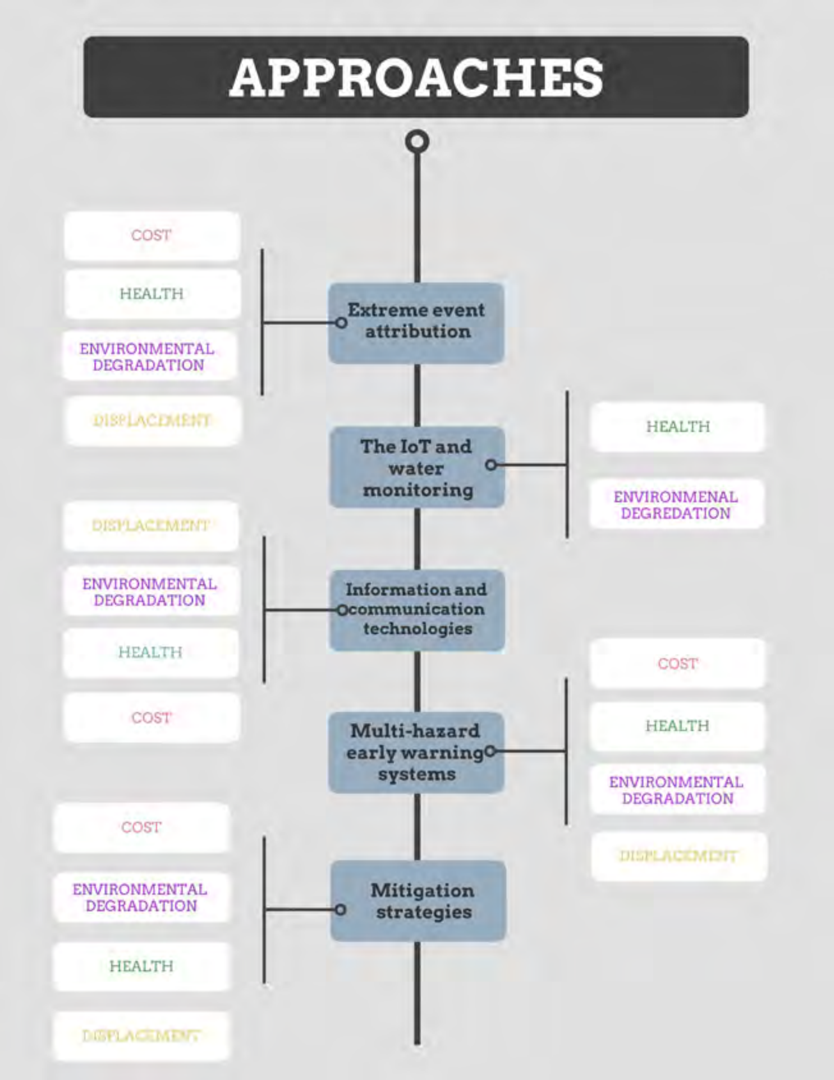
2020

Another Record-Setting Wildfire Season

In 2020, there were 52,113 wildfires that burned 8,889,297 acres in 2020, roughly 2.3 million more acres burned than the 10-year average and almost double the acreage burned in the 2019 season.

Trends
Worsening Wildfires
More frequent fires
More intense fires
Greater damage and cost
Extreme Heat
Intensity, frequency, and duration of heat waves on the rise
Urban heat islands
Contamination of water supplies
Increased demand for water
Strategic Approaches to Wildfires
Future fire mitigation
Collaborative approach
Federal oversight
Megadroughts
Prolonged and intense drought
Environmental and economic impact
Wildfire Budgeting
Changes to how funds are applied to wildfire mitigation and prevention
Establishment of reserve fund


AGENTS
ELECTED OFFICIALS
Local and state level
National level
WATER UTILITIES
Denver Water
AWWA
INDUSTRY
Recreation
Agriculture
Energy
COMMUNITIES
Individual Households and Local Neighborhoods
Rural Municipalities
Cities
GOVERNMENT AGENCIES
FEMA
EPA
Federal natural resource agencies
INNOVATORS
Entrepreneurs
Thought Leaders
Activists


APPROACHES
COST
HEALTH
ENVIRONMENTAL DEGRADATION
DISPLACEMENT
Extreme event attribution
The IoT and water monitoring
HEALTH
ENVIRONMENAL DEGREDATION
DISPLACEMENT
ENVIRONMENTAL DEGRADATION
HEALTH
COST
Information and communication technologies
COST
HEALTH
ENVIRONMENTAL DEGRADATION
DISPLACEMENT
Multi-hazard early warning systems
COST
ENVIRONMENTAL DEGRADATION
HEALTH
DISPLACEMENT
Mitigation strategies

Extreme Climate Events

Credit: David McNew *Getty Images*

Climate change is fueling the rising intensity and frequency of extreme weather and climate events such as drought, floods, wildfires, heat waves, extreme cold, and hurricanes. Attribution research names climate change a “threat multiplier” of extreme events and indicates human-caused climate change has played a role in the likely occurrence or severity of over 75% of extreme events in the past 20 years. Each year, these extreme events displace 20 million people globally as homes, and in some cases, entire communities are destroyed or made uninhabitable. The year 2019 broke records with 23.9 million people displaced due to weather-related disasters. The economic cost of extreme events is also staggering. In the U.S.,the federal government has spent an estimated $30 billion per year in the last 14 years on weather disaster assistance. Additional costs are borne by homeowners, farmers, ranchers, businesses, and local government. Both regionally and globally, women, children, and the poor are the populations most affected by extreme climate events resulting in compounded crises as extreme events exacerbate existing social inequities relating to health and safety, access to resources, and personal autonomy. Extreme climate events are wicked problems not only in the magnitude of their potential ramifications but in the difficulty to predict future events, particularly considering the uncertainty of climate change and the variability of regional landscapes, responses, and levels of preparedness.

Focusing Question: How might we reduce the harm and disruption caused by extreme events?

Contributing Factors	
Climate change (GGE, global warming, anthropogenic CO2 emissions) Population growth (rise in megacities, migration and climate refugees) Pre-existing water vulnerabilities (infrastructure, supply, quality, sanitation and hygiene) Land use and soil health	
History & Trends	
History Human influence on weather More--and more extreme--events	Trends Worsening wildfires Strategic approaches to wildfires Wildfire budgeting Extreme heat Intense drought More hurricanes
Populations & Agents	
Populations Vulnerable populations	Agents Water utilities Elected officials Communities/users Government agencies Industry sectors
Existing Approaches & Workarounds	
Approaches Disaster risk reduction Mitigation strategies Multi-hazard early warning systems	Workarounds Urban development and structural measures Reducing emissions Substitutions for oil

Information and communication technologies Extreme event attribution	Human response to risk

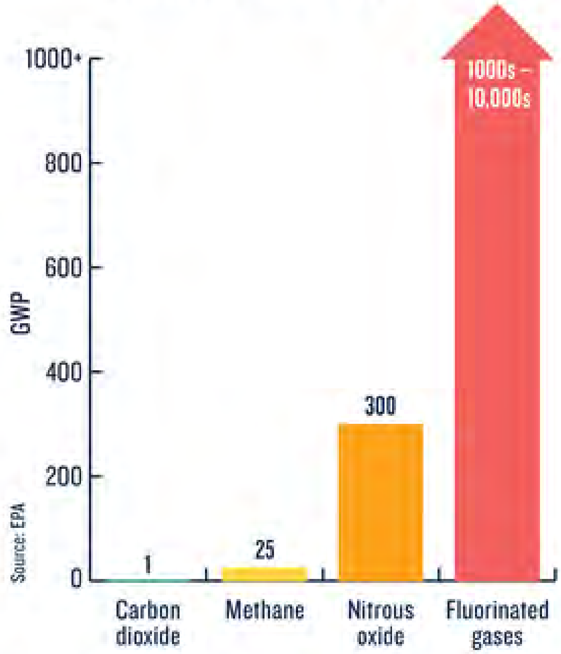
Contributing Factors

Climate change. Extreme event attribution is a field of study noting the connections between human activity, climate change, and extreme weather.

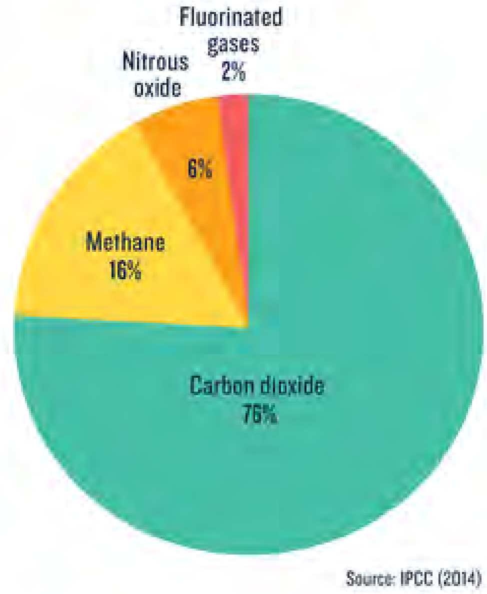
→ In particular, **global warming,** due to an increase in the amount of greenhouse gases released into the atmosphere, specifically carbon dioxide, contributes to extreme weather (see Figure ___). Greenhouse gases trap heat in the atmosphere, creating a warming effect across the globe (see Figure __). And a warming atmosphere produces more volatile weather. Higher temperatures lead to evapotranspiration, the process by which water evaporates from the soil and transpirates plant matter, facilitating drought and dry conditions suitable for wildfires. In other parts of the U.S. and the globe, rising temperatures increase the air's ability to hold moisture, creating rain and storm events such as hurricanes and floods. In sum, climate change enhances the frequency and severity of extreme weather events. It also means dry areas become drier and wet areas become wetter, with implications for water use as well as overall safety and economic security.

An important note is the distinction between climate and weather. While weather refers to what we may experience in terms of temperature and precipitation day to day, climate is a more long term view of weather patterns over decades. The difference between climate and weather helps explain differing views on the February 2021 extreme cold event and snowstorm in Texas. In general, however, an increased frequency of any extreme events, be they droughts or snowstorms, is a sign of a transitioning climate.

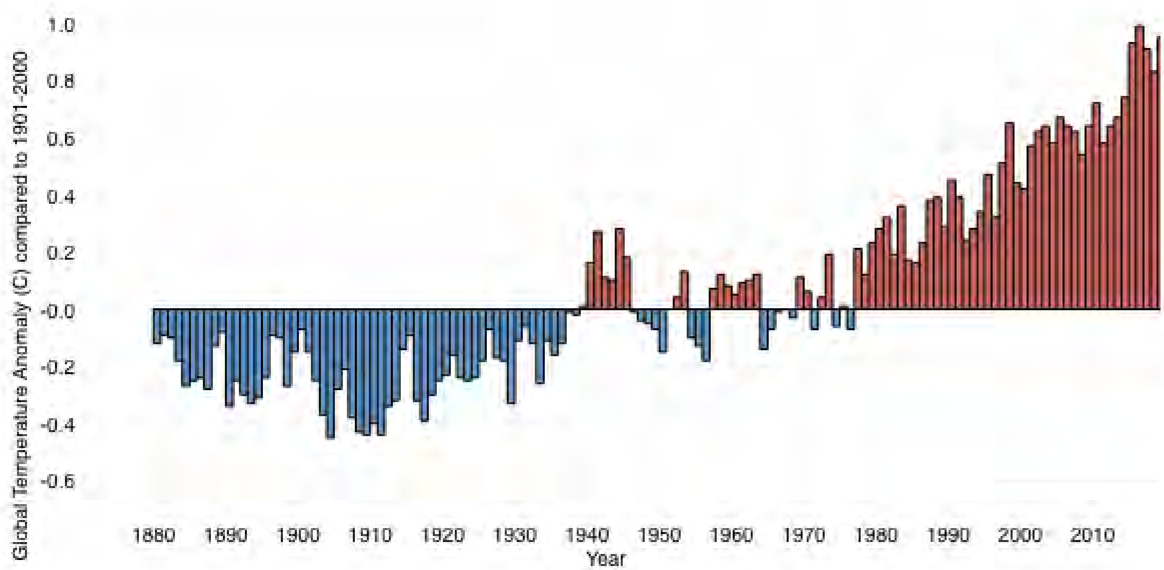
HOW GREENHOUSE GASES WARM OUR PLANET



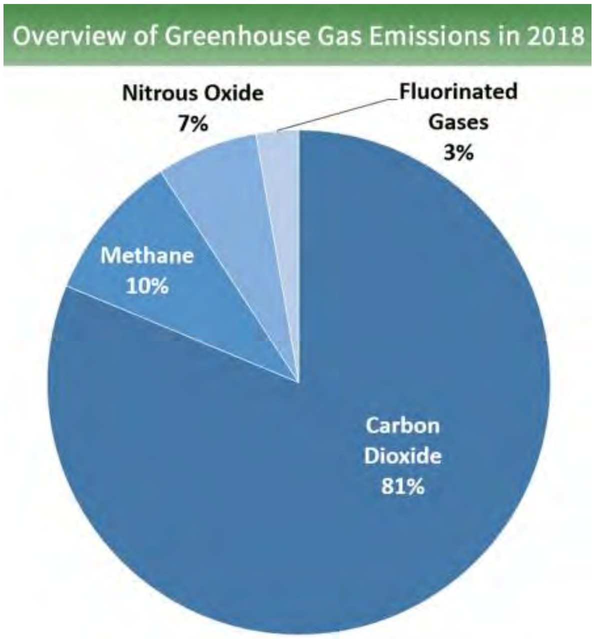
The global warming potential (GWP) of human-generated greenhouse gases is a measure of how much heat each gas traps in the atmosphere, relative to carbon dioxide.



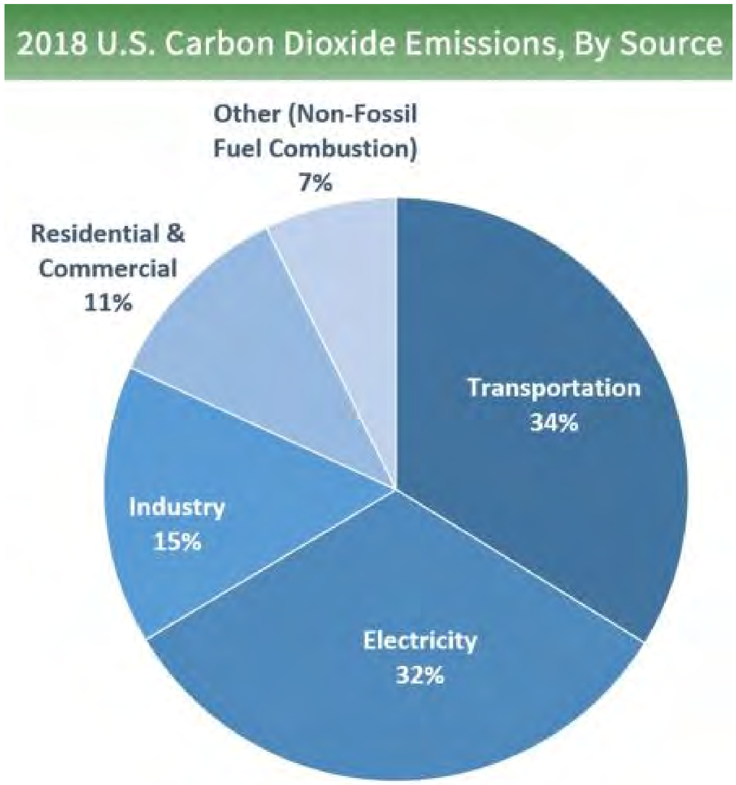
How much each human-caused greenhouse gas contributes to total emissions around the globe.



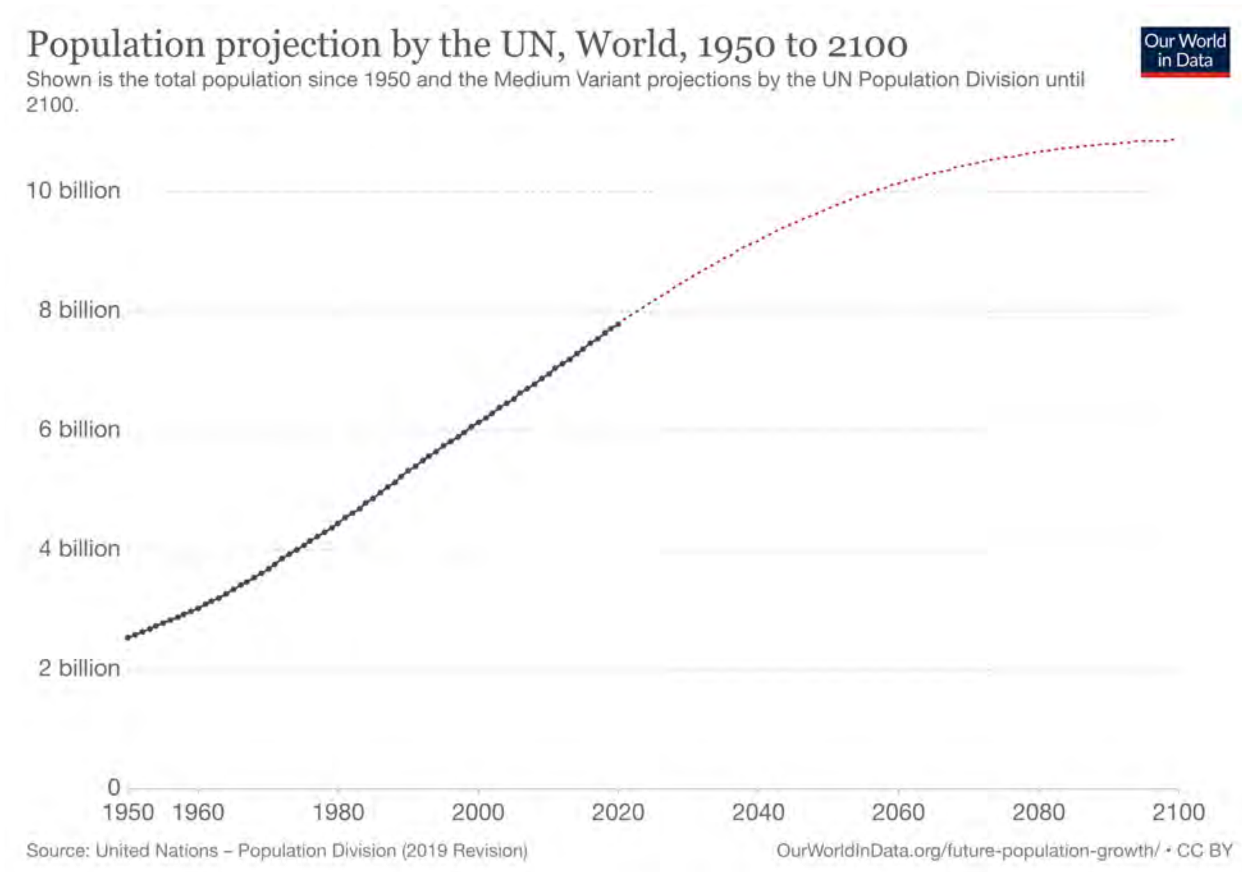
→ **Anthropogenic carbon dioxide (CO_2) emissions** increase the greenhouse gas in the atmosphere and drive global warming. Those emissions primarily stem from the combustion of fossil fuels for heat, energy, electricity, and transportation. Figures __ and __ below illustrate greenhouse gas emissions by type of gas and related industry. For more information on the topic of U.S. CO2 emissions, see page ES-4 to ES-15 of the executive summary to the expansive Inventory of U.S. Greenhouse Gas Emissions and Sinks (1990-2018).



Caption: Total U.S. GHG emissions in 2018 = 6,677 Million Metric Tons of CO2 equivalent. Percentages may not add up to 100% due to independent rounding.

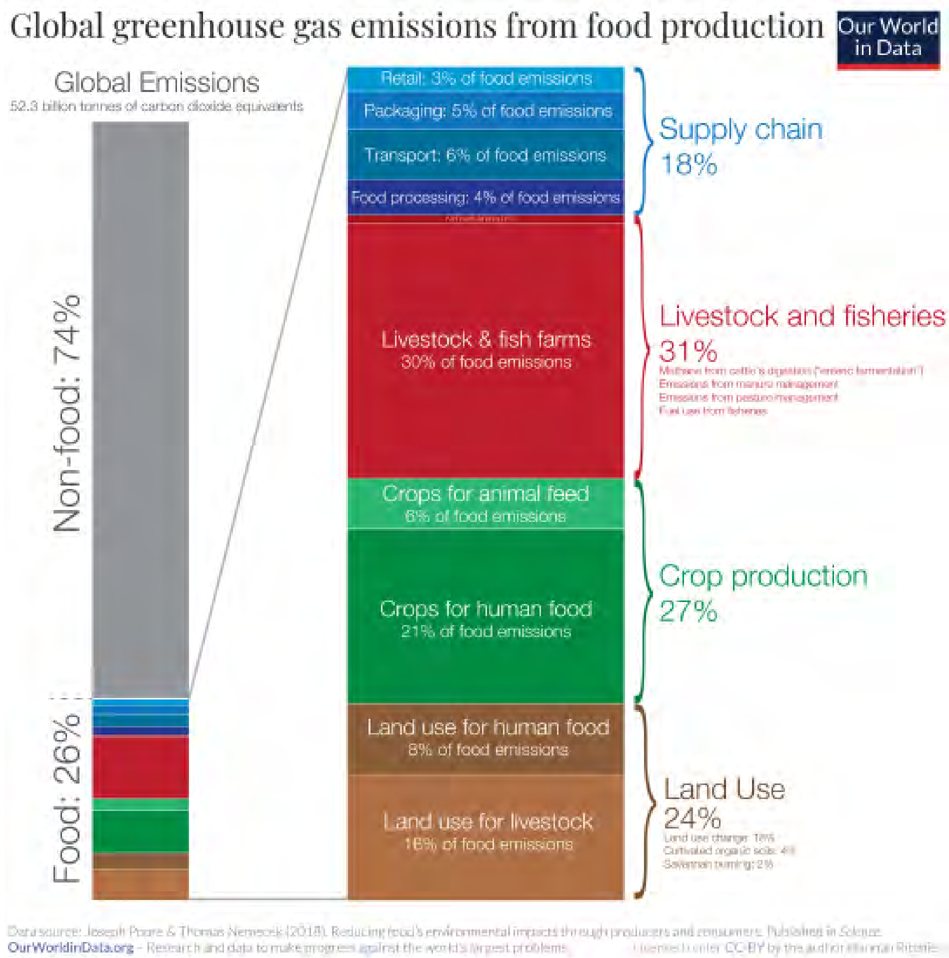


Population growth. The current global population is 7.79 billion--a product of exponential growth over the past decades and one expected to continue in the decades to follow until we reach a “leveling off” around the year 2100 as the population nears the 10 billion mark (see Figure ___). One way to think about the rise in population and the corresponding draw on earth’s resources is Earth Overshoot Day. This is the day in a calendar year wherein the human population’s demand on the planet’s resources exceeds what the earth can regenerate in a year. In 2020, Earth Overshoot Day fell on August 22, meaning in only 234 days, humans had used up the earth’s resources for the year.



[EOD video]

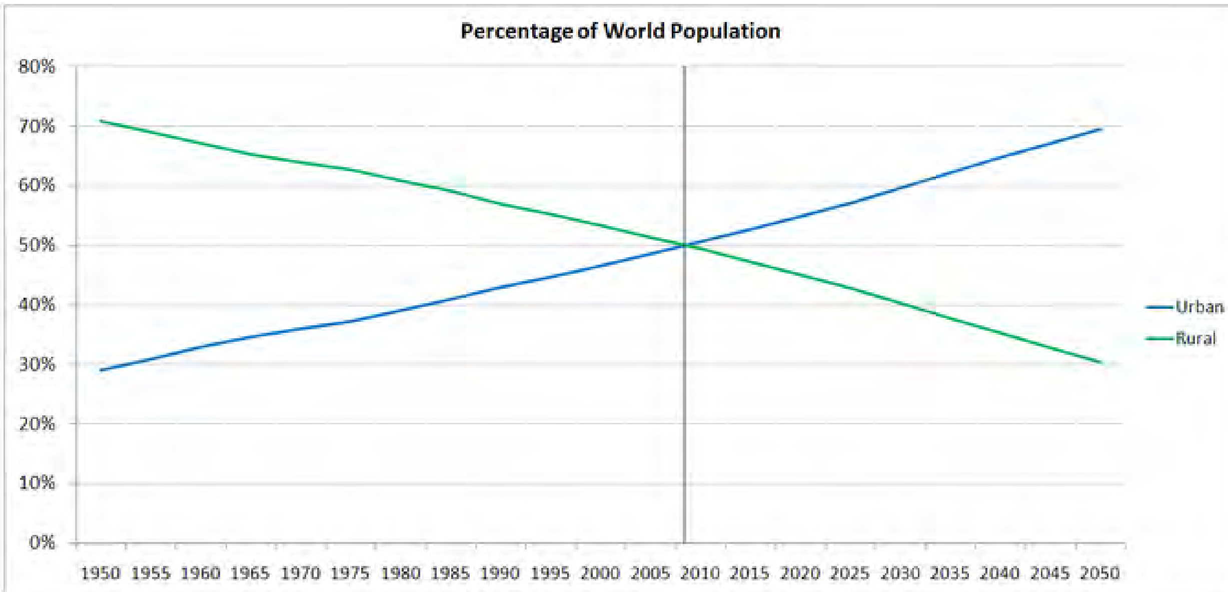
Growth in the global population creates strain on the planet. Such strain is felt primarily in two areas, each in turn accelerating climate change: one is the production of resources such as energy and food (see Figure __ for more information on the components of food production creating GGH emissions) and the second is the concentration of population in specific geographic areas like megacities. While these trends contribute to climate change, they also exacerbate vulnerability to extreme climate events.



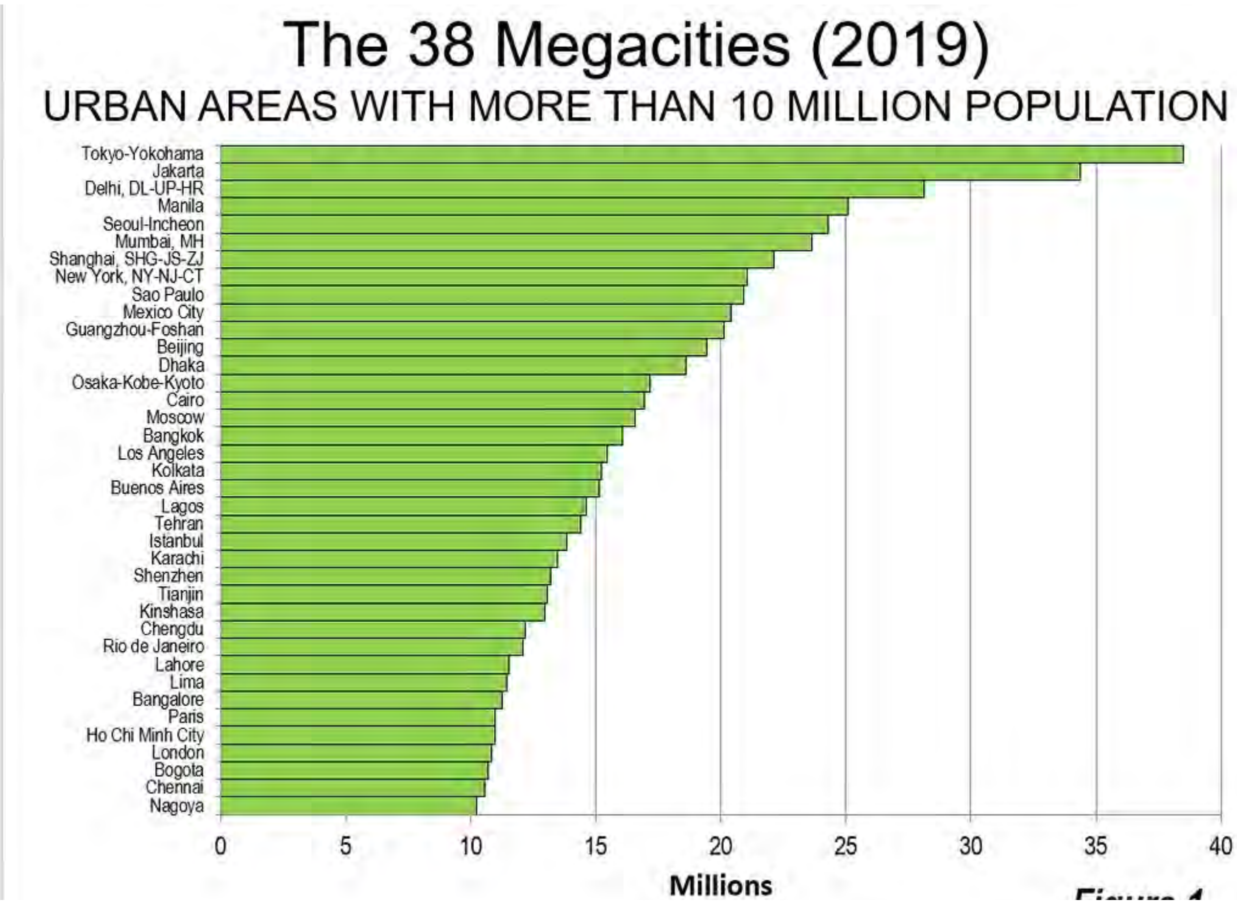
→ **Increased food production.** From 1961 to 1970, land use for food production (cereal crops) increased by 240%. The increase in production not only contributes to GGE; the change in land use for agricultural purposes also leads to degradation and desertification (see Land and Water Use section below).

