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Water Scarcity: What History Teaches Us About Water Resource Management

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Our world is reeling. The combination of climate change and population growth is stressing Earth's capacity to support its inhabitants. One trend – increasing scarcity of water – is particularly alarming and highlights the inadequacy of water resource management in today's highly complex and interdependent world. Lessons learned from civilizations that collapsed when faced with similar conditions tell us that we must change our approach to reflect a more encompassing, disciplined and collaborative long-range strategy.
Lessons Learned: Although the cultures, locales and sizes of five collapsed civilizations differ, each faced severe water scarcity brought about by prolonged climate change and growing populations. Their experiences provide valuable lessons for contemporary water resource management:

- Migration is a last resort strategy that relies on the existence of hospitable locales
- Lack of a long-term strategy prompts reactive, short-term responses that fail
- Importing food and water is risky when adverse conditions become widespread
- Collaboration between local experts and centralized leadership is essential
- Inadequate maintenance of water infrastructures causes catastrophic failure

To avoid the ruinous fate of these civilizations, we must adopt a new framework for water resource management. By combining traditional resource management, such as that used in formal projects, with present-day natural resource management, and by expanding the scope and time horizon of current practices, we can better cope with water scarcity in the short term as we work to mitigate it in the long term.

INTRODUCTION

Thirst is at best uncomfortable and at worst fatal. We humans need water to regulate blood pressure and temperature, to distribute nutrients and to lubricate our bodies. But these requisites for personal survival are the tip of the iceberg when it comes to water's criticality: Water is life.

Unfortunately, our current approach to managing our water resources is inadequate as evidenced by those who have barely enough water to survive. Over two billion of Earth's eight billion people live in areas where water is scarce.[1] Five of the world's eleven regions suffer water stress; three of these are highly or extremely stressed.[2] Countries in Northern Africa and Western Asia, for example, use *all* of their renewable water and depend upon dwindling aquifers.

> WATER SCARCITY AND WATER STRESS
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> **WATER SCARCITY:** There are two types of water scarcity. Ecological conditions create physical scarcity; inadequate water infrastructure causes economic scarcity.
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> **WATER STRESS:** Water stress occurs when water supply cannot meet demand. Physical and economic water scarcity contribute to water stress. The level of stress is the ratio of withdrawals to total renewable water supplies. When this ratio is at least 25% (a quarter or more of renewable water supplies are being used), the region is considered water-stressed. High water stress means the ratio is over 40%; extreme water stress is above 80%.
>
> SOURCE: Klobucista & Robinson (2022)

Furthermore, water stress – the result of water scarcity – is rising. Experts predict that by 2025 half of the world's people may not have adequate water.[3] The issue is so serious that food and water crises ranked among the top four critical global threats in 2022.[4]

But regional water scarcity is only part of the issue. Its consequences are spreading like invasive kudzu vines into every nook and cranny. We are all touched regardless of whether our patch of ground is inundated with precipitation or our reservoirs are empty. Water scarcity anywhere has ripple effects on the economy and on water basins everywhere.[5] Because agriculture and industry together use over 80% of the world's freshwater, as water scarcity increases, so will food shortages and economic setbacks.[6]

Although effective management of water has always been a vital societal priority,[7] today it is a matter of survival that transcends current practices. To sustain life on this planet, we can no longer tolerate the fragmented, localized water resource management that characterizes our often conflict-ridden activities.[8] We must change.

1 Klobucista & Robinson, 2022

2 UN-Water, 2022a

3 UNICEF, 2022

4 World Economic Forum, 2022

5 Dolan et al., 2021

6 Klobucista & Robinson, 2022; UN-Water, 2022b

7 Grey & Sadoff, 2007

8 Sondermann & de Oliveira, 2022; Ukpai, 2022

To appreciate the criticality of water scarcity and help us alter our approach, we look to the early successes and ultimate failures of collapsed civilizations. But before delving into the past, let us understand why water scarcity is increasing.

PRIMARY CONTRIBUTORS

Water stress brought on by water scarcity is a simple matter of imbalance: demand exceeds supply. However, the causes of water scarcity are not simple. Primary contributors are the complex issues of climate change and population growth.