→ **The rise and shift of megacities.** As more of the earth's population becomes concentrated in urban areas (see Figure __) and megacities, those cities become increasingly vulnerable to adverse effects on water systems and sources due to extreme events. Megacities are urban areas wherein the population exceeds 10 million (see Figure __ for a list of the 38 megacities in the year 2019). Increasingly, the earth's population concentrated in megacities will be outside the high-income world. Predictions indicate the urban area of New York (including New Jersey and Connecticut), for example, will fall off the list of largest urban areas--those with populations above 10 million--in the coming decade as other cities, particularly those in Asia and Africa, grow at faster rates. For in-depth information related to trends in demography in urban areas, see the Demographia World Urban Areas report from 2020.

The growth in urban population is also relevant to the western United States. According to [2020 U.S. Census Bureau data], the western U.S. experienced rapid population growth since 2010. Denver, Los Angeles, San Diego, Seattle, and Phoenix are five of the fifteen fastest growing cities in U.S. in the past decade.



Data Source: United Nations, http://esa.un.org/unup/p2k0data.asp



→ **Vulnerability to system disruption.** Megacities, particularly those in the low-income world, are vulnerable to disruptions in services providing necessary resources such as water, food, and power. A single extreme event such as a hurricane or severe drought has the potential to create a wide breakdown in a city's infrastructure. Yet such an event is difficult to plan for and predict. Researchers note baseline information for predicting and preparing for droughts is grounded in historical data and trends largely insufficient in the face of climate change. And while water utilities recognize the need to make shifts in water policies and practices, representatives from these facilities also acknowledge the need for better response and intervention mechanisms to address drought, floods, wildfires, and other extreme events.

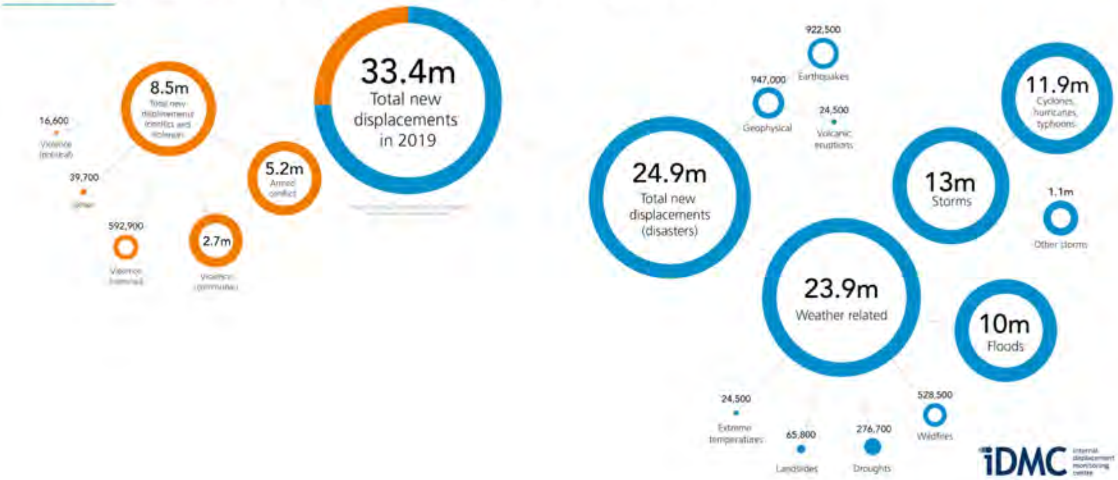
Water supplies are particularly vulnerable. In coastal areas, rising sea levels and storm surges contaminate fresh water supply sources. Flooded areas face challenges related to water quality and safety as sanitation systems are overrun. Heat waves and droughts create demand on power and water systems, increase the level of pollutants in the air and water, and enhance the likelihood of wildfires which in turn affect water and air quality. For a deep dive into the relationship between climate change, weather, air quality, and water quality, see the 2013 research publication on the state of knowledge in the field. For more information on how water and wastewater utilities prepare for extreme heat, see the EPA's Incident Action Checklist.

On the other hand, water also serves as an adaptation resource in some areas. For example, cities continue to explore how water may be deployed to help residents cope with extreme heat.

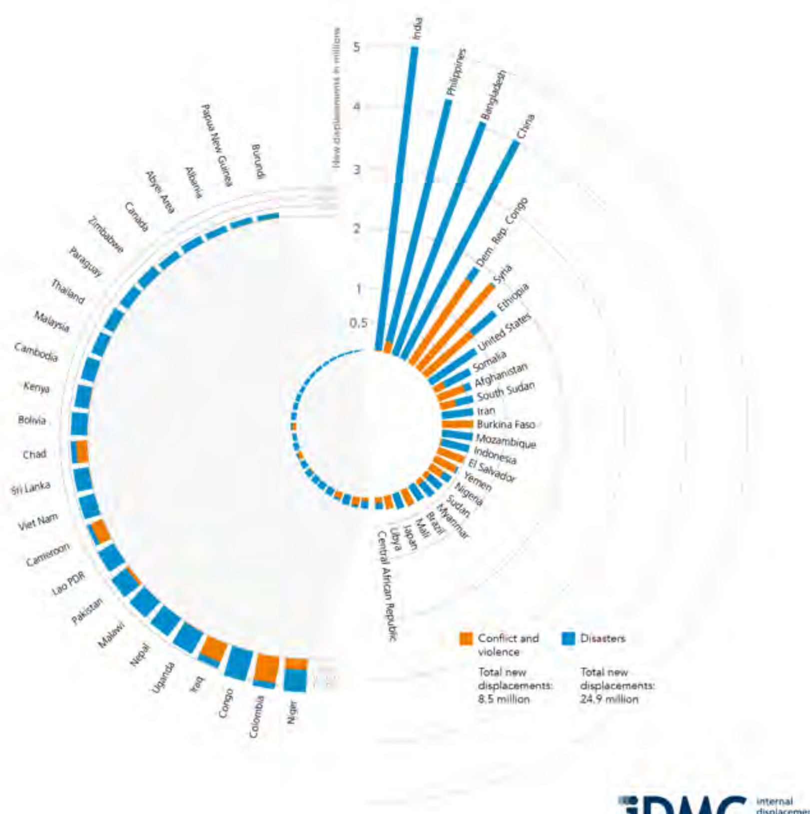
→ **Migration and climate refugees**. Breakdowns in infrastructure caused by extreme climate events will lead to migration of populations seeking refuge from the aftermath of an extreme climate event. Disruption in services and resources are experienced most acutely by vulnerable populations such as older adults, children, women, and those living in poverty. In turn, those populations are susceptible to the most harm from migration. Additional factors such as COVID-19 and the inevitable continued appearance of global pandemics further complicate migration and vulnerability.

In 2018, the UN General Assembly adopted the Global Compact on Refugees, in part acknowledging the increasingly significant role climate change--experienced through extreme events--would play in driving refugee movements. According to the Internal Displacement Monitoring Center's 2020 report on population displacement within nations, new displacements in 2019 numbered 33.4 billion: 8.5 million of those displacements were the result of conflict and violence while 23.9 were the result of weather-related disasters (see Figures ___ and ___ for a breakdown of those displacements by disaster event and nation).

New displacements in 2019: breakdown for conflict and disasters



50 countries and territories with most new displacements in 2019



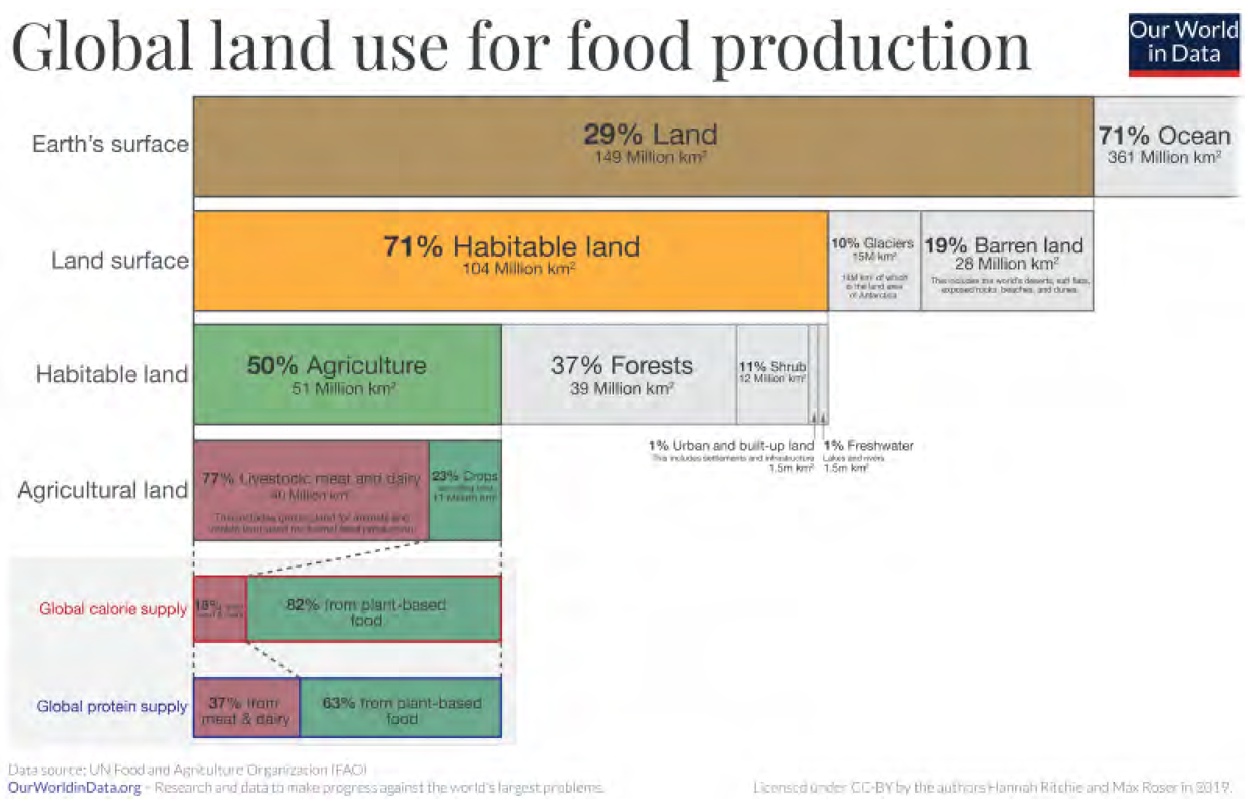
The U.S. recorded over 916,000 disaster-related internal displacements in 2019. A majority of those were the result of floods and wildfires. Wildfires triggered more than 423,000 displacements in 2019; 400,000 of those in the state of California. This year saw the two largest Colorado wildfires on record and burned roughly 700 square miles at a cost of over $215 million.

For more information on what has been called The Great Climate Migration, including images of those displaced, see *New York Magazine*'s 2020 special issue.

Climate refugees in California after the Camp Fire tore through Paradise and left tens of thousands homeless. Photo credit: GABRIELLE LURIE / SAN FRANCISCO CHRONICLE / POLARIS / PHOTONEWS VIA GETTY IMAGES

Land use practices and soil health. The health of our soil is integral to the health of our water. Soil is a natural filtration system for water. It acts as a sponge to prevent runoff and maintain moisture. And when soil suffers, water does, too.

Half of the habitable land on the planet is used for agriculture (see Figure __). As mentioned earlier, shifts in land use to meet food production demands often lead to land degradation and desertification, processes that in turn contribute to the negative effects of extreme events. Rainfall in degraded areas--although often badly needed--is not absorbed into the ground due to packed soil and lack of vegetation. These areas then become primed for floods due to precipitation runoff. Lack of water or poor water quality resulting from degradation and desertification contribute to a myriad of health risks including malnutrition and the spread of water- and airborne diseases. Responsible agricultural practices help ensure the soil and land--as well as the water used to cultivate the land--remains healthy and therefore more resistant to extreme events. Those practices include regenerative farming, greenhouse or vertical farming, terracing, and strip cropping. For an in-depth look at healthy soil and agricultural practices in the U.S., see the 60 minute documentary *Living Soil* below.



[Living Soil video]

History & Trends

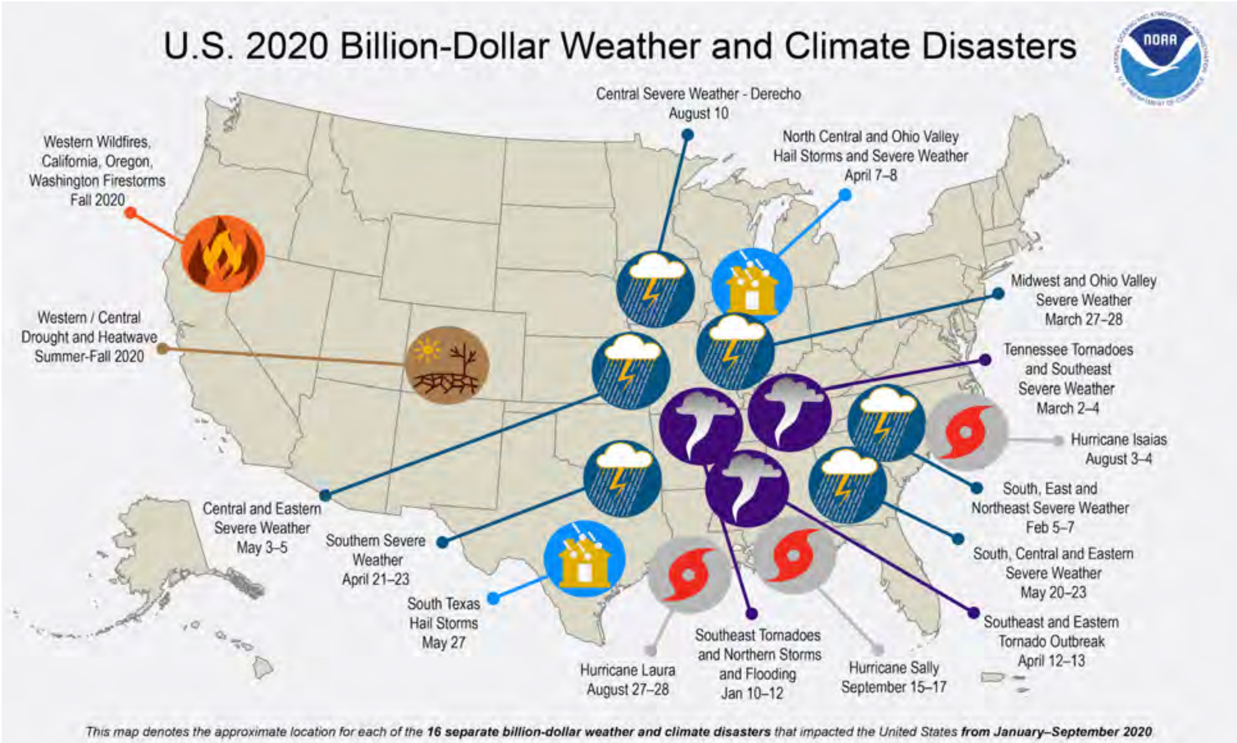
History

Human influence on weather. Weather is nothing new. Even the extreme variety has a long and storied history of influence over human activities. What is relatively new is the ability for human activity to influence weather. The 1930s Dust Bowl drastically changed agriculture and living conditions across the Great Plains and made a significant impact on the U.S. economy.

However, the Dust Bowl was also caused in part by changes in land policy, agricultural practices, and cultural philosophies. Also new is the intensity, frequency, and magnitude of extreme weather events as a result of climate change. Over the past 4 decades, extreme weather events occur more frequently. The global instances of floods, for examples, have quadrupled since 1980.

Farm machinery buried by a duststorm in South Dakota, May 1938. Credit: United States Department of Agriculture via Wikimedia Commons

More--and more intense--extreme events. More extreme events with greater intensity and reach facilitate another historical shift: a rise in cost. The annual average of billion dollar events from 1980-2019 is 6.6. As of October 7, 2020, the number of billion dollar extreme events in the U.S. was 16 (see Figure ___). By every indication, these costs will continue to rise in correlation with frequency. For more information on the rising cost of extreme events, see the 2017 report from the Center for American Progress Extreme Weather, Extreme Costs.



Trends

Worsening wildfires. Bigger fires. And more of them. That's the global trend over the past decade. In the U.S., California has become "ground zero for meteorological turmoil" in part stemming from dry conditions, high winds, and hot temperatures. After California, Texas and Colorado are the states most threatened by wildfire risks (see Table ___).

Top 10 States At High To Extreme Wildfire Risk, 2019 (1)

Rank	State	Estimated number of properties at risk	Rank	State	Percent of properties at risk
1	California	2,019,800	1	Montana	29%
2	Texas	717,800	2	Idaho	26
3	Colorado	371,100	3	Colorado	17
4	Arizona	237,900	4	California	15
5	Idaho	175,000	5	New Mexico	15
6	Washington	160,500	6	Utah	14
7	Oklahoma	153,400	7	Wyoming	14
8	Oregon	151,400	8	Oklahoma	9
9	Montana	137,800	9	Oregon	9
10	Utah	136,000	10	Arizona	8

(1) As of September 2019.

Source: Verisk Wildfire Risk Analytics used data from FireLine®, Verisk's wildfire risk management tool.

More wildfires mean significant deterioration to water supplies and quality. Most of the drinking water in the U.S.--roughly 80%--originates from forested watersheds and wildfires threaten the safety this of source. In communities devastated by fire, water supplies often contain high levels of contaminants such as benzene, naphthalene, and styrene, all associated with cancer. Treating water after wildfires--removing debris like ash, as well contaminants, and sediment--is costly. Adding to the cost is the likelihood of flood following wildfires. Denver Water estimates it spent over $26 million to repair infrastructure and remove sediment from the flash floods following wildfires in 1996 and 2002. For more information on the interaction between wildfires and water quality, see Denver Water's site "From Forests to Faucets."

Strategic approaches to wildfires. In 2014, the Wildland Fire Leadership Council (an entity jointly established in 2002 by the U.S. Secretaries of the Interior and Agriculture) adopted a strategic approach to mitigating future wildfires. The approach, titled a *National Cohesive Wildland Fire Management Strategy* and often referred to as the "Cohesive Strategy" highlights three key areas (see also Figure __):

1. Restore and Maintain Landscapes
2. Fire Adapted Communities
3. Response to Fire

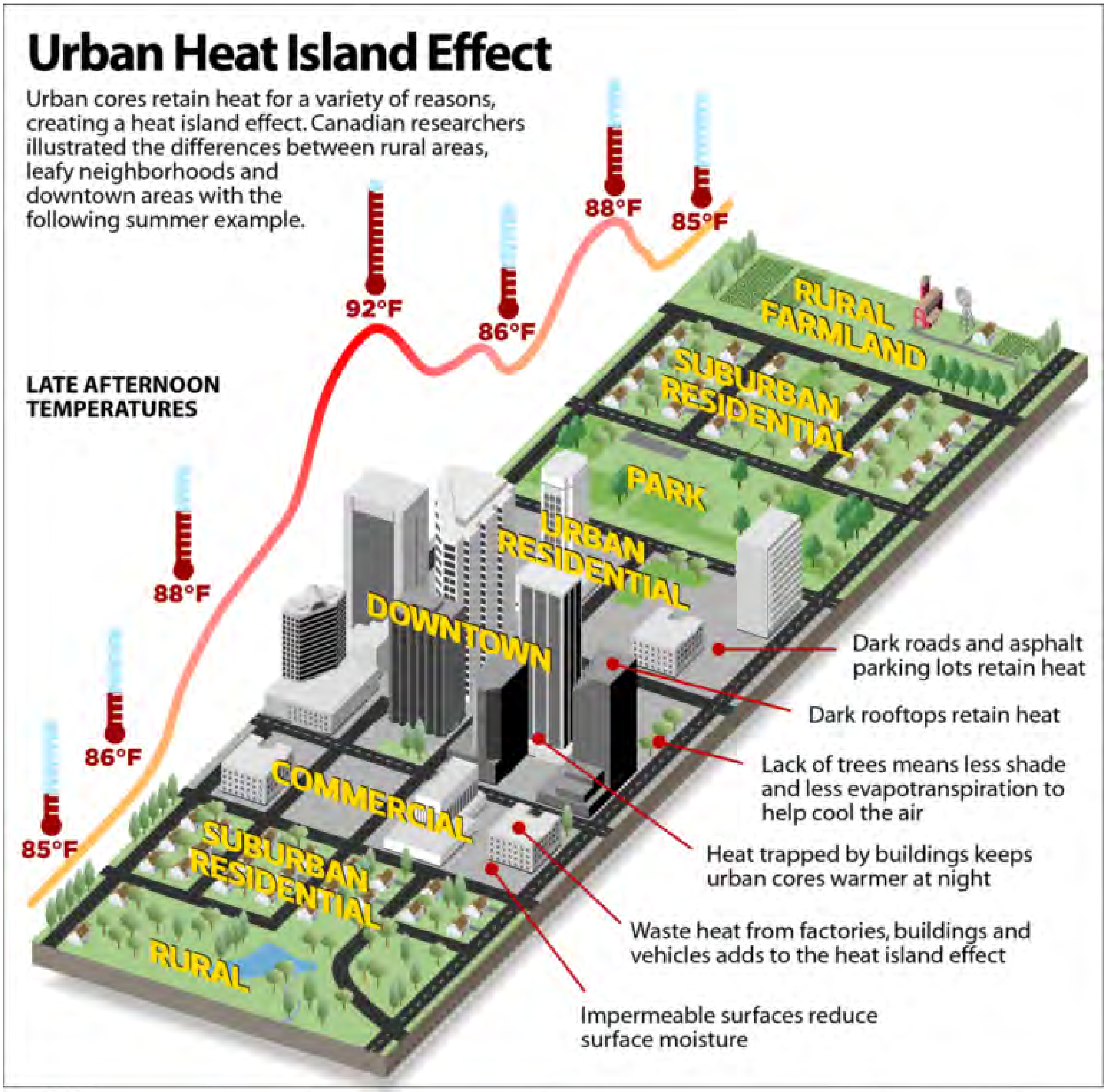
The Cohesive Strategy continues to set the tone for current approaches to wildfire management and mitigation.

Wildfire budgeting. In 2018, in response to the year's massive and deadly wildfires, including the fire in Paradise, CA, Congress passed a funding package that included changes to how funds are allocated for and applied to wildfires. The "fire funding fix" began in fiscal year 2020 and continues through 2027; it approaches wildfires like other natural disasters and appropriates funds for suppression and establishes a reserve fund for deployment during extreme wildfire seasons.


A melted high density polyethylene water pipe burned in a 2020 fire in the San Lorenzo Valley, CA. Credit: James Furtado/San Lorenzo Valley Water District

Extreme heat. It's getting hot in here. And then hotter on top of that. Extreme heat is measured by intensity, frequency, and duration and all three factors have been on the rise in past decades due to climate change. Researchers predict higher temperatures and more extreme heat in every region in the U.S. by the year 2100. By that time, current high temperatures could increase by 10 degrees. Health effects of heat waves include heat stroke, respiratory illness, and cardiovascular illness.

Extreme heat is detrimental to agriculture--both crops and livestock--hobbles the energy infrastructure, and threatens the daily life of residents in cities. Major U.S. metropolitan areas like Atlanta and New York are expected to see the largest rates of human exposure to extreme heat in the coming decades. City planning and layout create "heat islands" wherein temperatures are significantly warmer within the city region than the surrounding rural areas, mostly as a result of human activity and human construction (see Figure ___).



SOURCE: D.S. Lemmen and F.J. Warren, Climate Change Impacts and Adaptation   PAUL HORN / InsideClimate News

Water is a resource in extreme heat. Drinking plenty of water tops the list of health recommendations during heat waves and water can be used to cool bridges and other structures susceptible to heat failure. This in turn, affects supply levels in cities and areas wherein water resources are needed to safeguard against fire danger.

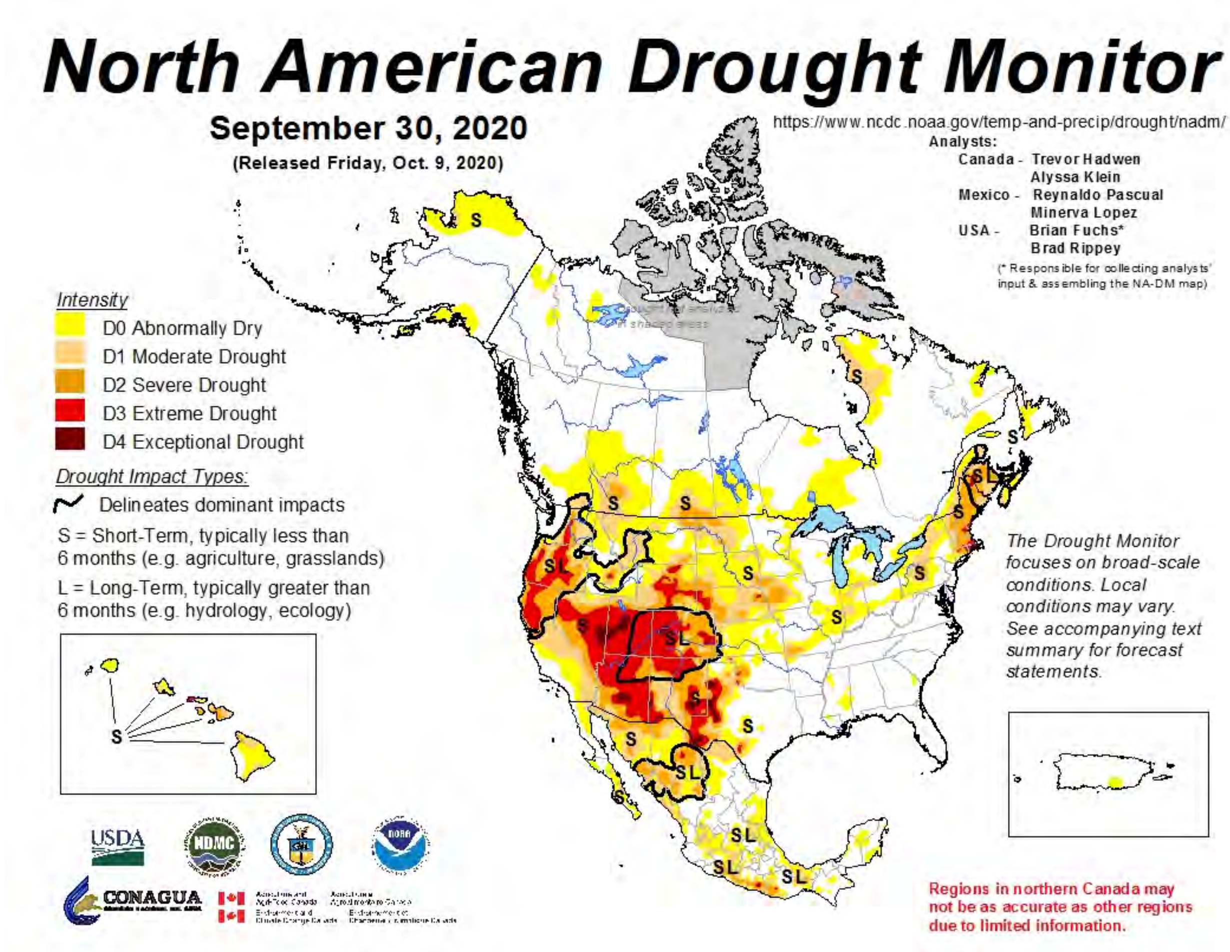
Water quality is also vulnerable in extreme heat conditions. Rising water temperatures in freshwater systems harm fish and other aquatic life with negative effects for the $4.61 billion recreational fishing industry. Warmer water means ripe conditions for algae blooms which not only harm fish but create toxic water conditions, making freshwater unsafe for recreational use and consumption. For more information on the effect of climate change on fishing and aquaculture, see the comprehensive report from the Food and Agricultural Organization of the United States. Ohio experienced an algal bloom-caused water quality emergency in 2014. High temperatures combined with agricultural runoff allowed a harmful algae bloom (HAB) to flourish in Lake Erie and eventually overwhelm the water supply intake serving over 500,000 people in and around the city of Toledo. The city issued a “do not boil/do not drink” mandate, the governor declared a state of emergency, and the National Guard arrived to help distribute water to residents. Six years later, the city is still grappling with the aftermath of its water emergency as it works to rebuild small businesses and community trust.