WATER SUPPLY AND DEMAND

WATER SUPPLY: Freshwater has three sources: surface water, groundwater and precipitation. Water collected in streams, lakes, rivers and reservoirs comprise surface water. Groundwater comes from underground aquifers that feed wells and springs. Shallow aquifers may be recharged by surface water, but deeper aquifers, whose water was trapped during the Ice Age, can be replenished very little. Precipitation includes rain and snow.

Water from sources that can be replenished is called *renewable*.

WATER DEMAND: Today, the demand for water comes from three primary users[1]:

72% Agriculture (mostly food)
16% Households and services
12% Industries

[1] UN-Water (2021)

Climate Change: Dwindling Supplies

The widespread, destructive consequences of climate change have overshadowed arguments about whether it is real. Experts agree that "water is the primary medium through which we will feel the effects of climate change."[9] Most obvious among these consequences are the rise in Earth's surface temperature and extreme weather, both of which diminish water supplies.

Rising surface temperature. The year 2021 marked the 45th consecutive year in which global temperatures exceeded the twentieth century average. In fact, nine of the ten warmest years on record were 2013 through 2021.[10] These trends have significant repercussions on water supplies. Scientists predict that for every 1.8º F increase in surface temperature, renewable water sources will decrease 20% and affect an additional 7% of the population. Consequently, the

9 UN-Water, 2022a

10 National Centers for Environmental Information, 2022

number of areas suffering water stress will increase and conditions in already stressed areas will worsen, as research on rainfall in the vulnerable Middle East confirms.[11]

Rising heat also heightens evaporation in reservoirs, lakes and rivers, and increases agricultural and household demand for water. Estimates are that a 5º F rise in temperature (which may occur by 2080) will cause evaporation to decrease water levels in most western reservoirs by two to six inches.[12] Such evaporation will affect other hot regions similarly.

Extreme weather. In a 20-year overview, the UN reported that climate-related disasters grew 83% and total people affected rose 22%. Among these disasters are droughts that diminish water supplies, and floods that destroy sanitation facilities and contaminate sources. From 1980 to 2019, droughts increased by 25% and floods by 134%.[13] Their effects on water supplies caused grave concern in 2022:

- Record drought reduced Lake Mead – the largest U.S. reservoir – to an all-time low of 27% capacity. Hydroelectric power dropped 25% at Hoover Dam (which forms Lake Mead). If the lake drops another 175 feet, water will no longer flow through the dam – a condition that could occur as early as 2023.[14]

- Europe is suffering its worst drought in 500 years; 15% of its land and 17% of its population were affected. Rivers have a third less flow than normal.[15]

- Widespread flooding in Mississippi damaged two water treatment plants and left its capitol city without safe water for two months. Repair will cost about $200 million.[16]

- Sichuan, China rationed electricity and closed factories for 6 days to ease a power shortage. Scorching heat and drought dried up parts of the Yangtze River and reduced hydropower generation even as demand for electricity soared. Because Sichuan factories make products such as fertilizer, lithium batteries and semiconductors, we will all feel the pinch.[17]

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11 Zeleňáková et al., 2022

12 Bureau of Reclamation, 2015

13 UNDRR, 2020; UN-Water, 2022a, This report compared the twenty-year period 1980-1999 with the twenty-year period 2000-2019.

14 Di Liberto, 2021; NASA, 2022. Statistics from National Centers for Environmental Information (NCEI); Ramirez et al., 2021; Smith, 2022

15 ABC News, 2022; Rai, 2022

16 Pettus & Goldberg, 2022

17 Davidson, 2022; He, 2022

- In Kenya, drought killed twenty times more elephants than poaching did; it destroyed about 70% of Kenyan crops. Seven million livestock in Ethiopia, Kenya and Somalia have died of thirst since fall of 2021.[18]
- Flooding in Pakistan, heightened by melting glaciers and excessive rainfall, killed nearly 1,500, left a third of the nation underwater and caused at least $30 billion damage.[19]

Population: Escalating Demand

On the flip side of water supply is demand. Two phenomena contribute to the burgeoning requirement for water: population growth and increased per capita usage. This duo caused a four-fold increase in water consumption between 1900 and 2010.[20] Prior to current droughts, more people, energy production and agriculture soaked up groundwater in the U.S. three times faster between 2001 and 2008 than during the *entire* twentieth century.[21]

Population growth. At eight billion, world population is huge and growing. As Figure 1 shows, from one billion in 1804, population had doubled by 1927. Then, in under a century, it quadrupled.[22] Judging by the rise in water scarcity, this massive population exceeds Earth's carrying capacity, i.e., its ability to support its people, which some estimate at two billion.[23]

Increased per capita usage. We are using more water per person than ever. Changes in eating habits and lifestyles plus increased energy production account for some of this growth. Average global usage per capita is rising about 1½% each year.[24]

LESSONS FROM HISTORY

For decades, experts have studied collapsed civilizations to learn from their mistakes. Recent advances in paleoclimatology, archeology and anthropology, as well as contemporary analyses that now include climate change have deepened our insight and apply directly to current water resource management.

Five Collapsed Civilizations: Five civilizations typify similarities and differences in how ancients around the globe responded to sustained climate change.[25] Although all five eventually crumbled, we can learn from their short-term successes and long-term failures.

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18 Hassan, 2022

19 Reuters, 2022

20 Kummu et al., 2016

21 Konikow, 2013

22 World Population Clock: 7.97 Billion People (2022) - Worldometer (worldometers.info)

23 Kummu et al., 2016; Pimentel et al., 1999; 2 billion is based on a European standard of living and sustainable use of natural resources

24 Water Use Statistics - Worldometer (worldometers.info)

25 Information in this section was compiled from multiple sources: Dermody et al., 2014; D'Odorico et al., 2010; European Geosciences Union, 2014; Fagan & Durrani, 2021; Gill, 2000; Gill et al., 2007; Harper, 2017; Leary, 2021

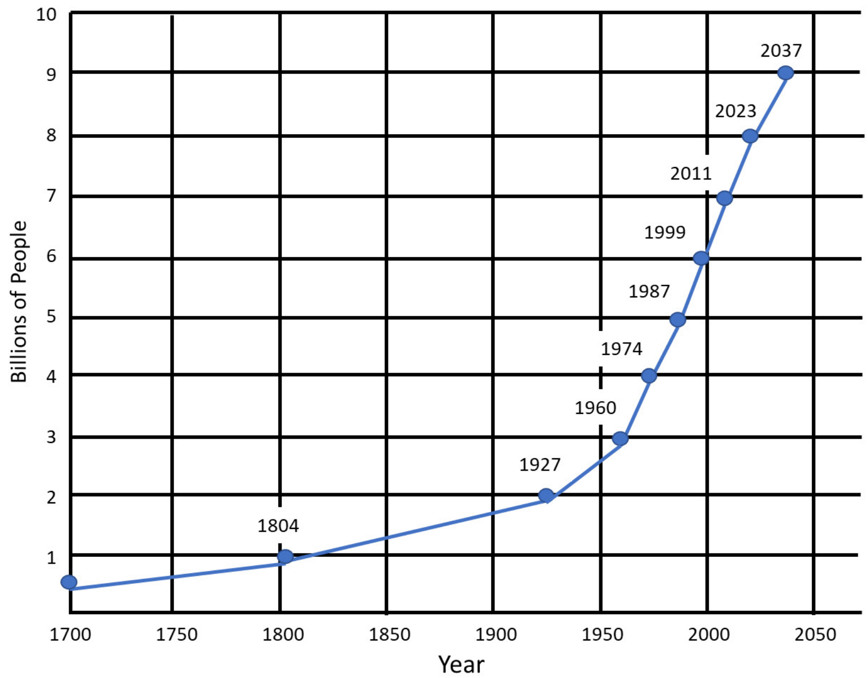

Figure 1. World Population Since 1700
DATA SOURCE: World Population by Year - Worldometer (worldometers.info)

- *Indus Civilization, present-day Pakistan:* The Indus Civilization thrived for nearly seven centuries, then disappeared about 1800 BCE. Rather than depending on an elite cadre of leaders like its Egyptian and Mesopotamian contemporaries, the Indus Civilization was egalitarian. Its relics reveal granaries, wells, and flood protection instead of golden shrines and palaces. In this nonhierarchical, decentralized society, farmers adapted to local environments using practices such as planting multiple crops on the same land.