Algal bloom in Lake Erie’s western basin. Photo: © John Delmotte

Heat waves aren’t just for land anymore, or freshwater. Rising marine water temperatures, dubbed “marine heat waves” are on the rise. Recent years have seen two substantial marine heat waves off the United States’ west coast: one known affectionately as “The Blob” persisted and grew from 2014-2016. The more recent was noted in 2019. Marine heat waves have dire consequences for fisheries and aquaculture as well as the overall marine ecosystem.

As temperatures rise, moisture evaporates from soil and vegetation, contributing to drought conditions.

Intense drought. Feeling parched may be the new norm for many parts of the world as droughts persist and intensify. In some places of the United States, the term drought doesn’t cut it anymore. Only “megadrought” will do. According to research, the western U.S. is in the midst of a megadrought the likes of which haven’t been seen in the last 1,200 years (see Figure ___).



The rising temperatures of climate change have contributed to the duration of the drought as well as its acceleration. Drought is, of course, tied directly to water, or a lack thereof. Drought occurs when a period of low rainfall leads to a shortage of water. The environmental results include lower flows in rivers, dry out along river edges resulting in the death of plant and animal life, reduced fish migration, algae blooms, and a reduction in the health of wetlands, agricultural areas, and natural vegetation. And don’t forget wildfires.

While a lack of water causes drought, drought has numerous effects on water quality and quantity. Less water means less opportunity for pollutants to become diluted in water. Contaminants become more concentrated and harmful. Ground water sources decrease and grow more salinated. Supply deteriorates, threatening roughly 40% of the world’s population with water scarcity. As many as 700 million people are at risk of displacement as a result of drought and water scarcity across the globe by the year 2030. The escalating realites of drought are not lost on water utilities. For more information on how water utilities address drought, see the Environmental Protection Agency’s guide to drought response and recovery.

More hurricanes. Forays into the Greek Alphabet--necessary for naming hurricanes after the Latin alphabet has been exhausted in a hurricane season--may be the new norm. The 2020 hurricane season was the busiest on record and by many indications, climate changes contributes to this uptick. Climate change not only ups the frequency of hurricanes, but makes hurricanes more dangerous as well.

Populations & Agents

Vulnerable Populations

While all populations are vulnerable to extreme events and climate change there are varying degrees of vulnerability due to demographics and socioeconomic factors. The factors contributing to vulnerability include:

- Poverty
- People under the age of 5
- People over the age of 65
- Renters (those who are not homeowners)
- Language proficiency
- Vulnerable households (older adults living alone, single mothers, households without a car)
- Educational attainment
- Vulnerable people (those living with disabilities, those without health insurance)

Neighborhoods at Risk provides census-tract based maps of vulnerable populations in line with the above measures. For information on each of the measures or to explore vulnerability in a particular area, see their interactive website.

Agents

Category	**What they do**	**Examples**
Water Utilities	Safe and timely distribution of water and other related services, such as wastewater treatment. Water utilities are generally local but may operate across states. Create and follow (or in some cases, neglect) disaster avoidances plans related to extreme events.	Denver Water American Water Works Association XYLEM Eversource Energy

Elected Officials	Determine energy and water policy at a local level; this policy connects to water issues in the wake of extreme events, as was the case in Texas' energy deregulation	State Water Policy handbook for state of Colorado See the Western State Water Policy database for specific policies
Communities/Users	End users grappling with disruption in water services and water quality and safety issues as a result of extreme events. May face displacement.	Households Businesses Neighborhoods
Government Agencies	Regulate resources, monitor environmental protections, and respond to disasters	FEMA, EPA, Federal natural resource agencies
Industry Sectors	Use water on a larger scale and with specific needs. May experience service interruptions due to water supply and safety with ramifications for business and production.	Agriculture, Energy
Insurance Companies	Addresses a portion of the cost of some extreme events (flooding is considered an insurance gap in the U.S: only 15% of U.S. homeowners have a flood insurance policy)	Ieuter Insurance Group AON (see AON's 2020 Annual Report on mitigating risk of climate change) Allstate Amica
Disaster Mitigation and Response Sector	Offer services for reducing risk in extreme events or in cleanup post event	Colorado State Forest Service Mitico Wind Mitigation Retrofit Solutions Front Range Arborists

Existing Approaches & Workarounds

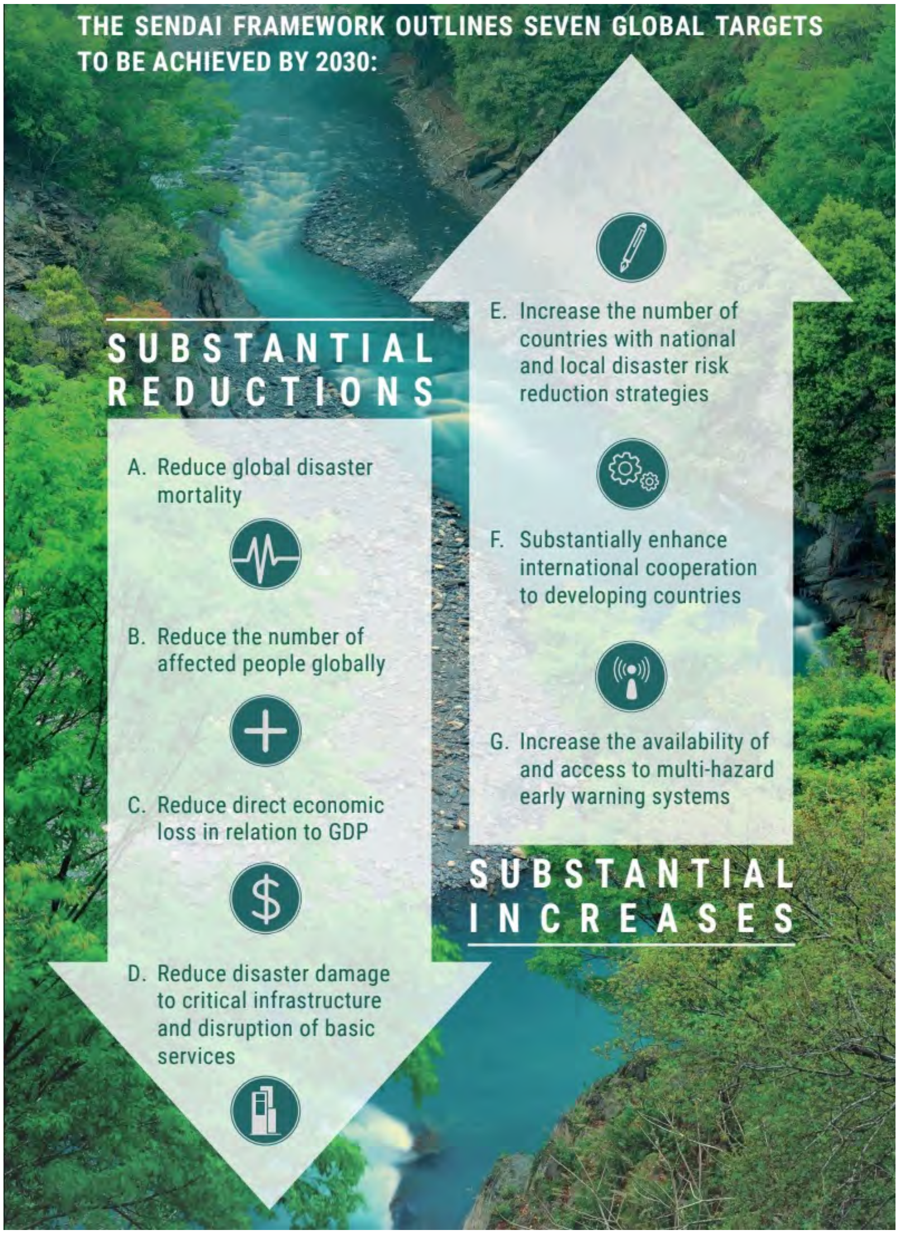
Approaches

Disaster risk reduction (DRR). Disaster risk reduction is a broad term referring to any efforts to reduce the risk of natural disasters. The United Nations has an office dedicated to it--the UN

Office of Disaster Risk Reduction (UNDRR). And a plan. The Sendai Framework for Disaster Risk Reduction 2015-2030 outlines targets and priorities (see Figure __) for reducing the harm of disasters, enhancing preparedness, and fostering resilient recovery. In 2015, the UN also created the Private Sector Alliance for Disaster Resilient Societies (ARISE), a membership network of private enterprises from around the world working to incentivize risk reduction. Roughly 520 billion USD is lost globally each year as a result of disasters and as the UNDRR states, disaster risk reduction is “everybody’s business.” What exactly that business looks like is quite varied.

The multi-national nonprofit organization CADENA, based in Mexico, is one example of an entity working to reduce risks posed by disasters and help communities recover and rebuild. Funded in part by support from large corporations such as Wal-Mart, Home Depot, and Volvo, and P&G, CADENA serves a logistics hub for DDR.

In the for-profit sector, DRR often takes the form of prediction and monitoring. One example is Divirod, an analytics company using data to help manage potential water risks. Satellite technology and drones are the foundation for new technologies and services in monitoring and predicting weather, climate change, and extreme events. Companies like Baron and FT Technologies develop new technologies and approaches to enable more accurate forecasting of extreme events.



Mitigation strategies. Prevention is not often possible with extreme events, therefore, mitigation--actions to reduce risk to life, property, and disruption of social and economic activities--is an important route in DDR. Despite the benefits of mitigation activities, many communities are reluctant to adopt them, citing barriers such as cost, time and effort, or political will. For each extreme event, there are multiple mitigation strategies offering insight into how to manage resources, work with weather and climate in particular areas, and simultaneously pursue economic and community development. A few examples of mitigation strategies are listed below for droughts, wildfires, and floods.

- Drought mitigation. Drought mitigation strategies include interventions for crop and animal agriculture such as crop rotation, erosion control structures, and rainwater harvesting, reduction in herd numbers, and percolation ponds. Additional strategies are policy or consumer based.

- Wildfire mitigation. Strategies for mitigating wildfire intensity and frequency include how to protect individual buildings as well as cities (see examples of city plans from Palo Alto, Boise, and Colorado Springs). Forest management is a significant tool in wildfire mitigation.

For the private sector, disaster mitigation slides into recovery and restoration, and usually follows the route of construction clean up or data recovery. Exploring the realm of prevention through risk and damage mitigation (rather than the realm of reaction post extreme event) seems a relatively open market opportunity with numerous potential target markets from large corporate campuses to agricultural. Of course, risk denial--see below can be a barrier to prevention and mitigation approaches.

Multi-hazard early warning systems. These systems provide warnings for extreme events. They are much more than a simple warning, however. To be effective, early warning systems require monitoring, forecasting, and communication. For more information about the components of warning systems--including their promise and shortcomings--see the World Meteorological Organization's Multi-hazard Early Warning Systems: A Checklist. In the wake of the COVID-19 pandemic, health and disaster researchers have invested more effort in exploring the use of multi-hazard early warning systems for global health risks.

Information and communication technologies. Warning systems can be considered an off-shoot of the Information and Communication Technology sector as warnings require a means by which to relay information and reach a variety of audiences. Figuring out how best to reach various groups requires review of informational channels and platforms and consideration of who has access to different modes of communication. Existing ICTs are increasingly deployed to collect and relay information about extreme weather events. The technologies involved range from satellite imaging to text messaging.

A 2014 report from the International Telecommunication Union explores the connection between the ICT sector and climate change, specifically exploring the role ICT can play in addressing climate change related disasters. Opportunities lie not only in thinking about how to deploy ICT in service to warning systems, information gathering, and outreach but in how to continue to ensure ICT resilience in the face of extreme events.

Extreme event attribution. Making evidence-based connections between extreme weather events and climate change is a growing scientific research field. This work helps enhance an understanding of the role of climate change, grounds mitigation, and DRR efforts in predicting and preparing for extreme events. Determining how to plug this new field into existing and emerging technologies and services in the ICT sector or within DRR efforts will be an increasing need in coming years. Extreme event attribution fills a gap in knowledge by taking into account a growing body of data in the age of climate change and has implications for designing infrastructure, legal liability, insurance, and a number of additional fields.

Workarounds

Urban development and structural measures. Traditional approaches to spatial planning in urban development include structural measures to lessen the risk from extreme events. These are often engineering approaches such as seawalls, embankments, and floodgates or building retrofitting like HVAC systems for heating and cooling or strengthening buildings to withstand extreme weather conditions. Decision-making to adopt these approaches is often based on a cost analysis benefiting higher income areas. Buildings and neighborhoods in lower income areas may not be included or may suffer from "down stream" measures--the effects of implementing structural changes in one area thereby making another area even more vulnerable to damage. For more information on these discussions and structural measures, see pp. 291-306 in the Intergovernmental Panel on Climate Change special report, "Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation."

Reducing emissions. While it is important to decrease the amount of CO2 in the atmosphere, research shows reductions in emissions have little overall effect on global temperatures and reduction strategies must go hand in hand with additional measures.

Substitutes for oil. Fuel alternatives receive a lot of attention. However, often the production of those alternatives requires oil and gas, and in some cases, energy alternatives are used to extract more oil. Any discussion of fuel alternatives must occur with a critical look at how that alternative is produced and brought to market.

The human response to risk. You know that thing many of us do when we think about risk? We tend to see risk as more relevant to people other than ourselves. Sure, Bob down the street may see his home go in a wildfire, but ours will be ok. Sometimes we ignore risk because we don't know much about the risk or its relevance to us. Other times, we very pointedly elect not to think about or take efforts to avoid risk, despite the information available. This is called neglected risk. One of the most well-known examples of neglected risk is the city of New Orleans. Various stakeholders had been aware of the risk posed by extreme weather and a weakened levee system for years but elected to neglect the risk. For a fascinating look at large scale neglected risk see Kathryn Shulz's *New Yorker* article "The Really Big One."

Additional Resources

- For more information on the connection between extreme events and the energy industry, see https://nca2014.globalchange.gov/report/sectors/energy and https://www.energy.gov/sites/prod/files/2013/07/f2/20130716-Energy%20Sector%20Vulnerabilities%20Report.pdf

- For more on drought across the globe and in specific regions, see https://noaa.maps.arcgis.com/apps/Cascade/index.html?appid=aec0b8fc5b504a449f99ba162af904fd

- For more on climate change and extreme events, with expansive attention to managing the risk of extreme events, see https://www.ipcc.ch/site/assets/uploads/2018/03/SREX_Full_Report-1.pdf

- For more information on neighborhoods at risk for extreme events and climate change, see https://toolkit.climate.gov/tool/neighborhoods-risk

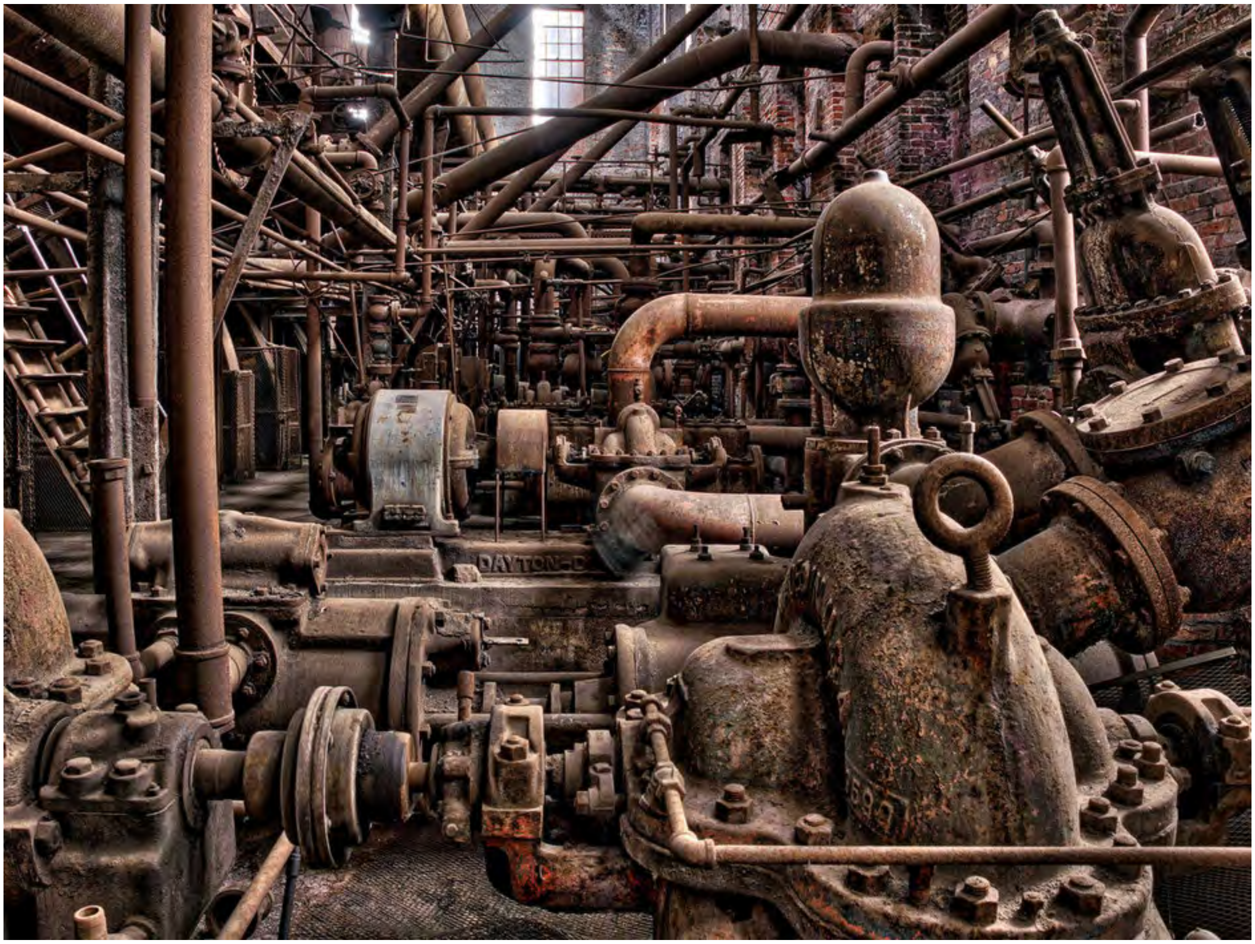
- For more on the Incident and Emergency Management market (Figure ___), see https://www.marketsandmarkets.com/Market-Reports/incident-emergency-management-market-1280.html

- For more information on climate change and climate refugees, see https://www.brookings.edu/research/the-climate-crisis-migration-and-refugees/
- For more on vulnerable populations and extreme events, see https://www.samhsa.gov/sites/default/files/dtac/srb-low-ses_2.pdf
-

e-estimated, p-projected

https://in2ecosystem.com/wp-content/uploads/2021/01/IN2-State-of-the-Cleantech-Landscape-White-Paper-2021_final.pdf

Infrastructure



Infrastructure: The average age of water and sewage pipes in the U.S. is 45 years; in over 600 towns and cities in the U.S. the age of pipes is north of 100. These pipes--in some cases exceeding their intended life span by more than four decades--are not aging gracefully. A water main breaks in the U.S. every two minutes, resulting in a loss of 6 billion gallons per day and an estimated cost of $7.6 billion in treated water per year. Climate change worsens the conditions of aging infrastructure via an onslaught of extreme events such as storms or floods that stretch the limits of infrastructure resiliency. To combat the deluge in costs and face ongoing threats, local governments will spend an estimated $300 billion on repairing and updating water and sewage pipes in the next ten years. These figures represent the deteriorating nature of much water infrastructure locally and globally. And it’s not just pipes. Water infrastructure refers to the systems, including the workforce, the technology, and the processes related to the treatment, delivery, storage, supply, and resource management of drinking water, wastewater, and stormwater, increasing the complexity of infrastructure challenges. The American Society of Civil Engineers gave grades of D and D+, respectively, to the entire U.S. water and wastewater infrastructure systems. As these systems continue to age, the cost of operating and maintaining them will rise, exponentially increasing the cost of deteriorating infrastructure and further opening infrastructure to the threats of climate change, including rising water demands in response to heat waves, drought, and other extreme events. Not only is water infrastructure essential to individuals and households, entire industries from healthcare to manufacturing to mining rely on water and wastewater systems to function. Without significant investments to and changes in water infrastructure within the shifting reality of climate change, service disruptions could cost water-reliant businesses roughly $250 billion by the year 2039 and costs to U.S. households could reach seven times that of current water costs. Finally, a deteriorating water infrastructure produces a multitude of health risks, be it metal seeping into the water from aging pipes as was the case in Flint, Michigan, to waterborne diseases resulting from sewage contamination. These risks threaten familial and community health and often occur in municipalities and neighborhoods with high levels of poverty, further complicating mitigation or innovation efforts.

How might we create resilient water infrastructure in the face of growing demand and climate change threats?

<table>
<tr><th colspan="2">Contributing Factors</th></tr>
<tr><td colspan="2">Aging infrastructure (lead service lines)
Climate change (extreme events, pollution)
Underinvestment
Population growth</td></tr>
<tr><th colspan="2">History & Trends</th></tr>
<tr><td>History</td><td>Trends

Workforce challenges
Rising O&M costs
Full-cost pricing
COVID-19
Public opinion
Water quality regulations</td></tr>
</table>

Populations & Agents	
Existing Approaches & Workarounds	
Workarounds Business as usual/failure to act Energy efficient appliances	Approaches

Contributing Factors

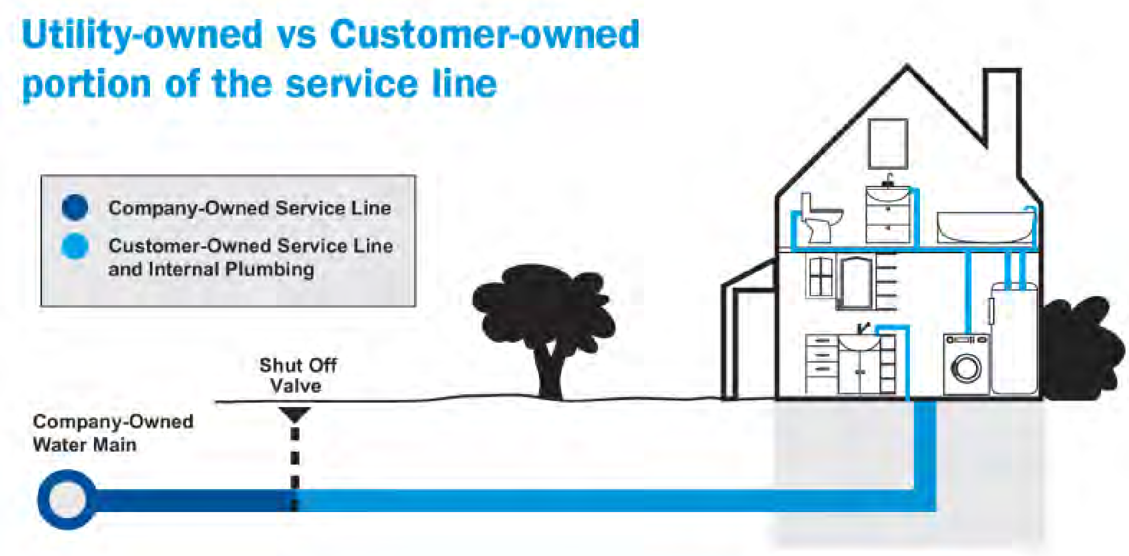
100 years and counting. Much of the infrastructure in the U.S. is old. Decades, and in some cases, centuries old. This is a problem in a number of areas, from transportation to water, as each of these systems experience further degradation and potentially failure. The American Society of Civil Engineers (ASCE) regularly reviews the state of U.S. infrastructure and in its last review, awarded U.S. infrastructure in general a grade of D+, with the a D and D+ for the nation's water and wastewater systems respectively.

Water infrastructure represents the structures, facilities, operations, and personpower required to provide drinking water as well as wastewater and stormwater services to a majority of U.S. homes and businesses through public or investor-owned utilities. It's the treatment facilities, the workforce operating the facility, the pumps, the storage, and the pipes. All of it is aging and all of it requires investment, innovation, and attention.

According to the American Water Works Association (AWWA), a majority of water pipes in the U.S. will need to be replaced by the year 2040. These pipes have outlived their intended lifespan (see Table __). The AWWA also releases a yearly report on the state of the water industry. The report includes data from surveys of water professionals across the U.S. and Canada. For the past five years, addressing aging infrastructure has topped the list of concerns facing the industry (see Table ___). Old pipes are dangerous and costly. They may leach materials and minerals into the water supply, as was the case in Flint, MI, and are prone to leaks and breaks. The gallons of water lost per year due to leaks and breaks is roughly 1.7 trillion at a national yearly cost of $2.8 billion. In one year, from 2017-2018, the rate of water main breaks increased by 27%, resulting in 250,000-300,000 water main breaks per year, or an average of a break every 2 minutes.

Component	Useful Life (years)
Reservoirs and dams	50–80
Drinking water treatment plants (concrete structures)	60–70
Wastewater treatment plants (concrete structures)	50
Drinking water and wastewater treatment plant structures (mechanical and electrical)	15–25
Drinking water trunk mains	65–95
Drinking water pumping stations (concrete structures)	60–70
Drinking water pumping stations (mechanical and electrical)	25
Drinking water distribution	60–95
Wastewater collection	80–100
Force mains	25
Wastewater pumping stations (concrete structures)	50
Wastewater pumping stations (mechanical and electrical)	15
Interceptors	90–100

Property lines delineate the pipes and systems under the purview of utilities and those for which a homeowner or business are responsible (see Figure __). Repairing breaks or leaks within a home or individual property is also costly. The average cost of water main break repair for homeowners is between $800-$1,200. Finding and fixing leaks, on the other hand, can lead to roughly 10% in monthly water bill savings.



Useful lifespan of water infrastructure components.

Top 10 Issues Facing the Water Industry, 2016–2020

	2020		2019	2018	2017	2016
1	Renewal and replacement of aging water and wastewater infrastructure	↔	Renewal and replacement of aging water and wastewater infrastructure	Renewal and replacement of aging water and wastewater infrastructure	Renewal and replacement of aging water and wastewater infrastructure	Renewal and replacement of aging water and wastewater infrastructure
2	Financing for capital improvements	↔	Financing for capital improvements	Financing for capital improvements	Financing for capital improvements	Financing for capital improvements
3	Long-term water supply availability	↔	Long-term water supply availability	Public understanding of the value of water systems and services	Long-term water supply availability	Public understanding of the value of water systems and services
4	Public understanding of the value of water systems and services	↔	Public understanding of the value of water systems and services	Long-term water supply availability	Public understanding of the value of water systems and services	Long-term water supply availability
5	Watershed/source water protection	↔	Watershed/source water protection	Public understanding of the value of water resources	Public understanding of the value of water resources	Public understanding of the value of water resources
6	Public understanding of the value of water resources	↔	Public understanding of the value of water resources	Watershed/source water protection	Watershed/source water protection	Watershed/source water protection
7	Aging workforce/ anticipated retirements	↑	Groundwater management and overuse	Aging workforce/ anticipated retirements	Emergency preparedness	Public acceptance of future W/WW rate increases
8	Emergency preparedness	↑	Aging workforce/ anticipated retirements	Public acceptance of future W/WW rate increases	Cost recovery (pricing water to accurately reflect cost of service)	Water conservation / water use efficiency
9	Compliance with current regulations		Emergency preparedness	Emergency preparedness	Public acceptance of future W/WW rate increases	Cost recovery (pricing water to accurately reflect cost of service)
10	Groundwater management and overuse	↓	Cost recovery (pricing water to accurately reflect cost of service)	Governing board acceptance of future W/WW rate increases	Water conservation / water use efficiency	Groundwater management and overuse

American Water Works Association

Climate change. Anticipating gradual changes in climate is part of the long term planning process for infrastructure needs and capital improvements. It's called climate stationarity--the use of past data to provide a picture of the relative stability of climate in the future. Except, climate stationarity doesn't apply today in the same way it did 50 or 100 years ago, when much existing infrastructure was designed and built. Today, the intensity and rate of climate change throws one giant monkey wrench into anticipating the demand on infrastructure and that reality is most evident when considering extreme events.

→ Extreme events. When something is old and degrading, it's generally not able to stand up to extreme circumstances. This is certainly the case when it comes to water infrastructure. Aging pipes and facilities are increasingly under pressure from the manifestations of a changing climate, especially the pressure of extreme events. Hurricanes, droughts, floods, and heat waves strain existing systems. The 2020 AWWA State of the Water Industry report notes water professionals ranked extreme events as the most significant large-scale phenomena of negative impact for water utilities. The year 2020 was the sixth consecutive year in which the U.S. experienced ten or more billion dollar weather and climate events, meaning the cost in damage to cities, utilities, homeowners, and business totaled at least $1 billion. These events are not costly in the immediate term but wreak havoc on water systems and facilities, often exacerbating current states of disrepair. See Table ___ for more detail on how climate change affects various components of water infrastructure. For the complete table, see pages 4-8 of the USAID Climate Resilient Infrastructure Report.

Table 1: Climate Change Impacts on Various Components of Water Supply Infrastructure

CLIMATE DRIVERS AND EFFECTS	INFRASTRUCTURE IMPACTS AND CONSEQUENT RISKS
Increased Mean Annual and/or Intensity of Precipitation	
Higher intensity rainfall and flooding during storms Extreme precipitation events are location-specific and can cause flooding and landslides when downpours exceed the capacity of river or urban drainage systems. Uncertain climate projections, expected to intensify in some areas.	**River Water Resources** • Increased water turbidity after heavy storm events • Shifts in river morphology from increased erosive capacity of river during storm events may affect water withdrawal • Need for dredging to remove sediment, rocks and debris deposited after storm events **Water Impoundments** • Additional storage facilities needed to capture water during shorter, higher intensity storms • Higher turbidity of stored water due to erosion requires more treatment chemicals and time for clarification during treatment; temporary suspension of treatment of stored water may also occur in cases of extreme turbidity • Decrease in storage capacity of impounding reservoirs due to high sediment deposition **Wells and Spring Sources** • Well contamination from flooding • Physical damage to structures from flooding • Intake pipes on soft soils or steep slopes prone to landslides • Destruction of spring boxes on steep areas from landslides • Need for relocation of water intake structures due to shifting riverbed and sediments during storm events • Higher maintenance costs to keep water intake structures clear of debris deposited after storm events • Cracks in or total destruction of spring boxes from landslides **Storage Tanks** • Contamination due to flooding for cisterns • Physical damage due to landslides **Pipelines** • Corrosion of metal pipes weaken structures over time • Physical damage to pipes from flooding and landslides

- Network contamination from pipes damaged by flooding or landslides

Treatment Facilities
- Physical damage to structures from flooding
- Water damage to chemical supplies due to flooding
- Lower treatment effectiveness due to higher than normal turbidity or disrupted/shorter treatment operation
- Need for higher treatment plant capacity due to higher precipitation depending on capacity of transmission lines

Auxiliary Services
- Loss of power supply
- Loss of telecommunication facilities
- Loss of data

The terms "resilient infrastructure" or "infrastructure resilience" appear often in considering how to address the threat of extreme events on water systems and refer to the ability to recover from or withstand disruptions, thereby saving costs and potentially saving lives. The National Infrastructure Advisory Council includes people/processes and infrastructure/assets into its thinking about the four fundamental concepts of resilience in infrastructure: robustness, resourcefulness, rapid recovery, and adaptability (see Figure __). Each of these areas represents potential for innovation and intervention in helping water utilities prepare for extreme events.

→Water quality and pollution. Extreme events alter water quality and contribute to pollution, further taxing infrastructure. Water runoff and rising sea levels increases the salinity in water, requiring extensive treatment. The chemicals historically used to fight wildfires make their way into the water yielding dangerous levels of what are referred to as "forever chemicals" or PFSAs in groundwater, surface water, and drinking water supplies. Treating water to eliminate pollutants is not only costly, it is an every-shifting battle as nascent contaminants require monitoring and testing to ensure safe water.

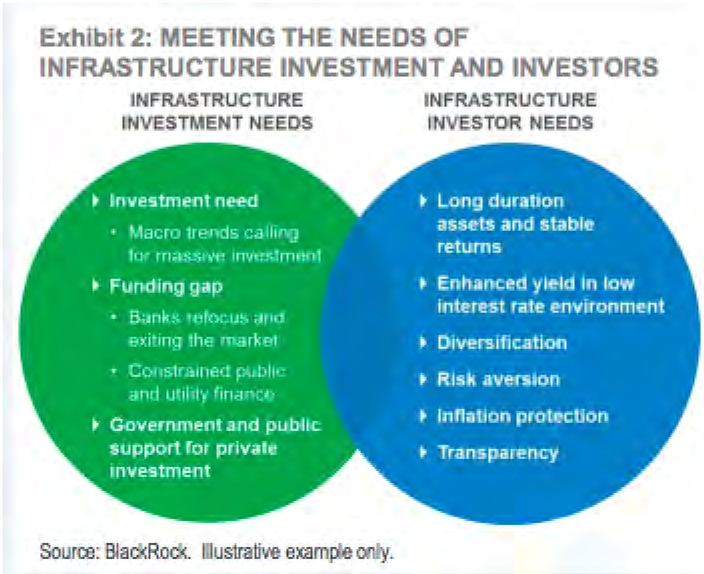
Underinvestment. Addressing the nation's aging infrastructure will require significant financial investment. The EPA estimates the investment needed to bring water infrastructure up to date by making repairs and replacing deteriorating systems is $472.6 billion over the next 20 years. Current infrastructure investments cover a small portion of this amount. The ASCE notes the US. needs to invest $129 billion per year in water infrastructure to keep water systems working. In 2019, that investment total was $48 billion for a gap of $81 billion. As investments fail to keep pace with need, the infrastructure investment gap will continue to grow. Currently cities cover a majority of water externally funded infrastructure costs, with local governments covering 95% to 98% of drinking water and wastewater infrastructure costs. Utilities and local and state governments seeking to invest in infrastructure do so by funding it directly through spending reserves or rate increases or through financing such as loans or bonds repaid over time. See Table ___ for a list of utility funding sources as noted in the AWWA 2020 State of the Water Industry Report.

Utility 2020 Funding Sources

RANKING	UTILITY FUNDING SOURCES RANKED BY % MENTIONS
1	Rate increases (25%)
2	Bonds (18%)
3	Grants (14%)
4	Operational savings (13%)
4	Reserves (13%)
4	State Revolving Funds (SRFs) (13%)
5	Water Infrastructure Finance and Innovation Act (WIFIA) (4%)

American Water Works Association ©AWWA 2020 State of the Water Industry

The potential return for investing in water infrastructure is substantial, in part due to the reliance of a variety of industries on water. The US Department of Commerce's Bureau of Economic Analysis estimates for each additional dollar of revenue invested in the water or wastewater industry in a year, the increase in economic output across all industries is $2.62 in that year. In the long term, each dollar invested increases the GDP by $6.53. The return on investment is also experienced in job growth. The same analysis by the Bureau of Economic Analysis notes adding one job in water and wastewater management and infrastructure creates 3.68 jobs in the national economy, or a total of 1.3 million American jobs.



→ Rising costs. As utilities stretch to address the gap in infrastructure investment, one lever they can pull is raising rates. In fact, most utilities plan to raise costs in the coming year, causing challenges for some customers. For more information on how water utilities need to adjust their financial benchmarking and consider new models to address rising costs, see the video below.

Link to video: https://youtu.be/pfs0brT_jkU

Population shifts. The U.S. population, currently at ___, is expected to hit __ by 2050. Much of this growth will occur in areas of water scarcity such as the American West (see Table ___). Population growth and internal migration in the U.S. will contribute to strain on infrastructure by increasing demand for treated water and taxing the facilities for drinking and wastewater treatment. And it's not growth alone. Shrinking populations in smaller communities also presents challenges to water utilities due to shrinking customer bases and decreasing revenue. To learn more about internal population shifts, see the interactive internal migration map from *Forbes.*

Rank	Top Sending Counties	Top Receiving Counties
1	Los Angeles County, CA	Los Angeles County, CA
2	Cook County, IL	Harris County, TX
3	Harris County, TX	Maricopa County, AZ
4	Travis County, TX	Cook County, IL
5	Dallas County, TX	Dallas County, TX
6	Kings County, NY	San Diego County, CA
7	New York County, NY	Riverside County, CA
8	San Diego County, CA	Orange County, CA
9	Maricopa County, AZ	Tarrant County, TX
10	Orange County, CA	King County, WA
11	Queens County, NY	San Bernardino County, CA
12	King County, WA	New York County, NY
13	Santa Clara County, CA	Broward County, FL
14	Tarrant County, TX	Clark County, NV
15	San Bernardino County, CA	Kings County, NY
16	Riverside County, CA	Travis County, TX
17	Miami-Dade County, FL	Fulton County, GA
18	Fulton County, GA	Orange County, FL
19	Alameda County, CA	Alameda County, CA
20	Fairfax County, VA	Queens County, NY

History & Trends

History

The history of water and wastewater infrastructure is the history of development. As settlements grew into towns and cities, infrastructure was required to literally "build America." Today, we hear "rebuild America" as an oft repeated refrain, one pointedly employed during President Barack Obama's second term. Rebuilding America refers to the need to upgrade infrastructure--from aviation to roads and bridges to school to hazardous waste to water--across the U.S. and in so doing, create jobs. It's also a history of economic growth and public-private partnerships. Canals were built to facilitate transport goods. Businesses and cities together bore the cost of canal construction. Railroads, then highways replaced canals as the predominant form of traversing distance, yet the combination of public-private partnerships remained constant.

The history of water infrastructure is similar, with the addition of health as an influential factor. As cities became more crowded during the Industrial Revolution, concerns about safety and hygiene grew more prominent and water was seen as a connection to either sickness or health. Safe and accessible water was needed to quell disease, help grow businesses, and protect the community from fire. In 1850, there were 83 public water supplies in the U.S., 50 of which were privately owned. That number grew to 136 by 1886 and reached 3,000 by the turn of the century, split relatively equally between public and private entities. Not long after these entities were established, they began to serve important roles in health. As early as 1908, the city of Jersey City, NJ was treating its drinking water to ensure its safety.

Photo: Nebraska State Historical Society, image RG2608.PH2494

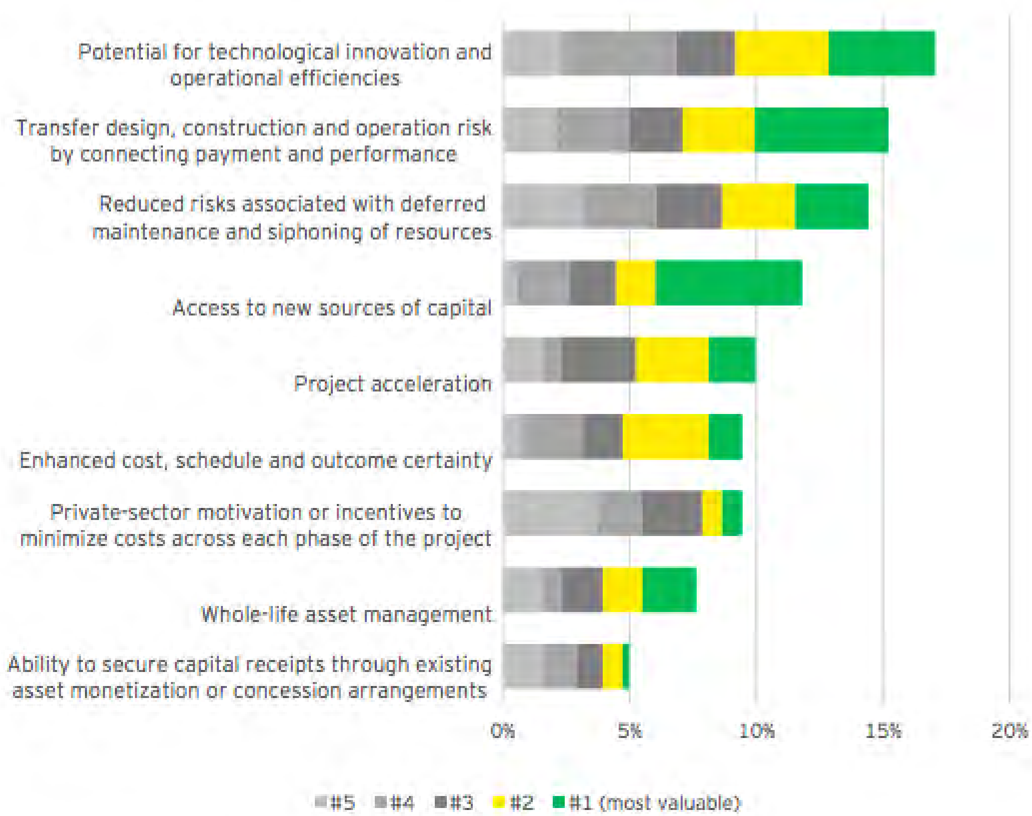
Sewer pipe installation in Kearney Nebraska, 1889.

The provision of wastewater services by way of comprehensive sewage systems emerged in the U.S. in the mid 19th century. Around this time treatment of wastewater became part of the wastewater process. Previously, sewage was pumped back into the nearest body of water which usually doubled as a community's water source. In 1892, the U.S. included only 27 cities with wastewater treatment works. Most cities thought treating wastewater was an unnecessary cost. Thinking changed in the mid-20th century. In 1948, the Federal Water Pollution Control Act outlined the need for sanitation infrastructure and directed local and state governments to pursue this need. Decades later, the 1972 Clean Water Act made wastewater treatment mandatory and in 1974, the Safe Drinking Water Act was adopted to regulate public drinking water supplies. For an expansive review of the history of the Safe Drinking Water Act see the EPA's report *Twenty-five Years of the Safe Drinking Water Act: History and Trends*.

Drinking and wastewater regulation continues today. Dictated and enforced by the EPA, these regulations pose opportunities for providing safe and reliable water services but also present challenges in ongoing compliance requirements. For a full list of drinking water regulations see the EPA's table of National Primary Drinking Water Regulations. For more information on wastewater, see the EPA's National Pollutant Discharge Elimination System program areas. Stormwater collection is also a primary function of most water utilities; for more information on stormwater management see the EPA's NPDES' Stormwater Program.

Trends

Public private partnerships. While public private partnerships (P3s) have a solid place in the history of building infrastructure in the U.S. a developing trend is the return to these partnerships to help address rising costs, supply funds for improvements, and provide technology and innovation. P3s allow utilities to partner with outside entities to bring in the investment and expertise needed to address the expanding challenges of water supply and treatment (see Figure ___). According to the AWWA, more than 2,000 municipalities have entered into a P3 arrangement for all or part of their water supply needs. For more information on P3s in water infrastructure, see the AWWA's report T*o P3 or not to P3*.



Typically cited benefits deemed most appealing to P3 involvement.

COVID-19. Water utilities have felt the repercussions of the pandemic in budget shortfalls. As water use in areas like restaurants and hospitality dip drastically and many businesses are closed, revenue--based on usage--falls. Rural community utilities are some of the hardest hit, bringing in roughly half of typical monthly revenue. The pandemic has also heightened inequities around water access and vulnerable populations reinforcing the need to examine cost, access, and supply to those who need it most.

An infrastructure bank. In recent years a number of trends have emerged to address the need to finance infrastructure projects across the U.S. One of these trends is the National Infrastructure Reinvestment Bank, proposed by legislators in 2007 and backed by President Obama in 2008. The bank's proposal has since been through many iterations the most recent of which was introduced in Congress in June 2020 as the Infrastructure Bank for America. Unlike previous proposals, the Infrastructure Bank of American would be privately owned, managed, and funded.

Climate bonds. Fixed-income financial instruments, climate bonds (also known as green bonds) have positive environmental or climate benefits. Proceeds from their issuance are applied to pre-specified projects such as the creation of a hydropower plant. Projects must comply with standards established by the Climate Bonds Initiative. For more information on climate bonds see the Climate Bonds Initiative website.

Green cities. As more people populate cities and many cities in turn work to curb carbon emissions, development of green cities and green city planning is on the rise. This year, Resonance Consultancy identified the world's ten greenest cities based in part on a city's walkability, public transportation, number of green spaces, and levels of air pollution. Water systems and water planning will increasingly play a role in the creation and maintenance of green cities as cities consider how to plan for future events and build and develop in line with water conservation practices.

Public support. Support for investment in infrastructure is one of the few bipartisan areas of agreement. A whopping 80% of Americans support investing in infrastructure and 84% support investment in water infrastructure specifically. For more on public opinion about water infrastructure see the presentation from the Value of Water Campaign.

Regulation. Emerging contaminants mean the need for more regulation addressing harmful elements in water. While regulation is necessary, meeting shifting regulatory requirements is costly for utilities. Water utilities are regulated at the national level by the EPA and the Safe Drinking Water Act but are also subject to state and a variety of local regulations as well.

Deregulated electricity markets. Since mid-February of 2021, Texas is the best-known state with a deregulated electricity market. While a number of states have deregulated electricity markets, the recent extreme cold weather in Texas and near-catastrophic barely-avoided complete grid failure has drawn attention to the difference between regulated and unregulated markets and what those differences mean for water quality and availability.

Regulated electricity markets mean energy utilities own and control the entire energy vertical, from energy production to individual home energy metering. Market competition is minimal or nonexistent. In a deregulated market, a number of providers may be responsible for electricity supply, allowing for more market competition and in turn, the potential for better prices and services.

Texas deregulated its electricity market in 1999. Texas is also completely energy independent. By refusing to share energy across state lines, Texas isolated itself from the national energy grid and avoided regulations for utilities involved in interstate commerce. Deregulation and energy independence-turned-isolation were significant precursors to the disaster wrought by days of cold weather in mid-February. Temperatures plummeted, households across the state turned up their heat, and the energy draw coupled with lack of energy reserves and safeguarding procedures, saw the state seconds away from a catastrophic blackout event.

Families huddled in their cars or gathered closely together around makeshift campfires to stay warm. As communities across the state faced ongoing outages, more challenges unfolded, turning the crisis in energy into a water crisis. Pipes in homes and businesses and domestic violence shelters froze, cutting off the water supply, and then burst causing extensive damage. Water treatment plants struggled to keep up with broken water mains, pipes, and inactive pumps and treatment mechanisms useless without power. Water reservoirs were depleted due to leaks and increased use. More than 800 public water systems serving 13.1 million people experienced disruptions. The state of Texas implemented a boil water notice for roughly 7 million individuals in response to concerns over the water's safety due to utilities' inability to maintain water pressure. The crisis in Texas demonstrates the interconnectedness of energy and water and the susceptibility of water utilities to disruption as a result of crises in other infrastructure sectors.

Skilled workforce. The average age of the water infrastructure workforce is higher than the average age of the overall workforce, revealing the need for the water infrastructure sector to consider how to replace retiring workers. As the industry increasingly incorporates technological approaches and solutions, the need for a skilled and tech-savvy workforce will be all the more pressing, requiring water infrastructure players adopt new approaches to securing a future workforce.

Populations & Agents

Vulnerable Populations

A neighborhood's racial composition is a strong indicator of the degree to which its infrastructure is capable of withstanding threats, or its degree of deterioration. In contrast to communities of predominantly white residents, communities of people of color and low-income communities have a disproportionate amount of outdated infrastructure systems, putting them at greater risk for water scarcity, safety issues, and hazardous conditions resulting from extreme events.

Yet issues related to water infrastructure also span the nation. A few of the cities listed as having the worst tap water problems in the nation include Pittsburgh, Milwaukee, Detroit, and Baltimore. And Mississippi, Massachusetts, and New Jersey are at the top of the list of states with the worst infrastructure. Despite the prevalence of infrastructure issues, vulnerable populations such as those of lower socio-economic status, or those experiencing unstable housing conditions, are most susceptible to the intersection of challenges accompanying poor infrastructure including less access to healthcare and other basic resources.

Agents

Category	**What they do**	**Examples**
Regulatory bodies	Oversee issues related to water quality and safety.	EPA FDA
Water utilities	Provide water supply systems, maintain infrastructure	Denver Water American Water Works Association
Associations	Provide resources and expertise as well as an external check for infrastructure.	ASCE AWWA
Communities	Neighborhoods, cities, or municipalities with varying degrees of water service and infrastructure needs.	Rural communities Urban areas
Consumers	Receive varying levels of infrastructure support and water supply. Shape water conservation and reuse practices via public opinion. Advocate for access to safe water and engage in a range of water use behaviors.	Indian Tribes Urban centers Rural communities
Industry	Rely on water to produce goods/services and sustain industry. Participate in both positive and harmful water use practices thereby affecting other industries and their water uses.	Recreation Agriculture Energy
Investors	Provide financial backing for water infrastructure and in some cases, own water utilities.	Water Asset Management Climate Change Bond funds

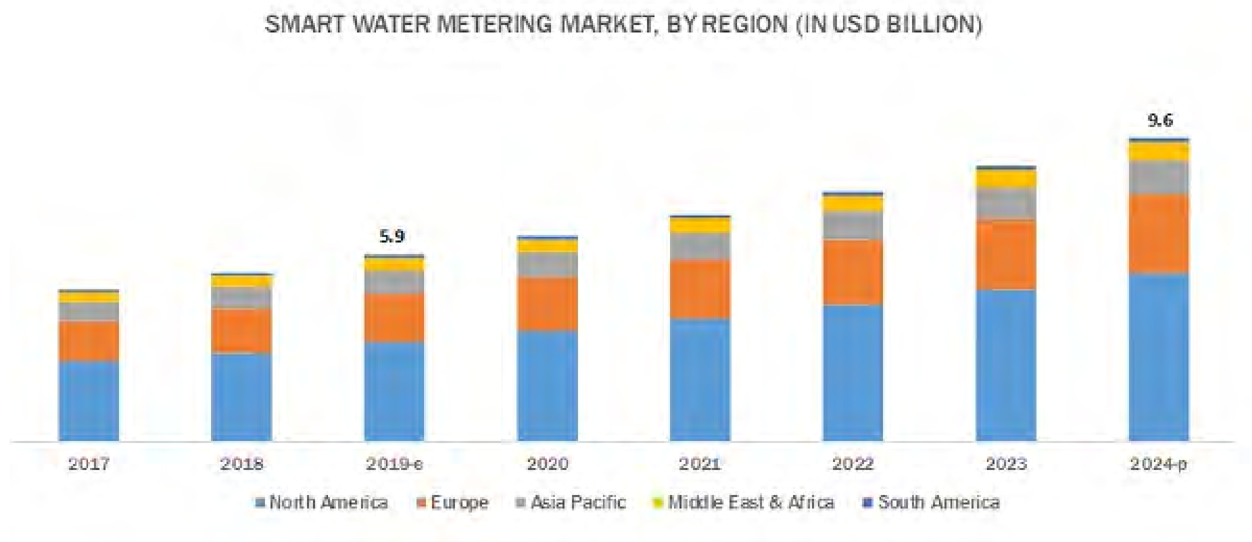
Existing Approaches & Workarounds

Approaches

Smart water management and advanced metering infrastructure. Smart water management includes the hardware, software, processes, analytics, and advanced pressure management systems for monitoring water via the IoT. As a whole, the smart water management market was $9.6 billion in 2017 and is expected to reach $31.6 billion by 2024.

Advanced metering infrastructure is one technological innovation within smart water management. Integrated sets of smart meters work together to create advanced metering infrastructure (AMI). AMI allows for advanced data collection, as well as the potential for two-way communication between the customer and utility. Unlike traditional water meters requiring regular visits from utility personnel to a household or businesses, automatic meter readers (AMRs) provide ongoing data to a utility on an hourly basis. AMI is one step up, enabling data sharing with the customer as well as the utility. While AMI presents many possibilities for utilities in the realm of more accurate and immediate data and benefits to the customer, transitioning to AMI also presents cost challenges as utilities segue to new hardware and structures as well as new employee skill sets. Smart metering companies include Itron, Inc, WaterSmart, Badger Meter, and Elster Group.

The AMI market consists of smart meters and the communication modules required for their use, with the smart meters representing the larger share of the market. Market expectations are strong in the near future due in part to pressures on utilities to improve customer service and increase efficiencies. The worldwide smart water metering market is $5.9 billion and expected to reach $9.6 billion by 2024 (see Figure ___ for global growth predictions).



A range of technological innovations are increasingly helping to protect against leaks and breaks, both in the home and on behalf of utilities. Smart water metering as addressed through devices like [WaterOn] offer automated water monitoring (see Figure ___) for apartment buildings or multi-family homes to reduce consumption and help identify leaks and potential water waste. Geographic Information System (GIS) data as supplied by companies like [Esri] through their service [ArcGIS aids utilities] by providing location specific data. To learn more about the integration of ArcGIS with utilities, see the [Esri case study of Arkansas water].

Example of WaterOn's information dashboard.

Green infrastructure. Effective, economical, and environmentally sound, green infrastructure--sometimes referred to as natural infrastructure--uses natural processes and materials to manage water and protect the water cycle. Often, green infrastructure may supplement or replace costly traditional infrastructure; restoring wetlands and green spaces instead of investing in a water treatment plant, for example. In addition to saving costs, green infrastructure also creates jobs. New York City's sustainability plan is projected to create 4,449 water infrastructure jobs per year.

In Nevada City, California, a rain garden is used to catch rainwater runoff from parking lots and allow the water to sink into the ground. Photo: Jacob Dyste.

Further examples of green infrastructure include rain gardens, permeable pavement, and green or blue roofs.

Retrofitting medium-sized office, apartment, or retail buildings with green infrastructure is expected to yield positive returns in energy savings, incentives, and reduced risks for extreme events as well as non-monetary benefits to livability, community, and quality of life (see Figure ___).

POTENTIAL BENEFITS	
Energy savings due to reduced demand for heating and cooling	$3,560 Annually
Avoided costs for conventional roof replacement	$607,750 net present value over 40-year analysis period
Tax credit	$100,000 one-time credit in year of installation
Increased retail sales	$1.2 MILLION per year
Stormwater fee reduction	$14,020 Annually (projected to increase 6% per year)
Total present value benefits (over 40-year analysis period)	$24,202,000 + (including $22,963,800 in increased retail sales, which accrue to the tenants)

NON-QUANTIFIED BENEFITS	
Water conservation	+
Increased property value	++
Reduced infrastructure costs due to use of permeable pavement system	+/U
Reduced crime	+/U
Improved health and employee satisfaction	+ (for tenants and employees)
Reduced costs associated with flooding	U

+ would likely increase net benefits;
++ would increase net benefits significantly;
U direction of net change is uncertain.

Potential benefits of green infrastructure in a mid-size retail center.