  The Indus Civilization survived the famous 4.2 Kiloyear Aridification Event[26] but the eventual drying of the Saraswati River triggered a final exodus. Ultimately, the large population could no longer adapt to weather conditions. When crop yields decreased and food surpluses disappeared, people migrated to more favorable areas.

- *The Western Roman Empire:* For three centuries after 150 CE, the Western Roman Empire successfully adapted to aridification and erratic weather. Armed with generations of experience, local farmers were its greatest defense. Self-sufficient communities helped one another, diversified crops, and stored food and water in surplus years. However, this localized strategy did not work for a growing Empire. When the population outgrew water supplies, their leaders built aqueducts, harbors and cisterns to import and store water, and

26 The 4.2 ka Event refers to the 4.2 kiloyear aridification event ca. 2200 BCE.

established supply chains to import food from water-rich areas. Although beneficial, these supply chains also had a downside: they spread the Bubonic Plague.

Success encouraged population growth until there was not enough food and water to feed everyone. When other locales felt the effects of climate change, supply chains were disrupted and scarcities rose. To top it off, around 350 CE, droughts and famines caused the Huns to migrate to greener pastures; they attacked the already stressed Romans. By 476 CE, the Western Roman Empire had dissolved.

Because they hadn't considered that climate change might be long-lived, Romans reacted instead of planning ahead. Thus, scarcities caused by extended droughts and temperature change provoked economic and social upheaval, and war. Many died of starvation or plague; some migrated.

- *Maya Civilization, Yucatan Peninsula:* For nearly 4,000 years, the Maya successfully managed the inherently challenging environment on the Yucatan Peninsula. They created reservoirs to store water and built canals to deliver it. By understanding local crops and adapting to changes in rainfall, they withstood two lengthy droughts.

  However, their expanding population depended on an agricultural system that could not withstand prolonged drought. Over-exploitation of marginal soil and uncontrolled erosion coupled with extensive deforestation to increase farmland were devastating. In addition, with its hierarchical social structure, the Maya looked to elite leaders for water management guidance. But when water became scarcer at the end of the 8th century, leaders could not care for their people. Ravaged by drought and famine, political and social networks fell apart; warfare followed. Food and water finally ran out. Some migrated elsewhere; many died. By 930 CE, millions of Maya had simply disappeared.

- *Chaco, Southwestern U.S.*: The Chaco were highly dependent on rain and river water for their water-intensive crops. This ancestral pueblo civilization had thrived for centuries in its marginal environment by maintaining grain reserves and constructing water management systems. Their culture reflected a flexible autonomy of households, cooperation, and reciprocation bolstered by the belief that everyone worked for the common good. These values served them well until the population outgrew the carrying capacity of the land; they became vulnerable to capricious precipitation cycles. Severe drought in 1280 CE finally prompted mass migration.

- *Greater Angkor, Cambodia:* From its beginning in 802 CE, the wealthy Khmer Empire peaked in the decades before 1150 CE. At the center of this magnificent empire was Greater Angkor, whose one million people were widely dispersed. To manage the risk of food shortage for a growing population, leaders cleared forests to plant fields. Because a major issue was availability of water, Angkor's rulers managed it carefully. They built huge reservoirs to store water during monsoons and canals to distribute it. Although their massive water infrastructure was effective during ordinary fluctuations, it could not be rapidly modified. When monsoons struck in 1347 CE, the 500-year-old water system failed, dams broke and channels were blocked. Food surpluses were inadequate. Disenchanted with their rulers, people revolted. The elite relocated, abandoning the artisans and farmers who had supported them. By 1430 CE, the city was no longer habitable. Many migrated.

Lessons Learned: Although cultures, locales and sizes differ, all five civilizations succumbed to climate change and population growth. We can glean several lessons from their experiences.

1. <u>Migration is a last resort strategy that relies on the existence of hospitable locales</u>. Adapting to environmentally-induced water scarcity worked well until growing populations and extended periods of adverse climate overwhelmed the land's capacity to support its inhabitants. Ignoring conditions in the hope that they would disappear failed miserably. When droughts, floods and heat took away the basics of life, people revolted, economies collapsed and political factions conflicted. Ultimately, faced with death, and lacking the knowledge to mitigate water scarcity (i.e., address its root cause), people migrated to more favorable regions or died.