Philadelphia, PA, has adopted widespread green infrastructure projects to conserve and protect water. I highly recommend checking out the abbreviated Green City, Clean Waters plan as well as the video below for inspiration. In the semi-arid west, green infrastructure may also be referred to as low-impact development (LID). See the city of Fort Collins for example of LID.

Video link: https://vimeo.com/17306371

According to the Organization for Economic Development and Cooperation (OECD), roughly 60% of urban infrastructure that will exist in 2030 has yet to be built. For more information on how to invest in and scale up green infrastructure see chapter three of the OECD's online report Green Infrastructure in the Decade for Delivery.

Green infrastructure companies include Pattern Energy Group, Clearway Energy Group, Hannon Armstrong, and Brookfield Renewable Partners.

New materials. Water pipes of old were often iron or even wood. Today, a variety of materials are considered to replace aging pipes. These materials range from a variety of plastics to pre-stressed concrete (see Table __ for comparison info on pipe material). Rehabilitation of existing pipes is expected to be the greatest category of spending for utilities in the near future with annual growth from $253 million in 2019 to $576 million by 2028. Pipe rehabilitation and replacement is generally conducted by utilities or private developers. According to *Water Finance and Management Magazine*, the market and capital spend for "legacy materials" such as iron and steel still comprises a large segment of material use--65% representing $32 billion over ten years--however, plastic and emerging materials are growing and represent the remaining 35% of market share for $17.3 billion over a ten year period. Additionally, emerging materials growth is outpacing the sector as a whole. Average annual growth of plastic pipe investment is 4.5% versus 2.1% for legacy materials.

PIPE MATERIAL	LENGTH MILES	NUMBER OF FAILURES	FAILURE RATE #/(100mi)/(year)
CI	33611.0	8204	24.4
DI	33238.7	1620	4.9
PVC	26840.3	689	2.6
CPP	2355.3	128	5.4
Steel	4300.1	581	13.5
AC	13502.8	954	7.1
Other	3755.3	787	21.0
TOTAL	**117603.4**	**12963**	**11.0**

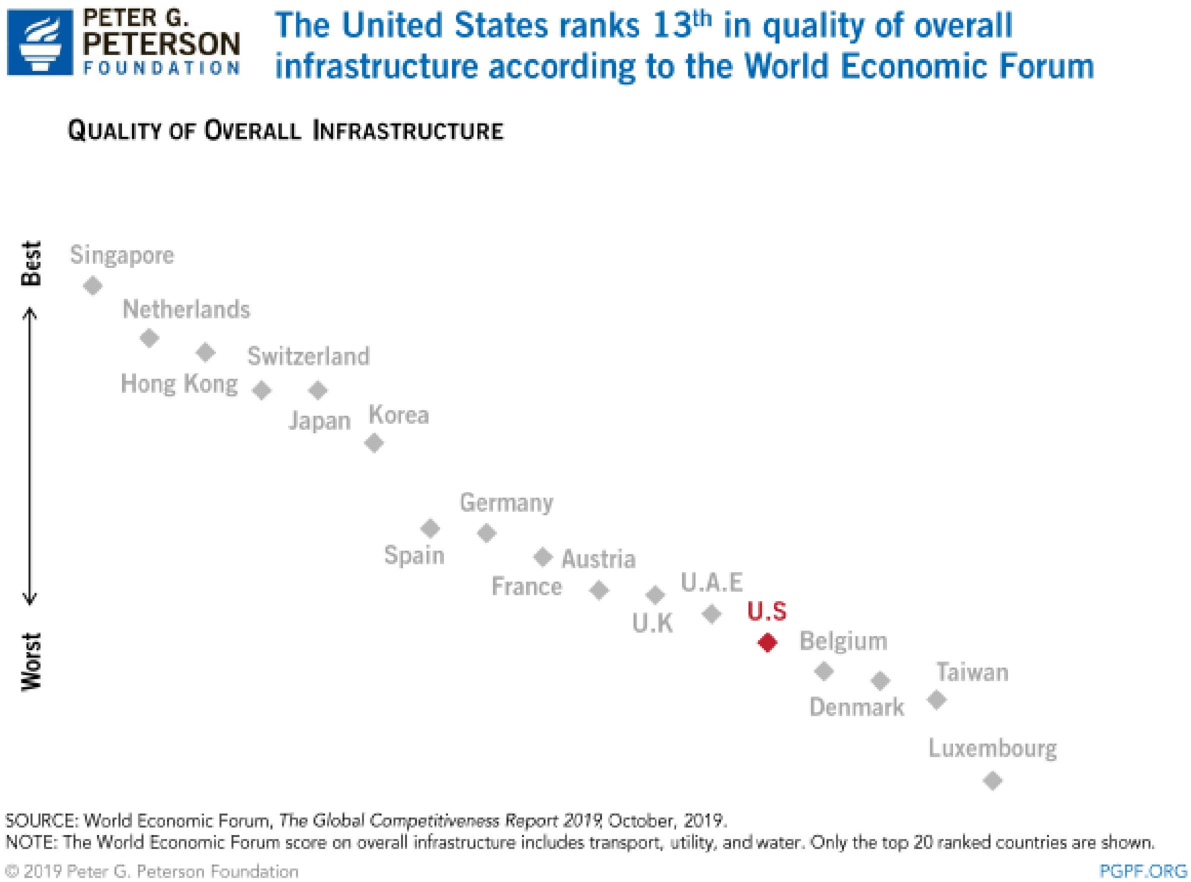
Water Main Failure Data Over A 12-Month Period. Source: Water Main Break Rates in the USA and Canada, April 2012, by Steven Folkman, Utah State University (CI=cast iron, DI=ductile iron, PVC=polyvinyl chloride/non-metallic coated plastic, CPP=concrete pressure pipe, AC=asbestos cement)

Investing in water. Infrastructure investment is increasingly an approach to addressing infrastructure needs and offers the potential for payoff, albeit with a turn around often involving decades and specific risk considerations, for investors who are looking for alternatives to traditional investments (see Figure ___ for an example from BlackRock regarding infrastructure and investor needs met from infrastructure investment). Infrastructure private equity is similar to real estate private equity in that both invest in properties but with one key distinction: infrastructure private equity invests in properties that in some way involve the provision of an essential service. For more on infrastructure investment and private equity see Mergers and Acquisitions' *Infrastructure Private Equity: The Definitive Guide* and for more information regarding who finances infrastructure see the American Rivers' Advocates Guide on Drinking Water Infrastructure.

Workarounds

Failure to act. Also known as looking the other way or kicking the can down the road. It represents much of the U.S. approach to infrastructure needs over the past few decades, which is why the U.S. ranks 13th globally for the state of its infrastructure (see Figure ___). The American Society of Civil Engineers estimates a continued failure to respond to the increasingly pressing demands in water infrastructure needs will have significant economic costs. To quote the ASCE report:

- Service disruptions would cost water-reliant businesses $250 billion by 2039.
- Underinvestment would lead to a cumulative $2.9 trillion decline in the gross domestic product by 2039.
- Costs incurred by US households due to water and wastewater failures would be seven times higher in 20 years than they are today.
- Failing water infrastructure would result in $7.7 billion in cumulative healthcare costs to households over the next 20 years.



Home water-leak management. As soon as I read an article telling me to manage leaks and cut down on water waste by putting food coloring in my toilet bowl, I stop reading. I'm all for mitigating water loss and doing my part in the home but when home solutions start to sound like 15 step craft projects I am out. However, and as mentioned earlier, these kinds of artsfair activities call attention to the blurry lines between home systems and community infrastructure. Is it possible to find simple, shared approaches to infrastructure issues in the home and beyond?

Trained incapacity. Literary theorist Kenneth Burke, using a concept from an earlier economic theorist, Thorstein Veblen calls attention to the idea of trained incapacity in Burke's 1954 book, *Permanence and Change*. Trained incapacity, Burke says, is the state wherein one's training or education may function as blindness. In other words, Burke believed our way of seeing things limited our ability to see potential solutions and closed us off to possibilities. For example, when faced with congested highways the solution often seems to be to add more lanes and increase the number of cars on the road, which only causes more congestion. This solution is in part a function of the training and previous experience of those tasked with addressing the problem. If infrastructure like roads or water pipes has served a particular purpose for a century, and people have been trained to address any deterioration in those roads or pipes, then an ongoing cycle of repairing and rebuilding infrastructure as it currently exists seems like the only viable solution.

Indeed, that is the predominant approach to water infrastructure issues. Rather than rely on repair and rebuild is it possible to transcend our blindnesses and also include reinvention in our approaches?

In the meantime, the water infrastructure repair market is substantial. Top players in the industry include companies such as Xylem (its tagline is "Let's Solve Water"), Danaher Corporation, Mueller Water Products, Aegion, Black and Veatch, and Sulzer working in every region across the globe. Each company presents varying levels of innovations in addition to repair. Black and Veatch devote services to sustainable infrastructure and Mueller Water Products features the smart water hydrant. As of 2019, the global water infrastructure repair market size was $88,190 million with a compound annual growth rate of 6.9% over the next few years to reach $141,410 million by the end of 2026.

Additional Resources

The ASCE runs an ongoing list of #Gamechangers in water and infrastructure on its website: https://www.infrastructurereportcard.org/solutions/gamechangers/

More information on infrastructure bank proposals throughout history: https://www.enotrans.org/article/look-infrastructure-banks-part-1/

Check out this case study of a the state of Connecticut's Green Bank: https://cdn.gihub.org/umbraco/media/2631/usa-case-study.pdf

For more on climate bonds, see https://climatetrust.org/climate-bonds-overview/

A list of the top companies in water and wastewater treatments: https://meticulousblog.org/top-10-companies-in-water-wastewater-treatment-market/

Water Supply & Scarcity

According to the United Nations, water is “at the heart” of adaptation to climate change. Human-caused climate change, including the contributing factor of population growth, has resulted in less reliability in water supply resources as well as greater variability between water excesses and shortages. The result is growth in the frequency and intensity of water scarcity across the globe and escalating uncertainties concerning water supply. Over 748 million people around the world are without basic water access. That’s more than twice the population of the United States. As population growth continues--particularly in urban areas--so will instances of water supply scarcity. Almost *half the world's population* will be living in areas of high water stress by 2030 and water scarcity in some arid and semi-arid places will displace between 24 million and 700 million people. Climate change can significantly alter the water cycle, making predictions and planning for scarcity or water crisis events all the more challenging. As scarcity increases, attention to various sources and supplies of water, as well as more efficient water allocation and use, become essential for human survival and for economic growth. The estimated cost benefit to the U.S. of reducing agricultural water scarcity globally is $94 billion a year. Each water source--from groundwater, to sea water, to rivers, to rainfall, to reused water--includes climate change related challenges ranging from pollution and supply levels to consumer comfort and cost. Further, supply issues overlap with infrastructure and capacity limitations, technology considerations, and neglect of rural areas.

How might we provide water to those who need it and protect or enhance water supply sources?

Contributing Factors

Water in the West
The Colorado River
Climate change (varying snowmelt, drought)
Pollution
Competing stakeholder interests
Consumer comfort
Data/information
Water policy and water rights
Sourcing

History & Trends

History	Trends
Western waters Developing the West Selling the West The Law of the River Environmental Movement	Population growth Conflict and collaboration Water use Extreme events Municipal utility consolidation Tribal water rights

Populations & Agents

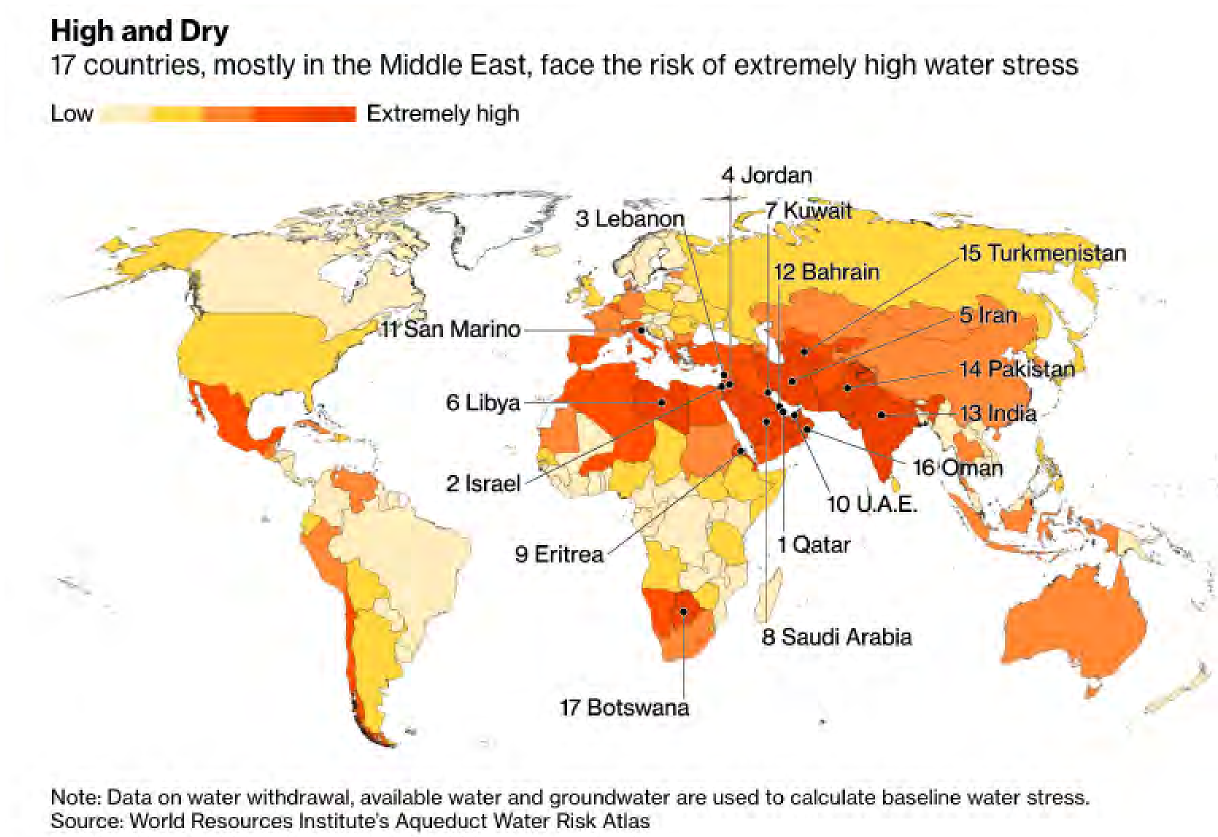
Populations	Agents
Women and children Residents of water scarce areas	Industry sectors Consumers Water-managing bodies

Existing Approaches & Workarounds	
Approaches Ancestral and Indigenous water practices Water markets and water trading Desalination Water-sensitive cities Water and technology Satellite data	Workarounds Deeper wells drawing more groundwater Ignoring infrastructure Privatization of water sources Water rights sector Private companies

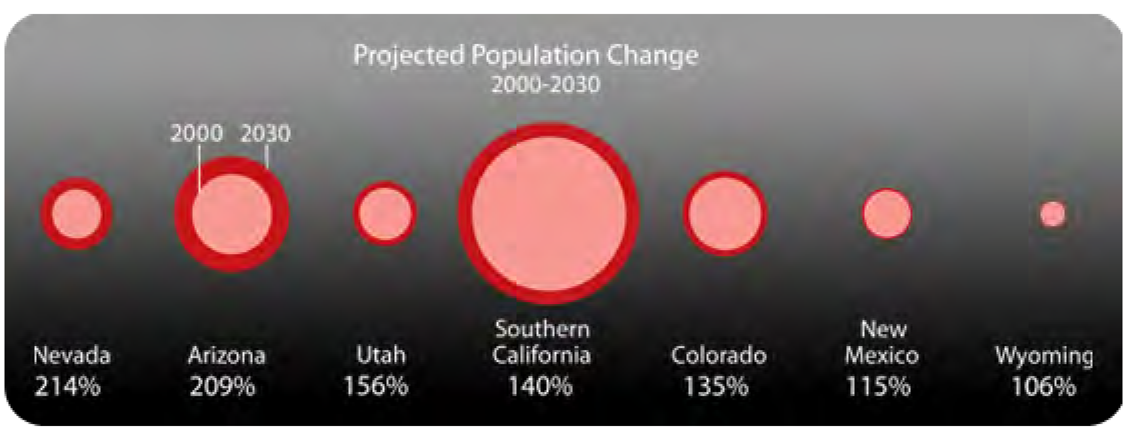
Contributing Factors

Water in the West. Water scarcity and supply issues are relevant in many places all over the globe. In fact, the countries most at risk of a water crisis are located primarily in the Middle East (Figure __). While issues of water in the West may not be the most pressing globally when it comes to water supply and scarcity, in many ways, the West is a microcosm wherein two pressing realities related to water intersect. The first is interconnectedness. Water in the West represents a level of interconnection demonstrating the need for collaboration and transparency when it comes to water challenges in any region. What happens in the Rocky Mountains has direct results for how water is used in California. And vice versa: how water is allocated in California affects supply levels and demand in the headwater state of Colorado. The second reality is in some ways paradoxical to the first: water issues--despite the interconnectedness of regions--are driven and molded by local concerns. When communities are suffering from drought or dwindling water supplies, local concerns take precedence over conditions in the next state over. Is it possible to reconcile local concern with regional interdependence? In many ways, this question is at the crux of water issues in the West and serves as inspiration for further exploration.

"It seems odd to characterize an entire region by what it lacks, but water has always been the most consistent and frequently cited tie that binds the West." -- Fahlund, Choy, and Szeptycki, "Water in the West"



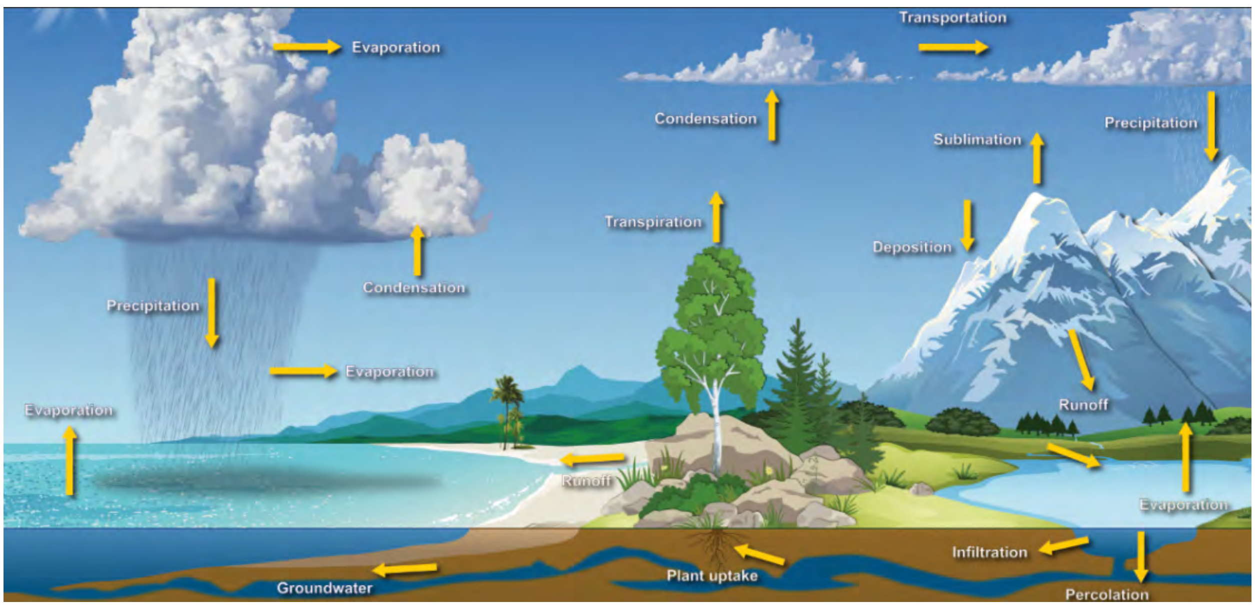
The Colorado River. It's been called "The American Nile." Indeed, the Colorado River is the lifeblood of much of the western U.S. and plays a central role in the economic vibrancy of nearly half of the United States. But as climate change and population growth (see Figure __) have increased pressure on the river, much of the west has grappled, and will continue to grapple, with best managing this resource. For in depth exploration of the challenges relating to the Colorado River, see the Yale School of the Environment five-part series titled, *Crisis on the Colorado*.



The population of Colorado River basin states is expected to grow 53% by the year 2030.

Climate change. The effects of climate change on water include a change in the *timing* of water availability as snowpack melts faster due to increased temperature, change in *demand* due to higher temperatures or drought conditions, change in surface water *availability* and groundwater storage levels, change in the number and intensity of extreme events, change in sea levels, and a change in water *quality* due to varying levels of chemicals, toxins, and saline. In sum, climate change interferes with segments of the hydrologic cycle (Figure ___). This interference makes it difficult to predict and count on water resources. Cities, industries, and consumers face increasing uncertainty when it comes to water.

→ Varying snowmelt. One of the most significant factors related to water in the western United States is snowpack levels. Roughly 75% of the water supplying the western U.S. comes from snowmelt. Less snow, or snow melting earlier in the year due to increasingly warm winter and spring temperatures means less water for many of the states relying on

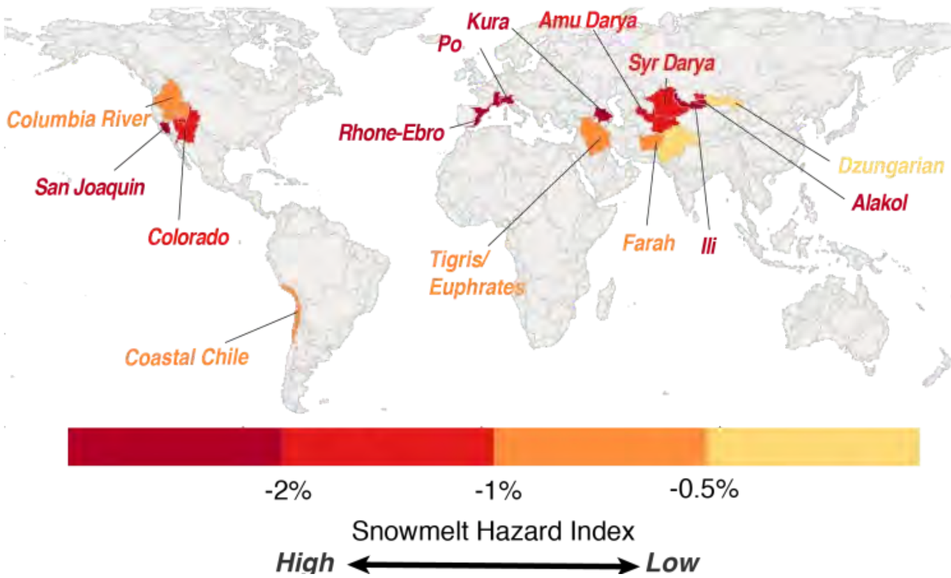


these supplies. The amount of food grown in some of the most productive agricultural counties in the U.S. depends on surface water originating from snow in the Rocky Mountains (see Figure __). California is the leading producer of fruits and vegetables (Figures __ and __) yet the state's climate is primarily desert. Farmers rely on snowmelt to fill rivers; those rivers become irrigation sources for farmers.

→ Drought. As temperatures warm less snow falls and in general, warming temperatures due to climate change contribute to drought conditions. Prolonged drought in turn leads to water scarcity. In times of drought, the water in rivers, streams, and lakes dries up causing communities to rely more heavily on other sources, such as groundwater--a resource itself depleted in times of drought. Drought is tied to the economic health of a region. Cities, communities, and industries require resilient water sources in times of drought, yet, particularly in arid climates, resiliency is difficult to achieve.

Highest risk agricultural areas as climate warming shrinks snowpack

Mountain snowpack serves as a natural slow-release reservoir for agriculture, but climate warming will lead to less snow. A projected 7-degree increase in temperatures could reduce the contribution of melting snow from 38% to 23% of the water available to grow crops in the Colorado River Basin. *Map courtesy of Nature Climate Change, "Agricultural risks from changing snowmelt."*

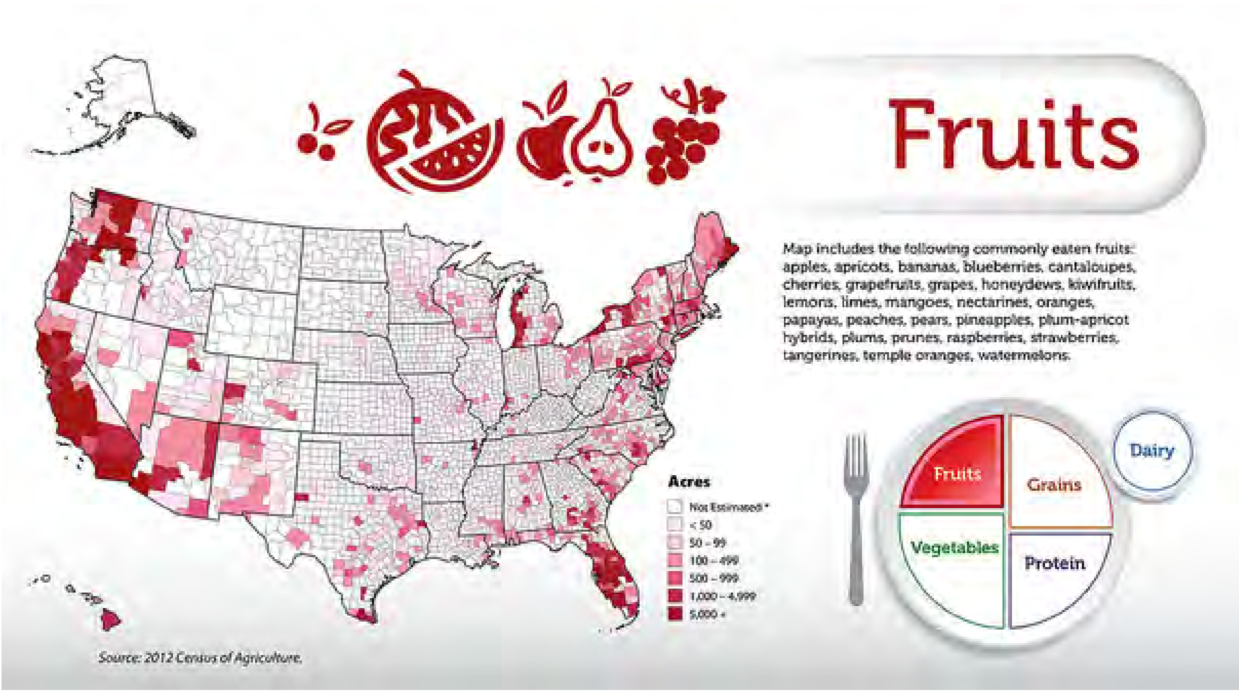


Leading Vegetable States in 2017

Rank	Area harvested		Utilized production		Value of utilized production	
	State	Percent of total	State	Percent of total	State	Percent of total
1	California	39.1	California	57.3	California	56.7
2	Florida	6.6	Washington	5.5	Arizona	12.1
3	Minnesota	6.6	Arizona	5.0	Florida	7.6
4	Wisconsin	(D)	Florida	5.0	Georgia	3.3
5	Washington	6.2	Wisconsin	(D)	Washington	2.4

(D) Withheld to avoid disclosing data for individual operations.

Source: USDA NASS Vegetables 2017 summary



Pollution. Water seems plentiful. In fact, 72% of our planet is covered in water. And there's even more under the ground. So we are ok, right? Not exactly. Of that bounty, most--97%--is seawater and only 1% of the freshwater on the planet is available to us. A majority is locked away in icecaps. Pollution threatens the freshwater we do have, decreasing the supply of safe water consumed in homes, agricultural, and business. Water pollution, in the form of toxins, chemicals, or microorganisms, degrades water quality and the surrounding environment. Causes of water pollution include sewage, industrial water, eutrophication, and nuclear waste. For a thorough exploration of the myriad causes of water pollution, including exploration of the types of water pollution like microplastics and chemicals, see *The Water Pollution Guide*.