2. <u>Lack of a long-term strategy prompts reactive, short-term responses that fail</u>. Without the ability to anticipate or alter weather extremes, and without a disciplined long-term strategy, ancient civilizations responded reactively. Although some stored enough food and water to last a few years, unfavorable conditions persisted beyond their stockpiles. They had not believed in, anticipated or planned for the longevity of their situation.

3. <u>Importing food and water is risky when adverse conditions become widespread</u>. Relying on food and water from other locales ameliorated regional water scarcity for a while. However, it also facilitated population growth and spread disease. In addition, when climate change and political unrest caused vital food and water supply chains to collapse, effects of water scarcity became severe.

4. Collaboration between local experts and centralized leadership is essential. Dependence on leaders who reacted slowly or not at all resulted in failure, distrust, social upheaval, political breakdown, and disintegration. Alternatively, although decentralized expertise provided flexibility, it couldn't support huge populations when climate change persisted. Civilizations that relied on *both* local experts and government actions were most successful early on.

5. Inadequate maintenance of water infrastructures causes catastrophic failure. When floods and drought destroyed old, unmaintained structures, people were left hungry and thirsty with no way to recover.

A NEW STRATEGIC FRAMEWORK

Like ancient civilizations, the increase of water scarcity places us in uncharted territory. In our highly interdependent and densely populated world, complexity has escalated and has made current fragmented water resource management practices inadequate and obsolete. For example, the 276 transboundary water basins shared by 148 countries and the 300 shared aquifer systems in the world[27] tell us that independent, piecemeal efforts can no longer work. Unlike in ancient times, water scarcity today is no longer regional. It cannot be resolved with policies, practices and plans of local institutions or with individual efforts. It has become global.

Although multiple studies address world-wide water scarcity, other than highlighting ominous statistics and the need to manage water, suggestions are generic.[28] Rather than simply acknowledging the severity of the issue, we must generate an executable plan whose scope extends beyond regional suboptimization and whose timeline goes beyond the here-and-now. Successful practices of countries such as Israel, Australia and Singapore where long-range planning and exemplary technology have been in place for years can serve as inspiration.[29]

27 The World Bank, 2022

28 The World Bank, 2022; UN-Water, 2021, 2022a, 2022b

29 Siegel, 2015

RESOURCE MANAGEMENT

WATER RESOURCE MANAGEMENT involves the planning, producing, distributing, controlling and managing the optimum use of water resources with the goal of conserving and protecting Earth's limited water resources. Developing infrastructures, strengthening institutions, managing information, using legal and regulatory tools, providing incentives, and investing in technologies that enhance productivity, conservation and protection are a few of the methods used in water resource management. Current water resource management efforts are localized, independent and often impotent in the presence of conflicting interests.

TRADITIONAL RESOURCE MANAGEMENT incorporates the planning, scheduling, and allocating of people, money, and technology to a program to achieve the greatest value for the organization. Good resource management results in the right resources being available at the right time for the right work. It requires identifying available resources as well as determining the use, capacity, prioritization, and allocation of those resources.[1] Balancing short-term with long-term requirements and consideration of all stakeholders are parts of this approach. Software tools often enhance its inherent discipline.

[1]https://www.planview.com/resources/guide/resource-management-software/resource-management-leverage-people-budgets/

The blending of current water resource management practices with the inherent discipline of traditional resource management such as that used in formal projects and lessons-learned from collapsed civilizations suggest a new strategic framework better suited to contemporary challenges. Such a framework would include the following fundamentals:

1. Incorporate short-term and long-term actions. As we learned from failed civilizations, short-term thinking is a non-starter. Because creating infrastructures, policies, institutions and awareness takes time, we must consider the future *now*. Unlike the ancients who thought conditions were temporary, our water resource management today must include long-range plans and investments to reduce water scarcity in the coming decades. Within these actions, assessment of supply and demand for global water resources, measurable milestones and clear accountability are crucial.

   Short-term actions:

   - *Dispel the tendency to ignore our situation*. History tells us that ignoring water scarcity is disastrous; today it is catastrophic because it affects billions rather than thousands. Water resource management must therefore include extensive communication to increase awareness and inspire involvement.

- *Reduce migration*. While migration was somewhat successful as a last resort for ancient civilizations, it is impractical if not impossible today. People in water-stressed areas cannot easily relocate and are often unwelcome in today's densely populated, environmentally favorable regions. The Central American crisis illustrates these limitations. With food and water shortages growing, desperate migrants are overwhelming countries such as Mexico, Costa Rica, Panama and the U.S.[30] To diminish migration attempts, we must share techniques such as water collection, storage and conservation with water-stressed locales.

- *Strengthen adaptation activities*. Adapting to water scarcity initially worked for collapsed civilizations and can be used today – at least for a while. Like those who thrived for centuries in harsh conditions, successful adaptation requires proactive water resource management, as well as "creative and innovative thinking" on both the supply and demand side.[31]

  For us, adaptation dictates unprecedented lifestyle changes, particularly for those who live well. A new strategic framework must include restrictive policies and expand education and collaboration with the goal of using water wisely. For individuals, activities include eliminating lush lawns and recreation areas, reducing food waste, and relying less on water-intensive foods such as almonds and cattle. Agricultural practices should assimilate new water saving techniques and promote crops suited to dry conditions.

  Small scale adaptation has begun. For example, some local governments require water conservation and assess fines for non-compliance. In another example, Latin America proposes recognizing "legal personhood for Nature." Because property rights play a major role in water resource management there, better outcomes are possible when Nature is included in these rights.[32]

Long-term actions:

- *Mitigate root causes of water scarcity*. This action is our only long-term choice. Fortunately, we know more than past civilizations and can use advanced technology. Water resource

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30 Mendez, 2021

31 Sondermann & de Oliveira, 2022

32 Álvez et al., 2022

management institutions should join with governments at all levels and in all nations to reduce fossil fuel use and fund renewable energy solutions. They must publicize and encourage acceptance of inevitable repercussions on economies.

2. Reduce reliance on imported water and food and strengthen supply chains. It is tempting to depend on water and food imported from water-rich areas rather than address local shortages. However, recent droughts and a pandemic taught us that supply chains can be disrupted. Furthermore, nations that previously produced abundant food may be unable to export in the future. Water resource managers must augment education on region-appropriate agriculture and join with other institutions to encourage lifestyle changes attuned to local conditions. Bolstering supply chain redundancies would also be wise (e.g., when rivers run dry, the fallback may be trains).

3. Broaden and strengthen collaboration among individual, local, national and international efforts. A new strategic framework should ensure collaboration among global stakeholders – from nations and organizations to individuals. It should expand coalitions with non-water related national and international institutions that affect agriculture, health, education and transportation. Actions must focus individual efforts and provide feedback on progress.

   Contemporary failures underscore the importance of collaboration. One example is Madagascar's decentralized water policy. Although the intent was admirable, without government policies and infrastructure investment to balance community empowerment, water scarcity there has increased.[33] Another study cites individuals in Nepal who are attempting to harvest rainwater on their own; it finds the approach ineffective and recommends increased government involvement.[34]

4. Invest in water infrastructures. A new framework should assess, prioritize and increase infrastructure investment for efforts such as equipment renovation, water recycling and collection, water treatment plant refurbishment, dam repair, and desalination plant expansion on a broader scale. Collaboration and joint projects among stakeholders must increase. Large-scale water recycling and collection, such as the new reservoirs and aquifers proposed in California, exemplify positive steps.[35]

33 Marcus, 2012

34 Thapa et al., 2022

35 Borba, 2022

CONCLUSIONS

Water scarcity has already exceeded human experience. Its causes are colossal. Its effects are brutal and far-reaching. Ultimately, water scarcity is not someone else's problem. It cannot be solved in the undisciplined, piecemeal fashion we are using today. Before water scarcity overwhelms us, we must alter our current approach to address today's interdependencies and complexities. By incorporating lessons-learned from ancient collapsed civilizations and the discipline of traditional resource management in a revised framework for water resource management, we can better prepare for a challenging future.

Managing our limited water resources must become a way of life for us all – one that includes long-term and short-term planning, accountability and collaboration. Following in the footsteps of collapsed civilizations is unwise; petty political divisiveness deters progress. To avoid the fate of collapsed civilizations, we must act together beginning now.

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