Competing stakeholder interests. Because everyone needs water, everyone has a stake in how it is used. Table ___ breaks down a number of the stakeholder groups involved in water discussions. Often these groups have different approaches and opinions. The amount of water in any given area at a particular time is unpredictable and certainly finite. Therefore, what are called "water wars" or water conflicts can be contentious as they crop up among different groups and populations as well as different countries. Water conflict in the western U.S. is an ongoing concern as exemplified in the story of Porterville, CA, a small town where wells ran dry during the state's 2011-2019 drought and hundreds of residents were left without water. Water restrictions in urban areas were met with pushback and criticism, particularly from those who felt the agricultural industry, responsible for 40 to 80% of water use in the state (depending on the data source), wasn't sacrificing enough. Competition for water among various stakeholders including urban, agricultural, and energy sectors will most likely increase as population and demand also rise.

SECTOR	STAKEHOLDER
Public	Utilities, local governments
	Hydropower generation companies
	National environmental authority
	Local environmental authorities
	Water authorities
	Irrigators
Private	Utilities
	Hydropower generation companies
	Bottled water and soft-drink companies
	Agricultural associatons
	Industries
Academic	Research Centers
	Universities
Local Communities	River associations, water boards, irrigation boards
	Indigenous communities
International Cooperation	Multilaterial co-op organizations (e.g. WB, IDB)
	Governmental co-op agencies (e.g. GTZ, USAID)
	Non-Governmental Organizations

Many Porterville residents had to import water from outside their homes for basic use. Here, Guillermina Andrade, who hadn't had water for two years, pours water into her toilet to flush it. Credit: Genaro Molina, LA Times.

Consumer comfort. As traditional water supplies come under threat from climate change, increased demand, and pollution, alternative water sources are an option. Sea water and recycled water (also called reclaimed water or referred to as "toilet to tap" efforts) are two of the most referenced alternative sources. While these alternatives present viable possibilities for water supply, they aren't well accepted among consumers and the costs of desalination can be prohibitive. Research demonstrates recycled water is often met with disgust and associations of contamination from consumers. See Table __ below for common associations researchers found related to recycled and desalinated water from sample groups in Africa and Australia. Transcending existing consumer comfort levels will be key to moving forward with supply alternatives.

Frequencies and column percentages (in brackets) of the affective imagery of respondents for country and type of water.

Category	South Africa		Australia	
	Recycled water	Desalinated water	Recycled water	Desalinated water
1. Cleanliness (clean, clear, pure, purified, hygienic)	57 (26.4%)	59 (27.2%)	22 (10.7%)	31 (15.9%)
2. Disgust (disgusting, rotten, eew, yuck, toilet, urine, poo, stinky, gross)	25 (11.6%)	0 (0.0%)	29 (14.1%)	3 (1.5%)
3. Contamination (dirty, polluted, used, wastewater, waste, grey water, impure)	33 (15.3%)	17 (7.8%)	47 (22.9%)	18 (9.2%)
4. Organoleptics (tasty, salty, tasteless, taste, fresh, refreshing, cold)	8 (3.7%)	29 (13.4%)	8 (3.9%)	11 (5.6%)
5. Environment (environment, conservation, green, planet, sustainable)	12 (5.6%)	3 (1.4%)	24 (11.7%)	6 (3.1%)
6. Cost (expensive, cost)	3 (1.4%)	6 (2.8%)	2 (1.0%)	14 (7.2%)
7. Minerals (Minerals, NaCl, salt)	0 (0.0%)	28 (12.9%)	0 (0.0%)	38 (19.5%)
8. Uses (Garden, irrigation)	6 (2.8%)	2 (0.9%)	10 (4.9%)	0 (0.0%)
9. Bottled water (Bottled water, valpre, aqua, volvic)	10 (4.6%)	7 (3.2%)	3 (1.5%)	1 (0.5%)
10. Saving water (saving water, less wastage)	15 (6.9%)	0 (0.0%)	9 (4.4%)	0 (0.0%)

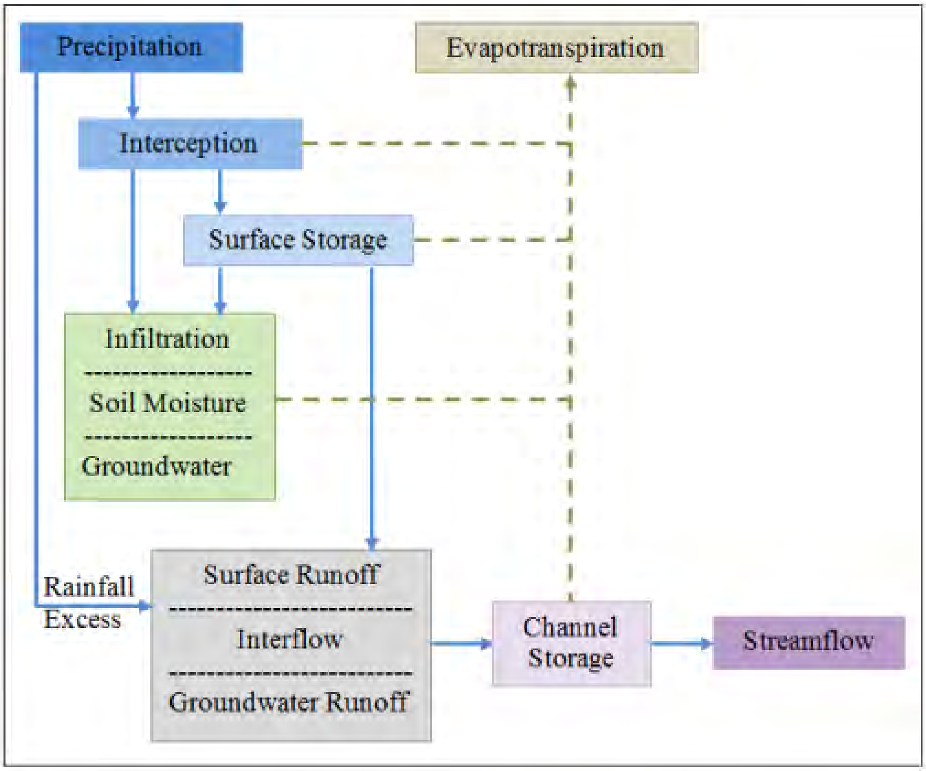
Data and information. Water use is measured via withdrawal and consumption. Although these metrics appear relatively straightforward, there is much we don't know about measuring water and even more we don't utilize when it comes to data-sharing. There are currently no frameworks for measuring water resiliency, for example. To explore attempts to create such a framework see, the 2018 UK "Measuring Resilience in the Water Industry" report. Additionally, Groundwater science is an increasingly significant area of study focusing on groundwater levels, movement, and use.

Challenges relating to data and information include data sharing, particularly among regions, entities, or nations using varying metrics and platforms as indicators of water supply. For an indepth look at the challenges and possibilities related to water and data, see the Aspen Institute's report *Internet of Water: Sharing and Integrating Water Data for Sustainability.*

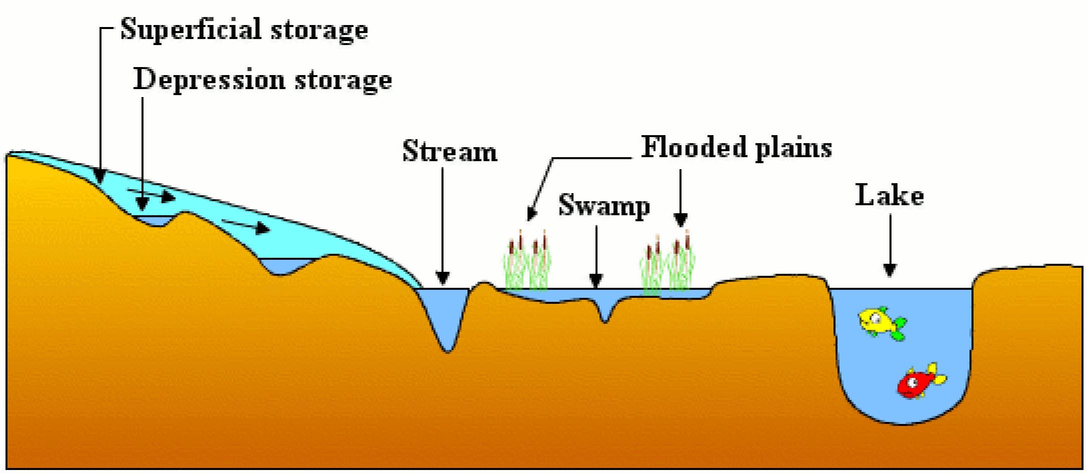
Additional measures, like city sustainability are relevant to understanding water supply data, but are also nascent. One example is the Water Sensitive Cities (WSC) Index, a tool from the Cooperative Research Center for Water Sensitive Cities. See the "Approaches" section below for more information on the WSC Index.

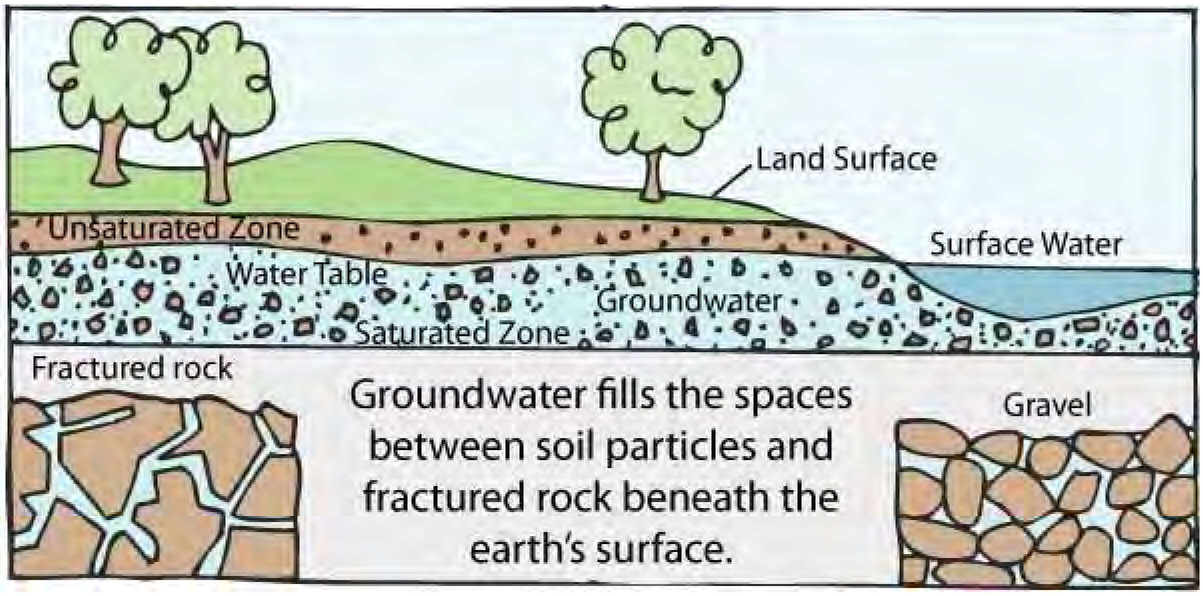
Water policy and water rights. Water is a mobile resource. It moves and is therefore difficult to bind and contain much less own. Yet, particularly in the American West, this hasn't stopped anyone from trying to do just that for centuries. In the west, appropriative water rights dominate (as compared to the east wherein riparian water rights are used) which means water is disconnected from land ownership. Via appropriative rights, water can be diverted at one point and appropriated to use at another point. Priority is given to the most senior appropriators--those who were "first in line" may use as much water as is appropriated to them--and states grant water rights to users. For more information on water rights see the overview provided by the National Agricultural Law Center or see the slideshow breaking down western water rights via the example of Arizona. Water rights, and the contentions they cause in considering tribal water rights, play a role in supply. Increasingly, there is more water appropriated than there is water available for use.

Sourcing. A variety of sources provide the freshwater needed for consumption, agriculture, and additional water needs. Each of those sources involves distinct challenges (such as pollution) and opportunities for supplying water. Reviewing the hydrologic cycle offers further insight into the connectedness of each water source (see Figure ___ for a schematic representation). In essence, a few factors serve as core components of the hydrologic cycle: precipitation, evaporation, storage, and runoff. Precipitation may be in the form of snow or rain; storage involves intercepting precipitation in some way and includes surface storage (see Figure ___) such as lakes or rivers, or below surface storage via groundwater and aquifers (Figure ___). Interception may be naturally occurring or involve human participation, such as rainwater collection. Each component influences the availability of water at a given time and location. California, for example, has turned to groundwater in the face of ongoing drought and must replenish aquifers. Nineteen of Colorado's 64 counties rely heavily on groundwater. Globally, over half of aquifers are at a critical threshold of sustainability as groundwater is withdrawn faster than it is replenished. For more information on components of the water cycle, including a review of the variables and equations used to determine water availability, see the European Commission's technical report on water balances.



The hydrologic cycle, represented schematically.





History & Trends

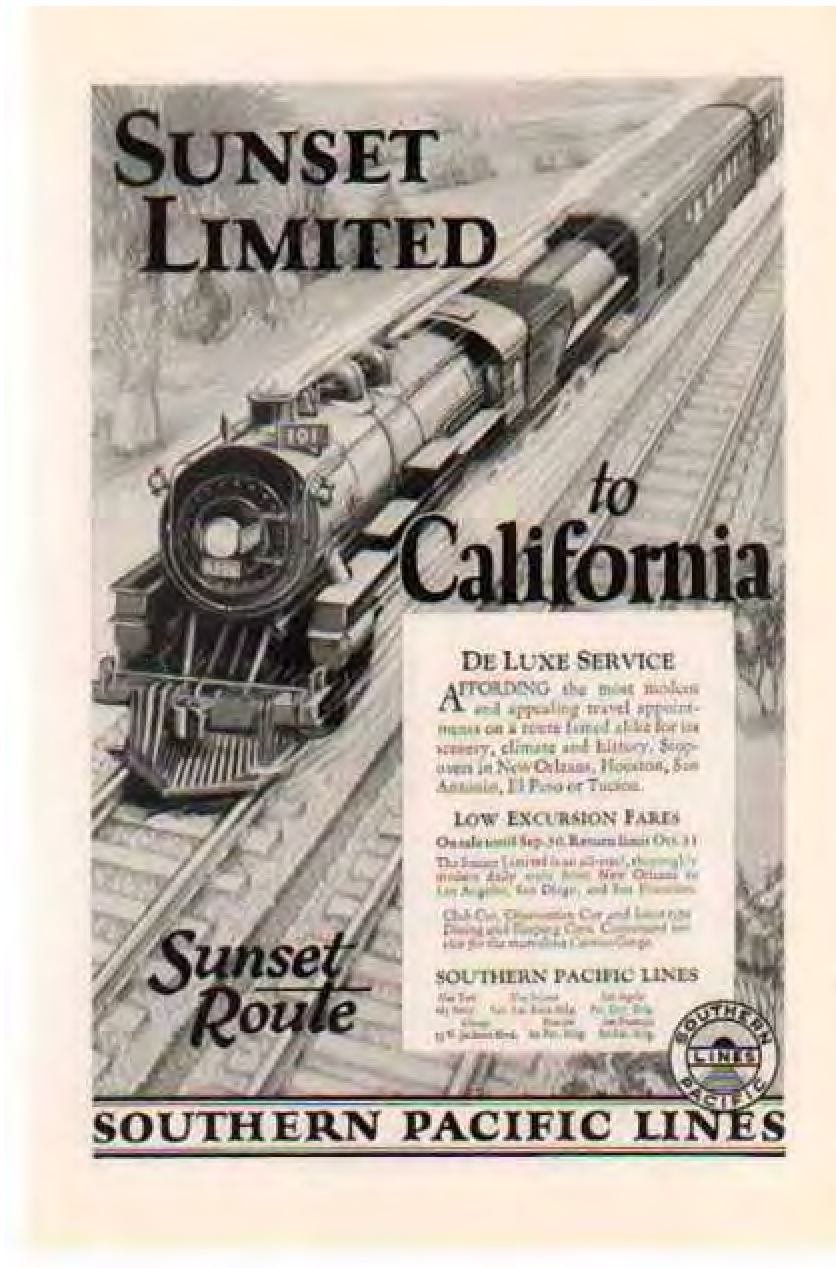
History

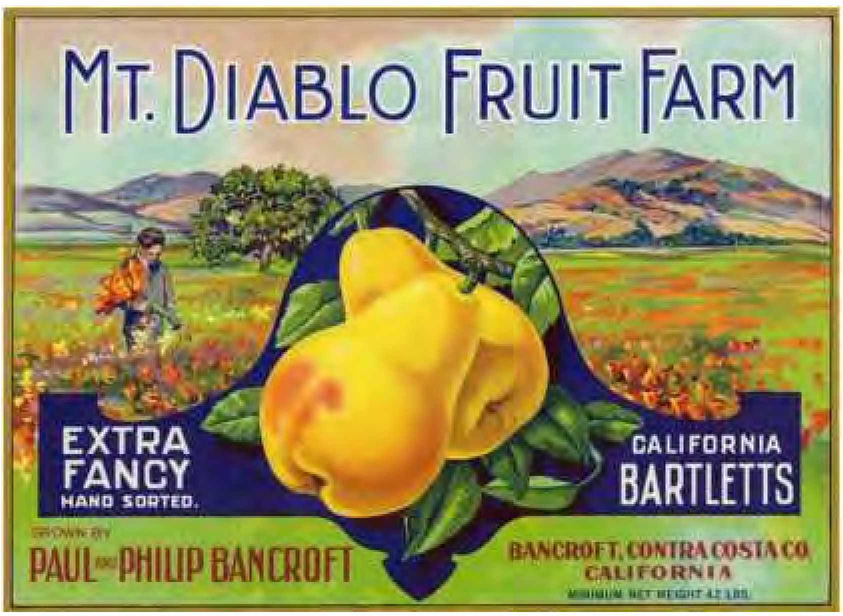
Western waters. The tale of water in the West is, in many ways, the tale of a connection between Colorado, the headwater state for the Colorado River as well as secondary rivers such as the Fraser and Eagle, and California, where the river ends just shy of the Gulf of California. All along the Colorado River's 1,450-mile course are human interventions--places where the river has been diverted, dammed, siphoned, and piped--in service to making the arid and semi-arid landscape not only habitable, but hauntingly hospitable. One of the most heavily engineered waterways in the world, the Colorado River has been a fundamental mechanism in fulfilling the promise of the American West.

Developing the West. Much of the West was settled in response to mining booms. These settlements, and the mining itself, required water. And because water as a resource was less abundant than it was in the East, water rights were grounded in whoever got their first (often referred to as "first in, first in right"). This system allowed miners, and later farmers to divert water from its source and put it to "good use." Historically good use referred to irrigation, mining, domestic, or municipal use. The foundation of this system still exists today via prior appropriation water rights.

Water in the West short video: https://youtu.be/qq6JCVguHtM

Selling the West. In his book *The Dreamt Land: Chasing Water and Dust Across California*, author Mark Arax refers to the early 1900s as a time infiltrated by the “folklore of California climatology.” And this folklore was everywhere. Sponsored by the California State Agricultural Society and companies like the Southern Pacific railroad, editorials and articles appeared in the likes of *Harper’s* alongside ads for travel by train. While advertisements featured a paradise of plenty--oranges and watermelons the size of small boulders--Arax notes the subterfuge behind the sales pitch: “This was fertility supercharged by irrigation and the science of the Agricultural College at the University of California--the most extensive and intensive farming experiment in the world. No other landscape in history had been so bent by the design of man.”





As settlements in the West continued to grow, it became clear the water resources couldn't keep up with demand. The federal government intervened in the early 20th century with the passage of the Reclamation Act, allowing the Bureau of Reclamation under the Department of the Interior to study and fund water development projects in each state. The Great Depression and subsequent public works and job creation efforts meant more water development projects in the early to mid 1900s. While many of these projects were initially intended to provide the infrastructure for irrigation, federal projects--and emerging state water projects--expanded to provide water infrastructure for cities. Las Vegas, Phoenix, and Los Angeles experienced rapid growth in population as well as storage and sanitation infrastructure. For an expansive education on public work projects in the West, see *The History of Large Federal Dams: Planning, Design, and Construction in the Era of Big Dams*, a report by the U.S. Bureau of the

Interior Bureau of Reclamation, the U.S. Army Corps of Engineers, and U.S. Department of the Interior National Park Service.

The Law of the River. It may sound like an early 90s western starring Kevin Costner, but the Law of the River is a term used to represent the laws, court decisions, governing documents, and policies directing management of the Colorado River. The foundation is the Colorado River Compact of 1922, entered into by seven western states. The Compact outlines how the water of the Colorado River is divided among the states. It's governed use for decades but as climate stress continues to cause drought the ongoing utility of the agreement is a topic of debate.

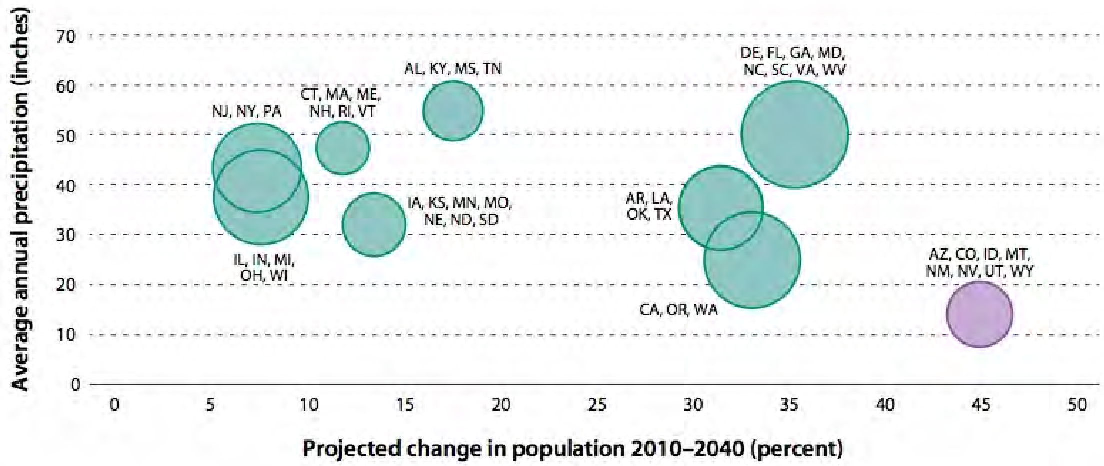
The Environmental Movement. The burgeoning modern environmental movement of the 1960s and 1970s featured a greater understanding for the health of water ecosystems, including the role of water pollution in environmental degradation. A string of legislation reflected the desire to protect water as a resource: the Wild and Scenic Rivers Act of 1968, the National Environmental Policy Act of 1970, the Clean Water Act of 1972, and the 1973 Endangered Species Act. Ongoing development in some cases collided with environmental concerns, setting the stage for conflicting perspectives that continue today.

Trends

Population growth. Population growth is a global phenomenon and, for the West, a local one as well. Western states--the driest in the U.S.--have seen some of the largest population increases in the past decade (see Figure __). Population increases put pressure on resources, including water. Yet we seem to be doing more with less. A 2015 report from the U.S. Geological Survey found as a result of water efficiency behaviors and technologies, water use levels in American households decreased to usages rates not seen since the 1990s.

Average Precipitation and Projected Percent Change in Population, by Census Division

The fastest growing area of the country receives the least precipitation.



Sources: National Oceanic and Atmospheric Administration n.d.; U.S. Census Bureau 2012, n.d.; Weldon Cooper Center for Public Service 2012; authors' calculations.

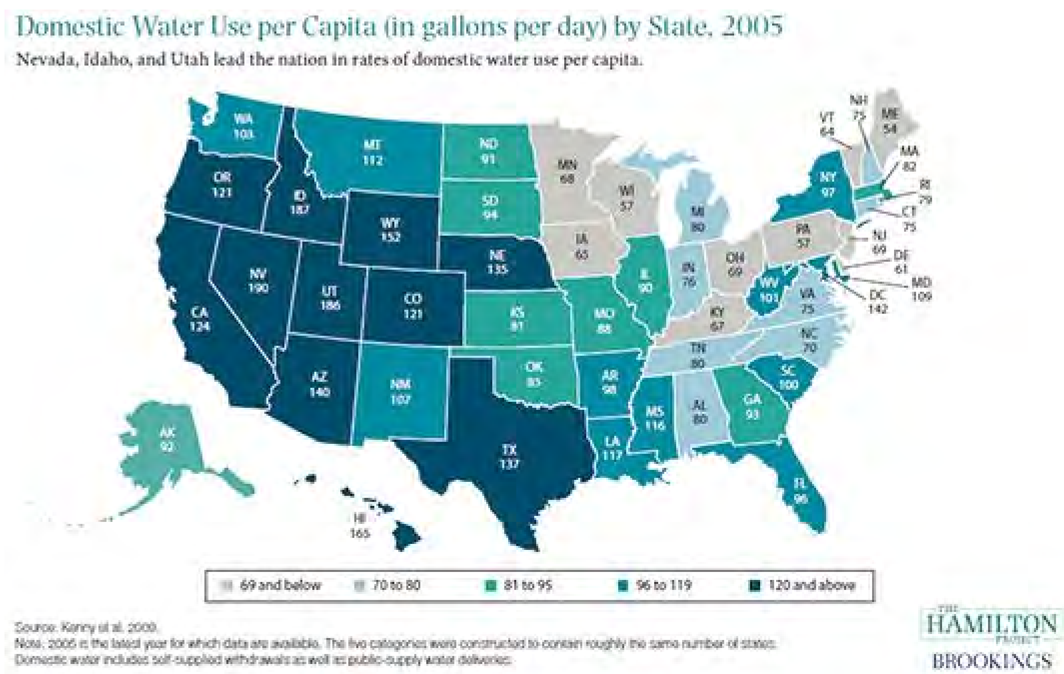
Note: Circle sizes are proportional to the population in each division in 2010. Alaska and Hawaii are excluded from the analysis. The population growth for each division as well as the average annual precipitation for each division are weighted averages using the 2010 Census population of each division. For more details, see the technical appendix.

THE HAMILTON PROJECT BROOKINGS

Conflict and collaboration. While water conflicts have continued into the 21st century, cooperative approaches are increasingly common. Examples include the Colorado River Cooperative Agreement of 2013 and efforts among utilities to collaborate when it comes to supply options.

Addressing water conflict globally via collaboration is a means to not only prevent scarcity, but protect vulnerable populations and build peace. For more on water conflict and global peace building, see the brief animated short from the Wilson Center.

Water use. The driest states also tend to include the greatest domestic consumers of water per capita (see Figure __), in large part because of landscaping and lawn watering.



Extreme events. Extreme weather events, made more intense and frequent due to climate change, affects water supply and scarcity. Intense drought and extreme heat contribute to water scarcity and test resource resiliency. Dry areas are more prone to wildfire threats and, due to dry and hard packed soil, precipitation runoff and floods.

Municipal utility consolidation. The water industry has long been a fragmented market. The predominant model is one in which each community is served by its own water utility. There are roughly 53,000 water suppliers in the U.S. compared to around 3,300 electricity suppliers. Shrinking populations in rural markets and the need for high-volume service to generate profit have prompted water utilities like EJ Water Cooperative to consider consolidation. Other recent consolidations include the DELCORA Aqua merger and a variety of in process deals facilitated by the expansion of Fair Market Legislation. FML allows municipalities access to resources for infrastructure improvements.

Tribal water rights. To refer to tribal water rights as a "trend" feels egregious, however, it is representative of the extent to which the rights of indigeneous people have been granted consideration over the past few hundred years. The Supreme Court case *Winters v. United States* confirmed water rights were implicitly granted to reservations at the time of their creation, granting them senior prior appropriation. In 2018, the Bureau of Reclamation and the Ten Tribes Partnership produced the Colorado River Basin Ten Tribes Partnership Tribal Water Study. The study quantified the amount of water allocated to the 29 tribes in the Colorado River Basin and acknowledged--despite the significant amount of over 2.8 million acre feet allocated to tribes each year--the ongoing conditions of water scarcity for many tribes. The report also concludes: "none of the Partnership Tribes currently has the basic infrastructure or legal and administrative flexibility to fully use or realize the full economic value of its reserved water rights." For more information on Indian water rights see the 2019 Congressional Research Service report *Indian Water Rights Settlements*.

Populations & Agents

Vulnerable Populations

Women and children. Water scarcity places an undue burden on women and children. Globally, women walk an average of 4 miles a day--often with children in tow--to retrieve water. A study in Tanzania found reducing the journey a girl takes to retrieve water from 30 minutes to 15 minutes results in a 12% increase in girls' attendance at school. Further, low water supply levels are often accompanied by other risks such as decreased water quality and sanitation, both of which also affect women and children in greater numbers.

Residents of water scarce areas. Additional populations at risk include those in regions where water is scarce and drought is more likely such as the western United States, and the Middle East. Within these regions, water scarcity and supply challenges affect a variety of industries beyond agriculture and recreation. Affected industries include the paper and pulp industry, the semiconductor industry, and textile production.

Agents

Category	**What they do**	**Examples**
Industry Sectors	Rely on water to produce goods/services and sustain industry. Participate in both positive and harmful water use practices thereby affecting other industries and their water uses.	Recreation Agriculture Energy
Consumers	Receive varying levels of infrastructure support and water supply. Shape water conservation and reuse practices via public opinion. Advocate for access to safe water and engage in a range of water use behaviors.	Indian Tribes Urban centers Rural communities
Water-managing bodies	Represent larger water interests including various populations, spread out among different areas, with a range of water needs. Plan for water needs and collaborate with other entities to address needs via policy, infrastructure, or conservation.	Bureau of Reclamation (manages much of the Colorado River's supplies) Regional water boards

		Transboundary river basin management authorities
Water rights sector	Industries and professions related to water that offer advice or guidance on water supply issues.	Attorneys Land management
Private companies	Package and sell water, often in plastic bottles.	Nestlé Waters Danone
Water utilities	Provide water supply systems, maintain infrastructure	Denver Water American Water Works Association

Existing Approaches & Workarounds

Approaches

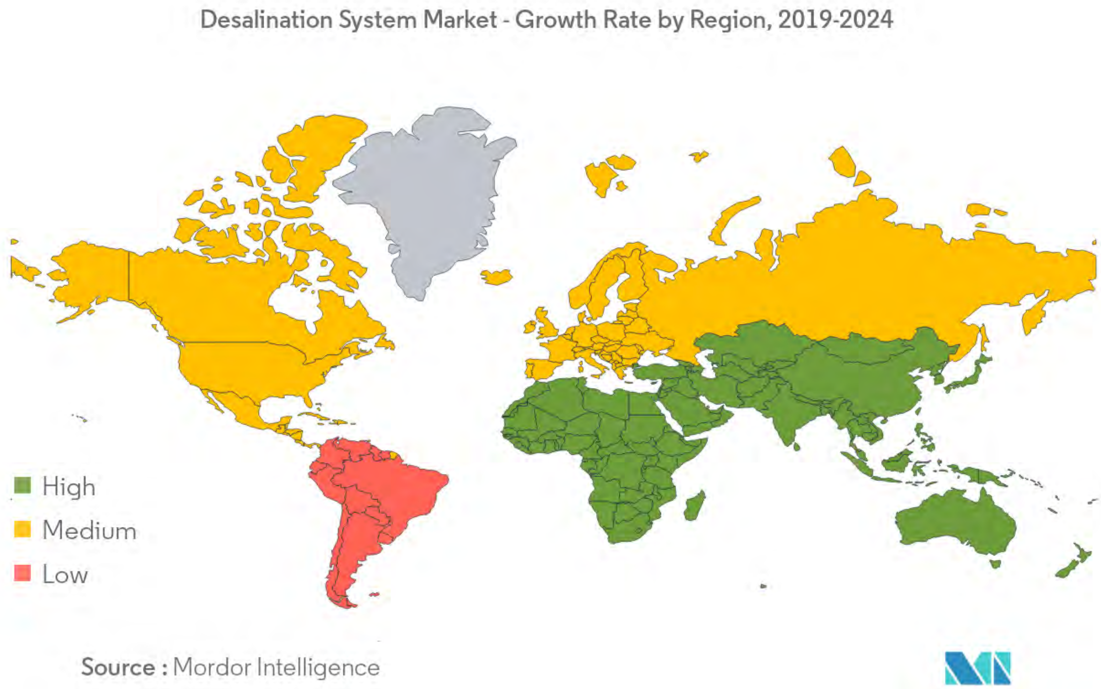
Before analog was analog. When it comes to water, everything old is new again. Communities in South America are returning to ancestral and Indigenous water practices to conserve water resources and increase resiliency. Studies or these ancient practices are revealing new ways to think about water technology.

Water markets and water trading. Water markets introduce a degree of flexibility into existing water rights arrangements. Water is traded and sold through short and long term leases as well as permanent sales. In December of 2020, water became the most recent commodity to be traded on Wall Street with $1.1 billion in contracts tied to water prices in California. The Nasdaq Veles California Water Index (NQH2O Index)--launched in 2018 at a value of $371.11 per acre foot--monitors the price of water rights across California's largest regions for water trading. As of January 20, 2021 the value was $506.66, representing water leases and sales of the prior week. For more information on water markets, see the article, "Water Markets in the United States: Trends and Opportunities."

Reactions to water futures and water trading are mixed. Do these mechanisms commodify water in ways antithetical to notions of water as a human right or do they offer safety nets for water consumption in an uncertain future?

Desalination. Seawater is abundant. So can we convert that abundance into a means of addressing the scarcity of freshwater in some regions? Desalination--the process of removing mineral components from salt water--is an increasingly common practice, with more than eleven desal plants in California and over 20,000 worldwide serving more than 300 million people. But it is also costly and not without its environmental drawbacks. What happens to all of that salt, for example? Recent resource retrieval efforts are exploring ways to reuse the brine produced as a byproduct of desalination.

The desalination market is delineated by the technological method used to separate salt from the water such as membrane or thermal technology. The compound annual growth rate for the market overall is 10% in the next five years, with the largest growth opportunities in the Middle East and North Africa (see Figure ___). Major market players include Veollia, Suez, ITT Corporation, and Fisia Italimpianti.



Water sensitive cities. Learning how cities may do more with less is a growing consideration and one that applies to water. The Water Sensitive Cities (WSC) Index charts a city's progress to water sustainability and is an example of an holistic approach to a city's water supply.

Water sensitive cities index video: https://youtu.be/ybG9lOhbDDc
https://watersensitivecities.org.au/solutions/wsc-index/

Water and tech. The digitization of water. The internet of water. There are many ways to talk about the growing synergies between water and technology and a good deal of those synergies apply to water supply and scarcity. A few examples involve the use of data to aid consumers, the use of drones to locate water leaks, and the use of "smart membranes" to desalinate water. The EPA released a report in 2014 outlining a number of promising areas within water ripe for technological innovation and encouraged broader application of technology to the water sector. Thought leaders agree and discussions over the future of water technologies are interesting entry points into understanding the myriad of possibilities. Examples of companies devoted to noteworthy water technologies (as identified by BlueTech Forum, a water innovation conference and showcase) include Nijhuis Industries' mechanism to desludge water and WaterMax's aeration technology for wastewater treatment.

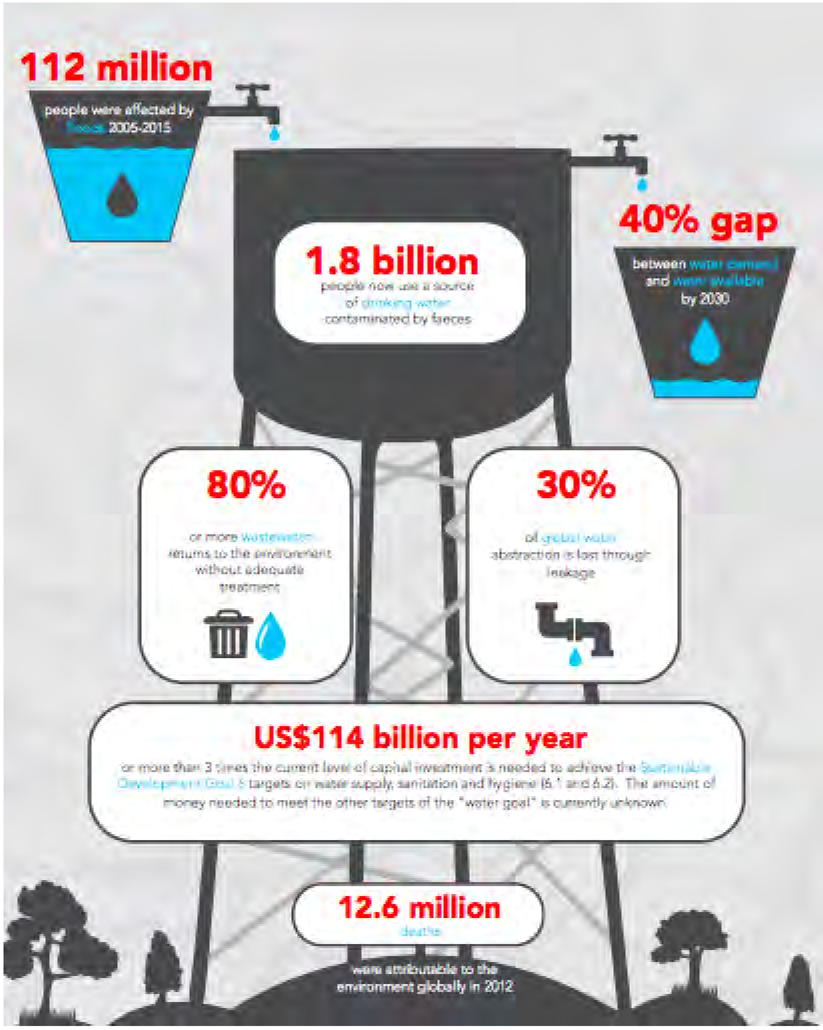
Water reuse and repurposing. One of the most promising areas for the application of technology is reusing and repurposing waste water. Wastewater facilities in the U.S. discharge roughly 32 billion gallons of wastewater per day. Reusing that water would alleviate much of the stress on existing sources of supply, like groundwater. This burgeoning area of innovation is not without its hurdles, however, chief among them is public reaction to wastewater reuse. A handful of cities around the world have seized upon repurposing as a solution; their work and efforts serve as examples for greater attention to water reuse and repurposing more broadly. The global water and wastewater treatment market is expected to reach $211.3 billion by 2025.

Satellite data. On-the-ground data has traditionally been the only way to learn about water supply. Today, satellites help provide more accurate data about surface water and more importantly, can reveal info about water quantity under the ground. NASA's Gravity Recovery and Climate Experiment (GRACE) mission has been providing satellite data and imagery regarding global water levels for the past 15 years and will continue to provide information via a launch of Grace Follow On (GRACE-FO) in 2018. Future considerations, however, include how to best make sense of, compare, and share the vast amounts of incoming satellite data across platforms. A Sentinel-1 satellite for example, maps the world every 12 days and delivers 1 raw terabyte of data per day. Where to store that data, how to organize it, and how to train users on its application are just a few of many pertinent questions.

Workarounds

Deeper wells drawing more groundwater. Groundwater depletion is the state of groundwater extraction exceeding replenishment. When surface water resources are depleted, groundwater is even more taxed. But more and deeper wells drawing greater quantities of groundwater is a short term solution to an ongoing problem.

Ignoring infrastructure. Roughly 2.1 trillion gallons of treated water is lost each year in the U.S. due to infrastructure failings such as leaky pipes or broken water mains. In fact, 30% of global water is lost each year due to infrastructure failings (see Figure ___).



Privatization of water sources. Blame bottled water. As sales of bottled water have boomed in recent decades companies have eagerly gobbled up sources. Nestle, for example, owns 50 freshwater springs in the U.S. Access to natural springs and pristine supplies are central marketing claims for companies selling water in a bottle. Criticisms of these efforts are numerous and widespread, ranging from the use of plastics (and the ramifications for the body as well as the planet) to how the privatization of water denies water to those in close proximity to a source.

Additional Resources

For a story map depicting the issues related to water in the west, see https://storymaps.arcgis.com/stories/7dcc2493f3a04e9e972b36914a9c66b7

For more on the “Groundwater Crisis” see https://blogs.ei.columbia.edu/2015/08/03/the-growing-groundwater-crisis/

For one of the most celebrated tomes on water in the West, read *Cadillac Desert: The American West and its Disappearing Water,* by Marc Reisner.

For more on water affordability in Colorado see the article from Water Education Colorado on COVID-19 and water cost.

For more information on water affordability nationwide, see the National Association of Clean Water Industries 2019 Clean Water Index.

Water Quality and Safety

More people die from unsafe water than from all forms of violence, including war. While surface water quality has improved in many parts of the developed world in recent decades, those improvements face threats from economic growth, population increases and shifts, and climate change. Climate change and its effects increase the possibility of compromised water quality in the U.S. and around the globe. A warming climate produces warmer water temperatures wherein harmful bacteria or algal toxins thrive, creating dangerous conditions for water use and water recreation. The growing frequency and intensity of extreme climate events such as storms and floods means more water runoff, eutrophication, and pollution of water sources and in coastal areas, salt-water contamination of freshwater sources poses a threat to water quality. Those living in poverty, in rural areas, and those who are members of vulnerable communities are disproportionately susceptible to unsafe water. Populations most at risk for lead exposure in drinking water, for example, are low-income, minority status, in urban areas, or residing in buildings constructed prior to 1978. Water quality is also tied to food production. Salinated water, resulting from runoff, poor irrigation systems in dry areas, and intrusion of sea water reduces global agricultural output each year by numbers equal to feeding 170 million people. Finally, water quality runs downstream. Literally. When the quality of a river is compromised, economic growth for areas downstream drops by roughly one-third due to water quality's central role in recreation and tourism, community health, agriculture, energy production, and manufacturing. Water quality is a wicked problem for many reasons. It is highly connected to other wicked problems such as extreme climate events, infrastructure, and sanitation. It is highly susceptible to the various effects of climate change. Finally, there is a great deal of unknowns when it comes to measuring, understanding, and regulating water quality, including the potential harm of emerging pollutants like microplastics and pharmaceuticals. Despite these challenges, a concern over water quality tops public opinion on water issues throughout the U.S. and safe, accessible water is fundamental to human growth and development around the world.

How might we safeguard water quality to provide clean, safe water to all users?

<table>
<tr><th colspan="2">Contributing Factors</th></tr>
<tr><td colspan="2">Climate change (rising temperatures, vulnerability to extreme events, scarcity, pollution)
Public opinion
Individual households (lack of plumbing, waste disposal, individual wells)
Community challenges (contamination, depletion, cost, infrastructure)
Data gaps</td></tr>
<tr><th colspan="2">History & Trends</th></tr>
<tr><td>Development and urbanization
Water treatment
Pollution and Policy</td><td>Tribal water access
Online plumbing
Stress on urban water systems
Rising income inequality</td></tr>
<tr><th colspan="2">Populations & Agents</th></tr>
<tr><td>Infants and older adults
Rural and urban populations</td><td>Regulatory agencies
Water utilities
Individual households
Industry
Environmental and advocacy groups</td></tr>
</table>

	Private companies Food and beverage sector Tourism and recreation sector
Existing Approaches & Workarounds	
Information sharing Water monitoring technologies The IoT Water safety planning Septic technologies	Bottled water Nonprofit assistance In-home systems Dated regulations

Contributing Factors

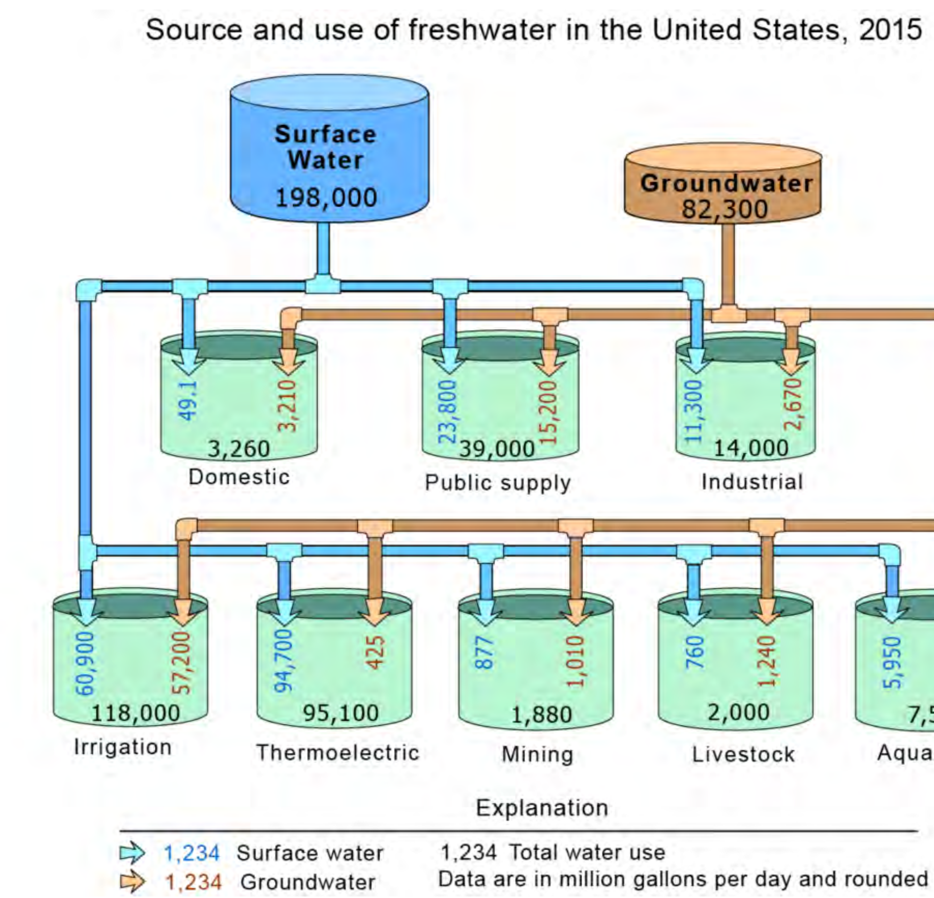
Climate change. The change in our climate has consequences for the quality and safety of water. This is not difficult to imagine. After all, climate is a term used to represent the interconnected conditions of temperature, precipitation, humidity, atmospheric pressure, and other meteorological events over time. A change in one has consequences for the other components of this connected system. Interventions in any of the following contributing factors related to climate change will have an effect on water quality and safety.

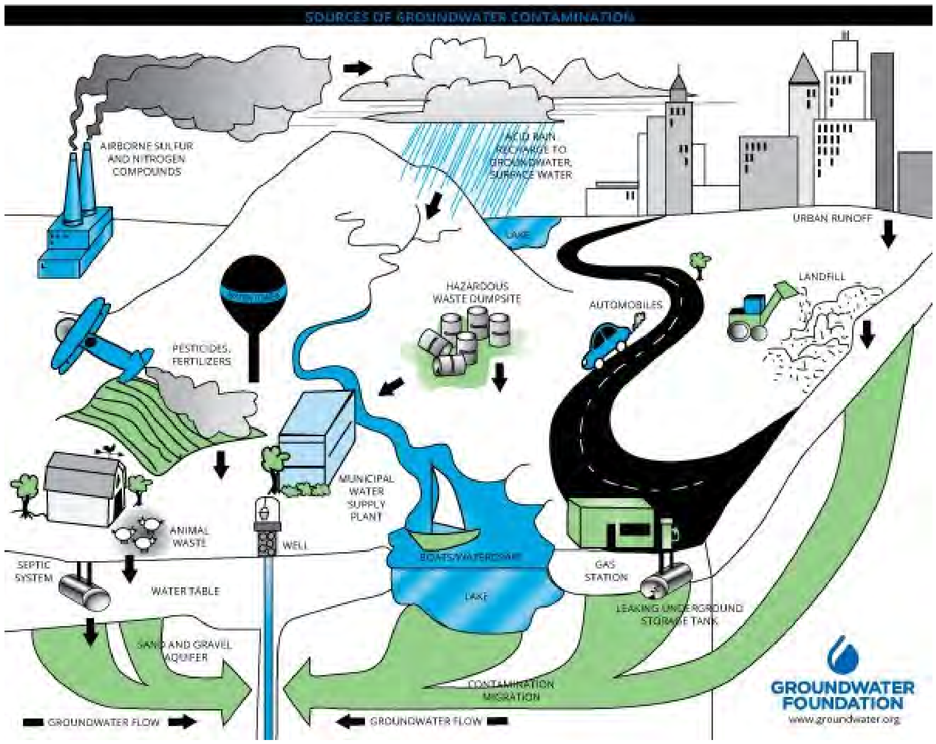
→ **Rising water temperatures.** Greenhouse gases in the air--a result of fossil fuel emissions--directly contribute to the air's warming temperature. In turn, rising temperatures have a number of consequences for water quality. Rising air temperatures means corresponding rises in water temperatures with effects on the levels of pollutants, pathogens, microbes, and toxins.

→ **Pollution.** Burning fossil fuels releases a variety of gases and chemicals into the air. Many of those make their way back to the earth's surface via precipitation and pollute water supplies. Pollution isn't simply toxic chemicals, however. Metals, organic materials, microplastics, and pharmaceuticals are all found in drinking water supplies in various amounts and all pose risks to individual, community, and economic health. The existence of each of these pollutants in drinking water is the result of human activity, often stemming from unsustainable growth, climatic conditions, or failure to take note of or invest in "downstream" consequences of waste disposal, manufacturing, and energy production.

There are multiple methods for decontaminating water as well as resources for avoiding water risks in the first place. For the latter, see the World Health Organization's *Water Safety Plan Manual*. For an in-depth discussion of water safety in the face of climate risk, see the World Health Organization's report on *Climate Resilient Water Safety Plans*.

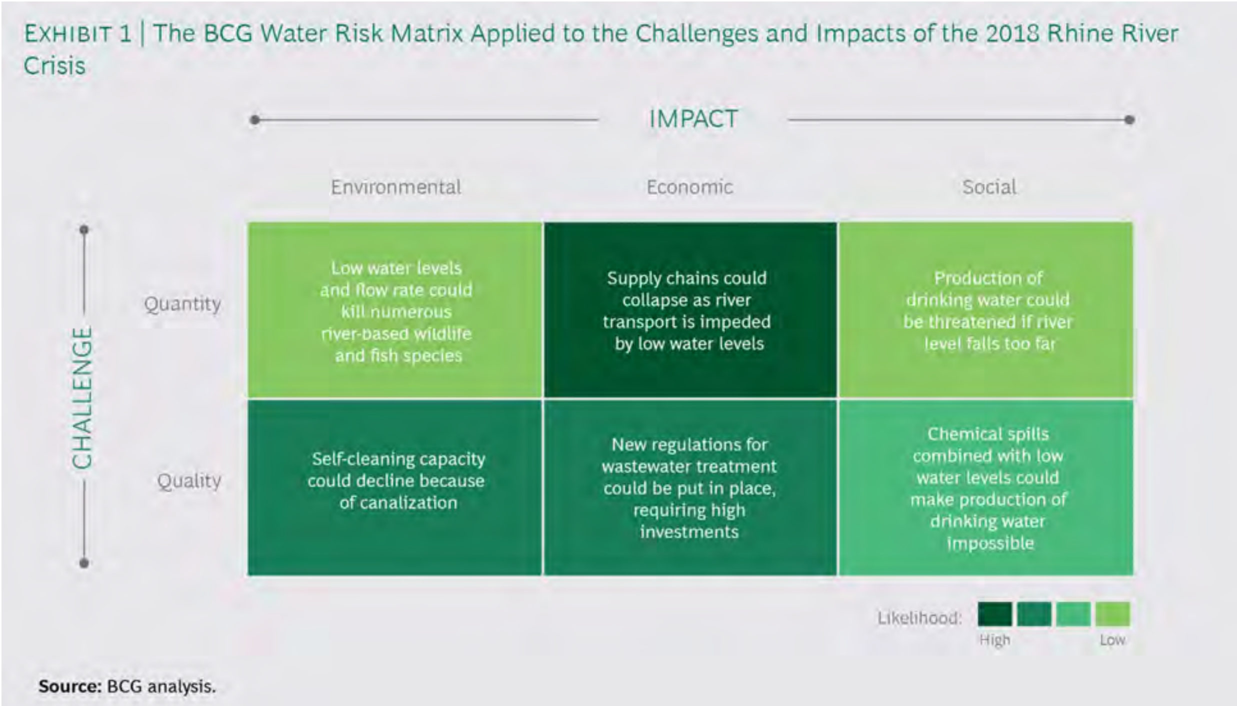
Groundwater pollution is an additional concern. Roughly 26% of our drinking water comes from groundwater, which is also used for other sources such as agriculture (see Figure ___). Groundwater pollution may be caused by infiltration of chemicals into the soil and underground water supply. Oil and chemical spills, urban runoff, and illegal waste dumping are a few potential sources of groundwater pollution (see Figure __).





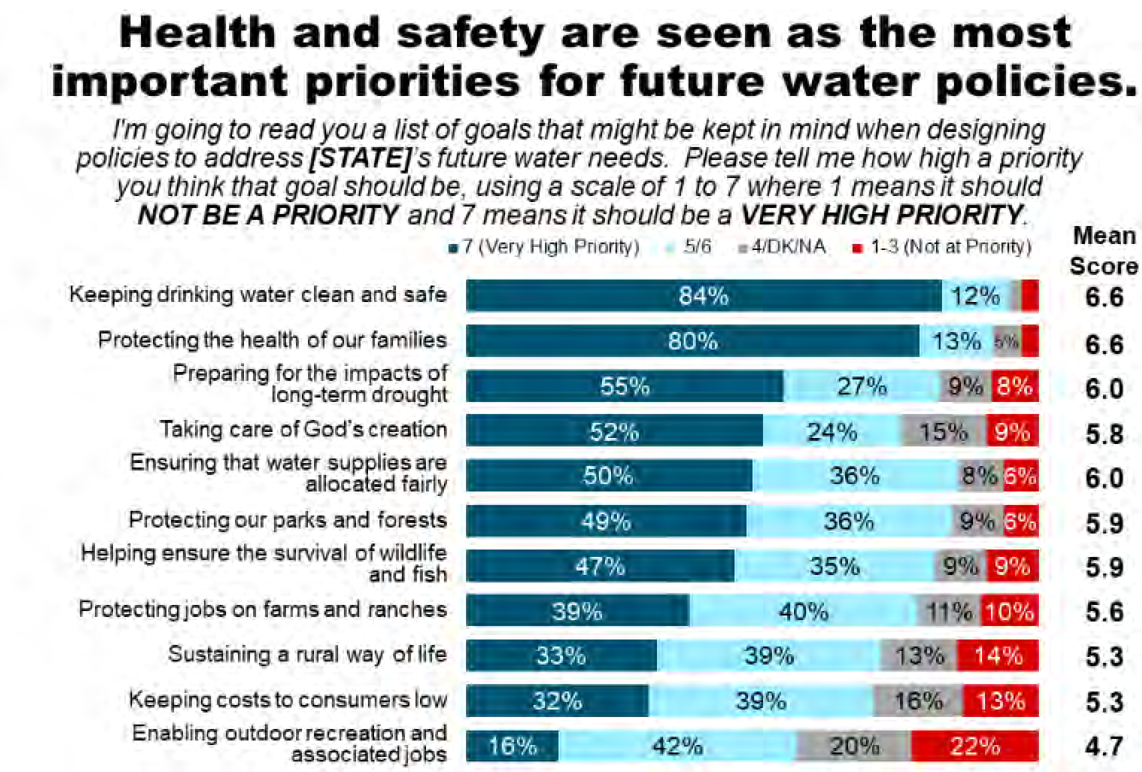
→ Vulnerability to extreme events. Climate change increases the frequency and intensity of extreme events such as hurricanes, droughts, floods, and wildfires. Each of these events threaten water safety both by affecting access and the quality of water sources. Hurricanes and floods can overwhelm water and sanitation systems, creating overflow and potential contamination. Droughts create water scarcity scenarios wherein health and safety of communities is at risk due to less access to water supplies. Wildfires leave landscapes barren, thereby increasing the likelihood of water runoff and the presence of contaminants in supplies. Wildfires also threaten infrastructure, creating dangerous scenarios regarding the ability to get clean, safe water to those who need it.

→ Scarcity. Extreme heat, droughts, and growing populations place demand on existing water supplies. When supplies are already limited and then overtaxed, water safety becomes an issue (see Figure __). Existing wells may need to be dug deeper into groundwater supplies, an untenable solution. Communities may need to consider costly mechanisms for importing water. Water scarcity may also create poor sanitation conditions.

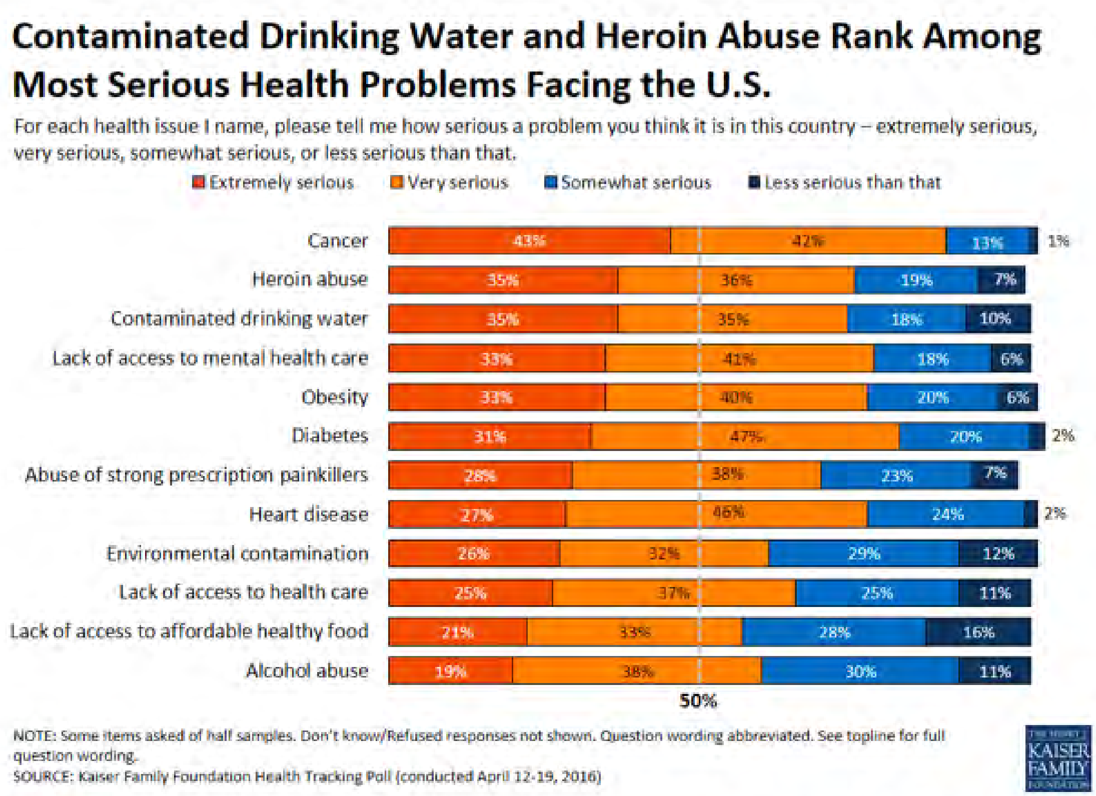


The Water Risk Matrix reflects the connection between water quality and quantity.

Public opinion. In the midst of a social and political climate wherein it seems difficult to find a group of people who agree about anything, there appears to be one uniting factor: clean, safe water. According to a Water Foundation poll of U.S. voters in the west, clean, safe water tops the list of water concerns (see Figure __) and transcends party lines. A national poll reveals Americans rank safe water as a top health concern, less serious than cancer but in line with heroin use (see Figure __).



Water pollution rated as serious as heroin abuse



WaterPolls.org

Source: 2016 Kaiser Health Tracking Poll

Infrastructure. Infrastructure plays a large role in water quality and safety. It includes what is available to individual households as well as the mechanisms used to get water to cities and towns via community systems.

→ Individual households. It is tempting to think of water access and safety issues as irrelevant to the United States. When we think about those without access to clean, safe water, we tend to consider places across the globe. In fact, access to clean, safe water is an issue closer to home than many of us realize.

Indoor plumbing. More than 2 million Americans lack access to safe running water and basic indoor plumbing. This includes roughly 1.6 million households without at least one of the following: indoor plumbing providing hot and cold running water, a sink, a bathtub or shower, or a flush toilet. Native American households are 19 times more likely than white households to lack indoor plumbing. For a comprehensive view of access to safe and clean water, see the report titled *Closing the Water Access Gap in the United States: A National Action Plan*.

Substandard waste disposal. Over 21 million households in the U.S. use a private septic system, and not the public sewer system, for waste disposal. Underground septic tanks are most common in rural areas, particularly in New England and the South. The number of septic systems for individual homes is on the rise, an area of concern during stay-at-home orders during the pandemic. However, there is a good deal of missing information when it comes to septic system use. The last time each household was asked about their waste disposal system was the 1990 U.S. Census. While regions and communities may keep track of this data individually, it is not widely shared or standardized, contributing to data gaps in our understanding of the issue. Private septic systems may be more prone to failure and pose a health risk, especially for those with older systems, and are vulnerable to disruption in times of disaster or extreme events.

One example of this health threat is the resurgence of hookworm in the rural South. Associated with regions of extreme poverty, hookworm's widespread appearance in Lowndes County, Alabama, is a wakeup call for facing the disparity in access to safe water.

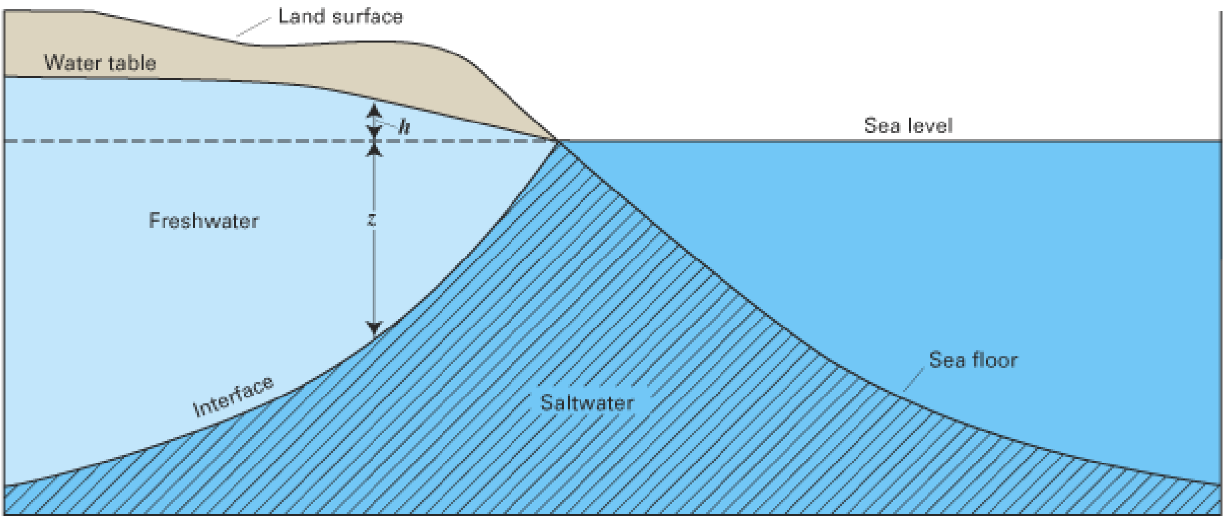
Untreated sewage in a Blackbelt neighborhood. CREDIT ALABAMA CENTER FOR RURAL ENTERPRISE

At-risk wells. About 43 million people--15% of the population in the U.S.--get their water from private wells. These wells are not regulated by the Federal Drinking Water Act or by state laws and regulations. A 2009 study of private wells found roughly 1 in 5 wells contained at least one containanment at higher than human-health benchmark levels. The rates of contamination emphasize the need for widespread testing and monitoring. See the US Geological Survey study for a complete review of these contaminants and the implications of each.

→ Community system issues. In addition to the challenges within individual households, infrastructure challenges exist within the water systems serving cities and towns. Those challenges include:

Contaminated systems. Contaminated groundwater can threaten an entire city's drinking water supply. Denver, Colorado, is one example of a metro area with traces of "forever chemicals" in the groundwater. Forever chemicals, called so for their resistance to any decomposition or dilution, include per- and polyfluoroalkyl substances (PFAS) used in firefighting foam and some consumer products. While the PFAS levels were found to be under EPA health advisory guidelines in most tested areas, four locations exceeded these levels and a number of surface water sources also exceeded health advisory levels. For complete sampling data, see the sampling dashboard. The state of Colorado has passed new restrictions on use of the firefighting foam but concerns remain, especially given the moniker of the contaminants. Adding to concerns are questions regarding the accuracy and safety of the EPA health advisory guidelines and the need for more current and appropriate metrics. Personal note: as a result of learning more about PFAS, this researcher is installing a reverse osmosis system under her kitchen sink.

Depleted systems. What happens when the water runs out? This is a question more and more communities in the west are finding themselves answering. A study of groundwater wells in western states found one out of every 30 wells was dry between 2013-2015 and in the Central California Valley and the western High Plains, that number was one out of five. When already depleted systems are pumped for more water, the quality of the water may decline as surface water or proximate saltwater reserves are inadvertently pumped into the aquifer (see Figure __). Accurate and ongoing well and aquifers measurements are necessary to monitor and track supply and quality.



Cost and affordability. The cost of water services vary widely, even within a county (see Table ___). In areas where many people live below the poverty line, water customers may have difficulty keeping up with rates and can face interruptions in their water service. This is even more pointed during the pandemic. Certain areas in the U.S. are seeing increase in water rates due to drought or the cost of needed infrastructure improvements. Water utilities may make financial assistance available to customers but these efforts fall short of meeting the needs of the increasing number of low-income households nationwide. Rates in Baltimore, Maryland, for example, are projected to more than double in an eight-year period. Water shut offs have health repercussions for individuals and unpaid water bills can increase the cost for utilities. For more information on the issue of affordable water and the legal challenges involved in providing water assistance, see the University of North Carolina's Environmental Finance Center overview of "Navigating Legal Pathways to Rate Funded

Customer Assistance Programs" and the EPA compendium on Customer Assistance Programs.

Table 1. Most and Least Expensive Water Systems in Los Angeles County

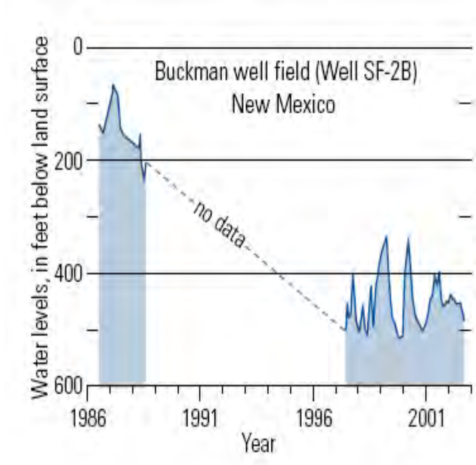
System Name (Population Served)	Annualized Cost for 18 CCF
Five Most Expensive Systems	
1. CA Water Service Co.—Lake Hughes (711)	$2,244
2. CA Water Service Co.—Leona Valley (1296)	$1,834
3. LA County Water Works Dist. #21—Kagel Canyon (991)	$1,658
4. Park Water Company—Bellflower/Norwalk (67,200)	$1,539
5. Park Water Company—Lynnwood/Compton (45,400)	$1,502
Five Least Expensive Systems	
1. Maywood Mutual Water Co. #1 (5,500)	$145
2. Pico Rivera Municipal Water Co. (39,000)	$192
3. Lomita Municipal Water (20,256)	$235
4. City of Industry Waterworks System (7,000)	$278
5. LA County Waterworks Dist. #40—Antelope Valley (9,822)	$282

Source: Greg Pierce, UCLA. "Ensuring Drinking Water Affordability: Challenges and Opportunities in Current Policy Making at Local, State and National Levels." Water and Health Conference 2017. 17 Oct. 2017.

Aging infrastructure. Perhaps the most challenging component of the issues related to infrastructure is their intersection. Who is responsible for maintaining pipes throughout a city once those pipes reach into a home? This question became a pressing one in the case of Flint, Michigan, where one contributing factor in the water crisis was lead leakage from aging pipes stretching throughout the city and into homes. For more on the complex story of water quality in Flint see "Flint Water Crisis: Everything You Need to Know."

A corroded pipe a Flint, Michigan, resident removed from her home. PHOTO: KIMBERLY P. MITCHELL/ZUMA PRESS

Data gaps. When it comes to water, there is a lot we don't know. There is even more we don't share. Gaps in data may occur within a particular area, as is the case of the Buckman well field in New Mexico where water level data was collected for years then inexplicably ignored for nearly a decade (see Figure ___). Over this period the water level declined almost 300 feet. Gaps in data also occur across wide swaths of the country as demonstrated by failure to collect data on in-home plumbing over the past thirty years. And while individual communities may collect their own data on water quality and quantity, there is no existing mechanism for sharing that data with other regions or communities, despite the interconnectedness of water sources. For more information on the opportunities related to data and water, see Deloitte's report on the top trends in the water sector.



A hydrograph showing ground-water-level declines in the Buckman well field, which supplies water for Santa Fe, New Mexico. No measurements were made between August 1988 and June 1997, during which time water levels declined nearly 300 feet, emphasizing the importance of continual monitoring. Long-term data that document the evolving response of aquifers to ground-water development are particularly important for calibrating ground-water-flow models used to forecast future conditions.

History & Trends

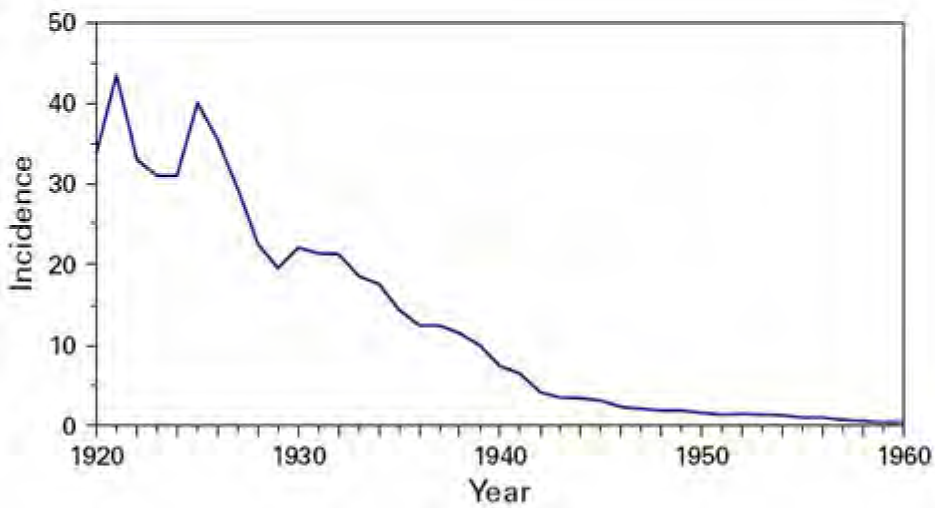
History

In the 5th century BCE, the Greek physician Hippocrates wrote *Airs, Waters, and Places*, believed to be the first book connecting health and human disease to the physical environment. In it Hippocrates notes the effect of water quality on health. In the millennia since his observation, we still struggle with how best to manage the relationship between healthy communities and water quality.

Development and urbanization. Historically, problems with water quality in the U.S. were often tied to development. More people in an area meant the need for more water and reliable access to it. This, in turn led to the creation of informal systems for delivering water. These systems became quickly overtaxed and degraded, resulting in water quality and sanitation problems and the eventual rise of illness.

Increasing urbanization in the 19th century and the rising population of the working poor in condensed urban neighborhoods in part ushered in the era of sanitation. Called "The Great Sanitation Awakening" the first half of the nineteenth century featured changes in engineering and health recognizing the connection between "cleanliness"--be it on the streets or in the drinking glass--and lower instances of disease. More money and attention was paid to the mechanisms of supplying and accessing water, resulting in extensive public works efforts for the next century.

Water treatment. The turn of the century saw the introduction of water treatment processes to ensure safe water and prevent disease. Chlorination--the purification of water through the application of compressed, liquefied, chlorine gas--became widespread practice in the U.S. in the early 20th century and drastically reduced the instances of typhoid, cholera, and dysentery (see Figure ___).



Incidence of Typhoid Fever, 1920-1960.

https://www.entrepreneurshipinabox.com/18013/plumbing-innovations-new-breakthrough-technology/

Pollution and policy. The Industrial Revolution supercharged the American economy. It also supercharged levels of industrial waste in lakes and rivers as factories dumped waste directly into bodies of water. Pollution was met with policy meant to regulate levels and protect water quality. The Water Pollution Control Act of 1948 was the first federal law to address water quality and gave the Surgeon General the ability to sue states polluting transboundary waterways. A pivotal moment in addressing water pollution came when the Cuyahoga River caught fire in Cleveland, OH, in 1969. The fire itself wasn't that unusual--the river, rife with chemicals and manufacturing pollutants, had caught fire nine times already in the past few decades. But this time, and in line with the growing environmental movement, public sentiment across the nation demanded more attention to the health of rivers. A few years later in 1972, in response to widespread concern over environmental and public health as a result of pollutants, the Environmental Protection Agency was formed. To this day, the EPA provides guidelines on the quality and safety of water. That year Congress also passed the Clean Water Act to reduce pollution, regulate waste, and set quality standards for water. In 1974, Congress passed the Safe Drinking Water Act. The SDWA regulates the public drinking water supply for the U.S. and was updated in 1986 and 1996 to expand protections. To learn more about the SDWA, its enforcements, economic impact, and specific regulations, see the EPA's SDWA overview.

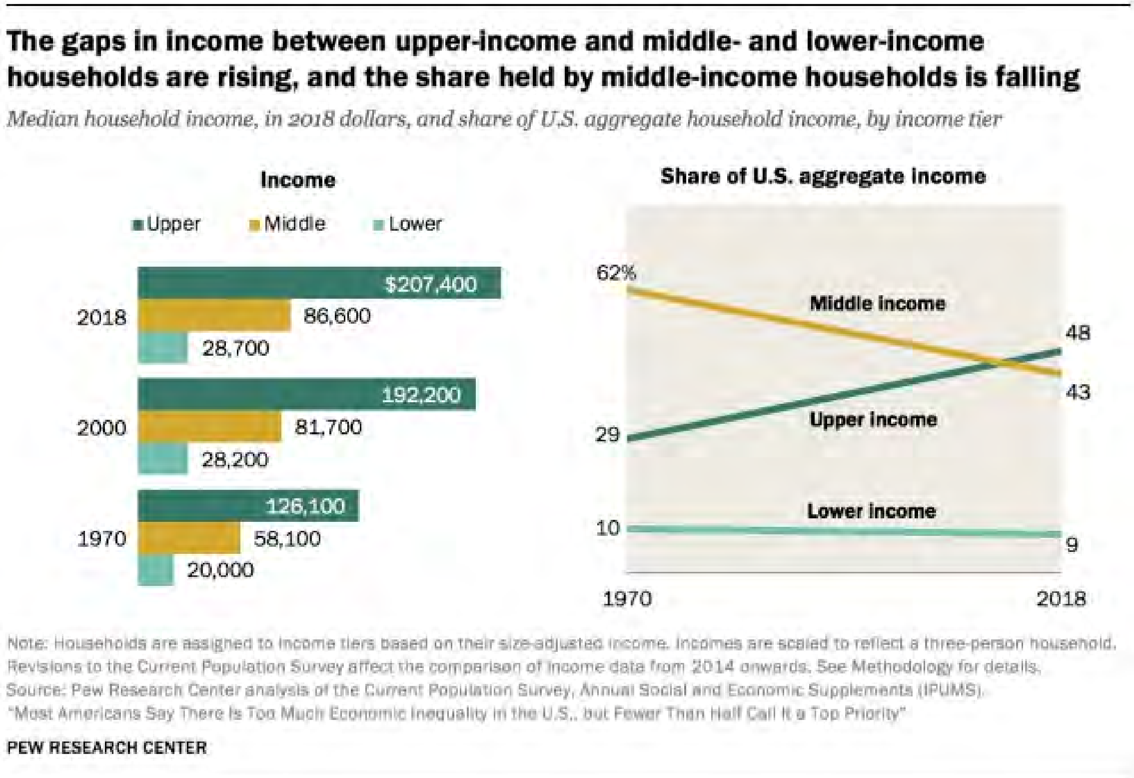
Trends

The ongoing failure to provide water to tribes. Although tribes often hold the most senior water rights in most western water basins, roughly 48% of all tribal homes do not have access to clean, reliable sources of water. Tribes are often left with what is referred to as "paper water"--meaning despite their water rights, they lack the financial resources to create the infrastructure for receiving water. Lack of infrastructure can also threaten the safety of the water sources and supply systems that are available on tribal lands. Rising public consciousness of the history and current realities of indigenous peoples will hopefully lead to closing the gap between the right to water and access to it.

Home plumbing online. Smart sinks, toilets, and showers. These may be terms we hear more and more about in the coming years. As our homes in general go online and get "smarter," we can expect the same for our water fixtures. Smart plumbing can identify leaks, help eliminate overuse, and provide information on water quality and quantity. 'As these monitoring systems take off, it raises the possibility of similar interventions for wider application. Smart pipes? Smart wells?

Stress on urban water systems. Population growth, climate change, and the stressors both place on urban infrastructure will continue. As these trends march forward, so must innovation and new thinking when it comes to how cities manage water quality.

Rising income inequality. The ongoing rise of income inequality in the U.S. will mean lower standards of living for more of the population, affecting household ability to access the resources they need, including clean and safe water. The distance between the haves and have nots (see Figure ___) will not only be financial but geographic. Those who can afford it will live in areas with higher quality infrastructure and those who cannot will live in neighborhoods with substandard pipes, plumbing, and services.



Populations & Agents

Vulnerable Populations

Infants and older adults. There are many groups vulnerable to unsafe drinking water. Infants and older adults may be especially vulnerable to microbial contaminants, even when drinking tap water deemed safe by EPA standards. The same goes for those who immunocompromised from HIV, cancer, or other disease.

Rural and urban populations. Additional vulnerable populations include those in rural areas who may not have access to public water systems and therefore rely on private water and septic systems. The CDC and EPA do not regulate private systems. On the flip side, people in urban areas may be vulnerable to infrastructure or system failure in the wake of extreme events. When a city's resources shut down, the danger of disease increases, as does the potential for populations to migrate in search of the needed resources. Climate refugees--those who are displaced due to climate related extreme events--are more likely to be those of lower socioeconomic status. For more information on migration and water, see the report from the Stockholm International Water Institute report *Water, Migration, and How They Are Interlinked*.

Agents

Category	What they do	Examples
Regulatory agencies	Monitor water quality, provide alerts, sometimes inform new policy and regulation for water safety	EPA CDC US Fish and Wildlife Services
Water utilities	Measure water quality for communities and neighborhoods, provide water treatment services and maintain infrastructure	Denver Water American Water Works Association
Individual households	Possess varying degrees of access to safe, reliable water and via a range of mechanisms	Households with private wells and septic Households without plumbing
Industry	May contribute to pollution levels or work to alleviate water contaminants	Suncor Thor Industries
Environmental and advocacy groups	Work to provide quality water for those without access	Environmental Defense Fund Colorado Water Trust Water Education Colorado
Private companies	Sell bottled water	Nestlé Waters Danone
Food and beverage sector	Require clean and safe water sources for production	Nestlé PepsiCo Tyson
Tourism and recreation sector	Conduct business on or in conjunction with water such as lakes, rivers, and the ocean	Colorado Tourism Board Recreational Fishing Industry and Lobby

Existing Approaches & Workarounds

Approaches

Information sharing. Decentralized Water Resource Collaborative, an effort of the EPA, is an entity to foster collaborative research and data sharing among the many decentralized water and wastewater systems across the U.S. Additional means of sharing information include gamification and simulations. One example is the UVA Bay Game, a simulation allowing participants to take part in managing the Chesapeake Bay Watershed.

Water monitoring technologies. Referred to in some cases as water quality surveillance and response systems, water quality monitoring is an industry unto itself (projected to be worth $4.69 billion by 2025) and one that continues to see innovation and fresh approaches. A variety of technologies are deployed to measure water safety. These approaches rely on a range of methods from bio-sensors to radiology to detect an array of potential contaminants such as carbon content, chlorine residuals, and biological organisms in a variety of water sources from groundwater to surface water to safeguard against a milieu of dangers like chemical warfare or the introduction of biological agents into the water supply. These technologies are designed to serve water treatment plants or food and beverage companies more so than individual households. For more information on the need, market, and call for innovation in water technologies, see the EPA's blueprint for *Promoting Technology Innovation for Clean and Safe Water*.

The IoT and water monitoring. It used to be water monitoring--be it for quality or quantity--had to be done manually. That has changed in recent years with the emergence of remote, smart water monitoring via the Internet of Things. IoT water monitoring has opened the door for innovation and a variety of new approaches to monitoring. Examples include system-wide monitoring of water supply and site-specific buoys to monitor surface water quality. The water sensor, monitoring, and IoT industry is a growing market with a range of applications to various industries including agriculture and recreation as well as household use.

Water safety planning. Water safety plans (WSPs) employ risk assessment and management to ensure the safety of drinking water through all stages of the water supply chain. The call for plans originated from the World Health Organization's Guidelines for Drinking Quality (GDWQ). The Guidelines recommend WSPs as the most effective means to guarantee drinking water and circumvent a public health disaster. The WHO offers a library of resources for WSP creation purposes, including information on how to ensure WSPs are equitable and serve vulnerable populations. WSPs are increasingly being used to mitigate risks in individual buildings as well as wider water systems. Despite the need for WSPs, they may be difficult to implement due to cost and financial restraints. Further, it is increasingly challenging to accurately assess and plan for risk in the face of growing climate uncertainty.

Septic technologies. No one could blame you if you don't immediately associate layered cake with addressing challenges in wastewater treatment. Yet there is a connection. The layered cake approach is one example of an innovation from the Massachusetts Alternative Septic System Test Center. The MASSTC is a third-party research and testing facility for innovative and alternative septic system approaches. Additional projects include wastewater hydroponics and a study of virus removal in wastewater systems. For a full list of projects, see the Test Center's "Project Hub" webpage.

Top innovations:
https://www.wqpmag.com/trends-forecasts/top-5-innovations-water-quality-technology-2020

Workarounds

Nonprofit assistance. Organizations like DigDeep and The Water Well Trust help alleviate the pressures related to water quality and safety. These are not long term solutions but stop gaps meant to aid individuals with water problems.

Bottled water. It may still be big business but it is not a solution and in many ways, produces more problems than it solves. The chemicals and plastics in bottled water often makes this water source less safe than water from a tap.

In-home apparati. In home water treatment systems such as a reverse osmosis system may be a good option, but with price tags in the hundred of dollars, it is not an option for everyone. Water filtration and treatment systems further increase the distance between those who can afford "good water" and those who can not. In-home systems also circumnavigate the need for larger infrastructure or supply-wide fixes. Who needs to clean up the toxic chemicals in the surface or groundwater when "everyone"--or those most likely to advocate for better water due to the resources at their disposal--can address the problem themselves?

Over two decades-old regulations. The last amendment to the Safe Drinking Water Act was in 1996, raising concerns about the need for updates in response to a changing climate and increasing presence and levels of chemicals in the water. Most public water systems only test for the chemicals mandated for testing by the EPA and although the EPA may identify new chemicals to test, it hasn't done so since 1996. Not a single new chemical has been added to its list of 89 chemicals, bacteria, or viruses in over two decades. This boggles the mind, especially as the EPA is also required to keep track of new chemical substances used in the U.S.--a list numbering over 86,000 chemicals.

Additional Resources

For more information on innovation in water monitoring see Innovative Biological Approaches for Monitoring and Improving Water Quality.

For interactive maps of water quality on state and local levels see the American Geosciences website.

For more on tribal water rights, see a list of tribal water issues from the Water Education Foundation.